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Drake Passage Summary Report:
Cruises on RRS *JAMES CLARK ROSS,*
1993 - 2000

Drake Passage repeat hydrography: WOCE Southern
Repeat Section 1b – Burdwood Bank to Elephant Island

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ABSTRACT

This report documents five early cruises in the Drake Passage annual repeat series conducted by Southampton Oceanography Centre in collaboration with the British Antarctic Survey. The series began under the auspices of the World Ocean Circulation Experiment as southern repeat section SR1b with a SeaSoar (towed undulating profiler) occupation in 1992. We document cruises from 1993 (JR0a), 1994 (JR0b), 1996 (JR16), 1997 (JR27) and 2000 (JR47). The cruises were all hydrographic CTD sections across Drake Passage between Burdwood Bank and Elephant Island, comprising 30 stations. One cruise (JR27) was occupied at higher resolution with 52 stations; also additional chemical measurements were made. On two cruises (JR16 and JR27), a lowered acoustic Doppler current profiler (ADCP) was introduced to provide full-depth water velocity profiles. Other measurements (vessel-mounted ADCP, sample salinity, navigation, expendable bathythermographs, etc.) are described in context.

KEYWORDS

ADCP, ANTARCTIC CIRCUMPOLAR CURRENT, ANTARCTIC OCEAN, ACOUSTIC DOPPLER CURRENT PROFILER, CRUISE 1993-2000, CTD OBSERVATIONS, DRAKE PASSAGE, *JAMES CLARK ROSS*, LADCP, LOWERED ADCP, SOUTHERN OCEAN, VESSEL-MOUNTED ADCP, WOCE, WORLD OCEAN CIRCULATION EXPERIMENT

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Over the course of the cruises reported in this document, the scientific work was the responsibility of five Principal Investigators: Steve Alderson, Mark Brandon, Stuart Cunningham, Liz Kent and Brian King.

The PIs are grateful to the masters of the JCR, Captains Chris Elliott and Jerry Burgan, and to the ship's officers and crews, for their unfailing support.

This programme was initiated by Brian King and it is due to his technical and logistical expertise that it continues today.

1 INTRODUCTION

Sheldon Bacon

The World Ocean Circulation Experiment established a repeat hydrographic section across Drake Passage and designated it SR1. This section was occupied by the R/V *Meteor* in 1990 (Roether *et al.*, 1993). Subsequently, the section was shifted to the east in order for it to lie on a satellite ground track. The endpoints were now at the south side of Burdwood Bank, south of the Falkland Islands, and off Elephant Island at the north end of the Antarctic Peninsula. This revised section location was designated SR1b and was first occupied by the R/V *Polarstern* in 1992 (Gersonde, 1993). The first UK occupation of SR1b followed on RRS *Discovery* later the same year, and was a SeaSoar (a profiler which undulates between the surface and ~400 m) tow (Turner, 1993; Read *et al.*, 1993). Between that time and the time of writing of the present document (2005) there have been 10 UK occupations of SR1b at nearly one section per year, all on RRS *James Clark Ross*, all with full-depth CTDs and latterly with LADCP also. However, only three of the more recent occupations have been properly documented with published cruise reports. It is our intention in this report to remedy the absence of published documentation for five of the earliest occupations.

1.1 Affiliations

RRS *James Clark Ross* (JCR hereafter) is a research and logistics vessel operated by the British Antarctic Survey (BAS), and we have relied on logistical, technical and occasionally scientific support from BAS over the years. While 'we' have not essentially changed jobs in this time, our host institution has altered around us. Until 1987, that institution was the Institute of Oceanographic Sciences (IOS) based in Wormley, Surrey. After then, it was renamed IOS Deacon Laboratory (IOSDL). In 1991, in advance of the establishment of Southampton Oceanography Centre (SOC), the James Rennell Centre (JRC) was founded in a science park in the north of the city of Southampton as the lead institute for UK WOCE. In 1995, both IOSDL and JRC were subsumed into SOC. This period of organisational change covers the early years of the UK occupation of the Drake Passage SR1b section and all preceding acronyms will be used to describe the affiliations of the responsible scientists. In addition to the fundamental work by SOC and BAS, support has occasionally been received from scientists and students from the Proudman Oceanographic Laboratory (POL) at Bidston, Liverpool and the University of East Anglia (UEA) in Norwich.

1.2 UK SR1b summary

In this section, we provide a brief overview of all UK SR1b section occupations to date, listed in Table 1.1, with references for the documented cruises that will not be further described here.

As mentioned above, the first UK SR1b occupation was a SeaSoar section in November 1992 as part of RRS *Discovery* cruise 198. See Turner (1993) for an expedition overview and Read *et al.* (1993)

for a description of the SeaSoar data. All subsequent occupations of the section have been aboard the JCR. Now BAS provides scientific cruises (or projects within expeditions) with serial designators that begin with the letters JR and are followed by a serial number. Logistics (supply) legs are not provided with such a designator. Since the SR1b occupations occur in 'piggyback' mode – they constitute a brief scientific delay, usually to the first supply run to Rothera each year – they were not initially provided with such designators. In order to enable the WOCE Hydrographic Programme Office (WHPO: http://whpo.ucsd.edu/) to identify the first two JCR occupations of SR1b in November-December 1993 and November-December 1994, they were arbitrarily called JR0a and JR0b by us. For convenience, the WHPO converted these to JR00_1 and JR00_2.

Following a gap in 1995, the fourth occupation of the section was cruise JR16 in November-December 1996; the fifth was JR27 in December 1997 – January 1998. In March–April 1999, the original SR1 section was part of the 'Albatross' cruise: see Heywood and Stevens (2000). The sixth SR1b was JR47 in January 2000. The seventh occupation in November-December 2000, JR55, is reported in Cunningham (2001). The eighth and ninth occupations were carried out in November-December 2001 (JR67) and December 2002 – January 2003 (JR81) and were reported in Bacon (2002) and Bacon (2003). The reports of the tenth occupation, JR94, December 2003 – January 2004, and the eleventh occupation, JR115, December 2004, await publication. So the cruises to be reported below are JR0a, JR0b, JR16, JR27 and JR47.

There have been various short reports on the UK SR1b programme published in the 'grey' literature in recent years; these will be cited in the context of the cruises to which they refer. We note here that the main results of the programme to date have appeared in Alderson and Cunningham (1999), Cunningham *et al.* (2003), Bryden and Cunningham (2003) and Cunningham and Pavic (2005). See also Olbers *et al.* (2004) for a fine recent review. Standard station positions are presented in Table 1.2 and Figure 1.1.

1.3 Non-UK SR1b summary

For the sake of completeness, we also mention here other WOCE-era (post-1990) occupations of the section known to us. Occupations by R/V *Meteor* in 1990 and R/V *Polarstern* in 1992 are mentioned above. Additionally, there were three Spanish occupations on R/V *Hesperides* in the month of February in 1995, 1996 and 1998. Results from these sections are reported in García *et al.* (2002). There have also been regular Chilean occupations of the 'old' SR1 line from R/V *Vidal Gormaz* (ex-US *Thomas Washington*) in November-December of 1993, 1994, 1995, 1996 and 1998. Some of the data from these sections are presented in Rojas *et al.* (1998). As an interesting supplement, there has been a US programme of expendable bathythermograph (XBTs) deployments in Drake Passage since 1996. Data up to 2001 are presented in Sprintall (2003).

Year	Start date	End date	Designator	LADCP	Comments
1992	11/11/1992	17/12/1992	D198	n	SeaSoar only; cruise called *Sterna*
1993	20/11/1993	18/12/1993	JR0a	n	Designator also JR00_1
1994	13/11/1994	12/12/1994	JR0b	n	Designator also JR00_2
1996	13/11/1996	07/12/1996	JR16	y	
1997	17/12/1997	08/01/1998	JR27	y	Extra stations
1999	12/02/2000	16/02/2000	JR47	n	Odd positions
2000	21/11/2000	14/12/2000	JR55	y	
2001	19/11/2001	17/12/2001	JR67	y	
2002	18/12/2002	02/01/2003	JR81	y	
2003	27/11/2003	17/12/2003	JR94	y	
2004	01/12/2004	19/12/2004	JR115	y	Technical problems with LADCP

Table 1.1: List of UK occupations of Drake Passage section, WOCE designation SR1b.

Notes: "Year" is the year of the start of the relevant southern season. "LADCP" shows which cruises carried that instrument (y=yes, n=no), noting that the most recent occupation (JR115) experienced some technical difficulties (reported elsewhere). All occupations aimed to occupy the standard station positions, listed in Table 1.2 and shown in Figure 1.1. D198 was occupied with an undulating profiling instrument, SeaSoar, with no full-depth CTDs. Extra stations were occupied on JR27, effectively doubling the mid-Passage resolution. JR47 happened to occupy the 'geostrophic velocity' positions, ie the mid-point between the standard positions.

station number	lat °S	lat min	lon °W	lon min	nominal depth
1	61	03.00	54	35.23	400
2	60	58.86	54	37.80	600
3	60	51.02	54	42.66	1000
4	60	49.99	54	43.30	1500
5	60	47.97	54	44.55	2500
6	60	40.00	54	49.49	3100
7	60	20.00	55	01.88	
8	60	00.00	55	14.28	
9	59	40.00	55	26.67	
10	59	20.00	55	39.07	
11	59	00.00	55	51.47	
12	58	41.00	56	03.24	
13	58	22.00	56	15.02	
14	58	03.00	56	26.79	
15	57	44.00	56	38.57	
16	57	25.00	56	50.35	
17	57	06.00	57	02.12	
18	56	47.00	57	13.90	
19	56	28.00	57	25.67	
20	56	09.00	57	37.45	
21	55	50.00	57	49.23	
22	55	31.00	58	01.00	
23	55	12.86	58	12.24	3500
24	55	10.25	58	13.86	3000
25	55	07.27	58	15.71	2500
26	55	04.18	58	17.62	2000
27	54	57.66	58	21.67	1500
28	54	56.62	58	22.31	1000
29	54	55.34	58	23.10	600
30	54	40.00	58	32.61	250

Table 1.2: List of Drake Passage standard station positions, in south-to-north order; see Figure 1.1.

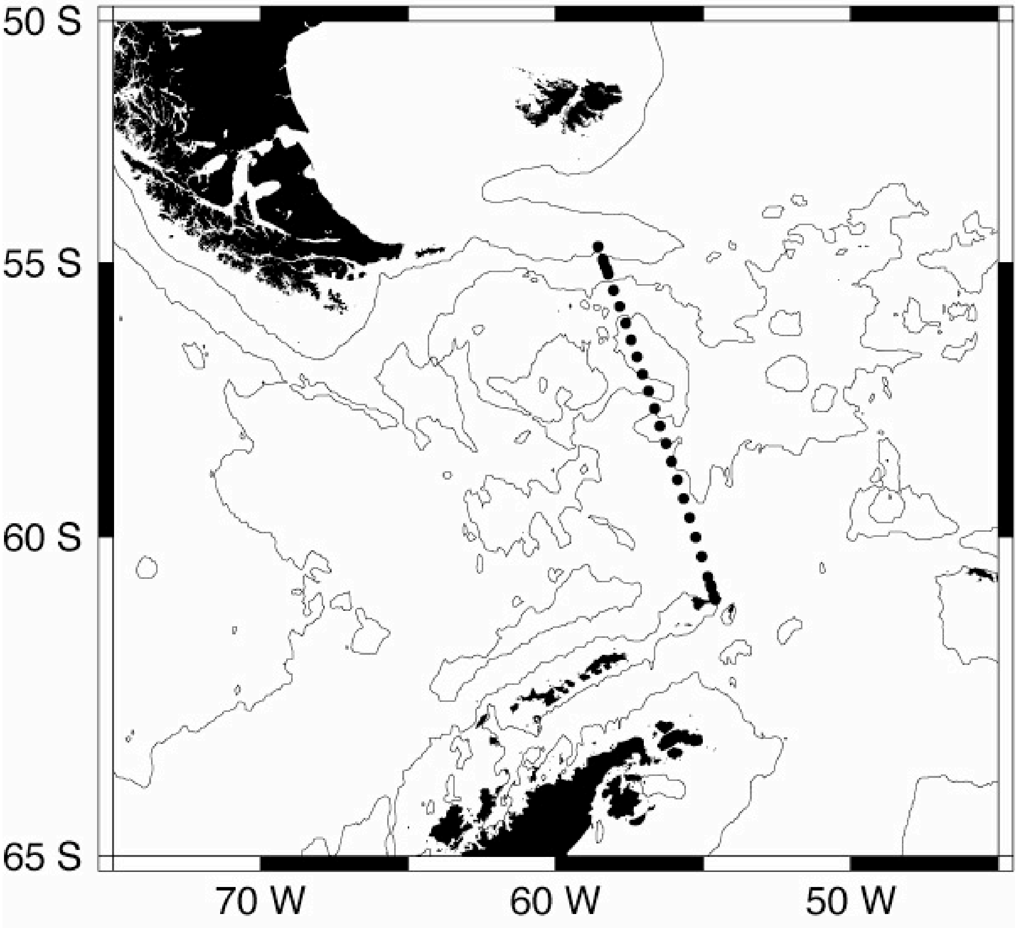

Figure 1.1: Drake Passage standard station positions, between Elephant Island in the south and Burdwood Bank in the north. Depth contours are 500 m and 4000 m.

2 JR0a, 20 Nov – 18 Dec 1993, by B A King and S G Alderson

2.1 Authors and Affiliations

Author	Affiliation
King, B. A.	IOSDL (now SOC)
Alderson, S. G.	IOSDL (now SOC)

2.2 Overview

A total of 39 CTD/rosette stations were occupied using a General Oceanics 12 bottle rosette equipped with 12 1.7-litre Niskin water sample bottles, and a NBIS Mk III CTD. No other sensors were connected to the CTD. Up to twelve salinity samples were drawn per station. A small number of reversing thermometer measurements were made. A 10 kHz pinger for near-bottom approach was mounted on the rosette frame. Apart from Digital Reversing Thermometers supplied by IOSDL, the entire underwater package was supplied by BAS. Mark Preston and Ash Johnson of BAS, en route to Rothera, were responsible for electronics support for CTD operations.

Other measurements were made throughout the cruise. XBTs were launched, generally between CTD stations. Acoustic Doppler Current Profiler (ADCP) measurements were made continuously employing a hull mounted 150 kHz unit manufactured by RDI. In support of the ADCP measurements a GPS3DF receiver manufactured by Ashtech, Inc provided heading information superior to that of the ship's gyro. Furthermore, raw GPS pseudorange measurements were made once per minute. These have been corrected by post-processing with pseudorange corrections recorded in Stanley, Falkland Islands, to provide Differential GPS (DGPS) position fixes. Underway measurements of surface temperature and salinity were made by a Seabird thermosalinograph. Water depths were recorded using a mixture of a Simrad EA 500 Echosounder and an IOSDL Mk IV Precision Echo Sounder. Other navigation information was supplied by a Trimble GPS receiver and all data were logged by networked SUN workstations.

Brief descriptions of the cruise have been published in King and Alderson (1994) and Alderson, King and Preston (1994).

2.3 Sample Salinity Measurements

Salinity samples were analysed by B. King on the BAS Guildline Autosal model 8400, S/N 45363, modified by the addition of an Ocean Scientific International Ltd. (OSIL) peristaltic pump. The instrument had been to OSIL immediately before the cruise (August 1993) for servicing and electronic alignment. The instrument was located in the Mic. Rad. Lab. Although this lab is not temperature controlled, it provides a satisfactorily stable environment for Autosal operations. This was achieved by a combination of adjustments to the ducted air supply by the 2/Eng and use of the lab thermostat. The lab temperature varied between 20.5°C and 21.7°C, and the Autosal water bath was set to 24°C.

Initially, samples were drawn from all Niskin Bottles. Sample quality improved as sample procedures improved and watchkeepers gained experience. Also, two bottles (numbers 6 and 10), were identified as leaky and not used. Data from these bottles are believed to be acceptable where given a quality flag of 2. Bottle 6 sometimes had a leaky bottom end cap (weak bungee), and bottle 10 had a dribbly bottom tap. No spares were available.

385 CTD samples were analysed using 43 ampoules of P120 standard seawater. Of these, 2 ampoules were bad (high salinity). Also there were several ampoules in this crate of P120 for which it was very difficult to clear the tip before opening, because the neck where the tip joins the main part of the ampoule was too narrow. Five ampoules of the latest batch (P123) were also used for comparison with P120. There was a consistent offset of 4 units of the Guildline display between standardisation with the two batches. Reported salinities would have been 0.0005 to 0.001 lower if P123 had been used as the standard.

A problem was occasionally encountered whereby tiny bubbles would be seen entering the Autosal cell with the sample. Bubble size varied from 'obvious' to 'barely visible'. Care was required to ensure that unnoticed bubbles did not lead to poor readings. If these bubbles did not pass through the cell, then they would generally have an effect on the reading. The solution adopted was to use the highest pump speed (speed 3) for flushing the cell, and to use speed 1 for filling the cell when a reading was required. The pump would then be switched off as soon as the cell was full, and a reading taken. Furthermore, when taking a reading, the Autosal display was observed for a suitable period, 15 to 20 seconds, and the highest persistent value recorded. The highest value was selected because any undetected bubbles would cause the display to be biased low, but never high. The following conclusions were reached:

(a) When bubbles were not present, switching off the pump to take a reading had no detectable effect on the value displayed.

(b) The integrity of all the sample lines was thoroughly checked, and various sections replaced. However, this had no effect on the bubbles. The conclusion was reached that the bubbles were dissolved gas in the samples, being released as the sample passed through the Autosal water bath. Since many of the samples were initially very cold, they were quite oversaturated when brought to Autosal temperature. Although samples were allowed to equilibrate (in temperature) before analysis, the disturbance of being pumped through the Autosal probably caused the release of further gas.

(c) Sometimes bubbles would accumulate in the pump itself. However, the sample tubing was thoroughly checked, and great care taken to ensure that air did not enter the intake tube when changing samples.

(d) Although statistics were not kept, the problem seemed to occur mainly with samples, not Standards.

(e) From time to time, the sample lines were cleaned with Decon solution. These seemed to solve the problem for the next 10 to 20 samples. We conjecture that very clean tubing provided less tendency for the formation of the tiny bubbles. However, it is not practical to clean the tubing after each station.

(f) A few samples were run using the air pumps instead of the peristaltic pump. The bubble problem seemed to be much less common on these runs. This was attributed to the air pumps producing less agitation of the sample and consequent outgassing. However, the extra time required was not thought to be justified, since the procedure adopted with the peristaltic pump was satisfactory.

(g) The bubble problem may well have been reduced by flushing the cell with the pump at speed 1, again because of less agitation of the sample. However, this would have unnecessarily reduced sample throughput.

We conclude that care needs to be taken on future cruises to look out for this problem. It may have a particularly tendency to occur at high latitudes, where surface samples, and indeed deeper samples in regions of deep convection, have high percentages of dissolved gas saturation when the sample is brought to laboratory temperature. However, when the problem occurs, it can be effectively dealt with, without deterioration of data quality.

Of the 385 samples analysed, 78 were duplicates (samples drawn from a second Niskin bottle closed at the same depth). For the 69 pairs of samples where both samples were flagged as 'good' (quality flag = 2), the rms of the salinity difference was <0.001.

2.4 CTD Measurements

Bottle depths per station are shown in figure 2.1. CTD station data are listed in table 2.1.

2.4.1 Gantry and Winch Arrangements

The CTD was deployed from the Midships gantry. The gantry is an A-frame, with the addition of a pendulum and roller. The distance from the pivot of the A-frame to the block is considerable, which has the advantage of giving the gantry a large outboard reach, but makes it more difficult to keep the package near the point of suspension. With a small package and generally calm seas, this was not a problem. However, when in air, the package was controlled by two seamen each with a hand-held line. The wire was a single conductor 10mm steel rope manufactured by Rochester Cables, hauled by a 10T traction winch. The only noteworthy problem with the winch was a burst hose in the winch room which caused one station to be abandoned after paying out 150 metres of wire. The package was recovered and a repair carried out. The station was then completed normally.

2.4.2 Equipment, Calibrations and Standards

The CTD equipment used on this cruise was provided by BAS. The following equipment was used on the underwater package:

(1) Neil Brown Mk. 3 CTD (no oxygen sensor) (BAS)

(2) 12 x 1.7 litre GO rosette (BAS)

(3) 2 SIS digital reversing thermometers and 2 reversing pressure meters (IOSDL)

(4) 10 kHz pinger for near bottom approach. (BAS)

There were no spares available apart from a spare CTD conductivity cell provided by IOSDL. The shipboard equipment consisted of a Neil Brown Mk III deck unit and GO water bottle firing unit. Real time display was on an IBM PS2 system, which employed EG&G software, and provided for raw data backup by dumping disk files onto a tape streamer. The primary data acquisition route was via the shipboard level ABC system.

2.4.2.1 Temperature Calibration, 26 August 1993

CTD temperature was calibrated at IOSDL on 26 August 1993 at 13 temperatures on the ITS-90 scale, at temperatures between -2°C and 25°C. The transfer standard had been calibrated at the triple points of Mercury and water, and at the melting point of Gallium.

Initial investigation of the temperature calibration had shown an unsatisfactory non-linear response near zero degrees centigrade. This is associated with the electronics of the instrument near the change of sign. Accordingly, a temperature offset of about 2°C was introduced, so that likely oceanographic temperatures were all reported by the instrument as positive. The following calibration resulted, with an rms error of 0.2 millidegrees.

```
T  =  -2.0851  +  0.99029xTraw  +  1.091E-5xTraw**2
```
(1)

2.4.2.2 Pressure Calibration, 16 August 1993

CTD pressure was calibrated at IOSDL on 16 August 1993 at 15 pressures between 0 and 6000 dbar, and at temperatures of 10.7°C and 20.9°C. The calibration was performed using a deadwieght tester in series with a Paroscientific Digiquartz model 240 portable transfer standard; the Digiquartz was taken as the standard. The resulting calibration information was analysed for temperature dependence and hysteresis between calibrations at increasing and decreasing pressure. It was previously known that the type of pressure sensor used on this CTD had an offset at atmospheric pressure which varied with temperature; corrections were made for this in the shipboard data processing. However, careful calibration work with the sensor, including calibration at various laboratory temperatures, showed that the variation of offset with temperature was itself pressure dependent. Indeed, the sense of the variation was opposite at 6000 dbar to the variation at zero dbar. We were previously unaware of this behaviour at IOSDL. Accordingly, the CTD postprocessing software was modified to allow a temperature dependence which is quadratic in pressure. The details are provided below.

2.4.3 CTD Data Collection and Processing

2.4.3.1 Data Capture and Reporting

CTD data are passed from the CTD Deck Unit to a small dedicated microcomputer (‘levelA’) where one-second averages of all the raw values are assembled. This process includes checking for pressure jumps exceeding 100 raw units (10db for the pressure transducer on the CTD) and discarding of spikes detected by a median-sorting routine. The rate of change of temperature is also estimated. A fuller account of this procedure is given by Pollard et al. (1987). The one-second data are passed to a SUN workstation and archived. Calibration algorithms are then applied along with further editing procedures. Partially processed data are archived after various stages of processing. CTD salinity concentrations are reconciled with sample values, and any necessary adjustments made. CTD temperatures and pressures are compared with reversing measurements. The downcast data are extracted, sorted on pressure and averaged to 2db intervals: any gaps in the averaged data are filled by linear interpolation. Information concerning all the CTD stations is shown in the accompanying station list. With reference to the stated requirements for WHPO data reporting, note that:

(a) The number of frames of data averaged into the 2db intervals is not reported. The IOSDL data processing path does not keep track of this information.

(b) Some stations had the 1 db level missing from the averaged 2db files; ie, the shallowest level was the 3db level. This situation would arise on stations where poor weather did not allow the CTD package to be brought close to the surface for the start of the downcast after the ‘soaking’ period at 10 m depth. On such stations, the data have been extrapolated to the surface by replicating the T and S data from the shallowest available level (usually 3 db, occasionally 5 db). Such extrapolated data have been assigned a data quality flag of 2.

2.4.3.2 Temperature Calibration

The calibration of eq. (1) above was applied to the CTD temperature data. This calibration was in ˚C on the ITS-90 scale, which was used for all temperature data reported from this cruise. A post-cruise temperature calibration was determined from a 12 point calibration on 24 June 1994 as follows:

$$T = -2.0887 + 0.99055 \times Traw + 0.638E\text{-}5 \times Traw^{**}2 \qquad (2)$$

This differs from the pre-cruise calibration by 3.5 m˚C near zero. In view of the disagreement between the CTD data calibrated on the cruise and the SIS thermometer, it appears that the drift in the CTD calibration mainly occurred between the pre-cruise calibration and the acquisition of the data. Accordingly, the data calibrated during the cruise will be offset by –0.0035°C.

For the purpose of computing derived oceanographic variables, temperatures were converted to the 1968 scale, using T68 = 1.00024xT90, as suggested by Saunders (1990).

In order to allow for the mismatch between the time constants of the temperature and conductivity sensors, the temperatures were corrected according to the procedure described in Crease et al. (1988). The time constant used was 0.20 s. Thus a time rate of change of temperature (called deltaT) was computed, from 8Hz data in the levelA, for each one-second data ensemble. Temperature T was then replaced by T + 0.20 x deltaT.

2.4.3.3 Pressure Calibration

On 16 August 1993, pressure had been calibrated in the lab at 10.7 and 20.9 degrees. It was found that not only did the offset vary with temperature, which was expected, but the variation was found to be pressure dependent, which was unexpected. The CTD calibration software was therefore modified to allow the temperature correction term to be pressure dependent, and so, using the 10.7°C calibration as the initial calibration:

```
P  =  -5.8  +  0.99981xPraw  -  3.47E-7xPraw**2
```

followed by an addition of

```
ΔP  =  (Tlag-10.7) x (-0.15  +  0.00008xP  -  0.15E-9xP**2)
```

Here Tlag is a lagged temperature, in ˚C, constructed from the CTD temperatures. The time constant for the lagged temperature was 400 seconds. Lagged temperature is updated in the following manner. If T is the CTD temperature, tdel the time interval in seconds over which Tlag is being updated, and tconst the time constant, then

```
W  =  exp ( -  tdel/tconst )

Tlag(t=t0+tdel)  =  WxTlag(t=t0)  +  (1-W)xT(t=t0+tdel)
```

The value of 400 seconds for tconst is based on laboratory tests.

A final adjustment to pressure is to make a correction to upcast pressures for hysteresis in the sensor. This is calculated on the basis of laboratory measurements of the hysteresis. The hysteresis after a cast to 5500m (denoted by dp5500(p)) is given in Table 2.2 for pressures at 500db intervals. Intermediate values are found by linear interpolation. If the observed pressure lies outside the range defined by the table, dp5500(p) is set to zero. For a cast in which the maximum pressure reached is pmax dbar, the correction applied to the upcast CTD pressure (pin) is

```
pout  = pin  -  (dp5500(pin)  -  ((pin/pmax)  *  dp5500(pmax)))
```

A post-cruise pressure calibration at IOSDL on 27 June 1994 provided a laboratory calibration of

```
P  =  -5.9  +  0.99883xPraw  -  1.97E-7xPraw**2
```

at 10 degrees. This differs from the pre-cruise calibration by less than 2 db over the range 0-6000 db. The data from the pre-cruise calibration were therefore accepted unchanged.

2.4.3.4 Salinity Calibration

Salinity was calibrated during the course of the cruise, by comparison with upcast sample salinities. This was done on a station by station basis. A cell conductivity ratio of 0.97849 was estimated from early stations, and this was applied to all station data as an initial calibration. The initial calibration was followed by the correction to conductivity ratio:

```
Cnew = Cold  x  (1 - 6.5E-6 x (T-15) + 1.5E-8 x P )
```

After reconciliation with sample salinities, vertical profiles of residuals showed a systematic depth dependence. A final salinity calibration on a station by station basis was made by fitting the residuals with the form

```
a + b * T + c * P
```

2.5 XBTs

Thirty-three XBTs (T5s and T7s) were deployed from a hand-held launcher attached to a Sippican Mk 9 deck unit interfaced to a PC. Data were transferred for further processing by means of ASCII listings of depth-temperature pairs using floppy disks.

2.6 Acoustic Doppler Current Profiler (ADCP) Measurements

2.6.1 Instrument performance

The *JCR* has a 150 kHz hull-mounted RDI unit with transducer offset from the fore-aft direction by approximately 45 degrees. On this cruise the firmware version was 17.07 and the data acquisition software (DAS) was 2.48. For the two transects across Drake Passage, the instrument was used in the water tracking mode, recording 2 min averaged data in 64 x 8 m bins. 'Blank beyond transmit' was 4 m and the depth of the transducer is approximately 5 m. On the shelf at the start of the cruise, and across Burdwood Bank, bottom tracking was used. A considerable amount of bottom tracking data was collected during the logistics work to the west of the Antarctic Peninsula. The bottom tracking configuration had the same number and size of bins, and one bottom ping per four water pings.

Before leaving port, this instrument provided much concern, by refusing to display a correct heading in the DAS display. After removing and reseating the various connectors, and rebooting the DAS PC and the deck unit, the problem was cleared and normal logging could proceed. One hypothesis was that the heading hung up because of some part of the system being rebooted while the connector that provides voltages from the gyro was not properly seated. An alternative was that the order of powering up the electronics unit, PC and DAS was to blame. However, once started, no other operational problems were noted.

Compared with other ships used by IOSDL, the ADCP on *JCR* has a unique feature: in order to provide protection from ice the transducer is located in a sea chest, recessed in the hull. The sea chest is closed by a 33 mm thick window of Low Density PolyEthylene (LDPE), and filled with a silicone oil. The temperature of the oil is measured, and returned to the DAS as “water temperature”.

Obtaining reliable information about the oil used to fill the sea chest has proved impossible. It seems that the sea chest was filled by the shipyard when the ship was first built three years previously, and has had no attention since then. The UK representative for RDI attended the ship only to commission the electronics, and could not say what oil had been used. RDI suggested that Dow Corning 200 Fluid, 100 centistokes viscosity, might have been used. However, since sound speed in that oil is around 1000 m/s this would a) have been quite unsuitable, b) have been revealed by subsequent analysis of the data. Extensive enquiries on the ship have shown that the sea chest is essentially 'maintenance free'. None of the Deck or Engineering Officers has any recollection of the sea chest being drained or topped up; there seems to be no stated requirement for such procedures.

Depth penetration depended, as ever, on sea state. However, it can be said that reasonable data were generally collected over the upper 200-300 m, with bottom tracking generally available in depths down to 450 m. While it is difficult to make a definitive statement, a subjective view is that the depth capability is significantly less than on RRS *Discovery* in a comparable sea state. There seems little doubt therefore that depth capability is reduced by the necessary presence of the LDPE window. It is to be hoped that 250 m will be found to be sufficient for many analyses.

2.6.2 Determination of speed correction factor

Knowledge of the speed of sound in the fluid surrounding the transducer is crucial because the relative velocities reported by the ADCP depend on the Doppler frequency shift and the sound speed *at the transducer*. As the sound propagates through the water column, sound rays will be refracted as local sound speed changes, according to Snell's Law. However, the amount of Doppler shift that occurs when the ray passes through a given shear in the water column also varies as a function of the angle at which the ray encounters the shear. These two effects exactly compensate for one another, so that the ray angle and sound speed need only be known at the transducer.

Accordingly, the RDI DAS computes water velocities relative to the ship using the known angle of the transducers (30° to the vertical) and the speed of sound at the transducer. This may be specified to be a fixed value or, optionally, computed in the DAS from a fixed salinity and the temperature measured at the transducer. Unfortunately, the DAS does not seem to have an option for installations where the transducer is not surrounded by water; the option to compute sound speed in the DAS uses the equation of state for seawater. The PIs having failed on the cruise to grasp the significance of the oil filled sea chest, the data on this cruise were all acquired by employing a sound speed calculated from the reported temperature of the fluid surrounding the transducer, and the equation of state of seawater! The use of the seawater equation is particularly bad because not only is the sound speed in oil different from that in water but, crucially, the variation of sound speed with temperature is opposite.

In seawater, sound speed increases with temperature, while in a wide range of silicone oils it decreases by about 3 m/s per degree centigrade. Happily, this error can be corrected in post-processing, as described below.

The problem with the sound speed became apparent when the bottom tracking data were analysed with a view to producing a speed and direction calibration. A good amount of bottom tracking data were available because, apart from data on the continental shelf near the Falklands, a considerable amount of time was spent in shallow water west of the Antarctic Peninsula. The ratio of along-track speeds determined from GPS positions and ADCP bottom-tracking was found to be of the order of 0.95 to 0.98, rather than very close to unity as in previous experience. Furthermore, it showed a strong temperature dependence. This led to the identification of the incorrect speed of sound employed in the DAS.

It became further apparent that the oil in use was not Dow Corning 200 Fluid (100 centistokes) as had been suggested. With a speed of sound around 1000 m/s this would have led to wildly wrong velocities. Also, with considerable refraction, water depths determined by the ADCP would have been wrong; however, they seemed to be in reasonable agreement with the PES data.

Dow Corning kindly provided the sound at temperatures between 0 and 50°C for a range of their silicone oils, including several different viscosities of Dow Corning 200 Fluid. From this it was noted that the proportional variation of sound speed with temperature was much the same across the range, with the absolute value varying from oil to oil. Furthermore, the variation was generally well described by a quadratic function of temperature. Accordingly one oil was chosen (Dow Corning 710) that had a sound speed near 1500 m/s. A function of temperature was then deduced that would provide a correction factor for sound speed in seawater (at S = 35) to sound speed in the chosen oil, as follows:

```
F = 1 - 0.004785xT + 0.0000355xT**2
```

The ADCP data were then reanalysed from raw 2-minute ensembles of water velocity relative to the ship. East and north velocities were converted to speed and direction, and all speeds multiplied by the scaling factor. The calibration of ADCP speeds by examination of bottom tracking revealed that the obvious temperature dependence had been removed, although the absolute value had not been got exactly right. After analysis of the 'best' bottom tracking data (selection of the best data is described below), a further scaling factor of 1.0055 was introduced applied to relative speeds.

2.6.3 Determination of heading misalignment

All data were corrected for the variation in the ship's gyrocompass heading errors by employing data from the Ashtech GPS 3DF heading system, described elsewhere. Ashtech-gyro differences had been determined by comparing the two instantaneous measurements of heading, and smoothed to two minute averages. These differences were merged onto the ADCP two-minute ensembles, and relative direction modified by the addition of Ash-gyro difference. In principle the ADCP data were now referenced to heading determined from the GPS system, and needed to be corrected only for the fixed misalignment between the direction defined by the GPS antennas and the direction of the ADCP transducer.

As with the determination of the speed error, comparisons were made between the direction of the ship over the ground determined from the GPS position fixes (DGPS fixes were used when the data were post-processed ashore), and the direction of the ship over the ground from the ADCP bottom tracking. The difference should be the required misalignment, which was calculated as follows:

a) Two-minute ensembles were merged with DGPS positions, and ship's east and north velocity calculated. Absolute ADCP bottom tracking velocity was also calculated.

b) The data were then averaged into 30-minute periods. A 30-minute ensemble was accepted only if: (i) At least 13 two-minute ensembles had bottom tracking data (ie at least 26 minutes of good data in the 30 minutes). (ii) The two-minute averages of speed must have a range of no more than 20 cm/s. (iii) The two-minute averages of direction over the ground must have a range of no more than 20 degrees. Thus 30-minute averages were chosen which contained a high percentage of present data, collected while the ship was steaming on a steady heading at a steady speed. There were 45 periods which passed this selection procedure.

c) The speed and misalignment errors were computed for each 30-minute period as (speedGPS/speedADCP) and (directionGPS - direction ADCP). The resulting direction difference would need to be added to all ADCP directions to produce correct ship-over-ground or ship-over-water velocities. The final speed correction factor was 1.0055 as given earlier.

The GPS minus ADCP directions form a reasonably consistent set. The mean value is - 1.73 degrees, with the standard deviation 0.13. Although this was not quite as tight a determination as had been anticipated, it seemed to be the best that could be found.

2.6.4 Further analysis of data

All ADCP data were thus reprocessed using the speed and direction corrections as determined above. Subsequent analysis of the underway and station data, however, suggested a systematic bias between the cross-track components of the average of underway data collected between a pair of stations, and the average of the data collected while located on the stations at each end of a steaming segment. This bias is, of course, characteristic of a residual misalignment error. Although the differences between station and steaming averages are necessarily noisy, (the two selections do not sample the same water, and station data can be unrepresentative of the steaming data in between), it was found that the systematic bias could be removed by assuming an ADCP misalignment of 2.1 degrees, instead of the 1.73 degrees mentioned above. Thus at the time of writing (October 1994), the ADCP data have been reworked by adding - 2.1 degrees to the ADCP directions.

2.7 Navigation

2.7.1 GPS-Trimble

Navigation during the cruise was provided by the ship's Trimble 4000 receiver, with fixes roughly once per second.

2.7.2 Differential GPS

An experiment into the use of Differential GPS (DGPS) for improved ship positions, with consequent benefits for the accuracy of ADCP data, was carried out during the cruise. It had been ascertained that a DGPS fixed station had been established in Stanley by Signal Computing Ltd, of Guildford, Surrey, UK, as part of a larger experiment by INMARSAT. The receivers used for this experiment consisted of a 10-channel Novatel GPS card installed in a PC, making L1 C/A code measurements.

Signal Computing were contracted to arrange for data collection at the fixed station in Stanley (operated for them by Cable and Wireless), to provide a suitable receiver and logging software for the *JCR*, and to postprocess the data to both uncorrected and Differential GPS positions.

The DGPS system was installed in September 1993, before the ship left the UK. The antenna was fixed to the rail on the starboard side of the wheelhouse roof, on a square groundplane provided by Signal Computing. The antenna cable was run down into the wheelhouse to the PC, which was located on the bench on the starboard side of the wheelhouse. After the cruise, the antenna, groundplane and PC were removed, but the cable was left in place.

Raw pseudorange data were logged once per minute to PC hard disk, on even multiples of 60 seconds of GPS week (9 seconds different from exact minutes of UTC at that time). From time to time, the hard disk was archived to 60 Mb 1/4 inch cartridges, using software installed on the PC by Signal. Two cartridge copies were made.

After the cruise, the shore based data were collected from Cable and Wireless on similar cartridges, and the whole dataset passed to Signal for postprocessing. Signal then provided floppy disks with two ASCII datasets. One consisted of the DGPS positions for the cruise, the other consisted of the positions determined from the shipboard dataset alone.

2.7.3 Results

The DGPS measurements proved to be an outstanding success. The quality of the data can be judged from periods when the ship was securely moored, in which case variation in ship position can be attributed to GPS errors. Initially, the ship was moored at the FIPASS quay in Stanley (51°42' S, 57°50' W), a few km from the base station. Here, the rms of the position was 20 m in each of lat and lon for the ordinary GPS, and less than 5 m for the DGPS.

The second extended period of mooring was at the Biscoe Wharf at the British Antarctic Survey Base at Rothera (67°34' S, 68°08' W), a range of about 1800 km from the base station. There was a little over two days worth of data collected here. The rms of the standard GPS positions was again 20 m, but the DGPS provided rms variation of just 3 m in latitude and 1.7 m in longitude, based on 24 hours of 1-minute instantaneous fixes. Since the processing requires 4 common satellites between the two receivers, the DGPS dataset was not quite complete: 1428 positions out of a possible 1440 were calculated, giving a data return of better than 99%.

The absolute accuracy of the fixes at this range cannot be determined from these data, of course. However, since ADCP data processing requires information about ship movement, the 4 m accuracy is the appropriate figure to use when estimating the error in ADCP data arising from changes in ship position.

Since there was no apparent deterioration in the accuracy of the DGPS positions as the distance from the base station increased from 2 to 2000 km, we cannot determine the maximum range at which DGPS corrections may be useful. Clearly the technique will be limited eventually by the number of common satellites tracked by the two receivers. The postprocessing used in this experiment required four common satellites; in principle, it is possible to produce DGPS positions using only three common satellites if the altitude of both stations is known, so that only the lat and lon of the mobile antenna is required.

The postprocessing also involves the assumption that pseudorange corrections calculated at one station may be applied at the other. This assumption becomes less accurate as the separation increases, because the two receivers view the satellites at different angles. Evidently a baseline of 2000 km does not introduce significant errors for our purposes. Since the satellites are in orbit at a height of order 10 000 km, we may suppose that the geometry starts to introduce significant errors when the baseline increases to, say 3 000 to 4 000 km. At such ranges, the number of common satellites will also start to reduce significantly.

We also note in passing that the pseudorange corrections include the effect of the ionospheric delay along the path from satellite to fixed receiver. Although the receiver and postprocessing software will include an ionospheric model, the model will not be perfect. Some of the deficiencies in the model will be corrected by these measurements. The validity of these corrections will be governed by the extent to which they are consistent at the two sites. It may be that we benefited from making measurements during a quiet sun period so that the ionosphere is in a low during its 11-year cycle of activity. Solar activity, and therefore ionospheric disturbance, will increase during the coming years. The use of dual frequency systems, so that ionospheric delay is directly measured at both sites, may become desirable in due course.

