SOUTHAMPTON OCEANOGRAPHY CENTRE

CRUISE REPORT No. 35

RRS *JAMES CLARK ROSS* CRUISE JR55
21 NOV - 14 DEC 2000

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

Principal Scientist

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2001

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ABSTRACT

This report describes the sixth repeat hydrography section across Drake Passage, first established during the International World Ocean Circulation Experiment. Through continuation of this time series the nature of the interannual variability in the location and properties of the ACC at this choke point between South America and the Antarctic Peninsula can be determined.

Across the 753km section from Burdwood Bank to Elephant Island, thirty one CTD/LADCP stations (including one test station) were made on the southbound journey with a maximum station spacing of 33km. Water samples were drawn for salinity analysis and CTD conductivity calibration. The underway measurements included; Vessel Mounted Acoustic Doppler Current Profiler, measuring currents to depths of 300m beneath the ship, navigation, sea surface temperatures recorded by thermosalinograph, meteorology logged via the oceanlogger system and Simrad echo sounder determining water depths.

CTD station 32 was at the Rothera time series (RaTs) site just off Rothera Pier, carried out primarily for collecting water samples for nutrient analysis back at SOC.

On the northbound crossing of Drake Passage, to the west of the southbound section, an extra two full depth CTD/LADCP stations were made to test CTD DEEP03. XBTs were deployed at two hourly intervals and underway data logged.

This report was compiled by Louise M. Duncan.

KEYWORDS

ANTARCTIC CIRCUMPOLAR CURRENT, ANTARCTIC OCEAN, ACOUSTIC DOPPLER CURRENT PROFILER, CTD OBSERVATIONS, DRAKE PASSAGE, *JAMES CLARK ROSS*, CRUISE 55 2000, LOWERED ADCP, SOUTHERN OCEAN, VESSEL MOUNTED ADCP, WOCE, WORLD OCEAN CIRCULATION EXPERIMENT, XBT

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CONTENTS

SCIENTIFIC AND SHIP'S PERSONNEL

TABLE 1a

Scientific Personnel

Name		Institute
Cunningham	Stuart A.	SOC
Brown	Susan	Univ. of Edinburgh
Cooper	Pat	BAS, ISG
Duncan	Louise M.	SOC
Edwards	Natalie	SOC
King	Brian A.	SOC
Meredith	Mike	BAS
Price	Martin	Univ. of East Anglia
Robst	Jeremy	BAS

TABLE 1b

Ship's Personnel

Name		Rank
Burgan	Jerry	Master
Chapman	Graham	Chief Officer
McCarthy	Justin	2nd Officer
Macleod	Neil	3rd Officer
Anderson	Duncan	Chief Engineer
Smith	Colin	2nd Engineer
Macaskill	Robert	3rd Engineer
Armour	Gerry	4th Engineer
Trevett	Doug	Deck Engineer
Gibson	Hamish	Purser/Catering Officer
Mee	Steve	Radio Officer
Bradbury	Pippa	Doctor
Brookes	Russell	Deck Cadet
Burnett	Dean	Engineer Cadet
Lang	Colin	Bosun
Peck	David	Bosun's Mate
Dale	George	Seaman
Dickson	Keith	Seaman
Chappell	Kelvin	Seaman
Bown	Martin	Seaman
Trussler	Luke	Seaman
Parsley	Richard	Motorman
Allen	Erwin	Motorman
McManamy	Danny	Chief Cook
Macaskill	Tracey	2nd Cook
Jones	Lee	2nd Steward
Hadgraft	Simon	Steward
Wiers	Michael	Steward
Raworth	Graham	Steward

INTRODUCTION AND SCIENTIFIC OBJECTIVES

The Southern Ocean is a major component of the coupled ocean-atmosphere climate system. It connects all the other major oceans and influences the water mass characteristics of the deep water over a large proportion of the world. Hence, the Southern Ocean plays a pivotal role in global ocean circulation, which in turn regulates the global climate.

The major Southern Ocean current, the Antarctic Circumpolar Current (ACC), transports large volumes of water west to east around the world, around 136 million tonnes per second. Measurements of the total amount and detailed structure of the transport in the ACC can provide critical tests of numerical model dynamics, as well as of proposed paradigms of the global ocean circulation, ocean variability and climate change.

Drake Passage is an advantageous location to observe the ACC. At this choke point between South America and the Antarctic Peninsula the meridional spread of the ACC is constrained and transport measurements can be attempted. The Drake Passage section is possibly the most important Southern Ocean choke point section, because of its accessibility, because it is the narrowest, and because it provides the immediate link between the Pacific and Atlantic Oceans.

The International World Ocean Circulation Experiment's primary goal was to provide a one-time survey of the global ocean circulation. To help assess the representativeness of the one time survey, sections of particular significance were identified, to be repeated as often as possible. The Drake Passage is one such section. Since 1993 scientists from the Southampton Oceanography Centre and British Antarctic Survey have completed five hydrographic sections across Drake Passage (Figure 1).

The principal objectives are;

- To determine the interannual variability of the position, structure, transport and other properties of the ACC at Drake Passage. Adding lowered ADCP to the CTD and shipboard ADCP measurements, to increase the inventory of direct current measurements that spans the full depth and width of the ACC at Drake Passage.
- To examine the fronts associated with the Antarctic Circumpolar Current. Their strengths and positions will be determined.
- By comparing geostrophic velocities with those from the lowered ADCP, determine the size of ageostrophic motions, and attempt to estimate barotropic components.
- To examine the temperature and salinity structure of water flowing through Drake Passage.

Using high quality CTD measurements the significant water masses will be identified.

§ To calculate the total flux of water through Drake Passage. By combining CTD, lowered ADCP and shipboard ADCP measurements, to make the best possible estimate of the transport.

Overview

Timetable (Julian Days)

Fri. 17th Nov. (322)

Depart Brize Norton 2245GMT for Mount Pleasant Airfield, Falkland Islands via Wide Awake Airfield, Ascension Island.

Sat 18th Nov. (323)

Arrive MPA at 1730GMT and join ship in Stanley in time for dinner

Sun 19th – Mon 20th (324-325)

Mobilising, the many tasks were divided amongst the scientist, primarily to ready computers, instruments and equipment. Severe problems were encountered with the CTD pylon – many hours of trials failed to make the pylon fire or return bottle fire codes for logging by DAPS. This problem consumed so much time that the important task of preparing data processing paths was entirely neglected.

Tue 21st (326)

RRS *James Clark Ross* (JCR) left the FIPASS berth at 0930 local and moved to the outer harbour. We remained there until mid-afternoon. A safety briefing was conducted and emergency muster and boat drill practiced. The scientific staff appreciated that this necessary briefing and drill took place in the quiet waters of the outer harbour and it afforded us a few valuable hours to continue work on the pylon problem.

Fault diagnosis continued on the pylon and finally, after advice from John Smithers at SOC, the pylon was closing bottles. Fire codes were not being returned but we set up a system to send fake firing codes to be logged by DAPS.

We steamed a direct route to the POL 8 mooring, but while we were in water shallower than 500m ship's speed was kept to 8knots for bottom track ADCP calibration data.

Wed 22nd (327)

Arrived at the POL8 site at 1518. The mooring, a bottom pressure recorder (BPR), was recovered. We then steamed slowly offshore to 2000m water depth for a test CTD station.

Thur 23rd (328)

After the test station we returned to the POL8 mooring site and deployed the replacement BPR and then proceeded to the top of Burdwood Bank to begin the Drake Passage repeat hydrography section.

Stations 002 to 008 were completed.

Fri 24th (329)

Stations 009 to 013 were completed.

Sat 25th (330)

Stations 014 to 018 were completed.

Sun 26th (331)

Stations 019 to 022 were completed. Immediately after station 019 the POL9 BPR mooring was recovered and the refurbished BPR from POL8 redeployed.

Mon 27th (332)

Stations 023 to 027 were completed. After station 025 the POL6 BPR and inverted echo sounder (IES) were recovered.

Tue 28th (333)

Stations 028 to 031 were completed. Station 031 is the last station on the repeat hydrography section. Immediately after station 031 we steamed back to the POL9 mooring site and redeployed the refurbished BPR and IES. We then headed southward down the Antarctic Peninsula towards the main destination Rothera.

Wed 29th – Sat 2nd Dec (334 – 337)

En route to Rothera, we visited Port Lockroy (to disembark two summer staff) and Vernadski base (the old Faraday, to deliver mail). There were many magnificent views down this part of the Peninsula – Gerlache Strait, Neumayer Channel, Lemaire Channel, icebergs and wildlife. We arrived in Rothera Bay, Adelaide Island just after lunch and completed CTD 032, at the Rothera time series (RaTs) site in 300m of water just off Rothera Pier. This station was occupied at the request of Richard Sanders, SOC and the objective was to gather water samples for nutrient analysis. The samples have been frozen and will be returned to SOC for analysis when JCR returns to Grimsby in May 2001.

Only small amounts of sea ice were encountered and almost the entire trip to Rothera was in open water.

Sun 3rd – Tue 5th (338 –340)

The ship discharged cargo and collected the base gash. Scientific staff helped with the awkward break bulk cargo, frozen goods and beer. Good use of the time here was spent catching up on data processing.

Wed 6th - (341)

Depart Rothera at 1300 en route for Stanley. As we travelled northward we visited several scenic and historic sites including Port Lockroy (again), Paradise Bay and Deception Island.

Sat 9th – Sun 10th (344 – 345)

On the northbound crossing of Drake Passage, westward of the southbound section, we deployed XBT's at two hourly intervals and continued logging the various underway data. On Saturday two full depth stations were occupied as trials of CTD DEEP03.

Mon 11th (346)

Berth at FIPASS at 1400 local. Navigation streams end logging and data read into PSTAR. Packing and data archiving occupy the rest of the day.

CTD MEASUREMENTS

Equipment

The following equipment was used on the CTD frame:

Neil Brown MkIIIc CTDs – DEEP03 and DEEP04
Chelsea Instruments Transmissometer - S/N 161/2602/003
Simrad Altimeter 200 m range
10kHz pinger
FSI Rosette Pylon no. 2
12 x GO and FSI 10 litre Niskin bottles
SIS Thermometers S/N's T1684(sd), T1545
SIS Pressure meters S/N's P6571(sd), P6394(sd). Note (sd) indicates that the mean and standard deviation of the averaging interval is reported by these instruments.
New oxygen sensor
Self contained Broadband ADCP's (30° and 20° beams) and battery pack

Data Capture and processing

A total of 34 full depth CTD stations, shown in Figure 1 and Table 2, were completed during JR55: one test station, 31 full depth stations along the SRIb section, one in Margerite Bay at the Rothera time series site and two further deep water test stations on the return journey to Stanley. Salinity samples were drawn on all stations for calibrating the CTD (Figure 2).

TABLE 2

Summary of CTD Stations

Stat num	CTD type	JDAY	hhmmss	Lat deg	min	Lon deg	min	Depth	CTD depth	Pmax dbar	Wireout metres	Ht off metres	depth - (ctd_depth + alt)
001	03	327	222831	-55	03.52	-58	17.84	219.4	1710.4	1733.4	1700	-999.0	-999.0
002	03	328	053910	-54	39.26	-58	33.56	219.4	220.1	222.3	215	13.0	-13.7
003	03	328	081830	-54	55.34	-58	21.70	605.8	598.6	605.1	595	16.2	-9.0
004	03	328	094409	-54	56.62	-58	23.26	1037.7	1037.6	1049.9	1030	15.8	-15.7
005	03	328	114634	-54	57.65	-58	22.09	1550.1	1566.6	1587.1	1555	14.7	-31.2
006	03	328	144421	-55	04.18	-58	17.39	2060.1	2061.5	2090.9	2050	6.2	-7.6
007	03	328	173143	-55	07.27	-58	15.47	2510.4	2507.7	2546.1	2494	6.3	-3.6
008	03	328	203409	-55	10.20	-58	14.03	2945.4	2971.6	3020.3	2959	5.1	-31.3
009	03	328	235510	-55	12.86	-58	13.71	3717.3	3736.1	3804.1	3720	15.5	-34.3
010	03	329	051117	-55	31.42	-57	59.25	4230.6	4217.6	4299.2	4217	8.9	4.1
011	03	329	105349	-55	49.26	-57	52.05	4638.4	4644.1	4738.8	4620	8.1	-13.8
012	03	329	153927	-56	07.74	-57	40.48	3686.1	3692.8	3759.9	3673	8.8	-15.5
013	03	329	203504	-56	27.72	-57	30.89	3572.1	3575.4	3639.5	3555	9.8	-13.1
014	03	330	004226	-56	47.09	-57	18.51	2531.1	2533.7	2573.0	2520	13.1	-15.7
015	03	330	052005	-57	05.46	-57	07.32	4391.8	4387.7	4475.0	4365	11.2	-7.1
016	03	330	101014	-57	25.81	-56	55.73	3966.5	3958.8	4033.7	3940	8.6	-0.9
017	03	330	150328	-57	44.06	-56	40.56	3418.7	3420.9	3481.4	3410	9.9	-12.1
018	03	330	192545	-58	02.98	-56	32.35	4006.6	4002.5	4078.8	3981	11.7	-7.6
019	04	331	024501	-58	22.04	-56	21.11	3814.3	3810.8	3881.9	3788	9.5	-6.0
020	04	331	124728	-58	41.31	-56	09.32	3779.4	3775.6	3845.8	3754	6.3	-2.5

Stat num	CTD type	JDAY	hhmmss	Lat deg	min	Lon deg	min	Depth	CTD depth	Pmax dbar	Wireout metres	Ht off metres	depth - (ctd_depth + alt)
021	03	331	173039	-58	59.85	-55	57.76	3766.8	3766.3	3836.3	3745	5.7	-5.2
022	03	331	221946	-59	19.05	-55	42.68	3720.9	3714.7	3783.4	3695	8.9	-2.7
023	04	332	030226	-59	39.03	-55	31.15	3674.4	3671.4	3739.1	3654	8.7	-5.7
024	04	332	075546	-60	00.27	-55	19.11	3496.8	3490.0	3552.9	3470	9.0	-2.2
025	04	332	122812	-60	20.25	-55	04.64	3434.3	3429.8	3491.2	3409	7.8	-3.3
026	04	332	195056	-60	40.50	-54	48.71	3107.7	3098.6	3151.8	3080	10.1	-1.0
027	04	332	230005	-60	47.98	-54	43.17	2568.9	2590.4	2631.8	2574	8.4	-29.9
028	04	333	011607	-60	50.01	-54	43.37	1693.8	1602.9	1624.9	1595	-999.0	-999.0
029	04	333	025609	-60	50.99	-54	42.70	966.4	1017.9	1030.5	1010	9.1	-60.6
030	04	333	045415	-60	58.89	-54	37.21	581.1	577.7	584.3	570	7.8	-4.4
031	04	333	062527	-61	03.12	-54	36.17	371.6	372.9	377.0	367	8.7	-10.0
032	04	337	162508	-67	34.64	-68	07.83	311.8	320.6	324.2	317	4.7	-13.5
033	03	344	123935	-60	12.54	-61	10.46	-999.0	3936.0	4011.2	3917	9.1	-999.0
034	03	344	180130	-59	55.84	-61	04.20	-999.0	4071.5	4150.5	4050	104.0	-999.0

Raw CTD data were captured and stored to the hard disk of the CTD acquisition PC. These data were also recorded directly from the CTD deck unit onto the SOC DAPS (Data Acquisition and Processing Software) system, running on an Ultra-Sparc SUN workstation. Currently DAPS uses routines based on those in the Research Vessel Services (RVS) level A, B, C system. It includes a one second de-spiking and averaging routine for the raw 25Hz data. The one second averaging procedure for each variable is described below:

§ For each second of data, remove large spikes by comparing each value with the previous value. The spike value for each variable is defined in an Instrument Control Parameters file.
- Calculate the temperature gradient as the last good temperature in the frame minus the first good temperature and divide this by the number of good samples.
- Median despiking
    - Sort the samples in the frame. Take the absolute value of the difference (diff) between the value at the mid-point, and the previous value. Also calculate the mean of these two values.
    - Set the upper and lower limits based on the average value +/- (diff * number of good samples)
    - Calculate mean of all samples within these limits
- Return the one-second mean values

DAPS stores two ASCII files for each cast, one for CTD data and another for bottle firing data. Time is included in the ASCII files as decimal Julian day to one millisecond resolution.

