CRUISE REPORT – JR106b

RRS JAMES CLARK ROSS

NERC *AUTOSUB UNDER ICE* THEMATIC PROGRAMME

KANGERDLUSSUAQ FJORD AND SHELF
EAST GREENLAND

September 2004

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1. AUTOSUB UNDER ICE CRUISE JR106b, EAST GREENLAND

1.1 INTRODUCTION
(Julian Dowdeswell)

The aims of the *Autosub under Ice* programme are to investigate the interactions between ice and ocean in both the Arctic and Antarctic, using the innovative technology of the Autosub autonomous underwater vehicle (AUV) together with more conventional shipboard measurements. Cruise JR106b provides part of the Arctic component of the study, in this case linking glaciers in Greenland with the adjacent fjord and ocean waters.

The project aims to investigate the glaciological, physical oceanographic and biological processes occurring beneath and adjacent to glaciers and ice sheets, the interaction between the polar ocean and the underside of the shelves, and their role in determining the mass balance of the ice shelves and the larger scale oceanic conditions. These processes are believed to be important for climate, both through conditioning the ocean water and in determining rate of ice melt from the undersides of the ice. These processes cannot yet be included in global climate models, but that is the ultimate goal. Very little is currently known about the water beneath and near glacial ice.

The study area for JR106b was the glacier-fjord-shelf system focussed on Kangerdlussuaq Fjord in East Greenland (Fig. 1.1). The ship tracks of the cruise are shown in Figures 1.2 and 1.3. This area was chosen because the fjord was only about 70 km long, making it logistically tractable. However, the inner fjord system proved to be un-navigable during the study period due to the breakout of a large area of sikussak (a mix of multi-year sea ice and icebergs) at the time that we entered the fjord, releasing a huge amount of floating ice (Fig. 1.4), and to the very high winds in the inner fjord system. However, successful Autosub and ship deployments were made elsewhere in the fjord system, and data were collected immediately adjacent to a tidewater glacier.

We used a combination of Autosub and ship-based measurement, reported below, with Autosub achieving near-ice and synoptic surveys that were not possible with the ship. Several notable features of cruise JR106b are:

- Acquisition of the first AUV swath and sub-bottom profiler data from adjacent to the tidewater margins of glaciers
- First acquisition of synoptic CTD data from close to tidewater glacier ice cliffs
- First successful use of Aqualab, a water sampling device installed in Autosub, to collect samples for the analysis of stable isotopes of oxygen.
- Sea-floor photographs in glacier-influenced waters using Autosub, showing the nature of both the marine biota and of ice-rafted debris
- CTD and bathymetric data collected to enable the calculation of meltwater flux to the adjacent ocean from one of the ten major fast-flowing outlet glaciers of the Greenland Ice Sheet.

In addition, a number of other comprehensive datasets on the geology, oceanography and marine biology of this Arctic fjord-shelf region were acquired. A significant aspect of cruise JR106b was that a number of these datasets, when combined, will form an innovative interdisciplinary contribution to the scientific literature. Three different *Autosub under Ice* projects (PIs Dowdeswell, Heywood and Tyler) were undertaken on the cruise, and we intend to write up a number of papers that add value to these individual projects by combining evidence from the earth, ocean and biological sciences acquired using both the Autosub AUV and the *James Clark Ross* as science platforms.

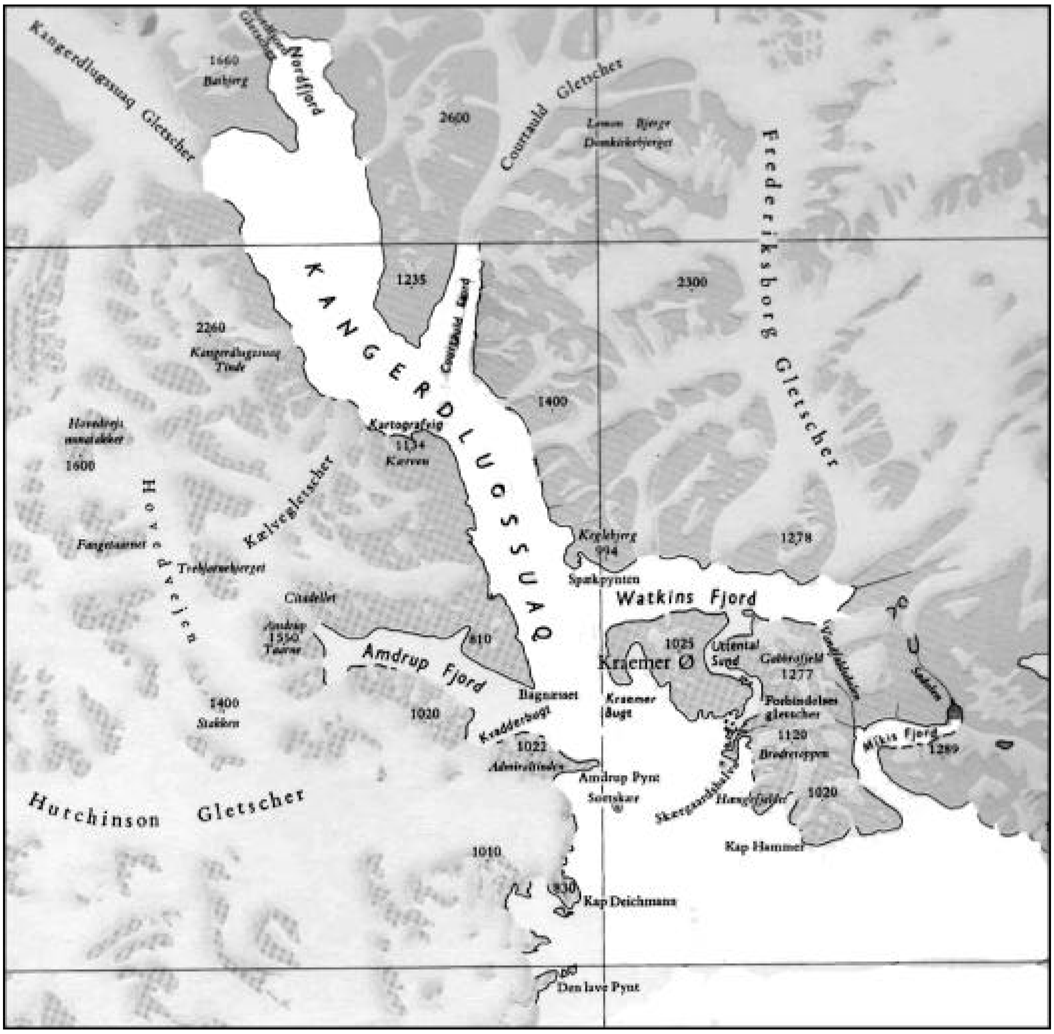

Figure 1.1 Map of Kangerdlussuaq Fjord, East Greenland

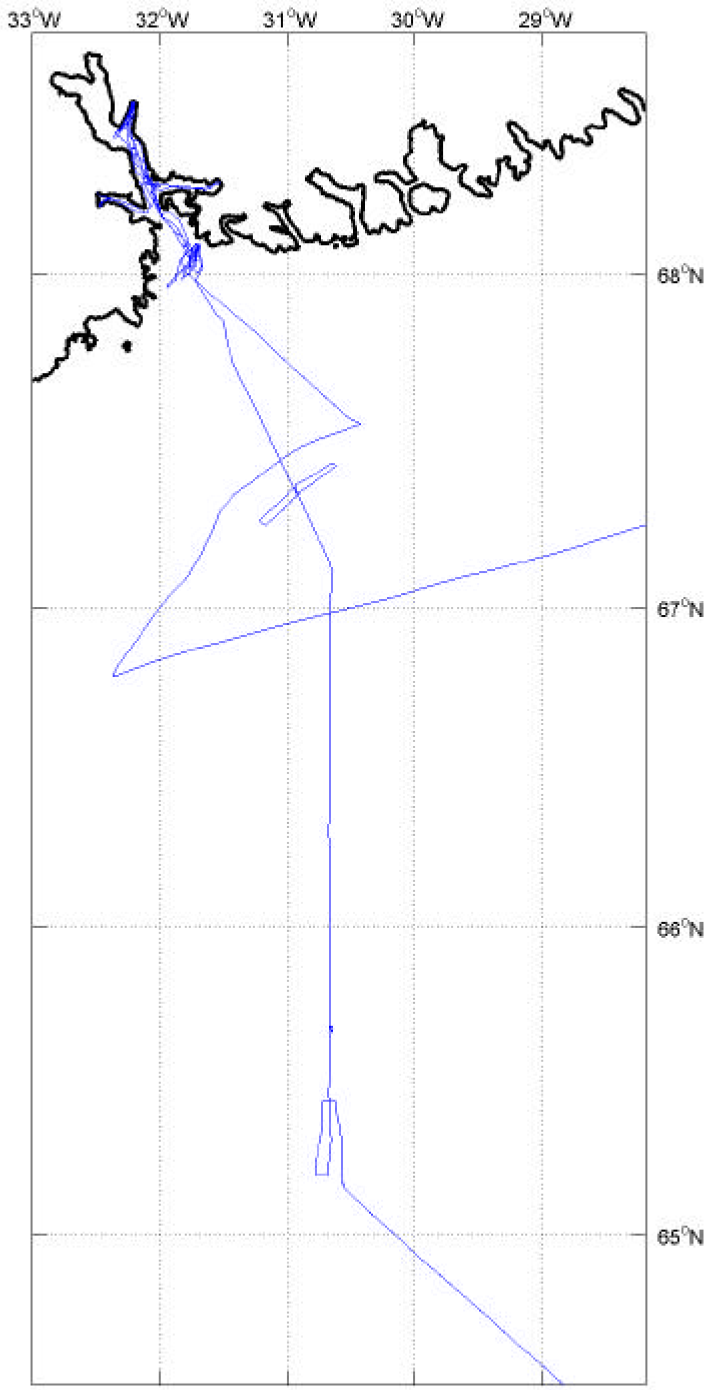

Figure 1.2. Ship tracks in the Kangerdlussuaq Fjord and Shelf region during cruise JR106b to East Greenland.

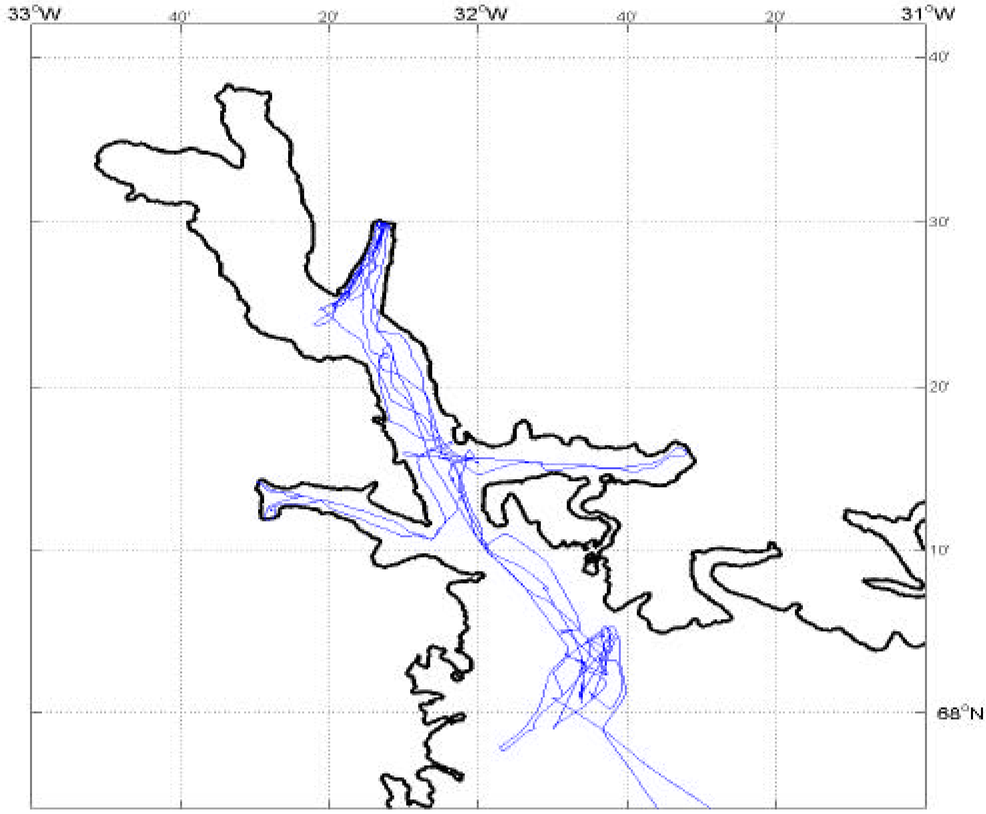

Figure 1.3. Detail of ship tracks within Kangerdlussuaq Fjord on cruise JR106b.

Fig. 1.4. An impenetrable mix of icebergs and sea ice blocks the way to the margin of Kangerdlussuaq Glacier, East Greenland. The glacier front is about 20 km distant.

1.2 CRUISE PARTICIPANTS

Julian Dowdeswell (PSO)	SPRI
Jeff Evans	SPRI
Colm Ó Cofaigh	SPRI
Ruth Mugford	SPRI
Steve McPhail	Autosub Team
Miles Peabody	Autosub Team
Peter Stevenson	Autosub Team
Andrew Webb	Autosub Team
Dave White	Autosub Team
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Martin Price	UEA
Patricia O'Mahoney	UEA
Louise Sime	UEA
Paul Clement	UEA
Paul Dodd	UEA

Brian Bett	SOC
Dan Jones	SOC
Paul Tyler	SOC
Darrel Swift	Glasgow
Terry Edwards	UKORS
Pat Cooper	BAS
Andy Tait	BAS
Doug Willis	BAS

SPRI	Scott Polar Research Institute, University of Cambridge
UEA	School of Environmental Sciences, University of East Anglia
Autosub	Autosub Team, Southampton Oceanography Centre
SOC	Deep-Sea Biology Group, Southampton Oceanography Centre
Glasgow	Department of Geography, University of Glasgow

1.3 CRUISE NARRATIVE
(Julian Dowdeswell)

Monday 30 August
JCR arrived at Isafjordur in NW Iceland at 10.00. The scientists for JR106b boarded the ship and began mobilisation of the equipment which had not already been used on the first leg of the AUI cruise. The corer was assembled and made fast in position, and the ship left Isafjordur at 17.00, making across Denmark Strait for the continental shelf edge off Kangerdlussuaq Trough. The weather had deteriorated during the day from a fine morning to a damp and windy evening. At 17.00 it was decided to alter course to approach the mouth of Kangerdlussuaq directly as the weather deteriorated further and a poor forecast was received.
Noon position: alongside in Isafjordur, NW Iceland.

Tuesday 31 August
Poor weather throughout the day. Force 8-9 with high and confused seas in the morning, moderating to about force 6 in the afternoon and approaching force 8 again in the evening. No scientific work, except for swath data acquisition, was possible and our course had to be altered several times to avoid severe rolling. A 32º roll necessitated a further course alteration and we hove to in heavy and confused seas for part of the night.
Noon position: 66° 58.2’ N, 30° 47.5’ W

Wednesday 1 September
We approached the mouth of Kangerdlussuaq Fjord at about 08.00 and the mist cleared to reveal the mountainous coastline of East Greenland. Collected five CTDs and swath data across the fjord mouth in improving weather conditions with a rising barometer. We had our first look up the fjord as the fog cleared further about lunchtime. Proceeded up the main fjord in afternoon, passing Amdrup and Watkins fjords which both appeared to be quite full of ice. Weather calm and beautiful glaciers and mountains. Headed into Courtauld Fjord, after getting a view up Kangerdlussuaq Glacier to the interior of the Greenland Ice Sheet. Courtauld Fjord is a six mile-long and two mile wide inlet trending NE. Saw Inuit hunting party operating from small boats. Approached to within

200 m of the tidewater ice front of Courtauld Glacier and obtained swath coverage. Overnight collected 5 CTDs and 3 gravity cores in Courtauld Fjord, together with swath coverage, still in calm conditions.
Noon position: 68° 07.7' N, 31° 44.0' W

Thursday 2 September
WASP deployed at 0.5 NM from the tidewater front of Courtauld Glacier at 09.00 for a half-hour traverse. A second deployment then took place at 3.4 NM off the glacier in deeper water. Inspection of the imagery collected showed that the water close to the sea floor was generally turbid, but some starfish were noted. Moved down-fjord to open water near the mouth of Watkins Fjord to undertake a buoyancy test of Autosub with fins attached. Passed kill site where hunters had skinned seals on an ice floe. Overnight work hampered by 25 knot winds blowing off the ice sheet, moving ice rapidly down-fjord. However, two CTDs acquired when wind died down in early hours.
Noon position: 68° 26.6' N, 32° 15.0' W

Friday 3 September
Autosub tested with fins in open water at the fjord mouth at 06.00. Weather overcast with light winds, but appeared to be clear and sunny in the inner part of the fjord. Successive deployments of WASP and then trawling gear were then undertaken in about 600 m of water. A helicopter overflew the ship after lunch. During the afternoon, further tests of Autosub to attempt to overcome the buoyancy problem associated with low salinity water. A two hour run was successful except that the vehicle failed to reach close to the sea floor. Overnight collected cores and CTDs and proceeded up the main fjord to reach Courtauld Fjord about 07.00.
Noon position: 68° 03.3' N, 31° 46.2' W

Saturday 4 September
Initially calm conditions in Courtauld Fjord allowed completion of the JCR swath dataset and the collection of two gravity cores. A transect of CTDs was then taken across the fjord and a trawl for macro-benthos. Autosub was prepared for an afternoon mission to collect swath data, CTDs and water samples close to the ice front of Courtauld Glacier. Unfortunately, the mission failed due to a mechanical problem. The stern plane became locked and the vehicle dived to the bed. The mission was aborted and Autosub recovered. The vehicle will be out of action for the next day or so. The wind rose during the early evening, and cleared Courtauld Fjord of ice. However, ice from the main arm of Kangerdlussuaq Fjord was forced south down the fjord, and winds of about 30 knots kept us pinned in the shelter of Courtauld Fjord overnight.
Noon position: 68° 29.7' N, 32° 13.2' W

Sunday 5 September
The problem with Autosub was less severe than first thought, so the day was devoted to Autosub missons. The aim was to run tracks close to the front of the tidewater Courtauld Glacier. The wind appeared to have cleared out most of the ice and the mile or so close to glacier was largely free of ice. A morning mission was aborted early due to the vehicle sensing an object, which was probably the sea floor. A further run in the afternoon was longer. The vehicle was late in surfacing, but was recovered satisfactorily. In the evening we proceeded to the mouth of Courtauld Fjord, with a view to attempting to go up the main fjord towards Kangerdlussuaq Glacier itself. The inner fjord was almost completely blocked by ice. In addition, high winds were moving very large bergs, with keels of up to about 400 m about at several knots. A CTD was attempted in mid-channel before work was abandoned for safety reasons due to the strong winds and moving ice. The night was again in the shelter of Courtauld Fjord.
Noon position: 68° 29.8' N, 32° 12.4' W

Monday 6 September

Once again we started from Courtauld Fjord at first light with a view to taking a transect of CTDs across the main channel and then to moving up to Kangerdlussuaq Glacier. High winds and very heavy ice were again encountered. After consultation with the Captain, it was agreed that the nature of the ice in the inner fjord precluded travel in that direction. Study of satellite imagery received during the cruise indicated that the very large amount of ice in the inner fjord was probably due to the partial breakup of the 'siksuaak' (a mix of large bergs and multi-year sea ice) fringing the floating terminus of Kangerdlussuaq Glacier. This had injected a huge volume of ice into the inner fjord during the cruise. CTDs across the fjord were again attempted, but high winds and fast-moving ice again forced us to move down-fjord. We entered Watkins Fjord with a view to finding a site to deploy Autosub close to the margin of Fredrikborg Gletscher at the fjord head. This fjord was mapped using the JCR swath and five sediment cores were collected, given that wind conditions were calm once out of the main fjord. Inspection showed that there was no shore lead close to the ice front, which would have made Autosub deployment in the almost ten tenths ice cover very difficult. A battery change for Autosub took place, making it ready for use the following day.

Noon position: 68° 16.0' N, 31° 31.9' W

Tuesday 7 September

Overnight sheltering from high winds in entrance to Watkins Fjord. At first light attempted CTDs in the main fjord, but blown off station. Headed for the more sheltered Amdrup Fjord, looking for open water to deploy Autosub near one of the several glacier fronts here. Proceeded up the ten mile-long fjord with swath running and taking gravity cores. Inspected each ice front, but all were barred from Autosub or WASP deployments by heavy ice. Continued to collect swath and cores from ice-proximal locations throughout the day. Returned to the main fjord in the evening, where winds provided sub-optimal but just workable conditions for the acquisition of the two remaining CTD stations needed to complete a transect across the main fjord. Again sheltered in Watkins Fjord mouth overnight.

Noon position: 68° 13.8' N, 32° 28.1' W

Wednesday 8 September

Steamed from Watkins Fjord to the mouth of Kangerdlussuaq Fjord at first light. An Autosub mission was planned and the vehicle deployed. The mission was in part successful but the telemetry system unit failed and recovery was difficult. We then undertook several WASP runs at 300 m and 400 m of water depth, followed by successful dredges. Some delicate cold-water corals were among the organisms collected. The failed unit on Autosub was replaced with a spare and a new mission was planned to run overnight. The vehicle was deployed at 23.30, and a further WASP runs at 500 m and 700 m were made. Weather good in the fjord mouth with a declining swell.

Noon position: 68° 03.9' N, 31° 42.2' W

Thursday 9 September

After a successful Autosub mission at the mouth of Kangerdlussuaq Fjord, the vehicle was recovered and a calibration CTD was obtained. At about 08.30 we left the Kangerdlussuaq Fjord mouth for our final pieces of swath and CTD of work on the shelf. Proceeded SE and then S along the cross-shelf trough, which is about 190 NM from the fjord mouth to the shelf break. Taking CTDs at regular intervals and collecting swath data. Obtained one block of swath imagery over glacial lineations in the trough.

Noon position: 67° 40.2' N, 31° 26.3' W

Friday 10 September

Continued CTD and swath transect across the shelf. Reached the shelf edge about noon and collected a further block of swath data and CTDs at 1000 m and 1500m before setting sail for the UK at about 19.00. Noon position: 65° 22.0' N, 30° 29.7' W

Saturday 11 September
Made good passage past Iceland in increasing winds
Noon position: 62° 49.4' N, 23° 42.3' W

Sunday 12 September
Winds increased to NE gale or severe gale and ship hove to at about 14.00. Remained hove to and moving slowly NE for the rest of the day. Cruise dinner postponed until weather improves. Clear that the gales will preclude us from reaching Immingham for Wednesday morning.
Noon position: 62° 36.4' N, 12° 50.9' W

Monday 13 September
Remained hove to west of the Faeroe Islands in NE gales until about 13.00, when the Captain turned the ship and we ran with the sea on a course just west of south. Weather largely unchanged. Took another NE tack in the night.
Noon position: 62° 01.1' N, 09° 51.3' W

Tuesday 14 September
Gale still blowing in morning. At about 13.00 were able to resume direct passage to UK as wind slowly reduced from gale force.
Noon position: 60° 40.9' N, 08° 18.0' W

Wednesday 15 September
Off Dunnett Head and through the Pentland Firth by 07.30, then sailing down the North Sea with a following wind.

Thursday 16 September
Arrived at Immingham Dock in early afternoon for demobilisation.

2. AUTOSUB OPERATIONS

2.1 AUTOSUB MISSIONS
(Steve McPhail)

Kangerdlugssuaq Fjord posed serious operating difficulties for Autosub:

- The Fjord system had high coverage of icebergs of a variety of sizes, from small lumps to 400 m draught icebergs, calved off the main glacier. The main hazards were floating bergs of estimated 50 m draught. (Fig. 2.1).
- The northern end of the Kangerdlugssuaq Fjord glacier was totally inaccessible, even for the ship, due largely to a major breakout of 'sikussak', a mix of multiyear sea ice and icebergs, just before our arrival.
- The waters in most of the inner fjord system were extremely turbid. With a minimum safe flying altitude of 10 m, there was no hope of getting any images with the Autosub camera close to ice fronts. Wasp managed some photography in the fjord mouth at about 1 m altitude.
- The only area in the fjord system where relatively safe operation of Autosub was possible was at the tidewater glacier front of the Courtauld Fjord. This had a rather limited working area of half a mile wide, constrained by a grounded iceberg to the west, and the sides of the fjord. Floating bergs were in constant motion, driven by wind and swirling currents, making choice of a safe recovery position difficult.

- The Courtauld Fjord working area, with water depth ranging from 100 to 170 m, had less than ideal headroom between the estimated draught of icebergs (50 m), and the ideal operating altitude for swath survey (70 m).
- Poor acoustics, due to reverberation in the enclose area, limited our confidence in use of homing system to guide Autosub to a safe recovery area.
- The salinity near the ice front ranged from 20 ppt on the surface to 34 ppt at depth, causing serious buoyancy problems for Autosub. We quickly found out that neither the ship-lowered CTD or the underway sensors (inlet at 6 m) adequately sampled the surface layer, critical to whether Autosub floats at the end of the mission. Even a seawater density reading obtained by sampling the sea surface with a bucket was affected by the ship's motion and thrusters mixing up the surface layers. To obtain a reliable surface density measurement 5 m out from the ship, we resorted to using one of the ship's cranes and a bucket.
- The prevalence of surface ice precluded any attempt to dive using a surface run-up. In one of the first missions all the propeller blades were cut off by surface ice. This meant that each mission had to use a dive weight, and the vehicle recovered between deployments, with a consequent time penalty.

With the observed salinity problem, we engineered a solution and test in the fjord mouth. After four attempts we came up with "wings", attached aft of the centre of gravity of Autosub which provided the necessary extra downward force to overcome the extra buoyancy at depth. These tests were carried out in the mouth of the Kangerdlugssuaq Fjord (Missions 369 to 372 on 2/9 and 3/9/04.). At the end of mission 372, the Autosub bumped the ship on recovery, fortunately with only very minor damage.

Three missions were attempted approximately 300 m off the Courtauld glacier front, to carry out a lawn mower pattern swath survey and make CTD measurements in the water affected by the glacier melt- water.

The first mission (Mission 373 on 4/9/04) crashed straight into the seabed due to a wet connector failure (not related to previous problems with Autosub connectors). Current had tracked between two pins on the connector, damaging both the bulkhead connector and the plug. We suspected a slight water leakage past the 'O' ring seal. The tracking caused failure of the of the Hall effect sensors in the sternplane actuators, and consequently failure of the actuator. We released the Autosub by sending an "End Mission" command by acoustic telemetry.

Autosub damage was fairly superficial. Damage to front panels, slight bending of front sub frame, plus the repairs needed to the sternplane actuator. Autosub was ready for the next mission within 24 hours.

The next two missions (374 and 375 on 5/9/04) were plagued by the forward collision sensor causing the vehicle to enter collision avoidance mode, and finally giving up on mission. The second mission went some distance, and swath (Figure 1)+ CTD data were collected in a small area in front of the glacier. The initial thoughts were that the system was falsely triggering, but later analysis indicated that it had acted correctly in initiating collision avoidance. On one occasion it detected a definite near surface target (an iceberg presumably) on another two occasions seabed topographic features caused triggering of the collision avoidance behaviour. It is apparent that the shipboard swath tends to smooth out seabed features, thereby missing potential hazards.

Finally we ran two missions in the mouth of the Kangerdlugssuaq Fjord. The first attempt (Mission 376 on 8/9/04) to try and acquire camera data was unsuccessful, although swath data was obtained during this mission. Again, this was due to triggering of the collision avoidance system. The acoustic telemetry and command system (Seapam) completely failed on this mission, hence we had little knowledge of the state of the Autosub. The only way we could track the Autosub was by measuring the arrival time of the ten-minute transmissions of the emergency beacon. With Autosub commanded to circle a waypoint at the end of the mission at 150 m depth, and with no acoustic command system, we had to wait for the automatic abort system to surface the Autosub 8 hours after the start of the mission.

The final run of JR106 south (Mission 377, 8 to 9/9/04) was a 7-hour CTD section across the Kangerdlugssuaq Fjord mouth, ending with a camera run at 10 m altitude and 550 m depth (Figure 2.2). This was almost entirely successful, although the camera system took only 20 photographs. Again, the collision avoidance system repeatedly commanded the Autosub away from the seabed during the camera run, hence limiting the number of photos taken within the useful 10 m range. The CTD profile was successfully obtained. Swath data was also obtained. Table 2.1 summarises the Autosub Missions.

Table 2.1. Missions Summary Log JR106b

#	Date	Location	Time: Start - End	Start Position	Description and comment
369	02/09/04	Kangerdlugssuaq Fjord Mouth	17:40, Restarted 17:59. End 18:14	Positional navigation not used.	Wings Test. First version of wings to try and help the vehicle cope with density changes of 1016 on surface to 1025 at depth. Surface run up dive heading 120 then 5 minutes at 110m then return for 5 minutes on heading 300 at 80m. Autosub failed to dive as there was insufficient run up speed. The propeller blades were then broken off by ice on a second run up attempt. Consequently the Autosub was recovered to the ship.
370	03/09/04	Kangerdlugssuaq Fjord Mouth	06:42 – 07:10	Positional navigation not used.	Wings Test 2 Drop weight dive to 15m then heading 120 for 5 minutes then heading 300 for 5 minutes. Spiral to surface and stop. Autosub dived and maintained depth but mission data showed control was only just stable. The conclusion was that the buoyancy at depth was too great and that although the wings were helping they were not effective enough.
371	03/09/04	Kangerdlugssuaq Fjord Mouth	15:00 – 15:30	Positional navigation not used.	Wings Test 3 Wings test with the new improved wing design. Further back, sturdier and better aspect ratio. Wings are 0.4 m chord and 0.3 span, each side just in front of the aft ring. Head out for ten minutes, return for ten minutes. Mission data showed that these wings were effective and control stable.
372	03/09/04	Kangerdlugssuaq Fjord Mouth	16:57 – 20:24	N:68:05.0, W:031:47.45	Wings and Homing Surface dive to wp2, return to wp1 and descend to wp1 at 750m, then track wp1-wp2 at 75m then wp2-wp1 at 10m then hold at 170m awaiting homing signal and commands. Autosub control stable and homing system functioning.
373	04/09/04	Courtauld Fjord Glacier front	14:40 – 15:20	N:68:29.9, W:032:11.9	Courtauld Fjord Survey 1 Plan: Drop weight dive then to wp2 via wp1 to start first survey. 4 patterns at increasing altitudes end at holding waypoint at holding depth. Needs command to surface. What happened: Autosub crashed into the seabed, and continued bumping along the bottom until we sent a mission end command by acoustic telemetry. Cause was faulty underwater connector on stern plane actuator.