2.7.4 Electromagnetic Log and Gyrocompass

Ship speed is determined by an electromagnetic log. Unfortunately this is only a one-component log, providing fore/aft speed but not athwartships. This is not really satisfactory for the analysis of meteorological data, where both components are required for converting winds measured relative to the ship to winds relative to the water. However, the instrument functioned without problem.

The ship is fitted with two identical gyrocompasses - Sperry Mk 37. The instrument used for ship navigation was also the one logged via a level A and to provide headings to the repeaters in the labs and to the ADCP. While the ADCP is supplied via a synchro pickup, the lab repeaters measure relative changes, and have to be initialised to the correct heading individually. The ADCP and the level A receive the same voltages from the synchro pickup on the gyro, but digitise them separately. No problems with the gyrocompass were noted.

2.7.5 Ashtech GPS3DF

Experience with the GPS heading measurements on RRS *Discovery* had demonstrated the significant errors inherent in ship's gyrocompass measurements. An Ashtech GPS 3DF system was therefore installed on *JCR*. A new set of antennas and cables was purchased from UK WOCE Capital funds, and the antennas were installed on the wheelhouse roof. Funds were not available at the time for the purchase of a new receiver, so the receiver was transferred from *Discovery*. At the end of the cruise it was returned to *Discovery* for use on Cruise 207, although the antennas were left as a permanent installation. Since this cruise, a second GPS 3DF receiver has been purchased.

The receiver is located in the wheelhouse, next to the Trimble receiver. The receiver sends ASCII messages which are logged to the ship's computer system via a level A. The ASCII message $GPPAT contains time, position and attitude (pitch, roll, heading). The message is further time-stamped with ship master clock time at the level A. This ensures that the same time base is used for merging with gyrocompass data and determining gyro errors.

The antenna geometry was surveyed using the Ashtech software and data collected in Grimsby in September 1993. Several hours data, collected at 20-second intervals, was subdivided in various ways and each segment analysed. After inspecting the diagnostics of each set of calculations, the best was chosen. Subsequent calibrations in Stanley and later in Grimsby using the replacement receiver did not yield a significantly different calibration. The port side aft antenna is designated as number 1; port-fwd is 2, stbd-fwd is 3, stbd-aft is 4. The relative positions are given in the table of receiver parameters below. They XYZ vectors have been adjusted so that the heading is defined by the direction normal to the 1-4 baseline, ie that baseline has Y=0.

Data coverage and reliability of the level A logging were all much improved from the experience on *Discovery* during the 1992/3 season. Firmware upgrades in the GPS 3DF had been made, resulting in the new GPPAT message. Previous problems with level A hangups no longer occurred. A bug whereby the receiver got stuck sending the same attitude message if its internal memory was full had also been fixed.

Data coverage was improved over previous experience by changing some of the receiver parameters from their factory defaults to ones suggested by T. Chereskin, who had been experiencing difficulties getting a reasonable data return on the R/V Thompson. The parameters used were as follows (mainly set in menu 4 or its submenus).

```
Menu 4

posn                    0,0,0
Alt known               N
Ranger                  0
UnhealthySV             Y
Rec intvl               060
Min SV                  4
elev mask               10
pdop mask               40
PortA                   nmea         off
                        real time    off
                        VTS          off
                        baud         9600
PortB (level A logging) nmea         on
                        baud         9600
                        options      PAT ON
                                     1 second send rate

ATTD CNTRL MENU

max rms      010
search ratio            0.5
one sec update          Y
3SV search   N
             tau        T0           Q            R
Hdg          999        000          1.0e-2       1.0e0
pitch        020        000          4.0e-2       1.0e0
roll         020        000          4.0e-2       1.0e0
Kalman filter reset     N

ATTD SETUP MENU
             X          Y            Z
1-2          2.943      4.745        0
1-3          11.493     4.753        -0.006
1-4          13.222     0            0
OFFST        0          0            0
max cycle               0.200        smoothing    N
max magnitude           0.080        max angle    020
```

Attitude data were logged at a rate of 1 Hz. With the new receiver parameters, a typical day might have 75% of good one-second values. Following previous data processing paths, these were subjected to various data quality control procedures and merged with gyro measurements. Ashtech minus gyro headings were averaged into two minute intervals on a daily basis, of which 80–95% contained data. On *Discovery* Cruise 199 (WHP section A11; Saunders, 1993), only about one third of these averages contained data, and so an elaborate interpolation scheme was required. The gaps in coverage were now sufficiently small that linear interpolation was employed to provide a complete set of gyro corrections. These have been used in processing the ADCP data.

2.8 Underway Observations

2.8.1 Echosounding

The *James Clark Ross* is fitted with an IOS Mk IV PES, whose display is located in the UIC lab, and a Simrad EA 500, whose display and controls are located in the wheelhouse. Initially, the logging of EA 500 depths via level A was not working, although depth was shown correctly on the EA 500 display. The EA 500 data were also logged to colour hardcopy in the wheelhouse. Early in the cruise, time did not permit investigation of the cause of the failure to log EA 500 data. The cruise depth record was therefore constructed by annotating and reading the depth from the PES Mk IV hardcopy, in the time-honoured manner. The PES display in the UIC lab was also used for monitoring the 10 kHz pinger on the CTD rosette during near-bottom approaches. Echo sounding was carried out using the hull transducer for most of the cruise, with the fish transducer in use for a short period. The correct depth of the hull transducer is 6 m. The fish was not particularly satisfactory, due to the poor state of the fairing, which was repaired by taking pieces of undamaged fairing and new clips from a cable found in the scientific hold. The hull transducer was, however, quite adequate for our purposes.

One major problem with the PES Mk IV is that the array depth control is uncalibrated, and turns easily. It was found part of the way through the cruise that it was set to maximum, producing a depth offset of approximately 40 m. It is believed that it had been inadvertently moved while an adjustment was made to the nearby loudspeaker volume control.

Once the main CTD section had been occupied, time was available to investigate the level A logging of Simrad data. Two data leads run to the Simrad electronics unit. One may be used for synchronisation signals if the EA 500 is to be used in conjunction with other echo sounders. The second is for the Simrad to send depth messages. It was discovered that the wrong lead had been plugged in to the data port on the forward side of the main bench in the wheelhouse. Data logging was straightforward as soon as the correct lead was plugged in. The EA 500 digital depths were used as the depth record for the remainder of the cruise. The hardcopy Simrad record for the first part of the cruise was compared with the depths from the PES Mk IV, and used to correct the error introduced by the erroneous array depth setting. The bridge officers were requested to keep a careful watch on the EA 500, and to make whatever adjustments were needed to ensure that the automatically determined depths were in agreement with the visually determined depth from the echo display. This they did with admirable efficiency, so a good depth record is available for the cruise. It was corrected on board using the RVS software which incorporates the Carter Table corrections.

The 3.5 kHz echo sounder was also switched on and run for a short period. It seemed to work satisfactorily apart from an intermittent fault on the hardcopy recorder. This fault had occurred before, but has proved impossible to isolate. Since routine operation of this echo sounder would have required watchkeeping effort that was unavailable, it was not operated and no 3.5 kHz records were kept from the cruise.

2.8.2 Meteorological Measurements

A new and updated version of the Met-Logger software was brought from Cambridge, this was installed quickly and with no problems. The fore-mast anemometer and wind vane that were also carried to the ship in hand luggage were fastened in place and rewired while the ship was in Stanley. The instruments gave no problems during the duration of the cruise. The parameters recorded during the cruise were: airtemp, sstemp, humidity, PAR, TIR, airpressure, and relative wind. The logging software combined these measurements with fluorescence and salinity from the pumped seawater supply.

2.8.3 Thermosalinograph Measurements

The Thermosalinograph sensors had been returned to the manufacturers for service. The instrument was carried to the ship as hand luggage and installed while the ship was in Stanley. It performed well during the southbound leg of the cruise, and, along with the pumped seawater supply, was then switched off when the ship encountered ice. Logging was restarted for the northbound leg across Drake Passage. Unfortunately, salinity data were bad on the northbound leg, the instrument reading much too low. It appeared to recover somewhat as the passage continued, but there is, effectively, no salinity record for the northbound leg. Temperatures appeared to be OK. The reason for the problem was not identified. The sensor housing had been filled with freshwater during the central portion of the cruise. Data from the southbound leg were calibrated by comparison with samples drawn once per watch. Thermosalinograph data were assembled with the meteorological data on the oceanlogger PC, and logged to the shipboard computing system.

2.9 Shipboard Computing

The *James Clark Ross* has a level ABC system equivalent to that on the research ships operated by RVS. It comprises 3 distinguishable parts or levels. Each level is referred to by one of the following letters A, B or C, and the whole system is called the 'ABC' system.

A level A consists of a microprocessor based intelligent interface with firmware which collects data from a piece of scientific equipment, checks and filters it, and outputs it as SMP (ship message protocol) formatted messages. The messages are time-stamped by a ship master clock time, all the level A processors being attached to the same ship clock. The level A processors were all of MkII type. In addition there are pseudo level A's which are in fact PCs around which a piece of equipment is based, which are also capable of generating SMP messages.

The level B collects each of the level A SMP messages and writes them to disk and backup cartridge tape. The level B monitors the frequency of these messages, and besides providing a central display for the data messages also warns the operator when messages fail to appear. The level B collates the data and outputs it to the network.

The level C is a SUN unix workstation. Here the data are parsed into RVS datafiles. These datafiles are constructed on a RVS styled database for speed of access. Data are then further archived in raw form, and are also available for processing and analysis.

The level C is part of an ethernet network consisting of three SUN workstations, and a number of PCs and printers. In addition, IOSDL took a Macintosh IIsi, a Mac Powerbook and an Apple laserwriter, all connected to the network.

Data processing was carried out using the IOSDL 'PSTAR' suite of software, installed in Grimsby prior to the ship leaving the UK. D. Richmond from BAS came to the ship in Stanley to ensure the computer system was running smoothly before the ship sailed at the start of the cruise, but did not sail with the ship. Management of the level ABC system was therefore in the hands of the PIs from IOSDL.

No special computing problems were encountered during the cruise. The CTD level A, attached to the demodulator in parallel with the PC running the EG&G acquisition software, was prone to hanging up occasionally, requiring the winch to be stopped while the level A was rebooted. This occurred two or three times during 30 stations. Depending on the vigilance of the watchkeepers, a varying amount of data would be lost to the level A; typically a few hundred metres. These data were recovered from the PC, and inserted into the level C data file.

Archiving of processed data was onto 150Mb 1/4 inch cartridges and 8mm exabyte tapes. 20 1/4 inch cartridges were used, including a complete duplicate record. In addition 12 level B tapes were generated (also 150Mb cartridges).

2.10 Acknowledgements

This cruise, a UK contribution to the World Ocean Circulation Experiment (WOCE), was set up at very short notice (less than four months elapsed between the allocation of ship time and the start of the cruise). It was possible to identify and prepare the equipment required only because of the cooperation of a wide range of staff in BAS, IOSDL and RVS, to whom the PIs are very grateful. P. Woodroffe ensured that all our requests for the use of CTD and underway equipment were met. P. Gwilliam and S. Keene arranged CTD calibration, R. Bonner, M. Hartman, E. Cooper and D. Lewis contributed to various aspects of the Ashtech GPS 3DF installation. D. Richmond made the return trip to Stanley to ensure the shipboard computing system was in order. After some determined negotiation, the personnel department in Cambridge managed to arrange a swap with the RAF on our outbound flight to get us onto a supposedly full plane. This turned out to have been a substantial contribution to our shipboard preparation when the original flight arrived 36 hours late. M. Booth ensured we were well looked after in Stanley.

The welcome and assistance received on the RRS *James Clark Ross* was exemplary, and helped to ensure not only the scientific success of the programme, but the enjoyment of the participants. Although the work described in this report was ‘opportunistic’, the PIs were given every consideration by the ship's personnel. It is a pleasure to acknowledge the contribution made by the Master, C. Elliott, his officers and his crew. The 2/E, Bill Kerswell, was especially vigilant in ensuring that the winch system did all that was required of it; T. Gill and C. Chalk worked long shifts of winch driving. The Deck Officers ensured prompt arrival an stations and accurate station keeping. The provision of accommodation while in port by the catering department is not the norm on RVS ships, but made visits to the ship in the UK considerably more sociable and effective.

XBT probes were provided by the Hydrographic Department.

Stn/ Cast		Date mmddyy	Time (UTC)			Latitude			Longitude			Depths (m)			pmax	Sam	Notes
			Start	Bot	End	deg	min		deg	min		u-wat	ho	wire	db	#	
1	2	112093	2316	2355	0130	53	12.32	S	57	02.22	W	1893	40	1780	1839	12	
2	1	112193	1542	1551	1613	54	39.33	S	58	33.80	W	225	10	199	203	5	note 1
3	1	112193	1809	1826	1855	54	55.34	S	58	21.71	W	619	25	580	591	8	
4	1	112193	1950	2009	2049	54	56.61	S	58	23.26	W	1068	20	1020	1045	10	
5	1	112193	2232	2305	2354	54	57.74	S	58	22.04	W	1610	20	1560	1601	8	
6	1	112293	0121	0202	0306	55	04.18	S	58	17.51	W	2096	20	2030	2085	11	
7	1	112293	0434	0524	0638	55	07.28	S	58	15.52	W	2549	25	2470	2537	12	
8	1	112293	0734	0829	0950	55	10.20	S	58	14.33	W	2991	20	3010	3083	11	
9	1	112293	1035	1150	1349	55	12.87	S	58	13.73	W	3750	45	3680	3785	12	
10	1	112293	1615	1729	1922	55	31.40	S	58	00.75	W	4260	50	4200	4277	12	
11	2	112393	0039	0158	0345	55	49.26	S	57	52.03	W	4651	60	4550	4687	12	
12	1	112393	0627	0732	0858	56	07.80	S	57	40.53	W	3718	20	3644	3749	12	
13	1	112393	1139	1243	1411	56	27.72	S	57	30.86	W	3638	20	3530	3633	11	
14	1	112393	1638	1724	1840	56	47.10	S	57	18.55	W	2595	60	2470	2535	12	
15	1	112393	2059	2215	2354	57	05.45	S	57	07.36	W	4468	65	4320	4425	12	
16	1	112493	0213	0321	0453	57	25.81	S	56	55.73	W	4051	45	3890	4005	11	
17	1	112493	0655	0755	0916	57	44.12	S	56	41.86	W	3480	55	3347	3419	10	
18	1	112493	1111	1219	1356	58	03.45	S	56	33.13	W	4025	25	3866	3981	11	
19	1	112493	1705	1845	1848	58	21.83	S	56	21.49	W	3908	50	3748	3849	12	note 2
20	1	112493	2054	2159	2340	58	41.34	S	56	09.42	W	3873	50	3700	3813	10	
21	1	112593	0157	0301	0439	58	59.84	S	55	57.77	W	3859	30	3704	3811	12	
22	1	112593	0649	0752	0919	59	19.02	S	55	42.59	W	3812	35	3697	3767	12	
23	1	112593	1146	1248	1423	59	38.78	S	55	31.04	W	3767	30	3630	3725	11	
24	1	112593	2121	2221	2344	60	00.30	S	55	19.09	W	3591	30	3440	3533	11	
25	1	112693	0207	0303	0425	60	20.36	S	55	04.75	W	3530	50	3357	3461	11	
26	1	112693	0630	0726	0838	60	40.48	S	54	48.67	W	3205	30	3080	3145	10	
27	1	112693	1117	1204	1318	60	47.97	S	54	43.15	W	2654	20	2595	2663	9	
28	1	112693	1354	1428	1519	60	49.99	S	54	43.42	W	1674	45	1750	1803	9	
29	1	112693	1610	1632	1704	60	51.07	S	54	42.84	W	1025	45	940	959	9	
30	1	112693	1807	1823	1847	60	58.83	S	54	37.11	W	630	10	565	581	7	
31	1	112693	1945	1952	2010	61	03.12	S	54	36.15	W	415	20	350	361	7	note 3
32	1	121593	1010	1021	1047	62	11.04	S	55	30.40	W	496	20	470	479	10	
33	1	121593	1358	1444	1550	61	46.16	S	55	30.12	W	2418	25	2500	2571	10	
34	2	121593	1929	1938	2001	61	33.72	S	55	48.59	W	503	25	470	483	10	
35	1	121793	2332	2340	2357	53	48.08	S	59	00.99	W	321	18	321	317	6	
36	1	121893	0040	0056	0118	53	45.61	S	59	03.02	W	708	10	703	721	6	
37	1	121893	0233	0306	0352	53	35.61	S	59	08.00	W	1807	15	1790	1841	10	
38	1	121893	0607	0621	0644	53	16.20	S	59	18.60	W	663	10	650	669	6	
39	1	121893	0815	0822	0839	53	02.90	S	59	25.31	W	292	15	280	287	5	

Table 2.1: JR0a station positions, 1993. Date refers to start time, Bot is time at bottom of cast; time after start time may be on the following day. Under 'Depths' are u-wat (uncorrected water depth), ho (height off bottom), wire (wire out). pmax is maximum pressure on cast. Sam is number of water samples per station.

Notes:
- Note 1: Start section
- Note 2: Report upcast data
- Note 3: End section

p	dp5500(p)
db	db
5500	0.0
5000	1.5
4500	2.4
4000	3.7
3500	4.5
3000	5.1
2500	5.7
2000	5.8
1500	6.3
1000	5.9
200	3.9
100	2.7
0	0.0

Table 2.2: Laboratory measurements of hysteresis in pressure sensor dp5500(p) = (upcast - downcast) pressure at various pressures, p, in a simulated 5500m cast.

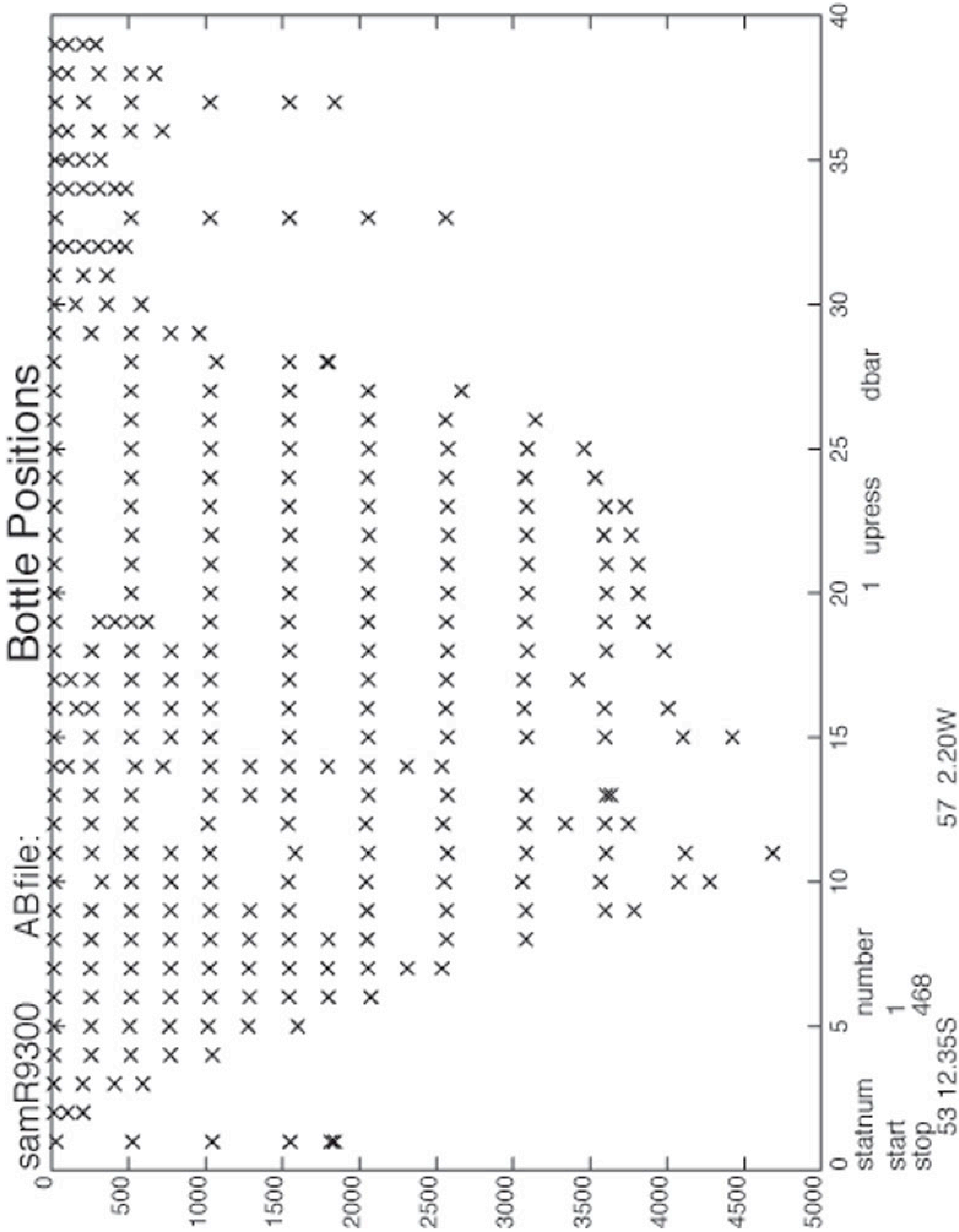

Figure 2.1: JR0a bottle depths versus station number.

3 JR0b, 13 Nov – 12 Dec 1994, by S A Cunningham and S G Alderson

3.1 Authors and Affiliations

Author	Affiliation
Cunningham, S. A.	JRC (now SOC)
Alderson, S. G.	JRC (now SOC)

3.2 Overview

During Voyage 4 (R94) of the *JCR* across the Drake Passage, the WOCE Section SR1b was occupied. Full depth CTD stations were taken across the section and currents measured using a ship mounted ADCP. A brief description of the cruise was published in Alderson *et al.* (1995).

3.3 Sample Measurements

3.3.1 Sample salinity measurements

Salinity samples were analysed using the IOSDL Guildline Autosal model 8400B. This Autosal was modified by the addition of an Ocean Scientific International (OSI) peristaltic salinometer pump. The pump was fitted according to instructions supplied by OSI. It was set to speed setting two ($\equiv$ 25 ml/min nominal) and was switched via an in line toggle switch, rather than through the flow speed switch.

The Autosal was observed to have a *zero* reading of + 6. The manual suggests that a reading within ± 5 is appropriate for a "within calibration" Autosal. The + 6 *zero* value was stable over all sample measurements (during a period of 7 days). Four weeks later, during which the Autosal had not been used, the *zero* reading was 0. The stability over the measurement period is the critical factor.

Initially the Autosal heaters were observed to be permanently off. No heater cycling could be observed. On investigation the power lead to the heat extractor fan was found to be detached.

The salinometer was situated in the Micro-Radio Room (MRR). The air temperature in the MRR is controlled in the following way: (i) the temperature of the air supplied to the air conditioning is modified by adjusting the flow of hot water through a heat exchanger; (ii) by adjusting a reheat thermostat controlling an electric heater situated within the air conditioning, close to the vent in the MRR. Step one has to be adjusted by the ship's Engineering Department and two allows local control within the MRR. The easiest approach to obtain reliable temperature stability is as follows. Switch off the reheat thermostat in the MRR. Have the Engineering Department adjust the heat exchanger to supply air to the MRR at about 2 to 3 °C below that required. This step is not precise. Then use the reheat thermostat to raise the air temperature to that required. It was found that if the air flowing into the MRR (measured just downstream of the reheat element) was 1 to 2°C colder than the mean air temperature of the MRR, lights, Autosal and bodies provided the additional heat required.

In Port the Chief Engineer stabilised the MRR at 22.0 ± 0.5 °C. The Autosal bath temperature was set to 24°C. However, on crossing the Polar Front the outside air temperature dropped to –1.5°C, very close to the sea-surface temperature. The (MRR) temperature dropped by several degrees. Again the Chief Engineer was required to adjust the inlet air temperature. Adequate temperature stability could only be achieved at 19.0 ± 0.5°C. The Autosal bath temperature was then set to 21°C and left to re-equilibrate at this new temperature.

Samples from stations 02 through 14 and the first 24 underway surface salinity samples were analysed with the bath temperature set to 24°C. For the remaining samples a bath temperature of 21°C was used.

The distilled water was a highly aerated water supply. When flushing the cell with distilled water many small bubbles were seen to be flushed into the measuring cell. This effect did not occur if the distilled water was left overnight before being flushed through the cell. Highly aerated distilled water is not a concern. However, it later seemed further evidence for sample degassing which was sometimes problematic and which is discussed below.

Bubbles appearing in the cell of the Autosal introduced via the inlet tube have been noted on recent past cruises in high latitude regions, [*Bacon*, 1993]. We believe that a similar effect was observed during this cruise. Highly oxygenated, cold samples equilibrating to a higher temperature have less ability to hold gas in solution. The salinity samples appear not to equilibrate (in gas concentrations) for their new equilibrium temperature before analysis. The speculation is that increased agitation through the peristaltic pump and through metal/plastic pipe junctions in the Autosal heat exchanger encourage bubbles to form as the samples out-gas. These bubbles eventually appear (sometimes as a stream of bubbles) in the Autosal cell, leading to unstable noisy readings. This was dealt with by pumping the sample side of the Autosal clear of all sample and flushing with air. If this was done as required then the Autosal readings were satisfactory. See Section 2.3 for a more detailed discussion of these effects.

384 CTD salinity samples and 65 underway salinity samples were analysed using 30 ampoules of P120 standard sea water. Of these, 2 ampoules of standard sea water were unusable because the necks were too narrow to allow the peristaltic pump tube to enter. No duplicates (samples drawn from different Niskins closed at the same depth) or replicates (two or more samples drawn from the same Niskin bottle) were drawn.

A comparison of salinity measurements was made with the results of JR0a, an identical section made in 1993. From the data of JR0a (Section 2) it is seen that there is a linear θ/S relationship in the deep water of the Drake Passage for $-0.3 < \theta < 0.6$, $34.66 < S < 34.71$. Linear least squares regression between bottle salinities and up cast potential temperatures are given in Table 3.1 for:

$$\theta = A + B \times S \qquad (3.1)$$

Figure 3.1 shows the fits given in Table 3.1. In the deep water at a potential temperature of -0.2 °C the JR0b data are fresher by about 0.002 psu, which reduces to 0 psu at 0.6 °C. While the same batch of standard seawater was used both on this cruise and JR0a, the batch was by now a year older. A more detailed statistical approach should reveal whether this difference is significant.

3.3.2 Oxygen Isotope Samples

In addition to salinity samples, oxygen isotope samples were drawn at each station and depth. These were stored in small, wax sealed winchester bottles for post-cruise analysis on return to the UK. These samples were drawn for Russell Frew, University of East Anglia.

3.4 CTD Measurements

CTD station data are listed in Table 3.2.

3.4.1 CTD Frame and Termination

The BAS CTD frame is adequate for CTD deployments with a 12 position GO Rosette and 1.7 l bottles. The lifting arrangement is as follows: four wire strops are attached by shackles to four points on the top of the frame. The strops are then attached by shackles to welded metal rings, one for each strop. These metal rings are in turn attached to a larger single metal ring. This larger metal ring is then in turn attached by shackle to the eye around which the CTD cable is bent. The CTD termination cable must then be lead down between this assortment of strops, shackles and rings. Consequently there is chance of wear or damage to the termination. Twice during the cruise the termination came under strain causing it to fail. On the first occasion, a strop became entangled with the CTD cable. On the second, the strops had been replaced due to wear on the old ones. Unfortunately, the new strops were longer so that the termination length was insufficient, and it was pulled apart on deployment. Some simplification of the lifting arrangement is desirable.

3.4.2 Gantry and Winch

The CTD was deployed from the amidships gantry. All deck operations were undertaken by deck crew. On deployment and recovery light throwing lines were used to maintain close control of the package. A 10T traction winch was used to haul the package on the 10 mm Rochester single conductor cable. At the end of each down cast a cable washing system had to be fitted: this took five minutes. The package was hauled 50 m clear of the bottom before the cable washer was fitted, ensuring the safety of the package close to the bottom.

3.4.3 Equipment, Data Capture and Calibrations

3.4.3.1 Pylon and Water Bottles

After teething problems due to difficulties with the termination, the GO 12 position pylon worked satisfactorily. Occasional misfires were reported which in fact had fired a bottle. Only on one occasion did the pylon misbehave. This was on station 21 after a partial flooding of the termination at 4000 m caused an intermittent short to the power supply.

The deck unit in operation with the pylon did not allow uninterrupted power to the CTD during bottle firings. This created bad CTD data during firing of bottles. A switch was fitted between the deck unit and the Level A which allowed the data stream to the Level A to be interrupted at bottle firing. This procedure meant that during the bottle firing there is a time gap of approximately 45 s in the CTD data stream. However, this time gap provided a robust marker to indicate bottle fires.

The bottle depths are shown in Figure 3.2. These depths were chosen to coincide with the depths sampled during JR0a.

The following was noted about the BAS 1.7l GO sample bottles. First, bottle 1 had smashed rosette mountings. This loss was particularly unfortunate as it was one of only three bottles with reversing frames. Second, being old bottles two different types of air vent were used. One had a narrow threaded plastic bung. Two of these sheared when being closed for the first cast. A spare was taken from bottle 1 and the second was replaced by a stainless washer and bolt. Samples were obtained by allowing air to fill the bottle by tipping the top end cap. The following bottles all had intermittent leaks at petcocks and/or O-rings: 3, 11, 5, 6, 10, 4. In addition bottles 5 and 6 had weak bungee.

3.4.3.2 CTD Equipment

The following instruments were fitted to the underwater package:

1. Neil Brown Mk III CTD (no oxygen sensor), S/N 01-3838-1086, conductivity cell S/N C75 (BAS);
2. 12 x 1.7 litre GO rosette (BAS);
3. Three SIS digital reversing thermometers and one SIS precision reversing pressure meter (IOSDL);
4. 10 kHz pinger for near bottom approach (BAS).

The shipboard equipment consisted of:

1. Neil Brown Mk III deck unit and GO water bottle firing unit;
2. IBM PS2 system employing EG&G CTD data acquisition firmware for real time display of data and raw data backup by dumping disk files onto a tape streamer;
3. Primary data acquisition was via the shipboard Level ABC system.

3.4.3.3 Data Capture

CTD data were passed from the CTD Deck Unit to the Level A dedicated microcomputer. In real time this despiked the data and computed one second averages. The time rate of change of temperature was also computed over the one second average. These averages were then passed to the Level B, a SUN workstation. These data are passed to Level C archiving. [*Pollard et al.*, 1987] gives an account of this system. The Level A was prone to serial over-runs. The cause of this is not yet known. The result was the loss of a few seconds of data from each cast, thus losing a few (2 to 4 dbars) of data at each over-run. A more serious problem was when the Level A "locked", failing to pass data to the Level B, constituting a loss of data. This was inconvenient as the data had to be recovered later from the pc and processed using software written to imitate Level A operations. On one occasion after a Level A crash, on re-set the time base jumped ahead. Again the reason for this is not yet known.

3.4.3.4 Temperature Calibration

CTD temperature was calibrated at IOSDL on 24 June 1994 (Issue no. CT007) at 13 temperatures on the ITS-90 scale, at temperatures between -2°C and 25°C. The transfer standard had been calibrated at the triple points of Mercury and water, and at the melting point of Gallium. As for JR0a (Section 2) a temperature offset of about 2°C was introduced, so that likely oceanographic temperatures were all reported by the instrument as positive. The following calibration was applied to CTD temperature data:

$$T = -2.0887 + 0.99055 \times T_{raw} + 0.6380E - 5 \times T_{raw}^2 \tag{3.2}$$

This calibration was in ˚C on the ITS-90 scale, which was used for all temperature data reported from this cruise. For computing derived oceanographic variables, temperatures were converted to the ITS-68 scale, using:

$$T68 = 1.00024 \times T90 \tag{3.3}$$

as suggested by [*Saunders*, 1990]. The mismatch between the time constants of the temperature and conductivity sensors is minimised using a time constant, $\tau = 0.20s$ in:

$$T = T + \tau \times \Delta T \tag{3.4}$$

where ΔT is the time rate of change of temperature over a one second temperature sample (32 Hz) computed in the Level A, as described in Crease *et al.* (1988).

3.4.3.5 Pressure Calibration

CTD pressure was calibrated at IOSDL on 27/6/94 (Issue no. CP0004) at 14 pressures between 0 and 6000 dbar, and at temperatures of 20°C, 10°C and 1°C. The calibration was performed using a dead-weight tester in series with a Paroscientific Digiquartz model 240 portable transfer standard; the Digiquartz was taken as the standard. The resulting calibration information was analysed for temperature dependence and hysteresis between calibrations at increasing and decreasing pressure. As found for JR0a (Section 2), the pressure offset varied with temperature. This effect had not been noted before as the pressure calibration had never been done at different temperatures. The mean in situ temperature of the Drake Passage Section in 1993 was 1.4301 °C with a standard deviation of 1.2265 °C: the pressure calibration at 1°C was applied:

$$P = -6.8 + 0.99917 \times P_{raw} - 2.96E - 7 \times P_{raw}^2 \tag{3.5}$$

followed by the temperature dependent pressure offset correction:

$$\Delta P = \left(T_{lag} - 10.0\right) \times \left(-0.08 + 5.0E - 5 \times P + 1.4E - 9 \times P^2\right) \tag{3.6}$$

Here T_{lag} is a lagged temperature (˚C) constructed from the CTD temperatures. The time constant for the lagged temperature was 400 seconds. Lagged temperature is updated in the following manner. If T is the CTD temperature, t_{del} the time interval in seconds over which T_{lag} is being updated, and t_{const} the time constant, then:

$$W = \exp\left(-t_{del} / t_{const}\right) \tag{3.7}$$

$$T_{lag}\left(t = t_0 + t_{del}\right) = W \times T_{lag}\left(t = t_0\right) + \left(1 - W\right) \times T\left(t = t_0 + t_{del}\right) \tag{3.8}$$

The value of 400 seconds for t_{const} is based on laboratory tests. A final adjustment to pressure is to make a correction to up cast pressures for hysteresis in the sensor. This is calculated on the basis of laboratory measurements of the hysteresis. The hysteresis after a cast to 5500 m (denoted by *dp5500(p)*) is given in Table 3.3. Intermediate values are found by linear interpolation. If the observed pressure lies outside the range defined by the table, *dp5500(p)* is set to zero. For a cast in which the maximum pressure reached is p_{max}, the correction applied to the up cast CTD pressure (p_{in}) is:

$$p_{out} = p_{in} - \left(dp5500\left(p_{in}\right) - \left(\left(p_{in} / p_{\max}\right) \times dp5500\left(p_{\max}\right)\right)\right) \tag{3.9}$$

3.4.3.6 Conductivity Calibration

The conductivity sensor was calibrated on 04/06/94, (Issue no. 90924), by calibration against a Guildline Autosal Model 8400B, S/N 238707 standardised with standard sea water batch P123. The following calibration was obtained:

$$C_{new} = 0.00955 + 0.9783 \times C_{old} \tag{3.10}$$

This was followed by the cell material deformation correction:

$$C_{new} = C_{old} \times \left[1 + \alpha \times \left(T - T_0\right) + \beta \times \left(P - P_0\right)\right] \tag{3.11.1}$$

where the coefficients for the cell material are:

$$\alpha = -6.5E^{-6} {}^\circ C^{-1} \tag{3.11.2}$$

$$\beta = 1.5E^{-8} dbar^{-1} \tag{3.11.3}$$

$$T_0 = 15^\circ C \tag{3.11.4}$$

$$P_0 = 0 dbar \tag{3.11.5}$$

and P, T and C_{old} are CTD pressure, temperature and conductivity.

The conductivity cell was found to be defective, as revealed by a severe hysteresis between down cast and up cast conductivities, and by large station to station changes in the conductivity offset and slope corrections. The cell *C75* was an old cell which had been returned to the manufacturers for re-platinisation of the electrodes. Typically, over a range of 0 to 100 mS/cm the accuracy of the cell should be about 0.0015 mS/cm with a resolution of 0.000002 mS/cm. More importantly, conductivity electrodes drift at varying rates, 0.01 mS/month may be typical. This requires that the calibration is constantly updated. It is, in practice, preferable to group stations for determining a conductivity calibration. The assumption is that the CTD sensor is stable and that by fitting over a group of stations the uncertainty of water sample variability is reduced.

We found for the cell *C75*: (i) hysteresis between down and up casts, amounting to up to 0.06 psu at the surface; (ii) a large station to station offset in salinity (and hence conductivity), of order 0.05 psu per station. The second problem is addressed by determining a conductivity calibration on a station by station basis, admitting that an increase in uncertainty in the calibration will result. However, before that can be done the hysteresis in conductivity must be eliminated. Millard and Yang (1993) document the theory and practice of CTD conductivity calibration.

To determine the relationship between the down and up cast conductivities they were matched on pressure. Conductivity, salinity and in situ temperature differences were then computed at each level. The difference data were then further selected by keeping differences only where the in situ temperature difference was within 0±0.001˚C. For shallow stations with more natural variability between down and up cast this was relaxed to 0±0.003˚C. In the deep water, where the natural variability is least and the water most homogeneous, a pressure match between down and up will reasonably match water parcels. In situ temperature is probably a better water parcel marker than pressure, however matching introduced prohibitive additional computation that was not considered to be useful.

On plotting (down-up) cast conductivity differences a linear relationship with pressure was found for all stations. It is not understood whether this represents a real pressure effect on a failing conductivity cell or whether pressure fortuitously provides a useful variable for describing a model of the (down-up) cast conductivity differences. Note that in practice a model was constructed for the *salinity* differences rather than the *conductivity* differences. Once the old up cast salinity had been corrected a new up cast conductivity was calculated.

The following up cast salinity correction ΔS_{up} was computed:

$$\Delta S_{up} = \left(S_{down} - S_{up}\right) = A + B \times P \qquad (3.12)$$

where new up cast salinity is:

$$S(new)_{up} = S(old)_{up} + \Delta S_{up} \tag{3.13}$$

The new up cast conductivity is then obtained from:

$$C(new)_{up} = SAL78\Big(S(new)_{up}, T, P\Big) \tag{3.14}$$

where $SAL78$ is the equation of state converting salinities to conductivities. Table 3.4 contains model coefficients for (3.12). The coefficients $A1$ and $B1$, Table 3.4, are a second set of up cast salinity correction parameters, obtained after the first conductivity calibration and applied before the final salinity calibration discussed below. Table 3.4 also includes the salinity correction at the maximum pressure of the station $A + B \times P_{\max}$ and R^2. The salinity correction at the minimum pressure is just $A + B \times P_{\min}$ with $P_{\min} = 0$ and hence is equal to the coefficient A. Stations 23 and 18 appear anomalous. No particular reason was found for this. Stations 32 and 33 are shallow.

Figures 3.3 and 3.4 show the bottle - up cast conductivities after the conductivity up cast correction and before the station by station conductivity calibration, plotted against station number and against pressure. Note the large station to station changes in conductivity of the order 0.025 mS/cm and over the cruise of order 0.15 mS/cm (~1.0 mS/cm/month). This is to be compared with typical sensor drifts of the order 0.01 mS/month. Thus the drift in the sensor is two orders of magnitude worse than can be reasonably expected. Due to the large scatter, no apparent depth dependence of residuals is evident in Figure 3.4.

Having corrected the up cast conductivities we then determined a station by station conductivity calibration. Bottle conductivities were regressed against (bottle - up cast) conductivities to obtain coefficients for the conductivity sensor model (10). Bad data were eliminated by eye where the data seemed "obviously" bad. Table 3.5 contains the station by station trends for the conductivity offset and slope calibration coefficients.

The conductivity calibrations in Table 3.5 were applied followed by the material deformation correction (11.1). We then recomputed a new correction for the upcast conductivities as described earlier, coefficients $A1$ and $B1$ in Table 3.4. Figures 3.5 and 3.6 show the (bottle - up cast) conductivity differences plotted against station number and against pressure. These figures may be compared to Figures 3.3 and 3.4. The station by station trends in conductivity difference have now been reduced. A noticeable depth dependence remains. This could be due to some other physical effect of the instrument or could be a description of the lack of fit of the model used to correct the up cast conductivities. In the second case nothing could be done except to fit a more sophisticated model to correct up cast conductivities. In the first case however an appropriate salinity correction could be applied.

The mean (bottle - up cast) conductivity difference is 0.0001 mS/cm with a standard deviation of 0.0034 mS/cm for 251 out of 289 samples. The scatter is about twice what one might expect for a good cell.

3.4.3.7 Salinity Calibration

Having observed a systematic depth dependence in the bottle - up cast conductivities and in the (bottle - up cast) salinity differences, a final salinity calibration on a station by station basis was made by fitting the residuals with:

$$dsalin = a + b \times P + c \times T \tag{3.15}$$

The most likely reason why this fit was necessary is that the conductivity offset and slope corrections were not determined with sufficient accuracy with a maximum of 11 bottles per cast over the water depth. Errors in these model coefficients would lead to a systematic depth dependence in salinity through the effects of the (non-linear) equation of state for sea water.

The $dsalin$ correction at (P_{max}, $T[P_{max}]$) may, in normal circumstances, be used as an estimate of the cell drift. However, here we should have accounted for the cell drift and $dsalin$ thus represents the remaining (random) errors left from the original fit (which will of course be removed by the correction). The corrections at P_{max} and P_{min} are given in Table 3.6 with the coefficients for (3.15).

