RRS James Clark Ross

Cruise JR106

Autosub under Arctic Sea Ice

UNIVERSITY OF CAMBRIDGE

Cruise Report

SCOTTISH ASSOCIATION *for* MARINE SCIENCE

Peter Wadhams, Steve Ackley, Ken Collins, Pat Cooper,
Terry Edwards, Jeffrey Evans, Gwyn Griffiths, Nick Hughes,
Arthur Kaletzky, Steve McPhail, Duncan Mercer,
Colm Ó Cofaigh, Kieran Rutherford, Andy Webb,
Jeremy Wilkinson, Guy Williams and Doug Willis

NATURAL ENVIRONMENT RESEARCH COUNCIL

Grant NER/T/S/2000/00985

CONTENTS

INTRODUCTION

Peter Wadhams (DAMTP/SAMS)

Cruise JR106a was the second of four planned cruises by *James Clark Ross* to be carried out for the NERC Autosub-under-Ice (AUI) programme. The first cruise was in 2003 towards Pine Island Bay in the Antarctic. The third, in fact the second leg of JR106 (JR106b), is to south-east Greenland in September 2004; the fourth, JR97, will be to the Weddell Sea in January 2005. The purpose of AUI is to obtain data from beneath sea ice, glacier tongues and ice shelves using Autosub, and to develop Autosub's capabilities as a cryospheric research tool.

During the cruise reported here the Autosub was operated highly successfully under both moving pack ice and fast ice, obtaining some 400 km of high quality upward looking swath sonar data as well as oceanographic data. It undertook necessary avoidance manoeuvres for both deep pressure ridges and shallow seabed hazards in a classical manner as designed, and procedures for use of the acoustic homing system were developed to the point where the vehicle could be returned with confidence to an area covered with loose moving pack ice in the knowledge that it could be sent to a holding pattern out of which it could be steered towards the ship and recovered. This is a cause of increased confidence for the future use of the vehicle in regions covered with sea ice.

Thanks are due to Steve McPhail and the entire AUV technical team for the quiet efficiency and hard work which underlay every mission and which was the chief cause of success. We are grateful for the contribution of all the other scientific groups on board, including the ice drilling teams, the ice watch, the SPRI group which ran the swath sonar system, and the CTD operators. We thank those who came as observers – Steve Ackley, Ken Collins and Gwyn Griffiths – but who willingly undertook onerous watchkeeping tasks. Especial thanks are due to the Captain, Chris Elliott, and the officers and crew of *James Clark Ross* for their unending support. We are grateful also to the Alfred Wegener Institute and to Professor Peter Lemke for the assistance of *Polarstern* in the ice thickness validation exercise on 25 August. For help in Reykjavik we offer special thanks to Professor Ingibjorg Jonsdottir, University of Iceland.

The cruise was carried out under NERC grant NER/T/S/2000/00985 to Professor Peter Wadhams at Department of Applied Mathematics and Theoretical Physics, University of Cambridge, currently on leave at Dunstaffnage Marine Laboratory, Oban.

SCIENTIFIC STAFF

Peter Wadhams	DAMTP/SAMS	peter.wadhams@sams.ac.uk
Jeremy Wilkinson	SAMS	jeremy.wilkinson@sams.ac.uk
Nick Hughes	SAMS	nick.hughes@sams.ac.uk
Duncan Mercer	SAMS	duncan.mercer@sams.ac.uk
Russell Ladkin	SAMS	russell.ladkin@bas.ac.uk
Arthur Kaletzky	DAMTP	ak283@cam.ac.uk
Gwyn Griffiths	Autosub	gxg@soc.soton.ac.uk
James Perrett	Autosub	James.Perrett@soc.soton.ac.uk
Kieran Rutherford	Autosub	K.Rutherford@soton.ac.uk
Mark Squires	Autosub	masqu@soc.soton.ac.uk
Andrew Webb	Autosub	A.Webb@soc.soton.ac.uk
Dave White	Autosub	David.White@soc.soton.ac.uk
Peter Stevenson	Autosub	P.Stevenson@soc.soton.ac.uk
Stephen McPhail	Autosub	s.mcphail@soc.soton.ac.uk
Dr. Colm O Cofaigh	SPRI	co232@cam.ac.uk
Dr. Jeffrey Evans	SPRI	je10007@cam.ac.uk
Ruth Mugford	SPRI	rm423@cam.ac.uk
Ken Collins	SOC	kjc@soc.soton.ac.uk
Zoe Roberts	SOC	zlr@soc.soton.ac.uk
Terry Edwards	UKORS	txe@soc.soton.ac.uk
Guy Williams	ACECRC	gdwillia@postoffice.antcrc.utas.edu.au
Steve Ackley	USA	sackley@pol.net
Pat Cooper	BAS	
Doug Willis	BAS	

SAMS – Scottish Association for Marine Science
Dunstaffnage Marine Laboratory
Oban
Argyll PA37 1QA
Scotland

DAMTP – University of Cambridge, Department of Applied Mathematics and Theoretical Physics
Centre for Mathematical Sciences
Wilberforce Road
Cambridge CB3 0WA
United Kingdom

Autosub – Autosub Mission Team
Southampton Oceanography Centre
Waterfront Campus
European Way
Southampton SO14 3ZH
United Kingdom

SPRI – Scott Polar Research Institute
University of Cambridge
Lensfield Road
Cambridge CB2 1ER
United Kingdom

SOC – Southampton Oceanography Centre
Waterfront Campus
European Way
Southampton SO14 3ZH
United Kingdom

UKORS – United Kingdom Ocean Research Services
Southampton Oceanography Centre
Waterfront Campus
European Way
Southampton SO14 3ZH
United Kingdom

ACECRC - Antarctic Climate and Ecosystems Co-operative Research Centre
Marine Ecosystems Group
University of Tasmania
Private Bag 80
Hobart 7001
Australia

USA - Clarkson University
Potsdam, New York.

PURPOSE OF CRUISE

Peter Wadhams

The purpose of the cruise was to obtain ice thickness distributions from the upward-looking swath sonar system aboard Autosub, to validate the thickness values against other data collected simultaneously from the surface and the air, and to conduct transects across and within Fram Strait so as to obtain estimates of ice flux. An important aspect of the cruise also was the development of operating methods which are suitable for ice-covered waters.

The moving sea ice in Fram Strait in August 2004, following a long period of calm weather, was a very diffuse cover which spread far to the east but with a coverage of only 1-2/10. This was an unfavourable type of ice for Autosub for three reasons. Firstly the low concentration meant that not much ice was profiled per hard-won mile of Autosub mission track, with additional problems arising from the extensive calm water causing a loss of lock in the sonar (described later by Arthur Kaletzky). Secondly, the concentration, while diffuse, was sufficient to make surfacing of the Autosub dangerous, so the homing system had to be (and was) developed much further than before to allow the vehicle to return to a point, circle submerged, then be led out to the ship which places herself in the nearest available open water. Thirdly, the overall distances involved were so great that even a series of Autosub missions would not suffice to cross the very large width of the East Greenland Current in Fram Strait that was affected by ice.

For these reasons, after initial experiments, the decision was made to move to the fast ice edge for more intensive experiments and validation work. This has many positive advantages. The fast ice edge was well defined by satellite imagery, and the fast ice comprised formerly moving ice which had become pinned to certain shoals, and so comprised all kinds of ice (first and multi year, undeformed and ridged) at 100% concentration. The fact that it was stationary meant that the planned helicopter coverage of the Autosub tracks by the helicopter-borne EM system of *Polarstern* need not take place at the exact time, or even on the same day, as the Autosub mission. Unfortunately, on the day of *Polarstern's* visit, fog conditions did not allow more than minimal flying. Nevertheless, the surface EM and drilling validations could be fitted more exactly to the Autosub tracks, given that the sea ice platform was not moving.

Supporting work included along-track ice monitoring using the manual watch system developed for the ASPeCt programme in the Antarctic; some CTDs over the NE Greenland shelf, particularly in the Belgica Trough just south of Nordostrundingen which forms a part of the Northeast Water Polynya in winter; continuous operation of the Simrad swath sounding sonar system from the ship; tests of the SAMS Homer; and deployment of a Nagurny ice thickness buoy and a Hardy continuous plankton recorder.

CRUISE NARRATIVE

Peter Wadhams

AUGUST 10, TUESDAY

The group based at SAMS (Peter Wadhams, Jeremy Wilkinson, Nick Hughes) and at DAMTP (Arthur Kaletzky) arrived in Reykjavik from Glasgow and London respectively, and moved into apartments of the University of Iceland kindly provided through Prof. Ingibjorg Jonsdottir, formerly Peter's student. The weather in Reykjavik was sunny and intensely hot, more than 30°C, a long-term record.

AUGUST 11, WEDNESDAY

James Clark Ross arrived in the morning from her previous cruise for Woods Hole Oceanographic Institution around south Greenland, and moored in inner harbour. The day was spent dealing with the agents, Nesskip, and locating our equipment. More scientists arrived. *James Clark Ross* offloaded the Woods Hole scientists and equipment.

AUGUST 12, THURSDAY

James Clark Ross began loading equipment for the new cruise in the morning, and scientists were able to move aboard in the afternoon. The ship was visited by Professor Detlef Quadfasel, Institut für Meereskunde, University of Hamburg, whose group was joining *A.V. Humboldt* for a cruise to Denmark Strait together with a group from SAMS.

AUV technical team were hard at work preparing Autosub for operation, and carried out a float test over the stern in the harbour, to test ballasting of vehicle. The weather continued hot and sunny.

AUGUST 13, FRIDAY

Most people spent the morning enjoying the final hours of an extraordinary week of Mediterranean weather in Iceland. A huge number of outdoor cafes enjoyed a vast and unexpected clientele. By coincidence the only cloud seen for four days began to appear as we prepared for departure, and soon low cloud filled the sky to provide a more normal Icelandic environment.

James Clark Ross sailed at 1600 (all times in GMT), passing out of the harbour between the French cruise ship *Le Diamant* and the Danish ocean patrol vessel *Vaedderen* which herself was bound for NE Greenland. Outside the harbour the pilot boat *Jotunn* departed with the pilot, leaving us to cope with an offshore fog bank through which large numbers of fishing vessels loomed. While *James Clark Ross* handled this tricky navigational problem there was a safety briefing for the scientists, featuring lifejackets, immersion suits, alarm signals, getting into lifeboats, and watertight doors.

At 1830 we streamed the Hardy-Longhurst continuous plankton recorder, to obtain a continuous transect up to and from Fram Strait. This was a project for Dr. Chris Reid of the Alister Hardy Research Foundation, Plymouth. Position was 64°23.72'N, 22°40.30'W. Swath bathymetric mapping began, manned by the SPRI group, and continued throughout the voyage.

In the evening we saw the volcano of Snaefellsnes to starboard, covered with snow, in a sunny twilight.

AUGUST 14, SATURDAY

A scientific meeting was held at 1000 to organise the cruise and assign watches. I arranged general watches as 6-on-6-off with Jeremy Wilkinson, Nick Hughes and Guy Williams on 0000-0600, 1200-1800; and myself, Duncan Mercer and Russell Ladkin on 0600-1200, 1800-2400. The general watch-keepers do CTDs, ice work, general co-ordination and processing. Steve Ackley is looking after the ice observations log, using the ASPeCt system (developed for the Antarctic) with Kieran Rutherford (Gwyn's student), Ken Collins, Guy Williams and Gwyn Griffiths. Zoe Roberts is assisting the three SPRI personnel doing multibeam watch-keeping. The AUV team set up their own system of working together independent of fixed hours.

Along-track logging of all environmental parameters was under way; Nick reprogrammed the logging system on the ship's ADCP. One XBT is taken per day in support of the swath bathymetry, which is now showing iceberg scours on the Icelandic shelf.

Late in the evening the sun's image distorted itself into a mirage as it sank into a perfectly calm Greenland Sea at 2220. I thought I saw the green flash, but as usual my eyes probably deceived me. As the sun sank, some low lying very distant land was silhouetted. A look at the chart showed that this was part of Knud Rasmussen Land in Greenland, just south of Kap Brewster, and that it was some 25 miles away.

Noon position 67°08.3'N, 23°35.6'W.

AUGUST 15, SUNDAY

Contact was established by email with Peter Lemke, Chief Scientist of *Polarstern,* and plans evolved for our joint work later in the cruise. In the evening I gave a talk on the background to the cruise in relation to climate change in the Arctic. The ship progressed to the NE.

Sea calm, but not as flat calm as yesterday. Fiery sunset again at 10.30 pm. Cassette in plankton recorder changed today at 1045 am; a single cassette lasts for 500 nautical mile (n.ml.).

Noon position 70°48.9'N, 15°08.9'W.

AUGUST 16, MONDAY

Finally established direct radio contact with *Polarstern,* at 83°N in the Arctic Ocean, and set up a daily radio schedule at 1000 with Lemke. Held scientific meeting at 1000 to plan tomorrow's work when first experiments start.

We are receiving three types of satellite imagery daily (QuikSCAT and two types of AMSR) via an Iridium link with Danish Technical University (Dr. Leif Toudal) with further wide-swath Envisat from Richard Hall, Norsk Polarinstitutt. Copies of all images are passed to the bridge. Thanks to this wealth of sea ice information it was possible to see that we would have to modify our initial goal of running a transect at 78°50'N from E to W, crossing the moored upward sonar systems of Norsk Polarinstitutt for validation, and continuing W.

This year the ice in Fram Strait is extremely diffuse, and the imagery showed no significant ice east of 6°W at 78° 50'N. We made this our initial goal and decided to work westward from there towards a wide band of fast ice which still existed against the Greenland coast.

At 1940 the first ice was seen – a thin tabular berg originating from the Flade Isblink. Position was 76°37.0'N, 7°14.0'W. It showed up well on radar. A further berg was visible on radar ahead at 76°54.1'N, 7°13.6'W. We began to see very diffuse ice all around – eroded brash and blocks of old ice. The ice watch was started. At 2150 the plankton recorder was brought in because of possible ice hazard.

It was very calm with little or no wind and a lazy swell. Many internal wave slicks were visible – evidence of a thin surface melt layer from melting ice which has not mixed down because of absence of wind. Surface salinity was a very low 29.63.

Noon position 75°03.5'N, 8°13.6'W.

AUGUST 17, TUESDAY

We spent the night threading our way slowly through an ice promontory which extended unusually far E at a lower latitude than Fram Strait. This slowed us to the point where we could not expect to reach 78°50'N today. In order to give the AUV a full day of initial tests we stopped at 77°37'N, 3°07'W and started work there. Three missions were carried out during the day (358, 359 and 360).

In the first, the AUV went into the water and did preliminary test of systems, then a test of acoustic tracking and homing systems. Problems with telemetry meant that the AUV surfaced after 40 minutes at the start way point. Then we ran the ship 6 n.ml. westward into the ice and deployed Autosub to run eastward out to the original site (which was in nearly open water with just occasional small cakes and brash). This was mission 359. We followed with the ship, running a video system and keeping an intensive ice log along the track. This gave us the first partially validated under-ice data, although the ice concentration was only about 10-20%. Finally the AUV did more tests at the outer site (mission 360), on the homing system. The vehicle homed at 1 km and 12 km range.

We looked at the sonar data from mission 359 and found that although floes were clearly visible and resolvable in shape and thickness, the topography was superimposed on a parabolic false contour which ranged from zero at the mid-line to 20 m at extreme slant range. We set out to examine the theoretical reasons for this, and it was tentatively assigned to a loss of lock caused by the mirror-like sea surface, the low reflectivity of open water, and the very open nature of the icefield.

Noon position 76°36.6'N, 3°06.2'W.

AUGUST 18, WEDNESDAY

We headed N overnight (although there is no darkness) in open water for rapid transit to get to 78°50'N by breakfast time. In fact this meant that the ship sailed far to the E to avoid all ice, which greatly added to our journey time. Most of the day was spent trying to recoup our position. We sailed to 78°50'N at 1°W then headed directly W, in fog and very diffuse ice, at no greater than 6 kts. The news from *Polarstern* is that AWI has instructed her to head back N to 83° and recover and clean up the remains of the abandoned Russian ice station NP32 which they passed earlier. This will delay our rendezvous.

During the afternoon we crossed the longitudes of the NPI moorings (at 4-6°W), but the AUV could not be launched as the ice, although diffuse, was sufficiently uniform in floe spacing that there was no hole large enough for a safe retrieval at this early stage in homing system development. The same applied to three tabular icebergs which were embedded in the pack ice.

Finally we reached the continental shelf, passing the last NPI mooring position at 6°W. At a water depth of 305 m we were able to do an AUV run to NW, towards fast ice edge observed on satellite imagery. This is because at these water depths the vehicle can use bottom tracking rather than dead reckoning, which greatly increase the precision of retrieval, While the AUV was in the water we did the first CTD (1045) at 78°50.7'N, 6°25.0'W. This showed polar surface layer with the Atlantic layer (200 m peak at 2.0°C) below it penetrating onto the shelf. Some surface warming had occurred, so polar water temperature minimum of –1.8°C was at 100 m. The AUV run, again under diffuse drift ice, yielded 6 n.ml.of data (mission 361).

We then continued NW towards the fast ice edge through frustrating ice, too dense for safe AUV operation but not dense enough to really provide a good test for AUV.

Noon position 78°48.0'N, 0°43.20'W.

AUGUST 19, THURSDAY

At 0050 we manoeuvred to bring the AUV in from mission 361, then we set off NW towards a sharp ice edge, probably fast ice edge, shown by satellite imagery. At 0107 our position was 78°50.6'N, 6°26.1'W. I ran the digital video recorder from the bridge as we ran along the track followed yesterday by the AUV.

Jeremy took over watch while I got a small amount of sleep until 0600. At 0630 we stopped in an opening of more than average open water to do CTD (water depth 170 m) and see if this is a good launch site for AUV. Ice cover was still only 2-3/10, but with larger floes (50 m or so), mostly first-year with melt pools. The CTD was complete by 0715 and Steve McPhail engaged in preparing for an Autosub mission. Several problems occurred with the software, so at 1430 we set off towards the ice edge while they were still being resolved.

At 1708 we came across a very wide large multiyear floe some 1 mile across, which looked like broken-out fast ice. We decided to do an AUV test, but could see many tabular icebergs behind it, so sailed round it so as to launch AUV outwards from behind the floe and avoid danger of hitting iceberg. Also the floe drift was eastward and would have brought the floe over the launch site. We did a CTD in 189 m of water just before this manoeuvre then launched AUV. While it was in the water we closely inspected a tilted tabular iceberg, near us, with pockmarked surface, veined dirt-filled cracks down side, and faintly green appearance. It was at 79°27.6'N, 9°31.1'W.

The AUV mission (362) was 3 n.ml. out, 3 n.ml. back, crossing the big floe. We launched at 2010. Upon recovery we headed for this mass of big tabular bergs with a view to surveying with AUV. Found that this is actually a shoal on which they are stranded. One that we came close to had a freeboard of 11-11.5 m, thus a possible draft of up to 80 m, and was in 93 m of water. It didn't seem to move. There were no fewer than 12 icebergs together in a great mass, most tabular, but with one white randomly shaped berg obviously from the Arctic Basin. We sailed through them, finding 83–100 m of water and thus are pretty sure that they are aground. But still this is a good site for getting SAR imagery for an iceberg detection study. We carried on to NW after extensive photography.

Noon position 79° 15.6'N, 8° 22.9'W.

AUGUST 20, FRIDAY

I rose at 6 after only 3 hours sleep to find us still running NW towards fast ice edge as shown by satellite imagery. The ice cover was very open indeed, almost pure open water, although tabular icebergs littered the scene – six in sight. At 0619 we reached 79°29.8'N, 13°12.4'W. At 0400 am we had done an along-track CTD in about 200 m of water. At 0700 I recorded iceberg positions on radar and found 9 that I could correlate with visual observation.

By 0708 we were at 79°30.1'N, 13°55.5'W and were now heading due W towards the ice edge, which soon appeared as a white line in the distance, with further tabular icebergs clearly embedded within it and the mountains of NE Greenland looming faintly in the far background. At 0718 I ordered a CTD, although the water depth was only about 100 m.

By about 0830 we reached the fast ice edge, behind which lay a continuous sheet of what looked like thick first-year or thin multi-year ice, with occasional ridges and many melt pools. I called Steve and proposed a long Autosub mission into the fast ice. He planned a 20 hour mission – 30 miles in and back. The chart shows 35 miles from the ice edge westward to the beginning of shoaling water on the W side of the Belgica Trough, so all seemed OK. He got down to the task of preparation.

At 1000 I called Peter Lemke. *Polarstern* had successfully salvaged the abandoned Russian NP32 camp, saving 300 drums of fuel, but this had put them back. They cannot reach us until August 25, but the advantage of them doing the surveys then is that they can do them all in one go – because we are dealing with fast ice there is no longer the necessity of doing simultaneous helicopter and AUV profiles. His present position was 80°36'N, 2°21'W.

Finally, after lunch, Autosub was launched (mission 363), submerged quickly and set off. We moved the ship into the fast ice edge at what we calculated was the exact point of entry of Autosub and started an ice characterisation exercise. First workers on the ice were Jeremy, Duncan, Nick and me. We went over the side in a weird rope buoy contraption labelled "Wor Geordie". We laid out a line of holes at 5 m intervals for 100 m, and drilled away until the drill got stuck. At this very moment a fog bank came in and we were recalled to the ship since polar bears would be invisible (a watch was being kept from the bridge). We had to leave the drill, 2 m of flights and the power head on the ice.

After dinner the fog had cleared, so we went out again with Steve Ackley and Ken. The drill released itself easily, and we went on to complete 40 holes (2 x 100 m rows at 5 m intervals) and take a core. Typical ice thicknesses were 1.6-1.8 m. Towards the end we were advised that Autosub had reappeared, so we finished off quickly and set out to locate it. It was found and interrogated. It had encountered a 60 m water depth somewhere and had been programmed to turn round and come out if this happened, so it was doing the correct thing.

Noon position 79°30.0'N,14°24.2'W.

AUGUST 21, SATURDAY

The decision was to send Autosub into ice again at midnight for a 12 hour run on the same track as on the 20th but shallower depth (30 m) and with more depth tolerance. During night we would do swath bathymetry locally. At 0800 we would get back to ice edge for ice work.

The reality was quite similar. The AUV did get into water soon after midnight (mission 364). Then we did swath bathymetry. At 0800 we started listening for AUV (not due until after 1200) and it turned up. It had been turned back quite early by a 25 m pressure ridge, with little data acquired, and had been hanging around the way point for hours.

We recovered the AUV at 0910 in some minor grease ice which had formed during night, and the AUV team started changing the battery pack, a 6 hour task. They found that the previous mission, on Aug 20, had been turned back at 79°28.02'N, 15°20.54'W. It had generated a 136 m swath width, which looked good, but which needs validation.

At 1000 I called Peter Lemke and found that *Polarstern* was at 78°50'N, 01°50'W, picking up moorings. They said bad weather was forecast (up to force 7 to 8) overnight and on Sunday, according to their onboard meteorologist. Peter is sending email of weather forecast to us.

Then we went out to do ice work. We forced way into ice a little forward of previous position. We extended yesterday's ice line from 100 m to a further 100 m (away from ice edge) and added a 100 m cross 50 m along new section. We did two cores. We stayed out over lunch with hot dogs and chips lowered to us. 6 people did it: usual gang (me, Duncan, Jeremy, Nick) plus Ken Collins and Zoe.

We came back aboard. and talked to Steve about the next mission. Then we tried drilling again, to do cores in a dirty ice area in front of ship (multi-year?). Visibility was marginal, but we did 2 cores in area of dirty ice, photographed the layout of melt pools, laid out new cross line at end of 200 m main line, did snow depths but then were called in because the AUV was ready to go.

The AUV went into the water at 1840. It did a float test first because of change of batteries. Then it dived and went off. We started a bathy swath again.

Noon position 79°29.9'N, 14°24.8'W.

AUGUST 22, SUNDAY

The situation as of 0730 was that during the night, when we listened for the AUV at 0100 and 0700 (due back 1840) and did bathymetric swaths between times, the wind, far from breaking up the fast ice, packed in the moving ice against it. This created a band of close pack against the fast ice edge. This allowed the ship to be forced off the listening site until we were now a mile away. The wind was still strong, and the prospect was for more pack ice to move in and for the ship to move further away until it is out of listening range of the recovery position (79°30'N, 14°20.5'W).

We did a CTD, suffering a delay while the tracking winch was fixed. We finished CTD at 1140 then listened – no signal yet. We went N for 90 mins, following the fast ice edge through mainly open water – the packing-in was occurring to the S. We did another CTD after 1 hr, seeing three large tabular Flade Isblink bergs within the pack, with clear visibility to the mountains and glaciers of Greenland behind. The CTD was at 79°40.17'N 14°16.48'W. After 90 mins of our run (in which swath bathymetry was done) we did a second CTD very near another large tabular berg which was grounded in open water. This was to see if melt water from the berg can be detected. Position was 79°44.58'N, 14°11.84'W, situated 0.25 ml from the berg. Water depth was 84 m. I took several photographs of the berg.

We now ran back to the start point but found that more ice had packed in and we could now only get within 1.9 mls of recovery point. We put out hydrophone, hoping for best. The wind was still strong at force 7, snow whipping along, grey sky, like a typical winter ice edge.

Wonder of wonders! At 1840, promptly, it replied. Saved! We all had dinner (of Indian food) then set out to recover it. Steve sent a message via hydrophone ordering the AUV to swim out to the position of the ship, which we had placed just outside the ice edge in an open water area, 2.54 nml from the AUV. Amazingly, the AUV responded straight away and swam obediently towards us, to come up a couple of hundred yards off our bow. What a relief! And what an achievement for the AUV team. The vehicle had reached right across Belgica Trough in deep water (500 m, uncharted), had avoided several obstacles, and had recorded a huge amount of data.

Congratulations all round, relaxation in lounge then question of where to go next. I favoured southern entrance to Belgica Trough, but captain thought that way south was blocked by driven-in ice. So we went north towards northern entrance to Belgica Trough and area of North East Water Polynya (NEW).

We coasted alongside the fast ice edge (widened by addition of pushed-in moving ice), occasionally having to come out to the E to avoid an iceberg and heavy pack ice. All seemed well. I left instructions, and so did the captain, that this was to continue, bringing us to Belgica Trough about breakfast time.

Noon position 79°30.3'N, 14°12.8'W.

AUGUST 23, MONDAY

Heavy ice and poor visibility caused the ship to turn back. At 0600 we were only 10 miles north of where we had started. We immediately returned to a northward run, but we had lost many hours of work.

The storm had gone, and we spent the morning heading north. I called Peter Lemke at 0830 about meeting plans. The ice soon eased and we made more rapid progress, coming round to the end of a northward peninsula which opened out to the W into the axis of Belgica Trough (or Dijmphna Sound), which appeared to be ice-free. Presumably the warm Atlantic water entering near the bottom was warming the surface. We decided to launch the AUV on the S side of the Sound and have it run into the ice on a 225° course, keeping slightly away from the Sound axis. We set it for a 12 hour mission. We would validate the ice conditions then do CTDs. Temporarily visibility was clear and we could see across to the coast.

We launched the AUV just off the ice edge at 80°17.12'N, 13°00.82'W (mission 366). Then we ran into the ice (about 1500) and did a highly efficient ice profiling exercise, using 7 people (self, Jeremy, Nick, Zoe, Steve, Duncan, Guy). We did a 100 m line along the axis of the ship, a 100 m cross-line, two cores and five snow samples, all in two hours. What speeded things up was to have one person drilling with 1 m of flights and another following with a separate drill with 2 m of flights. The ice was relatively uniform first-year, between 1.2 and 1.5 m, thick. The small-scale variability in thickness will be a good test of how well the sonar resolves small depth variations.

Then we pulled out, did a CTD, then ran NW at 330° doing CTDs at 5 mile intervals. We managed 4 in all, the last featuring heavy ice, which carried us across the deepest part of the Sound, about 340 m deep, and into slightly shallower water. Then we ran back to have a listen at the retrieval site in case the AUV had come back early (it is due back at 2.40 am). No sound.

Noon position 80°11.3'N, 12°53.9'W.

AUGUST 24, TUESDAY

At 0030 we did a small excursion along 030° for 5 miles to do one more CTD (CTD15) while waiting for retrieval. We got back at 0240 and put down the hydrophone, The AUV responded immediately at a distance of 1 km. We guided it in to us (it lost lock once and went back to the 1 km mark) and brought it to the surface. The idea was to re-programme it for an 8 hr run to flatten the battery, but the team found that the battery was already flat. Until we talked to *Polarstern* about the best location to meet we did not want to move significantly, so while the Autosub team started the 6 hour task of changing the battery packs we carried out some CTDs in the northern arm of the Belgica Trough.. The first took us 10 miles away on 030°. The next went on a further 5 n.ml. on 330° and took us back into heavy ice. We changed plans to return to a 330° line and do a station every 5 miles, a slanted run across the Belgica Trough. We did a line of 6 stations in all, leading to a Furthest North for the voyage of 80°38.74'N, 11°47.73'W, water depth 264 m.

At 1000 I phoned Peter Lemke and we settled on 79°30'N as a place to rendezvous. *Polarstern* does not finish her other work until 0400 and does not have time to come far north, while we cannot get far south. So it is back to our original stamping ground. We will go there now, get set up, start running the AUV, and then they will join us with the helicopters and an 8-strong ice thickness team. We started making plans for validation and for a lawn-mowing AUV routine.

