JR84 Cruise Report

Autosub Under Ice Cruise
to the Amundsen Sea

RRS James Clark Ross

28 February to 4 April 2003

Report complied by Adrian Jenkins

from the contributions of the scientific party:

Chris Banks, Toby Benham, Mark Brandon, Jon Copley, Julian Dowdeswell, Jeff Evans, Sarah Hardy, Dan Hayes, Adrian Jenkins, Steve McPhail, Nick Millard, Colm O'Cofaigh, Miles Pebody, James Perrett, Ziggy Pozzi-Walker, James Riggs, Pete Stevenson, David Vaughan and Andy Webb.

Contents

Introduction

Adrian Jenkins (PSO), British Antarctic Survey

Summary

JR84 was the first cruise of the NERC Autosub Under Ice (AUI) thematic programme. The aim of the programme is to investigate the marine environment of floating ice shelves in Antarctica and Greenland using Autosub, the autonomous submersible vehicle developed at the Southampton Oceanography Centre. The target area for the first cruise was Pine Island Bay, in the eastern Amundsen Sea, with the main focus being autosub deployments beneath Pine Island Glacier.

Cruise participants included the Autosub technical team, the AUI science coordinator and scientists working on four separate projects funded by the programme:

Evolution and impact of Circumpolar Deep Water on the Antarctic continental shelf — Principal investigator: Adrian Jenkins, British Antarctic Survey.
Autosub investigation of ice sheet boundary conditions beneath Pine Island Glacier — Principal investigator: David Vaughan, British Antarctic Survey.
Marine geological processes and sediments beneath floating ice shelves in Greenland and Antarctica: investigations using the Autosub AUV — Principal investigator: Julian Dowdeswell, Scott Polar Research Institute, University of Cambridge.
Sea ice thickness distribution in the Bellingshausen Sea — Principal investigator: Mark Brandon, Open University.

The planned activities for the cruise included Autosub missions beneath Pine Island Glacier, neighbouring glacier tongues and the multi-year sea ice that was expected to be present to the west of the bay. Planned activities for the ship included CTD measurements and swath mapping in Pine Island Bay and the neighbouring continental shelf, as well as measurements on ice floes and the deployment of three Argos beacons in the multi-year pack.

In case of sea ice conditions in the Amundsen Sea barring access to Pine Island Bay, most of these activities could have been moved to either Ronne Entrance or Marguerite Bay, with George VI Ice Shelf becoming the main focus for Autosub work. Failing this other alternatives, including Larsen Ice Shelf had been identified.

In the event, sea ice prevented the ship getting within 100 miles of any ice front, so the only under ice Autosub missions were run beneath multi-year sea ice to the north of Thurston Island. Technical problems with the vehicle meant that these were somewhat limited in scope and extent. Ice floe sampling and the deployment of the drifters were also completed in the same area. The remaining shipboard activities focussed on a seabed trough that cut the Amundsen Sea continental shelf break at 113–115°W. The marine geological interest here was in the connection of the trough to the deep inner shelf regions near Pine Island Bay and the record of past ice stream activity. From an oceanographic viewpoint the trough appears to act as a conduit by which warm Upper Circumpolar Deep Water is guided onto the shelf and possibly flows all the way to Pine Island Bay.

Scientific Party

Personnel from British Antarctic Survey, Natural Environment Research Council (High Cross, Madingley Road, Cambridge, CB3 0ET):

Pat Cooper	Electronics
Dan Hayes	Oceanography
Adrian Jenkins	Oceanography
Jeremy Robst	Computing
David Vaughan	Glaciology
Doug Willis	Computing

Personnel from Southampton Oceanography Centre, University of Southampton (Waterfront Campus, European Way, Southampton, SO14 3ZH):

Jon Copley	AUI Science Coordinator
Steve McPhail	Autosub
Nick Millard	Autosub
Miles Pebody	Autosub
James Perrett	Autosub
James Riggs	Autosub
Pete Stevenson	Autosub
Andy Webb	Autosub

Personnel from Department of Earth Sciences, The Open University (Walton Hall, Milton Keynes, MK7 6AA):

Chris Banks	Sea ice
Mark Brandon	Oceanography/Sea ice
Sarah Hardy	Oceanography
Ziggy Pozzi-Walker	Oceanography

Personnel from Scott Polar Research Institute, University of Cambridge (Lensfield Road, Cambridge, CB2 1ER):

Toby Benham	Marine geology
Julian Dowdeswell	Marine geology
Jeff Evans	Marine geology
Colm O'Cofaigh	Marine geology

Ship's Company

Officers:

Christopher Elliott	Master
Robert Paterson	Ch/Off
Andrew Liddell	2/Off
Michael Golding	3/Off
John Summers	Dk/Off
Charles Waddicor	R/Off
David Cutting	C/Eng
Vincent Blocke	2/Eng
Gerard Armour	3/Eng
Steven Eadie	4/Eng
Simon Wright	D/Eng
Norman Thomas	Elect
Kenneth Olley	Cat/O

Crew:

George Stewart	Bosun
David Williams	Bos/Mate
John McGowan	Sea 1
Marc Blaby	Sea 1
Derek Jenkins	Sea 1
David Rees	Sea 1
Lester Jolly	Sea 1
Mark Robinson	M/Man
Sydney Smith	M/Man
Richard Turner	Ch Cook
Raymond Collins	2nd Cook
Clifford Pratley	S/Stwd
Derek Lee	Stwd
Kenneth Weston	Stwd
James Newall	Stwd

Ship's Doctor:

Alex Ramsden

Chronological outline of cruise

28 Feb 2003: JCR departed Port Stanley, Falkland Islands, at 09:00L. We headed for S54°30', W059°35' to commence a swath bathymetry and towed magnetometer section across Drake Passage. The ocean logger and ADCP were also running.

1 Mar 2003: We completed the Drake Passage section and commenced our transit to Gerlache Strait. Underway systems were running throughout the passage.

2 Mar 2003: In transit.

3 Mar 2003: We arrived in Dallmann Bay early in the morning. Autosub passed its buoyancy test in calm waters among the Melchior Islands. The ship proceeded to Gerlache Strait for the first Autosub trial missions (M307/8). We ran a swath survey in Gerlache Strait overnight.

4 Mar 2003: The swath survey finished in the morning, ready for a further Autosub trial (M309) run. A CTD test cast (001) was run during the Autosub mission. After the vehicle was recovered, the ship left Gerlache Strait via Neumayer Channel to start the transit to Peter I Island.

5 Mar 2003: In transit. Underway systems logging.

6 Mar 2003: In transit. Argos drifters were activated on the after deck.

7 Mar 2003: The ship passed Peter I Island early in the morning and headed for sea ice north of Thurston Island.

8 Mar 2003: We found the ice edge at first light and located a suitable site for an Autosub deployment (S70°27', W102°09'). The aim was to test the vehicle to full depth in open water before commencing the sub-ice missions. Mission M310 was run coincident with CTD cast 002. The Autosub mission was aborted part way through and the vehicle was recovered to investigate the problem. The ship headed into ice to deploy the first drifter on a floe at S70°59', W101°10'. Snow and ice thickness were measured on the floe. The ship then returned to the ice edge and ran a swath survey overnight.

9 Mar 2003: A further Autosub test mission (M311) in the morning revealed a continuing problem and was aborted almost immediately. We entered the ice again to deploy the two remaining sea ice drifters and sample the floes near S70°55', W102°10'. The ship once again returned to the ice edge and ran a further swath survey overnight.

10 Mar 2003: Autosub test mission (M312) failed at depth. A full ocean depth CTD cast (station 003) was run. At midday local time the ship headed further west to access Pine Island Bay along the W106° meridian.

11 Mar 2003: The ship's track was pushed further west because the sea ice extending west from Thurston Island was blocking the intended route. We begin heading south along W111°.

12 Mar 2003: Our southerly progress was halted overnight when we encountered sea ice and icebergs. At first light we continued southward along a narrow corridor between the sea ice to the east and a line of icebergs coming from Thwaites Glacier to the west. New ice was forming all around the ship. The ship turned north through the heavier ice to test the condition of the tongue that could potentially block off our retreat from the Bay. The ship ran a swath survey outside the ice overnight.

13 Mar 2003: Another Autosub deployment (M313) ended with similar problems. We started a five station (004-008) CTD section perpendicular to the continental slope.

14 Mar 2003: The CTD section was completed overnight and the ship returned to deep water for another Autosub test in the morning (M314). It was decided that the continuing freeze-up to the south and the westward movement of the ice from Thurston Island put operations in Pine Island Bay out of the question. We moved westward (to W110°) overnight, broadening the swath survey along the continental slope.

15 Mar 2003: At first light the ship moved out to deep water to start another CTD section (stations 009 and 010) across the continental slope. Autosub was deployed at the second station (M315), but the systems cut out at depth. The Master was unhappy about continuing the CTD section into the ice at night, so the ship headed for W113°20' (where a trough cutting the shelf edge had been identified in 2000), taking a line well north of the ice edge. A CTD section across the slope was started.

16 Mar 2003: Overnight the five station (011-015) CTD section was completed. We then returned to deep water along a track that maximised the swath coverage. Autosub mission (M316) encountered further problems at depth, so we recovered the vehicle and headed south onto the continental shelf as far as we could while staying well clear of ice for overnight operations. We located the western edge of the seabed trough near W114°15' and started a swath and CTD line (stations 016-024) across it.

17 Mar 2003: The transect across the trough was finished by morning and we headed for the 2000 m isobath at W114°. Autosub completed another two test missions (M317/8), which left the technical team feeling that most of the problems were solved for missions to a few hundred metres depth. We started another CTD section (stations 025-029) across the shelf break. With this complete an extensive swath survey was started, aimed at mapping the seaward end of the trough and the upper continental slope beyond.

18 Mar 2003: In the morning the swath survey was suspended for an Autosub test mission (M319) involving dives to increasing depth, to establish a safe depth limit for vehicle operations. The mission was successful, but during recovery in strengthening winds Autosub was knocked by the ship, causing damage to both the vehicle and some of its sensors. The swath survey continued for the remainder of the day and into the night.

19 Mar 2003: The swath survey of the trough was completed by morning and the ship returned to the 2000 m isobath at W113°40', to run another CTD section (stations 030-035) up onto the shelf. The swath mapping of the upper slope was used to place two of the stations over the deep gullies that descend from the mouth of the trough. With this complete the ship started on a swath survey of the upper continental slope as far west as W115°.

20 Mar 2003: Part way along the return leg of the swath survey the ship headed out to the 2000 m isobath to commence a final CTD section (stations 036-040) back onto the shelf. With this complete the ship headed south to find calm water within the pack ice for a buoyancy test on the repaired Autosub. With the buoyancy checked the vehicle was sent on a successful dive to 300 m and back (M320). Movement of the ice forced a recovery of the vehicle, and the ship headed back to the shelf break. The swath survey was completed back to the deepest part of the trough, then the ship headed to deeper water to extend the swath mapping and CTD sections in this region. Poor weather overnight made for slow progress.

21 Mar 2003: The eastern CTD section was extended by one station (041) during the morning, before a strengthening of the wind ruled out further work. Since the swath was producing poor data, the decision was taken to begin heading east to find multi-year ice for Autosub thickness-mapping runs. We followed the shelf edge, then ran parallel to our outgoing track, to maximise the benefit of the underway swath mapping.

22 Mar 2003: At first light the ship turned south to the ice edge to find a suitable site for an Autosub mission. We entered the ice and deployed the vehicle on a mission (M321) at S70°58', W105°44' to map the underside of the ice over a box, then dive deep and head for open water. Ship and Autosub rendezvoused in open water in the evening, and we continued further east overnight.

23 Mar 2003: A repeat of yesterday. We entered the ice to deploy Autosub (M322) at S70°39', W102°40' in the morning, then followed it out to rendezvous in open water in the evening. After the deployment a CTD (station 042) was run to 500 m depth. The ice thickness mapping section of the mission was aborted as a result of navigational errors in the early stages. We made further easterly progress overnight.

24 Mar 2003: At first light the ship began the usual search for a suitable site for a sub-ice mission site. The ice edge (at S70°32', W100°43') was tighter, so the decision was taken to launch Autosub from open water outside the ice edge. After the launch (M323) another 500 m CTD (station 043) was run. Following the recovery of Autosub the ship proceeded eastward.

25 Mar 2003: A repeat of yesterday. Autosub was launched (M324) in open water north of the ice edge at S70°25', W098°30', and a 500 m CTD (station 044) was run. The vehicle was recovered late because of navigational errors accumulated as it drifted with the current. Following the recovery the ship began its transit to Rothera.

26 Mat 2003: In transit. Underway systems logging. Slow progress in heavy seas near Peter I Island.

27 Mar 2003: In transit.

28 Mar 2003: In transit. Cruise dinner in the evening.

29 Mar 2003: Ship arrived at Rothera in the early hours and undertook some swath mapping in Ryder Bay. High winds (gusting to 50 knots) prevented us mooring in the morning, so the ship undertook further swath mapping including tests of the system under differing speed and heading. Wind abating, but still too strong to go alongside at Biscoe Wharf.

30 Mar 2003: The ship went alongside at Rothera, but the planned Autosub swath trial was cancelled because of the weather. Cargo work all day.

31 Mar 2003: Cargo work completed by midday local. Ship departed for Jubany.

1 Apr 2003: In transit. Afternoon passage through Lemaire and Neumayer channels.

2 Apr 2003: Cargo work at Jubany in the morning. Passage to the Falkland Islands commenced after lunch.

3 Apr 2003: In transit. Underway systems logging. Good speed through calm seas.

4 Apr 2003: With continuing fair weather, the JCR arrived in Port Stanley at 14:00L.

Sea ice conditions in the Amundsen Sea during JR84

Adrian Jenkins
(British Antarctic Survey)

The summer of 2003 was unusual in the Amundsen Sea in that the whole of Pine Island Bay and the continental shelf to the west was almost completely clear of sea ice. This situation persisted up to the end of February, when JR84 commenced. Indeed, at the time of our departure from the Falklands, Pine Island Glacier appeared to have the most accessible ice front of any ice shelf in the south-east Pacific sector of Antarctica (Figure 1a). It seemed that the main problem might be finding suitable multi-year floes for the sea ice programme. These autosub missions had to be run prior to those in Pine Island Bay. Their shorter duration and the possibility that the vehicle might be retrievable by ship if anything failed made them an ideal lower risk test environment for many of the new Autosub features.

The area to the north of Thurston Island was selected for the sea ice work. On arrival in this region, the open conditions further south and west in Pine Island Bay appeared to be stable, although a tongue of multi-year ice was beginning to move west, threatening to close off access to the Bay (Figure 1b). By the time JCR attempted to access Pine Island Bay on 12/13 March, the situation was changing rapidly. The tongue of ice had moved further west, leaving a corridor only 40 miles wide between it and a line of icebergs extending north-west from Thwaites Glacier Tongue. A persistent southerly breeze brought cold temperatures, causing new ice to grow over the entire open area to the south of the sea ice tongue. While only a few inches thick, it appeared to be rapidly consolidating, and would already have presented a significant hazard to Autosub.

On 14 March (Figure 1c) the decision was taken to abandon further attempts to access the Bay. Conditions at the other ice fronts of the Amundsen and Bellingshausen seas had not improved sufficiently to justify a long transit eastward, and indeed a week later (Figure 1d) the new ice growth had effectively barred access to any conceivable ice shelf work site. The only part of the Amundsen Sea continental shelf that was relatively free of ice was further to the west, where a trough cutting the shelf break had been identified during a Nathaniel B Palmer cruise in Feb/Mar 2000. This location had the potential to be of scientific interest for two of the four projects on board, so was made the primary location of JR84 work. Further work on the multi-year sea ice north of Thurston Island was conducted on the eastward return leg of the cruise.

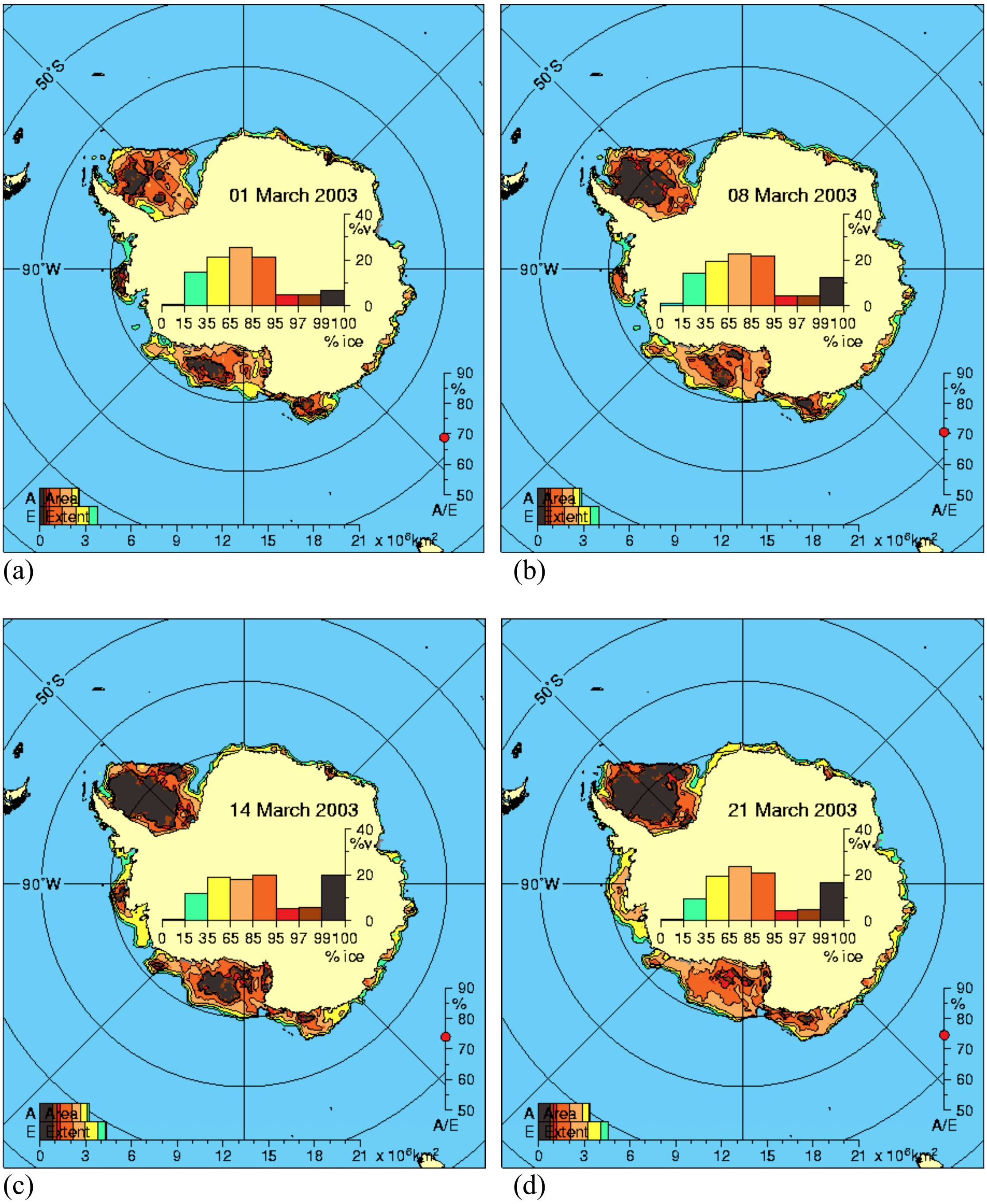


Figure 1: Sea ice concentrations on (a) 1 March 2003, (b) 8 March 2003, (c) 14 March 2003 and (d) 21 March 2003.

Outreach activities

Jon Copley
(Southampton Oceanography Centre)

Diary webpages

A "live" cruise diary was published on the web as part of the Autosub Under Ice webpages. Regular entries were produced aboard the JCR and emailed to Southampton where they were uploaded to the server hosting the AUI webpages. The webpages were also made available on the JCR intranet. The narrative of the cruise diary presented background the science activities of the cruise through more than 9,000 words of text, over 70 images, video and audio clips.

Press contact

Press activity was co-ordinated through NERC Communications following the Pine Island media plan. Press contact passed on to the ship included requests for information from Nature's online news service and images for Newsweek. As Autosub was neither lost nor deployed beneath an ice shelf, no press releases were prepared.

Image archive

An archive of video footage and still images was compiled during the cruise, covering launch and recovery of Autosub, ship operations and Antarctic environments including open water, sea ice and coastline. Over 5 hours of video and 400 still images were shot. This material will be used to produce media packages to support future Autosub Under Ice cruises and for outreach activities such as the exhibit at the Royal Society summer science festival and a possible future DVD for schools.

Marine-Geophysical Investigations

J.A. Dowdeswell, J. Evans, C. Ó Cofaigh, T.J. Benham
(Scott Polar Research Institute, University of Cambridge)

Introduction

Our original intention had been to collect marine-geophysical data from Pine Island Bay using the EM120 swath-bathymetric system and TOPAS sub-bottom profiler. This work would have complimented that of the Autosub vehicle beneath Pine Island Glacier. However, given that sea-ice conditions precluded ship operations in all but the outer shelf of Pine Island Bay, our plans were reorganised.

The reconstruction of past ice-sheet flow, and the delivery of sediments to the Antarctic continental margin, remained the central scientific theme of our work, but the geographical focus of this now became the outer shelf of Pine Island Bay and the adjacent continental slope of the Amundsen Sea (Fig. 2). This area has been very little studied before (Lowe and Anderson, 2002), and so our work was largely breaking new ground.

Our marine geophysical work can be divided into several parts, relating to both scientific questions and geographical locations. The five areas were:

1. The outer shelf of Pine Island Bay
2. The Amundsen Sea continental slope, off Pine Island Bay
3. The abyssal ocean plain in the Bellingshausen Sea
4. Gerlache Strait, Antarctic Peninsula
5. Marguerite and Ryder bays, adjacent to Rothera

Work in areas 3-5 was undertaken on an opportunistic basis, mainly on passage to Pine Island Bay or during bad weather when other scientific operations were suspended.

Outer Shelf of Pine Island Bay

Our survey area penetrated up to 200 km inshore of the shelf break, between 108º and 114ºW (Figs. 2, 3). The major topographic feature, identified for the first time, was a cross-shelf trough trending SE-NW, up to about 100 m deeper than the surrounding shelf. The trough had a well-defined eastern margin and a less steep western side. It was about 50 km wide and approximately 600 m at it deepest. This trough is to the west of the main areas covered by the earlier marine-geophysical work of Lowe and Anderson (2002), who identified a mid- and inner-shelf trough further east and south in front of Pine Island Glacier. We refer to it as 'Thwaites Trough' (Fig. 3).

Two main types of bedform were observed on the shelf. Based on TOPAS records, these appear to be composed of soft sediments that are thin and discontinuous laterally. Streamlined, elongate bedforms were observed in the cross-shelf trough (Fig. 3). These bedforms were most clearly defined on the innermost part of the shelf we examined, but appeared in more subdued form on the outermost shelf too. These features are interpreted as glacial lineations (Stokes and Clark, 1999), and are inferred to be a product of soft-sediment deformation beneath former ice streams draining large interior basins within the Antarctic Ice Sheet. We interpret the streamlined features in the newly-described trough on the western side of outer Pine Island Bay in the same way, as indicating past ice-stream flow. The direction of streamlining is SE-NW, and we suggest that this may mark the former flow of an expanded Thwaites Glacier on the outer shelf, given that Lowe and Anderson (2002) report S-N orientated lineations from further east in the Bay, which are more probably related to the past flow of a full-glacial Pine Island Glacier.

TOPAS records from the area of lineations in the cross-shelf trough show that the sea-floor is sedimentary and that there are in some places reflectors at a few metres depth defining an upper unit in whose surface the lineations are formed. It is noteworthy that on the steep, eastern side of the cross-shelf trough, several reflectors appear to cross-cut one another, each with a similar acoustic unit above. This may mark the shifting margin of the palaeo-ice stream.

The second main feature observed on swath-bathymetric images of the shelf was grooves of varying width, depth and orientation. The grooves were formed mainly in water depths of less than about 460-490 m (Fig. 3). They are similar to the scours produced by iceberg keels on many glacier-influenced continental shelves and represent the irregular drift tracks and grounding of icebergs derived from Thwaites and Pine Island glaciers. The floating tongues of these ice streams are known to be about 500 m thick, and to produce icebergs with deeper keels than, for example, the Ross, Ronne and Amery ice shelves whose bergs are typically about 300-330 m in thickness.

TOPAS records from the shallower areas of the shelf where scouring has taken place show a very uneven sea floor related to the berms and central troughs of the scour marks. No internal acoustic stratification is present in iceberg scoured areas, as the ploughing action of the keels reworks the surficial sediments.

The Amundsen Sea Continental Shelf Break and Slope

We also undertook geophysical measurements of the Pine Island Bay shelf edge and shelf continental slope; shelf processes are clearly likely to influence sediment delivery to the continental slope. Swath-bathymetric and TOPAS data were collected along the shelf break and upper slope from 108º to 115ºW, a distance of about 220 km (Fig. 2). Two large blocks of swath-bathymetric and TOPAS data were collected from the shelf break and upper slope, connected by either single or double lines of data. The two blocks on the shelf break and upper slope were of approximately 2,200 km^2 and 800 km^2 in area, centred at113º20'W and 108º40'W, respectively (Fig. 2).

Where the shelf break was at less than about 500 m, iceberg scours impinge right to the shelf edge. In deeper water they are present only very occasionally, and here streamlined sea-floor lineations are found even close to the shelf break. These lineations are less well-defined than those further inshore on the shelf. It appears that grounded glacier ice reached the shelf edge, presumably at the Last Glacial Maximum.

The main morphological features on the upper slope are gullies or channels, some up to about 100 m deep (Fig. 2). Our preliminary use of the terms ‘gully’ and ‘channel’ is interchangeable; this will be refined on further analysis of the features concerned. The gullies are not present along the whole of the shelf edge off Pine Island Bay. Instead, they are found mainly along two stretches, each of about 50 km width around 113º20’W and 108º40’W. The more westerly system of gullies is located offshore of the cross-shelf trough, Thwaites Trough, described in the previous section. At the shelf break there is a gully about every kilometre. This gully or channel system forms an arborescent network. The system is of stream-order four; that is, the network has a maximum of four confluences. The longest trunk channels are at least 30 km in length. The second, more easterly channel system has straighter channels, which coalesce to form a channel system of only stream-order two on the upper slope. Between the channel systems, the shelf edge is much less dissected by more isolated and less well-developed channels.

On the mid-slope, there is some evidence of chutes and wider channels (Fig. 2). The largest channels occur at about 107ºW, in water of at least 3,500 m in depth. This indicates that downslope transfer of sediment takes place from the continental slope to the abyssal plain of the Amunsden Sea.

No sediment cores are available to provide sedimentological or chronological data on the timing of gully development or activity. However, modern oceanographic data suggest that mixing between dense, cold water produced during sea-ice formation in Pine Island Bay and the warmer waters of the Amundsen Sea, will act against the production of large quantities of very dense bottom water. Thus, the predominant character of water flow at and beyond the shelf break is along-slope and large amounts of downslope-flowing bottom water are probably not responsible for channel development, although analysis of CTD data collected from JR84 will provide a more detailed view of this

It appears more likely that the systems were formed when glacier ice filled Pine Island Bay at the Last Glacial Maximum, and grounded ice reached the shelf edge. The streamlined sedimentary bedforms observed in both our work and that of Lowe and Anderson (2002) confirm that grounded ice was present on the outer shelf (Fig. 3). These bedforms also suggest that fast glacier flow may have been taking place along cross-shelf troughs at about 113º and 108ºW. Thus, during full-glacial conditions, the shelf and upper slope would have been considerably higher-energy environments than the interglacial setting of today, when the fronts of Pine Island and Thwaites glaciers are about 500 km distant. Sediments and meltwater would have been delivered from the ice front directly at the shelf break, leading to increased sedimentation rates and downslope mass -wasting, probably in the form of turbidity currents and debris flows. It is likely, therefore, that the gully or channel systems illustrated in Figure 2 were formed by mass-flow activity under full-glacial conditions.

The Abyssal Plain in the Bellingshausen Sea

The ship traversed twice across the Bellingshausen Sea and eastern Amundsen Sea, in deep water approximately parallel to the shelf edge, on its way to and from Pine Island Bay. Where possible, the inward and outward tracks were contiguous to provide overlapping swath bathymetric coverage. Three main types of feature were observed during the crossing of the Bellingshausen Sea.

Bedrock Ridge. We mapped a bedrock ridge, presumably of tectonic origin, trending SSW-NNE, running to the edges of our mosaic between about 70º31'S 102º55'W and 70º12'S 102º40'W. The ridge is broken into two parts, each with the same trend. The gap is at about 3,400 m, the approximate level of the abyssal plain. The ridge extends about 800 m above the plain to 2,600 m. There is an indication that the plain is higher on the east than on the west side of the ridge. The single strong surface return on TOPAS records confirms that this is a bedrock feature.

Sediment Waves. We observed a field of well-developed sediment waves on the abyssal plain at a water depth of over 3,000 m. They are located at about 69ºS between 92º and 98ºW (about a 200 km length), beginning about 70 km south-west of Peter I Island. The crests of these sea-floor sediment waves have a wavelength of a few 100 m and amplitudes of up to about 5 m. The waves appear to be between 1 and 2 km in length. However, the edges of our swath coverage truncate many of them. The wave crests are orientated between WMW-ESE and NW-SE. TOPAS records have penetration of several tens of metres though the acoustically-stratified sediments making up the waves. The waves are presumably related to currents running along the sea-floor close to the base of the continental slope.

Charcot Canyon. We traversed Charcot Canyon twice, on courses that provided sections across it in water depths of about 3,800 to 4,100 m at about 67º30'S 77ºW. Three types of acoustic facies are seen on TOPAS records across the canyon. First, there are acoustically-stratified sediments, with penetration of the signal often exceeding 30 m beneath the sea floor. This acoustic facies is interpreted as turbidites. Secondly, there is a series of isolated lens-shaped semi-transparent units bedded within the acoustically-stratified facies. The lenses are up to about 5 m thick and several hundred metres wide. These lenses are interpreted as debris flows. Thirdly, there are some small channel-like features at the surface of the acoustically-stratified facies. These are probably submarine channels, perhaps linked to turbidity-current activity. These acoustic facies, and the sediments they describe from our two sections across Charcot Canyon, are presumably derived from mass-wasting processes on the Bellingshausen Sea continental slope to the south.

Gerlache Strait

During the initial testing phase of the Autosub AUV, there was an opportunity to run a number of swath and TOPAS lines overnight in the Gerlache Strait, Antarctic Peninsula. The swath-bathymetric image mosaic produced covers an area of about 650 km^2 (Fig. 4). Streamlined bedforms, presumably related to past glacial action are mapped. TOPAS sub-bottom profiler records document two types of sea-floor return. The first is a highly-reflective and irregular surface with little or no acoustic penetration. This predominates over the bulk of the sea floor in Gerlache Strait. This suggests that the streamlined bedforms observed on swath records are predominantly composed of bedrock. A second, diffuse acoustic return is also found in some areas of the sea floor, especially in the region of fluting and lineations. It indicates that these features are formed in a thin, laterally discontinuous unit of sediment. The bedforms are draped for the most part by a thin cover (<2 m) of postglacial glacimarine sediment. Using these streamlined bedrock and sedimentary sea-floor features as indictators of ice-flow direction, it appears that ice flowed from the SW into Gerlache Strait, and then turned to the NNE to join a former ice-stream described by Canals et al. (2000) that flows across Bransfield Strait to the continental shelf break (Fig. 4).

Additional swath lines were obtained from Neumayer Channel and from the NE of Gerlache Strait, passing Twin Hummock Island, into Bransfield Strait. The section into Bransfield Strait demonstrates clearly the convergence of two sets of large-scale sea-floor lineations, one from Gerlache Strait, and another from the east.

Marguerite and Ryder bays, adjacent to Rothera

Due to high winds at Rothera we were unable to dock immediately, and took the opportunity to collect swath-bathymetric data in the approaches to the BAS base and the arm of Marguerite Bay to the south of it. An area of about 550 km^2 was surveyed (Fig. 5).

Preliminary inspection of the image mosaic and sub-bottom profiler records shows that the sea floor is mainly of bedrock, with a strong surface return on TOPAS. There are few pockets of sediment. Some of the bedrock features, especially in the south-eastern part of the image mosaic, are streamlined in a NNE-SSW direction; that is, approximately along the long-axis of the fjord. We interpret the streamlining of bedrock to be a product of glacial erosion, and that the forms record past ice flow from the NNE (Fig. 5).

References

Lowe, A.L. and Anderson, J.B., 2002. Reconstruction of the West Antarctic ice sheet in Pine Island Bay during the Last Glacial Maximum and its subsequent retreat history. *Quaternary Science Reviews*, **21**, 1879-1897.

Stokes, C.R., and Clark, C.D., 1999. Geomorphological criteria for identifying Pleistocene ice streams. *Annals of Glaciology*, **28**, 67-74.

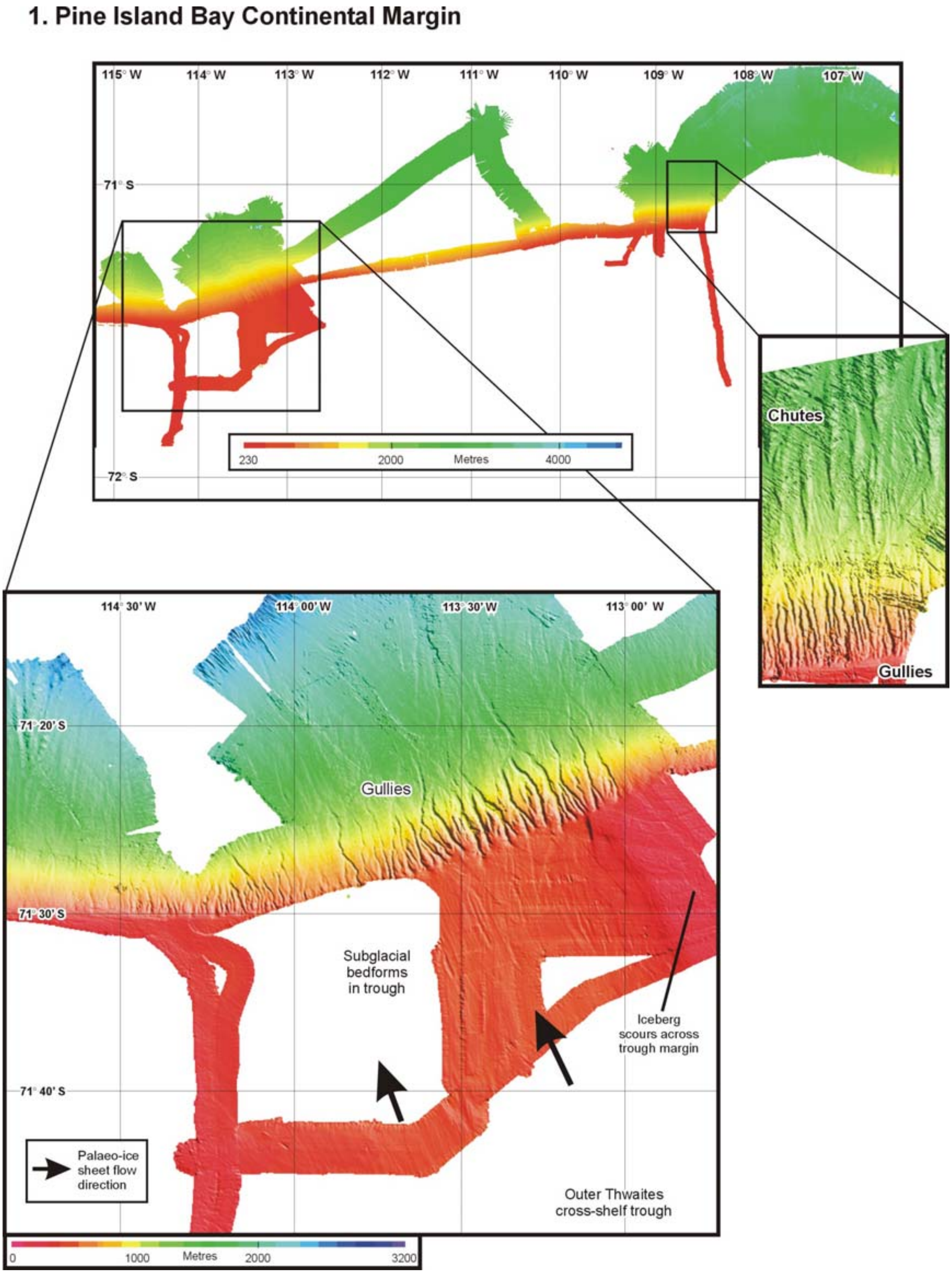


Figure 2: JR84 swath-bathymetric coverage between 107º and 115 Wº on the Amundsen Sea continental margin offshore of Pine Island Bay. Gullies and chutes can bee seen on the upper continental slope. The outer shelf is scoured by icebergs at shallower depths, and glacial lineations are also observed in the 'Thwaites Trough'.

2. Thwaites cross-shelf trough

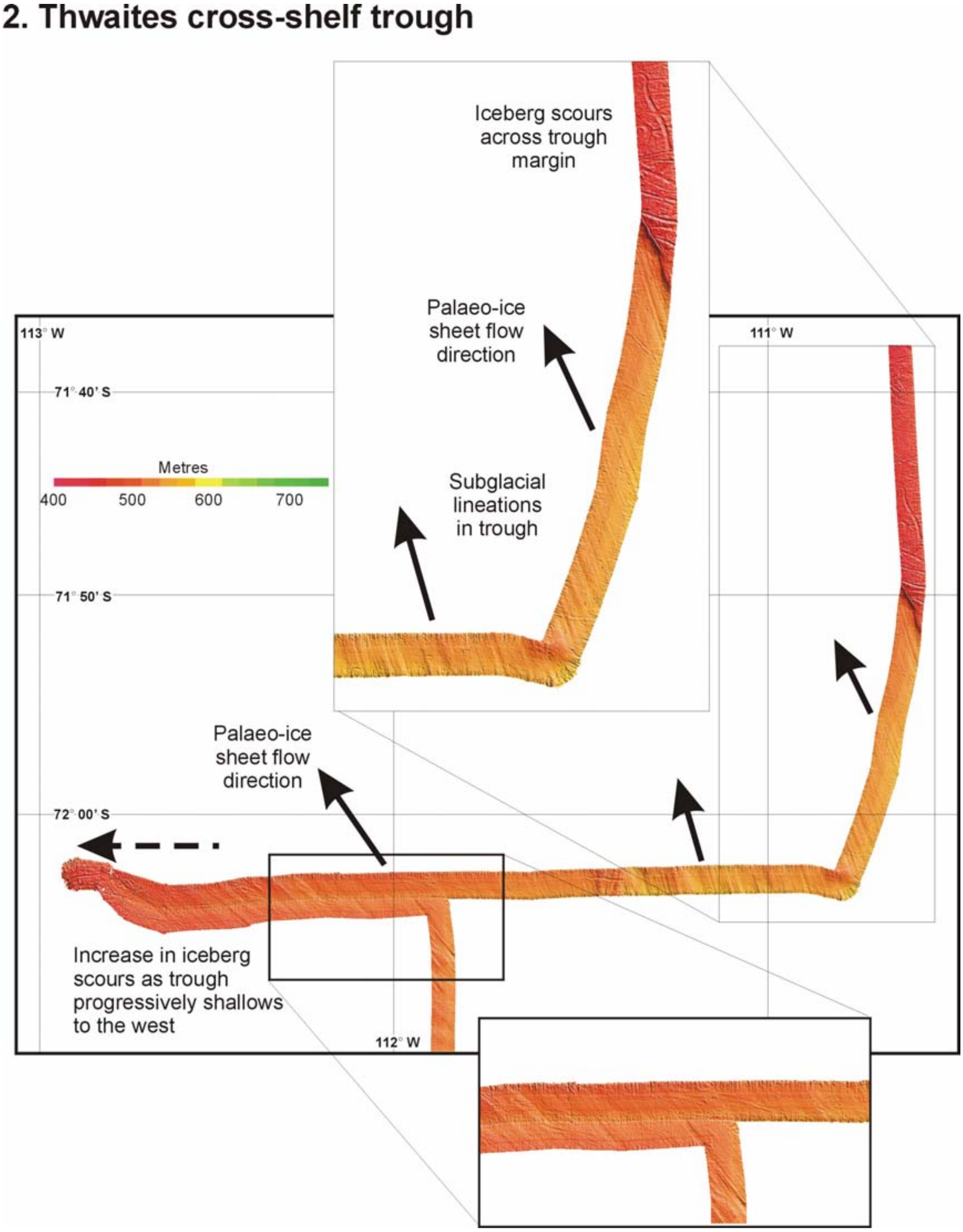


Figure 3: Swath bathymetry showing glacial lineations in sediments of the Thwaites Trough. The direction of past glacier flow can be inferred from the orientation of the lineations. Icebergs scours are present in shallower areas.

3. Gerlache Strait

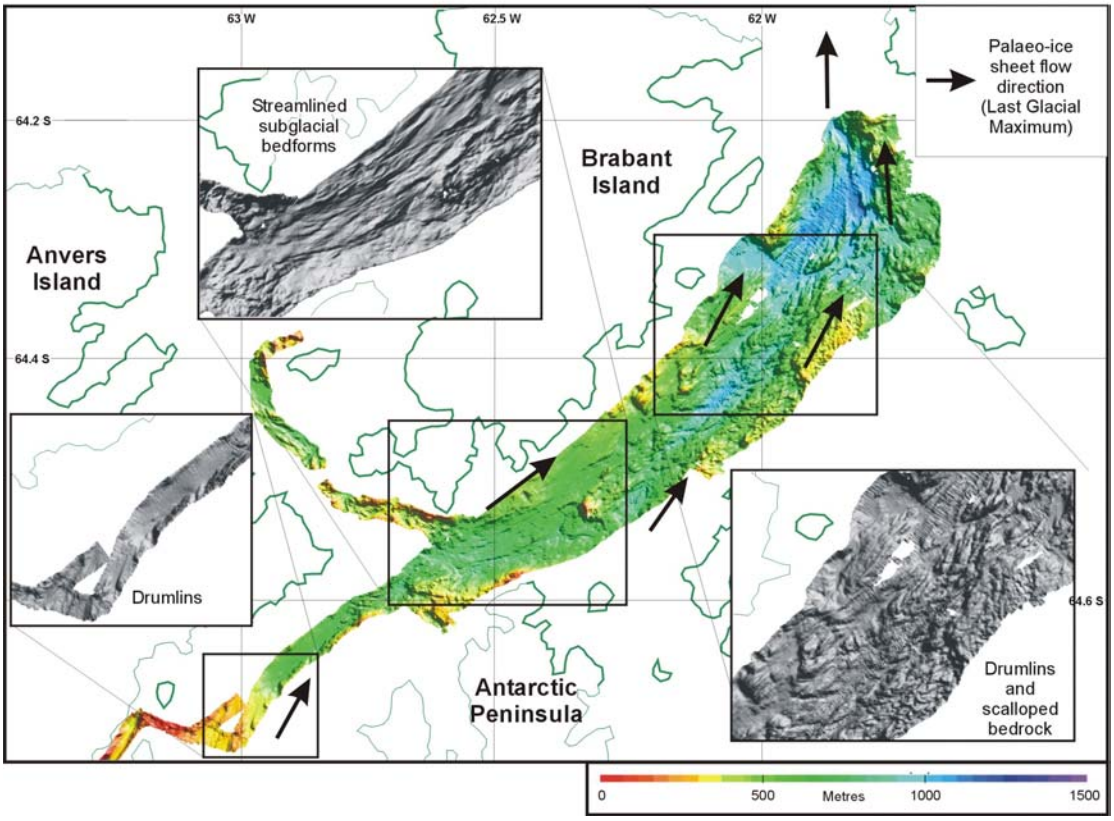


Figure 4: Swath bathymetry of the Gerlache Strait, western Antarctic Peninsula. Streamlined glacial erosional and depositional forms are illustrated and are used to infer the direction of past ice flow.