3.4.4 Reversing Pressure and Temperature Measurements

Four reversing instruments were available: three SIS RTM's and one SIS RPM.

3.4.4.1 Reversing Pressure Measurements

One digital SIS RPM, P6132H, was available, installed on the rosette in position 1. P6132H was calibrated by the manufacturer on 22/02/90 and the following calibration data were supplied:

(P6132H pressure (db), correction applied (db)), (6,-6), (975,+12), (1949,+12), (2930,+12), (3919,+8), (4907,-4), (5405,-11), (6022,-22).

The last point is an extrapolation. The following equation was used to correct the RPM data:

$$P = -6.0 + 1.01493 \times P - 2.941E - 6 \times P^2 \tag{3.16}$$

and fits the manufacturers calibration data to better than 1 db. The (P6132H - up cast) pressure differences against depth. are 0 db at 0 db, up to -18 db at 3500 db and -12 db at 4500 db. This is typical of residuals observed with this RPM, as observed on WOCE cruise A11 [*Saunders*, 1993] when using an IOSDL CTD. For comparisons deeper than 1500 db the mean pressure difference is -14.4 db with a standard deviation of 2.2 db (22/32 points). For the A11 cruise a mean difference over the same depth range was 14 db.

3.4.4.2 Reversing Temperature Measurements

Three digital SIS RTMs were available. They were calibrated using the linear fits given in Table 3.7.

$$T_{cal} = A + B \times T_{raw} \tag{3.17}$$

Table 3.8 gives the means and standard deviations of the temperature residuals (RTM - CTD). The mean (RTM - CTD) temperature difference is 4 m˚C with a standard deviation of 1.6 m˚C. It was noted in section 2 that the BAS CTD changed its temperature calibration by 3.5 m˚C between calibrations. However, until we have further evidence from the next CTD temperature calibration the CTD temperature data are concluded to be satisfactory.

3.4.5 Final comments on the salinity data

Figures 3.7 and 3.8 summarise the final (bottle - upcast) salinity differences. The mean difference within 0±0.01 psu is –0.0001 with a standard deviation of 0.0018 for 251 out of 281 samples. What must remain in mind is this: due to a failing conductivity cell a model of the difference between down and upcast conductivities has been constructed. The object of this model was to correct the observed hysteresis between down and up casts. This correction to upcast conductivities then allowed a typical calibration to be done against salinity samples. This process was necessary because it was impossible to achieve a satisfactory match between down cast data and bottles in the variable upper layers. The extent to which we believe the residuals described above represent the real CTD data errors is entirely dependant on our simple linear correction of the upcast conductivities.

3.5 Underway Observations

3.5.1 Thermosalinograph

To calibrate the thermosalinograph (TSG) salinity samples were drawn from the TSG tank overflow at two hourly intervals. A Sea-Bird Electronics TSG was run continuously where ice conditions allowed. Samples for calibration were drawn only on the southward crossing of the Drake Passage. The TSG was calibrated on 21/06/94. The temperature sensor (no. 593) gave a mean difference to a bath temperature of 0.00017 °C with a standard deviation of 0.00084 °C. The temperature sensor (no. 820) gave a mean difference to a bath temperature of 0.00011 °C with a standard deviation of 0.0009 °C. The conductivity sensor (no. 820) gave a mean difference to a salt bath of -1.0E-05 mS/cm with a standard deviation of 5.3E-04 mmho/cm. Note that the surface temperature sensor was digitised to 0.1 °C.

TSG salinity measurements at 10 s intervals were averaged to 2 minute intervals and then median despiked, discarding data more than 0.01 psu from a mean computed over 5 adjacent data values. The data were further despiked by hand and then filtered using a top hat filter (sum of weights = 1) with a width of 30 minutes. These data were then merged with the underway salinity samples and the underway salinity minus TSG salinity difference computed. This difference was filtered with a top hat filter (sum of weights = 1) with a width of 28 hours and was then added to the TSG salinities.

The mean difference (within ±2σ) for the TSG minus bottle salinities is 0.0012 psu with a standard deviation of 0.0193 for 54/57 samples.

3.5.2 Echosounding

The *JCR* is fitted with an IOS Mk IV PES, whose display is located in the UIC lab, and a Simrad EA 500, whose display and controls are located in the wheelhouse. The EA 500 depths were logged via a level A as usual. The EA 500 data were also logged to colour hardcopy in the wheelhouse. It was realised near the end of the cruise that the sound speed assumed in the EA 500 software was 1471m/s and not 1500m/s as required by Matthew's or Carter Table corrections. In order to apply the RVS prodep correction to the data, depths in the raw data files were first scaled by 1500/1471. The PES display in the UIC lab was also used for monitoring the 10 kHz pinger on the CTD rosette during near-bottom approaches.

3.6 XBTs

Eleven XBTs (T7s) were deployed from a hand-held launcher attached to a Sippican Mk 9 deck unit interfaced to a PC. Table 3.9 gives station positions. The data were logged using the Sippican software on the PC into files with extension SIP, and then converted into files with depth/ temperature pairs with extension EXP. These ASCII files were transferred for further processing on the SUN sytem using floppy disks. These data were then converted into PSTAR format. A program written at the James Rennell Centre by Mike Griffiths was then used to convert the profiles into TESAC message format. This is a general purpose routine which also works with CTD and ADCP data. One problem encountered with the XBT system concerned the electrical connection between the XBT probe and the launcher. It was discovered that on attempting to enter the launch mode on the PC, the software would not recognize that a probe had been loaded. This could be resolved by removing and reloading the probe repeatedly until the software responded.

3.7 Acoustic Doppler Current Profiler (ADCP) Measurements

3.7.1 Instrument performance

Instrument, software and operations were as described in 2.6.1.

3.7.2 Determination of speed correction factor

The determination of, and reason for, of the sound speed correction factor is described in 2.6.2. The form of the factor F adopted here is:

$$F = 1.0055 \times \left(1 - 0.004785 \times T + 0.0000355 \times T^2\right) \tag{3.18}$$

3.7.3 Determination of heading misalignment

All data were corrected for the variation in the ship's gyrocompass heading errors by employing data from the Ashtech GPS 3DF heading system, described below. Ashtech-gyro differences had been determined by comparing the two instantaneous measurements of heading, and smoothed to two minute averages. These differences were merged onto the ADCP two-minute ensembles, and relative direction modified by the addition of Ashtech-gyro difference. In principle the ADCP data were now referenced to heading determined from the GPS system, and needed to be corrected only for the fixed misalignment between the direction defined by the GPS antennas and the direction of the ADCP transducer.

The misalignment error (and any remaining amplitude error) was calculated as follows:

a) Two-minute ensembles were merged with GPS positions which had been filtered over 2 minutes, and ship's east and north velocity calculated. Absolute ADCP bottom tracking velocity was also calculated.

b) All good data were then listed and divided by eye into periods of between 20 and 30 minutes in which: (i) at least 10 consecutive two-minute ensembles had bottom tracking data; (ii) two-minute averages of speed had a range of no more than 20 cm/s; (iii) two-minute averages of direction over the ground had a range of no more than 20 degrees. 30 such intervals were found and then averaged together to give estimates of speed and direction from GPS and ADCP. Each average thus represented a period when the ship was steaming on a steady heading at a steady speed.

c) The speed and misalignment errors were computed for each averaging period as (speedGPS/speedADCP) and (directionGPS - direction ADCP). The resulting direction difference would need to be added to all ADCP directions to produce correct ship-over-ground or ship-over-water velocities.

The ratio of GPS and ADCP speeds average to 1.00 with standard deviation 0.04 units. The GPS minus ADCP directions have mean value -2.14 degrees, with standard deviation 0.30. These are remarkable results. These numbers are the same as those calculated for the previous year’s data (section 2.5) but using differential GPS data. Results are given in Table 3.10.

3.8 Navigation

3.8.1 GPS-Trimble

Navigation during the cruise was provided by the ship's Trimble 4000 receiver, with fixes roughly once per second. Data were logged while the ship was tied up at FIPASS and at Rothera in order to assess the noise level of the positional information. RMS errors in position were calculated from the FIPASS data over 10 minute intervals. The resulting rms's have average 24 m and standard error 1 m. Using 20 minute intervals does not appreciatively improve the errors, so 10 minute averages have been adopted for the ADCP data on this cruise. These rms errors may introduce nominal uncertainties in velocity of 4 cm/s on station. The precision should be greatly improved once differential GPS data is used.

3.8.2 Differential GPS

After the success of last year's use of differential GPS data (section 2), the Trimble receiver on the *JCR* was upgraded in order to deliver one half of the differential signal required. The second part is to be acquired from a ground station in Santiago, Chile. It remains to be seen how successful this will be given the increasing distance between the two differential sites with time.

Raw pseudorange data were output via a serial port and the ship's patch panels to a PC in one of the laboratories. Software on the PC supplied by Trimble recorded the data in sets of files on the hard disk. Data were recorded at 1 Hz in files of length 1 hour during the transect, but then the frequency was reduced to 0.1 Hz thereafter. The elevation mask for the data was inadvertently left at a default value of 15°, which will reduce the amount of useful data. A value of 5° would have been more useful.

One difficulty encountered was that the PC was not connected to the ethernet, consequently backing up the data required transfer by floppy disk, which proved onerous at times. A limitation of the PC software was that filenames were generated using a day number and a sequence number incremented from the last file present in the current directory. This meant that restarting the logging in other directories for neatness risked the creation of files with identical names on the system.

The receiver and PC ran without problems throughout the cruise.

3.8.3 Gyrocompass

The ship is fitted with two identical gyrocompasses - Sperry Mk 37. The instrument used for ship navigation was also the one logged via a level A and to provide headings to the repeaters in the labs and to the ADCP. While the ADCP is supplied via a synchro pickup, the lab repeaters measure relative changes, and have to be initialised to the correct heading individually. The ADCP and the level A receive the same voltages from the synchro pickup on the gyro, but digitise them separately. The gyrocompass in use was swapped at Rothera by the Second Officer. No problems with the gyrocompass itself were noted. However, at the beginning of the cruise the level A was observed to only output integral values of heading. This was because of the limited resolution programmed into the level A application. The problem was resolved by swapping the gyro application EPROMS with those from an old level A.

3.8.4 Ashtech GPS3DF

An Ashtech GPS 3DF system was purchased from UK WOCE Capital funds and installed on the *JCR* while the ship was at Grimsby by RVS. The antennas and cables were still in place from the year before. The receiver is located in the wheelhouse, next to the Trimble receiver. The receiver sends ASCII messages which are logged to the ship's computer system via a level A. The ASCII message $GPPAT contains time, position and attitude (pitch, roll, heading). The message is further time-stamped with ship master clock time at the level A. This ensures that the same time base is used for merging with gyrocompass data and determining gyro errors. The antenna geometry was surveyed using the Ashtech software and data collected in Grimsby both in 1993 and 1994, but of course with different receivers. No significant differences in calibration were found. The port side aft antenna is designated as number 1; port-fwd is 2, stbd-fwd is 3, stbd-aft is 4. The relative positions are given in the table of receiver parameters below. The XYZ vectors have been adjusted so that the heading is defined by the direction normal to the 1-4 baseline, ie that baseline has Y=0. The parameters used for this cruise were as follows (mainly set in menu 4 or its submenus).

```
Menu 4

posn         0,0,0
Alt known          N
Ranger             0
UnhealthySV        Y
Rec intvl          001
Min SV             4
elev mask          10
pdop mask          40
PortA        nmea  off
             real time   off
             VTS   off
             baud  9600
PortB (level A logging)  nmea  on
             baud  9600
             options     PAT ON
                   1 second send rate

ATTD CNTRL MENU

max rms      010
search ratio       0.5
one sec update     Y
3SV search   N
      tau    T0    Q     R
Hdg   999    000   1.0e-2      1.0e0
pitch 020    000   4.0e-2      1.0e0
roll  020    000   4.0e-2      1.0e0
Kalman filter reset      N

ATTD SETUP MENU
      X      Y     Z
1-2   2.943 4.745 0
1-3   11.493       4.753 -0.006
1-4   13.222       0     0
OFFST 0      0     0
max cycle          0.200 smoothing    N
max magnitude      0.080 max angle    020
```

Attitude data were logged at a rate of 1 Hz. Following previous data processing paths, these were subjected to various data quality control procedures and merged with gyro measurements. Ashtech minus gyro headings were averaged into two minute intervals on a daily basis, of which 80-95 % contained data. Linear interpolation was employed to provide a complete set of gyro corrections. These have been used in processing the ADCP data.

The main problem encountered with this instrument was that while the ship was at FIPASS, the attitude data was poor, and based on old information. The manual suggested that low signal to noise ratios on the reception from each satellite were responsible. However the data did not improve on sailing from Stanley. Eventually, clearing external and internal memory kicked the receiver into giving sensible attitude data. The problem seemed to recur after Faraday and a second reset was performed during the visit to Rothera. The result of this second reset was not as clear cut as the first, since intermittently thereafter poor data would be recorded as the satellite configurations changed.

Year	A	SE	B	SE	N	R2	COV
1993	-596.074	0.005	17.19	0.27	70	0.984	4.84E-03
1994	-559.272	0.006	16.13	0.38	40	0.977	4.42E-03

Table 3.1: Fit statistics for the data of figure 3.1. SE is the standard error, N is the sample number, R2 correlation coefficient and COV the covariance.

Stn	Date	Time (UTC)			Latitude	Longitude	Depths (m)				pmax	sam	Notes
	yymmdd	Start	Bot	End	deg min S	deg min W	u-wat	c-wat	ho	wire	db	#	
01	941115	054930	061000	063500	-53 34.70	-59 06.38	1910.5	1881.9	n/a	1256	n/a	0	Note 1
02	941115	190135	092540	101214	-53 34.19	-59 05.91	1898.7	1870.2	n/a	n/a	1711	8	Note 2
03	941115	163129	164742	170451	-54 39.08	-58 33.61	209.2	205.6	24	180	183	3	Note 3
04	941115	190135	192012	194600	-54 55.49	-58 21.63	670.6	657.7	30	640	651	1	Note 4
05	941115	222541	225333	233007	-54 57.58	-58 23.00	1464.7	1440.6	n/a	1440	1473	9	Note 5
06	941116	032058	040655	045453	-54 57.36	-58 21.55	1508.8	1484.2	15	1440	1453	9	Note 6
07	941116	113154	120935	131200	-55 04.15	-58 17.25	2083.1	2053.6	20	2026	2069	10	
08	941116	140149	144636	155315	-55 07.29	-58 15.41	2546.0	2514.5	20	2470	2535	11	
09	941116	164521	173729	190300	-55 10.30	-58 14.82	3025.3	2993.8	60	2898	2991	10	
10	941116	194501	204701	220745	-55 12.82	-58 13.55	3765.6	3739.8	180	3552	3641	10	
11	941117	003955	015645	033400	-55 31.24	-58 00.31	4246.1	4227.1	n/a	n/a	4247	10	
12	941117	061740	073950	092509	-55 49.11	-57 52.26	4627.9	4615.9	10	4563	4691	11	
13	941117	113233	123626	140620	-56 07.72	-57 40.26	3736.2	3701.1	20	3660	3717	11	
14	941117	164444	174542	193300	-56 27.33	-57 29.55	3579.6	3542.9	50	3531	3555	11	
15	941117	214823	223729	235125	-56 47.14	-57 18.27	2598.2	2559.7	n/a	2650	2699	10	
16	941118	030358	042301	060109	-57 05.58	-57 07.21	4423.9	4398.9	40	4350	4455	11	
17	941118	084349	095317	112609	-57 25.73	-56 55.66	4006.7	3974.2	20	3919	4017	11	
18	941118	134740	144820	163400	-57 44.10	-56 42.11	3418.9	3381.4	n/a	3392	3447	11	
19	941118	184322	195946	213813	-58 03.42	-56 32.95	3979.7	3940.0	65	n/a	4015	11	
20	941119	002005	012607	030900	-58 21.68	-56 20.86	3863.1	3822.2	50	3739	3837	11	
21	941119	061400	072334	090512	-58 41.62	-56 09.53	3839.4	3798.3	20	3750	3853	11	
22	941119	112219	122530	135300	-58 59.76	-55 57.88	3820.3	3779.0	15	3730	3837	11	
23	941119	222728	233905	011900	-59 35.79	-55 51.95	3707.3	3664.8	40	3597	3693	11	Note 7
24	941120	033222	043549	060229	-59 18.68	-55 42.04	3774.6	3732.8	35	3660	3771	11	
25	941120	083422	093805	112000	-59 38.81	-55 30.96	3724.8	3682.6	26	3625	3723	11	
26	941120	134515	144314	160712	-60 00.29	-55 19.66	3548.2	3504.7	40	3434	3533	11	
27	941120	183831	193533	205250	-60 20.16	-55 04.80	3481.7	3438.2	60	3340	3437	11	
28	941121	034213	043817	055752	-60 40.86	-54 48.72	3145.2	3100.7	28	3033	3115	10	
29	941121	070525	075149	085909	-60 48.05	-54 43.12	2597.4	2553.9	15	2505	2571	10	
30	941121	122044	125047	134851	-60 49.80	-54 43.04	1699.7	1664.2	40	1679	1729	8	
31	941121	144438	150043	152919	-60 51.12	-54 42.72	951.2	927.7	30	896	919	6	
32	941121	164145	165158	171122	-60 58.92	-54 37.34	604.5	587.9	46	536	551	6	
33	941121	181756	182539	184819	-61 03.01	-54 36.02	396.1	381.7	15	351	357	4	Note 8

Table 3.2: JR0b station positions, 1994.

Notes:
Note 1: Test cast, aborted
Note 2: Test cast
Note 3: Start of section – conductivity bad
Note 4: Conductivity bad
Note 5: Conductivity bad
Note 6: Conductivity OK, repeat of station 5
Note 7: Station west of section
Note 8: End of section

P	dp(5500(P))
db	db
5500	0.0
5000	0.9
4500	1.7
4000	2.5
3500	3.2
3000	4.1
2500	5.1
2000	6.0
1500	6.7
1000	6.5
500	3.3
300	2.7
100	0.6
0	0.0

Table 3.3: CTD pressure (P) hysteresis dp(5500(P))

Stn	A	B	R2	A2	B2	R2	Scorr
01	n/a	n/a	n/a	n/a	n/a	n/a	n/a
02	-2.14E-02	1.17E-05	0.890	-2.12E-02	1.17E-05	0.891	-1.28E-03
03	-1.58E-01	1.23E-03	0.985	-1.46E-01	1.14E-03	1.000	6.24E-02
04	-1.01E-01	8.96E-05	0.086	-1.01E-01	8.96E-05	0.086	-4.28E-02
05	-1.95E-01	1.36E-04	0.790	-1.95E-01	1.36E-04	0.790	5.52E-03
06	-4.71E-02	3.11E-05	0.976	-4.77E-02	3.15E-05	0.976	-1.89E-03
07	-4.73E-02	2.13E-05	0.943	-4.70E-02	2.11E-05	0.943	-3.26E-03
08	-4.58E-02	1.70E-05	0.938	-4.52E-02	1.68E-05	0.938	-2.59E-03
09	-6.64E-02	2.05E-05	0.977	-6.57E-02	2.03E-05	0.977	-4.92E-03
10	-4.29E-02	1.10E-05	0.976	-4.21E-02	1.08E-05	0.976	-2.85E-03
11	-3.59E-02	8.01E-06	0.978	-3.55E-02	7.93E-06	0.978	-1.83E-03
12	-2.67E-02	5.28E-06	0.967	-2.63E-02	5.20E-06	0.967	-1.92E-03
13	-2.90E-02	7.10E-06	0.923	-2.85E-02	6.99E-06	0.923	-2.52E-03
14	-3.13E-02	8.05E-06	0.961	-3.07E-02	7.90E-06	0.961	-2.59E-03
15	-3.28E-02	1.11E-05	0.979	-3.20E-02	1.08E-05	0.979	-2.79E-03
16	-1.91E-02	4.06E-06	0.968	-1.87E-02	3.97E-06	0.968	-1.02E-03
17	-1.72E-02	4.09E-06	0.944	-1.69E-02	4.01E-06	0.944	-7.68E-04
18	-3.57E-02	5.73E-06	0.941	-3.49E-02	5.61E-06	0.942	-1.56E-02
19	-2.35E-02	5.66E-06	0.927	-2.29E-02	5.53E-06	0.927	-7.33E-04
20	-1.37E-02	3.46E-06	0.682	-1.35E-02	3.39E-06	0.682	-4.55E-04
21	-1.35E-02	3.38E-06	0.266	-1.32E-02	3.31E-06	0.267	-4.63E-04
22	-1.09E-02	2.64E-06	0.886	-1.06E-02	2.58E-06	0.886	-7.31E-04
23	-6.24E-02	1.67E-05	0.971	-6.13E-02	1.64E-05	0.971	-6.61E-04
24	-2.02E-02	5.08E-06	0.914	-1.96E-02	4.95E-06	0.914	-9.84E-04
25	-1.39E-02	3.50E-06	0.806	-1.36E-02	3.42E-06	0.806	-8.88E-04
26	-1.01E-02	2.67E-06	0.890	-9.80E-03	2.60E-06	0.891	-6.05E-04
27	-1.35E-02	3.83E-06	0.768	-1.32E-02	3.75E-06	0.768	-3.05E-04
28	-1.83E-02	5.49E-06	0.755	-1.79E-02	5.36E-06	0.755	-1.19E-03
29	-8.33E-03	3.18E-06	0.606	-8.21E-03	3.14E-06	0.606	-1.43E-04
30	-1.04E-02	4.37E-06	0.358	-1.01E-02	4.28E-06	0.358	-2.74E-03
31	-2.73E-03	2.64E-06	0.210	-2.67E-03	2.57E-06	0.209	-3.06E-04
32	-2.00E-02	3.52E-05	0.877	-1.93E-02	3.41E-05	0.878	-5.67E-04
33	-6.32E-03	1.69E-05	0.015	-3.12E-02	8.99E-05	0.815	8.54E-04

Table 3.4: Fit parameters for eq. 3.12; see text for explanation.

Stn	A	B	R2
01*	0.0000	1.0000	n/a
02	-0.2057	0.9935	0.920
03*	0.0000	1.0000	n/a
04*	0.0000	1.0000	n/a
05*	0.0000	1.0000	n/a
06	-0.8564	1.0140	0.797
07	-0.2723	0.9964	0.396
08	-0.0173	0.9889	0.865
09	-0.0502	0.9909	0.832
10	0.1109	0.9842	0.863
11	-0.1533	0.9918	0.867
12	-0.0675	0.9886	0.965
13	0.0030	0.9859	0.922
14	0.0668	0.9838	0.774
15	0.2399	0.9787	0.970
16	0.1499	0.9810	0.982
17	0.1215	0.9817	0.994
18	0.1749	0.9802	0.982
19	0.1616	0.9801	0.942
20	0.0709	0.9828	0.958
21	0.0909	0.9820	0.866
22	0.1108	0.9812	0.994
23	0.1073	0.9834	0.992
24	0.2778	0.9761	0.943
25	0.1183	0.9810	0.997
26	0.2632	0.9759	0.996
27	0.1238	0.9803	0.994
28	0.1331	0.9802	0.964
29	-0.1556	0.9895	0.944
30	0.0720	0.9820	0.998
31	0.1041	0.9808	0.999
32	0.4559	0.9687	0.997
33	0.2726	0.9749	0.933

Table 3.5: Trends for conductivity slope (B) and offset (A) calibration coefficients by station. Bad fits (*) set to A=0, B=1.

Stn	A	B	C	Pmin	T(pmin)	Pmax	T(pmax)	dsalin Pmin	dsalin Pmax
02	137.16	-0.0520	-25.90	42.4	5.205	985.8	3.325	0.000	0.000
03									
04									
05									
06	-51.23	0.0146	10.65	12.9	5.645	1447.0	2.511	-0.009	
07	-48.57	0.0178	9.45	10.9	5.540	2066.2	2.155	-0.004	-0.009
08	-39.15	0.0145	7.06	15.6	5.638	2534.8	1.837	-0.001	-0.011
09	-29.54	0.0176	5.29	10.8	5.691	2989.5	1.439	-0.001	-0.031
10	-30.77	0.0086	5.49	14.5	5.639	3637.3	0.767	0.000	-0.005
11	-24.92	0.0069	5.19	15.5	5.549	4246.0	0.164	-0.004	-0.005
12	-15.45	0.0047	3.01	13.8	5.466	4687.5	0.189	-0.001	-0.007
13	7.28	-0.0042	-1.75	12.1	5.451	3716.3	0.711	0.002	0.010
14	-9.58	0.0042	0.93	14.2	4.104	3554.0	0.541	0.006	-0.006
15	1.15	0.0027	-3.49	77.7	1.508	2696.7	0.973	0.004	-0.005
16	-4.58	0.0012	0.53	16.5	0.971	4454.4	0.028	0.004	-0.001
17	0.15	0.0016	-0.91	10.7	0.198	4016.2	-0.094	0.000	-0.007
18	22.63	-0.0054	-11.12	20.0	-0.038	3445.6	-0.081	-0.023	-0.005
19	-0.77	0.0020	-1.80	16.6	0.076	4014.3	-0.268	0.001	-0.008
20	-0.18	0.0002	-2.64	11.3	0.119	3835.9	-0.225	0.000	-0.001
21	15.79	-0.0055	-12.11	14.3	-0.187	3852.2	-0.366	-0.018	0.001
22	1.08	0.0004	-0.06	9.7	0.121	3836.2	-0.330	-0.001	-0.002
23	2.26	0.0079	-4.47	13.8	0.274	3690.5	-0.359	-0.001	-0.033
24	-4.05	0.0018	-1.73	19.8	0.223	3771.6	-0.353	0.004	-0.003
25	-0.79	0.0007	-0.30	17.0	-0.738	3722.7	-0.367	0.001	-0.002
26	-2.02	0.0006	-1.15	16.6	-0.401	3532.2	-0.348	0.002	0.000
27	-2.03	0.0000	-0.25	18.4	-0.668	3436.6	-0.268	0.002	0.002
28	-2.10	0.0012	-1.18	15.9	-0.902	3115.5	-0.332	0.001	-0.002
29	-5.85	0.0027	2.80	11.2	-0.890	2571.2	-0.097	0.008	-0.001
30	0.08	-0.0011	0.90	12.1	-0.439	1727.3	0.110	0.000	0.002
31	2.16	-0.0022	1.99	14.1	-0.780	918.7	0.195	-0.001	-0.001
32	-12.36	0.0061	-14.73	102.1	-0.755	550.0	-0.552	0.001	0.001
33	49.48	0.0765	106.60	17.1	-0.703	356.6	-0.730	0.024	0.001
							mean	**0.000**	**-0.005**
							stdev	**0.008**	**0.009**

Table 3.6: Final salinity calibration. See text (section 3.3.5) for explanation.

PoR	RTM	A	B	DoC	SRC
1	T714	1.51E-02	1.000879	07/06/1994	IOSDL
3	T401	-1.93E-02	1.000635	07/06/1994	IOSDL
3	T746	-5.11E-03	1.000502	07/06/1994	IOSDL

Table 3.7: Digital RTM calibrations. See text (section 3.3.6.2) for explanation.

Pair	N	mean	sd	N(<2sd)	mean	sd
T714-CTD	32	0.1913	0.9993	23	-0.0051	0.0021
T401-CTD	29	0.0118	0.3681	29	-0.0044	0.0014
T746-CTD	30	0.0148	0.3659	20	-0.0029	0.0013

Table 3.8: Statistics of temperature residuals (RTM–CTD).

XBT Number	Probe Type	Day Number	Time UCT	Latitude		Longitude		PES Depth	Surface Temp.
				degrees	minutes	degrees	minutes		
	T7	322	0625	-57	6.6	-57	3.7	4335	
839095	T7	322	0743	-57	17.4	-56	58.1	4069	0.2
	T7	322	1232	-57	36.6	-56	47.3	3211	
839097	T7	322	1241	-57	37.8	-56	46.4	3418	0.1
839096	T7	323	0439	-58	32.4	-56	13.8	3848	0.3
839104	T7	323	1500	-59	9.6	-55	48.9	3713	0.4
	T7	324	0207	-59	27.7	-55	45.9		0.3
	T7	324	0725	-59	30.0	-55	35.0	3749	
	T7	324	0731	-59	30.6	-55	34.6	3747	
	T7	324	1204	-59	47.4	-55	25.0	3678	
	T7	324	1222	-59	49.8	-55	23.7	3635	-0.4

Table 3.9: XBT launches.

Number in average	Ratio of GPS to ADCP speed	GPS direction	ADCP direction	GPS-ADCP direction difference (allowing for 180° ambiguity)
15	0.988	-105.540	72.210	2.250
15	0.996	-106.132	71.513	2.354
14	1.013	-105.677	71.347	2.976
15	1.004	-105.832	71.529	2.639
15	1.000	-106.254	71.292	2.454
15	0.992	-106.644	71.273	2.083
15	0.996	127.724	-54.086	1.810
15	1.002	126.705	-55.711	2.415
13	1.006	-170.334	7.579	2.088
12	1.005	178.760	-2.948	1.708
11	1.018	-91.780	86.277	1.942
15	0.994	-93.168	84.420	2.412
11	0.993	-109.633	67.920	2.447
15	1.001	-110.748	67.136	2.117
15	0.992	-110.710	66.911	2.378
14	0.994	-110.603	67.217	2.181
15	0.995	-112.004	65.563	2.433
15	0.998	-76.496	101.440	2.064
10	0.996	-76.250	101.818	1.932
14	1.004	-75.793	102.256	1.951
14	0.989	-75.396	102.656	1.948
15	0.996	-73.242	104.612	2.146
14	0.995	-72.242	106.022	1.737
12	1.006	-70.951	106.981	2.068
15	0.984	-67.090	110.969	1.941
13	0.998	-69.277	108.694	2.029
11	1.016	43.607	-138.118	1.724
11	1.004	-138.289	39.473	2.239
15	1.007	-112.958	65.451	1.591
13	1.002	-134.130	43.693	2.178

Table 3.10: Average ADCP speed and heading corrections.

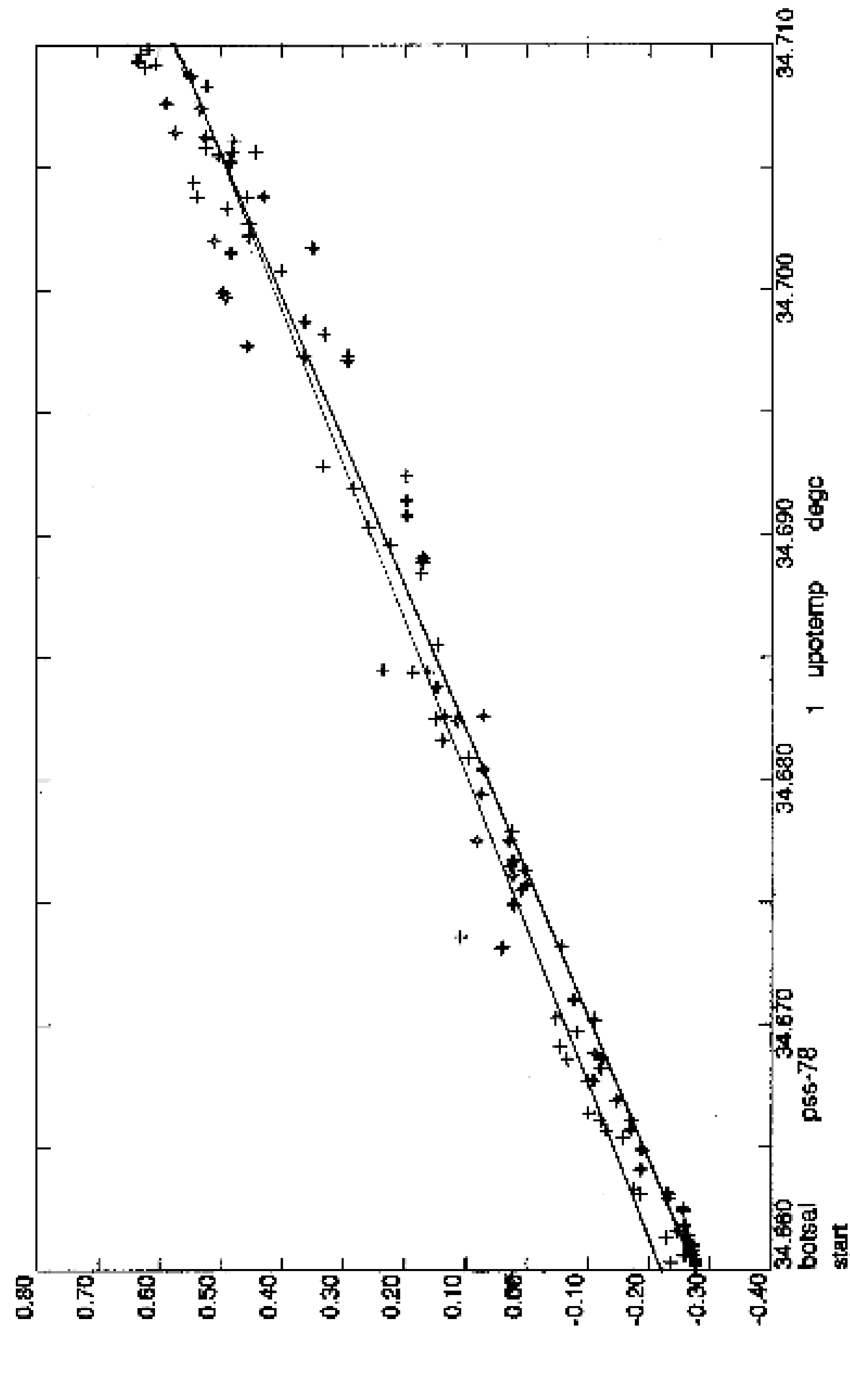

Figure 3.1: Potential temperature vs bottle salinities for R93 (JR0a, star) and R94 (JR0b, plus).

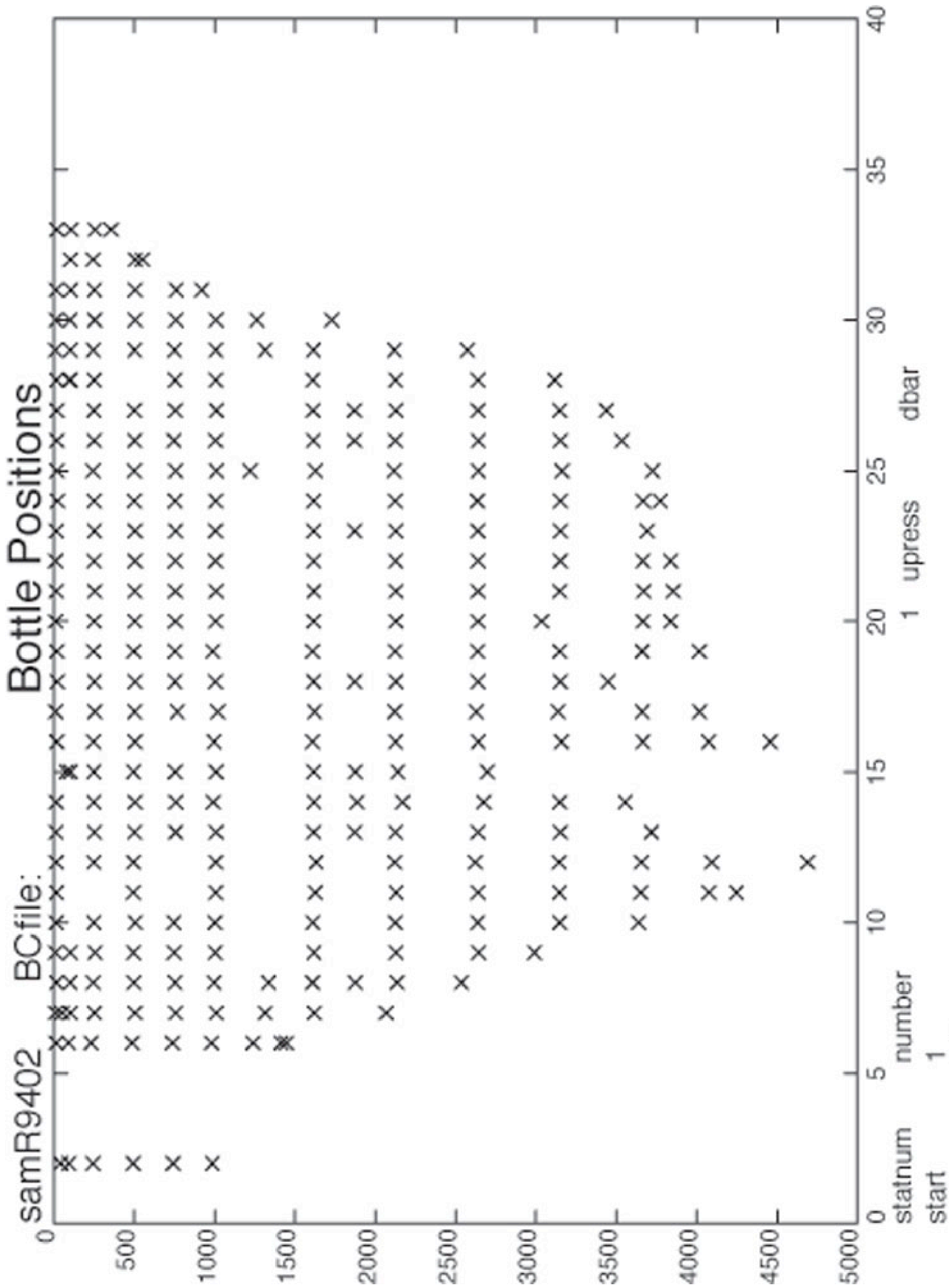

Figure 3.2: JR0b bottle depths versus station number.

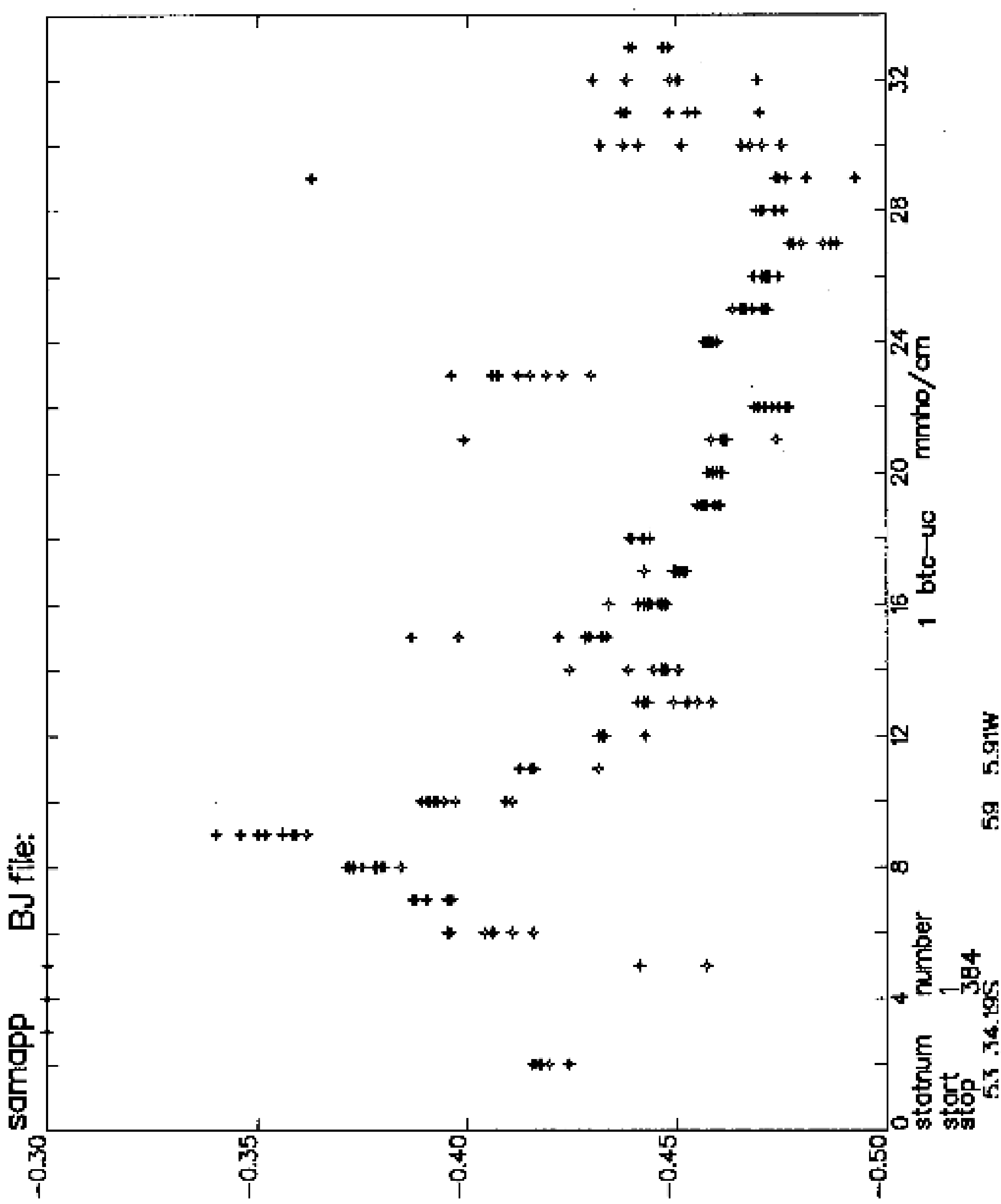

Figure 3.3: (bottle minus up cast) conductivity differences after applying equations (3.12) to (3.14) against station number.

