# SOUTHAMPTON OCEANOGRAPHY CENTRE

## CRUISE REPORT No. 28

## RRS *DISCOVERY* CRUISE 242
## 07 SEP - 06 OCT 1999

Atlantic - Norwegian Exchanges

*Principal Scientist*
**S A Cunningham**

**2000**

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# DOCUMENT DATA SHEET

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*ABSTRACT*

This report describes RRS *Discovery* cruise 242 from 07 September to 06 October 1999. The cruise title is Atlantic - Norwegian Exchanges. There are two distinct parts to this experiment with closely related objectives. The first is to measure the pathways and flux of warm, upper ocean water northward through the Iceland Basin and Rockall Trough to high latitudes. The second is to measure the returning flux of cold, deep water that flows through the Faroe Bank Channel into the North Atlantic. A full depth hydrographic section was occupied between Scotland and Iceland, repeating the frequently occupied Rockall Trough section (occupied 36 times between March 1975 and January 1996) and it's recent extension from Rockall to Iceland (occupied in 1997, 1998 and now in 1999). A second section was occupied from southeast Iceland to Lousy Bank (occupied in 1962,1990 and 1996). These two sections comprised CTD/LADCP stations with discrete vertical samples for salinity, oxygen, silicate, nitrate and phosphate. Horizontal station spacing was ~30 km in the Iceland Basin but much closer over steep bathymetry and in the Rockall Trough. Ancilliary measurements of transmittence and reversing temperature and salinity were also made. Shipbourne observations were made throughout the cruise and comprised ADCP, navigation, meteorology, waves, echosounding and surface temperature and salinity. These two sections were designed to measure the pathways of the northward flow through the Iceland Basin and Rockall Trough. Differences to earlier occupations will show the time variability of these flows. In the Faroe Bank Channel and on the Iceland Ridge eight sections were occupied (some repeats) to examine the cold outflow into the North Atlantic. These sections were made in the Faroe Bank Channel and downstream of the sill, at a horizontal separation of between 15 km and 40 km. Five of these were standard CTD/LADCP sections with chemistry observations. Three sections were also occupied using the BRIDGET deep tow vehicle. This vehicle carried a CTD and 12 bottle rosette for water samples as well as some auxiliary sensors. The key novelty was the mounting of self-contained downward and upward looking ADCP's. BRIDGET was towed at 100 m off bottom giving cross-stream measurements at high resolution of the velocity structure of the overflow. These sections were taken in and just downstream from the Faroe Bank Channel sill. We will examine the initial adjustment of the overflow and with contemporaneous observations made in the Faroe Shetland (Fisheries Research Services, Aberdeen) the role of hydraulic control at the Faroe Bank Channel sill. The two sections in the Iceland Basin cross the overflow 360 km and 660 km downstream from the source defining the far field location and properties of the overflow. A short section of XBT observations was made along the Wyville-Thomson Ridge to measure the temperature at two saddle points where it is occasionally observed that cold Faroe Bank Channel water passes into the Rockall Trough.

*KEYWORDS*

ACOUSTIC DOPPLER CURRENT PROFILER, BRIDGET MOUNTED ADCP, BRIDGET, CTD OBSERVATIONS, DEEP TOW VEHICLE, *DISCOVERY* CRUISE 242 1999, FAROE BANK CHANNEL, FLOW THROUGH GAPS, ICELAND BASIN, ICELAND RIDGE, LOWERED ADCP, NORTH ATLANTIC, OVERFLOW, OUTFLOW, ROCKALL TROUGH, VESSEL MOUNTED ADCP, WATER EXCHANGE, WATER MASSES, XBT

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## SCIENTIFIC AND SHIP'S PERSONNEL

Table 1a Scientific Personnel

| Surname | Initials | Institute |
|---|---|---|
| Cunningham | S.A. | SOC, JRD |
| Alderson | S.G. | SOC, JRD |
| Benson | J.R. | SOC, RVS |
| Bryden | H.L. | SOC, JRD |
| Carvalho | N.V. | SOC, SOES |
| Craig | D.W. | U. of Edinburgh |
| Duncan | L.M. | SOC, JRD |
| Harris | A.J. | SOC, OTD |
| Hart | V. | SOC, SOES |
| Hartman | M.C. | SOC, GDD |
| Holliday | N.P. | SOC, GDD |
| Inall | M.E. | SAMS/DML |
| Jones | A. | SOC, RVS (SIG) |
| Knight | G. | SOC, RVS (ISG) |
| McLachlan | R. | SOC, RVS (SEG) |
| Paterson | K. | SOC, SOES |
| Phipps | R.A. | SOC, RVS (SEG) |
| Rourke | E. | SOC, RVS (ISG) |
| Rudnicki | M.D. | U. of Cambridge |
| Sherring | A. | SOC, RVS (SEG) |
| Slater | D. | SOC, SOES/JRD |
| Snaith | H.M. | SOC, JRD |
| Wright | A.P. | SOC, JRD |

Table 1b Ships Personnel

| Surname | Initials | Rank |
|---|---|---|
| Plumley | R.C. | Master |
| Chamberlain | R.J. | C/O |
| Sykes | S. | 2/O |
| Owoso | T. | 3/O |
| Jethwa | K. | C/E |
| Royston | J. | 2/E |
| Healy | T. | 3/E |
| Bishop | D. | 3/E |
| Stewart | D. | ETO |
| Trevaskis | M. | CPOD |
| Luckhurst | K.R. | POD |
| Allison | P. | SG1A |
| Cook | S.J. | SG1A |
| Cooper | G. | SG1A |
| Day | S.P. | SG1A |
| Johnston | R. | SG1A |
| Dick | D.T. | MM1A |
| Staite | E. | SCM |
| Haughton | J. | CHEF |
| Duncan | A.S. | M/STWD |
| Link | W.J. | STWD |
| Link | S.E. | STWD |

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## OBJECTIVES

This cruise had two goals. The first was to continue the long time series of hydrographic sections from Scotland to Rockall and its recent extension to Iceland. The objectives of the UK to Iceland time series are to identify the pathways for the warm water flow into the Norwegian Sea and to quantify the interannual to decadal variability in this circulation. The second goal was to study the outflow of deep water from the Faroe Bank Channel (FBC). The objectives for the FBC outflow experiment are to quantify the climate variability in the deep water exiting the FBC and to analyse the downstream evolution of the deep water as it descends into the Iceland Basin.

From this cruise it should be possible to achieve the following specific scientific objectives:

- Identify the relative importance of the different pathways for the warm water flows through the Northeast Atlantic to the Polar Seas and determine their variability.
- Quantify the volume, salt and heat fluxes into the Nordic and Polar Seas between the UK and Iceland.

Identify interannual to decadal changes in the circulation and water mass properties both of the warm, upper water flows into the Norwegian Sea and of the cold deep water outflow into the North Atlantic.

- Relate the transport of deep water outflow over the sill of the Faroe Bank Channel to the physical structure of the sill section and to the reservoir conditions of the waters behind the sill using hydraulic theory.
- Evaluate the amount of friction and entrainment in the descending outflow exiting from the Faroe Bank Channel and develop methods to include such effects realistically in large-scale numerical models of ocean circulation.

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## OVERVIEW

We completed 125 full depth CTD stations (Figure 1) all with discrete sampling for nutrients and oxygen and of these 124 stations had lowered ADCP measurements. The vertical distribution of water samples along various sections is shown in Figure 2. Underway and on station VMADCP, GPS, depth, meteorological, wave and surface observations were made throughout. Four BRIDGET tows were completed, one as a trial and three across different sections of the FBC outflow on the Iceland Ridge. Complimentary to our data set Bill Turrell (Oceanography Section, Fisheries Research Services, Aberdeen) completed a CTD section across the Faroe Shetland Channel towards the end of September. This section defines the upstream conditions at the time of our FBC observations. An XBT section along the Wyville-Thomson Ridge was completed at the end of the experiment.

The following description can be followed by reference to Figure 1. On the Scotland-Iceland section we occupied the Rockall Trough (the Ellett line) at a resolution not achieved in some of the recent occupations. This high resolution reveals the small horizontal scale of flows and steeply sloping property isolines near bathymetry. Additional stations near the Scottish shelf edge give extra resolution in the Scottish shelf edge current. Across the Iceland Basin LADCP currents are weak except on the western edge of the Rockall-Hatton Plateau (the North Atlantic Current) and on the Icelandic continental slope. This last strong flow is our furthest downstream observation of the FBC overflow. From south east Iceland to Lousy Bank we made a particular effort to obtain high vertical resolution samples of nutrient and oxygen at each CTD station especially in the bottom 200 m (Figure 2b). This shows in unprecedented detail the overflow in nutrients and oxygen giving a good opportunity to explore the relationship between the nutrient and hydrographic properties. On the Iceland Ridge and FBC we completed six (and one partial) CTD or BRIDGET sections across the outflow. One section downstream from the sill was occupied three times, twice with CTD stations (only one good section of LADCP velocities were recovered) and once with BRIDGET giving an opportunity to compare data from two different techniques. The ADCP observations made from BRIDGET and from the CTD give exciting and complimentary views of the overflow.

## Narrative

In this narrative times are given in GMT. Throughout the cruise we worked in BST (GMT+1). *Discovery* station numbers started at 13630 following on from the last station number used by Ian Rouse on RRS *Discovery* cruise 240. Day of year numbers in parenthesis following date.

Friday 3rd (246)

Loading commenced at 0730 and craning operations were completed by 0900. CTD setup and computing commenced early afternoon. An upgrade installation of the Ashtech caused the receiver to hang. The receiver was taken to the manufacturer in Reading for the upgrade.

Saturday 4th and Sunday 5th (247, 248)

Not officially loading days but several of the scientific staff attended for parts of these days to continue setting up the main laboratory. The VMADCP PC would not speak to the deck unit.

Monday 6th (249)

VMADCP PC finally made to work and a spare brought aboard. BRIDGET ballasting and loading completed in the morning and workstation and peripherals installed in the afternoon. Chemists completed a day of running the nutrient autoanalyser and oxygen kit to their satisfaction. GPS logged throughout the afternoon and the Ashtech refitted and sending data at 1500. By the end of the day most instruments were logging through the Level A.

Tuesday 7th (250)

Sailed on time at 0800, leaving SOC to a fine quayside gathering. Weather fine and wind over tide gave a lovely chop to the water as we passed the Needles. Computing and processing paths continued. TSG intake found to be leaking due to a missing or damaged gasket. Ashtech finally made to produce good heading data after a reinstallation of the antenna parameters. Good bottom track VMADCP obtained through the English Channel. A period of one hour from 1300 to 1400 steaming was limited to 8 knots over the ground, data from this period to be used for VMADCP heading and amplitude calibration.

Wednesday 8th (251)

Steaming approximately due north into St. George's Channel at breakfast time. Processing paths still being set up. Recently repaired 30° BBADCP not waking up, problem was traced to the PC. Watches started at 0700 this morning.

Thursday 9th (252)

Slow progress towards test station due to wind force 9, gusting 10. Forced to heave to for most of the night.

Friday 10th (253)

Two consistent calibrations for the ADCP derived from bottom track data. Progress towards the test station slow due to continuing foul weather. Reached test station on the Scottish Continental slope in 2000 m of water. Station (13630) started at 2118 and completed by 0055. Slow cast due to winch problems. The 10 mm hydrographic wire is laid badly on the drum and this caused the wire to jump from sheaves on two occasions. In the first the wire had to be stopped to release tension on the sheave so the wire could be relocated. On the second a hammer solved the problem. Veer and hauls speeds were low. Analysis of the winch data for the test stations shows that the overboard tension high frequency signal had a standard deviation of 0.3 T. The CTD package causes a tension of 0.9 T on deck and this drops to 0.6 T in water. As the wire pays out overboard tension increases by about 0.26 kg/m (the cable's safe working load is 3.1 T) which suggests that the cable should reach 5000 m wire out under similar swell/wind conditions of the test station. Bad wire lay and low overboard tension caused slow haul and veer speeds throughout the cruise.

Saturday 11th (254)

We steamed eastward to 8°W to begin the Scotland to Iceland section (beginning 13631) completing eight stations working steadily westward along the Ellett line. The weather moderated throughout the day to light breezes and sunny spells.

Sunday 12th (255) and Monday 13th (256)

Station work continues, working our way westward towards Rockall. Weather moderate.

Tuesday 14th (257)

Station work continued, completing the Rockall station (13654) at about 0300. Continued station work across the Rockall Hatton Plateau. The weather deteriorated all morning with decreasing pressure with wind increasing to 15 m/s gusting to 20 m/s. The BRIDGET vehicle is fully ready for a trial deployment as soon as an opportunity arises (we had hoped mid-afternoon today). The 30° BBADCP (upward looking for BRIDGET) has continued to give trouble switching on or off. Eventually Mark Hartman and Andy Harris traced the problem to jumper switches on the main processor board which had been changed by RDI whilst at the factory.

Wednesday 15th (258)

CTD station work continues.

Thursday 16th (259)

From CTD station 13663, starting at 0640, we made a trial deployment of BRIDGET on the edge of the Rockall Hatton Plateau in about 1500 m water depth. BRIDGET was towed at 100 m off bottom, back up the slope for about 45 minutes at speeds between 2 and 3.5 knots. The vehicle dynamics were satisfactory and the CTD and LADCP data are being analysed. A first look suggests that both ADCPs worked. Only problem was that the wire out encoder for the 20T winch that feeds the Seamatrix metering system packed up as we started to haul BRIDGET. As we were already using the spare unit (the primary unit was damaged at SOC on loading day) we had no backup. A second backup unit that is not connected via the winch metering system will give a readout of wireout and winch speed in the winch cabin. Wireout values are required to estimate the position of BRIDGET behind the ship. CTD station work then continued from 13662.

Friday 17th (260)

CTD station work continued to station 13671 which finished at 0700. We then steamed up 20°W to reach Vestmannaeyjar (63° 26.5'N, -20° 15'W) to collect a new water evaporator pump. We then started CTD work from the northernmost station (13672) at approximately 1700, working southward for the remaining five stations on this section.

Saturday 18th (261)

Strong winds of over 25 m/s prevented any station work from midnight on Friday to 1000 on Saturday. A rapid moderation allowed the last two stations 13675 and 13676 to be completed by 1630. We then steamed north-westward to the first station on the Iceland to Lousy Bank section.

Sunday 19th (262)

The first CTD station (13677) on the Iceland to Lousy Bank section was deployed at 0330. As we steamed south a southerly swell developed driven by a low pressure system to the south, but wind and waves from the east made station keeping difficult. Completed station 13680 at 1356 and steamed to 13681 where conditions were too bad for CTD operations. As darkness fell, thick fog with wind and swell perpendicular made station keeping impossible.

Monday 20th (263)

Weather moderated sufficiently to deploy CTD by 0550. CTD stations then continued for the rest of the day.

Tuesday 21st (264)

At CTD station 13686 cast ended at 0500 as winds rising to 20 m/s meant station keeping became too difficult. The following 31 hours were spent hove to.

Wednesday 22nd (265)

Continued CTD station 13686 at 1056 in moderate weather.

Thursday 23rd (266)

We completed Iceland to Lousy Bank section at 1830 (13696) and from there proceeded to line S/T to begin BRIDGET work.

Friday 24th (267)

Deployed BRIDGET (station number 13697) at 0330 towing along line S/T until 1613. Some cold bottom water was observed in a narrow channel at the eastward end of line S/T. After BRIDGET recovery at 1613 we completed three CTD station across the deep channel (bottom temperature 1.2°C in the channel) numbers 13698 – 13700. T5 XBT's were deployed at 45 minute intervals throughout this and all subsequent BRIDGET tows.

Saturday 25th (268)

Deployed BRIDGET (station number 13701) at 0240 towing along line S until 2400. Weather since Thursday has been flat calm, no waves very slight swell. Ideal for BRIDGET work.

Sunday 26th (269)

Steamed to the north end of line Q. This section was completed as a CTD section (13702 - 13715) with stations at three nmile spacing. This gave a break for the BRIDGET drivers and allowed time for assessment of the data before committing to additional BRIDGET work.

Monday 27th (270)

Line P was occupied with BRIDGET between 1400 and 2200. On completion we immediately reoccupied this line with CTD's (13717 to 13727). The CTD section was interrupted between stations 13722 and 13723 for six hours due to wind speeds greater than 20 m/s.

Tuesday 28th (271)

Section P CTD station work continued from 1800.

Wednesday 29th (272)

On completion of line P at 0300 we proceeded to the FBC sill to occupy a short CTD section. Stations 13728 to 13731 were completed when it was realised that the WHOI LADCP had developed a bad beam and this affected data from stations starting at 13720. We abandoned this sill section and steamed to a position in the FBC on the upstream side of the sill. On completion of this upstream station (13732) the LADCP was replaced by the upward looking 30° ADCP from the BRIDGET vehicle. Begin the FBC section at 2100.

Thursday 30th (273)

Complete the FBC CTD section by 1430 (13733 to 13743). Disappointed by the performance of the 30° upward looking ADCP so replaced by the 20° downward looking ADCP. Proceed to P for a second reoccupation of this section (13744 to 13754). Strong winds again delayed station work on this section.

Friday 1st October (274)

Continued with section P after a weather break.

Saturday 2nd (275)

Complete P by 0400. Proceed to the sill section where we completed three stations (13755 to 13757) before work ends at 0900. Sail for SOC. Enroute deploy 20 XBT's along the Wyville-Thomson Ridge

Sunday 3rd (276) to Wednesday 6th (279)

On passage to SOC past the Butt of Lewis then down through the Minches. Bright, dry passage through the Irish Sea. Past Lizard Point about 0800. Data processing ended by 1200. Archiving ended by approximately 2100. Lifeboat exercise near Falmouth. Beautiful weather, sunny and calm. Arrive Needles at 0530, collect Pilot at 0700, enter Empress dock at 0800. Tied up by 0830. Demobilisation began at 0900 and completed by mid-afternoon.

## SHIPBOARD COMPUTING

The following data was logged using the Level ABC System ((Voss et al., 1986)): Chernikeef Log; Ships Gyro; Trimble GPS; Ashtech ADU; Ashtech Glonass GPS; Surface Logger; CTD; Winch Monitoring; Echo-Sounder. Level A: The Ashtec Glonass GPS receiver functioned correctly during the first week of the cruise, however increasingly long periods of failing to produce any output were noticed as the cruise progressed. The fault was eventually traced to the receivers power supply, which was replaced and no further problems occurred. The Chernikeef Log Level A failed at 04.00 hours on Wednesday 28th September. The failure was not noticed until 09.00 hours of the same morning. The Level A was replaced and logging continued. Level B: The level B system crashed on the evening of Wednesday 28th September. The system was reset with data loss occurring for 3 minutes. Normal functionality returned with no further problems. Computing: Prior to sailing and during the passage to the work area the ships network was augmented by the addition of users computing systems. This consisted of two Sun workstations, two PC's, six Mac computers and a networked printer. Packages served to users from the onboard network of Sun workstations were: Matlab. *Discovery*7 and *Discovery*5 (until 30th September); Uniras. *Discovery*7; GMT *Discovery*2; Fortran77. *Discovery*5; Pearl. *Discovery*7; Rvs. *Discovery*1

XBT data were moved from the XBT PC onto the Translation PC and converted from binary to ASCII using the XBT2.exe software. The data was then transferred onto level C where they were converted to RVS data files. A new matlab two user floating licence was installed on

*Discovery* 7, as the current licence was due to expire on the 1st October. The licence on *Discovery* 5 also expired at this time. Problems with the licence manager on *Discovery* 7 in the early part of the cruise were eventually traced to an old licence manager locking files being owned by a previous pstar user id. *Discovery* 2 suffered a disk crashed on the 21st August when trying to access the local disk space. Diagnostic checks were run on the disk to update any bad block information and the machine rebooted, after which no further problems occurred.

Gareth Knight and Elizabeth Rourke

## Additional computing

PEXEC was installed before the ship sailed from Southampton and ran without incident throughout. Two copies were required because of the two different operating systems on board. A single id was used for data processing purposes, so this was set up to use the correct copy of the package for the machine in use.

To reduce network traffic on the system, data areas were created so that each dataset to be processed used data from the same partition or disk. Users were then encouraged to use the machine on which their data resided. This seemed to alleviate some of the data blockages apparent on previous cruises.

In the later part of the cruise, the RVS programme *datapup* became slower and slower to recover data. This was a recurrence of problems from earlier cruises. The patch written then was resurrected and applied to a user copy of the programme. This introduces a binary chop search to find the start point of the data requested. The original programme inspects each datapoint to find the start time. This means that for large files, lots of effort is spent just identifying the data to recover. This patch worked successfully for the rest of the cruise except when retrieving data from the beginning of a data file, when it failed. A proper fix to the RVS programme is required.

Archiving of data at the end of the cruise took its usual stressful form. Because of the mixture of machines certain combinations of machine and device were so slow as to be unusable. This problem will hopefully be corrected when the ships computer system is upgraded in the new

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year. The archive was to erasable optical disk. A problem arose here in that half of the disks supplied were "write-once" and could not be used on the ship system. By scrounging disks from users and RVS, enough were available for two copies of the data. The DLT drive installed on *Discovery*7 was also used, but because this was its first trip to sea, was not relied on. Again because of throughput issues, using the DLT to copy data from machines other than *Discovery*7 was impossibly slow. Eventually it was found that piping to a remote shell on *Discovery*7 resulted in acceptable (but still slow) archiving.
Steven Alderson

## SHIPBOARD ENGINEERING

### WINCH SYSTEMS

20 T and 10 T Winch Systems, including 300 kW Power Pack.

The CTD cable which was terminated at the beginning of the cruise gave no problems during deployments and the 300 kW power pack with 10 T winch system worked without fault during the cruise. The deep tow conducting cable was terminated with a TOBI type termination and operated without problems during use. An intermittent fault did occur on the 300 kW power pack and 20 T winch system had during deployments. After a period of time of running with the winch stationary it was found when the speed control was moved from the stationary position the winch would not haul or veer. It was found the winch would operate correctly again if the 300 kW power pack was shut down and then restarted. The fault occurred several times when the BRIDGET package was already deployed and once when the system was switched over to the 10 T Cobra for a CTD deployment.

## 20 T and 10 T Storage System, including 37 kW Power Pack and Inboard Compensators

The 20 T system was used with the 17 mm conducting cable for the deployment of BRIDGET and operated satisfactorily during deployments. The 10 T system was used for CTD deployments with the 10 mm conduction cable. Prior to the first deployment it was found the CTD cable was poorly scrolled on the storage drum with numerous crossovers. During the first deployment the wire jumped off the scrolling sheave at about 1800 m wire out. The wire subsequently jumped the sheave another three times during deployments despite slowing the winch speed down where the crossovers occurred. Later deployments of the CTD were carried out at a maximum of speed of 40 m/min which prevented further occurrences. The maximum wire out used was 2720 m and the point at which the bad spooling commences is several lays below this. The wire should be wound off , spooling alignment checked and rewound prior to its next use.

## 10 T & 20 T Kley France Cable Haulers, including Power Pack.

Both sets of cable haulers were used throughout the cruise without problems.

## Seametrix System

The system operated satisfactorily when deploying using the 10 T winch with the exception of the occurrence of a “spike” and simultaneous re-zeroing of the wire out reading once during recovery of the CTD. When used in conjunction with the 20 T system the wire out/speed failed during the first deployment of BRIDGET. On investigation it was found the encoder driven by the spurling pipe top sheave was damaged. The wire out/speed readout from the old LED display in the winch cab was used for deployments of BRIDGET.

Mid-ships Hydraulic Power Pack, including Deck Hydraulic Systems one and two

Used extensively for starboard gantry operations during cruise without problems.

Mid-ships Gantry

Used without problems for deploying the CTD. Several leaks were found from hose end fittings on the gantry. These were rectified during the cruise.

Stern Gantry

Used successfully for the deployment of BRIDGET only.

Precision echo sounder winch and davit

No problems noted.

Non-Toxic System.

Pump three only used throughout cruise without problems.

Laboratories, including Scientific Workshop and Winch Control Room.

No problems reported

Richie Phipps, Alan Sherring and Rob Mclachlan

## CTD MEAUREMENTS

### Instrumentation

A total of 125 CTD casts were completed during this cruise, utilising two underwater unit configurations (Table 2). The first cast (13630) was a preliminary check out for the CTD. The first 19 casts (13630 - 13648) the configuration was as follows:

24-way rosette frame
CTD underwater unit: OTD Neil Brown MK IIIc, s/n DEEP04
Pylon: FSI HPS-EC-24, s/n 1327
Aux 0) pressure temperature
Aux 2) oxygen current
Aux 3) oxygen temperature
Aux 4) Chelsea Mk III Aquatracka fluorimeter, s/n 88/2960/163
Aux 5) Chelsea Alphatracka transmissometer, s/n 161/2642/003
Aux 6) Simrad Mesiotech altimeter

The next 29 casts (13649 - 13676) the configuration was the same as above with the exception of the CTD underwater unit, which was replaced with the OTD Neil Brown MK IIIc, s/n DEEP03 instrument. The reason for the change in the configuration was evidence of hysteresis present in the conductivity cell data on the upcasts. The conductivity cell s/n N-29 in CTD DEEP04 was replaced with conductivity cell s/n P-20.

After cast 48, CTD DEEP03 was replaced with CTD DEEP04 for the next 10 casts (13677 - 13686). CTD DEEP03 experienced noise (fluctuations) in temperature readings between the depths of approximately 100 to 200 m on both upcasts and downcasts. Although these spikes were not evident in the 1Hz post-processed data, the accuracy of the temperature sensor was in question necessitating the change to the other deep underwater unit.

CTD DEEP04 had periodic voltage spikes in the oxygen, transmissometer and fluorimeter channels for a number of casts; cleaning and re-seating of the connectors, replacing cable leads eventually removed the spikes. At cast 59 (13687), DEEP04 was again replaced with unit DEEP03, as DEEP04 was still exhibiting similar drift in the salinity readings during the upcast. The pressure sensor in DEEP04 is suspect. CTD underwater unit DEEP03 was used for the remaining casts of the cruise; after 10 casts the oxygen sensor was replaced, as examination of the data revealed a lack of sensor responsiveness. At cast 74 (13704), the oxygen sensor failed to function; this was caused by a loss of connection of the current reading wire, from the bulkhead of the front of the sensor to the sensor head. At cast 84 (13714), the problem repeated itself in the earth connection; in both cases repairs enabled the same sensor head to continue to be used successfully. . A possible cause of these problems is thought to be the position of the LADCP transducer heads in the centre of the frame, which may be producing a wake effect around the CTD sensors. At cast 92 (13722), the underwater unit was shifted away from the LADCP a short distance to attempt to improve the data quality. As there was only one complete oxygen sensor for both CTD underwater units, the sensor was changed back and forth between CTD instruments as needed.

Jeff Benson

## CTD Data Processing

Raw CTD data were captured in three streams: raw files by the CTD console PC, the RVS Level A and one-second data by the SOC DAPS software. The main stream for processing was DAPS to PSTAR. DAPS utilises an Ultra-Sparc SUN workstation with an expansion box giving 16 extra serial ports. It captures the CTD profile and firing data directly from the CTD console, and stores the data as individual ASCII files for each cast. DAPS checks the data for pressure jumps, averages the 25 Hz data to one second time intervals, and calculates the temperature gradient over the one second samples. The first column of the ASCII files is decimal Julian day (with one millisecond resolution).

The two CTDs used were DEEP03 and DEEP04. The preferred CTD initially was DEEP04 because of concerns about the stability of the temperature sensor of DEEP03. However early problems with DEEP04 meant both instruments were used during the cruise. In the end several problems were encountered with both instruments and these are described later.

Since the purchase of DEEP03 and DEEP04 in 1993 we have monitored the history of instrument calibrations, particularly for the pressure and temperature sensors.

For both instruments the pressure calibrations have been stable; only varying between calibrations, by one of two dbar at full scale. Pressure hysteresis has remained small at about 0.6 dbar for a 5500 dbar pressure cycle.

The history of the temperature sensors of the two instruments show a marked difference from one and other. The change in temperature offset (the first number on the right hand side of equation two or three below) between calibrations is changing much more slowly for DEEP04 than for DEEP03. The average rate of change since 1993 for DEEP04 is 0.4 m°C/year and for DEEP03 is 6 m°C/year. For DEEP03 the offset is becoming larger negative and for DEEP04 smaller positive, implying that as the sensors age they tend to measure warm.

The slope of the temperature calibrations (the second number on the right hand side of equation two or three below) also varies. At full scale DEEP04 varies by -0.4 m°C/year and DEEP03 by -0.8 m°C/year.

The following paragraphs describe the conversion and calibration coefficients used for both instruments.

