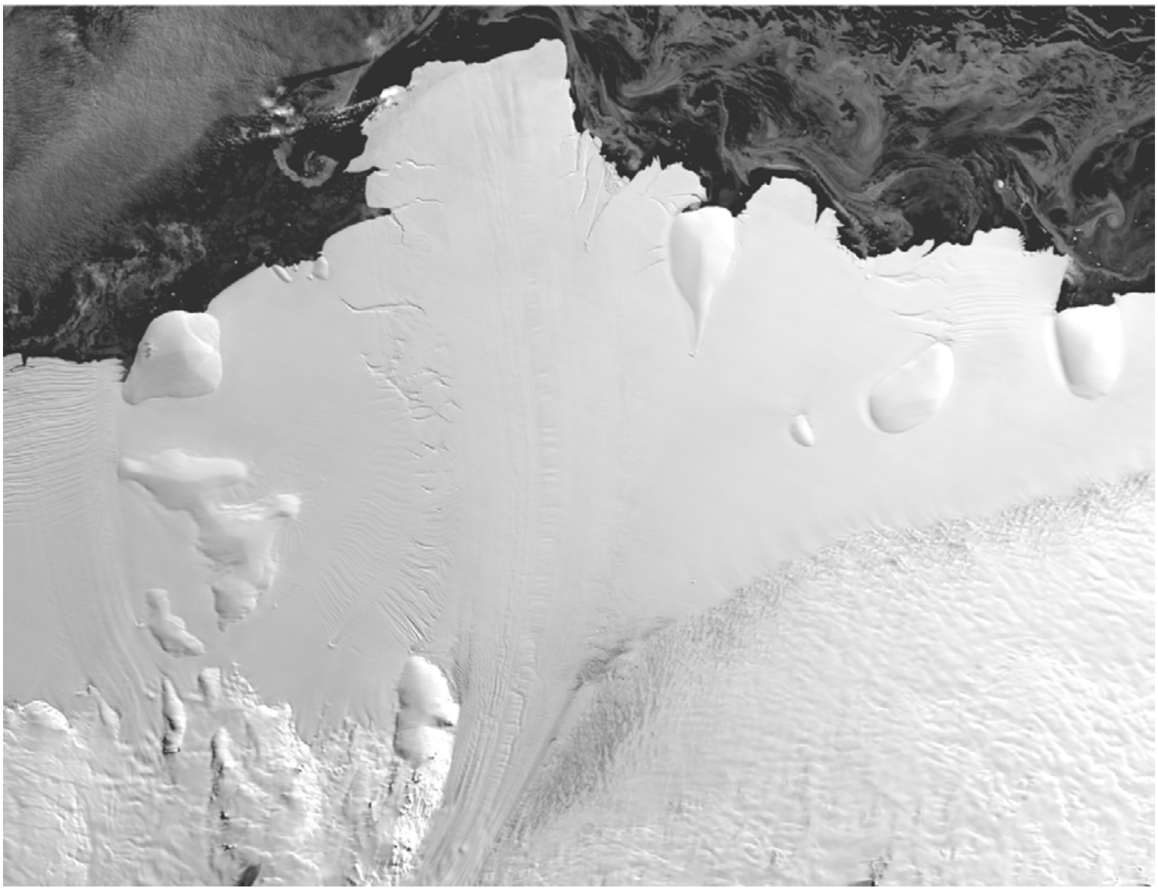
JR097 Cruise Report

Autosub Under Ice Cruise to the southern Weddell Sea

RRS James Clark Ross

3 February to 11 March 2005



Compiled by Keith Nicholls from contributions by:

Povl Abrahamsen, Jeff Benson, Brian Bett, Justin Buck, Paul Dodd, Colin Goldblatt, Nick Hughes,
Daniel Jones, Arthur Kaletsky, Gregory Lane-Serff, Stephen McPhail, Nick Millard,
Keith Nicholls, Kevin Oliver, James Perrett, Martin Price, Carol Pudsey, Kevin Saw,
Kate Stansfield, Martin Stott, Andrew Webb and Jeremy Wilkinson.

Table of Contents

Introduction

Keith Nicholls

Overview

JR097 was the third and final cruise associated with the NERC thematic programme: Autosub Under Ice (AUI). The rationale for the programme is given on the AUI website (http://www.soc.soton.ac.uk/aui/aui.html), but, in brief, the programme's aim is to study the marine environment of floating ice shelves using a combination of Autosub missions and conventional ship-based measurements. The first cruise (JR084) was to the Pine Island Bay region of Antarctica; the second cruise was to study sea-ice conditions in Fram Strait (JR106N) and the marine environment in Kangerdlugssuaq Fjord, Greenland (JR106S); and this, the final cruise, was to target the Filchner-Ronne Ice Shelf in the southern Weddell Sea.

The science party represented four projects:

> ISOTOPE: Ice Shelf Oceanography: Transports, Oxygen-18 and Physical Exchanges (PI: Karen Heywood, UEA);
>
> Oceanographic Conditions and Processes beneath Ronne Ice Shelf (PI: Keith Nicholls, BAS);
>
> Observations and modelling of coastal polynya and sea ice processes in the Arctic and Antarctic (PI: Peter Wadhams, DAMTP, Cambridge);
>
> Controls on benthic biodiversity and standing stock in ice covered environments (PI: Paul Tyler, SOC).

The Heywood and Nicholls projects are physical oceanography studies, and rely on both ship-based observations over the continental shelf seaward of the ice front, and on data and water samples collected from within the sub-ice shelf cavity. The Wadhams project aimed to obtain data from the sea-ice margin of a shorelead, primarily using Autosub-mounted upward-looking swath and oceanographic sensors. Ideally, this would be during an episode active polynya development: freezing conditions and offshore winds. The Tyler project was to obtain ship-based photographic imagery of the sea floor, together with imagery from beneath the ice shelf using a camera mounted on Autosub.

Difficult sea-ice conditions routinely make Filchner-Ronne Ice Front inaccessible to ships. A secondary target ice shelf had therefore been identified: Fimbul Ice Shelf on the prime meridian. In the absence of extensive fast ice, Fimbul Ice Front is generally accessible, and this ice shelf has the advantage of having a sub-ice cavity whose topography is relatively well known. The principal disadvantage with this work area was the absence of sea-ice conditions suited to the aims of the Wadhams project.

Nick Hughes describes the evolution of the sea ice conditions during the 2004-05 summer season in the Satellite Data section. In summary, although the conditions during the pre-cruise planning meeting in mid-January suggested that Ronne Ice Front was inaccessible, Filchner Ice Front could be accessed, as confirmed by over flights from Halley. The imagery also confirmed that the secondary target of Fimbul Ice Front was entirely free of sea ice. These conditions lasted until we were *en route* from Port Stanley to the Filchner Ice Front, when satellite imagery showed that conditions north of Filchner Ice Front had worsened: even if the ship had been able to gain access to the ice front, it would have been very difficult to operated Autosub. The decision was then taken to divert to Fimbul Ice Shelf.

At this time heavy brash ice in the coastal current was bearing down on the Fimbul area from the east. The Fimbul ice tongue, which overhangs the continental shelf break, created an effective barrier for the sea ice, however, and the ship was able to operate in clear water on the western side of the tongue. Autosub trials began, as did a swath survey of the open continental shelf west of the

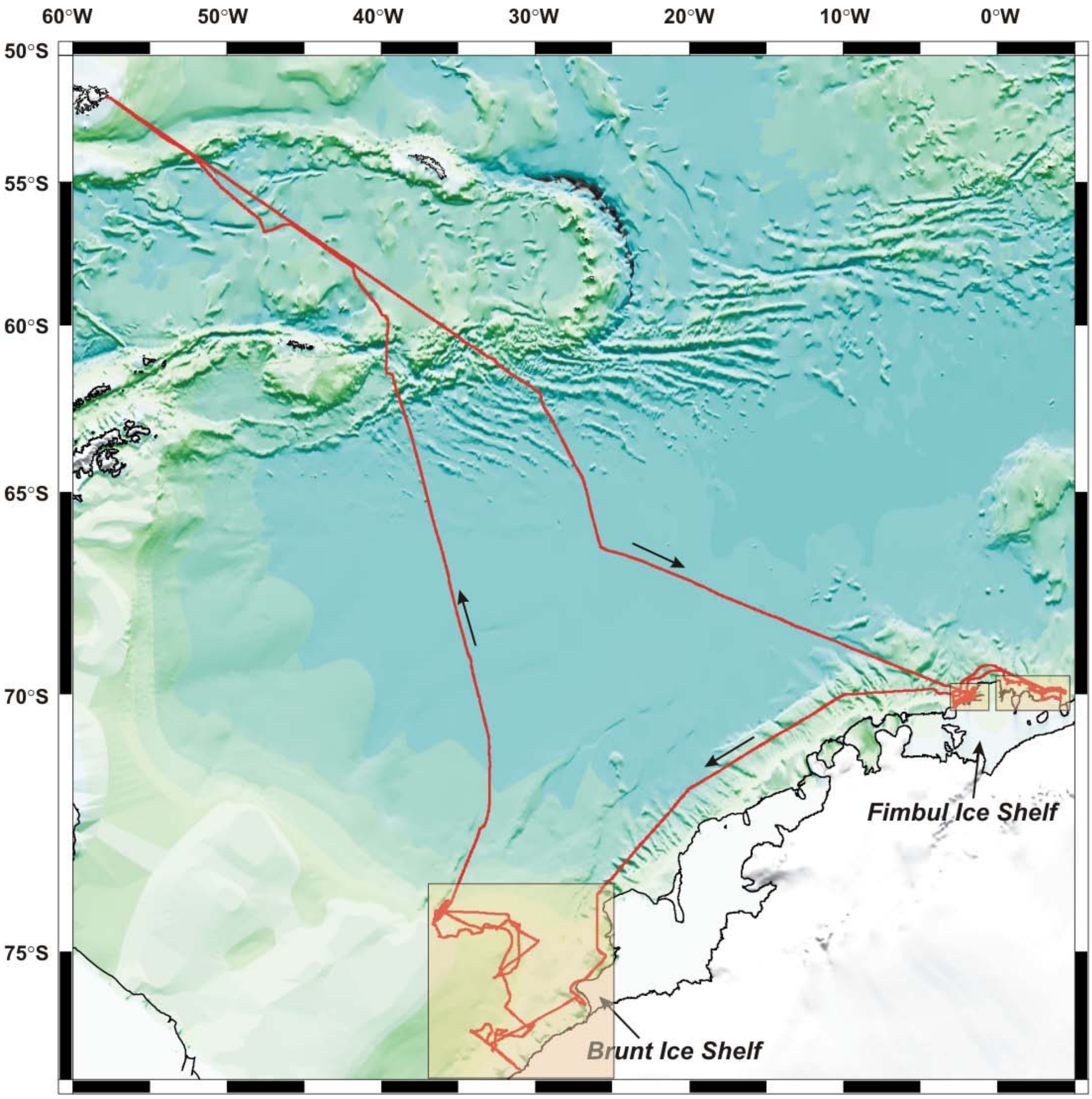


Figure 1. Plot of the track of RRS James Clark Ross during cruise JR097. The three boxes (Fimbul west, Fimbul east, and Brunt area) are expanded in figures 2, 3 and 4.

ice tongue. About 11 days were spent in the vicinity of Fimbul Ice Shelf, yielding seven WASP stations (benthic photographic surveys), comprehensive swath and CTD/LADCP surveys of the western side of the ice tongue, several CTD/LADCP stations in challenging sea ice conditions east of the ice tongue and a successful Autosub mission beneath Fimbul Ice Shelf. That period also saw the unfortunate loss of Autosub beneath the ice shelf.

The ship then sailed for the Brunt Ice Shelf area. The aims here were to attempt to achieve at least some of the objectives of the polynya/sea ice project, but also to conduct a study of the ice shelf water-rich plume that flows down the continental slope north of Filchner Ice Shelf. A CTD/LADCP section was occupied in support of the polynya work, two sea-ice buoys were deployed, and pancake ice was sampled at various stages of its formation. The plume study consisted of a CTD/LADCP section across the plume (down the slope), and two yo-yo-type LADCP deployments.

While in the vicinity of Brunt Ice Shelf, two current meter moorings were recovered, and five personnel were transferred from *RRS Ernest Shackleton*, in support of BAS logistics. While in the vicinity of the sill at the continental shelf break north of Filchner Ice Shelf, a long term current meter mooring was recovered, serviced, and then re-deployed.

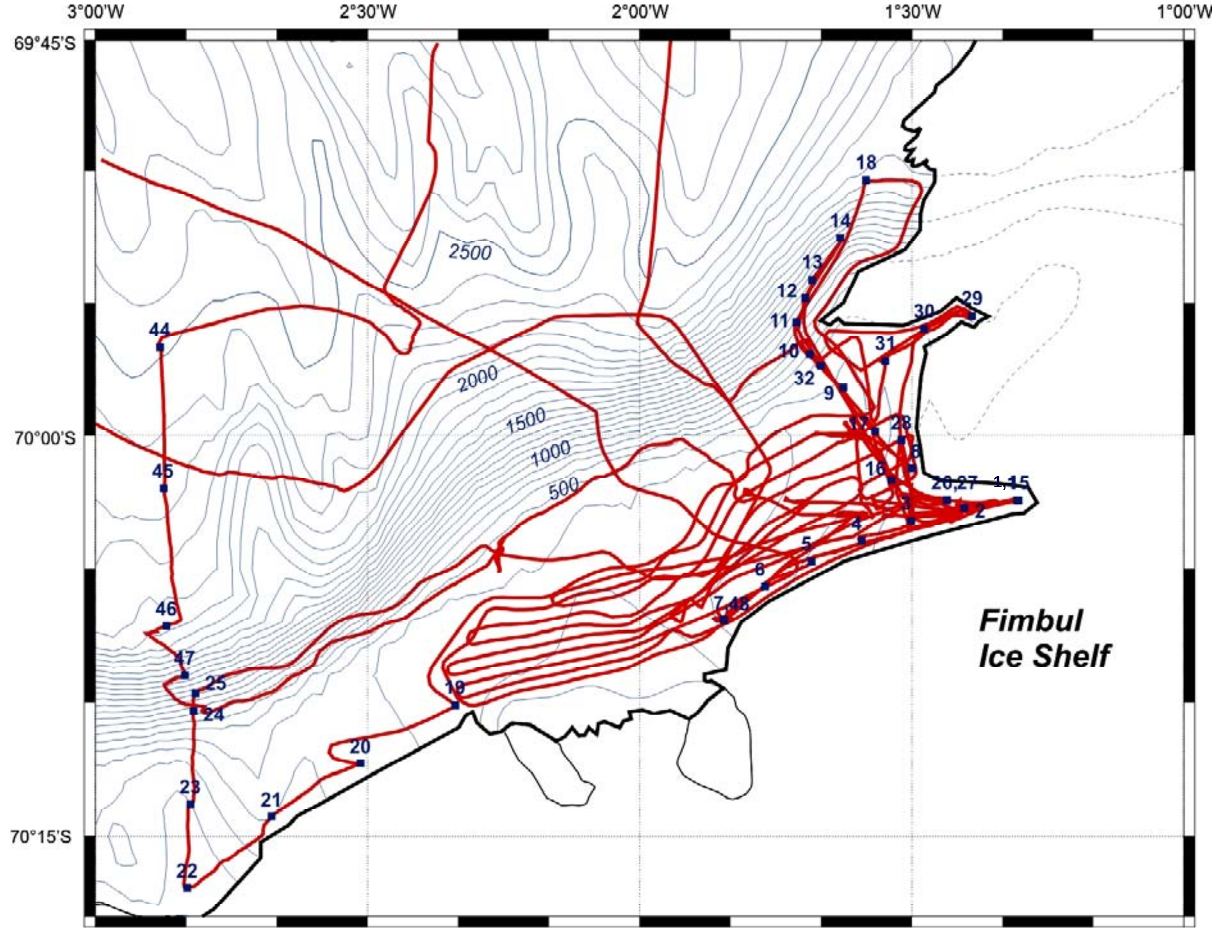


Figure 2. Ship track in work area west of the Fimbul ice tongue. The numbers indicate CTD stations.

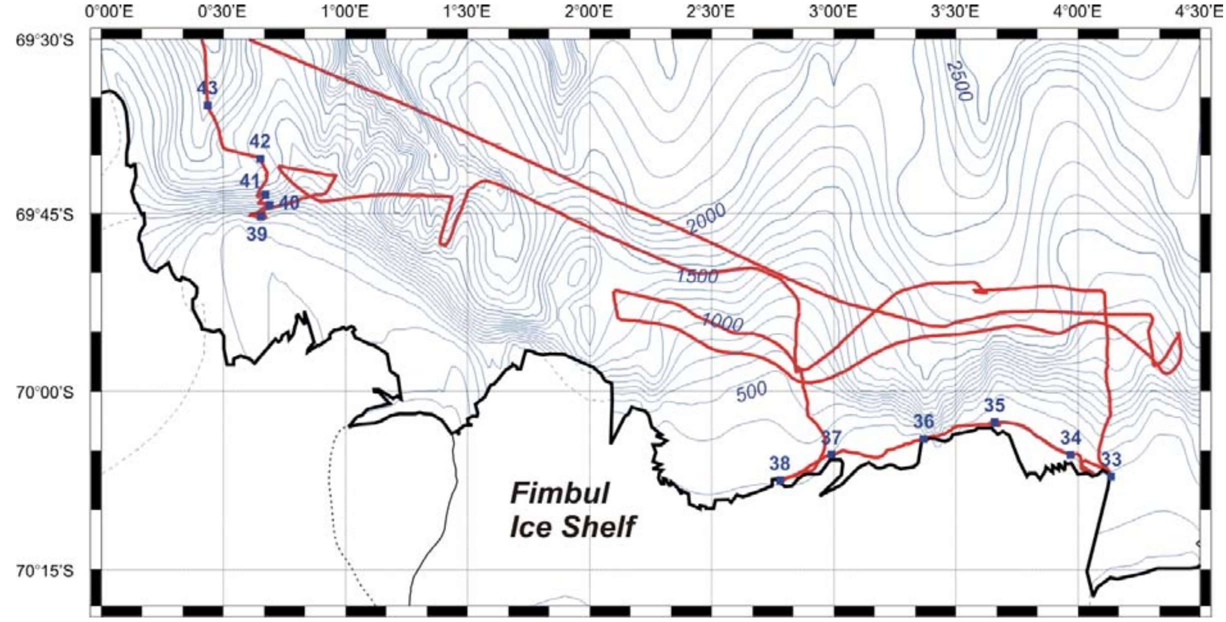


Figure 3. Ship track in work area east of Fimbul ice tongue. Numbers indicate CTD stations.

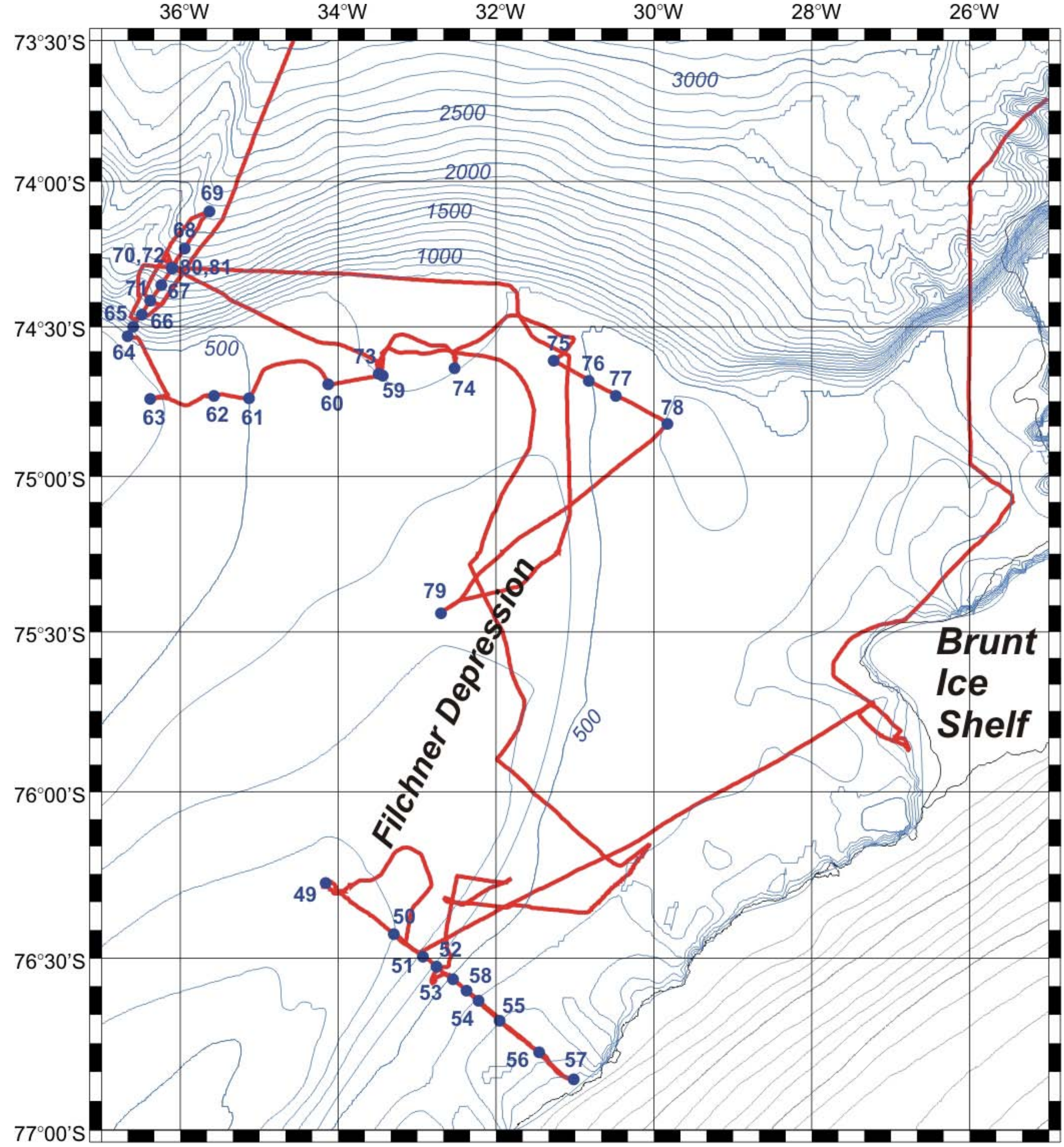


Figure 4. Ship track in work area near Brunt Ice Shelf. Numbers show locations of CTD stations.

Cruise diary

3 Feb 2005	Set sail from Port Stanley for JR097. Deploy magnetometer and initiate swath survey using the shipboard EM120. Swath and magnetometer surveys were continued throughout the cruise whenever conditions allowed.
4 Feb 2005	Passage towards Scotia Sea. Initiate shipboard ADCP and underway instrumentation. Underway instrumentation was active and logged during the entire cruise, except for instruments using the water inlet, which was closed when in sea ice.
5 Feb 2005	Continue passage
6 Feb 2005	Continue passage
7 Feb 2005	Continue passage
8 Feb 2005	In the light of satellite imagery from the Filchner ice front region, the ship diverts towards Fimbul Ice Shelf.
9 Feb 2005	Trial CTD deployment (Station 999) to check out CTD, LADCPs, the Idronaut 320 CTD, and the sampling rosette. Continue passage towards Fimbul Ice Shelf.
10 Feb 2005	Arrive at the west side of Fimbul Ice Tongue at 1400. Commence swath survey of continental shelf area west of the tongue.
11 Feb 2005	Position at launch site for trial missions. This was in open water some kilometers from the ice front. Trial missions 378, 379 and 380 were undertaken during the day to test a number of different systems. CTD stations 001 to 007 along the ice front were occupied overnight (see Figure 2).
12 Feb 2005	Deploy short-term current meter mooring at CTD station 007. Proceed to Autosub trials launch site and launch trials mission 381. Recover Autosub. Continue CTD profiling overnight, along western edge of ice tongue, to a depth of ~2200 m (stations 008 to 014 – see Figure 2).
13 Feb 2005	Steam to launch site and launch sub-ice shelf Mission 382. Listen to 10-minute transmissions from Autosub until vehicle turned to come back. Re-occupy CTD Station 001 (Station 015) (Station 001 data compromised by frozen sensors). Steam to Autosub pick-up point and recover vehicle. CTD profile at the recovery site (Station 016 – Figure 2). Fill in CTD station 017 (between Stations 8 and 9), and then extend the line of CTDs along the western side of the ice tongue (Station 018). Difficult sea-ice conditions prevented extending further.
14 Feb 2005	Fill-in swath, and extend east-west ice front CTD section (stations 019 to 022 – Figure 2). Begin cross-shelf CTD section north to the shelfbreak as far as Station 25. Proceed to Autosub launch site for mission 383. On arrival at the launch site increasing winds and an invasion of sea ice from the north resulted in the postponement of Mission 383. Attempt a box core in the southern inlet in the ice tongue, and then shelter from gale. Start yo-yo CTD (Station 026).
15 Feb 2005	Break from yo-yo to take water samples for salinity, and to inspect ice conditions outside creek. Restart yo-yo at same site (Station 027). Stop yo-yo when fast ice broken out from the head of the inlet is blown past the ship. Reposition ship outside inlet, but still in the shelter of the ice tongue and recommence yo-yo (Station 028).
16 Feb 2005	Weather abated, so finish yo-yo and position at launch site for Mission 383. Launch Mission 383. Steam to WASP site for two dredging runs. Listen for Autosub: clear that Autosub aborted beneath ice shelf. Proceed to second inlet to complete swath

	survey and occupy CTD stations 029 to 032. Ice and wind conditions prevent further CTD profiling along the ice tongue, so proceed to eastern end of the Fimbul Ice Shelf work area (see Figure 3).
17 Feb 2005	On passage to eastern end of work area. Sea-ice conditions too difficult to get to ice front, so swath and take box core during the night.
18 Feb 2005	Break through pack to reach ice front pools. Occupy CTD stations 33 to 38, breaking from one pool to the next. Break north out of ice. Steam west to eastern edge of the Fimbul ice tongue.
19 Feb 2005	Break through heavy pack and occupy CTD Station 39, deploying the CTD over the stern. This was as far south as it was possible to take the ship without risking becoming trapped. Break north through pack to occupy CTD stations 40 to 43. Make passage towards the western edge of the Fimbul ice tongue.
20 Feb 2005	Satellite imagery shows the inlets and western side of the ice tongue to be full of pack ice. Proceed to western cross-shelf CTD section and continue the section, starting from the northern end (stations 44 to 47 – see Figure 2), breaking ice as necessary. Proceed northeast along continental shelfbreak towards one of the WASP survey sites.
21 Feb 2005	Conduct five WASP surveys; listen to Autosub emergency beacon at three locations in order to determine its position beneath the ice shelf; recover the current meter mooring and obtain a CTD profile at that position (Station 48). Make passage to Brunt Ice Shelf work area.
22 Feb 2005	Continue passage.
23 Feb 2005	Continue passage.
24 Feb 2005	Rendezvous with *RRS Ernest Shackleton* to pick up 5 pax. Steam to B1 mooring site. Recover B1. Steam to B2 mooring site. No response either from the location of mooring B2, or along the route an iceberg would be expected to drag it. Steam to B3 mooring site. Recover B3. Proceed to the intersection of the sea ice edge with the CTD section to be occupied in support of the polynyas project (Figure 4).
25 Feb 2005	Proceed along line into sea ice. Deploy tiltmeter ice buoy on thick floe. Drill for thickness profile. Occupy CTD station 49. Break out of heavy pack ice, and then return to CTD line to occupy Station 50. Continue CTD deployments along line southeast towards coast, stopping for pancake sampling as required.
26 Feb 2005	Finish CTD section to coast (stations to 57). Return along CTD line towards sea ice for further pancake sampling. Occupy fill-in CTD Station 58. Poor weather prevents further CTD stations or pancake lifting.
27 Feb 2005	Proceed around pack ice to the location of mooring S2 (at CTD Station 59 – see Figure 4). Sample pancakes where appropriate en route. Recover S2, occupy CTD Station 59, and extend CTD section to west.
28 Feb 2005	Complete CTD line to west (up to Station 63). Proceed to occupy CTD section down Filchner slope (stations 64 to 71 – Figure 4). Perform CTD/LADCP yo-yo through plume (Station 72).
1 Mar 2005	Finish Station 72 yo-yo and steam to S2 to redeploy mooring and take a CTD profile (Station 73). Continue CTD section eastward across the Filchner Sill from the location of S2 (stations 75 to 78).
2 Mar 2005	Complete sill CTD section and then proceed into the pack ice (Figure 4) to find a suitable floe to deploy the second sea-ice buoy. Deploy the buoy. Occupy trial CTD

station (Station 79) to test the conductivity sensors. Carry out additional pancake ice sampling, and steam out and then around the pack ice to return to the slope area.

3 Mar 2005 Arrive at plume site. Profile with the Idronaut 320 CTD slung beneath the rosette (Station 80), and then continue CTD/LADCP experiments through plume (stations 81 and 82).

4 Mar 2005 Box core at site on the slope, then make passage to Port Stanley.

5 to 10 Mar 2005 Continue passage. Arrive Port William 2150L.

11 Mar 2005 Berth at FIPASS, Port Stanley.

Scientific party and responsibilities

Project	Institute	Name	Specific responsibility
Autosub technical	SOC	Stephen McPhail	
Autosub technical	SOC	Andrew Webb	
Autosub technical	SOC	James Perrett	
Autosub technical	SOC	Kevin Saw	
Autosub technical	SOC	Nick Millard	Autosub team leader
Instrumentation	UKORS	Jeff Benson	Shipboard CTD&LADCP
ITS	BAS	Jeremy Robst	Ship fit IT
ETS	BAS	Mark Preston	Ship fit instrumentation
OPRIS	BAS	Keith Nicholls	PSO
OPRIS	BAS	Povl Abrahamsen	CFCs, moorings, 320, Autosub ADCPs
OPRIS	U of M	Gregory Lane-Serff	Ship ADCP
OPRIS	U of M	Justin Buck	CFCs
Swath	BAS	Carol Pudsey	EM120, TOPAS, box coring
AUI	SOC	Kate Stansfield	Autosub ADCP&CTD
ISOTOPE	UEA	Colin Goldblatt	Underway data
ISOTOPE	UEA	Paul Dodd	Salinometry
ISOTOPE	UEA	Kevin Oliver	LADCP data
ISOTOPE	UEA	Martin Price	Shipboard CTD
Benthic biodiversity	SOC	Brian Bett	WASP, dredge, trawl
Benthic biodiversity	SOC	Daniel Jones	Web diary
Polynyas and sea ice	U of M	Martin Stott	
Polynyas and sea ice	DAMTP	Arthur Kaletsky	
Polynyas and sea ice	SAMS	Jeremy Wilkinson	Sea ice sampling, ice buoys
Polynyas and sea ice	SAMS	Nick Hughes	Satellite imagery

SOC	*Southampton Oceanography Centre*
BAS	*British Antarctic Survey*
SAMS	*Scottish Association of Marine Sciences*
DAMTP	*Dept. of Applied Mathematics and Theoretical Physics, University of Cambridge*
UEA	*University of East Anglia*
UKORS	*UK Ocean Research Service*
U of M	*University of Manchester*

Satellite Data

Nick Hughes

Timely provision of satellite data on sea ice conditions in the Weddell Sea and around the Fimbul Ice Shelf was essential for planning fieldwork operations. The main difference from the previous Autosub Under Ice cruise to the Arctic last summer (JR106N) was that a full satellite internet link had been installed on *RRS James Clark Ross*. This meant that, rather than waiting for data to be e-mailed to the ship and occasionally downloaded, it was possible to acquire data from the providers directly as required.

There were three main sources of satellite data for JR97 fieldwork:

- Daily AMSR, QuickSCAT and Envisat GMM data were provided by Leif Toudal of the Danish Centre for Remote Sensing (DCRS) and downloaded from the *http://www.seaice.dk/* website.
- MODIS data was acquired from NASA's Earth Observing System (EOS) Data Gateway at *http://edcimswww.cr.usgs.gov/pub/imswelcome/*. Because each set of 250 and 500 metre resolution files for each image is so large (~550Mb) these were uploaded to a SAMS computer and processing carried out using an ssh terminal link to command-line processing programs before the final result was downloaded onto the ship.
- Acquisition of Envisat WSM data to cover the fieldwork was ordered by SAMS from ESA prior to the cruise and arrangement made to access these through the ESA rolling archive sites at ESRIN (*http://pfd-ns-es.esrin.esa.int/es_pfd_web/*) and Kiruna (*http://pfd-ns-ks.esa-salmi.irf.se/ks_pfd_web/*). These covered large areas of the Weddell Sea and the Fimbul area on 16 January, 4, 11, 17 and 23 February and 2 March. The internet link provision allowed processing of the images by uploading them to a SAMS computer and generating quicklooks using ESA's BEST software. Compression of the full data scenes also allowed them to be downloaded onto *JCR* during quiet periods overnight. As a backup, in the event of the internet link not being available, processing of the data to derive quick look images and e-mailing of these to the *JCR* was also carried out by Richard Hall of the Norwegian Polar Institute (NPI).

QuickSCAT

The algorithm for the QuickSCAT sensor on the SeaWinds satellite is designed to detect the presence of low concentrations of sea ice and areas of open water. In the past this has been found useful in determining areas where new ice formation is taking place. The images are often affected by areas of high wind speed causing greater water surface roughness and appearing as ice. QuickSCAT is also a fairly low resolution (25 km) instrument and cannot resolve areas of detail. This meant that although it was useful in monitoring the situation in the Weddell Sea the level of data was too coarse for it to be useful in the Fimbul area. An example image from the Weddell Sea on 26 February is shown in Figure 5. In this the edges of the main ice pack are clearly defined. Also visible is the effect of a storm system, outside the main ice edge, and poor data quality around the coastlines.

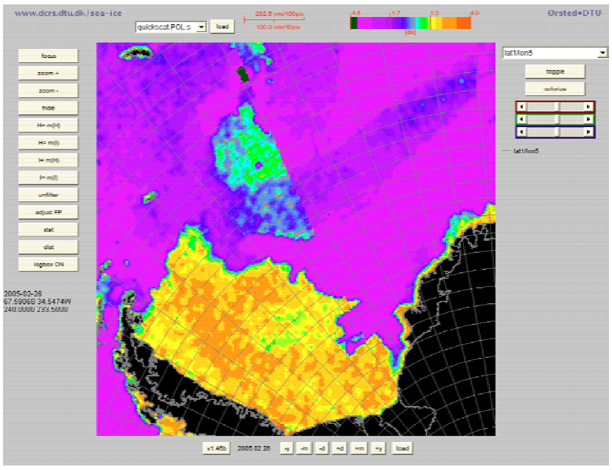


Figure 5. Example of QuikSCAT image

AMSR Ice Concentration

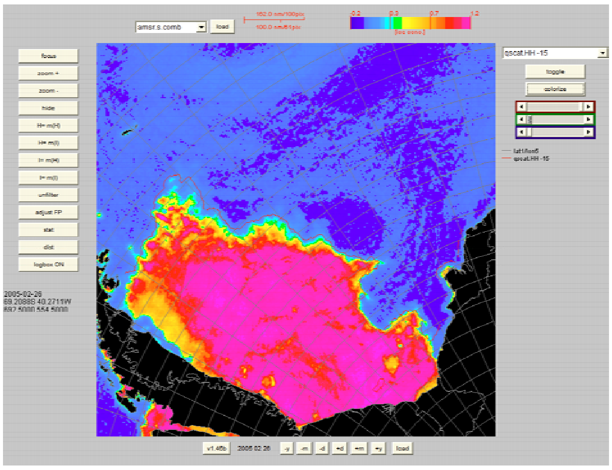


Figure 6. Example of passive microwave image

Lower frequency channels provided by AMSR provide good measurements of sea ice concentration (percentage cover of sea ice within an area) during autumn, winter and spring. During summer AMSR, like the other passive microwave SSM/I sensors and its predecessors SMMR and ESMR, is affected by surface snow melt. Areas of meltwater on a floe are seen by the satellite as open water, even though there is ice beneath. Summer ice concentration estimates tend therefore to be less reliable and lower than those from optical sensors. However, unlike in the Arctic last summer, snow melt and pools were not observed on any of the Antarctic sea ice encountered. Therefore it would appear that passive microwave sensor observations of Antarctic sea ice are more accurate than their Arctic counterparts. In the example in Figure 6 the QuickSCAT ice limit is shown as a thin red line and is seen to be consistent with the ice limit shown by AMSR.

Envisat GMM

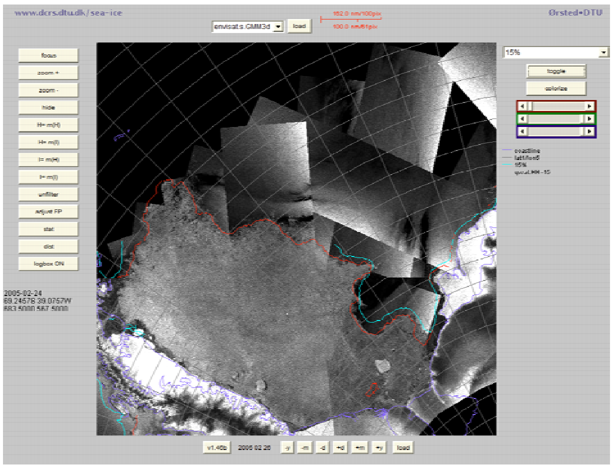


Figure 7. ASAR image of Weddell Sea

The Global Monitoring Mode (GMM) of ESA's Envisat Advanced Synthetic Aperture Radar (ASAR) sensor is used for wide area coverage when the sensor is not tasked with specific data acquisitions. SAR or active microwave produces a high resolution image of the surface radar energy backscatter beneath the sensor. In GMM image resolution is reduced to 1 km to reduce data processing load and allow global coverage. GMM shows up the boundaries of ice and water areas as well as some large floes. The example in Figure 7 is from 26 February and is a mosaic produced by DCRS of the previous 3 day's images. It covers the entire Weddell Sea. Open water with waves scattering radar energy appear on the right side of the image. Open water with little or no wave activity does not reflect radar energy so well and appears as the black areas in the image. Sea ice floes and open water appear as the various levels of grey inbetween. Envisat GMM images are useful in supplementing the WSM images received from Envisat.

The big advantage of SAR sensors like Envisat is that they can see, at high resolution, through the cloud and darkness prevalent in polar regions. This makes them in invaluable tool for planning fieldwork in these areas. A minor negative point is that interpretation cannot be automated and has to be done by human eye. This makes the classification subject to debate especially where open water generates a radar backscatter return similar to ice.

MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard NASA's Terra (EOS AM) and Aqua (EOS PM) satellites. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths covering visual and infrared. During JR97 use was made of a processing stream that had been set up to generate quicklook images to monitor a buoy deployment on the fast ice off East Greenland on JR106N. This takes 250 and 500 metre resolution MODIS data files ordered through the EOS

Data Gateway and uploaded to SAMS, takes out 3 channels used to generate a visual image, and presents them in the form of a geo-located image as shown below. Quicklooks were designed to be of the same map projection and grid as the AWI bathymetry chart used for planning fieldwork.

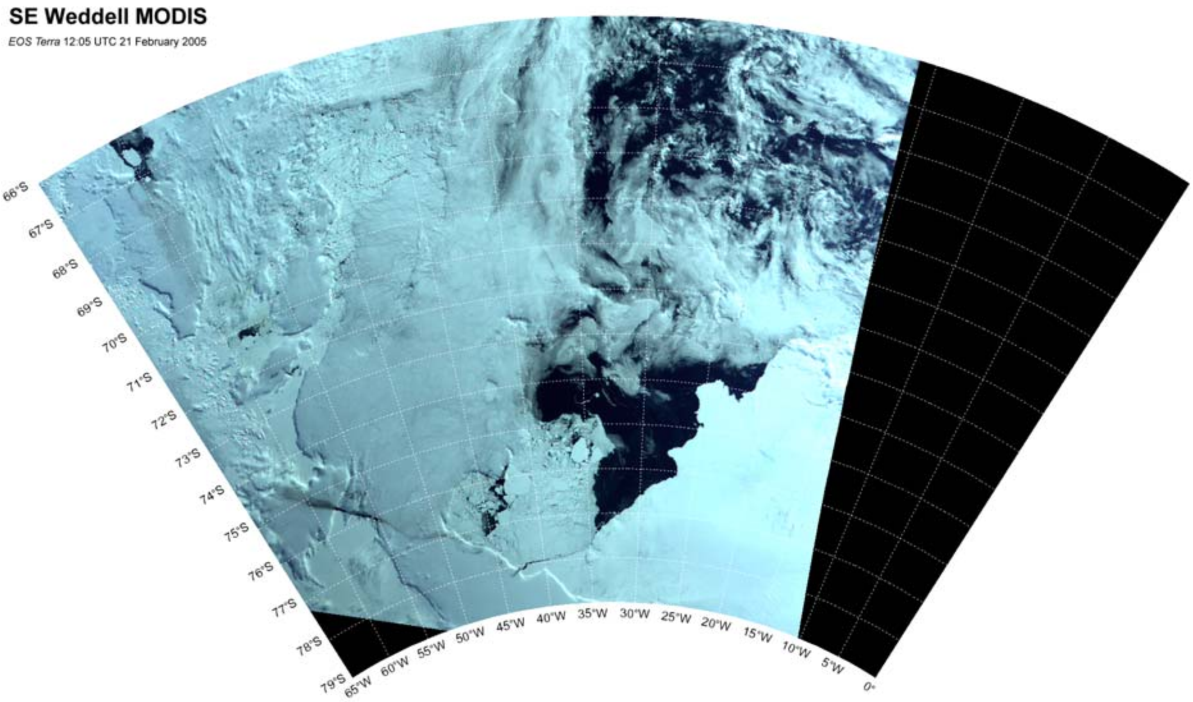


Figure 8. MODIS image of the southern Weddell Sea for 21st February 2005

As MODIS is an optical sensor it is affected by cloud and darkness. During JR97 this seemed to be the prevalent state of the south-east Weddell Sea and the image in Figure 8 is one of the few where the ice in this region can be clearly seen. However there is a solid blanket of cloud over the rest of the Weddell Sea.

Envisat WSM

Envisat's Wide Swath (WSM) mode provides the same width of coverage as GMM but with a greater resolution of 150 metres. It was arranged that the position of JCR at the time of the satellite overpass would be e-mailed to NPI to allow the position of the ship to be marked in the image and a full resolution of an area around the ship to be produced.

16 January (Pre-cruise Planning)

The image from 16th January (Figure 9, generated by NPI) shows the situation in the Weddell Sea two weeks before the cruise. In the south the ice edge is clearly defined but is diffuse in the north.

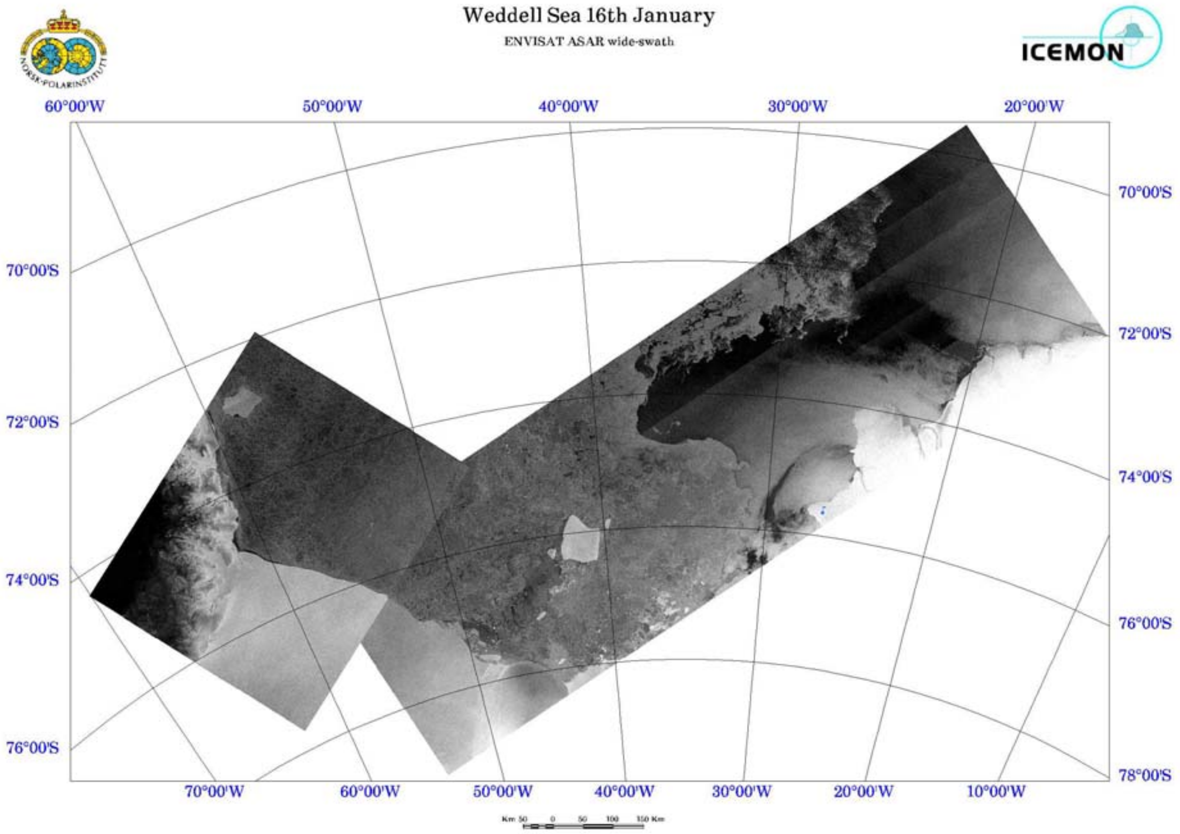


Figure 9. See text

Around Fimbul Ice Shelf (Figure 10), there is no indication of any sea ice and the ice shelf front is totally clear.

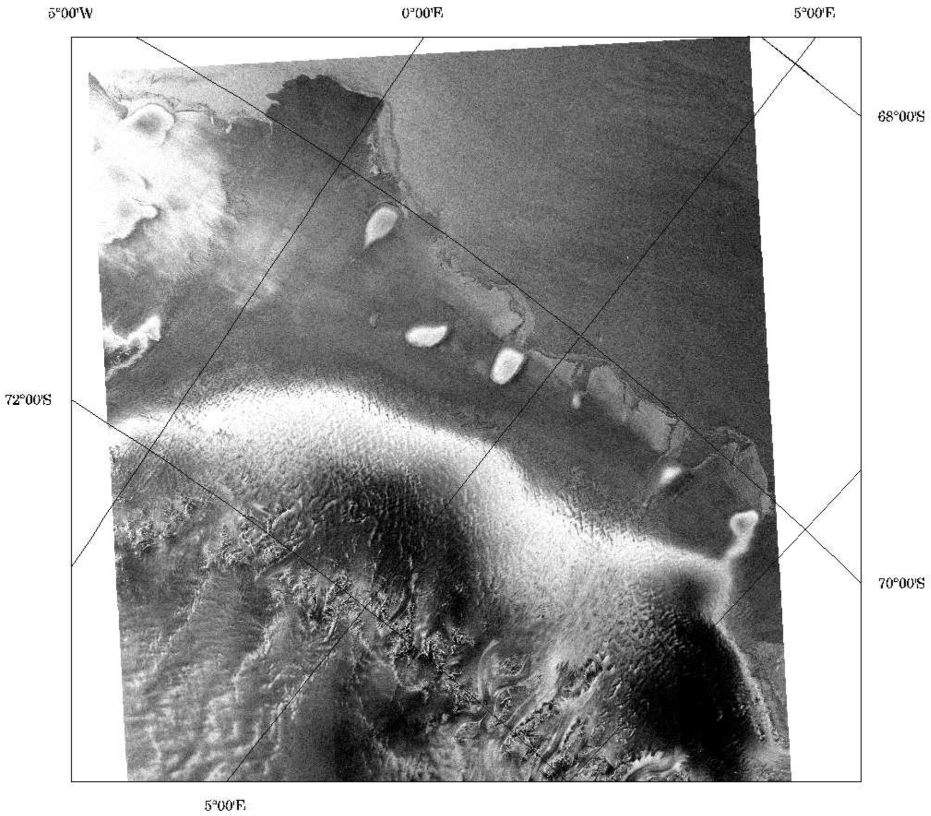


Figure 10. See text

4 February

There was a problem with delivery of images on 4 February. ESA failed to process the images until 8 February. As a result planning had to be done on the less detailed, and so subject to more debate, uncorrected GMM images.

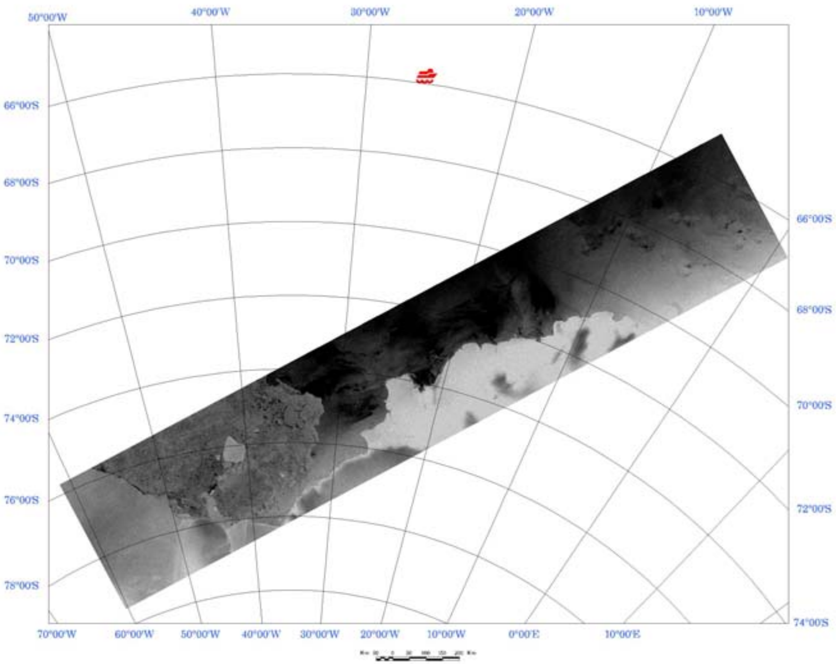


Figure 11. See text

In the GMM image (Figure 11) there is clear open water on the eastern side of the Weddell most of the way south to the Filchner Ice Shelf along the Coats Land coast. Unfortunately in the critical area the incidence angle of the SAR and the increased water backscatter mask out the ice.

11 February

The set of images delivered on 11 February for the south-east Weddell Sea gave the first clear indication of the ice conditions in that area. Figure 12 shows the image with a division of the scene into different ice regimes.

