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CRUISE REPORT NO. XXX

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RRS *JAMES CLARK ROSS*

20 NOV 1993 - 18 DEC 1993

WOCE SR1 IN DRAKE PASSAGE

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ABSTRACT

Keywords

WOCE

CONTENTS

1. CRUISE NARRATIVE

1.1 Highlights

Expedition Designation

WHP Repeat Hydrography, SR1. The line SR1 was relocated during 1992; this cruise was along the new position, sometimes known as SR1b.

Chief Scientist

The cruise was principally a logistics leg for RRS *James Clark Ross*, so there was no chief scientist. The Principal Investigators for the WOCE work were Brian A King and Steven G Alderson, IOSDL.

Ship

RRS *James Clark Ross*. Length 99 metres.

Ports of Call

Stanley, Falkland Islands.

Cruise Dates

November 20, 1993 to December 18, 1993

1.2 Cruise Summary

Cruise Track

The cruise track and station locations are shown in Figures 1 and 2.

Sampling

Up to twelve salinity samples were drawn per station. Neither time nor expertise was available for oxygen or nutrient samples to de drawn or analysed. A small number of reversing thermometer measurements were made. Continuous CTD profiles (no oxygen) were recorded.

Number of Stations

A total of 39 CTD/rosette stations were occupied using a General Oceanics 12 bottle rosette equipped with 12 1.7-litre Niskin water sample bottles, and a NBIS Mk III CTD. No other sensors were connected to the CTD, which does not have an oxygen interface board. A 10 kHz pinger for near-bottom approach was mounted on the rosette frame. Apart from Digital Reversing Thermometers supplied by IOSDL, the entire underwater package was supplied by British Antarctic Survey.

Reporting

Electronic versions of the text of this document, plus hard copy figures are lodged with the WOCE Hydrographic planning office, Woods Hole, Mass and with the British Oceanographic Data Centre at Bidston, Merseyside. We plan to lodge electronic copies of most of the data from the cruise at these same sites during 1994.

1.3 Principle Investigators

BAS made two berths available for this work, which were occupied by staff from IOSDL, as indicated in section 1.1; responsibility for all the WHP measurements made during cruise were shared between them. Additionally, Mark Preston and Ash Johnson of BAS, en route to Rothera Base, were responsible for electronics support for CTD operations.

1.4.1 Scientific Programme and Methods

The principal objectives of the cruise were:-

a) To estimate the volume flux across the section, i.e. the flux of the Antarctic Circumpolar Current at Drake Passage

b) To determine the water mass characteristics on the section and to determine whether and where secular changes are found, and

c) To submit to the WHPO a data set, and thereby contribute to the global measurements necessary to meet the objectives of WOCE.

The principal instruments employed in the measurement programme consisted of a NBIS Mk III CTD, General Oceanics rosette and 10 kHz bottom location pinger. Two of the rosette bottles were fitted with SIS digital reversing thermometers and pressure meters. The wire was a single conductor 10mm steel rope manufactured by Rochester Cables, and the winch was of traction winch design. The package was deployed using the midships A-frame gantry, which is fitted with a pendulum and roller arrangement. Although the weather was generally kind, the size and stability of the ship, combined with the gantry arrangements, meant that no time was lost to weather during the week of measurements.

After a cast the rosette was brought into the water bottle annex, which can be closed off with a roller shutter and heated with warm air. This made sampling pleasant, even in the worst conditions.

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

A description of the methods of measurement, calibration and analysis of the data received from these various sources will be found in Section 2 of this report.

1.4.2 Preliminary Results

Figure 3 shows the distribution of salinity sample observations made on the section; Figures 4 and 5 show CTD potential temperature and salinity sections. Figure 6 shows geostrophic velocity from the CTD data calculated relative to the deepest common level between stations. The accumulated cross-track transport from the velocity field in Figure 6 is shown in Figure 7; the total is approximately 132 Sv.

Analysis of the ADCP data is underway at the time of writing this report. The analysis is complicated by the fact that the transducer is enclosed in a sea-chest filled with oil, in which the speed of sound is different from that in water, both in absolute value and in variation with temperature. Unfortunately, the RDI data acquisition system makes no correction for this. This is further discussed in Section 2.4. Figure 8 shows 10-minute averages of the absolute velocity at 125 metres, determined from shipboard ADCP measurements and DGPS positions, for the southbound crossing of the section.

The DGPS data from various periods when the ship was moored have been analysed. In particular, the rms difference of position about the mean has been determined for 24 hour periods both in Stanley (a few kilometres from the fixed station), and while the ship was moored to the wharf at the UK Rothera Base (1800 km from the base station). In each case the rms is approximately 4 metres in each of latitude and longitude. The accuracy of the DGPS measurements at such a large range from the fixed station was considerably better than expected. These measurements are discussed further in Section 2.5b, and illustrated in Figure 9.