Temperature

Temperature counts were first scaled by (1) then calibrated using (2 or 3):

$$T_{raw} = 0.0005 \times T_{raw} \tag{1}$$

DEEP03: $$T = -2.1443 + 0.991259 \times T_{raw} \tag{2}$$

DEEP04: $$T = 0.1309 + 0.999278 \times T_{raw} \tag{3}$$

To correct the mismatch in the temperature and conductivity measurement temperature is "speeded up" by (4):

$$T = T + \tau \frac{\partial T}{\partial t} \tag{4}$$

where the rate of change of temperature is determined over a one second interval and the time constants used were

DEEP03: $\tau = 0.25$

DEEP04: $\tau = 0.20$

Pressure

Raw pressure counts were scaled by (5) and then calibrated using (6 or 7):

$$P_{raw}=0.1\times P_{raw} \tag{5}$$

$$\text{DEEP03:}\quad P=-39.3+1.07489\times P_{raw} \tag{6}$$

$$\text{DEEP04:}\quad P=-37.8+1.07378\times P_{raw} \tag{7}$$

Laboratory calibrations show the pressure sensors in DEEP03 and DEEP04 show little temperature-dependence or pressure hysteresis and no further corrections were made.

Conductivity

Raw conductivities were first scaled by (8) and then calibrated with (9 or 10):

$$C_{raw}=0.001\times C_{raw} \tag{8}$$

$$\text{DEEP03:}\quad C=-0.002+0.964\times C_{raw} \tag{9}$$

$$\text{DEEP04:}\quad C=-0.0238+0.9552\times C_{raw} \tag{10}$$

This was followed by the cell material deformation correction (11):

$$C=C\times\left[1+\alpha\times\left(T-T_0\right)+\beta\times\left(P-P_0\right)\right] \tag{11}$$

where the coefficients for the cell material are: $\alpha=-6.5E^{-6^\circ}C^{-1}$, $\beta=1.5E^{-8}dbar^{-1}$, $T_0=15^\circ C$ and $P_0=0dbar$. The offset and slope were determined using bottle samples and subsequently small offsets were applied compensating for fluctuations in the CTD and in the bottle sampling. The corrections applied to the offset are listed in Table 3. They were obtained by slightly different procedures according to the CTD used, largely because of the hysteresis problems affecting

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DEEP04. For DEEP03 bottle conductivities were calculated from bottle salinity, pressure and temperature at firing times, and directly compared to the CTD upcast conductivities. DEEP04 had hysteresis in the conductivity and salinity profiles and so the downcast was calibrated directly. The part of the downcast water column that corresponded to the upcast sample was found by matching on potential temperature. The bottle conductivities were then calculated using the matched downcast data and compared to CTD conductivity. The DEEP03 calibration resulted in a series of small offsets applied to groups of stations. However the hysteresis of DEEP04 often occurred as jumps in the conductivity, so the offsets derived from the samples were applied individually for each station.

After the conductivity calibration, the salinity residuals (bottle salinity - CTD salinity) revealed no pressure dependence for either DEEP03 or DEEP04 (Figure 3a and 3b) or station dependence (Figure 3c). Table 4 gives salinity residuals statistics; DEEP04 residuals show a greater variance because of errors introduced by matching the samples to the downcast data.

## Transmittance, Fluorescence and Altimetry

Fluorescence or transmittance was converted to voltages (12 or 13); this is a calibration of the voltage digitiser in the CTD. The altimeter had the calibration (14 or 15) applied:

$$\text{DEEP03: } V = -5.027 + 1.534\times10^{-4}\times V_{raw} - 3.704\times10^{-12}\times V_{raw}^2 \tag{12}$$

$$\text{DEEP04: } V = -5.656 + 1.727\times10^{-4}\times V_{raw} - 2.244\times10^{-12}\times V_{raw}^2 \tag{13}$$

$$\text{DEEP03: } alt = -234.5 + 7.16\times10^{-3}\times alt_{raw} - 0.95\times10^{-10}\times alt_{raw}^2 \tag{14}$$

$$\text{DEEP04: } alt = -249.7 + 7.62\times10^{-3}\times alt_{raw} + 1.04\times10^{-10}\times alt_{raw}^2 \tag{15}$$

Fluorescence or transmittance voltages can be calculated using the clear air and blank voltages, recorded at frequent intervals throughout (Table 5).

## Digital Reversing Temperature and Pressure Meters

Four digital reversing meters were used, T1545 and P6534 on rosette position one, and T995 and P3694 on rosette position four. T1545 and P6534 also recorded the standard deviation of the mean temperature or pressure that they measured. All four instruments worked satisfactorily throughout the cruise. The mean and standard deviations of the differences between the reversing instruments and the CTD values are shown in Table 6. The offsets in temperature highlight the difference between the temperatures sensors on DEEP03 and DEEP04: the latter measuring consistently higher values than the former. The range of pressures and temperatures sampled provide an unusual and interesting opportunity to look at the temperature and pressure dependence of the reversing instruments. Figure 4 shows the differences (CTD minus reversing instrument) plotted against DEEP03 upcast temperature and pressure for 70 stations. While the temperature differences show no trend, the pressure differences appear to be greater at depth. However, the apparent pressure dependence is in fact temperature dependence; the cluster of 4-6 dbar offsets at 600-900 dbar are actually the low temperature readings (<1°C) from the FBC.

## Oxygen

The oxygen model of (Owens and R.C. Millard, 1985) was used to calibrate the oxygens (16):

$$O_2 = \rho \times oxysat(S,T) \times (O_C - \chi) \times \exp\{\alpha \times T_{CTD} + (1-f) + \beta \times P\} \tag{16}$$

where ρ is the slope, oxysat(S,T) is the oxygen saturation value after (Weiss, 1970), $O_C$ is oxygen current, χ is the oxygen current bias, α is the temperature correction, f is the weighting of $T_{CTD}$ the CTD temperature and a lagged temperature $T_{lag}$ and β is the pressure correction. Five parameters, ρ, α, β, f, χ were fitted for each station. This approach minimises the residual bottle oxygen minus CTD oxygen differences but places complete reliance on the bottle oxygens being correct.

The oxygen temperature is not measured directly, instead a lagged temperature is calculated from the CTD temperature values. The values of oxygen current, temperature, lagged temperature and salinity from the downcast are merged with the bottle oxygen values on pressure. The program *oxyca3* takes initial estimates of the five parameters in the above equation and alters them iteratively to obtain the best fit to the measured oxygen samples. The program returns the 'best fit' parameter values and the mean sum squares error of the resulting fit with the bottle values.

Once the best fit parameters have been obtained, they are applied to the 1Hz CTD files using program oxygn3, and then the 2db files are recalculated and merged with the original sample files to give the final residuals of the calibrated oxygen - bottle values. An inconsistency was found between the equation used for the fit and that used for the calibration. The calibration routine (using the –oxycal option) used the values given above, but the fitting routine used negative β and a script was written to allow the output from *oxyca3* to be input directly to *oxygn3*.

The first attempts at calibrating the oxygen sensor were not started until the second week of the cruise, and it was found that the sensor was no longer detecting features consistent with the bottle values. The oxygen sensor was changed at this point, and after rewiring produced much better oxygen current values. Typical profiles of the original sensor and the new sensor are shown in Figure 5. The original sensor (station 13690) failed to detect even the major oxygen minima at 1000 m evident in the bottle data. The replacement sensor clearly shows the oxygen maximum near 1000 m (station 13722). Several attempts at forcing a fit, by fixing the CTD/lagged temperature ratio and the oxygen current offset, did not improve the fit.

Some of the earliest stations seemed to show some promise, and a reasonable fit was obtained for station 13641. Using the final parameters from this station as initial parameters, the fitting routine was run over all the stations before the sensor was changed. Although solutions were found in most cases, the residual sum square errors were very high, and there was no consistency in the values of the parameters. The shallow stations proved particularly difficult to obtain solutions for. Only those stations where the residual sum of squares errors in the fit was better than 5 µmol/l were calibrated.

After the new sensor had been fitted, and rewired, new calibration runs were made. These calibrations gave much better results, with the parameters varying much more slowly. For stations 12744-13756 there were no bottle oxygen values to calibrate the sensor, but an estimate of the calibrated values has been made using the previous station parameter values. Oxygens were calculated in µmol/l. Table 7 gives the parameters for each station and Table 8 the post-calibration residual (bottle oxygen - CTD oxygen) statistics.

Summary of CTD Oxygen Data Quality:

Stations 13630 to 13648. The oxygen sensor produced noisy data; fits obtained with bottle oxygens, but the data remain suspect. For shallow stations 13630 and 13631 no satisfactory fit could be obtained and the coefficients for 13632 were used, but large residuals remain. Stations 13649 to 13698: The oxygen data were unrealistic and data values set to absent in the 1Hz files. Stations 13699 to 13703: The new oxygen sensor performs satisfactorily and reasonable fits obtained to the bottle data. Stations 13704 to 13705: Failure of the sensor; no oxygen data. Stations 13706 to 13710: The re-fitted sensor produces realistic data and reasonable fits obtained with the bottle data. Stations 13711 to 13714: The sensor produces much higher oxygen current data until it fails completely during 13714; data values set to absent in the 1Hz files. Stations 13715 to 13757: The re-wired oxygen sensor produces realistic data and reasonable fits obtained with the bottle data. Note there were no bottle data for stations 13737 and 13744 to 13756 so the coefficients from the preceding stations were used and these data should be used with caution.
Helen Snaith

## CTD Instrument and Data Quality Problems

### Conductivity Cells

The CTDs and auxiliary sensors suffered a number of problems during the cruise (Table 9). Of the two CTDs, DEEP04 was initially the instrument of choice based on laboratory calibration results over the last five years. The temperature offset for DEEP03 from November 1994 to June 1997 had changed by 0.028°C, whereas the offset for DEEP04 was more stable. Thus the first stations were completed using DEEP04. Alarm bells were raised during the test station 13630 when the conductivity jumped to higher values close to the bottom of the cast during a prolonged winch-stopped period. The CTD technician noted that such adjustment jumps were common to instruments that had not been used for a prolonged period of time, so the decision was made to continue with DEEP04. However after the first deep stations it became clear that the salinity values from DEEP04 were exhibiting some hysteresis due to a positive offset at the bottom of the cast, and possibly increasing offset during the upcast. A failed conductivity cell was diagnosed and DEEP03 deployed while the cell was replaced in DEEP04. At station 13677 DEEP04 was redeployed, but again, deep stations exhibited a similar hysteresis problem. So from station 13687 onwards only DEEP03 was used. The cause of the hysteresis is as yet undetermined; was it really the conductivity cell on both occasions, or is there another problem?

### Salinity Spikes

Initial inspection of the CTD profiles led to the impression that the salinity profiles were quite noisy. For both instruments (DEEP03 and DEEP04) down-profiles were noisier than up-profiles and the spikes toward higher salinity were larger in regions of stronger vertical temperature gradient. Visual comparison of the 2 dbar CTD station near 61° 20'N, 20°W (13669) with *Discovery* 230 (4X-station 118) and *Discovery* 233 (CHAOS-station 13507) stations nearby showed that the current stations were exhibiting substantially more and larger spikes in salinity.

(The CHAOS station is the quietest of the three). Varying the lag correction times for conductivity from its standard value of 0.2 s over a range of -0.25 to +0.5 s had very little effect on the salinity spikes. Inspection of the raw 25 Hz profiles revealed that the salinity spikes were associated with order five dbar (approximately five second) variations in both conductivity and temperature. Thus, varying the conductivity lag time is unlikely to solve the problem.

Seeking alternatives, we contacted Nick Crisp and John Smithers (SOC) and Robert Millard (WHOI). Crisp reported salinity noisiness during the Albatross cruise in the Southern Ocean in April and his solution had been to average the raw profiles over 3.5 s. Millard reported noisiness in one of McCartney's data sets which he traced to small eddies caused by the interference from the wake of a nearby LADCP: small vortices caused the conductivity and temperature sensors to sample different waters. He urged us to examine the relative position of instruments on the Rosette frame. Smithers noted that the only substantial change since last year's CHAOS cruise apart from the addition of a fin was our use of a shorter LADCP.

To accommodate the installation of an LADCP on the Rosette frame during recent cruises, the frame has been lengthened so that the CTD conductivity and temperature sensors sit about 38 cm above the bottom of the frame. In addition, the temperature and conductivity sensors are just above (15 cm) and outboard (6 cm) of a metal plate to which the pinger is attached. For most of this cruise, the WHOI LADCP was installed on the frame. This LADCP is shorter than the two SOC instruments that were normally used so that its transducer heads were appreciably closer to the CTD sensors than on previous cruises. The top of the nearest transducer was just below the metal plate. It seems possible that as the package descends through the water the nearest transducer head channels water up onto the flat metal plate producing wake vortices which could interact with the CTD sensors.

Due to failure of one of its beams, the WHOI LADCP was replaced by one of the SOC LADCP's. Station 13731 was made using the WHOI LADCP, station 13732 was made with no LADCP, and station 13737 was made with the longer SOC LADCP, all in the FBC encountering similar water mass transitions at similar depths of order 600 m. Surprisingly station 13732 with no LADCP exhibited very regular but very large oscillations in salinity through the deep temperature gradient region. Station 13731 with the WHOI LADCP exhibited a typically (for this cruise) noisy salinity profile. Station 13737 with the longer SOC LADCP exhibited substantially smaller salinity noise throughout the water column. Our conclusions then are that:

- the metal plate may be the origin of small scale vortices which differentially affect the CTD temperature and conductivity sensors;
- the shorter LADCP effects a small amount of mixing before the approaching water interacts with the plate;
- the longer LADCP protruding to the bottom of the CTD frame mixes up the approaching water so that the CTD sensors measure well-mixed waters passing through the frame.

It follows that up-profiles where the approaching water is heavily mixed by the bottles instruments and frame above before it reaches the CTD sensors may offer the best data set for CTD stations during this cruise.

For future cruises we would favour positioning the CTD below the metal plate so that the temperature and conductivity sensors would sample nearly undisturbed waters at a level commensurate with the LADCP transducers. An initial fix might be to cut off part of the metal plate near the CTD that is not needed for attachment of other instrumentation at present. For processing the ANE CTD stations, we concluded that using the well mixed, less noisy up profiles of temperature, conductivity, and salinity is preferable to developing the extensive editing, filtering routines required to eliminate the noise in the down profiles.

Penny Holliday and Harry Bryden

## SELF CONTAINED ADCP MEASUREMENTS

### Introduction

Three Self Contained Acoustic Doppler Current Profilers (SCADCP) were used on *Discovery* cruise 242 to measure water currents. Two of these with 32.5 inch long pressure cases were mounted in BRIDGET; one upward looking, the other downward. These can be called BRIDGET-up and BRIDGET-down respectively. The third unit, on loan from WHOI was fitted to the CTD frame and used as a lowered ADCP (LADCP). BRIDGET was towed behind the ship at a nominal altitude of 100 m primarily to measure benthic currents. Due to problems with the LADCP the other two units were subsequently separately mounted in the CTD frame. All three instruments positions were marked with respect to their surrounding framework so that they can be reoriented for a post cruise compass swing.

## Power supplies

Four different battery packs and pressure cases were used between the three instruments, two containing 50 V alkali packs comprising D cells the other two containing four rechargeable lead-acid 12 Ah batteries. For the first short test deployment a rechargeable pack used to power the upward looking ADCP whilst the downward unit was powered by an alkali pack. For all subsequent deployments used alkali packs for BRIDGET_up and BRIDGET_down.

The LADCP was powered throughout by one of the lead-acid packs which was recharged all the time that it was not being used for a CTD cast. This arrangement functioned without problems except for the bulkhead recharging connector which developed a step on one of the pins which had to be filed flat, a suitable fly lead brought up onto on of the CTD frame uprights would help in future. After remedial action had been taken on the offending pin there were no recurrences.

## Configurations

### LADCP

The WHOI ADCP has quite a short pressure case so that when supported by the CTD frame brackets the transducer assembly was only just below the lower bracket mounting flange. The LADCP functioned flawlessly from cast 13630 to 13721 where it suffered a beam three failure, the cause of which at present is undetermined. This failure only became apparent after station 13731. The unit would start pinging on deck but would not produce velocities until after it had locked on to the bottom thus loosing half the cast data, it is doubtful also that the remaining data are valid. An attempt at running the LADCP with three-beam solutions was made on a short cast to 400 m but despite attempts to modify the processing software, meaningful data retrieval proved unsuccessful. The LADCP was removed from the frame by lying it flat on the deck and making CTD cast 13732 without an ADCP. The ADCP that had previously been used as BRIDGET-up was placed in the CTD frame and used for CTD stations 13733 to 13743. Although producing measurements there was some discrepancy between the results from the down and the up casts. This lead to the replacement of this unit by BRIDGET-down for casts 13744 through to the final cast, 13757. The LADCP deployments are summarised in Table 10 and the command file used throughout is given in Table 11a.

## BRIDGET

BRIDGET was instrumented with two broad band ADCPs: BRIDGET_down with a 20° beam angle was sited aft of the towing yoke on the port side of the vehicle. BRIDGET_up with a 30° beam angle also sited aft of the towing yoke but on the starboard side and slightly aft of BRIDGET_down (Figure 6).

The two instruments were configured to give alternate pings (Figures 7), so pings from either instrument would not interfere with each other. This was achieved by accurately setting their clocks prior to each deployment and by offsetting the time of the first ensemble for one instrument by half of one ensemble time. This arrangement could be checked prior to deployment by listening to the transducers. To measure current speed relative to the ground we subtract the speed of the vehicle over the ground from the measured water velocities relative to the vehicle. The speed of the vehicle over the ground is measured by BRIDGET_down by including a bottom track ping every ensemble. This estimate of vehicle speed over ground can be used to calculate absolute water velocities for both instruments. Examples of the configuration files are given in Tables 11b and 11c and the variations of ensemble lengths and pings for the various deployments are given in Table 12.

The configuration of the downward looking ADCP was dictated by the requirement that we wanted to measure the current velocity close to the ground. To do this the depth close to ground that is contaminated by the first acoustic side lobe returning directly beneath the transducer before the main beam whose signal returns at the transducer head angle and therefore follows a longer path should be minimised. The contaminated depth can be calculated from:

$$z_{con} = D(1-\cos\theta) \tag{17}$$

where $D$ is the distance from the transducer head to the ground, $\theta$ is the angle of the transducer head relative to the vertical and $Z_{con}$ is the thickness of the contaminated layer next to ground from which no velocity estimates can be derived. We flew BRIDGET 100 m off bottom so the contaminated depth is typically 6 m when using the 20° instruments. For the 30° instrument the contaminated depth would have been 13 m.

Although the 20° instrument can make velocity estimates closer to the ground than the 30° instrument there is an increase in the standard deviation of the ensemble velocity estimates, given by ((RDInstruments, 1995)):

$$v_{sd} = \frac{1.6\times10^{7}}{F\times I\times B\times\sqrt{P}} cm/s \qquad (18)$$

where F is the ADCP acoustic frequency (153600 Hz), I is the transmit pulse length (=bin depth), B is the beam angle coefficient (0.684 for 20° and 1.0 for 30°) and P is the number of pings per ensemble. These theoretical standard deviation estimates are given in Table 12 for the different configurations we tried. The standard deviation of the velocity estimates can be driven down by ensemble averaging. For example a seven minute ensemble average corresponds to a horizontal distance of 840 m (vehicle speed 2 m/s) and for sections S and P implies that the standard deviation of the ensemble averages would be 2 cm/s

Mark Hartman and Stuart Cunningham

## LADCP PROCESSING

### Water Track

The processing paths and software for the LADCP processing were set up by Brian King, SOC before the ship sailed from Southampton.

On completion of a cast the raw ADCP data files were downloaded from the instrument ROM to a PC in the deck laboratory, converted to raw binary files using the RDI utilities and then FTP'd to the main Unix system. Once on the UNIX system, the files were processed using a system of perl scripts, c programs and Matlab routines. This system was simplified slightly by creation of script files to run the routines in the correct order, but could still prove problematical if some part of the processing failed, *e.g.* if there was not a free Matlab license at the time of processing.

The first part of the processing on the Unix system creates velocity shear estimates from the raw LADCP files and provide plots of basic variables such as: U, V and W water flow past the package, heading, tilt, number of shear estimates in each 5 m bin and u, v, and w velocity profiles calculated by integrating the calculated shear relative to some arbitrary zero. The plots contain down, up and mean or totals. This processing is carried out using a single script which carries out the following procedures:

- determine the magnetic deviation using the Matlab routine geoeval. The output from geoeval is written to the ASCII file mag_var.tab
- scan the raw data file for basic parameters using the perl script scanbb.prl
- load the raw data into the CODAS self contained data base using another perl script, loadbb.prl the WHOI LADCP used up to station 13730 requires the velocities to be rotated. This part of the processing was removed for the SOC LADCPs. The WHOI ADCP internal compass was not aligned with beam 3, as assumed by the ADCP when converting beam referenced velocities to Earth co-ordinate velocities. This meant that reported velocities had to be rotated by 90°. This was corrected by using a C routine (lrotate.c) written by Eric Firing (10/8/98) which corrects heading errors in the LADCP database which applies a correction of the form hcorr=h_offset+h_cos*cos(head)+h_sin*sin(head) where the coefficients h_offset, h_cos and h_sin are read from a control file. We set h_offset=90, h_cos and h_sin=0.
- merges a file with time ranges and bottom depths to the LADCP. At this stage the CTD data are not available for accurate ranges and bottom depths and nominal values are used.
- produce a set of summary plots in Matlab using routine do_abs.

Once the CTD data have been merged with navigation and finally calibrated, they can be merged onto the LADCP file to correct the LADCP time base and vertical position in the water column and produce absolute velocity profiles. ASCII files are produced from the CTD 1 Hz file and a Matlab routine (di9909ts) prepares the CTD data to be merged with the LADCP data. A second Matlab routine (fd) then matches the CTD data to the LADCP data based on vertical velocity. Where there are problems with the LADCP data, particularly where there are a large number of absent data on the downcast, as happened when the WHOI ADCP suffered a beam failure, this matching has to be done largely by hand. Otherwise the optimisation routine matches the data well. An ASCII file (proc.dat) now has to be edited to install the corrected water depth and true position of the end of the down cast, from the CTD file. If the true position is different from the nominal position then the magnetic variation must be recalculated (and previous entries removed) and the database reloaded, remembering to delete the scdb files first and deleting duplicate lines in mag_var.tab and proc.dat. The CTD data are now ready to be merged with LADCP data using two perl scripts (add_ctd.prl and domerge.prl). The navigation file must be prepared for entry into Matlab. This can be carried out in several blocks, rather than for each station, as it is rather time consuming. The merged LADCP/CTD can then be plotted using a final Matlab routine (do_absN) to give a similar set of plots as before.

There are several potential pitfalls in the processing scheme. As the matlab routines often require intervention to select correct maximum depths, or offsets etc, the station number has to be entered at several times during the processing, and in several different formats for different routines. This gives chances of errors in the processing steps and it would be an advantage if the station number could be entered at a single time and be picked up by all the different parts of the processing scheme in the appropriate format. A second possible cause of error is when reloading the databases after the station positions are fixed from the CTD file. If you have to reprocess a station you must remember to delete the scdb files from previous processing. Rerunning loadbb causes a second version of the cast to be appended to the database giving spurious results. Editing the ASCII proc.dat and mag_var.tab files can also introduce potential mistakes. I would recommend that a more streamlined version of the processing scheme be designed to eliminate some of the repetition and potential pitfalls in the scheme.

Once LADCP data had been merged with the CTD file, depth, u and v values were extracted into pstar format. To do this, a ‘cutdown’ version of the do_absN Matlab routine was created. This version (mk_abs.m) did not contain any of the graphical sections but simply calculated the mean up/down cast u and v values. This routine was called from within the pstar routine pmatlb in order to write the required variables from Matlab to pstar format files. The

script mk_p.exec was created to automate this procedure, and to edit the header information (using pheadr) to match the header information (pinq) for the associated CTD file.
Helen Snaith

## Bottom Track

Bottom track data were extracted from the raw LADCP binary file using the PC utility *BBLIST*. This data was then transferred by ftp to the UNIX system where it was processed using *MATLAB* script bottomexec.m. The latter was written by Elaine McDonagh (UEA) and modified by Brian King (SOC). For this cruise a bug was fixed that would only manifest itself for data in the northern hemisphere. The script was also tidied by moving all editable parameter definitions to the beginning.

The processing uses the following steps:

- Initialisation - set up the parameters to be used in the processing. These include the cast number (typically nnn_mm where nnn is the station number and mm is the cast number); the binsize (16 m); the sound speed used in the instrument (1500 m/s); the data editing criterion on percent good (for a 20 ° beam instrument this is 94%, for a 30° it is 85%).
- Preparation - read the ASCII bottom file (created by *BBLIST*) into *matlab*; deal with absent data, and convert data to proper units.
- Time - calculate time in the correct format.
- Position and magnetic variation - extract latitude and longitude and magnetic declination from ASCII file mag_var.tab created as a by-product of the standard preliminary LADCP processing.
- CTD data - read in the CTD data from an ASCII file produced for the standard LADCP processing of absolute velocities. This calculates the sound velocity from CTD pressure,

temperature and salinity data in order to correct the depth of the LADCP bins relative to the instrument, and to correct the measured velocities.

- Depth - read the water depth from file proc.dat that is created for use in the standard preliminary LADCP processing. At this point absolute near bottom water velocities are calculated by subtracting the bottom velocities from the water track velocities.
- Tides - tidal velocities are calculated using an external tidal model, in this case TPXO ((Egbert and Bennett, 1994)).
- Averaging - all velocities are then averaged back onto the original bins (the sound speed correction displaces the bins).
- Corrections - the magnetic declination is then used to correct the compass. This involves a simple vector rotation.
- Tidying - finally, the data is plotted and saved to a *matlab* MAT file. Profiles of near bottom velocities were produced for most casts during the cruise.

Bottom track processing requires both CTD and LADCP data to be upto date before it is carried out. Mistakes in either propagate into the bottom track data. Because this processing is not self documenting, careful records need to be kept to tie this data set to the correct versions in the other two. The alternative is to assume the worst and always reprocess the bottom track data when either of the other two datasets are modified. One other limitation of this processing is that no direct measure of error is calculated. Bottom track data were used to examine the shear currents in the bottom boundary layer (science preview section).

Steve Alderson

## VMADCP AND NAVIGATION

### Introduction

RRS *Discovery* has an RDI 150 kHz broadband ADCP mounted in the hull 1.75 m to port of the keel, 33 m aft of the bow at waterline and at an approximate depth of 5 m. The instrument had been refitted immediately prior to sailing following dry-docking. It was therefore essential to perform a calibration exercise early in the cruise. No instrument malfunctions occurred during the cruise though occasional interference between the VMADCP and the LADCP was noted, see below for details. During the calibration exercises and throughout our outbound passage the VMADCP was operated in bottom-track mode. Prior to leaving the continental shelf, for the CTD and BRIDGET test station, the VMADCP was switched to water-track mode. Bottom-track mode was reselected for our homeward passage, and another calibration exercise performed. Tables 13a and 13b contain set-up configuration files for water track and bottom track respectively.

The processing of the VMADCP data followed the processing as laid out in Navigation and ADCP processing by Raymond Pollard (*pers. comm.*).

### Operational modes

Throughout the cruise, the ADCP recorded two minute averaged ensembles in 64x8 m bins, spanning from 9 m to 513 m water depth. While in bottom-track mode a ratio of one bottom-track ping to one water-track ping was selected by entering the command "FH00001" in the Direct Control menu. This was done to provide the best possible bottom-track information for the calibration exercises.

## Calibration exercises

### D242 - ADCP calibration

Calibration of the ADCP is necessary to accurately determine the orientation of the transducer in the hull and any velocity amplitude error. After refit, as on this cruise, calibration is essential. Three repeat calibration exercises were performed, two on the outward passage and one on our return passage. During all three, ships speed and heading were steady, DGPS fixes were available continuously and ASHTECH heading information was uninterrupted. Table 14 summarises the calibration exercises. Results from the first run were used in all processing, since the ship's speed was lowest and the heading the most steady.

The ADCP uses its own internal clock that drifts by order seconds per hour, but linearly. To correct this to the ship's master clock, careful track must be kept of the clock drift: the difference was recorded manually approximately every four hours. This correction was then applied to the ADCP time base (*adpexec1*). A file of the corrections is produced by the exec for error checking. Horizontal velocities were corrected to reference them to ashtech headings rather than gyro headings in *adpexec2*. This exec also converts east and north ADCP velocities to speed and direction. We then calibrated the ADCP data (*adpexec3*): so for the actual calibration exercise, the velocity amplitude correction (A) is set to one and the heading misalignment correction (phi) is set to zero. Then merge the ADCP data with the master navigation file to add positions and calculate absolute velocities (*adpexec4*).

