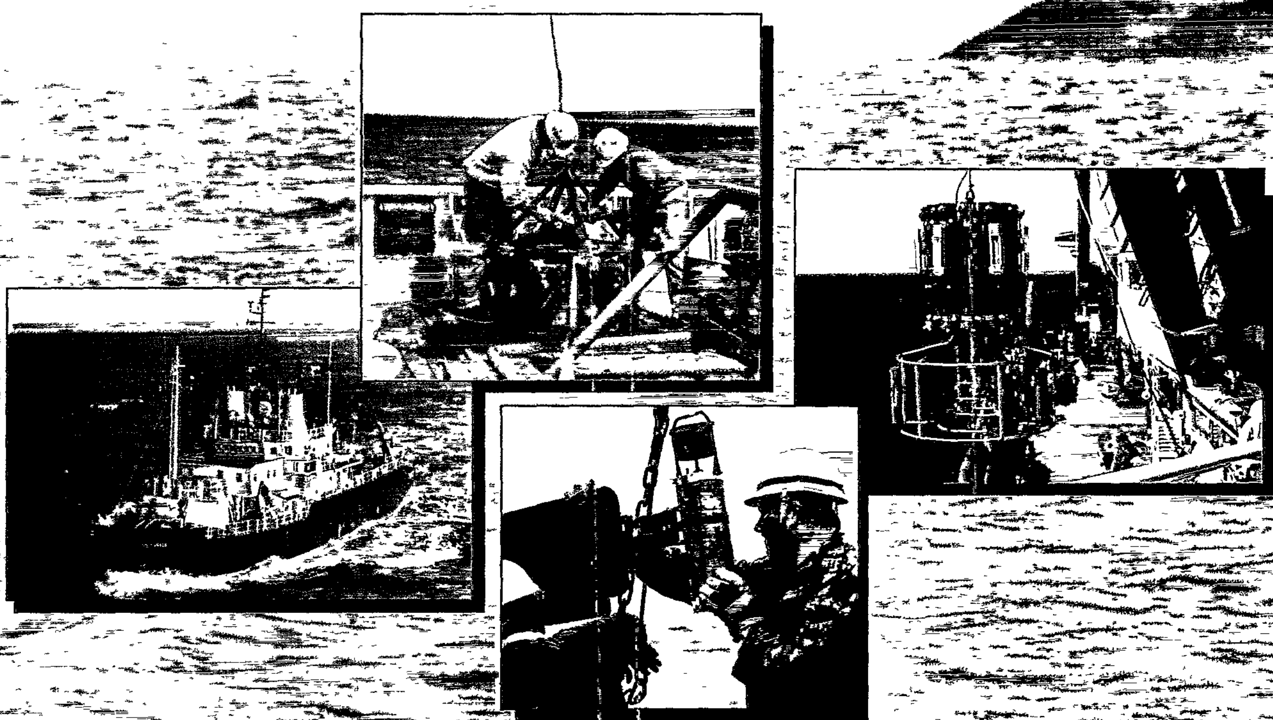
Southampton Oceanography Centre

Cruise Report



Natural Environment Research Council

University of Southampton

SOUTHAMPTON OCEANOGRAPHY CENTRE

CRUISE REPORT No. 16

RRS *DISCOVERY* CRUISE 230
07 AUG - 17 SEP 1997

Two hydrographic sections across the boundaries
of the subpolar gyre: FOUREX

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1998

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ABSTRACT

This report describes RRS *Discovery* Cruise 230, designed as a repeat of the International Geophysical Year (IGY) survey section 4, roughly from Cape Finisterre (Spain) to Cape Farewell (Greenland). IGY 4 was first surveyed in 1957, so this repeat gives a 40–year look at decadal variability in the North Atlantic from the eastern boundary regime via the junction of subtropical and subpolar gyres to the western boundary regime. Additional short sections were measured (a) midway between Cape Farewell and Denmark Strait, (b) across Denmark Strait and (c) from Iceland to Scotland in order (i) to assess the spatial variability of the western boundary regime up the east Greenland coast to Denmark Strait, (ii) to assess the exchange between the northern North Atlantic and the Nordic Seas, (iii) to create a large scale North Atlantic closed box for evaluation of the circulation, and (iv) to continue the long time series of Rockall Trough sections. Sections were measured with stations for CTD, LADCP and tracer chemistry (CFCs, oxygen, nutrients, CO2). Continuous measurements of high precision position and heading navigation data were made; also of VM–ADCP, depth and TSG. Continuous high–quality meteorological measurements were made, with a view to assessing Ekman fluxes, and comparing with fluxes inferred from Irminger Basin float data. This cruise is a UK contribution to the World Ocean Circulation Experiment.

KEYWORDS

ADCP; ATLN; CARBON DIOXIDE; CFC; CHARLIE-GIBBS FRACTURE ZONE; CO2; CRUISE 230 1997; CTD OBSERVATIONS; DENMARK STRAIT; *DISCOVERY*; IBERIAN ABYSSAL PLAIN; ICELAND BASIN; INTERNATIONAL GEOPHYSICAL YEAR; IGY; IRMINGER BASIN; LADCP; NORTH ATLANTIC; NUTRIENTS; OXYGEN; ROCKALL TROUGH; WATER EXCHANGE; WOCE

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Key

SOC:	Southampton Oceanography Centre
GDD:	George Deacon Division
JRD:	James Rennell Division
OTD:	Ocean Technology Division
RVS:	Research Vessel Services
IIM:	Instituto de Investigaciones Mariñas, Vigo
IFREMER:	Institut Français de recherche pour l'exploitation de la mer, Brest

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LEATHER	Ceri	Mate
SYKES	Syd	Second Mate
REYNOLDS	Pete	Third Mate
SUGDEN	Dave	Radio Officer
McDONALD	Bernie	Chief Engineer
CLARKE	John	Second Engineer
BELL	Steve	Third Engineer
JACKSON	Greg	Third Engineer
POOK	Tiny	C. P. O. (D)
LUCKHURST	Kevin	P. O. (D)
COOK	Stuart	SG1A
CRABB	Gary	SG1A
DICKINSON	Bob	SG1A
EDWARDS	Tim	SG1A
MACLEAN	Andy	SG1A
MICKMAN	Bill	MM1A
PERRY	Clive	S. C. M.
HAUGHTON	John	Chef
DUNCAN	Andy	Mess Steward
CARTER	Shiela	Steward
ORSBORN	Jeff	Steward

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ACKNOWLEDGEMENTS

Without meaning to anticipate the encomia which will doubtless be forthcoming, I must thank first the Master, Captain Mike Harding. This may well have been his last research cruise as Master, in view of his impending retirement, and I wish to thank him for helping to make my first cruise as PSO such a pleasure. There was a '70's theme party during the cruise, and all were amused by Mike's wilful misinterpretation of the invitation as over-70's rather than 1970's. He appeared with walking stick and pension book, and wearing a slightly disreputable tweed jacket, in anticipation of times to come, one supposes. Mike will be sorely missed by all, and I take this opportunity to wish him well for the future.

John Smithers is less an electronics technician and more a wizard. I express my sincere thanks to him, particularly in respect of the Lowered Doppler Affair. It is hard to imagine that this cruise would have been anything like the success it was without the benefit of his remarkable expertise.

I am most grateful to Sue Scrowston, Andy Louch and Jackie Skelton of the RVS Operations Office for their sorting out much of the mundane logistics – hotels, flights, freight etc. I am particularly grateful to Sue and Andy for their near-instant response in the Lowered Doppler Affair, which ensured that minimal time was lost in fetching replacement gear. Thanks also to Rob Bonner (SOC-OTD) for logistical help.

In the same (aforementioned) context, thanks to Nick Crisp (SOC–OTD) for arranging the replacement LADCP parts.

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Thanks to Aida Rios (IIM, Vigo), for her considerable help in arranging the participation of IIM scientists (Marta and Iris) to look after the CO2 measurements on this cruise.

Finally, and most importantly, my sincere thanks to the responsible authorities of Greenland, Iceland, Spain and Portugal, for their gracious granting of permission to work in their respective territorial waters, without which much of this cruise would have been meaningless.

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Sheldon Bacon

1. THE CRUISE

a. SCIENTIFIC OBJECTIVES

During 1996-1997 the intense measuring effort put into the North Atlantic under the aegis of international WOCE has several aims in accordance with Goal 1 of WOCE (WOCE Implementation Plan, 1988). Firstly, meridional transports of heat, mass and freshwater will be measured, from exchanges with the South Atlantic across the Equator to exchanges with the Northern Seas between Greenland and Scotland via the Sub-Tropical and Sub-Polar Gyres. Secondly, decadal variability will be examined through exact track repeats of cruises from the International Geophysical Year (IGY) expeditions in 1957-1958, and others. IGY is the first large-scale field program which can be used as a basis for modern comparitive work because its measurements are the first which approach modern standards of accuracy. Thirdly, there will be a focus on the Sub-Polar Gyre, intending to quantify the rates and to study the physics of the formation of mode waters and deep waters. The main or most immediate aims of this cruise, designated WOCE cruise A24, go under four headings:

(1) Repeat survey of IGY Section 4 (Portugal to Greenland), for climate change analysis;
(2) Determination of heat, mass and freshwater fluxes across IGY Section 4, and across northern 'closure' sections; thus, exchanges between the Sub-Polar Gyre and (to the north) the Nordic Seas, and (to the south) the Sub-Tropical Gyre.
(3) Continuation of the Ellett (Dunstaffnage Marine Laboratory) time series section across Anton Dohrn Seamount;
(4) Production of data suitable for inclusion in the WOCE North Atlantic data set.

Subsidiary or longer-term aims are/were:

(i) collaborating with European and North American colleagues to produce a "Summer of '97" synoptic view of the northern North Atlantic circulation, particularly WOCE sections A1 (55°N) and A2 (48°N), AR7W (Labrador Sea), with ancilliary data such as satellite altimetry (ERS2, TOPEX/POSEIDON) and floats (Arcane/Eurofloat, PALACEs);
(ii) comparisons of PALACE float profiles and inferred surface fluxes with fluxes and profiles measured on board and estimated from climatology;
(iii) comparisons between model (GCM – OCCAM) output and measured / inferred circulation;
(iv) testing an acoustic rainfall-measuring buoy.

b. OVERVIEW

Although the odd spat of nasty weather halted operations for short periods, overall the weather was splendid, enabling us to achieve all our major goals for this cruise, and several lesser ones. The weather only really deteriorated during the final week as autumn drew in, in the vicinity of Rockall. The cruise track and station positions are shown in figures 1.1 and 1.2.

The cruise progressed clockwise around the northern North Atlantic, beginning in Vigo, Spain on 7 August 1997. The initial work line was 41°30'N, between 9°W and 20°W. We proceeded directly from Vigo to 9°W, 41°30N, then out to deep water (>5000 m) at 41°30'N, 12°30'W for 2 test stations, one firing all bottles at one depth, one for a bottle profile. Then we ran back to 9°W at 8 kn for an acoustic current profiling survey; the section proper began with a station on the 200 m contour at 9°13'W. Over the next few days, as we worked across the southern flank of the Galicia Bank and down the continental slope, it became apparent that the LADCP was seriously malfunctioning, and could not be persuaded, either by attention to hardware or software, to behave. We decided to have a replacement unit, complete but for pressure case, sent out to Leixões, the port of Oporto in Portugal. We broke off work immediately after station 21 (2200Z, 12 August, 12°9'W) to run in and collect the gear which had been flown out overnight, and was waiting for us on the dockside on arrival. A short wait of a few hours in port enabled an unexpected excursion for some of the scientific party to a nearby beach to bathe and skylark. We departed promptly at 1630Z. Station 22, begun at 0700Z on 14 August, was a cast to 2000 m to ensure the watertight integrity of the original LADCP pressure case with the replacement transducer head. Station 23 later the same day was an 'overlap' station, repeating 21. Thus only a day and a half were wasted; and although LADCP data are sparse for this part of the first section, we have no less than *five* ADCP transects, which should give a decent reference for subsequent geostrophic calculations.

Station 35 was the 'corner', the last of line along 41°30'N, after which we turned north-west for the rest of the section along the rhumb (Mercator-straight) line between 41°30N, 20°W and Cape Farewell. Stations 21–34 crossed the bottom of the Iberian Abyssal Plain. Much of the remainder of the section consisted of a rather oblique cut along the Mid-Atlantic Ridge, with stations 35–40 passing seamounts of the Azores–Biscay Rise and stations 41-42 at the bottom of the north-western corner of the King's Trough, a small deep basin closed below *ca.* 3500-4000 m. Passing the Maxwell and Faraday Fracture Zones in the vicinity of 27°W and 29°W (along the track, respectively), we arrived at the Charlie-Gibbs Fracture Zone with stations 62–67, where 63 was at the bottom of the Southern Transform Valley and 65 at the bottom of the Northern. Stations 70–73 spanned the crest of the Reykjanes Ridge, after which we descended to the bottom of the Irminger Basin around stations 78–81. Rising up the Greenland continental slope with nominal resolution of topography at 250 m depth increments, station 92 arrived at the

200 m contour, and station 93, the final one on this repeat of IGY section 4, was our closest approach to land, in 150 m of water about 2 miles from the coast.

Next we made a low-speed acoustic profiling transect of the western boundary current regime, retracing our path back to the position of station 81 in the middle of the Irminger Basin, at 5 kn. Thus a 10-minute ADCP average translates, with good navigation, to 1.5 km horizontal resolution with about <1cm/s accuracy in currents. Following this exercise, we made for the start of the next section, the East Greenland Central Section, which was selected by consultation with Alexander Sy (BSH, Hamburg), who was out in the same area at the same time as us, on the FS *Meteor*, but circuiting the North Atlantic in the opposite sense to us. We had hoped to meet at Cape Farewell, but our LADCP-derived delays contrived to make us miss. The *Meteor* however was engaged in a suite of sections down East Greenland as part of the VEINS program, and for comparative purposes, we carried out a repeat of the section most appealing to us – the most northerly one which still had a narrow continental shelf. This began in mid-basin with station 94; topographic resolution was 500 m nominal, ending in about 300 m water depth 5 miles from the coast, surrounded by grounded icebergs, in the dark.

Next we headed north for the Denmark Strait Section. Running from west to east, station 103 was our furthest north at 65°31'N, finishing at station 110. Bad weather was holding us up on what should have been the final station of this section in 200 m of water, so it was abandoned and we ran before the weather to the start of the final section south of Iceland on 20°W. Also, since the Greenland shelf is so broad in the region of Denmark Strait, we began in about 500 m water depth, so there may be cause for concern over both endpoints of the Denmark Strait section.

The Iceland–Scotland Section began with station 111 in 200 m water depth. The centre of the Iceland Basin was reached around stations 121–122, after which we rose up the western flank of the Rockall–Hatton Plateau. Station 127 was on the top of Hatton Bank, 129 was the deepest in the Hatton–Rockall Basin, and 132–133 were on the top of Rockall Bank. Rockall itself was passed at night in murky weather and was just visible, unlit, as a small black lump on a black background. Then the Rockall Trough was crossed by stations 134–140. Station 137 was on the top of Anton Dohrn Seamount. The last three stations, 141–143, were on the Hebridean Shelf, after which we went home.

c. NARRATIVE

Discovery station numbers are given, not the cruise station numbers. For stations 1–21, Discovery number = station number + 13201 (so station 1 = 13202). No Discovery number was alloted to station 22. For station 23 onwards, Discovery number = station number + 13200. The last station was 143, Discovery 13343.

Friday 1st August 1997: Preparations were made for the winding on of the new CTD wire. Familiarisation procedures for new marine staff were placed in hand.

Saturday 2nd August 1997: Further cleaning work around the laboratories was carried out and a slow start was made at winding on the new CTD wire.

Sunday 3rd August 1997: Wire-winding was continued but great difficulties were encountered and little progress was made.

Monday 4th August 1997: Wire-winding resumed and good progress was made, the cause of the difficulties having been identified. Storing operations were commenced in the forenoon and the port lifeboat lowered to the water. Storing was largely completed in the afternoon and at 1645B bunkering operations were commenced. At 2055B the winding on of the CTD wire was finally completed and at 2220B the bunkering operation was completed.

Tuesday 5th August 1997: Loading of scientific equipment was commenced in the forenoon and the lorry backloaded by early in the afternoon. The inflatable dinghy was taken away under power for prolonged testing in the afternoon.

Wednesday 6th August 1997: The majority of the scientific staff joined the vessel in the forenoon and spent the day setting up and commissioning their equipment. Fresh water tanks were topped up. The final members of the scientific staff joined the vessel at 2300B.

Thursday 7th August 1997: Familiarisation procedures of scientific staff were commenced at 0900B. At 1000B sailing preparations were carried out and at 1054B the pilot boarded. At 1058B singling up commenced, the vessel proceeded to the master's orders and at 1103B all moorings were gone and clear. At 1112B the pilot disembarked and the vessel sailed down the Ria Vigo. From 1136B to 1144B in the wider reaches of the bay, the vessel was stopped in the water to facilitate the deployment of the starboard lifeboat to the water. At 1218B with the Isla Boreiro light bearing 025°T X 1.9', full away was ordered and the vessel proceeded into the open sea. Course was set Southwards along the meridian of 009° 00'W and at 1600B course was altered to the West along the latitude of 41°30.0'N, our first line of survey. At 1600B also, alarms were sounded and staff proceeded to emergency drill stations, followed by muster at and boarding of the boats and instruction for the deployment and boarding of the liferafts. At 2040B the Precision Echo Sounder fish (PES) was deployed.

Friday 8th August 1997: At 0650B the vessel was hove to in readiness to commence the first of two test stations. At 0757B the CTD+ was hove outboard to commence station 13202, the first of two test stations, which finished 1018B. The second test station 13203 commenced at 1245B and was back inboard at 1638B. These and future stations were to consist of the lowering of a CTD rig overside with watersampling bottles attached along with an LADCP system and a fluorometer. At 1640B course was set 090°T at 8 knots of the ground to carry out an ADCP and PES survey to the point of origin of the survey line in position 41°30.0'N 009°00.0'W. The Principal Scientist and the master met together to review the progress of the cruise and make plans for the future on the first of many occasions. Frequent forked lightning displays were observed to the East as the ship headed back overnight.

Saturday 9th August 1997: The day opened with but light airs giving a calm sea with a very low swell, the skies were cloudy and visibility was but moderate. As the morning progressed and the ship came into shoaler water thick fog developed. Having just cleared the fog the vessel reached the end of the survey line in position 41°30'N 008°59.91'W at 1145B. Coming about and re-entering the fog the first station of the day 13204 was occupied. In the afternoon the skies cleared and bright sunny weather gave everybody an optimistic mood. After station 13205, an LADCP fault caused a delay before the commencement of each of the next two stations.

Sunday 10th August 1997: The day opened with light airs, a glassy sea and a low swell, cloudy skies prevailed at first but soon cleared to give an almost tropically warm sunny day. Stations 13208-11 were occupied.

Monday 11th August 1997: The start of the day was with winds of force 4 from SSE, a slight sea was running with a low swell and skies were cloudy and overcast, a slight haze reduced the visibility. Stations 13212-7 were occupied.

Tuesday 12th August 1997: The day opened cloudy and overcast with light rain, the winds were from the South South West at about 8 knots, the sea was rippled with a low swell. Stations 13218-13221 were occupied.

Wednesday 13th August 1997: At 0012B with the rig from station 13222 inboard and secured course was set to 097°T for the port of Leixões in Portugal to where spares for the LADCP were being airfreighted from the U.K., the LADCP not having been functioning properly. The day opened with light variable airs and a rippled sea with a low swell, skies were fine and clear with clear horizons. Between 1047B and 1104B the PES fish was recovered. At 1443B the pilot boarded in the approaches to Leixões (the seaport for Oporto), the vessel secured on berth at 1540B. The port authorities boarded in order to complete the necessary formalities and the spares were loaded. The vessel was cleared to sail by the port authorities at 1830B, letting go the berth at 1831B the vessel sailed down the harbour, the pilot disembarking at 1843B. Full away was rung at 1854B with the breakwater bearing 060°T by 0.9' and course was set to 332°T. The vessel proceeded at full speed to the parallel of 41°30'N and then altered course to 270°T.

Thursday 14th August 1997: The day opened with the wind from North by West at 9 knots with a slight sea and low to moderate swell, skies were generally fine and horizons clear. At 0909B a deployment of the casing for the new LADCP casing to 2000 m was commenced in order to give it a pressure test. This was not given a Discovery station number, but it was given a scientific one (22). The PES fish was re-deployed at 0930B. At 1030B the CTD rig was brought inboard and course set to the West. Station 13223 was occupied in the evening.

Friday 15th August 1997: The day opened generally cloudy with a fine haze, winds were from the North West at about 10 knots giving a rippled sea with a low swell. At 1600B all hands were exercised and trained at emergency drills, completing with a muster at boat stations. Stations 13224-13227 were occupied.

Saturday 16th August 1997: The day opened with cloudy skies, the wind being from the South West by West at 11 knots giving a slight sea accompanied by a low swell. On station 13230 29 minutes were lost when the rig had to be recovered after initial deployment, a system malfunction having occurred with some of the equipment mounted on the frame. Stations 13228-30 were occupied.

Sunday 17th August 1997: Light rain fell most of the night, clearing away with the dawn when skies were cloudy and clear, with the wind from West by North at 8 knots giving a rippled sea with a low swell. Stations 13231-3 were occupied.

Monday 18th August 1997: A series of small depressions passing just north of the vessel caused freshening winds overnight and slowed the vessel's progress somewhat between stations. The last station on the direct East to West line, 13235, was then occupied in the morning. Stations 13234-7 were occupied.

Tuesday 19th August 1997: In the early morning freshening winds blew from the South West at about force 4, with the dawn they backed into the North West bringing rain showers, seas were slight to moderate with a low swell. Stations 13238-41 were occupied.

Wednesday 20th August 1997: After further overnight rain the day opened with the wind from South West by West at 18 knots giving a moderate sea with a low swell, skies were clouded with low overcast and visibility through the day was generally moderate. In the forenoon the crew was mustered and both lifeboats swung out to the embarkation deck. A safety committee meeting was held in the ship's library at 1030B. In the afternoon a slight diversion from track was made in response to a distress call relayed from Falmouth Marine Rescue Co-ordination Centre, course was altered at 1350B and resumed at 1425B after receipt of message informing us that the alarm had been accidentally triggered. Stations 13242-5 were occupied.

Thursday 21st August 1997: Fog, mist and rain overnight gradually cleared away in the morning and at dawn the wind was from South West by West at 20 knots with moderate seas and a low swell, skies were cloudy and overcast with moderate visibility. Stations 13246-9 were occupied.

Friday 22nd August 1997: A cool gray, cloudy, overcast dawn with light variable airs, a rippled sea and low swell presaged. Emergency fire and boat drill took place between 1615B and 1630B. Stations 13250-3 were occupied.

Saturday 23rd August 1997: The weather at the start of the day gave promise of fine weather, skies being fine with some cumulus cloud, winds were variable and light at about 4 knots with a rippled sea and a low swell. Stations 13254 to 13257 were occupied. In the evening, in deteriorating weather, slow progress was made from station 13257 to 13258.

Sunday 24th August 1997: At 0300B having arrived upon the next station position the decision was made to suspend operations due to winds of 40 to 45 knots which were blowing accompanied by a heavy swell. At dawn the skies were heavily clouded and overcast, winds were from North West by West at about 30 knots with moderate to rough seas and moderate to heavy swells. At 0856B with conditions moderating the vessel came about and at 1013B resumed station. Stations 13258-9 were occupied during the remainder of the day.

Monday 25th August 1997: At 0200B the ship's clocks were retarded one hour to Alpha time. Light rain overnight persisted into the forenoon, the day opening with winds from the North North East at 6 knots giving a rippled sea accompanied by a low swell with cloudy overcast skies. Stations 13260-4 were occupied.

Tuesday 26th August 1997: The day opened with freshening winds from North West by West at 30 knots, a moderate sea and swell were accompanied by skies that were cloudy and fine with good visibility. Stations 13265-8 were occupied.

Wednesday 27th August 1997: The day opened with winds from North West by West at 20 knots, giving a moderate sea and swell, with heavy cloud and overcast with frequent passing showers. Stations 13269-73 were occupied.

Thursday 28th August 1997: The day opened cloudy overcast and clear, winds were from the North West by West at 13 knots with a slight sea and a low swell. Stations 13274-7 were occupied.

Friday 29th August 1997: The day opened cloudy and overcast with the wind from SSW at 13 knots, seas were slight with a low swell. At 1122A speed was reduced to about 8 knots to allow for engine room maintenance work. At 1600A emergency drill was held with various instruction classes followed by man overboard drill when at 1626A a 'dummy' (representing the Master) was dropped overside. The dummy was brought on board with the vessel in the hands of the Mate. The vessel was underway again by 1641A. Station 13281 was notable in that during the period of the work our first iceberg of the cruise was sighted seven miles distant, closer to a growler proved impressive to those unused to working in high latitudes, these sightings were about 135 miles from land and just within the maximum indicated limit for icebergs in the month of August. Stations 13278-81 were occupied.

Saturday 30th August 1997: Speed in darkness was now reduced to five knots. The day opened cloudy and clear with a wind from West North West at 18 knots giving a slight to moderate sea with a low swell. At 1600A, the weather having deteriorated with winds reaching force 8 to 9 the vessel hove to and scientific work was suspended pending an amelioration of conditions. At 2330A it having become apparent that then worst was over the vessel came about and steamed towards the next station position. Stations 13282-4 had been occupied.

Sunday 31st August 1997: The vessel resumed station at 0115A and work commenced at 0134A. The day opened fine and clear with winds force 3 from West by North giving a slight sea accompanied by a low to moderate swell. During the afternoon, our second significant piece of ice was passed at about two miles distant, a towering pinnacled (Arctic) giant rising to about 297 feet. Being now within the maximum iceberg limit speed in the hours of darkness was restricted to a maximum of 5 knots. Stations 13285-92 were occupied.

Monday 1st September 1997: The final station of our line from Portugal to Greenland was to be 13293 just over two miles from the Greenland coast East of Cape Farewell, close to Cape Hoppe. Series 1 was reported as a failure having gone to 150 m depth at 0031A, series 2 reached a depth of 150 m at 0055A. At 0107A, the equipment having been brought inboard course was then set to carry out an under way profiling run. The day dawned fine and clear with light variable airs giving a rippled sea with a low swell. The profiling run continued throughout.

Tuesday 2nd September 1997: Profiling continued until 0350A when arrived at position 58°05.5'N 040°37.44'W course was altered to 036°T. At daybreak skies were fine and clear the wind however had gathered strength and was blowing from the North at about 25 knots giving a moderate sea accompanied by a low swell, speed was increased at this time to maximum. Despite being on maximum speed however progress was relatively slow, the growth of weed and barnacles on the hull and the swell combining to reduce speed at times to seven knots. During the hours of darkness, being within the maximum iceberg limit, speed was reduced to five knots.

Wednesday 3rd September 1997: Weather conditions moderated overnight and the dawn was one of those beautiful occasions with winds from the North at 12 knots, a roseate sunrise illuminating a deep blue-gray sea under clear skies and a few circling seabirds ever hopeful skimming the slight sea and low swells in our wake. Passage towards the next line of survey continued until arrival on station 13294 at 1308B. At 1823A whilst approaching the next station (13295) an experimental rain buoy was deployed astern and remained there for most of the station.

Thursday 4th September 1997: The day dawned with very light airs, a glassy sea and a low swell under fine and cloudy skies. Stations 13296-13301 were occupied.

Friday 5th September 1997: At 0219A on station 13302 the system went down to a depth of 293 m. It was not advisable to work closer in towards the coast due to the large number of icebergs and at 0234A course was set 118°T, then at 0300A course was set 061°T towards the start of the line of positions running across the Southern approaches to the Denmark Strait.

Saturday 6th September 1997: In the forenoon, visibility was reduced and became quite thick just after noon, in consequence the afternoon was spent at reduced speed as the vessel approached the first station (13303) of the line across the southern approaches to the strait. When approaching station 13305 speed was reduced at 2044A and the rain buoy deployed at 2053A. The rain buoy deployment was concluded at 2155A. At 2350A the vessel hove to on station 13306, but due to deteriorating weather work was suspended at 2400A.

Sunday 7th September 1997: At 0720A the vessel proceeded to resume station. Winch problems caused a small delay on station 13307. Stations 13306-9 were occupied.

Monday 8th September 1997: After station 13310, the vessel reached the next station in deteriorating weather conditions, winds coming out of the North West at 40 to 45 knots and science was suspended. At 0712A the decision was made to abandon the station and in consequence course was set for the line of stations commencing from the Southern coast of Iceland and proceeding South along the meridian of 20°W.

Tuesday 9th September 1997: At 0800A the vessel arrived just a few miles to the East of the new (1963) volcanic island of Surtsey and resumed scientific work on station 13311 at 0802A. The day had opened with much ameliorated conditions, winds were from the West at 5 knots, with a rippled sea and low swell, skies were clouded and there was a slight haze but visibility was good. Stations 13311-6 were occupied.

Wednesday 10th September 1997: the vessel arrived on the next station at 0412A having made slow progress due to deteriorating weather conditions, the vessel remained hove to for a while and at 0704A station was resumed. The day opened cloudy/overcast and clear with a moderating wind blowing at about 23 knots from WNW, seas were moderate to rough and the swell was moderate. Stations 13317-20 were occupied.

Thursday 11th September 1997: The day opened with fresh winds from the North West at 25 knots giving a moderate sea and swell, cloudy and fine with occasional showers. From 1414A to

1506A for station 13322, a trial deployment was made with a CTD sensor mounted inside a water bottle in parallel with the sensor mounted on the frame in attempt to check that time necessary for water within an open water bottle to match that of its surroundings, unfortunately the the trial failed. At 1600A emergency drill was carried out with various classes of instruction in fire fighting and life saving followed by a muster at boat stations. Stations 13321-5 were occupied.

Friday 12th September 1997: The day opened with cold Northerly winds at 15 knots and frequent violent squalls of wind with rain showers, moderate seas and swells were running and skies were clouded and overcast. In the evening station 13331 took place at 2024A, the vessel now coming up onto the Rockall Bank. The last station of the day took place in increasingly unsettled weather with heavy swells coming down from the North. Stations 13326-32 were occupied.

Saturday 13th September 1997: Having rounded Rockall, station 13333 to the South of St. Helen's reef was occupied. When the next station was attempted, problems were experienced with the wire going slack as the ship rose and fell in the heavy swells. The decision was made to press on to the next station in the hope of some amelioration in conditions occurring. The day dawned with the winds from the North West at about 35 knots, with rough seas and heavy swells, skies being cloudy and fine with good visibility. Station 13335 took place after lunch, however this station was not without incident as during recovery at 1430A there was a failure of the CTD termination. Coming up onto the Anton Dohrn Bank for station 13337. Stations 13333-7 were occupied.

Sunday 14th September 1997: The day opened with the wind from West South West at 20 knots, giving a moderate sea and swell, skies were cloudy and overcast with continuous light rain. With station 13341, the vessel was coming onto the shelf just West of the Hebrides. After station 13342, the vessel remained on site whilst vertical profiling was carried out. On the final station of the cruise (13343), the system was finally landed on deck at 1752A, the PES fish was brought inboard at 1800A and sampling was completed at 1820A at which time a course of 142°T was set home in rapidly deteriorating conditions.

Monday 15th September 1997: At midnight conditions had deteriorated so much that course was adjusted to 180°T in order to ease the extreme movments of the ship in the heavy South Westerly swells, at 0200A course was again adjusted to 210°T. At 0500A conditions reached their most extreme as a front approached and the vessel manoeuvred variously, once the front had passed an easing of the wind strength plus a marked veer in direction enable the vessel to come about and assume a course of 110°T, this course was maintained until 0800A when it became necessary to put a further dog's leg in our progress when course was altered to 180°T. The day opened with the wind from South West at 30 knots, seas were still rough with a moderate swell, skies were generally cloudy with good visibility. At 0912A in much eased conditions course was finally altered to 108°T directly towards the North Channel. Progress through the Irish Sea however proved slow the run of the tides proving contrary to the vessel's progress. Some slight progress towards cleaning up the scientific laboratories was made by a now thoroughly worn out scientific complement.

Tuesday 16th September 1997: The day opened with the wind from right ahead being South by West at 18 knots, seas were moderate, skies were cloudy and overcast with good visibility. Tuskar rock was passed, distant 13.7 miles at 0800A. Progress was slowed again by contrary tides and the freshening wind which although it veered to the South West did not decrease until the vessel was approaching the region of Land's End late in the evening. The vessel turned Eastwards to head up channel off Wolf rock at 2148A.

Wednesday 17th September 1997: The weather in the English Channel was extremely fine and favourable and good progress was made, some lost ground being recovered. The day opened fine calm and clear and remained that way with glassy sea and sunny skies. Start Point was passed at 0640A distant 4.7 miles. End of passage was rung at 1300A and the Needles fairway buoy was passed at 1308A, at 1357 we were abeam of Hurst Point. At 1429A the pilot boarded just before Hamstead Ledge, the vessel entered Empress Dock at 1623A and was alongside the berth at 1635A, finished with engines was rung at 1640A and the vessel was all secure at 1650A. Scientific staff disembarked soon after.

Captain M. A. Harding

For me, the highlight of the cruise was the East Greenland work. On the way in to Cape Farewell, we passed an enormous castellated iceberg with a huge hole right through the middle so you could see through to the other side. The lower parts of the berg were polished by wave action, and the interior of the hole had that shade of ice blue which you don't see anywhere else. The weather was glorious – calm, clear, often sunny by day, and starry by night. There were regular and improving auroral displays, with greens, whites and occasional reds, and lots of swirling arches and wavy curtains. The section in to Cape Farewell was completed with station 93, less than 2 miles from the extraordinary landscape of rocky pinnacles with ice and snow which is the coast of Greenland. The sun had set over the Cape as we finished, and the water was so very calm that Jupiter was reflected as a shining path. Seals were swimming near the ship. On the second approach to Greenland (not quite as close as the first) we had another remarkable sunset, with sunbeams shining through the peaks of the coast mountains to illuminate a thin layer of mist in a peachy-orange colour.

