# RRS Charles Darwin, Cruise 160, 5-24August 2004

RAPID moorings and BPR deployments

Principal Scientist: Dr. Michael Meredith

**Contents**

# Personnel

## Ship

| | |
|---|---|
| Master | Peter Sarjeant |
| Chief Officer | Malcolm Graves |
| Second Officer | Titus Owoso |
| Third Officer | Kieron Hailes |
| Chief Engineer | Kishorkumar Jethwa |
| Second Engineer | Alex Greenhorn |
| Third Engineer | Adam Jackson |
| Third Engineer | Glynn Collard |
| ETO/elec. | James McIntyre |
| Chef | Peter Lynch |
| Assistant Chef | Wally Link |
| Steward | Peter Robinson |
| SCM | Raymond Bell |
| CPO (deck) | Kevin Luckhurst |
| Seaman PO (deck) | Bob Johnson |
| Motorman | Carl Moore |
| Seaman | Mark Squibb |
| Seaman | John Dale |
| Seaman | Gary Crabb |
| Seaman | David Anderson |
| Deck Cadet | Alexander Sleven |

## Scientific/Technical

| | |
|---|---|
| Michael Meredith | POL, Principal Scientist |
| Peter Foden | POL, Bottom Pressure Recorders/Inverted Echo Sounders |
| Jeff Pugh | POL, Bottom Pressure Recorders/Inverted Echo Sounders |
| Ian Waddington | UKORS, moorings |
| Rob Mclachlan | UKORS, moorings; Technical Liaison Officer |
| David Childs | UKORS, moorings |
| Jeff Benson | UKORS, CTD/LADCP |
| Paul Duncan | UKORS, computing |

## Introduction

RRS Charles Darwin cruise 160 (CD160) was the second fieldwork component of a project under the auspices of the NERC Rapid Climate Change thematic programme (Rapid). Through Rapid, funding was awarded to Dr. Chris Hughes (POL), Dr. Ric Williams (University of Liverpool) and Prof. D. Marshall (University of Reading), working in collaboration with Woods Hole Oceanographic Institution; Dr. M. Meredith (POL) was later including in this grouping. The overall aim of the project was to investigate how signals propagate from higher latitudes down the western boundary of the North Atlantic, with a view to understanding the influence they might have on the large-scale overturning circulation in the Atlantic, and ultimately on climate. The fieldwork aspect of the project was to deploy arrays of Bottom Pressure Recorders (BPRs) and CTD moorings along specified satellite altimeter groundtracks off the eastern continental slope of Canada and the United States. The first stage of the deployments was conducted by RV Oceanus earlier in 2004, with one line of six BPRs being deployed on a line out towards Bermuda from the US. The purpose of CD160 was to deploy twelve further BPRs (some with Inverted Echo Sounders; IESs) and ten CTD moorings along two lines, one running approximately southwest from the Grand Banks, and a second running approximately southeast on the continental slope in front of Nova Scotia (Figure 1). The deployments were scheduled to be of two years duration, with recovery and redeployment in 2006, and a second recovery in 2008. Continuation beyond this would depend on future availability of funding.

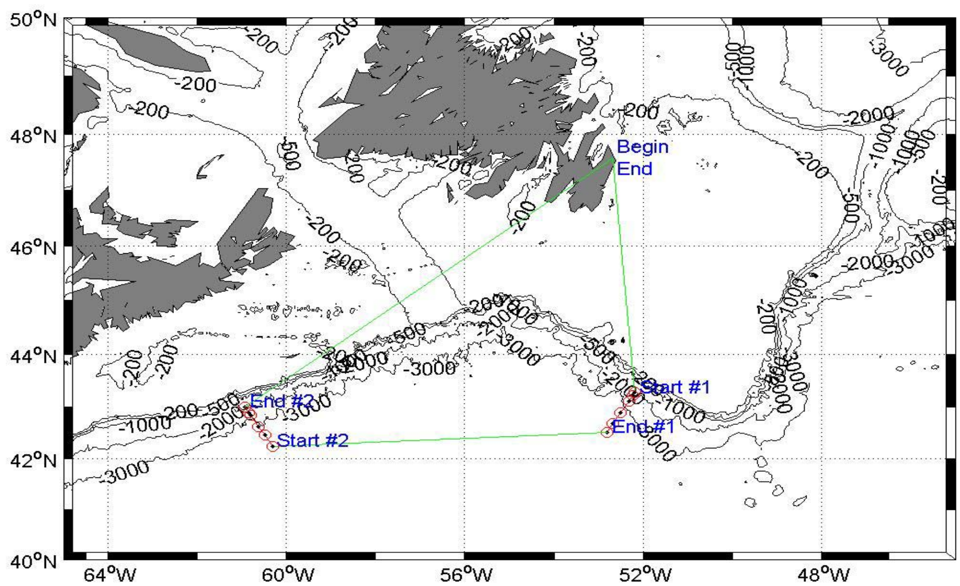



*Figure 1. Locations of BPRs and moorings to be deployed during CD160, with a rough intended cruisetrack. CTD stations and tracer sampling were also scheduled at each BPR site.*

Whilst the top priority of CD160 was the BPR and mooring deployments, it was intended to also conduct CTD casts at each of the twelve sites. The CTD frame was fitted with two Lowered Acoustic Doppler Current Profilers (LADCPs; one 150kHz and one 300kHz) to gain information on full-depth current velocities. Samples were to be drawn from the CTD rosette-mounted Niskins and stored for future analysis for the ratio of oxygen isotopes in seawater ($\delta^{18}O$), and iodine-129 ($I^{129}$). The first of these provides information on the high-latitude sources that provide freshwater signals to the Deep Western Boundary Current (DWBC) of the North Atlantic. The second is the signature of discharge from European nuclear power plants; as a radioactive (and therefore time-dependent) tracer, it provides information on timescales for waters to circulate northward past Europe, circuit or short-circuit the Arctic, and subsequently flow southward in the DWBC. Each of these measurements would provide differing insights into the region under study, and contribute to answering the larger question of how the ocean influences climate.

Dr. Mike Meredith, Principal Scientist, CD160

## Overview
**(Mike Meredith)**

*Sunday 1st August, 2004, Jday 215*

Sailing of Darwin from St.Johns Newfoundland, originally scheduled for August 3rd, has been put back to August 4th. This is to use some of the spare time in port so that gear can be assembled in a calmer environment. Processing scripts for underway data ported from Pstar to Matlab for this cruise; it has been intended for some time to do this, and with the extra time available this is a good opportunity. (Pstar is no longer supported by its developers; possibly its days are numbered).

*Tuesday 3rd August, 2004, Jday 216*

Sailing possibly delayed, due to approach of Tropical Cyclone Alex. Intention is to sail at 3pm on August 4th, and steam slowly (with Chernikeeff log calibration en route) to first position (0A).

*Wednesday 4th August, 2004, Jday 217*

Sailed from St.Johns, Newfoundland at 3pm local time (1730Z). Navigation, surfmet and echosounder logging by 1800Z; this can be the start of the cruise for data purposes. Thermosalinograph turned on around midnight GMT, Jday 217/218. Contemplating moving toward westernmost line (Line B) first, so as to allow Alex to pass to the south of us.

Foggy; moving very slowly.

UKORS have brought two fewer CTDs than the moorings require; designs modified to account for this. Mooring 1 on both Lines A and B now 100, 200*, 300, 400*; mooring 5 on Lines A and B now 100, 200*, 300, 400, 500, 900, 1400*, 1900, 2300*, where numbers represent height of CT loggers above seabed, and starred numbers represent height of CTDs above seabed. Ian Waddington happy with these changes.

Sample interval for mooring CTDs decided to be 30 minutes; this gives 876 days of battery life (2years, 3 months, 16 days).

*Thursday 5th August, 2004, Jday 218*

Cruise briefing in the main lab, with brief talks by Master and PSO.

*Friday 6th August, 2004, Jday 219*

Lumpy weather overnight denoting effect of Alex. Precision Echo Sounder (PES) fish deployed at 1540Z - the hull-mounted echo sounder was giving noisy data, probably due to bubbles under the hull.

First site (A0); target depth 1800m corrected (1820m uncorrected, according to Carter's tables). CTD into water at 1820Z, uncorrected depth drifting between 1790 and 1820m. Quite a lot of drift during CTD, due to strong currents – dynamic positioning not available on Darwin.

BPR deployed at A0 at 2058Z, uncorrected depth 1807m.

*Saturday 7th August, 2004, Jday 220*

Site 1A, target depth 2200m (corrected). CTD into water at 1126Z, with depth of 2208m uncorrected. The position of 1A (selected by depth) is quite a way further along the line than the nominal position. BPR into water at 1416Z. UKORS mooring deployed at 1630Z (time when anchor weight released into water).

Problem with shipborne ADCP: very few good returns. Paul Duncan will try bleeding some air out.

Site 2A. CTD into water at 1744Z, 2724m depth (uncorrected). BPR deployed at 2035Z (2716m uncorrected). Mooring released at 2143Z (2719m uncorrected).

*Sunday 8th August, 2004, Jday 221*

Calm, sunny conditions, with a slight swell. Site 3A; CTD into water at 1051Z, depth 3228m uncorrected. BPR deployed at 1342Z, 3220m uncorrected depth. Original intention was to deploy a BPR/IES at this location, but the IES code was not ready in time, so a straight BPR was deployed. Mooring released at 1708Z, 3222m uncorrected depth. Shipborne ADCP still performing poorly; configuration and signal strength seem to be fine (signal checked by Jeff Benson). Speculation concerning whether something is obscuring the transducers, or whether there is a lack of sufficient scatterers in the water to produce good returns.

Site 4A. CTD into water at 2050Z, 3672m uncorrected depth. During recovery, the CTD was winched into the block, with the wire breaking as a result. CTD package lost onto seabed. Decision made to try dragging for the package, since we have time in hand, and it contains the UK's only 150 kHz LADCP. Also, have the advantage that the pinger on the frame enables good locating of it. Night spent running boxes around the package, and using the pinger signal on the echosounder to work out its exact location.

*Monday 9th August, 2004, Jday 222*

Grey, drizzle, poor visibility. Dragging for CTD. First attempt failed; CTD appears to have moved (as judged by signal from pinger), but was not recovered. Plan is to run boxes around the CTD again overnight, so as to pinpoint its new location, and make a decision in the morning concerning what to do next. An option is to proceed with moorings and try dragging again later in the cruise, should time permit, but the pinger will only last maximum ~100 hours.

*Tuesday 10th August, 2004, Jday 223*

Calm, sunny, very clear. Decision made to drag again for CTD while pinger still alive. Dragging commenced at 1342Z. Jeff Benson has contacted Bedford Institute of Oceanography (BIO; Halifax, Nova Scotia), who can lend us a CTD for the remainder of the cruise if we can collect. Second drag failed. Decision made to finish dragging, and deploy BPR and moorings here. This will preclude further dragging, but given that two attempts (with the pinger alive) have failed, further attempts would be unlikely to have succeeded anyway. Future recovery by ROV now the only real option.

BPR deployed at 2243Z, 3666m uncorrected depth (site 4A). Mooring released into water at 2325Z, 3666m uncorrected depth.

*Wednesday 11th August, 2004, Jday 224*

Site 5A. Calm, sunny, excellent visibility. BPR deployed at 1059Z, 4122m uncorrected depth. Problem during mooring deployment – the current changed direction, so the ship passed the mooring site before the full mooring had been laid out. This necessitated a large, slow turn and another run and the mooring site. Mooring released into water at 1713Z, 4119m uncorrected depth.

Now head for Halifax NS (BIO) to collected replacement CTD. Hope to arrive late on Friday 13th (Jday 226).

*Thursday 12th August, 2004, Jday 225*

Calm, sunny, excellent visibility. Steaming to Halifax NS. Fire drill at 1615L. A large number of pilot whales seen off port side at 1300L.

*Friday 13th August, 2004, Jday 226*

Due to be met by Halifax pilot at ~1330L, and be alongside an hour later. Intention is to have ~3 hours alongside before heading back to sea.

Shipborne ADCP seems to be giving better data in shallower water – more scatterers? Put into bottom-track mode at 1120L.

Docked alongside BIO, Halifax NS, at 1500L. Collected replacement CTD, kindly lent to us by Canadian colleagues, plus 24 bottles, oxygen sensor. Sailed at 1830L, but problem with engines developed at 1930L – cut out just as ship coming up to full speed. Apparently an electrical problem; ship's power system disrupted, and switched to emergency generator.

Jeff Benson has set up new CTD with SOC sensors as primary temperature and conductivity, and BIO sensors as secondary. (SOC sensors more recently calibrated).

*Saturday 14$^{th}$ August, 2004, Jday 227*

Still at anchor close to exit of Halifax harbour. Electrical fault with engines still not fixed; not clear how long this will take, or whether assistance from shoreside is needed. RVS data streams turned off due to electrical problems; logging stopped late Jday 226.

*Sunday 15$^{th}$ August, 2004, Jday 228*

Decision taken to go alongside and seek shoreside assistance with engine problems. Alongside at Pier 23 at ~1600L.

*Monday 16$^{th}$ August 2004, Jday 229*

Moored in Halifax. Divers sent down to examine underside of ship. No obvious problems with prop. Some growth cleaned from ADCP transducers – might have been causing poor data? Electricians have examined engines, and taken away drawings; will return tomorrow for further work.

*Tuesday 17$^{th}$ August 2004, Jday 230*

Engine repairs complete. Shore leave due to end at 2000L, with sailing straight afterwards. Not much time left to complete cruise, but intention is to conduct as much work as possible, with priority given to the mooring and BPR deployments.

*Wednesday 19$^{th}$ August 2004, Jday 213*

Heading toward site 0B. Bright, sunny, slightly choppy. Line B is looking feasible, but returning to Line A to conduct the missing CTD at 5A looking very doubtful.

ADCP put into water-track mode at 1220L – not looking like good data though. Problems with meteorology sensor package. Paul Duncan (UKORS) scaled foremast to investigate and fix problems with meteorology sensors.

PES fish into water at 1638Z.

Site 0B. BPR deployed at 1713Z, uncorrected depth of 1838m. This is slightly deeper than the target uncorrected depth of 1815m, but hopefully within acceptable bounds. BPR deployed before CTD so it could be tracked down while CTD was being conducted, without losing time. CTD into water at 1740Z. Termination failed, being brought back in at 1810Z. No time to wait for retermination here, move to next site (1A).

Site 1B. BPR into water at 2016Z, 2217m uncorrected. Mooring released into water at 2143Z, 2213m uncorrected depth.

Site 2B. BPR into water at 2302Z, 2714m uncorrected.

*Thursday 19th August 2004, Jday 232*

Perfect weather conditions: clear, sunny, excellent visibility, almost glassy calm.

Site 2B still. Mooring released into water at 0017Z, 2714m uncorrected depth.

Site 3B. BPR/IES deployment at this site deferred whilst new IES code is trialled. CTD retermination completed by Jeff Benson. CTD into water at 1306Z, 3209m uncorrected depth. Termination failed again, at about the same depth as previously. Package recovered for further work on the termination. Mooring deployed at 1635Z, 3209m uncorrected depth. Steam to 4B

Site 4B. BPR deployed at 1821Z, 3665m uncorrected depth. Mooring deployed at 2024Z, 3665m uncorrected.

*Friday 20th August 2004, Jday 233*

Again perfect weather. Site 5B. CTD was deployed at 1412Z, but the cast was aborted when communication was lost with the package. The final mooring was deployed at 1900Z, 4099m uncorrected depth. A BPR/IES was deployed at 1907Z (same depth) – this is the first instrument of the cruise to have an IES on it. CTD was deployed again at 2121Z, and this time was successful. Sampling for oxygen isotopes and iodine-129 was conducted.

*Saturday 21st August 2004, Jday 234*

CTD deployed at 1122Z, 3648m uncorrected depth (Site 4B). Apart from the BPR/IES at Site 3B, nothing remains other than conducting as many CTDs as possible in the time left. Weather conditions look favourable for this: misty to begin with but quickly burned off; calm with only a slight swell and occasional whitecaps.

The final BPR/IES was deployed (Site 3B) at1629Z, 3221m, followed by the CTDs for Site 3B (at 1714Z) and Site 2B (2202Z).

*Sunday 22nd August 2004, Jday 235*

The final CTD of the cruise was conducted at Site 1B (2214m depth), commencing at 11:07Z. We end up 2 CTDs short of completing the full programme, but given the technical problems encountered it is a relief to have achieved as much as we have. Now commence the ~2 days steam back to St.Johns.

P.M., PSO RPC – BBQ. We were joined by a whale of undetermined flavour, and a large school of dolphins. We were royally entertained by the dolphins, who played in the bow wave for a good half hour.

*Monday 23rd August 2004, Jday 236*

A day of just steaming, heading back to St.Johns. Everyone busy packing, sorting out data, contributions to cruise report etc. Boat drill in pm. Another friendly visit from our favourite dolphins, who can't get enough of that bow wave, it seems. ETA lunchtime tomorrow.

*Tuesday 24th August, 2004, Jday 237*

Arrived back in a rainy St.Johns, shortly after lunch, at the end of an eventful (but ultimately successful) cruise.

*Wednesday 25th August, 2004, Jday 238*

Demob in the morning; signing off and disembarking afternoon.

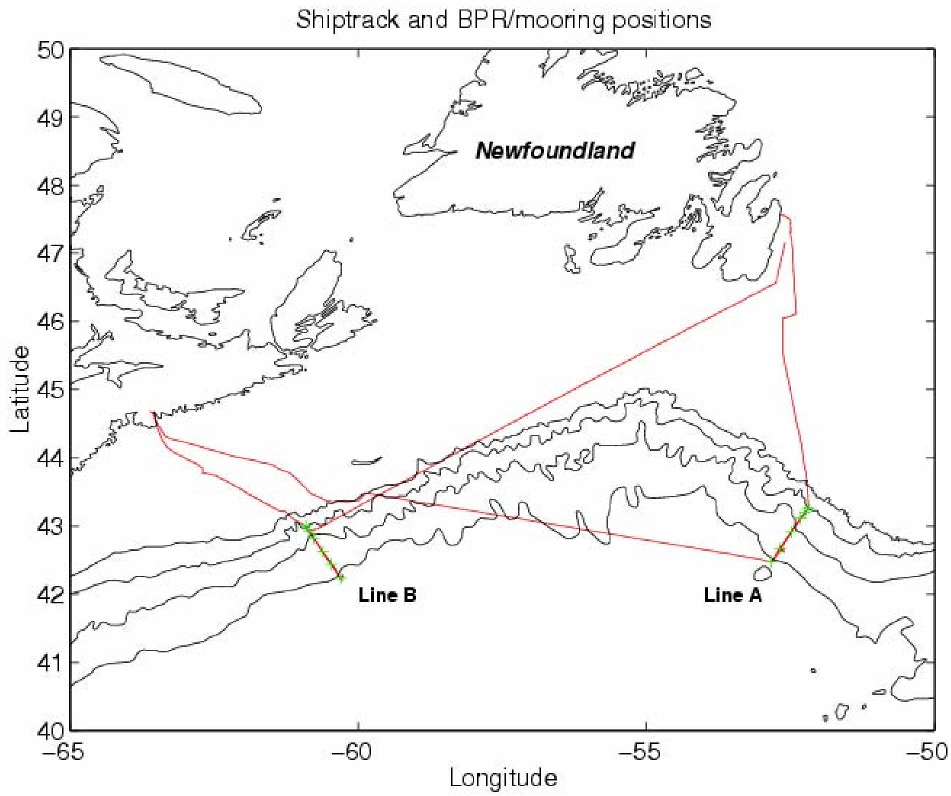



*Figure 2: Cruise track during CD160 (St.Johns, Newfoundland to Halifax, Nova Scotia to St.Johns, Newfoundland).*

## Mooring Operations
**(Ian Waddington, Rob McLachlan, Dave Childs)**

10 mooring deployments were carried out during the cruise, comprising two lines of 5 moorings designated lines A and B and moorings 1 to 5.

| MOORING Site number | DATE AND TIME UKORSgmt | | | Bridge Log Posn. N | W | Best Nav N | W |
|---|---|---|---|---|---|---|---|
| Mooring 1A | 2004/24 | 1600 | 07Aug 2004 Day 220 | 43 12.81 | 52 14.60 | 43 12.00 | 52 14.96 |
| Mooring 2A | 2004/25 | 2142 | 07Aug 2004 Day 220 | 43 06.62 | 52 19.42 | 43 06.62 | 52 19.44 |
| Mooring 3A | 2004/26 | 1708 | 08Aug 2004 Day 221 | 42 54.84 | 53 23.96 | 42 54.85 | 52 28.96 |
| Mooring 4A | 2004/27 | 2325 | 10Aug 2004 Day 223 | 42 40.10 | 52 40.84 | 42 40.10 | 52 40.83 |
| Mooring 5A | 2004/28 | 1714 | 11Aug 2004 Day 224 | 42 28.64 | 52 50.29 | 42 28.62 | 52 50.28 |
| | | | | | | | |
| Mooring 1B | 2004/29 | 2144 | 18Aug 2004 Day 231 | 42 55.68 | 60 51.71 | 42 55.71 | 60 51.75 |
| Mooring 2B | 2004/30 | 0017 | 19Aug 2004 Day 232 | 42 49.21 | 60 46.49 | 42 49.25 | 60 46.50 |
| Mooring 3B | 2004/31 | 1636 | 19Aug 2004 Day 232 | 42 37.34 | 60 40.77 | 42 37.34 | 60 36.98 |
| Mooring 4B | 2004/32 | 2024 | 19Aug 2004 Day 232 | 42 26.42 | 60 28.31 | 42 26.43 | 60 28.31 |
| Mooring 5B | 2004/33 | 1900 | 20Aug 2004 Day 233 | 42 13.94 | 60 18.33 | 42 13.95 | 60 18.33 |

All the moorings are constructed of 8mm polyester line supported with glass buoyancy. Instruments are SeaBird SBE37SMP clamped to the lines. Ixsea acoustic releases are provided on each mooring. Anchoring is a deadweight steel clump with additional embedment Danforth anchor. All capital equipment is logged to an Excel Spreadsheet for later transfer to UKORS database.