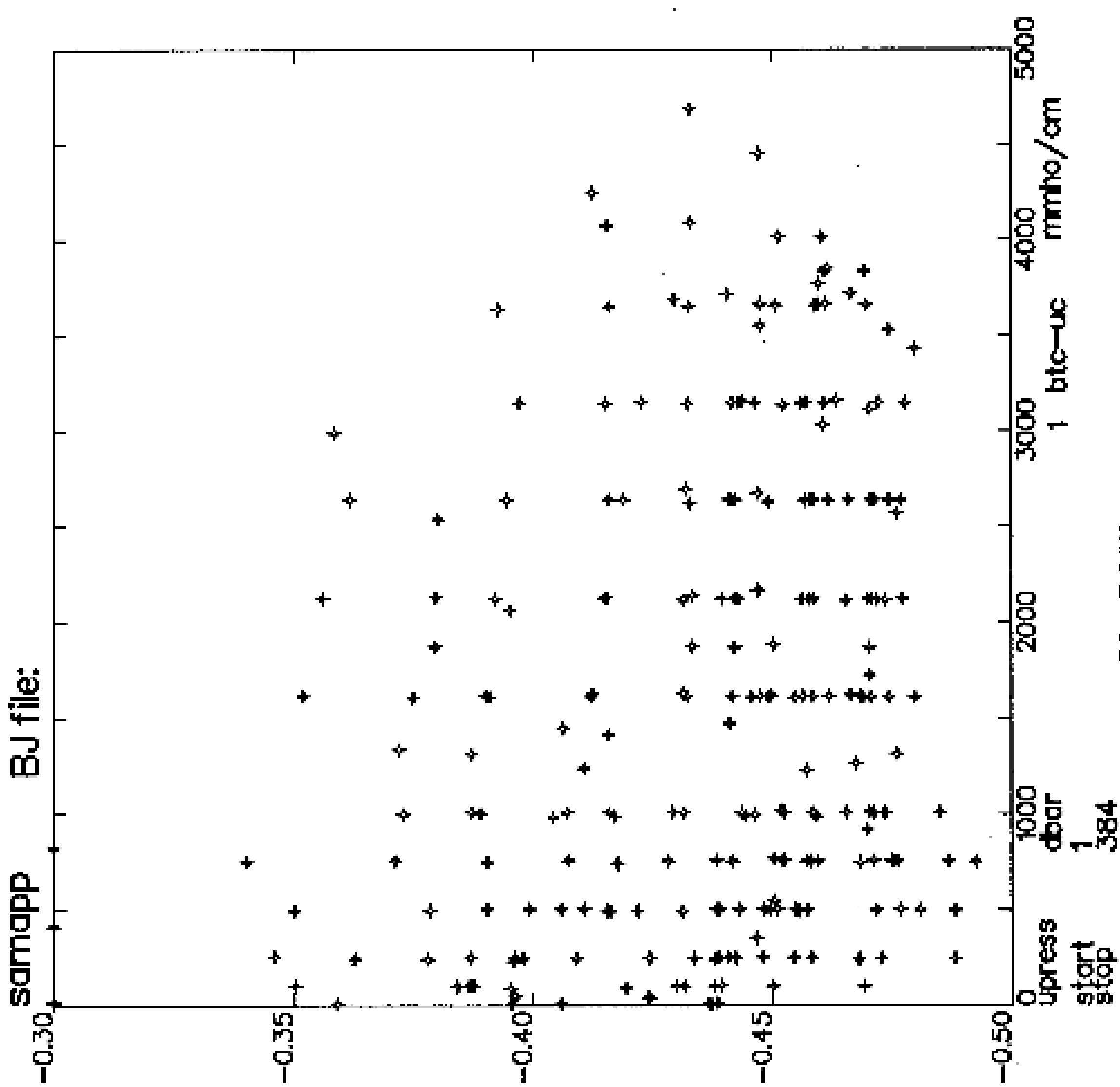

Figure 3.4: (bottle minus up cast) conductivity differences after applying equations (3.12) to (3.14) against pressure.

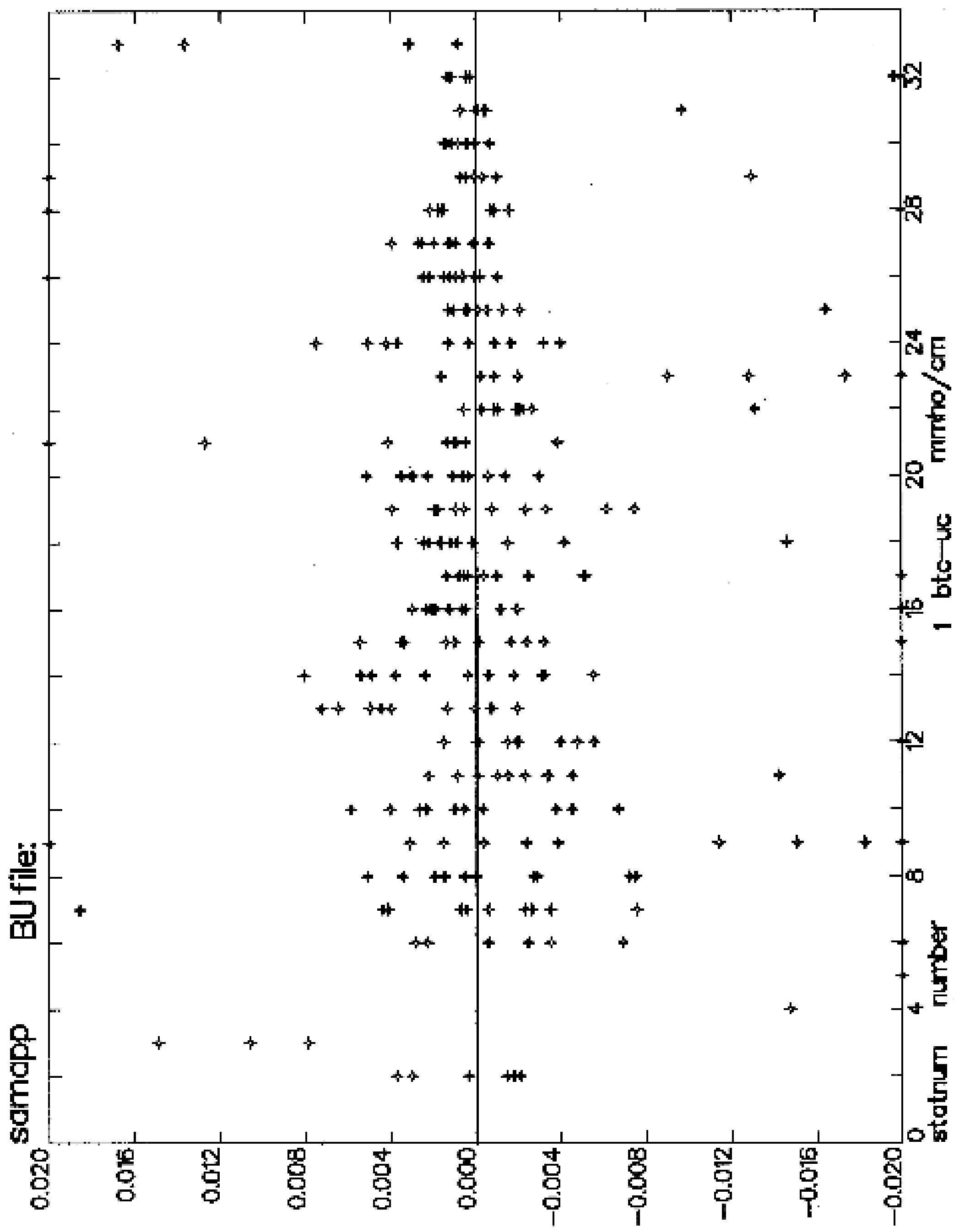

Figure 3.5: (bottle minus up cast) conductivity differences after upcast conductivity correction and station by station conductivity calibration against station number.

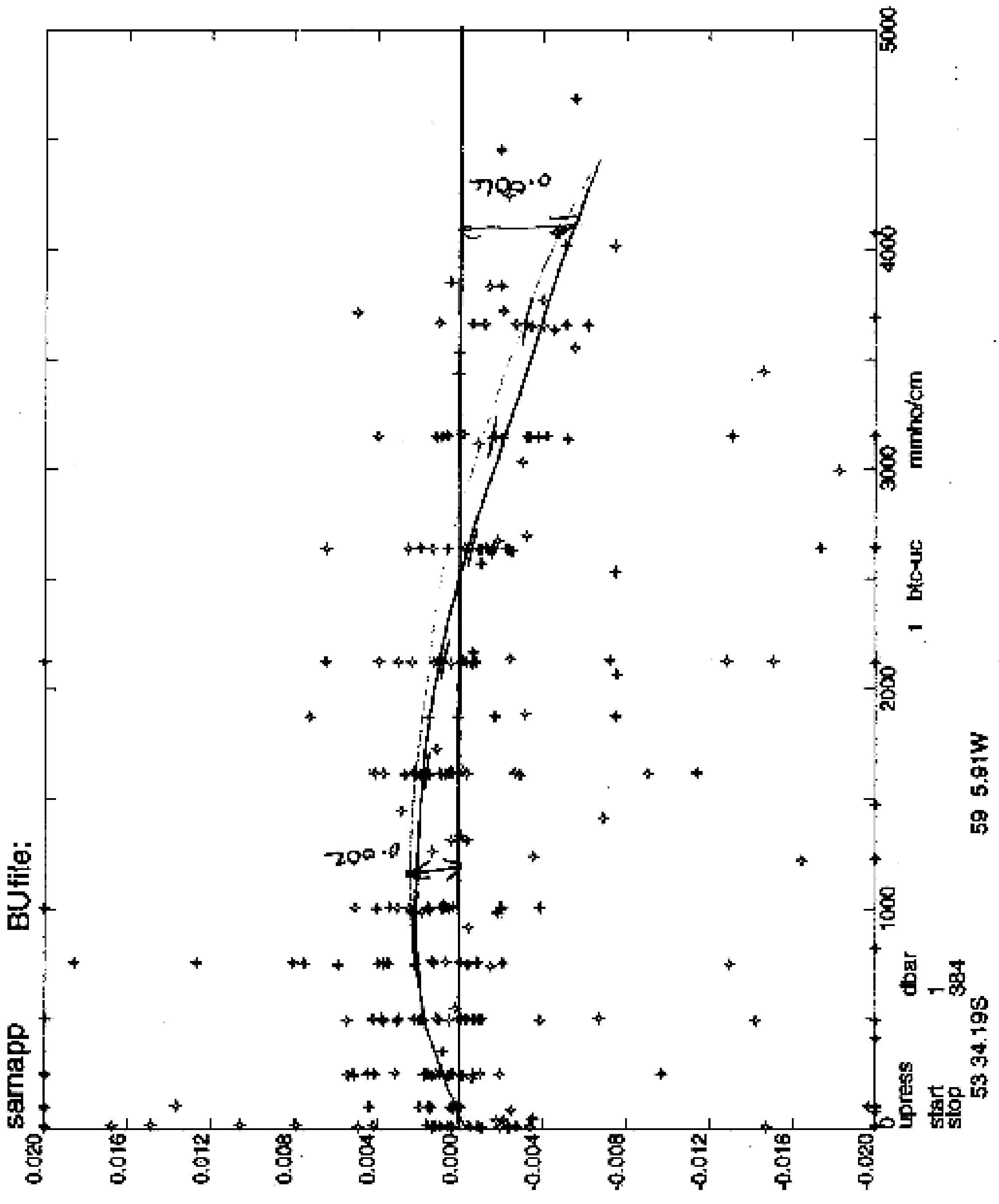

Figure 3.6: (bottle minus up cast) conductivity differences after upcast conductivity correction and station by station conductivity calibration against pressure.

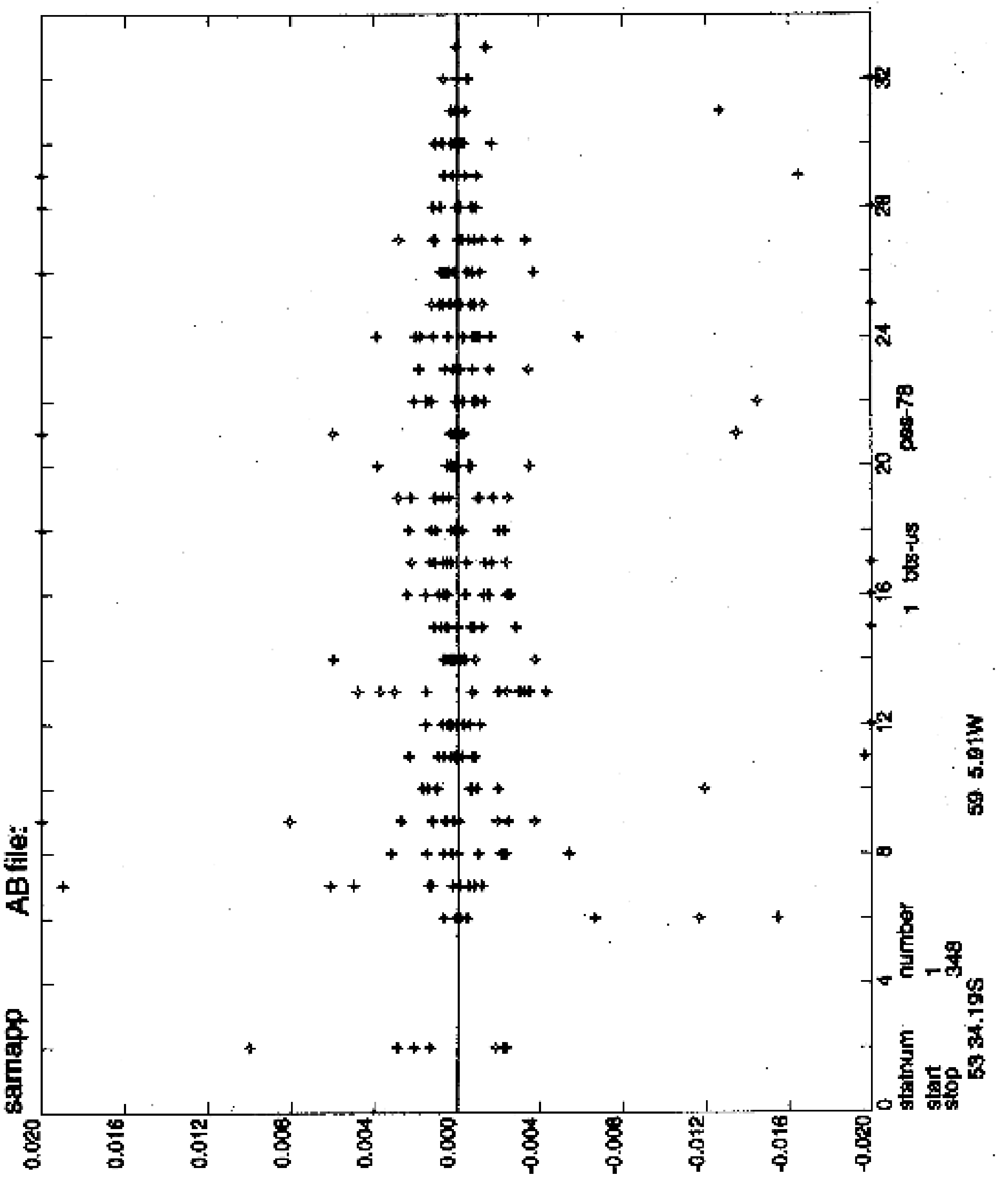

Figure 3.7: Final (bottle - up cast) salinity differences plotted against station number.

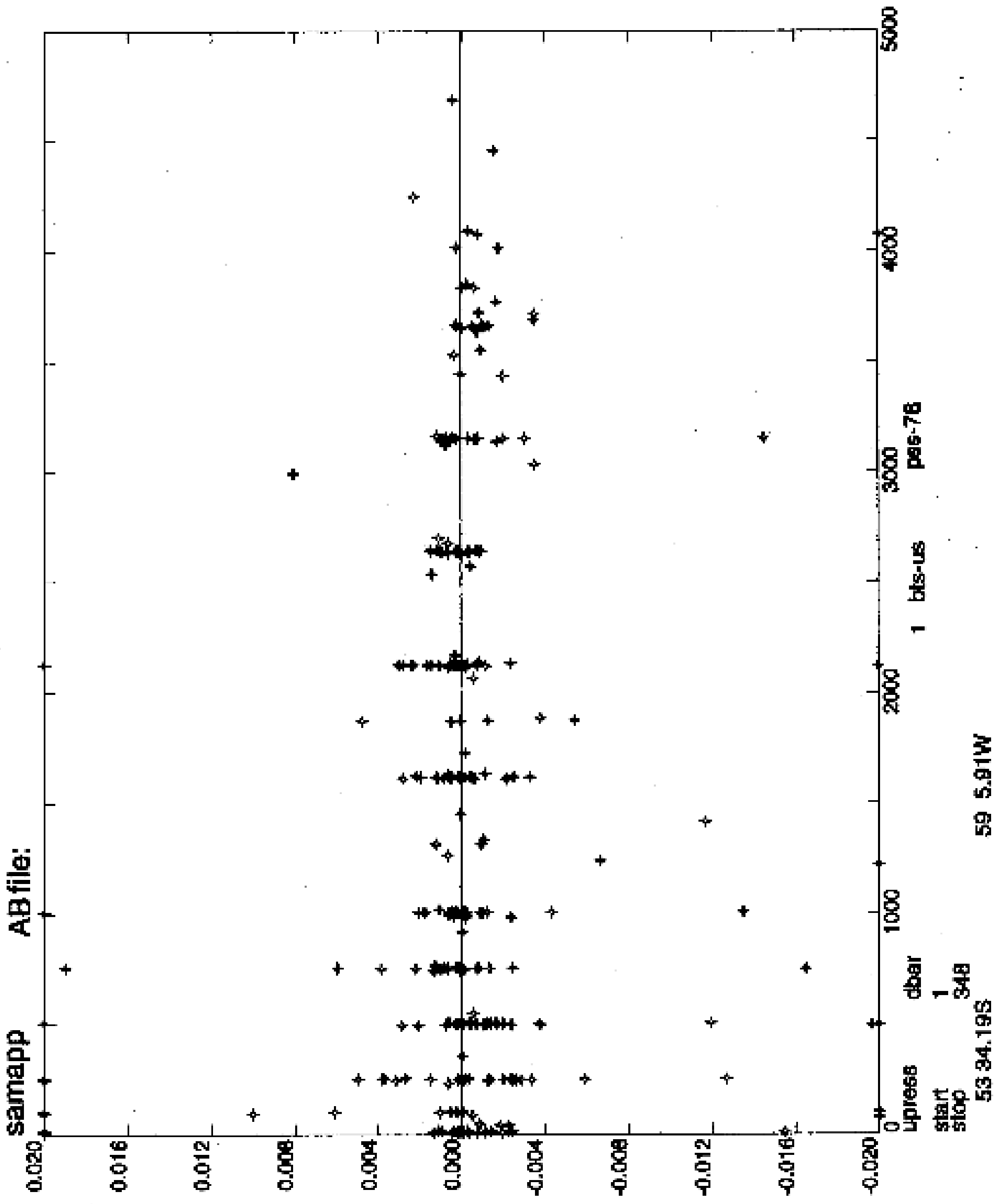

Figure 3.8: Final (bottle - up cast) salinity differences plotted against pressure.

4 JR16, 13 Nov – 7 Dec 1996, by B A King *et al.*

4.1 Authors and Affiliations

Author	**Affiliation**
King, B. A.	SOC
Cunningham, S. A.	SOC
Griffiths, M.	SOC (since left)
Brandon, M.	BAS (now Open University [OU], Milton Keynes, UK)
Lamden, B.	BAS
Wright, S.	BAS

4.2 CTD measurements

4.2.1 Engineering Report

The cruise has been affected to no great degree by problems with the ship's fixed scientific installations. I have been very satisfied with the equipment under my charge during the cruise. The systems used were the 10 T traction winch and midships gantry for the deployment of a CTD package on a single conductor, torque balanced cable from Rochester Cables. There follows a brief explanation of any faults that did occur;

Station No. 4: The cable required reterminating after it slipped off the side of the roller at the top of the midships gantry during deployment. This resulted in it becoming trapped between the previous sheave and its cheek plate which damaged the wire. It is assumed that the wire moved due to the ships motion when it was slack between stations.

Station No.16: A kink in the cable occurred during deployment, which it was impossible for the deck crew to control, resulting in the cable having to be reterminated. This occurred just after the ship was informed that the ADCP data indicated that the package was rotating in the same direction on veer and haul, hence winding up the cable. This appears to have started after an alteration to the water bottle configuration was made to the rosette. After this, a stabilising fin was fitted to the package which prevented further rotation, however an estimated 60 - 80 rotations had still been imposed on the cable.

Station No.19: A kink in the wire caused it to jam on the sheave at the top of the spurling pipe from the winch room when the package was being lifted off the deck. The cable appeared to have a lot of "life" in it and as a retermination would be required about 50 metres was cut to remove some other suspect areas. At this point it was decided to deploy the cable after reterminating and blanking to 3000 metres with a weight and swivel in an attempt to unwind the cable. This appears to have had some effect as on subsequent deployments the cable showed very little twisting at the outboard end.

Occasionally the package was disconnected and the cable allowed to relax which removed a further half or one turn from it.

Station No.27: Just before the package reached the surface on haul a hydraulic hose failed, however this did not prevent the package being recovered. The hose fed an auxiliary function on the gantry so it was possible to blank the hose off until the section had been completed.

4.2.2 Underwater Instrumentation and Shipboard Equipment

The following underwater instrumentation and equipment were fitted to the large Aluminium CTD frame with the additional stainless skirt and mounts for the LADCP.

CTD EG&G NB MkIIIc 25 Hz	DEEP03	Stns 1–6
CTD EG&G NB MkIIIc 25 Hz	DEEP04	Stns 7–30
Rosette Multisampler	SOC 2	
Simrad Altimeter		
IOSDL 10 kHz pinger		
Seatech Transmissometer	Sn 35	
Chelsea Instruments		
Transmissometer		
SIS Pressure Sensors	P6394H, P6393	
SIS Temperature Sensors	T995, T989	

Niskins: A mixture of FSI 10 l and GO 1.7 l bottles with no more than 12 mounted on the rosette.
CTD Frame Fin (0.255 m x 1.067 m. Area = 0.24 m^2)
RD Instruments 150 kHz ADCP

The mixture of bottles was necessitated by the failure of many of the FSI bottles and it is likely that the mixture of bottles unbalanced the package underwater causing the observed spinning. From the heading measurements of the LADCP about 60 turns were put in the CTD wire on the first 15 stations. This started to cause problems when slack wire came under tension on deployment leading to wire failures. In an attempt to remove the twists the cable was veered out to with a weight and swivel to 3000 m before station 16. This certainly helped a little, however it was, for the next few stations necessary to remove the termination from the package to release the twists between package and gantry. Eventually this proved unnecessary as the twisting was removed. On station 16 a fin was fitted to the underwater package in an attempt to prevent rotation of the package. LADCP heading measurements showed that this was almost completely successful.

The following were installed in the Underway Instruments Control suite for the operation and data capture from, the underwater package.

In duplicate:
EG&G demodulator 1401

EG&G non data interrupt rosette firing module

Kepco power supply ATE150-0.7M

IBM PS/2 PC with 150Mbyte tape drive. Raw data were acquired with General Oceanics Data Acquisition (DA) software version 5.2 revision 2.

4.2.3 CTD Data Collection and Processing

CTD data were passed from the CTD deck unit to the level A. This despikes the raw data, computes the rate of change of temperature over one second and assembles one second averages of the raw data. These data are then passed to level B logging and to level C archiving [Pollard et al., 1987]. One irritating problem for data transfer from the RVS level C to pstar was the bit map reversal of logged data from the multiplexed channels of the CTD as detailed in Table 4.1.

Raw binary CTD data were also logged by the deck unit PCs. This is the first log of the raw, demodulated 25 Hz data and the .RAW files produce by the GO DA software were archived to tape. Raw data were able to be recovered using the DOS BACKUP command to copy raw files to floppy and then using sneakernet to transfer them to a UNIX workstation. There a C program, mk3c.c, was able to reassemble the raw binary file and output an ascii file. Subsequently a FORTRAN program levela.F imitated the level A, to produce a one second averaged file. This route was used once during the cruise due to a level A crash.

On a previous WOCE cruise [Heywood and King, 1996] using the same level A on board the *JCR* serious and unresolved problems with the level A were experienced. In that case frequent crashes of the CTD level A, and subsequent data loss, were reported. We had one such incident. A new logged parameter is the number of frames making up the one second average output by the level A. We found that the level A unacceptably decimated the data to around the 40 to 50 % level. The level A software emulation did no such thing. Whilst it cannot be guaranteed that the emulation software and the level A were identical the suspicion is that the level A cannot cope with a 25 Hz data rate and is as a consequence losing good data. This is unacceptable and in future it is to be recommended that the level A is removed from the data path.

4.2.4 Summary

CTD data are logged to a PC running General Oceanics control software and the RVS ABC system. Raw data backup was accomplished by dumping the data to a tape streamer. The CTD level A, mainly through historical reasons, averages the data at this point to 1 second averages and passes the data through a simple editing procedure. During this editing procedure pressure jumps of greater than 100 raw units (this is equivalent to 10 db for the pressure transducer) are removed along with spikes in individual channels through a median sorting routine. The rate of change of temperature change is also calculated. The one second data are then passed to the ship's UNIX system and archived. Calibration routines are then applied and will be described below. The SOC Deep03 was used for stations 1–6 but erratic performance then led to the change to Deep04. This unit was used for the rest of the section, from station 7 onwards.

In this report we first give details of the calibration route before describing the calibration procedure in detail. In all CTD stations the downcast data are reported as the final product with the exception of station 16. At this station some of the upcast was copied out and sorted to reverse the pressure signal to replace a data gap caused by a combined Level A and PC crash.

The serious problems encountered on WOCE section A23 in May 1995 have been greatly improved by the replacement of the CTD Level A in January 1996. However, the level A is still unsatisfactory and it crashed on five occasions listed in Table 4.2 as well as the numerous and still unexplained “serial overuns”. Unlike on A23 all of the level A crashes were recoverable by resetting the unit. A more serious problem with the current level A application is the amount of apparently good data it rejects.

4.2.5 Bottle and Pylon problems

Twelve FSI GO 10 litre bottles were deployed on a 24 bottle pylon for the collection of samples for calibration of the CTD. Figure 4.1 shows bottle depths per station. Once mounted the bottles were lashed into place. Several problems were experienced with these bottles during the first 10 stations. Problems on the first two casts were caused by faulty construction of the CTD frame in that the top bottle mounting plate was not parallel to the bottom plate. This meant that the mounting was least secure at bottles six and seven where the plates were furthest apart. The complete loss of bottles, before this problem was identified and cured, was prevented by the aforementioned lashings. More significant problems were caused by bottles fracturing at their mounting point. We believe this is due to poor bottle construction. During the first ten stations four of the 10 litre bottles were lost and replaced by BAS 1.7 litre General Oceanic bottles. All the bottle problems encountered are detailed in Table 4.3.

Problems were experienced with bottle pylon misfires. It was hoped to be able to control the pylon firing through the CTD control software. However, new software had been installed on both of the CTD deck unit PC’s that offered choices that none of the team had seen before when a bottle was fired from the keyboard. We therefore chose to fire all bottles manually from the CTD deck unit, the bottle firing signal being logged to a level A data stream. During the section the pylon signalled misfires on 9 casts although with only twelve bottles on the pylon any problems caused were easily spotted and cured. Table 4.4 summarises the pylon misfires.

4.2.6 CTD calibration

As two units were used during the section after each calibration equation we report both sets of coefficients. For the salinity calibration we report three sets of coefficients. This is described in greater detail below. Deep03 was calibrated by S. Keene (Ocean Scientific International Limited) on 9 July 1996 and Deep 04 was calibrated by S. Keene in July 1996.

4.2.6.1 Temperature calibration

The temperature calibration applied to the data was through the following equation:

$$T = a + b\ Traw + c\ Traw^2$$

and the results are in ˚C in the ITS-90 scale.

For Deep03 the coefficients were:	a = -2.1232	b = 0.99115	c = 4.2e-6.
For Deep04 the coefficients were:	a = 0.013079	b = 0.999316	c = 0.0

The large difference between the two sensors takes into account the fact that deep03 has been adjusted to give it a better response at low temperatures. To allow for the mismatch in response times between the temperature sensor and conductivity sensor, the temperature was lagged. This lag was achieved by adding a fraction FRAC of the rate of change of the temperature that is output from the level A (dT) to the temperature. The temperature is then

$$Tnew = T + FRAC * dT$$

From experiment the conductivity spiking was minimised for Deep03 with a FRAC of 0.25, and for Deep04 with a FRAC of 0.3.

Pressure temperature was derived from the following equation:

$$Tpress = a + b\ Tpraw + c\ Tpraw^2$$

For Deep03 the coefficients were:	a = 65.31984	b = -2.3346	c = 1.776e-4
For Deep04 the coefficients were:	a = 86.5386	b = -2.2711	c = 3.648e-4

The fast response temperature probe of the CTD although not used as yet was calibrated following the equation:

$$Tfast = a + b\ Tfraw + c\ Tfraw^2 + d\ Tfraw^3$$

For Deep03 the coefficients were:	a = 3.23738	b = 1.0568	c = -6.2633e-3	d = 1.34e-4
For Deep04 the coefficients were:	a = -0.45889	b = 1.03814	c = -5.661e-3	d = 1.202e-4

4.2.6.2 Pressure calibration

A pressure calibration was applied to the CTD pressure data through the following equation:

$$P = a + b\ Praw + c\ Praw^2$$

For Deep03 the coefficients were:	a = -38.9	b = 1.07449	c = 4.8e-8
For Deep04 the coefficients were:	a = -37.5	b = 1.07328	c = 6.9e-8

We are still discussing the applicability of a static pressure correction to the data. For both Deep03 and Deep04 a correction was applied in the form

P = P + Pstat, and Pstat = (0.075 - 0.0 *Praw) * (Tpress - 10.0)

Given the temperature range encountered during this cruise this correction factor is small.

Extraction of upcast data: the upcast data were selected by merging the firing file as logged on the level A with the 10 s averaged data file. The full process is detailed below.

4.2.6.3 Salinity calibration

For this cruise we calibrated the conductivity and then derived salinity. A full data processing route is detailed below. In brief, first we applied a calibration of the form:

cond = 0 + 1 * cond_raw

Then from the salinity samples we calculated bottle conductivity using in-situ temperature and pressure. We then calculated the difference of bottle and CTD conductivity to derive a value we call deltaC. We then plot bottle conductivity (*x variable*) against deltaC (*y variable*). This gives a straight line graph where

deltaC = m (bottle conductivity) + c

with slope *m* and intercept *c*. After rejecting suspect bottles we use the pstar programme plreg2 to derive m and c for deltaC. Now, as

deltaC = bottle conductivity - CTD conductivity

the calibration coefficients for the CTD conductivity are derived through substitution and the CTD conductivities are now

cond = a + b * cond_raw, where a = c / (1 - m) and b = 1 / (1-m)

The processing route is then repeated and the new graph of deltaC against bottle conductivity gives the conductivity residuals, which should now be random with a mean of zero.

For deep03 and stations 1 to 6 the values of a and b were: a = -0.044672, and b = 0.94518

This calibration procedure does have a feature in that as we moved south along the section and moved into waters where the entire water column was of lower conductivity than the station used for the initial calibration the validity of the original m and c are called into question because of extrapolation. To overcome this for we used stations as calibration points.

Stns. 7–15 were calibrated with values based on stn. 11, for which a = -0.10062 and b = 0.9705;
Stns. 16–30 were calibrated with values based on stn. 26, for which a = 0.00263 and b = 0.9671

After applying these calibration coefficients to the relevant stations there is still a residual drift within the conductivity signal and time. For each station this drift is *deltaC = residual drift*, and from substitution we remove the residual drift from the signal. The conductivity calibration details are summarised along with the residual drift in Table 4.5.

4.2.6.4 Conductivity Calibration Quality

After applying the calibration coefficients and adjusting for the residual offset the salinity of the bottle was differenced with the derived CTD salinity. After rejecting 9 samples detailed in Table 4.5, the mean of the remaining 305 samples was 0.0000 with a standard deviation of 0.0017 psu. In figure 2 we show the residual salinity offset against station number and in figure 3 the residual salinity offset against pressure. The greater variability of the residual for the stations using Deep03 show that the unit was behaving badly.

4.2.6.5 Transmissometer calibration

The transmissometer data was treated in a different way to that of past cruises as the CTD had both a Sea Technology 1 m path length unit and a Chelsea Instruments 0.25 m path length instrument. To enable the units to be compared more easily the FOTRAN programme ctdcal.F was modified to output data from the Sea Tech instrument in the same form as that from the Chelsea instrument, ie, with raw transmissometer data from both instruments being output in volts.

The calibration equation to the Sea Tech instrument is of the form

$$\text{Trvolt} = a + b\ \text{rawTrvolt} + c\ \text{rawTrvolt}^2$$

For Deep03, a = -5.0273 b = 1.5344e-4 c = -3.7038e-13
For Deep04, a = -5.656 b = 1.7267e-4 c = -2.2442e-12 (although the instrument is the same, the A-D converter boards are different and so the coefficients change).

For the Chelsea Instruments transmissometer the equation is of the form

$$\text{Chvolt} = a + b * \text{rawChvolt} + c\ \text{raw Chvolt}^2$$

For Deep03, a = -5.027 b = 1.534e-4 c = -3.704e-13
For Deep04, a = -6.6776 b = 1.8762e-4 c = 2.24385e-12

The Sea Technology transmissometer SN35 has a history of erratic performance. During JR16 the unit showed the same behaviour before the problem was partially cured by changing the unit leads on station 16. The Chelsea instruments unit caused no specific problems although it is less sensitive than the Sea Tech unit due to the shorter path length. Both instruments had frequent drop outs and the data will require editing to produce usable data.

4.2.6.6 Simrad Altimeter

The altimeter on the CTD frame did not perform as well as hoped and it had some problems. In previous cruises it was noted that the altimeter had held a value of 205 m until coming within range of the bottom. Then as the package was lowered towards the sea floor the altimeter counted down the height off bottom. On this cruise on some casts when the package was descending, the altimeter value flickered between 1.5 m and 205 m. Problems with the altimeter are summarised in Table 4.6. The altimeter lead was changed at one point but it is not mentioned in the CTD deck log.

The calibration equation for the altimeter is

$$Alt = a + b\ rawAlt + c\ rawAlt^2$$

For Deep03,	a = -249.7	b = 7.62e-3	c = -1.04e-10
For Deep04,	a = -234.5	b = 7.16	c = -9.48e-5

4.2.6.7 IOSDL 10 Khz Pinger

The 10 Khz pinger worked well throughout the cruise with only one exception. During station 26 the return echo from the pinger was very diffuse. This was most likely due to the slope of the sea floor rising rapidly coupled to the orientation of the package. The top shackle was replaced after this station as it was very twisted.

4.2.7 CTD processing route

Step 1: ctd0

Purpose: To read in the CTD data from the RVS stream. The programmes are

datapup	read in the data from an RVS stream into a pstar file.
pcopya	reset the raw data flag in the pstar file.
pheadr	set the header of the pstar file.

The output of the exec is in the form ctdCCC$num.raw As in all execs with the 0 extension, it simply transfers the data from the RVS system to a pstar data format.

Step 2: ctd1

Purpose: To calibrate the ctd data. The programmes are

ctdcal	to apply a nominal calibration to the ctd data (on JR16 this program was modified to deal with the Chelsea transmissometer data and was called "ctd").
pcopya	select out the relevant variables. Output file is extension .du.
pavrge	average the .du file on 10 seconds. Output file is extension .10s.

The output files are ctdCCC$num.du and ctdCCC$num.10s

Step 3: fir0

Purpose: To read in the bottle firing data. The programmes are

datapup	read in the data from an RVS stream into a pstar file
pcopya	reset the raw data flag in the pstar file
pheadr	set the header of the pstar file

The output of the exec is in the form firCCC$num.tim

Step 4: fir1

Purpose: To merge the bottle firing file with the 10s ctd file. The programmes are

pmerge	merge .tim file with the .10s file

The output of the exec is in the form firCCC$num

Step5: recexec1

Purpose: To create a text file to match with the samples

mlist	create an ascii file
ed	edit out unwanted information from the ascii file

The output of the exec is in the form matCCC$num

Step 6: Matching of sample files

The matching of sample files is slightly tricky. The rosette functions by having a stepper motor that rotates through 360˚ releasing 24 bottles (one bottle every 15˚). However, the General Oceanic (GO) rosettes have repeatedly proved unreliable. If the motor is not exactly lined up with its start point, as it rotates through 15˚ to trip one bottle, the trigger can trip two bottles to close instead of one. With all 24 bottles on the rosette, it is not uncommon to get two samples taken at one sample level, and no sample at another level. It is usually quite obvious when this has happened because the salinity values in the sample file are identical when in fact one thought they were sampled from water hundreds of metres apart. For a JR16 we had twelve 10 litre water bottles in alternate positions on a 24 point GO rosette pylon. In the sampling strategy we therefore triggered the rosette twice at each sampling point and ended up with two data cycles in the bottle firing file for each rosette sample. This meant that in the firCCC$num.tim and consequently the firCCC$num file we have 24 data cycles but only a maximum of twelve samples to match. It should be easy simply to delete every other data cycle in these files to a perfect match. In practice, this was not the case. Problems, when encountered, were usually between the first bottle to be closed (bottle 1) and the last (bottle 12), and meant that a surface sample could be matched with a deep water position in the firing file. The problem was most probably caused by the trigger point in the sampling rosette being at the wrong place at the start of a CTD cast. The sample values and reversing pressure and thermometers on bottle 1 will readily reveal the problem. On one occasion on JR16 the reversing sensors were not set to sample data on the CTD cast and on another occasion the lanyard to trigger the sensors apparently snagged. On three consecutive occasions there were “long” misfires on rosette positions 9 and 10. With a “long” misfire it is usual to assume that samples have been taken but on two of these casts bottles had not closed and we ended up with double samples at the next sampling point.

Sample data path

First assemble the relevant information on the Macintosh. The file must be saved as a text file.

Step 7: sal.exec

Purpose: To read in the sample file from the mac to the unix system. The programmes are

getexel.exec	reads data file from the mac

The output files must be renamed: samp.nnn must be renamed to samp.nnn.txt; samp.bot must be renamed to samp.nnn

Step 8: ed_fir_in

Purpose: To read in the corrected "mat" firing file and merge it with the sample data. The programmes are

pascin	read in the corrected matCCC$num file
pcopya	copy in five extra variables
pheadr	set the header of the new file
ppaste	paste in the sample data from samp.nnn

The output file is in the form sampCCC$num

Step 9: sr1_ctd_cal

Purpose: Compute the differences in conductivity between the ctd and sample file. The programmes are

peos83	derive a conductivity from in-situ T and P from the sample
parith	calculate the delta conductivity
mlist	get a scatter plot of conductivity against delta conductivity

The output file is in the form sampCCC$num.cond

Step 10: Determine the ctd offset

Use phisto to calculate the final ctd conductivity offset from our data.

Step 11: ctd_final_cal

Purpose: To add the station by station final offset. The programmes are

pcalib	add the offset to the .du extension file
pcalib	add the offset to the .10s extensioned file
peos83	derive the salinity from corrected conductivity in the .du file
peos83	derive the salinity from corrected conductivity in the .10s file
pmerg2	merge the .tim file withcorrected .10s file
mlist	create an ascii file from the new firing file
ed	edit out unwanted information from the ascii file

The output of the exec is in the form matCCC$num.final. Note that the last three programmes include fir1 and recexec1 that were on the first iteration

Step 12: Edit the corrected "mat" file

Here we edit the new mat file in exactly the same way as we did in step 6.

Step 13: final_fir_in

Purpose: To read in the corrected CTD data and merge it with the sample data. The programmes are

pascin	read in the corrected matCCC$num.final file
pcopya	copy in five extra variables
pheadr	set the header information
ppaste	paste in the sample data from samp.nnn
parith	calculate the salinity offsets now

The output files are in the form sampCCC$num.final and sampCCC$num.offsets

Step14: ctd2

Purpose: To get the final result from the ctd data. The programmes are

pcopya	copy out the downcast from the .du file
pmdian	remove the large spikes from P, T, cond, salin and potemp
pintrp	interpolate the missing data removed by pmdian
psort	sort the file on pressure. output file extension .1hz
pavrge	average the .1hz file to 2db levels. ouput file extension .2db
pintrp	remove missing data from the .2db file

The output files of the exec are in the form ctdCCC$num.1hz and ctdCCC$num.2db

The following execs are 'extras'.