Figure 10 shows the surface temperature and salinity record for the portion of the cruise southbound along SR1.

1.5 Problems Encountered on the Cruise

No major problems were encountered, although there were a few minor holdups. The CTD conductivity cell fouled badly at the very beginning of the first station; although the cell was cleared, it continued to drift up in conductivity for several following stations, but eventually stabilised and performed adequately thereafter. Station 11 was aborted when the CTD signal was lost; it was completed after an electrical wiring fault was corrected. Station 34 was aborted, but subsequently completed, after a hydraulic hose burst in the winch room.

Although the traction winch arrangements on the ship are complex, and had been subject to various revisions after unacceptable performance on early cruises, there were no apparent problems on this cruise apart from the burst hose referred to above. The vigilance of the ship's Engineering Officers, particularly the 2nd Eng. ensured smooth operation throughout. Maximum wire out was 4550 metres on station 11.

The pumped seawater supply to the thermosalinograph was discontinued while the ship was doing logistics work and likely to encounter ice. Upon restarting the supply, the TSG read very low in salinity, although the situation gradually improved. Unfortunately, therefore the northbound crossing of Drake Passage does not have a good salinity record.

1.6 Cruise Diary

All times used in this report will be given in UTC. Ship local time was UTC - 3 hours.

Saturday 20 Nov (Day 324)

RRS *James Clark Ross* left the FIPASS pontoon at Stanley at 324/1140, just as RRS Bransfield was entering Stanley Harbour through the Narrows. A boat drill, which included launching and recovery of one of the lifeboats, was conducted while Bransfield moored up. the *James Clark Ross* then went alongside Bransfield for the transfer of a tracked vehicle and various small packages destined for Rothera Base. The vehicle was then secured on the aft deck. The ship left Stanley Harbour at approximately 324/1330, heading for the site of the first (test) CTD station.

Underway logging commenced and the ADCP was initialised in bottom tracking mode. Underway at 13.5 kts, no good ADCP water tracking data were obtained, but bottom tracking in 350 metres of water was satisfactory. Later on, by 1715, the ADCP was providing about 250 metres of water track data at 13.5 knots, with sea conditions calm.

Steaming over the Falklands Trench XBTs were launched in 500 750 1000 and 1500 metres of water depth.

After reaching water of sufficient depth, a trial CTD station was conducted during daylight hours. Unfortunately the conductivity fouled badly right at the start of the downcast. Although the cell was cleared, it continued to drift for the next several stations, finally settling down to stability later in the cruise. The station was aborted on the downcast, and then repeated to 1800 metres. Bottles were closed in pairs at six depths.

One SIS digital reversing thermometer failed on this test station, water apparently having entered the battery compartment. It was unusable for the remainder of the cruise.

After the station, which was also used to wire test acoustic releases for the POL moorings, XBTs were deployed overnight along the southern slope of the Falklands Trench and up onto Burdwood Bank.

Sunday 21 Nov (Day 325)

A POL Bottom Pressure Recorder (BPR) was released and recovered without incident in 1000 metres of water on the slope to the south of Burdwood Bank. The ship then steamed up the slope to the 200 metre contour, and commenced the CTD section with stations in 200, 500 and 1000 metres. After completing the 1000 metre station, the BPR was redeployed, various components having been refurbished while the CTD work was in progress. Further CTD work down the slope continued after the mooring deployment.

The capacity of the weather for rapid change was revealed by the appearance of sleet, bright sunshine and snow within the space of a couple of hours.

Monday 22 Nov (Day 326)

The CTD and XBT section down the slope was completed, and the main section was commenced with stations 35km (19 nm) apart. Five stations were occupied this day, with weather still changing rapidly. Winds varied between 15 and 35 knots, with quite large swell and a wind sea that varied as rapidly as the weather situation. The passage between stations was somewhat uncomfortable.

The temperature of the laboratory containing the Autosal had now settled down, so salinometer work commenced.

Station 11 was aborted after loss of signal at 800 metres on the downcast. On recovery, the problem was traced to the lead joining the sea cable termination to the CTD unit. After making up a new cable, the CTD was redeployed approximately 3 hrs after the initial deployment. A Strong east/northeast drift during the station swept us approx 1.5 miles off station during the cast.

Tuesday 23 Nov (Day 327)

Excellent progress continued, with stations at 35 km intervals. Five more stations were occupied.