Sheldon Bacon

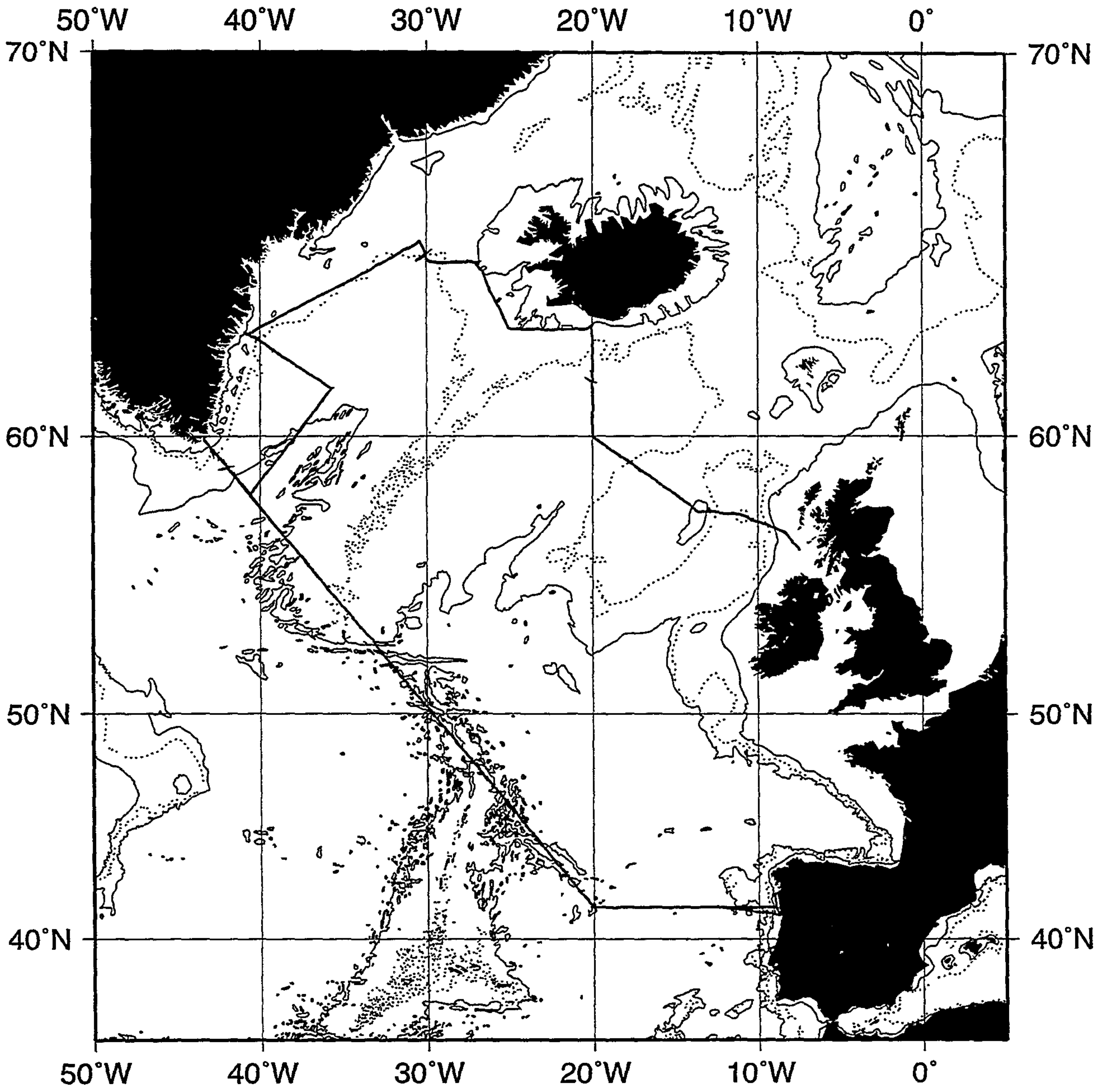

Figure 1.1: *Discovery* Cruise 230 track, Vigo to Southampton. Bathymetry is 200 m (solid), 1500 m (dots), 3000 m (solid).

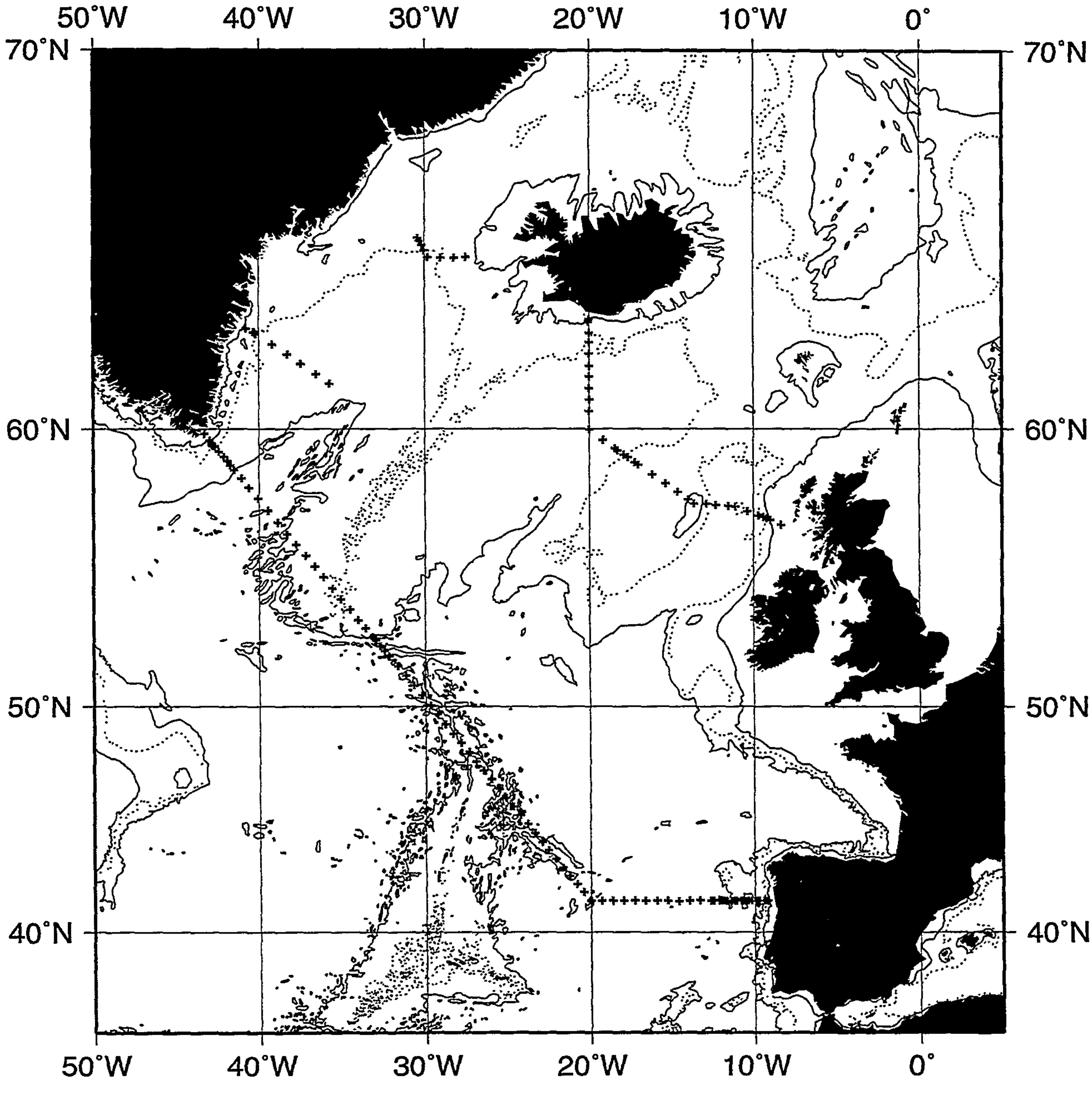

Figure 1.2: *Discovery* Cruise 230 station positions. Bathymetry is 200 m (solid), 1500 m (dots), 3000 m (solid).

2. CTD MEASUREMENTS

a. EQUIPMENT

The equipment used during the cruise was as follows:

Neil Brown MKIIIb/c CTDs DEEP01 and DEEP02
Chelsea Instruments Fluorometer S/N. 88/2050/95
Chelsea Instruments Transmissometer S/N. 161/2642/003
FSI OCM-D-112 S/N 1325-011592
FSI OTM-D-112 S/N 1333-011592
Simrad Altimeter 200 m range.
LADCP and battery pack
FSI Rosette Pylon No.1
GO and FSI 10 Litre Niskin Bottles
SIS Thermometers S/N T741 and T989
SIS Pressure Meters S/N 3192H and 3694H

Both CTDs are MKIIIb instruments converted to a MKIIIc format. Deep02 was specially modified for this cruise to accept data from two FSI modules: one FSI OTM (Platinum Resistance Thermometer Module) and one FSI OCM (Conductivity Module). These mount on a specially modified 10 litre GO water bottle which has external rubbers linking the endcaps as opposed to an internal Epoxy coated spring.

During this cruise 143 stations were occupied with a depth range of 130-5478 m. As the 10 mm CTD wire does not have the load capacity to reach depths in excess of 4500 m (approx), the 17 mm deep tow cable was used and linked to the CTD package with a TOBI swivel. Although the combination of swivel and shackle is quite large (1 m approx), there was sufficient clearance to allow the package to be deployed without the need to remove the ship's rail. This arrangement was used until the deeper stations had been completed after the Vigo to Greenland section and performed well. However, in heavier sea conditions above Force 6, handling became more difficult due to the closer proximity of the package to the ship's side during deployment and recovery.

The sheave over which the cable runs is much further inboard than the 10 mm CTD cable. From station 103 onwards, the 10 mm CTD cable was used with a swivel fitted between the cable and package. This increased the working clearance which proved fortuitous as the majority of bad weather occurred after the cable change.

CTD Stations 1-135 were occupied using instrument DEEP01. There was an initial problem with loss of the Fluorometer signal at approximately 600 m on each upcast. This proved to be a faulty lead connecting the Fluorometer to the CTD. After replacement, this gave no further problems. The CTD and other associated sensors worked without fault for the duration of the cruise. The FSI pylon performed reliably, but after some time failed to fire bottle number 23. As sufficient bottles were available, this was not changed for the spare unit. The LADCP was fitted to the package for all stations but was not without problems (see LADCP report for details).

CTD DEEP02 was mounted on the frame along with the modified 10 Litre bottle carrying the FSI OTM and OCM modules. Although the FSI sensors worked both Conductivity and Oxygen sensors were unusable along with a loss of Altimeter signal. The cast was abandoned and DEEP01 reinstalled and the modified bottle removed.

During the upcast of station 136 electrical contact with the CTD was lost. On recovery this was traced to a fault in the swivel which had gone electrically short circuit. The swivel was removed and DEEP02 plus bottle mounted. The Conductivity and Oxygen sensors had been replaced and the loss of Altimeter signal traced to a broken connection within the CTD. The remaining stations 136-142 were completed with this arrangement. The bottle was removed for station 143 for fear of damage in the heavy seas as the OTM and OCM protrude beyond the safety of the CTD frame.

During the cruise a new software package to acquire and display CTD data was under development. Although much remains to be done to bring this to a finished product, it proved essential for the stations where CTD DEEP02 was used. Due to the non standard format of this instrument, the GO software normally used was able to log raw data but not display the multiplexed analogue channels. The most important of these for operational use is the Altimeter, necessary to avoid sea bed contact. The new software was able to handle the data format from DEEP02 and display all data channels.

The level A system failed to log data on three stations but the data were recovered with the use of appropriate software designed for the purpose.

John Smithers

b. DATA CAPTURE

CTD data were passed from the CTD Deck unit to the Level A. The level A averaged the raw 16 Hz data to data at 1 Hz. Before averaging, the data are checked for pressure jumps and median despiked. The gradient of temperature over the 1 second sample of data is calculated. From the Level A, data are passed to the Level B (logging) and then to Level C (archiving). Bottle firing times were logged using a separate Level A.

As with previous cruises, the CTD Level A caused 'serial overruns' when accepting and processing data from the CTD deck unit. This caused a loss of data of as much as 20 seconds per cast. The problem was alleviated by removing the clock input to the Level A. The Level A did not consume processor time synchronising with the clock but was able to handle CTD data. Serial overruns were still observed but they did not lead to data loss. The internal clock on the CTD Level A is sufficiently accurate over a cast if the Level A is allowed to communicate with the clock between stations.

The CTD unit DEEP01 was calibrated in the laboratory on the 11th of June 1997. A final decision on the calibration will be made after a post-cruise calibration. Attached to the CTD were a Chelsea 0.5 m transmissometer and a fluorometer. These instruments passed their data via the CTD multiplexed channels.

Temperature

Temperature raw counts were first scaled by (2.1) and then calibrated using (2.2):

$$T_{raw} = 0.0005 \times T_{raw} \tag{2.1}$$

$$T = -1.94178E\text{-}2 + 0.998608 \times T_{raw} \tag{2.2}$$

To correct the mismatch in the temperature and conductivity measurements temperature is 'speeded up' by (2.3)

$$T = T + \tau \frac{dT}{dt} \tag{2.3}$$

where the time rate of change of temperature is determined over a one second interval. After inspection of 'stairs' beneath Mediterranean water where step function changes were observed, the time constant chosen to minimise salinity spikes was $\tau = 0.175$ s. Temperatures are reported using the ITS-90 scale. ITS-68 is used for computing derived quantities. Temperatures are converted to ITS-68 by (2.4), as suggested by Saunders (1990).

$$T_{68} = 1.00024 \times T_{90} \tag{2.4}$$

Pressure

Raw pressure counts were scaled by (2.5) and then calibrated using (2.6):

$$P_{raw} = 0.1 \times P_{raw} \tag{2.5}$$

$$P = -10.94 + 1.0027284 \times P_{raw} + 1.36753E\text{-}6 \times P^2_{raw} - 1.0313E\text{-}10 \times P^3_{raw} \tag{2.6}$$

The pressure sensor is temperature dependent: the CTD gave a larger pressure when it was colder. The correction (2.7) gave deck pressures which average to -0.0191 dbar with a standard deviation of 0.1220 dbar whilst the CTD was on the deck for temperatures varying between 3°C and 23°C,

$$P = P + 0.14(\text{ptlag} - 25.4) \qquad (2.7)$$

where ptlag is a lagged version of the CTD temperature, and is constructed by (2.8) and (2.9):

$$W = \exp(-\text{tdel}/\text{tconst}) \qquad (2.8)$$

$$\text{ptlag}(t_0 + \text{tdel}) = W \times \text{ptlag}(t_0) + (1 - W) \times T(t_0 + \text{tdel}) \qquad (2.9)$$

where T is the CTD temperature, tdel is the time interval in seconds over which ptlag is updated with tconst = 400 s..

Pressure is adjusted to compensate for hysteresis between down and up casts: the pressure hysteresis is a function of the maximum pressure of the cast:

$$P_{out} = P_{in} - \left\{ \text{dp6000}(P_{in}) - \left[(P_{in}/P_{max}) \times \text{dp6000}(P_{max}) \right] \right\} \qquad (2.10)$$

where dp6000(P) is the hysteresis and is given in Table 2.1, P_{max} is the maximum pressure of the cast and P_{in} is the upcast CTD pressure.

Conductivity

Raw conductivity was first scaled by (2.11) and then calibrated with (2.12):

$$C_{raw} = 0.001 \times C_{raw} \qquad (2.11)$$

$$C = 0.046595 + 0.9877211 \times C_{raw} \qquad (2.12)$$

The offset and slope were determined using bottles deeper than 2000 dbar over stations 001 to 047. Over groups of stations small offsets were added to this correction compensating for fluctuations in the CTD or in the bottle sampling. The corrections applied to the offset are listed in Table 2.2.

The conductivity sensor was calibrated for the cell material deformation correction (2.13):

$$C = C \times \left(1 + \alpha \times (T - T_0) + \beta \times (P - P_0)\right) \qquad (2.13)$$

where $\alpha = -6.5E\text{-}6$ °C^{-1}, $\beta = 1.5E\text{-}8$ $dbar^{-1}$, $T_0 = 15$ °C and $P_0 = 0$ dbar.

CTD Instrument DEEP02

After station 135 and to the end of the cruise, station 143, CTD DEEP02 was used. DEEP02 had been modified, pre-cruise, to accept inputs from two FSI Ocean Temperature and Conductivity modules. These modules were fitted inside a Niskin bottle to investigate the effect of flow through the bottle. The intention is to investigate the relationship of water surrounding the Niskin sample bottle to that inside the bottle. DEEP02 was calibrated in a similar mannor to DEEP01. The following equations were applied (Calibrations from Oct. 1994),

$$T = -2.8434\text{E-}3 + 1.0067956 \times T_{raw} + 7.287\text{E-}6 \times T_{raw}^2 \quad (2.14)$$

$$\tau = 0.2 \quad (2.15)$$

$$P = 3.42 + 1.002348 \times P_{raw} - 3.9467\text{E-}6 \times P_{raw}^2 \quad (2.16)$$

$$P = P + 0.28(\text{ptlag} - 41.86) \quad (2.17)$$

with $R^2 = 0.97$ for $n = 7/8$ points for $10.6°\text{C} < \text{ptlag} < 13.5°\text{C}$

$$C = 9.08698\text{E-}3 + 1.02002066 \times C_{raw} \quad (2.18)$$

All offsets, lagged temperatures and conductivity cell model were applied as outlined above for DEEP01. The pressure hysteresis data used are given in Table 2.3.

Salinity

After the conductivity calibration, salinity residuals (bottle salinity - CTD salinity) showed a depth dependence. This dependence looks like a temperature effect in the upper 500 m of the water column and a pressure effect below. The shape of the residuals over the station groupings was modelled using pressure and temperature,

$$\text{dsalin} = a + bP + cT \quad (2.19)$$

where dsalin is the correction to salinity. This correction was then added to the CTD salinity. Table 2.4 lists the coefficients determined. Salinity residual statistics are given in Table 2.5.

Post-cruise an intercomparison of starndard sea water used during the cruise revealed that the standard sea water used for stations 001 to 044 lead to salinity samples being 0.0015 fresh. Therefore, 0.0015 has been added to CTD salinities for these stations. Full details may be found in section 7.f.

Analysis of bottle salinities in the Eastern North Atlantic

Stations 020 to 034 were taken at a latitude of 41.5°N between 12°W and 20°W, within the Eastern North Atlantic (ENA). These 15 stations had 73 bottle salinity samples taken at potential temperatures colder than 2.5°C. Saunders (1985) first proposed that the deep basin of the ENA may be used as an oceanic calibration facility given that systematic measurement errors between instruments (and standard sea water) are bigger than the *in situ* variations of temperature and salinity. Saunders proposed that between 15-30°W and 20-46°N the relationship between potential temperature and salinity could be accurately described by the linear fit (2.20):

$$S = 34.698 + 0.098 \times \theta \qquad (2.20)$$

Our bottle salinity samples are 0.0044 fresher with a standard deviation of 0.0008 than this. Later Mantyla (1994) used two cruises which covered the ENA to propose refinements to this line accounting for latitudinal variations. At 41.5°N the relationship given by Mantyla is (2.21):

$$S = 34.9163 + 0.1000075 \times (\theta - 2.25) \qquad (2.21)$$

For this cruise we have (2.22):

$$S = 34.9143 + 0.100304 \times (\theta - 2.25) \qquad (2.22)$$

with $R^2 = 0.9954$. Therefore at 2.25°C our data are 0.002 fresher than the Mantyla data. For 73 samples spanning 2.0 to 2.5°C the mean difference is 0.0021 fresher with a standard deviation of 0.0008. At 2.25°C the salinity predicted by the Saunders relation is 34.9185. The $\Delta S/\Delta\theta$ gradient varies by about 0.015 psu/°C between 20°N and 50°N (the $\Delta S/\Delta\theta$ gradient is about 0.1 psu/°C at 41.5°N). The difference in $\Delta S/\Delta\theta$ gradient in the two equations above is much smaller than any latitudinal variation. We therefore conclude that the variation between our data and that of Mantyla is due to variations in standard sea water and does not suggest any environmental difference.

Due to a standard sea water problem, post-cruise it was found that stations 001 to 044 were 0.0015 fresh. This value has subsequently been added to our data making our data 0.0005 fresher than Mantyla, 1994.

Oxygen

The oxygen model of Owens and Millard (1985) was used to calibrate the oxygens (2.23):

$$O_2 = \rho \times \text{oxysat}(S,T) \times (O_c - \chi) \times \exp\{\alpha \times [f \times T_{CTD} + (1-f) \times T_{lag}] + \beta \times P\} \qquad (2.23)$$

where ρ is the slope, oxysat(S,T) is the oxygen saturation value after Weiss (1970), O_c is oxygen current, χ is the oxygen current bias, α is the temperature correction, f is the weighting of T_{CTD}

the CTD temperature and a lagged temperature T_{lag} computed exactly as the pressure temperature lag earlier, and β is the pressure correction. Five parameters, ρ, α, β, f, χ were fitted for each station. This approach minimises the residual bottle oxygen minus CTD oxygen differences but places complete reliance on the bottle oxygens being correct. Oxygens were calculated in µmol/l. DEEP02, stations 136 to 143 have no CTD oxygen data. Table 2.6 gives the parameters and the sum square residual for each station.

Transmittence, Fluorescence, and Altimetry

On DEEP01, Fluorescence was converted to voltages (2.24); this is a calibration of the voltage digitiser in the CTD. Transmittance was similarly calibrated to voltages (2.25). The altimeter had the calibration (2.26) applied.

$$\text{fvolts} = -1.7196\text{E-}3 + 1.21971\text{E-}3 \times f_{raw} + 3.48596\text{E-}10 \times f_{raw}^2 \tag{2.24}$$

$$\text{trvolts} = -1.7196\text{E-}3 + 1.21971\text{E-}3 \times tr_{raw} + 3.48596\text{E-}10 \times tr_{raw}^2 \tag{2.25}$$

$$\text{alt} = 0.2 + 5.148\text{E-}2 \times alt_{raw} - 5.8\text{E-}8 \times alt_{raw}^2 \tag{2.26}$$

On DEEP02, fluorescence (2.27), transmittance (2.28) and altimeter (2.29) calibrations were:

$$\text{fvolts} = -3.44\text{E-}4 + 1.21971\text{E-}3 \times f_{raw} - 2.813\text{E-}11 \times f_{raw}^2 \tag{2.27}$$

$$\text{trvolts} = -3.44\text{E-}4 + 1.21971\text{E-}3 \times tr_{raw} - 2.813\text{E-}11 \times tr_{raw}^2 \tag{2.28}$$

$$\text{alt} = 4.73\text{E-}2 + 5.41\text{E-}2 \times alt_{raw} - 1.9\text{E-}8 \times alt_{raw}^2 \tag{2.29}$$

Digital Reversing Temperature and Pressure Meters

Two digital reversing temperature meters (RTM) were used, T746 and T989 and two reversing pressure meters (RPM) P6132H and P6394H. T746 and P6394H were at position one on the CTD rosette, T989 and P6132H were at position four. T746 failed on station 054 due to low battery power. No spare batteries were available so the thermometer could not be used throughout the remainder of the cruise. After station 054 T989 was placed in position one on the rosette. P6132 was calibrated by (2.30):

$$P_{cal} = -6.7 + 1.02 \times P_{raw} - 3.3\text{E-}6 \times P_{raw}^2 \tag{2.30}$$

This calibration was obtained from the first 92 stations where it was observed that residuals from this instrument had a quadratic shape with depth. The other instruments have had no calibrations applied. Table 2.7 summarises data from the reversing instruments.

Throughout the cruise no trends or offsets were identified in pressure or temperature. There were insufficient data to determine if there are any biases between CTD DEEP01 and DEEP02. Post-cruise calibration of pressure and temperature sensors will be our method for identifying calibration shifts.

Stuart Cunningham and Mickey Tsimplis

c. POST CRUISE CALIBRATION

DEEP01

DEEP01 was used on the first 135 out of 143 stations. The post cruise calibration showed that the pressure sensor was stable and was continuing to give the same pressure response. Therefore, nothing was done to pressure. The post cruise temperature calibration revealed that the temperature sensor was underreading by 0.0040°C. Too few reversing temperature measurements were made to reveal if temperature offsets occured during the cruise. Therefore, a linear difference in time between the pre and post cruise calibrations suggests that 0.0028°C should be added to the temperatures recorded during the cruise. A calibration of +0.0028°C has been added to stations 001 - 135. All variables dependant on temperature have been recalculated.

DEEP02

DEEP02 was used on stations 136 - 143 in the Rockall Trough. The post cruise calibrations were sufficiently different from the pre cruise calibrations that the post cruise calibrations were applied to the raw data, ignoring the pre cruise calibrations. The following equations were applied (Calibrations from Nov. 1997).

Temperature

Temperature raw counts were first scaled by (2.1) and then calibrated using (2.31):

$$T = 6.0194E\text{-}4 + 1.00702 \times T_{raw} \qquad (2.31)$$

Equations and values (2.3) and (2.15) still apply. Temperatures are reported using the ITS-90 scale.

Pressure

Raw pressure counts were scaled by (2.5) and then calibrated using (2.32). Equation (2.17) is replaced by (2.33). The pressure hysteresis data of table 2.3 are replaced by those of table 2.8.

$$P = -2.8 + 0.9928896 \times P_{raw} - 1.33E\text{-}6 \times P_{raw}^2 + 2.015E\text{-}10 \times P_{raw}^3 \qquad (2.32)$$

$$P = P + 0.28(\text{ptlag} - 19.36) \tag{2.33}$$

Conductivity

Raw conductivity was first scaled by (2.11) and then calibrated with (2.34). The cell deformation correction (2.13) was unchanged.

$$C = 0.0176 + 0.97959165 \times C_{raw} \tag{2.34}$$

Salinity

Following the conductivity calibration salinity residuals were examined for pressure and station dependance. There are few stations and no measurements deeper than 2500 dbar, so no residal shape was identified. The residual statistics are appended to table 2.5.

Digital Reversing Temperature and Pressure Meters

Comparisons between CTD DEEP02 and reversing instruments are given in table 2.9. All relevant information is as reported above for these instruments. Neither the means or variances were different from those obtained when using DEEP01.

Stuart Cunningham

References

Mantyla, A. W., 1994: The treatment of inconsistencies in Atlantic deep water salinity data. *Deep-Sea Res.*, **41** 1387-1405.

Owens, W. B., and R. C. Millard, 1985: A new algorithm for CTD oxygen calibration. *J. Phys. Oceanogr.*, **15** 621-631.

Saunders, P. M., 1986: The accuracy of measurement of salinity, oxygen and temperature in the deep ocean. *J. Phys. Oceanogr.*, **16**, 189-195.

Saunders, P. M. (1990) The International Temperature Scale 1990, ITS-90. International WOCE Newsletter No. 10, p 10.

Weiss, R. F., 1970: The solubility of nitrogen, oxygen and argon in water and seawater. *Deep-Sea Res.* **17** 721-735.

Table 2.1: Laboratory measurements of pressure hysteresis for DEEP01 made on 31/10/94 at 9.44°C. Intermediate values of pressure hysteresis are found by linear interpolation.

P	dP6000(P)
dbar	dbar
0	0.0
400	3.9
1000	6.0
1500	5.9
2000	4.8
3000	2.0
3500	1.0
5000	0.0
6000	0.0

Table 2.2: Corrections to the conductivity offset.

Station	Correction	Notes
numbers	mmho/cm	
001 - 035	-0.0024	westward leg to turning stn.
036	-0.0047	
037 - 039	-0.0026	
040 - 049	-0.0010	
050 - 069	0.0000	
070 - 089	0.0028	
090 - 093	0.0118	fresh and shallow stations
094 - 097	0.0028	
098 - 102	0.0118	fresh and shallow stations
103	-0.001	
104 - 110		bts-us=-5.45e-8xstatno+6.722e-2
104 - 110	-0.007	
111 - 129	0.0052	
130	0.0012	
131 - 135	0.0073	135 last station with DEEP01
136 - 140	0.0000	136 first station with DEEP02
141 - 143	-0.0031	143 end of cruise

Table 2.3: Laboratory measurements of pressure hysteresis for DEEP02. Intermediate values of pressure hysteresis are found by linear interpolation.

P	dP5500(P)
dbar	dbar
0	0.0
100	0.9
200	1.6
300	2.1
400	2.3
500	1.9
1000	4.3
1500	4.6
2000	4.0
2500	3.7
3000	2.7
3500	2.1
4000	1.5
4500	0.9
5500	0.0

Table 2.4: Salinity correction coefficients

Stations	a	b	c	Notes
001 - 035	0.838	-0.000017	-0.460610	westward leg
036 - 049	0.800	-0.000191	-0.419474	
050 - 069	1.782	-0.000113	-0.508926	
070 - 089	1.875	-0.000234	-0.616385	
090 - 093	1.947	-0.000594	-0.404307	
094 - 097	1.875	-0.000234	-0.616385	
098 - 102	1.947	-0.000594	-0.404307	
103 - 135	2.360	-0.000254	-0.453748	135 last DEEP01
136	15.079	-0.003484	-0.871264	first DEEP02
137	-1.927	-0.004599	0.480528	
138	-3.178	0.003279	0.511432	
139	7.312	-0.001061	-0.200623	
140	11.539	-0.002944	-0.578537	
141 - 143	0	0	0	end of section

Table 2.5: Salinity residual statistics

Stations	all p	all p	all p	p>2000	p>2000	p>2000
	mean	stdev	n	mean	stdev	n
001 - 035	0.0000	0.0012	650/688	0.0000	0.0009	152/163
036 - 049	-0.0001	0.0018	317/321	0.0000	0.0007	51/52
050 - 069	-0.0001	0.0011	409/451	0.0000	0.0008	74/77
070 - 089	0.0000	0.0015	507/534	-0.0002	0.0010	60/63
094 - 097	0.0000	0.0015	507/534	-0.0002	0.0010	60/63
090 - 093	-0.0002	0.0016	82/111			
098 - 102	-0.0002	0.0016	82/111			
070 - 102	0.0000	0.0012	557/645			
104 - 110	0.0000	0.0009				
111 - 129			p>1500	0.0000	0.0007	51/55
130 - 135	0.0000	0.0011				
001 - 135	0.0000	0.0018	2554/2659	0.0000	0.0009	366/385
136 - 143	0.0000	0.0016	110/112	<-- post	cruise	
001 - 143	0.0000	0.0011	2483/2781	0.0000	0.0009	370/389

Table 2.6: Oxygen coefficients and sum square residuals

num	ρ	α	β	f	χ	n	sumsq
							μmol/l
001	2.2825	-0.0270	0.0001684	0.2603	-0.033	22	0.71
002	2.2628	-0.0263	0.0001957	0.2653	-0.055	19	3.04
003	2.4315	-0.0241	0.0007435	0.0000	-0.111	6	1.11
004	2.2825	-0.0270	0.0001684	0.2603	-0.033	22	0.71
005	2.2844	-0.0279	0.0000638	0.2358	-0.005	13	1.40
006	2.6819	-0.0270	0.0003048	0.7497	-0.126	15	9.18
007	2.4749	-0.0336	0.0001282	0.5787	-0.033	20	1.59
008	2.4324	-0.0300	0.0001735	0.5399	-0.060	17	1.86
009	2.2763	-0.0221	0.0002494	0.2377	-0.083	15	1.79
010	2.3307	-0.0265	0.0001970	0.3299	-0.058	20	2.40
011	2.3818	-0.0270	0.0002109	0.2517	-0.067	19	2.03
012	2.3456	-0.0236	0.0002328	0.0078	-0.075	19	1.65
013	2.2872	-0.0250	0.0002059	0.2344	-0.056	20	2.22
014	2.3238	-0.0273	0.0001851	0.2970	-0.044	21	2.75
015	2.2988	-0.0257	0.0001956	0.2651	-0.047	21	3.38
016	2.3099	-0.0271	0.0001919	0.3056	-0.045	20	1.66
017	2.3219	-0.0252	0.0002421	0.2369	-0.073	18	2.84
018	2.3162	-0.0249	0.0002150	0.1653	-0.058	15	2.01
019	2.3629	-0.0285	0.0001726	0.2765	-0.033	21	1.39
020	2.4225	-0.0287	0.0001792	0.3771	-0.041	21	1.49
021	2.4291	-0.0296	0.0001732	0.3683	-0.037	20	1.21
022	2.3886	-0.0286	0.0001741	0.2549	-0.033	20	1.61
023	2.3886	-0.0286	0.0001741	0.2549	-0.033	20	1.61
024	2.3886	-0.0286	0.0001741	0.2549	-0.033	20	1.61
025	2.4124	-0.0249	0.0002266	0.2634	-0.067	22	1.43
026	2.4270	-0.0283	0.0001877	0.2922	-0.045	22	1.35
027	2.3836	-0.0288	0.0001754	0.2180	-0.033	21	1.59
028	2.4391	-0.0283	0.0001899	0.1251	-0.046	18	1.25
029	2.3690	-0.0307	0.0001493	0.3272	-0.012	19	1.63
030	2.3380	-0.0272	0.0001888	0.2055	-0.038	18	1.29
031	2.3542	-0.0293	0.0001407	0.1468	-0.005	19	1.25
032	2.4067	-0.0290	0.0001747	0.2487	-0.035	18	1.72
033	2.4206	-0.0301	0.0001696	0.3481	-0.030	19	0.98
034	2.4523	-0.0281	0.0001866	0.1682	-0.043	20	1.02
035	2.2878	-0.0269	0.0001771	0.2669	-0.019	19	1.49
036	2.3696	-0.0286	0.0001691	0.2794	-0.025	19	1.15
037	2.6065	-0.0326	0.0001459	0.1831	-0.026	18	0.99
038	2.2542	-0.0272	0.0001688	0.2040	-0.008	18	1.70
039	2.2542	-0.0272	0.0001688	0.2040	-0.008	18	1.70
040	2.3552	-0.0302	0.0001615	0.3183	-0.013	18	1.73
041	2.3939	-0.0310	0.0001483	0.2621	-0.011	19	1.88
042	2.3557	-0.0307	0.0001372	0.2276	-0.001	19	1.63
043	2.3362	-0.0295	0.0001350	0.2239	0.004	15	1.83
044	2.2448	-0.0295	0.0001289	0.2208	0.018	18	2.34
045	2.3659	-0.0306	0.0001301	0.1685	0.006	22	1.31