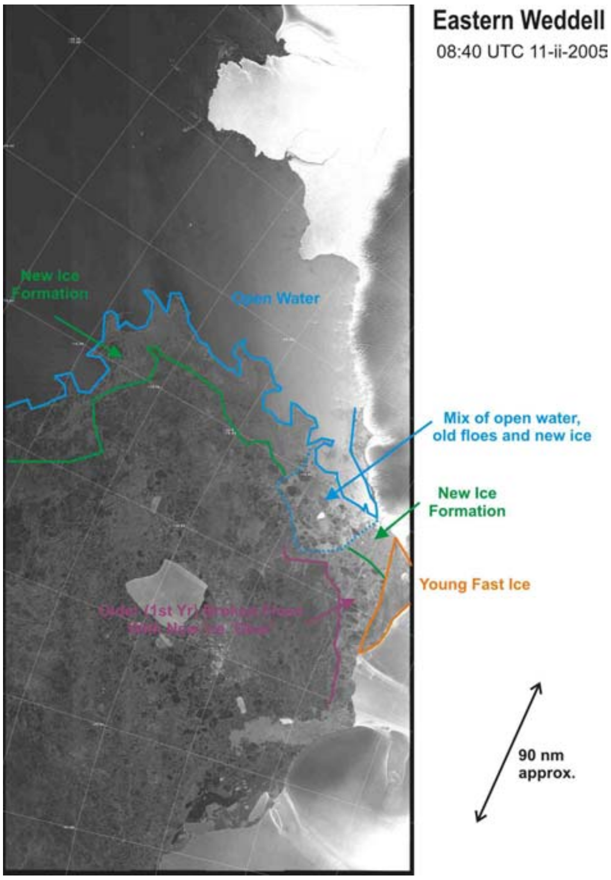


Figure 12. See text

In the Fimbul area (Figure 13) a stream of brash ice can be seen being advected in from the east by coastal currents.

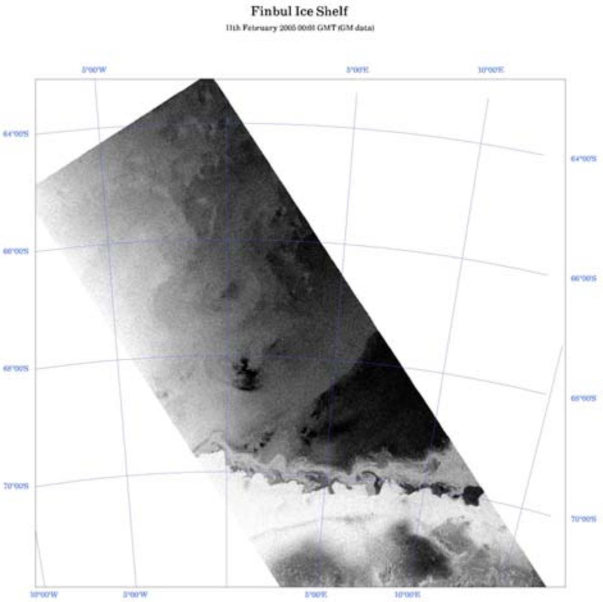


Figure 13. See text

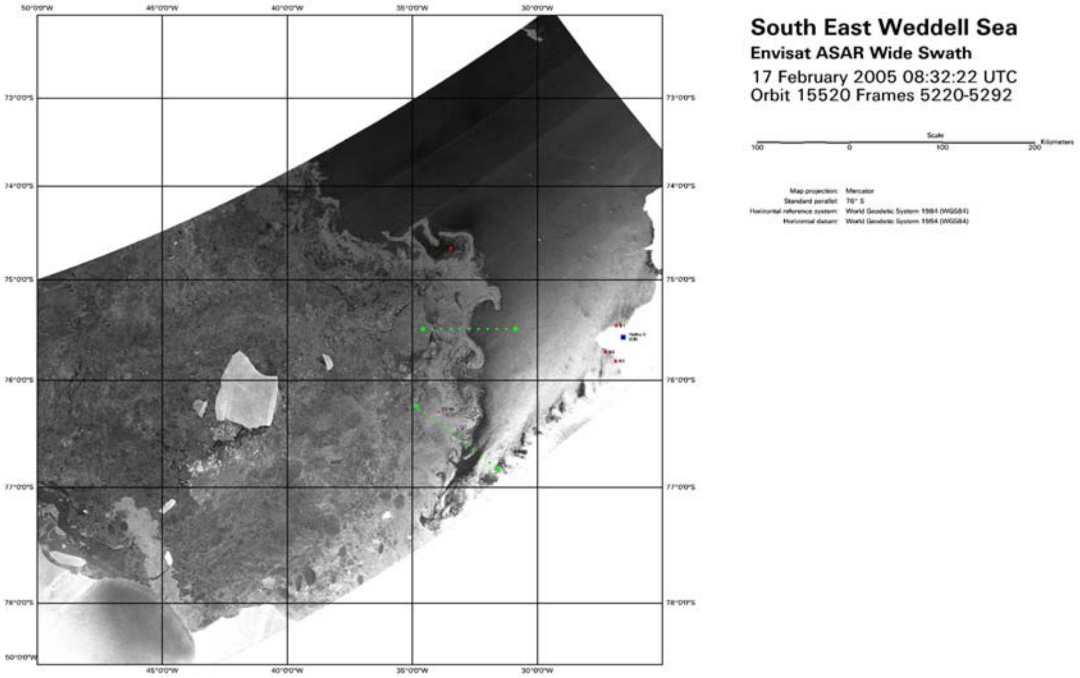


Figure 14. See text

17 February

The 17 February image of the south-east Weddell Sea is shown in Figure 14. This image was used for planning the sea ice work in the area. The green dotted lines represent proposed transects into the ice. Also marked are the positions of the BAS moorings around the Brunt Ice Shelf and at the Weddell Sill.

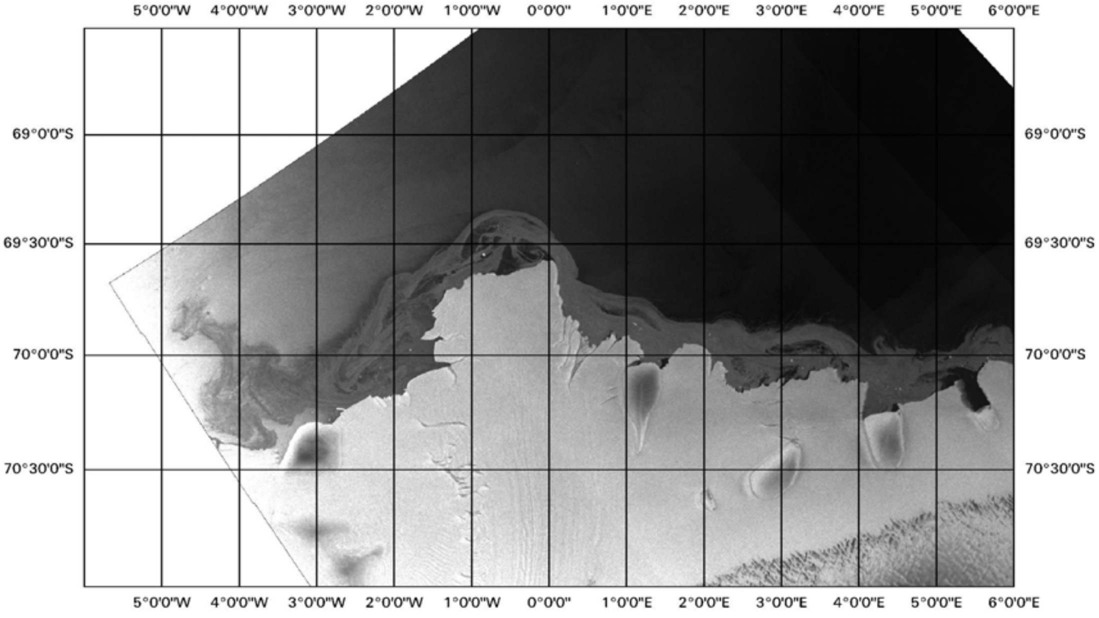


Figure 15. See text

19 & 20 February

As the Fimbul image from 17 February was unavailable (as a result of a delay in processing by ESA) updates of the Fimbul for the 19th and 20th February were obtained as the *RS Polarstern* was in the area. The most comprehensive of these, from 20 February, is shown in Figure 15, and covers the entire coastline from 4°W to 6°E. This was used to generate a coastline vector for the multibeam swath plots. A stream of sea ice can be seen being carried westward around the ice tongue and filling the western creeks. A finger of ice shelf has also broken off in the 24 hours since the last image and can be seen at 70°15’S 2°40’W.

23 February

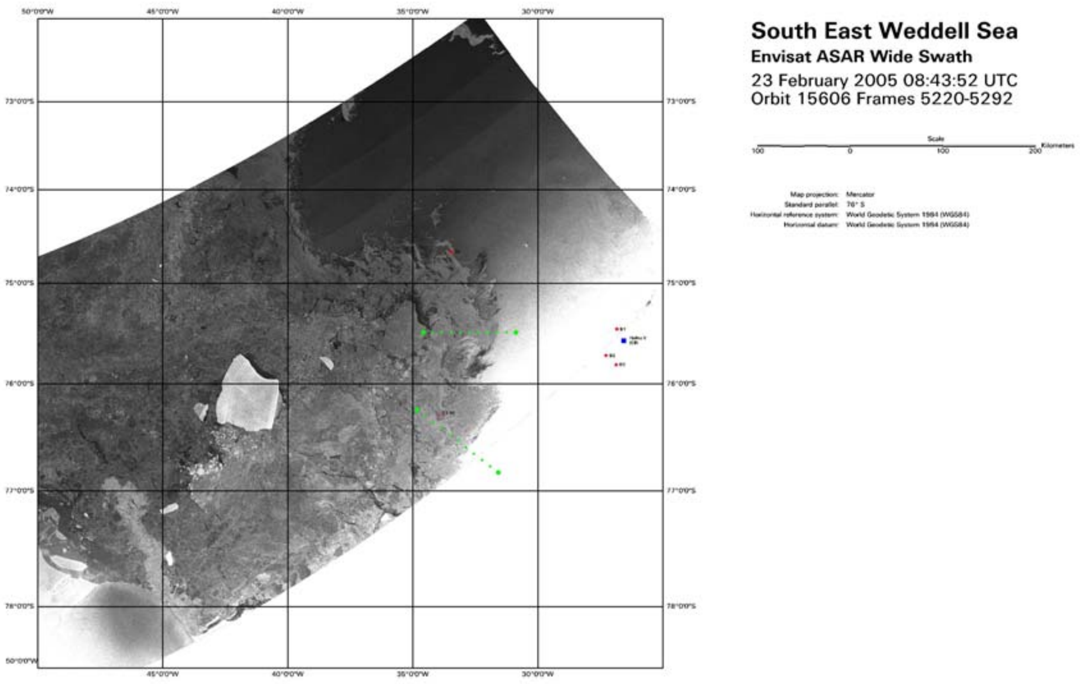


Figure 16. See text

The next southern Weddell Sea image (Figure 16) just missed covering the open water area we were interested in. However the ice edges remained stable, as confirmed by a transect into the ice on 26 February.

2 March

With final Envisat scene from the Weddell Sea (Figure 17) being available on the *JCR* less than 3 hours after acquisition by the satellite it was possible to undertake some validation with recognisable sea ice features.

The transect into the ice started at a large, several miles wide, tabular iceberg clearly visible in the satellite image (see photograph in Figure 18). Comparison of this image with GMM images from previous days showed that this iceberg was drifting south in the Weddell Gyre. The satellite also showed the existence of a gap in the ice pointing towards a large unbroken floe.

The transit into the ice encountered the sea ice types and concentrations indicated by the image, starting with sheets of grease ice and following on through pancakes to broken 1st year floes.

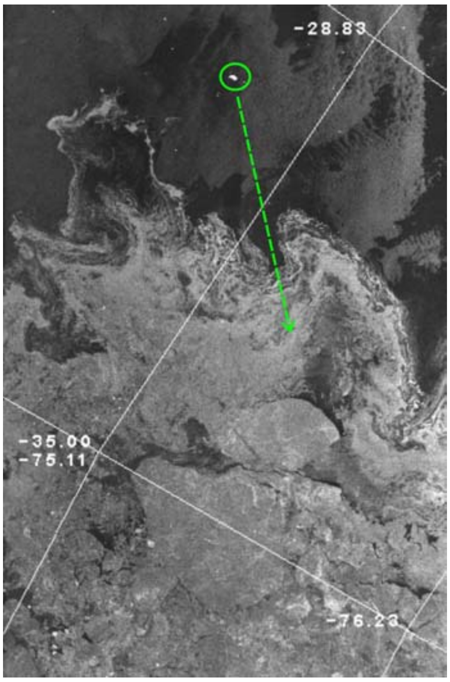


Figure 17. See text

Figure 18 See text

Autosub Missions

Test Missions

On 11th February, we arrived in the working area near the Fimbul ice shelf, and began some basic shakedown of systems and sensors testing with Autosub.

Mission 378

As well as a basic systems and sensors test we planned to test high altitude control, and yo-yo profiling. Unfortunately, due to a procedural mistake (a wrong version of the mission script was compiled and downloaded), upon diving, the vehicle immediately head off in a northerly direction. A timeout on the holding pattern prevented the Autosub getting into serious trouble, and it surfaced 1 hour later. The mission in practice ran at a constant 200 m altitude for 1 hour (6km).

Mission 379

Mission 379 was a re-run of the planned mission 378, with a test of the homing system at the end of the run. It was completed without incident. The homing trails were partially successful. The Autosub homed in when at range of 1000 m, but always lost the homing signal, when its range had decreased to around 300. The reason for this, we surmise, is that with Autosub travelling at a homing depth of 200 m, which is 100 m below the ship's homing beacon, that the geometry for signal reception becomes poor as the horizontal range to Autosub gets shorter. In future we must ensure the homing depth is only a little deeper than the homing beacon.

The altitude control appeared to be quite unstable when at high altitude, with high pitch excursions. Further analysis suggested that the algorithm which corrected the ADCP ranges for pitch was ineffective. The software was changed so that the internal ADCP tilt sensors were used instead of the INS systems.

Mission 380

This was a simple, short, out and back mission to test the altitude control. The altitude control, although improved, still showed excessive oscillation in depth and pitch when at a high altitude. The algorithm was changed again (this time to use the average of the four ADCP ranges, rather than try to pitch correct the two forward beams). The mission was terminated by homing the vehicle into towards the ship, then sending an acoustic end mission command.

Mission 381

This was another short mission to test altitude control at high altitude (450 m and 350 m). The results for altitude control were now acceptable.

Missions under Fimbul Ice sheet

Mission 382

The planning for mission 382 was based upon previously carried out seismic soundings of the Fimbul ice shelf. Figure 19 illustrates the mission profile.

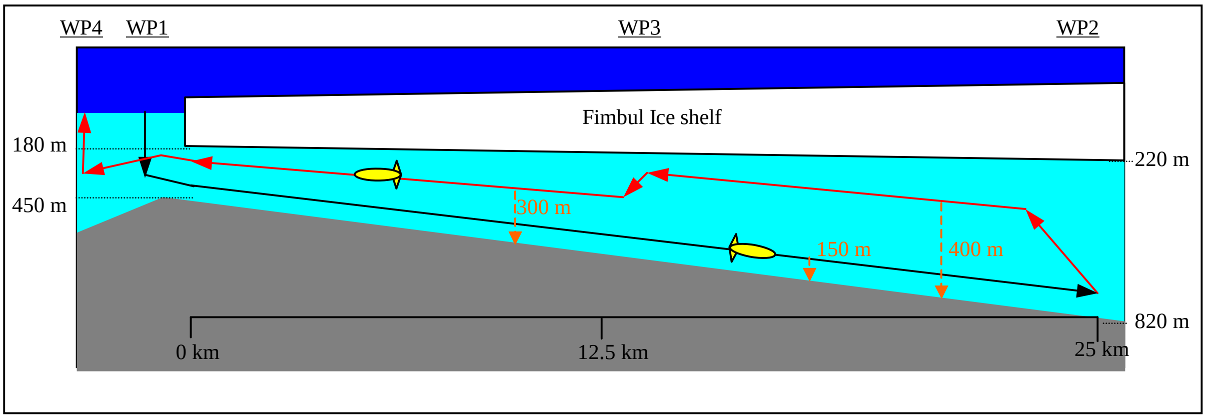


Figure 19. Planned profile for mission 382

After a dive weight assisted dive, the Autosub circled waypoint 1 (WP1 in Figure 19) at an altitude of 200 m while we checked via an acoustic telemetry link that all systems and sensors were functioning correctly. We then sent a "Start" command (using the acoustic command system) and Autosub proceeded under the Fimbul ice shelf.

The transit in was in constant altitude mode at 150 m off the seabed. At WP2, Autosub turned back onto a reciprocal track, this time at an altitude of 400 m. At WP3 it descended to 300 m, and continued until it reached the recovery waypoint, WP4, which was set further away from the ice shelf, to allow for navigation errors. The reason for the change in altitude during the return, was an attempt to maximize the amount of time that the Autosub would be able to survey the underside of the ice shelf using the upward looking swath system.

During the mission we measured the range to Autosub (up to 18 km range), by listening for the emergency beacon transmission, which Autosub transmits at 10 minutes intervals.

The mission proceeded without problems. When recovered, the Autosub Navigation estimate had drifted 400m to the south west of the actual position. This drift, representing 0.8% of total distance traveled, was worse than anticipated (0.2%). The most likely explanation for now is that the drift was a result of the long-range bottom tracking during the return leg, giving larger errors than normal. However more investigation is needed. A further problem noted was that the speed through the water, as measured using the upward looking ADCP was about 1.6% faster than the speed through the water measured suing the downward looking ADCP. The scale factor for the upwards looking ADCP was adjusted to correct for this. Again we need to investigate this.

Waypoints:

WP_1 = S: 70:03.00, W:01:30.00

WP_2 = S: 70:09.70, W:00:49.60

WP_3 = S: 70:06.35, W:01:09.80

WP_4 = S: 70:02.50, W:01:33.00

Event Times (13th February 2005):

1223	*Dived*
1241	*Acoustic Start (ending circling, beginning mission)*

2317 On surface

2359 Recovered

Mission 383

The mission plan was to travel a similar distance under the ice shelf as Mission 382 (25 km). The main difference was that the Mission was planned to yo-yo profile inwards (see Figure 20), then at the turning point to travel out on the reciprocal line at 80 m under the ice shelf. The Mission Plane is illustrated below. After circling the start waypoint, (waiting for an acoustic start command while systems are checked out via telemetry), the Autosub headed into the ice cavity at a constant 100m off the seabed. After progressing about 2 km into the ice cavity Autosub was to begin yo-yo profiling between 80 m off the seabed and 80 m from the ice shelf. At the turning point (or if an obstacle had been encountered), the Autosub would turn onto the reciprocal course and swath the underside of the ice at an altitude of 80 m. The seismically measured ice drafts and water depths for this run were similar to the first, although Mission 383 had a more southerly outbound course compared to mission 382, 135 degrees rather than 100 degrees.

Six hours after the start of the mission the ship returned to the proximity of the launch site to monitor the emergency beacon. It was heard to be transmitting every minute rather than its normal 10 minute interval. This was a sign that Autosub had aborted its mission and further monitoring of the signal revealed that Autosub was stationary under the ice.

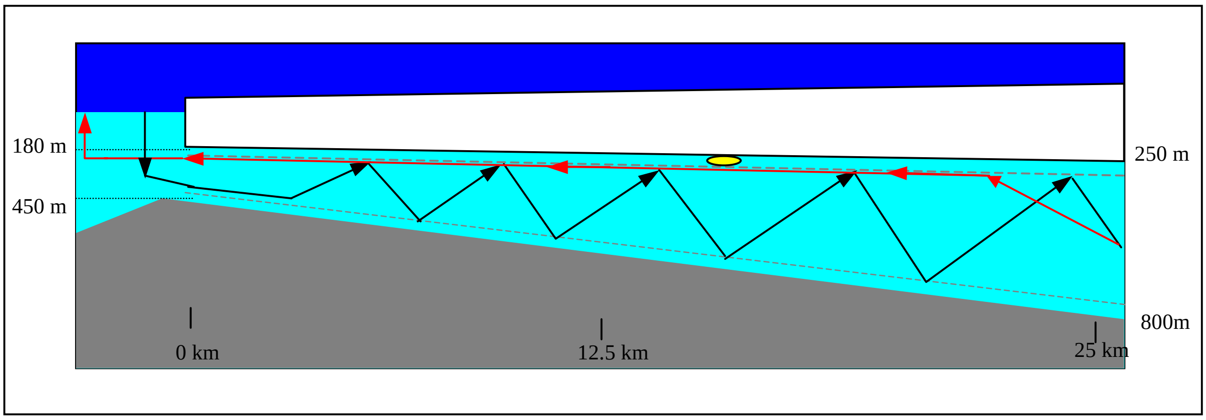


Figure 20. Planned Autosub Mission 383, under the Fimbul ice shelf. Black traces are the inbound run, profiling, red the outbound run, swathing the underside of the ice. The Ice draft was about 180 m at the edge of the ice sheet, 250 m at the turn around point, 25 km in. The yellow ellipse marks the supposed present position of the Autosub.

Known Facts about Mission 383

0733 16th February 2005.

- Vehicle was launched and dived, using dive weight.
- Position. S: 70 03.50, W 01 30.00.

The launch and start of Mission 383 was similar to Mission 382, and nothing abnormal was noted. The launch used a dive weight, avoiding a surface run up (with can be hazardous in areas where ice is present, because of the risk of damaging the propeller blades). Following launch the vehicle circled around the start waypoint, at an altitude off the seabed of 200 m, waiting for an acoustic command to start it on it's under ice mission.

Acoustic telemetry and emergency beacon times are listed in the JR97 Autosub log book. Extracts are copied to this document.

```
0743  Acoustic telemetry (all angles in degrees, all distances in m). :
```

```
Depth: 214, Altitude: 280 , Heading: 046, Range to Go: 32, Speed: 1.03 m/s, Pitch: -14.0, Roll: -
0.38, Fwd range sensor: 1000 (over range), Stern plane: 10.77, RPM:  350. Leak Voltage 1.65
(normal)., Battery Voltage 97.45 volts. , Battery Temperatures 23.7 C, 20.8 C.
```

The Stern plane reading seemed a little high, but within normal bounds. It was necessary to check that it returned to a value of less than 5 degrees. The system was interrogated again. Stern plane was now 4.29 degrees.

```
0744  Transmission from Emergency beacon received . Up Chirp 51.26 seconds , Down Chirp 51.85
seconds
```

```
0745 Acoustic telemetry: Depth: 263, Altitude: 205, Heading: 129, Range to go: 5,  Speed: 1.25,
Pitch: -2.16.
```

0748 The Telemetry seeming normal, the command start signal was sent acoustically from the ship. Autosub acknowledged the signal, and proceed on its mission. No more acoustic telemetry was received from the Autosub. This is normal, as when the Autosub turns away from the listening position, the telemetry transducer on Autosub has an unfavorable path for telemetry.

The emergency beacon normally chirps every 10 minutes on Autosub, and until 0823, four more emergency beacon chirps were received, confirming the Autosub increasing range. The acoustic tracking system also showed the Autosub to be heading off in the correct direction and speed. Tracking ceased at a range of 3000 m (this is normal range). At 0828 the emergency beacon listening transducer was pulled inboard, freeing the ship for other science activities.

The launch point was 1 km from the ice front, hence the vehicle was 2 km under the ice shelf when we ceased monitoring. All seemed normal. When we monitored the Emergency Beacon transmission, 6 hours after the start of the mission 383, we found that it was transmitting at the 1 minute interval. The emergency beacon is a 4.5 kHz acoustic transmitter. When an abort event occurs on the vehicle, the acoustic projector array is dropped on a 15 m cable under the Autosub, and it begins to transmit at a 1 minute (rather than normal 10 minute) interval. This mode would also be triggered if the projector array had been mechanically dropped for any other reason, as a reed switch position sensor detects this event. The reasons for beacon drop and triggering without the abort system are, electrical supply failure to the drop circuit or mechanical shock (quite extreme).

Acoustic position fix using emergency beacon

Ranging and triangulation using three positions of the arrival time of the beacon transmission indicated that the vehicle was at a distance of 17.5 km from the start position of S: 70 03.5, W: 01 30.0 and is a perpendicular distance of 194 m south west of the vehicle intended track (the turn waypoint was S:70 13.04, W: 01 02.3). This would suggest that Autosub was following its intended track when it aborted.

On 21st February, the ship returned to the ice shelf front, and we listened for Autosub again. Triangulation placed Autosub less than 250 m from the original position. This displacement is within the error bounds of the measurement, given that the clock on the beacon had drifted by 1.72 seconds. Hence we conclude that the Autosub had probably not moved in the past 6 days. We received a strong signal from a range of 26 km.

Table 1. Summary of Autosub Missions on JR97

#	Start Time	End Time	Description	Comments
378	11/2/2005 11:47	11/2/2005 13:12	Test of profiling between 30 alt, and 30 m depth. Test of constant altitude modes 350 m , 450 m .	Incorrect initial waypoint programmed in. Surfaced after 1 hour. 200 m constant altitude run
379	11/2/2005 15:24	11/2/2005 21:14	Repeat of 378. Homing System tested at the end of the run	Instability in high altitude depth control. Homing system lost tracking when Autosub was less than 300 m range. Presumably due to bad geometry for sound path.
380	11/2/2005 22:10	12/2/2005 00:40	Short out and back test mission to test high altitude depth control at 500m and 350 m.	Depth control improved, but still not acceptable. Algorithm for ADCP range correction changed again.
381	12/2/2005 18:30	12/2/2005 19:30	Rerun of mission 380, to test depth control.	Depth control at high altitude now acceptable.
382	13/2/2005 12:23	13/2/2005 23:18	Head Under Fimbul Ice Shelf. 150 m altitude in. 400m and 300 m altitudes out. Swathing the under ice surface on the way out.	Successful completion. Drift of 400 m in Navigation over the mission. Upward ADCP velocity scale factor was an unexplained 1.5 % different from downward looking velocity scale factor.
383	16/2/2005 07:34	-	Plan to profile in between 80 m off the seafloor to 80 m off the ice shelf, then turn and run reciprocal track, swathing the underside of the ice shelf at 80 m range.	Autosub lost 14km under the ice shelf. Presumed floating. Emergency beacon had dropped, and was transmitting at 1 minute interval, indicating "abort" state.

Autosub Scientific Sensors

Sensor suite

For JR106 the Autosub vehicle was fitted with the following scientific sensors:

- RDI 150kHz ADCP looking downwards
- RDI 300kHz ADCP looking upwards
- Kongsberg EM2000 Multibeam swath system looking upwards.
- Seabird 911 CTD system.
- Edgetech FSAU sub-bottom profiler

These instruments are described separately in the following sections. Figures 3, 4 and Table 1 in the Autosub Mechanical section of this report shows the exact sensor locations. All the electronic systems on the vehicle are connected to a single control network. The data from all sensors apart from the multibeam system are recorded on the Autosub data logger. The Autosub logger uses a proprietary data format but the data is translated into standard ASCII text files using the Logger File Translator software running on a PC. This software also translates the CTD data into a standard Seabird format file. The resultant ASCII file is then imported into the Axum processing software and a standard script is run to produce the general post processed navigation file (.bnv file) and various instrument specific files including a navigation file for the EM2000 multibeam system.

Sensor Synchronisation

The time synchronisation of the various on-board systems is important, especially where data from different systems is likely to be merged at a later date (post processed navigation data for the EM2000 is one example of this). Wherever possible the network time protocol (NTP) system is used which allows for time comparisons with a resolution of better than 1millisecond. The primary reference is a GPS receiver which sends an accurate pulse on each second boundary to the Autosub shipboard data server. The Edgetech sub-bottom profiler acts as the primary Autosub vehicle time server and uses the Autosub shipboard server as a reference whenever Autosub is in contact with the ship. The Autosub logger can synchronise to the Edgetech on start up and the Kongsberg EM2000 is synchronised to the logger. One problem is the poor quality of the logger clock which can drift by 10 seconds in 12 hours. The data processing system can measure and compensate for this drift so that the data output in the navigation files is correct. In the case of the EM2000, it was realised towards the end of the cruise that the instrument continues to use its internal clock to timestamp the data. The difference between the internal clock and Autosub time is recorded and any post processing software must take this difference into account.

The same GPS referenced NTP system is also used to provide time information for the emergency beacon receiver software.

The Autosub TimeSync monitoring software is run during each mission in order to monitor the clock drift between underwater systems and various shipboard systems. The results are stored in the TimeSync directory. The .txt file is the more verbose version while the .dit file contains the differences in an ASCII table which can be read by most data processing software.

Seabird 911 CTD system

Autosub is fitted with a Seabird 911 CTD system, which includes two sets of conductivity and temperature sensors. These are mounted in a ducted system with sea water pumped through them at a precisely known rate. Depth is measured by a Digiquartz pressure sensor. In addition, a Seabird SBE 43 oxygen sensor is fitted which is situated in the same duct as the secondary CT sensors. The output from these sensors is recorded at a rate of 24Hz.

Sensor	Location	Serial Number
Primary Temperature	Port Side	2342
Primary Conductivity	Port Side	2760
Secondary Temperature	Starboard Side	2912
Secondary Conductivity	Starboard Side	2730
Oxygen	Starboard Side	0259

Data from the system are continuously logged whenever Autosub is switched on but, in order to prevent excessive wear on the pump, water is only pumped through the C/T sensors once a predetermined pressure threshold has been exceeded. The data are stored on the Autosub logger in a proprietary format but is normally translated into a Seabird format data file (.dat) at the end of each mission. This data file, together with the necessary configuration file was then passed to the scientific party for further processing. Sensor calibration data is stored in a separate file with the .con extension. For the JR97 cruise the data was processed using the JR097new.con file which contained calibration data from October 2004.

Edgetech FS-AU Sub-Bottom Profiler.

The Edgetech FS-AU is a sub-bottom profiler that transmits a swept frequency tone or ‘chirp’ containing frequencies between 4 and 12kHz and listens for the return. It can determine information about the seabed and the layers just under the seabed from the characteristics of the return echoes.

On Autosub the instrument is triggered by a controller connected to the vehicle’s LONWorks network. This controls the pulse rate and also allows the trigger pulse to be synchronised with other systems in order to control interactions between instruments. The FS-AU has been shown to affect acoustic communications with the vehicle and it is therefore disabled whenever these communications are taking place.

For the JR97 cruise the instrument was set to ping on every fourth sync pulse which resulted in a ping repetition period of approximately 6.5 seconds. Data was collected on all missions where Autosub approached close enough to the seabed. A quick first look using the supplied J-Start diagnostic software suggests that the data appears to be good but Autosub was flying too far from the bottom for J-Star to give much information. This is due a range limitation of 190 metres with the J-Star software.

Kongsberg EM2000 Multibeam Swath System.

The Kongsberg EM2000 is a multibeam swath bathymetry system which operates at a frequency of 200kHz and can give up to 111 beams of data with an angular coverage of up to +/-60 degrees under favourable conditions.

On Autosub the instrument is triggered by a controller connected to the vehicle’s LONWorks network. This controls the ping rate and also allows the trigger pulse to be synchronised with other systems on the vehicle in order to control interactions between instruments. This controller also sends time, range aiding and navigation information to the instrument. A second LONWorks controller sends attitude and depth information to the instrument.

For JR106 this system was fitted with the transmit transducer mounted in the nose of the Autosub vehicle and the receive transducer was mounted in the tail section facing upwards. The transducers were mounted behind polythene windows in the vehicle’s fibreglass outer panels. (See table ? in the Mechanical section of this report for exact sensor locations).

The initial instrument settings used were those that appeared to have given good results on the JR106(N) cruise. The beam spacing was set to be equidistant and the maximum beam angles were

+/- 60 degrees. The sensor roll settings were set to zero, which meant that the system would place the returns from the bottom of the ice shelf below Autosub rather than above it. Further post processing would be necessary to compensate for this. This post processing software, which was started on the JR106 cruise, is still unfinished at the time of writing.

When first tested on deck, the EM2000 did not respond at all. It was necessary to open the instrument’s housing and connect a video monitor to diagnose the problem. When this was done it was found that the flash memory that was used to boot the system had failed. The processor card was replaced and the current version of software loaded which resulted in a working system.

Later in the cruise it was found that the EM2000 had again become unresponsive. This time it was possible to connect to it via FTP for a few seconds after booting up. This problem had appeared before and, as before, the solution was to delete the ‘runtime’ file and reload this file from a backup. It is possible that this corruption is caused by a problem with an imperfect radio link between Autosub and the EM2000 controller software, which updates the runtime file every time it is started. This controller software has not been designed with AUV use in mind and must be used with caution. The alternative EMControl software is available but this has not been developed sufficiently to be user friendly.

It was also found that the transmit pulse timing jitter was higher than expected at around 200mS. High levels of jitter had been seen on previous cruises and the triggering software in the controller had previously been changed in order to improve this. It was decided to change the software further and remove any little used parts of the code in order to improve the jitter performance.

The only mission to give data from the EM2000 was Mission 382, which was run under the Fimbul ice shelf. The return leg of this mission was run with a minimum overhead clearance setting of 100 m. This is greater than the optimum distance for the EM2000 but, given that the features of the underside of the ice are unknown, it was felt that this was a safer distance whilst still giving the opportunity of collecting a limited amount of data from the EM2000.

The picture in Figure 21 shows a typical section from the run out. The top left corner shows an area where the underside of the ice shelf was out of range while the flatter sections show areas of good returns. This section of data has not had the rotation applied to correct for the incorrect sensor orientation but it gives an indication of data quality. There are obvious features present, which can be analysed further once the post processing software has been completed.

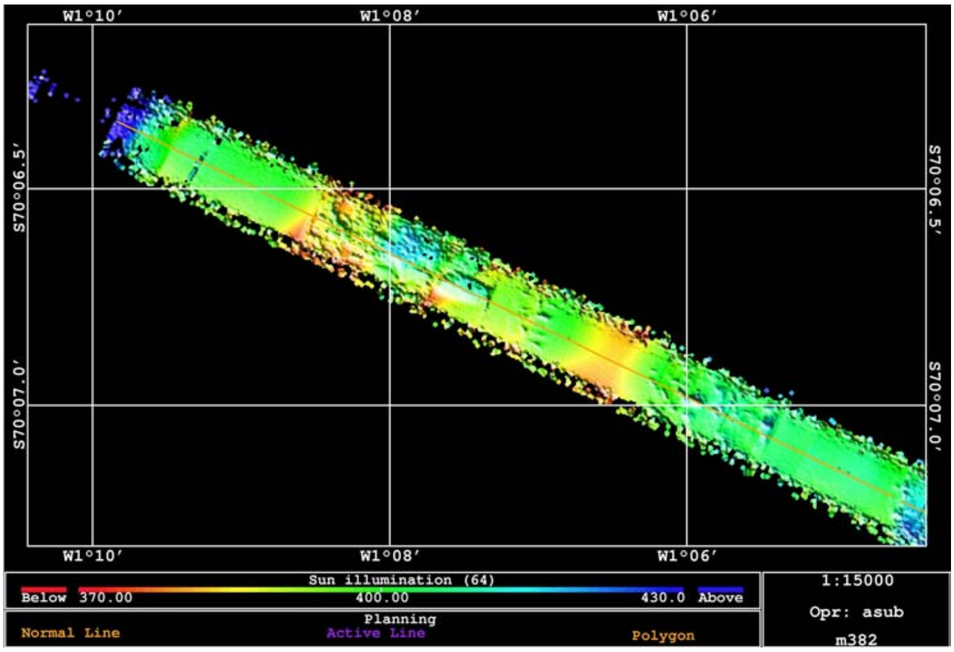


Figure 21. Sample of Autosub EM2000 data from Mission 382.

Results from the upward mounted EM2000 during mission 382

Introduction

On the return leg of Mission 382, Autosub-2 was programmed to stay 300 m from the sea floor, and maintain a distance of 100 m from the underside of Fimbul Ice Shelf (FIS). The route that Autosub-2 took from under FIS meant that bedrock elevation decreased as it headed closer to the ice shelf edge, and hence open water. This was due to Autosub-2 travelling out across the northwestern slope of the large central cavity beneath FIS. At approximately 24 km from the ice shelf edge, the water column thickness was less than 400 m, causing Autosub-2 to stay 100 m from the underside of FIS as opposed to staying 300 m from the underlying bedrock. It was during this time that the EM2000 started to be receive echoes from the underside of FIS. The following description describes the processing procedure used to process to raw EM2000 data.

Removing Autosub-2’s attitude from the EM2000 data

The EM2000 collects waveforms from a few physical directional hydrophone transducers. It does not output them externally at all. Instead it uses phased-array synthesis to synthesise up to 111 virtual beams and reports a number of data about what it considers to be the most distinct echo in each virtual beam. The data is reported in a set of sequential files suffixed `.all`, one for approx 30 minutes of the mission. Each `.all` file consists of a sequence of datagrams, which are records of various types. The datagram we primarily use is the raw range datagram which reports the distances of the echoes in each beam, the beam angle, which varies from scan to scan, presumably in an attempt to locate the clearest echo within an angular region and whether the echo was detected by amplitude or phase shift. Amplitude-detected echoes are generally considered to be more reliable.

The `.all` files also contain attitude and position datagrams, but difficulties in decoding these (which have since been apparently overcome) led us to use the navigation record file (with suffix `.bnv`) for those data and correlate them to the `.all` data using time fields in each file.

Processing began by concatenating all the `.all` files of a mission into a single, time-ordered `.all` file by using the Unix `cat` command. The C program `dg_out` was then run with the `.all` as input producing 2 files: `.out`, which has space separated fields with the raw range for each beam, reflectivity (intrinsic echo strength) for each beam, speed, time, calculated distance since mission start, easting, northing, depth, pitch and roll. Note that at the time of processing, the position and attitude data were unreliable. However, we considered it useful to do data cleaning on this file. Thus plots of this file were produced (see Figure 22) and manual data cleaning was done on it. In particular, manual removal of the cylindrical tunnel roof artefact first seen on JR106N was done at this stage. In order to keep the fixed-column file format data points could not simply be removed. We had to replace them by NaN (not-a-number) indicators.

The above `.out` and `.bea` file formats are designed to be suitable for Matlab input. The `.out` and `.bnv` file were input into the Matlab function `interp_mb2`, which, after correcting for drift and offset between the times in the two input files, interpolated position, speed, pitch, roll and yaw from the .bnv into the appropriate fields of the .out file. The resulting file, of a format similar to that of .out, has the suffix `.cor` .

The `.cor` and `.bea` files were then input to the Matlab function `form_swath2`.

This applies the relevant attitude (pitch, roll and yaw) to each beam individually and to produce a N * 111 * 3 array. The first index is the scan number, the second the beam number. This selects a 3-vector of the echo's [somewhat spherical] coordinates: longitude, latitude and negative depth. This array is stored in a `.pos` file and can then be plotted and have other operations performed on it, e.g. statistics.

Removing erroneous data points

The EM2000 ice draft data from mission 382, after being corrected for Autosub-2's attitude (section above), is shown in Figure 22. At this stage the results are not presented in terms of distances, rather in terms of the 9,133 *pings* that EM2000 sent out, with each ping being synthesised into 111 individual *beams*. To get an idea for length scales at this stage, pings were sent out typically every 4 m (though this is dependent of the speed of Autosub through the water), with the beams being spaced roughly 2 m apart.

Notice in Figure 22 how the outermost beams (numbers 1-15 and 105-111) returned very little data. The reason for this is the way that the upward mounted EM2000 onboard Autosub-2 was set up for mission 382. It was set up so that the 111 beams were synthesised with a nominally fixed angle between them. This fixed angle was calculated from either the maximum angle of the swath being ±60° from vertical, or the swath being no wider than ±120 m from the vertical.

For demonstration purposes, assume Autosub-2 was completely stable (i.e. pitch = yaw = roll = 0°) and flying 100 m from the underside of a flat ice shelf, which was parallel to the horizontal. In this case, an angle of

$$\pm\, arctan(120/100) \;\approx\; \pm 50.13^\circ$$

from the vertical would create a swath 240 m wide (±120 m from vertical). This suggests that the second rule above would have decided the fixed angle between the 111 beams during mission 382. In creating a swath of ±120 m from the vertical, however, the length of the two outermost beams (usually numbers 1 and 111) to the underside of the ice shelf would be

$$(100^2+120^2)^{½} \;\approx\; 156\text{ m},$$

which exceeds the maximum range of the EM2000. This offers an explanation for the poor percentage of returns from the outermost beams of EM2000 during mission 382. It is also evident from Figure 22 that there were a high number of dropouts even in the centre beams of the EM2000. Again, this is most likely to be due to the fact that the distance Autosub-2 was flying beneath the FIS was close to the maximum range of its upward mounted EM2000.

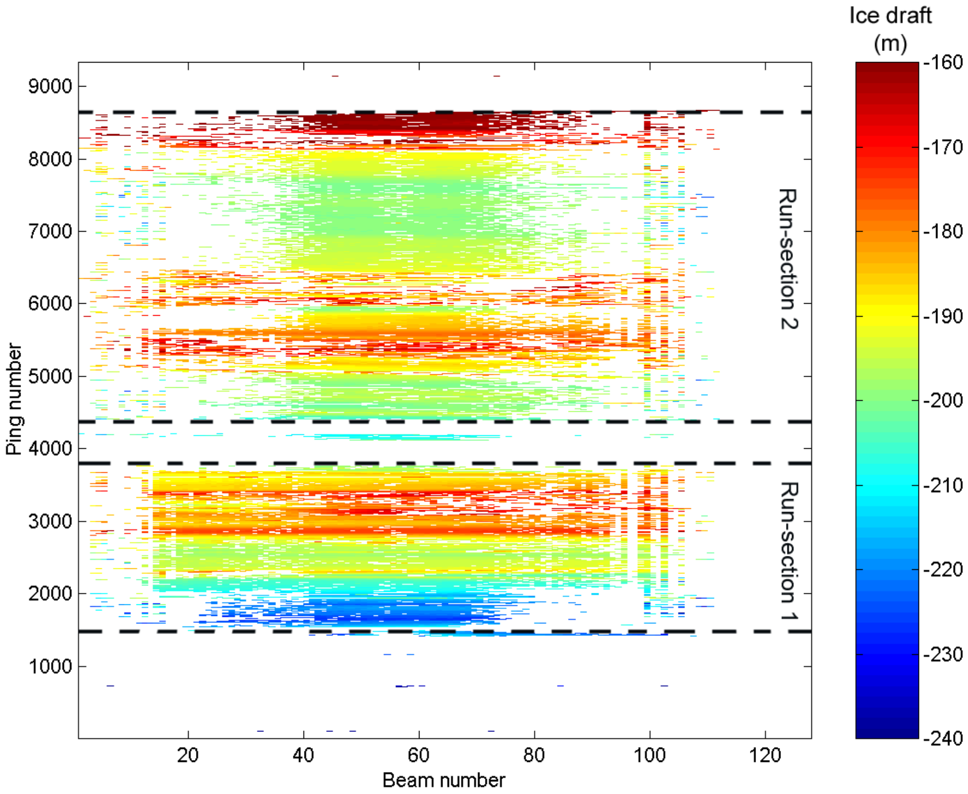


Figure 22. EM2000 ice draft data from Mission 382, after being corrected for Autosub's movement. The data are presented in terms of the 111 individual beams (x-axis) from the 9,133 pings (y-axis) sent out by the EM2000. The horizontal dashed lines indicate where the data were split into two *run-sections*.

There were approximately 1,500 pings from the start of the original data set that contained very little data (Figure 22). Additionally, there is also a large section of the run, between pings 3,900 and 4,200, where a negligible amount of data were received by the EM2000. The data were therefore split into *run-sections* 1 and 2, as shown in Figure 22.

Although not really visible in Figure 22, there is a notable portion of the ice draft data that did get back to Autosub-2, which was obviously erroneous. The programming needed to remove these data points automatically was considered too complex for now, so the decision was made to remove these erroneous points manually. For this task, a MATLAB routine was created (Figure 23). This routine took each of the two run-sections individually, displayed the 111 beams from 25 consecutive pings of the EM2000 in turn. To *clean* the data of erroneous data points, the routine allowed a box to be drawn around a group of points, which would remove them. The axes would then be rescaled automatically, enabling more accurate boxes to be drawn. Erroneous data points were removed until the only points left from the 25 pings were those that were considered "believable". The next set of 25 pings was then displayed, and the process repeated until all pings in both run-sections were *cleaned*.

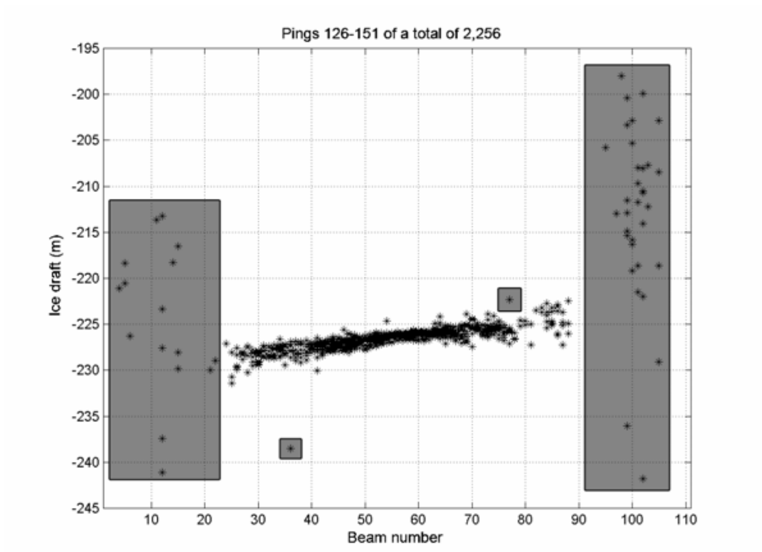


Figure 23: A screenshot of the MATLAB routine used to clean the ice draft data from the upward mounted EM2000 onboard Autosub. Shown are the 111 individual beams (*x*-axis) from pings 126-151 in run-section 1. The y-axis is ice draft. Data points that are considered erroneous are removed by drawing boxes around them. Boxes that were drawn for the 25 pings presented are shown in semi-transparent grey.

The two run-sections of ice draft data, after cleaning was completed, are shown in Figure 24. Comparing this with Figure 22, it is evident that most of the erroneous data points existed in the outermost beams. This is most visible for beams 1-15 of run-section 1 where almost no data are left after cleaning.

For display purposes only, Figure 25 shows the ice draft data, in terms of distance parallel with, and perpendicular to, Autosub-2's track, for that part of the data that suffered the least dropouts. In terms of pings from the EM2000, and the individual beams from each ping, this corresponds to beams 19-91 from pings 600-2150 of run-section 1, as shown in Figure 24. It is stressed that the horizontal axes in Figure 25 have very different scales.

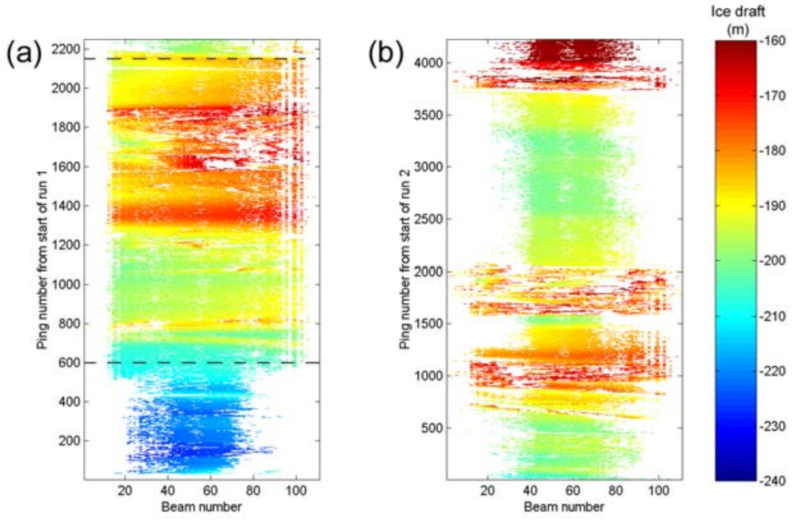


Figure 24. EM2000 ice draft data left from (a) run-section 1, and (b) run-section 2 after *cleaning* (see text). The horizontal dashed lines in (a) show the portion of run-section 1 presented in Figure 25.

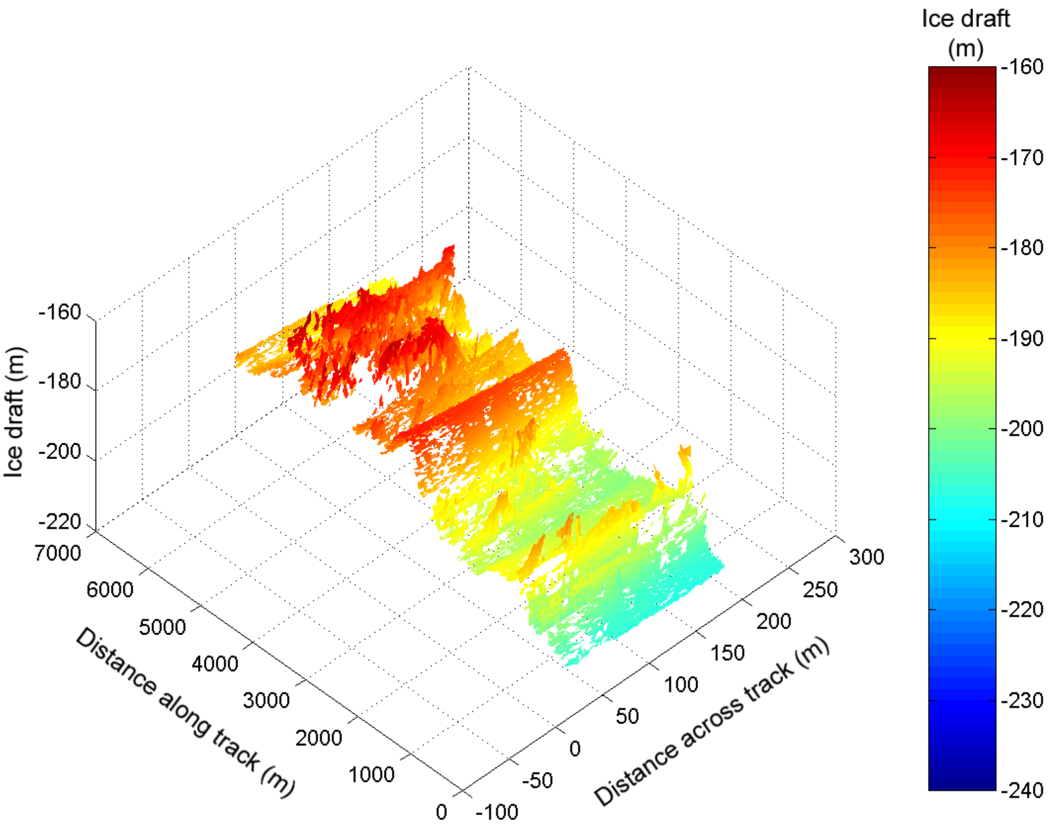


Figure 25. A surface plot of ice draft beneath the Fimbul Ice Shelf. The region shown corresponds to beams 19-91 of pings 600-2,150 from run-section 1 (Figure 24), and is the part of the total run which suffered the least dropouts. Note the differing scale on the *x*-, *y*- and *z*-axis.