### Instumentation

### Seabird SBE 37- SMP MicroCAT

Sixty Seabird SBE37SMP units were supplied direct from the manufacturer to the Charles Darwin in St Johns Newfoundland. All the units were fitted with battery packs onboard and a series of tests carried out to check correct operation of the instruments. Instruments were allocated to the mooring positions and each unit checked for correct sensor allocation and fitting.

Briefly, each instrument was powered up and set to sample at the deployment interval of 30 minutes and then placed in a seawater tank fed by the ship pumped non-toxic supply. After approximately 12 hours in the tank each instrument was downloaded and logging and data quality checked.

Instruments were then sequentially powered up using the ships clock as the reference time, all times recorded in GMT. All tests and setups are logged as Capture files

### Ixsea AR861 Acoustic Releases

Twelve Ixsea AR861 acoustic releases were delivered direct from the supplier to Fairlie, Scotland, prior to the ship sailing on cruise CD159 and were supplied powered up and tested. All the units were tested onboard for correct operation and electronic build sheets generated for each.

**Buoyancy**

**Benthos SRM17 inch dia Glass Spheres**.

The support buoyancy of Benthos glass spheres was provided direct to St Johns from the manufacturers. Several packages were damaged and two spheres broken. As spares had been allowed for in the order this did not compromise the deployment. The first 80 spheres were drilled during the mobilisation in St Johns to fit mooring shackles with the remainder stowed in the hold to free off working deck space. At the port call in Halifax all remaining spheres were prepared on deck.

**McLane Marker floats**

The marker floats are constructed of McLane buoyancy fitted with SOC supplied masts and fittings. The floats were supplied direct from the manufacturers to St Johns where the units were assembled during the mobilisation period.

**Novatech Xenon lights**

The lights supplied direct from the manufacturers to St Johns are all double flash units and were tested and fitted to the marker buoys during the mobilisation in St Johns.

**Anchoring**

The anchors are all former inshore iron sinkers each weighing 450 kg and fitted with additional 10 kg Danforth anchors. The 1/2" riser chain to the mooring is 9 metres long and the chain to the Danforth embedment anchor is 5 metres long, this to prevent the Danforth or its chain becoming entangled or damaging the polyester mooring line during deployment.

**Mooring fittings**

The shackles used throughout are federal spec. yellow pin and green pin. Release links are special product galvanised. Swivels are special product high strength stainless steel, fitted with insulating bushes. All chain is long link galvanised.

**Mooring line**

The mooring line is 8mm diameter braid on braid manufactured by Iron Strand and is supplied from the manufacturers ready spliced, whipped and fitted 12mm galvanised heart thimble. The line was supplied in cardboard boxes flaked down and was simple to transfer to fish baskets or winch. However if the weather should have been poor there could have been problems with the boxes collapsing when wet. At each SBE37 attachment point the line was wrapped with pvc tape to add protection.

**Deployment operations**

Deployments were all carried out from the aft deck streaming the moorings buoy first. Anchor drop was freefall from the aft cranes. All deployments were carried out over the aft rail, with no requirement for safety harnesses or lifejackets. Normal on deck PPE. The short moorings were deployed by hand, method as used on Discovery 227, with the addition of crane lifting for the six pack of glass spheres and the acoustic release - glass package. All lines are flaked down into fish baskets and easily hand deployed over the side with the ship making controlled headway to suit safe deployment. Deployment of the moorings to the anchor was achieved in most cases in 10 minutes. Towing onto position could then be accurately forecast and time of tow was usually quite short.

The longer 1400 metre and 2500 metre moorings were first wound on to the Double Barrel Capstan winch (DBC) prior to deployment. Deployment was then conventional buoy first with the winch being used for pay out. With all the mooring deployed to the anchor the tow on to position could be made.

**Mooring Interrogation**

Moorings 1B to 5B were all interrogated and checked to be on position during the subsequent CTD stations. This opportunity was also used to test the four acoustic deck units onboard for subsequent use for CD165 and JCR AFI. Moorings 1A to 5A were not interrogated. All interrogation details logged in Cruise Mooring Diary.

Mooring diagrams are provided in Appendix A.

## Emergency Dragline Operations
**(Ian Waddington, Rob McLachlan, Dave Childs, Pete Foden, Peter Sarjeant)**

An Emergency Dragline Operation was put together onboard in response to the loss of the CTD package on the 8th August 2004 Day 221. At the point of loss the GPS position was noted down immediately on the ship's navigating bridge to define a loss position. The descent of the package was monitored to the seabed using the 10kHz CTD pinger, descent rate averaged at 2 metres per second, this relatively slow descent being probably due to the closed Niskin bottles creating a significant hydrodynamic drag in descent. It was felt that the package might not descend vertically through the water column and a fix system was devised using the 10 kHz precision pinger still operational on the CTD package.

Within a very short period of the package arriving on the seabed a pattern of boxes was made around the loss position navigating the package using the 10kHz CTD pinger. This pattern of boxes was devised by the ships captain and officers and monitored on the EA500 display in the main laboratory, relaying beam on positions to the ship's bridge by radio. This pattern was maintained for several hours gradually reducing errors in location until it could be established that the package was actually on the drop position noted by the bridge officers at the point of loss. This indicating a vertical descent to the seabed at 42 39.21N, 52 40.33W.

On the morning of the 8th of August the UKORS emergency dragline was broken out from its stowage and transferred to the aft deck where the dragline wire could then be wound onto the main ships winch. Lengths of 2 x 500 metres and 1 x 200 metres were measured on with swivels and attachment points inserted. A dragline layout was devised to give the best attempt with the warp available.

With all the wire being wound on and the ship positioned at a start point selected by the captain, the dragline was deployed with the ship hove to. Thus the dragline was hanging vertically in the water column. The main warp was then deployed such that the dragline tail end was close to the seabed. The ship then got underway at slow speed matching ships speed over the ground to winch pay out. The dragline was then streamed on the seabed in the direction of drag required.

**9th August 2004 Day 222** *(extract from UKORS Mooring Diary )*
2005 gmt dragline deployed
2006 gmt paying out
2014 gmt paying out 60m/mim ships speed 2kts
2024 gmt paying out 40m/min ships speed 1.1kts
2048 gmt 6000 metres of dragline deployed 2.8 to 3.5 tonne
2217 hauling 30m/min 4.5 tonne load
2233 Tension drop 3.4 tonne
2245 Tension increasing to 5.8 tonne
Bottom echo observed on pinger to 40m off bottom
2302 3.3 to 4.8 tonne

2320 Winch stopped - restart Ship position 42 40.5N 52 40.7W
2332 Pinger lost
2358 Hauling 50 m/min

The tension increase at 2245 gave a possible indication of snagging something on the seabed. With the ship virtually stopped in the water at this point it was decided to continue the slow haul in.

The pinger change indication at 2245 was observed on the EA500 which was tuned to achieve the best signal strength. The bottom echo seen clearly showed the pinger on the CTD lifting off the seabed. However this echo did not continue to separate and the echo was lost some minutes later. Tension dropping at 2302 possibly indicating that the CTD had detached from the dragline. Hauling continued with ever decreasing loads as the warp was retrieved.

On deck it was observed that all the weights and grapnels had been in the mud of the seabed which was of a clay consistency. The spring grapnel was severely bent, three prongs being folded over and signs of metal scraping seen.

A further series of box patterns and across position runs was then made as the 10 kHz pinger on the CTD package was still running. The box pattern and beam on system was revised somewhat by the Captain and improved "beam ons" to the CTD obtained. A new position was determined which indicated that the CTD package had indeed been moved by the dragline in the direction of tow.

A second dragline attempt was prepared with the spring grapnel prongs being straightened out by oxy-acetylene and hammering to achieve a good profile and operating springs. Some revision was made to the layout to attempt to improve on the catching ability.

A repeat dragging attempt was undertaken using previous techniques.

**10th August 2004 Day 223** *(extract from UKORS Mooring Diary )*

Dragline changed by moving leading weight 500m up line towards main warp
Spring grapnel straightened using gas axe Rob MacLachlan
1330 Last weight deployed
1654 Dragging 6000m warp out Water depth 3687m
1800 Hauling at 20m/min
1854 Load at 5.8 tonne
1858 Tension fall to 5.3 tonne
1906 Load at 6.4 tonne 4748 wire out
1924 Tension drop to 3.5 tonne 4380m wire out
1931 Load at 5 tonne
1956 Load peaks to 5 tonne 3735m wire out
Increase haul rate to 40m/min

All recovered - Mud lodged in grapnels, spring grapnel one prong bent
At 2328 gmt Ship position 42 40.0W 52 40.8 W

Again warp tension increases indicated possibly catching the CTD package, but the 10 kHz pinger gave no indication of this. The dragline when recovered had mud forced well into the grapnel tubes and on the chains. The spring grapnel had one prong bent.

Due to time constraints no further dragline attempts could be made at this time. A final navigation pattern was run on the 10kHz pinger as it was felt that if further dragline attempts were to be made, this pinger would have failed on return to the site due to battery exhaustion. The position was confirmed as being where determined on completion of the first drag attempt. It can be assumed therefore that the second drag attempt either contacted lightly and did not catch or missed altogether and warp tension increases could be due to other causes. 0236 gmt 42 40.0 N 52 40.8 W.

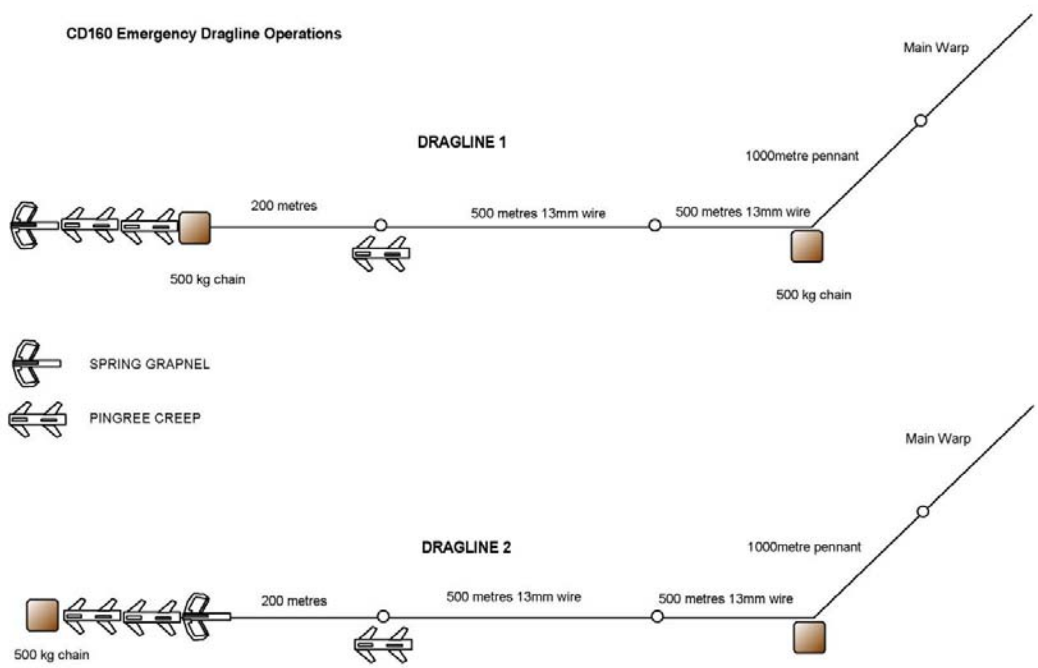



*Figure 3. Diagram of emergency dragline operations equipments.*

## Bottom Pressure Recorder/Inverted Echo Sounder Deployments
**(Pete Foden and Jeff Pugh)**

### Cruise Objective

To deploy 12 self-contained, pop-up landers to measure bottom pressure and temperature, at each of the sites 0A to 5A and 0B to 5B. Duration of deployment is two years.

### RapidLander description

The lander consists of two 13" Vitrovex spheres in orange hard hats. The hard hats are bolted together and there is an acoustic transducer on the top sphere and a release plate at the bottom, which can be bolted to the steel tri-pod ballast frame with corrodible bolts.

The bottom sphere contains three lithium battery packs and is slightly positively buoyant. The upper sphere contains the sea level sensor, electronics and Benthos release; it provides the majority of the buoyancy to bring the package to the surface on recovery. There is a radio beacon which is triggered by release and transmits continuously until the batteries expire.

The instrumentation consists of a Digiquartz 10,000 psi pressure sensor operating continuously, the pressure and temperature frequency outputs are counted over 15 minute intervals and the data stored to flash disk. On two instruments at sites, 3B and 5B, additional instrumentation has been added to provide an Inverted Echo Sounder (IES) function. An extra circuit board containing a CF2 PC card and 1 Gigabyte flash card provides a 12 kHz to 8 kHz 'chirp' every four hours. The acoustic return from the surface is digitised and stored to flash. About 50,000 samples are recorded for each second's worth of signal received. These measurements will give travel times for the chirp to travel to the sea surface and back down to the IES again, a measurement of dynamic sea height. This measurement will enable us to understand more about the bulk properties of the ocean.

The release mechanism consists of a modified 'fizz-block', it is a burn wire mechanism that consists of a loop of solid inconel wire that secures the end of a lever that holds a fastening in place between the bottom of the lander and the tri-pod ballast frame. By passing a current between the burn wire and another electrode the wire loop can be dissolved and the lever released which in turn detaches the lander from the ballast frame.

### Lander deployment

The landers are easily deployed using the starboard crane and the ship's release hook. The lander is lowered into the water and when the weight comes off the release hook the lander is released and free falls to the sea bed. The lander can be tracked to the sea bed using the Benthos Deck Unit connected to a PC, which runs a software program providing a waterfall display of the track to the bottom. When the lander contacts the sea bed the display goes vertical indicating a safe descent and landing. All twelve deployments were monitored safely down to the sea bed. GPS position, depth and barometric pressure are all recorded at deployment.

**Observations**

All launches went smoothly and the modularity of the RapidLander made them easy to assemble and prepare for deployment. Towards the end of the deployments trouble was experienced with the deck unit exhibiting lack of sensitivity and intermittent loss of transponder signal. This found to be a wear and tear break in the over side transducer cable close to the cable gland. The transducer was cut off and a spare ITC ceramic ring transducer temporarily fitted, this enabled the last couple of deployments to be monitored down to the sea bed albeit with reduced performance. The original transducer cable was repaired and refitted and normal operation of the deck unit restored.

**Details of deployments**

A0 BPR: 43º 15.69'N, 52º 11.20'W, 20:56, 6/8/04 (Jday 219), 1807m uncorr.
A1 BPR: 43º 11.82'N, 52º 14.92'W, 14:16, 7/8/04 (Jday 220), 2227m uncorr.
A2 BPR: 43º 06.74'N, 52º 19.56'W, 20:35, 7/8/04 (Jday 220), 2716m uncorr.
A3 BPR: 42º 54.89'N, 52º 29.06'W, 13:42, 8/8/04 (Jday 221), 3220m uncorr.
A4 BPR: 42º 40.02'N, 52º 40.82'W, 22:43, 10/8/04 (Jday 223), 3666m uncorr.
A5 BPR: 42º 28.66'N, 52º 50.36'W, 10:59, 11/8/04 (Jday 224), 4122m uncorr.

B0 BPR: 42º 59.84'N, 60º 54.57'W, 17:13, 18/8/04 (Jday 231), 1838m uncorr.
B1 BPR: 42º 55.64'N, 60º 51.63'W, 20:16, 18/8/04 (Jday 231), 2217m uncorr.
B2 BPR: 42º 49.15'N, 60º 46.44'W, 23:02, 18/8/04 (Jday 231), 2714m uncorr.
B3 BPR/IES: 42º 37.20'N, 60º 36.72'W, 16:29, 21/8/04 (Jday 234), 3221m uncorr.
B4 BPR: 42º 26.43'N, 60º 28.27'W, 18:21, 19/8/04 (Jday 232), 3665m uncorr.
B5 BPR/IES: 42º 13.86'N, 60º 18.41'W, 19:07, 20/8/04 (Jday 233), 4099m uncorr.

Note that depths stated above are as recorded (uncorrected) by the ship's EA500 echosounder: these overestimate the true depth, since the system assumes a constant sound speed of 1500 m/s. In choosing deployment sites, Carter's tables were used to correct to actual depths. Times above are GMT.

## CTD System Operation
**(Jeff Benson)**

1) A total of 5 CTD casts were completed on the cruise utilising this 24-way frame arrangement, with the following configuration:-

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

2) The configuration for the CTD was as follows, from cast 01 through cast 05:-

Sea-Bird 9+ underwater unit, s/n 09P-23241-0598
Sea-Bird 3 Premium temperature sensor, s/n 03P-2758 (frequency=0)
Sea-Bird 4 conductivity sensor, s/n 04C-2840 (frequency=1)
Digiquartz temperature compensated pressure sensor, s/n 78958 (frequency=2)
Sea-Bird 3 Premium temperature sensor, s/n 03P-2880 (frequency=3)
Sea-Bird 4 conductivity sensor, s/n 04C-2637 (frequency=4)
Sea-Bird 5T submersible pump, s/n 05T-3853 (primary)
Sea-Bird 5T submersible pump, s/n 05T-3829 (secondary)
Sea-Bird 24 position Carousel, s/n 32-34173-0482
Sea-Bird 11+ deck unit, s/n 11P-347173-0676

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

V0 = Sea-Bird 43 dissolved oxygen sensor, s/n 43-0076
V2 = Benthos PSA-916T altimeter, s/n 876
V5 = Chelsea Aquatracka MKIII fluorometer, s/n 088241
V6 = WETLabs/SeaTech LSS, s/n 635
V7 = Chelsea Alphatracka MKII transmissometer, s/n 161-2642-003

The configuration for the remaining instruments was as below:-

RD Instruments Workhorse Monitor 300 KHz, s/n 3726 (downward-looking/master)
RD Instruments Broadband 150 KHz, s/n 1308 (downward-looking/slave)
SOC stainless steel battery pressure case, re-chargeable cells, s/n 01
SOC/Sea-Bird Breakout Box, s/n BO19108

SOC 10KHz Beacon, s/n B11
Sonardyne HF Marker Beacon, s/n 217322-01 (12,000 metre)

3) A total of 5 CTD casts were completed on the cruise utilising this 24-way frame arrangement, with the following configuration:-

Sea-Bird 9/11+ CTD
Sea-Bird 24 position Carousel
SOC 10KHz beacon
24 by 10L Ocean Test Equipment water samplers

4) The configuration for the CTD was as follows, from cast 06 through cast 10:-

Sea-Bird 9+ underwater unit, s/n 09P-31240-0720
Sea-Bird 3 Premium temperature sensor, s/n 03P-4301 (frequency=0)
Sea-Bird 4 conductivity sensor, s/n 04C-2841 (frequency=1)
Digiquartz temperature compensated pressure sensor, s/n 90573 (frequency=2)
Sea-Bird 3 temperature sensor, s/n 03-1638 (frequency=3)
Sea-Bird 4 conductivity sensor, s/n 04-1375 (frequency=4)
Sea-Bird 5T submersible pump, s/n 05T-3090 (primary)
Sea-Bird 5T submersible pump, s/n 05T-3609 (secondary)
Sea-Bird 24 position Carousel, s/n 32-19817-0243
Sea-Bird 11+ deck unit, s/n 11P-347173-0676

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

V0 = Sea-Bird 43 dissolved oxygen sensor, s/n 43-0133

The configuration for the remaining instrument was as below:

SOC 10KHz Beacon, s/n B01

**Miscellaneous**

1) Salinometer----Two Guildline Portasals, models 8410A and 8410, s/n's 65738 and 62507 were used throughout the trip. A total of 96 salinity samples were analysed, 72 from CTD casts and 24 from TSG sampling. The salinometers were sited in a temperature-controlled lab; readings were very stable and drift was constant.