Some data from the Ashtech GPS3DF were lost when the ship rolled more than five degrees from horizontal. It was found that a receiver parameter had been set which considered roll only up to +/- 5 degrees. Since the ship was rolling by +/- 10 to 15 degrees, some PRH data were lost. The problem was corrected by changing the MAX ANGLE parameter setting.

Wednesday 24 Nov (Day 328)

The Polar Front was dramatically reached and crossed in the early hours, SST dropping from 4 degrees to near zero.

SST crossed zero at 1045Z, at a latitude of 58°S

Just before starting station 19, it was noticed that there were some frayed strands in one of four wire strops holding CTD frame. The station was completed with the frayed strop, which was then replaced for station 20. Station 20, was also used for acoustic trials for POL releases to be used later in the cruise.

Thursday 25 Nov (Day 329)

Three further stations were completed, before proceeding to the site of the POL MYRTLE mooring. This is an experimental long-term mooring consisting of a deep-sea tide gauge, from which capsules of data can be released on demand. One such capsule was released at XXX in bright sunshine, which almost immediately gave way to fog. After two hours of ascent, the capsule was located on the surface by radio beacon, without which it would have been very difficult to find. The buoyancy was eventually spotted about 100m away, dead ahead. The capsule was picked up about 1 mile from the mooring location, at XXX (time). Visibility improved markedly almost as soon as it was inboard. After returning to the mooring and a brief period of communication with the MYRTLE rig still on the seabed, the ship proceeded to the next CTD (station 24).

Friday 26 Nov (Day 330)

Stations 25 and 26 were completed, the latter being in 3000 metres of water, and the last of the evenly spaced stations.

Before commencing the last series of CTD stations, intended to be at every 500 metres of water depth change, a third POL mooring site was visited, and a BPR recovered from 1000 metres depth. The mooring was popped up in fine weather, and spotted 100m off the starboard bow, the ease of recovery disguising the 6 metres of swell.

The ship then backtracked to 2500 metres water depth and completed the CTD section with stations 27 to 31. The Continental Water Boundary was crossed, characterised by a weak drop in SST and an increase in surface salinity. Station 31 was completed at 330/2010.

The ship then steamed back to the POL mooring position, to redeploy the BPR.

The 'hosepipe' which enables the pumped seawater supply to be collected approximately one metre below the hull was brought inboard at 330/2330, although the pumped seawater supply was left on.

Underway ADCP and other data collection continued.

Saturday 27 Nov (Day 331)

There now followed a period of BAS logistics work. However, navigation and ADCP data logging continued throughout. Periods at anchor, and moored at Faraday and Rothera Bases will be of interest in the analysis of DGPS data. These are therefore highlighted in the subsequent entries.

Sunday 28 Nov (Day 332)

Anchored overnight in Whalers Bay, Deception Island.

Monday 29 Nov (Day 333)

Pumped seawater supply switched off, in anticipation of encountering ice.

Tuesday 30 Nov (Day 334)

Anchored at Damoy 334/1120 to 334/1515.

Moored at Faraday 334/1930 to 336/0040.

Sunday 5 Dec (Day 339)

Arrived Rothera 339/1645. Moored at wharf.

Wednesday 8 Dec (Day 342)

Departed Rothera 342/1415.

Anchored at Horseshoe Island overnight.

Thursday 9 Dec (Day 343)

Stopped in the sea ice at Stonnington Island 343/1605 to 344/0650

The automatic logging of Simrad EA 500 echo sounder data on the shipboard computer system was fixed.

Friday 10 Dec (Day 344)

A brief call was made at Rothera. (344/1305 to 344/1700)

Saturday 11 Dec (Day 345)

Anchored off at Faraday 346/0115

Sunday 12 Dec (Day 346)

Departed Faraday 346/1210

Arrived Palmer Station 346/1720. Anchored off.

Tuesday 14 Dec (Day 348)

Anchored off in Admiralty Bay.

Wednesday 15 Dec (Day 349)

Progress to date had meant that there was now time for further CTD work to be carried out. However, shortage of scientific personnel meant that round-the clock watchkeeping was not possible. Accordingly, three stations in Bransfield Strait and five stations in the Falklands Trough were planned.

Stations 32, 33 and 34 were occupied in Bransfield Strait this day. A burst hose in the winchroom meant that the first cast on station 34 was abandoned at 150 metres of wire out. After repairs, a second cast on that station was completed.

Confused wind sea meant that, unfortunately, poor ADCP data were obtained in Bransfield Strait.

Thursday 16 Dec (Day 350)

A ship's power failure occurred at XXX UTC. However, mains power to the laboratories was quickly restored via the emergency generator, and only a few minutes of data were lost.

Friday 17 Dec (Day 351)

CTDs in Falklands Trough commenced at 351/2332 with station 35.