The journey back involved crossings of some sunlit MIZs, sightings of bear tracks, and some beautiful calm vistas of the sun and clouds reflected in perfectly calm water. Then we got into tougher ice and made slower progress. We passed four tabular icebergs recognisable from the journey north and plotted their positions. It was nearly midnight before we reached the fast ice edge at approximately the right latitude, then we had to coast south until there was enough of a slot of open water to seaward to launch and retrieve the AUV.

Noon position 80°38.7'N, 11°47.6'W.

AUGUST 25, WEDNESDAY

We inserted ourselves into the fast ice edge at the intended location for the big experiment at 0015, at the position 79°20.56'N, 13°52.127'W. The ice appeared to be thick first-year or second-year ice with a network of well developed meltwater pools and some pressure ridging. One disadvantage is that a small berg 1.23 n.ml. inside the ice edge would be a barrier to deep penetration by Autosub, but we resolved that the best experiment would be a lawnmower survey of a 2 x 2 km experimental area (which would take 21 hours at 50 m line spacing) to cover validation work by ourselves and *Polarstern*, so the iceberg is not a problem.

Steve drew up a plan for the survey, with 15 lines at right angles to the ice edge. Everyone got a small amount of sleep, then the ship was pulled out of the ice and Autosub was launched at 0600. The ship moved back in, breaking out a couple of segments of ice edge zone by the impact, and was firmly embedded in position for validation work. Meanwhile *Polarstern* was 24 miles away, heading towards us, having finished her line at 78°50'N, 10°W at 0400

We could not go out on the ice ourselves because we had no guns to defend against polar bears and the visibility was very low. A dense fog had descended at 0400 and looked unfortunately set to last all day, which it did. I talked to Lemke at 0800 and again at 1000. We arranged that they would come in and moor at the ice edge to the S of us (we were in the centre of the experimental box) and that we would share the calibration work, with them offering polar bear protection through three armed personnel. Just before noon a very vague shape loomed out of the fog and moored to the ice edge – coming alongside the edge rather than running into it – and lowered a gangway. After much discussion about polar bear protection, *Polarstern* ended up sending an armed escort the few hundred yards across the ice to us. I brought Steve Ackley with me, and we visited the ship where we had a session with Peter Lemke, Captain Donke and the sea ice scientists. We decided that one group from AWI would profile along lines of the survey with an EM system mounted in a hand-drawn kayak; one group would do resistivity measurements at an appropriate spot (Jim Bishop, formerly from Australia); and one would help us do drilling lines, especially by providing polar bear protection. This comprised Jan Leser, a sea ice meteorologist who is working on the SITHOS project.

We headed back to *James Clark Ross* where Jeremy had already organised the ice squad to be ready for action. We laid out two 200 m lines in front of *James Clark Ross* running along the axis of the AUV survey lines, and a third line of 50 m across a distinct, though shallow, pressure ridge. The AWI kayak gang later covered both these lines and extended them to about 500 m, while Jim Bishop set up half way along line 1. The weather remained foggy and the helicopters could not fly, a real blow to the validation which we expected from the airborne EM system.

We worked until 1800 and then Jan went off to escort a deputation from *Polarstern* across to our ship. We went back to *James Clark Ross*. The arriving group comprised Peter Lemke, Jan and four ships' officers. We gave them a reception in the mess then dinner with wine. Straight afterwards everyone headed over to *Polarstern* for a party which they had set up on the afterdeck with glüwein. At the same time a big group from *Polarstern* wended their way across the ice to *James Clark Ross* for a party there. The groups disentangled themselves at 2200 when *Polarstern* was due to sail. There was some hope during the evening when the weather cleared and the helicopter took off with the EM system, but it came back after doing only one line, saying that the laser could not lock on because of the mist.

Everyone thought it a great party, and we did not even see *Polarstern* leave, as the fog was so bad that she was invisible although only 500 m away.

Noon position 79°19.5'N, 13°50.8'W.

AUGUST 26, THURSDAY

We sat in the ice through the early part of the night, hoping that the fog would clear enough to allow deployment of the Nagurny buoy on a pressure ridge which we saw some 250 m inland yesterday, but it did not. At 3 am we pulled out of our ice berth to retrieve Autosub, which was achieved swiftly and effectively thanks to the homing system, after a 21 hour mission (367). The weather is getting colder and a thin skim of nilas is now forming on the cold calm open water, especially because the fog is blocking out the sun. On surfacing Autosub was seen to be ploughing through this nilas like a semi-submerged icebreaker.

Autosub was brought in because we believed that this was the last mission. The ship pushed back into the ice in her original position (but facing outwards) to allow us a final short experiment on the ice surface. We wanted to do a core, to establish the age of the ice in the survey zone, and to deploy the buoy. We were made wary by the sight of fresh polar bear tracks covering the beaten walkways developed by yesterday's comings and goings, and also covering the floe edge beside yesterday's mooring position. According to the deck crew, these had not been here at 3 am when we pulled out. Therefore we – that is, Jeremy, Duncan and myself – did the core right at the point where we were landed from the basket, and chose a smaller hummock near the ship (which had had the 50 m transect done on it yesterday) to be the site of the Nagurny buoy. This will probably mean that its lifetime will be short, but one can but hope.

Back on board I received the serious news that the Autosub had only recorded data for the first third of the lawnmower survey, which did not include any of the survey lines run by ourselves or AWI yesterday. If we wanted to do something in the very short time still available there were only two alternatives – move the ship to the surveyed area and do a new line of holes, or relaunch the AUV and do a small number of lawnmower lines specifically to cover the survey lines. I hovered between the two, but was persuaded to go for the AUV by what happened next.

One of the crew spotted three heads in the water in line, off the starboard beam. They looked like large ducks but it was soon clear that they were polar bears. I rushed up to the bridge and gave out the news. Immediately everyone rushed to look, deserting the bridge, and the sighting was piped over the PA system. Obligingly, the bears, comprising a mother and two cubs, hauled themselves out on a nearby ice floe, shook themselves, then started to gaze at the ship making sniffing movements with noses outstretched. Very likely it was the smell of bacon frying which attracted them – it made me hungry too. The ship drifted slowly back on them so that they were within a few yards of the stern, offering perfect photo opportunities for everyone. This of course slowed down preparations for the AUV launch, but it was not to be missed.

Eventually the three bears plunged into the sea again and swam across to the main ice edge where they hauled out and ran swiftly away. Soon we saw the reason – a male bear pulled out on the floe which the mother and cubs had left. Obviously he was someone that they didn't want to meet. He too sniffed the air, but plunged quickly back into the sea when we started to move forward and create turbulence from the stern. Very clearly this area is dangerous for surface operations, and we were very lucky not to be threatened yesterday.

Steve now completed calculations for a 4-leg mini lawnmower covering our survey line, and the AUV was relaunched at 9.30 am. This was completed by 11.30, and after a nail-biting period when Autosub made a couple of homing runs which overshot, the vehicle was successfully recovered from mission 368 at 12.30, completing a highly successful series of missions on this cruise.

We now began the journey home by extricating ourselves from the heavy polar pack which lay to seaward of us. Aided by Envisat images supplied by Richard Hall at NPI, we initially went north, then east and then gradually bore to the south.

Noon position 79°20.1'N, 13°50.4'W.

AUGUST 27, FRIDAY

In the morning we began to cross the continental margin and came close to the 2500 m water depth required for a test of the SAMS Lander. A small deviation of course brought us to the 2500 m level on a shelving continental slope at 77°36.74'N, 4°07.08'W where we stopped. Duncan Mercer lowered the Lander, with its floats and chain weight, and tracked it acoustically as it sank to the seabed. Meanwhile the ship carried out a CTD, CTD20. With the Lander on the bottom we moved away 2000 m to see if tracking still worked. At this range it faded, but returned at 1500 m. With these tests complete, the signal was sent to trip the release, and the Lander was then tracked as it rose to the surface, where it arrived after half an hour and was recovered.

The ship then resumed her southward journey, continuing to collect swath bathymetry. The southward track is close enough to the outward track to allow overlapping parallel swaths. The Hardy-Longhurst continuous plankton recorder was streamed again as soon as we got under way, at 77°36.2'N, 4°06.4'W.

In the evening I gave a talk on W.S. Bruce and the exploration of the Weddell Sea.

Noon position 77°36.3'N, 4°6.7'W.

AUGUST 28, SATURDAY

We continued SW towards Iceland. The formal cruise dinner was held in the evening, followed by a party Plankton recorder cassette was changed.

AUGUST 29, SUNDAY

Final run-in towards Iceland, for arrival in Isafjordur on August 30.

AUTOSUB MISSION SUMMARY LOG

Steve McPhail (Autosub)

	Date	Start/ End	Start Position	Far WP	Comment
358	17/8 17/8	0942 1030	N:77:37.1, W:003:35.0		Short shakedown test. Autosub had been programmed to surface if it did not receive an acoustic command within 40 minutes. Problems with the acoustic telemetry system prevented us doing this, and consequently Autosub surfaced after 40 minutes at the start waypoint. Position was off the continental shelf, hence no bottom track navigation.
359	17/8 17/8	1843 2109	N:77:37.1, W:003 25.0		3km run through 10% ice back to recovery position. No bottom track navigation.
360	17/8 18/8	2142 0135	N:77:36.1, W:003 05.35		Homing Test. Autosub homed towards JCR at 1 km and 12 km range. No bottom track navigation.
361	18/8 19/8	2215 0036	N:78:50.71, W:006:25.02	N:78:52.71, W:006:34.52	Head for 3 miles NW under ice flow, then back again. Bottom track navigation (and for all subsequent).
362	19/8 19/8	2000 2300	N:79 :17.22 W: 008: 31.1	N: 79 17.22 W 010 01.1	Run underneath large ice flow and back again. For the first time the Em2k was configured with roll set to 0(as if looking downward).
363	20/8	1345 2222	N:79:30.0, W:014:20.5	N:79:23.75 W:017:35.0	Run into pack ice. Intended 18 hr mission, but Autosub only ran for 7 hrs. It turned back because the collision avoidance was triggered due to limited depth of water.
364	20/8 21/8	2356 0830	N:79:30.0, W:014:20.5	N:79:23.75 W:017:35.0	Same mission as 363. Autosub went a few miles into pack. Turned due to forward collision sensor sensing imminent collision.
365	21/8 22/8	1840 2041	N:79:30.0, W:014:20.5	N:79:23.75 W:017:35.0	Ran for 24hrs into pack and back. Autosub collision avoided during return leg. Used homing system to aid recovery as the intended recovery waypoint had become covered with ice.
366	23/8 24/8	1426 0330	N:80:16.13, W:013:07.67	N:80:03.40 W:014:22.98	Run 12 hours into pack. Completed successfully. Homing system was used to guide Autosub out from under pack ice for recovery.
367	24/8 25/8	0602 0438	Corner 1 N:79:20.539 W:13:50.906 Corner 2 N:79:19.741 W:13:56.048	Corner 3 N:79:20.271 W:13:49.687 Corner 4 N:79:19.473 W:13:54.827	Lawn Mower run under fast ice at survey site. 50m track spacing. Run at 40m depth. Only 1/3 of mission completed successfully. Autosub appeared to have homed in the direction of the Polar Stern, possibly due to acoustic emissions from its survey systems. Homing started at 1232 on 24/8/04. Homing system used to aid recovery. Figure 1.
368	26/8 26/8	0920 1250	Corner 1 N:79:20.167 W:13:49.219 Corner 2 N:79:19.369 W:13:54.357	Corner 3 N:79:20.105 W:13:48.937 Corner 4 N:79:19.307 W:13:54.075	Re run of section of survey mission 367 which had been planned to overlap with ground truthing and was missed due to the vehicle homing. Mission completed successfully. Figure 2. There is a moderate navigation anomaly between the dead reckoned position and the GPS fix at the end of the mission of 42 m east, 137 m north. The expected jump for this length of missions would be only +/- 20 m. The post processing software assumes, estimates and corrects for a constant velocity error between GPS fixes.

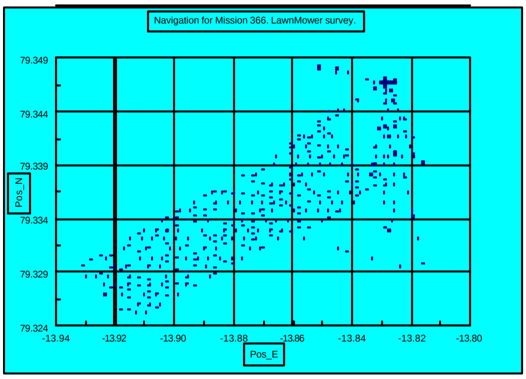


Figure 1: Navigation for Mission 367. Survey was interrupted by Autosub entering homing mode at 1232 on 24/8/04.

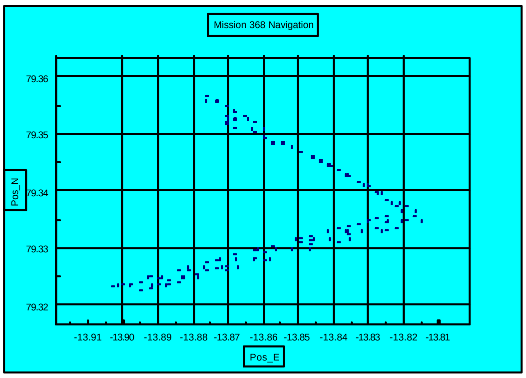


Figure 2: Navigation for Mission 368. Post processing assumes a constant velocity error between GPS fixes. This causes some distortion to the apparent track.

AUTOSUB NAVIGATION SYSTEM PERFORMANCE

Steve McPhail

One of the pre-cruise concerns was how would the Inertial Navigation System (IXSEA PHINS, Fibre Optic Gyro based) cope with the high latitudes. INS systems generally perform less well at higher latitudes, both in terms of accuracy, and the time they take to align following power up.

The alignment issue was quickly resolved. Even at 80ºN, the INS settled within 10 minutes of power up.

The accuracy of the combined navigation system, when aided by ADCP bottom tracking is examined in Table 1. The missions without bottom tracking are not included in the analysis. The errors given are the difference between the dead reckoned position and the GPS fix at the end of the mission.

Table 1. Navigation accuracy for Autosub. Missions 361 to 368.

Mission	**Latitude deg N**	**North Error (m)**	**East Error (m)**	**Radial Error**	**Distance Travelled (km)**	**Error % of distance travelled**	**Dive Weight Dive ?**
361	78.5	-7	-34	36	11.0	0.32	Y
362	79.3	55	2	55	13.3	0.42	Y
363	79.5	-26	-6	28	42.1	0.066	N
364	79.5	162	-110	195	22.2	0.86	N
365	79.5	111	-24	114	145	0.079	N
366	80.3	145	-193	242	80.28	0.30	N
367	79.3	-64.7	-7.6	65	73.5	0.089	Y
368	79.3	137	-32.1	140	14.9	0.93	Y

At first sight these results are a little perplexing. The results appear to fall into two groups either very good (average 0.08% of distance travelled), or rather mediocre (average 0.6% distance travelled). The accuracy does not seem to correlate with latitude, whether the mission is long or short, or whether a dive weight or surface run is used.

ADCP data for the "bad" navigation run, show no obvious problem. The ADCP mode remains fixed at '0', (bottom track) throughout the mission, and there is no apparent missing ADCP data.

Another possible cause is GPS outages. On Mission 368, a jump of 80 m in GPS position at the start of the mission is indicates that there may be a problem with GPS jumps.

AUTOSUB COLLISION AVOIDANCE

Several of the JR106 missions where carried out in conditions where there was limited headroom between the seabed below and the under ice surface above. In such conditions the operation of the collision avoidance system on Autosub was critical. The collision avoidance system takes sensor data from the upward and downward looking ADCP ranges, and from a single beam echo sounder pointing forward.

The system is triggered when either of two conditions occur:

The safe lower depth limit (set by minimum altitude, or maximum allowed depth settings) and the upper depth limit (set by minimum range to the base of the ice or minimum depth setting) overlap. For example if the Autosub minimum altitude is set to 30m, and the minimum depth is 40 m, then the collision avoidance is triggered if the water depth falls below 70m.

A 120 kHz echo sounder, pointing forward registers a target with continuous decreasing range, for 10 seconds (configurable), and less than a critical range of 100 m (also configurable).

The challenge is in adjusting the operating parameters (e.g. minimum altitude, minimum depth and the time / range settings for the forward echo sounder) in an attempt to make the system sufficiently robust against false triggering, while responding to real threats.

The behaviour of the vehicle following triggering of the collision avoidance state, is configurable. In most cases, when an obstacle is encountered when the Autosub is heading out, we configured it to abandon the mission and head back towards the recovery waypoint. This occurred on missions 363 (due to limited headroom), and for mission 364 (due to collision imminent sensed by the forward echo sounder). Following this we reduced the minimum altitude to 25 m and set the Autosub off on a long 24 hour under ice (mission 365). On this occasion the Autosub was able to get to the destination waypoint, but detected an imminent collision on the way back. In this situation, Autosub attempts to find a way around the hazard, by first retreating along is path (known to be safe), and then attempts to round the hazard by trying a different track. If it encounters the obstacle again, it repeats this behaviour but with a randomly chosen new track. Figure 1 shows that it took three attempts for Autosub to find its way around the obstacle.

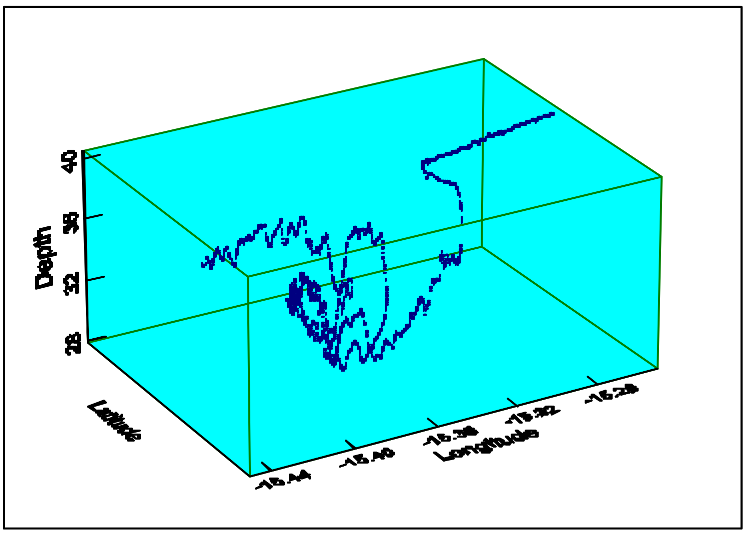


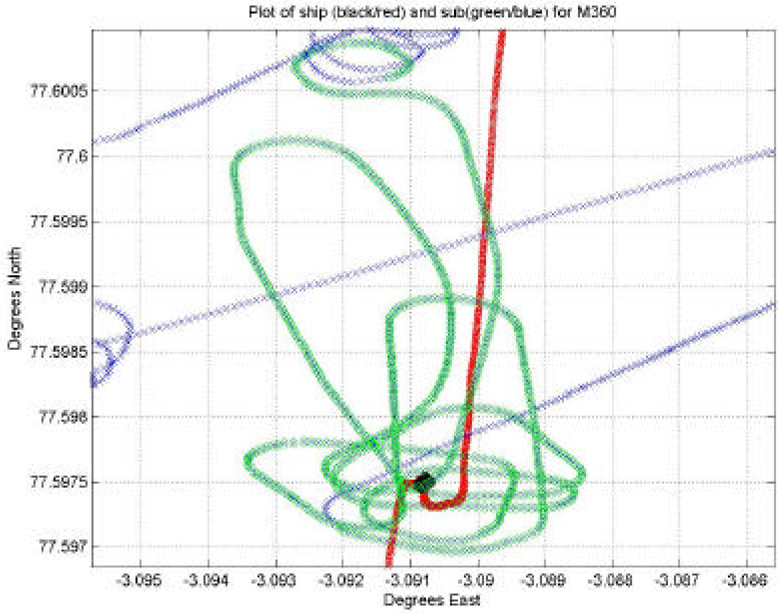
Figure 1. Track and depth of Autosub as it manoeuvred around an obstacle detected by the forward looking sonar, during the return leg of mission 365. The Autosub track is from left to right (heading Eastwards). It turns around twice and retreats, finally succeeding in avoidaing the hazard on the third attempt.

Analysis of the engineering data showed that during the first approach to the obstacle, the Autosub control system did not react to the first occasion that the obstacle was detected. This was due to loss of one “collision imminent” message on the control network. Following this, we changed the protocol for the message passing for this message from unacknowledged to acknowledged, making a repeat of such an occurrence extremely unlikely.

AUTOSUB HOMING SYSTEM AND ACOUSTIC TRACKING

Homing System

There were two tests of the homing system before it was used in anger. On M359 the sub was successfully made to home from a range of 13.2km, and it then returned to its pre-programmed recovery waypoint ten minutes after homing ceased. On M360 the sub was successfully called tot he ship and circled several times at a range of less than 100m for more than 90% of the time. Below, the green portion of the otherwise blue track shows the position of the sub in homing mode and the black portion of the red track shows the position of the ship at the same time. Apart from one excursion to 300m the sub heard the homing



signal within 100m of the ship and turned back towards the ship after passing it. All passes were within 50m and the three were within 10m, the closest being about 3m. Both of these missions were in a water depth of 3000m. It was noted that the sub received the homing signal more readily when heading towards the ship than away from it, as expected from the position of the receiver array.

Most of the operational homing was carried out in a water depth of 100m-160m:
M363: The sub's recovery position was under and ice floe, and it was called to the ship and given the surface command from a range of 500m.
M365: The pack ice moved in to cover the recovery position and the sub was called to the ship from a distance of just over 3.9km
M366-368: On these occasions the sub's recovery waypoint was considered unsafe. The ship was moved to open water 300m-800m away and the homing signal was used to call the sub to us. The mission script was altered so that the sub would circle up to the surface on command, enabling it to be surfaced 200m-300m from the ship. On M367 the thickness of fresh sea ice was such that it was detected by the sub, which stayed circling at 30m until the "surface" command was used to override this. Also on M367, the sub received several false homing commands. These appeared to emanate from the R.V. "Polarstern", which was stationary alongside the sea-ice for several hours. It is likely that they were transmitting with a chirp profiler which was interpreted incorrectly by the homing system.

Deploying and recovering the homing transducer array from the ship with 45m of cable was made easier by the use of a roller clamped to the rail, provided by the boatswain.

The emergency beacon was set to transmit every ten minutes. This was used to detect the approach of the vehicle before the acoustic tracking could pick it up, and usable ranges were obtained out to 9km slant range. On more than one occasion the sub returned early due to the obstacle avoidance being activated, and listening for the emergency beacon meant that its approach was detected and it could be recovered or reprogrammed with the minimum waste of time.

Acoustic Tracking and communications

The primary acoustic tracking system, the ORE Trackpoint-2, did not function and had to be replaced with the backup system, the LXT. The LXT transducer was successfully mounted on the tow-fish but the plotting program, the IPS, did not always plot the transponder replies. The stability and accuracy of the LXT, however, meant that using the raw data to get the sub's range and bearing was straightforward. Usable ranges of up to 4.5km with the sub approaching the ship were obtained in 160m of water, but reliable ranging was generally at 2km or less.

It was not generally possible to steam with the tow-fish deployed because of the danger of snagging the cable on sea-ice.

The Applied Acoustic digital acoustic link was used over ranges of 500m or less, and worked as well as it had done on the most recent trials cruises.

AUTOSUB MECHANICAL REPORT

Steve McPhail and Andy Webb (Autosub)

Mobilisation

Autosub mobilisation began at Portland in July following the ship's refit and sea trials and prior to cruise 105. At this time the launch and recovery gantry was bolted to the deck matrix, the aft container secured in place with its roof extension raised and the Autosub vehicle secured in its container. This work enabled the completion of mobilisation at Reykjavik (fixing the second container and installation of forward acoustic fish, installation of computer and aerial systems) to finish ahead of schedule. The layout on the aft deck was the same as the previous AUI campaign in 2003 (JR 84). Figure 1 shows a plan view of gantry and Autosub's purpose made containers on the aft deck.

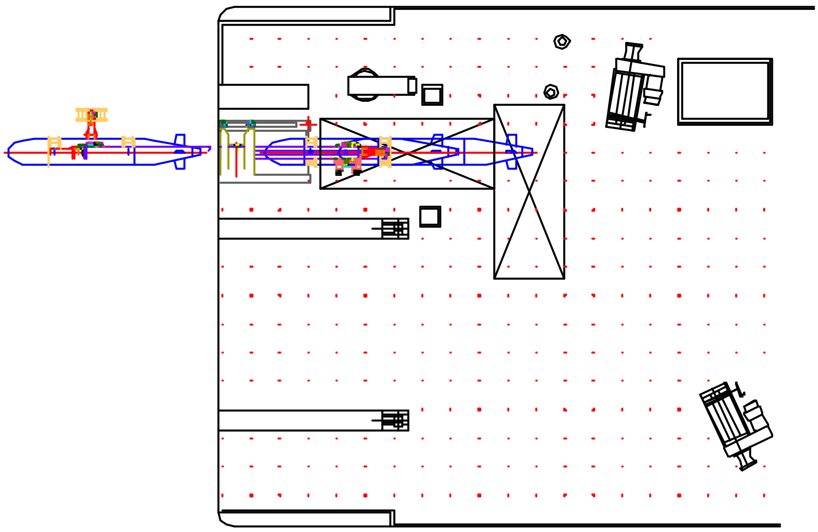


Figure 1 Plan layout of the containers on the aft deck

Vehicle configuration

Figure 2 is a schematic showing the basic vehicle layout, Table 2 is the relative positions of the sensors on board, with respect the vehicle datum (the bottom of the forward bulkhead joint, see Figure 2).

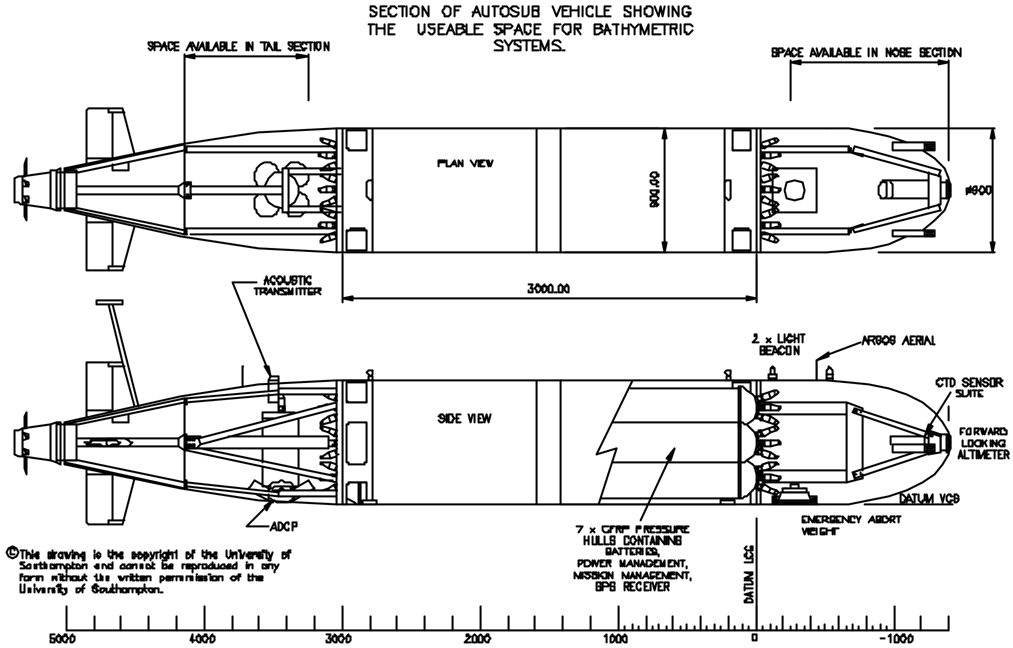


Figure 2. Vehicle layout showing sensor space and datum.

Sensor	Longitudinal centre of gravity wrt vehicle datum (m)	Vertical centre of gravity wrt vehicle datum (m)	Remarks
CTD (port and starboard)	-1.1	0.45	Ports side, Temp1, Ser No. 03P2342. Cond1 Ser No. 2730 Starboard side, Temp 2 Ser No. 03P2912. Cond2 Ser No. 2760
Oxygen sensor	-0.57	0.45	Plumbed in the starboard side with Temp2 and Cond2
Digiquartz Depth sensor	-0.5	0.65	
EM 2000 Transmitter	-0.65	0.8	Position of transducer head looking upwards
EM 2000 Receiver	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 10m
Aqualab water monitor	-0.69	0.55	Position of sampling ports (Not used for Leg 1of the cruise)

Table 2. 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 measurements were made using water from the sea water supply in the Wet Lab and a floating hydrometer. The Autosub vehicle was floated in Reykjavik harbour with lines attached as a check that no significant change in weight had occurred as a result of the battery change made at the SOC. The water density and vehicle weight estimates indicated a buoyancy of 18kg. The vehicle just floated (circa2kg buoyancy) when floated with 13.5kg of ballast taped on top, indicating the estimates were sufficiently accurate. Table 1 shows the history of the density measurements and the changes made to the vehicles ballast and trim throughout the campaign.

Autosub started the leg with fresh batteries and underwent two battery changes throughout the science time. The battery packs were from two suppliers, A1 Marketing Ltd, Bordon, Hants (Rayovac cells), and Steatite Ltd, Redditch, (Fujitsu cells). In addition to the problems of variable weights between the two sorts, there is evidence of the Fujitsu cells having less capacity than the Rayovac cells. The Autosub team will investigate this further.

