WHP Cruise Summary Information

WOCE section designation	A11
Expedition designation (EXPOCODE)	74DI199/1
Chief Scientist(s) and their affiliation	Peter Saunders, IOSDL
Dates	1992.12.22 – 1993.02.01
Ship	DISCOVERY
Ports of call	Punta Arenas, Chile to Cape Town, South Africa
Number of stations	91
Geographic boundaries of the stations	30˚13.50''S 00˚09.35''W 17˚50.72''E 45˚04.62''S
Floats and drifters deployed	none
Moorings deployed or recovered	none
Contributing Authors (In order of appearance)	B. A. King S. Bacon P. Chapman S.E. Holley D.J. Hydes D. Smythe-Wright S.M. Boswell D. Price S. Jordan R. Phipps S. Whittle T.J.P. Gwilliam S.R. Thompson R. Marsh M.G. Beney A.J. Taylor K.J. Heywood P.K. Smith S. Cunningham M.P. Meredith V.C. Cornell

INSTITUTE OF OCEANOGRAPHIC SCIENCES

DEACON LABORATORY

CRUISE REPORT NO. 234

RRS *Discovery* Cruise 199

22 DEC 1992 - 01 FEB 1993

WOCE A11 IN THE SOUTH ATLANTIC

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ABSTRACT

RRS Discovery cruise 199 was a UK contribution to the World Ocean Circulation Experiment (WOCE) one-time survey, its designation A11. The cruise ports were Punta Arenas, Chile to Cape Town, S. Africa. 91 full-depth stations were worked with a NBIS Mk3b CTD and a GO 24x10 liter rosette water sampler. Salinity, oxygen, silicate, nitrate, phosphate were measured on each station, CFC-11, CFC-12, and CFC-113 measured on every other station and XBT drops (mostly T7) made between stations. Meteorological parameters, sea-surface temperature and salinity, and current profiles to 300m (from a hull-mounted RDI 150 kHz ADCP) were measured throughout the cruise. To improve estimates of the ship's heading (and hence currents) a 3-dimensional gps receiver from Ashtech was employed.

Provisional examination of the data indicates that it is of sufficient quality to meet the principal aim of the cruise, namely to determine the exchange of physical and chemical properties between the S. Atlantic and Southern Ocean.

Electronic versions of the text of this document, plus hard copy figures are lodged with the WOCE Hydrographic Planning Office, Woods Hole, Mass and with the British Oceanographic Data Centre at Bidston, Merseyside.

Keywords

ACOUSTIC DOPPLER CURRENT PROFILER (ADCP)

A11 WOCE ONE-TIME SURVEY

CFC 11,12,113

CORE PROJECT 1

CTD OBSERVATIONS

"DISCOVERY"/RRS - CRUISE (1992-3) 199

NUTRIENTS

OXYGEN

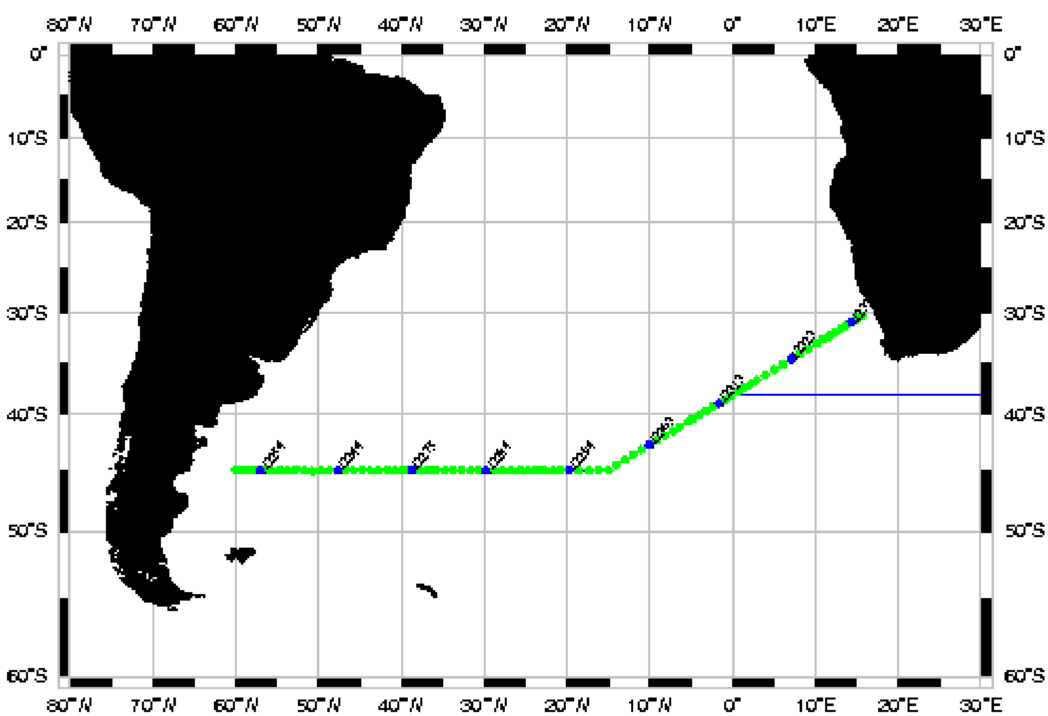
WOCE

WHP Cruise and Data Information

Instructions: Click on items below to locate primary reference(s) or use navigation tools above.

CONTENTS

Station locations for a11



(Produced by .SUM files by WHPO)

1. CRUISE NARRATIVE

1.1 Highlights

Expedition Designation: WHP One-time Survey, A11

Chief Scientist: Peter M Saunders, IOSDL

Ship: RRS Discovery, newly lengthened to 90.2m

Ports of Call: Punta Arenas, Chile to Cape Town, S. Africa

Cruise Dates: December 22, 1992 to February 1, 1993

1.2 Cruise Summary

Cruise Track

The cruise track and station locations are shown in Figure 1: only small volume samples were taken.

Sampling

The following water sample measurements were made:- salinity, oxygen, total nitrate, phosphate, silicate and CFCs 11,12 and 113, the freons on alternate stations. CTD salinity and oxygen were also measured.

The depths in m sampled were:- 5(10), 50, 100, 150, 200, 250, 350, 500, 750, 1000, 1250, 1500, 1750, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000 meters.

Number of Stations

A total of 91 CTD/rosette stations were occupied using a General Oceanics 24 bottle rosette equipped with 24 10-litre Niskin water sample bottles, and a NBIS Mk IIIb CTD equipped with a SensorMedic oxygen sensor, Sea Tech Inc 1 m path transmissometer, Simrad altimeter model 807-200m, and IOSDL 10 kHz pinger.

Floats, Drifters, and Moorings

No floats, drifters, or moorings were deployed on this cruise.

Reporting

Electronic versions of the text of this document, plus hard copy figures are lodged with the WOCE Hydrographic planning office, Woods Hole, Mass and with the British Oceanographic Data Centre at Bidston, Merseyside. We plan to lodge electronic copies of most of the data from the cruise at these same sites by the end of 1993.

1.3 List of Principle Investigators

The principal investigators responsible for the major parameters measured on the cruise are listed in Table 1. The responsibility for all tasks undertaken on the cruise will be found in table 2.

TABLE 1: PRINCIPAL INVESTIGATORS

Name	Responsibility	Affiliation
B. King	CTD	IOSDL
S. Bacon	Salinity	JRC
D. Hydes	Nutrients	IOSDL
P. Chapman	Oxygen	Texas A & M
D. Smythe-Wright	CFC	JRC
P. Saunders	ADCP	IOSDL
P. Smith	Meteorology	IOSDL
S. Thompson	XBTs	IOSDL
M. Meredith	Satellite imagery (MACSAT) and thermosalinograph	UEA

1.4.1 Scientific Programme and Methods

The principal objectives of the cruise were:-

a) To estimate the exchange of heat, freshwater, nutrients and freons across the section, i.e. between the Southern Ocean and the South Atlantic
b) To determine the water mass characteristics on the section and to determine whether and where secular changes are found, and
c) To submit to the WHPO a data set, a fit companion to other WHP one time survey cruises, and thereby contribute to the global measurements necessary to meet the objectives of WOCE.

The principal instruments employed in the measurement programme consisted of a NBIS Mk IIIa CTD and General Oceanics rosette mounted within a tubular aluminum frame of dimensions 1.8m height x 1.5m diameter. The package was weighted to give a free fall speed in excess of 2 ms^{-1}. Subsidiary instrumentation consisted of a 1m transmissometer, altimeter (with 200m range for bottom finding) and 10 kHz location pinger. Four of the rosette bottles were fitted with SIS digital reversing thermometers (6) and pressure meters (2). The wire was a single conductor 10mm steel rope manufactured by Rochester Cables, and the winch was of traction winch design built by Kley France. A complex folding gantry of RVS Barry design ensured the virtually automatic launching and recovery of the CTD/rosette package in all conditions within which the ship could be safely operated.

After a cast the rosette was placed on deck and secured, the rosette pylon was drenched in fresh water and the CTD sensors covered with protective housings. Subsequently digital instrumentation was read and freon samples were drawn followed in order by samples for oxygen, nutrient and salinity analysis. The rosette was stored on deck throughout the cruise and all sampling was performed there. In moderate weather the rosette would be pushed forward on a railway about 3 m to obtain further shelter. In rain umbrellas could be clamped to the rosette frame in order to protect the samples and in rough seas the ship remained on station until sampling was completed.

Other and, in some cases, crucial additional measurements were made throughout the cruise. XBTs were launched between CTD stations and more frequently in the slope regions at each end of the cruise section. Acoustic Doppler Current Profiler (ADCP) measurements were made continuously employing a hull mounted 150 kHz unit manufactured by RDI. In support of the ADCP measurements a GPS3DF receiver manufactured by Ashtech, Inc provided heading information superior to that of the ship's gyro. Underway measurements of surface temperature and salinity were made by a FSI thermosalinograph and a Simrad 500 Echosounder provided continuous water depth measurements. Other navigation information was supplied by a Trimble GPS receiver and all data were logged by networked SUN workstations with terminals widely available in the main and computer labs.

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

1.4.2 Preliminary Results

Figure 2 shows the distribution of sample observations made on the A11 section. Since data from the South Atlantic Ventilation Experiment (SAVE) were available on the ship (thanks to WHPO), we were able to compare A11 and SAVE sample data. The property distributions were very similar, but small differences were noted in the deep water which became evident with potential temperature < 1.0˚C or salinity in the range 34.66 - 34.72. A11 salinity measurements agreed well with the SAVE 5 leg data, but were more saline by 0.002 than adjacent SAVE 4 data: the differences amongst the SAVE data were not previously known to us. Nitrates showed agreement with both SAVE 4 and 5 measurements, but at the deepest levels silicates and oxygens were slightly lower by 2.5 μmol/kg (Figure 3) and 2.5 μmol/kg (Figure 4) respectively; phosphates were lower by about 0.08 μmol/kg. These preliminary results, whose magnitude but not sign depends on which historic set is compared, apply principally within the Argentine Basin, and possible causes of the differences are under investigation.

A more unexpected result, which owed nothing to the accuracy of the measurements, was the extreme northern position of the Subtropical Convergence on the NE leg of the track (Figure 1). Although the water became progressively warmer along this leg, the surface salinity remained below 35 until a ring was encountered centered on 36°20'S and 4°00'E. The ring had a thermostad of temperature 13.5°C, salinity 35.2 and a maximum depth of 600m. An anticyclonic circulation of 30 cms^{-1} was observed by the ADCP. It may have been an Agulhas ring which had over-wintered south of the convergence, or a Brazil Current ring shed in the WBC retro-flexion zone which had migrated eastward. Opinions in the scientific party were split about equally, but a closer post-cruise examination of the data may well resolve the question. Beyond its NE edge, near 35°40'S and 5°00'E we encountered the subtropical gyre, with a surface salinity exceeding 36 and temperature of 20°C. This observation appears to confirm Deacon's (1937) assertion of the northward migration of the convergence in summer in this region.

Within the subtropical gyre a second hydrographic feature was encountered. This was defined by two hydrographic casts and 5 XBTs and was centered at 33°30'S, 9°45'E and extended for 300 km along the track. Within it, the 15°C isotherm plunged to a depth of 250m, while outside it the same isotherm was nearer a depth of 100m. An anticyclonic circulation was measured by the ADCP with currents approaching 75 cms^{-1}. This was undoubtedly a recent Agulhas ring.

The ADCP instrumentation furnished, we believe, important new data on the cruise: it functioned incomparably better than when installed on the previous 10m-shorter version of the ship. The most important results derived from it were found in the western boundary region. On the Argentine Slope, on two crossings of the Falklands Current, large and persistent northward velocities were found at 100m depth (30 - 50 cms^{-1}). These were considerably in excess of those predicted by the geostrophic shear (relative to the bottom), and consequently bottom velocities of 15 - 30 cms^{-1} are inferred. The consequences for transport in the WBC and exchange across the section are considerable. On the South African slope, along-slope velocities were also observed on a crossing of the Benguela Current. However these were quite small and variable in direction and a preliminary analysis suggested they were dominated by transient (tidal or inertial) components.

Also of note were ADCP observations made in a storm near 45˚S 21˚W: winds approached 30 ms^{-1} for a brief period, and striking inertial oscillations (circa 40 cms^{-1}) were recorded. Since meteorological measurements were made aboard the ship, it is hoped that given the high quality of the ADCP data, it may prove possible to deduce the integrated Ekman drift on this cruise.

1.5 Major Problems Encountered on the Cruise

Two GO rosettes were available and both were utilized. Misfiring and double tripping were initially widespread, but when their sensitivity to the lanyard tension was recognized it became possible to reduce them to acceptable levels. Nevertheless a post-cruise review estimates the overall number of double trips as nearly 10% of the total number of samples. Thus a larger than expected number of duplicate samples was achieved. It is our recommendation and intention for the future that lanyard tensions be measured, monitored and set to a value which allows a properly reliable operation of the unit.

As mentioned in Section 1.4.1 the winch was of complex traction winch design; it was put to use only on the previous cruise and because of its newness, inevitably there were difficulties. On the 1st of January at 0600, control failure occurred: it was approximately 36 hours before the fault was identified, the electronic component replaced and control settings optimized to allow station work to proceed. The efforts of all involved deserve recognition and thanks. Although we believe this was a unique situation, a different problem occurred twice and was potentially liable to occur anytime there was a large swell. Because the CTD/rosette takes time to shed air from all its component parts, very close to the surface it is vulnerable to heavy swell: it may 'float'. In such circumstances the wire goes slack, and on both occasions the wire jumped out of a sheave pair at the foot of the gantry (where the wire direction changed from horizontal to vertical). Even in the short term this is probably a rectifiable fault, but on the cruise it cost us 4 hours both times it occurred.

Concerning the instrumentation for analysis, two problems were noted. Early on, the SIS unit for determination of oxygen concentration became unreliable: the photometric end point detection system was no longer stable. Fortunately a backup amperometric system, the Metrohm 686 titroprocessor, was available, and this was used for the bulk of the cruise measurements.

The CFC measurements also experienced difficulties which led to the loss of some data. Shortly after the start of the cruise the CFC-12 measurements exhibited severe contamination which was believed to be due to the accidental release of oil from the ship and its capture in the non-toxic seawater system used to store the sample syringes. To bypass this problem, syringes were stored in surplus sample water, a practice however, which did not eliminate the contamination. Early CFC-12 measurements may be expected to be of lower quality than expected on the cruise, but the CFC-11 and CFC-113 measurements should be unaffected.

1.6 Other Observations of Note

On the 16th January, a large iceberg was sighted: its location was determined as 44°50'S 14°22'W. In view of a much more southerly position and crossing of the Falkland Current three weeks earlier in the cruise, this was an odd location to observe one for the first time.

On the 19th January in about 3700m of water, RRS *Discovery* passed over a flat-topped seamount near 40°48'S 5°40'W: it is not recorded on the GEBCO chart and its minimum depth was near 750m. We propose the name New Discovery Seamount for this 3000 m high feature.

1.7 List of Cruise Participants

The members of the scientific party are listed in Table 2, along with their responsibilities.

TABLE 2: CRUISE PARTICIPANTS

Name	Responsibilities	Affiliation
S. Bacon	Salinity	JRC
M. Beney	Data acquisition	RVS
S. Boswell	CFCs	JRC
P. Chapman	Oxygens, nutrients	Texas A & M
V. Cornell	Data archiving, Macsat	JRC
N. Crisp	CTD operations	IOSDL
S. Cunningham	CTD/sample analysis	JRC
P. Gwilliam	CTD operations (IC)	IOSDL
V. Gouretski	ADCP/historical hydrography	UEA
K. Heywood	CTD/sample analysis	UEA
S. Holley	Oxygens, nutrients	JRC
D. Hydes	Nutrients, oxygens	IOSDL
S. Jordan	Mech. Eng (IC)	RVS
B. King	CTD/sample analysis	IOSDL
R. Marsh	ADCP	JRC
M. Meredith	Thermosalinograph, Macsat	UEA
D. Price	CFCs	JRC
R. Phipps	Mechanical Engineer	RVS
P. Saunders	PSO, ADCP	IOSDL

Name	Responsibilities	Affiliation
P. Smith	CTD operations, Meteorology	IOSDL
D. Smythe-Wright	CFCs (IC)	JRC
A. Taylor	Electrical Engineer	RVS
S. Thompson	GPS, XBTs	IOSDL
S. Whittle	Mechanical Engineer	IOSDL

Abbreviations

IOSDL	Institute of Oceanographic Sciences, Deacon Laboratory - Wormley
JRC	James Rennell Centre - Southampton
RVS	Research Vessel Services - Barry
UEA	University of East Anglia - Norwich
IC	In charge of

2 MEASUREMENT TECHNIQUES AND CALIBRATIONS

A general note on data quality checking (Oct 93)

by: B. A. King

Note that a number of sections on data quality checking have been added to this report (the .DOC file kept by the WHPO) since the submission to the WHPO of the initial cruise report in February 1993. Such additions are identified with dates in the subheadings. The consequence of maintaining a single report file is that some figures are introduced out of order, and some information may appear more than once in the text.

One problem when looking for small differences between two profiles of sample data for example between adjacent stations in a single data set or a comparison of data from different cruises, is that the size of any difference is likely to be smaller than the variation of the property over a few hundred meters in the vertical. This combines with the fact that the samples are not necessarily collected at the same vertical coordinate (usually pressure or potential temperature) to create something of a difficulty.

However, the following procedure has been found to be a useful way round this problem, both for checking the internal consistency of the data set and in the comparison with historical data.

(i) The deep data are plotted in a theta-property plot, and a fraction of the data selected which are closely described by a linear regression of the sample value on potential temperature. This invariably led to different regressions for the western and the eastern basin. Typically, the western basin regression would be calculated from data with theta < 1.0 degree, and the eastern basin regression from data with theta < 1.2 degrees.

(ii) For each sample value, the chosen regression is used to compute a 'predicted' value of the sample, and the anomaly between the observed value and this predicted value is calculated. If the data are well described by a linear fit with theta, these anomalies should be small, probably an order of magnitude smaller than the variation in the vertical of the fitted data.

(iii) There are now a number advantages: first, it is now straightforward to compare samples collected at different depths, by comparing their anomalies; second, any offset between profiles of a magnitude greater than the normal scatter in the anomalies is immediately apparent; third, the mean value of the anomalies for a station provides a simple and objective way to summarize the property value for that station in a single number.

The key to this technique is to use the same prediction for every station being considered for inter-comparison. For comparisons between cruises it is not particularly important which data set is used to determine the fitting equation, so long as it removes the background distribution in each data set. We have used linear fits based on the present data.

Comparison with historical data (Oct 93)

In the course of assessing the quality of the present data, comparisons have been made with data from the following cruises. Station positions are shown in Figure 8 using these symbols:

Present Cruise, WHP A11: 'pluses'

SAVE leg 4: 'crosses'

AJAX (N-S section on 1 east): 'inverted triangles'

Atlantis II cruise 107 (W-E section on 46 south): 'triangles'

All SAVE 4 data have been considered, and only extracts from the AJAX and Atlantis II-107 data. Analysis of the deep data from SAVE 4 shows gaps for the central stations; these were shallower stations while crossing the Mid-Atlantic Ridge.

Data from the western basin have been compared where potential temperature is cooler than 1.0˚, and eastern basin data when potential temperature is cooler than 1.2˚.

Duplicate analyses from multiple trips of Niskin bottles (Oct 93)

From time to time throughout the cruise, there were casts on which the multi-sampler had problems in tripping Niskin bottles correctly. This could result in either zero or two bottle closures for one trigger signal. While this unreliability was a nuisance in some respects, and led to quite a lot of careful scrutiny of sample analyses to sort out the depths at which bottles had closed, it had the advantage of providing a number of duplicate samples for all the tracer analyses. While these are not quite independent duplicate samples, in the sense that they were generally analyzed in the same run by the same analyst, they were more independent than replicate samples drawn from the same Niskin bottle. Furthermore, the fact that they were duplicates will have been unknown to the analyst at the time the analysis was performed.

The total number of such duplicates for which the salinity, oxygen and three nutrients are all good is 198 (out of 1642 samples with all tracers good); i.e. about 12% of the total number of samples. Out of these 198, 87 are from depths greater than 3000 meters. The mean and standard deviations of these five tracers (198 samples) is as follows (units are μmol/kg except for salinity, percentages of full-scale in brackets):

	standard deviation
salinity	0.0017 (0.0009 for pressures > 3000)
oxygen	0.86 (0.3%)
nitrate	0.15 (0.4%)
phosphate	0.026 (1%)
silicate	0.30 (0.2%)

For the 87 samples from pressures greater than 3000 decibars, the statistic for salinity is better than for the full set; this is a reflection of the greater homogeneity of the water column there. The statistics for the other tracers are not significantly different.

2.1 Sample salinity measurements
by: S. Bacon

On RRS Discovery cruise 199 the salinity analysis of samples was carried out exclusively on the IOSDL Guildline Autosal salinometer model 8400, modified by addition of an Ocean Scientific International peristaltic-type sample intake pump. The instrument was operated in the ship's constant temperature laboratory at a bath temperature of 24°C with the laboratory set to 20.5°C. This difference in temperature was larger than normally employed and only arose through a misunderstanding, but was allowed to remain rather than disturb the salinometer again when it became clear that the machine was quite 'happy' operating thus. Standardization was effected by use of IAPSO Standard Seawater batch P120, of which 110 ampoules were consumed. Two of these were imperfectly sealed, and were discarded; two were evidently of incorrect (too high) salinity, and one more was thought dubious. These latter three were not used as standards. The standardization history of the salinometer has been constructed, in which standardization drift is represented as equivalent salinity (ES) change referenced to the first standard measurement of the cruise. The instrument was remarkably stable, not changing from its initial standardization by more than 0.001 ES until the last ten days of the cruise, when the seas generally were calmer and the outside temperature increased, although it is difficult to associate such changes in external conditions with the observed behavior of the salinometer, unless the ship's power supply is implicated in some way. Excluding the two bad standards, the mean standardization drift was 0.0007 ES, with a standard deviation of 0.0007 ES, for 108 standards.

There were 46 pairs of replicate (i.e. from the same rosette bottle) samples drawn; and 210 pairs of duplicate (i.e. from different rosette bottles fired at the same depth) samples. Of the duplicate pairs, 87 were from below 3000 m. The standard deviations of the three groups of sample pairs are given in table S1 below.

TABLE S1

Salinity replicate and duplicate statistics

Quantity	Standard deviation	Number of pairs
Duplicates	0.0019	208
Duplicates (from >3000m)	0.0009	87
Replicates	0.0008	46

See text above table for the distinction between replicates and duplicates.

Reconciliation with CTD data, and data quality control (Oct 93)
by: B. A. King

Salinity samples values reported by the analyst were considered for data quality flagging according to three criteria:

a) The analyst may have marked the sample as suspect or bad if the analysis was unsatisfactory in some way.

b) Sample values were compared with those from neighboring stations in property-property plots. It was found that the salinity samples could be described by
$S = 34.6760 + 0.04746 \times \theta$ for $\theta < 1.0$ in the western basin,
and by
$S = 34.6762 + 0.08052 \times \theta$ for $\theta < 1.2$ in the eastern basin.

Note in passing that the regressions for the two basins intersect at a salinity of 34.676 and at a potential temperature indistinguishable from zero degrees.

The sample salinity anomalies (for theta < 1.0 and theta < 1.2 in the two basins) have been calculated relative to these regressions and averaged for each station. The result is shown in Figure 9. Station 12296 appears to be somewhat different from the others, but was the last station occupied in the western basin before encountering the mid-atlantic ridge. Although the deep water at 12296 is slightly more saline than the preceding stations, it is still much fresher (order 0.04) than the eastern basin stations.

c) Having established the station-to-station consistency, individual bad samples were sought by comparing sample values with calibrated CTD salinity values. Note that samples with large residuals had already been rejected from the CTD calibration procedure, but not yet flagged as suspect. The rms of the residuals was 0.001 for 430 samples at depths greater than 3000 meters. Of these, 407 samples had residuals smaller than 0.002. All samples with residuals greater than 0.005 were then inspected on an individual basis, and a reason sought for the large residual. Mostly these were traced to regions where there is a strong vertical gradient in salinity. Many cases were found where the sample salinity corresponded to the CTD salinity measured a few meters deeper than where the winch was stopped and the Niskin bottle closed. It is therefore concluded that the 'flushing distance' for the Niskin Bottle is of the order of five meters. Commonly, the residual was 2 meters times dS/dz, the vertical Salinity gradient per meter. dS/dz could be up to 0.005 per meter; some residuals were as large as 0.020. In these cases, the sample salinity flag was left as 2, there being no reason to doubt either the correctness of the drawing of the sample, nor the accuracy of the analysis. Examples of large residuals are sample numbers 26622, 27823

The majority of other cases of large residuals occurred when the upcast CTD salinity was noisy for some reason: for example, when the ship was rolling and the CTD was in a significant salinity gradient. Again, in such cases the sample flag was left as 2 so long as there was no other reason to flag the sample as suspect.

In some cases, where the CTD salinity seemed to be good, and no reason could be found for there to be a large residual, the sample was flagged as suspect or bad.

The residuals for all samples flagged as good are plotted against pressure in Figure 10. (Stations 12251-12255 and 12325 are excluded from this figure. This is because of particular uncertainties in the CTD data for those stations; this is discussed in detail in the section on CTD data.) Note the quite large residuals in the upper 500 m which arise mainly from the Niskin flushing problem. Note also that there is a small but perceptible systematic variation in residuals. This is of order 0.001 or less at depths greater than 1500 meters. This could arise from the flushing problem, or some residual behavior of the CTD salinities. It is considered to be sufficiently small that it can be ignored, so it remains uncorrected in the CTD data.

Comparison with historical data (Oct 93)

Figure 11 shows the anomaly of the SAVE leg 4 salinities (station averages) with respect to the standard fit; SAVE leg 4 data are seen to be generally fresher, on average by 0.0015 to 0.002. However, at the intersection of our cruise with SAVE leg 5, the deep salinity data were found to be in agreement.

Figure 12 shows the anomaly of the Atlantis II salinities, which are slightly higher than ours. However, the discrepancy is not quite as high as it appears from the figure, which shows station averages and is therefore susceptible to individual large anomalies: the mean anomaly for 69 deep samples is 0.0025.

Note in passing that Figure 9 also shows the trend in the deep theta-S relation across the western basin as observed on the present cruise: 0.0035 in salinity across 40 stations. The rms of the station averages about the trend is 0.0009.

Conclusion

The salinity sample data are believed to be of a high standard, with good precision and internal consistency. Although there are biases with respect to some other fairly recent historical data, we see no reason to doubt the absolute accuracy of our data. We note for emphasis that all our samples were calibrated with respect to batch P120 of Standard Seawater.

2.2 Sample oxygen measurements

by: P. Chapman, S.E. Holley and D.J. Hydes

Equipment and techniques

Bottle oxygen samples were taken in calibrated clear glass bottles immediately following the drawing of samples for CFCs. The temperature of the water at the time of chemical fixation was measured to allow corrections to be made for the change in density of the sample between the closure of the rosette bottle and the fixing of the dissolved oxygen. Analysis followed the Winkler whole bottle method. The thiosulphate titration was carried out in a controlled environment laboratory maintained at temperatures between 21 and 22°C. Thiosulphate normality was determined on a daily basis and whenever new reagents were made up. Duplicate samples were taken on every cast; usually these were from the deepest four bottles.

For the early stations, the end point was determined by an automatic photometric method manufactured by SIS (Germany). After station 12253, however, the instrument began giving erroneous endpoint readings since a distinct yellow colour was sometimes still visible in the titration flasks. This was not consistent, and some analyses within each run appeared to titrate correctly; however, all samples from stations 12253, 12254, 12255, and 12257 have been flagged as suspect. For stations 12258 to 12337, i.e. the bulk of the cruise, an "amperometric titration to a dead stop" following the method of Culberson and Huang (1987) was used. A Metrohm Titrator and a Dosimat 665 (10 ml) automatic burette was employed. Titration volumes in deep waters were approximately 5 ml and the smallest increment from the burette was 2 microlitres.

The volume of oxygen dissolved in the water was converted to mass fraction by use of the factor 44.66 and an appropriate value of the density; corrections for the volume of oxygen added with the reagents and for impurities in the manganese chloride were also made as described in the WOCE Manual of Operations and Methods (Culberson, 1991).

Reproducibility of measurements

Approximately 1900 samples were taken during the cruise; in addition, a large number of duplicates were analyzed. Statistics on the duplicates are given in Table O1. These include both duplicates taken from the same bottle (replicates) and those taken from different bottles fired at the same depth and invariably unknown to the analysts.

While the photometric method was being used, 22 samples were taken from separate bottles all fired at a depth of 2500 m at station 12240 (Table O1). The data gave a standard deviation of 0.63 μmol, or 0.3%. However, 12 pairs of duplicates taken from the same bottle for stations 12250-12256 gave a mean difference of 1.2 μmol with a standard deviation of 1.29 μmol (approximately 0.56%, Table O1). Duplicates from 223 pairs of samples taken from the same bottle later in the cruise while the amperometric method was in use had a mean difference of 0.64 μmol, and standard deviation of 0.85 μmol, while 13 samples from 5455m from station 12277 gave a standard deviation of 0.35 μmol (0.15%, Table O1).

A further series of multiple samples was taken from different bottles fired at the same depth as a result of double trips by the rosette. The results of these are also given in Table O1. The mean difference for 166 sets taken over all depths and analyzed by the amperometric method was 0.57 μmol; the standard deviation of the differences was 0.65 μmol. These figures are not significantly different from duplicates taken from the same bottle (replicates).

Comparisons with historical data

Data taken at on this cruise on stations 12271-12274, 12282-12286, and 12296-12299 were compared SAVE stations 289-293, 260-264, and 200-203 respectively. Additionally, stations 12313-12316 were compared with data obtained at AJAX stations 46 and 47 near the Greenwich meridian. Some of this is shown in Figs. 3 and 4. Apart from difference in the near surface data resulting from changes in water masses in the area, there is a large measure of agreement. However, at the deepest levels the present cruise data at a given potential temperature (or salinity) shows an offset of between 2 and 6 µmol kg-1, in all cases less than the historic data. We are currently investigating the cause of these offsets.

References

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

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

TABLE O1

Statistics of duplicates and replicates obtained by both the photometric and amperometric methods. Sample depths are given where appropriate.

stn(s)	number	depth(s)	oxygen concentration µM/kg			
		m	mean	(diff)	std dev	%mean
Photometric method						
12240	22	2500	208.5		0.63	0.3
12250-56	12	all		1.2	1.29	0.56
Amperometric method						
12277	13	234	230.1	0.35		0.15
12258-337	223	all		0.64	0.85	0.40
12258-337	166	all		0.57	0.65	0.30

Reconciliation with CTD data, and further data quality control (Oct 93)
by: B. A. King

Oxygen samples were assessed for data quality and data quality flagging in the following manner:

a) The analyst may have flagged the sample as suspect or bad.

b) The data were plotted in station groups, with both pressure and potential temperature as the vertical coordinate. This enabled outliers to be identified and investigated. Very commonly, some other evidence was found which resulted in a flag of suspect or bad. However, samples were not flagged as suspect solely because they were outliers.

c) Sample values believed to be good were used for calibration of CTD oxygens, as described elsewhere. Residuals between sample oxygens and CTD oxygens were then calculated and inspected on a sample by sample, station by station, basis. On the basis of this inspection, a small number of samples previously marked as suspect were promoted to good. More commonly, samples were downgraded from good to suspect, or suspect to bad. It was recognized that in certain parts of the water column, particularly where vertical gradients were strong, quite large residuals could genuinely arise. These could arise from a number of sources, including the following

i) the Niskin Bottle flushing length, discussed in the salinity section
ii) the relatively slow response of the CTD sensors
iii) mismatch between oxygen samples collected on the upcast, and CTD oxygen values collected on the downcast (see the discussion in the CTD section)

Samples with large residuals (>5 μmol/kg) were permitted to retain a good flag if it was believed that one of these effects was responsible for the size of residual.

d) Sample numbers for which other tracers had been found to be suspect (especially nutrients) were given special scrutiny in oxygen, and vice-versa, and flags adjusted where necessary.

Final reconciliation with CTD data (Oct 93)

After the data quality procedures had been completed, the CTD oxygens were re-calibrated using, in general, only data flagged as good. However, there were some exceptions. For stations 12253-12257, there were not enough good data (see the analysts' discussion above); accordingly those stations were calibrated using data flagged as suspect. The list of suspect (flag 3) sample numbers used in CTD calibration is as follows:

25301, 25302, 25303, 25304, 25305, 25307, 25308, 25309, 25310, 25312, 25313, 25316, 25317, 25318, 25319
25401, 25402, 25403, 25404, 25406, 25407, 25408, 25410, 25411, 25412, 25413, 25416, 25417, 25419
25501, 25502, 25503, 25504, 25505, 25506, 25507, 25508, 25509, 25510, 25511, 25512, 25513, 25514, 25515, 25516, 25517, 25518, 25519
25603
25701, 25702, 25703, 25704, 25706, 25707, 25708, 25710, 25711, 25712, 25713, 25714, 25715, 25716, 25717, 25718, 25719, 25720, 25721, 25722

Similarly, there are sample data believed to be good, which were unsuitable for use as CTD calibration samples, mainly because of the reasons given in (c) above. The following good (flag 2) samples were excluded from the CTD calibration:

25824
25914, 25915, 25924
26622
26720
27230
27736
27921
29428
30119, 30120
30213, 30218, 30219
30322
30520, 30521
30614, 30615, 30619
30720
30820
31119, 31120
32117
33210, 33214
33315

Finally, the CTD calibration sometimes lacked a good sample near the surface (for example on stations 12269 and 12270, where there were multi-sampler problems). In these cases, plausible near-surface sample values were 'invented', solely for the purpose of CTD calibration, and based either on neighboring stations or slight over-saturation (2%) of near-surface water. The list of sample numbers for which this was done is as follows:

25108, 25109
26010, 26011, 26012
26914, 26915, 26916
27013, 27014, 27015

Summary of sample minus CTD residuals (Oct 93)

The residuals between all samples eventually flagged as good, and the CTD oxygens, are summarized in Table O2:

TABLE O2

Residuals of sample-CTD oxygens, averaged into 500 meter depth bins.

pressure	mean	std dev	# in sample
>6000	-1.41	0.49	4
5500-6000	-2.34	1.12	19
5000-5500	-0.73	1.16	93
4500-5000	-0.11	1.65	70
4000-4500	0.67	1.55	72
3500-4000	0.54	1.83	79
3000-3500	1.14	1.46	83
2500-3000	-0.01	1.80	75
2000-2500	0.71	2.00	147
1500-2000	0.65	1.94	165
1000-1500	-1.10	1.73	165
500-1000	-0.98	2.60	175
0-500	0.28	3.30	532
All	0.03	2.66	1686
All > 3000	0.14	1.73	420

Note that 1679 out of 1686 samples have a residual smaller than 10 µmol/kg.

Temperature used for converting µmol/l to µmol/kg (Oct 93)

Requirement: Oxygen concentrations were reported by the analysts in µmol/l, and need to be converted to µmol/kg by introducing the density of the water at the time when the oxygen fixing reagents were added on deck. The density is computed from the sample salinity and an estimate of the temperature at time of fixing. Note that for a salinity of 35, 0.1% in density is equivalent to 4˚ at 20˚C and 8˚ at 2˚C. We should therefore aim to get the temperature at time of fixing correct to about 2˚ or 4˚.

An attempt was therefore made to measure the temperature of the oxygen sample at the time that the oxygen fixing reagents were added on deck. This was done by flushing a spare sample bottle with water from the Niskin Bottle, and measuring the temperature of the sample with a PRT; temperatures were recorded for 80% of the oxygen samples drawn. These temperatures are reported as OXYTMP in the .SEA file.

For deep samples, OXYTMP is always warmer than THETA, the CTD potential temperature measured at the time the Niskin Bottle is closed. This is what would be expected. However, it was found that for many shallow samples, especially in the eastern basin where sea surface temperatures could be as high as 20 degrees, OXYTMP was cooler than THETA. On some occasions, this could be traced to night-time stations where the air temperature was up to 4 or 5 degrees cooler than SST; on other occasions there was no apparent reason why OXYTMP should be any cooler than THETA, so the observations remain as a mystery. We therefore conclude that these apparently improbable values result from inconsistent or otherwise inadequate procedure for measuring OXYTMP. For example, the probe may have been permitted to be subject to evaporation, or incomplete temperature equilibration. This procedure will be investigated further on subsequent cruises.

Note in passing that during the cruise, the probe used to measure OXYTMP failed. After repair, it was calibrated against a SIS digital reversing thermometer at 20 points between zero and 30˚. The resulting linear calibration had residuals of no greater than 0.1˚.