Saturday 18 Dec (Day 352)

CTD station 39 completed at 352/0839.

Ship moored at FIPASS at 352/1850.

1.7 List of Cruise Participants

The Principal Investigators are listed in Table 1, along with the ship's personnel. Also shown is a list of BAS staff en route to Antarctic bases who assisted with watchkeeping, and two scientists from POL who were engaged in the POL global sea-level programme.

TABLE 1: CRUISE PARTICIPANTS

Name	
S. Alderson	IOSDL
B. King	IOSDL
P. Foden	POL
D. Smith	POL
M. Preston	BAS (CTD electronics support)
R. Coggan	BAS
J. Gorman	BAS
D. Haigh	BAS
A. Johnson	BAS
J. Killingbeck	BAS
D. Thomas	BAS
C. Wareham	BAS
C. Elliott	Master
J. Marshall	C/O
R. Jackson	2/O
A. Gatti	3/O
D. Cutting	C/E
W. Kerswell	2/E
R. Caldwell	3/E
M. Inch	3/E
M. Gloistein	R/O
N. Thomas	Elec/O
H. Gibson	Cat/O
T. Gill	Bosun
C. Chalk	Bosun's Mate
K. Beck	SG1
M. Bowen	SG1
H. Owen	SG1
D. Peck	SG1
M. Riddy	SG1
A. Macaskill	Motorman
D. Summers	Motorman

M. Davis	2nd Cook
D. Edwards	A. Cook
N. Greenwood	Steward
J. Hanley	Steward
S. Hewitt	Ch. Cook
A. McMasters	2nd Steward

2. MEASUREMENT TECHNIQUES AND CALIBRATIONS

2.1 Sample Salinity Measurements

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

Initially, samples were drawn from all Niskin Bottles. A number of bad samples were obtained early in the cruise, probably because inexperienced watchkeepers were assisting with the sampling. The problem was rectified after the first few stations, as procedures were improved, experience increased and watchkeepers given further instruction and encouragement. Also, two bottles (numbers 6 and 10), were identified as leaky and not used. Data from these bottles are believed to be acceptable where given a quality flag of 2. Bottle 6 sometimes had a leaky bottom end cap (weak bungee), and bottle 10 had a dribbly bottom tap. No spares were available.

385 CTD samples were analysed using 43 ampoules of P120 standard seawater. Of these, 2 ampoules were bad (high salinity). Also there were several ampoules in this crate of P120 for which it was very difficult to clear the tip before opening, because the neck where the tip joins the main part of the ampoule was too narrow. One was so narrow that the sample tube was very tight in the neck; it would have been unusable without the peristaltic pump. Five ampoules of the latest batch (P123) were also used for comparison with P120. There was a consistent offset of 4 units of the Guildline display between standardisation with the two batches. Reported salinities would have been 0.0005 to 0.001 lower if P123 had been used as the standard.

A lack of spare tubing of correct size to go with the peristaltic pump was noted, although none was in fact needed. OSI now supply spare tubing with the pumps.

Only one significant problem occurred during sample analysis. The same problem had been seen on Discovery Cruise 201 (also in the Southern Ocean), but not really resolved. Cruise 201 employed a different peristaltic pump on a different Autosal. The problem and solution was as follows:

Sometimes, as the cell of the Autosal was filling, one or more (sometimes it could be described as 'a stream') of tiny bubbles would be seen entering the cell with the sample. The size of bubbles varied from those that were 'obvious', to those that were 'barely detectable'. Care was required to ensure that unnoticed bubbles did not lead to poor readings. If these bubbles did not pass through the cell, then they would generally have an effect on the reading. The solution adopted was to use the highest pump speed (speed 3) for flushing the cell, and to use speed 1 for filling the cell when a reading was required. The pump would then be switched off as soon as the cell was properly full, and a reading taken. Furthermore, when taking a reading, the Autosal display was observed for a suitable period, 15 to 20 seconds, and the highest persistent value recorded. The highest (rather than, for example, median) value was selected on the grounds that any undetected bubbles would cause the display to be biased low, but never high. Occasionally, a bubble would find its way through the cell during an observation period, but its effect was eliminated by selecting the highest reading. Since this procedure represented a departure from previous practice a number of tests were carried out, leading to the following conclusions:

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

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

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

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

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

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

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

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

Of the 385 samples analysed, 78 were duplicates (samples drawn from a second Niskin bottles closed at the same depth). There were 69 pairs of samples where both samples received a quality flag of 2, ie good. The rms of the difference between these 69 pairs was smaller than 0.001, suggesting that the bottle salinity analyses are of a high quality.