Step 15: add_stat_num

Purpose: To add the station number as a variable. The programmes are

pcopya	copy in an extra variable to the .final file
pheadr	change the extra variable name to station number in .final
pcalib	make the variable equal to station number in .final
pcopya	copy in an extra variable to the .offset file
pheadr	change the extra variable name to station number in .offset
pcalib	make the variable equal to station number in the .offset file

Step 16: add_position

Purpose: To add the latitude and longitude as variables. The programmes are

pcopya	copy in an two variables to the .final file
pheadr	change the two variables names to latitude and longitude
pcalib	make the two equal to lat and lon in .final

pcopya	copy in an two variables to the .offset file
pheadr	change the two variables names to latitude and longitude
pcalib	make the two equal to lat and lon in the .offset file

4.2.8 Final station information

Station details are listed in Table 4.7.

4.3 XBTs

Thirty-three stations were taken using Sippican T-5 XBTs - see Table. Data were logged on a PC, running the Sippican Mk. 9 Data Acquisition System software (version 5.2). Post station, the data were exported to ASCII files containing depth and temperature, using the Sippican Post Trace Analysis Application software. Using the ever-trusty sneakernet, data were transferred to UNIX and converted to PSTAR. Although the XBTs were stored on deck before use, the first few records for each cast were bad, as the probe rapidly changed temperature. This transient response, plus further spikes throughout the trace, and noise as the wire breaks, were graphically edited, and this is all that was done to the data. XBT launch positions are listed in Table 4.8.

4.4 VMADCP Measurements

An RD Instruments 150 kHz, hull mounted ADCP (referred to as the Vessel-Mounted ADCP, VMADCP) is fitted to the *JCR* with the transducer orientation at 45 degrees to the fore-aft direction. Firmware version 17.07 and data acquisition software (DAS) version 2.48 were used. For water depths was less than 500 m the ADCP was operated in bottom track mode with one bottom track ping to four water track pings where and for water depths greater than 500 m, water track mode was used. Both bottom and water track modes recorded two minute averaged data in 64 x 8 m bins. 'Blank beyond transmit' was four m and the depth of the transducers is five m putting the centre of the first bin depth at 13 m.

4.4.1 Speed Correction Factor

The sound speed correction factor applied to the raw velocities is described in Section 2.6. The form employed here is

$$F = 1 - 0.004785 \times T + 0.0000355 \times T^2$$

4.4.2 Clock Correction

The internal clock for the ADCP drifts at about one second per hour. To correct this to the ship’s master clock, this difference was recorded manually every four hours. This correction was then applied to the ADCP time base.

4.4.3 Heading and Velocity Amplitude Correction

ADCP data were corrected for heading by merging with Ashtech GPS3DF minus gyro differences giving velocities relative to the forward direction of the Ashtech. This process is described in other ADCP sections in this document. A final correction is required to correct the heading misalignment between the direction defined by the Ashtech GPS3DF antenna and the direction of the ADCP transducers. The procedure of section 2 was followed and is noted below.

1 Two minute ensembles were merged with GLONASS GPS position fixes, and ship's east and north velocity from the GLONASS fixes calculated. Absolute ADCP bottom tracking velocities were also calculated.

2 The data were then averaged into 30 minute periods. A 30 minute ensemble was accepted if (i) at least 13 two minute ensembles had bottom tracking data, (ii) the two minute averages of speed had a range of no more than 20 cm/s, (iii) the two minute averages of direction over the ground had a range of no more than 20˚.

3 Velocity amplitude (speedGPS/speedADCP) and direction (dirnGPS - dirnADCP) corrections were calculated using data gathered on cruise JR17. Mark Brandon operated the ADCP on that cruise and over 3000 minutes of bottom track data were obtained around the shelf off South Georgia.

The resulting direction difference is added to all ADCP directions to produce ship over ground or ship over water velocities. A new exec botcal.exec was written to determine the calibration from selected data cycles. Table 4.9 is a summary of estimates made on JR17 cruise.

4.4.4 Absolute Velocities

Absolute ADCP velocities were obtained using bestnav navigation to subtract remove the speed of the ship through the water (see section 4.6 for bestnav details). Here bestnav was primarily one second GLONASS measurements averaged to 30 s with backup provided by GPS where the GLONASS data contained gaps.

4.5 Lowered ADCP (LADCP) Measurements

New to this section was the deployment of an RDI 150 kHz Broadband ADCP on the underwater package, providing direct measurements of the ACC in Drake Passage with unprecedented vertical and horizontal resolution.

The LADCP was the 'long-case' type with internal battery packs. It was mounted centrally in a large CTD frame which was modified by the addition of a 'skirt' at the bottom to provide clearance for the LADCP. The LADCP needed to be removed from the frame in order to access the end cap when the battery packs needed to be replaced.

The LADCP was used on two cruises on RRS *Discovery* around this time: cruise 214, the Agulhas Current Experiment in February–March 1995 (Bryden, 1995), and cruise 230, *Fourex*, in August–September 1997 (Bacon, 1998). The former describes the engineering aspects of the LADCP setup and the latter the data processing route in some detail, so these will not be repeated here. Note that on *Fourex* the LADCP had been modified to provide a battery pack separate from the (shortened) electronics pressure case.

Of particular interest on this cruise was the use of the LADCP in bottom-tracking (BT) mode. BT data were acquired on 29 of the 30 stations, and enabled water velocities to be calculated when the instrument was within 350 m of the seabed. Cunningham *et al.* (1997) describe the comparison between the VM-ADCP data, the LADCP water-track data (processed to absolute velocities using University of Hawaii software made available by Eric Firing) and the (independent) BT data.

4.6 Navigation

4.6.1 GPS Trimble 4000

Position fixes from the receiver were logged once per second throughout the cruise. Although previously the primary navigation stream this year great success with the Ashtech GLONASS receiver meant that the Trimble 4000 data were considered as secondary to the GLONASS GPS data set. For 86400 s of data whilst moored at FIPASS, Stanley the RMS position errors for Trimble fixes were about 20 m in latitude and longitude. Differential GPS will not be necessary because of the quality and reliability of the GLONASS.

4.6.2 Ashtech GPS3DF

Ashtech GPS3DF GPPAT messages containing time, position and attitude messages were logged, via a level A, once per second and merged on time with gyro data to provide a correction for gyro headings. The system and installation are described in section 2.

In Grimsby in summer 1996 new antenna were fitted to the wheelhouse top. The antenna geometry was surveyed using the Ashtech software using data collected in Grimsby in September 1996. The best solution for the relative positions may be found in the receiver parameters listed below. As before the port-aft antenna is designated as number 1; port-fwd is 2; stbd-fwd is 3; and stbd-aft is 4. The XYZ vectors have been adjusted so that the heading is defined by the direction normal to the 1-4 baseline, i.e. that baseline has Y = 0.

Data coverage was excellent except for a very unfortunate period near the start of the cruise whilst attempting to gather bottom track ADCP data for calibration. This meant that only 35 minutes of usable Ashtech data were available and consequently no heading corrections available for ADCP calibrations. Coverage was 98 % of 200 s intervals containing data.

Ashtech GPS3DF receiver parameters (menu 4 and submenus).

POS	54:17.0S,35:40.0W,+0.0m
Alt known	N
Ranger	0
Unhealthy Sv	N
Rec. Intv	20
Min no. Sv	4
Elev mask	10
Pdob mask	40

Port A	
nmea	off
real time	off
VTS	off
baud	9600
Port B	
(level A logging)	
nmea	on
real time	off
VTS	off
baud	4800
OPTIONS	PAT ON
	1 s rate

Attitude Control Menu

max mrms	8			
search ratio	0.5			
1 s update	Y			
3 Sv search	N			
	TAU	T0	Q	R
Hdg	999	000	1.0e-2	1.0E-2
Pitch	020	000	4.0e-2	1.0E-2
Roll	020	000	4.0e-2	1.0E-2
Kalman filter reset	N			

Attitude Setup Menu

Vector	X(R)	Y(F)	Z(U)
1-2	2.955	4.751	0.0
1-3	11.499	4.754	0.0
1-4	13.227	0.0	0.0
offset	0 (H)	0 (P)	0 (R)
Max cycle	0.2 cyc	Smoothing	N
Max mag	0.08	Max angle	10

4.6.3 Ashtech GG24 (GLONASS)

The Ashtech GG24 receiver accepts data from both GPS and GLONASS satellites. Not only do the Russian GLONASS satellites give much improved position information (the data are not dithered, as for the GPS with selective availability), the extended constellation (forty-eight vehicles instead of twenty-four) gives supposed better data coverage. A GG24 receiver was fitted installed on the *JCR* at the start of the cruise, the first time such a receiver has been installed on a British research vessel. The antenna was mounted on the Wheelhouse Top (starboard side), and connected to the receiver (innocuous, black box) installed on the Bridge (starboard side, behind the SWDSI Distress and Saftey Equipment). A cable was routed under Bridge floor to a 25 way D-type connector (Radio Room partition, DDBO/CX), therby giving a connection to the Electrical Locker.

All data output from the GG24 is ASCII NMEA messages, although which flavour of NMEA message is produced, is controlled by the user. Prior to the cruise, it was decided that the 'POS' message, the format for which is given below, was the most appropriate.

NMEA 'POS' message format:

```
n,qq,hhmmss.ss,ddmm.mmmmm,s,dddmm.mmmmm,s,saaaaa.aa,seeeee,ttt.t,ggg.g,svvv,pp.p,hh.h,vv.v,tt.
t,vvv
```

Item	Significance
n	Raw/differential position flag (0 for raw)
qq	Number of satellites used in position fix
hhmmss.ss	UTC time
ddmm.mmmmm	Latitude (degrees & minutes)
s	Latitude sector (N or S)
ddmm.mmmmm	Longitude (degrees & minutes)
s	Longitude sector (E or W)
saaaaa.aa	Altitude (metres)
seeeee	reserved/unused
ttt.t	True course over ground (degrees)
ggg.g	Speed over ground (knots)
svvv	Vertical velocity (decimetres per second)
pp.p	Position dilution of precision
hh.h	Horizontal dilution of precision
vv.v	Vertical dilution of precision
tt.t	Time dilution of precision
vvv	Firmware version

Example message:

```
$PASHR,POS,0,14,193638.00,5141.50762,S,05749.36107,W,+00037.50,,000.0,000.0,+000,01.3,00.8,01.
0,00.7,GA00*13
```

Before the cruise, the level A application to read the NMEA 'POS' messages was written by RVS at SOC before the cruise, and EPROMs created. These were installed in a Mk2 Level A on the ship, but it was not possible to log data. This was thought to be due either to cable problems (much confusion over pin numbers) or a change in the specified NMEA format (an unused four character variable was not present, giving a shorter record length). Instead, the data were logged to a PC in the UIC, using the ship's trunking to get the data to the lab. On the PC, the 'Terminal' program was used to receive the NMEA messages, (9600 baud, 8 bits, 1 stop, XON/XOFF, no parity), with the data logged as text files. These text files were downloaded daily to the UNIX system (using FTP). From UNIX, the ASCII data were parsed into PSTAR, and edited and processed using PEXEC.

4.6.3.1 Processing

A FORTRAN program (pglon.F) was written to parse the data from NMEA to PSTAR format. The data were then edited, with position data set to absent where:

- the number of satellites was 3 or less (nsv < 4),
- the position dilution of precision was greater than 10 (pdop > 10),
- the horizontal dilution of precision was greater than 10 (hdop > 4),
- the vertical dilution of precision was greater than 10 (vdop > 4),

- the time dilution of precision was greater than 10 (tdop > 4).

Data were then graphically edited (plxyed) to remove jumps in position or time. The edited data for the Drake Passage and Bransfield Strait section were appended to one master file and converted to RVS format so that the program 'bestnav' could be run. bestnav was set such that data gaps larger than 300 seconds were filled with data from the GPS 4000 Trimble (RVS data stream gps_trim). Remaining data gaps were filled by dead-reckoning with data from the Chernikeeff log (data stream relmov). The final bestnav file was read to PSTAR using the same C-shell scripts as for the GPS Trimble. Data quality is much improved over the GPS 4000 Trimble.

On several occasions, no position data were received, and blank NMEA messages were sent. This was despite the fact that GPS satellites were clearly visible (GPS_4000 was receiving data, for example). The problem was usually resolved by re-initialising the receiver (i.e. switching off and on, and setting up port A again). Only once did this method fail to kick the receiver into action, and on that occasion, the receiver was left and on returning with a cup of tea, POS messages had miraculously appeared again. If left unattended, these periods of no position data extended to many hours (e.g. all of day 337). The table shows the data coverage (all data, including bad) for the section across the Drake Passage, and Bransfield Strait. After this, the nature of the ship operations meant the PC wasn't checked as often as necessary. The receiver hung on several occasions, unnoticed, causing data to be lost, in one case for over a day. Such gaps in the data caused problems with the parsing program, which became confused about what day it was and introduced time jumps.

Day	Number of records
317	9490
318	81554
319	83086
320	82953
321	82587
322	85301
323	72394
324	70199
325	76230
326	75355
327	81765
328	79903

4.6.3.2 Instructions For Logging And Processing GG24 Data

<u>Setting up the receiver</u>

The receiver has two ports (A and B); during JR16, data were sent on port A, leaving port B free to interrogate the receiver, using the ship's portable PC. The PC has been installed with the Ashtech

Evaluate software, which sets up and monitors the receiver. (Once correctly set-up, it is not necessary for the PC to remain connected).

1 Connect port B to serial port on PC, and run Ashtech Evaluate.
2 Connect to receiver using COM1, (9600 baud, 8 bits, 1 stop, no parity). Make sure the 'Turn off ALL NMEA messages on detach' box is not ticked.
3 Go to the GPS option, and select the Terminal. This displays the messages on port B, and allows commands to be sent to the receiver. Click on 'type', to manually send commands to the receiver.
4 To start POS messages on port A, type $PASHS,NME,POS,A,ON then press Send. By default, SAT messages may be sent to port A. To switch these off, type $PASHS,NME,SAT,A,OFF then press Send.

PC logging

Before running windows, login as user 'gd24', password 'glonass'. This allows you to use FTP at a later time, without having to quit the Windows environment.

1 Run the TERMINAL program (under ACCESSORIES folder).
2 Go to the SETTINGS option, and select COMMUNICATIONS. Set to 9600 baud, 8 bits 1 stop no parity XON/XOFF. Data should appear on the screen straight away.
3 To start logging, go to the TRANSFERS option, and select RECEIVE TEXT FILE. Enter a file name and press RETURN.
4 When changing to a new file, go to the TRANSFERS option and select STOP. Then start logging to a new file. Once logging to a new file, you can use FTP (under the ASHTECH EVALUATE folder) to copy the file to UNIX.

FTP

1 Connect to jrue, as user pstar (password 1pexec).
2 Copy files to directory /users/mlsd/pstar/data/glonass.

Initial UNIX processing

As user 'pstar', and under directory /users/mlsd/pstar/data/glonass, run the following C-shell scripts and programs.

1 ggexec0 - parses ASCII data to binary PSTAR (program pglon)
2 ggexec1 - edits data, on condition of nsv, pdop, hdop, tdop and vdop.
3 plxyed - time jumps, position jumps
4 papend - append daily files to one file.

Creating bestnav navigation file

By default the RVS software looks at the data areas under /rvs/[pro|raw]_data. For this exercise, an alternative 'bestnav' navigation file is created under the PSTAR data areas. This prevents confusion (and possible disaster) by keeping clear of the 'real' bestnav data. As well as the new GG24 data, the bestnav program needs an alternative position file (GPS_4000 here), and the Chernikeeff Log data file (relmov), for dead-reckoning.

1) Set the environment to look at the PSTAR data areas by typing
   source $HOME/data/glonass/rvs.source
2 Create an RVS file called glonass under ~pstar/pro_data
   datapup ./appended_file glonass -
3 Ensure all data points are labelled as status GOOD.
   edstatus -n GOOD glonass -
4 Create a streamstates entry
   setstr glonass
5 Test this has worked by using
   lookc
   dfinfo glonass
   listit -s ????????? -e ????????? glonass lat lon
6 Copy across gps_trim and relmov data from the RVS directories, and create streamstate entries for these, as above.
7 If bestnav and bestdrf files already exist under the PSTAR pro_data directory, delete (or rename) these, and remove the streamstates entry.
   garstr bestnav
   garstr bestdrf
8 Generate empty bestnav and bestdrf files. Copy bestnav.frm and bestdrf.frm files from /nerc/packages/rvs/control/frm to ~pstar/control/frm, then
   credat bestnav (crtl-Z to setup file)
   credat bestdrf (crtl-Z to setup file)
   setstr bestnav
   setstr bestdrf
9 Copy bestnav.menu from /nerc/packages/rvs/control/menu to ~pstar/control/menu.
10 Ready to go. Run bestnav, checking details (primary file should be glonass), then ctrl-Z to finish. bestnav program runs on background until end of file (or a problem).

4.6.4 Gyrocompass and Electomagnetic Log

Heading was determined from a Sperry Mk 37 model D gyrocompass. Voltages from a synchro pickup are passed to the level A and ADCP are digitised separately to 0.1° intervals. Laboratory repeaters for the gyro measure relative changes and are initialised with a correct heading. Of the two gyros available gyro 1 was used throughout.

Gyro performance relative to Ashtech GPS3DF measurements showed the gyro to be latitude dependant. The offset (a-ghdg) was about -1.5° near 53°S and drifted to -3.5° by 64°S. The relationship between offset and heading was less clear as the data were contaminated by latitude dependence. The gyros did not show any unexpected behaviours and were corrected using ashtech GPS3DF measurements.

4.6.5 Processing VMADCP, Navigation and Gyrocompass measurements

A complete reworking of navigation, 3-D GPS and ADCP processing was carried out by Raymond Pollard on Discovery Cruise 223 to the North Atlantic, August - November 1996. We were fortunate to be able to follow the path now laid down in that report (Leach and Pollard, 1998). Few changes were necessary and a few differences have arisen with data from the JCR. They are listed briefly below.

1 BESTNAV GLONASS, Trimble 4000, dead reckoning no smoothing, 30 s fixes

2 Primary real time navigation from GLONASS: better or as good as differentially processed GPS Trimble.

3 Ashtech GPS3DF, editing of pitch, roll data now includes routine for estimating the mean of these parameters. Operating round a zero mean was a poor assumption for the *JCR*.

4 VMADCP, an exec was written to extract suitably chosen records from the bottom file to determine the amplitude and heading misalignment factors. An exec was written to extract good data cycles from the final calibrated file, produce a file of good data and to determine on station and underway average profiles.

4.7 Underway Measurements

4.7.1 Oceanlogger

The oceanlogger system is a BAS designed and built (P. Woodroffe, I.S.G.) PC based logging system. It emulates the function of several RVS level A systems and it has an input from the ships master clock coupled to real time display of data. This allows the logging of meteorological and sea surface data to the RVS ABC system with a ship's time stamp on the data. The instruments with an analogue output are connected to self contained digitising Rhopoint modules located close to the relevant instrument. The modules are then interrogated by the controlling PC using the RS485 standard. A full list of the sensors used is given in Table 4.10.

During JR16 the sampling period was set to 5 seconds and the oceanlogger was run from leaving Mare Harbour on day 318 to the end of section SR1 and into the Bransfield Strait on day 327. At this point the intake pump of the thermosalinograph was switched off to prevent fouling by ice. The intake pumps were switched back on day 337 for the XBT section during the second crossing of Drake Passage and again run until Mare harbour on day 339. The wind speed and direction are not logged by the oceanlogger and it was decided to merge this data into the initial pstar file rather than leave the stream as a stand alone data set.

The processing route of the data involved six distinct steps that are described in full below. The first step was a shell script named oclexec0. It read the oceanlogger data from the RVS system, read in the anemometer data and then merged the two data sets together on time. The output data file had the extension .raw and was archived. Step two was the shell script oclexecl. The script copied out the meteorological section of the data (that is last five data streams in table one) the data being archived as a meteorological file, archived with a .raw extension and no further work on this data set was undertaken. The sea surface data was also copied (the first three sensors in table 1) to a separate file, a raw salinity derived and navigation added. During A23 (Heywood and King, 1996) it was noticed that the conductivity from the SBE21 lagged the temperature of the housing (temp_h) causing spiking in the derived salinity signal. This was overcome on A23 this by applying a lag through a filter to temp_h. On JR16 we tried filters of varying length and value before settling on a 48 one way filter with n successive coefficients given by $w(1-w)^{n-1}$ and a w found by experiment to reduce the salinity spiking best with a value of 0.03. The shape of the 96 (48 points being equal to zero) filter is in figure 4.2 and it had an effect over the last four minutes of data. This filter was applied in the third step of the processing route in oclexec2 where the data were appended together, filtered and a new salinity derived, navigation data was also added to a 1 minute average of this file.

There now remained the calibration of the oceanlogger. Salinity samples were taken at a nominal time spacing of 4 hours throughout the section, the samples being analysed in the same manner as the CTD samples. The sample salinities were calculated on an Apple Macintosh and transferred to the unix system in step four of the processing route using a script called ocl_samples. In the fifth step, oclexec3, the time in this sample file was converted to the RVS format of seconds since the beginning of the year. Finally in step six, oclexec4, we derive a calibration drift against time for the salinity. For the 24 samples collected during the first crossing of the Drake Passage five were rejected as being clearly bad, the mean of the residuals between the samples and the calibrated oceanlogger file were 0.000 with a standard deviation of 0.003.

4.7.1.1 The Oceanlogger data processing route for JR16

<u>Step 1: oclexec0</u>

Purpose: To read in the oceanlogger data from the RVS stream. The programmes are:

datapup	read in the data from the RVS oceanlogger stream into a pstar file.
pcopya	reset the raw data flag in the oceanlogger pstar file.
datapup	read in the data from the RVS anemometer stream into a pstar file.
pcopya	reset the raw data flag in the anemometer pstar file.
pmerge	merge the two files together on time.

pheadr	set the header of the pstar file.

The output of the exec is in the form oclCCC$num.raw

<u>Step 2: oclexec1</u>

Purpose: To copy out the relevant file sections, and in one case merge in the navigation. The programmes are:

pcopya	copy out the segment of the oceanlogger that is sea surface data.
pheadr	set the variable names in the sea surface data file.
pedita	take out the large spikes in the flow sensor.
pcopya	copy out the segment of the oceanlogger that is meteorological data.
pcalib	set the dummy pressure variable created in the first pcopya to zero.
pmdian	take out spikes of greater than 0.05 mmho/cm in the sea surface data.
peos83	derive a raw salinity for the sea surface data.
pavrge	average the sea surface data to 2 minutes.
pmerge	merge the bestnav navigation to the 2 minute averaged sea surface data.

There are three output files. These are metCCC$num.raw, oclCCC$num and oclCCC$num.2min.

<u>Step 3: oclexec2</u>

Purpose: To append all of the one day files together and derive a better salinity. The programmes are:

pheadr	change the dataname on the first file to a dummy dataname.
papend	add all of the relevant oceanlogger files.
pfiltr	apply 48 point filter to temperature at the housing (see text for details).
pheadr	set the variable name of rawsalin to press.
pcalib	set the dummy pressure to zero.
peos83	derive a salinity from the filtered temperature and the dummy pressure.
pheadr	set the dataname of the file to something sensible.
pavrge	average the appended file into 1 minute bins.
pmerge	merge navigation to the averaged file from the bestnav file.

There are two output files. These are oclCCC and oclCCC.nav.

<u>Step 4: ocl_samples</u>

Purpose: To read in the sample data from the macintosh. The programmes are:

getexcel.exec	read sample data from the mac.

The output file is oclbt$num.bot.

<u>Step 5: oclexec3</u>

Purpose: To reformat time in the oceanlogger file. The programmes are

pcopya	copy in an extra jday variable.
pheadr	change the name of the extra jday to time (seconds).

pcalib	take one from the time variable.
pcalib	multiply time by 86400, hrs by 3600 and mins by 60.
parith	add time and hours.
parith	add time and minutes.
parith	add time and seconds.

The output file is oclbt$num.samples

Step 6: oclexec4

Purpose: To apply a calibration to file oclCCC.nav The programmes are:

pmerge	merge oclbt$num.samples to oclCCC.nav.
parith	determine residuals (botsal - oceanlogger salinity).
phisto	get statistics of the residuals.
plreg2	fit the residuals to salinity correction = a + b * time.
pcopya	copy an extra time variable to oclCCC.nav.
pheadr	change the name of the extra time variable to fit.
pcalib	make fit = a + b * time.
parith	add fir and salinity in the oclCCC.nav file.
pmerge	merge oclbt$num.samples to the corrected oclCCC.nav.
parith	determine new residuals (botsal - corrected oceanlogger salinity).
phisto	get statistics of the residuals.

The output files are oclCCC.nav.cal and oclbt$num.res.

4.7.2 Echosounding

For the Simrad EA-5000 Echo Sounder, data were logged via the Level B to the Level C, and stored in two separate data streams - sim500 (the raw, uncorrected depths), and prodep (containing depths corrected using the Carter Correction Tables). Both datasets were read and converted to PSTAR. Spikes in the corrected data were graphically edited. On completion of this task, data were extracted at the times when the CTD was at the bottom of each cast. Then, it was noticed the corrected water depths didn't match the values on the CTD logsheets (taken from the level B display and corrected by hand). The raw data used in creation of the prodep file had first been multiplied by a PES Correction Factor (1.01972), before correction using the Carter tables. This correction factor comes about since the SIMRAD collects data assuming a speed of sound of 1470 cm/s, whereas the Carter Tables are based on a speed of sound of 1500 cm/s. At the start of the cruise, it was thought that the EA-500 had been set to transmit data converted to use a speed of sound of 1500 cm/s. So, prodep was reconstructed using a PES Correction Factor of 1.0000, the data reprocessed, and again the depths extracted for the bottom of CTD casts. This time, it was noticed that the water depths were often shallower than the water depths computed from the maximum CTD depth and altimeter height off. Reprocessing all data (again) with a PES Correction Factor of 1. 01992 (1500/1470.6 cm/s) lead to water depths too great (100m too deep in some cases) and still some stations with water depths shallower than the CTD plus altimeter figure. O me miserum.

4.8 Shipboard Computing

4.8.1 Introduction

Computing facilities available onboard the *JCR* include IBM compatible PC's networked via Novell NetWare to central file servers; Sun Unix workstations running SUNOS 4 and Solaris 2; and the RVS ABC Data Acquisition and Logging System. The main workhorse for data analysis during the cruise was a Sun UltraSparc I Creator running Solaris 2.5.1 with 20GB of disk space. PCs were used almost exclusively as an interface to the BAS Messaging System which provides an E-mail connection to the outside world, plus a small amount of word processing at the end of the cruise. One of the general purpose PCs was dedicated to logging GPS/GLONASS data. SOC provided their own Apple Macs which were used for word processing, spreadsheet, and frontending the Unix systems. Two Tektronix Xterminals were also available as frontends to the Unix systems. A4 monochrome and colour, and A0 colour HPGL/Postscript printers were available. Data analysis was mainly undertaking using PSTAR.

4.8.2 Data Logging and the ABC System

The majority of data streams were logged without difficulty. However problems were encountered in the following areas.

1 The CTD Level A did not capture all data output by the CTD (see the CTD report for more details). Also encountered were occasional forward clock jumps during hardware resets. This can result in backward time jumps in data files after the clock is corrected unless the data file is corrected or a new file started before logging recommences.

2 The Trimble GPS receiver "locked up" on two occasions and output duplicate time and position data until reset. The Level A application did not detect this "lock up" and flagged the duplicate data as GOOD (status 50). This data was reflagged REJECT using edstatus.

3 It was not possible at the beginning of the cruise to establish data logging for the new Ashtech GPS+GLONASS receiver via the ABC system. This appeared initially to be due to cabling difficulties. Latterly a problem with the Level A application has been suggested. The application was developed prior to data being available and it was likely that minor modifications to the application would be required. It is now believed that the cabling difficulties have been resolved. RVS have provided advice on amending the application and work is underway at the time of writing.

4 At some point during the cruise a problem occurred with the system clock on the PC running the ADCP data acquisition software. This resulted in the date logged at the end of the cruise being

two days behind. Time appears to have been logged correctly. This is under investigation at the time of writing.

5 There were occasional ship master clock jumps. At one point all Level As needed resetting due to this.

6 The Ashtech GPS receiver outputs a value of “666 degrees” when satellite coverage is poor. This results in an alarm message being sent from the Level A continuously until satellite coverage improves.

4.8.3 Summary of Data Recorded

Data recorded are summarised in Tables 4.11 (data stream and file size, etc.), and 4.12 (data stream and variables).

CTD bit map	CTD A/D channels	Variable order for CTD A/D channels	RVS bit map	RVS ANCIL
001	1	press_t	100	4
010	2	oxyc	010	2
011	3	oxyt	110	6
100	4	fluor	001	1
101	5	trans	101	5
110	6	alt	011	3
111	7	chelsea tran	111	7
000	8	CTD zener voltage	000	0

Table 4.1: Multiplexed CTD to RVS channels. The variable appearing on multiplexed channel one appears on RVS ANCIL channel four etc.

JDAY	Station
320	4
320	5
321	11
322	12
323	16
325	29

Table 4.2: Level A crashes on JR16

Station	Problem	No of bottles on CTD frame
1	7 out of rack - not sampled replaced	12
2	6 and 7 out of rack. Top plate of rosette not level	12
3	Bottle 10 broken	10
4		9
5	Bottle 9 broken	9
6	Bottle 4 broken	9
7		9
8		9
9		9
10	Installed 4 BAS 1.7l bottles. Seal changed on bottle 10.	12
	For All further casts there were 12 bottles	
18	seal replaced on bottle 11	

Table 4.3: Bottle problems encountered during JR16

Station	Position	Type of Misfire
4	1	Long
5	12	Long
16	3	Long
17	5	Long
19	9	Long
	10	Long
21	9	Long
	10	Long
22	9	Long
	10	Long
	24	Short
23	9	Long
	10	Long
25	7	Long

Table 4.4: Pylon misfires during JR16

station	residual offset	CTD	conductivity calibration	rejected samples
1	0.1417	Deep03	station 4	
2	0.0119	Deep03	station 4	202
3	-0.0171	Deep03	station 4	316
4	0.0002	Deep03	station 4	
5	0.0195	Deep03	station 4	517
6	0.0046	Deep03	station 4	
7	0.0072	Deep04	station 11	
8	0.0042	Deep04	station 11	
9	0.0019	Deep04	station 11	
10	0.0007	Deep04	station 11	
11	-0.0001	Deep04	station 11	
12	-0.0002	Deep04	station 11	1217
13	0.0011	Deep04	station 11	
14	-0.0006	Deep04	station 11	1419
15	-0.0031	Deep04	station 11	
16	0.003	Deep04	station 26	
17	0.0018	Deep04	station 26	
18	0.0016	Deep04	station 26	1821
19	0.0007	Deep04	station 26	
20	0.0003	Deep04	station 26	
21	0.0003	Deep04	station 26	2121
22	0.0005	Deep04	station 26	
23	0.0008	Deep04	station 26	
24	0.0002	Deep04	station 26	2423
25	-0.0002	Deep04	station 26	2501
26	0	Deep04	station 26	
27	-0.0008	Deep04	station 26	
28	-0.0007	Deep04	station 26	
29	0.0011	Deep04	station 26	
30	-0.0005	Deep04	station 26	

Table 4.5: Conductivity calibration details for the CTD stations

Station	Problem
3	altimeter dropped out towards bottom but sea floor falling off a lot.
4	no altimeter information
5	no altimeter information
10	altimeter dropping out but OK at crucial moments.
26	altimeter disagreed with 10 Khz pinger, possibly caused by rising bottom or the orientation of the frame (the top shackle was replaced after this cast).

Table 4.6: Problems encountered with the Altimeter mounted on the CTD package.

			Time, GMT		Position, degrees		Depth (m)		
Stn	Day	Start	Bottom	End	Latitude (S)	Longitude (W)	Cor.Wtr	CTD max	Alt.
1	319	0943	1031	1129	53 30.22	58 07.88	2348.98		141.0
2	320	1042	1056	1114	54 47.46	58 27.11	397.54	386.98	16.1
3	320	1256	1317	1345	54 55.85	58 21.19	876.15	849.26	30.0
4	320	1444	1514	1602	54 57.94	58 20.85	1583.11	1586.12	0.0
5	320	1720	1759	1847	55 04.07	58 16.28	1981.63	1985.02	0.0
6	320	2213	2307	0019	55 06.80	58 13.26	2460.65	2479.21	13.2
7	321	0449	0544	0657	55 10.25	58 13.11	2961.56	2970.31	6.1
8	321	0757	0913	1035	55 12.63	58 12.60	3746.12	3785.69	16.7
9	321	1246	1403	1531	55 31.31	58 02.03	4240.32	4225.14	14.2
10	321	1730	1852	2036	55 49.15	57 52.51	4621.93	4613.26	11.7
11	321	2240	2349	0119	56 06.97	57 38.96	3662.18	3686.08	12.8
12	322	0416	0525	0649	56 27.93	57 31.45	3597.62	3588.56	10.0
13	322	0849	0940	1046	56 47.49	57 18.09	2566.63	2559.13	17.6
14	322	1512	1630	1756	57 05.41	57 07.44	4387.45	4381.87	13.2
15	322	2000	2111	2233	57 26.29	56 55.13	3966.22	3958.14	14.1
16	323	0238	0342	0507	57 43.39	56 39.71	3428.34	3430.30	9.0
17	323	0724	0836	1009	58 03.48	56 31.46	3993.29	3985.16	16.9
18	323	1448	1603	1731	58 22.38	56 21.31	3811.73	3804.13	15.0
19	323	2305	0014	0148	58 41.54	56 09.26	3786.98	3776.78	10.7
20	324	0405	0513	0639	59 00.13	55 59.11	3784.49	3776.68	10.1
21	324	0844	0949	1115	59 18.84	55 41.41	3729.93	3716.24	15.0
22	324	1326	1430	1551	59 38.93	55 31.12	3676.05	3663.56	13.6
23	324	2144	2247	0013	60 00.64	55 19.44	3498.30	3482.28	20.0
24	325	0238	0339	0459	60 20.47	55 03.94	3440.47	3421.76	14.6
25	325	0735	0831	0943	60 40.41	54 47.86	3100.30	3090.02	8.6
26	325	1327	1413	1510	60 48.12	54 42.72	2259.41	2395.78	68.0
27	325	1553	1624	1715	60 50.14	54 43.48	1580.13	1685.59	39.0
28	325	1916	1938	2008	60 51.09	54 43.20	1064.25	1122.86	21.8
29	325	2113	2124	2148	60 59.04	54 37.42	583.07	574.48	10.5
30	325	2231	2241	2254	61 02.11	54 36.97	504.05	499.42	12.6

Table 4.7: CTD station list

	Time		Position	
No.	Day	HHMM	Latitude (S)	Longitude (W)
1	320	0040	54 46.14	58 38.72
2	324	1225	59 29.71	55 35.56
3	324	2026	59 50.05	55 24.96
4	324	2033	59 50.96	55 24.34
5	325	0126	60 9.99	55 12.15
6	325	0644	60 34.75	54 52.90
8	337	1024	60 1.36	47 12.88
9	337	1203	59 46.57	47 48.75
10	337	1329	59 33.57	48 19.86
11	337	1458	59 19.99	48 50.56
12	337	1630	59 6.42	49 22.62
13	337	1805	58 51.91	49 55.05
14	337	1930	58 39.12	50 24.02
15	337	2100	58 26.52	50 53.18
16	337	2228	58 14.51	51 22.55
17	337	2353	58 2.22	51 48.61
18	338	0123	57 48.57	52 16.14
20	338	0258	57 34.84	52 45.78
21	338	0426	57 24.75	53 9.10
22	338	0604	57 13.89	53 34.77
23	338	0734	57 2.51	53 59.19
24	338	0854	56 52.12	54 21.62
25	338	1028	56 39.55	54 47.14
26	338	1200	56 26.23	55 13.98
27	338	1329	56 15.34	55 40.13
28	338	1500	56 3.07	56 7.31
29	338	1628	55 50.10	56 31.62
30	338	1802	55 37.76	56 58.43
31	338	1932	55 24.71	57 26.23
32	338	2100	55 11.94	57 53.97
33	338	2230	54 57.82	58 21.26

Table 4.8: XBT Launch Positions

JDAY	durn. mins	n obs A	A (ratio)	n obs phi	phi (°)	hd sigma (°)	Ve sigma cm/s	Vn sigma cm/s
356	240			120	-2.13	0.93	17.02	9.73
358	150	75	1.032	75	-2.29	1.04	8.51	16.00
358	80	40	1.026	40	-1.94	1.19	20.21	21.66
358	138	69	1.027	69	-2.15	1.11	26.56	13.17
359	56	28	1.028			0.68	5.48	10.97
359	60	30	1.028	30	-2.59	1.96	17.07	10.83
359	138	69	1.026	69	-1.78	1.02	17.76	12.71
359	130	65	1.031	65	-2.28	1.93	11.78	18.31
359	52	26	1.032	26	-1.94	0.59	28.33	19.04
360	70	35	1.021	35	-2.36	0.86	16.00	14.83
360	118			59	-1.93	1.54	18.96	18.12
360	68	34	1.034	34	-1.88	0.55	15.54	29.06
361	64	32	1.028	32	-2.22	0.93	23.57	42.87
361	114	57	1.020	57	-1.77	0.90	8.66	10.02
361	78					1.56	18.45	14.16
362	44					0.40	56.84	17.37
362	110	55	1.018			0.63	13.33	10.34
362	88	44	1.025	44	-1.87	1.24	24.80	14.46
363	46	23	1.035	23	-1.60	0.87	11.32	10.24
363	146	73	1.030	73	-2.38	1.39	13.89	19.03
364	176	88	1.026	88	-2.18	1.14	9.47	10.78
364	120	60	1.026	60	-2.06	1.42	16.00	12.56
364	94	47	1.019			0.82	4.10	10.01
364	46	23	1.027	23	-1.84	1.03	10.10	3.72
364	94	47	1.025	47	-2.11	1.77	14.20	6.83
365	28	14	1.031	14	-2.51	1.40	5.67	10.00
365	80	40	1.022	40	-1.90	0.76	12.02	12.48
366	50	25	1.032			0.45	11.19	8.84
366	30			15	-1.99	0.98	14.19	14.80
1	52	26	1.035	26	-2.45	0.71	6.75	13.58
2	76	38	1.026	38	-2.28	1.34	16.38	8.52
2	66			33	-1.74	1.03	11.49	19.26
2	118	59	1.033	59	-2.07	1.09	10.38	16.70
3	124	62	1.031	62	-2.31	1.83	15.55	25.40
		MEAN =	**1.0276**	**1356**	**-2.09**	**1.09**	**15.63**	**14.89**
		STDEV =	**0.0047**		**0.25**	**0.41**	**9.34**	**7.19**
		SE =	**0.0002**		**0.0069**			

Table 4.9: JR17 ADCP Calibration Information

Instrument	Type	Location	Field Name
sea temperature	4 wire PRT	Transducer space	sstemp
flow meter	Liter Meter	prep lab	flow
Thermosalinograph	Sea Bird SBE 21	prep lab	temp_h and cond
Air temperature	vector T351	foremast	atemp
PAR sensor	Didcot DRP1	foremast	par
TIR sensor	Kipp & Zonen CM5	foremast	tir
Barometer	VaisalaPA11	UIC	Press
Ships anemometer		foremast	wnd_speed, wind_dir

Table 4.10: The instruments connected to the oceanlogger.