Autosub CTD

Kate Stansfield

General CTD description (by James Perrett)

Autosub is fitted with a SeaBird911 CTD system which includes two sets of conductivity and temperature sensors. These are mounted in two separately ducted systems with sea water pumped through them at a nominally known rate if the pumps are operating correctly. Depth is measured by a Digiquartz pressure sensor. In addition, a SeaBirdSBE 43 oxygen sensor is fitted which is situated in the same duct as the secondary CT sensors. The output from these sensors is recorded at a rate of 24Hz.

Data from the system is continuously logged whenever Autosub is switched on but, in order to prevent excessive wear on the pump, water is only pumped through the C/T sensors once a predetermined pressure threshold has been exceeded. The data is stored on the Autosub logger in a proprietary format but is normally translated into a SeaBirdformat data file (.dat) at the end of each mission. This data file, together with the necessary configuration file is then passed to the scientific party for further processing. Sensor calibration data is stored in a separate file with the .con extension. For the JR097 cruise the data was processed using the JR097new.con file which contained the most recent calibration data prior to the start of the cruise.

CTD configuration

The CT sensor pairs are mounted on opposite sides of the Autosub nose cone (see Figure 26), the primary sensor pair on the port side and the secondary sensor pair on the starboard side. Each pair of sensors has a short inflow duct that protrudes through the front of the nose cone and is directly connected to the intake of the temperature sensor and hence to the sensors own CT-duct. Similarly each sensor pair also has a an outflow duct which also protrudes through the Autosub nose cone and is located as near as is practically feasible to the intake duct to minimise any pressure head effects across the ducted system (See Figures 26 and 27).

Internally, the CT sensor pairs are held against the inner surface of the nose-cone panel via the plastic plate that houses the inflow and outflow ducts (see Figure 28). The sensors are then covered by a moulded fibre glass cover (the black pen marks around the sensors in Figure 28 shows the approximate dimensions of the cover) which in turn is insulated from the main payload cavity of the nose cone using a flexible layer of foam (not shown). The space housing the CT sensors is flushed directly with seawater by means of a series of holes through the nose cone panels fore and aft of the sensor location (see Figure 28). These precautions are undertaken in an attempt to minimise any thermal contamination of the data due to water being stored and/or warmed within Autosub’s nose cone.

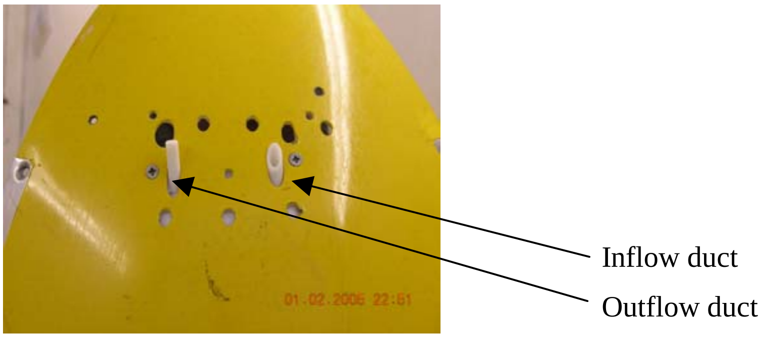


Figure 26. Nose cone of Autosub showing the location of the two CT-sensor pairs and the inflow/outflow ducts.

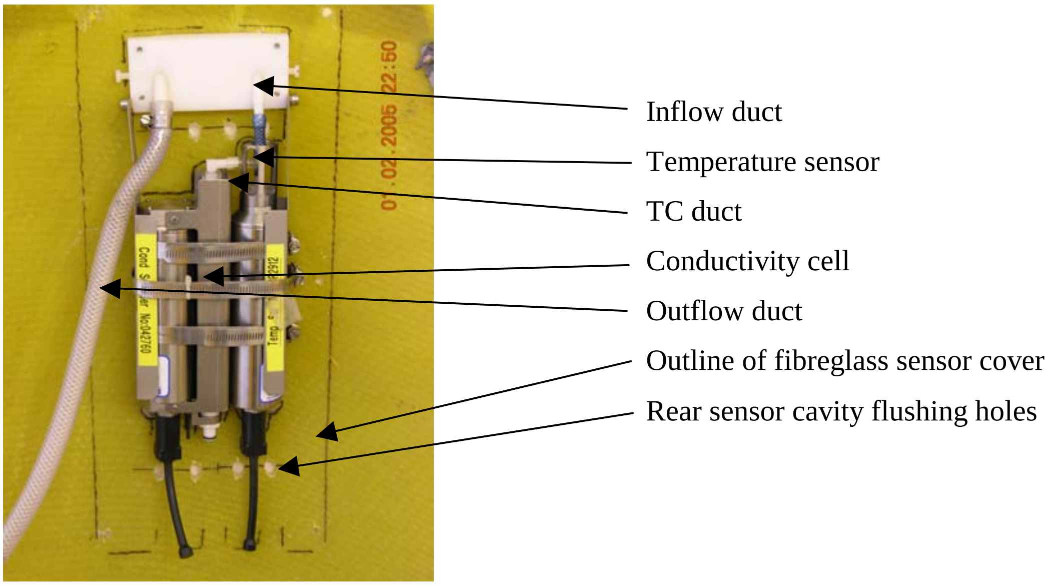


Figure 27. **Close up of the inflow and outflow ducts protruding through the Autosub nose cone. Also shown are the forward holes in the nose-cone that allow the CT sensor cavity to flush with seawater.**

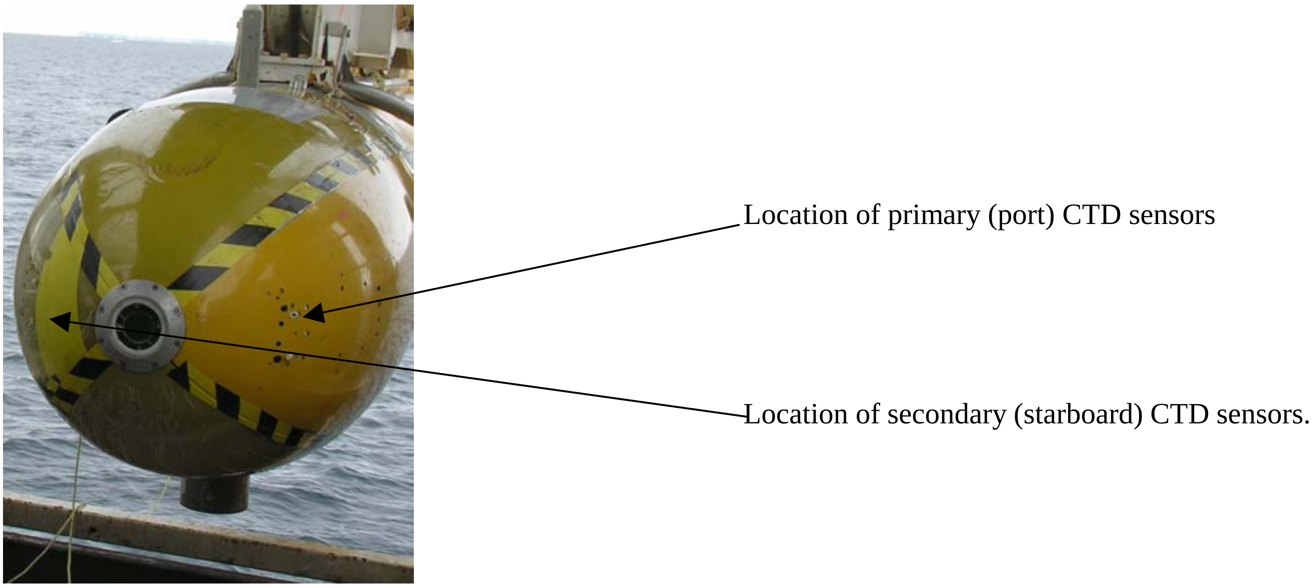


Figure 28. Interior set-up of the CT sensors

Details of the individual instrument location, type/model, serial number and last calibration date are given in Table 2.

Instrument	**Type/Model**	**Serial Number**	**Calibration Date**
Underwater Unit (central payload cavity)	SBE 9 plus	09P-?	N/A
Conductivity (primary – port CT cavity)	SBE 4	04C-2760	07-Oct-04
Temperature (primary – port CT cavity)	SBE 3 plus	03P-2342	09-Oct-04
Conductivity (secondary – starboard CT cavity)	SBE 4	04C-2730	07-Oct-04
Temperature (secondary – starboard CT cavity)	SBE 3 plus	03P-2912	29-Oct-04
Pressure (central payload cavity)	Digiquartz	90573	06-Sep-02
Dissolved Oxygen (central payload cavity)	SBE 43	43-0259	01-May-02
Pump (central payload cavity)	SBE 5T	5T-3090	-
Pump (central payload cavity)	SBE 5T	5T-3609	-

Table 2. Instrument location, type/model number, serial number and last calibration date of the CTD sensors used on JR097.

Output from the primary temperature and conductivity sensors was logged on frequency channels 0 and 1 respectively of the underwater unit, digiquartz pressure on frequency channel 2, secondary temperature and conductivity on frequency channels 3 and 4 and oxygen on voltage channel 4. No other channels were used.

Outline mission descriptions

CTD data were collected on 5 successful missions.

Mission #	Start Time	End Time	Description
378	11/2/2005 11:47	11/2/2005 13:12	Test of profiling between 30 alt, and 30 m depth. Test of constant altitude modes 350 m , 450 m .
379	11/2/2005 15:24	11/2/2005 21:14	Repeat of 378. Homing System tested at the end of the run
380	11/2/2005 22:10	12/2/2005 00:40	Short out and back test mission to test high altitude depth control at 500m and 350 m.
381	12/2/2005 18:30	12/2/2005 19:30	Rerun of mission 380, to test depth control.
382	13/2/2005 12:23	13/2/2005 23:18	Head Under Fimbul Ice Shelf. 150 m altitude in. 400m and 300 m altitudes out. Swathing the under ice surface on the way out.
383	16/2/2005 07:34	-	Plan to profile in between 80 m off the seafloor to 80 m off the ice shelf, then turn and run reciprocal track, swathing the underside of the ice shelf at 80 m range.

Data processing

The SBE 9plus is configured for twelve 24-bit words of data sampled at 24 scans per second. Raw data are logged by the Autosub central data logger. Data are initially extracted from the mission (.log) file using the Autosub wgetasc software. This produces a SeaBird format (.dat) file that can be processed using the standard Sea-Bird SEASAVE-Win32 processing package (in this case v5.32a).

At this stage a clock correction factor is calculated which is applied to the log-sorted data based on the drifts of the data logger clock relative to the SeaBird clock.

The (.dat) files were processed in accordance with the recommendations of Sea-Bird Inc. for SBE-911plus data with oxygen. The binary files were passed through the following processing routines which form part of the Sea-Bird SEASAVE-Win32 v5.32a processing package.

1) *Data Conversion* - data conversion

2) *Align CTD* - advance conductivity (0.073 seconds) and oxygen (6 seconds) relative to pressure.

4) *Cell Thermal Mass* - perform conductivity cell thermal mass correction

using a thermal anomaly amplitude (α) of 3 and a thermal anomaly time constant of 7. ($1/\beta$).

3) *Wild Edit* - mark a data value with badflag to eliminate wild points using

2 standard deviations for pass one, 20 standard deviations for pass two, and 100 scans per block (default values).

5) *Bin Average* - average data into 2 second bins for merging with the ADCP and navigation data.

A brief description of the function of each of the utilities is given below. The reader should refer to the Sea-Bird SEASOFT win-32 manual for further details.

Data Conversion

Converts raw data from an input .dat file to engineering units, and stores the converted data in a .cnv file. Converted data includes: scan number, pressure (db), temperature1 (ITS-90), conductivity1 (S/m), salinity1, temperature2 (ITS-90), conductivity2 (S/m), salinity2, and dissolved oxygen (ml/l). Other diagnostic variables may be appended. Scan number must be output as the first variable. The configuration file JR097new.con was used for this cruise. The International Temperature Scale of 1990 (ITS-90) is used throughout.

Align CTD

Aligns parameter data in time, relative to pressure. This ensures that calculations of salinity, dissolved oxygen concentration, and other parameters are made using measurements from the same parcel of water. Typically, Align CTD is used to align temperature, conductivity, and oxygen measurements relative to pressure. When measurements are properly aligned, salinity spiking (and density) errors are minimized, and oxygen data corresponds to the proper pressure (e.g., temperature vs. oxygen plots agree between down and up profiles). For the SBE-911plus conductivity must be advanced relative to pressure, the default is by 0.073 seconds (1.75 scans). The SBE oxygen sensor data is advanced by 6 seconds relative to pressure.

Wild Edit

Marks wild points in the data by replacing the data value with badflag. The badflag value is documented in the input .cnv header. The Wild Edit algorithm requires two passes through the data: the first pass obtains an accurate estimate of the data’s true standard deviation, while the second pass replaces the appropriate data with badflag.

Cell Thermal Mass

Uses a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. In areas with steep temperature gradients, the thermal mass correction is on the order of 0.005 psu. In other areas the correction is negligible.

In this case the standard values of $\alpha =$ and $1/\beta =$ were used.

Bin Average

Average data into desired time bins.

Following the SeaBird processing the files were converted into matlab format using the Matlab script cnv2mat_asub. This allows merging with the Autosub ADCP data which is describe elsewhere in the cruise report. cnv2mat_asub - converts the .cnv file to a .mat file containing seven variables, data, which is an nvals x nvars dimensional matrix (where nvals is the number of variables and nvars is the number of scans) names, sensors, ctdmatdate, and datstr. Variables other than data contain "header" information about the cast.

CT sensor performance

Using data below 100 metres, the relative offsets between the primary and secondary sensors were calculated for mission 382. The results are shown in Table 3.

Quantity	**Units**	**Mean**	**Std**
CTD C2-C1	S/m	-0.00014	0.00067
CTD T2-T1	°C	0.00006	0.0110

Table 3. Relative sensor differences on mission 382 based on 2-second data below 100 m

Initial investigations into the data collected on the test missions revealed that the secondary temperature sensor was producing noisy data (see Figure 29). The secondary temperature sensor had been repaired and re-calibrated by SeaBird in October of 2004 so it was surprising that the data should be so poor. A test was made by changing the leads to the sensor but no improvement in data quality was achieved. The suspicion (unconfirmed) is that the noise may be due to faulty circuitry within the main SeaBird under water unit.

Because of the noisiness of the secondary temperature sensor data, data from the primary sensors are to be preferred. At this time no drift correction has been applied to either primary temperature or primary conductivity based on calibration histories (see below).

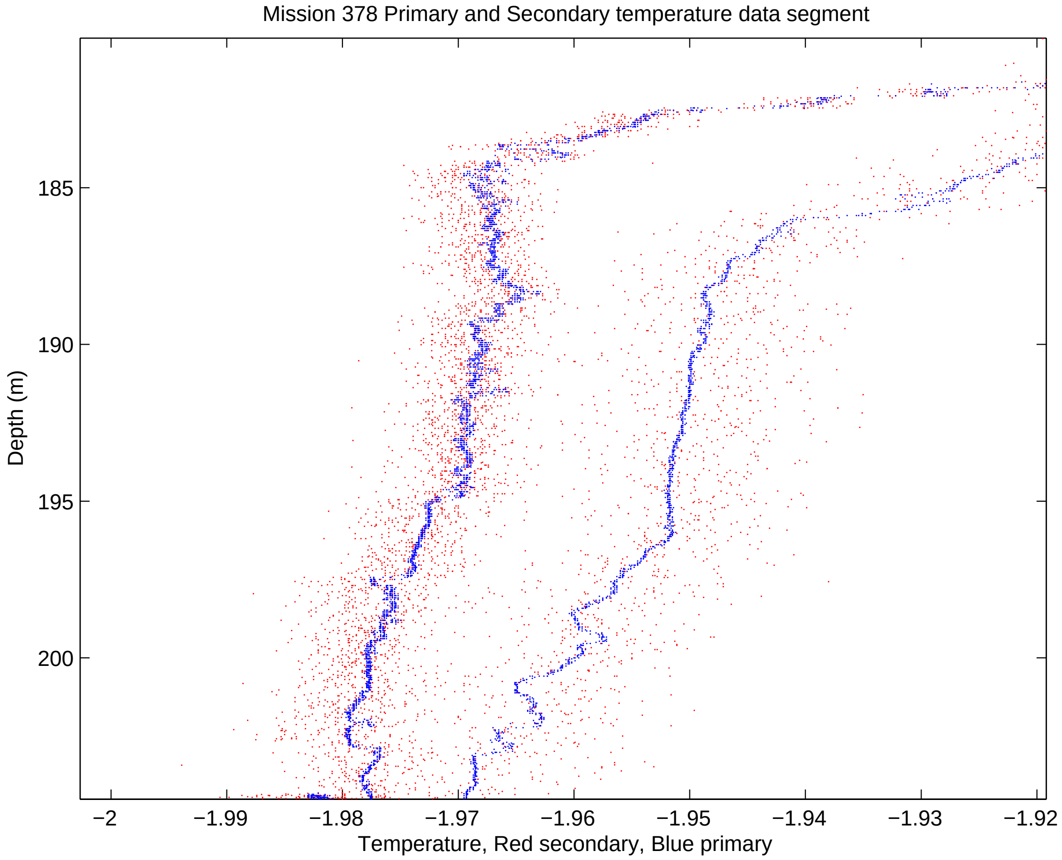


Figure 29. CTD primary & secondary temperature data: example data segment from mission 378 showing noisy secondary temperature sensor data.

General problems

The Autosub TimeSync monitoring software is run during each mission in order to monitor the clock drift between underwater systems and various shipboard systems. The results are stored in the TimeSync files. The .txt file is the more verbose version while the .dit file contains the differences in an ASCII table which can be read by most data processing software.

The corrected time information for missions 379 and 380 should be ignored. There was an interruption to the SeaBirdCTD data stream which is used to correct for the logger time drift. This interruption was caused by updating the software on the EM2000 LONWorks node while the system was running. The files in the logger directory with a b suffix have been reprocessed with an estimated time correction. If it is necessary to relate logger time to real time then the information in the TimeSync files should be treated as the most reliable.

Calibration Histories

As post cruise calibrations of the CT sensors are not possible I include what is known about the sensor calibration histories. The primary temperature (03P-2342) and primary conductivity sensor (04C-2760) had only been returned for one calibration since they were purchased. The pressure (90573) and oxygen sensor (43-0259) calibrations are the originals, as they were never returned for calibration. The secondary conductivity sensor (04C-2730) received a new conductivity cell in March of 2004, so the calibration history before that date is of no use, as is the case with the secondary temperature sensor (03P-2912) which received a new temperature probe in Oct 2004. Table 4 summarises the sensor drifts since last calibration (where applicable).

Instrument	**Serial Number**	**Calibration Date**	**Date of previous calibration**	**Drift since last calibration**
Conductivity (primary – port)	04C-2760	07-Oct-04	10-Jul-02	-0.00050 psu/month
Temperature (primary – port)	03P-2342	09-Oct-04	25-Jul-03	-0.00044 deg C/year
Conductivity (secondary – stbd)	04C-2730	07-Oct-04	14-Mar-04	-0.00180 psu/month
Temperature (secondary – stbd)	03P-2912	29-Oct-04	None	N/A
Pressure	90573	06-Sep-02	None	N/A
Dissolved Oxygen	43-0259	01-May-02	None	N/A

Table 4. Summary of sensor drifts since last calibration.

Example data

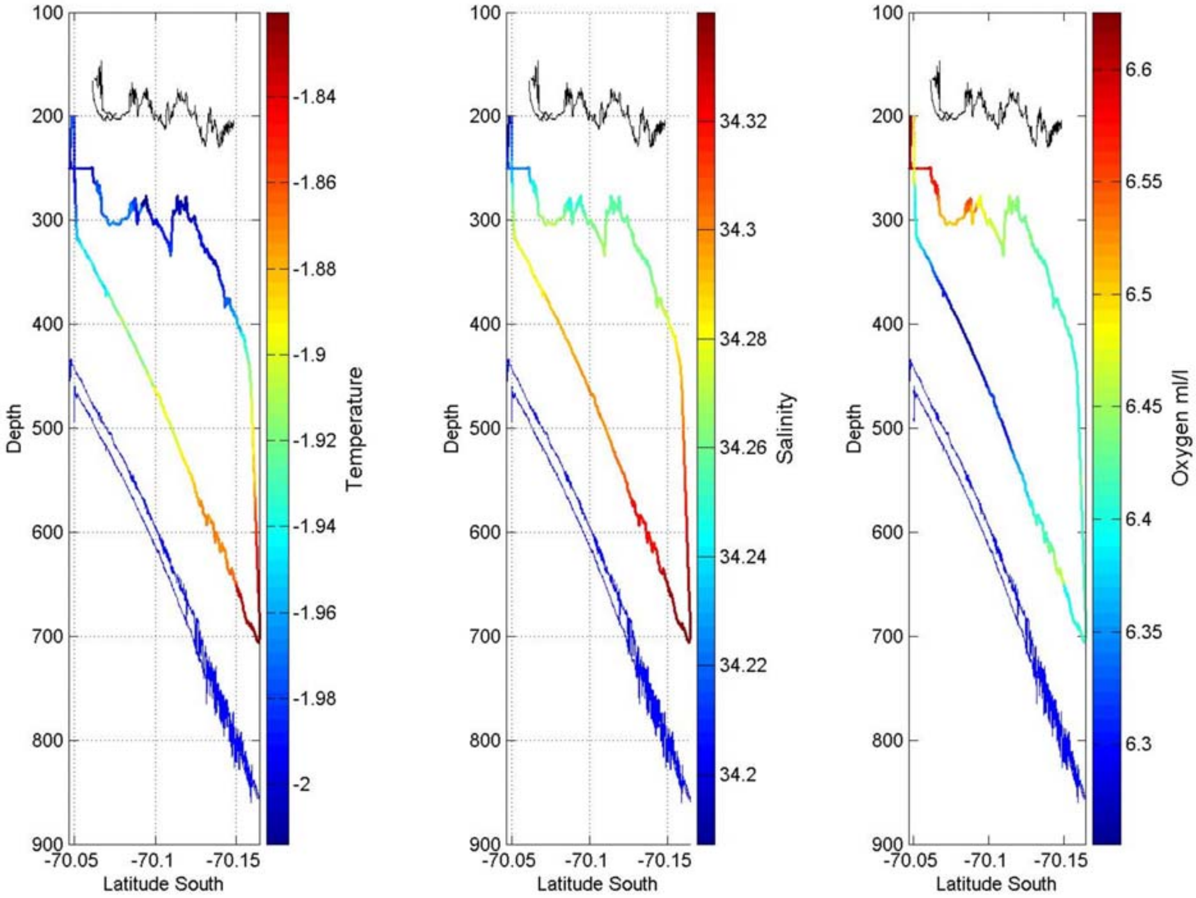


Figure 30 Temperature, salinity and Oxygen data from below Fimbul ice shelf on Mission 382.

The Aqualab water sampler

Martin Price

On this cruise the Aqualab developed a problem during testing, which, while rectified relatively quickly, unfortunately meant that no scientifically useful samples could be collected.

Description of Aqualab

The Aqualab is an autonomous water sampling system fitted in the front instrument bay of the Autosub. It consists of a motorised syringe of 200 ml volume, which draws water through a motorised rotary valve that can connect it to any one of 50 ports. Port 1 is the inlet, which draws water from outside Autosub, while each of the remaining ports is connected to a 500 ml plastic sample bag (perenteral nutrition bags are used – see photo in Figure 31). The connections are made with lengths of small diameter flexible hose. There is space for up to 50 full 500ml sample bags in the front instrument bay of the Autosub, and the instrument has been successfully tested in this configuration during on deck trials. The photo shows 25 full sample bags in the front bay of the Autosub after a successful deployment on Autosub Under Ice cruise JR106S. The control systems are housed in a separate pressure case, and programmed with scripts containing a series of motor and timer commands.

Figure 31. Arrangement of sample bags in nose cone.

In Autosub, the Aqualab is configured to be used in either of two ways:

1. In stand-alone mode, the Aqualab is programmed to take water samples at a set time interval.
2. In sampling-on-command mode, Autosub issues sampling commands at chosen events, for example on reaching a waypoint.

Stand-alone mode has been tested far more thoroughly than sampling-on-command, and is therefore used wherever possible.

The Aqualab, connecting hoses and sample bags all contain rigid non-crushable parts. The sample bags in particular would be damaged by hydrostatic pressure if they were deployed empty. Consequently, the instrument is deployed with 40ml of ‘prime’ water in each bag to prevent the rigid parts being damaged. Ideally, the prime water would be extracted before sampling, and the sample bags and connecting hoses flushed at least three times. However, extraction of water from the sample bags by the Aqualab has been found to be unreliable, with unpredictable volumes of water being left in the bags. In addition, both the rotary and syringe motors operate relatively slowly, so that it takes almost an hour for a full cycle of prime water extraction, flushing, and taking a 400ml sample. Such a long sampling interval would dramatically reduce the usefulness of the Aqualab in Autosub.

Therefore, we have developed a method that allows us to leave the prime water in the sample bags during sampling. The salinity and the concentration of the tracer to be measured in the prime and final mixture are accurately measured (using a salinometer for salinity and the appropriate technique for the tracer), and the salinity of the sample is measured by the Autosub’s Seabird CTD system. The latter is critical, so the instrument must be in good order and have been recently calibrated. These measurements allow the ratio of prime water to sample to be calculated, and thus the concentration of the tracer in the sample. Details of this method are set out in the JR106S cruise report, but are omitted here because of the failure of the Aqualab during this cruise.

Aqualab performance on this cruise

On arrival the Aqualab was found to have erased the flash memory on which all the sampling scripts had been stored. The system otherwise appeared in good order, so the scripts were all uploaded again, and the problem did not recur. We do not know why or how the flash memory was erased, but suggest that future users may wish to install recent firmware upgrades to the system in case a firmware bug was to blame.

During on-deck testing the Aqualab initially appeared to be working well. However, a few of the sample bags were found to contain less than the expected volume of water. With further testing, including during Autosub trial missions 378 to 381, it became apparent that not only were the sample volumes becoming more erratic, but the total volume of water was less than expected (i.e. the errors were not explained by water being put into the wrong bags). Although in the past problems with the Aqualab have been caused by the rotary valve becoming too stiff for the motor to turn, these errors are not consistent with that problem, because with rotary valve problems the *total* volume of water will usually be correct. The rotary valve was stripped and serviced, but found to be in good order.

Further testing revealed that the linear syringe motor was operating intermittently and with very little force – insufficient to power the syringe reliably. The problem was found by stripping the linear motor down, as described in the Autosub Mechanical Report by Andy Webb and Kevin Saw (see also the photographs in that section: figures 42 and 43). Seawater had been drawn through the motor and had corroded the connections to at least two of the stepper motor’s windings. I am very grateful for the help of Mark Preston, who was able to repair the windings, Andy Webb and Kevin Saw who improved the oil seal on the motor housing and refinished the syringe shaft, and Paul Dodd who helped with testing.

The motor seems to have been restored to good working order. Sadly, the repair was completed as the news arrived that the Autosub had been lost under Fimbul Ice Shelf, so no under ice samples were collected. The instrument has been rebuilt, however it is *essential* that the stepper motor is replaced and the oil seal repair fully tested before the instrument is redeployed. For this reason, the linear motor pressure housing has not yet been refilled with its pressure-balancing oil.

Autosub ADCP

Povl Abrahamsen & Kate Stansfield

Autosub is equipped with two Acoustic Doppler Current Profilers, ADCPs: one downward 150 kHz Workhorse Navigator, and one upward 300 kHz Workhorse Sentinel, both produced by RD Instruments. The ADCPs are triggered alternately, approximately every 1.6 s, and data are provided in 2-second bins. The variables recorded are the velocities in a forward-starboard-up reference frame, an error velocity, and returned ping intensity in raw counts for each bin. The downward ADCP uses 24 8-meter bins, while the upward one uses 15 bins. In addition, bottom/surface-track data is provided when in range, as well as ranges for each beam. While the instruments theoretically cover 200 m below Autosub and 125 m above, in practice they rarely, if ever, achieve this range, possibly as a result of a lack of scatterers in polar waters.

The data processing software for Autosub's ADCPs was originally written by Kate Stansfield for earlier Autosub missions in the Straits of Sicily. However, in preparation for JR097, this software has been extensively revised to improve the data processing and optimize the code, as well as to take into account several changes that have occurred in the ADCP settings, particularly during JR106. The new software runs in Matlab, is fully platform-independent, and is optimized for Matlab 6.5 (release 13). However, it does require CTD data that have been processed using Sea-Bird Electronics' SBEDataProcessing-Win32 software, currently at version 5.32.

A very brief summary of the processing follows:

- CTD data are loaded from the processed .CNV file (scan number, pressure, temperature, and salinity are required, while oxygen is optional; scan number must be in field 1, the order of the remaining variables is arbitrary)
- BNV (best navigation data) are loaded into a Matlab matrix.
- LS2 (logger data in 2-second bins) are loaded into a Matlab matrix. Only variables relevant to ADCP-processing are saved.
- All these data are loaded into Matlab, and times are synchronized.
- The ADCP data are extracted into separate matrices, and rotated from a forward-starboard-up coordinate system into east-north-up orientation.
- Corrections for the speed of sound are performed.
- Next, there are several options for reprocessing the navigation information. This should produce a more accurate navigation, since bottom/surface track speeds are corrected for speed of sound variations. In addition, a better dead reckoning solution is used if both bottom and surface track are lost. However, this did not occur in JR097.
- Autosub's velocity is added to the measured currents, to get absolute currents.
- Absolute bin depths are calculated, and intensities are converted to backscatter gains. This step is later described in more detail.
- Attitude information is extracted, and options are given to truncate the time series to remove times when Autosub is circling at the beginning and end of each mission.
- There are several choices for removing data above the surface or below the bottom. These options have not been used in the data shown below.
- Next, data are binned into fixed 8-meter vertical bins and then into 100-meter horizontal bins.
- Upward and downward beam ranges are transformed into target positions in geographical coordinates.

Following this processing, a Matlab file with positions, times, and raw and binned velocities is saved.

The result can be visualized as a section. M378 was a simple line, where bottom tracking was in range all the time. The measured current across the section (in 100-metre horizontal bins) is shown in Figure 32.

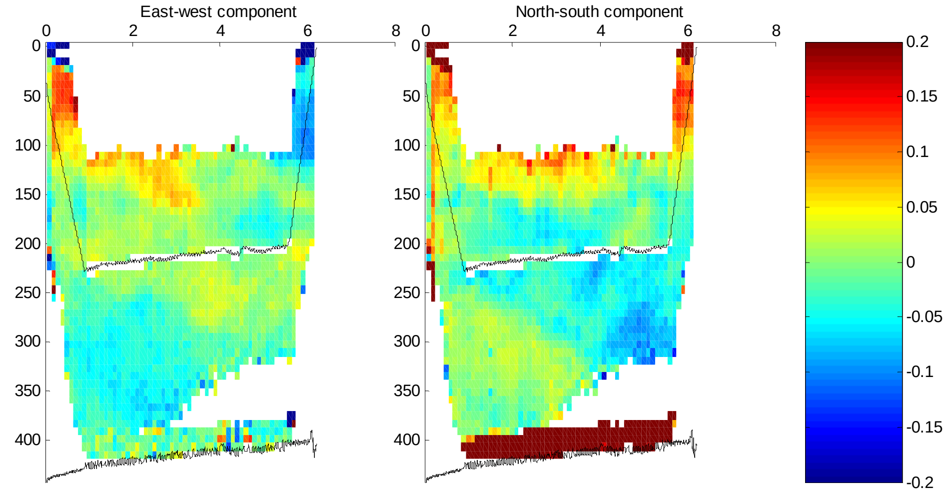


Figure 32. ADCP data from mission 378 plotted as a function of distance.

Here, an upward range of 100 m, and a downward range of up to 175 m was achieved, and gives a coherent image of the currents. The bins just above the bottom are clearly contaminated with bottom pings (this mission was just one line from south to north, so the signal is most visible in the v component). These bins are easily removed during processing, but have been left in here as an example. This mission was on a shelf with a relatively large number of scatterers, and the rest of the signal appears to be quite independent of these bottom pings. It is known that reflections from beam sidelobes pointing straight down will influence measurements within approx. 15% of the distance from the bottom to the instrument.

Mission 382 was the first mission under an ice shelf, and here the data looked quite different. There were extremely few scatterers, which wreaked havoc on the ADCPs. While the bottom/surface track worked quite well, there seems to be a problem with many of the water velocities. As can be seen from Figure 33, Autosub's velocity (SE going into the ice shelf cavity and NW returning) appears fairly consistently in the first bin of the upward data, and sometimes also in the first downward bin. In addition, the outer bins appear to show some traces of this velocity. The most likely explanation for this is that the backscatter is so low that ringing from the pulse transmission is significant in the first bin. This means that a signal with no Doppler shift is detected, which is interpreted as zero (relative) velocity. After this there may be a few bins with useful currents, but towards the end of the range of detected currents there appear to be some artifacts. One area that could contain useful information is the upward-looking data 35-55 km into the mission. Here we see a strong westward current under the base of the ice shelf. It appears to follow Autosub's depth, which follows the base of the ice shelf, and this does not look particularly realistic. However, the north-south component has a slight southward component, while Autosub was traveling northward. So it is possible, although not certain, that these currents in fact are real.

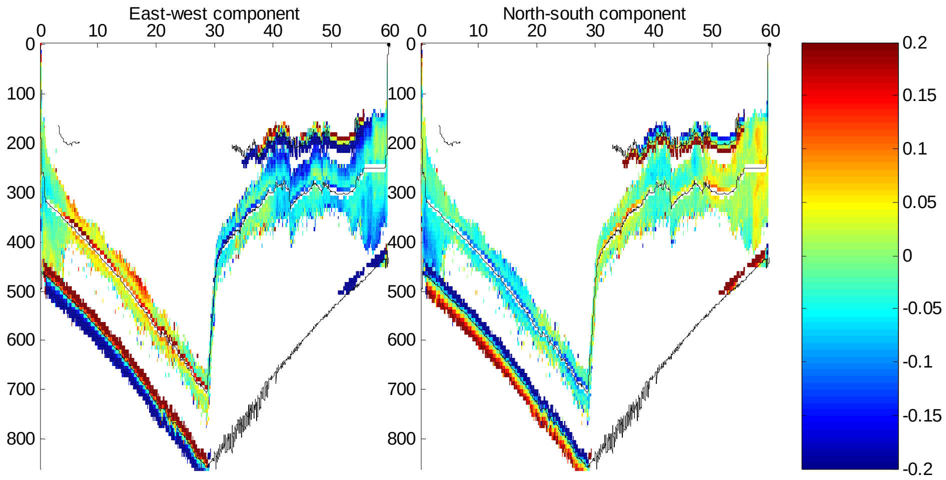


Figure 33. Currents from mission 382.

The number of bins containing currents (regardless of how good or bad these currents may be) is plotted in Figure 34. Regardless of the quality of the current data, it is interesting to see that the number of bins returned drops off rapidly when Autosub enters the ice shelf cavity. There is a slight difference between when Autosub enters and exists the cavity; this may be due to tides. The plots do appear to be somewhat symmetric, indicating that there may be two bands of currents parallel to the ice shelf front, containing a higher number of scatterers than in the rest of the cavity; this increases coincides with the presence of ISW on the outward track. These currents appear to be in the same location as two inverted depressions under the base of the ice shelf, and may be topographically steered.

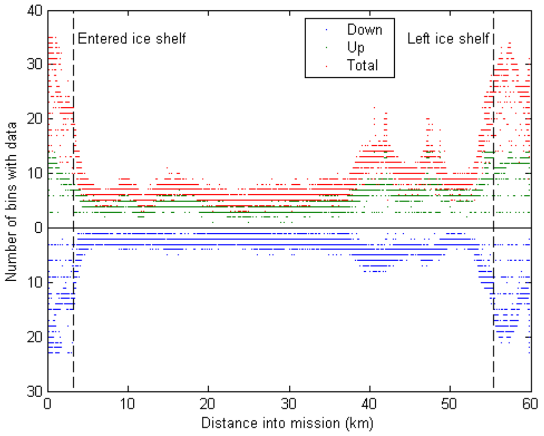


Figure 34. Number of bins containing current data for mission 382.

A mathematical attempt at investigating the quality of the Autosub ADCP data can be made by looking at the correlation between the direction of the measured currents (after Autosub's velocity has been added), and the direction in which Autosub is traveling. If we do have a problem with the bottom track velocities contaminating a certain bin, it would certainly come out here. This has been plotted in Figure 35, for missions 365 and 380-382.

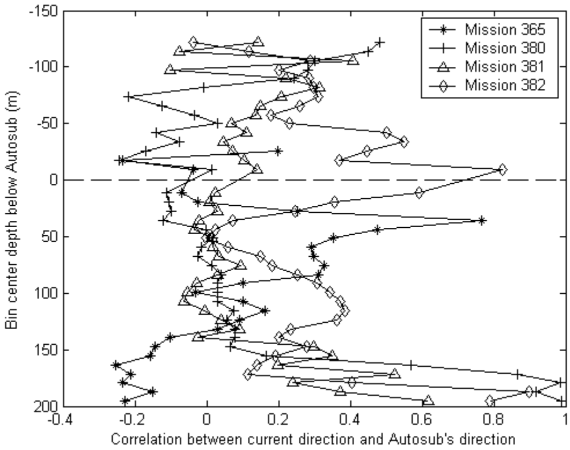


Figure 35. Correlations between measured current directions and the direction of travel.

The first conclusion is that we should disregard data more than 150 m below Autosub. These are most probably bottom track pings that have not been properly masked out in the final stage of processing (all data used for this plot have had bottom/surface track pings removed, but a few points may have slipped through). Missions 365 and 382 appear to have quite different profiles than test missions 380 and 381. Mission 365 has a large peak in downward-looking bin 4; this artifact, probably due to timing issues between the two ADCPs, was clearly visible in all data from JR106. It has apparently been eliminated with the new timing scheme used in JR097. However, upward-looking bin 1 and, to a lesser extent, downward-looking bin 1 appear to have high correlations with Autosub's direction. This cannot be due to timing issues between the ADCPs, as it is not visible in missions 380 and 381, but must be due to the small signal/noise ratio under the ice shelf. For future under-ice shelf work, it may be a good idea to increase the blanking depth by at least 5 m, particularly if bin 1 data are to be used for navigational purposes.

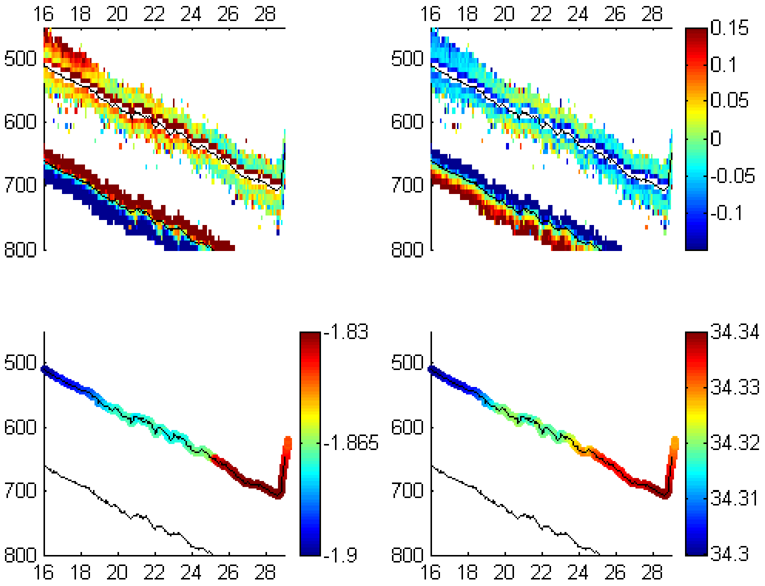


Figure 36. Detail of currents and CTD data from mission 382. The upper plotsshow east-west and north-south velocities, bottom left is temperature, bottom right is salinity. Note that the color scale differs from Figure 33.

One bit of data that may actually contain useful information should also be highlighted. One of the more surprising features in the CTD data was the existence of a very sharp temperature front around 25 km into the mission. The ADCP and CTD data for this section are plotted in Figure 36. Here a shift in currents is noticeable: from a weak eastward current to a slightly stronger and clearer southwestward current. In addition, there is a slight fall in the backscatter from downward bin 1 from around 22 km until the front is passed.

To summarize: the performance of Autosub's ADCPs is disappointing under the ice shelf. Data are very sparse, and of dubious quality. However, the lack of scatterers is an interesting result in itself, and the backscatter and number of bins can, with some more work, be used as a proxy for the number of scatterers. This may in turn offer some useful hints about the current structure and water masses under the ice shelf.

ADCP-backscatter

The backscatter strength depends on the volume concentration, size, shape and density of the scattering "particles". The received intensity signal has to be corrected for sound absorption of clear water, beam spreading, ADCP settings, varying transmit power, and varying receiver efficiency/noise.

To calculate the absolute backscatter, Sv, the following processing was carried out:

1) Calculate the range as a function of bin.

$$R(n,L,Bk) := \left[Bk + (n-1)\cdot L + \frac{3}{4}\cdot L\right]\cdot\frac{1}{\cos(30\cdot deg)}$$

Where:

R is the range (m).

L is the bin length. (4m or 8 m)

Bk is the blanking distance. (1.75 m for the 300kHz, 3.5 m for the 150 kHz).

n is the bin number. (2 for bin2)

Then the backscatter strength, Sv, is calculated from the sonar equation [Deines (1991), Eqn(2)]:

$$Sv(C,T,n,L,P,\alpha,Kc,E,Er,Bk) := C + 10\cdot\log\left[(T+273)\cdot R(n,L,Bk)^2\right] - 10\cdot\log(L) - P + 2\cdot\alpha\cdot R(n,L,Bk) + Kc\cdot(E-Er)$$

Where:

Sv is the backscatter strength (db)

C is an instrumental constant (-153.3 dB for the 150 kHz ADCP, -143 dB for the 300kHz ADCP).

T is the temperature (Celsius).

L is the transmit pulse length (m)

P is the transmitted power (dB). 14.8 dB for the 300kHz, 15.4 dB for the 150 kHz.

α is the attenuation of sound in seawater. 0.044 db/m at 150 kHz, 0.066 dB/m at 150 kHz.

Kc is the constant converting instrument count to dB. (Taken as 0.45 dB , although this is approximate.)

Er is the no signal intensity count. Lowest ever seen for the instrument is taken as the value. 40 for the 300 kHz, 42 for the 150 kHz.

The second term on the right hand side of the equation compensates for geometric beam spreading, the fifth term corrects for the 2-way signal attenuation.

See Deines (1991) RDI Application note FSA-008 for further information.

On examining the data back at SOC, it was decided that data where the intensity count was less than 48 should be regarded as noise and set to NaN.

This results in the backscatter shown in Figure 37 for Mission 382.

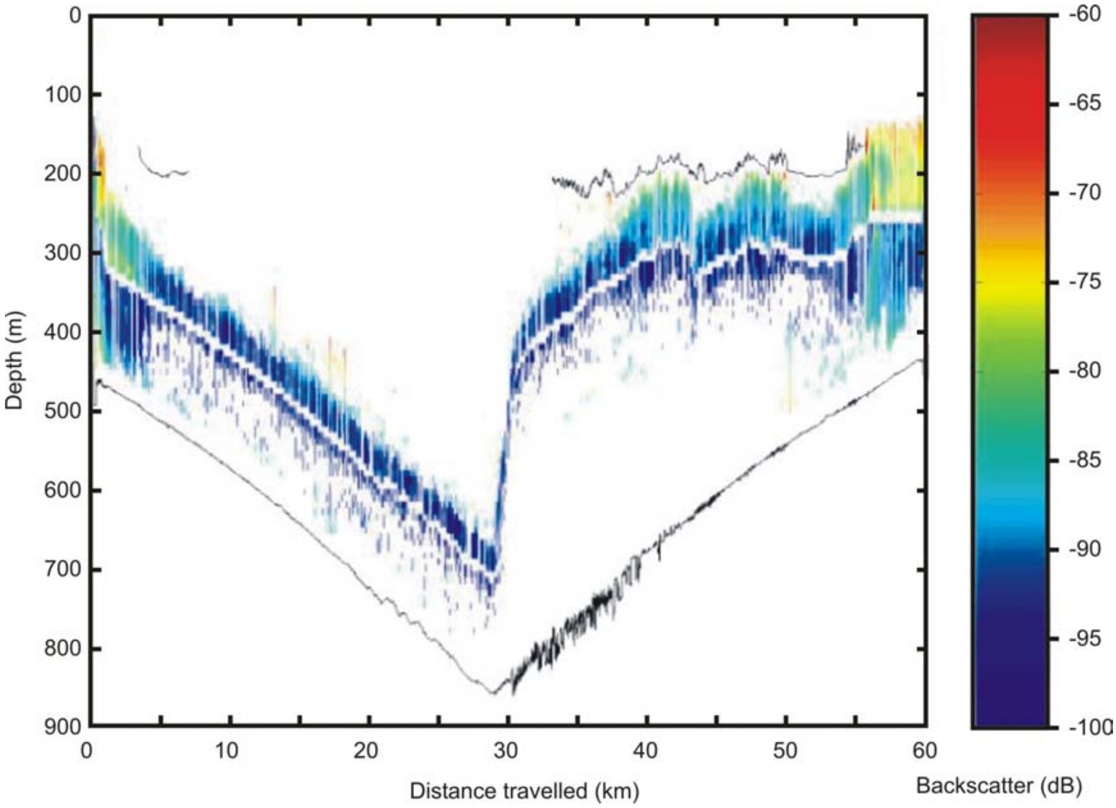


Figure 37 Backscatter from Mission 382.

Autosub: Mobilisation and Mechanical

Andy Webb, Kevin Saw

Mobilization

Autosub, its launch and recover gantry, ancillary equipment and 7 sets of batteries were loaded into 3 x 20 foot containers for shipping from Southampton to the Falkland Islands on the 8th November 2004 and were awaiting the ships arrival in Stanley on 30th January 2004.

Mobilisation began on the 31st January and continued until the ship sailed on the morning of the 3rd February. Two of the transportation containers had been modified to double as garage space and workshop for Autosub, and were located on the aft deck, just forward of the launch and recovery gantry on the port quarter. The third open top container used to ship the gantry and was unloaded and left ashore. The fish containing the tracking and telemetry acoustics was loaded on to the PES winch on the starboard side just forward of the bridge.

Ship fitting

Autosub and acoustic fish mobilisation was carried out in Stanley, F.I. on Sunday 30th and Monday 31st January. The layout on the aft deck was the same as the previous AUI campaign in 2004 (JR106). Figure 38 shows a plan view of the gantry and Autosub's purpose made containers on the aft deck of the James Clark Ross.

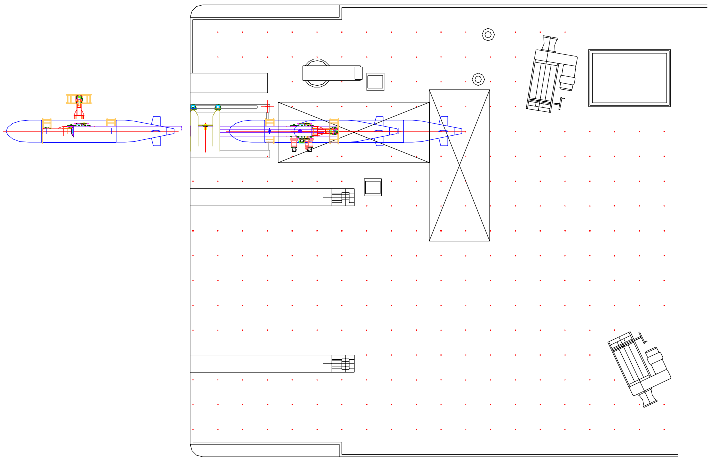


Figure 38. Plan layout of the containers on the aft deck

When unpacking the tail section it was noted that a structural weld had failed on the upper starboard aluminium box section (A5803-00-040 issue C) causing the plate that fixes to the stainless steel bulkhead ring to become detached (see Figure 38). This was satisfactorily repaired by a local contractor in Stanley.

Figure 39. Failed weld on upper starboard tail frame section

Vehicle configuration

Figure 40 is a schematic showing the basic vehicle layout, Table 5 gives the relative positions of the sensors on board, with respect the vehicle datum (the bottom of the forward bulkhead joint, see Figure 40).

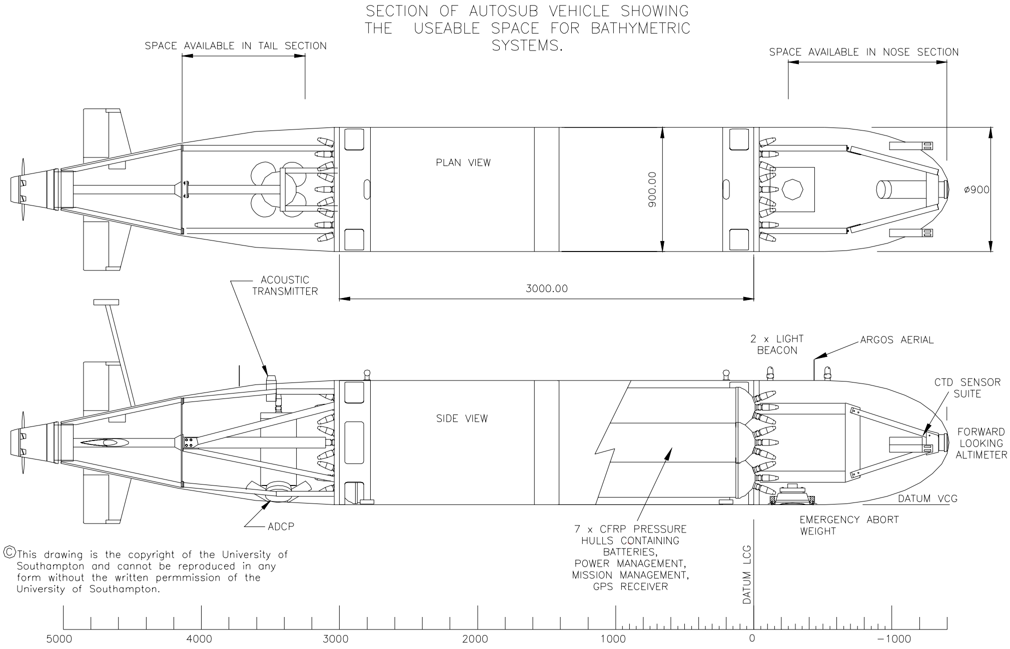


Figure 40. Vehicle layout showing sensor space and datum.