2) RO and Milli-Q water systems----OED system serial numbers 003 and 004 were installed in the wet lab prior to sailing, and were operated without problems for the duration of the cruise. One chlorine cleaning cycle was performed, and one pre-filter used.

**Table of Casts**

**CTD stations conducted with original (UKORS) SeaBird 911+ instrument:-**
Site A0: 6/8/04, 18:20Z, 1810m depth, 43º 16.38' N, 52º 11.40' W
Site A1: 7/8/04, 11:26Z, 2212m depth, 43º 11.84' N, 52º 14..59' W
Site A2: 7/8/04, 17:44Z, 2724m depth, 43º 06.58' N, 52º 19.60' W
Site A3: 8/8/04, 10:41Z, 3228m depth, 42º 54.79' N, 52º 29.20' W
Site A4: 8/8/04, 20:50Z, 3672m depth, 42º 40.02' N, 52º 40.71' W

**CTD stations conducted with replacement (Bedford Institute of Oceanography) SeaBird 911+ instrument:-**
Site B5: 20/8/04, 21:21Z, 4105m depth, 42º 13.81' N, 60º 17.62' W
Site B4: 21/8/04, 11:22Z, 3648m depth, 42º 26.72' N, 60º 27.70' W
Site B3: 21/8/04, 17:14Z, 3229m depth, 42º 37.06' N, 60º 36.49' W
Site B2: 21/8/04, 22:02Z, 2748m depth, 42º 48.86' N, 60º 46.03' W
Site B1: 22/8/04, 11:07Z, 2214m depth, 42º 55.83' N, 60º 50.97' W

Note that water depths given above are from EA500 echosounder, assuming a constant 1500 m/s speed of sound in seawater. Corrected depths will be between 5 and 20m shallower than this, based on Carter's tables.

Logsheets for the CTD casts are given in Appendix B.

## CTD Data Processing
**(Mike Meredith)**

CTD data were processed on CD160 using a combination of SeaBird software (SBEDataProcessing-Win32) and Matlab. This was done in addition to the routine processing done by Paul Duncan using solely SeaBird software, and detailed separately see Computing Report). Some of the Matlab routines used were based on ones written on JR80 (ShagEx), but were modified and adapted for purposes specific to CD160. The steps were as follows:-

*(SeaBird routines:-)*

`datcnv` To read the "CD160_XX.dat" file and "CD160_XX.con" file appropriate to the cast, and write output to "CD160_XX.cnv". The variables written were:-

1. scan count
2. pressure, digiquartz, (dbar)
3. temperature, ITS90, degC
4. temperature2, ITS90, degC
5. conductivity, mS/cm
6. conductivity2, mS/cm
7. altimeter, m
8. beam transmission, Chelsea/Seatech/Wetlabs
9. fluorescence, Chelsea Aqua 3, ug/l
10. oxygen saturation, ml/l
11. oxygen voltage, SBE43
12. oxygen, SBE43, ml/l
13. pump status

`filter` Low-pass filter the conductivity (0.03 seconds) and pressure (0.15 seconds) to increase pressure resolution prior to `loopedit`. (Loop Edit operates on three successive scans to determine velocity - this is such a fine scale that noise in the pressure channel from counting jitter or other unknown sources can cause `loopedit` to mark scans as bad in error). Output file called "CD160_XX_filt.cnv".

`align` Oxygen variables were advanced by 7 seconds relative scan, to account for time constants of sensors and water transit time delay in the pumped plumbing line. This value was derived by Paul Duncan by comparison of upcast and downcast profiles. More insight into the best value to use might have been obtainable had bottle samples been measured for oxygen concentration, but on CD160 they were not. No alignment was made for conductivity, since the deck unit was programmed to advance both primary and secondary conductivity with respect to pressure by +1.75 scans (at 24 Hz, this is 1.75/24 = 0.073 seconds, the typical value suggested by SeaBird). Previous versions of the deck unit firmware only advanced primary conductivity, hence this alignment was then required, but this was not the case for CD160. Output was “CD160_XX_align.cnv”.

`celltm` Applies a recursive filter to remove conductivity cell thermal mass effects from measured conductivity. Thermal anomaly amplitude (alpha) was set to 0.03; thermal anomaly time constant (1/beta) was set to 7. Output was “CD160_XX_celltm.cnv”.

`loopedit` This routine marks scans where the CTD package is moving less than minimum velocity or traveling backwards due to ship roll. For CD160, the minimum velocity was fixed, and set to 0.25 m/s. SBE911+ CTDs have been observed previously to show significant wake effects when working on large packages; routines such as `loopedit` have been shown to be effective at minimising the effects of these processes. Output was “CD160_XX_loop.cnv”.

(`wildedit` In addition to the above routines, cast 1 (a rather noisy profile) was `wildedit`ed using to remove large fliers).

*(Matlab routines:-)*

`ctdread.m` This program reads data stored in the “CD160_XX_loop.cnv” file into Matlab matrices by invoking the `cnv2mat.m` routine, and names them accordingly. Output is “ctdXX.cal”.

`editctd.m` Reads “ctdXX.cal”, and launches an interactive editor to enable manual despiking. Pairs of values (temperature1/conductivity1; temperature2/conductivity2) are set to missing if either are manually excluded, so as to avoid errors in calculation of salinity that would arise from original temperature and interpolated conductivity, or vice versa. Other variables were also edited. Output was “ctdXX.edt”.

`offpress.m` This was a substantially cut-down version of the code of the same name used on JR80, which did far more than was necessary. This version enabled the inputting of an offset pressure (default 0), and set variables to missing if the pumps were not operational (judged by pump status). Output was “ctdXX.wat”

`makebot.m` Reads the SeaBird “CD160_XX.ros” file and the “ctdXX.wat” file to create a bottle file (“botXX.1st”). CTD data corresponding to the bottle firings were derived as the median values obtained between the start and stop scans given in the .ros file. Temperature on the IPTS-68 scale was derived (used for input to Matlab seawater routines), and salinity and potential temperature calculated using `ds_salt.m` and `ds_ptmp.m`. Warnings were written if large standard deviations in the CTD data corresponding to the bottle firings were obtained. The "CD160_XX.bl" file was read to determine which bottle was fired where.

`readsal.m` This loads the text file of bottle salinities, "CD160_XX_sam.txt", sets a flag according to presence/quality of salinity measurement, and outputs "salXX.mat".

`addsal.m` This reads the "botXX.1st" file, and adds the sample salinity. Output is "botXX.sal".

`setsalflag.m` Sets flag to zero for instances where the standard deviation of any of conductivity1, conductivity2, temperature1 or temperature2 at the bottle firing levels is greater than 0.002 in the "botXX.sal" file.

`salplot.m` Produces plots of CTD and bottle salinity with depth, and CTD-bottle salinity difference with depth. Enables determination of which bottles should be used to determine offsets to be applied to the CTD data to reconcile them with the bottle data. Flags were changed in the "botXX.sal" file for this by loading the file, manually changing the salflag variable, and re-saving it.

`salcal.m` Calculated the adjustment to nominally calibrated CTD salinity required to get the best fit to bottle data. Calls the `sw_cndr.m` routine to calculate conductivity from the bottle salinities at the temperature and pressure of the corresponding CTD salinities. The derived offsets are placed in the "botXX.sal" file.

`salcalapp.m` Applies the derived offsets to the CTD conductivities, calculates salinity, potential temperature, potential densities (sigma0, sigma2, sigma4). Works on CTD data stored in both CTD file and bottle file. Outputs to "ctd01.var" and "bot01.cal".

`splitcast.m` Divides the CTD cast into an upcast and a downcast, with the dividing point being determined via the maximum value of pressure. Output is "ctdXX.var.dn" and "ctdXX.var.up".

`gridctd.m` Reads the downcast profile and derives 2 dbar averages of all properties. Writes to "ctdXX.2db".

`fill_to_surf.m` Used in instances where very surface layers contained missing values, due to CTD not being brought sufficiently close to surface before commencing downcast. Extends shallowest measured level to levels above. Output again to "ctdXX.2db".

Miscellaneous points:

1) Best values for salinity, temperature etc were stored as variables “salin”, “temp” etc, alongside the primary and secondary values (“salin1”, “temp1” etc.), to indicate the preferred sensor to use.

2) On cast 1 (site 0A), the secondary salinity was set to missing since it was extremely noisy.

3) Cast 5 (at site 4A) had no bottle samples, since the CTD package was lost during recovery. No conductivity offsets were applied to the data from this cast.

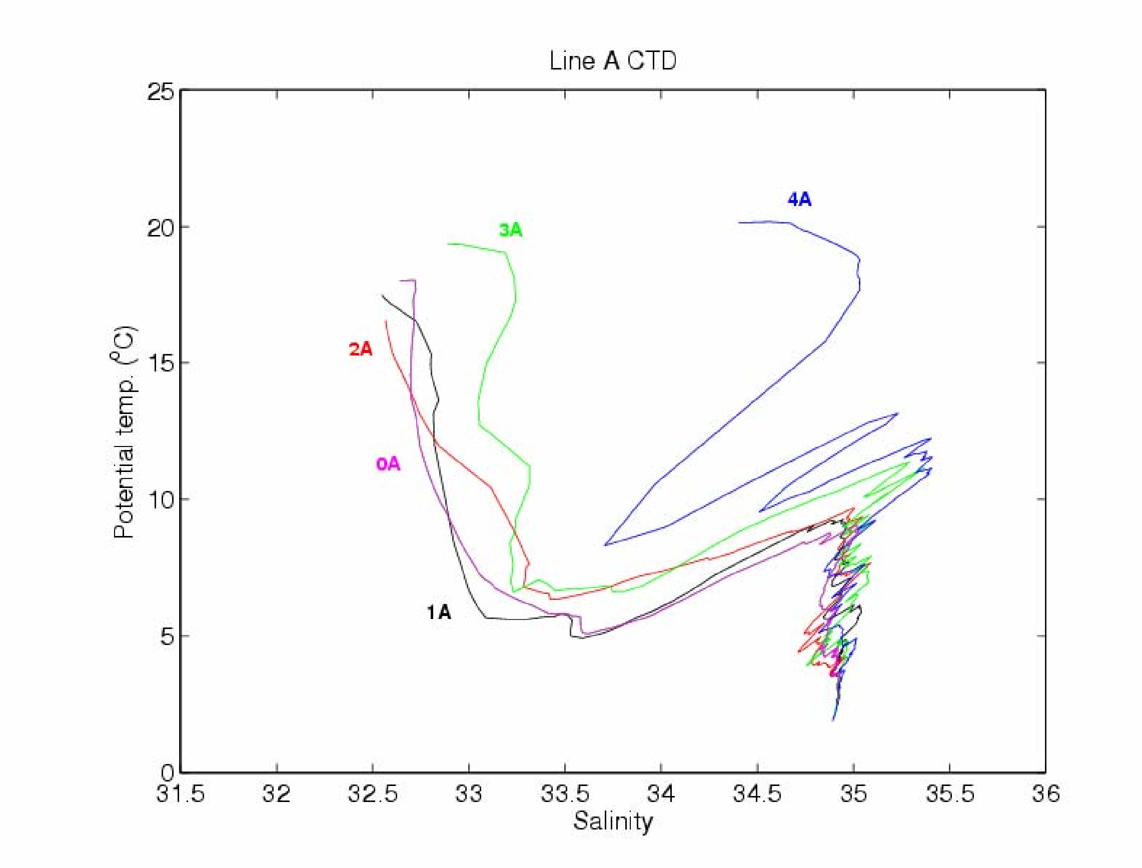



*Figure 4: Potential temperature-salinity diagram for calibrated 2bar CTD data collected along Line A. Curves are coloured according to site.*

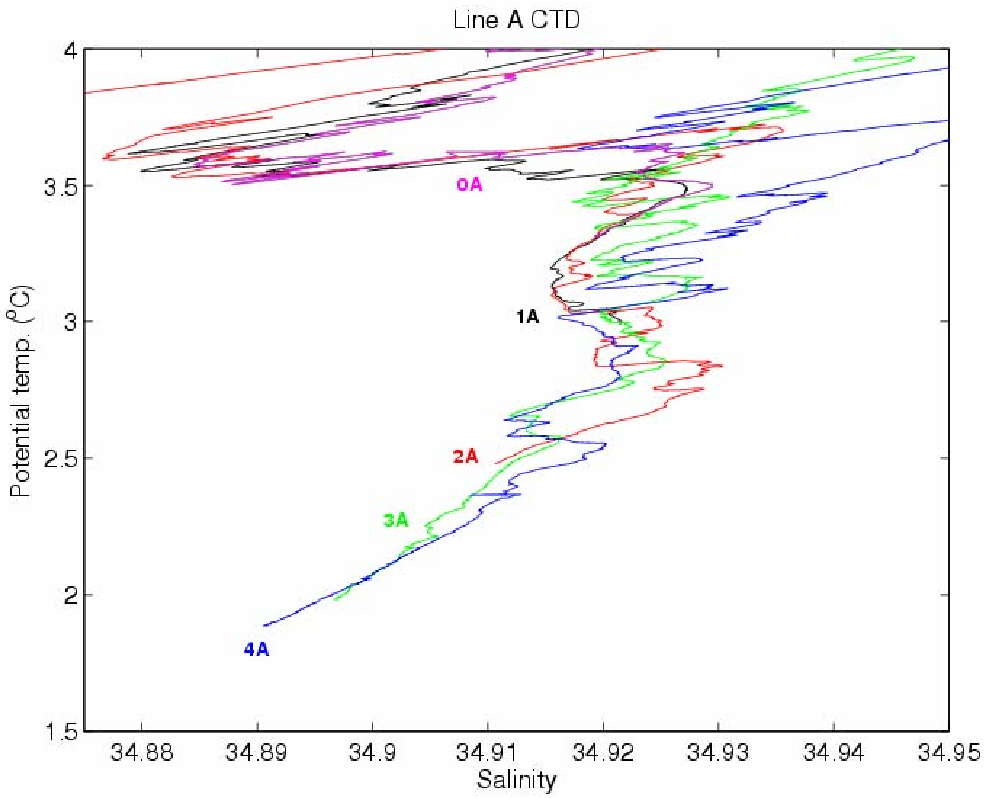



*Figure 5: Potential temperature-salinity diagram for calibrated 2bar CTD data collected along Line A. Curves are coloured according to site. Bottom waters only.*

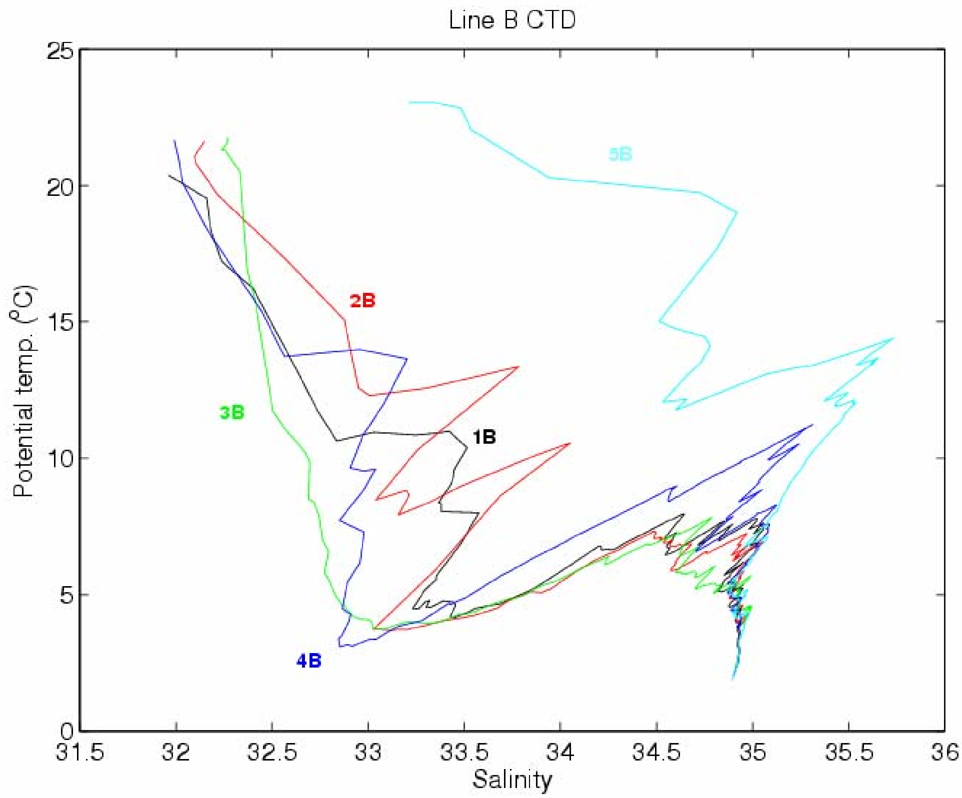



*Figure 6: Potential temperature-salinity diagram for calibrated 2bar CTD data collected along Line B. Curves are coloured according to site.*

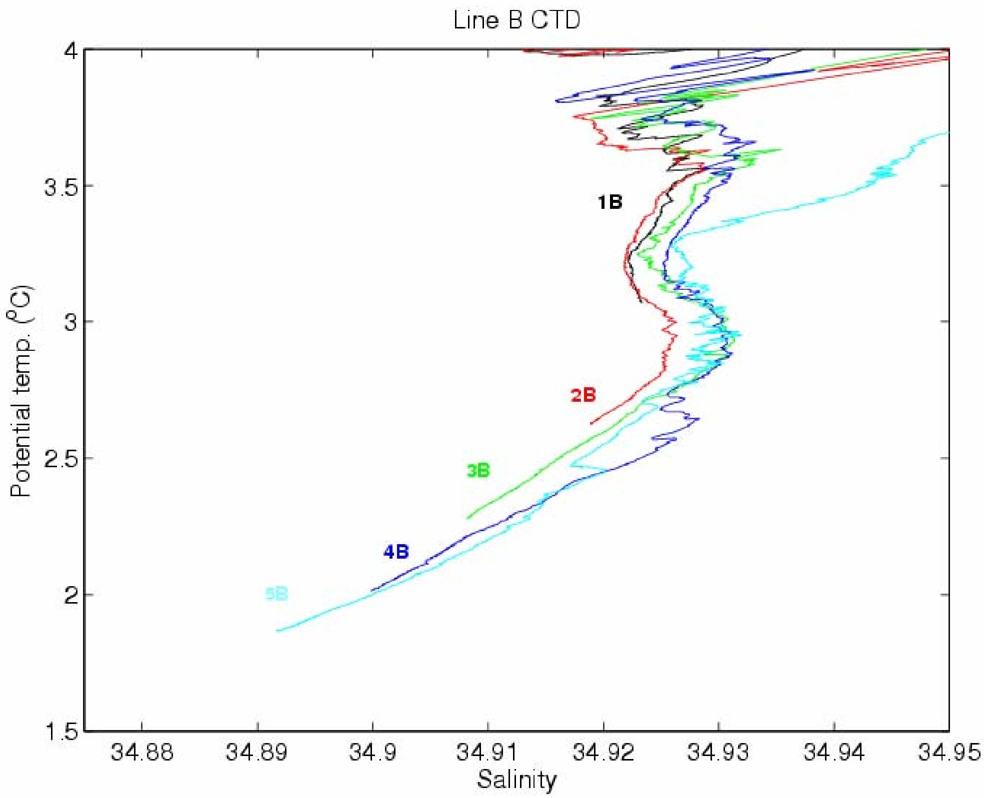



*Figure 7. Potential temperature-salinity diagram for calibrated 2bar CTD data collected along Line A. Curves are coloured according to site. Bottom waters only.*

## Tracer Sampling
**(Mike Meredith)**

Each of the CTD casts was sampled for tracers, with the exception of the cast at Site 4A where the CTD package was lost during recovery. Samples for oxygen isotope analysis were drawn from the Niskins into 150 ml medical flat bottles with rubber seals in the caps. These had been rinsed with sample prior to collection, and were then filled leaving a small (~1-2 cm) air gap for sample expansion. Bottles were dried, and then sealed with Parafilm©. Samples for iodine-129 were drawn into 1-litre plastic bottles, with separate neck inserts. All Niskins were sampled for oxygen isotopes, with the exception of a small number where the Niskin was believed not to have closed properly. Around 11-13 Niskins from each station were sampled for iodine-129, with a sampling strategy designed to emphasise the bottom waters and the depths of the CTDs on the moorings. Samplings are detailed on the CTD logsheets (Appendix B). Samples were boxed for shipping back to the UK for laboratory analysis.