For JR55, a different method was used to send bottle firing data to DAPS. The Smitherware software, on the rosette PC, which sends and receives signals from the pylon failed to send fire confirmation messages to the CTD terminal. As a result, fire confirmation messages had to be typed manually and sent via a laptop to prevent missing firing codes in the DAPS bottle file. This system was used throughout the section. Following comparisons between the CTD package depth and bottle fire times for each cast, variations were found on times when the codes were sent to DAPS. To minimise the effect on bottle/CTD conductivity comparisons, firecode times were corrected to ensure they coincided with periods when the CTD package was stationary. Firing data were also found to be stored incorrectly with two firecodes, one and three, being recorded for each fire. These had to be edited during processing in the fir55nnn.tim files to leave just firecode one.

Nearing the end of JR55, frequent "data time outs" and "frame sync errors" for CTD data logging to DAPS led to data loss for some of the casts in the DAPS ASCII files.

Both CTD instruments DEEP03 and DEEP04 were used during the cruise. DEEP03 was used for stations 1-18, 21, 22, 33 and 34 with DEEP04 used for stations 19, 20 and 23-32. The performance of each CTD is described in the next section. A description of the CTD calibrations applied to each instrument are described below:

Temperature

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

$$T_{68} = 1.00024 \times T_{90} \tag{1}$$

Raw temperatures were scaled according to,

$$T_{raw} = 0.0005 T_{raw} \tag{2}$$

then calibrated using the coefficients provided by Ocean Scientific International (OSI) for DEEP03 (August 2000) and DEEP04 (September 2000),

$$\text{DEEP03: } T = -1.86750 + 0.992088 T_{raw} \tag{3}$$
$$\text{DEEP04: } T = 0.12306 + 0.999249 T_{raw} \tag{4}$$

Due to a lag between the conductivity and temperature sensor measurements the time rate of change of temperature is used to "speed up" the temperature measurements according to,

$$T = T + \tau \partial T / \partial t \tag{5}$$

where the rate of change of temperature is determined over a one second interval (see data capture and processing). Estimates of τ from Cunningham (2000) were used.

$$\text{DEEP03: } \tau = 0.25 \tag{6}$$
$$\text{DEEP04: } \tau = 0.20 \tag{7}$$

Pressure

Raw pressure measurements were first scaled according to,

$$P_{raw} = 0.1P_{raw} \tag{8}$$

and were then calibrated initially using the OSI coefficients for DEEP03 (August 2000) and DEEP04 (September 2000)

$$\text{DEEP03: } P = -39.7 + 1.07439P_{raw} \tag{9}$$
$$\text{DEEP04: } P = -36.9 + 1.07330P_{raw} \tag{10}$$

Following observations of pressure values before and after each cast for DEEP03 and DEEP04 it was evident that a correction was required to set pressure readings to zero. The adjustments made were -1.8 dbar and -7.6 dbar for DEEP03 and DEEP04 respectively, changing the above coefficients to

$$\text{DEEP03: } P = -37.9 + 1.07439P_{raw} \tag{11}$$
$$\text{DEEP04: } P = -29.3 + 1.07330P_{raw} \tag{12}$$

The offset was determined by taking the mean pressure values before entering the water and on deck after each cast and calculating the mean pressure. The mean pressure was used to adjust the pressure offset. No relationship between pressure offset and temperature was revealed.

Salinity

Raw conductivities were scaled according to,

$$C_{raw} = 0.001C_{raw} \tag{13}$$

then calibrated initially with the coefficients provided by OSI for DEEP03 (August 2000) and DEEP04 (September 2000),

$$\text{DEEP03: } C = -0.01851 + 0.94717C_{raw} \tag{14}$$
$$\text{DEEP04: } C = -0.07645 + 0.96242C_{raw} \tag{15}$$

This was followed by the cell material deformation correction

$$C = C \times \left[1 + \alpha \times (T - T_0) + \beta \times (P - P_0)\right] \tag{16}$$

where the coefficients for the cell material are: $\alpha = -6.5E^{-6\circ}C^{-1}$, $\beta = 1.5E^{-8}dbar^{-1}$, $T_0 = 15^{\circ}C$ and $P_0 = 0dbar$.

Further adjustments to the conductivity offset were determined using bottle samples. Bottle samples were obtained from the Niskin bottles mounted on the CTD frame, which were fired at various depths (Figure 2). Each sample had its salinity determined relative to standard seawater by a Guildline 8400A salinometer. Bottle conductivities were calculated using bottle salinity, with CTD pressure and temperature measured at bottle firing times on the upcast for all stations except station 16.

Station 16 suffered much fouling on the upcast so the downcast was used for calibration. The column of water corresponding to the upcast sample for station 16 was found by matching on potential temperature.

Differences between bottle and CTD conductivities were determined and the residuals plotted against pressure, station number and bottle conductivites. The residuals varied significantly station by station so offsets were derived on a station by station basis. These offsets are given in Table 3 and displayed in Figures 3 and 4.

Stations 21, 22 and 34 however required a linear fit which changed the coefficients of DEEP03 to

$$\text{Station 21: } C = -0.72010 + 0.96761 C_{raw} \tag{17}$$

$$\text{Station 22: } C = -0.61127 + 0.96456 C_{raw} \tag{18}$$

$$\text{Station 34: } C = -5.68525 + 1.09593 C_{raw} \tag{19}$$

Using the modified coefficients in Table 3 the conductivity residuals were recalculated. Final results show mean conductivity residuals all within 0.005 – -0.015 mmho/cm for DEEP03 and DEEP04 (Figure 3). Over all stations and for residuals within 0±0.01 mmho/cm (324/335 data points) the mean = 0.0001 mmho/cm with sd = 0.0013 mmho/cm. After the conductivity calibration, CTD salinity was recalculated. The salinity residuals (bottle salinity - CTD salinity) showed no pressure or station dependence and it was decided that salinity needed no further correction (Figure 5). The 1hz files were edited using the PEXEC programme *plxyed* to remove spikes and loops in the temperature and salinity profiles. To create the 1hz and 2db CTD data files a mixture of upcasts and downcasts were used, indicated in Table 3.

TABLE 3

Conductivity Offsets

Cast Number	CTD	Cast Used	Conductivity offset
001	03	D	0.0050
002	03	D	-0.0010
003	03	D	-0.0017
004	03	D	-0.0033
005	03	D	-0.0049
006	03	D	-0.0058
007	03	D	-0.0097
008	03	D	-0.0099
009	03	D	-0.0104
010	03	D	-0.0104
011	03	D	-0.0110
012	03	D	-0.0111
013	03	D	-0.0115
014	03	D	-0.0120
015	03	D	-0.0114
016	03	D	-0.0121
017	03	U	-0.0133
018	03	U	-0.0143
019	04	U	0.0003
020	04	U	-0.0059
021	03	U	0.0000
022	03	U	0.0000
023	04	D	-0.0077
024	04	D	-0.0078
025	04	D	-0.0080
026	04	D	-0.0088
027	04	D	-0.0098
028	04	D	-0.0096
029	04	D	-0.0087
030	04	D	-0.0077
031	04	D	-0.0087
032	04	D	-0.0051
033	04	D	-0.0111
034	04	D	0.0000

Transmittance and Altimetry

Transmittance was converted to voltages (20 or 21); this is a calibration of the voltage digitiser in the CTD. The altimeter had calibration (22 or 23) applied,

$$\text{DEEP03: } V = -5.027 + 1.534\times10^{-4}V_{raw} - 3.704\times10^{-10}V_{raw}^{2} \qquad (20)$$
$$\text{DEEP04: } V = -5.656 + 1.72669\times10^{-4}V_{raw} - 2.24\times10^{-12}V_{raw}^{2} \qquad (21)$$
$$\text{DEEP03: } alt = -249.7 + 7.62\times10^{-3}alt_{raw} - 1.04\times10^{-10}alt_{raw}^{2} \qquad (22)$$
$$\text{DEEP04: } alt = -234.5 + 7.16\times10^{-3}alt_{raw} - 9.48\times10^{-11}alt_{raw}^{2} \qquad (23)$$

CTD problems

Stations 001 to 018 were completed using DEEP03 (conductivity cell S/N L53). Bottle - CTD conductivities (Table 3, Figure 3, the first coefficient on the right hand side of equ. 14) have a large systematic station by station drift, such that the CTD is reading higher conductivities on subsequent stations. On stations 016 to 018 upcast salinities were higher than on downcast and the downcast T/S had a different shape to the upcast T/S, with the upcast T/S being more closely related to the shape of stations 013 to 015 and data from earlier occupations of this section. This behaviour seemed to be related to jumps to higher conductivities at the start of the upcast, and with hindsight it appears that the large station to station drift in conductivity offset was related to a failing conductivity cell. The net conductivity drift is of the order 0.02 mmho/cm over these 18 stations. This is poor compared to past experience. For example during D230 (Bacon (1998)) conductivity was stable over groups of up to 35 full depth stations, and changes in conductivity offset were step like between station groups. Millard Jr. and Yang (1993) quote an expected stability of these conductivity sensors on the order of 0.01 mmho/cm per month.

Stations 019 and 020 were completed using DEEP04. For both stations the upcast was saltier and had a different T/S shape relative to the downcast. However, the upcast shape seemed more consistent with previous stations and with historical data.

Stations 021 and 022 were completed using DEEP03 with a new conductivity cell (conductivity cell S/N Q47). Both stations showed a large drift to fresher salinities throughout the casts, possibly related to the new cell.

Stations 023 to 032 were completed using DEEP04. Behaviour on stations 019 and 020 now seems to have settled so that down and upcasts have the same T/S shape.

Stations 033 and 032 were completed using DEEP03 with conductivity cells S/N Q47 and S/N G149. Again profiles had large salinity drifts to fresher salinities. Unfortunately, no further time was available to explore these problems.

Reversing temperature instruments (see section later) also suggest a 5m°C temperature discrepancy between DEEP03 and DEEP04: DEEP03 measures warm relative to DEEP04. Post cruise calibrations should reveal the accuracy of the reversing instrument analysis.

Reversing pressure and temperature

Four reversing instruments were used throughout the cruise, T1545 and P6571 on bottle one and T1684 and P6394 on bottle five. All except P6394 reported the standard deviation of the average value. The reversing instruments worked reliably, and only a few rogue comparisons to CTD values were recorded, and these could be identified as the reversing frame tripping on deployment of the CTD package.

Temperature or pressure differences are calculated as reversing instruments minus CTD upcast value. CTD DEEP04 was only used south of the ACC and never sampled temperatures warmer than 2°C, so we restrict our comparison of the temperature residuals to these cold temperatures.

TABLE 4a

Temperature differences – (T1684-CTDup)

CTD	T range °C	Mean	sd	n
03	<0.5	0.0074	0.0017	15/18
04	<0.5	0.0017	0.0001	6/11

TABLE 4b

Temperature residuals – (T1545-CTDup)

CTD	T range °C	Mean	sd	n
03	$0.5<T<2.0$	0.0057	0.0016	8/9
04	$0.5<T<2.0$	0.0007	0.0018	6/9

The difference in the means of the temperature differences (03-04) is -0.0057°C for T1684 and -0.005°C for T1545. Both CTD's measure temperature cold compared with the two reversing instruments and DEEP03 measures 0.005°C warm compared with DEEP04. Although there are only a handful of differences, the standard deviations of the temperature differences are small and the difference of the means is large compared with the standard deviations, so that the comparison is significant.

We conclude that, despite satisfactory pre-cruise CTD temperature calibrations, there is during the cruise a large and significant difference in the temperatures reported by DEEP03 and DEEP04. Only a post-cruise calibration will reveal which of the instruments has changed from its pre-cruise calibration.

The pressure difference for both reversing pressure instruments versus both CTD's is linearly related to the reversing pressure. We fitted a linear least squares fit of the pressure difference to the reversing pressure,

$$\Delta P = mP_{rev} + C \tag{24}$$

where ΔP is the reversing pressure minus CTD pressure, m is the slope, C is the offset and P_{rev} is the reversing pressure.

TABLE 5

Coefficients of a linear least squares regression between pressure difference and pressure from (24).

Reversing Instrument	CTD	C	m	R^2
P6571-Pup	03	-0.9	-0.003053	0.99
	04	-2.2	-0.00316	0.99
P6394-Pup	03	-5.5	0.001758	0.74
	04	-6.0	0.001616	0.70

For P6571 the pressure difference between DEEP03 and DEEP04 at zero dbars is 1.3 dbar and the difference at 5000 dbar is 1.8 dbar, so that over the range of pressures experienced on this cruise both CTD's give the same pressure. For the second reversing pressure instrument P6394, the differences have the opposite sign of slope to P6571, confirming that this slope characteristic is due to the reversing pressure instrument and not the CTD's. At zero dbars the pressure difference between DEEP03 and DEEP04 is 0.5 dbar and at 5000 dbar it is 1.3 dbar.

These results suggest that both CTD pressure sensors were stable and accurate throughout the cruise.

Post Cruise CTD calibrations

Post cruise calibrations for DEEP03 and DEEP04 were completed by OSI in April 2001. For temperature,

$$DEEP03: T = -1.8472 + 0.992186 T_{raw} \tag{25}$$
$$DEEP04: T = 0.12019 + 0.99930 T_{raw} \tag{26}$$

For DEEP03 the temperature offset at zero counts has changed (pre-post) by -0.0203°C. This is a very large shift in the calibration and is consistent in sign with the difference DEEP03 - DEEP04 noted from the analysis of reversing temperature instruments (assuming DEEP04 measures temperature accurately). For DEEP04 the change in offset at zero raw counts is 0.0029°C which is typical for this instrument between calibrations: if this drift is linear in time between pre and post cruise calibrations then at the time of the cruise DEEP04 may have been measuring warm by 0.001°C. Considering that this correction is within the accuracy we are trying to achieve and we have no independent information on how the drift actually occurs then no post cruise correction for DEEP04 is required. There are no significant changes in slope calibration for either instrument. The difference in temperatures measured by DEEP03 and DEEP04 is consistent with a DEEP03 drift as confirmed by the post cruise calibrations. Therefore, DEEP03 temperature data should be offset by +0.006°C. Salinity is calibrated to bottles and does not require adjustment for this temperature offset. Variables that are a function of in situ temperature will be recalculated.