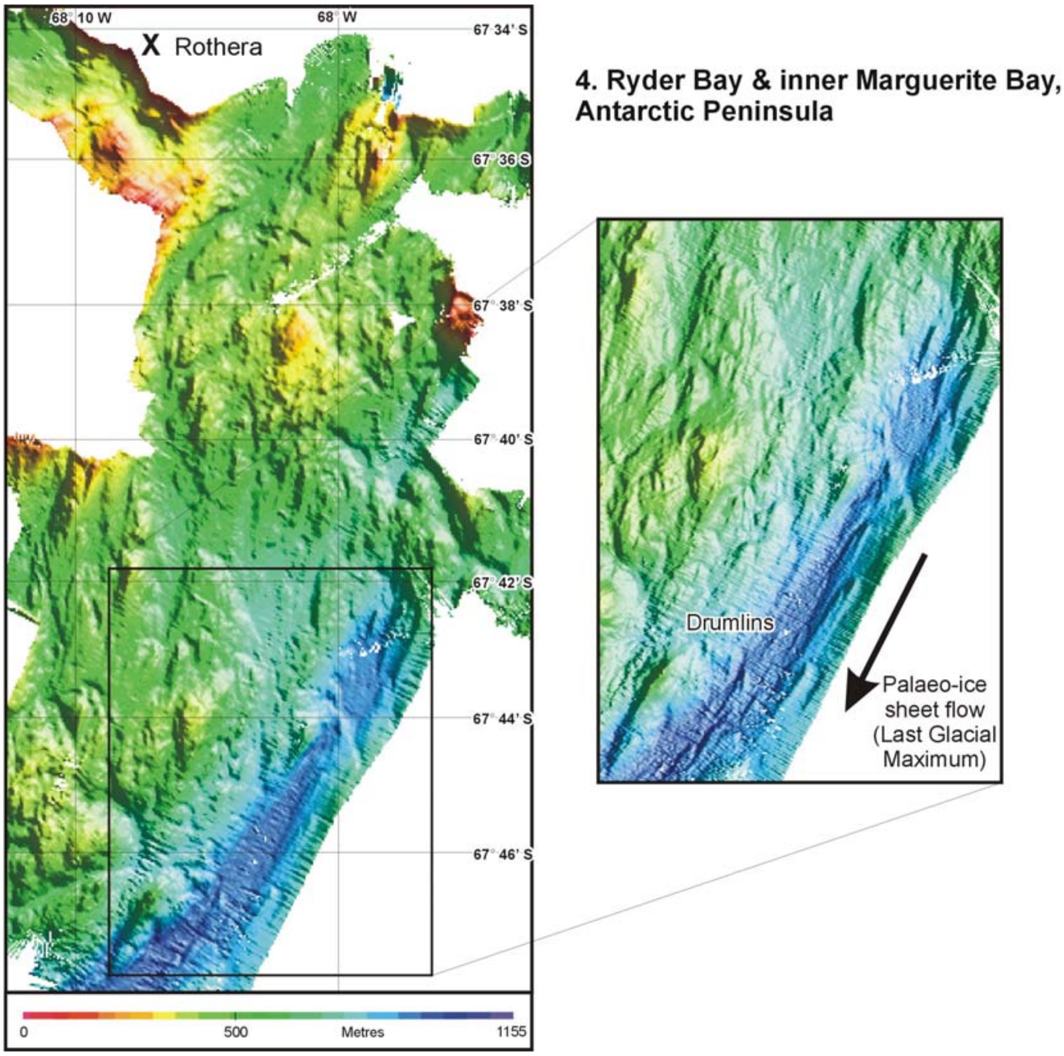


Figure 5: Swath bathymetry of part of Ryder Bay and the inner eastern arm of Marguerite Bay. Rothera is located. Note the drumlinised streamlined bedrock.

EM120 (Colm Ó Cofaigh, Jeffrey Evans)

We gratefully acknowledge useful discussions with **Jeremy Robst** and **Doug Willis** (BAS ITS) and **Pat Cooper** (BAS ETS).

The EM120 was operated throughout the cruise apart from JD89 when were alongside at Rothera, giving a total of 34 days data collection. Angular coverage was set to "Manual" and beam spacing was set to "Equidistant". The beam angle used throughout the cruise varied according to sea conditions, water depth and sea-bed type but was usually between 50-65 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 (~ 10%) level of overlap. Post-processing of the EM120 data was carried out using the Kongsberg-Simrad Neptune software.

In general, the EM120 worked reasonably well throughout the cruise, especially in shallow water (<1000 m) on the continental shelf. Poor returns or an inability of the system to find the seabed occurred from time to time, usually during bad weather. In these situations the most useful technique was to use the "Force Depth" command with a depth slightly less than the true seabed. Two other methods were also found to be useful: varying the beam angles by generally reducing them to a narrow beam width, and then, once the seabed was found, gradually increasing them again; and, secondly, restricting the maximum and minimum depths to a tight range around the true seabed depth.

Problems

These can be broadly grouped into:

(1) Continuous poor returns or drop-outs on the EM120 when the wind direction is onto the beam. This problem was the subject of much discussion during the cruise and some effort was spent near Rothera research station trying to determine the conditions under which it occurred. This is documented separately (see section "*Swath Trials*" by Doug Willis).

(2) Synchronisation of EM120, EA500 and TOPAS via the Simrad Synchronisation Unit. Both CÓC and JEV spent much time during the cruise working on this and testing various settings and what follows is a summary of problems and recommendations based on our experience. It should be noted that this summary also discusses TOPAS as the problems appear to collectively relate to the EM120, EA500 and TOPAS. We further note that (a) to our knowledge these problems did not occur on JR71 in February-March 2002 (which both CÓC and JEV participated in and helped operate the EM120 and TOPAS) and (b) the EM120 and SSU software was upgraded subsequent to JR71 in October 2002.

The principal problem that we noted relates to the EM120 returns in deep water. In water depths generally from 2000-4000 m, the individual ping display can show a centre track anomaly in which beams (approx.) 77-134 (maximum range) are consistently much deeper (on the order of 100-300 m) than the outer beams on either side and the centre beams (90-98), giving the appearance of a deep valley with a single large spike in the middle. In some cases the valley base was so deep that the bottom was not actually recorded by the system. Sometimes the anomaly consisted of a single deep “trough” with no spike of shallower depths in the middle. Amplitude detection was very high where the anomalous depths were recorded and the data quality was poor with little or no phase detection. Ship speed was generally 10-15 knots as the problem happened mostly when we were in transit across deep-sea areas.

Initially we thought that this problem might be due to an incorrect sound velocity file being used in the survey. We tested this by doing XBT’s casts and uploading them to the survey. However, this produced no improvement and in some cases the anomaly became worse. Hence we concluded that this was not a sound velocity problem. Correspondence received from Kongsberg-Simrad during the cruise (Kjell Nielsen, product manager Multibeam, KS) stated that this centre track effect was due to a timing problem with the software upgrade installed in October 2002 and related to the 1-degree receiver. He stated that the problem had now been fixed. A patch was subsequently e-mailed to us on the ship and Jeremy Robst (BAS ITS) installed it. However, the problem has since occurred (again in deep water). It should be noted that the problem first occurred during the initial transit south across Drake Passage from Stanley during a period when we were not running TOPAS.

Through adjustment of the SSU settings (principally by increasing the amount of time given to the EM120 to transmit and receive using the “Fixed Time” option under “Time Usage”) we found that the problem could be alleviated. Throughout the cruise it was generally found that using the “Fixed Time” option gave a better (less anomalies) record on the EM120. We did use “Calculated Time” for both the EM120 and EA500 on several occasions. In deep water when the centre track anomaly occurred it was notable that this did not solve the problem. Furthermore, this also appeared to adversely affect the trigger pulse of the EM120 on the SSU display whereby the transmission pulse turned grey (instead of red) followed by a period of red, then green and then an additional short period of red. This was not regarded as a stable set-up and so the system was generally run throughout the cruise on fixed time, with the time allocated dependent on water depth. This obviously necessitated manual changes to the SSU by us.

In deep water there is also a problem of low data density for each of the echo sounders. On previous cruises (JR71 and JR59) this problem was addressed by operating TOPAS in manual triggering mode. This was also tried on JR84 in areas of deep water. However, the result appeared to adversely affect the transmission and reception of the EM120 in that the transmission pulse appeared grey, implying that the EM120 was no longer under SSU control. Again this was not considered very reliable and so all three echo sounder were triggered by the SSU in deep water with the EM120 and EA500 generally on fixed time usage and TOPAS on calculated.

Recommendations

The patch supplied by Kongsberg-Simrad did not solve the EM120 centre track problem noted above. We suggest that the SSU and software, and the EM120 operating software need to be checked by Kongsberg-Simrad to make sure they are functioning correctly.

SSU Settings

Some examples of SSU settings that were used on JR84 are given below. It should be noted that these were not the only settings used but are included here as examples. It is anticipated that these will be modified between and during individual cruises. Note the EK60 was off throughout JR84 and the SSU Groups used were: EA&EM EK TOPAS. The EA500 was kept in passive mode when the EM120 was operating.

1. Water depths: 500-700m
   EM120: Fixed Time 5000 ms
   EA500: Fixed Time 5000 ms; Time add-on 80%
   TOPAS: Calculated Time; Time add-on 50%;
   Depth: Auto

2. Water depths: 500-1000m
   EM120: Fixed Time 3510 ms
   EA500: Fixed Time 3510 ms; Time add-on 80%
   TOPAS: Calculated Time; Time add-on 10%;
   Depth: Auto

3. Water depths: Water depths 900-1030m
   EM120: Fixed Time 6000-7000 ms
   EA500: Fixed Time 5000- ms; Time add-on 70-80%
   TOPAS: Calculated Time; Time add-on 50%;
   Depth: Auto

4. Water depths: ~1400 ms
   EM120: Fixed Time 6000-7000 ms
   EA500: Fixed Time 5000 ms; Time add-on 0%
   TOPAS: Calculated Time; Time add-on 0%; multipulse: on with 1000 ms time interval
   Depth: Auto

5. Water depths: 2600-2700 ms
   EM120: Fixed Time 7000-8000 ms
   EA500: Fixed Time 5000 ms; Time add-on 0%
   TOPAS: Calculated Time; Time add-on 0%; multipulse: on with 1000 ms time interval
   Depth: Auto

TOPAS (Colm Ó Cofaigh, Jeffrey Evans)

TOPAS was run throughout the cruise apart from JD89 when were alongside at Rothera. In the latter area, repeated surveying of the same area of steep irregular topography during EM120 testing was felt to be unnecessary due to the rather poor TOPAS returns obtained. We stopped logging TOPAS at 21.44 on JD93.

General settings
The following settings were used throughout the cruise:
Sampling rate 10 kHz; trace length 400 ms; file size 10 MB; under "processing" Swell OFF, Dereverb OFF; Stacking OFF.

Shallow water settings (<1000 m water depth)
Burst source, period 1-3, level 100%, secondary frequency 2800 Hz.
SSU triggering (ping interval set to 0), Gain 15-25 dB depending on seabed type and conditions). Processing: filter ON, AVC ON, Scale 2000%.

Deep water settings (>1000 m water depth)
Chirp source, 15 ms pulse length, 1-1.5 kHz, level 85%, bandpass filter settings 1400-1600/4900-5100 Hz.
SSU triggering (ping interval set to 0), Gain 20-30 dB depending on sea bed type and conditions.
Processing: filter ON, Deconvolution ON (1 ppm), TVG ON (manual start about 200-300 ms above seabed, slope generally ranged from 50-90 dB/s), AVC ON, Scale 3000%

As with previous cruises, it was found that TOPAS produced poor returns on steep slopes and undoubtedly works best on a fairly flat sea-bed where impressive records can be achieved in both Burst and Chirp modes. The 400 ms trace length meant that in steep, irregular topography frequent delay changes were required. Post-processing of selected TOPAS files was done during the course of the cruise. In previous cruises and cruise reports it had been noted that it would be advantageous to have EM120 and TOPAS post-processing software available on different workstations. However, this problem has now been alleviated following the production and installation of the new (2002) PC-based TOPAS post-processing software.

Problems

See section pertaining to the SSU under "EM120"

EPC Chart Recorder (Colm Ó Cofaigh, Jeffrey Evans)

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 from 6 to 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 varied from 75-100, contrast centre setting. A ten-minute time mark was supplied from the radiocode clock at the aft end of the UIC room.

The EPC chart recorder worked without any problems throughout the cruise until JD88 (Rothera) when it stopped working abruptly. This followed a short period when it had been turned off but no reason could be ascertained as to why failure had occurred. No spares were available on the ship during this cruise and therefore the EPC chart recorder could not be repaired. BAS ETS personnel (Pat Cooper) said further information and spares from the supplier are required in order to fix it.

XBT's (Colm Ó Cofaigh, Jeffrey Evans)

Based on our experience of processing EM120 data, it is very desirable that the correct sound velocity data are applied to the survey during acquisition and logging. This alleviates the necessity of having to correct for this during post-processing in Neptune, which can be difficult. To this end, XBT's were collected throughout the cruise. T5's were used in deep water (>760 m) and T7's were used in shelf areas (water depths <760 m). The casts were made from the starboard side of the ship due to access considerations. The ship was slowed to a speed of 6 knots or less during T5 casts, while T7's were done at <15 knots. Most of the T5 casts went to the full T5 depth of 1830 m.

Originally it was intended that a large amount of time would be spent surveying on the shelf in Pine Island Bay. Hence a larger number of T7's than T5's were carried on-board. We had intended to carry out XBT casts every 6-9 hours throughout the course of the cruise. However, because sea ice prevented full access into Pine island Bay, more time was spent surveying in deeper water than originally planned. As a result we had to reduce the frequency of T5 casts so as not to run out prematurely before the end of the cruise. In practice this was not a problem as the EM120 data did not need frequent updates to the sound velocity files (which we judged based on the appearance of the beams – arching upwards or downwards). Deep water XBT's were generally carried out therefore every 1-2 days and the data immediately exported and applied to the current survey.

XBT Stations

Cast no.	EDF file	Time/date	Lat S	Long W	Water depth (m)	JR84 *.asvp file
1	T5_0002.EDF	15.13/060	55º 24.65 S	60º 17.84 W	4000	JR84_1.asvp
2	T5_0004.EDF	22.16/060	56º 29.76 S	61º 10.20 W	4370	JR84_2.asvp
3	T5_0006.EDF	07.00/061	57º 52.14 S	62º 28.73 W	3541	JR84_3.asvp
4	T5_0007.EDF	16.00/061	59º 53.90 S	62º 38.52 W	4040	JR84_4.asvp
5	T5_0008.EDF	22.06/061	61º 19.54 S	62º 45.66 W	3512	JR84_5.asvp
6	T7_0009.EDF	07.10/062	63º 15.11 S	62º 58.03 W	703	JR84_6.asvp
7	T7_0010.EDF	16.10/062	64º 35.19 S	62º 34.09 W	683	JR84_7.asvp
8	T7_0011.EDF	03.00/063	64º 13.33 S	61º 49.86 W	868	JR84_8.asvp
9	T7_0012.EDF	17.04/064	65º 52.48 S	70º 15.14 W	361	JR84_9.asvp
10	T5_0013.EDF	21.00/064	66º 10.13 S	72º 04.44 W	2926	JR84_10.asvp
11	T5_0014.EDF	08.20/065	66º55.26 S	76º 45.36 W	3737	JR84_11.asvp
12	T5_0015.EDF	13.15/065	67º18.31 S	79º05.31 W	3917	JR84_12.asvp
13	T5_0016.EDF	19.11/065	67º43.19 S	81º53.45 W	4008	JR84_13.asvp
14	T5_0017.EDF	09.40/066	68º49.32 S	89º11.74 W	3683	JR84_14.asvp
15	T5_0018.EDF	06.10/067	70º14.79 S	99º40.07 W	3970	JR84_15.asvp
16	T5_0019.EDF	04.35/070	70º15.58 S	101º54.12 W	3710	JR84_16.asvp
17	T7_0020.EDF	20.03/070	71º14.83 S	109º 15.80W	503	JR84_17.asvp
18	T7_0021.EDF	04.10/071	72º04.01 S	111º03.39 W	563	JR84_18.asvp
19	T7_0022.EDF	19.00/071	72º46.28 S	109º25.11 W	470	JR84_19.asvp
20	T5_0023.EDF	11.30/072	71º02.63 S	108º28.82 W	2077	JR84_20.asvp
21	T5_0024.EDF	19.34/073	70º49.43 S	106º54.14 W	2840	JR84_21.asvp
22a	T5_0025.EDF	-	-	-	-	Failed – wire snap
22b	T5_0026.EDF	00.32/075	71º00.64 S	111º44.38 W	2709	JR84_22.asvp
23	T7_0027.EDF	18.00/076	71º35.84 S	113º28.12 W	621	JR84_23.asvp
24	T7_0028.EDF	-	-	-	-	Failed – wire snag
25	T7_0029.EDF	07.00/076	71º42.72 S	113º39.27 W	590	JR84_24.asvp
26	T7_0030.EDF	08.50/077	71º31.56 S	113º21.75 W	624	JR84_25.asvp
27	T7_0031.EDF	00.37/078	71º30.04 S	112º49.04 W	422	JR84_26.asvp
28	T7_0032.EDF	06.25/079	71º28.24 S	114º48.74 W	963	JR84_27.asvp
39	T5_0033.EDF	07.55/080	71º20.18 S	114º05.77 W	1900	JR84_28.asvp
30	T5_0034.EDF	00.22/082	-	-	-	Failed
31	T5_0035.EDF	00.35/082	70º42.63 S	105º50.86 W	3111	JR84_29.asvp
32	T5_0036.EDF	10.58/084	70º11.99 S	98º21.78 W	4046	JR84_30.asvp
33	T5_0037.EDF	-	-	-	-	Failed – wire snap
34	T5_0038.EDF	17.30/086	68º33.88 S	84º51.22 W	3680	JR84_31.asvp
35	T7_0039.EDF	16.15/087	67º40.77 S	73º07.19 W	485	JR84_32.asvp

SIMRAD EA500 Bathymetric Echo Sounder

Mark Brandon
(Open University)

The RRS *James Clark Ross* is equipped a Simrad EA500 echo sounder with the transducer mounted on the hull just to starboard, with the primary visual display and controls located on the bridge. The system was run virtually continuously during cruise JR84. Exceptions were when the AUV was close to the ship and the system was turned off to reduce interference with the telemetry to the vehicle.

EA500 data were logged by the SCS into the simulated level C data stream SIM500 and retrieved into twice-daily Pstar files using the script `jr84_sim`. This ran the Pstar routine `datapup`, taking the jday and am or pm as the requisite inputs. This data stream features uncorrected depth, i.e. it produces bottom depth calculated assuming a mean vertical sound velocity of 1500 m s^{-1}. The unix script then ran `pedita` on the uncorrected depths to remove spurious zeroes and replace them with absent data markers. Since the data are often very spiky, `pmdian` was run from whereby each successive value was replaced with the median of a moving window of five adjacent data cycles (equivalent to a window of 2 minutes 30 seconds). Navigation data were then merged in from pstar bestnav data set (see navigation report). Finally corrected depths were calculated using `pcarter`, which feeds the ship's position into a set of 'Carter' reference tables to correct for the assumption that vertical sound velocity averages to 1500 m s^{-1}. The output files created by `jr84_sim` were 84sim[jday][a/p].raw (containing the raw data from the SCS), 84sim[jday][a/p] (containing the cleaned data), 84sim[jday][a/p].mrg (the cleaned data plus merged navigation}, and 84sim[jday][a/p].corr (the above data corrected using a more representative speed of sound).

Sea Ice Observations

Chris Banks and Mark Brandon
(Open University)

Sea ice observations were made from the bridge as progress and personnel permitted using the standardised ASPECT[1] approach. Information collected included type(s) of ice, floe size, estimate of thickness, snow cover (type and depth), topography, longitude and latitude, time and basic meteorological data. The observations will be validated by the use of digital photographs and video images back in the UK, which will allow more accurate descriptions of coverage. In addition, thickness can be estimated from comparison with parts of the ship visible in the photographs. There is a possibility that some of the earlier images have been corrupted, this is yet to be confirmed.

Sea ice observations were carried out on the 8, 9, 10, 12, 13, 14, 15, 20, 22, 23, 24 and 25 March 2003, data were recorded on paper and then entered into the ASPECT software. These data should be of particular interest because the process of sea ice formation in relatively calm water has been observed.

Measurements on Ice Floes

Three locations were used to measure ice thickness. The first site was on the afternoon of 8th March. There were two sites on the 9th March one in the morning and a second in the afternoon. The measurements were designed to act as ground truth for the Autosub missions. Unfortunately there were no under ice missions within the next few days due to testing of Autosub taking longer than planned. Floes were selected based on their suitability (safety) for working on. As such the sampled floes were larger in area and were likely to be thicker (i.e. more stable) than most within the region.

On the floe on 8th March (Floe Station 1 – FS1) the OU auger was used, this proved ineffective at drilling through the ice and a large amount of time was spent digging the auger out when it became stuck. The ice could only be measured as greater than 1m as it would not have been prudent to use the extension rods to drill further. Snow depth measurements were made and produced a range of depth between 6cm and 95cm with a mean and standard deviation of 47.4±21.1cm (n=103). The floe was occupied from 0000Z (i.e., actually on the 9th March) until 0050Z. Longitude was 101^{o}09.76’ and latitude was 70^{o}58.84’.

FS2 on the morning of the 9th March used the JCR’s ice anchor drill, this proved more efficient compared to the previous day’s drill. The depth of the sea ice (not including snow depth) was 1.91m. Again snow depth measurements were made across the floe. Range of snow depth values was from 5cm to 88cm with a mean and standard

[1] Worby, A. P. 1999. Observing Antarctic sea ice: A practical guide for conducting sea ice observations from vessels operating in the Antarctic pack ice. A CD-ROM produced for the Antarctic Sea Ice Processes and Climate (ASPeCt)
program of the Scientific Committee for Antarctic Research (SCAR) Global Change and the Antarctic (GLOCHANT) program, Hobart, Australia.

deviation of 39.2±20.3cm (n=114). The floe was occupied from 1730Z until 1840Z. Longitude was 102^{o}00.0' and latitude was 70^{o}51.35'.

FS3 on the afternoon of 9th March used the ship's ice anchor drill for the first two metres. The OU drill head and extension rods were then used, attached to the ship's anchor drill for further deeper drilling. Three holes were drilled, the last of which failed to clear the thickness. The depths at the three holes were 2.43m, 2.66m and greater than 2.7m (excluding snow depth). The snow depths at the first two points were 27cm and 34cm. There was no measurement made of snow at the location of the third hole as no measure of ice thickness could actually be made either. It is perhaps not surprising that the third hole was so deep as the measurement was made adjacent to a surface ridge. Snow depth measurements were made on this floe too, with a range of between 2cm and 86cm with a mean and standard deviation of 45.3±15.6cm (n=107). The floe was occupied from 2015Z until 2118Z. Longitude was 102^{o}21.4' and latitude was 70^{o}53.0'.

Sea Ice Drifters

Adrian Jenkins
(British Antarctic Survey)

Three sea ice drifters, supplied by Hartmut Hellmer of the Alfred-Wegener-Institute, were deployed on multi-year floes (FS1–3) north of Thurston Island. This work was carried out on 8–9 March as part of the floe sampling work described above. The buoys transmit position, air temperature and atmospheric pressure every three hours via the Argos satellite system. They were unpacked and set up on the after deck two days prior to deployment, to check that the Argos transmitters were working.

The aim was to deploy the drifters in a broad triangle, with at least one of them over the continental shelf. In the end the positions were dictated by the ice conditions, which meant that there was only a narrow latitudinal band between ice that was too loose to risk deployment and ice that was too heavy to penetrate with the ship. The final arrangement ended up close to linear, and a period of strong southerly winds shortly after deployment pushed all the drifters well north of the continental slope.

Deployment sites and drift tracks over the main work period of JR84 are shown in Figure 6.

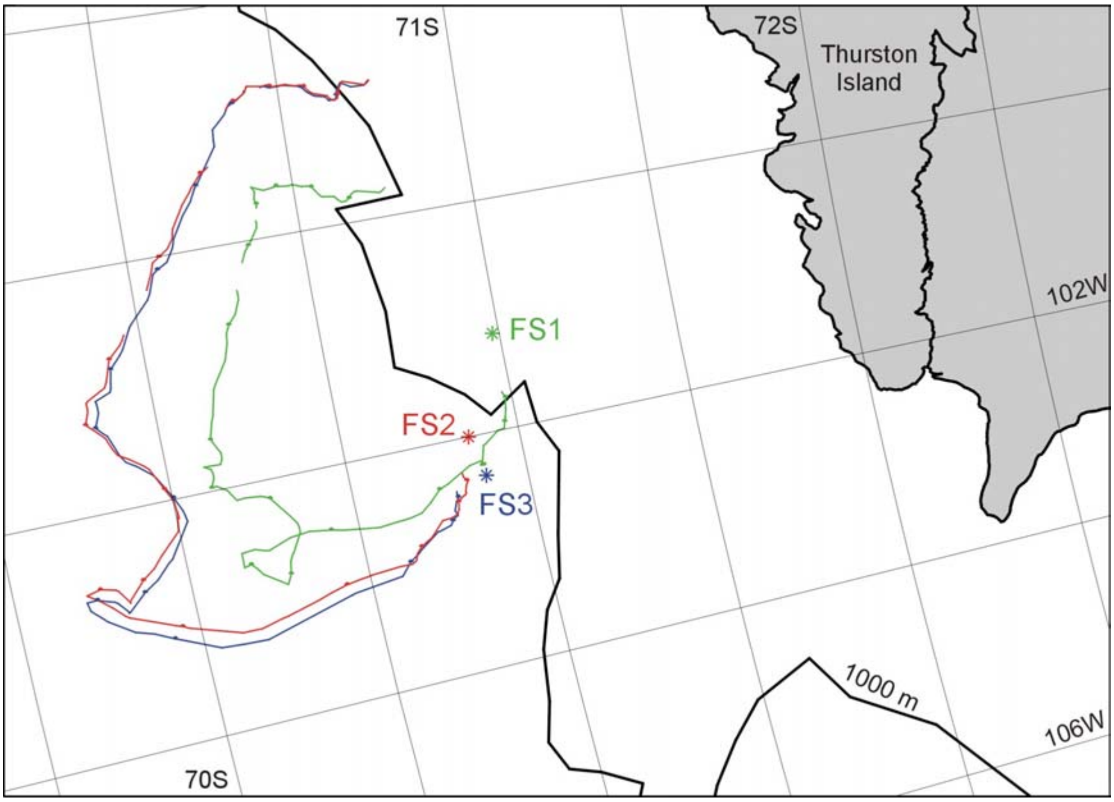


Figure 6: Sea ice drifter tracks from 18:00 on 11/03/03 to 21:00 on 27/03/03 for Argos buoys 8058 (blue), 8059 (red) and 8064 (green). Original deployment sites are indicated by the stars. The 1000 m contour is inaccurate, but provides a rough indication of the location of the continental slope.

Physical Oceanography

Mark Brandon, Ziggy Pozzi-Walker, Dan Hayes, Adrian Jenkins
(Open University and British Antarctic Survey)

The main aim of the physical oceanography programme was to investigate the processes by which Upper Circumpolar Deep Water (uCDW) intrudes onto the continental shelf of the Amundsen Sea. When it reaches the floating ice masses to the south, uCDW causes the highest melt rates observed in Antarctica. In total 44 CTD stations were occupied. These were arranged in five sections aligned perpendicular to the continental slope and one section parallel to the shelf break approximately 10 km onto the shelf. Most of the work focussed on a seabed trough that cut the shelf break near 113.5°W. The trough had been identified during a Feb/Mar 2000 Nathaniel B Palmer cruise to the Amundsen Sea. The studies this year clearly delineated a warm tongue extending along the eastern side of the trough. Temperatures in excess of +1.2°C within this core are the highest yet observed on the Amundsen Sea shelf. In addition, a few isolated CTD stations were occupied at the sites of Autosub deployments. Data from casts 2 to 44 are shown in figure 7 and the locations of the stations in figure 8. Station 1 was a test cast in Gerlache Strait. Examples of sections along and across the shelf break are shown in figure 9.

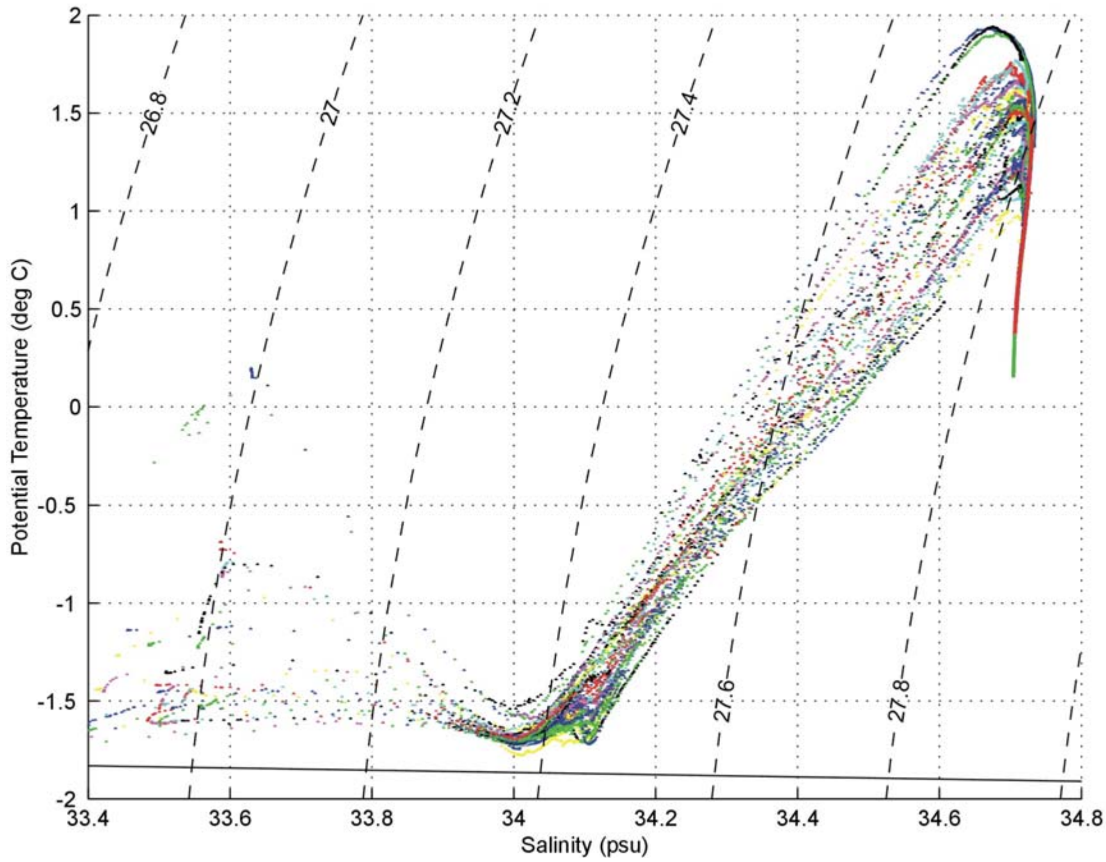


Figure 7: Scatter plot of potential temperature versus salinity data (2 dbar averages) from CTD stations 2 to 44. The solid black line indicates the surface freezing point, the labelled, dashed lines are isopycnals referenced to surface pressure

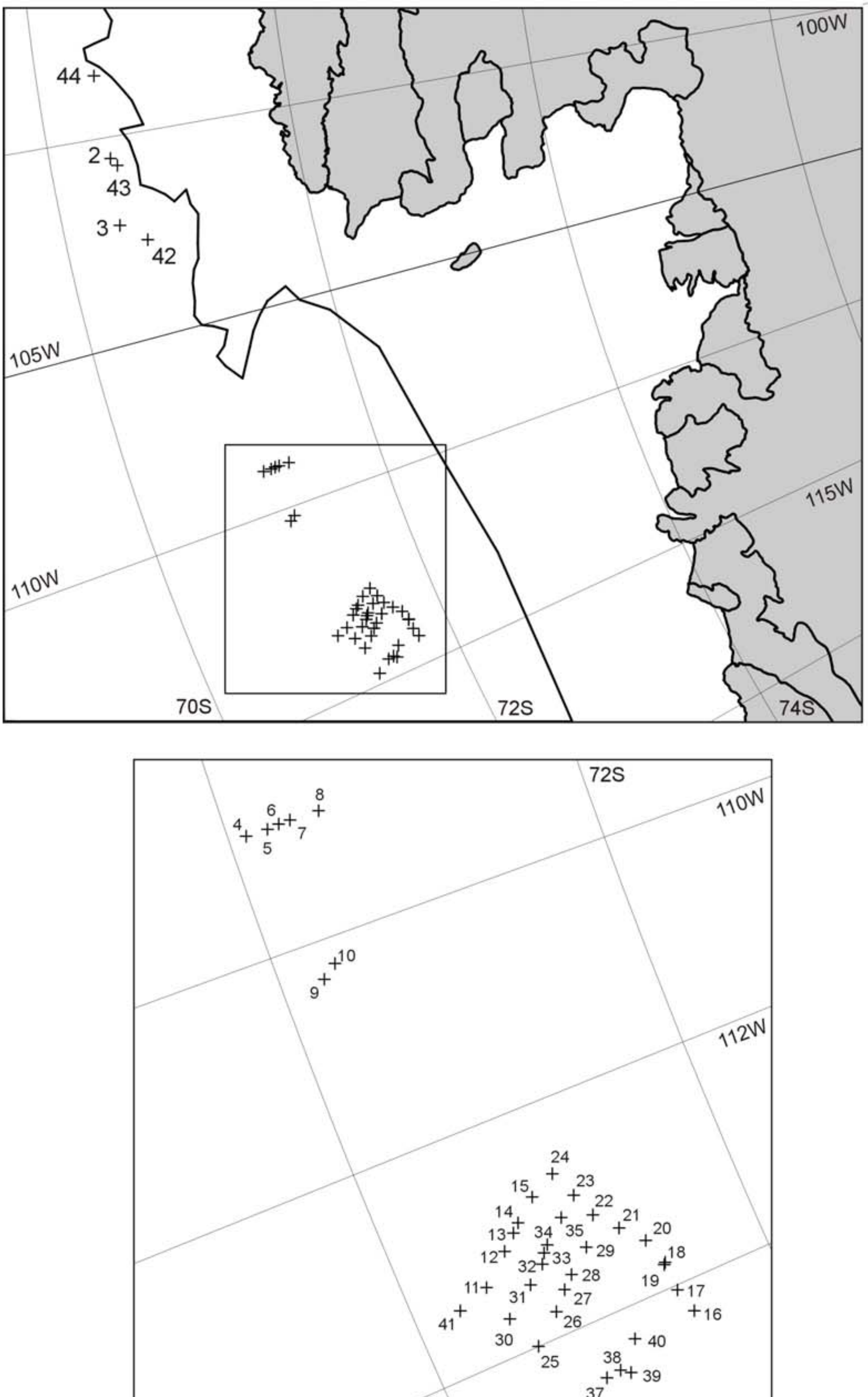


Figure 8: Locations of CTD stations occupied during JR84. The lower panel is an enlargement of the boxed area in the upper panel.

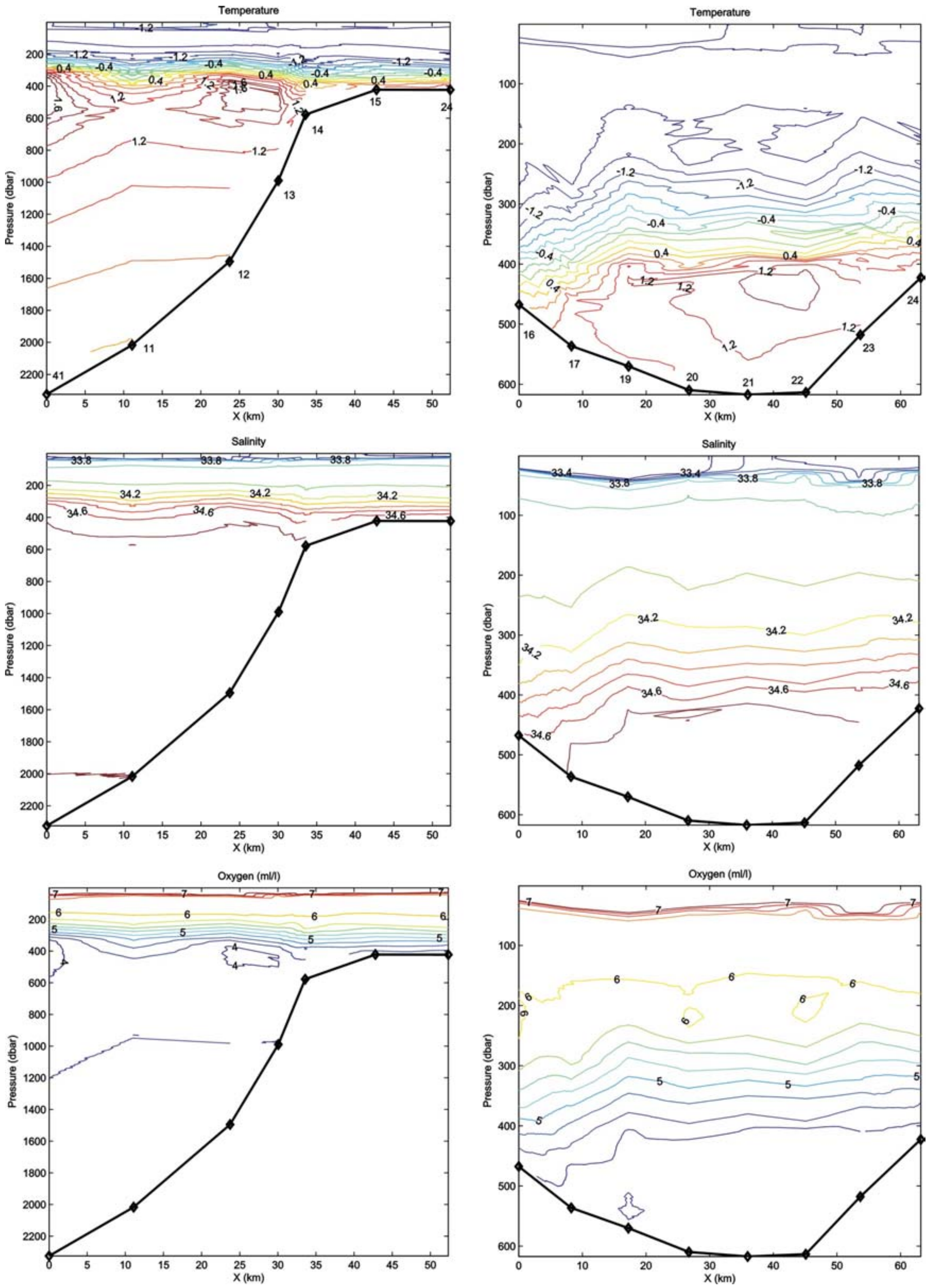


Figure 9: Temperature, salinity and dissolved oxygen sections perpendicular (left) and parallel (right) to the shelf break.

JR84 CTD Operations

Summary

This section of the report describes the method of acquisition and calibration of 44 CTD stations collected on JR84. The system performed excellently throughout the cruise with no serious problems encountered. For all CTD stations the 2 dbar averages of the downcast data are reported as the final product.

The CTD equipment

The CTD unit used for the measurement program was a Sea-Bird 911 plus with dual temperature and conductivity sensors, an altimeter, dual SBE 43 oxygen sensors and a Chelsea instruments Fluorometer. The configuration and serial numbers of the sensors used are in table 1 below. A copy of the full calibration coefficients for the CTD is in the appendix to this section.

Table 1: CTD configuration throughout JR84.

CTD sensor	Serial Number	date last calibrated
Sea-Bird 911 plus	09P15759-0480	
Series 410K-105 Digiquartz pressure transducer	067241	30-Jun-2000
Primary SBE 4C conductivity sensor	042289	19-Jul-02
Primary SBE 3 plus temperature sensor	032366	19-Jul-02
Primary pump SBE 5 T submersible pump	051813	
Secondary SBE 4C conductivity sensor	019112	19-Jul-02
Secondary SBE 3 plus temperature sensor	032191	19-Jul-02
Secondary SBE 5 T submersible pump.	651807	
Tritech PA200/20-5 Altimeter	2130.26993	not known
Primary Seabird SBE 43 Oxygen sensor	0245	27-Aug-02
Secondary Seabird SBE 43 Oxygen sensor	0242	27-Aug-02
Fluorometer, Chelsea Aqua 3	088216	11 june-01

All calibration coefficients are given in the Appendix.

The CTD was connected to an SBE 32, 12 position carousel water sampler (S/N 3215759-0173) carrying 12 10 L bottles. In addition the CTD was connected to an SBE 35 Reference Temperature Sensor (S/N 0315759-0005).

Deployment of the CTD package was from the mid-ships gantry and A-frame, on a single conductor torque balanced cable connected to the CTD through the BAS conducting swivel. This CTD cable was made by Rochester Cables and was hauled on the 10T traction winch. There were no problems deploying the CTD package and no re-terminations were required throughout the cruise.

The CTD data were logged via an SBE 11 plus deck unit to a 486 Viglen PC, running Seasave Win32 version 5.25 (Sea-Bird Electronics Inc.). This new software is a great leap forward compared with the DOS version in that one can draw several graphs of various recorded parameters in real time, as well as having numerical lists of data to the screen. The data rate of recorded data for the CTD was 24 Hz.

