MINISTRY OF AGRICULTURE FISHERIES AND FOOD
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RRS DISCOVERY CRUISE 200

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Circulation and structure in the Southern Ocean between 20°E and 90°E and 40°S and 65°S. Part of the World Ocean Circulation Experiment

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SCIENTIFIC OBJECTIVES

The main scientific objectives and activities of *DISCOVERY 200* form part of a wider international investigation into the rates and pathways of the global abyssal circulation as a component of the World Ocean Circulation Experiment (WOCE), and are intended to coordinate with other research programmes being undertaken in the Southern Ocean as part of the UK WOCE effort.

The principal objectives were as follows:

1. To make direct measurements of the flow of deep and bottom waters passing eastwards from the Enderby Abyssal Plain to the Southern Indian Ocean via deep topographic gaps to the northeast and southeast of the Kerguelen Plateau. Specifically, to lay two main arrays of current meters with 10 moorings (42 current meters) and 2 Bottom Pressure Recorders in the main gap between Crozet and Kerguelen, supplemented with a mooring in the deep cleft immediately to the west of Crozet Island, and a further 5 moorings (13 c/m) in the Princess Elizabeth Trough between the Kerguelen Plateau and Antarctica.

2. To extend two of the moorings of the main Crozet-Kerguelen array up into the near-surface layers to aid the subsequent SWINDEX investigation into the interactions of the Agulhas and Antarctic Circumpolar Currents (*DISCOVERY 201*).

3. To use a range of tracers including the CFCs10,11,12,113, inorganic nutrients, dissolved oxygen, and oxygen and hydrogen isotopes (indicating meltwater content) to partition the deep throughflow into its constituent watermasses and to identify these as to source using a widely-spaced set of upstream measurements [on this cruise and using the complementary data set from the Swedish Antarctic Research Program, (SWEDARP) aboard *RV LANCE* in the Weddell Sea area].

4. To make discrete measurements of CO_2 partial pressure in seawater (pCO_2), total seawater CO_2 content (TCO_2) and appropriate measures of biological activity throughout the cruise-track as a BOFS/PRIME component of the BAS Antarctic Special Topic, and as a necessary determinand of WOCE.

5. To make measurements of biogenic dimethylsulphide (DMS) and its precursor (DMSP) at regular intervals throughout the ship's track, as a component programme of the BAS Antarctic Special Topic.

6. To monitor a suite of discontinuous and continuous environmental variables throughout the cruise, including bathymetry from PES, XBT, ADCP, multimet, wave recorder and thermosalinograph.

7. To use a range of satellite-derived ice and weather intelligence where possible and appropriate.

All these objectives were met in full with the exception of number 4. There the lack of a fluorometer restricted the ancillary monitoring of biological activity to hourly filtered samples, and the earlier inadvertent loss of the WOCE TCO_2 standard during the Ship's passage south in 1992 reduced the usefulness of these measurements also, as it had for *DISCOVERY 198*. The outcome is that WOCE standards will be met on this cruise for pCO_2 but not TCO_2.

NARRATIVE (Figures 1(a)-(c))

During the few days prior to sailing, our chief preoccupation was with the CFC gear from the University of Goteborg which had been embargoed by Customs/DTI at Heathrow while passing through to Cape Town under carnet. This problem was resolved in time to catch the late night plane on Friday 5 February so that this final consignment arrived aboard ship in the early afternoon of Saturday 6 February/Day 37. (Day numbers and GMT will be used throughout the remainder of this Narrative.) The ship sailed from Cape Town at 1302, day 37, only a few hours later than planned. Heading south towards our first main working area, the ADCP was calibrated on a straight-line course while on bottom-track, and a trial of a suspect load cell on the CTD winch was conducted when the bottom deepened to 1500 m. The PES fish was deployed at 1840, and watches began thereafter. For the remainder of the cruise except during the more intensive periods of station and mooring work, when personnel were deployed to other duties, these watches maintained continuous monitoring of the suite of environmental parameters — bathymetry/PES, ADCP, Multimet, thermosalinograph and four-hourly XBT. Later during day 37 the ADCP recorded a spectacular Agulhas signal of about 100 cm s^{-1} westward.

Day 38, which began with 30 knots on the bow and a good swell was largely spent in setting-up, with continued trials of the CTD winch system to check the effect of repairs. It was at this stage, during the setting-up and first trials of the pCO_2 and DMS analysis systems that the lack of a fluorometer was noticed for the first time. The hourly filtration and freezing of phytoplankton samples began as a substitute and was to continue throughout the cruise, but the lack of any continuous measure of a variable as rapidly-changing as phytoplankton standing stock was a continuing and serious drawback to the interpretation of both pCO_2 and DMS distributions. This was compounded in the case of TCO_2 by the continuing effect of the inadvertant destruction through freezing and breakage of the appropriate WOCE standard during the vessel's passage southwards the previous year. This meant that while pCO_2 determinations were to WOCE standard, the TCO_2 results were not. It was at this stage too that the CFC system was experiencing an unacceptably high contamination level, but this problem was overcome and it remained clean throughout the cruise, although — at the levels of accuracy demanded by our deep water objectives — not without a considerable and continuing effort to keep it that way, and a few transient alarms.

By day 39, all systems were sufficiently up and running to justify a full-depth CTD station, and this was worked to 4818 m in the Agulhas Basin, combined (as was to be our usual practice) with the deep wire-test of two acoustic releases mounted on the outer ring of the Multisampler rosette. Although both releases were subsequently discovered to have fired when examined aboard ship, the loss of the Waterfall system (which had crashed its hard disk) and the noisy acoustic conditions with 30 knots and a large swell made the actual wire test somewhat ambiguous. The chemistry posed few problems on this first run, although we found no way to operate the UCNW endpoint detection system for oxygen and had to rely on more traditional methods. This situation persisted throughout the cruise but the comparison of the bottle oxygens with those from the CTD O_2 sensor proved no worse than on the previous cruise, *DISCOVERY 199*.

The remainder of our southward passage to our first main working area passed uneventfully, although the early appearance of our first substantial bergy bits of ice on day 41 at 47.5°S accelerated the demand for the fullest possible range of ice intelligence by the Master; from then on since we were rarely free from the presence of ice, the ship's speed was reduced to 5-6 knots during the hours of darkness to minimise the risks of collision with sea ice too small to be detected on radar. This practice continued until the vessel passed northwards through the Antarctic Convergence once again some 21 days later, and though it might have affected progress around our long sea-track, in practice it had no noticeable effect since nights were short and daytime sea-states were such as to allow full speed.

Some replanning of an optimum cruise track for following the Weddell Sea outflow eastwards towards Kerguelen had taken place during the steam south. It was thought that the original plan of working a zonal line of widely-spaced stations would suffer from ambiguities of not knowing where they were located in relation to the expected zonal tongue of tracer. Accordingly it was decided that the tongue and its eastward change in characteristics would be better defined by adding a further meridional section across the tongue to supplement the existing or prospective SWEDARP, A-23 and AJAX freon sections further west and the I-6, ANTARES, and our own freon sections further east.

With some regard to the need to reduce our track-length where practicable, a 900 mile 7-station section was planned running southeastwards from the Southwest Indian Ridge crest at 52°S 18°E, to the Gunnerus Ridge which carries the Antarctic Continental Margin northwards clear of the ice-edge at 64°S 32°E approximately. This section was worked without incident and in steadily-improving weather from 1107, day 42 to 0914, day 48. Pairs of acoustic releases were wire-tested on each lowering, and during the lengthy period of sequential sampling from the 24-bottle rosette before the ship moved off-station, the opportunity was taken to stretch mooring cable over the stern using the double barrel capstan winch in preparation for mooring-work to come.

This protracted period of CTD work highlighted the recurrence of an old problem of misfiring by the Multisampler, encountered on earlier cruises, and which — even with a great deal of painstaking work by RVS staff — we were never to be free from for more than three or four stations on this cruise. While misfiring was light to moderate, we were well able to assign the true bottle-firing sequences and depths by reference to silicate levels and bottle: CTD salinity differences. However the heavy misfiring that occurred towards the end of this first CTD section began to cost us valuable vertical resolution as an unacceptable number of double-firings took place, and on the final station, continuous misfiring from mid-depths upward forced a second cast.

A second potential problem that proved more tractable was the fact that on the abyssal plain stations deeper than 5000 m, the wire loadings from the wire weight and from our draggy rosette were nearing or exceeding the preferred RVS working limit of 2.25 t. Calm weather and the removal of unneccessary instruments (releases) from the rosette solved the problem for the few remaining very deep stations.

Thereafter, from leaving the Gunnerus Ridge at 0914, day 48 until arrival at our second main working area in the Princess Elizabeth Trough (PET) at 0800, day 54, advantage was taken of the long steam to strip down and repair the multisampler, recalibrate the ADCP on a zig-zag run off Cape Ann, complete analysis and fault-finding on the freon system, and to begin a series of informal seminars for all ship's staff. In addition, the vessel diverted close-in to the Antarctic Slope to re-work a French freon station that had found enhanced near-bottom freons 5 years earlier, and essentially-similar conditions were found.

To aid our eastward navigation around the ice-edge and to prepare us for conditions in the Princess Elizabeth Trough, every possible form of ice intelligence was brought to bear, including direct imagery, analyses of ice-edge position from NOAA and the Met. Office, the ice edge from satellite altimetry by the Mullard Space Science Lab and some preliminary radio interchanges with the nearby Australian bases at Mawson and Davis. In the event, ice conditions proved light and were no problem to our PET operations.

From arrival 0800, day 54 to departure at 0415, day 56, *DISCOVERY* was able to work her full planned programme of 8 full-depth CTD casts and 5 current meter moorings across the Trough in moderate-to-placid weather conditions, including a double dip at the southernmost point to obtain a Cadmium profile for Dr. Frew. At 2000, day 56, watches were resumed for the steam north along the Kerguelen Plateau to our third and final working area in the Crozet-Kerguelen Gap. The resumption of the Multisampler's misfire problems on the final Trough station because of water in the wafer switch, and some brief contamination worries in the freon system brought the same needs for repair work en route. Wind and swell conditions worsened more or less continuously during this north-bound leg bringing extended periods of steaming at reduced speed, and station work was restricted to the collection of a full 24-bottle rosette sample from the deep freon minimum layer (1000 m) west of Heard Is. to check the multisampler for possible freon contamination (negative).

On arrival west of Kerguelen, the vessel immediately started into the heavy work schedule of her third main working area. From 0900, day 63 until 1540, day 69 and despite recurrent and persistent rough weather conditions, the ship was able to complete her full planned programme of 10 Current meter moorings in the Crozet-Kerguelen Gap, including two full-depth rigs during temporary lulls on days 65 and 68 and after bathymetric survey had confirmed suitable topography in each case; the two POL Bottom Pressure Recorders had been precisely located on the 3600 m contour at either end of the array; and a total of 9 full-depth and fully-sampled CTD/freon stations had been worked between the moorings. During this period, the vessel was forced to abandon work and dodge on only one occasion from noon day 66 to noon on the following day while windspeeds gusted to 60-70 knots, and on only one other occasion (during mooring 93-13) did working conditions become marginal. They were almost continually difficult however and the fact that we fulfilled our entire work schedule on time in this key area is due in no small measure to the skill and willingness of the Ship's officers and crew in taking each realistic chance that offered.

Only one of the 10 moorings (93-08) failed to respond to interrogation after deployment suggesting a possible problem next year, but this may merely reflect the poor acoustic conditions prevailing at that time.

From 1540, day 69 with the work east of Crozet completed and in the first calm and sunny conditions for several days, *DISCOVERY* continued west to the detached mooring site in the deep cleft west of Crozet. There, the final (eighteenth) mooring was set by 1345, day 70, followed by its corresponding CTD station by 1715. During this station, most components of the CTD system began to show signs of fatigue: the gantry initially refused to go through its usual deployment evolutions, an altimeter connector problem caused data dropout, the multisampler started to register multiple misfires (although without actually misfiring), and a hydraulic hammering began to be obvious in the pipes of the CTD winch.

Accordingly, with her full work programme essentially complete, *DISCOVERY* set sail for Cape Town, and watchkeeping with XBT and environmental monitoring as normal was resumed from 2000. Thereafter, with the exception of a shallow CTD dip to 500 m on day 73 to check on repairs to the system and to provide a third near-surface Cadmium profile for Dr. Frew, the work programme was run down, and after an afterdeck barbeque, slide show and RPC on the afternoon of day 75, *DISCOVERY* continued uneventfully to Cape Town, docking at 1115, day 77.

The almost complete fulfillment of such a complex set of objectives over a cruise track some 7673 miles long and often in trying circumstances says much for the capabilities of the renewed vessel; the high morale of the scientific staff throughout the cruise was as much the result of the astonishing quality of the catering as a reflection of their own undoubted achievements; and finally, it is a pleasure to acknowledge the considerable part played by the entire ship's complement in meeting the demands of our work programme with skill and flexibility. Together, these elements made for a memorable and enjoyable cruise.

RRD, PSO
RRS DISCOVERY 200

March 1993

INDIVIDUAL PROJECT REPORTS

CTD (Figure 1(b))

CTD operations

The CTD/multisampler package consisted of the IOSDL NBIS Mk IIIB with Beckman oxygen sensor. The CTD lay horizontally with the axis of the conductivity sensor vertical and alongside the SeaTech 1m folded-path transmissometer. These were located beneath the General Oceanics 24 x 10 l multisampler and all enclosed within a weighted protective frame. The package was also fitted with a Simrad 200 kHz altimeter which measured height above bottom when within the lockout range of 204.8 m. On early stations a 10 kHz bottom finding pinger was attached but this was removed after the first station as its signals interfered with the interpretation of the tests of acoustic releases which were carried out by attaching the release units to the outside of the CTD frame.

The CTD package was prepared initially by cleaning the transmissometer glass faces and measuring the voltage output. However by the middle of the cruise persistent problems were encountered with noisy transmissometer data. Changing the cable harness did not cure the problem which was traced to corrosion of one of the connector pins on the transmissometer. In view of this, from station 12373 onwards the transmissometer faces were cleaned but the air calibration voltage not measured. The deck values of pressure and temperature were noted before deployment.

Many stations were worked in conditions of large swell and, to avoid having to keep the CTD package near the sea surface at the start of each station, data logging was started with the CTD on deck and lowering was continuous once the CTD had entered the water. Lowering rates were low (30 m/min or less) for the top 1000 m or so of each cast, depending on sea state, and increased to 50-60 m/min at deeper levels. This ensured that there was little chance of damaging the wire and indeed the only requirement to re-terminate the wire during the cruise was when it was damaged by welding work on deck.

The CTD was lowered typically to within 20 m of the sea bed, the down cast terminated and the bottles fired on the up cast. Hauling rates ranged from 50-70 m/min but were slower to avoid high tensions on stations to 5000 m or more early in the cruise. There were, as on almost all cruises, persistent problems with the multisampler reliability.

On recovery the deck values of CTD pressure and temperature were again noted, bottles checked for leaking taps and end caps and the digital pressure and temperature meters on bottles 1,4,8 and 12 recorded.

Sampling was in the following sequence

CFCs
Oxygen
Nutrients
Salinity
Oxygen/hydrogen isotope ratios.

Information on individual stations is given in Table 1.

Apart from the transmissometer problems mentioned above, the CTD ran faultlessly until the last full depth station (12385). Here pressure spikes and data dropout started and persisted throughout the cast despite a change to the duplicate CTD power supply. The fault was later identified as being in a leaking connector on the altimeter. This and an accumulation of dirt on the winch slip rings was causing a drop in cable voltage and hence affecting other data channels. The fault was recified prior to the final station.

PGT, WJG, JB

Rosette multisamplers

A modified General Oceanics 24 bottle rosette multisampler, fitted with 10 l Niskin bottles was used with the CTD package. The modification incorporated a set of EG&G electronics modules, which permitted bottle firing without loss of CTD data. Whilst the EG&G units worked fine, the General Oceanics electromechanical pylon assemblies (s/n 1 and 2) persistently gave trouble. The problems experienced on *DISCOVERY 199* recurred, s/n 1 double fired and occasionally jammed whilst s/n 2 was prone to leakage. S/n 1 was found to have a worn ramp shaft assembly and loose motor housing; s/n 2 had a pitted ramp shaft o-ring groove and a corroded motor housing. S/n 2 was serviced and performed adequately for most of the cruise. During the last CTD section another slight leakage caused corruption of the confirmation signals but did not affect bottle firing. Replacement spare parts were requested for *DISCOVERY 201*.

PGT

CTD data processing (Figure 2)

Processing of CTD data was in two parts; one for the continuous, 1 hertz data, the second for the bottle sample data. The two parts met for the purpose of calibrating the continuous salinity and oxygen data against the bottle samples.

Continuous CTD data were read from the level C, and converted to PSTAR. The raw data were calibrated using established PEXEC routines which, having been documented in previous cruise reports, are not described in great detail here. Readers are referred to the CTD data report for *DISCOVERY 189* for more detail. In brief, the following processing was carried out on the data. Pressure data were corrected with an exponential decay to offset the response of the cell to changes in temperature with time. Additionally, upcast pressures were adjusted to minimise the effects of hysteresis. Because the temperature sensor responds more slowly than the conductivity sensor, temperature data were accelerated (approx. 0.2 seconds) to match with the conductivity measurements. Temporary calibrations were applied to the salinity and oxygen data, and were updated after comparison with the bottle data. The 1 hertz data from the downcast were median despiked, with gaps filled using linear interpolation, then averaged into 2 dbar intervals.

Bottle firing times and codes were logged on the RVS level C. These data were read to PSTAR and merged with winch data (cable out), and 10 second averaged, continuous data from the CTD upcast. Since oxygen data from the upcast is unreliable, (due to the inconsistent flow past the sensor), oxygen data from the downcast were used, matching on pressure with the upcast. The resulting firing file contained continuous CTD data at the times when bottles were supposedly fired, (which in some cases was more than the number of bottles). By comparing these data with the sampled data, the true sequence of firing depths was produced, and the firing file was reordered accordingly to contain 24 values.

Meanwhile, sample data from the bottles (including reversing thermometer and pressure sensors) were collected in separate Excel spreadsheets on one of the Apple Macintosh Classics, and these were transferred to the Sun workstations using ftp, and converted to PSTAR. For each CTD station, a master file of bottle data was created, containing all sample data, and the matching continuous CTD data from the firing file. Once the sample and continuous data were combined, salinity and oxygen calibration coefficients were calculated, and the 1 hertz data was recalibrated. All data were then reworked to ensure the calibrated salinity and oxygen data filtered through to the master sample file.

All processing was carried out using Unix C-shell scripts, developed on the previous *DISCOVERY* cruise and all worked reliably.

Additionally, on this cruise, CTD data from the Kerguelen Crozet Trough were formatted into TESAC messages, to supplement the XBT data sent onto the GTS (Global Telecommunications System). TESAC messages are composed of TEmperature, SAlinity and Current data, although current data is optional and was not sent in any of our messages. The message protocol (WMO Code FM-64V) allows up to 25 records of depth, temperature and salinity to define the water column. These data were selected from the two decibar averaged CTD data using an algorithm developed at NOS (National Oceanographic Service) in the USA, which uses changes in the property gradient to pick out data. Software written at IOS implemented this algorithm, and allowed the users to interactively de-select chosen points or choose alternatives. These data were then formatted to FM-64V, written to floppy disk and transferred to the XBT personal computer (pc). On the pc, a version of the Seas software (modified at IOS), loaded the TESAC data into the MET buffer, ready for transmission. Unfortunately, a request to Darmstadt for a new METEOSAT transmission id was not forthcoming, so TESAC data had to be transmitted at the same time as XBT data. To prevent loss of XBT data, TESAC messages were planned for periods when no XBTs were dropped; i.e. the mooring sections. To add insult to injury, after the first message had been sent (ctd12349), the satellite transmitter developed a fault, preventing further data from being transmitted. Subsequent TESAC data were sent (along with the now beleaguered XBT data) direct to the RTH in Hamburg, with the routine meteorological observations submitted by the ship's officers. We await confirmation that these messages were received intact. Messages were formatted and sent for the following stations:

ctd12349 ctd12364 ctd12368 ctd 12369 ctd12372 ctd12373 ctd12380 ctd12381
ctd12383 ctd12385

MJG, WJG

Reconciliation of bottle and CTD data and CTD calibrations

The first task in the production of calibrated CTD data was the confirmation of the depths of closing of the multisampler bottles (Table 2). The performance of the sampler remained problematical throughout the cruise and the confirmation of sample depths was therefore important. Three information sources were used :-

1. Digital pressure/temperature meters
2. Bottle salinities.
3. Nutrient values.

Digital P/T meters were only used at 4 bottles and therefore could not define all levels. The nutrient values could, in areas of nutrient gradients, identify where bottles had fired in pairs but could not provide information on what that level had been. The bottle salinities were compared with those values (calibrated using a nominal initial calibration) in the firing file. The firing file is generated by the CTD and records values averaged for 5 seconds either side of the bottle firing. Experience showed that the CTD-bottle differences changed smoothly throughout the depth range of the cast and so in all but areas of very weak salinity gradient the salinity information combined with the other data allowed an unambiguous sequence of bottle firing depths to be established for each station.