The vehicle performed well with few faults. The mechanical problems encountered were:-

- 1 abort weight jettisoned unnecessarily (network problems)
- 1 sink weight dropping off the safety pressure release (tolerance problem on the design of the dive weight)
- Intermittent sternplane servo positioning problems (traced to a dry soldered joint on the feedback potentiometer).
- Sluggish performance of the launch and recovery gantry in icy conditions
- Intermittent braking problems on the rotary carriage drive on the launch and recovery gantry (to be investigated by the Autosub team at a later date)

The vehicle needed no repairs beyond normal maintenance of:-

- Battery changes
- 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

The major consumables used were:-

- 3 battery sets (28 packs/set). Some usable life still remains for the trials on the following leg.
- 1 Abort weight
- 7 sink weights (one dropped in error)

Date	Time	Location	Water Density (kg/m^3)	Changes made to Autosub ballast	Changes made to Autosub trim	Remarks
12/08/04	-	Reykjavik harbour	1027 (16C)	No change	No change	Judged to be 2kg buoyant with 13.6kg lead ballast added
17/08/04	-	Prior to mission 358	1025.5 (1.4C)	No change (see note 1)	No change	Very calm conditions with potentially very little mixing of fresh melt water on the surface. Vehicle appeared only marginally buoyant and slightly nose down after mission.
18/08/04	20:30	Prior to mission 361	1025.5	1kg removed	No change	-
19/08/04	-		1026	No change	+1.4kg.m (nose up)	
21/08/04	17:15	Prior to mission 365	1026	13.4kg added	-2.3kg.m (nose down) see note 2	1st battery change (2nd pack), the fresh battery packs were 13.4kg lighter than the 1st pack.
23/08/04	-	Prior to mission 366	1025.5	No change	+2.3kg.m (nose up)	Trim error corrected to make vehicle neutral again.
24/08/04	13:00	Prior to mission 367	-	9kg removed	No change	2nd battery change (3rd pack), batteries 4.3kg lighter than the 1st pack

1) The water temperature of 16C compared with 1.4C temp causes an estimated contraction of the foam and pressure vessels (the main sources of buoyancy) of 0.7 litre
2) Made in error, trim should have been left without any change.

Table 1. History of trim and ballast changes

AUTOSUB SCIENTIFIC SENSORS

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.

In addition an Edgetech sub-bottom profiler was also fitted but not used on this cruise.

These instruments are described separately in the following sections. Table 2 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. However, in the case of the EM2000, it was realised towards the end of the cruise that the raw time must be used for the post processed position timestamps rather than the drift compensated position. A revised version of the logger file translator software (V2.90.06) was produced which outputs both raw and compensated time but, due to time constraints, the post processed navigation files intended for use with the EM2000 will have to be re-processed after the cruise using a revised data processing script (JR106WithHomingAndEM2kNavV2.axs).

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	2730
Secondary Temperature	Starboard Side	2912
Secondary Conductivity	Starboard Side	2760
Oxygen	Starboard Side	0259

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 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 JR106 cruise the data was initially processed using the 0696Plym04bPre.con file which contained the most recent calibration data prior to the start of the cruise. An unprocessed section of the data from mission 361 is shown below. This appears to show a good correlation between the primary and secondary sensors although the secondary temperature sensor (the blue line) appears more noisy. This data would normally be further processed to compensate for the time delay between T and C sensors in order to remove any false salinity spikes.

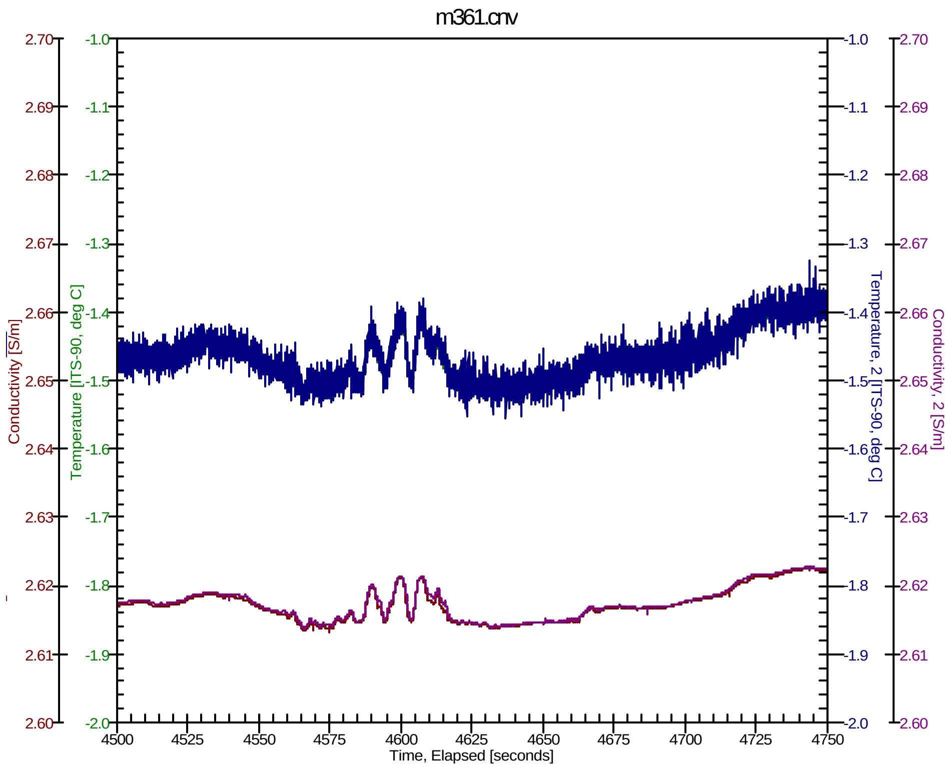


Figure 1. Primary and Secondary Conductivity and Temperature Data for a Section of Mission 361

However, towards the end of the cruise it was noticed that the data from the SBE 43 Oxygen sensor was not giving sensible results. On further investigation in appears that the sensor had been connected to analogue input 4 rather than input 0. A new configuration file, 0696JR106Start.con, was produced which will accept oxygen data on analogue channel 4. The oxygen sensor data for the same period as figure 1 is shown below in figure 2.

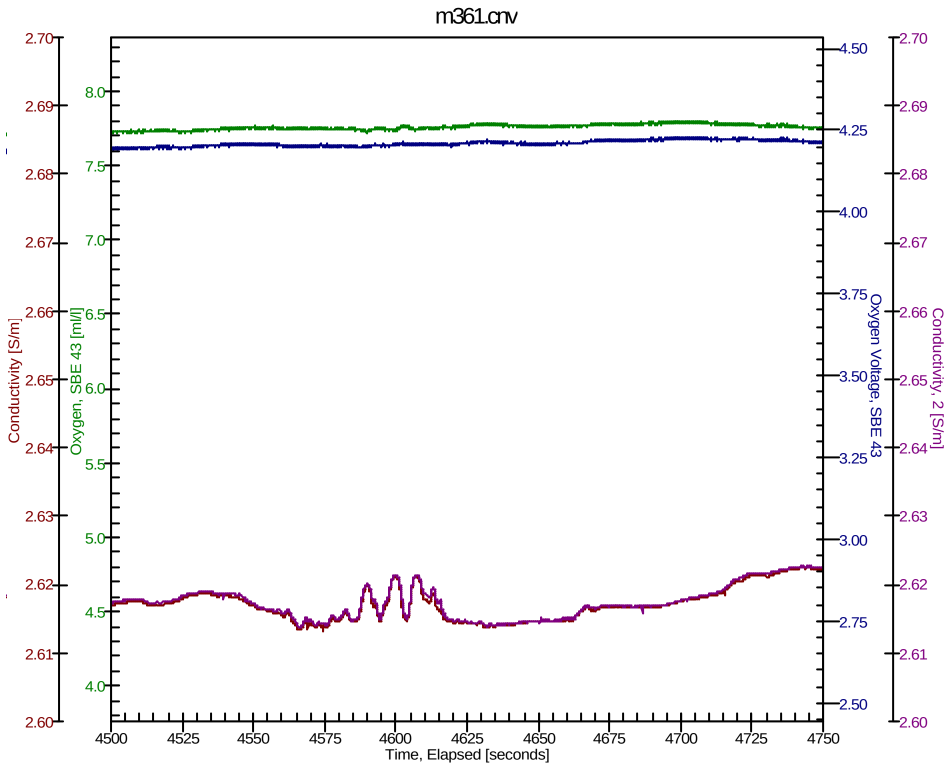


Figure 2. Oxygen and Conductivity Data for a Section of Mission 361

Some of the sensor calibrations are now rather old and it would be advisable to have these sensors re-calibrated when the equipment is returned.

AUTOSUB - 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 and navigation information to the instrument. A recent software update to the EM2000 now allows it to receive range aiding data from this controller. This range aiding, which gives the distance from the seabed or from the surface as appropriate, seems to have improved the data quality from 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 2 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 recent Plym04b trials cruise. The EM2000 rejects any data that appears to come from above the sea surface. When looking upwards it is possible that legitimate data may appear to be above the mean surface level so a depth sensor offset of –1.5metres was introduced to counteract this. The beam spacing was set to be equidistant and the maximum beam angles were +/- 60 degrees.

The first mission to give data from the EM2000 was mission 359 which was run in reasonably open water with a few well spaced ice floes. A short section is shown below in Figure 1. There appear to be returns from the ice but the sea surface does not appear to have been properly detected as the outer beams show increasing depths rather than a flat sea surface and, given the depth sensor offset, the sea surface should be at a greater depth than found in this data. Two factors were identified which could have caused this; a) the instrument sound speed was set to $1500ms^{-1}$ while the true sound speed was closer to $1450ms^{-1}$ and b) the depth sensor offset may have been too low. Both of these factors would cause the sea surface to appear to be above zero.

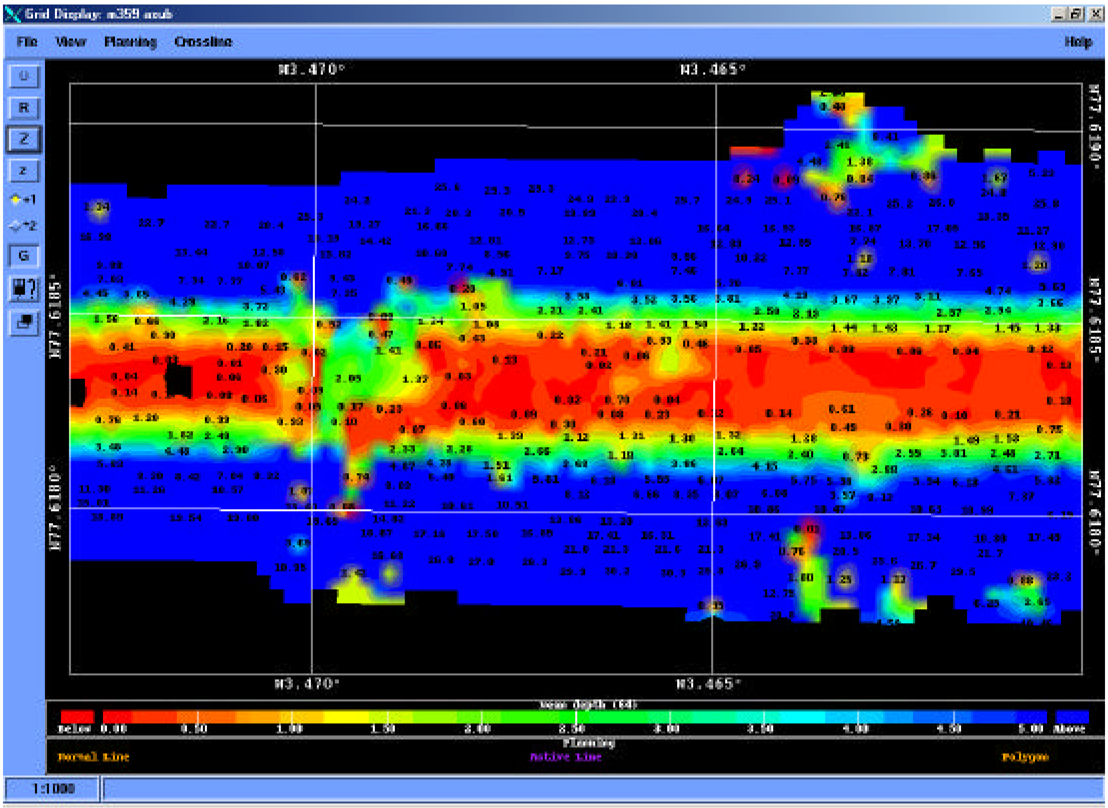


Figure 1. Section of Gridded EM2000 data from Autosub Mission 359

The next mission suitable for running the EM2000 was mission 361 where the depth sensor offset was increased to 2.5m. An attempt was also made to change the sound speed used by the instrument but it appears that, although the speed appeared to have been updated in standby mode, the instrument actually retained the 1500ms^{-1} setting when pinging. The upwards looking ADCP had appeared to only see the sea surface intermittently on mission 359 so the source of the depth aiding information was also changed from the upwards looking ADCP to the depth sensor.

This time the instrument did appear to see the sea surface in the vertical centre beams but the increasing depth at the outer beams remained. In open water the centre beams showed consistent depths of around 0.3m when Autosub was running at a depth of 30m and 0.6m when running at 40m. The change in centre depth is approximately 3% of the depth difference which could be consistent with the incorrect sound speed setting which was 3.4% higher than it should have been but this should have resulted in the surface appearing to be further away with increasing vehicle depth. This has not yet been satisfactorily explained. After further investigation it appears that any sea surface reflections in the outer beams are being swamped by the extremely strong vertical reflection which results in the apparently curved sea surface. The sea conditions were very calm during this mission, as they were for most of the cruise, which could explain the poor returns obtained from the outer beams.

In order to ensure that no data which appeared to be above the surface was discarded it was decided to change the sensor roll settings to make the instrument appear to be looking downwards. The S1R and S2R parameters in the install file were set to zero. This also removed the need for the depth sensor offset which was now also set to zero. This change has very major implications for the data processing as the Kongsberg supplied software will no longer be able to handle this data properly. In this configuration the port and starboard sides are reversed and the pitch angle must also be inverted before the data can be used.

Mission 362 and all later missions were run in this configuration. While, from an engineering point of view, the system appeared to be collecting data, it will not be possible to look at the data in any real detail until suitable processing software has been written. The plot below highlights some of the problems that have still to be addressed by the additional processing software.

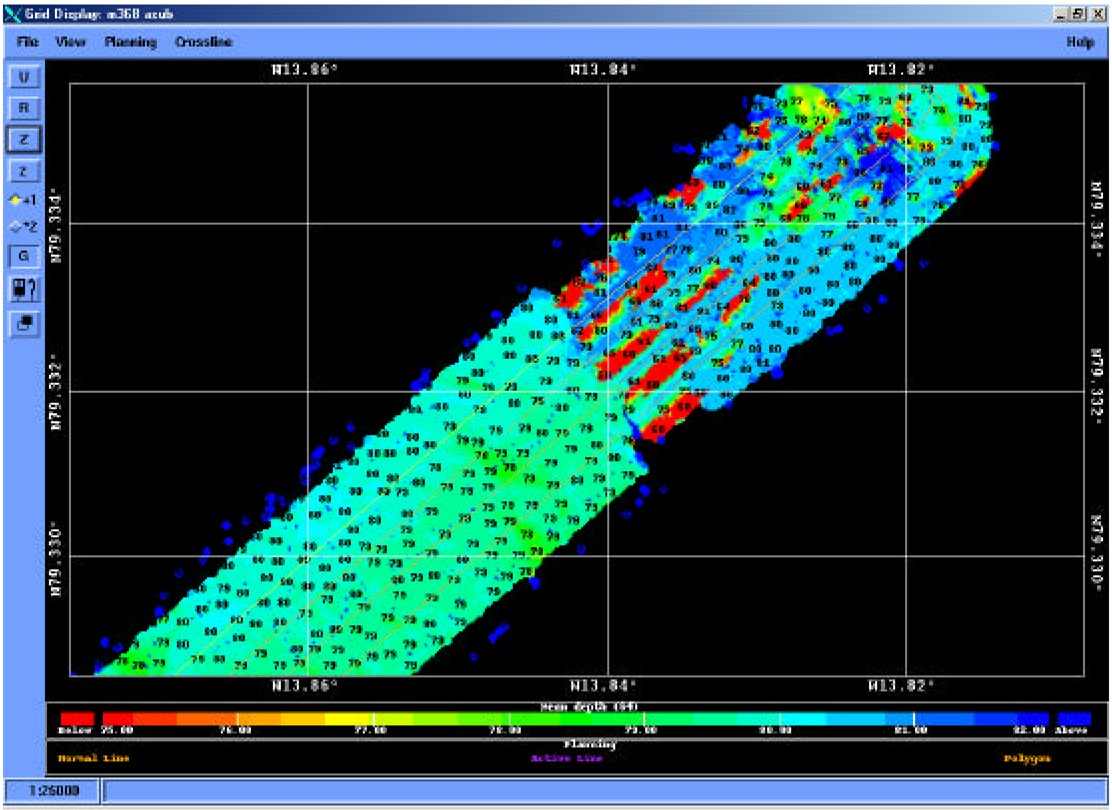


Figure 2. Section of Gridded EM2000 data from Autosub Mission 368 showing anomalies due to deliberate false roll setting.

The edge of the fast ice can be clearly seen but there are discontinuities between adjacent beams caused by the port/starboard reversal and the deeper depths shown by the red sections are caused by the vertical echo swamping the sea surface returns where no ice is present.

The Autosub tracks shown in this diagram come from Autosub's internal navigation system. This navigation data can be greatly improved by post processing using GPS information at the start and end of the mission. Kongsberg have supplied the Hugin2Survey software which can accept a post processed navigation file and incorporate this information into their gridded data format. Any additional processing must also have the ability to import this navigation data.

Towards the end of the cruise Kongsberg emailed an update to the EM2000 DSP code to improve vertical surface echo rejection in the outer beams but this was not used on the cruise as Kongsberg had not had the opportunity to fully test it and it would have required us to run a number of test missions with different rejection settings in order to ensure that it improved the vertical echo rejection while not impairing the under ice imaging.

The upward-looking EM2000 multibeam sonar tunnel roof artefact

Arthur Kaletzky (DAMTP)

The AUV was launched for the first time on this cruise on .... at position ....

Among the data resulting from this mission were several EM2000 upward looking sonar “raw” (actually, semiprocessed for virtual beam forming and edge detection, since the EM2000 cannot output raw stave data) data files. The run was conducted in very still, largely open water with some ice floes.

The plots resulting from further processing of these data were surprising. Most scans depicted a curve symmetric around the zenith of the AUV in the vertical plane containing its roll axis. The curve descended sharply and symmetrically on each side of the zenith and was first thought to be a parabola, for which there was no apparent physical explanation. However, when the plot axes were made of equal scale, it was seen to be a circular arc (it was actually an arc of an ellipse when z was exaggerated as customary). The immediate hypothesis arose that all of the virtual beams were somehow being polluted by a strong and sharp omni-directional ping. Software was written to examine the “raw” depth and “raw range” datagrams in the “raw” files and it was found that actually the strength of the reflected signal dropped off rapidly with increasing angle between the virtual beam and the AUV zenith, but was nevertheless sufficient to dominate all other returns in most virtual beams and thus be detected by the EM2000 embedded software as the defining edge of the imaged object - thus the circular arc, which when the successive scans were put together formed the “cylindrical tunnel roof” artefact.

In some but not most scans, there were beams which contained reflections stronger that the “roof”, and then the correct images of the reflecting objects were formed. By comparing these and later mission data, it was seen that the artefact was most prominent when there was very still water rather than rougher water or ice overhead the AUV.

The obvious conclusion was reached - the specular reflection from overhead still water is so strong that it leaks into virtual beams pointing in other directions. The virtual beams, just like the physical stave beams from whose data they are derived, are not perfect - they have side lobes with greatly reduced but nonzero transfer functions. Because multibeam sonar unlike electromagnetic radar depends on a multidirectional source with all reflections of a scan being caused by a single multidirectional ping, a very strong reflection (several orders of magnitude greater than any other in the scan) can leak into other beams through their side lobes creating the tunnel roof artefact.

This artefact can be fairly easily recognised and removed using specially-written post-processing software which we are now developing. However, because the EM2000 does edge detection onboard using proprietary embedded software which deletes all reflection data not near the “detected edge”, we cannot replace the deleted reflections with more credible ones. Thus, until we can deal with this problem with the manufacturer, we must simply reject scans where this artefact occurs, all scans with still water rather than ice or rough water overhead. We have contacted the manufacturer and received an onboard software patch from them by Inmarsat e-mail. However, we decided not to apply the patch on this cruise because of schedule risk (there were only 2 more mission days available when the patch was received) and good ice cover which prevented the artefact from appearing.

AUTOSUB POST-PROCESSED NAVIGATION DATA FORMAT

Steve McPhail

Post processed navigation data is provided in a file Mxxx.bnv, where xxx is the mission number. The file is ASCII text with comma separators. The first line is the column headers. Missing data is represented by "–999". The frequency of data output is once every 2 seconds.

Table 1. Data Field Definition Table

Field	Units	Description
Date	m/d/yr	mm:dd:yy Julian Data.
Time	hr/mn/s	hh:mm:ss. UTC
Seconds	s	Seconds Since 00:00:00 1/1/1970
Elapsedtime	s	Since start of navigation file.
Pos_E	degrees	"Best estimate" Longitude.
Pos_N	degrees	"Best estimate" Latitude.
Depth	m	Depth of vehicle.
Vel_E	ms^{-1}	"Best estimate" East Velocity component.
Vel_N	ms^{-1}	"Best estimate" North Velocity component.
PosRaw_E	degrees	Raw (unprocessed) Longitude.
PosRaw_N	degrees	Raw (unprocessed) Latitude.
PosError	m	Estimate of the position error.
Posfix_E	degrees	GPS Fix: longitude
Posfix_N	degrees	GPS Fix: latitude
FixType	enumeration	GPS fix type. 2 (D),3 (3 D),4 (2 D diff.), or 5 (3 D diff).
TSLF	s	Time since the last accepted GPS fix.
ADCPVelMode	enumeration	ADCP mode of operation: 0,1,2
LineIndex	Integer	Mission Line number.
ADCPVel_E	ms^{-1}	East Velocity output by Autosub ADCP.
ADCPVel_N	ms^{-1}	North Velocity output by Autosub ADCP.
ADCPAlt	m	Altitude measured by ADCP.
Driftrate_E	ms^{-1}	North Drift rate (or current) estimate.
Driftrate_N	ms^{-1}	East Drift rate (or current) estimate.
Travelled_km	km	Distance traveled (over ground) in km.
LPVel_E	ms^{-1}	North component Low pass filtered velocity.
LPVel_N	ms^{-1}	East component Low pass filtered velocity.
Vwater_E	ms^{-1}	North velocity through water.
Vwater_N	ms^{-1}	East velocity though water.
WaterSpeed	ms^{-1}	Speed through water.
LPGroundSpeed	ms^{-1}	Ground speed. Low pass filtered.
LPWaterSpeed	ms^{-1}	Through water speed. Low pass filtered.
Pitchdeg	degrees	Pitch of vehicle (degrees)
Headingdeg	degrees	Heading of vehicle (degrees)
Rolldeg	degrees	Roll of vehicle (degrees).
Splanedeg	degrees	Stern Plane degrees
Rudderdeg	degrees	Rudder degrees
prop_rpm	Rev per minute	Propeller Radial Speed
WaterDepth	m	Depth of water. Is Depth + ADCPAlt
MissionNum	REAL	Mission Number: +Number at Start of Mission. - Number at the end of the mission.
MCLongDem	degrees	Longitude and Latitude Demands from Mission Control. Effectively are the mission waypoints.
MCLatDem_		
Total Power	Watts	Total electrical power usage.
battery_V	Volts	Battery Voltage.

AUTOSUB ADCP DATA DEFINITION (JR106)

Steve McPhail

Physical Arrangement

Autosub has two RDI ADCPs:

A 300 kHz RDI Workhorse pointing upwards.
A 150 kHz RDI Workhorse pointing downwards.

Both can provide velocities in bottom tracking mode (or ice tracking for the upward looking ADCP), as well as current profiling. The range information for the four beams is also used in the control of the vehicle, where it is set to keep a constant distance from the seafloor, or under the ice. The collision avoidance system also takes input from the ADCP beam ranges.

Approximate performances seen during JR106 are:

Up ADCP. Ice tracking 100 to 200m. Water profiling to 80 m (typical)
Down ADCP. Bottom tracking to 450 m range. Water profiling to 144 m (typical).

Both are currently set with 8m profiling bins. This can be changed, although shorter bins will give higher noise values (particularly for the down looking 150 kHz), and it would complicate processing to have different up and down bin lengths.

Files:

The ADCP data is contained within the ASCII mxxx.ls2 files, where xxx is the mission number. The first line of this file is a header of field names). The second line are the units used. The data is 2 seconds sorted (new set of data each 2 seconds).

This file also contains Autosub engineering and (unprocessed) navigation data, some of which might be of interest. For post processed (more accurate) navigation data, you might want to use the Mxxx.bnv (best navigation) file which is described in a separately.

Where there is no data within a 2 second period the missing data value is represented by –999.

The ADCPs produce new data every 2.6 seconds. This explains why, in the 2 second binned data file (ls2), there are regular missing data values (-999).

The ADCPs themselves use –32678 to represent no or bad data.

ADCP Data Fields in the Mxx.ls2 files

Table 1. ADCPbin[0] Frame 0 is a special frame with ADCP configuration data

Field Name	UNIT	Description
CellIdx0*	0.24 dB	ADCP beam 3 intensity for bottom target
Inten0*	0.24 dB	ADCP beam 1 intensity for bottom target
Veast0	mm/s	Starboard velocity relative to seabed
Vnorth0	mm/s	Forward velocity relative to seabed
Vdown0	mm/s	Down velocity relative to seabed
Verr0	mm/s	Error velocity
ADCPVersion		RDI firmware version and revision
ADCPRev		
HeadingBias	0.01 deg	Always set to 0.
Number of Water Pings		Number of water pings per ensemble. Usually set to 1.
Size of cell	Cm	Vertical length of profile cell in cm.
Blank after TX	Cm	Blanking distance. 1st bin begins after this.
Number of Cells		Number of profiling bins. Up to 48.
Minimum Threshold		64 usually
Heading Align	0.01 deg	4500 for the down. –4500 for the up. The ADCPs heading axis are rotated 45 degrees relative to the vehicle.
Salinity		User set Salinity used in velocity calculation. Eg. 35
SoundSpeed	m/s	Calculated by ADCP based on Salinity (fixed), temperature (measured in ADCP and, and depth (externally measured).
ADCPTemp	(0.1 Celsius)	ADCP measured temperature.

Table 2. ADCP water profiling data bins[1 to N]. Example shown for the first bin (index 1)

Field Name	UNIT	Description
CellIdx1*	0.24 dB	ADCP beam 3 intensity.
Inten1*	0.24 dB	ADCP beam 1 intensity.
Veast1	mm/s	Water profile velocities are in levelled ship frame of reference, relative to the PHINS forward axis. starboard, forward, down, and error.
Vnorth1	mm/s	
Vdown1	mm/s	
Verr1	mm/s	

For the Upward looking ADCP, the field names have '_2' appended.

Table 3. Other Data fields in the ls2 files which are of interest to users of ADCP data

Field Name	Units	Description
Date	e.g.17/08/2004	Date
Time	e.g. 09:40:02	Time of day (UTC)
Seconds	e.g. 1092735602.0000	Seconds since 1/1/1970
Roll	Radians	Roll angle of Autosub. (+ve to starboard).
Pitch	Radians	Pitch angle. +ve node up.
Heading	Radians	Heading. In Navigation convention. Heading north is 0. East is pi/2.
INSLat	Degrees (decimal)	Latitude (not post-processed)
INSLong	Degrees (decimal)	Longitude (not post-processed)
INSDepth	Metres	Depth of Autosub (m).

* There is a bug in our logging software, which causes the intensity values to "wrap around" for values greater than 127. The correction, easily applied in Matlab is :

```
// for all val..
if(val <0); val = val+256; end;
```

Hints for processing the ADCP data

You'll only get good current data when the down ADCP has bottom track.

Processing steps:

Transform "Ship Levelled" to geographical.

e.g.

Vnorth = Vfwd*cos(heading) -Vstbd*sin(heading)
Veast = Vfwd*sin(heading)+ Vstbd*cos(heading).

(In the ls2 file : Vfwd is *called* Vnorth , Vstbd is *called* Veast).

Produce Current profiles from the vector equation. Vwater(geog) = Vbottomtrack(geog)+ Vcurrent(geog).

Map the current profiles to real depths, by adding on the Depth sensor reading to the profile depths (based on bin size, bin number, blanking distance).

SEA ICE VALIDATION PROGRAMME

Peter Wadhams

Drilling

When AUV transects were carried out under fast ice, the primary means of validation consisted of lines of holes drilled through the ice near to the ship (which was forced into the ice edge) and oriented along and over a known track of the AUV. The procedure was as follows:

A start point, marked by a flag, was defined by portable GPS as lying over an Autosub track line. A 100 m line was laid out in the direction of the AUV transit, marked at 50 m intervals. Holes were drilled at 5 m intervals using a petrol-driven power head and a CRREL 2-inch augur. Measurements were made of: snow thickness at three points near the hole; total ice thickness using a scissor-type probe; and ice freeboard. Features such as melt pools along or near the track were noted.

A 100 m cross-line was then surveyed starting from the centre of the primary line and the survey repeated. If time permitted, the primary line was extended to 200 m. Finally, snow samples were taken with a standard sampler to obtain snow density measurements.