## Underway Equipment
**(Jeff Benson)**

1) Simrad EA-500----The echo sounder had no working problems; the HP colour printer was tested and operated normally.

2) PES towed body----The "fish" was deployed from the beginning of the cruise, and operated successfully throughout.

3) Chernikeeff EM Log----The EM Log was again out of calibration at all speeds, especially impacting the lower range. A calibration run of five legs was completed shortly after sailing, consisting of five different RPM ranges, and run for one GPS measured nautical mile on reciprocal courses.

4) VMADCP----VM-DAS was installed with the cruise specific parameters modified upon departure. Percent Good data deteriorated soon thereafter; the transducer housing for the ADCP was vented of air, but the problem persisted. Built In Tests continued to pass throughout, indicating the instrument was performing normally. Power supplies and voltages were investigated, and no failures were found. Suggested causes are trapped debris, such as fishing line, or lack of scattering particles in the water column. During in port in Halifax divers cleaned the transducer faces of soft growth. Hard calcification deposits were noted; no debris fouling was found. Post-clean the VMADCP performance was improved somewhat.

5) EM12----The SWATH system was operated throughout the cruise, primarily for bathymetry along the CTD/BPR/mooring stations. No problems with data acquisition or performance found.

6) Gravity meter----The system was installed prior to cruise CD158 and was operated for the duration of CD160 without problems.

**SurfMet**

1) The SurfMet system was installed for this cruise in the following configuration:

A) TSG system:
housing temperature FSI OTM s/n 1361
remote temperature FSI OTM s/n 1370
housing conductivity sensor FSI OCM s/n 1358
flow-through 20cm transmissometer WetLabs/SeaTech s/n T-1019D
flow-through fluorometer WETLabs s/n WS3S-134

All the above sensors are calibrated with the exception of temperature and conductivity which have their calibration stored internally. Rhopoint DGH convertors are used to give +/- 5 volts for the transmissometer and fluorometer data. The transmissometer and fluorometer were cleaned at weekly intervals throughout the cruise, with air and blank values recorded pre- and post-cleaning to monitor sensor drift.

B) Met system:

air temperature/relative humidity Vaisala HMP44L s/n S504004
barometric pressue Vaisala PTB100A s/n S3440009:
(Julian Day 217 through 227)
barometric pressue Vaisala PTB100A s/n S3440012:
(Julian Day 231 through 237)
port PAR sensor Didcot/ELE DRP-5 s/n 5143
starboard PAR sensor Didcot/ELE DRP-5 s/n 5144
port TIR (pyranometer) sensor Kipp & Zonen s/n 962276
starboard TIR (pyranometer) sensor Kipp & Zonen s/n 962301
anemometer Vaisala WAA s/n P22306
wind vane Vaisala WAV s/n R21213

Barometric pressure sensor failed during the power fluctuations whilst in port in Halifax, and was replaced. The wind speed and direction are not calibrated; all other meteorlogical sensors have calibrations. Met system data is collected through a Vaisala QLI50 sensor collector. All SurfMet data is polled once every second; a thirty second average is then taken and sent to the OED shipboard data collection for application of calibration constants. In addition, salinity is calculated using the housing temperature and conductivity sensors, and calibrated throughout the cruise by salinity samples.

## Routine Underway Data Processing
**(Mike Meredith)**

For CD160, all processing of underway data was done in the Matlab environment. It had been intended for some time to port the existing Pstar code to Matlab, to make the processing more independent of platform, and to enable use of structured arrays available in Matlab. This was done now, since time was available at the start of CD160 for this coding to take place. Some of the code was developed from programs written on JR80 by D. Stevens et al., but with developments and modifications as appropriate.

### Navigation

*Gyrocompass*

| | |
|---|---|
| `get_gyro` | Invokes the RVS `listit` command to retrieve 24 hours of gyrocompass data, corresponding to JDAY XXX, and write to an ascii file "gyro.XXX" |
| `loadgyro.m` | Matlab code to read "gyro.XXX", arrange into matrices and name accordingly. Saves output as "gyroXXX.mat". Produces a rough plot of heading against time, for quick check of data completeness and integrity. |
| `gyroall.m` | Matlab code to append "gyroXXX.mat" to the master file "gyro_all_cd160.mat" |

*Bestnav*

| | |
|---|---|
| `get_bestnav` | Invokes the RVS `listit` command to retrieve 24 hours of bestnav data, corresponding to JDAY XXX, and write to an ascii file "bestnav.XXX" |
| `loadbestnav.m` | Matlab code to read "bestnav.XXX", arrange into matrices and name accordingly. Saves output as "bestnavXXX.mat". Produces a rough plot of ship's position over the 24 hour period, for quick check of data completeness and integrity. |
| `bestnavall.m` | Matlab code to append "bestnavXXX.mat" to the master file "bestnav_all_cd160.mat" |

*Ashtech*

`get_gpsash` Invokes the RVS `listit` command to retrieve 24 hours of Ashtech data, corresponding to JDAY XXX, and write to an ascii file "gpsash.XXX"

`loadgpsash.m` Matlab code to read "gpsash.XXX", arrange into matrices and name accordingly. Saves output as "gpsashXXX.mat". Produces a rough plot of ship's position over the 24 hour period, for quick check of data completeness and integrity.

`gpsashall.m` Matlab code to append "gpsashXXX.mat" to the (raw data) master file "gpsash_all_cd160.mat"

`gpsgyrmerge.m` Matlab code to read "gpsashXXX.mat", and merge in gyrocompass data from gyro master file "gyro_all_cd160.mat". Uses Ashtech time stamps for interpolation, and calculates heading difference (Ashtech minus gyro). Ensures that heading difference lies in the range -180 to +180º. Produces a quick plot of Ashtech heading, gyro heading and the heading difference. Saves as "gpsashgyrXXXmerge.mat".

`gpsgyrclean.m` Cleans up merged Ashtech and gyro. Rejects heading difference (Ashtech minus gyro) for which the following criteria apply:-
Ashtech heading > 360 or < 0
Ashtech minus gyro heading difference < -5 or > 5
Ashtech pitch < -5 or > 5
Ashtech roll < -7 or > 7
Ashtech attf < -0.5 or > 0.5
Ashtech mrms < 0.00001 or > 0.01
Ashtech brms < 0.00001 or > 0.1
Runs a 9 point median filter over the heading difference, and creates 2 minute averages (ensuring that time stamps of 2 minute averages are even integers, to enable future concatenation)
Produces a quick plot of heading difference (raw) and heading difference (2 minute averages), and interpolates across missing data in the output file "gpsashgyrXXXclean.mat"

`gpsgyredit.m` Launches a basic interactive editor to enable manual cleaning of the 2 minute averaged Ashtech-gyro heading. Interpolates across removed points, and produces a quick plot of original data and final data. Saves output to "gpsashgyrXXXedit.mat"

`gpsgyrashaveall.m` Reads output of `gpsgyredit.m` and appends to master file of cleaned, edited data, "gpsgyrave_all_cd160,mat". Produces a quick plot of heading difference in master file.

*GPS NMEA*

`get_gpsnmea` Invokes the RVS `listit` command to retrieve 24 hours of nmea data, corresponding to JDAY XXX, and write to an ascii file "gpsnmea.XXX".

`loadgpsnmea.m` Matlab code to read "gpsnmea.XXX", arrange into matrices and name accordingly. Saves output as "gpsnmeaXXX.mat". Produces a rough plot of ship's position over the 24 hour period, for quick check of data completeness and integrity.

`gpsnmea_all.m` Matlab code to append "gpsnmeaXXX.mat" to the master file "gpsnmea_all_cd160.mat"

*GPS4000*

`get_gps4000` Invokes the RVS `listit` command to retrieve 24 hours of gps4000 data, corresponding to JDAY XXX, and write to an ascii file "gps4000.XXX".

`loadgps4000.m` Matlab code to read "gps4000.XXX", arrange into matrices and name accordingly. Saves output as "gps4000XXX.mat". Produces a rough plot of ship's position over the 24 hour period, for quick check of data completeness and integrity.

`gps4000all.m` Matlab code to append "gps4000_XXX.mat" to the master file "gps4000_all_cd160.mat"

*Acoustic Doppler Current Profiler (ADCP)*

`get_adcp` Invokes the RVS `listit` command to retrieve 24 hours of adcp data, corresponding to JDAY XXX, and write to an ascii file "adcp.XXX".

`loadadcp.m` Matlab code to read "adcp.XXX", arrange into matrices and name accordingly. Subtracts 45$^o$ from heading variable, to account for orientation of transducers in hull – this would not be needed on certain other ships. Velocities converted to cm/s, automatic gain control (agc) converted to db, and time moved to centre of 2 minute ensemble. Absent values replaced with NaN (Matlab missing data code). Water velocity data saved as a matrix into "adcpXXXwater.mat", bottom velocity data saved as an array into "adcpXXXbottom.mat".

`adcpashcorr.m` Reads "adcpXXXwater.mat" and the master Ashtech/gyro merged file "gpsgyrave_all_cd160.mat". Interpolates Ashtech/gyro heading correction to times of adcp data. Uses imaginary numbers to calculate speed and direction from adcp east and north velocities, then adds Ashtech/gyro heading correction to adcp direction. Converts speed and direction back to east and north velocities, then saves output as "adcpXXXwater_true.mat". Repeats above for bottom velocities, saving output to "adcpXXXbottom_true.mat".

`adcpcal.m` Loads "adcpXXXwater_true.mat" and "adcpXXXbottom_true.mat". Asks if a dummy or real calibration is being applied (if dummy, offset correction phi is set to 0 and scaling factor A is set to 1. These values are derived more accurately toward the end of the cruise, and data reprocessed from this stage with correct values of phi and A). Working on bottom velocity data: calculates speed and direction from adcp east and north velocity, applies cals for A and phi, and convert back. Saves output as "adcpXXXbottom_cal.mat". Repeats above for water velocity data, but in addition removes velocities for which percentage good is less than 25. Saves output as "adcpXXXwater_cal.mat".

`adcpvelabs.m` Reads "adcpXXXwater_cal.mat", "adcpXXXbottom_cal.mat", and "bestnav_all_cd160.mat" (bestnav master file). Moves timebase (temporarily) to end of 2 minute ensemble, interpolates bestnav latitude and longitude to times of adcp time stamps, and calls `sw_dist.m` to calculate distance and angle (of ship's course) from navigation data. Distance converted to cm, and speed (in cm/s) calculated from this and the time interval. Speed and angle then used to calculate ship's east and north velocities. Timebase moved back, and work saved to "adcpXXXbottom_abs.mat". Ship's east and north velocities interpolated to times of adcp time stamps, and absolute water velocities calculated by adding water velocities (east and north) to ship's velocities. Output saved as "adcpXXXwater_abs.mat". A quick plot of vectors at a randomly-chosen bindepth is produced.

**Echosounding**

*Simrad EA500*

`get_ea500` Invokes the RVS `listit` command to retrieve 24 hours of ea500 data, corresponding to JDAY XXX, and write to an ascii file "ea500.XXX".

`loadea500.m` Matlab code to read "ea500.XXX", arrange into matrices and name accordingly. Saves output as "ea500_XXX.mat". Produces a rough plot of uncorrected depth over the 24 hour period.

`cleanea500.m` Loads "ea500_XXX.mat", removes large spikes with `dspike.m`, and launches basic interactive editor for further cleaning. A second run of `dspike.m` is enabled, followed by a 101-point median filter. Discarded depths are interpolated across, and output saved to "ea500_XXXclean.mat".

`ea500nav.m` Loads file "ea500_XXXclean.mat", interpolates across missing values and puts data on a regular 5 second interval, from which 2 minute averages are derived. The bestnav master file "bestnav_all_cd160.mat" is loaded, and latitudes and longitudes interpolated to the times of the ea500 timestamps. A quick plot of depth along the ship's track is produced, and data are saved to a file "ea500_XXXnav.mat".

`ea500all.m` Load "ea500_XXXnav.mat", and appends to master file "ea500_all_cd160.mat"

*Prodep*

`get_prodep` Invokes the RVS `listit` command to retrieve 24 hours of prodep data, corresponding to JDAY XXX, and write to an ascii file "prodep.XXX".

`loadprodep.m` Matlab code to read "prodep.XXX", arrange into matrices and name accordingly. Saves output as "prodepXXX.mat". Produces a rough plot of corrected depth over the 24 hour period.

`cleanprodep.m` Loads "prodepXXX.mat", removes large spikes with `dspike.m`, and launches basic interactive editor for further cleaning. A second run of `dspike.m` is enabled, followed by a 101-point median filter. Discarded depths are interpolated across, and output saved to "prodepXXXclean.mat".

`prodepnav` Loads file "prodepXXXclean.mat", interpolates across missing values and puts data on a regular 5 second interval, from which 2 minute averages are derived. The bestnav master file "bestnav_all_cd160.mat" is loaded, and latitudes and longitudes interpolated to the times of the prodep timestamps. A quick plot of depth along the ship's track is produced, and data are saved to a file "prodepXXXnav.mat".

`prodepall.m` Load "prodepXXXnav.mat", and appends to master file "prodep_all_cd160.mat"

**Surface meteorology and thermosalinograph**

`get_surfmet` Invokes the RVS `listit` command to retrieve 24 hours of surfmet data, corresponding to JDAY XXX, and write to an ascii file “surfmet.XXX”.

`loadsurfmet.m` Matlab code to read “surfmet.XXX”, arrange into matrices and name accordingly. Saves output as “surfmet_XXX.mat”. Produces rough plots of sea surface temperature, sea surface conductivity, air temperature, barometric pressure and surface fluorescence over the 24 hour period.

`cleansurfmet.m` Loads “surfmetXXX.mat”, and runs dspike.m to remove large spikes in conductivity, housing (CTD) temperature and remote (hull) temperature. Interpolates across removed points, then launches basic interactive editor for further cleaning of conductivity, housing temperature and remote temperature. Calls `ds_salt.m` to calculate surface (uncalibrated) salinity from conductivity and housing temperature. Output saved to “surfmetXXXclean.mat”.

`truewind.m` Loads file “surfmetXXXclean.mat” and master file “gyro_all_cd60.mat”. Interpolates gyro heading onto same time stamps as surfmet, and ensures that they lie in the range 0 to 360. Note that, on the Darwin, the convention is that the surfmet wind direction is the direction the wind is blowing TO, not FROM (this is because, when the ship is on station, i.e. head-to-wind, the direction would otherwise be flicking around 0/360, which would cause problems with averaging. Hence it is made that when ship is head-to-wind, direction is ~180). Read wind direction is obtained by adding surfmet direction to gyrocompass heading. Surfmet wind speeds and (real) directions are broken into east and north velocity components. Ship’s velocity is derived from position fixes, and this speed and angle are converted to ship’s east and north velocities. These are interpolated to the same timestamps as the surfmet data. East and north components of real wind and derived by adding the east and north components of ship’s velocity and wind velocity. These are converted back to true wind speed and direction, with direction forced to lie in range 0 to 360. Two direction variables are defined, one being the direction the wind is blowing to and the other being the direction the wind is blowing from (this to avoid any possible confusion!). Output is file “surfmetXXXwinds.mat”.

`surfmetnav.m` Loads file “surfmetXXXwinds.mat”, interpolates data onto 5 second interval and derives 2 minute averages (uses proper vector averaging for wind direction, to avoid problems with cyclicity giving incorrect averages). Loads master file "bestnav_all_cd160.mat", and interpolates latitude and longitude to timestamps of surfmet data. Produces quick plots of sea surface temperature, sea surface salinity, and wind vectors along ship's track. Saves output to master file "surfmetXXXnav.mat". Ensure, that `truewind.m` was run immediately before `surfmetnav.m`.

`surfmetall.m` Loads "surfmetXXXnav.mat" and appends to master file "surfmet_all_cd160.mat". Produces quick plots of sea surface temperature, sea surface salinity and wind vectors along ship's track for the duration of the cruise to date.

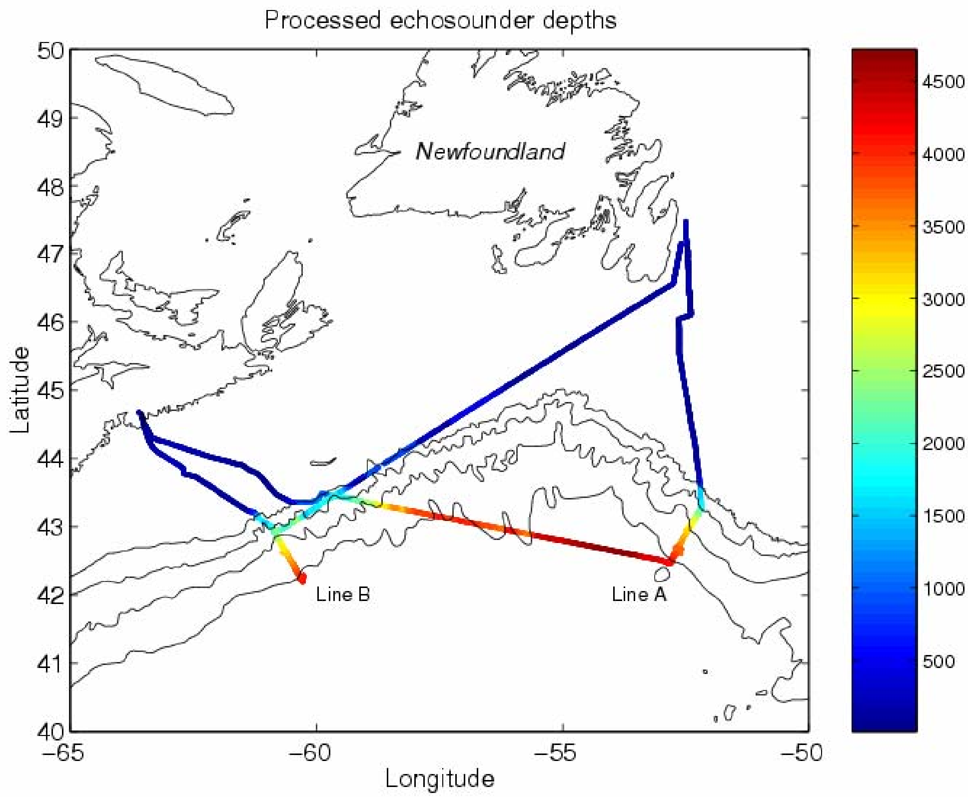



*Figure 8: Processed echosounder depths along the CD160 cruisetrack.*

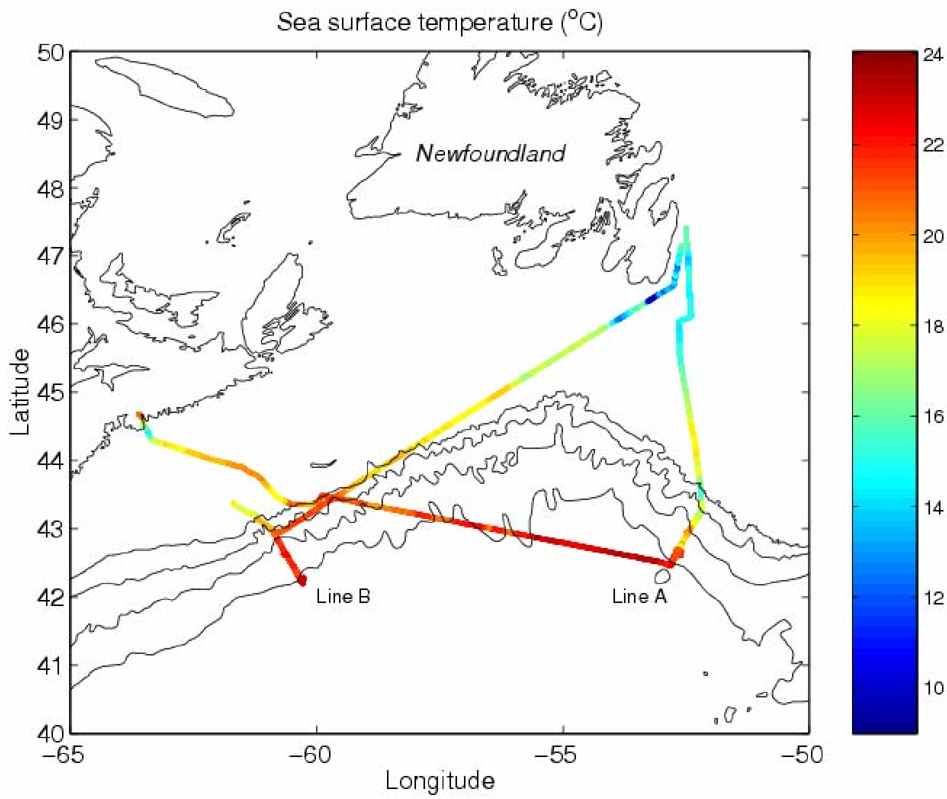



*Figure 9. Sea surface temperature from the thermosalinograph along the CD160 cruisetrack.*