In reaching a final decision on which temperature to use for converting volume to mass units, there are thus two main considerations:

a) OXYTMP is unavailable for about 20% of samples. This includes a series of stations in mid-cruise (12272-12277) between the failure of the probe and the introduction of the repaired probe. It is necessary to use some method for creating OXYTMP for samples where it was not measured.
b) We have some reservations about the reliability of individual OXYTMP measurements.

It was therefore decided to use a simple function of THETA to predict the OXYTMP used for data conversion, this function being based on the observed OXYTMP values. This has the advantages of providing a complete set of OXYTMPs, and removes the vulnerability to a single poor temperature determination on deck. The chosen fit was

THETA > 12 : OXYTMP = THETA
THETA < 12 : OXYTMP = 3.612 + 0.699 x THETA

The coefficients in the regression equation are the least squares fit to 1296 samples with THETA < 12, constrained to pass through OXYTMP=THETA=12 degrees. Thus OXYTMP was found to be about 3.5 degrees warmer than THETA when THETA was near zero.

The residuals of 'measured' OXYTMP about 'predicted' OXYTMP are shown in Figure 13 (measured minus predicted), where they are plotted against THETA. We are satisfied that the resulting predictions are adequate for converting the oxygen units. For THETA cooler than 12 degrees, the residuals have zero mean, standard deviation 0.9 and all but one residual is smaller than 4 degrees. For THETA warmer than 12, the mean residual is -0.9, standard deviation 1.3 and 153 out of 156 residuals are within 4 degrees of the mean.

We repeat for clarity and emphasis, that the OXYTMP reported in the .SEA file is the observed value, when present. However, the value used for conversion of oxygen concentration units was calculated from THETA according to the above formulae. These formulae are not expected to be definitive for all ocean basins. The amount of warming expected as a Niskin Bottle is hauled through, say 3000 meters of the water column will clearly depend on the temperature profile. However, we believe our present prescription to be amply adequate for the present purpose.

Further comparisons with historical data (Oct 93)

Further comparisons of sample data with historical data have been undertaken using anomalies with respect to average conditions, as introduced in the discussion of salinity. The standard fits were defined using least-squares fits to the data from A11, using data where theta < 1.0 in the western basin, and theta < 1.2 in the eastern basin. The resulting theta-oxygen relations were then (in μmol/l)

western basin: $O_2 = 223.90 - 17.53 \times theta$

eastern basin: $O_2 = 216.14 + 4.57 \times theta$

Using a density of 1.028 kg/l, these are equivalent to (in μmol/kg)

western basin: $O_2 = 217.80 - 17.05 \times theta$

eastern basin: $O_2 = 210.25 + 4.45 \times theta$

Note that not only are the deep oxygen values somewhat different between the two basins, but that the vertical gradients are of opposite signs. The intersection of the regressions is at a potential temperature of 0.35, where the oxygen value is 212 μmol/kg.

The A11 data may now be compared with other data and inspected for bias by comparing the anomalies with respect to these standard fits, illustrated in Figures 14 to 17.

Relative to A11 data (Figure 14), the following represent the median offsets:

Figure 15	SAVE leg 4	+ 4.0 (+/- 1.9) μmol/kg
Figure 16	AtlantisII-107	+ 1.0 (+/- 1.7) μmol/kg
Figure 17	AJAX	+ 7.0 (+/- 0.75) μmol/kg

Our data seem to be quite clearly lower in oxygen than the AJAX and SAVE leg 4 data; the comparison with Atlantis II data is somewhat inconclusive. The reason for the biases between the data sets is something of a mystery; we merely note them here.

2.3 Nutrients

by: D.J. Hydes, P. Chapman and S.E. Holley

Equipment and techniques

The nutrient analyses were performed on an Alpkem Corporation Rapid Flow Analyzer, Model RFA-300.

The methods used were: - Silicate: the standard AAII molybdate-ascorbic acid method with the addition of a 37°C heating bath (Hydes 1984) to reduce the reproducibility problems encountered when analyzing samples of different temperatures, noted on an earlier cruise when the standard Alpkem method was used (Saunders et al 1991, c.f. Joyce et al 1991). Phosphate used the standard (Murphy and Riley 1962) reagents and reagent to sea water ratios but with separate additions of ascorbic acid and mixed molybdate - sulphuric acid - tartrate to overcome the problem of the instability of a mixed reagent including ascorbic acid. Nitrate was determined using the standard Alpkem method.

Previous experience has shown that better reproducibilities are achieved when the instrument is run in a laboratory with a stable temperature. The Alpkem was located in the new constant temperature laboratory on *Discovery*. The temperature was maintained between 21 and 22°C. A drawback of this location was that the large air circulation in the laboratory leads to enhanced evaporation of samples in the open cups sitting in the analyzer tray, and possibly to some contamination due to dust circulating in the air-stream. This was ameliorated by fitting a cardboard skirt round the sample tray lid.

Sampling Procedures

Sampling of nutrients followed that for trace gases (CFCs on this cruise) and oxygen. Samples were drawn into virgin polystyrene 30ml Coulter Counter Vials (ElKay). These were rinsed three times before filling. Samples were then analyzed as rapidly as possible after collection to avoid build up of a sample back log. Samples cups of 2.0 ml capacity were used. These were rinsed once by filling completely before filling with analyte. Tests carried out on the cruise showed that samples from all depths stored for a week in a refrigerator at 4°C were not significantly effected by storage.

Calibration and Standards

The calibrations of all the volumetric flasks used on the cruise were checked before packing and these were re-calibrated if necessary.

Calibrations of the three Finn pipettes used on the cruise were checked before packing. The six Eppendorf fixed volume pipettes were delivered too late to be calibrated before the cruise. However in use no difference was detectable between the results achieved with the Finn pipettes and Eppendorfs.

Nutrient standards

Nutrient primary standards were prepared from salts dried at 110°C for two hours and cooled over silica gel in a dessicator before weighing. Precision of weighing was to better than 1 part per thousand.

Nitrate

0.510g of potassium nitrate was dissolved in 500 ml of distilled water in a calibrated volumetric PP flask at a temperature of 21-22°C.

Nitrite

0.345g of sodium nitrite was dissolved in 500 ml of distilled water in a calibrated volumetric PP flask at a temperature of 21-22°C.

Phosphate

0.681g of potassium dihydrogen phosphate was dissolved in 500 ml of distilled water in a calibrated volumetric PP flask at a temperature of 21-22°C. Working standards were prepared from a secondary standard made by diluting 5.00 ml of the primary standard measured using a Finn pipette Digital 1.00 to 5.00 ml adjustable volume, in a 100 ml calibrated glass volumetric flask.

Silicate

0.960g of sodium silica fluoride was dissolved in 500 ml of distilled water in a calibrated volumetric PP flask at a temperature of 21-22°C. Dissolution was started by grinding the fluoride powder to a paste with a few drops of water in 30 ml polythene beaker using a plastic rod for three to four minutes.

Secondary calibration standards.

A uniform set of six mixed secondary standards were prepared in artificial seawater, Concentrations (µM) were Nitrate 40, 30, 20, 10, and 0; Phosphate 2.5, 2.0, 1.5, 1.0, 0.5 and 0, Silicate 150, 100, 75, 50, 25 and 0 up to station 12288 and 150, 120, 90, 60, 30 and 0 thereafter.

The artificial seawater was a 40ppt solution of Analar grade Sodium Chloride. Nutrients were undetectable in these solutions relative to Ocean Science International (OSI) Low Nutrient Sea Water which contains 0.7µM Si, 0.0µM NO3 and 0.0 µM PO_4. On one occasion the solution was found to contain 0.6µM PO_4 and consequently was not used.

Establishment of a Quality Control QC Sample

At a test station 12240 occupied on 26 December a large volume of deep water was collected with the idea of using this as a quality control standard when its stability had been verified. Samples of this water where run at intervals over the next two weeks.

From station 12291 onwards a sample of 12240 water was measured as a "QC" sample on each analyzer run. The scatter of the data are shown in Fig 5. Silicate returned a consistent result with occasional flyers. The phosphate results suggest that the first (up to 12301) and second (up to 12319) one liter sub-sample were unstable but the third sample was stable. This may be due to the surface of the polythene bottle storage equilibriating with the sample. The sharp shift in the apparent nitrate concentration in the QC between stations 12311 and 12312 is currently inexplicable. It does not correspond to a change in primary standard concentration. It was difficult to detect in the contour plots, but does appear to be present when concentrations were compared along isopycnal surfaces.

Reproducibility

For the QC standard 189 measurements were made. The means were Silicate 78.85, Nitrate 28.85, Phosphate 1.79, percent standard deviations Silicate 1.05, Nitrate 2.45, Phosphate 2.35.

For 10 replicates of the top standard run after station 12337 the percent standard deviations were Silicate 0.22, Nitrate 0.25, Phosphate 1.1.

Reference

HYDES, D.J. 1984 A manual of methods for the continuous flow determination of ammonia, nitrate-nitrite, phosphate and silicate in seawater.
Institute of Oceanographic Sciences Report No 177, 40pp.

JOYCE, T., CORRY, C. and STALCUP, M. 1991 Editors of WOCE operations manual, part 3.1.2 Requirements for WOCE hydrographic programme data reporting.
US WOCE WHP Office 90-1, 71pp.

MURPHY, J and RILEY, J.P. 1962 A modified single solution method for the determination of phosphate in natural waters.
Anal. Chem. Acta, 27,31-36.

SAUNDERS, P.M., GOULD, W.J., HYDES, D.J. and BRANDON, M. 1991 CTDO and nutrient data from Charles Darwin cruise 50 in the Iceland Faroes region. Institute of Oceanographic Sciences Deacon Laboratory, Report No 282, 74pp

Further data quality control of nutrient samples (Oct 93)
by: B. A. King

Data quality control was tackled in a similar way as for salinity and oxygen, but of course there is no CTD sensor to assist in the rejection of poor sample values. Initially therefore, property-property plots were used to identify the sample numbers of outliers. These were mainly with theta or pressure as one coordinate, but plots of pairs of nutrients were also used. Outliers identified by this means were then inspected individually, and reasons sought for why they might have occurred. Suspect or bad flags were assigned to some or all of the nutrients in a total of 18 samples.

Conversion between mass and volume units (Oct 93)

The appropriate density for converting volume to mass units of nutrient analyses is the density in the lab where known volumes of sample were measured. Using a lab temperature of 21° and a mean salinity of 35, gives a density of 1.025 kg/l; density changes due to salinity variation amount to about 0.1%, and have been ignored. A density of 1.025 kg/l has been used to convert the data reported in the .SEA file.

Internal consistency and comparison with historical data(Oct 93)

As with the other tracers, standard regressions of the deep data onto potential temperature were defined in each basin, and used for comparing station data within and outside the cruise.

The standard fits were as follows (μmol/l):

western basin:	NO2+3 = 33.88 - 1.42 x theta
	phspht = 2.228 - 0.121 x theta
	silcat = 126.90 - 17.85 x theta
eastern basin:	NO2+3 = 33.523 - 3.91 x theta
	phspht = 2.319 - 0.303 x theta
	silcat = 134.12 - 35.58 x theta

At a density of 1.025 kg/l, these are equivalent to (in μmol/kg)

western basin:	NO2+3 = 33.05 - 1.385 x theta
	phspht = 2.173 - 0.118 x theta
	silcat = 123.80 - 17.41 x theta
eastern basin:	NO2+3 = 32.705 - 3.815 x theta
	phspht = 2.262 - 0.296 x theta
	silcat = 130.85 - 34.71 x theta

Using the anomalies relative to these fits, it was possible to monitor the variation in the deep properties of the calibrated nutrient data. Note in passing that the eastern basin nitrate data fell in two families, offset from one another (discussed below). The regression was determined from just one family of data.

Nitrates (Oct 93)

A plot of the station average anomaly against station number made it immediately apparent that there was a problem (of the order of 1 μmol/l) in the consistency of standardization between groups of stations. Furthermore, abrupt changes in the deep nitrate values corresponded to changes in the nitrate value in the QC sample shown in Figure 5. Further investigation showed that all the significant changes in the apparent deep nitrate values occurred at stations where some adjustment had been made to the auto-analyzer. For example, adjusting the sensitivity to keep the instrument response to the top standard near the top of the scale, or a reactivation of the cadmium column.

That such adjustments should lead to changes in the calibrated sample data is clearly not entirely satisfactory. After all, the whole point of standardization is that the concentration in the sample is being determined relative to that of the standard, and should be independent of the instrument settings used. Clearly the adjustments that were made had different affects on the standards and on the samples. The reason for this is not known.

The cadmium column was reactivated before the analysis runs for stations 12284, 12312 and 12322. The first two of these were marked by a fall in the apparent concentration of deep sample nitrates. Calibration of the deep samples appeared unchanged after the third event.

As part of the investigation of the standardization of the auto-analyzer, the instrument peak heights for the various standard concentrations came under renewed scrutiny. Time series plots of these peak heights were found to be a useful way of monitoring the performance of the instrument, and led to the identification of some hitherto unnoticed poor standard values. Joint inspection of the peak heights for the standards with the calibrated sample values was found to be illuminating. For example, it enabled a poorly determined baseline to be identified and corrected, which led to adjustment of some sample values. It also facilitated the correlation of instrument changes with apparent, but what we now know to be spurious, changes in deep sample values. It is our intention that on future cruises we will maintain this practice of carrying the information about instrument standardization and adjustment through to the inspection of sample data.

Another result of the scrutiny of the standard peak heights was some investigation of the appropriate order of polynomial that should be used in the calibration. Unfortunately, the SOFTPAC software used to apply the calibration and drift corrections does not seem to have a facility for displaying the residuals between the standard concentrations and the fitted polynomial. Instead, the standard concentrations and the fitted polynomial are displayed on a graph, which ranges over the full scale of the variable. This makes it very difficult to determine the relative merits of one polynomial compared with another, and also makes it difficult to identify poor values that should be discarded from that particular set of calibration data. For example, a standard which has a lack of fit of 0.5 μmol/l should probably be discarded from the fit, but is hard to detect in the graphical display. Accordingly, the standard peak heights were reanalyzed in Excel spreadsheets, and the following conclusions drawn:

a) The instrument peak heights should be calibrated using a second order polynomial fit. The coefficient of the quadratic term is positive. After fitting the polynomial to six standard concentrations, the rms error is of the order of 0.1 μmol/l.
b) In a number of stations, poor peak heights for individual standards had been retained in the ship board calibration of the data, which should have been discarded. This was made apparent by inspection of the residuals after fitting the quadratic polynomial. Although for future cruises errors of this size should be eliminated, they were not considered to have had sufficient impact to make it worthwhile re-calibrating the data.

Fixing the offsets arising from instrumental adjustment: As described earlier there are spurious changes in the deep sample values, associated with auto-analyzer adjustments. These have been fixed as follows:

a) Stations 12284 to 12287: This group of stations, immediately after a reactivation of the cadmium column, were low relative to adjacent stations. The jump to lower values was clearly associated with the change to the column, but it is not clear why the values increase again. The average anomaly of deep nitrates for these four stations were compared with the average for four stations on either side (12279-12283 and 12288-12291) and found to be 1.56 μmol/l low. Using a mean deep nitrate value of 33.5 μmol/l, it was decided to scale all the sample nitrates for those four stations by a factor of 1.046.
b) Stations 12312 to 12337: This group again follows a reactivation of the column, which was combined with an adjustment to the sensitivity of the instrument, and has lower values than preceding stations; however the nitrates do not appear to return to a higher value. The nitrate value in the QC sample shows the same behaviour. There was sufficient difference between the stations before and after 12312 that the standard regression for nitrate on potential temperature in this basin was determined from one group only, stations after 12312 being chosen. It was decided that one group of eastern basin stations should be adjusted relative to the other to bring them into agreement. There being no absolute means of deciding which were superior, the

adjustment was applied to stations 12312 and following. Comparison of the deep nitrate anomaly for 12312-12337 with 12302-12311 indicated that a correction of 1.46 μmol/l was required. With a mean concentration of 30 μmol/l, this led to a scaling by a factor of 1.048 for all nitrate data for station 12312 to the end of the cruise. Note that since the standard regression had been calculated on data from these stations, all the deep eastern basin data are now about 1.5 μmol/l higher than the standard fit.

Silicates (Oct 93)

A plot of deep silicate anomaly against station number showed that as with nitrates there were some stations which were offset compared with adjacent stations. Unlike the nitrates, however, the silicate values did not seem to be so susceptible to adjustments of the instrument. Five stations stood out in particular, and these were examined and adjusted as follows:

a) Station 12287: Examination of the calibration peak heights showed that they were about 10% low compared with preceding stations; there had clearly been a loss of sensitivity in the instrument for the analysis of this station. Accordingly, silicates for this station were scaled by a factor of 0.989 (-1.4 μmol/l at a concentration of 125 μmol/l) to bring the deep values into agreement with stations 12284-12290.

b) Stations 12318, 12319, 12323, 12325. These stations all had unusually high anomalies for the deep silicate. 12318, 12323, 12325 all show up as spuriously high in the QC values of silicate shown in Figure 5. 12318 and 12319 also had lower than usual peak heights for the standardization. We therefore decided to reduce all four stations by a uniform factor, to bring their mean anomaly into agreement with the average for stations 12320, 12321, 12322, 12324, 12326. The required adjustment was -2.092 μmol/l at a mean value of 108 μmol/l, so a scaling factor of 0.981 was applied.

Phosphates (Oct 93)

No special adjustments were considered necessary for the phosphate data. The relatively greater uncertainty in the phosphate measurements means that the kind of corrections identified for nitrate and silicate are either unnecessary or undetected.

Comparison with historical data (Oct 93)

The internal consistency of the nutrient data (albeit after corrections to some stations) and comparison with other cruises is summarized in Figures 18 (nitrate), 19 (silicate) and 20 (phosphate); each figure has three parts (a) is this cruise, (b) is SAVE leg 4 data and (c) is AJAX data. These figures enable offsets to be identified, as well as showing the degree of scatter in each data set. The symbols show station averages of the deep sample anomalies.

The relative offsets are further summarized in Table N1. The data were sorted into bins of size 0.25, 0.5, 0.025 µmol/l for nitrate, silicate and phosphate, and the center value of the bin containing the median is shown. Standard deviations of the station average anomalies are given in brackets. The standard error of the estimate of the mean/median is somewhat smaller than the standard deviation.

TABLE N1

Medians of station-average offsets between sample data and standard regressions, for various data sets. Units are µmol/l. Values in brackets are standard deviations of the station average anomalies around the mean.

	A11	SAVE	AJAX
nitrate (west)	0.25(0.39)	-0.25(0.73)	none
nitrate (east)	1.5 (0.22)	0.75 (0.24)	0.5(0.09)
silicate	-0.5(1.33)	2.5(1.53)	0.5(0.37)
phosphate	0(0.025)	0.125(0.06)	0.05(0.015)

Compared with SAVE, our nitrates are seen to be about 0.5 µmol/l (1.5%) high, silicates 2.5 µmol/l (2%) low and phosphates 0.125 µmol/l (5%) low. These differences are all significantly more than the internal uncertainty in the data. This demonstrates that our ability to maintain reproducibility over the period of a cruise is rather better than our confidence in the absolute accuracy of the data. The upper limits for accuracy given in the WOCE requirements are 1% for nitrate, 3% for silicate and 2% for phosphate.

2.4 CFC-11, CFC-12, and CFC-113

by: D. Smythe-Wright, S.M. Boswell and D. Price

Sample collection

All samples were collected from depth using 10 liter Niskin bottles. These had been cleaned prior to the cruise using a high-pressure water jet. All 'O' rings, seals and taps were removed, washed in Decon solution and propanol then baked in a vacuum oven for 24 hours. Cleaning and reassembling of the bottles was carried out at the commencement of the cruise to minimize contamination due to long storage. Of the 24 bottles initially assembled three had to be replaced due to leakage. None of the 27 working bottles showed a CFC contamination problem during the entire cruise. All bottles in use remained outside on deck throughout the cruise, those not in use were stored in aluminum boxes inside the hanger where there was a free flow of air to minimize contamination.

Equipment and technique

Chlorofluorocarbons CFC-11, CFC-12 and CFC-113 were measured on a total of 46 stations. The analytical measuring technique was a modification of that described in Smythe-Wright (1991a & b). In the modified system trapping was achieved using a 10 cm Poracil B trap cooled to below -45°C. Subsequent desorption was by means of a water bath at 100°C. The trap was positioned on the exterior of the GC oven and not on the extraction board as in the original system. Valves V6 and V7 were replaced respectively with automated 8 port and 6 port Valco valves sited inside the GC oven to give better chromatographic resolution. Gases were forward flushed off the trap into a 3 m pre-column and subsequently chromatographcally separated using a 75 m long DB 624 megabore column. The pre-column was of the same material as the main column. Samples for analysis were drawn first from the Niskin bottles and stored under clean seawater. The analysis was completed mostly within 12 hours of the samples coming on board. Duplicate samples were run on most but not all casts due to the long analytical turn over time. Air samples were run daily from an air intake high up on the foremast. Air was pumped from this location through a single length of Dekoron tubing using a metal bellow pump.

Calibration

All CFC-11 and CFC-12 analyses were calibrated using 12 point calibration curves constructed from a gas standard calibrated by Weiss at SIO. This standard was contained in an Airco spectra seal cylinder as recommended in WHP, 1991. CFC-113 analyses were calibrated in a similar fashion using a compressed air standard prepared at the JRC and calibrated by Haine at PML.

Contamination

Because of a delay in customs clearance of the airfreight, the CFC equipment was delivered to the ship less than 24 hours before departure. This delay had a knock-on effect and compounded a number of teething problems, mainly due to two blocked valves and a contamination problem which masked the CFC-12 chromatographic peak. This resulted in the loss of data from a number of stations at the beginning of the cruise. The nature and source of the contamination problems was never totally discovered. It seemed to be related to the aquarium baths and the nontoxic seawater supply used for storing the syringes prior to analysis. The problem appeared some days after sailing and was overcome chromatographically by reducing the carrier gas flow and thereby separating the contamination from the CFC-12 peak. This meant that the overall analysis time was lengthened to 25 minutes and consequently restricted CFC analysis to every other CTD cast.

Comparison with historical data

Data accuracy was checked by comparison with SAVE leg 4 and 5 data and with data from the Ajax experiment. Some comparisons are given in Figure 6. Since four years has elapsed since these programmes some deviation in the data was expected particularly in the surface and deepest waters. In all cases deviations were consistent with the increase in atmospheric concentrations over the four-year period.

Reference

SMYTHE-WRIGHT, D., 1990a. Chemical Tracer Studies at IOSDL I. The design and construction of analytical equipment for the measurement of Chlorofluorocarbons in seawater and air.
Institute of Oceanographic Sciences Deacon Laboratory Report No 274, 78 pp.

SMYTHE-WRIGHT, D., 1990b. Chemical Tracer Studies at IOSDL II. Method manual for the routine shipboard measurement of Chlorofluorocarbons in seawater and air.
Institute of Oceanographic Sciences Deacon Laboratory Report No 275, 64 pp.

WHPO, 1991 WOCE Operations Manual. WHP Office Report WHPO 91-1 WOCE Report No 68/91. Woods Hole Mass, USA.

2.5 Samples taken for other chemical measurements

a) Oxygen and Hydrogen isotope ratios
by: S.M. Boswell

A total of 241 samples were collected from 12 stations for isotope analysis by UEA. These included 18 duplicate samples from station 12333. Samples were collected directly into 50 ml glass vials following an initial rinse and two filling/emptying method. The caps were then sealed using parafilm and stored in the refrigerator. A total of 8 samples from the first three stations were lost when the fridge opened in rough weather. Samples thereafter were stored in the cold store.

b) Iodine
by: P. Chapman

A total of 78 samples were collected from full water depth casts at Stations 12255, 12288, 12305 and 12335. These will be analyzed by Dr G Luther, University of Delaware USA.

2.6 CTD Measurements

a) Gantry and Winch Arrangements

by: S. Jordan, R. Phipps, S. Whittle

Midships Gantry

This gantry is of a novel design, and basically acts in the manner of a parallelogram-lifting table. While the gantry is moving from the inboard to outboard positions, the block from which the package is suspended describes an arc of a circle; due to the lifting action of the gantry, no winch movement is normally necessary while the package is being lifted outboard. Various loads, in our case the CTD package, can be safely deployed in virtually any sea state in which the ship can keep station. The performance of the gantry surpassed expectations. One reservation of note concerns the leading of the wire around a number of sheaves required to make the wire follow the parallelogram shape of the gantry. On two occasions, during deployment and with the CTD package at the sea surface, there became sufficient slack in the wire for it to jump off one of the sheaves.

10 Ton Traction Winch

The CTD package was deployed using the 10T Traction Winch. The maximum descent/ascent rate required was 60m/min, therefore only one boost and two main pumps were required for successful operation (two boost and four main pumps being available). The following problems were noted:-

a) A bearing on the scrolling gear was found to be excessively worn. This was replaced with a minimal loss of scientific cruise time (25/12/92). Inspection of the bearing showed it to be incorrectly designed or assembled.

b) The 37kW storage system hydraulic power packs failed to provide power, a fault which persisted after various valves were stripped, cleaned and reassembled (1/1/93). The fault was eventually traced to an erratically operating potentiometer (by P.Gwilliam and A.Taylor). Approximately 36 Hours of scientific time was lost.

c) Inboard compensator and back tension adjustments were needed more or less continuously. Although these were carried out with no loss of scientific time, a satisfactory solution was not found on the cruise.

With known limitations the winch worked reasonably well and appears to have future expansion potential. It must be noted that the manufacturers intend to modify some of this system during the next ship refit, which should eliminate the problems encountered. The mechanical technicians are gaining more knowledge and confidence of the traction winch system and are especially pleased to have managed to repair/maintain the system with minimal down time.

b) Equipment, calibrations and standards

by: T.J.P. Gwilliam

The CTD equipment used on this cruise was the property of IOS. The following equipment was deployed on the CTD/multi-sampler underwater frame:-

1. Neil Brown MK. 3 CTD complete with Sensormedics oxygen cell. IOS identification: DEEP01
2. Sea Tech. 100cm folded path transmissometer. Serial No.: 35.
3. General Oceanics 10 liter 24 bottle rosette. Model 1015. IOS identification: 01.
4. Six SIS (Sensoren Instrumente Systeme) digital reversing thermometers and two SIS digital reversing pressure meters. Serial numbers are detailed elsewhere in the report.
5. Simrad Altimeter, Model 807-200M
6. IOSDL 10 kHz. pinger.

Backup equipment consisted of spare CTD, transmissometer, rosette, Niskin bottles, pinger and underwater frame.

The shipboard equipment consisted of two complete integral systems for demodulating and displaying the CTD data as well as controlling the rosette multi-sampler. Each system included the following major units:-

1. EG&G demodulator. Model 1401.
2. IBM PS2 PC system with 80Mbyte tape system for archiving the data.
3. EG&G non-data interrupt rosette firing module.

Calibration of the MK3 CTD temperature and pressure sensors was carried out at the IOSDL calibration facility. Conductivity and oxygen cell calibration was carried out at sea by reconciliation with sample values. Reversing thermometers were also calibrated in the lab, three at IOSDL and four at the Research Vessel Base.

CTD temperature calibration - IOSDL DEEP01 - 19 June 92 was calibrated in degrees centigrade in the ITS-90 scale at six temperatures ranging from 0.19 to 25.3°. The transfer standard had been calibrated on 25 March 92 at the triple points of Mercury and water, and at the melting point of Gallium. The following linear fit for CTD temperature was found, with a rms error of 0.4 millidegrees.

$$T = 0.9986622 \times Traw - 0.01282084$$

No post-cruise laboratory calibration is available at present (March 1993). The CTD equipment is required on *Discovery* for two subsequent cruises, and will not be returned to IOSDL until at least June 1993. Stability of temperature calibration during the cruise was monitored by comparison with reversing thermometers, and this is discussed in the description of reversing thermometer data.

CTD pressure calibration - IOSDL DEEP01 - 24 June 92 was calibrated by comparison with a Paroscientific Digiquartz model 240 portable transfer standard, in series with a deadweight tester; the Digiquartz was used as the pressure standard. The following quadratic fit for CTD pressure was found at an ambient temperature of 20°C, with a rms error of 1.8 dbar.

P = 3.066286E-07 x Praw**2 + 0.9978454 x Praw - 12.6

Further corrections were applied during data processing for variation of offset with temperature, and up/down hysteresis.

Equipment performance

General

With deployments at approximately four hourly intervals, power to the CTD was maintained throughout the cruise to minimize interruption problems. For satisfactory operation the optimum sea cable input voltage and current levels were 80 volts at 640 milliamps. Power distribution for the CTD, rosette and altimeter was controlled by a simple circuit in a separate 6 inch diameter pressure case mounted on the frame. The sea cable was terminated before sailing and a further three times during the cruise when cable damage occurred on deployment in heavy swell conditions. In two of the instances, the slack was sufficient to bounce the cable from the winch gantry pulleys, resulting in the instrument package free falling through the water for several meters. Approximately 30/40 meters of cable had to be discarded when this occurred.

CTD

As usual at the start of a cruise, the oxygen sensor was renewed before installing the system into the underwater frame. The first cast, to test the winch and CTD system, highlighted a wiring fault with the conductivity electronics which was quickly identified and corrected. Before station 12287 (near mid-cruise) the conductivity cell was flushed out with 10% hydrochloric acid as data from the previous two stations had indicated contamination.

24 Bottle Rosette System.

It was this system that gave the most problems, non-closing of bottles and double bottle closing producing a lack operational confidence. Cures seemed, at times, to be the result of a "black art" rather than engineering expertise. The pylon was washed down immediately after each recovery with hot fresh water and the mechanical switching mechanism lubricated with silicon oil before the next deployment. Several times during the cruise the operational rosette pylon (01) was serviced on the frame and also interchanged with the backup unit (IOS identification 02) for a more detailed mechanical inspection and overhaul.

The present system of codes, indicating bottle-firing information, is not satisfactory. Misfire codes transmitted when one or more bottles had in fact closed, multiple trips that could not be identified, and a lack of cam position information are just a few of the problems that need to be resolved.

In one instance seawater ingress via the camshaft, on pylon 01, caused corrosion damage to the 24-way rotary code switch which had to be replaced. Perhaps there would have been greater protection had the switch been mounted on the shaft beneath the motor.

Prior to the cruise the springs in all the bottles had been changed for ones of a different type at the request of the CFC analysts: these alternative springs had a different length and tension from the originals. Unfortunately, during the cruise the spring fastenings on the bottle end caps were mechanically breaking down to such an extent that the original springs were restored. During the cruise, three bottles were changed as suspected "leakers".

Transmissometer.

The transmissometer worked well throughout most of the cruise, but there were times when noise on the data, although not at an unacceptable level, proved difficult to trace and eliminate. The voltage in air was 4.310 volts, and the blackout offset was 16 millivolts. Towards the end of the cruise a slight leak in the prism pressure balancing mechanism was observed, which will require attention back at the laboratory.

SIS Thermometers and Pressure Meters.

Apart from routine battery replacements, one unit, T228, was removed after station 12248; the temperature readings were found to be in error by several hundred millidegrees. Comparison studies with the CTD data to check stability and accuracy were carried out and the results are shown elsewhere in this report.

Altimeter and 10 kHz Pinger.

This was the first IOSDL cruise where "depth off bottom" information was included into the CTD data stream and digitally displayed on the CTD monitor: the results were very satisfactory. The unit invariably locked onto the bottom from a range of 200 meters and tracked to the depth required with no problems. The 10 kHz. pinger, working in conjunction with the ship's Echosounder had in the past been the only way of obtaining this information. As the cruise progressed, and confidence increased with the altimeter, the 10 kHz. system was used more in a backup role. Apart from requiring battery changes the pingers themselves were totally reliable.

Shipboard Equipment

Overall the deck equipment worked satisfactorily with only one minor problem on one of the 1401 deck units. The acquisition software worked well and 12 tapes of 80 Mbytes of backup CTD data were archived.

c) CTD Data Collection and Processing (updated June 94)

by: B.A. King

Data Capture and Reporting

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

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

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

Station 12286

In general downcast CTD data are reported. One exception is station 12286, where upcast data are reported. The conductivity had a number of fouling events on the downcast, identified by a number of jumps of order 0.002 to low values in the T/S relation. The upcast data appear to be satisfactory. The sorted, averaged 2db file was therefore compiled from the upcast data for all variables. After this station the conductivity cell was cleaned with dilute acid. After this the quality of the salinity data considerably improved, and the required cell offset changed by about 0.006 in salinity, suggesting that an accumulation of contamination had also been cleared away.

Temperature calibration

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

T = Traw x 0.998662 - 0.01282

This calibration was in degrees C on the ITS-90 scale, which was used for all temperature data reported from this cruise. It was determined from a six-point calibration on 19 June 1992.

A post-cruise temperature calibration was determined from a 12-point calibration on 8 July 1993 as follows:

T = Traw x 0.998559 - 0.01409.

This being sufficiently close to the initial calibration (a change in offset of about 1.3 millidegrees during the intervening 12 months), no changes were made to the temperature data.

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

T68 = 1.00024 T90

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

In order to allow for the mismatch between the time constants of the temperature and conductivity sensors, the temperatures were corrected according to the procedure described in the SCOR WG 51 report (Crease et al., 1988). The time constant used was 0.20 seconds. Thus a time rate of change of temperature (called deltaT) was computed, from 16Hz data in the level A, for each one-second data ensemble. Temperature T was then replaced by T + 0.2 x deltaT.

Pressure calibration

The following calibration was applied to the CTD pressure data, based on the 24 June 1992 calibration:-

P = Praw **2 x 3.066286E-7 + Praw x 0.997845 - 9

The calibration applied to the data included an offset different from that found in the lab calibration and given in section 2.5b. The chosen offset gave correct pressures on deck and over the top few meters of the cast. A post-cruise pressure calibration at IOSDL on 7 July 1993 provided a laboratory calibration of

$$P = Praw^{2} \times 4.172168E-7 + Praw \times 0.996952 - 9$$

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

A further correction was made for the effect of temperature on the CTD pressure offset:-

$$Pnew = Pold - 0.4 (Tlag - 20) .$$

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

$$W = \exp (- tdel/tconst)$$

$$Tlag(t=t0+tdel) = W \times Tlag(t=t0) + (1 - W) \times T(t=t0+tdel).$$

The values of 400 seconds for tconst and the sensitivity of 0.4 db per ˚C are based on laboratory tests. During the cruise, the variation of deck pressure value with ambient temperature was monitored. A least squares linear fit to the set of 73 deck pressure/temperature pairs collected had a slope of 0.49 and an offset of 5.4 db at 10°: this agrees with the applied correction to within 1.5 dbar over the range 0 to 20°C.

A final adjustment to pressure is to make a correction to upcast pressures for hysteresis in the sensor. This is calculated on the basis of laboratory measurements of the hysteresis. The hysteresis after a cast to 5500m (denoted by dp5500(p)) is given in Table H1a for pressures at 500db intervals. Intermediate values are found by linear interpolation. If the observed pressure lies outside the range defined by the table, dp5500(p) is set to zero. For a cast in which the maximum pressure reached is pmax dbar, the correction applied to the upcast CTD pressure (pin) is

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

Two thirds of the way through the cruise, at station 12303, a slight hysteresis between the up and down theta-S relationship was noted; upcast salinity was lower than the down. The size of the difference was small near the bottom of the cast, growing to a maximum of about 0.002 at about 3000 meters. At shallower depths the shape of the theta-S curve made it impossible to determine differences to the required accuracy. After some consideration, it was felt that the most likely cause of this was the CTD pressure (after the above correction for hysteresis) still reading slightly too high on the upcast. Accordingly the size of the hysteresis correction was increased, so that upcast pressures read slightly lower, and Table H1b was used.

TABLE H1

(a) Laboratory measurements of hysteresis in pressure sensor dp5500(p) = (upcast - downcast) pressure at various pressures, p, in a simulated 5500m cast. (b) revised form of hysteresis used for stations 12303-12337

	(a)	**(b)**
p	**dp5500(p)**	**dp5500(p)**
db	db	db
5500	0.0	0.0
5000	1.0	0.0
4500	1.2	1.2
4000	1.8	2.8
3500	2.4	4.4
3000	3.0	6.0
2500	3.4	6.8
2000	4.8	6.6
1500	5.6	6.5
1000	6.0	6.4
500	6.3	6.3
0	0.0	0.0

Extraction of upcast data for calibration

Following procedures developed on previous cruises, CTD data were extracted for salinity and oxygen calibration as follows:

The Niskin bottle firing events were logged using a level A microprocessor dedicated to that purpose. This provided accurate times of the bottle closures.

The CTD data after nominal calibration were averaged into 10-second bins, and merged onto the firing events using linear interpolation on time; the time for both the CTD data and the firing events were provided by the ship's master clock, and were therefore reliable. The 10-second averages were believed to be representative of the CTD data for the water sampled.

After coefficients for calibration of the CTD oxygen or salinity had been calculated and applied to the 1 Hz data, the averaging and merging procedure was repeated as often as necessary, until the calibration was finalized. In this way, residuals were always calculated between the sample values and the latest estimate of the calibrated CTD data.

Salinity calibration

Salinity was calibrated during the course of the cruise, by comparison with upcast sample salinities. This was done on a *station by station* basis. A cell conductivity ratio of 0.996683 was estimated from early stations, and this was applied to all station data as an initial calibration. The initial calibration was followed by the correction to conductivity ratio:-

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

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

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

The need for this procedure is not understood. We do not necessarily believe that this correction represents some physical response of the cell to temperature and pressure. Rather, it is simply a convenient way of fitting the salinity residuals with two variables which have different variation over the water column; however, since it successfully removes most of the systematic part of the salinity residuals, it is considered to be a satisfactory tool for the correction of the CTD salinity data. The offset at the bottom of each station introduced by the expression above, which may be used as a description of the drift of the cell, was monitored and varied between -0.008 and +0.008 (but not monotonically). A full list of the coefficients appears in Table H4, which is located at the end of this section.