Results are given in Appendix A.

Coring

Ice cores were taken from at least two locations in each survey area, using a CRREL 4-inch corer supplied by Kovacs Instruments. The cores were stored temporarily in the ship's deep freeze, then sliced in 10 cm sections, melted, and the salinities determined with a conductivity meter. Parts of each 10 cm section were saved separately for subsequent analysis for quantity and origin of dirt content.

Collaboration with *FS POLARSTERN*

Helicopter

The intention of this joint work was to have the *Polarstern* helicopters fly over all the tracks in fast ice carried out by Autosub before August 25; then for the helicopters to fly a local pattern of tracks over the 2 x 2 km experimental survey area of August 25. The towed EM bird system would provide thickness validation for the Autosub sonar. Unfortunately on the day of our meeting fog prevailed all day, and only one local flight was accomplished which had to be aborted because of failure of the laser to lock on. At this time it is not known whether any useful data were obtained.

EM31 ground system

The *Polarstern* sea ice team carried out several 500 m – 1 km transects of the experimental survey area using a manually-towed kayak carrying an EM31 electromagnetic sounding system and snow probe. Together these give snow depth and total ice thickness at high horizontal resolution (approximately ice thickness, i.e. 1-2 m). The transects included those already drilled, to provide further cross-validation. In addition, a resistivity survey was carried out of a pressure ridge to give a high-resolution view of its block structure.

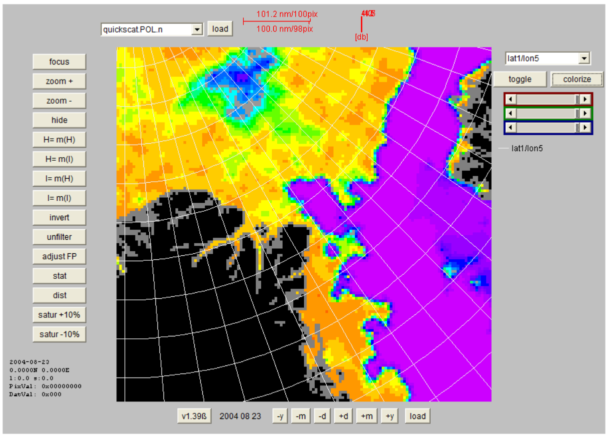
SATELLITE DATA

Nick Hughes (SAMS)

Timely provision of satellite data on sea ice conditions in the Fram Strait and Belgica Bank area was essential for planning fieldwork operations as the JCR lacks helicopters to carry out ice reconnaissance. There were two main sources of satellite data for JR106 Autosub-Under-Ice fieldwork.

AMSR, QuickSCAT and Envisat GMM data were provided by Leif Toudal of the Danish Centre for Remote Sensing and e-mailed daily to the ship by Dave Meldrum at SAMS.

Acquisition of Envisat WS data to cover the fieldwork was ordered by SAMS from ESA prior to the cruise. Delivery of 4 of the scenes in near-real time (NRT) to cover 8, 17, 20 and 24 August was ordered from Kongsberg Satellite Station (KSAT) in Tromsø, Norway. Processing of the data to derive quick look images and e-mailing of these to the JCR was carried out by Richard Hall of the Norwegian Polar Institute (NPI).

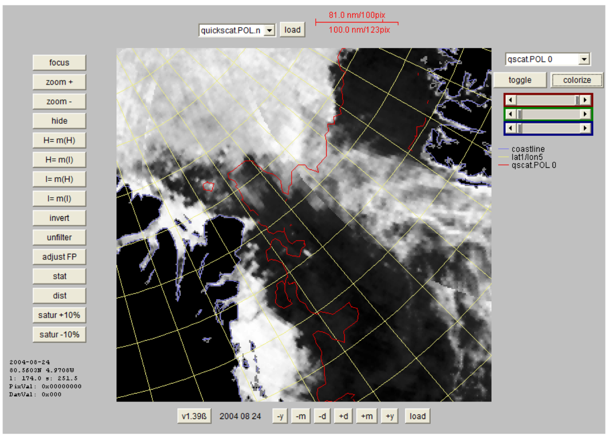


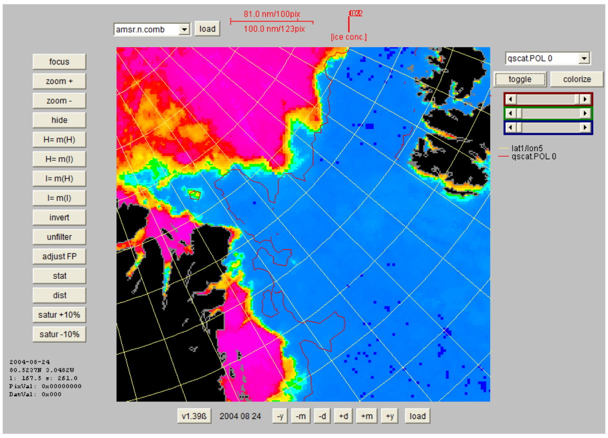
QuickSCAT

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. During JR106 the daily images were used to estimate the position of the ice edge and any useful areas of open water. On approaching the Belgica Bank small scattered floes were found which were well outside the area delineated as ice by the QuickSCAT. Therefore it was assumed that the algorithm was under-detecting ice and that open water areas within ice were suspect. 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. An example image from 23 August is shown to the right.

AMSR 89GHz Ice

The 89 GHz vertical and horizontal polarity channels of the Advanced Microwave Scanning Radiometer (AMSR) sensors on NASA's EOS Aqua and Terra satellite are used to derive high resolution (6.25 km) maps of sea ice concentration. The high frequency makes the 89 GHz susceptible to interference from atmospheric moisture (as shown in the example from 24 August on the right). However they are good for showing areas of concentrated sea ice and some indication of lower concentrations of floes. In this image the fast ice fringing the east of Greenland is clearly shown along with a few broken-off ex-fast ice floes in Fram Strait. A weather system is visible in the eastern half of Fram Strait.



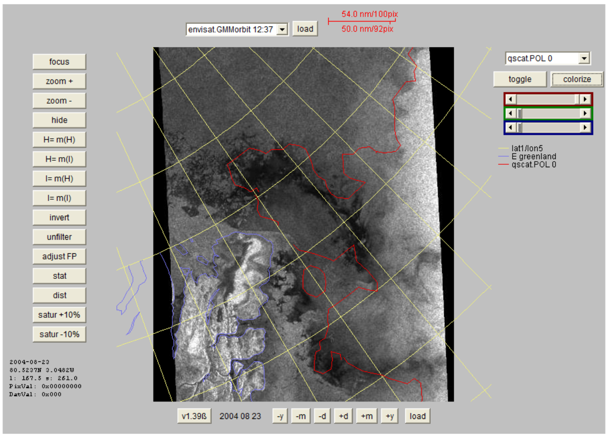


AMSR Ice Concentration

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 melt pools. These areas of water ponded on a floe are seen by the satellite to be open water even though there is ice underneath. Therefore summer ice concentration estimates tend to be less reliable and lower than those from optical sensors. In the example above the QuickSCAT ice limit is shown as a red line and is seen to be well outside the ice limit shown by AMSR.

Envisat GMM

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.

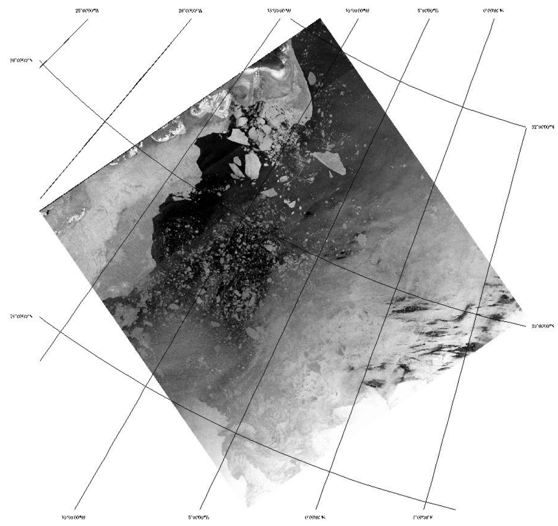


GMM shows up the boundaries of ice and water areas as well as some large floes. This example from 23 August shows the far north-east corner of Greenland in the lower right with the fast ice encountered by the JCR stretching away down the coast to the south. Open water with waves scattering radar energy 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 were received on 14, 19, 23 and 25 August and were useful in supplementing the WS images received from Envisat.

Envisat WS

Envisats Wide Swath (WS) 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.



8 August:

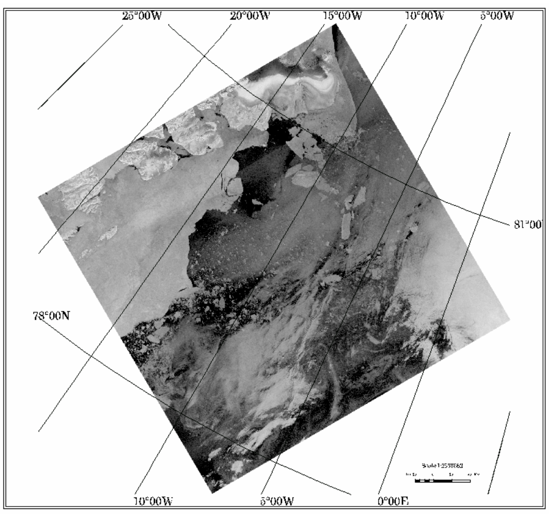
The image to the left was produced before the start of JR106 and shows an expansive fast ice edge on the east coast of Greenland. This ice has already started to break-up near the far north-east tip with large floes drifting out into Fram Strait.

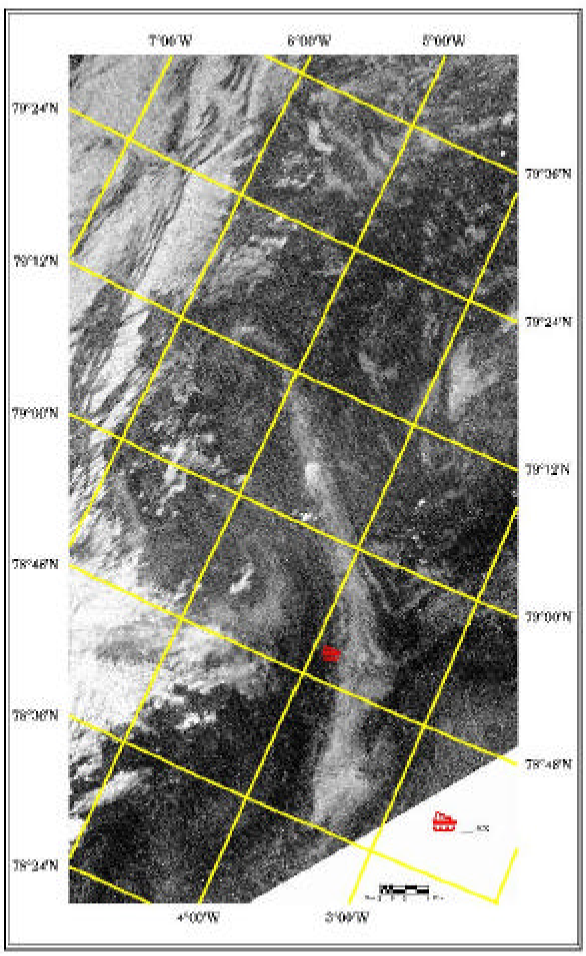
Also visible is a distinct variation in radar energy backscatter from the fast ice closer in to the coast with that on the outer edge. It is hypothesized that this may be a division between first year and multi year fast ice and is something that a run by Autosub underneath the ice may by able to clarify.

17 August:

By this date JCR was just outside the area of acquisition, the full quick look of which is shown below. However shortly after entering it on the following day a large tabular iceberg was encountered at the position shown in the full resolution image to the right. A photograph of the iceberg is shown on the following page.

It is possible that some of the bright speckle seen in the SAR images are icebergs. This will be the subject of further investigation after the cruise. The large ex-fast ice floes seen 8 days earlier furthest east in Fram Strait have broken up.



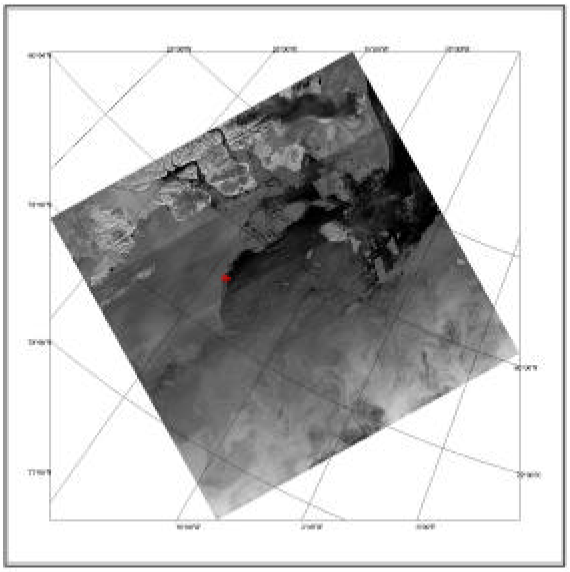


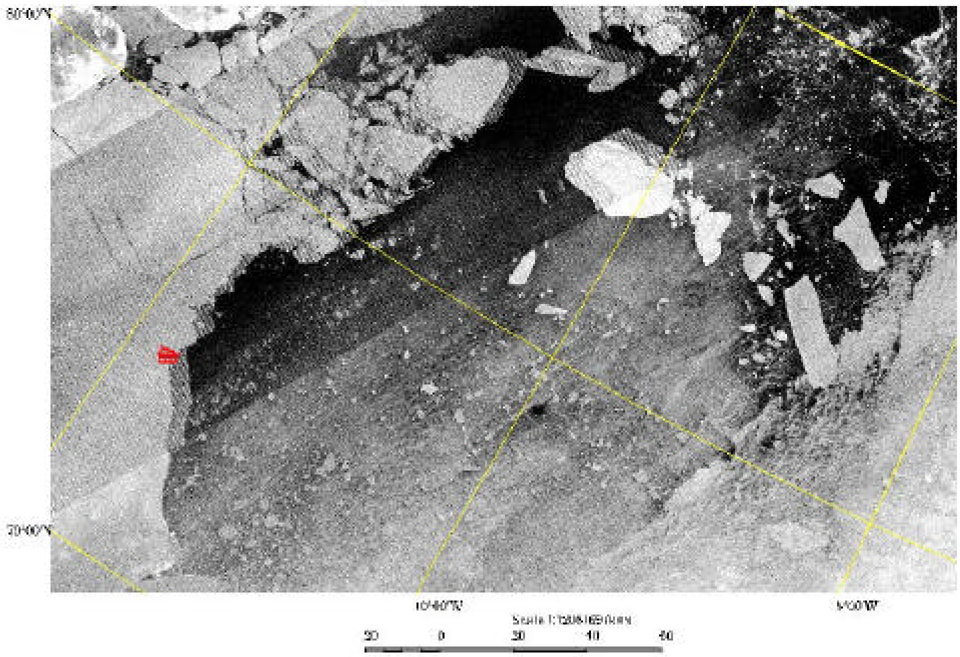
Large tabular iceberg encountered on 18 August.

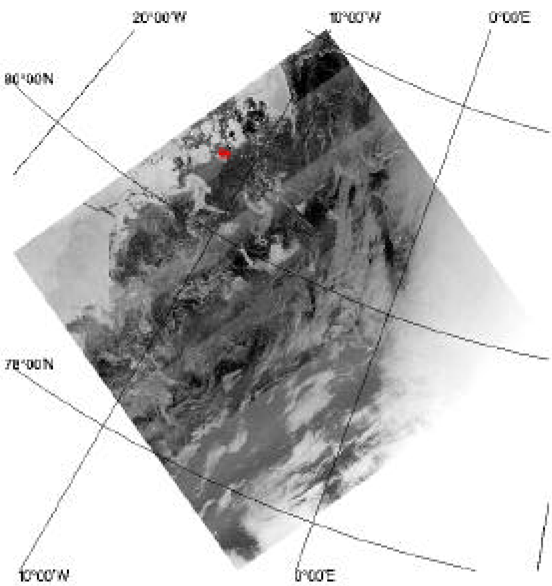
20 August:

On this day JCR was at the first of the ice stations on the fast ice edge. The Envisat image provided suffered from geo-correction problems in one of the bands used to produce the average backscatter values covering where JCR was located. This resulted in a double image but an extraction of a full resolution portion, shown below, clearly shows the fast ice to the north developing an east-west fissure.

The fast ice further out in Fram Strait continued to drift south-east and break-up.

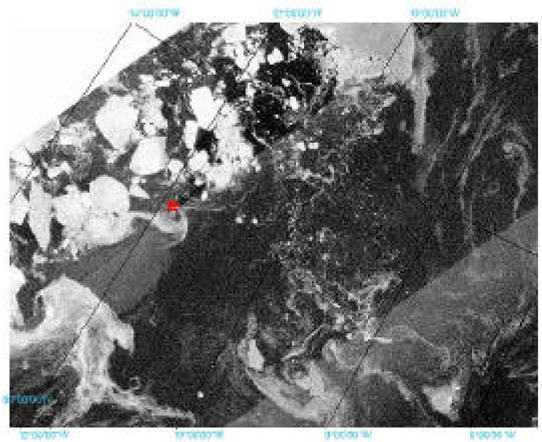






24 August:
The final Envisat image, shown to the left, delivered for this portion of JR106 still shows the distinct fast ice edge between 79ºN and 79º40'N still as it was at the beginning of the series of images. The fast ice floes broken off to the north were broken up and swept down to the south by a day of storm conditions in the Greenland Sea.

On the afternoon of 24 August JCR negotiated several of these bands sailing south to meet up with the German icebreaker Polarstern at the fast-ice edge. The full resolution image based



on JCR's position at the time of acquisition is shown above.

A second full resolution image shows the swirls of broken-up fast ice travelling southward along the fast ice edge. This is shown to the right. Conditions beyond this area of broken up ice were fairly open with plenty of open water for navigation exiting east from the Belgica Bank area.

SEA ICE WATCH

Steve Ackley (USA), Kieran Rutherford (SOC),
Ken Collins (SOC) and Gwyn Griffiths (SOC)

Introduction

We conducted hourly sea ice observations while the *JCR* was underway from the first encounter with pack ice at 1820 on 16 August 2004, until we left the ice at 0800 on 27 August 2004. Observations were conducted according to the ASPeCt protocols developed for Antarctic sea ice (A. Worby, CD titled ‘Observing Antarctic Sea Ice’). Using the World Meteorological Organization (WMO) classification for snow and sea ice, codes are entered for each hour of underway travel, for a 1 km diameter observing area at the time of observation, describing the ice and snow. The parameters described are: total concentration, open water (distance between floes), and for up to three ice types the concentration by type, the type of ice, ice thickness, floe size, topography(area and height of ridged ice), snow type and snow thickness. The codes are entered into a sea ice log and using software available on the CD, summaries of ice conditions can be computed according to the parameters described, for example the ice and snow thickness distributions, either total or any average of track length desired. Figure 1 shows a cruise track plot with blue dots keyed according to ice concentration for example, and positions of Autosub launches and recoveries and furthest excursion shown in red.

Describing sea ice in this manner therefore gives a survey of observed conditions that are comparable to other methods of data collection for sea ice, from the broad scale available from satellite data, through higher resolution and intermediate distance scales such as from Autosub upward looking swath imagery and submarine and mooring upward looking sonar from the region, and high resolution, short distance records such as the hole drilling campaigns for ice thickness conducted at the fast ice during the cruise.

The accompanying data CD has two other folders along with the sea ice log. The first is of the photographs taken from the bridge (starboard, forward and port) during the ice observation when visibility conditions allowed. These are indexed to time and date and can therefore be cross indexed with the date and time of the corresponding entry in the ice log. A second folder, of satellite data images from EnviSat, are also archived. These are of the whole area on a given day and can be co-located with the corresponding log date for the short track on any given image.

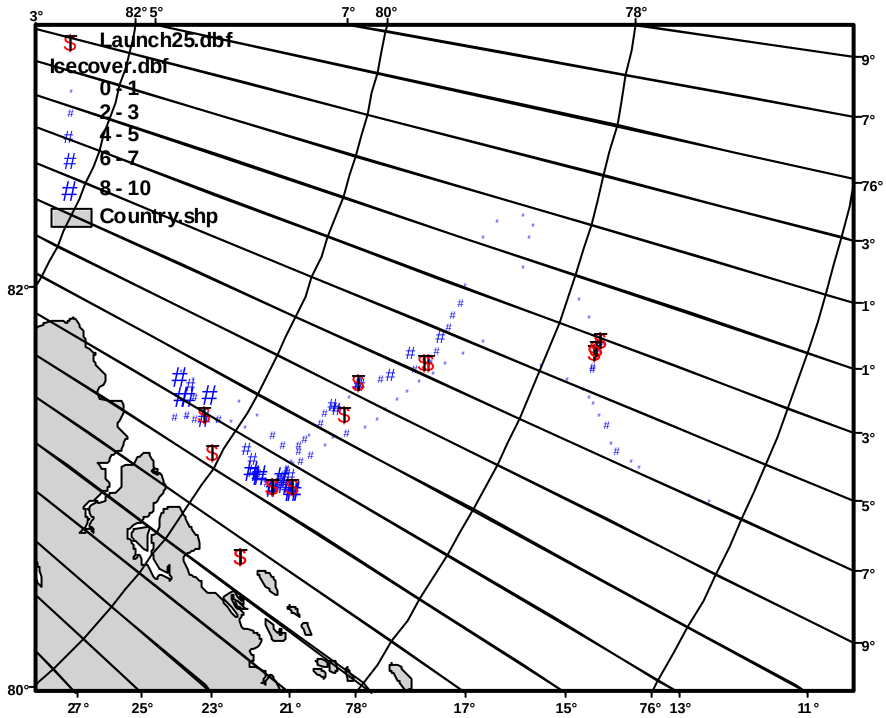


Figure 1: Ice concentrations from ship observations along Leg 1 (blue) and Autosub launch/recovery and furthest excursion positions (red).

Ice Concentration

Figure 1 shows that generally low ice concentrations were observed except near the coast of Greenland where we encountered either fast ice (attached to the shore) or vast floes (>2 km diameter) that were recently broken out from the fast ice. Offshore no more than 3/10 ice concentration was observed in the pack on the inbound track while up to 5/10 was seen occasionally on the out ward bound track. The outer pack was highly dispersed, reflected in the floe sizes also, which were less than the 100 m diameter category in the outer parts indicating they were broken apart by heavy waves and swell at one time. No high concentration feature identifiable as a distinct ice edge was observed, only a broad area of dispersed floes, (Figure 2.) indicating northerly to north-westerly winds had prevailed for a length of time prior to our arrival.

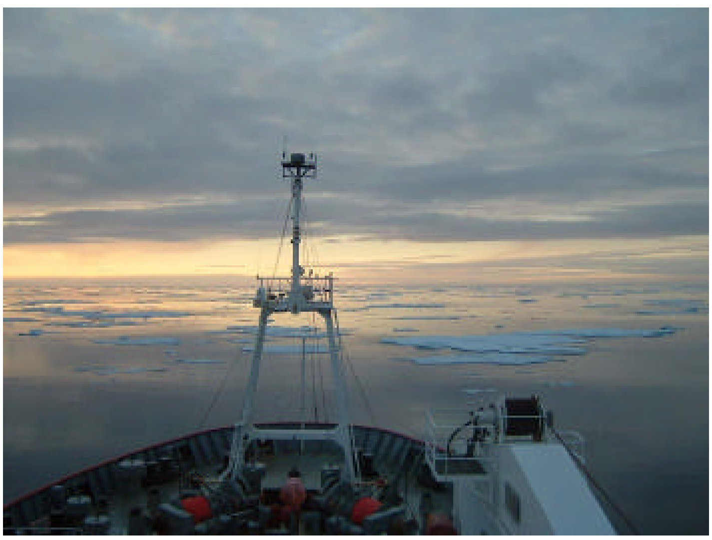


Figure 2: Ice watch photo 17 August, 0100, showing dispersed floes and lack of distinct ice edge.

Ice Types

The ice types varied also with predominantly multiyear ice seen in the outer regions with thicknesses (of level ice) estimated at 200 cm. Floes with high densities of ridges were also seen occasionally which would serve to raise the mean thickness.

Another indicator of the multiyear age is the observations of sediment on the surfaces of the older ice floes seen quite commonly in the outer reaches of the ice pack. Sediment in the ice originates from incorporation during first ice formation in turbulent conditions found primarily in shallow water on the Siberian Shelves such as in the Laptev and Kara Seas. The sediment accumulates progressively on the surface as ice melts during summer, so darker floes have drifted long enough to last through two summers' melt.

Figure 3. Sediment on surface of floe (dark area) in photo center also some lighter, smudgy areas of sediment on floe in the foreground, 19 August 0300.

At the fast ice, proportionally larger amounts of first year ice were seen, with thicknesses in the 1 to 1.5m categories and only very occasional bits of thicker ice with sediment showing. Ridging was also quite low in the first-year ice seen in the fast ice, reflective of the growth in quieter conditions and younger age as it attached or nearly attached to the shore at the time of its formation. From the 21 to 26 August, we observed new ice formation conditions (grease ice and nilas, to 10 cm thickness). On the last days, 25 and 26 August, these new ice types survived past midday suggesting the end of the summer season and beginning of the ice growth period was initiated at this time.

Surface Conditions (Snow Cover and Melt Ponds)

In the early part of the cruise, the full melting condition of the summer pack was in evidence. Estimates of melt pond coverage (tested at low salinity as essentially fresh water from snowmelt) were generally from 15 to 25% coverage of the ice surface. In almost all cases, however, there was approximately a 10 cm thick snow cover remaining throughout the region between the melt ponds (Figures 3 and 4). Some melt ponds were observed to completely perforate the floe to the ocean below. The snow cover was highly metamorphosed, with ~0.5 cm grains indicative of the grain growth that takes place when the snow is saturated with melt water. Channels into and between melt ponds also were evident showing the pathways of water flow from the higher topography of the floe to the low spots where the water pooled. (Figures 3 and 4).

Figure 4: 18th August 1700 showing melt ponds and channels at full development of summer melt. Snow cover is still present but fully 'ripened' with large grains.

From the 22 August, new snow accumulated on the floes, measured at 5 to 10 cm from the surface measurements. Melt ponds were also frozen over with a thin layer of new ice starting from this time (Figure 5), another indicator of the transition to fall-winter conditions and the start of the ice growth season, as indicated by the new ice types observed as noted above.

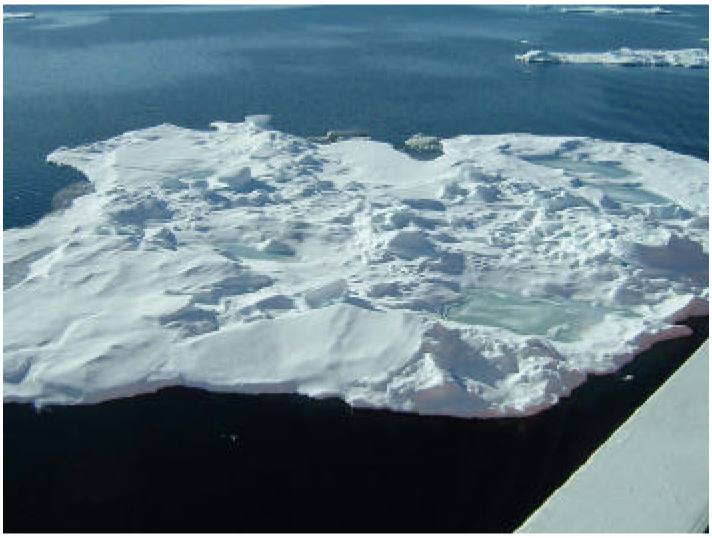


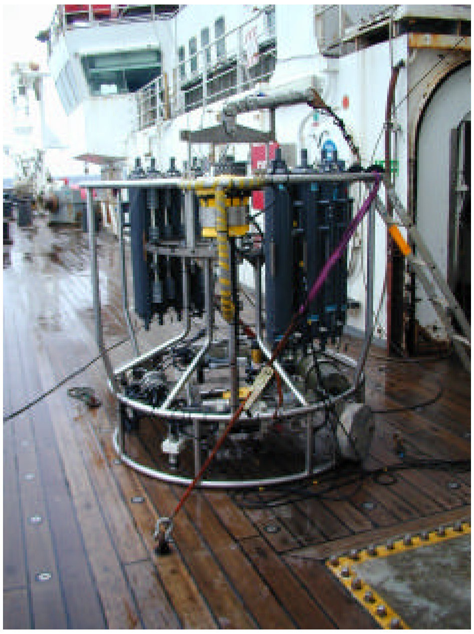
Figure 5: Photo from 26 August, 1500 showing frozen-over melt ponds and new snow cover at start of fall-winter transition in NE Greenland.

PHYSICAL OCEANOGRAPHY

Jeremy Wilkinson (SAMS) and Terry Edwards (UKORS)

The main aim of the physical oceanography programme was to support the Autosub operation in and around the North East Water Polynya. As a result physical oceanographic measurements were obtained from the ship-borne Seabird 911, the AUV mounted Seabird 911 system and a hand held SBE 19. All systems are described below:

Ship borne unit:



The on-board CTD unit was the Sea-Bird 9 plus (Ser: 0528) with duel temperature and conductivity sensors, SBE 43 oxygen sensor, Chelsea instruments MkIII fluorometer, Chelsea Instruments Alphatracka 25cm 660nm Transmissometer, Benthos PSA/916T Altimeter and a Digiquartz Pressure transducer. The temperature, conductivity and oxygen sensors were attached their respective pumps.