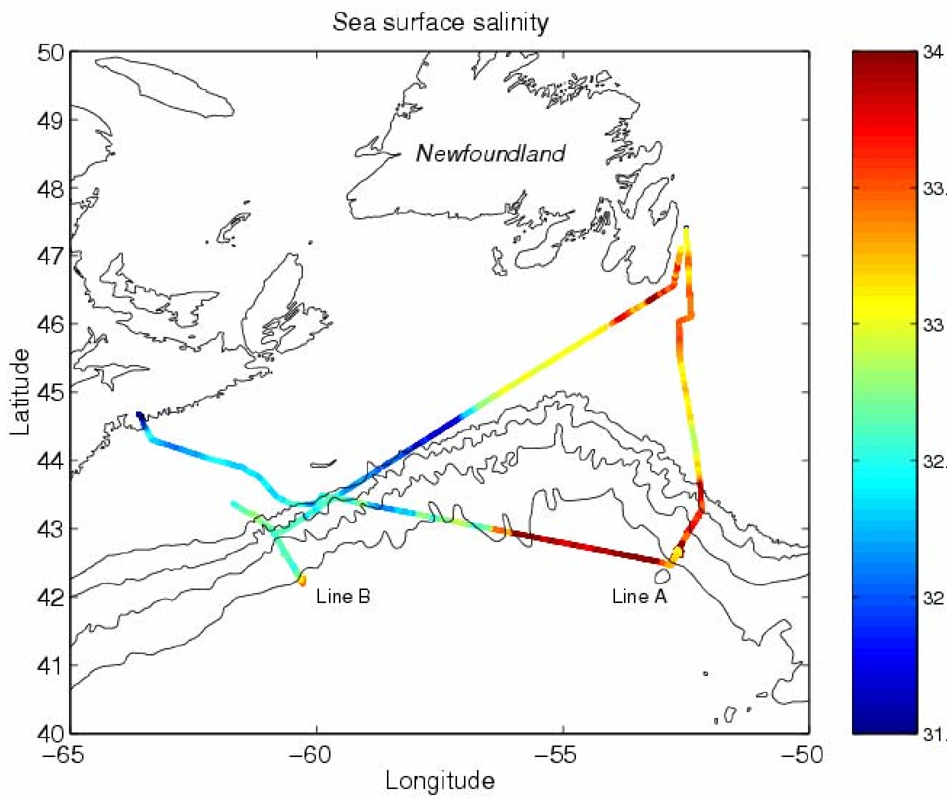



*Figure 10. Sea surface salinity from the thermosalinograph along the CD160 cruise track.*

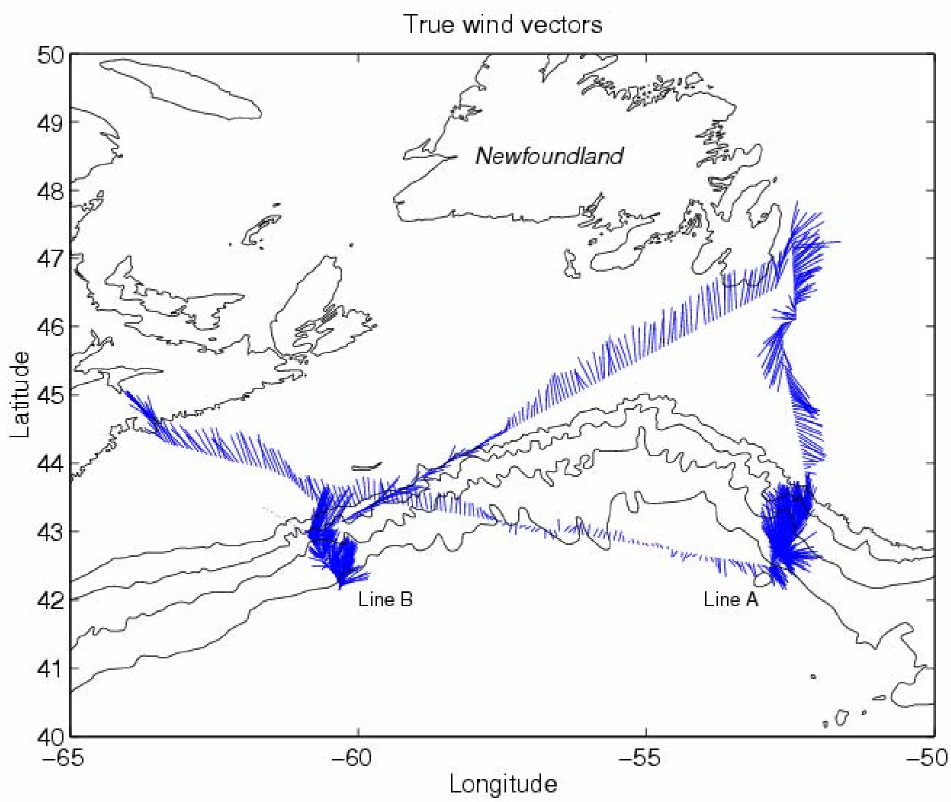



*Figure 11. Wind vectors (corrected for ship's speed, heading and course) along the CD160 cruisetrack.*

## Computing
**(Paul Duncan)**

### Data Logged

The following data were logged from RVS Mk II Level A systems:

GPS_4000 Trimble 4000DL GPS receiver (printer output)
GPS_ASH Ashtech ADU-2 4 antenna attitude GPS receiver
EA500D1 Simrad EA-500 10KHz echo sounder
GRAVITY Lacoste & Romberg gravity meter (S/N: S40)
GPS_NMEA backup of the GPS_4000 stream, logged via a printer to NMEA converter
GYRONMEA Ship's gyro
GPS_G12 Ashtech/Fugro Seastar differential GPS receiver (NB: this receiver is primarily used to feed differential corrections to the Trimble 4000DL receiver
LOG_CHF Chernikeeff two component electro-magnetic speed log

The following date were logged from PC type Level A systems:

WINCH Wire type, wire out, tension and haul/veer rate from the *CLAM* system
SURFMET Various sea surface and meteorological data

Data from the RDI 150KHz narrowband vessel-mounted ADCP were logged direct to the *darwin1* Sun workstation

The Simrad EM-12S swath bathymetry system was also turned on during this cruise, and data logged on the *mermaid* Sun workstation. No processing was performed, but the raw data was displayed on both the bridge and the main lab using the *Merlin* system.

The Seabird 9/11+ CTD system was logged using the CTD PC, the data were then "walknetted" across to the translation PC via Zip Disk, and the data were then copied to the *darwin1* system, where they were able to be backed up with the other data, and exported on a network drive for processing on the translation PC.

### Data Processing

Standard navigation processing, consisting of the *relmov* and *bestnav* programs, was used on this cruise. *relmov* takes in data from the EM log and gyro in order to generate a relative motion file. This relative motion file is then combined with one or more fix files by the the *bestnav* program in order to generate two files, bestnav and bestdrf. The original idea behind *bestnav*, was that it would take infrequent fixes, such as those from older transit satellite systems (typically several hours between fixes), or even fixes manually input from sextant sightings, and then dead-reckon between those fixes. Today, with GPS fixes coming in every second, its dead-reckoning facility is only used for periods when GPS drops out, for instance due to an aurora.

Wind speed and direction logged via the Surfmet system were processed into absolute windspeed and direction using the *windcalc* program, taking into account the ship's heading and speed.

Depth data from the Simrad EA-500 echo sounder were corrected for Carter Area using the *prodep* program.

Salinity data was derived from temperature and conductivity data logged via the Surfmet system using the *protsg* program.

The standard Seabird processing software was used to process the ten CTD casts. The following processing steps were performed:

> Data Conversion - used to convert the raw .dat files into .cnv files which can be used for further processing. Frames can be skipped as well, which can be useful for removing data logged during the soak period before the CTD starts down.
> Cell Thermal Mass - used to take account of the speed at which the conductivity cell heats up and cools down in reaction to changing water temperature.
>
> Align - used to compensate the time taken by slower sensors such as oxygen to sample. The principal scientist was performing his own CTD processing during this cruise (using Matlab), and so a 7 second oxygen alignment was used.
>
> Filter - This is used to reduce frequency digitisation errors, particularly with the pressure data.
>
> Loop - removes the effects of ship heave from the data.
>
> Derive - calculate additional variables from the logged data. Mainly used for calculating sound velocity for input into the Simard EM-12S.
>
> Bin Average - used to average the data in seconds or into pressure/depth bins. Data was averaged into two files, one for one metre bins, and the other for ten metre bins.

**Equipment**

RVS A/B systems running on bespoke 68000/68020/68030 based hardware, using the Microware OS-9 real time operating system.

Level C software running on a Sunblade 1500 computer (*darwin1*) with 1GB of RAM, 2 x 80GB hard disks, Sun DLT-7000 tape drive, QIC150 tape drive, and the Solaris 8 operating system.

*darwin2* - A Sun Ultra 10, with around 20GB of local disk and running the Solaris 7operating system. Used as the main printer server, SAMBA server (to allow PC's access to disk space on the Suns). Used as a general user machine with Matlab software, C compiler and currently Pstar software available.

*darwin2ng* - A Sunblade 150, with 1GB of RAM, a 40GB drive and running the Solaris 9 operating system. This will ultimately take over from the current *darwin2* system, currently it acts as the ship's NIS and DNS server. It has the new Sun Studio C compiler installed, as well as Adobe Acrobat reader, Tcl/Tk and the GNU C Compiler. New Matlab software should be installed before the end of the year as well as new SAMBA software. Finally, the system will take over as print server.

*darwin3* - This is basically a Sun Ultra 5 with two external SCSI disk drives, a Sun DLT-7000 tape drive and running the Solaris 7 operating system. Typically this is used as a data server to store data from instruments or systems that generate lots of data, such as the 3.5KHz sub-bottom profiler.

*darwin5* - A sunblade 150, with 1.1GB of RAM and a 40GB drive. This provides a DHCP facility for the ship, allowing people to come on board with PC's, plug them into the network, and select automatic, or server-assigned, IP address, instead of having the computer person manually allocate and address. This system is also used to run a web server with the SquirrelMail web front end to the E-mail system. This system does have about 27GB of free disk space which can be allocated to a user if required.

*mermaid* - A Sun Ultra 1 with 128MB of RAM, three external SCSI disk drives and the Solaris 7 operating system. This system is used to log data from the Simrad EM-12S multibeam echo sounder.

*Darwin-comm* - A PC running the Red Hat Linux 6.2 operating system. The system is used to run the British Antarctic Surveys AMS – E-mail transfer system, and provides the SMTP server for outbound scientific E-mail and POP3 and IMAP servers for reading inbound E-mail. It was also used as an informal web server for things such as cruise diaries, disseminating information on the new NERC research vessel, and other things.

Tranlation PC - A Dell PC running Windows XP, with a USB hub to allow easy access for USB disks etc, a multi-standard memory card reader, and flat-bed A4 scanner. Various software such as Microsoft Office is installed on this system.

## Concluding Remarks and Acknowledgements

The aims of the cruise at the outset were to deploy 12 BPRs (some with IESs) and 10 CTD moorings, and conduct CTD/LADCP profiling at each of the deployments sites. In practice, it was not possible to entirely meet all of these aims. Whilst the BPR, BPR/IES and mooring deployments went well, technical problems resulted in less CTD data and tracer samples than would have been ideal. The loss of the initial CTD/LADCP package on Line A was a blow; Canadian colleagues from Bedford Institute of Oceanography generously lent us a replacement CTD for the duration of the cruise, but further LADCPs were not available. Problems with the ship's engines meant that less time than ideal was available for the use of this replacement CTD, with 2 stations omitted from the intended programme. The mooring and BPR deployments were all successfully made, however, along with >75% of intended CTD data collected; it is thus considered that CD160 has been a success and a useful contribution to the project overall.

It should be stressed that, due to the technical problems encountered, this was not an easy cruise for any of the officers, crew, scientists or technicians involved. However, all onboard worked extremely hard during the cruise, and showed great professionalism throughout in dealing with the difficulties. Without this effort, the work we completed would not have been possible. Sincere thanks are due to Peter Sarjeant and the officers and crew of Darwin, and to the scientific and technical teams that participated in CD160.