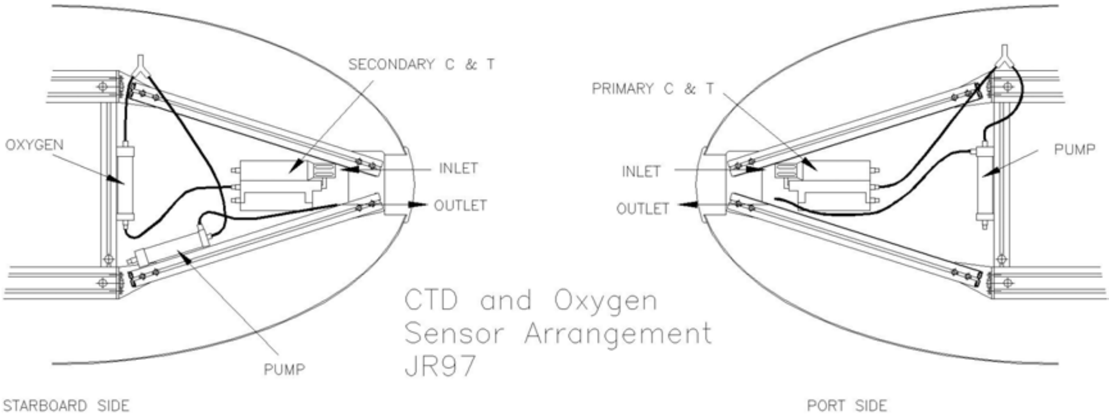


Figure 41. CTD arrangement.

Sensor	**Longitudinal centre of gravity wrt vehicle datum (m)**	**Vertical centre of gravity wrt vehicle datum (m)**	**Remarks**
CTD (port and starboard) (see figure 4)	-1.1	0.45	Ports side (primary) Temp.1, Ser No. 03P2342. Cond.1, Ser No. 042760 Starboard side (secondary) Temp. 2, Ser No. 03P2912. Cond. 2, Ser No. 042730
Oxygen sensor	-0.57	0.45	Plumbed in the starboard side with Temp2 and Cond2
Digiquartz Depth sensor	-0.5	0.65	
EM 2000	-0.65	0.8	Position of transducer head looking upwards
EM 2000	3.87	0.7	Position of transducer head looking upwards
300kHz ADCP	3.33	0.85	Position of transducer heads looking upwards
150kHz ADCP	3.45	0.1	Position of transducer heads looking downwards
Forward looking echo sounder	-0.14	0.45	Position of transducer head looking forwards
Camera	4.0	NA	
Camera flash	-0.97	NA	Tilted to illuminate spot beneath camera at XXm
Aqualab water monitor	-0.69	0.55	Position of sampling ports (Not fitted for mission 383)

Table 5 Positions of sensors relative to vehicle datum.

Operations

The ballast and trim of Autosub has to be carefully tailored for the local conditions to be 8 to 12kg buoyant and neutral trim in order for it to both float and control without difficulty. Sea water density and temperature measurements were made using sea water obtained from Stanley Harbour and a floating hydrometer and thermometer. Density was recorded at 1024 $kg.m^{-3}$ and temperature at 12°C. The Autosub vehicle was floated in Stanley Harbour with lines attached to check for adequate buoyancy. Although conditions were not ideal, being very windy with a significant chop on the water, the buoyancy was estimated at 12kg. The water density and vehicle weight estimates indicated a buoyancy of 8kg. The vehicle just floated (circa 2kg buoyancy) when floated with 10kg of ballast taped on top, indicating the estimates were sufficiently accurate. Table 6 shows the history of the density measurements and the changes made to the vehicles ballast and trim throughout the cruise.

Autosub started the cruise with fresh batteries and no battery changes were carried out throughout the science time. The battery packs were from Steatite Ltd, Redditch, (Fujitsu cells).

Mechanically, the vehicle performed well with few faults. The mechanical problems encountered were:

- Weld failure on tail frame as described above (failed during transit to F.I. not during operation).
- GPS antenna mount on top fin continually worked loose due to ineffective insert – (permanent fix required for Autosub 3).
- Sluggish performance of the launch and recovery gantry in icy conditions as experienced on previous polar cruises.
- Intermittent braking problems on the gantry rotary carriage drive were not apparent on this cruise but gantry not operated in rough conditions.
- Rotary carriage controls are reversed, i.e. clockwise control rotates carriage in a counter clockwise direction and *vice-versa*.
- Difficulty was encountered in connecting CTD inlet stub to stub-pipe mounted in nose panel due to axial misalignment of the two.
- The AquaLAB water sampler malfunctioned during mission 381. A subsequent strip-down of the syringe drive housing revealed that seawater had entered the housing via the lip seal (Figure 41) on the syringe drive shaft, exacerbated by poor quality of the shaft surface finish (Figure 42). This was probably a gradual, long-term leak evidenced by fairly advanced corrosion on the drive motor winding solder connections and rotor (Figure 43).

Figure 42a. Lip seal on syringe drive shaft

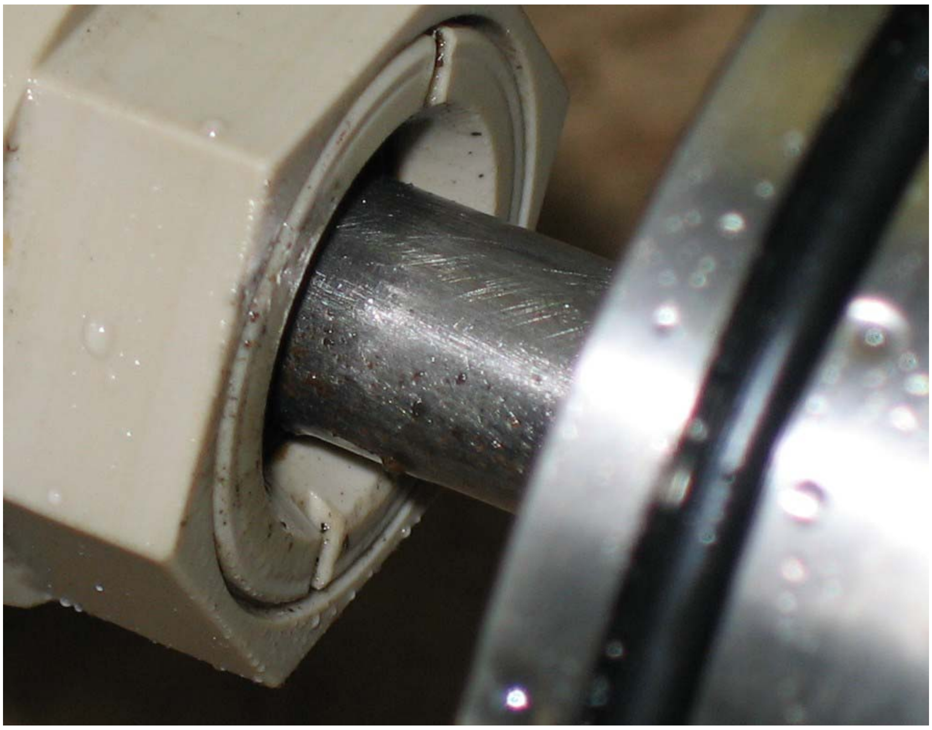


Figure 42b. Poor quality shaft surface finish

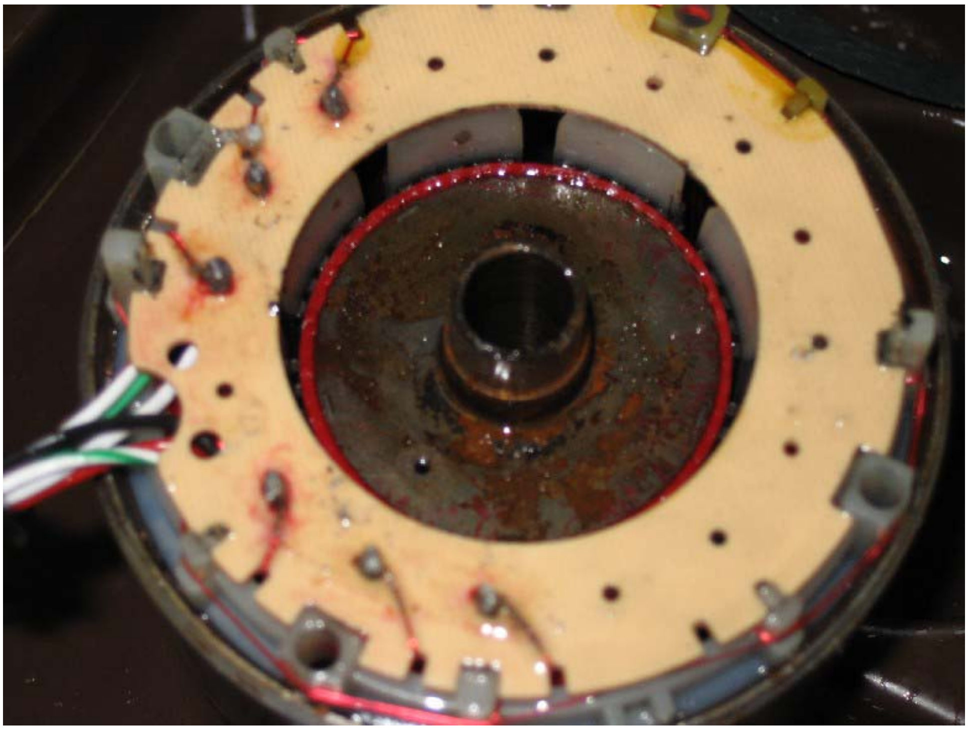


Figure 43. Corrosion on winding solder connections and rotor

The vehicle needed no repairs beyond normal maintenance:

- Re-siting CTD sensors as described in Table 5.
- Flushing of CTDs
- Cleaning and re-greasing propulsion motor bearings
- Recovery line stuffing
- Packing the “Jack in the Box” grappling line
- Adjustments to ballast and trim
- Replacement of a number of spire clips.

The major consumables used were:-

- 1 battery set (28 packs/set).
- 1 Abort weight.
- 5 sink weights.

Date	*Time*	**Location**	**Water Density (kg/m^3)**	**Changes made to Autosub ballast**	**Changes made to Autosub trim**	**Remarks**
03/02/05	1030h	Stanley harbour	1024 (12C)	No change	No change	Judged to be 2kg buoyant with 10kg lead ballast added
11/02/05	1135h - 1348h	Mission 378 (trial) off Fimbul Ice Shelf	1026.61 (-0.6C)	Nose: +2.2kg lead at -0.84m, 0.8m. Tail: +2.5kg lead at 3.8m, 0.8m	No change	Density and temp from ship's CTD. Spreadsheet indicated weight in water as -13.6kg before change and -9.3kg after. Sub not recovered.
11/02/05	1522h - 2114h	Mission 379 (trial) off Fimbul Ice Shelf	-	No change	No change	Sub not recovered.
11/02/05	2210h	Mission 380 (trial) off Fimbul Ice Shelf	-	No change	No change	Sub recovered at 0043h, 12/02/05.
12/02/05	1825h	Mission 381 (trial) off Fimbul Ice Shelf	-	No change	No change	Sub recovered at 1925h. AquaLAB malfunctioned.
13/02/05	1217h	Mission 382 under Fimbul Ice Shelf	-	No change	No change	Sub recovered at 2240h. AquaLAB fitted but not functioning. First mission under ice shelf.
16/02/05	0748h	Mission 383 under Fimbul Ice Shelf	-	Nose: +17.1kg lead at -0.7m, 0.26m, +4.5kg lead at -0.6m, 0.26m	No change	AquaLAB removed and stripped down for repair. Lead ballast added to compensate. Sub did not return.

Table 6. **History of trim and ballast changes**

Shipboard CTD System Operation

Jeff Benson

A total of 83 CTD casts were completed on the cruise, including 4 "yo-yo" stations, utilising a 24-way frame arrangement with the following configuration:

- Sea-Bird 9/11+ CTD
- Sea-Bird 24 position Carousel
- Chelsea Technologies Group fluorometer
- Chelsea Technologies Group transmissometer
- RD Instruments Workhorse LADCP (downward-looking)
- RD Instruments Broadband LADCP (upward-looking)
- WETLabs BBRTD Light Scattering Meter
- Benthos altimeter/Tritech altimeter
- Sonardyne High Frequency Marker beacon
- SOC 10KHz beacon
- SOC/Sea-Bird Breakout Box
- 24 by 10L Ocean Test Equipment water samplers

The configuration for the CTD was as follows, from cast 999 through cast 82:

- Sea-Bird 9+ underwater unit, s/n 09P-31240-0720
- Sea-Bird 3 Premium temperature sensor, s/n 03P-2919 (frequency=0)
- Sea-Bird 4 conductivity sensor, s/n 04C-2407 (frequency=1)
- Digiquartz temperature compensated pressure sensor, s/n 90573 (frequency=2)
- Sea-Bird 3 Premium temperature sensor, s/n 03P-4116 (frequency=3)
- Sea-Bird 4 conductivity sensor, s/n 04C-2450 (frequency=4)
- Sea-Bird 5T submersible pump, s/n 05T-3090 (primary)
- Sea-Bird 5T submersible pump, s/n 05T-3609 (secondary)
- Sea-Bird 24 position Carousel, s/n 32-24680-0344
- Sea-Bird 11+ deck unit, s/n 11P-24680-0589

The configuration for the A/D channels was as follows:

- V0 = Sea-Bird 43 dissolved oxygen sensor, s/n 43-0612
- V2 = Benthos PSA-916T altimeter, s/n 874/Tritech PA-200 altimeter
- V3 = Chelsea Aquatracka MKIII fluorometer, s/n 088244
- V6 = WETLabs BBRTD Scattering Meter, s/n BBRTD-115R
- V7 = Chelsea Alphatracka MKII transmissometer, s/n 161050

The configuration for the remaining instruments was as below:

- RD Instruments Workhorse Monitor 300 KHz, s/n 4908 (downward-looking/master)
- RD Instruments Broadband Monitor 300 KHz, s/n 1855 (upward-looking/slave)
- SOC LADCP aluminium battery pressure case, re-chargeable cells, s/n WH003
- SOC/Sea-Bird Breakout Box, s/n BO19110
- SOC 10KHz Beacon, s/n B1
- Sonardyne HF Marker Beacon, s/n 213797-01 (4,000 metre)

3) The WETLabs Scattering Meter produced erratic data on several casts because of low-pressure leakage of a connector on the Breakout Box. The cable was eventually mated securely and no further problems were encountered.

4) During the CTD “yo-yo” stations, the Chelsea transmissometer shifted signal output on the downcast, either to the decreased or increased output side, and did not correct the error until well into the up cast. As the shift was only observed during repeat “yo-yo” casts, it is suspected the CTG transmissometer is susceptible to electronic variations when continuously deployed over several hours and subjected to the extremes of pressure/depth and cold temperatures. Discussions with the manufacturer are ongoing and have not as of yet yielded an explanation. Subsequent casts have not displayed any evidence of signal shift.

5) Prior to cast number 33, the BAS-owned Sea-Bird 35 Deep Ocean Standard Thermometer, s/n 0047, was added to the package to determine which of the primary or secondary Sea-Bird 3+ Premium Temperature sensors was the most accurate. The Sea-Bird 35 was removed after cast number 48. The cause of the shift in temperature readings of the primary sensor was attributed to sensor fouling, and after a number of casts the sensor resumed operating comparably to the secondary sensor.

6) At cast number 45, the Benthos altimeter was exchanged for the BAS-owned and modified Tritech PA-200 altimeter, s/n 2130.27001, for a comparison study. No changes were required in the configuration or calibration files, and the original file remained unaltered.

7) Beginning with cast number 73, both Sea-Bird conductivity sensors shifted and began to read in error compared to salinity samples taken. The cause is suspected to be ice damage from freezing water left in the conductivity cells. A post-cruise evaluation of both sensors will be undertaken at Sea-Bird.

8) During the “yo-yo” cast of CTD 82, the fluorometer signal failed. Upon investigation at the end of the cast, the cable was found to have leaked, and was replaced.

CTD Data Processing

Martin Price and Colin Goldblatt

Overview

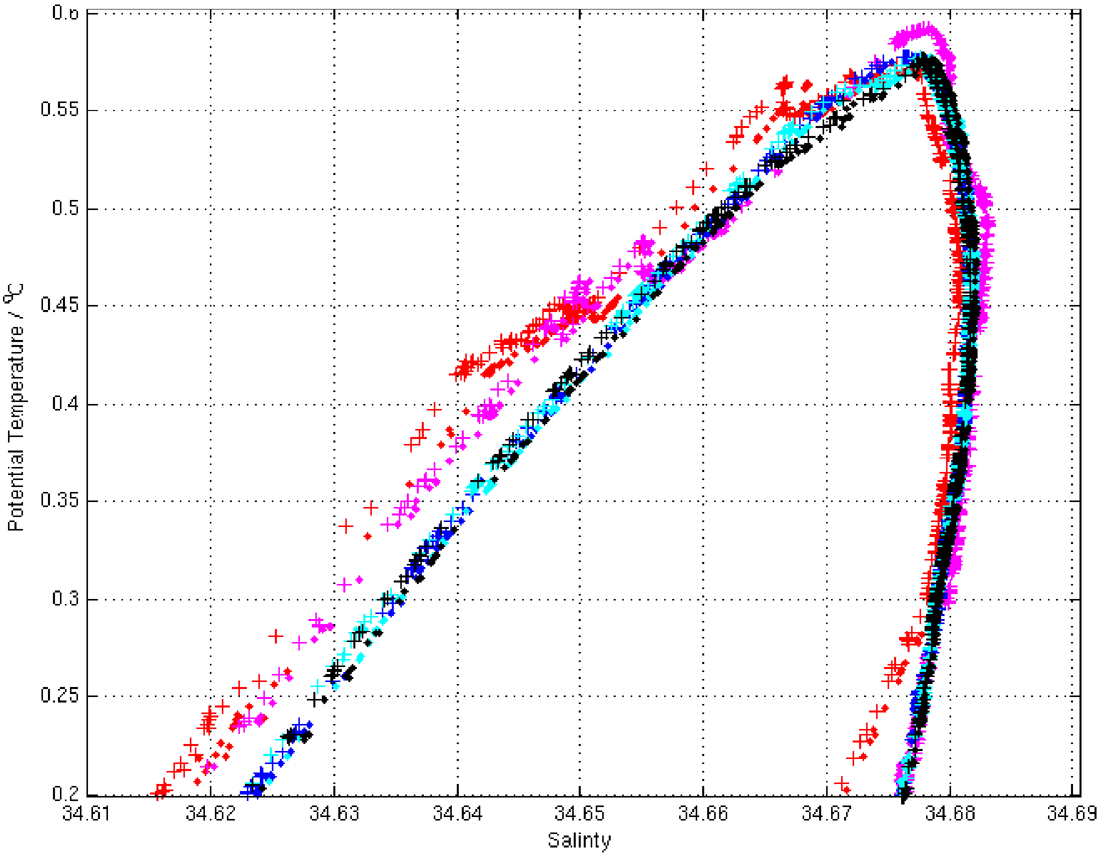
Eighty-two CTD stations were occupied during cruise JR97, 48 on the continental slope and shelf to the north of the Fimbul Ice Shelf (figures 2 and 3), and the remaining 34 in the vicinity of the Brunt Ice Shelf and Filchner Sill (Figure 4, see also the table of station positions at the end of this section). These used a Seabird CTD and dissolved oxygen sensor, transmissometer, fluorometer, altimeter and 24 x 20 litre bottle rosette. Instrument details are given in the previous section by Jeff Benson.

Overall the performance of the Seabird CTD sensors has been good, however there have been a few problems:

- The primary temperature sensor was slightly unstable between stations 20-38, varying by up to 0.002°C compared to the secondary temperature sensor. We were able to fit BASs SB35 Deep Ocean Standards Thermometer (serial number 0047, last calibrated 25th March 2004 and expected to be accurate to within 0.001°C), which takes a very accurate temperature reading during bottle firings. This confirmed that the secondary temperature sensor was stable and correct to within 0.0005°C. Therefore the primary temperature sensor was calibrated by adding the median difference between it and the secondary sensor (the SB35 was not available for all casts).
- The secondary conductivity sensor showed a fairly steady linear drift between stations 1 and 72 of around 0.0025 mS, equivalent to around 0.0025 in salinity. Bottle salinities confirmed that between stations 1 and 72 the primary conductivity cell did not drift appreciably, and was reading around 0.0018 mS low, while the secondary cell started the cruise reading only around 0.0005 mS low but drifted to around 0.003 mS low by station 72.
- Between stations 72 and 73 water is believed to have frozen in the sensors, with the result that from station 73 onwards the conductivity offset is large – a median of 0.0169 mS in conductivity for the primary cell (0.0129 in salinity), and 0.0271 mS in conductivity for the secondary (0.0352 in salinity). These offsets have been applied and we believe them to have successfully calibrated the salinities to an accuracy of close to 0.001 on average. As a check, calibrated data from stations 70, 72, 81 and 82, which were all in the same place, have been compared in a salinity-potential temperature diagram (See figure CTD1). Where there are stable water masses all stations agree to within a range of 0.002 in salinity. This adds confidence that the calibration has worked well. However, the sensor damage may have introduced an offset that is a function of salinity, pressure, temperature or a combination of all three. If so, then the error must be smaller than around 0.003 in salinity at low pressure and salinity, but this will be investigated further on our return to the UK.

Bottle salinities have been of adequate quality for calibration to around 0.001 in salinity (these are the values reported above). However, low pressure / high salinity gradient bottles have both a larger scatter and a larger offset than the deeper bottles. At this stage we suspect this is caused by a stratification dependent error in sampling i.e. the bottle contains water different from that seen by the Seabird sensors and the problem is exacerbated where the stratification is high. If the offset were caused by the bottle being higher in the water column than the sensors, the bottle salinity would be lower than the CTD salinity. This is the opposite of what is seen, so is not the cause. Checks have confirmed that salinity analysis is not introducing a significant systematic salinity dependent error (see the section by Paul Dodd). Further investigation will follow after the cruise, but we suspect the error is to do with the bottles taking a finite time (or distance through the water) to flush. At this stage, salinity calibrations have been calculated from the deeper salinities only – below around 600m the offset asymptotes to a constant value per station. However, this may be

Figure 44 Potential temperature-salinity diagrams for stations 70 (red), 72 (magenta), 80 (blue) and 82 (black). Primary and secondary sensor pairs shown by dot and cross respectively.



revised later if the low pressure offsets turn out to be real. This is the reason why a pressure or salinity dependent offset in stations 73-82 (see above) cannot be ruled out at this stage.

The data produced during the cruise are believed to have a systematic error in both temperature and salinity of no more than 0.001°C / PSU for both sensor pairs, at least up to and including station 72 (see above). However, station by station errors may be slightly higher. A good deal of further work and analysis will take place on our return home before a final calibrated data set will be produced. This will include manual despiking and a more thorough analysis of the conductivity offsets. At present, there is no strong reason to choose between the primary and secondary sensors. The primary temperature and secondary conductivity both have small errors that have been calibrated out. The secondaries *may* be slightly better, since the primary temperature error was slightly unstable whereas the secondary conductivity drifted steadily. We don't believe the difference to be significant, however.

A station list is provided in Table 7. Most stations were standard, with the downcast used to provide the best CTD data and the upcast used to fire bottles for calibration salinities, oxygen isotope samples and CFC samples. However, some stations were unusual:

- During station 1 the package was deployed with fresh water still in the sensors, and the CTD data are poor. For the rest of the cruise, the CTD package was kept in a heated annex and flushed with warm seawater before deployment. Station 15 was a repeat of station 1, so station 1 is probably best discarded.
- Stations 39-41 and 47-47 were deployed in heavy sea ice cover off the stern of the ship (usually the CTD package is deployed over the starboard side). No useful data can be recovered from approximately the top 20m of these casts, because the ship's propeller was

run to create a hole in the ice for deployment and recovery, and will have stirred up the upper water column.

- Stations 26 to 28 were ‘yoyo’ stations, in which the package was raised and lowered between near surface and near bottom without being recovered. Stations 26 and 27 were at one location, station 28 at another nearby (we had to move because sea ice was making operation at the first site difficult). Stations 26 and 27 contain respectively 18 and 13 casts, and took a total of 12 hours and 40 minutes. Station 28 contains 27 casts and took 10 hours and 20 minutes.
- Stations 72 and 82 allowed the Lowered ADCPs (in a high vertical resolution configuration) to hang at 90m off bottom and 180m off bottom to profile the currents in the ice shelf water plume downstream of the Filchner Sill. The package was repeatedly allowed to hand at 90m then 180m off bottom for 30 minutes each, with downcast CTD profiles between each stationary period. Finally a normal upcast was completed, including bottle samples. Station 72 contained 3 such cycles and took 6 hours and 15 minutes, while station 82 contained 8 cycles and took 12 hours and 45 minutes.

Figure CTD2 (following page) shows a sample CTD section, from south to north to the west of the Fimbul ice tongue. On the shelf, a pool of ice shelf water can be seen ($\theta < -1.9$°C, $S \approx 34.3$). Over the slope, winter water ($\theta \approx -1.6$°C, $S \approx 34.3$) can be seen between 200 db and 700 db, warm deep water ($\theta \approx 0.4$°C, $S \approx 34.7$) between 700 db and 1600 db and Antarctic bottom water ($\theta < 0$°C, $S \approx 34.7$) between 1600 db and the sea bed.

Dissolved oxygen, beam transmission and fluorescence have been carried through all the processing stages. We have no means of calibrating them, however, and so, while they may be useful in a relative sense, they must be treated with caution.

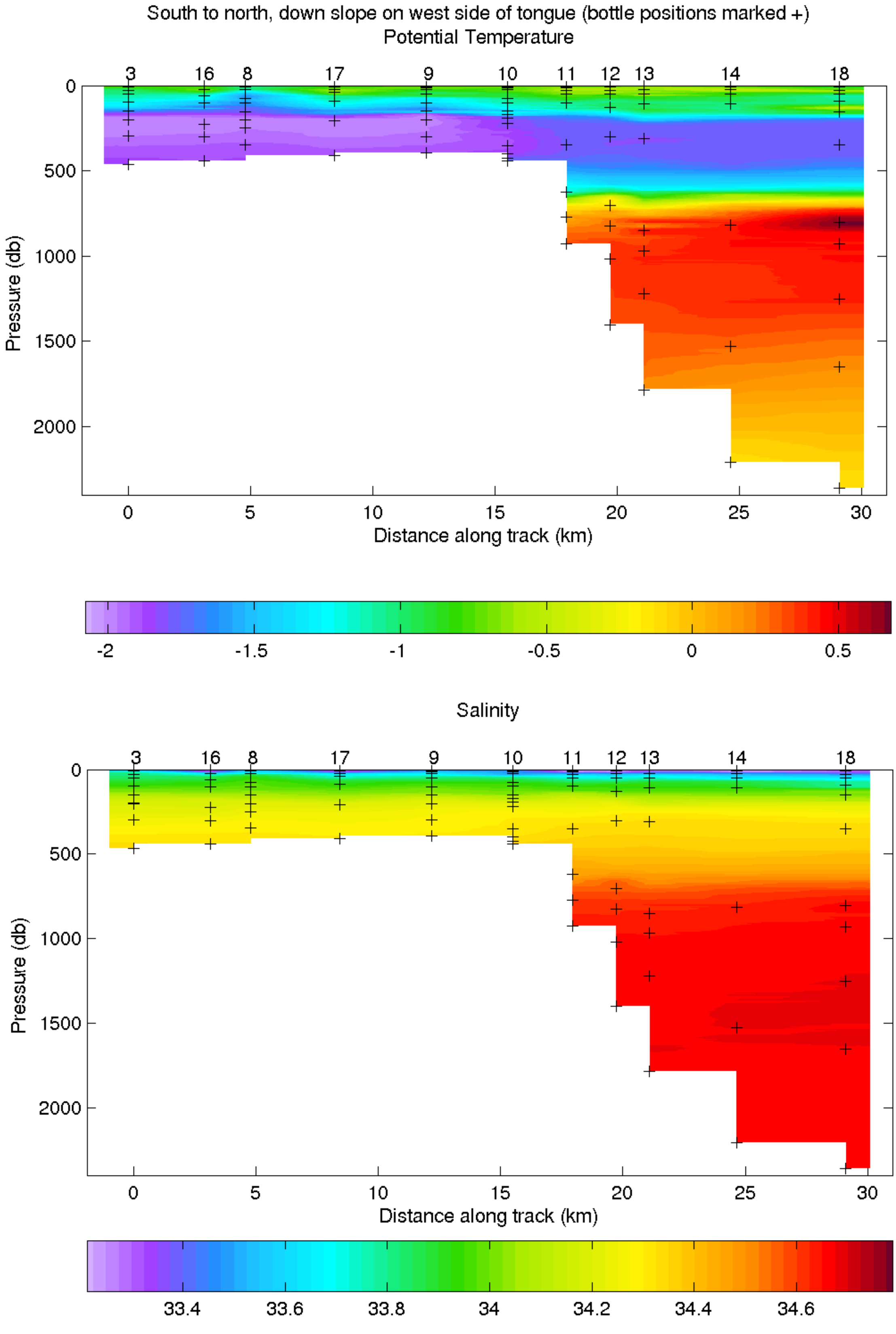


Figure 45 Temperature and salinity sections along the west side of the Fimbul Ice Tongue.

Seabird data capture and initial processing

[The remainder of the CTD section of this report is based on the JR106S cruise report by Karen Heywood.]

Seabird's Seasave program was used to capture and save the output from the CTD. There are five output files per cast, with extensions .DAT, .HDR, .BL, .CON and .NAV. The binary information from the CTD is saved in the .DAT file, while the .HDR file contains header information including a GPS NMEA start time and position. The .NAV file contains GPS NMEA position and time at the start, bottom and end of each cast. The .CON files contain the most recent calibration coefficients for each of the sensors, and are used during the first stage of processing. The .BL file contains information on when bottles were fired during each cast.

Initial data processing was done using Seabird's SBE Data Processing version 5.31b. The routines we used were *Data Conversion*, *Align CTD*, *Cell Thermal Mass*, and *Ascii Out*. Data Conversion takes the .DAT file and, using the calibration information in the .CON file, outputs a binary file in Seabird's .CNV format. Align CTD applies a time shift to selected sensors to assign measurements from the same parcel of water to the same scan number. In the setup used on JR97 the Seabird deck unit internally aligns temperature and conductivity, so the only post-processing change was a 5 second delay to the dissolved oxygen sensor to allow for the relatively slow response time of the sensor. The results were saved in files named *align.cnv. Cell Thermal Mass makes corrections for the thermal mass of the conductivity cell (important in strong temperature gradients). The constants used were those recommended by Seabird: alpha = 0.03 and 1/beta = 7. The output was saved in files named *aligncelltm.cnv. Ascii Out then produces ascii files that can easily be read into Matlab, where the remainder of our processing takes place.

For all CTD casts, the following variables are output at every stage:

1. Scan Count
2. Pressure, Digiquartz [db]
3. Temperature [ITS-90, deg C]
4. Temperature, 2 [ITS-90, deg C]
5. Conductivity [mS/cm]
6. Conductivity, 2 [mS/cm]
7. Altimeter [m]
8. Beam Transmission, Chelsea/Seatech/Wetlab CStar [%]
9. Fluorescence, Chelsea Aqua 3 Chl Con [µg/l]
10. Oxygen, SBE 43 [µg/kg]
11. Pump Status (on or off)

The remainder of the processing pathway was essentially the same as during JR40, JR80 and JR106, and uses a series of Matlab scripts. Each cast has a numbered directory in the main 'ctd' directory, e.g *001, 002, 003*. All the files for a given station can be found in this directory. A README file was also maintained in each *nnn* directory and was updated manually every time any modifications were made. In addition to data from all the sensors, the Matlab files for each station carry through the cast start time (called *gtime*), and the station latitude and longitude from the GPS NMEA stream (in *lat* and *lon*).

Initial Matlab processing

ctdcal.m

This reads in the CTD_*nnn*_aligncelltm.asc ascii data file and the CTD_*nnn*_aligncelltm.hdr header file, using the functions *cnv2mat.m* and *hdr2mat.m*. They read the files, give useful names to all the variables, save the data in a matlab file ctd*nnn*.cal.

offpress.m

This reads the ctd*nnn*.cal files, plots the data near the surface, and asks the user to choose a pressure offset to apply. During JR97 these offsets were always small, typically less than 0.2 db. The script also removes any data when the *pumps* variable is zero, indicating that the Seabird pumps were not on. The resulting data are saved as ctd*nnn*.wat.

spike.m

This checks for, and sets to *NaN*, large single point spikes in conductivity, temperature, fluorescence, transmittance and oxygen. It uses the despiking routine dspike.m. The resulting file is ctd*nnn*.spk.

interpol.m

The programme finds any data set to *NaN* in any of the temperature, conductivity, fluorescence, transmittance and oxygen variables, and interpolates across them to produce a continuous data set. The output file is ctd*nnn*.int. At this point we have 24 Hz data for the up and down cast. We then need the bottle salinity data to calibrate conductivity, however interim versions of the data were always created so that we could look at the uncalibrated data quickly.

makebot.m

This uses the CTD_*nnn*.BL file to extract CTD data at the time of each bottle firing. The .BL file contains ‘start’ and ‘end’ scan numbers that apply to each bottle firing, which are used to extract the appropriate data from the ctd*nnn*.int file. Median values for each CTD variable are calculated for each bottle firing. The standard deviations of the temperatures and conductivities are stored to indicate the stability of the measurements during the bottle firing. A warning is given to the user if large standard deviations are found. The median values and standard deviations are stored in the output file, bot*nnn*.sal. Makebot also creates variables for bottle salinity, botsal, initially set to NaN, and a salinity bottle flag, salflag, initially set to 0. We do not use Seabird’s .ROS files for two reasons. Firstly, our ctd*nnn*.int file has already been processed to remove spikes and bad data (station by station manual despiking will be done at a later date, and will be inserted before the ctd*nnn*.int stage of processing), so the resulting bottle data are of better quality. Secondly, the range of scans selected is somewhat arbitrary (the start scan is usually when the bottle fire instruction was sent, and the end scan is a user determined number of scans later), and our method allows us to easily examine the effect of changing either the start or end times on the calibrations.

newvar.m

This calculates salinity from conductivity and temperature, and also derives potential temperature and a selection of potential densities. The output is ctd*nnn*.var. This script exists simply to create an interim version of the data before salinity calibrations are available.

splitcast.m

This splits the data from ctd*nnn*.var into an upcast and a downcast file, ctd*nnn*.var.dn and ctd*nnn*.var.up. These are the final 24 Hz versions of the data.

ctd2db.m

This produces a convenient 2 decibar binned version of the 24Hz down cast, which is much smaller and easier to handle and adequate for most purposes. A median filter is used which tends to produce profiles of good quality even before manual despiking of the 24 Hz data.

Initial matlab processing for non-standard sections

Stations 27-28

For yo-yo sections the package did not resurface between casts so pressure offset could not be determined for each cast. Minor alterations were made to the standard processing sequence and pressure offset is taken from initial cast at each station. The processing stream used was controlled from *yoyomaster.m* and consisted of *yctdcal.m, yoffpress.m, yspike.m, yinterpol.m, ynewvar.m, ysplitcast.m* and *yctd2db.m*.

Stations 39-41 and 47-47

When the CTD was deployed from the stern it was not brought back to the surface after soaking. Consequently, data from above the soaking depth, which was typically 15 – 20m, should be regarded as bad. extrareject.m was used between *offpress.m* and *spike.m* to select the scan number corresponding to the end of the soaking time and reject data from before then.

Stations 72 and 82

For the LADCP experiments, the CTD was repeatedly raised and lowered in the bottom of the water column, meaning that the standard programs to split the cast and average could not be applied. In place of *splitcast.m*, *xsplit.m* was used to split the cast into various sections and makes one second averaged data. When run the first time, *xsplit.m* interactively determines the split; this information is saved in *splitlog*xxx*.mat* and applied automatically subsequently. *xsplit.m* is appropriate for any non-standard cast.

Temperature and salinity calibration

gestalts.m

This adds bottle sample salinity, botsal, to the bot*nnn*.sal file. Bottle salinities are read from the matlab *ctd_salts.mat* matlab file provided by Paul Dodd. The salinity flag, salflag, is set to 1 where there are data, and 0 where data are absent. Salinity and conductivity offsets between the bottle and CTD values are calculated and stored in the bot*nnn*.sal file.

setsalflag.m

This checks the standard deviations of the CTD temperature and salinity data in bot*nnn*.sal. If either of these for the primary sensors exceeds a threshold of 0.001 (usually when the bottle in fired in the halocline), the salflag for that bottle is set to 0. The output file is bot*nnn*.flg.

salplot.m

This plots the bottle salinity and CTD salinity. It is used to identify bad data points in botsal, whose salflag is then set manually to 0.

sb35read.m

The SB35 Deep Ocean Standards thermometer was available for stations 34-47. The output was captured into a text file (extension .cap) using Seabird's Seaterm program. *sb35read.m* reads this output file and stores the SB35 data in a filed called bot*nnn*.sb35.

sb35comp.m

This calculates the difference between the SB35 temperatures and CTD temperatures during bottle firings and stores them as *sb35t1* and *sb35t2* in the file bot*nnn*.sb35.

sb35diff.m

Plots the SB35 – CTD temperature offsets for all the stations for which the SB35 was fitted, and calculates the median offset for both CTD temperature sensors. This confirms that the secondary temperature sensor is stable and offset by around -0.0005°C, but that the primary sensor was unstable before station 39. The median offsets are stored in the Matlab file *calvalues.mat* in the root ctd directory.

sensdiff.m

Calculates the median difference between the primary and secondary CTD sensors on a station by station basis, and stores the results in the Matlab file *calvalues.mat* in the root ctd directory.

calbottemp.m

Uses the calibrations calculated by *sb35diff.m* and *sensdiff.m*. The secondary temperature sensor has the median offset calculated above applied, while the primary sensor is corrected by this plus the station by station median difference between the secondary and primary sensors (because the SB35 was only available for a handful of stations, not including the ones when primary temperature was most inaccurate). Bottle conductivities are recalculated (they depend on temperature at the CTD cells when the sample was taken), as well as CTD salinities during bottle firings and the appropriate offsets. The output is stored in bot*nnn*.caltemp.

salaanalyse.m

Plots the offsets of bottle salinity – CTD salinity (from the bot*nnn*.caltemp files) for all bottle firings against pressure, temperature, salinity and station number. The variable *salflag* is used to ignore values with a high standard deviation. Also plots the conductivity offsets against the same things. Station by station conductivity calibration values are stored in the Matlab file *calvalues.mat* in the root ctd directory. The choice of median or linear fit offsets for each station is explained in the overview.

calbotsal.m

Applies the conductivity calibrations calculated by *salanalyse.m* to the bottle firing CTD values, and saves the result in bot*nnn*.calsal. Bottle to CTD offsets are recalculated also. An optional input to *salanalyse.m* and *salplot.m* allows the final calibrated bottle – CTD offsets to be inspected, to make sure the calibrations have the desired effect.

salcalapp.m

Provided the results in the bot*nnn*.calsal files are satisfactory (which they are), this applies the temperature and conductivity calibrations to the CTD data from the ctd*nnn*.int file.

The CTD data are also calibrated and the derived variables calculated: salinities (sal1 and sal2), potential temperatures (potemp1 and potemp2), and potential densities (sig0, sig2 and sig4, based on the secondary cells). The output file ctd*nnn*.var replaces the uncalibrated interim file created by *newvar.m*.

splitcast.m and *ctd2db.m* are then re-run on the calibrated ctd*nnn*.var file to produce the final ctd*nnn*.var.dn, ctd*nnn*.var.up and ctd*nnn*.2db files.

Table 7. CTD station positions, maximum depth, and the number of each type of sample taken

Station Number	Date Started	Time Upcast Started	Latituede (N)	Longitude (W)	Max. Pressure	Max. Depth	Min. Distance Off	Salinity Samples	O18 Samples	CFC Samples	Barium Samples	Comment
1	12/02/2005	03:00:38	-70 2.43	1 18.37	557	550.6	9.9	9	9	5	5	
2	12/02/2005	04:36:37	-70 2.72	1 24.21	509	503.2	8.2	10	10	6	5	
3	12/02/2005	06:18:04	-70 3.20	1 30.06	465	459.8	10.8	9	9	10	5	
4	12/02/2005	08:06:25	-70 3.94	1 35.51	441	436.1	6.2	11	10	-	6	
5	12/02/2005	09:27:47	-70 4.73	1 41.02	427	422.2	4	12	12	9	6	
6	12/02/2005	11:18:27	-70 5.66	1 46.15	399	394.6	4.7	8	8	5	4	
7	12/02/2005	12:47:57	-70 6.94	1 50.70	341	337.3	9.3	8	8	5	5	
8	12/02/2005	21:45:49	-70 1.22	1 29.97	459	453.8	3.9	8	10	-	-	
9	12/02/2005	23:47:58	-69 58.19	1 37.52	393	388.7	3.9	7	9	-	-	
10	13/02/2005	01:20:55	-69 56.93	1 41.22	441	436.1	4	8	13	-	-	
11	13/02/2005	02:48:05	-69 55.73	1 42.73	927	915.6	4.9	14	14	-	-	
12	13/02/2005	04:36:01	-69 54.82	1 41.76	1401	1382.2	4.7	15	15	-	-	
13	13/02/2005	06:41:06	-69 54.13	1 40.99	1783	1757.5	9.9	11	11	-	-	
14	13/02/2005	09:01:51	-69 52.54	1 37.87	2207	2173.2	9.7	9	9	-	-	
15	13/02/2005	18:33:54	-70 2.44	1 18.24	565	558.5	3.4	6	8	7	5	
16	14/02/2005	01:02:56	-70 1.68	1 32.24	443	438	4.8	7	7	-	-	
17	14/02/2005	02:14:53	-69 59.83	1 34.01	411	406.4	5.8	5	6	-	-	
18	14/02/2005	04:39:21	-69 50.34	1 35.02	2363	2326	4.1	9	12	-	-	
19	14/02/2005	10:39:22	-70 10.11	2 20.33	191	189	4.8	7	8	5	-	
20	14/02/2005	12:10:26	-70 12.29	2 30.78	287	283.9	3.9	5	7	4	-	
21	14/02/2005	13:35:55	-70 14.26	2 40.58	291	287.8	7.3	4	7	4	-	

22	14/02/2005	15:12:13	-70 16.91	2 49.86	203	200.8	4	7	7	4	-	
23	14/02/2005	16:42:17	-70 13.81	2 49.50	273	270.1	5.1	7	7	-	-	
24	14/02/2005	18:27:51	-70 10.32	2 49.17	527	521	4.7	8	8	-	-	
25	14/02/2005	19:37:05	-70 9.67	2 48.96	1023	1010.1	8.1	10	10	-	-	
26*	15/02/2005	09:00:00	-70 2.42	1 26.11	491	485.5	6.9	2	2	-	2	Yoyo station
27*	15/02/2005	15:20:00	-70 2.43	1 26.13	495	489.4	4.5	3	3	-	-	Yoyo station
28*	15/02/2005	06:07:10	-70 0.17	1 31.14	441	436.1	6.1	4	4	-	4	Yoyo station
29	16/02/2005	20:50:09	-69 55.49	1 23.37	499	493.4	4.8	5	6	-	-	
30	16/02/2005	22:25:31	-69 55.97	1 28.63	485	479.5	4.6	7	7	-	-	
31	16/02/2005	23:33:12	-69 57.19	1 32.89	449	444	5.2	9	9	-	-	
32	17/02/2005	01:32:29	-69 57.36	1 40.00	419	414.3	4.4	6	6	-	-	
33	18/02/2005	12:19:17	-70 7.19	-4 8.12	331	327.4	6.8	7	7	6	7	
34	18/02/2005	13:52:33	-70 5.39	-3 58.18	215	212.7	4.5	3	3	-	-	
35	18/02/2005	15:37:34	-70 2.64	-3 39.49	293	289.8	4.7	5	5	4	-	
36	18/02/2005	17:56:04	-70 4.07	-3 22.05	355	351.1	4.7	4	4	4	-	
37	18/02/2005	20:03:31	-70 5.37	-2 59.40	389	384.7	4.9	8	8	6	8	
38	18/02/2005	21:26:47	-70 7.50	-2 46.79	487	481.5	5.2	6	6	6	6	
39	19/02/2005	13:27:12	-69 45.26	0 39.15	475	469.7	11	4	4	4	4	
40	19/02/2005	15:14:12	-69 44.17	0 41.51	925	913.6	10.5	4	4	4	4	
41	19/02/2005	16:39:14	-69 43.37	0 40.17	1295	1277.9	7.2	5	5	5	-	
42	19/02/2005	18:58:13	-69 40.28	0 39.02	1717	1692.7	6.7	9	5	5	-	
43	19/02/2005	21:20:58	-69 35.71	0 26.07	2049	2018.4	4.9	7	7	7	-	
44	20/02/2005	10:13:10	-69 56.66	2 52.93	2565	2523.6	7.4	6	6	-	-	
45	20/02/2005	13:11:06	-70 1.98	2 52.48	2173	2139.9	4.7	5	5	-	-	

46	20/02/2005	16:28:44	-70 7.14	2 52.22	1883	1855.6	9.8	6	6	-	-	
47	20/02/2005	18:39:44	-70 9.01	2 50.17	1477	1456.9	10.4	7	7	-	-	
48	21/02/2005	14:40:00	-70 6.89	1 50.72	347	343.2	4.4	-	-	-	-	
49	25/02/2005	18:29:49	-76 16.64	34 09.91	817	806.9	5.7	6	6	1	-	
50	26/02/2005	03:21:58	-76 25.77	33 18.02	807	797	5.5	5	5	-	-	
51	26/02/2005	06:05:57	-76 29.75	32 55.81	679	670.8	5.8	5	5	1	-	
52	26/02/2005	07:40:03	-76 31.54	32 45.53	577	570.2	6.8	5	5	1	-	
53	26/02/2005	09:18:59	-76 33.77	32 33.06	487	481.3	5.1	5	5	1	-	
54	26/02/2005	10:41:35	-76 37.52	32 13.63	387	382.6	6.8	5	5	1	-	
55	26/02/2005	12:00:15	-76 41.08	31 57.42	293	289.7	6	4	4	1	-	
56	26/02/2005	13:33:14	-76 46.64	31 27.38	227	224.5	6.2	5	5	1	-	
57	26/02/2005	14:53:54	-76 51.32	31 01.13	215	212.6	4.1	5	5	1	-	
58	26/02/2005	17:38:16	-76 35.80	32 22.64	427	422.1	6.3	6	6	-	-	
59	28/02/2005	00:27:01	-74 39.92	33 26.25	583	576.1	3.5	7	7	7	-	
60	28/02/2005	02:17:36	-74 41.63	34 07.68	537	530.7	7.4	6	6	-	-	
61	28/02/2005	05:16:08	-74 44.43	35 07.78	487	481.4	4.1	5	5	-	-	
62	28/02/2005	07:04:35	-74 43.94	35 39.73	435	430	7	4	4	-	-	
63	28/02/2005	08:56:32	-74 44.54	36 23.06	389	384.6	6.2	4	4	-	-	
64	28/02/2005	11:34:53	-74 31.88	36 40.28	465	459.7	5.4	5	5	-	-	
65	28/02/2005	12:55:16	-74 29.94	36 36.06	789	779.3	6.3	7	7	-	-	
66	28/02/2005	14:32:17	-74 27.50	36 29.71	1041	1027.6	6.7	8	8	-	-	
67	28/02/2005	16:51:16	-74 21.53	36 14.70	1425	1405.4	4.1	6	6	3	-	
68	28/02/2005	19:15:29	-74 14.02	35 56.89	1825	1798.3	3.7	9	7	1	-	
69	28/02/2005	21:52:05	-74 6.22	35 38.11	2129	2096.3	4.2	7	7	-	-	

70	01/03/2005	01:04:30	-74 17.99	36 06.42	1649	1625.5	4.6	7	7	-	-	
71	01/03/2005	04:10:32	-74 24.62	36 22.95	1227	1210.7	4.6	5	5	-	-	
72†	01/03/2005	11:52:51	-74 18.04	36 06.36	1655	1631.4	2.7	6	6	-	-	Plume expt.
73	01/03/2005	18:43:15	-74 39.45	33 29.18	585	578.1	3.5	6	6	-	-	
74	01/03/2005	22:13:29	-74 38.38	32 31.87	599	591.9	3.7	8	8	-	-	
75	02/03/2005	02:44:26	-74 36.85	31 16.33	549	542.6	5.3	4	4	-	-	
76	02/03/2005	04:37:23	-74 40.88	30 49.69	497	491.3	5.5	6	4	-	-	
77	02/03/2005	06:23:05	-74 43.89	30 29.00	451	445.8	6.2	11	3	-	-	
78	02/03/2005	08:13:48	-74 49.60	29 49.75	399	394.5	5	5	5	-	-	
79	02/03/2005	16:35:07	-75 26.52	32 41.93	647	639.3	8.4	4	-	-	-	
80	03/03/2005	08:27:55	-74 18.01	36 06.61	1635	1611.8	20.5	4	4	-	-	
81	03/03/2005	10:08:38	-74 17.99	36 06.44	1653	1629.4	3.3	17	17	14	-	
82†	03/03/2005	02:17:05	-74 17.99	36 06.47	1651	1627.5	4.9	9	8	5	-	Plume expt.

*Stations 26-28 are ‘yoyo’ stations, consisting of 18 (stn. 26), 13 (stn. 27) and 27 (stn. 28) casts within the same deployment. Samples were taken on the final upcast, and the time given is the final time at bottom.

†The package was alternately raised, lowered and hung steady in and above the dense Ice Shelf Water plume for this experiment (see text). The samples were taken on the final upcast and the time given is the final time at bottom.

Tests of an Idronaut OceanSeven 320 CTD probe.

Povl Abrahamsen

Description of the instrument

During JR097 a CTD probe from Idronaut, the OceanSeven 320, was mounted on the rosette to compare the performance of this instrument with a Sea-Bird Electronics (SBE) 911+ CTD system. The Idronaut CTD belongs to BAS, and has been used in the past for taking CTD casts through holes drilled in the Ronne-Filchner Ice Shelf. It has a 7000 m pressure casing, a 4000 dbar pressure sensor, and dual temperature/conductivity sensors. In addition, a mechanical bottom sensor switch and FSK telemetry circuitry are installed, although they were not used on this cruise. There is also a magnetic on/off switch on the end of the instrument. Data were stored in 1 MB of internal memory, as well as on a 128 MB memory expansion card. The probe was running the newest available firmware, version 8.017, and had been returned to the factory in November 2004 for recalibration following an upgrade of the conductivity preamplifier circuitry, the design of which has been recently improved.

Data were downloaded in three ways: using Idronaut's REDAS software, version 3.25, which is primarily intended for real-time data acquisition, as well as with Idronaut's terminal emulator Iterm, which also has functions for downloading and saving data from the probe. In addition, several Matlab scripts were written in order to download data directly from the probe using REDAS 5 binary mode. It was verified that data downloaded in this way matched the data from Iterm, albeit with more precision, while there were very small differences (rounding errors?) between these data and the data from REDAS.

Logging modes

Several different logging modes were utilized on the cruise. When the instrument is connected to a computer on an RS232 cable or through an FSK deck unit, it can transmit data at a rate near 20 Hz; the time stamps, which are added by the instrument to live data, have a mean time difference of 51.5 ms. However, when the instrument logs internally, the options are somewhat more limited and confusing.