To calculate A and phi, we reverse the direction of the ADCP data (as the ground relative to the ship is in the opposite sense of the ship relative to the ground). Selected data cycles were then copied out from the bottom track file and the variation of speed and heading for this selection determined. We then averaged the record to a single datacycle and computed speed and direction of the ship over the ground measured by the ADCP (adpSPD, adpDIRN). Having computed the speed and direction of the ship over the ground using the GPS (gpsSPD, gpsDIRN), the velocity amplitude correction $A = (gpsSPD/adpSPD)$ and heading misalignment correction $phi = (gpsDIRN - adpDIRN)$ could be determined.

Contents

Daily processing

- adpexec0. Acquisition of ADCP water tracking and bottom tracking velocities from RVS data stream, and conversion to pstar format.
- adpexec1. Correction of the times of ADCP velocity profiles, taking into account the approximate one second per hour time gain of the ADCP PC clock.
- adpexec2. Correction of the ADCP velocity profiles for gyro heading error. The ADCP data stream is merged with the ASHTECH master file (ash242i1.int) to allow this correction to be applied (see section on Navigation).
- adpexec3. Velocity profiles corrected for transducer misalignment and signal amplitude error (see Calibration subsection above).
- adpexec4. Velocity profiles (relative to the ship) merged with the bestnav position fixes (see section on Navigation) to produce absolute velocity profiles.

Occasional processing

- adpstaplot: Extract absolute velocity ensembles corresponding to times when CTD was deployed and deeper than 10 m. Ensembles averaged, with the mean, standard deviation, rms of error velocities, and mean of percent good plotted and saved to file. These profiles were then used in a cast-wise comparison between VM and LADCP data.
- adptrackplot: Times corresponding to steady course and speed were manually extracted, then fed into adptrackplot. Velocity profiles corresponding to these times were contour plotted and saved to file.

- Sections of interest were identified (e.g. Scotland to Iceland Section, Faroe Bank Channel Section) and the relevant 'station' and 'underway' velocity profiles appended in the correct order, contour plotted and saved to file.

List of Plots

- All CTD station profiles of U, V (mean and +/- st dev), rms error velocity profiles, mean percent good profiles.
- Contours of U and V for all underway times between CTD stations or course/speed changes.
- Contours of U and V from files of appended profiles of CTD stations and underway portions for the following synoptic CTD or BRIGET sections: Scotland to Iceland, Iceland to Lousy Bank, Line S/T, Line S, Line P, Line Q, Faroe Bank Channel Line (FBC).
- Contours of U and V for Scotland to Iceland Section, constructed purely from CTD station profiles (for comparison with LADCP section).
- Current vectors on 8 km grid at selected depths for Scotland to Iceland Section, overlaid on Sandwell and Smith ((Sandwell and Smith, 1997)) bathymetry.
- Profiles of difference in U and V between VMADCP and LADCP for the Iceland to Scotland Section CTD stations.

ADCP performance

The ADCP performed without malfunction for the entire cruise. The only detected error was an intermittent error message displayed on the ADCP control PC: 'bit error on beam 1,2,3,4 sig, spw, freq'. The message was only seen at times when the LADCP was being hauled or veered at depths between 25 and 30 m wire out. It is speculated that this error was associated with interference between the LADCP and the VMADCP, since both units had the same operating frequency. Since no error logging is performed by the RDI DAS software, systematic investigation of the effect this intermittent error may have had on the velocity profiles has not be possible. However this possibility must be borne in mind, particularly when considering the frequently poor correspondence between VM and L ADCP shears in the upper 50 m of the water column.

## Comparison between VMADCP and LADCP

A comparison between the vessel mounted and the lowered ADCPs was carried out for all available absolute LADCP profiles, which comprised 40 stations on the Scotland to Iceland section. Profiles of U and V were merged on bindepth and the differences taken. Velocity difference profiles were plotted and saved to file, the mean and standard deviation of the differences for each profile are given in Table 15. In 17 of the 40 profiles examined the largest discrepancies between the VMADCP and the LADCP occurred in the upper 70 metres of the water column.

## Comparison with Tidal Prediction

Barotropic tidal predictions were made using the Egbert global tidal model ((Egbert and Bennett, 1994)) for the time period spanning our occupation of the S line. Amplitude and phase predictions were found to agree well (by eye) with the ADCP measured currents at 300 m. The predicted barotropic tide had and amplitude of approximately 22 cm/s. This is of significant amplitude in comparison to the mean flow through the channel (of order 100 cm/s), and may have implications for the structure of the bottom boundary of the overflow water.

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## Navigation

Three satellite receiver navigation devices are fitted to RRS *Discovery*. A Trimble-4000 receiver provides differentially corrected positional information from the GPS satellite configuration, the differential correction is calculated using ground stations throughout Europe, and delivered to the Trimble-4000 by a swath satellite transmission. The Glonass receiver acquires fixes using a combination of GPS satellites and GLONASS satellites. The GLONASS transmissions do not have an intentionally applied error to their transmissions (the so-called “selective availability” applied to the GPS signals), thus the Glonass receiver returns more accurate fixes than GPS, but less accurate fixes than the differentially corrected GPS. Glonass thus represents a back-up system to the GPS-4000. The third system fitted to *Discovery* is the Ashtech ADU 3DF GPS system. This system comprises four GPS satellite receiving antennae mounted on the bridge top. By comparing phase differences between the four incoming signals the Ashtech unit calculates the heading, pitch and roll of the vessel, nominally every second. A less accurate (see section on calibration of the VMADCP), but more reliable (i.e. not dependent on transmissions external to the ship) estimate of the ship’s heading is obtained, using the gyro compass. This instrument is subject to latitudinally dependent error, heading dependent error and has an inherent oscillation with a period of 84 minutes following a change in heading.

### Bestnav

A standard PSTAR navigation file, bnv24201, was maintained throughout the cruise, from day 249, 15:44 hours to day 276, 12:00 hours. This was appended daily with the RVS "bestnav" position data at 30 second intervals. Daily processing consisted of acquisition of RVS 'bestnav' navigation data from level A.

### GPS-4000

Positions were logged in port at the start of the cruise from the GPS-4000. The standard deviation for the position error was found to be 0.000003° latitude, 0.000004° longitude, which is approximately 0.3 m.

Using the RVS 'gaps' utility at the end of the cruise, the following time gaps in navigation (gps_4000) were found:

time gap : 99 249 17:42:07 to 99 249 17:44:00 (1 min 53 s)
time gap : 99 264 21:04:45 to 99 264 21:05:28 (43 s)
time gap : 99 265 16:35:30 to 99 265 16:36:06 (36 s)
time gap : 99 270 18:00:17 to 99 270 18:01:54 (1 min 37 s)
time gap : 99 273 19:58:41 to 99 273 20:02:16 (3 mins 35 s)

## Ship's Gyro

Ship heading was logged every second via the level A. Daily processing effectively consisted of acquisition of gyro heading data from RVS files using the gyroexec0 program. Data were edited for headings outside the 0-360° range, producing file gyr24201.

## GPS Ashtech

Every second, the Ashtech measures ship attitude (heading, pitch, roll) and these data are used in post-processing to correct ADCP current measurements for heading error. This post-processing is necessary because in real-time the ADCP uses the less accurate but more continuous ship's gyro headings to resolve east and north components of current. In post-processing, small drifts and biases in the gyro headings are corrected using the Ashtech heading measurements. Each attitude acquired, measures of the maximum measurement error, rms error and the maximum baseline rms error, allow poorly determined attitudes to be flagged during processing.

Daily processing consisted of the following:

- Acquisition of Ashtech data from RVS files using the ashexec0 program;
- Quality control of Ashtech data using ashexec1;
- Averageing into 2-minute bins to be compatible with ADCP data
- Data from the gyro were merged with the GPS ASHTECH master file, and used to calculate a difference between the headings derived by the two instruments (a-ghdg) using ashexec2.
- Plotting daily time series of 'a-ghdg' and manually editing out any remaining outliers using 'plxyed' (PSTAR program). A list of the edited points was also printed.
- Interpolating 'a-ghdg' and plotting the resulting file. The appended master Ashtech file is ash242i1.int.

Data quality for the GPS ASHTECH was based on:

hdg accept data between 0°,360°
pitch accept data between -5°, 5°
roll accept data between -7°, 7°
mrms accept data between 0.00001m, 0.01m
brms accept data between 0.00001m, 0.1m

attf accept data between -0.5,0.5
a-ghdg accept data between -9°, 9°

The GPS ASHTECH worked well throughout the cruise, giving 94% coverage in heading data. Most of the gaps in the heading data were less than 10 *mins.* in length. There are 61 gaps of between 10 and 30 minutes, 11 gaps of between 30 and 60 minutes, 1 gap of 66 minutes. (on JDAY 258 at 1600 hours), 1 gap of 120 minutes (on JDAY 257 at 1155 hrs) and 1 gap of 190 minutes. (on JDAY 252 at 0055 hours).

## BRIDGET

### BRIDGET operations

The BRIDGET system is a deep towed CTD+ sensor package which has been jointly developed between the University of Cambridge and Southampton Oceanography Centre. Instrument preparations were carried out at SOC and the Bullard Laboratories, University of Cambridge. Modifications made sinced the last BRIDGET cruise (D228) include better support for running multiple CTDs, and modifications of the frame to allow two ADCPs to be carried.

The BRIDGET deep tow vehicle carried the following sensors:

- FSI micro CTD serial number 1327 (BRIDGET CTD)
- W.S. Ocean Systems Marine Monitor UMI-2SB15, serial number 2161
- Chelsea Instruments Alphatracka Transmissometer, 25cm path length
- Chelsea Instruments Aquatracka nephelometer
- Simrad Mesotech Acoustic altimeter (500m range)
- Dual clinometer attitude sensor and fluxgate compass unit.

- General Oceanics 12 position rosette pylon (modified for BRIDGET) equipped with 12x2.5 l Niskin bottles.
- Two ADCPs, upward looking, the other downwards.

Narrative

During the cruise a total of four tows were made (Table 16), described briefly below.

| | |
|---|---|
| BGT01 | A test deployment to determine vehicle stability at tow speeds up to 3.5 knots. 12 water samples collected. TOBI swivel. |
| BGT02 | First survey tow. 50 km covered in 13 hours. During the tow the Simrad altimeter was found to be intermittent during periods of hauling. The instrument was replaced with a 200 m range Simrad altimeter borrowed from OTD. 12 water samples collected. BRIDGET swivel. |
| BGT03 | 110 km covered in 22 hours. 12 water samples collected. BRIDGET swivel. |
| BGT04 | 40 km covered in 9 hours. 12 water samples collected. BRIDGET swivel. |

Appraisal

Deployment and recoveries were carried out in a variety of sea conditions, calm for BGT02-03 and marginal for the recovery of BGT04. This experience has indicated the use of heavier recovery ropes. The TOBI swivel was used for BGT01, but periods of line noise caused the modems to drop communications several times, this suggestes that this swivel might be noisy. The BRIDGET swivel was replaced for the remaining tows, resulting in decreased incidence of drop-outs during BGT02 and no drop-outs during BGT03/4. The noise during BGT02 appeared to be related to an indicated wire-out of around 1760 m. It is clear that reliable BRIDGET operations demand a high quality deep tow cable and a well maintained swivel. The BRIDGET 500 m Simrad altimeter lost contact with the bottom for periods during BGT02, and was replaced with an OTD 200 m Simrad altimeter which provided a more continuous indication of altitude. The BRIDGET FSI CTD performed well throughout the tows. The W. S. Ocean Systems Marine Monitor was to be used as a spare CTD in the event of a failure of the FSI. Initially, the instrument would not accept a change of settings, a problem resulting from a dead coin cell. A replacement was directly soldered into the unit. Pressure and temperature measurements appeared to be in line with FSI data, but were much noisier. No valid conductivity data were recorded- the cell and associated electronics need to be checked out before redeployment. The BRIDGET software ran well, logging to ZIP disc due to the failure of the 2.1 Gb hard drive. BRIDGET completed four survey tows, covering 200 km.

## BRIDGET flight

In general, the vehicle was quite straightforward to "fly " and operate. Controlling the pitch was not simple on steep upslopes, as hauling in rapidly generated a simultaneous increase in the pitch angle. Over reasonably level bathymetry, the vehicle was very stable and took minimal interference to maintain a constant height off the bottom. We recommend a forward looking altimeter to monitor bottom slopes ahead of the vehicle and modification of the towpoint to eliminate radical changes of pitch angle or use of depressor weight and change of vehicle to neutrally buoyant package. Real time logging and display of ADCP data would be helpful to monitor vehicle motion through the water or over the bottom.

Jeff Benson

## Data processing

All BRIDGET data excluding the self contained ADCP data, were passed via modem to a deck unit. Post-collection processing of BRIDGET data consists of two steps. First, the ship's navigation is appended to the BRIDGET CTD data files. Second, the wire log file is used in

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conjunction with the ship's navigation and BRIDGET depth to calculate the slant range and thus the position of BRIDGET during the tow. Unfortunately, the winch monitoring system failed during BGT01 and once 'fixed' ran backwards without logging on subsequent tows. Also, it was noted that during deployment, the calculated wire out was always less than the BRIDGET depth (approximately 80% of the BRIDGET depth). Therefore, during the calculation of the BRIDGET position it has been assumed that the wire out information from the winch was reading 80% of true wire out. These files were archived.

A c-shell routine *bgtexec0* read BRIDGET ASCII files to pstar format and computed time in seconds relative to the BRIDGET start time for data logging. The bgt### (where ### is tow number) files contain the following variables: time, bdepth, bpotemp, bsalin, btemp, bcond, bpress, bnephels, balt, broll, bpitch, bhead, btrans, ship_lat, ship_lon, blat, blon. A mismatch in data transmission between the FSI CTD and the modem used to transmit BRIDGET data up the sea cable lead to a number of btemp drop outs to zero. These were removed using datpik or peditc. Where the water temperature had a range across zero, limits of +/- 1m°C removed dropouts without removing real data.

The BRIDGET sample data for salinity, oxygen, nitrate, silicate and phosphate where processed in the same way as lowered CTD sample data. These data are reported in four files that include bottle firing times: sambgt01, sam13697, sam13701, sam13716. The BRIDGET FSI CTD will be calibrated using the sample data post cruise.

## ADCP

On completion of each tow the ADCP data were downloaded to PC. The *bblist* utility was used to provide an ASCII list of the upward looking water track data, the downward looking water track data and the bottom track data. These data were then FTP'd to a UNIX workstation. The c-shell exec *bladexec0* read the ASCII files to pstar. The variables recorded were: a. upward looking water track, ensemble, year, month, day, hour, minute, second, centisec, day, bin, heading, pitch, roll, temp, ve, vn, vw, verr, pcg1, pcg2, pcg3, pcg4, ampl1, ampl2, ampl3, ampl4; b. downward looking water track, ensemble, year, month, day, hour, minute, second, centisec, day, bin, heading, pitch, roll, temp, ve, vn, vw, verr, pcg1, pcg2, pcg3, pcg4, ampl1, ampl2, ampl3, ampl4; and c. downward looking bottom track, ensemble, year, month, day, hour, minute, second, centisec, day, bin, bve, bvn, bvw, bverr, range1, range2, range3, range4, depth1, depth2, depth3, depth4, corr1, corr2, corr3, corr4. The c-shell exec *bladexec1* edited the pstar header and computed time in seconds.

Only basic processing of this data was completed at sea. Data were edited according to a percent good criteria recorded in (RDInstruments, 1995) Table D-7 BBADCP Percent-Good Data Format. The bottom track data were then merged on the water track data and absolute velocities calculated. Averaging along row numbers then gave plots of the absolute velocities.

Considerable post-cruise processing of the data are required to correct heading data and to merge the water track and bottom track data. These corrections will be dependent on post-cruise calibrations of the compass headings. These will be reported elsewhere. The following list of processing steps will be required: correction of ADCP headings based on a compass swing experiment; correction of heading data for the local magnetic variation; recalculation of water and bottom velocities relative to BRIDGET; edit water and bottom track data on the percent good, velocity error, backscatter amplitudes and beam correlation statistics; merge bottom and water track data; calculate absolute velocities; determine bin height off bottom; determine velocity error decrease as a function of averaging data in height off bottom bins.

Mark Rudnickii, Steven Alderson, Stuart Cunningham

## CHEMISTRY

### Nutrient Measurements

#### Sampling Procedures

Samples for the analysis of dissolved inorganic nutrients: dissolved silicon (also referred to as silicate and reported as $Si0_3$), nitrate and nitrite (referred to as nitrate or $N0_2$+$N0_3$) and phosphate $P0_4$, were collected after oxygen samples had been drawn from the Niskin bottles. Samples were collected into 30 ml "diluvial" sample cups, rinsed 3 times with sample before filling. These were then stored in a refrigerator at 4 °C until analysed between 1 and 12 hours after collection.

A total of 114 casts were sampled for nutrients during the cruise. Samples were transferred into individual 8 ml sample cups, mounted onto the sampler turntable and analysed in sequence. The nutrient analysis was performed using the SOC Chemlab AAII type Auto-Analyser coupled to a Digital-Analysis Microstream data capture and reduction system.

#### Calibration

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

Mixed working standards were made up once per day in 100 ml calibrated polyethylene volumetric flasks in artificial seawater (@40 g/l NaCl). The working standard concentrations, corrected for the weight of dried standard salt and calibrations of the 500 ml and 100 ml volumetric flasks are shown in Table 17.

A set of working standards was run in duplicate on each analytical run to calibrate the analysis. The top standard was also run in duplicate at the start of each analytical run as it had been shown to increase the linearity of the standardisation ((Holley, 1988)).

## Silicon

Dissolved silicon analysis followed the standard AAII molybdate-ascorbic acid method, with the addition of a 37°C heating bath ((Hydes, 1984)). The colorimeter was fitted with a 50 mm flow cell and a 660 nm filter. The gain was adjusted to 2.9 for a maximum response at 40 µmol/l.

There were problems with the analysis of silicon throughout the cruise due to the photometer being sensitive to any vibrations, as previously observed ((Smythe-Wright, 1998)), especially during use of the CTD winch system, resulting in the baseline jumping. The base of the colorimeter was placed on a rubber and sponge matting, which reduced (but did not eliminate) this problem. It is recommended that the colorimeter be replaced for future work at sea and to use shock-absorption material as standard procedure.

## Nitrate

Nitrate (and nitrite) analysis followed the standard AAII method using the sulphanilamide and naphtylethylenediamine-dihydrochloride with a copperised-cadmium filled glass reduction column. A 15 mm flow cell and 540 nm filter was used with again set to 2.9, adjusted for concentrations of up to 40 µmol/l. Nitrite standards equivalent in concentration to the third nitrate standard were prepared each day to test the efficiency of the column.

## Phosphate

For phosphate analysis the standard AAII method was used ((Hydes, 1984)) which follows the method of (Murphy and Ripley, 1954). A 50 mm flowcell and 880 nm filter were used and the gain set to nine throughout the cruise, for concentrations of up to 2 µmol/l.

## Operation and maintenance

Reagents for each of the nutrients analysed were made up as and when required from pre-weighed salts. All pump tubes were replaced once per week. The autoanalyser required some maintenance. A glass coil on the silicate channel was replaced due to a hairline fracture. The photometer regularly needed to be switched off and on during the day, when not functioning.

## Precision - Duplicate and quality control measurements

A limited number of samples were analysed in duplicate due to the number of samples analysed daily and the instability of the photometer. Several quality control samples were also

analysed on each run. Two quality control samples were made up from standard solutions supplied by OSI (prepared daily in plastic volumetric flasks using NaCl solution). The concentrations were adjusted to be equivalent to the 2nd and 4th working standard concentrations so the QC material is referred to as QC2 and QC4 respectively). In addition a deep water sample was collected from the test station at ~1915 m. The deep water QC samples were decanted into clean rinsed plastic diluvial containers and stored in the cold store until required, using one per analytical run. Results are shown in Figure 9.
Virgine Hart, Adrian Wright, Karen Paterson, David Craig

## D242 Sample Dissolved oxygen measurements

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

The temperature of the water remaining in the Niskin, after salinity samples were drawn, was measured using a hand held electronic thermometer by inserting the temperature probe into the spigot. This temperature was assumed to be the same as that of the oxygen sample at fixing and was used to calculate any temperature dependent changes in the sample bottle volumes.

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

The normality of the thiosulphate titrant was checked against an in house potassium iodate standard of 0.01 N at 20°C at the beginning of each analytical run and incorporated into the calculations. A total of five standards were used throughout the duration of the cruise. Consistency of the thiosulphate normality improved with time, except for station 13648 because of persistent bubbles within the plastic tubing. Subsequently the tubing was replaced and the titrino worked well for the remainder of the cruise. Blank measurements were also determined at the start of each run to account for the introduction of oxygen with the reagents and impurities in the manganese chloride, as described in the WOCE Manual of Operations and Methods ((Culberson, 1991)). Thiosulphate standardisation was carried out by adding the iodate after the other reagents and following on directly from the blank measurements in the same flask, as on the cruises D223 and D227. Changes in the thiosulphate normality are shown in Figure 10a.

Absolute duplicate differences for each station are shown in Figure 10b for a sample size of 251 pairs of duplicate measurements. Duplicate differences > 1.0 µmol/l accounted for 23.5 % of these duplicate pairs: ignoring these high duplicate differences the mean (±standard deviation) duplicate difference was 0.4124 µmol/l( ± 0.2867). The duplicate difference achieved was not related to the individual calibrated bottle ( Figure 10c) and high duplicate differences seemed to occur at random.

## Problems

The ambient temperature range of the CT laboratory often varied between 18 °C and 20 °C throughout the cruise. The temperature of the laboratory was noted for each analytical run. Temperature recordings using the hand held electronic thermometer were subject to a certain amount of variability and on occasion it was difficult to determine an accurate temperature of the water sample. For the first few days and during part of the second week the oxygen samples could not be stored under water, however, this probably did not affect the recorded values. On station 13739 the Anechem dispenser for manganese chloride had to be replaced because it was accidentally knocked from the reagent stand.

Adrian Wright, David Craig and Karen Paterson

## Sample Salinity Measurement

### Sampling

Salinity samples were taken from each CTD Niskin using 200 ml glass sample bottles, closed with disposable plastic inserts and screw-on caps. Each bottle and cap was rinsed three times with sample water to remove any old sample and any salt crystals from the neck of the bottle. The bottle was then filled to the base of the neck, the top and neck wiped dry and then sealed with a plastic insert. Once every four hours a sample was also taken from the outflow of the TSG for calibration purposes. Whilst BRIDGET was in the water, TSG outflow samples were taken every hour. Samples were left in the constant temperature laboratory for at least 24 hours before being analysed in order for the temperature to equilibrate.

## Analysis

All analyses were carried out using a Guildline Autosal model 8400A fitted with an OSI peristaltic sample intake pump. An Autosal model 8400 was also on board and operable but was used as a backup system only as it is more difficult to take good readings on this machine.

The salinometers were situated in the constant temperature laboratory. The laboratory temperature was set at 18°C and the salinometer water-bath temperature at 21 °C. The laboratory temperature was initially set at 20 °C but the temperature close to the salinometers was found to be running at just over 21 °C and the salinometer heaters were not cycling properly. The laboratory setting was therefore dropped to 18 °C. The CT laboratory works by means of a compressor which cools the air extracted from the labs and pumps it back in using a series of fans. Approximately once per hour the fans stopped for a de-icing cycle which lasted up to 15 minutes. Whilst the fans were on the laboratory consistently ran at 19 °C (measured close to the salinometers) but during the de-icing cycle, the temperature could rise as high as 20.5 °C. This is below the salinometer operating temperature and did not seem to cause a serious problem, but may need to be addressed for other applications.

On 24th September the compressor ceased working during analysis of samples from station 13693, due to overloading of the ship's electric circuits. At the start of the analysis the temperature was approximately 20 °C but the salinometer soon began to behave erratically and the standard reading at the end of the cast was 0.00012 in conductivity (0.002 salinity equivalent) higher that that at the start of the cast. Salinity values from this cast should be treated as suspect at better than 0.002. It was several hours later that it was noticed that the laboratory temperature was running high (24°C) and the compressor was reset. Although the laboratory temperature returned to normal after only ten minutes or so, the salinometer was left for 24 hours to regain stability before more samples were analysed. The compressor cut out again on 26th September, but only for approximately half an hour. Although the laboratory temperature had risen to 23°C, the salinometer heaters were still cycling regularly and analysis was only stopped for 6 hours. On this occasion, the engineers removed the de-icing cycles from the fans so the compressor ran continuously. From then on the laboratory consistently ran at approximately 19.5°C.

There were some initial problems with the 8400A. Before the first test station, 30 samples from a previous cruise were analysed. After the first 12 samples, the cell began to fill progressively more slowly, until it finally ground to a halt and refused to fill at all. The peristaltic sample pump also began to leak at the input to the salinometer. The samples were completed on the 8400 which was very unstable. This was before the laboratory temperature was reset to 18°C and this instability may have been the result of slightly warm sample temperatures. Over the following two days, the 8400A was left to soak in 10 % decon solution and rinsed several times in distilled water; had the sample tubing flushed using a syringe; had the peristaltic pump retubed; had the flushing tubes cleaned with fine wire and had the water bath topped up. By the end of this intensive care treatment, the salinometer seemed to be feeling much more like its old self and began to perform in it's highly delightful, stable fashion once more. Complete duplicate samples were taken from the first test cast, one being processed on the 8400 and one on the 8400A. The results were very similar, but the 8400 was biased low by 0.0008 in salinity. Clouds of micro bubbles were frequently seen to form in the first arm of the cell, causing very unstable, low readings.

All analyses were carried out by Helen Snaith, Deb Slater and Louise Duncan.

Helen Snaith, Deb Slater, Louise Duncan

## Standardisation

Standardisation was achieved by use of IAPSO standard seawater ampoules. Only a single standard batch P136 (143 ampoules) was used during the cruise. Standards were run at the beginning and end of each crate of 24 TSG samples, or samples from every one or two CTD casts (typically 20-26 samples).

The correction to the Guildline ratio obtained from the standards throughout the cruise is shown in Figure 11a. The corrections to the Guildline ratios determined from the standards ranged from -0.00012, or -0.0024 Salinity Equivalent (SE) to 0.00008 (0.0016 SE). The variability in the standards was very small over the cruise, (s.d 0.00004, 0.0009 SE) but with a definite drift over the cruise.

Duplicates were drawn from Niskin bottle 1 on each cast and also from a second bottle, usually near half depth. In addition, repeat firings were sometimes made in the deepest water. These repeat firings were "blind" to the analysts. In all 266 duplicates and repeats were taken. The standard deviation of salinity differences between all these duplicate readings was 0.00053. There was no significant difference between the duplicates at shallow or deep stations, or between duplicates or repeat firings, indicating that sampling and analysis were consistent throughout. A summary of the duplicate results is given in Table 18 and Figure 11b.

## Test Standards

We were supplied with a batch of ten trial standards by OSI to assess during the cruise. These trial standards were packaged in bottles with 'foil' lids over halo-butyl seals, rather than the traditional ampoules. These standards were run as additional samples immediately after a normal standard in order to test their consistency in use at sea.

The new bottles were much simpler to use than the traditional ampoules, although the foil lids could prove difficult to remove. The new bottle was much simpler to stabilise on the sample platform, and it was also much simpler to ensure that the standard was well mixed than with the old ampoules, where water could become 'trapped' in the ampoule tails.

The readings for the test standards proved as consistent as those for the old ampoules (Figure 11c) with a mean offset of -.00002 (0.0003 SE) and s.d. of 0.00001 between the new and old standards.

Helen Snaith

# UNDERWAY MEASUREMENTS

## Meteorology Measurements

For cruise D242 meteorological measurements were not high in priority and the normal RVS instrument suite was used. Continuous measurements of sea surface and meteorological data including air and sea temperatures, wind speed and direction, air pressure and downwards radiation (short wave and photosyntheticaly active) were collected by sensors and displayed directly to the level B of the ship's computing system. The information from sensors was transferred to PC via RS 485 serial links. The data were averaged over 30 seconds with times taken from the ships clock by an RS 232 link. All instruments and logging systems performed well. Details of the variables logged can be found in Table 19.

## True wind and speed calculations

The only difficulty, in processing of meteorological data at the outset of the cruise concerned the calculation of true wind speed and direction within the program smtexec2. It was noticed that the direction of the true wind would change direction dramatically each time the ship moved onto and off CTD stations. This obviously implied an error in the algorithm calculations. Following a discussion with Jeff Benson, we realised that the relative wind directions from surfmet are based on the ship heading at 90°: 0° is port beam, 90° is forward, 180° is starboard beam, 270° is aft and the relative direction is the direction from which the wind is coming. To determine the wind direction relative to the ship we subtracted 90° from the surfmet direction and then added the ship's heading. For the ship's heading we used the gyro heading corrected for its offset from the Ashtech heading. The Ashtech correction is discussed under the ADCP section of this report. The east and north components of the measured wind speed and relative wind directions were then found and the ship's velocity subtracted to obtain the true east and north wind velocities and then true wind speed and direction. For the ship's velocity, we used the speed and course over ground determined from DGPS navigation over two minute intervals. These calculations were checked and the new code implemented in program smtexec2. The subsequent plots of true wind speed and direction obtained on a daily basis no longer contained sharp changes coming on or off station.