#	Date	Location	Time: Start - End	Start Position	Description and comment
374	05/09/04	Courtauld Fjord Glacier front	13:24 – 15:01	N:68:29.9, W:032:11.9	Courtauld Fjord Survey 1 Drop weight dive then to wp2 via wp1 to start first survey. 4 patterns at increasing altitudes end at holding waypoint at holding depth. Needs command to surface. What happened: Prevalence of collision imminent indications from forward range sensor meant that the avoidance-failed event triggered an early termination of the mission.
375	05/09/04	Courtauld Fjord Glacier front	17:02 – 19:13	N:68:29.9, W:032:11.9	Courtauld Fjord Survey 2 Drop weight dive then descent via wp1-wp2 then track wp1-wp2, wp3-wp4 at alt1 then cross to wp2 then track wp2-wp1,at alt 2 and wp1-wp2 at alt 3 then go to holding waypoint at holding alt and wait for command. What happened: Most extensive mission so far but trouble with avoidance triggers still prevalent. Mission terminated early.
376	08/09/04	Kangerdlugssuaq Fjord Mouth	11:51 – 18:12	N:68:4.2, W:031:42.0	Kangerdlugssuaq Fjord Mouth Photo Run Drop weight dive. Head to wp2 while descending to 400m. When got depth turn to wp3 and continue descent to 10m photo altitude Track wp3-wp4, wp4-wp3 Track to holding waypoint at holding depth to end What happened: Mission ran well but avoidance during the photo run meant that few if any images were taken. SeaPam failed at or before mission start so there was no telemetry or tracking. Mission ended on mission timeout abort.
377	08/09/04 – 09/09/04	Kangerdlugssuaq Fjord Mouth	08/09/04 23:39 – 09/09/04 06:44	N:68:7.56, W:31:51.38	Kangerdlugssuaq Fjord Mouth Survey 1 Drop weight dive to HOLD at WP_1 at HOLDING_DEPTH - MTE_1 on segment timeout to surface. Leg1 wp1-wp2 at DEPTH_1 Leg2 wp2-wp1 at DEPTH_2 Leg3 wp1-wp3 at DEPTH_3 Track wp3-wp4 to get to photo run. Leg4 wp4-wp5 at PHOTO_ALT Run to HOLDING_WP at HOLDING_ALT What happened: Mission ran to plan. Photographs acquired despite some collision avoidance activity on the low altitude leg.

Figure 2.1. Typical conditions at glacier front on Courtauld Fjord.

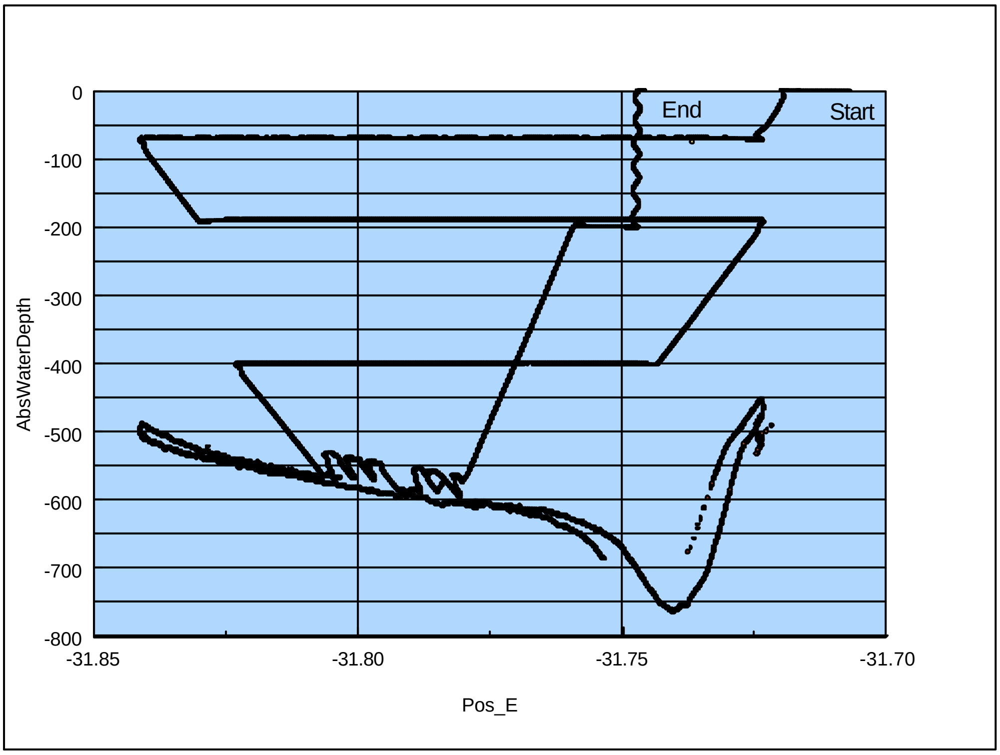


Figure 2.2. Mission 377. Final Autosub Mission of JR106b. Shows depth profile of Autosub track (verses longitude). Lower brown track is the seabed profile measured using the Autosub's downward looking ADCP.

2.2 AUTOSUB MECHANICAL REPORT

(Pete Stevenson and Andy Webb)

Mobilisation

The configuration of Autosub for the second leg of JR 106 was similar to the first leg. Changes made before sailing from Isafjordur were:-

- Changing the EM2000 multibeam system from looking upwards to looking downwards.
- Removing two battery packs (42 kg total), one from pressure vessel 3, one from pressure vessel 4. This was in anticipation of low-density fresh water layers close to the glacier edges where Autosub potentially would have insufficient buoyancy to float.

The layout on the aft deck of the Autosub gantry and the two containers was the same as the previous AUI campaign in 2003 (JR 84) (Fig. 2.3).

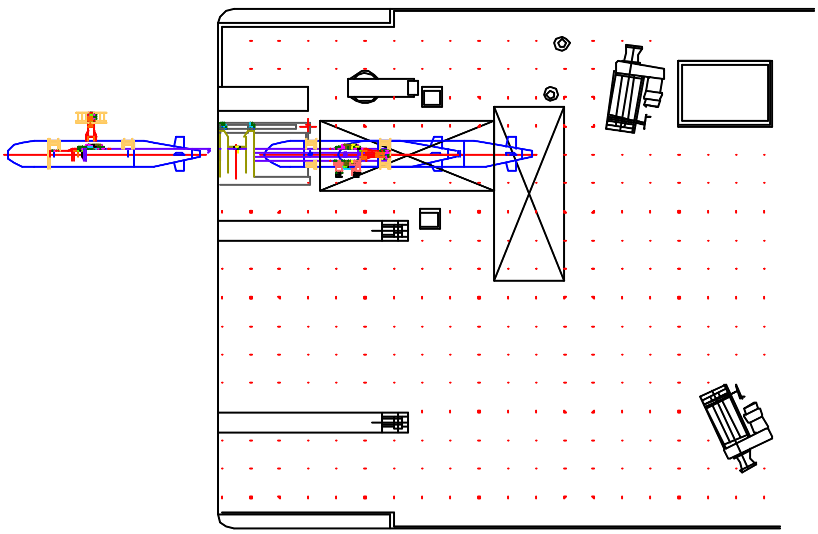


Figure 2.3 Plan layout of the containers on the aft deck

Vehicle configuration

Figure 2.4 is a schematic showing the basic vehicle layout. Table 2.2 is the relative positions of the sensors on board, with respect the vehicle datum (the bottom of the forward bulkhead joint).

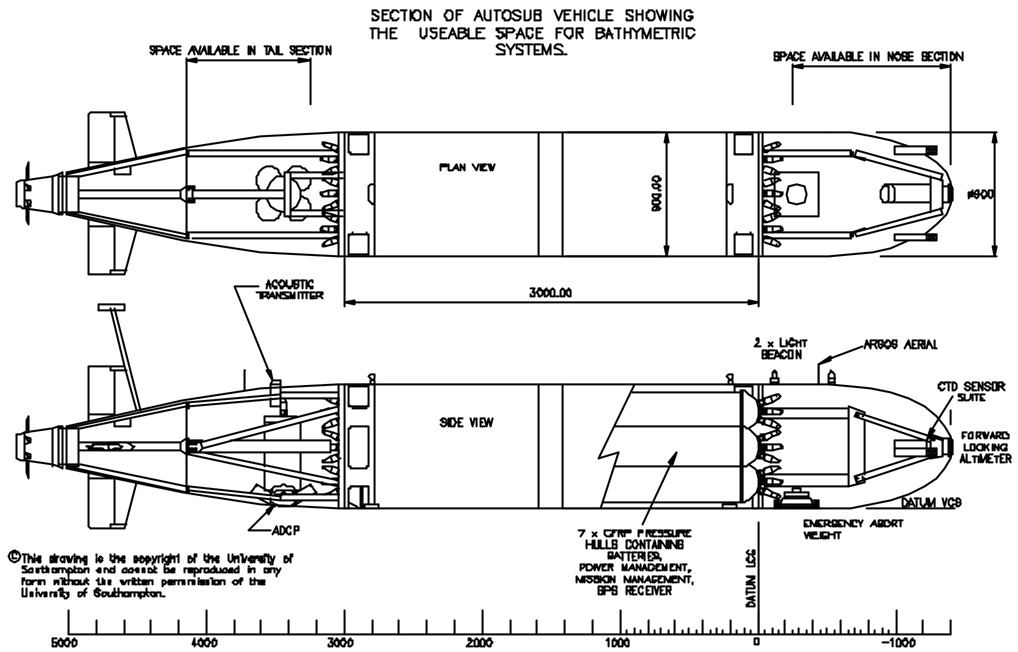


Figure 2.4. Vehicle layout showing sensor space and datum.

Sensor	Longitudinal position of sensing element wrt vehicle datum (m)	Vertical position of sensing element wrt vehicle datum (m)	Remarks
CTD (port and starboard)	-1.1	0.45	Ports side, CTD Temperature 1, Conductivity 1. Starboard side, CTD Temperature 2, Conductivity 2
Oxygen sensor	-0.57	0.45	Plumbed in the starboard side with Temp2 and Cond2
Digiquartz Depth sensor	-0.5	0.65	
EM 2000 Transmitter	-0.65	0.8	Position of transducer head looking upwards
EM 2000 Receiver	3.87	0.7	Position of transducer head looking upwards
300kHz ADCP	3.33	0.85	Position of transducer heads looking upwards
150kHz ADCP	3.45	0.1	Position of transducer heads looking downwards
Forward looking echo sounder	-0.14	0.45	Position of transducer head looking forwards
Camera	4.0	0.1	Mounted vertically
Camera flash	-0.97	0.1	Tilted to illuminate spot beneath camera at 10m altitude
Aqualab water sampler	-0.69	0.55	Position of sampling ports

Table 2.2. Positions of sensors relative to vehicle datum.

Operations

Autosub is designed to operate with 8 to 12 kg buoyancy. This helps give a fail-safe mode whereby the vehicle will float if all systems have failed but will dive and control pitch without the need of complex buoyancy control systems. This mode of operation has served Autosub programmes well but does assume a relatively constant water density (within 2 kg/m^3). Fresh water outflows close to the edge of the glaciers could give variations in density that could either prevent Autosub from floating on the surface or not being able to control depth due to the increase in water density making the vehicle too buoyant for the stern planes to control.

Density measurements were taken through the night of 1st – 2nd Sept using a bucket lowered over the side and a hydrometer to measure the water density. This showed a range of 1020.5 to 1024 kg/m^3 but it was noted the ship, although stationary, had disturbed the very top layer. Measurements taken later on (4th Sept) showed a density of 1024 taken from the starboard side and 1016.5 taken from the ship's bow, before it was disturbed by the ship's passage. These fresh layers failed to be detected by the ship's salinometer or the CTD casts.

Strategies to cope with such density differences were either:-

- to run the sub with an additional weight to give the correct buoyancy at depth. This would be jettisoned when the sub had finished its mission as was required to float.
- To add winglets to the body to provide additional down force, enabling the stern planes to control the depth.

The second option was chosen, long thin winglets from aluminium sheet 130mm wide 1500mm long, were fitted to the rear half of the centre section (Fig. 2.5). A test run showed the pitch and stern plane response was adequate to control depth but the stern planes tended to be at a high angle with little margin left for responding to sudden demands in depth changes (Fig. 2.6). A Mark II style of wing was fitted with a similar area but more stubby and fitted further aft to improve the vehicle's stability (Fig. 2.7).

Figure 2.5 Slender wings fitted to rear half of the centre section

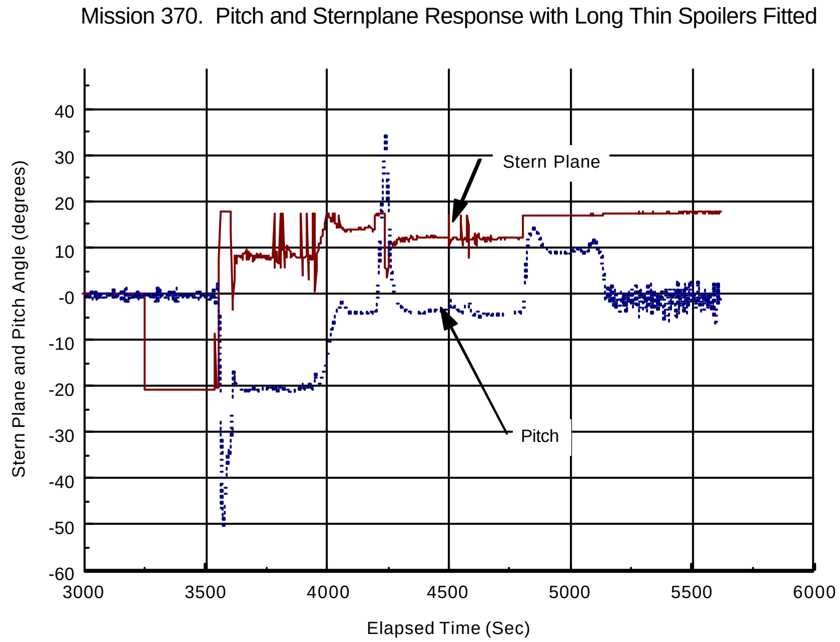


Figure 2.6. The time period from 4300 to 4700 seconds show the time of level, steady flight, the stern plane angle of 12 degrees is close to its full travel (17 degrees).

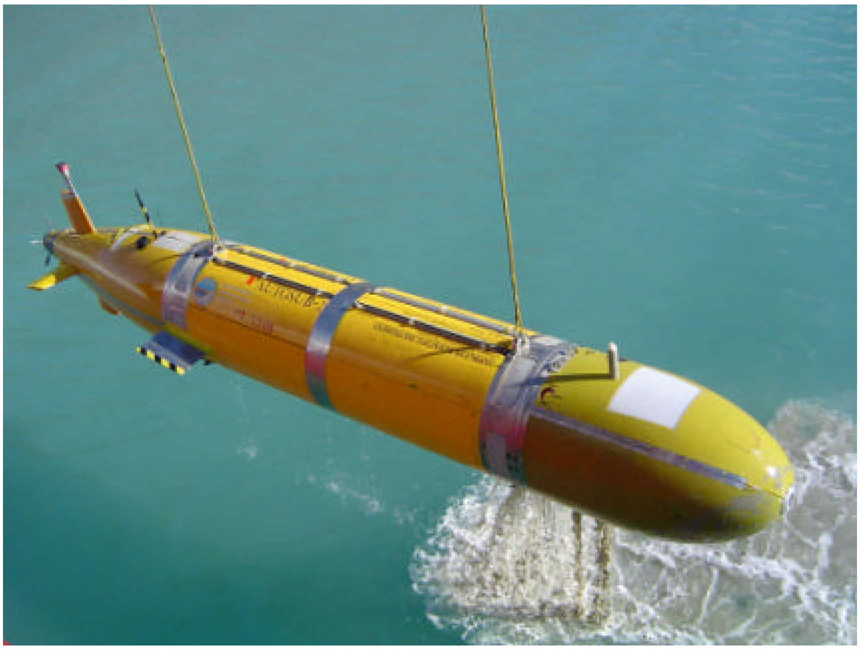


Figure 2.7. Shorter, stubbier wings made to improve vehicle stability

The change in aspect ratio and position had the desired effect in enabling the vehicle to fly at modest pitch and stern plane angles (Fig. 2.8). The vehicle was operated in this configuration for all the missions in Leg 2. The dive weight used to at launch to sink the sub beneath any brash ice was increased from 20kg to 30kg to ensure the vehicle would not be suspended in a dense layer, unable to reach the depth required to switch on the propulsion motor. This did not cause any difficulties in operations other than using up the supply of 10kg abort weights to supplement the sink weight.

It was noted that the vehicle roll angles were excessive when turning and showed signs of instability. This was corrected during the battery change by installing 6 packs in tube 2 and 5 (on the centre line of the vehicle) and 7 packs in tubes 3 and 4. In addition, a 9.7 steel ballast weight was lowered 440mm to increase the BG value (the vertical centre of buoyancy less centre of gravity) from 14 to 19mm. This brought back the roll extremes to acceptable limits. A full log of the ballast and trim changes made throughout are logged in the NAVAUI JR106 2004 MissionN°.xls Excel spreadsheets.

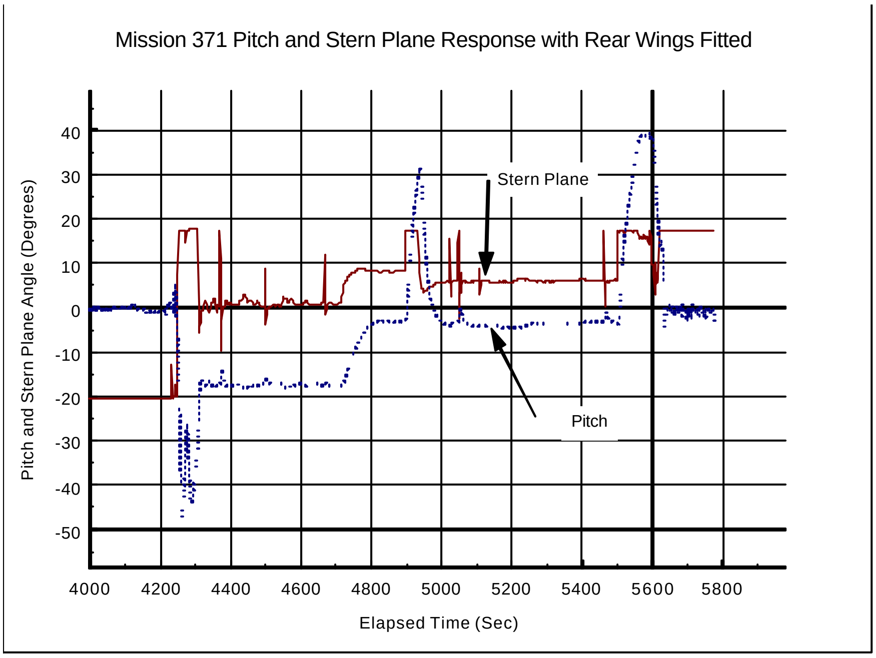


Figure 2.8. The time period from 5100 to 5400 seconds show the time of level, steady flight, this time with a less pronounced stern plane angle.

With one exception, the vehicle performed well, with few mechanical faults. Problems encountered were:-

- Stern plane jammed down, making the vehicle unable to control depth. The sub crashed into the soft bottom and was returned using an acoustic command from the ship. The problem was traced to a failed underwater connector. This was replaced, checked out and caused no further problem.
- The top rudder was knocked askew by a piece of ice during a recovery. The zero was mechanically reset without any problems.

Repairs and maintenance to the vehicle included:-

- Flushing out CTDs after scooping sediments off the bottom (see above)
- Repair of Starboard GFRP panel and straightening of nose famework (result of bottom crash)
- Battery changes
- Flushing of CTDs after each mission
- Cleaning and re-greasing propulsion motor bearings
- Recovery line stuffing
- Packing the “Jack in the Box” grappling line
- Adjustments to ballast and trim

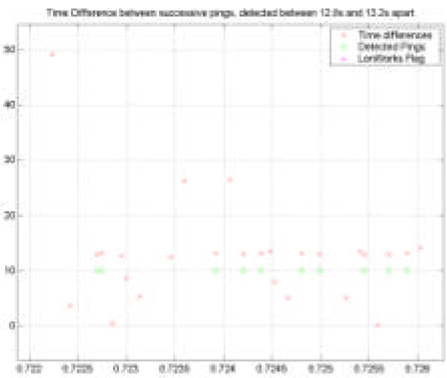
The major consumables used were:-

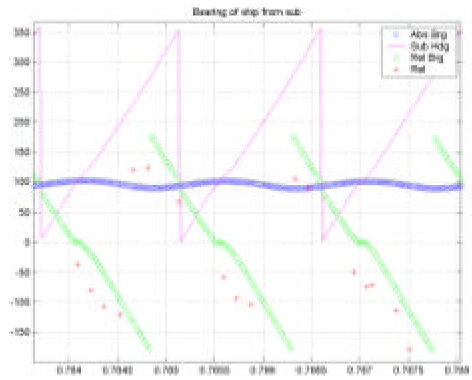
- 2 battery sets (26 packs/set).
- 10 Abort weight
- 6 sink weights

2.3 AUTOSUB HOMING AND TRACKING SYSTEMS
(Miles Peabody)

Homing System

The homing system was not used on any of the missions, but on M375 it was tested. The mission was run at the head of Courtauld Fjord, close to the ice edge. Transmissions at a 13 second repetition rate show that a homing signal would be correctly detected and interpreted, despite the adverse acoustic conditions. The green diamonds on the left hand diagram show the number of successful detections. The right hand diagram shows the relative bearing detected by the sub (red crosses) and the relative bearing of the ship from the sub (green diamonds).





There is a slight offset on the detected bearing which is due to a clock error on the PC used to log the ship's position. Otherwise the pings would have been detected and the sub would have turned in the correct direction towards the ship.

Acoustic Tracking and Communications

The primary acoustic tracking system, the ORE Trackpoint-2, did not function and had to be replaced with the backup system, the LXT. The LXT transducer was mounted on the tow-fish but the plotting program, the IPS, did not always plot the transponder replies. The stability and accuracy of the LXT, however, meant that using the raw data to get the sub's range and bearing was straightforward. Usable ranges of up to 2km in the fjords were obtained, but reliable ranging was generally at 1km or less.

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

The Applied Acoustic digital acoustic link was used over ranges of 1000m or less, and worked as well as it had done on the first leg.

On M376 there was no acoustic communication or tracking from the sub. After the mission it was determined that the SeaPam transponder's receiver had failed, and it was replaced for the final mission. The sub's position was determined by three fixes using the emergency beacon transmission, which was set to go off every ten minutes during the mission. In the absence of any digital commands, the sub timed out and dropped the abort weight.

2.4 AUTOSUB POST-PROCESSED NAVIGATION DATA FORMAT
(Steve McPhail)

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

Table 2.3. Data Field Definition Table

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

Field	Units	Description
MCLongDem	degrees	Longitude and Latitude Demands from Mission Control. Effectively are the mission waypoints.
MCLatDem_		
Total Power	Watts	Total electrical power usage.
battery_V	Volts	Battery Voltage.

2.5 AUTOSUB SCIENTIFIC SENSORS
(Steve McPhail)

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

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

These instruments are described separately. Table 2 in the Autosub Mechanical section of this report shows the exact sensor locations. All the electronic systems on the vehicle are connected to a single control network. The data from all sensors apart from the multibeam system are recorded on the Autosub data logger. The Autosub logger uses a proprietary data format but the data is translated into standard ASCII text files using the Logger File Translator software running on a PC. This software also translates the CTD data into a standard Seabird format file. The resultant ASCII file is then imported into the Axum processing software and a standard script is run to produce the general post processed navigation file (.bnv file) and various instrument specific files including a navigation file for the EM2000 multibeam system.

Sensor Synchronisation

The time synchronisation of the various on-board systems is important, especially where data from different systems is likely to be merged at a later date (post processed navigation data for the EM2000 is one example of this). Wherever possible the network time protocol (NTP) system is used which allows for time comparisons with a resolution of better than 1millisecond. The primary reference is a GPS receiver that sends an accurate pulse on each second boundary to the Autosub shipboard data server. The Edgetech sub-bottom profiler acts as the primary Autosub vehicle timeserver and uses the Autosub shipboard server as a reference whenever Autosub is in contact with the ship. The Autosub logger can synchronise to the Edgetech on start up and the Kongsberg EM2000 is synchronised to the logger. One problem is the poor quality of the logger clock that can drift by 10 seconds in 12 hours. The data processing system can measure and compensate for this drift so that the data output in the navigation files is correct. However, in the case of the EM2000, the raw time must be used for the post-processed position timestamps rather than the drift compensated position. A revised version of the logger file translator software (V2.90.06) was produced which outputs both raw and compensated time (JR106.axs).

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

Seabird 911 CTD System

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

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

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

2.6 AUTOSUB ADCP DATA DEFINITION
(Steve McPhail)

Physical Arrangement

Autosub has two RDI ADCPs:

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

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

Approximate performances seen during JR106 are:

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

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

The beam arrangements are : (Looking down)

Upward looking ADCP:

```
           FWD
        3    :   1
PORT         :          STARBOARD
        2        4
           AFT
```

Downward looking ADCP

FWD
1 : 3
PORT : STARBOARD
4 : 2
AFT

Files

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

This file also contains a lot of Autosub engineering and (unprocessed) navigation data, some of which might be of interest.For post processed (more accurate) navigation data, you might want to use the Mxxx.bnv (best navigation) file which is described in a separate document. Where there is no data within a 2 second period the missing data value is represented by –999

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

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

ADCP Data Fields in the Mxx.ls2 files

Table 2.4. ADCPbin[0] Frame 0 is a special frame with ADCP configuration data

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

Table 2.5. ADCP water profiling data bins[1 to N]. Example shown for the first bin (index 1)

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

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

Table 2.6. Other Data fields in the ls2 files which are of interest to users of ADCP data

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

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

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

Hints for processing the ADCP data.

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

Processing steps:

Transform "Ship Levelled" to geographical.

e.g.

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

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

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

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

2.7 AUTOSUB CAMERA

Hardware

The camera system onboard Autosub is a Starlight SXV-H9, a black and white CCD imager intended for use by amateur astronomers. The imager was selected for its good sensitivity (particularly in the important blue part of the spectrum), low readout noise (about 20 photons rms equivalent), and high dynamic range. An integral data logger records the images on hard disc, which can be accessed via the Autosub radio network. The camera is installed in the tail section of Autosub, and a Minolta Zoom flash is installed within a pressure case at the nose of Autosub. Separation between flash and camera is 4.5 m.

The camera aperture was set to f2.8, and the lens has a focal length of 70 mm. The image sensor has an array of 1040 by 1392 of 6 μm square pixels, making an imager size of 6.24 by 8.35 mm. (11 mm diagonal). With an air-water magnification factor of 1.4 this equates to an image diagonal of 2.2 m at a flying altitude of 10 m.

The Autosub Navigation file is processed to produce files with name Mxxx.cam where xxx is the mission number. The fields in this text files are:

```
FrameDate,FrameTimes,FrameNum,FrameAlt,FrameDepth,FrameLat,FrameLng,FrameHeading,FramePitch,FrameRoll

example of data:
05/17/04,18:12:04,7.00,28.81,199.24,48.2516,-9.5967,274.58,-17.47,-2.37
```

Depth and altitude is in metres. Latitude, Longitude (negative to west), Pitch, Heading and Roll in degrees.

The camera data is stored in a raw 16 bit binary format. This data is archived but for quick viewing, but for a first look, Duncan Mercer (SAMS) has kindly provided a C program, which takes the raw data file and produces 8 bit .bmp files, which are automatically adjusted to a produce a reasonably good contrast image.

We have already done this processing on the images provided so far. To run the Mercer program, copy “autosubIMGparser.exe”, and “CallParser.bat” to the directory where the .img files are stored, then run the batch file.

Results, Limitations and Suggested Improvements

We obtained a total of 22 usable images on mission 377. The number of frames collected was reduced by the Collision avoidance behaviour, which repeatedly commanded the Autosub to a safe altitude of 40m, from its flying altitude of 10 m.

You will notice that the direction of the shadows indicates that the images are presented (by the Mercer program) with the bottom of the frame corresponding to the forward direction of Autosub.

The flash does not fully illuminate the frame. Some automatic (software) means of levelling the illumination might prove useful. This could be combined with processing software which preserves the 16 bit dynamic range of the signal.

Some image quality improvement may be obtained by attempting dark frame and / or backscatter frame subtraction.

3. OCEANOGRAPHIC OPERATIONS

3.1 NAVIGATION, BATHYMETRY AND OCEAN LOGGER

(Patricia O'Mahony and Louise Sime)

Navigation

On a daily basis an ascii file, get_bestnav, containing the RVS 'bestnav' position data at 30 second intervals is produced contained the ship's latitude, longitude, distance travelled and direction.

The resulting navigational output is converted into a .mat file, a standard Matlab output file with the application of a Matlab script, Create_goodnavdata_jr106s.m (by relying on a function, func_loadbestnav.m). The above Matlab script combines all daily output produced into a master file, bestnav_all_jr106.mat and also checks to see if the values are flagged as good values.

Bathymetry

Sea-floor depth measurements from an Simrad EA500 hydrographic echosounder and a hull mounted transducer were converted into an ascii file on a daily basis using the get_sim500 script, at 2-6 second intervals.

From the bathy.*** file produced daily by the get_sim500 script, by using the command 'source get_500sim', the bathymetry data was put into the same time interval as the navigational that is, 30 second intervals with the use of the Matlab output file, bestnav_all_jr106.mat (time,longitude and latitude). This step was carried out using the Matlab script Create_30secbathy_jr106s.m for the first day of analysis. This script evaluates a 30 second interval by looking at the 15 seconds on either side of the 30 second bin value. This script uses the function, func_loadsimrad.m, to extract the depth data from the bathy.*** file.

For proceeding days of the analysis, instead of using the script Create_30secbathy_jr106s.m which would redo the 30 second binning for all bathy.*** files, there is an option of using an append script, Append_30secbathy_jr106s.m. This script adds the latest depth data to previous day(s) data, enabling the output file, mergered_all_jr106s.mat to be reproduced much quicker.

NOTE: Since the time interval applied is the same as in the navigational output, the bathymetry step must be applied after the navigation step.

Ocean Logger

The data were read into Unix daily using the script get_oceanlog, by using the command 'source get_oceanlog', to produce an ocean.*** file for the particular Julian day, at intervals from 2 seconds upwards.