A full station list is given in table 2 below.

Calibration of the CTD data

Four files were created when the Seasave Win32 version 5.25 module was exited at the end of each CTD cast: a binary data file, with the extension .dat, an ascii configuration file containing calibration information with the extension .con, an ascii header file containing just the sensor information with the extension .hdr, and an ascii file containing the data cycle numbers at which a bottle was closed on the rosette, with extension .bl. After the CTD the data were converted to ascii engineering units by running the Sea-Bird Electronics Inc. Data Processing software version 5.25 *Data Conversion* module. The full data processing path is described below.
The calibration for each sensor was as follows:
For the Pressure Sensor:

$$P = C\left(1 - \frac{T_o^2}{T^2}\right)\left(1 - D\left(1 - \frac{T_o^2}{T^2}\right)\right)$$

Where P is the pressure, T is the pressure period in μS, D is given by

$$D = D_1 + D_2 U$$

U is the temperature in degrees centigrade, T_o is give by

$$T_o = T_1 + T_2 U + T_3 U^2 + T_4 U^3 + T_5 U^4$$

and C is

$$C = C_1 + C_2 U + C_3 U^2$$

all other coefficients are listed in the Appendix.
For the Conductivity Sensor:

$$cond = \frac{\left(g + h f^2 + i f^3 + j f^4\right)}{10\left(1 + \delta t + \varepsilon p\right)}$$

Where the coefficients are given in the Appendix, δ = CTcorr and ε = Cpcorr, *p* is pressure and *t* temperature.
For the Temperature sensor:

$$Temp\ (ITS-90) = \left\{\frac{1}{g + h(\ln(f_o/f)) + i(\ln^2(f_o/f)) + j(\ln^3(f_o/f))}\right\} - 273.15$$

Where all of the coefficients are given in the Appendix, and *f* is the frequency output by the sensor.

Table 2: Full details of CTD measurements taken on JR84

STATION	YYYY/MM/ DD	Day of Year	HH:MM	Decimal Long	decimal Lat	Long deg.	long min	Lat	lat min	uncorr wdept	ctd Max P	dpth dist_off
84ctd001	04/03/2003	063	13:39	-62.0959	-64.4892	-62	5.75	-64	29.35	475	466	4.84
84ctd002	08/03/2003	067	14:17	-102.1523	-70.4582	-102	9.14	-70	27.49	3230	1018	-999
84ctd003	10/03/2003	069	15:15	-100.5158	-70.4913	-100	30.95	-70	29.48	3525	3532	-999
84ctd004	13/03/2003	072	20:13	-108.9342	-71.0498	-108	56.05	-71	2.99	2050	2061	8.79
84ctd005	14/03/2003	073	05:13	-108.9368	-71.1133	-108	56.21	-71	6.8	1502	1476	6.16
84ctd006	14/03/2003	073	07:00	-108.9248	-71.1482	-108	55.49	-71	8.89	984	986	5.28
84ctd007	14/03/2003	073	08:25	-108.924	-71.1814	-108	55.44	-71	10.89	515	525	2.78
84ctd008	14/03/2003	073	09:59	-108.9284	-71.2664	-108	55.71	-71	15.99	484	478	2.69
84ctd009	15/03/2003	074	12:55	-110.3287	-71.1222	-110	19.72	-71	7.33	2088	2066	5.93
84ctd010	15/03/2003	074	15:05	-110.2314	-71.1656	-110	13.88	-71	9.94	1544	1506	8.6
84ctd011	16/03/2003	075	05:09	-113.3457	-71.2231	-113	20.74	-71	13.39	2094	2017	4.42
84ctd012	16/03/2003	075	07:46	-113.1163	-71.3099	-113	6.98	-71	18.59	1489	1495	8.25
84ctd013	16/03/2003	075	09:34	-112.9995	-71.3529	-112	59.97	-71	21.18	1024	991	5.31
84ctd014	16/03/2003	075	11:04	-112.9324	-71.3762	-112	55.94	-71	22.57	594	578	6.37
84ctd015	16/03/2003	075	12:34	-112.7708	-71.441	-112	46.25	-71	26.46	428	422	8.45
84ctd016	17/03/2003	076	02:27	-114.2756	-71.732	-114	16.53	-71	43.92	482	468	2.76
84ctd017	17/03/2003	076	04:03	-114.0445	-71.7126	-114	2.67	-71	42.76	558	536	4.98
84ctd018	17/03/2003	076	05:29	-113.7719	-71.7122	-113	46.31	-71	42.73	594	41	-999
84ctd019	17/03/2003	076	06:01	-113.7878	-71.7075	-113	47.27	-71	42.45	594	571	6.64
84ctd020	17/03/2003	076	07:36	-113.5234	-71.6871	-113	31.4	-71	41.23	631	610	5.62
84ctd021	17/03/2003	076	09:07	-113.3254	-71.6319	-113	19.52	-71	37.92	636	617	2.81
84ctd022	17/03/2003	076	10:34	-113.1269	-71.5787	-113	7.61	-71	34.72	620	618	7.28
84ctd023	17/03/2003	076	12:00	-112.8989	-71.5509	-112	53.93	-71	33.05	541	518	7.37
84ctd024	17/03/2003	076	13:32	-112.6505	-71.5187	-112	39.03	-71	31.12	442	426	3.13

84ctd025	17/03/2003	076	17:33	-113.9987	-71.291	-113	59.92	-71	17.46	2028	2044	8.06
84ctd026	18/03/2003	077	03:18	-113.7842	-71.3764	-113	47.05	-71	22.58	1556	1485	7.13
84ctd027	18/03/2003	077	05:20	-113.6346	-71.4221	-113	38.08	-71	25.33	1090	1011	2.47
84ctd028	18/03/2003	077	07:00	-113.5368	-71.4573	-113	32.21	-71	27.44	651	631	8.35
84ctd029	18/03/2003	077	08:34	-113.3675	-71.5257	-113	22.05	-71	31.54	637	626	6.4
84ctd030	19/03/2003	078	14:32	-113.6786	-71.2478	-113	40.71	-71	14.87	0	1997	7.96
84ctd031	19/03/2003	078	16:53	-113.4769	-71.3399	-113	28.62	-71	20.39	1543	1535	8.74
84ctd032	19/03/2003	078	18:35	-113.351	-71.3933	-113	21.06	-71	23.6	1030	946	8.11
84ctd033	19/03/2003	078	20:36	-113.2656	-71.4102	-113	15.94	-71	24.61	776	782	8.28
84ctd034	19/03/2003	078	22:02	-113.2112	-71.4275	-113	12.67	-71	25.65	642	632	7.91
84ctd035	19/03/2003	078	23:34	-113.039	-71.4936	-113	2.34	-71	29.61	550	539	9.18
84ctd036	20/03/2003	079	09:35	-114.7384	-71.3146	-114	44.3	-71	18.88	2057	2082	2.47
84ctd037	20/03/2003	079	12:25	-114.4983	-71.4302	-114	29.9	-71	25.81	1494	1467	2.3
84ctd038	20/03/2003	079	14:14	-114.4873	-71.4739	-114	29.24	-71	28.43	1027	1022	1.22
84ctd039	20/03/2003	079	16:00	-114.5441	-71.4982	-114	32.65	-71	29.89	615	606	7.89
84ctd040	20/03/2003	079	17:35	-114.2854	-71.5471	-114	17.13	-71	32.83	525	513	7.59
84ctd041	21/03/2003	080	12:28	-113.4412	-71.1291	-113	26.47	-71	7.75	2297	2325	8.06
84ctd042	23/03/2003	082	20:45	-102.6363	-70.6548	-102	38.18	-70	39.29	4100	507	-999
84ctd043	24/03/2003	083	20:01	-100.7157	-70.5355	-100	42.94	-70	32.13	3401	507	-999
84ctd044	25/03/2003	084	19:08	-98.4754	-70.4689	-98	28.52	-70	28.13	3579	507	-999

This output an ascii file, with the extension cnv. Finally the Sea-Bird Electronics Inc. Data Processing software version 5.25 *Cell Thermal Mass* module was used to remove the conductivity cell thermal mass effects from the measured conductivity. This correction followed the algorithm

dt = temperature - previous temperature

ctm = (-1.0 * b * previous ctm) + (a * dcdt * dt)

and

corrected conductivity = c + ctm.

and

a = 2 * alpha / (sample interval * beta + 2)

b = 1 - (2 * a / alpha)

dcdt = 0.1 * (1+ 0.006 * (temperature - 20)

with alpha set to = 0.03, beta set to = 7.0. This routine output a file also with extension cnv, but with a different filename.

This series of files were then copied to the UNIX system using samba.

SBE35 High precision thermometer

Every time a water sample is taken using the rosette, the SBE 35 recorded a temperature in EEPROM. This temperature was the mean of 10 * 1.1 seconds recording cycles (therefore 11 seconds) data. The thermometer has the facility to record 157 measurements but we downloaded the data approximately every 5 casts (60 measurements) using the Sea-Bird Electronics Inc. Terminal programme. Data were converted to temperature using the Sea Bird calibration routines:

$$t_{90} = \frac{1.0}{a_o + a_1 \ln(n) + a_2 \ln^2(n) + a_3 \ln^3(n) + a_4 \ln^4(n)} - 273.15$$

and

$$t_{90} = slope \times t_{90} + offset$$

and n is the output from the SBE 35, the other constants are listed in the appendix.

Salinity Samples

Either six or twelve salinity samples were taken from each CTD station throughout the cruise, giving a total of 411 samples with 36 duplicates. The salinity samples were taken in 200 ml medicine bottles, each bottle being rinsed three times before being filled to just below the neck. The rim of the bottle was then wiped with tissue, a plastic seal inserted and the screw cap replaced. The salinity samples were then placed close to the salinometer (sited in the chemistry lab) and left for at least 24 hours before measurement. This allowed the sample temperatures to equalise with the salinometer.

The samples were then analysed on the BAS Guildline Autosal model 8400B, S/N 63360 against Ocean Scientific standard seawater (batch P141). One vial of OSIL standard seawater was run through the salinometer at the beginning, and at the end of each crate of samples enabling a calibration offset to be derived and to check the stability of the salinometer. Once analysed the conductivity ratios were entered by hand into EXCEL spreadsheet before being transferred to the UNIX system and read into a pstar data file following the scheme detailed below.

O^{18} Samples

Samples were taken for oxygen-18 analysis at a number of CTD stations. Samples were taken by rinsing 200 ml medicine bottles three times before drying the top of the bottle with a tissue and then screwing down the cap. Bottles were sealed by stretching 'parafilm' around the neck. Table 3 below shows the CTD stations where oxygen samples were taken. The number of samples and their respective sample numbers are also given.

Table 3: Samples taken for O^{18} analysis on cruise JR84

CTD Station	Number of Samples	Sample Number
004	10	D1 – D10
006	5	D11 – D15
008	3	D15 – D18
011	5	D19 – D23
013	5	D24 – D28
015	3	D29 – D31
016	3	D32 – D34
019	4	D35 – D38
021	5	D39 – D43
023	3	D44 – D46
032	4	D47 – D50
033	4	D51 – D54
034	4	D55 – D58

Radon Samples

Samples were taken at three stations for radon analysis. Samples were taken by rinsing 200 ml plastic sample bottles three times before drying the top of the bottle with a tissue and then screwing down the cap. Bottles were again sealed by stretching 'parafilm' around the neck. The number of samples and their sample numbers are given in table 4 below.

Table 4: Samples taken for Ra analysis on cruise JR84

CTD Station	Number of Samples	Sample Number
001	12	84ctd001-(1-12)
002	12	84ctd002-(1-12)
008	6	84ctd008-(1, 3, 5, 7, 9, 11)

CTD Data Processing

In the following notes the term CC refers to the cruise number, and the term NNN refers to the event number.

The CTD data are recorded using the Seabird data module ***seasave***. The raw data files created are: **CCctdNNN.dat** (raw data file), **CCctdNNN.con** (configuration file), **CCctdNNN.bl** (bottle information file), **CCctdNNN.hdr** (header information file).

1. To process the data in the ctd unit

The raw data are stored as binary files. These must be converted to ASCII data files for further processing with the UNIX CTD scripts. The programs used are:

Data Conversion **module**
This program converts the binary file to ASCII. Although it can be used to derive variables, we only use it to convert the file, our further processing being carried out in UNIX. The output file is in the format CCctdNNN.cnv.

Cell Thermal Mass **module**
This program takes the output from the datcnv program and re-derives the pressure and conductivity, to take into account the temperature of the pressure sensor and the action of pressure on the conductivity cell. The output file is of the form CCcnvNNNtm.CNV. A second file of the form CCctdNNN.ros is also created.

These files were saved on the D:\ drive of the CTD PC with a separate folder for each CTD. They were then transferred to the UNIX system *jruf* and placed in the directory *~/pstar/data/ctd/ascii_files/84ctdNNN/** where NNN is the event number of the cast.

2. To process the SBE35 data

Communication must be established between the CTD PC and the SBE35 by switching on the deck unit. The program used to process the data is:

Seabird terminal programme
This is a simple terminal emulator set up to talk to the SBE35. Once you open the program the prompt is ">". You can ask the SBE35 how it is by typing DS:
ds This stands for ***d****isplay* ***s****tatus*. The SBE35 responds by telling you the date and time of the internal clock, and how many data cycles it currently holds in memory.
The next thing is to click the capture toolbar button and enter a sensible filename. Once done the data can be downloaded by typing
dd This stands for ***d****ump* ***d****ata*. The data currently held in the memory is listed to the screen. This can be slow due to the low data transfer rate.
Once finished downloaded one clicks on the 'capture' button to close the open file, and the clears the memory of the SBE 35 using the command
samplenum=0

Finally one should type ***ds*** to check that the memory is clear before shutting down the system.
The SBE35 data files were transferred to the directory *~pstar/data/ctd/ascii_files/sbe35/**.

3. Further processing of the CTD data (in UNIX)

Salinities
Salinity data from the bottle samples is needed for further processing. Using the spreadsheet created with values obtained from the salinometer and with reference to the original deck log, samples should be matched up to individual bottles. A new spreadsheet file should then be created to contain three variables: *bottle number*, *botsala* and *botsalb*. Missing data should be designated with -999.0. This file should be saved as an ascii file with the filename **84samNNN.txt**. It should then be ftp'ed to *jruf* and placed in the directory *~pstar/data/ctd/samples*.

SBE35 temperature data
There is one file for each day on *jruf* in the form **jday.txt**. This file must be split into 12 records for each station (one level for each bottle). The file can be created using an editor such as emacs or vi, and will again need reference back to the original CTD deck log. There is no processing other than the deletion of all records except the 12 relating to the relevant station. The data must be saved as a file called **CCsbeNNN** in the same directory (i.e *~pstar/data/ctd/ascii_files/sbe35/*).

CTD processing using pstar execs
The execs assume that the files are tidied up after each one is run. They will check for the files when running and say where the files should be.

84seactd0 This exec converts data from seabird ASCII format to pstar. The output files are **CCctdNNN.raw** and **CcctdNNN**. The .raw file should be moved to the directory */raw/** and the other to the directory */rough/**.

84seactd1 This exec requires the SBE35 data to have been transferred and downloaded, and the salinity data to have been transferred, as described above. This exec produces four files:

CCctdNNN.bottle	containing the CTD data at the bottle firing points
CCtdNNN.samp	containing the above file with the addition of the bottle salinity data and the SBE35 data
CCsamNNN.diff	containing some residuals from the above file
sampNNN.bot	containing salinity data from the spreadsheet in a pstar file

This exec uses the **CCctdNNN.samp** file to derive the conductivity of the salinity samples. mlist is used to produce a quick and dirty plot of botcond vs deltaC. A plot of bottles over the salinity profile of the CTD is then produced. These plots will be produced both on the screen and printer - as they are only rough plots the cast number should immediately be written on, for future reference. The output file is:

CCctdNNN.cond	containing the conductivity variable deltaC

After running the exec the files should be moved to the directories */samples/bottle/**, */samples/samp/**, */samples/diff/**, */samples/salts/** respectively.

84seactd2 This exec plots out the salinity profiles of the CTD stations and overlays the bottles on top of the profiles. Obvious bad salinity samples can be spotted very rapidly.

ctdoff This program requires the file **CCctdNNN.cond** and produces the mean conductivity residual, and the standard deviation. These numbers should be written on the plot produced from seactd2 for further reference.

On the basis of the results of seactd1 and ctdoff it must be decided whether some bottles should be rejected and the conductivity residual recalculated. For example on JR84 the cruise protocol meant that some bottles were fired at depths where the salinity gradient was very steep - so that some bottle samples were unsuitable to use in calibration.

The .cond file should then be moved to directory */samples/cond/**.

84seactd3 This exec requires the output of ctdoff (the conductivity residual). The conductivity offset is added to the rough version of the ctd file (**CCctdNNN** - the output of seactd0), and the salinity re-derived with this new conductivity. The output is **CCctdNNN.cal**

The file **CCctdNNN.cal** should then be moved to the directory */cal/**.

84seactd4 Use mlist to select the downcast. It is important to remember that the cast will go down to 10m and return to the surface before starting the true downcast. The output files are **CCctdNNN.24hz** and **CCctdNNN.2db**. These should be moved to the directories */24hz/** and */2db/** respectively.

84seactd5 This exec (similar to 84seactd1) uses the updated values of salinity rather than the raw data. At this stage the second conductivity and temperature variables are dropped - they may be useful in difficult stations, but in general give no more information than the primary sensors. The output files are **CCctdNNN.cbottle**, **CCctdNNN.csamp**, **CCsamNNN.cdif** which should be moved to the directories */samples/cbottle/**, */samples/csamp/**, */samples/cdif/** respectively.

The quality of the CTD calibration

The mean difference in the 36 duplicate salinity samples was 0.00011 salinity units, therefore we have to assume that the analysis of salinity samples was good. Once the salinity data had been analyzed some samples were excluded from the derivation of calibration offsets because they were clearly sited in a poor calibration region (i.e. in a strong vertical gradient of salinity) or because of clear contamination. A list of excluded bottles is in the table 5 below and although there appears to be many, they are almost all at shallow depths and within the halocline.

Table 5: Bottles excluded from the CTD calibration.

CTD station	Bottles excluded
84ctd001	8, 9, 11, 12
84ctd002	1,12
84ctd003	11,12
84ctd004	8,9,10,11,12
84ctd005	10
84ctd006	9,11,12
84ctd007	7,11
84ctd008	5,3,11
84ctd009	9,10,11,12
84ctd010	7,11
84ctd011	9,12
84ctd012	10,12
84ctd013	9,11,12
84ctd014	3,5
84ctd015	3,5,9,11
84ctd016	3, 11
84ctd017	1,3
84ctd018	
84ctd019	5,11
84ctd020	3,5,11
84ctd021	5,12
84ctd022	3,5,11
84ctd023	3,6
84ctd024	9,11
84ctd025	8,11
84ctd026	12
84ctd027	12
84ctd028	3,11
84ctd029	3,5,11
84ctd030	8,12
84ctd031	8,11,12
84ctd032	6,7,12
84ctd033	12
84ctd034	2,6,8,12
84ctd035	
84ctd036	10,12
84ctd037	8,9,10,11,12
84ctd038	6,7,10
84ctd039	12
84ctd040	2,12
84ctd041	9,12
84ctd042	8,12
84ctd043	11
84ctd044	7,9,11

A real problem was during the analysis of the salinity samples for stations 84ctd033 to 84ctd037 (shaded in the table above). Here the salinometer lab appears to have heated up during the analysis, and unfortunately the person making the measurements neglected to run a standard through at the end of the analysis. The safest thing to do was to ignore these samples completely. Figure 10 shows the primary conductivity offset against station number (figure 8) with stations 33 to 37 excluded.

Figure 10 suggested that a constant correction was perhaps not the best way forward for calibrating the CTDs. When plotted against time (Figure 11) a similar pattern emerges and so it was felt that a time dependant offset would provide a better calibration. The calibration values applied to each cast are shown in the table 6 below. NB these values have only been applied to the PRIMARY CONDUCTIVITY CELL.

Table 6: CTD calibration offsets applied to the Primary Conductivity cell for JR84

CTD Number	Correction	CTD Number	Correction
84ctd001	0.00508	84ctd023	0.00686
84ctd002	0.00563	84ctd024	0.00687
84ctd003	0.00592	84ctd025	0.00690
84ctd004	0.00636	84ctd026	0.00695
84ctd005	0.00641	84ctd027	0.00696
84ctd006	0.00642	84ctd028	0.00697
84ctd007	0.00643	84ctd029	0.00698
84ctd008	0.00644	84ctd030	0.00716
84ctd009	0.00659	84ctd031	0.00717
84ctd010	0.00661	84ctd032	0.00718
84ctd011	0.00669	84ctd033	0.00719
84ctd012	0.00670	84ctd034	0.00720
84ctd013	0.00671	84ctd035	0.00721
84ctd014	0.00672	84ctd036	0.00727
84ctd015	0.00673	84ctd037	0.00728
84ctd016	0.00681	84ctd038	0.00729
84ctd017	0.00682	84ctd039	0.00730
84ctd018	0.00683	84ctd040	0.00731
84ctd019	0.00683	84ctd041	0.00742
84ctd020	0.00684	84ctd042	0.00775
84ctd021	0.00685	84ctd043	0.00788
84ctd022	0.00686	84ctd044	0.00801

After the conductivity offset was applied as per the description above, the samples were merged with the corrected CTD data and new corrected sample files derived. Figure 12 shows the residual offset of 251 samples against pressure for cruise JR84. There is no apparent pressure effect with the residuals shown in figure 12, and the mean offset for the corrected data against the CTD data is 0.0000 with a standard deviation of 0.0013.

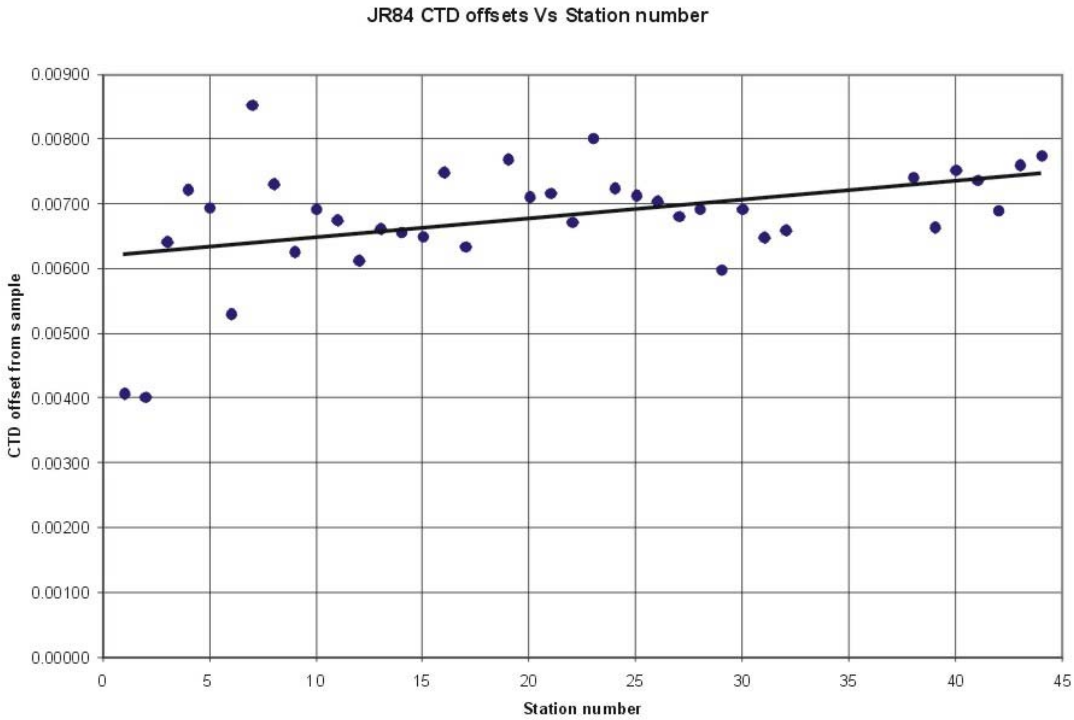


Figure 10: Conductivity offsets versus station number for JR84.

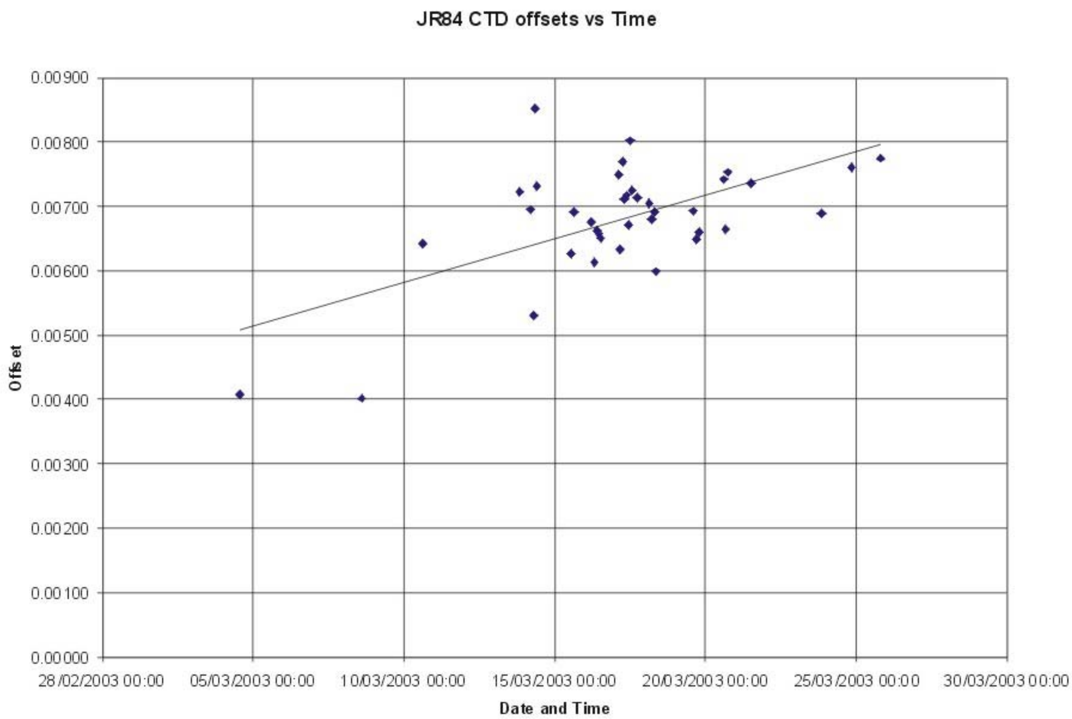


Figure 11: Conductivity offsets versus time for JR84.

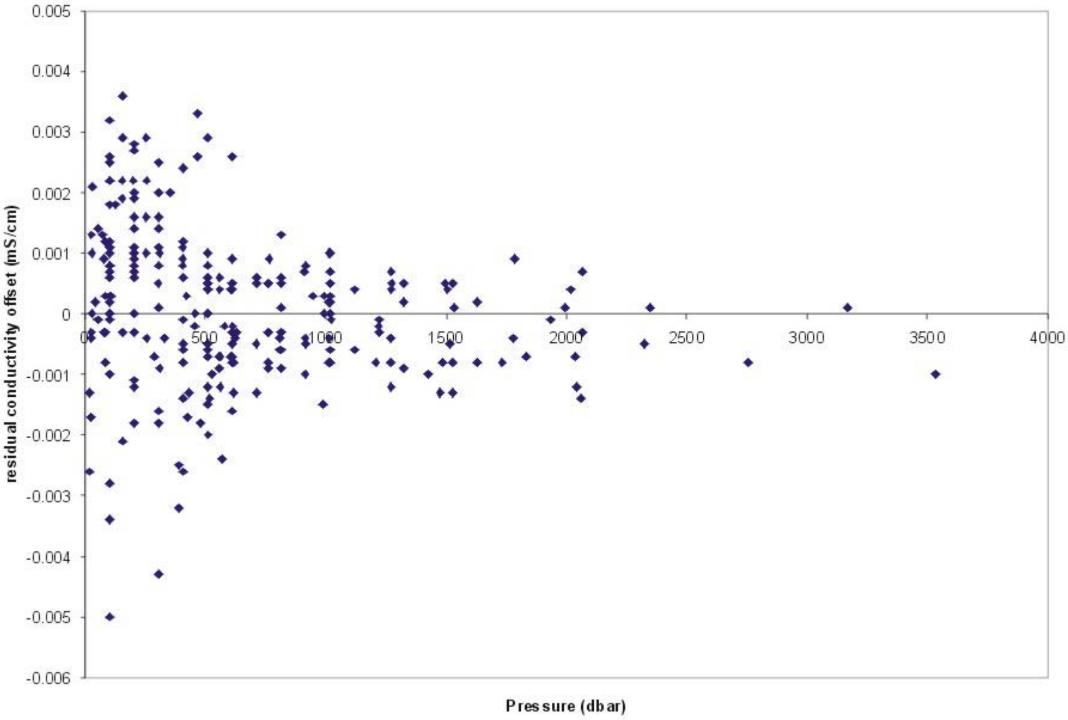


Figure 12: Residual offsets of the corrected CTD data against pressure for the JR84 data set.

The SBE35 data

On brief inspection, offsets between the SBE35 thermometer and the primary conductivity cell showed that for 516 samples the mean offset was 0.00296˚C, with the SBE 35 being lower. Comparison of the SBE35 with the secondary temperature cell showed that for 516 samples the mean offset was slightly lower at 0.00257˚C

Problems during JR84

Station 84ctd003: There was severe spiking in the primary circuit on the downcast between 180 and 255 dbar. This depth range was removed from the downcast and copied in from the up-cast.

Station 84ctd015: A Jellyfish was ingested by the CTD on the up-cast. This spoilt the calibration samples and also forced a thorough cleaning of the instrument.

Station 84ctd018: This cast was aborted at 40 dbar depth due to a failure in the dynamic positioning system of the ship. Station 19 was at the same location.

SBE43 Dissolved Oxygen Sensors

Two new SBE43 DO sensors (serial numbers 0245 and 0242), purchased during summer 2003, were used throughout the cruise. Neither performed well. There was always an offset of ~1 ml/l between the readings from the two instruments (figure 13). While the overall level of the secondary sensor looked the better of the two, this one also suffered markedly from pressure hysteresis with an offset of up to 0.3 ml/l between downcast data (when the sensor was being loaded) and upcast data (when it was being unloaded). During stops in the upcast, when niskin bottles were being fired, the reading from the secondary sensor relaxed to a value intermediate between the down- and up-trace. The primary sensor showed much less hysteresis, but never recorded oxygen levels close to saturation, even at the surface in open water. Since no underway Winkler titrations were performed, processing of the data will have to await the post-cruise calibration of the sensors by Seabird. Although the final absolute oxygen concentrations are likely to be subject to relatively large errors, the main motivation for recording the data was to help quantify mixing within the main pycnocline. For this, relative changes in concentration through the water column are most important. Any future users of the sensors who require accurate absolute concentrations are advised to ensure that there is a Winkler titration system available on board.

There is a bug in the version of SeaSave Win32 that was used. While it is apparently possible to enter two sets of SBE43 calibration coefficients, only one set is saved and then applied to both sensors. The only way around this is to edit the configuration file manually with an ascii editor. Once this is done, care should be taken not to resave the configuration file from SeaSave, otherwise the secondary sensor calibration coefficients will be overwritten.

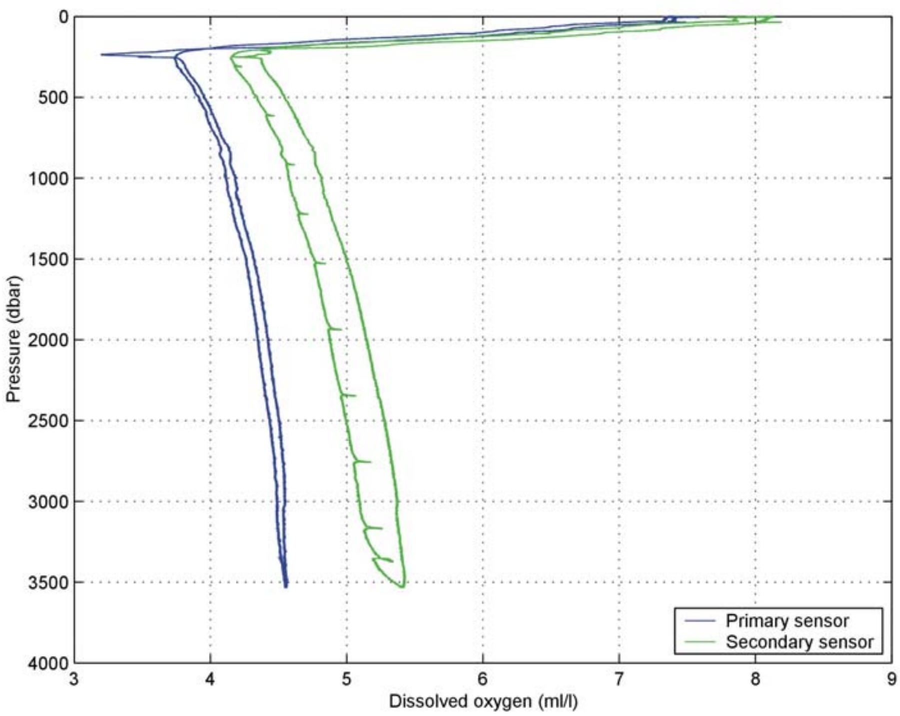


Figure 13: Dissolved oxygen profiles recorded at CTD station 003.

Appendix: Calibration data.

Configuration report for SBE 911/917 plus CTD from JR84.con

Frequency channels suppressed : 0

```
Voltage words suppressed      : 0
Computer interface            : RS-232C
Scans to average              : 1
Surface PAR voltage added     : No
NMEA position data added      : No
Scan time added               : No
```

1) Frequency channel 0, Temperature

Serial number : 032366

Calibrated on : 19-Jul-02

```
G              : 4.31950826e-003
H              : 6.43754128e-004
I              : 2.32220252e-005
J              : 2.19161783e-006
F0             : 1000.000
Slope          : 1.00000000
Offset         : 0.0000
```

2) Frequency channel 1, Conductivity

Serial number : 042289

Calibrated on : 19-Jul-02

```
G              : -1.04108582e+001
H              : 1.38996218e+000
I              : -3.42550982e-003
J              : 3.12641143e-004
CTcor          : 3.2500e-006
CPcor          : -9.57000000e-008
Slope          : 1.00000000
Offset         : 0.00000
```

3) Frequency channel 2, Pressure, Digiquartz with TC

Serial number : 67241

Calibrated on : 30-Jun-2000

```
C1             : -4.461418e+004
C2             : 3.038286e-002
C3             : 1.224130e-002
D1             : 3.645500e-002
D2             : 0.000000e+000
T1             : 2.999608e+001
T2             : -3.512191e-004
T3             : 3.729240e-006
T4             : 4.918760e-009
T5             : 0.000000e+000
```

```
Slope          : 0.99992000
Offset         : -0.88150
AD590M         : 1.283280e-002
AD590B         : -9.474491e+000
```

4) Frequency channel 3, Temperature, 2

Serial number : 032191

Calibrated on : 19-Jul-02

```
G              : 4.31967419e-003
H              : 6.38837657e-004
I              : 2.27990979e-005
J              : 2.17976156e-006
F0             : 1000.000
Slope          : 1.00000000
Offset         : 0.0000
```

5) Frequency channel 4, Conductivity, 2

Serial number : 019112

Calibrated on : 19-Jul-02

```
G              : -4.16212062e+000
H              : 5.36713913e-001
I              : -7.86598365e-004
J              : 6.80295512e-005
CTcor          : 3.2500e-006
CPcor          : -9.57000000e-008
Slope          : 1.00000000
Offset         : 0.00000
```

6) Voltage channel 0, Altimeter

Serial number : 2130.26993
Calibrated on : N/A
Scale factor : 15.000
Offset : 0.000

7) Voltage channel 1, Free

8) Voltage channel 2, Oxygen, SBE 43

Serial number : 0245

Calibrated on : 27-Aug-02

```
Soc            : 4.0080e-001
Boc            : 0.0000
Offset         : -0.4413
Tcor           : 0.0014
```

```
Pcor          : 1.35e-004
Tau           : 0.0
```

9) Voltage channel 3, Free

10) Voltage channel 4, Oxygen, SBE 43, 2

Serial number : 0242

Calibrated on : 27-Aug-02

```
Soc           : 4.5920e-001
Boc           : 0.0000
Offset        : -0.4597
Tcor          : 0.0001
Pcor          : 1.35e-004
Tau           : 0.0
```

11) Voltage channel 5, Free

12) Voltage channel 6, Fluorometer, Chelsea Aqua 3

Serial number : 088216

Calibrated on : 11/june/01

```
VB            : 0.260700
V1            : 2.035000
Vacetone      : 0.326300
Scale factor  : 1.000000
Slope         : 1.000000
Offset        : 0.000000
```

13) Voltage channel 7, Free

Oceanlogger (Underway Measurements)

Mark Brandon
(Open University)

Throughout JR84, underway measurements were made with the ship's oceanlogger. The oceanlogger system is comprised of a thermosalinograph and fluorometer connected to the ship's non-toxic pumped seawater supply, plus meteorological sensors measuring duplicate air pressure, duplicate air temperature, duplicate humidity, duplicate total incident radiation (TIR) and duplicate photosynthetically available radiation (PAR). There were 18 sensors logged in total within the oceanlogger system. To complete the meteorological data set I merged in the windspeed and direction from the anemometer. Data are time-stamped using the ship's master clock.

Calibration details

Up to date calibration certificates for all sensors was provided by the Pat Cooper (ETS).

Data Processing

Oceanlogger data were processed in 12 hour segments throughout the course of JR84. Three Unix scripts calling PSTAR software routines were used for this processing:

`84oclexec0`: Reads the oceanlogger data streams into a PSTAR format and merges in relative wind speed and direction from the anemometer data stream. Output files are 84ocl[jday][a/p].raw and ocl841. The former of these is the 12-hour data segment for morning (a) or afternoon (p) of Julian day jday. The latter is the master file to which successive 12-hour sections are appended.

`84oclexec1`: Divides the data into ocean data and meteorological data files, writing meteorological data to a separate file. Output file is 84met[jday][a/p].raw (containing the meteorological data).

`twvelexec`: Merges the met data file with gyrocompass and navigation data streams in order to calculate ship motion and true wind velocity. Output file is 84met[jday][a/p].true.

Problems

Our passage and out of the ice meant that there were frequent periods where the system did not function due to ice blockage of the intake pumps. The salinity data are will have to be re-calibrated on the basis of the post season check.

ADCP Measurements

Sarah Hardy and Mark Brandon
(Open University)

Summary

This report describes the method of acquisition of ADCP data on JR84. The system was operated in two modes: water-track mode, when water depths were greater than ~ 500m and bottom-track mode in shallower waters. In general, the ADCP worked very well with water-track velocity information generally obtained to ~ 350m depth and bottom-track velocity information to ~ 550m.

The configuration of the ADCP

The RRS *James Clark Ross* is fitted with an RD Instrument's 150 kHz (although actually 153.6 kHz), hull-mounted Acoustic Doppler Current Profiler (ADCP). Unlike other NERC research ships, the orientation of the transducer head on the JCR is offset by approximately 45° to the fore-aft direction in hope that the instrument will give a better response in the main direction of motion (i.e. fore-aft). To provide protection from ice, the transducer is mounted in a sea-chest recessed into the hull of the ship, which is again, different from the design of other British research ships.

The contents of the sea-chest are isolated from the surrounding sea water by a 33mm thick window of Low Density PolyEthylene (LDPE). Within the sea-chest, the transducers are surrounded by a liquid composed of 90% de-ionised water and 10% ethylene glycol.

The version of the firmware used by the ADCP was 17.07 and the version of RDI Data Acquisition Software (DAS) was 2.48. The software ran on a Pentium 2 266Mhz running DOS.

For JR84, the ADCP was configured to record data in 64 x 8 bins and in ensembles of 2 minute duration. The 'blank beyond transmit ' was 4m, which when added to the approximately 6m depth of the transducer, resulted in the depth of the centre of the first bin depth, being 14m.

In water depths of less than 500m, the ADCP was operated in bottom-track mode. Water-track mode was used in deeper water. The bottom-track mode was configured through the Direct Command menu of the DAS software using the command FH0004. This sets the instrument to one bottom-track ping for every four water-track pings.
The ADCP does not log to the SCS system, unlike all other underway scientific instruments on the RRS James Clark Ross, but instead, the 2 minute ensembles of data are fed directly into the ship's Level C system. In the event of a problem with the ship's Level C system, the data has to be recovered from the PC files, but no such problems were encountered during JR84.

Standard method of processing

The steps involved in processing the data are detailed below and summarised in the flowchart in Figure 14. The data were read into pstar files of 12 hour periods from the Level C system and processed using the pstar processing software. The programs involved, also require data from several navigation streams (described in the navigation data report).

Step 1.

Reading data

The data were read in and saved in 12 hour periods (00:00 to 11:59 and 12:00 to 23:59) using the Unix script *84adpexec0*. This processing produces two output files: one containing the water-track data and one containing the bottom-track data. When the ADCP was set to record only water-track information, the bottom-track file contains only engineering data and zero's for the bottom velocity.

Output files: 84adp**** (**** = 3 digit Julian day plus a or p for am or pm)
84bot****

Step 2.

Water velocity / temperature correction

84adpexec0.1 performs a correction on the water- and bottom-track velocity data due to the presence of the de-ionised water / ethylene glycol mix within the sea-chest. This correction was derived by Mike Meredith (BAS) and Brian King (SOC). The following text is Dr Meredith's description of the steps involved:

"The ADCP DAS software assumes that the fluid surrounding the transducers is ambient seawater and derives a speed of sound through measured temperature at the transducer head and an assumed salinity of 35. However, a correction is clearly needed to account for the fluid being the 90% de-ionised water / 10% ethylene glycol mixture instead of seawater.

From point measurements obtained from RDI, we previously derived the following equation for the speed of sound through the mixture as a function of temperature:-

$$C = 1484 + 3.6095t - 0.0352t^2$$

The individual velocity measurements from which this equation was derived to an accuracy of 0.01%, with the environmental conditions being known to within ± 35kPa pressure and ± 0.5°C temperature was used to derive a correction term to adjust the speed of sound assumed by the DAS to one appropriate for the mixture in the sea-chest. The correction term was:-

$$(1484 + 3.6095t - 0.0352t^2\ ) / (1449.2 + 4.6t - \ 0.055t^2\ 0.00029t^2)$$

This correction is applied to both the raw water and bottom-tracked velocities using the Unix script *84adpexec0.1*. A further correction for temperature is applied in this script, due to the temperature-dependency of the velocity scaling correction A (see later). This correction was the value derived on JR55, i.e. (1-0.00152*temp)."