Dr. Mike Meredith, Principal Scientist

# Appendix A – Mooring Diagrams

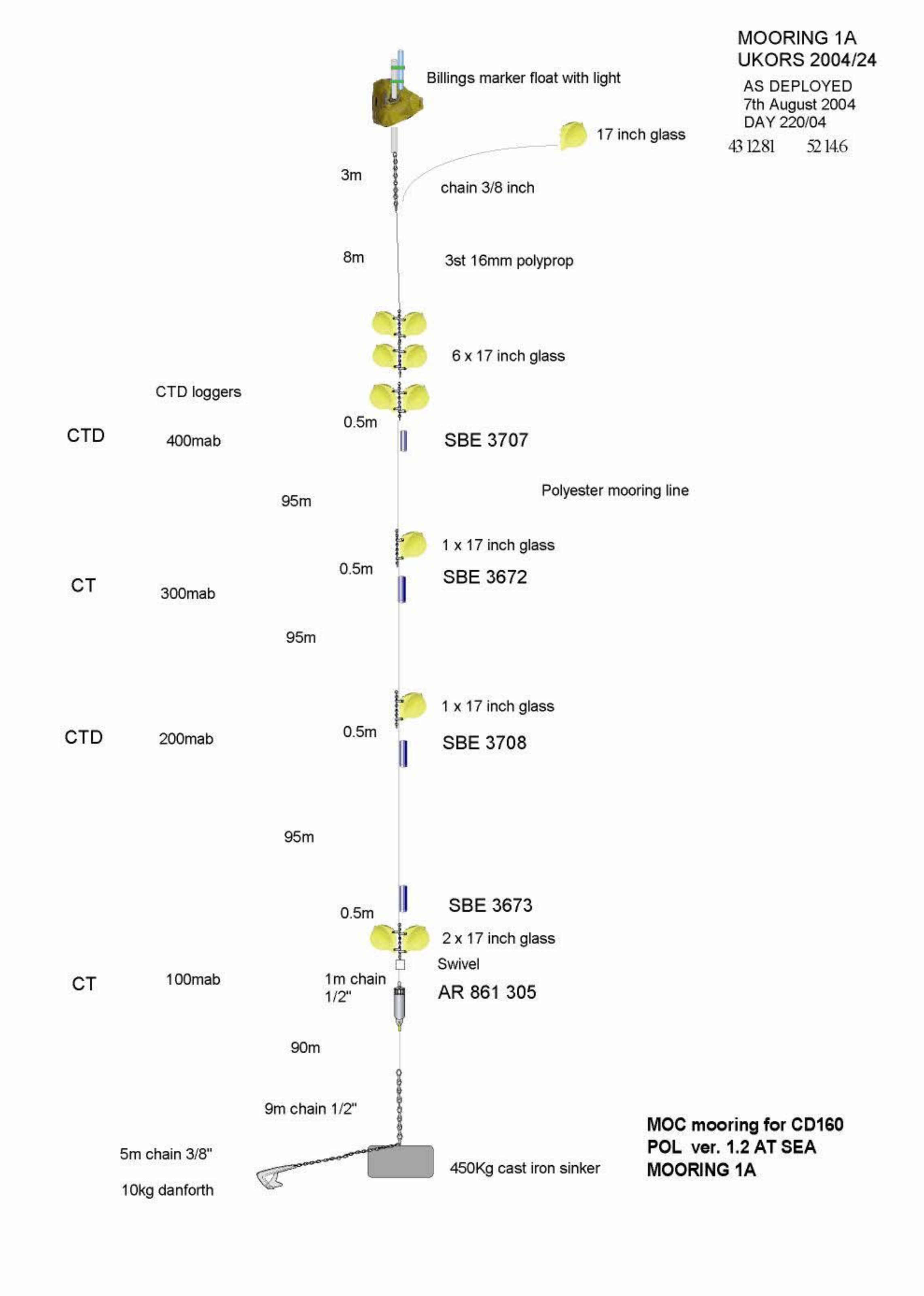



*Figure 12. Mooring diagram for Site 1A.*

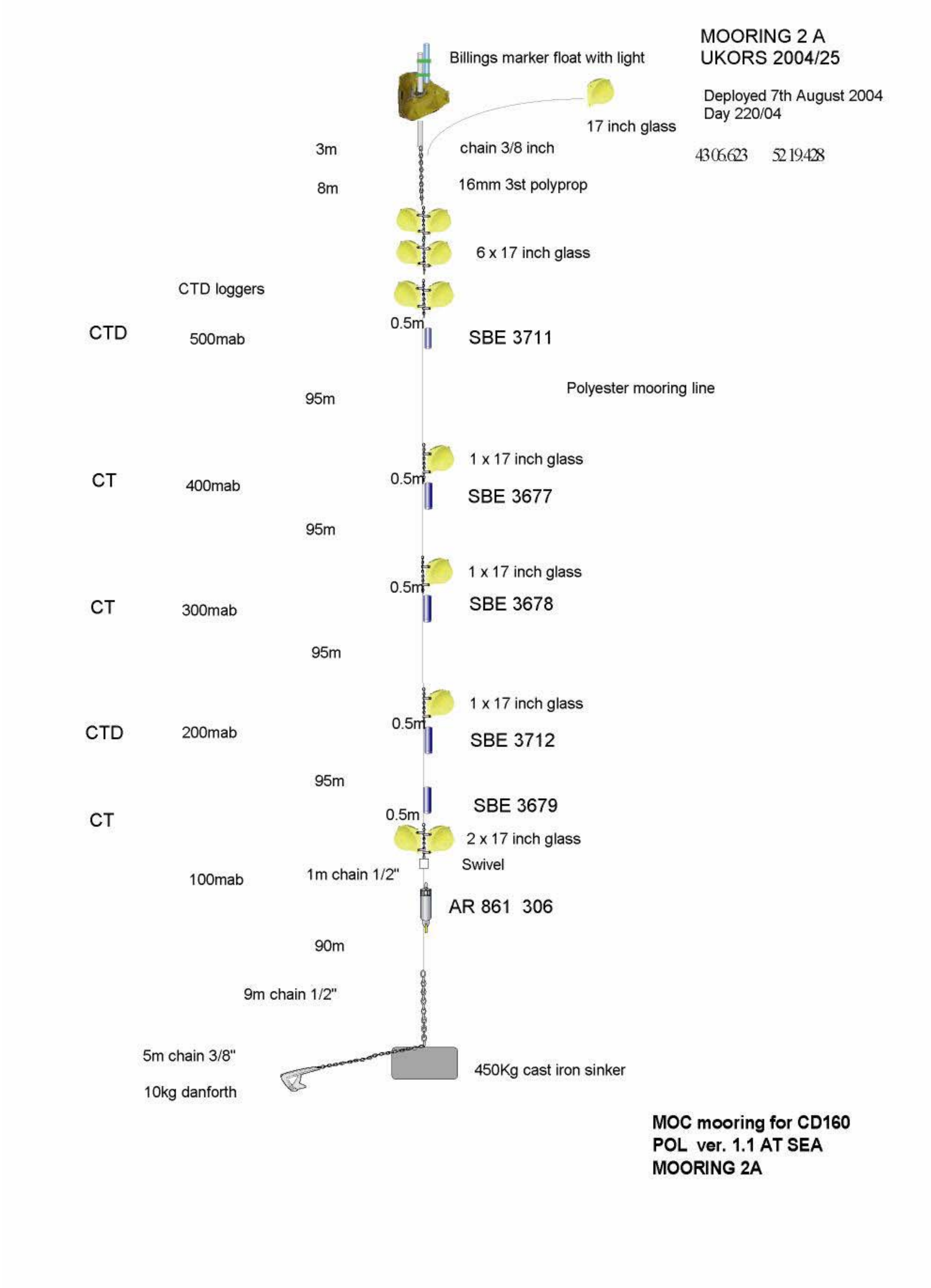



*Figure 13. Mooring diagram for Site 2A.*

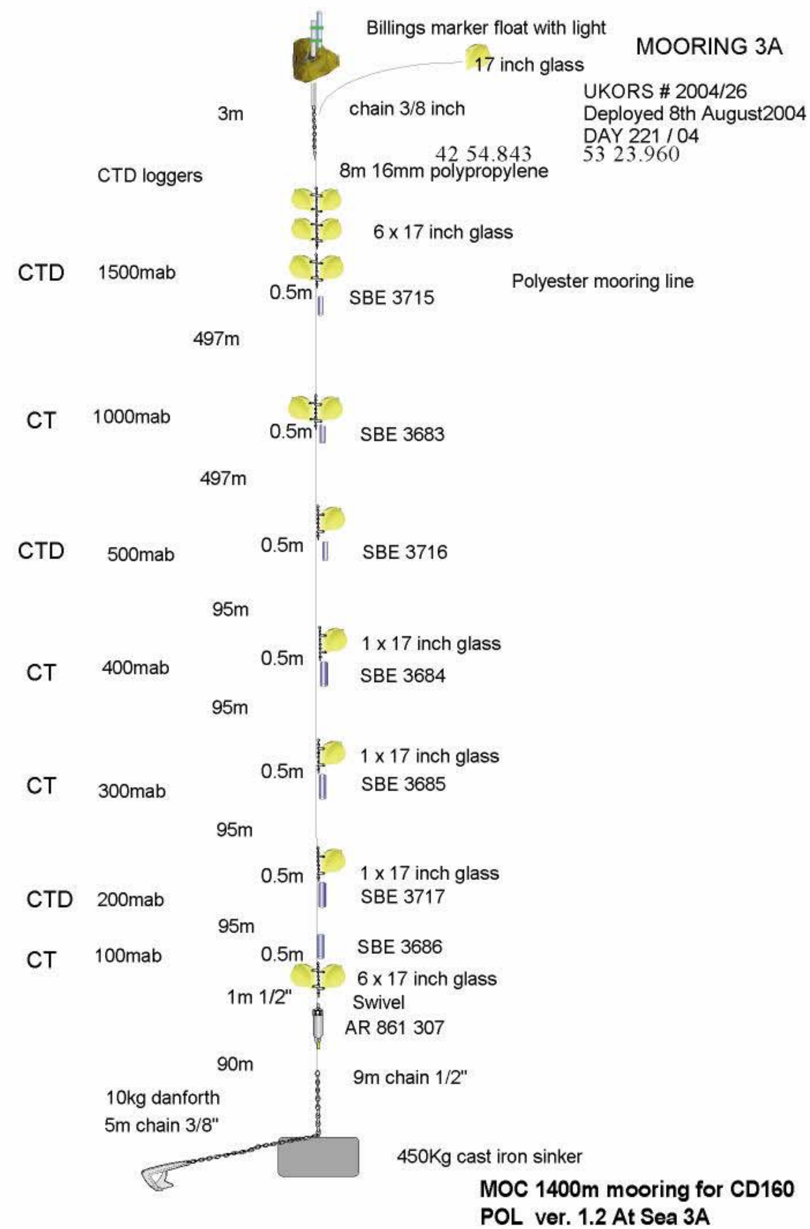



*Figure 14. Mooring diagram for Site 3A.*

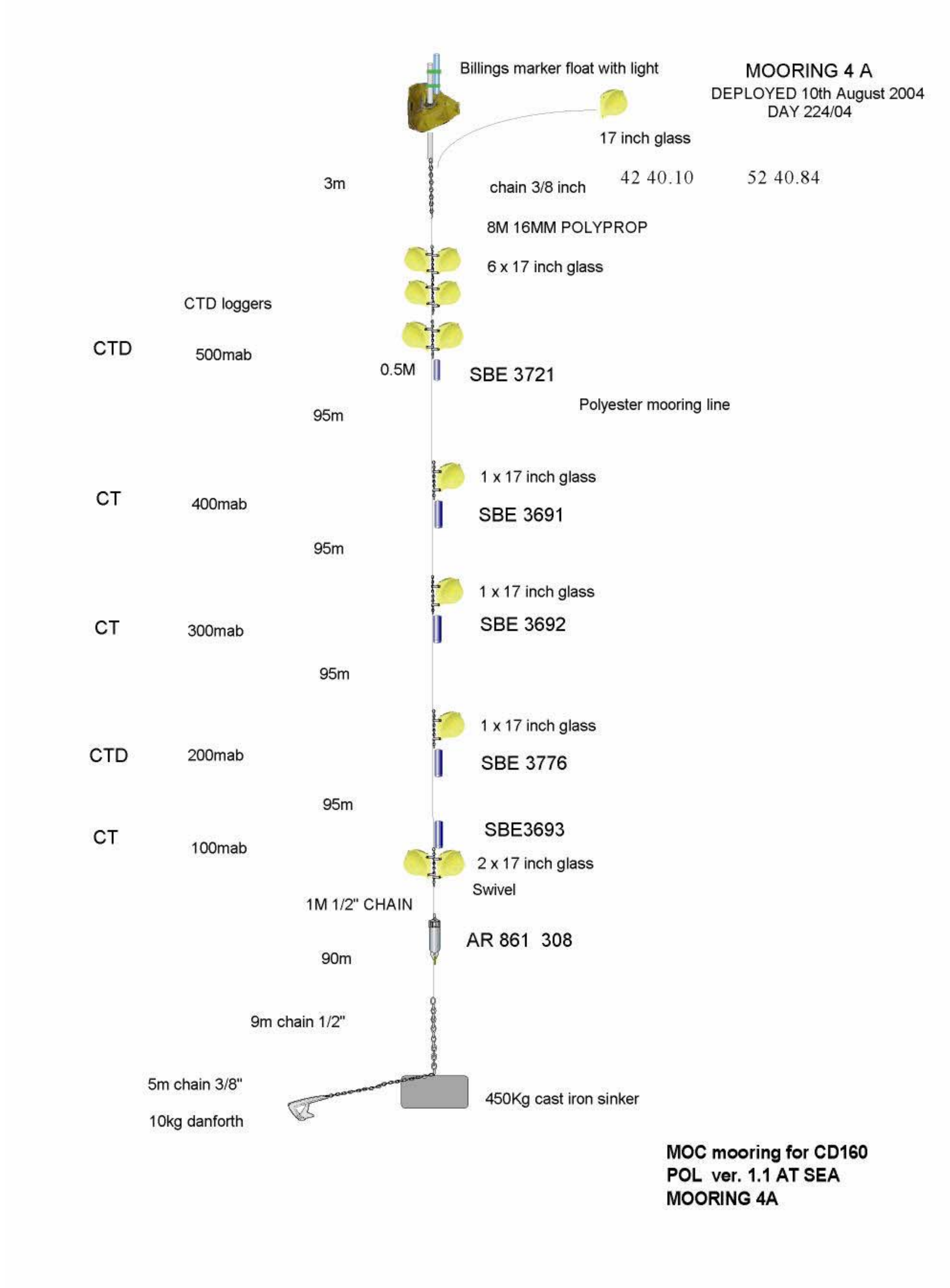



*Figure 15. Mooring diagram for Site 4A.*

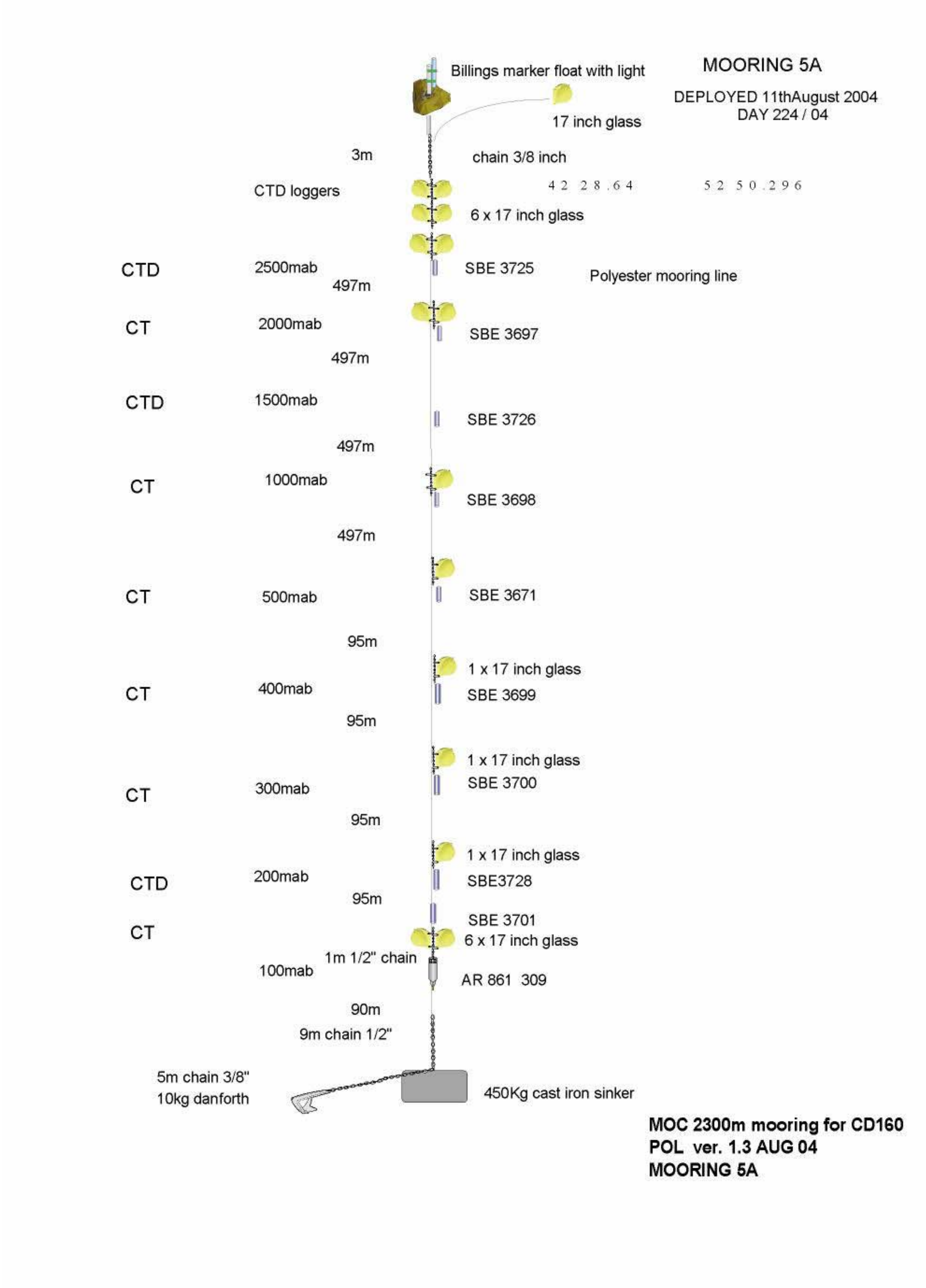



*Figure 16. Mooring diagram for Site 5A.*

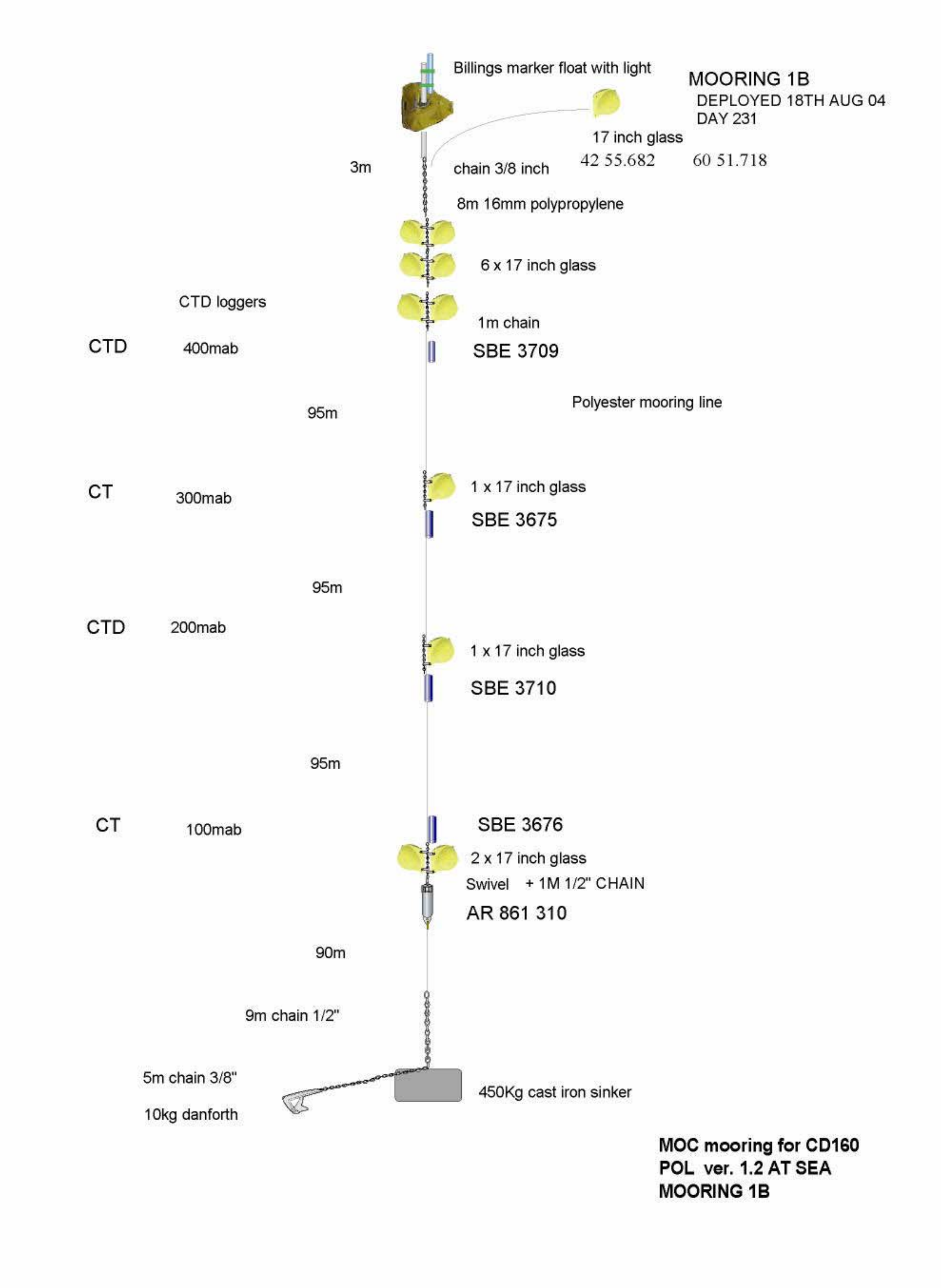



*Figure 17. Mooring diagram for Site 1B.*

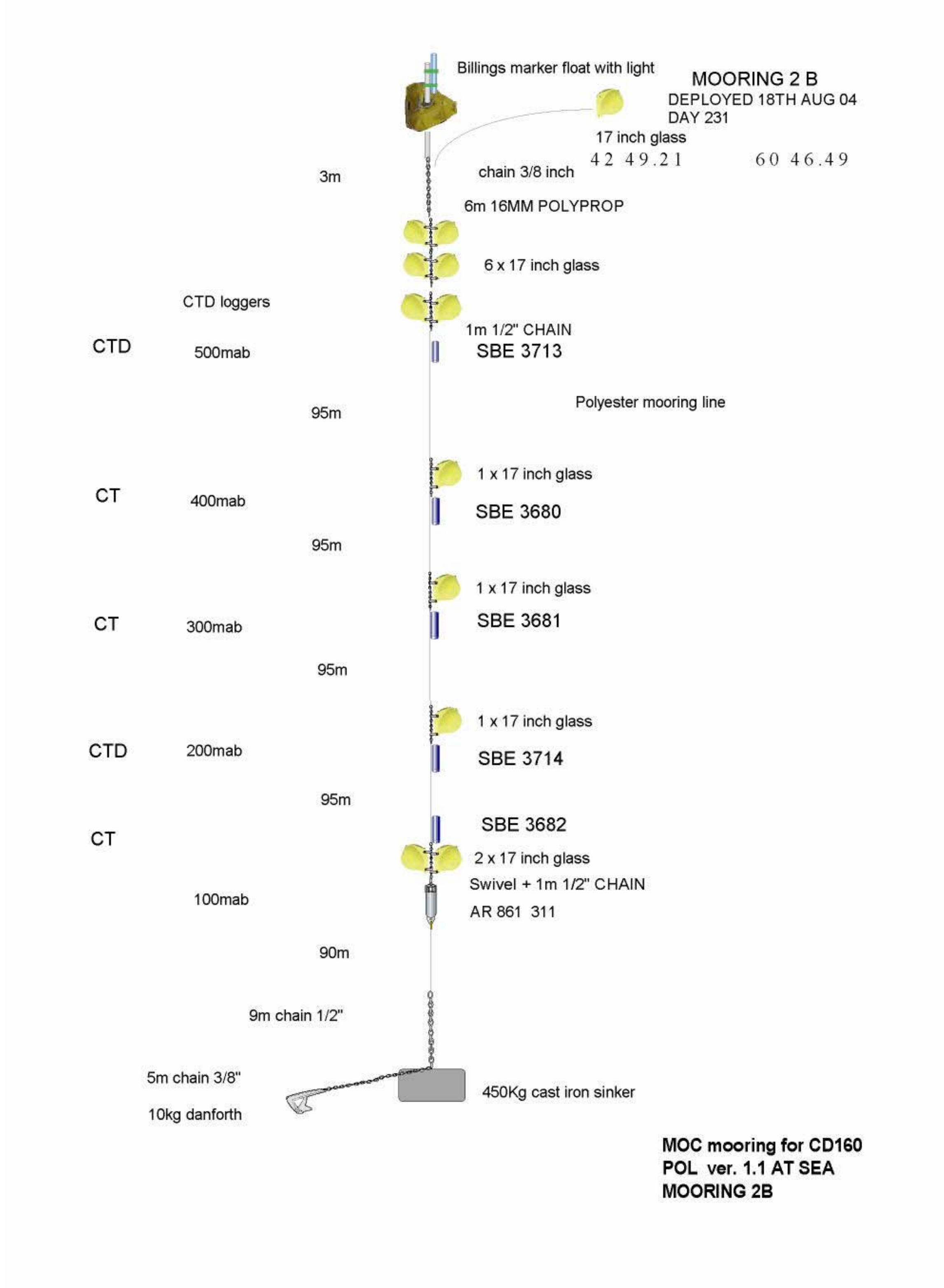



*Figure 18. Mooring diagram for Site 2B.*

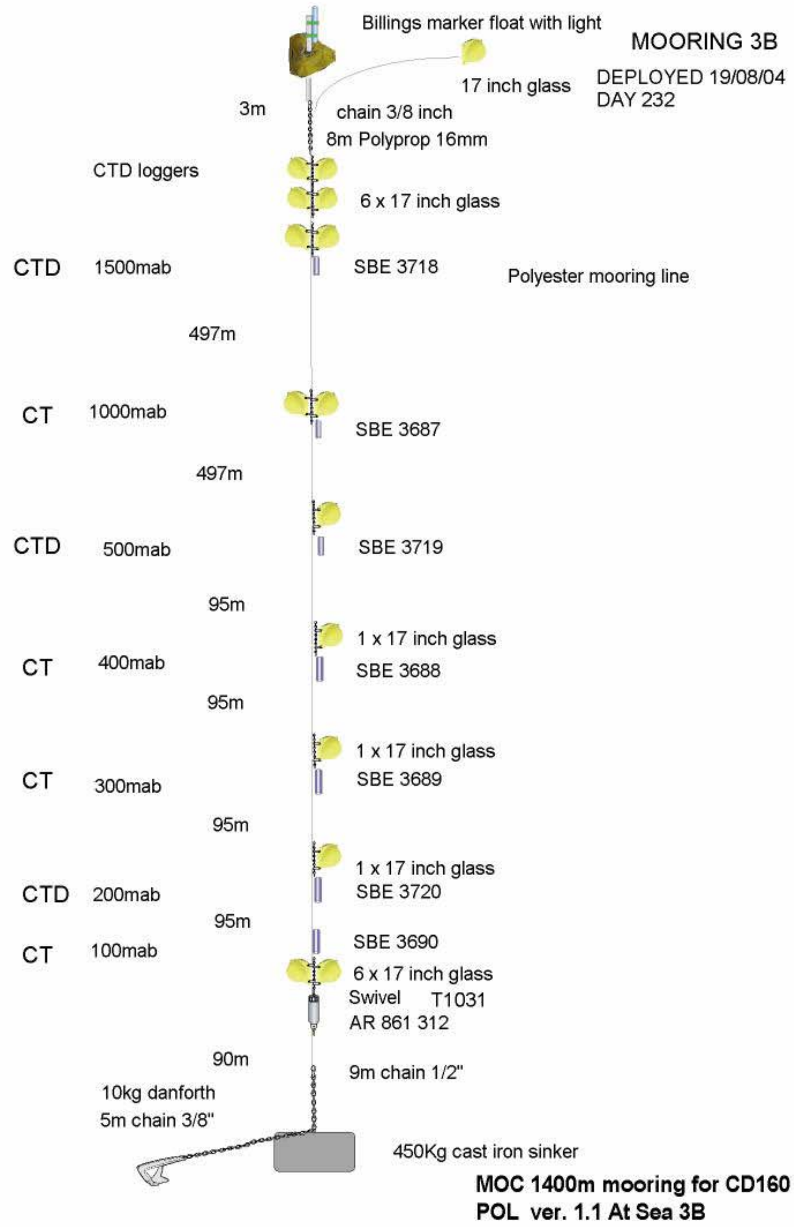



*Figure 19. Mooring diagram for Site 3B.*

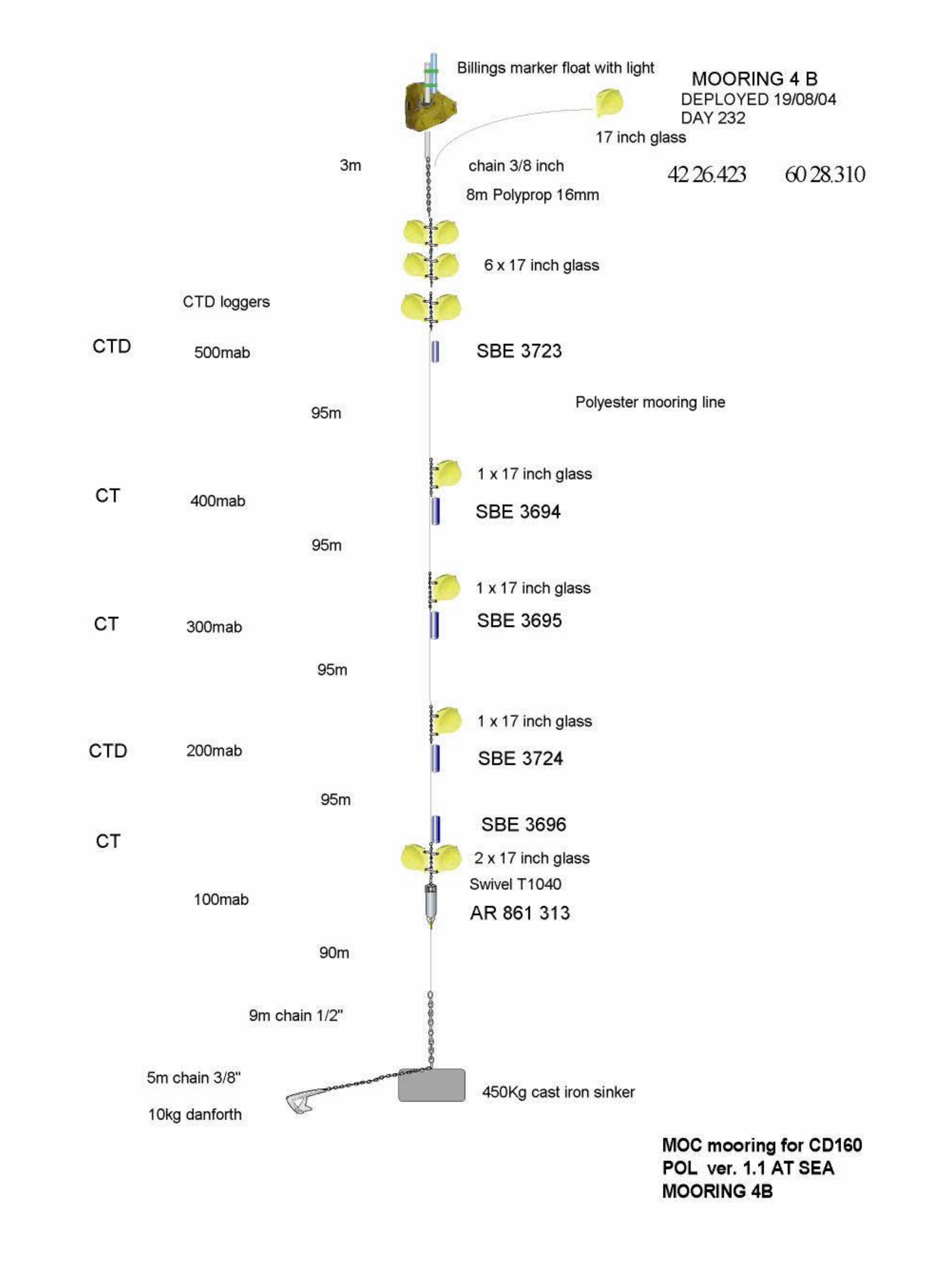



*Figure 20. Mooring diagram for Site 4B.*

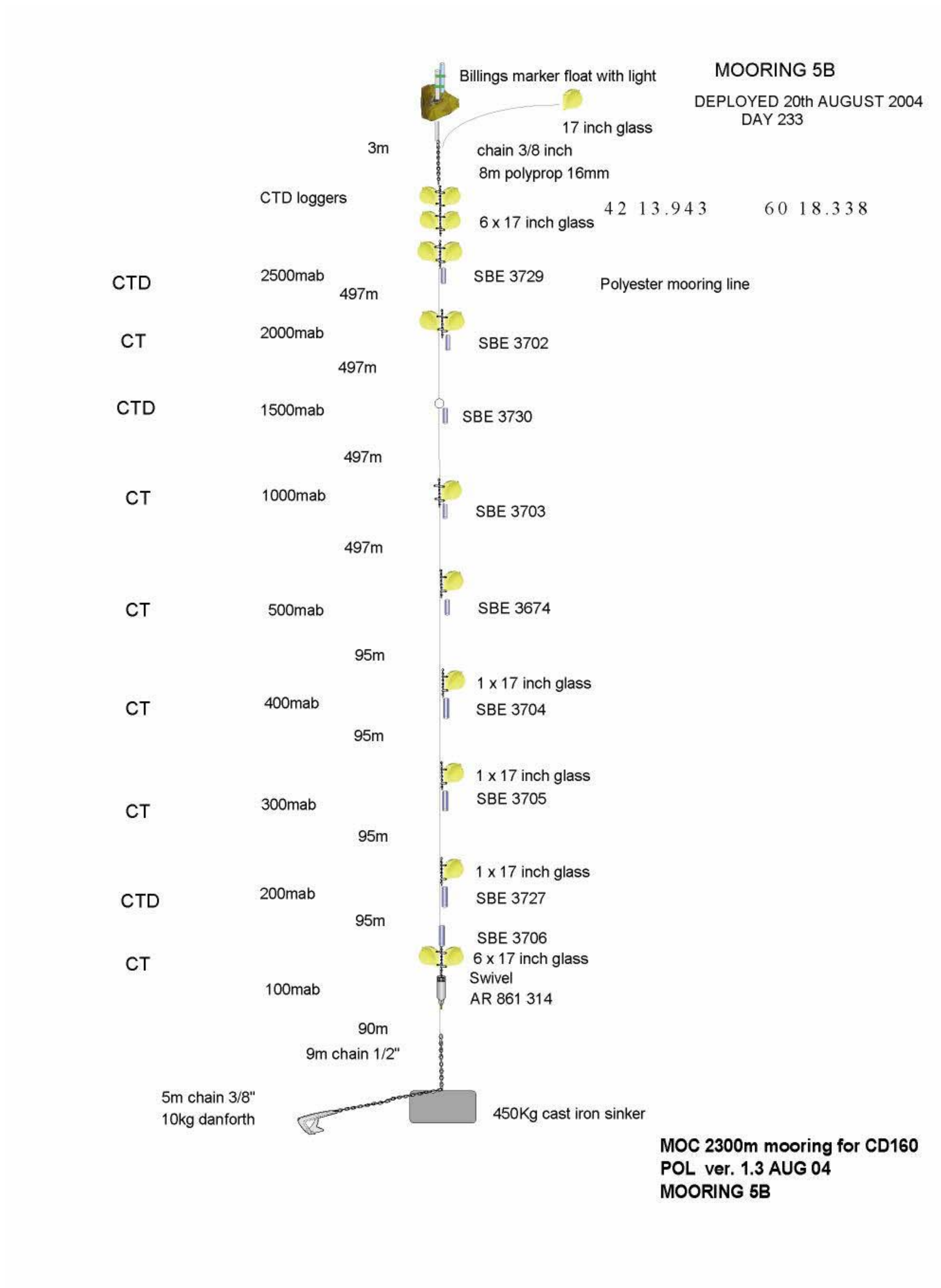



*Figure 21. Mooring diagram for Site 5B.*

# Appendix B – CTD cast logsheets

**Charles Darwin CD160**: **STATION** ØA **DATE** 6 AUGUST 2004 / JD 219

**Start Position**: Lat 43° 16.474 N Lon -52° 11.519 W **Water Depth** 1825

**PC filename:** CD160-01.DAT **Pressure on deck** -0.1

**Time in water** 1818 **Time start down (after soak & surface)** 1821

**Time at bottom** 1859 **Wire out** 1735 **Press** 1753 **Water depth** 1754

**Time start up** 1901

**Time inboard** 2008

**End Position:** Lat 43° 15.824 N Lon -52° 10.916 W

ALTIMETER HEIGHT = 8 METRES OFF BOTTOM

| Rosette Number | Bottle Number | Wire Out | Press (yes, press) | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1735 | 1752 | 169 | 1-1 | 1-1 | |
| 2 | 2 | 1685 | 1704 | | 1-2 | 1-2 | |
| 3 | 3 | 1685 | 1703 | | 1-3 | 1-3 | |
| 4 | 4 | 1633 | 1649 | 170 | 1-4 | | |
| 5 | 5 | 1583 | 1600 | | 1-5 | 1-4 | |
| 6 | 6 | 1534 | 1550 | | 1-6 | | |
| 7 | 7 | 1484 | 1499 | 171 | 1-7 | 1-5 | |
| 8 | 8 | 1435 | 1446 | | 1-8 | | |
| 9 | 9 | 1387 | 1400 | | 1-9 | 1-6 | |
| 10 | 10 | 1338 | 1350 | 172 | 1-10 | | |
| 11 | 11 | 1288 | 1300 | | 1-11 | 1-7 | |
| 12 | 12 | 1239 | 1250 | | 1-12 | | |
| 13 | 13 | 1189 | 1200 | 173 | 1-13 | 1-8 | |
| 14 | 14 | 1090 | 1100 | | 1-14 | | |
| 15 | 15 | 991 | 1000 | | 1-15 | | |
| 16 | 16 | 891 | 900 | 174 | 1-16 | | |
| 17 | 17 | 793 | 800 | | 1-17 | 1-9 | |
| 18 | 18 | 694 | 700 | | 1-18 | | |
| 19 | 19 | 595 | 601 | 175 | 1-19 | | |
| 20 | 20 | 496 | 501 | | 1-20 | | |
| 21 | 21 | 396 | 401 | | 1-21 | 1-10 | |
| 22 | 22 | 296 | 300 | 176 | 1-22 | | |
| 23 | 23 | 197 | 200 | | 1-23 | | |
| 24 | 24 | 97 | 100 | | 1-24 | 1-11 | |

Sample Crate number............ colour.......

**Charles Darwin CD160: STATION** 1A    **DATE** 7 AUGUST 2004 / JD 220

**Start Position**: Lat 43° 11.778 N Lon -52° 14.417 W    **Water Depth** 2207

**PC filename:** CD160-02.DAT    **Pressure on deck** -0.1

**Time in water** 1127    **Time start down (after soak & surface)** 1133

**Time at bottom** 1212    **Wire out** 2190    **Press** 2215    **Water depth** 2212

**Time start up** 1214

**Time inboard** 1347

**End Position:** Lat 43° 10.871 N    Lon -52° 14.753 W

ALTIMETER HEIGHT = 2.5 → 5 METRES OFF BOTTOM

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2190 | 2185 | | 2-1 | 2-1 | |
| 2 | 2 | 2155 | 2150 | 177 | 2-2 | | |
| 3 | 3 | 2105 | 2100 | | 2-3 | 2-2 | |
| 4 | 4 | 2055 | 2049 | | 2-4 | | |
| 5 | 5 | 2006 | 2000 | 178 | 2-5 | 2-3 | |
| 6 | 6 | 1906 | 1902 | | 2-6 | 2-4 | |
| 7 | 7 | 1804 | 1801 | | 2-7 | 2-5 | |
| 8 | 8 | 1701 | 1700 | 179 | 2-8 | 2-6 | |
| 9 | 9 | 1602 | 1600 | | 2-9 | 2-7 | |
| 10 | 10 | 1502 | 1500 | | 2-10 | | |
| 11 | 11 | 1404 | 1400 | 180 | 2-11 | 2-8 | |
| 12 | 12 | 1303 | 1300 | | 2-12 | | |
| 13 | 13 | 1204 | 1200 | | 2-13 | 2-9 | |
| 14 | 14 | 1104 | 1101 | 181 | 2-14 | | |