Linear mode will supposedly log at full speed, taking a maximum of a certain number of samples within a preset pressure interval. Only the downcast is recorded. The settings recommended by Idronaut are 20 samples and a bin size of 0.2 dbar. We used this on some profiles, and on some profiles we used 100 samples per bin. In practice, the timestamps in this mode are spaced very irregularly, mostly oscillating between being 10 and 90 ms apart, but occasionally with large jumps. For instance, in cast 3, a sequence of time stamps (in hundredths of seconds) is:

5170 5171 5180 5181 5190 5191 | 5290 5291 5292 5293 5294 5295 5296 5297 5298

5299 5300 5301 5302 5303 5304 5305 5306 5307 5308 5310 5320 5321 5330 5331

5340

These large jumps are few and far between, and the time stamps do appear to try to "catch up", but it seems unlikely that they correspond to the actual time of measurement. Instead, they may be the time when data are written to memory. In linear mode, the mean time difference (during an uninterrupted downcast) was found to be 57.5 ms.

In timed mode, a constantly spaced time series can be recorded. Here, the time stamps are quite regularly spaced, but the highest sampling frequency available is 10 Hz. The time stamps are usually 100 ms apart, but with bursts of four samples spaced 200, 10, and finally 90 ms apart; occurring exactly every 11 seconds. This will average out to 100 ms. More worrying are longer gaps, which occasionally occur, and where data simply are missing. These occur in several stations, and appear to happen consistently within 1 s of timestamps 178890, 358890, and 539090 (i.e. half an hour apart), when there is a dropout of more than one second. An example (from station 24) is:

178870 178880 178890 | 179010 179011 179020 179030 179040 179050 179060

Timed mode and linear mode can both be started using the magnetic switch, making them much easier to use if the instrument is mounted on the rosette (without having to plug in a computer).

Finally, there is a fast acquisition mode, which cannot be started using the switch, but which is supposed to log to memory at full speed. In this mode, the time stamp differences also appear to oscillate between 90 and 10 ms, as in linear mode, and also exhibit the half-hourly data dropouts seen in timed mode. However, the effective sampling rate still appears to be best in this mode, with samples taken 50.5 ms apart on average.

Experiments

A summary of the casts taken is given in Table 8.

The instrument was in rosette position 5 except during station 80, when it was suspended by a kevlar rope approximately 10 m below the rosette. When the probe was mounted in the rosette, its pressure port was 48.5 cm above that of the SBE CTD. The SBE CTD was mounted horizontally near the bottom of the rosette; the outflow from its pumps pointed slightly upwards, possibly leading to a slight difference in flow rate between upcasts and downcasts.

Table 8. Summary of casts using the OS320 probe during JR097. Parameters are only indicated when they were set, i.e. the magnetic switch was used between casts when "-" is indicated.

Station	Mode	Parameters
999 (test)	Linear	0.2 dbar, 20 samples
1	Linear	0.2 dbar, 100 samples
2	Linear	-
3	Linear	-
Sampling stopped for unknown reason. Batteries changed.		
15	Timed	0.1 s, 1000000 samples
16	Timed	0.1 s, 1000000 samples
18	Timed	-
19	Timed	-
20	Timed	-
21	Timed	-
22	Timed	-
23	Timed	-
24	Timed	-
25	Timed	-
33	Timed	0.1 s, 1000000 samples
34	Timed	-
35	Timed	-
36	Timed	-
37	Timed	-
Batteries ran out. Changed.		
79 (test)	Fast	n/a
80	Timed	0.1 s, 1000000 samples
Sampling stopped at 1600 dbar. See text.		

The probe is powered by 2 packs containing 10 AA batteries each. The batteries only ran out once, after Station 37. However, there are some gaps in the sampling. During stations 1-14 the probe was in linear acquisition mode, and the probe was not connected to a computer between stations. When the probe was connected to a computer after station 14, it did not enter logging mode when the switch was turned, and only three casts had been stored. Apparently the probe had somehow left linear logging mode, which is very disconcerting if the probe is to be used as a "closed box" system by an untrained operator. The same thing may have happened during station 80. However, here the acquisition stopped in the middle of the profile, restarting briefly later in the cast. It is possible that the connector between the endcap and the circuit board came loose before or during this cast; the probe was not opened after Station 79, where it functioned correctly.

An initial look at the data shows that the sensors do give slightly different readings. There is an offset between the two sets of temperature/conductivity sensors, and this offset drifted between casts. The median difference between the temperature/conductivity sensors from the casts (truncated to when the instrument was in the water) is shown in Figure 46; the offset from the primary sensor on the Seabird is shown in Figure 47. It is surprising that the recently calibrated sensors have not maintained their calibrations better. While the conductivities should be readily correctable using bottles, it would be much harder to fix the temperatures; assuming that one sensor is correct, the other would have drifted over a range of 0.007 °C; a preliminary comparison with the SBE CTD in sections of near-constant temperature showed that both sensors appeared to change with respect to the Seabird sensors. However, at least once during the cruise, the SBE CTD did also suddenly shift its calibration. The temperature calibration of both instruments could be checked against a SBE 35 deep ocean standards thermometer, which was used on some casts.

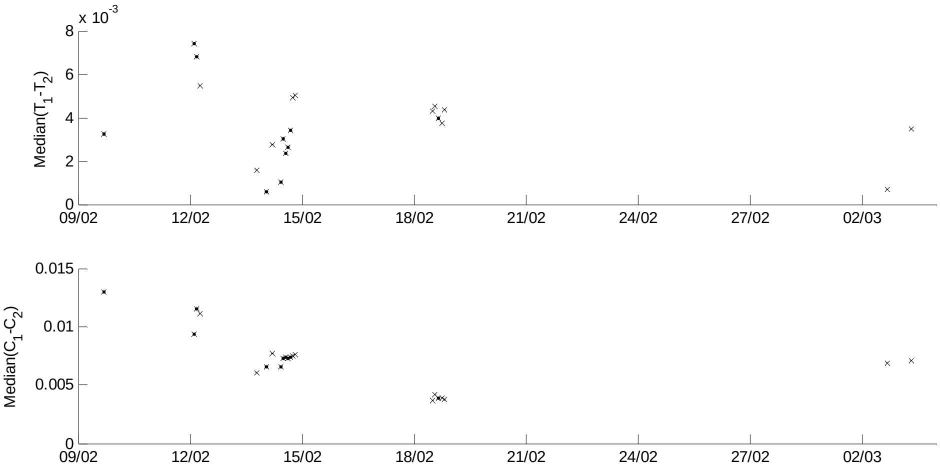


Figure 46. .Differences between the two sets of sensors on the OS320 probe.

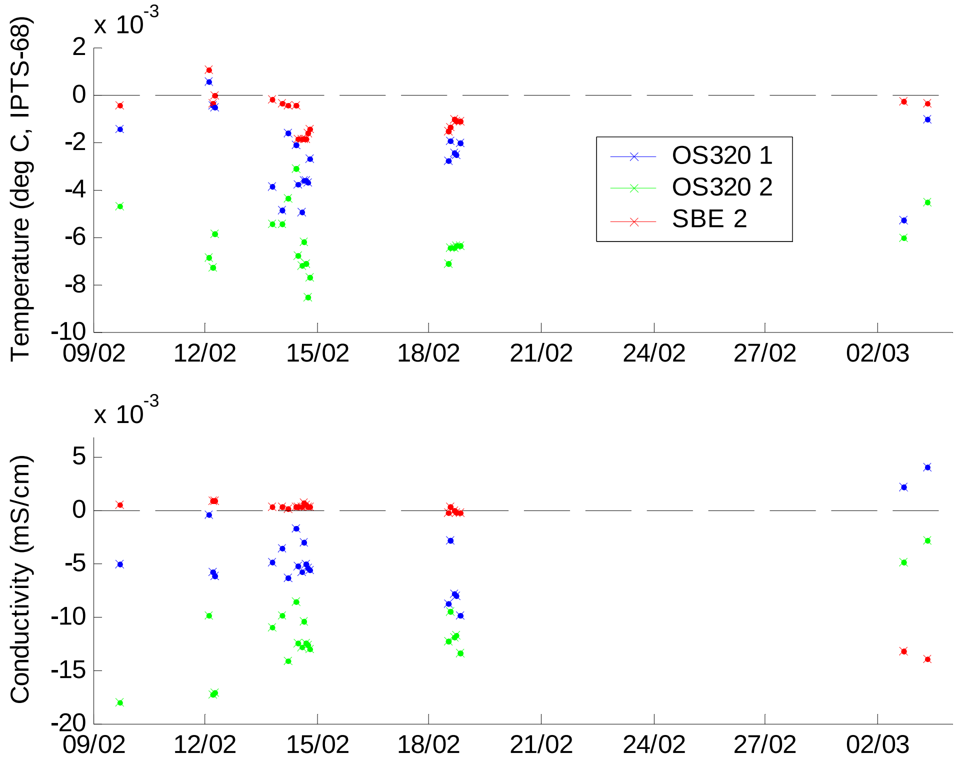


Figure 47. Median offsets between the OS320 and SBE9+ measurements, relative to primary SBE C/T sensors, for all stations where both instruments were run. Station 1 data from the second SBE sensor has been omitted from the bottom plot, as it was filled with ice, and is far off the scale.

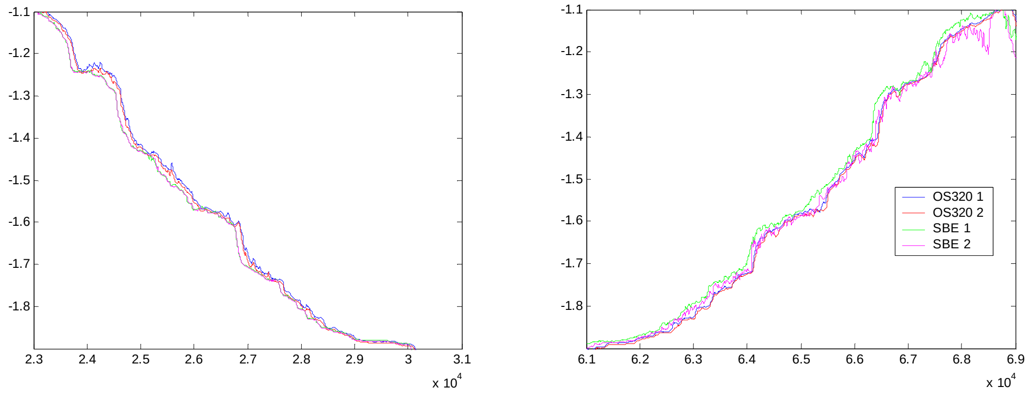


Figure 48. Detail of temperatures from the downcast and upcast from station 23.

Generally the OceanSeven 320 temperatures and conductivities appear to exhibit more variation (noise/fine-scale structure?) than those of the SeaBird on the downcast. However, on the upcast the opposite appears to be the case. There is a slight lag between the temperature and conductivity sensors on the OS320 that does not appear to be present in the Seabird (presumably as a result of its pumped system). This lag does vary with descent rate; the lag is particularly high on station 80, where the descent rate was 0.5 m/s, and the mode of the lag is around 0.7 s. Generally the lag is much smaller. Although no clear correlation was found with rate of change of temperature, it is possible that the thermal mass of the conductivity cell is causing some of the lag.

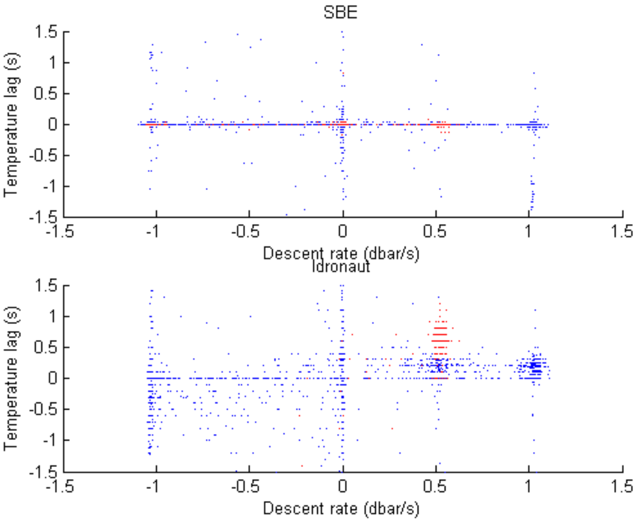


Figure 49. Temperature/conductivity lags for primary sensor pairs. Each point corresponds to the mode of the cross-correlation of a 15-second window. All casts in table 1 are plotted here; station 80 is plotted in red.

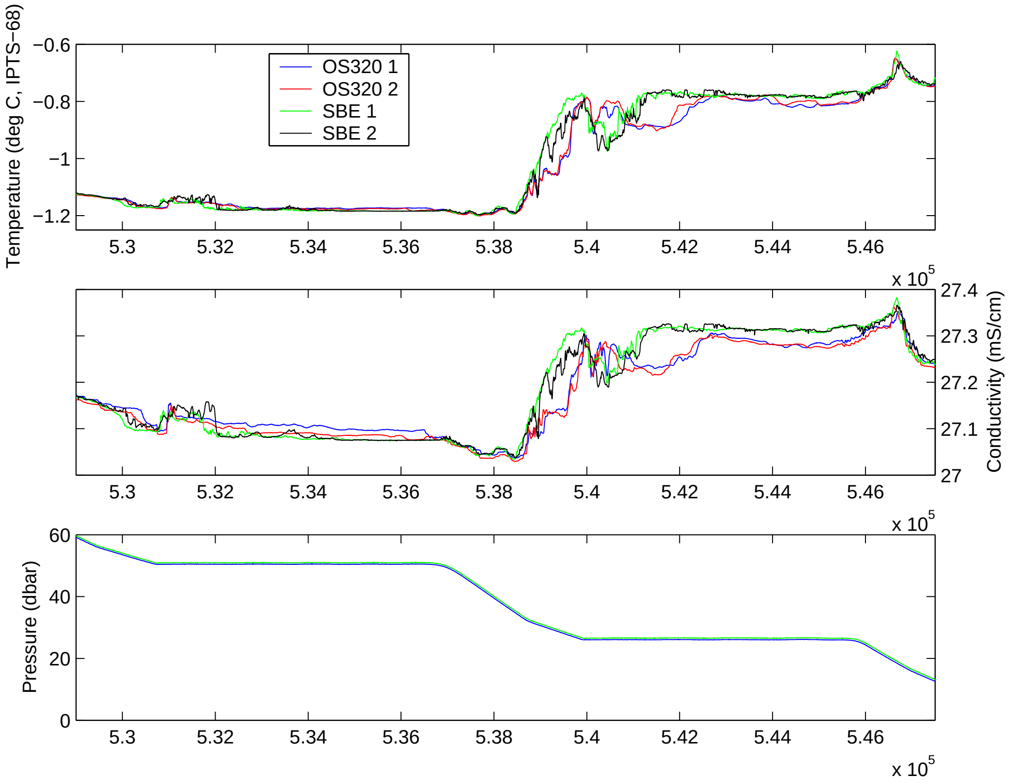


Figure 50. A detail from the upcast of station 18. The domain covers approx. 3 minutes (ticks are 20 s apart).

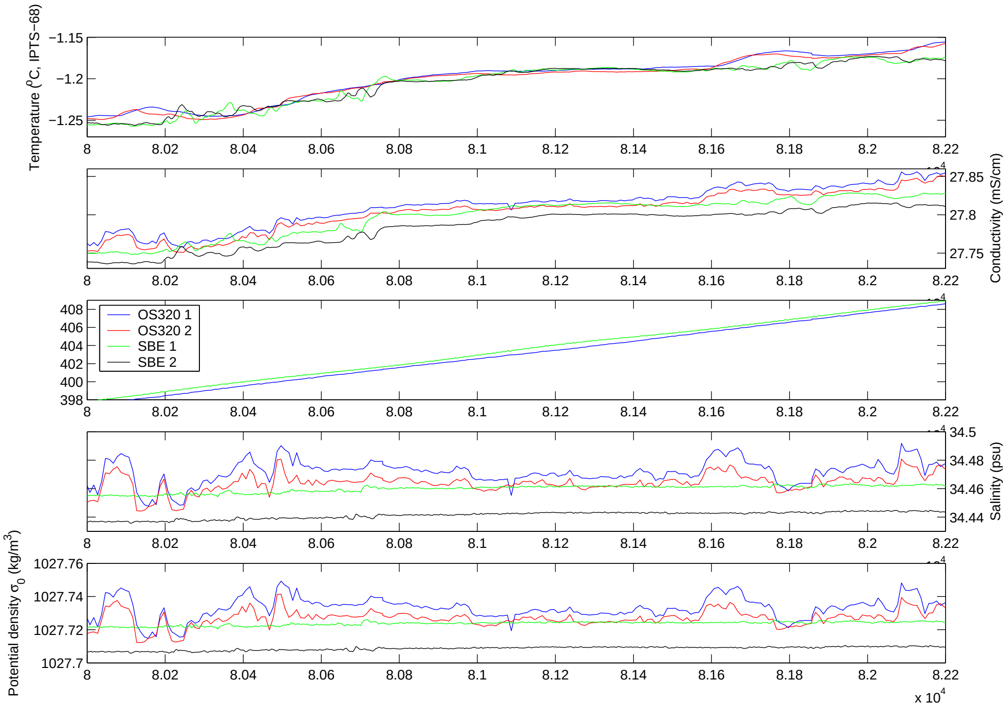


Figure 51. A detail from station 80. Temperature, conductivity, pressure, salinity, and potential density at 0 pressure have been plotted against time; each tick is 2 seconds apart. Note that the instruments were 10 m apart, and the package was moving downwards at a near constant rate. Therefore the spacing of the features may not be identical, although this is the same part of the water column.

Figure 51 shows a subsection of station 80; temperatures are increasing, as are conductivities (and salinities). Although the OS320 temperatures appear smoother than those of the Seabird, they are clearly not matched up properly against the conductivities, introducing salinity variations of up to 0.04. In contrast, the Seabird, whose conductivity appears to vary approximately the same amount as the Idronaut, but which has more variation in the temperature, produces a salinity ignal that does not vary more than 0.004 from a straight line over the plotted range.

Conclusions

- The OS320 cannot provide a regularly spaced time series at 20 Hz; for unattended profiling this is a clear disadvantage compared with the constant 24 Hz logging rate of the Seabird. However, it does have more complex logging options, which would be preferable for other types of deployments. Perhaps a constant logging rate can be provided in future firmware updates.
- Data dropouts of 1 s length occur every half hour.
- The recorded time stamps do not correspond to the time of measurement.
- Unattended use of the OS320 did not prove reliable during the cruise; on two occasions the instrument stopped logging, when it was supposed to be in an unattended mode.
- The calibration of the two temperature sensors constantly changed over the cruise; this difference is much greater than the stated accuracy. The Seabird sensors did also shift, although this occurred only once (as a step), and was a much smaller shift, possibly due to an electrical fault in the CTD.
- The conductivities also shifted during the cruise; again, this difference is much larger than the stated accuracies. This could be checked against water bottles.
- The sensors on the OS320 exhibit slightly higher variability than on the Seabird on the downcast; on the upcast the opposite is true.

- There is a lag between the conductivity and temperature measurements, which is not present on the Seabird (after conductivities have been advanced in the deck unit). The lag is variable, and appears to be worse when profiling at 0.5 m/s compared with 1 m/s. In addition, it is different between the upcasts and downcasts.

- The lag introduces large errors in derived variables, which a simple smoothing would not remove. Instead, it may be better to perform some more complex filtering to remove the mismatch; more research into the time response of the sensors while profiling (not just in a calibration tank) would probably be warranted. Perhaps the thermal mass of the conductivity cell is responsible for some of the errors.

Salinity Sample Collection and Analysis

Paul Dodd

Salinity samples were collected from Niskin bottles fired at selected depths on every cast for the purpose of calibrating CTD sensors, and every four hours from the ship's uncontaminated underway supply for calibration of the underway Oceanlogger system. Samples were stored in 200ml medicine flats, which were flushed with sample three times before filling to just below the shoulder to allow space for thermal expansion. Bottle necks were wiped dry to prevent salt crystallisation, before a single-use plastic insert and plastic screw cap were applied.

A Guildline 8400b Autosal salinometer (serial number SN60839) equipped with an Ocean Scientific International Ltd. peristaltic pump was used to analyse samples. The salinometer was sited in a constant temperature laboratory initially maintained at 21˚C but later at 24˚C as this was more stable. The salinometer water bath temperature was maintained initially at 24˚C but at 27˚C when the laboratory temperature was increased. Salinity samples were stored in open wire cages adjacent to the salinometer for 24 hours prior to analysis to allow them to reach laboratory temperature.

On leaving port the salinometer was standardised at a salinity of 34.995 using IAPSO standard seawater. The linearity of the salinometer's response was determined by analysing IAPSO standard seawater of salinity 30.005 immediately after the 34.995 standard. The standardizing potentiometer was then fixed for the duration the cruise and conductivity ratio corrections were applied in post processing. IAPSO standard seawater of salinity 34.995 was analysed before and after each crate of 24 samples so that a moving offset calculated from the linear trend between bracketing standards could be applied to each sample measurement. Additionally, a linear function of the difference between the offset required to standardize the salinometer at 30.005 and 34.995 was applied to each sample measurement to account for the non-linearity of the salinometer's response away from a salinity of 34.995. All of the samples analysed during the cruise had salinities between 30.005 and 34.995.

On 17 February 2005 algal growth became evident in the sample tube and at the extreme left hand end of the conductivity cell. This was probably due to inadequate flushing of the salinometer between sessions, but may indicate a leak between the conductivity cell and surrounding water bath. Growth within the cell was stemmed by flushing the salinometer with a solution of 80% methanol, 10% milliQ water and 10% detergent. The sample tube was also replaced.

On 5 March 2005 the peristaltic pump failed following extensive corrosion to one of the solder tabs on the unit's on/off switch. This corrosion arose because sample leaking from a joint between the pump outflow and the salinometer had accumulated within the pump housing. The connection to the switch was cleaned and re-soldered and the leaking joint repaired.

During the cruise, several salinity samples from pairs of Niskin bottles fired together were analysed to measure the repeatability of the combined sampling and salinometry procedure. Replicate salinities were consistent to within +/- 0.0003.

Lowered Acoustic Doppler Current Profiler (LADCP)

Kevin Oliver and Justin Buck

[This section is based on LADCP reports from JR80 (by Alberto Naveira Garabato, Jon Wynar, Ian Waddington and David Stevens) and JR106 (Louise Sime and Paul Dodd), with large sections of text drawn directly from these reports.]

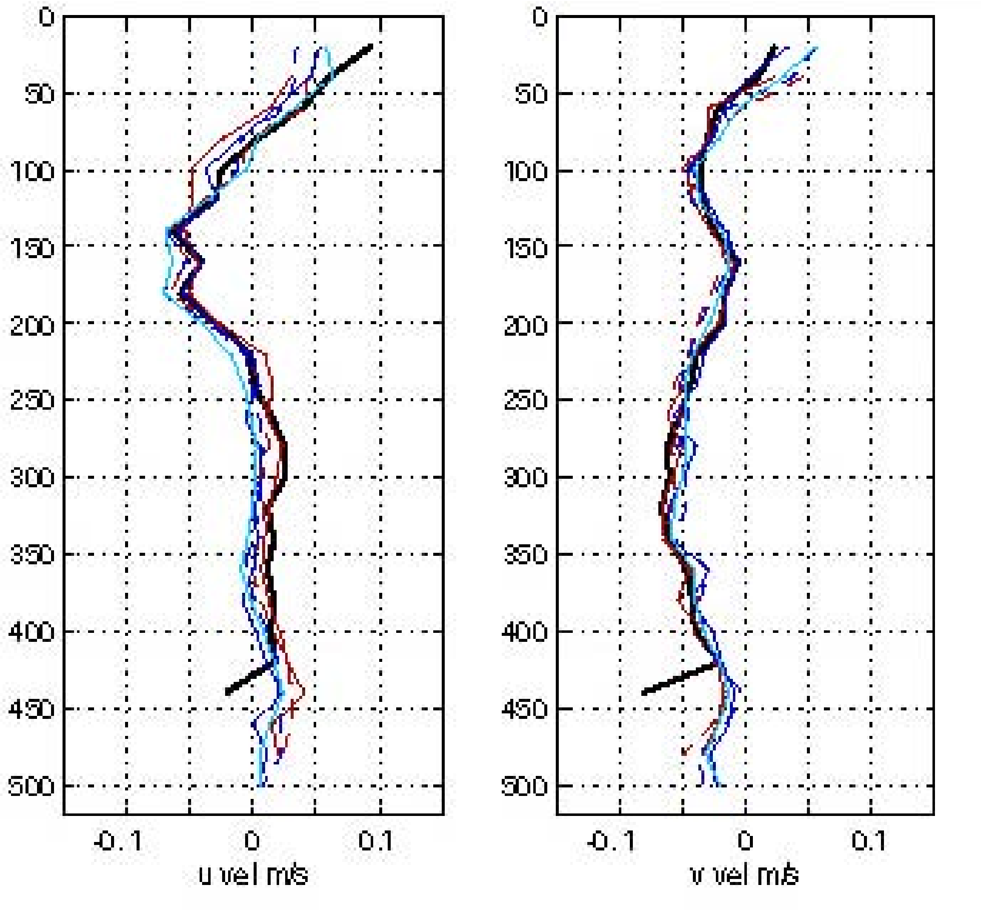
General configuration

The LADCP package used during JR97 consisted of a downward and an upward looking RDI 300 kHz Workhorse (WH) ADCP. The downward-looking WH (DWH; serial number 4908) was mounted off-centre at the bottom of the frame, and the upward (UWH; serial number 1855) on the outside of the frame. The details of their sampling configurations are described in section 2. Between stations, each ADCP was usually connected to a controlling PC in the Underway Instrument Control (UIC) room through a serial cable for delivery of pre-deployment instructions and post-deployment data retrieval. When sea-ice necessitated lowering the package from the aft of the ship, this was impossible due to insufficient length of cable, and the ADCPs were allowed to continue pinging between stations. The battery package was recharged after each deployment, by connection to a charging unit in the UIC room via a power lead.

Both instruments were deployed during every station except for station 79. At every other station except the test station (station 999), where no data were obtained as a result of a minor error in the command file for the master (DWH), they returned apparently reasonable raw data. The data quality during downcasts/upcasts was poorer during station 62-72 and 82 when alternative sampling configurations were used (see following section). For other stations, inspection typically revealed better agreement with the shipboard ADCP for DWH downcasts than DWH upcasts.

Processing of data from each workhorse was carried out independently using the University of Hawaii (UH; Eric Firing's group) software used on JR106 and JR80, detailed in the processing section. Because problems were encountered, the data was also processed using software by Lamont Doherty Earth Observatory (LDEO; Martin Visbeck's group). Use of this software is not detailed here. Because tables of the earth's magnetic variation were not updated to 2005 in the UH software, editing was necessary (see processing section). This provided magnetic field information for the equivalent date in 2004. The error associated with this is likely to be smaller than the precision of the ADCP compasses, and was not detectable from comparison with the LDEO software output for the DWH. Further problems with UH processing for the UWH were not resolved. There was good agreement between raw data from the DWH and the UWH. The output from domerge.prl (see processing section) showed good agreement on spatial scales greater than the range of the ADCPs but negative correlation on smaller spatial scales. On this basis, it is suspected that the UH software was either treating the UWH as a DWH, or was misinterpreting the bin distances from the UWH. Modification of the LDEO software has provided processed UWH data that agrees well with DWH data, so we expect that the same is eventually achievable with the UH software. An example of a processed station, using both software packages, is plotted in Figure LADCP1, with ADCP data for comparison.

Figure 52 Eastward and northward velocity components from the DWH on Station 2, processed using the UH (red) and LDEO (blue) software packages. Solid lines indicate downcasts; dashed lines indicate upcasts; the light blue solid line is a mean of down- and upcasts using the LDEO shear based (as opposed to inverse) method. The shipboard ADCP (with bottom tracking on this station), is included for comparison (black).



JR97 LADCP configuration files

Three different sampling configurations were used for different stations, depending on the primary purpose for which the ADCPs were used. The majority of stations consisted of conventional single down- and upcasts without pause except for bottle firing. For such stations, as well as for “yoyo” stations (stations 26-28), consisting of multiple repeats of conventional casts, the priority was obtaining the best possible current estimates despite package motion and a short observation period for each part of the water column. As is usual for this purpose, the ADCPs were operated with 16 large (10 m) bins and short ensembles (1 ping per ensemble; average 1 ping/second). At some stations, the package was held for up to 30 minutes at one or more depths (frequently with repetition), for observation of a dense plume from the Filchner continental shelf. In such cases, package motion and limited observation time were lesser concerns, and good quality ensembles with high spatial resolution were priorities. For stations 62-71, 27 four metre bins were used for each WH. This is true also of stations 72 and 82, with the further alteration that 300 ping ensembles were used. These stations are discussed further in Section 5. Command files are provided for each of these three sampling configurations in the appendix.

Instructions for LADCP deployment and recovery during JR97

This set of instructions is based on the LADCP section of the JR67 cruise report, written by Brian King and colleagues. It can be used in conjunction with the LADCP log sheet included in the present report.

Deployment

Connect the communication and battery leads for both instruments. The DWH should be connected to the com1 port and the UWH to the com2 port.

Downward looking Workhorse (DWH) LADCP

1. In the controlling PC, run **BBTALK** and open a window for COM1. Press <F3> to create a log file in which all subsequent BB-related BBTALK output will be stored. Enter filename of the form *c:\ladcp\jr97\log_files\##m.txt* (where *##* is the station number). And the *m* refers to the DWH master status.

2. Press <END> to wake up the DWH. If the connection fails, check that the communications lead is properly connected at the DWH end.

3. Check the DWH clock against the scientific clock. The DWH clock does not keep good time. Type *TS?* <ENTER> for a time in the form *YYMMDDhhmmss*. Reset the DWH clock to the scientific clock time by typing *TSYYMMDDhhmmss* <ENTER>.

4. Check the available memory of the DWH by typing *RS?* <ENTER>. If insufficient memory is available, clear it by typing *RE ErAsE* <ENTER>. The memory should only be cleared after all data has been transferred to the Suns and checked.

5. Type PA <ENTER> to run diagnostic checks. Note that the Receive Path (PT3) and Bandwidth (PT6) tests may fail if the WH is not in water. Other tests should pass.

6. If the batteries have been recharged, switch off the battery charge unit and check battery voltage. This step was generally carried out before the deployment procedure was started.

7. Press F2 then select the DWH configuration file. See appendix 2 for the master configuration file. The DWH is now ready for deployment.

8. Press F3 to stop the log file.

Ensure that entries 1-4 have been filled in in the log sheet as the deployment is carried out. This also helps ensure that no steps are omitted. The DWH should now be pinging.

Upward looking Workhorse (UWH) LADCP

Repeat steps 1-8 for the UWH. It is easiest if these are carried out in a separate adjacent window. Alternatively, toggle to *COM2.* On JR97, repetition was carried out step by step (i.e. repeat step 1 for the UWH after step 1 for the DWH, not after step 8). Note the following minor differences:

1. The UWH BBTALK log file should be named *c:\ladcp\jr97\log_files\##s.txt, w*here the *s* refers to the UWH slave status.

7. Select the slave UWH configuration file - see appendix for details.

Finally, detach communication cables, and charger is necessary, for both instruments and fit blanks to all cable ends.

Recovery

Remove blanks and attach the communication and charger cables, using fresh water and absorbent paper to minimise their exposure to salt water.

1. Run **BBTALK**. Select *COM1* for the DWH (master) and press <END> to wake up the LADCP. Use the adjacent COM2 window for the UWH and press <END> to wake up the LADCP.

2. Check battery voltage and switch on charger if necessary. Though this step can generally be left to the end for the workhorse type ADCPs.

3. Check the number of deployments by typing *RA?* <ENTER>. Then transfer the data to the PC. Go to *file, recover recorder*. Select the *c:\ladcp\jr97\master* for the DWH and

c:\ladcp\jr97\slave as the destination for the UWH recovered files. This can take ten minutes or more with large files. Once the data are transferred the WH should both be powered down by typing *CZ* <ENTER>.

4. Rename the default filenames to *c:\ladcp\jr97\master\jr97##m.000* for the DWH and *c:\ladcp\jr97\slave\jr97##s.000* for the UWH.

5. Note the file size down, and transfer the files by FTP or a zip disc to */export/home/jr097\ladcp_raw* on *shagex*. The program WINADCP on the LADCP PC can be used to check the number of ensembles and whether the data recovered looks initially reasonable. But this is not essential, since errors will come to like in the later processing.

The data are now ready for processing.

LADCP log sheet: – JR97

CTD CAST		Date:		JDAY	
Lat:		Long:		Depth:	

LADCP Deployment / Recovery Log Sheet

Pre-Deployment (Comms. and Charge leads should be in place)

In BBTALK:

	MASTER	SLAVE
1. Log file name (F3)	.txt	.txt
2. Time check (TS?) and time correction if necessary	: :	: :
3. Memory unused (RS?) and erase if necessary (RE ErAsE)	Mb	Mb
4. Run tests (PA)	☐	☐

5. Battery Voltage V (max. 52V) measure across charger

Deployment

6. MASTER deployment time, from master clock : :

Recovery

In BBTALK

7. Time of stopping MASTER logging : : Stop SLAVE

8. Battery Voltage V Measure on charger

Data Transfer

In BBTALK

	MASTER	SLAVE
9. Number of deployments (RA?)		
10. Default filename	-RDI- .000	-RDI- .000
11. Renamed file	m.000	s.000

In BBLIST

	MASTER	SLAVE
12. File size	***Kb***	Kb
13. Number of ensembles		

16. Comments

LADCP processing during JR97

Installing the UH software in the Suns

In the *…jr097/ladcp* directory, create a directory called *uh* . In that directory, download a tar'ed copy of the complex UH directory structure with some example files (DEMO.LAD.tar) from a CD provided by Brian King. A tar –xvf DEMO.LAD.tar in *…jr097/ladcp/uh* will set up the directory structure that the UH software needs to run.

From *uh.src.y2k* in the CD, copy a directory called *programs* and all its contents to *…jr097/ladcp/uh* .

In *…jr097/ladcp/uh* , configure the following environmental variables in the file *LADall*: LADCP_PROCHOME and LADCP_PROGHOME should be set to *…jr097/ladcp/uh* , LADCP_CRUISEID to jr097 and LADCP_YEARBASE to 2005. Then type *setup matlab* and *source LADall*.

Type *cd proc* . Edit the script *makelinks* and change the cruise identifier to jr097. Then execute *makelinks*.

Processing

At the time of writing this report, processing has been carried out up to and including step 7 only. Steps 1 to 6 allow the user to examine the quality of the data and to calculate relative velocity profiles in the absence of CTD or navigational data. Navigation, but not CTD, data, is included for step 7.

For yoyo stations or consecutive stations without recovery and redeployment, the raw (*.000) files must first be sliced into separate files for each station/cast. This is possible using the WINADCP PC software provided by RDI. After opening the file, adjust Options > Max Ensembles to a large number (e.g. 9999). Then, for each cast right-click on the section plot, and select the Subset ensembles for the given cast. This should be readily apparent from the distribution of missing data, and from comparison of the ensemble times to the CTD log sheet. Finally save by selecting File > Save Subset.

The raw (*.000) LADCP data should be placed in … *jr097/ladcp/uh/raw/jr097/ladcp* . We followed the conventional nomenclature and renamed the files as at SOC (i.e. jsss_cc.000, where sss is the 3-digit station number; cc is 02 for the master DWH and 03 for the slave UWH). Exceptions were the yoyo stations (stations 26-28); here, cc was the cast number for the DWH, and 50 plus the cast number for the UWH. For the yoyos, much of the below was automated, providing greater efficiency at the expense of removing some of the human quality checks.

0. Before each session of processing is carried out, *source LADall* needs to be run from the *…jr097/ladcp/uh directory.*

1. After typing *cd proc* , type *perl –S scan.prl sss_cc* to scan the raw data and create a station-specific directory structure in the *proc/casts* directory. Check that the details of the cast (depth, downcast / upcast times) agree approximately with those in the LADCP log sheet.

2. Enter station position information using *putpos sss cc latdeg latmin londeg lonmin* (where *latdeg* and *londeg* are lat and lon degrees, -ve if south or west; and *latmin* and *lonmin* are lat and lon minutes, always +ve).

3. Start *matlab* and type *magvarsm(sss.cc).* This will calculate a correction to the direction of the LADCP velocities based on the local magnetic declination. It will append the declination to *mag_var.tab* , and the date and position to *stations.asc* . On JR97, line 112 of geomag.m (called by magvarsm.m, via mag_var.m) was altered by replacing "year(index)" with "year(index)-1" so that this part of the software treated the data as if were collected on the equivalent date in 2004.

4. Exit matlab and type *perl –S load.prl sss_cc* . Reply ‘y’ at both prompts. This loads the raw data to start processing. Sometimes the program does not execute because path names in *LADall* are too long for the length of environmental variables predetermined in the UH software. Use symbolic links if this happens.

5. Type *perl –S domerge.prl –c0 sss_cc* to merge velocity shear profiles from individual pings into a single downcast or upcast profile. The option *–c0* states that we do not have CTD data yet.

6. In *matlab*, set the variable *plist = sss.cc* and run *do_abs* to calculate relative velocity profiles. Check that there is a reasonable agreement between the downcast and upcast profiles, and that the vertical velocity is of order 1 m s^{-1} and reverses sign between the downcast and upcast.

Obtaining a final absolute velocity profile requires the incorporation of navigational and CTD information into the processing.

7. To incorporate navigational data, a file called *sm.mat* needs to be created in *…jr097/ladcp/uh/raw/jr097/gps* . This file should contain the variable *sm*, which must have 3 columns in the following order: 1) time every 30 s; 2) GPS longitude; and 3) GPS latitude. Then type *cd proc* , *matlab* and set *have_sm=1* (to enforce the use of navigational information) and *plist=sss.cc* . Run *do_abs* .

8. The inclusion of CTD data permits a revision of the LADCP velocity profile according to more accurate estimates of depth and sound velocity. A file containing 1 Hz CTD data (calibrated and de-spiked) from both the downcast and upcast must be created for each station and LADCP in *…jr097/ladcp/uh/raw/jr097/ctd* . This should contain the variable *ctd*, which must have 4 columns in the following order: 1) time (Julian day expressed in s); 2) pressure; 3) temperature; and 4) salinity. In JR097, 24 Hz data from the Seabird CTD were binned to 1 Hz using the matlab script *readctd* .

9. Type *cd Pctd* and run *ctd_in* in *matlab* to read the 1Hz CTD data in. Still in matlab, type *cd Fitd* , set *plist=sss.cc* and run *fd* to align the LADCP and CTD data sets in time. This can be done in an automatic or an interactive mode.

10. Type *perl –S add_ctd.prl sss_cc* to add CTD data to the **.blk* LADCP files in the *scdb* directory.

11. Run *perl –S domerge.prl –c1 sss_cc* . The option *–c1* states that we now have CTD data.

12. Finally, in *matlab*, set *have_sm =1* and *plist = sss.cc* and run *do_abs* to calculate final absolute velocity profiles

In principle, combining the DWH and UWH data sets at the processing stage may be conducive to more accurate velocities. However, this was not possible with the UH software on JR97, because of the difficulties outlined above.

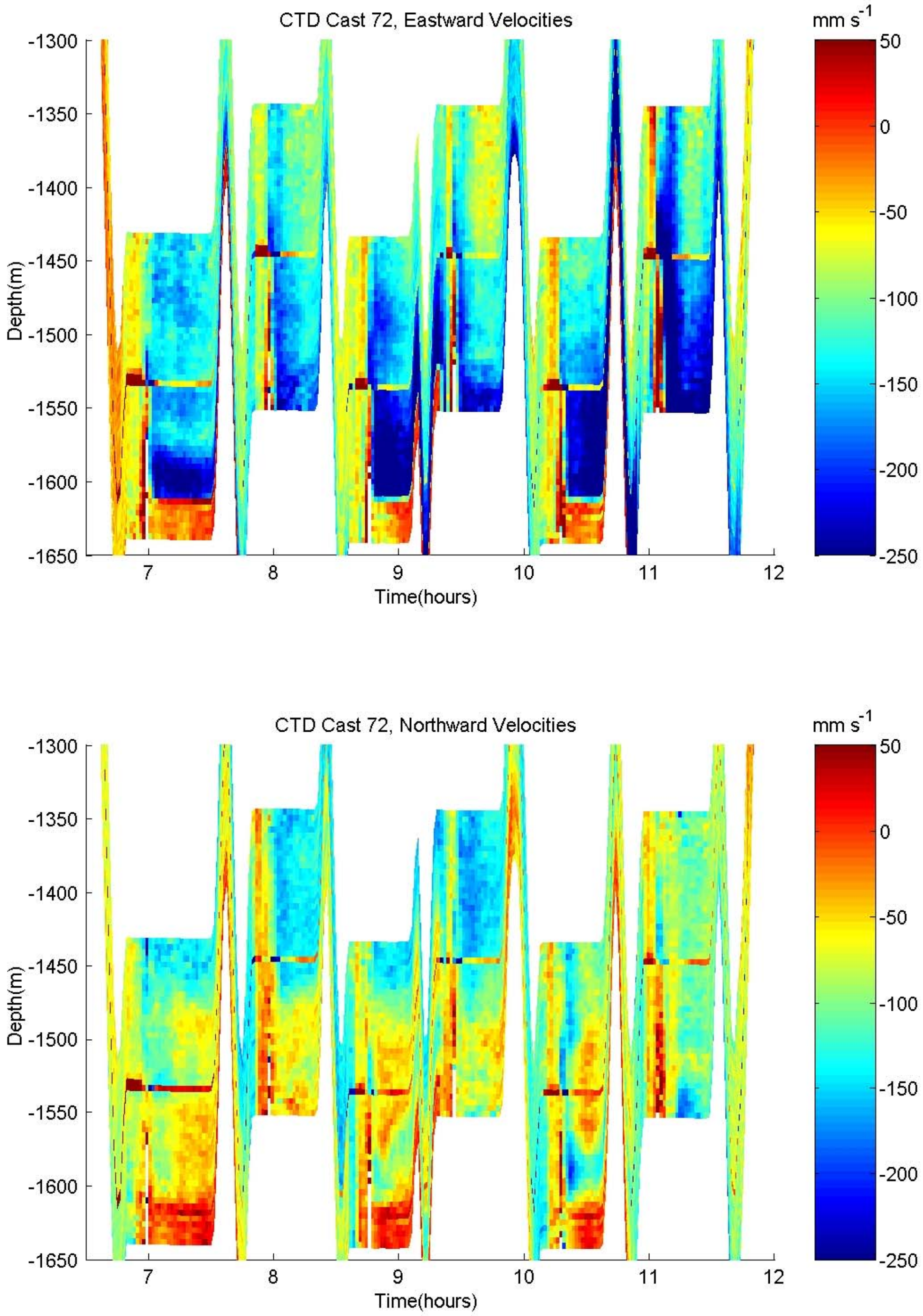
Plume stations LADCP data

The aim of stations 72 and 82 was to capture the plume of Ice Shelf Water (ISW) originating from the Filchner Ice Shelf Cavity and flowing into the deep Weddell Sea. The CTD package followed the cycle described in Table LADCP1. Along with the navigation being logged at each stage the temperature and salinity were noted at each stage. Although the processing described in Section 4 was carried out for these stations, as well as stations 62-71, this is of limited value. The aim is to analyse the temporal variability of the plume. The reason for choosing to hold the package at 90 m and 180 m above the bottom is so the LADCPs can get a profile for the whole plume. An example plot of station 72 is shown in Figure 53.

Table 9 Description of cycle for Filchner ISW plume experiments.

Stage in cycle	Description
1	CTD package lowered to 5m above sea bed
2	CTD raised to 90 m above bottom
3	CTD held at 90 m above for 30 minutes
4	CTD raised up and out of plume
5	CTD lowered to 5 m above sea bed
6	CTD raise to 180 m above sea bed
7	CTD held at 180 m above for 30 minutes
8	CTD raise up out of plume
9	Back to stage 1 and repeat cycle or bring CTD package back to surface

Figure 53. Package movements and raw ADCP data from Station 72.



LADCP command files

Configuration for all stations except 62-72 and 82.

DWH – master, run on COM1	**UWH – slave, run on COM2**
PS0	PS0
CR1	CR1
CF11101	CF11101
EA00000	EA00000
EB00000	EB00000
ED00000	ED00000
ES35	ES35
EX11111	EX11111
EZ0111111	EZ0111111
TE00:00:01.00	TE00:00:01.00
TP00:01.00	TP00:01.00
LD111100000	LD111100000
LF0500	LF0500
LN016	LN016
LP00001	LP00001
LS1000	LS1000
LV250	LV250
LJ1	LJ1
LW1	LW1
LZ30,220	LZ30,220
SM1	SM2
SA001	SA001
SW05000	ST0
CK	CK
CS	CS

Stations 62-71

DWH – master, run on COM1	**UWH – slave, run on COM2**
CR1	CR1
CF11101	CF11101
EA0	EA0
EB0	EB0
ED0	ED0
ES35	ES35
EX11111	EX11111
EZ0111111	EZ0111111
TE00:00:01.00	TE00:00:01.00
TP00:01.00	TP00:01.00
LD111100000	LD111100000
LF176	LF176
LN27	LN27
LP1	LP1
LS400	LS400
LV175	LV175
SM1	SM2
SA001	SA001
SW05000	ST0
LW1	LW1
CK	CK
CS	CS

Stations 72 and 82

DWH – master, run on COM1	**UWH – slave, run on COM2**
CR1	CR1
CF11101	CF11101
EA0	EA0
EB0	EB0
ED0	ED0
ES35	ES35
EX11111	EX11111
EZ0111111	EZ0111111
TE00:00:01.00	TE00:00:01.00
TP00:01.00	TP00:01.00
LD111100000	LD111100000
LF176	LF176
LN27	LN27
LP300	LP300
LS400	LS400
LV175	LV175
SM1	SM2
SA001	SA001
SW05000	ST0
LW1	LW1
CK	CK
CS	CS

Underway data: navigation, bathymetry and ocean logger

Colin Goldblatt

Introduction

We set up a series of scripts to automate the daily download of navigation, bathymetry and ocean logger data. The data were written to ASCII files, which can be read by matlab.

All work was done on the main server on board 'jrua', in the directory

`/users/mlsd/pstar/jr097/underway/`

For brevity, this is referred to as `/underway` below.

Data download

Automated download

Files to download data are contained in

`/underway/auto_download/`

There are three files used:

`launch_get_data.sh`

This is a shell script that sets up the environment variables needed by `get_data.pl` and then calls `get_data.pl.`

`data_list.mfmt`

This contains a list of data that we want to download to setup the `mutli` command which collects the data.

`get_data.pl`

This is the perl script which actually gets the data from the ship's RVS data streams, using the command `mutli`, formats it for matlab and puts it in the underway directory. The file written is `xxx.asc`, where `xxx` is a three digit Julian day.

The automation of downloading needs to be set up at the start of the cruise; this is done with the UNIX command `crontab`. In a terminal,

```
crontab -e
```

to edit the crontab file on jrua, paste the line of text from `crontab_file.txt` into this, then exit.

More detailed instructions are given in `/underway/auto_download/readme.txt.`

The scripts used are based on scripts written by Duncan Mercer, given to us by Jeremy Wilkinson (both of SAMS) and have been rewritten by Jeremy Robst (BAS ITS).

Manual download

get_data.pl can be called manually with arguments for start and end days and times. This should be used when download needs to be re-run if the data list has been changed, or part of a day's data is wanted.

Instructions for use are given in

`/underway/auto_download/readme.txt`

Data output

Data are collected at 0005Z every day for the previous day and written to

`/underway/xxx.asc`

The various data streams have different sampling intervals. The first five columns of `xxx.asc` describe time (year, jday, hour, min, sec). Further columns give the data value for each variable, or NaN if no data is reported.

Stream	**Interval (seconds)**	**Variable**	**Description**	**Units**	**Col. in xxx.asc**
Gps_nmea	1	Lat	Latitude	deg	6
		Lon	Longitude	deg	7
Anemom	1	wind_dir	Measured wind direction	deg	8
		wind_speed	Measured wind speed	knots	9
truewind	1	wind_dir	Corrected wind direction	knots	10
		wind_speed	Corrected wind speed	knots	11
em120	Irregular*	Cendepth	Swath bathymetry, centre depth, corrected for speed of sound	m	12
Sim500	Irregular*	Uncdepth	Navigational echosounder depth, uncorrected	m	13
bestnav	30	Lat	Latitude	deg	14
		Lon	Longitude	deg	15
		Vn	Velocity north	knots	16
		Ve	Velocity East	knots	17
		Cmg	Course made good	deg	18
		Smg	Speed made good	knots	19
		Heading	Heading	deg	20
		dist_run	Distance run	km	21
oceanlog	5	atemp1	Air temperature	°C	22
		hum1	Relative humidity	%	23
		par1	Photosynthetically active radiation	μmol/s.m^2	24
		tir1	Total incoming radiation	Wm^{-2}	25
		atemp2	Air temperature	°C	26
		hum2	Relative humidity	%	27
		par2	Photosynthetically active radiation	μmol/s.m^2	28
		tir2	Total incoming radiation	Wm^{-2}	29
		press1	Barometric pressure	hPa	30
		press2	Barometric pressure	hPa	31
		Saltemp	Temperature of conductivity cell	°C	32
		Cond	Conductivity of intake water	S/m	33
		Sal	Salinity of intake water	psu	34
		Velocity	Derived speed of sound in intake water	m/s	35
		Fluor	Fluorescence		36
		Fstemp	Temperature of Fluorometer	°C	37
		Flow	Flow rate of intake water	l/min	38
		Sst	Temperature of intake water	°C	39

* Data are recorded every time a ping is received; which varies with depth.

To find the contents of a stream, with units, in a terminal:

```
vars -u stream
```

Data processing

Two high level functions are used to read `xxx.asc` into matlab, process the data and average it:

```
average(jday,int,filename)
```

Reads in data for the Julian days given in vector `jdays`, rejects bad data and averages over interval `int`, in seconds. Saves to filename.mat if `filename` is specified, otherwise to default.

```
avappend(jday,int,partial,filein)
```

Appends a whole or partial days data to existing .mat file specified by `filein`.

Both of these call three lower level functions to do most of the real work:

```
checkint
```

Checks that the user supplied interval is reasonable.

```
averagingsheep
```

Median averages the data at the supplied interval. Additionally, checks whether the intake flow rate of seawater drops below a threshold and sets all data which depend on flow rate to NaN where flow is too low.

```
fmtdata
```

Formats the data output from `averagingsheep` and checks for any breaks. If any breaks are found, a row of NaNs is inserted.

More information is given by

```
help function
```

at the matlab prompt. Refer to this before using average or avappend.

Plotting scripts

Two plotting scripts are provided:

```
plotoneday(day,int)
```

Plots most of the more interesting variables against time for one day. The rationale is to check daily that everything is giving sensible results.

```
plottrack(filename)
```

This plots a pretty chart of the cruise track with a colour scale showing one variable.

More information is given by

```
help function
```

at the matlab prompt.

Figure 54 shows along track potential temperature and salinity for Julian days 35 – 64. Zonal temperature structure can be seen clearly on the outward passage, across the Scotia Sea, and very cold surface water, corresponding to regions of freezing, are seen in the Weddell Sea. Salinity structure is more complex, suggesting a strong influence of eddies or meandering fronts.