2.2 CTD Measurements

a) Gantry and Winch Arrangements

The CTD was deployed from the Midships gantry. The gantry is an A-frame, with the addition of a pendulum and roller. The distance from the pivot of the A-frame to the block is considerable, which has the advantage of giving the gantry a large outboard reach, but makes it more difficult to keep the package near the point of suspension. With a small package and generally calm seas, this was not a problem, however: when in air, the package was controlled by two seamen each with a hand-held line. It remains to be seen what procedures will be required when handling a full 24 x 10 litre rosette on the WHP cruise A23.

The wire was a single conductor 10mm steel rope manufactured by Rochester Cables, hauled by a 10T traction winch. The only noteworthy problem with the winch was a burst hose in the winch room which caused one station to be abandoned after paying out 150 metres of wire. The package was recovered and a repair carried out. The station was then completed normally.

b) Equipment, Calibrations and Standards

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

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

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

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

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

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

Temperature Calibration - 26 August 1993

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

Initial investigation of the temperature calibration had shown an unsatisfactory non-linear response near zero degrees centigrade, with errors of up to XXX millidegrees. This is associated with the electronics of the instrument near the change of sign. Accordingly, a temperature offset of about 2°C was introduced, so that likely oceanographic temperatures were all reported by the instrument as positive. The following calibration resulted, with an rms error of 0.2 millidegrees. The offset had the added effect, of course ,of reducing the maximum operating temperature of the instrument by 2°C as well, to about 30°C. This was not a limitation on this cruise, however !

$$T = -2.0851 + 0.99029 \times Traw + 1.091\,E\text{-}5 \times Traw ** 2$$

Pressure Calibration - 16 August 1993

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

Accordingly, the CTD postprocessing software was modified to allow a temperature dependence which is quadratic in pressure. The details are provided in Section 2.2c.

c) **CTD Data Collection and Processing**

Data Capture and Reporting

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

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

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

Temperature Calibration

The following calibration was applied to the CTD temperature data:-

$$T = -2.0851 + 0.99029 \times Traw + 1.091 E{-5} \times Traw ** 2$$

This calibration was in degrees C on the ITS-90 scale, which was used for all temperature data reported from this cruise. It was determined from a 13 point calibration on 26 August 1993.

A post-cruise temperature calibration was determined from a 12 point calibration on 24 June 1994 as follows:

T = -2.0887 + 0.99055 x Traw + 0.638 E -5 x Traw ** 2

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

For the purpose of computing derived oceanographic variables, temperatures were converted to the 1968 scale, using

T68 = 1.00024 T90

as suggested by Saunders (1990). However, all reported temperatures are in the ITS-90 scale.

In order to allow for the mismatch between the time constants of the temperature and conductivity sensors, the temperatures were corrected according to the procedure described in the SCOR WG 51 report (Crease et al., 1988). The time constant used was 0.20 seconds. Thus a time rate of change of temperature (called deltaT) was computed, from 8Hz data in the levelA, for each one-second data ensemble. Temperature T was then replaced by

T + 0.20 x deltaT.

Pressure Calibration

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

P = -5.8 + 0.99981 x Praw - 3.47 E -7 x Praw ** 2

followed by an addition of

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

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

W = exp (- tdel/tconst)

Tlag(t=t0+tdel) = W x Tlag(t=t0) + (1 - W) x T(t=t0+tdel).

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

A final adjustment to pressure is to make a correction to upcast pressures for hysteresis in the sensor. This is calculated on the basis of laboratory measurements of the hysteresis. The hysteresis after a cast to 5500m (denoted by dp5500(p)) is given in Table 2 for pressures at 500db intervals. Intermediate values are found by linear interpolation. If the observed pressure lies outside the range defined by the table, dp5500(p) is set to zero. For a cast in which the maximum pressure reached is pmax dbar, the correction applied to the upcast CTD pressure (pin) is

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

TABLE 2

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

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

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

P = -5.9 + 0.99883 x Praw - 1.97 E -7 x Praw ** 2

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

Salinity Calibration

Salinity was calibrated during the course of the cruise, by comparison with upcast sample salinities. (XXX more text will be inserted here with detail about problems of salinity fouling and calibration.) This was done on a station by station basis. A cell conductivity ratio of 0.97849 was estimated from early stations, and this was applied to all station data as an initial calibration. The initial calibration was followed by the correction to conductivity ratio:-

$$Cnew = Cold \times (1 - 6.5E\text{-}6 \times (T-15) + 1.5E\text{-}8 \times P)$$

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

$$a + b * T + c * P.$$

XXX Actually, it was rather more subtle than this. There were rather complex corrections over the first 10 or so stations, details of which need to be inserted after consulting data processing notes. The final text needs to include an estimate of the uncertainty of the CTD salinity cal.