Stream	Raw/Pro	Records	Size (MB)	Comment
adcp	r	863936	86.4	
adcp_raw	r	1133056	38.5	logged during homeward journey
anemom	r	2100998	33.6	
bestdrf	p	69041	1.9	
bestnav	p	69215	3.6	
bottlem2	r	705	0.01	
ctd12old	r	6912	0.66	test data prior to sailing
ctdbad_t	r	26616	2.5	data up to 4 day forward clock jump on day 320
ctdstn6	r	8376	0.8	CTD station 6 on day 320
ctd_12c	r	210924	19.8	data from day 321
dop_log	r	2073602	33.2	
em_log	r	922477	9.2	
gps_ash	r	2001582	116.1	
gps/glonass	n/a	1416728	97.3	logged to PC
gps_trim	r	2068012	144.8	
gyro	r	2075773	20.8	
oceanlog	r	350037	53.0	
prodep	p	202851	4.5	
rawdep	p	202871	2.0	generated from sim500 for prodep calculation
relmov	p	69223	2.4	
sim500	r	302115	8.5	
tsshrp	r	655401	22.3	

Table 4.11: Data recorded: stream and file size

Stream	Variables
adcp	bindepth roll pitch heading temp velps velfa velew velns velvert velerr ampl good bottoew bottomns depth
adcp_raw	rawampl rawgood beamno bindepth rawdopp
anemom	wind_dir wind_spd
bestdrf	vn ve kvn kve
bestnav	lat lon vn ve cmg smg dist_run heading
bottlem2	code
ctd12old	press temp cond fast_t uu press_t oxyc oxyt fluor trans alt chvolt ctdvolt deltat nframes
ctdbad_t	- as ctd12old -
ctdstn6	- as ctd12old -
ctd_12c	- as ctd12old -
dop_log	speedfa speedps
em_log	speedfa
gps_ash	sec lat lon hdg pitch roll nrms brms attf
gps/glonass	
gps_trim	lat lon pdop hvel hdg svc s1 s2 s3 s4 s5
gyro	heading
oceanlog	atemp mstemp sstemp hum par tir fluor flow psy1 psy2 soap press cond temp_h
prodep	uncdepth cordepth cartarea
rawdep	uncdepth
relmov	vn ve pfa pps pguro
sim500	uncdepth rpow angfa angps
tsshrp	hacc vacc heave roll pitch

Table 4.12: Data recorded: stream and variables

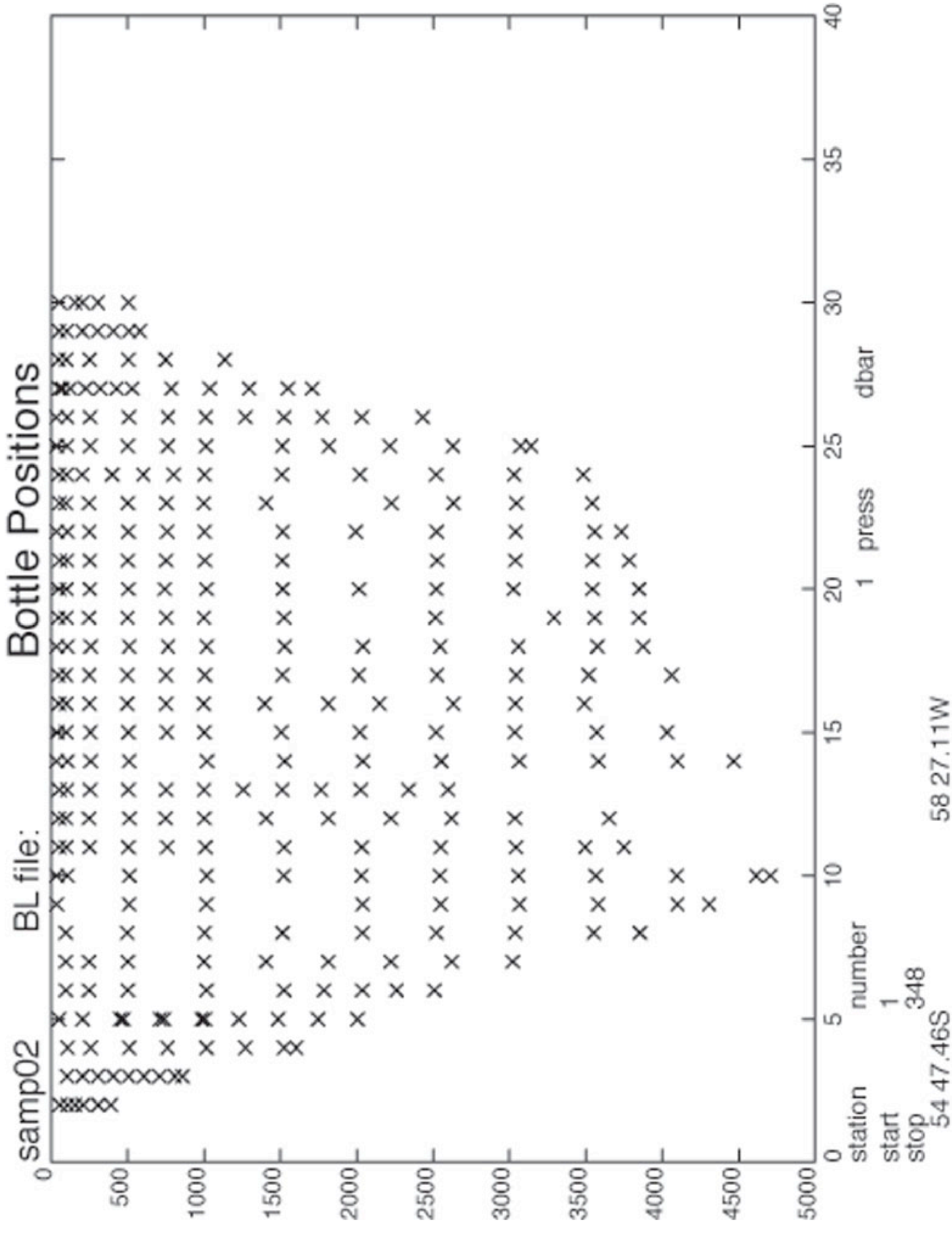

Figure 4.1: JR16 bottle depths versus station number

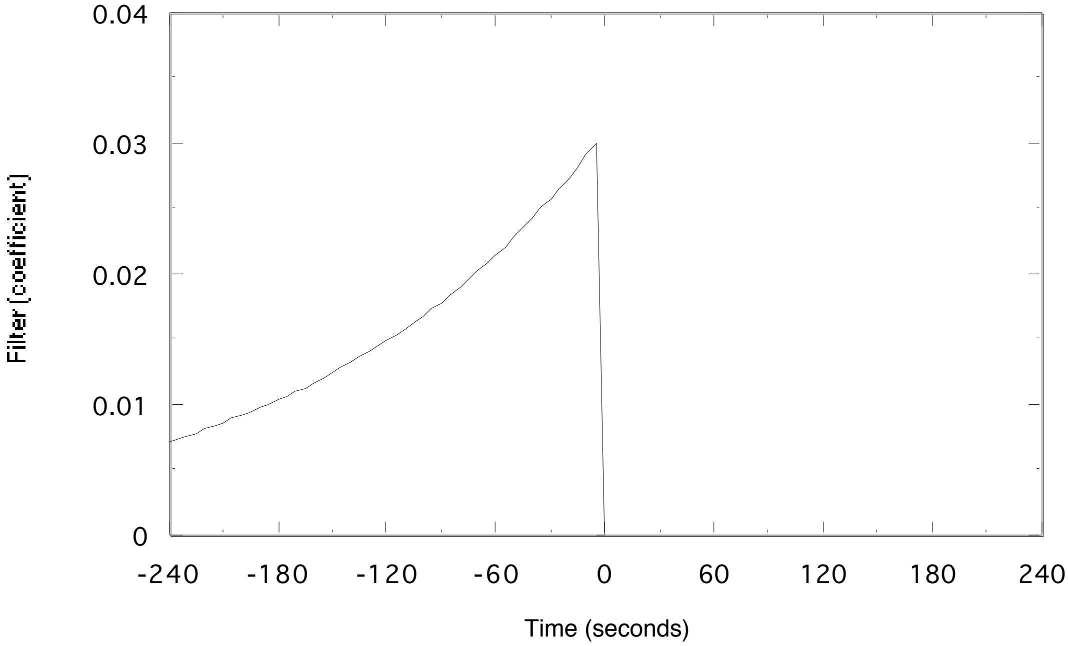

Figure 4.2: Filter applied to temp_h of the oceanlogger.

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5.1 Authors and Affiliations

Author	Affiliation
Cunningham, S. A.	SOC
King, B. A.	SOC
Kent, E. C.	SOC
Brandon, M.	BAS (now OU)
Marwood, T.	UEA (since left)
Jickells, T.	UEA
Sanders, R.	UEA (now SOC)

When the editors came to prepare this summary report, it was apparent that the only extant contemporary cruise report material for JR27 were the LADCP (Crisp), VM-ADCP (Kent) and Chemistry (Jickells and Sanders) elements (sections 5.2, 5.3 and 5.4 below). Therefore the remainder of the report was assembled by the editors with reference to contemporary processing records, deck logs, calibration records, and the data.

5.2 LADCP

5.2.1 Physical Location and Use

The 150 kHz RDI Broadband ADCP was mounted in an SOC CTD frame. The ADCP was situated centrally with the transducer heads approximately 10 cm inside the frame. The ADCP was powered by a battery pack located in a pressure case mounted horizontally on one side of the CTD frame.

The data lead, with male connectors on the end away from the ADCP, was fixed to a convenient upright on the CTD frame. At the end of each cast the blanking plug was removed and an extension cable running to a PC fixed in the Chemistry Lab. was fitted. Via this cable the ADCP receives power on deck so that data can be transferred from its internal memory. The extension cable was run through the window facing aft then draped over the top of the CTD frame. This relieves strain on the connectors and reduces the chances of the cable being pulled apart when there is power on it and data transfer is taking place.

5.2.2 Battery Packs

Within the battery pack, batteries were mounted in parallel, and voltage and current protected by a diode. The packs give 50 V off load. Statistics for hours of operation and voltage changes per cast are given in Table 5.1. Each battery pack lasted approximately 40 hours of operation, dropping 10 V before being changed. One pack which was left to rest for 2 days was retried. After this rest time the voltage increased by 6 V to 42.1 V and was used for a further 6 hours, a significant extra usage of the batteries.

5.2.3 Processing

5.2.3.1 Navigation

Navigation is important for converting the LADCP shear profiles to absolute water velocities. Since the cruise spanned a year boundary, the processing became complicated. Bestnav was used to provide navigation, the main contribution to bestnav is differential gps and is accurate to approximately 1 m. The bestnav data are split across the year boundary, time in seconds is converted into day of year ensuring that the 1998 portion starts with day of year equal one. ASCII listings of doy, lon, lat are then made. These can be read by matlab and saved as a mat file, e.g.

>matlab
run matlab
>load nav271.1997.ascii -ascii
read ascii navigation file
>sm=nav271;
save navigation to a new matrix called sm
>save sm.mat sm -mat
save the matrix sm to a mat file sm.mat

This is repeated for the 1998 portion saving the navigation data to sm.mat.1998. For processing profiles 001 to 014, navigation is from 1997; for 016 to 054, navigation is from 1998; e.g. cp sm.mat.1997 sm.mat then within matlab do_absN will work. Profile 015, which spans the year boundary, was processed back in the lab with help from Eric Firing (U. Hawaii). The navigation files should reside in

/data/jr27/ladcp/socproc/data/jr9712/DEVA

5.2.3.2 Water Track

Processing of the water track data follows the University of Hawaii processing software based on perl scripts and matlab. The following processing was done immediately after each cast. Station number_cast number sss_cc.
> perl -S scanbb.prl sss_cc
to make a preliminary examination of the data
> edit mag_var.tab
enter new line with magnetic variation and position e.g. jnnn,7,dd mm.mm S,dd mm.mm W where jnnn is the station number, 7 is the magnetic variation, dd is degrees and mm.mm is decimal minutes.
> edit stations.asc

enter new line with position and date e.g. nnn dd mm.mm -1 dd mm.mm -1 yyyy mn day where nnn is station number, dd is degrees mm.mm is decimal minutes, -1 represents south and west hemispheres, yyyy is year, mn is month, day is day of month.

> perl -S loadbb.prl sss_cc

load data into the self contained codas database. If this step needs to be repeated then the databases for this file must be deleted.

> perl -S domerge.prl -c0 sss_cc

-c0 for no CTD data

> matlab

plist=nnn.01

do_abs

produces profile plots which are saved as postscript files.

5.2.3.3 Bottom Track

Bottom track data were obtained in a manor different to previous cruises. A batch process was used, limiting the amount of manual intervention required. The RDI utility bbbatch was use to provide an ascii listing of required variables from the binary profiles. This was done using a DOS batch file called bt.bat with the following line,

for %%i in (j*.000) do bbbatch %%i bt2.fmt b%%i

which used a pattern match for the input file to bbbatch writing the output variables as listed in bt2.fmt to the ascii output file which is prefixed by "b". The following 23 variables are read from the binary file and output to ascii: binnum, ensemble, yy, mm, dd, hh, mm, ss, range1, range2, range3, range4, bote, botn, botvert, boterr, botpcgd, wate, watn, watvert, waterr, watpcgd. The ascii files on the pc can then be ftp'd to the UNIX system.

ladbexec0

Read the ascii data into pstar.

input: bjnnn_01.000

output: bjnnn.pst

ladbexec1

Edit ranges between 1 and 35774 cm. Not sure why this number is chosen but Brian and Mike used it in 1996. Compute the average of the four ranges and select data where the average range is between 0 and 35774 cm. At this point only data where bottom track data exist remain. Swap the absent data value to one recognised by pstar, calibrate ranges to be in m, velocities in cm/s, compute time in seconds, compute absolute velocities by subtracting bottom track velocities from water track velocities.

input: bjnnn.pst

output: bjnnn.bt

ladbexec2
Merge press and depth from CTD data onto LADCP profiles using time as the merging variable, calculate depth of the bins (=ctd depth + (16+16*binnum)), sort and average to give data in 16 m bins.
input: bjnnn.bt
output: btnnn

ladbexec3
Apply the magnetic variation correction to profiles
input: btnnn
output: btnnn

ladbctdexec
Copy time and pressure from a CTD 1hz file and calculate depth using latitude in the header of the CTD file. The 1 hz file must be down and up casts.
input: ctd27nnn.1hz
output: ctd27nnn

5.2.3.4 Notes

Profile 015 spans 1997 and 1998, bottom track data all in 1998 and there is no problem processing this data, however there is a problem processing the water track data so that do_absN will not run as there is a mismatch between the navigation time and time in the file. Somehow it is complicated to process across a year boundary and there is some problem with the UoH software.

Profiles 021 and 022 are not full depth and have no bottom track data. They cause the bottom track execs to crash.

5.3 Chemistry

5.3.1 Objectives

This work was funded by an NERC small grant to T. Jickells. The objectives of the work were twofold. Firstly to provide a high quality dissolved inorganic nutrient and dissolved oxygen data set to enable fluxes of these components to be generated in association with the heat, momentum and salt fluxes derived from the physical measurements. In addition these parameters, particularly dissolved oxygen and, in this area, dissolved silicate will be valuable in water mass characterisation, in support of the temperature and salinity measurements. The second component of the project involved analyses for dissolved organic nitrogen and phosphorus in the water column. These components have been rarely analysed for before on major oceanographic cruises and the data collected on this trip may represent the first available from Antarctic waters. Some results were published in Sanders and Jickells (2000).

5.3.2 Location of equipment

The oxygen analyses were conducted in the Chemistry Lab, which was very convenient for easy access to the water bottle sampling operation, though the lab did become crowded briefly after casts because of the necessity to also operate the LADCP computer in this location.

The autoanalyser for the nutrient analyses was set up in the Main Lab. On the previous cruise we participated in on the JCR this instrument was set up in the Biology Lab but this was unavailable on this trip due to equipment left installed from the previous cruise. The Main Lab proved a perfectly satisfactory alternative location though was further from the Prep Lab and had no sink.

The UV system used to oxidise organic nitrogen and phosphorus to inorganic phosphate and nitrate was set up in the fume cupboard in the Prep Lab with freshwater cooling supply run to the sink. This arrangement worked very well and allowed us to safely shield and vent the UV source.

Facilities on the JCR for these chemical analyses proved very satisfactory, with provision of high purity MilliQ water in both the Prep and Chemistry labs a real asset, along with the stability of the ship as a platform, a function no doubt both of the quality of the ship itself and the very good weather we enjoyed. One small point is that the oven in the prep lab was almost impossible to operate satisfactorily in the absence of an instruction manual.

The passage leg south to Rothera provided an excellent opportunity to optimise the analytical methods and equipment function

5.3.3 Methods

The oxygen and inorganic nutrient analyses methods were those used on a previous cruise on the JCR (A23: Heywood and King, 1996). All samples were unfiltered but we follow accepted practice and define our results as dissolved concentrations.

The oxygen analyses were based on the Winkler procedure using an automatic titration system with spectrophotometric end-point detection. Results were calculated using the Dickson equations as recommended in the WOCE manual. The reagent blank was determined as recommended by Dickson (WOCE manual) and were close to detection limit. Sagami standard iodate solutions were used for calibration. Standards were analysed throughout the cruise at regular intervals and there was no evidence of systematic drift in the standardisation from day to day. Oxygen concentrations on any particular day were calculated based on the most recent iodate standardisation. An evaluation of the accuracy of the analyses will be undertaken via a comparison with historical data. Oxygen analyses were usually completed within 6 hours of sample collection.

Dissolved inorganic nutrients (phosphorus, silicon and nitrate+nitrite) were analysed using a Skalar San Plus autoanalyser as on A23. Artificial seawater (40g/L NaCl in milli-Q water) was used for baseline and wash purposes. Based on various criteria, we believe that blanks associated with the artificial seawater were less than the detection limits of each of the analyses. Due to the relatively high nitrate+nitrite and silicate concentrations encountered, samples for both analyses were diluted with wash solution using in-line dilution loops to achieve dilutions of threefold and tenfold respectively. A brand new cadmium reduction column was fitted for nitrate+nitrite analyses at the start of the cruise. Standardisation was based on dried standards prepared at UEA made up as stocks on the ship and diluted appropriately. Fresh dilute standards were generally prepared daily. Sagami standards were also analysed for each nutrient. To check for day to day variations in calibrations and blanks, we also analysed each day a bulk seawater sample collected on the A23 cruise which had been preserved with $HgCl_2$. The values obtained for this sample varied apparently randomly over the sampling programme and were close to those obtained for the same sample on A23. An evaluation of the accuracy of the analyses will be undertaken via a comparison with historical data.

The analytical systems for both oxygen and nutrients worked satisfactorily throughout the cruise, with the following problems encountered. Silicate analyses on stations 20 and 24 were subject to considerable drift for an unknown reason. The logging system generated data were discarded and a manual calculation of results undertaken using the chart recorder output which accompanied every analytical run. The computer logging system failed on station 28, all results from this cruise have been generated from the chart recorder output. The temperature control for the phosphate analyses was not switched on for station 30. Half of these samples were rerun in the next analytical run and the remainder corrected using an appropriate conversion factor. For nitrate+nitrite, ship rolling can induce bubbles to pass into the photocell generating erroneous peaks. These incidences were identified on the chart recorder and edited carefully. In most cases it was possible to extract usable peak information and these peaks were then processed using the computer integration system. A full evaluation of the implications of these problems on the data quality is beyond the scope of this short report, however it will be completed in the near future. In a small number of cases the bubble peaks coincided with the peak maximum and it was considered impossible to extract accurate information for this sample. In some cases these samples were reanalysed but in some cases there was insufficient sample remaining and in these cases no data are reported. In general inorganic nutrient analyses were started within 2 hours of sample collection and completed within another two hours.

5.3.4 Sampling Strategy

At the start of the cruise we were uncertain of the rate at which we could process samples for oxygen, dissolved inorganic and organic nutrients. It was therefore agreed that we would initially sample up to 16 samples for dissolved oxygen and both inorganic and organic nutrients from each station (with fewer at the shallow stations). Later in the cruise as we grew more familiar with the organic nutrient analyses we were able to increase sample processing to include all 24 water bottles, though this often included several samples collected at the same depth and thus provided some replication. This increased sample throughput allowed us to target some additional sampling effort in the near surface waters where interesting gradients in organic nutrient concentrations were evident. The number of samples analysed for oxygen, and inorganic and organic nutrients was reduced somewhat at the northern leg of the cruise to cope with the very dense sampling strategy adopted.

Preliminary inspections of the data suggest patterns consistent with expectations with relatively high nitrate+nitrite and phosphate concentrations present in surface waters throughout the section declining northwards. South of the polar front, surface water silicate concentrations are very high, but decline sharply across the front. Concentrations of all nutrients increase with depth, consistent with biological utilisation in surface waters and regeneration at depth. At depth in the southern half of the section, the presence of a very high dissolved silicon concentration layer was evident. At present there has not been time to compare the results obtained with previous data from this area, though such a comparison will be undertaken.

5.3.5 Organic nutrients

Samples were irradiated with a high intensity Hg UV lamp to destroy organic matter and hence liberate organic phosphorus and nitrogen as inorganic species. Organic nitrogen and phosphorus concentrations are thus the differences between the measured dissolved inorganic phosphorus and nitrogen concentrations before and after oxidation. This approach has been used by various people in the past, most recently by Hansell and Whitehouse (1997), although these authors froze samples and analysed them in their home lab. We purchased a newly available small Metrohm UV oxidation system and were able to successfully use this on the ship allowing us to begin oxidation of samples usually within an hour of sampling, hence minimising concerns over possible storage artefacts.

During the first leg of the cruise we concentrated on optimising analysis procedures, particularly in terms of oxidation times. The full results of these investigations are still being evaluated and will be published separately. In summary we selected a 2 hour photoxidation period at a temperature of about 80˚C as adequate to destroy most of the organic nitrogen and phosphorus and short enough to prevent losses of phosphorus, which were evident with longer oxidation times. Earlier workers have added hydrogen peroxide to facilitate photoxidation, but we found this to be both unnecessary and liable to produce substantial blanks, and consequently we did not use hydrogen peroxide. We found no evidence of ammonium formation during photoxidation and consequently subsequently only analysed for nitrate+nitrite. Added ammonium spikes were oxidised to nitrate+nitrite, but recoveries were less than 100%, though there was no residual ammonium after photo-oxidation, implying production of other nitrogen species not analysed by our methods such as N_2 or N_2O. Similarly urea oxidation efficiency was less than 100%, again broadly consistent with other studies. Thus we believe the results we report represent lower limits since some species may not be completely oxidised to nitrate+nitrite by our procedures.

The quantification of these organic nutrients is done by difference as noted earlier and consequently in the nutrient rich waters of the Southern Ocean, this analysis is rather difficult, since it is necessary to calculate the *small* difference between two relatively large numbers. However, with the high precisions we were able to achieve with the inorganic nutrient analysis procedures we believe we have been able to achieve the best results possible for organic nitrogen and phosphorus concentrations using this analytical approach. With such a new technique we have decide to be cautious in our interpretation of results close to detection limits. Furthermore we have some concerns that ageing of the silica glass tubes used for photo-oxidation may have degraded the organic phosphorus methods and we have arbitrarily decided not to report results from any stations where more than 10% of the results obtained gave negative organic phosphorus concentrations outside the allowable range based on detection limits..

The full interpretation of this novel data set will take some time but several obvious features are evident at this stage. DON is ubiquitous with deep water concentrations of the order of 4 uM. These increase to 5-10 uM in surface waters. At some stations deep water maxima in DON are also evident suggesting a benthic source or possibly high DON water flowing from shelf systems into the deep water. DOP concentrations in deep water are close to detection limits but generally increase in surface waters and at the same place as the deep DON maxima. Thus the two parameters appear quite well correlated though the relationship does not necessarily imply a simple Redfield relationship which can be applied throughout the section.

5.3.6 Phytoplankton sampling

Samples for phytoplankton identification were collected for Dr. R. Raine U. Galway, Eire. Samples were collected using a vertically towed very fine mesh net over the upper 100 m of the water column once a day at approximately midday. Samples were preserved with Lugols Iodine and will be shipped to Galway for subsequent analysis. The sampling operation was run off the small winch mounted below the main hydrographic winch gantry, and thanks to the efficient work of the crew this operation was achieved safely and with minimum disruption to the main sampling programme.

5.4 VM-ADCP

For technical information on the JCR VM-ADCP installation and for description of the conventional processing route, see other sections in this document (eg. section 4.4).

The bottom tracking data collected on JR27 was poor, the calibration used on the cruise was therefore that derived by Mark Brandon on the previous cruise, JR26, where more bottom tracking data of better quality was collected; see Table 5.2. These values are plotted in figures 5.1 and 5.2. The CTD section was made on the return leg from Elephant Island to the Falklands (here called leg 2). The ADCP data on the southbound leg 1 was noisy as the bin depth selected (4 m) was too small. Leg 2 used a bin depth of 8 m and the data were of a better quality.

Neither the calibration values for JR26 or JR28 fully removed the ship's motion from the underway data for JR27 and an attempt to combine the bottom tracking data from JR26 and JR27 resulted in a ϕ value very different from those from the surrounding cruises (see Table 5.2). It was therefore decided to interpolate the calibration values as the values for cruises JR25, JR26 and JR28 seemed to show a consistent trend (see figures 5.1 and 5.2).

Figure 5.3 shows the JR27 data with interpolated calibration coefficients ($A = 0.99$, $\phi = -1.9^\circ$). The on-station data at 100 m are the dark arrows and the off-station data at 100 m are the grey arrows. The interpolated coefficients did a much better job of removing the ship motion from the 100 m current vectors than those for JR26 or JR28 (not shown) although there is still some disagreement between the two sets of vectors. It was decided to try slightly different values of the coefficients and to use the values that gave the best agreement between the on and off station vectors at 100 m depth. From the different values of coefficients tried it became apparent that different A and ϕ values were needed for different parts of the cruise.

The A and ϕ values were therefore calculated for each pair of profiles; profiles for stations 4, 6, 23, 27, 28, 41 and 47 were not used as they gave extreme values. Also the off-station sections 5.5 (ie the section between stations 5 and 6) and 46.5 were omitted. The calculated values of A and ϕ are shown in figures 5.4 and 5.5. The values calculated showed no trend with water temperature. The values applied to the data were the 200 km average values shown in figures 5.4 and 5.5 and are given in Table 5.3. The bottom tracking data were not used at all. Figure 5.6 shows how these values for A and ϕ give very good agreement between the on- and off-station current vectors at 100 m.

5.5 CTD

5.5.1 Equipment

The same instrumentation was used on JR27 as on JR16; see section 4.2 for description of calibration and data processing procedures. To confirm, the following (IOS) instruments were used: CTDs DEEP03 and DEEP04, RDI 150 kHz LADCP, Chelsea and SeaTech transmissometers, Simrad Altimeter, four SIS reversing pressure meters (P6393, P6394, P6132, P6075, the last two extra to JR16) and three reversing temperature meters (T989, T995, T401, the last one extra to JR16), a 24-place rosette multisampler and 24 10 litre Niskin bottles.

5.5.2 Stations and sampling

A total of 54 stations were occupied, of which the first inaugurated the Rothera Time Series (RaTS) off Biscoe Wharf, Rothera; the second was a test station; the section proper, stations 3 to 54, was carried out at double the normal (nominal) station resolution, with stations generally 10 nm apart, compared with the usual 20 nm. Two stations, 21 and 22, comprised part of a mid-section diversion to investigate an eddy, when several XBTs were also deployed (see below). Samples were drawn for salinity (for CTD calibration) from every station; samples for the various chemical analyses (described above) were drawn from alternate stations, except near the northern and southern boundaries, where all stations were sampled. Table 5.4 summarises station times and positions, etc., and samples drawn. Figure 5.7 shows bottle depths per station.

5.5.3 Calibrations

Temperature and pressure calibration values are obtained from calibration certificates provided by Ocean Scientific International Ltd. (OSIL) for calibration conducted in June 1997 (DEEP03) and March 1997 (DEEP04).

5.5.3.1 Temperature

Temperatures are reported in ITS-90. ITS-68 is used for computing derived quantities following the suggestion of Saunders (1990):

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

Raw temperatures were scaled as:

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

the calibrated using coefficients provided by OSIL using a 7-point fit between 0 and 28.6 ˚C (±2 m˚C; DEEP03) and a 6-point fit between 0 and 25 ˚C (±2 m˚C; DEEP04):

DEEP03: $T = -2.1429 + 0.99136 \times T_{raw}$

DEEP04: $T = 0.12797 + 0.9992847 \times T_{raw}$

Due to the lag between the conductivity and temperature sensors, the time rate of change of temperature is used to 'speed up' the temperature measurements as:

$$T = T + \tau dT/dt$$

For both DEEP03 and DEEP04, τ was set to 0.25 s.

5.5.3.2 Pressure

Raw pressures were first scaled as:

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

and then calibrated using coefficients provided by OSIL using a 13-point fit between 0 and 5500 dbar for DEEP03 and an 11-point fit between the same limits for DEEP04:

DEEP03: $P = -35.65 + 1.0745 \times P_{raw} + 5.17E{-8} \times P_{raw}^2$

DEEP04: $P = -37.685 + 1.07333 \times P_{raw} + 5.81E{-8} \times P_{raw}^2$

5.5.3.3 Salinity

Raw conductivities were first scaled as:

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

and then calibrated using the following initial nominal calibrations:

DEEP03: $C = -0.0127 + 0.9406 \times C_{raw}$

DEEP04: $C = 0.0801782 + 0.96473 \times C_{raw}$

This was followed by the cell material deformation correction:

$$C = C \times [\ 1 + a \times (T-T_0) + b \times (P-P_0)\ ]$$

where the coefficients are: $a = -6.5E-6$ °C^{-1}, $b = 1.5E-8$ dbar^{-1}, $T_0 = 15$ °C and $P_0 = 0$ dbar.

Final adjustments to the conductivity calibration were made on a station-by-station basis by comparison with bottle salinity sample measurements converted to conductivity. Salinity samples were analysed on the SOC Guildline 8400B standardised with IAPSO Standard Seawater Batch P132. The final linear calibration was of the form

$$C_{final} = A + B \times C$$

Values of A and B are listed in Table 5.5. A plot of all residuals (bottle minus upcast CTD salinity) versus pressure is shown in figure 5.N. The total number of residuals was 621; excluding 95 outliers outside the salinity range ±0.01 left a mean residual salinity difference of 0.0001, sd 0.0030. Restricting the calculation to data below 500 dbar left 351 values in total with 25 out of range, with mean residual –0.0002, sd 0.0025.

5.6 Other measurements

5.6.1 XBTs

A quantity of XBTs were launched during the voyage, in two groups: the first group (nos. 2 to 28) comprised a southbound section across Drake Passage. The second group (nos. 30 to 38, and 45 to 49) contributed the survey of an eddy during the northbound CTD section; this survey also included CTD stations 21 and 22. XBT launch times and positions are listed in Table 5.4.

5.6.2 Navigation

See section 4.6 for a description of navigational instruments and data processing procedures. As in that section, GPS Trimble 4000, Ashtech GPS3DF, Ashtech GG24 (GLONASS), Gyro, and Electromagnetic Log and Doppler Log were recorded and 'bestnav' created; bestnav was used as the primary source of navigation data, via the resulting 'abnv' file.

5.6.3 Others

Also recorded were: Simrad 500 Echo Sounder bathymetry; Oceanlogger parameters, including thermosalinograph; mean meteorology from the ship's fitted instruments.

Note added in press (*eds.*) from documentation provided by M. Brandon for cruise JR28, immediately following cruise JR27:

As described in section 4.6, the main navigational instruments were the Trimble 4000 GPS, the Ashtech 3DF GPS, the Ashtech GG24 (GPS plus GLONASS), plus the gyro and electromagnetic and Doppler logs. We note the following.

1. The Trimble 4000 GPS was modified by the addition of a Racal SkyFix Satcom unit to enable its operation in real-time differential mode (DGPS). It receives GPS satellite vehicle range correction data via INMARSAT B. During JR27 and JR28 the DGPS reference station at Stanley was used. DGPS was therefore the primary source of positional information for these cruises. Experiments from data when the ship was both at anchor and moored to a buoy at Stromness harbour, South Georgia, suggested an absolute positional accuracy of approximately 1.5 m.

2. The Ashtech 3DF GPS receiver parameters in menu 4 and submenus were identical to those described in section 4.6.2 are not repeated here.

3. The Ashtech GG24 gave a positional accuracy of order 7 m on JR17. On JR28 the data were so poor that the stream was no longer routinely used. The GG24 works by accepting data from both American GPS and the Russian GLONASS satellite clusters. This extends the constellation of available satellites to 48 and should be significantly more accurate than either cluster taken individually. However, in October 1997 the system was unserviceable. It was repaired on JR25 but the suspicion was that the instrument was still not operating correctly and so its quality was degraded. The unit would frequently hang. On these occasions it output a position of 0°N and 0°W, and more worryingly, the data were flagged as good in the RVS system. The instrument generally came back to life but occasionally it required ITS intervention (in the form of power cycling). There was no obvious reason for these dropouts as there certainly were satellites available for positional information: the other GPS instruments did not drop out.

Station No.	No. Ensembles	V start (volts)	V end (volts)	Battery Pack no.	mins. operation	op. hrs (cuml.)
01	1906		46.7	1	63.5	1.1
02	3300	47.6	44.8	1	110.0	2.9
03	1665	46.1	44.2	1	55.5	3.8
04	2083	45.1	43.6	1	69.4	5.0
05	2486	44.5	43.0	1	82.9	6.4
06	3477	43.9	42.4	1	115.9	8.3
07	3767	43.0	41.4	1	125.6	10.4
08	3713	40.8	39.3	1	123.8	12.4
09	4896	41.8	39.9	1	163.2	15.2
10	4569	41.1	39.3	1	152.3	17.7
11	4550	40.8	39.0	1	151.7	20.2
12	5366	40.5	38.7	1	178.9	23.2
13	4851	39.6	38.1	1	161.7	25.9
14	5002	39.6	37.8	1	166.7	28.7
15	4700	39.0	38.1	1	156.7	31.3
16	4811	38.4	36.8	1	160.4	34.0
17	4819	38.1	36.5	1	160.6	36.6
18	5235		35.9	1	174.5	**39.6**
19	4915	48.5	45.1	2	163.8	2.7
20	5092	46.1	43.6	2	169.7	5.6
21	2562	44.2	43.3	2	85.4	7.0
22	2583	44.2	43.0	2	86.1	8.4
23	5162	43.9	41.4	2	172.1	11.3
24	5670	42.7	40.5	2	189.0	14.4
25	4466	41.8	39.9	2	148.9	16.9
26	5190	41.1	39.0	2	173.0	19.8
27	4844	41.8	39.0	2	161.5	22.5
28	5310	40.5	38.4	2	177.0	25.4
29	5114	39.9	37.8	2	170.5	28.3
30	4341	39.3	37.5	2	144.7	30.7
31	4406	39.0	36.8	2	146.9	33.1
32	5259	38.7	36.8	2	175.3	36.1
33	4995	38.1	36.2	2	166.5	**38.8**
34	6159	48.8	44.8	3	205.3	3.4
35	5431	45.4	43.3	3	181.0	6.4
36	4600	43.9	42.1	3	153.3	9.0
37	5401	43.3	41.1	3	180.0	12.0
38	5106	42.4	40.5	3	170.2	14.8
39	4851	42.1	39.9	3	161.7	17.5
40	5119	41.1	39.3	3	170.6	20.4
41	5213	40.8	38.7	3	173.8	23.3
42	6213	40.2	38.4	3	207.1	26.7
43	5778	39.6	37.8	3	192.6	29.9
44	5642	39.3	37.8	3	188.1	33.1
45	5267	38.1	37.1	3	175.6	36.0
46	5300	38.7	36.5	3	176.7	**38.9**
47	4144	42.1	39.6	2	138.1	2.3
48	3539	40.2	38.4	2	118.0	4.3
49	3132	39.3	38.1	2	104.4	**6.0**
50	2639	49.1	46.7	4	88.0	1.5
51	2701	47.0	45.4	4	90.0	3.0
52	1788	45.7	44.5	4	59.6	4.0
53	1322	41.4	44.5	4	44.1	4.7
54	1062	44.5	43.9	4	35.4	**5.3**

Table 5.1: LADCP battery pack operational statistics.

Cruise	A	ϕ
JR10 (A23)	0.99	-2.38
JR16	0.98	-2.12
JR25	1.05	-2.54
JR26	1.03	-2.32
JR27-JR27 Combination	0.97±0.5	1.1±2.7
JR28	0.94	-1.55

Table 5.2: ADCP calibration values used on JR27.

Distance run (km)	A	ϕ
< 3600 km	0.885	-1.5
≥ 3600, < 3800	0.89	-1.3
≥ 3800, < 4000	0.91	-1.4
≥ 4000, < 4200	0.93	-0.8
≥ 4200, < 4400	0.945	-0.6
≥ 4400, < 4600	0.93	-0.4

Table 5.3: A and f values applied to data by distance run (distrun).