The post cruise pressure calibrations were consistent with the pre cruise calibrations to better than 0.5dbar at full scale pressure and no post cruise calibration is required.

Louise Duncan and Stuart Cunningham

SALINITY

Sampling

Salinity samples were taken from each CTD Niskin bottle using 200ml glass bottles, closed with disposable plastic inserts and screw-on caps. Each bottle and cap was rinsed three times with sample water to remove any traces of old sample and any salt crystals from the neck of the bottle. The bottle was then filled to the base of the neck, the top and neck wiped dry with a clean tissue and then sealed with the plastic insert. Thermosalinograph samples were drawn once every four hours from the thermosalinograph outflow (TSG), for calibration of the TSG salinity measurements. Samples were left in the micro radio laboratory for at least 24 hours before being analysed. This allowed the sample temperature to equilibrate with the salinometer room temperature and avoid any undue cooling of the salinometer water bath.

Analysis

All analyses were carried out using a Guildline Autosal model 8400A fitted with an OSI peristaltic sample intake pump. The salinometer was situated in the micro radio laboratory, which is not temperature controlled, but has satisfactory temperature stability. The temperature of the laboratory was monitored using a thermometer adjacent to the salinometer, and a constant temperature was maintained at about 20º C. The salinometer water-bath temperature was set to 21ºC and the salinometer heaters cycled effectively under these conditions. During the analysis of the last four samples from station 27 and the first of station 28 the air-conditioning was switched off as part of the ship's maintenance. The room heated up slightly and the salinometer heating element cycled less frequently. As soon as the change was noticed, the engineers were called and the situation was rectified before continuing the analysis of station 28. There were seven analysts; Cunningham, King, Edwards, Price, Meredith, Brown and Duncan.

Standardisation

The conductivity of the salinity samples was measured relative to IAPSO standard seawater. Three different batches of standard seawater were used; 11, P136 standards; 10, P138 standards and 17, 35N1 standards. The last two batches were in the new foil cap bottles with a K15 value of 0.99994 and the P136 batch in the traditional ampoules with a K15 value of 0.99996. Standards were run at the beginning and end of each crate of 24 samples.

Details of the Guildline ratio corrections are shown in Table 6. P136 has been separated into two sets, one with and one without the rogue values. All batches achieve an accuracy within the WOCE standard of 0.001.

TABLE 6

Guildline Ratio Corrections

	35NI	P138	P136 (with outliers)	P136 (without outliers)
Labelled Guildline Ratio	1.99988	1.99988	1.99992	1.99992
Range of Guildline Ratio Corrections	0 to -5e-5	-5e5 to -8e-5	2.5e-4 to 0.40e-4	0.7e-4 to -0.4e-4
Mean Guildline Ratio	1.9998512	1.9998200	2.0001307	1.9999178
Standard Deviation	1.69124e-5	1.24721e-5	6.77567e-4	3.38296e-5

Fifteen duplicate samples were taken, where two bottles were fired at the same depth, however no systematic duplicates were drawn. These duplicated results have a mean difference of 0.0004 and a standard deviation of 0.0023. One sample was out of range so the equivalent values for the 14, in range, duplicates are -0.0002 and 0.0011. Replicates were drawn from the next deepest bottle when a bottle failed to fire. Seven replicates were taken in total with a mean difference of 0.0115 and standard deviation of 0.0302. Again one sample was out of range and the equivalent values for the remaining six samples are 0.0001 and 0.0005.

Natalie Edwards, Louise Duncan, Susan Brown and Martin Price

LOWERED ACOUSTIC DOPPLER CURRENT PROFILER (LADCP) MEASUREMENTS

Instrument Setup

JR55 was equipped with two SOC LADCPs, from RD Instruments (RDI), referred to here as instruments L01 and L02. L01, the older 20 degree instrument, has always been reliable, while L02, a newer 30 degree instrument, has frequently been troublesome. Each instrument is a 150kHz Broadband self contained ADCP.

The system is presently configured to run from lead-acid batteries in a separate pressure case. The batteries, which were charged between stations, are nominally 4 x 12 volts giving 48V. Battery voltage was checked before and after each station. It turned out that the regime during this cruise, roughly two hours steaming and three hour stations, gave insufficient charging time. The battery voltage gradually dropped off such that one station was lost when the battery charge was insufficient for the station.

As usual on SOC cruises, the ADCP's were configured to have 10 x 16 m bins, with one water track and one bottom track ping in a two second ensemble.

LADCP performance

The section started with L02, which was installed in the frame in Stanley. The instrument was thought to be in good working order following several visits back to RDI. However, on no station did the backscatter amplitude decay with range from instrument in the manner expected. The backscatter amplitude variable became flat at approximately bin 2 or 3, instead of decaying through all bins, as would be expected and has always been the case with L01. Since the data initially seemed satisfactory on shallow stations, it was decided to persevere with L02. As stations deepened, the data quality in deep water, estimated from agreement between up/down cast shear, deteriorated. It was concluded that L02 was defective, probably with the same defect that has been seen on some previous cruises. The diagnostics suggest the problem is the same as occurred on JR40 ALBATROSS. The instrument will require investigation and repair on return to the UK. Until the problem is understood and fixed, it is suggested that the instrument should not be taken to sea again. Since other recent cruises have reported satisfactory data from L02, it may be that it is subject to repeated failure of the same component(s). In that case, the reason for the failure(s) should be identified. Apart from station 13, L02 was replaced by L01 after station 10 and used for the remainder of the cruise.

L01 suffered a problem not experienced by SOC before. The up/down switch became stuck in the 'upward looking' position. Unfortunately, this switch has no software override when configuring the instrument. Checks on the up/down setting is not part of normal pre-cast checks, and the problem was not noticed until processing the data from station 11. Since the instrument was set to 'upward', flow towards the instrument was interpreted with the wrong sign. Accordingly the University of Hawaii (UH) software (scan and load) was unable to determine start, bottom and end of a cast properly. In order to allow data processing to continue, scan and load were modified to reverse the values of U,V and W. The remainder of the UH software could then be used to check data quality and to display (possibly incorrect) velocity profiles. At this stage, the full implications of the up/down error on heading, pitch and roll were unknown. Since L02 was unserviceable, there was not time to investigate L01 off the frame until the end of the section.

Table 7 provides a summary of the LADCP casts.

TABLE 7

JR55 LADCP deployments.

L01 is 20 degree ADCP; L02 is 30 degree ADCP. Battery pack 1 (B01) was used for stations 1 to 16.

Station	ADCP	Battery, and voltage noted after cast	Deployment number (RY)	Comment
1	02	01 – 47.0	5	Test station; no valid bottom tracking data; did not approach bottom.
2	02	01 – 47.0	6	
3	02	01 – 47.6	7	
4	02	01 – 47.0	8	
5	02	01 – 47.0	9	
6	02	01 – 46.7	10	
7	02	01 – 46.7	11	
8	02	01 – 46.7	12	
9	02	01 – 46.4	13	
10	02	01 – 46.4	14	
11	01	01 – 46.4	3	
12	01	01 – 46.4	4	
13	02	01 – 45.7	16,17	Baud rate problem after cast; station successfully recovered; full cast in deployment #16. #15 looks like test data after station 10; #17 looks like a cold start on deck, just before data 'recovery' procedure. Low battery voltage.
14	01	01 – 46.4	5	

Station	ADCP	Battery, and voltage noted after cast	Deployment number (RY)	Comment
15	01	01 – 46.4	6	
16	01	01 – 46.4	multiple	Rubbish; memory erased after cast, battery changed.
17	01	02 – 48.2	1	
18	01	02 – 49.1	5	
19	01	02 – 48.2 02 – 47.6	6 7	First attempt aborted at 100 metres due to propulsion problem, second actual cast used, but designated as cast 01 for convenience in data processing.
20	01	02 – 47.3	8	
21	01	02 – 47.3	9	
22	01	02 – 47.0	10	
23	01	02 – 46.7	11	
24	01	02 – 46.7	12	Battery running low; swapped after cast as a precaution.
25	01	01 – 48.2	13,14,15	Concern about cold starts; battery swapped as a precaution; station pieced together from 3 files. Bulk of station was in #15.
26	01	02 – 47.3	16	
27	01	02 – 47.0	17	
28	01	02 – 46.7	18	
29	01	02 – 46.7	19	
30	01	02 – 47.0	20	
31	01	02 – 47.3	21	
32	–	–	–	Marguerite Bay; no ADCP on frame
33	01	02 – 47.9	1	Memory erased before cast
34	01	02 – 47.6	2	

After station 13, which had a cold start, there was a communication problem. BBTALK would not talk to the L02. BBSC would do so, and it was found that the instrument was stuck in 9600 baud. BBTALK was reconfigured to that speed, and used to set the instrument's baud rate back to 38400. Presumably the baud rate reset was associated with the cold start. Data were then downloaded satisfactorily.

On station 16 data were lost due to low battery charge. L01 performed multiple cold starts during the cast creating many meaningless deployment files, several were corrupt and would not download. Battery pack 2 (B02) was swapped in for stations 17 to 24. As the charge on B02 dwindled, B01, now fully charged, was swapped back in. However, two cold starts on station 25 gave cause for concern about a possible defect, and B02, which had now had several hours further charge, was once again swapped in and remained in for the rest of the cruise. However, no defect on B01 was detected. The voltage data from station 25 were examined and found to be satisfactory. No reason was found for the cold starts.

At the end of the cruise, B01 was left on board JCR for use with TUBA on the next cruise. The pressure case was left with one vent plug (2 O-rings) and one blank for each connector.

Data processing

Data were processed using the UH software suite, newly downloaded to SOC in October 2000. No special difficulties were found with the UH software, which was mounted on jruf. Matlab 5.3.1 and perl 5.005_03 were used.

Investigation and solution of L01 up/down problem

L01 and L02 were extensively investigated while alongside at Rothera. Instruments were suspended upside down from an eye bolt in the water bottle annex, in order to make observations while facing upwards. First, the behaviour of L02 to tilt and heading changes were determined as follows:

L02, facing down, sensed as down, viewed from above

beam 3 is forwards (y+)
beam 4 is backwards (y-)
beam 2 is right (x+)

beam 1 is left (x-)

tilt towards 4, so beam 3 higher than 4, gives pitch > 0
tilt towards 2, so beam 1 higher than 2, gives roll > 0
heading increases when ADCP rotated clockwise.

L02, facing up, sensed as up, viewed from above

beam 3 is forwards (y+)
beam 4 is backwards (y-)
beam 1 is right (x+)
beam 2 is left (x-)

tilt towards 3, so beam 3 higher than 4, gives pitch > 0
tilt towards 2, so beam 2 higher than 1, gives roll > 0
heading increases when ADCP rotated clockwise.

L01, facing down, sensed as up, viewed from above (ie as configured in frame)

beam 3 is forwards (y+)
beam 4 is backwards (y-)
beam 2 is right (x+)
beam 1 is left (x-)

tilt towards 4, so beam 3 higher than 4, gives pitch > 0 (CORRECT)
tilt towards 2, so beam 1 higher than 2, gives roll < 0 (INCORRECT)
heading decreases when ADCP rotated clockwise (INCORRECT)

ADCP L01 reports heading as heading x -1. ie +20 degrees reported as 340 (= -20). It would seem that the heading sensor determines the line of magnetic north through the compass, but then misinterprets this because it thinks it is upward looking.

L01, facing up, sensed as up

exactly as for L02.

Error in RDI Manual

In-depth investigation was particularly necessary since there is a contradiction in Appendix F of the RDI manual packed with the equipment. Section F-4.1 discusses coordinate systems. Page F-6 has an illustration (Figure F-3) and a table showing when pitch and roll would be positive for up and down looking instruments in terms of whether beams 3 or 4 and 1 or 2 are higher. This table agrees with our observations for L02. The text on page F7 in paragraph '*pitch*' contradicts both the table and our observations.

Data fix

Since the heading and roll were wrongly determined, no simple data fix was possible. The vertical speed was wrongly mapped into horizontal components. Therefore it was necessary to convert the reported U,V,W,E in earth coordinates back to Doppler shifts and then recalculate U,V,W,E in earth coordinates after correcting roll and heading. The equations given in the RDI manual were used. For the backwards procedure, 'upward' settings were chosen, since those would have been used by the instrument. For the forwards procedure, 'downward' settings were used. No firm information was available about the appropriate 'case' of pitch/roll mounting. However, it was assumed that case 1 (pitch and roll measures fixed to the instrument) was appropriate. Furthermore, upon applying the backwards-forwards procedure, the choice of case was investigated and found to cause insignificant differences. The backwards-forwards procedure results in slight loss of data for high tilt. There was a slant range correction by which bins of range-along-beam were mapped to reported depth bins. At high tilt the mapping was not one to one on all beams, so it was impossible to recover some of the original Dopplers. When roll has been modified, the missing Doppler causes a bin of missing data. Similarly, a bad velocity bin can propagate into adjacent bins. However, this problem was not severe.

Before the data could be fixed, it was necessary to unpack the RDI binary .000 files. This was done according to the format in the manual. L01 has a frame of 397 bytes, while L02 has a frame of 420 bytes. In fact, the manual could account for 385 bytes, but we were nevertheless able to identify the critical bytes containing pitch, roll, heading, 4 x 10 water track speeds and 4 bottom track speeds.

In order to be sure that the corrections to the water speeds were coded correctly, the calculations were performed on a test ensemble by two different people using two different programming languages. When agreement was reached, we were confident that all sign and logic errors had been eliminated.

The data fix was conducted in three stages, using two FORTRAN programs prepared by Brian King (BAK).

- First, the .000 file was scanned (using program scan000), with all data read in (unit 1) and written out (unit 2) unchanged. As the data passed through the program, Pitch, Roll, Heading (PRH) and speed data were written to an ASCII file (unit 7).

- Next, a program fix20d was run. This read data from unit 7, one complete ensemble at a time, and performed the data fix, back to raw Dopplers, change heading and roll, and forwards to U,V,W and error in earth coordinates. Then write to unit 8 in the identical ASCII format.

- Finally, scan000 was run again. The data were again read from unit 1 and written to unit 2. This time however, the PRH and speeds were read from 8 instead of written to 7. Other bytes of the ensemble were copied from unit 1 to unit 2 unchanged, and did not need to be unpacked. Two further fixes were made: the up/down bit (in byte 25) was altered to signify ‘down’, and the checksum (bytes 396, 397) was corrected for the new data. If the checksum is not fixed, BBLIST will not work, although the UH software will.

Thus new .000 files were made, which were, we believe, equivalent to what would have been recorded if the up/down switch were operating correctly. The original .000 files were changed to have suffix ‘raw’. The new .000 files were then processed normally.