| 15 | 15 | 1002 | 1000 | | 2-15 | | |
| 16 | 16 | 902 | 900 | | 2-16 | | |
| 17 | 17 | 802 | 800 | 182 | 2-17 | 2-10 | |
| 18 | 18 | 702 | 700 | | 2-18 | | |
| 19 | 19 | 603 | 600 | | 2-19 | | |
| 20 | 20 | 502 | 500 | 183 | 2-20 | | |
| 21 | 21 | 400 | 401 | | 2-21 | 2-11 | |
| 22 | 22 | 300 | 302 | | 2-22 | | |
| 23 | 23 | 198 | 200 | 184 | 2-23 | | |
| 24 | 24 | 97 | 100 | | 2-24 | 2-12 | |

Sample Crate number............ colour.......

**Charles Darwin CD160**: **STATION** 2A                DATE 7 AUGUST 2004 / JD 220

**Start Position**: Lat 43° 06.579 N Lon -52° 19.604 W **Water Depth** 2725

**PC filename:** CD160_03.DAT        **Pressure on deck** -0.1

**Time in water** 17 44      **Time start down (after soak & surface)** 1749

**Time at bottom** 1837   **Wire out** 2705   **Press** 2741   **Water depth** 2722

**Time start up** 1840

**Time inboard** 2012          ALTIMETER HEIGHT OFF BOTTOM = 2->5 METRES

**End Position:** Lat ........ N    Lon - ........ W

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | δ$^{18}$O bott. | I$^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2705 | 2702 | | 3-1 | 3-1 | |
| 2 | 2 | 2655 | 2651 | | 3-2 | | |
| 3 | 3 | 2603 | 2599 | 185 | 3-3 | 3-2 | |
| 4 | 4 | 2555 | 2500 | | 3-4 | | |
| 5 | 5 | 2505 | 2500 | | 3-5 | 3-3 | AIR VALVE OPEN |
| 6 | 6 | 2405 | 2400 | 186 | 3-6 | 3-4 | |
| 7 | 7 | 2305 | 2300 | | 3-7 | 3-5 | |
| 8 | 8 | 2205 | 2200 | | 3-8 | 3-6 | |
| 9 | 9 | 2105 | 2099 | 187 | 3-9 | | |
| 10 | 10 | 2006 | 1999 | | 3-10 | 3-7 | |
| 11 | 11 | 1907 | 1900 | | 3-11 | | |
| 12 | 12 | 1807 | 1800 | 188 | 3-12 | 3-8 | |
| 13 | 13 | 1706 | 1702 | | 3-13 | | |
| 14 | 14 | 1604 | 1601 | | 3-14 | 3-9 | |
| 15 | 15 | 1502 | 1500 | 189 | 3-15 | | |
| 16 | 16 | 1402 | 1400 | | 3-16 | | |
| 17 | 17 | 1302 | 1302 | | 3-17 | | |
| 18 | 18 | 1200 | 1201 | 190 | 3-18 | 3-10 | |
| 19 | 19 | 999 | 1000 | | 3-19 | | |
| 20 | 20 | 798 | 801 | | 3-20 | 3-11 | |
| 21 | 21 | 597 | 600 | 191 | 3-21 | | |
| 22 | 22 | 397 | 400 | | 3-22 | | |
| 23 | 23 | 196 | 200 | | 3-23 | | |
| 24 | 24 | 96 | 100 | 192 | 3-24 | 3-12 | |

Sample Crate number............. colour.......

**Charles Darwin CD160**: **STATION** 3A **DATE** 8 AUGUST 2004 / JD 221

**Start Position**: Lat 42°54.789 N Lon -52° 29.201 W **Water Depth** 3228

**PC filename**: CD160-04.DAT **Pressure on deck** -0.1

**Time in water** 1048 **Time start down (after soak & surface)** 1055

**Time at bottom** 1152 **Wire out** 3205 **Press** 3254 **Water depth** 3221

**Time start up** 1154

**Time inboard** 1323

**End Position**: Lat 42° 55.409 N Lon -52° 29.367 W

ALTIMETER HEIGHT OFF BOTTOM = 2->4 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3205 | 3202 | 200 | 4-1 | 4-1 | |
| 2 | 2 | 3105 | 3103 | | 4-2 | 4-2 | |
| 3 | 3 | 3001 | 3000 | | 4-3 | 4-3 | |
| 4 | 4 | 2901 | 2900 | 193 | 4-4 | 4-4 | |
| 5 | 5 | 2801 | 2800 | | 4-5 | | |
| 6 | 6 | 2701 | 2700 | | 4-6 | 4-5 | |
| 7 | 7 | 2601 | 2600 | 194 | 4-7 | | |
| 8 | 8 | 2500 | 2499 | | 4-8 | 4-6 | |
| 9 | 9 | 2400 | 2400 | | 4-9 | | |
| 10 | 10 | 2300 | 2300 | 195 | 4-10 | | |
| 11 | 11 | 2200 | 2200 | | 4-11 | 4-7 | |
| 12 | 12 | 2100 | 2101 | | 4-12 | | |
| 13 | 13 | 1999 | 2000 | 196 | 4-13 | 4-8 | |
| 14 | 14 | 1899 | 1902 | | 4-14 | | |
| 15 | 15 | 1799 | 1800 | | 4-15 | 4-9 | |
| 16 | 16 | 1698 | 1700 | 197 | 4-16 | | |
| 17 | 17 | 1598 | 1600 | | 4-17 | 4-10 | |
| 18 | 18 | 1398 | 1401 | | 4-18 | | |
| 19 | 19 | 1197 | 1200 | 198 | 4-19 | 4-11 | no $I^{129}$ bottle inset |
| 20 | 20 | 797 | 801 | | 4-20 | 4-12 | |
| 21 | 21 | 595 | 600 | | 4-21 | | |
| 22 | 22 | 395 | 400 | 199 | 4-22 | | |
| 23 | 23 | 195 | 200 | | 4-23 | | |
| 24 | 24 | 95 | 100 | | 4-24 | 4-13 | |

Sample Crate number............ colour.......