046	2.3208	-0.0294	0.0001391	0.3293	0.006	20	1.53
047	2.2890	-0.0305	0.0001183	0.2582	0.026	20	1.59
048	2.4680	-0.0360	0.0000775	0.0842	0.042	18	1.19
049	2.3151	-0.0315	0.0001177	0.1381	0.024	20	1.64
050	2.3796	-0.0335	0.0001086	0.1631	0.027	18	1.83
051	2.3648	-0.0320	0.0001186	0.1692	0.018	19	2.03
052	2.3658	-0.0317	0.0001164	0.1449	0.023	19	2.03
053	2.4367	-0.0347	0.0000997	0.0315	0.030	21	1.50
054	2.3321	-0.0353	0.0000864	0.1329	0.051	17	1.48
055	2.3887	-0.0336	0.0001113	0.0737	0.019	22	1.75
056	2.2867	-0.0324	0.0001171	0.2662	0.029	18	1.74
057	2.4469	-0.0330	0.0001462	0.3965	-0.013	17	1.19
058	2.2070	-0.0323	0.0001179	0.3879	0.037	20	1.11
059	2.3013	-0.0325	0.0001095	0.1302	0.032	21	1.61
060	2.3664	-0.0316	0.0001234	0.2593	0.010	19	1.59
061	2.3066	-0.0303	0.0001216	0.1403	0.019	20	0.80
062	2.2269	-0.0295	0.0001201	0.2851	0.029	18	1.12
063	2.2864	-0.0326	0.0001183	0.2685	0.027	17	1.04
064	2.2957	-0.0321	0.0001178	0.1529	0.027	17	1.20
065	1.9973	-0.0291	0.0000906	0.1577	0.092	18	1.59
066	2.2988	-0.0317	0.0001160	0.1189	0.025	15	1.22
067	2.2861	-0.0331	0.0001183	0.2724	0.024	18	1.26
068	2.2786	-0.0305	0.0001307	0.3364	0.014	20	1.03
069	2.2814	-0.0305	0.0001131	0.1592	0.027	20	1.19
070	2.3036	-0.0295	0.0001210	0.1306	0.018	18	0.48
071	2.2927	-0.0321	0.0001226	0.2229	0.021	18	0.72
072	2.2868	-0.0327	0.0001166	0.2158	0.027	18	1.03
073	2.2770	-0.0314	0.0001248	0.2770	0.022	17	1.57
074	2.2802	-0.0309	0.0001297	0.2710	0.019	21	0.94
075	2.2844	-0.0327	0.0001218	0.2533	0.025	22	1.17
076	2.1222	-0.0308	0.0001008	0.0920	0.062	21	1.58
077	2.1222	-0.0308	0.0001008	0.0920	0.062	21	1.58
078	2.1828	-0.0308	0.0001058	0.0211	0.048	19	1.12
079	2.2759	-0.0296	0.0001229	0.2951	0.019	19	1.08
080	2.2847	-0.0340	0.0001149	0.2511	0.029	19	1.36
081	2.3079	-0.0297	0.0001288	0.1159	0.009	17	1.19
082	2.0535	-0.0313	0.0000974	0.1836	0.075	20	1.19
083	2.3156	-0.0325	0.0001301	0.1584	0.012	19	1.50
084	2.2733	-0.0313	0.0001157	0.1963	0.026	15	1.54
085	2.3008	-0.0328	0.0001172	0.2376	0.023	21	1.12
086	2.3008	-0.0328	0.0001172	0.2376	0.023	21	1.12
087	2.2812	-0.0401	0.0000892	0.0706	0.052	22	1.40
088	2.2657	-0.0414	0.0000997	0.2733	0.051	17	1.03
089	2.2158	-0.0439	0.0000639	0.3214	0.082	15	1.25
090	2.2440	-0.0395	0.0000822	0.3276	0.047	11	0.88
091	2.2968	-0.0262	0.0001929	0.2442	-0.009	9	0.86
092	2.4012	0.0506	0.0012555	0.5984	-0.208	4	0.97
093	2.1295	-0.0395	0.0001195	0.0000	0.070	5	2.15
094	2.2812	-0.0342	0.0001146	0.2662	0.029	20	1.16
095	2.2994	-0.0332	0.0001078	0.1666	0.033		

096	2.2994	-0.0332	0.0001078	0.1666	0.033	17	1.13
097	2.2815	-0.0289	0.0001296	0.0321	0.018	18	1.83
098	2.2734	-0.0365	0.0001079	0.2735	0.039	16	1.24
099	2.2884	-0.0256	0.0001662	0.2640	-0.008	17	1.42
100	2.2862	-0.0265	0.0001815	0.2577	-0.006	13	1.24
101	2.3244	-0.0221	0.0002181	0.1490	-0.028	10	1.51
102	2.2439	-0.0359	0.0001770	0.2856	0.024	6	0.58
103	2.3530	-0.0595	0.0000412	0.0000	0.069	9	1.38
104	2.2769	-0.0403	0.0000218	0.0000	0.075	8	1.67
105	2.3269	-0.0125	0.0002820	0.1692	-0.076	14	1.34
106	2.2973	-0.0268	0.0001603	0.2879	-0.006	19	1.81
107	2.2587	-0.0344	0.0001165	0.3550	0.033	22	1.18
108	2.2881	-0.0287	0.0001474	0.2767	0.005	14	1.75
109	2.2819	-0.0281	0.0001598	0.2716	0.001	14	1.32
110	2.2290	-0.0352	0.0001361	0.1328	0.040	11	1.50
111	2.2798	-0.0731	-0.0005178	0.1834	0.351	6	1.22
112	2.2412	-0.0433	0.0000336	0.0232	0.112	9	1.12
113	2.2748	-0.0262	0.0001944	0.1882	-0.012	12	1.27
114	2.3349	-0.0431	0.0000342	0.0000	0.096	13	1.43
115	2.3349	-0.0431	0.0000342	0.0000	0.096	13	1.43
116	2.2806	-0.0303	0.0001356	0.2869	0.014	18	1.38
117	2.2795	-0.0297	0.0001416	0.2619	0.011	18	1.46
118	2.3396	-0.0333	0.0001178	0.1466	0.022	17	1.36
119	2.2927	-0.0277	0.0001506	0.2554	-0.001	18	1.67
120	2.4523	-0.0335	0.0001445	0.5229	-0.014	20	1.21
121	2.3220	-0.0323	0.0001284	0.2501	0.016	20	1.22
122	2.3252	-0.0343	0.0001170	0.3029	0.023	20	1.42
123	2.2708	-0.0292	0.0001507	0.2537	-0.004	14	2.37
124	2.2764	-0.0316	0.0001295	0.2799	0.020	15	1.55
125	2.2765	-0.0311	0.0001509	0.3369	0.008	15	0.98
126	2.3183	-0.0267	0.0001909	0.3770	-0.020	11	1.42
127	2.2652	-0.0256	0.0001868	0.1504	-0.013	9	1.20
128	2.5701	-0.0293	0.0002347	0.4126	-0.064	10	0.93
129	2.3546	-0.0366	0.0000932	0.4402	0.032	11	1.36
130	2.3133	-0.0593	-0.0002698	0.0000	0.310	8	3.40
131	2.2930	-0.0329	0.0001654	0.3108	0.019	5	0.86
132	2.2733	-0.0498	0.0001655	0.1263	0.104	5	0.12
133	2.2682	-0.0532	0.0000126	0.1704	0.139	4	0.24
134	2.2600	-0.0357	0.0001008	0.4163	0.044	9	1.21
135	2.2826	-0.0277	0.0001842	0.2604	-0.019	10	0.79

Table 2.7: Upcast CTD value minus reversing instrument. Temperature diffenences have been calculated within ±0.5 °C then ±2 sd, pressure differences have been taken within ±25 dbar then ±2 sd. n points is the number of points in the mean over the total number of data points.

all P	**mean**	**sd**	**n points**
T989 °C	0.0139	0.0088	104/122
T746 °C	0.0280	0.0098	47/52
P6394 dbar	1.2	1.8	116/130
P6132 dbar	0.1	1.0	101/119
P>2000 dbar	**mean**	**sd**	**n points**
T989 °C	0.0149	0.0041	46/58
T746 °C	0.0277	0.010	45/50
P6394 dbar	0.86	1.6	77/97
P6132 dbar	-0.24	1.1	27/40

Table 2.8: Post-cruise laboratory measurements of pressure hysteresis for DEEP02. Intermediate values of pressure hysteresis are found by linear interpolation.

P	dP5500(P)
dbar	dbar
0	0.0
100	0.9
200	1.6
300	2.1
400	2.3
500	1.9
1000	4.3
1500	4.6
2000	4.0
2500	3.7
3000	2.7
3500	2.1
4000	1.5
4500	0.9
5500	0.0

Table 2.9: Upcast CTD value minus reversing instrument. Temperature diffenences have been calculated within ± 0.5°C then ±2sd, pressure differences have been taken within ± 25 dbar then ± 2 sd. n points is the number of points in the mean over the total number of data points. For post-cruise DEEP02 calibration.

all P	mean	sd	n points
T989 °C	0.0033	0.0005	6/7
T746 °C	0		
P6394 dbar	2.5	3	6/7
P6132 dbar	-0.5	1.7	6/7

3. LOWERED ADCP MEASUREMENTS

a. DESCRIPTION

The LADCP package consisted of a RDI 150kHz BroadBand ADCP (phase III) with a pressure case rated to 6000 meters and 4 downward facing transducers with 20 degree beam angles. The LADCP was fitted centrally in the CTD rosette frame and power during casts was supplied from a second pressure case containing a 48 volt alkaline battery pack mounted horizontally near the bottom of the frame. The battery pack pressure case was aligned so that batteries could be replaced by simply removing the end cap of the case. A short lead was left permanently attached to the unit and tied to the frame to enable the external power/communications lead to be attached pre- and post-deployment.

A 15 m communications/power lead was routed through the Bottle Annex and Deck Lab and connected to a dedicated PC and power supply situated on the port side of the Deck Lab. While attached to the instrument the cable was taped to the CTD frame and draped over a deck light bracket to keep it clear of the boots and heads of samplers. During casts the free end of the cable was fed back through the opening into the Bottle Annex to keep it dry. For most of the cruise the CTD package was kept permanently at the aft end of its deck tracks, so it was necessary to extend the 15m cable with a spare short lead to enable connection. During set-up prior to a cast and for downloading data, external power was supplied to the unit via the communications lead. There is sufficient diode protection inside the ADCP for the battery supply to be overriden by applying external power at a slightly higher voltage (i.e. 50 volts, with the battery packs used on this installation).

Prior to each cast the instrument was subjected to a series of tests and sent a configuration (command) file which determines the mode of operation. The test results and deployment files were recorded for each cast. With some exceptions, the instrument was set to Water and Bottom Tracking Mode with 16 m bins and 10-bin ensembles for the whole cruise. The LADCP clock was checked and corrected if it was found to be more than 1 second from GMT. The power and communication cable was disconnected and a blank plug placed on the lead to the instrument and taped to the frame for security.

A total of 16 battery packs were available for the cruise, and 8 eventually used. The 48 volt alkaline battery packs (32 x 1.5 volts) were replaced when the power level dropped to around 34-35 volts to avoid potential data loss. The life of the battery packs ranged from 37,000m to 110,000m of casts, with an average of 91,000m per pack. The packs which had a shorter life were those used in regions with many shallower casts, ie a relatively high time spent within Bottom Tracking range. One pack was used solely in water tracking mode and was found to use approximately the same amount of battery power as the casts set to Bottom Tracking Mode over deeper casts (>1500m).

b. INSTRUMENT PROBLEMS

During the early part of the cruise performance of the LACDP was not wholly satisfactory. Data appeared to be logged correctly during the downcast but not for the whole of the upcast. Also, the power/communications cable was inadvertently disconnected whilst data was being downloaded. Further communications with the instrument failed after this. The pressure case was opened and the fault traced to 2 communication line fuses which had blown. These were of a wired in type of which no spares we carried. Fortunately, 2 were available from unused channels which were removed and resoldered in the appropriate lines. Communications were then re-established. The original problem with data loss continued however, and lack of any spare boards or parts resulted in a port call to Leixões (Oporto). Spare boards, transducer assembly and a complete electronics chassis were flown to Oporto. Rather than attempt to identify the exact cause of the problem it was decided to replace the transducer assembly and electronics chassis in total. The power conditioning circuit board from the original instrument was retained as this included the appropriate connections to the endcap. Before fitting the electronics chassis a cast to 2000 metres was performed with just the pressure case and transducer assembly to test the water tight integrity. This proved successful and the instrument was finally assembled. The complete set of tests available from the software suite was run and the instrument passed all satisfactorily.

Data logging for both up and down casts was now satisfactory and it was also noted that the Ping from the transducers could now be heard or at least sensed which was not the case with the original instrument.

c. DATA PROCESSING

This section briefly outlines the method of LADCP current calculation and the data processing path taken on D230. In essence the LADCP measures instantaneous relative velocities of scatterers in the water column and these can be converted into profiles of absolute currents by an elaborate processing path. The scatterer velocities are measured by utilising the Doppler frequency shift, phase changes and correlation between coded pulses transmitted and received by the four tranducers. The raw data must be scaled to velocity units by taking into account the depth and temperature dependent sound velocity (from CTD data). The directions can be inferred from trigonometric calculations based on the geometry of the transducer set, the orientation of the package (measured with a flux gate compass) and the local magnetic variation from true north. The depth of the instrument was first calculated by integrating the measured vertical velocity and later fine-tuned by matching to the CTD time and pressure data.

Velocity data are collected in 16m bins and each ping produces 10 bins which make up an ensemble. In order to remove relative velocites introduced by the motion of the package during the cast, shear profiles were calculated by differentiating the velocities within each ensemble. The data are then integrated up over the cast to produce a shear profile with a zero net velocity. This process also removes the barotropic component of the velocities which must be reinstated either from the ships displacement (from differential GPS data) or from the relative motion of the package over the sea floor (Bottom Tracking). The final velocity profile is therefore a sum of the baroclinic and barotropic components.

The processing of LADCP data is achieved using software developed by Eric Firing at the University of Hawaii. His software uses a combination of 'perl' scripts and MATLAB 'm' files to process the data, which are stored in a CODAS database. The processing stages were those outlined in the SOC LADCP Data Processing Manual written by N.Crisp, L. Beal and R. Tokmakian and are summarised below.

1) Extract binary ADCP files from instrument, and scan it using '*scanbb*' to give useful information about the cast - e.g. time in water, out of water, number of good ensembles, and the cast depth as an estimate of integrated vertical velocity.

2) Load the ADCP data into a CODAS database, including magnetic variation (information provided by the Bridge Officer at each station), nominal cast position, and only including good ensembles specified by the previous '*scanbb*' step. Raw data files (*.000), database files (*.blk), configuration and control files (*.cmd, *.cnt, *.def), scan files (*.scn), and deployment log and test files (*.txt, *.log) were copied to a location on the SUN using PC_NFS. All these files and their original file structure were periodically compressed and archived to an EO before some were removed from the SUN to conserve space. The necessary database and control files remained in individual cast directories on the SUN and were backed-up daily along with all cruise data.

3) The database files from the PC were converted to SUN format CODAS files using the program 'mkblkdir'.

4) The perl script 'domerge' calculated mean shear profiles (the baroclinic component of the current) and applied corrections and editing options which were kept constant throughout the cruise. Data were averaged into 5m bins. The MATLAB script 'do_abs' calculated absolute velocities, and produced a standard set of profiles. In the first instance the uncorrected data (down, up and mean profiles) were viewed and plotted as unreferenced shear profiles with the depth-averaged component set to zero.

5) Next the calibrated CTD data were interactively matched to the ADCP vertical velocities within MATLAB (set_***.m), and the true depth information merged into the CODAS database for the cast, together with sound speed data corrected for temperature and salinity (add_ctd then re-run domerge and do_abs).

6) One method of obtaining absolute currents is to use GPS data during the cast to restore the depth-averaged (barotropic) velocity component (equivalent to the ship's displacement) which

was removed when first calculating the shear. For all but 7 days of the cruise the GPS GLONASS 1-second data stream was used for calculating the ships displacement. For days ??? to ??? the GPS 4000 1-second data stream was used. The GPS data were subjected to a 5-second filter (pfiltr; 30 seconds for GPS 4000) and subsampled every 5 (30) data points to create a global GPS file (ascii file sm.asc, saved as Matlab file sm.mat). The GPS files were created every few days rather than at the end of the cruise, so in total 10 sequential sm.mat files were generated. Some GPS files caused 'non-monotonic' errors during do_abs so a short Matlab script was written to identify and remove any rogue non-monotonic rows in the sm.mat files. The absolute profiles calculated by do_abs were plotted and saved to file.

7) Each cast was rotated through the heading of the cruise track to calculate current components normal to the cruise track for comparison with geostrophic shear profiles from the CTD data (rotate.m). This stage also creates an ascii file containing the mean vertical, east, north, along-track and across-track components. The ascii file was imported into pstar (pascin) with position data extracted from the headers of the corrected CTD files (pinq) rather than the uncorrected positions found in the file latlon.asc created by domerge (ladcp.exec).

d. BOTTOM TRACKING DATA

On Stations 42 to 143 the LADCP was set to Bottom Tracking (BT) mode in order to obtain good measurements of the bottom currents particularly in the deep western boundary currents. In this mode the LADCP produces alternating pings for water tracking and Bottom Tracking when in range of the sea floor. The Firing software does not deal with Bottom Tracking data, so new pstar scripts were written to process the data. Following is a brief outline of the steps taken during the processing:

1) Ascii data are extracted from the binary BBADCP files (using conversion file D230BT.FMT and program 'bblist'). Variables extracted include ensemble number, time (Julian Day), BT velocities (east/u, north/v, vertical/w, error), water track velocities (east/u, north/v, vertical/w, error) and the BT range from the bottom from Beams 1/2 and 3/4.

2) Ascii data read are into pstar (pascin), absent data changed from 9999 to -999 (pedita), and time converted into days of the year (JDay plus 1) then seconds (ptime). User inputs the LADCP clock lag in seconds as necessary.

3) Currents are rotated by the local magnetic variation (pcmca2, pcalib) and the water velocity over ground calculated for each bin (water track velocities minus bottom track velocities) (parith). This step removes the package motion from the velocities.

4) The data are merged with CTD data on time (pmerg2) in order to match pressure (depth) data with the velocity profiles. No correction for velocity of sound variation has been made. Each 1

second ensemble then has an associated depth, and next the incremental depth of each bin is calculated according to the binsize specified in the LADCP configuration file.

5) Finally the data are averaged into depth bins (pbins) specified by the user (eg 16m) and can be compared to the absolute velocity profiles derived from the GPS data.

e. COMPARISON OF SHIPBOARD AND LOWERED ADCP MEASUREMENTS

Introduction and Summary

In order to estimate the accuracy of full-depth profiles of horizontal velocity obtained from the Lowered Acoustic Doppler Current Profiler (LADCP), we undertook a number of comparisons of the LADCP measurements with shipboard ADCP measurements in the upper water column and with bottom-tracking estimates of the flow in the bottom 200 m of water column during *Discovery* cruise 230. For comparisons in the upper water column at 31 stations, ADCP and LADCP velocity profiles exhibit generally similar structure so the difference at each station is estimated as an offset plus a standard deviation about the offset between ADCP and LADCP east or north velocities. The average absolute offset in east or north velocities is approximately 2.4 cm s^{-1}, while the average standard deviation for the vertical variability in structures is approximately 1.7 cm s^{-1}. For the bottom layer comparisons, the vertical structures of the LADCP and Bottom Track velocity profiles are very similar, as might be expected since the baroclinic structure is measured by the same instrument. More importantly, the Bottom Track currents show reasonable agreement with the absolute currents near the bottom as estimated by combining baroclinic LADCP velocity profiles with ship movement during station. For four stations in the deep western boundary current off Greenland where the bottom currents exceed 10 cm s^{-1}, the absolute velocity components for the two methods agreed within about 2 cm s^{-1}. Such agreement should help put estimates of the transport of the deep boundary current on a firmer foundation.

As discussed above, the LADCP measurements are initially processed as shear profiles and then vertically integrated to provide baroclinic profiles of east and north velocities. Baroclinic profiles are here defined to have zero depth-averaged values. The depth-averaged velocity components are then obtained by combining the movement of the ship during station as determined from GPS navigation with the time series of absolute velocities measured by the LADCP. A natural question arises as to the accuracy of the resulting absolute LADCP velocity profiles.

We have tried to answer this question of accuracy in two ways. First, we compare the LADCP velocities in the upper water column with the station-averaged ADCP velocities measured with the shipboard system. Secondly, we compare the estimates of absolute velocities from the LADCP with bottom-tracking estimates of the near-bottom flow. We also have plans to pursue a third approach to compare the overall LADCP velocity structure with geostrophic estimates of the baroclinic shear from simultaneous CTD casts, but this approach was not undertaken during *Discovery* 230.

Upper Ocean Comparisons

The ADCP measurements, as discussed in Section 5, were initially acquired as time averages over two minutes. For a typical CTD station lasting 2.5 hours, there are approximately 75 vertical profiles of velocity through the upper water column down to about 400 m depth by the shipboard ADCP system. In the on-station ADCP velocity profiles, there is inherent variability with a typical magnitude of 10 cm s^{-1} due to noise in ship's position which was estimated to be between 5m and 20m from time series of positions logged while Discovery was at the pier in Vigo and then Porto . An error of 10 m in ship's position translates into an error in velocity over two-minutes of 12 cm s^{-1}. Because the individual two-minute ADCP profiles penetrate to different depths, time-averaged velocities at each depth were considered to be of reasonable quality when at least 10 two-minute averaged velocities were available during the period of the station. For such averages, the navigation-induced error in the ADCP velocities should be less than 2 cm s^{-1}. An overall average velocity profile was estimated for the ADCP east and north velocities measured during each of 31 stations.

During a station the LADCP transits through the upper 400 m of the water column on the downcast over approximately 20 minutes and again on the upcast over about 20 minutes. We display the downcast and upcast profiles in addition to the average profile to indicate the variability in the LADCP currents. It is the average of the up and down LADCP profiles that is compared quantitatively to the shipboard ADCP profile for each station (Figure 3.1).

For comparisons at 31 stations, the shipboard ADCP and LADCP velocity profiles exhibit broadly similar vertical structure but with a varying mean offset. In order to quantify the agreement then, we estimate the mean difference between the shipboard ADCP and LADCP profiles and the standard deviation about the mean difference for each profile of east or north velocity on each station (Table 3.1). The average difference over all 31 stations is less than 1 cm s^{-1} indicating that there is no substantial bias between the ADCP and LADCP velocities. The similarity in vertical structure is apparent from the standard deviations about the mean difference for each station which are only 1.58 cm s^{-1} for east velocity and 1.81 cm s^{-1} for north velocity and there are only 3 instances where the standard deviation exceeds 3 cm s^{-1} . The overall measure of agreement which we prefer is the average absolute difference between the shipboard ADCP and LADCP velocities. For east and north velocities, the average absolute differences are 2.33 cm s^{-1} and 2.45 cm s^{-1} respectively. In summary, the absolute LADCP velocities exhibit similar vertical structure to the shipboard ADCP velocities and the mean offset between the LADCP and ADCP velocities measured on station is 2.4 cm s^{-1}.

Bottom Boundary Comparisons

For most of the LADCP profiles during Discovery 230, the instrument was set up to make alternate bottom-tracking pings as the instrument approaches the ocean bottom. Such bottom-tracking provides direct estimates of the movement of the instrument which can then be added to the velocity profiles relative to the instrument to create absolute velocity profiles for the water column within about 200 m of the bottom. Such absolute bottom velocities are effectively independent of the bottom velocities estimated in the overall absolute profiles because any problems in measuring velocity through the water column will not influence the Bottom Track velocities but will cause errors in bottom currents in the absolute profiles.

We compare absolute LADCP bottom velocities with Bottom Track velocities at 4 stations in the deep western boundary current off Greenland where the deep velocities are larger than 10 cm s^{-1}. For each of these stations, the scatter in Bottom Track velocity and the mean Bottom Track velocity profile are compared to the absolute LADCP over the bottom 200 m (Figure 3.2). Again we estimate a mean offset and a standard deviation about the offset between the absolute LADCP velocity and Bottom Track velocity (Table 3.2). The scatter in Bottom Track velocities surprised us. In general, the vertical structure of the average profiles is very similar, which should not be surprising because the baroclinic profile effectively represents the same measurements for each. The offset, however, is an independent quantity as discussed above. For these 4 stations in strong bottom currents, the offset varies from 0.04 to 4.14 cm s^{-1} with an average absolute offset of 2.5 cm s^{-1}. The perceptive reader might have noticed that in 7 out of 8 cases, the offset suggested by these bottom comparisons has the same sign as that suggested by the surface comparisons.

Conclusion

Based on comparison of absolute LADCP velocities with on-station shipboard ADCP velocities in the upper water column and with Bottom Track velocities in the bottom 200 m of the water column, we conclude that the present accuracy of absolute LADCP velocities is approximately 2.5 cm s^{-1}. Additional Bottom Track comparisons are needed to determine if the absolute LADCP velocities can be improved by consideration of the combined offsets for the independent surface and bottom comparisons.

Penny Holliday, John Smithers, Harry Bryden and Bob Marsh

Table 3.1: Upper ocean differences between ADCP and LADCP currents (cm s^{-1}).

Station	uADCP-uLADCP mean	std dev	vADCP-vLADCP mean	std dev
30	-1.36	2.14	-4.22	1.90
31	0.96	1.36	-0.35	2.62
32	-3.05	1.69	0.44	0.90
33	-4.28	0.98	-4.10	2.07
34	3.32	2.77	0.63	2.91
35	-2.98	1.94	0.03	2.09
36	1.64	1.25	1.51	0.76
37	-1.00	1.19	1.14	1.91
38	3.36	1.57	7.51	1.51
39	-4.42	0.62	-3.04	1.60
40	-0.85	2.14	2.46	2.52
41	-0.36	1.87	-1.00	1.60
56	-4.52	1.42	-0.65	1.91
57	-1.21	2.32	4.67	3.76
60	-1.18	1.43	0.61	1.16
80	3.64	0.96	-2.38	0.90
81	1.71	1.15	0.76	0.64
82	2.77	1.22	-4.25	1.25
83	4.12	1.23	-0.41	1.50
84	2.65	0.86	-1.66	1.69
85	5.47	1.16	-5.92	0.84
86	-2.15	1.34	0.23	1.08
87	0.97	1.10	1.10	1.15
88	1.29	1.25	-1.48	1.84
89	-0.82	2.52	-2.12	1.35
94	0.42	0.97	-1.54	0.71
95	1.62	0.68	3.51	0.60
96	5.12	0.71	-1.45	1.98
97	3.47	1.38	-5.10	1.59
98	0.70	5.28	1.04	2.91
99	4.63	2.39	6.97	6.86
Average	0.63	1.58	-0.23	1.81
Average Absolute Difference	2.33		2.45	

Table 3.2: Comparison of Absolute LADCP and BottomTrack Velocities in Strong Currents off Greenland

Station	uBT	vBT	uBT-uLADCP Mean	Std Dev	vBT-vLADCP Mean	Std Dev
84	13.62	-15.57	1.10	0.90	-1.47	1.89
94	-12.09	4.09	3.68	1.48	4.14	0.98
95	-14.91	10.40	0.65	0.85	2.80	0.92
96	-2.57	12.57	0.04	1.19	2.27	1.22

Average Absolute Difference 2.0 cm s^{-1}

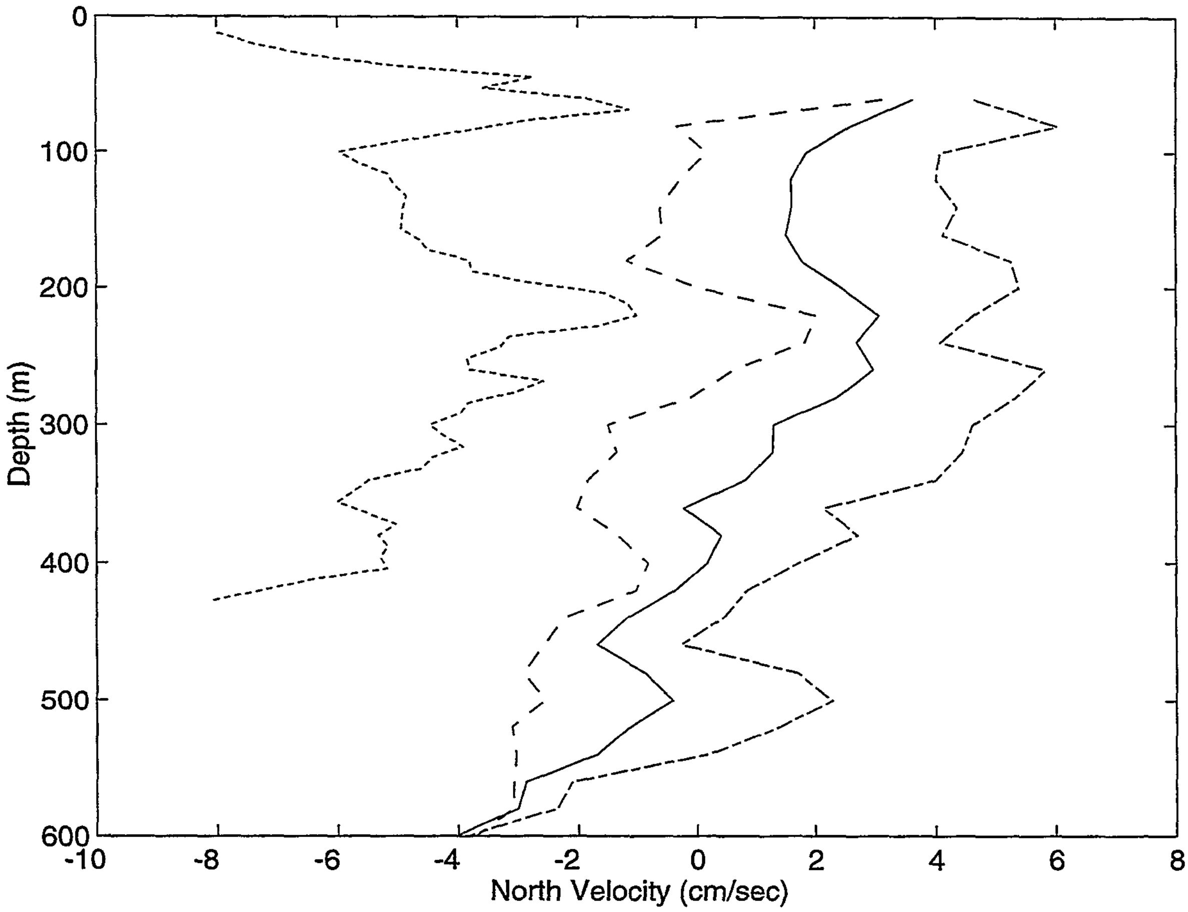

Figure 3.1: VM– and L–ADCP profile comparisons for station 85;
VM–ADCP: short dash; L–ADCP: down (chain), up (long dash), mean (solid).

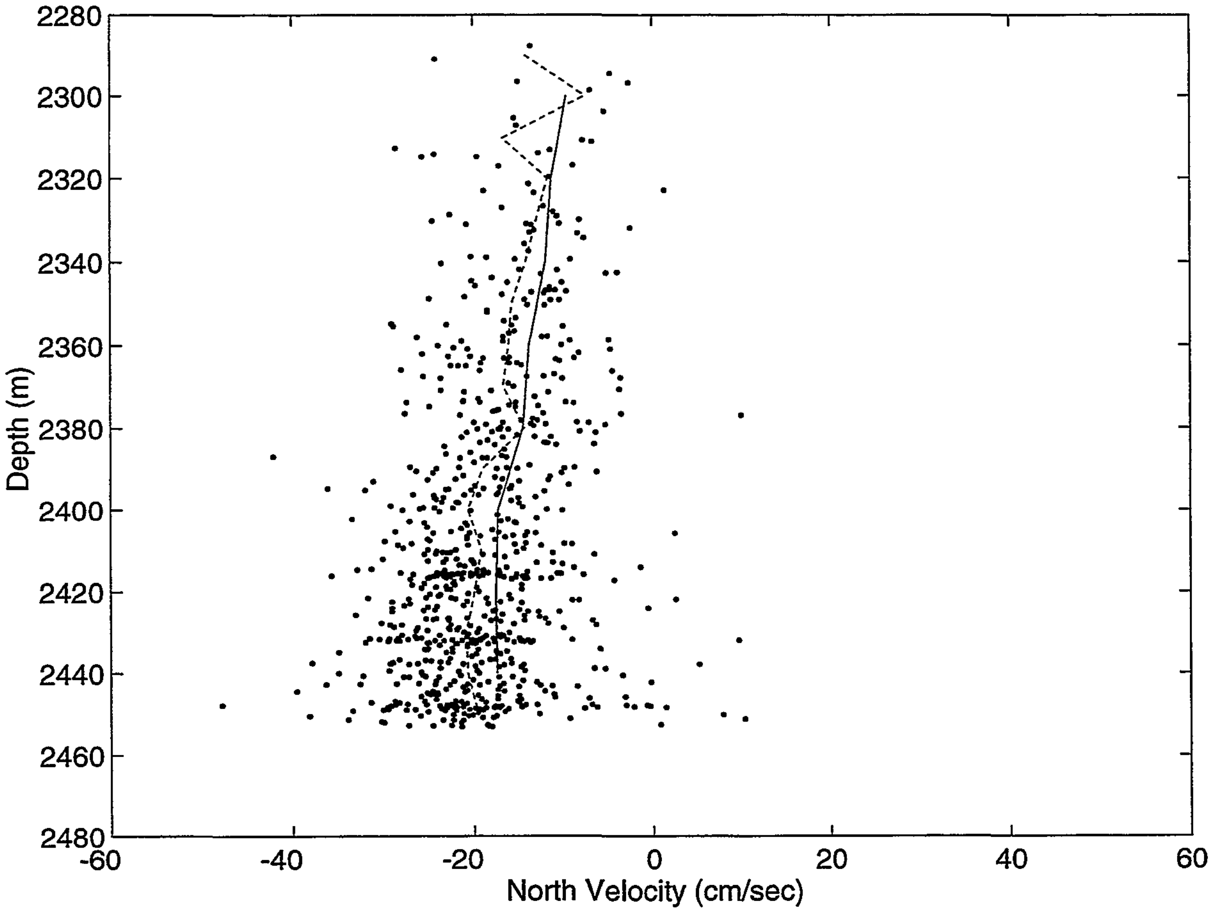

Figure 3.2: LADCP water track / bottom track comparison: station 85 bottom track velocity scatter plot with 10 m bin average (dashed line) and water track velocity (solid line).

4. NAVIGATION

a. BESTNAV

A standard PSTAR navigation file was maintained throughout the cruise. This was appended daily with the RVS "bestnav" position data at 30 second intervals.

Daily processing:
Level 0 acquisition of RVS 'bestnav' navigation data from level A.

b. GPS AND GLONASS

An Ashtech GG24 GPS-GLONASS receiver configuration (incorporating a Trimble-4000 receiver) enabled the acquisition of navigation data (ship position, heading, speed over ground, satellite fix parameters) from more than one source. Data were acquired every second from the GPS satellite constellation, and also from the more accurate "mix" of GPS (US, dithered) and GLONASS (Russian, undithered) constellations, dubbed "Glos".