The discrete bottle oxygen and salinity values were then used to calibrate each individual station, using the series of PSTAR executives detailed in the CTD processing section.

For salinity, grouped calibrations were established for each major work area (Enderby Basin, Princess Elizabeth Trough and Crozet/Kerguelen). Residuals between the calibrated CTD and the bottle salinities for these three groups are shown in Figure 3. All demonstrate a similar shape and one that is much like that established on *RRS CHARLES DARWIN 62* (CONVEX) using the same CTD and similar data processing path.

Similarly the CTD oxygen data were calibrated using the bottle values. The behaviour of the oxygen sensor is such that the recorded values are dependent on flow rate past the sensor. To reduce this effect, the discrete samples taken on the up cast were used to calibrate the CTD oxygens from the down cast. Matching was done on the basis of pressure. The up cast CTD oxygens were discarded. The algorithms used were as on *DISCOVERY 199*. These were found to give a poor reproduction of the deep oxygen profile and a modified algorithm developed by Brian King after this cruise was subsequently used to rework the calibarations.

Two other comparisons can be made that shed light on the quality of the data.

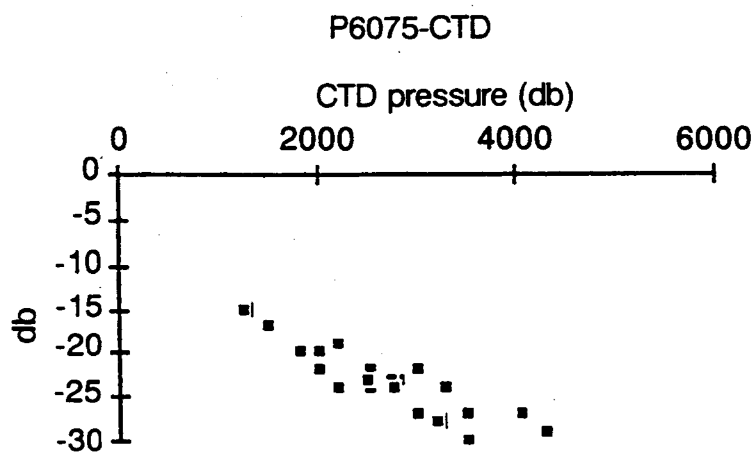
The digital temperature meters can be compared with each other (where they are paired) and in every case with the CTD temperatures from the firing files. The temperature meters had been calibrated and in what follows the results all apply to the calibrated data.

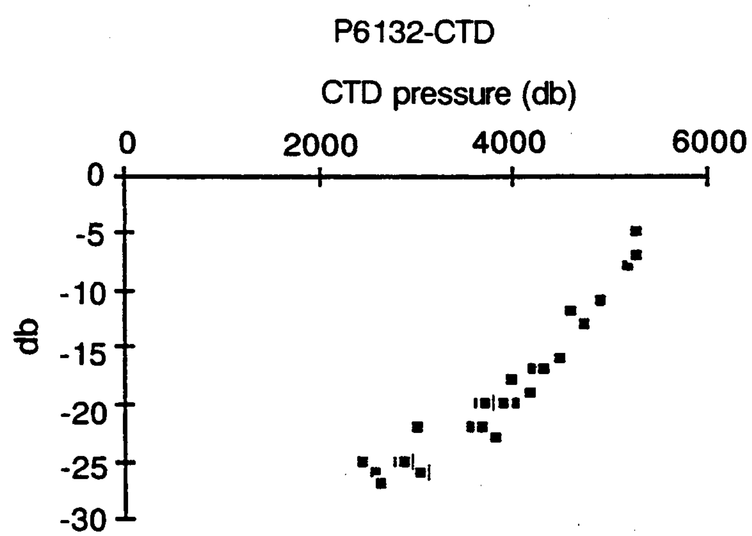
Thermometer no.	Therm - CTD (Mean±SD) m°C	Number of obs.
219	7.1 ± 5.0	26
220	-3.1 ± 2.6	25
238	-1.6 ± 1.7	24
399	1.6 ± 1.0	7
400	-1.4 ± 1.4	25
401	-3.8 ± 1.3	25

The results of the comparison of paired thermometers are:-

219 - 401	10.9 ± 4.6	26
399 - 400	0.7 ± 1.6	7

Similarly comparisons can be made between the CTD pressures and those recorded on the digital pressure meters. In this case the measurements were made over a considerable range of pressures and so we have investigated the pressure dependance of the differences. These are shown in the following two plots:





Clearly the behaviour of the pressure meters vis à vis the CTD is systematic and pressure dependent. The fact that the two meters have a pressure dependence of opposite sign suggests that the pressure dependent error is not in the CTD sensor.

Finally a check was made of the mismatch between the water depth on each station measured by the echosounder and corrected for the assumed speed of sound using Carter's Tables and that calculated from the CTD pressure (converted to depth according to Saunders, 1981) added to the height above bottom measured by the altimeter. The mean difference (water depth - CTD depth) = 1.1 ± 10.1 m for the 24 stations for which data were available. In view of the fact that several of the stations were in frontal areas where Carter's Tables might be in error, the results are most encouraging.

WJG

Bottle salinities

Bottle salinities were taken in order to calibrate the CTD and the thermosalinograph. Samples were contained in glass bottles sealed with push in polyurethane inserts and secured with a screw cap.

Sampling in every case involved emptying the old sample, rinsing three times with the new sample and finally filling to the shoulder of the bottle, drying the neck with a tissue and sealing the bottle. In the case of the multisampler all external water drops were removed from the area around the tap before sampling began.

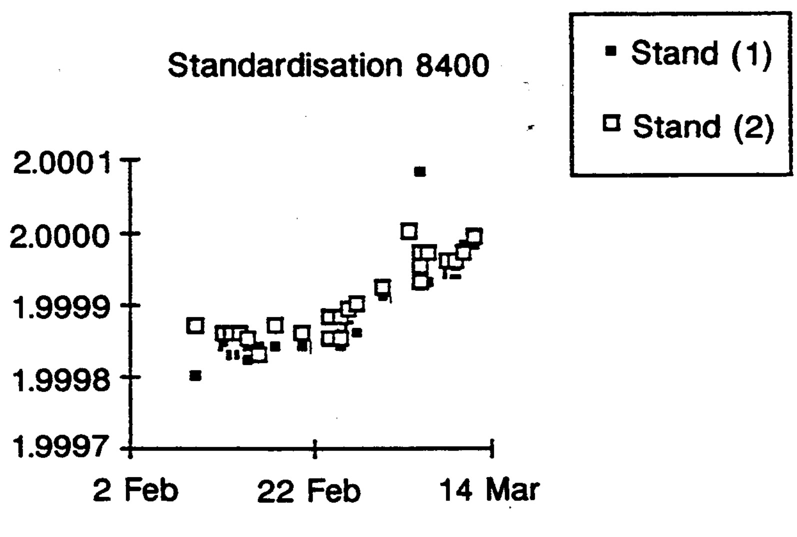
The bottles were in crates of 24. This meant that for the thermosalinograph it was sometimes 4 or more days between a sample being taken and its analysis on the salinometer. For the CTD samples this delay between sampling and analysis was never more than 24hrs. Sample crates were kept in the lab with the salinometer for the sample temperature to equilibrate before analysis.

The salinometer was the IOSDL Guildline Autosal model 8400A with a Ocean Scientific International peristaltic pump. The unit was housed in the constant temperature laboratory. The laboratory temperature was set at 21°C and the bath temperature at 24°C. The salinometer was powered by a filtered mains supply that had been installed on *DISCOVERY 198* to eliminate voltage spikes.

The salinometer was standardised with ampoules of P120 IAPSO Standard Seawater. The method adopted was to standardise with a new ampoule at the start of each box, to seal the ampoule with 'Blu Tac' and then to use the remainder of the ampoule to restandardise at the end of each box.

No problems were encountered with the operation of the salinometer. Its standardisation remained very steady and there were no problems with cell fouling.

The recorded standardisations are shown in the plot below:



The data show that with the exception of one standardisation there was a steady trend in the values that amounted to a shift of 0.0003 during the duration of the cruise. This continues a trend seen towards the end of *DISCOVERY 199*.

Duplicate salinities were taken from rosette bottles 1 and 12. Bottle 2 was in all cases closed at the same depth as bottle 1. An analysis of the differences show the following:-

Bottle 1 - duplicate	0.0010 ± 0.0012
Bottle 12 - duplicate	-0.0004 ± 0.0007
Bottle 1 - Bottle 2	0.0009 ± 0.0007

There seems to be a significant difference between the reproducibility of duplicates at the deeper bottle 1/2 level and at bottle 12.

The differences between bottles 1 and 2 are also larger than might be hoped. Inspecting differences between the CTD data and the salinities from bottles 1 and 2 suggests that there is less scatter in the bottle 2 data, perhaps indicating an occasional leakage in bottle 1.

SRJ, WJG

Chemistry

Oxygen

Much of the first few days was occupied by efforts to get a satisfactory performance from the photometric end-point detector recently purchased from UCNW Menai Bridge by MAFF. Unfortunately, due to container shipment deadlines there had been no opportunity to test the instrument in the laboratory at Lowestoft.

A major problem was that the instrument produced an output signal with an excessive noise-level sufficient to obscure anything meaningful that may have been underlying. We could find nothing amiss electrically or optically but are satisfied the noise is synchronous with the ship's motion. There was no alternative other than to revert to a visual end-point. Using the magnetic stirring and illuminating facilities of the UCNW instrument and manually operating the Metrohm 665 Dosimat, enabled titration to a visual end-point with starch indicator; somewhat less precise than the WOCE recommendations, but a reasonably satisfactory solution.

Some problems were encountered during the earliest stations. A hand-held repetitive dosing pipette proved unequal to the task of dispensing a relatively viscous reagent. Its internal ratchet mechanism developed an intermittent fault before it failed completely, and a few suspect oxygen values are traceable to this period. After reverting to a simpler more robust pipette, not quite so convenient to use but one whose performance could readily be seen and felt to be satisfactory, the problem was overcome.

Quality Control

The primary standard iodate solution used for standardising the thiosulphate titrant was supplied by WAKO Chemicals GmbH, Neuss, Germany, and is guaranteed by the Sagami Chemical Research Center. (Lot No. TWP8499).

The thiosulphate was checked on each occasion that analysis was carried out and its stability probably owes much to the fact it was prepared using high-purity water and all operations were under artificial light.

As a check on the overall precision of the method, the CTD multi-sampler filled twelve bottles at a depth of 1000 metres, and these produced oxygen concentrations in the range 4.21-4.24 ml/l.

Given that the readability of the digital burette is 1 microlitre, and a typical titration consumes 500, this level of precision is as good as we are entitled to expect.

Oxygen data

A total of 664 Winkler determinations were made.
Figures 4(a) and (b) show potential temperature/oxygen plots for Winkler and CTD oxygen respectively.
Figure 5 illustrates the differences between these as a function of depth. Differences are most likely to be greatest at depths where substantial gradients occur; the distribution is consistent with this assumption.

Nutrients

A total of 921 samples of seawater were analysed for nitrate, phosphate and silicate using the MAFF 'SKALAR' continuous-flow auto-analyser.

Of these, 652 came from 29 CTD casts, and the remaining 269 were 'surface' samples in support of pCO_2 and DMS measurements. (These were taken from the ship's non-toxic supply at approximately hourly intervals while steaming between 25 February and 14 March).

Procedures

Samples were drawn directly from the CTD rosette bottles into 1-litre polyethylene bottles and were analysed without filtration within one or two hours. The analytical methods used differ in some important details from those originally supplied by the manufacturer.

In general, changes have been made to bring them into line with recent improvements in current practice; for example, the silicate method (based on that of Grasshoff, 1983) has a calibration slope almost independent of salinity and laboratory temperature fluctuations. (Full details of these are due to be published soon by ICES in the 'TIMES' series, Techniques in Marine Environmental Science, entitled 'Nutrients : Practical Notes on their Determination in Seawater').

The auto-analyser's carousel uses 8-ml cups which are thoroughly rinsed with sample. Analysis was by single determination unless results appeared to be in any way 'oceanographically inconsistent', in which case repeats were performed to resolve the problem. (These were rare events, generally due to mild contamination of sample cups during handling).

Silicate analysis was of great value in confirming sampling depth, given that the firing mechanism of the CTD multi-sampler suffered intermittent faults. It also resolved a problem of mis-identification in freon analysis, the residual sample in a syringe being readily attributable to a particular depth.

Quality Control

During *DISCOVERY 199* a bulk sample of typical seawater was stored under refrigeration in a polyethylene carboy. Mean concentrations for this QC sample were supplied before *DISCOVERY 200* commenced, and regular analysis continued throughout the cruise.

The means are as follows -

	nitrate	phosphate	silicate
D-199	28.85	1.79	78.85
D-200	25.2	1.74	80.2

Agreement in phosphate and silicate is excellent.
D-199 reported a 'gradual decrease in nitrate' in this sample and at first glance the D-200 mean appears consistent with this, however, there is no time trend evident within the D-200 data.

Date	Nitrate	Phosphate	Silicate
08.02	25.5	1.70	80.4
09.02	25.8	1.70	80.6
11.02	25.6	1.74	80.3
15.02	25.5	1.79	80.2
25.02	26.3	1.76	80.6
04.03	24.6	1.78	79.2
13.03	25.2	1.69	80.3

This data suggests that the sample is now relatively stable and there may be a systematic dicrepancy between IOS and MAFF nitrate calibration materials or techniques.
This will be further investigated during *DISCOVERY 201* and in the laboratory at Lowestoft.
The lack of Certified Reference Materials in this field continues to be a serious drawback.

DSK

CFCs

The CFC system described here in brief was used to measure ambient atmospheric and dissolved marine concentrations of CFCs 11, 12, 113 and carbon tetrachloride (CCl_4). The prototype instrument was based on a gas chromatograph used by the PML CFC group previously. The main separation element was a megabore fused silica column (DB-624), whose exhaust was delivered directly to an electron capture detector. Seawater samples were stripped of volatile dissolved gases by bubbling in a sparging tower. An unpacked trap was used to concentrate these compounds as they were liberated from the seawater sample prior to injection onto the column. The trapping temperature was between -140°C and -180°C, maintained by placing the stainless steel loop in the headspace of a dewar containing liquid nitrogen. The trap temperature was raised to 90°C by immersion in hot water for the injection. The oxygen-free nitrogen gas used to strip the sample was treated by a hot palladium catalyst, then by a cold trap in the headspace of another dewar containing liquid nitrogen. The helium carrier gas was cleaned up by being passed over a short length of molecular sieve, immersed in liquid nitrogen. The ECD was calibrated by using samples of standard gas containing established proportions of CFCs 11, 12 and 113. A liquid standard was used for CCl_4 during the first half of the expedition, and then marine air was used as an effective standard for the rest of the cruise. The analysis was semi-automatic, controlled by an integrator which also provided data for a PC based chromatography package. By using a DB-624, precolumn trapped compounds which elute after CCl_4 were cut from the main column and so the analysis time for each sample was 9 minutes.

Few problems with contamination were encountered during the cruise. The syringes and taps used to draw samples from the water bottles were cleaned each day with detergent rinses. These syringes were also used to sample marine air from exposed, upwind parts of the ship. The results of an experiment where all the water bottles were closed at the same depth indicated that the CFC bottle blank from these was of the order of a few femto moles per litre (3 orders of magnitude lower than surface concentrations). This exercise revealed that 2 Niskin bottles were causing slightly elevated levels, but after the springs had been changed no further problems were noted.

Approximately 600 water samples were analysed from 25 stations. Precision on water samples was of the order of 1-2% or 10 femto moles per litre, whichever is larger, and routinely better than 0.5% for gas samples. The analytical detection limit was of the order of a few femto moles per litre for each compound. In all of the stations analysed, beneath the surface layers CFC loads were low, typically 20 times smaller than surface values. Near bottom elevation in CFC concentrations were noticed in several casts, although this was relatively modest in most cases. In the Crozet-Kerguelen section the bottom water revealed increased CCl_4 levels, but there was often insufficient quantities of CFC-11 to demonstrate a significant bottom enhancement in this species. This emphasises the utility of measuring dissolved CCl_4 distributions, which allow the tracer dating technique to be extended back to the first couple of decades of the 20th century. Practically no CFC-113 was observed in any intermediate or bottom waters (dating back to ~ 1973). Figure 6 shows preliminary data from typical profiles from each section analysed. On the steam east to the Princess Elizabeth Trough region an isolated station was occupied in order to compare with CFC data gathered from the same location 5 years previously.

A second, independent, CFC analysis system was used during the cruise for measuring the same four compounds as mentioned above. The two systems were largely identical, the main difference being that the second system did not have a pre-column in order to cut the chromatogram after CCl_4. With a 70 m long DB-624 column it is possible to separate at least 20 currently identified C_1 and C_2 halogenated compounds in 14 minutes, thus getting information on other anthropogenically produced halocarbons as well as a number of naturally produced ones. The lack of a pre-column, however, necessitates the use of temperature programming in order to empty and clean the column within reasonable time. The consequences of general importance are thus two: the sample throughput rate goes down (25 minutes per sample) and the sample-to-sample precision goes down. A total of about 300 water samples were analysed using this system during the cruise. No definitive results are yet available for presentation, since the concentrations have not yet been calculated. All general trends and features as described above can, however, be seen from this second data set as well.

The good quality of the CFC data gathered on this cruise was considerably helped by the assistance of everyone on board in refraining from using aerosols and other products containing CFCs.

TWNH, MK, AJW, MIL

Stable isotope and trace metal chemistry

A total of 690 samples were collected for analysis of stable oxygen and hydrogen isotope ratios. By combining stable isotope ratios with salinity measurements it is possible to distinguish water masses that have had their salinity changed by evaporation or precipitation from those that have been altered by freezing or melting.

Two sets of sample bottles were used, 250 ml salinity bottles with plastic neck inserts and 150 ml sample bottles with rubber seals. The 150 ml sample bottles were further sealed with paraffin wax. At 3 stations replicate samples were collected using both types of sample bottle to check for possible evaporation during transport. Analysis of these samples will commence on return to the laboratory.

Surface particulate samples were collected underway by filtering water from the non-toxic supply through precombusted GF/F filters until the filter blocked. The filters were then frozen for later analysis on return to the laboratory. One l of the filtrate was also collected in polythene bottles and preserved with mercuric chloride. These samples will be analysed for their nitrogen isotope ratios. Because the nitrogen isotopes are fractionated by the biota, comparison of the ratio in the particulate matter with that of the dissolved nitrate gives an indication of the extent to which the productivity is utilising the available nutrients. Fifty particulate and forty-eight nitrate samples were collected.

Trace metal samples were collected from profiles in the Princess Elizabeth Trough, just west of Crozet Island and north of the STC. A single sample was taken from each CTD cast in the PET and Kerguelen basin, these were taken from a 10 l 'GO FLO' bottle deployed on the CTD-rosette in position 22. For the profiles samples were drawn from the Niskin bottles as well. A total of 94 samples were collected. These samples will be analysed primarily for Cd to compare the Cd/P relationship through the different water masses sampled. Other biologically utilised trace metals (Ni, Cu) will be determined depending on the extent of contamination from the rosette and Niskins.

RDF

pCO_2

On the cruise pCO_2 was measured using a gas chromatograph and showerhead equilibrator. Air for the system was supplied by a compressor and hydrogen was fed in via copper pipes from the gas bottle store. The intention was to use the installed piped gas supply, however pressure testing on the hydrogen line whilst in Cape Town showed a small leak that could not be found so before sailing extra copper piping was used to connect the deck laboratory to the gas bottles.

The equilibrator was placed in the water bottle annexe as this kept it close to both the de-airated non-toxic supply and the GC in the deck laboratory. The water bottle annexe was kept cold, with auxillary heating switched off enabling us to keep the temperature in the equilibrator as close as possible to the *in situ* temperature. The programme for the system had a cycle time of 13 mins. During each cycle two measurements of the pCO_2 in the water were made bracketed by standard and marine air measurements. Marine air was approximately 355 ppm ± 2 ppm as measured throughout the cruise with no discernable change with latitude which is as expected in the Southern Ocean. The equilibrator caused a few problems as it kept filling up with water, this was controlled by keeping a close watch on the equilibrator and emptying it if necessary. There was an average increase in temperature of 1.5 degrees in the equilibrator from *in situ* temperature which is four times that experienced on previous cruises where this system has been used. This increase requires a substantial correction to the data once it has been processed (reducing the observed value by approximately 20 ppm). After about one week of constant use one motor on the system over-heated and had to be replaced. The motor driver board in the controller was also replaced following some resoldering by one of the RVS engineers on board.

The system was working almost continuously giving a pCO_2 value approximately every 6 minutes, this data is only preliminary and further calibration using a running standard and temperature corrections will be necessary. Initial calculations show that the pCO_2 as measured in the water was mainly below atmospheric levels for the majority of the track covered by approximately 10 ppm with the largest deficit being seen as the ship got closer to the ice-edge (100 ppm). The measured pCO_2 values (after calibration) for the outward and return legs of the cruise are shown in Figures 7(a) and (b) respectively.