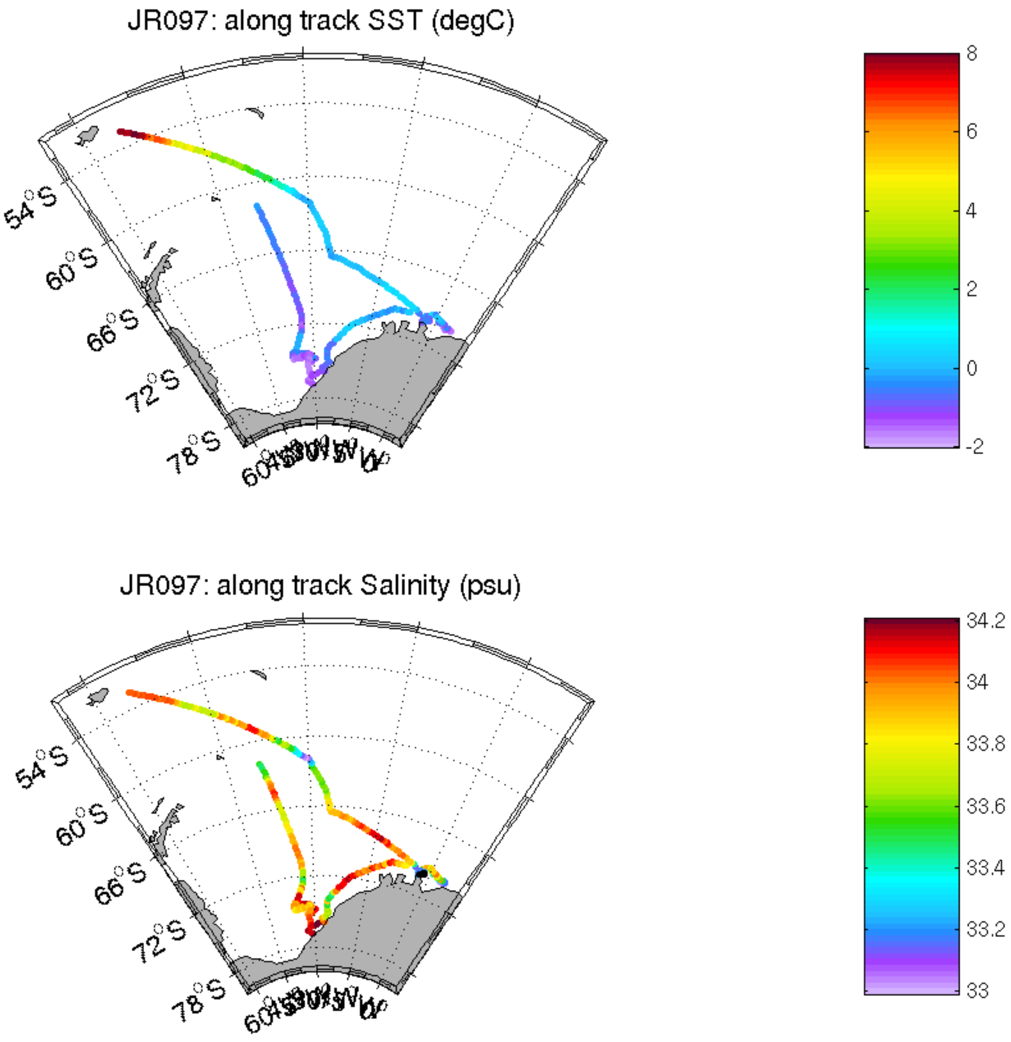


Figure 54. Alongtrack surface temperature and salinity.

Data coverage

Data are recorded from Jday 34 to the end of the cruise. All data are stored in files `xxx.asc` and can be read into matlab as desired.

When the ship travelled through ice, the ocean intake was blocked or turned off, so reported vales of SST, salinity, conductivity, fluorescence and speed of sound in `xxx.asc` are meaningless. These are set to NaN in matlab output.

Shipboard ADCP

Gregory Lane-Serff and Martin Price

Introduction

The shipboard ADCP was run continuously during the cruise, other than short breaks for reconfiguring the settings. Throughout the cruise it was configured to run with 64, eight metre bins. The centre of the first bin was effectively at a depth of 18 m, and thus the centre of the last bin was at 522 m. In practice, good velocities were obtained down to about bin 40 to 50 (330 to 410 m), depending on conditions (the clearer waters near the ice shelf presumably having fewer scatterers). When bottom tracking was enabled (as it generally was in shallow waters), good bottom tracking velocities were obtained down to depths of 600 to 700 m.

Several different types of processing were carried out:

(i) The usual processing based on pstar execs was carried out on all the shipboard ADCP data on a daily basis.

(ii) Data for periods when CTD stations were occupied were extracted and processed in a different way, typically averaging over the period the station was occupied and making use of bottom track information (where available) rather than using the normal, navigation-based methods for removing ship movements. In fact, the ship held position very steadily when on station (helped by the calm conditions at most stations), so that the effective ship speed during a CTD station was generally less than 1 cm/s. The main exceptions to this are for deployments in ice, when the CTD was deployed over the stern and the ship moved approximately with the ice with a bit of forward movement to keep an ice-free patch astern.

(iii) Some stations were occupied for prolonged periods of several hours, and for these stations the ADCP data were averaged in hourly periods to give information about the development of the flow with time.

(iv) We conducted a short ADCP transect at the Fimbul Ice Shelf, steaming at a steady 5 knots along a course to give a section across the western part of the main channel into the depression beneath the ice shelf.

(v) Finally, a gross averaging and gridding of all ADCP data obtained in the region west of the Fimbul Ice Shelf tongue gave mean velocity maps at three depth levels.

Initial calibrations were carried out based on bottom-tracked data obtained as we left the Falkland Islands, and further calibrations were carried out in the Fimbul Ice Shelf area and in the Filchner Depression. It is essential that at least the ADCP speeds (if not direction) are recalibrated when moving into waters of different temperature.

The procedure for running and calibrating the ADCP, and the processing undertaken onboard, are described in detail below. At the time of writing (March 2005), the ship’s ADCP is expected to be replaced during the coming summer, so some of the following may not be applicable in future years.

ADCP Set-up

The RRS James Clark Ross carries a hull-mounted RDI 153.6 kHz Acoustic Doppler Current Profiler (ADCP), serial number 361. The ADCP is recessed into the hull behind a sea chest, which contains 90% deionised water and 10% ethylene glycol. A 33 mm sheet of Low Density PolyEthylene (LDPE) closes the underside of the chest. The effective depth of the transducer is 6 m.

The ADCP is run through a PC (Pentium II) in the UIC, using version 2.48 of the RDI Data Acquisition Software (DAS) and version 17.07 of the firmware. The system is usually set up so that it restarts if the PC is switched on or re-booted. If the software isn't running, typing ADCP <Enter> at the command prompt should start it (in directory C:\ADCP248). When operating, accidental key-presses may pause the ADCP operation, so it is sensible to put the keyboard on the stack of computers (rather than the desk), with the keyboard cover on. In the following, we will refer to figures in the DAS user's manual (Change 1 – 01 October 90), and these should be referred to when setting up the ADCP.

Interrupt the program by pressing nearly any key ("a" works!); this should bring up the Interrupt Menu (Figure 21-1). (If this is done accidentally, hitting <Enter> should restart the acquisition.) Abort data collection (type A <Enter>) to go to the Main Menu (Figure 3-1). From here you can access the other menus, usually by entering a two-letter code.

DG – Diagnostics menu. This allows you to check that the ADCP is connected, and the software and firmware version numbers. (Figure 11-1).

AD – ADCP instrument set up menu. We set most of the parameters as in Figure 4-1, except for: Sampling interval 120.00 (not 30.00), Blank beyond transmit 4.0 (not 2.0) and Profiler link to Serial (not Parallel). Thus we had 64 bins of length 8 m (2^3), i.e. an overall depth of 512 m (plus a bit more for the depth of the transducer, blanking length, etc – see below). If a different number of bins are used, this will require some changes to the data processing procedure.

DP – Data processing/calculations menu. Changes from the values on Figure 4-2 are: Heading compensation YES, Calculate sound velocity … YES, Use bottom tracking YES (to start with), Use error velocity … YES, and Max error vel… 150.00 (not 100.00). The bottom tracking was used initially, while we were still in shallow enough water for it to work (<600 m) to provide information for calibration, but was turned off once we were in deeper water. Having bottom tracking on reduces the number of water tracking pings, since the ADCP is spending half its time doing bottom pings. The System scaling sub-menu is accessed from the DP menu, not the main menu.

SS – System scaling /calibration menu. All as in Figure 4-3 except for Offset for heading set to –45.00 (not 0.00). This is because the ADCP is mounted at approximately (minus) 45° to the ship's axis.

DR – Data recording menu. See Figure 4-4. The first four entries are all different: First recording drive G:, Second recording drive D:, Recording on disk YES, Auto-ping on start up YES. This ensures the Data are sent to the main system and the ADCP starts up after switching on or rebooting. In the next batch of parameters, the only changes from Figure 4-4 are in the second column: Record last raw AGC YES and Record Beam Statistics YES.

GC - Graphics control menu. Figure 13-1. Not really critical (except see warning below): you want Display to be set to GRAPHICS, Graphics Mode to be ENHANCED and pick a suitable velocity range (in cm/s). You could try playing with the items in the SG - select plotted variables sub-menu, though we managed to crash the program by trying to get it to display velocity as magnitude and direction instead of east and north components. The usual ones to display seem to be north/south vel, east/west vel, vertical vel, vel error, average agc (a relative measure of backscatter strength) and percent good (equal to percentage of good pings in our set up).

SR – Save/restore configuration menu. Enter ID to enter the cruise ID (e.g. JR097). Then use SV, save configuration to default file. This will ensure that any changes you have made will reload if the program restarts. You should do this again if, for example, you switch off bottom tracking or make any other changes. Then X to exit back to the Main menu and from there P – Ping Start Data Acquisition. (This entry also appears on some of the other menus.) After the first two minute ensemble the graphical display should appear. Note that the time displayed with the processed ensemble is NOT the time the data has been stamped with by the PC. The Data are stamped with the PC time at the end of the ensemble (when it has finished the countdown displayed on the screen) – unfortunately the time displayed on the screen is the PC time when the data has been processed and sent to the screen – typically about 9 seconds later.

ADCP monitoring

Hourly check: The ADCP display was checked to ensure that it was still operating, and the command 'lookd' used on one of the unix terminals to check the information was getting to the main system (the 'last updated' entry for 'adcp' should be the time of the end of the last ensemble). The most common reason for the ADCP to have paused is someone leaning on the keyboard: <enter> should restart. If a restart is necessary, an extra time drift check should be made, since the time difference may jump after a restart. The Ashtec heading was also checked: sometimes this system hangs and needs restarting.

Four-hourly time drift check. Every four hours we logged the time shown by one of the digital master clocks at the end of a two minute adcp ensemble (the countdown on the screen helps here). Note this is the time on the digital clock as the countdown ends, don't wait until the screen displays. The PC time that the data has been stamped with can be found using the lookd adcp entry at one of the terminals. It is also necessary to log the difference between the ship's computer system and the master clocks (e.g. by using the date command), though this only needs to be done occasionally since the ship's system clock is steady. A copy of the log sheet used is appended to this summary, which also gives the calculations needed to find the difference between the PC clock and the ship's computer system clock – required for applying corrections during the processing sequence.

Calibration

Calibration data can be acquired (and even processed) before getting the main processing suite set up. Since bottom tracking data is particularly useful for calibration, and since this works in shallower water (e.g. in the neighbourhood of the starting port) it is useful to start collecting this data from the very beginning of the cruise. We ran the ADCP in bottom tracking mode from the time we left port until the depth was too great for bottom tracking to work properly (about 600 m).

The ADCP data needs to be corrected for magnitude and direction. The corrections for magnitude are more straightforward and should be done whenever possible, while those for direction are more complicated and (if simply using the normal pstar processing suite) are less likely to be necessary (since the effective orientation of the ADCP within the ship is unlikely to change substantially). Calibrations can be calculated by running the usual pstar processing sequence, but editing adpexec3 (which makes the calibration corrections) to have dummy corrections of scale and direction of 1 and 0 respectively. By comparing the ship velocity (ve, vn) with the calibrated bottom track velocity (ebotcal, nbotcal) as given in the final output files of the form 097bot[jday]d.abs, one can find the necessary corrections to the magnitude and direction (which should then be inserted into adpexec3).

Scale

Errors in the magnitude of the measured velocities are caused by variations in sound speed, made more complicated by the ADCP being mounted in a sea chest filled with fluid at a different temperature from the sea water. The changes in scale factor observed in this cruise were of the order of 2%. This is unlikely to be important for measurements taken at stations, but for underway measurements when moving at speeds of ~ 5 m/s (~ 10 knots) this will give an error in the water velocity component in the direction the ship is moving of the order of 10 cm/s.

While the usual processing route will give the scale factors required, it is much simpler to directly compare the speed over the ground calculated from the bottom track ADCP data with the speed over the ground derived from the gps. Note that most of the main processing sequence is designed to correct for direction errors, which is not necessary when comparing speeds. A matlab calibration script (adcpcalg.m) was created in the directory ~jr097/adp/calibrate (more on the directory structure below). First a pair of files containing the adcp and navigation data need to be created using listit:

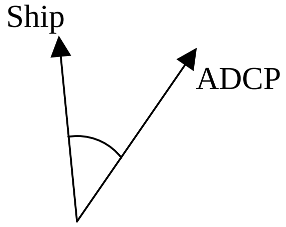
```
listit -s starttime -e endtime -i 60 adcp depth bottew bottns > adcp_start_bott
listit -s starttime -e endtime gps_ash lat lon > ash_start_bott
```

where starttime and endtime are in the usual pstar format YYDDDHHMM, e.g. 050341335 for 13:35 (GMT) on Julian day 034 (3rd Feb) 2005.

These instructions are repeated as comments in the matlab script. You should also edit adcpcalg.m to select the lowest depth you want to use data for (we used mindepth = 50 m). Note bad data are given a depth of –1, so this also acts as a useful filter. The script could easily be modified to also discard data above a certain depth (on the grounds that the results are less reliable at large depths). The script uses the file sw_dist.m (to find distances between points given in lon, lat form) and a single estimate of the clock difference is also required. The array 'scale' then contains the necessary scaling needed for the calibration (see below): e.g. use mean (or median) and std, perhaps after discarding further 'bad' points, to find the average scale factor.

The scale factor from the initial data near the Falkland Islands was 1.0265, and this value was used for days 34 to 37 on the southward journey and days 66 onward on the return journey (nominally "warm" waters). For the bulk of the cruise a value of 1.0409 was used, based on measurements around the Fimbul Ice Shelf. This was checked periodically, including in shallower waters around the Filchner Depression, and was not found to change significantly (though the four decimal places in the value exaggerates the accuracy: changes of ±0.002 or so over the course of a single day are not uncommon). The values used here are comparable with the range of 1.021 to 1.0426 found by Gwyn Griffiths on a cruise in the Greenland area (JR106).

Direction

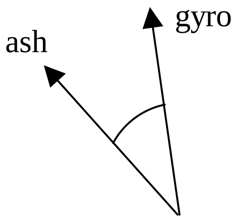


The absolute water velocity is calculated by adding the ship's velocity calculated from the Ashtec gps system to the water velocity calculated using the ADCP. When steaming at 10 knots, small errors in the relative velocity directions would give significant errors in the absolute water velocities

The ADCP is not perfectly aligned with the centre-line of the ship, so that even if the ship's heading were known perfectly, the velocities returned by the ADCP need to be rotated to give the true velocities.

This offset can be calculated using the processed bottom track files of the form 097bot[jday]d.abs, as discussed earlier. We found an offset of phi = –1.78° (i.e. the ADCP velocities need to be rotated by 1.78° anticlockwise). This is within 1/10° of the value found by Gwyn Griffiths (-1.69°).

It is important to note that this offset is not the same as the offset returned by the matlab script adcpcalg.m in the array coursediff. This latter offset is the difference between the course calculated from the ADCP bottom track and the course calculated using the Ashtec gps positions. To determine the ship's heading, the ADCP uses the ship's gyrocompass, not the Ashtec gps heading.



The difference between the Ashtec heading (generally taken to be the true heading) and the gyro heading varies with time, affected by the direction the ship is heading in, sharp turns, and a latitude dependent error. The variation with latitude was particularly noticeable on this cruise, with errors increasing at high latitudes.

The usual pstar processing sequence attempts to eliminate the gyro error, and information on this error is returned in several of the processed files as "a-ghdg" (Ashtec – gyro heading). Thus it is only the misalignment angle, phi, that is needed in the final calibration of the ADCP velocities (script adpexec3 – see below). These various offsets are not independent: the mean value of the difference between the Ashtec and ADCP headings (returned as “coursediff”) is equal to the sum of the mean Ashtec – gyro heading error (a-ghdg) plus the ADCP misalignment offset, phi.

For the processing at CTD stations the usual processing scripts were not used, so a correction based on the difference between the Ashtec and ADCP headings was required. This was either based on summing mean values of a-ghdg and phi, or by direct comparison of ADCP bottom track and Ashtec position data (using the adcpcalg.m script). Errors here are less important, since the ship’s speed is very small, and so we used a fixed offset value of –3.9° for all the stations in the Fimbul Ice Shelf area and –5.2° for all the stations in the Filchner Depression area. The difference is accounted for by an increase in the mean Ashtec-gyro error from approximately –2.1° in the Fimbul area (latitude 70 S) to –3.4° in the Filchner Depression (latitude 75 S). While the information supplied by the Ashtec system is generally good, it is prone to occasional glitches, such as the example in Figure 55. From this you can see that the Ashtec data is usually smoother than the gyro compass at short time scales, and the gyro compass also has latitude and other errors, but the Ashtec heading has periods where it is significantly wrong. Ideally these should be corrected during the processing, though no attempt to do so was made during the cruise.

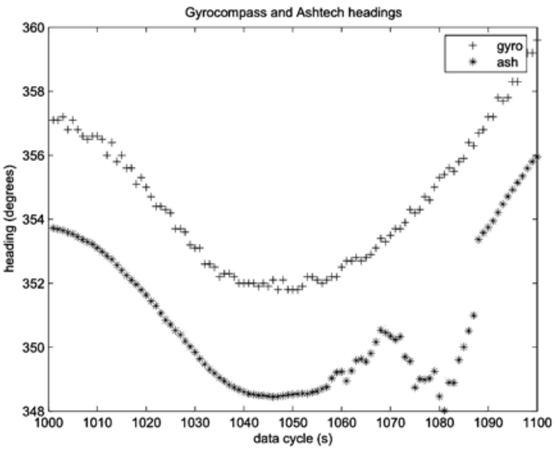


Figure 55. Ashtec vs gyro headings.

Data processing 1: Pstar

We begin with the processing based on pstar execs that were applied to all the Shipboard ADCP data.

Initial set-up

In /nerc/packages/pexec/ the file pexec_setup needs to be edited so that the variables CRUISE and YEAR are correct (in our case “097” and “050101” – this has to be first day of the current year).

If logged on to the main system as user pstar, the base directory should be /users/mlsd/pstar, and ~ will be assumed to be this directory in what follows. The file ~/.cshrc needs to be edited so that the right cruise directories (in our case …/jr097/…) appear in the variables PEXEC_HISTORY, PATH and DAT. The following directories and contents are then required:

sub-directory (all ~/jr097/)	contains
pexec_history	[directory just needs to exist]
exec	[all the pstar execs, not necessary so long as all the standard pstar execs are accessible somewhere]
nav/gyr	gyroexec0
nav/ash	ashexec0, ashexec1, ashexec2
nav/bsn	navexec0, navexec1
adp	adpexec0, adpexec1, adpexec2, adpexec3, adpexec4 [pstar2mat, pst2mat.m needed only for post-processing]
adp/calibrate	adcpcalg.m, sw_dist.m [needed only for calibration]

Editing the processing execs

The processing generally assumes that you have whole day data. This is not the case on some days, especially the first day of the cruise. There is a similar part of each of the four “zero” files: gyroexec0, ashexec0, navexec0 and adpexec0, that needs editing so that a start time just after everything started running is used instead. These lines all look like:

```
if ( ${num} == 034 ) then
   set start = 05034133500
endif
```

and need editing as appropriate (in our case we started at about 13:30 on day 34 of 2005, and used a start time five minutes after this).

If you use different numbers or sizes of bins or blanking length, you need to edit adpexec0 further so that nbins is the number of bins (64 for us) and delta is the amount you have to add to the bin depths reported by the adcp to get the “real” depths. The total effective depth of the first bin is transducer depth + blanking length + bin length (a whole bin length, because of the way the averaging process works – this calculation is more complicated if the pulse length is longer than the bin length). For us this total is 6 + 4 + 8 = 18 m, while the depth reported by the adcp for the first bin is equal to half a bin length (at least it is if the pulse length is equal to bin length, but we didn’t try anything else), so delta is given by 18 – 8/2 = 14 m.

The calibration is fixed in adpexec3, and thus this file needs editing so that both calA and calB are equal to the mean scale factor (1.0265 or 1.0409 for us) and phi is the offset angle (-1.78).

Processing sequence explanation

gyroexec0 reads data from the ship’s gyrocompass, forcing headings to lie between 0 and 360 degrees and eliminating duplicate timestamps. A file `097gyr[jday]d.raw` is produced, and the data appended to a master file `097gyr01`.

The ship’s gyro has various errors (see above), and so the heading data is corrected using the Ashtec GPS. **ashexec0** reads in the Ashtec heading data, producing the file `097ash[jday]d.raw`. **ashexec1** combines the Ashtec and gyro data and calculates the difference (a-ghdg) between them, forcing the result to lie between -180 and +180 degrees, producing the file `097ash[jday].mrg`. **ashexec2** carries out quality control: discarding outliers, including removing data when there was large pitch or roll; despiking and averaging the a-ghdg data over two minute intervals, producing the two files `097ash[jday]d.edit` and `097ash[jday]d.ave`. The plot failure mentioned in the crib sheet happens at the end of the script and can thus be ignored.

At this point the `097ash[jday]d.ave` file is manually “papended” to the master file `097ash01.int` – on the first day the file just needs copying, since there’s nothing to append it to. Ideally at this point you should also manually edit the file to remove any glaring errors caused by glitches in the Ashtec heading (see previous section).

navexec0 reads the Bestnav data, calculates ship velocities (ve and vn), distance run, etc, and appends it to a master file `abnv0971`. **navexec1** averages and filters this data, putting the result in `abnv0971.av`.

Because the clock correction can push the adcp data into a later day, the next set of steps can only be carried out a day behind the earlier steps. E.g. you have to carry out all the processing in the nav subdirectories for days 038 and 039 before carrying out the adcp processing for day 038.

adpexec0 reads in the ADCP data, producing water track and bottom track files `097adp[jday]d` and `097bot[jday]d`, respectively. **adpexec1** adjusts the timing of the ADCP data to allow for the drift in the PC clock. It requires times (in terms of the PC clock) and appropriate corrections to be added to this to give the ship’s computer time – the corrections must cover the whole day and thus usually begin with the last correction from the previous day and end with the first correction from the next day. The corrected files produced are `097adp[jday]d.corr` and `097bot[jday]d.corr`, while information about the clock drift is put in `clock[jday]d`. **adpexec2** corrects for the errors in the gyro headings, making use of the differences between the gyro and Ashtec headings (a-ghdg) calculated in the ashexec sequence, producing the files `097adp[jday]d.true` and `097bot[jday]d.true`. **adpexec3** applies the calibration in scale and angle offset: this is contained within the script, not input, so adpexec3 needs editing if you want to change the calibration; the files produced are `097adp[jday]d.cal` and `097bot[jday]d.cal`. Finally, **adpexec4** subtracts the ship's velocity from the ADCP data to give absolute water velocities (absve, absvn), producing files `097adp[jday]d.abs` and `097bot[jday]d.abs`.

Post-processing

pstar2mat extracts the data from the `097adp[jday]d.abs` files, which are still in Pstar format, and produces an ascii file suitable for reading by matlab. The matlab script **pst2mat.m** reads this into a suitable set of arrays for displaying, etc, using matlab. E.g. quiver(lon,lat,absve(4,:),absvn(4,:)) gives a good quick look at the data from bin 4 (approx 40 m depth: Figure 56).

Processing sequence details

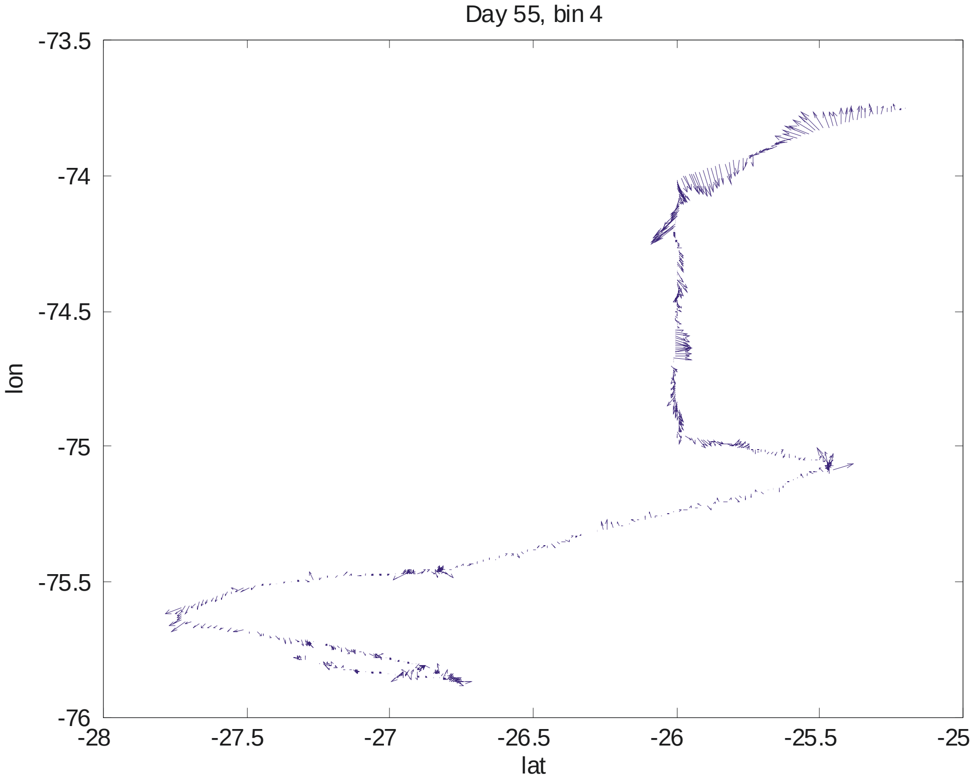


Figure 56. Example of quiver plot; see text.

The crib sheet given at the end of this section was used, which details the steps needed to process the data. A log sheet was produced with tick box spaces for all the execs, plus a column for the before/after number of data cycles for the manual papend operation (step 2e). A log sheet was also used for noting the clock drift. Both log sheets are also appended.

Data processing 2: CTD stations and other special processing

Standard CTD Stations

This processing was carried out in sub-directory ~/adp/station/. Many of the CTD stations occupied during the cruise were at sufficiently shallow depths for the shipboard ADCP to be able to use bottom-tracking mode. For most of the others, the ship's dynamic positioning system was sufficiently good that the water velocities relative to the ship, averaged over the period of occupation of a station, are within 1 cm/s of the true velocities.

Some simple matlab scripts were devised first to check the ship's position over time (**poslook.m**, which uses the output of a simple listit command – details in the script) against a somewhat arbitrary time co-ordinate. The time periods for station occupation were then based on times that covered the CTD deployment, and often some time either side of this, where the ship could be seen to hold a steady position. A further script (**adcpstn.m**, again requiring suitable listit output) then made use of this time period to produce corrected mean velocities (corrve, corrvn) at the bin-depths (bind), with the results output to matlab (v6) and ascii files of the form `ShipADCP_CTD[number].mat` and `.asc`. For cases where there was no bottom tracking, a script **adcpnobot.m** was used instead (or sometimes as well as adcpstn.m, if the bottom tracking was uncertain), producing files of the form `ShipADCPRel_CTD[number].mat` and `.asc`. Since no bottom-tracking information was used, greater care was taken in selecting periods of steady ship position, but the ascii files contain warnings that the velocities have been calculated relative to the ship. Both adcpstn.m and adcpnobot.m needed to be edited for the appropriate scale (1.0409 for all stations) and angle correction (–3.9° for the Fimbul Ice Shelf area and –5.2° for the Filchner Depression, as described earlier).

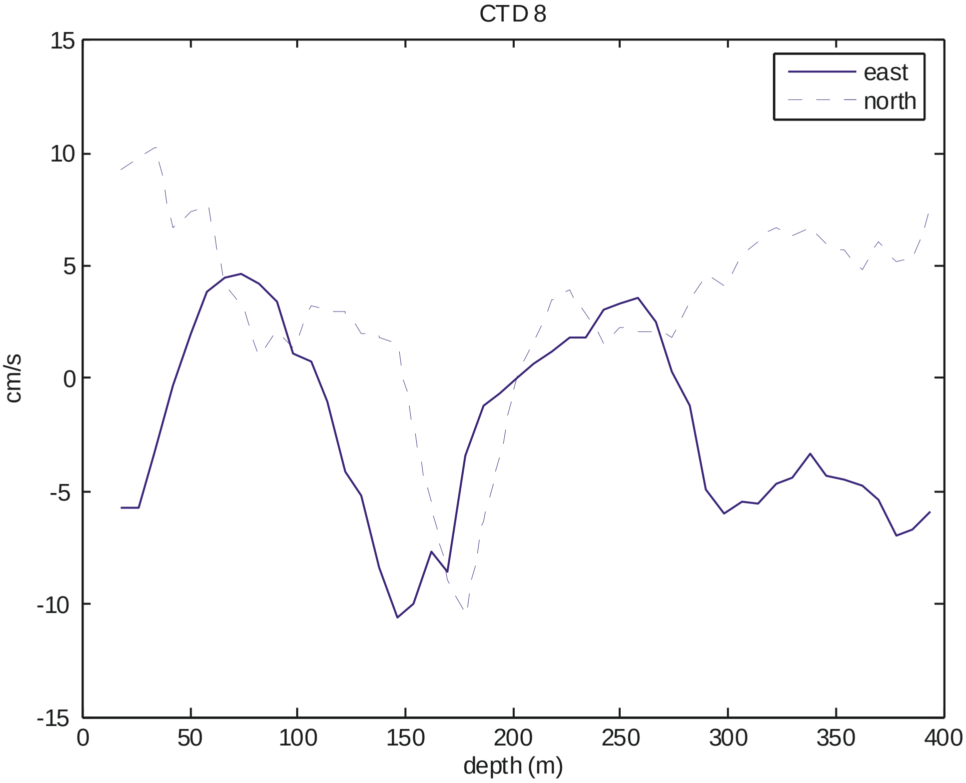


Figure 57. ADCP profile from CTD station 8.

In a few cases, where the CTD was deployed in ice conditions, the ship moved significantly during deployments when the depths were too great for bottom tracking. For these cases a period of reasonably constant velocity was identified, and the script adcpnobot.m used, but the ascii files have been edited to include an estimate of the ship's velocity – for true velocities this should be added to the relative velocities given in the files.

Long period (yo-yo) deployments

A number of sites at both the Fimbul Ice Shelf and the Filchner Depression were occupied for several hours, typically with the CTD package yo-yoing between surface and bottom or between other depths (and sometimes halted to use the LADCPs as effectively simple moored instruments).

In addition to the whole station average, as just described, hourly-averaged data was also compiled using the matlab script **yoyoadcp.m** or **yoyonobot.m**. (The hours are GMT hours, so the first average for a deployment starting at, for example, 12:30, would actually cover the period 1230 to 1300, subsequent averages covering 13:00 to 14:00, 14:00 to 15:00, etc.). Similar calibration details are required as for adcpstn.m. This processing was mostly intended for quick looks during the cruise, but the data is recorded with the velocities in arrays (corrve, corrvn) in matlab files: `yoyo1.mat` (CTD stations 26 and 27) and `yoyo2.mat` (CTD 28) from the Fimbul area and `plumeyoyo.mat` from the Filchner Depression outflow.

Transects

By steaming at a steady five knots on a section covering the western side of the deep channel into the cavity under the Fimbul Ice Shelf, good shipboard ADCP data were recovered which, with minimal processing (using the usual adcpstn.m script and doing some further steps), gave a good picture of the flow on this section. The corrected velocities along the transect are saved as arrays (tranve, tranvn) in the matlab file `transect.mat`. Similar processing was applied to a few other transects, though at higher ship speeds the results were less useful.

Large area average velocities

The region to the west of the Fimbul Ice Shelf was traversed and covered by numerous ship tracks and CTD stations during the cruise. All of this data was compiled and averaged to produce velocities on a regular spatial grid of 1 nm: i.e. 1 minute in latitude and 1/cos(70°) in longitude. This was further averaged into upper (bins 1 to 12), middle (bins 13 to 24) and lower (bins 25 to 36) depth intervals. The processing scripts are in sub-directory ~/adp/station/bigsurvey/, while the results are saved in the matlab file `bigone.mat`.

Vessel Mounted ADCP Processing Crib Sheet v1.2a

All our processing takes place in the **jr097** subdirectory of the **pstar** home directory. Before starting, log onto **jrua** and change to this directory. At various stages the programs ask for **yes/no** (y/n) prompts before continuing – read the question and (usually) answer yes. When asked for the Julian day you want to process, none of the scripts expect leading zeros (e.g. enter **1** not **001** and **35** not **035**). However year should be entered as the last two digits of the year (e.g. **05**).

1. a) start by entering the **jr097/nav/gyr** subdirectory.
   b) run **gyroexec0**. When prompted enter the year (as **05**) and Julian day.

2. a) change directory to the **jr097/nav/ash** subdirectory.
   b) run **ashexec0**, entering the year and Julian day when prompted.
   c) run **ashexec1**, entering the Julian day when prompted.
   d) run **ashexec2**, entering the Julian day when prompted. The script tries to plot the results but fails giving a warning. Ignore this.
   e) run **papend**. When first asked for an input disc file give the name of the cumulative ashtec file **097ash01.int**. Check the number of data cycles the file contains, shown near the top of the header information that is displayed, and note it on the log sheet as the "before" entry.

      When asked if you want to input filenames from a file enter **n**, then when asked for another file name enter the name of the file you've just created which will be of the form **097ash{jday}d.ave**, where **{jday}** will be the Julian day's data you're working on, in 3 digit format with leading zeros of necessary (e.g. **035** not **35**). Then enter **none** to indicate no more files to add. The new number of data cycles will be displayed – note this on the log sheet as the "after" value. It should be 720 more than the number you noted before.

3. a) change directory to **jr907/nav/bsn**
   b) run **navexec0**, entering the year and Julian day when prompted, and whole day.
   c) run **navexec1**, which doesn't prompt for any input.

The remaining steps sometimes have to be run one jday behind steps 1-3 because the ADCP clock correction can push the ADCP data into the next jday.

4. a) change to the **jr097/adp** directory.
   b) run **adpexec0**, entering the year and Julian day when prompted. The script also asks if you want to work on **am/pm/whole day** data – enter **d** for whole day (even on the first, partial, day).
   c) run **adpexec1**, entering the Julian day and **d** for whole day. You then have to enter the sets of **jday time offset** (e.g. **35 225928 5**) from the appropriate day's ADCP clock log sheet (where **time** is T3, the 'lookd' time, and **offset** is the 'total offset'). The clock drifts steadily, so omit any offset which are obviously out of place. Note that leading zeros are not used. The times you enter must completely enclose the day you're processing, so you must include the last entry from the previous day and the first entry from the next day. When you've entered them all, enter **0** to finish.

d) run **adpexec2**, entering the Julian day when prompted.

e) run **adpexec3**, entering the Julian day when prompted. This script does the calibrations, which are written into the script. Values are displayed.

f) run **adpexec4**, entering the Julian day when prompted.

5. a) still in the **jr097/adp** directory, create a text output file by running **pstar2mat**, entering the Julian day when prompted.

   b) the output can be loaded into Matlab using **pst2mat**, entering the Julian day when prompted.

			Gyros	Ashtec				Bestvan				ADCP					
jday of data	**jday**	**initials**	**gyro0**	**ash0**	**ash1**	**ash2**	**papend cycles before/after**	**nav0**	**nav1**	**jday**	**initials**	**adp0**	**adp1**	**adp2**	**adp3**	**adp4**	**pstar2mat**
							/										
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JR97 ADCP Clock Correction

Jday	Master Clock T1	ADCP screen T2	‘lookd’ ADCP time T3	Difference D1=T1-T3	Total Offset D1+D2	Comments

Computer system clock time TA (type ‘date’)	
Master clock time TB	
Difference D2 = TA – TB	

CFC Sampling

Justin Buck and Povl Abrahamsen

Introduction

The time seawater was last exposed to the atmosphere, and thus, the flushing timescale of the Fimbul and Ronne-Filchner Ice Shelves, is being considered by analyzing the CFC content of the water at different levels. CFCs are manmade chemicals and were only introduced into the atmosphere in the 20th century (industrial production began in the early 1930's) and only water masses that have been exposed to the atmosphere since this time, or have been mixed with water that has, will contain CFCs; particularly CDW is known to have extremely low CFC concentrations.

While there are past records of CFC concentrations in the southeastern Weddell Sea (see, e.g., Mensch et al., 1996, Prog. Oceanog. 38, 377-415), the atmospheric concentrations are changing, and thus any new measurements of the Weddell Sea water masses can be used to constrain the timescales for circulation under the Ronne-Filchner. In addition, the surface saturation of CFCs, partially in areas with ice cover, which limits the uptake of CFCs, is relatively poorly known, and will become increasingly important as atmospheric CFC concentrations fall. We took one section with just near-surface samples, on a line with varying ice cover.

The sampling equipment was lent to us by Dr. Bill Smethie, of Lamont Doherty Earth Observatory, Columbia University, Palisades, NY, and the water samples will be processed there to determine the CFC content. The method for collection and sealing of samples is shown in Figures 58 to 61 (courtesy of Bill Smethie), and photographs of the sealing of vials are in Figure 62.

The locations and depths at which the samples were taken are shown in Figure 63. Only vials that were successfully sealed are included in the figure. The vials were labelled with station and bottle number.

Difficulties

The method used to sample water from Niskin bottles on the CTD was found to be time consuming, with each sample taking around five minutes to collect. In very cold conditions (air temperatures < -12°C) the tees occasionally froze so the sample had to be started again. This was solved once the CTD annex was heated effectively.

The sealing of vials is a delicate and precise task requiring significant practice. Also, it is difficult to consistently get good seals, especially initially. The production of a good seal is dependent on the nitrogen flow (from 7-10 $cm^3 min^{-1}$) and flame settings (a hot narrow oxygen-rich blue flame) being at exactly the right level. The nitrogen flow was found to vary quite significantly between tees, with values drifting by up to 5 $cm^3 min^{-1}$, probably as a result of the varying shapes of the tees. When the nitrogen flow was too high the nitrogen back pressure would burst the seal once the glass was hot. If the vial was too full of water the evaporation of water would cause the same problem. Because of this, many of the vials collected at the start of the cruise were not sealed and samples were forfeited.

The seals obtained on the sample vials were not always as is shown as the correct seal in Figure 61 and examples of the seal produced are shown in Figure 64. The seals on the vials were tested after welding by shaking them vigorously once they were sufficiently cool.

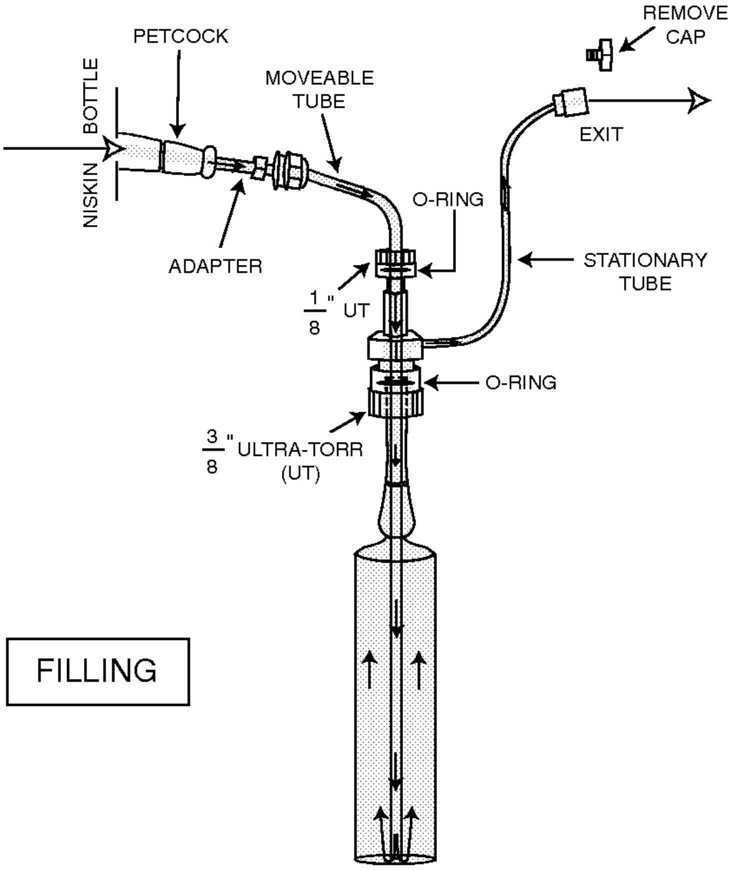


Figure 1

1. Push the ampoule into the bottom of the tee and hand-tighten the 3/8" ultra-torr fitting. Two o-rings should be used for this fitting to accommodate variability in ampoule neck diameter.
2. Slide the moveable tube to near the bottom of the ampoule as shown in Figure 1 and tighten the 1/8" ultra-torr. Repeat this for the other ampoules. This is the pre-sampling position.
3. Connect the adapter to the moveable tube.
4. Connect the tee/ampoule to the petcock via the adapter and start water flow.
5. Wait until water comes out of the stationary tube and then flush the ampoule with about 500cc of water.

Figure 58: CFC water sample collection and sealing methods 1.

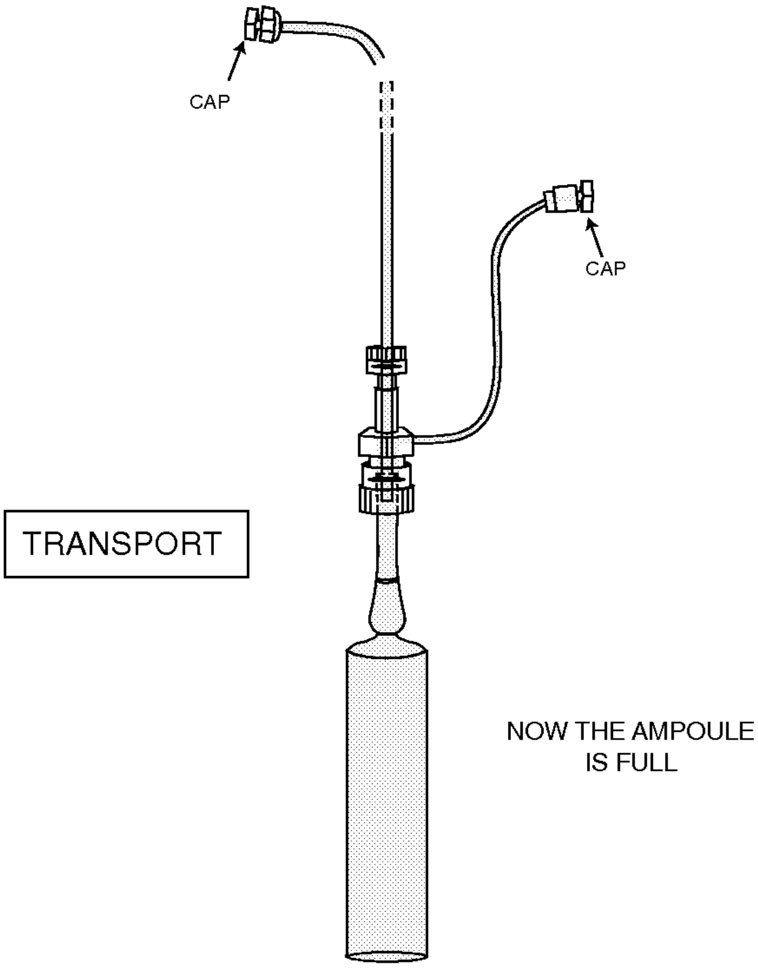


Figure 2

6. While still flushing, loosen the 1/8" ultra-torr and slide the tee/ampoule down the moveable tube to the position shown in Figure 2. Tighten the 1/8" ultra-torr nut.
7. Cap the stationary tube while the water is flowing.
8. Disconnect the tee/ampoule from the niskin, shut off the niskin flow, and replace the adapter on the moveable tube with a cap.
9. Put the filled ampoule in the rack.
10. Repeat steps 1 to 9 for the other ampoules. When sampling is finished proceed to sealing as soon as possible.

Figure 59. CFC water sample collection and sealing methods 2.

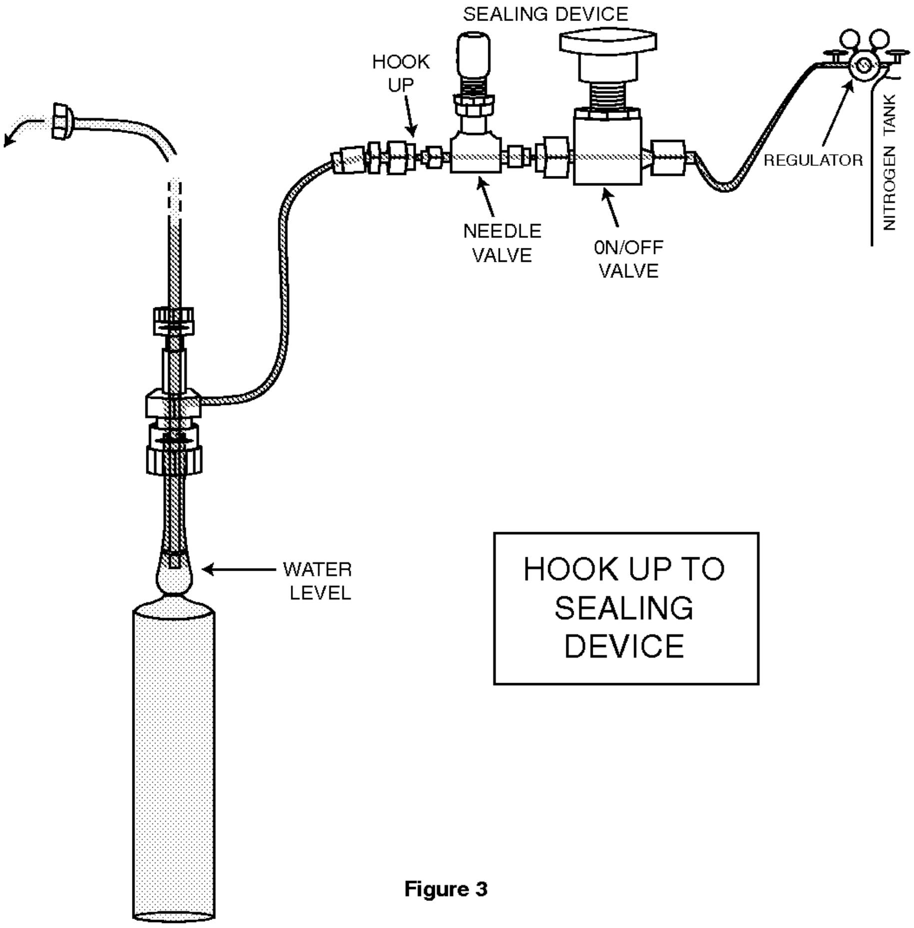


Figure 3

12. Set nitrogen regulator to approximately 3 psi (20 KPa) and turn on the nitrogen to flush the sealing device system.
13. Using a flow meter adjust the flow out of the needle valve to about 10 ml/min.
    NOTE: Too high a flow will create a bubble in the hot glass and the seal will fail. Too low a flow will not push the water out of the headspace. The flow should be checked at the beginning of each sealing session.
14. Light the torch's flame - it should be blue - and set the flaming torch aside.
15. Remove the cap from the stationary tube and connect to the needle valve with nitrogen flowing.

16 Remove the cap from the moveable tube. Water in the tee will be displaced by nitrogen.

17. Loosen the 1/8" ultra-torr nut and push the moveable tube down as shown in Figure 3. This will push out the water in the ampoule's neck. If it doesn't, then there is a leak in the system or the nitrogen flow is too low.
    NOTE: A likely location for a gas leak is the o-ring seal around the ampoule neck. Retighten the ultra-torr nut.
18. The water level should be below the gold band.

Figure 60. CFC water sample collection and sealing methods 3.

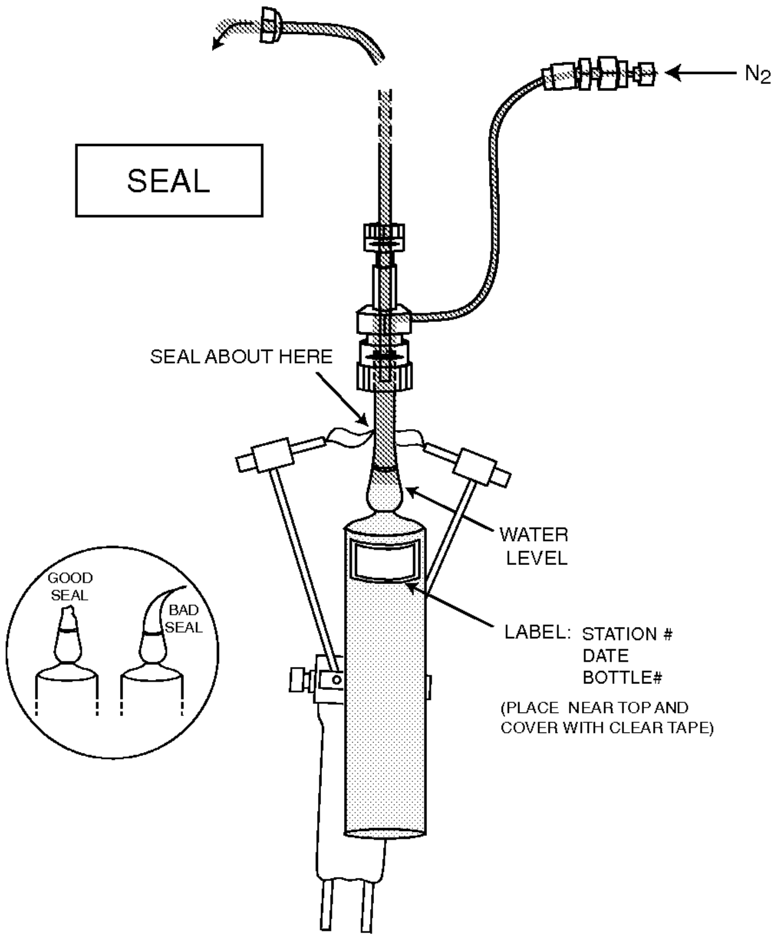


Figure 4

19. With the nitrogen still flowing, slide the moveable tube up as shown in Figure 4 and tighten the 1/8" ultra-torr fitting.
20. With the torch warm up the neck of the ampoule above the gold ring. Do not keep the flame close to the 3/8" ultra-torr fitting for too long as this will burn the o-ring.
21. Seal: heat one spot around the ampoule neck by rotating the torch and pull gently when the glass is ready.
22. When the ampoule separates, continue to heat the top briefly to create a smooth seal (see Figure 4 inset).
23. Finish the other ampoules and label them appropriately.
24. After the ampoules have cooled, the seal can be checked by inverting the ampoule to see if water leaks out from the seal.