Input files: 84adp****
84bot****

Output files: 84adp****.t
84bot****.t

Step 3.

Time correction

The DAS software time stamps the ADCP data. This time stamp comes from the Pentium 2, which drifts at a rate approximately one second per hour. To correct this to the ship's master clock, the two clock times were read several times a day and the difference calculated. The Julian date (JDAY), ADCP clock reading and calculated time differences were entered into the time correction file, *84_start_adp_go* (which also runs *84adpexec0*, *0.1* and *1*). From this calculated time drift, a correction was derived and applied to the ADCP data time using the Unix script *84adpexec1*.

Input files: 84adp****.t
84bot****.t

Output files: 84adp****.corr
84bot****.corr

NB: *84adpexec1* should be run 12 hours in arrears to allow for the corrected time falling outside of the 12 hour input file period, which will cause the program to fall over.

Step.4

Correction for gyrocompass error

The ADCP measures water velocity relative to the ship. To calculate east and north water velocities from ADCP data, information is required on the ship's heading and velocity over the ground. This is partially fulfilled with input from the ship's gyrocompass (described in the ship's navigation report). However, it is well known that in addition to having an inherent error, gyrocompasses can oscillate for several minutes after a turn, before steadying on a new course. There is also an additional deviation of the gyrocompass that varies as cosec (latitude).

To overcome these difficulties, the ADCP is 'corrected' with data from the Ashtec ADU-2 (see navigation report). The Ashtec cannot be used instead of the gyrocompass because Ashtec coverage is not continuous, but the data can be corrected on an ensemble by ensemble basis. As a result of the 'standard processing' as detailed in the navigation report, the edited Ashtec data is held within a file as data of

2 minute averages. This data still contains large ‘spikes’, which are removed using an interactive editor. Any gaps created by this editing or previously existing in the data, are linearly interpolated by a further program. The gyrocompass correction file (84ash01.int) is then applied to the ADCP data through the Unix script *84adpexec2*.

The east velocity (velew) and north velocity (velns) from the ADCP are converted to speed and direction and the heading correction (as calculated from the gyrocompass correction file) applied to both the gridded water-track data and non-gridded bottom-track data. The program then converts the data back to east and north velocities ready for the *A* and ∅ calibrations performed in the next processing step.

Should there be no Ashtec correction to be made, this exec can be replaced by one that adds a dummy (zero value) correction variable (a-ghdg) or subsequent processing steps can be modified to omit this variable.

Input files: 84adp****.corr
84bot****.corr
84ash01.int

Output files: 84adp****.true
84bot****.true

Step 5.

Calibration of the ADCP data

A final correction is now required to correct for the misalignment between direction as defined by the Ashtec ADU-2 antenna array and the actual direction of the ADCP transducers. This correction is called the heading misalignment, ∅. There is also an inherent scaling factor, *A* associated with the ADCP, by which the water velocities must be multiplied to scale them correctly. The method of calculating *A* and ∅ is described in Box 1. These calculated corrections were then applied to both water-track and bottom-track velocity data through the Unix script *84adpexec3*.

The calibration values used during JR84 were: *A* = 1.0284 and ∅ = -1.68.

Input files: 84adp****.true
84bot****.true

Output files: 84adp****.cal
84bot****.cal

Step 6.

The data now contains calibrated water velocity relative to the ship. To derive absolute velocity, the files are merged with position form the ‘bestnav’ navigation file (see navigation report) and derive ship velocity between ensembles. This velocity is then removed from the water velocity data to give absolute water velocity. This is performed using the Unix script *84adpexec4*.

Input files: 84adp****.cal
84bot****.cal

Output files: 84adp****.abs
84bot****.abs

BOX 1

Method of derivation of the calibration coefficients A and ∅

1. Periods when the ADCP gave bottom-track velocities (i.e. when the ship was working in water depths generally less than 500m) were identified.

2. The files with bottom-track velocities were then calibrated with a nominal scaling in 84adpexec3 by setting the scaling factor, *A*, to one and the misalignment angle, ∅, to zero.

3. The two minute ensembles of ADCP data were then merged with 'bestnav' position fixes. From these 'bestnav' fixes, the ship's east ad north velocity over ground were calculated. Time periods within each data file were then identified where the ship's heading and velocity did not deviate greatly over a period of at least 6 minutes.

4. The ADCP bottom-track velocities were then multiplied by –1 as the velocity of the ship given by the 'bestnav' fixes is in the opposite sense to the velocity of the bottom as derived by the ADCP.

5. Values for *A* and ∅ for each time period were then derived using vector mathematics and the following formulas:

$$A = U_{GPS} / U_{ADCP}$$

Where U_{ADCP} is the bottom-track ADCP derived ship speed and U_{GPS} is the GPS position fix derived ship speed (that is, ship speed over ground)

$$\varnothing = \varnothing_{GPS} - \varnothing_{ADCP}$$

Where $\varnothing_{GPS}$ is the direction of motion of derived from the GPS navigational fixes and $\varnothing_{ADCP}$ is the direction of motion as derived from the bottom-track ship's motion. This was achieved using the Unix script *adcp_calibration_exec*.

Input files: 84bot****.abs

Output files: 84bot****.abs.#2 (where # = a or p for am or pm)

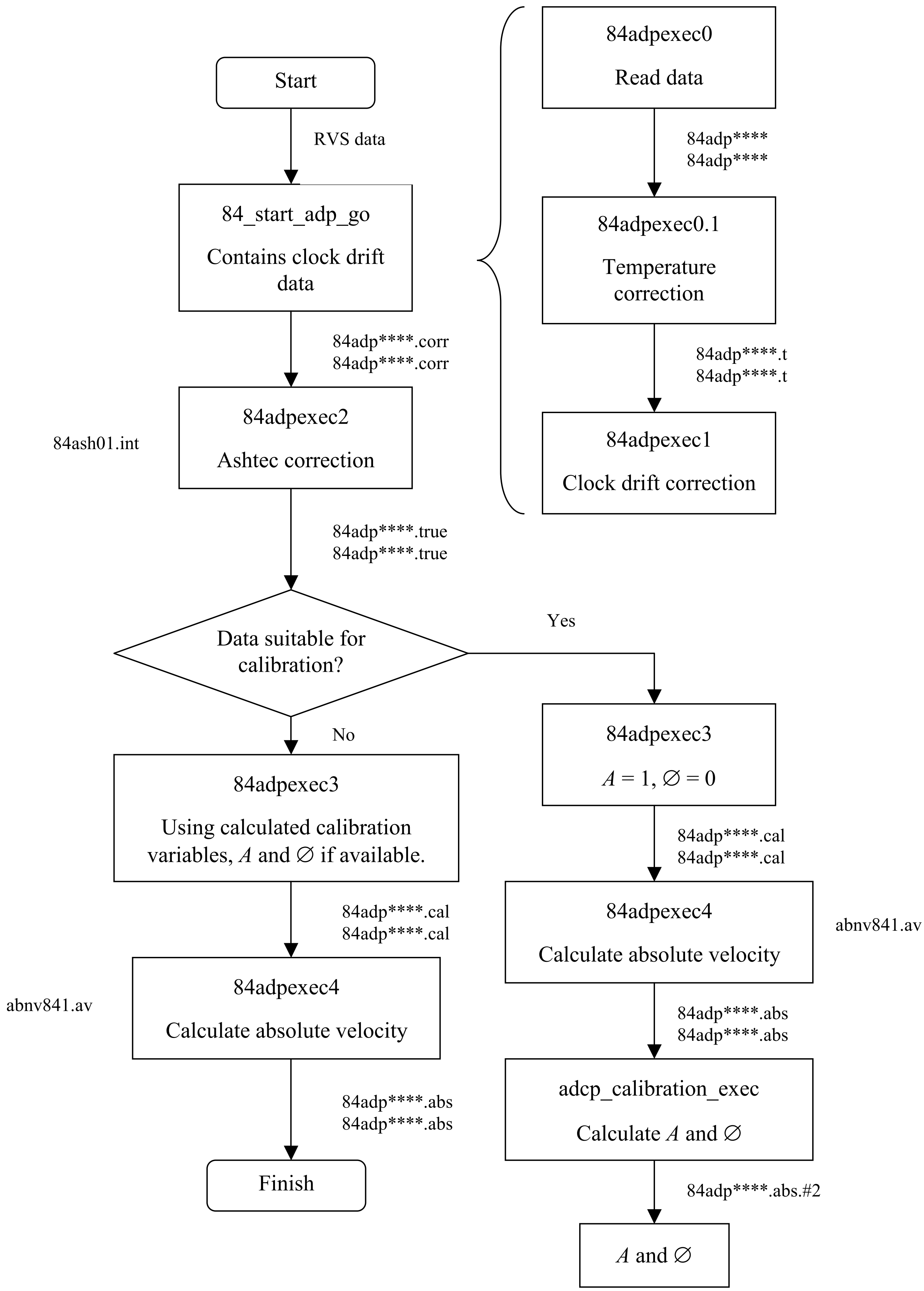


Figure 14: ADCP Processing Flow-Chart

File variables.

84adp***			84bot***		
1	Time	s	1	time	s
2	bindepth	m	2	heading	degrees
3	Velew	cm/s	3	bottomew	cm/s
4	Velns	cm/s	4	bottomns	cm/s
5	Velvert	cm/s	5	depth	m
6	Velerr	cm/s	6	temp	degrees C
7	Ampl	db			
8	Good	%			

84adp***.t			84bot***.t		
1	Time	s	1	time	s
2	bindepth	m	2	heading	degrees
3	Velew	cm/s	3	bottomew	cm/s
4	Velns	cm/s	4	bottomns	cm/s
5	Velvert	cm/s	5	depth	m
6	Velerr	cm/s	6	temp	degrees C
7	Ampl	db			
8	Good	%			

84adp***.corr			84bot***.corr		
1	Time	s	1	time	s
2	bindepth	m	2	heading	degrees
3	Velew	cm/s	3	bottomew	cm/s
4	Velns	cm/s	4	bottomns	cm/s
5	Velvert	cm/s	5	depth	m
6	Velerr	cm/s	6	temp	degrees C
7	Ampl	db			
8	Good	%			

84adp***.true			84bot***.true		
1	Time	s	1	time	s
2	bindepth	m	2	heading	degrees
3	Velew	cm/s	3	bottomew	cm/s
4	Velns	cm/s	4	bottomns	cm/s
5	Velvert	cm/s	5	depth	m
6	Velerr	cm/s	6	temp	degrees C
7	Ampl	db	7	a-ghdg	degrees
8	Good	%			
9	a-ghdg	degrees			

84adp*.cal**

1	Time	s
2	bindepth	m
3	Evelcal	cm/s
4	Nvelcal	cm/s
5	Velew	cm/s
6	Velns	cm/s
7	Velvert	cm/s
8	Velerr	cm/s
9	Ampl	db
10	Good	%
11	a-ghdg	degrees

84bot*.cal**

1	time	s
2	heading	degrees
3	ebotcal	cm/s
4	nbotcal	cm/s
5	bottomew	cm/s
6	bottomns	cm/s
7	depth	m
8	temp	degrees C
9	a-ghdg	degrees

84adp*.abs**

1	Time	s
2	Lat	
3	Lon	
4	Distrun	km
5	bindepth	m
6	Evelcal	cm/s
7	Nvelcal	cm/s
8	Absve	cm/s
9	Absvn	cm/s
10	Velvert	cm/s
11	Velerr	cm/s
12	Ampl	db
13	Good	%
14	a-ghdg	degrees
15	Ve	cm/s
16	Vn	cm/s

84bot*.abs**

1	time	s
2	heading	degrees
3	ebotcal	cm/s
4	nbotcal	cm/s
5	bottomew	cm/s
6	bottomns	cm/s
7	depth	m
8	temp	degrees C
9	a-ghdg	degrees
10	ve	cm/s
11	vn	cm/s
12	lat	
13	lon	

84bot*.abs.#2**

Velocity amplitude correction = …
Heading misalignment correction = …
Mean ve = …
Standard deviation of ve = …
Mean vn = …
Standard deviation of vn = …
Mean heading = …
Standard deviation of heading = …

Identifying CTD 'on-station' ADCP data

A CTD station was selected from those shown in Figure 15 below, and the corresponding Julian date and time (am or pm) were identified from the CTD log.

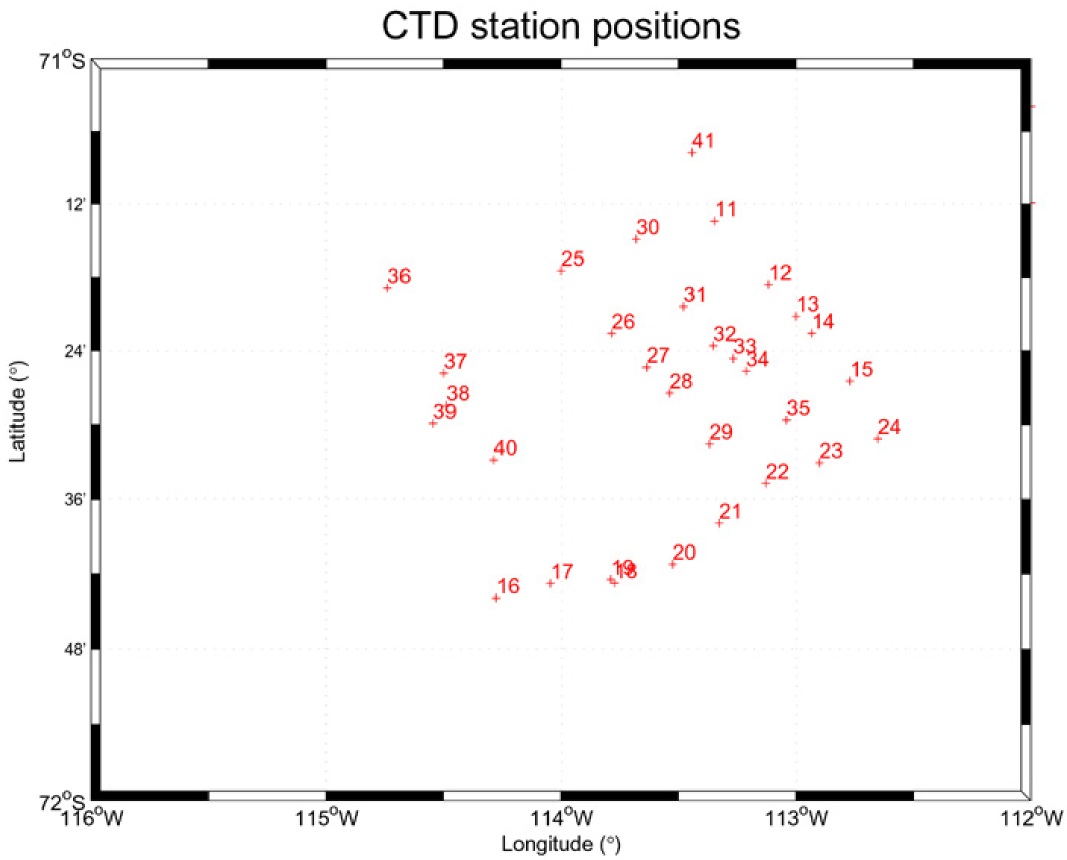


Figure 15: Plot of CTD stations

From the corresponding .abs file, the *ve* and *vn* variables (ship velocity averaged over 2-minute periods in the east and north direction respectively) were plotted. From this plot, approximate start and stop times of the period when the ship was stationary during the CTD deployment, were noted.

Using the same .abs file, every 64th data cycle (i.e. start of every 2-minute time-averaged ensemble) was listed using *mlis*t and displaying the variables; *time* (JDAY), *bindepth*, *absve*, *absvn*, *ve* and *vn*. From this list, those data cycles closest to the times noted previously from the ship's velocity plot, were identified. The data cycle closest to the start of the stationary period with *ve* and *vn* both nearing 0 cm/s was noted. For the end of the stationary period, the data cycle listed that clearly showed the ship to be moving off-station was located and the data cycle immediately preceding this was noted as this represented the last data cycle of the last 2-minute ADCP ensemble of the stationary period of the ship.

This block of data cycles was then copied to a new file using *pcopya* for further processing using *allav*, which averaged the data cycles over one ensemble (i.e. 2 minutes and 64 data cycles). The resulting file was then viewed on an arrow graph to provide a time averaged view of the on-station ADCP data (see Figure 16). This process was repeated for each CTD station identified in Figure 15.

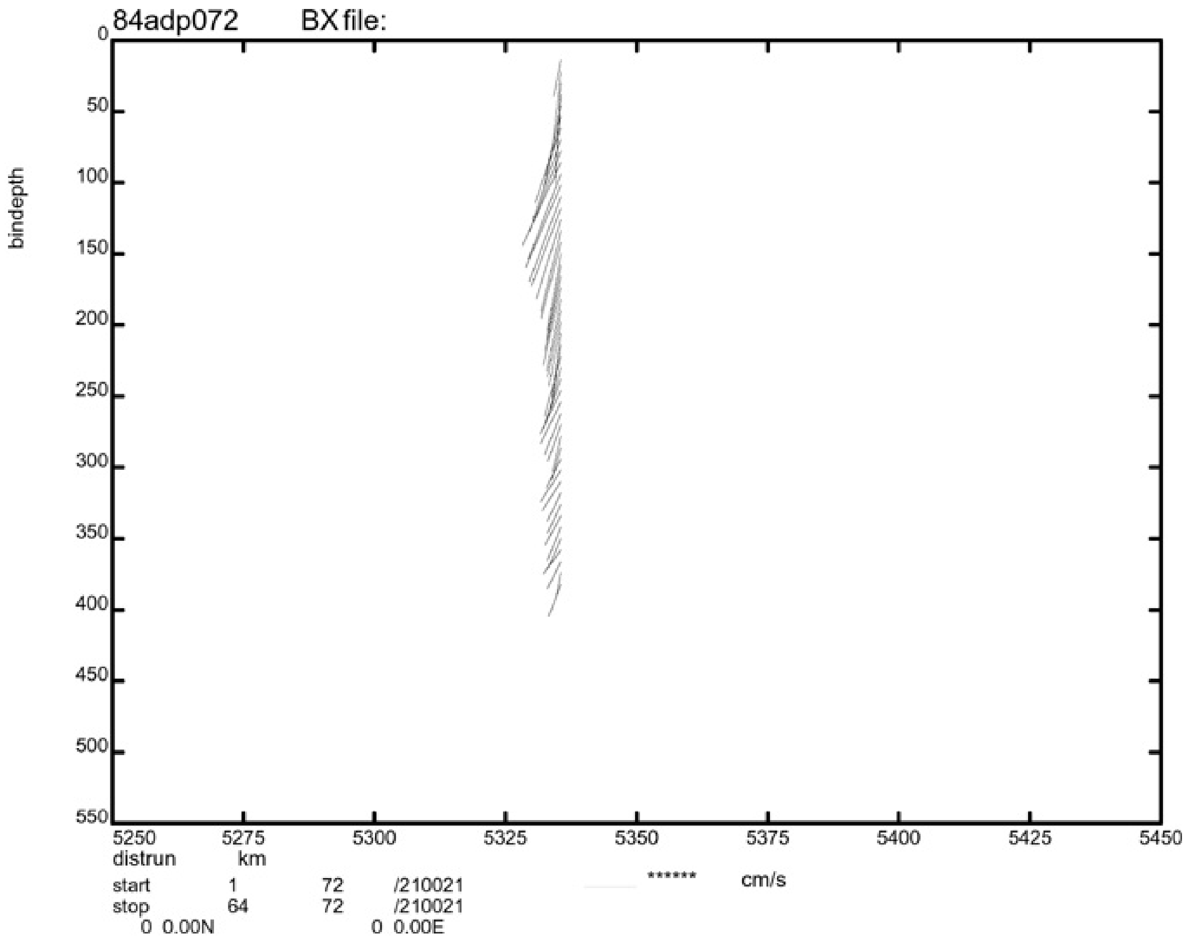


Figure 16: Arrow graph plot of time averaged on-station ADCP data

As well as listing the data cycles using *mlist*, an additional arrow graph plot of the original .abs file ADCP data for the approximate stationary period of the ship (see Figure 17), aided the identification of the relevant data cycles. The arrow graph plot proved useful if the *ve* and *vn* values of the data cycles for the start and stop times previously noted did not appear to fall particularly close to 0. If the ADCP arrow plot displayed consistent ADCP data within this time period, then the data cycles could be selected with greater confidence of providing accurate ADCP data. Any time periods of inconsistent ADCP data as displayed on the arrow graph, could also be identified and the relevant data cycles and removed. This sometimes resulted in more than one block of data cycles being copied over to the new file for averaging using *allav*.

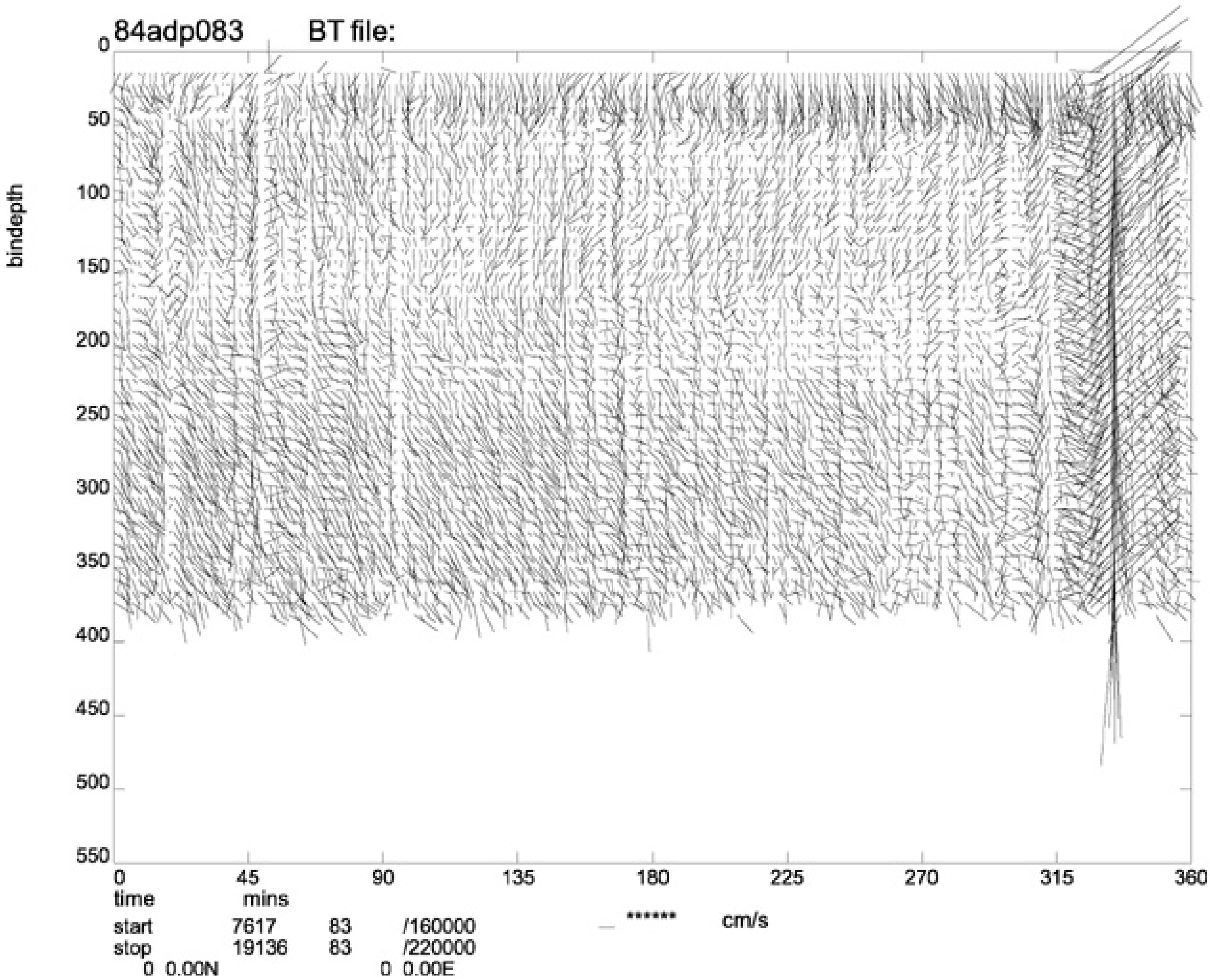


Figure 17: Arrow graph plot of .abs file ADCP data for duration of CTD deployment

Navigation data

Sarah Hardy and Mark Brandon
(Open University)

There were five navigational instruments for scientific use on the RRR *James Clark Ross* (listed in Table 7 below). Although the five instruments appear in some cases to be similar, they are all unique. As well as the three GPS systems listed in Table 7, there are additional GPS systems on board the JCR for the ship's use. These are a Leica MX400 and two Ashtec G12 receivers as part of the dynamic positioning system. In addition, there is a Racal Satcom, which receives GPS SV range correction data via INMARSAT B. This data is passed to the Trimble, Leica and G12 receivers allowing them to operate in Differential mode (DGPS). During JR84 the DGPS reference station at Stanley was used.

Instrument	Type	Code	Use
Trimble 4000	GPS receiver	gps	Primary positional information
Ashtec GG24	GLONASS / GPS receiver	glo	Positional information
Ashtec ADU-2	GPS receiver	ash	Attitude information
Gyrocompass	Sperry Mk 37 model D	gyr	Heading information
Electromagnetic Log	Chernikeeff log Aquaprobe Mk V	eml	Velocity information

Table 7

The collection and use of all of the navigation data are linked. All of the instruments are currently logged to the SCS system and then transferred to the old RVS Level C system where they are currently read.

During cruise JR84, the data for all five instruments and the standard editing procedures were done in one Unix script called *jr84_nav_go*. This script requires the Julian day and am or pm selection as input and then executes a further 8 C shell scripts to read in 12 hours of data and edit where necessary, all five streams. This report briefly describes each instrument and explains the processing as was performed on cruise JR84.

The instruments

Trimble 4000

The Trimble 4000 receiver in differential mode, was the primary source of positional information for the scientific work on JR84.

The data were logged at 1 second intervals and read into pstar files in 12 hour periods from the SCS derived Level C stream using the Unix script *gpsexec0*. Individual steps in this exec are as follows.

gpsexec0 - Reads Trimble data into pstar format

Steps:	*datapup*	- transfers the data from RVS binary files to pstar binary files
	pcopya	- resets the raw data flag on the binary file
	pheadr	- sets up the header and data name of the file
	datpik	- removes data with a dilution of precision (hdop) greater than 5

Output files: 84gps****.raw (just before editing stage)
84gps**** (following *datpick*)

Ashtec GLONASS (GG24)
The Ashtec GG24 accepts data from both American GPS and Russian GLONASS satellite clusters, giving a constellation of 48 available satellites and should, theoretically, be more accurate. However, experiments on previous cruises have suggested that the accuracy is significantly lower than the differential GPS.

Data were logged routinely using *ggexec0*, called from *jr84_nav_go*, but were not used in the processing of other data streams.

Output files: 84glo****.raw
84glo**** (following basic quality control of raw data)

Ashtec ADU-2
The Ashtec ADU-2 GPS is used to correct errors in the gyrocompass heading that are input to the ADCP. The configuration of the receiver is complex, made more so by the fact that the receiver can only be configured with the use of a laptop running a terminal emulation program.

Configuration data for the Ashtec aerial configuration is shown in Table 8. The port-aft antenna is designated number 1, port-fwd is number 2, stbd-fwd is number 3 and stbd-aft is number 4. the XYZ vectors have been adjusted so that heading is defined by the direction normal to the 1-4 baseline (i.e. that baseline has Y = 0).

Vector	X(R)	Y(F)	Z(U)
1-2	2.938	4.748	0.027
1-3	1.478	4.749	0.011
1-4	13.210	-0.0000	-0.036
Offset	0(H)	0(P)	0(R)
Max cycle	0.2 cyc	smoothing	N
Max mag	0.08	Max angle	10

Table 8

The Ashtec functioned well during JR84 apart from a number of periods when no data was received (see Table 9 for times and durations). This was very unfortunate because of the implications for ADCP processing. It also could have been easily avoided if we had maintained regular watches.

Day	Time	Duration (mins)
059	11:02:35	5.2
060	06:53:58	4.3
063	06:50:54	3.6
067	06:50:26	5.0
068	02:32:23	34.0
076	17:24:22	9.2
081	05:36:18	8.5
081	18:10:15	21.1
088	05:25:08	6.1
091	04:13:38	9.9
092	05:10:58	8.0
093	03:44:15	10.9

Table 9

Our complex data processing is designed with using the Ashtec to correct the gyrocompass error in mind. There are were three execs involved in the processing: *ashexec0*, *ashexec1* and *ashexec2*.

ashexec0 - Reads in data from the GPS3DF into pstar format

Steps:
- *datapup* - transfers the data from RVS binary files to pstar binary files
- *pcopya* - resets the raw data flag on the binary file
- *pheadr* - sets up the header and data name of the file

Output files: 84ash****.raw

ashexec1 - Merges Ashtec data to master gyro file from gyroexec0

Steps:
- *pmerg2* - merges the Ashtec file with the master gyro file
- *parith* - calculates the differences in the Ashtec and gyro headings (delta heading)
- *prange* - Forces delta heading to lie around zero

Output files: 84ash****.mrg

ashexec2 - Complicated exec as it edits the merged data file

Steps: *datapik2* - rejects all data outside the following limits:

heading outside 0° and 360°
pitch outside -5° and 5°
roll outside -7° and 7°
attf outside –0.5° and 0.5°
mrms outside 0.00001° and 0.1°
brms outside 0.00001° and 0.1°
delta heading outside -5° and 5°

pmdian - removes flyers in delta heading of greater than 1° from a 5 point mean

pavrge - sets the data file to be on a 2 minute time basis

phisto - calculates the pitch limits

datpik - further selection of bad data outside the following limits:

pitch outside the limits created
mrms outside the range 0 to 0.004

pavrge - again, sets the data file to be on a 2 minute time base

pmerge - merges the heading data back in from the master gyro file

pcopya - changes the order of the variables

Output files: 84ash****.edit
84ash****.ave

A manual editing procedure was then performed, as described in the ADCP data processing report.

Gyrocompass

The gyrocompass is a fundamental data stream. It is used by the RVS program *bestnav* to derive dead reckoning in the absence of GPS data, as well as being used for ADCP processing (ADCP report) and derivation of true wind velocity (ocean logger report). For JR84, the gyrocompass data was read in 12 hour time periods using the Unix exec *gyroexec*.

gyroexec0		- Reads in the gyrocompass data and removes the inevitable bad data
Steps:	*datapup*	- transfers the data from RVS binary files to pstar binary files
	Pcopya	- resets the raw data flag on the binary file
	Pheadr	- sets up the header and data name of the file
	Datpik	- forces all the data from the gyro to be between 0^{o} and 360^{o}

Output files: 84gyr****.raw

The script also appends the day file to the master file called *84gyr01*

Electromagnetic Log

The Electromagnetic Log gives water velocity relative to the ship in both the fore-aft and port-starboard direction. This data was read in 12 hour time periods using a simple exec *emlexec0*.

emlexec0		- Reads in data from the Electromagnetic Log into pstar format
Steps:	*datapup*	- transfers the data from RVS binary files to pstar binary files
	Pcopya	- resets the raw data flag on the binary file
	Pheadr	- sets up the header and data name of the file

Output files: 84eml****.raw

Doppler Log

The Doppler Log gives water velocity relative to the ship in both the fore-aft and port-starboard direction. This data was read in 12 hour time periods using *dopexec0*.

dopexec0		- Reads in data from the Doppler Log into pstar format
Steps:	*datapup*	- transfers the data from RVS binary files to pstar binary files
	pcopya	- resets the raw data flag on the binary file
	pheadr	- sets up the header and data name of the file

Daily navigation processing

As stated above, the data were read in as twice daily (12 hour) files; the time periods being either from 00:00Z to 11:59Z or 12:00Z to 23:59Z. Our primary navigation data were taken from the RVS file bestnav. This program uses the navigation data from various streams to construct a file with 30 second fixes. For JR84 the primary input to bestnav was the Trimble 4000 DGPS. This navigation file was read into a pstar file using the script *navexec0*.

Navexec0		- Reads in data from the bestnav stream into pstar format
Steps:	*datapik2*	- transfers the data from RVS binary files to pstar binary files
	pcopya	- resets the raw data flag on the binary file
	pheadr	- sets up the header and data name of the file
	posspd	- here we calculate the east and north velocities from position and time
	papend	- output file is added to the master file
	pdist	- recalculates the 'distance run' variable
	pcopya	- takes out the RVS calculated 'distance run'

Ouput files: abnv841

The output master file, abnv841, is used for all pstar required navigation information (e.g. ADCP processing).

The processed data were then averaged and filtered using *navexec1*.

Navexec1		- Averages and filters navigation data
Steps:	*pcopya*	- copies output file from navexec0 (abnv841) and changes data name
	pmdian	- removes spikes in velocity data
	pintrp	- interprets and replaces missing velocity data
	pfiltr	- data smoothed using top hat

Output files: abnv841.av

Microbiological sampling

Jon Copley
(Southampton Oceanography Centre)

Water samples were collected and preserved by Copley for microbial analysis with researchers associated with the NERC Marine and Freshwater Microbial Biodiversity programme. Samples for this purpose were taken using sterile 50 ml containers from Niskin bottles filled during several CTD casts.

For analysis of prokaryotes by flow cytometry and *in situ* hybridisation (Zubkov, SOC), 2 x 12 ml subsamples were transferred into 15 ml sterile tubes using clean pipette tips and each fixed with 600 µl of 0.2 µm filtered 20% paraformaldehyde. For investigation of viruses by electron microscopy and molecular techniques (Wilson, MBA), a further 1 ml subsample was transferred into a sterile 1.8 ml cryovial and fixed with 10 µl of 50% glutaraldehyde. All samples were inverted several times and left to fix in the cold room before being frozen at -80ºC. The frozen samples will be transported to the UK in the -80ºC freezer aboard the ship. As Autosub did not sample water beneath an ice shelf, no live microeukaryote samples were collected for Finlay at CEH.

The samples were collected from a range of depths during 5 CTD casts across the shelf break at the entrance to Pine Island Bay. Two of these casts were to ~2000 metres and three were to ~500 metres including one cast below sea ice. A total of 84 samples were collected and preserved for analysis of prokaryotes and viruses as shown in the summary table of microbial samples.

Table 10: Summary of samples collected and preserved for microbial analysis

Sample #	CTD #	Depth (m)	Description	Sample #	CTD #	Depth (m)	Description	Sample #	CTD #	Depth (m)	Description
25-1P	025	2044	2 x12 ml prokaryotes	30-3P	030	1527	2 x12 ml prokaryotes	34-10P	034	83	2 x12 ml prokaryotes
25-1V	025	2044	1 ml viruses	30-3V	030	1527	1 ml viruses	34-10V	034	83	1 ml viruses
25-2P	025	1733	2 x12 ml prokaryotes	30-4P	030	1219	2 x12 ml prokaryotes	34-12P	034	17	2 x12 ml prokaryotes
25-2V	025	1733	1 ml viruses	30-4V	030	1219	1 ml viruses	34-12V	034	17	1 ml viruses
25-3P	025	1424	2 x12 ml prokaryotes	30-5P	030	914	2 x12 ml prokaryotes	39-2P	039	606	2 x12 ml prokaryotes
25-3V	025	1424	1 ml viruses	30-5V	030	914	1 ml viruses	39-2V	039	606	1 ml viruses
25-4P	025	1120	2 x12 ml prokaryotes	30-6P	030	605	2 x12 ml prokaryotes	39-4P	039	508	2 x12 ml prokaryotes
25-4V	025	1120	1 ml viruses	30-6V	030	605	1 ml viruses	39-4V	039	508	1 ml viruses
25-5P	025	815	2 x12 ml prokaryotes	30-7P	030	454	2 x12 ml prokaryotes	39-6P	039	305	2 x12 ml prokaryotes
25-5V	025	815	1 ml viruses	30-7V	030	454	1 ml viruses	39-6V	039	305	1 ml viruses
25-6P	025	613	2 x12 ml prokaryotes	30-8P	030	302	2 x12 ml prokaryotes	39-8P	039	201	2 x12 ml prokaryotes
25-6V	025	613	1 ml viruses	30-8V	030	302	1 ml viruses	39-8V	039	201	1 ml viruses
25-7P	025	512	2 x12 ml prokaryotes	30-9P	030	204	2 x12 ml prokaryotes	39-10P	039	102	2 x12 ml prokaryotes
25-7V	025	512	1 ml viruses	30-9V	030	204	1 ml viruses	39-10V	039	102	1 ml viruses
25-8P	025	410	2 x12 ml prokaryotes	30-10P	030	104	2 x12 ml prokaryotes	39-12P	039	27	2 x12 ml prokaryotes
25-8V	025	410	1 ml viruses	30-10V	030	104	1 ml viruses	39-12V	039	27	1 ml viruses
25-9P	025	309	2 x12 ml prokaryotes	30-11P	030	54	2 x12 ml prokaryotes	42-2P	042	508	2 x12 ml prokaryotes
25-9V	025	309	1 ml viruses	30-11V	030	54	1 ml viruses	42-2V	042	508	1 ml viruses
25-10P	025	106	2 x12 ml prokaryotes	30-12P	030	28	2 x12 ml prokaryotes	42-4P	042	406	2 x12 ml prokaryotes
25-10V	025	106	1 ml viruses	30-12V	030	28	1 ml viruses	42-4V	042	406	1 ml viruses
25-11P	025	46	2 x12 ml prokaryotes	34-2P	034	631	2 x12 ml prokaryotes	42-6P	042	303	2 x12 ml prokaryotes
25-11V	025	46	1 ml viruses	34-2V	034	631	1 ml viruses	42-6V	042	303	1 ml viruses
25-12P	025	31	2 x12 ml prokaryotes	34-4P	034	457	2 x12 ml prokaryotes	42-8P	042	203	2 x12 ml prokaryotes
25-12V	025	31	1 ml viruses	34-4V	034	457	1 ml viruses	42-8V	042	203	1 ml viruses
30-1P	030	1996	2 x12 ml prokaryotes	34-6P	034	406	2 x12 ml prokaryotes	42-10P	042	102	2 x12 ml prokaryotes
30-1V	030	1996	1 ml viruses	34-6V	034	406	1 ml viruses	42-10V	042	102	1 ml viruses
30-2P	030	1833	2 x12 ml prokaryotes	34-8P	034	305	2 x12 ml prokaryotes	42-12P	042	16	2 x12 ml prokaryotes
30-2V	030	1833	1 ml viruses	34-8V	034	305	1 ml viruses	42-12V	042	16	1 ml viruses

Autosub Operations

Nick Millard, Steve McPhail, Miles Pebody, James Perrett, James Riggs, Pete Stevenson, Andy Webb
(Southampton Oceanography Centre)

Mobilisation

Autosub, its launch and recover gantry, ancillary equipment and battery boxes were loaded into 3 x 20 foot containers for shipping from Southampton to the Falkland Islands on the 10th December 2002 and were awaiting the ships arrival in Stanley on 24th February 2003.

Mobilisation began on the Afternoon of 25th February and continued until the ship sailed on the 28th February. Two of the transportation containers had been modified to double as garage space and workshop for Autosub, and were located on the aft deck, just forward of the launch and recovery gantry on the port quarter. The third open top container used to ship the gantry and was unloaded and left ashore. The fish containing the tracking and telemetry acoustics was loaded on to the PES winch on the starboard side just forward of the bridge.

Container workshop/garage

Experience gained from working on the vehicle on the open deck in the Weddell Sea 2 years previous highlighted the need for a warm storage and working environment for Autosub and the engineering team. To this end, two of the shipping containers were modified to be used as a workshop and garage. The workshop container was a refrigeration container and as such well insulated, fitted with a personnel door and window. A lifting beam with hoist ran its length to assist dismantling Autosub and moving heavy items. The garage container was a modified open-top container fitted with a lifting roof to accommodate the head of the gantry. It was also insulated, although to a lesser degree (none on the floor, an omission that needs to be rectified for the future) and curtains at the Autosub access end. The two were positioned in an offset 'T' formation forward of the gantry so that the submarine could loaded into its garage using the gantry's ability to run its beam inboard. Twist locks fitted to adaptor plates designed to fit the standard 1 metre deck matrix were used to fit them to the deck. Strops were added as a precaution. Heating (12kW), lighting and electrical outlets were supplied with both 'dirty' (for heating and lighting) and 'clean' electrical supplies from outlets on the after deck. Telephone, fire alarm and public address speaker were supplied and fitted by ship side. Mobilisation went well, with only minor adjustments needed to align heights and container deck plates. To achieve vertical alignment of Autosub and gantry head with the floor and roof of the garage the gantry was mounted on eight 200mm cotton reels'. A few minor problems were encountered during mobilisation and during operations it became apparent that a few changes could be made to improve the facility, e.g. better defences against rouge waves at the aft end. However, overall they provided a very satisfactory environment for garaging and working on Autosub in temperatures below -10°C.

Autosub configuration

The scientific payload comprised the following instruments:

Edgetech 4 – 12kHz sub-bottom profiler

Kongsberg-Simrad EM2000 200kHz multi-beam echosounder configurable to look either up or down

WS Envirotech AquaLAB 50 port water sampler

Seabird9 CTD with dual CT sensors, wetlabs transmissometer, fluoremeter and oxygen sensor

RDI 150kHz ADCP mounted looking down

300kHz ADCP mounted looking up

Trim and Ballast (Pete Stevenson)

Estimates of Autosub's weight, volume, centre of gravity and volume were made at SOC (filename otd1\autosub\pete\excel\AUI\AUIantarctic2003.xls, dated 5/12/02), where the build was estimated to be 10kg buoyant for a water density of 1026kg/m^3. Measurements in air and fresh water were made before shipping 6/12/03 and recorded on a Mathcad programme (filename TrimBuoyAntarctic2003.mcd, dated 06/012/02). Additional ballast of 2.3 kg in the nose and 4.5kg in the tail (lead weights) was added at SOC to give a final predicted buoyancy of 8.5kg in a density of 1026kg/m3.

A basic floatation test was carried out in calm waters with the winch lines still attached before any missions were run to ensure the vehicle floated. Table 11 shows the changes made throughout the campaign. Inspection of the data after mission 312 showed the rate ascent to be practically zero at around 40m depth while floating up without any propulsive power. A plot of the water density from the CTD showed a marked change from 1027.5 to 1026.9kg/m^3 at the same depth. This change in density equates to approximately 1kg change in vehicle buoyancy and should not have been particularly noticeable. The momentary state of neutral of buoyancy suggests the vehicle was marginally buoyant at the start and/or, there are parts of the vehicle that significantly compress with pressure. However, the vehicle had successfully dived to 1320m without any undue change needed in pitch or stern-plane angle to maintain control suggesting no undue compression was happening (Fig 18). The problem highlights the problems of running without an emergency abort weight, the vehicle should be reweighed back at SOC to determine if there were any errors made during the final ballast and trim measurements.