Hardware fix

An attempt was made to fix the switch problem in the hardware. The board with the up/down switch was located and removed from the ADCP. The up/down switch is a small cylinder, roughly 10mm high on the transducer controller board, marked MT1. This component was rattled, flicked and generally mistreated in an attempt to free the ‘stuck’ nature of the switch, which we believed to be mechanical inside. No sense could be made of attempts to measure across the contacts of the switch, since we could not be sure whether it should be open or closed for downward looking. A spare board was found in the spares kit, with an apparently identical switch. However, the board was significantly different in layout of components etc. This incompatibility was presumed to be a result of upgrades over the lifetime of the SOC ADCPs. No sense could be made of the open/closed nature of the switch contacts on this board either. Eventually, the ADCP was reassembled. We noticed in passing that one of the blue metal rods which secure the circuit board racks to the base of the assembly had a loose screw. This could only be tightened by detaching the entire assembly from the transducer head, which was duly done. This is a very tiresome task since several screw heads are awkward to access. In this regard the design is poor. The whole assembly was put back together with plenty of threadlock.

When preparing to seal the instrument endcaps, it was noticed that the silicone grease in the o-ring grooves had become quite hard and difficult to clean out properly. It can hardly therefore have been contributing to a good seal. Furthermore, BAK was overgenerous with fresh silicone grease when filling the grooves. As a result, it was impossible to fit the pressure case over the piston seal at the transducer end. The fit was too tight, and it was impossible to draw the pressure case onto the transducer endcap even with the retaining bolts. The pressure case was removed, and damage noted to the o-ring (due to squeezing) which was discarded. The grooves were cleaned and a new o-ring fitted with less silicone grease. No difficulty was experienced the second time. Having noted the hardening of the silicone, we suggest that in future an alternative lubricant be identified and used.

The result of our efforts was disappointing. At first, the switch was still stuck 'up'. Later the instrument was put horizontal and raised upright and correctly reported 'down', the first time it had done so all trip. By the time it was returned to the frame for stations 33 and 34 it was reporting 'up' again.

Conclusion

1) The data from L01 have been repaired, and correct PRH and bottom track and water track data can be read from the 000 files.

2) L01 is the primary instrument. The spares situation for L01 should be reviewed and a full set of spares for L01 obtained.

3) L01 has an intermittent fault in the up/down switch which needs to be resolved.

4) L02 is presently unserviceable. After repair, trials time is needed to demonstrate its performance before it can be considered a reliable instrument for a cruise.

Brian King and Natalie Edwards

VESSEL MOUNTED ADCP (VMADCP) MEASUREMENTS

Instrument setup

The VMADCP on the RRS *James Clark Ross* is an RD Instruments 153.6 kHz unit sited in a sea chest. This is recessed in the hull to offer protection from ice, and is closed to the sea by a 33 mm thick window of Low Density PolyEthylene (LDPE). Prior to the 2000/2001 Antarctic field season a swath bathymetry system was fitted to the ship. During this time, the VMADCP transducers were temporarily removed, and the fluid in the sea chest was changed from silicone oil to a mixture of 90% deionised water and 10% ethylene glycol.

For JR55, the VMADCP was configured to record data in 64 x 8m bins. Data were recorded in ensembles of 2 minute duration. The 'blank beyond transmit' was set to 4 m, this coupled to the depth of the transducer, being approximately 6 m, gave the centre depth of the first bin at 14 m. The VMADCP system used version 17.07 firmware and version 2.48 RDI Data Acquisition Software (DAS) run on a Viglen IBM-type 286 PC. The two minute ensembles of data were passed via the printer buffer directly to the Level C.

During JR55, data were collected in two modes. Water track mode was used where the water depth was sufficiently great to preclude useful bottom tracking, typically depths greater than 500 m. Bottom track mode was used otherwise (generally over Burdwood Bank and the Antarctic Peninsula shelf; Table 8), and was configured through the Direct Command menu of the DAS software. The command FH0004 sets the instrument to make one bottom track ping for every four water tracked pings. On some previous cruises (e.g. JR27), the command FF00020 was also used; this alters the sea floor detection capability of the instrument, thereby changing the amount of bottom track data available for calibration purposes. However, on JR55 the default setting of FF00040 was found to give good bottom tracking.

TABLE 8

Periods of VMADCP bottom tracking during JR55

DOY start	Time hhmm	DOY end	Time hhmm	Location
325	2206	327	0543	Falkland shelf
327	0932	328	1201	Burdwood Bank
333	0730	344	0212	Antarctic Peninsula shelf
345	2355	-999	-999	Burdwood Bank

Data processing

a) Read data into PSTAR

A UNIX script (*55adpexec0*) was used to read the data from the RVS Level C into the PSTAR processing software. Data were processed in 12 hourly chunks. Two files are written as the output of this script, one containing the water track data and the other the bottom track data.

b) Temperature correction

The VMADCP DAS software assumes that the fluid surrounding the transducers is ambient seawater and derives a speed of sound from the temperature measured at the transducer head and an assumed salinity of 35. However, a correction to sound speed is required to account for the different speed of sound for the 90% deionised water and 10% ethylene glycol mixture compared to seawater.

From measurements of the variation in sound speed versus temperature obtained from RDI, we derived the following equation for the speed of sound through the mixture as a function of temperature,

$$c = 1484 + 3.6095 \times T - 0.0352 \times T^2 \qquad (27)$$

where the individual velocity measurements from which this equation was derived were quoted to an accuracy of 0.01%, with the environmental conditions being known to within ± 35 kPa pressure and ± 0.5ºC temperature.

This equation was used to derive a correction term to adjust the speed of sound assumed by the DAS to one appropriate for the mixture in the sea chest. The correction term was:-

$$\left(1484 + 3.6095\,T - 0.0352\,T^{2}\right)\Big/\left(1449.2 + 4.6T - 0.055\,T^{2} + 0.00029\,T^{3}\right) \qquad (28)$$

This correction is applied to both the raw water and bottom tracked velocities using the UNIX script *55adpexec0.1*. A further correction for temperature is applied in this script, due to the temperature-dependency of the velocity scaling correction A (see later)

c) Clock correction

Since the VMADCP data stream is time stamped by the PC running the DAS software (rather than the ship's master clock, as most data streams are), there is a timing error associated with the raw data. The drift of the PC clock from the master clock is of the order of one second per hour. Accordingly, the time difference was measured several times a day and a correction applied to the data using the UNIX script *55adpexec1*.

d) Gyrocompass error correction

To calculate true velocities from the VMADCP, information on the ship's heading is required. The ship's gyrocompass provides near-continuous measurements of heading, however it has an inherent error, and can oscillate for several minutes after a turn. Accordingly, we correct the gyro heading using data from the Ashtech ADU-2 (see navigation report). The Ashtech system does not provide continuous data, and hence cannot provide a direct correction, but it does allow a correction to be applied on an ensemble by ensemble basis. The two minute averaged Ashtech-minus-gyro heading correction ("a-ghdg") is manually despiked and interpolated before use. The script *55adpexec2* applies the correction to the data.

e) Calibration

Two corrections to the VMADCP data are now required. The first is to compensate for the misalignment of the Ashtech antenna array relative to the VMADCP transducers (ϕ), and the second is an inherent scaling factor associated with the VMADCP velocities (A).

Initially, bottom tracked velocities were calibrated with a nominal scaling of $A = 1$ and $\phi = 0$, using the UNIX script *55adpexec3*. For calibration, the time stamps of the VMADCP data were then shifted by 60 seconds, so as to represent the end of each two minute ensemble rather than the midpoint. The VMADCP data were then merged with a smoothed version of the GPS navigation, and 20-minute average absolute speeds and headings from the satellite fixes were derived. Similarly, speeds and headings were derived from the bottom-tracked VMADCP data, and data outside the range 400-740 cm/s were excluded from the calibration procedure. A and ϕ were then calculated as:-

$$A = U_{\mathrm{gps}} / U_{\mathrm{VMADCP}} \tag{29}$$

$$\phi = \phi_{\mathrm{gps}} - \phi_{VMADCP} \tag{30}$$

where U_{gps} and U_{VMADCP} are the 20 minute averaged speeds from the GPS and bottom-tracked VMADCP respectively, and ϕ_{gps} and ϕ_{VMADCP} are the 20 minute averaged headings from the GPS and bottom-tracked VMADCP respectively.

The direction of ϕ was reversed to bring it into the correct orientation, and it was put in the range $-180^{\circ} < \phi < 180^{\circ}$. It was apparent that there was a residual dependence of A on temperature. From these calculations, and with outliers excluded, we derived

$$A = 1.0269(1 - 0.00152T) \text{ and } \phi = -1.55^{\circ} \tag{31}$$

This temperature dependency is likely to be an artefact of imperfectly known speed of sound through the fluid in the sea chest. Accordingly, a factor of $(1 - 0.00152T)$ was included in the script *55adpexec0.1*, with $A = 1.0269$ in this calibration.

A second calibration was performed by comparing water tracked VMADCP data from periods when the ship was steaming between stations and maintaining attitude on station. Periods of manoeuvring were manually excluded from the comparison. The values of A and ϕ determined in this manner showed a broader scatter than those determined from the bottom tracked data, but showed consistent mean values. In addition, the same dependency of A on transducer temperature was found, indicating that it is a real feature and hence needs to be included.

f) Absolute velocities

The data were reprocessed from raw with the new values for A and ϕ plus the temperature correction. Accordingly, calibrated water velocity relative to the ship was obtained. Ship's velocities between ensembles were then derived by merging in and processing the RVS bestnav navigation data. Absolute water velocities are then derived by removing the ship's velocities from the VMADCP data. This is performed using the UNIX script *55adpexec4*.

Problems

On two occasions (JDAY 341, 13:13 and JDAY 343, 19:56), the VMADCP data stopped being transferred to the RVS Level C. The cause of these interruptions to the data stream are not known. They were cleared by rebooting the VMADCP data logging PC, and restarting the relevant RVS data processes. On one further occasion (JDAY 344, 20:04), the VMADCP logging PC reported a disk full error. This was cleared by removing some of the "ping data" files from the harddrive.

Summary

The VMADCP performed well on JR55, and substantially better than it had been observed to perform prior to the refitting of the *James Clark Ross* in the summer of 2000. This is probably due in part to the favourable sea state experienced for the majority of the cruise. In water track mode, the instrument almost allows collected data to a depth in excess of 300 m (Figure 6a). In bottom track mode, good bottom tracked data were obtained in depths regularly exceeding 500 m (Figure 6b). The temperature of the 90% deionised water and 10% ethylene glycol mixture in the sea chest did not approach freezing at any point during the cruise; its minimum temperature never dropped below 2ºC, even during extended periods when the oceanlogger surface temperature was colder than 0ºC (Figure 6c).

Mike Meredith and Brian King

NAVIGATION

Data from three of the six scientific navigational instruments on RRS *James Clark Ross* were routinely used during JR55. These were the Trimble 4000 GPS receiver, used for primary positional information; the Ashtec ADU-2 GPS receiver, for attitude information; and the Sperry Mk 37 Model D Gyrocompass, which provided heading information. In addition, a Racal Satcom received GPS SV range correction data via INMARSAT B: this was passed to the Trimble and other GPS receivers to allow them to operate in differential mode. The navigation data were processed twice daily using a series of UNIX scripts. Each of these takes as input the Julian day, and whether the *am* or *pm* data is to be processed.

Trimble 4000

The Trimble 4000 in differential mode was the primary source of positional information on JR55. The data were processed using the UNIX script *gpsexec0*. This initially calls *datapup* to transfer the data from the RVS Scientific Computer System (SCS) data stream to PSTAR binary files. It then executes *pcopya*, which resets the raw data flag, and *pheadr*, which sets up the PSTAR dataname and header. Finally a *datpik* command was performed to remove data with a dilution of precision (hdop) greater than five. The two, twice daily output files, 55gps[jday].raw and 55gps[jday], were written before and after the *datpik* stage respectively. The processed data were then appended to a master file called 55gps01.

Gyrocompass

The data stream from the gyrocompass constitutes the most continuous information available on ship's heading. It was involved in processing data from meteorological instrumentation (so as to derive information on true wind velocity), and in processing the Acoustic Doppler Current Profiler (ADCP) data. It was also drawn into the bestnav stream (see below) to derive positional information by dead reckoning during periods of no GPS data coverage. Twice daily processing was performed using the UNIX script *gyroexec0*. This used *datapup*, *pcopya* and *pheadr* in a similar manner to *gpsexec0* to retrieve the information from the RVS data stream and set the header information; followed by *datpik* to force all the heading data to lie between 0 and 360 degrees. The output file was called 55gyr[jday].raw. The data were then appended to a master file called 55gyr01. On JR55, it was noted that the RVS SCS was providing gyro data with numerous duplicate time stamps. To correct for this, a PSTAR program (*pcopym)* was written and called from *gyroexec0* to exclude such data from the processed data stream.

Ashtec ADU-2

The ship's gyrocompass is subject to an inherent error and can oscillate for several minutes after a turn. Consequently, the Ashtec ADU-2 was used to correct errors in the gyrocompass heading prior to input of the data to the ADCP processing. The data were processed using the four UNIX scripts *ashexec0*, *ashexec1*, *ashexec2*, and *ashedit.exec*.

Ashexec0 used *datapup*, *pcopya* and *pheadr* to read in data from the RVS data stream, reset the raw data flag and set the header information. The output filename was 55ash[jday].raw. *Ashexec1* used *pmerge* to merge in data from the master gyro file (see below), followed by *parith* and *prange* to calculate the difference between the gyro and Ashtec heading, and force it to lie in the range +/- 180 degrees. The output file was 55ash[jday].mrg.

Ashexec2 edited the merged data file, using the following PSTAR programmes:

- *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
  - heading difference ("a-ghdg") outside -5° to 5°
- *pmdian* - remove outliers in a-ghdg of greater than 1° from a 5 point mean.
- *pavrge* - set the data file to 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 - reset the data file to a 2 minute time base.
pmerge - remerge in the heading data from the master gyro file.
pcopya - change the order of the variables.

The output files were 55ash[jday].edit and 55ash[jday].ave.

Finally, *ashedit.exec* was used to manually remove obvious outliers from a-ghdg and interpolate any gaps in the data, producing the output file 55ash[jday].ave.dspk.

Bestnav

Bestnav is a processed data stream, which contains 30 second interval position data. It uses the best available data source: GPS when available, dead reckoning from the ship's gyrocompass and speed otherwise. On JR55, the script *navexec0* was used to read 12 hours of data at a time, and append them to a master file called abnv551. Initially, the script ran *datapup*, *pcopya* and *pheadr* to retrieve the data and set its header information. The east and north velocities were then calculated using *posspd*, after which *papend* was used to append the data to the master file. Distance run was calculated using *pdist* and *pcopya* removed the RVS calculated distance variable.

Addendum: Notes on Ashtech data and corrections to gyro data

On JR55, it was noticed that the time stamping of the Ashtech data stream was delayed relative to that of the gyro data stream. Consequently, the difference in heading contained a component that was correlated with both the input streams, essentially adding a high-frequency component of variability to a-ghdg. Trials to minimise the standard deviation of a-ghdg by adjusting the time stamping of the Ashtech data identified a mean lag of around 0.9s. While the impact of this error is likely to be insignificant once averaging to two minutes is performed, it was nonetheless deemed to be unnecessary. The source of the error was not unambiguously identified, consequently it was removed by shifting the times of the Ashtech data forward by 0.9s.