The above instruments were attached to the bottom of the SBE32 carousel (Ser: 0344) (see picture left). There was the possibility to mount up to 24 bottles on the carousel, however our set up required only 8 bottles to be attached. There was also a RDI LADCP 300 kHz system attached to the upper and lower brackets of the carousel. The distance of separation between the 2 ADCP units was approx. 106 cm + each sensor was approximately 24 cm tall.

The date of the last calibration and serial numbers for the oceanographic sensors can be seen in Table 1. A full copy of the calibration coefficients for all instruments can be obtained from the PSO.

Channel	CTD Sensor	Serial Number	Date of calibration
1. Frequency	Temperature	4116	9/6/04
2. Frequency	Conductivity	2407	17/6/04
3. Frequency	Pressure, Digiquartz with TC	73299	8/5/02
4. Frequency	Temperature 2	2919	9/6/04
5. Frequency	Conductivity 2	2450	17/6/04
6. A/D voltage 0	Oxygen, SBE 43	0619	16/6/04
7. A/D voltage 1	Free	Free	Free
8. A/D voltage 2	Altimeter	874	23/4/01
9. A/D voltage 3	Fluorometer, Chelsea Aqua 3	88195	27/3/03
10. A/D voltage 4	Free	Free	Free
11. A/D voltage 5	Free	Free	Free
12. A/D voltage 6	Optical BackScatter, Seatech LS6000	N/A	N/A
13. A/D voltage 7	Transmissometer, Chelsea Aphatracka 25cm 660nm	161045	28/4/01

Table 1: CTD configuration used throughout JR106 for ship-borne CTD

Once we arrived at the designated station the CTD was 'made ready' by either Terry Edwards (12 pm to 12 am) or Pat Cooper (12 am to 12 pm). The deployment of the CTD was from the starboard mid-ship's gantry via an A frame. The logging was generally initiated using SeaSave the Seabird data acquisition software before the CTD was in the water. The salinity and temperature values were monitored until they were stable and then the CTD was lowered at about 1m/s. Water samples were 'fired' on the up cast in water identified by the down cast as having a low T and S gradient.

At the end of a station the CTD was taken back on deck and fastened to the ship before heading to the next station. The procedure of keeping the CTD outside should be avoided as we have had experiences on other cruises of the conductivity cell freezing and breaking in below freezing temperatures. This has occurred in instances of when the CTD has been outside for only a few minutes.

Autosub unit:

The instrument on board Autosub is a standard SBE9 plus. This pumped system had an inlet manifold at the front of the AUV. The system ran duel temperature and conductivity sensors, SBE 43 oxygen sensor and a Digiquartz Pressure transducer.

The date of the last calibration and serial numbers for the oceanographic sensors can be seen in Table 2. A full copy of the calibration coefficients for all instruments can be obtained from the PSO.

Channel	**CTD Sensor**	**Serial Number**	**Date of calibration**
1. Frequency	Temperature	2342	25/07/03
2. Frequency	Conductivity	2730	18/03/04
3. Frequency	Pressure, Digiquartz with TC	89080	2/26/02
4. Frequency	Temperature 2	2912	6/21/02
5. Frequency	Conductivity 2	2760	7/10/02
6. A/D voltage 0	Oxygen, SBE 43	0259	01-May-02
7. A/D voltage 1	Free	Free	Free
8. A/D voltage 2	Free	Free	Free
9. A/D voltage 3	Free	Free	Free
10. A/D voltage 4	Free	Free	Free
11. A/D voltage 5	Free	Free	Free
12. A/D voltage 6	Free	Free	Free
13. A/D voltage 7	Free	Free	Free

Table 2: CTD configuration used throughout JR106 for Autosub CTD

From Table 2 it can be seen that in general the date of calibration for most of the instruments is quite old. These instruments will be calibrated on return to the UK. The set up and logging of the instrument was controlled by the Autosub team.

Hand-held CTD:

In order to obtain the temperature and salinity profiles of the upper 50 m away from the influence of the ship a hand held SBE 19 was used. This system has been used successfully in the past both from a zodiac and from an ice floe.

However due to the work-load it was not possible to use this CTD in anger except on one occasion from the side of the ship. The one deployment was designed to monitor the upper 1 –2 m of the sea ice melt layer. To do this the system, which was connected to a buoy by a rope 1.5m long, was lowered over the side of the JCR. The pumped SBE-19 was recorded the T and S of the upper 1.5m every 0.5secs. The system was designed to free float away from the ship. The same rope that was used to lower the instrument was used to bring it on board.

CTD Post processing:

As the manufacturer, Sea-bird, was common to all three CTD systems the `SBE Data processing` software (5.1.26) was used to process and convert the data into ASCII. However the exact scripts used varied depending on the instruments. To run the data processing sequences an up to date configuration (.con) file for each instrument was needed.

The data processing sequence used on this cruise is as follows:

```
datcnv
alignctd
filter
celltm
loopedit  (this was not run on the AUV based system)
derive
```

To make life easy the above data processing scripts were included in a batch file, which was run in windows. An example of the batch file to process the ship based CTD was as follows:

```
@ Lines starting with @ are comment lines
@ Select Run in the Windows Start menu and run this line:
@ sbebatch D:\jeremy\jcr106\ctd\seabird911\prallcasts_jcr.txt
D:\jeremy\jcr106\ctd\seabird911
@ Comment lines have no effect on the results
datcnv    /i%1\*.dat /c%1\CTD_001.con /o%1
alignctd  /i%1\*.cnv  /o%1
filter    /i%1\*.cnv  /o%1
celltm    /i%1\*.cnv  /o%1
loopedit  /i%1\*.cnv  /o%1
derive     /i%1\*.cnv  /c%1\CTD_001.con /o%1
```

Each line in the batch file runs a different SBE Data Processing module. These modules are explained below and are generally taken directly from the Seabird manual.

Data Conversion (`datcnv`*):*

This programme converts raw data (.dat file) into ASCII file (.cnv format) as well as bottle data. As we planned to post-process the data with other SBE Data Processing modules, we selected only the primary variables to be converted. These were:

For ship mounted system:

```
# name 0 = prDM: Pressure, Digiquartz [db]
# name 1 = c0mS/cm: Conductivity [mS/cm]
# name 2 = t068C: Temperature [ITS-68, deg C]
# name 3 = c1mS/cm: Conductivity, 2 [mS/cm]
# name 4 = t168C: Temperature, 2 [ITS-68, deg C]
# name 5 = sbeox0Mg/L: Oxygen, SBE 43 [mg/l]
# name 6 = flC: Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]
# name 7 = xmiss: Beam Transmission, Chelsea/Seatech/Wetlab CStar [%]
# name 8 = altM: Altimeter [m]
# name 9 = v6: Voltage 6 (BOB)
```

For the AUV system:

```
# name 0 = prDM: Pressure, Digiquartz [db]
# name 1 = c0mS/cm: Conductivity [mS/cm]
# name 2 = t068C: Temperature [ITS-68, deg C]
# name 3 = c1mS/cm: Conductivity, 2 [mS/cm]
# name 4 = t168C: Temperature, 2 [ITS-68, deg C]
# name 5 = sbeox0Mg/L: Oxygen, SBE 43 [mg/l]
# name 6 = timeS: Time, Elapsed [seconds]
# name 7 = timeJ: Julian Days
```

Align CTD (`alignctd`*):*

Align CTD script 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. When measurements are properly aligned, salinity spiking (and density) errors are minimised, and oxygen data corresponds to the proper pressure. For the SBE 9plus the typical lag of conductivity relative to temperature is 0.073 seconds. The Oxygen data is also systematically delayed with respect to pressure. The two primary causes are the long time constant of the oxygen sensor, approximately 5 seconds at out sea temperature and an additional delay from the transit time of water in the pumped plumbing line. We compensated for this delay by shifting oxygen data relative to pressure 5 seconds. No shifts to conductivity were performed.

Filter (`filter`*):*

Filter runs a low-pass filter on one or more columns of data. A low-pass filter smoothes high frequency (rapidly changing) data. To produce zero phase (no time shift), the filter is first run forward through the data and then run backwards through the data. This removes any delays caused by the filter. Only conductivity and pressure data were filtered but at different time constants. These were:

Low pass filter A: 0.03 seconds for conductivity
Low pas filter B :0.15 seconds for pressure.

Loop Edit (`loopedit`*):*

Loop Edit marks scans bad by setting the flag value associated with the scan to badflag in input .cnv files that have pressure slowdowns or reversals (generally caused by ship heave). The badflag value is documented in the input .cnv header. Loop Edit operates on three successive scans to determine velocity. This is such a fine scale that noise in the pressure channel from counting jitter or other unknown sources can cause Loop Edit to mark scans with the badflag in error. As a result Loop Edit must be run after Filter on the pressure data to reduce noise in the pressure data. Sea-Bird recommends using a pressure time constant in Filter equal to approximately the time required for four scans. Thus for the SBE9 plus sampling at 24 Hz, we used a time constant of 0.125 seconds (time required for 4 scans). Due to the possible porpoising of the Autosub this procedure was not run on the AUV data.

Cell Thermal Mass (`celltm`*):*

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. Values for alpha and 1/beta were 0.03 and 7.0 respectively for both the primary and secondary temperature sensors.

Derive (`derive`):

As we post-processed the data with other SBE Data Processing modules we selected only the primary variables to be converted up to this stage. We now used Derive to compute derived oceanographic parameters; Salinity and Oxygen.

Derivation of other variables, e.g. salinity, density, potential temperature etc were performed in Matlab according to the Unesco technical papers. Temperature IPTS-68 were used in these computations. According to JPOTS t68 is assumed to be 1.00024 * T90 (-2 to 35C).

Calibration of the CTD data

CTD Performance

20 CTD profiles were carried out, most shallow, one to 2500m. 4 samples were taken from each profile for salinity checks. NMEA lat and long were added to the header file as was time synchronised to the ships clock. GGA was used as RMC string was not available.

Temperature and conductivity pairs performed well, however an offset appeared of .003 PSU between primary and secondary salinities on cast 20, showing up when in the stable section of the water column. This will be compared with salinity samples.

Pressure sensor performed well. On a number of casts there were a small amount of spikes in the data, though the cause of these could not be determined as the problem was very sporadic and not repeatable. The rogue data was removed during processing.

Oxygen sensor did not perform well exhibiting varying amounts of hysterisis on most casts. On cast 20 (2500m) the downcast appeared normal. The upcast showed no profile at all, the oxygen signal tapering off towards 2mg/l. This problem to be investigated. The entire ductings had been cleaned with milli Q water after every cast, but stored empty in case of freezing.

Carousel performed without problems.

Altimeter performed well, the usual spikes until it locked on, usually at around 70m from bottom.

LSS , transmissometer and fluorometer all performed without problems.

Salinometry

Refer to the accompanying spread sheet. It is shown that through out the series there has been a large variability between measured sample and CTD reading. This is due to the nature of the water column and associated instability. This is demonstrated clearly on cast 20 where the samples correlate very well, they were taken in deep water.

The offset between primary and secondary salinities shown on cast 20 is likely due to a build up of biological growth in the conductivity cells.

Samples 0-12 were performed on the BAS salinometer s/n 65763. However, due to problems with air bubbles in the system all other sampling was carried out on OED salinometer 56747.

All samples in the file marked 9999 are std seawater run to check standardisation.

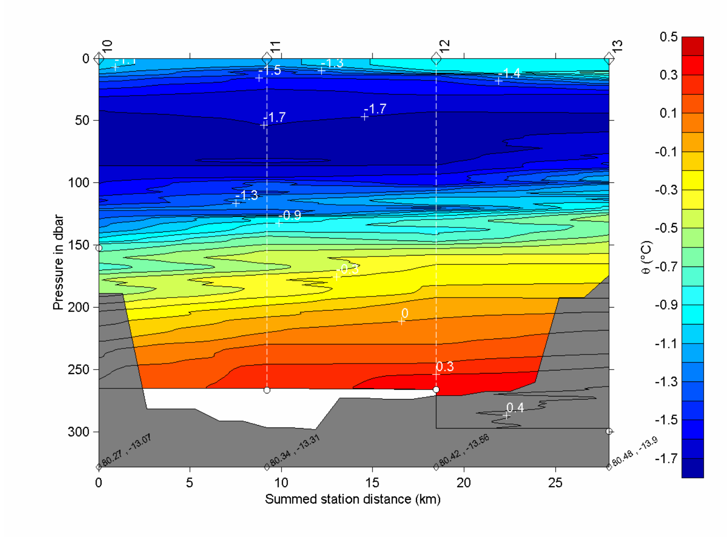
The salinometer was finally restandardised prior to running crate 11.

First results Ship based:

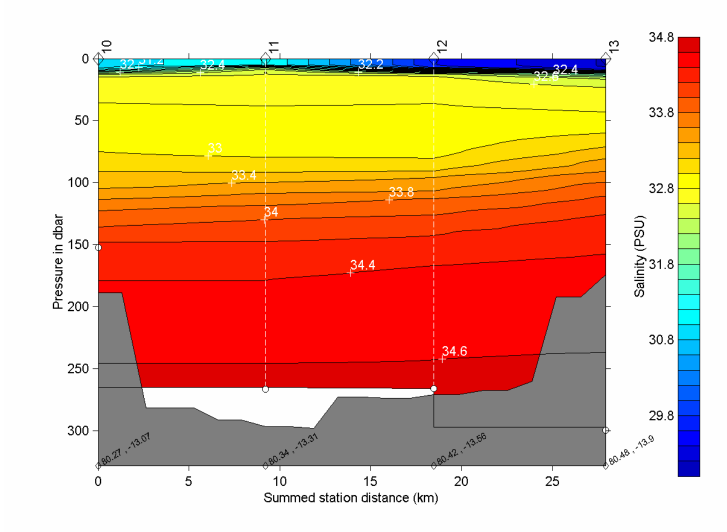
A total 20 full depth CTD stations were performed on JR106. The term ‘full depth’ is a bit misleading as most of the casts were in shallow water less than 200 m. The time of the casts and their location with respect to bathymetry and topography can be seen below:

Station	Time	Latitude	Longitude	Depth
1	18/8/04 10:48 PM	78.8454	-6.4166	298
2	19/8/04 6:43 AM	79.2891	-8.5097	172
3	19/8/04 5:45 PM	79.3703	-9.8712	172
4	19/8/04 8:38 PM	79.3982	-9.9315	180
5	20/8/04 4:04 AM	79.4945	-11.8022	214
6	20/8/04 7:40 AM	79.5046	-14.1134	105
7	22/8/04 11:16 AM	79.5052	-14.2141	131
8	22/8/04 1:26 PM	79.4985	-14.2538	105
9	22/8/04 2:24 PM	79.7395	-14.2115	87
10	23/8/04 5:16 PM	80.2705	-13.0817	165
11	23/8/04 6:14 PM	80.3447	-13.3130	282
12	23/8/04 7:26 PM	80.4171	-13.5613	281
13	23/8/04 9:07 PM	80.4801	-13.9038	317
14	24/8/04 1:26 AM	80.3583	-12.7806	256
15	24/8/04 6:28 AM	80.4299	-12.5313	290
16	24/8/04 7:55 AM	80.5056	-12.7839	295
17	24/8/04 9:21 AM	80.4927	-12.1823	280
18	24/8/04 10:33 AM	80.5735	-12.0443	270
19	24/8/04 11:45 AM	80.6448	-11.7938	264
20	27/8/04 10:04 AM	77.6053	-4.1118	2556

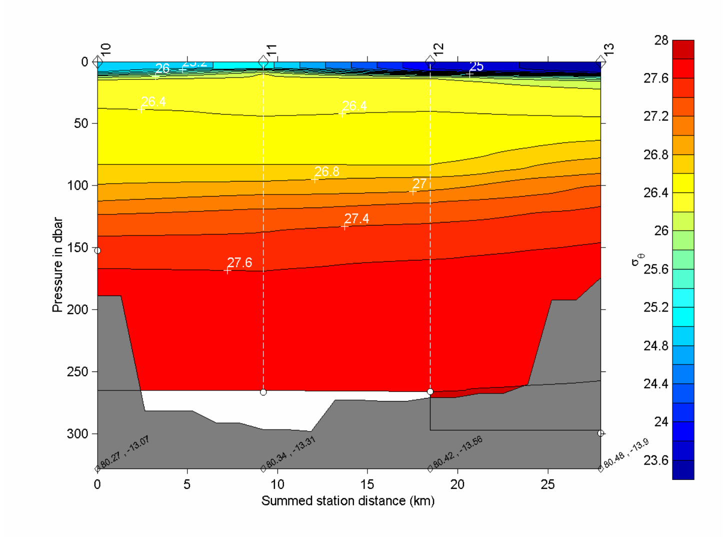
After batch processing was performed on the CTD data the resultant CNV file was then imported into Matlab for analysis. This proved very handy as we could produce plots and sections instantly. At this stage no other processing was performed to the data. An example of the hydrography over the Belgica Bank can be seen below. In this figure one can see a shallow fresh sea ice melt layer in the upper surface, under which lies water of Polar origin and finally under this layer is Atlantic based water.



Potential Temperature



Salinity

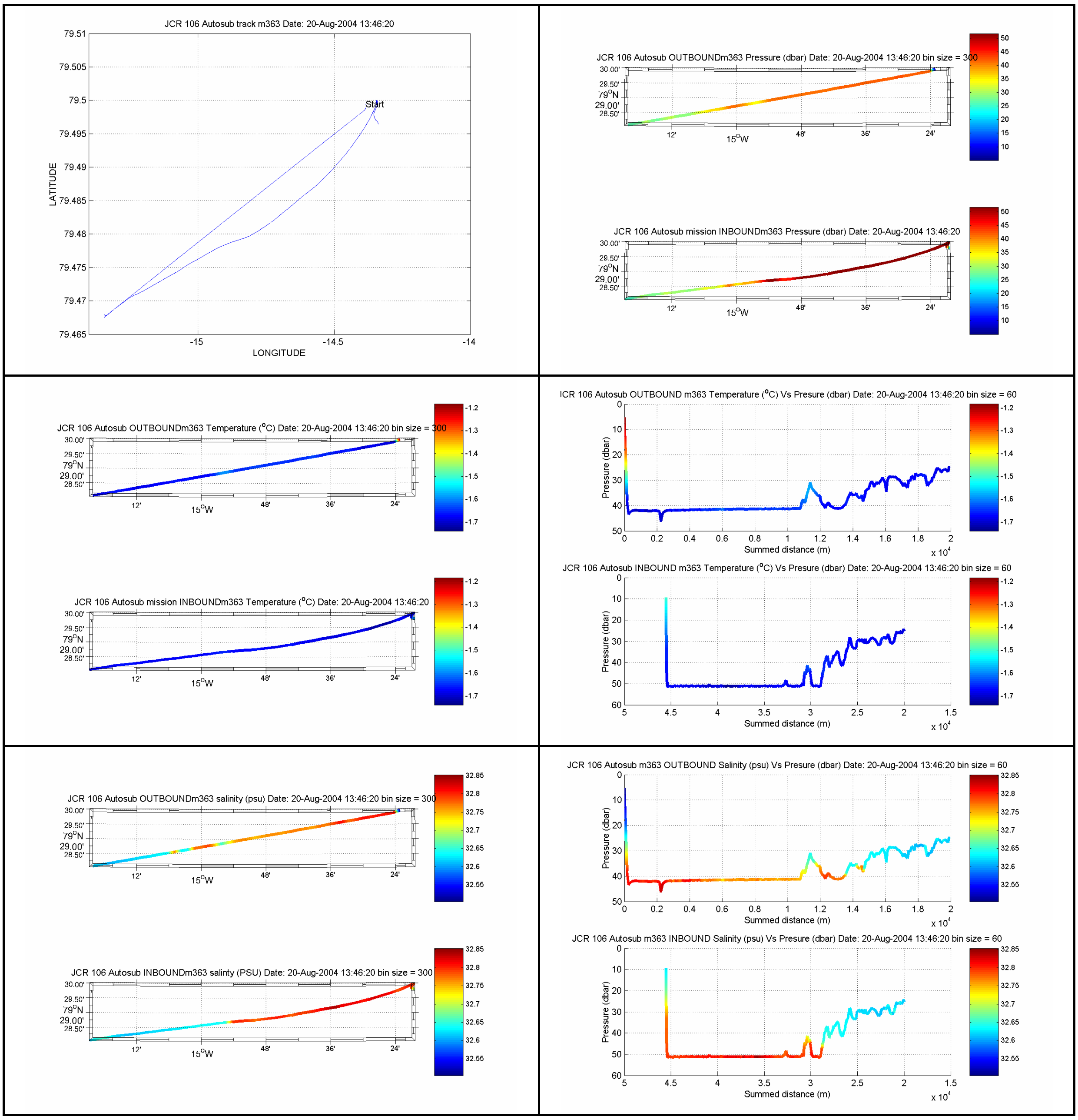


Potential Density

First results Autosub:

The processing of CTD data from the Autosub was slightly more complex than the ship-borne system as positional information had to be married to the .CNV file before it became usable. This occurred by running a series of matlab scripts that were written by JW whilst on board. These were in order of processing:

1. The first m-file loaded both the .CNV file and the navigational file .bnv from Autosub and interpolated the navigational data to the same resolution as the SBE 9 plus, i.e. 24Hz.
2. Once this was accomplished a second m-file removed all data when the Autosub was on the surface, i.e. above 5 m depth in our case. If two or more missions were run without the Autosub coming on board a different m-file would split the data into separate missions before removing data from the upper 5m.
3. The third m-file plotted each variable in turn and asked the user if it needs to be filtered (i.e. data spikes removed). If the data is particularly noisy it was filtered by calculating the mean and standard deviation over a user specified window size over the entire data. Data above a used defined number of standard deviations was removed. This procedure can be repeated a number of times.
4. The final m-file averages the data into user defined time steps. In our case data was averaged in to 1 second bins.
5. The final m-file plotted the data. An example of the output from this file can be seen below.


JCR 106 Autosub track m363 Date: 20-Aug-2004 13:46:20
Start
LATITUDE
LONGITUDE
JCR 106 Autosub OUTBOUNDm363 Pressure (dbar) Date: 20-Aug-2004 13:46:20 bin size = 300
JCR 106 Autosub mission INBOUNDm363 Pressure (dbar) Date: 20-Aug-2004 13:46:20
JCR 106 Autosub OUTBOUNDm363 Temperature (°C) Date: 20-Aug-2004 13:46:20 bin size = 300
JCR 106 Autosub mission INBOUNDm363 Temperature (°C) Date: 20-Aug-2004 13:46:20
JCR 106 Autosub OUTBOUND m363 Temperature (°C) Vs Presure (dbar) Date: 20-Aug-2004 13:46:20 bin size = 60
JCR 106 Autosub INBOUND m363 Temperature (°C) Vs Presure (dbar) Date: 20-Aug-2004 13:46:20 bin size = 60
JCR 106 Autosub OUTBOUNDm363 salinity (psu) Date: 20-Aug-2004 13:46:20 bin size = 300
JCR 106 Autosub INBOUNDm363 salinty (PSU) Date: 20-Aug-2004 13:46:20 bin size = 300
JCR 106 Autosub m363 OUTBOUND Salinity (psu) Vs Presure (dbar) Date: 20-Aug-2004 13:46:20 bin size = 60
JCR 106 Autosub m363 INBOUND Salinity (psu) Vs Presure (dbar) Date: 20-Aug-2004 13:46:20 bin size = 60
Pressure (dbar)
Summed distance (m)
x 10^4
79°N
15°W

MARINE TECHNOLOGY TESTS

Duncan Mercer (SAMS)

Greenland Arctic Shelf Ice Experiment (GreenIce)

Green Ice "buoy" on a previous deployment.

As part of the international Greenland Arctic Shelf Ice Experiment (GreenIce) project, an ice thickness measuring "buoy" was deployed onto a area of thick ice near to the ship. The buoy's position was chosen such that it was close to the centre of an area that had been surveyed previously, both by drilling and by an autosub swath mission. This location was chosen in order to allow cross comparison of various measurement methods. In addition to the measurements made by the JR106 team a series of E.M. measurements were made of the same area by the German teams from *Polarstern*.

This buoy was the fifth of the SAMS GreenIce buoys to be deployed (perversely enough the instrument was designated GreenIce01). The previous four buoys having been deployed north of Ellsmere Island in the Canadian Arctic ocean at latitudes of around 85ºN.

These buoys that were developed at SAMS are designed to make use of work by Nagurny. This work allows area averaged ice thickness "measurements" to be derived from measurements of ice dynamics. 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 across the Arctic Ocean through the ice cover. In the deep pack these waves have peak to peak amplitudes of around 1mm and periods of 30 seconds or so, though at the site for GreenIce01 these amplitudes were expected to be significantly larger. The primary sensor of these GreenIce buoys is a sensitive tiltmeter, this has to be able to resolve tilts in the surface ice cover, of 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 this 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 transmits it's data across the Iridium satellite phone network.

GreenIce01 was deployed onto the ice at 07:00Z 26/08/2004 at a position 79º19.87'N, 013º50.70'W. By the time of the buoys first measurement cycle at 18:00Z the buoy was lying on its side, all three of the independent tilt sensors (main, gross and "topple over") out of range. Given the carefully chosen deployment area of solid ice, and the buoy's inherent stability (wide base and very low centre of gravity) this "falling over" is extremely suspicious. The most likely explanation is polar bear activity. A set of tracks was seen in the snow prior to deployment and four bears were sighted in the area an hour or so after leaving the floe. At the time of writing it is hoped that a ship from the Norwegian Polar Institute may be able to visit the site sometime in the following month and investigate and right the buoy.

DWOS deep water Acoustic Modem trials

The DWOS (Deep Water Observing System) project is part of the UK's commitment to OSPAR (European Union, Oslo-Paris Accord). The aim of the project is to provide long term, real time measurements, of certain key water quality parameters. These measurements are to be made over the whole water column, off the edge of the UK continental shelf in water around 2-3 km deep. The JR106N cruise provided the ideal opportunity to test one of the key elements of the DWOS system, the acoustic telemetry link, in deep water.

"Acoustic modem trial" mooring being deployed.

The acoustic modem link (along with an Iridium satellite link) will enable real time two way communications with the DWOS profiling instruments when they are ultimately deployed in the North East Atlantic. The aims of the short trial on JR106 were to test some of the manufacturers claims about the acoustic modem selected for DWOS (a LinkQuest 4000), and to provide a series of controlled operational tests. These tests will ultimately be used to provide operational input into the final development of the DWOS profiler. The modem uses a spread spectrum chirp frequency range (12-20 KHz) and claims to provide a robust error corrected link across that channel.

The short mooring string (around 7m long) consisting of modem, release, anchor and buoyancy was deployed into 2500m of water at a position 77º36.33'N, 004º06.69'W. After deploying the mooring the JCR was allowed to drift such that the range from the mooring site gradually increased. This drift allowed the testing of the acoustic link between surface and seabed at a number of different distances. At each of the ranges a number of different data streams were transmitted surface to seabed and then back again, allowing some of the performance characteristics to be established. Data packet sizes of up to 10Kbytes were transferred. Initial results suggest that the link performed extremely well when the surface, seabed offset was 1000m or less. At greater ranges the performance was not quite as good as anticipated, though some of the problems might be related to the high background noise levels associated with ships. These trials suggest that the modem system will be suitable for use in the DWOS project, they do however highlight the need for the careful design of the transfer protocols to enable the system to cope with the more extreme ranges. Further consideration of the test results should inform this design of transfer protocol.

ALONG TRACK MEASUREMENTS

Jeremy Wilkinson

During the cruise the along track loggers recorded a number of meteorological and oceanographic parameters. In total 12 meteorological and 3 oceanographic parameters were logged. Both the oceanographic are meteorological parameters are explained below:

Oceanographic parameters

Oceanographic parameters recorded by the oceanlogger system which comprised of a thermosalinograph and fluorometer both of which were connected to the ship's non-toxic seawater supply. These parameters were recorded every 2 seconds. However due to our passage through ice covered seas the pumps to the logger were turned off in order for the sensors not to be damaged by ice. Time stamped bottles were taken to calibrate the salinity sensor.

Meteorological Parameters

A suite of meteorological sensors are on board JC. These include wind direction and speed, air temperature (x2), relative humidity (x2), barometric pressure (x2), Photosynthetic Active Radiation (x2), Solar Radiation (x2). Generally these instruments recorded at 2 second time intervals.

Other instruments

Other instruments that are generally logging continuously include the 5 navigational instruments, (Trimble 4000, Ashtec GG24, Ashtec ADU-2, Gyrocompass and Electromagnetic log) and a number of acoustic devices e.g. EM120, EA600, EK60 and TOPAS.

Database

The JCR database stores all along track data recorded during the cruise. This data can be accessed by a series of commands. Unfortunately we only had time to learn a few of the commands.