## Meteorological Records

While meteorological measurements are relatively smooth, there are occasional spikes and we have made no efforts to de-spike records.

## Pressure Calibration

Barometric pressures were logged uncalibrated. Table 20 contains calibration values that should be applied.

## Humidity and Temperature

$$Humidity(\%) = -0.2 + 1.021 \times Humidity \qquad (19)$$

The calibration of the air temperature sensor is a spot value against a reference: Tref = 22.18 °C, Tobserved = 22.11 °C.

PAR (port and starboard)

$$ppar(W/m^2) = V_{output} \times 3.2310 \times 10^{-4} \tag{20}$$

$$spar(W/m^2) = V_{output} \times 7.5358 \times 10^{-4} \tag{21}$$

Shortwave (port and starboard)

$$ptir(W/m^2) = V_{output} \times 9.8425 \times 10^{-4} \tag{22}$$

$$spar(W/m^2) = V_{output} \times 8.7873 \times 10^{-4} \tag{23}$$

Other sensors do not require calibration.

Louise Duncan and Harry Bryden

## Thermosalinograph

Continuous underway measurements of surface salinity and temperature were made with a FSI shipboard TSG. The TSG is comprised of two standard FSI sensor modules, an Ocean Conductivity Module (OCM) and an Ocean Temperature Module (OTM), both fitted within the same laboratory housing. Sea surface temperature is measured by a second OTM located at the non-toxic intake. The non-toxic intake is taken from 5 m below sea level on the starboard side at a rate of 45 l per minute. This non-toxic supply then passes through a vortex de-bubbler whence approximately 75 % of the flow goes through the two sensor modules. Data from the OCM and OTM modules is passed to a PC at 30 s intervals. Both OTM's were calibrated on 27th August 1999. For a polynomial fit to eight calibration points between 2 °C and 27 °C the temperature residuals relative to the calibration standard are all less than 0.3 m°C.

Salinity samples were drawn from the non-toxic supply approximately every four hours to calibrate the computed TSG salinity and every 45 minutes during BRIDGET tows. Samples were then analysed on a Guildline 8400A. The computed TSG salinity is calculated from the measured conductivity and temperature at the housing located in the hangar.

At the end of the cruise, all the computed TSG salinites were appended and despiked. For corrections to be applied to the TSG salinities, the difference between the computed and analysed salinity samples was calculated and filtered in time with a top hat filter of half width six data cycles to eliminate any high frequency noise (random error) due to sampling procedures. Due to the filter truncating the first and last differences, extra data cycles were added outside the data collection times with the same value as the neighbouring difference. The difference between the salinity values was seen to vary between the range 0.62 - 0.70. The standard deviation of the difference between calibrated and bottle salinities is 0.0084.
Louise Duncan

## Expendable Bathythermograph Measurements

A total of 82 XBT's were deployed. These were kindly provided by the Hydrographic Office (MoD), Taunton, on the condition that a copy of the data would be returned to them following the cruise, for incorporation into their data base.

The XBT's were deployed in the area of the FBC, along three sections occupied by the towed BRIDGET vehicle and also, along the Wyville-Thomson Ridge, where they were the primary source of thermal bathymetric information.

All XBT's used were Sippican Corp. Type T5's, depth rated to 1830 m at a maximum ship's speed of 6 knots (although during the Wyville-Thomson section, they transmitted good quality data between 10-12 knots). As with the XBT team on D233, the port side of the afterdeck proved the most suitable launching point, for minimising contact between the wire and the ship's hull. The only exception to this was in very rough weather when, for safety reasons, the launching site was moved to the starboard side, underneath the Winch Cab. However, this seemed to have no discernible effect on the resultant data, which was transferred to the RVS and PSTAR systems via floppy disk, for processing and analysis. This involved firstly removing any

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obvious data spikes, and the data from the seabed. Individual profiles were overplotted, to identify obvious outliers, and gridded to create contoured plots along section, e.g. Figure 12 showing cold water bottom flows along the BRIDGET Section S.

Of the 82 XBT's deployed, eleven failed to transmit any signal, while a further seven terminated prematurely before hitting the seabed (this is a significantly lower reliability rate than for D233, where 34 out of 35 deployments were successful). The remaining 64 XBT's provided good quality data on the thermal layered-structure of the ocean. The XBT failures occurred on section P (Figure 1). When the probes reached the top of the overflow where there are large shears with the overlying water, data from the probe ceased. No probes penetrated the high shears at the top of the overflow current despite repeated deployments trying probes from different batches. The following explanation was offered by Bert Green (now retired from the Stennis Space Centre (contact Zachariah R. Hallock hallock@nrlssc.navy.mil: "{XBT failures in the Somali Current} the probe got to about 60 to 80 meters and 'stuck' at constant temperature for a few 10's of meters, then failed. Noting that the probe is spinning at ~13 rps, strong shear will drastically increase the payout rate of the wire, put more lateral force on the top of the spinning probe, maybe causing tilt, wobble and dynamic instability. The hydrodynamics of the XBT's in those conditions {5-10/sec shears} are only imagined - certainly not observed".

Despite the high rate of failure, the XBT's displayed a high degree of repeatable precision. The difference between the XBT's temperature at 4 m depth and the ship's Remote Temperature is within limits equal to two standard deviations, 0.1273 °C (standard deviation of 0.0994 °C) colder than the remote temperature.

It is noteworthy to highlight the relative tighter spacing of the Wyville-Thomson group. The dataset was acquired over a shorter period of time, in much the same sea state , using the same launch team and computer operator (except for two launches). Thus continuity of procedure may also be a factor in data precision.

The data from the 64 successful XBT deployments will be sent to the Hydrographic Office, with thanks, as required.

David Craig

## Echosounding

The bathymetry equipment aboard on RRS *Discovery* during cruise D242 consists of a SIMRAD EA500 Hydrographic Echosounder, a hull mounted transducer array and a PES towed 'fish' transducer located on the port side of the ship. The hull mounted transducer is located 5.3 m below the sea surface, and the depth of tow of the PES fish is 11.5 m below the water line on station. While steaming the echosounder was approximately 2.0 m shallower, and so the measured depth is deeper than the real depth.

A visual display of the return signal was displayed on the SIMRAD VDU; hardcopy output of this display was not produced. A uniform sound velocity of 1500 m/s was used during the cruise, and the PES fish transducer was used in preference to the hull transducer.

Raw data were corrected daily for the speed of sound using Carter Tables (RVS Level C stream PRODEP) and transferred to PSTAR format (*simexec0*). Spikes and zero values due to null returns from the echosounder were removed using the program *datpik*. Then the files were merged with the daily GPS navigation file bestnav and averaged to 5 minutes intervals (*simexec1*) to smooth the final file after the manual de-spiking stage.

Three master files were created (*simexec2*) of all the bathymetry during cruise D242. The file dep24201.nav was appended from the single daily files onto the cruise depth file. The file dep24201.5min was appended from the single daily files onto average data into five minutes intervals. In the third master file, dep24201.track, data were rejected where the ship's speed was less than two knots, thus removing on-station data.

Nelson Carvalho

## SCIENCE PREVIEW

### Techniques to Estimate Bottom Friction in the Faroe Bank Channel Overflow

A key element in the dynamics of a descending entraining outflow plume is the amount of bottom friction. The bottom friction determines how rapidly the plume can fall across the depth contours as it flows principally along the isobaths banked up against a continental slope. The initial plan for determining bottom friction was to use LADCP measurements near the bottom to estimate the flow perpendicular to the principal orientation of the plume velocity in the bottom "Ekman" layer. Vertical integration of this perpendicular velocity, $u_p$, provides an estimate of the frictional bottom stress, $\tau\left[N/m^2\right]$;

$$\tau = f \int u_p dz \tag{24}$$

where $f$ is the Coriolis parameter. Discussion with James Girton (University of Washington) at the WOCE North Atlantic Workshop in Kiel in August raised the possibility that log-layer fits to the velocity profile in the constant stress layer just above the bottom might also be used to estimate the friction velocity $u_*$, where

$$u_*^2 = \tau \tag{25}$$

During *Discovery* 242, we made a study of the two approaches using selected LADCP profiles.

Girton is using XCP's to study the Denmark Strait overflow as it flows along the continental slope off Greenland. The advantage of the XCP's is that they sample right into the bottom, returning a profile through both the Ekman and logarithmic boundary layers. He fits a best line for the velocity profile versus the logarithm of the height above bottom in the deepest 20 to 30 m to estimate $u_*/k$. With $k = 0.4$, the value of the bottom stress $u_*^2$ is then determined.

It is unclear whether or not LADCP velocity profiles penetrate close enough to the bottom to measure the logarithmic, constant stress boundary layer. The LADCP is generally set up to profile at one second intervals over 16 m depth bins ranging down to 128 m below the instrument. For 30° transducer beams, the lowest 14 % of the water column is contaminated by bottom echoes. Thus, when the instrument is 100 m above the bottom it cannot sample the lowest 14 m, but when it is 50 m above bottom only the deepest 7 m is not sampled. A typical sampling pattern for LADCP station 13507 is shown in Figure 13a. LADCP measurements are typically averaged over 5 m bins and these bins are given right down to the bottom. The bottom-most bins, however have few samples and they may be contaminated by bottom echoes. Examination of a few LADCP stations is one way to assess the validity of profiles close to the bottom. Can we reliably see the "Ekman" layer? Does the LADCP sample deep enough to profile the logarithmic, constant stress layer?

We initially chose an LADCP station on the continental slope south of Iceland made on board *Discovery* during the CHAOS cruise in May 1998 (*Discovery* station 13507) because this station appeared to have been taken in the downstream continuation of FBC outflow and because it was available for examination at the outset of the ANE cruise. Near the end of the ANE cruise, we also examined one of the ANE stations (*Discovery* station 13676) taken in a similar location and in the outflow.

To obtain the first estimates of the bottom friction using LADCP station 13507, we followed the method by Girton to fit a number of best lines to the northern and eastern velocity profiles versus the logarithm of the height from the bottom (Figure 13a). In total six best fits were made, within 38m from the bottom, using three points in each fit. The first data point lies three meters above the sea floor with an increment of five meters thereafter. Best line one corresponds to the three points nearest the bottom. The gradients of these best fits provided estimates for $u_*$ and $v_*$, shown in Table 21.

To determine the friction velocity in the non-constant stress, 'Ekman' layer an initial plot of east velocity against the north velocity near the bottom enabled us to assess whether the velocity does spiral near the bottom, displaying the Ekman layer. For station 13507 (Figure 13b), a nice spiral was shown to which we could estimate the direction of the plume velocity by fitting a straight line from the velocity near the bottom to the maximum plume velocity. To make calculations simpler, the plot was translated such that one end of the spiral was at the origin. The angle of slope was determined and the velocities were rotated through this angle to have the velocity along and perpendicular to the shear. The integral of the perpendicular velocities, the sum of these velocities multiplied by the distance between points (5m), was used to obtain $\tau = 0.9415$ N/m$^2$ for the Corolis parameter at 62° 30'N.

The same techniques were applied to LADCP station 13676. For the estimate in the bottom Ekman layer we obtained $\tau = .9714$ N/m$^2$ (Figure 13d). Our values from the constant stress layer are shown below (Table 22). As for station 13507, three points were used to find each fit. The first point lying five meters from the bottom, with an increment of five meters for each successive estimate. Best line one corresponds to the three points nearest the bottom.

The method that provides the most successful estimates is by integrating the flow perpendicular to the plume velocity orientation. Each profile gave familiar characteristic spiral associated with an "Ekman" layer. For stations 13507 and 13676 the height of the maximum plume velocity was 65 and 80 meters respectively, which we take to be the depth of the Ekman layer. The logarithmic fits did not work as well, which can be seen in the tabulated estimates of friction velocities for both stations. The values vary greatly depending on which three points are used to make the estimate. We were using LADCP data which possibly gives unreliable velocity values near the bottom, therefore effecting the quality of our estimates in the constant stress layer. Best agreement between the Ekman and logarithmic bottom stress estimates is found when logarithmic fit are done with the deepest three LADCP velocities. The first east and north velocity values however, may be contaminated. Since rotation starts to occur within 20m depth above the bottom and we have velocity values in five meter intervals, there may not be enough reliable LADCP data points to use the method suggested by Girton.

The spirals we found are not the classic 45 ° Ekman spirals suggested by theory. For stations 13507 and 13676, the spiral angles were approximately 21 ° and 6 ° respectively. By looking at a number of velocity profiles it is hoped that in the FBC outflow the Ekman depth and bottom stress can be related to the maximum plume velocity, its width and the rate of descent as it flows along the continental slope.

Louise Duncan and Harry Bryden

## CONCLUSIONS

The two principal objectives of this cruise were to continue a long time series of hydrographic stations across the Rockall Trough and its recent extension to Iceland and to study the outflow of the Faroe Bank Channel. The scientific observations consisted of one hundred and twenty five full depth CTD stations all with discrete sampling for salinity, oxygen and nutrients (phosphate, nitrate and silicate). Of these 125 full depth stations 124 included lowered ADCP measurements. Using the deep tow vehicle BRIDGET we obtained three high resolution cross sections of the overflow in the Faroe Bank Channel and on the Iceland Ridge.

The main shipbourne data were underway ADCP observations to measure currents in the upper few hundred meters. Combining these data with ship's gyrocompass data, Ashtech heading data and differentially corrected GPS data gives resulting ten minute average velocities with an error of approximately 10 cm/s. Other underway observations included echosounding, wave height, meteorology, surface temperature and salinity and XBT's.

The standard CTD/LADCP stations make up seven sections. The two longest hydrographic sections are from Scotland to Iceland and then from south-east Iceland to Lousy Bank. The objectives of these sections are to identify and quantify the pathways of warm water flow northward through the Iceland Basin. Near Iceland these sections intersect the Faroe Bank Channel overflow giving measurements of the overflow far downstream from its source. The CTD downcast data are noisier than expected: this noise was ascribed to eddies generated by the LADCP transducer heads interacting with the CTD sensors. Most observations were made with CTD DEEP03 and salinity, temperature and pressure observations approach the rigorous WOCE standard: for the second CTD DEEP04 salinities are a little poorer because of hysteresis in the conductivity measurements.

Approximately 1533 water samples were captured for the analysis of salinity, oxygen, silicate, nitrate and phosphate. The average vertical spacing of water samples is 12 bottles per 1050 dbar. Through the Iceland Basin on the Iceland Ridge and in the Faroe Bank Channel six samples were taken within 250 m of the bottom. This was to give high resolution in the overflow. All analysis of discrete samples were made according to WOCE practice and accuracy.

Five shorter CTD sections were made in the Faroe Bank Channel and on the Iceland Ridge across the main core of the cold, fast outflow. The sections were made perpendicular to the Iceland Ridge and spaced between 15 km and 50 km apart will be used to determine the initial adjustment of the overflow. In addition, three BRIDGET sections were also occupied across the overflow downstream from the sill in the Faroe Bank Channel.

BRIDGET was modified to carry upward and downward looking ADCP's. This system for deploying the ADCP's was conceived to obtain high resolution velocity cross sections of the overflow, including measurements of flow in the bottom boundary layer. These measurements are designed to allow estimates of the bottom friction felt by the overflow. Flying at 100 m off bottom, the downward looking ADCP measures the speed of the water relative to the vehicle and the speed of the vehicle relative to the ground, hence the absolute speed of the water beneath the vehicle is simply determined. Speed of the vehicle relative to the ground is also used to derive absolute water velocities from the upward looking ADCP. These ADCP observations are novel. We are not aware of any other use of ADCP's on a deep tow sledge. The velocity error from a single ping measurement is large, between 6 cm/s and 40 cm/s. A 30 minute along track average giving a horizontal resolution of approximately 2500 m will drive the velocity error estimate down by a factor of 15. For the BRIDGET section P the velocity error for the downward looking ADCP is approximately 1.5 cm/s and for the upward looking ADCP 0.5 cm/s. These errors do not include the larger error that will accrue from residual heading errors. Once ashore the BRIDGET vehicle and instruments were "swung" for ADCP compass calibrations and the third set of vehicle heading measurements. These data are currently being used to calibrate the ADCP heading data. The downward looking ADCP has a larger velocity error than the upward looking ADCP because the bin size was reduced (increasing the velocity error) so that more velocity measurements would be recovered close to the bottom. This will help in making estimates of the bottom friction. Again post-processing will be required to determine the precise height from bottom of the ADCP velocity measurements. Good qualitative agreement between LADCP measurements and BRIDGET measurements is seen on a sction at the mouth of the Faroe Bank Channel.

The BRIDGET vehicle was limited as a stable deep tow platform for making ADCP velocity measurements for two reasons. One, the towing point was at the balance point in water. Towing from mid-vehicle gave good roll and heading stability but poor pitch stability. Two, the tow cable was joined directly to the vehicle. Therefore, ship motion (particularly pitch) was transferred down the tow cable to the vehicle. Under these restrictions maintaining an altitude of 100 m height off bottom and level vehicle attitude was a complicated function of the gradient of the bottom, ship speed and winch haul/veer speed. Hence, BRIDGET pilots needed constant vigilance to avoid flying into the bottom. The deployments made here occurred in good to moderate sea states and so were not limiting. Improvements to the vehicle dynamics would give a larger window of operations. A hindrance to ADCP measurements was the self-contained nature of the ADCP's. Power for the instruments was supplied by batteries mounted on BRIDGET and data logging was internal to the ADCP's. Therefore, the deployment time had to be known a priori so that battery consumption and the instrument memory capacity could be calculated before deployment. During lengthy deployments there is a risk of the instruments failing part way through a tow or of the battery/memory calculation being in error and not being discovered until vehicle recovery. The large amounts of data from the ADCP's can only be processed on recovery of the vehicle. The potential for a series of experiments to determine the optimum operating strategy of the ADCP's was limited to one (safe) guess per deployment. A solution to these problems would be to provide power (as happens for all other BRIDGET instrumentation) to the ADCP and to send data in real time from the instruments to the ship.

The BRIDGET tows were a great success. Initial inspection of the data reveal the cold overflow as a strong bottom flowing current with peak speeds of order 1 m/s. This compares well with the more familiar CTD/LADCP observations.

Despite some down time for bad weather nearly all pre-cruise objectives were achieved. Further examples of data from the cruise can be found at http://www.soc.soton.ac.uk/JRD/HYDRO/scu/d242.

## ACKNOWLEGEMENTS

A successful oceanographic expedition requires from those participants enthusiasm, patience, care and a willingness to work long hard hours in uncomfortable conditions. The scientists must have a high degree of scientific skill and without an equal measure of skill and co-operation from the ship's officers and crew far less science in far less safe conditions would be possible. I give all proper thanks to those people who worked so hard on this cruise. I would also like to thank those colleagues who helped ashore - particularly Brian King and Andy Louch.

Contents

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## TABLES

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Table 2 Summary of CTD stations

| stat<br>num | date<br>ddmmyy | UTC<br>time | lat<br>deg | <br>min |  | lon<br>deg | <br>min |  | depth<br>(corr.) | ht off<br>m | wireout<br>m | Pmax<br>dbar | nbot<br>fired | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13630 | 100999 | 224314 | 57 | 8.4 | N | 9 | 43.09 | W | 1942 | 20.5 | 1930 | 1947 | 25 | test station |
| 13631 | 110999 | 084126 | 56 | 46.73 | N | 8 | 1.62 | W | 117.2 | 9.5 | 110 | 115 | 7 | start S-I |
| 13632 | 110999 | 104357 | 56 | 49.89 | N | 8 | 20.09 | W | 128.2 | 12 | 120 | 123 | 8 |  |
| 13633 | 110999 | 122352 | 56 | 53.03 | N | 8 | 30.58 | W | 124.1 | 12.6 | 115 | 119 | 8 |  |
| 13634 | 110999 | 143924 | 56 | 57.08 | N | 8 | 47.03 | W | 123 | 10.8 | 115 | 119 | 8 |  |
| 13635 | 110999 | 163936 | 56 | 59.95 | N | 8 | 59.95 | W | 130.8 | 14.2 | 120 | 123 | 8 |  |
| 13636 | 110999 | 183742 | 57 | 3.27 | N | 9 | 13.58 | W | 338.9 | 14.8 | 325 | 331 | 7 |  |
| 13637 | 110999 | 201036 | 57 | 4.86 | N | 9 | 19.44 | W | 764.4 | 15.9 | 755 | 767 | 10 |  |
| 13638 | 110999 | 222405 | 57 | 6.24 | N | 9 | 24.69 | W | 1355.3 | 8.2 | 1355 | 1377 | 12 |  |
| 13639 | 120999 | 011125 | 57 | 7.51 | N | 9 | 33.86 | W | 1776.8 | 11.9 | 1765 | 1789 | 14 |  |
| 13640 | 120999 | 052401 | 57 | 9 | N | 9 | 42 | W | 1924.4 | 4 | 1916 | 1949 | 15 |  |
| 13641 | 120999 | 092104 | 57 | 13.83 | N | 10 | 2.48 | W | 2098.3 | 11.9 | 2099 | 2119 | 16 |  |
| 13642 | 120999 | 134537 | 57 | 17.67 | N | 10 | 22.3 | W | 2085.5 | 8 | 2210 | 2235 | 17 |  |
| 13643 | 120999 | 175100 | 57 | 22.31 | N | 10 | 39.27 | W | 2149.5 | 7.3 | 2145 | 2177 | 16 |  |
| 13644 | 120999 | 205005 | 57 | 24.17 | N | 10 | 50.69 | W | 810.9 | 18.3 | 805 | 803 | 9 |  |
| 13645 | 120999 | 233142 | 57 | 26.62 | N | 11 | 4.42 | W | 590.2 | 12.2 | 580 | 589 | 8 |  |
| 13646 | 130999 | 015237 | 57 | 27.97 | N | 11 | 18.52 | W | 738.3 | 12.7 | 2038 | 739 | 10 |  |
| 13647 | 130999 | 043625 | 57 | 29.19 | N | 11 | 32.11 | W | 2011.3 | 6 | 2005 | 2037 | 16 |  |
| 13648 | 130999 | 082046 | 57 | 30.13 | N | 11 | 49.24 | W | 1782.9 | 5.5 | 1788 | 1805 | 14 |  |
| 13649 | 130999 | 125126 | 57 | 30.48 | N | 12 | 15.48 | W | 1795.9 | 8.3 | 1790 | 1817 | 14 |  |
| 13650 | 130999 | 161958 | 57 | 32 | N | 12 | 38.18 | W | 1633.1 | 8.4 | 1625 | 1651 | 13 |  |
| 13651 | 130999 | 185321 | 57 | 32.69 | N | 12 | 52.04 | W | 1038.6 | 21.4 | 1030 | 1045 | 10 |  |
| 13652 | 130999 | 205329 | 57 | 33.53 | N | 12 | 59.47 | W | 302 | 5.6 | 292 | 297 | 7 |  |
| 13653 | 130999 | 234352 | 57 | 33.88 | N | 13 | 19.78 | W | 180.7 | 7.2 | 170 | 173 | 6 |  |
| 13654 | 140999 | 015140 | 57 | 33.78 | N | 13 | 37.89 | W | 124.3 | 12.8 | 110 | 111 | 6 | Rockall Station |
| 13655 | 140999 | 035203 | 57 | 41.55 | N | 13 | 56.95 | W | 157 | 6.9 | 147 | 149 | 6 |  |