Unlike the oxygen calibration procedure (q.v.), the agreement between upcast and downcast T/S profiles was good. It was therefore decided that the calibration of upcast CTD salinities by comparison with sample salinities would provide adequately calibrated downcast CTD salinity data.

Stations 12251-12255: These stations required special attention for salinity calibration. An extra temperature sensor (FSI) had been introduced on the rosette and interfaced to the CTD for evaluation purposes. This extra power demand on the CTD meant that the conductivity cell did not return to satisfactory values for some while after firing a bottle, while the rosette pylon was recharging. Once the problem had been properly identified the power supply to the CTD was increased, and the problem solved. In the mean time, however several profiles of data were collected for which the upcast salinities were suspect or useless. Accordingly, straightforward comparison of upcast CTD salinities with sample salinity could not be used for CTD calibration. The CTD data were therefore scrutinized to ensure that bad data cycles (sometimes several hundred meters worth) were excluded from the calibration. Some salinity sample values were not used, if it was not possible to find a suitable CTD value for comparison.

Sometimes a matching downcast CTD salinity would be used, in the manner employed for oxygen calibration. The final downcast CTD salinity values are believed to be satisfactory. However, there remain a number of sample minus CTD residuals which are quite large, mainly associated with poor upcast CTD salinities. The residuals for these five stations are therefore omitted entirely from Figure 10.

Station 12325: Two casts were required to complete station 12325. The rosette jammed part of the way through the upcast, so no samples were collected in the upper 1500 meters of cast 1. A second cast to 1500 meters was carried out to obtain a complete sample profile (sample numbers 32525-32538). The CTD data reported are the downcast of cast number 1. Having applied a single CTD salinity calibration to the two casts together, the salinity residuals for cast number 2 are rather large; basically, the CTD salinities are 0.003 to 0.005 higher than the bottle values. Two further pieces of evidence are available: (a) The CTD calibration was offset by about 0.002 for station 12326 & 12327 (see Table H4). (b) The FSI conductivity cell, described elsewhere, was in use on this station. Inspection of the conductivity data from the two sensors supports the suggestion that the NBIS salinity data did indeed drift to higher values on cast number 2. We therefore conclude that the cast 1 downcast salinities which form the cruise data set are satisfactory and that the cast 2 upcast CTD salinities, which appear in the sample .SEA file, are questionable.

Oxygen calibration

CTD oxygens were calibrated by fitting to sample values using the following formula:-

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

where the coefficients rho, a, b, the oxyc offset c and the weight W were chosen on a station by station basis to minimise the rms residual. W is forced to lie in the range 0 to 1.

The fitting of oxygen data at sea did not allow for an offset to the oxygen current, and required the weight W to be specified by the user. The resulting fits were not entirely satisfactory: rms errors were about 3-4 μmol/kg, and there was a tendency for the calibrated CTD data to produce the wrong oxygen gradient in the deep water. Introducing the time rate of change of oxyc had little effect but, in contrast, an offset in oxyc (of the order of -0.07 μA) produced a significant improvement. IOSDL has not previously found it necessary to introduce an offset in oxyc in order to achieve satisfactory oxygen fits, and the value required is rather greater than suggested in the WOCE Manual of operations and methods. With hindsight, we suspect that this offset indicates an unusual oxygen cell, which should probably have been replaced. However, having introduced the offset, there is no reason to doubt the quality of the derived CTD oxygen data. Table H5, located at the end of the section, gives oxygen fitting coefficients and residuals station by station. For a few stations, where there were insufficient sample values to fit all five coefficients sensibly, b and/or c were chosen from values on nearby stations.

For some stations, several passes through the fitting procedure were used to arrive at the final coefficients. After an initial fit, outliers were identified, and excluded from subsequent fits. In this way the CTD data were used to help identify sample values requiring 'suspect' or 'bad' flags. There is further discussion of this in the section describing the oxygen sample data. In general, samples believed to be suspect for any reason, were excluded from the CTD fitting. However, it was sometimes necessary to include them (stations 12253 to 12257, for example, where all samples were suspect), and such included samples are listed in the sample oxygen discussion. Furthermore some 'good' samples could not be fitted properly with the CTD data - typically in regions of strong vertical gradient. These samples were also excluded from the fit if their exclusion resulted in significantly improved residuals over the rest of the profile. Numbers of samples excluded for this reason are also listed elsewhere.

The residuals between CTD and sample oxygens are summarized in a table in Section 2.2, where they are averaged into 500 meter depth bins. The errors appear to have a systematic form. However, the rms difference of all samples is 2.66 μmol/kg, and 1.73 μmol/kg for samples from deeper than 3000 dbar. We therefore consider the CTD data to be acceptable in their present form.

Calibration of downcast CTD oxygen data using upcast samples: The calibration algorithm for the CTD oxygen data generally produced up and down profiles which did not match particularly well, either as pressure/oxygen profiles or as potemp/oxygen profiles. This is believed to be a widespread problem, arising from the calibration algorithm not being a sufficiently good model of the true response of the sensor. However, we know that some investigators find that they can get consistently good up/down matching. Whether this varies from cell to cell, is a subtle function of the electronics of the CTD, or a function of the way the algorithm is applied, we do not know. In the present data, up/down agreement varied from very good to appalling, with no apparent reason or change of procedure. The fact remains, therefore, that we require to bring the downcast CTD oxygens (which we report for all but station 12286) into agreement with the upcast samples. For each sample, we thus need to extract a downcast CTD data cycle (press, temp, oxyc, oxyt) for calibration against sample oxygen. Again following procedures developed on previous cruises, we extracted a downcast data cycle of CTD data as follows:

a) the pressure, potential temperature and potential density (referenced to the nearest round multiple of 500db) at the bottle closing time were extracted. This provided a choice of three parameters which could be used to find a suitable matching downcast data cycle. No one parameter was considered to be universally the best. Matching on pressure was not considered to be ideal, because of vertical motion of water during the elapsed time between down and up cast passing through the same water mass. In general, because of up/down salinity biases on some stations, potential temperature (supposed conserved while internal waves pass through) would seem to be the best, and preferable to potential density. However, the profiles encountered on this cruise included ones where, because of the salinity gradient, there were reversals in potential temperature, or regions of very weak potential temperature gradient. In these cases, potential temperature was not suitable for matching, and potential density was used. Potential density could not be used throughout, however, because apart from vulnerability to poor salinity values there were also regions where potential temperature and salinity had reasonable gradients but potential density had only very weak gradients. The matching procedure therefore usually employed potential temperature at pressures greater than 3000db, and potential density at pressures less than 3000db. Matched data cycles where the up/down pressure difference was greater than 10% were flagged and received special attention.

b) the CTD downcast was scanned for pairs of data cycles which bracketed the chosen parameter, and closer of the pair listed.

c) where step (b) produced more than one candidate data cycle (arising from potemp reversals, for instance), the one with the nearest pressure was chosen.

d) thus far, the procedure was entirely automated. Every matching data cycle was then examined for plausibility, by (subjective) consideration of agreement of pressure, temperature and salinity between up and down data cycles. If agreement was poor, or if the automatic procedure (ie choose the one with the nearest pressure from two or more possibles) had apparently chosen the wrong data cycle, a different data cycle was specified to be the matching one. This quite commonly occurred for the shallowest sample, when the data cycle with matching pressure might be specified instead.

e) the CTD values from the resulting set of up to 24 downcast data cycles were employed in the oxygen fitting algorithm.

Conversion from µmol/l to µmol/kg: Because of the sequence of events, and the careful thought that went into the conversion of oxygen units, the CTD oxygen data were fitted to sample data measured in µmol/l, that had not yet been converted to µmol/kg. Accordingly the CTD data also require conversion. Since the requirement is for the converted CTD data to fit the converted sample data, the CTD data throughout the cruise have been scaled using density calculated as for the sample data (see the discussion of sample oxygens), namely one calculated from measured salinity and a temperature which is a piecewise linear function of measured potential temperature.

Transmissometer data

Transmittance data from 1 one meter folded path transmissometer were routinely collected throughout the cruise. At present (June 1994) station to station inconsistencies in the calibration of these data mean that they are not ready for submission to the WHPO with the bulk of the CTD data. They will be submitted in due course, after completing best efforts at their calibration.

SIS thermometer data, and the stability of the CTD temperature sensor

Six SIS digital temperature meters and two digital pressure meters were used throughout the cruise. These, along with salinity and chemical data from the rosette water samples, were used to determine the depth of bottle firings.

Digital Reversing Temperature Meters (RTM)

The digital temperature meters were calibrated using the linear fits given in Table H2. In addition to these another sensor, T228, was discarded after the first station of the A11 cruise.

A comparison of CTD and RTM temperatures is given in Table H3 below. The table has four parts. Parts (a) and (b) present data from the entire section, with part (b) for temperature colder than 2°; as expected, the latter have generally smaller standard deviations. Parts (c) and (d) show the data colder than 2° further subdivided about station 12293, which is one of the stations over the mid-Atlantic Ridge. Three numbers of observations are given in each part, corresponding to the number of differences greater than 10 millidegrees, considered as outliers and discarded, the number less than 10 millidegrees, from which mean and standard deviation are calculated, and the number within two standard deviations of the mean.

The most significant feature of these tables is the change in mean value of ctd-T399 and ctd-T400 between the two halves of the cruise, the mean difference changing by 1.3 millidegrees. This is rather more than the standard deviation of the measurement, and much more than the standard error of the estimate of the mean for each group. Although this might be thought to indicate an offset in CTD temperature calibration (there being no change in the T400-T399 difference), there is no evidence for this in the ctd-T401 and ctd-T219 pairs. Our tentative conclusion is that the difference arises because the temperature observed at rosette position 1 is generally warmer in the eastern basin than in the western basin. Note the mean temperature of the observations, which is shown in the last column of Table H3 (c) and (d). We suppose that non-linearity in the response of either CTD or RTM temperature near zero may be the cause of the change in CTD-RTM difference. If it is the behavior of the RTM thermometers that is nonlinear, then it must be very similar in the two thermometers; this is not unreasonable for two instruments of the same type. On the other hand, we do not exclude the possibility of nonlinear behavior in the CTD temperature. When the CTD is re-calibrated on return to IOSDL, careful attention will be paid to establishing the linearity or otherwise of the calibration near zero. (Note added, May 1994: This effect was examined by careful calibration of the CTD near zero degrees in late 1993. Although some other CTD instruments have been found by IOSDL to have nonlinear errors of several millidegrees, the instrument used during A11 had errors of no more than 0.5 millidegrees, and then only within 0.2 degrees of zero. CTD non-linearity near zero is therefore unable to account for the observed change in CTD-RTM difference.) In any case the overall consistency of the CTD and RTM comparisons and the magnitude of the change in differences amongst them strongly imply that there was no significant change in the CTD calibration between the start and the end of the cruise.

Digital Reversing Pressure Meters (RPM)

Two reversing pressure meters were used :-

Rosette position	Pressure meter
1	P6132H
8	P6075S

Despite the shortcomings in the RPM performances, which are described below, their data were very useful in confirming or identifying the depth of bottle closures.

Calibration of P6075S were carried out by the manufacturer on both 13.2.88 and 27 3 90 the latter at temperatures of both 3 and 20°C. These indicated that corrections of between -7 and +3 dbar were required over the range 0 to 5400 dbar. However residuals between the calibrated RPM and the CTD were found on cruise 199 to exceed 30 dbar at pressures greater than 3000 dbar.

P6132H was calibrated by the manufacturer on 22.2.90. Linear interpolation was used to correct the RPM between the following calibration values in dbars:-
(P6132H pressure, correction applied), (0006,-6), (0975,+6), (1949,+12), (2930,+12), (3915,+8), (4907,-4), (5405,-11), (6022,-22).

The last pair was not supplied by the manufacturer, but was an extrapolation of the manufacturer's information. In general, after applying the above calibration, P6132H shows a consistent offset compared with the CTD of about 14 dbars over the range 1800 - 6000 dbar.

Discrepancies of similar magnitude between RPM and CTD pressures have been noted on a number of previous IOS cruises, see for example the CONVEX cruise report (Gould et al, 1992). On cruise 199 the CTD bottom pressures were converted to depth and were compared with corrected Echosounder depths minus depth of CTD off bottom: the differences had a mean value of 3 meters and 75 percent were smaller than 12 meters. On the CONVEX cruise an even smaller mean for nearly 100 stations was found. We are therefore quite confident of the CTD pressure calibration and in the near future plan to carry out calibration and other tests of the RPM instruments at IOSDL.

Reference

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

GOULD, W.J. et al. 1992 RRS Charles Darwin Cruise 62, 01 Aug-04 Sep 1991. CONVEX-WOCE Control Volume AR12. IOSDL, Institute of Oceanographic Sciences Deacon Laboratory Cruise Report, No 230, 60pp.

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

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

TABLE H2

Digital RTM calibrations. Tcal = b x Traw + a

Position on rosette	Thermometer	b	a	Date off calibration	Source
1	T399	1.00031	-0.00331	20/7/92	IOSDL
1	T400	1.00006	0.00146	20/7/92	IOSDL
4	T401	1.00016	-0.01002	20/7/92	IOSDL
4	T219	0.99992	-0.01250	18/8/92	RVS
8	T238	0.99992	0.00175	18/8/92	RVS
12	T220	0.99999	-0.00570	18/8/92	RVS

TABLE H3

Summary of RTM data

Pair	(a) All Data n >10 mdeg	n <10 mdeg	n <2sd	mean mdeg	sd mdeg	(b) T < 2° n >10 mdeg	n <10 mdeg	n <2sd	mean mdeg	sd mdeg
ctd-T399	1	92	90	1.0	1.6	0	75	72	1.1	1.5
ctd-T400	2	91	88	0.8	1.3	1	74	70	0.9	1.1
ctd-T401	3	90	84	2.1	2.2	2	60	56	2.0	1.7
ctd-T219	5	82	76	-6.7	2.3	2	56	52	-6.8	1.7
ctd-T238	9	80	75	1.6	2.5	0	17	16	0.7	3.0
ctd-T220	9	69	65	2.0	2.6	0	1	1	1.9	-
T400-T399	0	93	89	0.4	0.9	0	75	72	0.4	0.9
T401-T219	4	82	79	-8.7	1.8	2	56	55	-8.6	1.4

Pair	(c) stnnbr < 12293 n >10 mdeg	n <10 temp	n <2sd	mean mdeg	sd mdeg	mean temp degC	(d) stnnbr > 12293 n >10 mdeg	n <10 temp	n <2sd	mean mdeg	sd mdeg	mean temp degC
ctd-T399	0	38	36	0.6	0.9	0.33	0	36	35	1.9	0.8	1.19
ctd-T400	0	38	37	0.3	1.0	0.33	0	36	35	1.6	0.9	1.19
ctd-T401	1	39	37	2.0	1.5	0.60	1	20	19	2.2	1.8	1.46
ctd-T219	0	36	34	-6.8	1.7	0.48	2	19	18	-6.6	1.5	1.46
T400-T399	0	38	36	0.3	0.9	0.33	0	36	34	0.3	0.5	1.19
T401-T219	0	36	35	-8.9	1.5	0.48	2	19	18	-8.9	1.1	1.46

TABLE H4

**Final CTD salinity adjustments. S = S + (a + b * T + c * P)/1000
The number in the deep offset column was the offset applied to the CTD salinities at the bottom of the cast as a result of the residual fitting procedure.**

Station number	a	b	c	Deep offset	Comments
12247	-4.95	0.19	-0.00597	-0.0054	
12248	-2.80	0.00	0.00000	-0.0028	
12249	-2.00	0.00	0.00000	-0.0020	
12250	-2.00	0.00	0.00000	-0.0020	
12251	-2.00	0.00	0.00000	-0.0020	
12252	-1.87	0.09	-0.00141	-0.0054	
12253	-7.09	0.38	0.00128	-0.0025	
12254	-4.00	0.00	0.00000	-0.0040	
12255	-2.35	-0.15	0.00002	-0.0023	
12256	-2.20	0.11	-0.00058	-0.0050	
12257	1.58	0.10	0.00000	0.0016	
12258	-1.34	0.50	0.00015	-0.0004	
12259	3.35	-0.27	-0.00031	0.0015	
12260	3.50	0.00	0.00000	0.0035	
12261	3.86	-0.62	-0.00030	0.0018	
12262	0.04	0.28	0.00034	0.0022	
12263	3.60	-0.21	-0.00005	0.0032	
12264	4.70	-0.64	-0.00069	0.0006	
12265	3.90	-0.17	-0.00020	0.0028	
12266	2.90	0.00	-0.00013	0.0022	
12267	3.80	-0.37	-0.00029	0.0022	
12268	5.30	-0.25	-0.00045	0.0029	
12269	7.60	-0.78	-0.00151	-0.0004	
12270	2.40	0.00	0.00000	0.0024	
12271	2.60	0.02	-0.00029	0.0011	
12272	0.50	0.18	0.00052	0.0031	
12273	3.30	0.04	-0.00030	0.0018	
12274	1.10	0.16	-0.00032	-0.0005	
12275	2.10	-0.12	-0.00048	-0.0003	
12276	-1.50	0.35	0.00014	-0.0007	
12277	0.10	0.02	-0.00004	-0.0001	
12278	1.00	0.13	-0.00035	-0.0009	
12279	4.80	-0.30	-0.00068	0.0011	
12280	-0.60	0.30	-0.00032	-0.0022	
12281	2.00	-0.10	-0.00048	-0.0005	
12282	4.10	0.16	-0.00012	0.0035	

Station number	a	b	c	Deep offset	Comments
12283	0.20	0.13	-0.00048	-0.0023	
12284	0.80	0.06	-0.00018	-0.0001	
12285	6.40	0.27	0.00029	0.0078	
12286	4.90	-0.37	-0.00048	0.0026	
12287	-0.80	-0.45	-0.00063	-0.0040	Note 1
12288	-3.60	0.11	-0.00027	-0.0048	
12289	-8.00	0.58	0.00072	-0.0045	
12290	-3.60	-0.03	-0.00038	-0.0052	
12291	-2.20	-0.01	-0.00064	-0.0051	
12292	-0.90	-0.25	-0.00086	-0.0046	
12293	-0.50	-0.27	-0.00091	-0.0041	
12294	-6.89	0.39	0.00057	-0.0044	
12295	-8.45	0.55	0.00102	-0.0042	
12296	-1.02	-0.40	-0.00120	-0.0059	
12297	-5.67	0.05	0.00012	-0.0052	
12298	-6.96	0.31	0.00045	-0.0052	
12299	-4.61	0.01	0.00029	-0.0036	
12300	1.24	-0.39	-0.00039	-0.0008	
12301	1.53	0.07	-0.00056	-0.0005	
12302	1.62	0.21	-0.00063	-0.0006	
12303	1.90	-0.32	-0.00084	-0.0018	
12304	3.35	-0.43	-0.00096	-0.0009	
12305	-0.04	0.04	-0.00024	-0.0010	
12306	0.99	-0.18	-0.00047	-0.0010	
12307	-0.63	-0.02	-0.00011	-0.0011	
12308	2.03	-0.24	-0.00083	-0.0014	
12309	1.37	-0.22	-0.00031	-0.0001	
12310	-2.34	0.09	-0.00023	-0.0033	
12311	-0.51	-0.03	-0.00031	-0.0020	
12312	-0.03	-0.06	-0.00016	-0.0008	
12313	1.24	-0.14	-0.00011	0.0005	
12314	0.79	-0.05	-0.00031	-0.0008	
12315	0.99	-0.13	-0.00045	-0.0015	
12316	-0.55	0.11	-0.00032	-0.0021	
12317	-1.64	0.03	-0.00072	-0.0053	
12318	-1.07	-0.11	-0.00108	-0.0068	
12319	-2.59	-0.09	-0.00064	-0.0061	
12320	-1.56	-0.06	-0.00069	-0.0053	
12321	-2.92	0.31	-0.00050	-0.0052	
12322	-2.06	-0.27	-0.00058	-0.0055	
12323	-2.90	-0.10	-0.00041	-0.0052	
12324	-2.18	0.00	-0.00067	-0.0056	
12325	-2.64	-0.09	-0.00062	-0.0059	

Station number	a	b	c	Deep offset	Comments
12326	-5.69	0.05	-0.00036	-0.0075	
12327	-12.42	0.36	0.00659	-0.0078	
12328	-11.91	0.36	0.01548	-0.0025	
12329	-7.69	0.40	0.00176	-0.0046	
12330	-3.45	0.10	0.00079	-0.0020	
12331	-2.96	0.12	0.00048	-0.0016	
12332	-1.92	0.01	-0.00017	-0.0023	
12333	-0.83	-0.05	-0.00057	-0.0027	
12334	0.66	-0.13	-0.00110	-0.0035	
12335	-1.58	-0.17	-0.00083	-0.0052	
12336	-1.37	-0.03	-0.00033	-0.0029	
12337	1.62	-0.20	-0.00080	-0.0025	

Notes
1) The conductivity cell was cleaned prior to station 12287 with dilute acid.

TABLE H5

CTD oxygen fitting coefficients and residuals
O2 = oxsat(T,S) * rho * (oxyc + c) * exp(a * (W*ctdT + (1-W)*oxyT) + b*P)

Station number	rho	a	b	c	W	rms residual μmol/kg	No. of samples in fit
12247	1.3509	-0.04531	0.0002200*	-0.0500*	0.5232	4.50	5
12248	1.4430	-0.04985	0.0002200*	-0.0500*	0.3548	5.81	8
12249	1.5021	-0.05487	0.0001365	-0.0500*	0.4718	2.54	10
12250	1.3023	-0.04065	0.0002307	-0.0500*	0.4500*	10.31	10
12251	1.3957	-0.04580	0.0002102	-0.0564	0.4625	0.97	9
12252	1.3773	-0.04171	0.0001875	-0.0364	0.3563	3.75	18
12253	1.3662	-0.03939	0.0002661	-0.0798	0.5888	4.87	15
12254	1.4825	-0.04791	0.0002278	-0.0792	0.5610	5.06	14
12255	1.4115	-0.04461	0.0001792	-0.0342	0.4481	4.16	19
12256	1.5397	-0.03968	0.0002144	-0.0799	0.0288	4.60	22
12257	1.5118	-0.05284	0.0003048	-0.1309	0.4454	3.40	20
12258	1.3285	-0.03882	0.0001408	0.0145	0.4457	2.53	23
12259	1.4914	-0.03994	0.0002219	-0.0783	0.2443	3.49	21
12260	1.4591	-0.04499	0.0001978	-0.0549	0.6260	2.68	12
12261	1.5485	-0.04432	0.0002515	-0.1069	0.4804	3.57	24
12262	1.5619	-0.04913	0.0002569	-0.1128	0.3995	3.98	23
12263	1.2720	-0.03901	0.0001499	-0.0179	0.5207	3.92	24
12264	1.4108	-0.04008	0.0002459	-0.1271	0.3886	3.52	23
12265	1.3179	-0.03916	0.0002020	-0.0811	0.4963	3.38	23
12266	1.3719	-0.03900	0.0002317	-0.1109	0.4432	2.07	22

Station number	rho	a	b	c	W	rms residual μmol/kg	No. of samples in fit
12267	1.3776	-0.03755	0.0002525	-0.1244	0.5492	1.55	17
12268	1.3353	-0.03949	0.0002305	-0.1048	0.6906	2.30	23
12269	1.3596	-0.04107	0.0002267	-0.1036	0.5512	1.32	16
12270	1.2812	-0.03574	0.0002142	-0.0823	0.4933	1.96	15
12271	1.3696	-0.03904	0.0002298	-0.1067	0.6887	3.02	24
12272	1.3317	-0.03626	0.0002229	-0.0944	0.8601	2.89	20
12273	1.3189	-0.03277	0.0002282	-0.1049	0.4223	2.87	21
12274	1.3318	-0.03581	0.0002334	-0.1088	0.4931	2.27	23
12275	1.2802	-0.03730	0.0002004	-0.0718	0.6542	3.22	23
12276	1.3504	-0.04087	0.0002080	-0.0862	0.8183	4.58	23
12277	1.3447	-0.03611	0.0002030	-0.0817	0.4094	1.90	35
12278	1.3839	-0.03719	0.0002150	-0.0940	0.4477	2.11	24
12279	1.3907	-0.04412	0.0002012	-0.0813	0.7213	3.04	22
12280	1.3703	-0.04452	0.0002014	-0.0771	0.6437	2.57	24
12281	1.3132	-0.03819	0.0001860	-0.0599	0.4888	3.25	22
12282	1.3118	-0.03885	0.0001818	-0.0516	0.8816	3.88	23
12283	1.3900	-0.04221	0.0002096	-0.0952	0.5435	2.68	23
12284	1.4284	-0.04711	0.0001855	-0.0750	0.8929	3.56	22
12285	1.3718	-0.04497	0.0002173	-0.1035	0.4343	2.74	22
12286	1.4744	-0.05322	0.0001871	-0.0730	0.0000	2.33	21
12287	1.2674	-0.03658	0.0001526	-0.0035	0.6970	1.88	23
12288	1.3757	-0.04111	0.0001603	-0.0315	0.5249	3.25	21
12289	1.4411	-0.04461	0.0001840	-0.0607	0.4252	2.29	21
12290	1.3827	-0.04342	0.0001806	-0.0481	0.6347	3.20	20
12291	1.4099	-0.04423	0.0001728	-0.0461	0.6092	2.39	22
12292	1.3167	-0.03853	0.0001678	-0.0255	0.7202	1.91	19
12293	1.3517	-0.03807	0.0001819	-0.0454	0.5418	3.33	22
12294	1.2880	-0.03851	0.0002598	-0.1160	0.8752	2.95	20
12295	1.4685	-0.04358	0.0002230	-0.0930	0.6440	4.69	19
12296	1.3764	-0.03828	0.0002070	-0.0653	0.6122	1.76	21
12297	1.4189	-0.04084	0.0002023	-0.0662	0.4213	1.35	17
12298	1.3558	-0.04550	0.0001894	-0.0379	0.8781	3.33	17
12299	1.4762	-0.05084	0.0001891	-0.0593	0.6076	4.23	17
12300	1.3929	-0.04131	0.0001923	-0.0554	0.7530	3.63	19
12301	1.3777	-0.03845	0.0001937	-0.0532	0.4853	1.93	18
12302	1.2843	-0.03212	0.0001847	-0.0310	0.4087	1.52	16
12303	1.3022	-0.03259	0.0001876	-0.0385	0.4467	2.01	19
12304	1.3744	-0.03734	0.0001998	-0.0604	0.5594	2.55	19
12305	1.2735	-0.03122	0.0001826	-0.0271	0.4398	2.59	19
12306	1.2605	-0.03233	0.0001727	-0.0158	0.4381	3.27	14
12307	1.3993	-0.03702	0.0001913	-0.0598	0.4224	2.63	18
12308	1.3340	-0.03127	0.0001973	-0.0548	0.1266	2.75	19
12309	1.3658	-0.03775	0.0001957	-0.0576	0.6492	2.40	19
12310	1.3309	-0.03648	0.0002067	-0.0774	0.3781	2.64	22
12311	1.4089	-0.03736	0.0002030	-0.0756	0.2534	2.04	22
12312	1.3595	-0.03842	0.0002131	-0.0828	0.5908	1.22	22

Station number	rho	a	b	c	W	rms residual μmol/kg	No. of samples in fit
12313	1.4339	-0.03848	0.0002101	-0.0861	0.4055	2.40	23
12314	1.3870	-0.03763	0.0001923	-0.0628	0.5510	2.40	22
12315	1.4477	-0.04060	0.0002107	-0.0863	0.6599	2.24	23
12316	1.4004	-0.03675	0.0001983	-0.0709	0.3691	2.63	22
12317	1.3552	-0.03659	0.0002223	-0.0919	0.5974	2.50	22
12318	1.4037	-0.03577	0.0002085	-0.0817	0.2703	2.46	23
12319	1.3553	-0.03552	0.0002037	-0.0761	0.4580	2.49	24
12320	1.3557	-0.03484	0.0002043	-0.0762	0.3342	3.41	23
12321	1.3599	-0.03461	0.0001987	-0.0719	0.2483	1.95	21
12322	1.3645	-0.03356	0.0001958	-0.0723	0.1471	2.48	24
12323	1.3633	-0.03291	0.0001991	-0.0754	0.0926	2.95	23
12324	1.3647	-0.03653	0.0002016	-0.0756	0.4403	3.43	22
12325	1.3672	-0.03429	0.0001998	-0.0745	0.4250	3.41	22
12326	1.3245	-0.03249	0.0002033	-0.0732	0.2570	3.19	22
12327	1.2291	-0.03339	0.0001850	0.0055	0.2482	2.73	6
12328	1.2354	-0.03276	0.0002498	-0.0500*	0.6402	3.91	9
12329	1.1587	-0.02998	0.0002850	-0.0500*	0.8344	3.39	12
12330	1.2193	-0.03124	0.0003188	-0.0879	0.6940	3.60	12
12331	1.2067	-0.03070	0.0002420	-0.0538	0.5210	1.76	14
12332	1.2640	-0.03385	0.0002108	-0.0500*	0.5344	2.03	14
12333	1.3681	-0.03430	0.0002046	-0.0730	0.1478	2.33	17
12334	1.2027	-0.02930	0.0001942	-0.0238	0.2846	3.34	18
12335	1.3430	-0.03520	0.0002112	-0.0754	0.3253	4.67	21
12336	1.3180	-0.03468	0.0002247	-0.0888	0.3926	4.09	22
12337	1.3640	-0.03421	0.0002080	-0.0771	0.3187	3.31	21

Notes
1) Coefficients marked with an asterisk (*) were specified rather than fitted.
2) The rms residual is found from the sum of the squared residuals, divided by the number of samples used in the fit minus the number of fitted coefficients.

2.7 XBTs

by: S.R. Thompson

XBT profiles during Discovery cruise 199 were collected using the Bathy Systems Inc. XBT program version 1.1 and SA-810 XBT controller, with the probes launched from a Sippican Corporation hand-held launcher. The inflection points calculated by the program were transmitted to the GTS network after each launch via the GOES satellite. ASCII versions of the raw data were transferred to the RVS level A using a diskette.

An inter-comparison was carried out by comparing profiles made in a marked mixed layer with the surface temperature measured on the thermosalinograph in regions of low horizontal temperature gradient. Linear regression of TSG onto

XBT temperature gave a slope of 0.99 and an uncertainty of 0.01, with an offset of 0.2° at 10°C.

Launch 107 was a calibration run using the test probe. This yielded 14.85° for a resistor chosen to give a value of 15.0.

Two problems were noted with the software:-

1) The bucket temperature information in the header does not appear to be saved. This means that if a file is not transmitted to the satellite immediately after the launch then the temperature must be re-entered in the header.
2) The column indicating whether the file has been transmitted sometimes fails to show a 'Y' after transmission.

Information concerning all the successful launches is shown in the accompanying XBT station list (end of the report). All launches were T7 probes unless marked otherwise and breaks in the launch numbers indicate probe failures, of which there were nine (eight T7 and one T5). Launches 101 to 125 did not form part of the A11 section

2.8 Acoustic Doppler Current Profiler (ADCP)

by: P.M. Saunders and R. Marsh

The instrument used was a RDI 150 kHz unit, hull-mounted approximately 2m to port of the keel of the ship and approximately 33m aft of the bow at the waterline. On this cruise the firmware version was 17.10 and the data acquisition software was 2.48. For most of its operation the instrument was used in the water-tracking mode, recording 2 minute averaged data in 64 x 8m bins from 8m to 512m. On the shelf at the start and end of the cruise, the instrument was put into a mode in which both water and the bottom are tracked. Here 2 minute averaged data was collected in 50 x 4m bins from 6m to 200 m depth.

The performance of the instrument was excellent throughout the cruise: on station, profiles were almost always recorded to 300m depth, and whilst steaming, except in the heaviest weather, profiles in excess of 200m were the norm. Data were passed in real time from the deck unit to a SUN workstation acquisition area: once a day, 24 hours of the data were read into the processing area.

Our processing has much in common with that of Griffiths (1992) except in one or two important respects, but for completeness will be outlined here. Stage 0 was to capture the 24 hours of data and write it into an appropriate format. Stage 1 consisted of correcting the time base for instrument clock drift and changing the time stamp from end of data period to center of data period. Stage 2 consisted of applying misalignment corrections (to be described below), averaging data into 10 minute periods, merging with the ship's motion over the earth from GPS navigation and thereby deriving, by algebraic addition, current components averaged over the same interval. At this stage error velocities were displayed as time series to identify both depths of good data and periods of poor data: there were remarkably few of the latter.

Stages 3 and 4 of the processing were novel: average profiles were constructed in approximate 4 hour chunks whose boundaries were selected by inspection and corresponded to 'on station' and 'steaming' activities. Data for maneuvering periods were excluded. The average profiles were identified by the station number, with the addition of the letter A to indicate the steaming period after the station. A cruise data set was constructed by appending the files together and we expect to employ this modest body of data in a combined analysis with the hydrographic data. For more detailed studies of the Ekman layer, for example, and the response of the upper ocean to storm force winds, the 10 minute data set will be utilized.

As is well known, a key element in the determination of currents (water motion over the Earth's surface) from the ADCP is the ship's gyro. This allows the fore and aft and athwartships components of flow determined from the RDI instrument to be resolved into east and north components and so added to the ship's motion determined by navigation (GPS). The results are sensitive to gyro error, gyro drift, and the alignment of the transducers on the hull. In order to evaluate these errors, zigzag calibration exercises (Pollard and Read, 1989) were carried out on 4 occasions:- 24 December (courses 0˚, 090˚), 8 January (courses 045˚, 135˚), 21 January (courses 015˚, 105˚), and 31 January (courses 015˚, 105˚). The results from the first 3 calibration exercises showed a small increase in the misalignment angle from 0.5˚ to 1.0˚ to the right of the apparent gyro direction. On board the initial value of 0.55˚ was used in the preliminary analysis of the data. Ashore considerable post processing will be undertaken to correct for both directional and gyro errors (see the section 2.9c).

References

GRIFFITHS, G.1992. Handbook for VM-ADCP-PSTAR system as used on RRS Charles Darwin and RRS Discovery.
James Rennell Centre for Ocean Circulation Internal document No.4, 24pp.

POLLARD, R.T. and J.F.READ, 1989. A method for calibrating ship-mounted acoustic doppler profiles and the limitation of gyro compasses.
Journal of Atmospheric and Oceanic Technology, 6, 859-865.

2.9 Navigation

a) GPS-Trimble

by: P.M. Saunders and M.G. Beney

Navigation, i.e. ship position and velocity over the ground, was provided throughout the cruise by a Trimble GPS receiver. No rubidium clock was available so at least 3 satellites were required for a fix. The observations are interfaced via a level A microprocessor (see section 2.11 on computing) into the SUN acquisition system. In order to prevent hanging or crashing of the level A, which was of new design, the sample rate was set to 0 and data was logged at approximately 1 Hz. Editing of this data was carried out to exclude a small but tiresome number of zero times, zero latitudes, zero longitudes, northern hemisphere positions (!) or otherwise suspect data and sub-sampled at 30 second intervals. This data known as 'gps' was archived and provided coverage for approximately 95 % of the cruise.

In order to complete the navigation data set for 100 % of the time, during periods of absent or inaccurate GPS fixes the ship's gyro and Emlog data were combined to give a dead reckoning position. Such data is flagged and the data is known as 'bestnav'. Transit satellite data were not used on the cruise.

Positions were logged in port at the start of the cruise and a rms position error of approximately 30 m was found. Evidently selective availability was in operation at this time. Underway errors are known to be larger.

b) Electromagnetic log and gyrocompass
by: A.J. Taylor

Ship speed is determined by a Chernikeeff log with sensor head approximately 0.25 m beyond the hull of the ship. Because of a sensor failure on the previous cruise a new unit was installed in Punta Arenas and zeroed whilst at the dock. Initially when underway a nominal calibration was applied, but at 11.0 kt smg as determined by a navigation unit (decca Mk52), the indicated speed was 12.24 kt, so a scaling was introduced to bring the two into agreement. The same adjustment was made to the port/starboard component.

On January 8 the sensor head was rotated approximately 5° anti-clockwise to reduce a spurious athwartship drift of about 1.3 kt at full speed. Improved log calibrations will be obtained by comparison with ADCP data (including the zig-zags) but because this will have a minor impact on 'bestnav' calculations we do not anticipate recalculating navigation for this reason.

Two S.G.Brown gyrocompass units (SGB1000) are installed on the Bridge. Because of a long lag noted with unit 1 on the previous cruise, unit 2 was employed for primary navigation throughout cruise 199. The output was logged via a level A microprocessor at 1 Hz and was free of gaps. The accuracy of heading is discussed in the following section.

c) Ashtech GPS3DF Instrument

by: S.R. Thompson

This instrument, newly acquired for the cruise, measures not only the position but also the three dimensional attitude of the ship from the GPS system, i.e. ship's roll, pitch and, most significantly for the ADCP work, heading. The determination of attitude is performed by an array of four antennas approximately in the form of a square of side 8m. Data were logged in the deck unit of the receiver at 0.2 Hz frequency (because the level A failed to work reliably) and down loaded to the SUN workstations twice per day.

King and Cooper (1993) have described details of the instrument, its installation and preliminary results on a 7 day trial cruise of RRS Discovery. They demonstrated that the gyro error is a function of ship's heading and also that it changes with time after a ship maneuver: in port they confirm the accuracy claimed by the manufacturer of 0.05˚. On cruise 199 we elected to use the second of the two ship's Gyro compass units, (i.e. a different one from King and Cooper), and our preliminary results show that this instrument also experiences gyro error related to the ship's heading and time-dependent errors after maneuvering. Also long term drift of the gyro is apparent. For both instruments, these variations are of the order of 1˚.

Data quality control was implemented in the manner described by King and Cooper (loc cit). For reasons not currently understood only approximately one third of one minute averages of the difference between Ashtech and gyro headings contain data, far less than they encountered at the same latitude in the North Atlantic. Ten minute average differences have also been constructed and assembled in 5 day summaries. These will be used in post processing of the ADCP data and are expected to bring significant changes especially for underway estimates of currents.

References

KING, B.A. and E.B. COOPER, 1993. Comparison of ship's heading determined from an array of GPS antennas with heading from conventional gyrocompass measurements.
Submitted to Deep-Sea Research.

2.10 Underway Observations

a) Echosounding

by: A.J. Taylor

Equipment

The bathymetry equipment installed on RRS Discovery consists of:- Hull mounted transducer, Precision Echosounding (PES) 'fish' transducer, and Simrad EA500 Hydrographic Echosounder.

Operation

The Simrad Echosounder was used during the cruise for bottom detection and determining the height of the CTD off the bottom during casts. While in bottom detection mode the depth values were passed via a RVS level A interface to the level C system for processing. Data were logged at a 30 second interval.

The transducers were connected to the Simrad equipment via an external switch. A uniform sound velocity of 1500 meters/sec was used during the cruise.

A visual display of the return echo was displayed on the Simrad VDU. Hardcopy output was produced on a color inkjet printer and a Waverley thermal line-scan recorder.

Performance

While on station and steaming during the initial few weeks of the cruise, the PES fish transducer was used. This gave good return signals on station and adequate return signals whilst steaming at 10 knots. After the second week the return signal when steaming deteriorated rapidly and the hull transducer was used whilst underway. Upon recovery of the fish on day 025 prior to steaming for Capetown, it was found that the lowest section of fairing was split in two. This was probably hitting the fish and the cause of noise whilst steaming. The fairing was replaced before being re-deployed on day 028, and a good signals were obtained whilst underway for the remainder of the cruise.

When coming on station the PES fish sank considerably from its steaming depth: this resulted in a 17m offset between the PES fish and the hull transducer on the graphic display. The fish returned a lower depth than the hull transducer. The amount of cable submerged whilst on station was measured to be approximately 22m, thereby accounting for the offset.

The Hewlett Packard inkjet printer developed a fault after one week and was replaced by the Waverley line-scan recorder. This was quite unreliable and was itself replaced, when a new inkjet printer was delivered by the Capetown pilot on 27 January.

As is well known the automatic depth finder performance is adversely affected when the signal to noise ratio is small. In these circumstances the digitally recorded data is frequently unreliable. Given strip-chart records the situation can be recognized and rectified. Except for the first few and the last few days, such records are unavailable on cruise 199. Consequently the overall quality of the depth measurements is very disappointing. (Note added by P.M.Saunders, 9 Feb '93).

b) Meteorological Measurements
by: K.J. Heywood and P.K. Smith

The meteorological monitoring system used on RRS *Discovery* comprises the following instruments:-

- an R.M. Young Instruments Type 05103 wind velocity propeller - vane sensor, located on the foremast to port.
- two Vector Instruments psychrometers, located on the foremast to starboard (serial numbers 1072 and 1073).
- (1073 was replaced by 1071 during the cruise).
- two Didcot cosine collector PAR sensors (spectral range 400-700nm) located port and starboard on the foremast (serial numbers 0150 and 0151 respectively).
- two Kipp and Zonen total irradiance sensors located on the foremast to port and starboard (serial numbers 92015 and 92016 respectively).
- an Eppley longwave pyrogeometer located on the foremast top pole (serial number 26207F3).
- a hull-mounted RVS/RS Components platinum resistance thermometer, recording sea surface temperatures.
- a Väisälä DPA21 aneroid barometer, located in the main lab.
- a Gill sonic anemometer located on the foremast to starboard.
- a ship borne wave recorder.

Unlike most shipboard instruments that have a dedicated Level A interface, the metlogger PC emulates a standard Level A interface and transmits the data directly to the Level B in Ship Message Protocol (SMP). The data are transferred to the Level C and then reformatted from Level C to PSTAR format to allow processing under Unix, using a series of pexec scripts based on the set of scripts used for the IOSDL Multimet system. Data were recorded as 1 minute averages.

Processing

The Unix shell script metexec0 was used to retrieve data from the Level C and convert them into PSTAR format. Metexec1 was used to calibrate all instruments apart from the aneroid barometer and wind direction output from the wind velocity sensor. Ship's navigation data including gyro heading (bestnav, derived from GPS and dead-reckoning) were merged with the met file by metexec2. Metexec3 and metexec4 were not normally used for this cruise. A combination of the ship's velocity components and heading was used in metexec5 for the conversion from relative to absolute wind velocities. Metexec6, an appending script was used to generate a full time series from the individual files, metexecp was used to produce plots, and the Pstar program metflx was used to derive wind stress and heat fluxes.

Calibration

With the exception of the aneroid barometer and wind direction output from the wind velocity sensor where any conversion or calibration is performed by the metlogger PC and were therefore logged through to the Level B as calibrated output, all instruments were calibrated during PSTAR processing of the met. data. The calibration algorithms applied were derived either from manufacturers calibration certificates or from calibrations undertaken by RVS and IOSDL prior to the cruise. Details are given in Table M1.

Problems encountered

Air temperatures

The RVS PC display system showed slightly higher readings than expected. This was due to the calibration coefficients being only nominal values. Also the calibration file used a 2nd order polynomial, whereas the IOS calibration uses a 3rd order polynomial. Using the calibration data for each psychrometer, new values were calculated and entered into the calibration file. These gave good readings on the display. The correct 3 order coefficients were in the Pstar calibration file.

On 29/12/92 (day 364) the port psychrometer data became very noisy. It was replaced and new calibration coefficients entered into the calibration file (/pstar/src/extras/cal/met 199. cal). There is a gap in the port data between 1600 hrs and 1845 hrs. No further problems occurred during the cruise.

Long Wave Radiometer

This gave good readings at the start of the cruise, but began giving some low readings during 1st January (day 367). The signal slowly deteriorated becoming more erratic. The battery was replaced on 16th January (day 382) and good readings were obtained for the rest of the cruise.

Sonic Anemometer

The Asymmetric Sonic Anemometer was mounted on the foremast with North facing forward. The system gave good readings. The system stores processed data on both hard disk and floppy disk. To store the raw data an optical disk was installed with a capacity of 20 days' data. There was some difficulty in setting up the software but eventually the optical disk recorded raw data. There was some complex interaction between the system clock and the optical disk software. As the software needs the time and date information in the data files and in naming the files, the software halts if the internal clock is in error. This error occurred between once in 3 days to 3 times in a day. Re-booting and resetting the time and date resumed normal operation.

Ship Borne Wave Recorder

The computer and associated software worked well during the cruise with very few errors. The signal amplification/conditioning unit showed a large d.c. offset and low amplitude signal for the Port Pressure Transducer. This transducer was flushed, which considerably reduced the d.c. offset and increased the signal amplitude. Further flushing produced a further improvement but there was still a small d.c. offset and the amplitude remained slightly smaller than the starboard pressure transducer. The last calibration was at the refit and a d.c. offset was noted then.

Met Observations during the cruise

Weather conditions during the cruise were remarkably clement, with the exception of a storm in mid January. The maximum wind speed observed was 28 ms^{-1} on 13th January, producing the largest waveheights.

TABLE M1: Calibration coefficients for the met. sensors

Measurement	**Calibration coeffs** $y=a+bx+cx^2+dx^3$				**source if not IOS**
	a	b	c	d	
Wind speed	0	0.1	0	0	mfr
Wind dirn	0	1.0	0	0	mfr
swet	-21.63646	2.580562e-3	7.893778e-6	0.660868e-9	
sdry	-20.18834	9.733870e-4	7.835114e-6	0.525038e-9	
up to day 364					
pwet	-23.71101	6.848060e-3	5.626587e-6	1.077627e-9	
pdry	-23.84735	5.788879e-3	5.648462e-6	0.907665e-9	
after day 364					

pwet	-24.38268	6.720888e-3	5.840227e-6	0.969597e-9	
pdry	-23.36777	5.245053e-3	5.784058e-6	0.882978e-9	
sea	0.26705	0.99189	2.9755e-4	0	RVS
longwave	0	0.23364486	0	0	

	y=x/(ab)	
pPAR	5	12.86e-6
sPAR	5	12.87e-6
pirr	2	48.49e-3
sirr	2	43.63e-3

c) Thermosalinograph measurements

by: S. Cunningham

Instrument and Technique

Continuous underway measurements of surface salinity and temperature were made with a Falmouth Scientific Inc. (FSI) shipboard mounted thermosalinograph (TSG). Salinity samples were drawn from the non-toxic sea water supply at four hourly intervals, and used to calibrate conductivities obtained from the TSG. The instrument was run continuously throughout the cruise.

The TSG comprises of two FSI sensor 'modules', an Ocean Conductivity Module (OCM) and an Ocean Temperature Module (OTM) both fitted within the same laboratory housing. Sea surface temperature is measured by a second OTM situated on the suction side of the non-toxic supply in the forward hold. The non-toxic intake is 5 m below the sea surface.

Data from the OCM and OTM modules are passed to a personal computer (pc). The pc imitates the traditional Level A system, passing it to Level B at 30 second intervals.

Sensor Calibrations

The temperature modules are installed pre-calibrated to a laboratory standard and laboratory calibration data are used to obtain four polynomial coefficients. A similar procedure is employed for the conductivity module.

Underway Salinity Sampling

Salinity samples were drawn from the non-toxic supply at four hourly intervals. These samples were then analyzed on a Guildline 8400 using standard sea water batch P120.

Calibration of TSG Salinities against Underway Salinity Samples

TSG conductivity measurements at 30 second interval were median de-spiked, discarding data more than 0.01 mmho/cm from a mean computed over 5 adjacent data values. Conductivity of the bottle samples was calculated at a pressure of 0 dbar and at the temperatures of the TSG OTM. The TSG data were merged onto the bottle data and the conductivity difference between the bottles and TSG calculated. After excluding outliers, a linear regression between the conductivities was determined and applied to the TSG values. TSG salinities were computed along with the difference from the bottle salinities. This difference was filtered with a Gaussian filter of half width 12 hours and normalized peak height of 0.38. TSG salinities were then corrected by adding the filtered difference. A plot of the corrected salinity and temperature at the surface for the entire cruise is shown in Figure 7.

Estimate of the TSG accuracy and salinity residuals

Due to particular difficulties with the instrument, the estimate of salinity residuals has been split into two portions. For the period day of year=359 to day=23 (389) the mean difference between the bottle and TSG salinities was -0.0009 with a standard deviation of 0.0145. For the period day=23 to day=32 the mean salinity difference was 0.0005 with a standard deviation of 0.02.

Over the period from 23 0000Z to 27 0825Z the housing temperature sensor produced unreliable results. A current leakage was found between the platinum resistance thermometer and the surrounding seawater. This caused the probe to oxidize and eventually fail. At about the same time the pumps for the non-toxic supply failed and an alternative set were switched on. This caused a decrease in the flow rate and a corresponding increase in lag time for water from the non-toxic intake to reach the TSG, from approximately 5 to 10 minutes. Degradation of the conductivity results is likely. On day=26 at 0555Z the housing OTM was replaced. For the period 23 0000Z to 26 0555Z a reconstructed housing temperature was derived from the remote temperatures. Given the uncertainties in lag time and the alternative heating and cooling of the non-toxic supply through the ship (during this period for surface temperatures less than 20.2°C the supply is warmed and above that cooled) the reconstructed temperatures are not likely to be better than 0.2°C. The uncertainty probably accounts for most of the spread in the salinity residuals over this latter period.

d) Satellite Image Acquisition and Processing

by: M.P. Meredith and V.C. Cornell

Equipment and function

On this cruise equipment was installed for the capture, display and processing of polar-orbiting weather satellite imagery. This consisted of an omni-directional

VHF antenna mounted on the main mast, a pre-amplifier to compensate for feeder cable losses of up to 10db, a Dartcom system II receiver, an 8-bit 15MHz microcontrolled interface to control the frequency and mode of the receiver, and an Apple Macintosh IIsi computer with the MacSat 2.1 software supplied jointly by Dartcom and Newcastle Computer Services.

The equipment was used to receive data sent from the NOAA satellites 10, 11 and 12 via the Automatic Picture Transmission (APT) system at 137.50 and 137.62 MHz. Although the software allows the capture of geostationary weather satellite images, the hardware necessary for this was not present. No attempt was made to capture images from polar-orbiting satellites other than the NOAA series.

The data collected were from the Advanced Very High Resolution Radiometer (AVHRR), a five-channel radiometer featuring one visible, two near-infra red and two thermal infra-red channels, though the APT system only allows for the visible channel plus one infra-red channel to be received. The APT system also reduces the spatial resolution of the data from its maximum of 1.1 km square at nadir to approximately 4 km square. Data from almost all the radiometers' swath width is captured with MacSat; an 800 x 800 pixel image covers approximately 3000 km square, and has a maximum of 256 digitization levels per pixel.

Procedure

During the cruise, most of the longer satellite passes (>12 minutes) were captured. Shorter passes generally did not contain enough noise-free data to warrant their capture. The vast majority of images were from the infra-red channel, since the previous cruise experienced serial error problems with the Auto Save function (the function enabling both channels to be acquired simultaneously), which led to the loss of the images. Thus only one of the two channels was available, and the infrared data were deemed more useful than the visible for our purposes.

Once captured, the time/date, ship's position, and whether the satellite was in an ascending or descending pass was recorded, and a geographical overlay created for the image. This shows lines of latitude and longitude, ship's position at time of acquisition, and, if relevant, a coarse coastline. Three standard color palettes were created to enable depiction of sea brightness temperature. One would not suffice since the manual contrast stretch facilities of MacSat (adjusting the RGB response curves for the image) were found to be very cumbersome, and the Auto Contrast function is only useful for gray scale images.

Color hardcopies were produced for each image by using the Mac's screen-dump tool. This creates a TeachText picture of the screen, which can then be printed to a postscript file, transferred to the Sun workstations using ftp, converted to a PCL file and outputted to the HP Paintjet printer. This was considered a better procedure than using MacSat's print option, since not only can the whole image be displayed on one A4 sheet, but the geographical overlay can be also be printed on the image.

Some images were transferred to more sophisticated image processing software on the Suns; this, along with the image file format and file archiving, is discussed elsewhere.

Problems

Difficulties encountered on the previous cruise concerning the gross inaccuracy of the geographical overlay were to a large extent resolved. Updated files containing the Keplerian orbital elements for the satellites were obtained by fax from Newcastle Computer Services on two occasions as a matter of course, and on a third (1st Jan), when an error in the orbital element calculations became apparent. Also, the Mac's internal clock was corrected each day, since it gains approximately one second per day on GMT. Such an error is not insignificant for satellites travelling at 27,000 km/h, and would greatly affect the positioning of the overlay if left unaltered for a number of days. However, even with these measures being taken, the overlay could still be as much as a degree or two out, and the uncertainty should be borne in mind when considering images without coastline in them.

Noise contamination of images was a frequent problem, and although MacSat has a noise reduction filter, this is of use only for presentation purposes and obviously cannot replace missing data values. Whether the problem was caused by atmospheric conditions, insufficient signal amplification or faulty hardware remains unknown.

A further unsolved problem is the overlay tool's failure to plot lines of latitude for descending satellite passes. We think this can only be attributable to a bug in the program.

Initially, difficulties were encountered with the loss of images due to serial errors during acquisition. This was caused by a slowing of the Mac to the point where it could not keep up with the incoming data stream, and was solved by ensuring that there were no telnet connections active, no print jobs queued and no Appleshare volumes present on the workspace at the time of capturing an image.

Observations

Several significant oceanographic features were observed in the satellite imagery captured during the course of the cruise. The retroflexion of the Falkland Current at the Brazil Current was clearly visible, and when the thermosalinograph (TSG) showed an increase in temperature, the MacSat image revealed a warm ring shed from the conflict of the two currents. Many of the images showed the position of the Subtropical Front to the north of the cruise track, and, towards the end of the cruise, the coastal upwelling region associated with the Benguela Current is clearly visible. An Agulhas ring was possibly observed, but not certainly, since cloud contamination partially obscures the feature. The cloud images also proved illuminating, especially during the severe storm encountered on the 13/14th January 1993.

2.11 Shipboard computing

by: M.G. Beney and V.C. Cornell

RVS logging System 'ABC'

The RVS logging system comprises of 3 distinguishable parts or levels. Each level is referred to by one of the following letters A, B or C, and the whole system is called the 'ABC' system.

A Level A consists of a microprocessor based intelligent interface with firmware which collects data from a piece of scientific equipment, checks and filters it, and outputs it as SMP (ship message protocol) formatted messages.

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

The Level B collects each of the Level A SMP messages and writes them to disk and backup cartridge tape. The Level B monitors the frequency of these messages, and besides providing a central display for the data messages also warns the operator when messages fail to appear. The Level B, which is based on a 68030 processor using OS9 as the operating system, collates the data and outputs it to the network.

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

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

Level A	Datafile	Variables
BOTTLES(1)	bottles	code
CTD_17C(2)	ctd_17	press temp cond trans alt oxyc oxyt temp2 cond2 deltat nframs
GPS_ATT(2)	gps_att	hdg pitch roll mrms brms attf sec
GPS_TRIM(2)	gps_trim	lat lon pdop hvel hdg svc s1-s5
GYRO_RVS(2)	gyro_rvs	heading
LOG_CHF(2)	log_chf	speedfa speedps
METLOGGR(PC)	metloggr	winspd windir 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
WAVE(1)	wave	height
WINCH(PC)	winch	cabltype cablout rate tension btension comp angle

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

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

The following datafiles were archived:

relmov	gps	mx1107
bestnav	bestdrf	winch
wave	metloggr	surflog
adcp	adcp_raw	ctd and xbt.

These RVS archives have only limited life and are only intended as (fall-) backups.

Processing of data

Virtually all of the data processing was performed using the interactive "pstar" suite of about 300 documented programs (Alderson et al,1991). This continuously updated system is installed on RVS ships as well as at labs ashore. RVS data files were converted to "pstar" data files using the program 'datapup'.

Archiving of pstar files

Archiving took place on a daily basis. Copies were made of all processed files on Sony erasable magneto-optical disks. These were mounted as standard unix file systems. In addition files were copied to Quarter Inch Cartridge (QIC) tape in both raw sequential and unix tar format. Six sides of optical disk data were taken ashore at the end of the cruise, totaling about 1.5 Gigabytes.

Equipment available on cruise 199:-

Personal Computers (Operating under Apple system 7.01)

3 Apple Macintosh Classics	(40 Mb Hard Disc, 4Mb RAM)
1 Apple Macintosh ClassicII	(40 Mb Hard Disc, 4Mb RAM)
1 Apple Macintosh II si	(80 Mb Hard Disc, 5Mb RAM)

The last was connected to a Dartcom System II satellite image receiver.

Sun Workstations (Operating under Sunsoft's version 4.1.1)

Node name	**Type**	**Ram**	**Hard Disc** (Mb)	**Peripherals** (Mb)
discovery1	IPC	12	2x327	Exabyte drive
			1x207	QIC 150 tape
discovery2	IPC	12	1x207	Magneto/optic
			1x1200	QIC 150 tape
discovery3	Sparc stn	8	2x327	
discovery4	Sparc stn	8	2x237	

Output devices:-

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

Networking

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

References

ALDERSON, S.G., GRIFFITHS, M.J., READ, J.F. and R.T. POLLARD, 1991. PEXEX PROCESSING SYSTEM, Internal document, Institute of Oceanographic Sciences Deacon Laboratory, about 450 pp.

2.12 Cruise diary

by: P.M. Saunders

22 December Day 357/1992

RRS Discovery left Punta Arenas at 1700P (1400Z) with a pilot aboard, about 9 hours later than planned. All times are given as ship's time and the relation of ship's time to GMT stated whenever the relationship is altered. The delay was occasioned by the late arrival of the customs paperwork for the various items of airfreight. Amongst these was the CFC equipment which came on board, late on the 20 December. A new emlog was installed and an arbitrary calibration applied to yield reasonable ship's speed. The navigation and the Acoustic Doppler current Profiler (ADCP) were logged from departure.

23 December Day 358

Calm seas, some pitching motion as course is set 050° across the Argentine shelf 0430 (0730Z). At 0900 the first officer gave a safety briefing and this was followed by a science briefing by the PSO. At 1030 there was fire and boat drill, followed by a tour of the ship pointing out escape routes etc. Around 0130P (0430Z) the thermosalinograph was started up. At 0200 the Echosounder fish was streamed and after repairs to the fairing clips RRS Discovery resumed speed.

24 December Day 359

Given continuing fair weather it was decided to undertake an ADCP calibration exercise; this was performed between 1300 and 1600P. The results were satisfactory. See the ADCP account in this report.

25 December Day 360

A trial of the mid-ship winch was undertaken as station 12238 between 0628 and 0729P. A depth of 500m was reached and, after recovery, repairs were made to the winch scrolling gear and to the CTD, so that the exercise proved fruitful. Whilst the RRS Discovery continued northwards towards the latitude 45°S, crew and scientific party celebrated the festive occasion.

26 December Day 361

A test station 12239 was started in approximately 4000m of water at 0830P and was concluded about 1130P. The Rosette jammed after 5 firings and the ctd display was very noisy. The new altimeter unit worked well. Lanyard tensions were reduced and some cables replaced. An XBT was launched. A second station at the same location (45° 00'S 47° 30'W) 12240 to a depth of 2500m was more successful. With the wind 25-30kts samples were drawn on station, and at 1810P the ship turned west into an ADCP/XBT section. Some light rolling ensued.

27 December Day 362

A murky drizzly foggy morning turned into a bright sunny afternoon as 8 XBT/ADCP stations (12240-12247) were occupied in all. The wind died away and during passage, a tongue of cool surface water circa 8.5°C was encountered with warmer water 11.5°C to both west and east; it was the Falklands current.

COMMENCEMENT OF THE A11 SECTION (45°S, 60°W)

At 2000P station 122047, the first in the transoceanic section was begun: the water depth was about 250m and the initial objective was the Mid Atlantic Ridge nearly 1900 miles away. In order to assure good ADCP data, stations in the western boundary current were assigned a minimum duration of 2 hours.

28 December Day 363

Overnight stations in 500m, 1000m, and 1500m were occupied in calm seas the last within and close to the western edge of the Falklands current. Stations continued at 500m spacing down the slope, with spacing that varied between 3 and 30 n-miles.

29 December Day 364

Overnight the wind increased sharply and reached 35kts but by 0800P it decreased to 20kts under cloudless skies. Approximately 125kg of lead was removed from the rosette to reduce wire tension for the deeper casts. On station 12256 started near noon and completed at 1600P the deep western boundary current was detected; a nepheloid layer of thickness 400m defined it, at a depth below 4350m. The weather was fine enough for maintenance of the psychrometers on the foremast to be carried out.

30 December Day 365

Overnight the wind increased from the west to 30kts and the sea began to build. Station 12258 was begun at 0250P and after the cast had reached 2500m the ship's bow-thruster malfunctioned and the CTD/Rosette were recovered by 0450P. After repairs a second cast to the station was begun; it reached 5500m and was completed by 1240. (Subsequently it was learned that one of the motors that rotated the thruster needed parts which were not available on board.) Use was made of the railway to move the rosette to a protected position for sampling. This proved helpful.

Station 12259 was carried out between 1650. and 2150 to a depth of 5630m; by now seas had built and some difficulties were encountered in hauling at the bottom of the cast. Fire and boat drill engaged those not involved directly in station work.

31 December Day 366

At 0000 the ship's master-clock decided it had started a new year and clock day was reset to 0. Some difficulties are to be expected in the subsequent processing of the data!!

At this same time a station was started in about 5770m of water with strong SW squalls and high seas. This proved unwise. About two hours later it became quite evident that coupled with a strong current shear, the wire could no longer be controlled. Accordingly stn 12260 was abandoned at a depth of about 2800m. During the day wind and sea subsided and soon after midday stn 12261 was begun in 5900m of water. The station reached within 20m of the bottom where a very strong nepheloid layer was encountered and all gear was recovered by 1700. The performance of the winch in these circumstances was very satisfactory. At 2200 station 12262 was begun, again in nearly 5900m of water; the maximum expected water depth for the section was found between these latter casts.

1 January Day 001/1993

The New Year was welcomed whilst completing the station. Again a very strong nepheloid layer was seen. Unfortunately apart from this success little else went right on the day.

At 0600 the ship hove to on station; RRS Discovery remained in this vicinity for the remainder of the day as both the engineers on board and those at the RVS base, over 6000n-mi away, attempted to diagnose and repair a defunct winch. The timing was inopportune, occurring on a bank holiday followed by a weekend. To ensure a quiet night, there was no work programme.

2 January Day 002

After considerable effort overnight the problem was identified. A faulty electrical component in the control logic circuit was found and replaced with an identical unit from the main winch, which was unserviceable. At about 0630 a series of shallow lowerings was begun: these were employed to fix the winch control settings, which were quite different from those prior to the breakdown. At 1620 station 12263 was begun in approximately 5750m of water, in the location arrived at approximately 36 hours earlier. The weather for this entire period had been (gallingly) fine. Immediately after launch the transmissometer failed, due to a cable connection adrift, but the cast was continued to full depth. On subsequent stations the transmissometer performed well.

3 January Day 003

The normal routine of station work was resumed with XBTs at a location midway between CTD casts. Mud waves were spotted and the chart recorder of the Echosounder which had been malfunctioning repaired and activated. At 1204 the level B system stopped logging and approximately 8 minutes of data was lost. This was during station 12265. The CTD data was recovered from the deck unit PS2 , but other data was lost. On the following station 12266 a strong nepheloid layer was again seen, suggesting strong currents on the abyssal plain.

4 January Day 004

Fine weather and a flat calm prevailed and the depth of the abyssal plain continued to shallow. A large school of pilot whales investigated RRS Discovery on station 12269, which was also noteworthy because the rosette jammed in position 13 and all shallow samples were lost. As the ship steamed away from the station the flanks of the Zapiola ridge were encountered at 2000P. The action of the Echosounder chart recorder continued erratically. CFC measurements were halted because of contamination.

5 January Day 005

On station 12270, 0100 - 0500P, the Rosette jammed at or near position 13 and samples were not collected at shallow depths. Since the previous station had experienced a similar sample loss, the failure to add a second shallow cast was unfortunate. Samples were collected in the rain but the protection of umbrellas was deemed unnecessary. After station 12271 a NEly wind came up and the ships progress was hindered. The ADCP lost penetration and subsequent analysis revealed the presence of the bogus "current following the ship" of 50-80 cms^{-1} always(?) seen when heading into a sea. On station 12272 the rosette again jammed at mid bottle so a second cast was made to 1500m depth.

6 January Day 006

On the overnight station 12273 bottles 9 10 11 were not cocked but the Rosette again malfunctioned so that after the samples were drawn the Rosette was stripped of all equipment for an overhaul. The spare Rosette (No 2) was mobilized and functioned satisfactorily for the next station. The wind and sea were subsiding but low temperatures prevailed as the RRS Discovery re-entered the sub-Antarctic zone.

7 January Day 007

On the overnight and morning stations the rosette performed satisfactorily but on station 12277 all bottles were closed below 1500m so a second cast was undertaken. Together the casts lasted from 1115 to 1745. After the Zapiola ridge with crests near 4900m, stations were now on the abyssal plain with depths over 5300m. At 1615 there was fire and boat drill. The performance of the ADCP continued poor and air was bled from the sensor pod without significant improvement.

8 January Day 008

The clocks were advanced 1 hour at 0001P so that ship time was now GMT-2. Station 12278 at 3545W which was completed at 0200 in a flat calm had a depth of 5470m and was the maximum reached between the Zapiola ridge and the mid-Atlantic ridge; on this and subsequent stations the measurements differed substantially from the GEBCO chart. Mud waves continued to be seen.

At 1530 in continuing flat calm seas the emlog, which had shown a cross track drift of about 1.3 kts, was rotated anti-clockwise about 5° to a more nearly correct direction. On the completion of station 12280 at 1740 a second ADCP zig-zag calibration exercise was begun to attempt to verify the gyro drift measured by the Ashtech GPS receiver. The experiment concluded at 2100 still in very calm seas.

9 January Day 009

In the early hours of the following morning a seal was spotted close to the ship and the barometer began to fall. At 0900 ships time the wind began to freshen from the Southeast and the barometer fell precipitately. At the start of station 12283 the wind was 45 kts from the south; almost immediately it began to diminish and by the end of the station it was only 25 kts. The lowering and handling of the ctd was straightforward despite the conditions.

A comparison was made between measurements made on leg5 of SAVE near 45S and 41W (stns 290-293) and those on this cruise (12269-74). The salts and nitrates were in good agreement, the oxygens about 1.5% low and the silicates 3% low.

10 January Day 010

During the night the wind continued to come westerly and the considerable swell caused heavy rolling. This was uncomfortable for the ship's complement and on station led to very heavy snatch loadings. For the first time significant irregularities arose in the lay of the wire on the storage drum. At about 0745 station 12285 was commenced. About 4m down a high swell caught the Rosette and the wire was instantaneously so slack that it jumped off the sheave pair at the foot of the gantry. The wire was stopped off on the top of the Gantry, and inboard the wire was paid out, correctly rerouted and the load taken up again. The package was recovered on deck and a large kink located; about 20m of wire was cut off and the end reterminated.

At the same time the Rosette No 1 was restored since No 2 had starting registering numerous misfires. The station was then restarted at 1000 after a delay of 2hours 15 minutes, and proceeded normally until about 3500m on recovery when attempts were made to improve the lay of the wire on the drum. Eventually the station was completed at 1500. Meanwhile the sea was subsiding. BAK reported a green flash at sunset.

11 January Day 011

The day started fair and concern for the CTD performance proved unnecessary. The regulation 3 stations were performed and the first colored Macsat images with a grid of lat and lon lines and the position of the ship were printed. Some but not all of these features had been available previously. Prior to station 12289 two lead weights (125kg) were restored to the Rosette in order to improve the shallow descent rate on the down cast.

12 January Day 012

A stiff northerly blew up during stn 12291 (1040- 1400) now in only 4400m of water. The next stations were accompanied by increasing rigor of the conditions. On both of them the Rosette was moved forward on the railway and sampling was undertaken on station. The wind and sea increased although during the evening the sky cleared.

13 January Day 013

At midnight the ship's clock, on which time this log is based, was advanced one hour to become GMT-1. On station 12293 in 3500m of water (0130-0430) conditions deteriorated markedly and by recovery the wind was blowing 45kts gusting to 55. The wind was now from west-northwest and despite clear skies continued to blow a gale; the seas were the largest seen on the cruise so far. We remained jogging, i.e. going slowly upwind, for the rest of the day. The

ADCP functioned well and remarkable inertial oscillations were seen with an amplitude exceeding 50 cms^{-1}.

14 January Day 014

After midnight the wind began to build again and by 0400 reached 50-60 kts, slowly backing to the south of west. The seas were, without exaggeration, mountainous with continuous spume blown from the crests. The pitching of the ship was severe but tolerable but the occasional heavy rolling was very uncomfortable. Not surprisingly the ADCP functioned only poorly. During daylight hours wind and seas moderated only very slowly and not until 2000 was the ship able to run before the seas towards the next station position.

15 January Day 015

At 0320 RRS Discovery arrived on station and the work programme was resumed. The seas were moderate - as was the performance of the Rosette. A second cast was made to 1000m to collect samples in the upper ocean. The decision was made to increase station spacing to 50 nautical miles for the foreseeable future.

16 January Day 016

A series of routine stations were made in shallow water depths, until on station 12298 (1050-1300) in 2500m of water the crest of the Mid Atlantic Ridge was reached. A mid-cruise break and PES survey had been planned but in view of the recent enforced delay this was no longer possible. By now the sea had quieted down and the skies were clear.

THE TURNING POINT ON THE A11 SECTION (45°S, 15°W).

At 1300 RRS Discovery steamed away on a course 059° towards the coast of South Africa and the conclusion of the section just over 1700 miles away. Within a short time a large iceberg was sighted (!) and at 1500 was passed at a range of 6 miles.

17 January Day 017

A day of calm seas and routine station work. Having crossed the ridge warmer water is encountered at all levels. A new inductive FSI conductivity cell is fitted to the CTD and yields encouraging results. A substitute Echosounder chart recorder is in action at last . Light rain fell about 1930.

18 January Day 018

At 0000 ships time the clocks are advanced 1hour so that ships time and GMT now agree. A sunny morning gives way to a rainy cloudy afternoon; by 1900 the wind is northerly blowing 25-30 kts. The umbrellas and their clamps on the Rosette frame are in use for the first time. The transmissometer develops intermittent and persistent noise; it is not clear whether the noise is oceanic or instrumental. Casts continue at a 50 mile spacing up to station 12306 (2015 - 2345). The surface temperature remains near 13 -14°C. I had expected it would rise before now.

19 January Day 019

An eventful day. After the station it was decided to resume a 42 mile spacing which had been characteristic of the leg on 45S. During steaming between stations 12307 and -8 two remarkable topographic features were encountered. The first of these was seen at 0930 (XBT 72) at location 40 58S and 6 01W; a seamount was detected rising to about 2300m from a sea floor near 3700m. This was tentatively identified as the flanks of the Admiral Zenker seamount. As the proposed site of the CTD station was neared, a second seamount was observed. This rose to a depth of 750m at 1054 at which point XBT 73 was dropped, 40° 48'S 5° 40'W. The seamount was flat topped (a Guyot) and for a distance of about 6 miles the depth was less than 1000m. A further 8 miles on, station 12308 was completed in 3700m of water. There is no indication of the seamount on any charts available to us; the name New Discovery Seamount is proposed. An overcast morning gave way to a sunny day although a brisk NW'ly wind persisted.

20 January Day 020

Station 12310 started in conventional fashion just before 0100, but as the Rosette was raised towards the surface a wave carried it upwards, the wire went slack and jumped off the sheave pair at the foot of the Gantry. This was a repeat of the event of station 12285 on the 10th of January. Eventually the package was recovered, 35m of wire removed, a new termination made and the cast restarted about 0300.

For much of the day a moderate Westerly swell persisted and made the station work slightly difficult for the winch drivers. At the end of station 12311 when the package was recovered a kink was found in the wire which required cutting off about 10m of wire and a retermination - for the second time in the day.

21 January Day 021

During the night the swell diminished and station 12313 in over 5000m of water allowed the wire lay on the drum to be improved substantially. Surface water temperatures have now risen to 16°C but the absence of a marked subtropical convergence (RRS Discovery at 0700 is at 38.7S) has surprised a number on board. After station number 12315 we crossed the Greenwich Meridian at 2025 , a minor milestone. The crossing was made at the start of the third ADCP calibration exercise 2020 -2300 in which alternate courses were 015° and 105°.

22 January Day 022

The station work continues. After station 12316 maintenance work was carried out on the rosette and CTD cabling was replaced. Nevertheless a noisy transmissometer record was obtained. Shortly before station 12318 the surface salinity exceeded 35 for the first time (near 37°S 2°E).

23 January Day 023

Calm seas continue but the station spacing is augmented to 60 miles in order to anticipate a potential medical emergency and permit a dash to Cape Town if required. During the course of the day a remarkable lens of cool saline water is seen by XBTs 85-88 and CTD station 12320 and approximately 100 miles across. This takes the form of a 600m deep thermostad of temperature 13.5°C and salinity 35.2 which is capped by warmer fresher water. There is speculation that this is the remnant of an Agulhas ring, shed in the retroflection zone which has overwintered south of the convergence. But it is much cooler and fresher than any observed before. After passage through the ring the water freshens to 34.95 and temperature 18.5°C; perhaps Deacon's assertion (1937) that the seasonal migration of the sub-tropical convergence is large in this area with a maximum northwards location in summer is being verified on the cruise. At about 1930 there is an abrupt jump on the thermosalinograph. The salinity rises to 36 and the temperature to 20°C. Hallelujah! The latitude is 35° 40'S and the longitude 5° 00'E.

24 January Day 024

The routine continues in calm clear subtropical weather with 60 mile spacing of the stations. Even underway the ADCP penetration is 300m. For the past few days the winch operation under light loads has been erratic; lets hope it lasts to Cape Town. In the late afternoon a Barbecue on the after deck whist the ship was on station 12324 was a pleasant social occasion.

25 January Day 025

Today we passed through what is certainly an Agulhas ring. It took 20 hours and involved stations 12325 and 12326 and XBTs 097 - 102. The 15°C isotherm went from a depth of 100m or less outside the ring to over 350m within the ring. The extreme locations were 33° 49'S, 8 48°E to 33° 07'S, 10° 44'E, a distance of 105 n-miles. Both of the stations involved had problems. On station 12325 the rosette firing hung up at bottle 11; there were no samples above 1500m. Consequently a second cast was made to 1500m. On station 12326 a number of the hydraulic units shut down after start-up, attributed to a frozen cable-hauler, and the cast was delayed 30 minutes. During this cast the decision was made to proceed to Cape Town to put ashore the PSO whose medical condition was causing him and others concern. Prior to departure the Echosounding fish was brought on board. It was decided to launch XBTs every 2 hours on the way in. Dr. King agreed to act as PSO.

26 January Day 026

XBTs continued as RRS Discovery steamed into a stiff SE'ly wind, and later a 3 kt current. For only the second time in the cruise the ADCP data return was zero. The thermosalinograph failed due to a defective temperature element, which was replaced. It had given poor data for 3 days.

27 January Day 027

Clocks were advanced one hour to bring ships time to GMT + 2. Just outside Cape Town harbour, 2 miles off Green Point and at about 1200, the ship was met by a small boat and the PSO was put aboard. By 1330 the ship was underway and a speedy northward passage at an average speed of 13.5 kt was then made, with XBTs at 4 hourly intervals, to reach the eastern of the line and work south-westward from there toward station 12326. The ADCP housing was bled of air and repairs were made to clips on the Echosounder fairing. A new printer was installed for the Echosounder and for the first time excellent records were obtained

28 January Day 028

Station 12327 was commenced in 230m of water at 0730 and by 0800 was completed. Because of the pressure of time the decision was made NOT to remain for a minimum of two hours on station to obtain good ADCP records as we had in the WBC. On the following station in just under 500m of water, at 1045 the Echosounding fish was deployed. Thereafter stations were occupied at water-depth increments of 500m and at distances of between 10 and 40 n-miles, down the slope. The last station occupied on this day was 12332 in 2500m of water.

29 January Day 029

A superb calm day with a green flash at sunrise. Four stations were occupied today with the last, 12336, in a depth of water just under 4000m.

30 January Day 030

Today between 0530 and 0900 the last station 12337 was occupied at a distance of only 43 n-miles from station 12326. Thus the line is satisfactorily completed - a tribute not only to the entire scientific party but also to the entire ship's complement.

END OF A11 SECTION

Between 1200 and 1530 winch trials were carried out with the aim of improving the performance of the inboard compensation unit, and also to test the performance of the Mk 5 CTD. Unfortunately neither was successful, and at the end of them the Echosounding fish was recovered and course was set for Cape Town. Underway data logging was concluded at 2400 and watches were stood down at 1600.

31 January Day 031

In light winds the ship made good speed so that by 1720 it was possible to start the fourth ADCP calibration exercise of the cruise. The zig-zags were conducted on courses 105° and 015° respectively and ended at 2040.

1 February Day 032

The ship docked in Cape Town at 0830, concluding a most successful cruise.

Acknowledgements

This cruise, a UK contribution to the World Ocean Circulation Experiment (WOCE), was made possible by the parent body of (almost) all of the participants, namely The Natural Environment Research Council. Substantial support was also furnished by Ministry of Defense through the MoD/Research Council's joint scheme and by the generous provision of XBTs from DNOM, Taunton.

The scientific party is grateful to the professional dedication of the Master, Captain Keith Avery, the officers and entire crew of RRS Discovery, - especially for the smooth running of a long cruise encompassing both Xmas and the New Year. We also wish to acknowledge the support of the shore-side staff of the Research Vessels Base (Barry) and Mr. R. Bonner (IOSDL) for their expertise in the mobilization and demobilization of the cruise in distant ports.

CTD STATION LIST

Stn	Cast	date mmddyy	time, gmt start	bottom	end	latitude			longitude			depth, m uncwtr	ht off	wire	max p	Samples no	notes
12247	1	122792	2300	2312	2340	44	58.99	S	60	00.12	W	237	5	233	235	6	CFC
12248	1	122892	0143	0206	0229	44	59.66	S	59	56.35	W	476	8	455	461	9	CFC
12249	1	122892	0424	0458	0532	44	58.98	S	59	46.96	W	1007	9	963	971	10	
12250	1	122892	0936	1018	1109	44	58.85	S	59	07.14	W	1504	11	1480	1481	11	
12251	1	122892	1429	1516	1622	44	59.38	S	58	33.03	W	1908	10	1860	1891	7	CFC
12252	1	122892	1739	1831	1948	44	59.28	S	58	24.85	W	2603	10	2563	2613	18	
12253	1	122892	2112	2216	2338	44	59.93	S	58	21.71	W	3139	14	3080	3137	19	
12254	1	122992	0216	0325	0511	44	59.68	S	57	49.19	W	3447	9	3399	3455	19	
12255	1	122992	0915	1050	1258	45	00.59	S	57	24.73	W	4011	7	3965	4049	19	I
12256	1	122992	1509	1652	1844	45	01.16	S	56	59.79	W	4773	11	4755	4841	23	CFC
12257	1	123092	2209	0012	0240	45	01.26	S	56	29.90	W	5304	11	5313	5399	22	CFC
12258	2	123092	0817	1018	1239	45	01.47	S	55	45.28	W	5497	14	5555	5609	24	
12259	1	123092	1659	1904	2144	44	58.85	S	54	47.41	W	5648	28	5836	5765	24	CFC
12260	1	123192	0323	0501	0630	45	01.23	S	53	50.68	W	5784	-99	3121	2763	9	
12261	1	123192	1529	1739	1955	44	56.33	S	52	49.00	W	5901	21	5977	6037	24	CFC
12262	1	010193	0108	0320	0528	45	02.14	S	51	44.47	W	5916	18	5950	6051	23	
12263	1	010293	1919	2118	2331	45	02.34	S	50	44.74	W	5763	19	5795	5893	24	CFC
12264	1	010393	0324	0512	0710	45	01.47	S	49	45.10	W	5562	11	5547	5685	24	
12265	1	010393	1108	1259	1510	45	00.23	S	48	46.16	W	5390	10	5373	5499	24	CFC
12266	1	010393	1857	2047	2246	44	59.84	S	47	45.75	W	5271	18	5245	5367	23	
12267	1	010493	0248	0436	0639	45	00.58	S	46	45.22	W	5206	4	5185	5311	20	
12268	1	010493	1027	1208	1402	45	00.17	S	45	45.26	W	5127	12	5100	5223	23	
12269	1	010493	1750	1931	2124	44	59.33	S	44	44.39	W	5088	6	5065	5179	13	
12270	1	010593	0110	0256	0452	44	59.89	S	43	45.12	W	4899	12	4866	4977	15	
12271	1	010593	0855	1050	1253	44	59.98	S	42	45.23	W	5201	5	5205	5305	24	CFC
12272	1	010593	1808	2001	2208	44	59.62	S	41	45.07	W	4964	16	4946	5019	9	
12272	2	010593	2235	2315	0006	44	57.87	S	41	45.72	W	4924	-99	1500	1513	16	
12273	1	010693	0541	0740	0948	45	00.10	S	40	45.44	W	4980	13	4960	5055	24	CFC
12274	1	010693	1427	1606	1801	44	58.87	S	39	45.79	W	4990	6	4996	5075	23	
12275	1	010793	2229	0010	0202	44	58.90	S	38	43.82	W	4866	8	4842	4941	23	CFC
12276	1	010793	0612	0805	1011	45	00.55	S	37	42.91	W	5123	12	5155	5215	23	
12277	1	010793	1419	1611	1821	44	59.23	S	36	44.71	W	5328	6	5334	5457	24	
12277	2	010793	1925	2002	2037	44	59.72	S	36	45.03	W	5328	-99	1250	1264	12	
12278	1	010893	0027	0214	0417	44	59.43	S	35	45.06	W	5490	11	5470	5607	24	
12279	1	010893	0824	1013	1209	44	59.82	S	34	45.83	W	5311	8	5290	5413	23	CFC
12280	1	010893	1557	1742	1936	44	59.47	S	33	46.29	W	5172	4	5155	5267	24	
12281	1	010993	0115	0258	0450	45	00.88	S	32	46.44	W	5124	9	5092	5209	23	CFC
12282	1	010993	0850	1035	1232	45	00.11	S	31	43.23	W	5187	8	5170	5281	23	
12283	1	010993	1649	1847	2043	44	59.33	S	30	45.53	W	5096	12	5070	5185	24	CFC
12284	1	011093	0140	0346	0545	44	59.93	S	29	46.54	W	4933	15	4938	5009	22	
12285	1	011093	1209	1410	1659	44	59.87	S	28	44.49	W	4726	8	4695	4795	22	CFC
12286	1	011093	2048	2234	0021	45	00.32	S	27	46.34	W	4532	10	4510	4587	21	
12287	1	011193	0420	0603	0758	45	00.49	S	26	44.13	W	4764	9	4755	4853	23	CFC
12288	1	011193	1133	1326	1515	44	59.58	S	25	43.88	W	4648	8	4612	4717	21	I
12289	1	011193	1904	2040	2225	45	01.11	S	24	44.97	W	4523	11	4570	4605	21	CFC
12290	1	011293	0201	0334	0513	44	59.25	S	23	43.44	W	4221	12	4200	4259	20	
12291	1	011293	0848	1019	1158	44	59.65	S	22	45.72	W	4438	14	4405	4471	22	CFC
12292	1	011293	1608	1743	1918	45	00.89	S	21	44.24	W	3981	7	4108	4185	20	
12293	1	011393	0028	0156	0321	44	59.69	S	20	42.84	W	3527	17	3534	3599	22	CFC

Stn	Cast	date mmddyy	time, gmt start	bottom	end	latitude	longitude	depth, m uncwtr	ht off	wire	max p	Samples no	notes
12294	1	011593	0425	0554	0727	44 59.28 S	19 44.55 W	3830	15	3850	3895	10	
12294	2	011593	0810	0844	0917	44 58.70 S	19 45.83 W	3931	-99	1000	1008	12	
12295	1	011593	1338	1522	1656	45 00.91 S	18 34.32 W	3760	17	3906	3929	20	CFC
12296	1	011593	2106	2229	2353	45 00.03 S	17 23.82 W	-999	23	3710	3787	21	
12297	1	011693	0419	0547	0708	44 59.30 S	16 13.50 W	3322	10	3290	3327	19	CFC
12298	1	011693	1145	1253	1357	45 00.39 S	15 00.50 W	2757	23	2715	2747	17	
12299	1	011693	1824	1953	2114	44 32.66 S	14 00.18 W	3300	10	3335	3399	18	CFC
12300	1	011793	0133	0258	0421	44 06.73 S	13 00.66 W	3727	12	3658	3733	19	
12301	1	011793	0823	0946	1115	43 40.01 S	12 01.24 W	3612	12	3650	3709	20	CFC
12302	1	011793	1518	1644	1815	43 14.00 S	11 02.67 W	4006	10	3970	4049	19	CFC
12303	1	011793	2233	2355	0124	42 49.20 S	10 05.30 W	3840	11	3810	3877	22	CFC
12304	1	011893	0547	0712	0847	42 22.27 S	9 05.17 W	3841	7	3765	3843	19	
12305	1	011893	1302	1430	1558	41 55.79 S	8 10.09 W	3991	10	3964	4043	21	CFC,
12306	1	011893	2023	2151	2320	41 31.40 S	7 12.31 W	3715	68	3730	3769	19	
12307	1	011993	0311	0449	0624	41 09.32 S	6 24.00 W	4066	2	4065	4123	20	CFC
12308	1	011993	1218	1343	1512	40 42.26 S	5 26.50 W	3718	10	3680	3755	20	
12309	1	011993	1809	1938	2102	40 25.38 S	4 49.82 W	3979	10	3964	4023	19	CFC
12310	1	012093	0252	0449	0638	40 04.98 S	4 02.44 W	4627	6	4605	4709	22	
12311	1	012093	1030	1229	1414	39 43.22 S	3 15.24 W	4488	11	4507	4593	24	CFC
12312	1	012093	1758	1941	2133	39 21.31 S	2 28.67 W	4561	12	4535	4631	23	
12313	1	012193	0107	0255	0443	38 58.22 S	1 41.36 W	4924	11	5038	5151	23	
12314	1	012193	0814	1012	1207	38 36.46 S	0 56.54 W	4983	11	4996	5107	22	
12315	1	012193	1539	1733	1933	38 14.88 S	0 09.74 W	5184	10	5180	5299	23	CFC
12316	1	012293	0013	0202	0359	37 52.89 S	0 35.51 E	5013	10	4997	5107	22	
12317	1	012293	0733	0918	1107	37 31.26 S	1 21.00 E	5074	10	5080	5193	22	CFC
12318	1	012293	1435	1627	1825	37 09.08 S	2 06.23 E	5106	5	5135	5209	23	
12319	1	012293	2146	2335	0127	36 47.42 S	2 51.51 E	5154	10	5155	5267	24	CFC
12320	1	012393	0623	0815	1019	36 16.60 S	3 55.53 E	5190	12	5195	5305	23	CFC
12321	1	012393	1522	1715	1903	35 44.79 S	5 00.15 E	5201	12	5220	5307	23	CFC
12322	1	012493	2357	0200	0404	35 12.76 S	6 02.17 E	5257	10	5270	5369	24	
12323	1	012493	0915	1058	1247	34 42.33 S	7 04.20 E	5219	10	5220	5337	24	CFC
12324	1	012493	1751	1943	2159	34 09.16 S	8 07.24 E	4989	9	5035	5103	22	
12325	1	012593	0301	0457	0638	33 40.82 S	9 08.81 E	5017	5	5065	5135	23	CFC
12325	2	012593	0820	0903	0955	33 40.25 S	9 07.97 E	5019	-99	1500	1502	23	CFC
12326	1	012593	1547	1750	1944	33 05.25 S	10 08.97 E	4999	4	5075	5103	23	CFC
12327	1	012893	0533	0550	0604	30 13.59 S	15 37.16 E	238	4	230	233	6	CFC
12328	1	012893	0849	0915	0939	30 28.27 S	15 08.12 E	471	8	465	465	9	CFC
12329	1	012893	1101	1138	1209	30 34.23 S	14 58.84 E	999	9	992	997	12	CFC
12330	1	012893	1325	1411	1454	30 40.29 S	14 47.44 E	1497	10	1505	1495	12	
12331	1	012893	1612	1703	1759	30 45.31 S	14 38.59 E	1986	10	1965	1985	14	CFC
12332	1	012893	1948	2047	2145	30 53.45 S	14 22.05 E	2498	10	2460	2503	16	
12333	1	012993	0046	0151	0301	31 14.14 S	13 44.98 E	3044	9	3012	3063	18	CFC
12334	1	012993	0611	0733	0856	31 32.54 S	13 09.65 E	3497	10	3475	3531	18	
12335	1	012993	1303	1427	1553	31 57.82 S	12 21.75 E	4002	7	3980	4055	21	CFC,
12336	1	012993	1955	2127	2305	32 19.16 S	11 38.47 E	4412	9	4400	4483	22	
12337	1	013093	0330	0521	0700	32 42.47 S	10 53.87 E	4809	9	4795	4901	22	CFC

Notes

1) Position is reported for the time at the bottom of the cast
2) Salinity, oxygen, silicate, phosphate, nitrate+nitrite were sampled for all bottles
3) CFC denotes CFC-11, 12 and 113 and I denotes Iodine

XBT STATION LIST

		date		time, gmt					depth, m				Samples	
Stn	Cast	mmddyy	start	bottom	end	latitude	longitude	uncwtr	ht off	wire	max	p	no	notes
1	1	122692	1444			45 01.15 S	57 30.29 W	3872	-99	-999	1833			T5
2	1	122792	0025			45 00.03 S	57 59.88 W	3206	-99	-999	1833			T5
3	1	122792	0501			44 59.52 S	58 29.94 W	2059	-99	-999	1833			T5
4	1	122792	0924			44 59.76 S	58 59.97 W	1558	-99	-999	1793			T5
5	1	122792	1304			44 59.81 S	59 14.85 W	1412	-99	-999	1431			T5
6	1	122792	1617			44 59.68 S	59 30.39 W	1222	-99	-999	1241			T5
7	1	122792	1937			44 59.22 S	59 45.30 W	1047	-99	-999	1063			T5
8	1	122792	2248			44 59.28 S	59 59.68 W	238	-99	-999	237			
9	1	122892	0719			44 57.28 S	59 33.73 W	1200	-99	-999	763			
10	1	122892	0826			44 58.87 S	59 18.64 W	1389	-99	-999	763			
11	1	122892	1229			44 57.48 S	58 57.00 W	1610	-99	-999	763			
14	1	122892	2011			44 59.49 S	58 23.29 W	2705	-99	-999	763			
15	1	122992	0032			44 59.40 S	58 10.75 W	3376	-99	-999	763			
16	1	122992	0111			44 59.72 S	58 01.56 W	3110	-99	-999	763			
17	1	122992	0753			44 58.68 S	57 36.32 W	4200	-99	-999	763			
18	1	122992	1404			45 00.70 S	57 11.82 W	4333	-99	-999	763			
19	1	122992	2011			45 00.97 S	56 44.38 W	5073	-99	-999	763			
20	1	123092	0408			45 01.40 S	56 07.95 W	5380	-99	-999	763			
21	1	123092	1510			45 00.75 S	55 07.73 W	5550	-99	-999	923			
22	1	123192	0020			44 58.77 S	54 14.43 W	5731	-99	-999	763			
23	1	123192	1236			44 59.45 S	53 14.63 W	5846	-99	-999	763			
24	1	123192	2244			44 54.19 S	52 15.82 W	5954	-99	-999	763			
25	1	010193	0727			45 02.18 S	51 15.42 W	5844	-99	-999	763			
26	1	010393	0119			45 02.76 S	50 17.40 W	5685	-99	-999	763			
27	1	010393	0909			45 00.68 S	49 15.04 W	5440	-99	-999	763			
28	1	010393	1717			45 00.19 S	48 12.44 W	5300	-99	-999	763			
29	1	010493	0049			44 59.50 S	47 14.55 W	5572	-99	-999	763			
30	1	010493	0833			44 59.57 S	46 14.03 W	5860	-99	-999	763			
31	1	010493	1600			45 00.22 S	45 14.28 W	5026	-99	-999	763			
32	1	010493	2313			44 59.68 S	44 15.05 W	4946	-99	-999	763			
33	1	010593	0626			45 00.00 S	43 15.00 W	4980	-99	-999	763			
34	1	010593	1551			44 59.83 S	42 11.74 W	5060	-99	-999	763			
35	1	010693	0325			44 58.86 S	41 12.86 W	4919	-99	-999	763			
36	1	010693	1238			44 58.62 S	40 05.32 W	4804	-99	-999	763			
37	1	010693	2024			44 59.05 S	39 14.19 W	5000	-99	-999	763			
38	1	010793	0424			44 59.00 S	38 11.16 W	4752	-99	-999	763			
39	1	010793	1207			45 01.85 S	37 13.04 W	5151	-99	-999	763			
40	1	010793	2233			44 59.11 S	36 15.31 W	5460	-99	-999	763			
41	1	010893	0616			44 59.75 S	35 14.73 W	5475	-99	-999	763			
42	1	010893	1406			44 59.89 S	34 16.15 W	5220	-99	-999	763			
43	1	010893	2302			44 56.96 S	33 15.18 W	5051	-99	-999	763			
44	1	010993	0657			45 00.48 S	32 14.31 W	5050	-99	-999	763			
45	1	010993	1424			44 59.78 S	31 13.73 W	5170	-99	-999	763			
46	1	010993	2321			44 56.24 S	30 15.39 W	4945	-99	-999	763			
49	1	011093	0801			45 00.27 S	29 10.79 W	4638	-99	-999	763			
50	1	011093	1847			44 59.53 S	28 14.82 W	4650	-99	-999	763			
51	1	011193	0236			45 00.69 S	27 12.41 W	4684	-99	-999	763			
52	1	011193	0936			44 58.39 S	26 14.51 W	4780	-99	-999	763			
53	1	011193	1657			44 59.70 S	25 17.14 W	-999	-99	-999	763			

		date		time, gmt					depth, m				Samples
Stn	Cast	mmddyy	start	bottom	end	latitude	longitude	uncwtr	ht off	wire	max p	no	notes
54	1	011293	0013			45 01.56 S	24 14.14 W	4620	-99	-999	763		
55	1	011293	0649			44 58.98 S	23 15.42 W	4550	-99	-999	763		
56	1	011293	1410			45 00.38 S	22 13.35 W	3638	-99	-999	763		
57	1	011293	2207			45 00.06 S	21 15.61 W	4134	-99	-999	763		
58	1	011593	0237			44 59.22 S	20 13.85 W	3003	-99	-999	763		
59	1	011593	1136			44 59.68 S	19 08.56 W	3756	-99	-999	763		
60	1	011593	1851			45 00.33 S	18 00.20 W	3500	-99	-999	763		
61	1	011693	0215			44 59.82 S	16 45.68 W	3800	-99	-999	763		
62	1	011693	0934			44 58.69 S	15 36.62 W	1863	-99	-999	763		
63	1	011693	1601			44 47.01 S	14 31.47 W	3500	-99	-999	763		
64	1	011693	2318			44 20.51 S	13 30.92 W	3237	-99	-999	763		
65	1	011793	0614			43 54.69 S	12 32.06 W	3456	-99	-999	763		
66	1	011793	1308			43 27.77 S	11 33.83 W	3675	-99	-999	763		
67	1	011793	2022			43 01.46 S	10 34.51 W	3740	-99	-999	763		
68	1	011893	0333			42 35.99 S	9 36.56 W	3670	-99	-999	763		
69	1	011893	1056			42 08.83 S	8 37.80 W	3888	-99	-999	763		
70	1	011893	1808			41 42.77 S	7 42.57 W	3748	-99	-999	763		
71	1	011993	0115			41 20.75 S	6 49.00 W	3822	-99	-999	763		
72	1	011993	0920			40 57.97 S	6 00.83 W	3507	-99	-999	763		
73	1	011993	1056			40 48.49 S	5 39.99 W	800	-99	-999	763		
74	1	011993	1620			40 36.56 S	5 13.18 W	3804	-99	-999	763		
75	1	011993	2254			40 14.11 S	4 26.07 W	3559	-99	-999	763		
76	1	012093	0843			39 53.47 S	3 38.92 W	4327	-99	-999	763		
77	1	012093	1607			39 31.75 S	2 49.93 W	4400	-99	-999	763		
78	1	012093	2320			39 09.62 S	2 05.28 W	4520	-99	-999	763		
79	1	012193	0627			38 46.25 S	1 19.64 W	5306	-99	-999	763		
80	1	012193	1351			38 25.54 S	0 33.41 W	5800	-99	-999	763		
81	1	012193	2151			38 05.02 S	0 12.46 E	5147	-99	-999	763		
82	1	012293	0544			37 40.57 S	0 58.21 E	5250	-99	-999	763		
83	1	012293	1252			37 20.15 S	1 42.27 E	5050	-99	-999	763		
84	1	012293	2005			36 57.74 S	2 27.23 E	4901	-99	-999	763		
85	1	012393	0304			36 35.92 S	3 12.92 E	5200	-99	-999	763		
86	1	012393	0448			36 24.64 S	3 35.94 E	5185	-99	-999	811		T5
87	1	012393	0456			36 23.71 S	3 37.77 E	5185	-99	-999	763		
88	1	012393	1152			36 05.99 S	4 14.75 E	5086	-99	-999	763		
89	1	012393	1344			35 54.63 S	4 38.80 E	5086	-99	-999	763		
90	1	012393	2039			35 34.53 S	5 18.52 E	5196	-99	-999	763		
91	1	012393	2216			35 23.98 S	5 40.47 E	5218	-99	-999	763		
92	1	012493	0543			35 01.66 S	6 20.62 E	5350	-99	-999	763		
93	1	012493	0732			34 51.83 S	6 43.58 E	5230	-99	-999	763		
94	1	012493	1429			34 31.35 S	7 24.46 E	5128	-99	-999	763		
95	1	012493	1603			34 20.72 S	7 44.96 E	5197	-99	-999	763		
96	1	012493	2336			33 59.47 S	8 26.69 E	-999	-99	-999	763		
97	1	012593	0123			33 48.81 S	8 48.91 E	5047	-99	-999	763		
98	1	012593	1144			33 28.67 S	9 27.81 E	4968	-99	-999	763		
99	1	012593	1325			33 17.37 S	9 48.52 E	4994	-99	-999	1127		T5
100	1	012593	1335			33 16.45 S	9 50.40 E	4988	-99	-999	1832		T5
101	1	012593	2104			33 05.15 S	10 25.95 E	4800	-99	-999	1832		T5
102	1	012593	2240			33 07.38 S	10 44.54 E	4752	-99	-999	763		
103	1	012693	0002			33 09.10 S	11 03.09 E	4850	-99	-999	763		
104	1	012693	0203			33 11.80 S	11 30.40 E	4800	-99	-999	763		

Stn	Cast	date mmddyy	time, gmt start	bottom	end	latitude	longitude	depth, m uncwtr	ht off	wire	max p	Samples no	notes
105	1	012693	0400			33 14.49 S	11 54.79 E	-999	-99	-999	763		
106	1	012693	0559			33 16.76 S	12 18.73 E	-999	-99	-999	763		
108	1	012693	0802			33 18.47 S	12 43.31 E	4695	-99	-999	763		
109	1	012693	0957			33 20.03 S	13 06.57 E	-999	-99	-999	763		
110	1	012693	1204			33 22.71 S	13 32.09 E	5000	-99	-999	763		
111	1	012693	1400			33 25.48 S	13 56.13 E	-999	-99	-999	763		
112	1	012693	1559			33 27.22 S	14 21.13 E	4350	-99	-999	763		
113	1	012693	1800			33 29.98 S	14 46.22 E	4350	-99	-999	763		
114	1	012693	1959			33 32.10 S	15 11.23 E	-999	-99	-999	763		
115	1	012693	2204			33 34.89 S	15 36.97 E	3460	-99	-999	763		
116	1	012793	0006			33 37.37 S	16 00.34 E	3407	-99	-999	763		
117	1	012793	0200			33 40.10 S	16 25.13 E	3000	-99	-999	763		
118	1	012793	0400			33 42.98 S	16 54.44 E	1800	-99	-999	763		
119	1	012793	0600			33 45.64 S	17 25.31 E	530	-99	-999	599		
120	1	012793	1309			33 22.96 S	17 50.72 E	163	-99	-999	204		
121	1	012793	1500			33 01.59 S	17 35.71 E	250	-99	-999	305		
123	1	012793	1908			32 13.98 S	16 59.59 E	281	-99	-999	443		
124	1	012793	2259			31 28.25 S	16 28.93 E	363	-99	-999	405		
125	1	012893	0300			30 39.45 S	15 54.50 E	190	-99	-999	255		
126	1	012893	0732			30 21.31 S	15 21.89 E	280	-99	-999	340		
127	1	012893	0814			30 25.43 S	15 13.43 E	353	-99	-999	405		
128	1	012893	1036			30 32.45 S	15 01.53 E	750	-99	-999	763		
129	1	012893	1248			30 37.04 S	14 52.74 E	1288	-99	-999	1195		T5
130	1	012893	1552			30 44.33 S	14 39.77 E	1890	-99	-999	1216		T5
131	1	012893	1837			30 48.51 S	14 33.04 E	2250	-99	-999	1832		T5
132	1	012893	2308			31 02.28 S	14 05.94 E	2750	-99	-999	1260		T5
133	1	012993	0417			31 22.17 S	13 31.87 E	3250	-99	-999	1832		T5
134	1	012993	1104			31 46.48 S	12 44.51 E	3800	-99	-999	1207		T5
135	1	012993	1755			32 08.56 S	12 00.10 E	4160	-99	-999	1832		T5
136	1	013093	0112			32 30.27 S	11 16.38 E	4620	-99	-999	1832		T5

FIGURE LEGENDS

Figure 1. The A11 cruise track defined by CTD/Rosette stations. Isobaths of 200m and 3000m are superimposed

Figure 2. The location of 10 l water samples collected on cruise A11. Depth is in dbar.

Figure 3. Silicate concentration versus potential temperature for A11 (*) and SAVE 4 data: both are in the Argentine basin and for the whole water column. The inset, for the deepest levels, shows the small discrepancy between the data sets.

Figure 4. Dissolved oxygen concentration versus salinity for A11 (*) and SAVE 4 data: both are in the Argentine basin and for the whole water column. The inset, where the deepest levels form the left branch of the Y, shows the small discrepancy between the data sets.

Figure 5. Deep water collected on station 12240 from 2500m was used as quality control for the nutrient measurements: results are shown for the last 50 stations of the cruise.

Figure 6. A comparison of CFC-11 and CFC-12 data from (a) SAVE station 291 and A11 station 12273 and (b) SAVE station 200 and A11 station 12295.

Figure 7. Surface salinity (bold) and temperature (broken) on cruise A11. The cruise begins on the Argentine shelf, passes through the Falkland current (day363), the Brazil current retroflection (day 365),traverses the Subantarctic Zone until somewhere between day 386 and 390 it enters the subtropical gyre. The cruise ends in S.Africa

Figure 8. Location of A11 and historical data. Pluses, this cruise. Crosses, SAVE leg 4. Triangles, Atlantis II Cruise 107. Inverted triangles, AJAX.

Figure 9. This cruise: station averages of anomaly of salinity relative to standard fits. Horizontal axis: station number. Vertical axis: salinity anomaly.

Figure 10. This cruise: sample minus CTD salinity residuals for all samples flagged as good. Horizontal axis: pressure. Vertical axis: salinity residual.

Figure 11. SAVE leg 4: station averages of anomaly of salinity relative to standard fits. Horizontal axis: station number. Vertical axis: salinity anomaly.

Figure 12. Atlantis II Cruise 107: station averages of anomaly of salinity relative to standard fits. Horizontal axis: longitude. Vertical axis: salinity anomaly.

Figure 13. This cruise: comparison of measured with predicted OXYTMP. Horizontal axis: THETA. Vertical axis: measured minus predicted OXYTMP.

Figure 14. This cruise: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: station number. Vertical axis: oxygen anomaly (μmol/l).

Figure 15. SAVE leg 4: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: station number. Vertical axis: oxygen anomaly (μmol/kg).

Figure 16. Atlantis II Cruise 107: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: longitude. Vertical axis: oxygen anomaly (μmol/l).

Figure 17. AJAX: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: latitude. Vertical axis: oxygen anomaly (μmol/l). Intersects with A11 at 38 degrees south.

Figure 18. Station averages of nitrate anomaly relative to standard fits. Horizontal axis: station number or latitude. Vertical axis: nitrate anomaly (μmol/l). 18a - This cruise. 18b - SAVE. 18c - AJAX.

Figure 19. As Figure 18, but silicate.

Figure 20. As Figure 18, but phosphate.

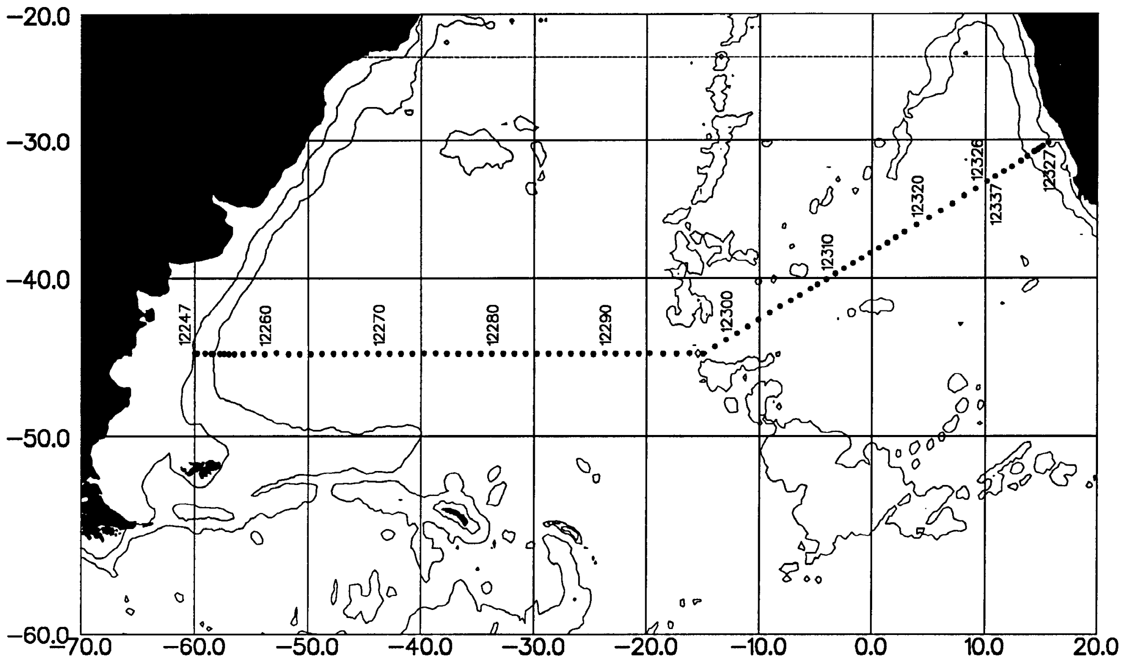


Figure 1. The A11 cruise track defined by CTD/Rosette stations. Isobaths of 200m and 3000m are superimposed

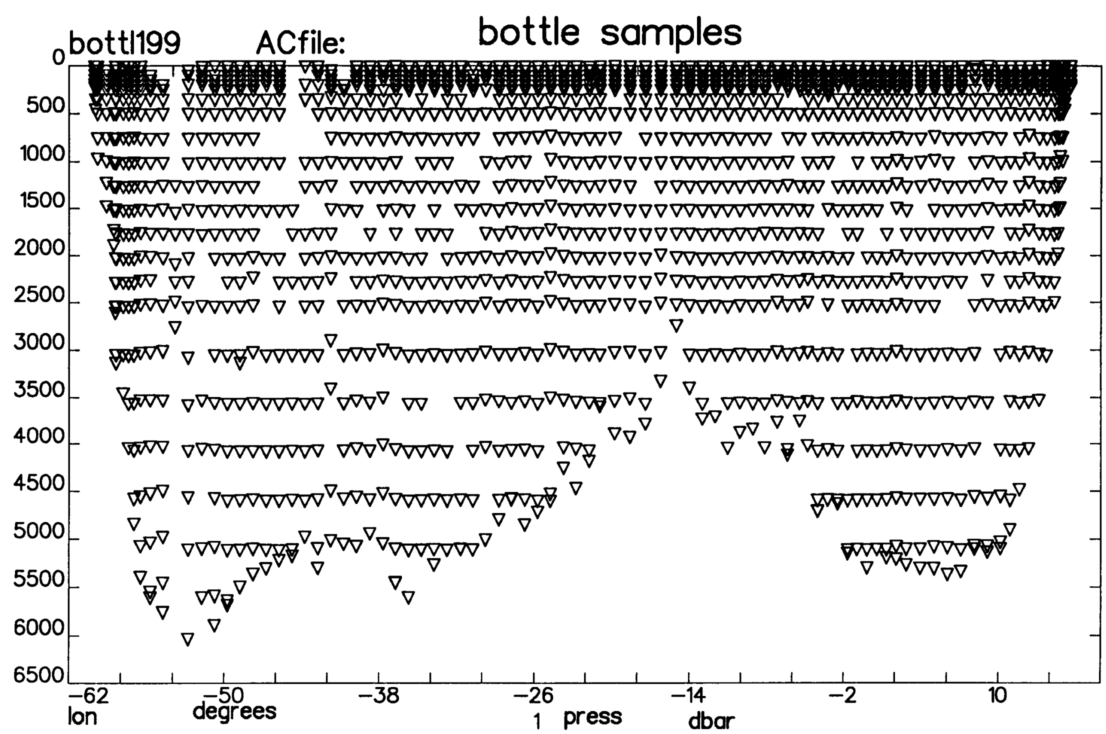


Figure 2. The location of 10 litre water samples collected on cruise A11. Depth is in dbar.

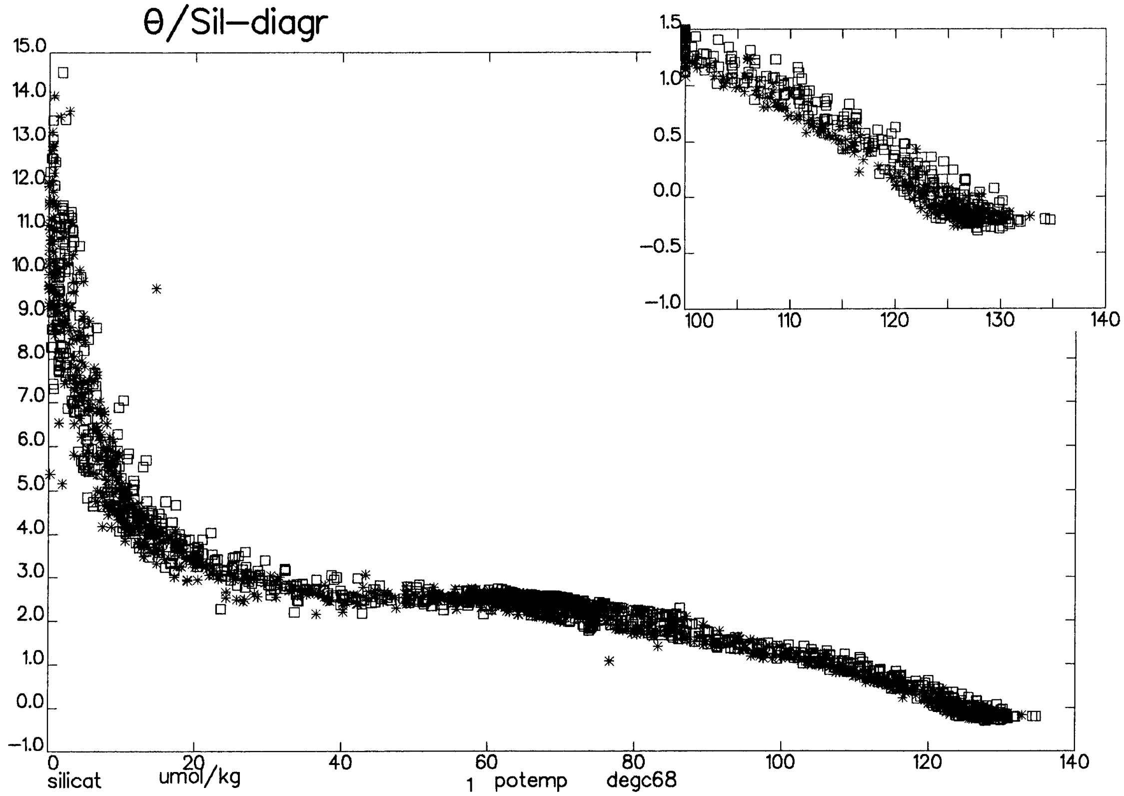


Figure 3. Silicate concentration versus potential temperature for A11 * and SAVE 4 data: both are in the Argentine basin and for the whole water column. The inset, for the deepest levels, shows the small discrepancy between the data sets.

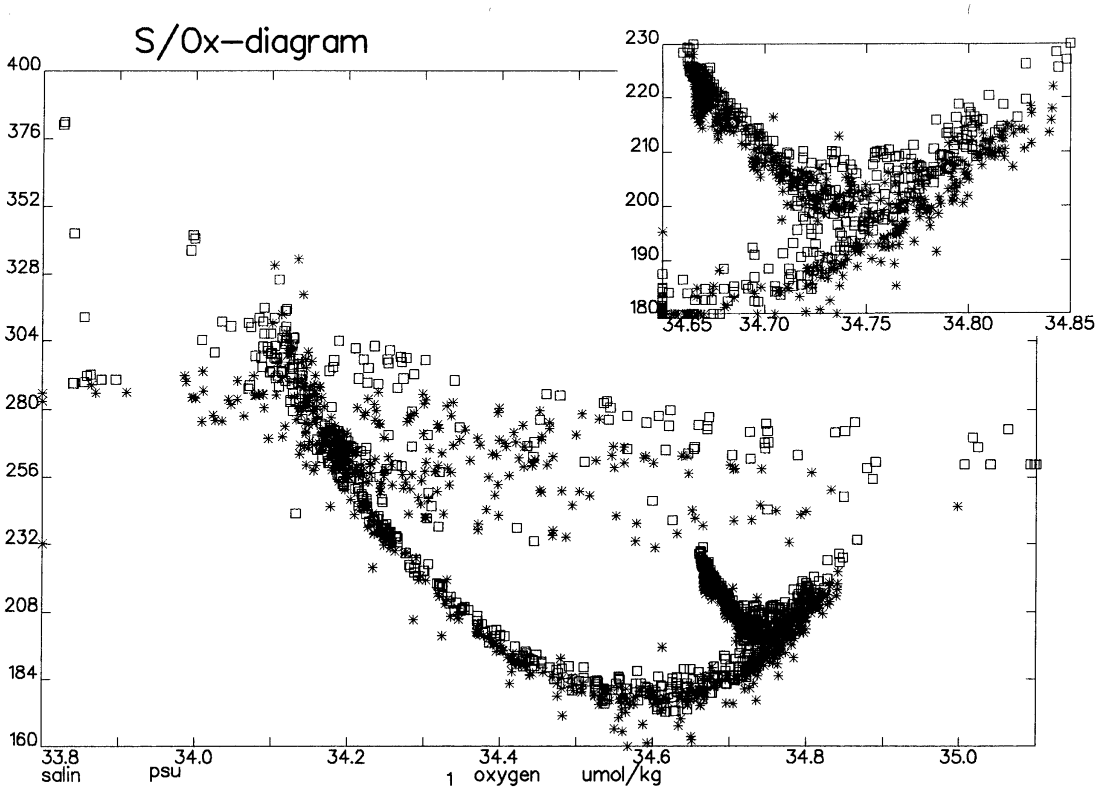


Figure 4. Dissolved oxygen concentration versus salinity for A11 * and SAVE 4 data: both are in the Argentine basin and for the whole water column. The inset, where the deepest levels form the left branch of the Y, shows the small discrepancy between the data sets.

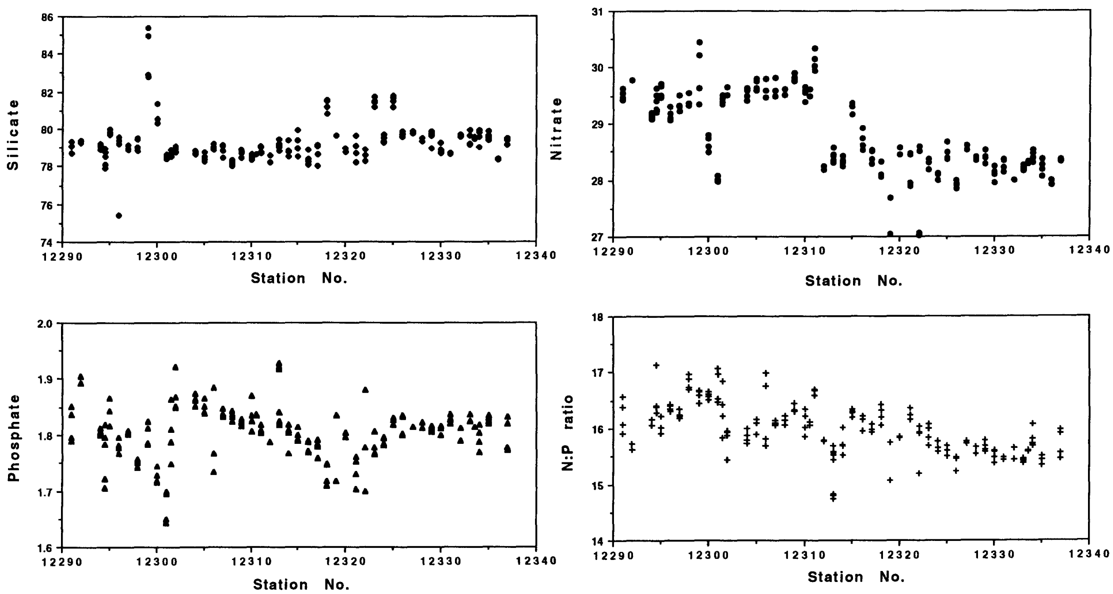


Figure 5. Deep water collected on station 12240 from 2500m was used as quality control for the nutrient measurements: results are shown for the last 50 stations of the cruise.

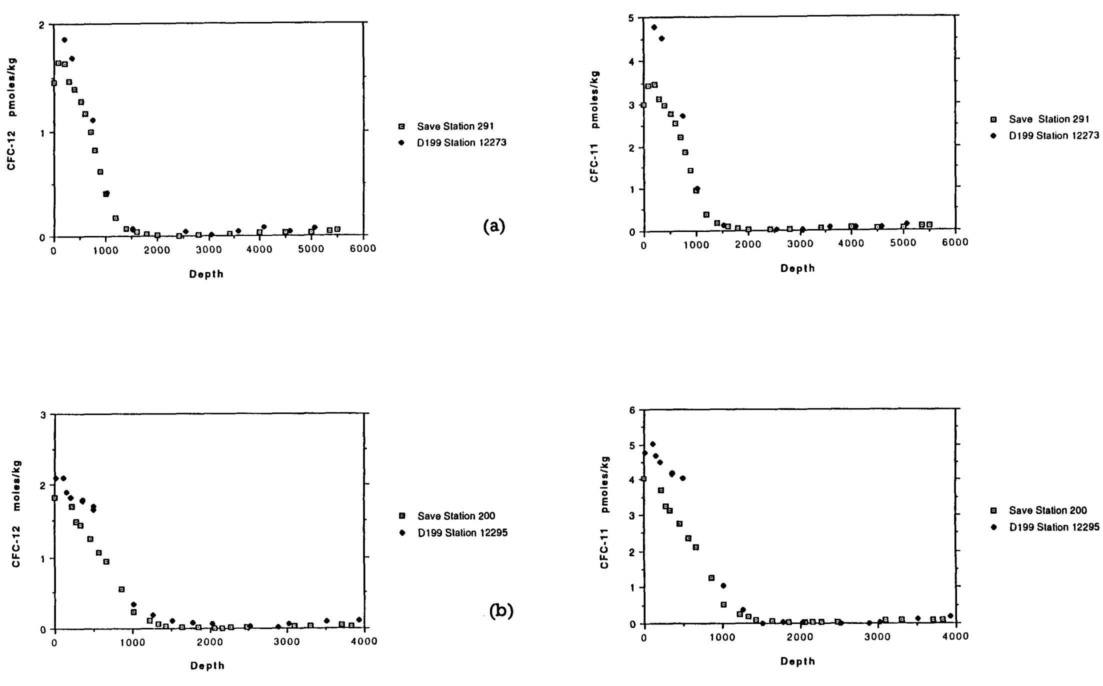


Figure 6. A comparison of CFC-11 and CFC-12 data from (a) SAVE station 291 and A11 station 12273 and (b) SAVE station 200 and A11 station 12295.

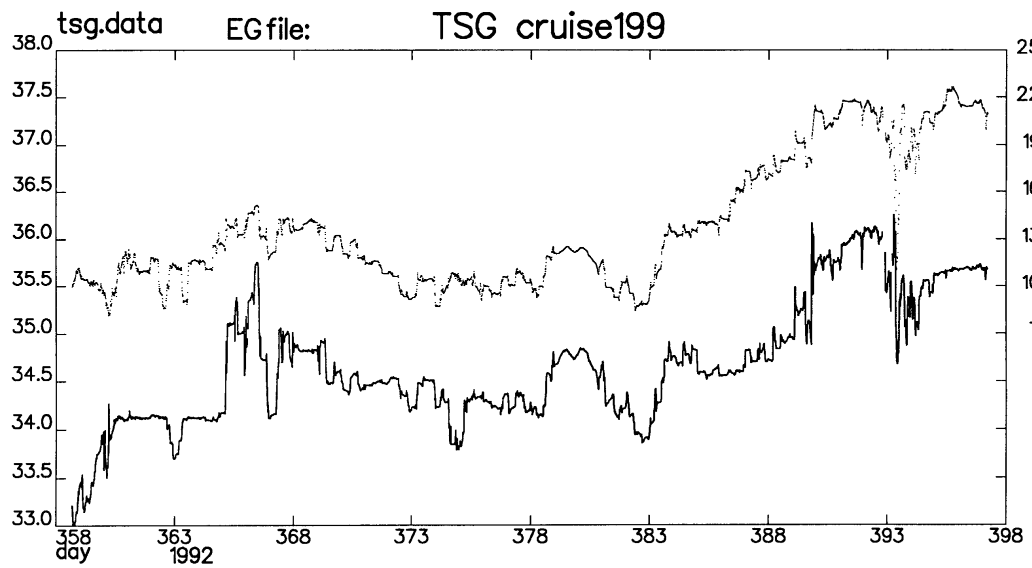


Figure 7. Surface salinity (bold) and temperature (broken) on cruise A11. The cruise begins on the Argentine shelf, passes through the Falkland current (day363), the Brazil current retroflection (day 365),traverses the Subantarctic Zone until somewhere between day 386 and 390 it enters the subtropical gyre. The cruise ends in S.Africa

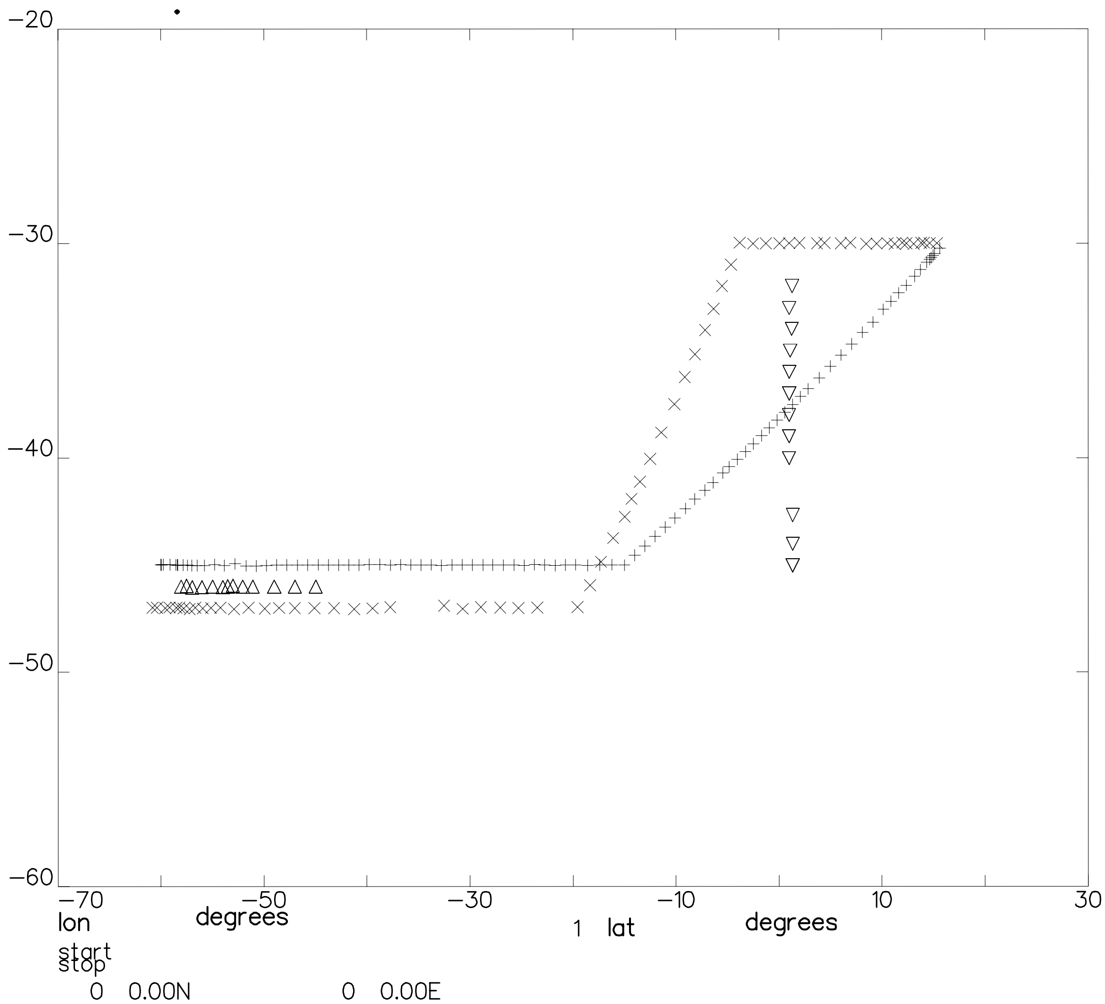


Figure 8. Location of A11 and historical data. Pluses, this cruise. Crosses, SAVE leg 4. Triangles, Atlantis II Cruise 107. Inverted triangles, AJAX.

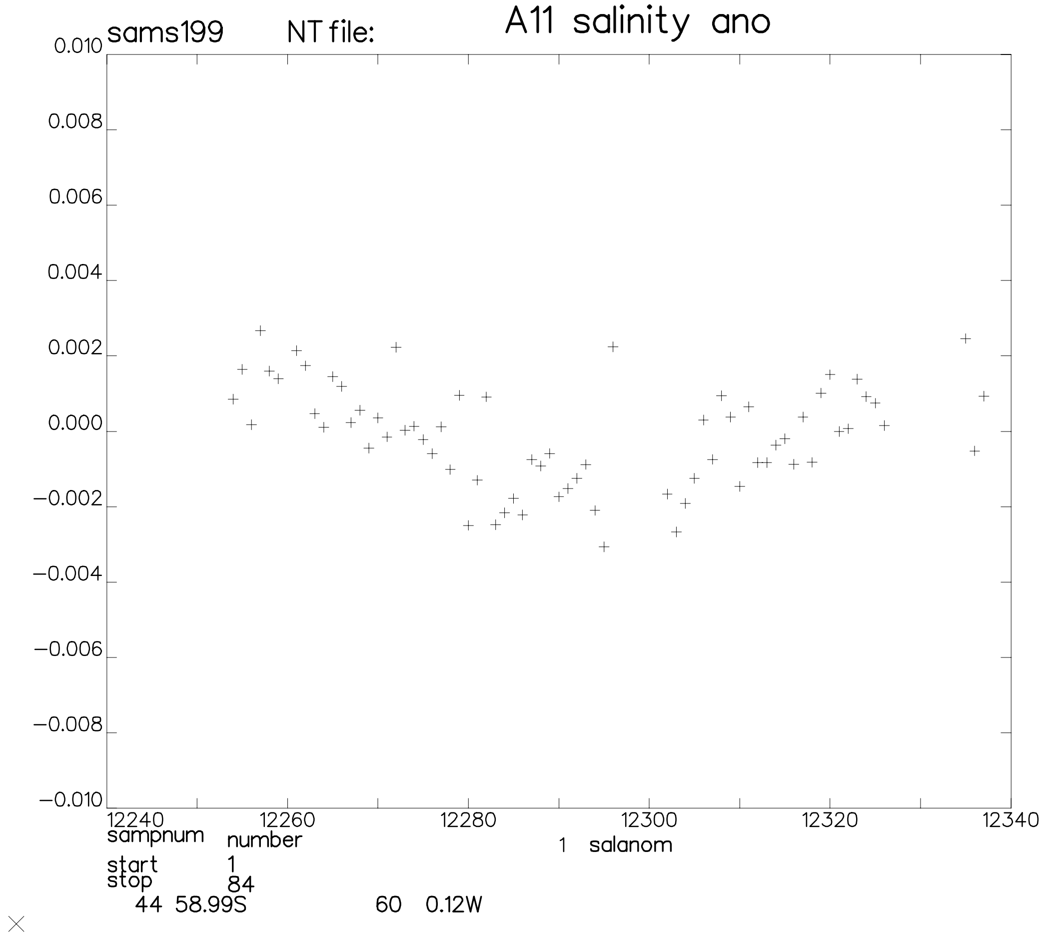


Figure 9 This cruise: station averages of anomaly of salinity relative to standard fits. Horizontal axis: station number. Vertical axis: salinity anomaly.

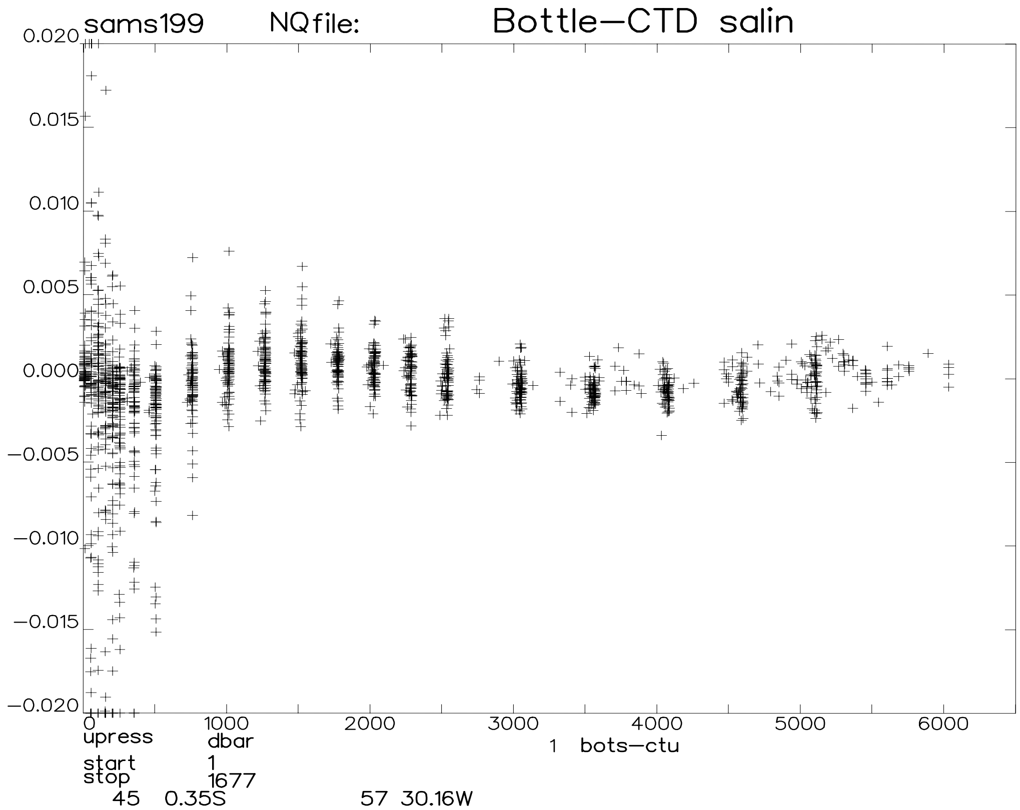


Figure 10 This cruise: sample minus CTD salinity residuals for all samples flagged as good. Horizontal axis: pressure. Vertical axis: salinity residual.

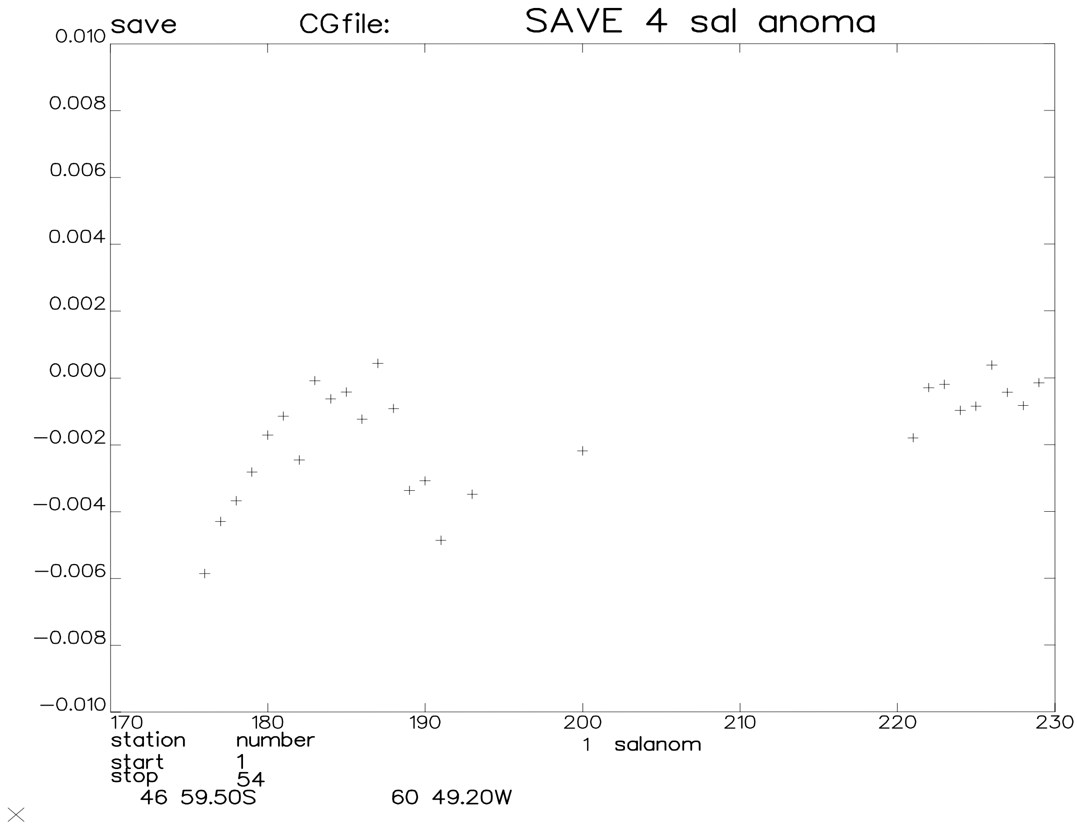


Figure 11 SAVE leg 4: station averages of anomaly of salinity relative to standard fits. Horizontal axis: station number. Vertical axis: salinity anomaly.

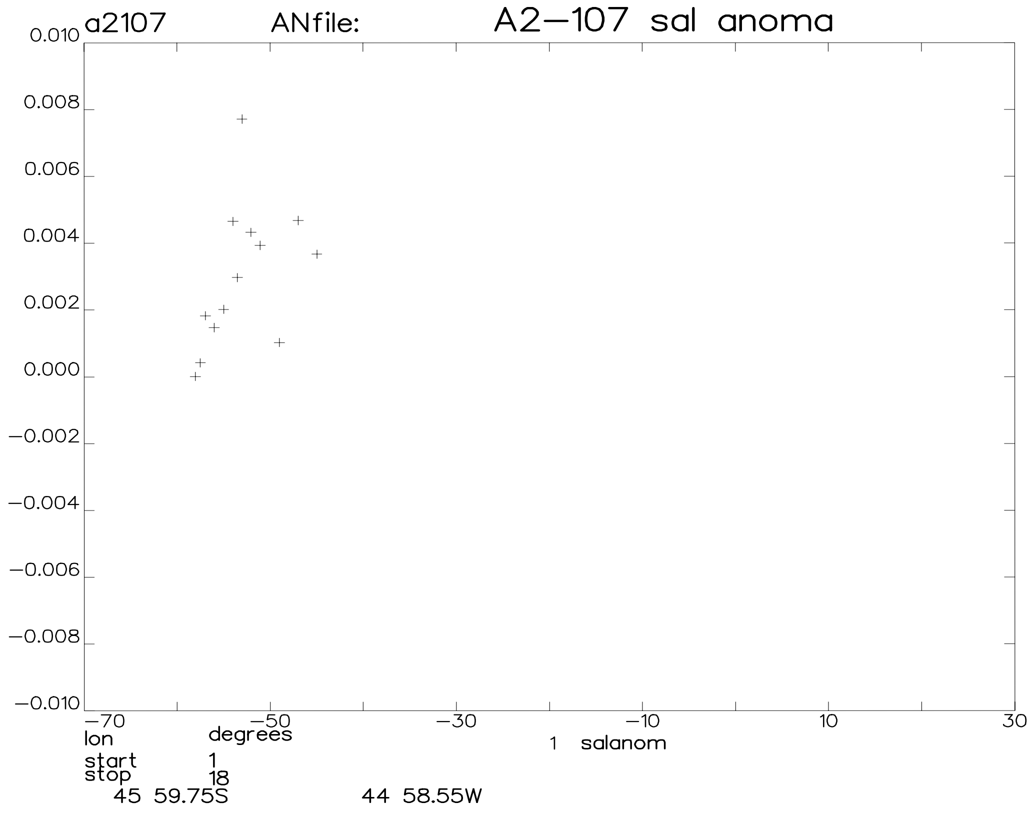


Figure 12 Atlantis II Cruise 107: station averages of anomaly of salinity relative to standard fits. Horizontal axis: longitude. Vertical axis: salinity anomaly.

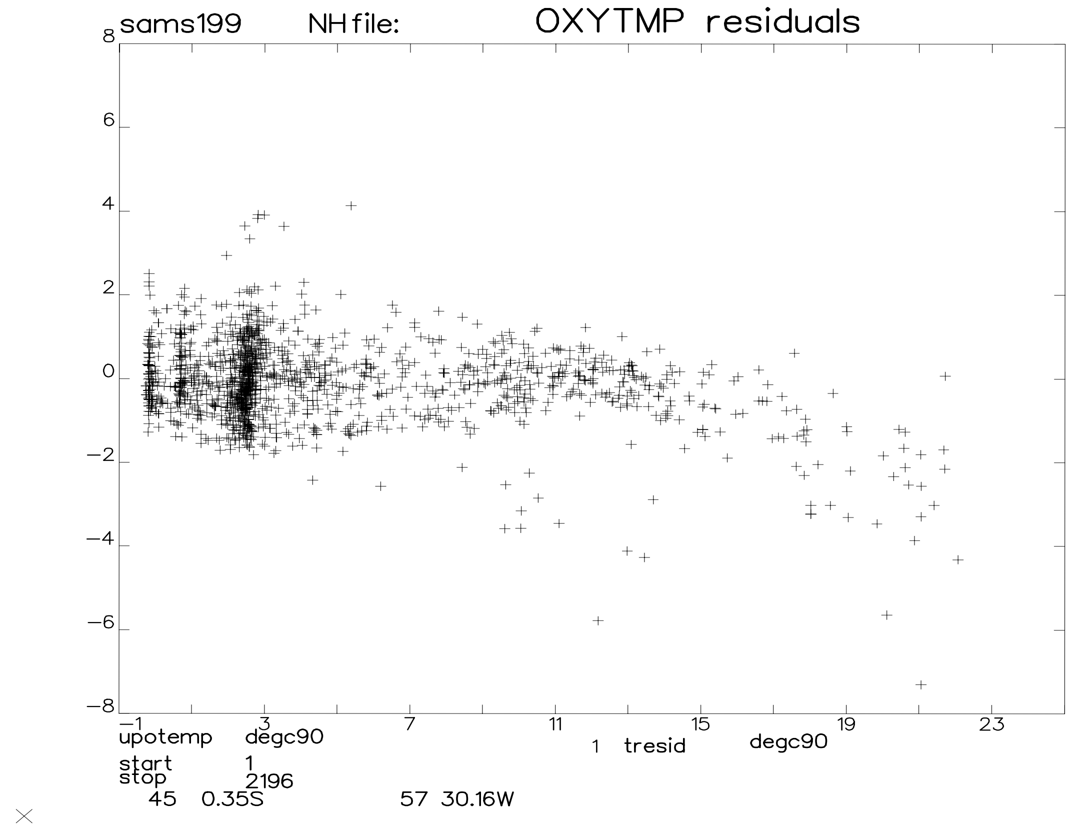


Figure 13 This cruise: comparison of measured with predicted OXYTMP. Horizontal axis: THETA. Vertical axis: measured minus predicted OXYTMP.

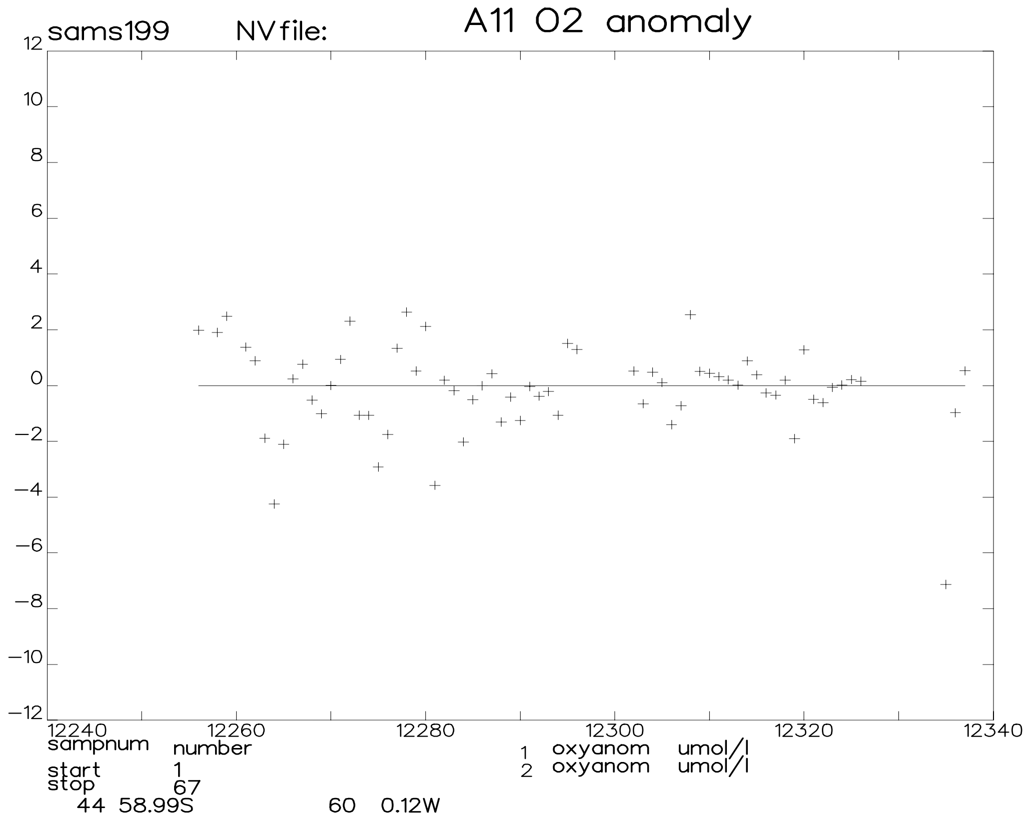


Figure 14 This cruise: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: station number. Vertical axis: oxygen anomaly (μmol/l).

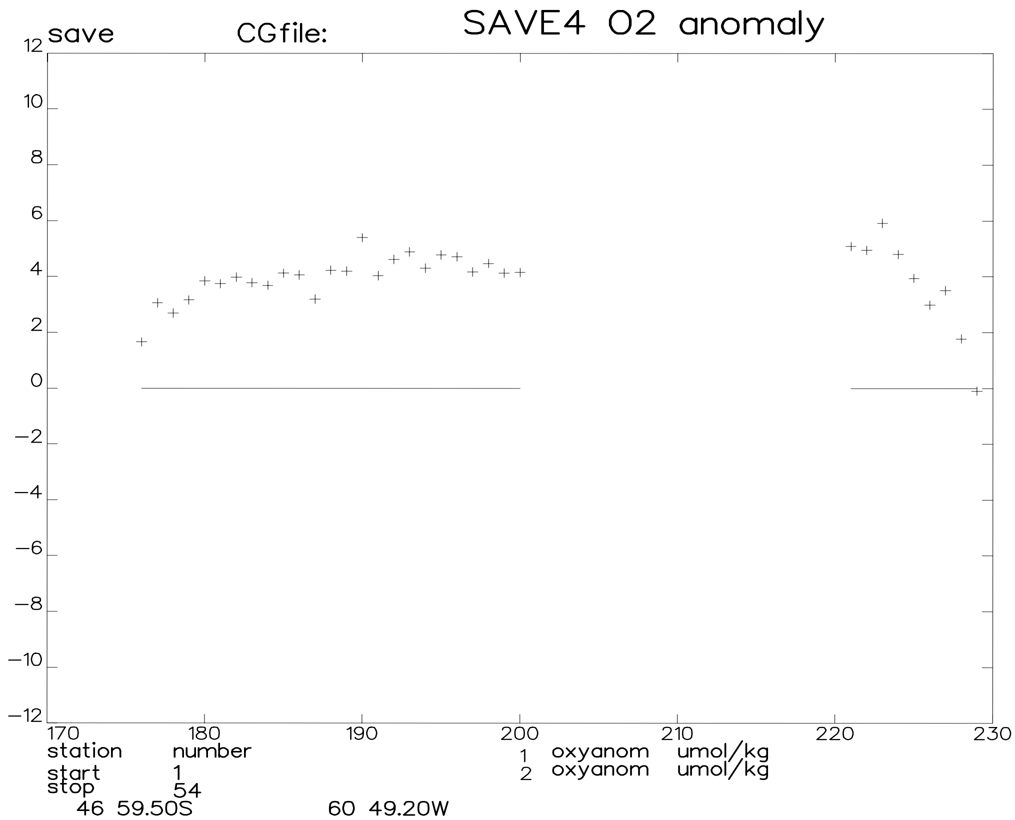


Figure 15 SAVE leg 4: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: station number. Vertical axis: oxygen anomaly (μmol/kg).

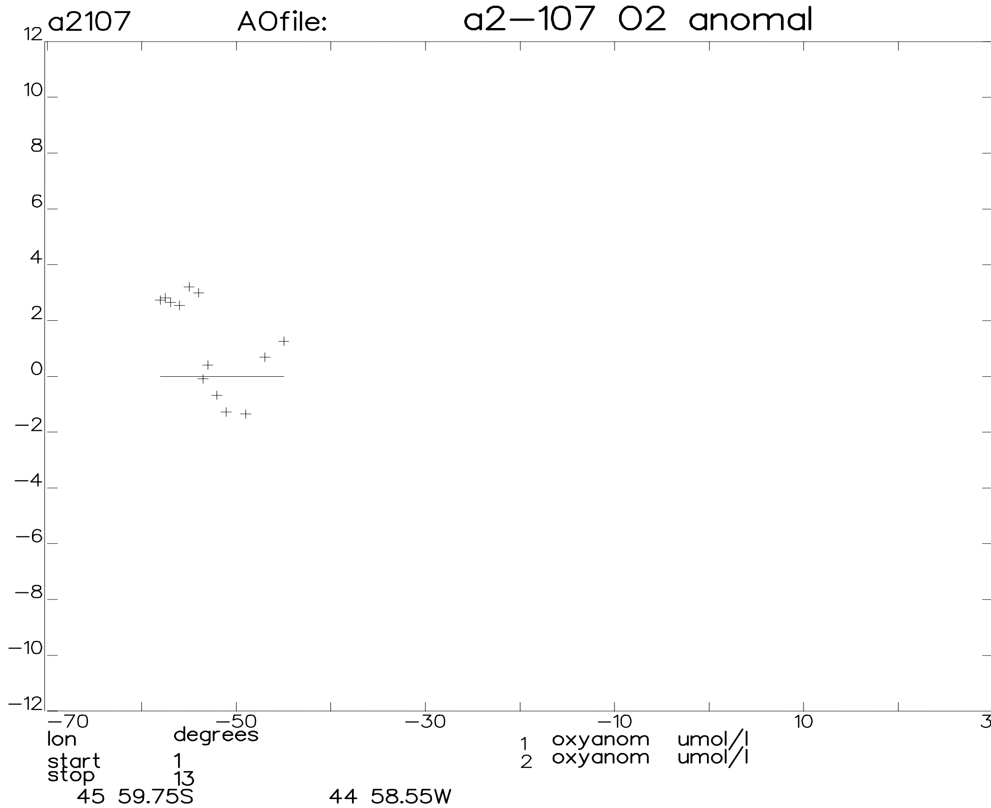


Figure 16 Atlantis II Cruise 107: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: longitude. Vertical axis: oxygen anomaly (μmol/l).

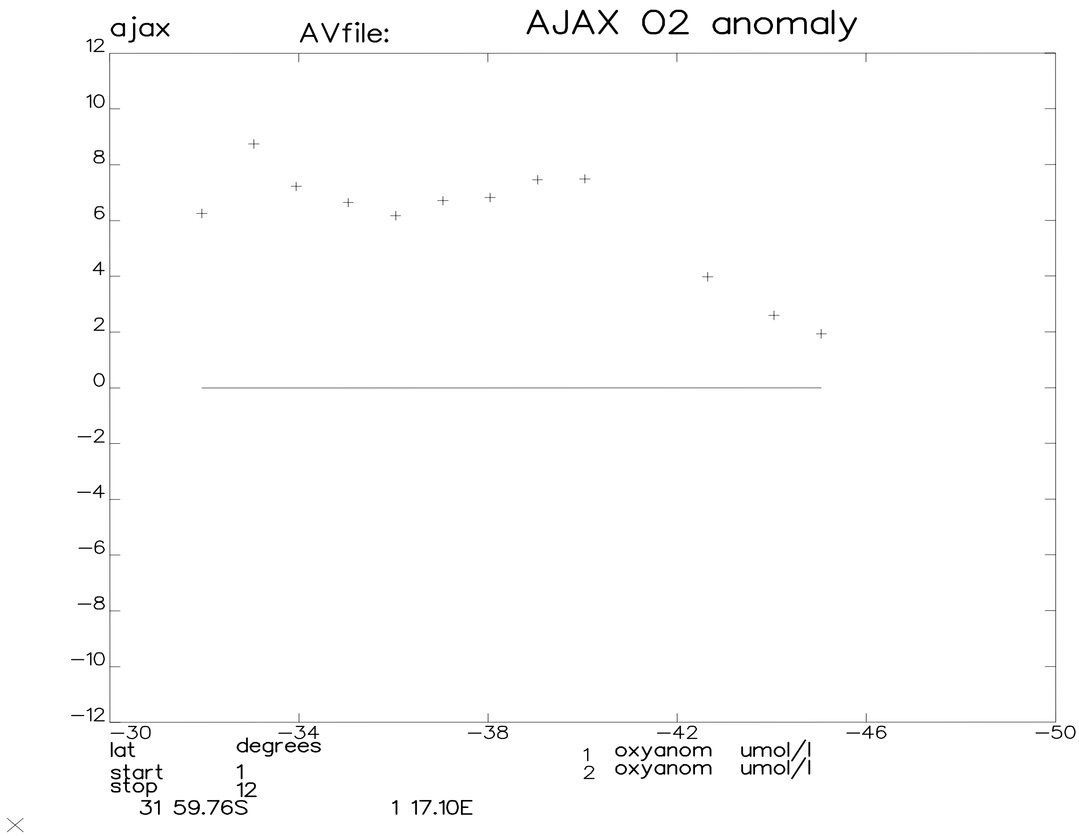
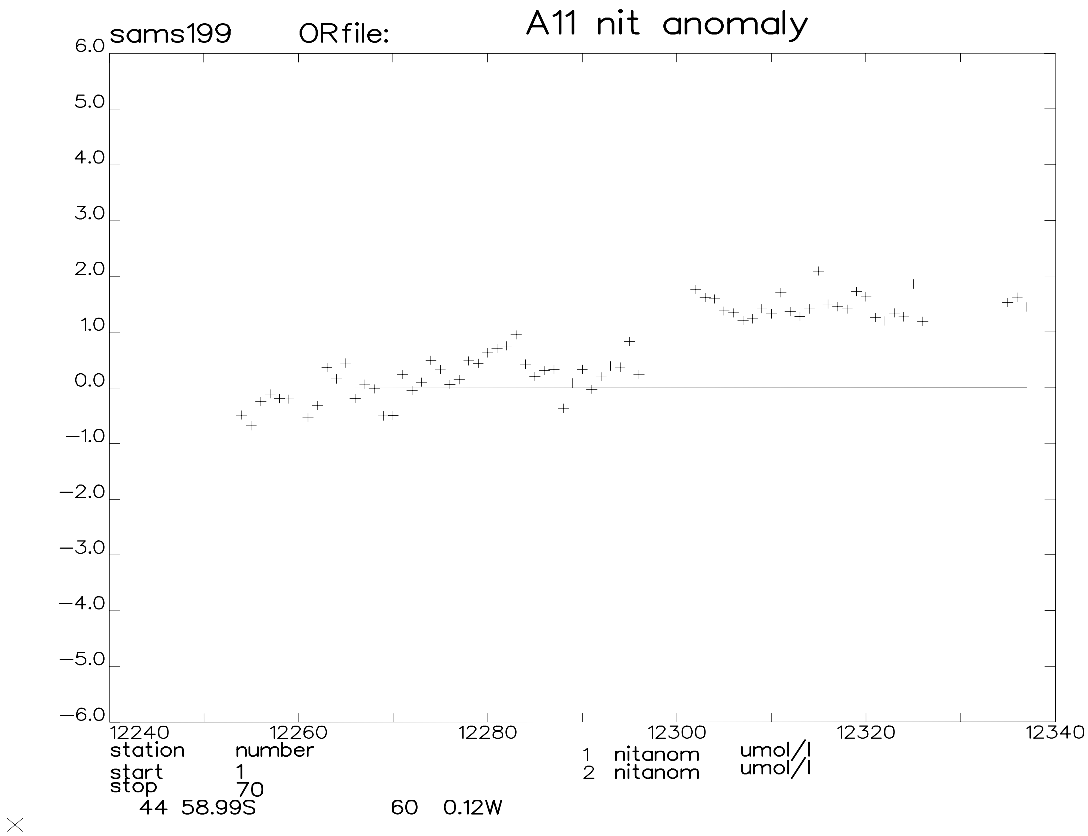
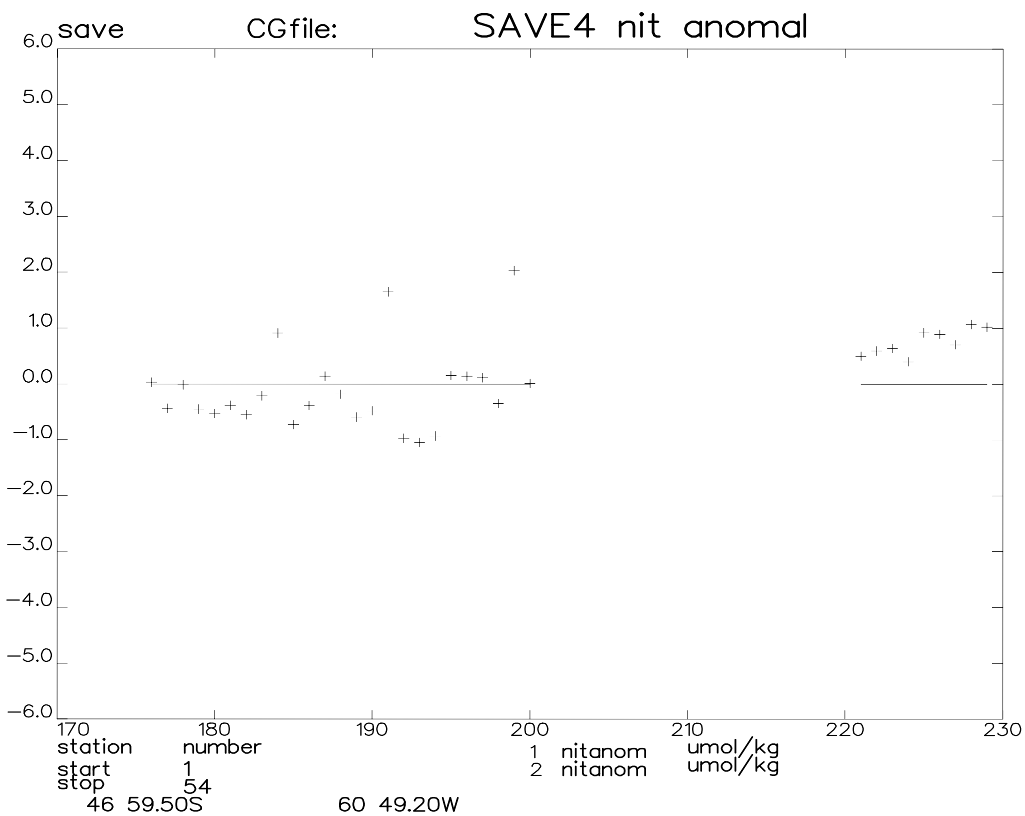


Figure 17 AJAX: station averages of anomaly of oxygen relative to standard fits. Horizontal axis: latitude. Vertical axis: oxygen anomaly (μmol/l). Intersects with A11 at 38 degrees south.



sams199
ORfile:
A11 nit anomaly
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
12240
12260
12280
12300
12320
12340
station number
start 1
stop 70
44 58.99S 60 0.12W
1 nitanom umol/l
2 nitanom umol/l


save
CGfile:
SAVE4 nit anomal
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
170
180
190
200
210
220
230
station number
start 1
stop 54
46 59.50S
60 49.20W
1 nitanom umol/kg
2 nitanom umol/kg

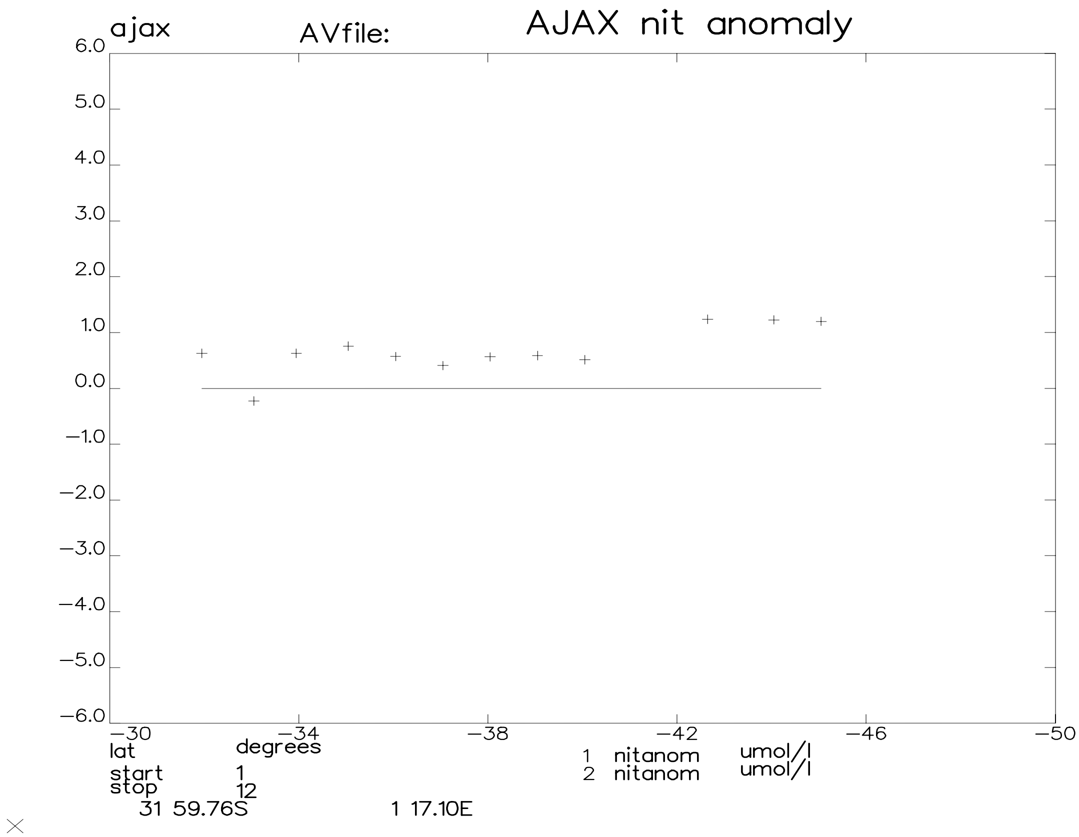
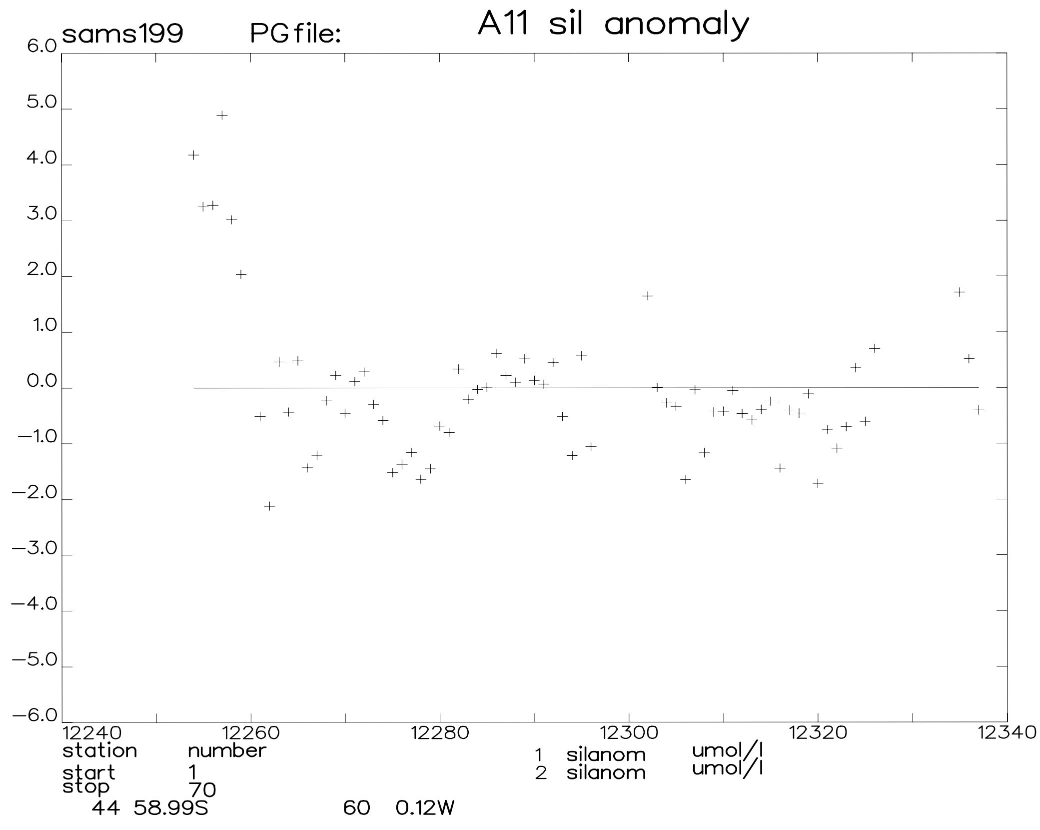
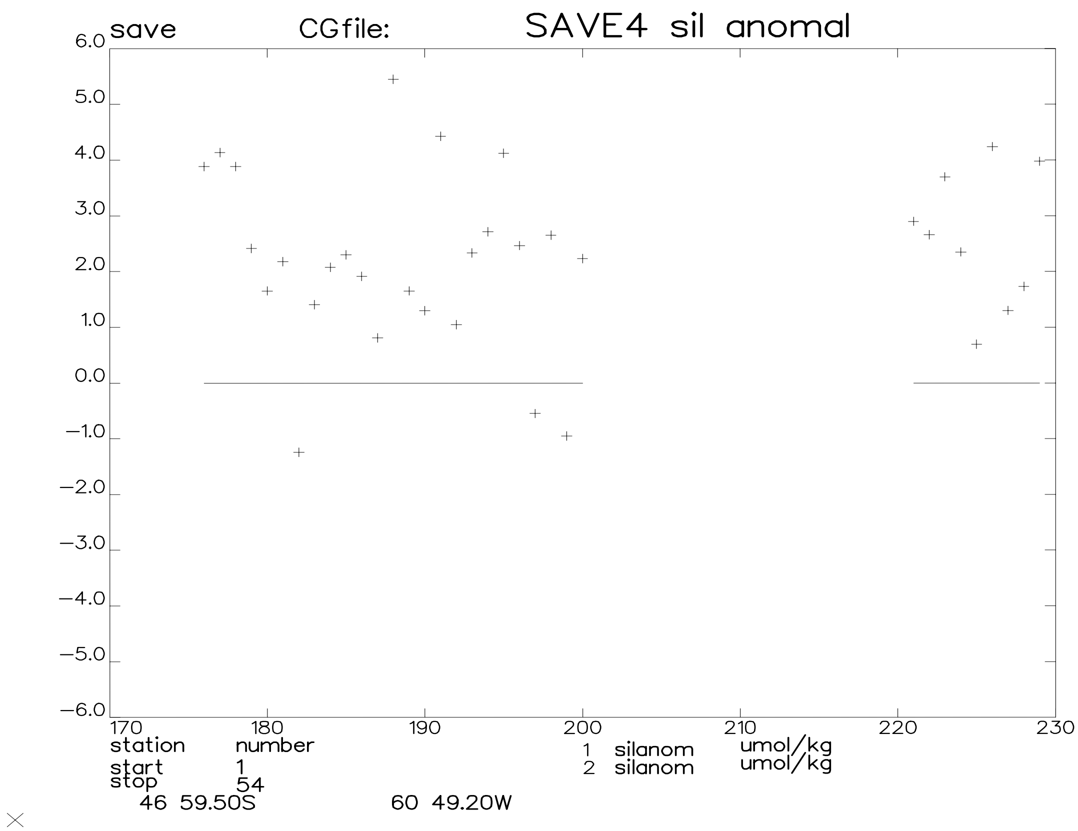


Figure 18 Station averages of nitrate anomaly relative to standard fits. Horizontal axis: station number or latitude. Vertical axis: nitrate anomaly (μmol/l). 18a - This cruise. 18b - SAVE. 18c - AJAX.



sams199
PG file:
A11 sil anomaly
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
12240
12260
12280
12300
12320
12340
station number
1 silanom umol/l
2 silanom umol/l
start 1
stop 70
44 58.99S 60 0.12W


save
CGfile:
SAVE4 sil anomal
6.0
5.0
4.0
3.0
2.0
1.0
0.0
−1.0
−2.0
−3.0
−4.0
−5.0
−6.0
170
180
190
200
210
220
230
station number
start 1
stop 54
46 59.50S
60 49.20W
1 silanom umol/kg
2 silanom umol/kg

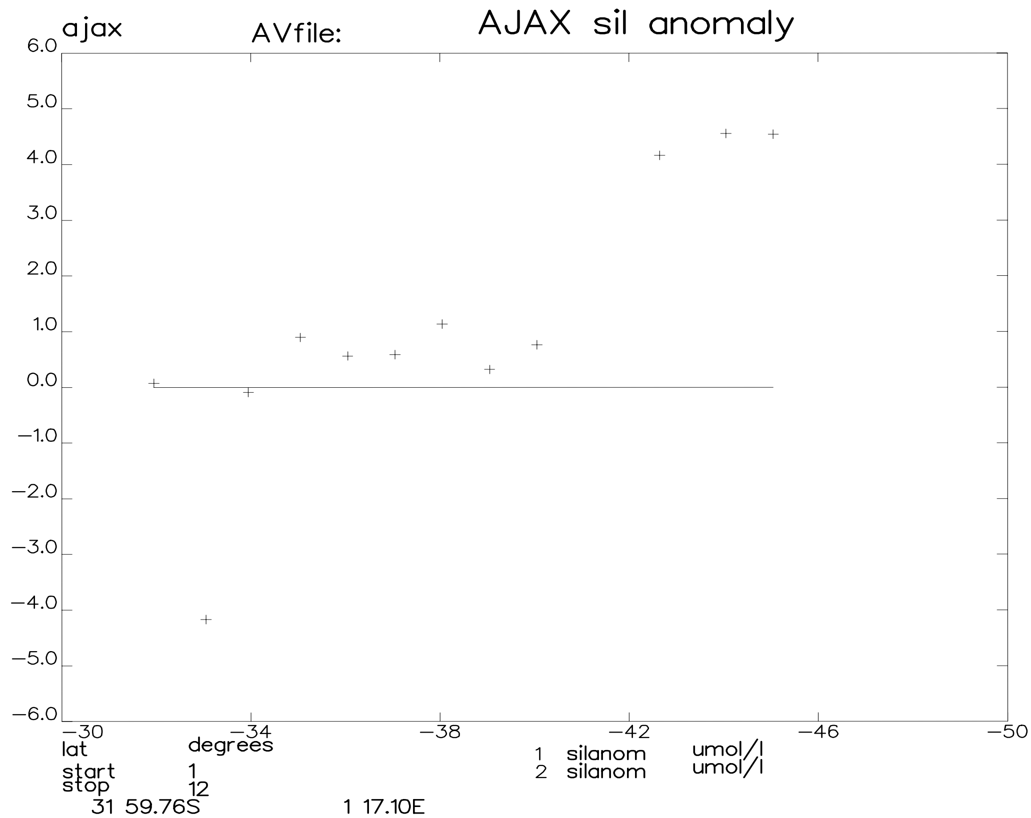
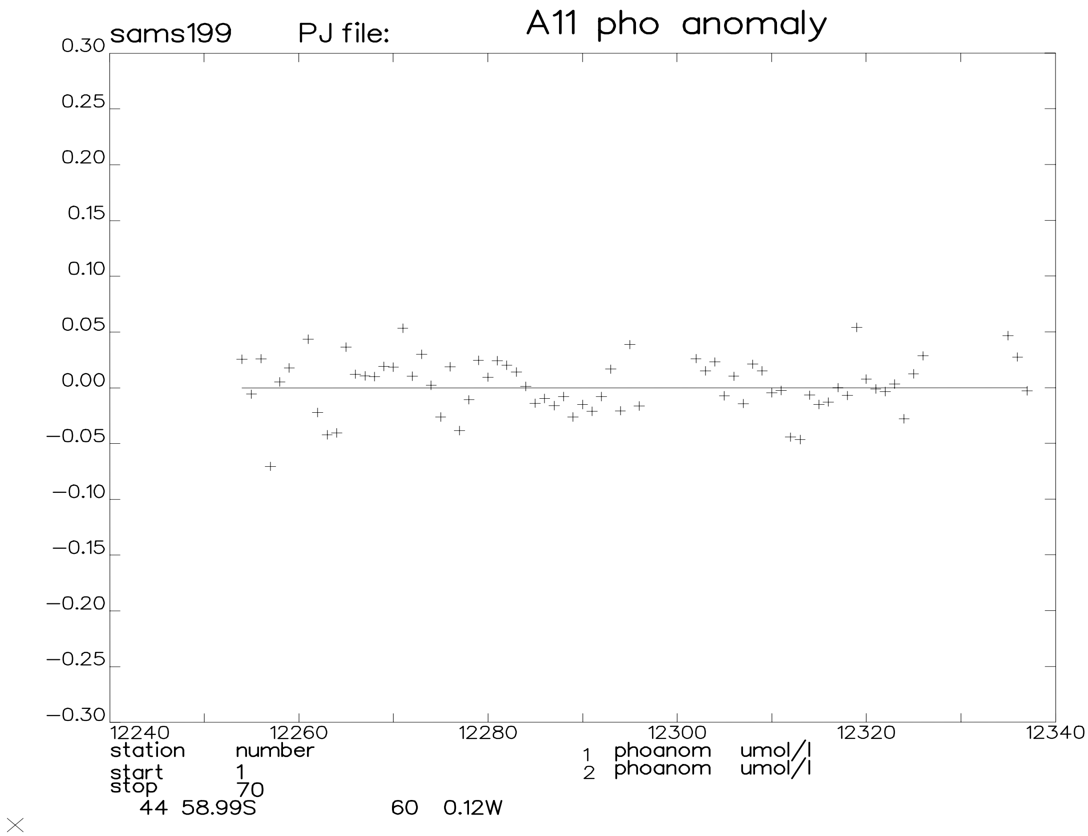
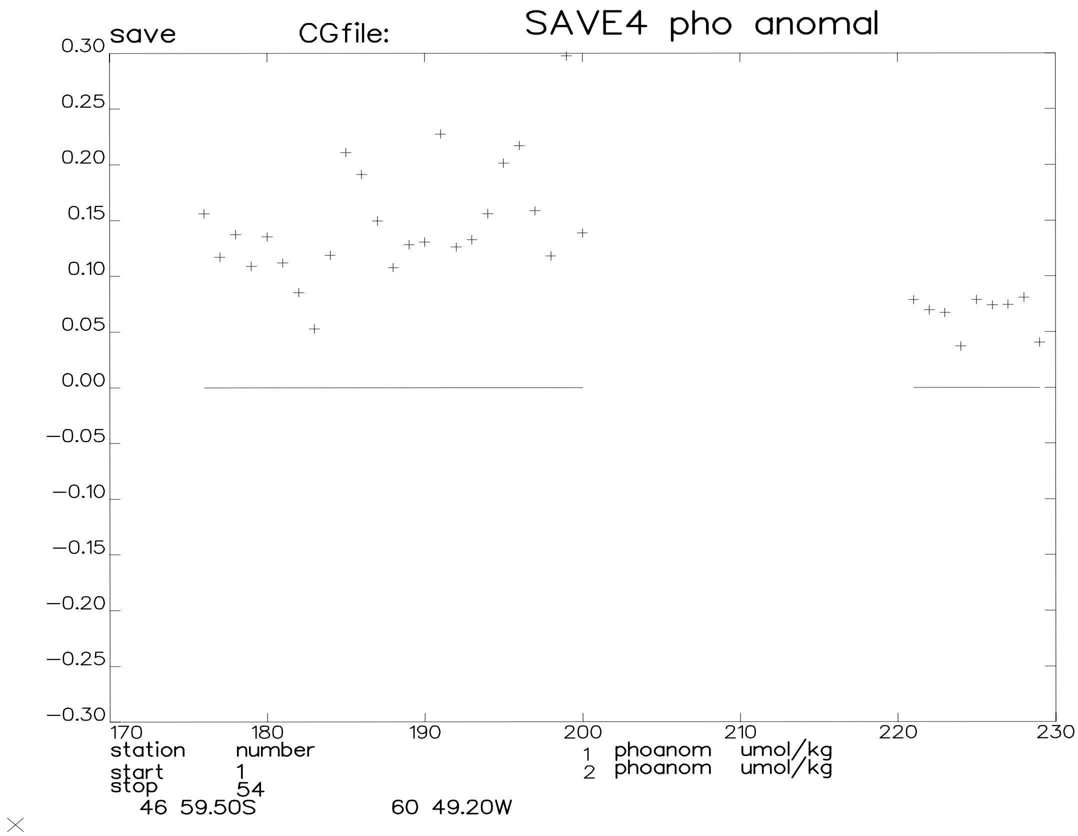


Figure 19 As Figure 18, but silicate.


sams199
PJ file:
A11 pho anomaly
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
12240
12260
12280
12300
12320
12340
station number
start 1
stop 70
1 phoanom umol/l
2 phoanom umol/l
44 58.99S
60 0.12W


SAVE4 pho anomal
save
CGfile:
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
170
180
190
200
210
220
230
station number
start 1
stop 54
46 59.50S
60 49.20W
1 phoanom umol/kg
2 phoanom umol/kg

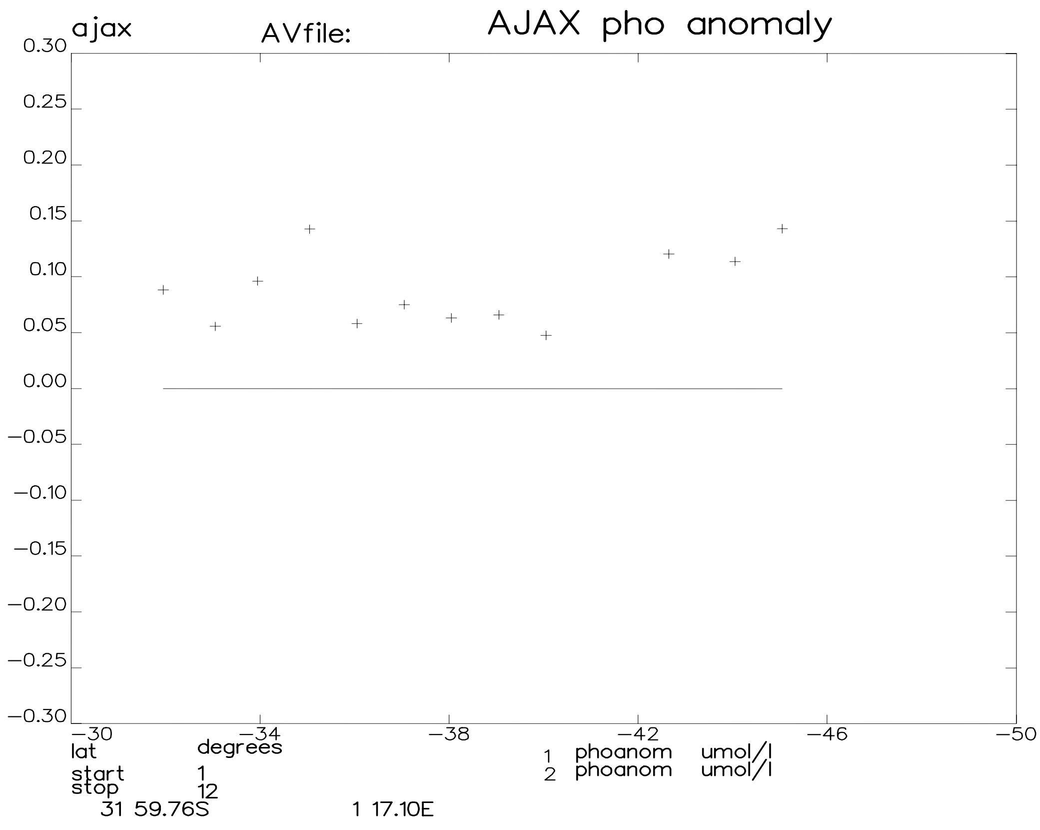


Figure 20 As Figure 18, but phosphate.

May 3, 1996

Bob Millard

Data Quality Control Report for WOCE cruise A11

The overall potential temperature versus salinity plot of figure 1a shows a range of variation of potential temperature from slightly less than zero to 22 C while the salinity varies from 33.75 to 35.65 psu. Figure 1b expands scales for lower layer and shows the two deep water masses, the colder and fresher Argentine Basin and the slightly warmer Cape Basin. A few noisy salinities are apparent in figure 1b. The oxygens values range from 155 to 330 Umol/kg, as the potential temperature versus oxygen plots of figure 2 show. Figures 1 and 2 contain all of the two decibar observations plus the water sample salinities and oxygens. To the resolution of these plots the temperature, salinity, and oxygen appear to be well behaved, except for a few noisy deep salinities.

The water sample file salinity and oxygen data for both the CTD and bottle data are examined and the DQE quality word for these four parameters set in the second quality word of file A11.RCM. The CTD oxygens in the bottle file were found on average to be 6.0 Umol/kg higher than the bottle oxygens and all CTD oxygens were flagged as questionable. I agree with most of the other salinity and oxygen quality word assessments of the PI. A summary of the modified quality words (except for CTD oxygen) is given in Appendix II. A total of 83 bottle observations had salinity or oxygen quality words adjusted. Most of these occurred in the station group 12251 to 12255 where the CTD salinity was originally flagged as questionable by the PI but I found the CTD salinity observation differed from the bottle data by less than 3 standard deviations and in some cases by less than 0.001 psu (see Ds (ctd-ws) in Appendix II).

The evaluation of the CTD data of WOCE cruise A11 examines the following two CTD data sets: individual 2 decibar down-profile data (a total of 91 station files) and the subset of the up-profile CTD observations stored in the bottle file together with the water sample oxygens and salinities. The cruise report (IOS Report # 234) covers the CTD calibration and processing methods including the the laboratory and in situ calibrations. The need to adjust the CTD salinity on a station by station to match the bottle salinities is contrary to my experience with the Neil Brown Mark III CTD. I did notice a few differences with how we correct conductivty at WHOI. At WHOI the CTD conductivity model expands the cell geometry corrections around a deep water value (2.8 and 3000 dbars) which tends to force the fit to match in the deep water independent of mismatches in the conductivity cell geometry effects (alpha=-6.5E-6 & beta = 1.5 E-8). We also allow another term in our fit, the conductivity bias. That said, both the CTD salinity and oxygen data in the bottle file (A11.HYD) and the individual 2-decibar down-profiles for WOCE cruise A11 are found to be well matched to water sample data with the exception of the CTD oxygen data in the bottle file which appears to have a systematic bias of about 6 Umol/kg.

To assess the CTD quality of the CTD data following data checks were carried out:

- Calibration checks: CTD and water sample Salinity and Oxygens

Checks involve both the individual 2 decibar profiles and the bottle file CTD subset. The calibration checks are divided into an assessments at all depths and then only the deeper levels (defined as pressures greater than 1000 decibars). The calibration checks of salinity and oxygen involved looking at the differences of the CTD minus the water sample values. Both the down and up-profile CTD salinity and oxygen data were examined against bottle values. The salinity differences presented are formed using the bottle file CTD data while the oxygen differences presented are created by interpolating the down-profile 2-decibar profiles CTD oxygens at the bottle depths.

- Check for spurious salinity and oxygen values deep:

An evaluation of the CTD salinity and oxygen noise levels with checks for spurious data values. To check for spurious salinity and oxygen observations in the 2 decibar CTD data the standard deviation (RMS) of the high-pass filtered oxygen and salinity with wavelengths between 4 and 25 decibars is summarized in the deep water depth ranges to the cast bottom. The RMS scatter value is plotted versus station for several depth intervals from the bottom to the surface. Stations with a large scatter compared to the cruise average are plotted versus pressure with suspect data values (values greater than 5 standard deviations) identified on the plots.

- Vertical stability check.

A check for density inversions provides additional information about spurious salinity and/or temperature values particularly in the near surface region where this method provides more a sensitive test than looking at the high wave number salinity variability. The vertical gradient of potential density (first difference) is calculated and checked for decreases in density with depth exceeding one of two thresholds : (-0.0075 and -0.01 kg/m3).

Salinity calibration

The bottle file salinity differences are plotted versus station number, first at all pressures (figure 3a) and then the subset below 1000 decibars with a station average value indicated by the solid line in figure 3b. The third panel, figure 3c, is a plot of salinity differences versus pressure from 500 decibars to the bottom. Figure 3c begins at 500 decibars to permit an expanded salinity range and indicates that the CTD salinity is well calibrated in the vertical. Both plots versus station (3a and 3b) show the CTD salinity (conductivity) to be well matched to the water sample salts, the only evidence of a station off-set in figure 3b is for stations 12254, 12270 and 12319. A look at the deep potential temperature- salinity for these and neighboring stations (not shown) does not reinforce these stations to be miscalibrated. A histogram of salinity differences is shown for all pressures in figures 6c and below 1000 dbars in figure 6d. The standard deviation for all salinity differences is 0.0047 psu. The standard deviation of the salinity differences below 1000 decibars is 0.0014 psu which is a very tight scatter indicative of careful water sample salinity sampling and analysis.

Oxygen calibration

Figures 4 a, b, c shows the interpolated down-profile oxygen differences versus station, overall and deep, and versus pressure. The average oxygen difference below 1000 decibars in figure 4b shows that the 2 decibar oxygens are well matched to the water sample oxygens across the entire cruise. The CTD oxygens below 1000 decibars for stations 12271-12273 and 12305-12307 may be from 1-2 Umols/kg high and are checked further. The oxygen differences versus pressure in figure 4c indicates that the CTD oxygen is overestimated from 4500 decibars to the bottom by an amount of up to 5 Umol/kg at 6000 dbars. Similar plots of the up-profile oxygen differences from the bottle file, shown in figures 5 a-b, indicate a systematic difference between the bottle file CTD and water sample oxygens with the CTD oxygens an average of about 6.0 Umol/kg greater than the water samples. As noted earlier, all CTD oxygens in the bottle file are flagged as questionable in the second quality word. A histogram of oxygen differences for all pressure levels figure 6a and below 1000 dbars in figure 6b. The standard deviation using all of the good interpolated down-profile CTD oxygen differences is 3.31 Umol/kg (using the up-profile CTD oxygens yields a standard deviation of 2.99 umol/kg). The oxygen differences below 1000 dbars are normally distributed with a standard deviation of 2.05 Umol/kg.

A series of waterfall plots consisting of down-profile CTD oxygen minus up water sample differences Dox= (OXctd_dwn - WS) Umol/kg versus station are shown encompassing the 12273-12274 (figures 7a) and 12305-12307 (figure 7b). There is no systematic depth off-set to either stations 12273-12274 or 12305-12307. On the other hand, the deepest oxygen differences (greater than 4500 dbars) of stations 12260-12265 do show the CTD oxygen to be high.

Spurious salinities and Oxygens

The standard deviation of the high-pass filtered salinity (between vertical wavelengths of 4 and 25 decibars) from 3201 decibars to the bottom is shown in figure 8a. The bottom pressure is plotted versus station number in figure 8c. The average RMS CTD salinity scatter over the cruise of 0.00033 psu becomes as low as 0.0002 psu (stations 12268-12272). The deep water salinity scatter is higher than the salinity noise level found on other cruises examined which have been observed to be as low as .00013 psu. Figure 8a indicates that stations 12292-12293 and stations 12306-12308 have elevated deep water noise levels. These stations are examined and contrasted with some better behaved profiles of salinity later.

The station averaged RMS oxygen scatter (noise level) for wavelengths between 4-25 dbars is over twice as large as the best cruises examined (~0.1 Umol/kg). This may, in part, be due to a larger oxygen current quantizing although this can't be verified. Stations

12286-12288, 12291 and 12313-12315 have abnormally large RMS oxygen scatters which carry over to the depth interval from 1199-3201 dbars shown in figure 9b. The stability of all 2 decibar CTD data is checked by looking at potential density differences that exceed one of two thresholds. A plot of the pressure levels at which these instabilities occur (table I) is shown in figure 10 with potential density differences exceeding -0.0075 kg/m3/dbar marked with an (x) and the subset of these data less than -0.01 kg/m3/dbar marked with a (*). A tabular listing of these 73 points with negative density gradients exceeding -.0075 kg/m3/dbar is given below. The data set has 33 levels exceeding -.01 kg/m3/dbar. For the most part, instabilities are in the shallow depths regions less than 500 decibars where the largest temperature and salinity gradients occur.

Some comments on individual or groups of stations

1: The salinities of stations 12291-12294 are overplotted and 12292-12294 show an elevated deep water noise level as figure 11 indicates when contrasted with figure 13. In addition there are spurious questionable salinity observations (x's) in stations 12292, 12293, & 12294. None appear to flagged in the quality word of the 2-dbars data files (see the quality word for the salt spikes of station 12292 at 3971-3973 dbars or sta. 12294 at 3461 dbars, all marked good).

2: The salinities of stations 12306-12308 are overplotted and show an elevated deep water noise level as figure 12 indicates when contrasted with figure 13. In addition there are spurious bad observations (x's) in stations 12306 & 12308. None appear to flagged in the quality word of the 2-dbars data files (see the quality word for station 12306 at 3493 dbars, marked good).