Using the Matlab script, Create_30sec_oceanlog_jr106s.m for the first day of analysis, the data are put into the same time interval as the navigational data (from the output file, bestnav_all_jr106.mat). Corresponding latitudes and longitudes from the bathymetry data are also included in the output file. The Matlab script uses the function, func_loadoceanlog.m to extract data such as sea surface temperature, salinity, flow, pressure and density from the oceanlog.*** file. See Table 1 for full list of variables included.

For proceeding days of the analysis, instead of using the script Create_30sec_oceanlog_jr106s.m which would redo the 30 second binning for all oceanlog.*** files, there is an option of using an append script, Append_30sec_oceanlog_jr106s.m. This script adds the latest oceanlogged data to previous day(s) data, enabling the output file, oceanlog_30sec_all_jr106s.mat to be reproduced much quicker.

Note: Since the time interval applied is the same as in the navigational output and the latitude and longitude values are applied from the bathymetry output, the oceanlogger step must be processed after the navigation and bathymetry procedures. Salinity samples were collected every 4 hours from the underway pump supply for calibration of the oceanlogger salinities. These calibrations have not yet been applied.

Table 3.1: Oceanlogger output variables

year	day	hour	minute	second	atemp1	Error1
hum1	Error2	par1	Error3	tir1	Error4	atemp2
Error5	hum2	Error6	par2	Error7	tir2	Error8
press1	Error9	press2	Error10	saltemp	Error11	cond
Error12	sal	E13	velocity	Error14	fluor	Error15
fstemp	Error16	flow	Error17	sst	Error18	

The following two figures (Figs. 3.1 and 3.2) show the ship's track in the fjord (from bestnav) coloured according to sea surface temperature and sea surface salinity (from oceanlogger data) respectively.

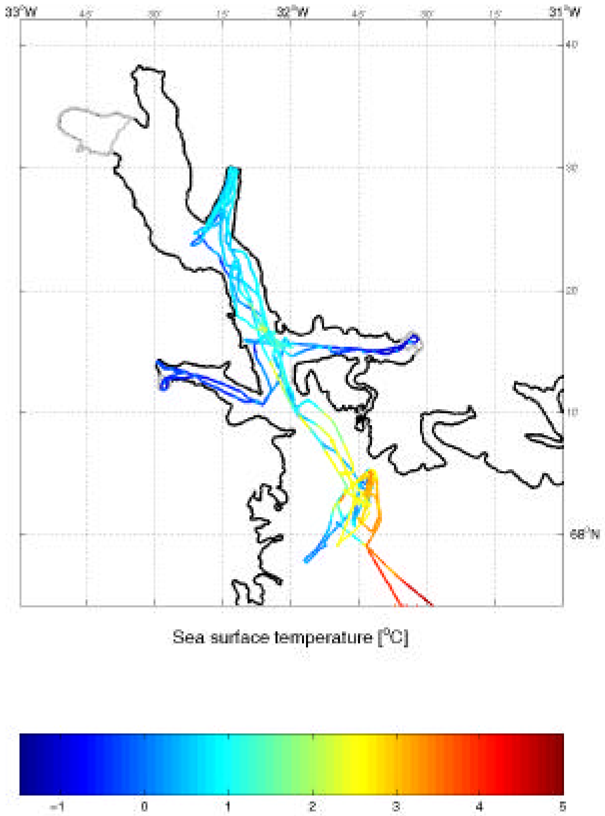


Figure 3.1 Sea surface temperatures in Kangerdlussuaq Fjord from oceanlogger data.

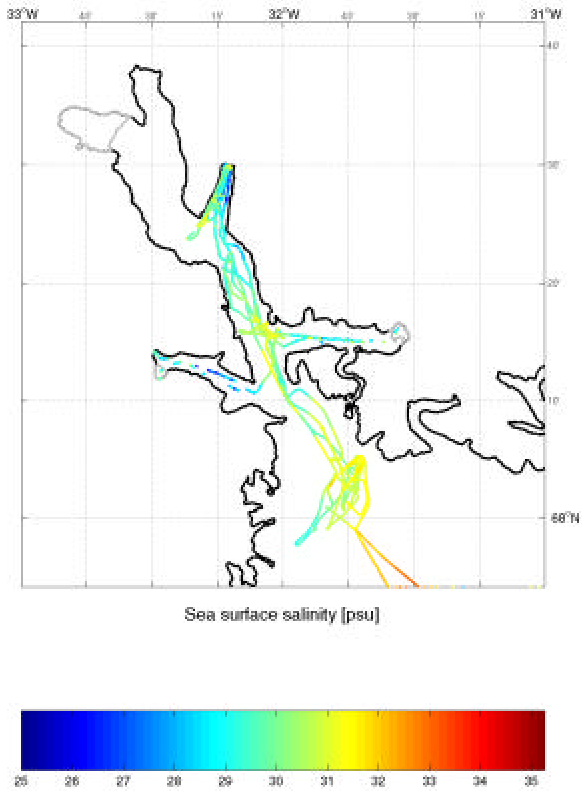


Figure 3.2. Sea surface salinity in Kangerdlussuaq Fjord from oceanlogger data.

3.2 CTD OVERVIEW AND PERFORMANCE
(Terry Edwards)

42 CTD profiles were carried out, ranging between 100m and 1500 m. NMEA lat and long were added to the header file as was time synchronised to the ships clock. GGA was used as RMC string was not available.

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

The above instruments were attached to the bottom of the SBE32 carousel (Ser: 0344). There was also a RDI LADCP 300 kHz system attached to the upper and lower brackets of the carousel. The distance of separation between the 2 ADCP units was approx. 106 cm + each sensor was approximately 24 cm tall.

The date of the last calibration and serial numbers for the oceanographic sensors can be seen below. A full copy of the calibration coefficients for all instruments can be obtained from Karen Heywood.

Channel CTD	Sensor	Serial Number	Date of calibration
1. Frequency	Temperature	4116	9/6/04
2. Frequency	Conductivity	2407	17/6/04
3. Frequency	Pressure, Digiquartz	73299	8/5/02
4. Frequency	Temperature2	2919	9/6/04
5. Frequency	Conductivity 2	2450	17/6/04
6. A/D voltage 0	Oxygen, SBE 43	0619	16/6/04
7. A/D voltage 1	Free		
8. A/D voltage 2	Altimeter	874	23/4/01
9. A/D voltage 3	Fluorometer,	Chelsea Aqua 3	88195 27/3/03
10. A/D voltage 4	Free		
11. A/D voltage 5			
12. A/D voltage 6	Optical BackScatter,	Seatech LS6000	
13. A/D voltage 7	Transmissometer,	Chelsea Aphatracka	161045 28/4/01

CTD001 highlighted a problem with noise on cond 2 sensor. This appeared to be a bad connection. Re-seating the cable appeared to solve the problem, but it re occurred intermittently on later casts. Sensor cable was replaced which cured the problem. The suspect cable appears to have a poor connection within the connector moulding.

CTD010 noticed the LBSS voltage was static. Traced this to poor insulation on 2 pins on the sensor and possible water ingress. The sensor was removed.

In later casts, the logging PC crashed several times on a number of casts. The problem has not yet been isolated. It could not be reproduced during deck tests. The network connection was removed as a precaution, meaning a manual check on he PC clock had to be carried out periodically. During post processing it was noted that bad data was created at these times. It is possible that a degrading termination causing the software to crash and an inability of windows XP to deal with serial communications may be the cause. Further investigations are necessary.

3.3 CTD DATA

(Karen Heywood)

Forty-two CTD stations were occupied during cruise JR106S in the vicinity of the fjord and continental shelf (Figs. 3.3 and 3.4). These used a Seabird CTD and dissolved oxygen sensor, transmissometer, fluorometer, altimeter and 24 x 20 litre bottle rosette.

Each station was processed initially on a laptop using the Seabird processing software Seasoft. The files that are output by Seasave are of the type .DAT, .HDR, .BL, .ROS, .CON. The .CON files for each cast contain the calibration coefficients for the instrument. These are updated when calibration sheets are received back from the manufacturer. The .HDR files contain the information in the header of each cast file. The .DAT files are the data files from each cast and are in binary form. The .BL and .ROS files contain information on bottle firings on the rosette.

For initial data processing we used Seasoft's programmes, SBE Data Processing version 5.31b. The options we used were *Data Conversion*, *Align CTD*, *Cell Thermal Mass*, and *Ascii Out*. Data Conversion takes the .DAT file with the .CON file and outputs a .CNV file and a .HDR file. We used the options for binary output, and to create both bottle and data files. Align CTD applies temporal shifts to align the sensor readings. The offsets applied were zero for primary and secondary temperature, and for primary conductivity, -0.073 for secondary conductivity, and 5 for oxygen. We saved the output as nnn_align.cnv files. Cell Thermal Mass makes corrections for the thermal mass of the cell (important in strong thermal gradients). The constants used were an alpha of 0.03 and 1/beta of 7. This outputs the result as nnn_aligncelltm.cnv files. Ascii Out takes these .CNV files and produces ascii files suitable for reading into matlab. We did not use the *loop edit* option. This does the same thing essentially as our *wake.m* Matlab routine mentioned below.

In all of our casts, the output variables in the .CNV files were

Scan Count
Pressure, Digiquartz [db]
Temperature [ITS-90, deg C]
Temperature, 2 [ITS-90, deg C]
Conductivity [mS/cm]
Conductivity, 2 [mS/cm]
Altimeter [m]
Beam Transmission, Chelsea/Seatech/Wetlab CStar [%]
Fluorescence, Chelsea Aqua 3 Chl Con [µg/l]
Oxygen, SBE 43 [µg/kg]
Voltage 6 *(this is from a backscatter instrument that UKORS technician Terry Edwards believes is not working properly)*
Pump Status (on or off)

All files were ftped to the ship's Unix machine jruh where all subsequent processing was undertaken.

The following protocol was followed to read the CTD data into matlab and produce processed data files. The processing was essentially the same as carried out during JR40 and JR80. Under the jr106s directory we created a number of sub-directories, including *ctd*. Under the *ctd* directory we created subdirectories for each CTD station, numbered as *001, 002, 003*, etc, that we designate *nnn*. All the CTD and bottle files at that station were kept in their own numbered directory. A README file was also maintained in each *nnn* directory and was updated manually every time any new version of the data set was created. Since we had two CTD sensors, we kept and calibrated the data from both sensors separately in all files. We did not record time as such, but used *scan*. Start time of data recording is logged as a variable that we carry through the processing as *gtime*. Latitude and longitude were also recorded from the NMEA data stream and appear in the headers. These were also carried through the processing and used as the station locations. This is a departure from our previous practice on JR40 and JR80 since accurate latitude and longitude were not previously passed to the CTD deck unit.

Creation of the CTD files

ctdcal.n

This reads in the CTD_*nnn*_aligncelltm.asc ascii data file and the CTD_*nnn*_aligncelltm.hdr header file. It runs the routines *cnv2mat.m* and *hdr2mat.m*. They read the file, rename all the variables to something comprehensible and save the data in a matlab file ctd*nnn*.cal.

offpress.m

This reads the ctd*nnn*.cal files, plots the data near the surface, and asks the user to choose a pressure offset to apply. During JR106S these offsets were always small, typically 0 to 0.4 db. The programme also removes any data when the *pumps* variable is zero, indicating that the Seabird pumps were not on. After applying the chosen pressure offset, the resulting data are saved as ctd*nnn*.wat.

spike.m

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

wake.m

The 'wake' programme was used on JR106s to remove data from the ctd*nnn*.spk files during the bottle firings. It was used only on the upcasts and not on the downcast data (unlike JR80 where it was used on the downcasts and not on the upcasts). It was found to be necessary since there was a good deal of rubbish data around the bottle firings which otherwise made their way into the bottle files. The programme sets to NaN any data when the rate of change of pressure falls below a threshold, thus when the package has slowed down. The resulting file is ctd*nnn*.wke.

interpol.m

The programme finds any data set to *NaN* in any of the temperature, conductivity, fluorescence, transmittance and oxygen variables, and interpolates across them to produce a continuous data set. The output file is ctd*nnn*.int. At this point we have 24 Hz data for the up and down cast. We then need the bottle salinity data to calibrate salinity. However the next steps can be (and were) undertaken on the data even if salinity is uncalibrated.

makebot.m

This reads in the CTD_*nnn*.BL file created by Seasoft. This contains the scan numbers to be used for extracting CTD data during bottle firings. The start and end scan numbers from this file are used as the start and stop scan numbers (we actually used stop+100) to read the ctd*nnn*.int file and extract CTD data when the bottle was fired. The reason that we do not use the Seasoft values is that we have despiked the .int files already and therefore know the quality of the data going into the bottle average. Median values for each CTD variable are calculated as representative of the CTD data during the firing. The standard deviations of the temperatures and conductivities are calculated as a means of determining if the bottle was fired in a region of strong gradient. A warning is given to the user if large standard deviations are found. All standard deviations are stored alongside all the other extracted variables in the output file, bot*nnn*.1st. Makebot also creates variables for bottle salinity, botsal, initially set to NaN, and a salinity bottleflag, salflag, initially set to 0.

newvar.m

This calculates salinity from conductivity and temperature, and also derives potential temperature and a variety of different densities. The output is ctd*nnn*.var.

splitcast.m
This splits the data from ctd*nnn*.var into an upcast and a downcast file, ctd*nnn*.var.dn and ctd*nnn*.var.up.

ctd05db.m
This does a 0.5 decibar binning of the CTD downcast data in ctd*nnn*.var.dn to produce ctd*nnn*.05db. The bin interval of 0.5 db was chosen rather than the usual 2 db because the stations were shallow, mostly a few hundred metres.

Salinity Calibration

salts_transfer_xl
This reads the bot*nnn*.1st file and adds bottle sample salinity, botsal, directly from an excel spreadsheet to create bot*nnn*.sal. The salinity flag, salflag, is set to 1 where there are data, and 0 where data are absent.

setsalflag.m
This checks the standard deviations of the CTD temperature and salinity data in bot*nnn*.sal. If either of these for the primary sensors exceeds a threshold of 0.002 (usually when the bottle in fired in the halocline), the salflag for that bottle is set to 0. The output file is bot*nnn*.flg.

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

salcal.m
This programme calculates conductivity from bottle salinities, and determines the mean offset between the bottle and CTD conductivities at that station for each sensor. These are saved as offset1 and offset2. The input files are bot*nnn*.flg and ctd*nnn*.int. The output file is bot*nnn*.sal to which the offset values are appended.

During JR106b, there was no apparent trend in conductivity offsets during the 42 stations, nor any trend with pressure. Since many of the stations were shallow, and with very large gradients, the offsets from these stations need to be regarded with caution. The average offsets for sensors 1 and 2 were 0.000 and 0.004, and these were the values applied to all stations.

salcalapp.m
This applies the offsets, offset1 and offset2, for cond1 and cond2. First the data in the bottle file bot*nnn*.flg have the salinity calibration applied. These are applied to ctdcond1 and ctdcond2. Salinities ctdsal1 and ctdsal2 for the two sensors are calculated. A final salinity, ctdsalin, is also derived. We used ctdsal1 since the primary cell was much less noisy on this particular instrument than the secondary cell. On JR80 we calculated a mean of the two cells. Potential temperatures, ctdpotemp1, ctdpotemp2 and ctdpotemp are derived together with densities ctdsig0, ctdsig2 and ctdsig4. All of these for each bottle are stored in the output file bot*nnn*.cal. The CTD data are also calibrated at the same time to derive sal1, sal2, salin, potemp1, potemp2, potemp, sig0, sig2 and sig4. The input file is ctd*nnn*.int and the output file ctd*nnn*.var.

splitcast.m as described above
ctd05db.m as described above

Points to Note

We encountered problems on three stations. During stations 036 and 042 the PC running the Seabird acquisition software crashed repeatedly and logging had to be restarted into files given the suffix a, b, c. During station 042 this was also associated with a crash of the CTD deck unit. This meant that processing had to be done in Seasoft on three separate files per station, and the bottle firing files resurrected manually. On station 041 the rough sea conditions meant that the CTD was lowered quickly into the water, and was not raised again to near-surface to wait for the pumps to come on. The pumps did not come on until the CTD package was at 30 m depth so we do not have data for the top 30 m of the downcast.

The CTD package is large and has a tendency to trap water within the package. When the rate of descent of the package is small, this trapped water tends to pass the sensors giving anomalous values. These are very clearly seen when plotting temperature or conductivity against pressure. On the downcast they are visible as spikes to the right in temperature (warmer water that has come from higher up the water column) and to the left in conductivity (fresher water from higher up). On the upcast the reverse is true. If plotted in potential temperature – salinity space, no anomalies are visible, indicating that the water properties are genuine but are simply displaced in the vertical. The anomalies correlate clearly with the rate of change of pressure. They tend to be worse during rough weather when the ship heaving can slow the package. Exactly the same phenomenon was observed with a similar package during JR80. A programme called *wake.m* was written during JR80 to remove these anomalies using the rate of descent of the package as an objective measure. At the time of writing, these anomalies have not been removed from the JR106b downcast data. This will be done back at UEA.

The secondary cell conductivities and temperatures were very noisy. This was a particular problem at station 001 after which the cell was cleaned. However it continued to be much poorer quality than the primary cell. Therefore it is our intention to use only data from the primary sensors, rather than an average of the two as we used on JR80.

During the cruise we encountered (as expected) very large gradients in conductivity and salinity, typically ranging from salinity values of ~28 at the surface to ~34 at 300 m. This means that many of the near surface bottles were fired in extreme gradients. We expect to undertake further study at UEA, to check that we have derived the most appropriate values of potential temperature and salinity for each bottle for use with our measurements of oxygen isotopes in these bottles. For example, the difference in depth between the CTD cells and the bottles is significant in these extreme gradients. This is not a problem for the CTD salinity calibration, since we only use bottle salinities in low gradients for that calculation.

Station	Julian Day	Date	Bottom Time (GMT)	Latitude	Longitude	Max. Pressure	Max. Depth	Min. Distance Off	Salinity samples	Barium samples	O18 (a) samples	O18 (b) samples	Sediment samples
1	245	01/09/2004	09:11:59	68 00.80	31 49.79	542.9	536.8	4.9	6	-	17	17	-
2	245	01/09/2004	11:24:55	68 04.66	31 43.11	435.3	430.5	3.9	4	-	12	12	-
3	245	01/09/2004	12:52:42	68 03.14	31 48.46	642.9	635.5	5	7	13	13	13	-
4	245	01/09/2004	14:31:27	67 59.07	31 52.58	309.4	306	5.5	4	-	10	10	-
5	245	01/09/2004	15:48:26	67 57.60	31 56.53	126.3	125	6.8	3	-	8	8	-
6	245	01/09/2004	22:27:37	68 29.67	32 12.52	196.9	194.9	5.1	3	-	9	9	9
7	245	01/09/2004	23:37:50	68 28.64	32 13.51	200.4	198.2	4.8	3	-	9	9	-
8	246	02/09/2004	00:47:13	68 27.41	32 13.69	169.8	168	4.8	3	-	9	9	9
9	246	02/09/2004	03:16:23	68 26.31	32 14.79	513.8	508	5.3	4	-	11	11	1
10	246	02/09/2004	05:46:06	68 25.23	32 17.08	724.8	716.3	4.6	4	-	13	13	-
11	246	02/09/2004	14:20:27	68 21.77	32 12.19	805	795.4	5.2	7	21	21	21	-
12	247	03/09/2004	01:55:21	68 07.62	31 51.21	878.8	868.2	4.5	4	17	17	17	-
13	247	03/09/2004	04:12:28	68 02.52	31 46.29	617.3	610.2	4.2	4	15	15	15	-
14	247	03/09/2004	22:32:28	68 10.09	31 58.99	879.9	869.2	4.8	4	14	22	22	-
15	248	04/09/2004	03:09:59	68 15.65	32 04.92	867.4	857	4.1	4	18	18	18	-
16	248	04/09/2004	11:28:01	68 29.76	32 13.79	79.9	79.1	4.1	3	-	7	7	7
17	248	04/09/2004	12:24:56	68 29.77	32 13.28	168.8	167	5.9	3	-	10	10	-
18	248	04/09/2004	13:16:28	68 29.74	32 12.79	181.9	180	4.9	3	-	10	10	10
19	248	04/09/2004	14:09:22	68 29.71	32 12.39	199.3	197.2	4.9	3	-	10	10	-
20	248	04/09/2004	16:28:43	68 29.68	32 11.98	173.3	171.5	5.1	3	-	10	10	-
21	248	04/09/2004	17:14:00	68 29.66	32 11.69	86.9	86	5.3	3	-	8	8	8
22	249	05/09/2004	21:38:12	68 23.78	32 22.03	700.8	692.6	17.2	4	14	14	14	-
23	250	06/09/2004	19:18:10	68 16.21	32 04.71	864	853.5	5.2	3	-	16	16	-
24	250	06/09/2004	20:28:21	68 16.44	32 03.85	391.4	387.1	5.3	3	-	13	13	-
25	250	06/09/2004	21:26:09	68 16.54	32 03.44	122.4	121.1	19.1	2	-	9	9	-
26	250	06/09/2004	23:10:35	68 15.93	32 10.09	372.9	368.8	5	3	-	12	12	-
27	251	07/09/2004	20:44:59	68 15.85	32 08.10	826.4	816.5	10.1	3	-	17	17	-
28	251	07/09/2004	22:06:37	68 16.14	32 06.14	865.9	855.4	4.9	4	-	18	18	-
29	252	08/09/2004	00:13:46	68 03.99	31 43.25	482.9	477.5	3.5	14	14	14	14	-
30	253	09/09/2004	05:56:29	68 01.32	31 45.29	579.8	573.2	3.7	12	12	12	12	-
31	253	09/09/2004	07:47:51	68 04.66	31 41.25	181	179.1	3.9	3	-	10	10	-
32	253	09/09/2004	09:48:07	67 52.52	31 33.14	517.8	512	3.2	4	14	14	-	-
33	253	09/09/2004	11:53:00	67 45.28	31 26.41	505.3	499.7	4.9	3	14	14	-	-
34	253	09/09/2004	14:20:51	67 30.04	31 07.78	534.8	528.8	4.4	4	14	14	-	-
35	253	09/09/2004	20:17:09	67 15.03	30 48.54	561.4	555.1	5.8	4	15	15	-	-
36	253	09/09/2004	22:48:48	67 00.01	30 39.84	545.4	539.3	4.4	7	15	15	-	-
37	254	10/09/2004	02:03:09	66 40.09	30 40.00	483.4	478.1	4.5	7	14	14	-	-
38	254	10/09/2004	04:46:21	66 20.01	30 40.12	430.4	425.7	4.6	5	13	13	-	-
39	254	10/09/2004	07:12:20	65 59.88	30 40.23	481	475.7	4.6	7	14	14	-	-
40	254	10/09/2004	09:45:02	65 39.90	30 39.28	405.9	401.5	4.4	6	13	13	-	-
41	254	10/09/2004	12:43:51	65 19.60	30 39.44	977.5	965.6	11.3	19	19	19	-	-
42	254	10/09/2004	17:52:08	65 10.18	30 33.87	1501.9	1481.8	4.7	23	24	24	-	-

Figure 3.3. Map of CTD station locations in the fjord.

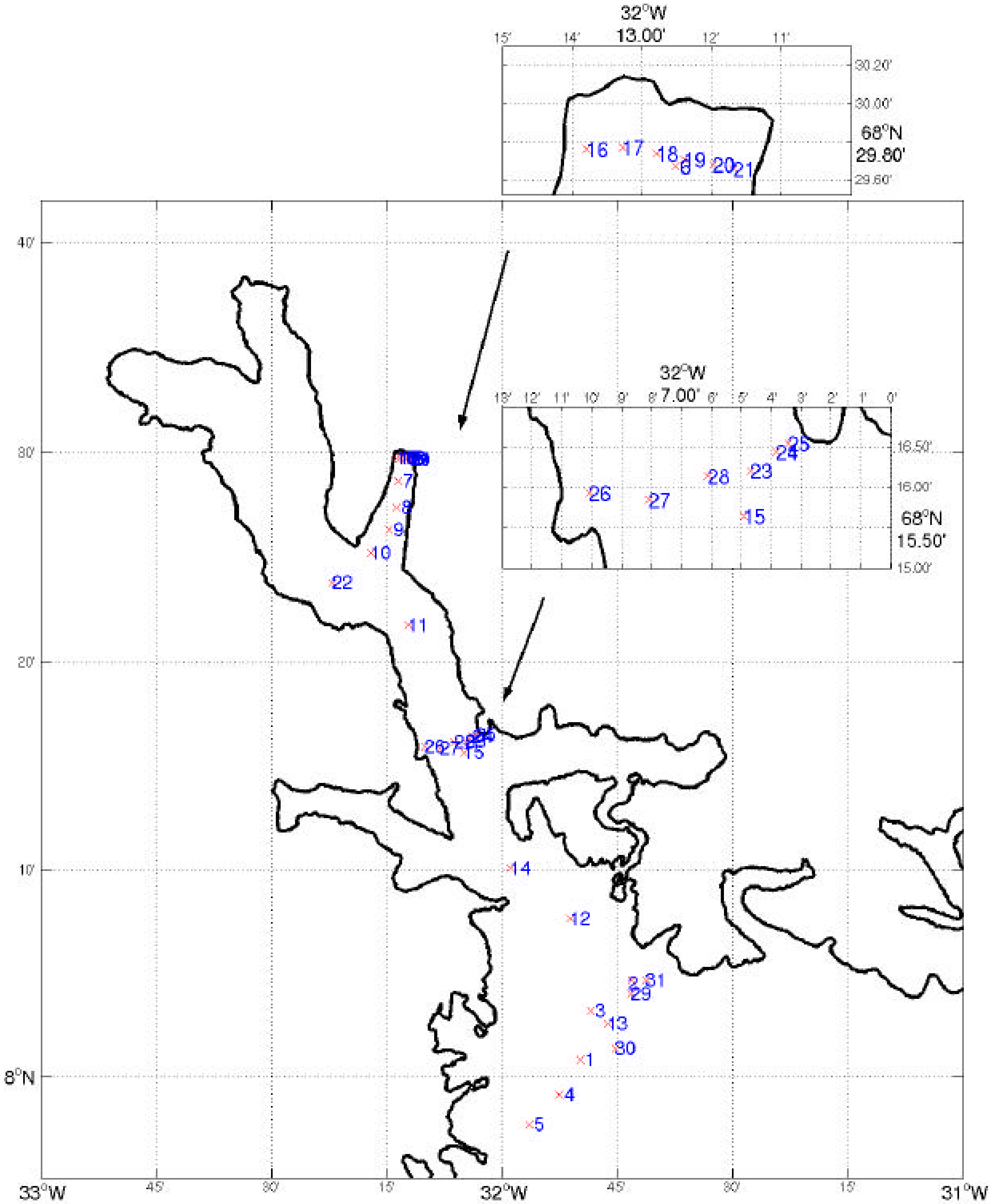
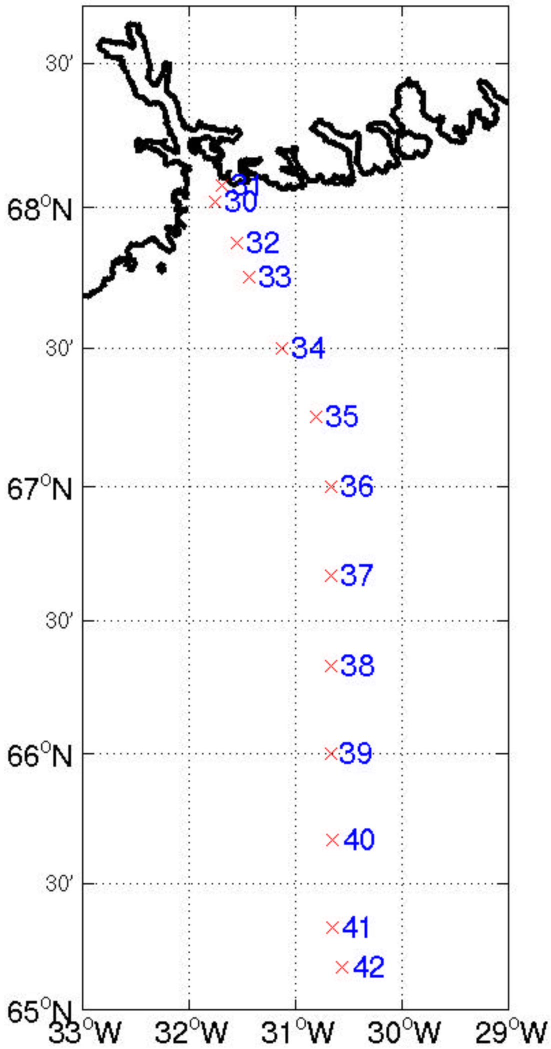


Figure 3.4. Map of CTD station locations on the continental shelf.



3.4 SALINITY AND d^{18}O SAMPLE COLLECTION AND ANALYSIS (Paul Dodd)

Salinity samples were collected from Niskin bottles fired at selected depths on every cast for the purpose of calibrating the CTD sensor, and every four hours from the ship's uncontaminated underway supply for calibration of the underway Oceanlogger system. Samples were stored in 200ml medicine flats, which were flushed with sample three times before filling to just below the shoulder, to accommodate thermal expansion. Bottle necks were wiped dry to prevent salt crystallisation, before a single-use plastic insert and plastic screw cap were applied. Crates of salinity samples were stored in the laboratory for 24 hours prior to analysis to allow the temperature of samples to equilibrate with the laboratory environment.

Two Guildline 8400b Autosal salinometers were set up at the start of the cruise, both equipped with Ocean Scientific International Ltd. peristaltic pumps. One salinometer, serial number SN60839, provided by UKORS contained a foreign body within the cell, which rendered it impossible to immerse two of the four electrodes completely in sample; this salinometer was not used. The other unit, serial number SN63360 provided by the British Antarctic Survey, initially gave unstable readings, due to a stream of small air bubbles that entered the cell from the sample supply tube during analysis. However, after re-assembling the peristaltic pump, this unit performed satisfactorily. The laboratory thermostat was set to 24°C while salinometer water baths were maintained at 27°C. A digital thermometer monitored laboratory temperature, which remained within ± 1°C for the duration of the cruise.

Rather than standardizing the salinometer by means of the front panel potentiometer, IAPSO standard seawater was analysed before and after each crate of 24 salinity samples and a moving offset was applied in post-processing. Also, at a midpoint in the cruise seawater standards of salinities 10, 30 and 35 were run successively such that any non-linearity of the salinometer's response could be accounted for.