Contents

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13656 | 140999 | 070733 | 57 | 57.59 | N | 14 | 38.15 | W | 479.5 | 9.5 | 470 | 473 | 8 | |
| 13657 | 140999 | 112013 | 58 | 14.94 | N | 15 | 22.2 | W | 682.7 | 9.4 | 680 | 679 | 9 | |
| 13658 | 140999 | 162031 | 58 | 33.41 | N | 16 | 10.01 | W | 1215 | 5.7 | 1205 | 1221 | 11 | |
| 13659 | 140999 | 213025 | 58 | 51.11 | N | 17 | 0.79 | W | 1156.7 | 16.6 | 1152 | 1151 | 11 | |
| 13660 | 150999 | 001628 | 58 | 56.92 | N | 17 | 13.86 | W | 850.1 | 5.8 | 840 | 851 | 10 | |
| 13661 | 150999 | 033720 | 59 | 7.89 | N | 17 | 39.13 | W | 996.9 | 13.4 | 1010 | 997 | 10 | |
| 13662 | 150999 | 121903 | 59 | 12.4 | N | 17 | 53.66 | W | 1547.1 | 8.8 | 1535 | 1557 | 14 | |
| | | | | | | | | | | | | | | BRIDGET trial |
| 13663 | 150999 | 155116 | 59 | 19.92 | N | 18 | 16.11 | W | 1918.7 | 5.1 | 1909 | 1939 | 15 | |
| 13664 | 150999 | 184935 | 59 | 24.51 | N | 18 | 25.33 | W | 2422.3 | 19.6 | 2476 | 2441 | 17 | |
| 13665 | 160999 | 003031 | 59 | 40.87 | N | 19 | 8.48 | W | 2680.1 | 17.2 | 2671 | 2701 | 24 | |
| 13666 | 160999 | 062740 | 60 | 0.26 | N | 19 | 59.79 | W | 2723.8 | 21.5 | 2720 | 2741 | 25 | |
| 13667 | 160999 | 124800 | 60 | 34.87 | N | 19 | 59.6 | W | 2465.1 | 6.2 | 2451 | 2489 | 21 | |
| 13668 | 160999 | 172129 | 60 | 56.12 | N | 20 | 0.04 | W | 2400 | 3.6 | 2400 | 2429 | 21 | |
| 13669 | 160999 | 213425 | 61 | 16.86 | N | 20 | 0.9 | W | 2373.5 | 10.6 | 2350 | 2391 | 21 | |
| 13670 | 170999 | 021724 | 61 | 38.65 | N | 19 | 59.81 | W | 2008.2 | 8.9 | 1994 | 2021 | 22 | |
| 13671 | 170999 | 060318 | 61 | 57.86 | N | 19 | 59.86 | W | 1788 | 2.2 | 1783 | 1805 | 21 | Steamed to Vestmanneyjar |
| 13672 | 170999 | 172410 | 63 | 17.78 | N | 19 | 59.56 | W | 213.5 | 9.6 | 200 | 203 | 6 | following five stations |
| 13673 | 170999 | 183207 | 63 | 13.74 | N | 19 | 59.64 | W | 475.5 | 9.5 | 460 | 465 | 8 | occupied |
| 13674 | 170999 | 212515 | 62 | 55.16 | N | 20 | 3.47 | W | 1172.8 | 18.7 | 1200 | 1179 | 12 | south to north |
| 13675 | 180999 | 103850 | 62 | 39.3 | N | 20 | 0.25 | W | 1498.5 | 10.5 | 1490 | 1505 | 17 | |
| 13676 | 180999 | 152957 | 62 | 19.5 | N | 20 | 0.5 | W | 1810.1 | 5.2 | 1805 | 1831 | 18 | end S-I |
| 13677 | 190999 | 035142 | 63 | 15.72 | N | 17 | 25.84 | W | 185.3 | 5.5 | 176 | 179 | 11 | start I-Lousy Bank |
| 13678 | 190999 | 064512 | 63 | 12.33 | N | 17 | 21.77 | W | 688.4 | 32.8 | 652 | 647 | 11 | |
| 13679 | 190999 | 094818 | 63 | 6.24 | N | 17 | 15.14 | W | 1168.1 | 206 | 1190 | 1185 | 15 | |
| 13680 | 190999 | 130835 | 63 | 0.56 | N | 17 | 7.81 | W | 1277.7 | 12.3 | 1270 | 1285 | 15 | |
| 13681 | 200999 | 062135 | 62 | 53.87 | N | 17 | 0.68 | W | 1544.4 | 13.1 | 1520 | 1545 | 17 | |
| 13682 | 200999 | 094841 | 62 | 48.32 | N | 16 | 55.35 | W | 1674.7 | 10.7 | 1680 | 1687 | 18 | |
| 13683 | 200999 | 135432 | 62 | 41.6 | N | 16 | 48.09 | W | 1818.1 | 2.8 | 1820 | 1835 | 18 | |
| 13684 | 200999 | 181652 | 62 | 30.11 | N | 16 | 33.21 | W | 2058.9 | 15.3 | 2050 | 2073 | 21 | |
| 13685 | 200999 | 224736 | 62 | 17.56 | N | 16 | 18.7 | W | 2136.4 | 13.3 | 2140 | 2147 | 21 | |
| 13686 | 210999 | 040301 | 62 | 3.27 | N | 16 | 3.84 | W | 2230.2 | 6.3 | 2217 | 2251 | 20 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13687 | 220999 | 114325 | 61 | 49.98 | N | 15 | 35.77 | W | 2278.9 | 14.1 | 2255 | 2293 | 21 | |
| 13688 | 220999 | 171330 | 61 | 36.15 | N | 15 | 6.74 | W | 2149.8 | 10.5 | 2135 | 2167 | 20 | |
| 13689 | 220999 | 213925 | 61 | 23.51 | N | 14 | 35.2 | W | 2072.6 | 9.6 | 2080 | 2087 | 20 | |
| 13690 | 230999 | 020928 | 61 | 7.93 | N | 14 | 6.22 | W | 1764.7 | 5.3 | 1753 | 1781 | 18 | |
| 13691 | 230999 | 055721 | 60 | 55.1 | N | 13 | 35.73 | W | 1665.8 | 10.5 | 1651 | 1675 | 18 | |
| 13692 | 230999 | 084207 | 60 | 50.62 | N | 13 | 25.4 | W | 1657 | 10.8 | 1650 | 1669 | 18 | |
| 13693 | 230999 | 115706 | 60 | 44.32 | N | 13 | 13.14 | W | 1444.2 | 8.7 | 1430 | 1451 | 17 | |
| 13694 | 230999 | 141428 | 60 | 39.19 | N | 13 | 2.62 | W | 1037 | 11.4 | 1020 | 1035 | 15 | |
| 13695 | 230999 | 162340 | 60 | 33.7 | N | 12 | 52.92 | W | 598.2 | 8.8 | 585 | 593 | 9 | |
| 13696 | 230999 | 181222 | 60 | 29.06 | N | 12 | 41.81 | W | 405.5 | 11 | 390 | 395 | 8 | end I-Lousy Bank |
| 13697 | | | | | | | | | | | | | | BRIDGET S |
| 13698 | 240999 | 173142 | 61 | 24.77 | N | 11 | 0.52 | W | 1221.5 | 8.2 | 1210 | 1227 | 14 | start S/T |
| 13699 | 240999 | 204555 | 61 | 26.17 | N | 11 | 6.79 | W | 1446.6 | 3.6 | 1443 | 1459 | 16 | |
| 13700 | 240999 | 225845 | 61 | 28.03 | N | 11 | 12.08 | W | 1209.3 | 9.6 | 1235 | 1231 | 15 | end S/T |
| 13701 | | | | | | | | | | | | | | BRIDGET T |
| 13702 | 260999 | 022427 | 61 | 57.96 | N | 8 | 54.91 | W | 451.8 | 11.4 | 435 | 441 | 11 | start Q |
| 13703 | 260999 | 035357 | 61 | 55.58 | N | 8 | 59.88 | W | 529.7 | 7.9 | 517 | 525 | 12 | |
| 13704 | 260999 | 053539 | 61 | 53.08 | N | 9 | 5.41 | W | 596.9 | 10.4 | 580 | 589 | 11 | |
| 13705 | 260999 | 070959 | 61 | 50.83 | N | 9 | 10.09 | W | 649.2 | 249.2 | 630 | 639 | 11 | |
| 13706 | 260999 | 103353 | 61 | 48.44 | N | 9 | 14.43 | W | 728.6 | 8.6 | 715 | 723 | 12 | |
| 13707 | 260999 | 123612 | 61 | 45.11 | N | 9 | 20.66 | W | 815.3 | 10.3 | 800 | 807 | 13 | |
| 13708 | 260999 | 143403 | 61 | 42.08 | N | 9 | 26.01 | W | 872.8 | 11.5 | 862 | 867 | 13 | |
| 13709 | 260999 | 163057 | 61 | 39.67 | N | 9 | 31.42 | W | 957.1 | 11.4 | 945 | 953 | 12 | |
| 13710 | 260999 | 182953 | 61 | 37.34 | N | 9 | 36.4 | W | 1013.2 | 7.2 | 1005 | 1015 | 13 | |
| 13711 | 260999 | 203451 | 61 | 34.97 | N | 9 | 42.19 | W | 1043.4 | 8.1 | 1035 | 1043 | 13 | |
| 13712 | 260999 | 224658 | 61 | 32.08 | N | 9 | 46.3 | W | 1070.5 | 9 | 1060 | 1073 | 14 | |
| 13713 | 270999 | 011926 | 61 | 29.23 | N | 9 | 52.32 | W | 1163 | 12.3 | 1165 | 1177 | 13 | |
| 13714 | 270999 | 033523 | 61 | 26.78 | N | 9 | 58.1 | W | 1196 | 249.2 | 1184 | 1201 | 13 | |
| 13715 | 270999 | 083217 | 61 | 24.53 | N | 10 | 3.61 | W | 1206.7 | 7 | 1204 | 1215 | 13 | end Q |
| 13716 | | | | | | | | | | | | | | BRIDGET P |
| 13717 | 270999 | 230134 | 61 | 43.62 | N | 8 | 23.44 | W | 204.3 | 10 | 190 | 193 | 4 | start P1 |
| 13718 | 280999 | 003135 | 61 | 42.19 | N | 8 | 26.56 | W | 509.4 | 8.2 | 500 | 505 | 11 | |
| 13719 | 280999 | 023716 | 61 | 40.67 | N | 8 | 29.73 | W | 688.7 | 7 | 675 | 685 | 12 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13720 | 280999 | 043959 | 61 | 39.28 | N | 8 | 32.42 | W | 762.5 | 6.1 | 746 | 757 | 12 | |
| 13721 | 280999 | 065245 | 61 | 38.13 | N | 8 | 35.6 | W | 814.6 | 9 | 798 | 807 | 12 | |
| 13722 | 280999 | 094407 | 61 | 36.78 | N | 8 | 39.03 | W | 882.6 | 12.6 | 900 | 873 | 13 | |
| 13723 | 280999 | 181033 | 61 | 34.94 | N | 8 | 41.7 | W | 876.3 | 5.3 | 865 | 875 | 12 | |
| 13724 | 280999 | 202612 | 61 | 33.68 | N | 8 | 44.64 | W | 842.2 | 7.9 | 840 | 837 | 12 | |
| 13725 | 280999 | 225254 | 61 | 32.56 | N | 8 | 46.33 | W | 748.9 | 5.4 | 745 | 743 | 12 | |
| 13726 | 290999 | 011223 | 61 | 30.4 | N | 8 | 49.59 | W | 558.2 | 7.3 | 545 | 553 | 11 | |
| 13727 | 290999 | 024837 | 61 | 28.98 | N | 8 | 52.92 | W | 466.9 | 7.6 | 454 | 461 | 11 | end P1 |
| 13728 | 290999 | 051116 | 61 | 23.98 | N | 8 | 33.69 | W | 421.9 | 9.2 | 410 | 413 | 11 | start FBS1 |
| 13729 | 290999 | 064646 | 61 | 25.63 | N | 8 | 30.84 | W | 608.7 | 7 | 600 | 607 | 11 | |
| 13730 | 290999 | 083401 | 61 | 27.97 | N | 8 | 27.92 | W | 852.3 | 10.2 | 840 | 845 | 13 | |
| 13731 | 290999 | 102845 | 61 | 29.52 | N | 8 | 24.89 | W | 817.1 | 13.8 | 810 | 809 | 13 | end FBS1 |
| 13732 | 290999 | 164224 | 61 | 16.66 | N | 7 | 55.55 | W | 860.1 | 4.4 | 855 | 867 | 12 | FBC upstream stn. |
| 13733 | 290999 | 210738 | 61 | 13.76 | N | 8 | 22.66 | W | 178.9 | 8.9 | 165 | 169 | 4 | start FBC |
| 13734 | 290999 | 221649 | 61 | 15.34 | N | 8 | 20.15 | W | 274.8 | 12.5 | 265 | 265 | 5 | |
| 13735 | 290999 | 233551 | 61 | 17.29 | N | 8 | 16.85 | W | 394.2 | 10 | 385 | 381 | 10 | |
| 13736 | 300999 | 014049 | 61 | 19.07 | N | 8 | 13.7 | W | 577.4 | 12.3 | 560 | 567 | 11 | |
| 13737 | 300999 | 034029 | 61 | 20.22 | N | 8 | 10.61 | W | 839.4 | 33.1 | -999 | 809 | 0 | |
| 13738 | 300999 | 045449 | 61 | 20.61 | N | 8 | 11.96 | W | 822.5 | 13.4 | 815 | 817 | 13 | |
| 13739 | 300999 | 065434 | 61 | 22.22 | N | 8 | 8.93 | W | 827.9 | 3.8 | 825 | 827 | 12 | |
| 13740 | 300999 | 091743 | 61 | 24.92 | N | 8 | 6.51 | W | 688.1 | 14.7 | 675 | 673 | 12 | |
| 13741 | 300999 | 111718 | 61 | 26.33 | N | 8 | 3.46 | W | 461.8 | 8.5 | 455 | 459 | 11 | |
| 13742 | 300999 | 130202 | 61 | 28.11 | N | 8 | 0.55 | W | 189.1 | 13.7 | 170 | 173 | 7 | |
| 13743 | 300999 | 142402 | 61 | 29.88 | N | 7 | 57.92 | W | 198.6 | 11.2 | 185 | 187 | 7 | end FBC |
| 13744 | 300999 | 182058 | 61 | 43.77 | N | 8 | 24.16 | W | 206 | 6.4 | 195 | 199 | 4 | start P2 |
| 13745 | 300999 | 191205 | 61 | 42.15 | N | 8 | 27.35 | W | 536.9 | 6.6 | 525 | 527 | 4 | |
| 13746 | 300999 | 202307 | 61 | 40.88 | N | 8 | 29.63 | W | 672.8 | 9 | 660 | 663 | 5 | |
| 13747 | 11099 | 163755 | 61 | 39.63 | N | 8 | 32.95 | W | 758.1 | 6 | 750 | 753 | 7 | |
| 13748 | 11099 | 181324 | 61 | 37.56 | N | 8 | 35.49 | W | 824.6 | 7 | 845 | 817 | 7 | |
| 13749 | 11099 | 195547 | 61 | 36 | N | 8 | 38.94 | W | 874.4 | 6.2 | 890 | 873 | 7 | |
| 13750 | 11099 | 213003 | 61 | 34.88 | N | 8 | 42.12 | W | 874.2 | 8 | 880 | 873 | 7 | |
| 13751 | 11099 | 230544 | 61 | 33.46 | N | 8 | 45.37 | W | 820.9 | 11.4 | 819 | 819 | 7 | |
| 13752 | 21099 | 004514 | 61 | 32.24 | N | 8 | 47.67 | W | 685.7 | 7.7 | 690 | 691 | 7 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13753 | 21099 | 020924 | 61 | 30.68 | N | 8 | 50.47 | W | 568.2 | 11.2 | 560 | 561 | 7 | |
| 13754 | 21099 | 032804 | 61 | 28.99 | N | 8 | 53.36 | W | 470.5 | 3.9 | 460 | 467 | 6 | end P2 |
| 13755 | 21099 | 053800 | 61 | 26.63 | N | 8 | 27.83 | W | 792.1 | 7.8 | 780 | 787 | 7 | start FBS2 |
| 13756 | 21099 | 065851 | 61 | 27.98 | N | 8 | 25.1 | W | 850.8 | 10 | 840 | 843 | 9 | |
| 13757 | 21099 | 083830 | 61 | 29.72 | N | 8 | 21.8 | W | 750.4 | 8.3 | 740 | 743 | 14 | end FBS2 |

Table 3 Corrections to the Conductivity Offset

| CTD | Station number | Correction |
|---|---|---|
| DEEP04 | 13630 | -0.0556 |
| " | 13631 | -0.0547 |
| " | 13632 | -0.0530 |
| " | 13633 | -0.0560 |
| " | 13634 | -0.0575 |
| " | 13635 | -0.0548 |
| " | 13636 | -0.0600 |
| " | 13637 | -0.0583 |
| " | 13638 | -0.0572 |
| " | 13639 | -0.0575 |
| " | 13640 | -0.0600 |
| " | 13641 | -0.0589 |
| " | 13642 | -0.0631 |
| " | 13643 | -0.0641 |
| " | 13644 | -0.0670 |
| " | 13645 | -0.0702 |
| " | 13646 | -0.0653 |
| " | 13647 | -0.0646 |
| " | 13648 | -0.0664 |
| DEEP03 | 13649 | -0.0018 |
| " | 13650-13651 | 0.0000 |
| " | 13652-13653 | 0.0020 |
| " | 13654-13656 | 0.0025 |
| " | 13657 | 0.0036 |
| " | 13658-13661 | 0.0025 |
| " | 13662-13670 | 0.0010 |
| " | 13671-13676 | 0.0000 |
| DEEP04 | 13677-13678 | -0.0010 |
| " | 13679-13680 | -0.0020 |
| " | 13681 | 0.0025 |
| " | 13682 | 0.0047 |
| " | 13683 | 0.0027 |
| " | 13684 | 0.0026 |
| " | 13685 | 0.0165 |
| " | 13686 | 0.0028 |
| DEEP03 | 13687-13690 | 0.0000 |
| " | 13691 | 0.0010 |
| " | 13692-13695 | 0.0045 |
| " | 13696 | 0.0000 |
| " | 13698-13700 | -0.0020 |
| " | 13702 | -0.0012 |
| " | 13703 | 0.0016 |
| " | 13704-13714 | 0.0050 |
| " | 13715 | -0.0010 |
| " | 13717-13721 | -0.0020 |

Contents

| | | |
|---|---|---|
| " | 13722-13725 | 0.0000 |
| " | 13726-13731 | 0.0010 |
| " | 13732-13734 | 0.0055 |
| " | 13735-13739 | 0.0075 |
| " | 13740-13757 | 0.0047 |

Table 4 Salinity Residual Statistics (bottle salinity minus CTD), excluding residuals outside range ±2 standard deviations from total mean.

| Stations | n | mean | stdev |
|---|---|---|---|
| 13630-13648 | 203 (of 208) | 0.0004 | 0.0073 |
| 13649-13676 | 332 (of 355) | 0.0000 | 0.0009 |
| 13677-13686 | 144 (of 152) | 0.0000 | 0.0069 |
| 13687-13757 | 697 (of 709) | 0.0002 | 0.0017 |

Contents

Table 5 CTD Transmissometer clear air and blank voltages

| CTD | JDAY | PRE CLEAN (V) | POST CLEAN (V) | BLANK VALUE (V) |
|---|---|---|---|---|
| DEEP04 | 254 | | 0.350 | |
| DEEP04 | 254 | 0.365 | | |
| DEEP04 | 254 | 0.229 | 0.450 | |
| DEEP04 | 254 | 0.350 | 0.489 | |
| DEEP04 | 254 | 0.307 | 0.261 | |
| DEEP04 | 255 | 0.354 | 0.137 | |
| DEEP04 | 255 | 0.456 | 0.352 | |
| DEEP04 | 255 | 0.435 | 0.270 | |
| DEEP03 | 256 | 0.444 | 0.259 | |
| DEEP03 | 256 | 0.417 | 0.572 | |
| DEEP03 | 256 | 0.451 | 0.373 | |
| DEEP03 | 256 | 0.359 | 0.316 | |
| DEEP03 | 257 | 0.402 | 0.451 | |
| DEEP03 | 257 | 0.494 | 0.301 | 1.498 |
| DEEP03 | 257 | 0.362 | 0.349 | 1.810 |
| DEEP03 | 258 | 0.350 | 0.400 | |
| DEEP03 | 258 | 0.290 | 0.445 | 2.558 |
| DEEP03 | 258 | 0.455 | 0.567 | 2.468 |
| DEEP03 | 259 | 0.481 | 0.400 | 1.880 |
| DEEP03 | 259 | 0.351 | 0.464 | 3.456 |
| DEEP03 | 259 | 0.393 | 0.351 | 1.579 |
| DEEP03 | 260 | 0.416 | 0.319 | 1.418 |
| DEEP03 | 260 | 0.322 | 0.516 | 2.080 |
| DEEP03 | 261 | 0.300 | 0.400 | |
| DEEP03 | 261 | 0.499 | 0.295 | 2.862 |
| DEEP04 | 262 | | 0.350 | |
| DEEP04 | 262 | | 0.300 | |
| DEEP04 | 262 | 0.314 | 0.242 | 2.630 |
| DEEP04 | 263 | 0.400 | | |
| DEEP04 | 263 | 0.475 | 0.281 | 3.232 |
| DEEP04 | 263 | 0.591 | 0.450 | 3.310 |
| DEEP04 | 263 | 0.388 | 0.461 | 2.648 |
| DEEP04 | 264 | 0.430 | 0.400 | |
| DEEP03 | 265 | 0.482 | 0.255 | 3.323 |
| DEEP03 | 265 | 0.390 | 0.514 | 2.675 |
| DEEP03 | 265 | 0.341 | 0.436 | 2.640 |
| DEEP03 | 266 | 0.322 | 0.527 | 2.573 |
| DEEP03 | 266 | 0.505 | 0.324 | 3.757 |
| DEEP03 | 266 | 0.408 | 0.433 | 1.692 |
| O2 | 267 | 0.333 | 0.425 | 2.099 |
| DEEP03 | 267 | 0.298 | 0.476 | 2.018 |
| DEEP03 | 269 | 0.490 | 0.448 | 2.307 |

Contents

| | | | | |
|---|---|---|---|---|
| DEEP03 | 269 | 0.448 | 0.480 | 1.997 |
| DEEP03 | 269 | 0.513 | 0.466 | 2.389 |
| DEEP03 | 269 | 0.410 | 0.441 | 2.014 |
| DEEP03 | 269 | 0.417 | 0.768 | 1.728 |
| DEEP03 | 269 | 0.457 | 0.309 | 2.412 |
| DEEP03 | 271 | 0.421 | 0.538 | 3.785 |
| DEEP03 | 271 | 0.310 | 0.515 | 3.177 |
| DEEP03 | 271 | 0.401 | 0.525 | 3.349 |
| DEEP03 | 271 | 0.424 | 0.384 | 3.114 |
| DEEP03 | 272 | 0.271 | 0.434 | 2.212 |
| DEEP03 | 272 | 0.481 | 0.512 | 3.134 |
| DEEP03 | 273 | 0.166 | 0.555 | 3.022 |
| DEEP03 | 273 | 0.300 | | |
| DEEP03 | 273 | 0.293 | 0.595 | 2.276 |
| DEEP03 | 274 | 0.550 | 0.529 | 3.247 |
| DEEP03 | 274 | 0.453 | 0.722 | 2.386 |
| DEEP03 | 274 | 0.304 | 0.394 | 3.166 |
| DEEP03 | 274 | 0.383 | 0.424 | 2.804 |

Table 6 Differences between Reversing Instruments and CTD Pressure and Temperature. Values within ±10 dbars and ±0.1°C included.

| Instruments | Mean Difference (CTD-rev) | Standard Deviation | Number of samples |
|---|---|---|---|
| DEEP03-T1545 | -0.0085 | 0.0167 | 76/87 |
| DEEP03-T995 | -0.0062 | 0.0186 | 71/84 |
| DEEP03-P6534 | 3.67 | 2.06 | 86/91 |
| DEEP03-P6394 | 2.79 | 1.01 | 88/90 |
| DEEP04-T1545 | 0.0050 | 0.0149 | 23/26 |
| DEEP04-T995 | -0.0033 | 0.0154 | 21/25 |
| DEEP04-P6534 | 3.54 | 1.52 | 25/27 |
| DEEP04-P6394 | 1.43 | 0.99 | 28/28 |

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## Table 7. Oxygen Parameters

| Station | ρ | α | β | f | χ |
|---|---|---|---|---|---|
| 13630 | 3.2116 | 0.0000924 | 0.03121 | -0.41087 | 0.2376 |
| 13631 | 3.2116 | 0.0000924 | 0.03121 | -0.41087 | 0.2376 |
| 13632 | 3.2116 | 0.0000924 | 0.03121 | -0.41087 | 0.2376 |
| 13634 | 3.2347 | 0.0012814 | 0.06544 | -0.06382 | 0 |
| 13635 | 3.7112 | 0.0003136 | 0.05695 | -0.27286 | 0 |
| 13636 | 3.6231 | 0.0001676 | 0.07035 | -0.21921 | 0.0000 |
| 13637 | 0.4688 | 0.0001184 | 0.02803 | 2.03586 | 0.0000 |
| 13638 | 1.7248 | 0.0003667 | 0.06768 | 0.51633 | 0.0000 |
| 13639 | 4.9307 | 0.0002554 | 0.08613 | -0.20902 | 0.0000 |
| 13640 | 2.8073 | 0.0000692 | 0.04931 | -0.15835 | 0.0000 |
| 13641 | 3.3985 | -0.0001542 | 0.03436 | -0.33603 | 0.0000 |
| 13642 | 4.9375 | 0.0000042 | 0.07314 | -0.30307 | 0.1458 |
| 13643 | 1.5019 | 0.0000625 | 0.02426 | 0.11161 | 0.0000 |
| 13644 | 3.9759 | 0.0000188 | 0.05392 | -0.27497 | 0.0000 |
| 13645 | 2.5527 | -0.0003518 | 0.00874 | -0.34097 | 0.4791 |
| 13646 | 3.5142 | -0.0000197 | 0.04949 | -0.24837 | 0.0000 |
| 13647 | 3.877 | 0.0001229 | 0.07029 | -0.15594 | 0.0000 |
| 13648 | 3.2661 | 0.0000703 | 0.05629 | -0.1605 | 0.0000 |
| 13651 | 11.612 | 0.0002723 | 0.11716 | -0.36577 | 0.0000 |
| 13673 | 0.2608 | -0.0000834 | -0.04761 | 1.71459 | 1.0000 |
| 13678 | 0.1385 | -0.0002337 | -0.07455 | 2.31089 | 0.5264 |
| 13679 | 1.783 | 0.0000357 | 0.0404 | -0.03014 | 0.0000 |
| 13695 | 0.1726 | -0.0001051 | -0.04031 | 2.90184 | 1.0000 |
| 13699 | 1.0701 | 0.0002118 | 0.04035 | 0.75348 | 0.1041 |
| 13700 | 11.8645 | 0.0006164 | 0.16272 | -0.13120 | 0.0000 |
| 13702 | 5.1076 | 0.0009676 | 0.15984 | 0.55971 | 0.0000 |
| 13703 | 3.2667 | 0.0003684 | 0.06672 | -0.00787 | 0.0000 |
| 13706 | 0.8655 | 0.0000785 | 0.01755 | 0.53318 | 0.0209 |
| 13707 | 3.5903 | 0.0001039 | 0.06315 | -0.13910 | 0.0000 |
| 13708 | 0.2051 | 0.0000878 | -0.00341 | 4.02144 | 1.0000 |
| 13709 | 1.7356 | 0.0002051 | 0.03994 | 0.33827 | 0.0000 |
| 13710 | 2.1503 | 0.0003632 | 0.06644 | 0.40498 | 0.0000 |
| 13715 | 4.6612 | 0.0003163 | 0.10797 | 0.00770 | 0.0000 |
| 13717 | 3.1066 | 0.0007303 | 0.01619 | -0.08511 | 0.3075 |
| 13718 | 2.2644 | 0.0003378 | 0.05378 | 0.27583 | 0.0000 |
| 13719 | 0.2525 | 0.0001029 | -0.00344 | 3.28640 | 1.0000 |
| 13720 | 1.0884 | 0.0001736 | 0.01669 | 0.58894 | 0.0000 |
| 13721 | 4.8161 | -0.0000523 | 0.05581 | -0.17814 | 0.0000 |
| 13722 | 0.4461 | 0.0001344 | 0.00193 | 1.73882 | 0.0000 |
| 13723 | 0.1588 | 0.0000765 | -0.00664 | 5.22782 | 1.0000 |
| 13724 | 1.1312 | 0.0001200 | 0.01807 | 0.46169 | 0.0000 |
| 13725 | 0.2108 | 0.0000819 | -0.00451 | 3.80552 | 1.0000 |
| 13726 | 0.3689 | 0.0002741 | 0.08609 | 5.49504 | 0.0291 |
| 13727 | 0.4045 | 0.0002204 | 0.05093 | 3.38625 | 0.0000 |
| 13728 | 0.4815 | 0.0002298 | 0.05336 | 2.81873 | 0.0000 |

Contents

| | | | | | |
|---|---|---|---|---|---|
| 13729 | 0.3416 | 0.0002083 | 0.05135 | 4.11442 | 0.0000 |
| 13730 | 0.4042 | 0.0001298 | 0.00351 | 1.92220 | 0.0000 |
| 13731 | 0.2056 | -0.0000054 | -0.00874 | 3.66360 | 1.0000 |
| 13732 | 0.2410 | 0.0001651 | 0.00279 | 3.59410 | 0.0000 |
| 13733 | 3.1423 | -0.0001190 | 0.08994 | 0.09837 | 0.0000 |
| 13734 | 3.0966 | 0.0003547 | 0.07726 | 0.08464 | 0.5440 |
| 13735 | 0.3320 | 0.0001941 | 0.03926 | 3.74712 | 0.0000 |
| 13736 | 0.4507 | 0.0002881 | 0.07346 | 3.90860 | 0.0000 |
| 13737 | 0.4507 | 0.0002881 | 0.07346 | 3.90860 | 0.0000 |
| 13738 | 0.5883 | 0.0001481 | 0.00930 | 1.20513 | 0.0000 |
| 13739 | 0.1982 | 0.0002000 | 0.00324 | 4.56162 | 0.0000 |
| 13740 | 0.2986 | 0.0000946 | -0.00175 | 2.60297 | 0.2855 |
| 13741 | 0.2263 | 0.0002783 | 0.03352 | 5.46462 | 0.0000 |
| 13742 | 0.2598 | 0.0004685 | 0.06147 | 6.51171 | 0.0000 |
| 13743 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13744 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13745 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13746 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13747 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13748 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13749 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13750 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13751 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13752 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13753 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13754 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13755 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13756 | 0.5913 | 0.0002975 | 0.07846 | 2.95281 | 0.0162 |
| 13757 | 0.1875 | 0.0000307 | -0.00749 | 4.06779 | 1.0000 |

Contents

Table 8 Oxygen Residuals (bottle minus CTD). Excludes residuals outside range ±2 stdev from total mean. See text for further details of which stations have reliable CTD oxygen data, and for information on stations with no bottle oxygens.

| Stations | n | mean | stdev |
|---|---|---|---|
| 13630-13648 (sensor 1) | 170/182 | 0.009 | 4.120 |
| 13699-13757 (sensor 2) | 377/377 | 0.007 | 3.795 |

Contents

Table 9 Changes of CTD instrumentation.

| Station | Action | Reason |
|---|---|---|
| 13630 | DEEP04 deployed | Thought to have most stable temperature sensor |
| 13649 | DEEP03 deployed | Apparent failure of 04 conductivity cell giving hysteresis in salinity |
| 13677 | DEEP04 deployed | New conductivity cell |
| 13687 | DEEP03 deployed | Hysteresis in 04 salinity profile still apparent in deep stations |
| 13698 | New oxygen sensor | Gradual failure of sensor |
| 13706 | Oxygen sensor re-connected | Wire broke during 13704 upcast (no A/D channels on 13705) |
| 13715 | Oxygen sensor re-wired | Failed completely during 13714 downcast |

Table 10. Summary of which ADCP's were used on which CTD stations

| ADCP | Beam Angle (degrees) | Station numbers |
|---|---|---|
| WHOI | 30 | 13630 - 13731 |
| BRIDGET_up | 30 | 13733 - 13743 |
| BRIDGET_down | 20 | 13744 - 13757 |

NB. WHOI failed on station 13721

Table 11a LADCP configuration file

| Command | Description |
|---|---|
| CR1 | Get factory defaults |
| PS0 | Show System config. |
| CY | Clear Error-Status-Word |
| CT0 | turnkey mode off. |
| EZ 0011101 | Don't calculate speed of sound. Enable tilt, roll, heading and temperature |
| EC 1500 | Set temp to 1500m/s |
| EX 11101 | Earch co-ordinates. Use pitch and roll. Do not allow 3-beam solutions. |
| WD 111100000 | Collect velocity, correlation, intensity and %good data. |
| WL 0,4 | Disable water reference layer. |
| WP 00001 | 1 water track pings |
| WN 010 | 10 bins |
| WS 1600 | 16 metre bin size |
| WF 1600 | 16 metre blank beyond transmit |
| WM 1 | Profiling mode 1 (for dynamic environments). |
| WB 1 | Medium bandwidth. |
| WV 400 | Ambiguity velocity 4 m/s. |
| WE 0150 | 15 cm/s Error velocity threshold. |
| WC 056 | Low correlation threshold 56 counts. |
| CP 255 | Use max power of High Power module. |
| CL 0 | Battery saver mode off. |
| BP 001 | Bottom Track on. |
| BD 25 | Number of ensembles between BT 'search' pings |
| BX 2500 | BT Max tracking depth 250m. |
| BL 0,200,600 | see manual |
| BM 4 | Bottom track mode 4. |
| TP 000100 | Time between pings 1 second. (within an ensemble). |
| TE 00000200 | Time per ensemble 2 seconds |
| &R20 | BT transmit power percent. |
| CF11101 | Disable serial output during data collection. |
| &? | |