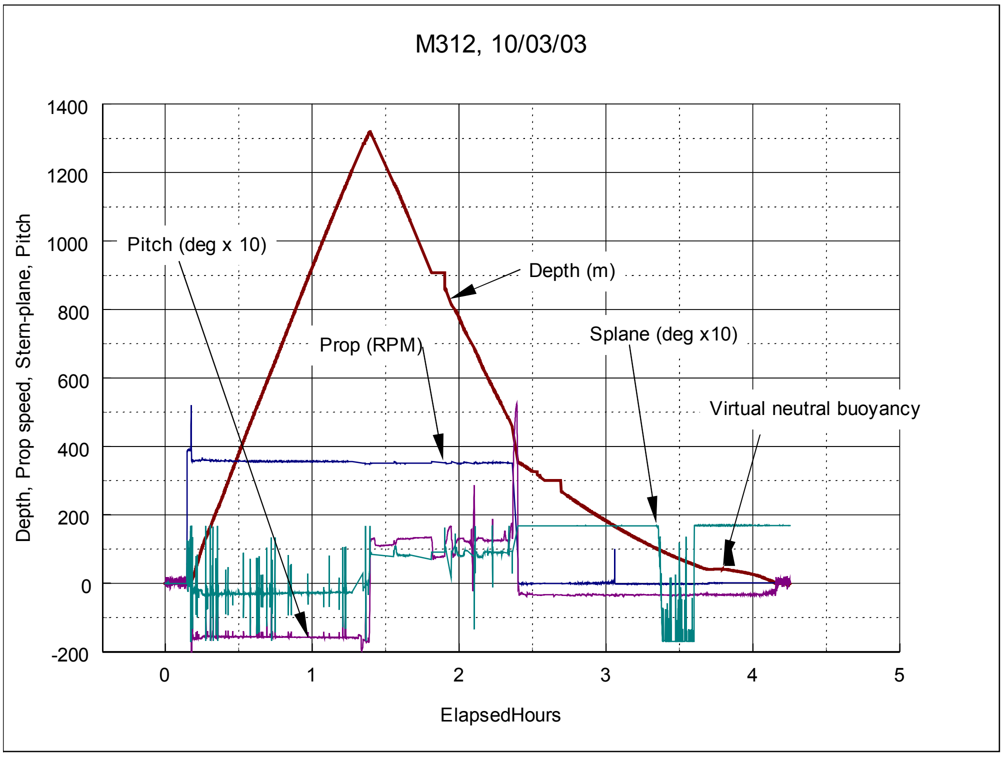


Figure 18: Mission 312 prior to adding more buoyancy

Date of change	Changes made (all ballast wts are lead)	Net Buoyancy change (kg)	After Mission No.*	Remarks
03/03/03	None	None	None	First dip in water at Gerlache Strait, to ensure it floats, sub left attached to winch lines.
06/03/03	1.1 kg added to nose, 1.1 kg added to tail	None	M309	Weight added to compensate for replacement of 2.2kg (in water) aluminium cable tray.
10/03/03	None	None	M312	Rate of ascent found to be marginal and considered to be nose heavy
13/03/03	2.2kg moved from nose to tail. 1.1kg removed from nose 4.5+1.1kg removed from tail. Extension Network cable added (2.2kg in water).	+4	M312	Ballast removed to increase buoyancy. Network cable added to eliminate nose harness from Data Dropouts investigation.
14/03/03	Digi Q depth sensor moved from nose to tail (2.1kg in water) Extension network cable removed. 2.2kg removed from tail. 4.5kg added to nose	None	M314	Possible difficulty in diving observed. Changes made to trim slightly nose heavy and accommodate re-allocation of depth sensor and cables as data drop out investigation continues.
19/03/03	See Remarks	None	M319	Nose badly damaged during recovery. Extensive changes made, see spreadsheet AUIantarctic2003PostRoughRecovery.xls
20/03/03	None	None	M319	Floated in water with winched lines attached as a basic floatation test.

*Note, changes were made after a mission and so the logged dates of mission numbers and ballast change date are not necessarily the same.

Table 11: Record of ballast changes made during the campaign.

Dive Weight System

The dive weight system had been developed for the AUI programme to enable the vehicle to be launched amongst floating ice without the need for run along the surface before diving, where there would be a high probability of striking a heavy piece of ice. Figure 19 shows the response of the vehicle using a 20kg steel weight hung beneath the nose and shows a gentle descent without loss of control of pitch.

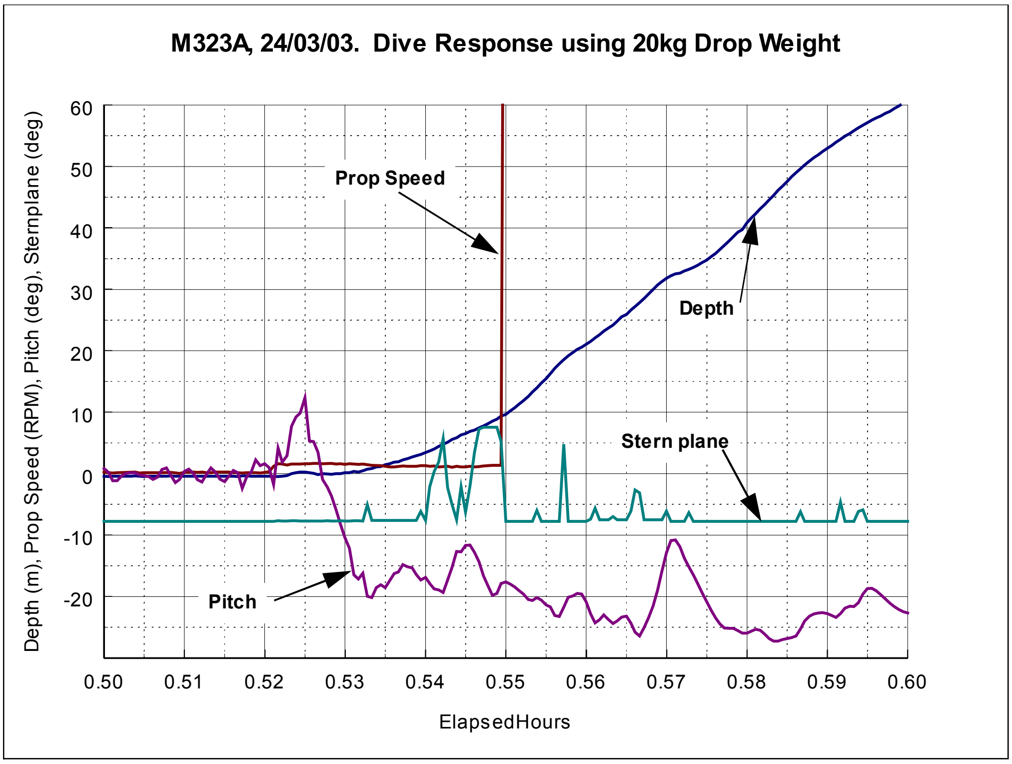


Figure 19: Vehicle Dive Response using the sink weight

The drop weight is a catastrophic single point of failure should it fail to drop, this was mitigated by holding the weight on a corrodable magnesium link with a total cross sectional area of $4mm^2$, the plan being that the link would corrode and drop the weight before the vehicle went beyond its safe working depth. When placed in sea water at temperatures around 0^0C, the link took between 30 and 60 minutes to break with a 100N load. This is rather too long and too variable to provide an effective fail-safe mechanism. Although the weight never failed to drop through firing the electro magnet, a more reliable provision for a passive fail safe link should be investigated. This could be a time or pressure based.

The 400N holding force magnet on the weight had caused problems on the Terschelling trials with ship movement causing the weight to wobble and drop. It was thought with the JCR being more stable and care taken to suspend the weight accurately about its centre of gravity, it would not be problem for the campaign. However, a weight was lost as Autosub was rotated in the gantry, the backlash in the rotary head and stop/start nature of the hydraulic valve was enough to shake the weight off. The solution for the campaign was to take extreme care in driving the gantry smoothly. For the future, a latched system needs to be developed along similar line to the latched abort weight.

Edgetech FS-AU Sub-Bottom Profiler (James Perrett)

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

On Autosub, the instrument is triggered by a controller connected to the vehicle's LONWorks network. This controls the pulse rate and also allows the trigger pulse to be synchronised with other systems in order to control interactions between instruments. The FS-AU has been shown to affect acoustic communications with the vehicle and it is therefore disabled whenever these communications are taking place. This may have resulted in the gaps in data mentioned by David Vaughn in his section of the cruise report.

For the JR84 cruise the ping interval was set to two seconds.

The instrument only gave useful data during the first three missions. Later missions flew too far above the seabed to produce any useful data. The transmit transducer was seriously damaged after mission 319 and the whole instrument was disconnected subsequently in order to save power.

Future Improvements

Currently no navigation or attitude information is stored with the FS-AU data as it was understood at the time of system integration that there was no method of reading this data. Edgetech have recently announced that they will be producing software that can use any navigation data stored with profiler data. It would require a simple wiring addition to send navigation data to the profiler so this may be an option worth implementing for future cruises.

Simrad EM2000 Multibeam Swath System (James Perrett)

The Simrad EM2000 is a multibeam swath bathymetry system which operates at a frequency of 200kHz and can form 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 second LONWorks controller sends attitude and depth information to the instrument.

This system was initially fitted with the transmit transducer mounted in the nose of the Autosub vehicle and the receive transducer mounted in the tail section facing downwards. The transducers were mounted behind polythene windows in the vehicle's fibreglass outer panels. Missions 307, 308 and 309 were run with this configuration. The data collected showed reduced seabed depths at the outer extremities of the swath. There was also a problem with poor resolution in the position information sent from the Autosub vehicle to the EM2000. This second problem was solved by a software modification to the LONWorks controller.

The system was then reconfigured for under ice work with the transducers looking upwards. The appropriate installation settings for sensor roll were also changed (S1R and S2R were set to 180.0). During the next few days a number of missions were run, for testing purposes, that included a short horizontal run at 100m depth in order to try to obtain data from sea surface reflections. Since the sea surface should present a flat surface to the swath system it was considered to be a good diagnostic test to see if the reduced ranges at the edge of the swath were still seen.

After examining the data, it was decided to change instrument settings to give beams at equal angles rather than equidistant across the seabed. Unfortunately the supplied control software did not work satisfactorily and the initial alternative method (adding the parameters to the install file) suggested by Simrad also did not work (mission 313). The next day Simrad supplied a small software utility which allowed us to successfully send runtime parameters to the instrument. This was used to set the instrument up for mission 314.

The results were still not satisfactory. The minimum depth setting was then changed from 3m to 0m with a slight improvement on mission 317. The system did not appear to allow a negative minimum depth setting to be set so it was decided to use a false depth sensor offset of –5.0metres to increase the usable range of depths. This finally appeared to give satisfactory results during missions 318 and 321.

Mission 319 gave little good data, probably due to the high pitch angles encountered during the mission although the parts of the mission where the surface was in range appear to show some sensible data.

No navigation data was recorded during mission 320 but, from looking at the raw data, there appears to be valid swath data. Unfortunately the Simrad processing software rejected this data. It may be possible to retrieve the swath data using alternative processing software although much of the mission was too deep for sensible swath data. The lack of navigation data appeared to be due to a change in the LONWorks controller software that was intended to correct backward jumps in the position timestamp. Reverting back to a previous version of software corrected the problem.

Missions 322, 323 and 324 gave no usable data due to a faulty connection in the transmit transducer cable.

If we had been able to run further missions it might have been a good idea to set the sound speed instrument parameter to be something closer to the real sound speed. The instrument assumes a sound speed of $1500 ms^{-1}$ while the real speed was closer to $1450 ms^{-1}$. The definition of the minimum and maximum depth parameters also needs to be made clearer as they seem to behave differently when the sonar head is inverted. The documentation appears to have been written as a reference manual rather than as a user manual and assumes that the user is familiar with the system already. Essential basic procedures are only mentioned in footnotes or at the end of the manual (for example, the first procedure needed to translate raw data isn't explained until page 400 of the Neptune manual and data logging is only mentioned as a footnote in the datagram descriptions). A user guide to the instrument and associated software is desperately needed.

AquaLAB (Miles Pebody)

Autosub was equipped with a WS-Envirotech AquaLab system that was to be used for collecting water samples during missions. The AquaLab is a further development of the AquaMonitor. The instrument consists of a 200ml syringe type pump and a rotary valve that selects one of fifty ports. Port number 1 is used to acquire water from the outside of the Autosub and the remaining 49 ports are fitted with sample bags. The requirement for this cruise was to take 49 samples of 250ml each.

Previous problems with this instrument and with the earlier AquaMonitor lead to extensive discussion with WS Envirotech prior to the start of the cruise. The programming and use of the device has proved to be complex and in the end ineffective. The following describes the strategy recommended by WS Envirotech:

- Bags were to be filled in the following sequence – Ports 25 down to 2 with anticlockwise rotary valve movement and ports 26 up to 50 with clockwise rotary valve movements. This sequence was considered necessary in order to avoid cross contamination of samples held in bags as the rotary valve passes their respective port.
- Prime all bags with 50ml water before attaching them to the AquaLab. This is to prevent undue stress on certain parts of the bags and seals at depth.
- Each sample process was then to proceed as follows:
  1. Extract the primed water – Move rotary valve to desired port – extract the primed water. Move rotary valve to port one and eject the prime.
  2. Flush the sample bag with 190ml. – Intake 190ml water, move to the target port fill and empty the bag, return to port 1 and eject the flush water.
  3. Take Water Sample – To sample 250ml two cycles of the syringe pump were required, each of 125ml – so the sequence: take in sample, move rotary valve to target port, fill bag, move back to port 1 was repeated twice.

The time taken to execute this procedure for a bag on port 25 took approximately 25 minutes. Therefore a sample frequency of 30 minutes was implemented using the AquaLab in an autonomous operation mode rather than one that received commands from the Autosub mission control. Because on occasion the AquaLab seemed to start up in an undefined way and failed to start its sampling script it was decided to manually start the AquaLab by command at the beginning of each mission. The AquaLab would then work on its own internal timer to take subsequent samples on a 30 minute basis.

It should also be noted that the demanded sample of 250ml generally resulted in a sample size of between 260ml and 265ml when the AquaLab was run on deck.
Results

Disappointingly the AquaLab failed to provide a reliable, consistent and uncontaminated series of water samples. On recovery of the Autosub the samples were found to be of varying volumes, some greater and some less than the requested 250ml. In addition it was apparent that during the sampling process many of the bags had their 50ml primed water extracted. It was not possible to ascertain whether this missing water was ending up as the extra volume in the sample bags. Although later missions without a primer also resulted in varying sized sample volumes.

3/3/03. All Primed 50ml

Bag On Port	Volume	Bag On Port	Volume
20	195	23	345
21	395	24	270
22	335	25	380

4/3/03. All Primed 50ml

Bag On Port	Volume	Bag On Port	Volume
1.		14.	25
2.	10	15.	empty
3.	25	16.	15
4.	50	17.	300
5.	20	18.	355
6.	5	19.	310
7.	40	20.	390
8.	15	21.	370
9.	empty	22.	340
10.	20	23.	310
11.	20	24.	340
12.	not recorded	25.	330
13.	10		

3/3/03. No prime, bags flushed only.

Bag On Port	Volume	Bag On Port	Volume
18	265	22	265
19	260	23	450
20	395	24	265
21	265	25	305

M312. 10/3/03. No prime, bags flushed only.

Bag On Port	Volume	Bag On Port	Volume
17	25	22	315
18	285	23	370
19	275	24	365
20	280	25	415
21	290		

Other bags below 17 were either empty of contained less than the 50ml prime water.

M313. 13/3/03. No prime, no flushing on bags 18-25.

Bag On Port	Volume	Bag On Port	Volume
17		22	270
18		23	265
19	265	24	395
20	265	25	260
21	265		

M316. 16/3/03. No prime, no flushing on bags 18-25.

Bag On Port	Volume	Bag On Port	Volume
17	280	22	275
18	295	23	275
19	285	24	275
20	280	25	275
21	275		

M317 & M318. 19/3/03. No prime, no flushing on bags 18-25.

Bag On Port	Volume	Bag On Port	Volume
17	145	22	175
18	275	23	175
19	270	24	175
20	265	25	170
21	210		

Conclusions

When operated on deck the AquaLab operated faultlessly on all sampling programs, including the extraction or primed water and flushing of the target bag. However, despite careful arrangement of the bags using string lines to ensure that the pipes and the bags were not kinked or folded the samples still came back after the mission with varying volumes of water. This would suggest that there is either a problem related to the instrument being immersed in water or a problem when operating at depth, or both.

A thorough examination of the AquaLab is required to check the integrity and operation of the rotary valve seals. It is suggested that any laboratory tests of the instrument need to be done in water and at pressures likely to be encountered on Autosub deployments.

Autosub SBE9+ CTD (James Perrett)

Configuration

The instrument was a standard SBE9+ instrument mounted in a titanium case which also incorporated a Burton 8 way connector at one end to connect to the standard Autosub wiring harness. A standard Autosub LONWorks controller was also mounted in the case.

The initial missions, 307-309, were run with temperature sensors, serial numbers 2342 and 2912 together with conductivity sensors 2730 and 2760. Conductivity sensor 2730 was found to be giving different values from both 2760 and the ship's CTD system when a comparative CTD cast was made. It was therefore replaced with an older spare, serial number 2179, which gave values much closer to those of the other sensors. An SBE-43 oxygen sensor, Wetlabs Wetstar fluorometer and Wetlabs AC3 transmissometer were also fitted (Figure 20).

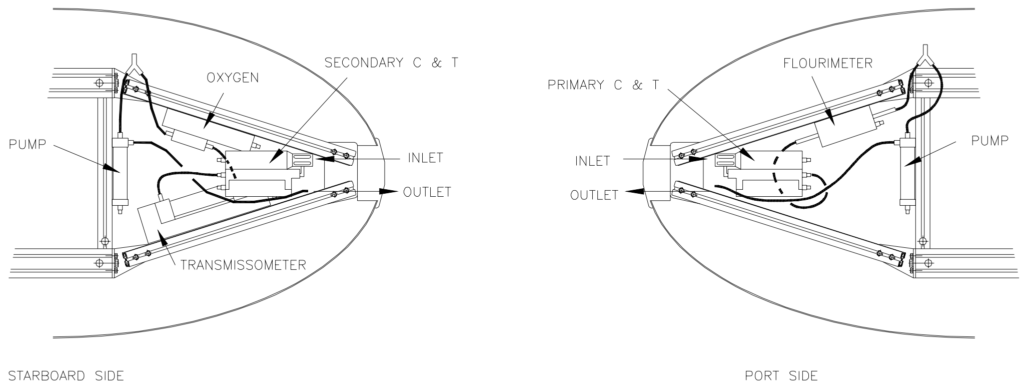


Figure 20: Configuration of CTD and associated sensors for missions 307 to 319 inclusive

After mission 310 the mating part of the Burton connector was found to have leaked and was replaced by an Impulse 7 way connector. An appropriate connecting cable was also made up. This was later modified in an attempt to rectify other network problems with the vehicle.

Following a difficult recovery after mission 319 the transmissometer was lost and the fluorometer was so damaged that it was not used on subsequent missions. The tubing on the input to the primary temperature sensor, number 2342 was also replaced with a modified version (figure 21).

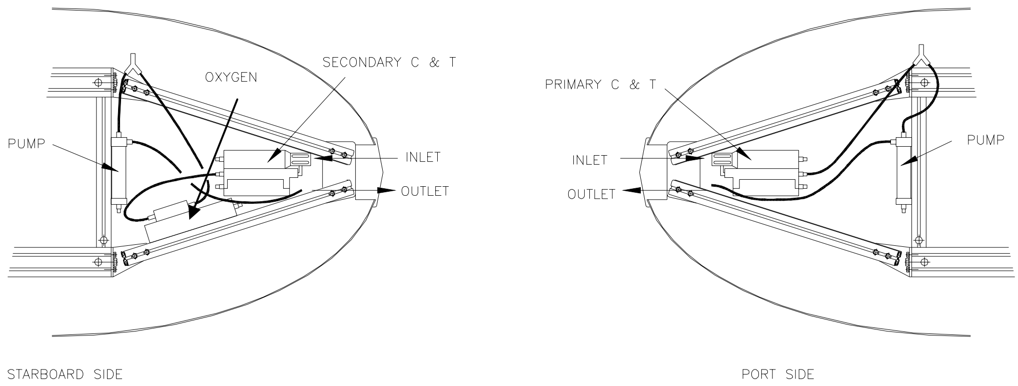


Figure 21: Configuration of CTD and associated sensors after mission 319

Software

This was the first opportunity to try the recently introduced Windows version of the Sea Bird processing software. Unfortunately this rejected data which had previously been accepted by the DOS version of the processing software. Missions 307 to 319 were therefore processed using the DOS software. The header produced by the Autosub Logger File Translator (version 2.90.04)was subsequently modified which enabled the data to be read by the Windows version of Sea Bird software. Missions 320 to 324 were processed with the new software. The final format of the data was identical with both versions of the Sea Bird processing software – the only difference should be found in the header.

The configuration files used were named 0696jr84.con for the missions with the original conductivity sensor and 0696jr84b.con for the missions with the replacement conductivity sensor. Missions … will contain no useful fluorometer and transmissometer data due to the absence of these sensors.

ADCPs and Navigation (Steve McPhail)

Configuration

For JR84 Autosub was configured with an upward looking 300kHz RDI workhorse Acoustic Doppler Current Profiler (ADCP), and a downward looking 150 kHz ADCP. Both fire through 3 mm polyethylene acoustic windows. An IXSEA PHINS Fibre Optic Gyro based inertial navigation system (INS) is coupled to the 150 kHz ADCP sonar head within a titanium pressure case, thereby maintaining fixed alignment offset between the ADCP and INS.

The INS position drift performance is known to be inadequate without a velocity input from the ADCPS. Navigation is most accurate (anticipated 0.2% of distance travelled), when the downward looking ADCP bottom tracks, which is usually possible at ranges up to 400m. The upward looking ADCP can provide velocity aiding when tracking the underside of a fixed surface (such as an ice-shelf), at anticipated ranges of up to 200m. If bottom (or top-surface) tracking data is not available from either ADCPS, then a water track velocity from the bin nearest to the Autosub is used. For navigation, data from the downward ADCP is used in preference to the upward ADCP. As well as velocity information, both ADCPs also provide ranges from each of the four beams. These ranges are used by the flight control system for constant distance flight of the Autosub from either the upper or lower surface, and are used to determine when the thickness of water within an ice-cavity is less than preset bounds, thence triggering a retreat out of the ice-cavity. The ranges are quantised at 1% of the range, and are scaled by a factor of cosine(30 degrees) to make a crude correction for the 30 degree beam-angle; however, no correction is made for the pitch and roll of the vehicle. Both ADCPs are triggered to operate on a two second cycle (by a network time synchronization message sent from the mission control node), to prevent acoustic interference between they and the other sonars. Within each 2-second period the ADCPs transmit one bottom track and one water track ping. Both the upward and downward ADCPs were configured with 15 of 8 m water track bins.

Performance

An early issue needing resolution was the function and performance of the navigation system, given the high operating latitude that is known to affect the accuracy of all gyro-based navigation systems. No problems were found with the INS up to the maximum latitude we achieved of 72 degrees south, although the absence of bottom track data precluded any determination of navigation accuracy, as the actual accuracy is determined solely by the magnitude of the currents, which for some missions were substantial (up to 0.2 m/s). The only adverse effect was that the INS alignment time following first GPS fix of the INS increased to about 10 minutes (normally about 5 minutes). To speed up Autosub deployments, a GPS antenna was mounted on the roof of the Autosub container, and plugged into the Autosub navigation system, so that INS alignment could be completed before the Autosub was taken out of the container.
During the early trails in Gerlach straights, we were able to check the bottom track performance of the ADCP. Bottom track navigation was achieved reliably at altitudes of up to 350 m off the sea-floor, occasionally up to 400m (which was set as the maximum range). Bottom tracking navigation was probably adversely affected by the

relatively steep descent and ascent angles (15 degrees) and so these figures can be considered to be minima.

Problems

Throughout the cruise, the downward looking ADCP gave an unacceptably high level of missed pings. Typically only 75% of the expected data were recorded. Unsuccessful attempts were made to track down the cause of this problem, which we think lies in either the ADCP hardware, or the network node software. On mission 309, the dropouts were particularly bad (only 50% of the data were recorded). Consequently we replaced the downward looking ADCP network interface electronic hardware, and (probably more importantly) removed a serial test lead which may have been picking up electromagnetic interference. This returned the good data rate to 75%, but did not totally cure the problem. This problem is still unresolved and will be investigated further back at SOC.

Water tracking range of the down ADCP was disappointing. Typical ranges were 48 m to 90m for the downward looking ADCP. The upward looking ADCP gave comparable or slightly better ranges. Whereas it is possible that the lack of range was due to lack of scatterers of the required size range, this apparently poor performance warrants further investigation.

Both the upward and downward looking ADCPs gave spurious range returns at times, particularly under the sea-ice missions. That the returns appeared on several of the beams at the same time, and also that there was often a group of contiguous returns, suggests that the ADCP was detecting real targets. The consequence of these spurious range returns was that the depth controller repeatedly pitched the vehicle upwards, to try and avoid the supposed collision with the seabed. On one occasion, there were sufficient contiguous returns at low enough range to trigger the collision avoid behaviour. This problem needs further investigation. We need to produce an algorithm that filters out such spurious range returns (not an simple task given the overriding requirement reliably to detect the seabed).

We had planned to use the upward looking ADCP for navigating relative to the under-ice shelf surface when bottom track data is unavailable from the downwards looking ADCP. This ability caused a problem in mission 322 (23/3/2003), an under-sea ice mission, where the water was too deep for bottom tracking, but the upward looking ADCP was able to track the sea-ice. The sea-ice, driven by the current and the wind, was drifting at an appreciable speed (0.5 knts south), hence seriously affecting the absolute navigation accuracy. This problem was overcome in subsequent missions by a minor software change in the upward looking ADCP: If the ice draught (determined as the vehicle depth minus the ADCP upward range) is less than 10m, then upward tracking mode is disabled (we would expect sea-ice to measure less than 10m draught, ice shelf ice to be more). Despite the problems that the tracking off the sea-ice caused to the vehicle navigation, it was useful to get the opportunity to operate the vehicle in this mode.

Mission Descriptions (Miles Pebody)

An Autosub mission consists of a pre-programmed series of navigation instructions that control the vehicle through a planned series of actions. Usually beginning with a dive and ending back on the surface. Autosub can be reprogrammed while still in the water although it must be on the surface and within radio range of the support ship. Consequently there may be more than one mission per deployment.

The course of the cruise was to begin with a number of Autosub test missions in the relative calm of Gerlache Strait. Once the vehicles systems were found to be in order following work was then to take place under sea ice, North of Thurston Island, and then under the Pine Island Glacier. On arriving at the sea ice work area a number of problems were found with the Autosub's control network which manifested at depths generally greater then approximately 500m. Consequently a number of test mission were run to locate, repair and retest the submarine. After a number of days it had been ascertained that it was not possible to get to the Pine Island Bay and so an extended series of under sea ice survey mission was planned to take place once a safe working depth for the Autosub had been found.

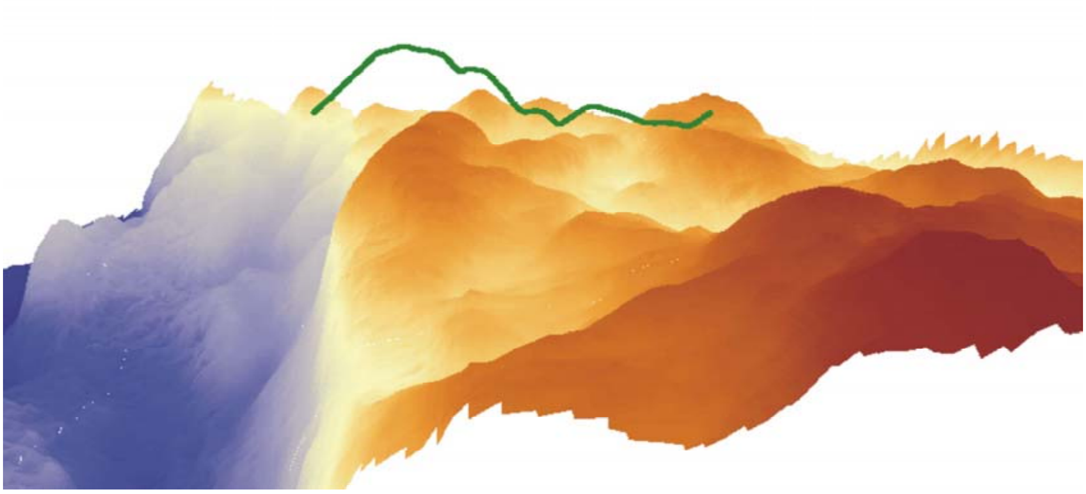


Figure 22: Autosub 100m altitude terrain following track over Gerlache Strait Bathymetry

02/03/03 – 04/03/03 Buoyancy and Test Missions – Gerlache Strait
Missions M307-M309

On 2nd March buoyancy trials were run with the vehicle being lowered into the water behind the ship. This completed the next two days were spent running test missions. The first was a general shake down run to make sure that all systems had survived the trip down from the UK and were working as they should.

Problems were initially encountered with the acoustic communications system, at the ship end, but generally all systems performed as expected.

08/03/03 – 10/03/03 Open Water Test Missions, N of Thurston Island sea ice. Missions M310-312

Mission 310 was to test an Autosub under ice mission template and also to test the vehicle in deeper waters. However, it ended with a failure of one of Autosub's main 48V power regulators. Once repairs had been made mission 311 was a rerun of mission 310 with an added dive to 1000m and an extra 20 minute run at 100m was added to collect upwards looking EM200 swath data. This mission was ended by command to surface after 15 minutes of the swath data collection leg. It transpired that the Autosub control communications network had been broken for periods during the deep part of the mission with one of the events long enough to trigger an emergency abort. The fact that the vehicle had not immediately surfaced was because the mission controller was not able to receive the abort command over the broken network. Mission 312 tested the sub to 1320m and the control network problem recurred.

13/03/03 – 20/03/03 Open Water Test Mission. 113° West. Shelf Break. Missions M313-M320

While the ship continued other work the root of the Autosub control network problems was searched for. Missions 313 – 315 were run with different control system configurations to try and isolate the fault and all resulted in the same symptoms: the vehicle control network communication breaking down intermittently when the vehicle was at depth. Finally, when mission 316 ended and the Autosub was recovered to the ship the problem was still evident and was traced to a faulty IE55 bulkhead connector. It was evident after retest missions 316 and 317 that a number of connectors of the same design were exhibiting similar failure modes. Because of this it was decided to restrict the maximum depths of the remaining Autosub missions. Mission 318 was a relatively shallow 100m mission to collect EM200 swath data and to demonstrate the control network stability. Deeper depths were then attempted in mission 319, first 150m and then 250m. These depths were considered adequate for under sea ice survey missions and the Autosub completed them successfully. Unfortunately, as a result of severe weather the Autosub was damaged on recovery to the ship after mission 319. Subsequent repair took 2 days.

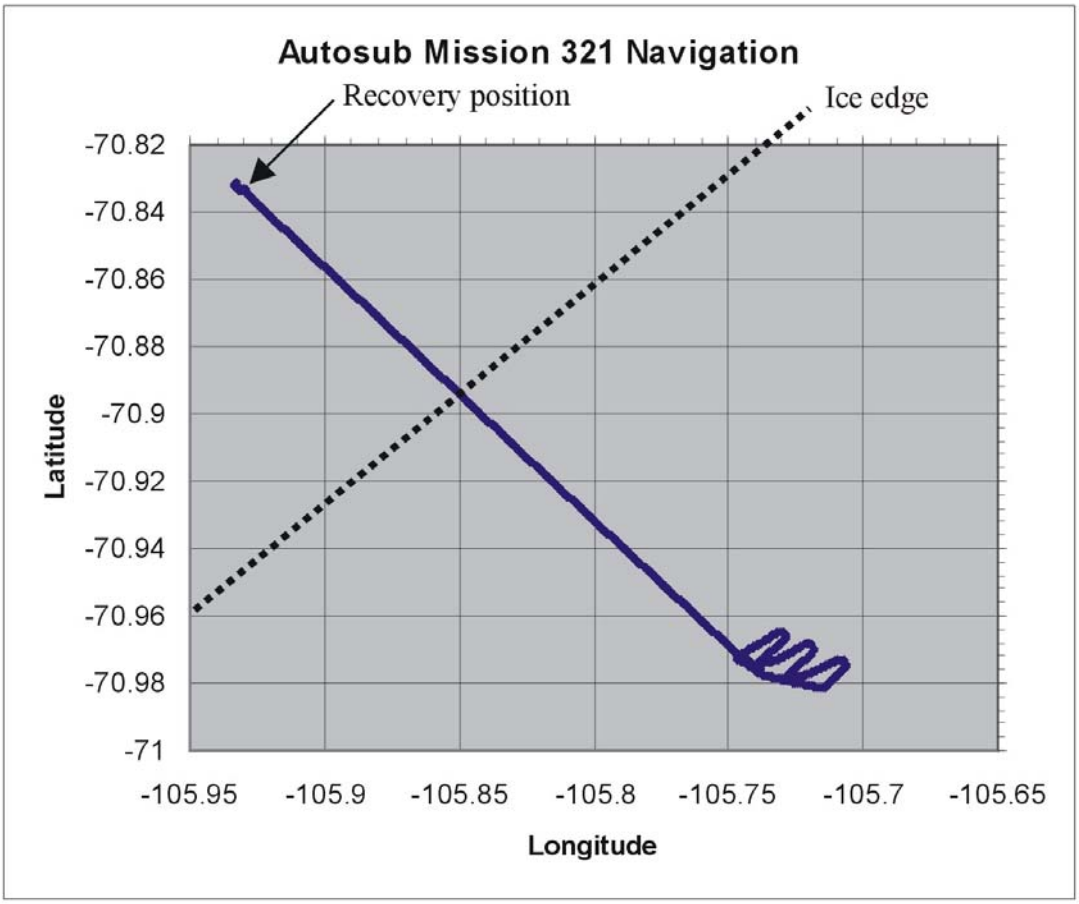


Figure 23: Mission track of M321

20/03/03 – 25/03/03 Open Water Test and Under Sea Ice Surveys. N of Thurston Island sea ice.
Missions M320-M324

Mission 320 was a short mission with a dive to 300m to test the acoustic telemetry system on board the Autosub that had been repaired after the accident at the end of mission 319. Missions 321-324 consisted of under ice surveys with the Autosub being programmed to transit to a survey area, navigate around a grid pattern of approximately 20km and return to a safe recovery position out side of the ice. During the acoustic communication and tracking test phase of mission 322 it was not possible to locate, or obtain status information of, the Autosub. Consequently the vehicle made its way to an emergency recovery position where it was safely taken back on board the ship. Missions 323 and 324 completed successfully although significant currents during mission 324 resulted in the Autosub surfacing 8km East of its programmed recovery position. Unfortunately during this time data from the upwards looking Em2000 swath system was not collected due to another connector problem.

Connector problems (Steve McPhail)

The JR84 Autosub campaign was marred by connector problems. We noticed the first of these in mission 310 (8/3/2003). A Burton 8 way connector assembly for the Seabird CTD had leaked seawater, causing a short circuit of the 48-volt vehicle supply, destroying a 48-volt switched mode power supply. Investigation suggested that there is a problem with type of connector becoming loose after a pressurisation/ depressurisation cycle, and combined with too tight a bend radius, seawater ingress can occur between the sealing faces. This problem needs further investigation, as this type of connector is specified throughout for the network harness for the second build of Autosub. Later in the cruise, a similar leak of a Burton connector, supplying the EM2000 transmitter, caused loss of all swath data for missions 322, 323, 324. It was unfortunate that the multiplicity of software configuration issues which we had had with the EM2000 directed our attention away from this hardware fault.

The more serious problem was with the Impulse IE55 19 way connectors, 12 of which distribute power and LonWorks communication network throughout the vehicle. The problem became apparent in mission 312 (10/3/2003), where the vehicle reached a depth of 1300 m, and then aborted the mission due to the release nodes detecting that there had been a network continuity failure. Analysis of previous mission data revealed that the fault had been intermittently occurring since the start of the cruise. The fault was manifest by intermittent network data dropouts during descent at around 400 to 1000m depth, and then the problem re-occurred when the vehicle returned to around 300 m depth. Dropouts were generally worse on ascent than descent, lasted longer and occurred at a lower depth value. During the next seven days we made extensive attempts to isolate the fault, including checking the resistance of all the network connections in the vehicle, and as a precaution replacing internal network connectors where the connector resistance was higher than normal. This failed to cure the problem, and so attention turned to the IE55 19 way connectors and wiring harnesses. We attempted to isolate the problem by successively removing parts of the network. Eventually one connection was found that could be made to fail open-circuit with light pressure applied to the harness moulding. We replaced the harness, and then replaced the bulkhead connector: still the problem persisted! At this stage we decided that there must be an endemic problem with possibly all the IE55 connectors, and that we would not be able to cure the problem during the cruise. Instead we proof tested the Autosub to an operating depth of 250 m (mission 319, 18/3/03), so that under sea ice missions could at least be carried out safely.

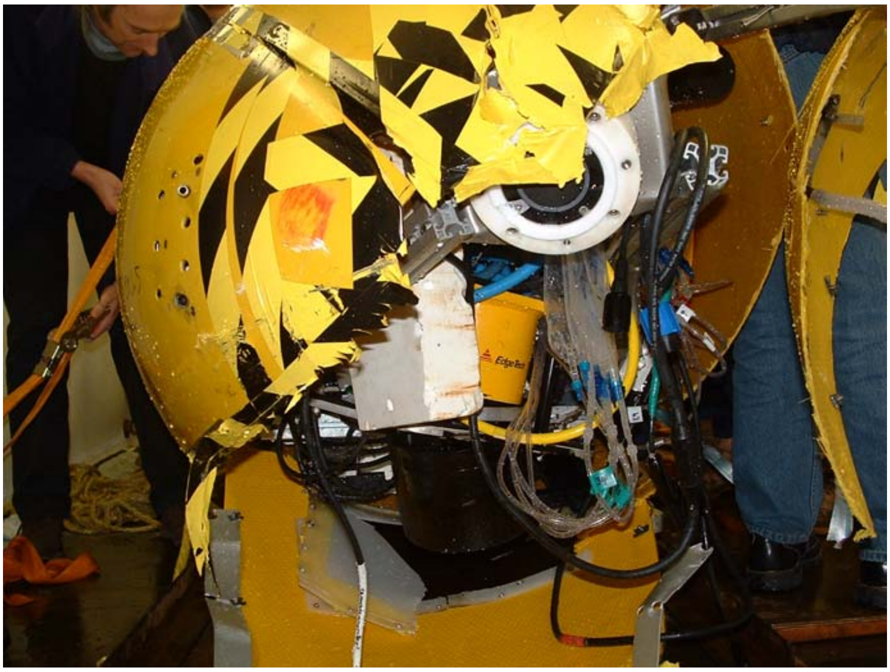
The problem with the pressure related open-circuit failure of the IE55 connectors persists, and we need to investigate further.

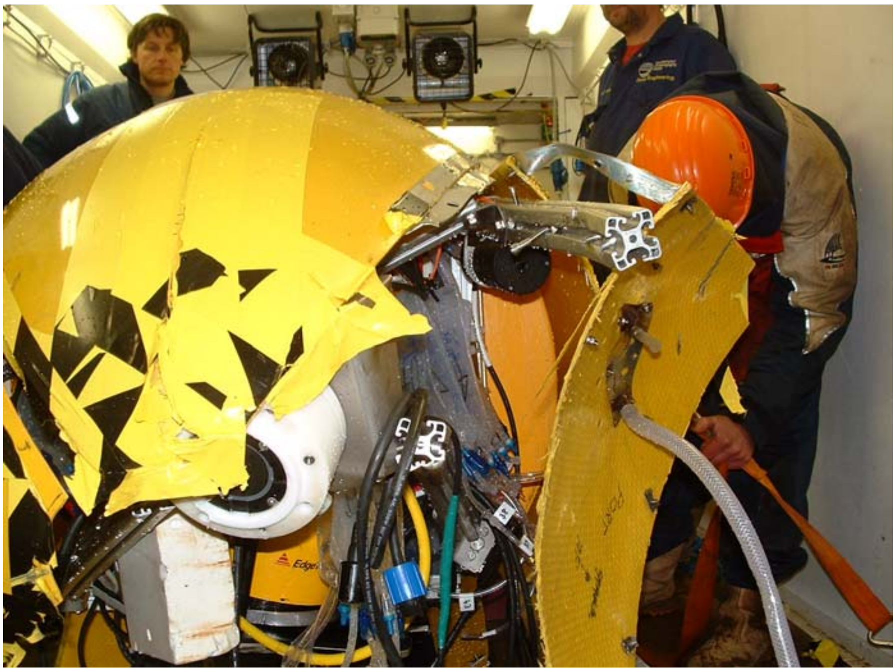
Damage sustained during recovery after mission 319 (Nick Millard)

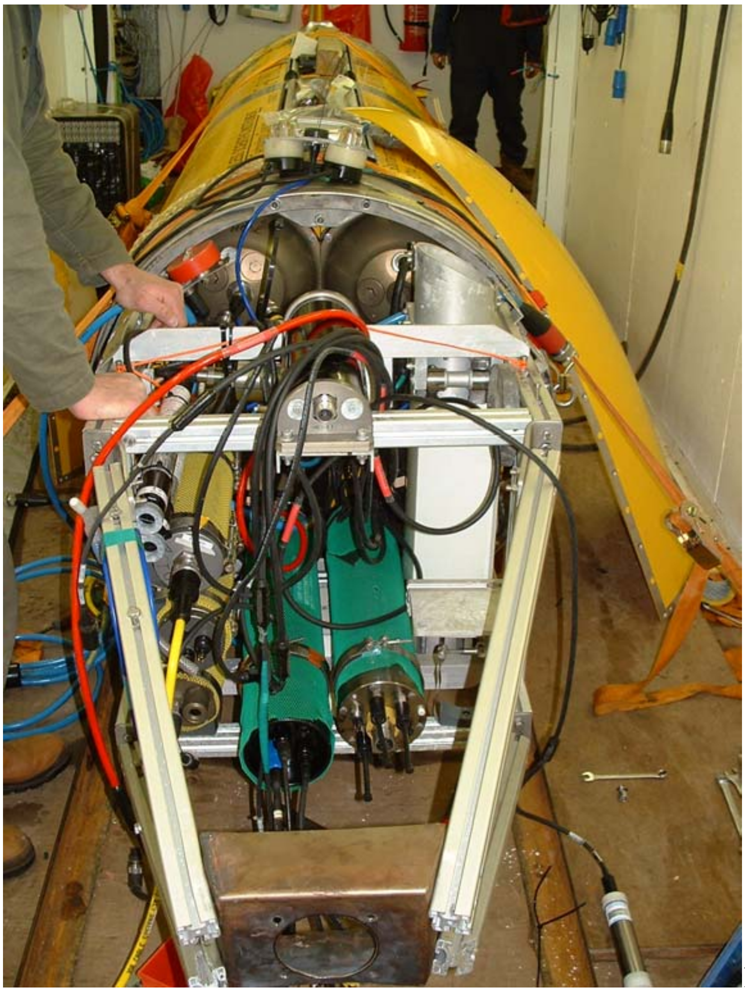
Launch for Mission 319 was carried out at 1615 18/03/03 in 25 knt SW wind in sea state 4/5. A dive weight was used to avoid possible collision with a scattering of ice. The sub surfaced at about 1732 by which time the wind had increased to 35 to 40 knts with sea arate 5/6. The jack in the box was fired and a close pass revealed that the recovery line was streamed nicely. An attempt to back the ship up to recover the line was aborted because of the strong wind and the ship made a Williamson turn to approach from down wind. The second pass was a little too distant to recover the stray line but the third pass was successful. The thin line could not be held initially and was made fast until the ship could drop back to relieve the tension. In the meantime a lump of ice, 2 thirds the length of Autosub drifted into and became entangled in the lines but luckily freed itself and the main recovery lines were attached in the normal way to the line leading aft. When passing close to the counter, Autosub appeared to accelerate towards the ship and disappeared briefly under the counter. Recovery was completed (during which the forward recovery line was partly cut when snagged by the damaged vehicle but luckily remained intact) The sub sustained serious damage.