**Charles Darwin CD160**: **STATION** 4A **DATE** 8 AUGUST 2004 / JD 221

**Start Position**: Lat 42° 40.019 N Lon -52° 40.730 W **Water Depth** 3663
**PC filename**: CD160-05.DAT **Pressure on deck** -0.1
**Time in water** 2049 **Time start down (after soak & surface)** 2053
**Time at bottom** 2200 **Wire out** 3675 **Press** 3722 **Water depth** 3687
**Time start up** 2203
**Time inboard** —
**End Position**: Lat 42° 39.069 N Lon -52° 40.332 W

ALTIMETER HEIGHT OFF BOTTOM = 10-12 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | δ18O bott. | I129 bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3675 | 3666 | | | | |
| 2 | 2 | 3555 | 3550 | | | | |
| 3 | 3 | 3455 | 3450 | | | | |
| 4 | 4 | 3357 | 3350 | | | | |
| 5 | 5 | 3257 | 3250 | | | | |
| 6 | 6 | 3157 | 3150 | | | | |
| 7 | 7 | 3108 | 3100 | | | | |
| 8 | 8 | 3009 | 3000 | | | | |
| 9 | 9 | 2909 | 2900 | | | | |
| 10 | 10 | 2709 | 2699 | | | | |
| 11 | 11 | 2510 | 2499 | | | | |
| 12 | 12 | 2312 | 2302 | | | | |
| 13 | 13 | 2210 | 2200 | | | | |
| 14 | 14 | 2010 | 2000 | | | | |
| 15 | 15 | 1908 | 1902 | | | | |
| 16 | 16 | 1805 | 1800 | | | | |
| 17 | 17 | 1704 | 1700 | | | | |
| 18 | 18 | 1603 | 1599 | | | | |
| 19 | 19 | 1403 | 1398 | | | | |
| 20 | 20 | 1203 | 1202 | | | | |
| 21 | 21 | 800 | 800 | | | | |
| 22 | 22 | 400 | 401 | | | | |
| 23 | 23 | 198 | 200 | | | | |
| 24 | 24 | 98 | 100 | | | | |

CTD LOST -> NO SAMPLES

Sample Crate number............ colour.......

**Charles Darwin CD160**: **STATION**....1B.....  **DATE** 22 AUGUST 2004 / 235 JD

**Start Position:** Lat. 42° 55.834 N Lon. -60° 50.968 W **Water Depth** 2214

**PC filename:** CD160 – 10. CAT **Pressure on deck** -0.0

**Time in water** 1107 **Time start down (after soak & surface)** 1110

**Time at bottom** 1200 **Wire out** 2165 **Press** 2199 **Water depth** 2191

**Time start up** 1202

**Time inboard** 1310

**End Position:** Lat. 42° N Lon. -60° W

PINGER HEIGHT OFF BOTTOM = 10 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2165 | 2170 | | 10-1 | 10-1 | |
| 2 | 2 | 2145 | 2150 | | 2 | | |
| 3 | 3 | 2094 | 2100 | 185 | 3 | 10-2 | |
| 4 | 4 | 2044 | 2050 | | 4 | | |
| 5 | 5 | 1995 | 2000 | | 5 | 10-3 | |
| 6 | 6 | 1895 | 1900 | 186 | 6 | 10-4 | |
| 7 | 7 | 1795 | 1801 | | 7 | 10-5 | |
| 8 | 8 | 1694 | 1700 | | 8 | 10-6 | |
| 9 | 9 | 1594 | 1600 | 187 | 9 | 10-7 | |
| 10 | 10 | 1493 | 1501 | | 10 | | |
| 11 | 11 | 1393 | 1400 | | 11 | 10-8 | |
| 12 | 12 | 1293 | 1301 | 188 | 12 | | |
| 13 | 13 | 1193 | 1201 | | 13 | 10-9 | |
| 14 | 14 | 1092 | 1100 | | 14 | | |
| 15 | 15 | 992 | 1000 | 189 | 15 | | |
| 16 | 16 | 892 | 901 | | 16 | | |
| 17 | 17 | 791 | 800 | | 17 | 10-10 | |
| 18 | 18 | 691 | 700 | 190 | 18 | | |
| 19 | 19 | 591 | 600 | | 19 | | |
| 20 | 20 | 491 | 500 | | 20 | | |
| 21 | 21 | 391 | 400 | 191 | 21 | 10-11 | |
| 22 | 22 | 291 | 301 | | 22 | | |
| 23 | 23 | 190 | 200 | | 23 | | |
| 24 | 24 | 90 | 100 | 192 | 10-24 | 10-12 | |

Sample Crate number............ colour.......

STOP AT 1052 METRES ON DOWNCAST TO CUT/REPAIR BROKEN STRAND (OUTER ARMOUR) OF CTD WIRE

**Charles Darwin CD160**: STATION 28 DATE 21 AUGUST 2004/234 JD

**Start Position:** Lat 42° 48.857 N Lon -60° 46.031 W **Water Depth** 2798
**PC filename:** CD160-09.DAT **Pressure on deck** -0.0
**Time in water** 2203 **Time start down (after soak & surface)** 2205
**Time at bottom** 2303 **Wire out** 2781 **Press** 2820 **Water depth** 2788
**Time start up** 2305
**Time inboard** 0022 22 AUGUST 2004 / JD 235
**End Position:** Lat 42° 48.765 N Lon -60° 46.266 W

PINGER HEIGHT OFF BOTTOM = 10 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ Metres | Salt bott. | δ18O bott. | I129 bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 2781 | 2778 | 177 | 9-1 | 9-1 | |
| 2 | 2 | 2654 | 2650 | | 2 | | |
| 3 | 3 | 2601 | 2600 | | 3 | 9-2 | |
| 4 | 4 | 2551 | 2550 | 178 | 4 | | |
| 5 | 5 | 2501 | 2500 | | 5 | 9-3 | |
| 6 | 6 | 2401 | 2400 | | 6 | 9-4 | |
| 7 | 7 | 2301 | 2300 | 179 | 7 | 9-5 | |
| 8 | 8 | 2202 | 2200 | | 8 | 9-6 | |
| 9 | 9 | 2102 | 2100 | | 9 | | |
| 10 | 10 | 2002 | 2000 | 180 | 10 | 9-7 | |
| 11 | 11 | 1901 | 1900 | | 11 | | |
| 12 | 12 | 1801 | 1800 | | 12 | 9-8 | |
| 13 | 13 | 1700 | 1700 | 181 | 13 | | |
| 14 | 14 | 1600 | 1600 | | 14 | 9-9 | |
| 15 | 15 | 1500 | 1501 | | 15 | | |
| 16 | 16 | 1399 | 1400 | 182 | 16 | | |
| 17 | 17 | 1299 | 1300 | | 17 | | |
| 18 | 18 | 1199 | 1200 | | 18 | 9-10 | |
| 19 | 19 | 999 | 1000 | 183 | 19 | | |
| 20 | 20 | 799 | 800 | | 20 | 9-11 | |
| 21 | 21 | 598 | 601 | | 21 | | |
| 22 | 22 | 397 | 400 | 184 | 22 | | |
| 23 | 23 | 197 | 200 | | 23 | | |
| 24 | 24 | 97 | 100 | | 9-24 | 9-12 | |

Sample Crate number............ colour.......

**Charles Darwin CD160**: **STATION** 3B **DATE** 21 AUGUST 2004 / JD 234

**Start Position:** Lat. 42° 37.059 N Lon. -60° 36.485 W **Water Depth** 3229
**PC filename:** CD160-08.DAT **Pressure on deck** -0.0
**Time in water** 1714 **Time start down (after soak & surface)** 1717
**Time at bottom** 1826 **Wire out** 3225 **Press** 3272 **Water depth** 3243
**Time start up** 1827
**Time inboard** 2004
**End Position:** Lat. 42° 36.897 N Lon. -60° 37.073 W

PINGER HEIGHT OFF BOTTOM = 8 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3225 | 3221 | | 8-1 | 8-1 | |
| 2 | 2 | 3104 | 3100 | | 2 | 8-2 | |
| 3 | 3 | 3004 | 3000 | 169 | 3 | 8-3 | |
| 4 | 4 | 2904 | 2900 | | 4 | 8-4 | |
| 5 | 5 | 2803 | 2800 | | 5 | | |
| 6 | 6 | 2703 | 2700 | 170 | 6 | 8-5 | |
| 7 | 7 | 2603 | 2600 | | 7 | | |
| 8 | 8 | 2503 | 2500 | | 8 | 8-6 | |
| 9 | 9 | 2402 | 2400 | 171 | 9 | | |
| 10 | 10 | 2302 | 2300 | | 10 | | |
| 11 | 11 | 2202 | 2200 | | 11 | 8-7 | |
| 12 | 12 | 2103 | 2100 | 172 | 12 | | |
| 13 | 13 | 2003 | 2000 | | 13 | 8-8 | |
| 14 | 14 | 1902 | 1900 | | 14 | | |
| 15 | 15 | 1802 | 1801 | 173 | 15 | 8-9 | |
| 16 | 16 | 1701 | 1700 | | 16 | | |
| 17 | 17 | 1601 | 1600 | | 17 | 8-10 | |
| 18 | 18 | 1400 | 1399 | 174 | 18 | | |
| 19 | 19 | 1201 | 1200 | | 19 | 8-11 | |
| 20 | 20 | 800 | 800 | | 20 | 8-12 | |
| 21 | 21 | 600 | 602 | 175 | 21 | | |
| 22 | 22 | 396 | 400 | | 22 | | |
| 23 | 23 | 197 | 200 | | 23 | | |
| 24 | 24 | 97 | 100 | 176 | 8-24 | 8-13 | |

Sample Crate number............ colour.......

**Charles Darwin CD160**: **STATION**......48...... **DATE**..21 AUGUST 2004 / JD 234..

**Start Position**: Lat..42° 26.72' N Lon..-60° 27.70' W **Water Depth**..3648......

**PC filename**: CD160 - 07. DAT...... **Pressure on deck** ..0.0.......

**Time in water**..11.22..... **Time start down (after soak & surface)** ..1124...

**Time at bottom**..1240..... **Wire out**..3632.. **Press**..3691.. **Water depth**....3651......

**Time start up**....1242.......

**Time inboard**..1420...

**End Position**: Lat..42° 26.656 N Lon..-60° 27.752 W

PINGER HEIGHT OFF BOTTOM = 5 METRES

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3632 | 3630 | 209 | 7-1 | 7-1 | |
| 2 | 2 | 3552 | 3550 | | | | LANYARD DID NOT CLOSE BOTTOM |
| 3 | 3 | 3451 | 3450 | | 7-3 | 7-2 | |
| 4 | 4 | 3351 | 3350 | 210 | 7-4 | 7-3 | |
| 5 | 5 | 3250 | 3250 | | 7-5 | | |
| 6 | 6 | 3151 | 3151 | | 7-6 | 7-4 | |
| 7 | 7 | 3100 | 3100 | 211 | 7-7 | | |
| 8 | 8 | 3000 | 3000 | | 7-8 | 7-5 | |
| 9 | 9 | 2900 | 2900 | | 7-9 | | |
| 10 | 10 | 2700 | 2701 | 212 | 7-10 | 7-6 | |
| 11 | 11 | 2499 | 2500 | | 7-11 | 7-7 | |
| 12 | 12 | 2299 | 2300 | | 7-12 | | |
| 13 | 13 | 2199 | 2200 | 213 | 7-13 | 7-8 | |
| 14 | 14 | 1999 | 2001 | | 7-14 | | |
| 15 | 15 | 1898 | 1900 | | 7-15 | | |
| 16 | 16 | 1800 | 1801 | 214 | 7-16 | 7-9 | |
| 17 | 17 | 1698 | 1701 | | 7-17 | | |
| 18 | 18 | 1597 | 1600 | | 7-18 | 7-10 | |
| 19 | 19 | 1397 | 1400 | 215 | 7-19 | | |
| 20 | 20 | 1197 | 1201 | | 7-20 | 7-11 | |
| 21 | 21 | 795 | 800 | | 7-21 | 7-12 | |
| 22 | 22 | 395 | 400 | 216 | 7-22 | | |
| 23 | 23 | 194 | 200 | | 7-23 | | |
| 24 | 24 | 94 | 100 | | 7-24 | 7-13 | |

Sample Crate number............. colour.......

**Charles Darwin CD160: STATION** 5B **DATE** 20 AUGUST 2004 / 233 JD

**Start Position:** Lat 42° 14.068 N Lon -60° 17.685 W **Water Depth** 4105
**PC filename:** CD160-06.DAT **Pressure on deck** -0.1
**Time in water** 2121 **Time start down (after soak & surface)** 2125
**Time at bottom** 2247 **Wire out** 4084 **Press** 4152 **Water depth** 4104
**Time start up** 2249
**Time inboard** 0028 21 AUGUST 2004 / JD 234

PINGER HEIGHT OFF BOTTOM = ~ 20 METRES

**End Position:** Lat 42°13.548 N Lon -60° 17.878 W

| Rosette Number | Bottle Number | Wire Out | ~~Press~~ METRES | Salt bott. | $\delta^{18}O$ bott. | $I^{129}$ bott. | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 4084 | 4080 | | 6-1 | 6-1 | |
| 2 | 2 | 4004 | 4000 | 201 | 6-2 | 6-2 | |
| 3 | 3 | 3904 | 3899 | | 6-3 | 6-3 | |
| 4 | 4 | 3804 | 3800 | | 6-4 | ≡ | lanyard problems - not sampled for $I^{129}$ |
| 5 | 5 | 3704 | 3700 | 202 | 6-5 | | |
| 6 | 6 | 3604 | 3600 | | 6-6 | 6-4 | |
| 7 | 7 | 3404 | 3401 | | 6-7 | | |
| 8 | 8 | 3203 | 3200 | 203 | 6-8 | 6-5 | |
| 9 | 9 | 3102 | 3100 | | 6-9 | | |
| 10 | 10 | 3002 | 3000 | | 6-10 | 6-6 | |
| 11 | 11 | 2902 | 2900 | 204 | 6-11 | | |
| 12 | 12 | 2702 | 2700 | | 6-12 | 6-7 | |
| 13 | 13 | 2501 | 2501 | | 6-13 | 6-8 | |
| 14 | 14 | 2200 | 2200 | 205 | 6-14 | 6-9 | |
| 15 | 15 | 2000 | 2000 | | 6-15 | | |
| 16 | 16 | 1800 | 1800 | | 6-16 | 6-10 | |
| 17 | 17 | 1700 | 1701 | 206 | 6-17 | | |
| 18 | 18 | 1599 | 1600 | | 6-18 | ≡ | (as per 4 above) |
| 19 | 19 | 1399 | 1400 | | 6-19 | 6-11 | |
| 20 | 20 | 1199 | 1200 | 207 | 6-20 | | |
| 21 | 21 | 799 | 802 | | 6-21 | 6-12 | |
| 22 | 22 | 397 | 400 | | 6-22 | | |
| 23 | 23 | 196 | 200 | 208 | 6-23 | | |
| 24 | 24 | 96 | 100 | | 6-24 | 6-13 | |

Sample Crate number............ colour.......

## Appendix C – Images from CD160

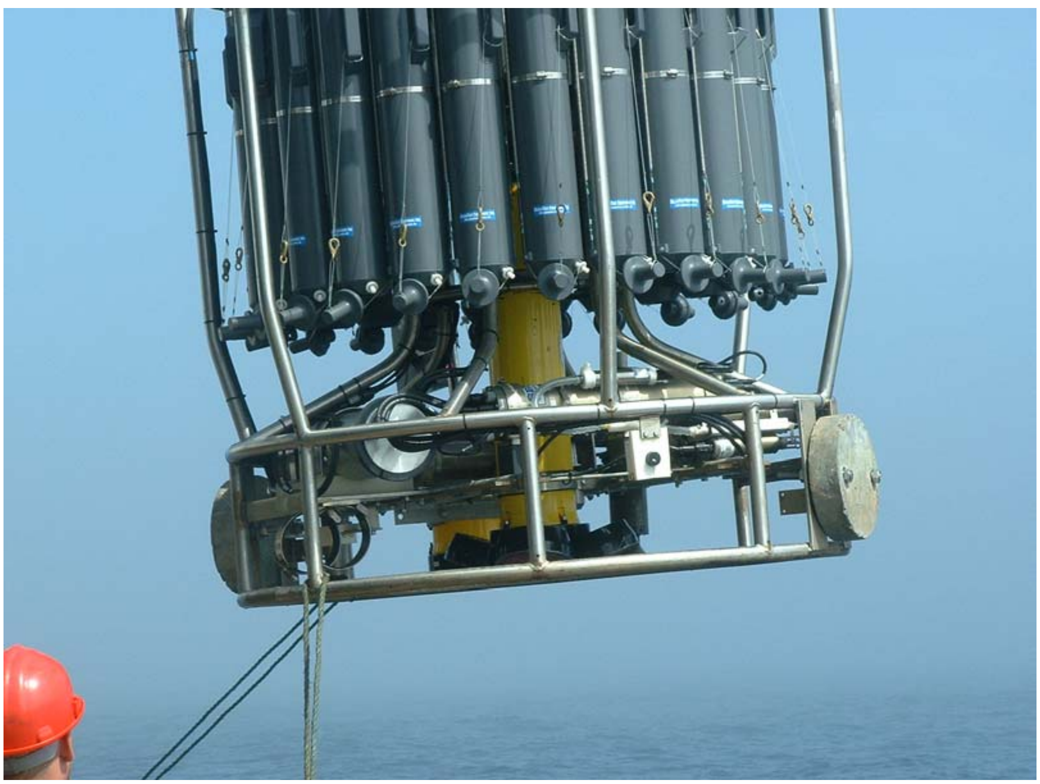

*Plate 1: RRS Charles Darwin at St. Johns, Newfoundland*

*Plate 2: A POL RapidLander BPR being readied for deployment.*

*Plate 3: A POL RapidLander BPR being deployed.*

*Plates 4 and 5: Deployment of a UKORS mooring.*

*Plates 6 & 7: Deployment of the CTD/LADCP package*



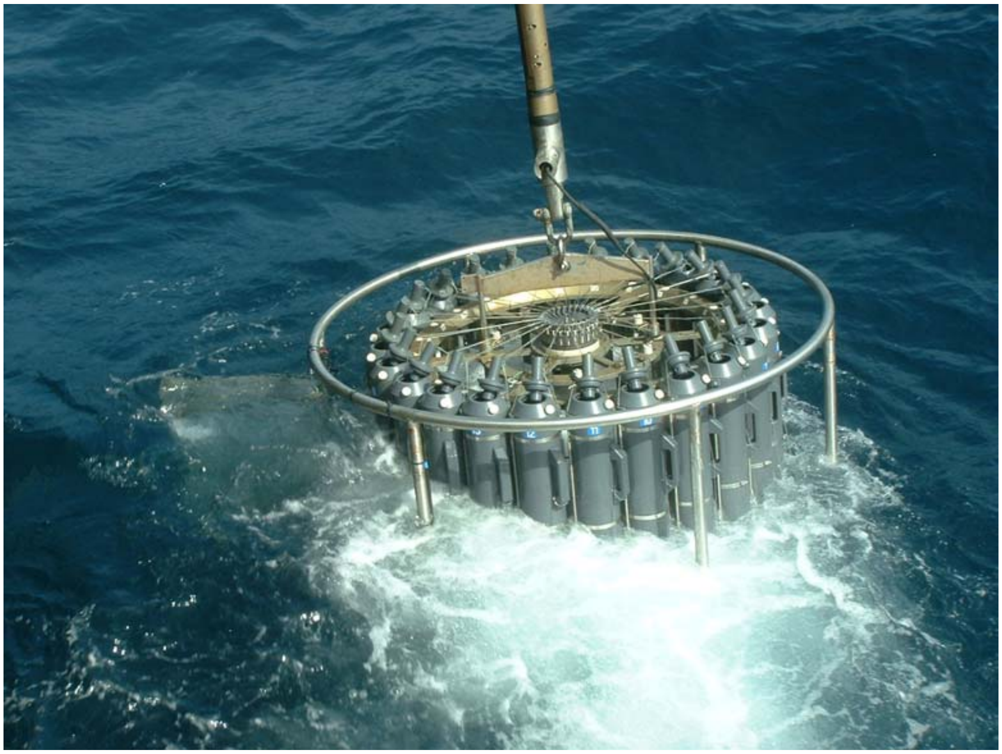


*Plate 8: Deployment of the CTD/LADCP package*

*Plate 9: Dragging for the lost CTD/LADCP package*


*Plate 10: RRS Charles Darwin in Halifax, Nova Scotia, undergoing repairs.*

*Plate 11: Dolphins playing in the ship's bow wave.*