Table 11b BRIDGET_down configuration file

| Command | Description |
|---|---|
| CR1 | Get factory defaults |
| PS0 | Show System config. |
| CY | Clear Error-Status-Word |
| EZ 0011101 | Don't calculate speed of sound. Enable tilt, roll, heading and temperature |
| EC 1500 | Set temp to 1500m/s |
| EX 11111 | Earch co-ordinates. Use pitch and roll. Allow 3-beam solutions. |
| WD 111100000 | Collect velocity, correlation, intensity and %good data. |
| WL 0,4 | Disable water reference layer. |
| WP 00001 | 1 water track ping. |
| WN 064 | 64 bins |
| WS 0400 | 4 metre bin size. |
| WF 0400 | 4 metre blank beyond transmit. |
| WM 1 | Profiling mode 1 (for dynamic environments). |
| WB 1 | Medium bandwidth. |
| WV 400 | Ambiguity velocity 4 m/s. |
| WE 0150 | 15 cm/s Error velocity threshold. |
| WC 056 | Low correlation threshold 56 counts. |
| CP 255 | Use max power of High Power module. |
| CL 1 | Battery saver mode on. |
| BP 001 | One Bottom Track ping. |
| BD 25 | Number of ensembles between BT 'search' pings. |
| BX 2500 | BT Max tracking depth 250m. |
| BL 0,200,600 | see manual. |
| BM 4 | Bottom track mode 4. |
| TP 000000 | Time between pings (within an ensemble). |
| TE 00000400 | Time per ensemble (4 seconds). |
| &R20 | BT transmit power percent. |
| CF11101 | Disable serial output during data collection. |
| CT1 | turnkey mode on. |
| CK | Store command set in EEPROM. |
| TF 99092303470200 | Time of first ping. |
| &? | |

Table 11c BRIDGET_up configuration file

| Command | Description |
|---|---|
| CR1 | Get factory defaults |
| PS0 | Show System config. |
| CY | Clear Error-Status-Word |
| EZ 0011101 | Don't calculate speed of sound. Enable tilt, roll, heading and temperature |
| EC 1500 | Set temp to 1500m/s |
| EX 11111 | Earch co-ordinates. Use pitch and roll. Allow 3-beam solutions. |
| WD 111100000 | Collect velocity, correlation, intensity and %good data. |
| WL 0,4 | Disable water reference layer. |
| WP 00002 | 2 water track pings. |
| WN 064 | 64 bins |
| WS 0200 | 2 metre bin size |
| WF 0400 | 4 metre blank beyond transmit |
| WM 1 | Profiling mode 1 (for dynamic environments). |
| WB 1 | Medium bandwidth. |
| WV 400 | Ambiguity velocity 4 m/s. |
| WE 0150 | 15 cm/s Error velocity threshold. |
| WC 056 | Low correlation threshold 56 counts. |
| CP 255 | Use max power of High Power module. |
| CL 1 | Battery saver mode on. |
| BP 000 | Bottom Track off. |
| BD 25 | Number of ensembles between BT 'search' pings |
| BX 2500 | BT Max tracking depth 250m. |
| BL 0,200,600 | see manual |
| BM 4 | Bottom track mode 4. |
| TP 000000 | Time between pings (within an ensemble). |
| TE 00000400 | Time per ensemble (4 seconds). |
| &R20 | BT transmit power percent. |
| CF11101 | Disable serial output during data collection. |
| CT1 | turnkey mode on. |
| CK | Store command set in EEPROM. |
| TF 99092502400400 | Time of first ping. |
| &? | |

Table 12 Theoretical velocity standard deviations for the ADCP configurations during BRIDGET deployments

| Dep | num | DOWN | | | | | | UP | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | et (s) | nb | l (m) | wt | bt | sd cm/s | nb | l (m) | wt | sd cm/s |
| trial | | 4 | 64 | 2 | 1 | 1 | 38 | 64 | 2 | 2 | 37 |
| S/T | 13697 | 4 | 64 | 4 | 1 | 1 | 38 | 64 | 8 | 2 | 9.2 |
| S | 13701 | 8 | 64 | 4 | 3 | 1 | 22 | 64 | 8 | 4 | 6.5 |
| P | 13716 | 8 | 64 | 4 | 3 | 1 | 22 | 64 | 8 | 4 | 6.5 |

where Dep is the deployment name, num is the deployment number, et is the length of the ensemble in seconds, nb is the number of ADCP bins, l is the length of the bins, wt is the number of water track pings per ensemble, bt is the number of bottom track pings per ensemble and sd is the standard deviation of the ensemble velocity estimates given by (18).

Table 13a VMADCP Water track configuration file

```
AD,SI,HUNDREDTHS 120.00 Sampling interval
AD,NB,WHOLE 64 Number of Depth Bins
AD,BL,WHOLE 3 Bin Length
AD,PL,WHOLE 8 Pulse Length
AD,BK,TENTHS 4.0 Blank Beyond Transmit AD,SI,HUNDREDTHS    120.00 Sampling interval
AD,NB,WHOLE          64 Number of Depth Bins
AD,BL,WHOLE           3 Bin Length
AD,PL,WHOLE           8 Pulse Length
AD,BK,TENTHS        4.0 Blank Beyond Transmit
AD,PE,WHOLE           1 Pings Per Ensemble
AD,PC,HUNDREDTHS     1.00 Pulse Cycle Time
AD,PG,WHOLE          25 Percent Pings Good Threshold
XX,OD2,WHOLE          5 [SYSTEM DEFAULT, OD2]
XX,TE,HUNDREDTHS     0.00 [SYSTEM DEFAULT, TE]
AD,US,BOOLE          NO  Use Direct Commands on StartUp
DP,TR,BOOLE          NO  Toggle roll compensation
DP,TP,BOOLE          NO  Toggle Pitch compensation
DP,TH,BOOLE         YES  Toggle Heading compensation
DP,VS,BOOLE         YES  Calculate Sound Velocity from TEMP/Salinity
DP,UR,BOOLE          NO  Use Reference Layer
DP,FR,WHOLE           6 First Bin for reference Layer
DP,LR,WHOLE          15 Last Bin for reference Layer
DP,BT,BOOLE          NO  Use Bottom Track
DP,B3,BOOLE          NO  Use 3 Beam Solutions
DP,EV,BOOLE         YES  Use Error Velocity as Percent Good Criterion
DP,ME,TENTHS      150.0 Max. Error Velocity for Valid Data (cm/sec)
DR,RD,BOOLE         YES  Recording on disk
DR,RX,BOOLE         YES  Record N/S (FORE/AFT) Vel.
DR,RY,BOOLE         YES  Record E/W (FORT/STBD) Vel.
DR,RZ,BOOLE         YES  Record vertical vel.
DR,RE,BOOLE         YES  Record error Good
DR,RB,BOOLE          NO  Bytes of user prog. buffer
DR,RP,BOOLE         YES  Record Percent good
DR,RA,BOOLE         YES  Record average AGC/Bin
DR,RN,BOOLE         YES  Record Ancillary data
DR,AP,BOOLE         YES  Auto-ping on start-up
XX,LDR,TRI         3 [SYSTEM DEFAULT, LDR]
XX,RB2,WHOLE          0 [SYSTEM DEFAULT, RB2]
DR,RC,BOOLE          NO  Record CTD data
XX,FB,WHOLE           1 [SYSTEM DEFAULT, FB]
XX,PU,BOOLE          NO  [SYSTEM DEFAULT, PU]
GC,TG,TRI          1 DISPLAY (NO/GRAPH/TAB)
GC,ZV,WHOLE           4 ZERO VELOCITY REFERENCE (S/B/M/L)
GC,VL,WHOLE        -100 LOWEST VELOCITY ON GRAPH
CG,VH,WHOLE         100 HIGHEST VELOCITY ON GRAPH
GC,DL,WHOLE           0 LOWEST DEPTHS ON GRAPH
GC,DH,WHOLE         500 HIGHEST DEPTHS ON GRAPH
```

```
GC,SW,BOOLE          NO  SET DEPTHS WINDOW TO INCLUDE ALL BINS
GC,MP,WHOLE           25 MINIMUM PERCENT GOOD TO PLOT
SG,PNS,BOOLE         YES  PLOT NORTH/SOUTH VEL.
SG,PEW,BOOLE          YES  PLOT EAST/WEST VEL.
SG,PVT,BOOLE         YES  PLOT VERTICAL VEL.
SG,PEV,BOOLE         YES  PLOT ERROR VEL.
SG,PPE,BOOLE          NO  PLOT PERCENT ERROR
SG,PMD,BOOLE          NO  PLOT MAG AND DIR
SG,PSW,BOOLE          NO  PLOT AVERAGE SP. W.
SG,PAV,BOOLE         YES  PLOT AVERAGE AGC.
SG,PPG,BOOLE         YES  PLOT PERCENT GOOD
SG,PD1,BOOLE         NO  PLOT DOPPLER 1
SG,PD2,BOOLE         NO  PLOT DOPPLER 2
SG,PD3,BOOLE         NO  PLOT DOPPLER 3
SG,PD4,BOOLE         NO  PLOT DOPPLER 4
SG,PW1,BOOLE          NO  PLOT SP. W. 1
SG,PW2,BOOLE          NO  PLOT SP. W. 2
SG,PW3,BOOLE          NO  PLOT SP. W. 3
SG,PW4,BOOLE          NO  PLOT SP. W. 4
SG,PA1,BOOLE         NO  PLOT AGC 1
SG,PA2,BOOLE         NO  PLOT AGC 2
SG,PA3,BOOLE         NO  PLOT AGC 3
SG,PA4,BOOLE         NO  PLOT AGC 4
SG,PP3,BOOLE         NO  PLOT 3-BEAM SOLUTION
SS,OD,WHOLE           0 OffSet for Depth
SS,OH,TENTHS        179.9 OffSet for Heading
SS,OP,TENTHS         0.0 OffSet for Pitch
SS,ZR,TENTHS         0.0 OffSet for Roll
SS,OT,HUNDREDTHS     45.00 OffSet FOR temp
SS,ST,HUNDREDTHS     50.00 Scale for Temp
SS,SL,HUNDREDTHS     35.00 Salinity (PPT)
SS,UD,BOOLE         YES  Toggle UP/DOWN
SS,CV,BOOLE          NO  Toggle concave/Convex  transducerhead
SS,MA,TENTHS        30.0 Mounting angle for transducers.
SS,SS,HUNDREDTHS  1500.00 Speed of Sound (m/sec)
XX,GP,BOOLE         YES  [SYSTEM DEFAULT, GP]
XX,DD,TENTHS         1.0 [SYSTEM DEFAULT, DD]
XX,PT,BOOLE          NO  [SYSTEM DEFAULT, PT]
XX,TU,TRI          1 [SYSTEM DEFAULT, TU]
TB,FP,WHOLE           1 FIRST BINS TO PRINT
TB,LP,WHOLE          64 LAST BIN TO PRINT
TB,SK,WHOLE           6 SKIP INTERVAL BETWEEN BINS
TB,DT,BOOLE         YES  DIAGNOSTIC TAB MODE
DU,TD,BOOLE          NO  TOGGLE USE OF DUMMY DATA
XX,PN,WHOLE           0 [SYSTEM DEFAULT, PN]
DR,SD,WHOLE           3 Second recording drive
DR,PD,WHOLE           3 First recording drive (1=A:,2=B: ... )
DP,PX,BOOLE          NO  Profiler does XYZE transform
SS,LC,TENTHS         5.0 Limit of Knots change
SS,NW,TENTHS          0.5 Weight of new knots of value
GC,GM,TRI           2 GRAPHICS CONTROL 0=LO RES, 1=HI RES, 2=ENHANCED
AD,PS,BOOLE          YES  YES=SERIAL/NO=PARALLEL Profiler Link
```

```
XX,LNN,BOOLE        YES  [SYSTEM DEFAULT, LNN]
XX,BM,BOOLE         YES  [SYSTEM DEFAULT, BM]
XX,RSD,BOOLE         NO  RECORD STANDARD DEVIATION OF VELOCITIES PER BIN
XX,DRV,WHOLE          0 [SYSTEM DEFAULT, DRV]
XX,PBD,WHOLE          3 [SYSTEM DEFAULT, PBD]
TB,RS,BOOLE         NO  SHOW RHPT STATISTIC
UX,EE,BOOLE        YES  ENABLE EXIT TO EXTERNAL PROGRAM
SS,VSC,TRI         0 Velocity scale adjustment
AD,DM,BOOLE         YES  USE DMA
TB,SC,BOOLE         NO  SHOW CTD DATA
AD,CW,BOOLE          NO  Collect spectral width
DR,RW,BOOLE          NO  Record average SP.W./Bin
DR,RRD,BOOLE          NO  Record last raw dopplers
DR,RRA,BOOLE          NO  Record last raw AGC
DR,RRW,BOOLE           NO  Record last SP.W.
DR,R3,BOOLE         NO  Record average 3-Beam solutions
DR,RBS,BOOLE         YES  Record beam statistic
XX,STD,BOOLE         NO  [SYSTEM DEFAULT, STD]
LR,HB,HUNDREDTHS     0.00 Heading Bias
SL,1,ARRAY5     1   1   8   NONE 19200  PROFILER
SL,2,ARRAY5     0   1   8   NONE  1200  LORAN RECEIVER
SL,3,ARRAY5     3   2   8   NONE  4800  REMOTE DISPLAY
SL,4,ARRAY5     2   1   8   NONE  9600  ENSEMBLE OUTPUT
SL,5,ARRAY5     0   1   8   NONE  1200  AUX 1
SL,6,ARRAY5     0   1   8   NONE  1200  AUX 2
DU,1,ARRAY6    100.00   100.00   60.00    0.00    0.00 YES D1
DU,2,ARRAY6   -100.00  -100.00   60.00    0.00    0.00 YES D2
DU,3,ARRAY6    200.00   200.00   60.00    0.00    0.00 YES D3
DU,4,ARRAY6   -200.00  -200.00   60.00    0.00    0.00 YES D4
DU,5,ARRAY6    200.00    19.00   60.00    0.00    0.00 YES AGC
DU,6,ARRAY6      0.00     0.00   60.00    0.00    0.00 NO  SP. W.
DU,7,ARRAY6      0.00     0.00   60.00    0.00    0.00 NO  ROLL
DU,8,ARRAY6      0.00     0.00   60.00    0.00    0.00 NO  PITCH
DU,9,ARRAY6      0.00     0.00   60.00    0.00    0.00 NO  HEADING
DU,10,ARRAY6     0.00     0.00   60.00    0.00    0.00 NO  TEMPERATURE
CI,1,SPECIAL "DISCOVERY 240" CRUISE ID GOES HERE
LR,1,SPECIAL " " LORAN FILE NAME GOES HERE
```

Table 13b VMADCP Bottom track configuration

```
AD,SI,HUNDREDTHS   120.00 Sampling interval
AD,NB,WHOLE          64 Number of Depth Bins
AD,BL,WHOLE           3 Bin Length
AD,PL,WHOLE           8 Pulse Length
AD,BK,TENTHS         4.0 Blank Beyond Transmit
AD,PE,WHOLE           1 Pings Per Ensemble
AD,PC,HUNDREDTHS      1.00 Pulse Cycle Time
AD,PG,WHOLE          25 Percent Pings Good Threshold
XX,OD2,WHOLE           5 [SYSTEM DEFAULT, OD2]
XX,TE,HUNDREDTHS     0.00 [SYSTEM DEFAULT, TE]
AD,US,BOOLE         YES  Use Direct Commands on StartUp
DP,TR,BOOLE          NO  Toggle roll compensation
DP,TP,BOOLE          NO  Toggle Pitch compensation
DP,TH,BOOLE         YES  Toggle Heading compensation
DP,VS,BOOLE         YES  Calculate Sound Velocity from TEMP/Salinity
DP,UR,BOOLE          NO  Use Reference Layer
DP,FR,WHOLE           6 First Bin for reference Layer
DP,LR,WHOLE          15 Last Bin for reference Layer
DP,BT,BOOLE         YES  Use Bottom Track
DP,B3,BOOLE          NO  Use 3 Beam Solutions
DP,EV,BOOLE         YES  Use Error Velocity as Percent Good Criterion
DP,ME,TENTHS        150.0 Max. Error Velocity for Valid Data (cm/sec)
DR,RD,BOOLE          YES  Recording on disk
DR,RX,BOOLE          YES  Record N/S (FORE/AFT) Vel.
DR,RY,BOOLE          YES  Record E/W (FORT/STBD) Vel.
DR,RZ,BOOLE          YES  Record vertical vel.
DR,RE,BOOLE          YES  Record error Good
DR,RB,BOOLE           NO  Bytes of user prog. buffer
DR,RP,BOOLE          YES  Record Percent good
DR,RA,BOOLE          YES  Record average AGC/Bin
DR,RN,BOOLE          YES  Record Ancillary data
DR,AP,BOOLE           NO  Auto-ping on start-up
XX,LDR,TRI          3 [SYSTEM DEFAULT, LDR]
XX,RB2,WHOLE           0 [SYSTEM DEFAULT, RB2]
DR,RC,BOOLE           NO  Record CTD data
XX,FB,WHOLE            1 [SYSTEM DEFAULT, FB]
XX,PU,BOOLE           NO  [SYSTEM DEFAULT, PU]
GC,TG,TRI           1 DISPLAY (NO/GRAPH/TAB)
GC,ZV,WHOLE             1 ZERO VELOCITY REFERENCE (S/B/M/L)
GC,VL,WHOLE         -100 LOWEST VELOCITY ON GRAPH
CG,VH,WHOLE          100 HIGHEST VELOCITY ON GRAPH
GC,DL,WHOLE            0 LOWEST DEPTHS ON GRAPH
GC,DH,WHOLE          500 HIGHEST DEPTHS ON GRAPH
GC,SW,BOOLE           NO  SET DEPTHS WINDOW TO INCLUDE ALL BINS
GC,MP,WHOLE           25 MINIMUM PERCENT GOOD TO PLOT
SG,PNS,BOOLE         YES  PLOT NORTH/SOUTH VEL.
SG,PEW,BOOLE          YES  PLOT EAST/WEST VEL.
```

```
SG,PVT,BOOLE         YES  PLOT VERTICAL VEL.
SG,PEV,BOOLE         YES  PLOT ERROR VEL.
SG,PPE,BOOLE          NO  PLOT PERCENT ERROR
SG,PMD,BOOLE          NO  PLOT MAG AND DIR
SG,PSW,BOOLE          NO  PLOT AVERAGE SP. W.
SG,PAV,BOOLE         YES  PLOT AVERAGE AGC.
SG,PPG,BOOLE         YES  PLOT PERCENT GOOD
SG,PD1,BOOLE          NO  PLOT DOPPLER 1
SG,PD2,BOOLE          NO  PLOT DOPPLER 2
SG,PD3,BOOLE          NO  PLOT DOPPLER 3
SG,PD4,BOOLE          NO  PLOT DOPPLER 4
SG,PW1,BOOLE          NO  PLOT SP. W. 1
SG,PW2,BOOLE          NO  PLOT SP. W. 2
SG,PW3,BOOLE          NO  PLOT SP. W. 3
SG,PW4,BOOLE          NO  PLOT SP. W. 4
SG,PA1,BOOLE          NO  PLOT AGC 1
SG,PA2,BOOLE          NO  PLOT AGC 2
SG,PA3,BOOLE          NO  PLOT AGC 3
SG,PA4,BOOLE          NO  PLOT AGC 4
SG,PP3,BOOLE          NO  PLOT 3-BEAM SOLUTION
SS,OD,WHOLE           13 OffSet for Depth
SS,OH,TENTHS         0.0 OffSet for Heading
SS,OP,TENTHS         0.0 OffSet for Pitch
SS,ZR,TENTHS         0.0 OffSet for Roll
SS,OT,HUNDREDTHS     45.00 OffSet FOR temp
SS,ST,HUNDREDTHS     50.00 Scale for Temp
SS,SL,HUNDREDTHS     35.00 Salinity (PPT)
SS,UD,BOOLE          YES  Toggle UP/DOWN
SS,CV,BOOLE           NO  Toggle concave/Convex  transducerhead
SS,MA,TENTHS         30.0 Mounting angle for transducers.
SS,SS,HUNDREDTHS   1500.00 Speed of Sound (m/sec)
XX,GP,BOOLE          YES  [SYSTEM DEFAULT, GP]
XX,DD,TENTHS         1.0 [SYSTEM DEFAULT, DD]
XX,PT,BOOLE           NO  [SYSTEM DEFAULT, PT]
XX,TU,TRI          1 [SYSTEM DEFAULT, TU]
TB,FP,WHOLE            1 FIRST BINS TO PRINT
TB,LP,WHOLE           64 LAST BIN TO PRINT
TB,SK,WHOLE            6 SKIP INTERVAL BETWEEN BINS
TB,DT,BOOLE          YES  DIAGNOSTIC TAB MODE
DU,TD,BOOLE           NO  TOGGLE USE OF DUMMY DATA
XX,PN,WHOLE            0 [SYSTEM DEFAULT, PN]
DR,SD,WHOLE            3 Second recording drive
DR,PD,WHOLE            3 First recording drive (1=A:,2=B: ... )
DP,PX,BOOLE           NO  Profiler does XYZE transform
SS,LC,TENTHS         5.0 Limit of Knots change
SS,NW,TENTHS         0.5 Weight of new knots of value
GC,GM,TRI            2 GRAPHICS CONTROL 0=LO RES, 1=HI RES, 2=ENHANCED
AD,PS,BOOLE          YES  YES=SERIAL/NO=PARALLEL Profiler Link
XX,LNN,BOOLE         YES  [SYSTEM DEFAULT, LNN]
XX,BM,BOOLE          YES  [SYSTEM DEFAULT, BM]
XX,RSD,BOOLE          NO  RECORD STANDARD DEVIATION OF VELOCITIES PER BIN
XX,DRV,WHOLE           0 [SYSTEM DEFAULT, DRV]
```

```
XX,PBD,WHOLE          3 [SYSTEM DEFAULT, PBD]
TB,RS,BOOLE         NO  SHOW RHPT STATISTIC
UX,EE,BOOLE         YES  ENABLE EXIT TO EXTERNAL PROGRAM
SS,VSC,TRI          0 Velocity scale adjustment
AD,DM,BOOLE         YES  USE DMA
TB,SC,BOOLE         NO  SHOW CTD DATA
AD,CW,BOOLE          NO  Collect spectral width
DR,RW,BOOLE          NO  Record average SP.W./Bin
DR,RRD,BOOLE          NO  Record last raw dopplers
DR,RRA,BOOLE          NO  Record last raw AGC
DR,RRW,BOOLE          NO  Record last SP.W.
DR,R3,BOOLE         NO  Record average 3-Beam solutions
DR,RBS,BOOLE         YES  Record beam statistic
XX,STD,BOOLE         NO  [SYSTEM DEFAULT, STD]
LR,HB,HUNDREDTHS      0.00 Heading Bias
SL,1,ARRAY5    1   1   8   NONE 19200  PROFILER
SL,2,ARRAY5    0   1   8   NONE  1200  LORAN RECEIVER
SL,3,ARRAY5    3   2   8   NONE  4800  REMOTE DISPLAY
SL,4,ARRAY5    2   1   8   NONE  9600  ENSEMBLE OUTPUT
SL,5,ARRAY5    0   1   8   NONE  1200  AUX 1
SL,6,ARRAY5    0   1   8   NONE  1200  AUX 2
DU,1,ARRAY6    100.00   100.00   60.00    0.00    0.00 YES D1
DU,2,ARRAY6   -100.00  -100.00   60.00    0.00    0.00 YES D2
DU,3,ARRAY6    200.00   200.00   60.00    0.00    0.00 YES D3
DU,4,ARRAY6   -200.00  -200.00   60.00    0.00    0.00 YES D4
DU,5,ARRAY6    200.00    19.00   60.00    0.00    0.00 YES AGC
DU,6,ARRAY6      0.00    0.00   60.00    0.00    0.00 NO  SP. W.
DU,7,ARRAY6      0.00    0.00   60.00    0.00    0.00 NO  ROLL
DU,8,ARRAY6      0.00    0.00   60.00    0.00    0.00 NO  PITCH
DU,9,ARRAY6      0.00    0.00   60.00    0.00    0.00 NO  HEADING
DU,10,ARRAY6     0.00    0.00   60.00    0.00    0.00 NO  TEMPERATURE
DC,1,SPECIAL  "FH00001" MACRO  1
CI,1,SPECIAL "DISCOVERY 242" CRUISE ID GOES HERE
LR,1,SPECIAL " " LORAN FILE NAME GOES HERE
```

Table 14 Summary of three VMADCP bottom track calibrations

| Run | smg knots | Sd u,v | Heading | Duration mins | A | Phi | Sd phi |
|---|---|---|---|---|---|---|---|
| 1. English Channel | 6 | 11.4, 3.9 | 270 | 60 | 0.9981 | 3.8 | 2.2 |
| 2. Irish Sea | 12 | 19.4, 18.0 | 355 | 60 | 1.0005 | 4.1 | 3.3 |
| 3. The Minch | 11.5 | 16.2, 17.7 | 178 | 120 | 1.0044 | 3.6 | 3.9 |

where smg is speed made good (i.e. speed over ground), Sd u,v is the standard deviation of smg over the duration of the calibration run.