Figure 61. CFC water sample collection and sealing methods 4.

Figure 62. Photographs of laboratory setup and the sealing of phials.

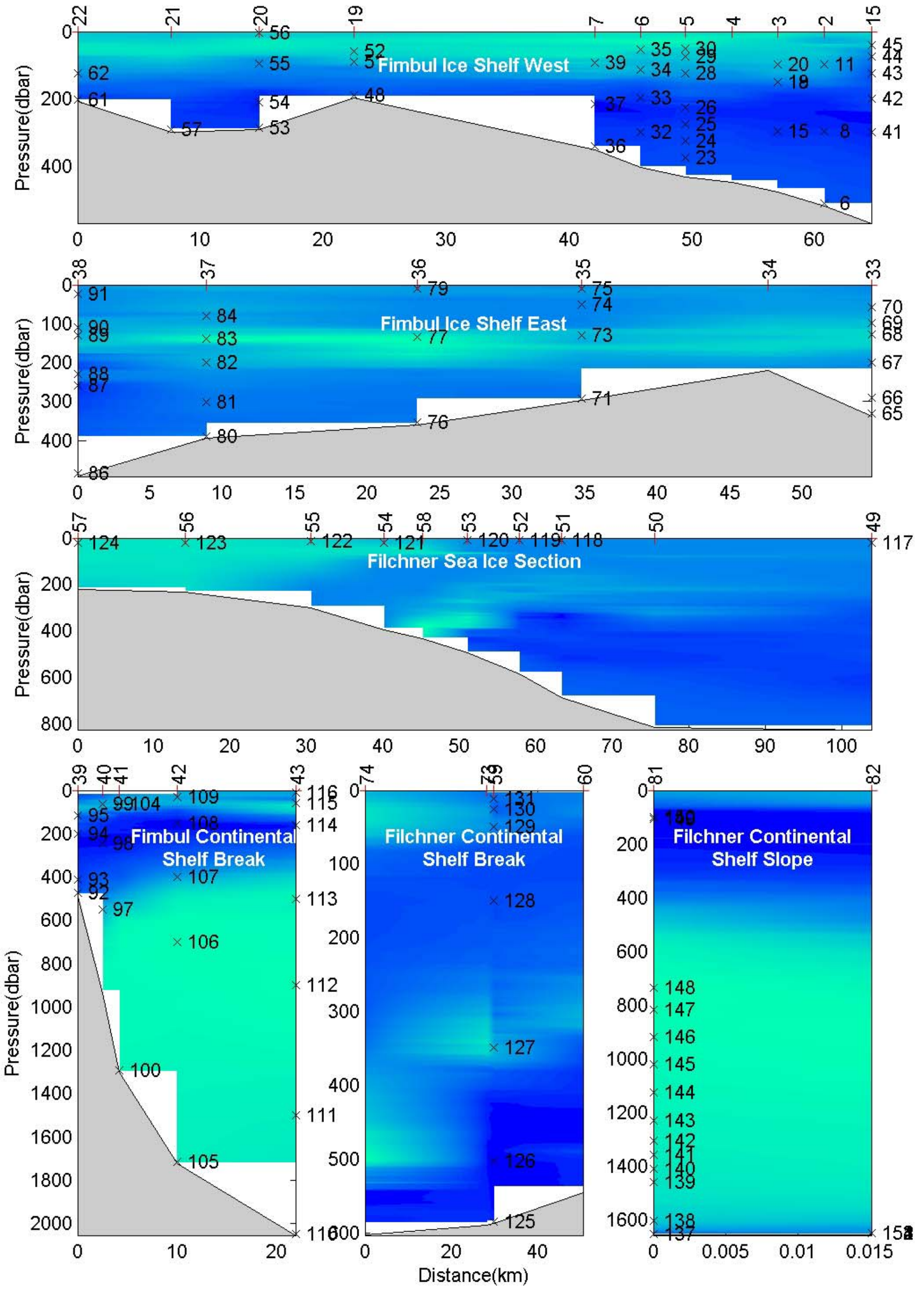


Figure 63. The locations of CFC samples on each transect. Station numbers are on the top axis and sample numbers next to the x symbols at the depths samples were taken. Blue represents cold water and green warm water, with the colour scales in each plot varying.

Figure 64. Examples of sealed CFC sample phials.

Mooring work on JR097/JR131

Povl Abrahamsen

During JR097 a mooring was deployed west of the ice tongue of the Fimbul Ice Shelf. In addition, three days were allocated for a separate cruise, JR131, dedicated to recovering and redeploying moorings around the Brunt Ice Shelf and the Filchner Sill.

These moorings were deployed from the RRS Ernest Shackleton in February 2003, and are part of two different projects. Three moorings around the Brunt Ice Shelf form part of the Lifetime of Halley project, and are intended to provide more information about melting rates and water stress under the Brunt Ice Shelf. Two moorings were deployed south of the ice shelf, and one on the north. In addition, one mooring was deployed on the Filchner Sill to monitor the outflow of Ice Shelf Water from the Filchner depression. This mooring is part of the BAS long-term monitoring program, and has been deployed in cooperation with the Bjerknes Centre for Climate Research at the University of Bergen, Norway. The last mooring was also re-deployed after servicing the current meters, and replacing and adding more current meter.

All the current meters used are produced by Aanderaa Instruments, and have temperature sensors; all but RCM7 #67 also have conductivity cells. In addition, RCM9 #195 and #630 have turbidity sensors, RCM9 #195 has dissolved oxygen, and RCM9 #195 and RCM7s #8240, #11676, and #11677 have pressure sensors.

The Fimbul mooring was deployed on 12/2 at 14:06 UTC by streaming it out behind the ship, and dropping the anchor last. During deployment, it is likely that the upper current meter became tangled in the mooring line. The mooring was recovered nine days later, and unfortunately both rotors were broken, one by a chain smashing into it, the other probably after it had been recovered on deck. The latter rotor was repaired onboard, by putting an M4 bolt through the stem; this was definitely an improvement over the original design, where the stem is glued onto the rotor itself. Accidentally RCM8S #5379 was in “momentary mode,” where vector averaging is disabled, and all directions are instantaneous measurements. In addition, this current meter’s vein was probably tangled in the mooring line, and all directions measured after the mooring was in position are between 85° and 135° true. This would be consistent with the compass being tilted more than a few degrees, which is what would happen had the line been tangled around the vein, pulling it upwards. Sampling was done at 5-minute intervals, and both current meters logged throughout the deployment. RCM8S #10067 did leak a bit of water, which was found to have entered through the cable connector on the top. The cover was not screwed fully onto this connector, and there was some salt residue inside the connector. The connector was cleaned out and sealed properly before the current meter was redeployed. Initial plots of the data from the mooring are shown in Figure 65.

After rendezvousing with the Shackleton on Feb. 24th, we proceeded to the B1 deployment site. After several spurious ranges from the acoustic telemetry unit used to communicate with the release on the mooring, the release was triggered at a range of approx. 2000 m, and was sighted from the bridge when it arrived at the surface. All parts from this mooring were recovered, and apart from a leak in an 11-inch plastic recovery float, all components were in good condition. The pressure record on the upper current meter indicates a fall in pressure for approx. two weeks, which may be due to the mooring being shifted around by icebergs. It is highly probably that the mooring was moved from its original position by being dragged by icebergs.

Following the recovery of B1, we proceeded to the B2 deployment site, but could not locate the mooring, either by sonar or acoustic telemetry. A search pattern was initiated approx. five miles SE along the ice shelf front, following the local iceberg track, as well as off the slope. However, the mooring was not located.

Mooring B3 was located by acoustic ranging, as it had been moved from its deployment site. Contact was achieved at a range of over 5 km, and by intersecting two ranges, the ship came within 500 m of the mooring. After being released, the mooring was sighted from the bridge, and was recovered. However, the top current meter and a 40-inch steel sphere were missing, the mooring line having been severed below them. Several current meters had been damaged, most likely by iceberg encounters, one had stopped logging after 1 year, but the others were all in working condition electronically. No instruments had leaked.

RCM7 #11675, which now is the upper current meter, was severely distorted, probably from being hit by an iceberg. The current record does indicate a few interesting features. For almost 40 hours, starting on 23/2/2003, the current speeds increase to an average of over 30 cm/s, peaking at 43 cm/s on the 24th, towards SE. On 22/3/2003 the current regime appears to change, with lower speeds and directions more towards SW, and lower speeds in all other directions. Most probably, the mooring has already been moved at this point, and the rotor shield has been bent, causing the fall in measured speeds. The mooring line was severed on 13/3/2004, and an iceberg probably hit the mooring again on 7/5/2004, since the compass direction on the upper current meter changed again on this date.

On both B1 and B3, mooring components were covered in marine growth. This included most of the rotors as well, although a few rotors were completely free of growth. This may be due to a change in the composition of the anti-fouling paint used on rotors.

Mooring S2 was recovered at its deployment site, with no outside damage to the instruments. Some components were slightly overgrown, but not nearly as seriously as on the Brunt moorings. The upper current meter, RCM9 #195 was found to have leaked, and when it was removed from its mooring frame, the pressure built up inside pressed the bottom out of the pressure case. The data storage unit inside was not in working condition, and is probably filled with seawater. However, it will be sent back to the manufacturer to see if any data can be recovered. The current meter itself was heavily damaged, although some of the attached sensors may be in working condition. The bottom current meter had run out of battery power after 14 months, but the middle current meter was still logging at the time of recovery.

S2 was redeployed with a current meter added at 50 m, and a sediment trap added at 15 m. The sediment trap is a BAS model, approximately 1 m high, with one bottle at the bottom. There was one modification to the current meters after the Fimbul mooring: since the rotor from RCM8S #10067 was irreparably broken and we had no replacements, the upper frame was replaced with the rotor shield of a paddle-wheel type RCM8, and a paddle-wheel rotor was attached. The redeployment was done anchor-first, due to the presence of sea ice. During deployment, the bottle came off the sediment trap, but was reattached using vinyl tape. In addition, the bottom rotor bearing came off the top current meter. It was hastily repaired using super glue, and the rotor was reattached. The rotor appeared to spin freely after the repair.

Table 10. Mooring deployment and recovery information

Mooring	Deployment time	Deployment position	Recovery time	Recovery position	Water depth	Instruments	Height above bottom
Fimbul Mooring	12/2/2005 14:06	70°06.9'S 001°50.6'W	21/2/2005 13:40	Same position	355 m	RCM8S #10067 RCM8S #5379	140 m 20 m
B1	7/2/2003 17:22	75°27.911'S 026°50.477'W	24/2/2005 14:58	75°28.1'S 027°55.7	228 m	RCM7 #11677 RCM8 #11216 Sediment trap #1	140 m 40 m 10 m
B2	6/2/2003 18:41	75°43.268'S 027°16.603'W	Not recovered		301 m	RCM7 #8240 RCM7 #6275 RCM8 #12297 Sediment trap	225 m 120 m 40 m 10 m
B3	6/2/2003 17:11	75°48.734'S 026°51.953'W	24/2/2005 21:20	75°52.24'S 026°46.02'W	329 m	RCM7 #11676 RCM7 #11675 RCM7 #11657 RCM8 #12302 Sediment trap #2	255 m 215 m 135 m 40 m 10 m
S2	10/2/2003 19:12	74°40.063'S 033°26.649'W	27/2/2005 22:39	74°40.02'S 033°26.71'W	596 m	RCM9 #195 RCM7 #67 RCM9 Mk2 #630	150 m 100 m 25 m
S2	1/3/2005 17:55	74°39.6'S 033°27.8'W	To be recovered in 2006/2007		595 m	RCM8S #5379 RCM8 #10067 RCM7 #67 RCM9 Mk2 #630 Sediment trap #2	150 m 100 m 50 m 25 m 15 m

Table 11. Current meter statistics

Mooring	Instrument	First record	Last record	U mean	U std.	V mean	V std.	T mean	T std.
Fimbul	10067	12/2/2005	21/2/2005	(4.52)[1]	(2.32)[1]	(-2.20)[1]	(1.89)[1]	-1.96	0.13
	5379	12/2/2005	21/2/2005	-1.71	5.86	4.16	3.76	-1.97	0.02
B1	11677	7/2/2003	15/4/2003	-2.77	7.41	-0.40	6.82	-1.81	0.28
	11216	7/2/2003	24/2/2005	-2.03	8.55	-0.40	7.18	-1.91	0.02
B3	11675	6/2/2003	24/2/2005	(1.65)[1]	(4.56)[1]	(-2.06)[1]	(3.38)[1]	-1.84	0.14
	11657	6/2/2003	24/2/2005	1.81	8.18	-4.23	6.03	-1.87	0.03
	12302	6/2/2003	26/2/2004	1.38	8.43	-3.77	6.71	-1.86	0.05
S2	67	10/2/2003	27/2/2005	-13.58	11.91	3.56	12.17	-1.83	0.28
	630	10/2/2003	7/4/2004	-13.19	11.39	5.78	12.66	-1.89	0.10

[1] Current meters were not functioning properly, due to reasons described above. These values should be treated with some suspicion, although the absolute speeds may be correct.

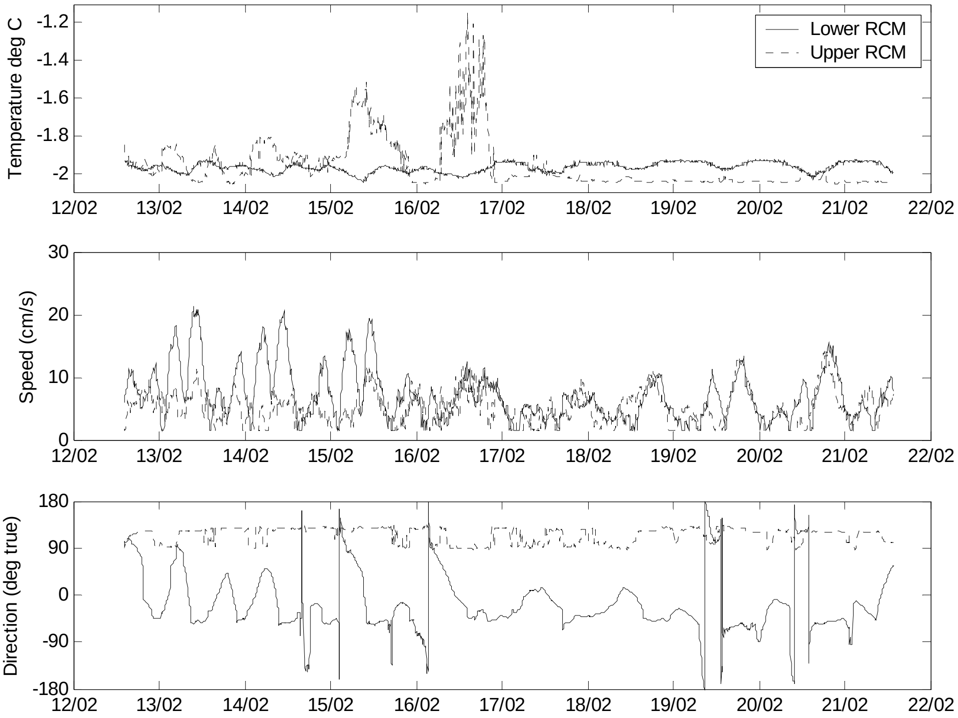


Figure 65. Preliminary plot of data from the Fimbul mooring.

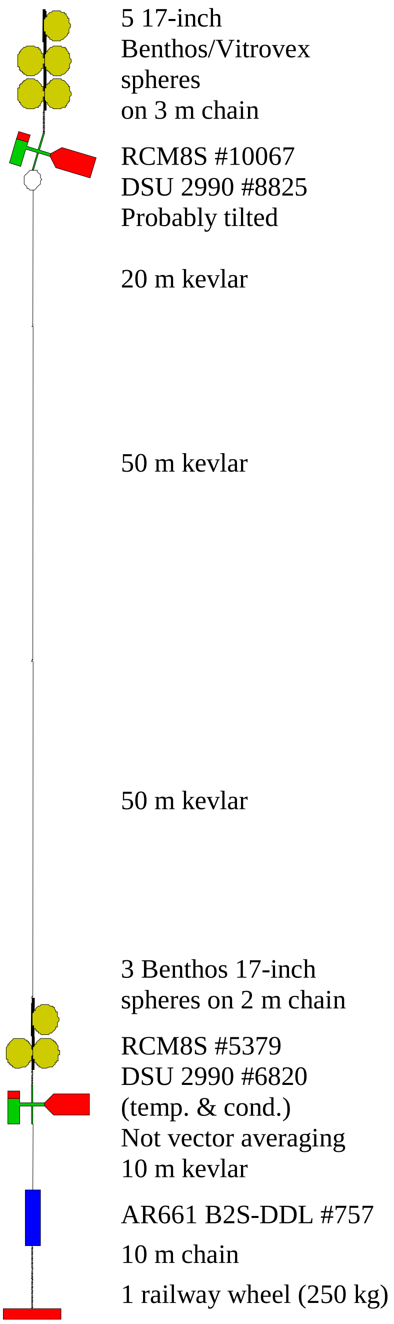


Figure 66a. Fimbul Ice Shelf mooring schematic

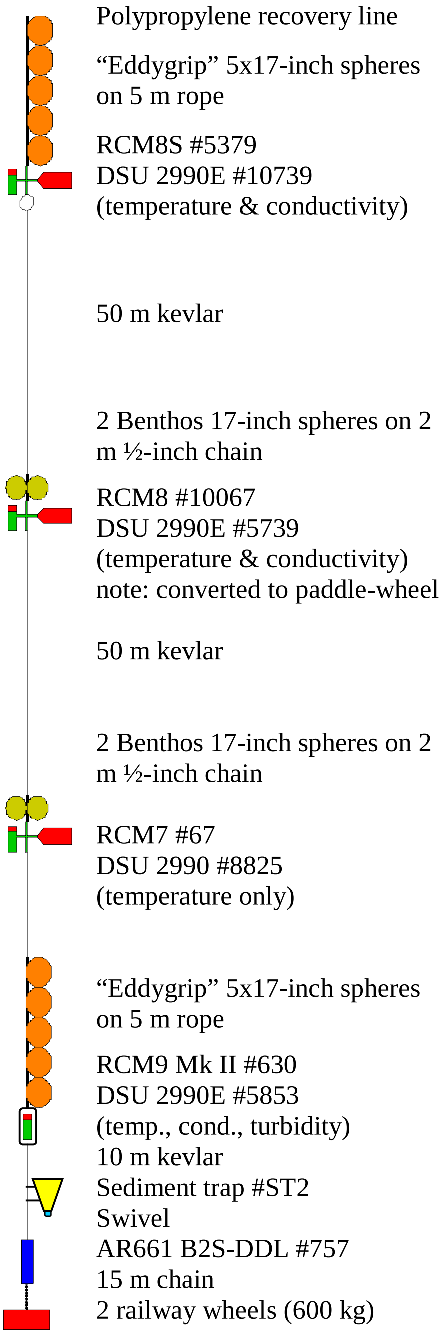


Figure 66b. S2 schematic

Note: Not to scale.

EM120 and TOPAS

Carol Pudsey

The EM120 swath bathymetry system and TOPAS sub-bottom profiler were run throughout the cruise except while on station, during a few periods of bad weather or while working particularly heavy ice. The data from the work areas were used as a background for oceanographic studies and the passage data will be added to the regional BAS database.

Calibration and velocity profiles

A roll calibration was carried out on the abyssal plain in the southern Weddell Sea and an offset of 0.6 degrees was applied to the system. Expendable bathythermographs (XBT's; Table 12) were launched once per day while on passage and the sound velocities from these casts input to the EM120. Only T-7 probes were available so the parts of the profiles deeper than 760 m had to be extrapolated. By experiment we found it best to edit the profile so that the velocity-depth gradient from the lower half of the XBT profile continued to 4000-5000m, rather than trying to fair it in to the "average ocean" gradient supplied with the Simrad sound profile editor. This was especially necessary over the flat Weddell abyssal plain, where even small errors in the sound profile result in an apparently curved seabed. The XBT cable failed near the start of the cruise and was replaced. Fortunately the XBT probes were extremely reliable; there were no complete failures and only one cast terminated at 200 m depth in rough weather.

Within the oceanographic study areas, sound velocity profiles from CTD casts were used. These were derived from the 2dB processed CTD data, using the standard sound velocity calculation routine provided with the Matlab Seawater routines. Jeremy Robst wrote a routine for uploading sound velocity data directly from the network (the XBT machine or the pstar drive), which was a great improvement on previous methods. To enable XBT uploads, go to the Applications menu (middle mouse button) and click on Start SVP Upload Interface. A small window will appear in the MBES screen. Select the cruise and the XBT required, click on Upload and proceed in the normal way.

Surveys and data processing

Ten surveys were completed (Figure 67a); the data were divided up in this way so that no individual survey became too unwieldy or slow to plot. Ship speed was 10-12 knots and beam angle was 60-65 degrees on the shelf and 52-58 degrees in deep water. The continental shelf surveys east and west of the Fimbul ice tongue were cleaned using binstat (global rule = remove data outside 2.0 or 2.5 standard deviations, plus manual editing). A 20 m grid was used for continental shelf data and a 60 m or 80 m grid for the slope and rise.

Detailed surveys were carried out at four of the WASP stations (see Benthic Biodiversity section), with an EM120 beam angle of 30 degrees and a ship speed of 7 knots. These data were quite noisy and required manual editing one ping at a time. The cleaned data (5 or 10 m grid) provide a link between the 20m grid of the initial survey and the metre-scale features seen on the WASP video (see figures 92 and 93, for example).

Equipment performance

The main problem encountered was pack ice. The general noise effects of the ship moving through ice are reasonably well known. They are unavoidable on TOPAS but can be remedied to some extent on the EM120 by setting the spike filter strength to Strong and the range gate to Small. It also helps to set a modest beam angle (45-50 degrees), to keep a small gap between Max and Min Depths and to force the correct depth every few minutes. Even so there were times in heavy pack ice when the EM120 lost the seabed completely and the echo sounder had to be restarted.

After working particularly heavy pack on day 056 the starboard beams deteriorated badly (Figure 67), an effect which lasted for several hours. A possible explanation is that fragments of ice entered the EM120 transducer space through the sea vents, floated to the starboard side as the ship heeled to port over the worst floe, and interfered with the acoustics until the ice eventually melted.

The EM120 logging machine hung early on day 059 while changing surveys, and the operator interface could only be restarted after a shutdown and restart of the system.

The Interference filter on the EM120 was found to be very effective at cutting out interference from TOPAS, in deep water when TOPAS was running on a 4 second cycle. However, this filter must be used with care because it also tends to wipe out areas of the EM120 return on rough slopes (when TOPAS interference is less of a problem anyway).

The EPC chart recorder had an intermittent fault which caused it to advance approx 1 cm per line intead of the setting of 1/75 inch. This could be cured by momentarily changing the lpi setting to 100 and back to 75, but remains undiagnosed. On day 064 the end of the take-up spindle came loose and had to be reassembled. Five-minute marks of time and EM120 centre depth were printed on the EPC from a Toshiba T1850 laptop; this hung up every couple of days and had to be rebooted.

At the start of the cruise the swath work area was reorganised by removing the sidescan plotter and putting the EPC in its place at the aft end of the side bench; there is now bench space for the watchkeeper to work at their own laptop, which is a big improvement.

1-page track chart with the swath surveys (a) to (j) in different colours, plus XBT stations

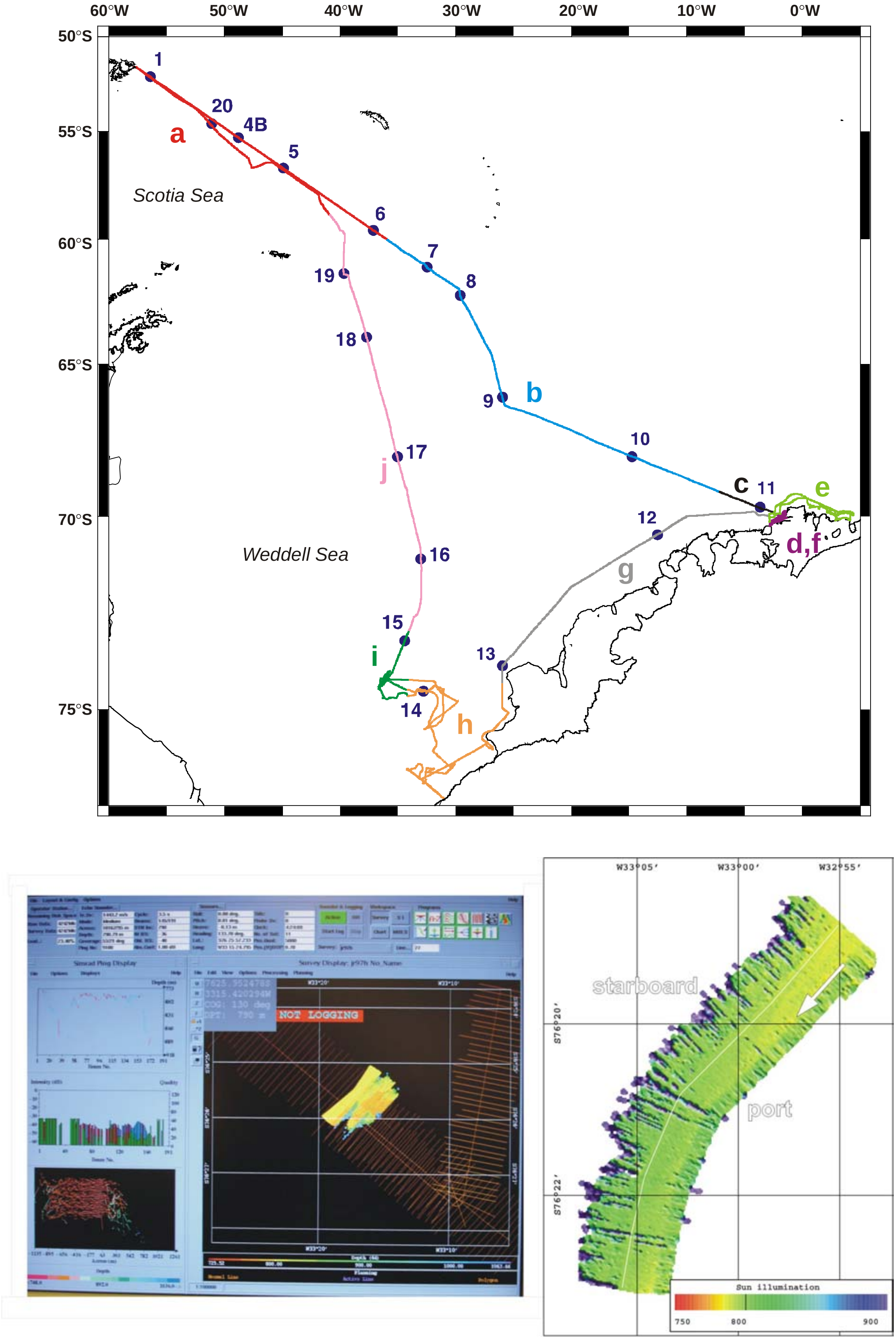


Figure 67. (a) Swath surveys. (b) Photograph of screen and section of data showing starboard beam dropouts.

Table 12. XBT casts

No	EDF file no	Time/day	Latitude S	Longitude W	Depth (m)	Cast length
01	T7_00002.EDF	2014/034	52 10.86’	56 25.78’	1041	760 m
03	T7_00005.EDF	2213/035	55 15.18’	48 54.70’	3670	760m [1]
04B	T7_00007.EDF	2245/035	55 17.80’	48 48.0’	3720	760 m
05	T7_00009.EDF	1142/036	56 46.78’	44 55.38’	3517	760 m
06	T7_00011.EDF	1143/037	59 36.61’	37 07.74’	3580	760 m
07	T7_00017.EDF	0246/038	61 11.17’	32 29.27’	3201	220 m [2]
08	T7_00017.EDF	1323/038	62 20.07’	29 36.42’	4576	760 m
09	T7_00019.EDF	1054/039	66 10.13’	25 57.88’	4900	760 m
10	T7_00020.EDF	1054/040	68 09.40’	14 45.50’	4888	760 m
11	T7_00021.EDF	0959/041	69 44.27’	03 39.02’	2433	760 m
12	T7_00022.EDF	2135/053	70 32.46’	12 33.92’	2135	760 m
13	T7_00023.EDF	0146/055	73 59.45’	25 56.68’	2959	760 m
14	T7_00024.EDF	2107/058	74 35.10’	32 47.29	638	760 m
15	T7_00025.EDF	1303/063	73 22.59’	34 23.50	3137	760 m
16	T7_00026.EDF	0033/064	71 13.47’	33 01.35	4122	760 m
17	T7_00027.EDF	1549/064	68 10.00’	35 03.28	4462	760 m
18	T7_00028.EDF	1211/065	63 58.13	37 42.30	4833	760 m
19	T7_00029.EDF	0149/066	61 27.22	39 40.82	3040	760 m
20	T7_00030.EDF	0112/069	54 41.87	51 07.31	4292	760 m

Notes 1. Problem with cable
2. Bad weather

Sea Ice Physics

Jeremy Wilkinson, Nick Hughes, Arthur Kaletzky and Martin Stott

The aim of the sea ice physics programme was to characterise the sea ice and oceanographic properties within the lead or polynya (open water region) that is frequently observed in front of the Filchner-Ronne ice shelf, through the use of ship and AUV based operations. Close monitoring of the ice conditions from satellite images during the Austral summer revealed that this open water region was indeed present. However, as we progressed towards the southern Weddell Sea, it became apparent (again from remotely sensed data) that sea ice was now filling the region to such an extent that the *JCR* and Autosub could not safely operate. As a result the main priority of the cruise was changed from the Filchner-Ronne to the Fimbul Ice Shelf. This was unfortunate as lead (and polynya) processes do not normally occur in this region at this time of year, and it also meant that the possibility for sea ice work was cut significantly. There was still the possibility of working near the Filchner-Ronne towards the end of the cruise if the conditions improved. However, the combination of the heavy ice conditions and time restrictions meant that attempting to reach the lead/polynya remained impractical and therefore our ice work focused on the eastern ice margins of the Weddell Sea.

A second blow to the sea ice campaign was the loss of the Autosub which meant that we had to rethink our sampling strategy, as many of the measurements we wanted to perform could only be achieved with the instrumentation onboard Autosub. Therefore sea ice work concentrated on deploying the 2 drifting ice buoys, and the analysis and description of young ice types that normally occur when a polynya is active.

The sea ice measurements obtained during the cruise can be broken down into the following sections:

- Ice log
- Remote sensing (see Satellite Data section of report)
- Buoy deployment
- Ice sampling
    - Sampling of biological material for CCAP
- CTD transect (see CTD section of report)
- Processing of multibeam data from Autosub mission 382

The remote sensing and CTD work are described elsewhere in the report. The remaining elements are covered in the following pages.

Sea Ice log

Nick Hughes, Jeremy Wilkinson, Martin Stott and Arthur Kaletzky

Introduction

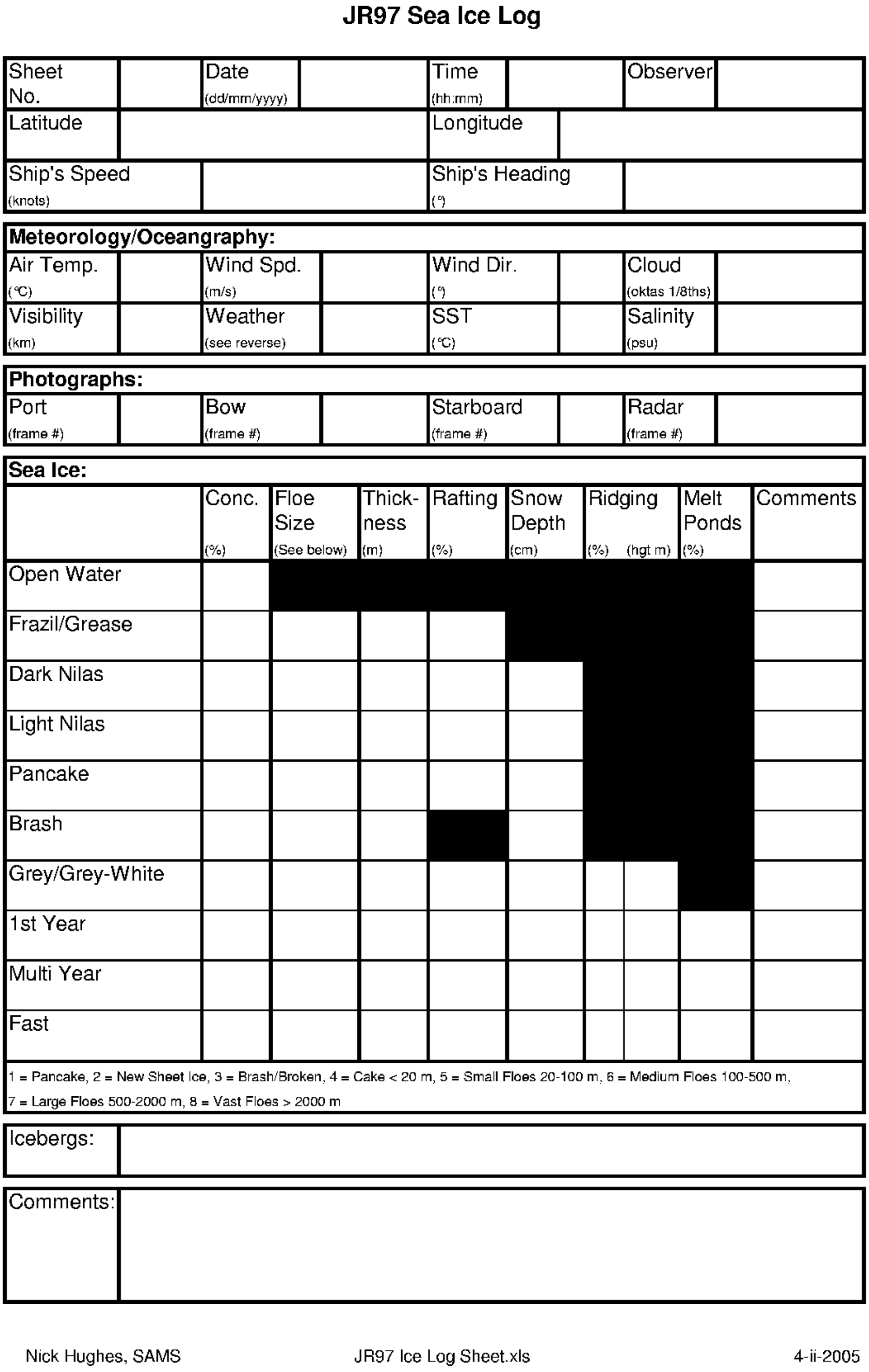
During JR97 hourly sea ice observations were conducted from the first encounter with pack ice at 07:50 on 10 February 2005, until we left the ice at 10:00 on 4 March 2005. Due to the diversion of the *JCR* to the Fimbul Ice Shelf less sea ice was encountered than was expected. Observations were conducted using the Sea Ice Group (SIG) (as used at SPRI and later SAMS/DAMTP) protocols for sea ice and the World Meteorological Organisation (WMO) codes for weather as defined by ASPeCt. It was felt that the ASPeCt method of describing sea ice, which is limited to primary, secondary and tertiary types, was too limited for a mixed sea ice pack. The SIG method uses a matrix grid in which it possible to record all types of sea ice and their characteristics should they occur together in the same hourly observation.

Not being familiar with the computer software used for processing ASPeCt observations an SIG method of recording the data in an Microsoft Excel spreadsheet and mail-merging the data output into an Microsoft Word document was designed for use with ice logs recorded on *RV Jan Mayen* (CONV-0) in 2001 and *RV Lance* (CONV-3) in 2002 for the EC CONVECTION project. The advantage of using a spreadsheet is that the data can be tabulated in a form suitable for processing by other programs and an output form with any layout can be created in the Word document.

The layout of the ice log sheet used to write down observations each hour is shown in Figure 68. For JR97 the ASPeCt/WMO weather codes were printed on the reverse side of the sheet. A pile of these was left on a table in the wheel house of *JCR* along with either a Fuji FinePix A203 or a Fuji FinePix M603 digital camera. Digital photographs have proved to be far superior and a more efficient means of delivering visual information into ice log reports than the traditional black and white film used on *RV Lance* (CONV-1).

Processing the ice log data for JR97 is now underway with the aim of producing a separate report. The data collected will also be tabulated in the spreadsheet to conform with the ASPeCt protocol and the method compared with that of SIG to see if improvements can be made to either method. Describing sea ice in this manner gives a survey of observed conditions that are comparable to other methods of data collection for sea ice. A broad scale is available in this region through satellite data but records of higher resolution and intermediate to shorter distance scales remain sparse.

Maintenance of an hourly ice watch is difficult in sporadic ice conditions and when personnel are also engaged with other duties. Reporting during JR97 was sometimes erratic. Quality of observations between observers also varies and this will be the task of the ice log editor to review. These issues do suggest that an automated, computerised ice watch system is required. This would also have the advantage of being able to record observations more frequently in rapidly changing ice conditions such as those found by a vessel operating in the Marginal Ice Zone (MIZ). An automated sea ice/environmental data logging system is available in the form of IceCam (Hughes, 2001) but funding pressures have meant that this system has not been as widely deployed as desirable and a unit was not available for JR97.



JR97 Sea Ice Log

Sheet No.		Date (dd/mm/yyyy)		Time (hh:mm)		Observer	
Latitude				Longitude			
Ship's Speed (knots)				Ship's Heading (°)			

Meteorology/Oceangraphy:

Air Temp. (°C)		Wind Spd. (m/s)		Wind Dir. (°)		Cloud (oktas 1/8ths)	
Visibility (km)		Weather (see reverse)		SST (°C)		Salinity (psu)	

Photographs:

Port (frame #)		Bow (frame #)		Starboard (frame #)		Radar (frame #)	

Sea Ice:

	Conc. (%)	Floe Size (See below)	Thick-ness (m)	Rafting (%)	Snow Depth (cm)	Ridging (%)	(hgt m)	Melt Ponds (%)	Comments
Open Water		■	■	■	■	■	■	■	
Frazil/Grease					■	■	■	■	
Dark Nilas						■	■	■	
Light Nilas						■	■	■	
Pancake						■	■	■	
Brash				■		■	■	■	
Grey/Grey-White								■	
1st Year									
Multi Year									
Fast									

1 = Pancake, 2 = New Sheet Ice, 3 = Brash/Broken, 4 = Cake < 20 m, 5 = Small Floes 20-100 m, 6 = Medium Floes 100-500 m,
7 = Large Floes 500-2000 m, 8 = Vast Floes > 2000 m

Icebergs:	

Comments:	

Nick Hughes, SAMS JR97 Ice Log Sheet.xls 4-ii-2005

Figure 68: Sea ice log sheet used on JR97.

Ice Concentration

The first iceberg was passed at 13:32 on 6 February in location 59°48’23”S 36°32’46”W. After this icebergs became a regular feature, often being too numerous to record except by referring to the radar screen in the wheelhouse. From the first sea ice log observation on 10 February JR97 can be viewed as being in three distinct parts:

Part 1 – 10 February 2005 to 22 February 2005, Fimbul Ice Shelf

During this period the *JCR* was operating around the margins of the Fimbul Ice Shelf between longitudes 4°W and 4°E conducting CTD and seabed mapping in support of the successful and terminal Autosub deployments. Data from both passive and active microwave satellite sensors showed that a coastal band of broken up first-year ice floes and brash was being advected around the ice tongue by a westward coastal current and winds. *JCR* had to penetrate this barrier if it were to conduct CTD’s anywhere near the ice shelf front. This band was narrow and forays in towards the ice shelf resulted in the ship entering the ice between observations.

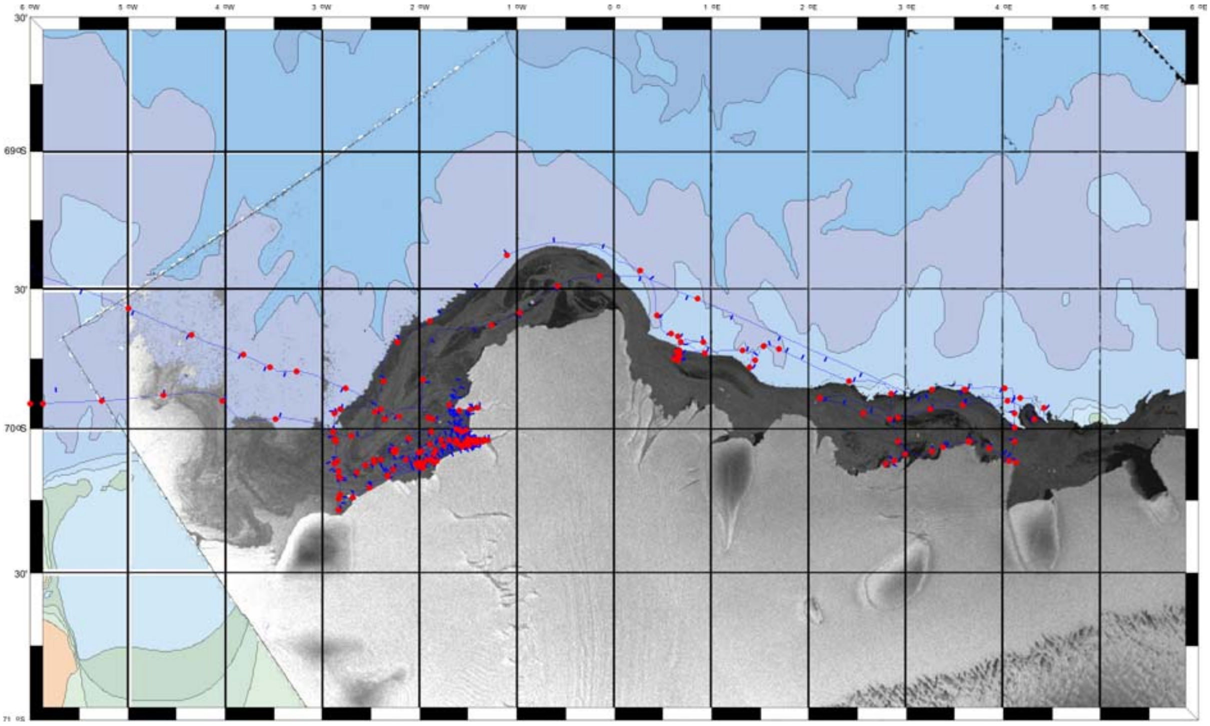


Figure 69. Map of the Fimbul Ice Shelf derived by combining GEBCO bathymetry and an Envisat WSM scene from 20 February 2005. The track of the JCR is marked as a blue line and ice log observations as red circles.

A typical two hours in the sea ice off the Fimbul Ice Shelf follows on the next two pages in the form of ice log reports and photographs.

Date/Time:	18/02/05 08:00	**Latitude:**	69°51.540’S	**Longitude:**	04°01.260’E
Observation No.:	LXXVII		Observer:	NEH	

Photographs:							
Port:	077prt.jpg	Bow:	077bow.jpg	Starboard:	077str.jpg	Radar:	077rdr.jpg
							

Concentrations:	
Open Water	50
Total Ice	50
Ice Types:	
Grease/Slush Ice	40
Pancake Ice:	
Dark Nilas	
Light Nilas	
Grey/Grey-White Ice	
1st Year Ice	
2nd Year Ice	
Multi Year Ice	
Brash Ice	10

Narrative:

JCR is running parallel with the main ice pack to starboard. Perpendicular to our course are bands of brash and grease ice. Some very young pancake formation.

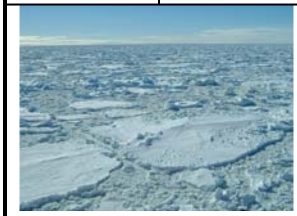
Icebergs:

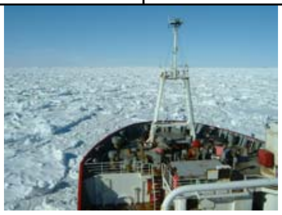
6 visible, 5 of these in sea ice pack to starboard.

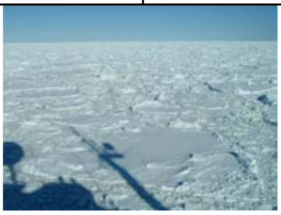
Date/Time:	18/02/05 09:00	**Latitude:**	69°56.700'S	**Longitude:**	04°07.080'E
Observation No.:	LXXVIII		Observer:	NEH	

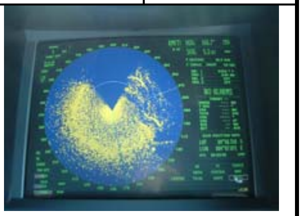
Photographs:

Port:	078prt.jpg	Bow:	078bow.jpg	Starboard:	078str.jpg	Radar:	078rdr.jpg









Concentrations:	
Open Water	0
Total Ice	100
Ice Types:	
Grease/Slush Ice	10
Pancake Ice:	
Dark Nilas	
Light Nilas	
Grey/Grey-White Ice	
1st Year Ice	40
2nd Year Ice	
Multi Year Ice	
Brash Ice	50

Narrative:

JCR is heading into the sea ice to get to the ice shelf front. Ice pack consists of 1st Year floes less than 20 metres in diameter (cakes) in a thick frazil/brash porridge. Swell waves are getting through so whole ice field is slowly undulating.

Icebergs:

More than 12 visible with most these being tabular.

Part 2 – 22 February 2005 to 25 February 2005, Transit to Halley

After leaving the Fimbul Ice Shelf area on 22 February the *JCR* steamed sou:th-west to pick up passengers from *RRS Ernest Shackleton* off the Brunt Ice Shelf near the BAS research station at Halley. No sea ice was encountered until the end of this period on 25 February when broken up fast ice was encountered around the ice shelf. A decision was made to maintain the ice watch but to concentrate on recording positions and morphology of icebergs. The aim of this was to provide supporting data for the development of satellite algorithms to detect and track icebergs. A typical report is shown below.

Date/Time:	23/02/05 08:55	**Latitude:**	71°43.320’S	**Longitude:**	18°31.620’W
Observation No.:	CLXXXIV		Observer:	NEH	

<table>
<tr><th colspan="8">Photographs:</th></tr>
<tr><td>Port:</td><td></td><td>Bow:</td><td></td><td>Starboard:</td><td>183str.jpg</td><td>Radar:</td><td>183rdr.jpg</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

<table>
<tr><th colspan="2">Concentrations:</th><th>Narrative:</th></tr>
<tr><td>Open Water</td><td>100</td><td rowspan="8">2 bergs - one close and one on starboard horizon. At 10:10 no icebergs in range. By 12:05 no icebergs in range.</td></tr>
<tr><td>Total Ice</td><td>0</td></tr>
<tr><td colspan="2">**Ice Types:**</td></tr>
<tr><td>Grease/Slush Ice</td><td></td></tr>
<tr><td>Pancake Ice:</td><td></td></tr>
<tr><td>Dark Nilas</td><td></td></tr>
<tr><td>Light Nilas</td><td></td></tr>
<tr><td>Grey/Grey-White Ice</td><td></td></tr>
<tr><td>1st Year Ice</td><td></td><td>**Icebergs:**</td></tr>
<tr><td>2nd Year Ice</td><td></td><td rowspan="3">Passed iceberg from previous hour on starboard side.</td></tr>
<tr><td>Multi Year Ice</td><td></td></tr>
<tr><td>Brash Ice</td><td>0</td></tr>
</table>

Part 3 – 25 February 2005 to 4 March 2005, South-East Weddell Sea

Oceanographic and ice work was conducted around the MIZ of the main Weddell Sea ice pack in the third and final part of scientific operations on JR97. During this period two transects from open water into the main pack were made. These put pressure on maintaining the ice watch as personnel were often engaged in other ice work. On the first of these runs an attempt was made to video log the transect from three different angles. This is reported later in this section. On the second transect on 2 March 2005 a near-real time Envisat Wide Swath (WSM) image was available. This allowed targeting of the ship on a particular course to enter the ice and ground truthing of the ice seen in the image.

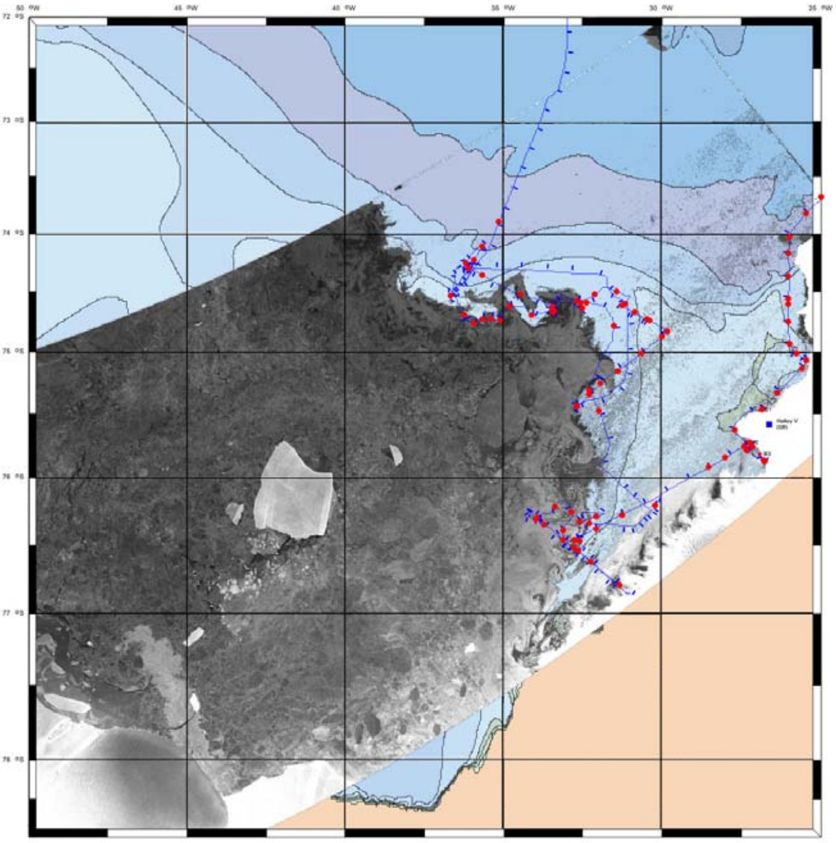


Figure 70: Map of the south-eastern Weddell Sea derived by combining GEBCO bathymetry and an Envisat WSM scene from 17 February 2005. The track of the JCR is marked as a blue line and ice log observations as red circles.

The first two hours from our first transect into the Weddell Sea ice pack is shown on the following page.