Daily processing:
Step 1: Level 0 acquisition of GPS navigation data (both GPS-4000 and Glos mix);
Step 2: Level 1 quality control of Glos data: data is deleted wherever poor positioning accuracy is indicated by satellite fix parameters:
$0 > PDOP > 10$
$0 > TDOP > 4$
$0 > VDOP > 4$
$0 > HDOP > 4$
Step 3: Determination of ship velocity and 2-minute averaging. The east and north components of ship velocity over ground were plotted daily to reveal any gaps in the GPS and Glos, and to indicate the timing and nature of ship manoeuvring (a subsequent aid in the manual editting of ADCP absolute velocity datasets, to eliminate spurious currents arising from ship turns, and to separate on station and underway profiles)

Uncertainties in Ship's Position and Velocity due to Navigation

While *Discovery* was at the pier in Vigo, positions were monitored using both GPS and Glos positioning systems. The standard deviation in 2068 10-second GPS positions was about 20 m in east and north components while the standard deviation in Glos positions was about 10 m (see table 4.1). Because the navigation is primarily used in the ADCP processing for determining ship's velocity over two-minute averages, 2 minute differences in ship's position at the pier were also estimated. For the GPS positioning, the two-minute differences had a standard deviation of 25.2 m in north and 17.6 m in east components. Such standard deviations would lead to uncertainties in ship's velocity over two-minutes of 21.0 cm s^{-1} in north velocity and 14.6 cm s^{-1}

in east velocity. The standard deviations of two-minute differences in Glos position were only 5.3 m in north and 5.0 m in east components. Such standard deviations would lead to uncertainties in ship's velocity over two-minutes of only 4.4 cm s^{-1} in north and 4.2 cm s^{-1} in east velocities. An opportunity also arose to monitor positions in Porto for 2.5 hours while *Discovery* was at the pier. The standard deviations in position were similar to those in Vigo, 20 m for the GPS positions but only 6 m for Glos. Because the Vigo record is longer, we use the Vigo position uncertainties as a measure of the uncertainties in ADCP velocities due to navigational uncertainties during *Discovery* Cruise 230.

Underway changes in GPS acquisition

We had to alternate between relatively noisy ship positioning, determined from the dithered GPS satellite constellation, and the more accurate Glos positioning [having accidentally chosen to switch from GPS/GLONASS mix to pure GLONASS from 1200 on day 226 to 1800 on day 232]

c. SHIP GYROCOMPASS

Two S.G.Brown gyrocompass units are installed on the bridge. Ship heading was logged every second via a level A microprocessor.

Daily processing:
Step 1: Level 0 acquisition of gyro heading data (logged every second) from level A.

d. ASHTECH 3DF GPS ATTITUDE DETERMINATION

The Ashtech 3DF GPS is a system of 4 satellite-receiving antennae mounted on the foredeck and bridge roof of the ship, and a receiver unit in the bridge house. Every second the Ashtech measures ship attitude (heading, pitch and roll) accurately, and this data is used in a post-processing mode to correct ADCP current measurements for 'heading error' (as the ADCP uses the less accurate but definitely continuous ship gyro headings to resolve east and north components of current). Accompanying each attitude are measures of maximum measurement rms error (mrms), and maximum baseline rms error (brms).

To set up the Ashtech, the following 'best' parameter values were set using menu 4 on the receiver unit:

in the ATTD SETTINGS sub-menu:

max mrms	0.007m	filter	N
max brms	0.060m	max angle	10 deg.

one sec sampling enabled

in the ATTD CONTROL sub-menu:
max cycle 0.20 cyc
Kalman filter reset N

Note however that setting the latter Y enabled acquisition of the first successful attitude data on the evening of day 223.

Daily Processing:

Step 1: Level 0 acquisition of Ashtech data (heading, pitch, roll, mrms, brms, logged every second) from level A;

Step 2: Level 1 merging of gyro and Ashtech data;

Step 3: Level 2 basic quality control of Ashtech data, averaging over 2-minute periods, and determination of heading error, 'a-ghdg' (correction applied to gyro data as determined from Ashtech-to-gyro comparison):

Step 4: Plotting the daily time series of gyro heading, a-ghdg, plus pitch, roll and mrms statistics, to enable inspection for remaining outliers and further editing, and linear interpolation of the tidied-up a-ghdg time series

The performance of the instrument throughout the cruise was not without problems. Unfortunately the Ashtech can be rather temperamental. It must maintain good satellite fixes to continue logging. Once fixes are lost for too many minutes, logging is interrupted, and it is necessary to switch off and on the receiving unit, and to reset the parameters (which re-assume undesired default values). S everal specific problems arose in the course of the cruise.

Problem 1: On sailing the instrument proved to be badly parameterized. On day 224, after five days, having determined appropriate parameters, we finally started to acquire accurate ship attitude data.

Problem 2: Logging stopped at 0300 on day 226, and this was not noticed until 0330 on day 227. It was necessary to switch the receiver off, clearing the internal memory, and resetting the appropriate parameters.Thereafter the instrument was carefully monitored, and performed at an acceptable level over the following 10 days.

Problem 3: There was a sudden failure to determine attitude after 1141 on day 237 (although position continued to be accurately fixed thereafter), discovered upon daily processing of Ashtech data on day 238 (watch checks only confirmed that Ashtech data was being logged). Initial efforts to solve the problem focussed on rebooting the receiver and resetting parameters, but to no avail. On day 239 it was noted that only three of the four antennae were locking to four satellites (the minimum number of satellites required to compute attitude, but only if locked-onto by all four antennae), raising suspisions that the fault lay with the hardware, specifically an antenna or cable connection. Sequential connection and disconnection, from the receiver, of the four antennae cables confirmed that no information was available from antenna 4. On day 240 the problem was finally traced to a faulty amplifier (which serves to improve signal-to-noise ratio) on the cable to antenna 4 (situated starboard on the boat deck). Salt deposits inside and outside the amplifier casing suggested seawater ingress, and tests revealed that the 9V signal from the antenna was being drawn off by the amplifier, reducing it to 5V. With no replacement amplifier available on board, the amplifier was removed and the cable re-terminated. After this renovation the Ashtech successfully continued to compute attitude from 1803 on day 240, having failed, on this occassion, for a total duration 3 days 6 hours 22 minutes.

Problem 4: During days 244 and 245, the Ashtech software hung on three separate occasions, and it was necessary to switch on and off, and, on the second occassion, to clear both the receiver internal memory and the data memory. These problems were accompanied by overheating of the receiver unit, which is in direct sunlight, persuading us to construct and fit a makeshift heat shield. However, the problems also coincided with strong variations in the Earth's electromagnetic fields (evidenced at night by the Aurora Borealis), which possibly interfered sporadically with satellite signals.

Overall the instrument performed acceptably, although considerable effort was necessary to maintain attitude determination. Performance (on days when the Ashtech logged continuously) are quantified in Table 4.2.

Where we failed to obtain good Ashtech heading data for more than an hour or so (as throughout, or for part of, days 220-223, 226, 236-240, 245 and 246), the heading error, a-ghdg, was estimated from gyro heading. In order to make this estimation, we derived a quadratic relationship between a-ghdg and gyro heading, asymmetric about true north, using a scatterplot of a-ghdg against heading data (in the manner of King and Cooper, 1993). Working fits were determined twice during the cruise, the first fit being based on a-ghdg data collected along 41.5°N (to estimate a-ghdg over days 220-223 and 226), the second fit being based on all data collected upto day 236 (to estimate a-ghdg over days 236-240, 245 and 246). The entire cruise dataset will be subsequently used to derive a comprehensive relationship between a-ghdg and heading, possibly accounting also for latitudinal variations of gyro error.

Bob Marsh

Table 4.1: Ship navigation error determined in port.

	Vigo		Porto	
	GPS	Glos	GPS	Glos
sd lat (m)	24.7	9.7	19.4	22.9
sd lon (m)	17.0	11.8	8.3	4.2
sd 2minydif (m)	25.2	5.3		
sd 2minxdif (m)	17.6	5.0		
yvelerror (cm s^{-1})	21.0	4.4		
xvelerror (cm s^{-1})	14.6	4.2		

Table 4.2: Summary of Ashtech performance statistics.

Julian Day Number	Number of bad 2-min. averaged headings	Daily %GOOD
224	256	61.0
225	281	64.4
228	278	61.4
229	174	75.8
230	237	67.1
231	311	56.8
232	128	82.2
233	211	70.7
234	228	68.3
235	216	70.0
241	163	77.4
242	220	69.4
243	200	72.2
244	319	55.7
247	131	81.8
248	160	77.8
249	69	90.4
250	259	64.0
251	444	38.3
252	188	73.9
253	214	70.3
254	173	76.0
255	134	81.4
256	166	76.9
257	245	66.0

5. VM–ADCP MEASUREMENTS

a. DESCRIPTION AND PROCESSING

The instrument used was an RDI 150 kHz unit, hull-mounted approximately 2 m to port of the keel of the ship and approximately 33m aft of the bow at the waterline. On this cruise the firmware version was 17.10 and the data acquisition software was 2.48. With the exception of a few interruptions (see Problems below), the instrument was operated continuously from day 219 (on leaving Vigo) to day 258 (after setting course for Southampton). For most of this time the ADCP was used in the water tracking mode, recording 2 minute averaged data in 64 x 8m bins from 8 m to 512 m water depth. On the continental shelves off Iberia, Greenland and Iceland (in water shallower than 500m), the instrument was switched to a combined water and bottom tracking mode, maintaining 64 x 8m bins. While in bottom-tracking mode, a FH-command (setting the number of water-track pings between bottom-track pings) of FH00001 was entered in the "Direct Control" menu - ensuring one water-track ping per bottom-track ping. The ADCP was otherwise operated with a default configuration.

Daily processing:

Step 1: Level 0 acquisition of ADCP water tracking and bottom tracking velocities from level A, and conversion to level C PSTAR format.

Step 2: Level 1 correction of the times of ADCP velocity profiles, taking account of an approximate -1 second per hour PC clock drift.

Step 3: Level 2 correction of the east and north components of ADCP velocities, accounting for the gyro heading error (determined as the difference between Ashtech and gyro headings).

Step 4: Level 3 calibration of the shear profiles, taking account of errors in signal amplitude and transducer alignment, using a working calibration based on bottom tracking into/out of Porto (later confirmed as sufficiently accurate by more extensive bottom-tracking off Greenland and Iceland).

Step 5: Level 4 merging of profiled velocities of water (relative to ship) with ship velocity determined from GPS [2 versions, depending on whether we had GPS-4000 or a GPS-Glonass mix]

Step 6: Manual editting to remove spurious currents implied by sudden changes in ship velocity (e.g. coming on/off station), or short gaps in navigation data.

Occassional processing:

Editing of daily absolute velocity files to create on station and underway files, to compare with LADCP mesurements and CTD-derived geostrophic calculations respectively.

Daily plotting:

1 plotted contoured "percent good" (PCG) over 0-500m, to determine quality of profiling (PCG > 25% is necessary to accept data for processing).

2 plotted 2-minute averaged currents, filtered with filter of width 10 minutes, in top 200m, to make first inspection of the raw absolute current data, especially useful for identifying problems with underway (steaming) data.

3 averaged data in bins 13-24, to determine 104-200m average current, averaged this over 10 minutes, and applied top-hat filter of width 50 minutes, and plot against latitude and longitude (as did Saunders and King, 1995), to identify features of the circulation.

4 where appropriate (e.g. across acoustic sections, wherever strong features were observed), resolved the east and north components of raw absolute current to along- and cross-track components, plotted contoured cross-track profiles.

b. CALIBRATING THE ADCP

The ADCP is routinely calibrated to take account of the orientation of the transducer on the hull (a misalignment angle - on *RRSDiscovery* the transducer orientation is intended to be fore-aft, pointing in the direction of steaming). Calibration exercises are undertaken to determine an amplitude factor A and the alignment angle error ϕ. On this cruise we used heading-corrected bottom tracking data to determine 2-3 hour averages of ship velocity (and hence speed over ground and heading), compared with GPS-derived ship velocity. The choice of 2-3 hour averaging periods is mindful of the noise in GPS-derived ship velocity. Details of when and where we switched from water tracking to bottom tracking are as follows:

1 steaming in/out of Porto (to change the LADCP) on day 225;

2 on the Greenland shelf between station 102 (at the coastward termination of the second East Greenland Current section) and station 103 (commencing the Denmark Straits section) on day 248;

3 on the Icelandic shelf, approaching station 111 (commencing the 20°W section) on day 252.

The Greenland shelf bottom tracking was quality controlled and split into six approx. 2.5 h duration segments. The bottom tracking south of Iceland was likewise quality controlled and split into two approx. 3 h segments. Details of the quality control are as follows. Bottom tracking data were not used wherever:

(a) depth exceeded 500 m;

(b) GPS-derived ship heading changed by more than 10° between 2-minute ensembles

(c) GPS-derived ship speed changed by more than 10 cm s^{-1} between ensembles.

The results of the calibration exercises are shown in Table 5.1.

Differences between estimates of A and ϕ and sizeable standard deviations are possibly due to noise in the heading correction. However, note that A and ϕ have changed very little since *Discovery* cruise 223 (for which A = 1.0054 and ϕ = 3.57; see Leach and Pollard, 1998). We also used bottom tracking data to confirm that the Ashtech minus gyro heading correction was correctly determined.

c. ADCP PERFORMANCE

The typical %good on/off station indicated depth penetration, along the 41.5°N line, of 300 m and 200 m respectively. The ADCP suffered complete deterioration of depth penetration on day 236, steaming into heavy seas, and occassionally thereafter, notably in transit between the Cape Farewell acoustic section and the East Greenland Central Section. When sea conditions were favourable, depth penetration improved markedly with latitude, to over 500 m during the Cape Farewell acoustic section, implying better back-scatter at higher latitude.

Problems encountered:

1. On three occasions the level A logging failed, and was restarted by RVS:
   (i) at 0800 on day 239 for 3 hours;
   (ii) at 0125 on day 245 for 1 hour 45 minutes (at the end of Cape Farewell acoustic section);
   (iii) at 1150 on day 245 for 3 hours 45 minutes.
   On these occassions ADCP data was later retrieved from the appropriate PINGDATA files, which are saved (one every 9 hours 16 minutes) on the PC.
2. A hardware failure at around 1800 on day 254, indicated on the PC by errors in all 4 acoustic beams and VERY WEAK TRANSMITTED SIGNAL error message. This was fixed by Dave Jolly of RVS, by reseating the boards in the VM chassis, and profiling resumed at around 1500 on day 255. On this occassion ADCP data was irretrievably lost.
3. On three occasions the PC was found to have hung and needed a reset:
   (i) at 2335 on day 239 for 25 minutes;
   (ii) at 1252 on day 255, for 4 hours;
   (iii) at 1048 on day 257, for 22 minutes.
   On these occasions ADCP data was irretrievably lost.

d. GENERAL DESCRIPTION OF OBSERVED CURRENTS

After completion of test CTD station 1 on day 220, the ship steamed eastward at 5 kn over the ground along 41.5°N, from 12.5°W to 9°W, in an acoustic survey of the eastern boundary. A northward coastal current of up to 30 cm s^{-1} was observed between 9°W and 10°W. Apart from the northward coastal current, we measured generally weak, although highly variable, currents along the 41.5°N line. On turning to follow a northwest heading at 20°W, currents strengthened, and underway profiling indicated a cyclonic feature, about 100 km across, centred on 26°W, 47°N, with northward currents, followed by southward currents, of up to 40 cm s^{-1} (associated with temperature and salinity anomalies of –0.5 °C and –1.3 psu). We then encountered a southeastward flow of up to 60 cm s^{-1} between 28.5°W, 49°N and 29.5°W, 50°N, presumed to be a southern branch of the North Atlantic Current (NAC). The main branch of the NAC was observed as a northeastward flow of up to 70 cm s^{-1}, between 30.9°W, 51°N and 31.5°W, 51.5°N. A northeastward flow of up to 25 cm s^{-1} was encountered between 32°W, 52°N and 33°W, 53°N, in the vicinity of the Charlie Gibbs Fracture Zone. We thereafter observed strong mesoscale variability in currents across the Irminger Sea, before reaching the East Greenland Current (EGC). The EGC exhibited southwestward flow of up to 60 cm s^{-1} between 41°W, 58.25°N and 43.5°W, 59.75°N, in the approach to Cape Farewell, and was very successfully resampled in a subsequent acoustic section back to 40.5°W 58°N. Weaker currents of up to 35 cm s^{-1} were observed on the following EGC transect, between 39°W, 62.5°N and 40.5°W, 63°N. Further strong southwestward flow was measured in transit bewteen that transect and occupation of the Denmark Strait section. On commencement of the Denmark Strait section (30-31°W, 65-65.5°N), strong (> 80 cm s^{-1}) northwestward currents were observed. Across the majority of the Strait we observed moderately strong (20-30 cm s^{-1}) northward surface flow, with the exception of strong southward flow centred on 29°W, 65°N (also measured by LADCP). Unfortunately the ADCP hardware failure on days 254-255 coincided with the second transit across the NAC (observed on station 121 with the LADCP at 60°N, 20°W). Near-surface currents of up to 30 cm s^{-1} were observed across the Rockall Trough, with northward and southward flows respectively on the west and east sides of the Anton Dohrn Seamount. Strong eastward currents (up to 70 cm s^{-1}) were observed at, and between, the final two CTD stations on the Hebridean shelf, possibly evidence for the coastal current.

ADCP current measurements along 4X were generally excellent, with very few gaps due to heavy seas, and no soft- or hardware related loss of data. Apart from problems with instrument reliability, good quality ADCP current measurements along the 20°W/Ellett section were frequently interrputed by heavy seas, and the profiling along this section was generally less successful than along the 4X section.

Bob Marsh

Reference

Leach, H. and R. T. Pollard, 1998: Discovery Cruise 230. Cruise Report, in preparation.

Table 5.1: ADCP calibration exercise results. A is amplitude scaling factor, ϕ is heading correction in degrees to starboard.

Calibration exercise	A	sd	ϕ	sd
Porto port call				
incoming	1.0032		3.503	
outgoing	0.9998		3.418	
all data	1.0012		3.454	
Off Greenland				
segment 1	0.9959	0.0122	3.414	0.591
segment 2	1.0004	0.0078	3.393	0.568
segment 3	1.0002	0.0091	3.424	0.624
segment 4	1.0003	0.0065	3.400	0.275
segment 5	1.0008	0.0080	3.487	0.455
segment 6	1.0008	0.0080	3.372	0.548
all data (15h)	0.9997	0.0086	3.415	0.522
South of Iceland				
segment 1	1.0025	0.0095	3.333	0.548
segment 2	1.0018	0.0098	3.408	0.466
all data (6h)	1.0021	0.0097	3.370	0.509

6. METEOROLOGICAL MEASUREMENTS

a. SURFACE METEOROLOGY

Aims

The aims of the surface meteorological measurements during cruise D230 included:

i Continuous measurement of mean meteorological variables such as air and sea temperatures, wind speed and wind direction, downwards radiation (long wave, short wave and photosyntheticaly active) and atmospheric pressure.

ii Determination of the momentum transfer (wind stress) and heat fluxes between the ocean and atmosphere.

All the instruments and logging systems functioned well throughout the cruise, and a high quality data set was obtained.

Sensors deployed

(a) Mean Meteorology

The GrhoMet meteorological instrumentation system uses the RVS Rhopoint network for connection to foremast, hull and laboratory sensors. In addition to the normal RVS instrument suite, further JRD/OTD sensors were mounted on the foremast and connected into the logging system. A total of 18 variables were logged (Table 6.1). These measured air temperature, air pressure, wind speed, wind direction, downward longwave, shortwave, and photosynthetically active radiation (PAR). The system acquired data at 5 second sampling rate and generated data files in raw and calibrated format which were written to the hard disk of a PC in the main lab. The GrhoMet system also output raw (uncalibrated) data via an RS232 link to the level B in SMP format, where the data was logged by the RVS computer system. The scientific clock was read through a serial port and used to update the PC clock once every 6 hours when a new data file was opened.

(b) Wind stress

A Gill Instruments Solent Sonic Anemometer (R2 Asymmetric Model, serial number 38) was mounted on the starboard side of the foremast platform. The anemometer was operated in Mode 1 and the 21 Hz sampled data were logged using a PC system situated in the main lab. This recorded the raw data stream on optical disk and also calculated and recorded wind speed spectra and spectral levels. These were based on about 12 minutes sampling period (n=1024*15) starting each quarter hour.

Sensor Performance

(a) Air temperature and Humidity

Four sensors provided dry bulb air temperature data: two psychrometers, the RVS air temperature sensor, and the temperature signal from the RVS humidity sensor. The air temperature from the humidity sensor was low by almost 1 degree compared to the data from the other three sensors. It was thought from previous cruise comparisons that the two psychrometers may over-estimate the dry bulb temperature by up to 0.15°C when the downward solar radiation is in excess of a few hundred W/m^2. However, examination of night-time data showed that the RVS air temperature sensor may read low by a similar amount for air temperatures of 15°C or more. Accurate calibration of the RVS sensor is required before the true cause of any trends can be determined. When extremes of temperature or large downwards solar radiation were absent, the two psychrometers and the RVS sensor agreed well: for downwards longwave radiation of less than 100W/m^2 and temperatures between 6 and 13°C, the mean difference was 0.03 ± 0.12°C or better. The starboard psychrometer dry bulb readings also exhibited an intermittent cold bias, probably due to dripping from the wet bulb wick. This problem occurred mainly during the first two weeks of the cruise. The mean difference between the wet bulb temperature values from the two psychrometers was negligible (-0.03 ± 0.05°C).

The humidity estimates from the two psychrometers were in very good agreement, with a mean differences of 0.0 ± 1.0%. The RVS humidity sensor compared well with the psychrometers: in this case the mean difference was 2.0 ± 1.5%.

(b) Radiative fluxes

Examination of night-time data showed that the starboard solarimeter read high by about 5 W/m^2. The port solarimeter showed a negligible bias. As observed on previous cruises, these instruments were sometimes shaded by the foremast extension and other instruments mounted nearby. Selecting the highest reading from the two instruments is recommended, but is not a complete solution since the two sensors were sometimes shaded simultaneously.

The port PAR sensor underestimated by 2.5 W/m2, and the starboard overestimated by 1.2 W/m^2 (again, night time data only). Use of data from the starboard sensor is recommended since it exhibited less scatter.

The comparison between the two longwave sensors showed an underestimate from LW2 of 5 W/m^2 for the higher values of downward longwave radiation, and 10 W/m^2 for the lower, clear sky values. From past instrument comparisons, LW1 is believed to be the more accurate sensor.

(c) Wind velocity and wind stress

Twelve minute averages of the mean relative wind speeds from the R.M. Young propeller-vane and the Solent Sonic anemometer were compared. For the entire data set, the mean difference was -0.1 ± 0.7 m/s. However, after selecting data for periods when the wind was blowing within 30 degrees of the ship's bow (i.e. the anemometers were well exposed), the mean wind speed difference was -0.3 ± 0.5 m/s. The mean 10 minute average wind speed during the cruise was about 8m/s; the maximum 10 minute wind speed observed was about 21 m/s. The wind stress estimates obtained from the sonic anemometer corresponded to drag coefficient values similar to those found on previous cruises.

(d) Sea Surface temperature

The GrhoMet system logged sea surface temperature (sst) data from the hull contact sensor which is located in the forward hold at a depth of about 3.5 m. The data from the hull sensor were compared to those from the thermosalinograph (TSG) which sampled water from an intake located at a depth of about 5 m. The TSG sensor produced bad data when the ship was in Oporto (day 225.5 to 225.7) and again during day 221. The cause of the latter period of bad data is not known. Previous comparisons between the hull sensor and the TSG suggested that the hull sensor underestimated sst by 0.5°C. Although this offset was incorporated in the calibration of the data from the hull sensor, the end of cruise comparison between the TSG and hull sensor data showed a residual offset which varied with temperature. For temperatures above 11°C the hull sensor underestimated by 0.12 ± 0.06°C, and below 11°C the hull sensor underestimated by 0.26 ± 0.13°C.

b. SBWR

Measurement details

The MK IV version of the Ship borne Wave Recorder (SBWR), developed through a collaborative programme between Ocean Technology Division of SOC and W. S. Ocean Systems Ltd., has been installed on Discovery since cruise 224. The electronic control and processing unit of the MK III system has been replaced by a PC running an application developed using LabWindows CVI. This converts pressure and accelerometer signals into a wave height value which is periodically processed to produce a wave energy spectrum. The logging system outputs summary data, such as significant wave height (Hs), to the RVS level B. However, this data has not been corrected for instrument response. The spectral data were periodically downloaded from the PC hard disk, and corrected for instrument response before recalculating Hs. Figure 6.1 shows that the uncorrected data underestimates Hs by around 40% on average.

c. ACOUSTIC RAIN BUOY

An acoustic rain gauge buoy was made available (by G. Quartly of JRD and K. Birch of OTD) for deployment trials during the cruise. Two attempts were made to deploy the buoy while the ship was hove-to, on station, during days 235 and 239. These attempts were unsuccessful since the buoy only drifted a few tens of meters from the ship, rather than the required 500 m. In order for the buoy to stream away from the ship it was necessary for the deployment to take place while the ship was steaming at half or one knot. This method was tried successfully on days 246 and 249. Some practical problems were encountered during these deployments; the rope used was very thin (about 3 mm) which made recovery by hand a slow process; the hydrophone cable tended to kink and tangle (which could be prevented by use of a "fishing reel" arrangement); it was necessary for someone to be on deck to observe the behaviour of the buoy throughout the deployment.

Communication with the buoy is relatively straightforward but the supplied terminal software has to be used. Several attempts were made to adjust the data rates. It should be possible to set up the buoy to output data every 90 seconds with 7 subsamples in that period. This was achieved on the bench but data rates reverted to 1 sample every 90 seconds after a 20 minute period. Either the buoy software is not the same as was thought or the manual did not provide clear enough instructions to do this. An external communications port is necessary to make any changes without having to open the buoy up every time. Further time on the bench is required to fully understand all of the available options, otherwise the instrument was relatively easy to use and communicate with.

Table 6.1: Variables and sensors logged by the GrhoMet system. The variable names in the data files are shown [thus]. For each instrument (RVS) indicates that the sensor is part of the standard ship's system; (JRD/OTD) that the instrument was added for the cruise.

Variable	Position	Instrument	Note
Wet and Dry Bulb [psyptd psyptw]	St'b'd side of foremast platform (forward sensor)	Psychrometer IO2003 to day 229.7, IO1030 thereafter. (JRD/OTD)	(1)
Wet and Dry Bulb [psystd psystw]	St'b'd side of foremast platform (aft sensor)	Psychrometer IO2002 (JRD/OTD)	
Humidity & air temp. [hum humt]	Port side of foremast platform	Vaisala HMP 35D (RVS)	
Air temp [atemp]	St'b'd side of foremast platform	Vector Inst. 209 (RVS)	
Longwave [lw1]	Top of foremast (port sensor)	Eppley PIR 31170 (JRD/OTD)	
Longwave [lw2]	Top of foremast (starboard sensor)	Eppley PIR 31171 (JRD/OTD)	
ShortWave [ptir]	Gimbal mounted on port side of foremast platform	Kipp & Zonen CM6B 962301 (RVS)	
ShortWave [stir]	Gimbal mounted stbd side of foremast platform	Kipp & Zonen CM6B 962276 (RVS)	
Photosynthetically active radiation [ppar]	Gimbal mounted on port side of foremast platform	Didcot DRP-1 0151 (RVS)	
Photosynthetically active radiation [spar]	Stbd side of foremast platform (not gimballed)	Didcot DRP-1 5143 (RVS)	
Wind Speed & Direction [ws1 wd1]	Port side of foremast platform	RM Young AQ 11276 (RVS)	
SST [sst1]	Hull mounted approx. 5 meters depth.	PRT (RVS)	
Pressure [baro]	Lab	Vaisala DPA21 (RVS)	
Time	Lab	Ship's clock (RVS)	

Notes: (1) The fan on psychrometer began to fail on day 226, but the instrument could not be replaced until calm weather permitted on day 229.

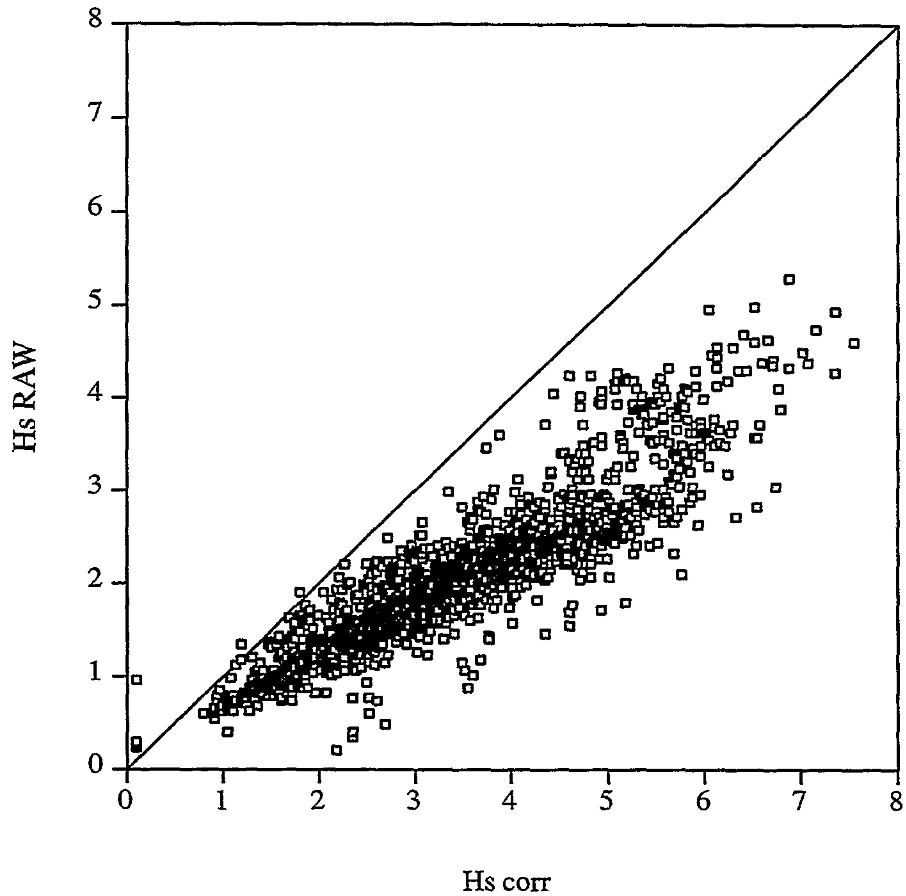

Figure 6.1: Comparison of Hs corrected (Hs corr) and Hs uncorrected (Hs raw)

7. CHEMICAL MEASUREMENTS

Samples for salinity, oxygen and nutrients were drawn from all bottles on all stations. A summary of the sampling regime for all other quantities described below is given in table 7.1, and again in the WOCE format station summary table, reproduced here as Appendix 1.

a. OXYGEN

Dissolved oxygen samples were drawn from each niskin bottle following the collection of samples for CFC analysis. Between one and four duplicate samples were taken on each cast, from the deepest bottles. The samples were drawn through short pieces of silicon tubing into clear, pre-calibrated, wide necked glass bottles and were fixed immediately on deck with manganese chloride and alkaline iodide dispensed using precise repeat Anachem bottle top dispensers. Thanks to Pete Mason for the construction of a reagent stand for use on deck. Samples were shaken on deck for approximately half a minute, and if any bubbles were detected in the samples at this point, a new sample was drawn. The samples were transferred to the constant temperature (CT) laboratory, and then shaken again thirty minutes after sampling and stored under water until analysis.

The temperature of the water in the Niskin bottles was measured using a hand held electronic thermometer probe. The temperature was used to calculate any temperature dependant changes in the sample bottle volumes.

Samples were analysed in the CT laboratory starting two hours after the collection of samples. The samples were acidified immediately prior to titration and stirred using a magnetic stir bar set at a constant spin. The Winkler whole bottle titration method with amperometric endpoint detection (Culberson, 1987) was used with equipment supplied by Metrohm. The spin on the stir bar was occasionally disturbed by the movement of the ship and also by the uneven bases on some of the glass bottles, leading to less effective stirring of the sample and thus longer titration times, although this probably did not effect the accuracy of the endpoint detection. The Anachem dispensers were washed out with deionised water, each time the reagents were topped up, to avoid any problems caused by the corrosive nature of the reagents.

The normality of the thiosulphate titrant was checked against an in house potassium iodate standard of 0.01 N at 20°C at the beginning of each analytical run and incorporated into the calculations. A total of seven standards were used throughout the duration of the cruise. Blank measurements were also determined at the start of each run to account for the introduction of oxygen with the reagents and impurities in the manganese chloride, as described in the WOCE Manual of Operations and Methods (Culberson, 1991). Thiosulphate standardisation was carried out by adding the iodate after the other reagents and following on directly from the blank measurements in the same flask, as on the cruises D223 and D227. Changes in the thiosulphate normality are shown in figure 7.1. The thiosulphate normality precision was poor initially for the first reagent batch in use. The precision improved for the second batch, between stations 027 and 047, although the thiosulphate normality was low. From station 048 the thiosulphate normality results remained constant despite further changes in reagent batch. Tests were also carried out on each batch of alkaline iodide used during analysis, since some variability has occured on previous cruises when the iodide batch was changed.

Absolute duplicate differences for each station are shown in figure 7.2a for cruise D230, for a sample size of 499 pairs of duplicate measurements. Duplicate differences > 1.0 µmol/l accounted for 24.25% of these duplicate pairs and ignoring these high duplicate differences the mean (±SD) duplicate difference was 0.3899 (± 0.2566). The duplicate difference achieved was not related to the individual calibrated bottle (figure 7.2b) and high duplicate differences seemed to occur at random.

Problems

The diurnal temperature range of the CT laboratory often varied between 18 °C and 20 °C throughout the cruise. The temperature of the laboratory was noted for each analytical run.

On station 135 the Anachem dispenser used for the alkaline iodide broke, when the bottles fell over during rough weather. The dispenser was replaced and the new one used for the rest of the cruise.

References

Culberson, C. H. and S. Huang, 1987: Automated amperoteric oxygen titration. *Deep-Sea Res.* **34** 875-880.

Culberson, C. H., 1991: WOCE Operations Manual (WHP Operations and Methods). WHPO 91/1 Woods Hole. 15pp.