Date YYYYMMDD	Time HHMMSS	stn no.	cordep m	lat DEGR min MIN	lon DEGR min MIN	pmax dbar	alt m	CTD	No. sal	Samp
19971227	140523	1	291.3	067 34.512 S	068 08.106 W					
19971227	141256	1	291.2	067 34.512 S	068 08.106 W	234.2	77.1	03	24	S
19971227	143959	1	286.8	067 34.512 S	068 08.010 W					
19971229	173055	2	1595.3	062 39.726 S	058 17.550 W					
19971229	180352	2	1593.2	062 39.582 S	058 17.778 W	1521.9	abs	03	9	A
19971229	185834	2	1595.3	062 39.288 S	058 17.952 W					
19971230	090402	3	397.2	061 02.946 S	054 36.126 W					
19971230	091754	3	411.0	061 02.862 S	054 36.372 W	407.5	12.1	03	7	A
19971230	093859	3	396.0	061 03.090 S	054 36.564 W					
19971230	103708	4	599.8	060 58.698 S	054 38.592 W					
19971230	105110	4	596.9	060 58.716 S	054 38.640 W	595.4	8.4	03	8	A
19971230	112859	4	620.2	060 58.188 S	054 39.696 W					
19971230	124900	5	966.8	060 51.324 S	054 42.960 W					
19971230	131045	5	969.2	060 51.330 S	054 42.960 W	1045.9	8.1	03	12	A
19971230	135059	5	967.1	060 51.330 S	054 42.972 W					
19971230	162122	6	1485.1	060 50.688 S	054 43.854 W					
19971230	165150	6	1468.7	060 50.700 S	054 43.824 W	1578.4	8.6	03	12	A
19971230	173959	6	1305.6	060 50.802 S	054 43.536 W					
19971230	184603	7	2166.3	060 49.410 S	054 44.604 W					
19971230	192537	7	1956.8	060 49.494 S	054 43.572 W	2214.6	1.1	03	12	A
19971230	202837	7	1733.5	060 49.662 S	054 42.258 W		L			
19971230	212143	8	2513.6	060 48.162 S	054 44.736 W					
19971230	221001	8	2470.7	060 48.066 S	054 44.028 W	2656.5	29.5	03	12	A
19971230	232543	8	2405.3	060 47.826 S	054 43.194 W					
19971231	005557	9	3109.8	060 44.730 S	054 47.556 W					
19971231	014935	9	3107.3	060 44.736 S	054 47.574 W	3145.9	11.6	04	12	S
19971231	030015	9	3105.2	060 44.736 S	054 47.568 W					
19971231	040555	10	3115.0	060 40.032 S	054 50.406 W					
19971231	050152	10	3114.7	060 40.032 S	054 50.400 W	3149.8	10.3	04	12	A
19971231	061329	10	3106.3	060 39.984 S	054 50.130 W					
19971231	075820	11	3384.6	060 30.030 S	054 56.844 W					
19971231	085838	11	3383.5	060 30.024 S	054 56.706 W	3429.2	7.1	04	12	S
19971231	101058	11	3383.4	060 30.006 S	054 56.652 W					
19971231	114957	12	3444.9	060 19.908 S	055 02.952 W					
19971231	125030	12	3446.8	060 19.998 S	055 02.862 W	3484.8	11.9	04	12	A
19971231	141658	12	3445.7	060 20.004 S	055 02.880 W					
19971231	154754	13	3429.7	060 09.894 S	055 09.156 W					
19971231	164935	13	3429.6	060 09.894 S	055 09.168 W	3469.9	9.5	04	12	S
19971231	181026	13	3429.8	060 09.906 S	055 09.162 W					
19971231	195211	14	3505.0	059 59.832 S	055 14.790 W					
19971231	205427	14	3505.5	059 59.772 S	055 14.580 W	3549.6	10.1	04	12	A
19971231	222258	14	3507.4	059 59.712 S	055 14.004 W					
19971231	235517	15	3590.5	059 49.992 S	055 21.324 W					
19980101	005838	15	3597.4	059 49.578 S	055 21.018 W	3645.7	10.2	04	12	S
19980101	021625	15	3609.6	059 48.894 S	055 20.862 W					
19980101	035016	16	3680.0	059 39.936 S	055 27.150 W					
19980101	045158	16	3678.6	059 39.732 S	055 26.574 W	3730.4	9.0	04	12	A
19980101	061411	16	3678.0	059 39.798 S	055 26.166 W					
19980101	074823	17	3712.2	059 29.928 S	055 33.828 W					
19980101	085049	17	3711.9	059 29.970 S	055 33.876 W	3758.8	13.6	04	12	S
19980101	100917	17	3712.4	059 29.976 S	055 33.798 W					
19980101	115310	18	3750.8	059 19.992 S	055 39.990 W					
19980101	125944	18	3750.5	059 19.986 S	055 39.996 W	3802.6	11.2	03	12	A
19980101	143143	18	3745.8	059 19.932 S	055 40.266 W					
19980101	161346	19	3702.1	059 10.014 S	055 46.230 W					
19980101	171915	19	3702.1	059 9.984 S	055 46.206 W	3752.0	11.1	03	12	S
19980101	184306	19	3702.7	059 10.014 S	055 46.104 W					
19980101	201839	20	3780.2	058 59.988 S	055 52.194 W					
19980101	212457	20	3779.7	058 59.988 S	055 52.338 W	3833.1	11.0	03	12	S
19980101	225956	20	3781.0	058 59.784 S	055 52.422 W					

Date	Time	stn	cordep	lat min	lon min	pmax	alt	CTD	No.	Samp
YYYYMMDD	HHMMSS	no.	m	DEGR MIN	DEGR MIN	dbar	m		sal	
19980102	030029	21	3667.5	059 13.110 S	056 05.112 W					
19980102	033027	21	3667.3	059 13.134 S	056 05.184 W	1835.6	abs	03	6	S
19980102	040907	21	3667.1	059 13.104 S	056 05.238 W					
19980102	083257	22	3821.8	059 06.924 S	055 27.738 W					
19980102	090616	22	3822.5	059 06.936 S	055 27.672 W	1828.6	abs	03	6	S
19980102	094459	22	3822.5	059 06.972 S	055 27.708 W					
19980102	133127	23	3845.9	058 50.550 S	055 58.122 W					
19980102	144223	23	3843.8	058 50.496 S	055 57.540 W	3902.9	8.3	03	12	S
19980102	161459	23	3843.1	058 50.628 S	055 57.186 W					
19980102	181414	24	3755.9	058 40.908 S	056 04.206 W					
19980102	192100	24	3755.6	058 40.962 S	056 04.200 W	3813.7	9.3	03	12	A
19980102	205206	24	3756.3	058 40.956 S	056 04.194 W					
19980102	233350	25	3782.8	058 31.536 S	056 09.984 W					
19980103	003819	25	3785.8	058 31.506 S	056 10.098 W	3852.4	12.5	03	12	S
19980103	015921	25	3785.0	058 31.524 S	056 09.924 W					
19980103	034236	26	3862.0	058 22.026 S	056 15.978 W					
19980103	045110	26	3853.1	058 22.128 S	056 16.662 W	3895.4	24.9	03	12	A
19980103	061337	26	3843.9	058 22.368 S	056 17.418 W					
19980103	173155	27	3756.2	058 12.432 S	056 21.876 W					
19980103	183810	27	3755.9	058 12.426 S	056 21.858 W	3811.6	10.6	03	12	S
19980103	200054	27	3761.8	058 12.408 S	056 21.876 W					
19980103	212342	28	3975.4	058 02.988 S	056 27.702 W					
19980103	223309	28	3976.0	058 02.982 S	056 27.702 W	4038.2	9.3	03	12	A
19980104	000229	28	3976.3	058 02.982 S	056 27.708 W					
19980104	015135	29	3960.8	057 53.232 S	056 33.678 W					
19980104	030002	29	3982.0	057 52.920 S	056 32.886 W	4029.1	14.1	03	12	S
19980104	042210	29	4014.2	057 52.326 S	056 31.560 W					
19980104	060628	30	3381.7	057 43.920 S	056 39.498 W					
19980104	070632	30	3430.5	057 43.632 S	056 38.496 W	3511.7	2.6	03	12	A
19980104	082557	30	3423.5	057 43.590 S	056 38.436 W		L			!op
19980104	094949	31	3365.5	057 34.962 S	056 44.934 W					
19980104	104631	31	3256.4	057 34.992 S	056 44.268 W	3364.9	31.2	03	12	S
19980104	120319	31	3106.5	057 34.836 S	056 43.374 W					
19980104	133637	32	3499.1	057 26.016 S	056 50.580 W					
19980104	144832	32	3769.9	057 25.602 S	056 49.026 W	3929.8	6.4	03	12	A
19980104	161758	32	3714.2	057 25.086 S	056 47.478 W					
19980104	182940	33	3977.1	057 15.342 S	056 56.556 W					
19980104	193931	33	3965.1	057 15.192 S	056 56.214 W	4030.2	10.0	03	12	S
19980104	210919	33	3975.2	057 15.060 S	056 56.556 W					
19980104	225539	34	4271.8	057 04.986 S	057 03.618 W					
19980105	001357	34	4175.5	057 04.716 S	057 03.318 W	4316.8	78.9	03	12	A
19980105	014633	34	4122.4	057 04.434 S	057 03.198 W		53.0			
19980105	031639	35	3898.6	056 55.968 S	057 09.276 W					
19980105	042532	35	3869.2	056 55.710 S	057 09.240 W	4021.3	52.3	03	12	S
19980105	054955	35	3807.3	056 55.482 S	057 08.790 W					
19980105	072540	36	3090.4	056 46.974 S	057 14.634 W					
19980105	082012	36	3083.1	056 46.908 S	057 14.502 W	3138.0	12.2	03	12	A
19980105	093543	36	3042.7	056 46.956 S	057 14.148 W					
19980105	105925	37	4175.5	056 37.494 S	057 20.508 W					
19980105	121244	37	4133.5	056 37.098 S	057 20.016 W	4216.6	8.5	03	12	S
19980105	134640	37	4089.3	056 36.624 S	057 19.854 W					
19980105	151735	38	3736.3	056 27.984 S	057 26.430 W					
19980105	162301	38	3627.2	056 27.456 S	057 25.896 W	3757.9	13.0	03	12	A
19980105	175059	38	3551.9	056 26.886 S	057 25.572 W					
19980105	193708	39	3254.7	056 17.994 S	057 32.046 W					
19980105	203519	39	3201.1	056 17.334 S	057 31.680 W	3278.9	10.6	03	12	S
19980105	215329	39	3065.9	056 16.278 S	057 31.596 W					
19980105	231655	40	3552.8	056 07.986 S	057 38.886 W					
19980106	002158	40	3593.3	056 07.326 S	057 38.466 W	3667.5	9.7	03	12	A
19980106	014758	40	3585.5	056 06.492 S	057 38.112 W					

Date YYYYMMDD	Time HHMMSS	stn no.	cordep m	lat DEGR min MIN	lon DEGR min MIN	pmax dbar	alt m	CTD	No. sal	Samp
19980106	031235	41	3919.3	055 58.488 S	057 44.604 W					
19980106	042131	41	3994.2	055 57.774 S	057 43.434 W	4037.4	12.2	04	12	S
19980106	054529	41	4056.0	055 56.916 S	057 41.892 W					
19980106	071700	42	4667.1	055 48.996 S	057 50.466 W					
19980106	084116	42	4743.8	055 47.946 S	057 50.736 W	4805.2	32.8	03	12	A
19980106	102508	42	4740.1	055 46.998 S	057 51.318 W					
19980106	113745	43	4496.1	055 39.978 S	057 56.262 W					
19980106	125634	43	4440.1	055 39.300 S	057 55.194 W	4530.9	9.1	03	12	S
19980106	143445	43	4429.2	055 38.820 S	057 53.664 W					
19980106	155742	44	4226.1	055 30.882 S	058 01.710 W					
19980106	171417	44	4202.9	055 30.570 S	058 00.480 W	4277.2	8.0	03	12	A
19980106	185008	44	4168.9	055 30.108 S	057 59.064 W					
19980106	202858	45	4206.6	055 21.918 S	058 07.164 W					
19980106	214017	45	4210.6	055 21.846 S	058 07.098 W	4279.1	8.9	03	12	S
19980106	230950	45	4213.0	055 21.786 S	058 07.128 W					
19980107	004933	46	3837.4	055 12.996 S	058 12.894 W					
19980107	020042	46	3899.8	055 13.056 S	058 12.570 W	4075.1	9.2	03	12	A
19980107	032549	46	3830.2	055 12.882 S	058 12.042 W					
19980107	042937	47	2920.8	055 10.002 S	058 14.532 W					
19980107	052108	47	2947.8	055 10.182 S	058 14.010 W	2993.0	13.9	03	12	A
19980107	063230	47	2967.2	055 10.248 S	058 12.864 W					
19980107	073255	48	2514.8	055 07.314 S	058 16.500 W					
19980107	081650	48	2509.0	055 07.260 S	058 16.326 W	2550.1	8.4	03	12	A
19980107	091239	48	2516.4	055 07.290 S	058 16.230 W					
19980107	100603	49	2038.0	055 04.074 S	058 18.318 W					
19980107	104050	49	2038.1	055 04.080 S	058 18.306 W	2066.5	12.8	03	12	A
19980107	114246	49	2047.2	055 04.170 S	058 18.402 W					
19980107	125047	50	1520.3	054 57.708 S	058 22.632 W					
19980107	132056	50	1530.9	054 57.702 S	058 22.488 W	1564.0	11.1	03	12	A
19980107	140958	50	1530.2	054 57.732 S	058 22.038 W					
19980107	145455	51	1007.8	054 56.466 S	058 22.980 W					
19980107	151612	51	1029.1	054 56.502 S	058 22.770 W	1040.2	12.3	03	12	A
19980107	155124	51	1156.3	054 56.712 S	058 22.236 W					
19980107	164443	52	464.2	054 55.290 S	058 23.838 W					
19980107	165710	52	458.1	054 55.248 S	058 23.736 W	636.4	7.8	03	8	A
19980107	171825	52	447.7	054 55.092 S	058 23.442 W					
19980107	195935	53	410.6	054 46.992 S	058 28.788 W					
19980107	201106	53	407.7	054 46.986 S	058 28.812 W	403.7	9.9	03	8	A
19980107	203148	53	411.0	054 46.974 S	058 28.734 W					
19980107	215040	54	167.3	054 38.922 S	058 34.062 W					
19980107	215543	54	166.0	054 38.874 S	058 33.972 W	149.9	13.5	03	8	A
19980107	221001	54	164.2	054 38.850 S	058 33.930 W					

Table 5.4: JR27 station summary table.

Notes:

(i) Three rows for each station correspond (in order) to start, bottom and end times and positions.

(ii) cordep is corrected Simrad water depth.

(iii) pmax is maximum CTD pressure recorded on station.

(iv) alt is altimeter height off bottom at pmax. abs indicates absent data. For station 2, the altimeter failed during descent; stations 21 and 22 were half depth and so did not get in range of bottom. L indicates 'landed', ie, the CTD frame probably touched the bottom on stations 7 and 30. Two values are given for station 34: the first is the altimeter value, the second the pinger value; the different readings resulted from the nature of the bottom.

(v) Column CTD shows instrument used: 03 = DEEP03, 04 = DEEP04.

(vi) Column No. sal shows the number of salinity samples drawn per station.

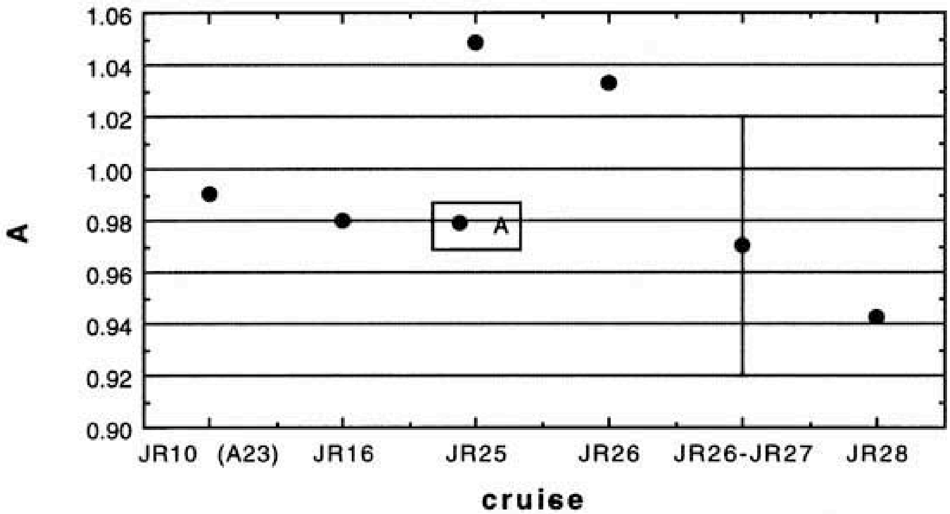
(vii) Column Samp shows S for salinity samples on the station, A for all chemicals sampled; !op on station 30 means no recorded organophosphates.

Station	A	B	Station	A	B
01	0.01530	1.000000	28	0.03000	1.000000
02	0.03100	1.000000	29	0.02990	1.000000
03	0.05460	1.000000	30	0.02200	1.000000
04	0.03200	1.000000	31	-0.13530	1.004531
05	0.21200	0.993509	32	0.00000	1.003379
06	0.05060	1.000000	33	-0.09550	1.005155
07	0.05000	1.000000	34	-0.09710	1.003233
08	0.04000	1.000000	35	-0.09710	1.003233
09	-0.09710	1.003233	36	-0.10700	1.005058
10	-0.09710	1.003233	37	-0.02470	1.002149
11	-0.09710	1.003233	38	-0.11940	1.005609
12	-0.09710	1.003233	39	-0.08830	1.004544
13	-0.09710	1.003233	40	-0.03630	1.003172
14	-0.05680	1.001915	41	-0.14720	1.006282
15	-0.09710	1.003233	42	-0.18330	1.007553
16	-0.09710	1.003233	43	-0.14050	1.006181
17	-0.09710	1.003233	44	-0.12260	1.006095
18	-0.00310	1.000000	45	-0.11030	1.005012
19	0.00000	1.000000	46	-0.05880	1.003272
20	0.00660	1.000000	47	-0.18520	1.008013
21	0.01550	1.000000	48	-0.17500	1.007495
22	0.03200	1.000000	49	-0.13750	1.005938
23	-0.09060	1.003889	50	-0.11530	1.005162
24	0.02080	1.000000	51	-0.08730	1.004232
25	-0.07160	1.003241	52	-0.11680	1.000000
26	-0.04340	1.002554	53	-0.22180	1.005679
27	-0.03830	1.002673	54	-0.10877	1.003456

Table 5.5: CTD conductivity final calibration statistics.

XBT No.	HH:MM	DD:MM:YYYY	Lat	Lon
xbt27002	7:18	19 12 1997	54 57.00 S	58 23.00 W
xbt27003	8:44	19 12 1997	55 10.80 S	58 30.20 W
xbt27004	10:18	19 12 1997	55 24.60 S	58 36.80 W
xbt27005	11:45	19 12 1997	55 38.50 S	58 43.10 W
xbt27006	13:17	19 12 1997	55 53.00 S	58 50.48 W
xbt27007	14:49	19 12 1997	56 13.00 S	58 58.00 W
xbt27008	16:13	19 12 1997	56 29.70 S	59 6.60 W
xbt27009	17:42	19 12 1997	56 48.40 S	59 17.90 W
xbt27010	19:13	19 12 1997	57 6.00 S	59 27.00 W
xbt27011	20:42	19 12 1997	57 24.00 S	59 36.00 W
xbt27012	22:07	19 12 1997	57 42.00 S	59 47.80 W
xbt27013	23:44	19 12 1997	58 2.00 S	59 59.00 W
xbt27014	0:27	20 12 1997	58 11.00 S	60 3.00 W
xbt27015	1:14	20 12 1997	58 21.00 S	60 8.00 W
xbt27016	2:45	20 12 1997	58 41.00 S	60 21.00 W
xbt27017	4:11	20 12 1997	58 58.10 S	60 32.00 W
xbt27018	5:45	20 12 1997	59 18.50 S	60 42.30 W
xbt27019	7:13	20 12 1997	59 37.19 S	60 52.57 W
xbt27020	8:42	20 12 1997	59 55.88 S	61 2.69 W
xbt27021	10:13	20 12 1997	60 15.00 S	61 15.00 W
xbt27022	11:44	20 12 1997	60 35.00 S	61 25.00 W
xbt27023	13:15	20 12 1997	60 52.20 S	61 37.60 W
xbt27024	14:41	20 12 1997	61 10.36 S	61 48.79 W
xbt27025	16:17	20 12 1997	61 30.01 S	61 58.29 W
xbt27026	17:49	20 12 1997	61 49.09 S	62 6.98 W
xbt27027	19:16	20 12 1997	62 0.00 S	62 0.00 W
xbt27028	20:46	20 12 1997	62 31.00 S	62 9.00 W
xbt27030	23:40	01 01 1998	58 55.00 S	55 55.00 W
xbt27031	0:16	02 01 1998	58 57.00 S	56 4.00 W
xbt27032	0:56	02 01 1998	58 59.00 S	56 14.00 W
xbt27033	1:30	02 01 1998	59 3.00 S	56 11.00 W
xbt27034	2:10	02 01 1998	59 8.00 S	56 9.00 W
xbt27035	5:05	02 01 1998	59 19.00 S	56 1.00 W
xbt27036	5:48	02 01 1998	59 16.00 S	55 52.00 W
xbt27037	6:28	02 01 1998	59 15.00 S	55 43.00 W
xbt27038	7:10	02 01 1998	59 14.00 S	55 33.00 W
xbt27045	10:40	02 01 1998	59 0.38 S	55 31.76 W
xbt27046	11:06	02 01 1998	58 57.07 S	55 33.75 W
xbt27047	11:31	02 01 1998	58 55.43 S	55 39.14 W
xbt27048	11:55	02 01 1998	58 53.93 S	55 44.95 W
xbt27049	12:29	02 01 1998	58 54.97 S	55 53.35 W

Table 5.6: XBT launch times and positions.



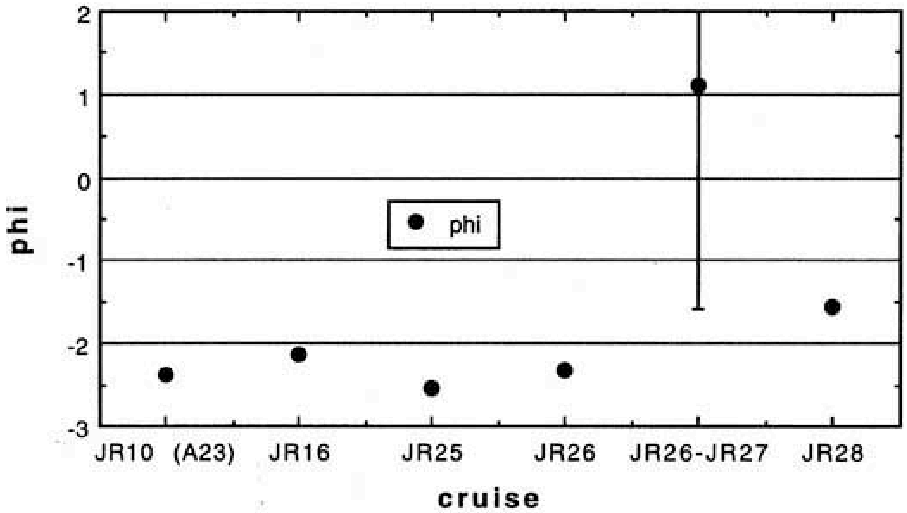


Figure 5.1 (upper): A values for different JCR cruises

Figure 5.2 (lower): ϕ values for different JCR cruises

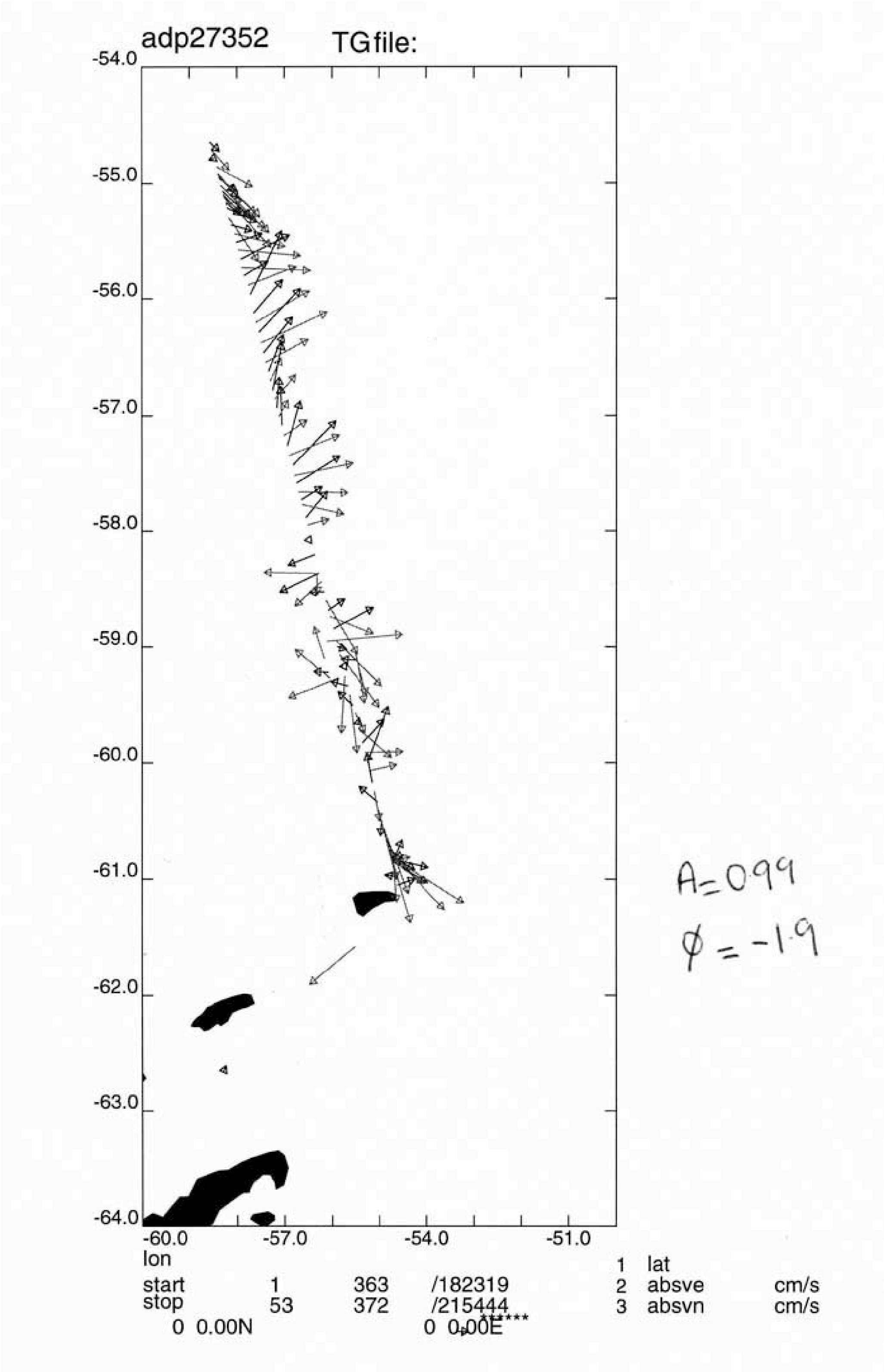
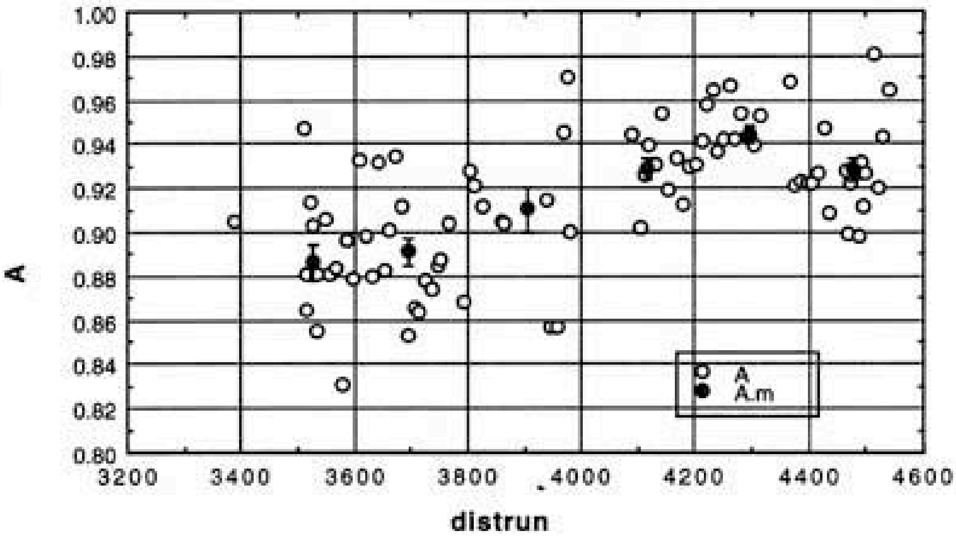


Figure 5.3: JR27 data with interpolated calibration coefficients



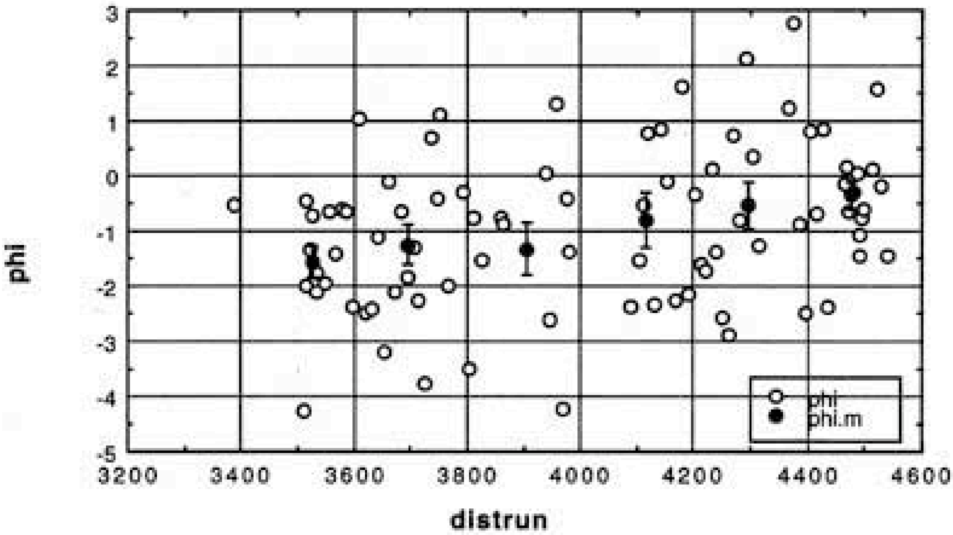


Figure 5.4 (upper): A values for pairs of on-station and off-station data from JR27 (open circles) and for 200 km bins (black dots).

Figure 5.5 (lower): ϕ values for pairs of on-station and off-station data from JR27 (open circles) and for 200 km bins (black dots).

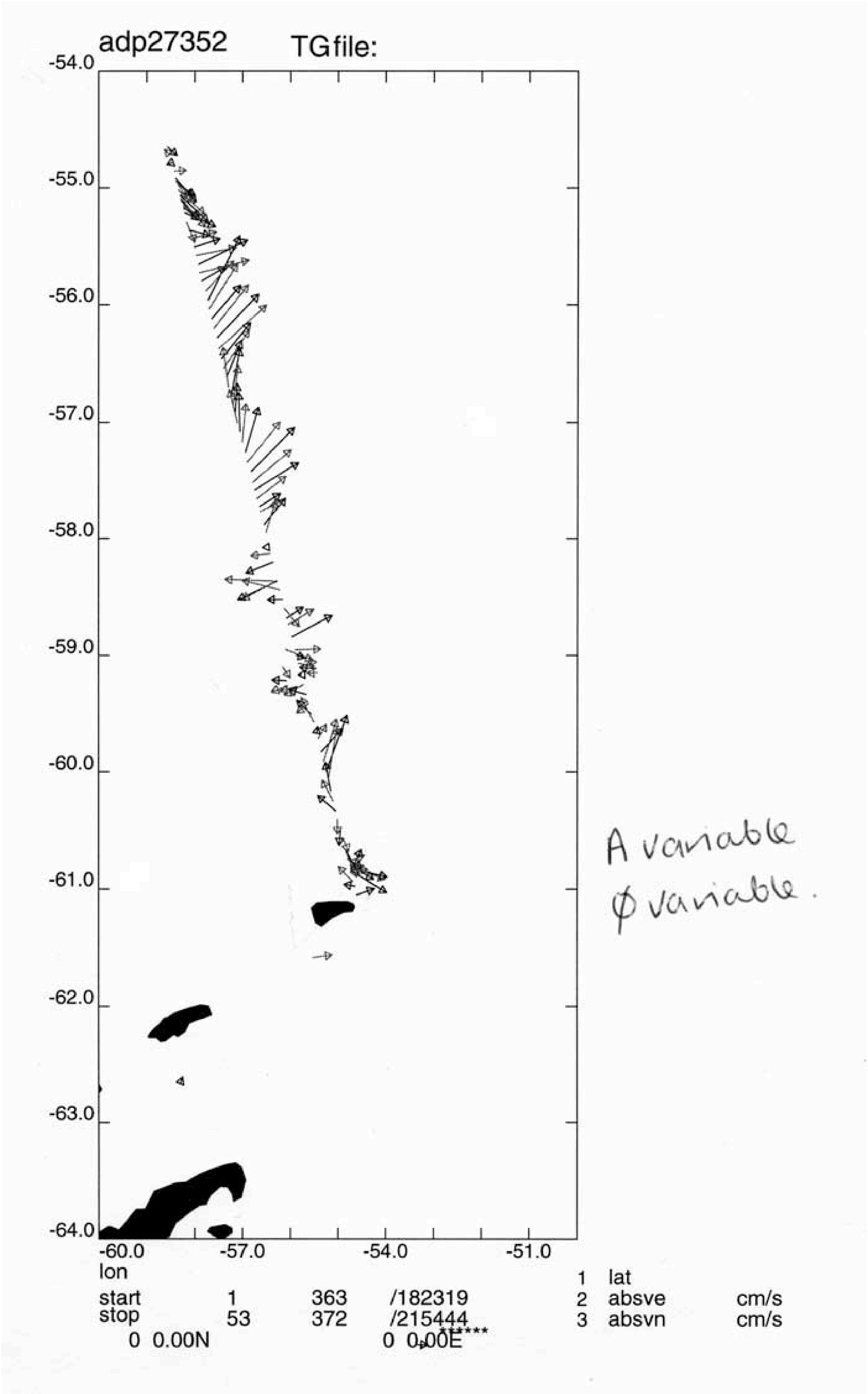


Figure 5.6: JR27 data with variable calibration coefficients

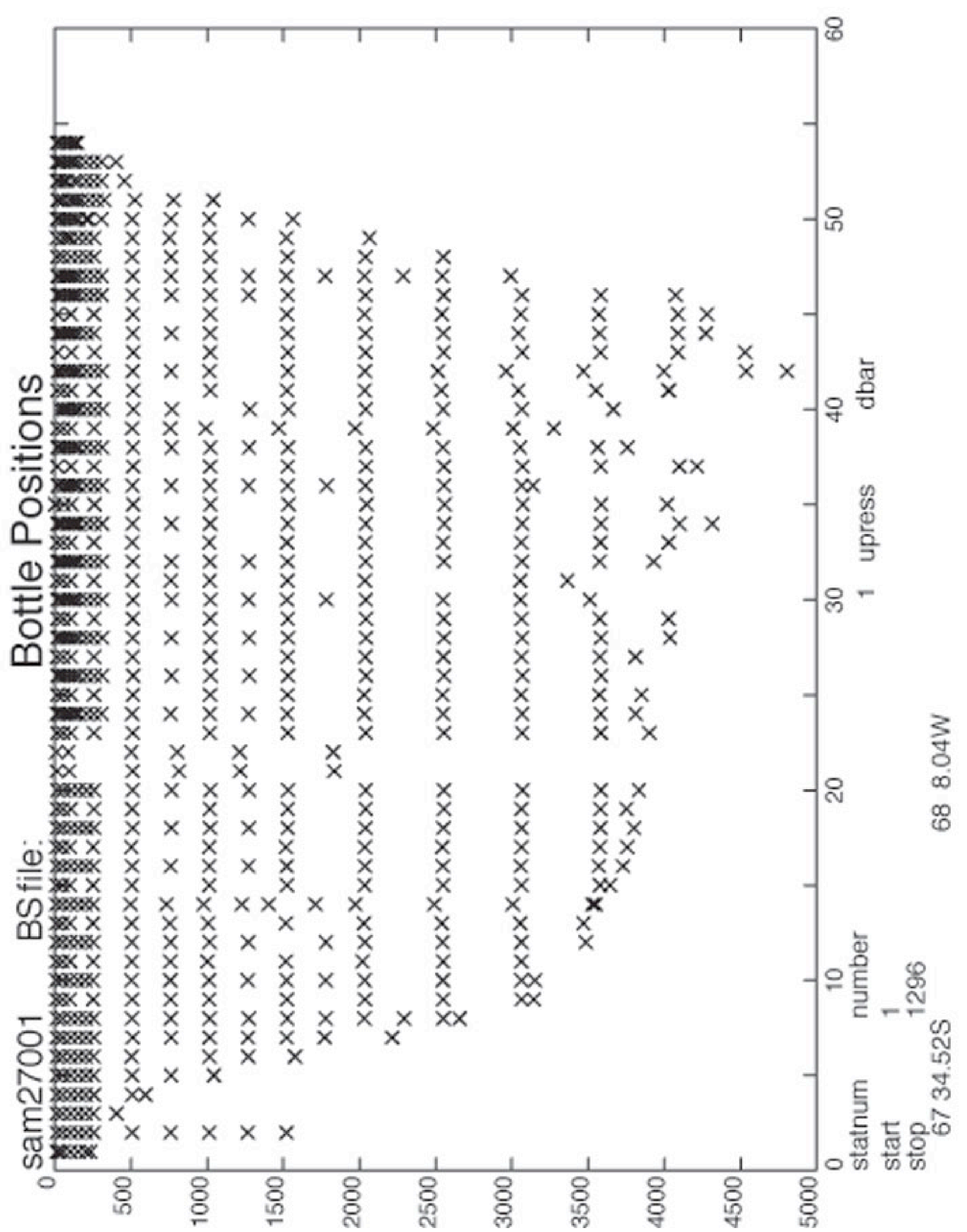


Figure 5.7: JR27 bottle depths versus station number.

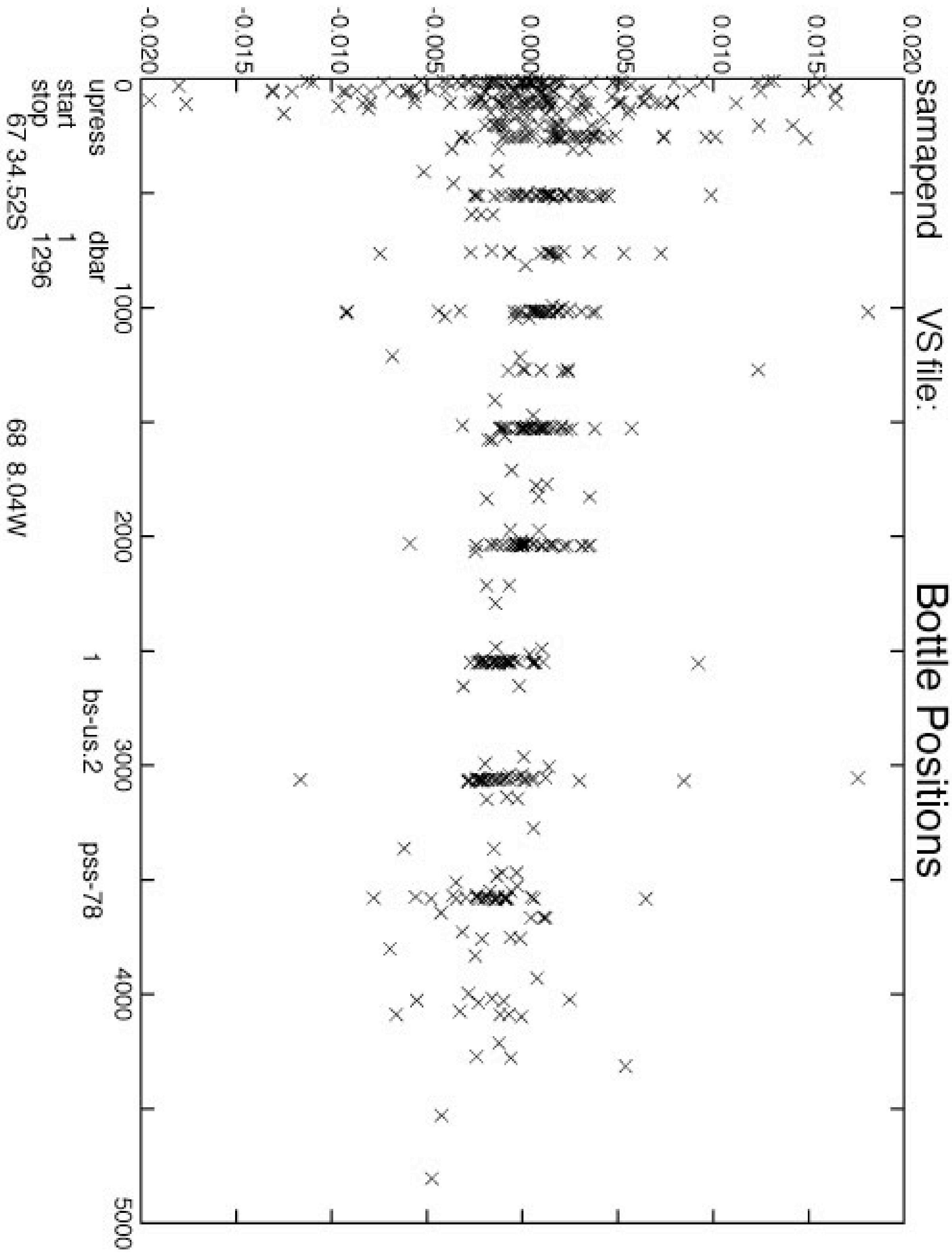


Figure 5.8: Final salinity residuals (bottle minus CTD) for all data.

6 JR47, 13 Jan – 17 Feb 2000, by M A Brandon

6.1 Authors and Affiliations

Author	Affiliation
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6.2 Overview

Occupation of the Drake Passage section on cruise JR47 was during a four day period from 12 February to 16 February at the end of a longer cruise across the Scotia Sea. The station positions for this cruise are different from the "standard" section and there are 30 stations in total. . The hard copy "deck" files for this cruise are stored at the British Antarctic Survey.

6.3 CTD measurements

6.3.1 Summary

Here we describe the method of acquisition and calibration of CTD data on JR47. The system performed excellently throughout. A full station list is given in Table 6.1. For all CTD stations the 2 dbar averages of the downcast data are reported as the final product.

6.3.2 The CTD equipment

The CTD unit used for the measurement program was a Sea-Bird 911 plus (serial number 09P15759-0480). This CTD had three primary sensors, and two secondary sensors. The primary sensors were a series 410K-105 Digiquartz pressure transducer (S/N 067241), a primary SBE 3 plus temperature sensor (S/N 2191) and a primary SBE 4C conductivity sensor (S/N 1913). The SBE 3 plus and SBE 4C were connected to an SBE 5T submersible pump (S/N 051813). The secondary sensors were an SBE 4C conductivity sensor (S/N 1912) and an SBE 3 plus temperature sensor (S/N 2307). The secondary sensors were connected to the CTD through an SBE 5 T submersible pump (S/N 651807). For three stations these sensors were connected to the alternative CTD unit - a Sea-Bird 911 plus (serial number MOD12P-0541) which had a Parascientific Inc. pressure sensor (S/N 75429), primary pump SBE 5T SN 052395 and secondary pump SBE 5T SN 52400. The CTD was connected to package with an SBE 32, 12 position carousel water sampler (S/N 3215759-0173) carrying 12x10 L bottles, a Tritech PA200/20-5 Altimeter S/N 2127.43723 and a 10 KHz pinger to enable accurate near bottom approach. On CTD stations deeper than 4200 m the Altimeter was removed. All calibration details are given below in Table 6.2. Bottle depths per station are shown in figure 6.1.

Deployment of the CTD package was from the midships gantry and A-frame, on a single conductor torque balanced cable. This CTD cable was made by Rochester Cables and was hauled on the 10T traction winch. There were no problems deploying the CTD package as close control was maintained with the jib arm and at least two deck hands whilst the package was suspended above the sea surface. The CTD data were logged via an SBE 11 plus deck unit to a 486 Viglen PC, running version 4.225 of Seasoft Data Acquisition Software (Sea-Bird Electronics Inc.). At the start of a CTD cast the PC clock was reset to the ship time and the SEASAVE module of the Seasoft software was initiated. The SEASAVE module allows real time data acquisition with control of the data acquisition rate. For this cruise the data rate was set to the maximum available of 24 Hz. The SEASAVE module also allowed the setting up of graphs of various properties (T, S etc.) in real time. At the end of cast when the SEASAVE module was exited four files had been created: a binary data file (extension .dat), a configuration file containing calibration information (extension .con), a header file containing sensor information such as serial numbers (extension .hdr), and a file containing the data cycle numbers at which a bottle was closed on the rosette (extension .bl). The data were converted to ASCII engineering units by running the SEASOFT module DATCNV.

Within the DATCNV module the calibration for each sensor was as follows:

Pressure sensor

$$P = C\left(1 - \frac{T_0^2}{T^2}\right)\left(1 - D\left(1 - \frac{T_0^2}{T^2}\right)\right)$$

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

$$D = D_1 + D_2U$$

And U is the temperature in ˚C. T_0 is given by

$$T_0 = T_1 + T_2U + T_3U^2 + T_4U^3 + T_5U^4$$

And C is

$$C = C_1 + C_2U + C_3U^2$$

All other coefficients are given in Table 6.2.

Conductivity sensor

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

The coefficients are given in Table 6.2, $\delta = C_{Tcorr}$, $\varepsilon = C_{Pcorr}$, p is pressure, t is temperature and *f* is the frequency output by the sensor.

Temperature sensor

$$temp(ITS-90)=\frac{1}{g+h\ln(f_0/f)+i\ln^2(f_0/f)+j\ln^3(f_0/f)}-273.15$$

The coefficients are given in Table 6.2 and *f* is the frequency output by the sensor. Finally the SEASOFT module CELLTM was then used to remove the conductivity cell thermal mass effects from the measured conductivity. This correction followed the algorithm

dt = temperature - previous temperature
ctm = (-1.0 * b * previous ctm) + (a * dcdt * dt)
corrected conductivity = c + ctm
a = 2 * alpha / (sample interval * beta + 2)
b = 1 - (2 * a / alpha)
dcdt = 0.1 * (1+ 0.006 * (temperature - 20)
alpha was set = 0.03, beta was set = 7.0.