Data processing:

Due to our lack of knowledge of the onboard PSTAR software we spent the first few days writing scripts in UNIX, PERL and Matlab to process the along track data. A PERL script by Duncan Mercer merged all the meteorological, oceanographic, depth from the EM120 and positional information in to one time stamped file. This script was automatically run once a day using the crontab function. A Matlab m-file by Jeremy then processed the data. An example of the daily plots that were made available to all on board can be seen below:

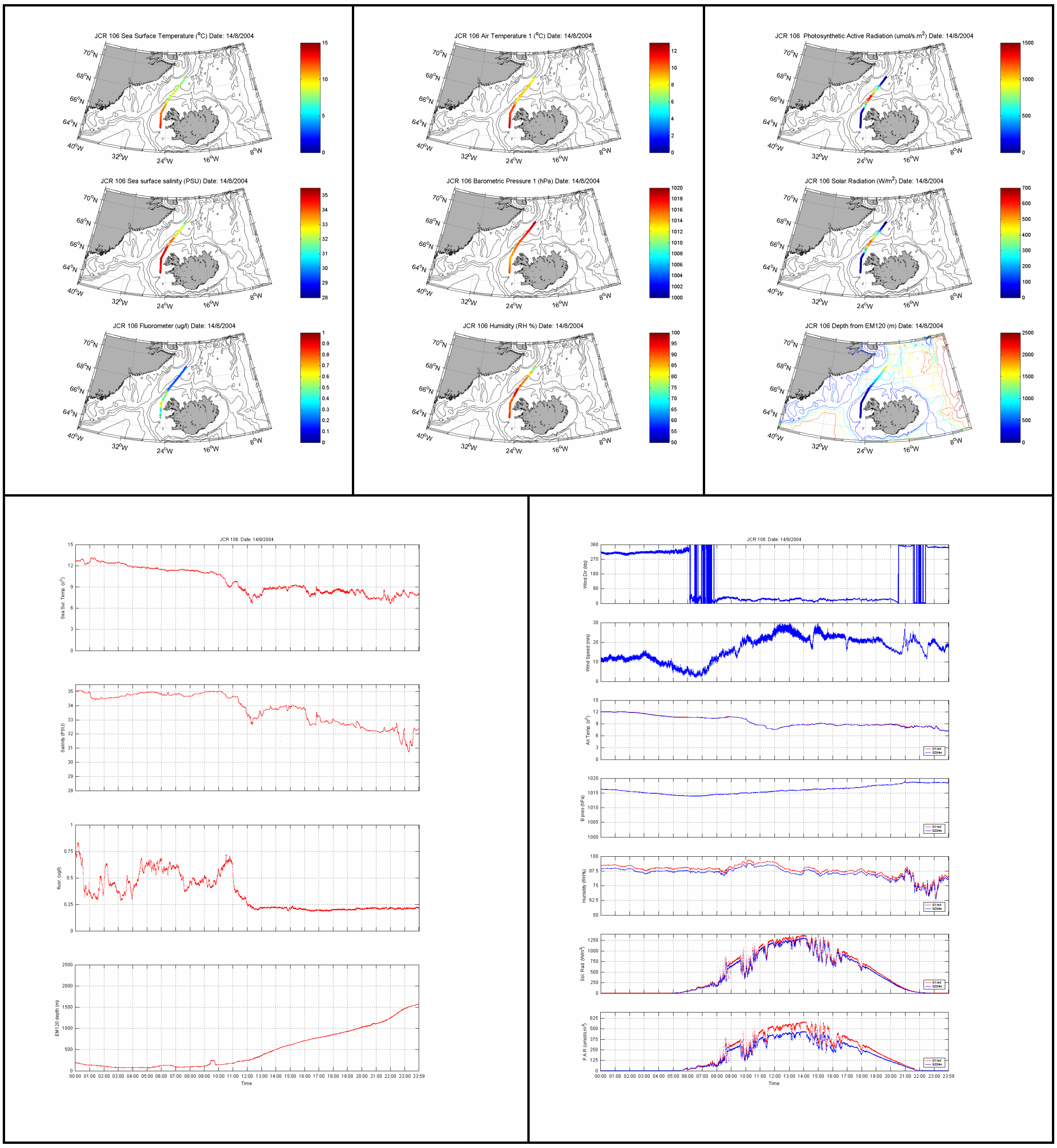


Figure: Visual display of the daily oceanographic and meteorological parameters logged on the 14 August 2004.

EM120 MULTIBEAM SWATH BATHYMETRY AND TOPAS

Jeffrey Evans (SPRI) and Colm Ó Cofaigh (SPRI)

1. Introduction

EM120 12 kHz multibeam swath bathymetric and TOPAS data was acquired continuously during the transit to, and from Iceland, and in the main study area of NE Greenland and the Fram Strait. This section provides an overview of the geophysical methods and data acquired from the NE Greenland continental shelf and adjacent slope along the western side of the Fram Strait. Data acquired during the transit to, and from Iceland, are not included here. Watch-keeping of the EM120 and TOPAS workstations was carried out by Jeffrey Evans (SPRI), Colm Ó Cofaigh (SPRI), Ruth Mugford (SPRI) and Zoe Roberts (SOC).

2. Data acquisition

2.1.1 EM120 Swath Bathymetry

The Kongsberg-Simrad EM120 multibeam swath bathmetry system was operated throughout the cruise. Angular coverage was set to “Manual” and beam spacing was set to “Equidistant”. The beam angle used varied according to sea conditions, water depth and sea-bed type but was generally between 60-68 degrees. During surveys, overlap between individual swath lines was achieved by means of the Helmsman’s Display on the bridge, which the Bridge Officer used to adjust the ship’s course and maintain a reasonable degree of overlap (10%) between lines. Limited post-processing of the EM120 data (gridding and data filtering) was carried out using the Kongsberg-Simrad NEPTUNE post-processing software. In general the EM120 worked well in water depths down to about 3000 m throughout the cruise, especially in shallow water (<1000 m) on the continental shelf. Where the system lost the sea-bed from time to time the most useful method was to use the “Force Depth” command with a depth slightly less than the true seabed. Restricting the maximum and minimum depths to a tight range around the true seabed depth was also useful.

The EM120 system performed well and problems encountered during previous cruises (notably with regard to the SSU on cruise JR84) were absent. The most significant problem that we did encounter concerned the map projection used on the transit survey north. We initially selected ”UTM” from the options available in the Merlin software. However above 78 degrees north the survey became unstable and would frequently crash when using the mouse to move around on the logging workstation screen. This problem was particularly prevalent when trying to set up the “Bridge Display”. Resolution of this problem could be achieved by creating a separate map projection for the UTM zone of the survey. This is a relatively straightforward solution when engaged in the survey of a specific area. However, during long transits it is less satisfactory as it would necessitate the progressive creation of a series of projection files. We solved this problem by check/replaying the transit lines on the NEPTUNE (processing) workstation, which then allowed us to select a different projection for the survey (Mercator 60). The survey was then exported back to the logging disk and re-opened on the logging workstation with the new projection. This appeared to solve the problem and no more crashes occurred.

As on previous cruises where the EM120 was used in pack ice (JR84 and JR104), it was found that when the ship was moving through the ice the swath signal deteriorated significantly. However, the signal returns in only a few metres of open water. The EM120 acquisition parameters used are described below:

MBES screen

Ping Mode: Auto

Sector Coverage

	Max Port Angle:	50-70
	Max Starboard Angle:	50-70
	Angular Coverage:	Manual
	Beam Spacing:	Equidistant

Pitch stabilisation:	On
Yaw stabilisation:	Off
Min depth:	Used to constrain depth when bottom is lost
Max. depth:	Used to constrain depth when bottom is lost

Sound Speed Profile

Current Sound Profile: jr104_xbt??.asvp

Sound Speed at Transducer:

From:	Profile
Sensor Offset:	0.0 m/s
Filter:	60s

Filtering

	Spike Filter Strength:	Medium
	Aeration:	Off
	Sector Tracking:	On
	Slope:	On
	Interference:	Off
	Range Gate:	Normal
Absorption Coefficient		
	Absorption (dB/km):	1.00
Seabed Imaging		
	TVG Crossover (deg)	6

2.1.2 TOPAS Sub-Bottom Profiler and EPC Chart recorder

The TOPAS system was used extensively throughout the cruise and generally performed very well. As in the case of the EM120, sea ice affects the TOPAS signal quite badly. It results in many high amplitude signals resulting in dark traces across the record. In heavy sea ice this can have the result of obliterating any meaningful data. In water depths of less than 1000 m we ran TOPAS using a Burst mode whereas in depths greater than this we used the Chirp. TOPAS acquisition parameters are outlined at the end of this section.

The EPC chart recorder worked without any problems throughout the cruise. TOPAS input to the EPC chart recorder was on Channel A. The settings used were: 0.5 second sweep; 0 delay; threshold 1/3 of a turn clockwise from the minimum setting; trigger level 0; gain generally about 8-10; sweep direction from left to right; print polarity +/- (centre setting). Chart settings: scale lines: on; take-up: on; mark/annotate: off (centre setting); chart drive: internal (centre setting), LPI was generally set to 75; contrast setting: centre.

Ten-minute time and EM120 centre depth data were relayed to the 9800 Series Graphic Recorder Computer and were automatically marked on the EPC Chart Recorder paper roll. On occasions the time and EM120 centre depths were not marked on the paper roll. This required a system reboot of the 9800 Series Graphic Recorder. This is carried out by: (a) ALT-X to Exit the software; (b) selecting ‘Return to DOS’ from the menu; (c) System reboot (flick main computer button off and then on); (d) Let system boot up and then select ‘Acquisition mode’ and the plotter will begin to automatically send time and EM120 centre depth data to the EPC paper roll.

(a) TOPAS Acquisition Parameters in <1000 m water depth

Parasource Menu

Level:	100%
Ping Interval:	0 ms (enables external SSU triggering)
Pulseform:	Burst
Period:	1 or 2
Secondary Frequency:	2800 Hz

Acquisition Menu

Ch_no:	0
Speed of Sound (m/s):	1500
Sample Rate:	20000 Hz
Trace Length (ms):	400
Gain:	12 – 28 dB
Filter:	1.00 kHz
Delay:	Manual

Processing Menu

Channel no:	0			
Filter:	ON			
	Low stop:	1200	Low pass:	4800
	High pass:	1700	High stop:	5200
Processing (deconvolution):	OFF			
Swell:	ON			
	Threshold:	60%		
	# traces:	1		
TVG:	OFF or AUTO or Man (all used at different times)			
	Slope:	(30 – 60 dB slope)		
	Start point:	Manual or Tracking or External		
Deverb:	OFF			
Stacking:	OFF			
AVC:	OFF			
Scale (%):	700 – 1000	Attribute:	INST.AMP	

LOG/Replay Menu

Medium:	DISK
Rate (ms):	1000
Channel:	0
File size (Mb):	10

(b) TOPAS Acquisition Parameters in >1000 m water depth

Parasource Menu

Level: 90 – 100%
Ping Interval: 2000 – 5000 ms (Manual triggering over rides SSU triggering)
Pulseform: Chirp
Chirp start frequency (Hz): 1500
Chirp stop frequency (Hz): 5000
Length (ms): 15
Period: 1 or 2
Secondary Frequency: 2800 Hz

Acquisition Menu

Ch_no: 0
Speed of Sound (m/s): 1500
Sample Rate: 20000 Hz
Trace Length (ms): 400
Gain: 20 – 32 dB
Filter: 1.00 kHz
Delay: Manual or External

Processing Menu

Channel no: 0
Filter: ON
Low stop: 1200 Low pass: 4800
High pass: 1700 High stop: 5200
Processing (deconvolution): DECONV
Filter factor (ppm): 1
Swell: ON
Threshold: 60%
traces: 1
TVG: OFF or AUTO or Man (all used at different times)
Slope: (30 – 60 dB slope)
Start point: Manual or Tracking or External
Deverb: OFF
Stacking: OFF
AVC: OFF
Scale (%): 1000 – 3000
Attribute: INST.AMP

LOG/Replay Menu

Medium: DISK
Rate (ms): 1000
Channel: 0
File size (Mb): 10

2.1.3 SSU – Sonar Sequencing Unit

The SSU was used throughout the cruise to synchronise the EM120, EA600 and TOPAS systems. The bridge echosounder (EA600) was run on passive, external trigger, and listened out for the EM120 centre-beam return and used this to calculate depth below the ship. Whenever, the EM120 was not active the EA600 was switched to Active, internal triggering. The TOPAS was triggered by the SSU in water depths shallower than 1000 m. In water depths deeper than 1000 m the TOPAS was internally triggered at 2000 – 5000 ms ping intervals. The main settings used on the SSU are listed below:

Group:	EM & EA, EK, TOPAS	
Trigger:	EM120 & EA600:	ON (both systems)
	EK60:	OFF
	TOPAS:	ON
Time usage:	EM120 & EA600:	Calculated (both systems)
	EK60:	OFF
	TOPAS:	Calculated
Time add on:	Not used for any of the systems	

2.1.4 Expendable Bathythermograph (XBT) System

Eight XBT casts were made during JR106 (North) (see Table 1). Five were deep-water T5 probes that record to 1830 m water depth. The remaining three were shallow water T7 probes that record to water depths of 760 m. All the XBT deployments were successful and the sound velocity profiles (SVP) input to the EM120 and used in the relevant surveys. Only a small number of XBT's were required during the cruise as the SVP remained fairly consistent within the study area. The SVP's used on the northbound transit were also used southbound.

The XBT system on the James Clark Ross worked well throughout the cruise. Individual SVP profiles were calculated from the XBT data by the system software, assuming a constant salinity. Salinity values were obtained from the Oceanlogger display (located in the UIC), and input to the XBT system software manually. The seawater supply to the Oceanlogger was switched off for periods during our work on the continental shelf due to problems caused by sea ice. On these occasions the most recent valid salinity measurement was utilised. The *.edf files (calculated sound velocity profiles) generated by the XBT system software were transferred to the multibeam data processing workstation, and the data then imported into the multibeam data acquisition system across the network.

Table 1. Summary of XBT stations.

Cast	Filename	Time/date	JDay	Latitude N	Longitude W	Geographical location
T7 - 1	T7_00011	15:31:55 08/14/2004	227	67° 32.146'	22° 48.999'	Northern Iceland continental shelf
T5 - 2	T5_00012	11:38:15 08/15/2004	228	70° 37.036'	15° 40.105'	Scoresby Sund continental slope
T5 - 3	T5_00013	20:23:03 08/15/2004	228	71° 55.365'	12° 17.006'	Greenland sea NW of Jan Mayen
T5 - 4	T5_00015	19:07:06 08/16/2004	229	76° 15.666'	7° 0.285'	NE Greenland continental slope
T5 - 5	T5_00017	11:26:37 08/18/2004	231	78° 38.338'	0° 28.6289'	Fram Strait
T5 - 6	T5_00019	17:14:37 08/18/2004	231	78° 49.744'	4° 13.652'	Fram Strait
T7 - 7	T7_00021	22:10:15 08/21/2004	234	79° 29.525'	14° 11.447'	Northwind Shoal, NE Greenland
T7 - 8	T7_00023	19:50:03 08/23/2004	236	80° 21.902'	13° 23.053'	Shelf trough north of AWI Bank

2.1.5 Oceanlogger

The Oceanlogger was operated during JR106 (North) in order to monitor changes in surface water characteristics that affect sound propagation, and to measure surface water salinity values for calculation of SVP's from XBT data. The Oceanlogger did not operate during our work in the ice on the continental shelf as the pump supplying seawater to the logger had to be stopped as fragments of ice clogged the filters. The seawater pump was operational during the north and south transits and also across the continental slope and parts of the shelf of the study area.

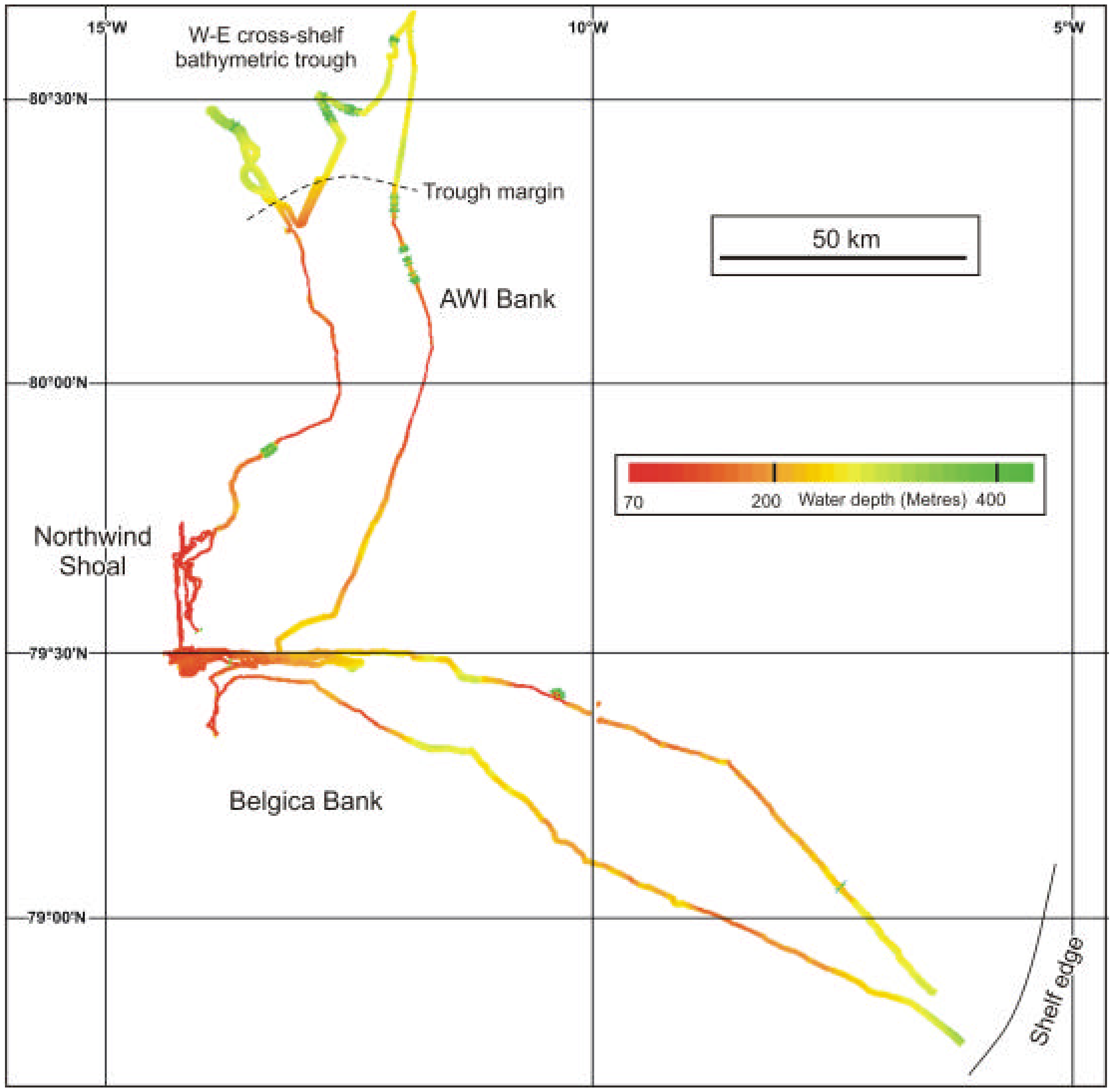


Figure 1. Unprocessed EM120 swath bathymetry acquired along the JR106 (North) track lines across the NE Greenland continental shelf. The Belgica Bank, Northwind Shoal and AWI Bank are marked.

2.2 Results and preliminary interpretations

2.2.1 Bathymetry

The NE Greenland continental shelf in the study area comprises a prominent shallow bank complex that is sub-divided into three main regions, the Belgica Bank in the south and west, Northwind Shoal to the west and the AWI Bank to the north. Water depths across these banks are 70-140 m (Fig.1). The bank complex is incised by a NW-SE trending trough with water depths of 145-300 m that extends to the outer shelf (Fig.1). A prominent W-E trending bathymetric trough also extends from the inner to the outer shelf north of the AWI Bank. Water depths in this trough range are 230-330 m and progressively deepen towards the inner shelf to the west, and north (Fig.1).

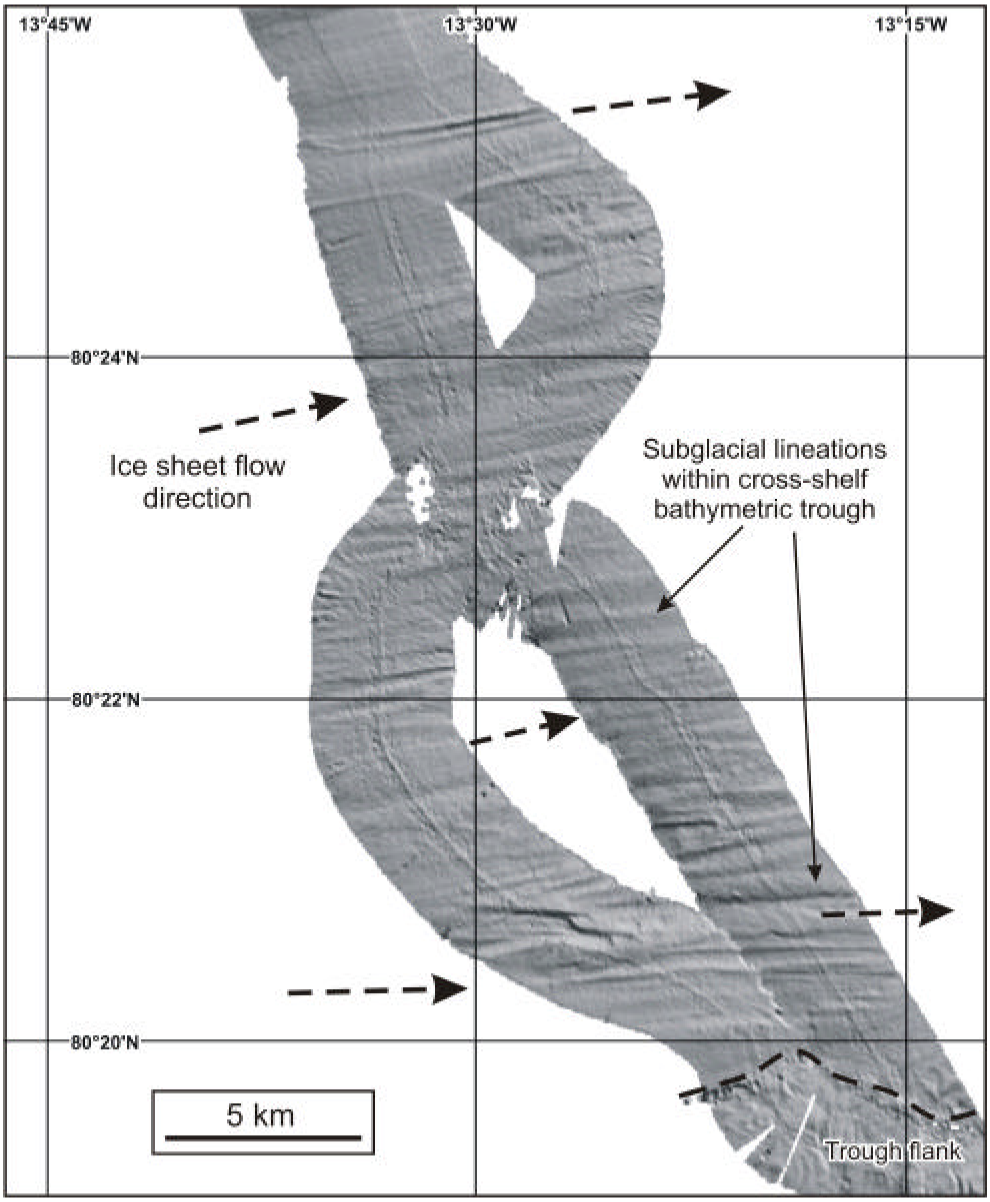


Figure 2. Unprocessed EM120 swath bathymetric shaded relief image of subglacial lineations in the cross-shelf bathymetric trough to the north of AWI Bank. The bedforms record former ice sheet flow to the east. Grid cell size = 30 m x 30 m.

2.2.2 Subglacial bedforms and iceberg scours

Streamlined subglacial bedforms and iceberg scours are observed on the swath bathymetric and TOPAS records from the NE Greenland continental shelf (Figs. 2 & 3). The subglacial bedforms provide evidence for an extensive Greenland Ice Sheet that extended onto the outer continental shelf of NE Greenland, and probably reached the shelf edge. Subglacial lineations (≥5.7 km in length and ≤0.4 km in width) are widely distributed and well preserved in the W-E trending bathymetric cross-shelf trough north of AWI Bank (Fig. 2). The distribution of bedforms within the trough indicate that the Greenland Ice Sheet drained eastwards following the convergence of flow emanating from Dijmphna Sund and Ingolf Fjord region of NE Greenland. The highly attenuated form of the lineations suggests that this outlet may have been fast flowing. Subtle subglacial lineations (≥4.3 km in length and ≤3.5 km in width) and ice-moulded bedrock are present within the NW-SE trending trough running between Belgica Bank, Northwind Shoal and AWI Bank indicating that palaeo-ice flow was channelled to the southeast across this area of the shelf. Subtle streamlined bedforms also occur on Northwind Shoal indicating ice flow to the northeast across this shallow shelf (Fig. 3).

TOPAS records indicate that the subglacial bedforms are formed in the surface of an acoustically transparent sediment layer that has a distinct continuous sub-sea floor basal reflector. This layer is interpreted as a till unit. TOPAS records from the trough east of Northward Shoal *i.e.* east of 14°30'W, are dominated by a series of reflectors that dip towards the shelf edge. This unit is interpreted as a 'till delta' or grounding-zone wedge where subglacial sediment was advected to the ice-sheet margin. These sediments are overlain and truncated by the acoustically transparent sediment unit in which the streamlined subglacial bedforms occur. This implies that the ice advance, which formed the bedforms, occurred after the formation of the grounding-zone wedges and, therefore, that these ice-marginal features are probably a result of deposition during ice-sheet advance rather than retreat.

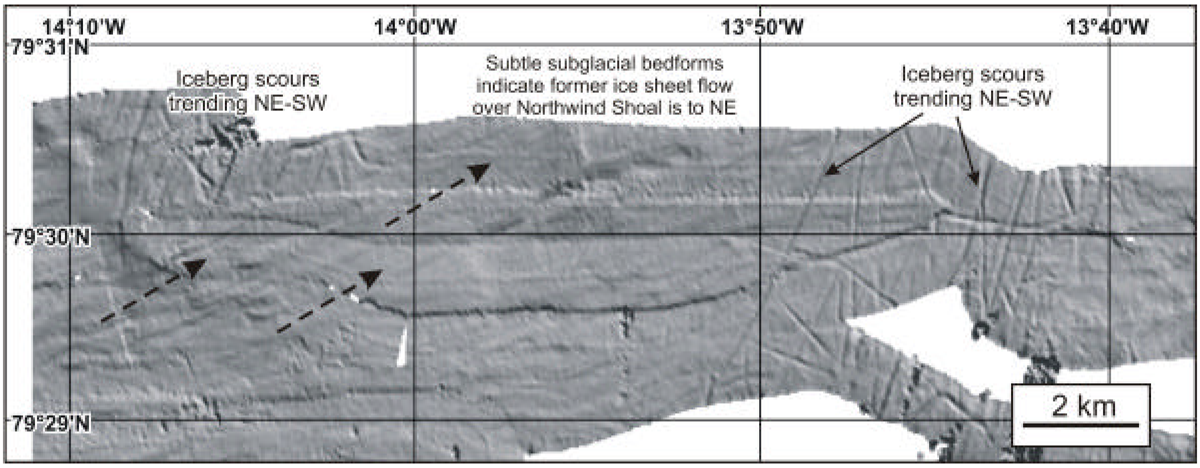


Figure 3. Unprocessed EM120 swath bathymetric shaded relief image of iceberg scours and subtle subglacial bedforms across Northwind Shoal on the NE Greenland continental shelf. Bedforms indicate that former ice sheet flow is to the NE. Grid cell size = 30 m x 30 m.

Swath bathymetric and TOPAS records indicate that the Belgica Bank, Northwind Shoal and AWI Bank for the most part, are dominated by discrete iceberg scours that are irregular to linear in form (Fig. 3). Iceberg scours are either randomly orientated or they have a preferred N-S, NW-SE or NE-SW orientation (Fig. 3) suggesting a strong influence of the southward flowing East Greenland Current on iceberg trajectories. TOPAS records indicate that iceberg scouring of the sea floor has homogenised the sedimentary record in this region.

TOPAS records from the continental slope adjacent to this region of the NE Greenland continental shelf comprise widespread, stacked, acoustically-transparent sediment bodies. These bodies are lens-shaped in an along-slope direction and are orientated downslope. They are interpreted as debris flow deposits. The widespread occurrence of debris flow deposits on the slope in this region supports the interpretation of an advance of the Greenland Ice Sheet to the shelf edge. The ice sheet delivered glacial sediment directly to the upper continental slope and this sediment was subsequently remobilised downslope by debris flow processes.

Prominent submarine channels are present on swath bathymetric and TOPAS records from the lower continental slope in >2500 m water depth between 73° and 76° N. The channels incise acoustically stratified sediments that are likely the result of turbidity current deposition.