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Table 15 Velocity differences (VMADCP - LADCP) in cm/s on the Scotland to Iceland section

| CTD Cast No. | U diff mean | st.dev | V diff mean | st.dev |
|---|---|---|---|---|
| 13636 | 6.1 | 1.0 | 7.1 | 1.1 |
| 13637 | 1.2 | 1.1 | 2.0 | 0.8 |
| 13638 | 0.8 | 1.0 | 1.2 | 0.9 |
| 13639 | 3.3 | 1.3 | 5.9 | 1.3 |
| 13640 | 6.4 | 1.7 | 1.3 | 2.2 |
| 13641 | 3.3 | 1.7 | 0.1 | 1.7 |
| 13642 | -0.62 | 0.9 | -0.6 | 1.4 |
| 13643 | -0.1 | 1.8 | 0.4 | 2.1 |
| 13644 | 0.5 | 4.4 | 9.9 | 3.4 |
| 13645 | 2.3 | 1.6 | 7.7 | 3.3 |
| 13646 | 2.5 | 1.5 | -2.4 | 1.1 |
| 13647 | 1.9 | 1.6 | 1.1 | 2.1 |
| 13648 | -0.4 | 1.5 | -0.1 | 1.8 |
| 13649 | -0.1 | 1.7 | 3.5 | 1.9 |
| 13650 | 2.4 | 1.5 | 0.7 | 0.9 |
| 13651 | 3.1 | 1.7 | -1.7 | 1.3 |
| 13652 | 2.7 | 2.8 | 3.7 | 2.0 |
| 13653 | 0.2 | 1.8 | 3.8 | 1.2 |
| 13655 | -13.0 | 4.6 | -21.0 | 4.5 |
| 13658 | 3.8 | 3.1 | 7.1 | 1.0 |
| 13659 | 9.6 | 2.3 | 3.1 | 2.7 |
| 13660 | 4.0 | 1.5 | -2.5 | 2.4 |
| 13661 | -10.3 | 2.0 | 1.6 | 1.4 |
| 13664 | -0.7 | 1.8 | -5.9 | 0.8 |
| 13665 | -2.7 | 1.2 | -0.5 | 1.1 |
| 13666 | 2.0 | 0.6 | 2.5 | 0.8 |
| 13667 | 1.6 | 1.3 | -0.6 | 0.5 |
| 13668 | 6.9 | 1.1 | 1.1 | 2.5 |
| 13669 | 0.7 | 1.3 | 2.3 | 1.4 |
| 13670 | 12.3 | 1.7 | 12.2 | 1.6 |
| 13671 | 2.7 | 0.8 | 5.3 | 0.8 |
| 13672 | -1.0 | 6.7 | 9.8 | 3.2 |
| 13673 | -4.8 | 1.8 | 0.3 | 2.2 |
| 13674 | 11.0 | 1.3 | 2.5 | 1.6 |
| 13675 | 3.6 | 1.6 | 3.2 | 1.3 |
| 13676 | 1.1 | 1.5 | 1.1 | 1.1 |
| **Full Section** | 2.2 | 4.7 | 2.1 | 4.4 |

Table 16 Summary of BRIDGET deployment - times and positions

| Dep | num | JDAY | START time hhmm | lat ddmm | lon ddmm | END time hhmm | lat | lon | dtime hhmm |
|---|---|---|---|---|---|---|---|---|---|
| trial | | 258 | 0627 | 59.12' | 17°54' | 1011 | 59°04' | 17°45' | 03 44 |
| S/T | 13697 | 266 | 0401 | 61°40' | 11°44' | 1517 | 61°23' | 10°57' | 11 16 |
| S | 13701 | 268 | 0243 | 61°22' | 11°01' | 2312 | 62°07' | 09°25' | 20 55 |
| P | 13716 | 270 | 1416 | 61°20' | 08°55' | 2130 | 61°26' | 08°26' | 07 15 |

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Table 17 Working nutrient standard concentrations

| Standard | Silicate (µmol l-1) | Nitrate (µmol l-1) | Phosphate (µmol l-1) |
|---|---|---|---|
| | 13631 - 13743 | 13631 - 13743 | 13631 - 13743 |
| S1 | 39.99 | 40.12 | 2.006 |
| S2 | 30.03 | 30.14 | 1.507 |
| S3 | 19.97 | 20.03 | 1.002 |
| S4 | 9.97 | 10.01 | 0.500 |

Table 18 Standard deviation of duplicate and repeat firing sample salinity differences

| | No. of duplicates | Standard deviation of salinity differences |
|---|---|---|
| Duplicates | 235 | 0.00052 |
| Duplicates from > 1000m | 91 | 0.00054 |
| Repeat Firings | 31 | 0.00040 |
| Repeat firings from >1000m | 28 | 0.00037 |
| All duplicates and repeats | 77 | 0.00053 |

Table 19 Location and serial numbers of meteorological instruments

| Variable | Position | Instrument/Serial No. |
|---|---|---|
| Humidity and air temp<br>(hum humt) | Port side of foremast platform | Vaisala HMP 44L s/n U1850014 |
| Shortwave<br>(ptir) | Gimbal mounted on port side of foremast platform | Kipp & Zonen CM6B s/n 994133 |
| Shortwave<br>(stir) | Gimbal mounted on stbd side of foremast platform | Kipp & Zonen CM6B s/n 994132 |
| Photosynthetically active radiation<br>(ppar) | Gimbal mounted on port side of foremast platform | Didcot DRP-5 s/n 0151 |
| Photosynthetically active radiation<br>(spar) | Stbd side of foremast platform (not gimballed) | Didcot DRP-5 s/n 1678 |
| Wind Speed & Direction<br>(ws1 wd1) | Port side of foremast platform | WAA151 Anemometer s/n s22308<br>& WAV151 Wind Vane s/n s212318 |
| SST<br>(sst1) | Hull mounted approx. 5 meters depth | PRT s/n 1340 |
| Pressure<br>(baro) | Lab | Vaisala DPA21 s/n v1420016 |
| Time | Lab | Ships clock |

Table 20 Pressure calibration for Vaisala DPA21 s/n v1420016

| Pressure (hPa) | Correction (hPa) |
|---|---|
| 811.1 | 0.1 |
| 850.6 | 0 |
| 1007.5 | 0 |
| 1059.6 | -0.1 |

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Table 21 Bottom friction estimates from best fits to the bottom log layer

| Best Line | u_(cm/s) | v_(cm/s) |
|---|---|---|
| 1 | 0.1917 | 0.6567 |
| 2 | 0.5879 | 1.5619 |
| 3 | 1.0582 | 2.4899 |
| 4 | 1.3220 | 3.0351 |
| 5 | 1.2938 | 2.9844 |

Table 22 Estimate of bottom friction velocity using the Ekman layer technique

| Best Line | u_(cm/s) | v_(cm/s) |
|---|---|---|
| 1 | 0.1917 | 0.6567 |
| 2 | 0.5879 | 1.5619 |
| 3 | 1.0582 | 2.4899 |
| 4 | 1.3220 | 3.0351 |
| 5 | 1.2938 | 2.9844 |

Contents

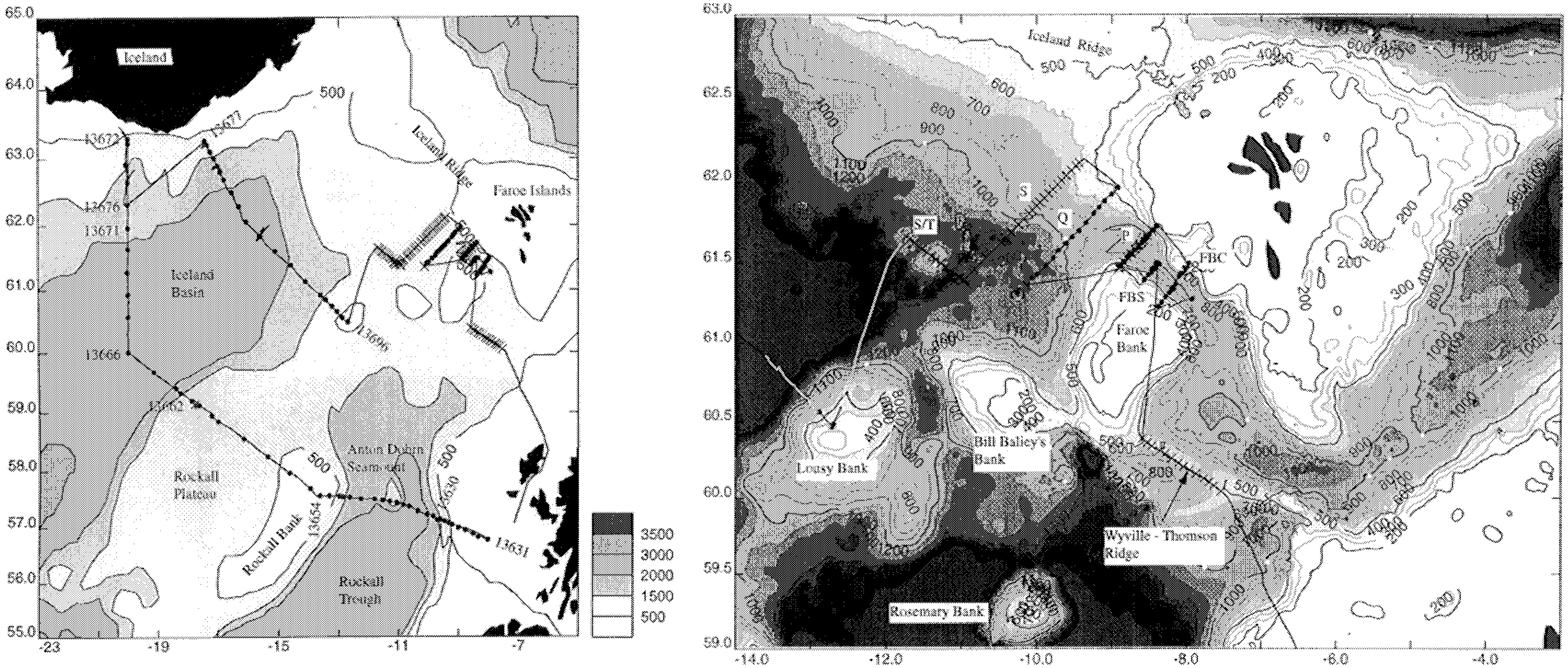


Figure 1. Cruise track for RRS Discovery Cruise 242 showing CTD stations (dots), XBT stations (crosses) and cruise track (thin black line). Bathymetry on the left hand figure is from the dbdb5 dataset, on the right hand plot is from the satellite derived bathymetry of Sandwell and Smith (1997). CTD sections and BRIDGET tows are summarised in the following list: [(Section/station Name), type, Station numbers, dirn. section taken]; [(test), CTD, 13630]; [(Scotland - Iceland), CTD, 13631 - 13676, NW]; [(south east Iceland - Lousy Bank), CTD, 13677 - 13696,SE]; [(S/T), BRIDGET, 13697, SE]; [(S/T), CTD, 13698 - 13700, NW]; [(S), BRIDGET, 13701, NE]; [(Q), CTD, 13702 - 13715, SW]; [(P), BRIDGET, 13716, NE]; [(P1), CTD, 13717 - 13727, SW]; [(FBS1), CTD, 13728 - 13731, NE]; [(FBC upstream), CTD, 13732]; [(FBC), CTD, 13733 -13743, NE]; [(P2), CTD, 13744 - 13754, SW]; [(FBS2), CTD,13755 - 13757, NE].

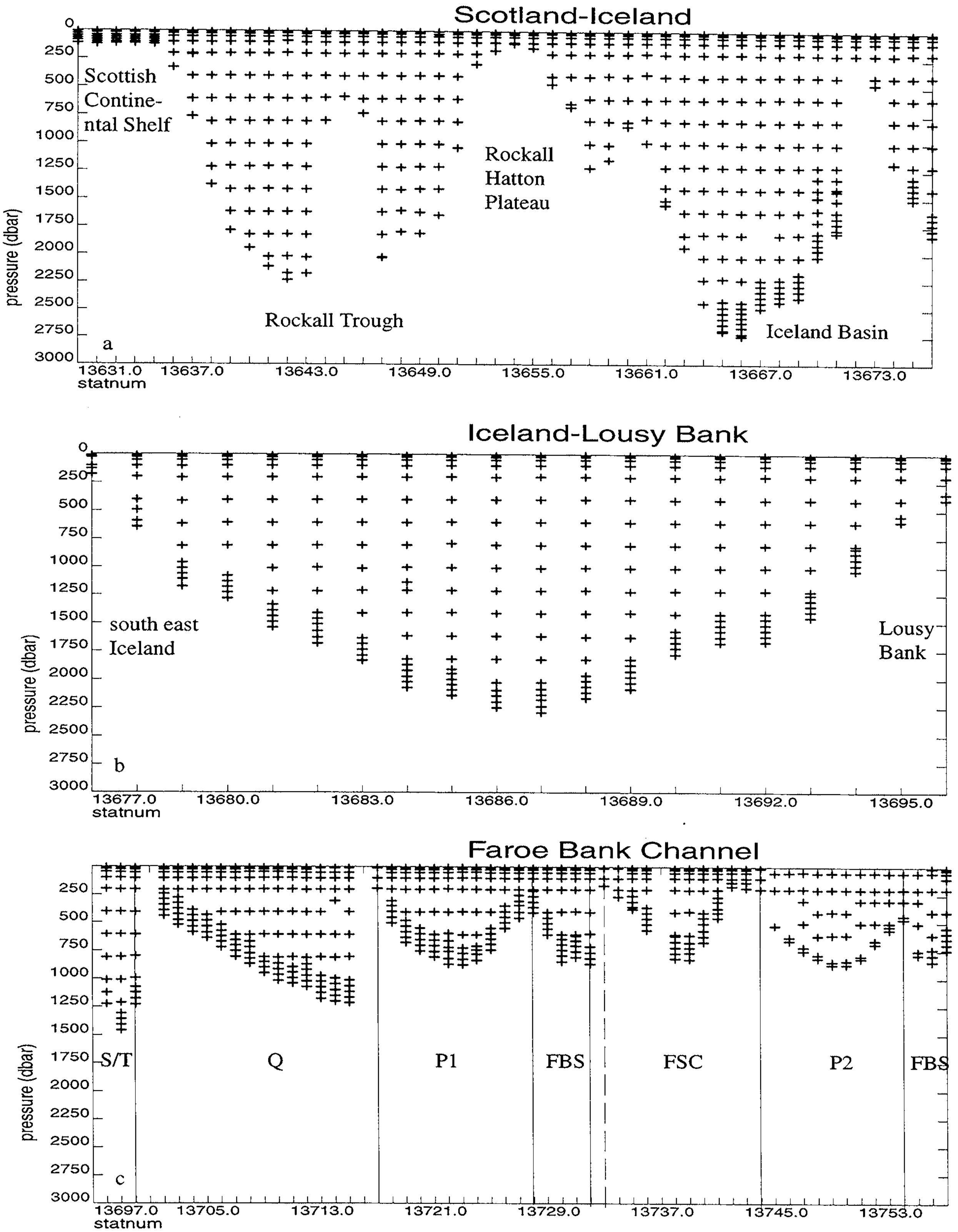


Figure 2. Distribution of water samples: a) Scotland to Iceland, test station 13630 not shown, the last five stations were completed southward from Iceland; b) south east Iceland to Lousy Bank; c) sections on the Iceland Ridge and in the Faroe Bank Channel. Section letters correspond to different sections with the station numbers listed in Table 1. The single dashed line is the upstream station taken in the Faroe Bank Channel.

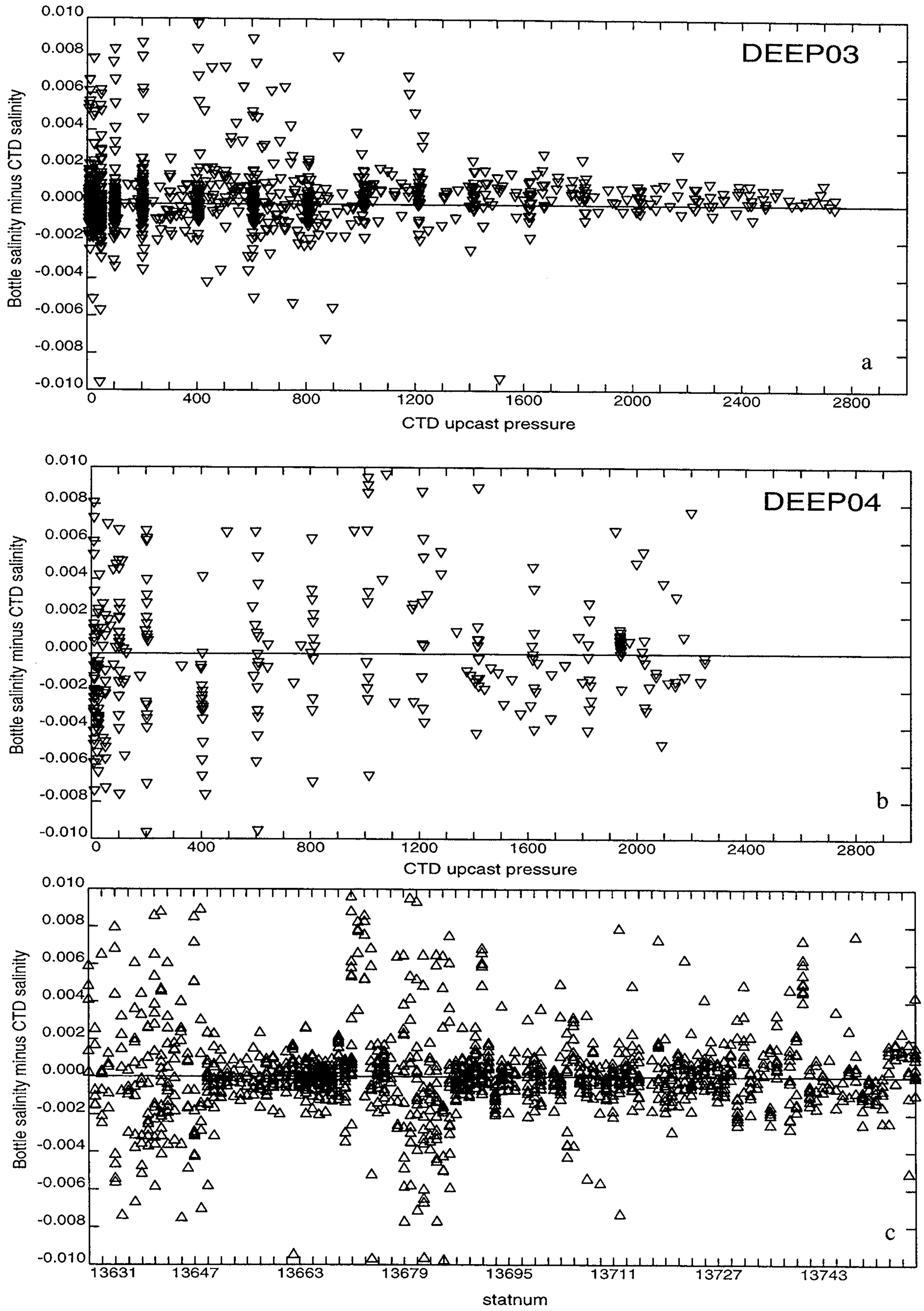
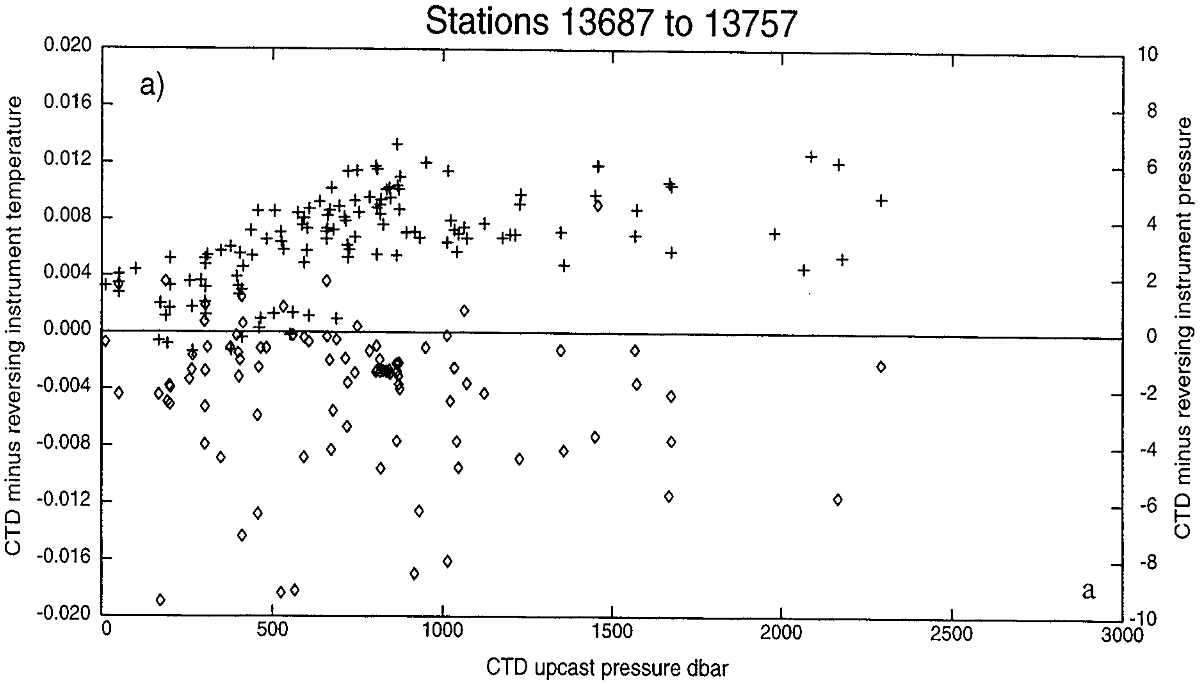


Figure 3. Salinity residuals. Bottle salinity minus CTD salinity versus: a) CTD upcast pressure for DEEP03; b) CTD upcast pressure for DEEP04; c) station number Does not include test station 13630.



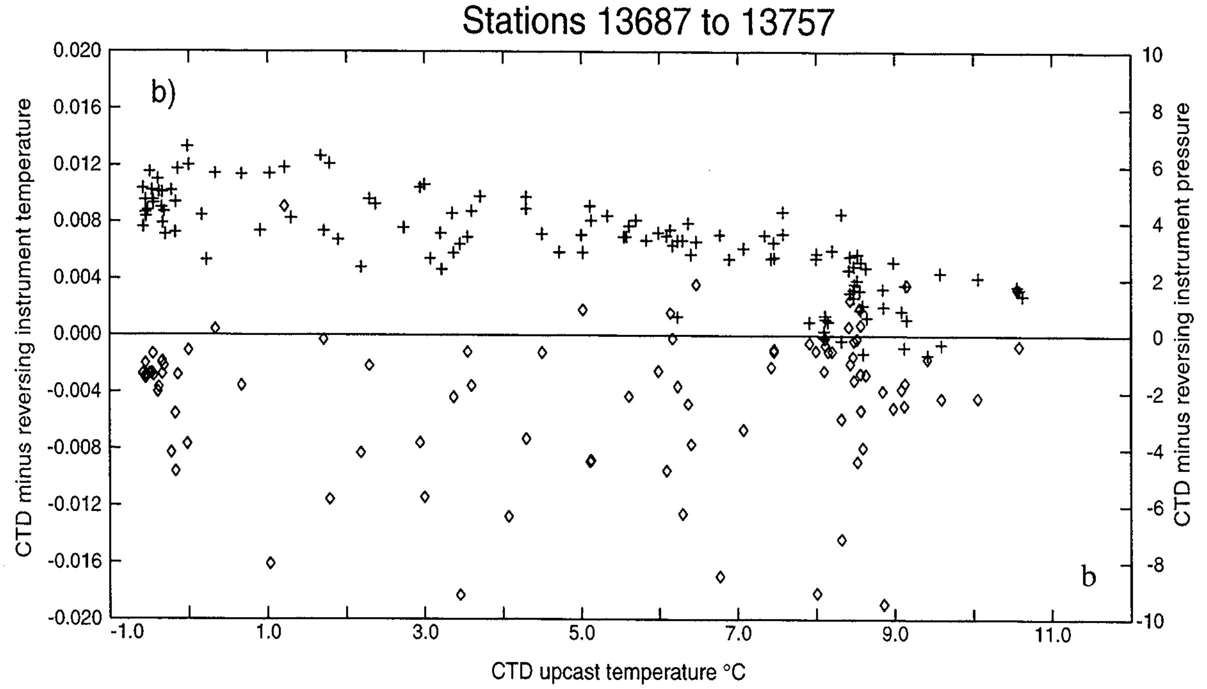


Figure 4. Differences between CTD and reversing instrument measurements, against: a) pressure and; b) temperature. All CTD data are DEEP03. Crosses are pressure residuals, diamonds are temperature residuals.

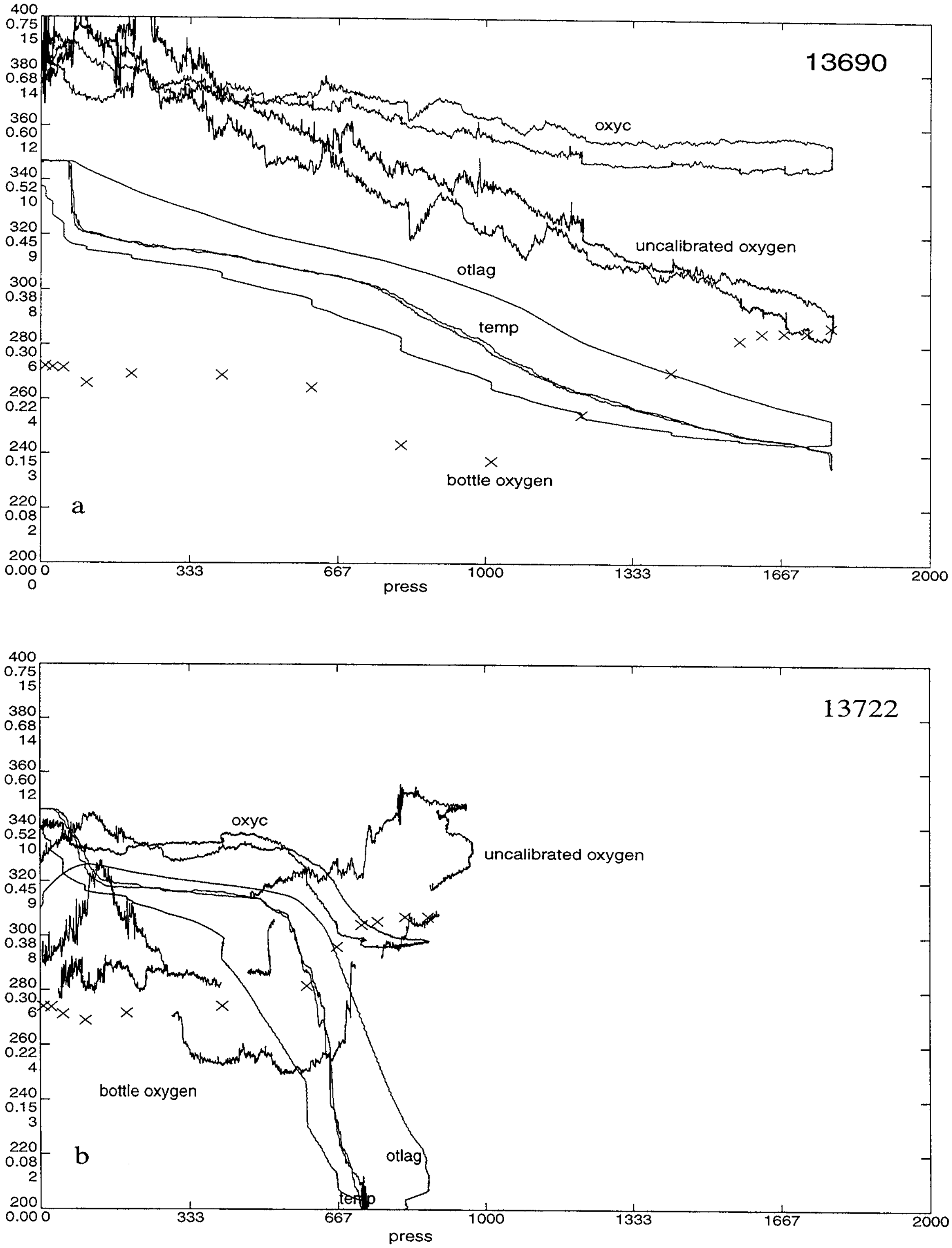


Figure 5. Contrasting oxygen data: a) station 13690 with the failed oxygen sensor for which no fit with the bottle data could be obtained; b) station 13722 with a new sensor that allowed a reasonable fit to the bottle data. The best fit CTD oxygen data are not shown.

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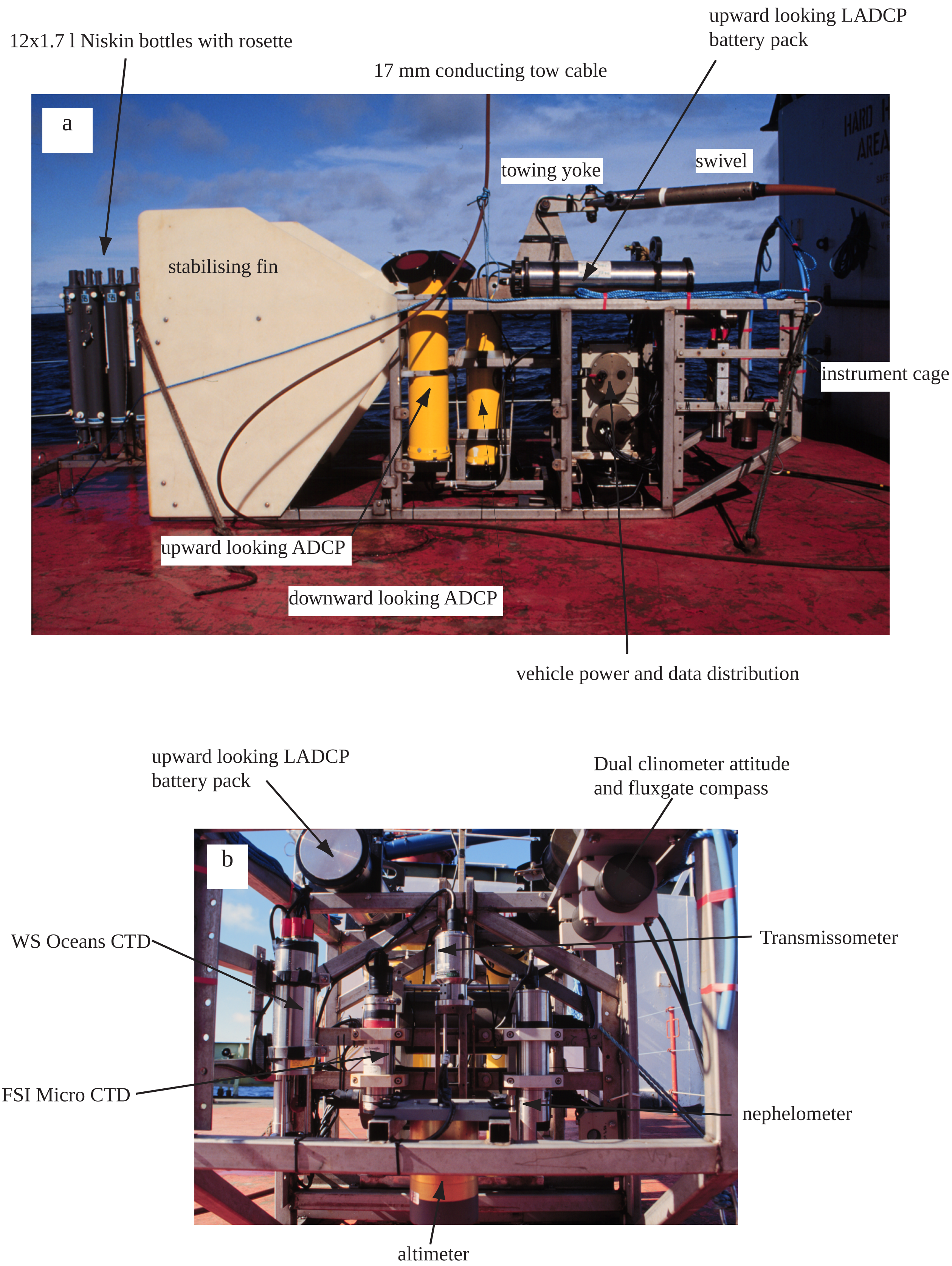
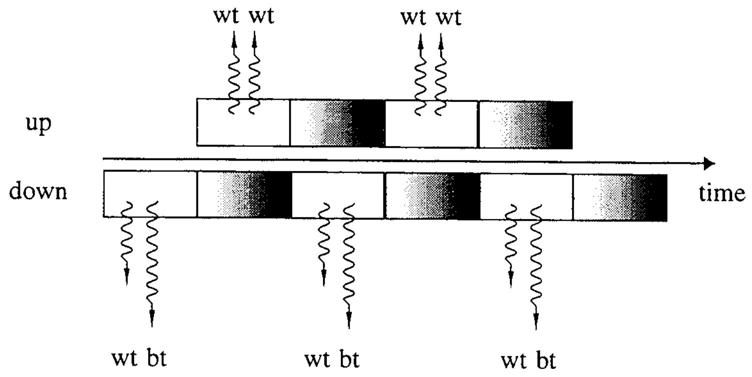


Figure 6. Photographs showing the BRIDGET vehicle and instruments: a) side view; b) front view showing instruments mounted in the nose of the vehicle.