An underway flow-through fluorometer was requested for the cruise in order to complement the measurements of both pCO_2 and TCO_2. Unfortunately this was not provided which caused a set-back to part of the interpretation of the data collected. As an alternative, hourly water samples were filtered for chlorophyll content and the filter papers frozen immediately. These samples will be returned to PML for fluorometric determination of chlorophyll content. In addition to hourly chlorophylls, nutrient samples were taken and analysed on board.

JR

TCO_2

Total CO_2 is a measurement of dissolved inorganic carbon and represents carbonate, bicarbonate and unionised species of CO_2. A thermodynamic relationship exists between TCO_2 and pCO_2, enabling the two measurements to be used to calculate both the alkalinity and pH of the seawater (although with reduced accuracy compared to direct measurements).

The analytical system consists of two main components, the extractor unit and the coulometric detector. A sea water sample is filled from the non toxic supply and is fed under gravity to a calibrated pipette. This is discharged into a stripping chamber where orthophosphoric acid quantitatively converts the DIC to CO_2. The CO_2 is purged by a nitrogen carrier gas flow into the reaction cell where it is coulometrically titrated to an end point.

It was originally intended to measure TCO_2 in continuous underway mode to parallel pCO_2 but several major problems made this impossible. The coulometer chemicals and the WOCE TCO_2 standards of known carbon content were stored in the deck lab chill store during transit from the UK. At some time during this period the temperature fell from the nominal 10°C to below 0°C and the standard bottles cracked. Apart from the financial loss, which was in excess of £500, the loss of standards meant that the quantity and quality of the science originally proposed for this cruise and the earlier cruise (*DISCOVERY 198*) was completely disrupted. The coulometer chemicals would also have been subjected to freezing temperatures and it is not certain what effect this had on the solutions. The chemical suppliers were contacted once freezing was suspected and they explained that the chemistry of the solutions may be sensitive to such a temperature change. These factors forced a change to discrete sampling from the non toxic supply and the analysis of up to 5 replicates of each sample to give a measure of confidence in analytical precision of the technique. Variations in the quality of the electrical supply which appeared to be a problem on *DISCOVERY 198* were not evident on this cruise and precision within the bottles sampled was increased (typically 1 S.E. = ± 1.5 µmol/kg) over that experienced on *DISCOVERY 198*. In discrete mode the system allowed, at best, a sample throughput of twenty samples a day which seriously reduced the spatial resolution of surface mapping compared with that achievable in underway mode. Nevertheless a number of discrete samples were processed whilst underway and two shallow CTD casts, one at the most southerly point of the cruise and another on the way back further north, were also sampled. On returning to PML the data will be recalculated to take into account calibration of the pipette volume and corrected thermosalinograph data.

JR

Dimethyl sulphide, dimethylsulphoniopropionate
and low molecular weight halocarbons

Measurements of DMS, its precursor, DMSP and halocarbons (e.g. methyl iodide, bromoform, chloroiodomethane) were made during passage, to assess surface water distributions and sea-air fluxes. Discrete samples were taken from the ship's non-toxic supply (non de-aerated) at regular intervals and analysed on two separate Gas Chromatographic (GC) systems. Water samples were purged with nitrogen gas (30 mins.) to strip out the dissolved trace gases, which were subsequently cryofocussed using liquid nitrogen vapour at -150° C. After thawing, the samples were injected into the GCs. For halocarbons, the sample was loaded onto a megabore DB624 column with a 3 stage temperature programme and were analysed using an electron capture detector. DMS was resolved using an isothermal Chromosil 330 column and quantified by flame photometric detection. Non-volatile DMSP was resolved into two fractions, particulate and dissolved, operationally defined by AP25 depth filters of nominal retention, 1.0 µm. Filter and degassed filtrate were each put into ground glass stoppered bottles with 10M NaOH. These were stored in the dark for at least 12 hours to allow for complete hydrolysis of DMSP, which produces DMS. The samples were then analysed as described above. Chlorophyll samples were also taken. These were frozen and will be sent back to the UK for analysis at UEA.

Trace gases and DMSP were also measured in two 200m depth profiles (D12357 and D12385). Additional samples were taken for Dr. Tim Jickells, for the determination of iodide/iodate ratios.

The levels of DMS in surface waters were low, with a mean less than the currently estimated global average. This is a little surprising, considering, not only the seasonal cycle that we have found in the northern hemisphere at similar latitudes, but also the very limited, published data for Antarctic waters. Generally speaking, concentrations of DMS and DMSP were lower in the southerly, colder waters, with marked changes associated with major oceanic fronts (Figure 8). The depth profiles showed shallow surface maxima, with very sharp decreases in concentration, coincident with the thermocline. Further data analysis is required for the large number of halocarbons measured, but preliminary assessment shows significant trends in MeI and $CHBr_3$.

This was a successful cruise with only minor equipment problems. Fortunately it had been possible to do a Zodiac transfer of a single detector sulphur GC from *JAMES CLARK ROSS* to *DISCOVERY* in December 1992, as the existing *DISCOVERY* dual detector instrument had suffered terminal damage. The UEA liquid nitrogen plant worked successfully, on its second cruise and produced ample supply for UEA, the PML Freon group and Mikael Krysell.

SMT

Current meters and moorings

Current meters (Figure 1(c))

A total of 57 Aanderaa recording current meters were prepared and supplied for this cruise, 49 by MAFF Directorate of Fisheries Research (DFR) and 8 by IOS Deacon Laboratory (IOSDL).

All the 35 RCM4s and 5s from DFR were powered by standard Aanderaa PP9 batteries and set to run at 1hr intervals with divide by 8 rotor counters. During set up and pre-deployment testing of the RCM5s it was found that, in one meter, a rotor counter magnet and ball race had become detached from its holder on the rotor counter and was 'stuck' to the rotor magnet through the end plate of the meter. From the colour and serial number it was obvious that this counter had been fitted recently, probably immediately before the cruise, and that two spares supplied were also faulty. All other similar coloured and numbered units were checked; a further 4 were found either loose or inadequately glued. All were carefully reglued with Araldite. Some earlier, different coloured, units were checked and were found satisfactory. A message was sent to Aanderaa via their UK agents, and a reply received stating that the assembly should be held together with 'Loctite' and that only a severe jolt will free the components. This explanation could hold for the fitted units but the two spares could not have been subjected to sufficient shock. The opinion on the ship was that 'Loctite' is not appropriate in this case and Aanderaa should revert to an epoxy type adhesive. An electronic failure of an older rotor counter was also found during the final preparation using, as usual, the Aanderaa check list. This was exchanged for one of the repaired new units.

All 22 RCM 7s and 8s from DFR and IOSDL were fitted with A1 Marketing Lithium battery packs, and as these are slightly magnetic they were fitted as high up in the instrument as possible, to reduce any effect on the compass, and each instrument was compass calibrated when already fitted with its deployment battery. The 8 old style DSUs were fitted with new batteries immediately before starting. All were set to run at 1 hr intervals.

Sensors

All instruments were fitted with the standard -2.46°C to +21.48°C temperature in Channel 2. In Channel 4, 26 had the Aanderaa 'Arctic' range of -2.5°C to +5.0°C, and 22 of various other ranges. In addition 11 were fitted with pressure sensors in either Channel 3 or 4, and 2 with conductivity sensors in Channel 3 of range 30-40 mmhos.

Moorings

Two arrays consisting of a total of 16 moorings were deployed. All designs were run through the knockdown calculation program 'MOOR', to optimise distribution of available buoyancy. The 14 'upper bottom' were designed and supplied by DFR and consisted of 2, 3, or 4 Aanderaa recording current meters, 10 mm Marlow Ropes KT3 Kevlar, and supported by various numbers of pairs of Benthos 18" or Corning 17" glass spheres. Each Aanderaa was fitted with a pair of 1 metre Kevlar strops, to ease insertion into the mooring.

The two 'full depth' moorings were supplied jointly by DFR and IOSDL with the detailed design by IOSDL, and consisted of 7 or 8 Aanderaa recording current meters, 6 mm jacketed steel wire and 10 mm polyester for the upper section and 10 mm KT3 Kevlar for the lower section. A set of 20 Benthos glass spheres was inserted between the upper and lower sections to reduce the tension in the mooring and to support the mooring in the case of loss of the main bouyancy unit, a 48" IOS steel sphere.

All moorings were laid buoy first, over the stern from the IOSDL supplied double barrelled capstan winch, using one of the stern cranes to support a wide sheave. The failure of the other stern crane before sailing meant that the gantry was used to deploy the buoyancy array at the start of each mooring. Two methods of deploying the release and the lower portion of the mooring were tried. The initial design with the acoustic release (A/R) 23 metres below the bottom meter meant that a 20 m slip rope was required to get the release safely in the water. This system worked well for the 'Mors' releases but fears that the rope could tangle more readily on the CR200 units led to the moving of these units up, to 1 metre below the bottom meter, with both the 23 m Kevlar strop and the 20 m wire below. This enabled the A/R to be winched into the water with the bottom meter and the rig to be released from the deck.

All ropes used in the the full depth mooring were 'stretched' and measured at their deployed tension before use to accurately ascertain the deployed length of these moorings. The difference between lab and loaded measurement (5%) of the DFR supplied Kevlar in these tests was used as a conversion factor for all other Kevlar lengths.

The mooring details, with instrument numbers, depths and positions are listed in Table 3, and general rig diagrams are shown in Figure 9.

1. Princess Elizabeth Trough array. (Figure 10)

Five moorings were laid across this section, covering the water column up to 2500 m, from a maximum depth of 3700 m using a total of 13 RCM5 instruments. All moorings were fitted with new Mors RT661cs acoustic releases in case ice cover in this area in 1994 prevents recovery.

2. Kerguelen- Crozet array. (Figure 11)

Eleven moorings , including one west of Crozet, were laid. The 9 'upper bottom' type covered the water column up to about 1800 m and the 2 full depth up to 300 m. Three were fitted with Mors RT661cs acoustic releases, the remainder with CR200 units, in both single and double configuration.

JWR, IW

Acoustic releases

9 Mors RT661CS
10 IOS CR200 supplied by MAFF
4 IOS CR200 supplied by IOS with single pyro

Mors

One Mors unit failed immediately its batteries were fitted. It drew excessive current because the 50 V inverter had failed causing the 50 V supply to rise to 90 V. Components in it were overheating and in danger of damaging the circuit board. As there were no spare electronic parts available, the unit could not be repaired. The remaining eight units worked in the lab and were all successfully tested under pressure. The batteries were arranged such that all six were available to the receiver and motor but only two of the six were available to the transmitter. The transmitter with its 50 V inverter was felt to be the least reliable part of the system and this battery arrangement leaves four batteries for the receiver and motor should the transmitter or inverter fail and draw excessive current. When attempting recovery, the Mors release should be commanded to release even if it cannot be communicated with although recovery will have to rely on visual location only.

Communication with the Mors when wire-testing was better with the IOS PES fish than with the dunking transducer. Communication from ship to release was very reliable, as demonstrated by turning the pinger on and off, but communication the other way was very dependent on weather and bow-prop activity. When the current meter rigs were laid, good ranges were obtained out to

4600 m with the ship steaming away at 12 knots. At shorter ranges, the diagnostic gave consistently reliable results. With one Mors release at 3000 m depth and the ship 4000 m away giving a slant range of 5000 m, better results were obtained with the dunking transducer. Eight out of ten ranges obtained were reliable and two of three diagnostic measurements were good. Weather conditions were good at this time.

CR200

All 14 CR200s were fitted with batteries and bench tested. One MAFF unit had a short circuit capacitor in its transmitter which was replaced. Some of the IOS supplied units showed signs of irregular counting in the release circuit and were therefore modified. The fifth CR200 wire-tested failed to fire its puffers. There was a consensus that the problem might be the new lithium batteries in the pyro-fire circuit. This type of battery can develop a passivation layer which reduces its current capability until the battery has been supplying current for some time. POL have modified their CR200s so they multiple-fire the pyro to get over this passivation problem. All MAFF CR200s were then fitted with a new firing circuit which fires the pyro every few seconds as long as the release signal is sent. A pair of much larger D size lithium batteries were fitted into each MAFF release to increase the pyro current capability.

The CR200s supplied by IOS were not fitted with the new pyro circuit, instead two units were fitted with an MN1604 manganese alkaline battery and multiple lithium packs were also fitted according to the space available. Although these four units were fitted with a single pyro connector, batteries were fitted to both relay contact circuits as the wiring was paralleled at the connector. There should be sufficient battery power on these IOS units to fire the pyro first time, but should it not fire first time, it will be necessary to reset the firing circuit with a short burst of 320 Hz and repeat the release frequency.

As a result of these modifications all the releases had to be wire-tested again and two units failed; one failed to give the release indication and the other came on in double ping mode. Investigations of these two failures showed that one unit de-sensitised itself while transmitting at 2 Hz so that it could not recognise the release signal and the other unit was found to respond to almost any frequency. Both these problems could be associated with the bandpass tone filters which require careful setting-up in the lab at two temperatures and it was felt inappropriate to tamper with them at sea.

The one spare set of electronics carried was fitted in place of one of the faulty units. As an exercise, this unit (2187) was fitted with another new design of release circuit which minimises the peak currents drawn from the battery. This unit could not be fitted with the repetitive pyro fire circuit.

Moorings 93-11 to 93-17 with CR200 releases were set pinging and watched until they landed on the seabed. The pingers stuttered on both the full depth moorings due to the shock load on the release relay of the heavy anchor but release was not initiated.

CR200 recommendations

A circuit was designed which would dispense with the pyro relay but still retain the advantage of electrical isolation between the pyros and the rest of the circuitry. Pyros can be fired by a mechanical shock to the release and this represents a significant danger and nuisance. It is recommended that this circuit be developed and fitted subject to finding room for it. The new circuit minimises the peak currents and controls the relay on time better than the original circuit. It is important to reduce the peak currents taken from the receiver battery as otherwise its voltage can fall significantly which can cause circuit malfunction. It does not have the repetitive-fire capability, the need for this mode should be removed by fitting an appropriate type of pyro battery, probably manganese alkaline which will be cheaper and safer.

Mors recommendations

As has already been mentioned, the Mors releases are able to hear transmissions from the ship in poor weather conditions but the ship's ability to hear them is a function of weather and bow-prop activity. More use could be made of the pinger as this can be seen on the waterfall display and Simrad EA500 under poor conditions. The pinger could pause and shift phase according to commands received. For example, the pinger could pause when the window command was received, re-start with a phase change when the release command was received and have a further phase change when the release motor completed its travel. If the release command were not received within the 60 s window period, the pinger would re-start without a phase change. The diagnostic command indicates battery voltage and verticality. This could also modify the pinger by phase changing the pinger in proportion to the voltage; advancing the phase if the unit is vertical, retarding the phase if the unit is horizontal. Once the pinger has started it continues until commanded to stop. It should have a time-out so it automatically stops after say 30 minutes. The options are endless, discussions must take place with Mors and IOS to agree on a specification. Hopefully Mors will accept that their system does need improvement in the deep sea. As the release uses a microprocessor, there should be no reason why these kind of changes should not be possible.

The six screws which attach the release hook to the end-cap have a screwdriver slot. These screws are inserted with a locking compound and therefore will be difficult to remove. They should be replaced with hex or socket head types.

The Simrad EA500 display updates every six seconds. For pinger work it would be desirable for the update rate to be increased to the actual pinger rate.

NDP

Bottom Pressure Recorders

Two POL Bottom Pressure Recorders (BPRs) were deployed on the Kerguelen-Crozet mooring line at ADOX positions 9307 and 9316. They were both at 3615 metres ± 5 metres, uncorrected depth and positioned almost at the extreme ends of the mooring array. There are three pressure channels and three temperature channels, recording integrated count every 15 minutes. The BPRs are self-contained and released from the bottom by a command to either a Benthos or CR200 acoustic release.

Mechanical detail

Figure 12 shows a schematic diagram of the instrument. Its dimensions are approximately 1.4 metres diameter and 1.2 metres high. The frame locates on a disposable steel ballast frame which is jettisoned for final recovery by a twin action titanium release assembly. On deployment from the ship the complete system free falls at 1 metre/sec from the sea surface to the seabed.

The BPR consists of a main logger tube, containing power supplies and the electronics, four Benthos 17" glass spheres for buoyancy and two separate acoustic release systems. The primary release system is a Benthos XT6000 in a 10" glass sphere with an external five-year lithium battery pack. The back-up release is a CR200 fitted with a high security relay, overcoming the CR200 problem of pre-release when subjected to shock. Both releases fire pyros connected to a titanium release mechanism retaining the steel ballast frame. The descent or ascent can be monitored using the Benthos transponder and DS7000 deck unit to give direct slant range or the CR200 to give displays on the Simrad echo sounder and IOSDL waterfall display.

Both BPRs are fitted with flashing strobe lights, a radio beacon and a forty-foot rope stray line to aid recovery. The flashing lights and radio beacon are activated by pressure switches which switch on at the sea surface. The stray line can be grappled and used to lift the BPR out of the water and onto the deck during the recovery process.

Instrument Electronics

Sea pressure and temperature signals are recorded by the logger onto solid-state memory. The three pressure sensors are clamped in an aluminium block connected to the endcap which acts as a heat sink and keeps them at the same temperature as the external sea water. The electronics consists of an accurate timebase, a six channel frequency counter card, a 16 bit microprocessor card, and a 4 Megabyte EPROM (Eraseable Programmable Read Only Memory) card. The pressure sensors are two Paroscientific Digiquartz and a Quartztronic. All three have internal temperature sensors and these together with the pressure signals are recorded on the six channel frequency counter board.

The loggers are set up for 15 minute integration periods and each scan is 'time-tagged' and stored in a 28 byte array in the EPROM memory. There is storage capacity for 149 796 (15 minute interval) scans or > 4 year's deployment. The microprocessor is powered up for about 1 second each scan and then goes into 'sleep' mode in between, ensuring maximum conservation of power. The power is supplied by a large lithium battery pack supplying 14 volts, the programming voltage for the EPROMs (12.5 volts) is supplied by an onboard voltage inverter logger, ensuring operation down to a battery voltage of 6 volts, maximising battery life.

BPR Launches

Both BPRs were deployed using the CTD winch located on the starboard side. High winds and a considerable swell prevented the use of the aft 'A' frame to deploy them as originally planned. Both deployments went smoothly despite the weather conditions. Additional short rope strops were used to lift the frames due to the limited height available underneath the gantry. A plastic toggle was used to release the strop once the BPR was in the water, and two steadying lines used to stop the frame swinging. The BPRs were both monitored down to the seabed using the CR200 and the waterfall display. The Simrad EA500 was also used on a five-times multiple of the ping repetition rate. Both display methods worked well but better contrast on the waterfall display could probably have been obtained by altering the colour pallet. This does not seem to be a simple process and it was easy to make the display disappear.

This is the first time that this configuration of logger has been used and the pressure sensors are mounted internally. The pressure sensor diaphragms are buffered from the sea water by tubes filled with silicone oil of the same density as sea water. The external plastic fittings for the pressure sensors had been left behind and new ones were expertly made by Colin Day from RVS.

There was some doubt about one of the Swagelock fittings leaking oil in logger No. 1 and so the logger was pressure tested to a maximum depth of 1000 metres for an hour with no leaks. The oil is thought to be from when the fitting was originally filled and was inside the sealing olive nuts.

Both deployments were most satisfactory and were correctly sited at 3615 metres as accurately as possible (± 5 metres).

PRF, GWH

ADCP

Several hours after departing Cape Town the ADCP was calibrated whilst within bottom track range. The Aghulas current, with speeds of up to 100 cm s^{-1} was detected late on day 37 (Figure 13). Two days out a data transmission problem arose, attributable to a loose PC board or connector, although the specific cause was not determined and there was no recurrence. Resulting from this, the sync cable from the gyro to the ADCP deck unit was found to be disconnected from 1800 day 39 to 1050 day 42. The fault wasn't detected as the default gyro reading was almost the reciprocal of the course travelled. During the southward track, ending on day 48 and blessed with a following wind, data return appeared good with penetration often to 450 m. At this point, the opportunity was taken to make a calibration run. On the eastward leg to the Princess Elizabeth Trough (PET) we again had a following wind and good data return. For a large part of the work in the PET conditions were favourable, but during the northward leg to the Crozet/Kerguelen site we steamed into the wind and the data quality was severely reduced, with the exception of that collected during CTD and mooring work. Bottom tracking was performed as we passed Heard Island, to the west of Kerguelen and also south of Crozet. The quality of data was not ideal. As the wind dropped on the return leg to Cape Town the quality of the data was much improved.

Evidently the instrument is severely limited when steaming into the wind or sea and apparently at a wider arc than the oft quoted $\pm 30^{o}$. It may be that the installation of an automatic bleed valve for the transducer well, might provide some improvement.

Before a complete assessment of the data can be made gyro offset errors derived from the Ashtec system need to be applied and the data thoroughly screened, but at this point there is no reason to suspect data quality, head winds and sea-state excepted.

JB, MDS

Support services and routine environmental monitoring

Expendable Bathythermographs (XBTs)

Throughout the cruise XBTs were launched six times per day (Table 4), except during the sections where the moored arrays were deployed. The majority of the probes were the T7 (760 m) type, but some of the deeper T5 (1800 m) type were launched at points of specific interest and when the ship was proceeding at the slower speed required (5 knots). The XBTs were launched from a Sippican Corporation hand launcher belonging to RVS, usually from the rear corners of the afterdeck. If the weather conditions were unfavourable or unsafe they were launched from just outside the Boatswain's workshop. The launches were controlled by a Bathy Systems SA810 controller and deck unit supplied by the SESU Hydrographic Office, Taunton, situated in the plot room and which used the Bathy Systems XBT Program version 1.1. The unit controlled the launch and logged the data, along with header information such as water depth, position and surface temperature (entered by the operator). It could also be used to list isotherms, to identify critical inflection points in the data, and to generate BATHY messages for transmitting to the GOES satellite and eventual insertion onto the GTS network.

The data were logged by the deck unit as a list of voltages at 10 Hz and probe depth was calculated based on time. At regular intervals the data were transferred using a 3.5 inch diskette from the deck unit to the RVS level C. Each profile then underwent a series of processes to format and archive the data and to improve the final quality by selective filtering. Header information was edited with data from bestnav to ensure the most accurate position for the launch time was used. Sections along constant or similar latitude and longitude were plotted to reveal various structures including fronts and horizontal layers.

A total of 152 XBTs were launched, leading to 123 good profiles. Of the failures, 7 were due to the wire breaking before the profile was finished, 11 were due to stretched wire, 8 were due to operator error, 1 was due to bad weather and 2 probes just gave a spurious reading for an unknown reason. The wire stretching and/or breaking was the biggest problem; some occurrences may have been down to the operator not holding the launcher correctly (it should be pointing 'down' the wire to avoid snagging on the tube), but it is likely that most were the result of the wire not spooling off correctly. When it occurred, stretching led to spuriously high temperature values being logged and was often not recognised until the data were processed and plotted. The stretching may have been a result of bad handling of the boxes of XBTs during loading, particularly as one whole box (12 probes) was faulty. The operator errors, usually failing to follow the procedures correctly, lead to profiles never being logged by the deck unit and in one case, lead to the profile being lost. The problem was often due to poor communication between the afterdeck and the plot room, particularly when the RVS radios were unavailable or faulty. If a problem was recognised with a profile at the time of deployment, another probe would be launched straight away. The boxes of XBTs were kept in the water bottle annex which is reasonably cool, to avoid the 'thermal shock' problem encountered during *DISCOVERY 198*.

Weaknesses in the Bathy System XBT Program and the deck unit became apparent. The time logged is the time when the operator confirms the header information entered by hand, and it may be up to 10-15 minutes after this time when the probe is launched, particularly if there were no radios or if conditions were difficult. It was necessary to make a note on the log sheet of the launch time so the correct GPS positions could be added later. Another problem resulted in one profile being lost; if the wrong key is pressed after the profile is finished but before inflection points are calculated then the drop is 'aborted' and the data lost.

For the first three weeks each successful profile had inflection points calculated and a BATHY message generated which was transmitted to the GOES satellite for insertion onto the GTS. However the transmitter failed to work after 27 February when a faint but ominous burning smell was detected in the alley between the plot room and the CT Laboratory. After that date, 2 profiles per day were selected and the BATHY messages telexed to the RTH in Hamburg with the regular meteorological observations.

NPH

Thermosalinograph (TSG)

Surface salinity and temperature were continuously measured using a Falmouth Scientific Inc. (FSI) shipboard mounted thermosalinograph located in the hangar. Bottle samples for salinity were taken every 4 hours from the non-toxic sea water supply and used to calibrate the conductivities from the TSG.

The TSG uses the non-toxic seawater supply which is drawn in 3 m below the surface and piped up to a header tank located opposite the winch control room at the hangar deck-head level. The header tank is maintained at a constant level by adjustable intake and outflow and provides an even flow for the TSG. For one short period (30 minutes) during rough weather the header tank became empty and the TSG was filled with air bubbles which meant no good data were logged for that period. The TSG itself has an Ocean Conductivity Module (OCM) and two Ocean Temperature Modules (OTMs); one fitted within the flow-through sensor holder (housing temperature) and another on the suction side of the non-toxic intake (remote temperature). The housing temperature is used to determine salinity.

Data are passed from the OCM and OTMs via an RS-485 data interface to a Viglen 386sx 25 MHz personal computer (pc) where they are formatted and passed to Level B at 5 Hz. The programme used is called 'surflog' and continually displays the last 3.27 hours of data as line graphs. Data were read from the RVS files in 24 hour segments each day, appended to the tsg200 master file and an averaged file generated. After each box of 24 bottles was completed and analysed, the bottle samples were merged with the averaged TSG data and the mean and standard deviation between the salinity data computed. Plots of uncalibrated TSG temperature and salinity and bottle salinity against time were generated.

The TSG salinity is slightly offset from the underway bottle salinities and so the TSG needs to be calibrated. Originally it was thought there might be a linear relationship between the temperature and the salinity offset, but further comparisons revealed that the best approach was to calculate the bottle conductivities (using housing temperature) and determine the relationship between the conductivity difference and conductivity. A least squares regression was performed on the conductivities producing the best linear fit, and the coefficients used to recalculate the TSG conductivities and hence salinities.

NPH

Satellite imagery and sea ice intelligence

Satellite imagery

Real time satellite imagery of the sea/ice surface was available on *DISCOVERY 200* through the use of a Dartcom Macsat Receiver, and associated software installed on a Macintosh PC. The primary use of this equipment was to acquire sea ice information in the area where it was most likely to affect mooring operations, at the southern end of the Princess Elizabeth Trough.

Images were routinely acquired 4-5 times per day from the NOAA series of satellites (National Oceanic and Atmospheric Administration, a US government funded agency). These satellites transmit both an infra-red and a visible image of the earth's surface, and the software on the Macintosh is theoretically capable of capturing both of these images. However, because of problems encountered on earlier cruises, only one image (infra-red or visible) was acquired per satellite pass.

Although the primary use of Macsat was its contribution to sea-ice intelligence, a number of infra-red images were acquired in the region of the sub-tropical front, and the surface temperature signature of this feature could be clearly seen in these. In addition, in an area of the world where accurate meteorogical forecasts are few and far between, images showing the location and size of local weather systems were of some help in the short term planning of operations sensitive to weather conditions.

Despite some initial doubts as to whether enough clear weather would be experienced to enable images of the ice-edge to be obtained, such images were regularly acquired. On average at least one good definition of ice edge was received every two days, once the scanning area of the visible satellites covered an appropriate region (whilst *DISCOVERY* was within ~10° latitude of the ice edge).

The real value of carrying a satellite receiver on a ship is in the information it can provide in real time to the scientist. On this cruise, satellite images were acquired regularly and reliably through the Macsat receiver, which fulfilled this requirement well.

Sea Ice Intelligence

The planned deployment of moorings at the southern end of the Princess Elizabeth Trough, close to the seasonal ice-edge, meant that accurate sea ice intelligence was required both before the start of the cruise and during the journey down to the mooring area. In addition, whilst sailing in areas of possible sea-ice, the ship's Captain is required to have all forms of sea ice intelligence that are available.

Such information was acquired through a number of routes. Weekly sea-ice maps acquired from the US Navy/NOAA Joint Ice Centre were faxed down to the ship from the James Rennell Centre in Southampton. In addition, estimates of the ice edge analysed from Passive Microwave Satellite data and from the altimeter on board the European Remote Sensing satellite ERS-1 were available on average once every three days (these two data sets were provided by colleagues at the Mullard Space Science Laboratories). Ice edge co-ordinates were also sent direct to the ship from the UK Meteorological Office. Images from Macsat complemented these sources of information. Local authorities in South Africa had been contacted with a request for information, but in the event they were unable to provide any significant help.

Icebergs were first encountered, unexpectedly early, at 47° 40'S 17° 50'E on day 041. Icebergs (on average 10-20m high and 50-100m long) were subsequently regularly in view up until our final departure from the mooring area in the Princess Elizabeth Trough (day 057). The edge of continuous sea-ice (approximately 7-9/10 concentration) was encountered at 65° 06'S, 85° 19'E on day 056.

Once all the forms of ice intelligence came together, a clear picture of the extent of the continuous pack was available on a day to day basis. Thus it was confirmed that the mooring area in the Princess Elizabeth Trough was free of ice, and that an easterly track (at~62°S) from the southern end of the section across the Enderby Abyssal Plain was feasible.

Unfortunately, none of these sources of ice intelligence are at present capable of identifying concentrations of smaller icebergs (of length < 10 km). For future cruises it may be worth contacting the Antarctic agencies of South Africa and Australia in advance of departure. Both countries regularly run supply ships to research bases in the area, and an Australian Antarctic station, Casey, operates a High Resolution Picture Transmission (HRPT) satellite receiver, which could provide further valuable information.

PDC

Multimet

The meteorological monitoring system operated on *RRS DISCOVERY* is a system jointly developed by the British Antarctic Survey and the Instrument and Sensors Group at Research Vessel Services (RVS), and was installed prior to the 1992-93 series of Southern Ocean cruises.

The multimet sensors operated during cruise 200 were identical to those of *DISCOVERY 199*, with the exception of the two psychrometers which had been replaced in Cape Town at the end of that cruise. The routine sensors comprise a wind vane and anemometer, two psychrometers, two photosynthetically active radiation (PAR) sensors, two total irradiance sensors, a long-wave pyrgeometer, a hull mounted sea-surface temperature sensor and an aneroid barometer. In addition to these routine sensors, a sonic anemometer and ship-borne wave recorder were operated. A backup tape device for data from the sonic anemometer was installed at the begining of the cruise, but due to problems with new software, tape backups of these data were only possible after day 051.

Logging of multimet data started shortly after departure from Cape Town (1311 day 37) and continued until day 77. The track of cruise 200 traversed a large latitude range and so the environmental variables exhibited sizeable variations; air temperatures ranging from -2.8^{o}C to 21^{o}C, sea temperatures from -0.9^{o}C to 21^{o}C, and wind speeds peaking at over 24 ms^{-1}. It is worth noting that the calibration of the sea-surface temperature sensor is only valid between +5^{o} C and +25^{o} C, so measurements outside this range should be recalibrated with data from another sensor (ADCP).

Processing of the data was carried out on a daily basis, using a series of Unix shell scripts, and daily summary plots thus produced were analysed to check sensor behaviour. Most sensors behaved well, though the port wet bulb sensor became noisy toward the end of the cruise. The only significant maintenance required was the replacement of the protective 'top hat' on the starboard psychrometer, after the original had blown away in strong winds.

PDC

Ashtech GPS data

An Ashtech Mk XII GPPS 3-D GPS receiver was used to produce accurate ships heading (and pitch and roll) data for later elimination of ship gyro errors for ADCP calibration. This cruise used the ship's number 2 gyro.

Two of the receiving antennae were mounted on the rails of the boat deck and the remaining two on the wheelhouse top. These were connected to the receiver unit in the wheelhouse.

The data were recorded throughout the cruise at 5 second intervals. At this rate the data buffer in the receiver filled in approximately 1 day. The data were typically then downloaded (to an IBM PC) twice per day (usually shortly after 0600 and 1800z). These files were then transferred to the Pstar system using software developed on *DISCOVERY 198* and *199*.

The processing path was also via executives developed prior to the cruise. Only the sd files containing attitude data were processed, the others were archived for possible future analysis.

The executives used were :-

ash1
- Requires as input Ashtech file name e.g. sd200k93.072 and number for Pstar file name e.g. att200XX
- Inputs data to Pstar
- Converts time from GPS week and seconds to seconds since start of year
- Note when a new GPS week started (0000z Sunday) data files had to be adjusted by using finctd to remove time base jump

ash2
- Requires as input the number of Pstar file
- Performs basic quality checks
- Removes data outside sensible ranges

ash3
- Requires as input the number of Pstar file
- Selects data good segments longer than 151 seconds

attexec2
- Requires as input Gyro file number e.g. Gyr200X
- Also requires time period for plot
- Merges Ashtech with Gyro data
- Computes heading difference
- Plots Gyro heading and heading difference as a function of time.

Finally all data were merged into one file (att200.av) and plotted against gyro heading. This gave the data shown in Figure 14.

It demonstrates a well defined relationship throughout the cruise between heading error and gyro heading. This was over a wide range of speeds, latitude and sea state and is encouraging as to the possibility of using such data to improve ADCP currents.

However data collection was far from continuous with often periods of 6 hours or more where the processing did not find data that fitted the selection criteria for good values.

The basic receiver performed well and only two problems were noted. On one occasion the GPS reception was in general very poor and the Ashtech receiver lost lock and then found a position in the northern hemisphere. This was not noticed until the following day when no heading information had been received. A manual position entry enabled data logging to start. At this stage the elevation mask was changed from 10 to 5 degrees and remained so for the rest of the cruise. On two occasions, both at night when there was poor lighting on the bridge, the wrong data file was accidentally erased. Finally on one evening when the data file was being deleted the receiver locked showing the message 'Wait for file to delete'. It stayed in this mode until the following morning and could only be reset by switching off power to the receiver. Thus a data segment was lost.

WJG

RVS logging system

The RVS 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.

The 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.

There are two versions of dedicated Level As, a MkI based on a 8085 processor using CEXEC as the operating system, and a MkII based on a 68000 processor running OS9 as the operating system. In addition there are pseudo Level As which are PCs around which a piece of equipment is based, which are also capable of generating SMP messages.

The Level B collects each of the Level A SMP messages and writes them to disk and backup cartridge tape. It 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. This level B, which is based on a 68030 processor using OS9 as the operating system, collates the data and outputs it to the network.

The Level C, which is a SUN IPC (4/40), takes this data and parses it into RVS datafiles. These datafiles are constructed on a RVS styled database for speed of access.

The following list shows the instrument Level As and the variables which were logged by the Level C. The first column shows the name used by the Level A. Brackets after the Level A name indicate whether it was a MkI (1), MkII (2) or IBM compatible PC (PC), based Level A. The 'ADCP' data was collected directly by the Level C through one of its serial ports (ttya). The data was written to the datafile named in column 2 with the variable names shown in column 3.

Level A	Datafile	Variables
BOTTLES(1)	bottles	code
CTD_17T(2)	ctd_17	press temp cond trans alt oxyc oxyt temp2 cond2 deltat nframes
GPS_TRIM(2)	gps_trim	lat lon pdop hvel hdg svc s1 s2 s3 s4 s5
GYRO_RVS(2)	gyro_rvs	heading
LOG_CHF(2)	log_chf	speedfa speedps
METLOGGR(PC)	metloggr	windspd winddir pwettemp pdrytemp swettemp sdrytemp seatemp ppar ptir spar stir lwave baro
MX1107(1)	mx1107	lat lon slt sln el it ct dist dir sat r status
SIM500(2)	sim500	uncdepth rpow angfa angps
SURFLOG(PC)	surflog	temp_h temp_m cond
WINCH(PC)	winch	cabltype cablout rate tension btension comp angle

The following list shows datafiles which contained data directly collected by the Level C.

adcp_raw	rawampl beamno bindepth
adcp	bindepth heading temp velew velns velvert velerr ampl good bottomew bottomns depth
xbt	depth temp

Archiving of RVS datafiles

The length of the cruise and the high volume of data generated by the gps, adcp, ctd and winch system necessitated regular archiving of these files. The frequency of this archiving was dictated largely by the demand for space on the raw data disk.

Report on individual Level As

CTD

This Level A differs from the normal MkII level A in that the hardware is based around a 68030 processor running the OS9 operating system. The software which it runs is almost identical to that running in a standard MkII level A. With the increase in processing power, the level A is able to read and average all 16 frames of CTD data it receives each second.

Gps_trim

Due to problems with the collection of data on the previous cruise a new set of Level A firmware provided by RVS was installed. This proved to successfully cure all the outstanding problems; however it also served to illustrate the cause of those problems - messages other than position data can cause the Level As input buffer to overflow resulting in the error message 'Serial overrun'.

Gyro

The Level A logged the gyro once a second. There were no problems with this Level A.

Log_chf

The log outputs to the level A once every 2 seconds. There were no problems with this Level A.

Metloggr

There were no problems with this instrument although it probably has the same software faults as the 'surflog'.

Mx1107

No major problems. The Level A had to be reset on two occasions when it produced alarm messages of 'loss of fix'. On one occasion the MX1107 decoded an incorrect date from a satellite. This was corrected manually and did not recur. The data from this Level A was not used and has therefore not been checked.

Sim500

This data was largely good but it is important that checks are made as part of routine watchkeeping. On a number of occasions during data editting it was noticed that the Simrad had selected an incorrect phase.

Surflog

In the light of experience on the previous cruise the data acceptance limits were widened and no further problems occurred. In both the surface and the met loggers there remains a problem with incorrect SMP (ship message protocol) messages (less than 0.1 percent) associated with the output of the time field.

Winch

When the winch monitoring system was started up, it was necessary to check that the Level B was receiving data. If data was not being received, the data lead connection was removed between the winch monitoring system PC and the Level B, and then reconnected. (The connector can be found at the forward end of the main lab behind the chart recorder in the wooden box. There are two wall 25 pin sockets. The furthest one, i.e. Starboard one, is the correct one. Access from the side by the door to the corridor is straightforward.) RVS have liaised with the manufacturer of the winch monitoring system and improved software will be installed for cruise 201.

Instruments generating data not through Level As.

ADCP

The ADCP was logged through /dev/ttya on the Level C. Raw data was also logged. There were no problems with the data collection.

XBT

Each XBT (ascii) datafile was transferred to the Level C from the PC on which it was collected by floppy disk. This file was processed by 'proxbt' and converted to an RVS datafile.

Report on Level B

During the cruise the Level B collected over 1 000 000 000 bytes of SMP data. This data was backed up to both disk and cartridge tape.

Report on Level C

The majority of the data processing was performed using the 'pstar' suite of programs. The exception to this was the navigation.

30 second values of good data from the raw gps (global positioning system) datafile 'gps_trim' were written to the datafile 'gps'. The ship's speed, 'log_chf', and heading, 'gyro_rvs', were averaged every 30 seconds to provide 'northerly' and 'easterly' vectors of speed in the datafile 'relmov'. These were used to generate dead reckoning positions to enable both a check on the quality of the gps data to be made and to allow interpolated positions to be produced when there was no 'gps' data.

The CTD data was processed to enable screen plots to be displayed to verify the data collection. The calibration values used in the processing were the same as those used by the PC CTD display system and were held in the calibration file '/rvs/control/cal/D199.ctd.cal'.

RVS datafiles were converted to PSTAR datafiles using the program 'datapup'.

Operation

In view of the length of the cruise (6 weeks) and the limited disk space available it was necessary to archive data to tape on a regular basis. The ctd, ADCP, winch and gps were all archived every 15 to 20 days. As most of the processing was performed by the 'Pstar' suite of programs, there was not much requirement to do any processing with the ABC system other than navigation and whatever else was necessary to ensure that the data was being collected correctly. The data was normally read into 'Pstar' format within 24 hours of being collected so it was possible to cycle some of the data files quite regularly.

The navigation files were made long enough to hold the complete cruise. This included 'relmov', 'gps', 'mx1107', 'bestnav' and 'bestdrf'. Likewise with the surface data, 'surflog', the meterological data, 'metloggr' and the echosounder data 'sim500'.

RBL

Simrad EA500 echo sounder

The Simrad EA500 was used throughout the cruise for routine echo sounding and acoustic release tests, the latter also being monitored on the IOS waterfall display. The fish transducer was used, which apart from the last couple of days gave excellent results. On recovery it was found to have a damaged fairing. This was subsequently repaired and gave no further problems. The performance of the hull transducer was poor when the ship was pitching, even moderately, but improved when the ship was on station or underway with a following sea. A Hewlett Packard ink jet printer was used to provide real time hard copy output.

Bathymetry data processing

PES data is logged from the Simrad 500EA echo sounder by the RVS Level ABC system at the same rate as the 'ping'. This data is subsampled at the navigation interval of 30sec. The RVS data editor is used to set the data status to 'suspect' when spikes or inconsistent data is detected. Largely the raw data has been of a very high quality with only two brief periods when the Simrad locked on to echoes in the wrong phase. Once edited the uncorrected depths were processed by the program 'prodep' to derive corrected depths using Carter's Tables.

RBL, PGT

PEXEC and PSTAR

PEXEC is the name given to a suite of programs developed by staff at the Institute of Oceanographic Sciences (IOS) to process hydrographic data, both at sea and in the lab. The range of programs covers all aspects of data processing, including calibration of data, arithmetic operations, derivation of oceanographic parameters and graphical display of data. All graphics are produced using the Uniras graphics library. At sea, routine calibration and processing is carried out using Unix C-shell scripts which execute a sequence of programs. The programs operate on data in a format called PSTAR. The first block of each PSTAR data file is a header which gives details of variables stored, limits and where the data was collected. All PSTAR headers also contain a dataname and version. Logsheets are maintained to record each operation, making it possible to identify the processing that has been carried out on each file. Remaining blocks in the data file contain the data, stored in binary format.

Backups and archiving

The pstar and archive directories were backed up each alternate night to 2Gbyte Exabyte tapes, using Unix 'tar' command. A 'rolling' style backup regime with five tapes was used.

All raw and processed data (including non-PSTAR data from Ashtech and MacSat) was archived to Sony erasable magneto-optical discs (mounted as standard unix file systems). Additionally, PSTAR data was archived to Quarter Inch Cartridge (QIC) tape using unix 'dd' command. At the end of the cruise, GF3 copies of fully calibrated data for CTD, ADCP, GPS, TSG and XBT were created and written to Exabyte tape.

Users employed a Unix script, developed on this cruise, to copy files to the archive area. This script updated a text database of all archived data; each entry in the database contained details of the directory, optical disk and (if applicable) the QIC tape number that the file has been archived to. This prevented duplicates of data being archived, and gave speedy retrieval of offline data.

Navigation

One minute values from Bestnav were read in from RVS level C each 24 hours, and converted to PSTAR. These 24 hour files are appended to form one navigation file. Distance along track was maintained, and the eastward and northward velocities were calculated from the position data. The velocity data were median despiked, discarding data more than 40 cm/s from a mean computed over 5 adjacent data values. Subsequent gaps were filled using linear interpolation. Finally, the velocity data were smoothed using a top hat filter applied over 11 data cycles, to produce a master navigation file.

Global Positioning System (GPS)

One hertz GPS data from the Trimble was logged on the RVS level C, and converted to PSTAR each 24 hours. No processing was carried out on the data. In general, GPS data coverage for the cruise was no more than adequate. For the entire cruise, there were over 20 periods when no GPS data were received for ten minutes or more. From day 58 to 59, coverage was particularly bad, with only 20 hours of data collected. In general, 2 to 3 hours of data were poor quality, with pdop greater than 5.

Ship's Gyro

Data from the ship's Number 2 gyro were collected each 24 hours at a rate of 1 hz. Heading data out of the range 0-360 degrees was discarded, but no other processing was carried out. The daily files were appended to a master file, used for processing the Ashtech GPS data.

Magnavox 1107

Data from the Magnavox were collected during the cruise and read into PSTAR format. No processing was carried out on these data.

Data Processing

All hardware remained the same as the previous cruise (D199); see below:

(compiled by VCC on D199)

Personal Computers

3 Apple Macintosh Classics	(40 Mb Hard Disc, 4 Mb RAM)
1 Apple Macintosh ClassicII	(40 Mb Hard Disc, 4 Mb RAM)

1 Apple Macintosh II si (80 Mb Hard Disc, 5 Mb RAM) - This was connected to a Dartcom System II satellite image receiver.

Sun Workstations

NodeName	Type	RAM (Mb)	Hard Disc (Mb)	Main Use	Peripherals
discovery1	IPC	12	2x327 1x207	Final data logging	Exabyte drive QIC 150 tape
discovery2	IPC	12	1x207 1x1200	Data processing Data storage/ Archiving	Magneto/ Optical drive QIC 150 drive

Partition Size	Name
227489	/pstar
872735	/pstar/data
182143	/archive

discovery3	Sparc Station 1	8	2x327	Data processing
			Partition Size	Name
			299621	/packages
			299621	/pstar/work
discovery4	Sparc Station 1	8	2x327	Data processing
			Partition Size	Name
			299118	/pstar/spare

Output devices

Apple LaserWriter II (Mono Laser Printer)
Hewlett Packard Paintjet XL (InkJet Colour Plotter)
Tektronix 4693RGB (Thermal transfer plotter)
Hewlett Packard LaserJet III (Mono Laser Printer)
NEC Pinwriter P5 (Dot Matrix line printer)
Bruning Drum-type Pen Plotter.

Networking

All PCs, workstations and a number of output devices were connected to a thin ethernet (10Base2) local area network. The Sun workstations have integral ethernet interfaces, the Apple Macintoshes were connected via external SCSI ethernet interfaces.

MJG

RVS Engineering Division

This is a brief report on the equipment used during *DISCOVERY 200* that falls under the RVS Engineering Division's responsibility.

Ship's winch system

The winch system functioned well for the duration of the cruise.

The winch was used predominantly for the deployment of the large IOS CTD package. Care had to be taken for the first few metres of deployment of the CTD in rough seas due to the package kiting in the swell, which on one occasion caused the warp to go slack, resulting in a large snatch loading.

The size of the package, the depth of deployment and frequently the sea state, resulted in some of the deployments being very close to and occasionally exceeding the maximum limits for the cable being used.

Gantries

The starboard gantry was used for launching tide gauges and deploying the CTD package. The gantry proved very effective and safe for handling the packages even in bad weather conditions. It operated well for the duration of the cruise with the exception of one occasion when a fuse in the 24V power supply failed. The gantry was operated manually for the associated deployment and was fixed prior to recovery.

The aft gantry and Rexroth winch were used for the deployment of the buoyancy for the current meter moorings. The gantry operated without any problems.

Cranes

The port aft crane was out of order due to one of the hydraulic rams being badly scored. This problem resulted in the deployment of the current meter moorings being centred around the starboard aft crane.

The starboard aft crane was the only one used during this cruise. It was used as part of the set-up for mooring deployments and functioned well for the duration of the cruise. The use of this crane to place chain clumps over the stern was tricky and required a very competent operator.

Double barrel winch

The double barrel winch was used for the deployment of the moorings. It operated well for the duration of the cruise provided the oil was kept warm in the very cold conditions to prevent the motor starting current from tripping the breakers.

Non toxic supply

The non toxic supply was continuously in use for the whole of the cruise and performed well.

PJM, CD

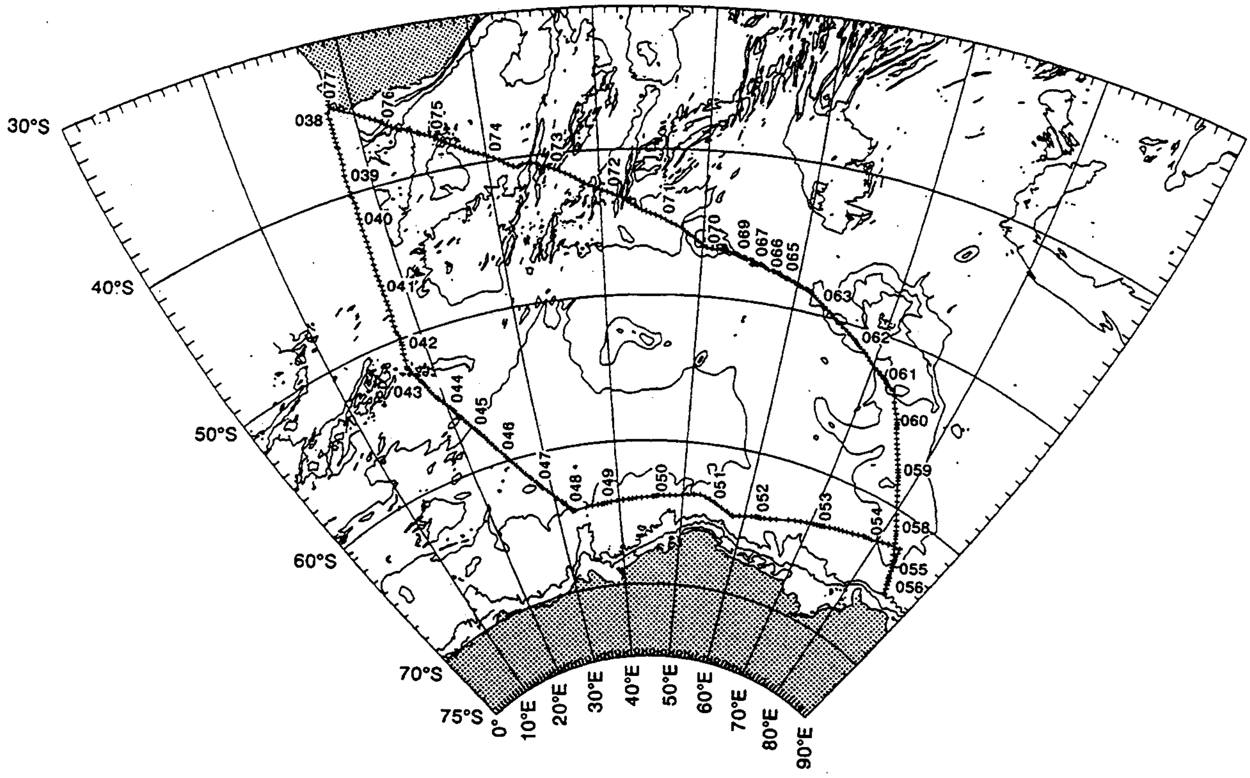


Figure 1(a). Track chart

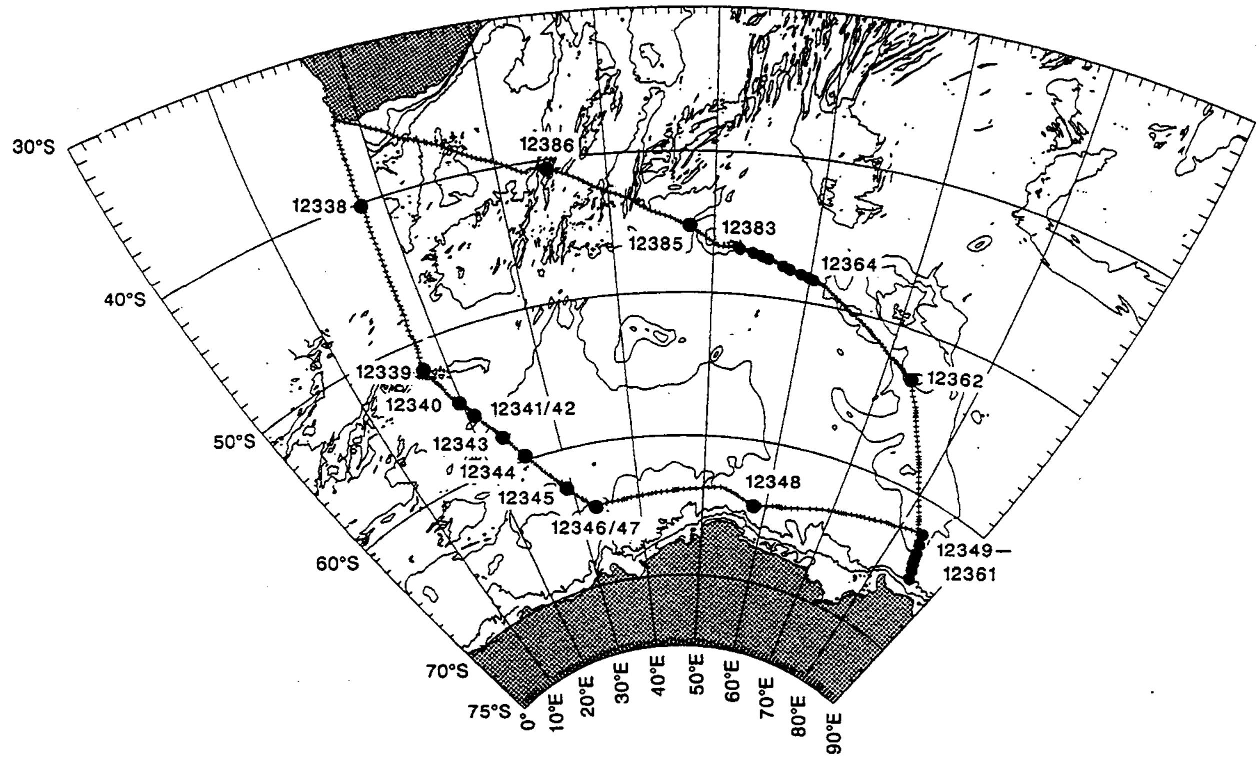


Figure 1(b). Chart showing CTD station positions

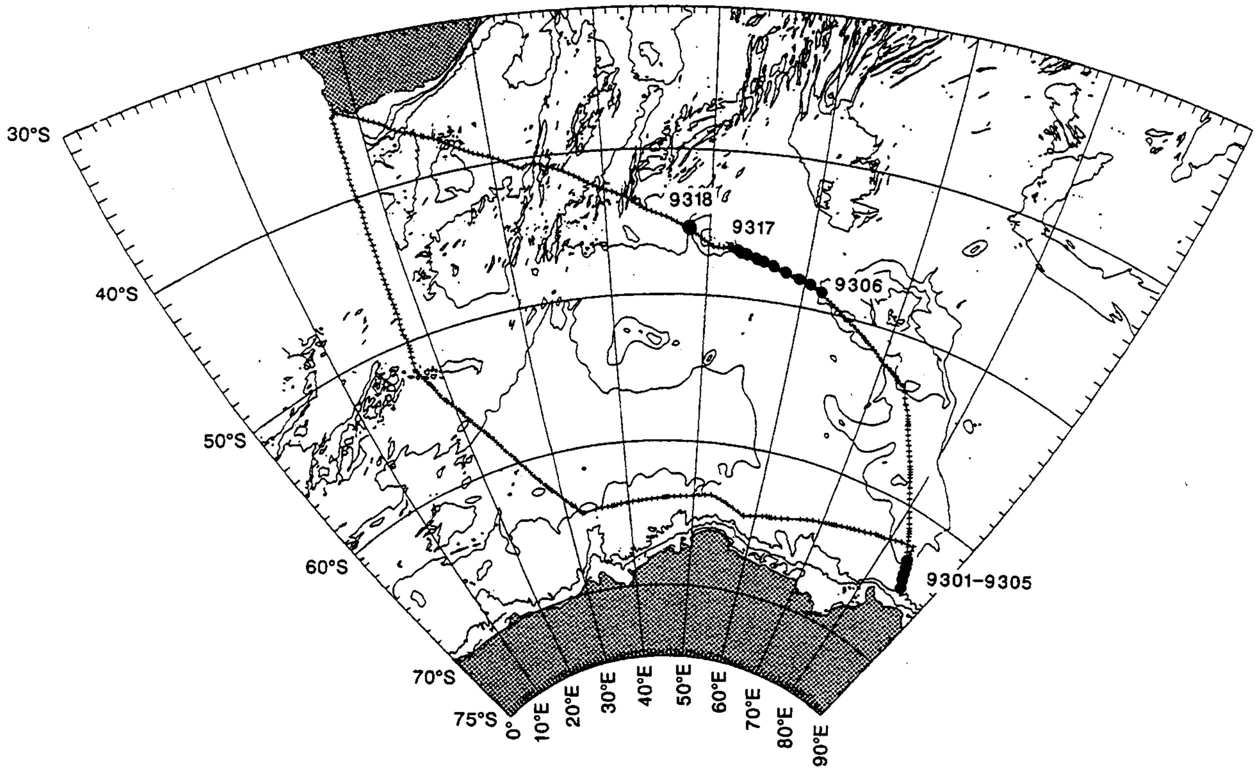


Figure 1(c). Chart showing current meter mooring positions

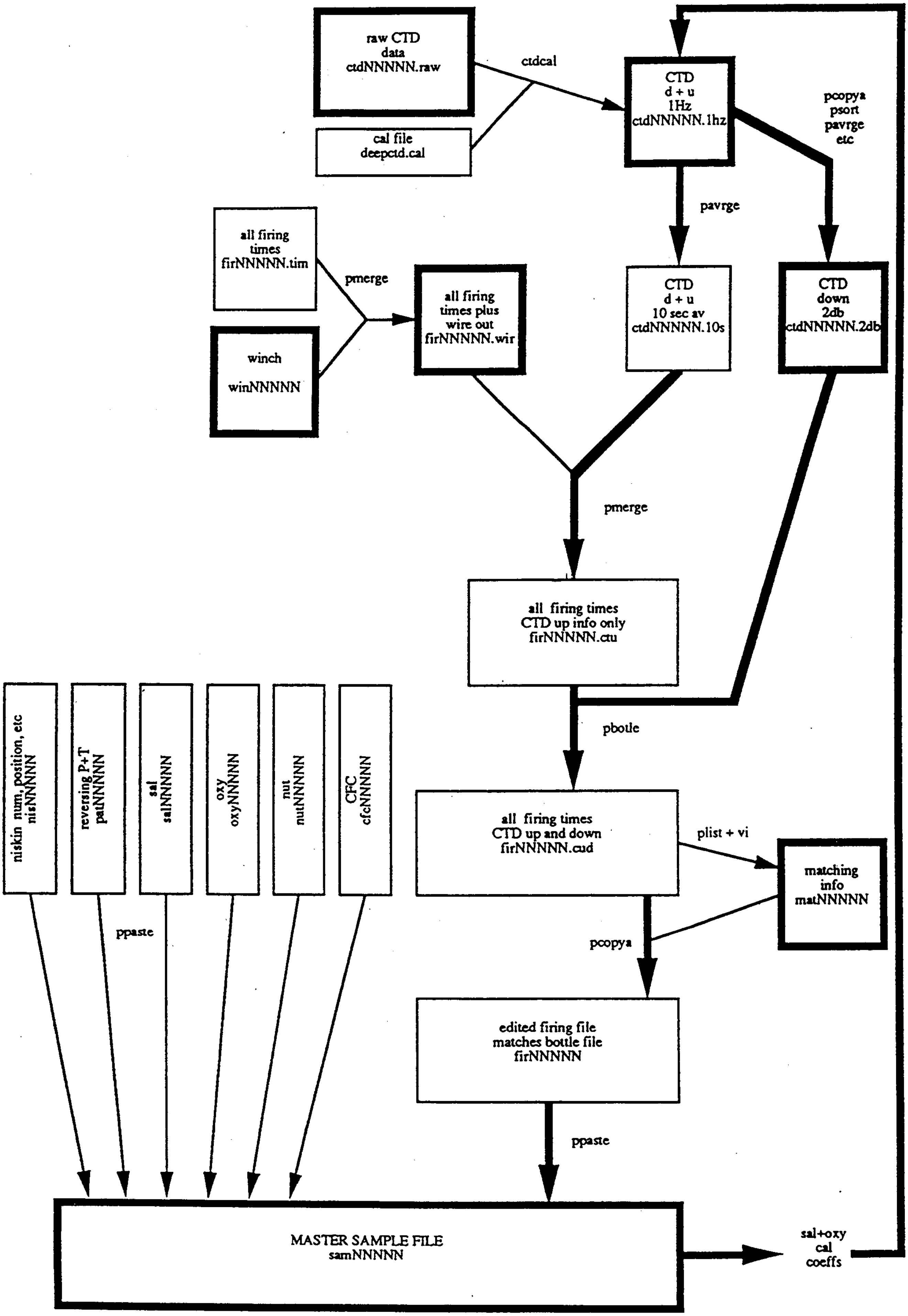


Figure 2. Cruise 200 data processing path

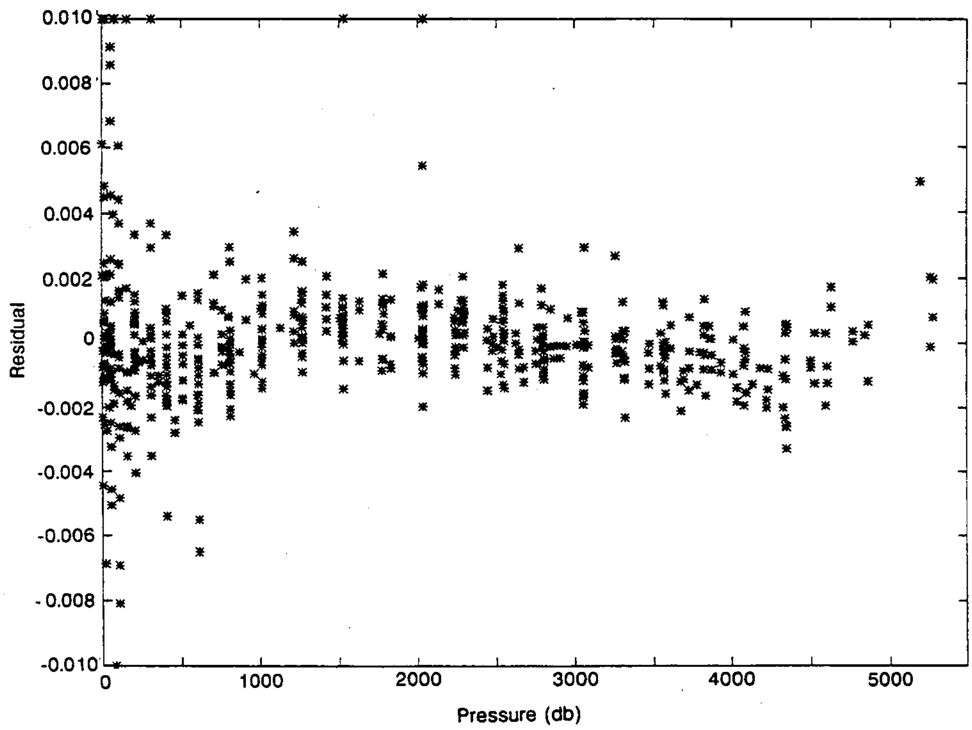


Figure 3. Residuals between calibrated CTD and bottle salinities

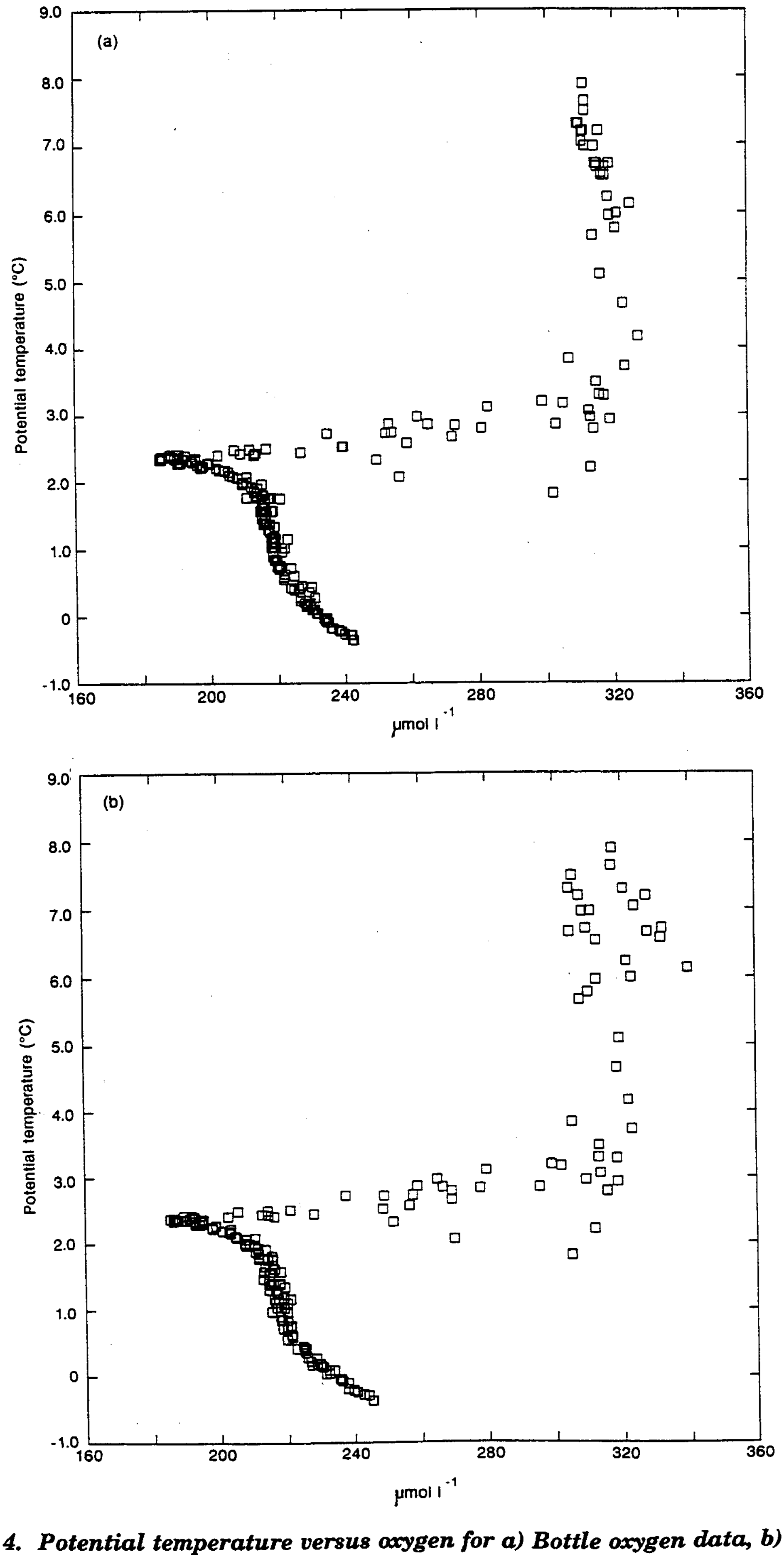


Figure 4. Potential temperature versus oxygen for a) Bottle oxygen data, b) CTD oxygen data

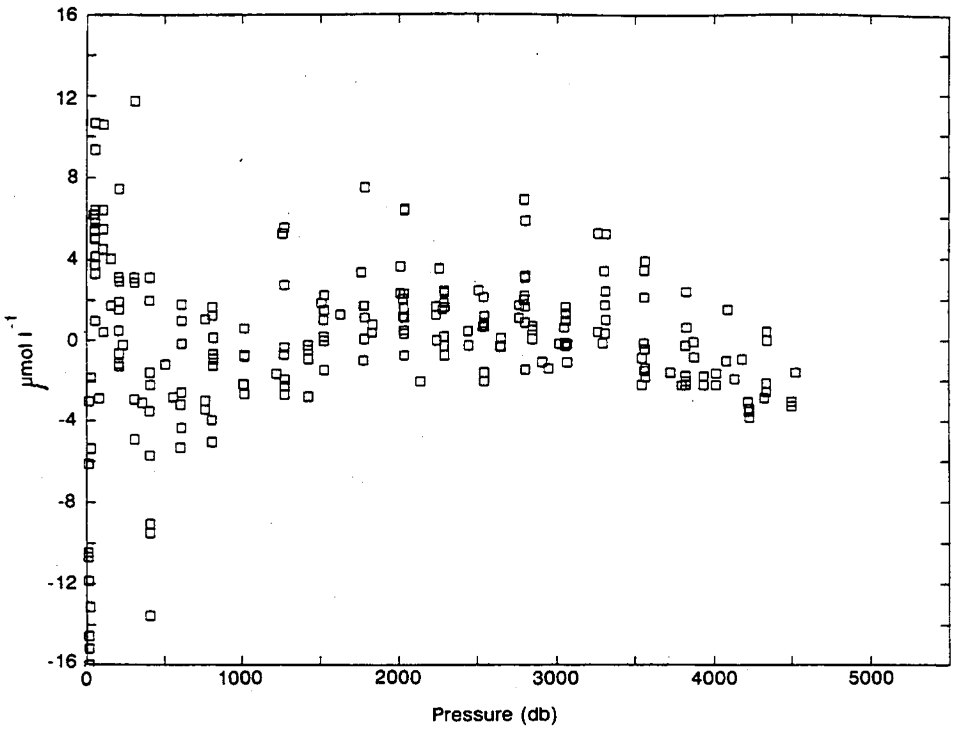


Figure 5. CTD and bottle oxygen comparison on the Kerguelen-Crozet section versus depth

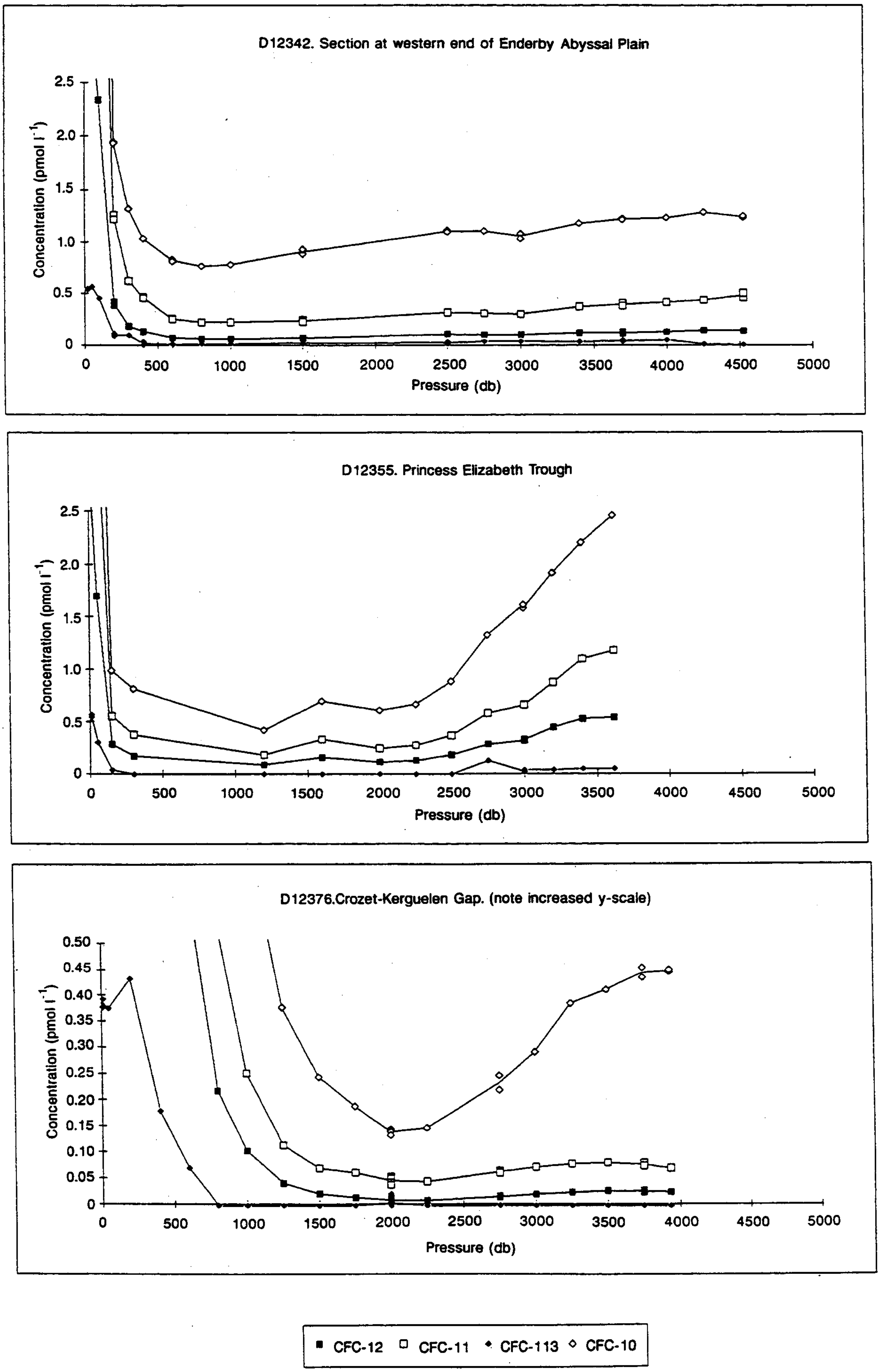
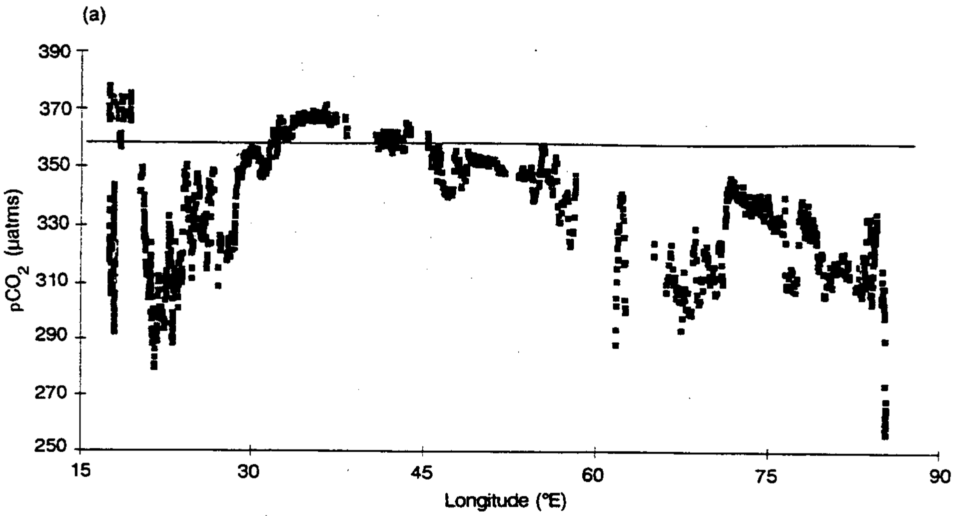


Figure 6. Preliminary CFC data from typical profiles on each of the three sections



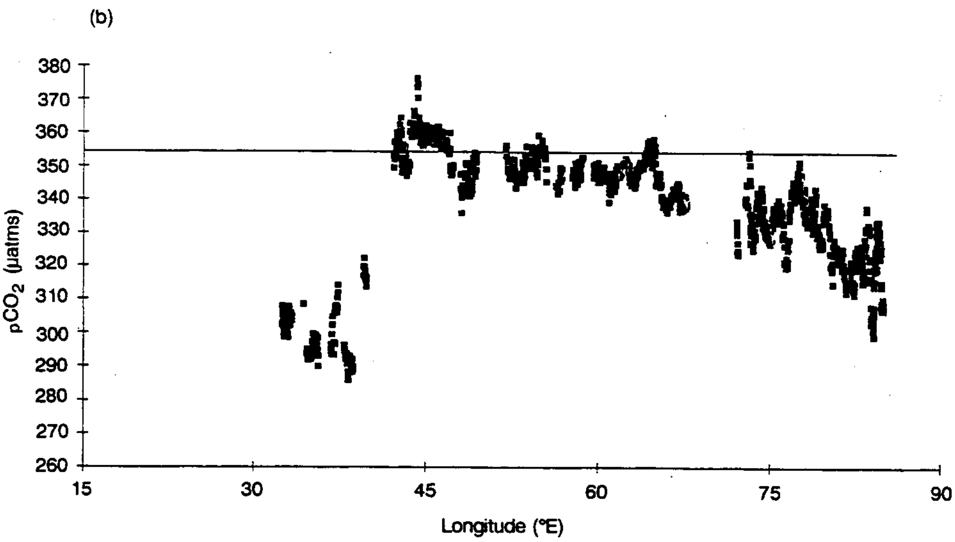


Figure 7. Measured pCO_2 values (a) outward leg, (b) return leg

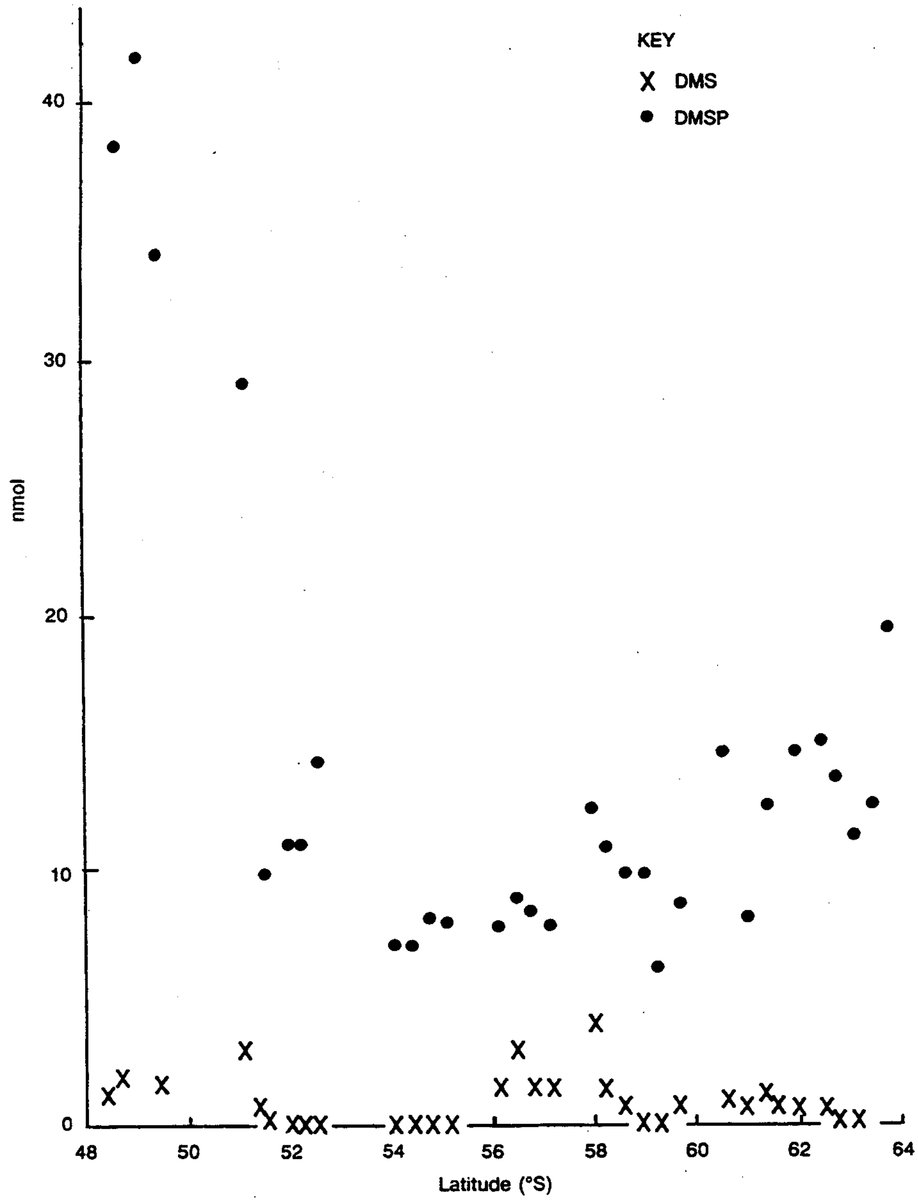


Figure 8. Surface concentrations of DMS and DMSP

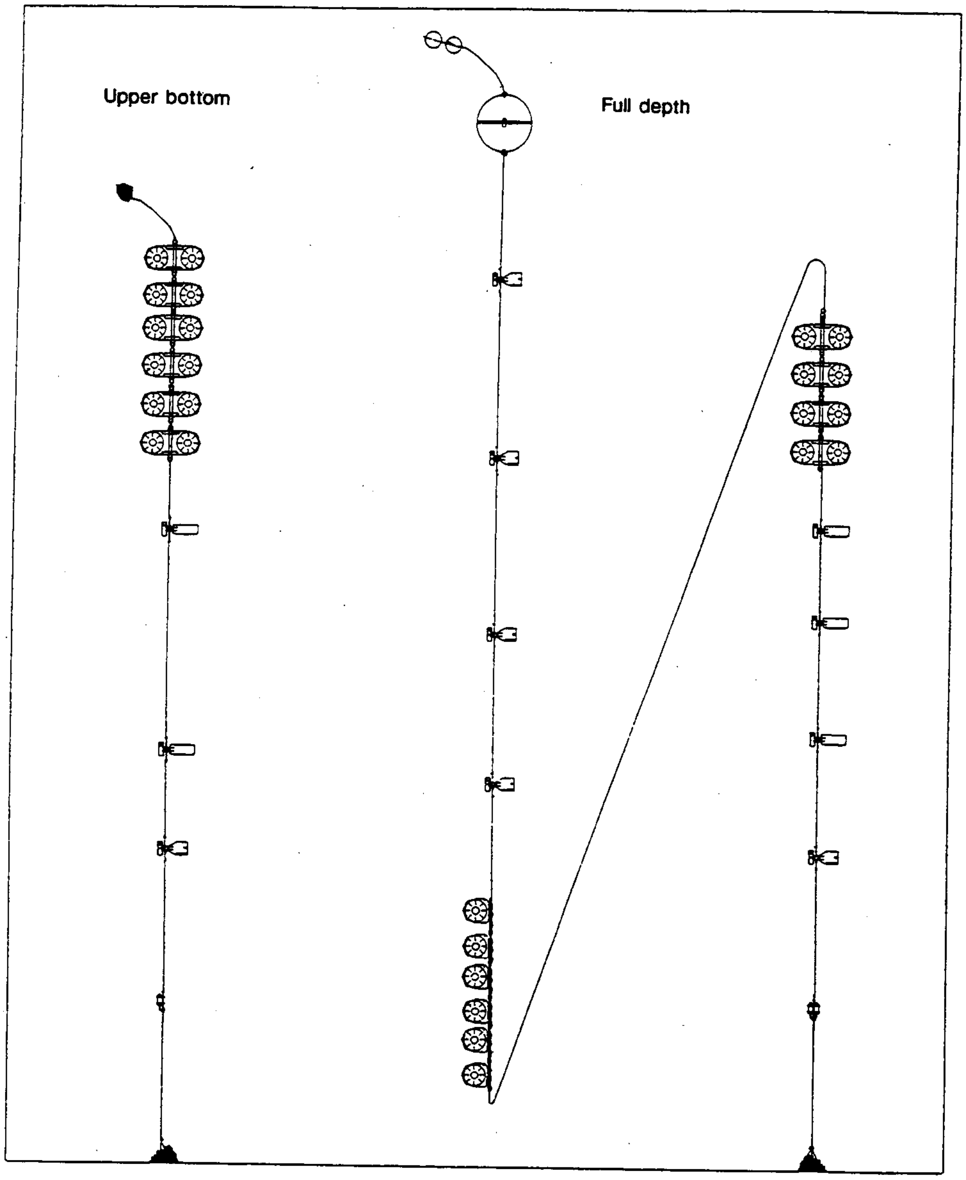


Figure 9. General current meter mooring diagram

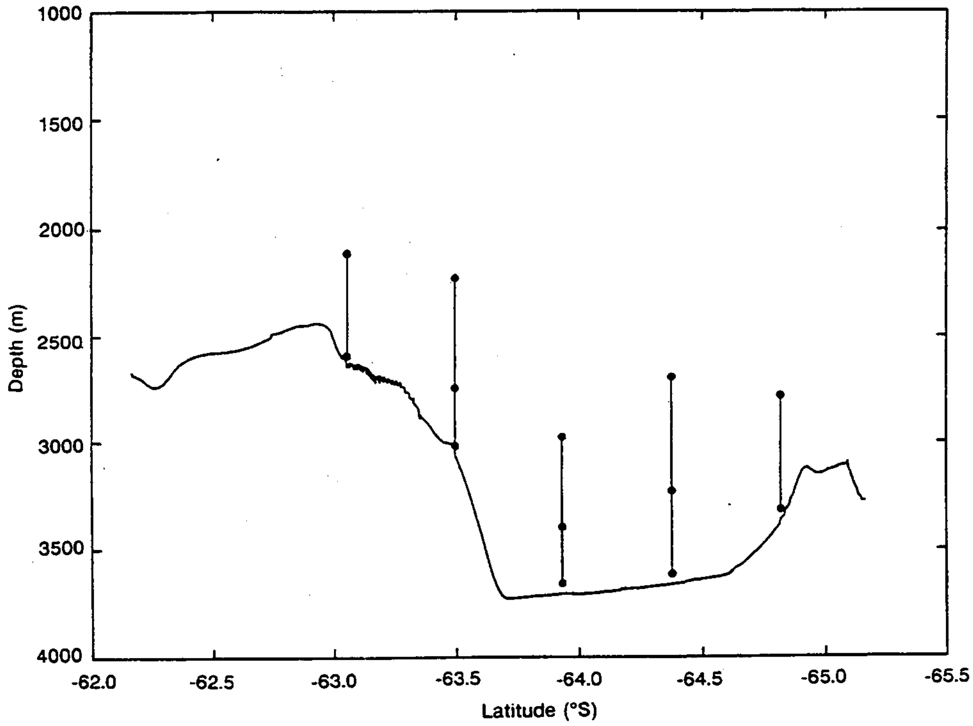


Figure 10. Moorings in the Princess Elizabeth Trough

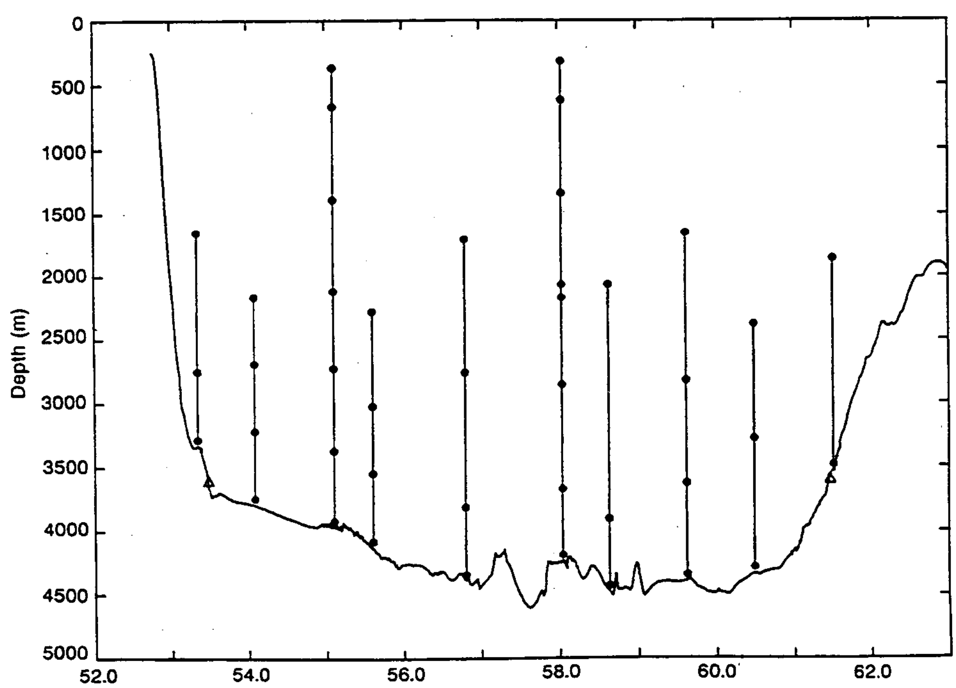


Figure 11. Moorings on the Kerguelen-Crozet section

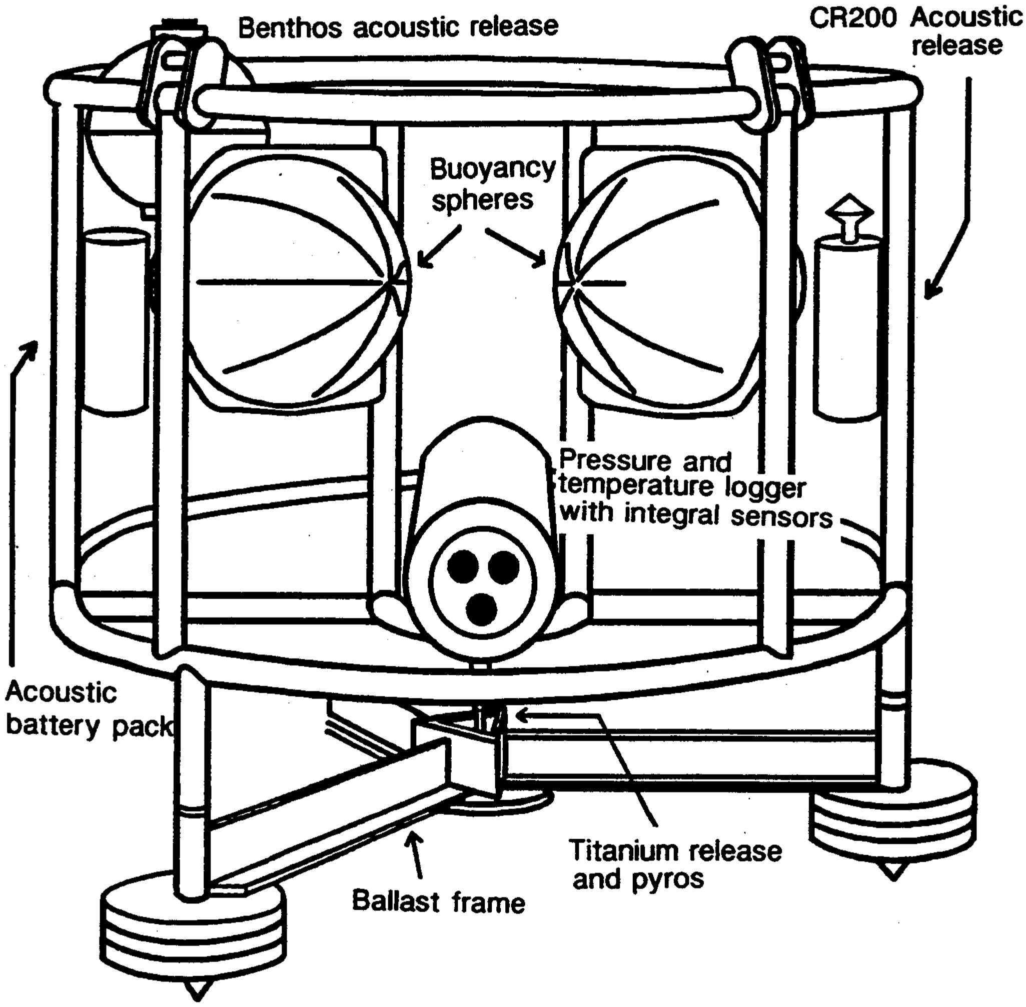


Figure 12. Schematic diagram of Bottom Pressure Recorder

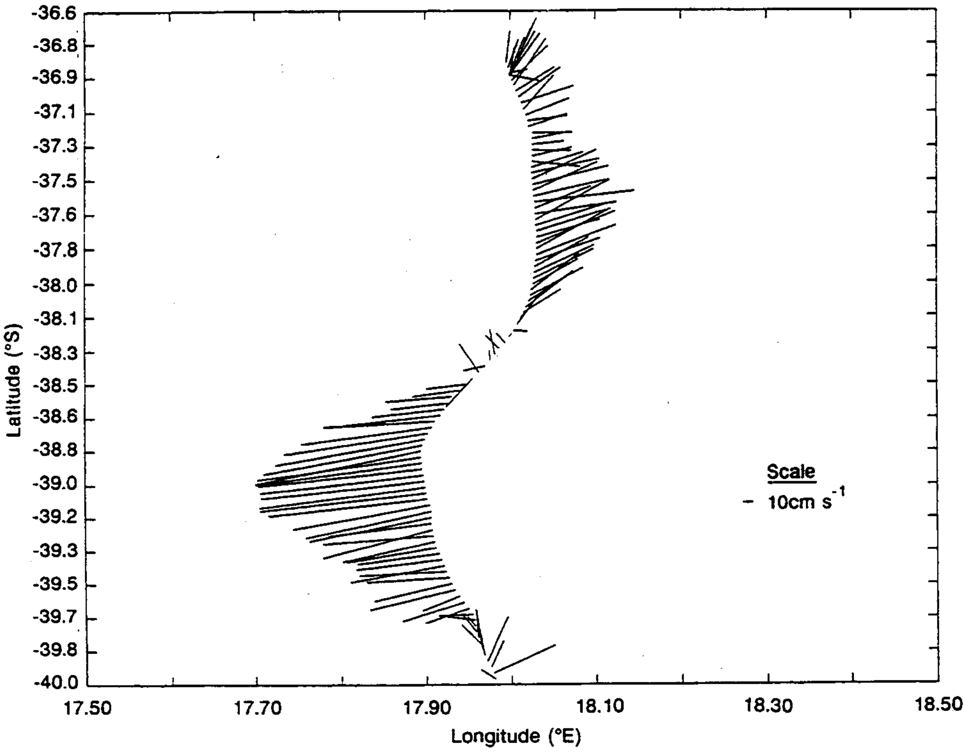


Figure 13. Plot of ADCP while crossing the Agulhas Current southbound

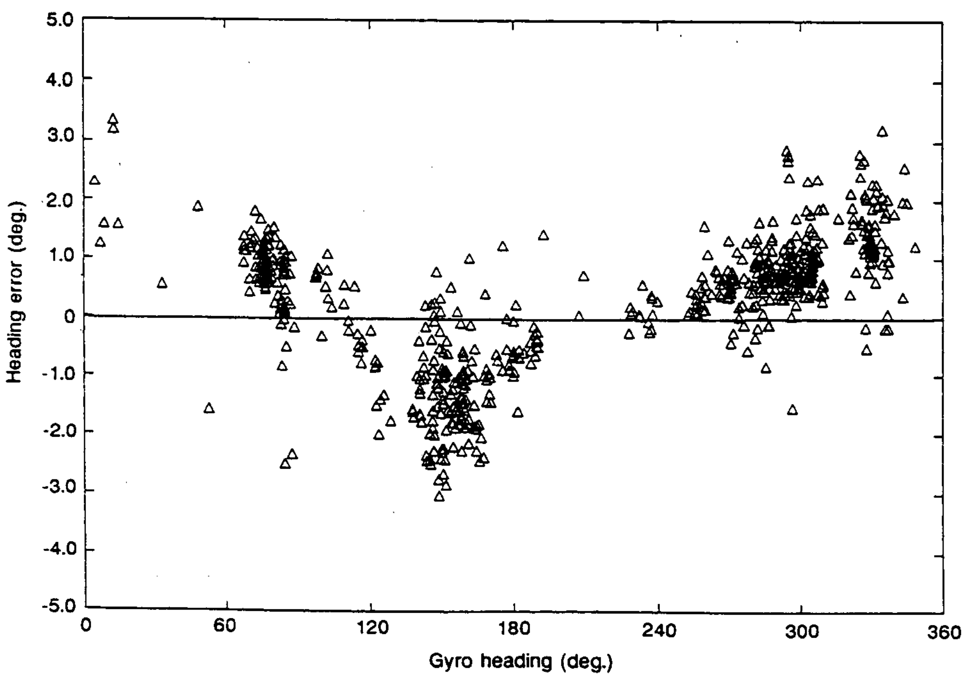


Figure 14. Heading errors versus gyro heading

Table 1. ADOX CTD Station list

Station No	Date/Day	Time (z)	Lat (S)	Long (E)	Depth (m)	Wire out	Ht Off	Levels sampled	Comments
		0915	40 10.5	17 59.2					
12338	08-II(39)	1113	40 10.6	17 59.4	4931	4818	99	13/14	
		1353	40 09.8	17 59.6					
		1109	52 00.0	17 30.1					
12339	11-II(42)	1159	52 00.1	17 30.2	2586	2568	85	16/18	
		1318	52 00.2	17 30.1					
		0906	54 30.0	19 20.1					
12340	12-II(43)	1035	54 30.0	19 21.0	3841	3777	21	15/18	
		1205	54 29.8	19 21.7					
		0550	56 09.9	20 59.8					Station aborted due to iceberg
12341	13-II(44)	0623	56 09.8	20 59.9	3896	1127		0	No samples
		0644	56 09.8	21 00.0					
		0740	56 15.8	21 07.5					
12342	13-II(44)	0911	56 15.6	21 07.6	4580	4523	23	19/19	Replacement for 12341
		1118	56 15.3	21 08.0					
		0419	58 02.7	23 04.3					
12343	14-II(45)	0604	58 02.1	23 04.5	5153	5077	27	19/19	
		0845	58 02.1	23 03.6					
		1817	59 40.5	24 55.1					
12344	14-II(45)	1957	59 40.8	24 53.8	5294	5150	106	19/20	
		2152	59 41.0	24 52.3					
		0413	62 26.0	28 41.3					
12345	16-II(47)	0549	62 26.3	28 42.6	5213	5155	17	18/20	
		0747	62 26.3	28 44.2					
		0237	64 28.4	32 26.9					Multisampler stuck at 3000m.
12346	17-II(48)	0400	64 28.3	32 26.8	4732	4655	23	8/8	
		0557	64 28.5	32 27.0					Continued as 12347
		0725	64 28.7	32 27.0					
12347	17-II(48)	0818	64 28.7	32 26.7	4728	2750		10/10	
		0914	64 28.4	32 26.8					
		0630	64 40.1	58 09.8					
12348	20-II (51)	0747	64 40.5	58 09.9	4009	3946	18	18/21	
		0943	64 40.8	58 10.6					
		0805	62 09.9	83 16.9					
12349	23-II(54)	0905	62 10.2	83 16.2	2706	2643	18	18/18	
		1017	62 10.2	83 15.5					
		1327	62 44.9	83 28.7					
12350	23-II(54)	1418	62 44.8	83 28.2	2507	2435	20	18/18	
		1549	62 44.9	83 28.3					
		2305	63 21.3	83 54.					
12351	24-II(55)	0014	63 21.3	83 55.5	2897	2814	20	19/19	
		0203	63 21.0	83 56.8					

Table 1. ***(continued)***

Station No	Date/Day	Time (z)	Lat (S)	Long (E)	Depth (m)	Wire out	Ht Off	Levels sampled	Comments
		1431	64 09.9	84 35.2					
12355	24-II(55)	1545	64 10.1	84 34.4	3700	3617	19	19/19	
		1745	64 10.1	84 34.4					
		2302	64 37.1	85 00.0					
12356	25-II(56)	0002	64 37.1	84 59.9	3619	3530	19	19/20	
		0230	64 37.5	84 59.3					
		0515	65 05.6	85 19.0					
12357	25-II(56)	0528	65 05.6	85 18.9	3114	400	-	14/14	Shallow cast for trace metals and DMS
		0604	65 05.6	85 18.7					
		0703	65 05.6	85 18.8					
12358	25-II(56)	0810	65 05.5	85 19.2	3104	3027	22	19/19	
		0932	65 05.5	85 19.4					
		2344	63 42.5	84 09.8					
12361(1)	26-II(57)	0053	63 42.7	84 10.0	3735	3650	17	13/14	
		0220	63 43.0	84 09.6					
		0344	63 43.3	84 08.6					
12361(2)	26-II(57)	0357	63 43.4	84 08.5	3732	600	-	7/7	Completion of station after multisampler failure.
		0414	63 43.3	84 08.3					
		1346	52 55.6	72 06.1					
12362	1-III(60)	1413	52 55.5	72 06.4	1416	1000	-	1/1	CFC calibration - all bottles at 1000m
		1450	52 55.4	72 06.4					
		1529	48 28.4	60 57.8					
12364	4-III(63)	1706	48 28.5	60 57.9	4206	4140	19	18/21	
		1921	48 28.8	60 58.0					
		1410	48 16.4	60 01.5					
12368	5-III(64)	1556	48 16.3	60 01.0	4485	4426	19	16/20	
		1803	48 16.5	60 00.9					
		2244	48 05.4	59 09.1					
12369	6-III(65)	0029	48 05.1	59 09.8	4466	4413	18	16/21	
		0227	48 04.8	59 09.8					
		1732	47 52.5	58 12.9					
12372	6-III(65)	1918	47 52.4	58 13.7	4309	4254	18	20/20	
		2057	47 52.5	58 14.3					
		0045	47 40.4	57 18.9					
12373	7-III(66)	0212	47 40.3	57 18.0	4170	4137	12	21/21	
		0405	47 40.8	57 17.8					
		1828	47 17.5	55 17.3					
12376	8-III(67)	2002	47 17.5	55 17.4	3996	3935	19	19/19	
		2130	47 17.8	55 17.5					
		1902	46 55.1	53 37.9					
12380	9-III(68)	2023	46 54.8	53 38.0	3720	3653	18	20/20	
		2140	46 54.3	53 38.3					

Table 1. (continued)

Station No	Date/Day	Time (z)	Lat (S)	Long (E)	Depth (m)	Wire out	Ht Off	Levels sampled	Comments
		0124	47 07.0	54 33.8					
12381	10-III(69)	0305	47 07.8	54 33.5	3922	3880	17	19/19	
		0435	47 08.7	54 33.6					
		1333	46 47.0	53 06.7					
12383	10-III(69)	1436	46 46.5	53 07.1	2905	2856	21	19/19	
		1540	46 46.5	53 07.2					
		1442	45 24.1	47 58.4					Start delayed due to gantry failure
12385	11-III(70)	1602	45 24.0	47 57.9	3082	3013	21	19/20	Fault on alt connector, noisy data.
		1715	45 24.1	47 57.4					Top 11 bottles sampled for trace metals
		0842	40 27.9	33 45.5					
12386	14-III(73)	0854	40 27.9	33 45.4	4846	500	-	15/15	Shallow dip for trace metals
		0921	40 28.0	33 45.3					

Notes:
Times are: First — Start down
Second — At bottom
Third — On deck

Positions are taken from abnav2001.av at times stated

Depth is depth recorded by Simrad PES (assumed 1500 ms-1 with 17 m added to account for sinking of the PES fish on station. Carters Tables corrections have not been made

Wire out is indicated value at bottom of cast

Ht off is height above seabed at closest approach as measured by the altimeter

Levels sampled x/y. x is number of individual levels at which bottles were closed, y is the number that should have been sampled if the multisampler had behaved perfectly

Table 2. Bottle firing depths (wire out (m))

Bottle Number	Station Number										
	12338	12339	12340	12342	12343	12344	12345	12346	12347	12348	12349
1	4818	2586	3777	4523	5077	5150	5155	4655	50	3946	2643
2	4818	2586	3777	4523	4750	5150	5155	4655	50	3946	2643
3	4818	2440	3600	4250	4500	4730	4750	4500	2	3740	2500
4	4818	2440	3600	4000	4250	4500	4500	4250		3500	2250
5	4500	2200	3400	3700	4000	4250	4250	4000		3250	2250
6	4000	2200	3200	3400	3500	4000	4250	4000		3250	2000
7	3500	2000	3200	3000	3500	4000	4000	3750		3000	1750
8	3500	1800	2500	3000	3000	3500	3500	3500		2500	1500
9	3500	1800	2500	2750	3000	3000	3000	3250		2000	1500
10	3500	1800	2200	2500	2500	2000	2500	3000		1750	1250
11	3000	1400	2000	2000	2000	1500	2000			1500	1000
12	2000	1200	1800	1500	1500	1000	2000			1113	800
13	2000	1200	1500	1500	1000	1000	1500			800	800
14	1500	900	1500	1000	800	948	1500		2750	800	600
15	1500	900	1200	800	800	860	1250		2750	450	400
16	1250	800	1200	600	600	700	1000		2500	450	300
17	1250	700	700	600	400	500	750		2000	150	200
18	1250	600	500	400	400	300	500		1500	150	150
19	1250	500	300	300	300	200	200		1000	100	99
20	1250	400	101	200	200	100	100		1000	100	75
21	1000	300	101	100	100	50	50		750	70	75
22	800	150	20	50	50	10	1		500	50	10
23	600	150		20	10				250	30	2
24	400	10							250	2	2

Bottle Number	Station Number										
	12350	12351	12355	12356	12357	12358	12361	12362	12364	12368	12369
1	2435	2814	3617	3530	400	3027	3650	1000	4140	4426	4413
2	2435	2814	3617	3530	400	3027	3650	1000	4140	4426	4413
3	2250	2750	3400	3400	300	2900	3500	1000	3750	4250	4245
4	2000	2600	3200	3200	250	2700	3250	1000	3750	4250	4245
5	2000	2600	3200	3200	200	2700	3250	1000	3500	4000	4000
6	1750	2400	3000	3000	200	2500	3000	1000	3250	3749	3750
7	1500	2200	2750	2750	150	2200	2750	1000	3000	3200	3500
8	1250	2000	2500	2500	150	2200	2500	1000	2500	3200	3500
9	1250	2000	2500	2500	100	2000	2500	1000	2500	2799	3250
10	1000	1750	2250	2250	100	1741	2250	1000	2250	2500	2750
11	800	1500	2000	2000	75	1500	2000	1000	2250	2500	2750
12	800	1250	1600	1750	75	1250	1750	1000	2000	2100	2250
13	600	1250	1600	1500	50	1250	1500	1000	1750	2100	2250
14	500	1000	1200	1250	50	1000	1250	1000	1500	1400	1750
15	400	800	900	1000	35	800	1000	1000	1250	1000	1750
16	300	600	700	600	31	600	600	1000	800	750	1250
17	200	400	500	600	31	400	600	1000	800	750	1250
18	150	300	300	400	26	300	600	1000	600	350	750
19	74	200	200	300	26	174	400	1000	400	350	750
20	74	100	150	200	20	99	300	1000	400	200	500
21	50	70	52	64	20	50	200	1000	300	100	300
22	10	70	30	64	15	15	150	1000	200	50	200
23	10	10	10	10	15	15	70	1000	100	50	100
24	3	2	10	2	0	0	10	1000	20	10	10

Table 2. (continued)

Bottle Number	Station Number							
	12372	12373	12376	12380	12381	12383	12385	12386
1	4254	4137	3935	3653	3880	2856	3013	500
2	4254	4137	3935	3653	3880	2856	3013	500
3	4100	4050	3750	3500	3750	2750	2900	450
4	3800	3800	3750	3500	3500	2600	2800	400
5	3800	3500	3500	3250	3500	2600	2800	400
6	3500	3250	3250	3000	3250	2400	2600	350
7	3250	3000	3000	2750	3000	2200	2400	300
8	3000	2750	2750	2500	2750	2000	2200	300
9	3000	2750	2750	2250	2750	2000	2200	250
10	2750	2500	2500	2000	2500	1800	2000	250
11	2500	2250	2249	1750	2250	1600	1800	200
12	2250	2000	2000	1500	2000	1400	1400	200
13	2250	1750	2000	1500	2000	1400	550	150
14	2000	1500	1750	1250	1750	1200	400	125
15	1750	1250	1500	1000	1500	1000	300	100
16	1500	1000	1250	800	1250	800	225	100
17	1250	800	1000	600	1000	600	150	75
18	1000	600	800	400	800	400	75	75
19	800	400	600	300	600	300	50	59
20	600	200	400	200	400	200	40	40
21	400	100	200	100	200	150	40	25
22	200	50	50	50	50	50	25	25
23	50	50	50	50	50	50	10	10
24	10	10	10	10	20	10		10

Table 3. Current meter mooring details

Mooring	9301 K	9302 L	9303 M	9304 O	9305 N	9306 J	9307 BPR	9308 I	9309 H	9310 G	9311 F	9312 E	9313 D	9314 C	9315 B	9316 BPR	9317 A	9318 P
DEPTH(m)	2636	3048	3700	3367	3654	3565	3610	4356	4393	4478	4240	4427	4141	3996	3809	3617	3345	3057
DATE	24/2/93	24/2/93	24/2/93	25/2/93	25/2/93	4/3/93	4/3/93	5/3/93	5/3/93	6/3/93	6/3/93	7/3/93	8/3/93	9/3/93	9/3/93	9/3/93	10/3/93	11/3/93
DAY	55	55	55	56	56	63	63	64	64	65	65	66	67	68	68	68	69	70
TIME Z	0449	0854	1238	1236	1552	1210	2135	0631	1225	0733	1547	0933	1532	0616	1224	1704	1202	1345
DOWN Z								2236				1619	1006	1601	0646	1249	1804	1225
POSN S	63-03.20	63-29.928	63-56.064	64-49.232	64-22.787	48 34.75		48-22.686	48 11.88		47 45.28				47.02			45 26.166
E	83-35.76	83-56.608	84-18.582	85-07.713	84-41.131	61 30.76		60-29.724	59 37.68		58. 02.79				54.0882			47 59.640
BESTNAV S	63 03.21	63 29.82	63 56.01	64 49.23	64 22.65	48 34.77	48 35.03	48 22.69	48 11.91	48 00.13	47 45.28	47 36.95	47 24.96	47 08.31	47 01.24	46 52.26	46 50.52	45 26.23
E	83 35.41	83 57.19	84 19.12	85 07.82	84 41.64	61 30.77	61 27.96	60 29.74	59 37.65	58 38.16	58 02.80	56 48.36	55 36.55	55 06.48	54 05.31	53 28.31	53 20.27	47 59.67
METER											10856							
Ht.(m)											3915							
METER											10862			10855				
Ht.(m)											3614			3600				
METER											9967			10854				
Ht.(m)											2895			3299				
METER											9968			10113				
Ht.(m)											2167			2580				
METER									155		238	178	555	9969	553			
Ht.(m)									2738		2064	2680	1847	1849	1630			
METER		124	002		490			397	696	855	652	607	606	611	523		213	
Ht.(m)		844	724		962			1956	1570	2413	1378	1627	1102	1239	1102		1681	
METER	037	373	046	526	879	801		743	109	644	331	703	278	234	442		825	128
Ht.(m)	533	316	305	577	431	1675		1053	763	573	562	574	574	590	574		581	781
METER	476	898	073	768	924	933		980	981	965	942	638	546	436	279		146	192
Ht.(m)	46	46	46	46	46	46		46	46	46	46	46	46	46	46		46	46
BEACON							160.725									160.725		
A/R #1	72	94	69	95	93	96	47124	71	267	2187	2345	2180	2184	2348	2333	46421	2344	76
PING ON	0644	4624	0524	2624	2584	4644		0624	320	320	320	320	320	318	320		318	2564
OFF/PER	0633	4613	0513	2613	2573	4633	RX11.5	0613	0.94	1.08	1.06	1.14	1.02	1.18	0.94	RX14.0	0.96	2553
WINDOW	0631	4611	0511	2611	2571	4631	TX12.0	0611								TX12.0		2551
RELEASE	0646	4626	0526	2626	2586	4646	CDE D	0626	299	338	280	240	400	418	442	CDE D	440	2566
A/R #2							2517				2402		2400	2401	2347	2518		
PINGER							322				319		319	321	320	322		
RELEASE							262				362		339	441	240	279		
PERIOD							1.18				0.98		0.94	0.96	1.02	1.16		

Table 4. XBT Drop List

Drop No.	Date (Day)	Time (z)	Lat (S)	Long (E)	Probe	TSG Temp.	XBT Sufrace T.	Comments
1	06-II (37)	2355	35 01.60	17 59.57	T7	20.5	20.84	
2	07-II (38)	0415	35 43.07	18 00.73	T7	20.2	20.89	
3	07-II (38)	1045	36 40.08	17 59.17	T7	19.8	19.77	
4	07-II (38)	1644	37 27.36	18 01.56	T7	20.7	20.48	
5	07-II (38)	1957	38 00.96	18 01.50	T7	20.7	20.45	
6	07-II (38)	2358	38 44.47	17 53.95	T7	23.2	23.51	
7	08-II (39)	0400	39 29.15	17 55.81	T7	20.8	20.72	
8	08-II (39)	1635	40 23.18	18 01.53	T7	20.5	20.91	
9	08-II (39)	2004	40 59.75	18 06.40	T7	20.4	20.70	
10	08-II (39)	2358	41 39.53	18 01.16	T7	18.2	18.63	
11	09-II (40)	0411	42 28.82	17 58.50	T7	16.4	15.78	
12	09-II (40)	0804	43 15.62	18 00.66	T7	10.2	10.02	
13	09-II (40)	1157	43 59.40	17 59.87	T7	11.6	12.02	
14	09-II (40)	1630	44 54.41	17 55.74	T7	9.9	9.86	
15	10-II (41)	0517	47 39.42	17 52.52	T7	7.4	7.06	
16	10-II (41)	0811	47 39.20	17 54.30	T7	6.2		Wire broke at approximately 40m
17	10-II (41)	0806	47 39.42	17 54.35	T7	6.0	5.88	
18	10-II (41)	1153	48 21.16	17 52.55	T7	4.7	4.87	
19	10-II (41)	1639	49 11.75	17 43.21	T7	4.3		Wire broke at approximately 50m
20	10-II (41)	1653	49 14.34	17 43.08	T7	4.3	4.90	
21	10-II (41)	2020	49 45.92	17 51.97	T7	3.5	3.45	
22	10-II (41)	2353	50 13.59	17 49.00	T7	3.4	3.49	
23	11-II (42)	0400	50 39.90	17 42.89	T7	3.4	3.35	
24	11-II (42)	0758	51 23.92	18 30.80	T7	2.5	3.32	
25	11-II (42)	1637	52 19.15	17 43.77	T7	2.1	2.01	
26	11-II (42)	2028	52 54.97	18 09.50	T7	1.5	1.66	
27	11-II (42)	2356	53 09.77	18 22.50	T7	1.3	1.62	
28	12-II (43)	0416	53 39.47	18 39.81	T7	1.5	1.53	
29	12-II (43)	1633	54 54.78	19 49.33	T7	1.6	1.69	
30	13-II (44)	0414	55 54.84	20 45.44	T7	1.5	1.51	
31	13-II (44)	1609	56 39.00	21 29.14	T7	1.5	1.56	
32	13-II (44)	2012	57 18.31	22 16.07	T7	1.6	1.62	
33	13-II (44)	2355	57 35.35	22 35.54	T7	1.6	1.76	
34	14-II (45)	1153	58 33.82	23 37.45	T7	1.6	1.80	
35	14-II (45)	1655	59 29.35	24 43.71	T7	1.9	1.80	
36	14-II (45)	0057	59 45.86	24 57.96	T5	1.8	1.95	
37	15-II (46)	0412	60 11.55	25 33.20	T7	1.6	1.62	
38	15-II (46)	0802	60 52.57	26 24.82	T7	1.6	1.61	
39	15-II (46)	1142	61 30.03	27 17.72	T7	1.3	1.42	
40	15-II (46)	1538	61 52.66	27 54.08	T7	1.2	1.28	
41	15-II (46)	2033	62 09.50	28 19.50	T7	1.2		Drop aborted - no trace on screen
42	15-II (46)	2048	62 10.55	28 20.74	T7	1.2	1.22	
43	16-II (47)	1150	63 02.36	29 47.91	T7	1.5	1.58	
44	16-II (47)	1549	63 40.86	30 58.74	T7	1.4	1.34	
45	16-II (47)	2013	64 07.57	31 53.82	T7	1.3	1.36	
46	16-II (47)	2350	64 19.46	32 15.81	T7	1.1	1.18	
47	17-II (48)	1152	64 24.49	33 40.24	T7	1.2	1.30	
48	17-II (48)	1556	64 19.54	35 37.24	T7	1.3	1.32	
49	17-II (48)	1959	64 17.57	37 15.31	T7	1.5	1.32	
50	17-II (48)	2358	64 14.26	38 03.49	T7	1.3	1.36	Wire stretch at approximately 75m

Table 4. (continued)

Drop No.	Date (Day)	Time (z)	Lat (S)	Long (E)	Probe	TSG Temp.	XBT Surface T.	Comments
51	18-II (49)	0410	64 09.67	39 45.62	T7	1.4	1.46	
52	18-II (49)	0742	64 05.74	41 25.81	T7	1.3	1.36	
53	18-II (49)	1152	64 01.55	42 43.20	T7	1.2	1.28	
54	18-II (49)	1556	63 56.95	44 27.77	T7	1.2	1.00	
55	18-II (49)	2012	63 53.56	45 37.80	T7	0.8	0.75	
56	18-II (49)	2354	63 50.88	46 14.72	T7	0.8	0.82	Wire stretch
57	19-II (50)	0409	63 47.76	47 57.85	T7	1.1	1.11	
58	19-II (50)	0815	63 44.23	49 53.77	T7	1.0	1.01	Wire stretch
59	19-II (50)	1155	63 37.38	51 36.62	T7	0.7		Wire stretch
	19-II (50)	1158			T7			Wire stretch
60	19-II (50)	1208	63 37.11	51 42.75	T7	0.7	0.67	Wire stretch at approximately 160m
61	19-II (50)	1548	63 41.74	53 23.33	T7	0.4	0.43	
62	19-II (50)	2348	64 04.32	55 21.42	T7	0.4	0.43	
63	20-II (51)	0407	64 28.10	57 11.95	T7	0.3	0.38	Wire stretch at approximately 90m
64	20-II (51)	1146	64 34.70	59 05.90	T7	0.2	0.25	
65	20-II (51)	1538	64 24.17	60 57.83	T7	0.5	0.40	
66	20-II (51)	2037	64 20.84	62 16.54	T7	0.6	0.64	
67	21-II (52)	0400	64 06.42	64 55.71	T7	0.6	0.58	
68	21-II (52)	1149	63 40.72	68 29.76	T7	0.9	0.88	
69	21-II (52)	1551	63 30.91	70 22.51	T7	1.0	0.97	
70	21-II (52)	2005	63 26.30	71 26.72	T7	1.1	1.05	
71	21-II (52)	2355	63 21.80	72 08.51	T7	1.0	1.05	Wire stretch at 460m
	22-II (53)	0354			T7			No trace on screen
	22-II (53)	0416			T7			No trace on screen
72	22-II (53)	0714	63 06.41	74 37.60	T7	1.1	1.19	
73	22-II (53)	1151	62 56.24	76 18.71	T7	1.2	1.20	
74	22-II (53)	1804	62 42.19	78 22.86	T7	1.4	1.47	
75	22-II (53)	2355	62 34.32	79 51.66	T7	1.2	1.21	
76	22-II (53)	0359	62 19.86	81 34.92	T7	1.4	1.38	
77	26-II (57)	0917	62 50.60	83 09.72	T7	1.0	0.90	
78	26-II (57)	1152	62 23.47	82 38.31	T7	1.2	1.19	
79	26-II (57)	2002	61 26.48	81 34.03	T5	1.3	1.36	
80	27-II (58)	0000			T7	1.2		Wire stretch
81	27-II (58)	0010	61 00.52	81 03.47	T7	1.2	1.32	GOES transmitter failed
82	27-II (58)	0402	60 20.29	80 12.07	T7	1.5		Profile not saved by SEAS unit
83	27-II (58)	0818	59 34.56	79 21.40	T7	1.1	1.07	
84	27-II (58)	1311	58 43.02	78 28.88	T7	1.6	1.61	
85	27-II (58)	1623	58 17.56	78 04.34	T5	1.6	1.63	Probe hit seafloor before finished
86	27-II (58)	2013	57 59.73	77 46.97	T7	1.7	1.72	
87	27-II (58)	2353	57 42.42	77 28.57	T7	1.9	1.88	
88	28-II (59)	0422	57 04.16	76 46.61	T7	1.7	1.69	
89	28-II (59)	0813	56 29.08	76 09.53	T7	1.8	1.65	
90	28-II (59)	1150	55 56.40	75 36.91	T7	2.0	2.06	
91	28-II (59)	1708	55 18.03	75 03.86	T5	2.9	2.89	
92	28-II (59)	2015	55 04.38	74 55.59	T7	2.8	2.84	
93	28-II (59)	2352	54 47.07	74 40.86	T7	2.6	2.55	Wire broke
94	28-II (59)	2355	54 46.60	74 40.31	T7	2.6	2.63	
95	01-III (60)	0403	54 08.31	73 54.54	T7	3.0	3.07	
	01-III (60)	0812			T7	3.4		No trace on screen
96	01-III (60)	0817	53 23.21	73 18.20	T7	3.4	3.43	
97	01-III (60)	1750	52 45.29	71 48.81	T7	3.6	3.58	

Table 4. (continued)

Drop No.	Date (Day)	Time (z)	Lat (S)	Long (E)	Probe	TSG Temp.	XBT Surface T.	Comments
98	01-III (60)	2013	52 38.55	71 34.06	T7	3.6	3.59	
	01-III (60)	2354			T7	3.6		Wire stretched and broke
99	01-III (60)	2358	52 29.97	71 08.46	T7	3.6	3.60	
100	02-III (61)	0410	52 10.74	70 10.31	T7	3.8	3.82	
101	02-III (61)	0800	51 54.21	69 27.72	T7	3.8	3.80	Wire stretch at approximately 130m
102	02-III (61)	1152	51 32.34	68 43.71	T7	3.9	3.96	Wire stretch at approximately 30m then broken
103	02-III (61)	1155	51 32.64	68 43.12	T7	3.9	3.92	
104	02-III (61)	1654	51 11.50	67 47.39	T5	4.1	4.11	
105	02-III (61)	2007	51 02.58	67 30.28	T7	4.2	4.19	
106	02-III (61)	2350	50 52.20	67 08.43	T7	4.1	4.11	
107	03-III (62)	0414	50 32.40	66 14.03	T7	4.3	4.20	
108	03-III (62)	0801	50 13.92	65 22.58	T7	4.9		Profile completely spurious (35C)
109	03-III (62)	0812	50 13.04	65 20.07	T7	4.9	4.87	
110	03-III (62)	1148	49 54.95	64 31.57	T7	4.9	4.82	
111	03-III (62)	1523	49 33.65	63 41.97	T7	5.0	5.91	
112	03-III (62)	2011	49 09.57	62 40.72	T7	5.4	5.50	Wind 40 knots. Wire across deck
113	10-III (69)	1858	46 43.11	52 16.80	T7	6.4	6.44	
114	11-III (70)	0003	46 37.56	50 49.53	T7	7.0	6.98	
115	11-III (70)	0340	46 26.99	50 04.81	T7	7.1	7.12	
116	11-III (70)	0805	46 00.12	49 07.51	T7	8.1	8.10	
117	11-III (70)	2013	45 09.86	47 15.29	T7	7.8	7.72	
118	11-III (70)	2356	44 50.75	46 19.49	T7	8.9	8.99	
119	12-III (71)	0403	44 30.68	45 17.13	T7	7.2	9.07	
120	12-III (71)	0805	44 15.93	44 22.72	T7	9.6	9.64	
121	12-III (71)	1155	44 01.74	43 38.77	T7	10.4	10.44	
122	12-III (71)	1633	43 40.04	42 50.31	T7	9.5	9.48	
123	12-III (71)	2001	43 18.21	42 06.28	T7	10.4		Spurious profile
124	12-III (71)	2008	43 17.61	42 04.60	T7	10.4	10.23	
125	12-III (71)	2352	43 01.54	41 11.72	T7	12.4	12.45	
126	13-III (72)	0408	42 44.55	40 10.28	T7	13.9	13.89	
127	13-III (72)	0805	42 27.56	39 18.77	T7	14.1	14.28	
	13-III (72)	1152			T7	16.3		Wire broke at approximately 250m
128	13-III (72)	1158	42 10.96	38 34.24	T7	16.3	16.34	
129	13-III (72)	1554	41 49.34	37 45.17	T7	15.0	15.04	
130	13-III (72)	2008	41 24.78	36 49.76	T7	14.6	14.60	Wire broke at approximately 650m
	13-III (72)	2340			T7	14.7		No trace on screen
	13-III (72)	2340			T7	14.7		No trace on screen
131	14-III (73)	0415	40 45.23	34 50.90	T7	16.4	16.38	T4 selected on menu => 450m depth
132	14-III (73)	0419	40 44.93	34 49.87	T7	16.4	16.37	
133	14-III (73)	1149	40 29.07	33 07.88	T7	18.3	18.38	
134	14-III (73)	1549	40 35.81	32 17.32	T7	18.6	18.00	
135	14-III (73)	2008	40 11.92	31 23.10	T7	20.9	20.59	
136	14-III (73)	2354	39 51.12	30 39.42	T7	18.5	18.59	
137	15-III (74)	0410	39 31.59	29 46.18	T7	20.5	20.45	Wire stretch at approximately 75m
138	15-III (74)	0758	39 14.98	28 55.65	T7	20.0	19.95	
139	15-III (74)	1153	38 58.41	28 14.76	T7	20.1	20.14	
140	15-III (74)	1649	38 33.03	27 19.85	T7	20.1	20.07	
141	15-III (74)	2000	38 15.58	26 44.48	T7	20.2	20.21	
142	15-III (74)	2351	37 51.41	26 01.27	T7	20.5	20.54	
143	16-III (75)	0420	37 28.54	25 05.26	T7	21.5	21.49	
144	16-III (75)	0810	37 16.77	24 35.65	T5	21.7	21.63	