Damage assessment:

1. Transmissometer lost, fell out as sub lifted out of water
2. Primary CT sensor swinging under sub during recovery, both C & T damaged but look repairable
3. SeaPam transducer hanging under sub during recovery, looks OK but need to check lead
4. Fluoremeter connecting tube broken
5. Edgetech transmitter transducer oil-filled boot ripped off, ingress of water may have seriously damaged ceramic element and tuning coil – rinsed with fresh water, oil impregnation possible saved ingress
6. Edgetech receiver array (port) torn from back plate but may be OK
7. Mesotech forward looking sonar hit by hard object but probably OK
8. Top panel – minor damage
9. Port panel badly damaged
10. Stbd panel – minor damage
11. Bottom panel badly damaged
12. Frame work – badly damaged in tapered section, lesser damage on parallel section apart from lower port junction with tapered section. This is possibly where propeller impact occurred (to be assessed)
13. Seabird connectorsn damaged by being forced backwards into domes
14. Oxygen and C2 cables damaged
15. SeaPam damaged internally (broken ferrites)


18/03/03 – 13:53


18/03/03 – 13:54


19/03/03 – 18:50

20/03/03 – 13:16

Summary of problems encountered during cruise (Nick Millard)

Date / mission info	Faults/symptons	Findings/actions
03/03/03, between Brabant and Anvers Islands in calm water for buoyancy test and emergency beacon test	No problems – all looked OK	
Mission 307 03/03/03 Gerlache Strait WP1= S:64:32.5, W:062:29.7 WP2= S:64:32.1, W:062:28.7 Drop weight dive Max depth 50m	1) TP II system not working	1) None at this time
Mission 308 03/03/03 Gerlache Strait Drop Weight Dive Position mode to wp1 at cruise depth of 50m	1. Cable tray hanging loose on recovery 2. TP II system not working	1. Adjusted support to prevent movement of tray 2. Removed TP II from fish 3. Wanted to use spare data telemetry transducer (new out of box) but found wrong gender connector fitted. Made up adaptor 4. TP II to transducer lead found to be pin to pin (spare lead provided by Octopus) rather than special 5. Found 4. had damaged pre-amp in transducer housing. Replaced 47 ohm resistor – luckily seemed to have been the only damage. 6. What was thought to be dodgy edge connector turned out to be something wrong with external trig (not needed so cured by disconnection) and signal processing board failing to boot properly on power up 7. Rigged battery back-up supply to allow transport to fish while powered up, there after leave connected with power on.
MISSION: 309, 04/03/03	1. Cable tray hanging loose on recovery	1. Replaced cable tray with plastic tube – much better 2. TP II working well

MISSION: 310 08/03/03 Basic Open Water Test 3	1. Could not talk to TP II for a while 2. EM beacon switched to 1 min transmissions 3. No digital acoustic comms 4. On recovery no nodes using 48V working	1. Replaced 48V master PS unit 2. TP II problem was broken lead in serial data connector at back of laptop
MISSION: 311 09/03/03 Basic Open Water Test 4	1. After PS replacement, launched for mission 311 but 48 volt current seen to be high – recovered sub 2. EM signal every 1 min 3. Acoustic telemetry indicated firing of jack/beacon/abort/dive weight 4. Very slow ascent	Before mission 311 1. Smelled chlorine around nose – traced to SB connector- what a mess! 2. Replaced SB Burton 8 way with Impulse IE 55 7 way bulkhead 3. Spliced IE 55 tail into adapter lead for SB After mission 311 1. Replaced IE 55 connector 2. Re-spliced adapter lead, shorting network leads to make SB a stub.
MISSION: 312 10/03/03 Basic Depth/Pressure Test Investigations continuing on into 11/03/03 Spiral down to 1320m	1. Reached 1300 m then 1 min EM signal 2. Acoustic telemetry indicated firing of jack/beacon/abort/dive weight 3. Very slow ascent after prop stopped (recovery line wrapped around it)	1. Looked at data - revealed network failure similar to before and at times complete failure 2. Removed Pressure 2 bottle (forward) and tested bulkhead connector for continuity and shorts to shell etc – nothing found 3. Checked internal connectors and connections in P2 – no problem found 4. Replaced IE 55 19 way bulkhead on P2 despite results from 2. 5. Leg 3 shorting connector replaced 6. Looked at cct diag for power node to check effect of plugging external power into network connector. + power went to -24V and – power went to +24V 7. Measured resistances into network , value into data logger node on the high side. 8. REMOVED NOSE AND TAIL 9. Removed dome 1 front (Edgetech) to measure resistance into network. Problem apparently at back. 10. Removed dome 1 rear (data logger) where resistance is between 3.6 and 2.3 ohms 11. HE 14 connectors suspect, change them in P2, data logger 12. Replaced CAT 5 cable to transceiver in data logger and lonworks module. 13. Removed 7.5kg ballast

MISSION: 313 13/03/03 Spiral down to 1320m	1. EM 2000 playing up 2. Network problems noted at about 1000 m	1. Phoned Simrad – provided fix? 2. Removed front 2 harnesses 3. Ran extension from rear harness to SeaPam in front (removed 2kg ballast weight) 4. Modified range and Seapam interface pots (joined network before internal connector and chopped pins off which were close to chassis. 5. Tightened loose bulkhead connector on AquaLAB 6. Moved P2 to rear 7. Moved P1 to nose but not used 8. Launched and left to wallow for 70 mins – data looked good.
Mission 314 14/03/03 – Run south for 15 mins at 100m, turn back to WP heading down to 1320m	Data after wallow test had some drop outs but acceptable Mission excecuted with no apparent problems	1. Closer scrutiny of data revealed that it was better but not good (dropouts at 700m descending and 200m ascending) 2. Analysis of data continuing 3. Remove extension 4. Re-instate front harness (connected through link from rear) 5. P1 moved to rear (to join P2) 6. Seabird in loop 7. AquaLab in loop 8. Range finder back in loop 9. Damaged SeaPam serial interface pot by plugging battery power into network (hopefully repaired) 10. Check individual skts on network connectors – all seem OK in rear 11. Plotting drop out counts against time and pressure indicated pressure related problem – suspect bulkhead connectors. 12. REMOVED TAIL to change network bulkhead connectors on GPS (had to REMOVE NOSE to free up trapped wire holding GPS unit in), power, MC/data logger.

Mission 315 15/03/03 Same as 314	1. Turned at southerly point but never made it back to WP 2. Surfaced 800m short of WP (was seen to be down at 250m) 3. No digital acoustics 4. No Radio link	Event 9 mission 314 involved splicing power lead to replace damaged connector – this failed
Mission 316 16/03/03 Same again	1. Checked abort status 3,3,0,0 – unusual set, found to be finger trouble 2. Rest of mission seemed to go ok except telemetered depth at 49 meters when on surface (should have know what that meant)	1. Data had major drop outs descending (600m) and ascending (200 – 0m) 2. Sub came aboard not working – first time ever! 3. Network connector on MC/data logger could be manipulated to stop / start vehicle 4. Added extension lead to try to ascertain whether bulkhead or harness – fault mostly went away 5. Cut into leg to short network leads and then blank leg 6. Cleaned all network connectors 7. Left running on shore power over night – lost power and would not power up in the morning – suspect switch transistor. 8. NOSE OFF 9. Removed power node, found dry joint on surge protector, fairly convincing fault.
Mission 317 17/03/03 Down to 1320 metres	1. Completed mission successfully	1. A few dropouts at 200m ish when ascending (none descending)
Mission 318 17/03/03 Run at 100 metres for swath	1. Completed mission successfully	1. No dropouts

Mission 319 18/03/03 Tests to 150m x 2 and 250m x 2	1. Completed mission successfully 2. No Seapam transmissions 3. Damaged under counter on recovery 4. Launch was carried out at 1615 in 25 knt SW wind in sea state 4/5. A dive weight was used to quickly take the vehicle below the surface to avoid possible collision with a sprinkling of various size bits of ice. The sub surfaced at about 1732 by which time the wind had increased to 35 to 40 knts in a sea state which had increased to 5/6. The jack in the box was fired and a close pass revealed that the recovery line was streamed nicely. An attempt to back the ship up to recover the line was aborted because of the strong wind and the ship made a Williamson turn to approach from down wind. The second pass was a little too distant for the grapneling party to reach but the third pass was successful. The thin line could not be held initially and was made fast until the ship could drop back to relieve the tension. In the meantime a lump of ice, 2 thirds the length of Autosub drifted into and became entangled in the lines but luckily freed itself and the main recovery lines were attached in the normal way to the line leading aft. When passing close to the counter, Autosub appeared to accelerate towards the ship and disappeared briefly under the counter and it became apparent that Autosub had sustained some damage. Recovery was completed (during which the forward recovery line was badly damaged when snagged by the damaged shell but remained intact) The sub sustained serious damage.	No dropouts Seapam yet to be investigated Damage assessment: 16. Transmissometer lost, fell out as sub lifted out of water 17. Primary CT sensor swinging under sub during recovery, both C & T damaged but look repairable 18. SeaPam transducer hanging under sub during recovery, looks OK but need to check lead 19. Fluoremeter connecting tube broken 20. Edgetech transmitter transducer oil-filled boot ripped off, ingress of water may have seriously damaged ceramic element and tuning coil – rinsed with fresh water, oil impregnation possible saved ingress 21. Edgetech receiver array (port) torn from back plate but may be OK 22. Mesotech forward looking sonar hit by hard object but probably OK 23. Top panel – minor damage 24. Port panel badly damaged 25. Stbd panel – minor damage 26. Bottom panel badly damaged 27. Frame work – badly damaged in tapered section, lesser damage on parallel section apart from lower port junction with tapered section. This is possibly where propeller impact occurred (to be assessed) 28. Seabird connectorsn damaged by being forced backwards into domes 29. Oxygen and C2 cables damaged 30. SeaPam damaged internally (broken ferrites)

Mission 320 20/03/03 Spiral down to 300 m	1. Found reasonable clearing in light ice 2. Mission completed successfully 3. Surfaced 200 m clear of ice edge 4. Ice surrounded sub whilst planning short under ice mission	1. Recovered with difficulty 2. Sub rapidly became depressed by ice and difficult to see 3. Argos continued to come in 4. Broke GPS antenna (sacrificial) 5. Bent port stern plane down – easily repaired.
Mission 321 Dive weight launch in ice Lawn mower survey then out at 250m.	1. Launched but came back to surface 2. Mission successful second attempt	1. Stopped mission 2. Timer set too short 3. Recover, repack lines 4. Adjust timer 5. No problems 6. Good data
Mission 322 Repeat of above but a bit further into ice (15 NM)	1. Launched but came back to surface 2. Went to wrong position top circle and seemed to continue drifting south and a bit east 3. Timed out and headed out of ice 4. SeaPam not talking well – no transponder and poor digital	1. Timer too short (15 secs instead of 15 mins) 2. Allowed to time out so started leg out of ice (considered a lot safer than surface) 3. Continuing with survey mission risky if southerly drift continued – may not go far enough to get out of ice (navigating using up ADCP relative to the ice, moving at 0.5 knts south!) 4. Strong current? 5. Repositioned SeaPam transducer
Mission 323 Launch outside ice and run in for survey	1. Apparently completed mission successfully	1. Sub took avoiding action on several occasions (down ADCP targets) 2. Swath data not looking so good ((wrong reset?)
Mission 324 24-25/0303 Launch outside ice, spiral to holding depth 100m, run for 0.5 hr at 10 m, into ice for 3 miles, grid survey, out to recovery point.	1. Waited at ice edge to intercept, could hear it on EM beacon but not on TPII Looked like it passed 4.5 km abeam (later found to be East). 2. Chased up to recovery 1 WP, no sign on TPII but established circling and appeared to be East. 3. Timed out and sub headed for recovery 2 4. Ship set of N to try to catch up sub 5. EM beacon showed aborted (mission time out) range 4 km. 6. Gonio signal, located sub 8 km east of track	1. Swath data no good 2. On 27th found transmitter lead on EM200 transmitter leaked 3. Strong current responsible for track error (0.3 knts mostly east)

Autosub Data Analysis

David Vaughan, Dan Hayes, Chris Banks, Ziggy Pozzi-Walker, Toby Benham, James Perrett
(British Antarcitc Survey, Open University, Scott Polar Research Institute, Southampton Oceanography Centre)

Edgetech FS-AU sub-bottom profiler (David Vaughan)

(With assitance from Toby Benham, James Perrett and Chris Banks)

The Edgetech sub-bottom profiler was configured to run from Autosub in a downward looking orientation. Prior to the Autosub under ice cruise, it produced data during the trials in August 2002, which confirmed it's correct installation. It is a valuable tool that should allow discrimination of seabed types and image sub-bottom structure in sedimentary sequences.

During the Autosub under ice cruise, it ran from M308 to M319. On the last mission Autosub collided with the ship and left the FS-AU transducers unserviceable. Since only a few short parts of these missions were conducted in bottom-tracking mode, useful data were acquired over only a short track. These data do, however, indicate that the system is satisfactorily installed and will provide a valuable method of observing the seabed

There follows a processing log for the data collected during M309. This processing scheme is not intended to indicate how one dataset was processed to yield profiles corrected for clock drift and vehicle depth.

Outstanding issues

1. The navigation data is not currently passed to FS-AU and so the output files do not contain position information. The facility exists but it is arguable whether supplying the raw position data to the FS-AU would be of much benefit. The final processing needs to take account of the "best" navigation data and since best navigation data is only available after the mission is completed, a level of post-processing will always be required.

2. There is a question over what is the best way to process the data from the FS-AU. The TOPAS software used to process the shipborne sub-bottom profiler data may be useful but at present there is no clear method for reformatting the .jsf data into TOPAS format. Edgetech do have software to do this, but this costs an additional ~$7k, and we are disinclined to recommend spending extra money on a facility that arguably should have been made available as part of the package. This may be a route for the future, but the route described below is based on using bespoke routines in Matlab, which do not provide a turn-key solution and require operator intervention.

Processing of M309 Profiler data

Jstar – quality assurance.

The Edgetech data are downloaded from Autosub in Edgetech's proprietary format (.jsf). Each file contains around ten minutes of data and this is a satisfactory arrangement for the present, although for longer missions fewer files might be easier to deal with quickly.

This format of the files is said to be a "variant on Seg-y", but it does not appear to be readable by any of the standard packages that read Seg-y format. Thus any similarities to Seg-y are not directly helpful and other arrangements to read the data are required. Furthermore those data formats are not sufficiently well described in the manual and we have spent considerable time and effort in reading the data both in Matlab and "C".

The basic software package supplied with the Edgetech is sufficient, however, to do basic quality assurance and control of the data, even though the Jstar manual is inadequate in explaining even the basic features of the software. For example, it should be noted that there is the facility to "capture" the .jsf data to jpeg images, allowing printout which is not described in the manual (see example below).

It is likely that at the end of each mission, Jstar should be used for to evaluate each file from a particular mission. At this stage one should assess bottom echo and the likely value of the data. Below is an example of my file-log for mission M309.

DATA0001173.jsf - Possible weak returns at 48, 95, 145 metres = multiples check sub-depth
DATA0001174.jsf - Possible weak returns at 48, 95, 145 metres = multiples check sub-depth
DATA0001175.jsf - No visible echo
DATA0001176.jsf - No visible echo
DATA0001177.jsf - Solid and repeating bottom return
DATA0001178.jsf - Solid and repeating bottom return
DATA0001179.jsf - Short file but solid bottom return
DATA0001180.jsf - Non-repeating bottom return
DATA0001181.jsf - More non-repeating bottom return
DATA0001182.jsf - No visible bottom echo, but funny straight echo in second part of file
DATA0001183.jsf - No visible bottom echo, but funny straight echo continues
DATA0001184.jsf - Couple of strange and steep returns noted, one at 80-120 m and other at 20-30 m . Hyperbolic = Possible whale (there are known to be whales in the area), check depth.
DATA0001185.jsf - No visible echo

From this brief assessment, I concluded that the data from files, DATA0001177-81, were appropriate for detailed analysis. Using the capture facility I concatenated and printed these files. (It later became clear that this sequence contained a gap in the data, but I wasn't aware of this from Jstar). Figure 24 shows the results.

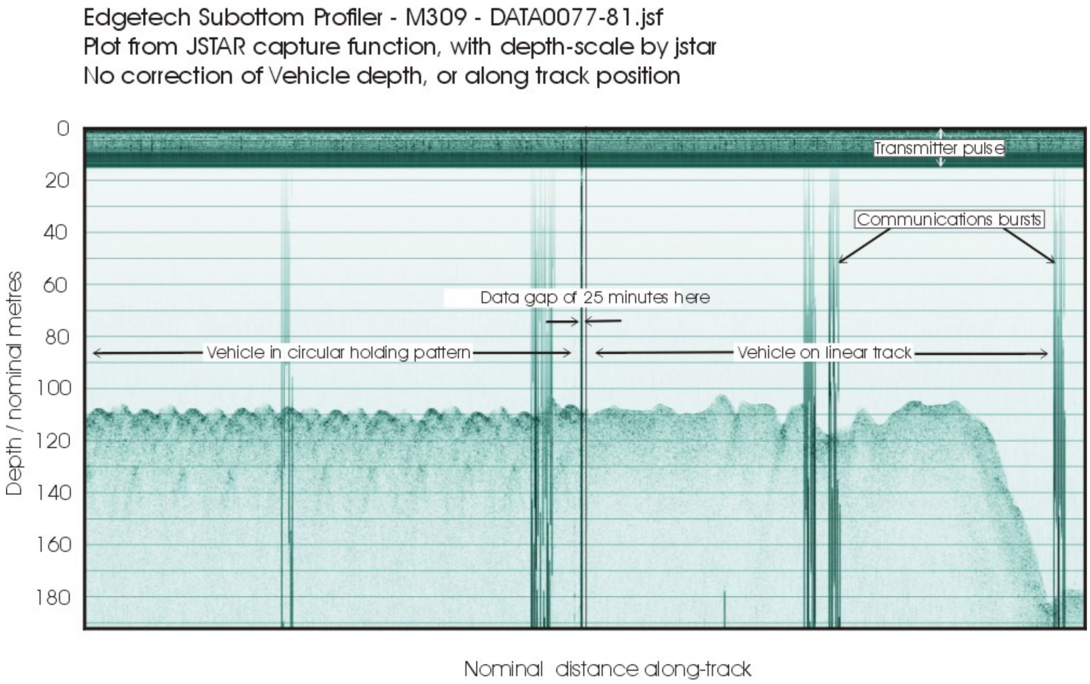


Figure 24: Jstar captured data from M309, and then tarted up in Coreldraw, showing the main features of the record.

Matlab processing

Since Jstar is not designed for processing data from an underwater vehicle it seems unlikely that it will prove to be sufficient to process the Edgetech data. I have written Matlab scripts that allow further processing, but these are not intended as a turnkey system and should be understood and modified as required before they're implemented.

They are:

Segyreader.m – sequentially opens a series of files and calls getsegy to read them
Getsegy.m – reads the .jsf format files and calls Unpackhdr if required.
Unpackhdr.m - reads the header fields if required
Depthinterp.m – reads .bnv file and interpolates the vehicle depth for each Edgetech trace and adds this to the start of each trace.
Imagedisp.m – displays concentenated files, with or without depth

Checking for data gaps

The first step is to run Segyreader to read files and print out the internal time for the first and last message in each file. This allows a determination of whether there are gaps between the files.

Sample output…

```
*********************************************
Opened file data0001177.jsf
Start 2003 3 3 16 40 47
End   2003 3 3 16 50 4.900001e+001
recordnum = 302        (1.84 secs per sample)
          ..........................No data lost here
Opened file data0001178.jsf
```

```
Start 2003 3 3 16 50 5.100001e+001
End   2003 3 3 17 0  51
recordnum = 301       (2.146 secs per sample)
            ..........................No data lost here
Opened file data0001179.jsf
Start 2003 3 3 17 0 53
End   2003 3 3 17 1 1.000008e+000
recordnum = 5         (1.6 secs per sample)
            ..........................29 min 4 sec data lost here
Opened file data0001180.jsf
Start 2003 3 3 17 30 5
End   2003 3 3 17 40 8
recordnum = 302       (1.99 secs per sample)
            ..........................No data lost here
Opened file data0001181.jsf
Start 2003 3 3 17 40 9
End   2003 3 3 17 50 3
recordnum =   298     (1.99 secs per sample)

            ***** Sgyreader ended *****
```

Note the times given here are referenced to the Edgetech clock Fsau-f014038. This is not the same clock as is used for navigation system or swath system and needs to be corrected (see below).

This analysis shows that there are two separate continuous segments, data0001177-79.jsf and data0001180-81.jsf , with a data gap between. These segments will be handled separately below. Some gaps occur because the Edgetech FS-AU has to be disabled whenever acoustic telemetry between the ship and Autosub is to be activiated. In this case (M309) the FS-AU was almost certainly switched off before the in order to tell the Autosub to leave its holding pattern.

Also there appears to be a date error on the .jsf files. The corresponding .bnv file correctly gives dates as 04/03/03, ie a day later.

Find corrections for the clocks

File timecomp.log gives corrections to clocks. The Edgetech uses its internal clock (Fsau-f014038), which is referenced to on board pc clock, Autosub9. Best navigation data from .bnv is referenced to Asublog1, which is referenced to Autosub9 and local (Asubtosh1). I used the following line of reasoning, based on the timecomp.log file to establish the time correction near the start and end of the mission.

```
At start of mission time for Fsau… is...
  Time at server \\Fsau-f014038 is: 13:34:53.55
  Local time is: 13:34:45.351
          Difference is 8.199000 seconds (i.e. difference onAsubtosh1)

At the same time...
  Time at server \\ is: 13:34:58.13
  Local time is: 13:34:48.856
  Difference is 9.274000 seconds

And...
  Time at server Asublog1 was 04/03/2003, 02:11:31
  when time at host was 04/03/2003, 02:11:32
  Local time is: 13:34:52.671
  Difference is -1.000000 seconds
  Difference = -1 s
```

so... Fsau is 8.199 s faster than local,
Autosub9 is 9.274 s faster that local,
and Asublog1 is 1 s slower than Autosub9.

Therefore Asublog1 is ((9.274-1) faster than local
FSau is 8.199 - (9.274-1) faster than Autosub9 (ie Nav)
= -0.075 sec
And at the end of the mission

Time at server \\Fsau-f014038 is: 20:54:49.56
Local time is: 20:54:40.976
Difference is 8.584000 seconds

Time at server \\Autosub9 is: 20:54:53.62
Local time is: 20:54:43.589 Difference is 10.031000 seconds
Time at server Asublog1 was 04/03/2003, 20:54:57
when time at host Autosub9 was 04/03/2003, 20:54:53
Local time is: 20:54:43.619 Difference is 4.000000 seconds

so... Fsau is 8.584 s faster than local,
Autosub9 is 10.031 s faster that local,
and Asublog1 is 4 s slower than Autosub9.

Therefore Asublog1 is ((10.031+4) faster than local
FSau is 8.584 - (10.031+4) faster than Autosub9 (ie Nav)
= 5.44 sec

Find time corrections for each file

I used excel to calculate a single time corrections for each .jsf file, by interpolating between the mission start and end corrections. I did this in Excel…

			Correction
Mission start	13:34:58	-0.075	
Mission end	20:54:50	-5.44	
Opened file data0001177.jsf	16:40:47	0	-2.34138
	16:50:05	0	-2.45481
Opened file data0001178.jsf	16:50:05	1	-2.45481
	17:00:51	1	-2.58613
Opened file data0001179.jsf	17:00:53	2	-2.58654
	17:01:01	2	-2.58817
Opened file data0001180.jsf	17:30:05	3	-2.94269
	17:40:08	3	-3.06527
Opened file data0001181.jsf	17:40:09	4	-3.06547
	17:50:03	4	-3.18622

Rounding to one-half second precision implies that a single correction of –2.5 should be used for the first segment and –3 sec for the second set. Although depth data is available only at one-second intervals, the interpolation of the depth as recorded in the .bnv file allows a correction that is less than one second.

Apply Autosub time/depth corrections

Now I used Matlab routine depthinterp.m to apply clock correction and interpolate depth. Re-reading data using segyreader.m but using the new time corrections gave…

```
Output from SGYreader
**********************************************
Opened file data0001177.jsf
data0001177.jsf, 2003 3 4 16 40 4.450001e+001
 Incorrect read of header
data0001177.jsf, 2003 3 4 16 50 4.650001e+001
recordnum =
   302
 Closed file
Opened file data0001178.jsf
data0001178.jsf, 2003 3 4 16 50 4.850001e+001
 Incorrect number for bytesToFollow 706394123
data0001178.jsf, 2003 3 4 17 0 4.850000e+001
recordnum =
   301
 Closed file
Opened file data0001179.jsf
data0001179.jsf, 2003 3 4 17 0 5.050000e+001
 Incorrect read of header
data0001179.jsf, 2003 3 4 17 0 5.850001e+001
recordnum =
     5
 Closed file
              ***** Sgyreader ended *****
```

Note that times are now –2.5 seconds less than on the previous read. Now I added the depth correction using Depthinterp and M309.bnv

Noting that for these files the sample interval is 64 msec (this can be read from the header). Which implies

=> 64e-6*1500/2 = 0.0480 metres per sample.

=> 1 metre = 20.8 samples

So for every metre of vehicle depth below datum (set in depthinterp.m as the minimum vehicle depth in the segment) we need to add 20.8 samples at the beginning of the trace.

Note that min depth in the segment must be added to get the absolute depth.

Display

I used imagedisp.m to display the depth corrected data. Note that the sampling frequency is much higher than the lowest frequency in the transmitted pulse. Thus we are sampling well above the nyquist and so to display must filter the data to produce something close to a power envelope (otherwise the data looks hopelessly noisy). I used a fifteen sample -long centre-weighted filter to give plot below of the first and second segments.

First Segment

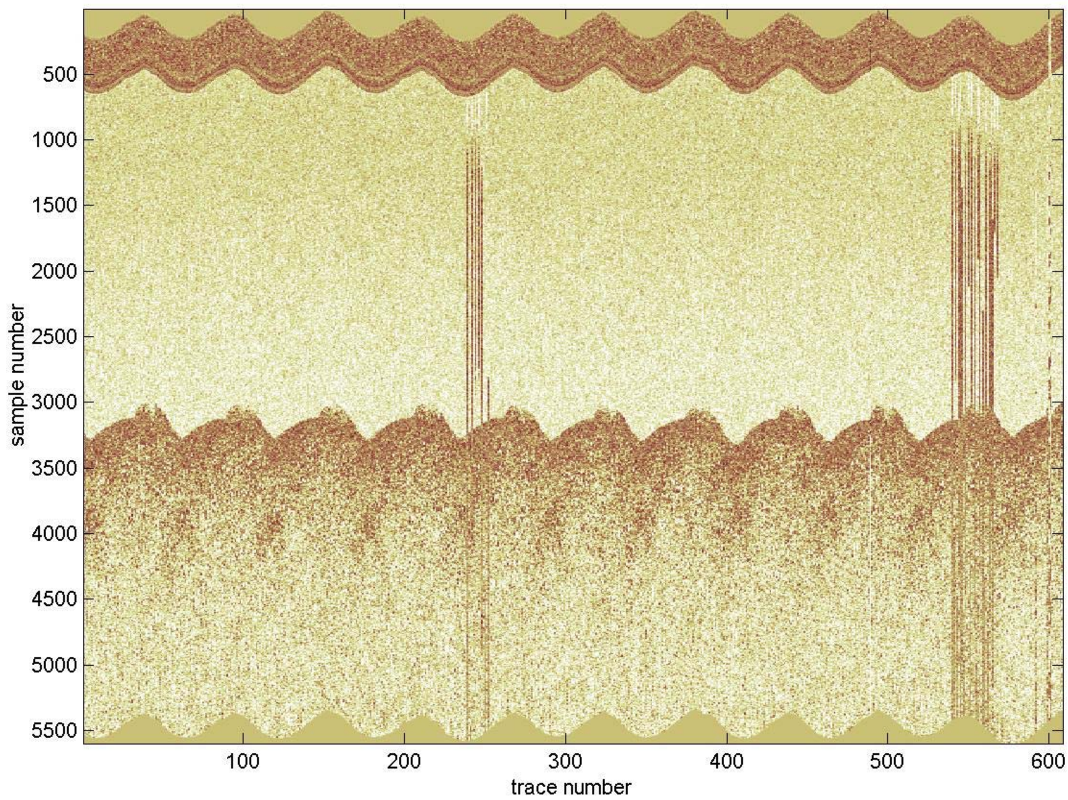


Figure 15: First segment from M309 corrected for sub depth. The upper lines is the transmitter pulse reflecting the changing vehicle depth and the bottom line is the seabed reflection.

In this plot the depth of the primary reflection is…

(3000 + 6801) samples = 9801

= 9801 * 0.048 = 470 metres.

And the amplitude of the undulations in the plot are…

300*0.048 = 14.4 metres

This segment is from the Autosub in a bottom-tracking holding pattern of 50 metre circles shown below.

Note the perfomance of Autosub in tracking the bottom. It is generally a little delayed and doesn't quite get into the troughs, but this is not entirely fair as a test because it's turning in circles at the same time. This is as expected from the configuration of the system and control software.

There are 10.5 pattern repetitions in the profiler data and 10.5 circles in the track data. This is good!

M309

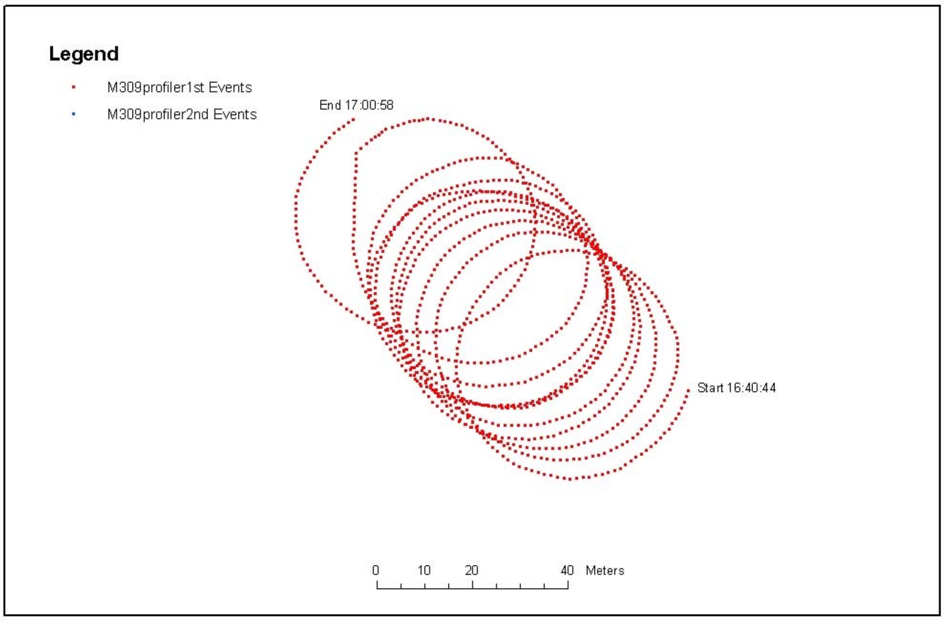


Figure 26: Track-plot of first segment for mission M309

Second segment...
Similarly for segment-2. Now use Matlab to apply clock correction and interpolate depth.

Note change in time correction to –3 sec.

```
Output from SGYreader
*********************************************
Opened file data0001180.jsf
data0001180.jsf, 2003 3 4 17 30 1.999992e+000
 Incorrect read of header
data0001180.jsf, 2003 3 4 17 40 4.999992e+000
recordnum =
   302
 Closed file
Opened file data0001181.jsf
data0001181.jsf, 2003 3 4 17 40 6
 Incorrect number for bytesToFollow 1256661583
data0001181.jsf, 2003 3 4 17 49 5.999999e+001
recordnum =
   298
 Closed file
***** Sgyreader ended *****
```

Note that times are now –2.5 seconds on previous read and add depth correction – using Depthinterp.m and M309.bnv

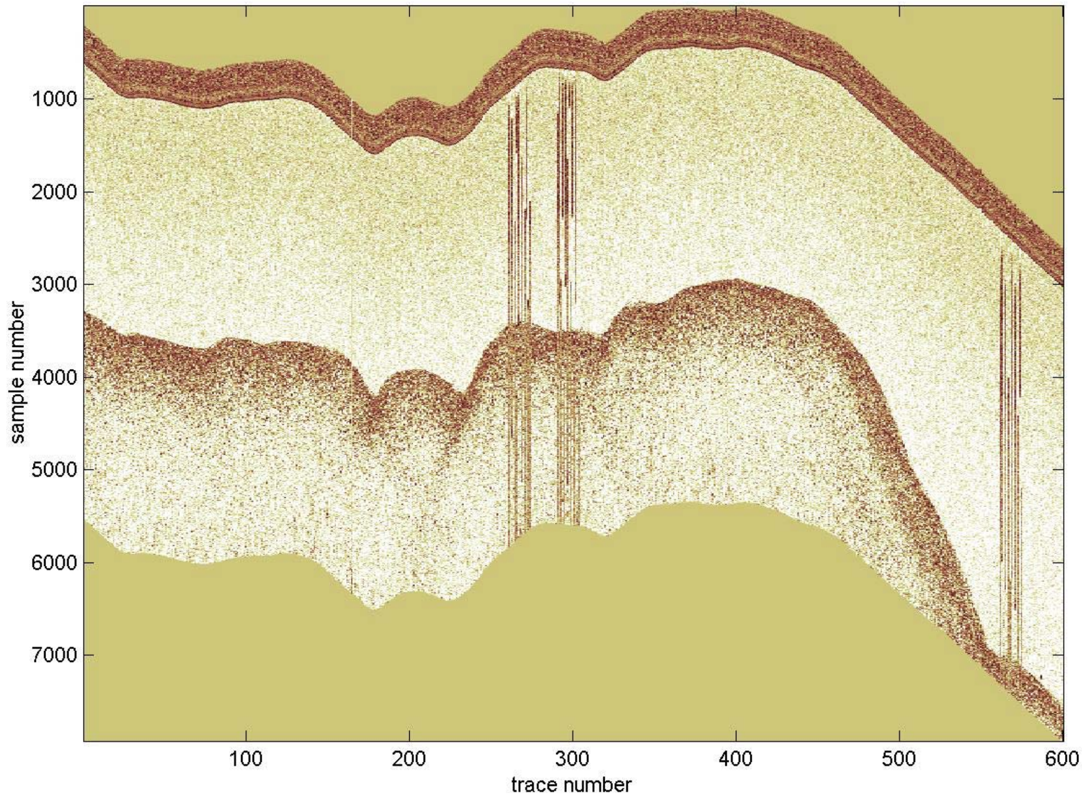


Figure 27: Segment -2 of profiler data from M309.

Here the depth of the start of the primary reflection is…

3400 samples + 432.07 metres = 595.5 m

and 1000 samples on the plot is 48.07 metres, so track at 150 metres above seabed.

We note that Autosub has tracked the bottom with some precision – we could do some calculation on this.

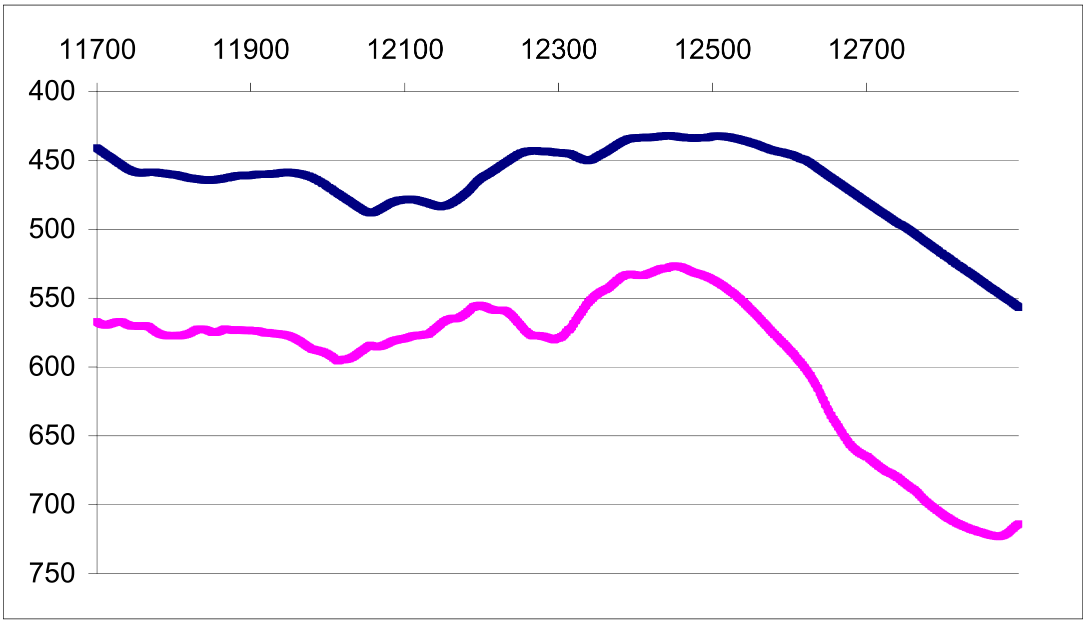


Figure 28: Comparable segment showing Autosub track (top) and bathymetry from shipborne EM120 system. Here y-axis is depth in metres, x-axis is tracenumber.

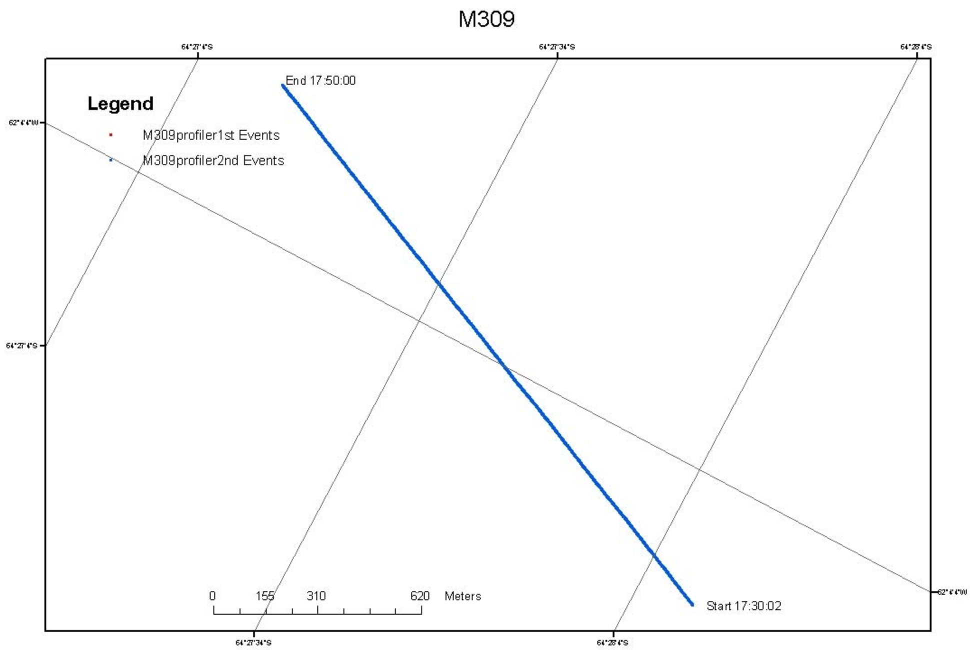


Figure 29: Trackplot for the second segment of M309.

Assessment of Simrad EM2000 multi-beam sonar (David Vaughan)

(With assitance from Toby Benham, James Perrett and Chris Banks)

The Simrad EM2000 system is installed on Autosub with an option of either up- or downward configuration. It was trialed in August, 2002, but was at that time not producing satisfactory results although the Autosub team, not being familiar with this swath bathymetry data, did not identify some of the problems. This lack of expertise on the trials was unfortunate but could not avoided after Lieve Vanneste resigned from her position on the Vaughan project, just prior to the sea trials.

During the early trials in Gerlache Strait (M307-), the installation of the EM2000 system, was steadily improved. And valuable science data was acquired beneath sea ice. This system is, however, not yet a turn-key system and will require some dedicated sea-trial time to reach a fully-operational state.

Outstanding issues

DSO correction

It appears that in the present configuration the EM2000 will reject any echo that is apparently above the nominal sea surface, calculated onboard using the vehicle depth, and the sound velocity that is given to the vehicle at setup. It needs to be confirmed with Simrad that this is indeed the case, but our current best assessment is that this is the case. This is, however, unsatisfactory in that while in upward-looking mode it is entirely possible for a valid return to appear to be above the sea surface. For example, this could occur either because the input sound velocity is too great, or because waves temporarily mean that the sea surface really is above the mean sea level. This appeared to be a significant problem for some of the upward-looking missions and remedial action was considered necessary. Our remedy was to alter the setup to introduce a Depth Offset Correction (DSO) of –5 m (and later –15 m). This should mean that the EM2000 calculates the vehicle as being 5 m below its actual depth and give us 5 m of extra window – the extra 5 m needs to be removed in post-processing and this is true of the data from mission M321.