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b. NUTRIENTS

Sampling Procedures

Samples for the analysis of dissolved inorganic nutrients: dissolved silicon (also referred to as silicate and reported as SiO_3), nitrate and nitrite (referred to as nitrate or NO_2+NO_3) and phosphate (PO_4), were collected after the CO_2 samples had been taken. All samples were taken into 30 ml plastic "diluvial" sample cups which were washed 3 times with sample before filling. The samples were transferred immediately to a refrigerator where they were stored until analysis. Storage times on D230 varied between 4 hours and being analysed immediately after collection.

A total of 141 casts were sampled for nutrients during the cruise. Samples were transferred into individual 8ml sample cups, mounted onto the sampler turntable and analysed in sequence. The nutrient analyses were performed using the SOC Chemlab AAII type Auto-Analyser coupled to a Digital-Analysis Microstream data capture and reduction system. Each sample was analysed in duplicate to ensure accuracy and increase precision.

Calibration

The primary calibration standards for dissolved silicon, nitrate and phosphate were prepared from sodium hexaflurosilicate, potassium nitrate, and potassium dihydrogen phosphate, respectively. These salts were dried at 110 °C for 2 hours, cooled and stored in a dessicator then accurately weighed to 4 decimal places prior to the cruise. The exact weight was recorded aiming for a nominal weight of 0.960 g, 0.510 g and 0.681 g for dissolved silicon, nitrate and phosphate, respectively. When diluted using MQ water, in calibrated 500 ml glass (or polyethylene for silicate) volumetric flasks these produced 10 mmol/l standard stock solutions. These were stored in the refrigerator to reduce deterioration of the solutions. Only one standard stock solution was required for each nutrient for the duration of the cruise, checked daily against OSI standards as described later.

Mixed working standards were made up once per day in 100 ml calibrated polyethylene volumetric flasks in artificial seawater (@ 40g/l NaCl). The working standard concentrations, corrected for the weight of dried standard salt and calibrations of the 500ml and 100ml volumetric flasks are shown in Table 7.2.

A set of working standard solutions was run in duplicate on each analytical run to calibrate the analysis. From station 046 the top standard was also run in duplicate at the start of each analytical run as this was found to increase the linearity of the standardisation.

The nutrient calibration data (sensitivity, correlation coefficient, standard error and percentage drift) was recorded for each analytical run. There was an apparent increase in stability of the instrument the longer it was left switched on. This will be discussed further in a more detailed report (Holley, 1998).

Silicon

Dissolved silicon analysis followed the standard AAII molybdate-ascorbic acid method with the addition of a 37°C heating bath (Hydes, 1984). The colorimeter was fitted with a 50 mm flow cell (as the 15 mm cell detector caused problems when initially set up) and a 660 nm filter. The gain was adjusted to 2 for maximum response at 40 µmol/l.

Nitrate

Nitrate (and nitrite) analysis followed the standard AAII method using sulphanilamide and naphtylethylenediamine-dihydrochloride with a copperised-cadmium filled glass reduction column. A 15 mm flow cell and 540 nm filter was used with a gain setting of 3.5, adjusted for concentrations of up to 40 µmol/l. Nitrite standards equivalent in concentration to the second nitrate standard were prepared each day to test the efficiency of the column. The column was topped up only once prior to station 033.

On a previous cruise, D223, there were problems on the nitrate channel after the pump tubes had been replaced, with some fluid being sucked back up the waste tube through the flow cell. This occurred when the system was re-tubed on station 052 possibly due to an increase in pressure in the system. A fine dust of Cadmium in the reduction column had a similar effect, this was removed using a syringe filled with buffer. Whilst these problems did not directly affect the data they caused delays in the analysis. An alternative means of keeping the cadmium in the column will have to be found on future cruises.

Phosphate

For phosphate analysis the standard AAII method was used (Hydes, 1984) which follows the method of Murphy and Riley (1962). A 50 mm flowcell and 880 nm filter were used and the gain set to 9.5 throughout the cruise, measuring concentrations of 0 -2 µmol/l (the gain was inadvertently changed to 6.5 for stations 111-123 resulting in lower phosphate peaks). There was a large amount of noise on this channel despite a change of colorimeter prior to the cruise. This was thought to be due to the age of the photometer as it had become increasingly sensitive to changes in ambient light.

The phosphate channel is particularly sensitive to variations in salinity at the flow cell which results in a characteristic 'refractive index' peak shape. This was seen at the start of the cruise (stations 003 and 004), a clear distinct peak resulted which could be separated out by the software. Unfortunately the problem reoccurred from station 126 corresponding to a change in NaCl. Despite two more changes in NaCl batch the problem could not be resolved and this resulted in falsely high results. This problem will need to be addressed and may be resolved by an improvement in the software used. Accurate records of the weight and batch of NaCl used should minimise this problem on future cruises.

Reagents for each of the nutrients analysed were made up as and when required from pre-weighed salts. All measurements were made in the deck laboratory. The autoanalyser required periodic maintenance throughout the course of the cruise. The tubing on the peristaltic pump was fully replaced prior to stations 024, 052 and 115 with further periodic changes of individual tubes as necessary to maintain maximum sensitivity in the analysis. The autosampler unit randomly mis-sampled up to 3 samples per analytical run from stations 011 until it was fixed (thanks again to Pete Mason) prior to station 037. Other than the problems described above the analyser performed well with regular cleaning and maintenance.

Precision - Duplicate and quality control measurements

All samples were analysed in duplicate. The mean absolute differences between the duplicate measurements and standard deviations (for the first 100 stations) were: 0.106 (±0.130) µmol/l for dissolved silicon, 0.216 (±0.212) µmol/l for nitrate and 0.052 (±0.075) µmol/l for phosphate. This indicates a full scale precision of 0.27%, 0.72% and 2.6% respectively. Only duplicate measurements denoted with flag number 2 were used, therefore data that were reported as questionable at the time was not included in the above estimate.

Several quality control samples were also analysed on each run. Two quality control samples were made up from standard solutions supplied by OSI (prepared each day in plastic volumetric flasks using LNSW). New stocks were opened at station 050 and 107. The concentrations were adjusted to be equivalent to the 3rd and 4th working standard concentrations (so the QC material is referred to as QC3 and QC4 respectively). In addition a deep water sample was collected from ca. 3500 m on station 001. The deep water QC samples were decanted into clean rinsed plastic diluvial containers and stored in the cold store until required, using 1 per analytical run. Each QC sample was analysed in duplicate on every run, variations in the results are shown in Figure 7.3. Where there was a marked increase or decrease for all three QC materials a correction factor could be calculated and applied to the samples. This was necessary on the following occasions as shown in Table 7.3. Causes for these variations will be examined in Holley, 1998.

References

Holley, S. E., 1998: Report on the maintenance of precision and accuracy of measurements of dissolved inorganic nutrients and dissolved oxygen over 43 days of measurements on *Discovery* Cruise 230 'FOUREX' (07 Aug - 19 Sep 1997). SOC Internal Document No. 30, 34 pp.

Hydes, D. J., 1984: A manual of methods for the continuous flow determination of nutrients in seawater. IOSDL Report 177, 40pp.

Murphy, J. and J. P. Riley, 1954: A modified single solution method for the determination of phosphate in natural waters. *Anal. Chem. Acta*, **27** 31-66.

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c. CARBON

The carbon system is defined by four variables: pH, alkalinity, partial pressure of carbon dioxide (pCO_2) and total inorganic carbon (TIC). The knowledge of two of these variables allows to calculate the other two by means of a set of equations deduced from the thermodynamic equilibria. During the FOUREX cruise, pH was measured by potentiometric and spectrophotometric methods whilst alkalinity was measured by potentiotemetric titrations. pH was measured in every station by means of potentiometric or spectrophotometric methods, sometimes using both, so a comparison between both type of measurements will be made. Alkalinity samples were collected every third station, according to the sampling strategy.

pH measurements

i) Spectrophotometric method: sampling and analytical methods.

Seawater samples for pH were collected after CFC and oxygen samples from depth in the stations listed on table 7.1, using cylindrical optical glass 10 cm pathlength cells which were filled to overflowing and immediately stoppered. Seawater pH was measured using a double-wavelength spectrophotometric procedure (Byrne, 1987). The indicator was a 1 mM solution of Kodak m-cresol purple sodium salt ($C_{21}H_{17}O_5Na$) prepared in deionized water with a 20% of ethanol content, the absorbance ratio of the concentrated indicator solutions ($R = A_{578}/A_{434}$) varied between 0.8 and 0.9. After sampling all the samples were stabilised at 25 °C, the temperature in the sample cell was monitored with a platinum resistance Pt-probe; all the absorbance measurements were obtained in the thermostatted (25 ± 0.5 °C) cell compartment of a Beckman DU-730 spectrophotometer. After blanking with the sampled seawater without dye, 100 µl of the dye solution were added to each sample using an adjustable repeater pipette calibrated before coming to the cruise. The absorbance was measured at three different fixed wavelengths (434, 578 and 730 nm), pH, on the total hydrogen ion concentration scale, is calculated using (7.1) (Clayton and Byrne, 1993):

$$pHt = 1245.69/T + 3.8275 + 2.11\times10^{-3}(35 - S) + \log\{(R - 0.0069)/(2.222 - 0.133R)\} \quad (7.1)$$

where R is the absorbance ratio ($R=A_{578}/A_{434}$), T is temperature in kelvin scale and S is salinity. As the injection of indicator perturbs the sample pH slightly, we corrected absorbance rations measured in the seawater samples to those values that would have been observed in the case of unperturbed analyses. This correction was quantified for each batch of dye solution, and it is calculated from a second addition of the dye to a series of samples over a range of seawater pH, the change in absorbance ratio per ml of added indicator (ΔR) is described as a linear function of the value of the absorbance ratio (Rm) measured after the initial addition of indicator (i.e., $\Delta R = A + B\,Rm$).

ii) Potentiometric method: sampling and analytical procedure.

Seawater samples were collected for pH analysis after CFCs and oxygen at all depths in the stations listed on table 1 in 50 ml plastic bottles, samples were filled to overflowing and immediately stoppered. A Metrohm 654 pH meter with a Ross (Orion 8104) combination glass electrode was used to measure pH. pH measurements were standardised according to the following sequence:

1 calibration of the combined electrode with a pH 7.413 NBS buffer solution;

2 checking of the electrode response with a pH 4.008 NBS buffer solution, as described by Perez and Fraga (1987a);

3 adaptation of the electrode to the strong ionic strength of seawater by means of a pH 4.4 seawater buffer containing 4.0846 g of $C_8H_5KO_4$ and 1.52568 g of $B_4O_7Na_2.H_2O$ in 1 kg of CO_2-free seawater.

Temperature at the time of measurement was checked using a platinum resistance Pt-100 probe to correct the effect of temperature on pH (Perez and Fraga, 1987a). All pH values were referred to a standard temperature of 15 °C (pH_{15}).

iii) Potentiometric method: calibrations and corrections.

At each station, pH of seawater substandard (pHsss) was measured before and after each series of samples. The seawater substandard is a "quasy-steady" surface de-aerated seawater taken from the non-toxic supply and stored in the dark into a large container (25 liters) during 2 days before use. From each calibration we get the pHis (pH isoelectric), the pH recorded at zero potential. This pHis can vary because of real variations in the electrode, changes in the buffer and/or an error during the calibration. The pH_{15} values will be corrected using the anomalies of SSS and the variations of pHis at the different calibrations inn order to refer them to the same base line. Likewise, in order to check the procedure followed during the pH determinations, samples of CO_2 reference material (CRM) were analyzed during the cruise.

Alkalinity measurements.

i) Sampling and analytical procedure.

Seawater samples for alkalinity were collected after CFCs, oxygen and pH samples, in 500 ml glass or 300 ml plastic bottles. Full water column profiles were analyzed at the stations showed on table 7.1. Samples were stored at dark until analysis, which were carried in one day time after sampling. Alkalinity was measured using an automatic potentiomentric titrator "Titrino Metrohm", with a Metrohm combination glass electrode. Potentiometric titrations were carried out with hydrochloric acid (HCl exact molarity wil be established at laboratory) to a final pH of 4.44 (Perez and Fraga, 1987b). The electrodes were standardised using NBS buffers of pH 7.413 and the nerstian slope checked using a NBS buffer of 4.008. As for pH measurements, a pH 4.4 buffer, made up in sea water, was used to adapt the electrodes to the strong ionic strength of sea water. Concentrations are given in mmol/kg-sw.

ii) Corrections and calibrations.

Samples of seawater substandard (SSS) and CRM of batch 37 were analysed at the beginning and at the end of each batch of analysis. The variations of SSS and CRM alkalinity values along the cruise will be used to correct the electrode deviations along time so the alkalinity results will be referred to the same base line.

References

Byrne R. H., 1987: Standardization of standard buffers by visible spectrometry. *Analytical Chemistry*, **59** 1479-1481.

Clayton, T. D. and R. H. Byrne, 1993: Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale concentration scale calibration of m-cresol purple and at-sea results. *Deep-Sea Res.* **40** 2115-2129.

Perez F. F. and F. Fraga, 1987a: The pH measurements in seawater on NBS scale. *Marine Chemistry*, **21** 315-327.

Perez F. F. and F. Fraga, 1987b: A precise and rapid analytical procedure for alkalinity determination. *Marine Chemistry*, **21** 315-327.

Marta Rodriguez and Iris Aristegui

d. HALOCARBONS

The were two main aims to the halocarbon work on D230: The first was to collect a comprehensive CFC tracer data set to WOCE standards for CFC-11, CFC-12, CFC-113 and carbon tetrachloride. Particular emphasis was placed on characterising the flow of Mediterranean Water and Antarctic Bottom Water in the Eastern North Atlantic, the flows through the Charlie Gibbs Fracture Zone and the Denmark Straits and the spread of Labrador Seawater across the entire North Atlantic. The second was to make measurements of as many halogenated compounds implicated in the ozone depletion and greenhouse gas debate as practically possible. The work forms part of a project to look at the natural oceanic sources of, for example, methyl bromide, methyl chloride, methyl iodide, methylene chloride and bromochloromethane together with the oceanic sink of the anthropogenic CFC replacements. Together with the phytoplankton speciation and pigment analysis described below, the work is a fundamental part of the SOC Sources and Sinks of Halogenated Environmental Substances - SASHES. programme. FOUREX is the second in a series of 4 cruises which enable cover of winter, summer and spring biological activity.

Sample Collection

Prior to the cruise the 10 litre Niskin bottles were checked for physical integrity and chemical cleanliness. Initial checks showed that none of the bottles were halocarbon contaminated and no contamination problems developed during the cruise. Samples were drawn first from the rosette, directly into 100 ml ground glass syringes and stored under a continuous flushing stream of surface sea water to keep gas tight integrity. Most samples were analysed within 12 hours of collection. When a delay did develop due to frequency of CTD stations there was no evidence of sample degradation for up to a further 12 hours.

Analysis

Halocarbon analyses were carried out using a modified version of the GC-ECD system described in Boswell and Smythe-Wright (1996). The primary modifications were the use of liquid nitrogen and 10 cm x 19 gauge OD traps filled with glass beads for the cryogenic trapping of the compounds as this gave sharper chromatography, and the replacement of the six port switching valve V3 to a 10 port valve. This latter modification totally alleviated the pressure surge problem seen on previous cruises. A further improvement was the use of a dual gas drying arrangement comprising a Nafion dryer continuously flushed with a stream of nitrogen gas from a gas generation system, followed by a conventional drying tube containing potassium carbonate rather than magnesium perchlorate as a drying agent. On previous cruises there was some indication that the perchlorate had an adverse effect on CFC-113 measurent, however potassium carbonate on its own does not have the drying efficiency of perchlorate. With these modifications the system worked reliably giving high quality measurements throughout the cruise. Using a 38 minute chromatography run up to 18 compounds of interest were measured in the sea water samples. Measurements were made on a total of 119 stations, with approximately half to full depth, whilst the others were either to 200 m to measure biogenic gases or focused on bottom to mid waters to achieve the CFC tracer aims of the cruise.

Two minor problems occurred during the cruise. The first was the ratchet system on the gas selection valve became unreliable and needed attention. Second the liquid nitrogen supply ran out at station 98, due to poor quality gas tanks. The latter was solved by changing to -80°C cryogenic trapping on 10 cm x 1/16 th traps filled with Unibeads and desorption at 140°C using electrical heated metal blocks. Thanks go to RVS technicians for their help in fixing the ratchet system and making metal sheaths to facilitate faster heating.

A GC-MS system was also used for halocarbon measurement but not routinely since its sensitivity was found to be not as good as the GC-ECD system. Primarily it was used for halocarbon identification and to establish the existence, if any, of coeluting peaks. Some experimental and development work was carried out to increase sensitivity and this proved to be helpful for future work. However, since the GC-ECD system was functioning exceptionally well there was no need to replicate the samples on the GC-MS system.

Calibration and precision

CFC tracers were calibrated using 20 point calibration from a gas standard prepared by the NOAA CMDL laboratory which had been cross calibrated to the SIO 1994 scale. Biogenic gases were calibrated using similar techniques but with gases supplied by a Kintek gas standards generator. Duplicate measurements were made at a number of stations and showed precision and accuracy of CFC tracers to be within the WOCE requirements: less than 1% or ± 0.005 pmol kg^{-1} for CFC-11 and CFC-12 at low levels.

Final comment

Although the chemistry laboratory on RRS Discovery provides a clean environment for halocarbon analysis it is not well ventilated. The lack of adequate cooling led to temperatures approaching the upper limit of the tracer equipment, particularly in the lower latitudes at the begining of the cruise. The provision of adequate cooling needs to be addressed prior to any further cruises, particularly ones to more southerly latitudes.

In addition, it would be much appreciated if a 'dirty' electrical supply of at least 6 sockets was installed in the laboratory and that some clean outlets had an uninteruptable power supply. Much of the halocarbon equipment is ancillary: eg, compressors, pumps, coolers/heaters, which are liable to cause power surges and effect the extremely sensitive analytical systems. The latter is particularly important to GC-MS and GC-ECD systems where electrical failure can severely damage the equipment.

Reference

Boswell, S. M. and D. Smythe-Wright, 1996: Dual-detector system for the shipboard analysis of halocarbons in sea-water and air for oceanographic tracer studies. *Analyst* **121** 505-509.

Denise Smythe-Wright, Steve Boswell and Craig Harris

e. PHYTOPLANKTON SPECIATION AND PIGMENT STUDIES

There is some evidence to support the idea that phytoplankton are natural producers of halocarbons which are either greenhouse gases or cause ozone depletion. The work carried out on this cruise forms part of the SASHES project, investigating the sources and sinks of halogenated environmental substances.

Sample collection

Pigment analysis focused on the surface layer with the top 6 Niskin bottles (usually fired at 200, 100, 50, 25, 10 and 5 m water depth) being sampled at stations where halocarbon measurements were made. Samples were collected last from the rosette into 5 litre carboys which were rinsed with the sample prior to being filled. For HPLC analysis, water samples (0.5 - 2 l) were filtered through 25 mm Whatman GF/F filters using a specially developed positive pressure filtration unit - TOPPFUN. Duplicates were also taken. The filter papers were then immediately placed in cryovials and stored in liquid nitrogen for HPLC analysis at SOC.

For chlorophyll analysis, two 100 ml aliquots were filtered through 25 mm Whatman GF/F filters at low pressure. The papers were then placed in glass vials containing 10 ml of 90% acetone and immediately stored in the dark at -20°C for 24 hrs to extract the chlorophyll. Phytoplankton samples were taken for speciation studies at SOC at the surface and at depths corresponding to the chlorophyll maximum. Two 100 ml glass bottles, one containing Lugol's iodine and the other formalin, were filled at each depth.

In total 103 stations were sampled, with 440 phytoplankton samples collected and over 3000 litres of water filtered.

Chlorophyll analysis

Following the extraction period samples were warmed to room temperature in a dark water bath before the fluorescence was measured using a Turner Designs Fluorometer. Four drops of 10% Hydrochloric acid were then added to the sample and the fluorescence remeasured in order to obtain phaeopigment data.

Calibration and results

Standard Chlorophyll solutions covering the expected concentration range of the samples were used for calibration. These were made up and measured along with blanks for each set of samples. Two primary standards were used to make up the calibration standards. The chlorophyll concentrations of these were calculated from the absorbance measured before and after acid addition at 665 and 750 nm using a Camspec UV-visible spectrophotometer.

Chlorophyll and phaeopigment concentrations were calculated using the equations from the JGOFS protocols (1994). The concentration ranged from 0.002 $\mu g\ l^{-1}$ to 2.045 $\mu g\ l^{-1}$ - the highest concentrations being found in the sub-polar gyre, around the Greenland coast where there was evidence of a late autumn bloom. The chlorophyll maximum also shifted from around 50-100 m in the sub-tropical gyre to between the surface and 30 m in the sub-polar gyre.

Inaccuracies

The main areas identified as sources of inaccuracies were filtering leakages and the effect the motion of the ship had on the Turner fluorometer where the normal readable accuracy of three significant figures was reduced because the needle swung with the ship. This could possibly be overcome by turning the fluorometer 90° or by placing the instrument on a gimbal table.

Russell Davidson and Cristina Peckett

f. SALINITY

Sample analysis

Salt samples were drawn from each bottle for each cast, usually with one duplicate sample per station. Samples were analysed on the (ex-IOS) Guildline 8400A salinometer, modified by the addition of an Ocean Scientific International peristaltic-type sample intake pump, in the *Discovery*'s Constant Temperature Laboratory in the usual manner. One of the old IOS 8400 salinometers was carried as a backup, but was not needed. The salinometer was standardised at the start of each crate of 24 samples. See section 2.b for CTD / sample salinity comparison statistics: achieved accuracy was within WOCE standards, ie, better than 0.001. There were five analysts: SB, MY, DJ, MF and VT. Salinometer operating temperature was 21°C. The CT lab was run at a nominal temperature of 19°C, but this needed to be watched, as the heating and cooling plant operation, improved since D223, still gets a little confused at near-ambient temperatures, resulting in actual temperatures more than 1°C higher than nominal. No difficulties resulted. Four 'duff' ampoules of standard seawater (SSW) (salinity > 35) were found and discarded. These were all from earlier batches, from a total of about 150 ampoules consumed. This is in accord with previous experience: we usually find about 1 in 50 to be high salinity, presumed due to imperfect sealing of ampoule. 136 pairs of replicate samples were analysed, of which 3 pairs were >0.002 different. Excluding these, the mean difference between pairs was –0.0001, standard deviation of difference about mean 0.0006.

Standard seawater salinity

Given the results of the CTD salinity analysis reported in 2.b above, and some suspicions generated during the cruise, we decided to look closely at the salinometer standardisation history. This was quite tractable given the use of one salinometer which appeared to retain good stability throughout the cruise (no adjustment to standard dial on salinometer, but this is normal practice), and no change to temperature regime (again, normal practice). Four batches of SSW were used during the cruise, ranging in production date from July 1995 (oldest) to April 1997 (newest). They were used (coincidentally) in age sequence. Two of each batch were kept back and analysed as samples, standardised against the newest batch: see table 7.4 for batch information and measurement results. Now SSW is intended to be supplied accurate to 0.001; therefore the oldest batch, P128, is out of specification, being >0.002 different from label salinity, where all the others are <0.001 different.

Further confirmation is provided by the standardisation history of the salinometer: see figure 7.4. When treating standards as samples, one must impose a standard or reference salinity. In fig. 7.4, we choose the mean measured salinity of the P132 batch, because there appears to be no significant instrumental drift throughout the use of the batch. The standard deviation about the mean of P132 salinity is <0.0004. This mean is then subtracted from salinities calculated for all standards. We then plot salinity difference, ie, standard salinity minus P132 mean salinity, versus standard number (in order of use throughout the cruise). The horizontal full lines show label salinity minus P132 mean salinity, and the horizontal broken lines show actual mean salinity minus P132 mean salinity. These lines are of course coincident for P132 which is standardised on its own mean salinity. Now this is not necessarily easy to interpret. All three older batches appear saltier than they ought to be; a consistent interpretation is that P132 *might* be 0.0005 saltier than specified, so P132 is still in specification (<0.001 different from label), but the other three are all brought closer to specification. This still leaves P128 >0.001 out of specification. Now there are no obvious trends, although there are small-amplitude oscillations about mean salinities, which would imply changes in the response of the salinometer itself, except for the first and earliest batch, P128. The trend, if real, implies a change due to salinometer sensitivity change equivalent to about 0.0005 from start to finish of that batch, within a lot of noise. The safest interpretation of fig. 7.4 and table 8.4, combined with the analysis of section 2.b, is that batches P130, P131 and P132 are all OK (within specification), but that, through aging, P128 has become saltier, to which we ascribe a value of +0.0015. Therefore all samples analysed with this batch are 0.0015 *fresh*, and so have been corrected by addition of 0.0015 to their salinity.

Sheldon Bacon

Table 7.1: Summary of chemical sampling regime during cruise. Column headings show sample type. CFCs: the number of samples drawn on each station generally alternated between full water column (*ca.* 23) and surface only (5/6) samples. C&P = chlorophyll *a* and phaeopigments; phy = phytoplankton; hpl = samples for HPLC analysis at SOC; pHp and pHs = pH by potentiometric and spectrophotometric methods, respectively; alk = alkalinity. SB = surface & bottom samples only. * = samples drawn, blank = no samples drawn. See text for clarification of regime.

Stn	CFC	C&P	Phy	HPL	pHp	pHs	Alk
1							
2					*	*	*
3	7		*	*	*	*	*
4						*	SB
5						*	*
6	18		*	*		*	*
7						*	*
8					*	*	SB
9	6	*	*	*	*		*
10	22	*	*	*			
11						*	*
12							
13	7	*	*	*		*	*
14	23	*	*	*			
15						*	*
16	7	*	*	*			
17	23	*	*	*		*	*
18							
19	11	*	*	*		*	*
20							
21	24	*	*	*		*	*
22							
23							
24	23	*	*	*	*	*	
25	5	*	*	*	*	*	
26	23	*	*	*		*	*
27	5	*	*	*	*	*	
28	23	*	*	*	*	*	
29	5	*	*	*		*	*
30	22	*	*	*	*	*	
31	6	*	*	*	*	*	
32	22	*	*	*	*		*
33	7	*	*	*	*	*	
34	13	*	*	*	*	*	
35	8	*	*	*		*	*
36	23	*	*	*		*	
37	7	*	*	*	*	*	
38	20	*	*	*		*	*
39	6	*	*	*	*	*	
40	18	*	*	*	*	*	
41	7	*	*	*		*	*
42	20	*	*	*	*	*	
43	6	*	*	*		*	
44	20	*	*	*		*	*
45	8	*	*	*	*	*	
46	21	*	*	*	*	*	
47	6	*	*	*		*	*
48	20	*	*	*	*	*	
49	7	*	*	*	*	*	
50	19	*	*	*	*		*
51	7	*	*	*	*	*	
52	17	*	*	*		*	
53	7	*	*	*			*
54	20	*	*	*	*	*	
55	3	*	*	*	*	*	
56	22	*	*	*		*	*
57	6	*	*	*	*	*	
58	23	*	*	*	*	*	
59	6	*	*	*		*	*
60	23	*	*	*	*	*	
61	6	*	*	*	*	*	
62	14					*	
63	23	*	*	*		*	*
64	6				*	*	
65	23	*	*	*		*	*
66	18				*	*	
67					*	*	
68	23	*	*	*		*	*
69					*		
70	20	*	*	*		*	
71	6	*	*	*	*		*
72	18	*	*	*	*		
73	8	*	*	*			
74	19	*	*	*	*		*
75	6	*	*	*		*	
76	20	*	*	*	*	*	
77	5	*	*	*		*	*
78	21	*	*	*	*	*	
79	6	*	*	*	*	*	
80	20	*	*	*		*	*
81	6	*	*	*	*	*	
82	23	*	*	*			
83	6	*	*	*		*	*
84	20	*	*	*			
85	4	*	*	*	*	*	
86	21	*	*	*	*		
87	2				*	*	*
88	17	*	*	*			
89	2				*	*	
90	13	*	*	*			
91					*	*	*
92	7	*	*	*			
93	5	*	*	*	*	*	*
94	22	*	*	*	*	*	*
95	5		*	*	*	*	
96	23	*	*	*	*	*	
97	6			*	*	*	*
98	17	*	*	*	*	*	
99	18	*	*	*	*		
100					*	*	*
101	11	*	*	*		*	
102	9	*	*	*	*	*	*
103	10	*	*	*	*	*	*
104	4				*	*	
105	18	*	*	*	*	*	
106	23	*	*	*	*	*	*
107	17	*	*	*	*	*	
108	4				*	*	
109	18	*	*	*	*	*	*
110	11				*	*	
111	6	*	*	*		*	*
112	11	*	*	*	*	*	
113	14	*	*	*	*	*	
114	16	*	*	*	*	*	*
115	22	*	*	*	*	*	
116	4				*	*	
117	19	*	*	*	*	*	*
118	19	*	*	*	*	*	
119	1					*	
120	13	*	*	*		*	
121	19	*	*	*		*	*
122	2				*	*	
123	4	*	*	*	*	*	
124	20	*	*	*	*	*	
125	13	*	*	*	*	*	*
126					*		
127	10	*	*	*	*	*	
128					*	*	
129	14	*	*	*	*	*	*
130					*	*	
131	10	*	*	*	*	*	
132					*	*	
133	5		*	*	*	*	*
134	10				*	*	
135	8				*	*	
136	21	*	*	*		*	
137					*	*	
138	20	*	*	*	*	*	*
139	10				*		
140	3				*	*	*
141					*	*	
142	7	*	*	*	*	*	
143					*	*	*

Table 7.2: Working nutrient standard concentration.

Standard	Silicate (µmol/l)	Nitrate (µmol/l) 001-45	Nitrate (µmol/l) 046-143	Phosphate (µmol/l)
S1	40.132	40.124	30.139	2.006
S2	30.145	30.139	20.034	1.507
S3	20.038	20.034	10.009	1.002
S4	10.011	10.009	5.000	0.500

Table 7.3: Correction factors applied to the nutrient data.