SIS Thermometer Data

XXX This paragraph needs to be written after checking with shipboard notes. Two SIS RTMs and two RPMs were used. One RTM failed on the first station.

2.3 XBTs

Thirty-three XBTs (T5s and T7s) were deployed from a hand-held launcher attached to a Sippican Mk 9 deck unit interfaced to a PC. A table of station positions is included elsewhere in this report. It had been intended to use the SEAS software provided by the Hydrographic Department (who had also provided the probes) to log the data and generate JJXX messages which could then be sent by electronic mail to the UK for transmission to the GTS. Unfortunately, the software could not be made to run correctly. The SEAS software would not interface to the receiver properly through the installed GPIB board. The data were therefore logged using the Sippican software already on the PC, and data transferred for further processing by means of ASCII listings of depth-temperature pairs using floppy disks. Since no suitable software was available for the automatic generation of JJXX messages, and since it was not practical to read off the inflection points by hand, only delayed mode data will be forwarded.

On future cruises on this ship, an IOSDL data processing program will be taken which will automatically generate the JJXX messages. These can then be transmitted to the UK, and forwarded to the GTS with only a minimum of delay.

The hand held launcher was rewired during the cruise, the insulation having become damaged at some previous time. There were no other hardware problems with the XBT system.

2.4 Acoustic Doppler Current Profiler (ADCP) Measurements

Instrument performance

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

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

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

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

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

Determination of speed correction factor

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

Accordingly, the RDI DAS computes water velocities relative to the ship using the known angle of the transducers (30° to the vertical) and the speed of sound at the transducer. This may be specified to be a fixed value or, optionally, computed in the DAS from a fixed salinity and the temperature measured at the transducer. Unfortunately, the DAS does not seem to have an option for installations where the transducer is not surrounded by water; the option to compute sound speed in the DAS uses the equation of state for seawater. The PIs having failed on the cruise to grasp the significance of the oil filled sea chest, the data on this cruise were all acquired by employing a sound speed calculated from the reported temperature of the fluid surrounding the transducer, and the equation of state of seawater ! The use of the seawater equation is particularly bad because not only is the sound speed in oil different from that in water but, crucially, the variation of sound speed with temperature is opposite. In seawater, sound speed increases with temperature, while in a wide range of silicone oils it decreases by about 3 m/s per degree centigrade. Happily, this error can be corrected in post-processing, as described below.

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

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

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

F = 1 - 0.004785 x T + 0.0000355 x T ** 2

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

Determination of heading misalignment

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

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

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

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

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

The GPS minus ADCP directions form a reasonably consistent set, as shown in Figure 10. The mean value is - 1.73 degrees, with the standard deviation 0.13. Although this was not quite as tight a determination as had been anticipated, it seemed to be the best that could be found.

Further analysis of data

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

2.5 Navigation

a) GPS-Trimble

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

b) Differential GPS

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

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

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

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

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

Results

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

The second extended period of mooring was at the Biscoe Wharf at the British Antarctic Survey Base at Rothera (67°34' S, 68°08' W), a range of about 1800km from the base station. There was a little over two days worth of data collected here. The rms of the standard GPS positions was again 20m, but the DGPS provided rms variation of just 3m in latitude and 1.7m in longitude, based on 24 hours of 1-minute instantaneous fixes. Since the processing requires 4 common satellites between the two receivers, the DGPS dataset was not quite complete: 1428 positions out of a possible 1440 were calculated, giving a data return of better than 99%. Figure 9 shows the scatter of standard and DGPS positions.

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

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

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

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

b) Electromagnetic Log and Gyrocompass

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

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

c) Ashtech GPS3DF

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

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

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

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

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

Menu 4

posn	0,0,0
Alt known	N

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

ATTD CNTRL MENU

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

ATTD SETUP MENU

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

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

An estimate of the misalignment between the ADCP transducer and the direction defined by Ashtech heading has been made by examining ADCP bottom-tracking data throughout the cruise. After adding the Ashtech-gyro heading differences to the ADCP water-past-ship directions, the best estimate of the misalignment is XXX degrees, which also needs to be added to the ADCP water-past-ship directions. The determination of this offset is beyond the scope of this report; however, it is expected that it will be described in a publication in due course.

2.6 Underway Observations

a) Echosounding

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

One major problem with the PES Mk IV is that the array depth control is uncalibrated, and turns easily. It was found part of the way through the cruise that it was set to maximum, producing a depth offset of approximately 40 metres. It is believed that it had been inadvertently moved while an adjustment was made to the nearby loudspeaker volume control. The ease with which this mistake can occur is not satisfactory.