Since the introduction of the DSO appeared to work in mission M321 but not on later missions means that we're at a loss to know if this was the entire problem. Furthermore the is ambiguity in the documentation regarding the sign of the DSO correction. Further tests in upward-looking configuration need to be completed before this issue is entirely resolved.

Navigation data

Only the "raw" navigation data is passed to the EM2000, and stored alongside the raw range data in the raw-files. This means that the best navigation data must be merged with the raw ranges at a later time. It is unclear if this can be achieved in the Simrad, Neptune software, or if a third party package will have to be used.

Poor quality of manuals/integral help
The manuals that describe the Neptune software and the installation of the EM2000 are very poor. The written English is difficult to understand and is often completely ambiguous. Description of the file formats is not good and procedures (e.g. for incorporating best-navigation data) are not described. Indeed, the documentation is actually so poor, that I believe that there is a strong argument that Kongsberg should be requested to update them.

For example, after queries to Simrad head office, we were supplied with two work-arounds to overcome particular problems we experiecing. Firstly, to prevent overwriting of raw-files during import/replay we were advised to use command files run from the MS-DOS command line as a batch file (.bat). For example:

```
cat 0012_20030304_153455_raw.all | handleEmX M309 dgv -l 0012_20030304_153455
cat 0012_20030304_160531_raw.all | handleEmX M309 dgv -l 0012_20030304_160531
cat 0012_20030304_163608_raw.all | handleEmX M309 dgv -l 0012_20030304_163608
cat 0012_20030304_170645_raw.all | handleEmX M309 dgv -l 0012_20030304_170645
cat 0012_20030304_173722_raw.all | handleEmX M309 dgv -l 0012_20030304_173722
cat 0012_20030304_180758_raw.all | handleEmX M309 dgv -l 0012_20030304_180758
cat 0012_20030304_183835_raw.all | handleEmX M309 dgv -l 0012_20030304_183835
```

Similarly, in order to produce valid coastline files we were advised to use the following…

```
Mcoast <input-text-file> -f <output-text-file> -r 0
```

Neither of these variations on the standard commands is properly described, and I would have not discovered them if they had not been pointed out.

Finally, I note that processing the EM2000 data from Autosub may never be entirely possible using the GUI/menu-driven Neptune system alone. I recommend that anyone attempting processing make themselves aware of the commands that can only be issued from the command line. Since, there are three distinct sources of information, the printed manual, the assorted .html help files, and the command line instructions accessed via the "–h" option. It is not clear to me how one goes about becoming familiar with these commands without a great deal of personal investigation. *I recommend that Simrad be informed of our dissatisfaction with their manuals, and be requested to rationalise these sources of information*.

Exporting grids
Kongsberg helpdesk have admitted that no facility is available to export gridded data, except as a list of xyz-points. This is not satisfactorily, in that it means that data would need to be exported from Neptune and then re-gridded in whichever package, one was hoping to use it. This is very poor practice and should be avoided if at all possible. We should request that Simrad supply a routine for outputting the grids in any of the standard formats for gridded geographic data, of which there are too many to mention. Otherwise, we need to write some basic code to reformat the xyz-files into a format that can be read directly into other packages for example GeoTiff.

Data cut-off
It appears that beam depths which are above sea level are automatically deleted in the acquisition by the EM2000. This might make sense in a system designed to measure seabed bathymetry, however, a system that is sold to be able to be configured in an upward-looking configuration and that should therefore be capable of imaging the sea surface, which can be several metres above notional sea level (due to waves, velocity anomalies, errors in depth calculations) this is nonsensical. *I suggest that Simrad be asked to explain this issue.*

Black-box syndrome
At present we suffer from a certain degree of black-box syndrome both from the point-of-view of implementation of the system in Autosub and from the point-of-view of using the data. We find that we do not have sufficient understanding of how the system works, in terms of finding, locking onto and tracking the bottom return, identifying return echoes using the so-called "amplitude" and "phase" detection schemes, or why data are eliminated at the time of acquisition. Although, it might be claimed that such issues are commercial-in-confidence, until some of these issues are resolved it is not clear that Simrad can demonstrate that the system is fit for purpose, i.e. operable in an autonomous environment. I note that when using the shipborne EM120 system operator intervention is sometimes required to force the system to lock on to the true bed echo.

Personally, if I am involved with using data from the EM2000 in future I will endeavour to import the raw data into an alternative and more explicit software package, such as MB-system, which is free, is installed on the JCR unix system and for which the code is available. James Perret believes that decoding the raw-files would be a simple task and may proceed with that.

Mission data assessments

After the initial unsuccessful testing in Gerlache Strait with the EM2000 in downward-looking mode, the system was turned into the upward-looking configuration for all of the remaining missions. It was deployed in both open-water for purposes of calibration and beneath sea ice to collect data on sea ice draft in support of the Brandon project. Successful data was collected from both these targets, during missions, M318 and M321 respectively. These data are reproduced below.

These datasets will be the subject of further analyses by Chris Banks (OU) as part of the Brandon proposal.

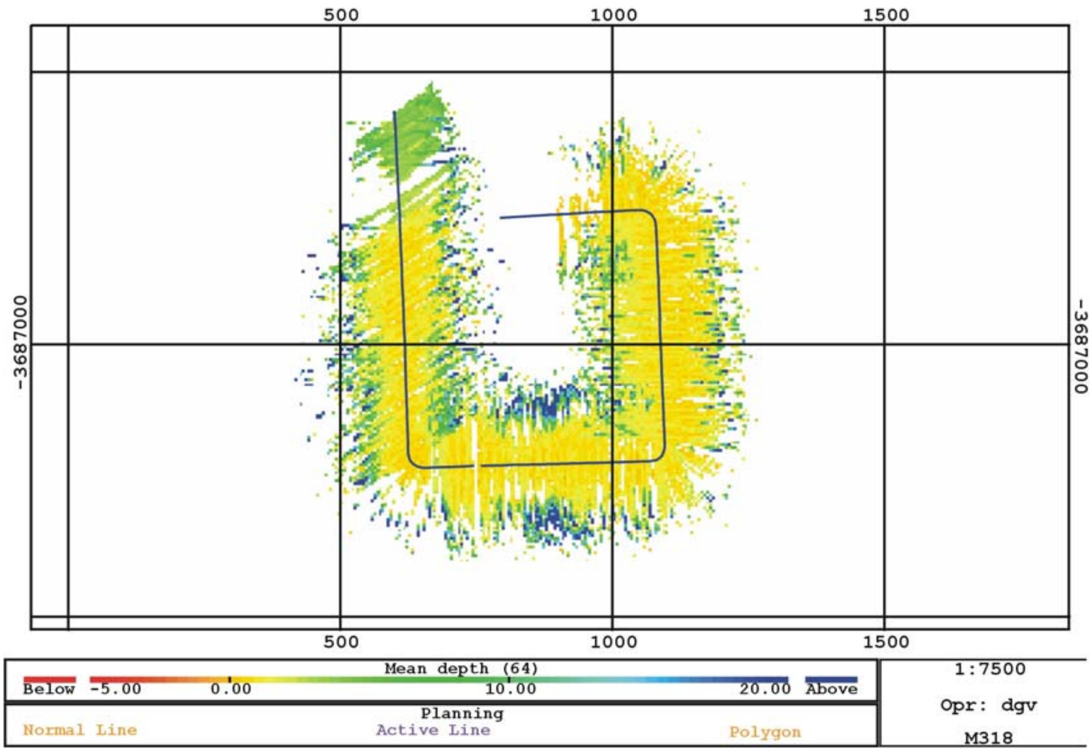


Figure 30: Autosub EM2000 data from Mission M318, showing strong sea surface return.

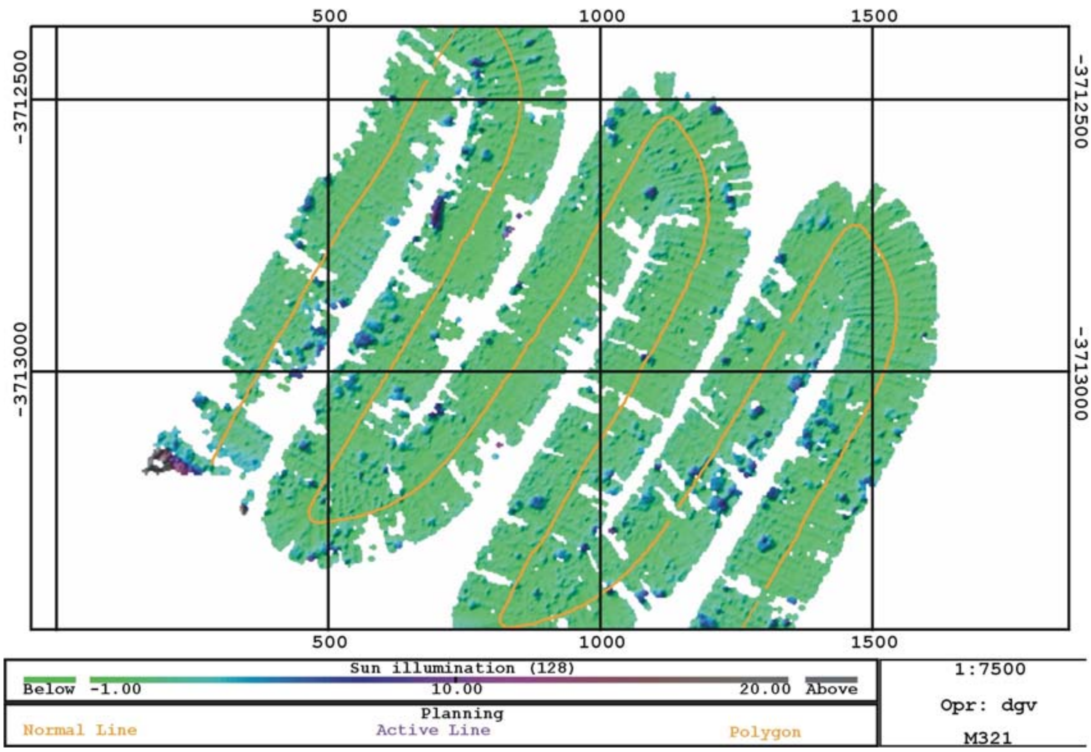


Figure 31: Autosub EM2000 swath bathymetry data from the underside of sea ice collected during M321.

Appendix: Autosub missions Log

M307 - 03/03/03 - Gerlache Strait test. Swath down. Imprecise lat/long position produces stepped navigation. All data is smiles.

M308 – 03/03/03- Gerlache Strait test. Swath down. Imprecise lat/long position produces stepped navigation. All data is smiles.

M309 – 04/03/03- Gerlache Strait test. Swath down. Imprecise lat/long position produces stepped navigation. All data is smiles.

M310 – 08/03/03- Off Thurston Island. Swath up. Mostly a dive test, spiral dive no profiler, but swath data looks like garbage.

M311 – 09/03/03- Off Thurston Island. Swath up. Swath data is available (only in central beams) but system still appears to think that it is looking down and has added the ROV depth instead of substracting it. Some of these data could be useable if corrected for upward looking and cleaned, but it is only looking at the sea surface.

M312 –10/03/03- Off Thurston Island. Swath up. Swath data is available but navigation appears to have gone potty. Lots of broken line segments. Still appears to be thinking that it's looking down.

M313 – 13/03/03- Continental shelf off PIB. No swath or profiler

M314 – 14/03/03- Continental shelf off PIB. Swath up data available. It's now looking up and understand that it is looking up. For section at a reasonable depth most of the data is deleted, because it is above the sea surface (<0). Where the sub dives the range becomes constant and is not tracking the sea surface.

M315 – 16/03/03- Continental shelf off PIB. Swath up data available. It's now looking up and understand that it is looking up. For the section at a reasonable depth most of the data is deleted, because it is above the sea surface (<0). Where the sub dives the range becomes constant and is not tracking the sea surface. Also the beams are appearing very non-perpendicular to the track?

M316 – 16/03/03- Continental shelf off PIB. Swath up data available. It's now looking up and understand that it is looking up. For section at a reasonable depth most of the data is deleted, because it is above the sea surface (<0). Where the sub dives the range becomes constant and is not tracking the sea surface. Also the beams are appearing very non-perpendicular to the track?

M317 – 17/03/03- Continental shelf off PIB. Short section of swath up available. Looks good but data is being deleted where it is above the sea surface (<0

M318 – 18/03/03- Continental shelf off PIB. Square box of good data. Looking up and with a depth sensor offset of –5 m to make sure the sea surface is accepted. Still with misalignment of beams to track on one leg.

M319 – 18/03/03- Continental shelf off PIB. No swath. Clobbered by ship. Profiler dead. No useable swath data because navigation is strange.

M320 – 20/03/03- Continental shelf off PIB. No swath. Swam into ice. Little bugger. Not swath data, because the data do not have time messages. Apparently this is due to a new version of the control software being installed. The old version will be restored.

M321 – 23/03/03- Sea ice zone off Thurston Island. Good data recorded on Swath.

M322 – 24/03/03 – Sea ice zone off Thurston Island. No data from swath, possibly due to reflection being above sea level.

M323 – 25/03/03 – In sea ice off Thurston Island. No data from swath.

M324 – In sea ice off Thurston Island. No data from swath.

Note: a dodgy connector may also be to blame for lack of data on Missions M322-M324. This was discovered during demobilisation.

Autosub Under Ice Missions (Chris Banks)

The Autosub AUV provides a potentially valuable platform for measuring the draft of Antarctic sea ice. Autosub was fitted with a swath (multibeam) bathymetry system (Simrad EM2000) that could be configured either in a downward looking mode or, as for the purposes of this study, in an upward looking configuration. In addition, the upward ADCP system can be used to calculate an independent measure of ice draft.

In addition to measurements from the vehicle, data were collected in the study regions in the form of sea ice observations (see Sea Ice Observations report) and video images whilst the ship was en-route to the deployment sites[2].

Table 11 shows the basic information (start and stop time and location, swell period) for each of the Autosub Under Ice missions during JR84. In Table 11 *No swath data* implies a mission where swath data were collected but from the preliminary analysis it is unlikely that any of the data will be of any use (see *Issues with EM2000 and Processing Software*).

Issues with EM2000 and Processing Software

1. A feature of the EM2000 and associated processing software is that it filters out what it considers to be spurious returns. These returns include signals received outside of a specified valid time period (see also sections by Autosub team and DGV). The time period is calculated based on the sound speed and an estimate of the travel distance. For example, any signal that apparently appears above the sea surface is coded as a zero (i.e. missing data), at this stage it is not clear whether these data are recoverable but it seems unlikely.

2. Figure 32 shows an example of the correlation plot produced by Neptune. When operating correctly the EM2000 uses two methods for detecting the seabed (or as in this case sea-surface) echo in the receiver time-series. Near to the centre of the swath the echo is detected using an amplitude threshold. Further from the centre of the swath, where the sea-surface echo is buried in noise, a correlation (phase) detection is used. It is highly unlikely that amplitude detection could be successfully applied to the outermost beams. As such a normal arrangement of amplitude and phase detected beams is a useful diagnostic of whether the system is functioning correctly.

3. When Autosub was flying deep on the journey from deployment to the survey area and on the return journey the apparent draft of the ice was very large (e.g., ~100m for mission 321). From visual observations these sections of the survey were under open water with only the occasional area of ice. The correlation plots show a characteristic hyperbola on most pings. This may result from a single acoustic spike near the detector being interpreted as a sea-surface return. This is further confirmed by the fact that it is detected by amplitude on all beams. Later analysis of the precise shape of the hyperbola may show that it agrees with this interpretation.

[2] Prior to the deployment, the ship surveyed the area for the presence of icebergs either from the ice edge using radar or by entering the ice and searching visually and using radar.

4. The appendices at the end of this section include summary information on each mission including information taken from the *.linestat files. The *.linestat files for missions 321, 322 and 323 include incorrect, low values for the distance travelled (the error is of an order of magnitude). The distance travelled for mission 324 is plausible.

5. After Mission 321 it is believed that there was a probable bad connector on the transducer. At this time of writing the Autosub team cannot be more specific but it is likely that it was not transmitting properly for these missions.

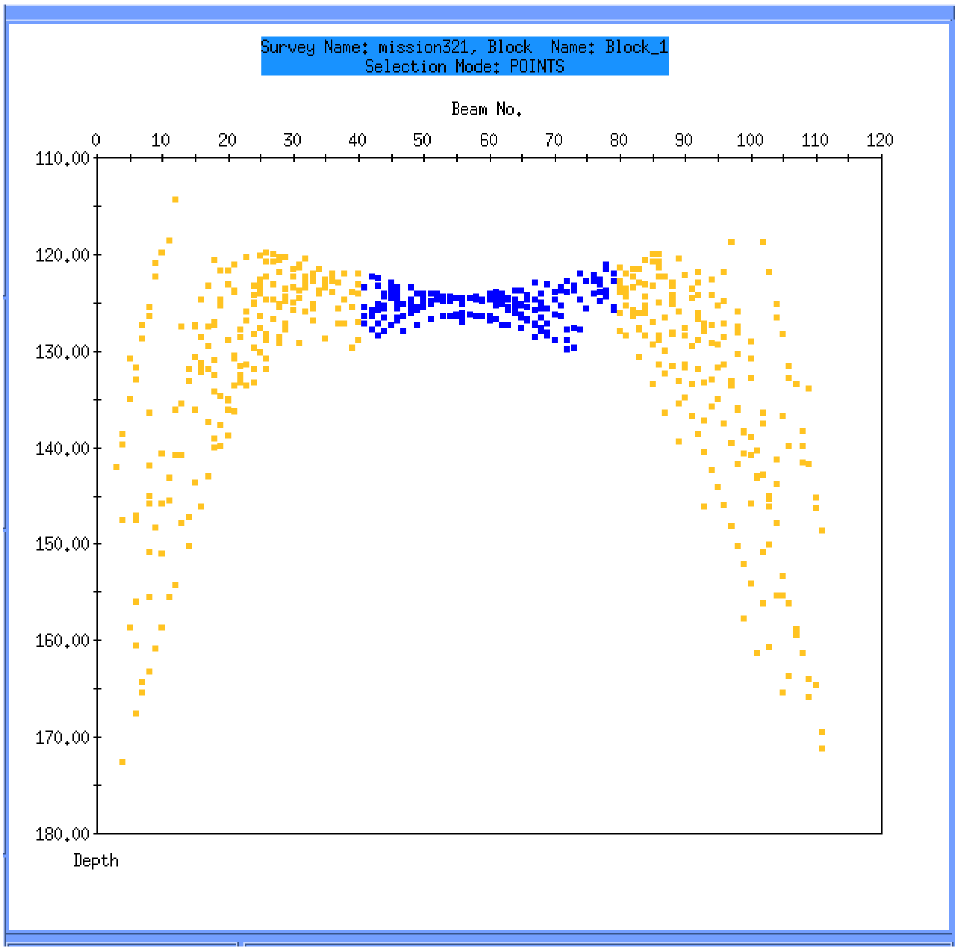


Figure 32: Example Correlation Plot from Mission 321

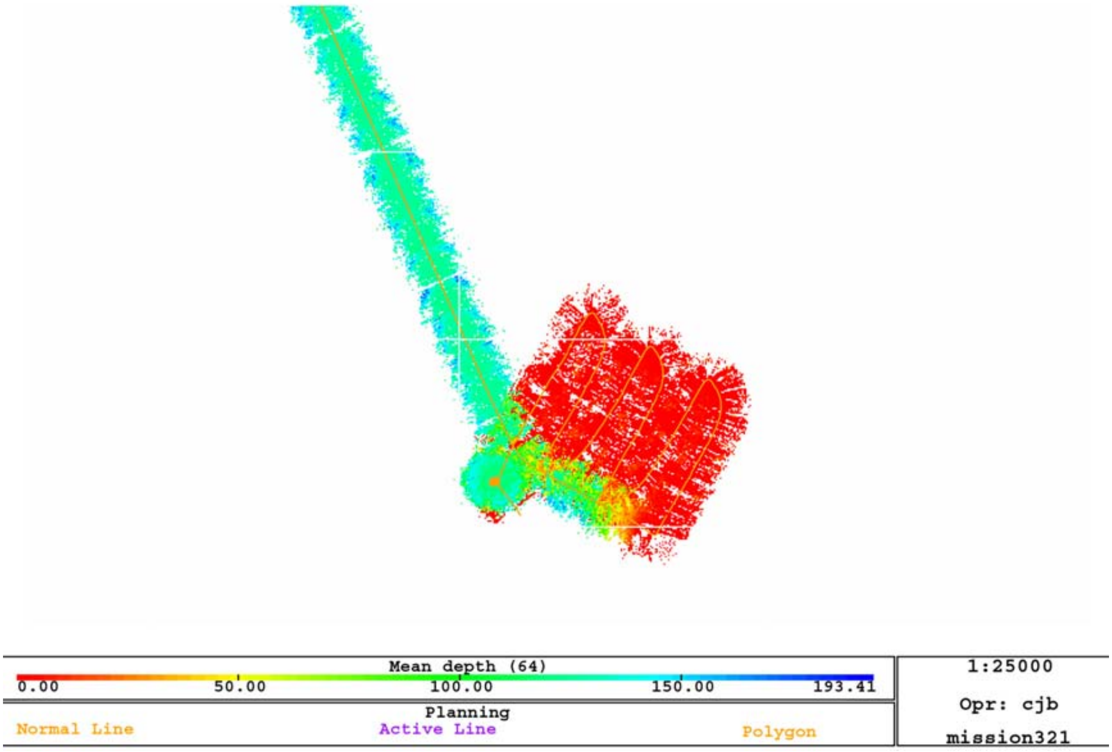


Figure 33: Results of Raw Multibeam Sonar Analysis of Ice Draft for Autosub Mission 321

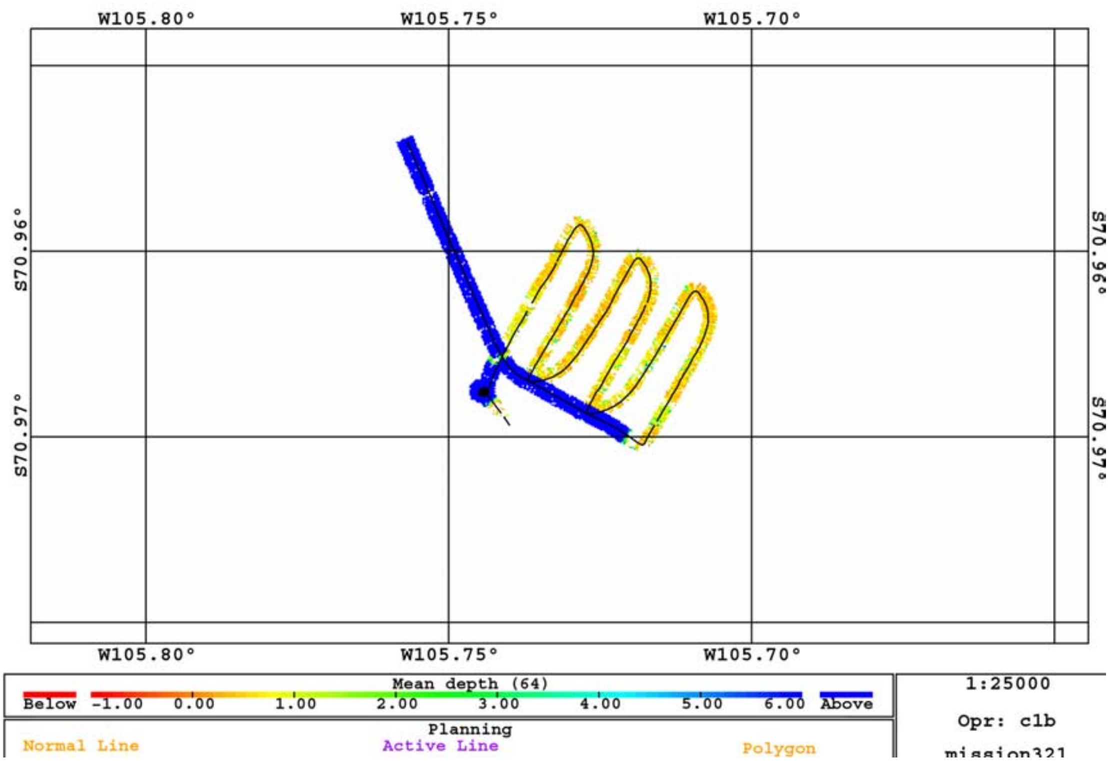


Figure 34: Results of Raw Multibeam Sonar Analysis of Ice Draft for Autosub Mission 321 for Survey Area

Table 11: Summary of Swath Bathymetry Data from Autosub Under Ice Missions

		At Deployment At Recovery			
Mission Number	Date & Time (GMT) of Deployment and Recovery	Longitude	Latitude	Swell Period[3] (seconds)	Notes
321	17:15, 22/3/03 TO 23:30 22/3/03	-105°44.3’ TO -105°55.83’	-70°58.5’ TO -70°49.77’	10-12	Provided large number of valid data points. There did not appear to be any ice over about 3metres draft, which is surprising, as the sea ice observations had identified ice thicker than this in the survey region. Further analysis of this mission is required. Figure 33 shows the results of the raw data from mission 321 as well as the track of the vehicle. Figure 34 shows the same data but for only the “lawnmower” survey area with the scale adjusted to show plausible ice draft values.
322	18:12, 23/3/03 TO 03:40, 24/3/03	-102°40.178’ TO -102°24.01’	-70°38.841’ TO -70°21.37’	8	No swath data
323	16:47, 24/3/03 TO 02:30, 25/3/03	-100°42.44’ TO -100°41.27’	-70°32.1’ TO -70°29.67’	6	No swath data After this mission it was realised that the current settings for the swath system could potentially lead to data drop out. Only values above a certain (to be ascertained) draft were measured, all other values were recorded as zero.
324	15:32, 25/3/03 TO 07:00, 26/3/03	-98°29.7’ TO -98°16.01’	-70°24.95’ TO -70°22.84’	6	No swath data The surface offset for this mission was set at 15 metres (compared with 5m for the previous missions). This offset was hoped would capture data about any values that were below zero (i.e. apparently above sea level).

[3] As estimated by bridge officers

Appendices

Summary of Performance of Mission 321

Line	Start Posn south	Start Posn West	End Posn South	End Posn West	No. of pings[4]	No. soundings[5]	No. Valid soundings	Max Depth (m)	Min Depth (m)	Mean Depth (m)	% Valid soundings
0015_20030322_163838_raw	S70°58.069'	W105°44.538'	S70°58.134'	W105°44.457'	1789	198579	1350	24.83	0.01	1.93	0.68
0015_20030322_170915_raw	S70°58.133'	W105°44.457'	S70°58.054'	W105°44.623'	1809	200799	98632	199.44	0	120.8	49.12
0015_20030322_173951_raw	S70°58.054'	W105°44.623'	S70°57.636'	W105°43.932'	1797	199467	95051	199.69	0	100.3	47.65
0015_20030322_181028_raw	S70°57.636'	W105°43.932'	S70°57.774'	W105°43.046'	1809	200799	83370	50.03	0	2.54	41.52
0015_20030322_184105_raw	S70°57.774'	W105°43.046'	S70°58.162'	W105°42.959'	1779	197469	99052	48	0	2.6	50.16
0015_20030322_191142_raw	S70°58.162'	W105°42.959'	S70°57.240'	W105°45.421'	1809	200799	102174	198.59	0	113.9	50.88
0015_20030322_194218_raw	S70°57.240'	W105°45.422'	S70°56.025'	W105°47.034'	1801	199911	105246	196.28	111.5	131.2	52.65
0015_20030322_201255_raw	S70°56.024'	W105°47.034'	S70°54.794'	W105°48.666'	1800	199800	109844	199.16	110.9	131.3	54.98
0015_20030322_204332_raw	S70°54.794'	W105°48.666'	S70°53.364'	W105°50.560'	1809	200799	112041	197	108.9	131.4	55.80
0015_20030322_211409_raw	S70°53.364'	W105°50.561'	S70°51.939'	W105°52.443'	1800	199800	111470	200.1	108.9	131.2	55.79
0015_20030322_214446_raw	S70°51.939'	W105°52.444'	S70°50.508'	W105°54.334'	1804	200244	111698	206.57	111	131.5	55.78
0015_20030322_221522_raw	S70°50.507'	W105°54.334'	S70°49.700'	W105°55.382'	1808	200688	118823	200.86	0.01	105.6	59.21

[4] Number of times pulse read
[5] Number of times pulse read multiplied by number of beams used

Summary of Performance of Mission 322

Line	Start Posn south	Start Posn West	End Posn South	End Posn West	No. of pings[6]	No. soundings[7]	No. Valid soundings	Max Depth (m)	Min Depth (m)	Mean Depth (m)	% Valid soundings
0015_20030323_171149_raw	S70°38.529'	W102°38.945'	S70°38.380'	W102°39.166'	1635	181485	0	-	-	-	0.00
0015_20030323_174226_raw	S70°38.380'	W102°39.166'	S70°38.519'	W102°38.675'	1806	200466	17376	135.31	0.02	64.05	8.67
0015_20030323_181303_raw	S70°38.519'	W102°38.675'	S70°38.503'	W102°38.516'	1795	199245	73713	147.61	59.51	79.98	37.00
0015_20030323_184340_raw	S70°38.503'	W102°38.516'	S70°38.519'	W102°38.340'	1802	200022	72228	140.84	60.71	80.09	36.11
0015_20030323_191416_raw	S70°38.519'	W102°38.340'	S70°38.490'	W102°38.365'	1804	200244	72597	140.02	60.86	80.04	36.25
0015_20030323_194453_raw	S70°38.490'	W102°38.365'	S70°37.768'	W102°38.113'	1795	199245	75558	138.52	59.26	79.6	37.92
0015_20030323_201530_raw	S70°37.768'	W102°38.113'	S70°36.074'	W102°37.549'	1796	199356	77776	140.26	62.2	79.99	39.01
0015_20030323_204606_raw	S70°36.074'	W102°37.549'	S70°34.370'	W102°37.118'	1806	200466	77310	143.5	59.2	80.13	38.57
0015_20030323_211643_raw	S70°34.370'	W102°37.118'	S70°32.729'	W102°36.893'	1813	201243	76012	140.02	56.82	80.03	37.77
0015_20030323_214720_raw	S70°32.729'	W102°36.893'	S70°31.124'	W102°36.316'	1802	200022	75002	139.78	58.46	80.72	37.50
0015_20030323_221757_raw	S70°31.123'	W102°36.316'	S70°29.610'	W102°35.522'	1796	199356	78738	139.73	47.8	79.58	39.50
0015_20030323_224833_raw	S70°29.610'	W102°35.522'	S70°27.982'	W102°35.139'	1798	199578	73255	142.86	61.52	80.73	36.70
0015_20030323_231910_raw	S70°27.982'	W102°35.139'	S70°26.513'	W102°34.355'	1796	199356	71976	144.49	53.64	79.53	36.10
0015_20030323_234947_raw	S70°26.513'	W102°34.355'	S70°25.050'	W102°33.482'	1796	199356	79546	140.78	59.83	79.97	39.90
0015_20030324_002024_raw	S70°25.050'	W102°33.482'	S70°23.572'	W102°32.577'	1788	198468	79588	139.83	59.92	80.28	40.10
0015_20030324_005100_raw	S70°23.572'	W102°32.577'	S70°22.088'	W102°31.687'	1801	199911	78332	140.37	58.73	79.42	39.18

[6] Number of times pulse read
[7] Number of times pulse read multiplied by number of beams used

Summary of Performance of Mission 323

Line	Start Posn south	Start Posn West	End Posn South	End Posn West	No. of pings[8]	No. soundings[9]	No. Valid soundings	Max Depth (m)	Min Depth (m)	Mean Depth (m)	% Valid soundings
0015_20030324_161200_RAW	S70°32.140'	W100°42.467'	S70°32.121'	W100°42.450'	1796	199356	8113	85.13	0.01	23.36	4.07
0015_20030325_012301_RAW	S70°29.999'	W100°42.783'	S70°30.490'	W100°43.245'	1802	200022	6551	97.38	0.01	27.04	3.28
0015_20030325_005224_RAW	S70°30.756'	W100°43.415'	S70°29.999'	W100°42.783'	1807	200577	88132	139.65	47.85	79.58	43.94
0015_20030325_002148_RAW	S70°32.188'	W100°44.579'	S70°30.756'	W100°43.416'	1793	199023	88115	142.31	62.58	80.31	44.27
0015_20030324_235111_RAW	S70°33.619'	W100°45.750'	S70°32.188'	W100°44.579'	1800	199800	88171	142.77	61.27	80.35	44.13
0015_20030324_232034_RAW	S70°35.056'	W100°46.923'	S70°33.619'	W100°45.750'	1799	199689	87897	144.12	60.41	79.8	44.02
0015_20030324_224958_RAW	S70°36.528'	W100°47.579'	S70°35.057'	W100°46.924'	1802	200022	80665	144.48	60.03	80.2	40.33
0015_20030324_221921_RAW	S70°37.166'	W100°46.629'	S70°36.529'	W100°47.579'	1801	199911	35970	275.46	0.01	136.1	17.99
0015_20030324_214844_RAW	S70°37.084'	W100°47.926'	S70°37.166'	W100°46.629'	1793	199023	2248	32.62	0.02	8.16	1.13
0015_20030324_211808_RAW	S70°36.980'	W100°47.680'	S70°37.084'	W100°47.926'	1803	200133	1663	30.76	0	7.4	0.83
0015_20030324_204731_RAW	S70°37.305'	W100°47.057'	S70°36.980'	W100°47.680'	1801	199911	26075	287.96	0.01	164.9	13.04
0015_20030324_201654_RAW	S70°37.351'	W100°46.713'	S70°37.304'	W100°47.057'	1794	199134	63835	289.42	0.01	177.7	32.06
0015_20030324_194617_RAW	S70°37.353'	W100°47.005'	S70°37.351'	W100°46.713'	1798	199578	40374	285.72	0.01	174.5	20.23
0015_20030324_191541_RAW	S70°37.700'	W100°46.650'	S70°37.352'	W100°47.005'	1796	199356	43181	290.07	0.01	186.9	21.66
0015_20030324_184504_RAW	S70°37.178'	W100°46.516'	S70°37.700'	W100°46.650'	1799	199689	26120	271.98	0.02	135	13.08
0015_20030324_181427_RAW	S70°35.713'	W100°45.879'	S70°37.178'	W100°46.516'	1787	198357	2351	32.5	0.02	8.03	1.19
0015_20030324_174350_RAW	S70°34.312'	W100°44.531'	S70°35.713'	W100°45.879'	1792	198912	1665	34.48	0.01	8.01	0.84
0015_20030324_171314_RAW	S70°32.861'	W100°43.132'	S70°34.311'	W100°44.531'	1798	199578	2075	31.49	0	8.4	1.04
0015_20030324_164237_RAW	S70°32.121'	W100°42.450'	S70°32.860'	W100°43.132'	1805	200355	42658	141.9	0.02	72.33	21.29

[8] Number of times pulse read
[9] Number of times pulse read multiplied by number of beams used

Summary of Performance of Mission 324

Line	Start Posn south	Start Posn West	End Posn South	End Posn West	No. of pings[10]	No. soundings[11]	No. Valid soundings	Max Depth (m)	Min Depth (m)	Mean Depth (m)	% Valid soundings
0012_20030325_150951_RAW	S70°25.265'	W98°30.390'	S70°25.007'	W98°30.005'	1806	200466	5741	51	-0.01	12.35	2.86
0012_20030325_154028_RAW	S70°25.007'	W98°30.005'	S70°25.280'	W98°29.999'	1792	198912	8977	57.27	-0.01	12.19	4.51
0012_20030325_161104_RAW	S70°25.281'	W98°29.999'	S70°26.633'	W98°30.019'	1798	199578	759	35.52	-0.02	9.98	0.38
0012_20030325_164141_RAW	S70°26.633'	W98°30.019'	S70°28.101'	W98°30.035'	1794	199134	7783	46.09	-0.02	11.24	3.91
0012_20030325_171218_RAW	S70°28.102'	W98°30.035'	S70°29.630'	W98°30.051'	1802	200022	6113	43.4	-0.02	10.93	3.06
0012_20030325_174255_RAW	S70°29.630'	W98°30.051'	S70°30.930'	W98°30.057'	1802	200022	7293	45.64	-0.02	10.54	3.65
0012_20030325_181331_RAW	S70°30.931'	W98°30.057'	S70°32.139'	W98°30.067'	1800	199800	7612	49.93	-0.02	10.16	3.81
0012_20030325_184408_RAW	S70°32.139'	W98°30.067'	S70°32.672'	W98°30.296'	1807	200577	7536	46.35	-0.02	11.84	3.76
0012_20030325_191445_RAW	S70°32.672'	W98°30.296'	S70°32.079'	W98°30.544'	1796	199356	5522	41.94	-0.01	10.18	2.77
0012_20030325_194521_RAW	S70°32.079'	W98°30.544'	S70°32.497'	W98°30.792'	1795	199245	6928	45.81	-0.01	11.23	3.48
0012_20030325_201558_RAW	S70°32.497'	W98°30.792'	S70°32.076'	W98°31.032'	1794	199134	7728	44.57	-0.02	11.2	3.88
0012_20030325_204635_RAW	S70°32.076'	W98°31.032'	S70°32.619'	W98°31.277'	1796	199356	6579	42.79	-0.02	10.87	3.30
0012_20030325_211712_RAW	S70°32.619'	W98°31.277'	S70°31.917'	W98°31.518'	1802	200022	7867	43.87	-0.02	10.93	3.93
0012_20030325_214749_RAW	S70°31.918'	W98°31.518'	S70°32.811'	W98°31.065'	1809	200799	7336	47.08	-0.02	10.58	3.65
0012_20030325_221825_RAW	S70°32.811'	W98°31.065'	S70°31.777'	W98°31.241'	1800	199800	7959	45.82	-0.02	11.12	3.98
0012_20030325_224902_RAW	S70°31.777'	W98°31.241'	S70°30.690'	W98°31.295'	1801	199911	86874	155.54	-0.02	81.29	43.46
0012_20030325_231939_RAW	S70°30.690'	W98°31.295'	S70°29.347'	W98°30.991'	1809	200799	100505	156.98	71.07	90.59	50.05
0012_20030325_235015_RAW	S70°29.346'	W98°30.991'	S70°28.064'	W98°30.701'	1796	199356	101902	154.98	58.45	91.37	51.12
0012_20030326_002052_RAW	S70°28.064'	W98°30.701'	S70°26.572'	W98°30.362'	1794	199134	102468	160.56	71.07	91.02	51.46
0012_20030326_005129_RAW	S70°26.572'	W98°30.362'	S70°25.021'	W98°30.001'	1809	200799	104618	153.46	56.15	91.05	52.10

[10] Number of times pulse read
[11] Number of times pulse read multiplied by number of beams used

0012_20030326_012205_RAW	S70°25.021'	W98°30.001'	S70°25.052'	W98°29.988'	1805	200355	98318	156.61	62.07	91.1	49.07
0012_20030326_015242_RAW	S70°25.052'	W98°29.989'	S70°25.043'	W98°30.031'	1810	200910	103095	152.89	71.84	91.82	51.31
0012_20030326_022319_RAW	S70°25.043'	W98°30.031'	S70°25.046'	W98°30.045'	1802	200022	104225	155.99	66.6	91.2	52.11
0012_20030326_025356_RAW	S70°25.046'	W98°30.045'	S70°25.010'	W98°29.996'	1791	198801	98816	152.31	71.59	91.86	49.71
0012_20030326_032432_RAW	S70°25.010'	W98°29.995'	S70°24.914'	W98°30.059'	1785	198135	100943	155.72	68.47	91.43	50.95
0012_20030326_035509_RAW	S70°24.914'	W98°30.059'	S70°23.507'	W98°30.127'	1798	199578	101795	156.48	65.88	91.26	51.01
0012_20030326_042546_RAW	S70°23.507'	W98°30.127'	S70°22.052'	W98°30.193'	1807	200577	102050	159.26	70.86	91.23	50.88
0012_20030326_045623_RAW	S70°22.052'	W98°30.193'	S70°22.739'	W98°17.157'	1807	200577	16097	157.52	-0.02	55.77	8.03

CTD, Water Sampler and ADCP (Dan Hayes and Ziggy Pozzi-Walker)

It is the purpose of this section to discuss the quality of the CTD, water sampler and ADCP data collected by the Autosub during cruise JR84. The Autosub carries a pair of pumped SeaBird Electronics Conductivity-Temperature cells. The SBE 911 system also includes a pressure sensor, oxygen probe, fluorometer, and transmissometer. Data are collected at 24 Hz. The water sampler can collect up to 49 water samples, taken every 30 minutes throughout the run. The Autosub carries upward- and downward-looking ADCPs which collect data every 2 seconds throughout the mission.

Conductivity-Temperature-Depth

Absolute levels of temperature and conductivity are investigated by comparing a shipboard CTD cast to an Autosub mission. On mission 316 (17:17 GMT, 16 March 2003, -71.215^o –113.320^o) the Autosub dived to 1200 m and returned. On cast 84ctd011, the ship's CTD system was lowered to 2000 m (05:10 GMT, 16 March 2003, -71.223^o, -113.345^o). The temperature, conductivity, and oxygen profiles in the depth range of overlap are shown. The two temperature sensors on Autosub are in excellent agreement, as well as the two conductivity sensors. See Table 12. The shipboard sensors are also shown for comparison. Both the temperature and conductivity profiles show the same broad features. However, the two casts show significant differences in detail, particularly above 700 meters. Given the separation in time and space of the two casts (12 hours and 1.6 km), and the internal consistency of the two instruments, these variations are acceptable. Below 700 meters, we expect nearly identical results, since the Circumpolar Deep Water found there is a large and slowly varying water mass. The differences there are very slight: a maximum of 0.01 deg C and 0.001 S m^{-1}. Although slight, these differences are significant. A plot of temperature versus salinity for the two instruments shows that water mass properties in the deep are close agreement. It should also be noted that neither of the data sets has been processed to account for a post-cruise calibration or salinity correction using a water samples and salinometer.

Initially it was thought that the temperature and conductivity sensors lagged the pressure sensor, and this may be the case. The pressure is recorded instantaneously, while the temperature and conductivity are measured after the water has been pumped from the intake to the sensors. An estimate of this time delay can be made with the flow rate and pipe diameter. The effect is not visible in our data. Some casts seem to show a depth offset, but it is the same on both the up and down casts while one would expect the offset to be of opposite sign. On these missions the offset is also much larger than can be explained by such a lag. Perhaps the effect would be measurable if a side-by-side cast were made. Even after adjusting for a time delay, the water entering the ports could be at a different depth than the pressure sensor, particularly while diving or climbing. This can be accounted for using vehicle pitch angle once the distance between ports and pressure sensor are known.