With the installation of the *James Clark Ross's* swath bathymetry system in the summer of 2000, a new navigational data stream became available. The Seatex system draws in gyrocompass and Ashtech data, and processes them in a more sophisticated manner than the derivation of a-ghdg outlined above. Consequently, it was hoped that navigational data from the Seatex system could be used to circumvent the need for the laborious manual processing of Ashtech and gyro data, and to generate a heading or heading correction more reliable than that available. A section of navigation data from the Seatex system was thus examined. The data featured a low noise level, but the difference between Ashtech and gyro heading was observed to be unstable. Essentially, the Seatex navigation heading tracked the Ashtech heading very well for periods, but then drifted towards the gyro heading (and back) for no apparent reason. Further investigation revealed that the Seatex was drawing its Ashtech data not from the ADU-2 antennae, but from its own two dedicated antennae. The data supplied to the Seatex from these antennae are clearly not as reliable as the ADU-2 data in terms of temporal coverage. It is suspected that the siting of the two antennae may be responsible, with satellite fixes often being masked by the ship's mast. If these antennae can be better sited in terms of satellite accessibility, it would certainly benefit the Seapath swath bathymetry, and could potentially be of great benefit to the processing of the ship's ADCP data.

Mike Meredith, Brian King, Martin Price

UNDERWAY MEASUREMENTS

Meteorology

During cruise JR55 continuous measurements of the mean meteorological variables were recorded such as air temperature, wind speed and direction, downwards radiation and atmospheric pressure. All the instruments and logging systems functioned well throughout the cruise with the exception of the air temperature which did not work at all. No data were recorded from 341 18:13 to 342 13:29 due to the SCS being shutdown.

Sensors

The oceanlogger system is a BAS designed and built PC based logging system. 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.

TABLE 9

Instruments connected to the oceanlogger.

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. 2148000820	prep lab	Tstemp and cond
Flurometer	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

This system logs sea surface data gathered from the ship's non-toxic pumped sea water supply and some meteorological data to the RVS level 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 RS 484 protocol. A full list of the sensors used is given in Table 9.

Sea Surface temperature and salinity

The thermosalinograph (TSG) was run continuously on both the initial and return journey across Drake Passage, from 327 10:56 to 333 05:42 and 343 22:56 to 345 23:59 respectively. It was switched off while travelling down and up the peninsula.

Salinity samples were drawn from the non-toxic supply approximately every four hours to calibrate the computed TSG salinity. These samples were treated in exactly the same manner as those taken for the CTD calibration. The 200ml sample bottle was rinsed three times, the sample taken, the neck of the bottle dried and an air tight plastic seal inserted. The samples were then stored in the micro radio laboratory beside the salinometer for at least 24 hours before the samples were analysed on the

Guildline 8400A. The computed TSG salinity was calculated from the measured conductivity and temperature at the housing located in the hangar.

Data Processing

The data were read into the UNIX system daily in 12 hour sections and processed in one step using an exec called *JR55_ocean*. This was performed following the processing of relevant navigation data for the same period. The following steps were performed in the exec:

Step 1: All raw data were read in from the oceanlogger and separated into met and ocean data and converted to PSTAR.
Step 2 (Met): The raw met data were despiked, averaged into two minute bins and merged with the navigation data.
Step 2 (Ocean): The raw ocean data was despiked, averaged into two minute bins and merged with the navigation data into a master file, *ocl551.filt.2min*.
Step 3 (Met): The true winds were derived from the measured winds and the navigation data.

Raw TSG salinities were then calibrated with the salinities derived from the bottle samples. Bottle salinity data were prepared in Excel and saved as a tab-delimited text file. These were transferred to the UNIX system from the Mac and converted to PSTAR using *pascin* and *pheadr*. Time was converted from days, hours and minutes to seconds using *ptime* and *pcalib*.

The bottle salinities were merged with the TSG salinities, to determine residual errors in TSG salinity using *pmerge*. The difference between the TSG salinities and the bottle salinities was plotted against time and visually examined. One outlying data point was removed and a three point top hat filter was applied to the difference to smooth out the calibration. The calibration was then applied to the master file, *ocl551.filt.2min* to determine the final salinities.

The final residual file gave the mean offset of the bottle samples from the TSG data as 0.0323 with a standard deviation of 0.1312. These values refer to the southbound data only. Figure 7 shows the sea surface temperature and the calibrated sea surface salinity against latitude for the southbound section of the cruise.

Susan Brown

Precision Echo Sounder

The RRS *James Clark Ross* is fitted with a SIMRAD EA500 Hydrographic Echosounder and a hull mounted transducer array, located approximately five metres below the water level. Raw data were logged by the SCS into the simulated level C data stream SIM500 and retrieved using *datapup* into a twice daily PSTAR file. Most of the processing on JR55 was performed by the script *jr55_sim.*

A visual display of the return signal was displayed on the SIMRAD VDU, with a hardcopy of the processed output produced on a colour inkjet. A uniform sound velocity of 1500 m/s was used.

The SIMRAD often produces zero depths when no good value is available, and these were reset to an absent data value using *pedita*. *Pmdian* was used to replace each value with the median from a moving window of five adjacent data cycles. Manual despiking was performed using *plxyed*, to remove any obviously spurious values, followed by *pintrp* to linearly interpolate onto the data cycles marked as absent. *Pcarter* was used to derive depth soundings corrected for the speed of sound, then navigation data was merged in from the BESTNAV data stream using *pmerge*. Finally the twice daily files were appended into a single master file (55sim01), and reduced to a five minute temporal resolution using *pavrge* (55sim01.5min).

On the outward journey, two parts of the section were traversed more than once, for Bottom Pressure Recorder moorings to be recovered and deployed by Ian Vassie and Pete Foden of the Proudman Oceanographic Laboratory. Only one crossing of the repeated sections was retained, using *pcopya*; namely those on which the hydrographic work was being undertaken. This leaves one noticeable discontinuity in a section of depth plotted against latitude, near 61.05 degrees south, where the difference is the result of a discontinuity in longitude between the two joined sections of the track.

The final outward and return sections of the journey have been placed into the separate files '55sim01.5min.out' and '55sim01.5min.ret'

The depth deduced from the bottom CTD pressure plus the bottom altimeter reading is consistently greater than the SIMRAD corrected depth. The difference is least, typically less than six metres, in the zone of relatively flat topography in the southern half of the section, and greatest, up to around 30 metres, in zones of steep topography, where shallower side echos are likely.

Martin Price

Expendable Bathythermographs Measurements (XBT)

During JR55 XBTs were dropped between CTD stations on the principal southbound CTD section and at 20 nmile intervals on the northbound crossing of Drake Passage. On the southbound crossing XBT deployments were concentrated in the southern part of Drake Passage. Additional drops were made at locations on the Antarctic Peninsula shelf where it was thought that sound velocity data would be of benefit to the ship's swath bathymetry system.

Sippican T5 and T7 probes were used, having been provided by the U.K. Hydrographic Office, Taunton. XBT's were deployed from a hand held launcher fixed to the rear port side of the aft deck. Data were logged by a Viglen IBM-type 486 PC running the Sippican WinMk12 software. On completion of a successful drop, data were transferred via ftp to the central UNIX system (jruf) for processing.

Two UNIX scripts were used to process the data:

1) xbtexec0 - This reads the data from ASCII into PSTAR format, sets up header information, and extracts navigation and water depth from the RVS data streams for the time of the drop.

2) xbtexec.edit - This runs a median despiking routine on the data, and launches the PSTAR program *plxyed*, which enables interactive editing of the XBT profile. This was used to remove any remaining spurious spikes, and to remove noise recorded after the probe had reached its terminal depth.

Successful drops are listed in Table 10. In addition to these, a large number of unsuccessful drops were made. These were generally aborted mid-drop, since it was clear from the real time display that the data were unrealistic, often excessive spiking was a common problem.

At the start of the cruise, there were problems with the logging PC crashing mid-drop. This happened on two occasions, but regularly rebooting the PC seems to circumvent the problem.

Mike Meredith

TABLE 10

XBT deployments during JR55

Drop no.	Date yymmdd	Time hhmmss	Latitude Degrees	Longitude degrees	Depth (m)	Probe type
1	001123	132700	-55.0157	-58.3209	1704	T7
2	001125	123400	-57.5929	-56.8010	3713	T5
3	001125	170500	-57.8687	-56.5699	3947	T5
4	001125	223900	-58.2511	-56.4237	3886	T5
5	001126	102800	-58.5259	-56.2610	3819	T5
6	001126	201600	-59.2081	-55.8100	3710	T5
7	001127	004600	-59.4825	-55.6175	3850	T5
8	001127	053500	-59.8320	-55.4175	3417	T5
9	001127	102000	-60.1805	-55.2043	3479	T5
10	001127	143000	-60.4487	-54.9986	3523	T5
11	001201	175100	-66.0786	-66.1634	570	T5
12	001201	182600	-66.0222	-66.3910	878	T5
13	001208	235700	-62.5362	-62.3032	377	T7
14	001209	010436	-62.2964	-62.1778	1838	T5
15	001209	020300	-62.0899	-62.0750	2973	T7
16	001209	030400	-61.8594	-61.9634	4754	T5
17	001209	040700	-61.6369	-61.8597	4064	T5
18	001209	060000	-61.2854	-61.7005	3655	T5
19	001209	080100	-60.8450	-61.4875	3702	T5
20	001209	100700	-60.4078	-61.2783	4012	T5
21	001209	155800	-60.1931	-61.1740	4101	T5
22	001209	211200	-59.5982	-60.9046	4007	T5
23	001209	231300	-59.2062	-60.7269	3466	T5
24	001210	011300	-58.8277	-60.5517	3382	T5
25	001210	031700	-58.4551	-60.3782	2654	T5
26	001210	050800	-58.1547	-60.2495	3580	T5
27	001210	072000	-57.7677	-60.0922	3238	T5
28	001210	091900	-57.4057	-59.9387	4268	T5
29	001210	112000	-57.0410	-59.7792	3966	T5
30	001210	131800	-56.6810	-59.6228	3657	T5
31	001210	153200	-55.9429	-59.3146	4099	T5
32	001210	172200	-55.9359	-59.3123	4106	T5
33	001210	193600	-55.5530	-59.1600	4228	T5
34	001210	211000	-55.2611	-59.0331	3497	T5
35	001210	230100	-54.9379	-58.9135	1791	T5
36	001210	235300	-54.7576	-58.8475	241	T7
37	001210	234800	-54.7791	-58.8559	604	T7

O_2 SENSOR TRIALS

Trials were conducted of a new dissolved oxygen sensor designed by SOC and the University of Southampton Chemistry department. The sensor head consists of a fine platinum wire, potted in a block of epoxy or glass, and protruding by an amount comparable to the diameter of the wire. Seven sensor heads were provided, of various wire diameters and potting materials. All were tested. The sensor heads were inserted into the endcap of a small pressure case containing the electronics. On the other endcap of the pressure case, a 4-pin bulkhead connector was connected to a splitter lead which provided connection to channels A and D of the CTD pie-con. The sensor electronics convert the current flowing in the sensor (nA) to voltages. The intention was that the primary CTD channel (logged as oxyv1 in the PSTAR files) would be of order a few volts, and the secondary channel (oxyv2) would be smaller by a scaling factor of 100. The CTD channels could report voltages in the range of +/- 5 volts. Note also that oxyv2 is of opposite sign to oxyv1.

In six cases the sensor was mounted with the pressure case horizontal (flow parallel to the sensor face) and low in the CTD frame, with the sensor clear of obstructions on the downcast. The sensor was therefore in the wake of the pylon/bottles on the upcast. In one case (sensor G) the pressure case was mounted vertically with the sensor facing downwards.

The voltages measured on the two CTD channels were not in perfect ratio of 1:100. Where both channels were reporting good data (ie not saturated - see below) they were correlated, but with r^2 typically 0.8. Furthermore the slope was not 0.01, but was typically biased by up to 10%. Clearly this requires further investigation. The voltages were passed through the CTD A to D converters. Previous experiments with transmissometers connected to channels B and D have shown that the consistency of A to D conversion is at least an order of magnitude better than the oxyv1/oxyv2 inconsistencies. The inconsistencies occurred with both CTD DEEP03 and DEEP04. In summary, the voltages were always inconsistent with DEEP03. They were consistent with DEEP04 at moderate voltages (say oxyv1 in the range 1 to 3 volts) but inconsistent at higher voltages (greater than 3.5 volts but less than the saturating value of about 4 volts). Further checking is required to verify that the CTD A to D calibrations are correct and that they have been correctly and uniformly applied in accessing raw CTD data. It is clear though that the v1/v2 inconsistencies are at least partly attributable to the sensor electronics. On station 34 (Sensor B, CTD DEEP03) the difference between v1 and v2 is obvious: there is most definitely an offset rather than (as well as) a scaling. After sign correction on oxyv2, a regression of the smoothed data gives

$$oxyv2 = 0.0093 \times (oxyv1 + 0.84) \qquad (32)$$

with $r^2 = 0.95$. On station 33 (again B and CTD DEEP03),

$$oxyv2 = 0.0084 \times (oxyv1 + 0.69) \qquad (33)$$

The coefficients of the regression are significantly different.

The sensor was clearly very sensitive to flow rate. A variable called 'panom' for pressure anomaly was calculated for each station. This was the difference between instantaneous CTD pressure and a 50-second smoothed CTD pressure. When paying out or hauling in at 1 m/s, this variable therefore represented the effect of ship roll on flow rate. While on the downcast, increasing panom represents flow rate greater than 1 m/s, while panom decreasing represented flow rate less than 1 m/s. Hauling in, the reverse is true. Station 15 (sensor B) was used to investigate flow rate effects. The 'noise' in oxyv1 was extracted as the difference between oxyv1 and the two minute smoothed series of oxyv1. The noise level was of order 0.2 volts over a mean of one volt, with noticeably more noise on the upcast. A simple correlation of noise with dp/dt had an r^2 value of 0.16 on the downcast (0.1 on the upcast where the noise level is higher), so the effects of flow rate variation are significant and need to be eliminated.

In an effort to limit the effects of flow rate, a further test was conducted on the final station 34. The sensors had been provided with a cylindrical cover to be used for protection between stations. Two 3mm diameter holes were drilled in the cover, opposite one another across the cover's diameter, and at the closed end. The modified cover was fitted to the sensor and taped in place, with the holes aligned vertically above one another. The enclosed volume of seawater was approximately 5600 mm^3. This had the effect of reducing, but not eliminating, the noise due to ship roll.

Elimination of cleaning cycle from data stream

The sensors have a cleaning cycle. Once every 40 seconds or so, a voltage of -5 volts is applied to the sensor for a period of a few seconds. This cycle was removed from the data stream by means of a new pexec program *peditk*. The program hunts for data outside a user specified range (eg 0 to 5 volts for oxyv1). On finding such a data cycle, the next N data cycles were set to absent. N was chosen to be ten for this purpose, so ten seconds of data were discarded after the first instance of a negative voltage in each cleaning cycle.

Sensitivity

The various sensors had different sensitivities, which had been estimated before the cruise from laboratory tests. The 50 micron sensors reported significantly higher voltages than the ten micron sensors, so much so that they tended to saturate (oxyv1 > 4) with the high dissolved oxygen content of cold southern ocean water. This is summarised in the Table 11. During the cruise there was some confusion about the appropriate scaling to be applied to convert voltages to dissolved oxygen content for the various sensors. Since the noise levels were in any case too high to provide useful dissolved oxygen data, this was not pursued during the cruise and was left for post-cruise analysis.