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

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

b) Meteorological Measurements

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

c) Thermosalinograph Measurements

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

Data from the southbound leg were calibrated by comparison with samples drawn once per watch.

Thermosalinograph data were assembled with the meteorological data on the oceanlogger PC, and logged to the shipboard computing system.

2.7 Shipboard Computing

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

A level A consists of a microprocessor based intelligent interface with firmware which collects data from a piece of scientific equipment, checks and filters it, and outputs it as SMP (ship message protocol) formatted messages. The messages are time-stamped by a ship master clock time, all the level A processors being attached to the same ship clock. The level A processors were all of MkII type.

In addition there are pseudo level A's which are in fact PC's around which a piece of equipment is based, which are also capable of generating SMP messages.

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

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

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

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

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

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

3. ACKNOWLEDGEMENTS

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

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

XBT probes were provided by the Hydrographic Department.

4. REFERENCES

CREASE, J. et al. 1988 The acquisition, calibration and analysis of CTD data. Unesco Technical Papers in Marine Science, No 54, 96pp.

POLLARD, R.T., READ, J.F. and SMITHERS, J. 1987 CTD sections across the southwest Indian Ocean and Antarctic Circumpolar Current in southern summer 1986/7. Institute of Oceanographic Sciences Deacon Laboratory Report No 243, 161pp.

SAUNDERS, P.M. 1990 The International Temperature Scale 1990, ITS-90. WOCE Newsletter No 10, p10. (Unpublished manuscript).

CTD STATION LIST

Stn	Cast	date mmddyy	time, gmt start	bottom	end	latitude		longitude		depth, m uncwtr	ht off	wire	max p	Samples no	notes
1	2	112093	2316	2355	0130	53 12.32	S	57 02.22	W	1893	40	1780	1839	12	
2	1	112193	1542	1551	1613	54 39.33	S	58 33.80	W	225	10	199	203	5	start section
3	1	112193	1809	1826	1855	54 55.34	S	58 21.71	W	619	25	580	591	8	
4	1	112193	1950	2009	2049	54 56.61	S	58 23.26	W	1068	20	1020	1045	10	
5	1	112193	2232	2305	2354	54 57.74	S	58 22.04	W	1610	20	1560	1601	8	
6	1	112293	0121	0202	0306	55 04.18	S	58 17.51	W	2096	20	2030	2085	11	
7	1	112293	0434	0524	0638	55 07.28	S	58 15.52	W	2549	25	2470	2537	12	
8	1	112293	0734	0829	0950	55 10.20	S	58 14.33	W	2991	20	3010	3083	11	
9	1	112293	1035	1150	1349	55 12.87	S	58 13.73	W	3750	45	3680	3785	12	
10	1	112293	1615	1729	1922	55 31.40	S	58 00.75	W	4260	50	4200	4277	12	
11	2	112393	0039	0158	0345	55 49.26	S	57 52.03	W	4651	60	4550	4687	12	
12	1	112393	0627	0732	0858	56 07.80	S	57 40.53	W	3718	20	3644	3749	12	
13	1	112393	1139	1243	1411	56 27.72	S	57 30.86	W	3638	20	3530	3633	11	
14	1	112393	1638	1724	1840	56 47.10	S	57 18.55	W	2595	60	2470	2535	12	
15	1	112393	2059	2215	2354	57 05.45	S	57 07.36	W	4468	65	4320	4425	12	
16	1	112493	0213	0321	0453	57 25.81	S	56 55.73	W	4051	45	3890	4005	11	
17	1	112493	0655	0755	0916	57 44.12	S	56 41.86	W	3480	55	3347	3419	10	
18	1	112493	1111	1219	1356	58 03.45	S	56 33.13	W	4025	25	3866	3981	11	
19	1	112493	1705	1845	1848	58 21.83	S	56 21.49	W	3908	50	3748	3849	12	report upcast data
20	1	112493	2054	2159	2340	58 41.34	S	56 09.42	W	3873	50	3700	3813	10	
21	1	112593	0157	0301	0439	58 59.84	S	55 57.77	W	3859	30	3704	3811	12	
22	1	112593	0649	0752	0919	59 19.02	S	55 42.59	W	3812	35	3697	3767	12	
23	1	112593	1146	1248	1423	59 38.78	S	55 31.04	W	3767	30	3630	3725	11	
24	1	112593	2121	2221	2344	60 00.30	S	55 19.09	W	3591	30	3440	3533	11	
25	1	112693	0207	0303	0425	60 20.36	S	55 04.75	W	3530	50	3357	3461	11	
26	1	112693	0630	0726	0838	60 40.48	S	54 48.67	W	3205	30	3080	3145	10	
27	1	112693	1117	1204	1318	60 47.97	S	54 43.15	W	2654	20	2595	2663	9	
28	1	112693	1354	1428	1519	60 49.99	S	54 43.42	W	1674	45	1750	1803	9	
29	1	112693	1610	1632	1704	60 51.07	S	54 42.84	W	1025	45	940	959	9	
30	1	112693	1807	1823	1847	60 58.83	S	54 37.11	W	630	10	565	581	7	
31	1	112693	1945	1952	2010	61 03.12	S	54 36.15	W	415	20	350	361	7	end section
32	1	121593	1010	1021	1047	62 11.04	S	55 30.40	W	496	20	470	479	10	
33	1	121593	1358	1444	1550	61 46.16	S	55 30.12	W	2418	25	2500	2571	10	
34	2	121593	1929	1938	2001	61 33.72	S	55 48.59	W	503	25	470	483	10	
35	1	121793	2332	2340	2357	53 48.08	S	59 00.99	W	321	18	321	317	6	
36	1	121893	0040	0056	0118	53 45.61	S	59 03.02	W	708	10	703	721	6	
37	1	121893	0233	0306	0352	53 35.61	S	59 08.00	W	1807	15	1790	1841	10	
38	1	121893	0607	0621	0644	53 16.20	S	59 18.60	W	663	10	650	669	6	
39	1	121893	0815	0822	0839	53 02.90	S	59 25.31	W	292	15	280	287	5	