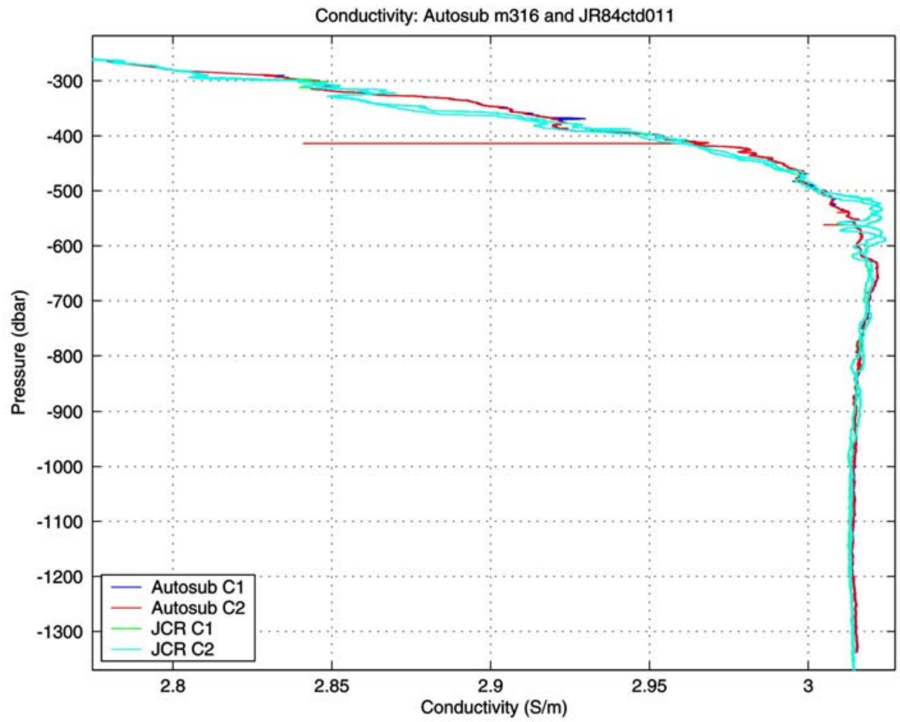


Figure 35: Comparison of Autosub and ship's CTD condictivities.

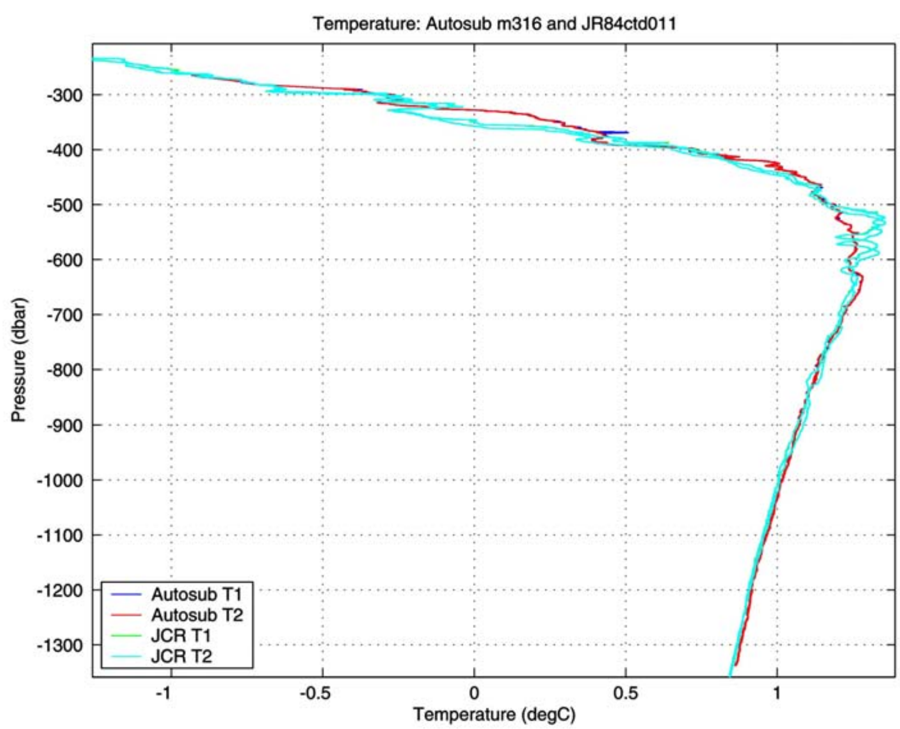


Figure 36: Comparison of Autosub and ship's CTD temperatures.

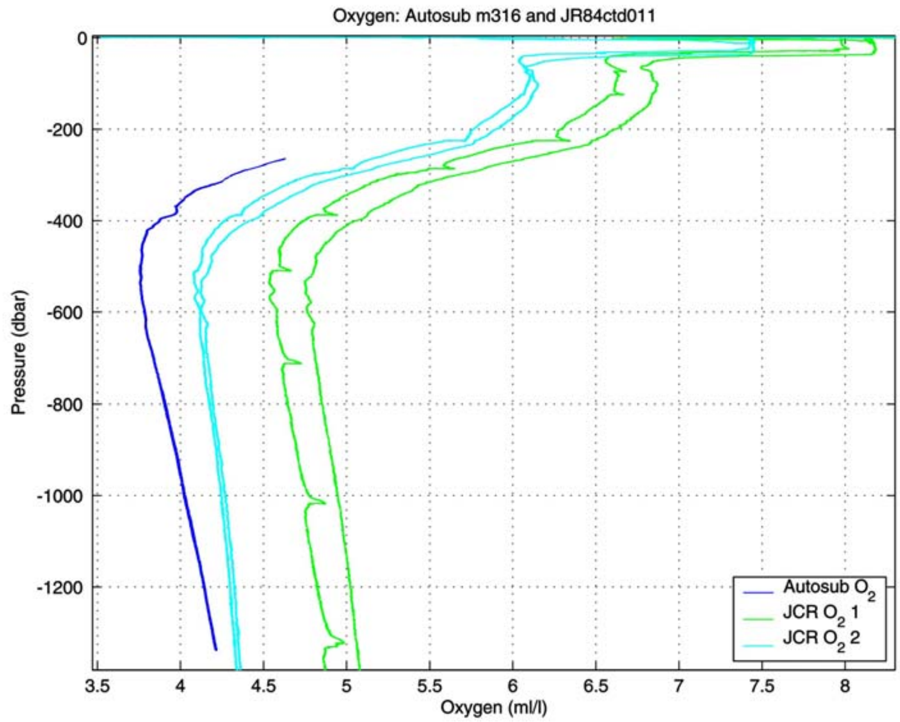


Figure 37: Comparison of Autosub and ship's CTD dissolved oxygen values.

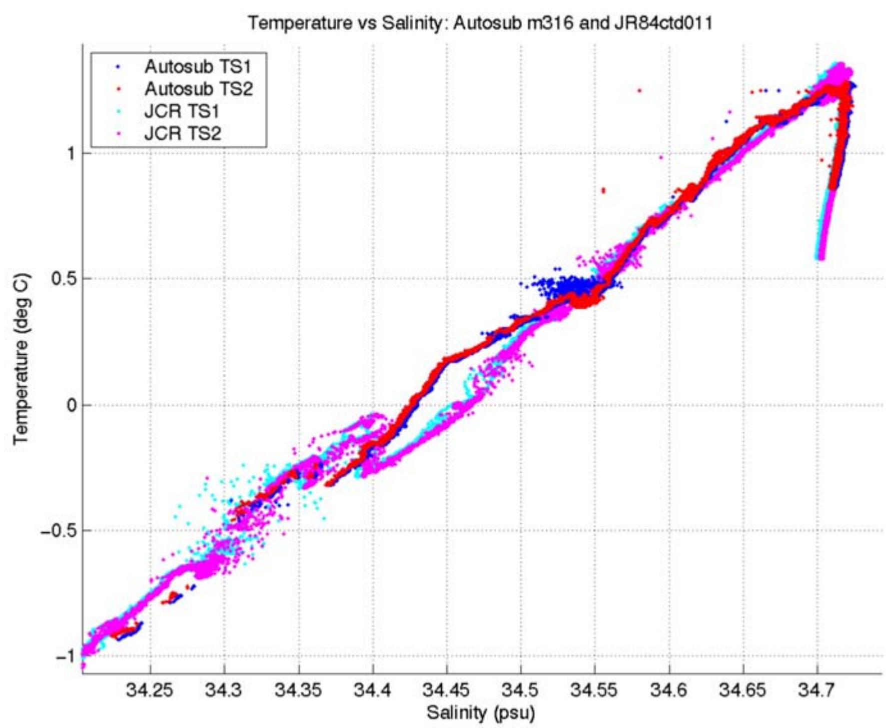


Figure 38: Comparison of Autosub and ship's CTD temperature/salinity values.

Another potential improvement is the minimization of frictional heating of the water sampled for temperature. The intake ports protrude from the hull near the nose, so they are already away from the boundary layer on the sub's surface. The piping to the sensor should be entirely vinyl or plastic, and currently the intake pipe is metal. This effect should be very small.

The oxygen probe is unfortunately in disagreement with both shipboard probes, which have problems of their own. It appears that the probe shows reasonable changes throughout the water column, however the absolute values seem low. This particular run shows a smooth oxygen trace, but later runs show more structure (m323 for example).

The transmissometer seems to be malfunctioning, with a constant value of 0.15 % transmission. The fluorometer shows a negligible depth dependence: a noisy trace between zero and –0.03 mg m^{-3}, while the ship's fluorometer shows a range of 0.14 to 0.09 mg m^{-3} over the same depth range. [One of the these was destroyed during recovery on XX March.]

Platform	Mean(T2-T1)	St.dev(T2-T1)	Mean(C2-C1)	St. dev(C2-C1)
Autosub	1.34×10^{-4}	5.48×10^{-4}	-1.24×10^{-4}	0.533×10^{-4}
Ship	-6.46×10^{-4}	3.81×10^{-4}	1.46×10^{-4}	0.400×10^{-4}

Table 12: Comparison of sensor pairs on 16 March 2003, Autosub mission 316 and CTD 011.

Water Sampler

The water sampler presented serious problems. Primarily, the sample bags contained unexpected volumes of water. The fact that sample bags returned with variable amounts of water suggests the possibility that leakage was contaminating the samples. Several changes were made in an attempt to solve this problem. See Autosub instrument section. Below is a table of sample volumes and salinities for five runs. Actual sample salinity was calculated using the shipboard salinometer. Samples were drained from their plastic bag directly into new, sterile glass bottles, and the volume of the remaining water was measured. CTD salinities are based on a 15 minute averages from the Autosub CTD system. Unfortunately, the sample times are not known to better than 15 minutes. When the vehicle is moving through stratified water, or when the exact location of the sampled water is required, this presents a serious problem that must be solved for the water sampler to be of practical use. When the sub is in the deep uniform water mass below 700 m, the CTD salinity is generally 0.03-0.05 psu lower than the samples. The error introduced by averaging over 15 minutes is very small in this case.

Mission Number	Bag Number	Volume (ml)	Sample Salinity (psu)	CTD Salinity** (psu)	Notes
M312	25	415	34.6966	34.7267	900 m
M312	24	365	34.7388	34.7214	1200 m
M312	23	370	34.7257	34.7253	800 m
M312	22	315	34.7355	34.6393	400 m*
M312	21	290	34.6737	34.1209	100 m*
M312	20	280	34.2223	33.6639	mixed layer halocline*
M312	19	275	33.8228	33.5430	less than 15 min*
M312	18	285	33.5790	N/A	CTD not logging
M313	25	260	34.6847	34.7210	500 m
M313	24	395	34.7526	34.7198	900 m
M313	23	265	34.7449	34.7172	1200 m
M313	22	270	34.7508	34.7227	800 m
M313	21	265	34.7498	34.7050	500
M313	20	265	34.3935	33.5853	mixed layer halocline
M313	19	265	33.6386	N/A	CTD not logging
M316	25	275	34.5158	N/A	CTD not logging
M316	24	275	34.7486	34.7181	less than 15 min, 800 m
M316	23	275	34.7408	34.7133	1100 m
M316	22	275	34.7498	34.7127	1200 m
M316	21	275	34.7545	34.7174	800 m
M316	20	280	34.6839	34.6608	mixed layer halocline
M316	19	285	34.1009	N/A	CTD not logging
M316	18	295	33.4728	N/A	CTD not logging
M317/8	25	170	34.3633	34.6438	600 m
M317/8	24	175	34.7072	34.7143	900 m
M317/8	23	175	34.7584	34.7092	1200 m
M317/8	22	175	34.7492	34.7134	700 m
M317/8	21	210	33.8797	34.4905	mixed layer halocline
M317/8	20	265	33.5417	33.4211	0 m
M317/8	19	270	33.4886	33.7308	0-100 m
M317/8	18	275	33.5062	32.9287	0-10 m
M317/8	17	145	33.4676	21.5205	0 m

*There appears to be a gap in the CTD file, which could offset the 15-minute averaging interval from the actual sampling interval.
**Average of salinity calculated from probes one and two.

Acoustic Doppler Current Profilers

The ADCP collected reasonable data, however not over the range it should have. An example from mission m323 on 24 March is shown. It is clear that the vehicle was changing course as the various components change sign. An absolute velocity reference was not available for any run except for m320 (21 March), which was bottom tracking. (Unfortunately, it was just traveling in a circle at this time.) On this run, the number of bins (each 8 m) containing valid data from the downward-looking ADCP was increased to 11 (or 85 m range). For all other runs, only 4-5 bins (31-40 m) were useful in the downward direction, while 7-9 bins (55-70 m) are typically useful in the upward direction. This problem has not been addressed satisfactorily as of yet. Previous Autosub data are more like m320. It seems likely that unsuccessful attempts to bottom track are somehow contaminating the downward ADCP data. The figure also shows that the data collected with the upward-looking ADCP at 90 m depth are apparently valid for the bins 9-11. On further examination it seems that this data may be contaminated by surface echos. In any case, the range to the tracked surface appears to be very good when within 100 m. When combined with the depth of the vehicle, the range can be used to calculate ice draft, a short example of which is also shown. (Note the different horizontal scale.) Another problem with the downward ADCP is that the range data sometimes indicate an approaching obstacle and cause the collision avoidance algorithm to be activated many times during the run (every 150 seconds or so in m324). This can cause extreme pitch angles (-10 to +25 degrees) and depth changes (up to 9 m) that must be carefully corrected for in the ice draft calculation.

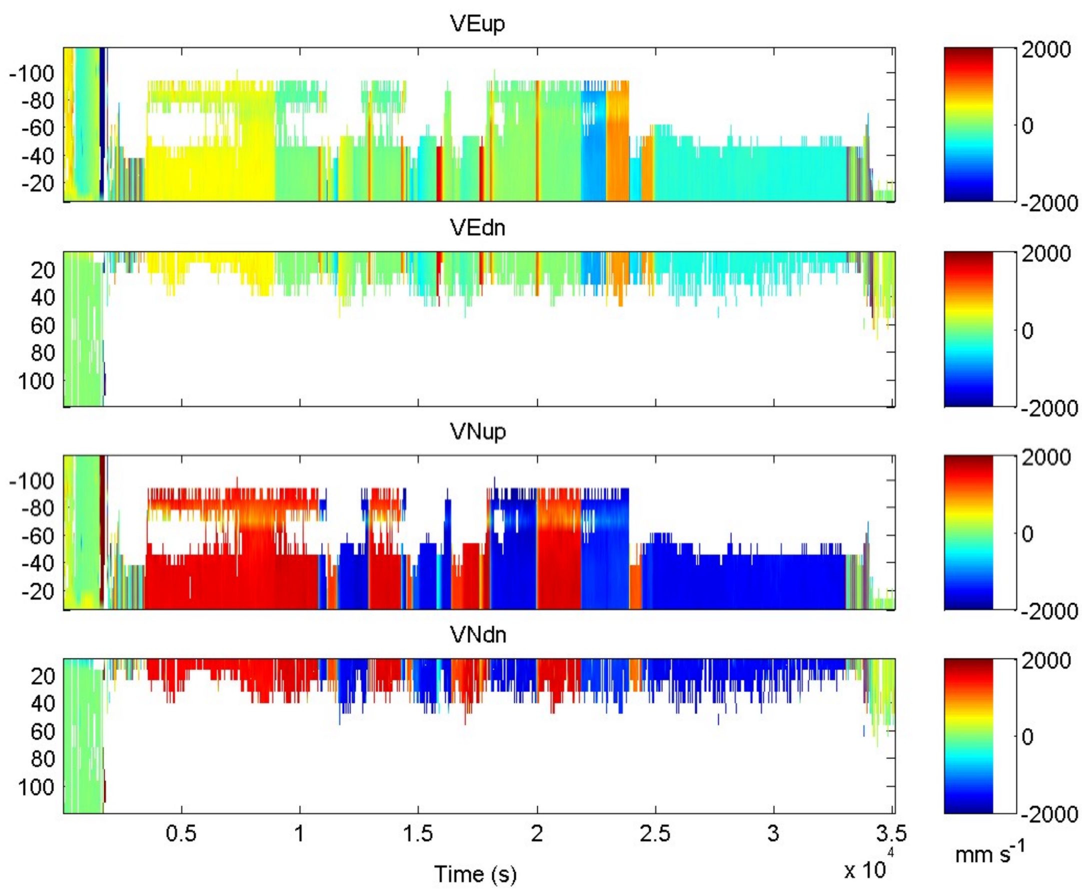


Figure 39: Autosub ADCP data for M323.

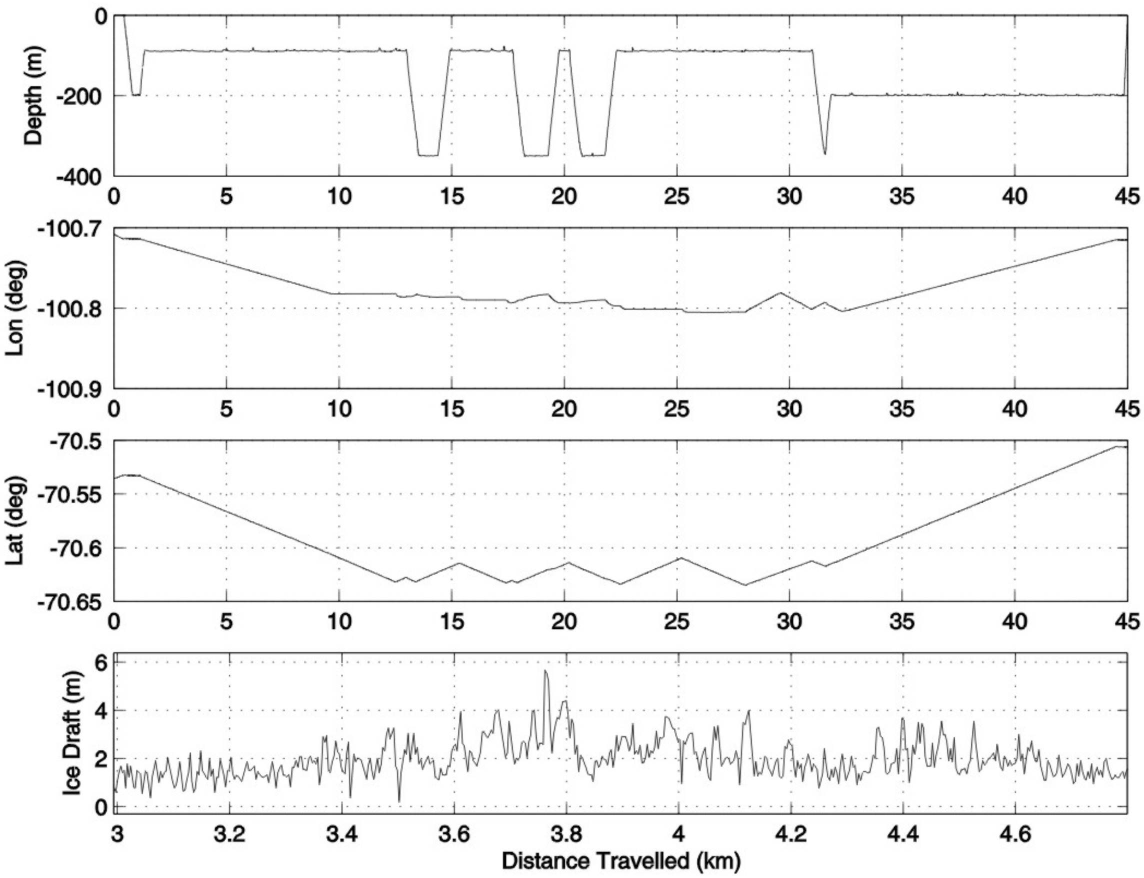
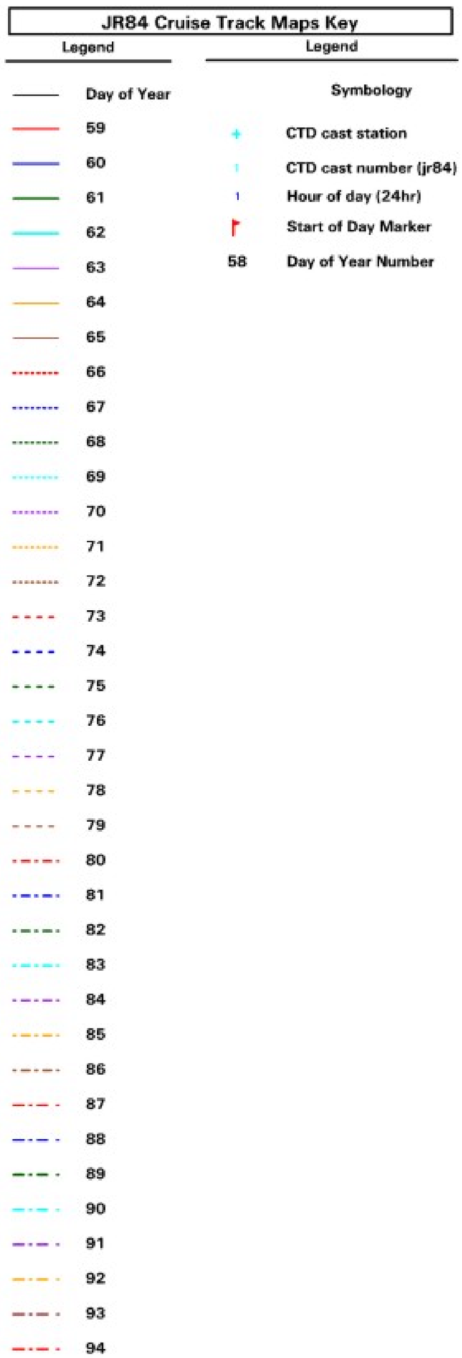
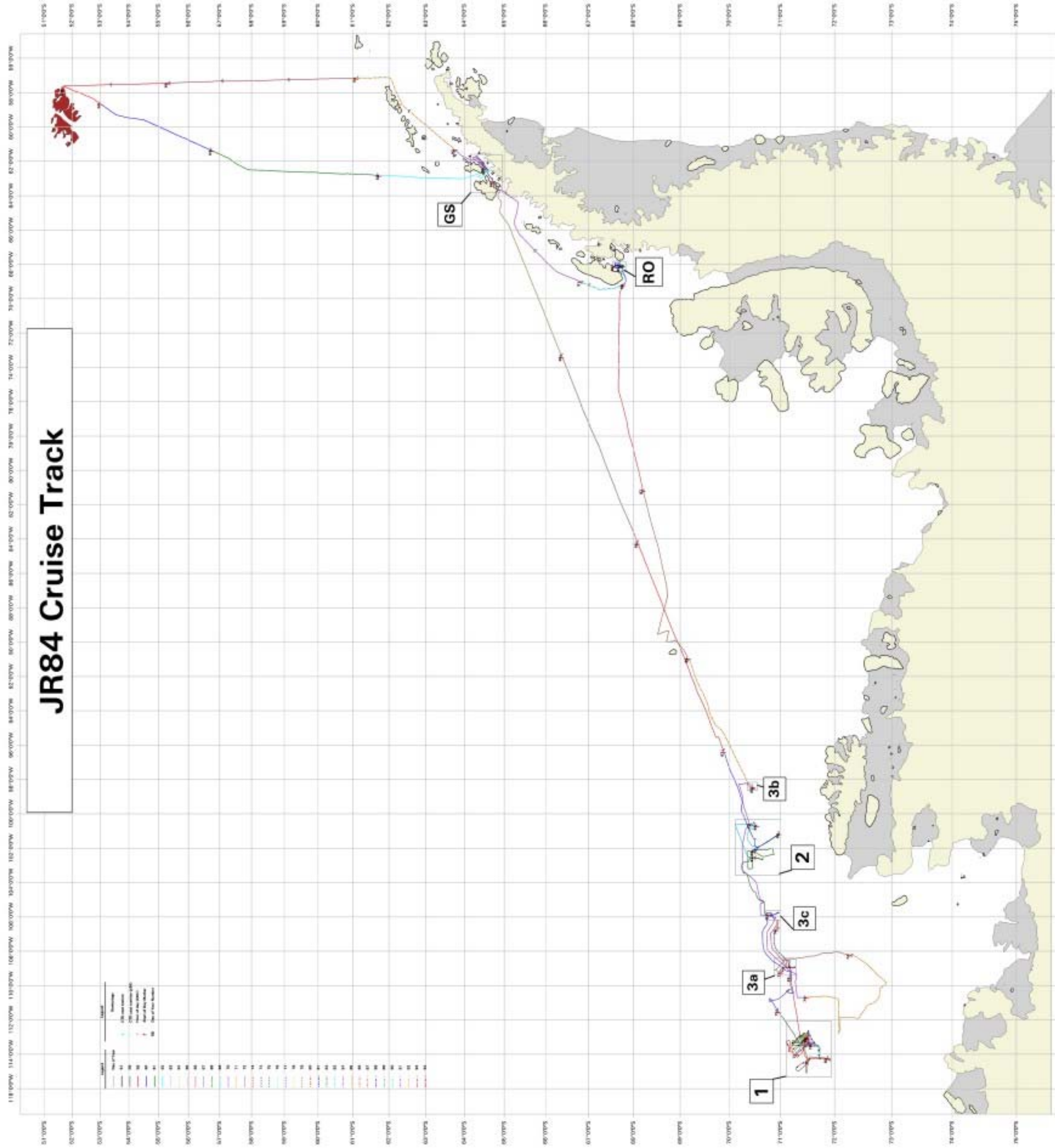


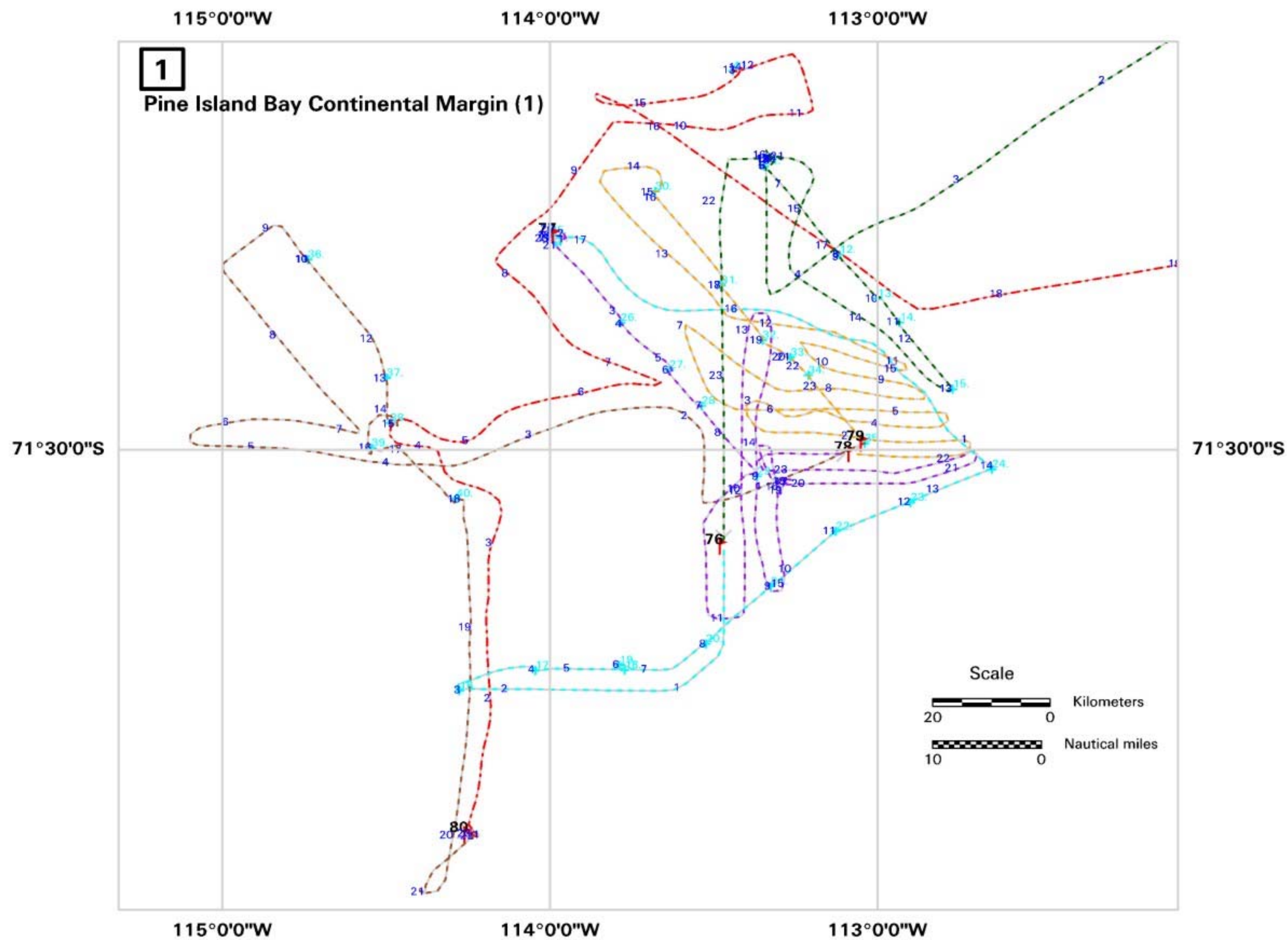
Figure 40: Autosub position and derived ice draft during M323.

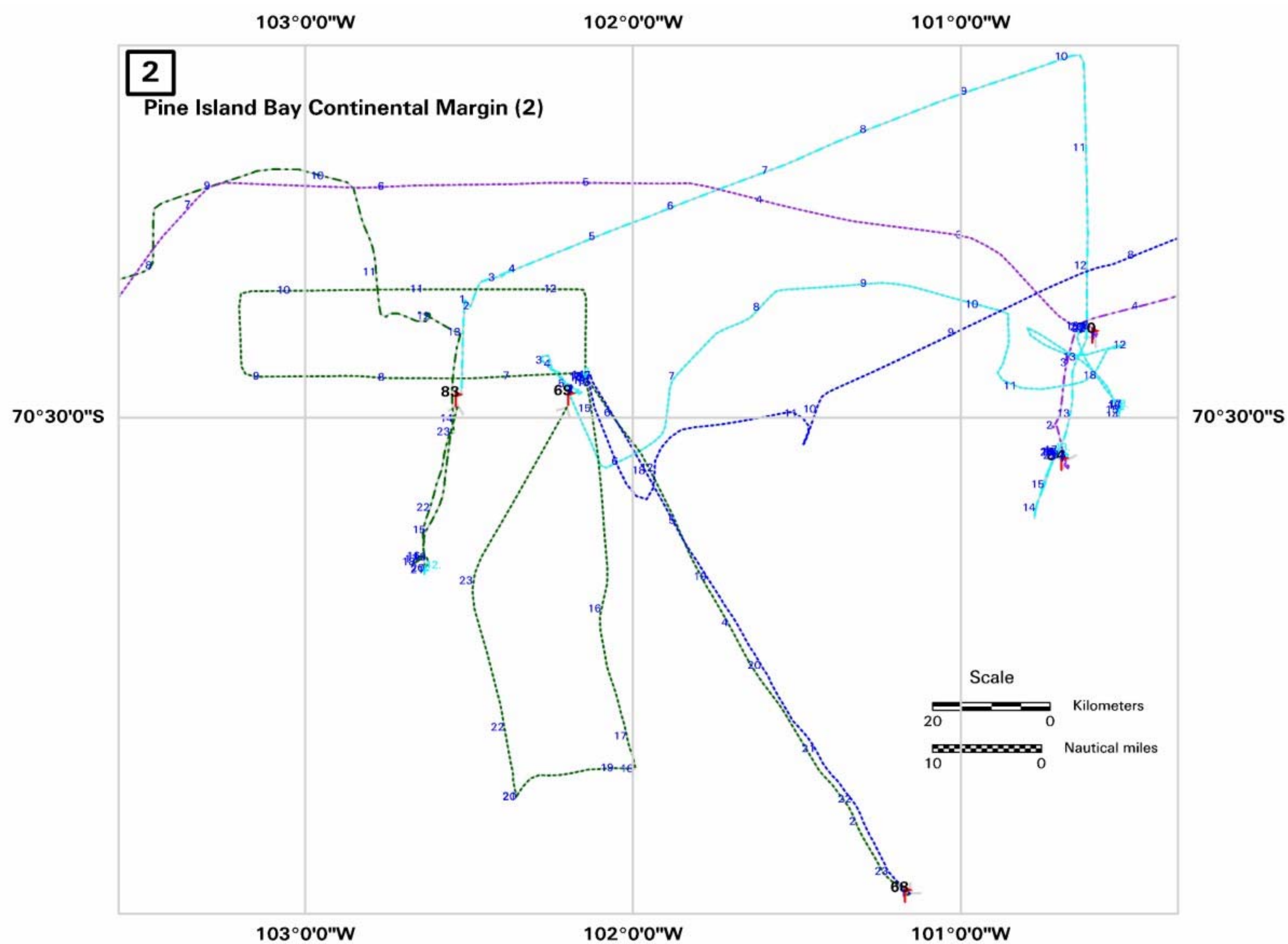
Cruise Track Plots

Toby Benham
(Scott Polar Research Institute)



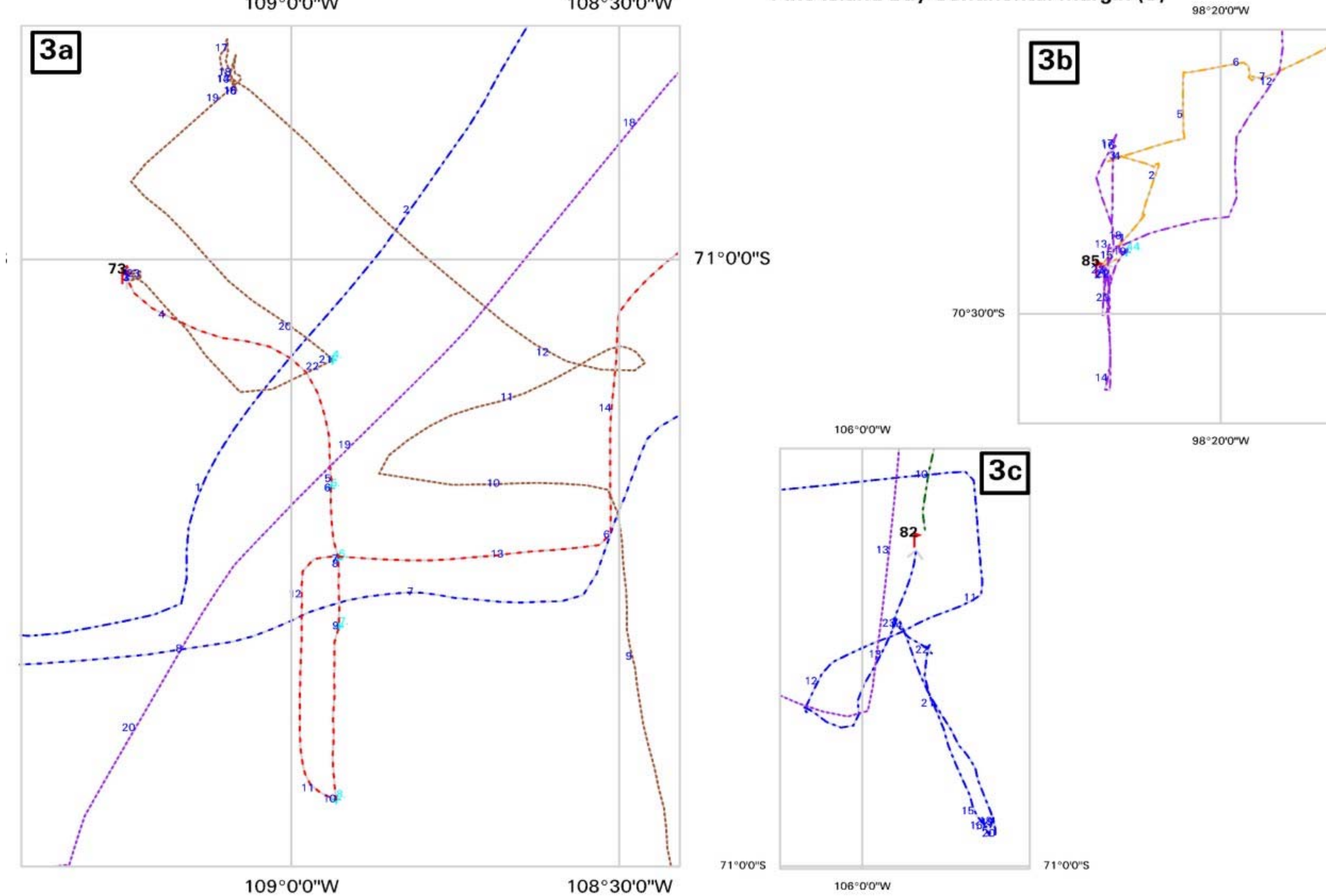

JR84 Cruise Track
GS
RO
1
2
3a
3b
3c

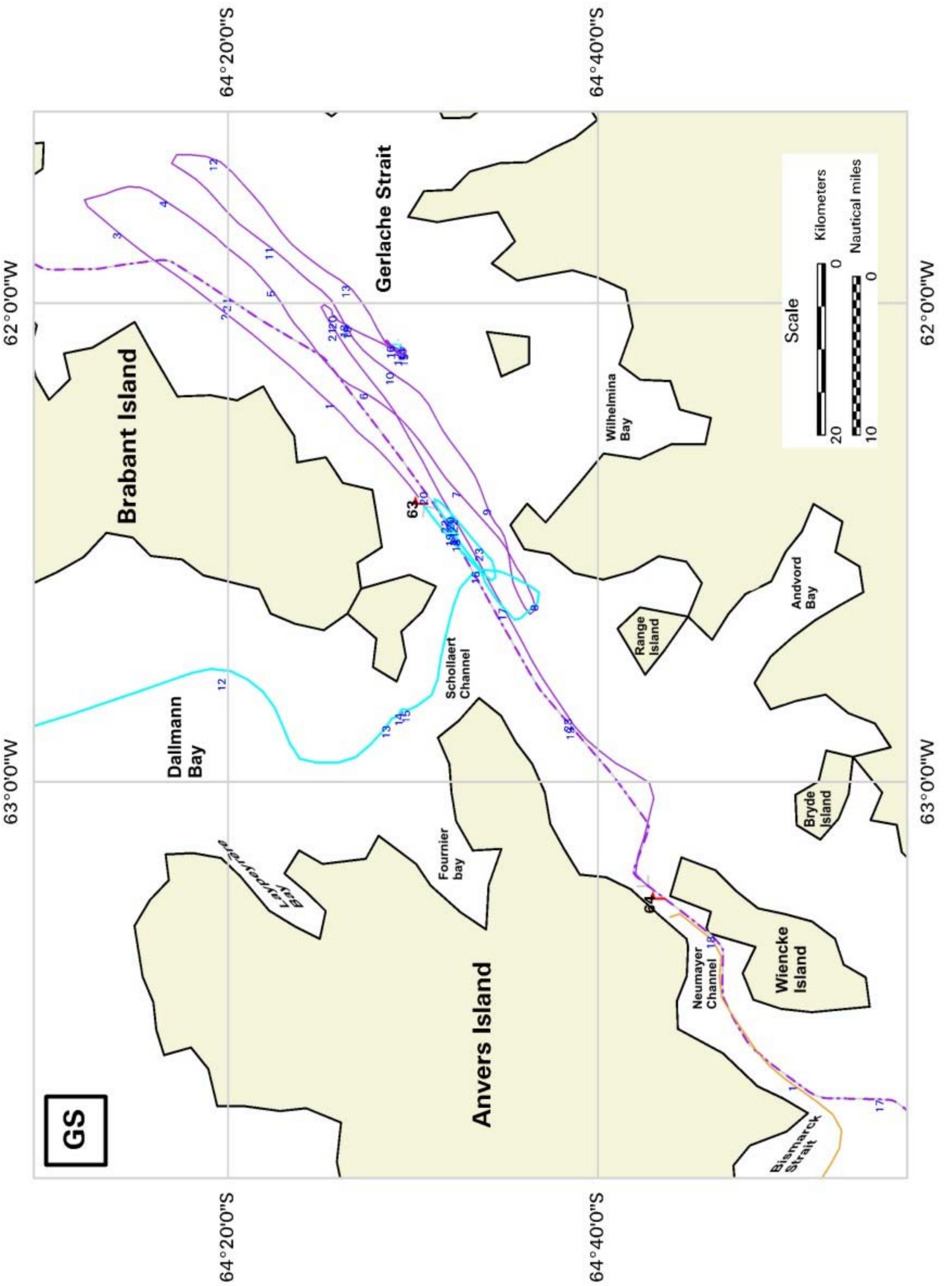

1
Pine Island Bay Continental Margin (1)
115°0'0"W
114°0'0"W
113°0'0"W
71°30'0"S
71°30'0"S
115°0'0"W
114°0'0"W
113°0'0"W
71
76
78
79
80
Scale
20
0
Kilometers
10
0
Nautical miles



103°0'0"W
102°0'0"W
101°0'0"W
2
Pine Island Bay Continental Margin (2)
70°30'0"S
83
69
68
Scale
Kilometers
20
0
Nautical miles
10
0

Pine Island Bay Continental Margin (3)




GS
64°20'0"S
64°40'0"S
63°0'0"W
62°0'0"W
Brabant Island
Anvers Island
Dallmann Bay
Gerlache Strait
Schollaert Channel
Fournier bay
Lapeyrère Bay
Wilhelmina Bay
Andvord Bay
Range Island
Bryde Island
Wiencke Island
Neumayer Channel
Bismarck Strait
63
64
Scale
Kilometers
Nautical miles
20
0
10
0

Rothera (Adelaide Island)