Salinity was calculated from salinometer log sheet double-conductivity ratio values using an Excel spreadsheet salts.xls consisting of two worksheets. On the first worksheet, values for individual samples and standards were entered and averaged, before mean values were transferred to the second worksheet where an offset was applied to each sample by means of a linear regression. This allowed an offset to be calculated for each sample based on the offsets required by a pair of standards analysed immediately before and after a crate of 24 samples. Corrected values were then halved to obtain the conductivity variable R_T from which salinity was calculated using the UNESCO equation, which was entered into the same worksheet.

Water samples for $d^{18}O$ analysis were collected in round 150ml bottles from all CTD rosette Niskin bottles, and from the ships uncontaminated underway supply at hourly intervals. Bottles were flushed three times with sample, before filling to just below the shoulder to accommodate thermal expansion. After filling, bottle necks were wiped with laboratory roll to avoid salt crystallisation and sealed using an aluminium screw cap with captive rubber insert. To prevent the aluminium caps from loosening, bottles were then further sealed with para-film, before being placed into cardboard boxes for later analysis.

3.5 LOWERED ACOUSTIC DOPPLER CURRENT PROFILER (LADCP) (Louise Sime)

JR106b operations

The LADCP package used during JR106b consisted of a downward and an upward looking RDI 300 kHz Workhorse (WH) ADCP. The downward WH was mounted off-centre at the bottom of the frame, and the upward on the outside of the frame. The details of their sampling configurations are briefly described below. The battery pack for both LADCPs was mounted horizontally at the level of the CTD. Between stations, each ADCP was connected to a controlling PC in the Main Lab through a serial cable for delivery of pre-deployment instructions and post-deployment data retrieval. The battery package was recharged after approximately every 4 deployments, by connection to a charging unit in the Main Lab via a power lead. The charging was carried out before the battery voltage dropped to 48 V, and generally at around 50 V.

Both instruments were deployed at every station. However, the upward looking workhorse (UWH) ADCP did not return any data for stations 3-4 and there were problems with the processing of station 21 (UWH), and 26 (downward looking workhorse - DWH). All other stations from 1-42 recorded and processed as expected. The configuration files which provide the ADCPs with their sampling specifications were changed at station 3 from those used on JR106 leg 1 to those used during JR80, however, after the failure of the UWH for stations 3 and 4, the configuration files were changed to a third final file (see appendix 2). This should have the same specifications as the JR80 sampling specifications. All configuration details are provided in appendix 1. The DWH ADCP returned data for all stations although station 26 did not process as expected. The sampling specifications for each of the WH units are identical.

LADCP configuration files

The configuration files from stations 3-end should be identical to those used for the down-looking WH in the RRS Charles Darwin cruise 139 (as described by Lisa Beal and Brian King in the cruise report). See appendix 1 and 2.

Instructions for LADCP deployment and recovery

This set of instructions is based on the LADCP section of the JR67 cruise report, written by Brian King and colleagues. It can be used in conjunction with the LADCP log sheet included in the present report. The reader is referred to the above-mentioned documents for a more detailed account of LADCP use.

Deployment

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

Downward looking Workhorse (DWH) LADCP

1. In the controlling PC, run **BBTALK** and open a window for COM1. Press <F3> to create a log file in which all subsequent BB-related BBTALK output will be stored. Enter filename of the form *c:\ladcp\jr106\logfiles\##m.txt* (where *##* is the station number). And the *m* refers to the DWH master status.

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

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

4. Check the available memory of the DWH by typing *RS?* <ENTER>. If insufficient memory is available, clear it by typing *RE ErAsE* <ENTER>. The memory should only be cleared after all data has been transferred to the Suns and checked. During JR106 this erase was done twice when the memory of each WH was about half full.

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

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

7.	Press F2 then select the DWH configuration file. This was referred to as the 4275_master_water file. See appendix 2 for the master and slave configuration files. The DWH is now ready for deployment.

8.	Press F3 to stop the log file.

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

Upward looking Workhorse (UWH) LADCP

Repeat steps 1-8 for the UWH. It is easiest if these are carried out in a separate adjacent window. Alternatively, toggle to *COM2.*

Note the following minor differences:

1,	The UWH BBTALK log file should be named *c:\ladcp\jr106\logfiles\##s.txt, w*here the *s* refers to the UWH slave status.

7.	Select the slave UWH configuration file (1885_slave_water), see appendix 1 and 2 for details.

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

Recovery

Remove blanks and attach the communication and charger cables.

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

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

3.	Check the number of deployments by typing *RA?* <ENTER>. Then transfer the data to the PC. Go to *file, recover recorder.* Select the *c:\ladcp\jr106\master* for the DWH and *c:\ladcp\jr106\slave* as the destination for the UWH recovered files. This can take ten minutes or more with large files. Once the data are transferred the WH should both be powered down by typing *CZ* <ENTER>.

4.	Rename the default filenames to *c:\ladcp\jr106\master\cd7##m.000* for the DWH and *c:\ladcp\jr106\slave\ctd##s.000* for the UWH.

5.	Note the file size down, and transfer the files by FTP or a zip disc to *jruh\jr106s\ladcp*. The program winADCP on the LADCP PC can be used to check the number of ensembles and whether the data recovered looks initially reasonable. But this is not essential, since errors will come to light in the later processing.

LADCP log sheet: – JR106b

CTD CAST		Date:		JDAY	
Lat:		Long:		Depth:	

LADCP Deployment / Recovery Log Sheet

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

In BBTALK:

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

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

Deployment

6. MASTER deployment time, from master clock

Recovery

In BBTALK

7. Time of stopping MASTER logging [: :]. Stop SLAVE

8. Battery Voltage [V] Measure on charger

Data Transfer

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

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

16. Comments

LADCP processing during JR106

At the time of writing this report, the WH data sets have not been fully processed. The primary tool used in processing each of the LADCP data sets during JR106 was the software originating from Eric Firing's group at the University of Hawaii (UH). Software packages (and a great deal of advice on their use) were facilitated by Brian King at SOC.

The LADCP processing sequence (the same DWH and UWH) during JR106 is outlined below.

Installing the UH software on the Sun Workstations

In the *…jr106/ladcp* directory, create a directory called *uh* . In that directory, download a tar'ed copy of the complex UH directory structure with some example files (DEMO.LAD.tar) from a CD provided by Brian King. A tar –xvf DEMO.LAD.tar in *…jr106/ladcp/uh* will set up the directory structure that the UH software needs to run.

From *uh.src.y2k* in the CD, copy a directory called *programs* and all its contents to *…jr106/ladcp/uh* .

In *…jr106/ladcp/uh* , configure the following environmental variables in the file *LADall*: LADCP_PROCHOME and LADCP_PROGHOME should be set to *…jr106/ladcp/uh* , LADCP_CRUISEID to jr0304 (i.e. JCR cruise in April 2003) and LADCP_YEARBASE to 2003. Then type *setup matlab* and *source LADall.*

Type *cd proc* . Edit the script *makelinks* and change the year base to jr0304. Then execute *makelinks.*

Initial UH processing stage

This processing stage allows the user to examine the quality of the data and to calculate relative velocity profiles in the absence of CTD or navigational data.

The raw (*.000) LADCP data should be placed in *… jr106/ladcp/uh/raw/jr106/ladcp* . We followed the conventional nomenclature and renamed the files as at SOC (i.e. jsss_cc.000, where sss is the 3-digit station number; cc is 02 for the master DWH and 03 for the slave UWH). Note each LADCP data file must be processed from steps 1-6 individually.

0. Before each session of processing is carried out, *source LADall* needs to be run from the *…jr106/ladcp/uh directory*. Then *cd proc*, followed by *source makelinks.*

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

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

3. Start *matlab* and type *magvarsm(sss.cc).* This will calculate a correction to the direction of the LADCP velocities based on the local magnetic declination. It will append the declination to *mag_var.tab* , and the date and position to *stations.asc* .

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

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

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

Later UH processing stage

Better ADCP data can be obtained by incorporating CTD data into the ADCP processing. However, this was not carried out during this cruise, so no details are presented here.

Appendix 1: Configurations used for each station:

Stations 1-2, configurations from JR106 leg1.

DWH – master, run on COM1	UWH – slave, run on COM2
>CR1 >CF11101 >EA00000 >EB00000 >ED00000 >ES33 >EX11111 >EZ0111111 >SM1 >SA001 >SI0 >SW75 >TE00:00:02.72 >TP00:00.50 >LD111100000 >LF0500 >LN015 >LP00003 >LS1600 >LV250 >LJ1 >LW1 >LZ30,220 >CK >CS	>CR1 >CF11101 >EA00000 >EB00000 >ED00000 >ES33 >EX11111 >EZ0111111 >SM2 >SA001 >ST0300 >TE00:00:02.72 >TP00:0.50 >LD111100000 >LF0500 >LN015 >LP00003 >LS1600 >LV250 >LJ1 >LW1 >LZ30,220 >CK >CS

Stations 3-4, configurations from JR80

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

These are the jr80 files. This water-track configuration should use 16 10-m bins per ping, a 5-m blank after transmit and an ambiguity velocity of 2.5 m s^{-1}. It has a ping cycle of 1.54 s.

Stations 5-end, should be equivalent configurations from JR80

DWH – master, run on COM1	UWH – slave, run on COM2
>CR1	>CR1
>CF11101	>CF11101
>EA00000	>EA00000
>EB00000	>EB00000
>ED00000	>ED00000
>ES33	>ES33
>EX11111	>EX11111
>EZ0111111	>EZ0111111
>SM1	>SM2
>SA001	>SA001
>SI0	>ST0300
>SW75	>TE00:00:01.00
>TE00:00:01.00	>TP00:1.00
>TP00:1.00	>LD111100000
>LD111100000	>LF0500
>LF0500	>LN016
>LN016	>LP00001
>LP00001	>LS1000
>LS1000	>LV250
>LV250	>LJ1
>LJ1	>LW1
>LW1	>LZ30,220
>LZ30,220	>CK
>CK	>CS
>CS	

These are based on the jr80 files, and should give equivalent sampling configurations.

Appendix 2: Files used for stations 5-end:

Master configuration file:

```
$P*******************************************************
$P**************  LADCP Master  ************************
$P*******************************************************
; Send ADCP a BREAK
$B
; Wait for command Prompt
$W62
;**Start**
;Display Realtime clock settings
tt?
$W62
;Set to factory defaults
CR1
$W62
CF11101
$W62
EA00000
$W62
EB00000
$W62
;Set transducer depth to zero
ED00000
$W62
;Set salinity to 33ppt
ES33
$W62
;Set system coordinate
EX11111
$W62
EZ0111111
$W62
;Set as MASTER ADCP
SM1
$W62
;Transmit SYNCHRONIZING PULSE before each WATER ping
SA001
$W62
;SYNCHRONIZING PULSE sent on EVERY ping
SI0
$W62
;Wait 75ms
SW75
$W62
;Set ensemble time 1s
TE00:00:01.00
$W62
;Set 1 second between pings
TP00:1.00
$W62
;set LADCP to output Velocity, Correlations, Amplitude and Percent Good
LD111100000
$W62
;Set blank to 500cm
```

```
LF0500
$W62
;Set record to 16bins
LN016
$W62
;Set 1 ping/ensemble
LP00001
$W62
;Set bin size to 1000cm
LS1000
$W62
;Set maximum radial water velocity to 250m/s
LV250
$W62
;
LJ1
$W62
;Set ADCP to narrow bandwidth
LW1
$W62
;
LZ30,220
$W62
;Save setup
CK
$W62
;Start Pinging
CS
;Delay 3 seconds
$D3
$P **************************************************************
$P ********** Disconnect ADCP from Computer *********************
$P **************************************************************
;Close log file
;$l
```

Slave configuration file:

```
$P**************************************************
$P**************  LADCP SLAVE  *********************
$P**************************************************
; Send ADCP a BREAK
$B
; Wait for command Prompt
$W62
;**Start**
;Display Realtime clock settings
tt?
$W62
;Set to factory defaults
CR1
$W62
CF11101
$W62
EA00000
$W62
EB00000
$W62
;Set transducer depth to zero
ED00000
$W62
;Set salinity to 33ppt
```

```
ES33
$W62
;Set system coordinate
EX11111
$W62
EZ0111111
$W62
;Set as SLAVE ADCP
SM2
$W62
;Listen for SYNCHRONIZING PULSE before each ping
SA001
$W62
;Wait up to 300s for SYNCHRONIZING PULSE
ST0300
$W62
;Set ensemble time 1
TE00:00:01.00
$W62
;Set 1s between pings
TP00:1.00
$W62
;set LADCP to output Velocity, Correlations, Amplitude and Percent Good
LD111100000
$W62
;Set blank to 500cm
LF0500
$W62
;Set record to 16bins
LN016
$W62
;Set 3 ping/ensemble
LP00001
$W62
;Set bin size to 1000cm
LS1000
$W62
;Set maximum radial water velocity to 250m/s
LV250
$W62
;
LJ1
$W62
;Set ADCP to narrow bandwidth
LW1
$W62
;
LZ30,220
$W62
;Save setup
CK
$W62
;Start Pinging
CS
;Delay 3 seconds
$D3
$P *********************************************************
$P ********** Disconnect ADCP from Computer ****************
$P *********************************************************
;Close log file
;$l
```

3.6 VESSEL-MOUNTED ACOUSTIC DOPPLER CURRENT PROFILER (VMADCP)

(Paul Clement)

Mounted within the hull of the RRS *James Ross Clark* is an RD Instruments 153.6 kHz Acoustic Doppler Current Profiler (ADCP). In order to provide the unit with protection from sea ice, it is sited in a sea chest that is recessed into the hull. The fluid within the chest is a mixture of 90% deionised water and 10% ethylene glycol. A 33 mm thick sheet of Low Density PolyEthylene (LDPE) closes the underside of the sea chest. The transducer head has an orientation offset from the fore-aft by approximately 45°. The system uses 17.07 firmware and version 2.48 of RDI Data Acquisition Software (DAS).

At the beginning of JR106b, the VMADCP was configured to record in 50 x 8 metre bins, and in two-minute ensembles. It was noticed that good data was being received at depths greater than 400 m, good data that can not be recorded with this configuration. As from 17:00 on Jday number 245, the VMADCP was altered to record in 64 x 8 metre bins. The transducer is at a depth of approximately 6 m, there is also a 'blank before transmit' distance of 4 m and a pulse distance of 8 m. Therefore the centre of the first bin is at a depth of 18 m (delta = 14). Bottom track mode was used throughout the cruise since mostly recording on the continental shelf.

Data Processing

Data from the VMADCP was processed in 24 hour sections (0000 to 2359 hrs) using the Pstar software suite. Procedures were identical to those used by Gwyn Griffiths (SOC) on JR106a. Below is a brief description of unix scripts used and the output files they create. They can be found on jruh in the jr106s directory.

1) jr106s/nav/gyr

   gyroexec0 was used to read data from the ship's gyrocompass. This calls the pstar programme *datapup* to transfer data from the RVS to Pstar binary files; *pcopya* to set the raw data flag; *pheadr* to specify the remaining header data; and *datpik* to force all heading data to lie between 0 and 360 degrees. To avoid duplicate time stamps in the gyro data, *gyroexec0* also calls a Pstar program *pcopym* to exclude this data from the processed data stream. The script produced one new output file `106gyr[jday]d.raw`. It also appends the data to a master gyro file `106gyr01`.

2) jr106s/nav/ash

   The Ashtech ADU-2 GPS is used to correct errors in the heading of the ship's gyrocompass before using the gyro information to process ADCP data. This is necessary as the gyrocompass can oscillate for several minutes after any ship manoeuvre due to an inherent error. Three UNIX scripts were used to process the Ashtech data.

   - *ashexec0* This exec used the Pstar programme *datapup* to read in data from the RVS data stream into a Pstar file; *pcopya* to set the raw data flag; and *pheadr* to set the other header information. The output file created was `106ash[jday]d.raw`.

   - *ashexec1* This exec combined the data from the Ashtech and gyro files into a new file. It used the Pstar programme *pmerge* to merge in data from the master gyro file and *parith* and *prange* to calculate the difference (a-ghdg) between the gyro and Ashtech headings, forcing the result to lie within the range of –180 to 180 degrees. This is an especially important correction in high latitudes where the gyrocompass error is magnified by the secant of latitude. The output file created was `106ash[jday]d.mrg`.

- *ashexec2* This exec carried out quality control functions. First it called the Pstar programme *datpik* to reject all data outside given limits. Then it despikes the a-ghdg data and forms an average over 2 minutes. The two output files created were `106ash[jday]d.edit` and `106ash[jday]d.ave`.

After running *ashexec2* the `106ash[jday]d.ave` file needed to be manually appended to a master file `106ash01.int` using the Pstar *papend* command.

3) jr106s/nav/bsn
navexec0 was used to read Bestnav data into Pstar format, appending the new data to a master file `abnv1061`. The scripts calls the Pstar programme *datapup* to input the RVS data and form a Pstar binary file; *pcopya* and *pheadr* to set the header information; *posspd* to calculate east and north velocities; *pdist* to calculate distance run; *pcopya* to remove the RVS distance variable; and *papend* to append the data to a master file.

navexec1 averages and filters the navigation data. The data input into the master navigation file `abnv1061` is smoothed and despiked and the resulting data is placed in `abnv1061.av.`

4) jr106s/adp
adpexec0 – This exec reads the RVS data into Pstar creating two output files `106adp[jday]d` and `106bot[jday]d`, containing water track and bottom track data respectively.

adpexec1 – The VMADCP data stream was time stamped by the Pentium PC clock running the DAS software. Although the PC clock is GPS synchronised over the network at the time of login, there was a large subsequent drift during the duration of the cruise. This resulted in there being a timing error associated with the raw data. During JR106, the time difference was recorded at approximate 4 hour intervals. This exec asks the user to input the difference and applies a correction to the data. Three files are created, namely, `106adp[jday]d.corr`, `106bot[jday]`
`d.corr` and `clock[jday]d`.
adpexec2 – The VMADCP measures the water velocity relative to the ship. To calculate true east and north water velocities over ground, we need to include information on the ship's heading and speed. For this we use the navigation data processed above, including the Ashtec-minus-gyro heading correction (a-ghdg). The required correction was then applied to the data creating the output files `106adp[jday]d.true` and `106bot[jday]d.true`.

adpexec3 – This exec applies the calibration to the velocity data. See below for details of the ADCP calibration. The two output files created were `106adp[jday]d.cal` and `106bot[jday]d.cal`.

adpexec4 – Ship's velocities between ensembles were derived by merging in position information from the navigation data. Removing the ship's velocities from the VMADCP data derived the absolute water velocities. These final velocities were output to the files `106adp[jday]d.abs` and `106bot[jday]d.abs`.

For the days that were configured to 50 x 8 metre bins, the adp execs were altered where necessary to read the data as such. For Jday 245, new adp execs were created. One set for the times when the ADCP was configured to read in 50 x 8 metre bins and another for when it was configured to read in 64 x 8 metre bins.

50 x 8m execs:	adpexec245a0	64 x 8m execs:	adpexec245p0
	adpexec245a1		adpexec245p1
	adpexec245a2		adpexec245p2
	adpexec245a3		adpexec245p3
	adpexec245a4		adpexec245p4

Problems encountered

When running *adpexec4*, there were problems with the pstar *pmerge* command. The error stated that data did not lie between the limits. This can be explained by the error between the navigation time and ADCP time. The way to avoid this problem is to run all execs up to *navexec1* for the following day before running the *adp* execs. There were also problems with *pmerge* when running *adpexec2*. The reason for this was found to be that the manual appending of `106ash[jday]d.ave` to `106ash01.int` after *ashexec2* was forgotten.

Calibration

Gwyn Grifiths (SOC), on JR106a, calibrated the ADCP. The initial calibration of the ADCP was checked against GPS during two runs, each of over two hours, on the NW Icelandic shelf. The scale factor (A) was found to be 1.021 +/- 0.001 and the offset angle (phi) was –1.65°. Therefore the ADCP vector needed to be rotated anticlockwise by 1.65°. This calibration was used throughout the second leg of JR106.

Summary

The VMADCP performed well on JR106 with an impressive performance range. It was usual that good data was recorded at depths in excess of 400 metres. Bottom tracking was achieved in water depths even deeper than 700 metres, much better than usually expected.

3.7 THE AQUALAB WATER SAMPLER

(Martin Price)

On JR106b, water samples for salinity, $d^{18}O$ and barium were successfully collected on Autosub missions m376 and m377 by the WS-Envirotech Aqualab.
The Aqualab is an autonomous water sampling system fitted in the front instrument bay of the Autosub. It consists of a motorised syringe of 200 ml volume,

which draws water through a motorised rotary valve that can connect it to any one of 50 ports. Port 1 is the inlet, which draws water from outside Autosub, while each of the remaining ports is connected to a 500 ml plastic sample bag (perenteral nutrition bags are used). Connections are made with lengths of small diameter flexible hose. The sample bags rest on top of a net suspended at the top of the front instrument bay, where there is ample space for 25 full bags. The photo shows the full sample bags in the front bay of the Autosub after recovery of mission m376. The control systems are housed in a separate pressure case, programmed with scripts containing a series of motor and timer commands.

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

On this cruise the prime water was not extracted from the bags prior to sampling, so that the final volume of water was a mixture of the prime and sample. Instead, the Aqualab, connecting hoses and sample bags were carefully flushed with prime water before deployment, and the properties of the prime water sampled. The quantities of interest are oxygen isotope ratio ($d^{18}O$) and barium concentration. Salinity is used as a marker, so that the concentration of prime water in the final volume can be calculated according to the linear mixing equation:

$$(r_s V_s + r_p V_p) S_f = r_s V_s S_s + r_p V_p S_p,$$

where *?* is density, *V* is volume, *S* is salinity, and subscripts *f*, *s*, and *p* indicate the final, sample and prime waters respectively. Salinity is measured in samples of the prime and final volumes directly using a Guildline 8400b Autosal salinometer, and salinity is measured on board Autosub using two independent conductivity sensors attached to a Seabird SBE9. This information is sufficient to correct for the presence of the prime water using the equivalent linear mixing equations for $d^{18}O$ and barium concentration, provided their values are sampled in both the prime and final volumes.

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

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

The Aqualab was successfully deployed on Autosub missions m376 and m377. On both missions, samples were taken in stand-alone mode every 20 minutes (which is the shortest sampling interval that allows completion of 400ml samples). Twenty four sample bags were used, attached to ports 2 to 25. These were used in reverse order (25 down to 2), so that completed samples were not subject to cross contamination as the rotary valve passed. Ports 26 to 50 were not used since no mission was long enough to allow a full 50 port sampling sequence.

Preparing for deployment

The objective during preparation is to ensure that only water of known properties is in the Aqualab, hoses and sample bags at deployment. The following procedure was used:

1. A 25 litre carboy of surface sea water was collected from the ship's under-way pump. The carboy was then sealed (apart from a small air inlet) to keep the water properties as constant as possible.
2. The prime water was sampled for salinity.
3. The sample bags were each flushed twice with the prime water. Each time, the water was left in the bags for a few minutes, agitated, then emptied as thoroughly as possible.
4. The prime water was again sampled for salinity, and also for $d^{18}O$ and barium.
5. Two 500 ml bottles of prime water were collected for flushing the Aqualab and connecting hoses (Step 8 below).
6. The sample bags were flushed a third time, then each received a measured 40 ml volume of prime water. Any air was forced out, then the bags were sealed with a clean, dry screw cap.
7. The prime water was again sampled for salinity, $d^{18}O$ and barium. Repeated sampling was intended to detect any change in the properties of the prime water.
8. The Aqualab inlet port and syringe were flushed with 50 ml of the prime water collected in Step 5, then 15 ml was pushed through each connecting port and hose (approximately three times the volume of the hoses). This was done by a pre-programmed Aqualab script. This step was repeated twice where time permitted before mission m376, but not before mission m377.
9. The primed sample bags were attached to the connecting hoses, taking care to minimise the amount of air in the system.

Sampling and recovery

During the deployments, before each sample was taken the syringe and inlet hose were flushed three times with 60ml of water. Then, two 200 ml syringes of water were taken to the target port. This was repeated for each subsequent port at 20 minute intervals. After recovery, the bags were detached from the connecting hoses and sealed with a clean, dry screw cap. From each bag a 150 ml salinity sample, two 50 ml $d^{18}O$ samples and one 25 ml barium sample were taken. The salinity and barium bottles needed to be flushed three times before sampling to ensure the samples were pure, however the $d^{18}O$ bottles were previously cleaned with distilled water and baked dry, so no flushing was necessary. This proved essential, since there was very little water to spare in the sample bags once all the bottles had been filled. After sampling, the sample bags, aqualab and the connecting hoses were cleaned and flushed with fresh water.

On both of the completed Autosub missions m376 and m377 the Aqualab successfully collected water in each of the attached 24 sample bags. On each mission one bag was found to contain less than the expected 440 ml of water – bag 17 on mission m376 and bag 12 on mission m377. Neither bag was found to leak, and neither of the Aqualab ports were blocked, so the reason has not been identified, but is likely to be the failure of a command in the sampling sequence for that port. All the other bags contained the correct volume of water on each mission, so the missing water seems unlikely to have been erroneously inserted into the wrong bag. Overall, the Aqualab has performed well on this cruise, and is expected to provide useful results once the samples have been analysed.

3.8 AUTOSUB CTD

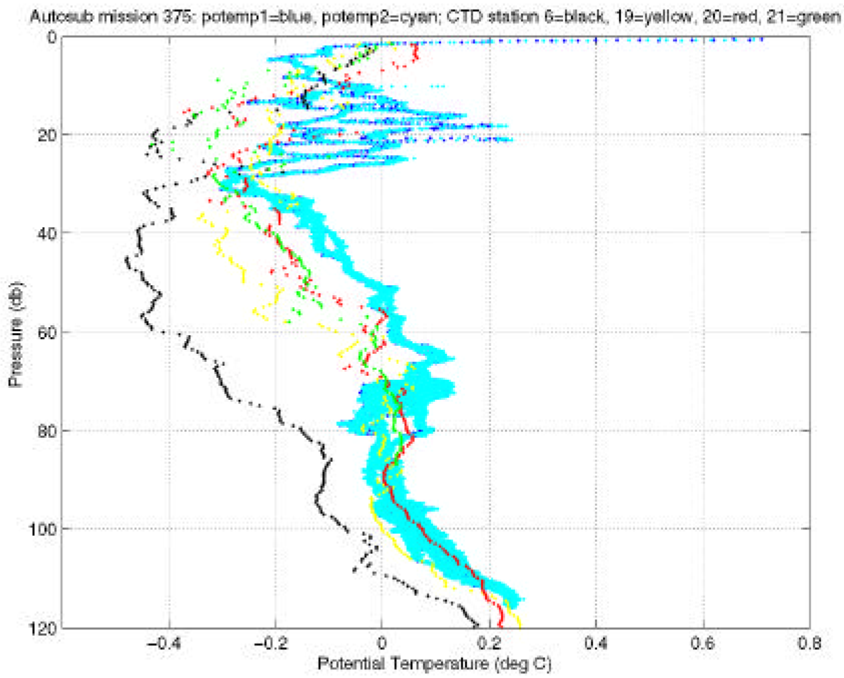
(Ruth Mugford and Karen Heywood)

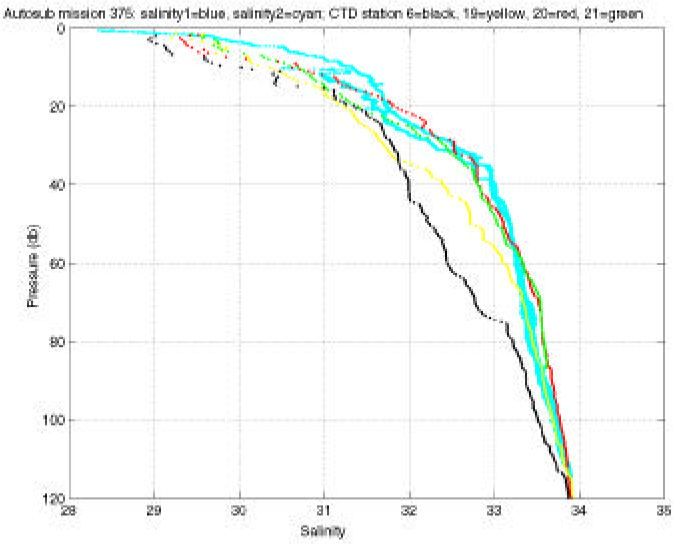
The Seabird CTD on Autosub was measuring the temperature and conductivity of the water at a rate of 24 Hz during all the missions. The raw data for mission number 375, where Autosub traversed in front of Courtauld Glacier, has been compared with a number of CTD stations taken from the ship in this area. For this initial look, the same processing options were used in Seasoft (the Seabird CTD processing software) as were used for the CTD package (data conversion, align CTD, and Cell thermal mass correction). The data were read into matlab following a similar path to the CTD package data.

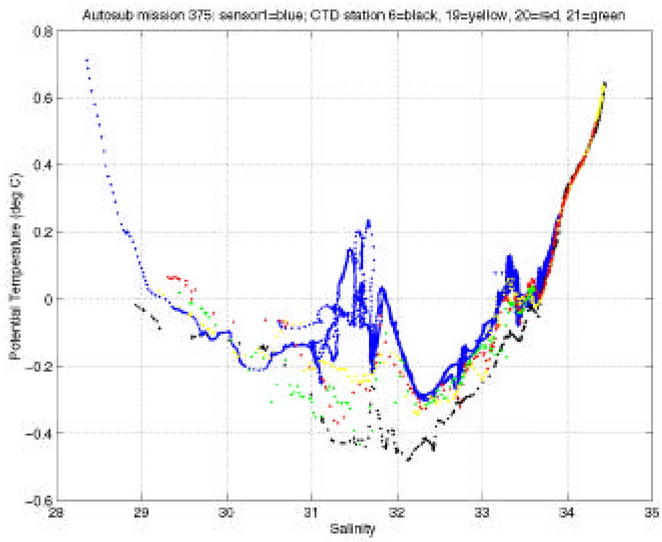
The depth was plotted against the temperature and salinity measured by Autosub during the entire mission; therefore only the vertical variation was seen. The ship-based CTD stations at different positions along Autosub's track match the data fairly well (with varying accuracy since Autosub travelled horizontally and parallel to the glacier); this provides some validation for the Autosub data. The data from the other missions has yet to be processed; the horizontal variation of temperature and salinity along Autosub's track will be analysed once all the data is available.

Some of the sensors on the Autosub CTD have not been calibrated for some years. Therefore it is important that the CTD is calibrated at Seabird immediately after JR106b and prior to JR097. The Autosub team have this in hand. Therefore new calibrations for temperature, salinity and pressure will become available for these sensors in the next few months. The data should be considered provisional until then. In addition we expect to calibrate the Autosub data against final calibrated CTD stations undertaken at the launch and recovery of Autosub. Calibration of the Autosub CTD salinity is particularly important for us since we are using the salinity of the Aqualab samples as a means of determining the volume of prime water in each bag.