Upcast/downcast differences

After fairly severe smoothing, with a two minute top-hat filter applied to the voltages (after peditk), a recognisable signal was produced by most sensors. It was obvious that all sensors showed a substantial up/down difference, of order 10 to 20 percent in reported voltage. The reasons for this will need to be investigated.

Physical deterioration

Most if not all sensors showed what appear to be cracks in the potting blocks. These will need to be investigated back in the laboratory.

Conclusion

The trials have definitely been worthwhile, showing up various issues that can now be considered ashore. In particular, flow rate, robustness of manufacture and up/down effects. The heavily-smoothed signals are recognisable as showing generally realistic variation with known climatological dissolved oxygen content. In order to progress with the development, every effort should be made to prepare a modified version for use at the next opportunity, which is likely to be the FISHES cruise in spring 2001. That cruise should provide an opportunity for a modified sensor to be deployed and compared with bottle oxygen data.

Brian King

TABLE 11

O2 sensor deployments.
Sensors are designated by the letters provided by Robin Pascal; 10 and 50 refer to the diameter in microns of the sensor wire.

Station	Sensor/CTD	Comments
01 to 11	E50/Deep03	v1 saturated
12,13,14	F50/Deep03	v1 saturated
15,16	B10/Deep03	Ok
17,18	D50/Deep03	v1 saturated at surface ? noisy
19,20	C10/Deep04	very low signal
21	C10/Deep03	very low signal
22	G10/Deep03	mounted vertically
23,24	G10/Deep04	mounted vertically; good agreement between v1 and v2
25 to 32	A50/Deep04	usable signal; the best of the 50's. good agreement between v1 and v2 when v1 < 3 volts, less good when v1 > 3 volts.
33	B10/Deep03	as station 15,16
34	B10/Deep03	modified sensor cover on

COMPUTING

The RRS James Clark Ross has been fitted with a new system for acquiring and processing real time data. This system is called the scientific computer system (SCS version 2.3 Benigni *et al.* (1999)) and replaces the RVS Level ABC for a number of the key data streams. The SCS acquires sensor data from shipboard and oceanographic sensors to timestamp these data and to provide information to the scientist in real time via text and graphic displays, while simultaneously logging the data to disk for later analysis. The SCS runs on a Windows NT 4.0 Server and a Windows NT 4.0 Workstation.

Navigation data (Trimble 4000 GPS and Ashtec ADU-2 GPS) and echosounding data were logged to the SCS. These were converted to equivalent RVS Level C files using the utility *scs2levC* and stored on the UNIX workstation jruf (Sun4u sparc SUNW, Ultra 60 with a 52 Gbyte hard disc).

Gyro data, VMADCP and oceanlogger data were logged via LevelA's or instrument dedicated PC's to jrub (Sun4u sparc ultra1) and then passed to jruf using the usual RVS utility to convert to PSTAR data. CTD data were logged to the DAPS Sun4u sparc ultra1 workstation, passed to jruf and read into PSTAR. LADCP data were downloaded at the end of each cast to PC and ftp'd to jruf for further processing.

Two Xterminal emulators (tektronix) were used for logging into jruf for data analysis and two mac 7200/90 s were used for word processing and as spare Xterminals.

TECHNICAL SUPPORT

Equipment for JR55 was unloaded and assembly started on Saturday 18th November. During the setup of the CTD and Rosette equipment there were difficulties getting various combinations of CTD and Rosette to work reliably in the UIC room.

Initially, the sea cable was terminated and wired to suit the new swivel. SOC provided a two pin tail for the rosette connection but the supply pins appeared to be reversed. An existing join in the SOC tail was removed and the connections crossed over. Tests were completed before heatshrinking and the power connections reversed again. Following reconnections with black-black and white-white, all was well.

To facilitate checks between the short test lead and the sea cable connections to the CTD, the sea cable was rerouted into the UIC room via the aft door. Many problems were still experienced with the deck unit to CTD/rosette communication and it was very difficult to get the system reliable for any length of time.

Further tests on the sea cable showed loop resistance to be around 115 ohms. This was not considered bad. A new cable measured 76 ohms, so given the complex resistance paths through several kilometers of rusty outer, it seemed reasonable. However, a Megger test showed that the cable was faulty.

The sea termination was cut off and measured again, but the result was the same. Investigations then moved to the slip rings, from which the cover was removed and sparks were seen to be jumping across two contact rings. The electrician cleaned everything but the problem still existed so the whole slipring assembly was removed and stripped down. Several of the brushes had been completely worn away and ten years worth of ferrite dust and oil had accumulated inside the lower brush carrier assembly. This was not a great piece of design and the two brush carriers have now been mounted horizontally instead of vertically. It is hoped that future brush debris will not accumulate in the same manner. The slipring assembly will now be inspected on a yearly basis. The contacts were rewired using three (centre core and two outer strands) unused sliprings. Doug and Keith will be improving access to the sliprings so future problems will not be so much hassle.

Returning to the CTD, further bench tests showed no real improvement following the slipring maintenance. Very little technical information was available so John Smithers (SOC) was contacted for ideas. It was established that one Rosette was completely unserviceable and both units were opened to swap top plates. The plates housed sea connectors and a choke for the communication system. One connector was found to be intermittent and different results were obtained by using a variety of CTD/Rosette connecting leads.

Consideration was given to using the BAS CTD and Rosette in the SOC frame for which permission had been given by BAS. Methods were investigated for securing the Seabird frame to the SOC frame. Thankfully we received additional info from SOC regarding the existing problems and paused to see if progress could be made.

John suggested tuning the deck unit on manual instead of using the auto setting but we had already spent most of a day trying this and getting nowhere. We also found differences between the two deck units. He also suggested monitoring a couple of points in the Rosette. It turned out that one of the controls was way out of adjustment. A quick tweak and we were able to reliably fire the Rosette. Unfortunately this situation did not last for long and the Rosette again worked intermittently.

After more head scratching and going round in circles we decided that the best way forward was to rebuild the complete system and carry out a test station. The Rosette connector was replaced, top plate sealed and bolted to the frame. The sea cable/swivel connections were reterminated and the whole system was left running overnight.

The system worked but communications were still a problem. Only 8 of the 12 bottles fired and we were getting garbage messages back from the Rosette. Bottle firing is achieved using the Smitherware pylon program. A laptop PC was connected to the DAPS logger so the operator can manually enter "CONF 1" when bottle 1 has been fired.

The above is only a brief description of what happened over 4 days. Thankfully we did persevere and succeeded in sampling all the stations.

Swivel

The swivel was supplied by BAS to prevent damage to the CTD/hydro sea cables caused by package rotation. Suitable connectors/tails were provided and it is recommended that the swivel be used for all future CTD operations. Before fitting, the swivel was load tested on the deck to about 1.2 tonnes. Compass data from the LADCP indicates that the SOC frame no longer rotates 360 degrees. A fin was fitted to the frame to provide extra stability.

The CTD does rotate when lifted clear of the water and caught by wind. The swivel rotates very freely, sufficiently to prevent the weight of the package defeating the bearings and twisting the cable.

During initial installation it was discovered that a small brass bush (undocumented feature) in the lower lifting slot prevented direct coupling to the CTD "A" frame. A shackle was inserted but after a week it was noted that this bush had "disappeared". Direct connection should now be possible.

Unfortunately the brass bush had not disappeared but had been pushed inside the swivel body. A large amount of oil leaked out possibly due to the bush puncturing the pressure diaphragm inside the unit. No documentation was available to help with a field repair so the unit was removed from the frame for the final two northbound test stations.

To prevent the swivel from fouling and damaging the top of the Rosette a support bracket was provided. This bracket took the form of a central torus which connects to the top of the frame via three support arms. Unfortunately the supplied bracket did not fit and was modified by Doug. The three arms have been extended by about 140mm using stainless bar and stainless 12mm studding. The system works well and allows full access to the Rosette for bottle operations.

A teardrop lifting block had been modified to suit the upper swivel slot. The stainless lifting pin locates smoothly and is secured using a split pin. Splaying the ends of the pin is a real problem as the lifting pin wants to rotate and there is no real way to prevent this. I suggest using tractor pins to do the job. These devices have a pin that locates in the hole and a spring loaded ring that folds over the lifting pin to prevent withdrawal. This method greatly simplifies assembly/dismantling.

However, one problem with the teardrop lifting block when fitted to the sea cable was the increase in overall size of the block. The cable now snags on the base of the lifting slot and prevents the cable and block from folding over. This in itself is not a problem but the deck crew have to climb on the frame, grab the cable and apply tension whilst the strain is taken. This procedure bends the sea cable at the top of the teardrop into an acute angle which will probably cause premature failure. The problem can be solved by providing another teardrop with the lifting hole moved further towards the base. I doubt that this will cause any weakening, especially if a stainless insert is incorporated as on the existing device. Another option may be to extend the lifting slot.

Misc & Spares

A suitable home needs to be found for the swivel. The device will be removed when packing up and needs to be stored in the water bottle annex. It should be possible to attach a suitable protective container somewhere on the wall. Blanks will be vital to protect the connectors.

The swivel uses a four pin connector system, plug at the entry and socket at the base. The first connecting lead that I made I forgot to fit the locking collar. Not having used these before I cut the cable, inserted the collar and remade the join. I did wonder why the collar came with a separate spring insert that fitted into a slot and just assembled these before fitting to the cable. Of course it eventually dawned on me that the collar can be fitted by sliding over the connector body. Fitting the spring insert afterwards prevented the collar from coming off and also locks the body in place. The second thing that caught me was that there are male and female versions of the locking devices.

The steel wire rope clamps used on the sea cable deteriorate quite rapidly when exposed to sea water. There never seem to be any spares and I do not know if they are supplied by the ship or ETS. I never feel happy putting worn devices back on the wire and they should be changed everytime a new sea cable termination is made. I suggest that ETS keep their own stock.

Acknowledgements:

Many thanks to Doug for the swivel frame modifications and to Doug & Keith for refurbishing the slipring assembly.

Doug Trevett

CONCLUSIONS

The WOCE scientific plans identified a number of sections, known as choke points, where the meridional spread of the ACC is constrained and transport measurements can be attempted, and where repeat sections give important information on ocean variability. The Drake Passage section is possibly the most important, because of its accessibility, because it is the narrowest, and because it provides the immediate link between the Pacific and Atlantic Oceans. The UK is currently established as the lead nation for the hydrography on this section. It is appropriate for us to take a lead in establishing a time series in the CLIVAR context. In addition to the hydrographic measurements undertaken by SOC/BAS, UK research in Drake Passage includes the network of deep tide gauges maintained by POL, analysis of satellite altimeter data at POL, UEA and JRD, and numerical modelling in JRD. This cruise makes valuable use of the passage leg across Drake Passage to Rothera on the first of season base resupply trip, adding three days to the passage time and includes time for POL to service their deep tide gauges.

The principal objective of this cruise was to complete a hydrographic section across Drake Passage along the WOCE SR1b line. The scientific observations along this section consisted of 31 full depth CTD/LADCP stations. At each station up to a maximum of 12 water samples were captured and analysed for salinity. Several oxygen sensors of novel design were trialed for the first time. Underway observations were shipboard ADCP, GPS navigation for position and ship's attitude, sea surface temperature and salinity, basic meteorology (but no air temperature) and water depth. A new shipboard data logging system (SCS) captured and time stamped some of the key data streams. However, other streams were logged and time stamped using the usual RVS Level ABC system. A discrepancy was noted between the timestamp for data from these two routes such that data logged via SCS had a later time stamp than those coming from the RVS Level ABC system. This merits further study.

During the 2000 summer refit, the shipboard ADCP transducer was removed during installation of a new swath bathymetry system. On refitting the ADCP transducers the sea chest was filled with a deionised water and ethylene glycol mix rather than silicone oil as previously used. This change seems to have been a great success. We have not quantified the improvement in ADCP performance but it seems that the range of good water track and bottom track data has increased greatly over previous data sets. At no time did the sea chest approach freezing point as highlighted in this report.

Computing resources (processors and disk space) are excellent. It makes a tremendous difference to the ease of data processing that these resources are of a very high standard.

Research using data from the repeat hydrography sections is ongoing. Particular progress has been made with regard to estimating the mean baroclinic transport and understanding the modes of variability. Limitations in our ability to estimate the depth independent flow has hindered attempts to calculate total transport: considerable effort has been spent in this area and only recently with the use of the lowered ADCP do we feel that we are making significant progress on this problem. The following references use data coming directly from this repeat hydrography: Alderson *et al.* (1995); Cunningham *et al.* (1995); King *et al.* (1996); Alderson and Cunningham (1999; King *et al.* (1998);Bryden and Cunningham (2000); Cunningham *et al.* (2000; Cunningham *et al.* (2001); Rubython *et al.* (2001).

ACKNOWLEDGEMENTS

I would particularly like to thank Jerry Burgan (Master), Graham Chapman (CO) and Duncan Anderson (CE) without whom the ship would drift aimlessly, collapse into anarchy and then sink. We had a successful scientific expedition and cruise thanks to the care and attention of all the ships crew, particularly when we had technical problems with the CTD instrumentation. As usual the winches were driven with splendid attention. We were well fed by the catering staff and Pippa took good care of the scientific party and made the very best of the science for the newsletter.

We were bothered by a number of technical problems with the scientific instrumentation. This provided a challenge for the scientific party. Jobs were swapped and we worked well as a team to sort out the problems. Thank you all.

