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RRS *DISCOVERY* CRUISE 213
06 JAN-21 FEB 1995

South West Indian Ocean Experiment (SWINDEX) recovery cruise

Principal Scientist
R T Pollard

1995

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ABSTRACT

RRS *Discovery* cruise 213 was a UK contribution to the World Ocean Circulation Experiment (WOCE) and was designed to be part of the enhanced studies of ISS1 (Indian Ocean Special Survey area 1). Sailing from Durban to Durban, South Africa, one CTD section was worked across the Agulhas Basin and Crozet plateau and three sections were worked to the north, across the Subantarctic and Subtropical Fronts and the Agulhas Return Current. In addition a small survey was made of the Agulhas Current near East London, S. Africa. A total of 106 CTD/rosette stations were made, with analysis for salinity, dissolved oxygen, nitrate-nitrite, phosphate, silicate and the freons CFC-11, -12, -113, and CCl_4 (carbon tetrachloride). Chlorophyll a samples were drawn from the top few bottles on most stations while oxygen isotope samples were drawn on selected stations. Three SeaSoar sections were also worked, two across the Subantarctic Zone and one across the Agulhas Current. Acoustic Doppler current profiler data were collected throughout the cruise, along with other measurements of meteorological parameters, sea surface temperature, salinity and fluorescence. XBTs were deployed where CTD casts were not possible.

One of the objectives of the cruise was to recover eight moorings deployed during *Discovery* cruise 201 in April 1993. Of these, three were fully recovered and found to be in excellent condition. Two were partially recovered - one had lost the upper part, while the lower part of the other was lost after the release failed and dragging operations recovered only the upper part. No sign was found of the other three moorings.

Other cruise objectives were to survey the Agulhas, Subtropical and Subantarctic Fronts between 30°E and 50°E, to occupy a complementary section across the Agulhas Current, and to survey the Subantarctic Zone north of the Crozet Plateau.

KEYWORDS

ADCP, AGULHAS BASIN, AGULHAS CURRENT, BIRDS, CARBON TETRACHLORIDE, CFC 11, CFC 12, CFC 13, CHLOROPHYLL A, CROZET PLATFORM, CRUISE 213 1995, CTD OBSERVATIONS, "*DISCOVERY*", FLUORESCENCE, INDIAN OCEAN SPECIAL SURVEY 1, ISS1, MADAGASCAR RIDGE, MOORING RECOVERY, NUTRIENTS, OCEAN CIRCULATION, OXYGEN, PRIMARY PRODUCTION, SALINITY, SEASOAR, SUBANTARCTIC FRONT, SUBTROPICAL FRONT, SURFACE TEMPERATURE, TOPEX-POSEIDON, WATER EXCHANGE, WOCE, XBT OBSERVATIONS

ISSUING ORGANISATION

Institute of Oceanographic Sciences
Deacon Laboratory
Wormley, Godalming
Surrey GU8 5UB. UK.

Director: Colin Summerhayes DSc

Telephone Wormley (0428) 684141
Telex 858833 OCEANS G.
Facsimile (0428) 683066

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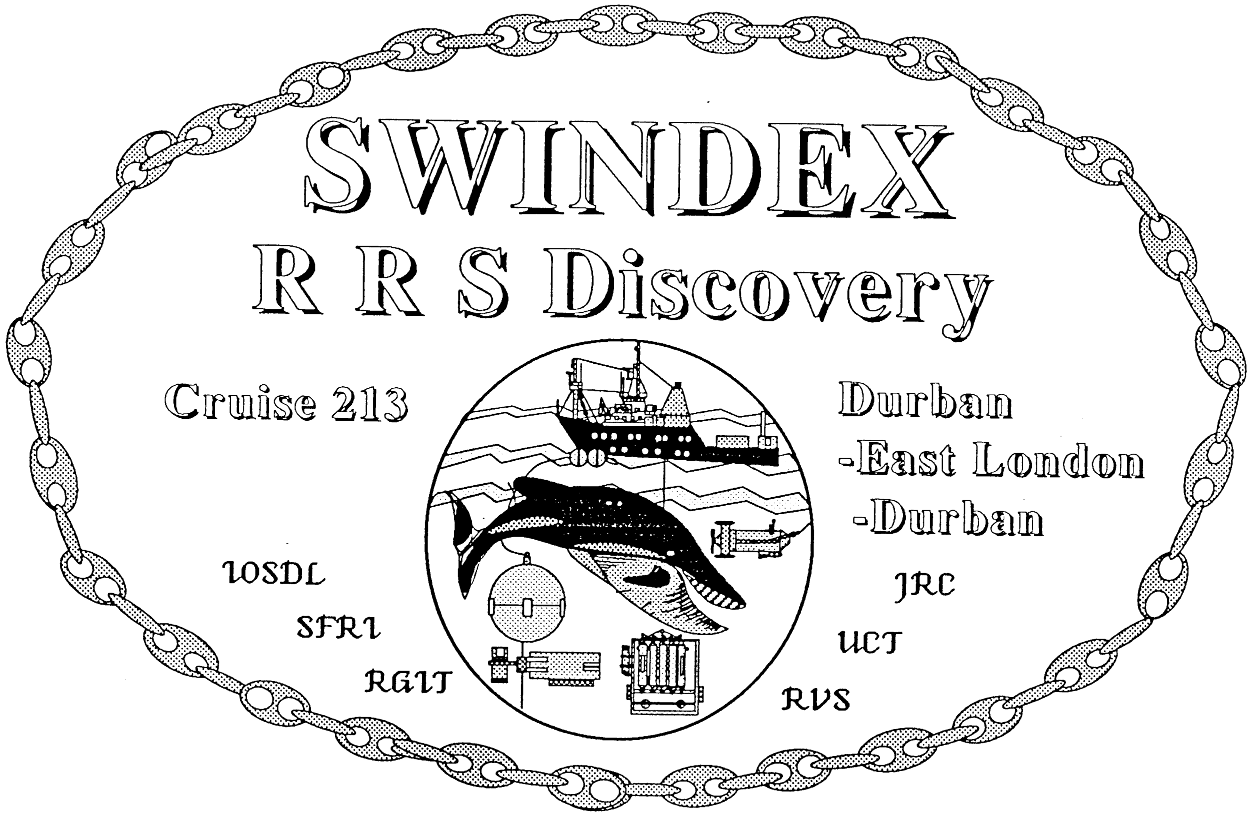
SWINDEX
R R S Discovery
Cruise 213
Durban
-East London
-Durban
IOSDL
SFRI
RGIT
JRC
UCT
RVS

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SCIENTIFIC PERSONNEL

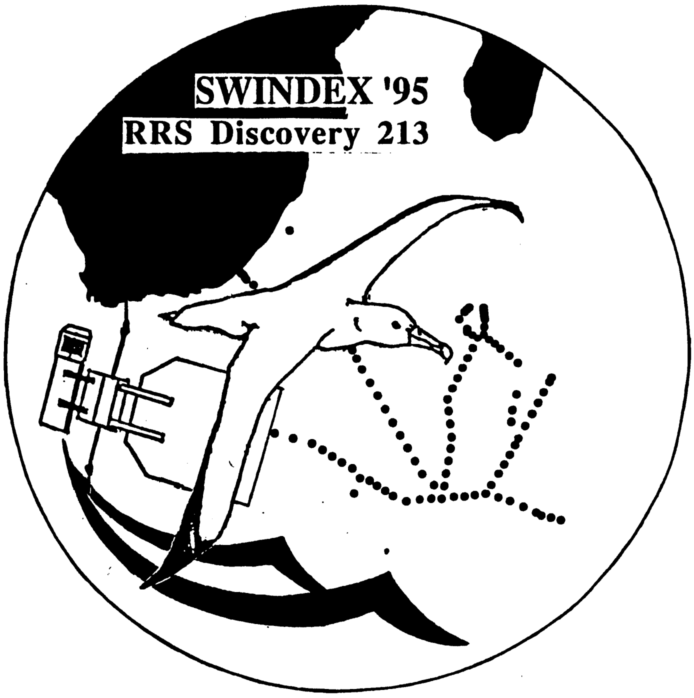
POLLARD, Raymond T.	Principal Scientist	IOSDL
BONNER, Rob N.	CTD/Mooring operations	IOSDL
BOSWELL, Steven M.	CFCs	IOSDL(JRC)
COITO, Paula M. de	Chlorophylls	Uni Cape Town
CROMWELL, David	DGPS/XBTs	IOSDL(JRC)
DAVIES, Mike A.	Mechanical engineer	RVS
GOY, Keith M.	Current meters	IOSDL
GRIFFITHS, Mike J.	CTD/SeaSoar calibration	IOSDL(JRC)
HALL, Steven P.	CFCs/Photography	IOSDL(JRC)
HARTMAN, Mark	Current meters	IOSDL
HOLLEY, Sue E.	Oxygens/nutrients	IOSDL(JRC)
HOLLIDAY, N. Penny	CTD/calibration/O18s	IOSDL
JONES, Matt S.	Bathymetry	MSSL, Uni . Coll. London
JORDAN, Stirling M.	Mechanical engineer	RVS
KENT, Liz C.	Meteorology	IOSDL(JRC)
READ, Jane F.	ADCP/navigation	IOSDL
ROURKE, Liz	Oxygens/nutrients	IOSDL(JRC)
SESSIONS, Heather E.	Oxygens/nutrients	Sea Fisheries Res Inst
SMITH, Paul K.	Met sensors	IOSDL
SMITHERS, John	CTD/SeaSoar electronics	IOSDL
SMYTHE-WRIGHT, Denise	CFCs	IOSDL(JRC)
SNAITH, Helen M.	Salinities/TSG	IOSDL(JRC)
TAYLOR, Alan J.	Computing/navigation	RVS
WADDINGTON, Ian	Moorings	IOSDL
WATTS, Simon F.J.	Electronics	RVS
WHITE, David	Acoustic releases	IOSDL

SHIPS PERSONNEL

AVERY, Keith O.	Master
CHAMBERLAIN, Roger J.	Chief Officer
MORSE, J. Terry	2nd Officer
HOLMES, Claire E.	3rd Officer
MACAULAY, Ian I.	Doctor
BAKER, Jeff G.L.	R.O.
MOSS, Sam A.	Chief Engineer
MCDONALD, Bernie J.	2nd Engineer
HOLMES, Jason S.	3rd Engineer
PARKER, Phil G.	Electrician
POOK, "Tiny" G.A.	CPO (Deck)
LEWIS, T. Greg	PO (Deck)
PERKINS, Jo R.	S1A
OLDS, Arthur E.	S1B
HEBSON, Harry R.	S1A
AVERY, Roy W.G.	S1A
CRABB, Gary G.	S1A
ELLIOT, Chris J.	S.C.M
WELCH, George A.	S.M
SMITH, Leo V.	M/Steward
ROBINSON, Peter W.	Steward
DUNCAN, Andy S.	Steward
BRIDGE, Alan M.	MM1A

CRUISE SUMMARY

Cruise Details



Expedition Designation: *Discovery* cruise 213, South West Indian Ocean Experiment (SWINDEX) recovery cruise.

Co-principal Scientists: Dr Raymond T. Pollard and Jane F. Read (IOSDL).

Ship: RRS *Discovery.*

Ports of Call: Durban to East London to Durban, South Africa.

Cruise Dates: January 6 to February 21, 1995 (with port call in East London 13-14 January).

Cruise Summary

Cruise Track and Stations

The cruise track with station positions is shown in Fig. 1, only small volume samples were taken, details are listed in Table 1. Locations of the eight mooring sites are also indicated in Fig. 1.

Equipment

The principal instruments used during the cruise were a NBIS Mark 3c CTD with oxygen sensor, transmissometer, fluorometer, Simrad altimeter model 807-200m and IOSDL 10 kHz pinger. These were mounted together with a multisampler rosette equipped with 24 10-litre Niskin bottles. Two of these carried SIS digital reversing thermometers and one carried a reversing pressure meter. Upon recovery each bottle was sampled in turn for CFCs, dissolved oxygen, nutrients, salinity, oxygen isotope and the upper six bottles for chlorophyll analysis. All sampling was done on deck.

Three sections were worked with a SeaSoar (profiling CTD) carrying a NBIS Mark 3 shallow CTD plus FSI conductivity cell and fluorometer (Table 2). Data were collected from the upper 500m of the water column

Throughout the cruise the upper ocean currents (to about 300 m) were measured with an RDI 150 kHz acoustic Doppler current profiler. Navigation information was provided by a Trimble GPS receiver supplemented by a Chernikeef electromagnetic log and S.G. Brown gyrocompass. Ships position and attitude were also measured by an Ashtech 3D GPS system.

Additional measurements were made with a Simrad echosounder, FSI thermosalinograph and fluorometer, IOSDL meteorological package, shipborne wave recorder and XBT's (Table 3).

Sampling

Nominal depths sampled were (Fig. 2): bottom, 5500, 5000, 4500, 4000, 3500, 3000, 2750, 2500, 2250, 2000, 1750, 1500, 1250, 1000, 750, 500, 400, 300, 200, 100, 75, 50, 25, 10m. On deep casts fewer shallow and intermediate bottles were fired. The maximum number of shallow bottles were fired to provide adequate coverage for interpretation of the chlorophyll data. Because of a shortage of Niskin bottles only 21 were used and this number was reduced to 19 in shallower water.

Number of Stations Occupied

A total of 106 stations were occupied during the cruise (Fig. 1) but two of these were aborted. The first CTD (12671) was worked as a test station and all the bottles were fired at depth, samples and CTD data are not reported. 1570 km of SeaSoar data were collected.

Moorings Recovered

Eight moorings had to be recovered (Table 4). Of these three were lost without trace (C, E, H) and three were recovered fully intact (A, B, F). Of the other two, one had lost the upper part (G) and the other failed to release and the lower part was lost (D).

List of Principal Investigators

R. Pollard and J. Read Co PIs

J. Read hydrographic data interpretation

- P. Holliday CTD, TSG, XBT
- R. Pollard SeaSoar
- S. Holley nutrients and oxygens
- S. Boswell CFC

R. Pollard Velocity data interpretation

- J. Read ADCP
- M. Hartman moored data
- D. Cromwell Topex-Poseidon

M. Lucas primary productivity

Scientific Objectives

The cruise objectives were to:

1. Recover eight moorings after their deployment in April 1993 between the Agulhas Plateau and Crozet Islands.

2. Survey the Agulhas, Subtropical and Subantarctic Fronts between 30°E and 50°E and occupy a complementary section across the Agulhas Current.

3. Survey the Subantarctic Zone north of the Crozet Plateau between 30°E and 50°E with CTD (plus oxygen, nutrients and CFCs), SeaSoar and acoustic Doppler current profiler.

Narrative

Discovery cruise 213 was the last in a series of *Discovery* cruises undertaken by IOSDL and collaborators between 1992 and 1995 to investigate the hydrography and circulation of the S. Atlantic and S.W. Indian sectors of the Southern Ocean. Cruise 213 was designed to contribute to enhanced studies of ISS1 (Indian Ocean Special Survey area 1). Objectives and methods overlap extensively with those of the SWINDEX deployment cruise (*Discovery* cruise 201) and reference to this cruise report may be found useful.

The beginning of the cruise was delayed by the failure of the ship's HF radio. *Discovery* was forced to remain in coastal water until spares or a replacement were located. This took a week and the ship had to dock briefly in East London to receive the new radio. The cruise was extended by four days to recover some of this lost time.

During the week between Durban and East London a small survey was made of the Agulhas Current. Eight CTD stations were worked across the current followed by three SeaSoar transects. After departure from East London the *Discovery* steamed south to the first mooring site. In between mooring recoveries CTD stations were worked along the same line as during the deployment cruise. Stations were worked at approximately 35 n.m. separation and to WOCE repeat hydrography standards.

Four north-south transects were made north of the mooring line. The first followed a Topex-Poseidon satellite track and was worked with both SeaSoar and CTD. It was followed by a CTD transect through the Indomed Fracture Zone. Two stations were lost through bad weather on this section but were replaced by 1500m XBTs (T5's) at 20 n.m. spacing. Closely spaced CTDs were worked around the gap in the Madagascar Ridge (35°S, 44°E) to determine the deep water exchange between the Madagscar and Mozambique Basins. The third transect was worked with CTDs along the western flank of the ridge back to mooring D where another attempt was made to recover the last parts of that mooring. The final transect followed another Topex-Poseidon track back towards Durban across the Mozambique Basin. One section of the last transect was repeated with SeaSoar.

Major Problems and Goals Not Achieved

Despite the prolonged delay in setting out the cruise went very well. Morale remained high throughout and bad weather caused the loss of only two CTD stations.

Two of the three SeaSoar transects were marred by serious fouling. Although small fouling events are a common and accepted hazard of using the SeaSoar, the events on this cruise were both major and dramatic. Salinity precision and accuracy were effectively halved from that which can normally be expected.

It was disappointing to lose three of the moorings. The culprit seems to be the release mechanism, and IOSDL has decided not to use pyros again, especially as reliable alternatives are now available. The top part of one mooring was sheared off, and the available evidence suggests this was the result of fish bite. The failure of the releases to let go one mooring resulted in the loss of two acoustic releases and two current meters despite extensive dragging operations. New methods are being sought to improve the reliability of dragging, which is, at present, a rather hit and miss affair.

One problem which became increasingly serious towards the end of the cruise was the unreliability of the processing computer. We were grateful that the logging system continued stolidly while the processing system crashed around it. The better part of two days after docking was needed to reconfigure the system, back-up and recover much of the data. It was impossible to clear and ready the system for the next cruise in the way we would have liked and it is expected that the computing problems will increase the time needed to process the data to the standards required by WOCE.

Despite these problems the major goals of the cruise were achieved.

MEASUREMENTS AND TECHNIQUES

Sample salinity measurement

H. Snaith

Sampling

Salinity samples were taken from each CTD Niskin bottle using 200ml glass sample bottles closed with disposable plastic inserts and screw-on caps. Each bottle and cap was rinsed three times with sample water and then filled to the base of the neck and sealed. Before filling, the neck of the bottle and the Niskin tap were wiped dry to remove any salt crystals or water droplets which may otherwise have contaminated samples. Samples from each CTD were left in the constant temperature laboratory for at least 24 hours to equilibrate before being analysed. Every hour a sample was taken from the outflow of the thermosalinograph.

Analysis

All analyses were carried out using the IOSDL Guildline Autosal model 8400 fitted with an Ocean Scientific International peristaltic sample intake pump. A mains filter was fitted in the adjacent socket to minimise problems with spikes in the ship's power supply. Before sailing it was found that one of the air pumps in the 8400 had seized so had to be replaced. The fault was due to lack of lubrication and after oiling the original pump was kept as a spare. During the replacement it was discovered that the 20V power supply unit to the pump had been detached, with the fixing bolts also loose within the chassis. This was also fixed. Bubbles began to appear regularly in the cell of the 8400 after day 020 and on day 024 (after station 12698) the cell was soaked in decon solution and rinsed with distilled water and old standard sea-water. After this bubbles formed less regularly.

The IOSDL Autosal model 8400A was also on board and operable but was not used due to problems with the cell not filling properly. The cell was soaked twice with 4% Decon solution and repeatedly rinsed in both distilled water and salt water, but it still only filled sporadically.

The salinometers were situated in the constant temperature laboratory. Initially the laboratory temperature was set at 20°C and the salinometer water-bath temperature was set at 21°C. However the temperature in the laboratory was found to be 22°C and the salinometer heaters were not cycling, so the bath temperature was increased to 24°C and the lab. was set to 22°C. The 8400 salinometer heaters were still only cycling very slowly and so the lab. temperature was decreased again to 21°C. Temperature readings in the lab. were consistently between 23 and 24°C but heaters on both the 8400 and the 8400A cycled regularly. A power failure on day 008 led to an increase in the lab. temperature to 29°C overnight. This returned to 24°C by the morning of day 009.

All analyses were carried out by Helen Snaith, Paul Smith and David Cromwell. Helen and David had no previous experience at salinity analysis but had both attended a salinity course run by Ocean Scientific Int. before the cruise and were conversant with current practises.

Results

Standardisation was achieved by use of IAPSO standard seawater ampoules. The primary cruise standard was batch P125 (150 ampoules) with two secondary standards used (20 of P124 and 12 of P115). Some ampoules of the secondary standards were retained for comparison with the primary standard. Standards were run at the beginning and end of each crate of samples (one CTD cast or 24 hourly thermosalinograph samples) until station number 12735. After this, to conserve the supply of standard seawater, secondary standards were used for shallow casts and thermosalinograph samples on every other crate. For deep casts, one standard per crate was maintained as far as possible.

The correction to the Guildline ratio obtained from the standards throughout the cruise is shown in Fig. 3. Two standards were rejected as they showed significantly higher readings than the following standard run and were assumed to have suffered from evaporation. The corrections to the Guildline ratios determined from the standards were all large at more than 0.0025, or 0.0338 Salinity Equivalent (SE), but it was decided not to restandardise the salinometer as it appeared to be fairly stable. During the first two weeks the correction increased from 0.00255 to 0.00261, a change of 0.004 SE. After soaking the cell in decon solution on day 25 the correction reduced to 0.0024 and further drift was restricted within 0.00008 (0.0002 SE). The reason for this change in drift is not understood.

The comparisons between the different batches of standards showed that the more recent standard (P124) had an offset of 0.00075 SE compared with P125 and so was only very slightly more saline, whilst the older standard (P115) had an offset of 0.002 SE. The older standard was only used for 2 shallow CTD casts and thermosalinograph analyses and the offset has been removed from all salinity measurements from these crates.

Duplicates were drawn from Niskin bottle 1 on each cast and also from a second bottle, usually near half depth. In addition, repeat firings were often made at the bottom and at other depths for the shallower casts. These repeat firings were "blind" to the analysts. In all 301 duplicates were taken. The standard deviation of salinity differences between all these duplicate readings was 0.0011. The worst results were from repeat firings at shallow depths and these larger differences may represent true differences between samples. A summary of the duplicate results is given in Table T1

Table T1. Standard deviations of duplicate salinity samples.

	No.of duplicates	Standard deviation of salinity differences
Duplicates	199	0.0006
Duplicates from > 3000m	98	0.0011
Repeat Firings	102	0.0017
Repeat firings from >3000m	67	0.0012
Repeat firings from <3000m	35	0.0023
All duplicates and repeats	301	0.0011

Sample dissolved oxygen measurement

S.E. Holley, E. Rourke, H.E. Sessions

Sampling

Oxygen samples were drawn from every bottle following the collection of samples for CFC analysis. Duplicate samples were taken on each cast, usually from the first four bottles. Samples were drawn into clear, wide necked calibrated glass bottles and fixed on deck with reagents dispensed using Anachem bottle top dispensers. The sample bottles used were changed on station 12735. The second batch of bottles had longer stoppers which reduced the number of bubbles trapped at the sampling stage. Samples were shaken on deck for half a minute. It was frequently suggested that this procedure could be automated, however useful checks were made at this stage including bubble spotting and stopper tightening. Such checks proved useful especially with the first batch of bottles, which frequently needed to be sampled again due to trapped bubbles and towards the end of the cruise when the stoppers became more difficult to tighten. The samples were shaken and checked again in the constant temperature laboratory 0.5 hour after collection. They were then stored under water until analysis.

Bottle temperatures were taken, following sampling for oxygen, using a hand held electronic thermometer probe. The temperatures were used to calculate any temperature dependant changes in the sample bottle volumes. The probe was damaged on station 12699 and replaced by an alternative.

Analysis

Samples were analysed in the constant temperature laboratory, starting one hour after sample collection, following the Winkler whole bottle titration method with amperometric endpoint detection, as described by Culberson and Huang (1987). The equipment used was supplied by Metrohm and included a Titrino unit and control pad, exchange unit with 5ml burette to dispense the thiosulphate in increments of 1µl and an electrode for amperometric end point detection.

At one stage the burette leaked letting in air which delayed the analysis of samples from station 12691 for two hours. The electrode was changed for an older alternative on station 12687. A software error occurred on a number of occasions at the start of the cruise, resulting in the Titrino parameters being over written, this only happened at the start of a sample run when the start volume was set and seemed to result from a faulty connection. This error message could be avoided with a redesign of the box that the equipment is held in as it was not designed for use with the laptop PC. Otherwise the equipment worked well. The Anachem dispensers had caused problems on previous cruises due to the corrosive nature of the chemicals, however washing out the units with deionised water before the reagents were topped up avoided any such problems on this cruise.

Results

At the beginning of the cruise a test station was used for training and as a check on the oxygen bottle calibrations.

The mean difference between duplicate samples improved from 1.47 µmol/l to 1.018 µmol/l after the change in electrode was made and to 0.79 µmol/l after the first set of bottles were replaced. Differences between duplicates of over 1 µmol/l accounted for 31% of the samples leading up to station 12735 when the bottles were changed and 22% after this station.

A third set of oxygen sample bottles have been purchased with longer stoppers and two of these bottles were tested on 10 occasions. The mean duplicate difference between the results obtained using the second and third batch of bottles was 0.91 µmol/l. The new bottles were impossible to tighten, although no bubbles appeared to get into the sample. These bottles will have to be returned to the manufacturer and they were not used for any of the samples on *Discovery* 213.

The thiosulphate normality was checked on each run and recalculated every time the reservoir was topped up, and every 3 days, against potassium iodate. The exact weight of this standard, the calibration of the 10 ml exchange unit (driven by a Metrohm Dosimat) and the 1L glass volumetric flask used to dispense and prepare the standard, were accounted for in the Excel worksheet used to calculate the oxygen values. The standardisation was also repeated when fresh iodate standard was prepared which was on five occasions during the cruise.

The introduction of oxygen with the reagents and impurities in the manganese chloride were corrected for by blank measurements made on each station, as described in the WOCE Manual of Operations and Methods (Culberson, 1991). Poor reproducibility of the blank measurements improved when the Eppendorf fixed 1 ml pipette, which had been found to be leaking, was replaced on station 12751.

The thiosulphate normality was checked on five occasions against a commercially prepared standard (Sagami Chemical Company, Japan). It was dispensed using an Eppendorf 5 ml positive displacement pipette. On each occasion the thiosulphate normality was exactly the same using the iodate working standard and that supplied by Sagami.

Data comparisons were made against Swindex 1993 data (*Discovery* cruise 201). The following stations were compared by overlaying profiles:- *Discovery* 201 stations 12393, 12396, 12402, 12405, 12409 and 12410 with *Discovery* 213 stations 12684, 12686, 12693, 12694, 12697 and 12698 respectively. The bottom water oxygen values differed by ± 1 μmol/l between the two sets of data (0.3% full scale).

References:

Culberson, C.H. and S.Huang, 1987, Automated amperometric oxygen titration. Deep Sea Research, 34, 875-880

Culberson, C.H., 1991, 15pp in the WOCE Operations Manual (WHP Operations and Methods) WHPO 91/1, Woods Hole.

Nutrient measurement

S.E. Holley, E. Rourke, H.E. Sessions

Sampling

Samples taken for nutrient analysis were analysed in duplicate, for silicate, nitrate and nitrite, and phosphate, using the IOSDL Chemlab autoanalyser. Nutrient samples were collected, following CFC and oxygen sampling, into new 30 ml plastic 'diluvial' containers that had been rinsed 3 times with sample. The samples were stored for up to 12 hours in the refrigerator prior to analysis then decanted into 8 ml analyser cups, rinsed thoroughly with sample. The samples froze on one occasion, station 12683, and the refrigerator temperature had to be adjusted.

Analysis

Primary calibration standards were prepared before the cruise from nutrient salt material dried at 110°C for 2 hours then cooled over silica gel in a dessicator before weighing (the precision of weighing was better than 1 part per thousand). 10 mmol/l stock solutions for silicate were prepared from 0.960g of sodium silica fluoride, dissolution was aided by initially placing the solution in an ultrasonic bath. The primary phosphate standards were prepared from 0.681g of potassium dihydrogen phosphate. Working phosphate standards were prepared from a secondary standard made by diluting 5.00 ml of primary standard to 100 ml in a glass volumetric flask, using a Finnpipette digital 1-5 ml adjustable pipette. The nitrate stock was prepared from 0.510g of potassium nitrate, and nitrite from 0.345g of sodium nitrite.

All primary stock standards were prepared in deionised water and made up in calibrated 500 ml plastic flasks. An error occurred in the calculation of the flask calibrations so it was necessary to apply a correction factor to the data to take account of this (see Table T2).

Table T2. Nutrient correction factors

Station	Parameter	Factor multiplied by
12673-12738	nitrate	0.988
12723-12748	silicate	1.0023
12739-12748	nitrate	1.0087

A set of six mixed working standards were prepared daily in 100 ml plastic volumetric flasks with 40g/l Analar grade sodium chloride artificial seawater.

Silicate analysis followed the standard AAII molybdate-ascorbic acid method with the addition of a 33°C heating bath (Hydes, 1984). In order to de-sensitise the system so that a linear response was obtained from the colorimeter over the concentration range up 0 to 150 µmol/l of silicate, the colorimeter was fitted with a 15 mm flow cell and a 660 nm filter.

The standard AAII method using sulphanilamide and naphtylethylenediamine-dihydrochloride was used for nitrate analysis with a cadmium-copper alloy reduction column. In order to de-sensitise the system so that a linear response could be obtained from the colorimeter over the concentration range up 0 to 50 µmol/l of nitrate, the colorimeter was fitted with a 15 mm flow cell, and a sample flow rate of 0.1 ml/min used. A nitrite top standard (40 µmol/l) was prepared with each set of working standards and analysed on each run to give an indication of the nitrate cadmium column reducing efficiency. The column was replaced at station 12763.

For phosphate analysis the standard AAII method was used (Hydes, 1984) which follows the method of Murphy and Riley (1962).

All measurements were made in the constant temperature laboratory. Previous cruises suggested that a stable temperature improved precision.

A sample of deep water was collected on the test station and stored in a polyethylene carboy. This water was then decanted into rinsed 'diluvials' and stored in the refrigerator. It was analysed throughout the cruise as a 'quality control' sample. The sample proved useful in detecting shifts in the data values. A further sample of seawater preserved in Mercuric chloride was run as a quality control sample. These two seawater samples are referred to as QC1 and QC2 in Fig. 4.

Results

Commercial standards obtained from the Sagami chemical company in Japan were run on a number of occasions, from three single batches of standards. The results, calculated over 7 runs, were as follows:- 9.72 µmol/l and 48.66 µmol/l for the 10 µmol/l and 50µmol/l silicate standards; 19.66 µmol/l for the 20 µmol/l nitrate standard; 0.99 µmol/l for the 1 µmol/l phosphate standard.

The data compared well with *Discovery* cruise 201 (1993) data. Out of six *Discovery* 201 station locations reoccupied on *Discovery* 213 the phosphate data was found to be higher on *Discovery* 213 by 0.2 µmol/l and the nitrate lower by 0.8 µmol/l on one occasion only. The data sets require further comparison.

The mean of the differences between duplicate measurements made on *Discovery* 213 were as follows:- silicate 0.268 µmol/l, nitrate 0.238 µmol/l and phosphate 0.048 µmol/l. This is equivalent to 0.18, 0.5 and 1.6% full scale for silicate, nitrate, and phosphate respectively.

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Murphy, J and J.P. Riley, 1962, A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. Acta, 27, 31-66.

Chlorophyll measurement

P. de Coito

Sampling

Water samples for fluorometric pigment analysis (chlorophyll a and phaeopigments) were taken in one litre polyethylene bottles from standard CTD depths. Typically these included 500m, 200m, 100m, 75m, 50m, 30m and 10m. The bottles were rinsed twice with the new sample prior to filling. A further sample was taken from the exhaust of the onboard flow-through Turner Designs fluorometer at each CTD station to allow a 5m ("surface") sample to be analysed. The supply to this instrument was the shipboard non-toxic supply.

Analysis

Analysis involved filtering 250 ml aliqots through Whatman GF/F 25 mm glass microfibre filters under low vacuum. After filtration each filter was placed in a glass vial and 20 ml 90% acetone added. The vials were then stored in the dark at -40°C for 24 hours. At the end of the extraction period the vials were shaken to ensure equal distribution of the extracted pigment and allowed to come to room temperature for 2 hours. Chlorophyll a concentration was then determined fluorometrically on a Turner Designs fluorometer Model 10-000R (Holm-Hansen, 1978; JGOFS Protocols) and phaeopigments were measured following the addition of 3 drops of 10% HCl. Calculations of the amount of chlorophyll a and phaeopigments followed those of JGOFS Protocols and Strickland and Parsons (1972).

In addition, to allow partial analysis of the contribution of nanoplankton to the total chlorophyll, all surface samples were size fractionated. 250 ml of seawater was filtered onto a GF/F filter (total) and a further 250 ml was passed through a 20 μm mesh plankton screen and then filtered (<20 μm fraction).

At selected stations all samples were fractionated in this way. Triplicates of the samples were filtered at various other stations.

Calibration of the fluorometer was done with pure Chlorophyll a (Sigma) in 90% acetone with the concentration of the standard first measured on a spectrophotometer.

Many thanks to Helen Snaith and Paul Smith for help with the sampling.

References

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CFC measurement

D. Smythe-Wright, S. Boswell and S. Hall

Sampling

CFC samples were drawn by Denise Smythe-Wright, Rob Bonner, Sue Holley, Matthew Jones, Liz Kent and Ian Macaulay. Samples were drawn into 100 ml ground glass syringes fitted with metal taps and stored under positive pressure in a seawater (non-toxic supply) bath in the chemistry laboratory to prevent contamination until analysed. Most samples were analysed within 12 hours of collection.

Analysis

Using a new single stripper/dual detector CFC system, water samples were analysed from 93 stations (albeit just 6 bottom depths on some) for CFC-11, CFC-12, CFC-113 and carbon tetrachloride. This was the first time the new system (to be described by Boswell and Smythe-Wright, in prep) had been used at sea. In essence it is an extended/modified version of the original Smythe-Wright (1990 a&b) design. A new standard gas sampling system comprising six calibrated loops replaced the original two loop system on the extraction board and a six port selection valve positioned after the water stripper was used to direct the flow of stripping gas into two separate streams for trapping. Subsequent separation and detection was carried out using two independent megabore columns and ECD detectors housed in one GC instrument. The advantage of the two detector system over the original single detector system (Smythe-Wright, 1990) is that each sample has a 40 minute sample analysis time, thereby ensuring good chromatography, but with two parallel trapping, separation and detector systems one sample can be analysed every 20 minutes. All samples were calibrated using CMDL ALM 39751 (a standard prepared and calibrated for JRC by CMDL, Boulder) and cross calibrated for CFC-11 and CFC-12 to Weiss 70340 (a standard prepared for JRC and calibrated to Weiss 1986 scale by SIO). Ten calibration curves were run at intervals during the cruise together with three air calibrations and a cross calibration of the CMDL to Weiss standard. In general the CFC work went well with just a couple of hours down time due to a blocked port in the gas selection valve. This was remedied by changing around the ports.

One minor problem throughout the cruise was the high temperature in the chemistry laboratory. At the beginning of the cruise the cryocool immersion cooler, which was fitted with a short probe and controlled to -30°C, would not function in the high temperature and humidity of the chemistry laboratory. Two industrial fans were purchased and once the ship sailed the cooler began to work. After a few days however it failed again and a back up cooler, although not ideal due to its long thin probe and higher cooling capacity, was brought into use. With careful adjustment a temperature of -30°C was maintained and the latter cooler was used for the remainder of the cruise. However it is clear that better air conditioning is required in the chemistry laboratory on the ship. At no point during the entire cruise could the temperature in the lab be reduced to less than 26°C and much of the time it was nearer 30°C. This was the second time that the cryocool had failed in the chemistry laboratory on *Discovery*. A similar situation occurred at the end of *Discovery* 199. The cooler was subsequently sent back to the manufacturers who returned it saying there was nothing wrong. The cooler had been functioning properly at the Rennell Centre for two years prior to this cruise.

Finally we should like to thank the agent and the ship's company for loading the CFC equipment and industrial gases first. Combined with the new access doors to the chemistry laboratory (our grateful thanks to RVS), this made set up far easier. There was some delay due to the containers not being loaded until the following day and at one point CFC mobilisation was a day behind schedule. However, the CFC equipment was in working order for the first station.

Results

Initial results suggest that CFC-11, CFC-113 and carbon tetrachloride are of good quality. Some low concentration CFC-12 data will require careful reanalysis due to coeluting compounds. Analysis of duplicates indicate precision better than 0.01 pmoles l^{-1}. Due to the time required for reanalysis and calibration only data from the section between moorings H and F were processed on board.

Three air calibrations were carried out on board were to intercompare our results with the international atmospheric ALE/GAGE and CMDL flask programme. While it is impossible to be conclusive without real time international data, our results compare well with extrapolated plots of the international data set.

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Oxygen isotope measurement

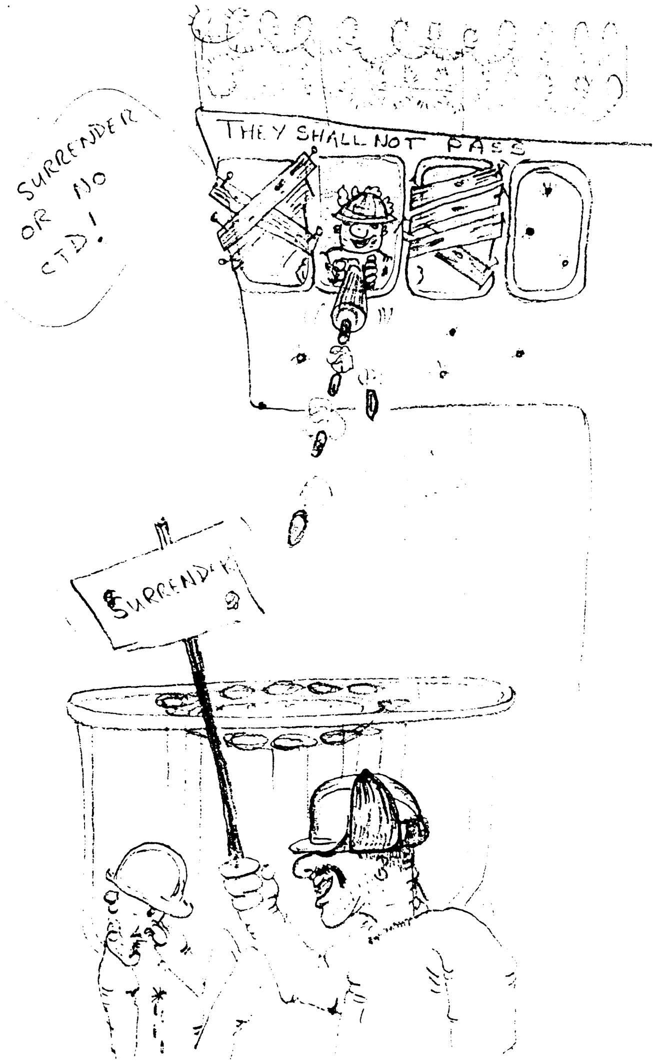
N.P. Holliday

Sampling

Samples for stable oxygen isotope analysis were drawn from 34 CTD stations (Table 1) on behalf of Russell Frew of University of East Anglia. Samples were drawn at nominal depths of 5000, 4500, 4000, 3500, 3000, 2500, 2000, 1500, 1000, 750, 500, 250, 100 m and the surface. Duplicate samples from the bottom bottle were taken on each cast. Stable isotope sampling has few contamination problems, with drops of water from other sources being the main concern. Bottles and caps were rinsed twice before filling. Evaporation could cause a change in the oxygen isotope ratio, so the bottles needed to be made airtight. Bottles caps were dipped in candle wax to provide an airtight seal to the lids. Bottles were sealed in batches several days after being filled; grateful thanks to the galley staff for allowing the use of their stoves for melting the candle wax, and generously sacrificing their Christmas decoration candles in the name of science.

A total of 391 bottles were filled, labelled, sealed and packed into old biscuit tins for transportation to UEA for laboratory analysis.

CTD measurements



Gantry and winch

S. Jordon, M. Davies

The 10 Tonne traction winch system was used to deploy the CTD package over the starboard cantilever gantry. Operationally, this proved very successful and the only limiting factors were the capability of the ship to hold position and limitations imposed by the safe working load of the CTD cable. The safe working mean load of 2.36 Tonnes prevented operation to depths greater than 5800 m with any type of swell conditions.

The very little science time lost due to breakdown (approximately one hour) was due to misalignment of the cable haulers and the scrolling gear selector falling to pieces! In reality the machinery operated extraordinarily well.

Equipment, calibration and standards

J. Smithers

The CTD equipment used during *Discovery* 213 consisted of a Neil Brown/General Oceanics MKIIIc CTD, General Oceanics 24 Bottle Rosette Multisampler Nos 1 and 2, SeaTech 1M Transmissometer, Simrad 200M Altimeter and Chelsea Instruments Fluorimeter.

During the cruise 106 CTD stations were occupied of which two were abandoned. This was the first cruise on which one of two newly acquired MKIIIc CTDs were used. The parameters pressure, temperature, conductivity and fast temperature were digitised at the full rate of 25 frames/second. Pressure, temperature, oxygen current, oxygen temperature, fluorimeter, transmissometer and altimeter used an 8 Channel 16 Bit digitiser with values multiplexed each frame and presented as words 11 and 12 in the data stream. The sign bit word provided the necessary information to decode which parameter was present. The MKIIIc CTD performed well throughout the whole cruise. The fluorimeter failed early due to a DC/DC voltage converter breaking down on power up. This was replaced with a spare and the instrument used for several casts. The DC/DC converter failed a second time when an over voltage was accidentally applied to it. The specification of this part requires 9-12 volt input. This part should be replaced with a 9-37 volt input device to avoid future occurence of this problem.

The transmissometer and altimeter performed without problems. Noisy transmissometer data on two casts were caused by a faulty cable which was replaced. Rosette pylon No 2 was fitted and used without misfires. This was shipped to the James Clark Ross when *Discovery* put into East London after the first 9 CTD casts. Pylon No 1 was then fitted and initially performed well. During the cruise it began to show signs of double firing. Salinity samples taken allowed the real position of bottle firings to be determined. The pylon was overhauled twice during the cruise.

The Sea Cable was reterminated on four occasions when data transmission failed or became noisy. Over several casts the data became noisy but was recoverable with despiking during processing. This was caused by a large build up of particles from the winch slip rings reducing the sea cable resistance to 30K ohms. The slip rings were cleaned and caused no further trouble. Further details may be found in the Diary.

All of the CTD deck unit equipment performed without fault.

Hydrographic bottles

D. Smythe-Wright

Prior to the first station the 23 bottles left on board after *Discovery* 212 together with 6 additional ones brought out for this cruise, were completely stripped of taps, springs and 'O' rings and thoroughly washed with sea water using a fire hose to maintain a high pressure of water. Particular care was take to clean the springs and around the tap orifices. The bottles were then reassembled using 'O' rings and taps which had previously been washed in isopropyl alcohol and subsequently heated to 70°C under vacuum. This procedure was necessary to ensure the cleanliness of the bottles for CFC analysis. At the first station 24 bottles were fired at 2900 m and a full suite of analyses performed to ensure the integrity and cleanliness of the bottles. Following this, particular attention was paid to any further bottles added to the rosette to replace bottle failures.

Some difficulty was experienced with the new FSI bottles during the cruise. Six came apart at the centre mounting block and had to be glued back using Durapipe ABS solvent (made by Glynwed Plastics Ltd) which appeared not to cause CFC contamination. Five end caps sheared at the spring fixing point making them irreparable. A number of top taps did not seal correctly and taps were replaced several times until suitable ones were found. The disc on the lower tap was found to be too small to get a good purchase to open and close the tap. This became more of a difficulty with time as the taps became stiff. The purchase of GO bottles in preference to those supplied by FSI must be further considered.

Digital reversing thermometers and pressure meters

J.F. Read, D. Cromwell

SIS digital reversing thermometers and pressure meters were used on all except the last (12776) CTD cast. The basic configuration is shown in Table T3. During CTD12683 deteriorating weather conditions led to the loss of instruments P6292H, T891 and T895. Also, T890 started leaking so had to be removed. After this T253 was removed and kept as a spare and the remaining instruments re-arranged as shown.

Table T3. Arrangement of reversing thermometers and pressure meters on the CTD multisampler rosette.

```
station no.:   671   673---------------682    683    684------------------------775
bottle 1       |------- T895 -----------------|  (lost)
               |------- T891 -----------------|  (lost)
               |------- P6292H -------------|    (lost)
bottle 3       |------ T892 -------------------------------------------------------------------|
               |------- T890 -----------------|  (leaking)
                                                        |----------- T399 ------------|
                                                                |--- P6075H ----|
bottle 11      |------- T253 ----------------------------------|  (removed for spare)
               |------- T399 ----------------------------------|
               |------- P6075H -------------------------------|
bottle 18      |------- T219 -------------------------------------------------------------------|
               |------ T255 --------------------------------------------------------------------|
```

Laboratory calibrations were applied, except in the case of P6075H, for which no information was available. The digital meters were used primarily as a check on the quality of CTD data and as an aid for determining bottle depths in the suspicion of a misfire. They were not used for correcting CTD data as experience has shown the stability of the CTD to exceed that of the reversing meters. However, rejecting various outliers, the reversing meters remained stable thoughout the cruise, as shown by the mean and standard deviation of differences between the CTD and meter data (Table T4). In noting the anomalously large difference between CTD pressure and P6075H it should be remembered that this pressure meter was not calibrated.

Table T4. Mean and standard deviation of differences between CTD and digital reversing meters.

meter no	measured range (°C)	sample no	average range (°C)	mean	standard deviation
Reversing thermometers					
ctd-T253	2-15	10		-0.0155	0.0177
ctd-T895	0-18	10	±0.6	0.0506	0.1604
ctd-T891	0-21	10	±0.6	0.0489	0.1792
ctd-T890	0-17	9	±0.08	0.0026	0.0241
ctd-T892	0-17	96	±0.08	-0.0131	0.0107
ctd-T399	0-16	91	±0.08	-0.0115	0.0087
ctd-T219	1-24	64	±0.22	-0.0748	0.0517
ctd-T255	2-24	62	±0.18	-0.0356	0.0546
Reversing pressure meters					
	(dbar)		(dbar)		
ctd-P6292H	80-4500	7	±10.	0.5	1.36
ctd-P6075H	150-5600	97	±100.	15.6	14.83

Initial calibration

R.T. Pollard, J.F. Read

Data were passed from the CTD deck unit to a dedicated microprocessor, a level A, in which the 25 frames per second raw data were averaged to 1 data cycle per second. The level A was designed to handle 16 frames per second and the increased data rate caused frequent serial overruns and crashes. When this happened the cast had to be stopped while the level A was re-started. The level A calculated the rate of change of temperature and used a median sorting routine to detect and remove pressure jumps exceeding 100 raw units (approx 10 dbar). During the first nine casts it was noticed that the data were still unusually noisy and a check of the coding showed that the pressure jump code had been commented out. It was re-implemented for all later casts and the first nine were re-processed.

The 1 second data were transferred (datapup) to pstar format where they were calibrated (ctdcal), the down cast extracted (pcopya) and a temporary file of 10 second averages created (pavrge) for merging with the bottle firing times and discrete bottle samples.

Initial calibrations applied (in ctdcal) were:

$$\text{press} = -38.3 + 1.07453 * (\text{praw} * 0.1) + 5.8\text{e-}8 * (\text{praw}*0.1)^2$$

Laboratory measurements showed only minor hysteresis in the pressure sensor. At the surface and at 5500 m no correction was applied, and between those depths and 1000 m linear interpolation to +0.7 at 1000 m was applied.

temp = - 2.1158 + 0.99132 * (traw*0.0005)

fast_t = 3.2374 + (ftraw*0.0005) * 1.0568 + $(ftraw*0.0005)^2$ * -6.2633e-3 + $(ftraw*0.0005)^3$ * 1.3417e-4

Although the fast temperature sensor was calibrated as above, and is in the data stream, it was not used, nor was it corrected for drift.

cond = 0.00164 + (craw*0.001) * 0.94422

The conductivity ratio of 0.94422 was calculated from salinity samples analysed after the first deep cast (to 2500 m), and this value was used throughout further processing. It's purpose is to give derived salinities that are nearly correct. Final corrections are made by applying a constant offset to salinity on a cast by cast basis (see below and Table 5). In calculating salinity, the temperature sensor was speeded up using a time constant of 0.20 seconds to reduce the mismatch between the response time of the temperature and conductivity sensors as described in the SCOR WG51 report (Crease et al, 1988).

Oxygen current (oxyc) and temperature (oxyt) were initially calibrated as follows:

oxyc = - 0.348 + (ocraw*0.00001) * 3.844 + $(ocraw*0.00001)^2$ * -0.2788

oxyt = - 12.434 + (otraw*0.0001) * 11.050 + $(otraw*0.0001)^2$ * -1.092 + $(otraw*0.0001)^3$ * 0.0876

oxyfrac = oxyc * exp (press * 0.00015 + ctemp * - 0.036)

where ctemp = temp*0.4 + oxyt*(1-0.4)

Most of these values were rederived in later recalibration (see below).

An altimeter, used primarily to detect the height of the CTD off the bottom when it was within 200 m of the bottom during the cast, was calibrated by

altimeter = - 227.06 + (araw*0.001) * 6.91 + $(araw*0.001)^2$ * -2.70e-4

The transmittance was calibrated as follows, but checking of the calibration, apart from despiking, has not been done.

trans = - 90.88 + (tnraw*0.0001) * 27.800 + $(tnraw*0.0001)^2$ * -4.2602e-2

After calibration of transmittance, potential transmittance was derived by first correcting for the aging of the light source,

trans2 = (trans * 4.355 * 1.0032) / 4.33

then compensating for the refractive index,

trans3 = trans2 / refindx(press, temp, salin) before correcting for the pressure effect,

potrans = trans3 ** (svol(press, temp, salin)/svol(surface press, temp, salin)

where svol is the specific volume

atten = log (potrans)

A nominal calibration for fluorescence was achieved with:

fvolts = - 4.512 + (fraw*0.0001) * 1.3624 + $(\text{fraw}*0.0001)^2$ * 2.1128e-3

fluor = exp (fvolts * 4.0 - 3.0)

The constants in the exponential fit need to be rederived from in situ samples (see below).

Resolution of firing depths

N. P. Holliday

Each CTD cast was checked for possible misfires or double trips of the multisampler rosette. To determine the firing depth of each Niskin bottle the CTD data were compared to the bottle data. A series of "firing" files was created as follows:

The CTD deck unit logged the time and confirmation code of each firing, and the firing time data were transferred via the Level A to the pstar data processing system (datapup). This file was successively merged with:

winch data - to obtain the winch cable out (pmerge)

10 second averaged CTD data - to obtain the CTD up cast parameters (pmerge) at the firing times

1 second CTD data - to obtain the CTD down cast parameters (pbotle)

Down cast data were matched (pbotle) with up cast data by potential temperature above 3000 dbar, and density (referenced to the nearest 500 dbar) below this. Pressure was used to limit the choice of either potential temperature or density. Extraction of down cast data is necessary only to calibrate oxygen, because of the hysteresis between down and up cast oxygens. For other parameters, primarily salinity, the up-cast values are used.

Problems occasionally arose in the creation of these files when less than 24 bottles were present. The firing file sometimes contained a firing time for absent bottles which received a signal at the end of the cast. In such cases the firing file was edited (pcopya) to remove the spurious last firing times before merging with the CTD data. The merging of the CTD data occasionally failed if the Level A had crashed and data were lost at the time the bottle was fired. When this occurred the most recent good data cycle in the CTD data file was merged into the firing file.

Data for each sample drawn from each Niskin bottle were collated into one master sample file for each station from various Microsoft Excel spreadsheets (pblankexec, ppaste). Salinity, oxygen, nitrate (+ nitrite) silicate, and phosphate, plus the corrected reversing thermometer and pressure readings were listed by bottle number for comparison with the firing data. CTD up cast salinities were compared with the bottle salinities and a poor match indicated either a misfire or a poor quality sample. Comparison of bottle and CTD salinities allowed the correct firing depth to be deduced. The other parameters confirmed misfires and sampling errors.

The order of the firing file was corrected (pcopya) to match that of the sample files and copied into the master sample file (ppaste).

Typical problems encountered (other than misfires) were samples taken from the wrong Niskin bottles, suspect salinity samples with typically a higher salinity than the normal offset from the CTD (where other parameters were "normal"), samples from apparently leaky Niskin bottles, and samples from depths with a high salinity gradient which appeared anomalous but were actually the result of the difference in position of the bottles and the conductivity cell on the multisampler. The number of samples taken from the wrong Niskin bottles was reduced considerably after each salinity bottle was labelled 1-24 in addition to their unique identification number. Typically there were two or more people drawing salinity samples at the same time and apparently there was some confusion over which bottles had been sampled. The number of suspect samples also decreased through time; many of the salinity samplers were new and as their experience increased the quality of their sampling increased.

Salinity Calibration

Once the master sample file was complete, the bottle minus CTD upcast salinity residuals were calculated (parith) (Table 5). The mean offset and standard deviation of the CTD from the bottle salinities were calculated, with suspect samples excluded from the mean. The mean offset from samples below 1000m where there was less spread was also calculated and the two means used to determine the calibration to be applied to the CTD salinity. If the two means were considerably different, the mean from the deep samples was taken in preference to the whole cast mean. The offset was typically of the order 0.001 to 0.008 (Table 5) with small drifts from station to station. Larger unexplained jumps occurred, although they could cometimes be traced to periods when the CTD was unused for a period (eg after a SeaSoar run).

The final calibrations were constant offsets (Fig. 5 and Table 5) applied to the CTD down cast file and the up and down cast data in the samples files (pcalib). The new residuals between the calibrated CTD up cast and bottle salinities were calculated (Fig. 6). The final mean calibrated residual across all CTD casts was 0.0015±0.0379 for all data points, but 0.0000±0.0032 in the range ±0.002.

CTD Position and Depth Information

M. Jones

The CTD position (from bestnav) and water depth (from the echosounder) at the down time of each CTD cast were placed into the header information for each CTD and sample file. This information is summarised in Table 1. Additional information in Table 1 includes the start, down and stop times of the CTD cast, the depth of the CTD from the bottom as given by the altimeter, and the CTD cast depth (obtained by converting maximum pressure to depth). Note that the sum of the cast depth and the height off the bottom will not usually equal the water depth.

Oxygen calibration

M. Griffiths

The method used during this cruise followed from that developed during the mooring deployment survey (*Discovery* 201).

An initial calibration was made using the equation:

O2 = oxsat(T,S)*rho*(oxyc+offset)*exp(a*(W*ctdT+(1-W)*oxyT)+b*P)

where rho, a, b, offset and W were chosen by using a least-squares fit to the bottle oxygen values. One fit for a, b, offset and W was attempted for all casts, leaving rho to vary cast by cast. However, it was found necessary to refit a and b on two occasions (see Table T5). Residuals left after this fit tended to be systematic with depth (e.g. values were too high through the oxygen minimum) and were further reduced by fitting a cubic spline to the error between the bottle data and the newly calibrated down cast oxygen, using in the following execs.

oxyexec : runs oxycal3 to give oxygen calibration coefficients. Optionally applies calibration to ctd data; produces plot of ctd oxygen profile with bottle data overlaid.

oxspln: creates spline error fit; reads the oxycal.nnn (where cast number was 12nnn) file created by oxyexec. The oxycal.nnn file was edited in some cases in order to fudge the fit.

splinex: merges error data from oxspln.nnn file created by oxspln program with ctd data. (oxyCal is the equivalent exec for the sam files).

At the start of the cruise, the positions of knots for the cubic spline fit were taken at those pressures where the error changed sign. However, the splines that this method produced became too spikey, and fewer knots (typically one or two) were fitted for later casts. Earlier casts (pre-12712) need to be reworked.

Various problems were encountered in the course of the calibration procedure. Oxygen sensor values at the bottom of the cast drifted low as the CTD stopped and settled. Bottom values were often ignored for this reason.

At depths (greater than 3000db), drifts/offsets appeared on the oxygen profile - no reason for this is known. Where drift was excessive, and the spline could not be rectified, the data will need to be deleted. This has not been done yet.

The sensitivity of the sensor deteriorated rapidly between stations 12712 and 12713 (due possibly to an oil contamination, see Diary), making it necessary to have more than one set of calibration parameters. In fact, after station 12716, the sensor characteristics changed sufficiently to require a third set of parameter values (Table T5).

Table T5. Calibration coefficients for CTD dissolved oxygen sensor

stations	a	b	offset	fraction
12763-12712	-0.0270	0.000152	0.0	0.35
12713-12716	-0.0230	0.000159	0.0	0.35
12717 12776	-0.0225	0.000149	0.0	0.35

From CTD12712, the measured oxygen showed a jump or discontinuity, typically at 1200 but ranging from 900 to 1400 dbars. The jump of 5 - 10 µmol/l occurred over 50 to 75 dbars. The method for dealing with this was to use all possible bottles for the oxygen calibration (even though differences between bottle and sensor values were high at mid-depths), and then letting the spline fit do the final correction as a discontinuity in the cubic spline can be forced by fitting two or more knots at a point.

For the spline to work properly, a discontinuity in the fit was needed, to apply (in general) a positive offset above the jump, and a negative offset for the deeper water. To do this, two extra data points were added to the oxycal file corresponding to the mid point of the jump, but 1 dbar apart. Errors for the extra data points matched the error before and after the jump. When fitting the spline, four knots were used, two at each of the added data points. Stations 12712 - 12776 have been completely reworked.

After calibration the residuals between bottle and CTD values were calculated (Table T6).

Table T6. Mean and standard deviation of CTD - bottle oxygen residuals after calibration

stations	range (umol/l)	no. of samples	mean difference	standarddeviation
12673 - 12709	all data	466	0.4179	7.5019
12673 - 12709	-16.0 to +16.0	451	0.2751	4.9328
12713 - 12776	all data	1141	-3.9638	67.2581
12713 - 12776	-16.0 to +16.0	1125	0.1853	2.4837

Spline fits need improving for stations 12673 to 12709 and will be done in the near future.

SeaSoar measurements

Winch

R.N. Bonner

The IOSDL horizontal drum SeaSoar winch was used in conjunction with the ships starboard rear gantry crane for all SeaSoar deployments. Although all deployments went well, two problems arose which need rectifying ashore.

On the first deployment one of the safety trips stopped the winch on several occasions whilst paying out. It was not possible to identify which sensor had operated the trip but when the ships electrician checked the current being drawn through it, he found that the setting was too low and that the switch was barely rated for this load. The switch was reset to its maximum setting, which prevented further cutouts, but further investigation of the other cutout sensors is required.

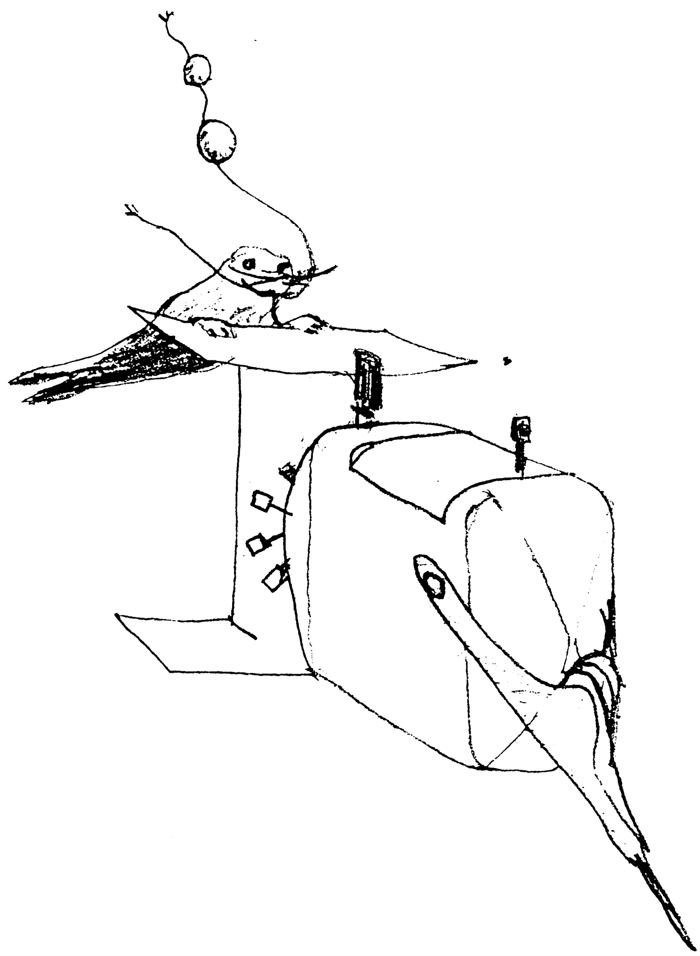
The second problem, high temperature of the hydraulic oil, has been encountered before, but became acute during this cruise due to the high ambient temperatures experienced. A maximum oil temperature of 90°C was attained on some occasions. This is 18°C above the recommended maximum and can lead to breakdown of some of the oil additives. For this reason, an oil cooler should be fitted in the circuit before further use. It is possible that the high oil temperature caused some of the cutouts experienced on the first deployment, but not all.

Equipment, calibration and standards

J. Smithers, R Pollard

The SeaSoar system used a shallow version of the Neil Brown Instrument Systems (NBIS) MKIIIb CTD, a 600m Chelsea Fluorimeter and a Par Lightmeter. A Falmouth Scientific Instruments (FSI) Ocean Conductivity Module was also fitted.

The NBIS conductivity cell is matched to a platinum resistance thermometer (PRT) in close proximity. It consists of a 4-electrode cell (30 mm x 1.8 mm x 1.8 mm) which gives high quality salinities with resolution better than 0.003 and lower noise. However it is prone to biological fouling, which can cause a calibration shift of 0.1 to 0.4 or more, resulting in serious drift until the fouling clears. The FSI cell is inductive, with a much larger annular sensor, 22.5 mm internal diameter and 45 mm external diameter. It had not been used on an IOSDL SeaSoar before, but should in principle be less prone to biological fouling than the NBIS cell because of its larger diameter, so should hold its absolute calibration better. The FSI cell is mounted 10 cm horizontally and 8 cm vertically offset above the NBIS sensors on a 10 cm long stalk protruding from the housing. Thus the FSI conductivity is some way from the PRT, which is significant when calculating the temperature effect on conductivity.



Four SeaSoar runs were completed (Table 2) with the instruments generally performing well. The FSI Conductivity module did not work on the first run as it was not switched to a mode suitable for use with the MKIIIb CTD. It worked for the second run but showed some hysteresis and temperature response problems (discussed below). A second unit was fitted for the third run which initially appeared better but then became very noisy and also interferred with the main CTD data.

The launch and recovery during each run was performed using an articulated crane. This was both relatively easy and safe for the SeaSoar vehicle. The vehicle itself "flew" well throughout each run giving some splendid datasets.

Initial Calibrations

J. F. Read, R.T. Pollard

Data were logged by a dedicated microprocessor, a level A, which reduced the 8 frames per second data to 1 second. The level A also calculated the rate of change of temperature and used a median filtering process to remove spikes. After such reduction and cleaning the data were transferred to pstar format (datapup) for further processing. After gross editing and interpolation of pressure (to ensure no gaps) the SeaSoar data were calibrated in much the same way as the deep CTD data:

$$press = (praw*0.01) * 0.998 + (praw*0.1)^2 * 7.4e-9 - 1.497$$

$$temp = (traw*0.0005) * 0.9880 + (traw*0.0005)^2 * 7.567e-6 - 0.11061$$

nbcond = (craw*0.001) * 0.99064

fsicond = (craw*0.001) * 0.941

fluor = fraw * 4.0 - 3.0

oxyc = (ocraw*0.00001) * 50

oxyt = otraw * 0.128

oxyfrac = oxyc * exp(press*0.00015 + ctemp*-0.036)

where ctemp = temp * 0.4 + oxyt * (1-0.4)

A time constant of 0.2 was used to reduce the mismatch between temperature and conductivity sensors.

To apply the calibration to the second conductivity cell (FSI) the data streams had to be separated (pcopya), calibrated (ctdcal) and re-merged (pjoin) because of a problem with the naming convention.

Oxygen data were stored and calibrated but were found to be unuseable due to excessive drift and noise.

Salinity Calibration

R.T. Pollard, E.C. Kent, M.J. Griffiths

Four separate SeaSoar runs were undertaken (Table 2) and the salinity calibration technique differed somewhat from run to run. The overall sequence of calibration was as follows:

(1) Compare the NBIS derived salinities from SeaSoar profiles done in close proximity to a CTD cast during the Agulhas Current survey. By iteration, determine a conductivity ratio that brings the NBIS SeaSoar salinities close to the CTD salinities. Use this ratio henceforth as the basis for relative calibration (stable in time) of SeaSoar salinity.

(2) Compare NBIS SeaSoar calibrated conductivity (C_{NB}) with the FSI conductivity (C_{FSI}) (uncalibrated) which should ideally be exactly the same. Examine the ratio of these conductivities (C_{NB}/C_{FSI}) for dependency on temperature, pressure, down v. up cast, etc to determine how to calibrate C_{FSI}. There ought to be no dependence on other parameters beyond weak cell characteristics.

(3) Use the dependencies derived in (2) to calculate C_{FSI} (calibrated), which should now match the SeaSoar NBIS relative calibration found in (1).

(4) Calculate salinity from both conductivities. Compare them profile by profile (depth profiles and T/S profiles) using the FSI salinities to help identify places where the NBIS sensor has fouled and more particularly to determine what salinity offset to apply in FINCTD to correct it. In the past, we have found it possible to achieve relative accuracies better than 0.01 by a similar technique, primarily looking for continuity of T/S relationships from profile to profile.

(5) Finally, once the CTD has been absolutely calibrated against bottle samples, use CTD T/S profiles to adjust the envelope of SeaSoar T/S profiles. The CTD should in the end have absolute errors less than 0.002. The absolutely calibrated SeaSoar salinities should have a mean bias no more than 0.005.

Calibration details for each deployment were as follows.

First deployment:

The first deployment caused no major calibration problems. SeaSoar profiles close to CTD12673 were compared and a conductivity ratio of 0.99064 was derived by iterationas in (1). This ratio was used as the default for all further NBIS relative calibrations. The NBIS conductivity cell suffered only intermittent fouling and the resulting offsets in salinity were removed or corrected. The new FSI conductivity cell was used for the first time but was wrongly set up so produced no usable data.

Second deployment:

The second deployment, along a Topex-Poseidon track running northeast from the Crozet Plateau, began in subantarctic waters with a temperature range of 4 to 10°C. At 1715, 28 January, the NBIS conductivity cell fouled badly causing an initial shift in salinity of 2.8. Over the remainder of the deployment salinity recovered by drifting with large jumps superimposed. By 1900/29 the sensor had a residual offset of 0.035 relative to the initial calibration which remained constant until the end of the run at 1430/30. In retrospect it might have been best to recover the SeaSoar, but similar fouling might have occurred, so it was decided to try to calibrate the FSI sensor rather than recover the SeaSoar. A straight conductivity ratio was tried first, and yielded 0.941. It was clear that this was inadequate, so step (2) was used on the first few profiles, and yielded a strong temperature dependence for C_{FSI} to calibrate to C_{NB} of

$$C_{NB} = 0.941 \times C_{FSI} \times (1. + 0.00135(T - 4.67))$$

where T is in °C and in the range 4-10°C.

There was also a marked hysteresis between down and up profiles with a difference between them of about 0.0003 in the conductivity ratio (about 0.01 in salinity). Varying the time constant, between 0.0 - 0.3 seconds, by which the temperature was speeded up made no difference.

The FSI conductivity, corrected by this relationship, was used to calculate salinity and compared to NBIS salinity profile by profile. In the past it has been possible to achieve relative accuracies better than 0.01 by such a technique. On this deployment it showed the NBIS salinity error to diminish from 2.03 to 1.19 in four hours, to 1.04 in the next four hours, to 0.78 in the next, then clearing fairly rapidly. NBIS data from the first 3.33 hours after fouling were too bad for correction and were removed from the record. FSI data for this period were inserted instead.

However, after crossing a major front, the maximum temperature rose to 17°C, and it was clear from the shape of the T/S profiles that the formula derived above to calibrate FSI conductivity was quite inadequate outside the temperature range 4-10°C for which it had been derived. However, the FSI sensor appeared to be stable and with the prospect of CTDs at the end of the deployment which could be used for calibration, the NBIS salinities were corrected to the FSI salinities at 10°C (a depth of about 150 m), where the profiles overlaid well. Because of the continuous drift, the offsets at 10°C were at first linearly interpolated (peditb, pintrp) to provide a gradual correction up to 1100/29. After this individual offsets for each cycle were used. Jumps in the offset were identified and corrected separately (finctd).

After the SeaSoar run, CTD casts were made back along the SeaSoar track and the envelope of T/S profiles obtained was used to adjust the envelope of SeaSoar T/S profiles. Using this technique the CTD data should have absolute errors less than 0.002, and the absolutely calibrated SeaSoar salinities should have a mean bias of no more than 0.005. In fact, CTD salinity showed the NBIS salinity profiles north of the front to have an offset of 0.05 which was corrected using 'finctd' and 'pcalib'. We estimate that the resulting absolute salinities are less than 0.02 in error and mostly less than 0.01.

Further problems with the FSI calculated salinities were noted. They tended to spike to high salinities by up to 0.1, apparently in high temperature gradients. This would be expected if the conductivity is shallower than the temperature used to match it. Towards the end of the 48 hour deployment, FSI derived salinities became very noisy near maximum depths, and became rubbish during particular parts of the down cycle. Causes could be vibration of the cell on its stalk, flow past and through the sensor at certain attitudes, or salt water leakage affecting the conductivity at certain attitudes. It appeared to recover on the up-cast.

Third deployment:

In case the FSI problems were simply caused by a malfunctioning sensor, the spare FSI conductivity sensor was substituted for the third run. C_{NB} did not foul for the first 6 hours, and the temperature range was greater than that found at the beginning of the preceeding run, so step (2) was more carefully reworked, and a stepwise linear formula (against temperature) derived, giving a conductivity ratio of 1.00093 at 4°C, 1.0080 at 9°C and 1.01558 at 16°C, with a clear break in slope near 9°C. Hysteresis of .0003 between down and up was again present, and the FSI derived salinities were generally noisier. Problems experienced on the second deployment also developed after some 12 hours, and by the end of the deployment the FSI salinities were wildly off for much of the cycle.

The NBIS conductivity sensor fouled seriously at about midnight on 15 January with an initial offset of about 1.2, diminishing over two steps in the next half hour to about 0.8. The stepwise linear correction obtained from C_{NB}/C_{FSI} was used to adjust C_{FSI}. When the FSI salinities degraded significantly, from 0600/46, only the upcasts at mid depth were usable for correction. After this the C_{NB} downcast was corrected with a constant offset derived from the offset between the C_{FSI} and the C_{NB} on the following upcast. The last hour and a half of the deployment showed a constant offset of 0.14 between the FSI and the NBIS.

Absolute calibration awaits final calibration of CTD profiles for this and the fourth deployment.

Fourth deployment:

On the fourth run, a day later, still with the second FSI cell mounted, the spiking problems and wild behaviour were not present at first in the 6 hour run, but began to develop again. However, the NBIS cell did not foul, and minor offsets were adjusted in the usual way.

In summary, while the FSI conductivity cell proved useful in correcting for unusually serious fouling of the NBIS cell during the rather short runs that were all we had time for, it could not be used as the primary sensor as (a) it exhibited strong temperature dependence and depth hysteresis, (b) it is much noisier than the NBIS cell and (c) it deteriorated rapidly within a day of deployment.

Fluorescence calibration

D. Cromwell, P. de Coito

An attempt was made to determine calibrated chlorophyll-a values from fluorescence data. An approximate method, of including only night-time fluorescence data to derive a calibrated unquenched yield was used (instead of using light measurements to describe the quenching factor).

Underway fluorescence data were collected continuously and four SeaSoar runs provided additional data. Surface samples taken from the non-toxic supply were analysed to provide calibrated chlorophyll data.

Samples analysed from the first SeaSoar deployment (Table 2) gave values clustered around 0.1 - 0.15 mg/m3. This small range was insufficient to provide a reliable calibration. Data from the final two SeaSoar deployments (Table 2) were not examined due to lack of time. The second SeaSoar run provided the best data for deriving a calibration. This section traversed possibly three ocean fronts with associated large changes in fluorescence yield.

After initial calibration the SeaSoar data were averaged to a 4km x 8m grid (pgrids) from which the "surface" values (actually 5m) were extracted (plevel). These data were then linearly regressed against the hourly chlorophyll-a samples (plregr2) giving a high correlation coefficient (r = 0.941). Daytime data were excluded from the analysis where "daytime" was somewhat arbitrarily defined as falling between 0200 - 1730Z (0400 - 1930B). A difference of 750 m was applied to compensate for the different sampling positions of SeaSoar and underway fluorometers (no account was taken of the pumped water supply time).

One - second underway fluorescence data were despiked (pmdian) and averaged to one minute (pavrge) and then regressed against the hourly chlorophyll-a samples (r = 0.955). To evaluate the two calibrations the SeaSoar fluorescence was compared to the underway data giving a good correlation (r = 0.976). Further details are shown in Table T7.

The analysis is based on surface chlorophyll samples and strictly only gives the horizontal distribution of fluorescence yield at the top of the mixed layer. Vertical variation in the mixed layer is likely to result from ambient light, phytoplankton population and other factors. More detail is available in the CTD samples but these have yet to be examined.

Table T7. Fluorescence regression statistics

X	Y	A1	B1	R	N
chl	ssfluor	-6.697E-02	0.9628	0.941	16
chl	ufluor	-0.9398	2.205E-04	0.955	18
ufit	ssfit	1.740E-02	0.9905	0.976	16

where Y = A1 + B1*X is the linear regression fit, R is the correlation coefficient, N is the number of data pairs used in regression, and chl, ssfluor, ufit and ssfit are in mg/m3 while ufluor is in arbitrary fluorometer units.

Data processing involved the following execs

fluorexec0: conversion of one-second underway fluorometer data from RVS to PSTAR format.

fluorexec1: despiked above data and created one-minute averaged files; merged with navigation file. Final appended file for the cruise was flr213.1min.

fluorexec2: created hourly calibrated chlorophyll sample files for SeaSoar runs and appended as file chlss.samples.

Surface chlorophyll data collected at selected CTD stations (as distinct from CTD bottle profile data) and midway locations between stations were also compiled.

References

Hemmings, J., 1992. "Data processing for SeaSoar/underway fluorescence calibration", internal JRC note, 28th October, 1992.

Expendable Bathythermographs (XBTs)

D. Cromwell, N.P.Holliday

XBTs were used twice during the cruise (Table 3). XBTs were launched from the stern quarters of the aft deck using a Sippican Corporation hand launcher. Data were logged by a Bathy Systems SA810 controller and deck unit located in the plot. The deck unit was supplied by the SESU Hydrographic Office, Taunton. Bathy Systems XBT program version 1.24 was used to log data and transmit profiles via the GTS in near real time. Prior to launch, depth, position and sea surface temperature were logged. Actual time of launch was logged for post correction of water depth (prodep) and best estimate of ship's location (bestnav). XBT data were transferred from the Bathy Systems pc to the level a/b/c computer on floppy disk and thence to the PSTAR data processing suite.

34 XBTs were launched: 22 T7s (750 m) and 12 T5s(1800 m). One of the T7s was a misfire. Data were processed using two UNIX scripts:

btexec0: convert from RVS to PSTAR format using datapup;

btexec1: median filtering, followed by linear interpolation through gaps.

The T7s were deployed at two-hourly intervals during the passage from East London to the first mooring site, H. The section showed a cold-core eddy-like structure centred near 37.7°S. T5s were used in the Indomed Fracture Zone when CTD casts had to be abandoned because of bad weather. This XBT section also suggested the presence of a cold-core eddy-like structure which correlated with the velocity structure. It appeared in approximately the same location as an eddy identified on a sea surface temperature map, derived from ERS-1 ATSR (along-track scanning radiometer) data, generated two weeks previously and faxed to the ship by Graham Quartly of the James Rennell Centre. XBT profiles taken at CTD stations 12728, 12729 and 12730 matched the corresponding CTD temperature profile very well, reflecting the high quality of the XBT data.

Acoustic Doppler current profiler

J. Read

Equipment

Upper ocean currents were monitored throughout the cruise with a hull mounted RDI 150 kHz acoustic Doppler current profiler (ADCP). On RRS *Discovery* the transducers (SN 34) are aligned fore and aft in the ships hull approximately 2m to port of the keel and 33m aft of the bow at the waterline and at a depth of 5m below the sea surface. With a 'blank beyond transmit' of 4m the total offset above which measurement cannot take place is 9m. During *Discovery* cruise 213, firmware version 17.10 and data acquisition software version 2.48 were used. Salinity was set to 35.0 psu for calculation of the speed of sound using the water temperature measured at the transducers by the ADCP. The ADCP was configured to give 2 minute ensembles with 64 levels of 8 m depth, and a minimum depth of 13m (ie currents were measured between 9m and 521m). Two configurations were used which were identical in every respect except for bottom or water tracking mode. In bottom track mode one bottom ping was transmitted for every four water track pings (FH00004). This configuration was used throughout the leg from Durban to East London and provided three calibration periods. On departure from East London the configuration was switched to water tracking mode for the remainder of the cruise.

The instrument performed well during the cruise. One minor problem was the loss of one of the fuses, which happened twice, once before sailing from Durban, and again on 19/1320z. It is thought that the failure was caused by overheating in the electronics. To replace the fuse the deck unit had to be removed from the racking and taken apart to gain access to the internal boards, thus half an hour or more data were lost.

In general good data were collected to 300-350m, but during steaming or bad weather depth penetration was reduced to 200-250m or less.

Data processing

Data were logged in real time by the shipboard level C computer and transferred once daily to the PSTAR processing system. The PSTAR data processing route involved two data streams. "Bottom" information was extracted from the gridded current file and stored separately. Both data sets were corrected by -60 seconds to centre each two minute time interval, and had a further clock correction applied to account for the drift of the ADCP pc clock. (This gained about 24 to 26 seconds per day). The current profiles were then averaged over 10 minutes. Both "bottom" data and current profiles (after averaging) were corrected for the misalignment angle and scaling factor.

Correction for the ship's heading was applied by the ADCP data acquisition software using the ship's no 2 gyro. It is known that gyro compasses are subject to various external effects, e.g. Schuler oscillations, latitudinal drift, etc. To correct for this the ship's heading was measured (to within 0.1°) by an Ashtech 3-dimensional GPS system and the difference between the Ashtech and gyro headings (a-ghdg) applied to the current direction. Current profiles were then merged with despiked and filtered navigation data (derived from bestnav) from which the vectors were corrected for ships speed over the ground to give absolute water current speed and direction.

To assist in cruise planning the current vectors at 101m were extracted, filtered (a one hour "top hat" filter) and mapped daily (Fig. 7).

Calibration

The misalignment angle of the ADCP transducers and the speed scaling factor were ascertained by bottom tracking on the continental shelf between Durban and East London. An initial calibration run in two directions, 46° and 223°, gave a misalignment angle of 2.09 and scaling factor of 1.006 from about 6 hours of data. Comparisons between the different navigation instruments demonstrated that the Ashtech and new GPS Trimble 4000DS gave more reliable results than the old GPS Trimble 4000AX.

Table T8. ADCP misalignment angle and scaling factor

Calibration run 1:

Heading 46°	Phi	A	Heading 223°	Phi	A
GPS ashtech	2.13	1.004		2.06	1.007
GPS 4000DS	2.16	1.005		2.02	1.007
GPS TrimbleAX	5.45	1.004		2.07	1.007

Thus the misalignment angle and scaling factor were respectively 2.09±0.04 and 1.006±0.0010 using the Ashtech GPS, and 2.09±0.07 and 1.006±0.0015 using the GPS 4000DS. Note the serious error introduced into the old Trimble data probably by a spurious fix.

To check the calibration, two further periods of steady steaming at a heading of 220° yielded the following values:

Run 2:	Phi	A
GPS ashtech	2.01	1.004
GPS 4000DS	2.00	1.003

Run 3:	Phi	A
GPS ashtech	1.84	1.004
GPS 4000DS	1.84	1.004

If the values from all three runs are averaged, values of phi and A of 2.01 and 1.005 result. However, Runs 2 and 3 were not to quite such a high standard as the calibration run. Bottom track was lost for several samples while crossing a canyon. The Ashtech values dropped out for 15 minutes. Also, Runs 2 and 3 repeated the 220° heading, as the continental shelf was not wide enough to permit calibration runs in any other direction. For these reasons, the values 2.09 and 1.006 from the main calibration run were retained.

Navigation

Absolute navigation

A. Taylor

Best estimates of ships position were made from a combination of GPS (Global Positioning System) data, logged by a Trimble GPS 4000DS receiver, S.G.Brown 1000 gyrocompass and Chernikeef electromagnetic log. The data collected were combined in a series of steps to produce a master navigation file (bestnav).

Raw GPS data (gps_4000) were filtered to produce a fix every 30 seconds (4000_av). The running filter had a slight centre weighting and spanned 5.5 minutes. The em log and gyro information were merged to produce 'relative' navigation (relmov) consisting of 30 second values of velocities and heading.

The GPS (4000_av) and relative (relmov) data were then combined to produce a master file (bestnav) where the GPS data were used for fixes and the relative navigation was used to dead reckon between gaps in the GPS data.

3-dimensional Ashtech GPS

J. Read

This system measured the ships position and attitude (pitch, roll, heading) via the GPS. The instrument consisted of four antenna mounted on the ships superstructure in a square of approximately 8m. Data were recorded every second via the shipboard level ABC computer and transferred every 24 hours to the PSTAR processing system. The data were merged with the one second gyrocompass (no 2) data and the difference used to correct the ships heading for the ADCP data processing.

The system worked well throughout the cruise with one exception. At midnight day 30 a subsecond jump in the master clock upset all the level A clocks. The Ashtech level A failed to resynchronise and adopted a time of its own. Over two days it drifted by 145 seconds from GMT before it was manually resynchronised. For days 31 - 35 the Ashtech satellite time was used instead of the level A time to merge with the gyro compass data. Although this left the Ashtech and gyro data one or two seconds out of phase the match was considerably better than achieved by the drifting level A clock.

Adjusting the default parameters of the Ashtech receiver gave much more extensive data coverage than during *Discovery* 201 (SWINDEX deployment cruise) leaving only occasional gaps of no more than 15-20 minutes. Critical parameters were in Screen 4, sub menu ATTD control: max rms 010, search ratio 0.5, one sec update Y, 3SV search N, and in the sub menu ATTD set-up: max cycle 0.2, max magnitude 0.08, max angle 020. Some of these settings were a compromise between good data and accepting poor quality data to avoid the receiver losing lock. Once in PSTAR the data were edited for pitch ±5°, roll ±5°, mrms <0.008, brms < 0.09, attf 0 (measured rms, baseline rms, attitude flag). Further manual editing was done to ensure a clean data set before merging the with ADCP data.

Differential GPS

D. Cromwell

DGPS enables accurate determination of ship position. Conventional GPS suffers from degradation due to selective availability implemented by the US Department of Defense. DGPS compares the data recorded at a roving station with that received at a static, well-surveyed base station. As long as the base - rover baseline is not too great, then both receiver stations can be assumed to have the same GPS signal errors, both selective availability and those due to atmospheric and ionospheric propagation effects. Since the base station is at a known location the errors in the GPS signal can be accurately estimated and removed, in real-time or in post-processing mode, from the ship position data.

Two sets of DGPS data were collected for later post-processing: one from the Ashtech GPS 3DF system, and the second from the Trimble 4000DS receiver. The intention is to compare the performance of both systems, including the respective post-processing capabilities. The Trimble logged at intervals of 10 seconds; the Ashtech, at 20 seconds. Both data sets were logged by pcs linked via an ethernet to the level C. The Trimble logging software automatically split output into hourly files, named according to the Julian Day and hour. The Ashtech data logger had to be stopped and restarted daily to create a new file. The resultant gaps, however, were only a few seconds long. Longer gaps, of several hours, occurred when the pc ethernet connection hung. The Ashtech pc was more prone to this problem than the Trimble pc. Additionally, on a couple of occasions, the Ashtech pc hung on losing communication with the Ashtech receiver. Restarting the Ashtech data logger software solved the problem. Nonetheless, DGPS coverage throughout the cruise is estimated to be at least 98% for the Ashtech dataset and even higher for the Trimble dataset. Data volumes were respectively of order 120 and 80 Mbyte.

Data collected at Haartebeesthoek, South Africa, and a recently inaugurated site on Kerguelen Island will be used to provide the differential corrections for *Discovery* 213. These stations are part of the International Geodetic System (IGS), a worldwide network of GPS base stations. Daily files are archived by NASA Goddard in Maryland, USA from where they are freely available by anonymous ftp, courtesy of CDDIS (Crustal Dynamics Data Information System).

References

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Echosounding

M. Jones, A. Taylor, S. Watts

The bathymetric equipment aboard *Discovery* 213 comprised a hull mounted transducer, a Precision Echo Sounding (PES) 'fish' transducer, and a Simrad EA500 hydrographic echosounder. For most periods the PES fish was deployed over the port side of the ship although for short times just before and after docking, bathymetry data were obtained via the hull mounted transducer.

Output consisted of a screen display, continuous paper chart trace and data logged at 1 second intervals via a level A to the level B/C computer. Raw data were subsampled at thirty second intervals and Carter corrected daily (a correction due to the speed of sound in water not being a constant 1500 ms^{-1}). Suspect data were flagged, and the resulting data were placed in a level B/C data stream.

Data were transferred to pstar format daily (datapup), and compared with the echosounder printout to identify any dubious values. Any problems were usually caused by the echosounder losing lock over rapidly changing topography, or by side echos from deep chasms causing confusion over the real depth (for more discussion of this see the section in this report on CTD depth comparisons). Also, on occasions, some contamination of the data was noticed when the PES fish was used to communicate with the moorings. It was usually much clearer from the printout than from the logged data whether unusual data corresponded to real topography or not. After editing (mlist, peditb), the data were averaged to six minute intervals (pavrge), and merged with navigation data (pmerge).

The hull mounted transducer was located 5.3m below the surface of the water, and this depth was automatically added to the depth measured by the echosounder to obtain the output depth. The PES fish, however, was supported at a depth below that of the echosounder, and hence some additional correction was necessary to accurately obtain the depth from the surface. This was further complicated by the tendency of the PES fish to rise as the ship's speed increased [Pollard et al, 1993]. Switching between the hull mounted transducer and the PES fish whilst hove to, in calm conditions over flat topography showed that the PES fish was supported 23 m below the hull mounted transducer. Similar comparisons whilst moving at a speed of 11 knots (the typical between station speed) showed that this reduced to a depth difference of 10 m.

Two master files were created of all the despiked, averaged and merged bathymetry. The file 'dp213.complete' contains the complete dataset, with no correction made for the depth of the PES fish, whereas the file 'dp213.uway' contains data whilst the ship is underway (data were rejected where the ship's speed was less than 4 knots), with a depth of 10 m added to the PES data to compensate for its different depth. Separate files were also created corresponding to specific cruise sections, to aid in plotting bathymetry for specific CTD/Seasoar sections. These files consist of underway data only (corrected for the PES fish depth), usually with data monotonically increasing with either latitude or longitude.

References

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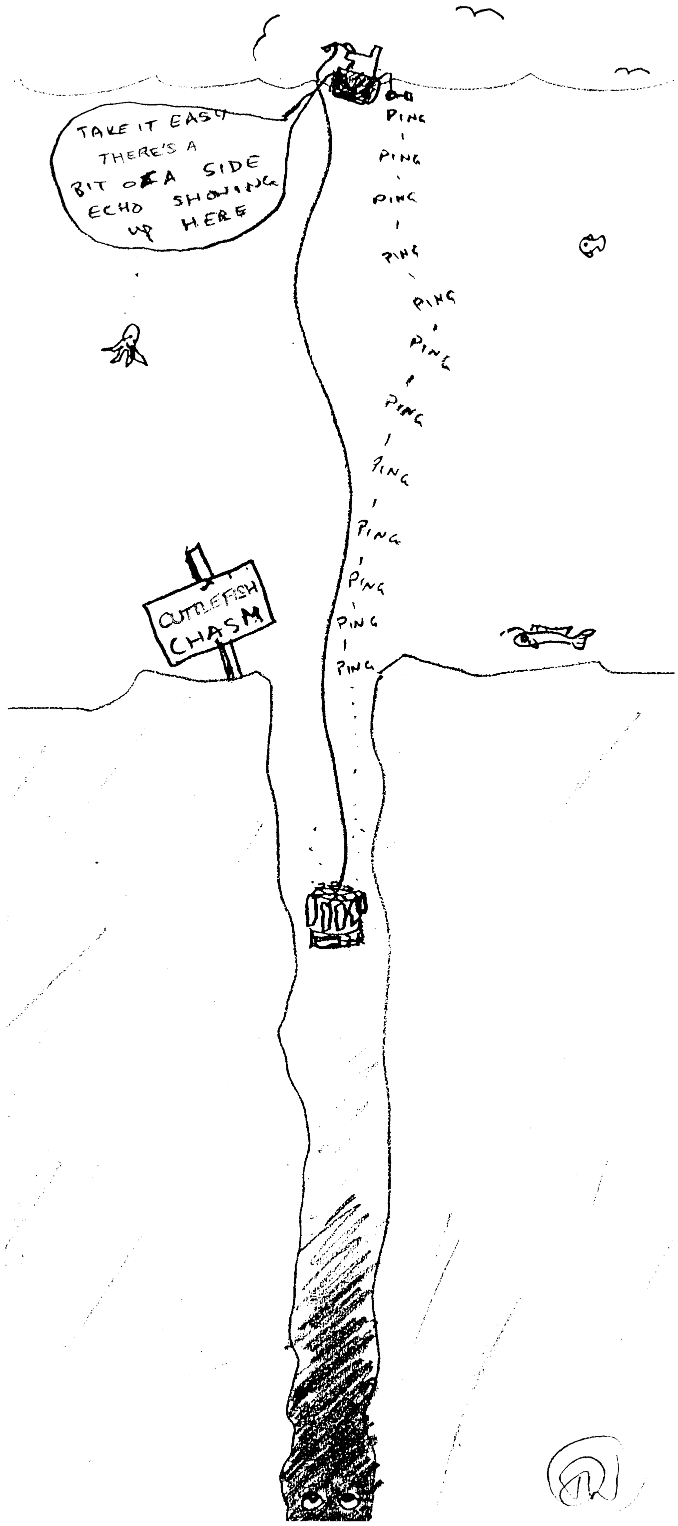
CTD and echosounder depth comparisons

M. Jones

Throughout *Discovery* cruise 213, measurements of depth were made using the bathymetric system described in this report. The CTD carried a pressure sensor, and an altimeter to measure the distance of the CTD from the bottom. Hence by converting pressure to depth and adding the altimeter distance, a second measurement of the total water depth was available to validate depth measurements made by the echo sounder system.

The altimeter had a range of 204m, and would typically be within range of the bottom for 5 to 10 minutes of each downcast. For each cast all the data within this period were used, and the average depth measured by the CTD within this time period was obtained by converting pressure to depth (pdepth), and adding the altimeter measurement. The corresponding average depth for this time period was obtained from the echo sounder, and comparisons were made. It was found that out of the 103 CTD casts analysed, 85 agreed within 30 m of the echo sounder depth (after applying the measured offset of 23 m to the echosounder data to compensate for the PES fish being deeper than the hull mounted transducer). The mean difference between these 85 comparisons (before application of any offset to correct for PES fish depth) was 19 m with a standard deviation of 10 m. This mean difference of 19 m corresponds reasonably well with the measured offset of 23 m between the hull mounted transducer and PES fish (see the echosounding section in this report - all these comparisons were made when the ship's velocity



was essentially zero, hence there was no correction to be made for the PES fish rising up as the ship's velocity increased). The fairly large standard deviation of the differences of 10 m is harder to explain. The combined altimeter / pressure sensor should have an accuracy of the order of 1-2 m. Remaining error sources are the echo sounder, (errors caused by deviations of the sound velocity from 1500 ms^{-1} not being adequately corrected for by the Carter corrections), or errors introduced by the CTD and echosounder measuring different depths due to the CTD not hanging precisely vertically beneath the ship, or due to the altimeter and echosounder having different footprint areas. It is likely that a combination of these effects caused the high standard deviation mentioned above.

Eighteen comparisons resulted in differences greater than 30m, with seven of these greater than 100m (CTDs 12690,12692,12717,12727,12728,12758 and 12771), the largest difference being 504 m! In each case, the echosounder data were examined closely. In the case of the larger differences it was found that the bathymetry was complex, and the echosounder was picking up a side echo and interpreting this as the real depth, whereas the actual depth was much deeper (in several cases this resulted in a bathymetry reading shallower than the CTD cast depth!) In most cases however, no good reasons were found for the large discrepancies between CTD and echosounder comparisons. The most feasible cause of this problem is probably due to the different footprint areas of the echosounder and altimeter. Hence if, for example, the CTD is positioned over a fairly deep but narrow depression, whereas most of the surrounding bathymetry is higher, this could cause discrepancies.

Meteorological measurements and ship-borne wave recorder

E. C. Kent, P. Smith

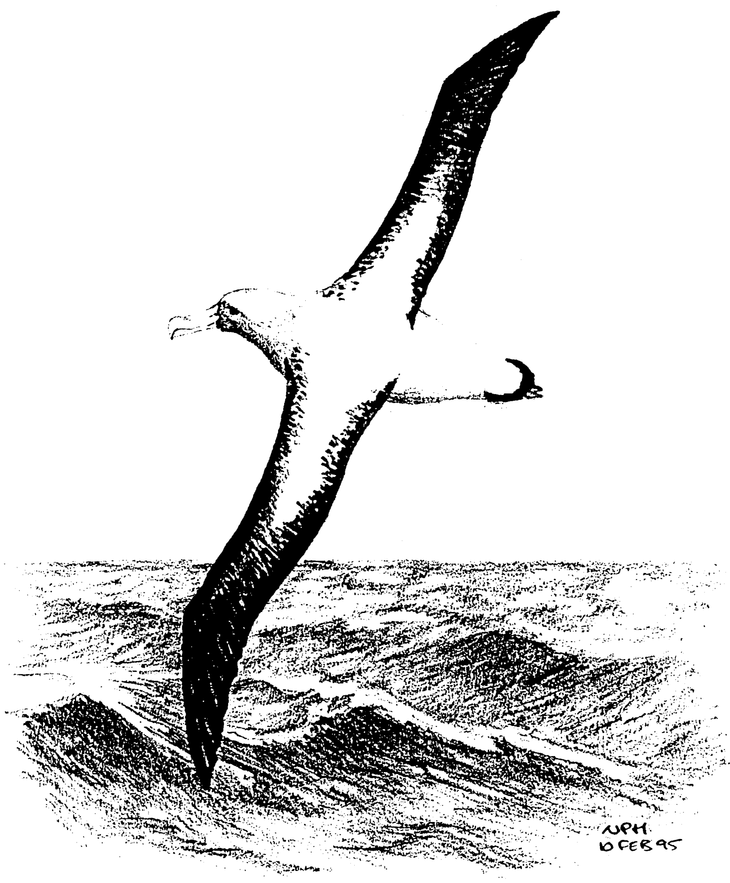
Meteorological instrumentation for *Discovery* 213 was the same as the SWINDEX deployment cruise, *Discovery* 201. The standard RVS sensors were supplemented by instrumentation supplied by the Division of Ocean Technology Development (DOTD) at IOSDL. RVS sensors were a R. M. Young Instruments Type 05103 propeller vane anemometer, two photosynthetically active radiation (PAR) sensors (spectral range 400-700nm) and two total irradiance sensors (TIR) installed on the foremast. A Vaisala humicap humidity and temperature sensor was present but the data were not logged. RVS also provided a ship borne wave recorder (SBWR), a hull mounted platinum resistance thermometer (prt) for sea surface temperature and a Vaisala aneroid barometer. DOTD enhanced these measurements with a Solent sonic anemometer to measure wind stress, a long-wave pyrgeometer and two psychrometers housing wet and dry bulb prt's.

Data (except the SBWR and sonic anemometer) were logged using an amended RVS program which writes raw data to level B rather than the usual system which logs calibrated data. This means that the calibration coefficients typed in the Met. display console are for display purposes only. The RVS temperature and humidity sensors were not logged. Data were nominally one minute averages but data were output every 61 seconds, with loss of about 200 minutes data per day. The loss of data was thought to be due to bad time stamps and occurred at random intervals. As the data loss was of single values and occurred intermittently the dataset should not be significantly be degraded. A new version of the logging software is being developed by RVS. SBWR and sonic anemometer spectral data were logged to pc's and the data transferred by floppy disk to the SUN's via ftp from a Macintosh. Raw transit times from the sonic anemometer were recorded to optical disk.

On day 9 the starboard wet bulb temperature drifted high by about 2 degrees but recovered the following day and worked well for the remainder of the cruise. The port wet bulb worked intermittently from day 23 to day 25 when it was replaced. The replacement port dry bulb was noisy but the data could be easily edited. The starboard TIR sensor after day 24 gave erroneous values near zero radiation. The large values recorded were easily removed and can be replaced with zero values if required. The remainder of the sensors worked for the whole cruise.

Data calibration, editing, merging with gps and emlog data and calculation of true wind speed and direction were performed using a standard set of UNIX scripts on the shipboard SUN system. A new version of the calibration program was written to allow new calibration equations to be used with the RVS sensors. Data were read in daily to enable checks on sensor performance to be made. Weekly summary data were also plotted (Fig. 8).

Air temperatures ranged from 5-25°C and sea surface temperatures from 6-25°C. Mean sea - air temperature was 1°C but the air was warmer than the sea for more than 40% of the time. Mean wind speed was 9 m/s but wind speeds of 20m/s were observed.



Satellite image acquisition

MacSat

M. Jones

Real time satellite imagery of the sea surface was provided by a Dartcom Macsat receiver and antenna, together with Macsat software installed on a Macintosh IIcx PC. This equipment was routinely used to receive images from the NOAA series of satellites.

On arrival the equipment was found to be in good working order, and reasonable quality images were readily received. After a few days problems started to occur, with the Macintosh not able to keep up with the data reception rate. (This caused the calibration bars on either side of a received image to track sideways at a constant rate across the screen.) After experimentation this problem was rectified by removing the Mac from the network. Shortly after this, the image quality started to degrade, corresponding to a decline in received signal strength. This problem was traced to slight corrosion in one of the connections to the pre-amp. Connections were remade resulting in a large improvement in image quality and signal strength. No other problems were experienced with the equipment during the cruise.

Clear infra-red and visible images were received from NOAA 10, 12 and 14. Infra-red images provide information about sea surface temperature, and an image identifying locations of fronts could, in theory, be used to aid cruise planning. In practise there are two problems with this. Firstly, and common to all images from infra-red radiometers, cloud presence completely masks sea surface temperature features. Hence a clear sky is necessary for useful images to be obtained. The second problem, particular to Macsat, is the difficulty in accurately locating the image. The accuracy to which location is possible is limited by the accuracy of the orbit prediction information and of the Macsat clock. One second out in the clock setting corresponds to approximately a 6 km error in image location. To limit this, the clock was reset each time an image was received. A larger problem seemed to be the accuracy of the orbit prediction information. For NOAA 14 in particular, predicted times were wrong by minutes, corresponding to a location error of the order of 100s of kms. If coastlines can be identified in the image then this can help the location problem. However, a large portion of the cruise was a considerable distance away from land, rendering any image received relatively useless. For this reason, few images were received during this part of the cruise.

In total 13 images were archived. These are mostly images of clouds, although a few showing sea surface features were obtained (there is a clear image of the Agulhas current, retroflecting at 35°E).

For the above reasons, in particular the image location problem, use of Macsat information to aid cruise planning was not possible, and it is doubtful whether it ever could be for open ocean cruises, unless the image location ability is improved.

<u>ATSR images</u>

T.N. Forrester, G. Quartly

Near real-time (NRT) Along Track Scanning Radiometer (ATSR) data were obtained by the James Rennell Centre. The European Remote sensing Satellite (ERS) help desk provided orbit data and the Tromso Satellite Station (TSS) provided data. TSS used the SADIST (Synthesis of ATSR Data Into Sea-surface Temperatures) ATSR processing system and provided data in SADIST version 600 format with an extra header of 127 bytes added to the beginning to make it European Space Agency (ESA) compatible. The data were compressed and transferred via anonymous File Transfer Protocol (FTP) to JRC where further processing took place. Details of each file; name percentage good data, SST range and latitude/longitude range were archived to a log file. Percentage good data was the amount of data per image that was usable after pixels contaminated by land or cloud cover had been identified. If there was at least 1% good data then the image was plotted to hard copy. Images were then inspected for SST features (i.e. fronts and eddies) which might be of use to the cruise. These were printed in grey scale and the appropriate SST features highlighted by hand before the image was sent to the ship by facsimile.

A total of 268 SST images were acquired between 4 January and 21 February 1995. Data acquisition was reduced for the first week of the cruise due to the late departure of the ship. Data were uncharacteristically noisy and the problem was identified by the Rutherford Appleton Lab. as being due to the ATSR instrument overheating because the onboard cooler was approaching the end of its mission life. The noisiness of the data was exaggerated because the generation of the SST product involved combining both the 11 m and 12 m infrared channels in the forward and nadir view, which multiplied the noise effect. The solution was to obtain a Brightness Temperature (BT) image from one channel. From 14 January 1995 TSS provided BT 11m nadir view data and the corresponding SST products were used to provide navigation and various ephemera's data, such as land and cloud flags, etc. A total of 154 BT products were received and 10 images were sent to the ship.

Satellite images were used to help clarify the interpretation of features seen in the sub-surface data and to help refine sampling strategy. Composite images (e.g. Fig. 10a) helped locate the Subantarctic Zone for SeaSoar surveys, while the pronounced cold core eddy (Fig. 10b) was sampled by XBTs when the weather was too bad for CTD work.

Thermosalinogaph

H. Snaith

Underway surface salinity and temperature measurements were continuously logged using the RVS surflog system (the fluorimeter and transmissometer channels were not used), the equipment consisted of a Falmouth Scientific Inc (FSI) remote temperature sensor (1340) mounted near the non-toxic intake in the forward hold, at a depth of 5 m and FSI conductivity (1331) and temperature (1339) sensors mounted in a polysufanone housing. A header tank was used to provide a constant flow of debubbled non-toxic water. Hourly calibration samples were taken from the thermosalinograph outflow and header tank checks were made throughout the cruise.

Data were sampled at 1Hz and averaged over 20 s periods before logging. The temperature and conductivity modules were initially calibrated using laboratory standards and calibration data. The 20 s averaged conductivity measurements were used to determine salinity, given a pressure of 0 bar and the housing temperature (peos83). These salinity values were then despiked (pmdian), records being rejected if salinity differed by more than 0.05 from a 5 point median. The data were than averaged over two minute periods (pavrge) and merged with the bestnav navigation data (pmerge) to include latitude and longitude.

In order to calibrate the thermosalinograph salinity values, the data were merged with salinity values from the hourly bottle samples (pmerge). The bottle conductivities were than calculated assuming pressure of 0 bar and the thermosalinograph housing temperature (peos83). Thermosalinograph conductivities were then calibrated using a linear fit of bottle conductivity to thermosalinograph values. These calibrated conductivities were than used to calculate calibrated salinities which could be merged with the bottle salinities to give the final residuals.

Results

Before calibration, the mean offset of the thermosalinograph salinities from the bottle salinities was -0.1997, with a standard deviation of 0.1119. The calibration used was:

calibrated conductivity = 0.112518429 + 0.992982479*conductivity

and after recalculation of the thermosalinograph salinity, the mean offset of the thermosalinograph salinities from the bottle values was -0.0002 with a standard deviation of 0.1069 (Fig. 11)

Photography

S. Hall

Photographs and video footage of day to day activities on board ship were taken throughout the cruise. Images include SeaSoar deployment and recovery by day and night, CTD deployment and recovery followed by sampling also by day and night, and various scenes taken on board to show the routine of cruise life, such as scientists at work in the main laboratory, chemistry laboratories and deck laboratory. Images of the seabirds that were seen daily were also taken. There are external shots of RRS "*Discovery*" alongside at Durban and East London, South Africa. The intention is that this footage will be available for use by scientists in their publications, also by the media and NERC/SOC (Southampton Oceanography Centre) public relations and schools links programmes.

Video material was taken on Fuji M221E E5-60 Hi8 PAL professional video tape using a new Sony TR2000 Hi8 camcorder (purchased by SOC) with timecode and optical image stabiliser. Image quality is near broadcast standard, and results from night use are excellent. Images can be edited using computer and video equipment currently being purchased for use at SOC, and short clips could be incorporated into the SOC Internet information pages on the World Wide Web. Mike Conquer at IOSDL (relocating to SOC summer 1995) will be custodian of the master video tapes. An index of the contents of each video tape will be available from him.

Photographs were taken using a Canon Sureshot A1 weatherproof camera and a Nikon F801S camera with Nikkor AF lenses. Film used was a mix of Kodak Gold 200 ISO print film and Kodachrome 200 ISO transparency film. The best images will be transferred onto Kodak Photo CD disks, and added to the Photo CD collection that Mike Conquer is compiling at IOSDL. Note that some photographs from previous IOSDL cruises are already available on Photo CD. Complete copies of the disk will be available on request (though there will normally be a charge), images can also be transferred digitally and incorporated into the Internet. Original slides and negatives will be available via the SOC library and information service. A catalogue of available images is expected to be available through the Internet later in 1995.

The equipment worked well throughout the cruise. An "EWA Video Cape" was used to protect the camcorder from sea spray but was of limited use due to condensation forming inside. Both the camcorder and the Nikon F801S experienced difficulties with autofocus "hunting" when taking pictures of the sea surface or seabirds, and so needed to be used in their manual focus modes. This was probably caused by a combination of low background contrast and in the case of the Nikon also the flat horizon line, which is difficult for parallax based autofocus systems to work with.

Shipboard computing

Level ABC system

A. Taylor

The level ABC system on RRS *Discovery* is split into three distinct parts. It comprises microprocessor based level A's, a VME based level B and an unix based level C.

The level A's receive data messages from various instruments and sensors. These data have basic error checks carried out before they are time-stamped and passed onto the level B system using Ships Message Protocol (SMP).

The level B system receives the SMP messages from all the level A's situated around the ship, backs up the data to 1/4" cartridge and transfers the messages onto the level C system. At this stage the individual messages from the various level A's can be viewed.

The level C system consists of a sun IPC workstation (discovery1). When the messages are received, the parsing program strips the data messages from the comment and alarm messages and stores the data in individual data files. From here the data are available to the users for processing using the pstar suite of programs on three networked workstations (discovery2, 3 and 4).

During the cruise a number of hardware and software faults occurred as detailed below.

For most of the cruise the CTD level A complained of serial overrun errors during casts and crashed frequently. This was probably due to the data rate from the CTD packages being higher than the level A could cope with (25 Hz compared to 16 Hz).

One of the tape drives on the level B failed early on in the cruise. This necessitated manually changing the cartridge in the remaining tape drive whenever it was full.

On day 016 the ethernet network slowed down to an unacceptable level and eventually brought communication between the sun workstations to a halt. The problem was traced to the ethernet connections on the Macsat computer. Once the ethernet cabling was changed no more problems were experienced.

On day 031 the Ashtech level A timestamp started to drift following a sub-second jump in the master clock. This was corrected and the timestamps of the data file modified.

The level C workstation crashed on day 036. Once the system was rebooted the workstation worked without problems for the remainder of the cruise.

On day 048 discovery2 crashed. This was caused by a faulty hard disk, the disk was repaired and discovery2 restarted. It crashed again on days 049 and 051 and the final crash was due to a faulty internal hard disk. This meant that discovery2 could not be used and because both discovery3 and discovery4 are diskless clients of discovery2 this meant that all three workstations were unusable. As the second crash took place one day before the end of the cruise much of the data on the user system was un-archived.

After the ship docked in Durban, discovery3 was reconfigured as discovery2 with a much reduced system, but one that permitted access to the data. This enabled recovery and archive of the processed and calibrated data from pstar format. Recovery from the last computer crash (day 051) took the first two days in port, thus delaying mobilisation for the next cruise.

PSTAR system

M. J. Griffiths

Three Mac Classics, one Quadra, and one IIsi were sited in the main lab. MacSat was located in the plot, and networked (some of the time). A PowerPC was networked in the chemistry lab and a further Mac Classic was sited in the deck lab (also networked). Finally, an ethernet connection was made to the PSO's office, allowing a PowerBook to be networked from there.

Printing and plotting were available via an HP Paintjet, an Apple LaserWriter, and the new RVS colour postscript printer. The latter performed well, and produced good quality plots, although using the 'hcposta4' driver and plotting took considerably longer than the trusty paintjet.

Problems were caused by breaks in the ethernet network, which stopped the Level C logging twice during the cruise. The problem was traced to the MacSat computer, which was first removed from the network, then later reconnected with new, thin ethernet cables - no problems occurred after this. The same problem was also experienced during the setting up phase in Durban, and again the remedy was to replace cables. The moral is to buy better quality cables, and also have a stock of different lengths so that the smallest length can be used where possible.

One Mac Classic developed a disk fault during the cruise, and was irreparable - it would not boot from floppy and re-installing new OS didn't work. The correct diagnostic tools were not available for us to make any further progress.

There is a known bug in the K-par software when unmounting an optical disk drive, which effectively crashes the host workstation. We had a problem once with this, when using 'umount /archive'. For the umount command to work properly, OpenWin could not be run, and the command 'umount /dev/sk0c' had to be used, after which no more problems were encountered.

A different brand of QIC tapes was used on this cruise (SM Storage master - Premier). Problems occurred (I/O error) when writing to some of these tapes, which did not happen with 3M tapes.

The demands for more data processing, documentation and spreadsheets (Excel) has highlighted the limited capabilities of the Mac Classics. Performance from these was infuriatingly slow; on one it was not possible to run telnet and excel simultaneously.

Cheap paper (delphax80) was used for the paintjet at the start, which did not absorb the ink properly, causing the picture to smudge. Fortunately we had one box of good quality paper (DataCopy), which should always be specified in future.

PSTAR data backup and archive

E. Kent, M.J. Griffiths

A seven day 'rolling backup' was made to exabyte of the data directories, pexec source code and all data not covered by the RVS backup and archiving. Data were not recovered from these routine backups during the cruise as the system crashes experienced did not corrupt the data storage areas.

There was not enough disk space to keep all the data from the cruise on-line at all times and an archiving system was used to ensure all data were securely stored in a format for easy retrieval whilst at sea and transferral to the IOSDL computer system.

A script (arch_cp) was used to copy files intended for archive, compress and copy the file to a holding directory, check the copy had been made correctly then delete the compressed original. The original files were not deleted, it remained the responsibility of the user to check the file had been archived and to delete the original. When a suitable amount of data were ready for archive (between 100 and 150 mb), files were copied to 150mb cartridge using the 'tar' command and a listing of the tarfile stored. Files were also copied to optical disk and again a listing was stored of the contents of each optical disk. The files on optical were intended as the primary archive to be retrieved on the ship if the data were required, as it was a simple procedure to locate the optical on which the file was held, mount the optical, copy the file to the sun system and uncompress it. It was not necessary on the ship to retrieve data from the cartridges. A further backup was made by copying the tarfiles to exabyte.

The cartridges supplied for use on the cruise (StorageMaster Data cartridge DC6150) were of poor quality and could only be written to on one of the drives. I/O errors were generated on the other drive, 3M cartridges could be written to on this drive with no errors. This meant that the data directories had to be mounted onto the sun acting as the RVS level C. Therefore archiving had to be scheduled around the routine RVS backups which also required this drive.

The optical disks initially proved difficult to mount and unmount. If this was attempted from within 'openwindows' the sun would hang and have to be rebooted. It was found however that if the filesystem name (/dev/sk0c) was mounted rather than the pathname location directory (/archive) opticals could be mounted and unmounted without any problem.

The final backup was made on Sunday 19 February. After this the computer system went down leaving data from 20 February not backed up. There was also a large amount of data

(~250mb) in the holding directory due to feverish archiving as the cruise drew to a close. All these data became unavailable from 10pm on 20 February until the data disks could be mounted onto the Level C computer. This was done on the 22 February in port after data logging had stopped and all raw data had been backed up. The data directories were luckily uncorrupted and were copied to exabyte and some data have been successfully recovered from this tape at JRC and IOSDL. The archiving of the stored data was then performed in the normal way.

The loss of the computer system means that there is still processing to be done on many datasets, especially the underway data. It is hoped however that all data have been recovered from the system.

Moorings

I. Waddington, K. Goy, M. Hartman, D. White, R. Bonner, P. Smith, S. Jordan, M. Davies

Recovery

I. Waddington

Eight current meter moorings were deployed on *Discovery* 201 for SWINDEX, between 098 - 102/1993 (Table 4). Full details of these moorings are given in IOSDL Internal Document No 337. The moorings were all to be recovered on cruise 213. Further details on hardware and mooring performance are to be prepared for an IOSDL Internal Document - SWINDEX Moorings, An Analysis of Performance.

Of the eight moorings scheduled for recovery only three were recovered intact - A, B, F, one partially with back up buoyancy - G and one partially by dragline operations - D. Three moorings were not detected on site, C, E, H, and were abandoned as having moved off site by either acoustic prerelease or interference.

The moorings recovered were in such good condition that the total losses appear to have occured at or beneath the acoustic releases. Unfortunately the lower part of mooring D which may have yielded some clue was not recovered.

Mooring G was cut, apparently by some extremely sharp object. This could have been fishbite which suggests that the wire length in the moorings should be extended to deeper than the 1000 metres which IOSDL has regarded as adequate until now.

Inspection of all recovered components revealed only very minor corrosion. Items needing further investigation are the acoustic release mechanism/pyros and the pressure balancing diaphragms on the stainless steel swivels, several of which had seawater in the oil.

The deck layout adopted was as *Discovery* 201, utilising the IOSDL Double Barrel Capstan mooring winch and auxiliary systems. Ships equipment was used as required and manned by the ships crew and RVS technical staff. The 20 Tonne traction winch system was used to trawl for unreleased moorings and worked well.

Mooring H

The vessel arrived on site at 0556Z and ran over the site to a recovery position and hove to. Interrogation of CR200 - 2417 and RT661 - 62 was attempted but with no contact being established .

The vessel then ran back to the mooring position (41° 06.3'S, 28° 53.0'E at 0700Z) to attempt interrogation through the echo sounder fish and overside dunker transducer but again with no contact.

A box search was started by running 0.5 mile to east followed by a 0.5 mile leg to the south, 1 mile to west followed by 1 mile to north then 1 mile to east. At the end of the easterly leg the ship headed back to the nominal mooring position and again attempted interrogation with fish and overside, but no contact could be established.

The vessel then steamed to a CTD station 0.5 mile from the nominal mooring position and acoustic tests were run on a CR200 attached to the CTD to determine acoustic reception. Switching a test CR200 on the CTD presented no problems and the received signal was good, with levels displayed on the laboratory screen thus verifyng acoustic transmission and reception conditions.

With deteriorating weather conditions a further search was inappropriate and dragging was not practical given no acoustic target. The mooring was abandoned as lost off site.

Mooring G

The ship arrived on site at 0556Z, 18 January 1995, and ran over the mooring site, heaving to in a recovery position. The acoustic releases, CR200 - 2385 and RT661 - 58 were interrogated, contact with the CR200 being made first.

The mooring release was initiated and completed successfully using RT661 - 58. The mooring released at 0339Z, 41° 51.77'S, 32° 49.48'E and the observed rise was 70 metres per minute, far less than the expected rate.

The steel buoyancy was not seen on the surface and was presumed missing. The mooring continued to rise and glass buoyancy was observed on the surface and grappled at 0434Z. The buoyancy was hauled inboard where two lines were seen to be leading from the buoyancy. Identification of the polyester 216 metres was made using line colour coding and this was hauled to ACM 1260 and a cut end of the polyester 311m confirmed loss of the upper two ACMs and the steel sphere.

The mooring was then recovered conventionally to the lower buoyancy which was inboard at 0515Z and the line hauled to current meter 10278 which was inboard by 0536Z. All the remaining line was then hauled to recover ACM10280 and the release assembly. The cut line, 311m, was subsequently measured and found to be 242 metres in length and had been severed as if by a sharp knife or bite.

Examination of the mooring components showed that the mooring was in extremely good condition with only very minor corrosion on any part. The glass spheres were removed from their chains for examination but no damage was noted.

Mooring F

The vessel arrived on site at 1111Z, 43° 23.8'S, 36° 03.7'E. The mooring was released at 1125Z and grappled at 1145Z. Recovery line floats were in board at 1149Z.

The first buoyancy hit the underside of ship but was not damaged and was on board at 1152Z. The vessel then gently steamed ahead to trail the mooring astern. The first CM (7517) was in board at 1157Z and showed no marine fouling. The jacket wire beneath the ACM had extensive hydroid type growths attached to it, samples of which were preserved in alcohol. The next CM (9587) had no marine fouling, however the jacket wire beneath had a decreasing number of hydroids attached with depth. The third CM (7943) was in board at 1230Z with the mooring line twisted around it. The CM was hauled inboard and the twisted lines were hauled on board together until the tangle could be relesed. The remainder of the mooring was recovered conventionally.

Examination of the mooring components showed that the mooring was in extremely good condition with only very minor corrosion on any part. The glass spheres were removed from their chains for examination and showed no damage.

Mooring E

The vessel arrived on position at 0807Z, 21 January 1995, 44° 37.6'S, 39° 00.4'E. Acoustic interrogation of the mooring was made but no contact could be established so a box search at 1 mile radius was made. No contact was established acoustically so the vessel hove to whilst further acoustic interrogations were attempted and a midwater dragline assembled. The dragline was deployed at 1341Z and courses steered around and across the mooring site. No contact was made and despite careful watch from the bridge no buoys were seen at the surface. The mooring was regarded as lost off site and the dragline recovered at 1750Z.

Mooring D

The acoustic units were located at 1125Z, 23 January 1995, and fired to release the mooring. However no bottom seperation was seen and after repeated attempts at acoustic release, a dragline was prepared and deployed at 1300Z, 44° 32.9'S, 41° 20.2'E.

Several passes were made on the mooring with the intention of cutting the mooring at or just above the anchor. Courses were steamed with a 10 kHz pinger located on the warp 100 m above the leading grapnel. A height of 50 m above bottom was maintained by slow steaming with a relatively short main warp deployed - warp to water depth of 1.25. On the final pass, in fading light, the four foot steel sphere was seen to surface spectacularly behind the ship, rising completely out of the water before settling with the waterline below the equatorial weld. This excess of buoyancy indicated that the mooring had been cut in the steel wire section.

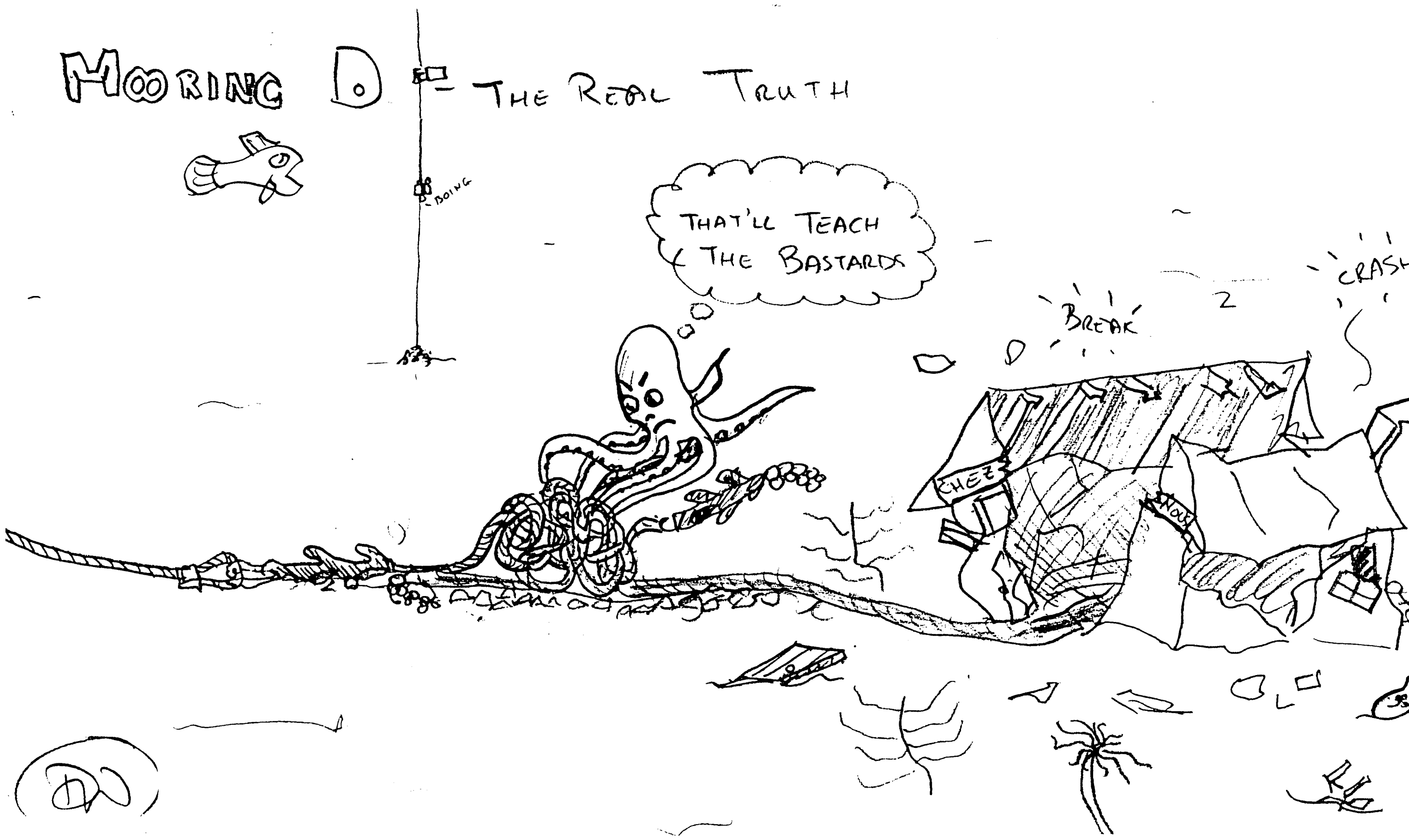
After hauling in the dragline a short search was needed using the ships searchlights to relocate the buoy in dark conditions, it was found at 44° 33.7'S, 41° 18.8'E, grappled at 1916Z and inboard at 1922Z. As the mooring passed astern the buoy hit the underside of the starboard quarter.

CM (5204) was brought on board at 1932Z, no fouling was observed. The thermistor string started to come on board at 1935Z and finished at 1946Z. The 200 m wire had some hydroids attached and the wire jacket was extensively damaged by the dragline. The parted end of the wire was inboard 1951Z.

The following day, 24 January 1995, a further dragging operation was initiated. A revised dragline was deployed such that the ship's main warp was deployed close to bottom with the pinger 1000 metres up the warp from the grapnel line. Courses were steamed around and across the mooring site with no apparent contact. The dragline was hauled clear of the seabed and on re-approaching the site while hauling a glass sphere assembly was seen on the surface.

The buoyancy was grappled into the sphere chain at 1432Z but became detached and a second attempt was made. The spheres were grappled again at 1443Z and buoyancy hauled inboard at 1447Z. The mooring lines were tangled and required some stopping off before hauling commenced at 1456Z with both lines being hauled aboard as a bight.

CM (3727) came out of the water at 1500Z twisted up with damaged remains of mooring line and the swivel. The CM was onboard at 1502Z. The mooring line was untangled and one length hauled in by hand starting at 1510Z and the parted end was in board at 1517Z. The mooring wire was hauled to the winch commencing at 1512Z.



CM (10857) came out of the water at 1521Z, but was tangled badly with the damaged mooring wire. The next CM was in board at 1522Z and the remains of the wire hauled in by hand. All equipment was in board at 1526Z.

A further dragline was deployed three weeks later, on 13 February, with changes made to improve the bottom following of the dragline. Courses were steamed throughout the day with two possible contacts being indicated by increases of main warp tension. However the mooring showed no sign of moving from the seabed. On recovery of the dragline the drag was severely tangled and two grapnels and a section of wire were lost. The tangle was probably due to later courses being steamed in a direction that reversed the dragline over itself. The remaining acoustic unit showed that the mooring was still upright and on position. The unit was switched off and further dragging abandoned.

The major difficulty encountered with this operation was identifying the dragline pinger height off the sea bed. It is essential that this height is known to establish the correct approach when deep water seabed dragging. Further investigation is needed to establish a more suitable system.

The navigation by the ships officers was of the highest standard and dragging advice from 2nd Officer Mr T Morse most welcome.

Mooring C

The vessel arrived on site at 0509Z, 25 January 1995. No acoustic contact could be established with the mooring. A search pattern was run up and down slope from 0557Z to 0913Z with no contact being established. The mooring was declared lost off site.

Mooring B

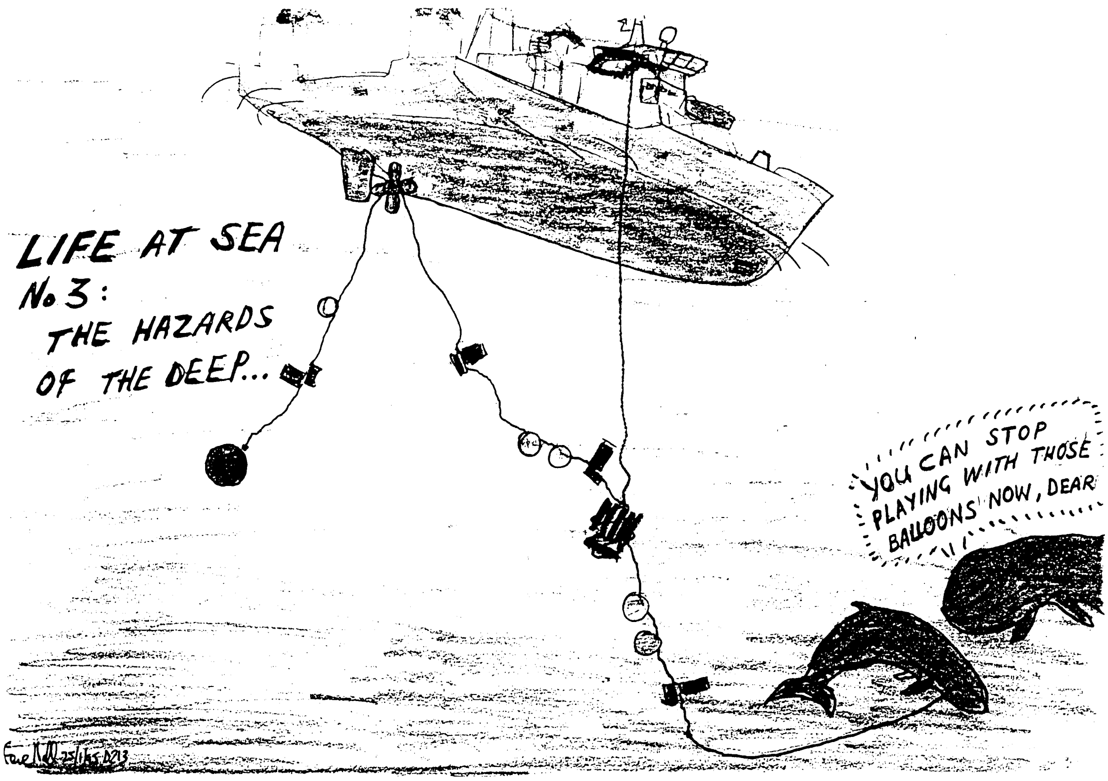
On arrival at the site, 26 January 1995, the mooring was located acoustically and released. The subsurface sphere was sighted on the surface at 0717Z and grappled at 0800Z with some difficulty, as the recovery line was tangled around and beneath the buoy. Hauling commenced at 0808Z with CM 6225 coming onboard at 0816Z. It could be seen that the top cap was coming out and the unit was opened on deck as a precaution should the unit have flooded, it proved to be the result of severe gasing of the battery .

By 0827Z CM 10864 was onboard and hauling commenced on the mooring line. Fishbite damage was seen on the mooring wire at 203 m and 661 m beneath CM 10864. This appeared as long incisive cuts to the outer jacket but with no penetration to the inner steel. The bitten areas were later cut out as samples.

At 0855Z CM 7948 and the acoustic releases were hauled on board.

Mooring A

The acoustic releases were interrogated at 0330Z, 27 January 1995. Both responded and were seen to be upright. The mooring was released at 0453Z and rise rates showed that the mooring was complete with subsurface and glass back up buoyancy. At 0458Z the steel subsurface buoy was spotted followed shortly after by the glass buoyancy, which came to the surface within 100 m of the steel sphere.



The recovery line was tangled at the steel sphere which was grappled at 0525Z. The grapple line and buoyancy went under the vessels counter and had to be let go. The vessel was then manoeuvred alongside the lower backup buoyancy at 0554Z but could not successfully grapple it. With the steel and upper glass buoyancy at the stern of the ship a successful grapple was achieved at 0557Z. The sphere and glass buoyancy were hauled out, tangled together, at 0559Z. All the buoyancy was removed and the polyester lines shackled together and let go so that the wire could be hauled. CM (2108) was in board at 0643Z along with the Thermistor logger T1806. Hauling continued, separating the themistor chain from the jacket wire. The mooring was then recovered conventionally with only minor tangling. All the mooring was inboard by 0821Z.

<u>Current Meters</u>

K. Goy, M. Hartman

A total of twenty Aanderaa current meters and two TR2 Thermistor loggers complete with 100 m long thermistor chains were recovered from the SWINDEX array. Of these, ten were the older type RCM4/5 modified to fit IOSDL deep pressure cases and the remainder were the newer type RCM7/8 with solid state loggers.

All instruments and associated hardware were inspected post recovery and found to be in excellent condition considering the deployment duration. There was very little evidence of marine fouling and rotor stops on fin bar assemblies indicated the instruments had not tilted significantly during the deployment. This was the result of good mooring design and careful balancing prior to deployment. The hypalon coating on the older instruments had bubbled in areas of poor paint adhesion but was generally in good condition.

The current meters were allowed to equilibriate to lab. temperature before uncasing. Even after this, the RCM4/5 instruments had a large pressure build up inside the pressure case which was sufficient to blow the top cap once the retaining clips had been removed. This is thought to be caused by gases from the Aanderaa supplied Leclanche alkaline cells, as there were no such problems with the RCM7/8 instruments fitted with Lithium cells. This problem has not been experienced before and will need to be rectified as there is a possibility that on recovery the pressure could blow the plastic retaining clips near the surface and allow the instrument to flood.

Data was read into a 486DX PC with PROCOMM software using either the Aanderaa Tape reader 2650 or DSU reader 2995. DSU clocks were checked for drift using P3059 software. The PROCOMM software produced an ASCII file with one record per line, each record comprising 6 words (12 in the case of the thermistor loggers), one word per instrument channel, with values ranging from 0000 to 1023 bits. Words with missing bits were marked with an asterisk. (A missing sync pulse may produce an error where more than 6 words are written per line). Prior to the cruise, a copy of the MAFF processing software package had been installed to enable fast processing of data as a "first look" method. A station log file, DQW.log, and calibration file, .Cal, for each instrument were written prior to the cruise and the processing operation onboard utilised five programmes.

CMDSU: converts the data from the raw data file into calibrated data and applies compass corrections.

CM3: Amends the output from CMDSU and interactively averages the data and converts to north / south components.

QWVA: Sets up the parameters that are required for Vecplot / Splot programmes.

VECPLOT: Plots speed and direction to postscript files.

SPLOT: Plots temperature, conductivity and pressure to postscript files.

Subsequent more detailed processing was carried out using PSTAR. The PROCOMM ASCII file was transferred via 3.5" diskette to an Apple Macintosh from which it was moved to a sun workstation using the file transfer protocol (ftp) available with telnet.

A script called rcmtidy was run next, this removed any blank lines and time stamps that were present. Data marked with an asterisk were replaced with the absent data value -999 and lines that were 12 fields long were split into two. Any lines that were not 6 fields long were flagged in a listfile along with any records that did not contain the reference number of the instrument as the first field. This aided manual editing of the file at a later stage.

Manual editing of the file consisted mainly of restructuring lines that were not the correct length. However other errors occurred that needed editing with care. e.g.. TC1723 had spuriously large errors (e.g.. 512 bits) added to the data and every other record of RCM2108 had an inconstant number of repeats of channel 4, 5 or 6. It was necessary in these cases to delete the corrupted data in order to salvage the remainder.

The ASCII files thus created were read into pstar format (pascin) and calibrated (pcalib). Pstar processing was performed via execs to simplify data handling. Compass readings were corrected for magnetic variation (pcalib) and adjusted to lie in the range 0 - 360° (prange). East and north vectors were calculated from speed and direction (pcmcal) and start and stop times in seconds were calculated and inserted in lieu of the instrument reference number in the first and last data cycles (peditb), the intermediate times were calculated by linear interpolation between these two points (pintrp) from which jday was calculated (ptimes). The resulting files were treated as the basic archive files to which further processing can be applied.

Overall data recovery rate was approx 84% for the instruments (Table 6). The older type RCM4/5s proved more unreliable despite extensive rework prior to the cruise and it is recommended that these are not used again for long term deployments. While reading the tapes on some of these instruments, data quality was intermittent and this may be associated with powdery deposits found on the recording heads which appears to have come from the tapes themselves.

The performance of the new RCM7/8 instruments was good but it was disappointing to find sensors going down during deployment on the first occasion they were used. These instruments are effectively still under warranty and the problem will be referred to Aanderaa.

Acoustic Releases

D. White

All the moorings were fitted with a double acoustic release package consisting of an IOSDL CR200 and a MORS RT661. Moorings G and H had RT661s with ferallium cases, the remainder were in IOSDL 20-inch aluminium cases. Each release was clamped to a titanium bar and rigged to fire one pyrolease on an IOSDL titanium release.

The one ferallium case that was recovered, RT58, showed minor surface corrosion on some of the transducer cage bars, which did not have a machined finish. No other parts showed any corrosion. There was some fouling on the neoprene cables on B, and two hydroids on the cable on A, which were preserved.

Four moorings were recovered in the normal manner, although on B the CR200, CR282, did not respond at all. Subsequent testing confirmed an intermittent type of fault, probably a broken wire in the harness. The releases on D gave every indication of having fired, but the mooring remained on the sea-bed. In addition the CR200, CR2314 failed to time out. This indicates a circuit between the pyro 0V and the transducer ground. It usually occurs when the pyrolease has been fired, but may occur if the pyro cable has been severed or pulled out.

Additional testing was carried out on a prototype release, a MORS-compatible release from Marine Acoustics Ltd. After some adjustment several ranging trials were successfully carried out to depths of 5800m.

Cruise logistics

R. Bonner

Mobilisation

Virtually all cruise equipment was shipped from IOSDL to Durban in four twenty foot containers, sailing from UK on the 3 December 1994 and arriving 23 December. Two general purpose 'dry freight' units were used for the lab equipment, one 'open top' unit was used for the mooring winches and hardware, and a 'flatbed' unit was used to ship the two SeaSoar winches. The total weight of the goods shipped was 26750 kg, of which the two SeaSoar winches chained to the flatbed unit were 11000 kg.

To satisfy shipping line requirements, the Dangerous Goods had to be divided between three of the containers. Inflammables, toxics and lithium batteries were placed in one dry freight unit, oxidising agents in the other and acids in the open top unit.

The remaining cruise equipment was divided into three separate airfreight consignments as two items, the Air Standard cylinders and some Pyroleases (for *Discovery* 214) were classified as Dangerous Goods and could not be shipped with the CFC equipment in a consolidated shipment. All airfreight left IOSDL on 15 December, and the last items (Pyroleases) were in Durban by 23 December. Total weight of airfreight was 526 kg.

Upon arrival of the first scientific party in Durban on 3 January, contact was made with the ships agent to confirm receipt of all freight from UK, and that the airfreight and the locally supplied specialist gases for CFC work would be the first items delivered the following day.

On arrival at the ship on the 4 January, we were disappointed to hear that the delivery of the containers would not now take place until the following day, as bunkering had been arranged for the first day in port, precluding any cranework. However, all the airfreight and locally supplied gases arrived on time, enabling the CFC system to be set up and purged with gas. By the middle of the afternoon it became apparent that most of the day had been wasted, as bunkering was not now going to take place, and that container loading could have been completed as originally planned.

The following morning 5 January, a mobile crane was alongside the vessel and all containers were on trailers ready for unloading. The first two onboard were the dry freight units, which were craned on to the aft deck side by side to unload all lab equipment. Once emptied they were both lifted into spare container slots on the fo'csle deck to stay on board until the vessels return to UK. Following this, the open top unit was positioned on the aft deck and the mooring winches and hardware were sited around the deck. The container was not emptied when it was transferred to the aft deck container flatbed as it was to be used to store the spare CTD Rosette frame and empty current meter boxes in readiness for recovered moorings. Finally the two Seasoar winches on the Flatbed unit were lifted directly onboard from the trailer and positioned on the aft deck.

Demobilisation.

As this was the first of two consecutive JRC cruises with similar requirements, most of the equipment remained onboard. The only equipment to leave the vessel in Durban, were spare Niskin Bottles and an Autoanalyser being transferred to the James Clark Ross in readiness for the WOCE cruise A23 in mid - March. All other equipment was either repacked in containers to remain onboard until after *Discovery* 214 or stayed secured on deck until the vessels return to UK in April.

CRUISE DIARY

R.T. Pollard

Wed 4 Jan - Day 04

Advance scientific party begins work on ship. Air freight and gas cylinders loaded. Not possible to load container because intention was to take bunkers by road tankers. This did not happen. Head start lost.

Thurs 5 Jan - Day 05

Three containers and flatbed loaded during the day. A lot of teething problems on computing side. New CTD level A software did not work at first. Bottle firing message from multisampler is now quite different, so needs new application. However, John Smithers had problems with new multisampler, so has gone back to the old one initially, and logging problem goes away. New GPS Trimble 4000 being installed.

Fri 6 Jan - Day 06

Couple of hours lost in the morning as whole party had to transfer to ship and then go to town to be seen by immigration. Remainder of scientific party arrived early afternoon. Order gradually being restored. Doubtful if scientific party can be ready for 0800 departure. However, at 1900B (local time), 1700Z (UK time), the radio was declared seriously u/s, spares needed from UK or spare set needs to be found in SA. UK Marconi office already shut. Hope to get a response on Saturday. Sailing delayed to noon at earliest.

Sat 7 Jan - Day 07

Nobody in Marconi UK office. No chance of ordering spares until Monday. Tried throughout the day to locate a spare radio in SA. No luck. Time used gainfully to complete most of setting up and lashing down of equipment. Sailed at 1700Z, cleared the Durban dock area, then did ADCP calibration runs along shelf and back (courses 045° and 225°), three hours each way. New GPS (Trimble 4000) has less scatter than the old Trimble, reducing outliers considerably. However, data in port fall mostly within a circle of radius 50 m, the selective availability degradation. Hence the 3 hour runs. For most of the run time, Ashtech data capable of giving DGPS were collected on a PC.

Sun 8 Jan - Day 08

Altered course to 214° at 0200Z, still in bottom track calibration mode. Turned offshore towards deep water for trial CTD cast at 0500Z. The PES fish was deployed at 0630Z. Disassembling, cleaning and correctly reassembling all the 10litre bottles took a fair time. Time was also needed for scientific, medical and safety talks and for tour of ship. New watchkeepers were introduced to the computing and logging systems. The CTD cast (station 12671) was successfully completed. All bottles were fired at the bottom. CFC duplicates were drawn from them all (48 samples took just over 2 hours to sample by one experienced sampler), also oxygens and salinities for practice sampling and calibration.

Passage southwest along the coast was slow because of a 40 kt headwind. Course was adjusted to make use of the Agulhas Current.

Mon 9 Jan - Day 09

Watches for underway logging began at 0600Z. Course was adjusted across the narrow continental slope to reach water in which bottom track ADCP mode was operative and course was maintained for East London. A radio set was located in Cape Town but apparently deemed to be unsatisfactory by RVS. By 1500B a decision had still not been taken and it was clear that no set could reach East London by the evening, and indeed might not for several days. Course 132° was therefore set perpendicular to the bathymetry to work a good section across the Agulhas. The deepest cast was planned to be in 2500m and was begun at 1625Z. At a depth of a few hundred metres it had to be aborted because the wire was fouling a wire guide. A 3 kt set was apparent, so the cast was restarted as CTD12673 at 1946Z, 4 n.m. upstream of the nominal station position. As the outer edge of the Agulhas Current had not been reached, a further CTD (12674) was begun in 3000 m extending the CTD line.

Tues 10 Jan - Day 10

During the day a line of CTD casts (12675-80) was worked back towards the shelf. Intended depths were 3000m, 2500m, 2000m, 1500m, 1000m, 500m, 200m and 100m. The combination of very strong currents and a narrow slope region made it impossible to pick these depths accurately however. Instead, each station was started up current a distance estimated to give station positions 3 - 4 n.m. apart, where the station position is taken to be the position when the CTD is at maximum depth. All casts were sampled for CFCs, oxygens, nutrients, salts and oxygen isotopes. This work was completed at 2025Z (2225 local).

By 1300Z it had become clear that a new 600W radio would have to be purchased in the UK and airfreighted out, possibly arriving by Thursday morning. This allowed the CTD line to be fully completed, and it was decided to test deploy the SeaSoar the next morning and run back along the CTD line, leaving open the option of entering East London harbour by early Thursday. Options to fit the radio in Durban or Cape Town had been proposed at various times, but East London minimises loss of scientific time, and a technician could be flown up from Cape Town.

Wed 11 Jan - Day 11

Overnight, the ship steamed offshore along the CTD line as far as possible, so as to deploy SeaSoar without the hindrance of the Agulhas Current. Having reached a position 30 n.m. beyond the 3000 m cast (CTD12674), the CTD line was first completed with CTD12681 to over 3700 m. The SeaSoar was deployed at 4 kts running northeast into the wind. 750 m of faired cable was streamed from the main SeaSoar winch. The winch had had to be mounted off the centre line of the vessel to the starboard side, because of the double-barrelled mooring winch on the port side. The starboard side crane was used to hang the outboard block. Conditions were marginal, but pitching was not excessive, and deployment was successful. The second conductivity sensor (a new FSI one) was not giving data (later found to be set to wrong mode); all other sensors worked.

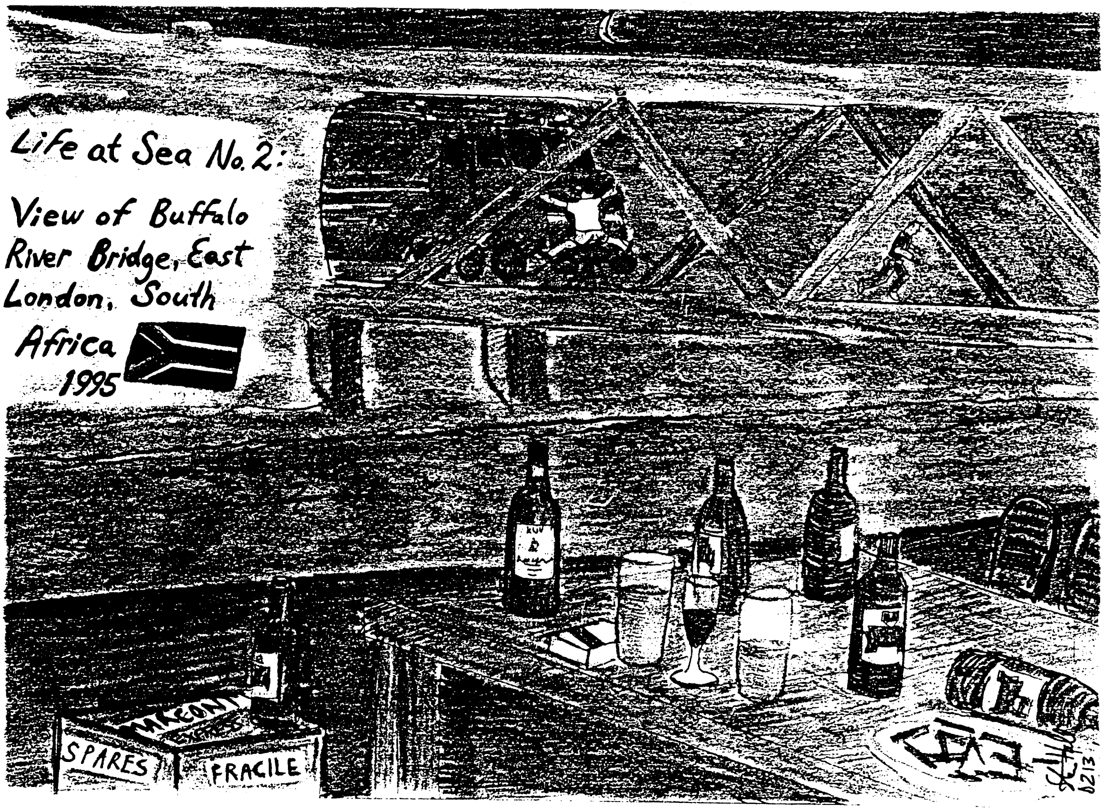
Once the SeaSoar was fully deployed, passage was set back along the CTD line, course 312°. By 1700Z, *Discovery* was moving crabwise across the strong Agulhas jet on heading 355° to maintain the 312° course. As it was by now confirmed that the radio would arrive on Friday, there was time to run two further SeaSoar legs offshore and onshore again. The 1000 m contour was reached shortly after 1800Z, and the course was altered to 040° (at 10° per minute) to run along the depth contours (about 700 m) before turning offshore to run a second leg parallel to the first, 10 n.m. upstream. The 4 kt current, combined with strong headwinds, reduced the ship's speed over ground to a mere 2 - 3 kts, so the short leg took 4 hours to complete. The course change onto the second leg (132°) was completed at 2244Z.

Thurs 12 Jan - Day 12

The SeaSoar run continued uneventfully throughout the day, although the second leg had to be terminated at 1130Z, an hour earlier than intended, when word came that ETA at the East London pilot had been brought forward from 1000B to 0700B on Friday. This decision followed earlier depressing information, later proved wrong, that the consignment was too large or too heavy to be carried on normal passenger flights within South Africa, so would not arrive until Saturday.

Fri 13 Jan - Day 13

The third SeaSoar leg had to be terminated an hour early to meet the East London ETA. Recovery was successful, with no complications other than that the winch overload tripped out twice. After docking through a sea fog, installation of the new aerial (sent from Cape Town) began immediately, prior to arrival of the main Sailor 600 Watt radio, which was expected in mid-afternoon. At 1730B we were informed that the transfer at Johannesburg airport had not been effected, and the set would not arrive until early the next morning. Nearly all the scientific party took the opportunity to spend the evening ashore at Latimers Landing, a break which proved a good morale boost.



Sat 14 Jan - Day 14

At 0730B the radio at last arrived, and after installation and testing *Discovery* left the berth at 1100B, and sailed into calm seas and thick near shore fog. The PES fish was launched at 1015Z, the non-toxic supply turned on, and underway watches began immediately to log surface parameters during the passage towards mooring H, which would cross both the Agulhas and the Agulhas Retroflection. After passing the 200 m bottom contour, XBTs were deployed every two hours, starting at 1300Z.

Sun 15 Jan - Day 15

Good speed was made throughout the day, averaging over 12 knots relative to water (under 12 knots over ground because of some adverse current), while underway logging and XBT deployment continued. Preparations for the first mooring recovery were completed and a barbecue enlivened the evening. Two-hourly XBT launches continued thoughout the day. At 2245Z the ethernet failure alarm went off. The Level B continued to log in standby mode and communication to the Level C system was soon re-established, but ethernet problems prevented communication between the RVS Level C (Discovery 1) and the PSTAR systems (Discovery 2, 3 and 4) for about 12 hours.

Mon 16 Jan - Day 16

The last XBT was deployed at 0535 on arrival at mooring H position, giving a total of 21 successful launches and 2 failures. An acoustic search for the mooring began, first at the deployment position, then in a box around that position. Sadly, after a two hour search, no response could be obtained at all. CTD12682 was worked near the mooring position, and course 103° was set to occupy a line of CTDs at 37 n.m. intervals on passage to mooring G. Sampling the bottles from CTD12682 while underway was marginal, because of spray and a developing sea, but was successfully completed. Likewise, conditions were still workable at the start of CTD12683. A small, rapidly moving low caused conditions to deteriorate rapidly during the cast, with the wind direction changing and a confused sea. At the end of the cast, with 26 m of wire out, the CTD signal was lost, so that the 10 m bottle could not be fired.

The ship occasionally rolled severely, but the CTD was lifted inboard during a stable period. However, just as it was being lowered to the deck, several rolls caused the multisampler frame to hit the bulkhead, and the frame was lowered hastily onto the deck. It took some time to attach securing lines and lift and secure the frame in the railway track brackets. Damage amounted to: bottle 11 damaged against the bulkhead, but probably repairable; thermometer frame (two temperatures, one pressure) on bottle 1 sheared off and lost (not during recovery); 2-ton shackle sheared out of true; cheeks of tear-drop shaped wire clamp bent in; and the conducting cable kinked in two places several metres above the clamping point. It is likely that only the bottle damage occurred during recovery, the remaining damage most likely having taken place when the wire went slack at some stage when the ship rolled during the cast.

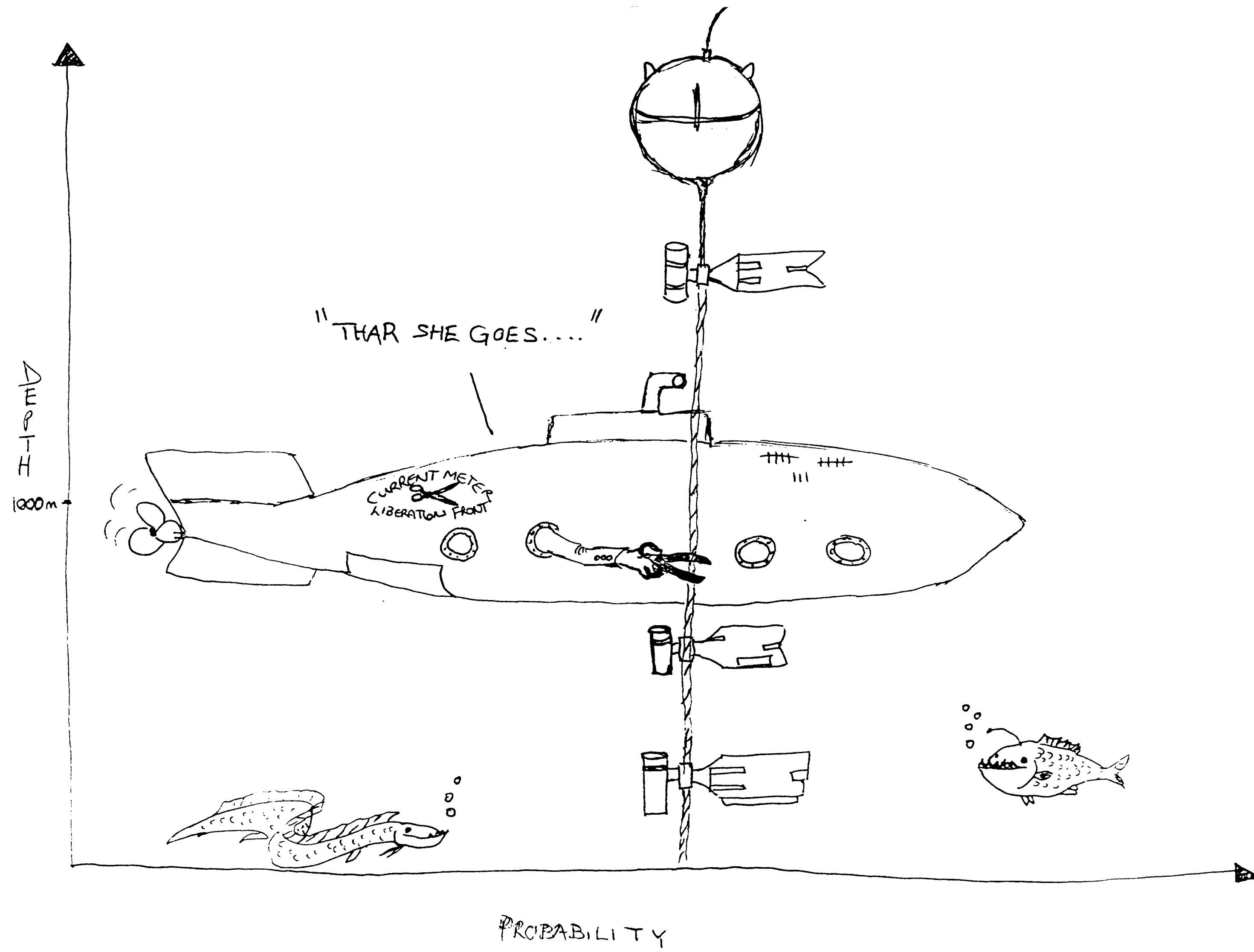
The ship remained hove to for 7 hours during sampling and thereafter.

Tues 17 Jan - Day 17

By 0322Z the weather and sea had abated considerably and passage was resumed. The CTD cable was reterminated and the bottle replaced. The start of the next CTD12684 was delayed for 40 minutes because of loss of power on the bow propellor (a fuse blown). The accumulated loss of time made it necessary to replace the three following CTDs at 37 n.m. intervals by two at 55 n.m. separation (the latter at mooring G).

Wed 18 Jan - Day 18

On arrival at the mooring site, the mooring was interrogated, and rapidly responded and was released. Only the backup buoyancy surfaced, and on recovery it was found that the line was clean cut at about 1170 m. The surface sphere and upper two ACMs were lost, but the lower three ACMs and releases were recovered. This mooring, set in a trench in a depth of 5900 m, was the deepest IOSDL has ever recovered. The deepest ACM was at 5812 m. CTD12686 to 20 m off the bottom was worked at the site. The multisampler returned several misfire signals, but the bottles were found to have tripped, so duplicate samples at 5000 m, 5500 m and 5800 m were collected in the trench.



Thurs 19 Jan - Day 19

Through the remainder of Wednesday and Thursday, 4 more CTDs (12687-90) were expeditiously completed on passage to mooring F, so that we arrived there early, at 1815Z, for recovery on Friday. After checking satisfactory acoustic contact, CTD12691was worked 10 n.m. south of the mooring, in 4400 m water depth in the Prince Edward Fracture Zone. The weather worsened during the cast, because of a large low to the south, so the ship remained hove to during sampling.

Fri 20 Jan - Day 20

On returning to the mooring site, recovery scheduled for 0230Z at first light had to be delayed because of 40 kt winds, developing swell and breaking waves. A short leg to the east was run to determine the bathymetry of the scarp where the Fracture Zone rises rapidly from over 4000 m to the 2500 m Del Cano Rise or Crozet Plateau. The weather had moderated sufficiently on return to the mooring site at 1100Z to recover mooring F, an operation which was smoothly and expertly completed by 1400Z despite the large swell.

During SWINDEX '93, a CTD section had been worked up the southern part of the Prince Edward Fracture Zone to a point about 2° south of mooring F. We wished to compete that section with a CTD 60 n.m. south of F, and also to resurvey the bathymetry near 44°S where GEBCO bathymetric charts show a block rising to under 3000 m in the 4000 m deep trench. If this block was correct it would prevent flow through the trench at the depth of the near bottom current meter from mooring F. Although passage south was slow against the swell and wind, it was well worth while, because the bathymetry was found to be in error, with depths of over 4200 m where the block was shown.

Sat 21 Jan - Day 21

CTD12692 was completed in the Fracture Zone, which is the easternmost channel deeper than 2500 m connecting the Enderby Abyssal Plain to the Agulhas Basin. *Discovery* then returned 60 n.m. to continue the same CTD line worked in SWINDEX'93 on passage to mooring E while the PSO gave a talk to the crew on the scientific objectives of the cruise. During the passage back, 165 m of CTD wire was cut and discarded because of apparent damage and the CTD connection reterminated. Despite that, the following CTD12693 was rather noisy on the deck unit, but the data logged by the Level A appeared clean. The fluorimeter, which had worked for most of the 45°S line, failed again. CTDs 12693-95 were worked on passage to mooring E.

Sun 22 Jan - Day 22

After the final CTD12696, the position of mooring E was reached at 0800Z. There was no acoustic contact, most probably because the mooring had pre-released as with mooring H. Nevertheless, after a 3-hour search, a midwater drag was prepared and run until 1800Z. During this interval, the cause of low impedance on the CTD wire was investigated, and found to be dirty slip-rings on the winch. After completing CTD12697 near the mooring position, course 084° was set for mooring D.

Mon 23 Jan - Day 23

In order to arrive at mooring D by early afternoon, only two CTDs (12698-99) were worked on passage, and the mooring site was reached by 1125Z. Full acoustic contact was established and both releases fired, but the mooring failed to release, so dragging was begun at 1300Z. Unfortunately, the drag wire cut the mooring line rather shallow, at about 500 m, so that the sphere came to the surface. By the time the drag was recovered, it was dark, and it was only just possible to relocate and recover the sphere, upper current meter and thermistor chain. However, the remainder of the mooring remained upright because of the backup buoyancy packages. After completing CTD12700, the vessel remained hove to close by, because the releases were in the firing position and there was a chance that the mooring would release overnight.

Tues 24 Jan - Day 24

After a necessary 8-hour break, the dragging operation recommenced at 0400Z (0600 ship's time) and continued until 1400Z. The intention was to hook the mooring if at all possible below the releases, in order to recover them for inspection. Despite good GPS navigation, we failed to snag the mooring until recovery of the dragging line, when a buoyancy package was sighted on the surface. It was recovered together with two Aanderaa current meters. The bottom of the mooring with two further current meters and the releases remained upright, held off the bottom by the second backup buoyancy package. However, it was decided to leave the site, continue with the recovery programme, and attempt to return for further dragging at a later date. After a check that the mooring position had not been shifted by the dragging operation, course 083° was set to do two CTDs (12701-2) on passage to mooring C.

Wed 25 Jan - Day 25

The second of the CTDs was completed at 0240Z, and mooring C was reached at 0500Z. Once again, there was no acoustic sign of it, and after a 4 hour search, CTD12703 was worked at the site. Three further CTDs were completed on passage to mooring B, CTDs12704 and 6 on the west to east line, with CTD12705 on a dogleg such that 12704 and 5 were the southernmost two CTDs on a Topex-Poseidon track to be worked once the final moorings had been recovered.

Thurs 26 Jan - Day 26

After completing CTD12706 at 0307Z, mooring B was reached at 0530 and recovered satisfactorily. The CR200 release did not operate, but the MORS release did, so for once the cause of failure of one release can be investigated. The CTD to be worked at the mooring site (CTD12707) was delayed because of oil that had leaked from the winch gantry on the hangar deck. Although the CTD and multisampler were covered during the cleaning operation, a thin coating of oil was apparent on some bottles even after hosing down with seawater. Luckily, only 17 bottles were mounted on the frame at the time because of the relatively shallow casts being done, so several oily bottles could be replaced with ones that had been removed and the oily ones cleaned during the CTD cast. The procedure was repeated on casts CTD12708-9 on passage to the site of mooring A. Some suspect bottles were not sampled for CFCs, and thankfully no problems became apparent during analysis.

Fri 27 Jan - Day 27

On arrival at mooring A at 0150Z, the acoustics were checked and CTD12710 completed before the mooring was released at 0500Z. The buoyancy packages came up very close together and tangled, but otherwise recovery was straight-forward, and the whole operation was completed within 4 hours. The two final CTDs (CTD12711-12) of the 45°S line were worked across the gap west of the Crozet Islands, ending at 1800Z. CTD watches were stood down (though CFC, oxygen and nutrients analysis had to continue) during the 20 hour passage run west towards the start of the Topex-Poseidon SeaSoar line, to provide a short break in the routine.

Sat 28 Jan - Day 28

The SeaSoar was deployed from 1345-1415Z and *Discovery* then turned onto the 034° Topex-Poseidon course. The course chosen was fortuitously a good one, heading away from a large, intense dipole depression to the south, and a steady 8 knots was maintained. Unfortunately, a few hours after deployment, the conductivity cell fouled, and, unusually, drifted back over the next 24 hours, rather than recovering in jumps. Recovery of the SeaSoar was contemplated, but it was decided instead to make use of a new FSI conductivity cell, known to be less prone to fouling, to recover absolute calibration. Details are described elsewhere.

Sun 29 Jan - Day 29

A very strong front was crossed at 43°S at about 0400Z, which ADCP plots later showed to coincide with a band of eastward currents up to 0.8 m/s which lay between 42°S and 43°S. North of that, currents were along track, consistent with the track coinciding with the eastern side of a large meander of the Agulhas Return Current that is observed in satellite data on altimeter variability, sea surface temperature and surface colour.

Mon 30 Jan - Day 30

Currents came round to the north between 41°S and 40°S then turned suddenly eastwards again. At the planned endpoint of the run at 39°S there was some evidence that we had not fully crossed the front, so the run was extended a short way, eventually terminating at 38°47'S at 1400Z. On recovery, a streak of grease was found on the nose of the SeaSoar, which, speculatively, may have been the cause of the unusual fouling. The fouling had eventually cleared, but a major effort was required to cross calibrate the NBIS and FSI conductivity sensors and to use the former wherever possible, because of its superior quality. Later analysis showed that, although the track had been extended north into depths less that 2000 m, it had still not fully crossed the surface front, with a significant eastward set when the first CTD12713 was worked at the SeaSoar recovery position.

A line of CTDs was then begun back along the track at about 30 n.m. intervals, but with the exact positions chosen to coincide with deepest bathymetry and to map the currents as best possible.

Tues 31 Jan - Day 31

CTDs12713-15 were worked overnight, and it was noticed that the sensitivity of the oxygen sensor appeared to have decreased markedly. An attempt was made to change it in the morning, before CTD12716, but the only spare was found to be useless, because of a pinhole in its packaging which had caused it to dry out. CTDs12716-18 were occupied through the day in remarkably fine and calm weather conditions. On the 209° course, we were running along the front, more or less in it. A line of small clouds along the eastern horizon may have marked the transition from warm to cold sea temperatures. Patches of discoloured and calmer water 100 m or so across were observed.

At 0000Z on day 031, several Level As had to be reset when a leap second upset them. Later, it was realised that the Ashtech level A clock had not been synchronised with the master clock since that time, and was drifting steadily, hence upsetting the gyro corrections used in the ADCP processing.

Wed 1 Feb - Day 32

Conditions deteriorated rapidly as we proceeded south. CTD12719 was completed satisfactorily, but conditions were unworkable by the time we hove to for the following cast with winds gusting to 50 knots. Lacking weather faxes for some 48 hours, it was impossible to predict for how long the bad weather would last, with pressure falling and wind from the northwest indicating a low to the southwest. In view of the importance of the CTD + SeaSoar line, however, it was decided to press on to the southernmost station, by which time perhaps the weather would have eased. The remaining stations could then be worked in reverse order. This plan worked out excellently. The wind came round to the southwest later in the day, pressure started rising and conditions gradually improved as the wind dropped. The southernmost CTD12720 was reached at 2200Z, and completed after half an hour's pause while a problem with the bow thruster cutting out was investigated.

Thurs 2 Feb - Day 33

Running north again, on a fine, bright, though windy morning. The Topex-Poseidon line of CTDs was completed with CTDs12721-23, and we then set course 352° towards the southern end of the Indomed Fracture Zone. At the first station an easterly current of order a knot was encountered, which made it difficult to ensure that the cast reached the deepest part of the narrow north-south aligned trench. CTD12724 was abandoned with only 600m of wire out in order to choose a better start position.

Fri 3 Feb - Day 34

After an hour to reposition the ship, the cast, now CTD12725 was restarted and completed satisfactorily. Two further casts, CTDs12726-27 were also completed but it again took an hour to find suitable water depth before the latter was started, even though it had been moved 11 n.m. north from the planned position to be in a wider part of the Fracture Zone. By the time we arrived on station for the next CTD at 2150Z, the wind had strengthened but was at an angle to the swell. It was decided that it was too hazardous to attempt the deploy the CTD and the station was abandoned.

Sat 4 Feb - Day 35

Conditions worsened overnight, and the vessel had to remain virtually hove to from 0200Z to 2300Z. There was a strong westward current, and the ship was repositioned several times to attempt the cast. It had been intended to make two casts, about 10 n.m. apart, close to the 4000 m contour on either side of the Fracture Zone. However, bathymetry during the hove to period showed that the channel was only a few miles wide. Given this fact, coupled with the current, it was decided to do only one cast. In the event, by 2300Z the wind was still too strong to attempt the cast, despite occasional slight lulls, and despite the fact that the barometer was rising slowly and the wind had backed right round from 310° to 240°. The station was abandoned and replaced by a 1500 m XBT, followed by two further XBTs at 8 - 10 n.m. intervals on the northward passage to the northernmost station of the Indomed line. It was hoped that this would help to clarify whether the westward set was part of an eddy centred on the north end of the line as suggested by a satellite image received earlier and dated 24 January, 11 days earlier.

Sun 5 Feb - Day 36

On reaching the northernmost position at 0300Z, 38°S 46°21'E, an XBT was launched (to intercompare with the CTD) followed by CTD12728, which unfortunately reached a depth of only 3764m (wire out). The signal failed on the up-cast between 1750 m and 2000 m and further bottles could not be fired. The data were nevertheless deemed adequate, and course 312° was set to work 4 CTD casts westward ending on the S.W. Indian Ridge. Two further XBTs were deployed on passage to CTD12729 and one on station, followed by a further two XBTs on passage and one on station for CTD12730. These, together with the CTDs, confirmed that we were heading out of the anomalous feature, but had still not recovered the structure before the eddy was encountered. A final XBT was therefore deployed midway between CTDs12730 and 31. The reeling gear on the winch failed with 600 m of wire out on CTD12730, and an hour was spent repairing it.

Mon 6 Feb - Day 37

CTD12732 to 1800 m was worked at the crest of the S.W. Indian Ridge just south of the gap between 35°S and 36°S where the S.W. Indian Ridge becomes the Madagascar Ridge. East of that, CTDs 12730-32 were at 24 n.m. intervals to observe any flow on the eastern flank of the ridge. From the crest of the Ridge, we continued 23 n.m. further west onto the Mozambique Basin side to begin a section comprising CTDs12733-39 across the 35°S-36°S gap mentioned above. An extra cast (CTD12736) was inserted at the deepest point of the gap (3400 m) after the previous cast had reached only 2500 m although planned to be on the 3000 m contour on the south side of the gap. Thus CTDs12735-39 were about 10 n.m. apart.

Tues 7 Feb - Day 38

After completing the shallow CTD12739 to 870 m just south of the shallowest point on the Madagascar Ridge (less than 600 m), there was a 45 n.m. passage run west to the start of the next short section, to run from the Madagascar Ridge southwest into deep water in the Mozambique Basin at 43°E. The first three stations CTDs12740-42 were again at 11 n.m. intervals, and the number of salinity sample bottles and CFC syringes was barely adequate. After that, however, several deep (over 4000 m) stations were worked at 30 n.m. intervals, and the pressure eased.

Wed 8 Feb - Day 39

CTDs 12742-44 were in deep water working south from the end of the section off the Madagascar Ridge to the start of the final boundary section (deep to shallow water) from the Mozambique Basin E.S.E. back to the S.W. Indian Ridge (CTDs12744-47 at 20 n.m. intervals), completing the section to CTD12733. Lack of syringes and the need to clear a contaminated valve on the CFC analysing kit meant that the normal pattern of sampling all bottles on alternate casts with the bottom 6 bottles inbetween could not be followed. However, the bottom bottles were sampled on all casts except CTDs 12746 and 47. Full CFCs were drawn on CTDs12741 in 3400 m just S.W. of the Madagascar Ridge and CTD12744, the westernmost cast of the section from deep water to the S.W. Indian Ridge. The evening barbeque turned out to be slightly damp as an unforecast low passed through, but the boerewors went down very well anyway.

Thurs 9 Feb - Day 40

Only the first 11 bottles fired on CTD12747, so the multisampler was stripped down and checked. A possible burr was noted which might have been catching. The multisampler appeared to work normally after cleaning and reassembly. A long section down the west side of the S.W. Indian Ridge was begun, which should take until Sunday evening to complete. It began with 7 casts (CTDs 12747-53 to about 3400 m along a line 209°, parallel to a Topex-Poseidon line, but 20 miles or so further west to be in sufficiently deep water to be sure of sampling the Deep Water. Full CFCs were drawn on alternate casts, the bottom 6 bottles only were sampled on the intermediate casts. CTDs12747-50 were completed. Passage between CTDs was slower than usual because of strong currents and an opposing wind.

Fri 10 Feb - Day 41

The final casts of the 209° course (CTDs12751-53) were completed by 1500, after which course 174° was set to do three CTDs (12754-56) in somewhat shallower water (2300 m) slanting towards the crest of the S.W. Indian Ridge before dropping just over the Ridge into a fracture zone just east of the ridge crest.

Sat 11 Feb - Day 42

The line of CTDs over the ridge crest was completed at 0600Z, and we then ran south (190°) to do four CTDs (12757-60), the deepest to 4894 m, along a fracture zone in the centre of the Southwest Indian Ridge along 42°30'E. No Bottom Water was found.

Sun 12 Feb - Day 43

After completing the last of the CTDs in the fracture zone, *Discovery* turned west to occupy the first CTD12761 of the section from mooring D to Durban. This dogleg avoided arrival too early at the mooring, and would save time later. With a couple of hours in hand, passage back to the mooring was preceded by a short bathymetric survey of a possible gap in the ridge, and a dogleg run via the last CTD (12760) of the previous line to ensure that ADCP data were collected on the straight passage from 12760 to the mooring site. After checking the acoustic releases on arrival, the CTD at mooring D, previously worked as CTD12700 was reworked, without CFC sampling, as CTD12762.

Mon 13 Feb - Day 44

Deployment of the drag line was begun shortly before midnight GMT, taking about 3 hours. Through the day, several circuits of the mooring were completed, and high tensions indicating snagging occurred at least twice. By 1515Z, with the light fading, it was reluctantly agreed to terminate the operation, and the drag line was recovered. It was found that the last 1000 m of the drag was seriously birdcaged, and it was cut away. Passage was begun along the line to Durban, while the PSO's RPC afforded all scientists with a much-needed break.

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Tues 14 Feb - Day 45

Passage on course 327° planned at 11 knots to the start of the SeaSoar run was slowed by fog, rain, an adverse current and a headwind to less than 10 knots. By 1700Z, although still about 30 n.m.

short of the planned start position, it was deemed advisable to deploy the SeaSoar before conditions deteriorated further. The vessel therefore altered course to 150° to run with the wind and swell during deployment, which went smoothly. The SeaSoar was then towed on course 151° along the Topex-Poseidon track along which the satellite had flown on 12 February. The FSI conductivity sensor was calibrated against the NBIS conductivity before the NBIS cell fouled seriously. Despite the poor resolution of the FSI cell, it appeared to maintain its calibration and helped greatly in correcting the NBIS cell for offsets.

Wed 15 Feb - Day 46

The SeaSoar run continued until 1130Z. After recovery, CTD12763 was worked at the recovery position, and the line of CTDs continued at 43 n.m. intervals back along the Topex-Poseidon track towards Durban, course 330°.

Thurs 16 Feb - Day 47

After completing 4 CTD casts (CTDs12763-66) back along the SeaSoar track, the SeaSoar was deployed at 1200Z for a final 43 n.m. run between CTDs 12766 and 67, thus completing the final stretch of the section that had been lost two days previously. During this run, the T/S structure changed abruptly from Subantarctic T/S conditions to Subtropical, with surface temperatures rising from 10°C to over 16°C. The SeaSoar was recovered at 1730Z and CTD12767 was occupied. At each of the CTD casts marking the start or end of a SeaSoar run, care was taken to position the ship so that the first or last SeaSoar profiles were within a mile of the CTD cast.

Fri 17 Feb - Day 48

CTDs12768-70 were worked at 46 n.m. intervals, with depths increasing to 5000 m. Transmissometer data errors became serious on casts 12767-68 and the lead was replaced before 12769. Despite good weather and a speed through the water of 12 knots, an adverse current of up to 3 knots (the Agulhas Return Current) added an hour or more to the passage time between stations.

Sat 18 Feb - Day 49

The three deepest CTDs12771-73 were occupied on the western half of the Mozambique Basin abyssal plain. Only the deepest, CTD12772 in over 5900 m, could not be worked to full depth to stay within the recommended loads on the CTD wire, but a depth of 5700 m was reached. A little time was spent in finding the optimum positions to ensure that the bottom water was sampled, as the positions of deep trenches in the bathymetric charts were sometimes out by a few miles. Data processing was halted by computer failure. The export partition on Discovery2, the main PSTAR computer, became corrupted because of bad blocks on the disk. The Level A/B/C system continued normally, so no data were lost, but a backlog of processing built up.

Sun 19 Feb - Day 50

The three final CTDs12774-76 were completed on the western margin of the abyssal plain, where it rises into the shallower Natal Basin. Depths shallowed further east than shown on the charts, so the cast planned for 5200 m of water (CTD12774) was worked in 4900 m and we had to run back 5 miles on the following cast to reach 4200 m, which was critical to sampling the upper limits of Antarctic Bottom Water. After completion of the last CTD at 1550Z, course was set for Durban. Underway logging of the thermosalinograph, bathymetry, meteorological data, ADCP and navigation continued. It proved impossible to patch the bad blocks on the faulty computer disk drive, and PSTAR programs were also corrupted. After archiving data, an alternative disk was substituted and partitioned and the system rebuilt without the export partitions to Discovery3 and 4 computers.

Mon 20 Feb - Day 51

The final salinity bottle samples were drawn at 0530Z. The non-toxic water supply was turned off at 1410Z. At about 1800Z, the rebuilt computer system crashed with the same error as before, on a completely different disk. This time the root partition was involved, and diagnostics revealed a bad block. This had been the first symptom before, had been fixed, and had been followed by irrecoverable errors the following day. For that reason, it was felt that the only safe course was to shut the system down until advice from the manufacturers could be sought. A considerable amount of final processing done during the day needs to be archived.

Tues 21 Feb - Day 52

RRS Discovery docked at 0830Z. After consultation with RVS, it was concluded that the Pstar computer Discovery2 was u/s. After backing up all data, tape and optical disk drives and other peripherals were transferred to Discovery3, which was then rebuilt as Discovery2. The scientific complement left the ship in two parties, the first at 1500B and the second at 1700B

Wed 22 - Thurs 23 Feb - Day 53 - 54

Final processing and archiving was completed as best possible.

ACKNOWLEDGEMENTS

The Principal Scientists would like to thank the Master, officers, crew and scientists of the RRS *Discovery* for making this such an enjoyable, as well as successful cruise.

And apologies to those whose cartoons and drawings I have plagiarised. I hope they bring as much interest and 'light relief' to this report as they did to the cruise - Jane.

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Table 1. CTD Station List

Statn	Date	Day of year	Time (gmt) Start	Down	End	Latitude (S)	Longitude (E)	Depth (corr m)	Depth of cast (m)	Hght.off bottom	O_{18}	Chl	CFC samples from bottles:
12671	8-Jan	008	12.30	13.29	14.34	30° 36.86	31° 35.19	2926	2871	47	-	-	1-24
12672	9-Jan	009	16.21	16.45	17.08	33° 13.88	28° 37.21	2622	289	aborted	-	-	-
12673	9-Jan	009	19.36	20.57	22.15	33° 11.78	28° 36.72	2464	2406	51	Y	-	1-3,4-7,9-16,18-22
12674	10-Jan	010	00.33	01.48	03.25	33° 20.94	28° 44.01	3068	3003	45	Y	-	1-4,6,8-12,14,16-22,24
12675	10-Jan	010	06.40	07.19	08.18	33° 6.59	28° 33.13	1766	1774	19	Y	-	1,3,5,7,9,12,13,15,17,19-22,24
12676	10-Jan	010	09.56	10.37	11.29	33° 4.05	28° 28.36	1344	1348	22	-	-	6,8
12677	10-Jan	010	13.13	13.50	14.40	33° 1.57	28° 23.97	972	916	21	Y	-	1,2,4,6,8,10-12,14,16,18-22,24
12678	10-Jan	010	16.31	16.49	17.19	33° 0.40	28° 23.39	558	522	32	Y	-	2,4,6,8,10,12,14,16,18
12679	10-Jan	010	18.42	18.52	19.04	32° 58.00	28° 20.87	154	142	13	Y	-	2,4,6,8
12680	10-Jan	010	20.13	20.18	20.29	32° 55.74	28° 18.65	97	81	16	Y	-	2,4,6
12681	11-Jan	011	06.05	07.25	09.10	33° 38.11	29° 12.17	3748	3739	19	Y	-	1-24
12682	16-Jan	016	09.31	10.58	12.45	41° 6.63	28° 52.25	4418	4380	26	-	Y	01-20
12683	16-Jan	016	16.26	18.09	20.03	41° 15.29	29° 40.47	4796	4771	19	-	Y	01-20
12684	17-Jan	017	08.35	11.01	13.01	41° 22.40	30° 28.02	4843	4817	20	-	Y	01-20
12685	17-Jan	017	19.00	20.37	22.30	41° 37.18	31° 37.93	4470	4450	14	-	Y	01-20
12686	18-Jan	018	07.53	09.57	12.14	41° 52.30	32° 50.77	5834	5811	18	-	Y	01-20
12687	18-Jan	018	16.00	17.39	19.40	42° 11.57	33° 31.54	4893	4867	14	-	Y	01-20
12688	18-Jan	018	22.51	00.36	02.23	42° 29.57	34° 10.17	4682	4680	19	-	Y	01-20
12689	19-Jan	019	05.22	06.57	08.43	42° 46.87	34° 47.19	4861	4836	13	-	Y	01-20
12690	19-Jan	019	12.06	13.39	15.14	43° 5.17	35° 26.54	4534	4312	17	-	Y	01-20
12691	19-Jan	019	20.03	21.35	23.15	43° 33.01	35° 58.3	4410	4385	15	-	Y	01-20
12692	21-Jan	021	02.18	03.57	05.30	44° 15.10	35° 34.3	3781	3897	14	-	-	01-20
12693	21-Jan	021	11.04	12.20	13.30	43° 39.86	36° 35.63	2852	2838	17	-	Y	01-20
12694	21-Jan	021	15.56	17.15	18.25	43° 55.01	37° 3.32	2639	2687	19	-	Y	01-17
12695	21-Jan	021	20.56	21.59	22.48	44° 9.35	37° 35.23	1939	1931	12	-	Y	1-3,6-7
12696	22-Jan	022	01.38	03.21	04.19	44° 24.54	38° 7.22	3438	3451	17	-	Y	1-7,9-18
12697	22-Jan	022	18.36	19.59	21.20	44° 39.46	38° 59.64	3420	3400	13	-	Y	01-17
12698	23-Jan	023	00.41	01.51	03.03	44° 35.58	39° 50.75	2590	2563	18	-	Y	01-17
12699	23-Jan	023	06.28	07.27	08.19	44° 33.36	40° 37.25	1830	1824	14	-	Y	-
12700	23-Jan	023	20.17	21.25	22.36	44° 34.65	41° 19.34	2684	2667	10	-	Y	01-17
12701	24-Jan	024	20.08	20.54	21.42	44° 29.39	42° 7.49	1905	1884	14	-	Y	-
12702	25-Jan	025	00.49	01.44	02.47	44° 28.47	42° 49.06	2155	2131	15	-	Y	01-17
12703	25-Jan	025	09.15	10.11	11.08	44° 25.14	43° 27.38	2459	2434	13	-	Y	01-17
12704	25-Jan	025	14.49	15.33	16.16	44° 21.88	44° 10.13	1899	1874	13	-	Y	01-17
12705	25-Jan	025	19.26	20.22	21.18	43° 57.11	44° 33.23	2461	2444	12	-	Y	01-17
12706	26-Jan	026	01.38	02.26	03.10	44° 32.11	44° 59.83	1737	1709	18	-	Y	-
12707	26-Jan	026	10.22	11.08	11.59	44° 43.97	45° 44.80	1618	1593	18	-	Y	1-3,7-12,14-17

Statn	Date	Day of year	Time (gmt) Start	Down	End	Latitude (S)	Longitude (E)	Depth (corr m)	Depth of cast (m)	Hght.off bottom	O_{18}	Chl	CFC samples from bottles:
12708	26-Jan	026	16.40	17.18	18.00	45° 0.31	46° 37.61	1757	1737	13	-	Y	-
12709	26-Jan	026	22.24	23.14	00.00	45° 17.10	47° 27.28	2065	2046	17	-	Y	01-17
12710	27-Jan	027	02.14	03.15	04.23	45° 25.75	47° 47.87	2810	2791	12	-	Y	01-17
12711	27-Jan	027	11.08	12.10	13.18	45° 31.63	48° 25.05	2843	2819	15	-	Y	01-17
12712	27-Jan	027	16.00	17.01	17.58	45° 38.21	49° 1.28	2666	2650	13	-	Y	01-17
12713	30-Jan	030	14.56	16.03	16.57	38° 47.29	48° 31.22	2106	2204	9	-	Y	-
12714	30-Jan	030	18.34	19.48	21.04	39° 0.70	48° 22.3	3061	3034	13	-	Y	01-17
12715	31-Jan	031	00.40	02.09	03.19	39° 32.31	47° 59.31	3405	3394	15	-	Y	1,3-8
12716	31-Jan	031	07.12	08.33	09.58	40° 3.29	47° 36.6	3558	3618	15	Y	Y	01-19
12717	31-Jan	031	13.57	15.13	16.24	40° 35.60	47° 13.55	3098	3470	10	-	Y	01-06
12718	31-Jan	031	20.44	22.00	23.21	41° 9.99	46° 46.95	3707	3707	16	Y	Y	01-19
12719	1-Feb	032	03.32	04.58	06.21	41° 45.90	46° 20.05	3663	3687	10	-	Y	01-06
12720	1-Feb	032	22.09	23.58	01.02	43° 25.04	45° 1.05	2993	3002	16	-	Y	01-07
12721	2-Feb	033	04.01	05.06	06.10	43° 0.05	45° 22.75	2937	2918	8	-	Y	01-19
12722	2-Feb	033	09.02	10.06	11.17	42° 32.83	45° 45.02	2978	2961	15	-	Y	01,03-07
12723	2-Feb	033	14.13	15.22	16.28	42° 5.19	46° 5.68	3405	3405	7	-	Y	01-19
12724	2-Feb	033	23.04	23.30	23.49	40° 59.58	45° 54.90	3804	682	aborted	-	-	-
12725	3-Feb	034	00.31	02.01	03.33	40° 59.40	45° 52.86	4149	4120	16	Y	Y	01-17,19,21
12726	3-Feb	034	07.13	08.39	10.02	40° 23.86	45° 56.50	4048	4063	16	-	Y	02-07
12727	3-Feb	034	15.35	17.08	18.54	39° 37.72	46° 14.00	4611	4758	8	Y	Y	1-17,19,21
12728	5-Feb	036	03.15	04.42	05.30	37° 59.8	46° 20.4	3592	3763	12	Y	-	01-08
12729	5-Feb	036	10.00	11.18	13.00	37° 36.61	45° 48.10	3445	3419	18	Y	Y	1-17,19,21
12730	5-Feb	036	16.15	18.36	19.50	37° 14.16	45° 15.03	2986	2978	12	-	Y	01-07
12731	5-Feb	036	22.20	23.30	00.34	36° 58.54	44° 52.57	2955	2933	15	Y	-	1-15,17,19
12732	6-Feb	037	02.56	03.42	04.25	36° 43.89	44° 30.15	1892	1878	13	-	Y	1,3,5,7-9
12733	6-Feb	037	06.41	07.55	09.10	36° 29.51	44° 8.83	3077	3082	13	Y	-	1-15,17,19
12734	6-Feb	037	11.27	12.38	13.44	36° 5.01	44° 12.52	3103	3078	15	-	Y	1,3-7
12735	6-Feb	037	16.16	17.13	18.05	35° 39.80	44° 16.28	2567	2545	11	Y	-	1-15,17,19
12736	6-Feb	037	19.12	20.27	21.37	35° 30.43	44° 14.10	3479	3451	14	-	-	01-11
12737	6-Feb	037	23.11	00.14	01.33	35° 20.47	44° 12.67	3348	3315	16	Y	-	1-15,17,19
12738	7-Feb	038	02.39	03.40	04.41	35° 12.40	44° 11.01	2617	2583	8	-	Y	-
12739	7-Feb	038	06.15	06.52	07.55	35° 3.89	44° 10.00	890	874	9	-	-	-
12740	7-Feb	038	11.36	12.13	12.51	35° 1.69	43° 14.64	1390	1428	19	-	Y	1-15,17,19
12741	7-Feb	038	14.02	15.10	16.22	35° 7.63	43° 3.79	3369	3365	11	Y	-	-
12742	7-Feb	038	17.35	19.03	20.40	35° 14.98	42° 55.46	4309	4297	10	-	-	01-07
12743	7-Feb	038	23.34	01.02	02.25	35° 39.62	42° 34.91	4378	4360	18	Y	Y	1-11,15,17,19
12744	8-Feb	039	05.37	07.07	08.43	36° 9.96	43° 5.84	4405	4381	17	Y	-	1,3-6,8-18,20
12745	8-Feb	039	10.55	12.24	14.02	36° 19.80	43° 5.84	4577	4553	20	-	-	1-4,6,8-11
12746	8-Feb	039	16.18	17.30	18.39	36° 30.12	43° 26.37	3381	3368	13	-	Y	-

Statn	Date	Day of year	Time (gmt) Start	Down	End	Latitude (S)	Longitude (E)	Depth (corr m)	Depth of cast (m)	Hght.off bottom	O_{18}	Chl	CFC samples from bottles:
12747	8-Feb	039	21.06	22.21	22.37	36° 40.16	43° 47.33	3202	3173	18	-	-	-
12748	9-Feb	040	03.45	04.49	06.60	37° 11.44	43° 27.44	3031	3012	24	Y	Y	1-10,12-14,16,18,19
12749	9-Feb	040	10.29	11.44	12.52	37° 41.99	43° 6.86	3444	3415	18	-	Y	01-07
12750	9-Feb	040	16.50	18.01	19.30	38° 14.54	42° 47.04	3508	3490	17	-	Y	1-5,7-13,15,17,19
12751	9-Feb	040	23.28	00.50	01.59	38° 45.90	42° 28.28	3534	3496	18	-	Y	01-07
12752	10-Feb	041	06.14	07.23	08.41	39° 17.48	42° 6.80	3363	3328	15	Y	Y	1-15,17,19
12753	10-Feb	041	12.24	13.33	14.49	39° 49.04	41° 45.02	3152	3137	18	-	Y	01-07
12754	10-Feb	041	18.30	19.20	20.15	40° 25.18	41° 50.61	2336	2314	14	-	Y	1-14,16,18
12755	10-Feb	041	23.30	00.25	01.17	41° 1.61	41° 55.11	2368	2351	17	-	Y	01-06
12756	11-Feb	042	04.42	05.27	06.18	41° 37.24	42° 0.71	2219	2193	13	Y	Y	1-11,13,15
12757	11-Feb	042	09.51	11.01	12.14	42° 12.34	41° 55.16	3411	3396	19	-	Y	01-07
12758	11-Feb	042	15.32	17.13	19.01	42° 47.72	41° 47.27	4389	4887	13	Y	Y	1-18,20,22
12759	11-Feb	042	22.18	23.56	01.28	43° 23.28	41° 37.15	4844	4824	22	-	Y	1,3-10
12760	12-Feb	043	04.49	06.07	07.44	43° 58.48	41° 30.52	4093	4094	15	Y	Y	1,3-5,7-17,19,21
12761	12-Feb	043	11.00	11.44	12.25	43° 54.76	40° 48.74	1921	1901	19	-	Y	1,3,4
12762	12-Feb	043	20.42	21.39	22.38	44° 33.79	41° 17.99	2689	2669	14	-	Y	-
12763	15-Feb	046	12.55	14.02	15.06	43° 22.89	40° 1.69	2820	2884	14	Y	Y	01-17
12764	15-Feb	046	19.34	20.46	22.06	42° 45.94	39° 32.41	3202	3176	16	-	Y	01-07
12765	16-Feb	047	02.43	04.11	05.10	42° 9.00	39° 3.48	2962	2936	17	Y	Y	1-6,8-14,16,18
12766	16-Feb	047	09.30	10.42	11.49	41° 31.50	38° 34.42	3321	3297	19	-	Y	1-15,17,19
12767	16-Feb	047	18.44	20.10	21.28	40° 55.52	38° 7.18	3886	3893	17	Y	Y	1-9,11-16,18,20
12768	17-Feb	048	02.29	04.06	06.02	40° 15.68	37° 37.98	4933	4954	16	Y	-	1-6,8-16,18,20
12769	17-Feb	048	11.07	12.54	14.43	39° 36.21	37° 10.59	5448	5431	27	Y	-	1-20
12770	17-Feb	048	19.50	21.25	23.57	38° 55.75	36° 40.81	4927	4892	22	Y	-	1-6,8,10,12-16
12771	18-Feb	049	03.53	06.00	07.46	38° 16.00	36° 10.82	5190	5372	17	-	-	1-18,20
12772	18-Feb	049	11.35	13.35	15.38	37° 39.97	35° 50.03	6092	5857	192	Y	-	1-8
12773	18-Feb	049	18.39	20.20	22.10	37° 12.34	35° 34.89	5209	5134	17	-	-	1-19
12774	19-Feb	050	01.50	03.21	04.47	36° 40.15	35° 10.83	4817	4800	15	Y	-	1-12
12775	19-Feb	050	07.36	08.58	10.13	36° 27.43	35° 4.05	4197	4173	17	-	-	1-19
12776	19-Feb	050	13.38	14.45	15.45	35° 56.51	34° 43.71	3440	3420	17	-	-	1-7

Table 2. SeaSoar Deployments

Run no	Section name	Deployed day:time	km	Recovered day:time	km	Duration day:time	km	4-hour files	section files
1	Agulhas	11:1100	1040	13:0130	1524	2:0230	484	01-10	01,02,03
2	48e	28:1348	5574	30:1400	6307	2:0015	733	11-22	07
3	38e	45:1730	10345	46:1206	10610	0:1856	265	23-29	08
4	38e	47:1202	10873	47:1811	10964	0:0609	91	30	09

Table 3. XBT Station List

Station	Date	Day of year	Time (gmt)	Latitude (S)		Longitude (E)		Depth (corr m)	Probe type
(East London to mooring H)									
xbt001	test								
xbt002	test								
xbt003	14-Jan	014	1256	33°	23.5'	27°	58.3'	1131	T7
xbt004	14-Jan	014	1508	33°	49.6'	28°	02.9'	3514	T7
xbt005	14-Jan	014	1712	34°	14.0'	28°	05.6'	3726	T7
xbt006	14-Jan	014	1904	34°	34.5'	28°	07.7'	4023	T7
xbt007	14-Jan	014	2102	34°	56.2'	28°	09.7'	4317	T7
xbt008	14-Jan	014	2312	34°	20.4'	28°	12.7'	4403	T7
xbt009	15-Jan	015	0000	35°	41.8'	28°	14.9'	4575	T7
xbt010	15-Jan	015	misfire						
xbt011	15-Jan	015	0327	36°	09.2'	28°	18.2'	4677	T7
xbt012	15-Jan	015	0501	36°	27.2'	28°	20.2'	4733	T7
xbt013	15-Jan	015	0705	36°	51.4'	28°	23.0'	4134	T7
xbt014	15-Jan	015	0902	37°	13.3'	28°	25.7'	4083	T7
xbt015	15-Jan	015	1110	37°	36.4'	28°	29.0'	3995	T7
xbt016	15-Jan	015	1306	37°	58.7'	28°	29.9'	3725	T7
xbt017	15-Jan	015	1500	38°	20.8'	28°	30.8'	4203	T7
xbt018	15-Jan	015	1658	38°	43.2'	28°	35.4'	4110	T7
xbt019	15-Jan	015	1859	39°	05.9'	28°	39.8'	4133	T7
xbt020	15-Jan	015	2100	39°	28.6'	28°	42.2'	4338	T7
xbt021	15-Jan	015	2308	39°	51.6'	28°	44.8'	4203	T7
xbt022	16-Jan	016	0108	40°	13.6'	28°	45.2'	3938	T7
xbt023	16-Jan	016	0303	40°	35.8'	28°	47.7'	3898	T7
xbt024	16-Jan	016	0532	41°	04.4'	28°	52.1'	4490	T7
(Indomed Fracture Zone)									
xbt025	4-Feb	035	2317	38°	34.7	46°	14.6	4474	T5
xbt026	5-Feb	036	0049	38°	23.1	46°	16.7	4658	T5
xbt027	5-Feb	036	0142	38°	14.2	46°	18.4	4694	T5
xbt028	5-Feb	036	0238	38°	04.4	46°	20.1	5029	T5
xbt029	5-Feb	036	0311	37°	59.9	46°	21.1	4209	T5
xbt030	5-Feb	036	0810	37°	47.2	46°	02.5	3246	T5
xbt031	5-Feb	036	0900	37°	42.0	45°	54.2	3154	T5
xbt032	5-Feb	036	0954	37°	37.2	45°	47.6	3411	T5
xbt033	5-Feb	036	1404	37°	28.4	45°	36.4	4103	T5
xbt034	5-Feb	036	1507	37°	21.4	45°	24.6	3578	T5
xbt035	5-Feb	036	1609	37°	14.3	45°	13.9	3062	T5
xbt036	5-Feb	036	2121	37°	04.7	45°	00.7	3263	T5

Table 4. Mooring Details

MOORING	A	B	C	D	E	F	G	H
LATITUDE	45 25.2S	44 44.1S	44 27.1S	44 33.4S	44 37.4S	43 23.7S	41 51.5S	41 06.3S
LONGITUDE	47 49.7E	45 45.3E	43 27.8E	41 19.2E	38 59.6E	36 03.9E	32 49.9E	28 52.3E
Day Deployed	102 1993	099 1993	098 1993	096 1993	095 1993	093 1993	091 1993	089 1993
TOP BUOY	299m	280m	270m	303m	332m	350m	366m	366m
INSTRUMENT DEPTH	ACM2108 330m	ACM6225 311m	ACM5205 301m	ACM5204 335m	ACM7517 364m	ACM7517 382m	ACM8010 398m	ACM1259 398m
INSTRUMENT INSTRUMENT LENGTH	TL806 TC1723 100m			TL879 TC1722 100m				
INSTRUMENT DEPTH	ACM4738 533m					ACM9587 683m	ACM9588 700m	ACM9590 698m
INSTRUMENT DEPTH	ACM10852 634m	ACM10864 612m	ACM10863 602m	ACM10857 638m	ACM9589 665m	ACM7943 1391m	ACM1260 1411m	ACM6372 1410m
BUOYANCY DEPTH	10x17" glass 1139m		8x17" glass 1107m	6x17"+3x16"	9x17" glass 1170m	10x17" glass	11x17" glass 1628m	11x17" glass 1632m
INSTRUMENT DEPTH	ACM7945 1360m		ACM3624 1327m	ACM3727 1364m	ACM6867 1391m			
BUOYANCY DEPTH	9x17"glass		8x17" glass 1657m	2x17"+6x16"	4x17"+4x16" 1914m	5x17"+3x16"	8x17"+1x16" 2155m	8x17" glass 2154m
INSTRUMENT DEPTH	ACM10279 2223m		ACM10274 2291m	ACM10276 2413m	ACM9648 2656m	ACM10275 2661m	ACM10278 2681m	ACM3726 2680m
INSTRUMENT DEPTH	ACM10277 2818m	ACM7948 1529m		ACM10281 2622m	ACM9965 3334m	ACM10273 4174m	ACM10280 5812m	ACM9963 4351m
CR200 REL FREQ PERIOD	2519 300 1.14	282 360 1.04	2522 460 1.06	2314 340 1.02	2557 460 1.00	2521 440 1.08	2385 340 1.04	2417 400 1.18
RT661 RELEASE CODE	57 64A1 6411	60 20A1 2011	54 42A1 4211	66 40A1 4011	64 62B1 6211	55 42B1 4211	58 64B1 6411	62 62A1 6211
ANCHOR	2906m	1614m	2379m	2710m	3403m	4262m	5900m	4430m

Table 5. CTD - bottle salinity residuals and CTD salinity corrections

CTD Station	Mean Offset (All Depths)	Standard Deviation (All Depths)	Mean Offset >1000 dbar	Standard Deviation >1000 dbar	Number of Samples >1000 dbar	Final Correction Applied	SSW Batch
12671	-0.0244	0.0008	-0.0244	0.0008	22	-0.024	P125
12672					00	0.000	
12673	0.0007	0.0023	0.0002	0.0009	07	0.000	P125
12674	0.0026	0.0038	0.0016	0.0024	10	0.000	P125
12675	-0.0003	0.0010	-0.0050	0.0007	06	0.000	P125
12676	-0.0008	0.0023	-0.0017	0.0029	06	0.000	P125
12677	-0.0012	0.0024			00	0.000	P125
12678	0.0008	0.0022			00	0.000	P125
12679	0.0028	0.0013			00	0.000	P125
12680	0.0031	0.0019			00	0.000	P125
12681	0.0011	0.0021	0.0007	0.0015	11	0.000	P125
12682	0.0085	0.0017	0.0095	0.0008	11	0.009	P125
12683	0.0077	0.0019	0.0074	0.0010	10	0.007	P125
12684	0.0056	0.0010	0.0054	0.0009	12	0.006	P125
12685	0.0078	0.0025	0.0080	0.0008	11	0.008	P125
12686	0.0056	0.0026	0.0061	0.0013	14	0.006	P125
12687	0.0060	0.0027	0.0065	0.0007	12	0.006	P125
12688	0.0058	0.0022	0.0063	0.0009	12	0.006	P125
12689	0.0060	0.0031	0.0060	0.0013	12	0.006	P125
12690	0.0040	0.0015	0.0040	0.0010	11	0.004	P125
12691	0.0063	0.0013	0.0057	0.0012	11	0.006	P125
12692	0.0059	0.0015	0.0050	0.0009	11	0.005	P125
12693	0.0055	0.0019	0.0051	0.0007	09	0.005	P125
12694	0.0049	0.0018	0.0051	0.0007	07	0.005	P125
12695	0.0057	0.0028	0.0062	0.0010	08	0.006	P125
12696	0.0063	0.0016	0.0058	0.0007	09	0.006	P125
12697	0.0059	0.0015	0.0051	0.0006	09	0.006	P125
12698	0.0071	0.0015	0.0067	0.0012	08	0.007	P125
12699	0.0063	0.0030	0.0063	0.0006	06	0.007	P125
12700	0.0081	0.0011	0.0078	0.0014	07	0.008	P125
12701	0.0069	0.0009	0.0065	0.0005	07	0.007	P125
12702	0.0086	0.0014	0.0088	0.0013	07	0.009	P125
12703	0.0074	0.0013	0.0071	0.0005	07	0.007	P125
12704	0.0086	0.0026	0.0072	0.0005	06	0.007	P125
12705	0.0071	0.0034	0.0070	0.0006	07	0.007	P125
12706	0.0106	0.0032	0.0098	0.0009	06	0.010	P125
12707	0.0106	0.0027	0.0087	0.0013	04	0.010	P125
12708	0.0108	0.0015	0.0101	0.0004	04	0.010	P125
12709	0.0105	0.0022	0.0091	0.0009	07	0.010	P125
12710	0.0104	0.0015	0.0098	0.0011	10	0.010	P125
12711	0.0094	0.0011	0.0088	0.0006	08	0.009	P125
12712	0.0097	0.0025	0.0082	0.0009	08	0.009	P125
12713	0.0081	0.0030	0.0086	0.0008	06	0.009	P125
12714	0.0073	0.0033	0.0077	0.0008	09	0.008	P125
12715	0.0075	0.0019	0.0066	0.0017	08	0.008	P125
12716	0.0068	0.0022	0.0068	0.0007	11	0.007	P125
12717	0.0063	0.0035	0.0072	0.0006	10	0.007	P125
12718	0.0068	0.0042	0.0072	0.0005	10	0.007	P125
12719	0.0064	0.0016	0.0069	0.0006	11	0.007	P125
12720	0.0081	0.0036	0.0055	0.0010	09	0.007	P125
12721	0.0079	0.0032	0.0067	0.0015	10	0.007	P125
12722	0.0080	0.0030	0.0072	0.0010	10	0.007	P125

CTD Station	Mean Offset (All Depths)	Standard Deviation (All Depths)	Mean Offset >1000 dbar	Standard Deviation >1000 dbar	Number of Samples >1000 dbar	Final Correction Applied	SSW Batch
12723	0.0053	0.0025	0.0060	0.0011	11	0.006	P125
12724					00	0.005	
12725	0.0054	0.0018	0.0051	0.0014	13	0.005	P125
12726	0.0044	0.0022	0.0051	0.0008	13	0.005	P125
12727	0.0054	0.0009	0.0055	0.0008	11	0.005	P125
12728	0.0055	0.0005	0.0055	0.0005	08	0.005	P125
12729	0.0049	0.0017	0.0056	0.0012	13	0.005	P125
12730	0.0046	0.0017	0.0052	0.0005	10	0.005	P125
12731	0.0048	0.0013	0.0049	0.0009	11	0.005	P125
12732	0.0063	0.0018	0.0071	0.0018	07	0.006	P125
12733	0.0053	0.0009	0.0056	0.0005	11	0.006	P125
12734	0.0061	0.0030	0.0074	0.0009	11	0.007	P125
12735	0.0049	0.0058	0.0067	0.0008	10	0.006	P125
12736	0.0063	0.0011	0.0064	0.0005	10	0.006	P125
12737	0.0055	0.0016	0.0063	0.0004	11	0.006	P124
12738	0.0068	0.0024	0.0071	0.0011	12	0.007	P124
12739	0.0046	0.0052			00	0.005	P124
12740	0.0047	0.0038	0.0082	0.0010	04	0.008	P124
12741	0.0048	0.0028	0.0053	0.0007	11	0.005	P125
12742	0.0048	0.0021	0.0043	0.0022	12	0.004	P125
12743	0.0019	0.0022	0.0025	0.0010	13	0.003	P115
12744	0.0024	0.0011	0.0026	0.0006	13	0.003	P115
12745	0.0036	0.0024	0.0029	0.0012	13	0.003	P124
12746	0.0031	0.0026	0.0036	0.0007	11	0.003	P124
12747	0.0039	0.0009	0.0039	0.0009	11	0.004	P125
12748	0.0038	0.0017	0.0039	0.0012	10	0.004	P125
12749	0.0026	0.0026	0.0037	0.0014	11	0.003	P125
12750	0.0027	0.0017	0.0022	0.0006	11	0.002	P125
12751	0.0014	0.0015	0.0012	0.0008	11	0.001	P124
12752	0.0008	0.0022	0.0016	0.0007	11	0.001	P124
12753	0.0004	0.0028	0.0015	0.0005	11	0.001	P125
12754	0.0028	0.0028	0.0032	0.0005	10	0.003	P125
12755	0.0007	0.0044	0.0031	0.0021	08	0.003	P124
12756	0.0021	0.0021	0.0021	0.0003	06	0.002	P124
12757	0.0019	0.0020	0.0023	0.0011	11	0.002	P125
12758	0.0024	0.0017	0.0021	0.0012	14	0.002	P125
12759	0.0020	0.0016	0.0015	0.0011	14	0.002	P124
12760	0.0027	0.0015	0.0017	0.0007	11	0.002	P125
12761	0.0035	0.0015	0.0030	0.0006	06	0.003	P124
12762	0.0037	0.0024	0.0036	0.0008	08	0.004	P125
12763	0.0063	0.0036	0.0053	0.0037	08	0.005	P124
12764	0.0033	0.0035	0.0044	0.0007	11	0.004	P125
12765	0.0052	0.0034	0.0039	0.0013	09	0.004	P125
12766	0.0036	0.0033	0.0035	0.0006	10	0.004	P125
12767	0.0012	0.0024	0.0019	0.0008	11	0.002	P125
12768	0.0001	0.0023	0.0007	0.0006	11	0.001	P125
12769	0.0017	0.0020	0.0015	0.0016	14	0.002	P125
12770	0.0046	0.0017	0.0049	0.0015	14	0.005	P125
12771	0.0081	0.0033	0.0083	0.0012	14	0.008	P125
12772	0.0073	0.0019	0.0070	0.0021	14	0.007	P125
12773	0.0073	0.0012	0.0078	0.0009	14	0.008	P125
12774	0.0082	0.0016	0.0076	0.0015	14	0.008	P125
12775	0.0080	0.0016	0.0079	0.0016	13	0.008	P125
12776	0.0045	0.0054	0.0082	0.0010	10	0.008	P125

Table 6. Aanderaa current meter data recovered during *Discovery* 213

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
Mooring G - 18 Jan 1995				
1260	11:17 + 30	18/1/95	8.32v	N/A
Numerous errors in tape record after approx 40 days. Unit checked but no actual fault found. Filed under cm2118.dat. 413 records				
10278	11:12 + 34 18/1/95	8.68v Lithium	1985	13:01 + 11 at 13 : 22 18/1/95
51636 words all good data. Filed under cm2126.dat. 7943 records				
10280	13:10 + 01 18/1/95	8.67v Lithum	1688	13:05 + 46 at 13 : 26 18/1/95
51636 words all good data. Filed under cm 2133.dat. 7943 records				
Mooring F - 20 Jan 1995				
7517	17:04 + 57 20/1/95	8.5v	N/A	
Data good initially, then degrades to unreadable. Unit checked appears o.k. Filed under cm 2103.dat. 747 records. Test tape run, fault appears after 300 records. Compass leaking. Savonius rotor broken on top surface.				
7943	17:09+44 20/1/95	8.24v	N/A	
Data good with few errors over complete deployment period. Filed under cm2119.dat. 5304 records.				
9587	17:17+40 20/1/95	8.46v Lithium	5529	23:16+33 at 2340 20/1/95
51732 words all good data filed under cm2111.dat. 7959 records				
10275	17:16+20 20/1/95	8.68v Lithium	5584	13:03 + 38 at 1332 21/1/95
51732 words all good data filed under cm 2127.dat. 7959 records.				
10273	17:15 + 50 20/1/95	8.67v	5583	16:56 + 51 at 1723 20/1/95
51732 words all good data filed under cm 2134.dat. 7959 records				
Mooring D - 24 Jan 1995				
5204	08:09 + 05 24/01/95	8.32V		
Data quality good, towards the end of tape ch 4 goes to 0 then ch 6 also but this reappears later. Filed under cm 2105.dat. 5310 records				
TL879+1722	08:00 + 46 24/1/95	8.12v		
Thermistor chain disconnected from logger at 06:03 24/1/95. On last data encoder rotated only one revolution, Battery voltage checked on load 4.3v. Data quality good but data degrades after approx 4500 records. Files under p3059 \879TL. 5018 records				
3727	08:04 + 29 25/1/95	8.32v		
Good data filed under cm2121.dat. 5318 records				
10857	07:16+29 25/1/95	8.67v	5530	08:31+43 at 08:57 25/1/95
51858 words all good data filed under cm 2113.dat. 7979 records. No speed values show on data. Unit checked on bench O.K. On recovery wire was wrapped around rotor and one paddle broken. Investigation of data using p3059 shows one value of 16bits on deployment then all 0. Unit cooled to 2.46° (222) bits for 24 hours and found still to be working. Probable fault: Rotor fouled on deployment.				

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error

Mooring B - 26 Jan 1995

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
7948	14:09 + 22	8.24V		

Short record on tape. Encoder had stopped in the correct position. Last data time correct and two records apparent on tape after recovery. Suspect temperature related problem with clock or associated trigger. Data filed under cm 2115.dat.909 records. Unit fitted with test tape and run for 6 days at 2°. Firsy data 0635 2.2.95, last data 0635 8.2.95 at 3 hour sampling.
48 records O.K.

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
6225	11:01 + 52 26/1/95	8.22v		

4700 records then poor data quality. White deposits on recording head presumed to be from tape. Filed under cm2107.dat. 4986 records

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
10864	13:17 + 40 26/1/95	8.68v	5532	11:16 + 42 at 11:33 26/1/95

51636 records all good data filed under cm2123.dat. 7943 records

Mooring A - 27 January 1995

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
10279	09:12 + 02 28/1/95	8.67v	5588	13:19 + 40 at 13:44 28/1/95

51552 words good data filed under cm2137.dat. 7930 records. Ch 4 temp appears to jump approx 0.5° after 3 months. On initial deployment, Ch 2 temp bit of 199 corresponded to ch 4 bits of 355 but then ch 4 value rose suddenly to 433 bits. Fault was thought to be temperature related. Fault is apparent in the lab. where ch2 value of 942 gives ch4 value of 612. Unit cooled and resistors wr14b and 15b checked for correct values. All appears O.K., suspect ch4 electronics.

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
10277	09:08 + 10 28/1/95	8.68v	5589	14:38 + 29 at 15:08 28/1/95

51552 words good data filed under cm2138.dat. 7930 records. Rotor appears to stop approx last two months.

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
10852	07:20 28/1/95	8.67v	5536	07:37 at 08:00 28/1/95

51498 words good data filed under cm2124.dat. 7923 records

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
2108	No last data	8.11v		

Tape had fully wound off spool. Fault traced to incorrect alignment of encoder cap pin to channel selector wheel resulting in channel overrun. Record good but with additional channels on many records. Filed under cm2108.dat. 3510 records.

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
4738	No last data	1.1v		

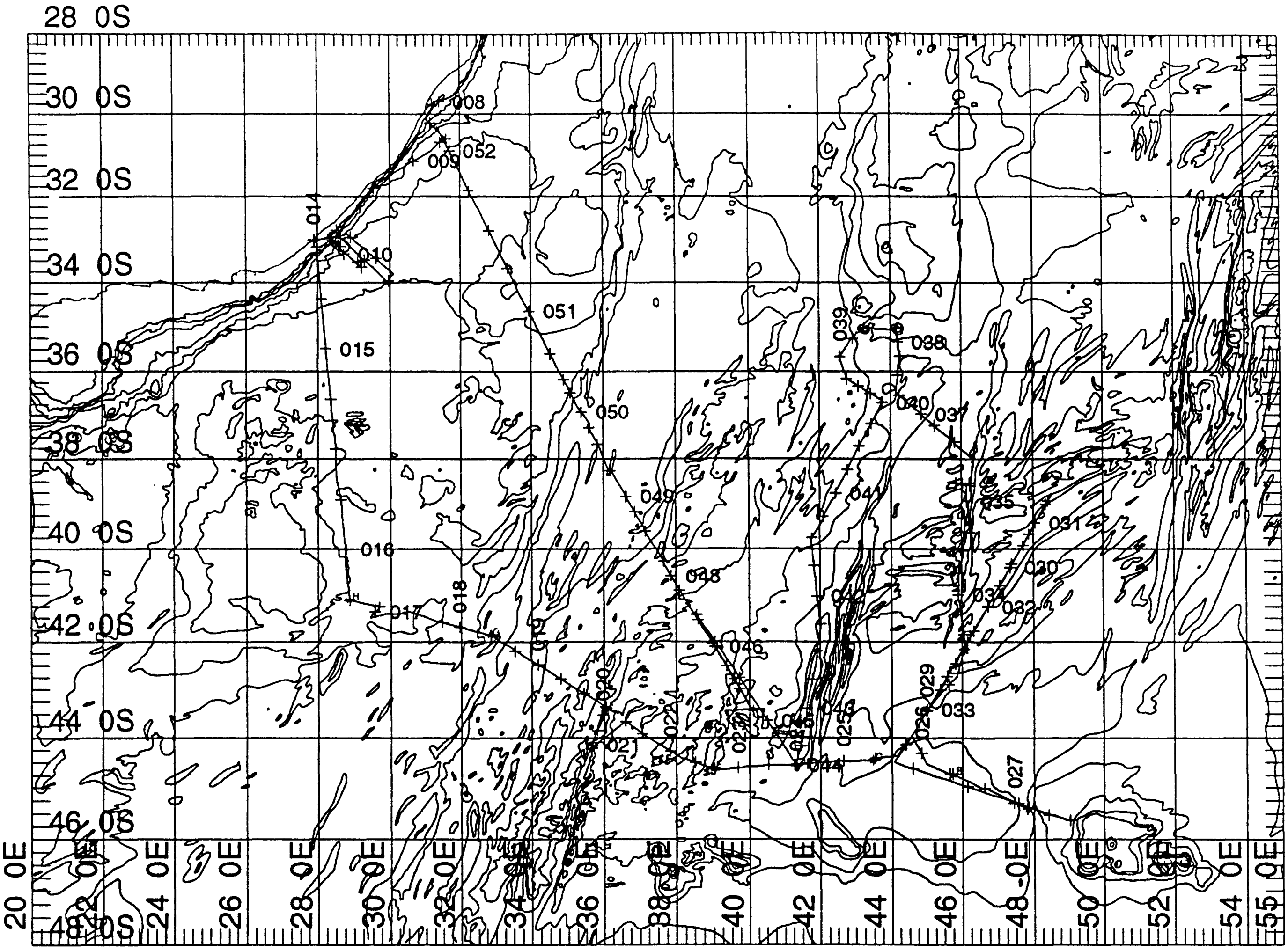
Battery voltage at only 1.1v. Current drain checked at 156mA. Suspect motor failure. Full record but degrades after 2000 records. Filed under cm2116.dat. 2168 records

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
7945	11:08 + 12 28/1/95	8.31v		

Data quality good. Filed under cm2131.dat. 5297 records

ACM No	Last Data	Battery volts	DSU serial no	DSU clock error
TL 806	11:03 + 18 28/1/95	8.11v		

Used with chain 1723. Good records with some bit errors. Record ends due to battery voltage failure. Unplugged at 13:19 27/1/95. Filed under TL 806. 5297 records.



MERCATOR PROJECTION

GRID NO. 1

SCALE 1 TO 22500000 (NATURAL SCALE AT LAT. 0)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE -45

Discovery D213 - Swindex Recovery Cruise

Figure 1a. Track chart of RRS Discovery cruise 213, 6 Jan - 21 Feb 1995.
Track annotated with day of year.

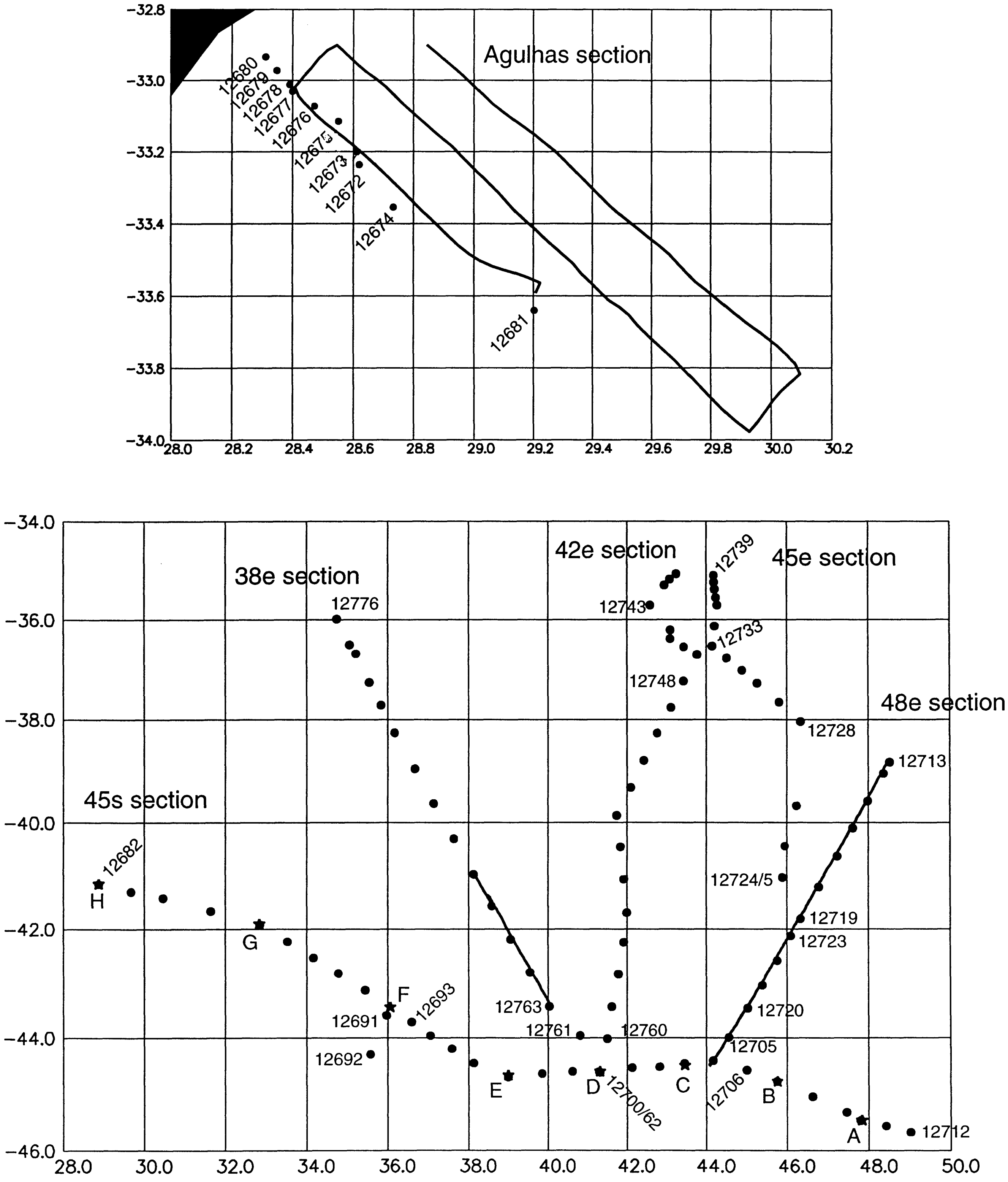


Figure 1b. CTD stations (dots), SeaSoar tracks (solid lines) and moorings (stars).
Upper panel shows details of Agulhas Current survey, lower panel shows main survey area.

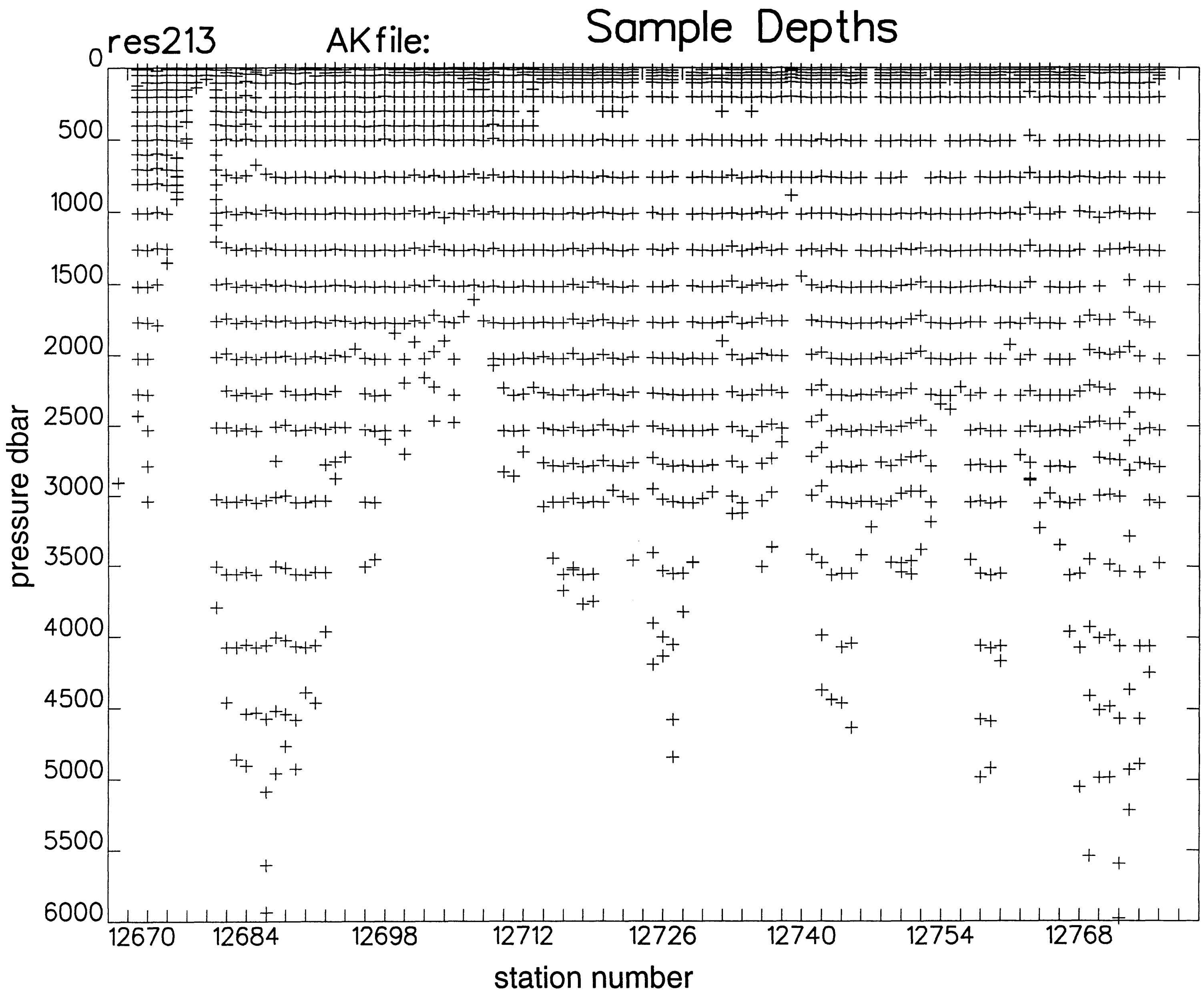


Figure 2. Vertical distribution of sample depths

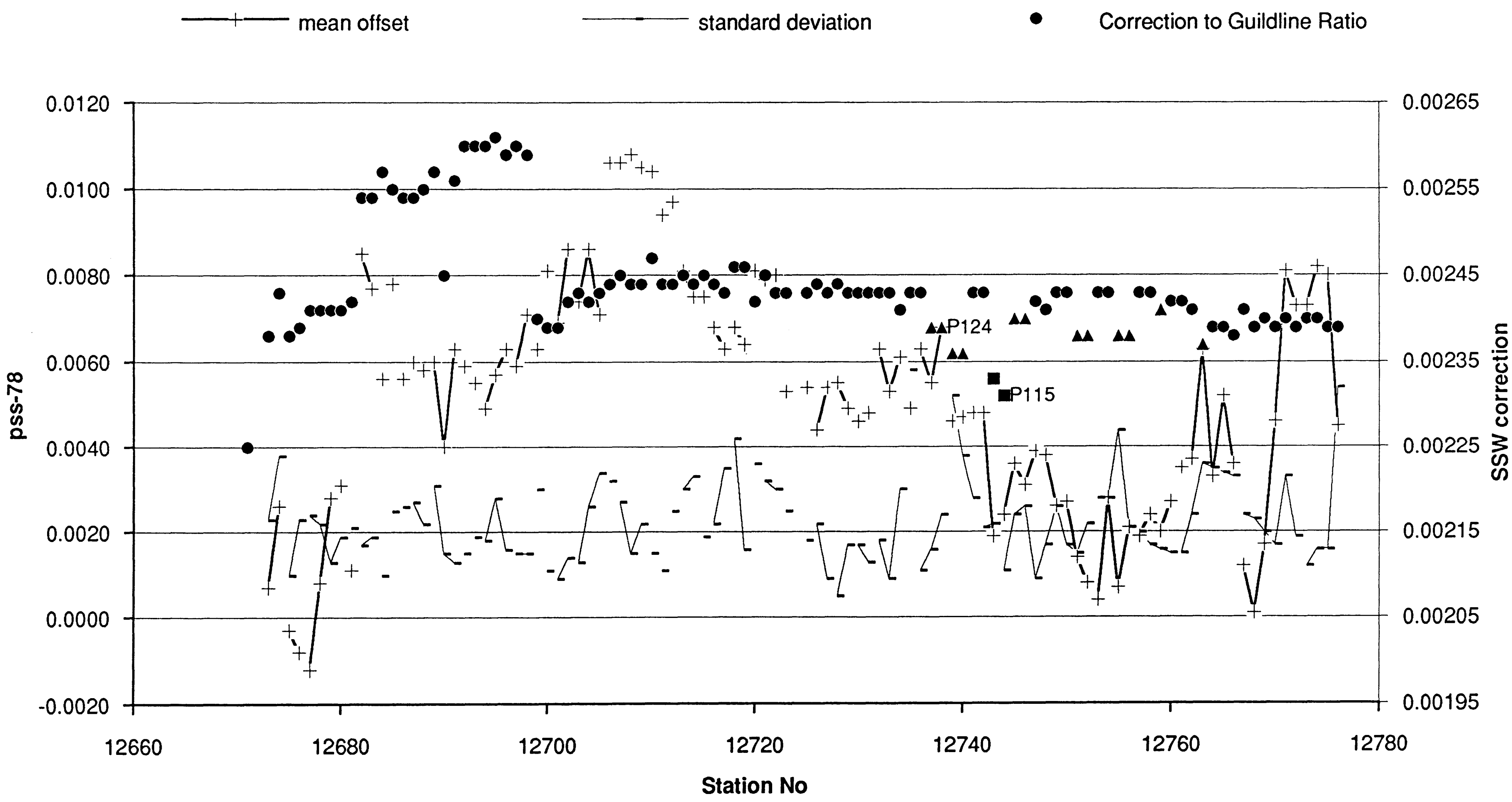
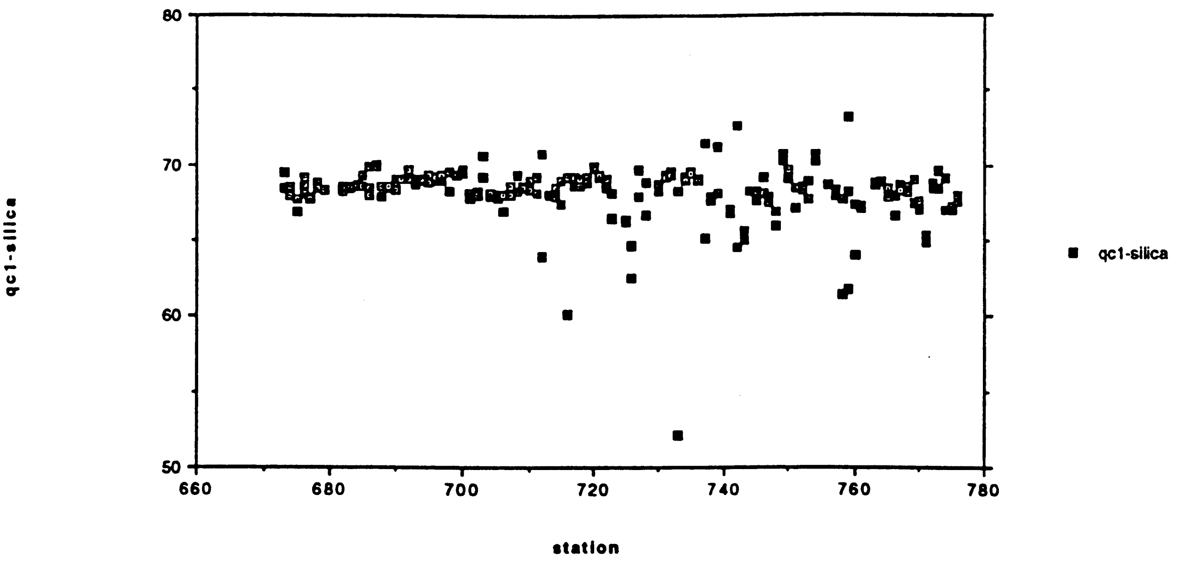
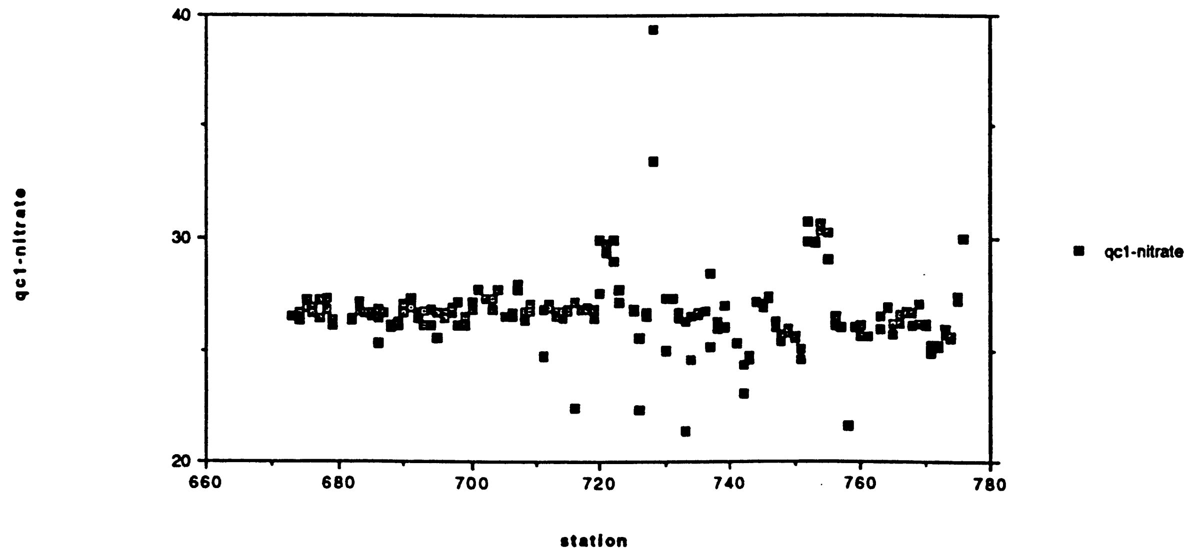


Figure 3. Differences of bottle and CTD salinity values and corrections for standard seawater readings





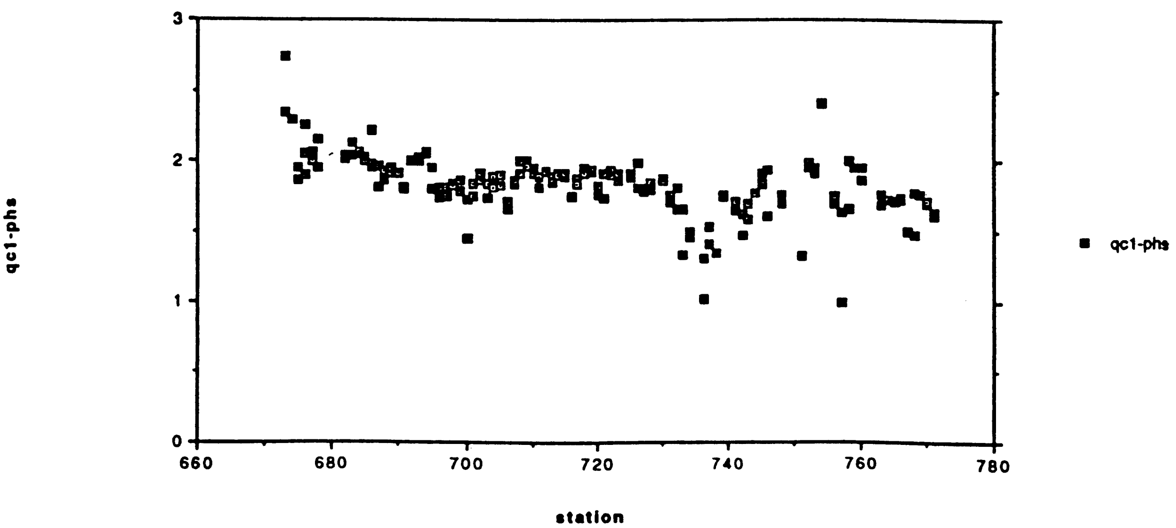
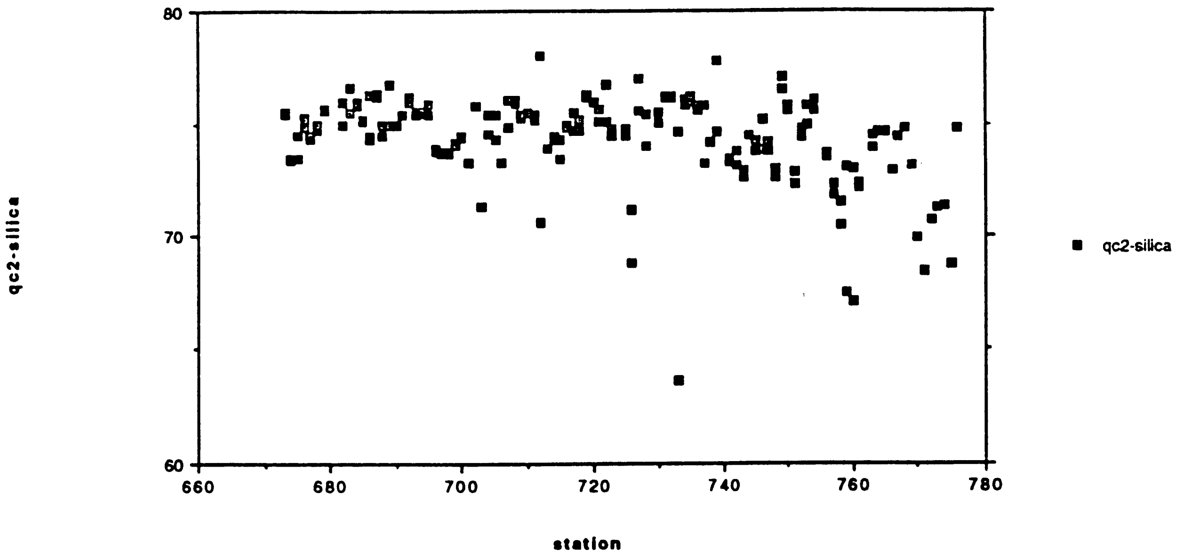
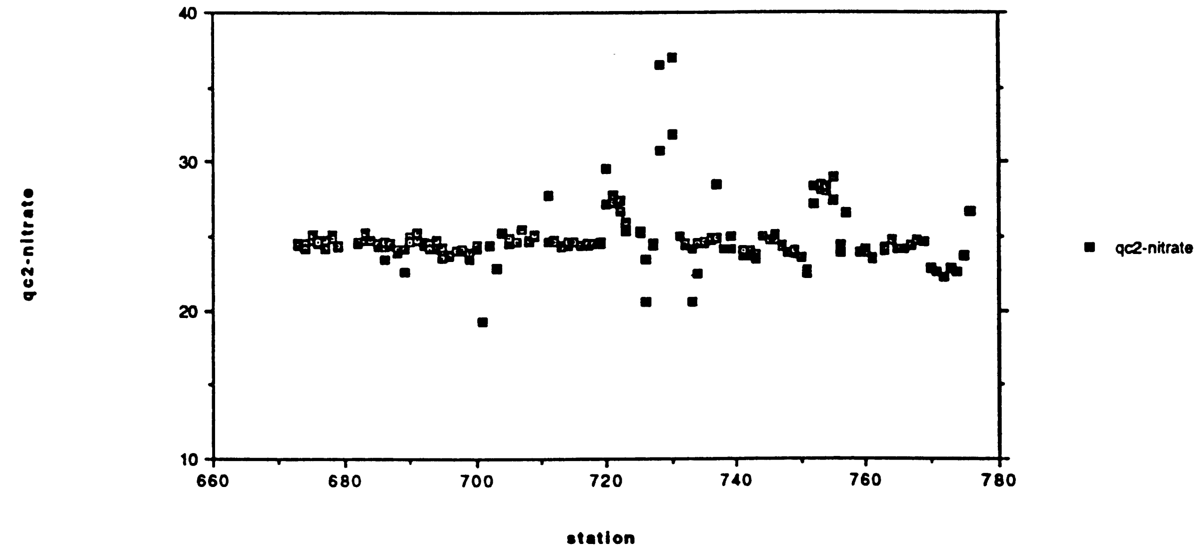


Figure 4a. Nutrient quality control, bulk sample from deep water (qc1)





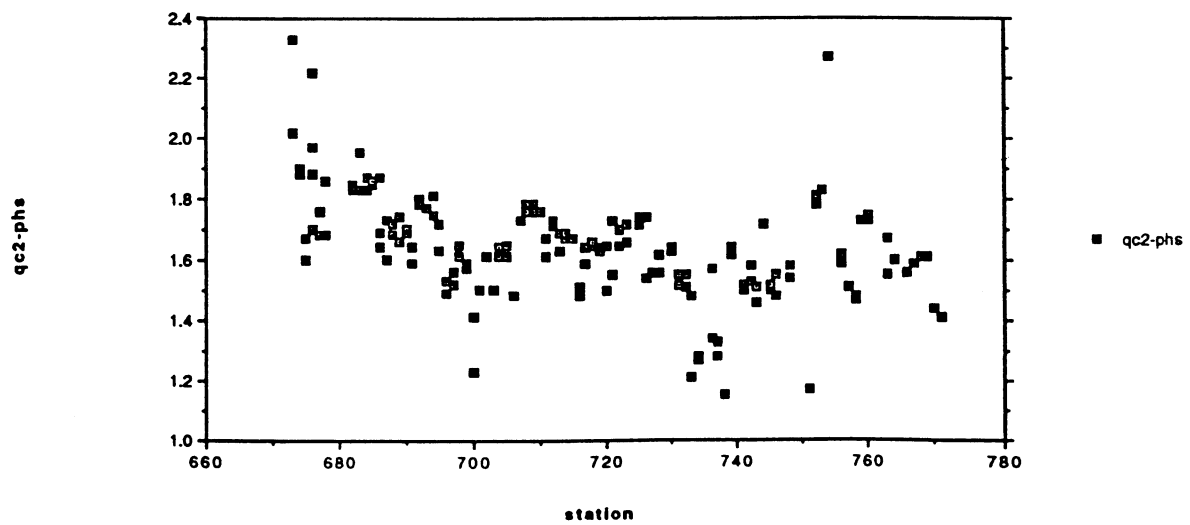


Figure 4b. Nutrient quality control, standard samples provided by OSI (qc2)

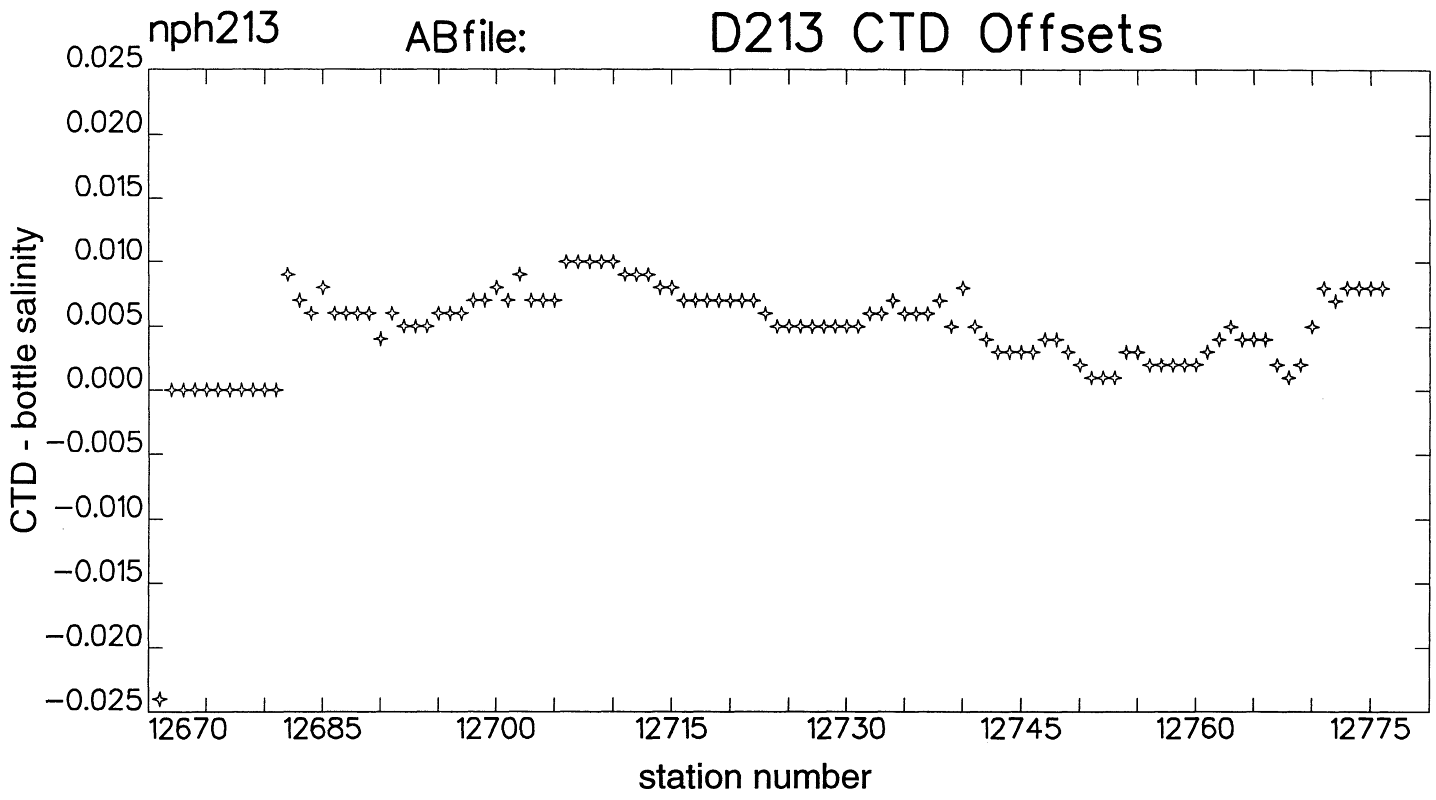


Figure 5. Mean CTD - bottle salinity residual per cast as used to correct CTD salinity

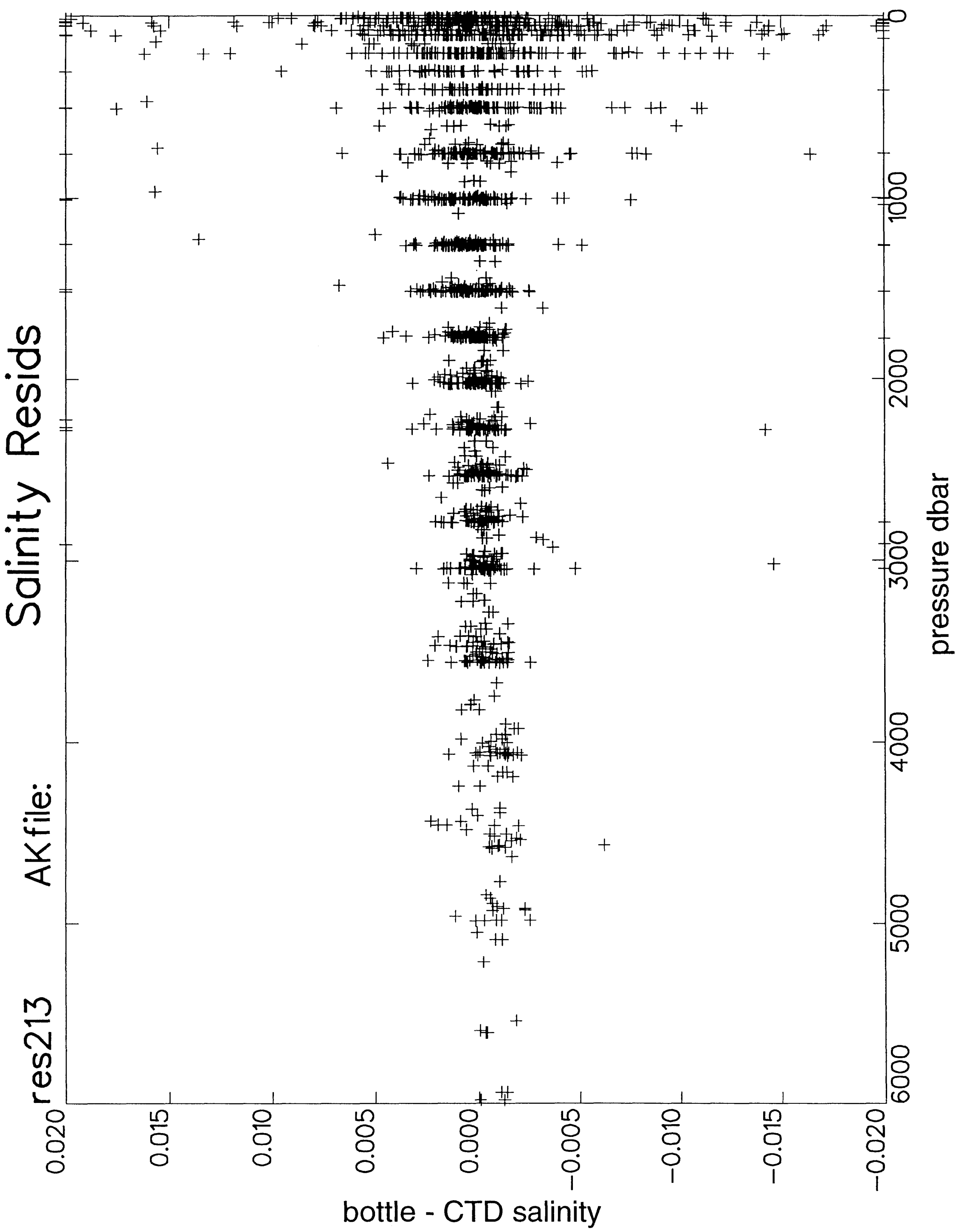


Figure 6. Bottle - CTD salinity residuals after calibration plotted by depth

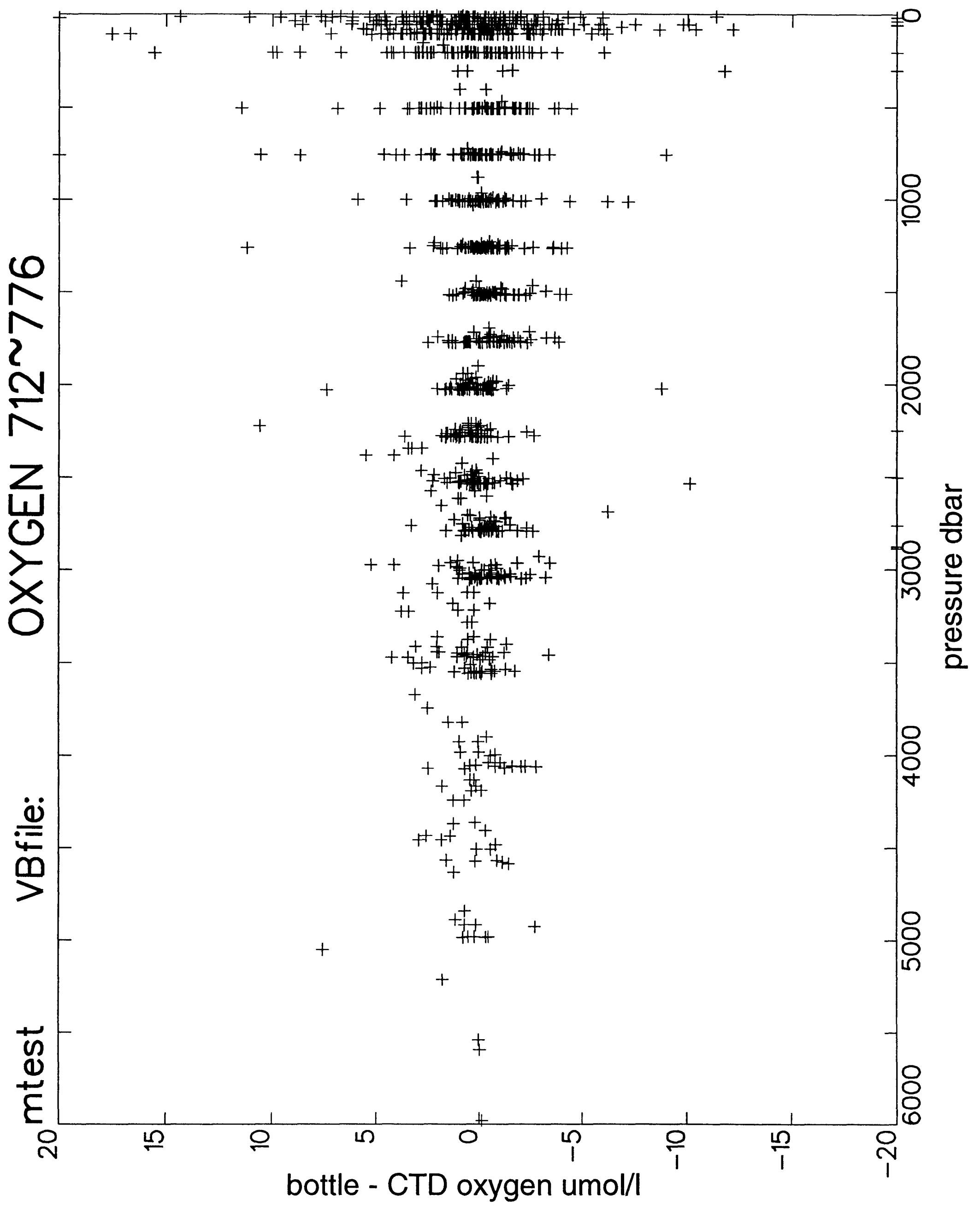


Figure 7. Bottle - CTD oxygen residuals after calibration plotted by depth

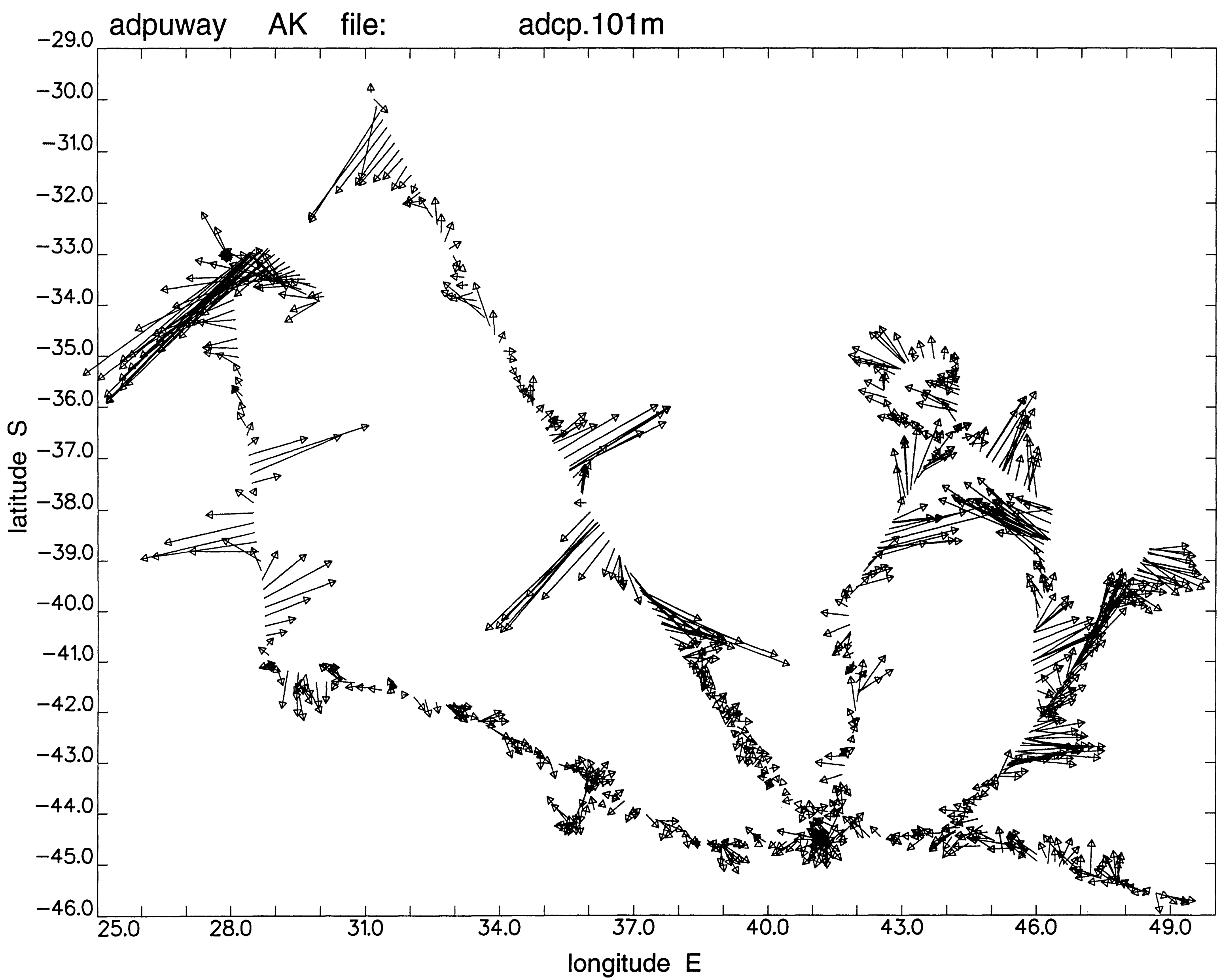


Figure 8. Smoothed, averaged (1 hour) ADCP currents at 101 m (scale 1cm to 50 cm/s)

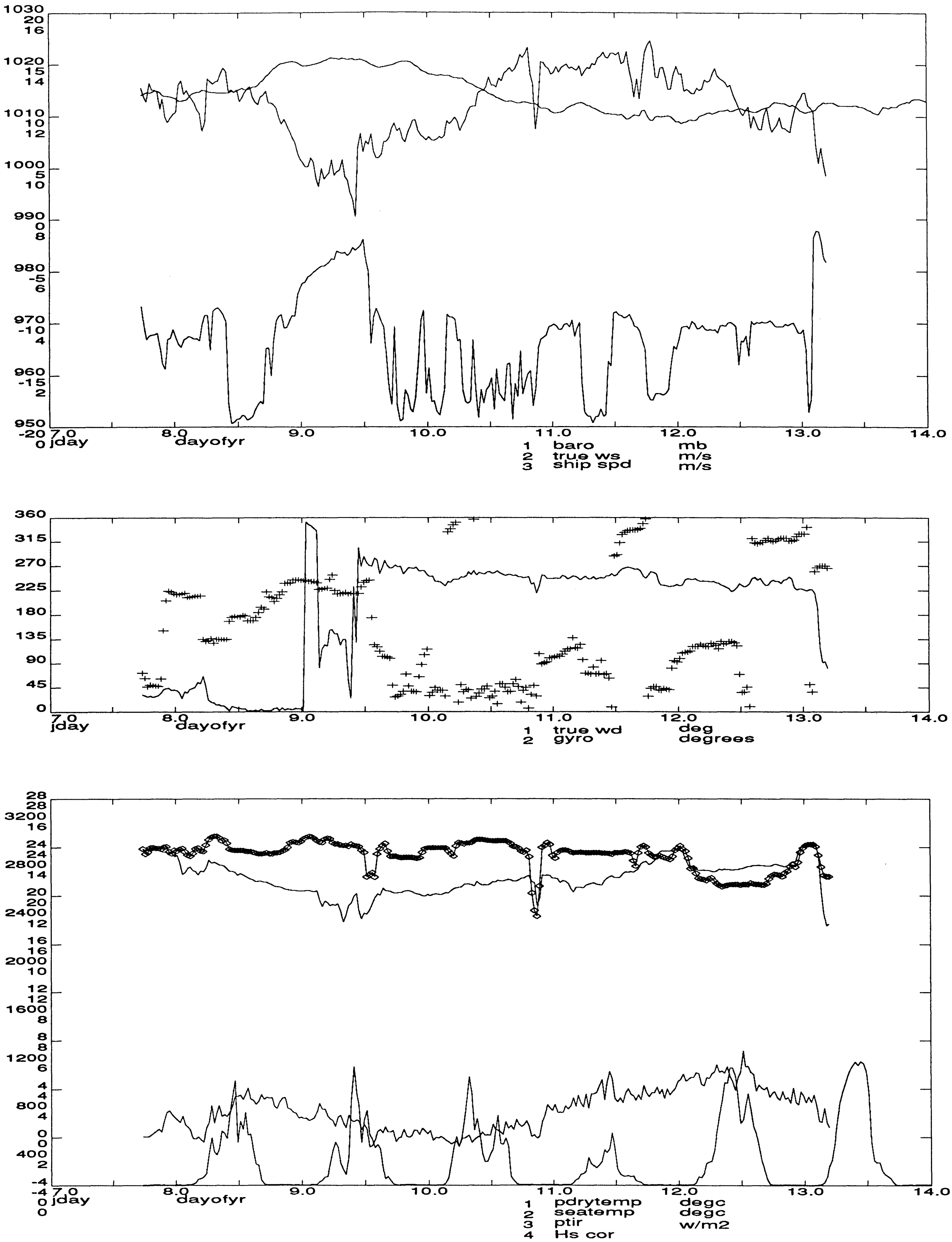


Figure 9. Weekly summary of meteorological parameters, 7 - 14 Jan 1995

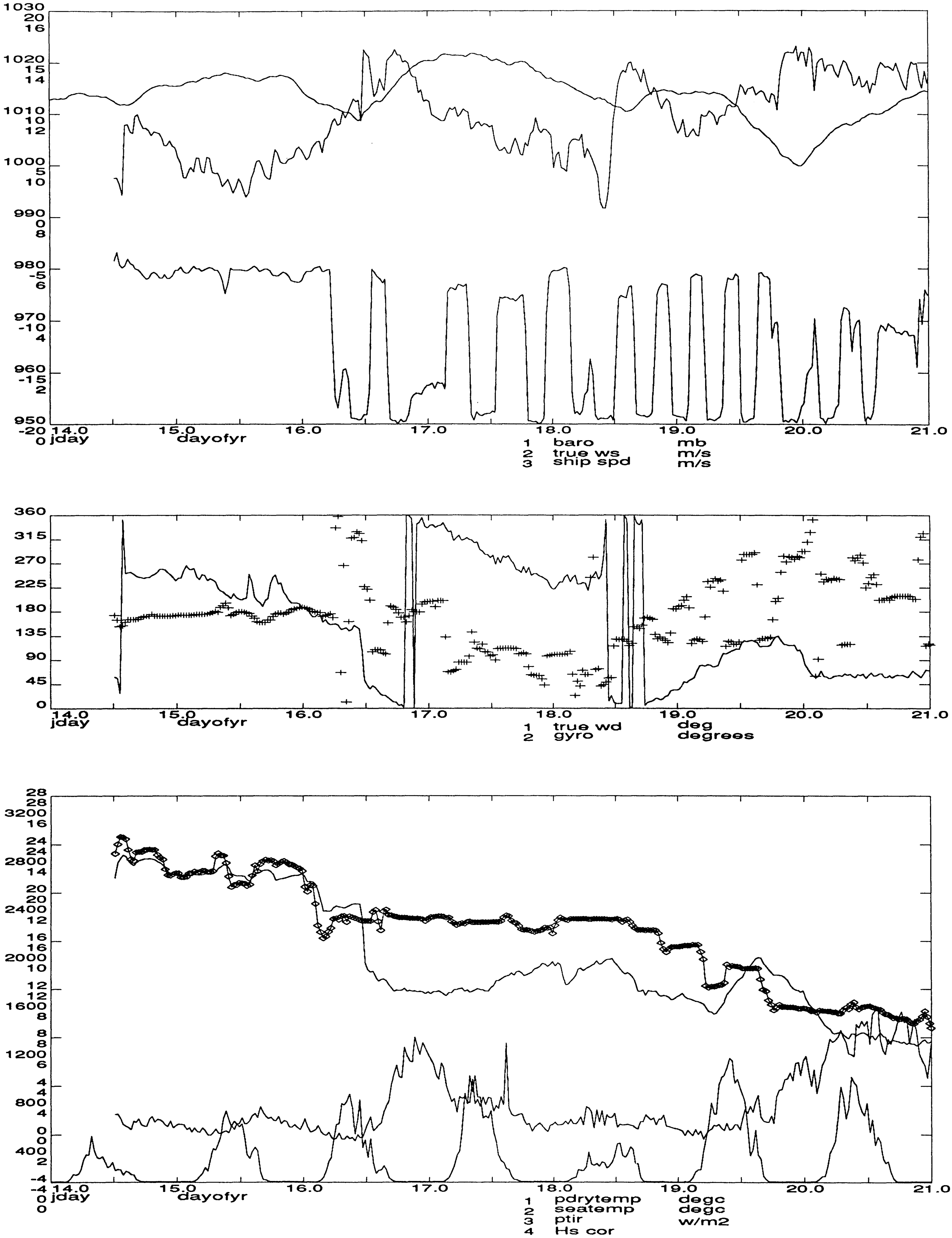


Figure 9. Weekly summary of meteorological parameters, 14 - 21 Jan 1995

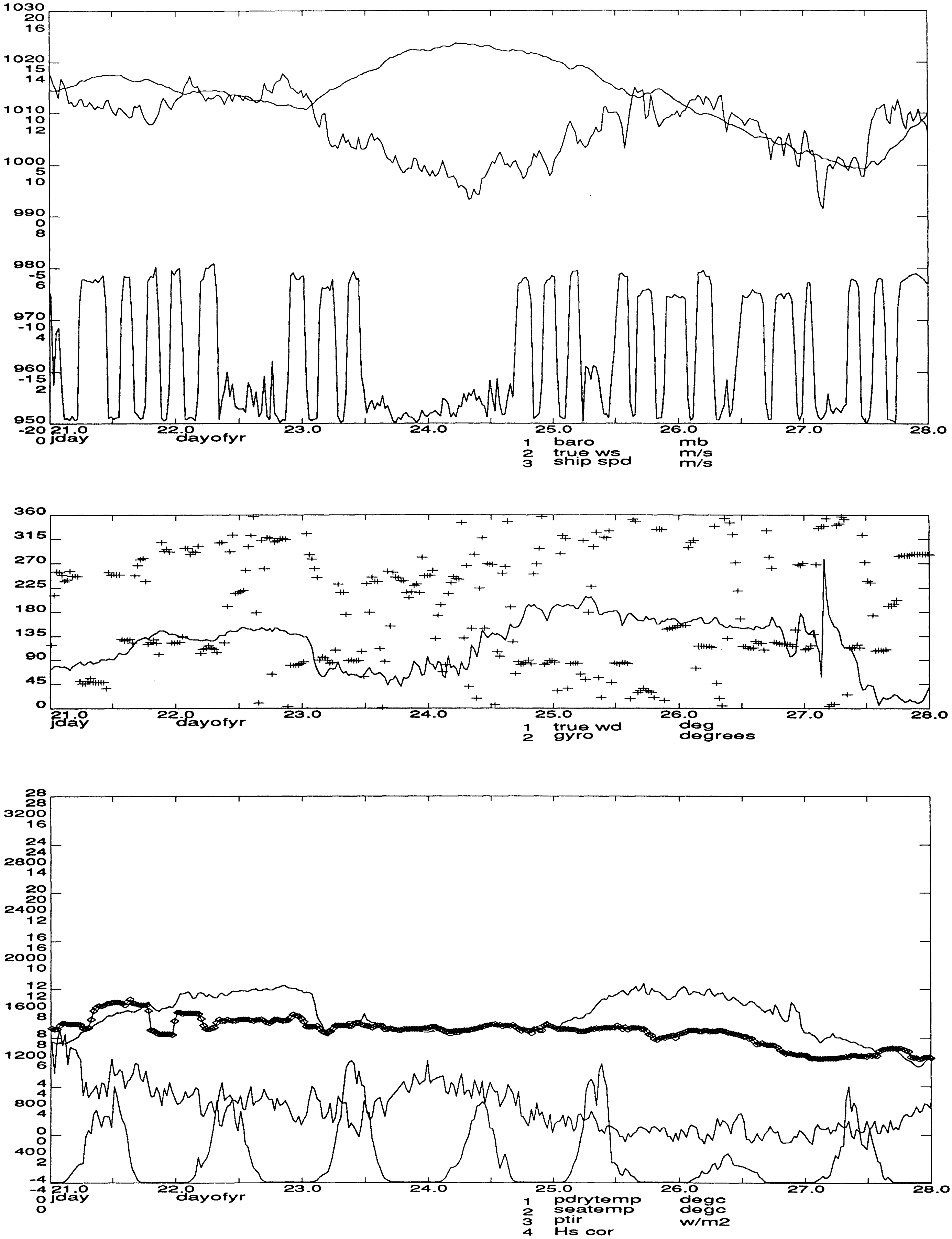


Figure 9. Weekly summary of meteorological parameters, 21 - 28 Jan 1995

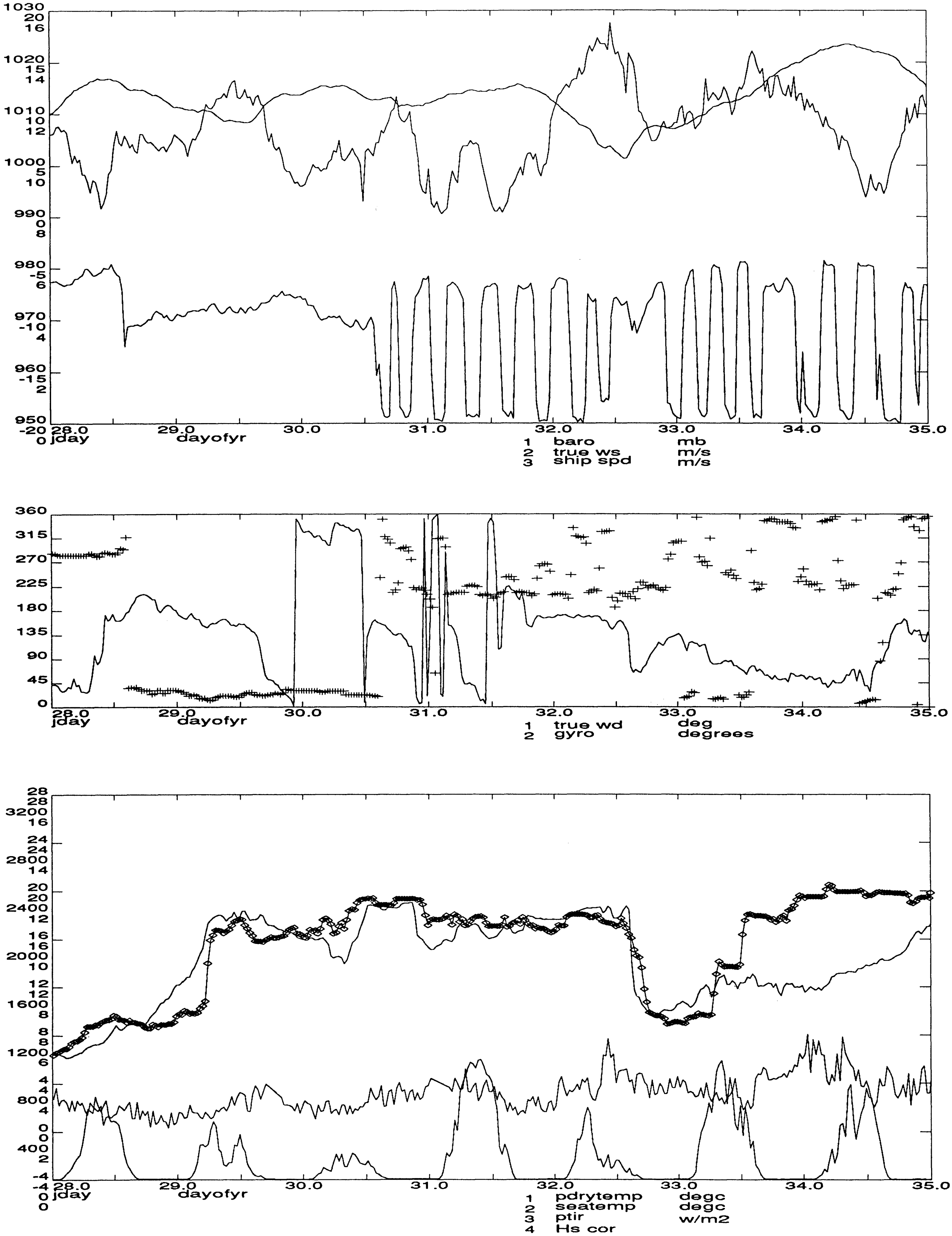


Figure 9. Weekly summary of meteorological parameters, 28 Jan - 4 Feb 1995

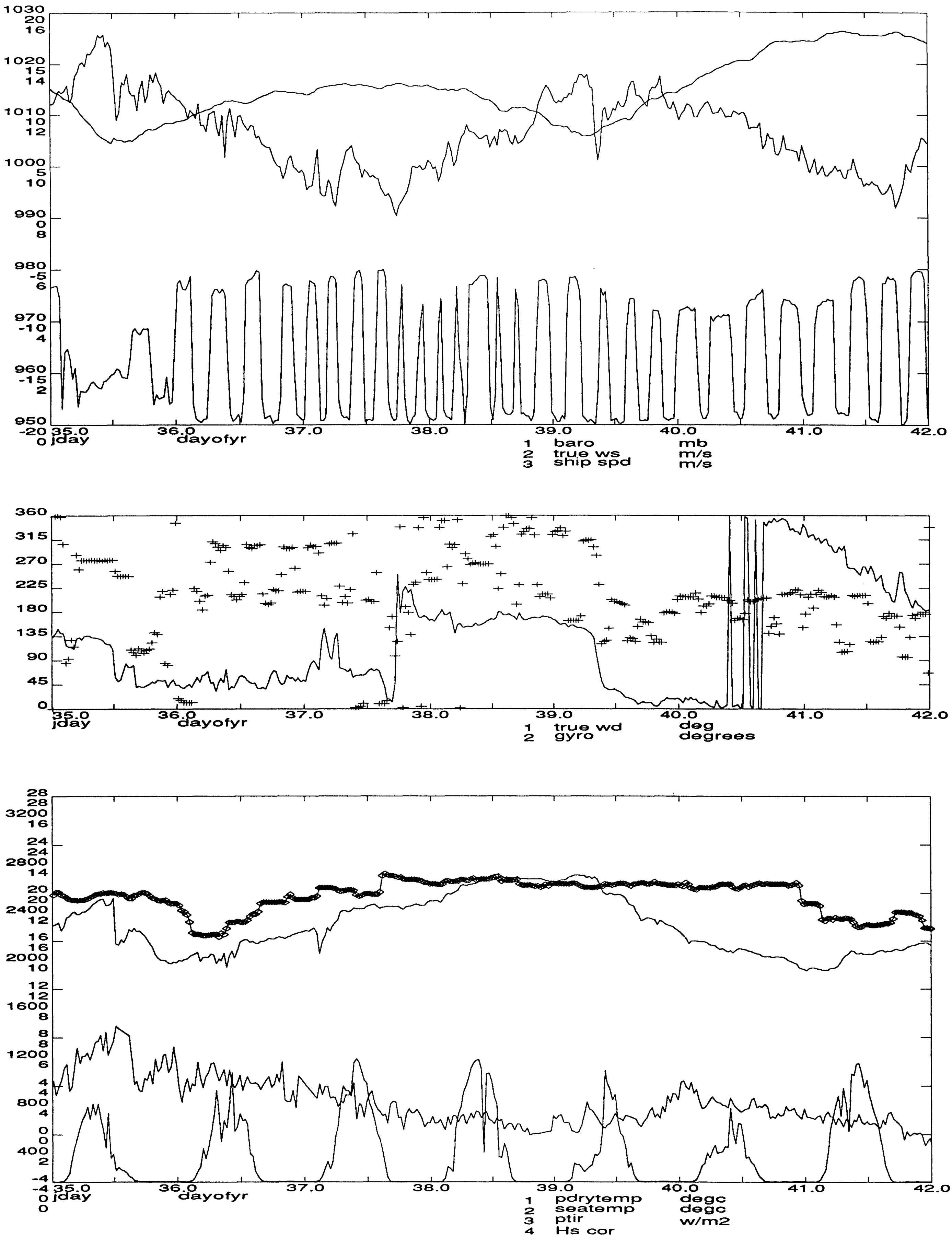


Figure 9. Weekly summary of meteorological parameters, 4 - 11 Feb 1995

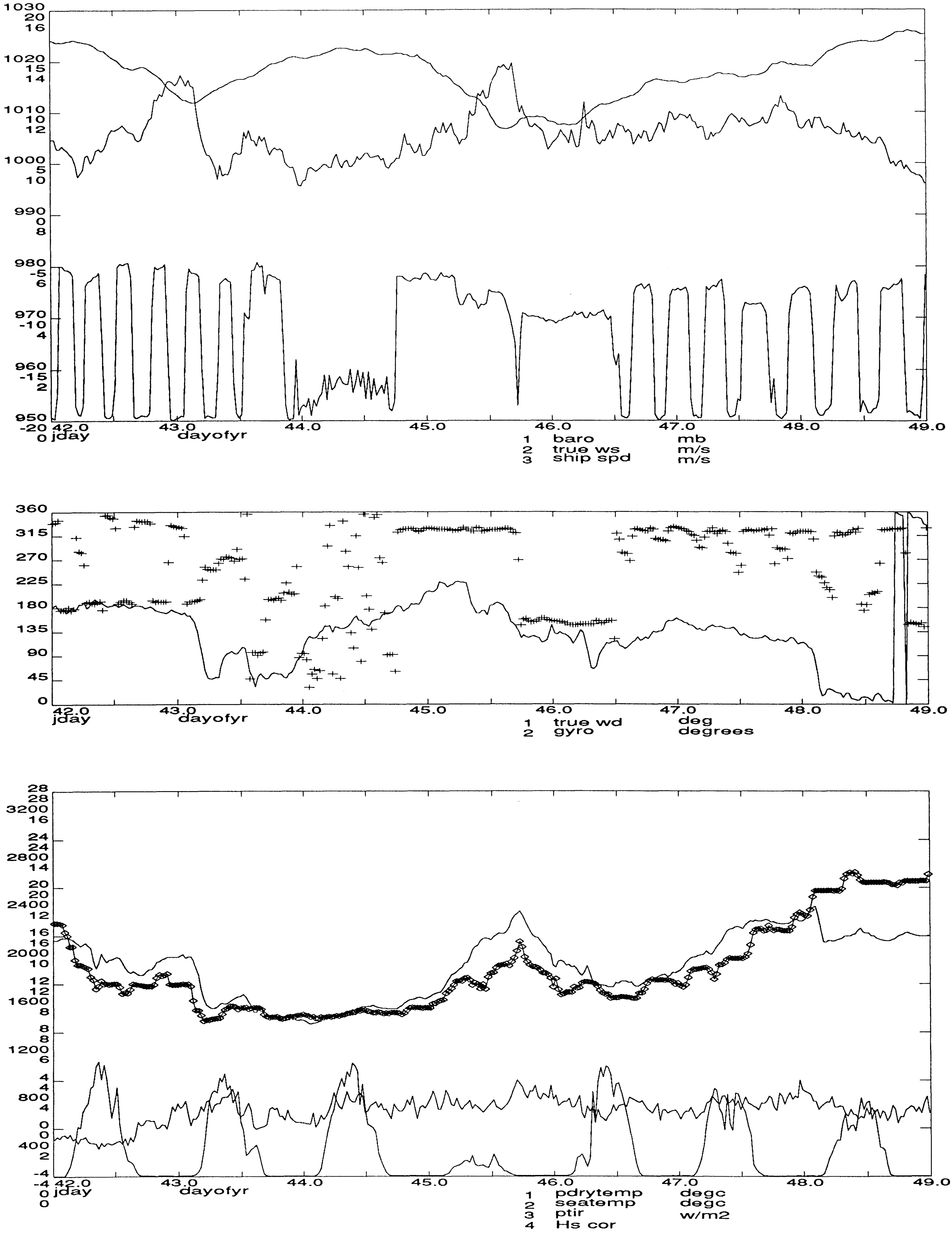


Figure 9. Weekly summary of meteorological parameters, 11 - 18 Feb 1995

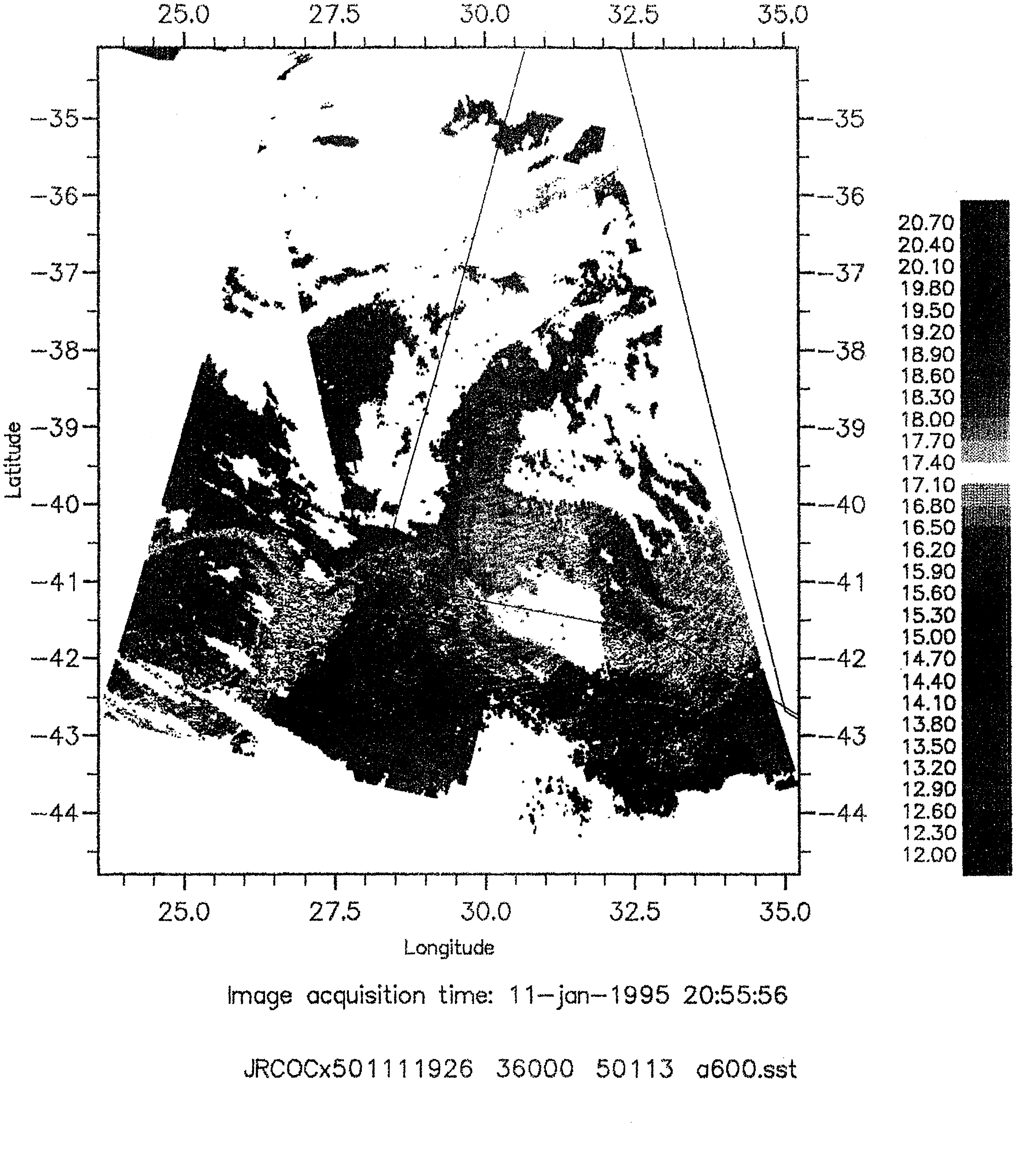


Figure 10a. Composite ATSR image from 11-12 Jan 1995 showing the Subantarctic Zone in the Agulhas Basin

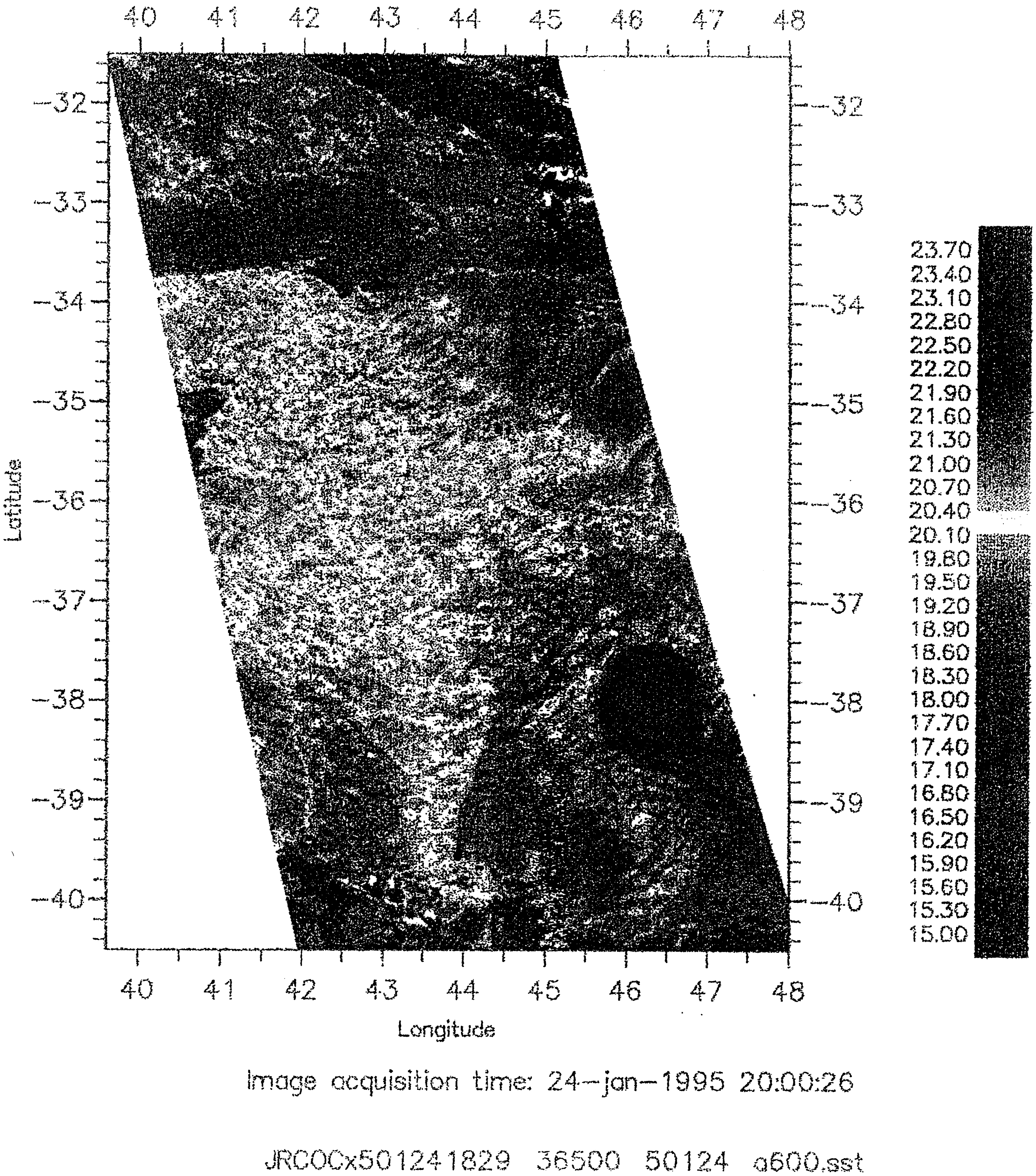


Figure 10b. Composite ATSR image from 24 Jan 1995 showing a warm tongue and cold core eddy across the South West Indian Ridge

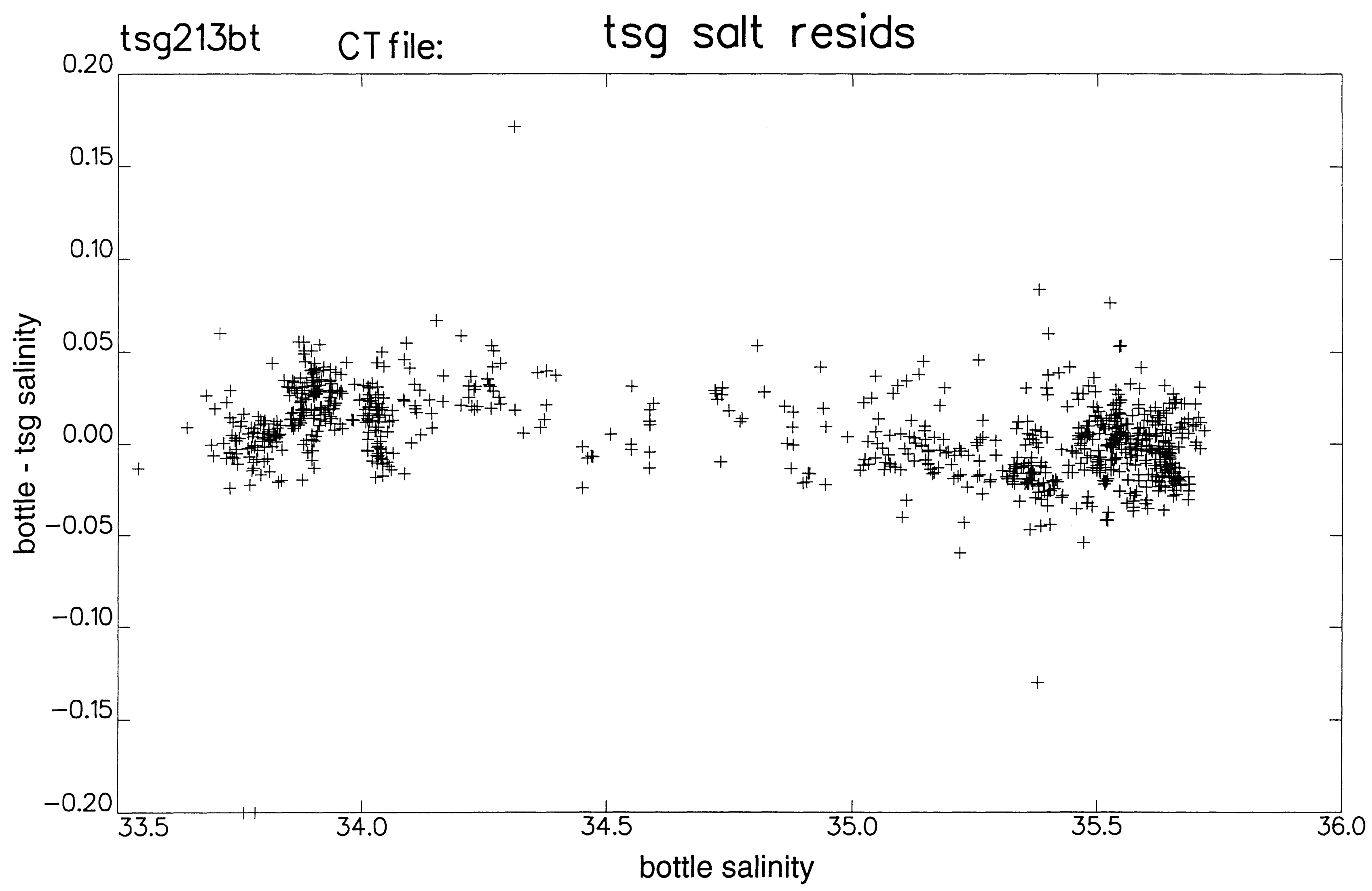


Figure 11. Bottle - corrected thermosalinograph salinity plotted against bottle salinity