Sections
i) Test
ii) S/T



Sections
i) S
ii) P

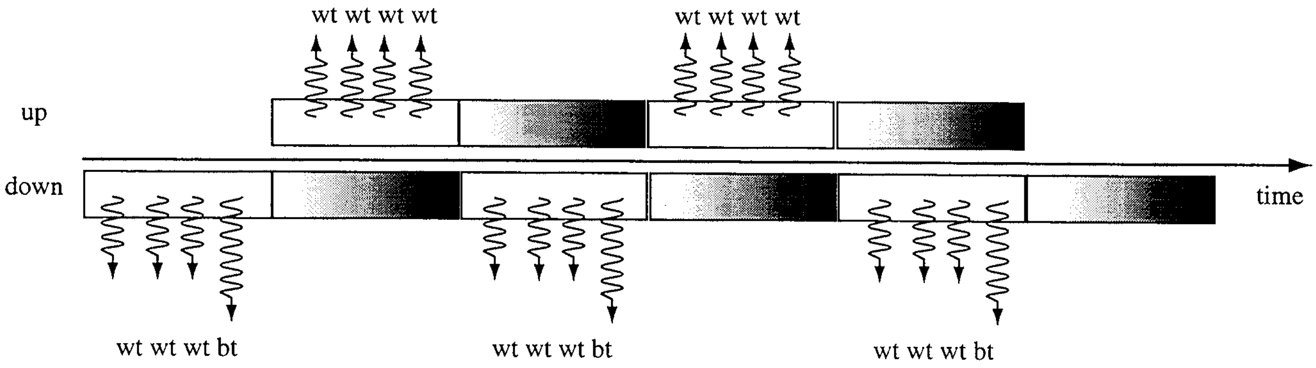


Figure 7. BRIDGET ADCP's ensemble ping configurations. An ensemble is represented by a white and a shaded box of equal length in time. For each ensemble the pings occur in the first half of the ensemble, while time in the second half is used for processing the pings. Whilst the ping processing occurs the second instrument emits its ping sequence. This timing setup could be confirmed whilst the instruments were still on deck by listening to the transducers. The upper panel shows the ensemble setup for the test BRIDGET tow and section S/T. The ensemble length is four seconds and the ensembles for the downward and upward looking ADCP's are offset by two seconds. The downward looking ADCP emits one water track and one bottom track ping per ensemble. The upward looking ADCP emits two water track pings per ensemble. The lower panel shows the ensemble setup used on sections S and P. The ensemble length is eight seconds and the ensembles are offset by four seconds. The downward looking ADCP emits three water track pings and one bottom track ping per ensemble. The upward looking ADCP emits four water track pings per ensemble.

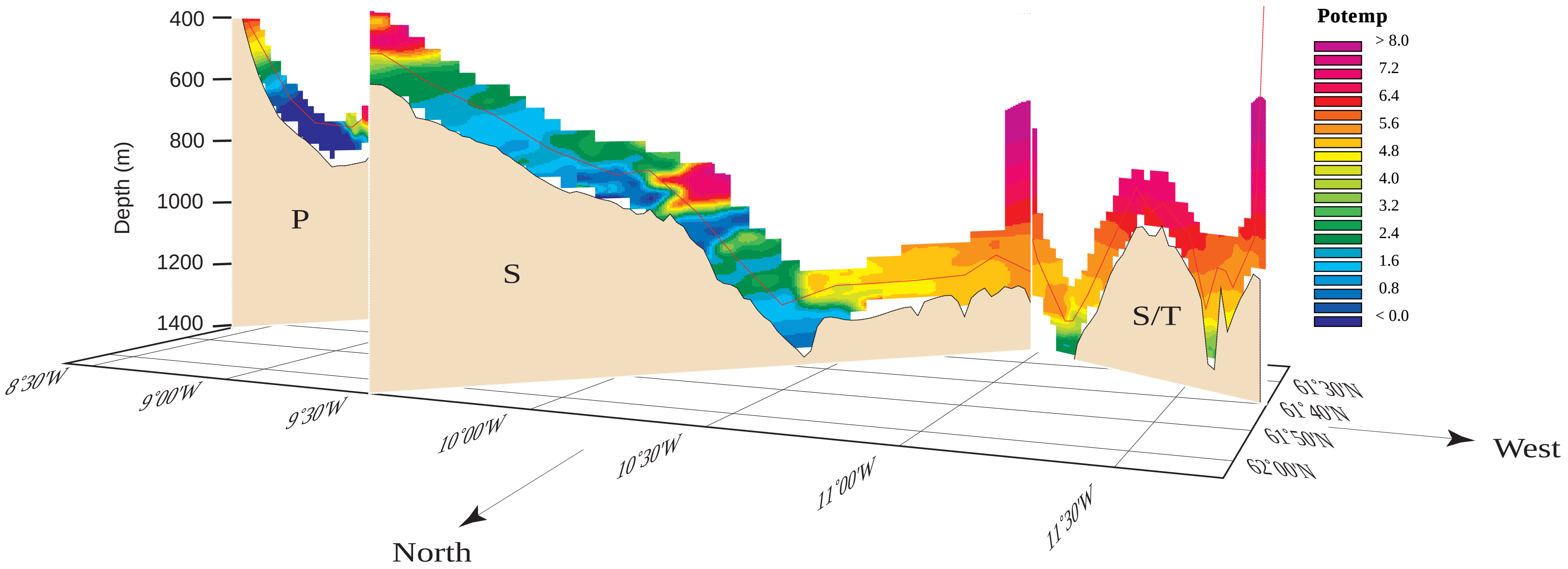


Figure 8. Three dimensional view of potential temperature measured by the CTD onboard BRIDGET. The path of BRIDGET is given by the red line and is about 100 m height off bottom throughout. The vertical excursions at the ends of section S/T and S show indicate BRIDGET deployment. On section P this is hidden.

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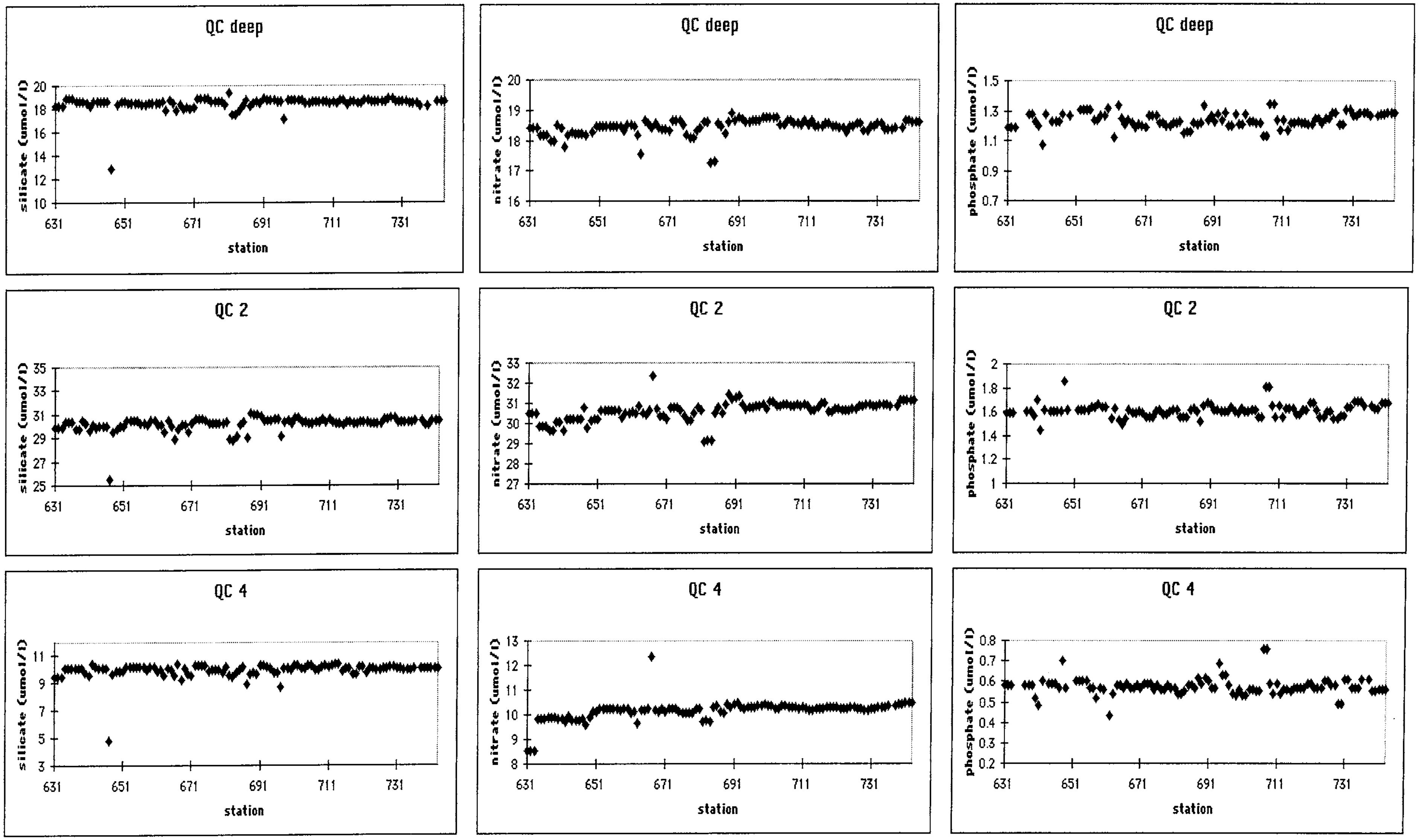

Figure 9. Silicate, Nitrate and Phospate quality control (QC) measurements. QC 2 and QC 4 samples were prepared from Ocean Scientific Instruments standard solutions with concentrations adjusted to the concentrations of the 2nd and 4th working standards. QC deep is a deep water sample drawn from approximately 1915 m on the test station (13630).

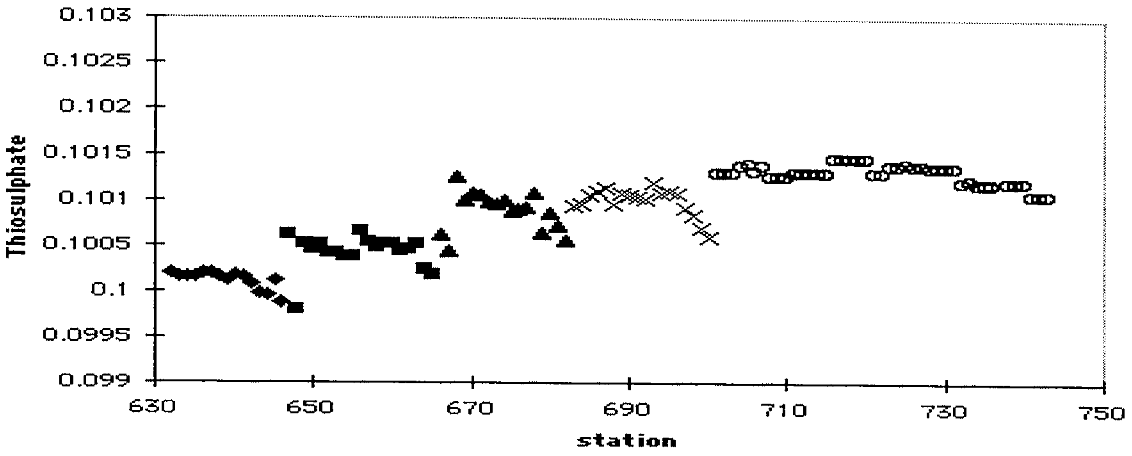

Figure 10a. Thiosulphate normality for cruise D242

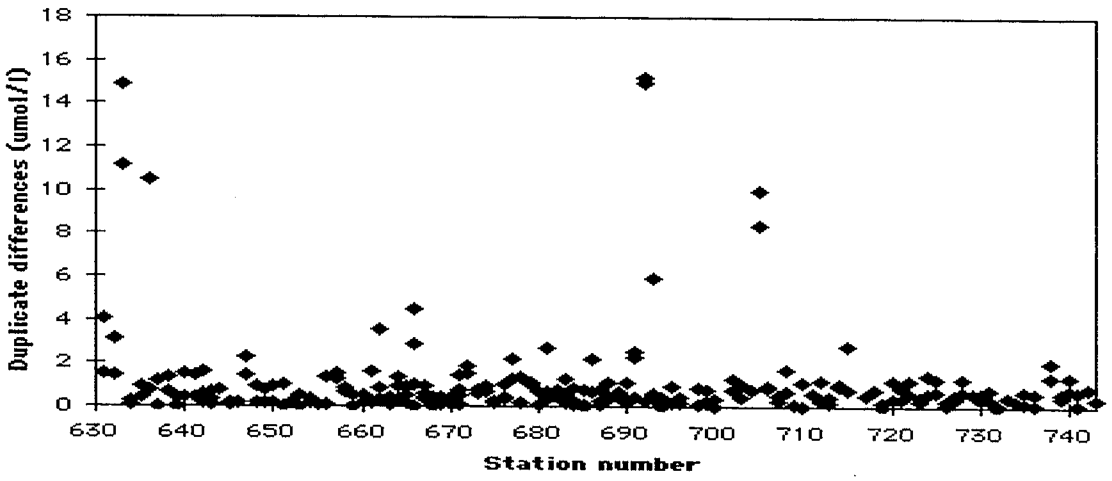

Figure 10b. Duplicate difference at each station

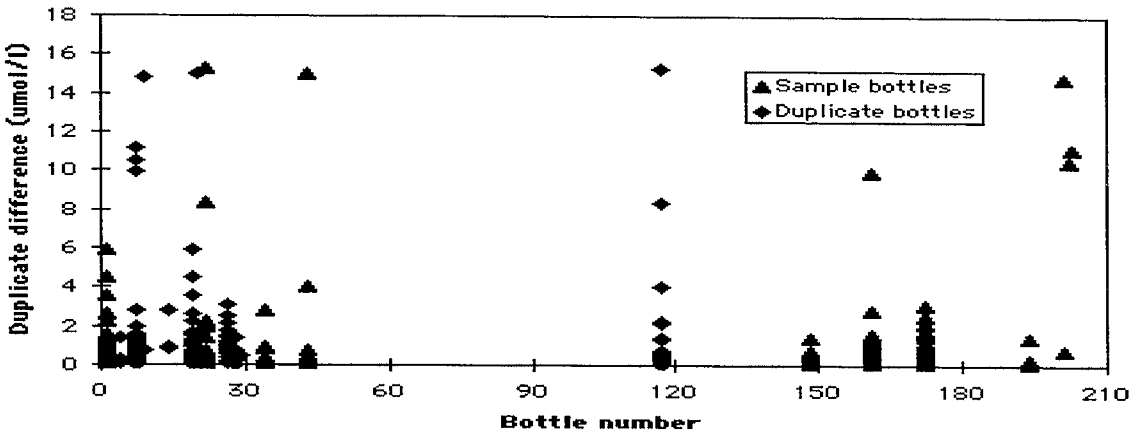

Figure 10c. Comparison of duplicate difference with bottles used

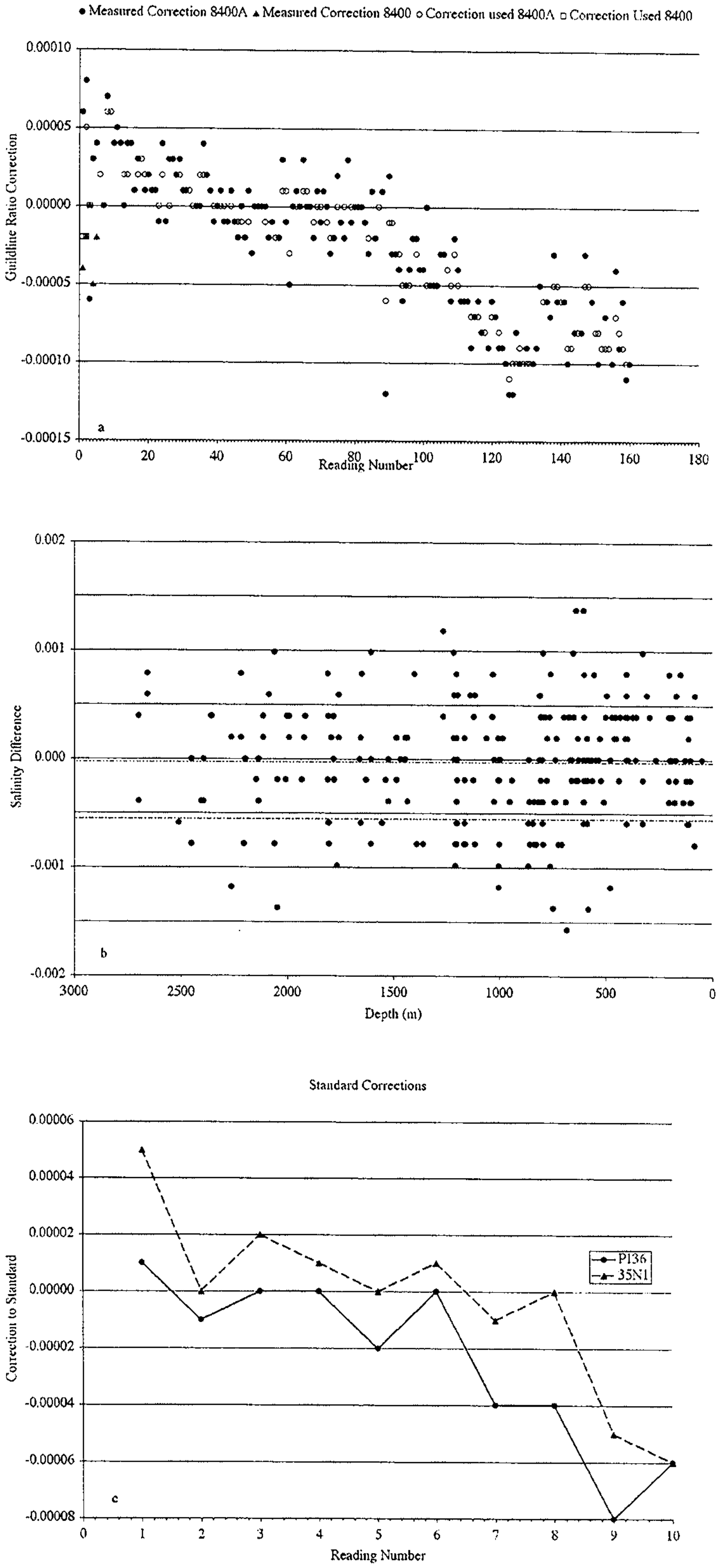

Figure 11. Analysis of standard seawater: a) correction to the Guildline ratios for SSW batch P136. Reading number is consecutive SSW number analysed; b) standard deviation of duplicate salinity samples drawn from the deepest Niskin bottle and a mid-depth Niskin bottle; c) correction to the Guildline ratios determined for the "gold top" standards batch 35N1.

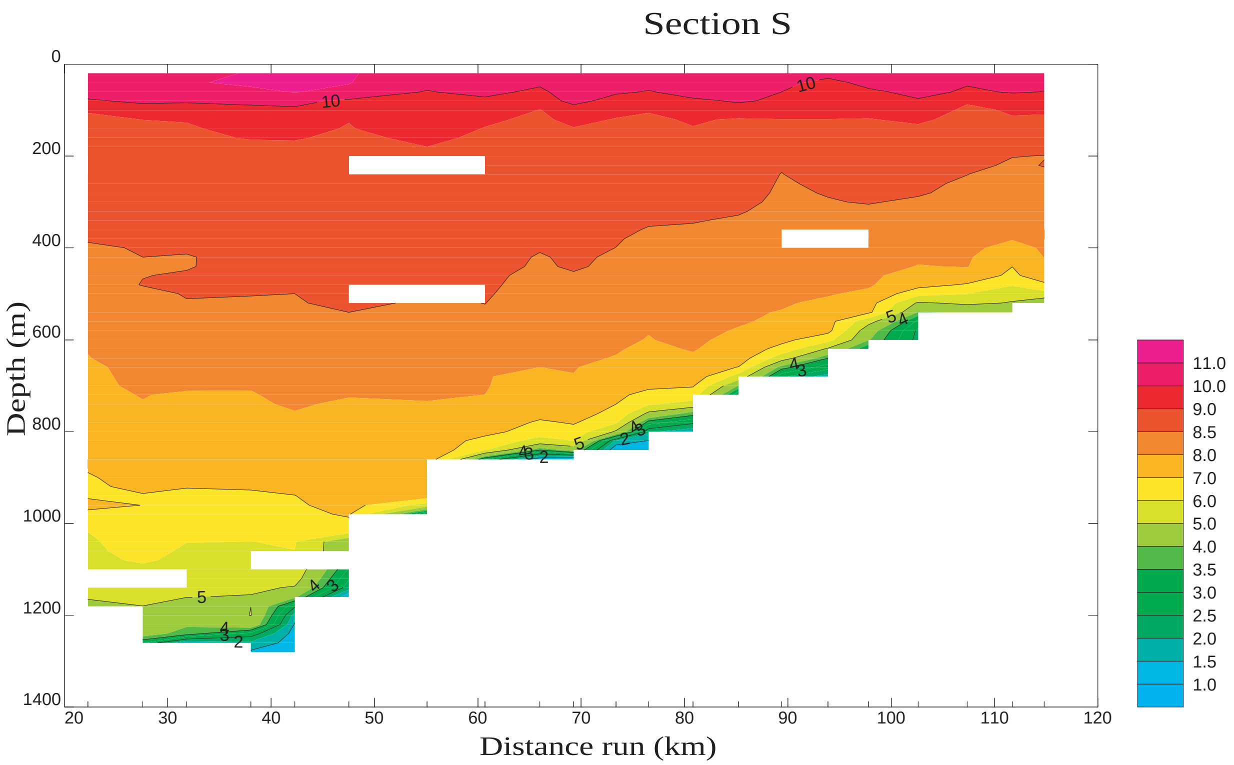

Figure 12.Temperature along section S measured by T5 XBT probes deployed at 45 minute intervals along track during a BRIDGET tow.

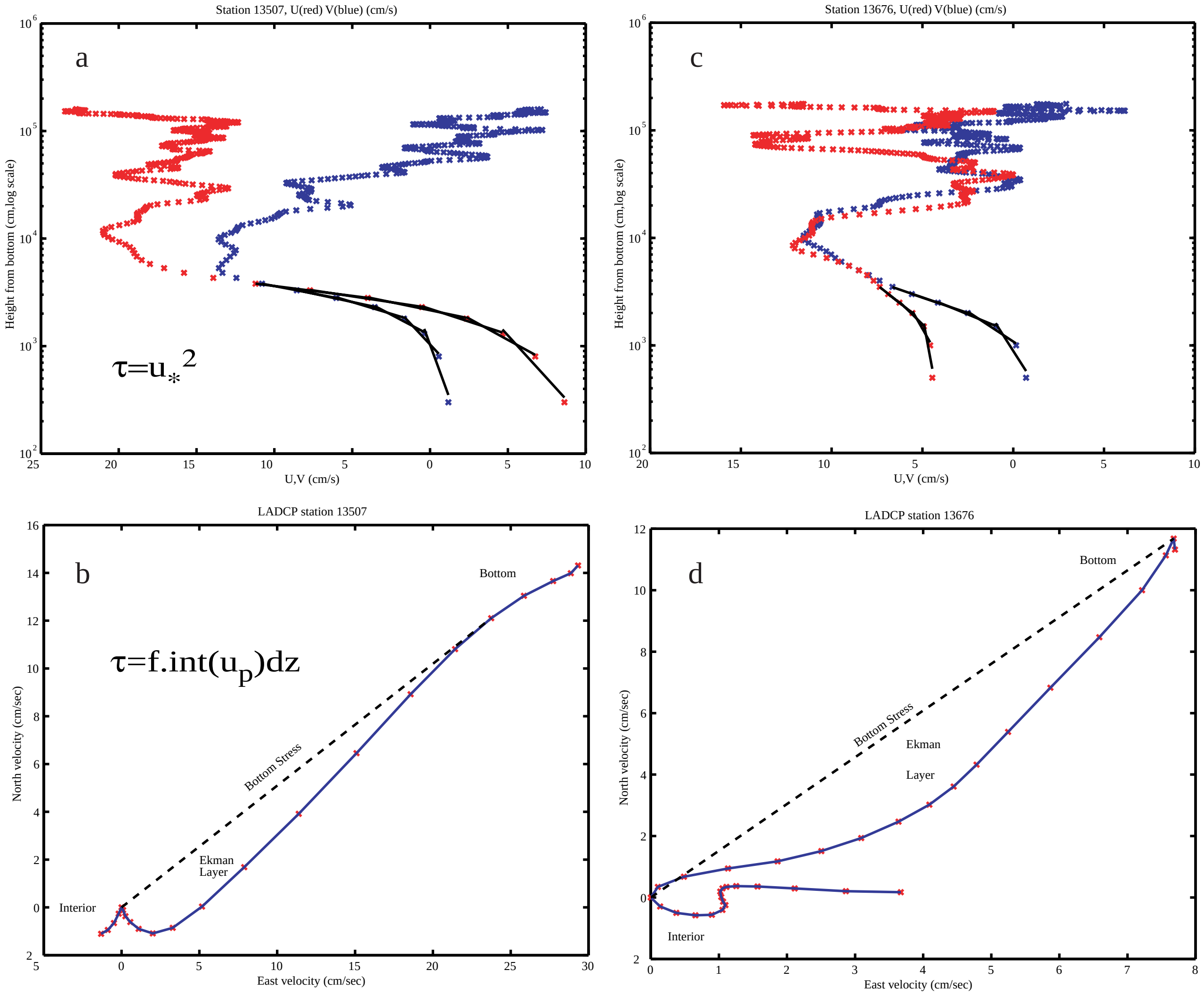

Figure 13. Estimates of bottom friction using LADCP velocities. Two methods are used: a) and c) by estimating the friction velocity in the bottom boundary layer and; b) and d) by estimating the Ekman spiral and integrating the velocity perpendicular to the core of the plume velocity: a) and b) from the CHAOS cruise in 1998; c) and d) from a station taken from this cruise.

## ACRONYNMS

| | |
|---|---|
| ADCP | Acoustic Doppler current profiler |
| BBADCP | Broad Band ADCP |
| BRIDGET | A deep tow platform |
| BST | British summer time |
| CT | Constant temperature |
| CTD | Conductivity, Temperature, Depth |
| DAPS | Data acquisition and processing system |
| DLT | Digital linear tape |
| DOY | Day of year |
| FSI | Falmouth Scientific Inc. |
| FTP | file transfer protocol |
| GMT | Greenwich mean time |
| GPS | Global positioning system |
| LADCP | Lowered ADCP |
| OSI | Ocean Scientific International |
| PC | Personal computer |
| PES | Precision echo sounder |
| QC | Quality control |
| RDI | RD Instruments |
| SCADCP | Self contained ADCP |
| TSG | Thermosalinograph |
| VMADCP | Vessel mounted ADCP |
| WHOI | Woods Hole Oceanographic Institution |
| XBT | Expendable bathythermograph |
| XCP | Expendable current profiler |

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