The figures below show provisional CTD data at the head of Courtauld Fjord, close to the glacier front, for both CTD stations and Autosub, and indicate good agreement to first order.







4. GEOPHYSICAL AND GEOLOGICAL OPERATIONS

4.1 GEOPHYSICAL & UNDERWAY INSTRUMENTS

(Colm Ó Cofaigh & Jeffrey Evans)

EM120 Multibeam Swath Bathymetry System

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

The EM120 system performed well. However, as on previous cruises where the EM120 was used in pack ice (JR84 and JR104), it was found that when the ship was moving through the ice the swath signal deteriorated significantly. However, the signal returns in only a few metres of open water. The EM120 acquisition parameters used are described in Appendix 1.

TOPAS Sub-Bottom Profiler

The TOPAS system was used extensively throughout the cruise and generally performed very well. As in the case of the EM120, sea ice affects the TOPAS signal quite badly. It results in many high amplitude signals resulting in dark traces across the record. In heavy sea ice this can have the result of obliterating any meaningful data. In water depths of less than 1000 m we ran TOPAS using a Burst mode whereas in depths greater than this we used the Chirp (see Appendix 1 for TOPAS acquisition parameters).

EPC Chart Recorder

The EPC chart recorder worked without any problems throughout the cruise. TOPAS input to the EPC chart recorder was on Channel A. The settings used were: 0.5 second sweep; 0 delay; threshold 1/3 of a turn clockwise from the minimum setting; trigger level 0; gain generally about 8; sweep direction from left to right; print polarity +/- (centre setting). Chart settings: scale lines: on; take-up: on; mark/annotate: off (centre setting); chart drive: internal (centre setting), LPI was generally set to 75; contrast setting: centre. Ten-minute time marks and EM120 depths were automatically plotted on the paper roll.

Expendable Bathythermograph (XBT) System

Eight XBT casts were made during JR106b (see Table). All were shallow water T7 probes that record to water depths of 760 m. Sound velocity profiles (SVP) obtained from the XBT deployments were input to the EM120 and used in the relevant surveys. The XBT system on the James Clark Ross worked well throughout the cruise. Individual SVP profiles were calculated from the XBT data by the system software, assuming a constant salinity. Salinity values were obtained from the Oceanlogger display (located in the UIC), and input to the XBT system software manually. The *.edf files (calculated sound velocity profiles) generated by the XBT system software were transferred to the multibeam data processing workstation, and the data then imported into the multibeam data acquisition system across the network.

XBT stations, JR106b

Cast no.	Filename	Time/Date	Julian Day	Latitude (N)	Longitude (W)	Water depth (m)
9	T7_00026.edf	10.20h 09/01/2004	245	68° 04.27’	31°42.39’	389
10	T7_00027.edf	23.45h 09/01/2004	245	68° 28.65’	32°13.55’	204
11	T7_00028.edf	14.51h 09/02/2004	246	68° 19.11’	32°12.4’	530
12	T7_00029.edf	15.53h 09/03/2004	247	68° 05’ 01.9’’	31°47’ 45.9’’	875
13	T7_00030.edf	09.40h 09/06/2004	250	68° 15.34’	31°50.68’	562
14	T7_00031.edf	08.24h 09/07/2004	251	68° 12.43’	32°15.69’	768
15	T7_00032.edf	08.29h 09/07/2004	251	68° 12.58’	32°16.93’	685
16	T7_00033.edf	12.58h 09/09/2004	253	67° 40.34’	32°20.68’	476
17	T7_00034.edf	00.15h 09/10/2004	254	66°52.62’	30°39.97’	490
18	T7_00035.edf	11.14h 09/10/2004	254	65° 31.51’	30°40.01’	393
19	T7_00036.edf	11.20h 09/10/2004	254	65° 30.04’	30°40.19’	393
20	T5_00037.edf	19.10h 09/10/2004	254	65° 6.08’	30°25.12’	1620

Oceanlogger

The Oceanlogger was operated during JR106b in order to monitor changes in surface water characteristics that affect sound propagation, and to measure surface water salinity values for calculation of SVP's from XBT data. The Oceanlogger did not operate during our work in the ice on the continental shelf as the pump supplying seawater to the logger had to be stopped as fragments of ice clogged the filters. The seawater pump was operational during the north and south transits and also across the continental slope and parts of the shelf of the study area.

Appendix 1. Sonar System Parameter Settings

EM120

MBES screen
Ping Mode: Auto
Sector Coverage

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

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

Sound Speed Profile
Current Sound Profile: jr104_xbt??.asvp

Sound Speed at Transducer:

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

Filtering

Spike Filter Strength:	Medium
Aeration:	Off
Sector Tracking:	On
Slope:	On
Interference:	Off
Range Gate:	Normal

Absorption Coefficient

Absorption (dB/km):	1.00

Seabed Imaging

TVG Crossover (deg)	6

TOPAS Acquisition Parameters

<u><1000 m water depth</u>

Parasource Menu

Level:	100%
Ping Interval:	0 ms (enables external SSU triggering)

Pulseform: Burst
Period: 1 or 2
Secondary Frequency: 2800 Hz

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

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

LOG/Replay Menu
Medium: DISK
Rate (ms): 1000
Channel: 0
File size (Mb): 10

<u>>1000 m water depth</u>

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

Acquisition Menu
Ch_no: 0
Speed of Sound (m/s): 1500

Sample Rate:	20000 Hz
Trace Length (ms):	400
Gain:	20 – 32 dB
Filter:	1.00 kHz
Delay:	Manual or External

Processing Menu

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

Deverb:	OFF
Stacking:	OFF
AVC:	OFF
Scale (%):	1000 – 3000
Attribute:	INST.AMP

LOG/Replay Menu

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

A1.3 SSU – Sonar Sequencing Unit

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

The bridge echosounder (EA600) was run on passive, external trigger, and listened out for the EM120 centre-beam return and used this to calculate depth below the ship. Whenever, the EM120 was not active the EA600 was switched to Active, internal triggering.

4.2 GRAVITY CORER

(Andy Tait)

Initial Set Up

The corer table consists of three identical 2 m long horizontal support tables and one fan-tailed angled one. The tables were set up on the centre line of the aft deck, underneath the stern gantry. The fan-tailed table was secured via tight lashes to the stern roller, such that it did not extend outboard of the roller. This required the bulwark to be lowered for the duration of the cruise. The remaining three tables are bolted together and to the deck matrix. The most forward of the tables did not line up with the matrix and this was chained to eyebolts in the deck. The side hangers are inserted into the tables at equal intervals along the length of the tables. Each hanger provided a hook to support a tube, which could be placed across the width of the tables. These supported the core barrels as they were inserted and removed from the corer weight stand. The hangers are also designed to store the unused core barrel and facilitate the liner's removal onto a sawing platform, from where the core could be processed. Initially a 6-metre barrel was placed on the port side of the table and a 3-metre one placed on the other side. Each barrel is then lashed to the side hangers via tight lashes and secured to the deck when not in use. The main weight stand was lifted into place using the main coring wire via the stern gantry. The weight stand was drawn as far forward on the table as possible in order to facilitate the removal of the core barrels.

Preparation

The plastic corer liners were cut into 3m lengths (for the 3m corer) or left uncut for the 6m cores. Each liner was marked with a line along its length and a number of equally spaced arrows, to indicate the direction in which the core was taken (arrows pointing towards the top of the core). A core catcher was fitted to the bottom of each core liner and two wraps of 1" wide insulation tape were used to secure it to the liner. The core barrel to be used (either 3m or 6m) had its end capped by screwing on a steel core cutter. The prepared liner (c/w catcher) was then inserted into the core barrel, where the liner was pushed fully home on to the core cutter. The chosen barrel size was then rolled over the steel tubes (inserted into the hooks of the hanging supports) and aligned with the corer weight stand. The holes in the flange of the corer barrel were aligned with the four quick release pins in the weight stand. The barrels were slid onto the pins and retained by two quick release steel plates. These in turn were secured by the use of two securing pins, which were then cable tied for further safety. The head of the weight stand was connected to the main coring warp using a 10-Tonne swivel, which was connected using a 6 ½ -Tonne shackle and secured to the centre tube of the weight stand. A securing rope was fed through a 5 tonne shackle connected to a wire strop connected to the bottom of the weight stand and then fastened to the deck on one side. The rope was then fed through an eyebolt in the deck during deployment, in order to steady the corer.

Deployment

With the barrel attached to the weight stand, deployment could commence. With all but the most aft cross tubes removed, the corer's weight was then taken on the main coring warp and driven aft by the stern gantry towards the remaining cross tube. Once the head of the weight stand was close to the cross tube, the corer was landed on the table and the tube removed. Once the end of the core barrel was sufficiently aft for the core cutter to slide down the fantailed table, the corer was lifted by the coring warp and driven using the stern gantry, out board of the stern of the ship to its vertical position. The steadying rope was recovered and the corer lowered at approximately 60 m/min to within 50m of the seabed. The corer was then lowered at 60 m/min in to the seabed. Confirmation that the corer had hit the seabed was observed by the sudden reduction of tension on the coring warp, displayed on the winch control monitor. The corer was then raised slowly out off the seabed. The tension on the coring warp indicated when the corer was free of the seabed. Once clear, it was raised to the sea surface at approximately 80 m/min.

Recovery

The corer was raised from the sea surface and steadied against the stern roller. The corer was then pressure washed down, to remove as much mud from the outer surface of the corer as possible. The corer weight stand was then landed as far along the horizontal support tables as possible. The tension on the coring warp was relaxed and a separate recovery wire was attached just below the 10-Tonne swivel. The recovery wire from the starboard mooring winch was used to pull the corer to the far end of the support tables via a diverter sheave secured to the deck. Once the corer was back in its deployment position, the core cutter was removed and the barrel removed in the reverse manner to its assembly. Once the barrel was secured in its hanging supports, the core liner was removed, cut in to sections, capped and removed for analysis.

Issues

1. The poor height alignment of the barrels required excessive manual lifting of the barrels during assembly and disassembly stages. This heavy and difficult work greatly increased the potential risk of back injuries.
2. The most forward of the coring tables could only be secured to the deck via chains to eyebolts in the deck. The table needs to be modified so that it can be bolted to the deck directly.
3. The lifting pin on the corer is in such a position as to cause the corer to twist when being lifted. This prevents the corer remaining parallel to the tables during deployment and recovery, making control difficult.
4. The buffer bar fitted to top corer table was removed in order that the main lifting cable could be connected to the corer. Blocks of wood were secured to the surface of the table, to prevent the corer weight stand from being pull too far up the table.

Recommended modifications

1. Side panels nearest to the weight stand need to be notched out to allow the coring barrel flange to pass over them without having to be lifted up.

2. A method of supporting the barrels at the correct height needs to be developed in order to allow easy assemble and disassemble of the barrels to and from the weight stand.

3. The top coring tables need to be modified so it can be bolted to the deck directly

4. A second cutting table should be purchased in order that the current table need not be continually repositioned between cores.

5. The lifting pin in the head of the corer needs to be replaced with a steel hoop. In order that the 10 tonne Swivel can be connected to the hoop directly.

6. All bolting down holes on the coring tables need to be enlarged to assist in the bolting down of the tables to the deck.

7. The Buffer fitter to the top coring table need to be relocated flat on the table surface.

Summary

In general the coring programme has proved very reliable and relatively easy to deploy and recover. A number of modifications will be necessary if this equipment is to be hired out in the future as detailed above.

Recommendations

1. It is vital that the alignment issue for the gravity corer (modification #2) be addressed in order to prevent future back injuries occurring.

2. The current lifting point of the corer must be modified as outlined above (modification #2).

4.3 CORES

Twenty four gravity cores were obtained during the cruise (Table 4.1). The maximum recovery obtained was >6 m.

Table 4.1. Gravity cores collected during cruise JR106b, East Greenland

Core No.	Latitude (N)	Longitude (W)	Water depth (m)	Recovery (m)	Geographical location	Acoustic Facies
JCR106_GC01	68°29.39'	32°12.30'	203	1.0	Inner Courtauld Fjord	Diffuse bottom reflector
JCR106_GC02	68°27.35'	32°13.52'	182	0.75	Middle Courtauld Fjord	Diffuse bottom reflector
JCR106_GC03	68°25.19'	32°16.54'	730	3.0	Outer Courtauld Fjord/Kangerdlugssuaq Fjord	Stratified sediments
JCR106_GC04	68°28.53'	32°11.92'	797	3.29	Middle Kangerdlugssuaq Fjord	Stratified sediments
JCR106_GC05	68°05.01'	32°47.60'	874	5.92	Outer Kangerdlugssuaq Fjord	Stratified sediments
JCR106_GC06	68°10.54'	31°59.57'	877	5.22	Middle-outer Kangerdlugssuaq Fjord	Stratified sediments
JCR106_GC07	68°26.76'	31°14.72'	488	0.83	Outer Courtauld Fjord	Diffuse bottom reflector
JCR106_GC08	68°29.16'	32°13.15'	245	1.52	Inner Courtauld Fjord	Stratified sediment pond
JCR106_GC09	68°15.79'	31°33.91'	452	Bag sample of gravel	Inner Watkins Fjord	Diffuse bottom reflector
JCR106_GC10	68°15.07'	31°36.54'	358	3.03	Inner Watkins Fjord	Stratified sediment pond
JCR106_GC11	68°15.01'	31°43.53'	303	5.23	Inner-Mid Watkins Fjord	Stratified sediment pond
JCR106_GC12	68°14.99'	31°43.95'	226	2.63	Inner-Mid Watkins Fjord	Draped sediments
JCR106_GC13	68°15.38'	31°53.58'	689	5.77	Outer Watkins Fjord	Diffuse bottom reflector
JCR106_GC14	68°13'35''	32°26'20''	212	Bag sample	Inner Amdrup Fjord	Diffuse bottom reflector

Core No.	Latitude (N)	Longitude (W)	Water depth (m)	Recovery (m)	Geographical location	Acoustic Facies
JCR106_GC15	68°13’45.4’’	32°28’34.7’’	138	213	Inner Amdrup Fjord	Diffuse prolonged reflector
JCR106_GC16	68°13’58.3’’	32°29’05.1’’	128	1.68	Inner Amdrup Fjord	Diffuse prolonged reflector
JCR106_GC17	68°14’10.8’’	32°29’36.8’’	114	1.23	Inner Amdrup Fjord	Diffuse prolonged reflector
JCR106_GC18	68°14’12.1’’	32°29’32.2’’	110	0.98	Inner Amdrup Fjord	Diffuse prolonged reflector
JCR106_GC19	68°14’12.1’’	32°29’32.2’’	440	2.76	Inner Amdrup Fjord	Stratified sediment
JCR106_GC20	68°11.89’	32°28.60’	198	Bag sample of gravel	Inner Amdrup Fjord	Diffuse bottom reflector
JCR106_GC21	68°11.91’	32°27.82’	231	Bag sample of gravel	Amdrup Fjord	Hard bottom – slightly diffuse
JCR106_GC22	68°12.45’	32°27.90’	253	2.92	Inner Amdrup Fjord	Stratified sediment
JCR106_GC23	68°13.06’	32°21.28’	470	6.0	Middle Amdrup Fjord	Stratified sediment
JCR106_GC24	68°10.85’	32°07.46’	859	6.10	Outer Amdrup Fjord	Stratified sediment

4.4 GEOPHYSICAL INVESTIGATIONS IN THE KANGERDLUGSSUAQ FJORD SYSTEM AND ADJACENT CONTINENTAL SHELF

(Jeffrey Evans, Julian Dowdeswell and Colm Ó Cofaigh)

Introduction

EM120 multibeam swath bathymetric and TOPAS data was acquired continuously in the Kangerdlugssuaq Fjord system and adjacent continental shelf, East Greenland. In addition, EM2000 swath bathymetry and sub-bottom profiler data were acquired by AutoSub from the sea floor immediately in front of Courtauld Gletscher at the head of Courtauld Fjord, and at the mouth of Kangerdlugssuaq Fjord. This section provides an overview of these datasets. Data acquired during the transit from the cruise start point in Iceland and back to the U.K. are not included in this report. Watchkeeping of the EM120 and TOPAS workstations was carried out by Jeffrey Evans (SPRI), Colm Ó Cofaigh (SPRI), Ruth Mugford (SPRI), Darrel Swift (Univ. of Glasgow) and Emma Wilson (JCR Doctor).

Results and preliminary interpretations of EM120 and TOPAS data

Kangerdlugssuaq Fjord

EM120 swath bathymetry shows that middle-outer Kangerdlugssuaq Fjord is narrow and very steep-sided, and has water depths down to ~850 m (Fig. 4.1). The sea floor is generally flat and featureless with only rare deep sills in the outer fjord. Water depths shallow at the mouth of the fjord and inner continental shelf, with a narrow trough running onto the inner shelf (Fig. 4.1). There are no prominent sills separating Kangerdlussuaq Fjord from the deep basins in outer Courtauld, Watkins and Amdrup fjords.

TOPAS sub-bottom profiling data along the centre of Kangerdlugssuaq Fjord comprises a thick sequence of ponded and acoustically-stratified sediment and distinct lenses of acoustically-transparent sediment. This sequence is interpreted to result from deposition from subaqueous debris flows and turbidity currents produced in response to the steep fjord margins and high sedimentation rates in the fjord. Additional sedimentation is also derived from rain out and suspension settling of iceberg rafted debris and sediment transported in meltwater plumes derived from glaciers draining into the Kangerdlugssuaq Fjord system.

There is little or no acoustic penetration of the sea floor along the margins of the deep fjord basin or across deep sills that protrude into the basin, implying either very little sediment cover or the presence of coarse-grained sediments. It is likely that the fjord's glacimarine sediments are postglacial and were deposited during the Holocene after the Greenland Ice Sheet receded through the fjord system during the last deglaciation.

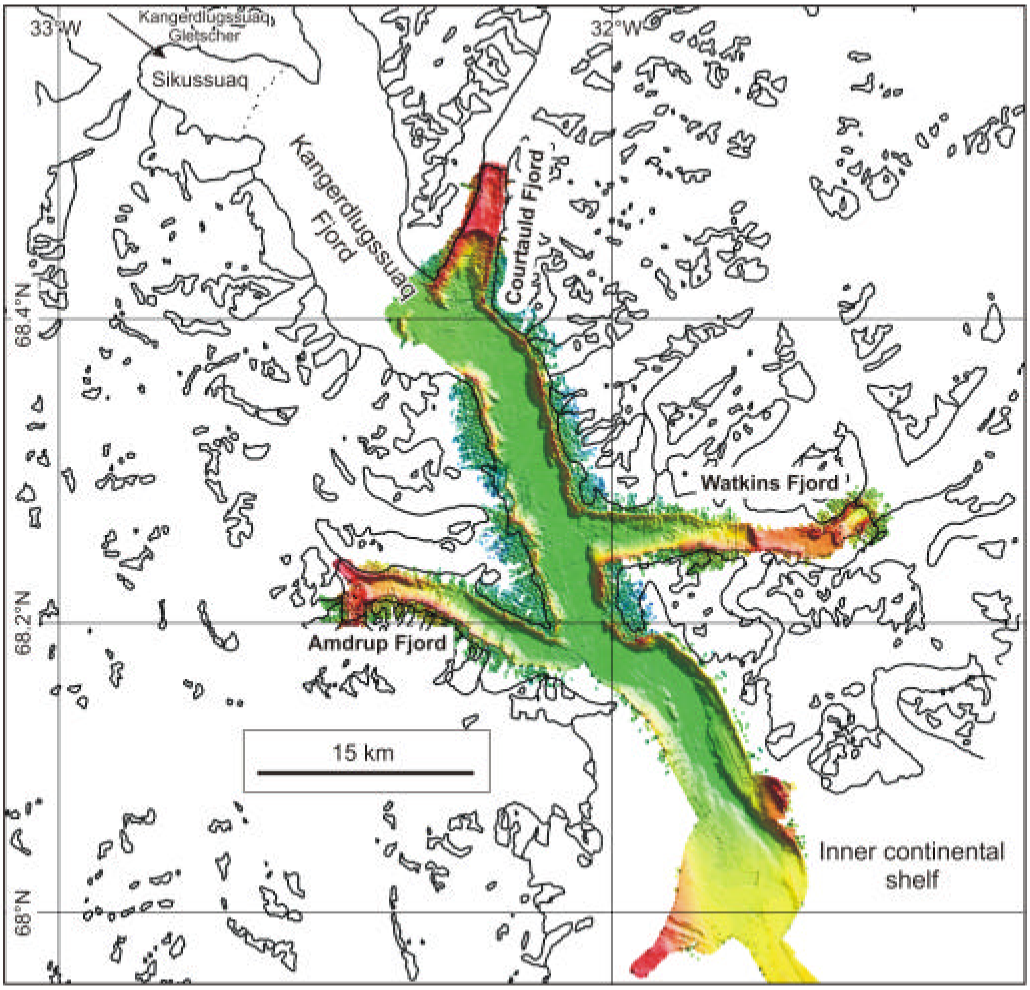


Figure 4.1. Unprocessed EM120 shaded bathymetric map of the Kangerdlussuaq Fjord system. The coastline has been digitised from a georectified Landsat ETM+ image of the region.

Courtauld Fjord

Courtauld Fjord forms a tributary to inner-middle Kangerdlugssuaq Fjord. Water depths range from 70 – 230 m in the inner fjord and 360 – 750 m in the outer fjord basin which are separated by a prominent steep-sided sill (Fig. 4.2a). Water depths in the outer fjord basin progressively deepen down fjord away from the middle-fjord sill. The deepest region of the outer fjord basin is located at the fjord mouth and it connects directly to the main basin of Kangerdlugssuaq Fjord (Fig. 4.2a).

Swath bathymetry shows that the sea floor of the inner fjord is characterised by distinct short, blunt to highly elongate drumlins and lineations (Fig. 4.2b). The presence of subglacial bedforms provides evidence for grounded glacier ice within inner Courtauld Fjord. These bedforms may have been produced by either ice advance during the Little Ice Age or, less likely, by an extended Greenland Ice Sheet during the last glaciation.

TOPAS records show a diffuse sea-floor reflector with little or no penetration beneath indicating the presence of only a thin cover of Holocene glacimarine sediment. Ponds of acoustically stratified sediment are present within small, isolated basins but these appear to be rare. Cores recovered from sediments in the inner fjord will provide ground-truthing of Recent and Holocene glacimarine sedimentary processes within the inner fjord.

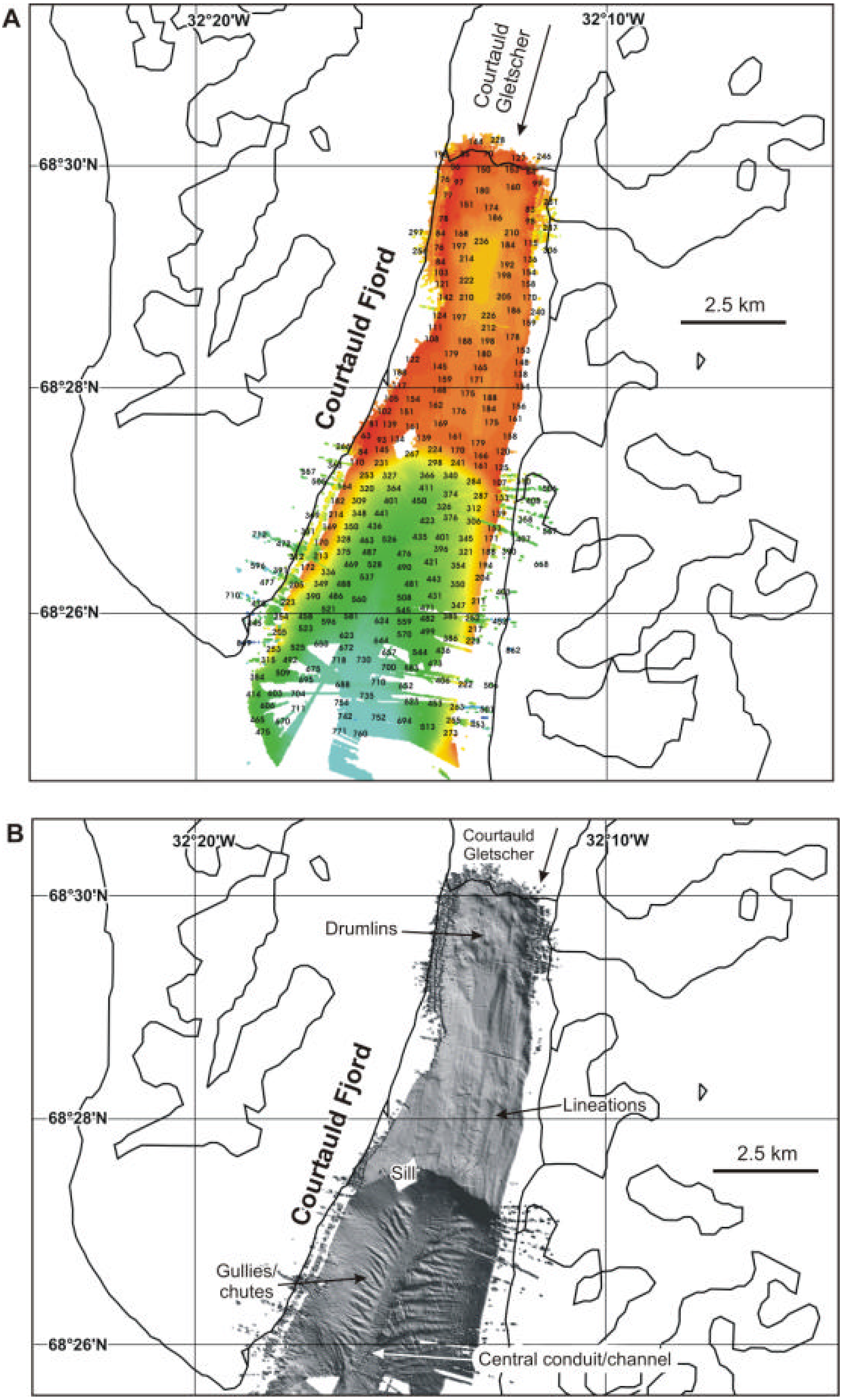

A
32°20'W
32°10'W
Courtauld Gletscher
68°30'N
68°28'N
68°26'N
Courtauld Fjord
2.5 km
B
32°20'W
32°10'W
Courtauld Gletscher
68°30'N
68°28'N
68°26'N
Drumlins
Lineations
Sill
Courtauld Fjord
2.5 km
Gullies/ chutes
Central conduit/channel

Figure 4.2 (previous page). (a) Unprocessed EM120 swath bathymetric map of Courtauld Fjord with water depths shown. The anomalous swath data that overlaps the coastline along the edge of the main swath coverage area result from the steep sided nature of the fjord. (b) Unprocessed EM120 shaded image of Courtauld Fjord showing sea floor features that include drumlins and lineations in the inner fjord, and gullies/chutes in the outer fjord.

The steep sides of the outer fjord are dominated by gullies or chutes (Fig. 4.2b). Gullies start at around 400 – 450 m water depth and feed into a large linear channel that runs down slope along the centre of the outer fjord (Fig. 4.2b). The channel opens out into the deepest region of the basin at the fjord mouth and into Kangerdlugssuaq Fjord. TOPAS records from the outer fjord show a distinct bottom reflector with no acoustic penetration beneath, and the presence of coarse-grained sediments. The gullies are likely to have acted as conduits for subaqueous mass-flows derived from the fjord margins that transported sediment into the deeper region of the outer fjord. Acoustically stratified sediment and lenses of transparent sediment are present in the deepest region of the basin at the mouth of the Courtauld Fjord and in adjacent Kangerdlugssuaq Fjord down slope of these gullies. These sediments are interpreted as being the result of deposition from subaqueous mass-flow processes derived from the gully system that become ponded within the deepest region of the basin.

Watkins Fjord

Watkins Fjord comprises a basin at the head of the fjord adjacent to Frederiksberg Gletscher where water depths reach 560 m (Fig. 4.3). Water depths in the inner-middle fjord beyond the inner basin are relatively shallower and reach 370 m. Water depths progressively deepen between the middle fjord and the outer fjord basin where maximum depths of 800 – 850 m occur at the mouth of Watkins Fjord and in the adjacent Kangerdlugssuaq Fjord (Fig. 4.3).

Swath bathymetry indicates the presence of rare streamlined subglacial bedforms across the sea floor at the head of the fjord adjacent to Frederiksberg Gletscher, and locally across the inner-middle fjord (Fig. 4.4). These bedforms were produced beneath glacier-ice when it last advanced across this region of the fjord. TOPAS records from the inner basin indicate a diffuse sea floor reflector adjacent to the ice front with evidence for stratification further down fjord. Cores recovered from sediments in the inner fjord will provide ground truthing of Recent and Holocene glacimarine sedimentary processes close to the glacier margin.

The middle-outer fjord is characterised by distinct to subtle gullies along its margins that feed into a central channel or conduit that in turn feeds down slope into a basin at the mouth of the fjord and Kangerdlussuaq Fjord (Fig. 4.4). TOPAS records across the middle-outer fjord indicate the presence of a diffuse hummocky sea floor reflector with some sub sea floor stratification locally. Acoustically stratified sediment and lenses of transparent sediment are present in the basin at the mouth of Watkins Fjord and Kangerdlugssuaq Fjord. The gullies and central channel would have acted as pathways for sediment transported by subaqueous mass-flows from the fjord margins to the fjord mouth and Kangerdlugssuaq Fjord.

Figure 4.3. Unprocessed EM120 swath bathymetric map of Watkins Fjord with water depths shown. Anomalous swath data that overlaps the coastline along the edge of the main swath coverage area at the head of the fjord and along its southern margin result from the steep sided nature of the fjord.