The resultant file from this processing had an extension .CNV. Finally all files from this processing were transferred to the UNIX system on the ship for further processing.

6.3.3 Salinity Samples

Twelve salinity samples were taken from each of the stations, with reasonably spaced samples from the shallow stations at the ends of the sections. This gave a total of 277 samples, with 6 duplicates. The salinity samples were taken in 200 ml medicine bottles, each bottle being rinsed twice before being filled to just below the neck. The rim of the bottle was then wiped with tissue, a plastic seal inserted and the screw cap replaced. The salinity samples were then placed in the Radio Lab close to a Guildline salinometer 8400B, S/N 63360. This salinometer was purchased from Ocean Scientific International in 1998 and serviced, cleaned and calibrated on 16 June 1999. Salinity samples were analysed two stations at a time using standard seawater (batch P132, 1997). One vial of OSIL standard seawater was run through the salinometer at the beginning and end of each station's samples to enable a calibration offset to be derived and to check the stability of the salinometer. Once analysed the conductivity ratios were entered by hand into a spreadsheet for conversion to salinity, then transferred to the UNIX system and read into a pstar data file following the scheme detailed below.

6.3.4 CTD Data Processing on the PC

In the following notes the term CC refers to the cruise number, and the term NNN refers to the event number. The CTD data is recorded using the Seabird data module ***SEASAVE***. The raw data files created are: **CCctdNNN.dat** (raw data file), **CCctdNNN.con** (configuration file), **CCctdNNN.bl** (bottle information file), **CCctdNNN.hdr** (header information file). The raw data are stored as binary files that must be converted to ASCII data files for further processing with the UNIX CTD scripts. The programs used were:

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

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

These files were saved from the c:\ drive of the CTD PC to the cruise directory on a network drive, with a separate folder for each CTD. They were also ftp'ed to the UNIX system *jruf* and placed in the directory *~/pstar/data/ctd/ascii_files/ctdNNN/** where NNN is the event number of the cast. Once saved the files were deleted from the CTD PC to free up space for further data collection.

6.3.5 Further processing of the CTD data (in UNIX)

6.3.5.1 Salinities

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

6.3.5.2 CTD processing using pstar execs

The execs assumed that the files were tidied up after each one was run. They will check for the files when running and say where the files should be.

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

seactd2 This exec required the salinity data to have been transferred, as described above. The exec produced four files:

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

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

seactd4 This exec used the **CCctdNNN.samp** file to derive the conductivity of the salinity samples. mlist was used to produce a quick and dirty plot of botcond vs deltaC. A plot of bottles over the salinity profile of the CTD was also produced. The output file was: **CCctdNNN.cond** containing the conductivity variable deltaC

ctdoff This program required the file **CCctdNNN.cond** and produced the mean conductivity residual, and the standard deviation. The numbers were written on the plots produced from seactd4 for reference.

On the basis of the results of seactd4 and ctdoff it was decided whether some bottles should be rejected and the conductivity residual recalculated. The .cond file was then moved to directory */samples/cond/**.

seactd5 This exec required the output of ctdoff (the conductivity residual) and added the conductivity offset to the rough version of the ctd file (**CCctdNNN -** the output of seactd0). The salinity was re-derived with this new conductivity giving an output file of **CCctdNNN.cal**

seactd6 This exec (similar to seactd2) uses the updated values of salinity rather than the raw data. At this stage the second conductivity and temperature variables were dropped. The output files were **CCctdNNN.cbottle**, **CCctdNNN.csamp**, **CCsamNNN.cdif** and these were moved to the directories */samples/cbottle/**, */samples/csamp/**, */samples/cdif/** respectively.

ctdoff This was run on the file **CCsamNNN.cdif**, rejecting the same bottles, to check whether the calibration is good. The file **CCctdNNN.cal** was then moved to the directory */cal/**.

seactd7 The downcast was selected from the calibrated file giving output files **CCctdNNN.24hz** and **CCctdNNN.2db**. These were moved to the directories */24hz/** and */2db/** respectively.

Table 6.3 shows the conductivity offsets applied in seactd5 to each CTD station along with the bottles rejected during the process. Final salinity calibration statistics (for bottle minus CTD salinity) were: for 277 points (excluding 11 outliers with difference >0.011), mean difference –0.0003 (sd 0.0020).

6.4 VM-ADCP

6.4.1 Summary

This report describes the method of acquisition of ADCP data on JR47 and the problems encountered. The system was operated in two modes: in water track when water depths were greater than 300 m and bottom track in shallower waters. In general the ADCP worked reasonably and showed the common problems associated with the installation on the RRS *James Clark Ross*. Velocity information generally obtained down to 250 m depth. The only significant problem was on day 039 when the method of logging had to be changed.

6.4.2 The configuration of the ADCP

The RRS *James Clark Ross* is fitted with an RD Instruments 153.6 kHz hull-mounted acoustic Doppler current profiler (ADCP), transducer Serial No.: 361, System Serial Number 471. In contrast to other research ships in the NERC fleet, the orientation of the transducer head is offset by approximately 45E to the fore-aft direction in the hope that the instrument would give a better response in the main direction of motion (i.e fore-aft). Another difference with other British ships is that to protect the transducer from ice, it is mounted in a sea chest that is recessed in the hull. This sea chest is closed to the sea by a 33 mm thick window of Low Density PolyEthylene (LDPE) and the cavity around the transducers filled with a silicone oil. The version of the firmware used by the ADCP was 1707 9009 224 and the version of RDI Data Acquisition Software (DAS) was 2.48 and the software ran on a IBM 386.

In water depths of less than 300 m the ADCP was operated in bottom track mode. Water track mode was used in deeper water. The Bottom track mode was configured through the Direct Command menu of the DAS software. This was done by entering the command FH00004. This means the instrument makes one bottom track ping for every four water tracked pings.

The ADCP recorded data in 2 minute ensembles in 64 x 8 m bins. The 'blank beyond transmit' was set to 4 m, this coupled to the depth of the transducer being approximately 6 m gave the centre of the first bin depth at 14 m. Unlike virtually all the other instruments on the RRS *James Clark Ross*, the ADCP has no Level A application and does not log directly to the Level B. The 2 minutes ensembles of data are fed through a printer buffer directly into the Level C. This means that when there is a problem with the ships Level C system data has to be recovered from the PC files. On Day 039 at 1306 Z this printer buffer broke down thus the only way of recovering data files was to recover the data from PC. This significantly altered the rate of data flow and analysis.

6.4.3 Standard Method of processing

The data, once in the Level C, were read into pstar files of 12 hours length and processed using the pstar data processing software. The processing of the ADCP is complex and involves data from several navigation streams (described in the navigation data report). A schematic of the data processing path for the ADCP data is shown in figure 6.2.

Step 1: Read in the data.

The data were read using our conventions for underway data in 12 hour chunks containing either the period 0000 to 1159 or 1200 to 2359. This was achieved with a Unix script 47adpexec0 which outputs two files, one containing the water track data and one containing the bottom track data. When the ADCP was set to record only water track information the bottom track file contains only engineering data and zero's for the bottom velocity.

Step 2: Correction for temperature around transducers

The bath of silicone oil surrounding the transducer head of the ADCP requires that a correction be made to the ADCP derived water speed data. The standard method of deriving the speed of sound at the transducer head within the DAS software is to use the temperature of the water around the transducer head (this is recorded by the DAS software as "water temperature") and a salinity of 35 psu. Unfortunately the DAS software has no facility for the problem when the temperature of the water reported is not that of water but of another substance such as oil. The oil causes a problem as variation of the speed of sound in the oil is opposite to that in of the variation of the speed of sound in seawater. This can lead to large errors in the derived water velocity. King and Alderson (1994) document the story of how they tried to find out exactly what oil is contained in the sea chest. In short, nobody knows exactly what the oil is and it has received no "topping up" or maintenance since the construction of the RRS *James Clark Ross* in 1990. Following section 2.6.2 of this report, we apply a correction factor based on the variation of the speed of sound with temperature in Dow Corning 710 silicone oil. This correction is then

$$\text{correction} = 1 - 0.004785T * 0.0000355T^2$$

and T is the "water temperature" reported by the DAS software. This correction is applied to both the raw water and bottom tracked velocities using the Unix script 47adpexec0.1.

Step 3: Correction for the PC clock drift

Another problem that has to be accounted for in ADCP processing is that the DAS software time stamps the data. Unfortunately this time stamp comes from the 386 PC clock which drifts at a rate of approximately one second per hour. To correct this to the ships master clock, the time drift was measured several times a day and a correction derived and applied to the ADCP data time using the Unix script 47adpexec1.

Step 4: Correction for the gyrocompass error.

The ADCP actually measures water velocity relative to the ship. To calculate east and north water velocities from the ADCP data, information is required on the ship's heading and velocity over the ground. This is partially fulfilled with input is from the ship's gyrocompass (described in the navigation report). However it is well known that in addition to having an inherent error, gyrocompasses can oscillate for several minutes after a turn before steadying on a new course. As well as that there is an additional deviation that varies as cosec (latitude). To overcome these difficulties the ADCP data is "corrected" with data from the Ashtech GPS3DF. We cannot use the Ashtech as a gyrocompass substitute because we do not have continuous coverage, we can however correct the data on an ensemble by ensemble basis. From the navigation report, after the "standard processing" the Ashtech data edited according standard criteria is a file of 2 minute averages. The data still however contains both gaps, and large spikes. These spikes are removed using an interactive editor, and the gyrocompass correction linearly interpolated. The correction is applied to the ADCP data through the Unix script 47adpexec2.

Step 5: Calibration of the ADCP data

A final correction is now required to correct for the misalignment between direction as defined by the Ashtech GPS3DF antenna array and the actual direction of the ADCP transducers. This correction is called the heading misalignment *N*. There is also an inherent scaling factor, *A*, associated with the ADCP by which the water velocities must be multiplied by to scale them correctly. The method of calculating A and *N* is described below. These corrections are applied through the Unix script 47adpexec3.

Step 6: Derivation of Absolute velocities

By this stage the data contains calibrated water velocity relative to the ship. To derive absolute velocity we merge the files with position from the "bestnav" navigation file (see navigation report for description) and derive ship velocity between ensembles. This velocity is then removed from the water velocity data to give absolute water velocity. This is performed using the Unix script 47adpexec4.

6.4.4 Method of derivation of the calibration coefficients A and N

To derive values for *A* and *N* a standard procedure was followed:

1. Periods where identified when the ADCP gave bottom tracked velocities - that is when the ship was working in water depths of generally less than 300 m. This data set is relatively limited in a cruise such as JR47 where most work is over deep water. There were still over six hours of data available for this analysis.

2. The files with bottom tracking velocities were then calibrated with a nominal scaling in 47adpexec3 by setting the scaling factor *A* to one and the misalignment angle *N* to zero.

3. The two minute ensembles of ADCP data were then merged with bestnav position fixes. From these bestnav fixes the ship's east and north velocity over ground were calculated. Time periods

within each data file were then identified where the ship's heading and velocity did not deviate greatly over a period of at least 6 minutes.

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

5. Values for *A* and *N* for each time period are then derived from vector mathematics using

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

where U_{adcp} is the bottom tracked ADCP derived ship speed and U_{gps} is the GPS position fix derived ship speed (that is ship speed over ground) , and

$$N = N_{gps} - N_{adcp}$$

where N_{gps} is the direction of motion derived from the GPS navigational fixes and N_{adcp} is the direction of motion as derived from the bottom tracked ships motion. This was achieved using a Unix script adcp_calibration_exec.

In the Synoptic Survey we have identified periods suitable for calibration totalling almost 8 hours of data. These data were then inspected carefully to see that the standard deviation of the ship's velocity and heading were small, and periods when the Ashtech data were poor were edited from the file. The data was then culled by stating that we will only use derived values of A and *N* within 2 standard deviations from their respective mean values. The final value used for A was 0.7918 (standard deviation 0.0059), and for *N* -2.319 (standard deviation 0.2). These calibration data give different results from previous years. This is discussed below.

6.4.5 Problems encountered

On day 039 at 13:06:45Z the ADCP stopped logging to the level C system. Extensive tests proved that the ADCP was operating well, and the problem was isolated to the printer buffer between the ADCP and the Level C. This meant that the individual pingdata files had to be transferred from the PC to the Level C manually. This worked well although there was a significant delay to the data analysis.

6.5 Navigation

6.5.1 Summary

There were six navigational instruments for scientific use on the RRS *James Clark Ross* (listed in Table 6.4). Although the six instruments seem in some cases similar, they are all unique. As well as the three GPS systems listed in table one, there are three additional GPS systems on board the JCR for the ship's use. These are a Leica MX400 and two Ashtech G12 receivers. In addition there is a Racal Satcom which receives GPS SV range correction data via INMARSAT B. This data is passed to the Trimble, Leica, and G12 receivers allowing them to operate in Differential mode (DGPS). During JR47 the DGPS reference station at Stanley was used.

The collection and use of all of the navigation data are linked. On this cruise the data for all six instruments and the standard editing procedures were all done in one Unix script called "JR47_nav_go". This script requires the Julian day as an input and then executes a further 8 C shell scripts to read in 12 hours of data, and edit where necessary all six streams. In this short report I briefly describe each instrument and explain the processing that was done.

6.5.2 Trimble 4000

The Trimble 4000 receiver in differential mode was the primary source of positional information for the scientific work. The data were logged at 1 second intervals and read into 12 hour pstar files using the Unix script gpsexec0. Individual steps in this exec are:

gpsexec0:
purpose: To read Trimble data into the pstar format.
The programmes are

datapup - transfers the data from RVS binary files to pstar binary files.

pcopya - resets the raw data flag on the binary file.

pheadr - sets up the header and dataname of the file.

datpik - removes data with a dilution of precision (hdop) greater than 5.

Two files are output from this script. One is just before the editing stage (datpik) and is called 47gps<jday>.raw; the other is after the datpik, this is 47 gps <jday>.

6.5.3 Ashtech GLONASS (GG24)

The *James Clark Ross* is the only British research ship currently installed with a GG24 receiver. The GG24 works by accepting data from both American GPS and the Russian GLONASS satellite clusters. This extends the constellation of available satellites to 48 and should theoretically be significantly more accurate. However, experiments suggested that the accuracy of the system was approximately 15 m.

6.5.4 Ashtech 3DF GPS

The Ashtech 3DF GPS is used to correct errors in the gyrocompass heading that are input to the ADCP. The configuration of the receiver is complex, for JR47 it was configured with the settings in Table 6.5. The coordinates in Table 6.6 are from a survey using the Ashtech software in Grimsby in September 1996. The port-aft antenna is designated number 1, port-fwd is 2, stdb-fwd is 3 and stbd-aft is 4. The XYZ vectors have been adjusted so that heading is defined by the direction normal to the 1-4 baseline (i.e. that baseline has Y = 0). Our complex data processing procedure is designed with using the Ashtech to correct the gyrocompass error in mind. There were three execs involved in the processing; these are ashexec0, ashexec1 and ashexec2.

ashexec0:

purpose: This exec reads in data from the GPS3DF into pstar format

The programmes are

datapup - transfers the data from RVS binary files to pstar binary files.

pcopya - resets the raw data flag on the binary file.

pheadr - sets up the header and dataname of the file.

The output file is in the form 47 ash < jday> .raw

ashexec1:

purpose: This exec merges the Ashtech data to the master gyro file from gyroexec0

The programmes are

pmerg2 - merge the Ashtech file with the master gyro file.

parith - calculate the differences in the Ashtech and gyro headings (delta heading).

prange - force delta heading to lie around zero.

The output file is in the form 47 ash < jday > .mrg

ashexec2:

purpose: This exec is complicated as it edits the merged data file.

The programmes are.

datpik - reject all data outside the following limits

heading outside 0° and 360°

pitch outside -5° to 5°

roll outside -7° to 7°

attf outside -0.5 to 0.5

mrms outside 0.00001 to 0.01

brms outside 0.00001 to 0.1

delta heading outside -5° to 5°

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

pavrge - set the data file to be on a 2 minute time base.

phisto - calculate the pitch limits.

datpik - further selection of bad data outside the following limits

pitch outside the limits created

mrms outside the range 0 - 0.004

pavrge - again set the data file to be on a 2 minute time base.

pmerge - merge back in the heading data from the gyro from the master gyro file.

pcopya - change the order of the variables.

The output files are 47 ash < jday > .edit and 47 ash < jday > .ave. We then followed an elaborate manual editing procedure following the suggestions and written notes of Raymond Pollard (SOC) that are described in the ADCP data processing report.

6.5.5 *Gyrocompass*

The gyrocompass is a fundamental data stream. It is used by the RVS program *bestnav* to derive dead reckoning in the absence of gps data - as well as being used for ADCP processing (ADCP report) and derivation of true wind velocity (ocean logger report). For JR47 the gyrocompass data was read in 12 hour chunks using the Unix exec gyroexec0

gyroexec0:
purpose: This exec reads in the gyrocompass data and removes the inevitable bad data.
The programmes are:

datapup - transfers the data from RVS binary files to pstar binary files.

pcopya - resets the raw data flag on the binary file.

pheadr - sets up the header and dataname of the file.

datpik - forces all data from the gyro to be between 0 and 360°.

The output file is in the form 47 gyr < jday > .raw
The script also appends the day file to a master file called 47 gyr 01.

6.5.6 *Electromagnetic Log*

The electromagnetic log gives the water velocity relative to the ship in a fore-aft direction but was completely unserviceable for JR47.

6.5.7 *Doppler Log*

The Doppler log gives water velocity relative to the ship in both the fore-aft and port starboard direction. There is clearly a problem with this sensor and it will be replaced soon. There were frequent dropouts when the instrument was power cycled by the officer on the bridge. This also meant the Level A unit had to be power cycled. This vector information was read in as 12 hour chunks the using a simple exec dopexec0.

dopexec0: This exec reads in data from the Doppler log into pstar format.

datapup - transfers the data from RVS binary files to pstar binary files.

pcopya - resets the raw data flag on the binary file.

pheadr - sets up the header and data name of the file.

The output file is in the form 47 dop < jday> .raw.

6.5.8 *Daily Navigation Processing*

As stated above the data was read in as twice daily (12 hour) files, the time periods being either from 0000 Z to 1159Z or 1200Z to 2359Z. Our primary navigation data was taken from the RVS file bestnav. This program uses the navigation data from various streams to construct a file with 30 second fixes. For JR47 the primary input to bestnav was the Trimble 4000 DGPS. This navigation file was read into a pstar file using the scrip navexec0.

navexec0: This exec reads in data from the bestnav stream into pstar format.

The programmes are.

datapup - transfers the data from RVS binary files to pstar binary files.

pcopya - resets the raw data flag on the binary file.

pheadr - sets up the header and data name of the file.

posspd - here we calculate the east and north velocities from position and time.

papend - the output file is added to the master file.

pdist - we now recalculate the distance run variable.

pcopya - and take out the RVS calculated distance run.

The output master file was called abnv471 and was used for all pstar required navigation information (i.e ADCP processing etc, true wind derivation etc.).

6.6 Oceanlogger data report

6.6.1 Summary

This report summarises the state of the Oceanlogger data collected on JR47. There were serious problems with some meteorological data streams. In addition there is a problem with the thermosalinograph that should be cured for future seasons.

6.6.2 Introduction

The Oceanlogger system is a PC based logging system that is BAS designed and built (P. Woodroffe, E.T.S.). It emulates the function of several RVS level A interfaces, has an input from the ship's master clock and has real time display of data. This system logs sea surface data gathered from the ship's non-toxic pumped sea water supply and some meteorological data to the RVS ABC system with a ship's master clock time stamp on the data. The instruments with an analogue output are connected to self-contained digitising Rhopoint modules located close to the relevant instrument. The modules are then interrogated by the controlling PC using the RS485 protocol. A full list of the sensors used is given in Table 6.7. During JR47 both the barometer and Vector T351 temperature sensor gave no data.

6.6.3 Calibration and logging

In general, information about instrument calibrations is sketchy and currently difficult to find aboard the JCR, the exception being the thermosalinograph. The last calibration of the Seabird SBE 21 was on 23 July 1998 by Seabird Inc, Seattle, U.S.A. One difficulty with the Oceanlogger system is that the Turner fluorometer and the SBE 21 have very different water requirements from the non-toxic supply. The fluorometer requires a flow of 2-3 litres-per-minute for maximum response. In contrast the SBE 21 requires up to 25-30 litres per minute for maximum response. Flow rate averaged 4.5 litres-per-minute during operation on JR47. This means that there is a fundamental compromise in the system with neither instrument at optimum performance.

For the duration of cruise JR47 the sampling rate was set to 5 seconds (the maximum the present system is capable of) and the data logged to the level B system. Although the anemometer is not strictly part of the Oceanlogger system (having a separate Level A interface), we consider it as such because we merge this stream into the data set at the earliest opportunity.

6.6.4 Routine Processing

The data were read into the UNIX system twice daily in 12 hour sections using a Unix script (JR47_ocean), the two time periods being 0000 to 1159 and 1200 2359. This script also produces a series of five diagnostic plots for the 12 hours of data against time. At this point the data are also split up into five files.

File 1: The raw data. This file contains all 5 second data cycles for the 12 hour period in a completely unedited form. Following standard MLS procedure the filenames are of the form
47ocl<jday><a or p>.raw

File 2: Ocean Data. This file contains the 5 second data for the sea surface streams and has some initial editing described below in the detailed description of the data processing route. The variables in this file are time, sea surface temperature (stream: sstemp), Thermosalinograph temperature (stream: tstemp), conductivity from the Thermosalinograph (stream: cond), flow from the Liter meter (stream: flow), raw fluorescence from the Turner Fluorometer (stream: fluor), and a derived raw salinity value. At this stage the salinity is usually very noisy as will be described below. Filenames were constructed in the form 47ocl<jday><a or p>.

File 3: Averaged data. This file contains 2 minute averages of file 2 with positional information merged in from the differential GPS level A stream. Thus, the file contains the same variables as above with the addition of latitude and longitude. This file was mainly used for rapid plotting of data using geographical coordinates. Filenames were constructed in the form 47ocl<jday><a or p>.2min

File 4: Meteorological data. This file contains the 5 second data for the meteorological parameters recorded by the Oceanlogger for a 24 hour period in a completely unedited form. The variables in the file are time, air temperature (stream: atemp), air pressure (stream: press), the total incident radiation (stream: tir), the photosynthetically active radiation (stream: par), and the wind speed and direction (streams: wind_spd and wind_dir). File names were constructed in the form 47met<jday><a or p>.raw.

File 5: Fluorescence specific data. This stream was constructed specifically to help in the analysis of the fluorescence data. The stream contains time, sea surface temperature, par, tir, flow and three different versions of the fluorescence. One of the fluorescence fields is the raw data, one with a median filter (1 minute window) to the raw data, and one with a 'top hat' filter over five minutes applied to the median filtered data. These data will be described in a subsequent section. Filenames were constructed in the form <jday><a or p>.fl.

6.6.5 Further processing

The meteorological data from file 4 above were combined with gyrocompass data and positional information from the bestnav data stream to derive true wind velocity using a Unix script called *twvelec*. Thus true winds were derived for the whole cruise at a resolution of 5 seconds.

6.6.6 Underway salinity samples

Salinity samples were drawn from the non-toxic supply as it left the thermosalinograph approximately once every six hours. These samples were treated in the exactly the same manner as those taken for the CTD calibration. The 200 ml sample bottle was rinsed twice and the neck of the bottle dried carefully before an air tight plastic seal was inserted and the cap screwed back on. The samples were then stored in the radio lab beside the Guildline Salinometer for at least 24 hours before the conductivity was measured against Ocean Scientific Standard Seawater batch P132. The sample conductivity values were entered into a Macintosh Excel Spreadsheet and transferred to Unix using the script *ocl_samples*. The data were then converted into a standard RVS format time using the script *oclexec3*. In total there were 57 underway salinity samples.

6.6.7 Problems

There were two serious problems in addition to the sensor failures already noted. The first problem is the unexplained lag in response between the temperature sensor and the conductivity cell in the thermosalinograph. The problem was first reported during WOCE leg A23 (JR10) when it was noticed that conductivity from the SBE - 21 lagged the temperature of the housing (tstemp). This of course causes a spike in the derived salinity signal. The A23 scientists overcame this by applying a lag through a filter to the stream tstemp (see section 4.7.1). On previous MLS cruises (CF reports for JR16 and JR17) we tried filters of varying length in time to lag the temperature before settling on a length 48 one-way filter with n = 48 successive coefficients given by $W(1 - W)^{n-1}$. W was found by experiment to reduce the salinity spiking best at a value of 0.03 for this data set. With the 5 second sampling rate the 48 point filter has an effect over 4 minutes. Although a solution this degrades the ability of the instrument to be used to investigate rapid changes in sea surface parameters. For example, at 10 knots - a typical survey speed, the filter smoothes data over distances of 1.2 km.

The second problem concerns the measurement of light (par and tir) which is essential to accurate calibration of underway fluorescence. At present it is clear that shading of the sensors by the foremast at certain times of day and on certain courses causes either massive underestimation or wildly spiked data as the sensor moves in and out of the direct sunlight. This is the most likely source of some of the extreme outliers found during calibration of previous cruises data. Either the sensors must be sited where they cannot be shaded or multiple sensors used with input being logged from the one with the largest reading - or perhaps from all so that this choice can be made during post processing.

Event	Station ID	Date m dd yyyy	Lat (south) deg min	Lon (west) deg min	Cast depth (db)	Water depth (m)
347	DP1	2 12 2000	61 03.05	54 33.10	275	278
348	DP2	2 12 2000	60 54.25	54 39.31	728	728
349	DP3	2 12 2000	60 51.11	54 41.71	942	965
350	DP4	2 12 2000	60 48.99	54 42.60	2237	2054
351	DP5	2 12 2000	60 45.95	54 44.61	3098	2891
352	DP7	2 13 2000	60 26.57	54 57.67	3508	3460
353	DP8	2 13 2000	60 07.70	55 11.07	3493	3445
354	DP9	2 13 2000	59 48.57	55 23.22	3660	3605
355	DP10	2 13 2000	59 29.66	55 35.68	3759	3700
356	DP11	2 13 2000	59 10.68	55 47.99	3745	3680
357	DP12	2 14 2000	58 51.72	56 00.36	3914	3843
358	DP13	2 14 2000	58 32.64	56 12.59	3830	3764
359	DP14	2 14 2000	58 13.80	56 24.50	3817	3750
360	DP15	2 14 2000	57 54.78	56 36.63	4002	3925
361	DP16	2 14 2000	57 35.67	56 48.35	3271	3075
362	DP17	2 15 2000	57 16.82	56 60.00	4184	4066
363	DP18	2 15 2000	56 57.81	57 11.73	3554	3750
364	DP19	2 15 2000	56 38.85	57 23.22	4221	4100
365	DP20	2 15 2000	56 19.75	57 34.73	3435	3352
366	DP21	2 15 2000	56 00.89	57 46.05	3786	3706
367	DP22	2 16 2000	55 42.99	57 57.28	4637	4512
368	DP23	2 16 2000	55 10.86	58 08.52	4253	4139
369	DP24	2 16 2000	55 07.44	58 15.91	3031	2932
370	DP25	2 16 2000	55 07.44	58 17.63	2576	2543
371	DP26	2 16 2000	55 03.92	58 19.63	2002	1989
372	DP27	2 16 2000	54 56.57	58 23.38	1493	1460
373	DP28	2 16 2000	54 56.57	58 23.81	1014	1016
374	DP29	2 16 2000	54 55.62	58 24.40	481	491
375	DP30	2 16 2000	54 39.33	58 33.79	225	226

Table 6.1: CTD stations during Drake Passage section of JR47. Each station was identified by the "event number" (Column 1).

CTD 09P15759-0480: Pressure tested by SBE on 28 June 1999 to 10000 psi.
Pressure Sensor SN 67241
Calibration date 28 June 1999.
Coefficients:
C1 = -44614.18 psia D1 = 0.036455
C2 = 3.038286E-02 psia / degc D2 = 0
C3 = 1.22413E-02 psia /deg c^2
T1 = 29.99608 _S
T2 = -3.512191E-04 _S / degc
T3 = 3.72924E-06 _S / deg c^2
T4 = 4.91876E-09 _S / deg c^3 T5 = 0
AD509M = 1.283280E-02
AD590B = -9.4744912E+00
Slope 0.99999
Offset -0.4942

SBE 3 plus temperature sensor S/N 2191
Calibration date 22 June 1999
g = 4.31952842e-03
h = 6.38524293e-04
i = 2.25683861e-05
j =2.12390152e-06
fo = 1000.000

SBE 4C conductivity sensor S/N 1913
Calibration date on 22 June 1999
g = -4.02324609e+00
h = 5.31347384e-01
i = -5.07365626e-04
j = 5.34311668e-05
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

Secondary Sensors

CTD 09P20391-0541 : Pressure tested by SBE on 28 June 1999 to 10000 psi.
Pressure Sensor SN 75429
Calibration date 13 March 1999.
Coefficients:
C1 = -43988.81 psia D1 = 0.036030
C2 = -0.5551403 psia / degc D2 = 0
C3 = 1.27949e-02 psia /deg c^2
T1 = 29.86716 _S
T2 = -5.274889e-04 _S / degc
T3 = 4.09290E-06_S / deg c^2
T4 = 1.61659E-09 _S / deg c^3 T5 = 0
AD509M = 0.12874155

AD590B = -8.793385903
Slope 1.0
Offset 0.0

SBE 3 plus temperature sensor S/N 2307
Calibration date 22 June 1999
g = 4.33420032e-03
h = 6.44223717e-04
i = 2.34955199e-05
j = 2.24393901e-05
fo = 1000.000

SBE 4C conductivity sensor S/N 1912
Calibration date on 22 June 1999
g = -4.15963737e+00
h = 5.36060167e-01
i = -6.52854797e-04
j = 6.04284482e-05
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

Table 6.2: Calibration constants for the CTD.

Event	Station	Offset	Bottles Rejected in Calibration
347	DP1	0.00279	9
348	DP2	0.00295	11
349	DP3	0.0027	8
350	DP4	0.00121	10,12
351	DP5	0.00078	9,10,11,12
352	DP7	0.00195	12
353	DP8	0.0017	11,12
354	DP9	0.00138	11
355	DP10	0.00167	11,12
356	DP11	0.00287	10,11
357	DP12	0.00284	9,11,12
358	DP13	0.00108	11,12
359	DP14	0.00154	11,12
360	DP15	0.00228	11,12
361	DP16	0.00252	11,12
362	DP17	0.00171	11,12
363	DP18	0.00201	none
364	DP19	0.00198	9,11
365	DP20	0.00359	12
366	DP21	0.0033	10,11,12
367	DP22	0.00308	10,11,12
368	DP23	0.00187	11,12
369	DP24	0.00288	none
370	DP25	0.00228	none
371	DP26	0.00422	12
372	DP27	0.00495	11,12
373	DP28	0.00549	1
374	DP29	0.00453	none
375	DP30	0.00565	none

Table 6.3: Calibration summary for CTD stations on JR47

Instrument	Type	Code	Use
Trimble 4000	GPS receiver	gps	Primary positional information
AshtechGG24	GLONASS / GPS receiver	glo	positional information
Ashtech GPS3DF	GPS receiver	ash	Attitude information
Gyrocompass	Sperry Mk 37 model D	gyr	Heading information
Electromagnetic Log	Chernikeeff log Aquaprobe Mk V	eml	Velocity information
Doppler Log	Sperry SRD 421	dop	Velocity information

Table 6.4: Scientific navigation instruments on the RRS James Clark Ross.

POS	54:17.0S, 35:40,W,+0.0m
Alt known	N
Ranger	0
Unhealthy SV	N
Rec. Intv	20
Min no. Sv	4
Elev mask	10
Pdop mask	40

PORT A (not used)	
nmea	off
real time	off
VTS	off
baud	9600
PORT B (Level A logging)	
nmea	on
real time	off
VTS	off
baud	4800
OPTIONS	PAT ON
	1 s rate

Attitude Control Menu

max rms	8			
search ratio	0.5			
1 s update	Y			
3 Sv search	N			
	TAU	**TO**	**Q**	**R**
Hdg	999	000	1.0e-2	1.0e-2
Pitch	020	000	4.0e-2	1.0e-2
Roll	020	000	4.0e-2	1.0e-2
Kalmann filter reset	N			

Table 6.5: The sub menu settings on the Ashtech 3DF GPS system (menu 4 and sub-menus)

Vector	X(R)	Y(F)	Z(U)
1-2	2.955	4.751	0.0
1-3	11.499	4.754	0.0
1-4	13.227	0.0	0.0
offset	0(H)	0(P)	0(R)
Max cycle	0.2 cyc	smoothing	N
Max mag	0.08	Max angle	10

Table 6.6: Ashtech setup values

Instrument	Type	Location	Field Name
sea temperature	4 wire PRT	Transducer space	sstemp
flow meter	Liter Meter	prep lab	flow
Thermosalinograph	Sea Bird SBE 21 serial No. 214800-0820	prep lab	tstemp and cond
Fluorometer	Turner Systems	prep lab	fluor
Air temperature	vector T351	foremast	atemp
PAR sensor	Kipp & Zonen CM5	foremast	par
TIR sensor	Didcot DRP1	foremast	tir
Barometer	Vaisala PA11	UIC	Press
Anemometer	Guildline Sonic	formast	wnd_speed, wind_dir

Table 6.7: The instruments connected to the Oceanlogger.

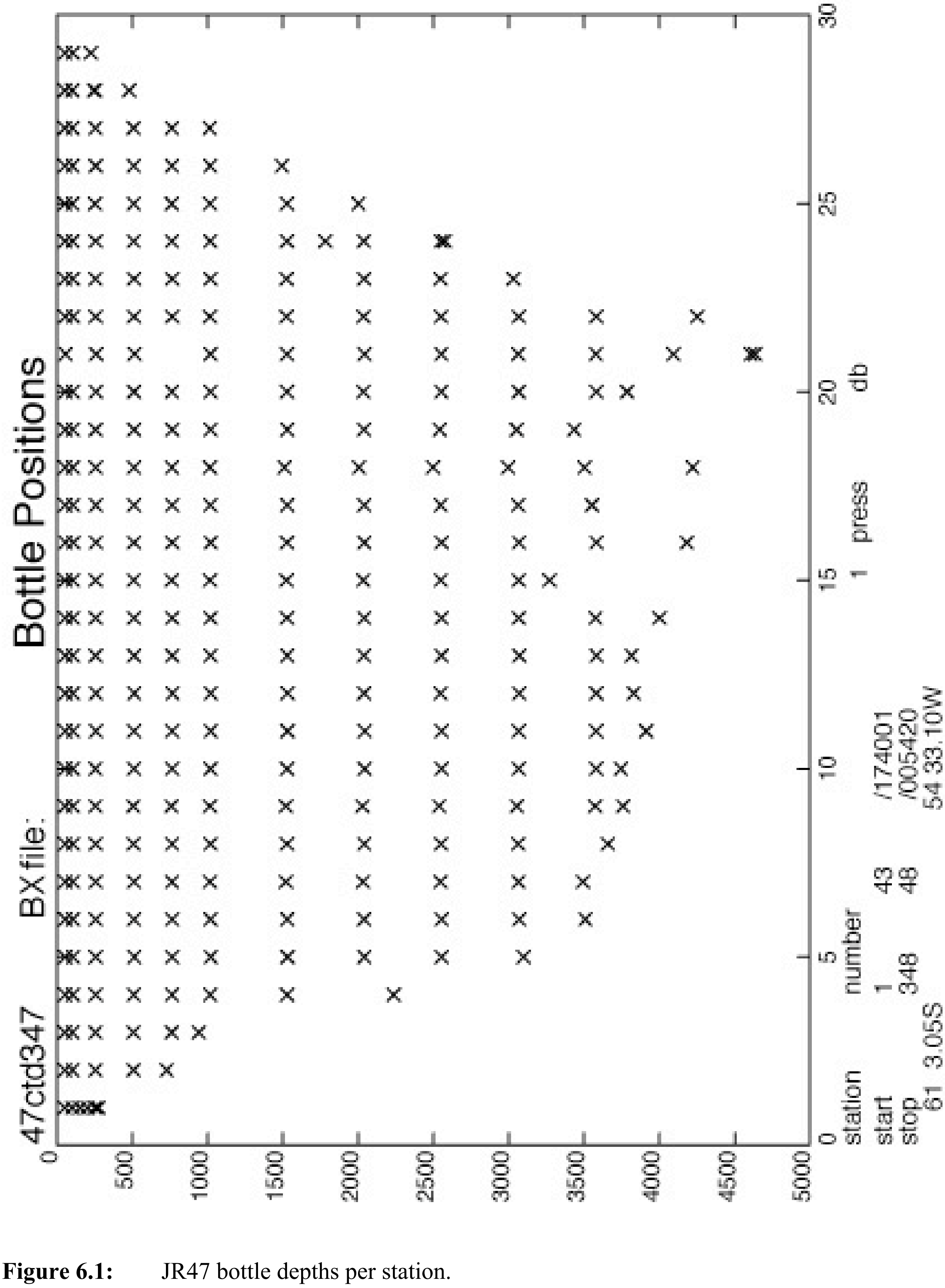

Figure 6.1: JR47 bottle depths per station.

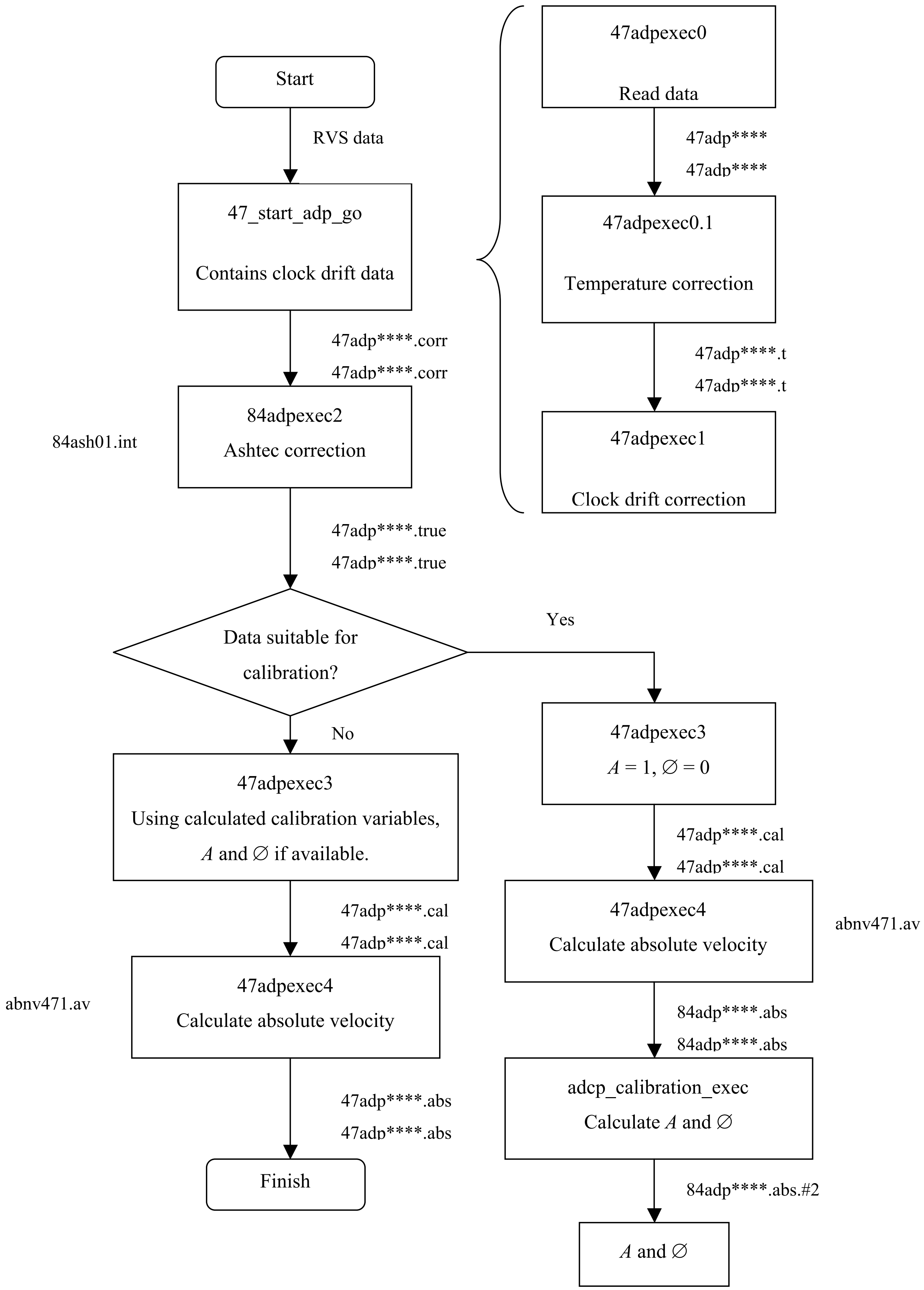

Figure 6.2: ADCP Processing Flow-Chart

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