Date/Time:	25/02/05 10:00	**Latitude:**	76°22.560'S	**Longitude:**	32°06.000'W
Observation No.:	CCXVIII		Observer:	NEH	

Photographs:

Port:	217prt.jpg	Bow:	217bow.jpg	Starboard:	217str.jpg	Radar:	217rdr.jpg




Concentrations:	
Open Water	20
Total Ice	80
Ice Types:	
Grease/Slush Ice	
Pancake Ice:	80
Dark Nilas	
Light Nilas	
Grey/Grey-White Ice	
1st Year Ice	
2nd Year Ice	
Multi Year Ice	
Brash Ice	0

Narrative:

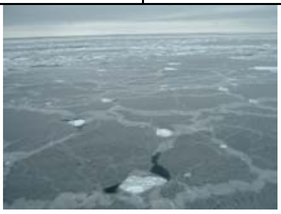
Pancakes conglomerated into thin, translucent (nilas) sheets. The majority are rafted. Some discolouration due to biological activity (diatoms?). No evidence of frazil formation. Minute amounts of grease ice between pancakes. Full iceblink from main pack (beyond visual range) to starboard.

Icebergs:

7 distant - mainly port side. Bergy bits amongst the pancakes.

	25/02/05 11:00	**Latitude:**	76°27.480’S	**Longitude:**	32°45.720’W
Observation No.:	CCXIX		Observer:	NEH	

Photographs:

Port:	218prt.jpg	Bow:	218bow.jpg	Starboard:	218str.jpg	Radar:	218rdr.jpg
							

Concentrations:	
Open Water	1
Total Ice	99
Ice Types:	
Grease/Slush Ice	1
Pancake Ice:	40
Dark Nilas	40
Light Nilas	10
Grey/Grey-White Ice	
1st Year Ice	8
2nd Year Ice	
Multi Year Ice	
Brash Ice	0

Narrative:

Sheets of flat grey nilas with finger rafting. Pancakes in between with scattered small 1st year floes. Some nilas sheets congealed into proto-pancakes.

Icebergs:

4 visual - radar cluttered with sea ice returns.

Ice Log Video

On a run into the ice on the evening of 26 February 2005 an ice log video was recorded simultaneous from 3 different cameras looking at the ice from different angles.

> Camera 1 – Forward look from the wheelhouse.
> Camera 2 – Downward look from the wheelhouse. A pink floatation ball was suspended from a spar marked with 10 cm increments as a scale indicator.
> Camera 3 – Sideways look from the UIC. This gave an oblique view of the ball and spar and the same ice beneath.

The ship ran along a transect between open water and the main ice pack. The line included grease and frazil ice being generated in the MIZ by a high wave state.

Ice Log Report

The full ice log report is being written up and will be released as a PDF file on the SAMS web server in due course – see ***http://www.sams.ac.uk/seaice/projects/autosub/jr97.html***. The report will include a reworking of the data to provide the equivalent ASPeCt measurements.

Buoy Deployments

As part of the polynya based sea ice work two buoys were to be released at the edge of the polynya in order to track the ice motion. However, as explained earlier, we could not reach the polynya in front of the Ronne-Filchner Ice shelf and therefore the buoys were deployed at two different locations in the Weddell Sea. Each buoy recorded and transmitted different parameters and at the time of writing both buoys were functioning well. The operation of each buoy is explained below.

Buoy 1: Tilt meter buoy

As part of the European funded Greenland Arctic Shelf Ice Experiment (GreenIce) project a new buoy was developed at SAMS to measure ice thickness using a new theory developed by the Russian scientist Nagurny. This work allows area averaged ice thickness “measurements” to be derived from the measurement of the wave spectra. The Nagurny method requires observations of the periods of flexural waves passing through the sea ice cover. These waves are generated by storms on the ice edge and then propagate through the ice cover. In the deep pack these waves have peak-to-peak amplitudes of around 1mm and periods of about 30 seconds, though in summer these amplitudes are expected to be significantly larger due to the reduced ice cover. The primary sensor of these buoys is a sensitive tiltmeter that has to be able to resolve tilts in the surface ice cover on the order of microradians. In order to provide these high resolution measurements, the buoy has an arrangement of stepper motors which provide a self levelling capability which ensures that the sensor can be correctly levelled at the start of each measurement cycle. Once deployed the buoy is not expected to be recovered and it transmits it’s data across the Iridium satellite phone network.

Deployment

The area chosen for the buoy deployment was on a large, thick multiyear floe deep inside the pack. This site was chosen as it should enable the buoy to survive any compaction of the pack due to storm activity. The buoy was deployed on a ridge in the middle of the floe (76.2700653 S, 34.1341476 W) at 15:58:00 on the 25 February and by the time we had finished surveying the floe at 17:24:00 it had drifted in a south westerly direction to 76.2742538 S, 34.1510010 W. The floe and its drift are shown in figures 71 and 72.

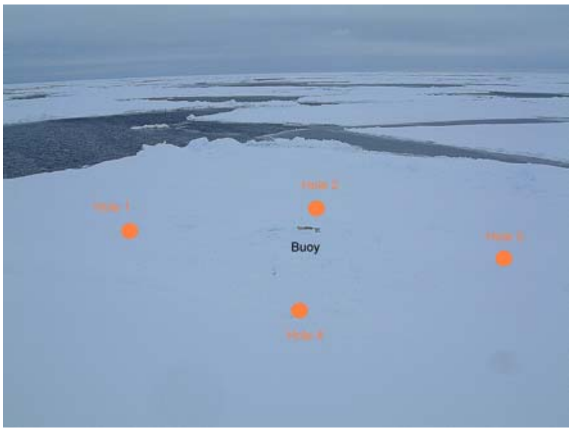


Figure 71. Picture of the floe taken from the bow of the JCR.

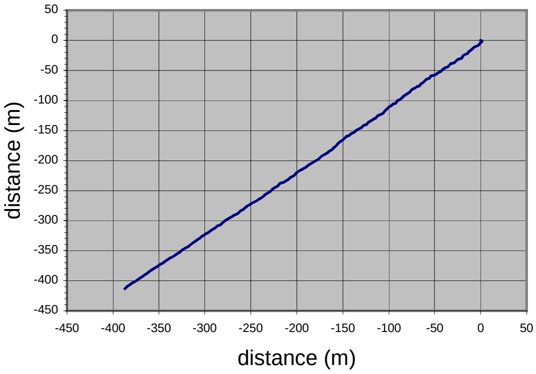


Figure 72. The drift of the floe in metres. Starting at the origin (0,0) the floe drifted in a consistent south-westerly direction.

Figure 73. Panoramic image taken from the buoy location and stitched together. The location of the people in the image relate to the location of the drill holes for thickness measurements.

In order to ground truth the ice thickness predicted by the buoy five ice thickness measurements were made on the floe, one at the buoy deployment site and the four others 10m from the site in a cross pattern. The thicknesses were as follows:

Name of hole	Total ice thickness	Freeboard	Snow thickness
Martin (at buoy)	5.90	Too deep to measure	0.10
Jeremy (1)	5.05	-0.05	0.90
Arthur (2)	3.10	0.10	1.10
Paul (3)	3.90	0.10	0.40
Nick (4)	4.30	-0.18	1.00

Buoy 2: Argos buoy

This buoy was a standard METOCEAN designed Lagrangian drifter (WOCE/SVP) designed to the specifications of the WOCE scientific community. For our use the 15 m drogue was cut off. The Argos PTT is activated by removing a magnet located on the side of the hull and has a normal operating life of two years.

Sensor sampling

All sensor data are updated every 30 minutes. The sea surface temperature and battery voltage are sampled at the Argos transmission interval of 90 seconds and a 7-sample average is developed. The submergence sensor is sampled 4 times every 90 seconds and the total number of times these sensors are underwater is summed over the 30-minute sampling period to determine the percentage of time the surface unit is submerged. The buoy meets or exceeds all the requirements of the DBCP Report #4, Rev 1, Global Drifter Programme Barometer Drifter Design reference. The sensor data is formatted for Argos transmission and reported information is updated every 30 minutes. The Argos message is transmitted every 90 seconds continuously.

Deployment

As with the tilt meter buoy this buoy was also deployed on a large, thick multiyear floe. The photograph in Figure 71 shows the floe with the tilt meter buoy. The buoy was deployed on a ridge in the middle of the floe on the 2 March at 14:53:25. It position was 75.4422760 S 32.7107582 W. This floe also drifted in a south-westerly direction.

In addition to the deployment of the buoy a hole was drilled to obtain the thickness of the floe (ice thickness : 6.2; freeboard: 0.7; Snow depth: 0.7) and two ice cores were taken for ice density and salinity analysis.

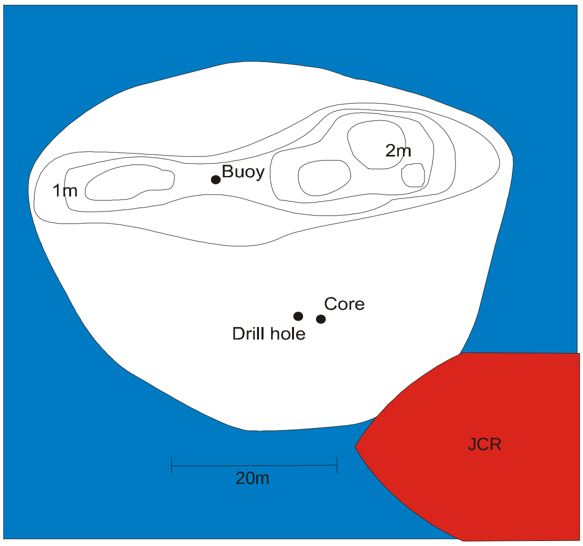


Figure 74. Schematic of the ice floe with location of the buoy, ridge system and drill hole and core hole.

Figure.75. SVP Argos buoy settling in.

Measurements of new ice formation

Once the surface of the ocean is cooled to freezing, any additional heat loss produces a slight *supercooling* of the water. Ice formation in the upper surface of the ocean can then occur once it has been supercooled to below freezing. The first stage of ice formation is the creation of small crystals, known as *frazil ice*. If the effects of both waves and wind are reduced, the agitation of these ice crystals ceases and the surface layer of frazil can begin to consolidate. This, in turn, enables the frazil to fuse together to form a continuous sheet of ice known as *nilas*. Nilas is observed to be extremely plastic and can easily bend with the waves. Further thickening of nilas will continue as a unidirectional process by which seawater freezes directly to the underside as heat is conducted through the ice. This is known as *congelation growth*. Nilas can also become thicker through rafting or ridging events.

If, however, wave action continues, *pancake ice* forms rather than nilas. The diameter of primary pancakes depends on the high-frequency part of the wave spectrum. Around the circumference of pancake ice is a raised ridge initially 1 or 2 cm higher than the surrounding plane of the pancake. These ridges, which are generally uniform in height, are the first part of the pancake to protrude above the water surface and are therefore the first indication that pancake ice is forming. They are formed by the piling of frazil ice around the edges of the pancakes by friction between them. This can be from general jostling and collisions between pancakes and the cyclic pressure pulses of the wave field *i.e.* as pancakes are compressed together at the trough of a wave frazil ice is pushed up on the sides of the pancake. The edges appear grey at first, but as the seawater drains they become white in appearance.

Inside the raised rim the surface is usually quite smooth and moist. The watery nature of the centre of a pancake is due to the greater salinity of mixed, separated brine and seawater. Snow falling on the central area of the pancake will melt due to this salinity. Over time, however, this will slowly reduce the salinity at the center of the pancake, enabling a full snow cover to develop.

Immediately upon formation pancakes, like nilas, are very porous and have little strength as the frazil bonds between the newly formed pancakes are very weak. When touched, for example, newly formed pancakes will break into horizontally floating discoids and they will also not sustain their own weight if removed from the ocean. As time passes, however, and sub-freezing air temperatures continue, the interstitial water between frazil ice crystals freezes, causing individual frazil ice crystals to grow and brine drainage to occur, all of which strengthens the pancake.

Over the years we have studied brine rejection in both frazil, pancake and nilas ice in the Arctic. This cruise gave us the opportunity to extend this study to the Antarctic.

Frazil ice measurements

Frazil ice concentration and thickness were measured by the use of a *frazilometer* from the side of the ship. The frazilometer is a 0.3 m log cylindrical tube with the bottom covered with 300 μm plankton netting. It was lowered, from the side of the vessel, directly through the frazil layer to a depth of about 5 m, *i.e.* well below the frazil layer. The frazilometer was then raised vertically through the water column and a frazil ice sample collected. Once aboard, the seawater from the sample was allowed to drain and the frazil crystals were then poured into a clean sample bottle. Several casts with the frazilometer were performed at most stations where frazil was in the water column.

The samples were then melted so that their volume and conductivity could be measured with the Hanna HI8733 conductivity meter. Conductivities were adjusted from the 25°C standard of the conductivity meter to 15°C, which is the standard for salinity measurements. Finally, conductivities were transformed to salinities using the UNESCO (1978) formula. The conductivity meter was calibrated before and after the measurements with a 1288 μS/cm buffer solution.

Pancake ice measurements

Pancake ice samples were obtained using a specially designed pancake ice lifter. The dimensions of the lifter are 1.5m x 1.5m x 0.5m and it can lift over 1000 kg of ice at a time. The lifter incorporates 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 analysis. This is the only feasible way to obtain analytical measurements of pancake or nilas ice as it cannot be cored *in-situ*, as is done with larger floes. The lifting of pancake or nilas ice onto the deck for detailed analysis can be performed in most weather conditions.

A typical station can be described as follows. First the ice lifter is coupled to the crane and lowered into the water. If the ice is closely packed, or there are large amounts of frazil ice between pancakes, the lifter may take some time to sink. Once the lifter has sunk to a depth of a metre or so the crane operator manoeuvres it under a pancake, or pancakes. The lifter was then raised, capturing the pancakes.

Captured pancakes are then brought aboard for analysis. Depending on their size they are either taken from the lifter to the dissection table or, if they are too big to be lifted manually, the sides of the lifter are released, so they lay flat with the base of the lifter, and the pancakes are slid onto the deck.

On this cruise, all the ice samples were of such a size that they could be transported to the dissection table where their dimensions and distinguishing features could be measured and photographed. When this was completed, a cross-section 0.1m wide was cut across the pancake's longest axis. 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) and salinity calculated (UNESCO, 1978). The salinity of the cross sectional pieces enabled the mean bulk salinity of the pancake to be determined as well as identifying different salinity layers within the pancake.

During the cruise 19 ice samples of both pancake and nilas ice were obtained from 9 ice stations. An additional ice station was performed to obtain an ice sample for biological analysis. An example of the data obtained can be seen in Figure 76. A fuller description of the data is available if needed.

Figure 76. (a) Retrieving pancake ice from station 4, (b) pancake ice sample awaiting analysis, and (c) Distribution of salinity within the pancake.

Biological operations

Daniel Jones & Brian J. Bett

Objectives

A digital still camera system has been integrated into Autosub to aid in the study of benthic biological diversity and standing stock in Arctic and Antarctic regions. Using seabed photography (from both Autosub and the towed camera platform WASP, see below), supported by trawl and dredge sampling, the biological study aimed to assess the megabenthos in three types of polar environment: 1. open water areas, 2. seasonal ice areas, and 3. permanent ice areas. By contrasting the ecology of these three environment types the study addresses the primary question: "What are the dominant controls on the diversity and standing stock of the benthos in polar regions?"

The specific objectives of the biological operations during the cruise were:

1. To assess the larger fauna (megabenthos and demersal fish) and general seabed conditions of contrasting environments in the area of Fimbul Ice Shelf using the WASP and Autosub camera systems.
2. To collect megabenthos specimen material (Agassiz trawl and rock dredge) from the same areas for identification / taxonomy and other studies (nutrition, reproduction, genetics) as appropriate.

WASP

The Southampton Oceanography Centre WASP (Wide-Angle Seabed Photography) system was used throughout the cruise in its standard configuration (Figure 77). Briefly, WASP is a self-contained, off-bottom, towed camera vehicle that provides still and video footage of the seabed, and is capable of operation to 6,000m water depth on a simple mechanical cable (i.e. conducting or fibre-optic cable not required). As deployed during RRS *James Clark Ross* cruise JR97, WASP was fitted with: OSIL Mk7 (stills) camera, OSIL 1200J flash gun, SOC OceanCam6000V (digital video) camera, 2 x 250W DSPL video lamps, 3 x DSPL 24V batteries, Simrad Mesotech 200kHz altimeter, and a SOC acoustic telemetry system (10kHz). Data from the altimeter is telemetered to a shipborne display enabling the operator to make fine adjustments of the amount of cable deployed with the aim of keeping the vehicle at a height of about 3 m above the seabed. The still and video cameras are both automatically activated by the altimeter when the range to the seabed is less than 10 m. For all deployments made during the cruise, the still camera was loaded with 30 m of Kodak Vision 250D film, and the video camera with a 63-minute MiniDV tape.

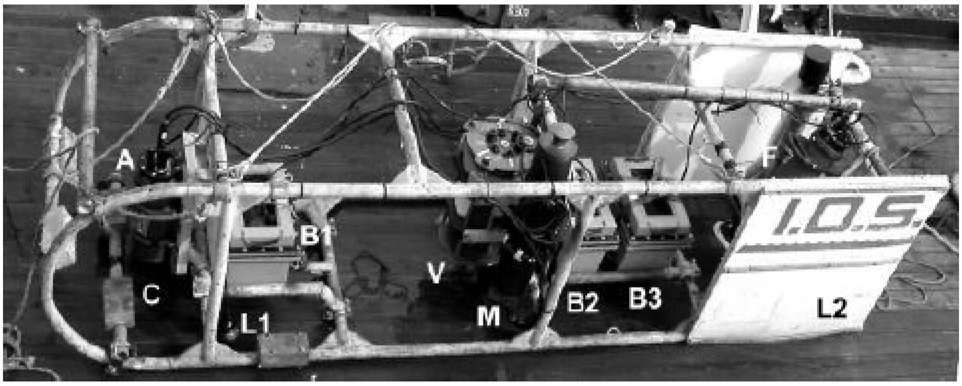


Figure 77. The Southampton Oceanography Centre WASP vehicle, showing locations of A-altimeter, C-still camera, L-video lamps, B-batteries, V-video camera, M-monitor (acoustic telemetry) and F-flashgun.

The acoustic telemetry from WASP was received through the ship's hull-mounted transducers and monitored with the BAS PES system. This system generally performed well, though two simple improvements could be considered for future operations:

a) Depth marks (vertical lines) are shown on the waterfall display, which are apparently produced in the waterfall software rather than the PES deck unit, these can complicate interpretation of WASP telemetry. An alternative version of the waterfall software would therefore be preferable. (Note also that the BAS waterfall software does not have a "clear screen" function.)

b) When using the BAS PES system, "moving" the traces is achieved by quickly flicking the sweep rate setting from 2 to 1 seconds. This is a hit and miss operation that would be much improved by addition of a "slew" button or control via the repetition rate thumb wheels (i.e. as per IOS versions).

Seven WASP deployments were undertaken during the course of the cruise (see Station List below), with film and video run on all occasions (see Material Retained below). All deployments had clear visibility and good quality video. The deployments spanned a bathymetric range of between 250-550m and should enable a study of the differential impact of iceberg disturbance of the seabed. The imagery appears to show evidence of seabed disturbance (e.g. overturned sediment, seabed furrows etc.). This is evident in both the seabed video and the ship-based swath bathymetry. There are variations in the fauna between sites observed in the video but no characteristic dominant forms could be identified at this stage. Echinoderms and cnidarians were the dominant phyla at all stations.

Table 13. WASP stations

Site	station	date	depth (m)	start time	lat start	long start	end time	lat end	long end
A	56607#1	21/02/2005	245	22:44:39	-70.11441	-1.93774	23:16:00	-70.11635	-1.92682
B	56608#1	21/02/2005	300	23:55:27	-70.10296	-1.90329	00:30:00	-70.10611	-1.89266
C	56603#1	21/02/2005	340	09:34:00	-70.03831	-1.78531	10:05:30	-70.03941	-1.77648
D	56606#1	21/02/2005	388	20:44:57	-70.04029	-1.70476	21:19:30	-70.04136	-1.69207
E	56604#1	21/02/2005	425	11:58:22	-70.04979	-1.62752	12:34:00	-70.05016	-1.61341
F	56605#2	21/02/2005	465	18:50:51	-70.04991	-1.54183	19:22:00	-70.04977	-1.53052
G	56601#1	13/02/2005	510	20:26:36	-70.04991	-1.43414	21:30:00	-70.04878	-1.40901

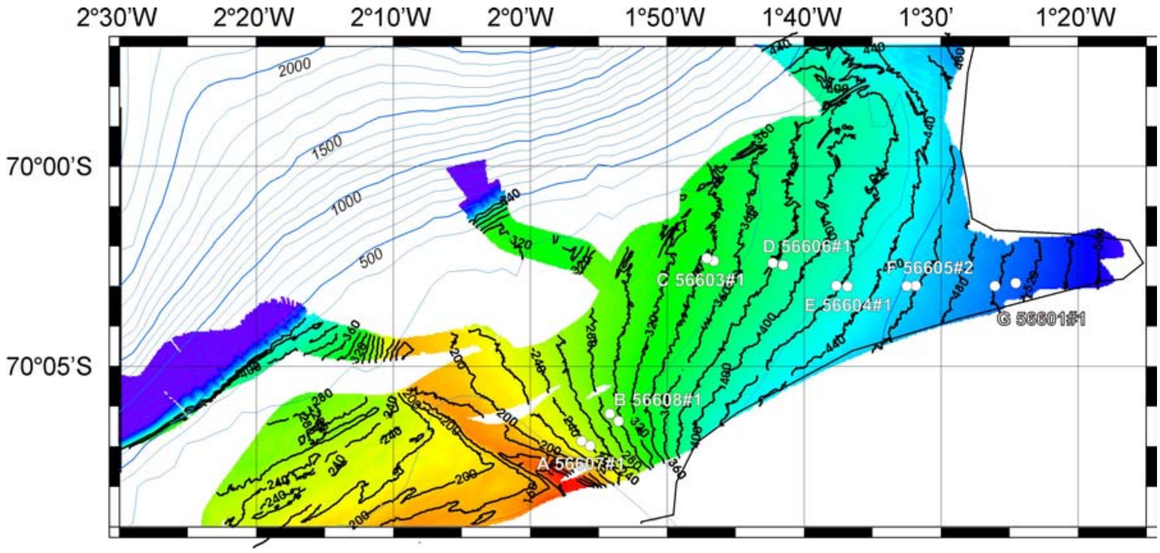


Figure 78. Positions of WASP stations overlaid onto swath bathymetry of western Fimbul area.

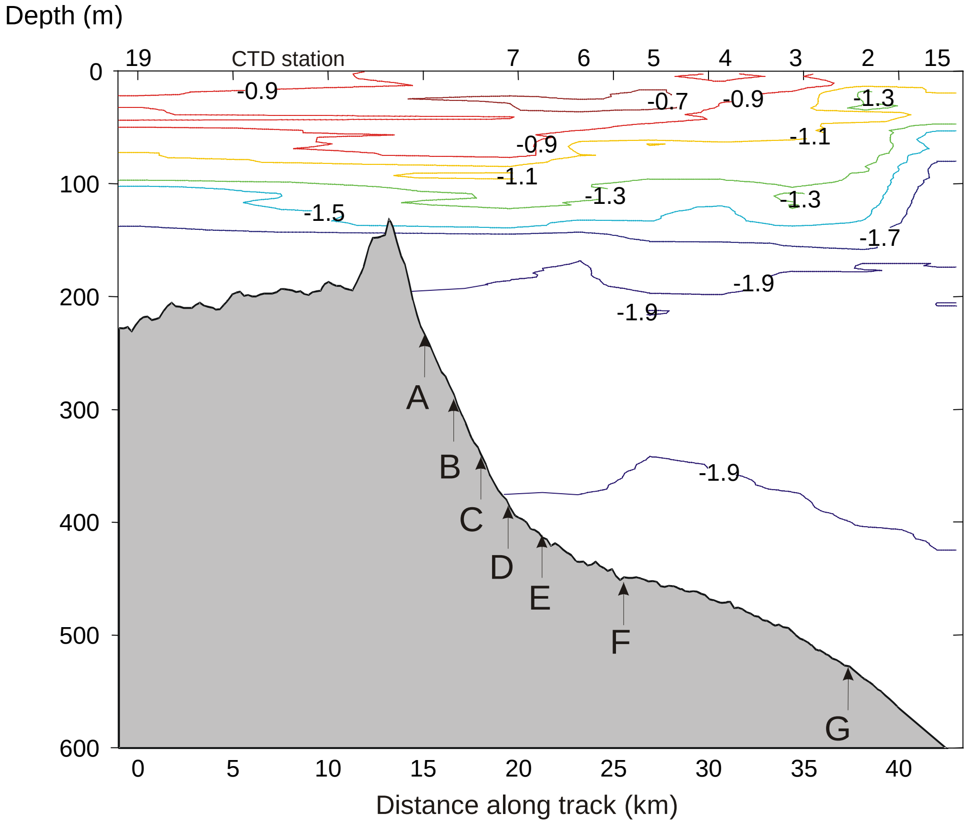


Figure 79. Cross section through WASP stations showing stations and seabed depths. Temperature contours from CTD casts 15, 2, 3, 4, 5, 6, 7, 19 with cast position and number.

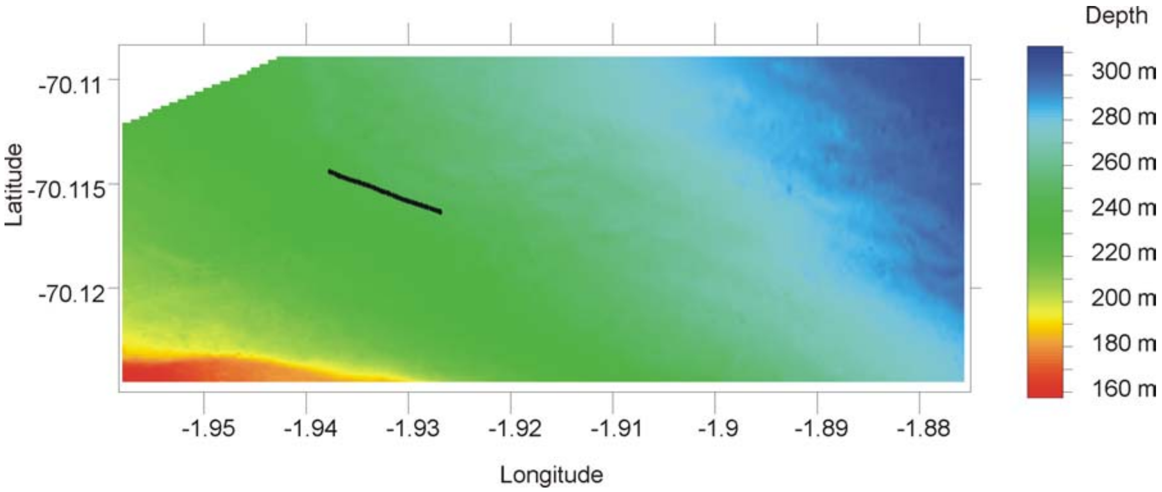


Figure 80. Processed EM120 shaded images of site A (station 56607#1) on the continental shelf showing WASP track. EM120 (60 degree beam angle, 10knots, 20x20m grid resolution).

Figure 81. Mosaic of 60 seconds of WASP video showing seabed at site A. Note small cliff left of centre and associated sediment types, feature probably owing to iceberg activity. Approximate width of mosaic 3m, each step represents 1 second of video.

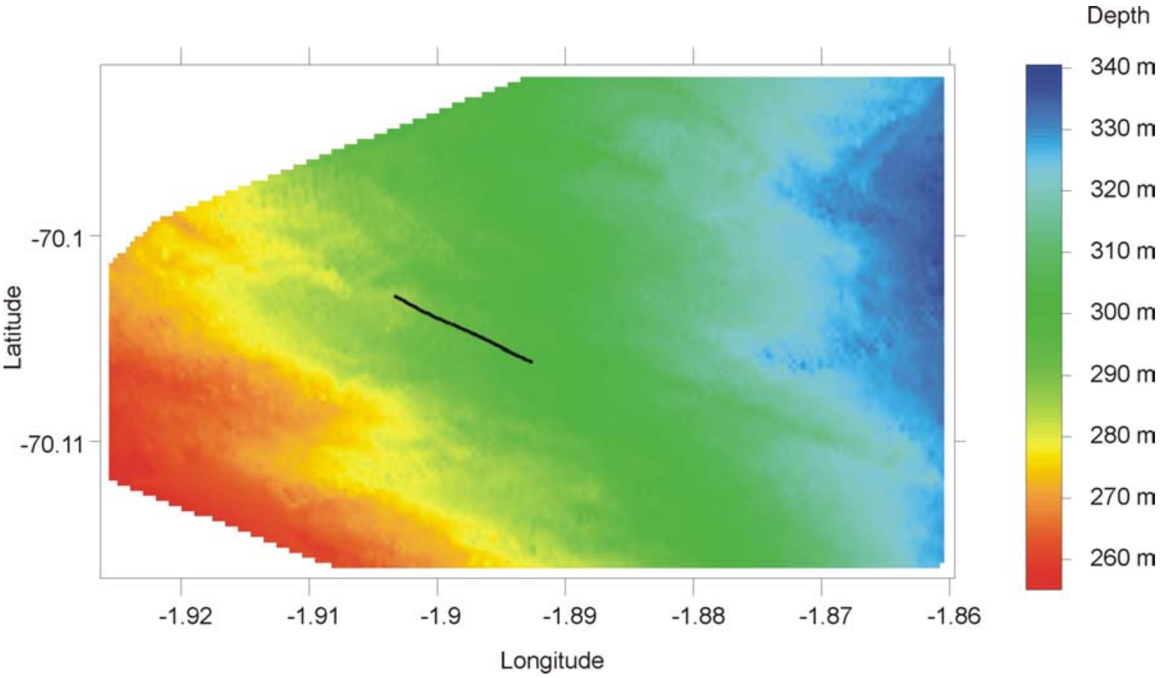


Figure 82. Processed EM120 shaded images of site B (station 56608#1) on the continental shelf showing WASP track. EM120 (60 degree beam angle, 10knots, 20x20m grid resolution).

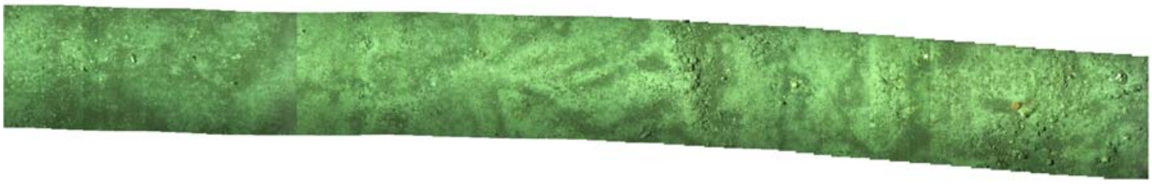


Figure 83. Mosaic of 60 seconds of WASP video showing seabed at site B, note sediment striations and rocky ridges, abundant cnidarian fauna on right of image. Approximate width of mosaic 3m, each step represents 1 second of video.

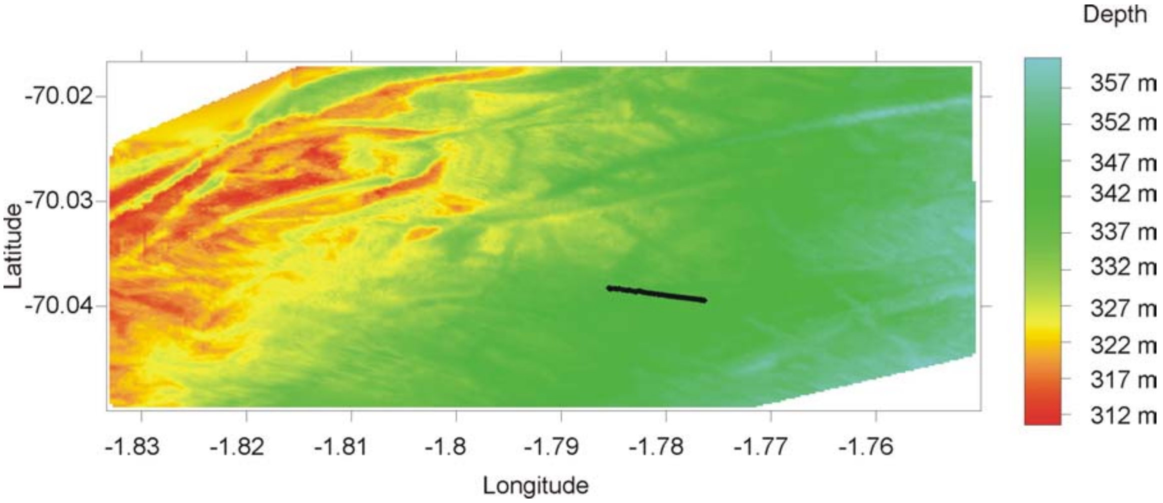
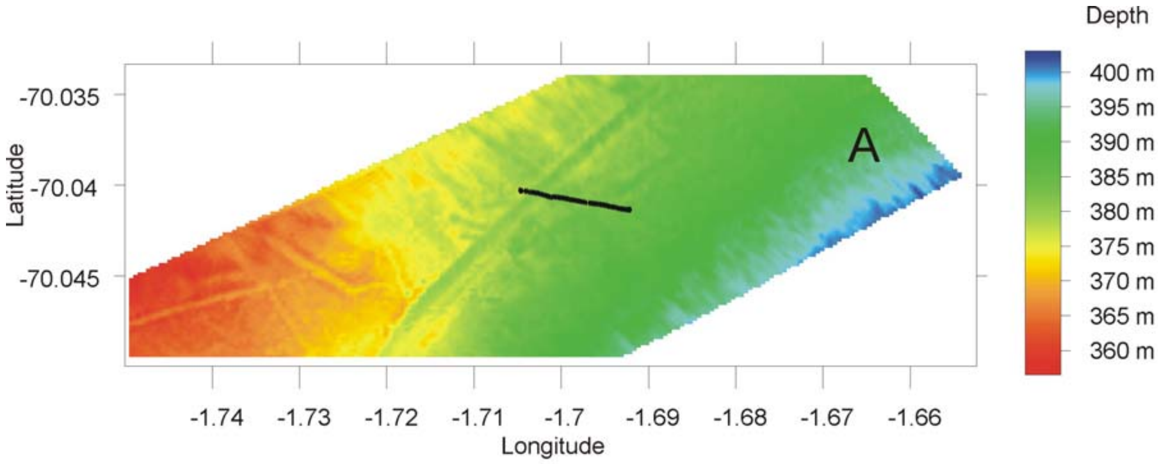


Figure 84. Processed EM120 shaded images of site C (station 56603#1) on the continental shelf showing WASP track. EM120 (60 degree beam angle, 10knots, 20x20m grid resolution). Iceberg plough mark features are clearly visible.

Figure 85. Mosaic of 30 seconds of WASP video showing seabed at site C, several large holothurians are visible. Approximate width of mosaic 2.5m, each line represents 1 second of video.



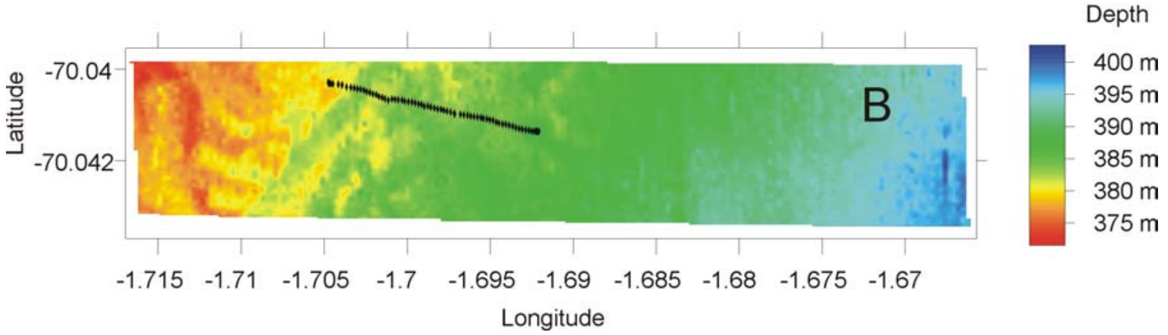


Figure 86. Processed EM120 shaded images of site D (station 56606#1) on the continental shelf showing WASP track. A = EM120 (60 degree beam angle, 10knots, 20x20m grid resolution), B = EM120 (30 degree beam angle, 5knots, 10x10m grid resolution).

Figure 87. Mosaic of 60 seconds of WASP video showing seabed at site D, the transition between boulders and soft sediment is shown, note large anemone and asteroid on cobble area right of centre. Approximate width of mosaic 3m, each step represents 1 second of video.

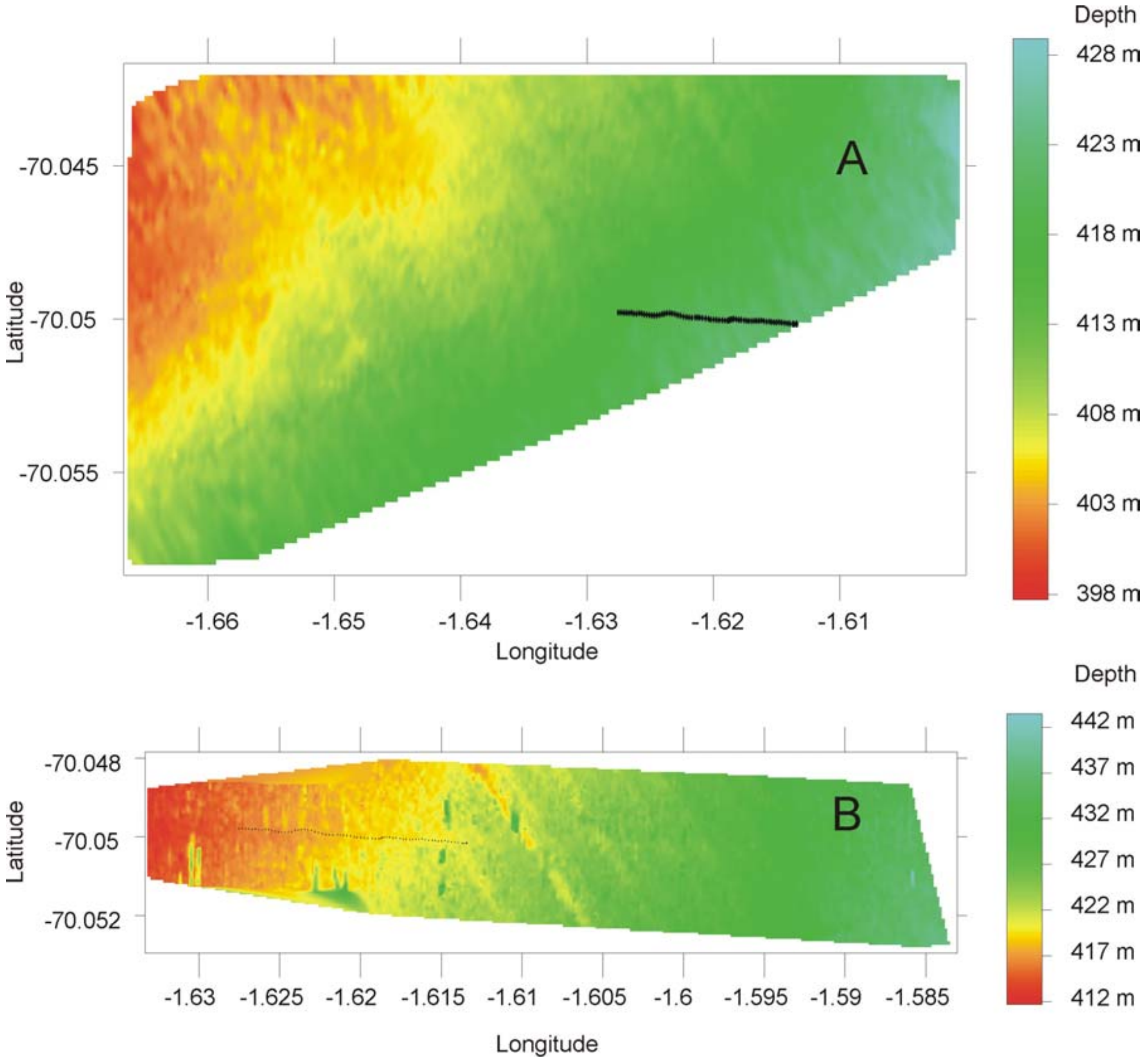


Figure 88. Processed EM120 shaded images of site E (station 56604#1) on the continental shelf showing WASP track. A = EM120 (60 degree beam angle, 10knots, 20x20m grid resolution), B = EM120 (30 degree beam angle, 5knots, 10x10m grid resolution).

Figure 89. Mosaic of 30 seconds of WASP video showing seabed at site E, the mid section has several boulders with large white ophiuroids visible. Approximate width of mosaic 3m, each step represents 1 second of video.

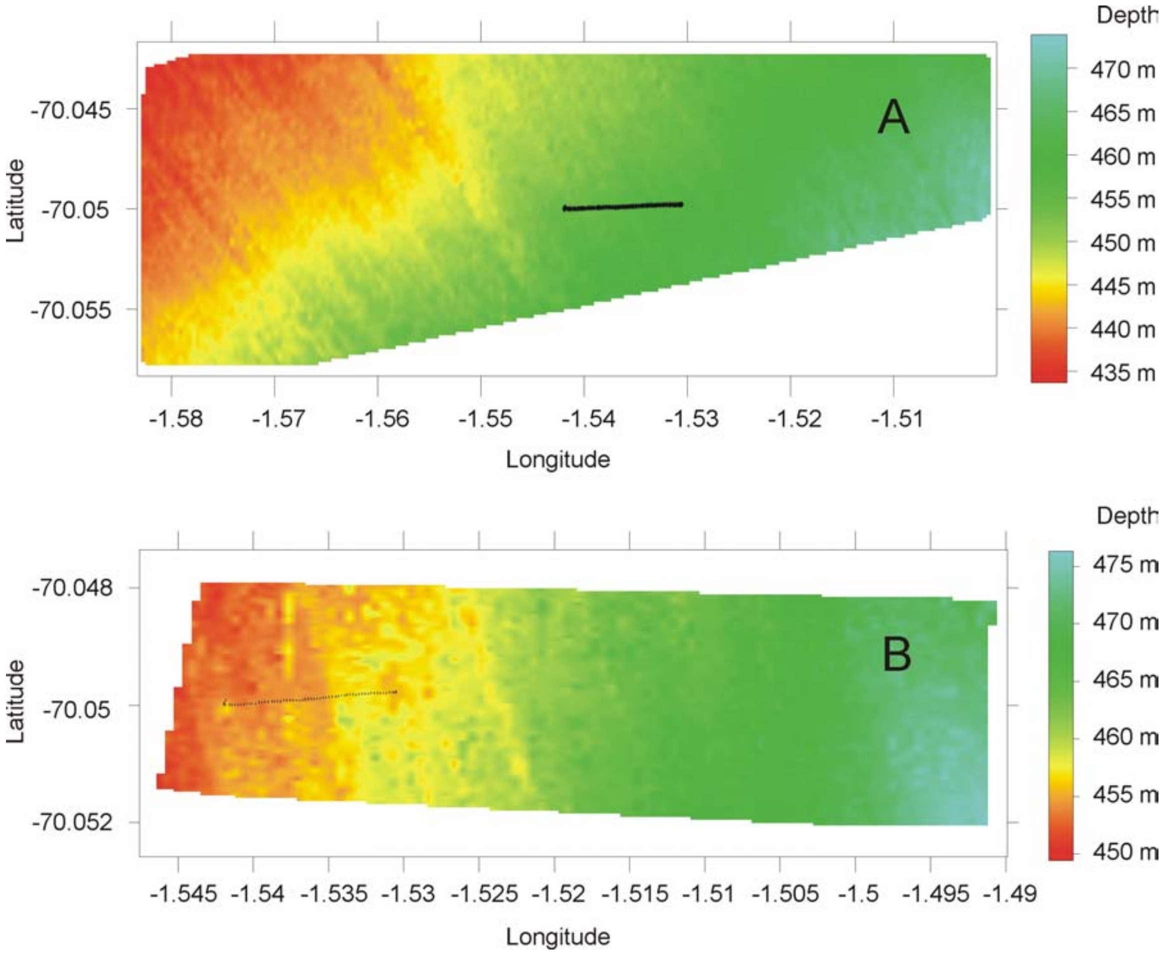


Figure 90. Processed EM120 shaded images of site F (station 56605#2) on the continental shelf showing WASP track. A = EM120 (60 degree beam angle, 10knots, 20x20m grid resolution), B = EM120 (30 degree beam angle, 5knots, 10x10m grid resolution).

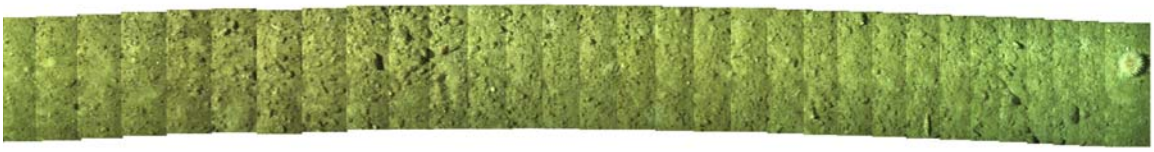


Figure 91. Mosaic of 30 seconds of WASP video showing seabed at site F, the transition between boulders and soft sediment is shown. Note large anemone at far right. Approximate width of mosaic 3m, each line represents 1 second of video.

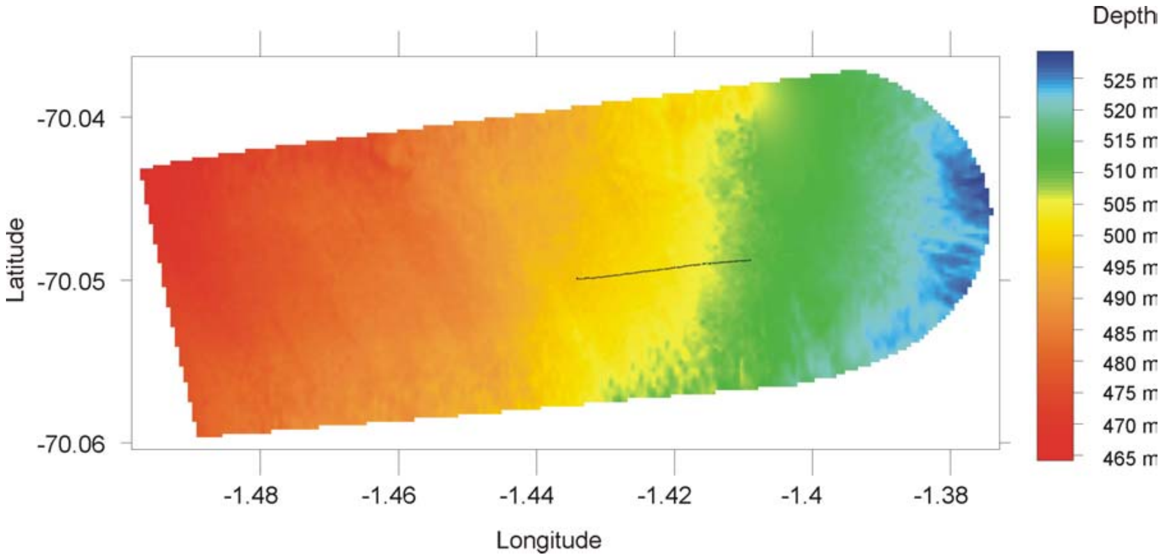


Figure 92. Processed EM120 shaded images of site G (station 56601#1) on the continental shelf showing WASP track. EM120 (60 degree beam angle, 10knots, 20x20m grid resolution).

Figure 93. Mosaic of 60 seconds of WASP video of seabed at site G, showing transition between rocky and sediment habitats associated with iceberg plough marks. Approximate width of mosaic 3m, each step represents 1 second of video.

Rock Dredge

A rock dredge was supplied from the UK National Marine Equipment Pool at Southampton Oceanography Centre. It was conventionally rigged (i.e. with dredge bucket), as shown in Figure 94.

The two deployments of the rock dredge (56602#1 and 56602#2) captured 1 x ophiuroid, 3 x holothurians (aff. *Psolidium gaini*), 1 x echinoid, 1 x pennatulid and 1 x sabellid.

Figure 94. The UK National Marine Equipment Pool (SOC) rock dredge as used during RRS James Clark Ross cruise JR97 conventionally rigged with dredge bucket.

Table 14. Dredge stations

Station	Date	Depth (m)	Start time	Lat start	Lon start	Time end	Lat end	Lon end
56602#1	16/02/2005	497	09:29:00	-70.04913	-1.422604	10:40:00	-70.04133	-1.415330
56602#2	16/02/2005	501	11:59:00	-70.04036	-1.411987	13:01:00	-70.04737	-1.415541

Material Retained

Table 15 details the material retained from the cruise that will be returned to SOC for further analysis, curation and storage.

Table 15. Material retained

Deployment	Station	Sample	type	Details	Preservation
WASP	G	56601#1	Video	63 mins	
			Stills	14m film	
WASP	C	56603#1	Video	31 mins	
			Stills	7m film	
WASP	E	56604#1	Video	31 mins	
			Stills	7m film	
WASP	F	56605#2	Video	31 mins	
			Stills	7m film	
WASP	D	56606#1	Video	31 mins	
			Stills	7m film	
WASP	A	56607#1	Video	31 mins	
			Stills	7m film	
WASP	B	56608#1	Video	31 mins	
			Stills	7m film	
Dredge	1	56602#1	Sample	1 bucket mixed catch	formalin
Dredge	2	56602#2	Sample	1 bucket mixed catch	formalin

List of Biological Stations

Deployment details for operations undertaken during RRS *James Clark Ross* cruise JR97.

Station: “*Discovery Collections*” numbering system

Gear: Sampling equipment descriptor

Start / End: of sampling / observation period

Date / Time: of sampling / observation period in GMT

Lat: Latitude, decimal degrees (- indicates south)

Long: Longitude, decimal degrees (- indicates west)

Z (m): corrected depths of sampling / observation period (based on EM120 output)

Table 16. Biological stations occupied during JR097

Station	Gear	Date	Z (m)	Time start	Lat start	Lon start	Time end	Lat end	Long end
56601#1	WASP	13/02/2005	510	20:26:36	-70.04991	-1.43414	21:30:00	-70.04878	-1.40901
56602#1	DREDGE	16/02/2005	497	09:29:00	-70.04913	-1.42260	10:40:00	-70.04133	-1.41533
56602#2	DREDGE	16/02/2005	501	11:59:00	-70.04036	-1.41198	13:01:00	-70.04737	-1.41554
56603#1	WASP	21/02/2005	340	09:34:00	-70.03831	-1.78531	10:05:30	-70.03941	-1.77648
56604#1	WASP	21/02/2005	425	11:58:22	-70.04979	-1.62752	12:34:00	-70.05016	-1.61341
56605#2	WASP	21/02/2005	465	18:50:51	-70.04991	-1.54183	19:22:00	-70.04977	-1.53052
56606#1	WASP	21/02/2005	388	20:44:57	-70.04029	-1.70476	21:19:30	-70.04136	-1.69207
56607#1	WASP	21/02/2005	245	22:44:39	-70.11441	-1.93774	23:16:00	-70.11635	-1.92682
56608#1	WASP	21/02/2005	300	23:55:27	-70.10296	-1.90329	00:30:00	-70.10611	-1.89266