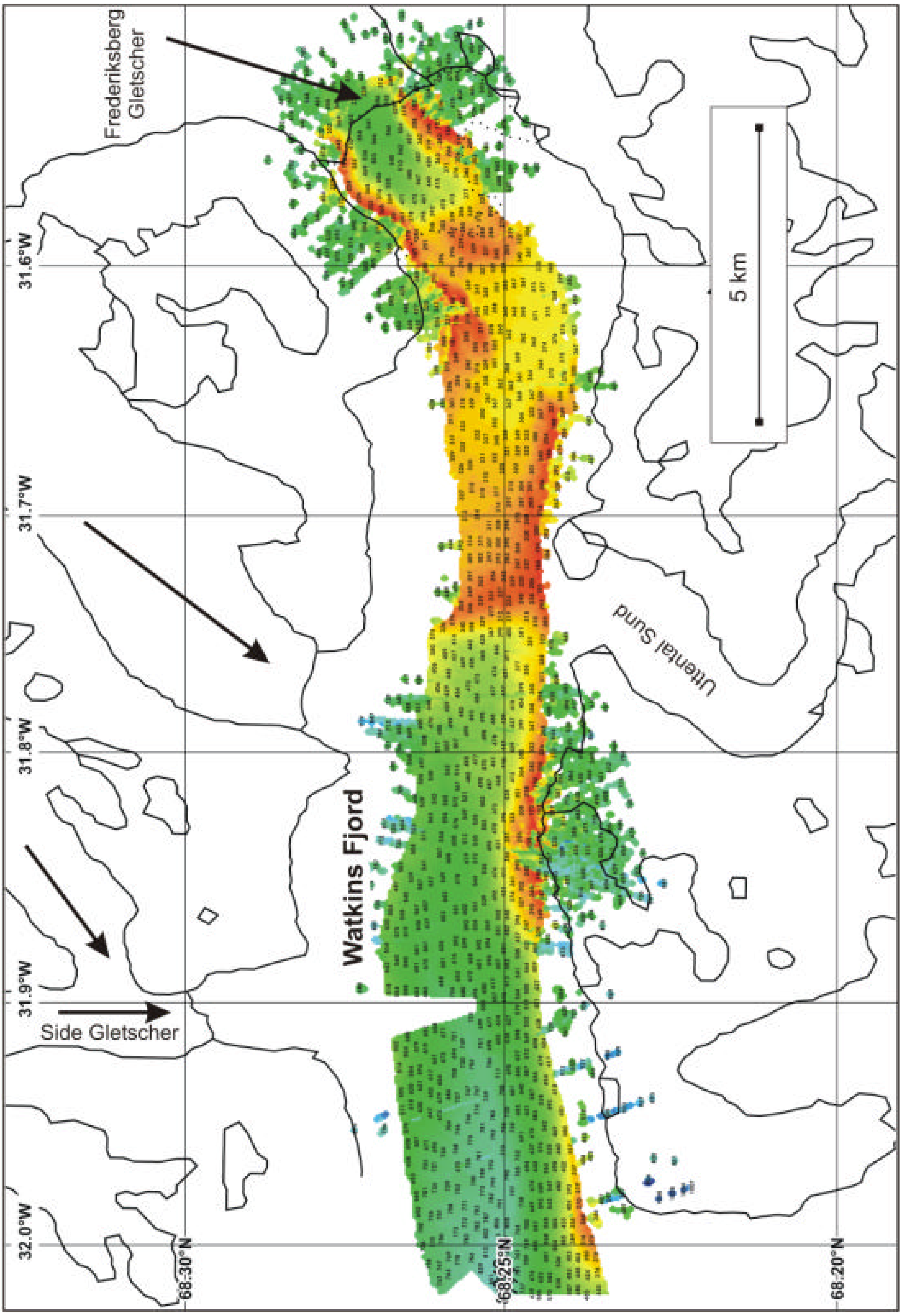
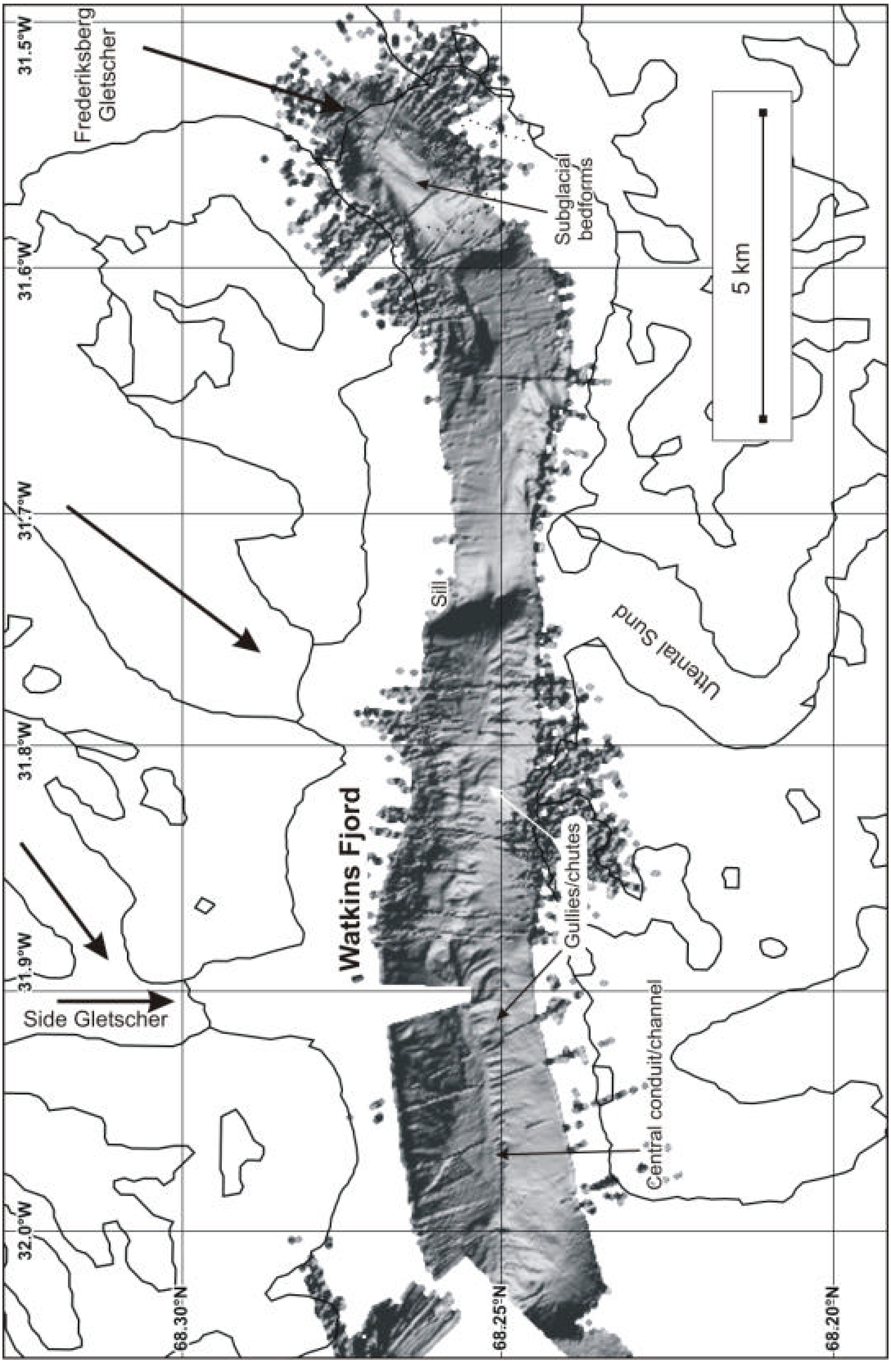


Figure 4.4. Unprocessed EM120 shaded image (sun illumination) of Watkins Fjord showing sea floor features that include subglacial bedforms in the inner fjord and gullies/chutes in the middle-outer fjord.



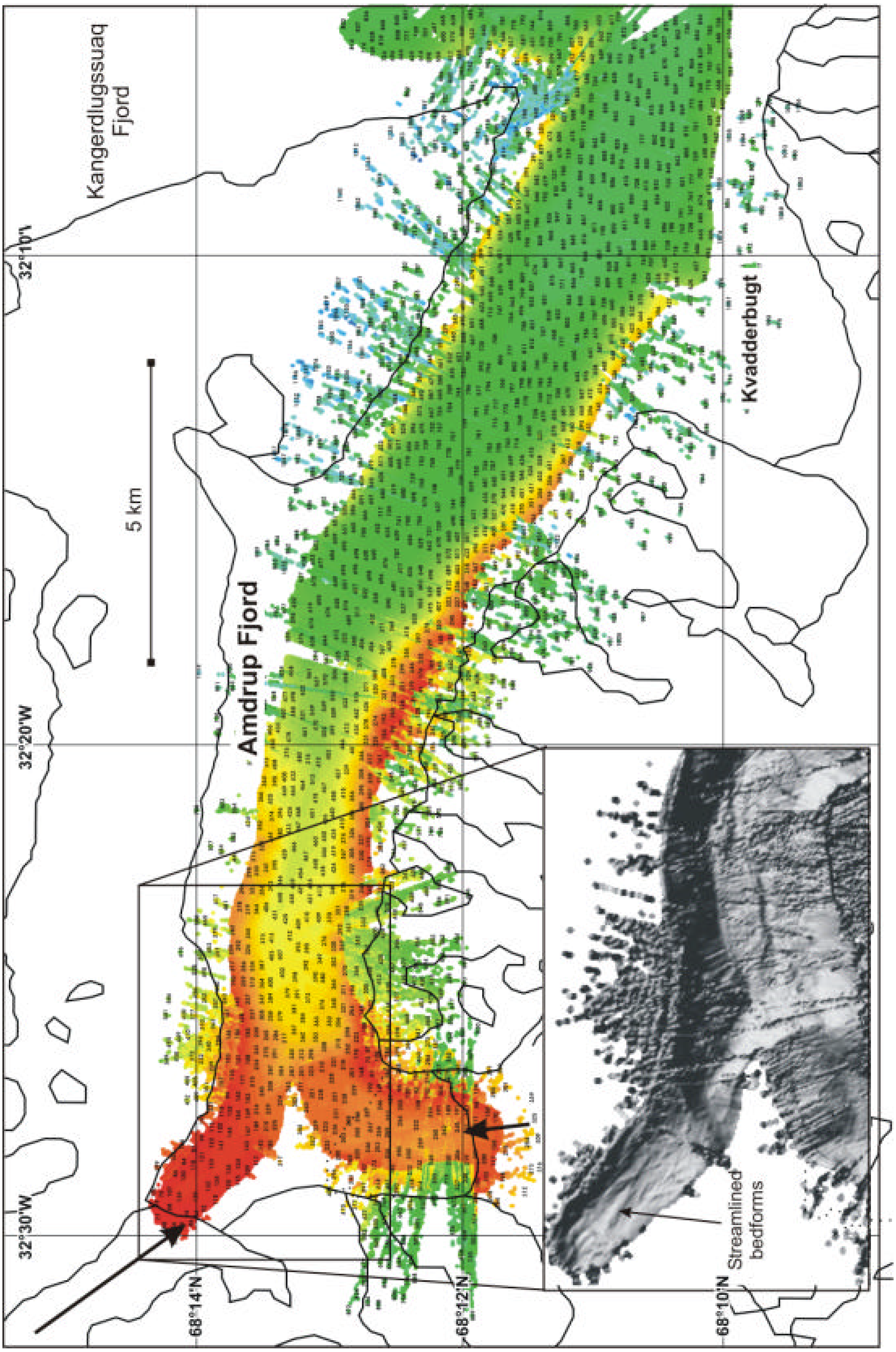


Figure 4.5. Unprocessed EM120 swath bathymetric map of Amdrup Fjord with water depths shown. Anomalous swath data that overlaps the coastline along the edge of the main swath coverage area result from the steep sided nature of the fjord. The inset shows a shaded image of the inner fjord with subglacial bedforms preserved on the sea floor.

Amdrup Fjord

Amdrup Fjord forms a steep sided and narrow fjord that is ~20 km in length (Fig. 4.5). The head of Amdrup Fjord is fed by three glaciers and water depths offshore of them reach between 130 m to 260 m (Fig. 4.5). Water depths progressively deepen down fjord and reach 870 m in outer Amdrup Fjord and adjacent Kangerdlugssuaq Fjord (Fig. 4.5). Swath bathymetry indicates the presence of attenuated drumlins and lineations in the inner fjord region. These bedforms were produced beneath glacier-ice when it last advanced across this region of the fjord.

TOPAS records reveal a diffuse to distinct sea floor reflector across the inner fjord with little or no acoustic penetration beneath. A pond of acoustically transparent sediment lenses and stratified sediment is present locally in the inner fjord, bounded by steep topography. These sediments were probably derived by subaqueous mass-flows of glacimarine and glacially-derived sediment deposited in front of the glaciers draining into Amdrup Fjord. A thick sequence of stratified sediment covers the slope connecting the inner and outer fjord basin and throughout the outer fjord basin. These are probably derived from a combination of subaqueous mass-flow and rain out and suspension settling of glacimarine sediment.

Continental shelf

EM120 swath bathymetric and TOPAS sub-bottom profiler data were acquired from Kangerdlugssuaq Trough on the East Greenland continental shelf. Water depths within the trough vary between 480 m to 600 m, and progressively shallow to 450 – 510 m close to the shelf edge. Streamlined subglacial bedforms and iceberg scours are observed on the swath bathymetric and TOPAS records (Figs. 4.6-4.7). The subglacial bedforms provide evidence for an extensive Greenland Ice Sheet during the last glaciation that reached onto the outer continental shelf in SE Greenland, and probably to the shelf edge. Subglacial bedforms in the trough on the inner shelf comprise well-developed NW-SE trending lineations (≥3.8 km in length and ≥470 m in width) that were produced by ice sheet flow to the SE (Fig. 4.6a). Sinuous channels are present in the inner-middle trough and are likely to represent subglacial meltwater channels (Fig. 4.6b). Highly attenuated drumlins, lineations and other crudely streamlined bedforms (≥2.5 km in length and ≥460 m in width) are present within the trough on the inner-middle shelf (Fig. 4.7). Bedforms trend NW-SE and N-S indicating ice sheet flow through the trough to the south and southeast. Drumlins commonly have crescentric overdeepenings around their blunt stoss sides, possibly generated by localised meltwater production (Fig. 4.7). Subtle lineations (≥4.3 km in length and ≥240 m in width) and well-developed iceberg scours dominate the outer trough. The lineations trend ~N-S, indicating ice sheet flow to the south. Iceberg scours also dominate the geophysical records acquired from the SE Greenland shelf outside Kangerdlugssuaq Trough in water depths <350 m.

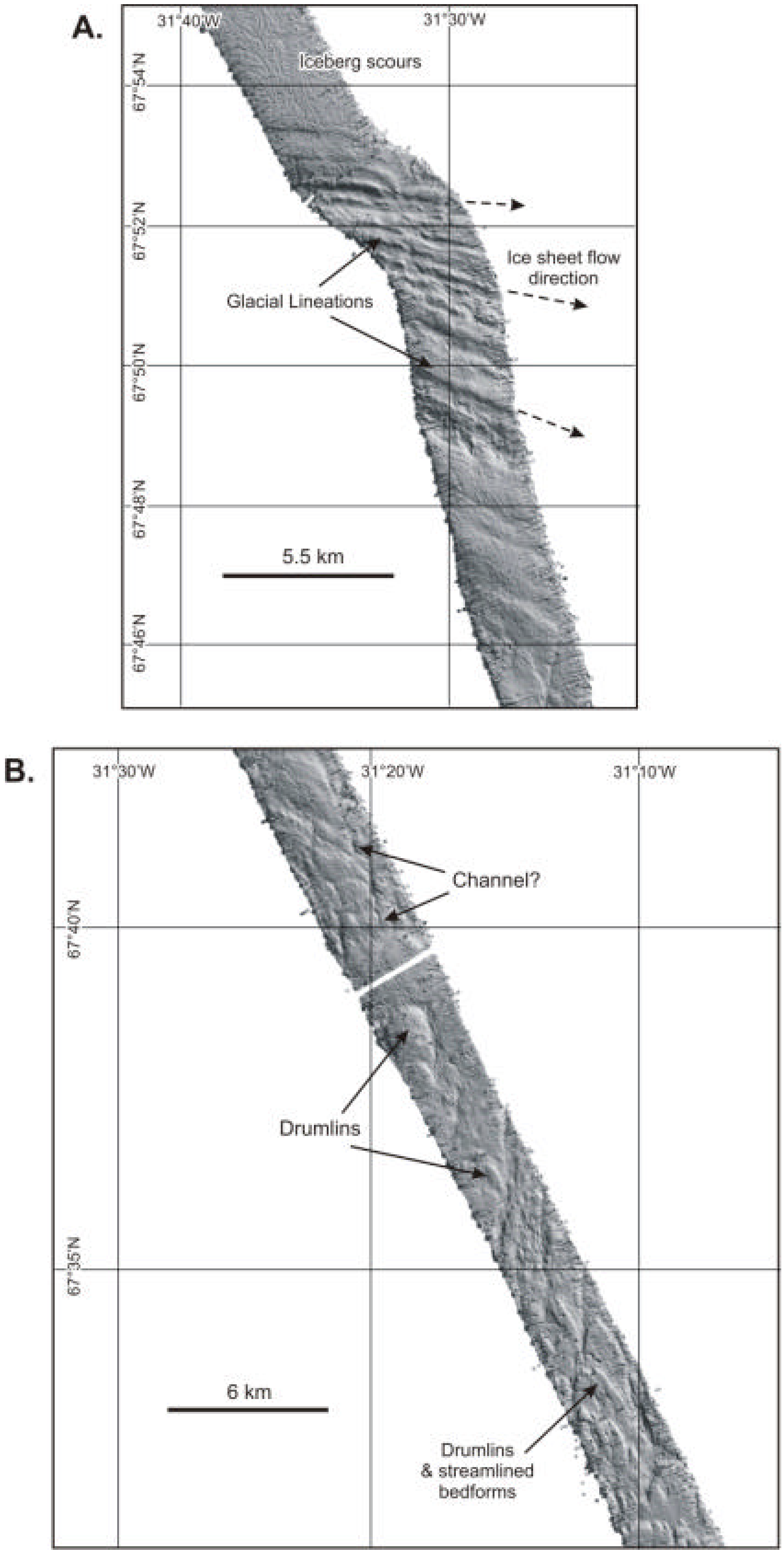


Figure 4.6. Unprocessed EM120 shaded images of the inner-middle Kangerdlugssuaq Trough on the continental shelf showing: (a) Subglacial lineations and iceberg scours, and (b) Drumlins and streamlined bedforms and channels.

TOPAS records indicate the presence of a thick drape of post-glacial sediments overlying the subglacial bedforms in some areas of the trough, particularly in the inner-middle trough. This may explain the subtle nature of some bedforms in this region. Where the drape is thin, TOPAS records show (particularly the middle-outer fjord) that subglacial bedforms are formed in the surface of an acoustically transparent sediment unit underlain by a distinct continuous sub-sea floor basal reflector. This is interpreted to represent till deposited by the ice sheet. However, it is difficult to determine the composition of bedforms in the inner-middle trough as there is a lack of acoustic penetration beneath the sea floor reflector. TOPAS records also indicate that iceberg scouring of the sea floor has extensively homogenised the sedimentary record in the outer trough and across the shelf outside Kangerdlugssuaq Trough.

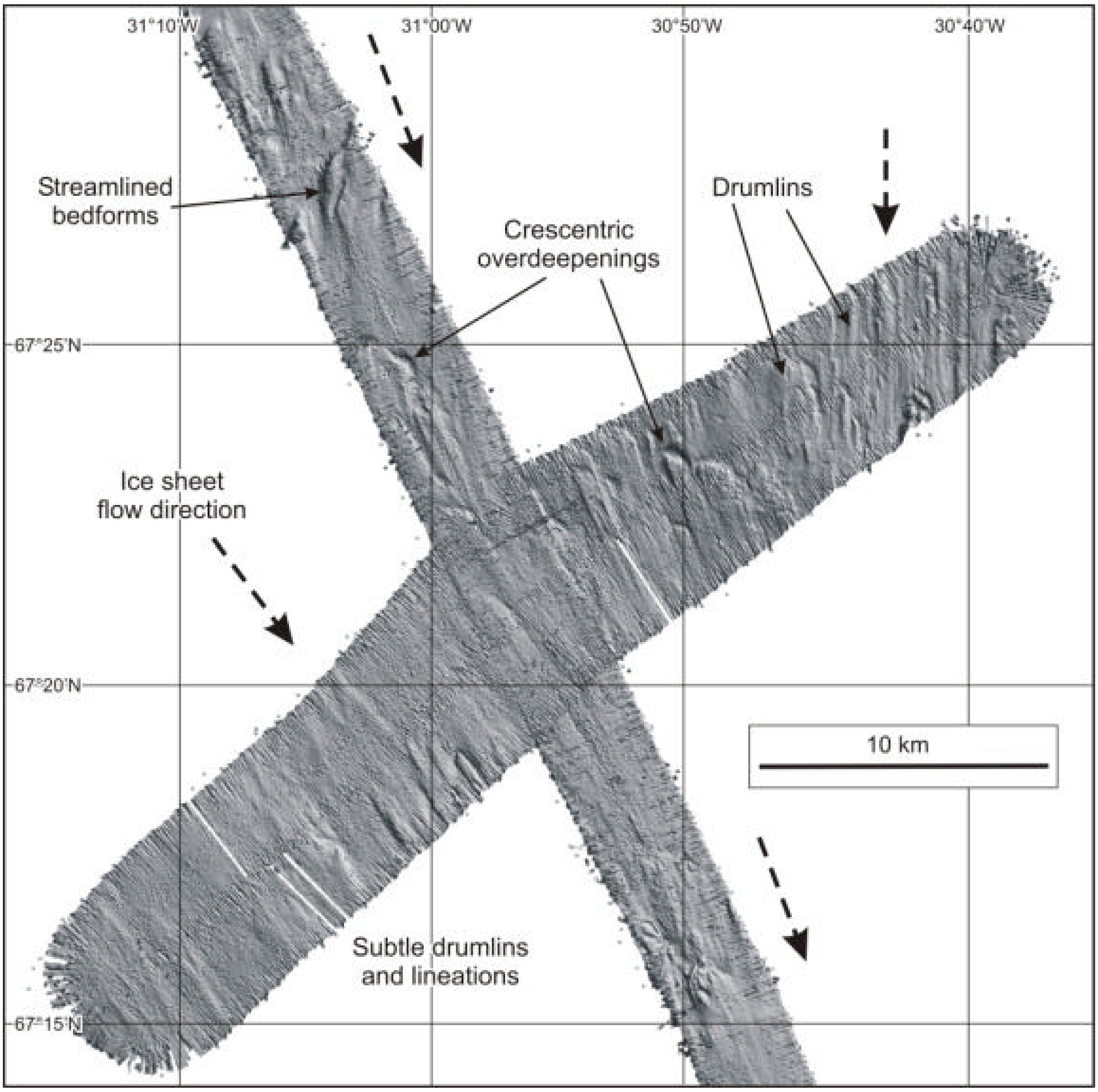


Figure 4.7. Unprocessed EM120 shaded image of the middle-outer Kangerdlugssuaq Trough on the continental shelf showing drumlins with crescentric overdeepenings around their stoss sides, subglacial lineations and streamlined bedforms.

TOPAS records from the continental slope adjacent to this region of the SE Greenland continental shelf comprise a distinct sea floor reflector with little or no acoustic penetration below this. Acoustically transparent lens-shaped sediment bodies are present on the continental slope below ~1500 m and are orientated in a down slope direction. These sediment bodies are interpreted as debris flow deposits. The occurrence of debris flow deposits supports an advance of the Greenland Ice Sheet to the shelf edge during the last glacial maximum, which delivered glacial sediment direct to the continental slope with subsequent remobilisation as debris flows.

4.5 AUTOSUB GEOPHYSICAL INVESTIGATIONS
(Jeff Evans, Julian Dowdeswell, Colm Ó Cofaigh)

AutoSub acquired EM2000 swath bathymetric and sub-bottom profiler data during several missions immediately in front of the eastern side of Courtauld Glacier, which drains into the head of Courtauld Fjord (missions 373, 374 & 375), and at the mouth of Kangerdlugssuaq Fjord (missions 376 & 377). AutoSub encountered problems during some of the missions in Courtauld Fjord which resulted in incomplete missions. Only part of the EM2000 swath data acquired during these missions was useable, with the remaining data of poor quality and difficult to interrogate and process. Sub-bottom profiler data will be analysed more fully after the cruise. The remainder of this section provides a brief overview of the AutoSub EM2000 data.

The swath data that could be interrogated produced more detailed and higher resolution images of the sea floor than that produced by the EM120 system. EM2000 data could be gridded at a cell size of 2 – 3 m, whereas the ship-based EM120 system could only be gridded at cell sizes of 10 m in Courtauld Fjord and 25 – 30 m in the deep region of outer Kangerdlugssuaq Fjord before the data quality deteriorated significantly.

Mission 373: AutoSub encountered problems on this mission (cf AutoSub section). The swath data show a number of sea floor ridges orientated ~NW-SE. However, the swath data also shows that water depths on this mission are shallower than those of the EM120 by some 20-30 m questioning the quality and accuracy of the data.

Mission 374: Swath data from the eastern region of the coverage shows an irregular sea floor with the possible presence of a streamlined sea floor feature (Fig.4.8).

Mission 375: Swath data show a semi-circular profile for each ping when processed using correlation plot in the Kongsberg-Simrad NEPTUNE software package. This could be a product of an incorrect sound velocity, possibly in response to the proximity of the glacier and fluctuating salinity of fjord waters controlled by meltwater discharge. This will require further investigation and, if possible, corrected by applying the correct sound velocity using the NEPTUNE processing software.

Missions 376 & 377: Swath data from the deep trough region of outer Kangerdlugssuaq Fjord shows a featureless sea floor and an irregular undulating margin slope to the trough (Figs. 4.9 – 4.10). Swath data acquired during mission 377 is of poor quality but may be cleaned with thorough processing with NEPTUNE.

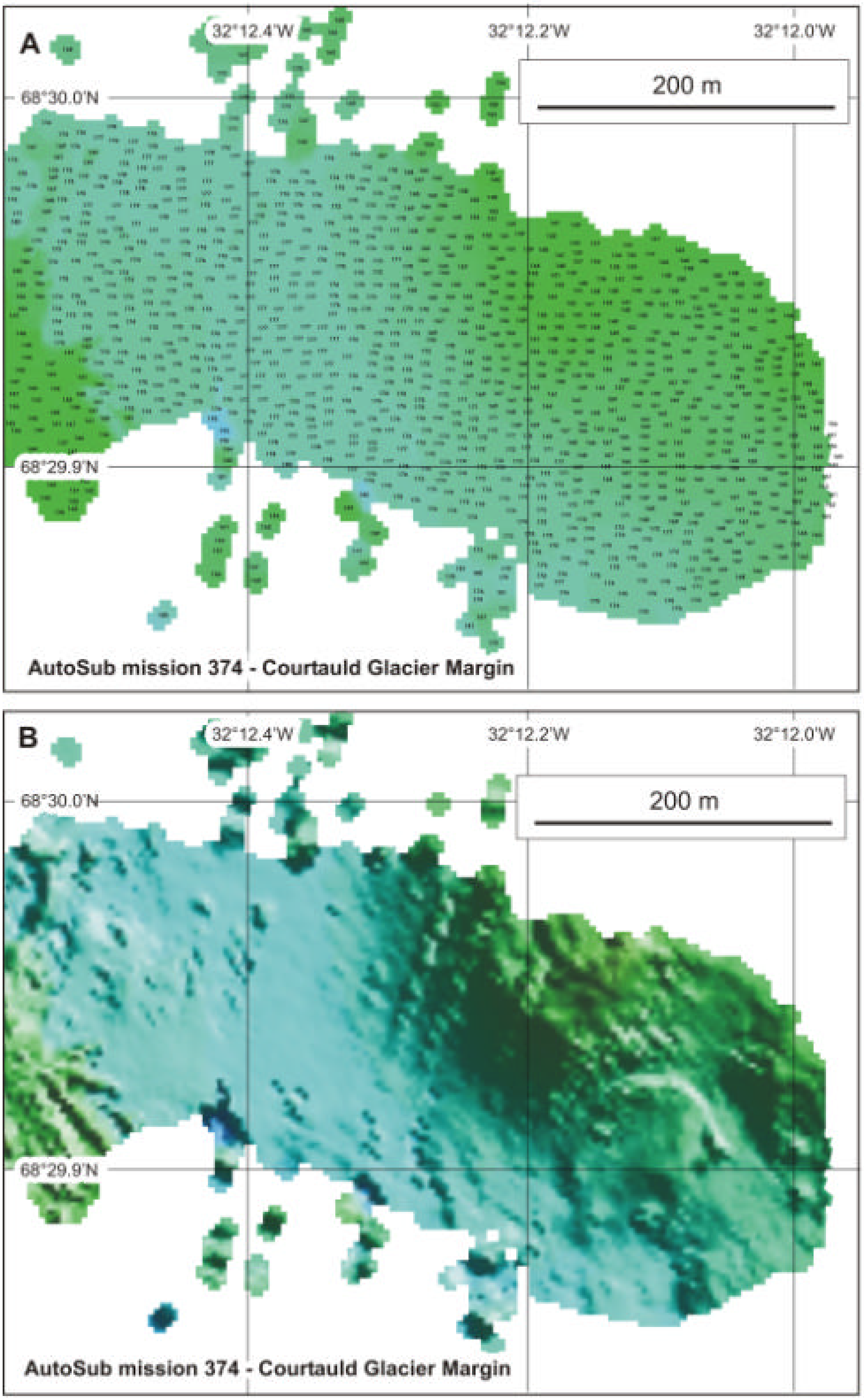


Figure 4.8. (a) EM2000 bathymetric map compiled from data acquired during mission 374 of AutoSub in front of Courtauld Glacier, Courtauld Fjord. Water depths are shown. (b) EM2000 shaded image of the sea floor compiled from the same data showing an irregular sea floor and a possible streamlined feature.