SHIPBOARD ADCP

Gwyn Griffiths (SOC)

The RD Instruments 150 kHz shipboard ADCP (VM-150) was used throughout the cruise for current profile measurements. No technical problems were encountered. Key configuration parameters were:

Ensemble interval: 2 minutes initially, then 5 minutes
Cell length: 8 metres
Number of cells: 50
Bottom tacking: enabled

The instrument was set to use the computed sound velocity for correcting its velocity data. The usual clock drift within the PC was noted each day for later correction. Data processing used the 'pstar' route, via the Level C 'adcp' data stream, through a series of unix scripts on jrua. Ancillary measurements from the ship's gyrocompass, the Ashtech ADU GPS-based heading reference and GPS position were acquired, processed and merged with the ADCP data as described in sequence below:

gyroexec0
reads in gyro data, performs checks and appends to a gyro data file for the cruise (106gyr01).

ashexec0
reads in Ashtech ADU data and edits the data based on limits set on the quality parameters mrms and brms.

ashexec1
merges the Ashtech and gyro data, to give the heading difference a-ghdg. This is an especially important correction in high latitudes where the gyrocompass error is magnified by the secant of latitude (errors at 80° being nearly three times those at 60°). In addition transient errors of several degrees due to damped Schuler oscillations caused by sharp changes of course needed to be corrected.

ashexec2
despikes the a-ghdg data and forms an average over 5 minutes.

navexec0
reads in the 'bestnav' navigation data and calculates ship speed and distance run over the ground from successive fixes.

navexec1
despikes the data and averages to 2 minutes.

adpexec0
reads in the adcp data, splits the (ungridded) bottom track data from the gridded water column profiles.

adpexec1
corrects the timing based on manual records of clock drift

adpexec2
merges in the heading correction from the ashexec2 file

adpexec3
applies the calibration to the velocity data

adpexec4
merges in the smoothed navigation data and calculates absolute currents. These files (styled 106adp'jday'd.abs) are then appended to form cruise files, which are then averaged to 10 minutes. From these files velocity profiles or single depth maps can be produced. ASCII copies of these averaged concatenated data files were also made available for processing using Matlab ®.

Calibration

The initial calibration of the VM-150 was checked against GPS during two runs, each of over two hours, on the NW Icelandic shelf. The scale factor (A) was found to be 1.021 +/- 0.001 and the offset angle (phi) was –1.65°. That is, the ADCP vector needed to be rotated anticlockwise by 1.65 degrees. This calibration was at an indicated temperature of 15.8°C. Later, it became clear that this calibration was in error when operating in water temperatures of less than 0°. At these times, the ADCP transducer temperature was in the region of 6°C, but it is not immediately obvious that this is not the correct temperature within the transducer well. Nevertheless, a calibration on the Greenland shelf showed that while the offset angle was no different, the scaling factor should be 1.0426. ADCP data for day 230 onwards was recalibrated. This calibration was used until the end of day 240.

Range and acoustic backscatter

The range performance of the instrument was impressive. During this cruise, with calm conditions, in excess of 400 m range was usual. With the ship locked into an ice edge, the indicated currents were reasonable, although bottom track was lost and the backscatter profile was anomalous in showing a faster decay than would be expected from spherical spreading.

An approximate calibration was applied to the acoustic backscatter from the VM-150 in order to assess the likely profiling range of the ADCPs on Autosub and for future reference against which the performance of Autosub's ADCPs could be checked.

Key ADCP and ancillary data files

Instrument	Pstar master file	Version	ASCII master file	Notes
Gyrocompass	106gyr01	AS	106gyr01.asc	Covers day 226-242(1040)
Ashtech	106ash01.int	AO	106ash01.int.asc	Covers day 226-242(1040)
GPS	106gps01	AN	106gps01.asc	Covers day 226-242(1040)
GPS (bestnav)	abnv1061	DB	abnv1061.asc	Covers day 226-242(1040)
GPS (bestnav)	abnv1061.av	CD	abnv1061.av.asc	As above, 2 min average
ADCP (water)	106adp01.abs 106adp01.abs.av	BI BE	106adp01.abs.asc 106adp01.abs.av.asc	Covers day 226-end 229 Iceland shelf calibration
	106adp02.abs 106adp02.abs.av	AH AQ	106adp02.abs.asc 106adp02.abs.av.asc	Covers day 230-end 240 Greenland shelf calibration
	106adp03.abs 106adp03.abs.av	AA AB	106adp03.abs.asc 106adp03.abs.av.asc	Covers day 241-242(1030) Iceland shelf calibration
ADCP (bottom)	106bot01	AC	106bot01.asc	Covers day 226-end 229 Iceland shelf calibration
	106bot02	AC	106bot02.asc	Covers day 230-end 240 Greenland shelf calibration
	106bot03	AA	106bot03.asc	Covers day 241-242(1030) Iceland shelf calibration

LADCP

Terry Edwards (UKORS), Guy Williams (ACECRC) and Pat Cooper (BAS)

Introduction

An upward s/n 1885 and downward s/n 4275 Lowered Acoustic Doppler Current Profiler (LADCP) was mounted on the CTD Rosette and deployed for each CTD cast during JCR106 to determine current velocity.

Setup

The downward looking LADCP was used as the master unit on all casts, reasons being purely historical. Master / slave synchronisation was carried out electronically between the two units. Casts 1 to 4 were set up using the script files in Part 1 of Appendix C. Casts 5 to 20 using the script files in Part 2 of Appendix C. The main differences being the number of pings per ensemble, time per ensemble, bin depths, number of bins and the ping interval. The RDI workhorse manual carries full descriptions of the parameter meanings and implications.

Both upward and downward looking units have the "lowered" option enabled. This allows a degraded bottom track facility. Although bottom tracking accuracy is reduced, a separate bottom tracking ping is not required so that current velocity measurements are not degraded. Range of "lowered" bottom tracking is approximately 150m.

Firmware version in both units was 16.18

Power was supplied to both units from a rechargeable battery pack mounted on the frame. Data downloaded using BBTALK software.

Operation

Cast	*Problem*
3	Upward-looking instrument did not record / not initialised successfully
5 – 20	Set-up file changed (Bin size, Bin No. Pings/Ensemble

Results

A preliminary set of results were generated using MATLAB scripts from Martin Visbeck and Lamont-Doherty Earth Observatory, Version 7, 2002. All result files are provided on the JCR106 cruise data CD.

Initial comparisons with the time-averaged Ship ADCP data for each cast were found to be promising (see below).

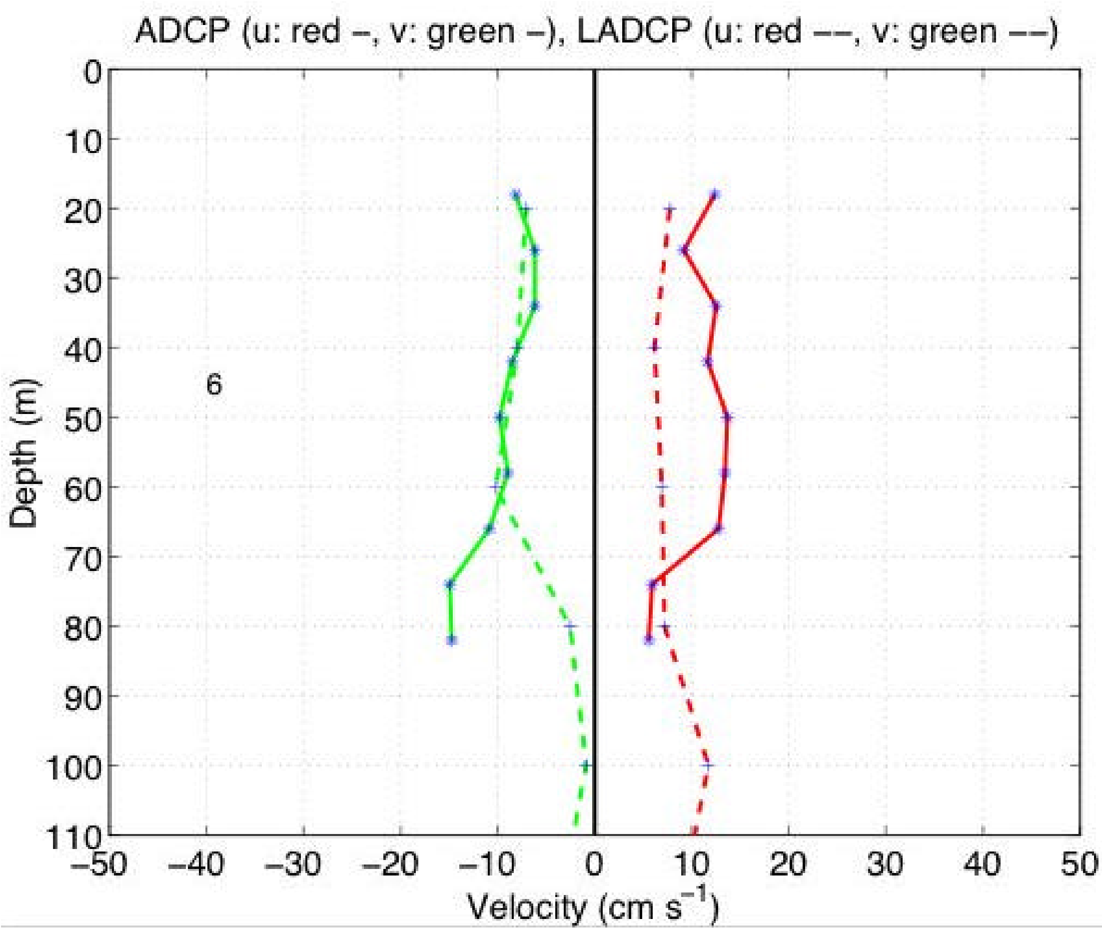


Figure 1. LADCP (dashed) and Ship ADCP (thick) velocities (u – red, v – green) for Stn 6. The Ship ADCP data are the time average velocities over the duration of the LADCP/CTD cast.

Discussion

The preliminary results show that the LADCP is fairly consistent in structure and magnitude with the ship-mounted ADCP for the majority of casts. Due to the lack of specialised expertise in processing the LADCP data on board JCR106, further work is expected to increase the accuracy of the results. This includes utilising the CTD data, ships navigation data and examining the bottom tracking capabilities of the instrument.

CONTINUOUS PLANKTON RECORDER

Peter Wadhams

A Hardy-Longhurst continuous plankton recorder (CPR) was deployed during the northward and southward passages of *James Clark Ross*. The recorder was provided by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), Plymouth. It consists of a towfish which funnels water through a collecting slit in which a section of silk is exposed, which is then wound against a second spool of silk and deposited in a formalin preservative bath. The recorder thus acts as a "tape recorder" for plankton types and quantities along track. Such recorders are towed behind merchant ships and provide a valuable survey of plankton variability in the ocean, but have not yet been used further north than Iceland.

The instrument was invented by Sir Alister Hardy and was first used on the first of the Discovery Committee investigations in the Southern Ocean in 1924, as described in his book "Great Waters".

The recorder was deployed two hours out of Reykjavik and used as far as 77°N. On the return it was deployed at 77°36'N for the run back to Iceland. The cassette is changed every 500 n.ml., and four were used during the experiment.

ITS REPORT

Doug Willis (BAS)

1. Netware / PCs

There were no problems with JRNA during the cruise.

1.1. Workstations/Laptops

A number of laptops were connected to the network of science use during the cruise. Most were Windows machines and connected using samba and the email was accessed using either IMAP or POP3.

2. AMOS Server

No issues outstanding and the system worked well.

2.1. SUS and Sophos services

Commissioned the Sophos and SUS services on JCR-AMOS-S1. The systems updated from BAS HQ and once they were up to date all the BAS supported machines were configured to collect their updates from these services. Two issues were found with configuring the workstations for the SUS service.

- Windows 2000 machines must be at service pack 3 before the update services work.
- Some machines had hat the auto update service disabled in the services control panel thus preventing the updates from being collected from the server.

3. Data Logging Systems

3.1. Logging

Currently logging the following sensors.

Number	***Sensor Name***	***Levc credat names***
001	Glonass	gps_glos
015	GPS-ADU	gps_ash
023	Trimble	gps_nmea
029	Anemometer	anemom
032	TSSHRP	tsshrp
038	Oceanlogger	oceanlog
058	Emlog	em_log
060	Dopplerlog	dop_log
063	Simrad-ea500	sim500
065	Simrad-em120	em120
082	Winch	winch
096	Truewind-spd	
097	Truewind-dir	
098	Seatex	seatex
101	SeaSpy	seaspy

108	NGYRO	ngyro

3.2. SCS

The SCS data logging system performed well and there were no faults.

Date	***Time***	***Events***
12/08/2004	08:19	Started logging
13/08/2004	15:51	AUD5 reset due to loss of heading information
26/08/2004	23:16	AUD5 reset due to loss of heading information
29/08/2004	18:00	Data logging stopped.

3.3. SCS data outputs.

Two serial navigation streams were setup for this cruise. One containing the gyro heading was passed down to the main lab for the AutoSub team to use and one containing GPS navigation data was passed to the CTD deck unit in the UIC.

3.4. EM120 Swath / TOPAS

The EM120 and Topas were run for most of the cruise.

The EM120 became unstable once we reached latitudes of 78° or more. The first symptoms were that the helmsman display would crash when the maximize button was clicked. To avoid the crash first zoom in than expand. Later the helmsman display would not start at all. This fault was traced to the projection that was being used at the time. The setting was UTM. Changing this fixed the problems.

The EM120 logging machine once ran out of disk space and had to have files removed from it to resolve this issue. The cause of this was the automated data checking routines were not functional on the Neptune system. This also caused a similar problem on the Topas machine. This has been resolved.

During the course of the cruise the Neptune processing machine experienced three unexplained re-starts. The system is being monitored and the latest crash dump is to be analyzed to identify the fault.

4. Unix Systems

4.1. License managers.

Currently the Uniras license manager is being run on JRUI as it will not run on Solaris 9 machines. There is an updated version at BAS that will be installed once the CODIS link is available to transfer the data.

5. Network

Work began on the CODIS link. The dish was commissioned and a link established to BAS HQ. The router configuration needs some modifications and this is has been passed to Richard Cable.

The 3com switches in the main lab were removed from their rack to try and trace the current fault. As yet no solution to their continued unreliability has presented its self. Work will continue on the next leg of the cruise.

APPENDIX A - ICE STATION DATA

Ice station 1, 20 August

Went on ice 1510. Position 79º29.94'N, 14º24.54'W. Started Line 1 of holes parallel to ship's head. 5 m intervals. Measured snow depth, freeboard, total ice thickness.

Table 1: Line 1

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0	5	9	145	79.4988861	-14.4091597	
5	15,13,12	13	147			
10	15,11,11	12	160			
15	12,12,15	15	175			
20	10,10,10	12	170			
25	8,8,9	12	175	79.4988327	-14.4105759	
30	10,15,9	13	173			
35	10,11,8	16	195			
40	8,8,8	15	162			
44-47						Melt pool
50	13,10,15	23	167	79.4988174	-14.4114819	
55	10,9,13	20	170			
60	11,10,10	18	222			
65	21,10,15	27	220			
70	8.7.11	20	226			
75	10,8,11	25	193	79.4987793	-14.4128284	
80	8,8,8	31	250			
85	5,7,7	28	196			
90	5,7,8	12	193			
95	10,10,9	2	161			
100	11,8,15	28	198	79.498764	-14.4141111	

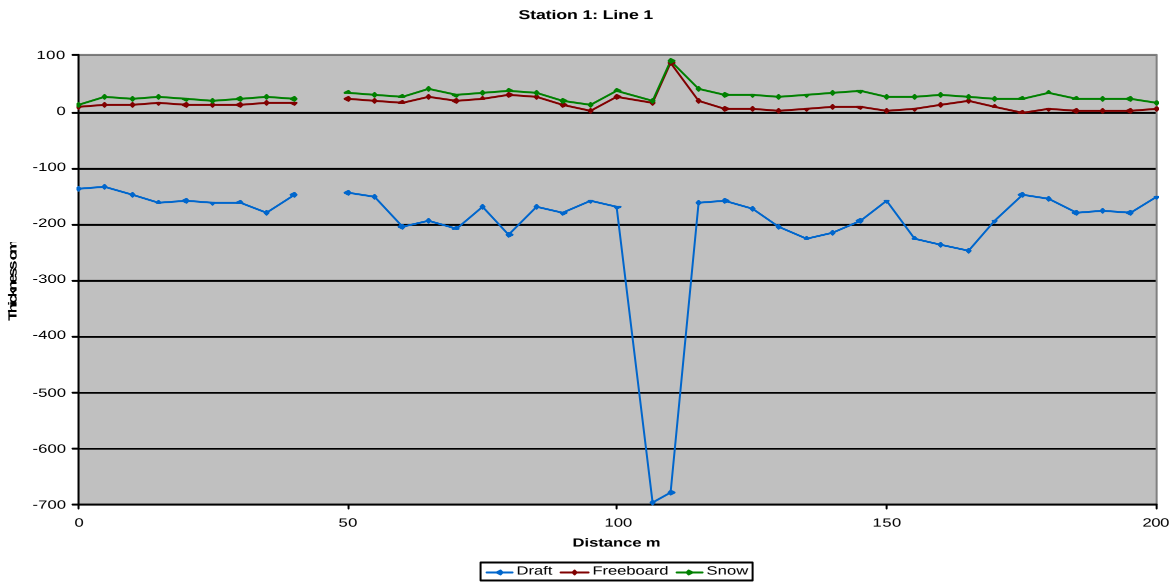
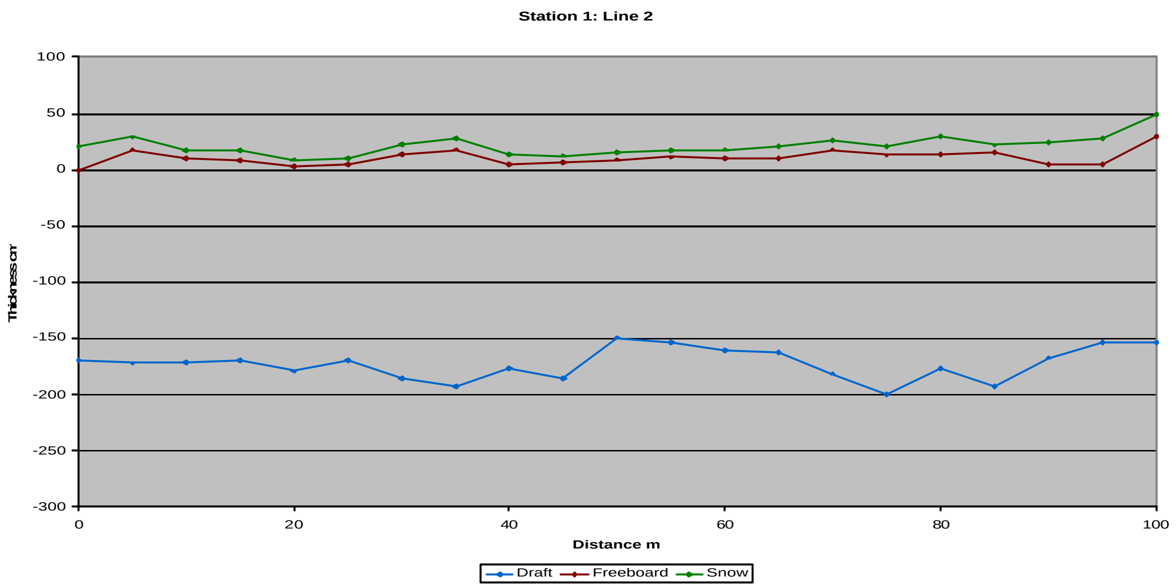


Table 2: Line 2, parallel to Line 1, 5 m away, also from 0 to 100 pointing along line of ship.

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Commenst*
0	20,22,20	0	169			
5	7,6,20	18	190			
10	7,8,8	10	181			
15	10,8,9	8	177			
20	6,6,6	3	182			
25	5,7,5	5	174			
30	7,12,8	14	199			
35	10,10,11	18	210			
40	9,8,8	5	182			
45	6,6,5	7	193			
47-48						Melt pool
50	8,6,7	9	158			
55	6,7,7	11	165			
60	8,8,8	10	171			
65	10,11,13	10	173			
70	8,10,8	18	199			
75	8,7,7	13	212			
80	16,14,16	14	191			
85	6,6,8	15	208			
90	23,22,15	5	172			Slushy
95	23,23,23	5	158			
100	17,22,17	30	184			



Also took core at about centre of line 2. Two 1 m sections saved in deep freeze.

Ice station 1 (cont.), 21 August

Continued line 1 of holes parallel to ship's head. 5 m intervals. Measured snow depth, freeboard, total ice thickness.

Table 3: Line 1 (continued)

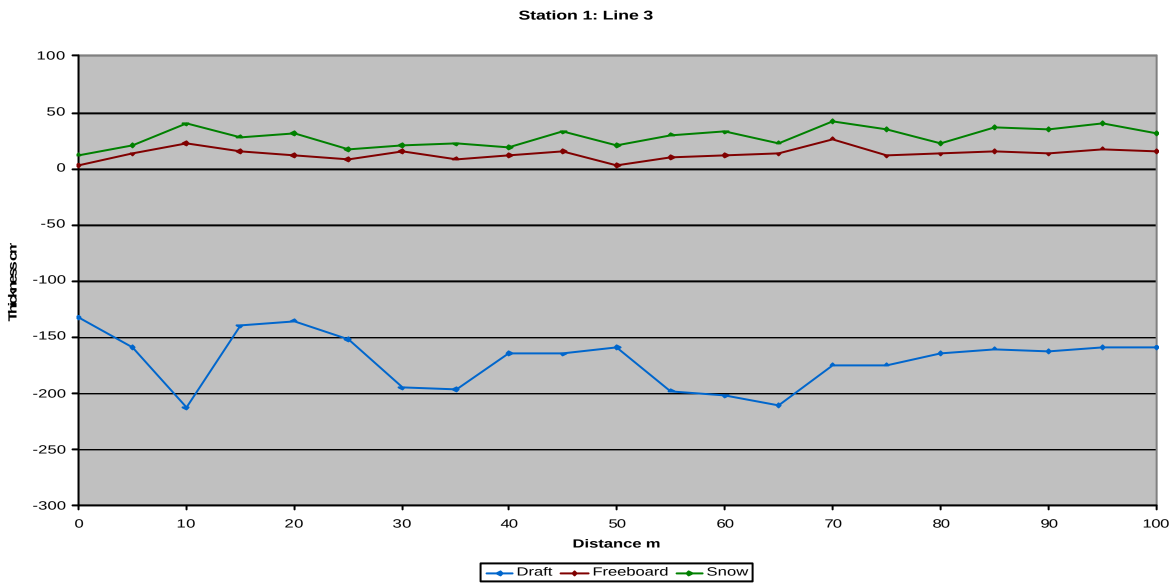
Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
106.5	5,5,7	15	709			Edge of melt pond which lies just past yesterday's 100 m mark
110	3,5,5	86	763			Ridge
115	26,17,20	19	180			Edge of ridge
120	30.20.26	6	164			
125	25.22.26	5	177	79.4987106	-14.4151726	
130	24.25.23	3	208			
135	22,27,26	4	228			
140	26.25.25	10	225			
145	30,23 32	8	201			
150	25,27,21	3	162	79.4986725	-14.4162245	
155	23.22.22	4	228			
160	18,19,18	13	250			
165	6,6,6	20	266			
170	19,9,10	11	206			
175	26,24,24	0	148	79.4986572	-14.4178762	
180	29,32,34	4	158			
185	24,24,24	1	180			
190	23,21,23	1	177			
195	19,21,22	3	183			
200	10,10,11	5	157	79.4986496	-14.4188099	

Cross-line 50 m along new line (i.e. 150 m from start point), going 50 m to right R and 50- m to left L, with zero at centre.

Table 4: Line 3, cross-line at 150 m on Line 1

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0 (50R)	10,8.5,10	3	135	79.4981842	-14.4168091	Starting at far right
5	11,9,6	13	172			
10	10,8,5	23	236			
15	18,15,16.5	15	155			
20	14,17,10	12	147			
25	19,22,16	8	160	79.4984283	-14.4165087	
30	11,7,9	15	210			
35	6,5,6	9	205			
40	10.15.5,13	12	176			
45	8.5,6,5.5	15	180			
50	18,17,18	3	162	79.4986725	-14.4164448	Same as 150 above in Table 3
55 (5L)	17,19.5,17	10	207			Moving left from centre
60	22,19,20	12	214			
65	20,22,19	13	223			
70	9,12,10.5	27	201			

75	13,15,17	11	185	79.4988937	-14.4163427	
80	17,25,32	13	177			
85	10,7,11	16	176			
90	21,20,21	13	176			
95	22,25,20	18	177			
100	19,17,12	16	175	79.4991379	-14.4161329	



Cores – done near beginning of line.

Core 1: black tape is top
2 sections
Top section is shorter than bottom

Core 2: top section came in 5 pieces
2 sections
Bottom section has short top bit, then long complete m core

Ice station 2, 23 August

Main line is along ship axis starting at stern. Cross line is R and L relative to looking forward. Cross lines run from 0 at centre to 50 at edges. The GPS measurements show that although the floe was once fast ice it has now become detached and is drifting at 0.138 knots south-east.

Table 5: Line 1 (Main Line)

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0	5,4,4	13	175	80.26732	-13.10927	
5	9,8,9	17	153	80.26728	-13.10963	
10	10,9,12	10	129	80.26726	-13.11013	
15	15,14,11	1	131	80.26722	-13.11046	
20	11,10,10	12	154	80.26719	-13.11075	
25	6,7,7	6	132	80.26717	-13.11109	
30	8,10,9	0	135	80.26711	-13.11154	
35	6,6,8	5	128	80.26708	-13.11196	
40	10,8,7	-0.5	124	80.26707	-13.11233	Flooded melt pool
45	9,9,9	6	152	80.26704	-13.11260	
50	9,11,10	9	140	80.26703	-13.11292	
55	6,5,6	10	142	80.26701	-13.11322	
60	5,4,6	10	146	80.26697	-13.11360	
65	6,6,7	9	167	80.26693	-13.11403	
70	6,8,5	14	166	80.26691	-13.11432	
75	7,10,8	8	137	80.26690	-13.11458	
80	15,15,16	-7	94	80.26688	-13.11473	Flooded melt pool
85	6,7,5	3	126	80.26683	-13.11519	
90	7,7,8	10	146	80.26679	-13.11550	
95	6,6,7	6	137	80.26676	-13.11575	
100	9,8,7	11	133	80.26670	-13.11619	

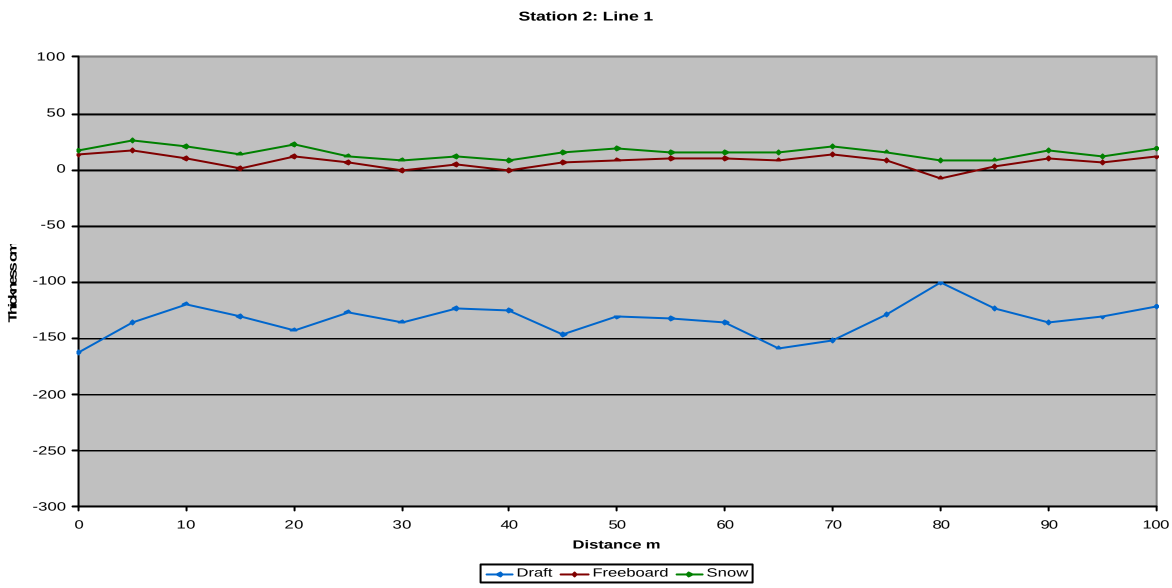


Table 6: Line 2, cross-line at 50 m on Line 1

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
50R	6,6,6	1	108	80.26748	-13.11135	
45R	12,12,12	20	155	80.26744	-13.11130	
40R	8,6,6	27	130	80.26738	-13.11117	
35R	7,6,6	6	113	80.26733	-13.11108	
30R	10,7,12	9	150	80.26731	-13.11106	
25R	7,7,7	10	142	80.26726	-13.11110	
20R	6,6,6	8	146	80.26722	-13.11113	
15R	7,7,7	13	142	80.26718	-13.11119	
10R	9,8,7	10	173	80.26716	-13.11124	
5R	7,6,6	11	174	80.26714	-13.11133	
0	9,11,10	9	140	80.26703	-13.11292	Same as 150 above in Table 5
5L	6,6,6	12	154	80.26706	-13.10913	
10L	6,6,6	12	158	80.26703	-13.10897	
15L	6,6,9	8	167	80.26701	-13.10868	
20L	7,6,6	13	169	80.26699	-13.10833	
25L	7,10,10	15	166	80.26694	-13.10767	
30L	6,5,6	12	150	80.26691	-13.10742	
35L	6,6,7	9	120	80.26688	-13.10713	
40L	5,5,5	9	135	80.26685	-13.10697	
45L	6,7,8	10	122	80.26682	-13.10665	
50L	7,7,7	4	138	80.26676	-13.10633	

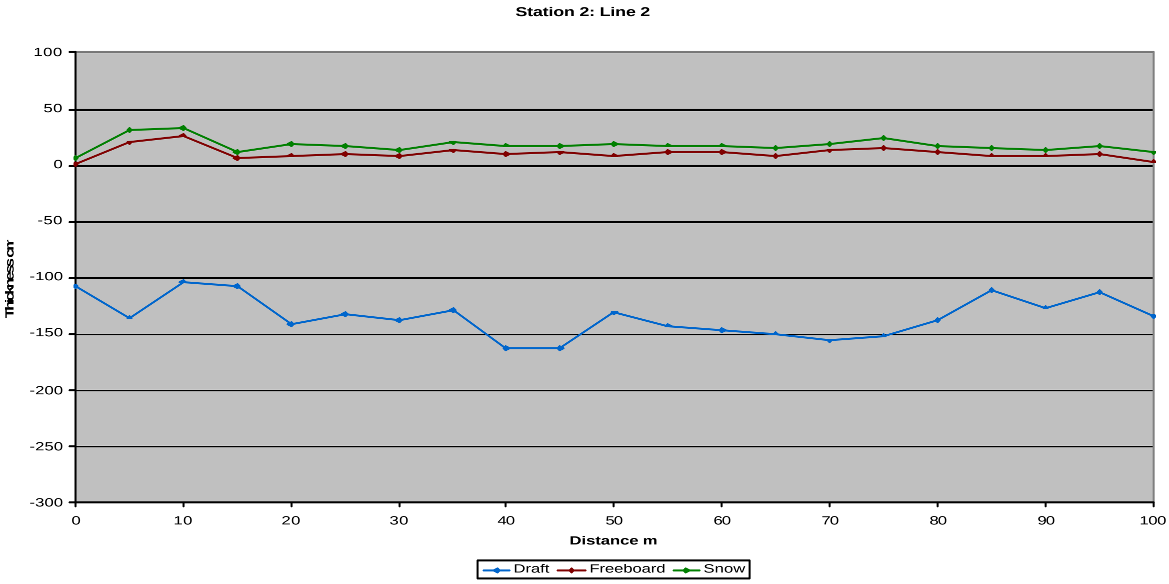


Table 7: Snow samples

Bottle no.	*Line/Hole*
596	10L
540	20L
239	30L
234	40L
578	50L

Ice station 3, 26 August

Line 1 - Main line is along ship axis starting at stern. 0 is beginning of line nearest ship.