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TABLES

FIGURES

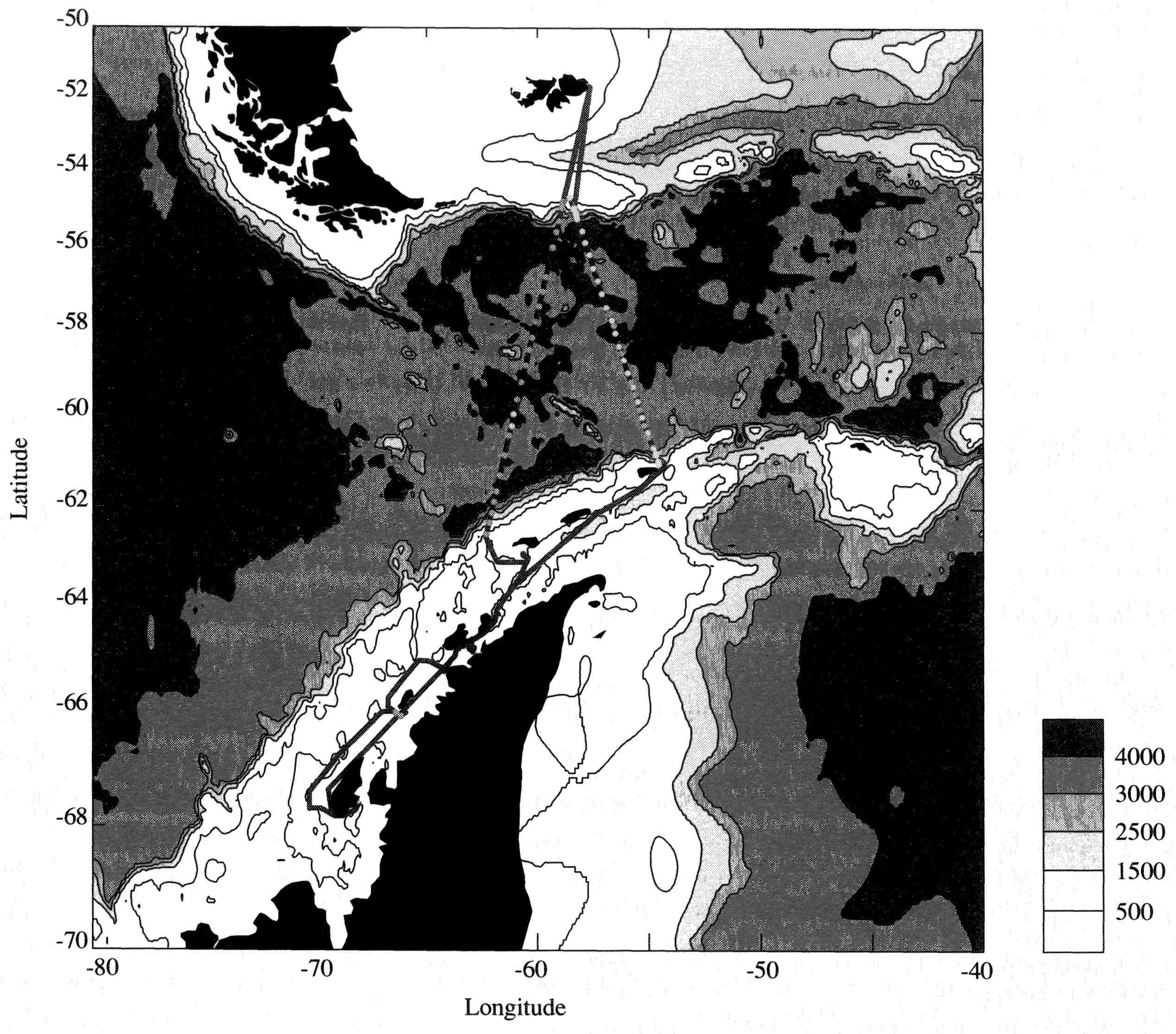


Figure 1. Cruise track for RRS James Clark Ross Cruise 55 (red line) showing CTD stations (yellow dots) and XBT stations (blue dots). Bathymetry is from the dbdb5 dataset.

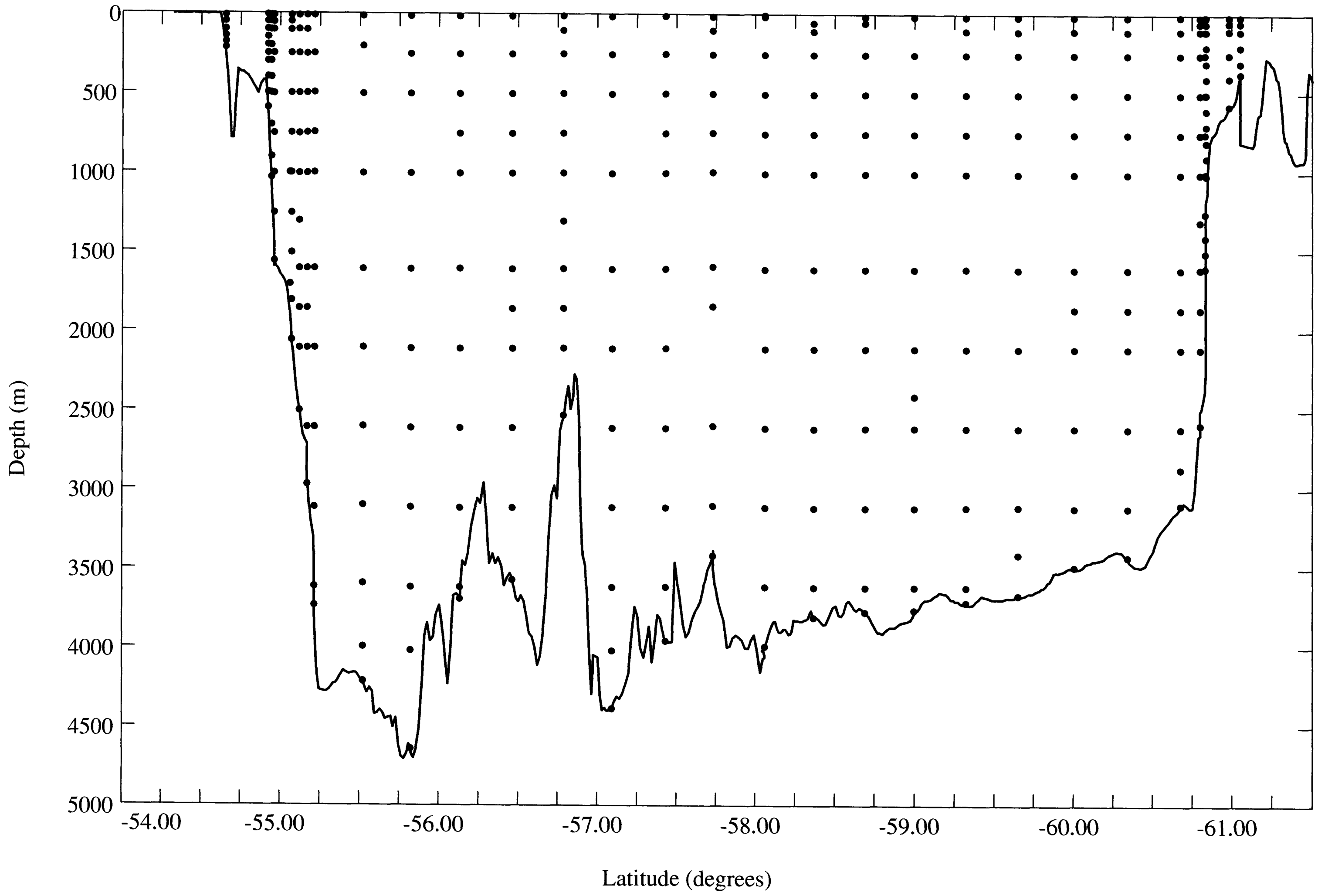


Figure 2. Distribution of water samples

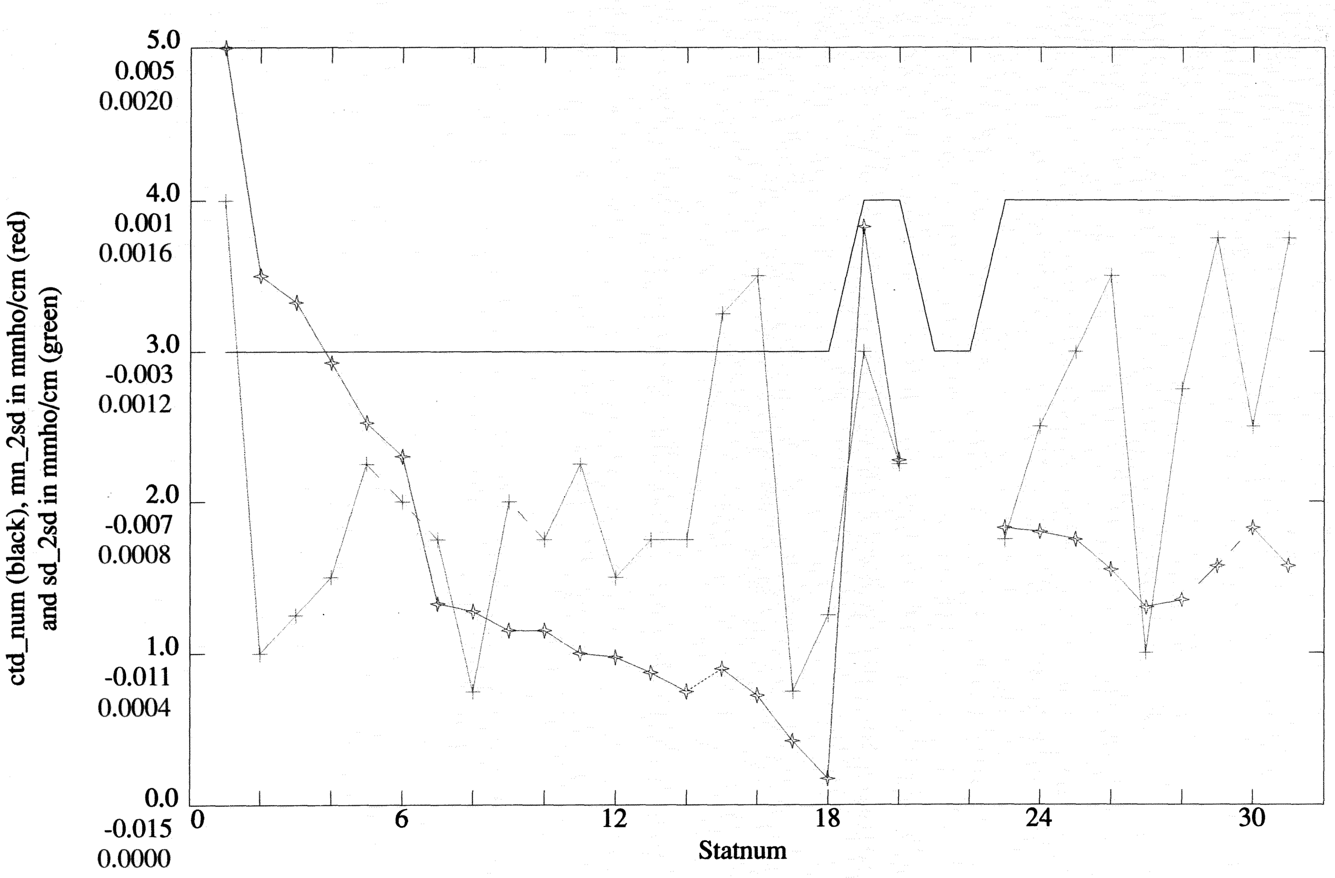
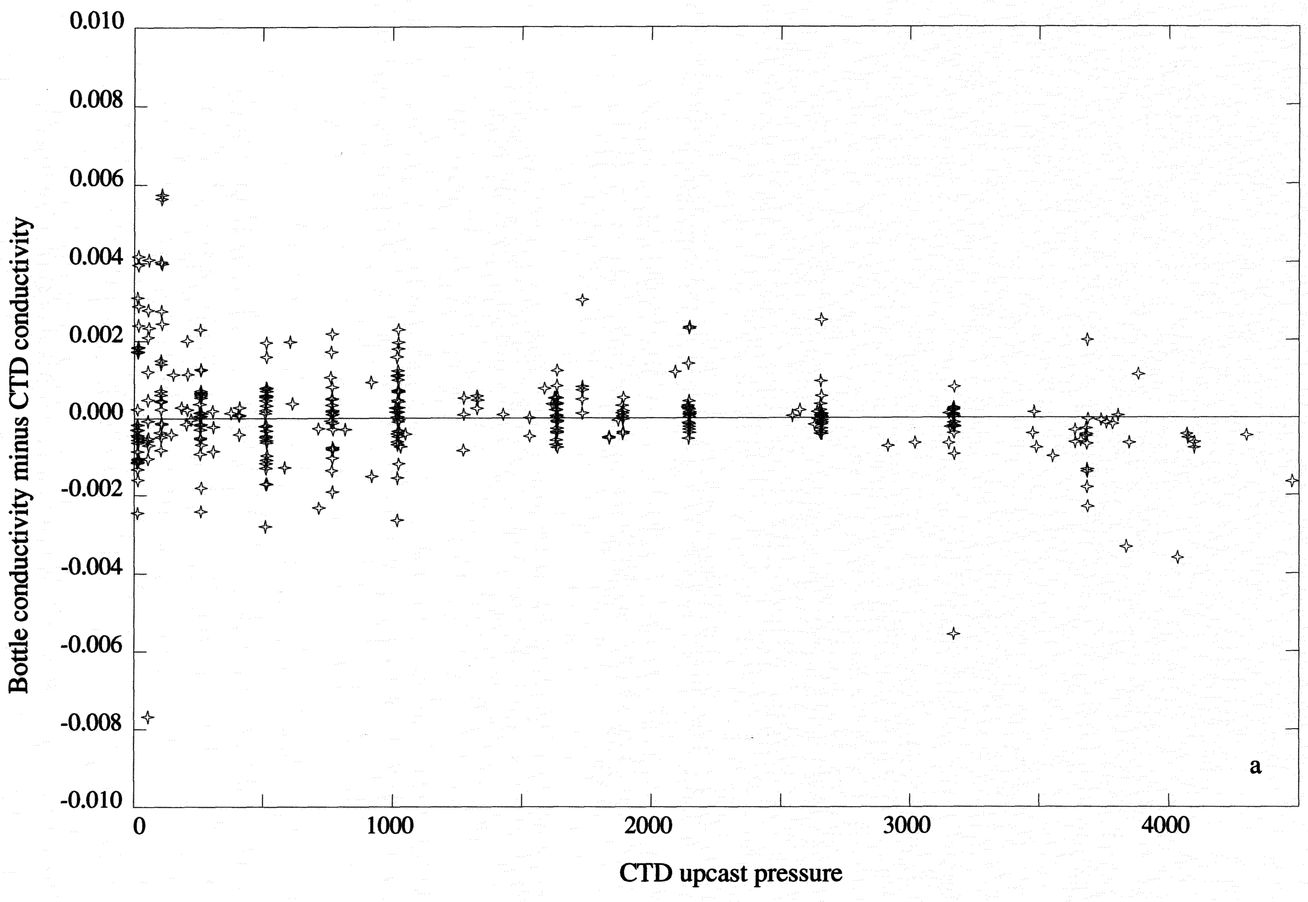


Figure 3. Conductivity offset means (red) and standard deviations (green) for Deep03 and Deep04.