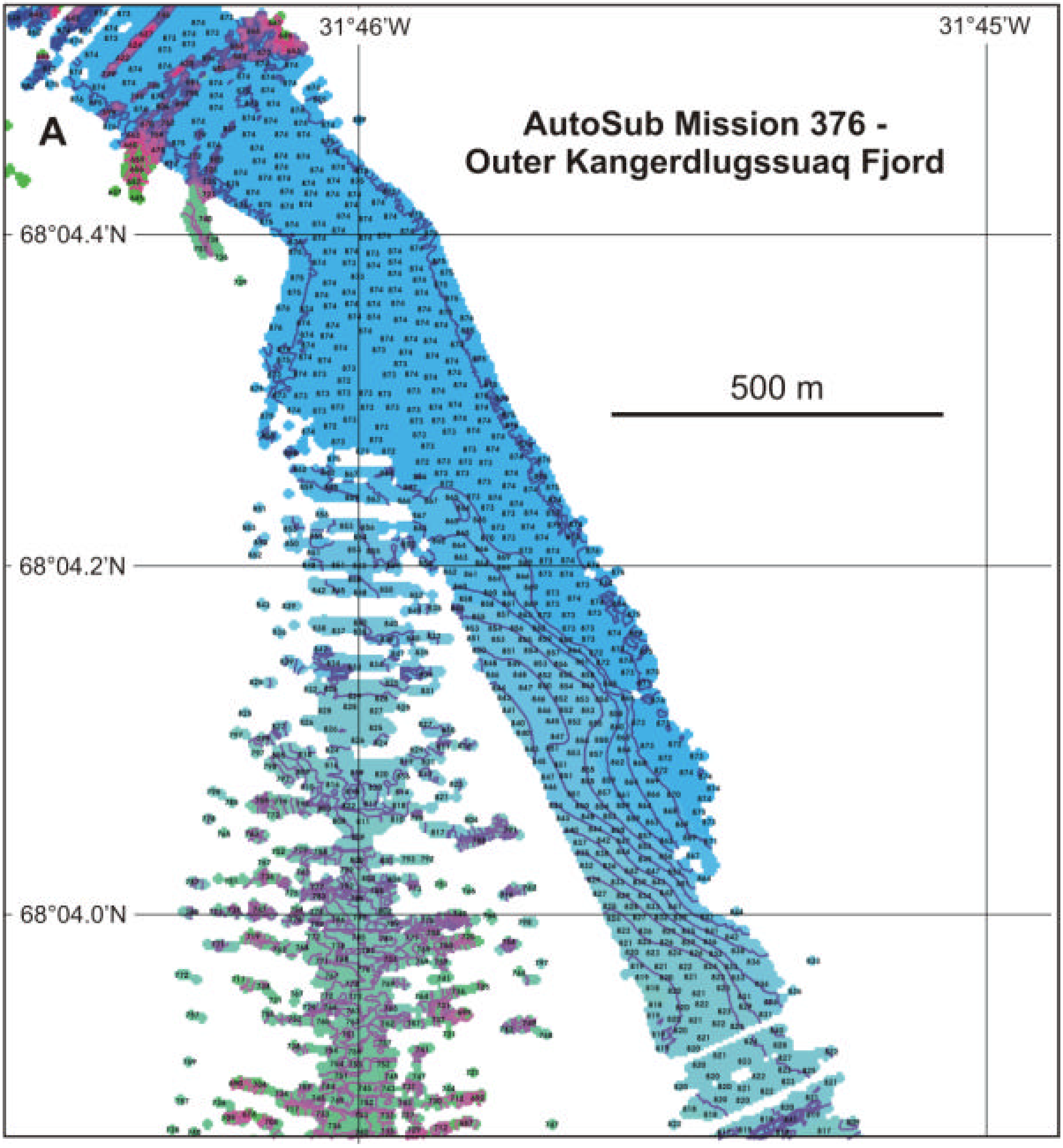


Figure 4.9. EM2000 bathymetric map compiled from data acquired during mission 376 of AutoSub in outer Kangerdlugssuaq Fjord. Water depths are shown and contours are at 5 m intervals.

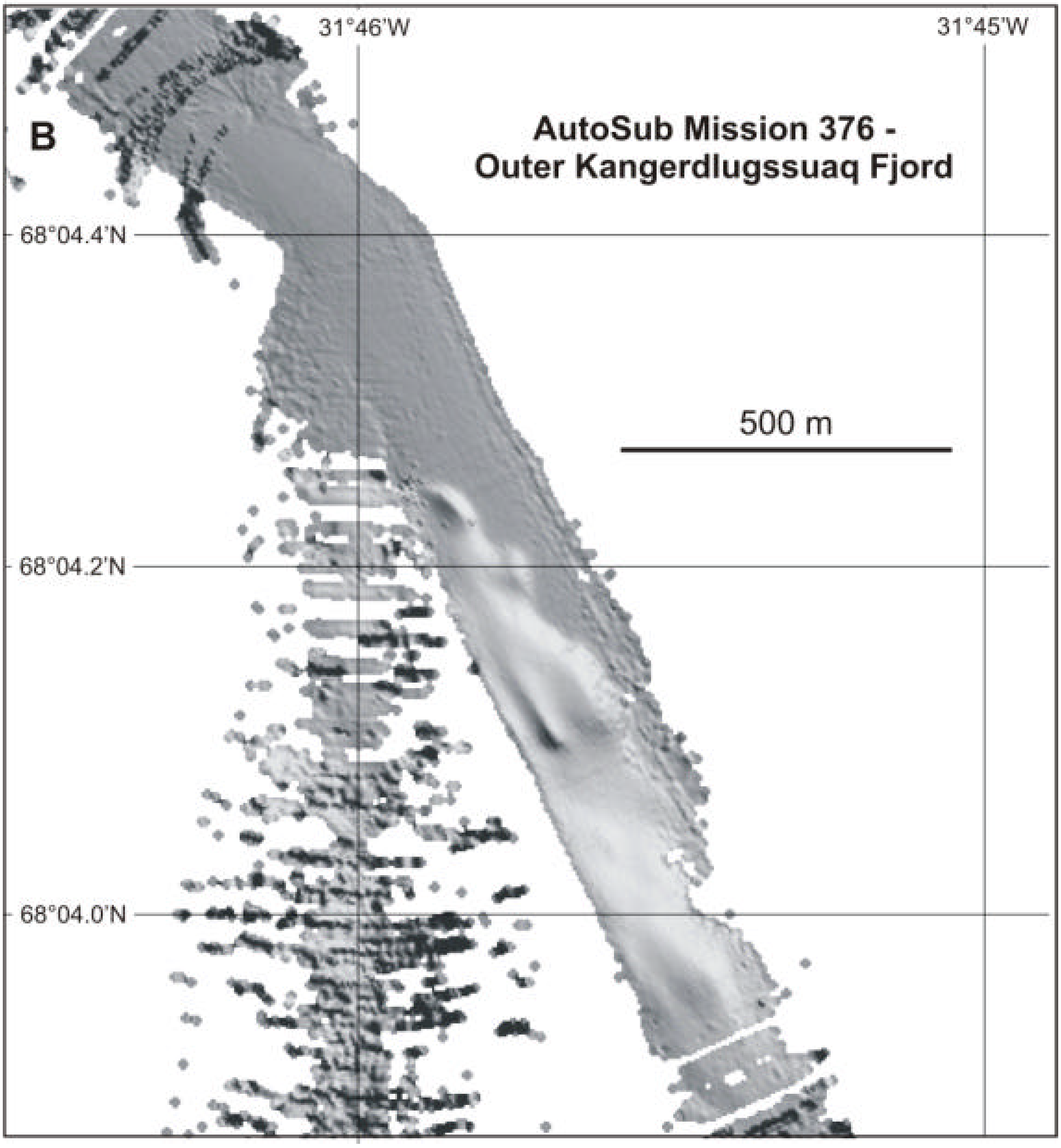


Figure 4.10. EM2000 shaded image of bathymetric data acquired during mission 376 of AutoSub in outer Kangerdlugssuaq Fjord.

4.6 GLACIAL SEDIMENTS AND PROCESSES (Darrel Swift)

Glaciers are widely assumed to be powerful agents of erosion that have been responsible for increased rates of sediment transfer from continents to oceans during the late Cenozoic. In addition, the generation of large quantities of finely-ground and highly chemically-reactive sediment during glaciation has been suggested to influence global climate by accelerating the weathering of silicate minerals, a process that sequesters carbon dioxide from the atmosphere. The widespread glaciation of North Atlantic margins during the late Cenozoic therefore had the potential to accelerate not only sedimentary deposition in offshore basins (an impact of great significance to petroleum exploration), but also late Cenozoic global cooling.

In Greenland, the onset of full glacial conditions predated glaciation in areas such as the Himalayas by 4–5 Ma, but its role in late Cenozoic climate change has been largely overlooked because rates of erosion during ice sheet glaciation are generally assumed to have been comparatively low. Diverse evidence, however, indicates rapid late Cenozoic denudation of North Atlantic margins that has recently been supported by apatite fission track thermochronometry from areas such as East Greenland. In addition, an apatite (U-Th)/He thermochronometric age of 5.8 ± 0.1 Ma determined for bedrock from Kangerdlugssuaq Fjord (Swift et al., 2004) indicates up to 2.5 km of denudation in the area since glacial intensification. Nevertheless, the relative inaccessibility of glacier margins in East Greenland means that the processes of glacial erosion in such contexts remain poorly understood.

The Autosub Under Ice cruise JR106b presented an excellent opportunity to investigate glacial sedimentary processes in proximity to large ice sheets that are crucial to the understanding of rates and mechanisms of glacial erosion and sediment transfer. Glacial sediment close to major glacier termini was collected for *micromorphological* and *thermochronological* analyses by both filtration of fjord water samples obtained during CTD profiling and sampling of glacimarine sediment obtained from fjord bottoms by gravity coring. Water samples were collected from Niskin bottles on the CTD package at CTD stations located near to Courtauld Glacier in Courtauld Fjord to obtain suspended sediment representative of recently evacuated subglacial debris. Samples were obtained by emptying of the contents of each Niskin bottle into three wide-necked 500 ml containers and then filtered individually using 0.45 µm papers. Sediment in the water column was found to be fine-grained and at low concentrations (up to a few hundred mg per litre) at distances ~ 200 to 1000 m from the glacier terminus. Larger quantities of sediment of more variable grain size that represent time-integrated samples of glacial erosional debris were obtained from sediments cored adjacent to major glacier termini within the Kangerdlugssuaq fjord system.

Analysis of sediment samples is to be undertaken on return to the UK. Sediment grain micromorphology is to be analysed using SEM microscopy to constrain the predominant sediment transport pathways within the glaciers of the Kangerdlugssuaq fjord system. The mechanisms of glacial sediment transfer have significant geomorphic implications because the efficiency of basal sediment evacuation will critically influence rates and styles of both ice motion and subglacial erosion (Alley et al., 2003). Sediment transported by hydraulically efficient subglacial drainage, for example, should show evidence of fluvial transport (such as grain rounding), as opposed to that transported within alternative and less efficient glacial transport pathways. Apatite (U-Th)/He thermochronometry (AHT) will also be undertaken on suitable apatite grains exceeding 60 µm diameter. As the lowest-temperature thermochronometer currently available, AHT is uniquely suited to constraining geologically recent rates and patterns of denudation (for example, due to glaciation). AHT ages for suspended and detrital sediment will be compared with ages from bedrock samples (Swift et al., 2004) that will enable unique assessment of the impact of ice sheet glaciation on denudation within the region of the Kangerdlugssuaq fjord system.

References

Alley, R.B., Lawson, D.E., Larsen, G.J., Evenson, E.B. and Baker, G.S. 2003. Stabilizing feedbacks in glacier-bed erosion. *Nature*, 424**:** 758–760.

Swift, D.A., Persano, C., Bishop, P., Stuart, F.M., Nienow, P.W., Hoey, T.B., Gallagher, K., Whitham, A. and Sugden, D. 2004. Impact of ice sheet glaciation on the late Neogene denudation of East Greenland. *10th International Fission Track Conference*, August 8th–13th 2004, Amsterdam.

5. BIOLOGICAL OPERATIONS

(Brian Bett, Dan Jones, Paul Tyler)

5.1 OBJECTIVES

The SOC DEEPSEAS Group, together with Prof. Andrew Clarke (British Antarctic Survey), are concerned with the AUTOSUB Under Ice project “The controls on marine benthic biodiversity and standing stock in ice covered environments” (NER/T/S/2000/00994). This project has integrated a digital still camera system with the AUTOSUB vehicle to aid the study of benthic biological diversity and standing stock in Arctic and Antarctic regions. Using seabed photography (from the AUTOSUB vehicle and the towed camera platform WASP, see below), supported by trawl and dredge sampling, the project aims to assess the megabenthos in three types of polar environment: 1. open water areas, 2. seasonal ice areas, and 3. permanent ice areas. By contrasting the ecology of these three environment types the project will address the primary question: "What are the dominant controls on the diversity and standing stock of the benthos in polar regions?"

For RRS *James Clark Ross* cruise 106b, the SOC DEEPSEAS Group’s objectives were:

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

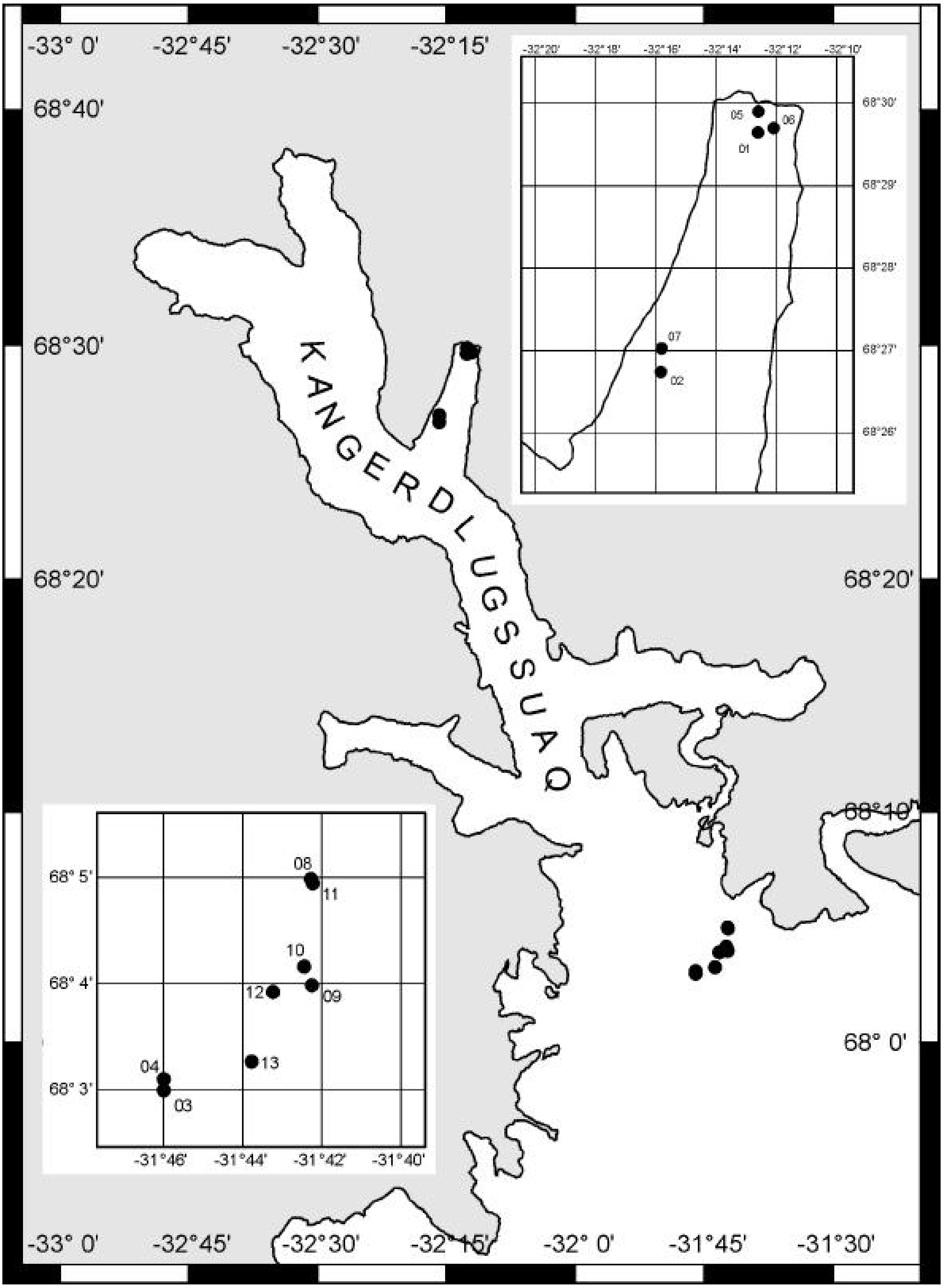
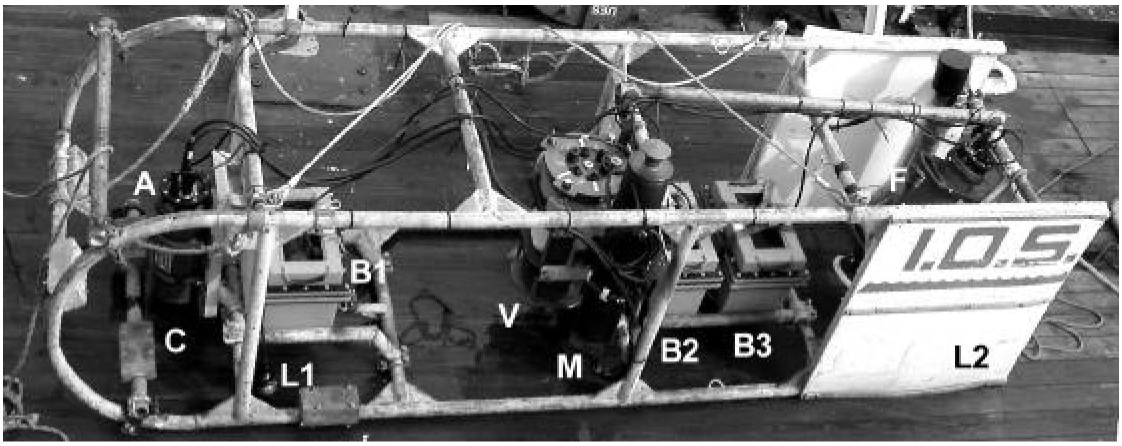


Fig. 5.1. Locations of SOC DEEPSEAS Group operations during RRS *James Clark Ross* cruise 106b. (Locations are designated by the last two digits of the station number, e.g. 56501#1 is shows as 01).

5.2 WASP

(see Figs. 5.2-5.8)

The Southampton Oceanography Centre WASP (Wide-Angle Seabed Photography) system was used throughout the cruise in its standard configuration. Briefly, WASP is a self-contained, off-bottom, towed camera vehicle that provides still and video footage of the seabed, and is capable of operation to 6,000m water depth on a simple mechanical cable (i.e. conducting or fibre-optic cable not required). As deployed during RRS *James Clark Ross* cruise 106b, WASP was fitted with: OSIL Mk7 (stills) camera, OSIL 1200J flash gun, SOC OceanCam6000V (digital video) camera, 2 x 250W DSPL video lamps, 3 x DSPL 24V batteries, Simrad Mesotech 200kHz altimeter, and a SOC acoustic telemetry system (10kHz). Data from the altimeter is telemetered to a shipborne display enabling the operator to make fine adjustments of the amount of cable deployed with the aim of keeping the vehicle at c. 3m above the seabed. The still and video cameras are both automatically activated by the altimeter when the range to the seabed is <10m. For all deployments made during the cruise, the still camera was loaded with 30m of Kodak Vision 250D and the video camera loaded with a 63 minute MiniDV tape.



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

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

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

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

Seven WASP deployments were undertaken during the course of the cruise (see station list below), with film and video run on all but one occasion (see material retained below). The failure of the still camera on the second deployment (stn. 56502#1) had no obvious cause and did not re-occur in the subsequent 5 deployments. The only other technical point of note was a spurious activation of the video on recovery from the sixth deployment (stn. 56512#1). The pressure switch on the system should prevent this from happening. The cause is unknown at this time, but did not impact on the subsequent deployment (stn. 56513#1).

The first two deployments undertaken in Courtauld Fjord (stn.s 56501#1 and 02#1) encountered highly turbid / coloured water and will generate little if any useful data. Though the video from the first deployment (56501#1) does show the presence of a dense population of brittlestars (ophiuroids) close to the glacier ice front.

The third deployment (56503#1), in the mouth of Kangerdlugssuag Fjord was rather more successful, showing clear water at the seabed. All subsequent deployments (56508#1, 09#1, 12#1 and 13#1) were carried out in this vicinity. The Kangerdlugssuag Fjord mouth deployments spanned a bathymetric range of c. 300-700m and should enable a study of the differential impact of iceberg disturbance of the seabed. The deployments at c. 300, 400 and 500m appear to show evidence of seabed disturbance (e.g. overturned sediment, seabed furrows etc.); similar features were not evident at c. 600 and 700m. The WASP sites split into the same groups on a general faunistic basis, with abundant featherstars (crinoids) present 300-500m and tube worms and burrowing fauna visually dominant 600-700m.

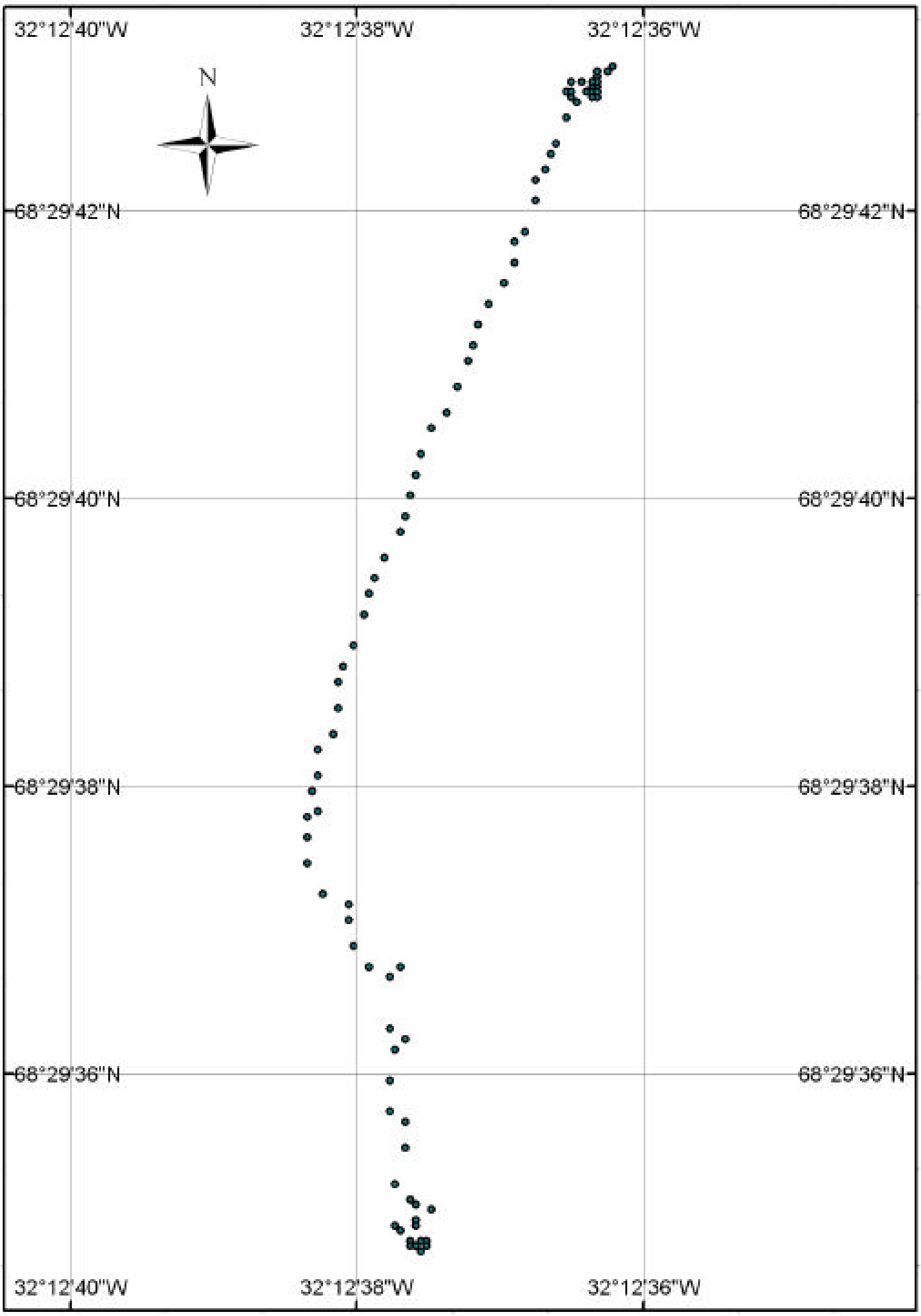


Fig. 5.2. Navigation data WASP deployment 1 (stn. 56501#1).

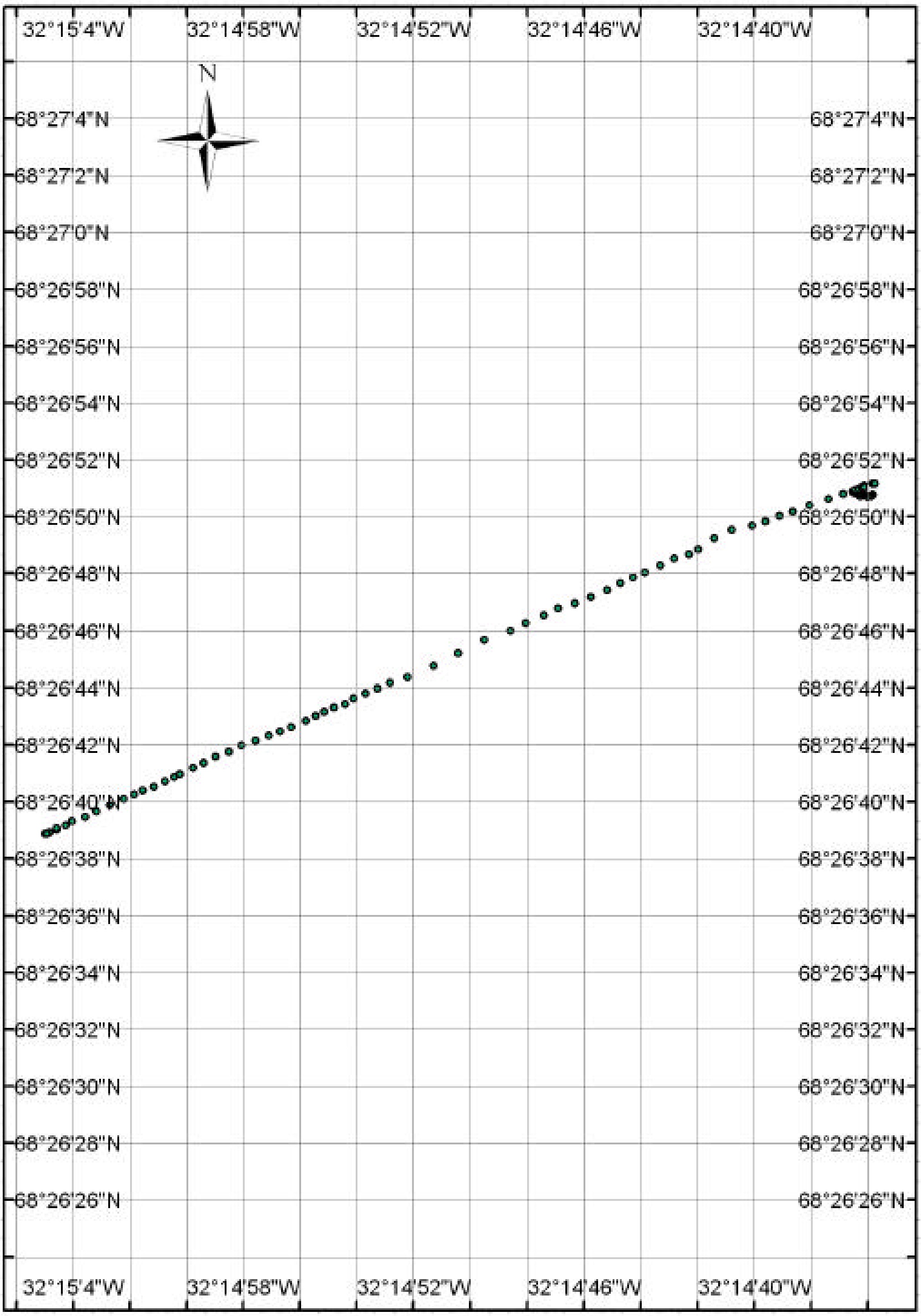


Fig. 5.3. Navigation data WASP deployment 2 (stn. 56502#1).

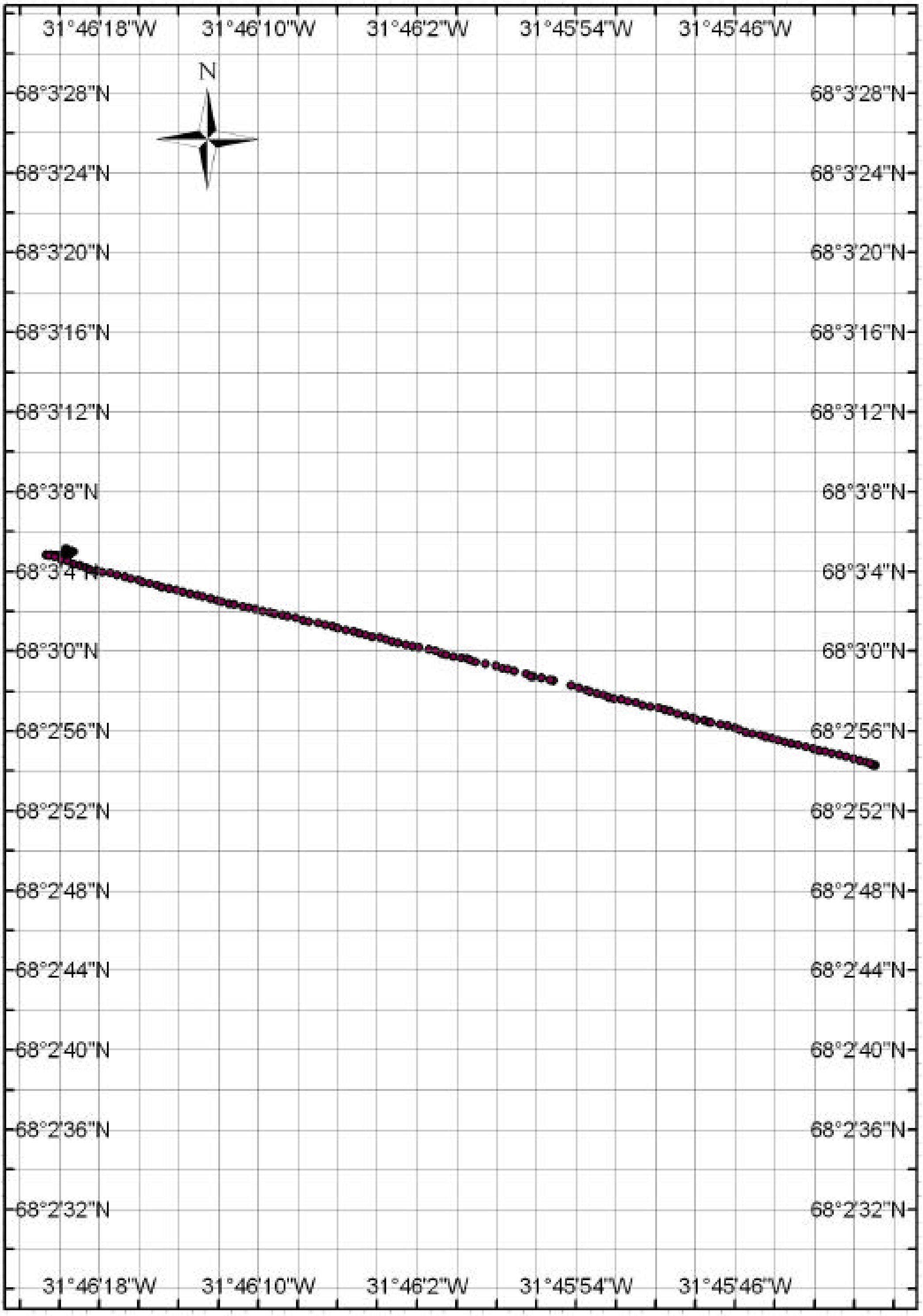


Fig. 5.4. Navigation data WASP deployment 3 (stn. 56503#1).