1	1	112093	2316	2355	0130	53 12.32	S	57 02.22	W	
2	1	112193	1542	1551	1613	54 39.33	S	58 33.80	W	start section
3	1	112193	1809	1826	1855	54 55.34	S	58 21.71	W	
4	1	112193	1950	2009	2049	54 56.61	S	58 23.26	W	
5	1	112193	2232	2305	2354	54 57.74	S	58 22.04	W	
6	1	112293	0121	0202	0306	55 04.18	S	58 17.51	W	
7	1	112293	0434	0524	0638	55 07.28	S	58 15.52	W	
8	1	112293	0734	0829	0950	55 10.20	S	58 14.33	W	
9	1	112293	1035	1150	1349	55 12.87	S	58 13.73	W	
10	1	112293	1615	1729	1922	55 31.40	S	58 00.75	W	
11	1	112393	0039	0158	0345	55 49.26	S	57 52.03	W	
12	1	112393	0627	0732	0858	56 07.80	S	57 40.53	W	
13	1	112393	1139	1243	1411	56 27.72	S	57 30.86	W	
14	1	112393	1638	1724	1840	56 47.10	S	57 18.55	W	
15	1	112393	2059	2215	2354	57 05.45	S	57 07.36	W	
16	1	112493	0213	0321	0453	57 25.81	S	56 55.73	W	
17	1	112493	0655	0755	0916	57 44.12	S	56 41.86	W	
18	1	112493	1111	1219	1356	58 03.45	S	56 33.13	W	
19	1	112493	1705	1845	1848	58 21.83	S	56 21.49	W	
20	1	112493	2054	2159	2340	58 41.34	S	56 09.42	W	
21	1	112593	0157	0301	0439	58 59.84	S	55 57.77	W	
22	1	112593	0649	0752	0919	59 19.02	S	55 42.59	W	
23	1	112593	1146	1248	1423	59 38.78	S	55 31.04	W	
24	1	112593	2121	2221	2344	60 00.30	S	55 19.09	W	
25	1	112693	0207	0303	0425	60 20.36	S	55 04.75	W	
26	1	112693	0630	0726	0838	60 40.48	S	54 48.67	W	
27	1	112693	1117	1204	1318	60 47.97	S	54 43.15	W	
28	1	112693	1354	1428	1519	60 49.99	S	54 43.42	W	
29	1	112693	1610	1632	1704	60 51.07	S	54 42.84	W	
30	1	112693	1807	1823	1847	60 58.83	S	54 37.11	W	
31	1	112693	1945	1952	2010	61 03.12	S	54 36.15	W	end section
32	1	121593	1010	1021	1047	62 11.04	S	55 30.40	W	
33	1	121593	1358	1444	1550	61 46.16	S	55 30.12	W	
34	2	121593	1929	1938	2001	61 33.72	S	55 48.59	W	
35	1	121793	2332	2340	2357	53 48.08	S	59 00.99	W	
36	1	121893	0040	0056	0118	53 45.61	S	59 03.02	W	
37	1	121893	0233	0306	0352	53 35.61	S	59 08.00	W	
38	1	121893	0607	0621	0644	53 16.20	S	59 18.60	W	
39	1	121893	0815	0822	0839	53 02.90	S	59 25.31	W	

these numbers are identical to previous page.