	Stations	Factor
Silicate	046 - 049	0.933
	085 - 089	0.9502
	090 - 093	0.94997
Nitrate	057 - 059	0.8865
Phosphate	046	0.939

Table 8.4: Standard seawater salinities

Batch	Measured salinity	Label salinity	Production date
P128	34.9967	34.994	18-Jul-95
	34.9965		
P130	35.0000	34.999	21-Mar-96
	34.9994		
P131	34.9949	34.994	10-Dec-96
	34.9949		
P132	34.9972	34.997	09-Apr-97
	34.9976		
	34.9976		

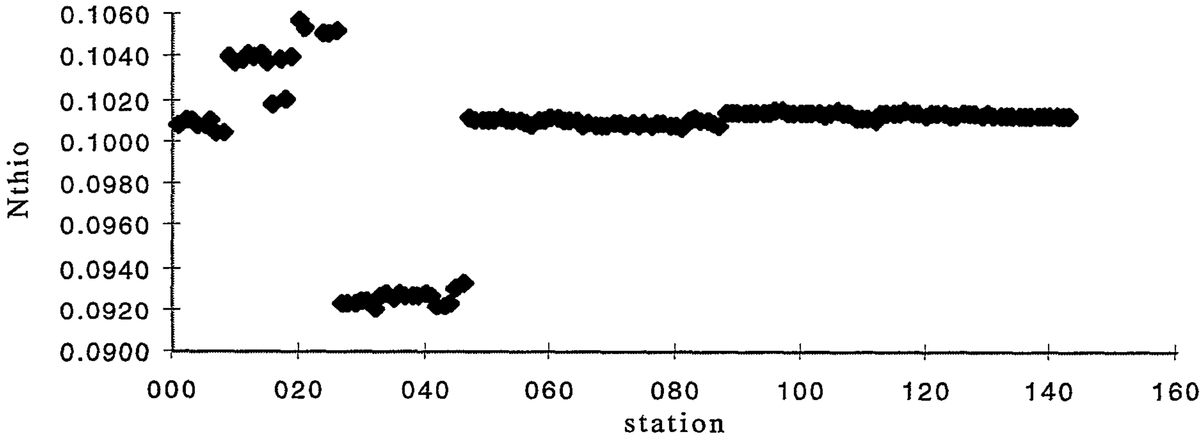

Figure 7.1: Variations in thiosulphate normality

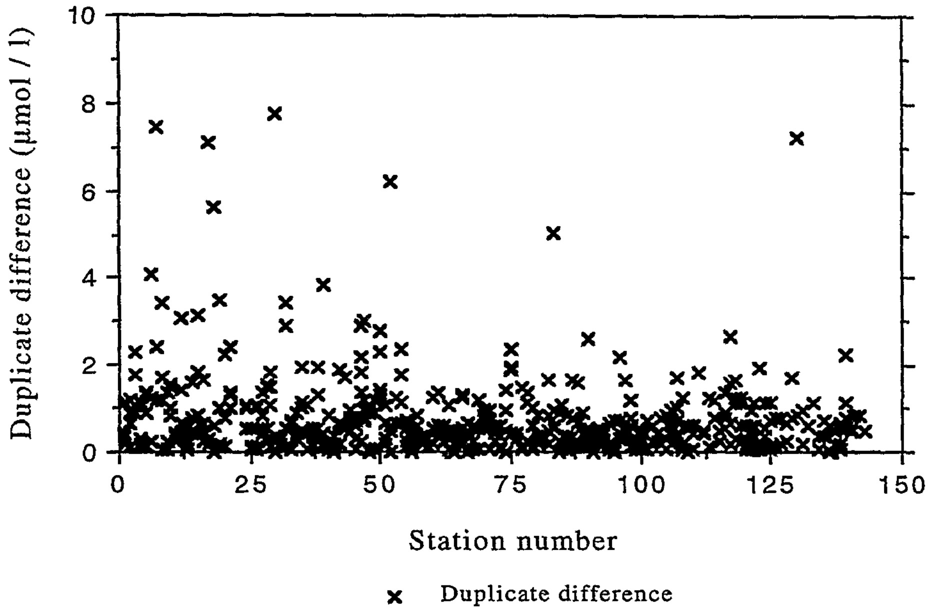

Figure 7.2a: Duplicate difference at each station

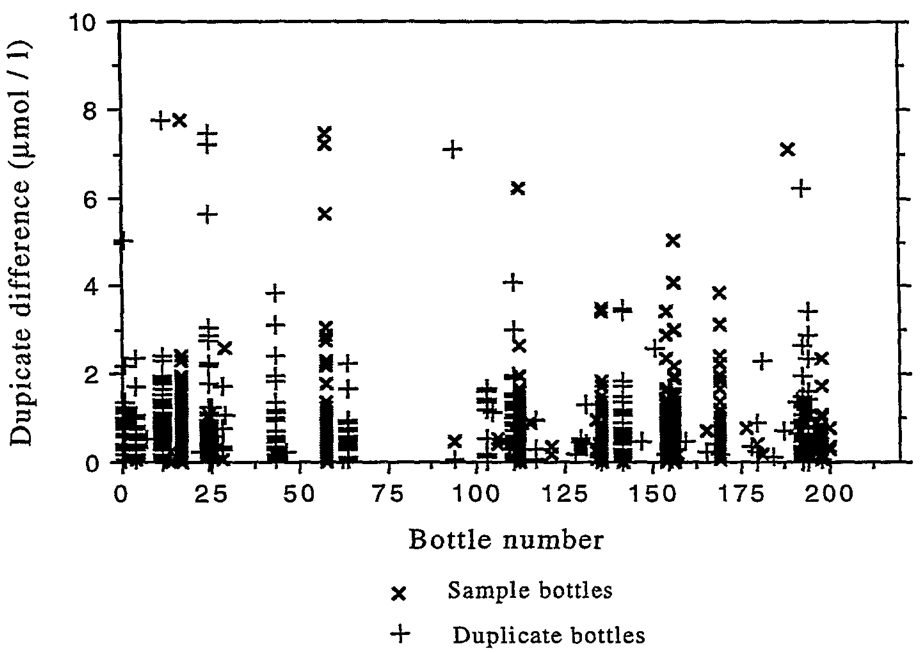

Figure 7.2b: Comparison of duplicate difference with bottles used

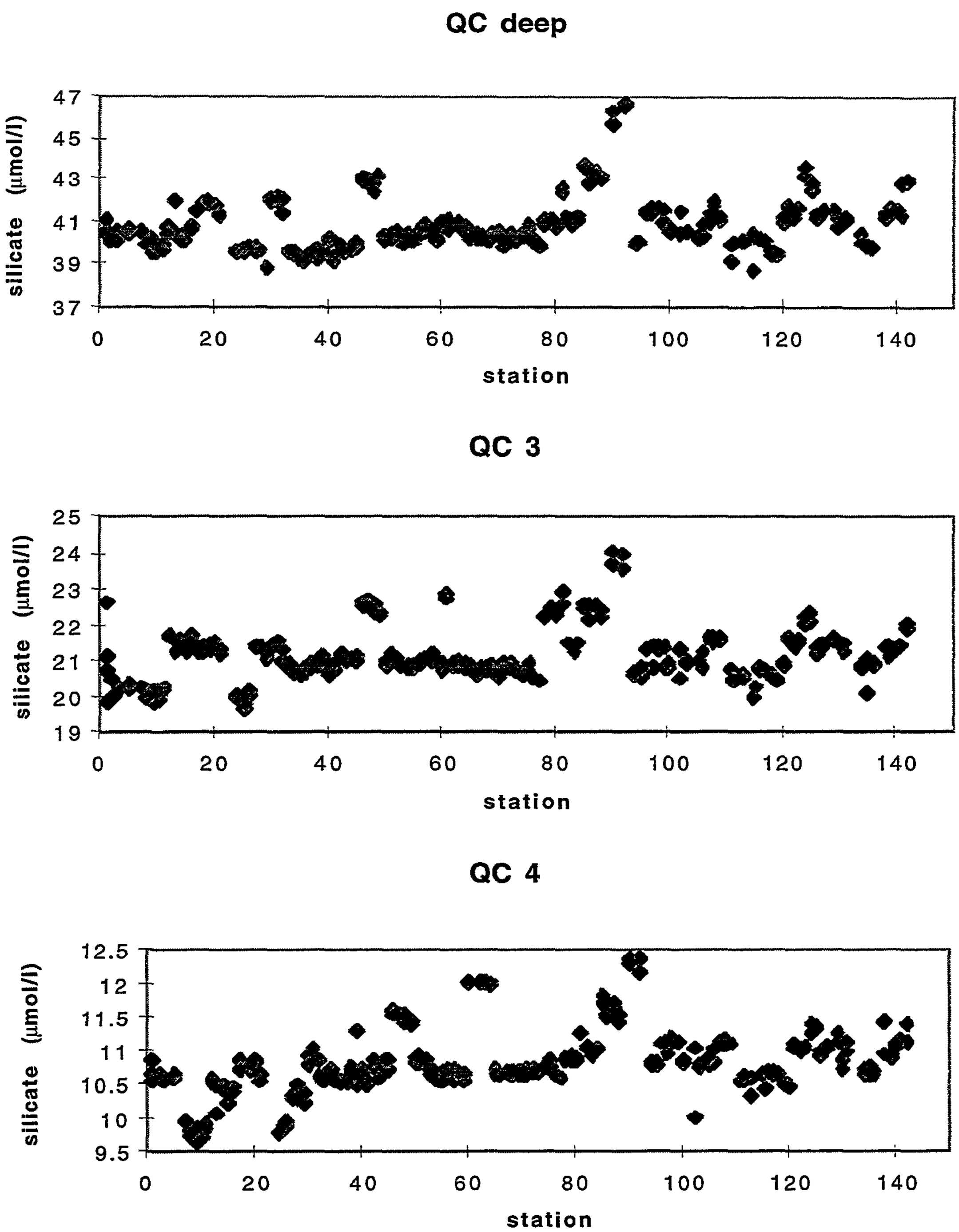

Figure 7.3a: Silicate QC Deep, QC 3, QC 4.

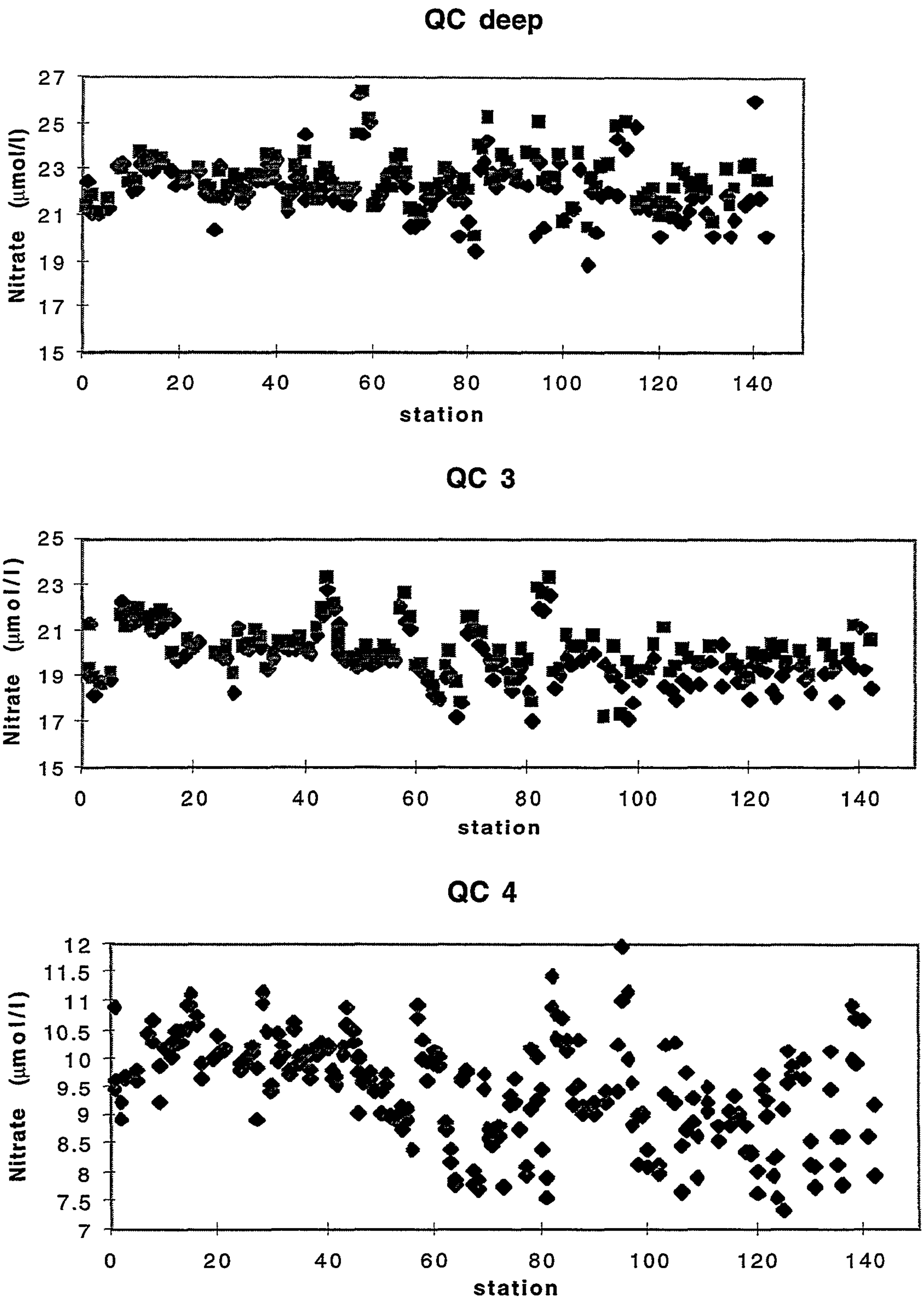

Figure 7.3b: Nitrate QC Deep, QC 3, QC 4.

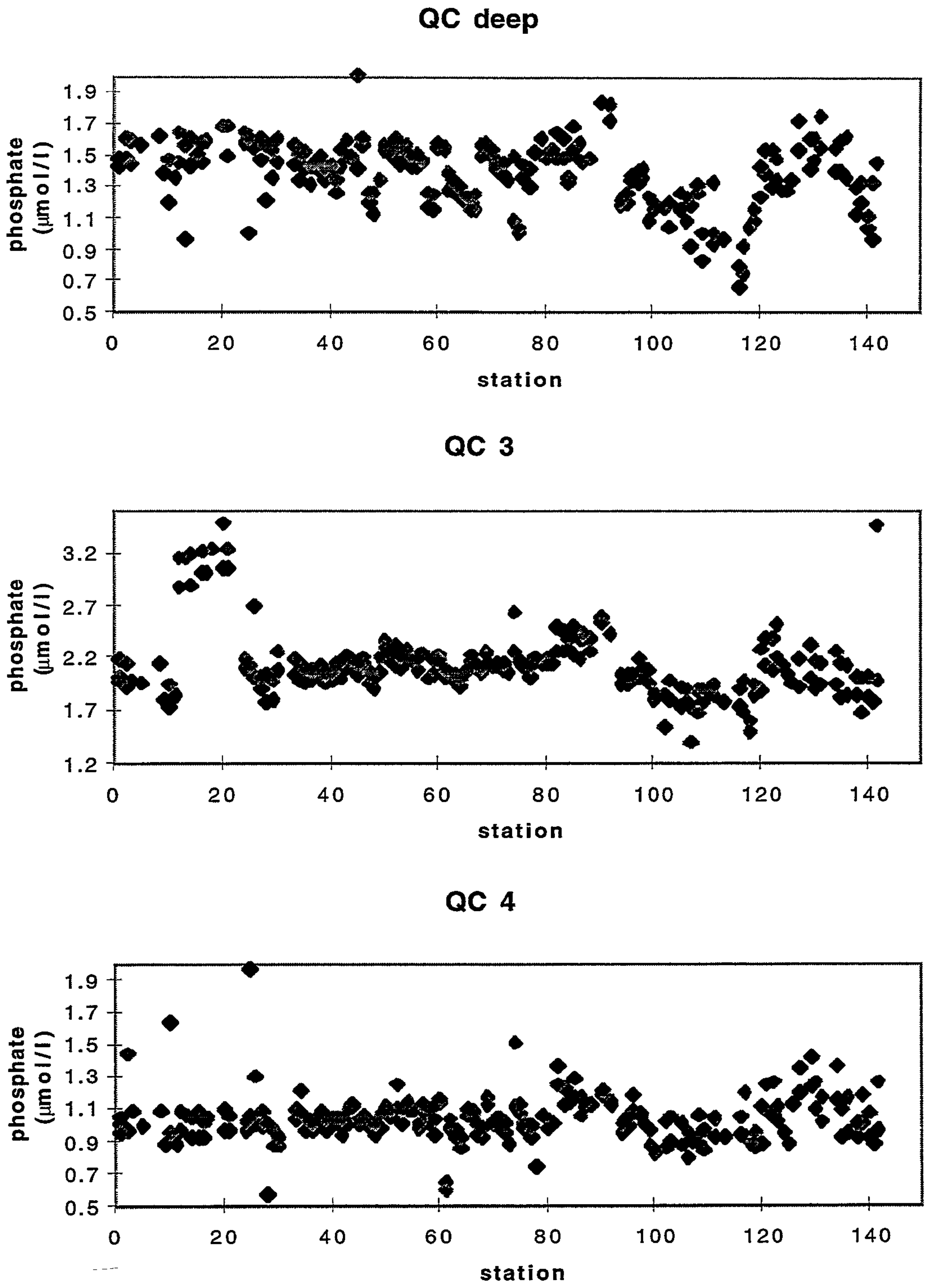

Figure 7.3c: Phosphate QC Deep, QC 3, QC 4.

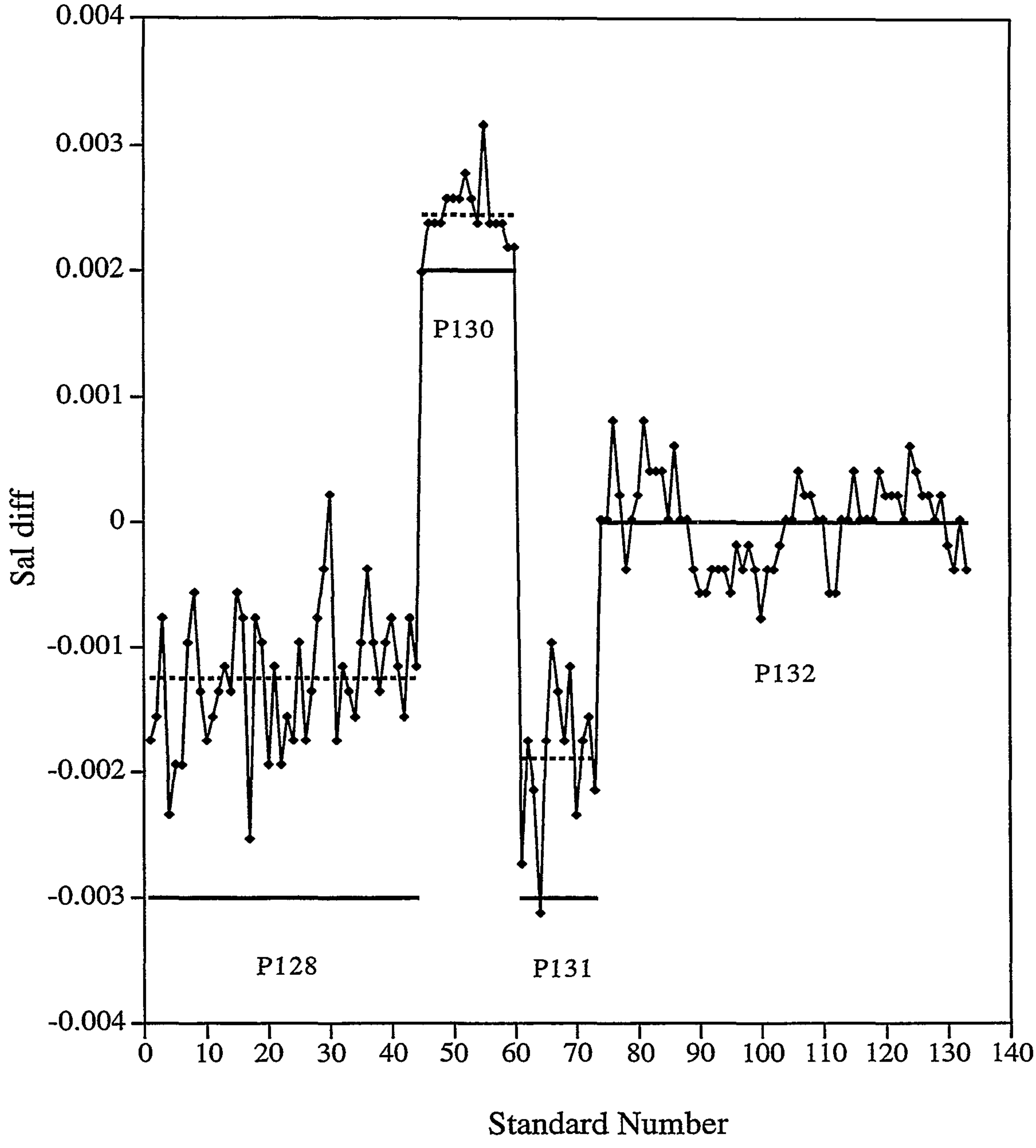

Figure 7.4: Salinity standard history. Broken lines show measured mean over each batch, full lines show mean assuming correct batch label salinity and P132 measured mean correct (same as label).

8. OTHER MEASUREMENTS

a. THERMOSALINOGRAPH

Continuous underway measurements of surface salinity and temperature were made with a Falmouth Scientific Inc. (FSI) shipboard thermosalinograph (TSG). The instrument was run continuously throughout the cruise, with the exception of the unscheduled port call at Porto, when the sea water supply was interrupted. The TSG comprises two FSI sensor modules, an Ocean Conductivity Module (OCM) and an Ocean Temperature Module (OTM), both fitted within the same laboratory housing. Sea surface temperature is measured by a second OTM situated on the suction side of the non-toxic supply in the forward hold. The non-toxic intake is 5 m below the sea surface. Data from the OCM and the OTM modules are passed to a PC, which imitates the traditional Level A system, passing it to level B at 30 second intervals.

The temperature modules are installed pre-calibrated to a laboratory standard and laboratory calibration data are used to obtain four polynomial coefficients. A similar procedure is employed for the conductivity module. Salinity samples were drawn from the non-toxic supply at approximately four hourly intervals for calibration of computed TSG salinity. These samples were then analysed on a Guideline 8400A in the usual way. The four-hourly bottle salinities from the non-toxic supply are used as true salinity from which to calculate an offset to be applied to the TSG salinities. TSG salinity is usually calculated from the measured conductivity (cond) and temperature at the housing located in the hangar (temp_h). The temperature of the surface water is measured by the remote or marine sensor (temp_m).

TSG data was processed on a daily basis in the following steps:

Step 1: Level 0 acquisition of raw TSG data (temp_h, temp_m, cond) from level A, and conversion to level C PSTAR format (TSGEXEC0);

Step 2: Level 1 despiking of raw TSG data, averaging to 2 minute intervals, and merging with navigation data from the Bestnav file (TSGEXEC1);

Step 3: Bottle salinity data are prepared in Excel and saved as a tab-delimited text file, which is ftp'ed from a Mac, converting the data to PSTAR format, and (Level 2) time is converted to seconds (TSG.EXEC, TSGEXEC2);

Step 4: Level 3 merging of bottle salinities and TSG salinities, to determine residual errors in TSG salinity (TSGEXEC3A).

Daily plots of despiked, 2-minute averaged temp_h, temp_m and cond revealed the degree of noise in TSG conductivity, and provided near real-time information on the location of major fronts and currents. Early in the cruise, the conductivity measured by the TSG was noisy or obviously wrong for periods from a few minutes up to 24 hours. These data were subsequently made absent from final datasets using PEDITB and the gaps interpolated over by PINTRP. After 15 days, these errors vanished. In areas of very low salinity, i.e. near Greenland and in the East

Greenland current, there was some doubt of the accuracy of the TSG. The final values for the mean offset of the bottle samples from the TSG data (-0.0099) and standard deviation (0.1271) were obtained by running PHISTO on the final residual file. TSGEXEC3A was used to make this residual file from the 2min averaged TSG data and the four hourly bottle samples. This exec calibrates according to conductivity thus eliminating the temperature dependence. This program was edited by Penny Holliday to include PMDIAN. This was to ensure that single points lying off the line of best fit did not affect the calculation of regression. Finally, the file containing the residuals was merged with navigation data. Calibrations etc will be reworked at SOC when time permits.

Maryke Fox, Bob Marsh and Penny Holliday

b. PRECISION ECHO SOUNDER

The bathymetry equipment installed on RRS *Discovery* consists of: Hull mounted transducer, Precision Echosounding (PES) 'fish' transducer and Simrad EA500 Hydrographic Echosounder. The Simrad Echosounder was used during the cruise for bottom detection. While in bottom detection mode, the depth values were passed via an RVS level A interface to the level C system for processing. The transducers were connected to the Simrad equipment via an external switch. A uniform sound velocity of 1500 m/s was used during the cruise. A visual display of the return echo was displayed on the Simrad VDU. Hardcopy output was produced on a colour inkjet printer. The amount of cable submerged whilst on station was measured to be approximately 9.6 meters. While steaming, the echosounder was 3 meters shallower than on station. So during steaming, the measured depth is 3 meters deeper than the real depth.

The PES fish transducer was used throughout the cruise, in preference to the hull transducer. This gave good return signals on station and adequate return signals whilst steaming at 10 knots. However, there was sometimes significant noise. Subsequent processing used Carter Tables corrections to sound speed to calculate corrected depth. It was interesting to compare actual depth on station with PES-recorded depth. This was done by converting maximum CTD pressure on station to depth, and adding the altimeter measurement of distance off bottom at closest approach. This depth estimate was then compared with corrected depth from the echo sounder; see table 8.1 for results. It is clear that the depth as recorded by the echo sounder is fairly accurate except over regions of steep bottom topography, occasionally on continental slopes but more so over the Mid-Atlantic Ridge, where depth estimates differ by >100 m. The average difference (echo-sounder minus CTD) for all 140 points is –10.6 m (sd 31.7). Excluding all points with absolute difference greater than 25 m, the mean difference is –0.3 m (sd 6.9, N=119). In steep topography, the difference is biased negative, ie, the echo sounder is picking up shallower side echos.

Virginie Thierry, Sheldon Bacon, Stuart Cunningham

Table 8.1: Comparison of actual depth with echo-sounder depth on station. Max prs is maximum pressure (dbar) measured by the CTD, max dep is max prs converted to depth (metres), alt is altimeter height off bottom at closest approach (metres), est dep is max dep plus alt (metres), sim dep is depth measured by echo sounder corrected for sound speed variation via Carter's Tables, and dif S–E is sim dep minus est dep (metres).

Stn Nbr	Max prs	Max dep	Alt	Est dep	Sim dep	Dif S-E
1	3613	3555	-999	-999	5178	-999
2	5267	5163	10	5173	5178	5
3	197	195	8	203	204	1
4	429	425	10	435	434	-1
5	857	848	5	853	794	-59
6	1561	1543	12	1555	1541	-14
7	2023	1997	12	2009	2006	-3
8	2255	2225	142	2367	2278	-89
9	3033	2988	11	2999	3004	5
10	3211	3162	8	3170	3176	6
11	3533	3477	9	3486	3496	10
12	3395	3342	10	3352	3348	-4
13	3079	3033	5	3038	3038	0
14	3135	3088	10	3098	3100	2
15	3183	3135	24	3159	3148	-11
16	2771	2731	11	2742	2738	-4
17	2985	2941	9	2950	2949	-1
18	3503	3447	7	3454	3444	-10
19	3791	3728	12	3740	3730	-10
20	4409	4330	10	4340	4342	2
21	5001	4905	9	4914	4914	0
22	2055	2029	-999	-999	3434	-999
23	5045	4947	11	4958	4961	3
24	5387	5279	12	5291	5294	3
25	5445	5335	9	5344	5346	2
26	5431	5321	23	5344	5348	4
27	5289	5184	10	5194	5190	-4
28	5151	5050	-999	-999	5348	-999
29	5463	5352	18	5370	5372	2
30	5583	5468	1	5469	5476	7
31	5613	5497	5	5502	5506	4
32	5521	5408	17	5425	5444	19
33	5503	5391	15	5406	5410	4
34	4781	4691	8	4699	4703	4
35	2563	2528	12	2540	2526	-14
36	4041	3972	11	3983	3989	6
37	3927	3860	11	3871	3856	-15
38	2713	2674	8	2682	2690	8
39	2753	2713	15	2728	2721	-7
40	2545	2509	15	2524	2511	-13
41	3933	3866	17	3883	3776	-107
42	4241	4165	12	4177	4155	-22
43	3213	3163	17	3180	3176	-4
44	3245	3194	13	3207	3218	11
45	3201	3151	22	3173	3162	-11
46	3139	3090	17	3107	3104	-3
47	3353	3299	17	3316	3312	-4
48	2987	2941	12	2953	2879	-74
49	2911	2867	13	2880	2870	-10
50	2973	2928	80	3008	2949	-59
51	2649	2610	11	2621	2624	3
52	2829	2786	11	2797	2767	-30
53	2583	2545	11	2556	2522	-34
54	2061	2033	8	2041	2078	37
55	3157	3107	109	3216	3021	-195
56	2503	2467	9	2476	2447	-29
57	2923	2878	12	2890	2815	-75
58	3291	3237	45	3282	3255	-27
59	3487	3429	8	3437	3443	6
60	2807	2764	7	2771	2772	1
61	3409	3352	61	3413	3372	-41
62	3031	2983	10	2993	2983	-10
63	4051	3978	29	4007	3995	-12
64	3173	3122	10	3132	3053	-79
65	4633	4543	9	4552	4554	2
66	3433	3375	10	3385	3358	-27
67	3143	3092	11	3103	3111	8
68	3015	2967	61	3028	2984	-44
69	2841	2797	31	2828	2815	-13
70	2035	2007	10	2017	2014	-3
71	2455	2419	6	2425	2296	-129
72	1925	1899	13	1912	1759	-153
73	1771	1747	16	1763	1650	-113
74	2485	2448	10	2458	2459	1
75	2607	2567	12	2579	2582	3
76	2839	2794	8	2802	2803	1
77	3089	3038	9	3047	2985	-62
78	3317	3261	9	3270	3275	5
79	3269	3214	11	3225	3226	1
80	3273	3218	11	3229	3232	3
81	3239	3184	10	3194	3199	5
82	3177	3124	9	3133	3140	7
83	3001	2952	10	2962	2967	5
84	2773	2729	7	2736	2745	9
85	2513	2475	10	2485	2486	1
86	2247	2214	6	2220	2222	2
87	2049	2020	10	2030	2030	0
88	1771	1747	9	1756	1751	-5
89	1375	1357	5	1362	1354	-8
90	935	924	10	934	917	-17
91	529	523	9	532	528	-4
92	193	191	9	200	198	-2
93	155	153	10	163	168	5
94	2929	2881	8	2889	2892	3
95	2755	2711	8	2719	2722	3
96	2571	2531	5	2536	2538	2
97	2377	2341	10	2351	2352	1
98	2015	1986	7	1993	1990	-3
99	1503	1483	13	1496	1494	-2
100	887	876	10	886	837	-49
101	553	547	4	551	527	-24
102	297	294	6	300	297	-3
103	377	373	4	377	381	4
104	571	564	12	576	574	-2
105	1087	1073	10	1083	1079	-4
106	1559	1538	7	1545	1548	3
107	1903	1876	8	1884	1886	2
108	1345	1327	12	1339	1334	-5
109	1009	996	5	1001	999	-2
110	497	491	9	500	501	1
111	203	201	11	212	214	2
112	591	584	13	597	595	-2
113	1199	1184	11	1195	1202	7
114	1509	1489	11	1500	1504	4
115	1825	1799	10	1809	1813	4
116	1799	1774	6	1780	1771	-9
117	2001	1972	13	1985	1989	4
118	2393	2357	10	2367	2373	6
119	2423	2386	11	2397	2403	6
120	2497	2459	9	2468	2472	4
121	2755	2711	8	2719	2722	3
122	2709	2666	10	2676	2679	3
123	2437	2400	6	2406	2409	3
124	1963	1935	10	1945	1942	-3
125	1557	1536	9	1545	1545	0
126	1005	993	9	1002	1003	1
127	847	837	11	848	846	-2
128	1159	1145	9	1154	1158	4
129	1221	1206	8	1214	1218	4
130	673	665	10	675	680	5
131	461	456	8	464	467	3
132	147	146	10	156	156	0
133	125	124	7	131	135	4
134	1037	1025	3	1028	1017	-11
135	1813	1788	12	1800	1807	7
136	2033	2004	11	2015	2017	2
137	587	581	8	589	588	-1
138	2241	2208	8	2216	2222	6
139	1955	1928	8	1936	1946	10
140	1409	1391	5	1396	1385	-11
141	295	292	14	306	304	-2
142	127	126	9	135	134	-1
143	129	128	8	136	134	-2

9. COMPUTING

Six Macs and two PCs were available. One of the PCs was dedicated to supporting the operation of the LADCP. The other was used for word processing and spreadsheets. All the Mac's were used as terminals for the workstations, data processing on spreadsheets and word processing. A Sun SPARC ST1 workstation was also available with a 4 GB disk attached to it. It was mainly used for data analysis and interactive editing of the ctd data. Shortage of memory on this workstation lead to repeated crashes. The reason was filling up of the memory by the screen output. When the non-scrolling option on the command shells was selected the problem was eliminated. Two printers an Apple Laserwriter II and a colour HP Paintjet were used for the production of CTD plots and text printing.

Data processing was based on version 4 of Pexec software; the only other data processing package available was MATLAB for which only one licence was available on board. Apart from a problem on program pdepth that seems to treat missing values as existing, the Pexec programs run reasonably well when the demanded formalities were observed.

Data backup was taking place daily (both in frequency and in duration). A tape drive that uses 150 MB cartridges stopped working as soon as the ship left Vigo. Thereafter the backup was done on Exabyte tapes, the drive of which was temperamental, and on optical laser disks. In view of the quantity of the data that needed backing up daily the failure of the tape drive was a rather fortunate event as both the Exabyte driver and the optical disks are clearly more efficient as far as space is concerned. Data archiving was taking place on optical disks according to the existing demand. One file was lost and recovered. Also two of the archived files had to be recovered. The time to actually reprocess the data from level-A would have been, at worse 2 h.

Despite the approximately 15 GB of disk space available this was proven to be insufficient at instances where reprocessing of whole sets of data was taking place during the later parts of the cruise. This problem was resolved by archiving parts of data or asking the users to compress or remove unessecary files.

At the end of the cruise two copies of the final form of the existing directories were created, which, together with a final backup on Exabyte tapes should provide adequate security against data loss.

In conclsion the computing facilities were generally more than adequate in all respects but two: a) it is thought unreasonable to provide 15 GB of disk space and not a more efficient system of backing it up, and b) availability of at least two more licences of matlab or an other data-processing package would have been beneficial.

Mickey Tsimplis

10. TECHNICAL SUPPORT

This report covers the equipment that is the responsibility of the RVS Scientific Engineering Group (seg) and was used during this cruise. Being a predominantly CTD cruise, the winch systems and the starboard gantry were the only equipment handling systems used throughout the cruise. The only other (seg) systems used during the cruise were the non-toxic water system and the Millipore ultra pure water system.

The winch system operated successfully for the duration of the cruise. The 20 tonne winch system was used with the deep tow conducting cable for the deep CTD stations, the deepest station being about 5500 metres. The CTD package was connected to the conducting cable via a TOBI type of conducting swivel. This combination of winch, cable, swivel and package proved to be very successful and should be borne in mind for future occasions where deep CTDs are required.

The 10 tonne winch system was used with the CTD cable for the shallower stations. The CTD cable was connected to the CTD package via a two tonne conducting swivel. Prior to its use the cable termination and the conducting swivel were subjected to a test load of two tonnes for a duration of five minutes. The use of the swivel proved to be successful and its use was probably the main contributing factor for eliminating the need to re-terminate the cable for the duration of the cruise.

The starboard gantry was used successfully for the deployment of the CTD throughout the cruise. The geometry of the gantry together with its location on the ship made it possible to deploy the CTD package safely, even under severe weather conditions.

The non-toxic system operated reliably throughout the cruise, providing water for the permanent underway systems and for use by specialised equipment brought on board for this cruise.

The ultra clean water system was moved from the chemistry lab and installed in the after end of the deck lab. The system operated successfully throughout the cruise providing ultra pure water as required. During the cruise the RO and Q filter packs were changed as a routine measure.

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APPENDIX: FOUREX STATION INFORMATION

We show here the standard WOCE format station summary table (WHP/WOCE, 1994). Colums headings are as follows:

Ship/crs expocode: the cruise code is constructed from the country code 74 (U. K.), ship code DI (*Discovery*), number 230 (cruise number), and extension 1 (leg number).

WOCE sect: the WOCE section designation for this cruise is A24.

Stn Nbr, Cast Nbr: Station number and cast number.

Cast Type: designation for cast type is ROS (for rosette plus CTD etc) throughout.

Date: date format is mmddyy throughout.

UTC Time: time (UTC, GMT, Z) format is hhmmss throughout.

Event Code: BE (beginning), BO (bottom), EN (end), referring to each cast.

Lat, Lon: positions corresponding to each of the above.

Nav: method of position determination for each of the above; GPS (Trimble_4000 GPS), G24 (Ashtech GG24 GPS / GLONASS). See section 4 for details.

Unc Dep: uncorrected depth (metres) from the echosounder (PES fish).

Ht Bot: height off bottom (metres) at closest approach as measured by altimeter.

Wire out: metres of wire deployed at bottom of cast.

Max prs: maximum CTD pressure recorded on cast.

Nbr btl: number of rosette bottles sampled on each cast.

Parameters: chemicals sampled during each cast:

1 (salinity), 2 (oxygen), 3 (silicate), 4 (nitrate), 5 (nitrite), 6 (phosphate), 7 (CFC–11), 8 (CFC–12), 24 (alkalinity), 26 (pH), 27 (CFC–113), 28 (carbon tetrachloride), 34 (Chl *a*), 35 (phaeophytin), 36 (halocarbons except CFCs).

Comments: used for section start / end, CTD instrument identification, test cast identification.

The accompanying figure (A1) shows bottle depths for the whole cruise plotted against station number.

Sheldon Bacon

Reference

WHP/WOCE, 1994: WOCE Operations Manual, Volume 3: The Observational Programme; Section 3.1: WOCE Hydrographic Programme; Part 3.1.2: Requirements for WHP data reporting, eds. T. Joyce and C. Corry. WHP Office Report 90–1 Revision 2, WOCE Report 67/91, Woods Hole, MA, U. S., 144 pp.