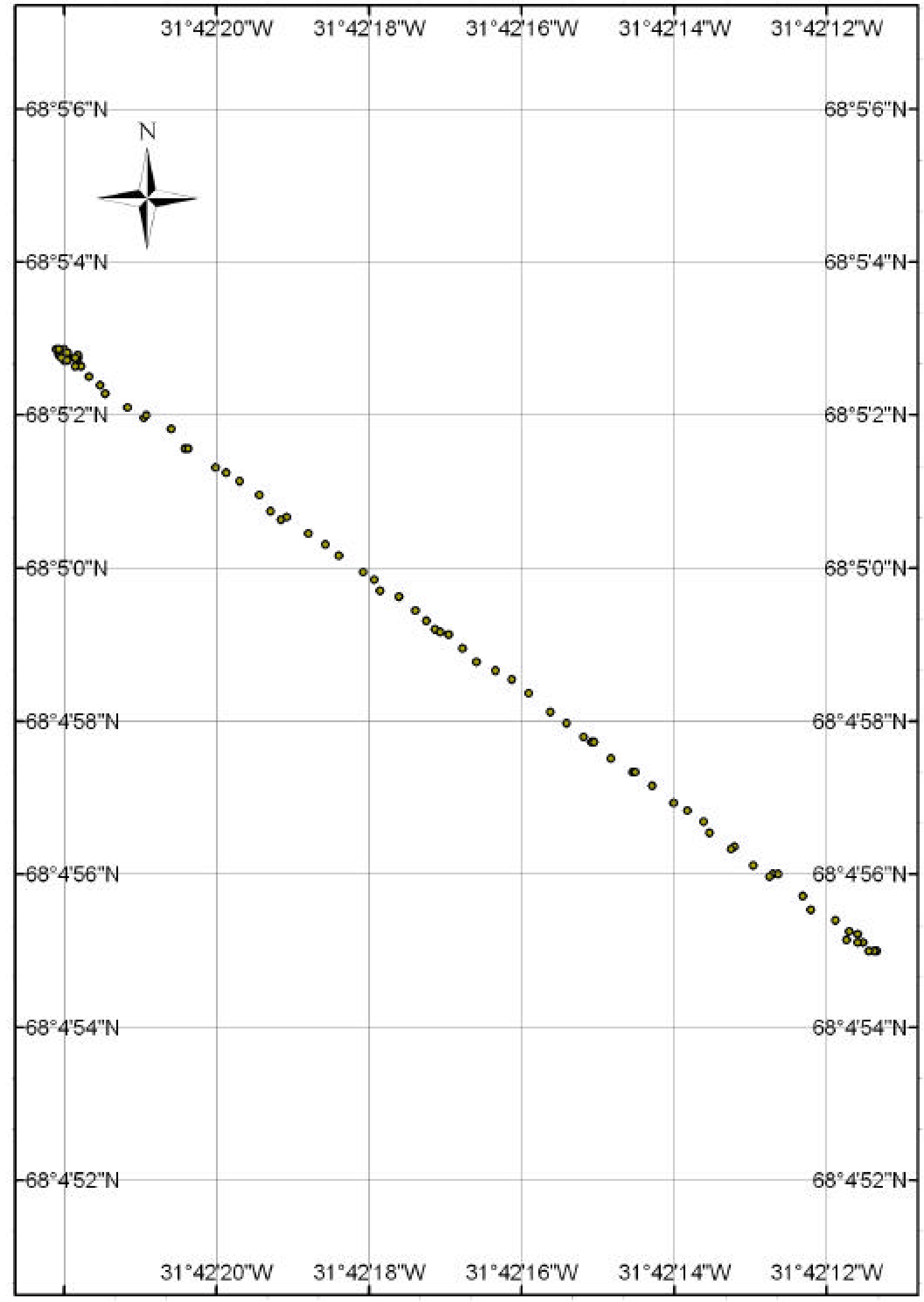


Fig. 5.5. Navigation data WASP deployment 4 (stn. 56508#1).

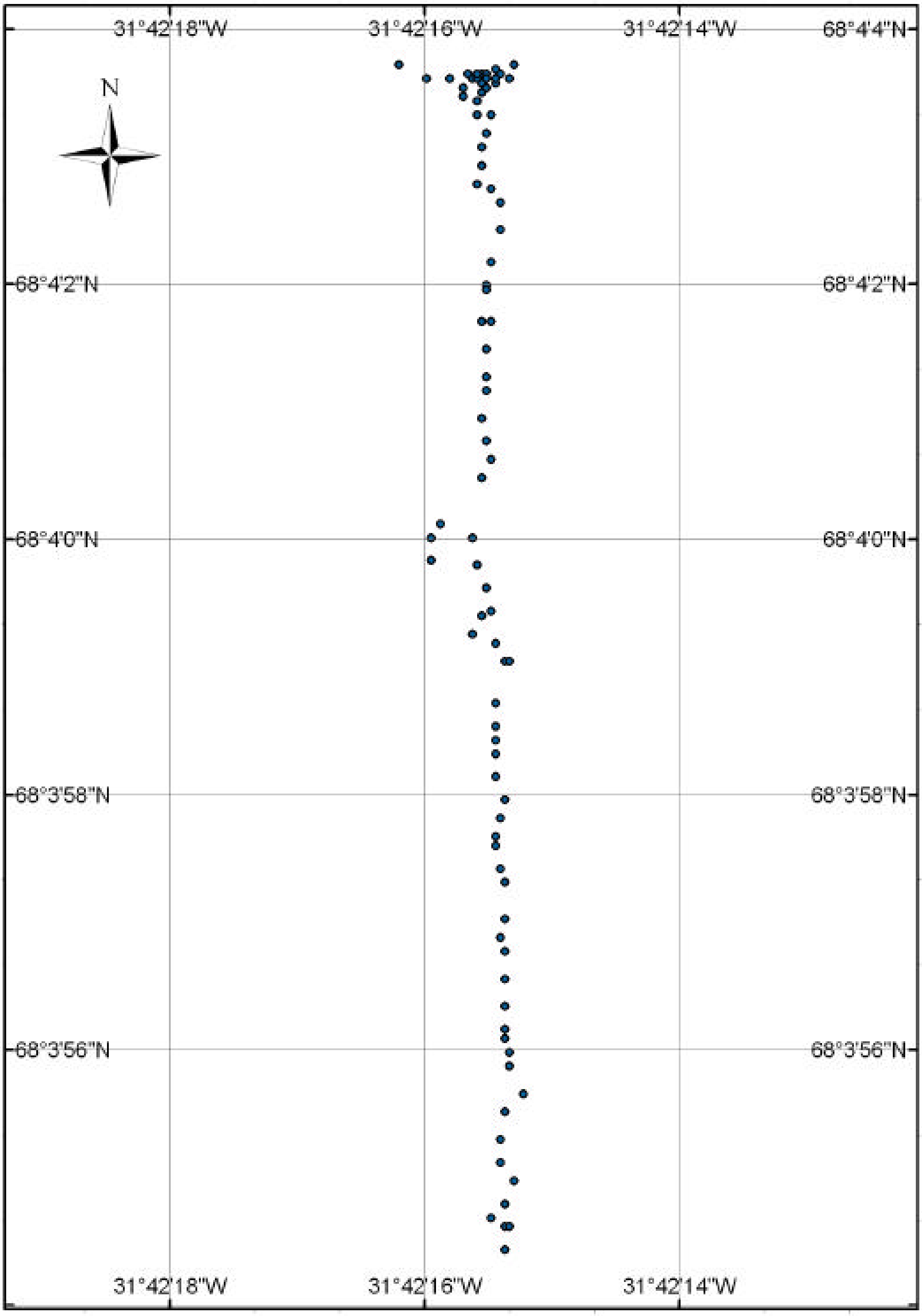


Fig. 5.6. Navigation data WASP deployment 5 (stn. 56509#1).

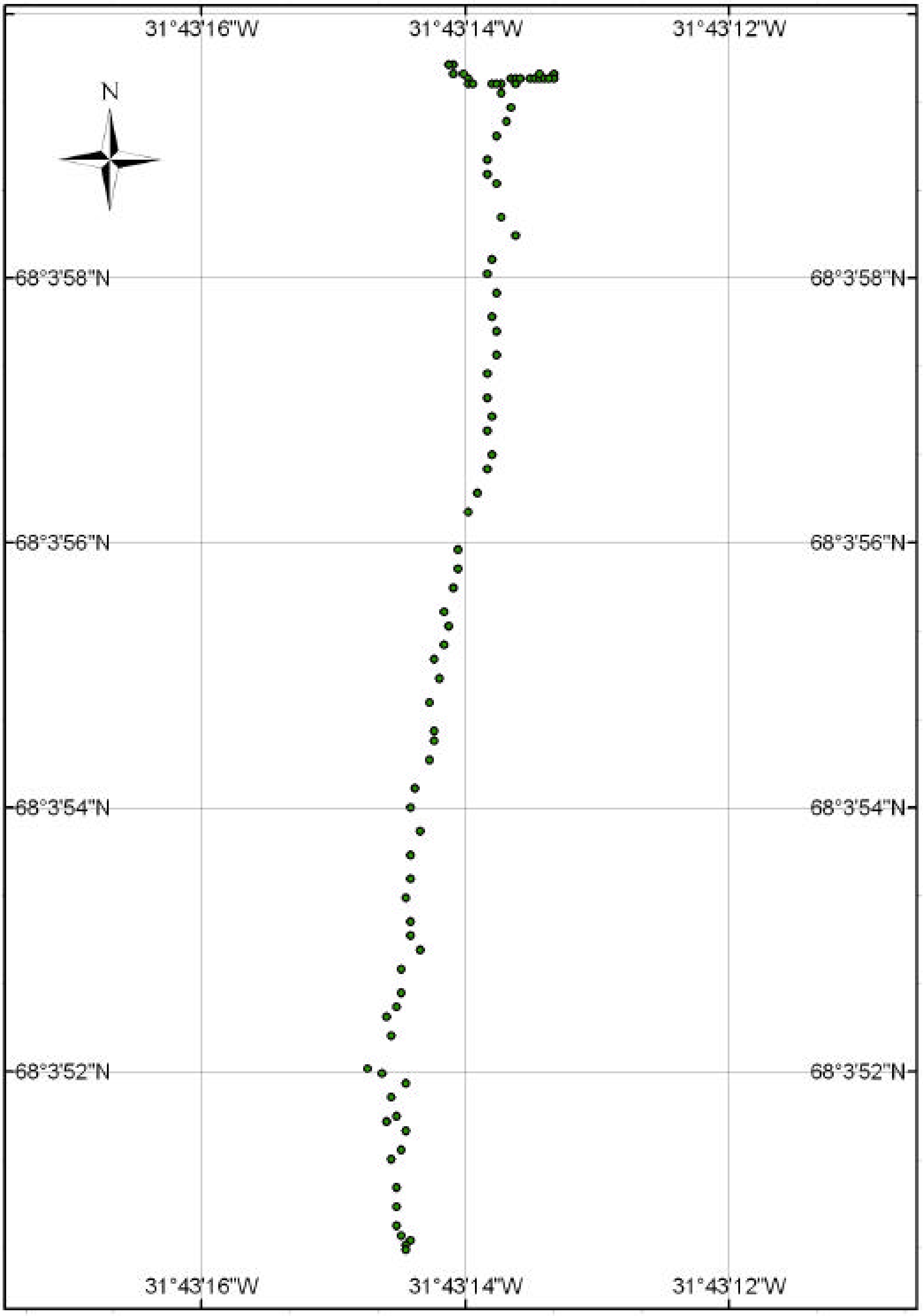


Fig. 5.7. Navigation data WASP deployment 6 (stn. 565012#1).

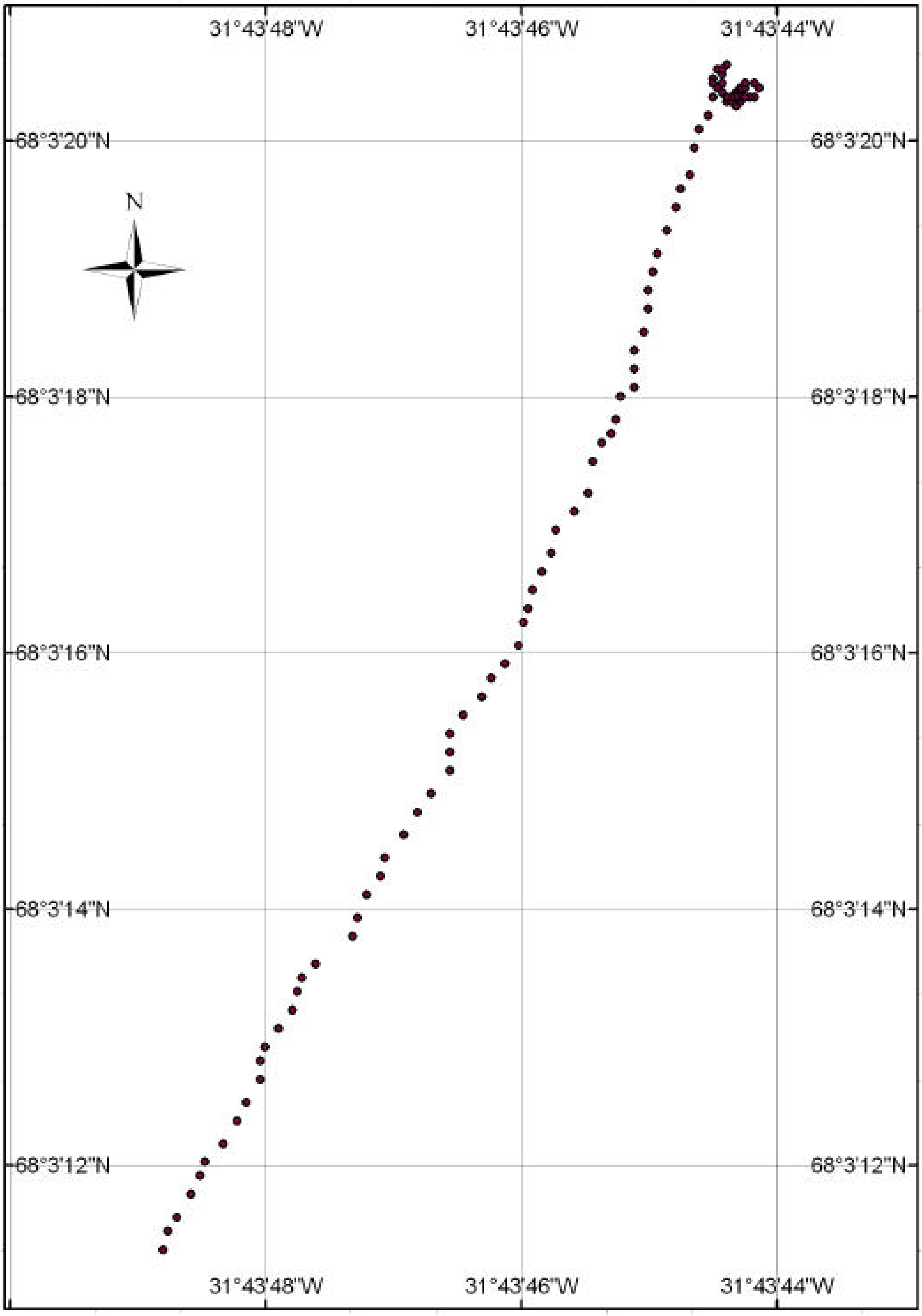


Fig. 5.8. Navigation data WASP deployment 7 (stn. 565013#1).

5.3 AGASSIZ TRAWL

An Agassiz trawl was supplied from the UK National Marine Equipment Pool at Southampton Oceanography Centre. The trawl was rigged and fished in a conventional manner. Two deployments (stn.s 56504#1 and 56505#1) were undertaken during the cruise, on both occasions the first weak-link parted as a result (presumably) of collisions with or accumulations of drop stones. Indeed on the second deployment the net was completely torn away, not a single remnant of the net remained.

The UK National Marine Equipment Pool (SOC) Agassiz trawl as used during RRS James Clark Ross *cruise 106b.*

The first trawl (56504#1) produced a limited but interesting catch (see material retained below), notable for the presence of a number of large molpadid sea cucumbers (holothurians). The second trawl (56505#1), having returned without its net, produced only a few worms caught on the ground chains.

5.4 ROCK DREDGE

A rock dredge was supplied from the UK National Marine Equipment Pool at Southampton Oceanography Centre. For the first two deployments (stn.s 56506#1 and 07#1) was conventionally rigged (i.e. with dredge bucket, see "a" below). For the second two deployments (stn.s 56510#1 and 11#1) the dredge bucket was removed and six un-stranded hemp rope "tangles added to the bucket chains (see "b" below).

The UK National Marine Equipment Pool (SOC) rock dredge as used during RRS James Clark Ross *cruise 106-south: (a) conventionally rigged with dredge bucket, (b) dredge bucket replaced with hemp tangles.*

The first dredge (56506#1) returned with a quantity of cobble and gravel drop stones plus one anemone and one moderate-sized errant polychaete. The second dredge (56507#1) returned with the first weak-link parted and a catch of cobble and gravel drop stones devoid of any obvious fauna. The subsequent removal of the dredge bucket appears to have allowed the dredge to "fish" more effectively among the drop stones and the tangles were successful at recovering additional fauna. Both of the final dredge deployments (stn.s 56510#1 and 11#1) produced useful catches (see material retained below).

5.5 AUTOSUB CAMERA

General details of the AUTOSUB vehicle and specifics regarding the digital still camera system are given in the AUTOSUB report. Only one AUTOSUB mission (number 377, stn. 56514#1) during RRS *James Clark Ross* cruise 106 yielded any useful photographs.

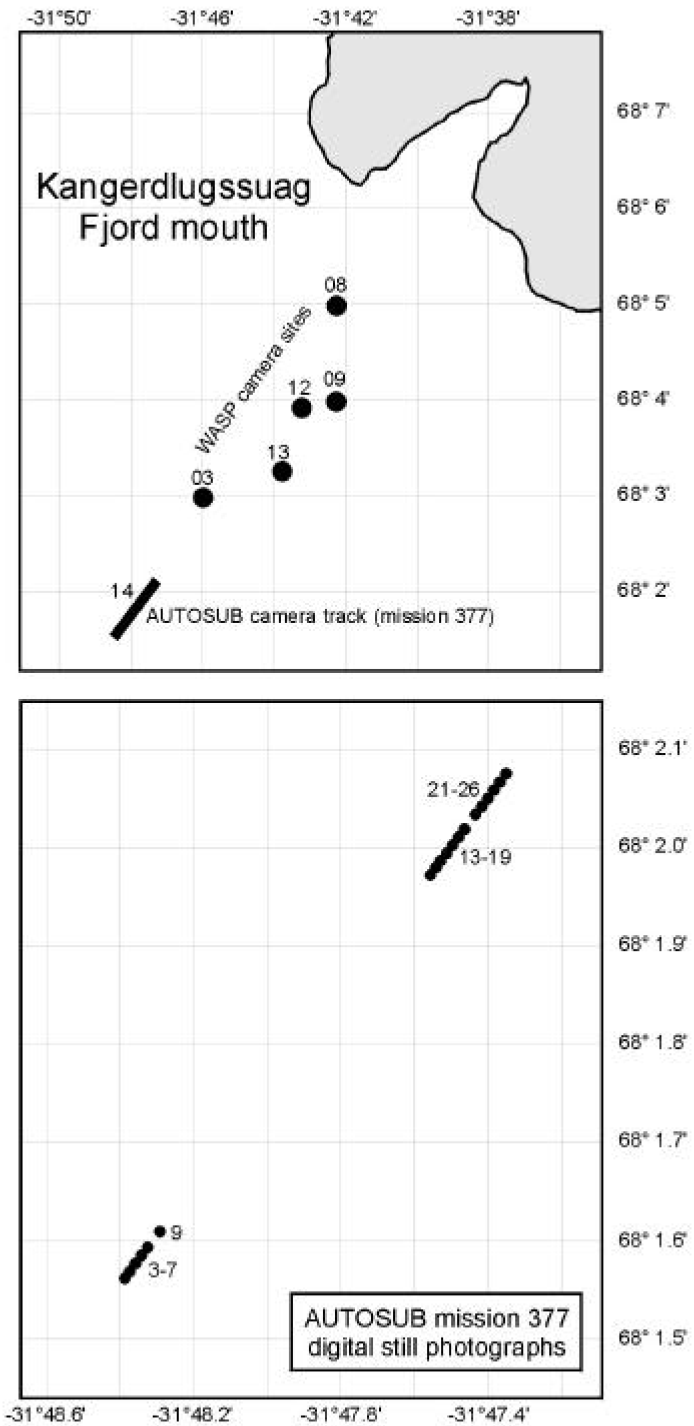


Fig. 5.9. Location of AUTOSUB mission 377 useful photographic operations. Upper panel, general location relative to WASP camera deployments; lower panel, locations of individual useful photographs.

A total of 32 digital still images were recorded during AUTOSUB mission 377, of these 19 are of suitable detail for further analysis as detailed below.

Date (04)	Time	Frame	Altitude (m)	Analysis
09/09	03:53:15	1	12.97	no
09/09	03:53:27	2	9.83	no
09/09	03:53:39	3	8.68	yes
09/09	03:53:49	4	8.79	yes
09/09	03:54:01	5	7.46	yes
09/09	03:54:13	6	10.34	yes
09/09	03:54:25	7	12.16	yes
09/09	03:54:37	8	15.32	no
09/09	03:54:49	9	13.53	yes
09/09	03:54:59	10	11.94	no
09/09	04:01:27	11	13.95	no
09/09	04:15:05	12	13.86	no
09/09	04:15:17	13	11.04	yes
09/09	04:15:29	14	9.13	yes
09/09	04:15:39	15	8.31	yes
09/09	04:15:51	16	8.57	yes
09/09	04:16:03	17	9.75	yes
09/09	04:16:15	18	11.32	yes
09/09	04:16:27	19	10.31	yes
09/09	04:16:37	20	9.52	no
09/09	04:16:49	21	7.91	yes
09/09	04:17:01	22	8.1	yes
09/09	04:17:13	23	8.92	yes
09/09	04:17:25	24	9.74	yes
09/09	04:17:37	25	10.43	yes
09/09	04:17:49	26	11.85	yes
09/09	04:17:59	27	11.43	no
09/09	04:18:47	28	na	no
09/09	04:24:25	29	14.19	no
09/09	04:24:37	30	12.94	no
09/09	04:24:49	31	13.75	no
09/09	04:31:37	32	12.81	no

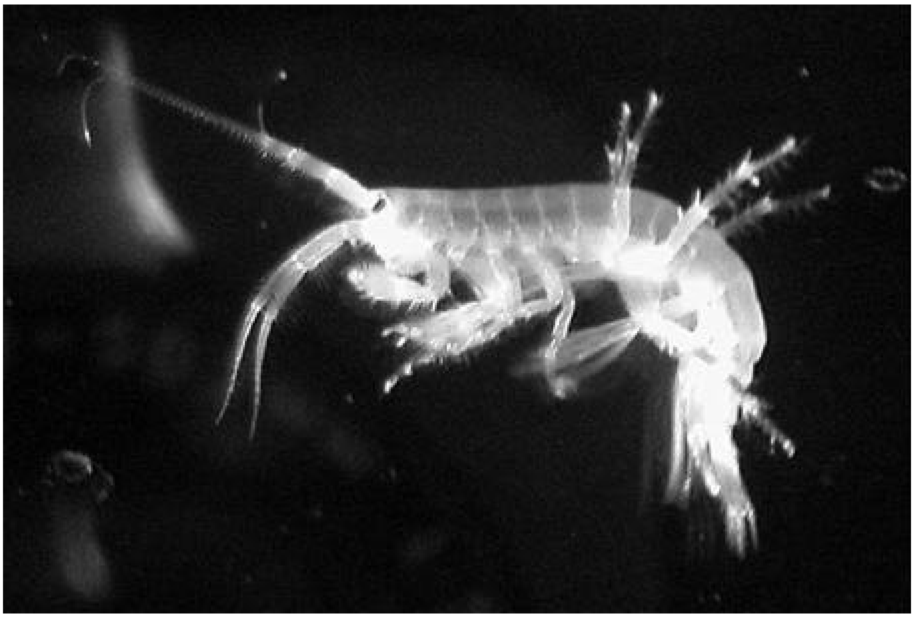
AUTOSUB mission 377 photographs. Suitability for further analysis is indicated as yes / no.

The photographs obtained indicate that both the vehicle and the camera system are capable of undertaking valuable photographic missions. The fjordic setting and level of ice cover did, however, limit operations.

Example photograph from AUTOSUB mission 377 (image 3 from altitude of 9 m at a depth of 564m). One cobble-sized drop stone, three large burrows and numerous tubeworms are visible.

5.6 ADDENDUM – under-ice amphipods

During the course of the cruise (within the Kangerdlugssuag Fjord system) four symphagic (under-ice) amphipods, believed to be *Gammarus wilkitzkii*, were recovered from the ship's non-toxic seawater supply system filters. These animals were maintained alive in local surface seawater in the ship's constant temperature laboratory at c. 2°C. It is hoped that the specimens can be returned alive to the UK for further study at SOC / BBC Natural History Unit.



Under-ice amphipod (aff. Gammarus wilkitzkii) photographed live in shipboard aquarium.

5.7 MATERIAL RETAINED

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

Deployment	Station	Sample type	Details	Preservation
WASP 1	56501#1	Video	30 minutes	
		Stills	7m film	
WASP 2	56502#1	Video	30 minutes	
		Stills	no film run	
WASP 3	56503#1	Video	60 minutes	
		Stills	14m film	
WASP 4	56508#1	Video	30 minutes	
		Stills	7m film	
WASP 5	56509#1	Video	30 minutes	
		Stills	7m film	
WASP 6	56512#1	Video	30 minutes	
		Stills	7m film	
WASP 7	56513#1	Video	30 minutes	
		Stills	7m film	
Agassiz 1	56504#1	Sample	1 bucket general catch including molpadid holothurians	formalin
			2 freezer bags containing one molpadid	-80 C
			1 molpadid	ethanol
Agassiz 2	56505#1	Sample	polychaetes in bottle but preserved in bucket from 54504#1	formalin
Dredge 1	56506#1	Sample	1 bucket general catch including anemone and polychaetes	formalin
Dredge 2	56507#1	No samples		
Dredge 3	56510#1	Sample	1 bucket general catch	formalin
			1 ophiuroid	ethanol
			1 ophiomixid	ethanol
			1 crinoid	ethanol
			1 bucket coral	ethanol
Dredge 4	56511#1	Sample	1 bucket general catch including crinoids, ophiuroids, worms	formalin
			1 crinoid	ethanol
			1 bucket coral	ethanol
Autosub 1	56514#1	Stills	19 digital stills	

5.8 STATION LIST

Deployment details for operations undertaken during RRS *James Clark Ross* cruise 106b.

Station:	"*Discovery Collections*" numbering system
Site:	Location descriptor
Start / End:	of sampling / observation period
Date / Time:	of sampling / observation period
DN MN:	degrees and minutes North
DW MW:	degrees and minutes West
Z (m):	corrected depths of sampling / observation period (based on EM120 output)
Sounding (m):	typical / average depth during sampling / observation period (based on EM120 output)
Comment:	brief note on operation

Station	Site	Gear	Start Date (2004)	Time	DN	MN	DW	MW	Z (m)	End Date (2004)	Time	DN	MN	DW	MW	Z (m)	Sounding (m)	Comment
56501#1	Courtauld-head	WASP	02/09	09:03	68	29.71	32	12.61	200	02/09	09:37	68	29.58	32	12.62	201	200	Very murky !
56502#1	Courtauld-mid	WASP	02/09	11:28	68	26.85	32	14.61	482	02/09	12:02	68	26.63	32	17.07	530	506	Very very murky! (No Mk7)
56503#1	Kang-mouth-600m	WASP	03/09	09:46	68	3.08	31	46.34	625	03/09	10:50	68	2.91	31	45.66	658	642	Good tow
56504#1	Kang-mouth-600m	AT	03/09	12:26	68	3.20	31	46.80	687	03/09	13:16	68	3.00	31	45.20	630	658	Weak link parted, fair catch
56505#1	Courtauld-head	AT	04/09	10:16	68	30.00	32	12.50	173	04/09	10:36	68	29.80	32	12.70	188	180	Net completely torn away
56506#1	Courtauld-head	DREDGE	04/09	17:45	68	29.70	32	12.00	182	04/09	17:55	68	29.70	32	12.20	197	189	A little catch
56507#1	Courtauld-mid	DREDGE	04/09	20:48	68	26.92	32	15.66	407	04/09	21:31	68	27.13	32	15.97	278	342	No catch
56508#1	Kang-mouth-250m	WASP	08/09	09:32	68	5.05	31	42.36	270	08/09	10:05	68	4.92	31	42.19	261	266	Good tow
56509#1	Kang-mouth-400m	WASP	08/09	10:48	68	4.06	31	42.26	374	08/09	11:20	68	3.91	31	42.25	371	373	Good tow
56510#1	Kang-mouth-400m	DREDGE	08/09	19:28	68	4.09	31	42.38	379	08/09	20:10	68	4.23	31	42.51	387	383	Fair catch
56511#1	Kang-mouth-300m	DREDGE	08/09	21:10	68	5.01	31	42.32	272	08/09	21:52	68	4.88	31	42.14	262	267	Fair catch
56512#1	Kang-mouth-500m	WASP	09/09	01:17	68	3.99	31	43.23	481	09/09	01:50	68	3.85	31	43.24	501	491	Good tow
56513#1	Kang-mouth-700m	WASP	09/09	02:52	68	3.34	31	43.74	722	09/09	03:24	68	3.19	31	43.81	725	723	Good tow
56514#1	Kang-mouth	AUTOSUB	09/090	03:53	68	1.56	31	48.39	563	09/09	04:18	68	2.08	31	47.35	588	579	First science mission photos !