Table 8: Line 1

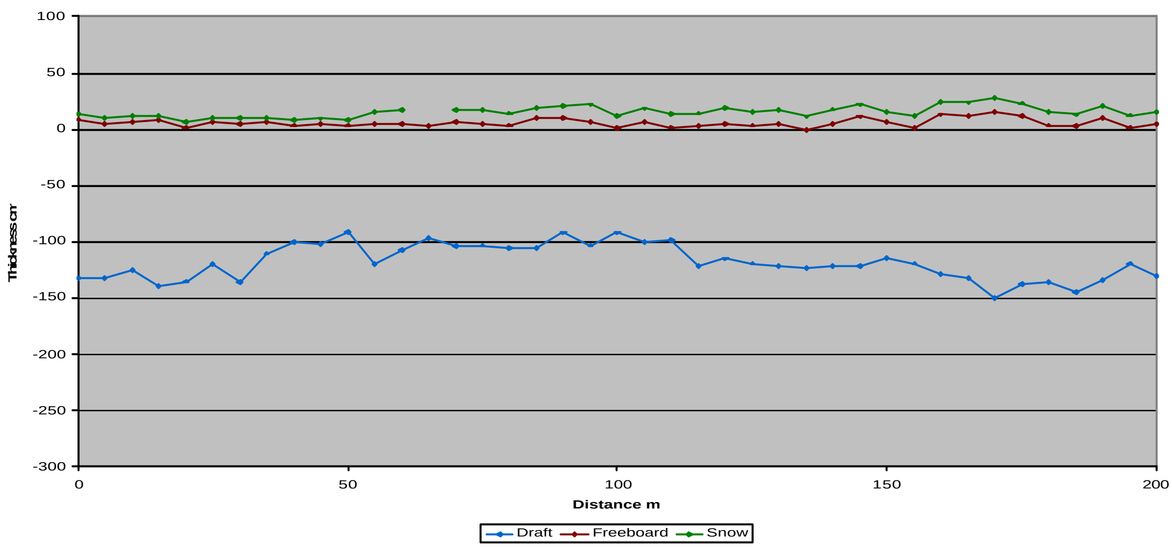
Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0	4,5,5	9	141	79.3316345	-13.848052	
5	5,5,5	5	137			
10	5,5,5	7	132			
15	4,4,4	8	147			
20	4,4,5	2	137			
25	4,5,5	6	126			
30	5,5,5	5	141			Melt pond alongside
35	4,4,4	6	116			Melt pond alongside
40	4,4,5	4	104			
45	4,5,4	5	107			
50	4,5,4	4	95	79.3312149	-13.8494577	Melt pool
55	10,11,10	5	125			.
60	12,12,11	5	112			Large melt pool runs parallel to line from 60 to 100
65	?	3	99			
70	10,12,12	6	110			
75	11,11,13	5	108			
80	11,11,9	4	109			
85	9,9,10	10	115			
90	11,11,10	10	102			
95	14,14,16	7	110			
100	11,11,11	1	93	79.3308487	-13.8502512	
105	12,12,13	6	106			
110	14,11,11	2	100			
115	11,12,11	3	125			
120	15,11,15	5	120			
125	11,12,11	4	123			
130	11,12,12	5	127			
135	11,11,11	0	123			
140	12,15,12	5	126			
145	11,11,11	11	132			
150	10,10,10	6	120	79.3305588	-13.8513241	
155	10,11,10	1	120			
160	11,10,12	13	142			
165	11,11,13	12	144			
170	10,12,12	16	166			
175	11,12,11	12	140			
180	12,13,11	4	140			
185	10,10,10	3	147			
190	10,11,10	10	144			
195	11,11,10	2	121			
200	11,11,10	5	135	79.3299942	-13.8526011	

Line 2 - Parallel to line 1 and about 40 m to right, looking from ship. Exact distance will be given by GPS.

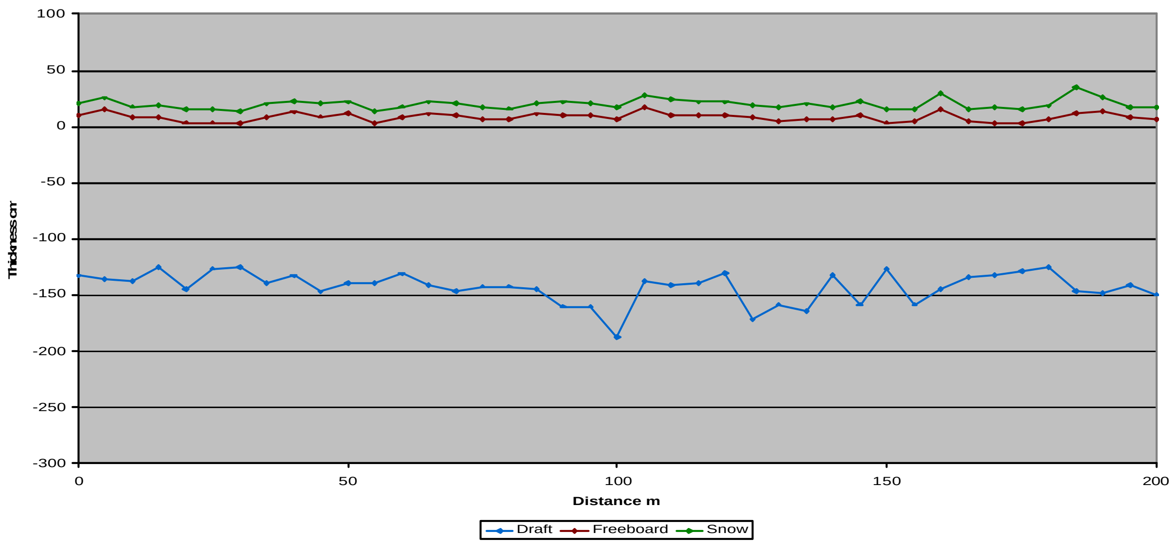
Table 9: Line 2

Hole position m.	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0	11,12,12	11	146	79.3318634	-13.8500261	
5	10,10,11	10	143			
10	10,11,10	15	151			
15	10,10,10	8	145			
20	11,11,11	8	133			
25	11,11,12	4	148			
30	12,12,12	4	130			
35	10,10,11	3	128			
40	12,12,12	8	147			
45	10,10,10	13	146			
50	12,11,11	9	156	79.3314743	-13.8511581	
55	10,10,10	12	151			
60	10,11,12	3	142			
65	10,10,10	8	139			
70	10,11,11	11	152			
75	10,10,11	10	156			
80	10,11,11	7	149			
85	10,10,11	6	148			
90	9,10,11	11	156			
95	12,12,12	10	170			
100	11,10,11	10	170			
100	12,12,11	6	193	79.3309708	-13.8520918	
105	11,11,11	17	155			
110	14,14,14	10	151			
115	10,13,13	10	149			
120	13,12,11	10	140			
125	11,11,11	8	180			
130	12,12,12	5	163			
135	13,13,13	7	171			
140	10,10,10	7	139			
145	13,14,12	10	168			
150	12,12,11	4	130	79.330574	-13.8527994	
155	10,11,12	5	163			
160	13,13,17	15	159			
165	11,11,11	5	139			
170	14,14,14	3	135			
175	14,14,11	3	132			
180	12,11,11	7	132			
185	15,29,26	12	158			
190	9,14,13	14	162			
195	9,10,9	8	149			
200	11,12,11	6	155	79.3301239	-13.8538189	

Station 3: Line 1



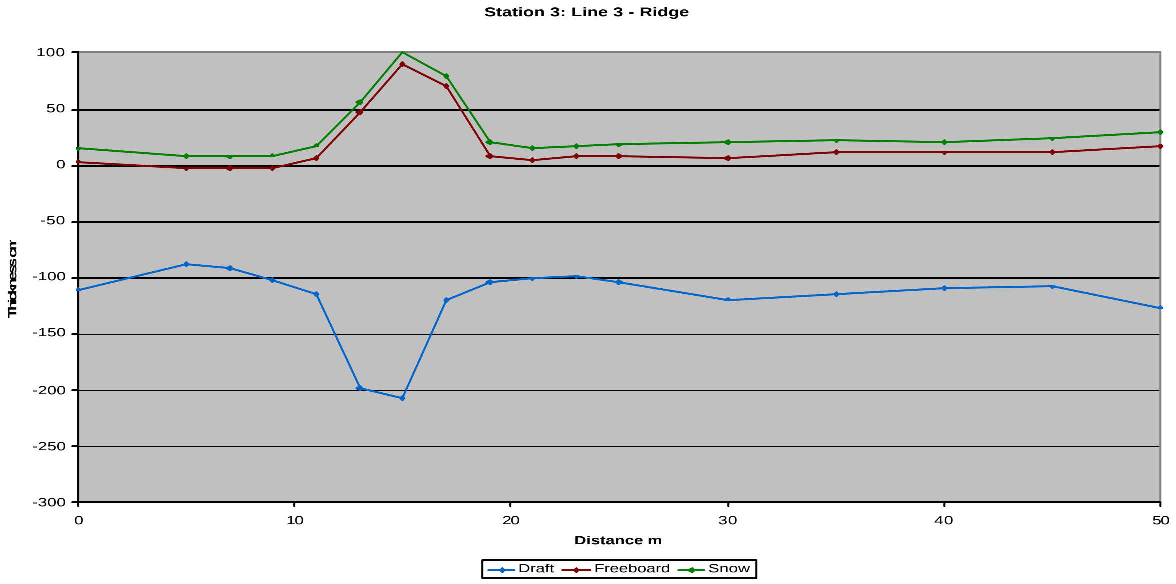
Station 3: Line 2



Ridge - Parallel to lines 1 and 2 and some 100 m to left, looking from ship. Holes are numbered in reverse, from 0 furthest from ship to 50 closest.

Table 10: Ridge Line

Hole position m	*Snow cm*	*Freeboard cm*	*Thickness cm*	*Latitude*	*Longitude*	*Comments*
0	11,10,11	4	114	79.3316422	-13.8448706	
5	11,11,11	-3	85			Standing water on top of ice
7	9,11,9	-2	89			
9	11,11,11	-2	100			
11	12,12,12	6	120			
13	9,9,10	47	245			
15	10,11,10	90	297	79.3313217	-13.8455687	
17	9,10,9	70	190			
19	10,14,14	8	112			
21	10,10,10	5	106			
23	9,9,10	8	107			
25	11,10,10	8	112			
30	13,10,20	7	126			
35	10,10,10	12	126			
40	10,10,9	11	120			
45	12,12,11	12	120			
50	12,12,13	17	143	79.3311996	-13.8456812	



APPENDIX B – SALINITIES

SHIP-------------	JCR
CRUISE--------	JR106 leg 1
DATE-----------	Aug-04

SEABIRD C.T.D. SALINITY DATA

CAST NO	BOTTLE	SAMPLE	SAL PRI	SAL SEC	SEC-PRI	PORTASAL	PRI-PORTASAL	SEC-PORTASAL
1	1	crate4 1	34.9049	34.904	-0.0009	34.9082	-0.0033	-0.0042
1	2	2	34.9051	34.9043	-0.0008	34.9072	-0.0021	-0.0029
1	13	3	34.9148	34.9143	-0.0005	34.9134	0.0014	0.0009
1	14	4	34.9148	34.9137	-0.0011	34.9163	-0.0015	-0.0026
2	1	5	34.7461	34.7455	-0.0006	34.7344	0.0117	0.0111
2	2	6	34.7468	34.7454	-0.0014	34.738	0.0088	0.0074
2	3	7	34.5808	34.5827	0.0019	34.6598	-0.079	-0.0771
2	4	8	34.5799	34.5847	0.0048	34.6671	-0.0872	-0.0824
4	1	9	34.5053	34.5044	-0.0009	34.4243	0.081	0.0801
4	13	11	32.9128	32.9145	0.0017	32.9406	-0.0278	-0.0261
5	1	13	32.8643	32.8643	0	32.8847	-0.0204	-0.0204
5	2	14	32.8642	32.864	-0.0002	32.8877	-0.0235	-0.0237
5	3	15	32.8436	32.8428	-0.0008	32.8632	-0.0196	-0.0204
5	4	16	32.8427	32.8425	-0.0002	32.8608	-0.0181	-0.0183
6	1	17	33.3153	33.3056	-0.0097	33.2862	0.0291	0.0194
6	2	18	33.3309	33.3246	-0.0063	33.3052	0.0257	0.0194
6	3	19	32.8472	32.8468	-0.0004	32.9019	-0.0547	-0.0551
6	4	20	32.8473	32.8469	-0.0004	32.9355	-0.0882	-0.0886
7	1	21	33.5511	33.5488	-0.0023	33.5432	0.0079	0.0056
7	2	22	33.5525	33.553	0.0005	33.5461	0.0064	0.0069
7	3	23	32.8833	32.882	-0.0013	32.9124	-0.0291	-0.0304
7	4	24	32.8828	32.8819	-0.0009	32.9555	-0.0727	-0.0736
9	3	crate 5 2	32.9544	32.9507	-0.0037	32.9305	0.0239	0.0202
9	4	1	32.9645	32.962	-0.0025	32.9301	0.0344	0.0319
9	13	3	32.8155	32.8135	-0.002	32.8349	-0.0194	-0.0214
9	14	4	32.806	32.8071	0.0011	32.8257	-0.0197	-0.0186
10	1	6	34.1528	34.1363	-0.0165	34.075	0.0778	0.0613
10	2	7	34.2021	34.1675	-0.0346	34.177	0.0251	-0.0095
10	13	8	32.8845	32.8968	0.0123	32.9291	-0.0446	-0.0323
10	13	9	32.8735	32.8716	-0.0019	32.8889	-0.0154	-0.0173
11	1	10	34.6125	34.6115	-0.001	34.6071	0.0054	0.0044
11	2	11	34.6171	34.6102	-0.0069	34.6121	0.005	-0.0019
11	13	12	32.8316	32.8304	-0.0012	32.9551	-0.1235	-0.1247
11	14	13	32.8312	32.8301	-0.0011	32.8518	-0.0206	-0.0217
12	1	14	34.6465	34.6438	-0.0027	34.6367	0.0098	0.0071
12	2	15	34.6463	34.6439	-0.0024	34.6491	-0.0028	-0.0052
12	13	16	32.8482	32.8474	-0.0008	32.8844	-0.0362	-0.037
12	14	18	32.8474	32.846	-0.0014	32.8656	-0.0182	-0.0196
13	1	19	34.7249	34.7209	-0.004	34.7076	0.0173	0.0133
13	2	20	34.7263	34.7251	-0.0012	34.7202	0.0061	0.0049
13	13	21	33.0475	33.0036	-0.0439	33.001	0.0465	0.0026
13	14	22	32.9319	32.9627	0.0308	32.9661	-0.0342	-0.0034
14	1	23	34.5802	34.5649	-0.0153	34.5511	0.0291	0.0138
14	2	24	34.5816	34.5778	-0.0038	34.5641	0.0175	0.0137
14	3	crate11 241	34.5362	34.5309	-0.0053	34.5397	-0.0035	-0.0088
14	4	242	34.5294	34.5276	-0.0018	34.5452	-0.0158	-0.0176
15	1	243	34.6361	34.6331	-0.003	34.631	0.0051	0.0021
15	2	244	34.6358	34.6343	-0.0015	34.6351	0.0007	-0.0008
15	3	245	34.5084	34.5065	-0.0019	34.5206	-0.0122	-0.0141
15	4	246	34.5082	34.5049	-0.0033	34.5485	-0.0403	-0.0436
17	1	247	34.7295	34.7268	-0.0027	34.7246	0.0049	0.0022
17	2	248	34.7297	34.7265	-0.0032	34.7232	0.0065	0.0033
17	13	249	34.5219	34.5206	-0.0013	34.5548	-0.0329	-0.0342
17	14	250	34.5191	34.5185	-0.0006	34.5349	-0.0158	-0.0164
18	1	251	34.674	34.6689	-0.0051	34.6832	-0.0092	-0.0143
18	2	252	34.7067	34.6969	-0.0098	34.692	0.0147	0.0049
18	13	253	34.5501	34.5477	-0.0024	34.5574	-0.0073	-0.0097
18	14	254	34.5502	34.5469	-0.0033	34.5547	-0.0045	-0.0078
19	1	255	34.7548	34.7515	-0.0033	34.75	0.0048	0.0015
19	2	256	34.7549	34.7516	-0.0033	34.752	0.0029	-0.0004
19	13	257	33.0092	33.0228	0.0136	33.2883	-0.2791	-0.2655
19	14	258	32.9997	33.0157	0.016	33.0825	-0.0828	-0.0668
20	1	259	34.9119	34.9089	-0.003	34.9098	0.0021	-0.0009
20	2	260	34.9119	34.9089	-0.003	34.9089	0.003	0
20	13	261	34.9137	34.9108	-0.0029	34.9125	0.0012	-0.0017
20	14	262	34.9138	34.9108	-0.003	34.9116	0.0022	-0.0008

APPENDIX C – LADCP SCRIPTS AND PROCESSING MESSAGES

PART 1

Cast 1 to 4 script files enabling running parameters. SM1 indicates master, SM2 indicates slave.

```
>CF11101
>EA00000
>EB00000
>ED00000
>ES35
>EX11111
>EZ0111111
>SM1
>SA001
>SI0
>SW75
>TE00:00:01.00
>TP00:01.00
>LD111100000
>LF0500
>LN016
>LP00003
>LS800
>LV250
>LJ1
>LW1
>LZ30,220
>CK
[Parameters saved as USER defaults]
>CS
```

```
>CF11101
>EA00000
>EB00000
>ED00000
>ES35
>EX11111
>EZ0111111
>SM2
>SA001
>ST0300
>TE00:00:01.00
>TP00:01.00
>LD111100000
>LF0500
>LN016
>LP00003
>LS800
>LV250
>LJ1
>LW1
>LZ30,220
>CK
[Parameters saved as USER defaults]
>CS
```

PART 2

Cast 5 to 20 script files enabling running parameters. SM1 indicates master, SM2 indicates slave.

```
>CF11101
>EA00000
>EB00000
>ED00000
>ES33
>EX11111
>EZ0111111
>SM1
>SA001
>SI0
>SW75
>TE00:00:02.72
>TP00:00.50
>LD111100000
>LF0500
>LN015
>LP00003
>LS1600
>LV250
>LJ1
>LW1
>LZ30,220
>CK
[Parameters saved as USER defaults]
>CS
```

```
>CF11101
>EA00000
>EB00000
>ED00000
>ES33
>EX11111
>EZ0111111
>SM2
>SA001
>ST0300
>TE00:00:02.72
>TP00:0.50
>LD111100000
>LF0500
>LN015
>LP00003
>LS1600
>LV250
>LJ1
>LW1
>LZ30,220
>CK
[Parameters saved as USER defaults]
>CS
```

PART 3 – Preliminary Processing Error Messages

```
Station1    WARNING  found 15 ensembles with bad checksum (d)
            WARNING  found 15 ensembles with bad checksum (u)

            warning mean ping rate not equal between both instruments
            up instrument is different by -91 ensembles
            found 13 bad bottom error velocities and discarded them
            removed 593 values because of high error velocity
            removed 4 bottom values because of high error velocity

            **  found  7  large horizontal velocities

            no SADCP data
            will use 82 % of data

---------------------------------------------------------------------

Station2    WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum
            warning mean ping rate not equal between both instruments
            up instrument is different by -88 ensembles
            found 23 bad bottom error velocities and discarded them
            removed 1591 values because of high error velocity
            removed 19 bottom values because of high error velocity

            removing 1039 values  below recognized bottom

            can not find SADCP data file:

            will use 86 % of data

---------------------------------------------------------------------
Station3    Error – no upward (slave) file recorded


---------------------------------------------------------------------

Station4    WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum
            warning mean ping rate not equal between both instruments
            up instrument is different by -108 ensembles
            found 10 bad bottom error velocities and discarded them
            removed 1199 values because of high error velocity
            removed 7 bottom values because of high error velocity
            can not find SADCP data file:

            will use 75 % of data


------------------  script file changed (see appendix) ----------

Station5    WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum
            best lag not obvious!  use time to match up-down looking ADCP
            found 4 bad bottom error velocities and discarded them
            removed 1399 values because of high error velocity
            removed 23 bottom values because of high error velocity
            **  found  9  large horizontal velocities
            can not find SADCP data file:
            will use 83 % of data
```

```
Station6     WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum
             best lag not obvious!  use time to match up-down looking ADCP
             found 6 bad bottom error velocities and discarded them
             removed 1302 values because of high error velocity
             removed 15 bottom values because of high error velocity


             WARNING one bean might be weak !
             weak up looking beam 2

             Outlier discarded 199 bins down looking
             Outlier discarded 80 bins up looking

             no bottom found

             given maximum profile depth : 107
             extracted bottom depth      : 143
             bottom depth error     : 22
             removing 944 values  below recognized bottom

             can not find SADCP data file:

             no bottom track data

             will use 80 % of data
---------------------------------------------------------------------

Station 7    WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum
             best lag not obvious!  use time to match up-down looking ADCP:
             mean lag is -108.9415 ensembles

             found 3 bad bottom error velocities and discarded them
             removed 1429 values because of high error velocity
             removed 20 bottom values because of high error velocity

             **  found  11  large horizontal velocities

             Outlier discarded 177 bins down looking
             Outlier discarded 86 bins up looking

             can not find SADCP data file:

             will use 85 % of data
```

```
Station 8    WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum

             best lag not obvious!  use time to match up-down looking ADCP:
             mean lag is -116.3464 ensembles

             found 9 bad bottom error velocities and discarded them
             removed 1483 values because of high error velocity
             removed 11 bottom values because of high error velocity

             Outlier discarded 189 bins down looking
             Outlier discarded 77 bins up looking
```

```
            WARNING one bean might be weak !
            weak up looking beam 2

            no SADCP data

            will use 78 % of data
```

```
Station 9   WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum

            best lag not obvious!  use time to match up-down looking ADCP
            mean lag is -129.7861 ensembles

            found 13 bad bottom error velocities and discarded them
            removed 887 values because of high error velocity
            removed 19 bottom values because of high error velocity

            Outlier discarded 158 bins down looking
            Outlier discarded 41 bins up looking

            no bottom found
            given maximum profile depth : 89
            extracted bottom depth      : 136
            bottom depth error     : 20
            removing 1687 values  below recognized bottom

            can not find SADCP data file:
            no bottom track data

            will use 80 % of data
```

```
Station 10  WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum

            best lag not obvious!  use time to match up-down looking ADCP
            mean lag is -129.0418 ensembles

            found 5 bad bottom error velocities and discarded them
            removed 925 values because of high error velocity
            removed 18 bottom values because of high error velocity

            Outlier discarded 204 bins down looking
            Outlier discarded 120 bins up looking

            can not find SADCP data file:

            will use 82 % of data
```

```
Station 11  WARNING  found 15 ensembles with bad checksum
            WARNING  found 15 ensembles with bad checksum

            best lag not obvious!  use time to match up-down looking ADCP
            mean lag is -127.6158 ensembles

            WARNING one bean might be weak !
            weak up looking beam 2

            Outlier discarded 235 bins down looking
```

```
              Outlier discarded 144 bins up looking

              no bottom found

              no SADCP data

              will use 80 % of data
```

```
Station 12    WARNING  found 15 ensembles with bad checksum
              WARNING  found 15 ensembles with bad checksum

              best lag not obvious!  use time to match up-down looking ADCP
              mean lag is -130.5368 ensembles

              found 12 bad bottom error velocities and discarded them
              removed 852 values because of high error velocity
              removed 22 bottom values because of high error velocity

              **  found  7  large horizontal velocities

              Outlier discarded 198 bins down looking
              Outlier discarded 141 bins up looking

              no bottom found

              removing 615 values  below recognized bottom
              no SADCP data
              will use 82 % of data
```

```
Station 13    WARNING  found 15 ensembles with bad checksum
              WARNING  found 15 ensembles with bad checksum

              best lag not obvious!  use time to match up-down looking ADCP
              mean lag is -124.4169 ensembles

              found 7 bad bottom error velocities and discarded them
              removed 429 values because of high error velocity
              removed 34 bottom values because of high error velocity

              Outlier discarded 290 bins down looking
              Outlier discarded 141 bins up looking

              no bottom found

              can not find SADCP data file:

              will use 81 % of data
```

```
Station 14    WARNING  found 15 ensembles with bad checksum
              WARNING  found 15 ensembles with bad checksum

              best lag not obvious!  use time to match up-down looking ADCP
              mean lag is -112.2189 ensembles

              found 8 bad bottom error velocities and discarded them
              removed 966 values because of high error velocity
              removed 29 bottom values because of high error velocity
```

```
             WARNING one bean might be weak !
             weak up looking beam 2

             Outlier discarded 241 bins down looking
             Outlier discarded 156 bins up looking

             no bottom found

             no bottom track data
             no SADCP data

             will use 84 % of data
```

```
Station 15   WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum

             best lag not obvious!  use time to match up-down looking ADCP
             mean lag is -92.751 ensembles

             found 9 bad bottom error velocities and discarded them
             removed 704 values because of high error velocity
             removed 25 bottom values because of high error velocity


             Outlier discarded 216 bins down looking
             Outlier discarded 126 bins up looking

             no bottom found

             no SADCP data

             will use 83 % of data
```

```
Station 16   WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum

             best lag not obvious!  use time to match up-down looking ADCP
             mean lag is -111.2592 ensembles

             found 11 bad bottom error velocities and discarded them
             removed 707 values because of high error velocity
             removed 22 bottom values because of high error velocity

             Outlier discarded 213 bins down looking
             Outlier discarded 113 bins up looking

             no bottom found

             can not find SADCP data file:

             will use 80 % of data
```

```
Station 17   WARNING  found 15 ensembles with bad checksum
             WARNING  found 15 ensembles with bad checksum

             best lag not obvious!  use time to match up-down looking ADCP
             mean lag is -109.1544 ensembles
```

```
              found 14 bad bottom error velocities and discarded them
              removed 1103 values because of high error velocity
              removed 34 bottom values because of high error velocity

              Outlier discarded 303 bins down looking
              Outlier discarded 169 bins up looking

              no bottom found

              can not find SADCP data file:

              will use 85 % of data
```

```
Station 18    WARNING  found 15 ensembles with bad checksum
              WARNING  found 15 ensembles with bad checksum

              best lag not obvious!  use time to match up-down looking ADCP
              mean lag is -112.6407 ensembles

              found 11 bad bottom error velocities and discarded them
              removed 898 values because of high error velocity
              removed 15 bottom values because of high error velocity

              WARNING one bean might be weak !
              weak up looking beam 2

              Outlier discarded 251 bins down looking
              Outlier discarded 181 bins up looking

              no bottom found

              can not find SADCP data file:

              will use 82 % of data
```

```
Station 19    WARNING  found 15 ensembles with bad checksum
              WARNING  found 15 ensembles with bad checksum

              best lag not obvious!  use time to match up-down looking ADCP
              mean lag is -112.4509 ensembles

              found 7 bad bottom error velocities and discarded them
              removed 1019 values because of high error velocity
              removed 18 bottom values because of high error velocity

              **  found  6  large horizontal velocities

              Outlier discarded 255 bins down looking
              Outlier discarded 156 bins up looking

              no bottom found

              no SADCP data

              will use 76 % of data
```

```
Station 20    found 15 bad bottom error velocities and discarded them
              removed 1031 values because of high error velocity
              removed 51 bottom values because of high error velocity
```

```
Outlier discarded 1227 bins down looking
Outlier discarded 862 bins up looking

no bottom found

no bottom track data
no SADCP data

will use 72 % of data
increased error because of shear - inverse difference
```