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	1	1	ROS	080897	055728	BE	41 29.992 N	012 30.032 W	G24	5129					1-6	CTD DEEP01
74DI230/1	A24	1	1	ROS	080897	071246	BO	41 29.896 N	012 29.999 W	G24	5128	-999	3500	3613	24		Test cast
74DI230/1	A24	1	1	ROS	080897	081931	EN	41 29.961 N	012 29.965 W	G24	5128						
74DI230/1	A24	2	1	ROS	080897	104442	BE	41 29.865 N	012 29.627 W	G24	5129					1-6,	CTD DEEP01
74DI230/1	A24	2	1	ROS	080897	121629	BO	41 29.924 N	012 29.191 W	G24	5129	10	5091	5267	24	24,26	Test cast
74DI230/1	A24	2	1	ROS	080897	144102	EN	41 30.276 N	012 27.678 W	G24	5127						
74DI230/1	A24	3	1	ROS	080997	115138	BE	41 29.928 N	009 13.080 W	G24	210					1-6,7,8,	CTD DEEP01
74DI230/1	A24	3	1	ROS	080997	115942	BO	41 29.875 N	009 13.084 W	G24	202	8	193	197	8	27,28,36,	Start, Spain -
74DI230/1	A24	3	1	ROS	080997	122905	EN	41 29.728 N	009 13.163 W	G24	198					24,26,34,35	Greenland Sect.
74DI230/1	A24	4	1	ROS	080997	140408	BE	41 29.766 N	009 14.124 W	G24	433					1-6,	CTD DEEP01
74DI230/1	A24	4	1	ROS	080997	141643	BO	41 29.671 N	009 14.042 W	G24	430	10	421	429	12	24,26	
74DI230/1	A24	4	1	ROS	080997	144949	EN	41 29.477 N	009 13.723 W	G24	387						
74DI230/1	A24	5	1	ROS	080997	175343	BE	41 30.012 N	009 15.899 W	G24	966					1-6,	CTD DEEP01
74DI230/1	A24	5	1	ROS	080997	182741	BO	41 29.946 N	009 15.517 W	G24	789	5	837	857	15	24,26	
74DI230/1	A24	5	1	ROS	080997	192106	EN	41 29.970 N	009 15.224 W	G24	677						
74DI230/1	A24	6	1	ROS	080997	214601	BE	41 29.903 N	009 17.600 W	G24	1525					1-6,7,8,	CTD DEEP01
74DI230/1	A24	6	1	ROS	080997	221449	BO	41 29.923 N	009 17.786 W	G24	1534	12	1520	1561	21	27,28,36,	
74DI230/1	A24	6	1	ROS	080997	232516	EN	41 29.788 N	009 18.418 W	G24	1448					24,26,34,35	
74DI230/1	A24	7	1	ROS	081097	031057	BE	41 30.071 N	009 26.051 W	G24	2014					1-6,	CTD DEEP01
74DI230/1	A24	7	1	ROS	081097	034843	BO	41 30.314 N	009 25.857 W	G24	2001	12	1970	2023	23	24,26	
74DI230/1	A24	7	1	ROS	081097	052000	EN	41 30.949 N	009 25.889 W	G24	2006						
74DI230/1	A24	8	1	ROS	081097	074126	BE	41 29.606 N	009 44.693 W	G24	2364					1-6,	CTD DEEP01
74DI230/1	A24	8	1	ROS	081097	082841	BO	41 29.446 N	009 44.532 W	G24	2269	142	2192	2255	24	24,26	
74DI230/1	A24	8	1	ROS	081097	100754	EN	41 28.889 N	009 44.402 W	G24	2189						
74DI230/1	A24	9	1	ROS	081097	122543	BE	41 30.261 N	009 54.920 W	G24	2999					1-6,7,8,	CTD DEEP01
74DI230/1	A24	9	1	ROS	081097	131430	BO	41 30.198 N	009 54.651 W	G24	2991	11	2945	3033	24	27,28,36,	
74DI230/1	A24	9	1	ROS	081097	145045	EN	41 29.821 N	009 54.022 W	G24	2993					24,26,34,35	
74DI230/1	A24	10	1	ROS	081097	164204	BE	41 29.981 N	010 11.978 W	G24	3157					1-6,7,8,	CTD DEEP01
74DI230/1	A24	10	1	ROS	081097	174031	BO	41 30.331 N	010 11.579 W	G24	3163	8	3125	3211	24	27,28,36,	
74DI230/1	A24	10	1	ROS	081097	192050	EN	41 30.558 N	010 10.291 W	G24	3146					34,35	
74DI230/1	A24	11	1	ROS	081097	212848	BE	41 29.896 N	010 25.671 W	G24	3461					1-6,	CTD DEEP01
74DI230/1	A24	11	1	ROS	081097	222720	BO	41 29.689 N	010 25.191 W	G24	3479	9	3432	3533	24	24,26	
74DI230/1	A24	11	1	ROS	081097	235806	EN	41 28.721 N	010 24.949 W	G24	3495						
74DI230/1	A24	12	1	ROS	081197	020142	BE	41 29.427 N	010 32.464 W	G24	3350					1-6	CTD DEEP01
74DI230/1	A24	12	1	ROS	081197	030544	BO	41 28.904 N	010 32.306 W	G24	3332	10	3300	3395	24		
74DI230/1	A24	12	1	ROS	081197	044401	EN	41 28.305 N	010 32.285 W	G24	3398						
74DI230/1	A24	13	1	ROS	081197	063445	BE	41 30.137 N	010 41.462 W	G24	3021					1-6,7,8,	CTD DEEP01
74DI230/1	A24	13	1	ROS	081197	073036	BO	41 30.509 N	010 40.943 W	G24	3025	5	2990	3079	24	27,28,36,	
74DI230/1	A24	13	1	ROS	081197	091048	EN	41 30.884 N	010 39.836 W	G24	2298					24,26,34,35	
74DI230/1	A24	14	1	ROS	081197	105326	BE	41 29.844 N	010 51.722 W	G24	3098					1-6,7,8,	CTD DEEP01
74DI230/1	A24	14	1	ROS	081197	114603	BO	41 29.473 N	010 51.235 W	G24	3087	10	3070	3135	24	27,28,36,	
74DI230/1	A24	14	1	ROS	081197	132022	EN	41 29.236 N	010 50.412 W	G24	3097					34,35	
74DI230/1	A24	15	1	ROS	081197	150739	BE	41 30.009 N	011 07.850 W	G24	3111					1-6,	CTD DEEP01
74DI230/1	A24	15	1	ROS	081197	161253	BO	41 30.322 N	011 07.009 W	G24	3139	24	3134	3183	24	24,26	
74DI230/1	A24	15	1	ROS	081197	174849	EN	41 30.039 N	011 06.445 W	G24	3227						
74DI230/1	A24	16	1	ROS	081197	193515	BE	41 29.798 N	011 14.557 W	G24	2702					1-6,7,8,	CTD DEEP01
74DI230/1	A24	16	1	ROS	081197	202459	BO	41 29.648 N	011 14.379 W	G24	2732	11	2689	2771	23	27,28,36,	
74DI230/1	A24	16	1	ROS	081197	214301	EN	41 29.278 N	011 14.550 W	G24	2780					34,35	
74DI230/1	A24	17	1	ROS	081197	232349	BE	41 29.792 N	011 24.928 W	G24	2951					1-6,7,8,	CTD DEEP01
74DI230/1	A24	17	1	ROS	081297	001530	BO	41 29.545 N	011 24.692 W	G24	2943	9	2901	2985	24	27,28,36,	
74DI230/1	A24	17	1	ROS	081297	015259	EN	41 29.017 N	011 24.343 W	G24	2901					24,26,34,35	

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	18	1	ROS	081297	041011	BE	41 29.938 N	011 40.038 W	G24	3453					1-6	CTD DEEP01
74DI230/1	A24	18	1	ROS	081297	051402	BO	41 29.772 N	011 39.695 W	G24	3433	7	3395	3503	23		
74DI230/1	A24	18	1	ROS	081297	070429	EN	41 29.337 N	011 38.775 W	G24	3398						
74DI230/1	A24	19	1	ROS	081297	084800	BE	41 29.963 N	011 50.023 W	G24	3738					1-6,7,8,	CTD DEEP01
74DI230/1	A24	19	1	ROS	081297	095711	BO	41 29.796 N	011 49.985 W	G24	3715	12	3670	3791	24	27,28,36,	
74DI230/1	A24	19	1	ROS	081297	114925	EN	41 29.703 N	011 50.959 W	G24	3693					24,26,34,35	
74DI230/1	A24	20	1	ROS	081297	132821	BE	41 30.232 N	011 59.860 W	G24	4320					1-6	CTD DEEP01
74DI230/1	A24	20	1	ROS	081297	144027	BO	41 30.102 N	011 59.692 W	G24	4314	10	4265	4409	24		
74DI230/1	A24	20	1	ROS	081297	164948	EN	41 30.152 N	012 00.039 W	G24	4325						
74DI230/1	A24	21	1	ROS	081297	181254	BE	41 29.944 N	012 09.002 W	G24	4881					1-6,7,8,	CTD DEEP01
74DI230/1	A24	21	1	ROS	081297	193859	BO	41 29.709 N	012 08.919 W	G24	4873	9	4832	5001	24	27,28,36,	
74DI230/1	A24	21	1	ROS	081297	214743	EN	41 29.410 N	012 09.272 W	G24	4879					24,26,34,35	
74DI230/1	A24	22	1	ROS	081497	071453	BE	41 30.243 N	011 38.844 W	G24	3419						CTD DEEP01
74DI230/1	A24	22	1	ROS	081497	075246	BO	41 30.307 N	011 39.171 W	G24	3422	-999	2000	2055	0		LADCP Pressure
74DI230/1	A24	22	1	ROS	081497	083148	EN	41 30.455 N	011 39.578 W	G24	3432						test cast
74DI230/1	A24	23	1	ROS	081497	140917	BE	41 30.883 N	012 09.885 W	GPS	4921					1-6	CTD DEEP01
74DI230/1	A24	23	1	ROS	081497	154030	BO	41 31.189 N	012 09.885 W	GPS	4918	11	4874	5045	24		Repeat of stn.
74DI230/1	A24	23	1	ROS	081497	175923	EN	41 31.088 N	012 10.587 W	GPS	4932						21
74DI230/1	A24	24	1	ROS	081497	215745	BE	41 30.096 N	012 40.046 W	GPS	5239					1-6,7,8,	CTD DEEP01
74DI230/1	A24	24	1	ROS	081497	233215	BO	41 30.063 N	012 40.238 W	GPS	5240	12	5200	5387	24	27,28,36,	
74DI230/1	A24	24	1	ROS	081597	013617	EN	41 29.606 N	012 40.308 W	GPS	5240					26,34,35	
74DI230/1	A24	25	1	ROS	081597	044015	BE	41 30.183 N	013 20.107 W	GPS	5291					1-6,7,8,	CTD DEEP01
74DI230/1	A24	25	1	ROS	081597	061831	BO	41 30.684 N	013 20.660 W	GPS	5290	9	5270	5445	23	27,28,36,	
74DI230/1	A24	25	1	ROS	081597	084410	EN	41 30.886 N	013 21.672 W	GPS	5291					26,34,35	
74DI230/1	A24	26	1	ROS	081597	114536	BE	41 30.032 N	014 00.027 W	GPS	5293					1-6,7,8,	CTD DEEP01
74DI230/1	A24	26	1	ROS	081597	131658	BO	41 29.848 N	013 59.982 W	GPS	5293	23	5240	5431	23	27,28,36,	
74DI230/1	A24	26	1	ROS	081597	153359	EN	41 29.454 N	014 00.143 W	GPS	5292					24,26,34,35	
74DI230/1	A24	27	1	ROS	081597	184342	BE	41 29.818 N	014 40.147 W	GPS	5145					1-6,7,8,	CTD DEEP01
74DI230/1	A24	27	1	ROS	081597	201353	BO	41 29.050 N	014 40.532 W	GPS	5140	10	5132	5289	23	27,28,36,	
74DI230/1	A24	27	1	ROS	081597	222947	EN	41 28.001 N	014 41.466 W	GPS	5153					26,34,35	
74DI230/1	A24	28	1	ROS	081697	013929	BE	41 29.966 N	015 20.076 W	GPS	5293					1-6,7,8,	CTD DEEP01
74DI230/1	A24	28	1	ROS	081697	030527	BO	41 29.551 N	015 20.156 W	GPS	5293	-999	4985	5151	23	27,28,36,	
74DI230/1	A24	28	1	ROS	081697	052659	EN	41 28.682 N	015 20.683 W	GPS	5292					26,34,35	
74DI230/1	A24	29	1	ROS	081697	084808	BE	41 29.995 N	015 59.851 W	GPS	5271					1-6,7,8,	CTD DEEP01
74DI230/1	A24	29	1	ROS	081697	102452	BO	41 30.013 N	015 59.073 W	GPS	5316	18	5275	5463	23	27,28,36,	
74DI230/1	A24	29	1	ROS	081697	124904	EN	41 29.864 N	015 58.243 W	GPS	5342					24,26,34,35	
74DI230/1	A24	30	1	ROS	081697	171808	BE	41 29.780 N	016 40.025 W	GPS	5420					1-6,7,8,	CTD DEEP01
74DI230/1	A24	30	1	ROS	081697	185609	BO	41 29.483 N	016 40.090 W	GPS	5412	1	5383	5583	23	27,28,36,	
74DI230/1	A24	30	1	ROS	081697	213200	EN	41 28.940 N	016 40.735 W	GPS	5377					26,34,35	
74DI230/1	A24	31	1	ROS	081797	010528	BE	41 29.850 N	017 19.852 W	GPS	5505					1-6,7,8,	CTD DEEP01
74DI230/1	A24	31	1	ROS	081797	024100	BO	41 29.288 N	017 18.831 W	GPS	5478	5	5467	5613	23	27,28,36,	
74DI230/1	A24	31	1	ROS	081797	045933	EN	41 29.628 N	017 19.026 W	GPS	5398					26,34,35	
74DI230/1	A24	32	1	ROS	081797	081543	BE	41 30.061 N	018 00.024 W	GPS	5153					1-6,7,8,	CTD DEEP01
74DI230/1	A24	32	1	ROS	081797	095606	BO	41 30.016 N	017 59.574 W	GPS	5380	17	5325	5521	23	27,28,36,	
74DI230/1	A24	32	1	ROS	081797	121331	EN	41 29.613 N	017 58.627 W	GPS	5426					24,26,34,35	
74DI230/1	A24	33	1	ROS	081797	160026	BE	41 29.845 N	018 39.887 W	GPS	5353					1-6,7,8,	CTD DEEP01
74DI230/1	A24	33	1	ROS	081797	174052	BO	41 29.196 N	018 39.735 W	GPS	5353	15	5320	5503	23	27,28,36,	
74DI230/1	A24	33	1	ROS	081797	195439	EN	41 28.241 N	018 39.817 W	GPS	5352					26,34,35	
74DI230/1	A24	34	1	ROS	081797	233843	BE	41 30.308 N	019 19.953 W	GPS	4654					1-6,7,8,	CTD DEEP01
74DI230/1	A24	34	1	ROS	081897	010137	BO	41 30.557 N	019 19.548 W	GPS	4666	8	4618	4781	23	27,28,36,	
74DI230/1	A24	34	1	ROS	081897	025918	EN	41 30.508 N	019 18.671 W	GPS	4621					26,34,35	

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	35	1	ROS	081897	065142	BE	41 30.010 N	020 00.101 W	GPS	2531					1-6,7,8,	CTD DEEP01
74DI230/1	A24	35	1	ROS	081897	073958	BO	41 29.960 N	020 00.429 W	GPS	2521	12	2485	2563	23	27,28,36,	
74DI230/1	A24	35	1	ROS	081897	085800	EN	41 29.897 N	020 00.909 W	GPS	2497					24,26,34,35	
74DI230/1	A24	36	1	ROS	081897	121232	BE	41 53.634 N	020 25.252 W	GPS	3968					1-6,7,8,	CTD DEEP01
74DI230/1	A24	36	1	ROS	081897	132341	BO	41 54.171 N	020 24.954 W	GPS	3969	11	3920	4041	23	27,28,36,	
74DI230/1	A24	36	1	ROS	081897	152345	EN	41 54.782 N	020 24.380 W	GPS	3938					26,34,35	
74DI230/1	A24	37	1	ROS	081897	183500	BE	42 16.622 N	020 50.198 W	GPS	3906					1-6,7,8,	CTD DEEP01
74DI230/1	A24	37	1	ROS	081897	193352	BO	42 15.938 N	020 50.441 W	GPS	3844	11	3824	3927	23	27,28,36,	
74DI230/1	A24	37	1	ROS	081897	205653	EN	42 15.052 N	020 51.286 W	GPS	3838					26,34,35	
74DI230/1	A24	38	1	ROS	081997	010711	BE	42 40.010 N	021 15.067 W	GPS	2612					1-6,7,8,	CTD DEEP01
74DI230/1	A24	38	1	ROS	081997	014750	BO	42 39.873 N	021 15.610 W	GPS	2692	8	2674	2713	23	27,28,36,	
74DI230/1	A24	38	1	ROS	081997	025538	EN	42 39.887 N	021 16.366 W	GPS	2766					24,26,34,35	
74DI230/1	A24	39	1	ROS	081997	062207	BE	43 03.745 N	021 39.698 W	GPS	2722					1-6,7,8,	CTD DEEP01
74DI230/1	A24	39	1	ROS	081997	070242	BO	43 03.913 N	021 39.846 W	GPS	2721	-999	2670	2753	23	27,28,36,	
74DI230/1	A24	39	1	ROS	081997	084058	EN	43 03.847 N	021 40.142 W	GPS	2546					26,34,35	
74DI230/1	A24	40	1	ROS	081997	123805	BE	43 26.845 N	022 04.945 W	GPS	2490					1-6,7,8,	CTD DEEP01
74DI230/1	A24	40	1	ROS	081997	132351	BO	43 26.613 N	022 05.007 W	GPS	2512	15	2470	2545	23	27,28,36,	
74DI230/1	A24	40	1	ROS	081997	143808	EN	43 26.416 N	022 05.506 W	GPS	2438					26,34,35	
74DI230/1	A24	41	1	ROS	081997	175950	BE	43 50.257 N	022 30.439 W	GPS	3842					1-6,7,8,	CTD DEEP01
74DI230/1	A24	41	1	ROS	081997	190923	BO	43 50.489 N	022 30.305 W	GPS	3781	17	3810	3933	23	27,28,36,	
74DI230/1	A24	41	1	ROS	081997	205925	EN	43 51.279 N	022 30.955 W	GPS	3711					24,26,34,35	
74DI230/1	A24	42	1	ROS	082097	003906	BE	44 13.375 N	022 55.936 W	GPS	4122					1-6,7,8,	CTD DEEP01
74DI230/1	A24	42	1	ROS	082097	015103	BO	44 13.145 N	022 55.657 W	GPS	4138	12	4105	4241	23	27,28,36,	
74DI230/1	A24	42	1	ROS	082097	040110	EN	44 12.858 N	022 54.693 W	GPS	4143					26,34,35	
74DI230/1	A24	43	1	ROS	082097	071556	BE	44 36.977 N	023 20.921 W	GPS	3166					1-6,7,8,	CTD DEEP01
74DI230/1	A24	43	1	ROS	082097	081220	BO	44 36.991 N	023 20.443 W	GPS	3172	17	3115	3213	23	27,28,36,	
74DI230/1	A24	43	1	ROS	082097	095717	EN	44 36.675 N	023 19.629 W	GPS	3162					26,34,35	
74DI230/1	A24	44	1	ROS	082097	135743	BE	45 00.152 N	023 46.800 W	GPS	3209					1-6,7,8,	CTD DEEP01
74DI230/1	A24	44	1	ROS	082097	145337	BO	44 59.701 N	023 46.259 W	GPS	3214	13	3170	3245	23	27,28,36,	
74DI230/1	A24	44	1	ROS	082097	163000	EN	45 00.083 N	023 47.069 W	GPS	3219					24,26,34,35	
74DI230/1	A24	45	1	ROS	082097	194201	BE	45 23.652 N	024 13.120 W	G24	3167					1-6,7,8,	CTD DEEP01
74DI230/1	A24	45	1	ROS	082097	203759	BO	45 23.319 N	024 13.175 W	G24	3165	22	3111	3201	23	27,28,36,	
74DI230/1	A24	45	1	ROS	082097	220809	EN	45 22.951 N	024 13.682 W	G24	3190					26,34,35	
74DI230/1	A24	46	1	ROS	082197	013950	BE	45 47.174 N	024 39.140 W	G24	3111					1-6,7,8,	CTD DEEP01
74DI230/1	A24	46	1	ROS	082197	023253	BO	45 47.301 N	024 38.760 W	G24	3106	17	3045	3139	23	27,28,36,	
74DI230/1	A24	46	1	ROS	082197	035955	EN	45 47.642 N	024 38.217 W	G24	3100					26,34,35	
74DI230/1	A24	47	1	ROS	082197	071154	BE	46 10.436 N	025 05.151 W	G24	3303					1-6,7,8,	CTD DEEP01
74DI230/1	A24	47	1	ROS	082197	081226	BO	46 10.028 N	025 05.090 W	G24	3308	17	3276	3353	23	27,28,36,	
74DI230/1	A24	47	1	ROS	082197	094600	EN	46 09.374 N	025 05.749 W	G24	3321					24,26,34,35	
74DI230/1	A24	48	1	ROS	082197	132631	BE	46 33.740 N	025 32.636 W	G24	2857					1-6,7,8,	CTD DEEP01
74DI230/1	A24	48	1	ROS	082197	141039	BO	46 33.770 N	025 32.718 W	G24	2879	12	2895	2987	23	27,28,36,	
74DI230/1	A24	48	1	ROS	082197	152537	EN	46 34.232 N	025 32.793 W	G24	3016					26,34,35	
74DI230/1	A24	49	1	ROS	082197	185325	BE	46 57.258 N	025 59.928 W	G24	2880					1-6,7,8,	CTD DEEP01
74DI230/1	A24	49	1	ROS	082197	194721	BO	46 57.664 N	025 59.938 W	G24	2864	13	2828	2911	23	27,28,36,	
74DI230/1	A24	49	1	ROS	082197	211350	EN	46 58.276 N	026 00.273 W	G24	2724					26,34,35	
74DI230/1	A24	50	1	ROS	082297	003346	BE	47 20.377 N	026 27.074 W	G24	2991					1-6,7,8,	CTD DEEP01
74DI230/1	A24	50	1	ROS	082297	012520	BO	47 19.829 N	026 27.542 W	G24	2946	80	2916	2973	23	27,28,36,	
74DI230/1	A24	50	1	ROS	082297	025348	EN	47 19.255 N	026 28.157 W	G24	2934					24,26,34,35	
74DI230/1	A24	51	1	ROS	082297	061411	BE	47 43.640 N	026 54.466 W	G24	2625					1-6,7,8,	CTD DEEP01
74DI230/1	A24	51	1	ROS	082297	070300	BO	47 43.255 N	026 54.457 W	G24	2628	11	2575	2649	23	27,28,36,	
74DI230/1	A24	51	1	ROS	082297	084500	EN	47 43.334 N	026 54.150 W	G24	2633					26,34,35	

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	52	1	ROS	082297	115637	BE	48 07.266 N	027 22.015 W	G24	2701					1-6,7,8,	CTD DEEP01
74DI230/1	A24	52	1	ROS	082297	124755	BO	48 07.014 N	027 21.309 W	G24	2771	11	2770	2829	23	27,28,36,	
74DI230/1	A24	52	1	ROS	082297	145107	EN	48 06.424 N	027 19.559 W	G24	2768					26,34,35	
74DI230/1	A24	53	1	ROS	082297	181753	BE	48 30.552 N	027 50.275 W	G24	2504					1-6,7,8,	CTD DEEP01
74DI230/1	A24	53	1	ROS	082297	190404	BO	48 30.483 N	027 50.641 W	G24	2526	11	2508	2583	23	27,28,36,	
74DI230/1	A24	53	1	ROS	082297	201402	EN	48 30.519 N	027 51.237 W	G24	2757					24,34,35	
74DI230/1	A24	54	1	ROS	082297	235208	BE	48 53.980 N	028 18.903 W	G24	1861					1-6,7,8,	CTD DEEP01
74DI230/1	A24	54	1	ROS	082397	002948	BO	48 54.119 N	028 18.780 W	G24	1984	8	2003	2061	22	27,28,36,	
74DI230/1	A24	54	1	ROS	082397	013511	EN	48 54.289 N	028 18.133 W	G24	2052					26,34,35	
74DI230/1	A24	55	1	ROS	082397	050042	BE	49 17.195 N	028 47.437 W	G24	3230					1-6,7,8,	CTD DEEP01
74DI230/1	A24	55	1	ROS	082397	060026	BO	49 16.859 N	028 46.783 W	G24	3017	109	3062	3157	23	27,28,36,	
74DI230/1	A24	55	1	ROS	082397	073527	EN	49 16.741 N	028 46.090 W	G24	2776					26,34,35	
74DI230/1	A24	56	1	ROS	082397	105843	BE	49 40.522 N	029 15.412 W	G24	2545					1-6,7,8,	CTD DEEP01
74DI230/1	A24	56	1	ROS	082397	114300	BO	49 39.978 N	029 14.951 W	G24	2458	9	2445	2503	23	27,28,36,	
74DI230/1	A24	56	1	ROS	082397	130856	EN	49 39.139 N	029 13.917 W	G24	2367					24,26,34,35	
74DI230/1	A24	57	1	ROS	082397	165813	BE	50 03.929 N	029 43.221 W	G24	3043					1-6,7,8,	CTD DEEP01
74DI230/1	A24	57	1	ROS	082397	175731	BO	50 03.386 N	029 42.616 W	G24	2825	12	2845	2923	23	27,28,36,	
74DI230/1	A24	57	1	ROS	082397	192406	EN	50 02.523 N	029 42.567 W	G24	2857					26,34,35	
74DI230/1	A24	58	1	ROS	082497	081714	BE	50 27.374 N	030 13.013 W	G24	3232					1-6,7,8,	CTD DEEP01
74DI230/1	A24	58	1	ROS	082497	092040	BO	50 27.215 N	030 13.048 W	G24	3260	45	3185	3291	23	27,28,36,	
74DI230/1	A24	58	1	ROS	082497	105624	EN	50 26.850 N	030 13.499 W	G24	3261					26,34,35	
74DI230/1	A24	59	1	ROS	082497	152912	BE	50 50.584 N	030 42.100 W	G24	3442					1-6,7,8,	CTD DEEP01
74DI230/1	A24	59	1	ROS	082497	163311	BO	50 50.315 N	030 41.703 W	G24	3446	8	3379	3487	23	27,28,36,	
74DI230/1	A24	59	1	ROS	082497	180423	EN	50 49.787 N	030 41.717 W	G24	3421					24,26,34,35	
74DI230/1	A24	60	1	ROS	082497	225443	BE	51 14.209 N	031 10.629 W	G24	2710					1-6,7,8,	CTD DEEP01
74DI230/1	A24	60	1	ROS	082497	234809	BO	51 14.656 N	031 09.772 W	G24	2786	7	2752	2807	23	27,28,36,	
74DI230/1	A24	60	1	ROS	082597	010955	EN	51 15.470 N	031 08.496 W	G24	2617					26,34,35	
74DI230/1	A24	61	1	ROS	082597	043134	BE	51 37.473 N	031 39.357 W	G24	3382					1-6,7,8,	CTD DEEP01
74DI230/1	A24	61	1	ROS	082597	053322	BO	51 37.314 N	031 38.897 W	G24	3380	61	3300	3409	23	27,28,36,	
74DI230/1	A24	61	1	ROS	082597	070148	EN	51 36.875 N	031 38.248 W	G24	3552					26,34,35	
74DI230/1	A24	62	1	ROS	082597	101941	BE	52 00.312 N	032 08.912 W	G24	2916					1-6,7,8,	CTD DEEP01
74DI230/1	A24	62	1	ROS	082597	111914	BO	52 00.420 N	032 09.067 W	G24	2999	10	2935	3031	23	27,28,36,	
74DI230/1	A24	62	1	ROS	082597	124449	EN	52 00.141 N	032 09.372 W	G24	3010					26	
74DI230/1	A24	63	1	ROS	082597	145335	BE	52 13.311 N	032 25.645 W	G24	3997					1-6,7,8,	CTD DEEP01
74DI230/1	A24	63	1	ROS	082597	155832	BO	52 13.496 N	032 25.570 W	G24	3996	29	3918	4051	23	27,28,36,	
74DI230/1	A24	63	1	ROS	082597	180500	EN	52 15.092 N	032 27.998 W	G24	3963					24,26,34,35	
74DI230/1	A24	64	1	ROS	082597	194805	BE	52 24.584 N	032 40.804 W	G24	3115					1-6,7,8,	CTD DEEP01
74DI230/1	A24	64	1	ROS	082597	204547	BO	52 24.388 N	032 41.173 W	G24	3081	10	3078	3173	23	27,28,36,	
74DI230/1	A24	64	1	ROS.	082597	220731	EN	52 24.388 N	032 41.759 W	G24	3060					26	
74DI230/1	A24	65	1	ROS	082697	005117	BE	52 38.318 N	032 58.307 W	G24	4540					1-6,7,8,	CTD DEEP01
74DI230/1	A24	65	1	ROS	082697	020948	BO	52 38.027 N	032 58.285 W	G24	4542	9	4477	4633	23	27,28,36,	
74DI230/1	A24	65	1	ROS	082697	040431	EN	52 37.551 N	032 58.548 W	G24	4296					24,26,34,35	
74DI230/1	A24	66	1	ROS	082697	060558	BE	52 42.291 N	033 03.957 W	G24	3360					1-6,7,8,	CTD DEEP01
74DI230/1	A24	66	1	ROS	082697	070848	BO	52 42.272 N	033 03.832 W	G24	3370	10	3325	3433	18	27,28,36,	
74DI230/1	A24	66	1	ROS	082697	084136	EN	52 42.190 N	033 04.754 W	G24	3333					26	
74DI230/1	A24	67	1	ROS	082697	104853	BE	52 46.213 N	033 08.707 W	G24	3120					1-6,	CTD DEEP01
74DI230/1	A24	67	1	ROS	082697	114908	BO	52 46.095 N	033 09.472 W	G24	3126	11	3045	3143	23	26	
74DI230/1	A24	67	1	ROS	082697	131701	EN	52 46.319 N	033 10.178 W	G24	3159						
74DI230/1	A24	68	1	ROS	082697	165416	BE	53 05.842 N	033 34.059 W	G24	2996					1-6,7,8,	CTD DEEP01
74DI230/1	A24	68	1	ROS	082697	175217	BO	53 05.932 N	033 33.989 W	G24	3002	61	2920	3015	23	27,28,36,	
74DI230/1	A24	68	1	ROS	082697	192229	EN	53 05.788 N	033 33.950 W	G24	2999					24,26,34,35	

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	69	1	ROS	082697	233355	BE	53 24.682 N	034 00.076 W	G24	2812					1-6,	CTD DEEP01
74DI230/1	A24	69	1	ROS	082797	002251	BO	53 24.554 N	034 00.652 W	G24	2834	31	2762	2841	23	26	
74DI230/1	A24	69	1	ROS	082797	014131	EN	53 24.334 N	034 01.593 W	G24	2861						
74DI230/1	A24	70	1	ROS	082797	051948	BE	53 48.153 N	034 31.346 W	G24	1968					1-6,7,8,	CTD DEEP01
74DI230/1	A24	70	1	ROS	082797	055941	BO	53 48.089 N	034 31.147 W	G24	2031	10	1975	2035	23	27,28,36,	
74DI230/1	A24	70	1	ROS	082797	072000	EN	53 48.036 N	034 31.577 W	G24	1906					26,34,35	
74DI230/1	A24	71	1	ROS	082797	111348	BE	54 11.383 N	035 03.303 W	G24	2406					1-6,7,8,	CTD DEEP01
74DI230/1	A24	71	1	ROS	082797	120401	BO	54 10.965 N	035 03.747 W	G24	2298	6	2400	2455	23	27,28,36,	
74DI230/1	A24	71	1	ROS	082797	132823	EN	54 10.656 N	035 04.378 W	G24	2334					24,26,34,35	
74DI230/1	A24	72	1	ROS	082797	165632	BE	54 34.866 N	035 35.499 W	G24	1922					1-6,7,8,	CTD DEEP01
74DI230/1	A24	72	1	ROS	082797	173352	BO	54 34.825 N	035 35.697 W	G24	1776	13	1870	1925	23	27,28,36,	
74DI230/1	A24	72	1	ROS	082797	184133	EN	54 34.934 N	035 36.165 W	G24	1776					26,34,35	
74DI230/1	A24	73	1	ROS	082797	220315	BE	54 58.145 N	036 07.663 W	G24	1696					1-6,7,8,	CTD DEEP01
74DI230/1	A24	73	1	ROS	082797	224317	BO	54 58.183 N	036 07.675 W	G24	1666	16	1720	1771	21	27,28,36,	
74DI230/1	A24	73	1	ROS	082797	234241	EN	54 58.223 N	036 07.996 W	G24	1605					34,35	
74DI230/1	A24	74	1	ROS	082897	030914	BE	55 21.457 N	036 40.352 W	G24	2480					1-6,7,8,	CTD DEEP01
74DI230/1	A24	74	1	ROS	082897	035755	BO	55 21.402 N	036 40.383 W	G24	2478	10	2408	2485	23	27,28,36,	
74DI230/1	A24	74	1	ROS	082897	051736	EN	55 21.184 N	036 39.975 W	G24	2497					24,26,34,35	
74DI230/1	A24	75	1	ROS	082897	084035	BE	55 44.991 N	037 12.972 W	G24	2605					1-6,7,8,	CTD DEEP01
74DI230/1	A24	75	1	ROS	082897	092700	BO	55 44.935 N	037 12.770 W	G24	2606	12	2525	2607	23	27,28,36,	
74DI230/1	A24	75	1	ROS	082897	105408	EN	55 44.675 N	037 11.914 W	G24	2596					26,34,35	
74DI230/1	A24	76	1	ROS	082897	141330	BE	56 08.372 N	037 46.952 W	G24	2831					1-6,7,8,	CTD DEEP01
74DI230/1	A24	76	1	ROS	082897	150342	BO	56 08.477 N	037 46.723 W	G24	2826	8	2750	2839	23	27,28,36,	
74DI230/1	A24	76	1	ROS	082897	162318	EN	56 08.587 N	037 45.911 W	G24	2786					26,34,35	
74DI230/1	A24	77	1	ROS	082897	193448	BE	56 31.559 N	038 20.964 W	G24	3051					1-6,7,8,	CTD DEEP01
74DI230/1	A24	77	1	ROS	082897	202757	BO	56 31.329 N	038 21.450 W	G24	3006	9	2999	3089	23	27,28,36,	
74DI230/1	A24	77	1	ROS	082897	214334	EN	56 30.907 N	038 21.831 W	G24	2995					24,26,34,35	
74DI230/1	A24	78	1	ROS	082997	005058	BE	56 55.214 N	038 54.720 W	G24	3293					1-6,7,8,	CTD DEEP01
74DI230/1	A24	78	1	ROS	082997	014916	BO	56 55.531 N	038 54.444 W	G24	3294	9	3213	3317	23	27,28,36,	
74DI230/1	A24	78	1	ROS	082997	031434	EN	56 55.987 N	038 54.138 W	G24	3294					26,34,35	
74DI230/1	A24	79	1	ROS	082997	060922	BE	57 18.395 N	039 28.437 W	G24	3250					1-6,7,8,	CTD DEEP01
74DI230/1	A24	79	1	ROS	082997	070825	BO	57 18.419 N	039 27.967 W	G24	3245	11	3165	3269	23	27,28,36,	
74DI230/1	A24	79	1	ROS	082997	085008	EN	57 18.685 N	039 27.568 W	G24	3253					26,34,35	
74DI230/1	A24	80	1	ROS	082997	120110	BE	57 41.849 N	040 03.006 W	G24	3249					1-6,7,8,	CTD DEEP01
74DI230/1	A24	80	1	ROS	082997	125657	BO	57 42.198 N	040 02.765 W	G24	3251	11	3170	3273	23	27,28,36,	
74DI230/1	A24	80	1	ROS	082997	143107	EN	57 42.419 N	040 02.718 W	G24	3252					24,26,34,35	
74DI230/1	A24	81	1	ROS	082997	175314	BE	58 05.141 N	040 37.524 W	G24	3219					1-6,7,8,	CTD DEEP01
74DI230/1	A24	81	1	ROS	082997	185504	BO	58 05.036 N	040 37.327 W	G24	3219	10	3140	3239	23	27,28,36,	
74DI230/1	A24	81	1	ROS	082997	202247	EN	58 05.046 N	040 38.079 W	G24	3219					26,34,35	
74DI230/1	A24	82	1	ROS	083097	000603	BE	58 24.524 N	041 03.262 W	G24	3159					1-6,7,8,	CTD DEEP01
74DI230/1	A24	82	1	ROS	083097	010355	BO	58 24.422 N	041 03.827 W	G24	3160	9	3086	3177	23	27,28,36,	
74DI230/1	A24	82	1	ROS	083097	023345	EN	58 24.662 N	041 04.575 W	G24	3159					34,35	
74DI230/1	A24	83	1	ROS	083097	070107	BE	58 41.535 N	041 28.380 W	G24	2984					1-6,7,8,	CTD DEEP01
74DI230/1	A24	83	1	ROS	083097	075513	BO	58 41.332 N	041 28.637 W	G24	2989	10	2905	3001	23	27,28,36,	
74DI230/1	A24	83	1	ROS	083097	093012	EN	58 40.978 N	041 28.917 W	G24	3002					24,26,34,35	
74DI230/1	A24	84	1	ROS	083097	111553	BE	58 51.661 N	041 44.881 W	G24	2759					1-6,7,8,	CTD DEEP01
74DI230/1	A24	84	1	ROS	083097	120613	BO	58 51.466 N	041 44.542 W	G24	2768	7	2697	2773	23	27,28,36,	
74DI230/1	A24	84	1	ROS	083097	133208	EN	58 51.062 N	041 44.633 W	G24	2786					34,35	
74DI230/1	A24	85	1	ROS	083197	003903	BE	58 59.676 N	041 54.347 W	G24	2516					1-6,7,8,	CTD DEEP01
74DI230/1	A24	85	1	ROS	083197	012552	BO	58 59.526 N	041 55.251 W	G24	2509	10	2479	2513	23	27,28,36,	
74DI230/1	A24	85	1	ROS	083197	024233	EN	58 59.215 N	041 56.363 W	G24	2507					26,34,35	

Ship/crs	WOCE	Stn	Cast	Cast		UTC	Event				Unc	Ht	Wire	Max	Nbr		
expocode	Sect	Nbr	Nbr	Type	Date	Time	Code	Lat	Lon	Nav	Dep	bot	out	Pres	Btl	Parameters	Comments
74DI230/1	A24	86	1	ROS	083197	045458	BE	59 07.872 N	042 08.298 W	G24	2240					1-6,7,8,	CTD DEEP01
74DI230/1	A24	86	1	ROS	083197	053717	BO	59 07.897 N	042 08.053 W	G24	2245	6	2188	2247	23	27,28,36,	
74DI230/1	A24	86	1	ROS	083197	064813	EN	59 07.637 N	042 07.899 W	G24	2255					26,34,35	
74DI230/1	A24	87	1	ROS	083197	085039	BE	59 17.675 N	042 24.952 W	G24	2073					1-6,7,8,	CTD DEEP01
74DI230/1	A24	87	1	ROS	083197	093008	BO	59 17.429 N	042 25.653 W	G24	2054	10	1990	2049	23	27,28,36,	
74DI230/1	A24	87	1	ROS	083197	103654	EN	59 16.877 N	042 26.916 W	G24	2059					24,26	
74DI230/1	A24	88	1	ROS	083197	124901	BE	59 27.285 N	042 38.231 W	G24	1780					1-6,7,8,	CTD DEEP01
74DI230/1	A24	88	1	ROS	083197	132023	BO	59 26.937 N	042 38.669 W	G24	1774	9	1737	1771	17	27,28,36,	
74DI230/1	A24	88	1	ROS	083197	142218	EN	59 26.043 N	042 39.662 W	G24	1718					34,35	
74DI230/1	A24	89	1	ROS	083197	153123	BE	59 28.744 N	042 48.412 W	G24	1401					1-6,7,8,	CTD DEEP01
74DI230/1	A24	89	1	ROS	083197	160309	BO	59 28.676 N	042 48.937 W	G24	1373	5	1340	1375	17	27,28,36,	
74DI230/1	A24	89	1	ROS	083197	165043	EN	59 28.239 N	042 49.966 W	G24	1238					26	
74DI230/1	A24	90	1	ROS	083197	173332	BE	59 30.939 N	042 50.985 W	G24	954					1-6,7,8,	CTD DEEP01
74DI230/1	A24	90	1	ROS	083197	175956	BO	59 30.757 N	042 51.883 W	G24	932	10	912	935	14	27,28,36,	
74DI230/1	A24	90	1	ROS	083197	183632	EN	59 30.607 N	042 52.943 W	G24	672					34,35	
74DI230/1	A24	91	1	ROS	083197	193412	BE	59 34.768 N	042 54.173 W	G24	551					1-6,	CTD DEEP01
74DI230/1	A24	91	1	ROS	083197	194619	BO	59 34.807 N	042 54.407 W	G24	538	9	515	529	11	24,26,	
74DI230/1	A24	91	1	ROS	083197	200905	EN	59 34.855 N	042 54.849 W	G24	522					34,35	
74DI230/1	A24	92	1	ROS	083197	205810	BE	59 39.316 N	042 58.474 W	G24	203					1-6,7,8,	CTD DEEP01
74DI230/1	A24	92	1	ROS	083197	210355	BO	59 39.288 N	042 58.663 W	G24	203	9	184	193	7	27,28,36,	
74DI230/1	A24	92	1	ROS	083197	211734	EN	59 39.255 N	042 59.105 W	G24	206					34,35	
74DI230/1	A24	93	1	ROS	083197	235124	BE	59 51.898 N	043 19.081 W	G24	168					1-6,7,8,	CTD DEEP01
74DI230/1	A24	93	1	ROS	083197	235529	BO	59 51.909 N	043 19.149 W	G24	168	10	150	155	6	27,28,36,	End of Spain-
74DI230/1	A24	93	1	ROS	090197	001138	EN	59 52.016 N	043 19.039 W	G24	163					24,26,34,35	Greenland Sect.
74DI230/1	A24	94	1	ROS	090397	121254	BE	61 25.762 N	035 43.975 W	G24	2914					1-6,7,8,	CTD DEEP01
74DI230/1	A24	94	1	ROS	090397	130321	BO	61 25.491 N	035 44.630 W	G24	2914	8	2844	2929	23	27,28,36,	Start E. Green-
74DI230/1	A24	94	1	ROS	090397	143142	EN	61 25.202 N	035 45.622 W	G24	2911					24,26,34,35	land Cent. Sect.
74DI230/1	A24	95	1	ROS	090397	175536	BE	61 42.883 N	036 34.760 W	G24	2746					1-6,7,8,	CTD DEEP01
74DI230/1	A24	95	1	ROS	090397	184749	BO	61 42.782 N	036 35.102 W	G24	2746	8	2672	2755	23	27,28,36,	
74DI230/1	A24	95	1	ROS	090397	200611	EN	61 42.699 N	036 35.992 W	G24	2745					26,34,35	
74DI230/1	A24	96	1	ROS	090397	232233	BE	62 01.018 N	037 27.844 W	G24	2563					1-6,7,8,	CTD DEEP01
74DI230/1	A24	96	1	ROS	090497	000748	BO	62 01.087 N	037 28.414 W	G24	2562	5	2495	2571	23	27,28,36,	
74DI230/1	A24	96	1	ROS	090497	012755	EN	62 01.040 N	037 29.218 W	G24	2560					26,34,35	
74DI230/1	A24	97	1	ROS	090497	072259	BE	62 17.995 N	038 19.280 W	G24	2379					1-6,7,8,	CTD DEEP01
74DI230/1	A24	97	1	ROS	090497	080335	BO	62 17.754 N	038 19.550 W	G24	2377	10	2300	2377	23	27,28,36,	
74DI230/1	A24	97	1	ROS	090497	092125	EN	62 17.362 N	038 19.807 W	G24	2374					24,26,34,35	
74DI230/1	A24	98	1	ROS	090497	122707	BE	62 35.057 N	039 13.755 W	G24	2019					1-6,7,8,	CTD DEEP01
74DI230/1	A24	98	1	ROS	090497	130433	BO	62 34.984 N	039 14.221 W	G24	2014	7	1962	2015	19	27,28,36,	
74DI230/1	A24	98	1	ROS	090497	141800	EN	62 35.702 N	039 15.869 W	G24	2005					26,34,35	
74DI230/1	A24	99	1	ROS	090497	173118	BE	62 53.362 N	040 11.867 W	G24	1516					1-6,7,8,	CTD DEEP01
74DI230/1	A24	99	1	ROS	090497	180229	BO	62 53.019 N	040 12.137 W	G24	1514	13	1460	1503	18	27,28,36,	
74DI230/1	A24	99	1	ROS	090497	185841	EN	62 52.840 N	040 13.302 W	G24	1482					26,34,35	
74DI230/1	A24	100	1	ROS	090497	195935	BE	62 56.298 N	040 17.881 W	G24	918					1-6,	CTD DEEP01
74DI230/1	A24	100	1	ROS	090497	201732	BO	62 56.242 N	040 18.098 W	G24	847	10	878	887	15	24,26	
74DI230/1	A24	100	1	ROS	090497	204912	EN	62 55.946 N	040 18.143 W	G24	815						
74DI230/1	A24	101	1	ROS	090497	214033	BE	62 56.140 N	040 19.074 W	G24	543					1-6,7,8,	CTD DEEP01
74DI230/1	A24	101	1	ROS	090497	215342	BO	62 56.066 N	040 19.093 W	G24	534	4	539	553	12	27,28,36,	
74DI230/1	A24	101	1	ROS	090497	221953	EN	62 55.928 N	040 19.138 W	G24	513					26,34,35	
74DI230/1	A24	102	1	ROS	090597	011355	BE	63 02.359 N	040 47.940 W	G24	323					1-6,7,8,	CTD DEEP01
74DI230/1	A24	102	1	ROS	090597	011959	BO	63 02.249 N	040 48.067 W	G24	304	6	293	297	9	27,28,36,	End E. Green-
74DI230/1	A24	102	1	ROS	090597	013436	EN	63 01.901 N	040 48.451 W	G24	277					24,26,34,35	land Cent. Sect.

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	103	1	ROS	090697	160059	BE	65 31.193 N	030 22.947 W	G24	384					1-6,7,8,	CTD DEEP01
74DI230/1	A24	103	1	ROS	090697	161256	BO	65 31.386 N	030 23.788 W	G24	385	4	372	377	10	27,28,36,	Start Denmark
74DI230/1	A24	103	1	ROS	090697	163841	EN	65 31.918 N	030 24.824 W	G24	389					24,26,34,35	Strait Sect.
74DI230/1	A24	104	1	ROS	090697	175353	BE	65 26.051 N	030 17.572 W	G24	606					1-6,7,8,	CTD DEEP01
74DI230/1	A24	104	1	ROS	090697	181052	BO	65 26.305 N	030 18.014 W	G24	581	12	570	571	10	27,28,36,	
74DI230/1	A24	104	1	ROS	090697	184500	EN	65 26.233 N	030 18.210 W	G24	590					26	
74DI230/1	A24	105	1	ROS	090697	200630	BE	65 19.703 N	030 09.154 W	G24	1102					1-6,7,8,	CTD DEEP01
74DI230/1	A24	105	1	ROS	090697	203714	BO	65 19.850 N	030 09.279 W	G24	1092	10	1086	1087	17	27,28,36,	
74DI230/1	A24	105	1	ROS	090697	212102	EN	65 19.851 N	030 09.940 W	G24	1087					26,34,35	
74DI230/1	A24	106	1	ROS	090797	084340	BE	65 11.328 N	030 02.033 W	G24	1555					1-6,7,8,	CTD DEEP01
74DI230/1	A24	106	1	ROS	090797	092037	BO	65 11.013 N	030 02.742 W	G24	1565	7	1540	1559	23	27,28,36,	
74DI230/1	A24	106	1	ROS	090797	102744	EN	65 10.454 N	030 04.066 W	G24	1583					24,26,34,35	
74DI230/1	A24	107	1	ROS	090797	131307	BE	65 00.273 N	029 49.051 W	G24	1905					1-6,7,8,	CTD DEEP01
74DI230/1	A24	107	1	ROS	090797	135030	BO	65 00.297 N	029 48.844 W	G24	1906	8	1877	1903	22	27,28,36,	
74DI230/1	A24	107	1	ROS	090797	152044	EN	65 00.423 N	029 42.744 W	G24	1902					26,34,35	
74DI230/1	A24	108	1	ROS	090797	170901	BE	64 59.777 N	029 01.922 W	G24	1385					1-6,7,8,	CTD DEEP01
74DI230/1	A24	108	1	ROS	090797	175851	BO	64 59.329 N	029 01.445 W	G24	1348	12	1330	1345	16	27,28,36,	
74DI230/1	A24	108	1	ROS	090797	185009	EN	64 58.935 N	029 01.170 W	G24	1412					26	
74DI230/1	A24	109	1	ROS	090797	205948	BE	64 59.826 N	028 13.206 W	G24	1021					1-6,7,8,	CTD DEEP01
74DI230/1	A24	109	1	ROS	090797	212424	BO	64 59.565 N	028 12.796 W	G24	1016	5	1022	1009	16	27,28,36,	
74DI230/1	A24	109	1	ROS	090797	220455	EN	64 59.398 N	028 12.957 W	G24	1011					24,26,34,35	
74DI230/1	A24	110	1	ROS	090897	002920	BE	65 00.244 N	027 29.753 W	G24	513					1-6,7,8,	CTD DEEP01
74DI230/1	A24	110	1	ROS	090897	004629	BO	65 00.256 N	027 29.900 W	G24	509	9	496	497	11	27,28,36,	End Denmark
74DI230/1	A24	110	1	ROS	090897	011457	EN	65 00.424 N	027 30.222 W	G24	517					26	Strait Sect.
74DI230/1	A24	111	1	ROS	090997	070832	BE	63 17.648 N	019 59.827 W	G24	213					1-6,7,8,	CTD DEEP01
74DI230/1	A24	111	1	ROS	090997	071618	BO	63 17.671 N	019 59.607 W	G24	215	11	200	203	6	27,28,36,	Start Iceland-
74DI230/1	A24	111	1	ROS	090997	073218	EN	63 17.613 N	019 59.438 W	G24	218					24,26,34,35	Scotland Sect.
74DI230/1	A24	112	1	ROS	090997	082611	BE	63 13.602 N	020 03.347 W	G24	574					1-6,7,8,	CTD DEEP01
74DI230/1	A24	112	1	ROS	090997	083956	BO	63 13.550 N	020 03.286 W	G24	602	13	580	591	11	27,28,36,	
74DI230/1	A24	112	1	ROS	090997	090440	EN	63 13.470 N	020 03.238 W	G24	616					26,34,35	
74DI230/1	A24	113	1	ROS	090997	111801	BE	62 54.497 N	019 59.829 W	G24	1210					1-6,7,8,	CTD DEEP01
74DI230/1	A24	113	1	ROS	090997	113941	BO	62 54.606 N	019 59.658 W	G24	1206	11	1181	1199	14	27,28,36,	
74DI230/1	A24	113	1	ROS	090997	123300	EN	62 54.166 N	019 59.483 W	G24	1232					26,34,35	
74DI230/1	A24	114	1	ROS	090997	141835	BE	62 39.097 N	020 00.044 W	G24	1513					1-6,7,8,	CTD DEEP01
74DI230/1	A24	114	1	ROS	090997	144609	BO	62 39.223 N	019 59.844 W	G24	1513	11	1492	1509	16	27,28,36,	
74DI230/1	A24	114	1	ROS	090997	153807	EN	62 39.120 N	019 59.236 W	G24	1521					24,26,34,35	
74DI230/1	A24	115	1	ROS	090997	175528	BE	62 18.986 N	019 59.908 W	G24	1828					1-6,7,8,	CTD DEEP01
74DI230/1	A24	115	1	ROS	090997	183243	BO	62 19.131 N	019 59.780 W	G24	1823	10	1794	1825	22	27,28,36,	
74DI230/1	A24	115	1	ROS	090997	193800	EN	62 18.919 N	020 00.094 W	G24	1829					26,34,35	
74DI230/1	A24	116	1	ROS	090997	222041	BE	61 58.286 N	019 59.414 W	G24	1798					1-6,7,8,	CTD DEEP01
74DI230/1	A24	116	1	ROS	090997	225848	BO	61 57.933 N	019 59.317 W	G24	1795	6	1783	1799	23	27,28,36,	
74DI230/1	A24	116	1	ROS	091097	000929	EN	61 57.342 N	019 59.926 W	G24	1795					26	
74DI230/1	A24	117	1	ROS	091097	062726	BE	61 38.693 N	020 00.492 W	G24	2016					1-6,7,8,	CTD DEEP01
74DI230/1	A24	117	1	ROS	091097	072121	BO	61 39.027 N	020 01.302 W	G24	2000	13	1970	2001	23	27,28,36,	
74DI230/1	A24	117	1	ROS	091097	083945	EN	61 39.049 N	020 02.301 W	G24	1991					24,26,34,35	
74DI230/1	A24	118	1	ROS	091097	110919	BE	61 17.206 N	019 59.989 W	G24	2385					1-6,7,8,	CTD DEEP01
74DI230/1	A24	118	1	ROS	091097	115531	BO	61 17.380 N	020 00.306 W	G24	2385	10	2352	2393	23	27,28,36,	
74DI230/1	A24	118	1	ROS	091097	131835	EN	61 17.625 N	020 00.498 W	G24	2381					26,34,35	
74DI230/1	A24	119	1	ROS	091097	154805	BE	60 55.872 N	019 59.582 W	G24	2413					1-6,7,8,	CTD DEEP01
74DI230/1	A24	119	1	ROS	091097	163954	BO	60 56.079 N	019 58.665 W	G24	2414	11	2382	2423	23	27,28,36,	
74DI230/1	A24	119	1	ROS	091097	175257	EN	60 56.327 N	019 56.936 W	G24	2411					26	

Ship/crs expocode	WOCE Sect	Stn Nbr	Cast Nbr	Cast Type	Date	UTC Time	Event Code	Lat	Lon	Nav	Unc Dep	Ht bot	Wire out	Max Pres	Nbr Btl	Parameters	Comments
74DI230/1	A24	120	1	ROS	091097	201514	BE	60 34.301 N	020 00.065 W	G24	2490					1-6,7,8,	CTD DEEP01
74DI230/1	A24	120	1	ROS	091097	210059	BO	60 34.322 N	020 01.025 W	G24	2483	9	2462	2497	23	27,28,36,	
74DI230/1	A24	120	1	ROS	091097	221809	EN	60 34.486 N	020 02.397 W	G24	2487					26,34,35	
74DI230/1	A24	121	1	ROS	091197	015327	BE	59 59.937 N	020 00.101 W	G24	2731					1-6,7,8,	CTD DEEP01
74DI230/1	A24	121	1	ROS	091197	025021	BO	59 59.807 N	020 00.068 W	G24	2732	8	2706	2755	23	27,28,36,	
74DI230/1	A24	121	1	ROS	091197	041606	EN	59 59.615 N	019 58.906 W	G24	2732					24,26,34,35	
74DI230/1	A24	122	1	ROS	091197	071907	BE	59 40.527 N	019 08.639 W	G24	2689					1-6,7,8,	CTD DEEP01
74DI230/1	A24	122	1	ROS	091197	081357	BO	59 40.366 N	019 08.936 W	G24	2689	10	2665	2709	23	27,28,36,	
74DI230/1	A24	122	1	ROS	091197	095424	EN	59 40.214 N	019 08.915 W	G24	2688					26	
74DI230/1	A24	123	1	ROS	091197	150444	BE	59 24.083 N	018 24.924 W	G24	2413					1-6,7,8,	CTD DEEP01
74DI230/1	A24	123	1	ROS	091197	155724	BO	59 24.145 N	018 25.265 W	G24	2420	6	2397	2437	23	27,28,36,	
74DI230/1	A24	123	1	ROS	091197	172500	EN	59 23.927 N	018 24.016 W	G24	2400					26,34,35	
74DI230/1	A24	124	1	ROS	091197	183427	BE	59 20.489 N	018 16.459 W	G24	1970					1-6,7,8,	CTD DEEP01
74DI230/1	A24	124	1	ROS	091197	191420	BO	59 20.444 N	018 15.926 W	G24	1953	10	1938	1963	20	27,28,36,	
74DI230/1	A24	124	1	ROS	091197	201642	EN	59 20.204 N	018 16.059 W	G24	1937					26,34,35	
74DI230/1	A24	125	1	ROS	091197	220629	BE	59 12.364 N	017 53.754 W	G24	1551					1-6,7,8,	CTD DEEP01
74DI230/1	A24	125	1	ROS	091197	223933	BO	59 12.364 N	017 53.668 W	G24	1555	9	1530	1557	19	27,28,36,	
74DI230/1	A24	125	1	ROS	091197	233340	EN	59 12.636 N	017 54.027 W	G24	1570					24,26,34,35	
74DI230/1	A24	126	1	ROS	091297	005319	BE	59 07.304 N	017 39.795 W	G24	990					1-6,	CTD DEEP01
74DI230/1	A24	126	1	ROS	091297	011757	BO	59 07.555 N	017 39.894 W	G24	1009	9	990	1005	15	26	
74DI230/1	A24	126	1	ROS	091297	015425	EN	59 07.825 N	017 39.872 W	G24	1016						
74DI230/1	A24	127	1	ROS	091297	035439	BE	58 56.985 N	017 13.424 W	G24	859					1-6,7,8,	CTD DEEP01
74DI230/1	A24	127	1	ROS	091297	041911	BO	58 56.918 N	017 13.933 W	G24	850	11	845	847	10	27,28,36,	
74DI230/1	A24	127	1	ROS	091297	044843	EN	58 57.013 N	017 14.587 W	G24	823					26,34,35	
74DI230/1	A24	128	1	ROS	091297	060100	BE	58 51.848 N	017 00.209 W	G24	1159					1-6,	CTD DEEP01
74DI230/1	A24	128	1	ROS	091297	063247	BO	58 51.716 N	017 00.374 W	G24	1161	9	1145	1159	10	26	
74DI230/1	A24	128	1	ROS	091297	071700	EN	58 51.958 N	017 00.763 W	G24	1157						
74DI230/1	A24	129	1	ROS	091297	104526	BE	58 33.385 N	016 10.204 W	G24	1222					1-6,7,8,	CTD DEEP01
74DI230/1	A24	129	1	ROS	091297	110721	BO	58 33.543 N	016 10.355 W	G24	1222	-999	1200	1221	14	27,28,36,	
74DI230/1	A24	129	1	ROS	091297	120224	EN	58 33.494 N	016 10.611 W	G24	1225					24,26,34,35	
74DI230/1	A24	130	1	ROS	091297	152315	BE	58 14.948 N	015 22.199 W	G24	683					1-6,	CTD DEEP01
74DI230/1	A24	130	1	ROS	091297	154753	BO	58 14.992 N	015 21.949 W	G24	680	10	662	673	8	26	
74DI230/1	A24	130	1	ROS	091297	161528	EN	58 14.990 N	015 21.731 W	G24	678						
74DI230/1	A24	131	1	ROS	091297	191131	BE	57 57.418 N	014 38.009 W	G24	469					1-6,7,8,	CTD DEEP01
74DI230/1	A24	131	1	ROS	091297	192417	BO	57 57.344 N	014 37.982 W	G24	470	8	451	461	10	27,28,36,	
74DI230/1	A24	131	1	ROS	091297	195125	EN	57 57.308 N	014 37.810 W	G24	470					26,34,35	
74DI230/1	A24	132	1	ROS	091297	223800	BE	57 41.754 N	013 56.697 W	G24	156					1-6,	CTD DEEP01
74DI230/1	A24	132	1	ROS	091297	224414	BO	57 41.736 N	013 56.834 W	G24	157	10	143	147	6	26	
74DI230/1	A24	132	1	ROS	091297	225607	EN	57 41.718 N	013 57.091 W	G24	156						
74DI230/1	A24	133	1	ROS	091397	010449	BE	57 33.291 N	013 36.626 W	G24	136					1-6,7,8,	CTD DEEP01
74DI230/1	A24	133	1	ROS	091397	010814	BO	57 33.286 N	013 36.804 W	G24	132	7	127	125	5	27,28,36,	
74DI230/1	A24	133	1	ROS	091397	012031	EN	57 33.278 N	013 37.288 W	G24	130					24,26,34,35	
74DI230/1	A24	134	1	ROS	091397	075317	BE	57 32.809 N	012 51.930 W	G24	1052					1-6,7,8,	CTD DEEP01
74DI230/1	A24	134	1	ROS	091397	082849	BO	57 32.977 N	012 52.285 W	G24	1020	3	1023	1037	11	27,28,36,	
74DI230/1	A24	134	1	ROS	091397	090802	EN	57 33.033 N	012 52.466 W	G24	1007					26	
74DI230/1	A24	135	1	ROS	091397	120329	BE	57 30.269 N	012 14.977 W	G24	1806					1-6,7,8,	CTD DEEP01
74DI230/1	A24	135	1	ROS	091397	125026	BO	57 30.255 N	012 16.169 W	G24	1813	12	1807	1813	11	27,28,36,	
74DI230/1	A24	135	1	ROS	091397	133300	EN	57 30.289 N	012 17.091 W	G24	1806					26	
74DI230/1	A24	136	1	ROS	091397	162707	BE	57 29.027 N	011 32.062 W	G24	2022					1-6,7,8,	CTD DEEP02
74DI230/1	A24	136	1	ROS	091397	172247	BO	57 29.167 N	011 31.811 W	G24	2023	11	1997	2033	23	27,28,36,	
74DI230/1	A24	136	1	ROS	091397	183500	EN	57 29.640 N	011 32.002 W	G24	2022					26,34,35	

Ship/crs	WOCE	Stn	Cast	Cast		UTC	Event				Unc	Ht	Wire	Max	Nbr		
expocode	Sect	Nbr	Nbr	Type	Date	Time	Code	Lat	Lon	Nav	Dep	bot	out	Pres	Btl	Parameters	Comments
74DI230/1	A24	137	1	ROS	091397	201747	BE	57 27.048 N	011 04.668 W	G24	592					1-6,	CTD DEEP02
74DI230/1	A24	137	1	ROS	091397	203802	BO	57 26.974 N	011 04.835 W	G24	590	9	581	587	11	26	
74DI230/1	A24	137	1	ROS	091397	210516	EN	57 26.898 N	011 04.970 W	G24	588						
74DI230/1	A24	138	1	ROS	091397	233527	BE	57 17.913 N	010 22.828 W	G24	2216					1-6,7,8,	CTD DEEP02
74DI230/1	A24	138	1	ROS	091397	235655	BO	57 17.596 N	010 23.049 W	G24	2220	-999	2281	2241	23	27,28,36,	
74DI230/1	A24	138	1	ROS	091497	013446	EN	57 16.218 N	010 24.808 W	G24	2241					24,26,34,35	
74DI230/1	A24	139	1	ROS	091497	040943	BE	57 09.250 N	009 42.378 W	G24	1938					1-6,7,8,	CTD DEEP02
74DI230/1	A24	139	1	ROS	091497	045553	BO	57 09.210 N	009 42.617 W	G24	1942	7	1920	1955	23	27,28,36,	
74DI230/1	A24	139	1	ROS	091497	060510	EN	57 09.425 N	009 42.644 W	G24	1943					26	
74DI230/1	A24	140	1	ROS	091497	072149	BE	57 05.863 N	009 24.945 W	G24	1413					1-6,7,8,	CTD DEEP02
74DI230/1	A24	140	1	ROS	091497	075752	BO	57 05.779 N	009 24.604 W	G24	1389	6	1385	1409	19	27,28,36,	
74DI230/1	A24	140	1	ROS	091497	091100	EN	57 05.704 N	009 23.803 W	G24	1326					24,26	
74DI230/1	A24	141	1	ROS	091497	100646	BE	57 02.973 N	009 12.787 W	G24	301					1-6,	CTD DEEP02
74DI230/1	A24	141	1	ROS	091497	101345	BO	57 02.955 N	009 12.825 W	G24	306	13	290	295	7	26	
74DI230/1	A24	141	1	ROS	091497	103830	EN	57 02.780 N	009 11.636 W	G24	257						
74DI230/1	A24	142	1	ROS	091497	115450	BE	56 59.858 N	008 59.479 W	G24	134					1-6,7,8,	CTD DEEP02
74DI230/1	A24	142	1	ROS	091497	115836	BO	56 59.863 N	008 59.366 W	G24	135	9	125	127	10	27,28,36,	
74DI230/1	A24	142	1	ROS	091497	122700	EN	56 59.853 N	008 58.897 W	G24	133					26,34,35	
74DI230/1	A24	143	1	ROS	091497	163718	BE	56 50.174 N	008 20.028 W	G24	134					1-6,	CTD DEEP02
74DI230/1	A24	143	1	ROS	091497	164234	BO	56 50.191 N	008 19.985 W	G24	134	8	125	129	5	24,26	End Iceland-
74DI230/1	A24	143	1	ROS	091497	165400	EN	56 50.238 N	008 20.000 W	G24	133						Scotland Sect.

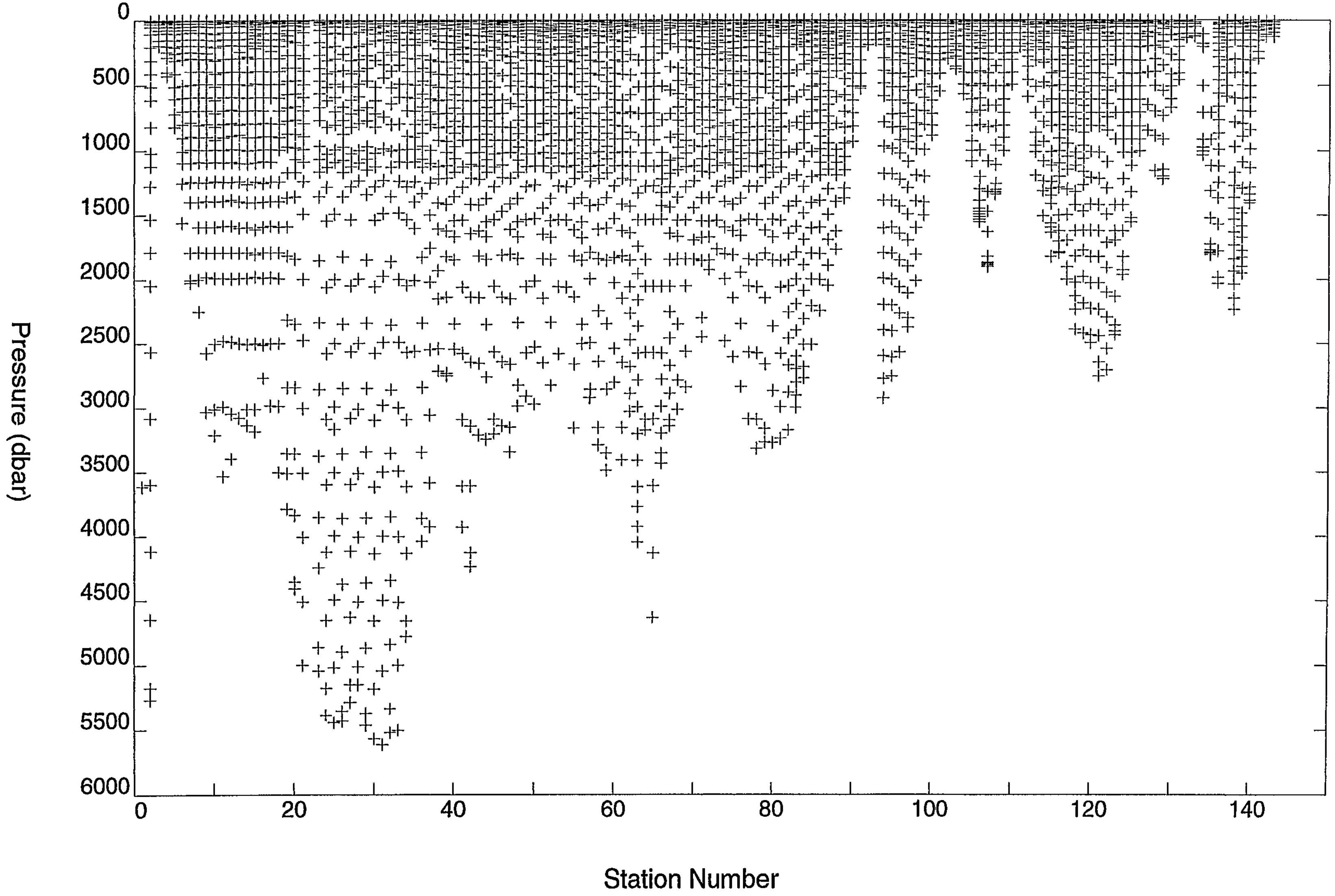

Figure A1: Bottle depths versus station number for *Discovery* cruise 230.

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