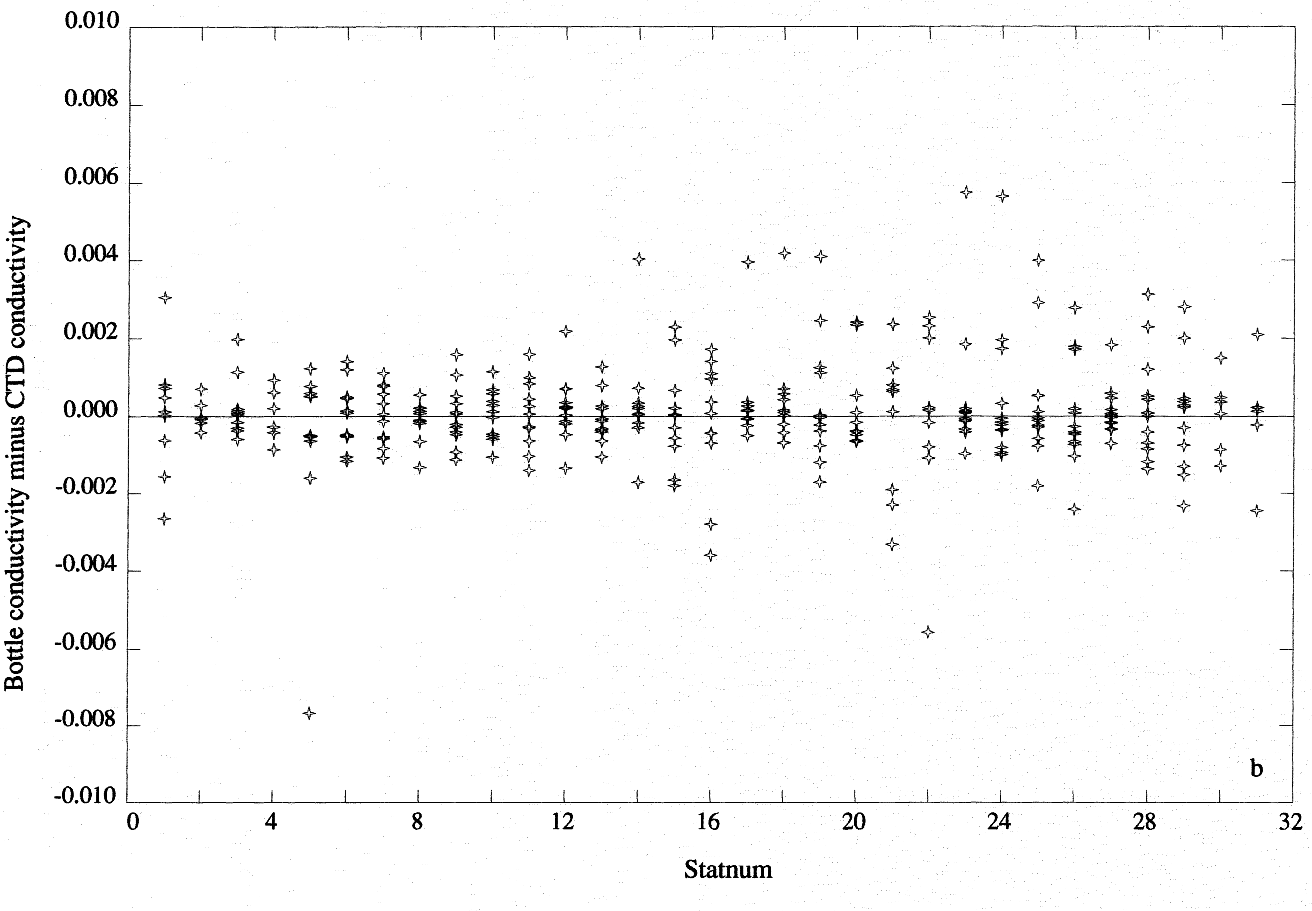


Figure 4. Conductivity residuals. Bottle conductivity minus CTD conductivity versus: a) CTD upcast pressure; b) Station number.

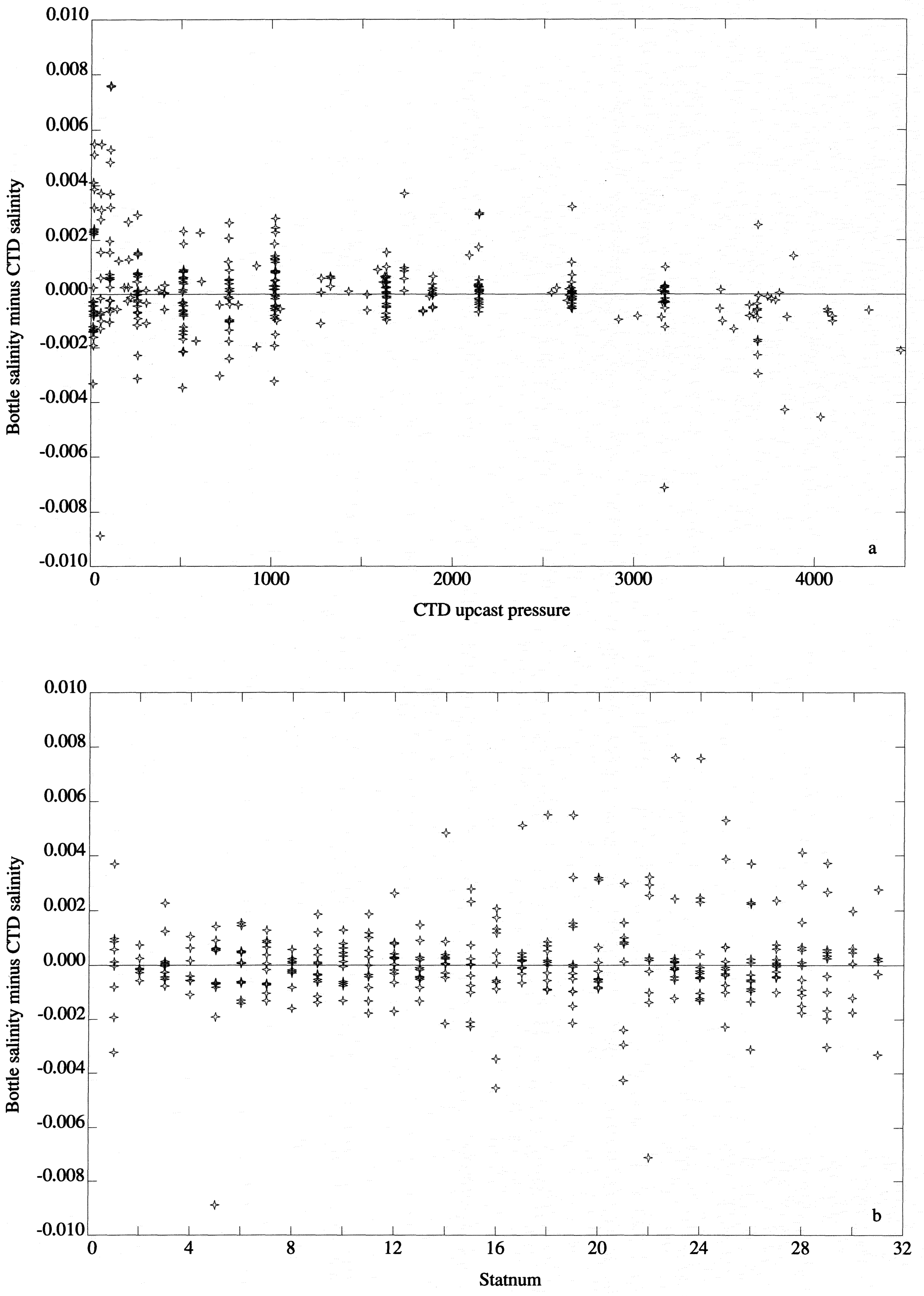


Figure 5. Salinity residuals. Bottle salinity minus CTD salinity versus: a) CTD upcast pressure; b) Station number.

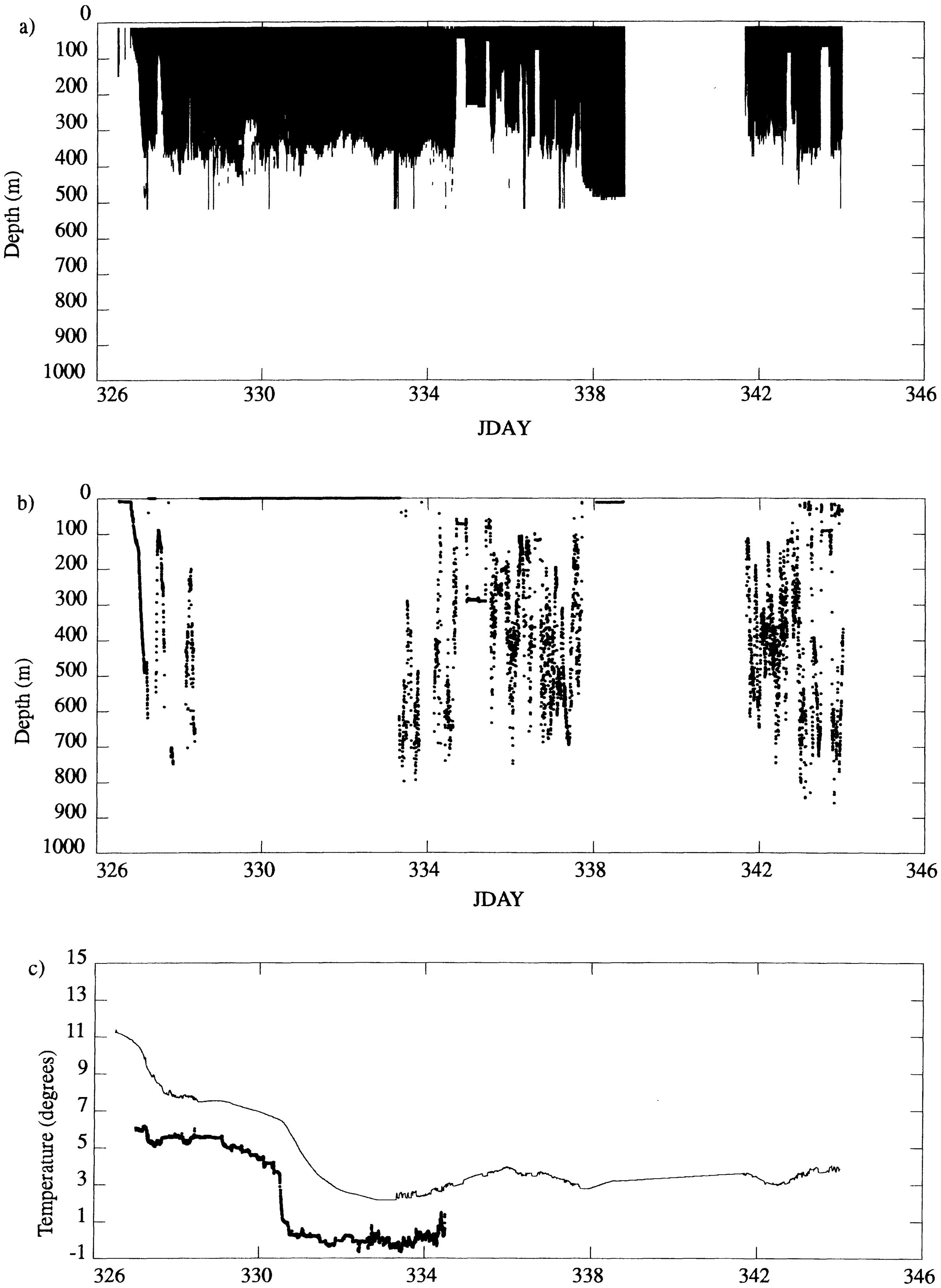


Figure 6. a) Depths from which good data (>25% good) were collected in water track mode during JR55 (black). b) Depths from which good bottom tracked data were obtained during JR55. c) Transducer temperature during JR55 (light line), plus oceanlogger sea surface temperature for the early part of the cruise when it was operated (heavy line).

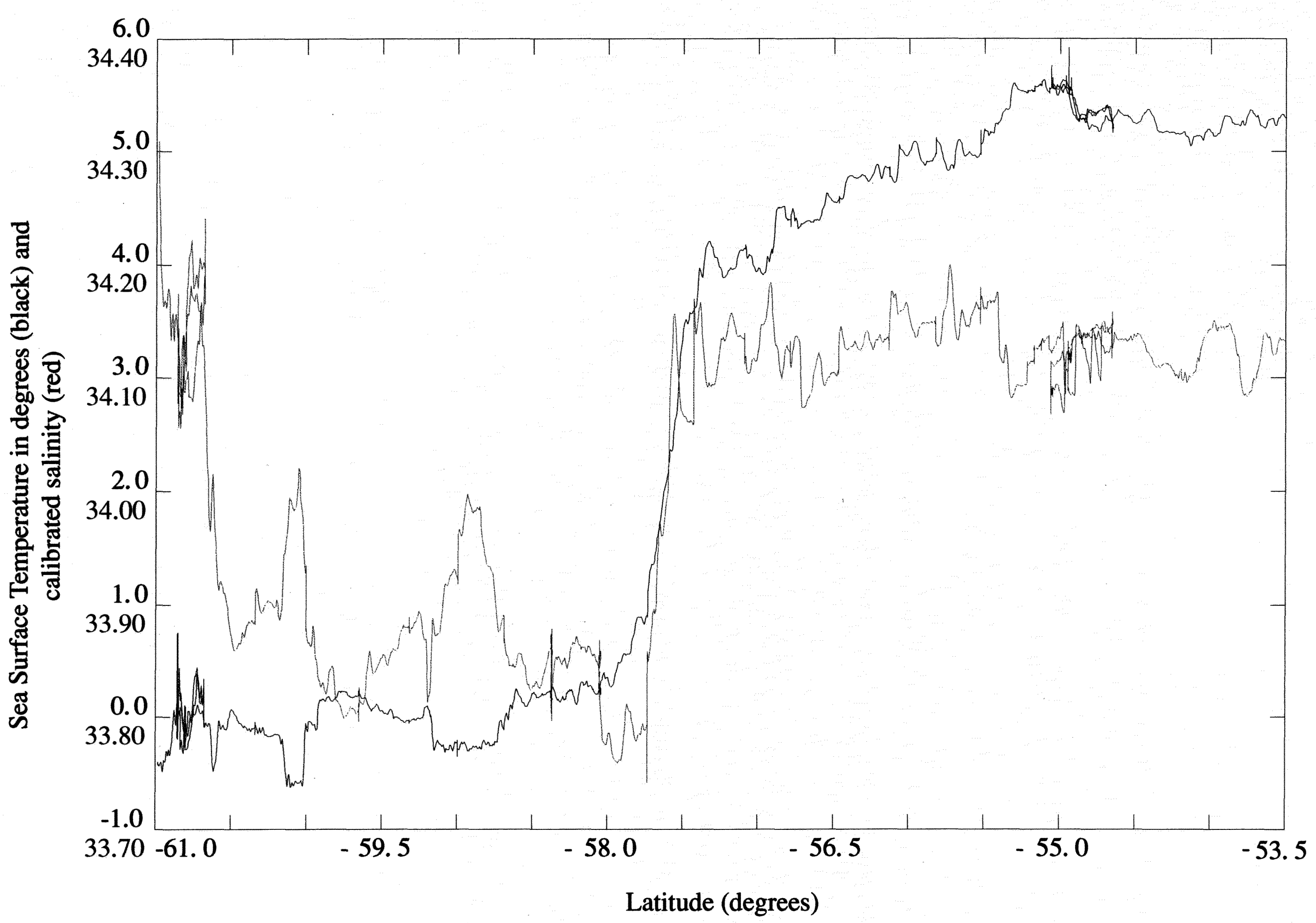


Figure 7. Sea Surface Temperature (black) and calibrated salinity (red) versus latitude.

ACRONYNMS

ADCP	Acoustic Doppler Current Profiler
BAS	British Antarctic Survey
CTD	Conductivity, Temperature, Depth
DAPS	Data Acquisition and Processing System
DAS	Data Acquisition Software
FTP	File Transfer Protocol
GMT	Greenwich Mean Time
GPS	Global Positioning System
IAPSO	International Association for Physical Sciences of the Ocean
JCR	James Clark Ross
LADCP	Lowered ADCP
LDPE	Low Density PolyEthylene
OSI	Ocean Scientific International
POL	Proudman Oceanographic Laboratory
RaTs	Rothera time series
RDI	RD Instruments
RVS	Research Vessel Services
SCS	Scientific Computer System
SOC	Southampton Oceanography Centre
TUBA	Towed Undulating Bio Acoustic Sensor
TSG	Thermosalinograph
UH	University of Hawaii
VMADCP	Vessel Mounted ADCP
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythmograph