

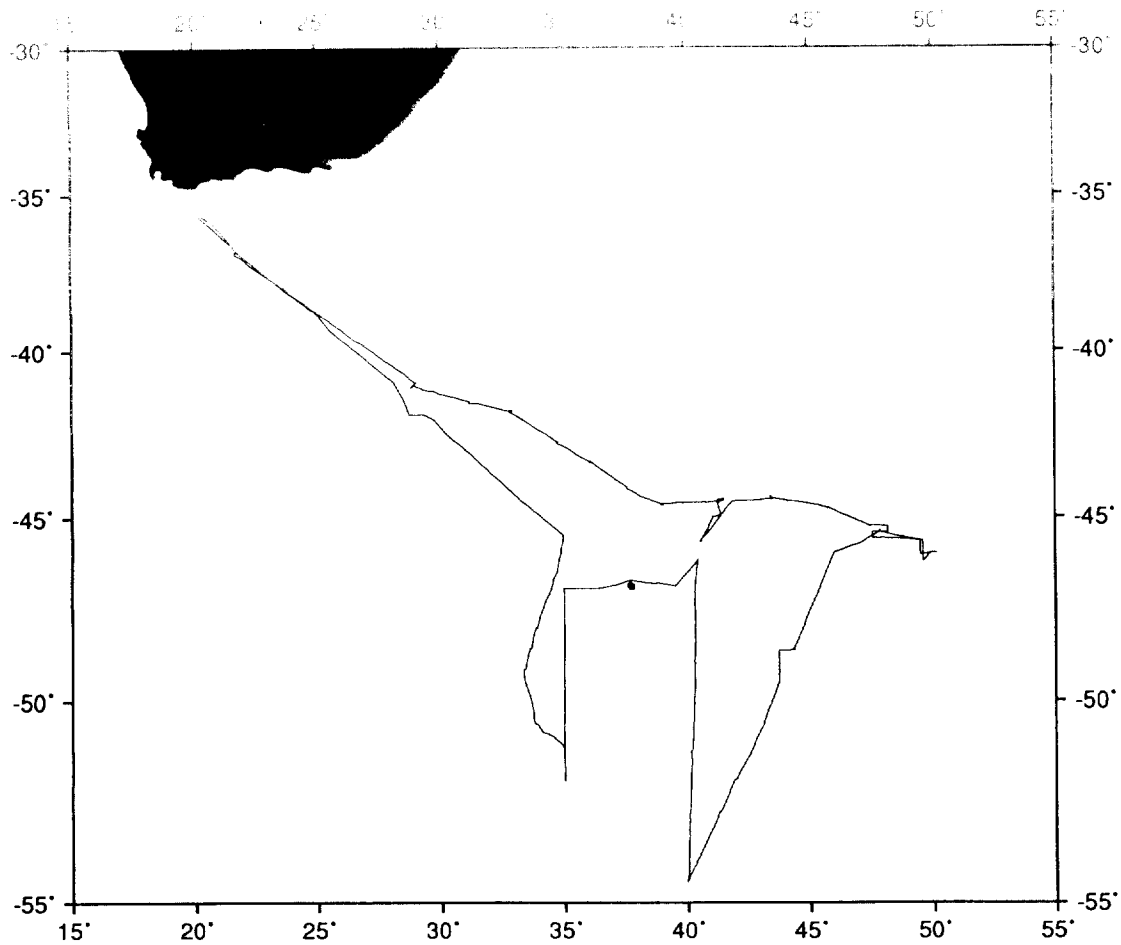


RRS *Discovery* Cruise 201

23 Mar - 03 May 1993

South West Indian Ocean Experiment (SWINDEX)

Cruise Report No 240 1994



**INSTITUTE OF OCEANOGRAPHIC SCIENCES
DEACON LABORATORY**

**Wormley, Godalming,
Surrey, GU8 5UB, U.K.**

**Telephone: 0428 79 4141
Telex: 858833 OCEANS G
Telefax: 0428 79 3066**

Director: Dr. C.P. Summerhayes

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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CRUISE REPORT NO. 240

RRS *DISCOVERY* CRUISE 201
23 MAR - 03 MAY 1993

South West Indian Ocean Experiment
(SWINDEX)

Principal Scientist
R T Pollard

1994

DOCUMENT DATA SHEET

<p><i>AUTHOR</i> POLLARD, R T & READ, J F et al</p>	<p><i>PUBLICATION</i> DATE 1994</p>		
<p><i>TITLE</i> RRS Discovery Cruise 201, 23 Mar-03 May 1993. South West Indian Ocean Experiment (SWINDEX).</p>			
<p><i>REFERENCE</i> Institute of Oceanographic Sciences Deacon Laboratory, Cruise Report, No. 240, 96pp.</p>			
<p><i>ABSTRACT</i></p> <p>RRS Discovery cruise 201 was a UK contribution to the World Ocean Circulation Experiment (WOCE) Core Project 2, The Southern Ocean. Sailing from Cape Town to Cape Town one section was worked across the Agulhas Basin and along the Crozet Plateau, and three sections were worked across the Polar Front. A total of 97 CTD/rosette stations were made with analysis for salinity, dissolved oxygen, nitrate-nitrite, phosphate and silicate. Samples for the freons CFC-11, -12, and -113 were taken approximately every other station and for oxygen isotope analysis every third station. Other measurements included currents of the upper few hundred meters with an acoustic Doppler current profiler, meteorological parameters, and sea-surface temperature and salinity. XBT drops were made in addition to the CTD casts. Eight moorings were laid across the Agulhas Basin and Crozet Plateau.</p> <p>The principal objectives of the cruise were to observe the structure of the Antarctic Circumpolar Current (ACC) between 28°E and 50°E and to infer whether any part of the ACC passes north of or across the Crozet Plateau, and by laying current meter moorings for a duration of up to two years, to observe the time dependence of currents along the crest of the Crozet Plateau to investigate whether any significant flow exists across the Plateau.</p>			
<p><i>KEYWORDS</i></p> <table style="width: 100%;"> <tr> <td style="width: 50%;"> <p>ADCP AGULHAS BASIN ANTARCTIC CIRCUMPOLAR CURRENT CFC 11,12,113 CORE PROJECT 2 CROZET PLATEAU CTD OBSERVATIONS</p> </td> <td style="width: 50%;"> <p>*DISCOVERY*/RRS - cruise(1993)(201) FREONS WOCE</p> </td> </tr> </table>		<p>ADCP AGULHAS BASIN ANTARCTIC CIRCUMPOLAR CURRENT CFC 11,12,113 CORE PROJECT 2 CROZET PLATEAU CTD OBSERVATIONS</p>	<p>*DISCOVERY*/RRS - cruise(1993)(201) FREONS WOCE</p>
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<p><i>ISSUING ORGANISATION</i></p> <table style="width: 100%;"> <tr> <td style="width: 60%; text-align: center;"> <p>Institute of Oceanographic Sciences Deacon Laboratory Wormley, Godalming Surrey GU8 5UB. UK.</p> <p>Director: Colin Summerhayes DSc</p> </td> <td style="width: 40%; text-align: right;"> <p>Telephone Wormley (0428) 684141 Telex 858833 OCEANS G. Facsimile (0428) 683066</p> </td> </tr> </table>		<p>Institute of Oceanographic Sciences Deacon Laboratory Wormley, Godalming Surrey GU8 5UB. UK.</p> <p>Director: Colin Summerhayes DSc</p>	<p>Telephone Wormley (0428) 684141 Telex 858833 OCEANS G. Facsimile (0428) 683066</p>
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<p>Copies of this report are available from: The Library, PRICE £21.00</p>			

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SCIENTIFIC PERSONNEL

<u>Name</u>	<u>Responsibility</u>	<u>Affiliation</u>
ALDERSON, Steven G.	ADCP/navigation	IOSDL
BEST, Steven	XBT/PES	Southampton University
BONNER, Robin N.	CTD operations/winches	IOSDL
BOSWELL, Stephen	CFC	IOSDL (JRC)
de CUEVAS, Beverly A.	ADCP/computing	IOSDL
DAVIES, Mike	Mechanical engineer	RVS
FERN, Adrian	Computing/navigation	RVS
GOY, Keith	Current meters	IOSDL
HALL, Stephen	CFC	IOSDL (JRC)
HARTMAN, Mark	Moorings/PES	IOSDL
HOLLEY, Sue	Oxygens/nutrients	IOSDL (JRC)
JORDAN, Stirling	Mechanical engineer	RVS
KIRK, Robert	CTD electronics/operations	IOSDL
LAUBSCHER, Richard	Oxygens/nutrients	Rhodes University, S.A.
POLLARD, Raymond T	Principal Scientist	IOSDL (JRC)
QUARTLY, Graham	TSG/Macsat	RASDU (JRC)
READ, Jane F	CTD/calibration	IOSDL
RIGGS, Paul	Oxygens/nutrients	Southampton University
SMITHERS, Jill	Oxygens/nutrients	IOSDL
SMITHERS, John	CTD electronics/operations	IOSDL
TAYLOR, Alan	Electronics/computing/PES	RVS
WADDINGTON, Ian	Moorings	IOSDL
WHITE, David	Acoustic releases	IOSDL
WOODGATE, Rebecca	Oxygen isotopes	Oxford University

YELLAND, Margaret

Salinity samples/met

IOSDL (JRC)

Abbreviations:

IOSDL	Institute of Oceanographic Sciences Deacon Laboratory - Wormley
JRC	James Rennell Centre for Ocean Circulation, IOSDL - Southampton
RVS	NERC Research Vessel Services - Barry
RSADU	Remote Sensing Applications Development Unit

SHIP'S PERSONNEL

HARDING, M.	Master
LOUCH, A.	Chief Officer
BOULT, T.	2nd Officer
GAULD, P.	3rd Officer
DONALDSON, B.	Radio Officer
MACAULAY, I.	Doctor
ADAMS, A.	Chief Engineer
MACDONALD, B.	2nd Engineer
PHILLIPS, C.	3rd Engineer
KEYS, R.	Electrician
DRAYTON, M.	CPO
VRETTOS, C.	CPO(D)
BUFFERY, D.	S1A
COOK, S.	S1A
CRABB, G.	S1A
GIBSON, M.	S1A
NEIL, P.	SCM
EDWARDS, J.	Chef
SMITH, L.	Mess Steward
DUNCAN, A.	Steward
LINK, W.	Steward
HEALY, A.	Motorman 1A

CRUISE NARRATIVE

Cruise Details

Expedition designation

Discovery cruise 201, South West Indian Ocean Experiment (SWINDEX)

Chief scientist

Dr Raymond T Pollard, IOSDL (JRC)

Ship

RRS *Discovery*

Ports of call

Cape Town to Cape Town, South Africa

Cruise dates

March 23 to May 3, 1993

Cruise Summary

Cruise track and stations

The cruise track and station locations are shown in Fig. 1, only small volume samples were taken, details are listed in Table 1. Locations of the eight moorings deployed are also indicated in Fig. 1.

Equipment

The principal instruments employed during the cruise were the NBIS Mark 3 CTD plus SensorMedic dissolved oxygen sensor, SeaTech Inc 1m path transmissometer, Simrad altimeter model 807-200m and IOSDL 10 kHz pinger. These were mounted in a frame together with a General Oceanics 24 bottle rosette, equipped with 24 10-litre Niskin bottles. Four of these (initially) carried SIS digital reversing thermometers and pressure meters. Upon recovery after each CTD dip the bottles were sampled, in order, for freon, dissolved oxygen, nitrite+nitrate, phosphate, silicate, salinity and oxygen

isotope analysis. All sampling was done on deck, the ship remaining hove-to when necessary to provide shelter in poor weather or sea conditions.

Throughout the cruise an RDI 150 kHz acoustic Doppler current profiler (ADCP) was used to monitor the currents of the upper 400-500m of the water column. Navigation information was supplied primarily by a Trimble GPS receiver, supplemented and checked by a Chemikoeff electromagnetic log and gyrocompass. To improve accuracy of ADCP measurements through possible gyro errors, an Ashtech GPS3DF receiver was used to obtain high quality directional information.

Additional measurements were made by the use of XBTs, FSI thermosalinograph, meteorological package and shipborne wave recorder.

Sampling

Discrete samples were drawn for analysis of dissolved oxygen content, nitrate-nitrite, silicate, phosphate, and salinities. CFC 11, 12 and 113 samples were taken on alternate stations and oxygen isotope samples were drawn on approximately every third station. Nominal depths sampled (m) were: 10, 50, 100, 150, 200, 300, 400, 500, 600, 800, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000, 3500, 4000, 4500, 5000.

Number of stations occupied

A total of 97 CTD/rosette stations were occupied (Fig. 1).

The first CTD station occupied (12387) was worked on the continental shelf for test purposes only. Samples and CTD data are not reported.

Moorings deployed

Eight moorings were deployed in a line along the approximate crest of the Crozet Plateau. Aanderaa current meters were located at nominal depths of 400m, 700m, 1400m, 2600m and 100m above the sea bed (Fig. 2).

List of Principal Investigators

Name	Responsibility	Affiliation
R. Pollard	Principal Scientist	IOSDL(JRC)
S. Alderson	ADCP	IOSDL
S. Boswell	CFCs	IOSDL(JRC)

S. Holley	Oxygen/nutrients	IOSDL(JRC)
J. Read	CTD	IOSDL
I. Waddington	Moorings	IOSDL
M. Yelland	Salinity	IOSDL(JRC)
M. Yelland	Meteorology	IOSDL(JRC)

Scientific Objectives

The principal objectives of the cruise were:

1. To observe the structure of the Antarctic Circumpolar Current (ACC) between 28°E and 50°E and to infer whether any part of the ACC passes north of, or across the Crozet Plateau.
2. To observe the time dependence of currents along the crest of the Crozet Plateau to investigate whether any significant flow exists across the Plateau.
3. To examine the structure and changes in structure of Subantarctic Mode Water and Antarctic Intermediate Water along a zonal section from 30°E to 50°E in the Subantarctic Zone.

Narrative

Cruise 201 was the last of three UK WOCE cruises in the Southern Ocean on board the newly lengthened RRS *Discovery*. Cruise 201 was a contribution to enhanced hydrographic measurements in WOCE Indian Ocean Special Survey area ISS1. The equipment and techniques used were the same as those on the WHP One-time survey A11 (RRS *Discovery* 199) and reference to this cruise report (Saunders et al, 1993) may be of use.

After an initial three-day delay because of an engine problem, the cruise went smoothly. After a practice CTD deployment and two deep CTD casts in the Agulhas Current, eight full-depth subsurface moorings were set along a line from the eastern flank of Agulhas Bank across the Agulhas Basin and Del Cano Rise (or Crozet Plateau), ending in the deep passage just west of the Crozet Islands (Fig. 1). CTDs at the mooring sites and at 35 n.m. or less intervals on passage comprised the first hydrographic section ("45°S") to WOCE repeat hydrography standards. Mooring positions were chosen as far as possible to be in trenches or rifts which typically ran from SSW to NNE.

Three sections were then worked southwards from the Crozet Plateau across the Polar Front, referred to as "45°E", "40°E" and "35°E" from their approximate longitudes. Only "40°E" was worked to the closely spaced WOCE specification of 30 n.m., with 60 n.m. separation for "45°E". Adverse weather forced a large gap in the southern half of "35°E", although it can be partially filled by XBTs and

underway surface data during the passage leg south. However, the northern part of "35°E", along the Prince Edward Fracture Zone, had station spacing of 30 n.m. The final leg WNW back towards Agulhas Bank was only partially completed because of poor weather conditions.

Fuller details of the cruise programme are given in the Cruise Diary.

Preliminary Results

The tracer data (temperature, salinity, dissolved oxygen and nutrients) showed a number of marked changes in the structure of the whole water column. These discontinuities could be traced from section to section and were identified as the Subtropical, Subantarctic and Polar Fronts. The Subtropical Front was crossed only once in the Agulhas Basin, the Subantarctic Front was crossed twice and the Polar Front four times. The three north - south CTD sections showed the Subantarctic and Polar Fronts to be merged in the west (about 35°E), but east of this point the two fronts separated, the Subantarctic Front turning to the north east and apparently following the topography of the South West Indian Ridge, while the Polar Front continued more nearly due east in two zones of enhanced eastwards transport centred at 48°S and 50.5°S.

Calculations of the baroclinic component of transport suggested that the flow of the Antarctic Circumpolar Current was greater in the west, where the two fronts were merged, and rather less on the two eastern sections. However there was little suggestion of any flow over the Crozet Plateau and northward transport was concentrated to the west and east of the Plateau. Current meters were successfully deployed in regions of high and low velocity currents, and on their recovery, planned for early 1995, it is hoped that they will show whether the conditions encountered during deployment were permanent or transitory.

Despite weather problems in the latter stages of the cruise, the cruise was very successful, with all objectives achieved despite the loss of three days at the start. In addition to the main hydrographic and mooring programmes, other particularly noteworthy items were

- Evidence for strong inertial shear with large horizontal scale between 45 m and 205 m depth,
- Unpublished bathymetry, made available to us by kind permission of Dr R Fisher, Scripps Institute of Oceanography, provided remarkably accurate topography which was of particular help in positioning CTD stations and moorings in the best locations,
- Two new seamounts, not indicated on the available charts of the region, were located using only the newly declassified data of gravity anomalies from Geosat data as published by Marks et al, 1993,

- Use of the meteorological sensor suite and shipboard wave recorder during all CTD casts significantly extended our data base of wind stress values in high wind and wave conditions.

References:

- SAUNDERS, P.M. et al, 1993, RRS *Discovery* Cruise 199, 22 Dec 1992 - 01 Feb 1993. WOCE A11 in the South Atlantic.
Institute of Oceanographical Sciences Deacon Laboratory, Cruise Report No 234, 69pp
- MARKS, K.M., MCADOO, D.C. & SMITH, W.H.F. 1993, Mapping the Southwest Indian Ridge with Geosat. EOS: Transactions, American Geophysical Union, 74(8), p. 81, 96.

Major Problems and Goals not Achieved

Throughout the cruise, and despite regular servicing, the multisampler kept misfiring. Once the extent and nature of the problem was appreciated, and because most of the survey took place in water less than 4500m deep, the 24th Niskin bottle was kept "in hand". The multisampler would be fired several times on the last (10m) sample, to ensure that we obtained a surface sample. The actual depth at which each bottle was fired was determined by careful checking of all the sample data available: salinity, oxygen, nutrients, reversing temperature and pressure readings. Full coverage obtained by the discrete samples is shown in Fig. 3.

On a few of the deepest stations it proved impossible to deploy the CTD to the full depth because of limits imposed by the maximum and peak winch loads. This was partly dependant on the weather conditions, thus in calm weather considerably greater depths could be achieved than in poor conditions. On just one station (12396) half the Niskin bottles were removed to enable a full depth cast to be made in 5800 m of water.

Gaps in the sequence of CTD stations were the result of equipment problems (numbers 12403, 12404, 12421 and 12451) and bad weather (12398).

The most serious problem was the near loss of the CTD package on cast 12451 after the cable jumped out of a diverter sheave on the winch. By the time the problem was located the armoured cable was already half severed, and the individual strands continued to part one by one as the engineers and deck crew hastened to stop off the cable with blocks. Fortunately they succeeded and the package was recovered with the crane and the station was abandoned to allow time for recovery and repair work.

Some difficulties were experienced with the freon analysis, several stations of CFC-113 data were lost as a result of system contamination incurred during overhaul before the start of the cruise. Air leakage into the glass stripping columns lead to irregular CFC-12 blanks, although it is hoped that

reprocessing will minimise this problem. Further samples were lost through other equipment problems.

MEASUREMENTS AND TECHNIQUES

Sampling and calibration techniques followed those used on *Discovery* cruise 199, see Saunders et al (1993).

Sample Salinity Measurement

M. Yelland

Sampling

Bottle salinity samples were taken from the CTD Niskin bottles and hourly from the thermosalinograph. The glass sample bottles were emptied of old sample sea water, rinsed three times with the new sample and then filled to the base of the neck before being dried and sealed using polyurethane stoppers and screw caps. Crates of 24 bottles were then left in the constant temperature lab. for a minimum of 24 hours for the temperature to equilibrate before analysis. This meant that there was usually a delay of two days between the sample being taken and the salinity values being entered into the computer for analysis.

Analysis

The temperature of the lab. was originally $\sim 20^{\circ}\text{C}$ but this was increased to 23° on day 091, since the bath temperature of the salinometer had been set at 24°C . The salinometer was the IOSDL Guildline Autosol model 8400, fitted with an Ocean Scientific International peristaltic pump, and powered by filtered mains supply which had been installed on *Discovery* cruise 198 to remove voltage spikes. The salinometer was standardised at the start and end of each crate of samples using ampoules of IAPSO Standard Seawater. Four different batches of Standard Seawater were used; P120, P121, P116 and P115 (Fig. 4, Table 2). A few of each batch were kept for intercomparison. The analysis of the samples was carried out by M. Yelland, S. Alderson, and J. Read with M. Hartman and I. Waddington taking over from R. Woodgate and G. Quartly (who were both initially untrained) after day 102.

The operation of salinity measurement is inherently tedious, and little can be done about this short of a continuous supply of cocktails and a cabaret in the corner of the lab. The operator's comfort and safety could be increased if lighting was improved and a stool of adjustable height was made available. There should also be some means of fixing the stool to the bench or floor, since the motion of

the ship made the risk of being thrown over backwards quite likely even in relatively good weather. In bad weather the operation of the salinometer became dangerous or impossible.

Results

The salinometer readings showed a steady downwards drift, especially with samples from deeper water even though these samples had reached the laboratory temperature. This problem was only present when the peristaltic pump was left running while readings were taken, whereas with the pump switched off the readings were very stable. From day 094 (about cast 12404) the pump was turned off at the toggle switch (installed on D199) during readings from all samples. (The drift is caused by very fine air bubbles that can enter the tube, S Bacon, personal communication.) It was decided to re-standardise the salinometer on day 097, since readings from the Standard Seawater were falling in between the 1.9 and 2.0 conductivity ranges. Duplicate samples were taken from all 24 Niskin bottles for CTD cast 12409. One set was analysed prior to the re-standardisation, and the other set after, in order to check for any discontinuities. Comparison of the two sets of samples showed no systematic error, giving a mean difference of 0.0002 psu with a standard deviation of 0.00048.

Despite the above changes in personnel, operating procedure, lab. temperature, standardisation and Standard Seawater, good results were obtained. Some of the effects of these changes are shown in Fig. 4. The batch number, K15*2 value and measured conductivity ratio are plotted together with the difference between the latter two ("correction"). [For those unfamiliar with the operation of the salinometer, the K15*2 value is the absolute value of Standard Seawater as determined by OSI; the measured value is that obtained by measuring Standard Seawater on the salinometer; and the difference between them is the correction to salinometer values needed to bring bottle samples to psu.] The stars are the cast-averaged corrections that have to be applied to the CTD values to correct them to salinometer values (themselves corrected for OSI batch values). Small drifts in the salinometer values can be seen in the "correction" changes within a single batch. Minor jumps (at the 0.001 level) in the CTD offset where the batch number changes may indicate temporal changes in the batch values that have occurred during storage. To investigate this effect a comparison of the different batches of sea water was made by running a series of ampoules through the salinometer. Seven or eight readings were made from each ampoule and the mean and standard deviation of these shows that they were stable to within 0.0002 psu.

standard	mean correction	standard
batch no	PSU * 10⁴	deviation
P120	18.2	2.7
P121	28.0	2.3
	30.2	2.0
	29.2	1.8
	30.5	1.5
P120	21.3	2.0
	20.9	1.2
P116	33.3	2.1
	33.1	2.3
	41.7	2.1
	36.8	2.0
	34.3	2.5
	34.8	2.2
P120	23.7	2.2
	23.0	2.2
P115	44.3	3.4
	42.4	2.9
	42.4	2.2
	42.1	2.4
	43.4	2.1
P120	23.9	3.3

Offsets of each batch from P120 (the batch to which the salinometer was reset) for P121, P116 and P115 were respectively 0.0008, 0.0014 and 0.0021. These are the corrections that must be added to "CTD offset" to calibrate the CTD relative to P120 for the entire cruise. These corrections will be applied to the CTD data before submitting data to the WHPO. It may be seen from Fig. 4 that their application will reduce the jumps where the batch number changed. Since P120 was used as the standard for the whole of cruise 199 (A11), this choice makes cruises 199 and 201 similarly calibrated. However, OSI advise us that P120 has tended to freshen with time, whereas most standards tend to become more saline. If the most recent batch, P121, had been adopted as the standard, the corrections to P120, P116 and P115 would have been -0.0008, 0.0006 and 0.0013, showing that Standard Seawater was in this case reliable within 0.0013. Since the cruise 201 CTD data have been calibrated against a standard that is fresher than its label by perhaps 0.0008, our best estimate is that the CTD salinities should be greater by that amount, 0.0008.

Apart from these jumps, occasional drift is seen in the cast-averaged CTD corrections (particularly from cast 12405 to 12422) and occasional jumps (between casts 12430 to 12431, for example). These errors most likely result from biological fouling of the CTD cell, particularly as it passes through the surface layer at the start or end of a cast. The cast-averaged correction has been applied to the whole of the relevant cast.

Sample Oxygen Measurement

S.E. Holley, J.A. Smithers, R.K. Laubscher

Sampling

Oxygen samples were drawn by P. Riggs, B. de Cuevas and S. Best, assisted by the three nutrient and oxygen chemists following the collection of samples for CFC analysis. Station 12387 was used as a training station and as a check on the oxygen bottle calibrations. 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 hand held repetitive Eppendorf pipettes. These pipettes were used to achieve precise repeat pipetting of reagents but were found to be unreliable, especially for the more viscous sodium hydroxide/ sodium iodide, awkward to use and wasteful of reagents. Therefore from station 12413 the Anachem bottle top dispensers, used on previous cruises, were re-introduced. Samples were shaken on deck for half a minute then again in the laboratory, $\frac{1}{2}$ hour after collection.

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 and will also be used in the calculation of density for conversion of $\mu\text{mol/l}$ to $\mu\text{mol/kg}$ units. The probe used was damaged on station 12399 and an alternative one was then used which differed in calibration by approximately 1.3°C .

Analysis

Samples were analysed in the constant temperature laboratory, starting one hour after sample collection. The Winkler whole bottle titration method, was used with amperometric endpoint detection, as described by Culberson and Huang (1987). The equipment used was supplied by Metrohm and included the Titrino unit and control pad, a new exchange unit with 10ml burette to dispense the thiosulphate in increments of $1\mu\text{l}$ and with an electrode for amperometric end point detection. Acid was added to the samples using a fixed volume 1ml Eppendorf pipette.

Unfortunately the new equipment was found to be faulty as the burette leaked, letting in air if not run at the slowest speeds. This slowed down analysis times and resulted in poor precision if the air introduced went unnoticed. After a number of tests the exchange unit, burette, aspirator tip and electrode were changed for the older alternatives, which had worked well on *Discovery* cruise 199, and the reproducibility improved. These changes were adopted from station 12427. An Anachem bottle top

dispenser was also used from this station to dispense acid in place of the Eppendorf pipette, due to its ease of use and reproducibility.

Results

With these changes the mean difference between duplicate samples improved from 1.065 $\mu\text{mol/l}$, up to station 12426 to 0.571 $\mu\text{mol/l}$ after the changes were made. Differences between duplicates of over 1 $\mu\text{mol/l}$ accounted for 40% of the samples leading up to station 12426 and 11% after this station, the differences between duplicates were frequently worse than 1 $\mu\text{mol/l}$ before the equipment changes. The method reproducibility was also checked by looking at data from duplicate firings of the Niskin bottles, the mean difference before station 12426 was 0.995 $\mu\text{mol/l}$ and 0.698 $\mu\text{mol/l}$ after this.

The thiosulphate normality was checked every time the reservoir was topped up, and every 3 days, against potassium iodate. The exact weight of this standard along with the calibration of the 10ml Knudson glass pipette and the 1L glass volumetric flask used to dispense and prepare the standard, were accounted for in the worksheet, used to calculate the oxygen values. The glassware calibrations resulted in lower results than if 10ml and 1L calibrations had been assumed as was the case on *Discovery* cruise 199. This standardisation was also repeated when fresh iodate standard was prepared which was on five occasions during the cruise. A conversion factor of 44.66 was used to convert from ml/l to $\mu\text{mol/l}$. 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).

Historical data comparisons were made against Conrad cruise 17 (Jacobs et al, 1980) data. Stations 12420 and 12419 were compared with Conrad 296, and 12433 and 12434 with Conrad 294. The Conrad data was found to be up to 8 $\mu\text{mol/l}$ higher than the *Discovery* cruise 201 data and this discrepancy remains to be investigated.

References

- CULBERSON, C.H. & HUANG, S. 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) US WOCE Hydrographic Program Report 91/1, various pagination. 1991.
- JACOBS, S.S., GEORGI, D.T. & PATLA, S.M. 1980, Conrad 17. Hydrographic stations, sea floor photographs and nephelometer profiles in the Southwest Indian - Antarctic Ocean. Jan-Apr 1974. Lamont-Doherty Geological Observatory, Report CU-1-80-TR1, 240 pp.

Nutrient Measurement

S.E. Holley, J.A. Smithers, R.K. Laubscher

Sampling

Samples taken for nutrient analysis were analysed in duplicate, for silicate, nitrate and nitrite, and phosphate, using the James Rennell Centre Alpkem Corporation rapid flow autoanalyser (model RFA-300). Sample collection followed collection of samples for CFC and oxygen analysis. Samples were taken directly into new 30ml plastic diluvial containers (from ElKay), rinsed 3 times with sample. Samples were stored for up to 1/2 hour in the refrigerator prior to analysis then decanted into 2ml analyser cups, rinsed thoroughly with sample.

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. 10mmol/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. 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 Finnpiquette digital 1-5ml adjustable pipette. 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 reverse osmosis, deionised water and made up in calibrated 500ml plastic flasks. Stock standards were changed on three occasions during the cruise.

A set of six mixed working standards were prepared daily in 100ml plastic volumetric flasks with 40g/l Analar grade sodium chloride artificial seawater. Nutrients were undetectable in the artificial seawater, relative to the Ocean Scientific International (OSI) Low Nutrient Seawater which contains 0.7 μM silicate, 0 μM phosphate and 0 μM nitrate. The concentrations of working standards were (μM):-silicate 150, 120, 90, 60, 30 and 0; phosphate 2.5, 2.0, 1.5, 1.0, 0.5 and 0; nitrate 40, 30, 20, 10, and 0. A nitrite top standard (40 μM) 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 methods of analysis used were:- silicate: the standard AAI molybdate-ascorbic acid method with the addition of a 37°C heating bath (Hydes, 1984). Phosphate: the standard reagents, and reagent to sea water ratios, of Murphy and Riley (1962) were used but with separate additions of ascorbic acid

and a mixed molybdate-sulphuric acid-tartrate reagent to overcome the problem of reagent instability. Nitrate was determined using the standard Alpkem method.

All measurements were made in the constant temperature laboratory as previous cruises suggested that a stable temperature improved precision. The temperature was maintained between 21 and 23°C. However, the air conditioning created the problem of increased evaporation, and possible sample contamination, which was resolved by the use of an extra evaporation cover as used on *Discovery* cruise 199. Any drift in the run was assessed by the use of drift standards analysed after every twelve samples.

Samples of deep water, collected on *Discovery* cruise 199 and stored in a polyethylene carboy, were analysed throughout *Discovery* cruises 199, 200 and 201, as a 'quality control' sample. Despite the continual decrease in values, especially for nitrate, the sample proved useful in detecting shifts in the data quality. The mean value for each parameter shifted low after station 12459 when a second batch of fresh quality control material was decanted from the bulk stock in the cold room into the smaller container kept in the refrigerator. The quality control values also shifted low for all parameters on station 12402 and high for silicate and nitrate on stations 12414 to 12416, the reasons for this have yet to be investigated (Fig. 5).

The table below shows a comparison of mean bulk seawater values ($\mu\text{mol/l}$) found on the three cruises:

	silicate	nitrate	phosphate
D199	78.85	28.85	1.79
D200	80.2	25.2	1.74
D201(up to 12458)	74.94	22.85	1.43
D201(after 12458)	71.79	21.44	1.25

The silicate quality control sample shifted low over stations 12491-12493 from a mean of 74.96 $\mu\text{mol/l}$ on previous stations to a mean of 67.84 $\mu\text{mol/l}$, then increased again when fresh working standards were prepared. Sample data were correspondingly low but there was insufficient sample to repeat the analysis again, once the problem had been identified, therefore a correction factor was applied to these data equivalent to the step in bulk seawater values. No other problems on the silicate analysis were encountered.

Drifts in the phosphate baseline due to antimony coating of the sample line resulted in a loss of sensitivity and adjustments of the photometer on some stations, this could be accounted for by the drift

standards so no data was lost. The problem was removed by a weekly wash of the line with Decon and Hydrochloric acid. No other problems were encountered with the phosphate analysis.

On the nitrate line the low and eventual loss of nitrogen through the line resulted in the loss of good data from stations 12390 to 12392. The preparation of a contaminated batch of imidazole buffer, which appeared to poison the cadmium column, resulted in problems on stations 12412-12416. Due to these problems the cadmium columns needed frequent reactivation during the cruise. The nitrate filter burnt out and was replaced at station 12391 and the lamp was replaced at station 12399. Excessive drift in the nitrate line, seen in the drift samples and some poor duplicates, suggested an instability in the cadmium column after station 12472, the column was replaced with an older one after station 12477 and this appeared to be more stable.

Commercial standards obtained from the Sagami chemical company in Japan were run twice, from one single batch of standards, during the cruise and gave results of silicate 9.56 $\mu\text{mol/l}$, nitrate 9.64 $\mu\text{mol/l}$, phosphate 1.003 $\mu\text{mol/l}$ compared to the expected values of 10 $\mu\text{mol/l}$, 10 $\mu\text{mol/l}$ and 1 $\mu\text{mol/l}$ respectively. The reasons for any apparent inaccuracies have yet to be investigated but the accuracy of these standards is only quoted by Sagami to be $\pm 1\%$.

Results

Historical data comparisons were made against Conrad cruise 17 (Jacobs et al, 1980) data, however nitrate was not measured on that cruise. Silicate compares well for the replicate stations Conrad 296 and 12420/12419 from *Discovery* cruise 201, although the Conrad silicates are higher for station 294 when compared to 12433 and Conrad 218 compared with 12463, by up to 1.3 $\mu\text{mol/l}$ or 0.6% over the 200 $\mu\text{mol/l}$ range of values. The phosphate data are also in close agreement between the two data sets for Conrad stations 294 and 218 compared with 12433 and 12463 respectively.

The mean of the differences between duplicate measurements made on *Discovery* cruise 201 were as follows:- silicate 0.323 $\mu\text{mol/l}$, nitrate 0.305 $\mu\text{mol/l}$ and phosphate 0.037 $\mu\text{mol/l}$. This is equivalent to 0.16, 0.76 and 1.23 % full scale for silicate, nitrate, and phosphate respectively.

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Freon Measurement

S. Boswell and S. Hall

Three of the chlorofluorocarbons (CFCs) were determined as part of this cruise, namely CFC-12, CFC-11 and CFC-113. These compounds act as conservative tracers of water mass movement and provide timescale information about this transport.

Sampling

Sampling was carried out from 10 litre Niskin bottles using ground glass 100ml syringes by J. Smithers, S. Holley and R. Laubscher. In order to minimise possible contamination, after sampling the syringes were stored in buckets supplied with water from the non-toxic supply. Where possible duplicate firings were made at the top and bottom of the cast and these were normally sampled.

Analysis

CFCs were determined at a total of 47 stations with between 12 and 16 samples being taken from each cast. Due to system contamination introduced while in Cape Town, CFC-113 was not measured for the first 6 of these. A further 2 stations of CFC-113 data were lost due to instrument problems (see below).

The instrument used was a modification of the system described by Smythe-Wright (1990a & b). Valves V6 and V7 are now mounted within a Shimadzu GC14-a with trap, packed with Porasil B, mounted on the outside of the oven. Trap cooling was by a -50°C propan-2-ol bath. Both column and precolumn are DB-624, being 65 and 3 metres in length respectively. Standards, syringe-sampled air and blanks were run periodically during analyses to allow correction for instrument drift or contamination. Calibration curves based on a gas standard for CFC-11 and CFC-12 were run at intervals throughout the cruise. CFC-113 data were calibrated against air samples.

The main source of problems with the instrument was the glass stripping column. Making airtight seals was extremely difficult and two strippers were broken during setup. Throughout the cruise the integrity of these joints posed a problem, resulting in irregular CFC-12 blanks. In order to reduce this effect, the methodology was changed so that sample injection occurred during the trap cooling period, thus minimising the time the sample spent in the stripper.

Valve V7 also presented a recurring problem. On several occasions gas flow through this valve dropped, apparently due to some obstruction in the fine gas channels. Valve cycling at 140°C and at increased gas pressure cleared this on two occasions. However this later became a recurrent problem, but cycling when this did occur normally cleared the problem.

Several stations were lost towards the end of the cruise due to a fault in the GC door switch. This disengaged the oven temperature control and made chromatography impossible. After advice from the distributors Alan Taylor bypassed this switch and no further problems were experienced.

During the storm preceding Station 12473, the stirrer Cryobath cooling the cold molecular sieves failed. The uneven cooling thus resulting caused problems with baseline fluctuations in some of the later analyses.

Results

The output from the analyses was reprocessed to check for the quality of the peak integration. These results were then entered into a spreadsheet and the bracketing standards used to fit a linear approximation to the calibration curve. To date no full curve fitting or blank correction have been done. Also, because an uncalibrated stripper had to be used, exact volumes are not yet available for the samples. Therefore the data precision and accuracy should be improved by subsequent recalculation.

Generally the precision of the duplicates is quite acceptable, with the surface water samples being of the order of 4% for all 3 compounds. The precisions in the deeper water are less good although still around 10 fmol/l for CFC-11. The CFC-12 data is more variable but may benefit from further reprocessing. Comparison with data from cruise 200 (Dickson et al) indicates that the absolute concentrations are in keeping with their results, though these stations are not close enough to be directly comparable.

Thanks to Alan Taylor and Stirling Jordan for help with keeping the instrument running.

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Oxygen Isotope Ratios

R. Woodgate

Sampling

At the request of Russell Frew of University of East Anglia, samples were taken from CTD casts to be analysed subsequently for oxygen isotopes.

The purpose of the investigation of oxygen isotopes is to ascertain the ratio of O₁₆ to O₁₈ in the water molecules. Due to the different atomic weights of the two isotopes, fractionation occurs on evaporation, precipitation and freezing. The heavier isotope is preferentially precipitated and locked in ice, and left behind during evaporation. Once fractionation has occurred, the water tends to maintain its isotope ratio. Thus this ratio can be used as a passive tracer of the water mass, and give some idea as to its formation.

The isotope ratio is measured by equilibrating the water with carbon dioxide of a known isotopic composition and determining the resulting O₁₈/O₁₆ ratio of the equilibrated carbon dioxide.

During this cruise no analysis was done, the samples being stored for later analysis in the UK. Samples were taken from all Niskin bottles on about a third of the total CTD casts, see Table 1, resulting in 742 samples. Samples were drawn last from the CTD rosette, and since the bottles used were new, only one rinse was required. Bottles were filled to allow for an expansion gap at the top of the bottle, (the error introduced by the carbon dioxide in the enclosed air being minimal). Though the bottle caps were rubber to ensure sealing, where time allowed, wax was used to seal the tops further to prevent evaporative losses. It was found that some of the seals were not as airtight as might have been hoped.

CTD Measurement

Gantry and winch

S. Jordan

The 10 tonne cobra winch traction system together with the midships gantry was used extensively throughout *Discovery* cruise 201. The winch was used to deploy a CTD package down to depths of approximately 4700m, this being the limit imposed by a 2 tonne safe working load (2.5 tonne peak) on the CTD cable. Operationally the winch performed satisfactorily, however, some problems did occur which should be rectified at the next refit. The following problems were encountered:-

- a) A bearing failed on the 10 tonne storage system, this was removed and replaced by another bearing taken from an unused part of the system.
- b) The speed control was found to be erratic and caused some minor problems, however, operator experience tended to overcome these difficulties.
- c) Of major concern was the CTD cable "jumping" out of a diverter sheave on the hanger deck. On one occasion the cable was severely damaged almost to the point of total separation which would have meant the loss of the CTD overboard.

It must be noted that the traction winch system has seen much use since the launch of the RRS *Discovery* and problems were unfortunately expected to occur, however, these problems are not insurmountable and should as previously stated be rectified during the next refit.

Recommended improvements/suggestions:-

- a) Redesign of bearing fitted to the 10 tonne storage drum system.
- b) More positive "feel" to the winch speed control.
- c) Redesign to the hanger deck diverter sheaves.

An area of improvement is the CTD package itself. These packages are getting larger and heavier and this has an adverse effect on the depth limit imposed by the safe working load of the CTD cable. Conversely the CTD package used appeared to be extremely buoyant upon entry to the ocean surface, which caused slack cable through the winch system and greatly increased the probability of the cable jumping out of the diverter sheaves.

Recommended improvements/suggestions:-

- a) Package to be lighter.

- b) Surface area decreased and package streamlined enabling outboard tensions to be decreased and causing less buoyancy at the water surface.

Equipment, calibrations and standards

J. Smithers, R. Kirk, R. Bonner and A. Taylor

A total of 97 stations were occupied during the cruise using the following equipment:

Instrument.	Serial Number	Range.
CTD NBIS MKIIIb	DEEP01	6500m,+32.676 °C, 65 mmhos.
Transmissometer	No35	7000m rating, 0-4.32 volts.
Altimeter	92010101	7000m rating, 0-200m range.
Rosette Multisampler		24 * 10 L Niskin bottles.
SIS Thermometer	T400	-2 to + 40 °C
SIS Thermometer	T219	▪
SIS Thermometer	T401	▪
SIS Thermometer	T238	▪
SIS Thermometer	T220	▪
SIS Pressure Meter	P6132	6000m
SIS Pressure Meter	P6075	6000m
Pinger	IOSDL	10kHz

T400, P6132 were mounted on Niskin bottle no 1.

T219, T401 were mounted on Niskin bottle no 4.

T238, P6075 were mounted on Niskin bottle no 8.

T220 was mounted on Niskin bottle no 12.

This arrangement was used until station 12478, changes were made as listed below

The sea cable was reterminated at the start of the cruise to remove kinks left after previous winch trials. This was repeated on several occasions as listed below.

Station (s)	Comments
12387	Good. Transmissometer Air Val 4.32v blanked 0.017
12388-12397	Good.
12398	Aborted after approx 600m. Winds gusting 50 kts.
12399-12402	Good.
12403	Aborted. Lev A not logging. Master clock jumped 4 hrs.
12404	Aborted. Same problem.
12405-12407	Good.
12408	Good.

Multisampler serviced after this station.

12409-12419	Good.
12420	Good. Transmissometer Air Val 4.31v blanked 0.015 .
12421	Aborted. Rosette - CTD connection loose. Plug and socket damaged by sea water.
12422-12450	Good.
12451	Aborted. Sea cable jumped from winch sheave

Damaged cable cut and reterminated.

12452-12456	Good.
12457	Good. T401 reading erratic.
12458-12462	Good. T401 still erratic.
12463	Good. Transmissometer Air Val 4.31v blanked 0.015.
12464-12467	Good. T401 still erratic. Removed after this cast.

Multisampler serviced.

Pinger changed for spare. (Low battery)

12468-12471	Good. Cable reterminated after cast (kinked).
12472-12478	Good.

12479 Niskin No 11 uncocked on entry into water.
Imploded at depth and wrecked Nos 10 and 12
Bottles replaced for next cast.
T238, P6075 not refitted.

12480-12484 Good.

Sea cable reterminated after cast.

The Dead-eye had been displaced and the cable kinked.

12485 Good.

12486 Good. Cast ended at 2000m. Weather deteriorating.

12487 Good. Cast ended at 800m. Weather even worse.

Final Transmissometer Air Val 4.32v blanked 0.016.

The CTD, altimeter and transmissometer worked faultlessly throughout with failures being confined on all but one occasion to the sea cable termination and usual rosette multisampler problems.

The use of the altimeter improved the ease and safety of CTD operations close to the sea bed. On one occasion the shipborne echo sounder indicated a depth that was considerably less than the actual because of a steeply sloping bottom. However, the altimeter provided a strong and clear indication of height from the bottom allowing full depth to be achieved without danger.

The damage to the sea cable on each occasion was caused by heavy swells. The instrument package has a large cross sectional area and weighs approximately 0.4 tonne in air. This caused high drag on entry into the water with the sea cable becoming slack as it was veered. This caused the cable to jump from a winch sheave and jam, on one occasion breaking most of the outer armoured layer. Through the quick and efficient work of Stirling Jordan, the day (and instruments) were saved by the use of cable stopper, etc. The cable was damaged again under similar sea conditions with the dead-eye being dislodged and the cable kinked.

The instrument package carries 4 * 50 kg lead weights to help alleviate this problem. However, problems then occur at depths in excess of 4500 m when the weight and drag of the package raise the wire loads to more than 2.5 tonne. Although this package fulfils the WOCE sampling requirements, casts to full ocean depth of 6000 m would not be possible. It must be said however, that the new CTD gantry provides a much improved and safer method of handling the package. In anything other than heavy weather conditions, only two people are necessary to steady the package.

The SIS digital reversing thermometers and pressure meters generally worked well. These were useful both as a check for possible temperature calibration jumps in the CTD and as a detective aid for determining depths at which the bottles actually fired.

There was some discrepancy between laboratory and actual thermometer calibrations when compared with the CTD. However the temperature ranges over which the thermometers were operated allowed cross checks to be made ensuring that the CTD was not in error. The thermometer results were analysed with obvious outliers in the data rejected. The standard deviations obtained for the thermometers show that they remained stable in use throughout the cruise. The pressure meters do not give quite such good results. The following table shows the differences compared with the CTD, after laboratory calibrations applied to the thermometer data.

Thermometer No.	No. obs	Mean Diff K	SDev
T400	89	1.5925E-03	1.8462E-03
T219	89	-9.269E-03	2.2833E-03
T401	53	5.2082E-03	2.1109E-03
T238	83	2.6809E-03	1.9642E-03
T220	72	4.7912E-03	2.6265E-03
Pressure Meter No.	No. obs	Mean Diff dBar	SDev
P6132	91	9.031868	6.965627
P6075	86	8.113952	7.100101

The CTD display and back up logging system generally worked without fault providing the data acquisition mode was started after the instrument was deployed. The DOS print function corrupted the CTD software but this was overcome by re-booting the PC before each cast.

Data processing and calibration

Initial calibration

J. Read, R. Pollard

CTD data were passed from the CTD deck unit to a dedicated microprocessor (Level A) in which the 16 Hz raw data were averaged to 1 second values. The microprocessor also calculated the rate of

change of temperature, and used a median-sorting routine to detect and remove pressure jumps exceeding 100 raw units (approximately 10 dbar).

The 1 second data were then transferred (datapup) to a Sun (unix) workstation running the pstar data processing package. The data were calibrated (ctdcal), the down cast extracted (pcopya) and a secondary file of 10 second averaged data created (pavrge) for merging with the bottle firing times and comparison with the discrete bottle samples.

The calibrations applied to the 1 second data were as follows:

$$\text{Pressure} = \text{Praw} ** 2 * 3.066286\text{E-}7 + \text{Praw} * 0.997845 - 9.0$$

The offset, which was different to that found in the calibration laboratory, was chosen to give the correct reading at the sea surface and over the top few metres.

Pressure was corrected for the effect of temperature on the CTD pressure offset:

$$\text{Pressure} = \text{Pold} - 0.4 (\text{Tlag} - 20.)$$

- where Tlag was a lagged temperature constructed from the CTD temperature, with a time constant of 400 seconds:

$$\text{Tlag} (t = t0 + \text{tdel}) = W * \text{Tlag} (t = t0) + (1 - W) * T (t = t0 + \text{tdel})$$

- where T was the CTD temperature, tdel the time interval over which Tlag was updated, and W was:

$$W = \exp (- \text{tdel} / \text{tconst})$$

- where tconst was the time constant.

The value of 400 seconds for the time constant and the sensitivity of 0.4 dbar per degree C were based on laboratory tests.

A further adjustment to pressure was made to correct the up cast pressures for sensor hysteresis. The adjustment was based on laboratory measurements of the hysteresis and was linearly interpolated between the values shown in the table below. For a cast where the maximum pressure reached Pmax dbar the correction applied to the up cast CTD pressure (Pin) was:

$$\text{Pout} = \text{Pin} - (\text{dp5500} (\text{Pin}) - ((\text{Pin} / \text{Pmax}) * \text{dp5500} (\text{Pmax}))$$

TABLE OF PRESSURE SENSOR HYSTERESIS CORRECTION.

Pressure	dp5500(p)	Pressure	dbar5500(p)
dbar	dbar	dbar	dbar
0	0.0	3500	2.4
500	6.3	4000	1.8
1000	6.0	4500	1.8
1500	5.6	5000	1.0
2000	4.8	5500	0.0
2500	3.4	6000	0.0
3000	3.0		

The temperature calibration applied was:

$$\text{Temperature} = \text{Traw} * 0.998662 - 0.01282$$

- to give temperature on the ITS-90 scale. For the calculation of derived parameters temperature was converted to the 1968 scale using:

$$T68 = 1.00024 * T90$$

as recommended by Saunders (1990).

To reduce the mismatch between the response time of the temperature and conductivity sensors the temperatures were corrected as described in the SCOR WG51 report (Crease et al. 1988) using a time constant of 0.20 seconds.

Salinity was calculated from conductivity using a ratio of 0.996683. This figure was obtained by comparison with sample salinities on *Discovery* cruise 199, (Saunders et al, 1993). Comparison of CTD salinities with discrete samples drawn on each station showed a gradual drift of order 0.005 - 0.009 psu (Fig. 4). For each CTD cast the differences between the CTD and sample salinities were averaged and the mean subtracted from the CTD values. This left the differences shown in Fig. 6 which suggest a depth dependant variation. No correction for this has been made yet.

Additional information

R. Woodgate, S. Best

Additional information was fed into the CTD pstar files as listed in Table 1. Start and stop times were extracted from the bridge log and down time from the CTD log. Latitude and longitude were taken from the bestnav file at the down time and the depth of the cast was taken from the greatest pressure (pdepth). Bottom depth was calculated as the sum of the CTD pressure converted to depth (pdepth) at the down time, plus the CTD altimeter reading. If out of altimeter range, ie more than 204m from the bottom, a corrected reading was taken from the echosounder (marked * in table 1), with an addition of 13m to correct for the fish depth (see below).

Resolution of Niskin bottle firing depths

J. Read, R. Pollard

Considerable problems were encountered with misfires and double trips on the multisampler rosette. To determine the depth at which each bottle fired two files, containing CTD and sample data respectively, were created as follows:

"Firing" files

The time at which each bottle was fired was logged on the CTD deck unit and transferred via the Level A to the pstar data processing system (datapup). This file was successively merged with:

winch data - to obtain the 'wire out' (pmerge)

CTD data - to obtain the CTD up cast parameters (pmerge)

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.

"Sample" files

Data for each sample drawn from each Niskin bottle were gathered together into one master file (pblankexec, ppaste) from various Microsoft Excel spreadsheets. Salinity, oxygen, nitrate (+ nitrite), silicate and phosphate were listed by bottle number for comparison with the "firing" data.

CTD (up cast) salinities were compared with sample salinities to locate problem bottle firings. Double trips and misfires were confirmed by the other parameters and the reversing temperature and pressure information.

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

Problems were encountered when the sequence of sample salinities did not match that of the CTD data, the main reason for this appeared to be that the samples were drawn from the wrong Niskin bottles. Although a rare occurrence, it was awkward when it occurred. On most watches there was more than one sampler and it is suggested that the procedure used for drawing oxygen isotopes be routinely used for taking salinity samples, i.e. instead of starting at bottles 1 and 13 and working separately, the samplers should start at bottles 1 and 2 and work as a pair. This has several advantages: i) only odd or even Niskin bottles are sampled by an individual, ii) for each bottle the sampler moves round a larger and more definite segment of the circle, and iii) two people are less likely to make a mistake than one person on their own.

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Oxygen calibration

R. Pollard, R. Woodgate

Following practice on A11 cruise 199 (Saunders et al, 1993), calibration was initially attempted using the equation

$$O_2 = \text{oxsat}(T,S) * \text{rho} * (\text{oxyc} + \text{offset}) * \exp(a * (W * \text{ctdT}) + (1-W) * \text{oxyT}) + b * P$$

with rho, a, b, offset and W chosen by least-squares fitting to the oxygen values from up to 24 samples. This technique has never proven entirely satisfactory, primarily because the least-squares solution is ill-conditioned in a and b, in particular, because on the whole T and P change monotonically with depth. The solution is thus sensitive to even a single bad sample as well as to the maximum pressure to which

the cast can be made. Note also that, while oxygens have to be drawn on the up-cast, CTD oxygen values have to be obtained from the down-cast because of the hysteresis of the sensor. Thus "bad" samples include cases where oxygen values on down and up casts at the same potential temperature and similar pressure are genuinely different, perhaps because of a small-scale intrusion of a different water mass. Even after much iteration to remove suspect samples, the fit has a systematic bias of order 1-2%, which is sufficiently large to mask differences between water masses, (of order 4%). This error is due to the slow response time of the instrument, and was aggravated near the surface because of the rapid changes in oxygen with depth and on occasion the fact that we chose not to soak the CTD at 5 m before starting the cast. A new procedure was therefore adopted towards the end of the cruise and applied to all casts.

1. The fitted constants from the best six deep casts (to a mean maximum pressure of 4720 dbar) were averaged, giving the values $\rho = 1.3033$, $a = -0.03643$, $b = 0.0001864$, $\text{offset} = -0.0462$ and $W = 0.3625$. (Note that the value of W implies that the slow response of the oxygen sensor is approximated by using $2/3$ of the internal oxygen temperature and only $1/3$ of the CTD temperature.)
2. The least squares fit was then repeated on all casts using the above values with the exception of ρ . ρ was allowed to vary (Table 3) because it changes from cast to cast and the residuals are very sensitive to it. Bottle values in the top 50 m were omitted. This procedure gave improved cast to cast repeatability, only slightly increasing the residuals in the top 500 m and on occasion changed the shape of the curve significantly.
3. A cubic spline was then fitted to the error between the bottle data and the equation fit, (ie truth - estimate) (oxspline) with no more than 5 knot points. The positions of the knots were chosen to give the best, smooth fit. The error profile was found to be similar in most cases, being initially negative at the surface, rapidly becoming positive with depth, turning negative again around 400-1000m and finally coming positive again, peaking at around 1300-2000m.
4. The error profile was then interpolated to correct the whole of the cast.

The resulting profiles fit the bottle data with standard deviation (Table 3) of only $1.0 \pm 0.5 \mu\text{mol/l}$ (<0.5%), with no bias. Also structure with a smaller vertical scale than the bottle samples has not been lost through this method.

The error profiles to which the spline was fitted agree with the theory of slow rise time of the device. The offset is worse in the surface layers where the oxygen concentration changes more rapidly, and changes of sign in the error function agree with the maximum and minimum of the oxygen profile.

The only biases remaining were in the surface layer, 50-200 m deep, in which the CTD oxygen values often change rapidly but the bottle values are usually constant within 1%. Land based processing will be used to delete the CTD oxygens in this layer and replace them by the value at 50 m. While the values can be flagged as suspect, they are in fact reliable given the typical wind conditions and mixed layer depths that prevailed.

CTD vs PES Bottom Depths

R. Woodgate

Throughout the cruise, the bottom depth was recorded using a towed Precision Echo Sounder (PES) fish. Since the CTD also carries an altimeter to measure height off bottom, it was possible (at most CTD stations) to compare the bottom depth as measured by the echo sounder with that deduced from CTD measurements.

The altimeter on the CTD has a maximum depth range of 204m. Where the cast came within this distance of the bottom, an estimate of the bottom depth could be obtained. The bottom pressure of the CTD was converted to metres using the pstar routine pdepth, after the surface pressure offset had been removed. The altimeter reading could then be added to this to give the total depth of water at the downtime. In all cases this reading was found to vary by less than a metre within 10 minutes of the downtime. (The wireout reading can not be taken as a depth estimate since the wire may not be vertical).

The PES fish was towed beside the ship on a wire 22m long. As such, its height relative to the sea surface is not constant, but depends on the ship's speed relative to currents, and varies from 10m at 11 knots to 17m hove-to (Fig. 7), there already being a 5m correction for the depth of the ship's hull.

On the majority of the CTD casts (65 out of 96) it was possible to make a reasonable comparison between the PES measurement and the CTD measurement. The difference in the two readings (CTD - PES) ranged from 4 to 20m with a mean, median and mode of 13m and a standard deviation of 4m. This is in remarkable agreement with the wire length, as between 10 and 17m must be added to the PES reading to get the depth from the surface! The scatter in this figure is easily accounted for by wave height and offset error on the CTD. However in a significant number of cases (20 casts) the discrepancy was found to be much larger, occasionally as much as 200m difference. The majority of these cases were attributed to errors in the PES measurement, since over a 20 minute period this reading could actually change by 50 to 100m.

It can be concluded that hove-to, over reasonable topography, the PES reading is of order 13m too low, the correction required being due to the suspended depth of the fish. Over sloping topography,

the PES reading appears to be less reliable. Other discrepancies between the readings may be attributed to CTD offset error, CTD altimeter error and possible differences in the bottom area over which the instruments are reading.

Expendable Bathythermographs (XBTs)

S. Best, A. Fern

Equipment

RRS *Discovery* Cruise 201 used an SA-810 XBT controller and the Bathy Systems Inc. XBT program (version 1.1) to record XBT launches. The XBT probes were launched from a Sippican Corporation hand-held launcher. The XBT program identified critical turning points on the temperature vs depth trace and sent the information to be transmitted in batches to the GTS network via the GOES satellite (after the cruise the data were sent to the Hydrographic Office on disk). The XBT data were transferred to the RVS level A by a 'walknet -- 3.5 inch diskette' method as no hard wiring existed between the XBT deck unit and RVS firmware.

The satellite 'window' was relatively short and held only 2-3 profiles at a time, transmission occurred about every 6 hours and so some of the xbt traces could not be sent immediately after they were recorded. Unfortunately the 'seas' program sometimes gave the impression that a profile had been sent when in fact it hadn't. To overcome this the drop directory was checked twice a day and those drops which hadn't been transmitted were sent as soon as possible.

A complete list of XBT launches is shown in Table 1. A total of 107 probes were launched successfully; 72 were T7's and 35 were T5's. Gaps in the sequential numbering of the XBT stations indicate launch failures. The majority of these were due to faulty probes. Of these, 7 were T5's and 2 were T7's. The computer hung up a few times just before the probe was to be launched and in two cases this resulted in a probe being wasted. In one case (xb201170) a T5 probe was recorded as a T7 and the probe had to be re-processed as a T7.

Data processing

For each XBT the time of launch was recorded by the Bridge officer, position was extracted from the navigation file 'bestnav', and water depth (cordepth) from the 'prodep' file (where no correction for the depth of the PES fish had been applied). Details are as in Table 1.

The data were converted from RVS raw data format to pstar using the process 'nbtexec0'. This created the file xp201nnn, where nnn was the XBT launch number. Spikes in the data were removed (pedita) and the profiles plotted (plotxy).

The data collected by releasing an XBT resides in a file on the collection PC whose name is controlled by the type of probe and the date together with the XBT 'drop' number. The extension part of the file name is the 'drop' number. Using a 720K floppy and the 'xbt2asc' process the ascii files were transferred to a suitable directory on the Sun. The UNIX program, 'proxbt' was used to convert the ascii files to 'listit' format, and the data were piped through 'titsil' into a previously initialised data-file. The data-file needed 2 variables called 'press' and 'temp'. On *Discovery* cruise 201, the Unix translation program, proxbt, was wrapped in a C shell script, called xbt :

```
#!/bin/csh
# C shell script 'xbt'
# process xbt ascii file into rvs datafile
if ($1 == "") then
    echo "usage: proxbt ascii_datafile"
    exit
endif
#
set datafile=`echo $1 | cut -f1 -d"."`
#
if ( -e /rvs/pro_data/$datafile ) then
    echo "$datafile" already exists, exiting"
    exit
endif
#
echo "creating new data file in /rvs/pro_data for "$datafile credat -i -g xbt $datafile
#
echo "translating "$1" to listit format and thence to "$datafile proxbt /rvs/pro_data/xbtasc/$datafile.asc |
titsil $datafile exit
```

Acoustic Doppler Current Profiler (ADCP)

B. de Cuevas, S. Alderson, A. Taylor, A. Fern.

Equipment

The RDI 150kHz unit on *Discovery* operated throughout the cruise without major hardware problems. The unit failed on 27th March and would not restart until a fuse was replaced in the data acquisition system, and again on 28th March when the power regulator board was replaced, but operated thereafter without problem. The unit is hull mounted approximately 2m to port of the keel of the ship and approximately 33m aft of the bow at the waterline. The firmware version 17.10 and the data acquisition version 2.48 were used for this cruise. The instrument was used in water tracking mode for most of the period of operation. Two minute averaged data were recorded in 64x8m bins from 9m to 521m. At the start and end of the cruise on the continental shelf as well as for a period in the middle of the cruise near the Ile aux Couchons, the instrument was put into bottom tracking mode, in which both water and the bottom are tracked for calibration purposes (see later).

The instrument performed well throughout the cruise with profiles usually recorded to 400m depth. Only in heavy weather (23rd-25th April and 28th-30th April) were data recorded to less than 200m for a significant period of time.

Data processing

Standard IOSDL preliminary processing (see Griffiths, 1992) was followed. Data were passed from the deck unit to a Sun workstation in real time. Once a day 24 hours of data were read into the processing area and written into the pstar format. The time base was then corrected for instrument clock drift and the time stamp changed from end of sample period to the centre of sample period. The data were then averaged into 10 minute segments, and merged with the ship's motion over the earth (obtained from GPS navigation), thereby deriving absolute water velocities over ground.

For further analysis, the daily data were appended to form a large dataset from which sections corresponding to periods 'on station' and 'steaming' could be extracted. These periods were selected by inspection of the navigation data. It is intended to use the 'on station' data for studies of the Ekman layer. As a preliminary to this, data from two bins corresponding to the mixed layer (bin 5: 45m depth) and a layer well below the mixed layer (bin 25: 205m depth) were extracted from the merged data file and the relative shear in the mixed layer calculated as an hourly average. The resulting time series showed a strong inertial cycle of period approximately 18 hours, whose amplitude was much reduced

(from $\pm 50\text{cm/s}$ to $\pm 10\text{cm/s}$) by averaging the data over 18 hours. This identified the need to average individual 'on station' data over 18 hours rather than forming an average for a single station (2-4 hours).

Data corresponding to 'on station' periods during sections of CTD casts were extracted, averaged over 18 hours and contour plots produced of the velocity perpendicular to the cruise track. These were compared with similar plots of geostrophic velocity obtained from the CTD data.

ADCP calibration

The instrument can be calibrated by comparing ship over ground velocities from the ADCP with those based on GPS navigation data. In water track mode where no velocities over ground are available, the ship must perform a series of zig-zags in which data before and after turns can be used to eliminate the unknown velocity of water over the ground. See Pollard and Read, 1989, for more details of this procedure. Three such calibration runs were performed: two as straight bottom tracking calibrations, and one as a series of zig-zags. The watertrack calibration over Agulhas Bank produced a pointing angle correction of 0.23° which was used in all later processing. This is comparable to a figure of 0.55° used on cruise 199 and is within the expected error from the GPS data. The first bottom calibration initially produced numbers of comparable magnitude. However on attempting to correct for gyro error using the Ashtech data, inconsistencies were noted between the two courses for which such data was available. These have not yet been resolved and further analysis is required. It is hoped that the final calibration undertaken on the return across Agulhas Bank will throw light on the problem.

References

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Navigation

A. Fern, S. Alderson, B. de Cuevas

Half minute values of good data from the raw GPS (Global Positioning System) data-file 'gps_trim' were copied to the datafile 'gps'. This was done so that a source of fixes was available throughout the cruise (raw 'gps_trim' was regularly archived and cycled). The ship's speed, 'log_chf', and heading 'gyro_rvs', were averaged every 30 seconds to provide northerly and easterly velocity

vectors in the data-file 'relmov'. These were used to generate dead reckoning positions to enable both a check on the quality of GPS fixes and to allow interpreted positions to be produced when there was no 'gps_trim' data. GPS coverage was generally good with short gaps at our most southerly extent. A data-file 'bestnav' was generated by combining raw GPS fixes from 'gps_trim' and dead reckoning, 'relmov', with transit sat fixes from 'mx1107' as fix backup. 'Bestnav', contained the variables: lat, lon, vn, ve, cmg, smg, dist_run, and heading. With the good GPS coverage, the 'bestnav' file was primarily a smoothed GPS file with a 30 second window.

However, these data were subject to the errors associated with 'selective availability'. In an attempt to estimate the magnitude of such errors, GPS data were collected whilst the ship was moored at Cape Town at the beginning of the cruise. Analysis of such data revealed a 50m rms error in position. Data were converted into PSTAR format on a 24 hour basis and after editing and despiking, averaged to 10 minutes for use with the ADCP data.

Ashtech GPS3DF

S. Alderson, A. Fern, A. Taylor

This instrument comprises a set of four antenna in the form of a square, with approximate side of 8m, mounted on the ships superstructure. Using the GPS system it determines the position and attitude of the platform (i.e. pitch, roll and heading). Initially data were downloaded from the receiver via a PC at intervals determined by how quickly the solid state memory of the receiver became full. At a 2 second collection interval this interval was less than 12 hours. After the first ADCP calibration a software upgrade was made to the Ashtech (Version 6H_1.0) to enable direct transfer of data from the receiver to the Level C via level A and B thus alleviating the PC data-file transfer problem. The new software generated a serial NMEA (\$GPPAT) message containing both position and attitude data. A new level A application was written to convert the NMEA format to SMP using a fixed sync data processing algorithm. The data were then passed to the Level C via the Level B in the usual manner.

The most serious problem encountered with the new software related to the data availability on the serial port. In operation it was observed that the level A data seemed to get stuck on the same values, and initially the only solution was to switch the receiver off, and on again. This would usually clear the solid state memory and the problem would go away. Eventually it was realised that the data used to create the NMEA message was a copy of the last message in the solid state memory. If the frequency set for the serial data was higher than that to the memory, serial data were repeated until a new value was stored in the receiver. When the memory was full, the last entry was continually sent as a serial message. The problem was resolved by setting the receiver internal logging rate to be the same

as the NMEA message frequency. Ashtech have been informed of this problem and are investigating. It is believed that the next software upgrade will solve this problem.

A by product of the problem meant that data at the beginning of the cruise were patchy, and had gaps which were not related to satellite availability. On the whole, data were available at similar intervals to *Discovery* cruise 199.

Data were converted to pstar format every 24 hours and processed in the same manner as Griffiths (1993). By carefully merging the Ashtech data with the gyro data, a correction has been established to the gyro heading data on a daily basis. It is intended that this correction should be used to correct any mispointing error in the ADCP data due to gyro error.

References

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Underway Observations

Echosounding

A. Taylor, M. Hartman, S. Best

The bathymetric equipment aboard RRS *Discovery* comprised the following:

Hull mounted transducer.

Precision EchoSounding (PES) 'fish' transducer.

Simrad EA500 hydrographic echosounder.

The transducers were connected to the Simrad equipment via an external switch allowing one or other of the transducers to be used. During *Discovery* cruise 201 only the PES 'fish' was used. In addition to being used for echo sounding the fish was used to communicate with acoustic release transponders during testing and mooring deployments.

The fish was a 10kHz multi element transducer array that was towed over the port side of the forecandle deck from a davit with a faired cable. This maintains a vertical sonar beam despite the ships movement, and frees the signal from attenuation induced by bubbles in the surface water (entrained by the hull). It enables the fish relatively free movement in the vertical plane and as the ships speed increases so the depth of the fish decreases. When stationary the fish was submerged at a depth of

approximately 22m. As the Simrad echosounder uses a depth offset of 5.3m the depth read by the echosounder is 17.7m less than the actual depth.

There were three outputs from the echo sounder; a visual display of the return signal on the screen, a hardcopy printer output and a serial depth reading calculated by the echo sounder that is passed to a RVS level A interface.

The fish was deployed on 27th March and depth readings passed to the level A interface. The bottom detection signal was very strong for the first few days but then started to deteriorate. The fish was recovered and repairs made to the cable fairing retaining clips before being redeployed.

The ability of the echo sounder to lock onto the bottom return signal was dependant on the weather and ships speed. At speeds below 11 knots very little noise was observed on the return signal and bottom lock was very good. At speeds above 11 knots the noise level increased rapidly until at 13 knots and above the echo sounder display was very poor and the bottom detection algorithm only worked for approximately 50% of the time.

Data were logged by the RVS level abc system into the 'sim500' file, and processed (corrected for the speed of sound through water, which the Simrad echosounder takes as a uniform 1500 m s^{-1}) into the 'prodep' file. From here the data were converted to pstar format (datapup) and then processed to take out the spikes in the data (pmdian, using a spike value of 100; plxyed to interactively remove spikes; datpik to remove gaps). The depth data were merged (pmerge) with navigation data for latitude, longitude and distance run and files were appended (papend) to produce one master file. The resultant file was then edited (pcopya, papend) so that it only consisted of the 'steaming times' between CTD stations and/or mooring sites where speed made good was greater than 5 knots.

The relationship between the depth of the PES fish and the speed of the ship was investigated by using the data collected during the mooring site surveys. Bathymetry for the eight mooring sites was extracted from the master file (pcopya) and contoured (ucontr) for the mooring technical report. During the survey of the mooring B site the bathymetry was found to be quite flat sloping gently upwards towards the North by approximately 10 metres over a distance of 7 km. The 30 second averaged data collected from the 5.5 hours of this survey were used to investigate the variation of the depth of the PES fish with the speed of the ship.

During the survey the ship's forward speed through the water ranged from -1 to 11 knots. The file was split into 12 files of one knot ranges e.g. one file from 0 to 1 knot the next from 1 to 2 knots etc. The Carter corrected depths were then plotted against latitude and were overlaid on the same plot. The differences in depth with speed were extracted from this (table below) and plotted (Fig. 7).

Speed/knots	Depth change/m
10 - 11	-1.3 ± 0.7
9 - 10	0 ± 0.5
8 - 9	2 ± 1.7
7 - 8	3 ± 1
6 - 7	4.2 ± 2
5 - 6	4.6 ± 0.5
4 - 5	4.6 ± 2
3 - 4	6 ± 1
2 - 3	6.7 ± 1
1 - 2	6.5 ± 1
0 - 1	5.9 ± 1
-1 - 0	6 ± 1

The curve

$$y = 0.24025 - 0.53385x + 0.27557x^2 - 3.3148x^3 + 1.7814 \times 10^{-3} .x^4$$

where y is depth change and x is ships speed, was fitted to the data with $R^2 = 0.984$ as shown above. This correction was then applied to the survey file with good result.

Meteorological measurements and ship-borne wave recorder

M. Yelland

The meteorological monitoring system used for *Discovery* cruises 198 through to 201 was developed jointly by the Instruments and Sensors group at RVS and the British Antarctic Survey. This system used some instruments supplied by RVS and some from IOS, and was supplemented by a Solent sonic anemometer. Instruments mounted on the foremast were; an R.M. Young propeller vane anemometer (RVS), two psychrometers (IOS), two photosynthetically active radiation sensors (RVS), two total irradiance sensors (RVS), a long-wave pyrgeometer (IOS) and the Solent sonic anemometer (IOS).

In addition to these were a hull-mounted sea surface temperature sensor, an aneroid barometer and the SBWR (ship borne wave recorder) (all RVS). Since the sensors all appeared to be working well at the end of *Discovery* cruise 200 they were left unchanged. The psychrometer water bottles were topped up prior to departure. The starboard psychrometer had lost its protective "top-hat" towards the end of *Discovery* cruise 200 and a spare was unavailable, so the "top-hat" from the port psychrometer was transferred across.

The metlogger PC emulates a standard level A interface and transmits the data directly to the level B. After the data were transferred to the level C, they were reformatted to pstar format and calibrated and processed under Unix using a series of scripts developed for the IOS MultiMet system. Data were recorded as 1 minute averages from all sensors except the SBWR and Solent sonic which both recorded spectra over 10 minutes. Daily and weekly plots were produced for all the measurements, and used to check sensor behaviour. All sensors performed perfectly, except for the port psychrometer wet bulb which tended to become extremely noisy in rough weather. However, it produced enough good data to act as a check for data from the starboard psychrometer. Air temperatures ranged from 0 to 28 degrees, sea surface temperature from 2 to 25 degrees, pressure from 980 to 1030 mb and wind speed from 0 to 30 m/s (with a mean of just under 10m/s) (Figs. 8 & 9). The calibration of the sea surface temperature sensor is only valid for temperature over 5 degrees, so values less than this should be recalibrated with ADCP data. Processed data were also plotted from the Solent sonic and the SBWR. Values of significant wave height briefly reached 16 m, but the average was less than 4m. Wind stress values calculated using the inertial dissipation technique peaked at 1.4 N/m^2 (Drag Coefficient $2.5 \cdot 10^{-3}$) with an average of 0.2 N/m^2 . Values produced from a bulk formula (Smith '80) were generally about 10% lower.

Satellite image acquisition and processing

G. Quartly

Equipment

The Macsat system consisted of an Apple Macintosh, a Dartcom receiver, preamplifier and aerial, and a software package provided by Newcastle Computer Services (Saunders et al, 1993). For this cruise, we used the NOAA series of polar orbiting meteorological satellites, and only the infra-red images from those.

The system as a whole was not working at the beginning of the cruise, although it had been reported as doing so near the end of the previous cruise. This setback was variously attributed to

operator ineptitude, poor satellite predictions, directionality in the antenna and even Table Mountain! However, after several days of suffering in silence, the pre-amplifier was replaced. Despite nothing having been obviously wrong with it, the improvement at this juncture was impressive — images started flooding in. This vindicated both the operator and the satellite prediction capability of the system! However, this only lasted for 5 or 6 days and after this reception became intermittent — periods of 5 or more days with nothing but a noisy signal at best, interspersed by a day or two in which at least 50% of sought for signals were recorded clearly. Many reasons for this behaviour have been propounded— rapid "frying" of the pre-amp from its propinquity to high power radio equipment; masking / echoes from the ship's funnel; directionality of the antenna (one of the 4 active elements had a non-negligible resistance) or a sudden death of all 3 satellites. However, the repeated recoveries in performance suggest something else; the last of the improvements occurred after removal of sharp coils from the cable. Thus over the whole cruise a large number of images were received and stored, albeit that they were not collected evenly over this interval.

Data processing

Of these many images, most were degraded to some extent by the poor quality of the reception. Interference or atmospheric turbulence could cause a few seconds of data to be masked by noise, which appear on the image as a line or two of speckle ('salt and pepper'). Some images were perfectly clear or had only a few disparate lines of noise. Others might have noise for 20 seconds or so, obscuring several lines. [A full image of 800 lines corresponds to about 6.7 minutes of reception.] An attendant problem is loss of synchronization which occurs after (or rather during) a period of noise. This commonly manifested itself as a shift of image lines to the left, with the right hand side being occupied by a block of white (i.e. high pixel value), then vertical stripes, then horizontal bars. This is then followed (if the shift has been great enough) by part of the image from the visible light channel. Occasionally loss of synchronization caused the lines to move right.

The Macsat package provides a facility for overlay of geographic co-ordinates and coastlines. On the occasions when coastline was indicated to be present in the image and the image was not swamped by cloud, a comparison could be made between the predicted and observed coastlines. This showed errors of several degrees in the geo-referencing. However, it is not clear how the spatial error in one image may be used to correct that in other images of the same satellite. Rather, it would be desirable to tweak the input to the overlay procedure such that minimal error occurred in the cases with visible coastline. The overlay is believed to be calculated purely from the time of reception and knowledge of the satellites' ephemerids. The internal clock on the Mac was corrected regularly to keep errors below about 4 secs (corresponding to $\sim 0.25^\circ$ of latitude). The satellite ephemerids were only updated once during the cruise. The majority of the images featuring land occurred towards the end of the cruise;

application of up to date orbital elements, may give greater confidence to the geo-location in other images. [Recent ephemerids were obtained by fax from Newcastle Computer Services; this took of the order of a week for a reply.]

The coastline database accessed by the Mac was found to be very coarse; the whole of southern Africa being covered by only 6 points, thus when plotted the coastline often consisted of a single straight line. It was found helpful to replace this database with another consisting of the South African coastline at far greater resolution. [The omission of lines of latitude for descending satellite passes (a known bug) *could* be overcome in a similar manner.]

Black and white prints were produced of all reasonable images. Alternatively, a colour scale may be inserted into the grey spectrum to highlight those parts deemed to be sea (a slightly subjective process). After much initial difficulty, some of these coloured images were plotted via the Suns. Selected cases were transferred to the Suns as data files for higher level processing (especially realignment) prior to display.

As stated earlier, a large number of images were eventually received over the whole 6 weeks (sometimes as many as 9 in one day). Those of reasonable quality or better were printed on a laser printer. However, due to shortage of storage space (each image requires over 600 kilobytes of memory), not all could be kept on the Mac. Some attempt was made at archiving via the Suns, but the images lost a little of their functionality, so a process of selective deletion was adopted. Images from the same satellite only 7 minutes apart are consecutive; some have been kept to complement their predecessor, rather than on individual merit. [A program exists on the Suns to produce an image spanning the two originals.]

Results

In all, the Macsat system and processing seemed to be mainly at the "proof of concept" level, as reception of clear images never became routine. It would seem that more care may be required in the installation of the equipment, specifically cutting cable to required length and avoiding coils of it, and a full set of spare parts should be available. The chosen sighting of the aerial may not be ideal (hence leading to some reception problems), but little flexibility exists here. However, the greatest barrier to use of Macsat for oceanographic studies during Swindex was the high degree of cloud cover (not unexpected) combined with the large uncertainties in the geo-referencing of those parts of the ocean that were visible.

List of Images Received

The list below gives all those retained on disk. The notation used follows that of previous cruises: first a satellite identifier (N10, N11 and N12 for NOAA10, NOAA11 and NOAA12 respectively), then the date in the form *ddmmyy*, then time of start of image (GMT), and finally a letter to indicate whether image is of infra-red (I) or visible (V).

The following list is in chronological order of reception:-

N10_280393_1715_I	N12_150493_1623_I	N11_260493_1428_I
N12_280393_1753_I	N12_150493_1630_I	N12_260493_1551_I
N12_280393_1801_I	N10_160493_0227_I	N12_260493_1735_I
N10_280393_1856_I	N12_160493_0352_I	N12_260493_1912_I
N12_290393_0514_I	N10_160493_0412_I	N11_270493_0016_I
N12_290393_0520_I	N12_160493_0533_I	N12_270493_0315_I
N11_290393_1335_I	N11_160493_1306_I	N11_270493_0456_I
N11_290393_1512_I	N12_240493_1813_I	N12_270493_1714_I
N12_290393_1731_I	N11_250493_1437_I	N12_270493_1850_I
N10_290393_1832_I	N12_250493_1751_I	N11_280493_0143_I
N11_020493_0021_I	N12_250493_1758_I	N12_280493_1830_I
N10_150493_0252_I	N12_260493_0516_I	N12_290493_0553_I
N11_150493_1320_I	N12_260493_0522_I	N11_290493_1353_I

It will be noted that after initial success with all 3 satellites, no images were received from NOAA10 in the second half of the cruise. During the middle part of the cruise, the ship's location (i.e. far south) and the then orbits of NOAA10 and NOAA12 meant that they were over the horizon simultaneously. As both emit at 137.50 MHz, some interference between their images might have been expected. However that captured was always that of NOAA12; it is not known whether it had the stronger signal or whether NOAA10 stopped transmitting.

Thermosalinograph

G. Quartly

Equipment

On *Discovery* Cruise 201, a Falmouth Scientific Inc thermosalinograph was used for continuous underway logging of surface temperature, conductivity, fluorescence and transmittance. The equipment consisted of:

- i) Temperature sensor near intake in hull
- ii) Conductivity and temperature sensors situated in the hanger area
- iii) Fluorometer and transmissometer in a tank in the hanger

To calibrate the conductivity cell water samples were taken from the sea water supply to the thermosalinograph every hour and assayed with a salinometer.

The thermosalinograph, and the tank containing the transmissometer and fluorometer were fed from separate header tanks to ensure a steady flow past each of the instruments, and to enable air bubbles to escape from the supply. The header tanks were examined hourly to check levels were constant and on one occasion they were found to be low. This caused a period of poor quality data.

Data processing

Data were collected at a rate of 1Hz, but averaged over one minute intervals before being logged by the RVS system. Real time data were displayed on a PC in the main lab, subsequent processing was done using PSTAR routines. Execs to do much of the preliminary work existed from previous cruises, some adaption was required as measurements from the fluorometer and transmissometer were not recorded then.

The basic underway measurements were used to calculate salinity and merged with navigation data and with salinities determined from bottle samples. The results were then displayed as functions of time, sections of latitude or longitude, or on map projections.

Despite averaging over a minute, the variables showed occasional spikes, which were most prevalent in the salinity values. They were deleted if difference from a local median exceeded a certain tolerance. Two large deviations still remained in the salinity measurements after this. One was due to air bubbles in the thermosalinograph affecting the conductivity cell, the cause of the other is unknown, but as no abrupt changes were observed in the other surface measurements, it is taken to be an

anomaly. Both "features" were deleted. The data from the fluorometer showed a lot of high frequency noise, so were smoothed with a 13-point filter.

Results

Comparison of salinity from the tsg and bottle samples showed the tsg to be about 0.15 psu high. This varied little across fronts or other features. The magnitude of the difference changed a little from sample to sample, which may be attributed to general noise in the measurements, but there were also short term drifts, usually a decrease in the overestimation by the tsg over an interval of 12-48 hours followed by a sharper rise. This was assumed to be due to biological material in the non-toxic supply gradually clumping on the cell and then being washed off as a mass.

At the beginning of the cruise, the bottle salinities were in the region of 35.5 psu. Across each front southwards, there was a decrease. The first front, marked by a decrease in surface temperature from 22.5°C to 18°C, showed little change in salinity. The second one, where temperature changed from 18°C to 14°C had a sharp decrease in salinity from 35.5 to 34.5 psu. The third major change was a reduction in salinity from 34.5 to 34.1 psu coincident with a temperature drop of 2.5°C to 10°C. For most of the southern section of the cruise, salinity showed minimal variation about the value of 34.1, although an unexpectedly large salinity excess was noted near the southern extreme of the second dog-leg.

The transmissivity was predominantly in the range 3900 to 4400 (raw units). Sudden changes in value usually coincided with features in the temperature and salinity profiles, with the lower transmissivity values on the cooler, fresher side of the features. The fluorescence values mainly occupied the range 1100 to 2200 (raw units). Fluorescence, being an indicator of biomass content generally showed a good inverse correlation with transmissivity, the latter showing lack of biological material and suspended matter.

Shipboard computing

The abc system

A. Fem

The Research Vessel Services integrated shipborne distributed data collection and processing system, known as 'The ABC System', is structured using three distinct, modular levels. The first consists of a collection of microprocessor based, firmware controlled, intelligent interfaces which collect, time-stamp, check and filter data from specific scientific or navigation instruments. Each of the

microcomputers at this level is referred to as a 'Level A'. The data collected by each Level A are formatted and packaged using Ship Message Protocol (SMP) for forwarding, via serial RS232 links, to the next level in the networked hierarchy. The Level B data logger collects each of the Level A SMP messages and archives them to disk and quarter inch cartridge tape, thus making data secure as soon as it is available. The Level B monitors message frequencies and provides a central 'window' on data throughput for system operators and watch-keepers. The Level B also provides automatic Level A alarm and data gap monitoring facilities to warn watch-keepers if problems arise. SMP data messages are passed in blocks, via ethernet, from the Level B to the Level C data processing system. The Level C, which is a SUN SPARCstation IPC (4/40) running the UNIX operating system, takes SMP data messages and parses them into a database consisting of RVS format data files. The Level C, along with three other networked SUN SPARCstations constitute the RRS *Discovery's* data processing system. A complete set of data reduction, processing, presentation and archiving software is available. For the purposes of cruise 201 the system became a platform for the PSTAR oceanographic data processing suite.

During cruise 201 the Level B collected over 1,330,000,000 bytes of SMP data. This data was backed up to both disk and cartridge tape. The majority of the data processing was performed using the PSTAR suite. The exception to this was navigation. RVS datafiles were converted to PSTAR data-files using 'datapup'. In view of the length of the cruise and the limited disk space available it was necessary to archive data to tape on a regular basis. The data was normally read into 'Pstar' format within 24 hours of being collected so it was possible to cycle some of the data files quite regularly. No major problems occurred with System hardware and software. However, a bug in the Level A operating system's clock driver software caused irregular time-stamp jumps to occur at midnight 4-4-93 (Jday 094). The problem was later discovered to be related to American Daylight Saving adjustments and a bug report was raised with MICROWARE, the supplier of the operating system software. Raw RVS datafiles were easily fixed using the RVS utility program 'modtime'.

Level A microcomputers and variables logged during cruise 201.

Level A	Datafile	Variables
BOTTLES (1)	bottles	code
CTD_17T (2)	ctd_17	press temp cond trans alt oxyc oxyt temp2 cond2 deltat nframes
GPS_ASH (2)	gps_ash	lat lon hdg pitch roll mrms brms atf sec
GPS_TRIM (2)	gps_trim	lat lon pdop hvel hdg svc s1 s2 s3 s4 s5
GYRO_RVS (2)	gyro_rvs	heading

LOG_CHF (2)	log_chf	speedfa speedps
METLOGGR (PC)	metloggr	windspd winddir pwettemp pdrytemp swettemp sdrytemp seatemp ppar ptir spar stir lwave baro
MX1107 (1)	mx1107	lat lon slt sln el it ct dist dir sat r status
SIM500 (2)	sim500	uncdepth rpow angfa angps
SURFLOG (PC)	surflog	temp_h temp_m cond trans fluor spr30v spr12v
WAVE (1)	wave	height
WINCH (PC)	winch	cabltype cablout rate tension btension comp angle
	adcp_raw	rawampl beamno bindepth
	adcp	bindepth heading temp velew velns velvert velerr ampl good bottomew bottomns depth
	xbt	depth temp

(Brackets after the Level A name indicate whether a MkI, MkII or IBM PC, based Level A was used. ADCP data were collected directly by the Level C through serial port ttya. XBT data were transferred by "walk-net" on 3.5 inch floppy copied from the control PC. Data were parsed and written to the Level C RVS data-files named in column 2 with variables shown in column 3.)

Pstar/archiving

B. de Cuevas

Backup

Backups of the pstar and archive working directories were made daily on exabyte tape throughout the cruise. Because of the good performance of the shipboard computer system, it was never necessary to restore data from backup.

Archive

Archive copies of all processed files were made on Sony erasable magneto-optical disks, mounted as standard UNIX file systems. Optical disks were used extensively for the first time on this cruise. They proved very reliable and extremely easy to use - transparently extending available disk

space. The only note of caution is a tendency to cause the workstation to which the optical disk drive is attached to 'hang' if the disk is unmounted while other processes are running. This is apparently caused by a bug in the disk drive software and necessitates a re-boot of the workstation.

Files were also copied to quarter inch cartridge tapes in UNIX dd (for pstar files) or tar (for ASCII files) format. With only one optical disk drive on board *Discovery*, it is advisable to maintain this secondary archive.

A separate directory was held for the temporary storage of files awaiting archive. It also contained a logfile listing all files already archived, with the names of the relevant optical disk and cartridge tape, as well as the files awaiting archive. Some of the routine processing automatically produced archive copies of files for transfer to this directory. The present archive system was designed as a multi-user system with write protection to avoid multiple simultaneous access to the archive directory and, more specifically, to the logfile. This protection sometimes caused conflicts and would be unnecessary if the responsibility for transferring files to the archive directory rested solely with the archiver. The production of duplicate archive copies of files at regular stages during the processing made it an easy task for the archiver to go through the working directories each day and transfer all files with the .arch extension to archive. If done on a daily basis, the duplication of filespace is not a problem. Responsibility for the removal of files from the working directory must remain with the user.

Moorings

I. Waddington

Eight current meter moorings were deployed for the SWINDEX experiment for a period of up to two years.

Design

IOSDL has previously deployed moorings in the North Atlantic at various locations for periods of 12 to 20 months and has been upgrading and developing materials and assemblies for the SWINDEX application. The moorings were designed at IOSDL to be depth adjustable as the topography at the proposed sites was not well known. Topography was best determined from DBDB5 information by S. Alderson, IOSDL, and approximate mooring designs for the depths run on the IOSDL Static Design Spreadsheet and MOORDSGN, (C.H.Darnall NOAA). Further topographic detail was made available onboard from the new unpublished GEBCO charts kindly made available by Prof R Fisher, Scripps Institute of Oceanography.

Each site was surveyed before deployment to establish topography and a site position and depth determined. The mooring design was then refined to suit the target depth and a revised layout tested on the Static and MOORDSGN programs. Modifications were made to give the best available configuration of sensors and buoyancy.

The moorings were designed as subsurface buoyed full depth types with the main buoyancy consisting of a steel sphere supporting a polypropylene coated steel wire section to 1000m depth. Below this a section of polyester braided line to the sea floor, with glass buoyancy spheres inserted to act as back up buoyancy should the steel sphere fail and to provide stiffening to the mooring to reduce mooring knockdown (Fig. 10).

The coated wires were prepared at IOSDL and were of known length. The polyester lines were prepared at IOSDL of known unstretched length and required stretching under load to establish their length in mooring tension conditions. These lines were stretched overside at convenient moments using the IOSDL mooring winch with known weights attached to the line. A maximum of 2000m of line was deployed over the stern with the vessel hove to and permitted to stretch/wet for several minutes when fully deployed. The line was then hauled in, and each length carefully measured on the IOSDL metre sheave. A selection of lengths was measured before each mooring to ensure an adequate stock of known lengths was available.

Deployment

A deployment scheme had been evolved and tested on RRS *Charles Darwin* Cruise 66 and installed and used successfully on *Discovery* Cruise 200 immediately prior to this deployment.

The moorings were all deployed buoy first from the aft deck through a wide throat sheave suspended on the starboard ACTA crane. The ships speed was adjusted between 0.5 and 1.5 knots to control the line tension throughout the operation. The IOSDL Double Barrel Capstan winch was the primary deployment winch with the ships A frame and Rexroth winch being used to deploy the steel buoyancy spheres. Instruments were inserted by stopping off the mooring line at joints in the mooring line. This was achieved by stopping off the joint to a towing chain on deck and transferring the outboard tension to this chain, the instruments could then be fitted into the line and deployed overside.

With all the mooring deployed astern the ship then increased speed to tension the line for anchor release, or to tow onto position.

Anchor launch was by cutting or slipping a securing line with the anchor overside on the starboard quarter bulwark. The anchor would then freefall to the sea floor. As the anchor was sinking, ships position, time and slant range to the acoustics package were monitored to determine where the

anchor deployed relevant to the launch position. This was established on the earlier moorings on near flat topography to assist positioning of anchor launch for more sloping areas encountered later in the cruise.

All the moorings were deployed successfully and at the correct depths for the instrumentation (Tables 4 & 5, Fig. 2).

The IOSDL Mooring team consisted of:

- I Waddington - Mooring design, deck supervision and topographic surveys.
- K M Goy - Current meters, instrumentation, deck operations.
- D White - Acoustic releases, topographic surveys.
- M Hartman - Current meters, acoustic releases, deck operations, anchor navigation.
- R Bonner - Mooring/current meter hardware, and winch operations.

RRS Discovery.

- M Drayton, boatswain - Deck and winch operations.

Many thanks to the deck crew for assisting in preparation and deployment of all the moorings.

A comprehensive document is in preparation for an IOSDL Internal Report title to be SWINDEX Moorings Technical Report 1993. This document will cover all aspects of design, preparation and deployment of the moorings.

Current meters

K. Goy

A total of 38 Aanderaa current meters and 2 thermistor loggers and chains were deployed on eight moorings A - H. These were a combination of RCM 7/8 and the older type RCM 4/5 instruments, the latter, with the exception of ACM 7401, were all fitted into IOSDL deep pressure cases.

All instruments were overhauled and calibrated at IOSDL prior to the cruise. Additional sensors were fitted to channel 3 on instruments allocated to the 300m and 600m positions on each mooring to record pressure and conductivity respectively and fine temperature ranging resistors were fitted on all current meters to provide higher resolution temperature measurements on channel 4.

Previous experience had shown that the RCM4/5 instruments frequently suffer mechanical misalignment during shipping and it was arranged for final setting up and checking to be done at the Sea Fisheries Research Institute in Cape Town during the two weeks prior to the cruise. All RCM4/5

instruments were checked for mechanical security and encoders and rotary switches reset. ACM 5205 was found to have an open circuit thermistor and other damage consistent with mechanical shock during transportation. The thermistor was replaced and the instrument recalibrated onboard at water depths of 50m, 150m and 250m using ACM 6225 as a calibration standard. All rotor counters were removed and the magnets inspected for security following reports from MAFF that some magnets on their instruments had become detached during shipping.

RCM4/5 and thermistor loggers were powered by the standard Leclanche battery packs and set for the maximum recording interval of 180 mins. This will give a deployment time, before maximum data capacity is achieved, of 3.5 years for the current meters, however the thermistor loggers record data at approx twice the rate and were fitted with extended length magnetic tapes in order to achieve the two year deployment required. The RCM7/8 instruments require a greater battery capacity for their vector averaging sampling regime and were fitted with 10 ampere hour lithium cells specially produced for IOS. The sampling interval on these instruments was set to the maximum of 120mins.

Switch on and first data times revealed two problems not previously encountered while at Sea Fisheries Research Institute. Passivation of the Lithium cell in ACM 10863 and 10862 prevented normal start up on switch on, however on the second attempt switch on was normal. Also problems were encountered with incompatibility of some new DSUs supplied prior to the cruise. These units would not write a timeword when switched on, yet when fitted to another instrument worked normally. This problem also occurred on the cruise 200 and has been referred back to the manufacturers, as yet no explanation has been received.

All deployments were straightforward and no damage to instruments or rotors was observed.

Acoustic releases

D. White

Two acoustic releases were used on each mooring, an IOS CR200 and a MORS RT661. The CR200 was configured to fire a single pyro using both sides of the relay, but was otherwise a standard release.

Each of the RT661s was configured to fire a single pyro using the release motor supply. They were powered by six 10.5V packs of three lithium thionyl chloride D-cells in parallel, with a 15V lithium manganese dioxide CR200 pinger battery to fire the pyro. All six packs were used to power the receiver and logic, four were used to power the pinger and two were used as a back-up for the pyro firing battery. The release was clamped to the CR200 titanium bar with its own titanium clamps and fired a single pyro. There were three different hardware configurations: one unit with the standard ferallium

pressure case and ceramic ring transducer, one unit with the standard pressure case and transducer but with the lifting lug and supporting ring removed and six in IOS hard-anodised aluminium pressure cases with Marine Acoustics' ceramic ring transducers. All eight cases had a single 2-pin XSG connector for firing a pyro.

Details of releases are given in Table 6.

Acoustic release trials

In addition to the usual tests, a number of acoustic ranging trials were carried out on the RT661s after each mooring had been laid. The purpose of this was to assess the acoustic performance of the new releases using standard ship-borne equipment, and to highlight any problems or quirks. The full report "Acoustic Trials of the MORS RT661 and TT301" is to be published as an IOSDL internal document.

Summary of Results

The RT661s were interrogated using a TT301 deck unit through a single element of the PES fish. Pinger signals were observed using an IOSDL waterfall display on a 286 AT-compatible machine through the same transducer. This gave adequate ranges in depths up to 4800m, with results similar to those obtained from the IOS CR200. In the one mooring deeper than this (5900m) the TT301 failed to range on the RT661, although the RT661 responded to 80% of commands, and the pinger was visible up to a similar range to that of the CR200. The RT661s in IOS pressure cases gave the best acoustic performance, with a strong pinger signal and bottom-echo. The ferallium-cased RT661s gave only an adequate signal with little or no bottom-echo. The anticipated improvement in performance by removing the steelwork from around the transducer was not observed. Better acoustic ranges were obtained with the TT301 by using a ceramic ring dunking transducer, as supplied by MORS.

Summary of recommendations

The recommended deck system for recovery and deployment of moorings is two TT301s (one for back-up) working through the single element of a PES fish. Where no PES fish is available, a ceramic ring Dolphin towed fish should be used. A ceramic ring should also be used where greater range is required, e.g. when navigating in a mooring in greater than 5000m of water. The IOSDL waterfall display (and back-up computer and software) should be used for observing pinger signals for watching moorings down, determining ascent/descent rates, observing time of release, etc. The TT301 should not rely on the internal Ni-cad battery but should have its own DC power supply.

If pyros are to be used, the IOS hard-anodised aluminium pressure cases and ceramic ring transducers are recommended. These units are much lighter than the ferallium cases, are compatible

with existing IOSDL hardware and have been proven over many years of use. They also give a better signal in pinger mode. A double acoustic unit with an RT661 and a CR200 or, once the RT661s prove reliable, two RT661s should be used.

Cruise logistics

R. Bonner

Cruise mobilisation.

All of the first four cruises following *Discovery's* conversion have been in the Southern Oceans with IOSDL and JRC staff and equipment participating in all of them. Consequently much of the equipment used for cruise 201 was already on board before the cruise started, and the mobilisation had been an ongoing process since the summer of 1992.

Shipping the variety of Dangerous Goods required on the cruises would have presented many problems due to the IMO regulations controlling their movement in commercial shipping. However this was overcome by taking the opportunity to load these and other items on board the vessel before its departure from the UK. In all, over 11 tons of IOSDL equipment including chemicals, gases, Pyros, buoys and the CTD system were loaded in August 1992 and shipped in this way.

During October the first of the container and airfreight consignments left the UK for Punta Arenas carrying mainly CFC and Chemistry equipment for cruises 199 and 201. Cruise 199 ran the WHP section A11 to Cape Town and was the first of the three consecutive WOCE cruises. At the end of this cruise, the CFC and Chemistry equipment was taken ashore to be set up in a laboratory at the Sea Fisheries Research Institute to be prepared for cruise 201.

Meanwhile in January 1993 the IOSDL Double Barrel Capstan and its associated equipment had been freighted out for the mooring work on cruises 200 and 201.

In February the final shipment of equipment for cruise 201 was loaded at IOSDL. This consisted of two 20ft soft-top containers loaded with anchor chain, floats, ropes, wires, and other mooring hardware, plus a 20ft Dry Freight container carrying current meters, releases and the remaining cruise hardware. This was shipped out earlier than would normally have been necessary to enable mooring team members to re-calibrate current meters at the Sea Fisheries Research Institute in time for the start of cruise 201.

The two soft-top containers were delivered to *Discovery* on her second day in port and their unloading was completed by lunchtime. Unfortunately the dry freight unit couldn't be located by the

agents until mid-afternoon as it had been taken back to the container terminal by mistake before unloading. However once traced the unit was delivered to the vessel in time to finish unloading that day as planned

Altogether over 47 tonnes of equipment were shipped to the vessel and with the exception of the equipment deployed at sea, all was returned to IOSDL at the end of the cruise.

End of cruise-unloading

Three containers were booked to take the cruise equipment back to the UK. A dry freight container (stored in the container space) and two soft-top containers.

Upon arrival in Cape Town, the dry freight container was transferred to the after deck for loading electronic equipment, equipment in cardboard packaging, fragile items and samples. The first soft top container also arrived on the day of docking and was parked on a trailer alongside the ship for loading the CTD multisampler frames, niskin bottles and deck track, plus dry chemicals, empty mooring boxes/rope etc and remaining equipment in aluminium and wooden boxes.

The second soft-top container arrived the following morning for the remaining mooring hardware plus the empty gas cylinders. The containers were returned to the UK in the first week of June.

CRUISE DIARY

Tues 23 March - Day 082

Sailed from Victoria Basin at 2000 local. Immediately went to anchor in Table Bay because of engine problems.

Wed 24 March - Day 083

By late afternoon it was clear the engine problem needed shorebased resources to solve. We returned to a tanker berth in Duncan Dock and Globe Engineering personnel came aboard immediately.

Thurs 25 March - Day 084

Fault found to be caused by a bolt from a cooling fan flap that had become detached and dropped into the motor windings, where it had become jammed between the side of an interpole and the motor armature. Repairs estimated to take 48 hours.

Fri 26 March - Day 085

Excellent workmanship resulted in repairs being completed in time to sail soon after 1700 local. We sailed into a thick sea fog so could not see the Cape Peninsular until the fog lifted near Cape Point. Then full ahead reaching speeds of 13 knots. Clocks were advanced one hour overnight.

Sat 27 March - Day 086

The PES fish was deployed at 0550 (GMT henceforth) and shortly thereafter the winch was tested with a chain clump followed by a shallow CTD cast (CTD12387) over the shelf. All bottles were fired, 12 each at the bottom and the surface, and used for training for new personnel in sampling CFCs, oxygens and salinities. The ADCP was calibrated with a series of 90° turns from 0920-1240. After leaving Agulhas Bank, the first full-depth cast (CTD12388) was successfully completed in 3000m at 1930. The station turned out to be right in the jet of the Agulhas Current, so the ship had to steam at 3.5 knots ENE to keep the wire vertical. During sampling, mooring line was stretched over the stern.

Sun 28 March - Day 087

Two CTD casts (12388-89) to 5000m were worked in Indian Ocean water east of the Agulhas Retroflection. Despite good conditions, the casts could not reach the bottom because of restrictions on the working and peak loads of the winch. Maximum engine revs on passage were also restricted in the warm 22°C waters to avoid overheating, resulting in a maximum speed of 11 knots. After completion of sampling and mooring line stretch tests after each CTD, passage was set over Agulhas Plateau for the first mooring site at 41°S 29°E.

Mon 29 March - Day 088

On passage all day, deploying T5 XBTs every 31n.m. on passage, 9 in all between CTD12389 and the mooring site.

Tues 30 March - Day 089

On arrival at the mooring site at 0412Z, a site survey showed a reasonably flat area, so deployment commenced at 0550. Deployment took 2.75 hours, time for the anchor to fall to the bottom was 0.5 hours, and a careful survey of the release position took a little under an hour. The whole operation lasted 5.75 hrs. After a fulldepth CTD (12391) a couple of miles east of the mooring position, course 141° was set for mooring G with 4 CTDs at 35n.m. intervals and intermediate XBTs.

Wed 31 March - Day 090

CTDs 12392-95 were completed on passage. During one of them, the PES fish was recovered and found to have several fairing clips missing.

Thurs 1 April - Day 091

The mooring site survey revealed that the flattest area was in a trench 5800m deep, part of a long fracture zone. Mooring G was accordingly lengthened and successfully deployed. The weather was sufficiently calm that it was possible to complete a CTD cast (12396) to full depth in the trench without exceeding the RVS guidelines for winch tensions. Course was then set for the next mooring, again with 4 CTDs (12397-12400) at 35 n.m. intervals and intermediate XBTs planned on passage.

Fri 2 April - Day 092

A front causing strong and variable winds forced abandonment of CTD12398 when the cast reached 600m. When the winds did not steady, it was preferred to continue to the next station in order not to delay the mooring programme. At cast 12400 a winch bearing was found to be breaking up. The cast was completed and the bearing replaced with that from the main winch during passage to the mooring position and mooring deployment, so no time was lost.

Sat 3 April - Day 093

Mooring site F was surveyed from 0200-0348 and found to be flattest in the centre of a rift valley. After successful deployment, CTD cast 12401 was done, then a line of 5 casts begun on passage. At 2200Z the ship's master clock apparently leapt forward 4 hours, taking the slaves and level A clocks with it, though by different amounts and at different times. It was found that the CTD level A was not logging during cast 12403, in consequence, and the cast was restarted, after an abortive run, as 12405, after an hour's delay.

Sun 4 April - Day 094

CTDs 12405-8 were completed, including a 1-hour pause after 12406 during which a brush on the main motor was changed and two current meters were lowered over the stern to recalibrate a temperature sensor that had been changed.

Mon 5 April - Day 095

CTD12409 was completed at the position of mooring E after a site survey late on 4th, and the mooring was laid and checked by 0700. During this period, the multisampler was disassembled, cleaned and adjusted. Three CTDs (12410-12) were completed on passage.

Tues 6 April - Day 096

The survey for mooring D revealed a difficult site, at the southern head of a rift valley sloping down to the north with clefts and debris. It was eventually decided to deploy the mooring at a flat site just to the west of the valley, somewhat shallower than planned. After CTD12413 at mooring D, a short line of CTDs was begun on course 210°, SSW from the main track. First a two-hour course perpendicular to the swell was run to allow measurements of the effectiveness of the ship's stabiliser system to be made. The rolling added an element of realism to the fire drill.

Wed 7 April - Day 097

Progress was slowed by 40 knot 350° winds, so the sideline of CTDs was terminated after the third (12416) and course 040° set back to the main survey line. CTDs 12417-19 were completed between moorings D and C.

Thurs 8 April - Day 098

Fairly smooth terrain made deployment of Mooring C relatively easy, the whole operation taking under 4.5 hours. CTD12420 was made at the mooring site. Awkward cross-swells causing rolling made deployment and recovery of the CTD difficult, and it was reported to have hit the ship's side two or three times during recent casts. Repair of the roller extension arm improved the situation by reducing the pendulum length. At the first CTD (12421) on passage east, leakage current when the CTD entered the water (which had been present on several recent casts) required immediate investigation, so the CTD was brought inboard and mooring line stretching undertaken during repair. A connector was found to have worked loose, and was replaced. The cast was reworked as CTD12421 and followed by three further CTDs (12422-4) on passage east.

Good Fri 9 April - Day 099

CTD12425 was worked on arrival at the site of Mooring B, followed by a site survey, deployment and mooring position survey, with all mooring related work completed in under four hours. Three further CTDs (12426-8) were completed on passage east in about 2000m over the eastern end of the Del

Cano Rise (or Crozet Plateau). An increase in northward flow was detected between the last two CTDs over the Rise, even before it descended into the channel west of the Crozet Islands.

Sat 10 April - Day 100

The day was spent surveying the channel, including the topography, position of ADOX mooring P, and CTDs to investigate where the geostrophic flow might be concentrated. CTDs 12429-35 were worked, with 12429-33 in a cross pattern and 12431-35 in a line across the channel. The survey revealed that flow was indeed concentrated on the western side of the channel, and the position of Mooring A was determined as the centre of the cross, about 7 miles west of the ADOX mooring.

Easter Sun 11 April - Day 101

The final CTD 12435 of the west to east survey was completed in the early hours of Easter Day, following which RRS *Discovery* ran into the shallow water around the western Crozet Islands in order to calibrate the ADCP. Courses south, east, west, southwest and north were run in bottom-track mode for long enough (up to three hours) to try to reduce angular errors (caused by GPS inaccuracies in selective availability mode) in the estimation of the misalignment angle of the ADCP installation to 0.1° . These courses took us close to Isle aux Cochons, but the island was disappointingly invisible in sea mist.

Mon 12 April - Day 102

After resurveying the topography around Mooring A, it was successfully laid in good conditions, ending a remarkably fine run of mooring deployments without loss of time. The CTD section has also shown that two of the mooring sites, on the western flank of the Southwest Indian Ridge and in the channel west of Crozet, are in positions where there is a significant northward transport.

We now began the first section south, beginning with three close-spaced CTDs (12436-8) across the south side of the Del Cano Rise to $46^\circ\text{S } 46^\circ\text{E}$.

Tues 13 April - Day 103

From there we turned SSW towards $55^\circ\text{S } 40^\circ\text{E}$, with CTDs planned at nearly 60 n.m. intervals, to see how broad is the span of latitudes that carry most of the ACC transport. At the third CTD down the line (12441) the PES registered a very poor bottom echo significantly shallower than the chart showed. However, the altimeter on the CTD functioned perfectly, and the CTD was lowered as usual to 10 m off the bottom. No reduction in transmittance was seen. Careful examination of the PES trace showed that we must be on the steeply rising scarp of a seamount, and indeed two seamounts could be inferred from the Geosat gravity anomaly map we had on board. Course was therefore set due west (to

go over the first seamount) then due south (to go over the second) en route to the next CTD station. Both seamounts were indeed found, with minimum depths of 1612 and 1388 m over an abyssal seafloor at 4200 - 4300 m. It is proposed to name them Rennell Seamount and Sam Mayl Seamount, the latter after an ex-Master of RRS *Discovery* (Fig. 11).

Wed 14 April - Day 104

Three CTDs (12442-44) were worked, and the Antarctic Convergence crossed. Passage speed overnight was therefore restricted to 6 knots. Positions of the remaining stations on this "45°E" section were adjusted to avoid doing a CTD on top of the Ob Seamount, and to end the section at 54.5°S rather than 55°S, because of time constraint.

Thurs 15 April - Day 105

The restricted night-time speed and need to remain hove to after each station for about an hour during sampling limited CTD casts to only two, 12445-46.

Fri 16 April - Day 106

An iceberg was sighted on radar during the night. The southern end of the "45°E" line was completed with CTDs 12447-48. The next section, "40°E", runs closely up 40°E, with 30 n.m. spacing between CTD casts. Each station is slipped 2' of longitude east until 40°20'E in order to avoid shallow casts over seamounts. After CTD12449, overnight speed was again 6 knots.

Sat 17 April - Day 107

After one CTD (12450) without incident, disaster struck at the second, at 53°S. The CTD signal went immediately after it had been deployed to 10 m. So did the winch. It was soon spotted that the wire had jumped off the shieves on the hangar top which turn it through 90°. This had happened a few times on Cruise 199, and cheek plates had therefore been fitted. These made matters worse, as the wire jammed between the cheek plate and the shieve and all the outer armour parted. It was a long 12 minutes before the senior RVS technician stopped off the wire on top of the gantry. Stirling Jordan's rapid action saved the whole CTD and multisampler, and is highly commended. It is recommended that a strong point and stopping off gear be fitted or quickly accessible, which would allow even quicker action on a future occasion.

Luckily the CTD was only 10 m deep, so it took less than 1.5 hours to retrieve the CTD and multisampler using the crane. The station was abandoned, and we progressed to 52.5°S for CTD12452.

Two further casts (12453-54) were completed overnight before another large iceberg was spotted 12 n.m. ahead, and speed was again restricted to 6 knots.

Sun 18 April - Day 108

Three CTDs (12455-57) were completed crossing the Polar Front before fog restricted overnight speed to 6 knots.

Mon 19 April - Day 109

Four CTDs (12458-61) were completed. Yet another iceberg was spotted on the radar as far north as 48°16'S. Could this have been one of those seen on Cruise 200 some ten weeks earlier at 20°E? If so it has tracked east at 20 cm/s.

Tues 20 April - Day 110

The "40°E" section was completed with CTDs 12462-65. After running up 40°20'E, the last two stations were on a line towards CTD12416, to complete the line run south from station D on 6/7 April, two weeks earlier. RRS *Discovery* then ran back to near 47°S to occupy a section along 47°S from CTD12463 at 40°20'E to 35°E. This section would be in deep (3600 m) water just south of the Del Cano Rise.

Wed 21 April - Day 111

CTD12466 was occupied overnight and CTD12467 in the morning, before the passage west past Marion Island. After overnight fog, the day was clear except for occasional rain-showers, and good views were had of Marion Island and briefly later of Prince Edward Island. The SA *Agulhas* was seen hove to off the South African base, and two C130 transport aircraft flew past, presumably dropping supplies to the base. We proceeded on to CTDs 12468-69.

Thurs 22 April - Day 112

The east-west section was completed with CTD12470-71, ending before noon local time. Weather was good, so passage south towards 52°S was begun at speeds up to 13.6 knots. T5 XBTs were launched every 0.5° to provide some information on where gradients were concentrated in case CTDs needed to be skipped on the return journey.

Fri 23 April - Day 113

After a fast run south, averaging 11.6 knots including slower speeds overnight in case of icebergs, the CTD12472 was completed at 52°S 35°E, intended to be the first of a northward line with 30 n.m. spacing along 35°E. However, passage to 51.5°S took 6.5 hours in worsening weather, and conditions on arrival were unworkable. The station was abandoned.

Sat 24 April - Day 114

By 0000Z, with 50 knot winds from 290°, the ship was forced to heave to, and remain so for most of the day. The spare multisampler frame was smashed from its lashed position on the starboard side. Gear broke loose in the hangar and had to be relashed down. Once conditions had moderated a little, all bottles were removed from the multisampler frame and stowed, the remains of the spare frame were moved to a safer position, and cages on the afterdeck with glass spheres in them were made safe. With the prognosis for a continuing strong westerly airstream north of two lows, the Master recommended we creep northwards as fast as possible. Heading 345°, but set eastward by the wind, passage NNW was made at about 6 knots overnight.

Sun 25 April - Day 115

By daybreak, the weather had moderated enough to resume work. Rather than return to 35°E, it was decided to resume the CTD section from where we were (49°10'S 33°25'E) and work NNE along the Prince Edward Fracture Zone. The start of the first CTD (12473) was delayed for 2.5 hours because, first, the CTD wire kinked as the CTD was lifted off the deck, necessitating retermination, and second, steering control was lost. After that, CTDs 12473-75 were completed without further delay.

Mon 26 April - Day 116

The section through the fracture zone continued with CTDs 12476-79. On recovery from the last of these, three rosette bottles were found to be broken, most probably because one imploded and took the other two with it.

Tues 27 April - Day 117

After occupying the last station in the trench, CTD11480, course was set for Cape Town. CTD positions were chosen to include a station in each of the fracture zones, and remained at 30 n.m. spacing to pin down the Subantarctic and Subtropical Fronts. However, by the last cast of the day,

CTD11483, conditions had become marginal, and it was necessary to alter course and reduce speed while sampling.

Wed 28 April - Day 118

Safety lines were rigged from the hangar door to the starboard quarter to enable XBTs to continue. After CTD12484, speed was restricted to 9 knots, and the number of CTDs remaining needed to be reduced because of restricted scientific time. Station spacing was increased to 60 n.m., with three T5 XBTs between. It appeared that by now we had crossed the Subantarctic Front, and it might be a long way before the Subtropical Front would be crossed. The next station occupied, CTD12485, was south of and in the same trench as the deepest station occupied on the outward leg, CTD12396 near mooring G. The weather had eased, and it appeared that more scientific time would be available.

Thurs 29 April - Day 119

However, by the start of the very next station, CTD12486, conditions had worsened again, as a strong Antarctic low unexpectedly moved north. The cast was therefore restricted to 2000 m. With winds gusting to 60-80 knots, the next CTD station was replaced with an XBT. At 45 n.m. on we tried another CTD (12487) but found that the wire was tending to go slack even when 800 m of wire was paid out. The danger of the wire jumping off the shieve was judged to be too great, and the cast was terminated. It proved to be our last. With the wind and sea close to the quarter, the ship's motion on passage was unpleasant, and progress was slow in severe conditions. Further XBTs were deemed too dangerous, and they too ceased.

Fri 30 April - Day 120

The last stations had been planned for mid-afternoon, but with no sign of the weather abating, and slow passage, no further work proved possible. The ship remained virtually hove-to overnight, and even completion of salinometer analysis was impossible. By 1000Z the wind had backed enough to the southwest that we could alter course to put it on the beam, and increase speed greatly from 3-4 knots to 11 knots. The prospect of arriving late in Cape Town receded.

Sat 1 May - Day 121

On passage all day, with the weather much improved, and the air and water temperatures significantly warmer. Final calibrations were completed, and packing begun. The PSO's RPC took place in the evening, and clocks were put back an hour to South African time at midnight.

Sun 2 May - Day 122

A final ADCP calibration was undertaken from 0800-1400Z, with 30 minute runs on courses 45° either side of the passage track, 310°.

Mon 3 May - Day 123

Docking, planned for 0830B, was delayed until 1530 because of fog that closed the port.

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TABLE 1.
CTD and XBT Station List

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hight off bottom	CFC	O-18
CTD12387	27 Mar	0842	0846	0900	35° 44.6'	20° 26.3'		147	123	24	-	-
CTD12388	27 Mar	1807	1933	2108	36° 53.4'	21° 44.0'		3195	3153	42	-	-
xb201147	28 Mar	0202			37° 26.2'	22° 6.9'	T7	3949				
xb201148	28 Mar	0414			37° 10.3'	22° 8.6'	T5	4258				
CTD12389	28 Mar	0643	0828	1136	37° 35.7'	22° 53.5'		5177	5013	164	Y	-
xb201149	28 Mar	1530			37° 48.5'	23° 52.6'	T5	5387				
CTD12390	28 Mar	1728	1912	2142	37° 59.8'	23° 36.1'		5309*	5011	285	Y	-
xb201150	29 Mar	0206			38° 18.7'	24° 8.3'	T5	4929				
xb201151	29 Mar	0508			38° 36.4'	24° 41.2'	T5	4177				
xb201152	29 Mar	0817			38° 55.0'	25° 14.6'	T5	3173				
xb201153	29 Mar	1119			39° 12.8'	25° 45.8'	T5	2621				
xb201154	29 Mar	1430			39° 31.7'	26° 17.9'	T5	2572				
xb201155	29 Mar	1719			39° 47.8'	26° 52.1'	T5	2508				
xb201156	29 Mar	2001			40° 6.2'	27° 25.0'	T5	2912				
xb201157	29 Mar	2243			40° 23.9'	27° 57.3'	T5	2858				
xb201159	30 Mar	0140			40° 41.9'	28° 32.2'	T5	3783				
CTD12391	30 Mar	1012	1158	1356	41° 6.6'	28° 54.1'		4419	4409	10	Y	Y
xb201160	30 Mar	1739			41° 11.7'	29° 17.0'	T5	4540				
CTD12392	30 Mar	1940	2125	2342	41° 14.8'	29° 39.8'		4781	4771	10	-	-
xb201161	31 Mar	0141			41° 21.0'	30° 1.9'	T5	4575				
CTD12393	31 Mar	0328	0510	0719	41° 24.8'	30° 25.1'		4855	4845	10	-	-
xb201162	31 Mar	0927			41° 29.7'	30° 48.4'	T5	4935				
CTD12394	31 Mar	1112	1259	1500	41° 34.1'	31° 11.1'		4863	4852	11	-	Y
xb201163	31 Mar	1805			41° 17.5'	31° 33.4'	T5	4672				
CTD12395	31 Mar	1941	2125	2342	41° 42.6'	31° 56.2'		4545	4538	7	Y	-
xb201164	1 Apr	0113			41° 46.7'	32° 19.6'	T5	4587				
CTD12396	1 Apr	1115	1342	1556	41° 53.1'	32° 50.5'		5827	5777	50	Y	-
CTD12397	1 Apr	1929	2114	2332	42° 12.4'	33° 32.3'		4889	4877	12	-	Y
xb201167	2 Apr	0054			42° 20.9'	33° 49.3'	T5	4173				
CTD12398	2 Apr	0233	0302	0332	42° 29.5'	34° 10.4'		4694*	625	aborted	-	-
xb201168	2 Apr	0711			42° 38.9'	34° 28.0'	T5	4477				
CTD12399	2 Apr	0903	1052	1320	42° 47.8'	34° 47.7'		4853	4842	11	Y	-

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hght off bottom	CFC	O-18
xb201169	2 Apr	1654			42° 58.1'	35° 7.4'	T5	4325				
CTD12400	2 Apr	1857	2054	2318	43° 9.2'	35° 27.8'		4656	4645	11	-	Y
xb201170	3 Apr	0030			43° 16.2'	35° 45.7'	T7	2575				
CTD12401	3 Apr	0900	1043	1248	43° 22.5'	36° 4.7'		4295	4285	10	Y	-
xb201171	3 Apr	1412			43° 30.4'	36° 17.0'	T7	3030				
CTD12402	3 Apr	1542	1649	1809	43° 39.4'	36° 35.4'		2865	2855	10	-	-
CTD12403	3 Apr	2254								aborted		
CTD12404	3 Apr									aborted		
xb201172	3 Apr	2124			43° 47.6'	36° 52.0'	T7	2440				
CTD12405	3 Apr	2352	0108	0223	43° 54.1'	37° 3.8'		2806	2797	9	Y	-
xb201174	4 Apr	0357			44° 1.4'	37° 24.0'	T7	2483				
CTD12406	4 Apr	0518	0619	0715	44° 9.5'	37° 34.6'		1964	1954	10	-	-
xb201175	4 Apr	0952			44° 16.4'	37° 50.3'	T7	2387				
CTD12407	4 Apr	1120	1238	1406	44° 24.6'	38° 7.3'		3428	3411	17	Y	Y
xb201176	4 Apr	1643			44° 27.2'	38° 19.7'	T7	2727				
CTD12408	4 Apr	1751	1834	1925	44° 31.1'	38° 33.7'		1900	1887	13	-	-
xb201177	4 Apr	2028			44° 34.3'	38° 45.8'	T7	2413				
CTD12409	5 Apr	0000	0122	0249	44° 38.7'	38° 58.7'		3409	3398	11	Y	Y
xb201178	5 Apr	0822			44° 37.1'	39° 17.2'	T7	2271				
CTD12410	5 Apr	0948	1057	1212	44° 35.5'	39° 36.8'		2398	2382	16	-	-
xb201179	5 Apr	1329			44° 35.8'	39° 54.1'	T7	2560				
CTD12411	5 Apr	1458	1559	1700	44° 35.2'	40° 11.8'		2475	2460	15	Y	-
xb201180	5 Apr	1831			44° 34.6'	40° 30.0'	T7	2410				
CTD12412	5 Apr	1954	2048	2200	44° 34.5'	40° 48.1'		2279	2287	12	-	-
xb201182	5 Apr	2336			44° 35.8'	41° 20.2'	T7	2564				
CTD12413	6 Apr	0501	0618	0741	44° 30.6'	41° 27.0'		3144	3133	11	Y	Y
xb201183	6 Apr	1350			44° 47.6'	41° 22.0'	T7	2118				
CTD12414	6 Apr	1613	1708	1807	45° 0.1'	41° 4.9'		2281	2270	11	-	-
xb201184	6 Apr	1920			45° 9.8'	40° 58.8'	T7	2253				
CTD12415	6 Apr	2051	2148	2250	45° 21.4'	40° 52.0'		1993	1983	10	Y	-
xb201185	6 Apr	2351			45° 30.7'	40° 43.2'	T7	1749				
CTD12416	7 Apr	0124	0213	0308	45° 42.0'	40° 33.8'		1941	1927	14	-	Y
CTD12417	7 Apr	1443	1530	1621	44° 33.4'	41° 53.1'		1628	1617	11	-	-
xb201186	7 Apr	1735			44° 32.8'	42° 9.2'	T7	1818				
CTD12418	7 Apr	1846	1933	2031	44° 32.1'	42° 25.3'		2046	2035	11	Y	-
xb201187	7 Apr	2149			44° 31.9'	42° 42.1'	T7	2012				
CTD12419	7 Apr	2300	0002	0107	44° 31.3'	42° 57.9'		2121	2115	6	-	Y

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hight off bottom	CFC	O-18
xb201188	8 Apr	0242			44° 29.2'	43° 14.9'	T7	2261	2366	5	Y	-
CTD12420	8 Apr	0821	0928	1042	44° 27.2'	43° 30.8'		2371		aborted		
CTD12421	8 Apr	1213			44° 29.7'	43° 49.2'	T7	2321				
xb201189	8 Apr	1503	1549	1633	44° 33.2'	44° 7.0'		1599	1591	8	-	Y
CTD12422	8 Apr	1754			44° 33.5'	44° 23.3'	T7	1511				
xb201190	8 Apr	1921	1957	2045	44° 34.9'	44° 40.3'		1539	1528	11	Y	-
CTD12423	8 Apr	2208			44° 37.2'	44° 57.4'	T7	1575				
xb201191	8 Apr	2339	0023	0110	44° 39.0'	45° 15.0'		1709	1702	7	-	-
CTD12424	9 Apr	0221			44° 41.6'	45° 29.8'	T7	1646				
xb201192	9 Apr	0332	0414	0458	44° 44.3'	45° 45.3'		1612	1602	10	Y	Y
CTD12425	9 Apr	0958			44° 49.3'	46° 2.3'	T7	1625				
xb201193	9 Apr	1124	1215	1256	44° 54.8'	46° 18.3'		1665	1655	10	-	-
CTD12426	9 Apr	1427			44° 59.9'	46° 35.8'	T7	1727				
xb201194	9 Apr	1601	1641	1730	45° 5.1'	46° 52.9'		1740	1730	10	-	-
CTD12427	9 Apr	1902			45° 10.4'	47° 10.9'	T7	1972				
xb201196	9 Apr	2031	2122	2224	45° 15.7'	47° 28.2'		2139	2130	9	Y	-
CTD12428	10 Apr	0050	0153	0306	45° 15.0'	47° 59.5'		3059	3049	10	-	Y
CTD12429	10 Apr	0650	0752	0900	45° 25.8'	47° 48.3'		2805	2795	10	Y	-
CTD12430	10 Apr	1144	1241	1336	45° 36.0'	47° 37.0'		2296	2291	5	-	-
CTD12431	10 Apr	1454	1629	1733	45° 35.8'	47° 53.5'		2799	2790	9	-	-
CTD12432	10 Apr	1909	2018	2130	45° 36.5'	48° 8.7'		3033	3025	8	Y	Y
CTD12433	10 Apr	2338	0041	0113	45° 37.3'	48° 33.9'		2796	2787	9	-	-
CTD12434	11 Apr	0403	0502	0607	45° 38.0'	49° 1.1'		2661	2653	8	Y	Y
xb201197	12 Apr	0942			45° 37.4'	47° 19.5'	T7	1673				
CTD12436	12 Apr	1048	1125	1208	45° 44.3'	47° 4.9'		1622	1614	8	-	Y
xb201198	12 Apr	1315			45° 48.7'	46° 49.2'	T7	1577				
CTD12437	12 Apr	1425	1506	1548	45° 52.1'	46° 33.1'		1610	1601	9	Y	-
xb201199	12 Apr	1658			45° 56.2'	46° 17.3'	T7	1841				
CTD12438	12 Apr	1815	1854	1940	45° 59.9'	46° 0.0'		1791	1785	6	-	-
xb201200	12 Apr	2226			46° 26.6'	45° 43.9'	T7	1889				
CTD12439	13 Apr	0121	0230	0330	46° 54.8'	45° 26.7'		3045	3035	10	Y	Y
xb201201	13 Apr	0634			47° 22.7'	45° 9.5'	T7	3582				
CTD12440	13 Apr	0911	1029	1156	47° 46.9'	44° 53.5'		3745	3735	10	-	-
xb201202	13 Apr	1445			48° 16.0'	44° 36.0'	T7	3930				
CTD12441	13 Apr	1702	1826	1938	48° 40.5'	44° 21.6'		3308	3302	6	Y	-
xb201203	14 Apr	0100			49° 8.1'	43° 45.1'	T7	1615				

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hight off bottom	CFC	O-18
CTD12442	14 Apr	0333	0502	0647	49° 33.4'	43° 44.5'		4566	4557	9	Y	Y
xb201204	14 Apr	0946			50° 3.7'	43° 26.1'	T7	4503				
CTD12443	14 Apr	1217	1351	1526	50° 32.7'	43° 9.3'		4345	4356	9	-	-
xb201206	14 Apr	1823			51° 1.8'	42° 47.6'	T7	3448				
CTD12444	14 Apr	2030	2138	2254	51° 21.3'	42° 34.0'		3179	3169	10	Y	-
xb201207	15 Apr	0306			51° 40.7'	42° 16.6'	T7	1928				
CTD12445	15 Apr	0539	0638	0739	51° 59.8'	42° 0.1'		2717	2706	11	-	Y
xb201208	15 Apr	1146			52° 24.8'	41° 39.7'	T7	2464				
CTD12446	15 Apr	1448	1543	1642	52° 49.9'	41° 19.7'		2399	2389	10	Y	-
xb201209	15 Apr	2310			53° 14.2'	41° 1.0'	T7	2588				
CTD12447	16 Apr	0410	0505	0607	53° 40.5'	40° 39.6'		2383	2379	4	-	-
xb201210	16 Apr	0849			54° 6.1'	40° 19.4'	T7	2543				
CTD12448	16 Apr	1135	1248	1350	54° 30.3'	39° 59.9'		2883	2875	8	Y	Y
xb201211	16 Apr	1545			54° 15.4'	40° 1.4'	T7	2751				
CTD12449	16 Apr	1820	1916	2027	54° 0.2'	40° 2.1'		2548	2542	6	-	-
xb201212	16 Apr	2312			53° 45.1'	40° 3.1'	T7	2333				
CTD12450	17 Apr	0143	0236	0328	53° 30.0'	40° 4.1'		2564	2555	9	Y	-
xb201213	17 Apr	0507			53° 15.3'	40° 4.4'	T7	2634		aborted		
CTD12451	17 Apr											
xb201214	17 Apr	0836			52° 58.4'	40° 5.2'	T7	2538				
xb201215	17 Apr	0949			52° 45.0'	40° 7.0'	T7	2614				
CTD12452	17 Apr	1148	1247	1350	52° 29.6'	40° 8.2'		2842	2835	7	Y	Y
xb201216	17 Apr	1515			52° 15.4'	40° 8.5'	T7	2870				
CTD12453	17 Apr	1643	1758	1907	51° 59.8'	40° 9.4'		2975	2966	9	-	-
xb201217	17 Apr	2046			51° 44.8'	40° 10.7'	T7	2879				
CTD12454	17 Apr	2245	0013	0126	51° 29.8'	40° 11.5'		3365	3357	8	Y	-
xb201218	18 Apr	0355			51° 15.7'	40° 12.5'	T7	3404				
CTD12455	18 Apr	0532	0645	0803	51° 0.1'	40° 14.6'		3526	3511	15	-	Y
xb201219	18 Apr	0929			50° 45.1'	40° 15.0'	T7	4153				
CTD12456	18 Apr	1056	1222	1351	50° 30.9'	40° 16.9'		4133	4123	10	Y	-
xb201220	18 Apr	1546			50° 15.3'	40° 1.7'	T7	4302				
CTD12457	18 Apr	1730	1848	2027	50° 0.4'	40° 17.5'		4241	4234	7	-	Y
xb201221	18 Apr	2203			49° 45.1'	40° 19.2'	T7	4224				
CTD12458	19 Apr	0026	0154	0327	49° 30.0'	40° 19.8'		4364	4353	11	Y	-
xb201222	19 Apr	0522			49° 14.9'	40° 19.3'	T7	4243				
CTD12459	19 Apr	0656	0820	0956	49° 0.2'	40° 18.8'		4472	4334	128	-	Y
xb201223	19 Apr	1122			48° 45.0'	40° 20.2'	T7	4898				

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hight off bottom	CFC	O-18
CTD12460	19 Apr	1245	1414	1550	48° 29.5'	40° 21.2'		4404	4395	9	Y	-
xb201224	19 Apr	1715			48° 15.0'	40° 20.6'	T7	4224				
CTD12461	19 Apr	1859	2018	2142	47° 59.2'	40° 21.4'		3968	3924	44	-	Y
xb201225	19 Apr	2256			47° 45.1'	40° 20.0'	T7	4030				
CTD12462	20 Apr	0016	0132	0253	47° 29.5'	40° 19.3'		3931	3921	10	-	-
xb201226	20 Apr	0416			47° 15.0'	40° 19.7'	T7	3698				
CTD12463	20 Apr	0544	0652	0811	46° 59.9'	40° 19.7'		3559	3542	17	Y	-
xb201227	20 Apr	0912			46° 48.1'	40° 21.5'	T7	3417				
CTD12464	20 Apr	1019	1125	1232	46° 36.4'	40° 23.6'		3222	3214	8	-	Y
xb201228	20 Apr	1340			46° 24.4'	40° 25.2'	T7	3110				
CTD12465	20 Apr	1449	1545	1653	46° 12.3'	40° 27.7'		2882	2871	11	Y	-
CTD12466	20 Apr	2242	2354	0110	46° 56.5'	39° 33.2'		3520	3511	9	-	Y
xb201229	21 Apr	0311			46° 53.6'	39° 10.2'	T7	3696				
CTD12467	21 Apr	0444	0554	0716	46° 51.8'	38° 46.1'		3635	3625	10	Y	-
xb201230	21 Apr	1715			46° 57.0'	36° 48.7'	T7	3739				
CTD12468	21 Apr	1320	1429	1548	46° 53.6'	37° 10.3'		3411	3403	8	-	-
CTD12469	21 Apr	1837	2003	2130	47° 0.0'	36° 29.2'		3871	3864	7	-	-
xb201231	21 Apr	2303			47° 0.0'	36° 6.1'	T7	3822				
CTD12470	22 Apr	0031	0149	0305	47° 0.0'	35° 45.0'		3658	3650	8	-	-
xb201232	22 Apr	0430			47° 0.1'	35° 22.8'	T7	3453				
CTD12471	22 Apr	0556	0708	0830	47° 0.0'	34° 59.8'		3657	3651	6	-	-
xb201233	22 Apr	1100			47° 30.1'	35° 0.1'	T5	3418				
xb201234	22 Apr	1321			47° 59.8'	35° 0.5'	T5	3608				
xb201236	22 Apr	1546			48° 30.5'	35° 0.5'	T5	3333				
xb201237	22 Apr	1806			49° 0.2'	36° 0.2'	T5	3897				
xb201239	22 Apr	2025			49° 31.1'	35° 0.2'	T5	3970				
xb201240	22 Apr	2240			50° 1.0'	34° 59.9'	T5	2752				
xb201241	23 Apr	0125			50° 30.1'	35° 0.0'	T5	4094				
xb201242	23 Apr	0445			50° 59.9'	34° 59.9'	T5	3123				
xb201243	23 Apr	0735			51° 29.9'	35° 0.5'	T5	5581				
CTD12472	23 Apr	1021	1205	1405	52° 1.3'	35° 0.3'		4867	4859	8	Y	Y
CTD12473	25 Apr	0704	0839	1014	49° 10.0'	33° 25.0'		4257	4243	14	Y	Y
xb201244	25 Apr	1155			48° 53.5'	33° 29.9'	T7	4371				
CTD12474	25 Apr	1334	1504	1633	48° 37.4'	33° 38.1'		4304	4384	20	-	-
xb201245	25 Apr	1815			48° 20.5'	33° 43.8'	T7	3978				
CTD12475	25 Apr	1950	2128	2315	48° 4.5'	33° 53.3'		4795	4784	11	Y	-
xb201246	26 Apr	0103			47° 47.0'	34° 1.3'	T7	3991				

Station	Date	Time Start	(gmt) Down	End	Latitude (S)	Longitude (E)	XBT Type	Depth (corr m)	Depth of cast (m)	Hight off bottom	CFC	O-18
CTD12476	26 Apr	0243	0413	0550	47° 29.8'	34° 10.8'		4643	4630	13	-	Y
xb201247	26 Apr	0721			47° 15.2'	34° 19.3'	T7	4576				
CTD12477	26 Apr	0850	1022	1200	47° 0.0'	34° 30.4'		4525	4514	11	Y	-
xb201248	26 Apr	1322			46° 45.2'	34° 34.6'	T7	4683				
CTD12478	26 Apr	1454	1628	1814	46° 29.8'	34° 44.2'		4776+	4571	204+	-	-
xb201249	26 Apr	1936					T7	4050				
CTD12479	26 Apr	2108	2239	0018	46° 2.0'	34° 52.3'		4671	4659	12	Y	Y
xb201251	27 Apr	0215			45° 45.7'	34° 55.8'	T7	5325				
CTD12480	27 Apr	0354	0519	0634	45° 30.9'	34° 59.9'		3710	3696	14	-	-
xb201252	27 Apr	0819			45° 19.7'	34° 40.7'	T7	2203				
CTD12481	27 Apr	1012	1139	1313	45° 8.8'	34° 21.3'		4255	4247	8	Y	Y
xb201253	27 Apr	1500			44° 59.6'	34° 6.5'	T7	3476				
CTD12482	27 Apr	1656	1832	2008	44° 50.7'	33° 50.6'		4433	4418	15	-	Y
xb201254	27 Apr	2154			44° 41.9'	33° 36.2'	T7	4868				
CTD12483	27 Apr	2346	0125	0319	44° 34.4'	33° 21.5'		4730*	4500	230	Y	-
xb201255	28 Apr	0006			44° 23.3'	33° 5.6'	T7	3654				
CTD12484	28 Apr	0758	0945	1120	44° 13.4'	32° 49.7'		4209	4162	47	-	Y
xb201256	28 Apr	1312			44° 3.1'	32° 33.9'	T7	4384				
xb201257	28 Apr	1449			43° 52.9'	32° 18.4'	T5	4114				
xb201258	28 Apr	1629			43° 43.2'	32° 2.3'	T5	5264				
CTD12485	28 Apr	1759	1940	2130	43° 34.3'	31° 50.7'		5778*	5014	764	Y	-
xb201259	28 Apr	2329			43° 24.2'	31° 35.1'	T5	5382				
CTD12486	29 Apr	0136	0228	0309	43° 14.0'	31° 20.6'		5356*	2007	3349	-	Y
xb201261	29 Apr	0556			43° 4.1'	31° 5.2'	T5	5232				
xb201262	29 Apr	0756			42° 54.1'	30° 50.2'	T5	5310				
CTD12487	29 Apr	1016	1055	11328	42° 44.8'	30° 33.3'		5243*	881	4362	Y	-
xb201264	29 Apr	1151			42° 45.1'	30° 33.4'	T5	5227				
xb201265	29 Apr	1401			42° 34.8'	30° 18.2'	T5	4504				

*prodep

TABLE 2.
Salinometer Standardisation

station/tsg	standard	K15*2	measured	correction	standard'n
12387	120	1.9997	1.99997	-27	236
12387	120	1.9997	1.99997	-27	236
12388	120	1.9997	2	-30	236
12389	120	1.9997	2	-30	236
12390	120	1.9997	2.00001	-31	236
tsg 087	120	1.9997	1.99999	-29	236
tsg 088	120	1.9997	2	-30	236
12391	120	1.9997	2.00003	-33	236
tsg 089	120	1.9997	2.00006	-36	236
12392	120	1.9997	2.00002	-32	236
12393	120	1.9997	2.00003	-33	236
tsg 090	120	1.9997	2.00003	-33	236
12394	120	1.9997	2.00003	-33	236
12395	120	1.9997	2	-30	236
tsg 091	120	1.9997	2	-30	236
12396	120	1.9997	2.00002	-32	236
12397	120	1.9997	1.99999	-29	236
tsg 092	120	1.9997	2.00001	-31	236
12398					
12399	120	1.9997	2.00002	-32	236
12400	120	1.9997	2	-30	236
tsg 093	120	1.9997	2	-30	236
12401	120	1.9997	2	-30	236
tsg 094	120	1.9997	2.00002	-32	236
12402	120	1.9997	2	-30	236
12403					
12404					
12405	120	1.9997	2.00001	-31	236
12406	120	1.9997	2	-30	236
12407	120	1.9997	2.00001	-31	236
12408	120	1.9997	2.00002	-32	236
12409a	120	1.9997	2.00003	-33	236
12409b	120	1.9997	1.9997	0	167
12410	120	1.9997	2.00001	-31	236
tsg 095	120	1.9997	2.00001	-31	236
12411	120	1.9997	2.00003	-33	236
12412	120	1.9997	2.00005	-35	236
12413	120	1.9997	1.9997	0	167
tsg 096	120	1.9997	1.99967	3	167
12414	120	1.9997	1.99969	1	167
12415	120	1.9997	1.99969	1	167
12416	120	1.9997	1.9997	0	167
12417	120	1.9997	1.99969	1	167
tsg 097	120	1.9997	1.99969	1	167
12418	120	1.9997	1.9997	0	167
12419	121	1.9997	1.99973	-3	167
12420	121	1.9997	1.99973	-3	167
12421					
12422	121	1.9997	1.99976	-6	167
12423	121	1.9997	1.99977	-7	167
12424	121	1.9997	1.99975	-5	167
12425	121	1.9997	1.99977	-7	167

station/tsg	standard	K15*2	measured	correction	standard'n
tsg 098	121	1.9997	1.99977	-7	167
12426	121	1.9997	1.99977	-7	167
12427	121	1.9997	1.99975	-5	167
tsg 099	121	1.9997	1.99976	-6	167
12428	121	1.9997	1.99976	-6	167
12429	121	1.9997	1.99976	-6	167
12430	121	1.9997	1.99977	-7	167
12431	121	1.9997	1.99976	-6	167
tsg 100	121	1.9997	1.99976	-6	167
12432	121	1.9997	1.99976	-6	167
12433	121	1.9997	1.99977	-7	167
12434	121	1.9997	1.99977	-7	167
12435	121	1.9997	1.99977	-7	167
tsg 101	121	1.9997	1.99976	-6	167
12436	121	1.9997	1.99976	-6	167
12437	121	1.9997	1.99976	-6	167
tsg 102	121	1.9997	1.99979	-9	167
12438	121	1.9997	1.99979	-9	167
12439	121	1.9997	1.99979	-9	167
12440	121	1.9997	1.99978	-8	167
12441	121	1.9997	1.99978	-8	167
tsg 103	121	1.9997	1.99977	-7	167
12442	121	1.9997	1.99978	-8	167
tsg 104	121	1.9997	1.99977	-7	167
12443	121	1.9997	1.99977	-7	167
12444	121	1.9997	1.99977	-7	167
12445	121	1.9997	1.99977	-7	167
tsg 105	121	1.9997	1.99977	-7	167
12446	121	1.9997	1.99977	-7	167
12447	121	1.9997	1.99978	-8	167
12448	121	1.9997	1.99978	-8	167
tsg 106	121	1.9997	1.99978	-8	167
12449	121	1.9997	1.99978	-8	167
12450	121	1.9997	1.99978	-8	167
12451					
12452	121	1.9997	1.99979	-9	167
tsg 107	115	1.99972	1.99992	-20	167
12453	121	1.9997	1.99975	-5	167
12454	115	1.99972	1.99991	-19	167
12455	115	1.99972	1.99991	-19	167
12456	115	1.99972	1.99991	-19	167
tsg 108	115	1.99972	1.9999	-18	167
12457	115	1.99972	1.99992	-20	167
12458	115	1.99972	1.99992	-20	167
tsg 109	115	1.99972	1.99992	-20	167
12459	115	1.99972	1.99992	-20	167
12460	115	1.99972	1.99992	-20	167
12461	115	1.99972	1.99992	-20	167
12462	115	1.99972	1.99991	-19	167
12463	116	1.99962	1.99981	-19	167
12464	116	1.99962	1.9998	-18	167
12465	116	1.99962	1.9998	-18	167
tsg 110	116	1.99962	1.99976	-14	167
12466	116	1.99962	1.99979	-17	167
12467	116	1.99962	1.99979	-17	167
12468	116	1.99962	1.99977	-15	167

station/tsg	standard	K15*2	measured	correction	standard'n
tsg 111	116	1.99962	1.99977	-15	167
12469	116	1.99962	1.99978	-16	167
12470	116	1.99962	1.99978	-16	167
12471	116	1.99962	1.99979	-17	167
tsg 112	115	1.99972	1.99991	-19	167
12472	115	1.99972	1.99991	-19	167
tsg 113	115	1.99972	1.99991	-19	167
tsg114	115	1.99972	1.99991	-19	167
12473	115	1.99972	1.99992	-20	167
12474	115	1.99972	1.99992	-20	167
tsg 115	115	1.99972	1.99993	-21	167
12475	115	1.99972	1.99994	-22	167
12476	115	1.99972	1.99994	-22	167
12477	115	1.99972	1.99995	-23	167
tsg 116	115	1.99972	1.99997	-25	167
12478	115	1.99972	1.99995	-23	167
12479	115	1.99972	1.99995	-23	167
12480	115	1.99972	1.99994	-22	167
tsg 117	115	1.99972	1.99995	-23	167
12481	115	1.99972	1.99992	-20	167
12482	115	1.99972	1.99994	-22	167
12483	115	1.99972	1.99997	-25	167
12484	115	1.99972	1.99997	-25	167
tsg 118	115	1.99972	1.99998	-26	167
12485	115	1.99972	1.99997	-25	167
12486	115	1.99972	1.99998	-26	167
12487	115	1.99972	1.99998	-26	167
tsg 119	115	1.99972	1.99996	-24	167
tsg 120	115	1.99972	1.99996	-24	167

TABLE 3.

CTD Oxygen spline calibration

Station	rho	rms error μmol/l	Station	rho	rms error μmol/l
CTD12388	1.1443	2.108	CTD12440	1.3409	1.440
CTD12389	1.1517	2.187	CTD12441	1.3433	0.994
CTD12390	1.2196	1.350	CTD12442	1.3432	1.060
CTD12391	1.2332	1.726	CTD12443	1.3433	1.841
CTD12392	1.2910	1.204	CTD12444	1.3572	0.587
CTD12393	1.2966	0.981	CTD12445	1.3266	0.494
CTD12394	1.2940	1.499	CTD12446	1.3283	0.445
CTD12395	1.3081	1.644	CTD12447	1.3437	1.189
CTD12396	1.2971	1.140	CTD12448	1.3285	0.724
CTD12397	1.3109	1.266	CTD12449	1.3417	0.897
CTD12399	1.3103	0.665	CTD12450	1.3178	0.400
CTD12400	1.3176	0.900	CTD12452	1.2422	0.865
CTD12401	1.3112	0.696	CTD12453	1.3211	0.670
CTD12402	1.3168	1.586	CTD12454	1.3443	1.074
CTD12405	1.3260	0.859	CTD12455	1.3489	1.103
CTD12406	1.3237	0.932	CTD12456	1.3212	0.837
CTD12407	1.3346	1.078	CTD12457	1.3123	1.081
CTD12408	1.3385	0.926	CTD12458	1.3027	0.468
CTD12409	1.3318	1.964	CTD12459	1.3118	0.695
CTD12410	1.3159	1.148	CTD12460	1.3079	0.467
CTD12411	1.3119	1.796	CTD12461	1.3108	1.064
CTD12412	1.3165	0.771	CTD12462	1.3068	0.923
CTD12413	1.3087	1.158	CTD12463	1.3160	0.797
CTD12414	1.3010	0.901	CTD12464	1.3067	0.915
CTD12415	1.2999	0.430	CTD12465	1.2970	0.819
CTD12416	1.3056	0.759	CTD12466	1.3088	0.858
CTD12417	1.3104	1.180	CTD12467	1.2974	0.845
CTD12418	1.3087	1.153	CTD12468	1.2663	0.886
CTD12419	1.3032	0.293	CTD12469	1.3047	0.996
CTD12420	1.2930	0.961	CTD12470	1.3377	0.957
CTD12422	1.2732	0.613	CTD12471	1.3493	1.043
CTD12423	1.3101	1.738	CTD12472	1.3231	0.737
CTD12424	1.3090	2.466	CTD12473	1.3033	0.598
CTD12425	1.3208	1.638	CTD12474	1.3299	0.885
CTD12426	1.2730	0.720	CTD12475	1.3396	0.891
CTD12427	1.2882	0.711	CTD12476	1.3458	1.556
CTD12428	1.3213	0.971	CTD12477	1.3364	0.822
CTD12429	1.3264	0.498	CTD12478	1.3393	0.751
CTD12430	1.3482	0.540	CTD12479	1.3250	0.899
CTD12431	1.3427	1.203	CTD12480	1.3387	0.918
CTD12432	1.3456	0.874	CTD12481	1.3098	0.857
CTD12433	1.3464	1.198	CTD12482	1.3281	1.239
CTD12434	1.3341	0.767	CTD12483	1.3225	0.974
CTD12435	1.3329	0.404	CTD12484	1.3154	1.153
CTD12436	1.3393	0.690	CTD12485	1.3123	1.277
CTD12437	1.3414	0.226	CTD12486	1.3214	1.100
CTD12438	1.3437	0.602	CTD12487	1.3257	2.600
CTD12439	1.3276	0.703			

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 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" 638m	9x17" glass 1170m	10x17" glass 1391m	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" 1914m	4x17"+4x16" 1914m	5x17"+3x16" 2155m	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.
Current meters

MOORING A

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
2108	IOS	1700 GMT 07-4-93	180 MINS	32
T.L 806 / CHAIN 1723		1700 GMT 07-4-93	180 MINS	N/A
4738	IOS	1700 GMT 11-4-93	180 MINS	32
10852	RCM7	0500 GMT 08-4-93	120 MINS	N/A
7945	IOS	1700 GMT 07-4-93	180 MINS	32
10279	RCM8	1500 GMT 07-4-93	120 MINS	N/A
10277	RCM8	1500 GMT 07-4-93	120 MINS	N/A

MOORING B

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
6225	IOS	1700 GMT 04-4-93	180 MINS	32
7948	IOS	1700 GMT 04-4-93	180 MINS	32
10864	RCM8	1700 GMT 04-4-93	120 MINS	N/A

MOORING C

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
5205	IOS	1700 GMT 04-4-93	180 MINS	32
10863	RCM7	1700 GMT 02-4-93	120 MINS	N/A
3624	IOS	1700 GMT 02-4-93	180 MINS	32
10274	RCM8	1500 GMT 02-4-93	120 MINS	N/A

MOORING D

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
5204	IOS	1700 GMT 31-3-93	180 MINS	32
T.L 879 / CHAIN 1722		1700 GMT 31-3-93	180 MINS	N/A
10857	RCM7	1500 GMT 31-3-93	120 MINS	N/A
3727	IOS	1700 GMT 31-3-93	180 MINS	32
10276	RCM7	1500 GMT 31-3-93	120 MINS	N/A
10281	RCM7	1700 GMT 31-3-91	120 MINS	N/A

MOORING E

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
7401	RCM4	1700 GMT 29-3-93	180 MINS	32
9589	RCM7	1500 GMT 29-3-93	120 MINS	N/A
6867	IOS	1700 GMT 29-3-93	180 MINS	32
9648	RCM8	1500 GMT 29-3-93	120 MINS	N/A
9965	RCM8	1500 GMT 29-3-93	120 MINS	N/A

MOORING F

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
7517	IOS	1700 GMT 28-3-93	180 MINS	32
9587	RCM7	1500 GMT 28-3-93	120 MINS	N/A
7943	IOS	1700 GMT 28-3-93	180 MINS	32
10275	RCM8	1500 GMT 28-3-93	120 MINS	N/A
10273	RCM8	1500 GMT 28-3-93	120 MINS	N/A

MOORING G

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
8010	IOS	1700 GMT 27-3-93	180 MINS	32
9588	RCM7	1500 GMT 27-3-93	120 MINS	N/A
1260	IOS	1700 GMT 27-3-93	180 MINS	32
10278	RCM8	1500 GMT 27-3-93	120 MINS	N/A
10280	RCM8	1700 GMT 27-3-93	120 MINS	N/A

MOORING H

ACM No	TYPE	1st DATA	SAMPLING INTERVAL	RPC
1259	IOS	1700 GMT 23-3-93	180 MINS	32
9590	RCM7	1500 GMT 27-3-93	120 MINS	N/A
6372	IOS	1700 GMT 23-3-93	180 MINS	32
3726	IOS	1700 GMT 23-3-93	180 MINS	N/A
9963	RCM8	1500 GMT 27-3-93	120 MINS	N/A

TABLE 6.

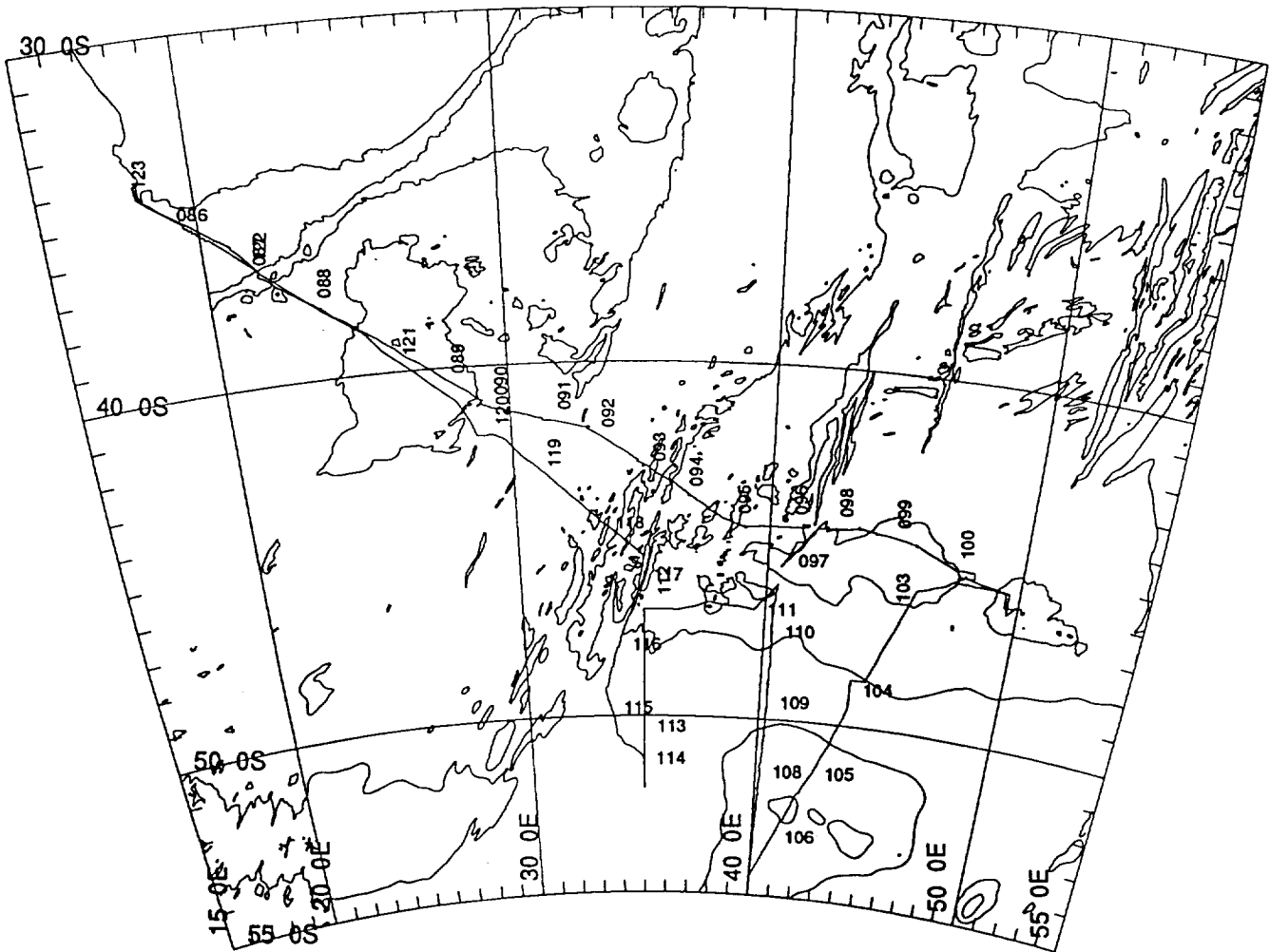
Acoustic Releases

Mrg	Release	CR200 frequency RT661 code	rep rate	No 10s bursts of FM
H	CR2417 RT62	316-323/397-402 62AX	1.18s	Timer
G	CR2385 RT58	314-321/336-343 64BX	1.04s	6
F	CR2521 RT55	316-325/437-445 42BX	1.08s	5
E	CR2557 RT64	317-323/454-467 62BX	1.00s	9
D	CR2314 RT66	315-325/336-344 40AX	1.02s	12
C	CR2522 RT54	316-325/456-463 42AX	1.06s	14
B	CR282 RT60	315-321/354-364 20AX	1.04s	6
A	CR2519 RT57	315-324/297-305 64AX	1.14s	5

RT661 command codes:

ON	X=2
PINGER	X=D
OFF	X=3
DIAGNOSTIC	X=7 (Wait 17-90s before next code)
WINDOW	X=1
RELEASE	X=11 (remove 3rd number of RT's code, A or B)

e.g. to release RT57 send 64A1 wait 17-90s 6411



TRANSVERSE MERCATOR PROJECTION

GRID NO. 1

SCALE 1 TO 20000000 (NATURAL SCALE AT C.M.)

C.M. 35E International Spheroid

RRS Discovery 201 - SWINDEX 1993 R. Pollard JRC

+

Scaled to fit

Figure 1a. Track chart of RRS *Discovery* Cruise 201, 23 Mar - 03 May 1993. Track annotated with day of year.

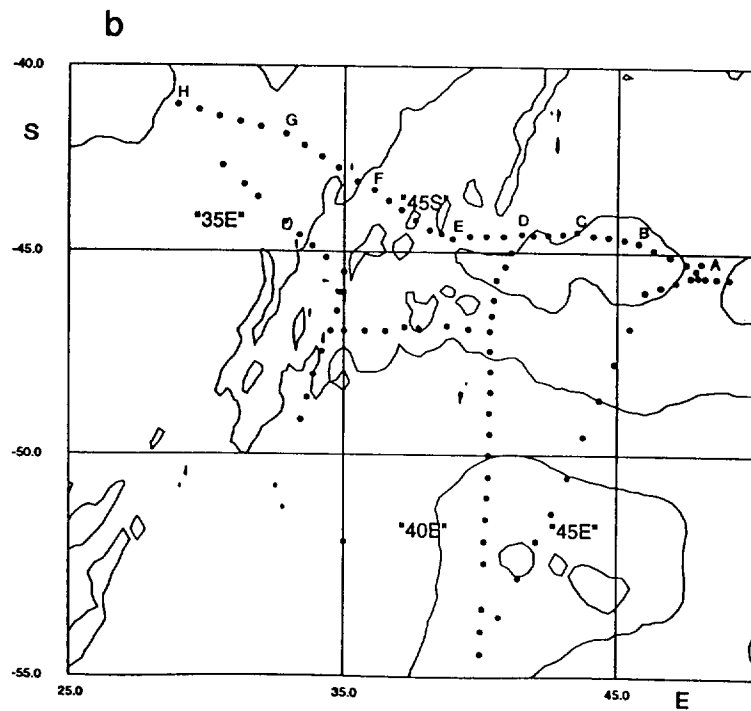
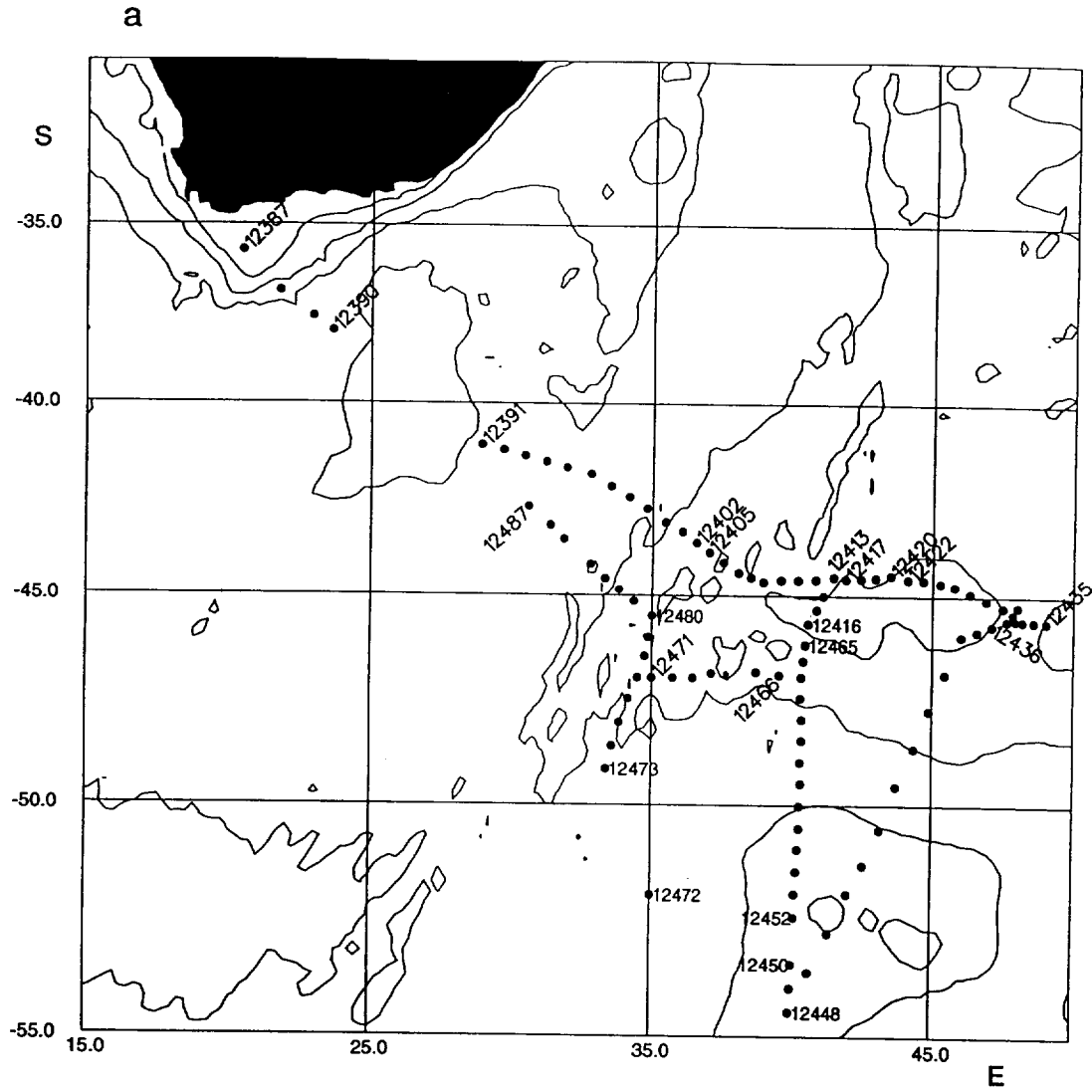


Figure 1. b) CTD station locations with isobaths of 2000m and 4000m superimposed. c) Mooring positions (A-H) and CTD station sections.

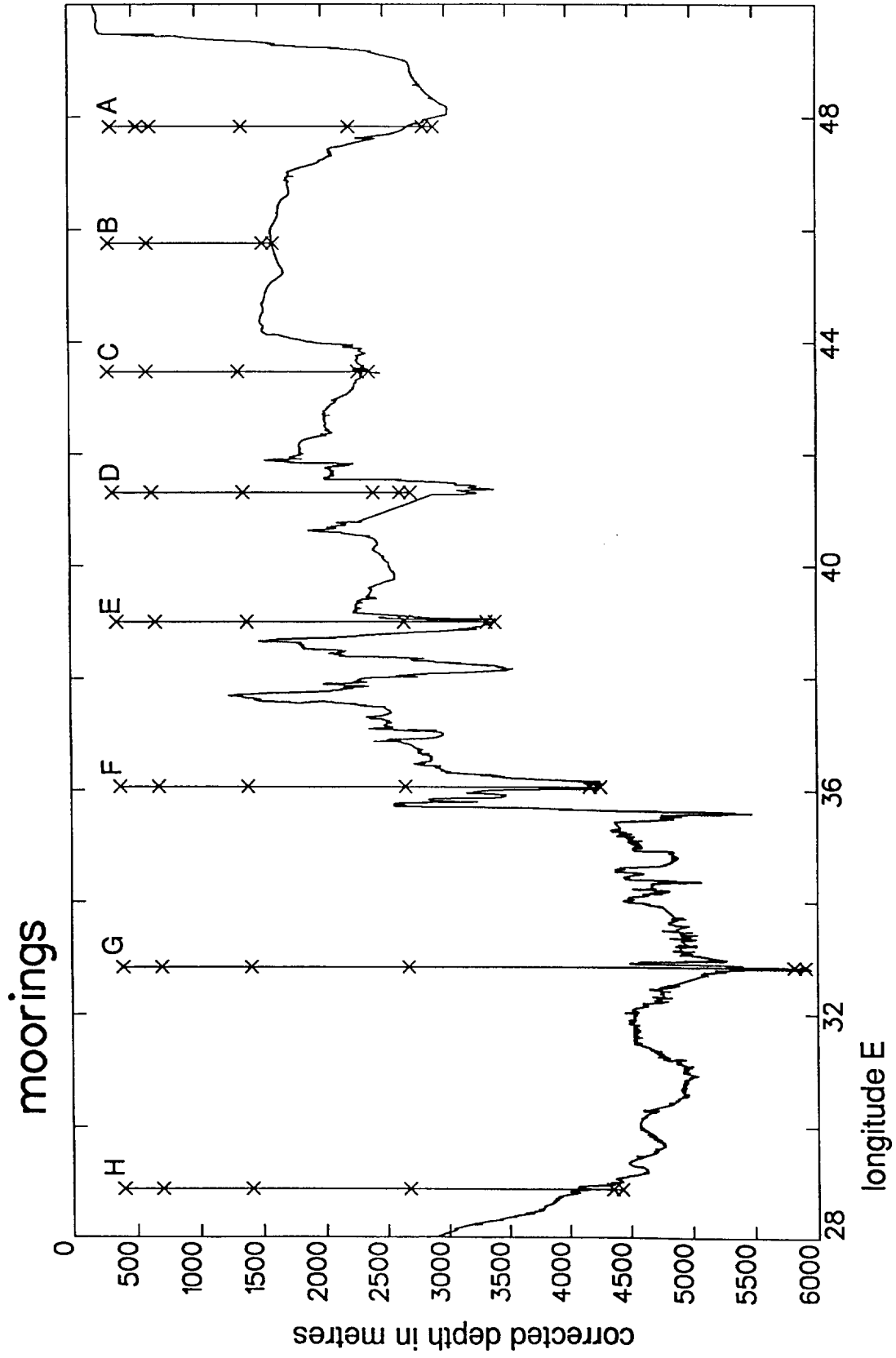


Figure 2. Depth and topography of moorings

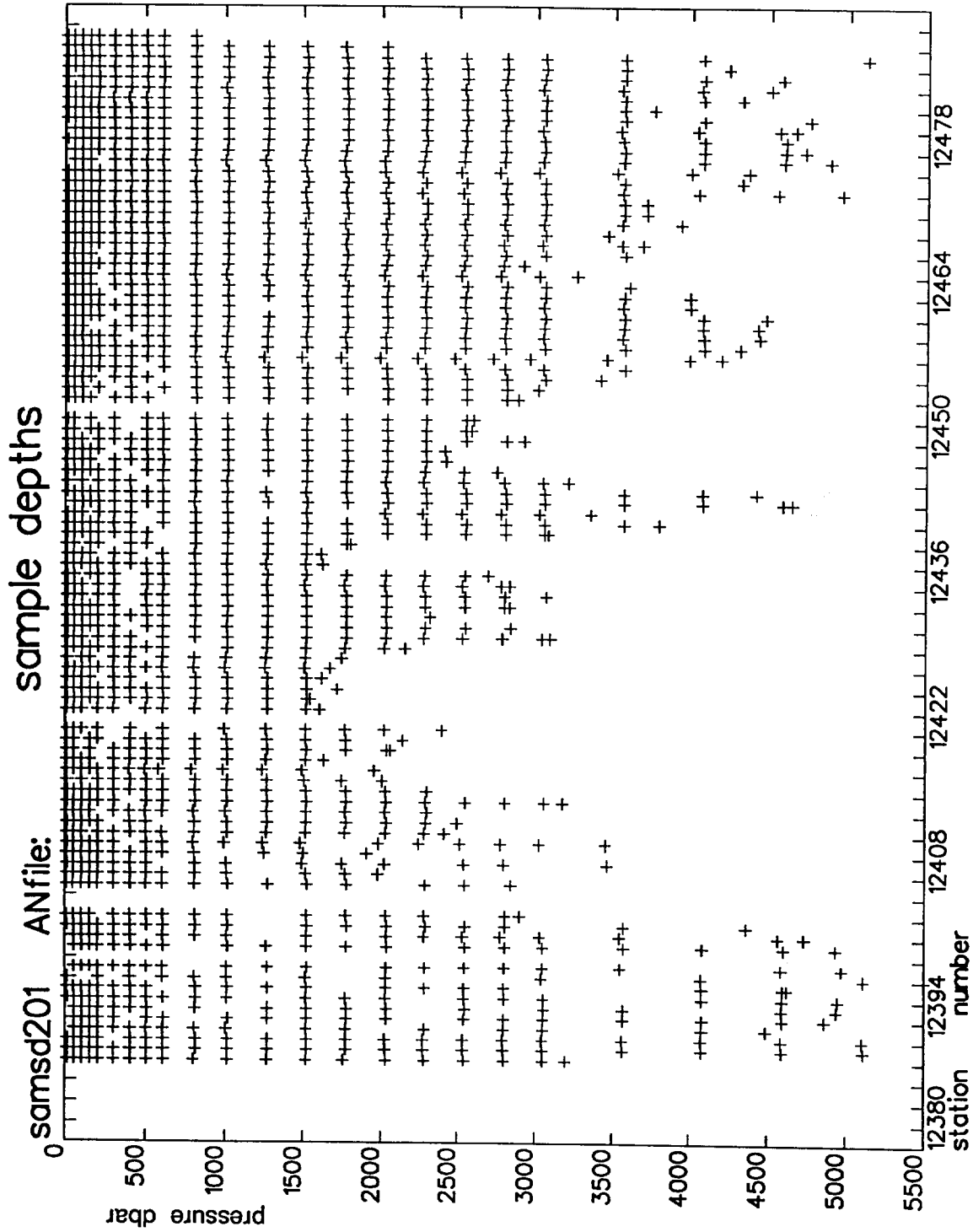


Figure 3. Vertical distribution of sample depths

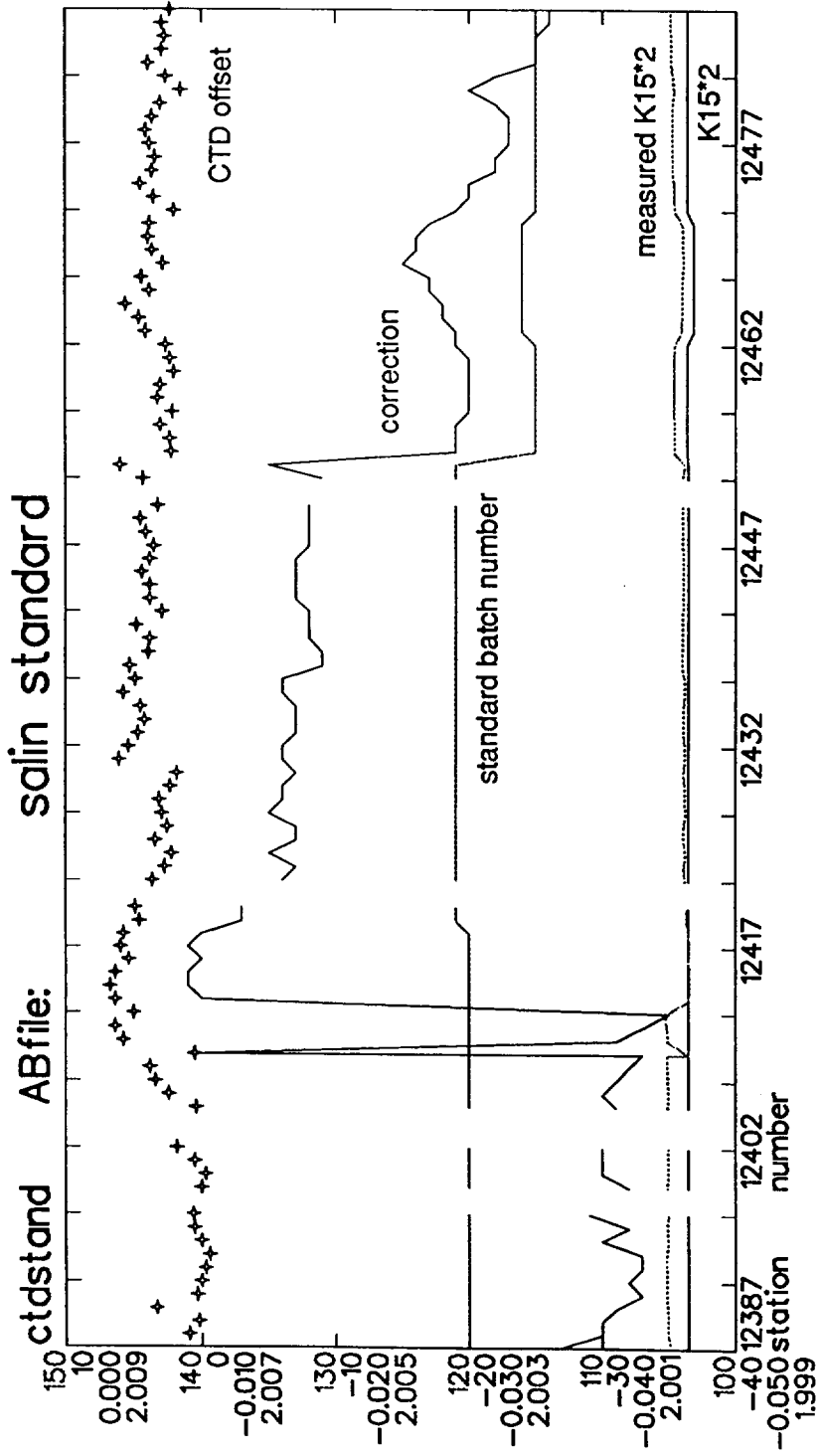


Figure 4. Bottle-CTD offset (psu) for each station as used to correct the CTD salinities, together with the standard sea water batch number, the labelled and measured conductivity ratio (K15) and the salinometer correction value.

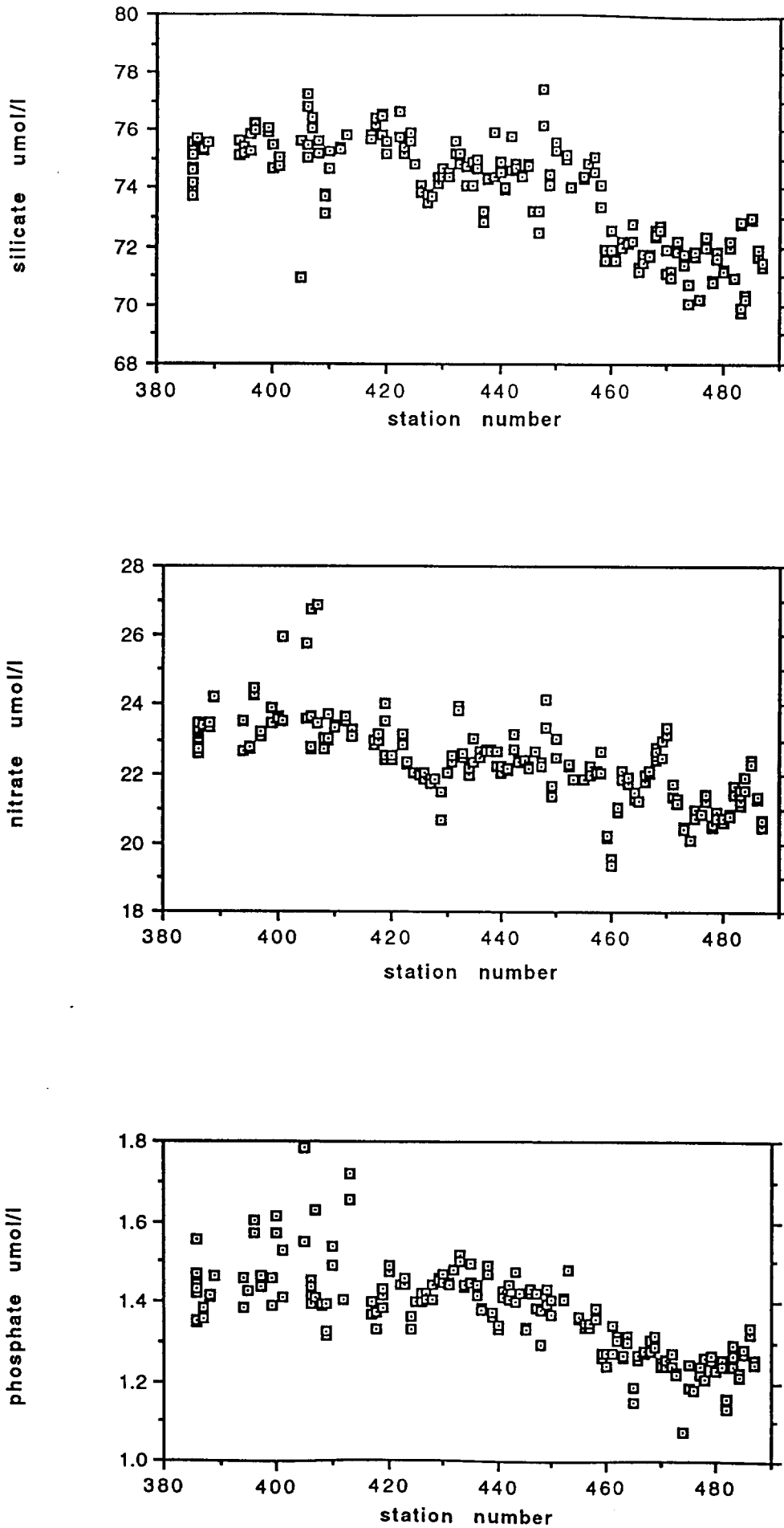


Figure 5. Drift of quality control sample between stations

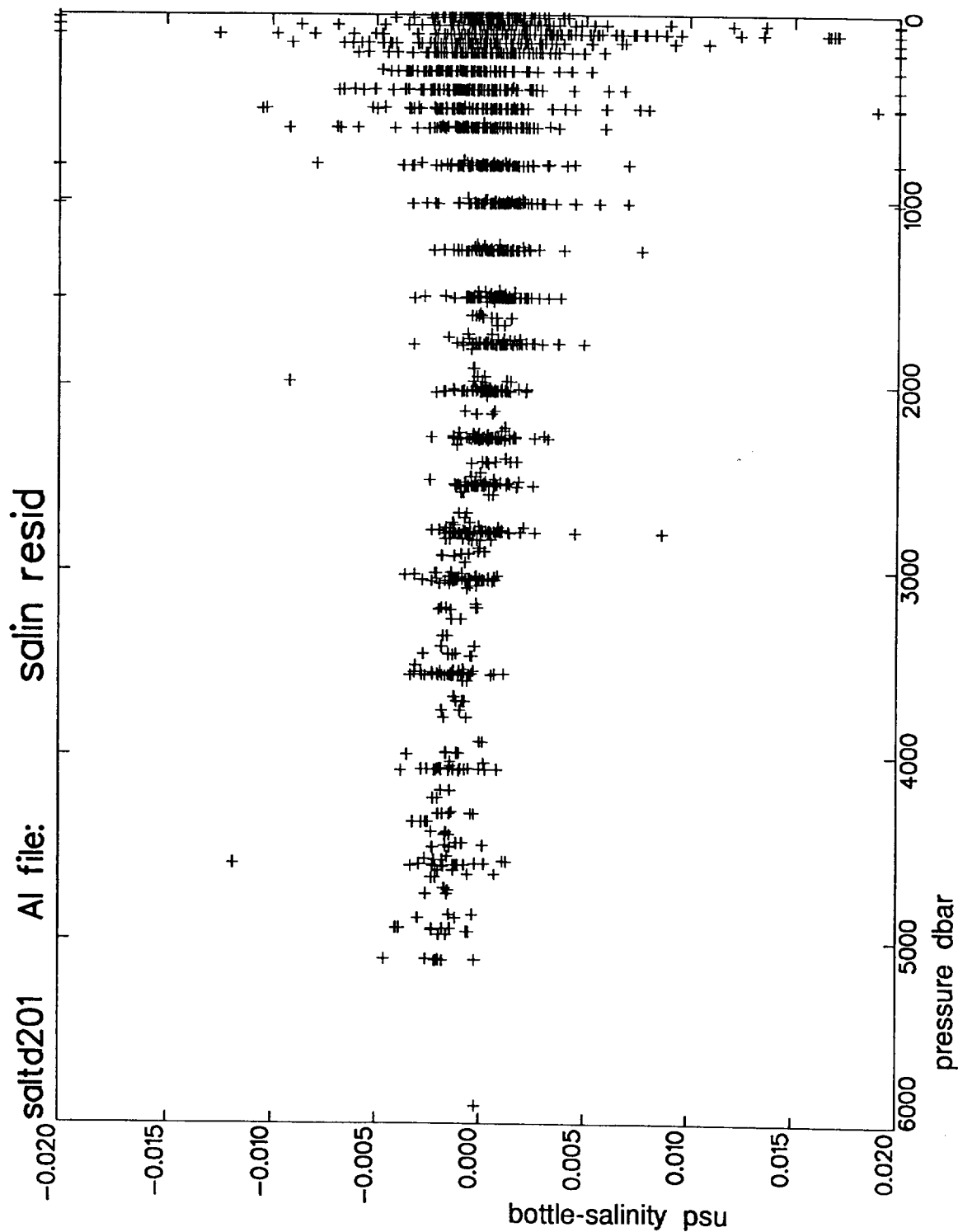


Figure 6. Bottle - CTD salinity residuals plotted by depth

Graph showing change in depth of PES fish with ship speed.

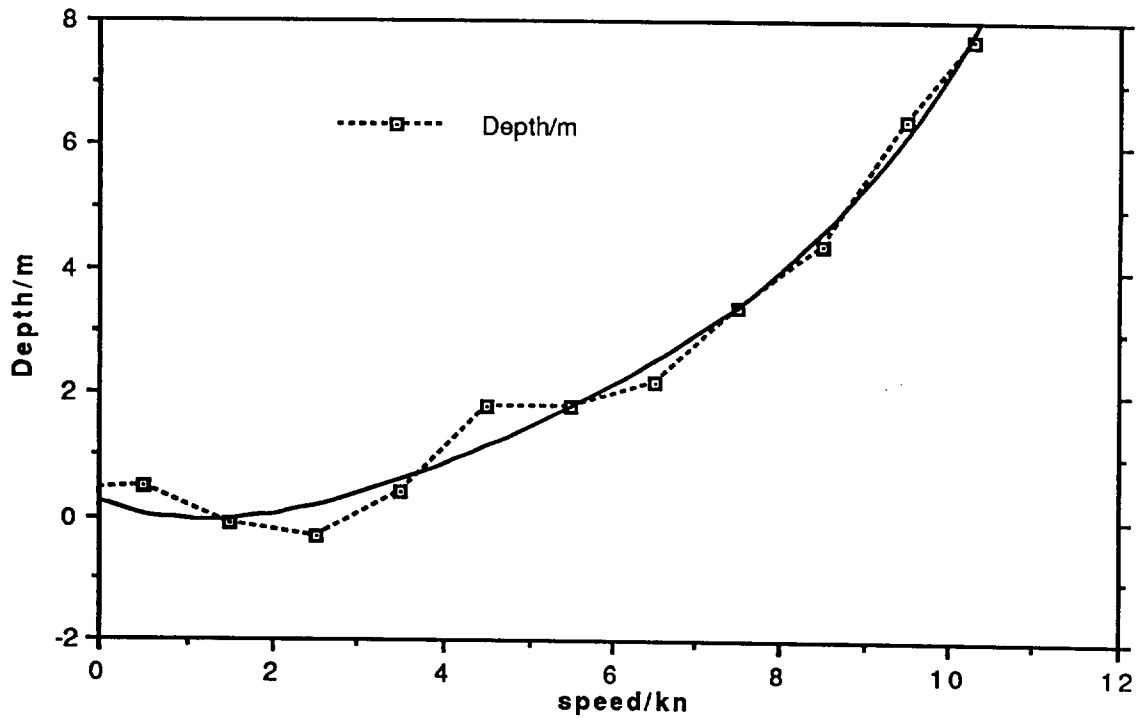


Figure 7. Precision echo sounder fish depth vs ship speed

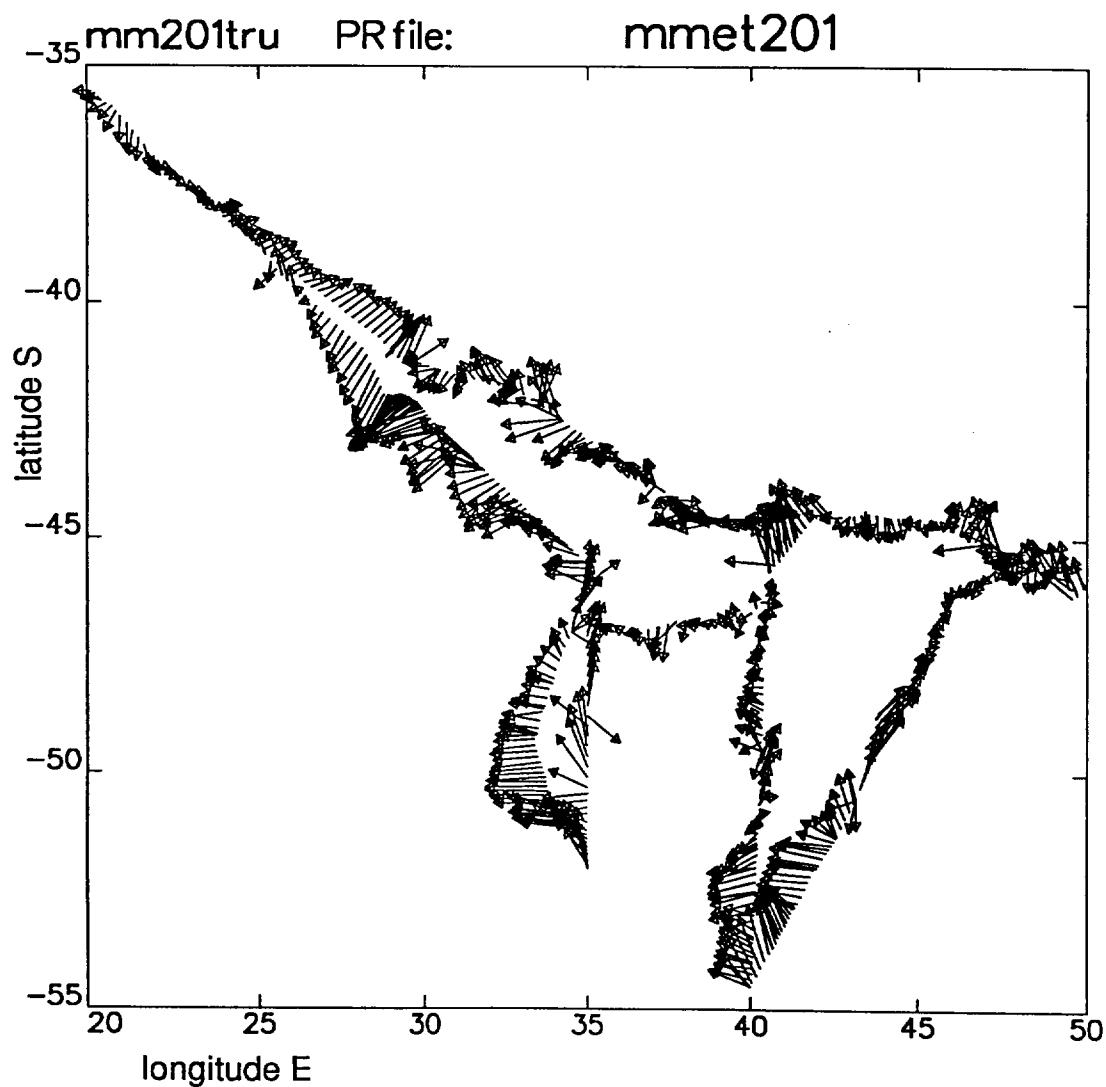


Figure 8. Wind speed and direction during Discovery cruise 201.
(0.5mm : 1.0m/s)

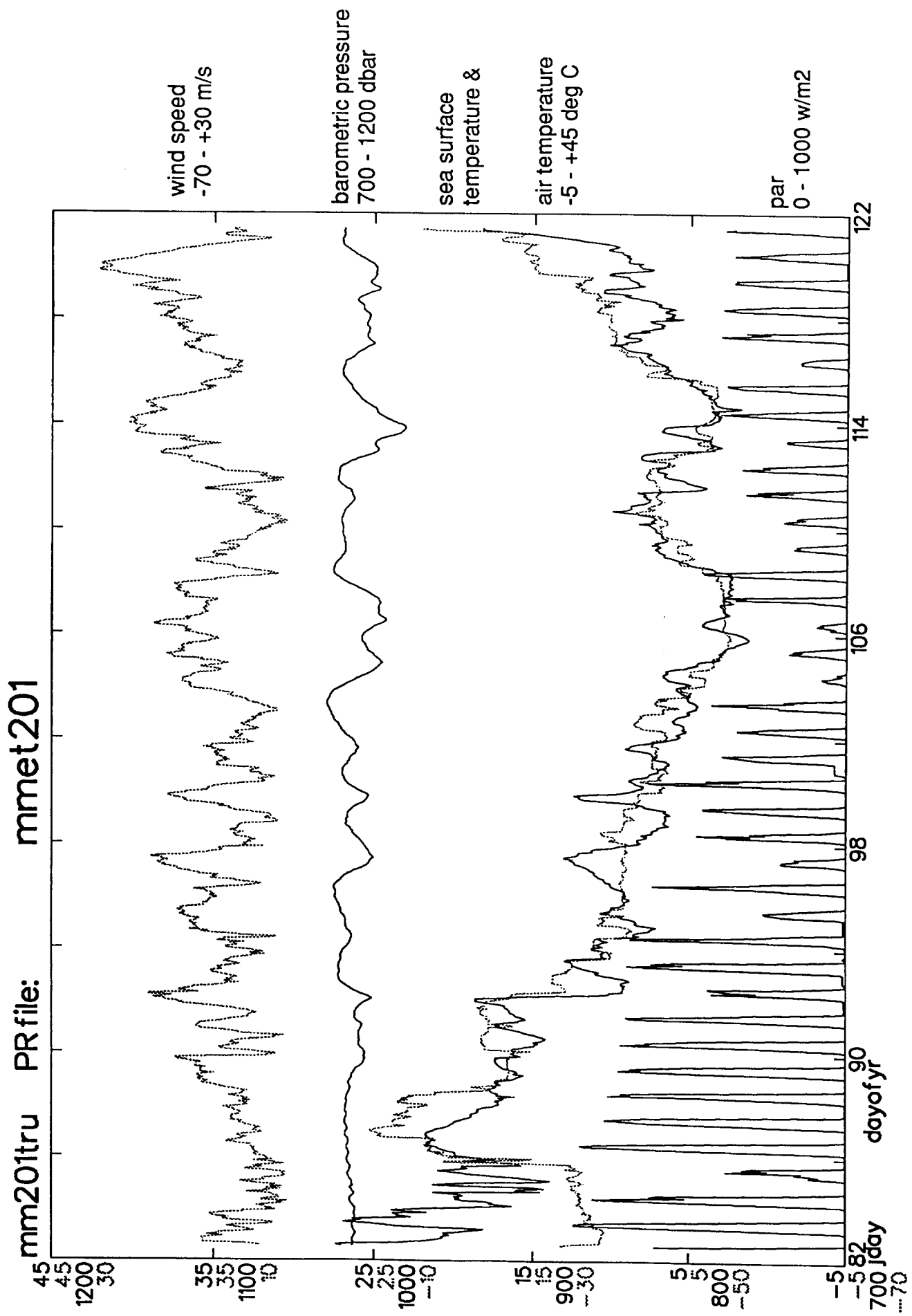


Figure 9. Air and sea surface temperature, barometric pressure, wind speed and photosynthetically active radiation (par) throughout Discovery cruise 201

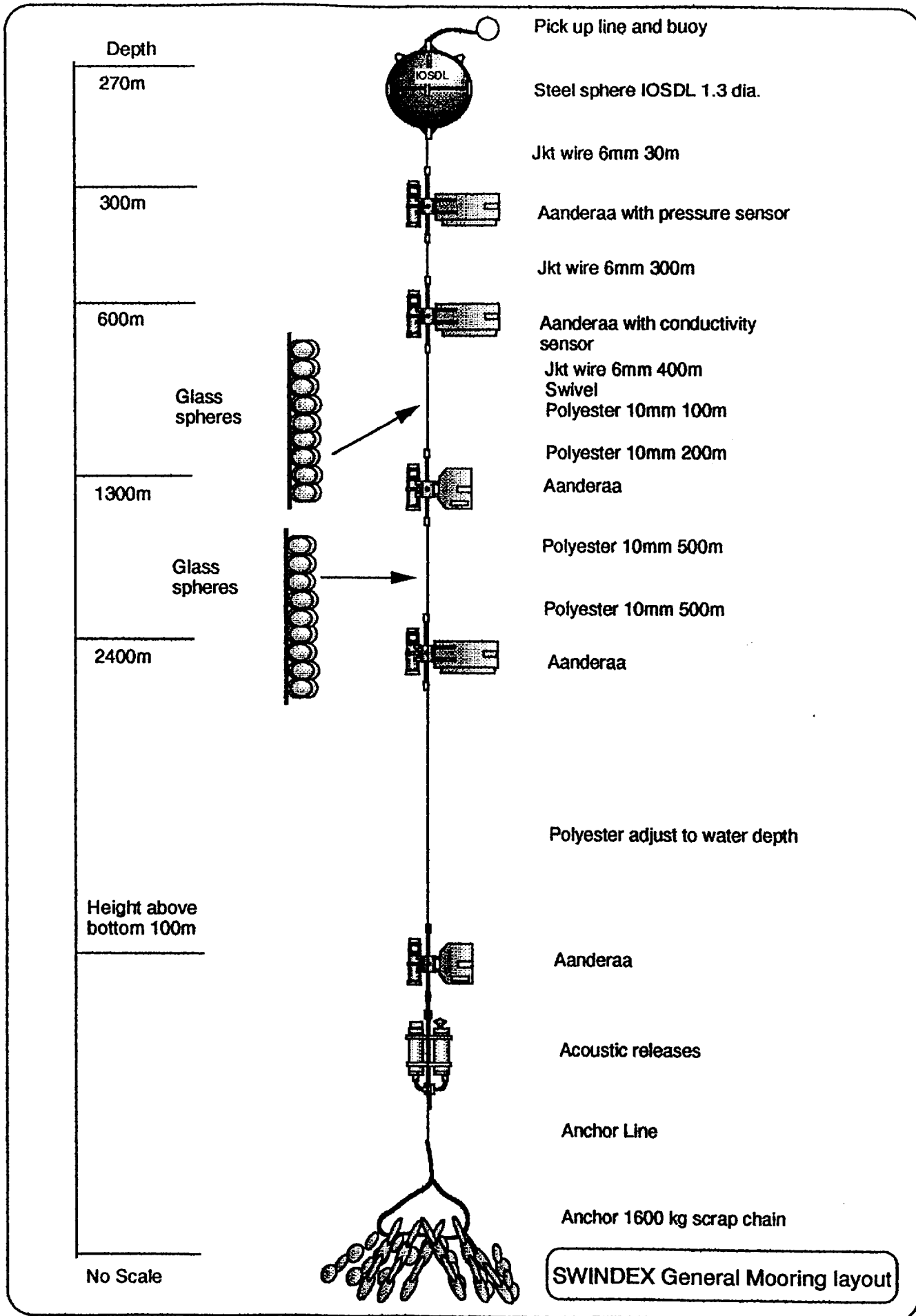


Figure 10. SWINDEX generic mooring design

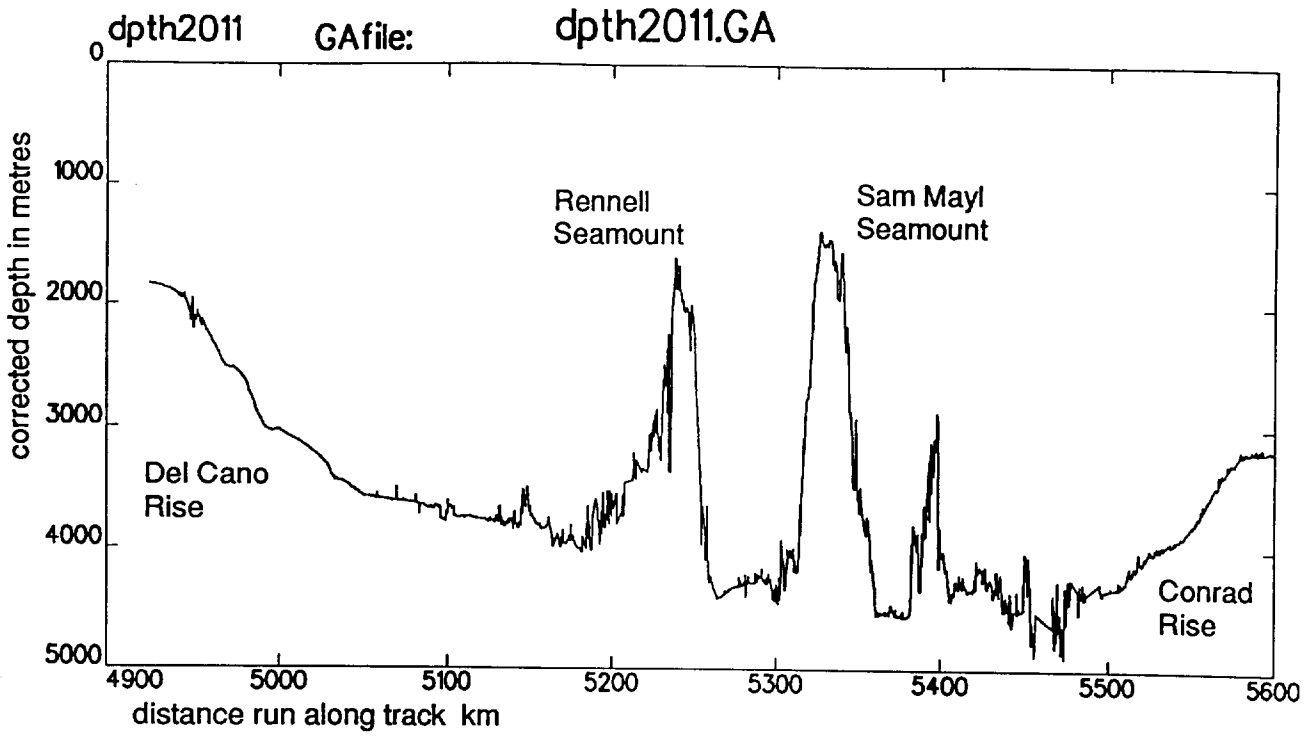


Figure 11a. Topography along 45E showing two new seamounts

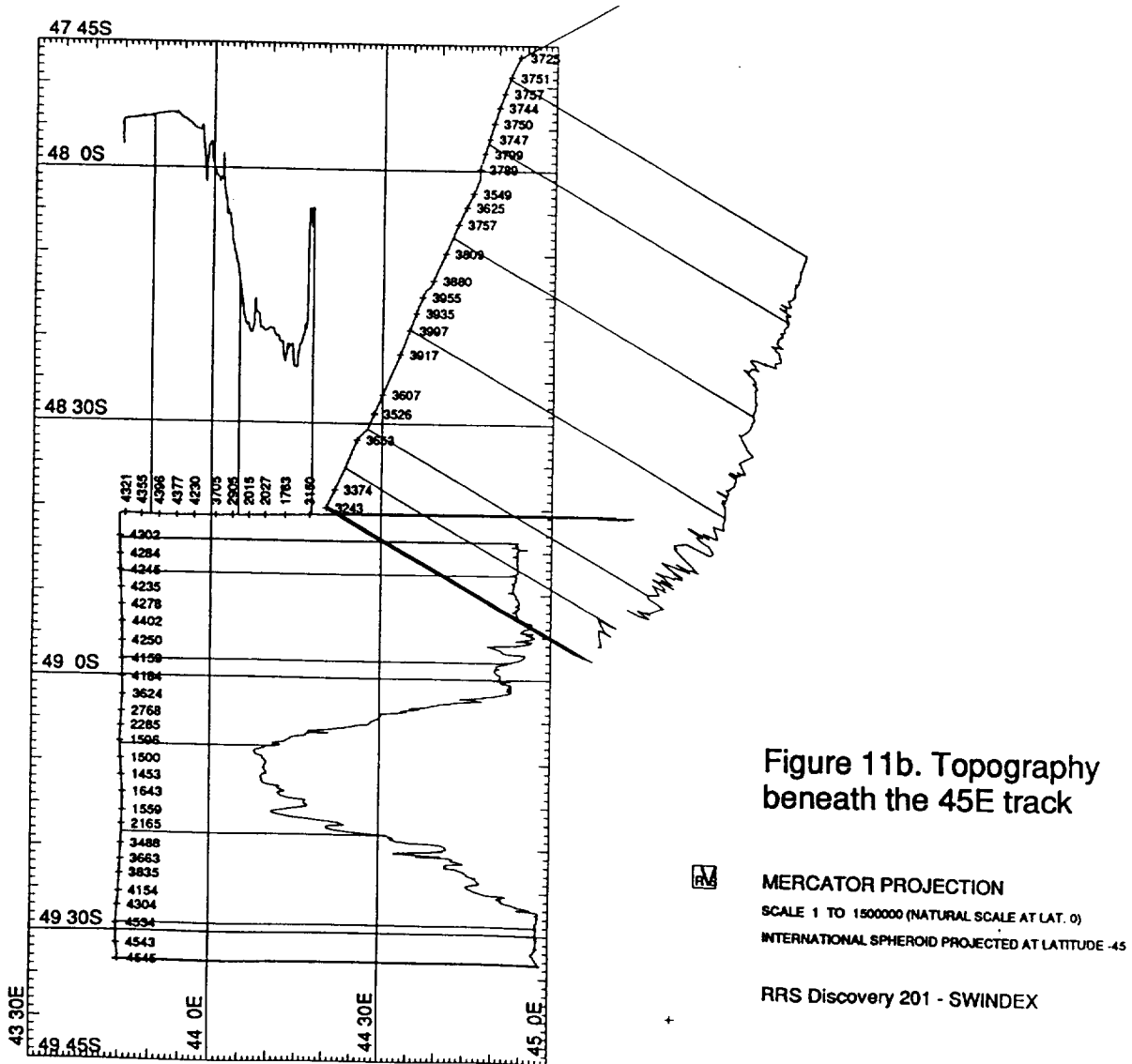


Figure 11b. Topography beneath the 45E track