3: The salinities of stations 12269-12272 are overplotted in figure 13 as a control for deep water salinity variations for this data set.

4: The oxygens of stations 12286-12287 are overplotted and show an elevated deep water noise level as figure 14 indicates when contrasted with figure 18. There are bursts of noisy oxygens particularly for stations 12286 & 12287. Stations 12285 seems free of excessive noise and 12288 also show fewer problems pressure levels.

5: The oxygens of stations 12288-12291 are overplotted and show an elevated deep water noise level as figure 15 indicates when contrasted again with figure 18. There are bursts of noisy oxygens in station 12291 while variations of 12290 seems reasonable.

6: The oxygens of stations 12311-12315 are overplotted and all show bursts of noisy oxygens as figure 16 indicates when contrasted with figure 18.

7: The oxygens of station 12317 are overplotted with stations 12316-12319 and shows spikes of noisy oxygens as figure 17 indicates.

8: The oxygens of stations 12269-12272 are overplotted in figure 18 as a control for deep water oxygens variations for this data set.

Table I

dsg/dp > -.0075 kg/m3/dbar

dsg/dp	station #	Prs dbars	salinity
-1.6825525e-002	1.2252000e+004	1.5650000e+003	3.4766700e+001
-1.4934576e-002	1.2252000e+004	1.5670000e+003	3.4716000e+001
-7.5215734e-003	1.2252000e+004	1.5710000e+003	3.4707500e+001
-8.9730034e-003	1.2254000e+004	1.9090000e+003	3.4810300e+001
-7.5567868e-003	1.2255000e+004	2.3450000e+003	3.4783100e+001
-9.8730225e-003	1.2256000e+004	2.5610000e+003	3.4772600e+001
-1.5949690e-002	1.2258000e+004	9.3000000e+001	3.4857600e+001
-1.2130733e-002	1.2258000e+004	1.3300000e+002	3.4938300e+001
-1.2609297e-002	1.2258000e+004	1.3900000e+002	3.4924600e+001
-8.8043772e-003	1.2258000e+004	1.8690000e+003	3.4663300e+001
-1.0486886e-002	1.2258000e+004	1.8790000e+003	3.4645100e+001
-2.4276438e-002	1.2259000e+004	1.1500000e+002	3.5164100e+001
-1.7380894e-002	1.2259000e+004	1.2300000e+002	3.5334300e+001
-8.4313404e-003	1.2259000e+004	1.6700000e+002	3.5076100e+001
-8.7635833e-003	1.2259000e+004	2.3300000e+002	3.4497100e+001
-9.4563893e-003	1.2259000e+004	2.3700000e+002	3.4442500e+001
-9.9873559e-003	1.2261000e+004	2.2900000e+002	3.4284300e+001
-1.9777770e-002	1.2261000e+004	2.3300000e+002	3.4254300e+001
-2.1413379e-002	1.2262000e+004	4.9000000e+001	3.4114500e+001
-2.8243981e-002	1.2262000e+004	5.3000000e+001	3.4137700e+001
-7.6608833e-003	1.2262000e+004	6.5000000e+001	3.4126100e+001
-9.4308111e-003	1.2262000e+004	7.3000000e+001	3.4149800e+001
-9.2692607e-003	1.2262000e+004	9.0900000e+002	3.4415100e+001
-9.2732815e-003	1.2262000e+004	9.1100000e+002	3.4395200e+001
-7.7542689e-003	1.2262000e+004	2.0010000e+003	3.4761900e+001
-1.6234888e-002	1.2262000e+004	2.0770000e+003	3.4758700e+001
-8.1060643e-003	1.2265000e+004	5.1000000e+001	3.4784700e+001
-9.6157972e-003	1.2272000e+004	2.2900000e+002	3.4240200e+001
-1.0727370e-002	1.2275000e+004	8.8300000e+002	3.4440400e+001
-2.4690527e-002	1.2277000e+004	8.7000000e+001	3.4541400e+001
-8.7019074e-003	1.2277000e+004	1.4500000e+002	3.4654500e+001
-8.1801374e-003	1.2278000e+004	4.9000000e+001	3.4259100e+001
-2.1828669e-002	1.2278000e+004	1.3090000e+003	3.4552400e+001
-1.1476531e-002	1.2279000e+004	8.5000000e+001	3.4497700e+001
-1.7991091e-002	1.2280000e+004	9.7000000e+001	3.3998300e+001
-8.9597959e-003	1.2282000e+004	1.8630000e+003	3.4758100e+001
-2.1340326e-002	1.2286000e+004	7.1000000e+001	3.4276500e+001

dsg/dp	station #	Prs dbars	salinity
-1.0336119e-002	1.2286000e+004	1.3700000e+002	3.4369500e+001
-9.2833570e-003	1.2286000e+004	1.6300000e+002	3.4295200e+001
-1.7413396e-002	1.2292000e+004	6.3500000e+002	3.4177000e+001
-2.6613984e-002	1.2294000e+004	1.8500000e+002	3.4405500e+001
-8.3040160e-003	1.2294000e+004	1.9100000e+002	3.4450400e+001
-8.4622237e-003	1.2294000e+004	3.8300000e+002	3.4178600e+001
-8.5588970e-003	1.2296000e+004	2.1100000e+002	3.4354600e+001
-3.2241057e-002	1.2298000e+004	1.0900000e+002	3.4019300e+001
-2.7949113e-002	1.2298000e+004	1.1300000e+002	3.4033200e+001
-9.3840991e-003	1.2298000e+004	1.4500000e+002	3.4153700e+001
-1.8078311e-002	1.2302000e+004	9.9700000e+002	3.4266500e+001
-8.5959918e-003	1.2305000e+004	4.5300000e+002	3.4358800e+001
-9.0837387e-003	1.2307000e+004	1.1230000e+003	3.4290100e+001
-1.5554406e-002	1.2308000e+004	8.5000000e+001	3.4682400e+001
-8.0072034e-003	1.2308000e+004	3.2900000e+002	3.4603000e+001
-9.0148257e-003	1.2310000e+004	2.8900000e+002	3.4445000e+001
-7.5515126e-003	1.2311000e+004	4.9500000e+002	3.4301700e+001
-1.4240604e-002	1.2312000e+004	8.9000000e+001	3.4771000e+001
-9.2638822e-003	1.2312000e+004	1.2900000e+002	3.4742700e+001
-8.9953691e-003	1.2312000e+004	2.8500000e+002	3.4653900e+001
-9.2608014e-003	1.2312000e+004	3.5100000e+002	3.4539100e+001
-7.8618847e-003	1.2314000e+004	4.4500000e+002	3.4546500e+001
-9.7132557e-003	1.2315000e+004	1.0300000e+002	3.4959000e+001
-9.2969453e-003	1.2316000e+004	6.9000000e+001	3.4942200e+001
-9.8689572e-003	1.2316000e+004	1.4500000e+002	3.4835500e+001
-1.2335594e-002	1.2316000e+004	2.0500000e+002	3.4847000e+001
-1.2643058e-002	1.2316000e+004	2.2900000e+002	3.4805400e+001
-9.7481726e-003	1.2316000e+004	2.8900000e+002	3.4829000e+001
-1.0933894e-002	1.2323000e+004	1.0970000e+003	3.4302100e+001
-8.3410129e-003	1.2325000e+004	3.0000000e+000	3.5632200e+001
-8.4431894e-003	1.2325000e+004	8.5000000e+001	3.5562300e+001
-2.9400095e-002	1.2325000e+004	8.3100000e+002	3.4416500e+001
-1.3439053e-002	1.2325000e+004	8.5300000e+002	3.4402400e+001
-1.6726372e-002	1.2325000e+004	8.8300000e+002	3.4316600e+001
-8.5529223e-003	1.2325000e+004	1.1050000e+003	3.4426400e+001
-1.0191833e-002	1.2326000e+004	8.5500000e+002	3.4393600e+001

Subset of above that exceed dsg/dp > -.01 kg/m3/dbar

dsg/dp	station #	Prs dbars	salinity
-1.6825525e-002	1.2252000e+004	1.5650000e+003	3.4766700e+001
-1.4934576e-002	1.2252000e+004	1.5670000e+003	3.4716000e+001
-1.5949690e-002	1.2258000e+004	9.3000000e+001	3.4857600e+001
-1.2130733e-002	1.2258000e+004	1.3300000e+002	3.4938300e+001
-1.2609297e-002	1.2258000e+004	1.3900000e+002	3.4924600e+001
-1.0486886e-002	1.2258000e+004	1.8790000e+003	3.4645100e+001
-2.4276438e-002	1.2259000e+004	1.1500000e+002	3.5164100e+001
-1.7380894e-002	1.2259000e+004	1.2300000e+002	3.5334300e+001
-1.9777770e-002	1.2261000e+004	2.3300000e+002	3.4254300e+001
-2.1413379e-002	1.2262000e+004	4.9000000e+001	3.4114500e+001
-2.8243981e-002	1.2262000e+004	5.3000000e+001	3.4137700e+001
-1.6234888e-002	1.2262000e+004	2.0770000e+003	3.4758700e+001
-1.0727370e-002	1.2275000e+004	8.8300000e+002	3.4440400e+001
-2.4690527e-002	1.2277000e+004	8.7000000e+001	3.4541400e+001
-2.1828669e-002	1.2278000e+004	1.3090000e+003	3.4552400e+001
-1.1476531e-002	1.2279000e+004	8.5000000e+001	3.4497700e+001
-1.7991091e-002	1.2280000e+004	9.7000000e+001	3.3998300e+001
-2.1340326e-002	1.2286000e+004	7.1000000e+001	3.4276500e+001
-1.0336119e-002	1.2286000e+004	1.3700000e+002	3.4369500e+001
-1.7413396e-002	1.2292000e+004	6.3500000e+002	3.4177000e+001
-2.6613984e-002	1.2294000e+004	1.8500000e+002	3.4405500e+001
-3.2241057e-002	1.2298000e+004	1.0900000e+002	3.4019300e+001
-2.7949113e-002	1.2298000e+004	1.1300000e+002	3.4033200e+001
-1.8078311e-002	1.2302000e+004	9.9700000e+002	3.4266500e+001
-1.5554406e-002	1.2308000e+004	8.5000000e+001	3.4682400e+001
-1.4240604e-002	1.2312000e+004	8.9000000e+001	3.4771000e+001
-1.2335594e-002	1.2316000e+004	2.0500000e+002	3.4847000e+001
-1.2643058e-002	1.2316000e+004	2.2900000e+002	3.4805400e+001
-1.0933894e-002	1.2323000e+004	1.0970000e+003	3.4302100e+001
-2.9400095e-002	1.2325000e+004	8.3100000e+002	3.4416500e+001
-1.3439053e-002	1.2325000e+004	8.5300000e+002	3.4402400e+001
-1.6726372e-002	1.2325000e+004	8.8300000e+002	3.4316600e+001
-1.0191833e-002	1.2326000e+004	8.5500000e+002	3.4393600e+001

Appendix II

Cruise A11 changes to Quality word of A1.hyd file

Below is a list of the bottles that have had a CTD or water sample salinity or oxygen flag changed. Only the first 5 field of the quality flags Qual1 and Qual2 (DQE) are given as these were the only ones modified. Note that all CTD oxygens have been flagged as questionable "3" as the CTD oxygens in the bottle file are systematically higher than the water samples by an average of 6.0 Umol/kg across the cruise. On the other hand, the CTD oxygens in the individual 2 decibar CTD files do not show a systematic error with water sample oxygens. Stations 12251 through 12255 CTD salts flagged questionable but the magnitude of the CTD water sample salinity difference (Ds) for the most part are small (less than 3 standard deviations) and don't substantiate flagging as questionable. The first two observations of 12251 below have ctd salt flagged missing when CTD O2 is the missing parameter. Sta. 12254 CTD up profile bottle data is systematically fresh except in deep water. Station 12325 CTD salts are flagged "3" in the upper 1200 dbars when bottle differences are consistent with vertical structure.

St. No.	Prs.	S_ws	Ox_ws	Ds(ctd-ws)	Dox(ctd-ws)	Qual1	Qual2
12251	3.0	-9.0000	271.9000	43.0880	-280.9000	29299	23999 ctd o2=9
12251	87.0	-9.0000	300.0000	43.1260	-309.0000	29299	23999 ctd o2=9
12251	504.6	34.2346	235.5000	0.0000	6.9000	23222	22322
12251	762.4	34.4159	186.8000	-0.0014	3.6000	23222	22322
12251	1011.6	34.5563	170.3000	-0.0006	4.7000	23222	22322
12251	1267.8	34.6339	167.3000	0.0008	5.5000	23222	22322
12251	1525.2	34.7052	175.1000	0.0005	5.4000	23222	22322
12251	1730.2	34.7571	189.6000	0.0017	4.8000	23222	22322
12251	1890.2	34.7321	182.4000	0.0025	4.7000	23222	22322
12252	10.0	34.0907	280.9000	-0.0005	4.8000	23222	22322
12252	55.6	34.1215	299.6000	0.0005	16.2000	23222	22322
12252	105.1	34.1246	300.8000	0.0037	3.8000	23222	22322
12252	154.9	34.1360	280.2000	-0.0011	10.4000	23222	22322
12252	204.3	34.1391	278.2000	0.0002	2.3000	23222	22322
12252	253.9	34.1503	268.7000	-0.0040	5.2000	23222	22322
12252	353.8	34.1483	266.4000	0.0000	4.8000	23222	22322
12252	498.9	34.2350	235.9000	0.0026	10.8000	23222	22322
12252	757.6	34.4173	193.3000	0.0008	6.4000	23222	22322
12252	1017.6	34.5653	172.0000	-0.0008	6.4000	23222	22322
12252	1267.2	34.6370	169.7000	-0.0010	3.7000	23222	22322
12252	1512.9	34.6965	175.3000	-0.0029	6.2000	23222	22322
12252	1768.4	34.7526	190.2000	0.0022	2.3000	23222	22322
12252	2029.3	34.7628	192.7000	-0.0011	2.3000	23222	22322
12252	2291.5	34.7455	192.2000	-0.0003	5.6000	23222	22322
12252	2547.6	34.7459	191.9000	0.0008	5.6000	23222	22322
12252	2611.8	34.7465	192.6000	0.0007	5.8000	23222	22322
12252	2611.8	34.7471	191.5000	0.0001	6.9000	23222	22322
12253	15.6	34.0895	285.6000	-0.0021	4.9000	23223	22323

St. No.	Prs.	S_ws	Ox_ws	Ds(ctd-ws)	Dox(ctd-ws)	Qual1	Qual2
12253	105.2	34.1221	304.1000	-0.0008	5.5000	23223	22323
12253	155.6	34.1350	289.0000	-0.0006	6.7000	23223	22323
12253	206.9	34.1370	264.2000	-0.0029	20.3000	23223	22323
12253	257.2	34.1348	333.4000	0.0021	-53.5000	23234	22324
12253	356.3	34.1452	272.1000	-0.0024	-0.3000	23223	22323
12253	504.8	34.2330	223.6000	0.0037	12.7000	23243	22323
12253	760.8	34.4286	192.7000	0.0005	-9.0000	23223	22323
12253	1015.5	34.5679	158.2000	-0.0004	7.1000	23223	22323
12253	1271.5	34.6502	163.4000	-0.0005	4.0000	23223	22323
12253	1526.6	34.7203	180.3000	-0.0007	0.6000	23223	22323
12253	2035.9	34.7355	176.3000	0.0006	14.1000	23223	22323
12253	2289.4	34.7384	186.9000	-0.0038	9.7000	23223	22323
12253	2543.9	34.7398	199.9000	-0.0019	4.7000	23223	22323
12253	3052.8	34.7260	197.1000	0.0005	9.3000	23223	22323
12253	3136.0	34.7258	199.2000	0.0041	2.8000	23223	22323
12253	3136.0	34.7272	199.3000	0.0027	2.7000	23223	22323
12254	3453.7	34.7089	202.7000	0.0009	4.2000	23223	22323
12254	3453.7	34.7085	197.3000	0.0013	9.6000	23223	22323
12255	9.8	34.0770	292.2000	0.0000	7.1000	23223	22323
12255	55.8	34.1199	307.0000	0.0022	15.5000	23223	22323
12255	106.2	34.1391	296.7000	-0.0013	-1.6000	23223	22323
12255	155.7	34.1456	294.7000	-0.0017	8.0000	23223	22323
12255	206.0	34.1432	287.9000	0.0002	6.0000	23223	22323
12255	256.4	34.1470	282.4000	-0.0005	9.5000	23223	22323
12255	355.7	34.1489	274.6000	0.0022	9.0000	23223	22323
12255	507.4	34.2501	238.0000	0.0025	4.8000	23223	22323
12255	763.8	34.3957	194.0000	-0.0009	10.2000	23223	22323
12255	1018.5	34.5243	178.0000	-0.0009	4.8000	23223	22323
12255	1273.3	34.6743	183.9000	-0.0010	3.6000	23223	22323
12255	1527.2	34.7510	194.8000	-0.0008	3.6000	23223	22323
12255	1781.0	34.7748	199.2000	-0.0014	10.4000	23223	22323
12255	2037.6	34.8212	214.6000	-0.0036	0.7000	23223	22323
12255	2548.5	34.7583	198.6000	-0.0028	5.0000	23223	22323
12255	3058.0	34.7368	201.9000	0.0000	6.0000	23223	22323
12255	3571.4	34.7072	207.4000	0.0007	5.2000	23223	22323
12255	4047.9	34.6789	217.7000	0.0006	7.3000	23223	22323
12263	1525.8	34.6011	177.0000	-0.0021	7.5000	22232	22322
12263	5590.2	34.6696	220.0000	0.0006	8.0000	22232	22322
12263	5889.8	34.6690	218.3000	0.0001	10.2000	22232	22322
12268	510.0	34.1905	261.1000	0.0011	6.1000	22232	22322
12271	1271.1	34.5404	179.7000	-0.0012	6.3000	22232	22322
12271	2029.7	34.7901	203.0000	-0.0015	6.2000	22232	22322
12288	357.7	34.1860	266.1000	0.0011	9.1000	22232	22322
12288	2281.4	34.7811	199.2000	-0.0019	6.4000	22232	22322
12318	358.1	34.7762	221.8000	0.0078	3.6000	22232	22322
12325	8.2	35.6719	221.1000	-0.0007	6.4000	23222	22322
12325	53.5	35.5839	221.2000	-0.0054	12.8000	23222	22322

St. No.	Prs.	S_ws	Ox_ws	Ds(ctd-ws)	Dox(ctd-ws)	Qual1	Qual2
12325	103.7	35.5527	200.1000	0.0009	0.5000	23222	22322
12325	154.0	35.5267	199.8000	0.0081	0.8000	23222	22322
12325	203.7	35.4352	197.0000	0.0055	4.0000	23222	22322
12325	353.8	35.1547	215.8000	0.0063	6.8000	23222	22322
12325	753.3	34.4864	198.9000	0.0043	12.2000	23222	22322
12325	1002.8	34.3861	196.6000	-0.0056	8.1000	23222	22322
12325	1239.0	34.4520	182.8000	0.0050	6.8000	23222	22322
12334	53.9	35.5565	224.1000	-0.0059	9.3000	22232	22322

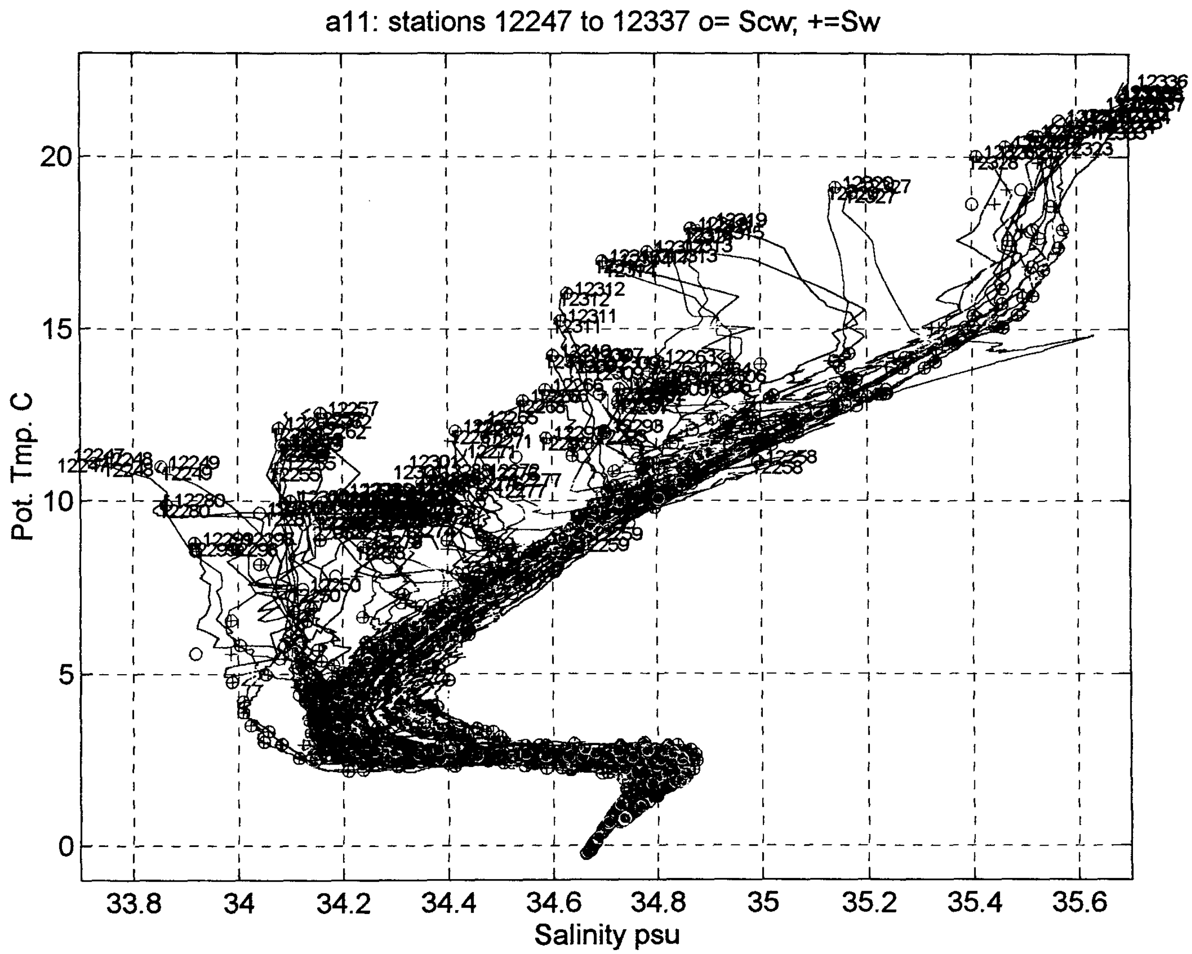
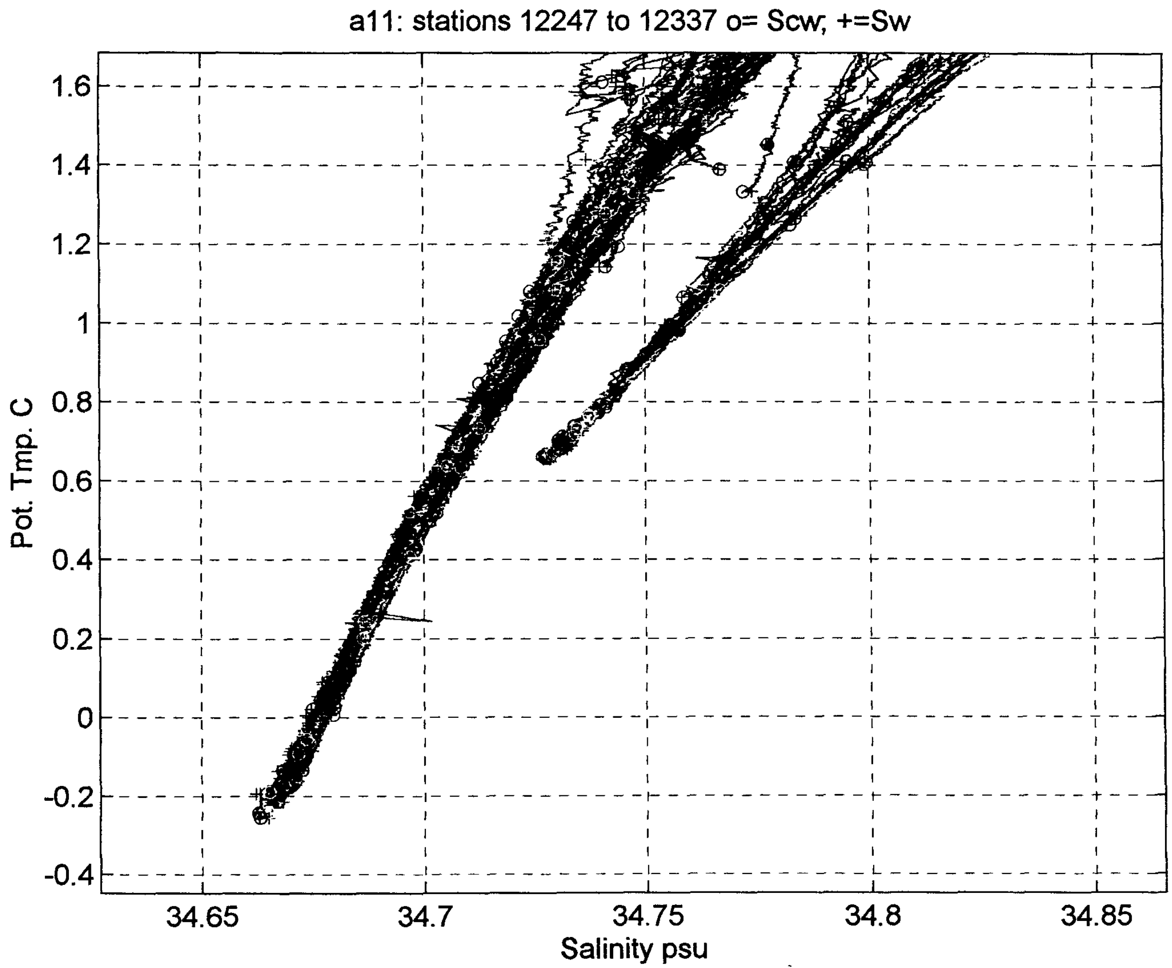

a11: stations 12247 to 12337 o= Scw; +=Sw
Pot. Tmp. C
Salinity psu
20
15
10
5
0
33.8
34
34.2
34.4
34.6
34.8
35
35.2
35.4
35.6

Figure 1a



a11: stations 12247 to 12337 o= Scw; +=Sw
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
Pot. Tmp. C
34.65
34.7
34.75
34.8
34.85
Salinity psu

Figure 1b

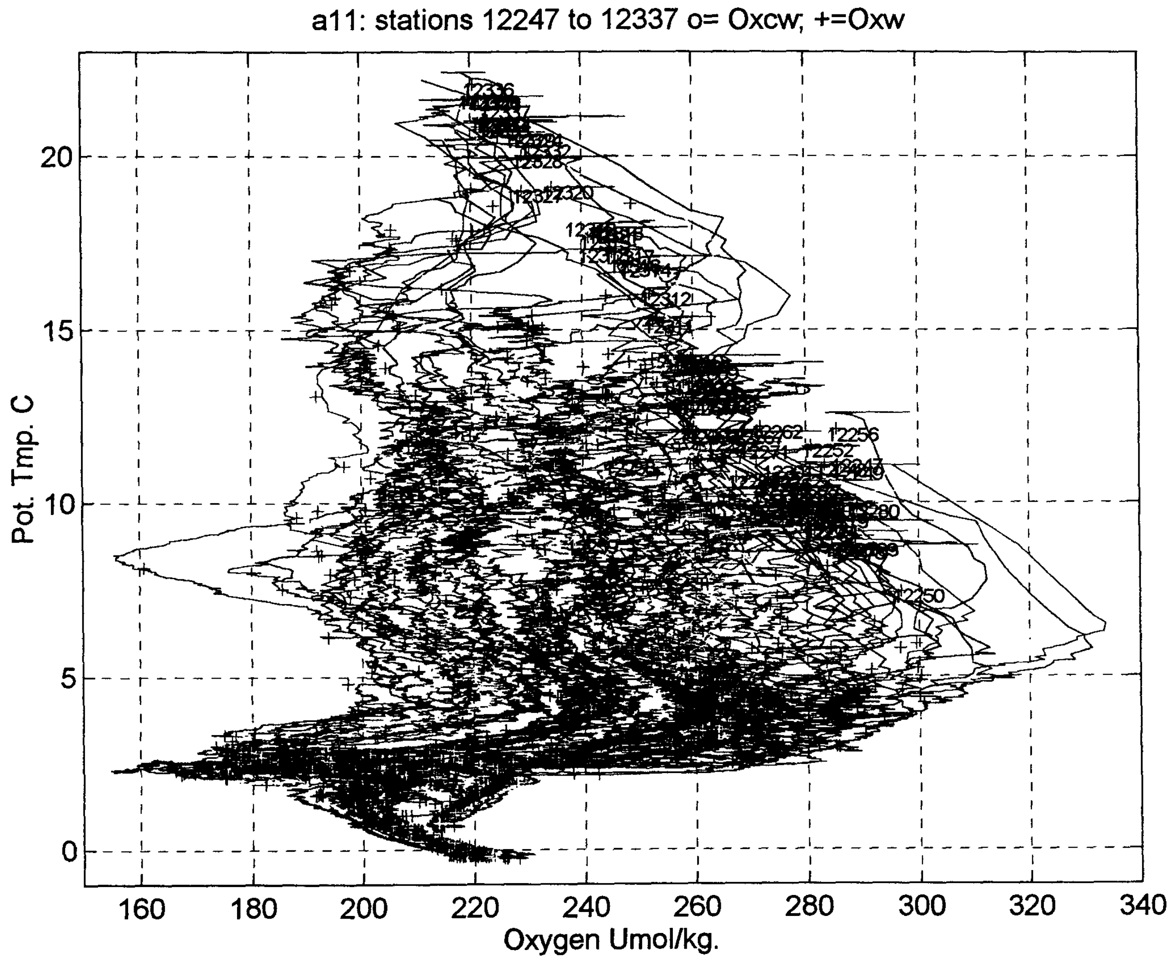
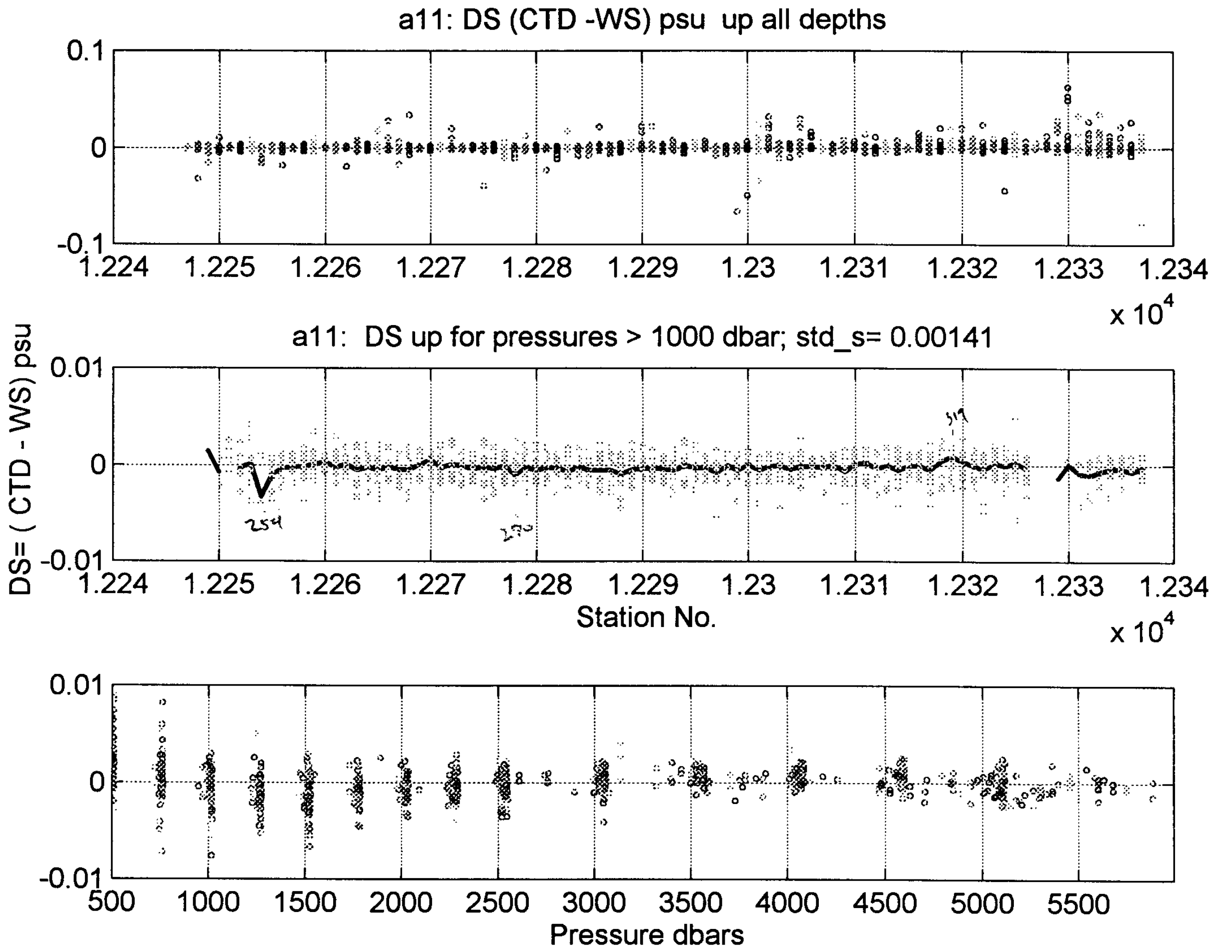
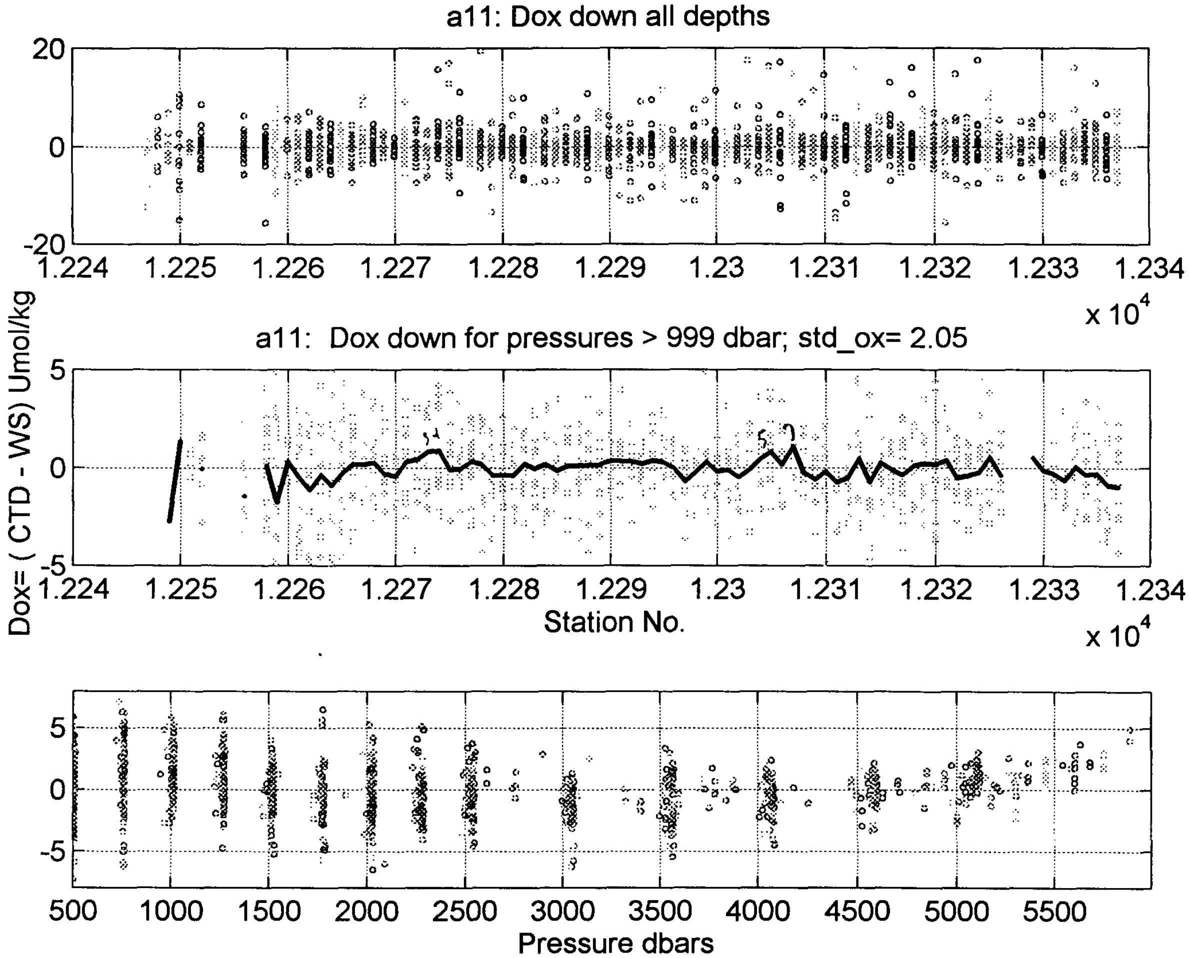

a11: stations 12247 to 12337 o= Oxcw; +=Oxw
Pot. Tmp. C
Oxygen Umol/kg.
0
5
10
15
20
160
180
200
220
240
260
280
300
320
340

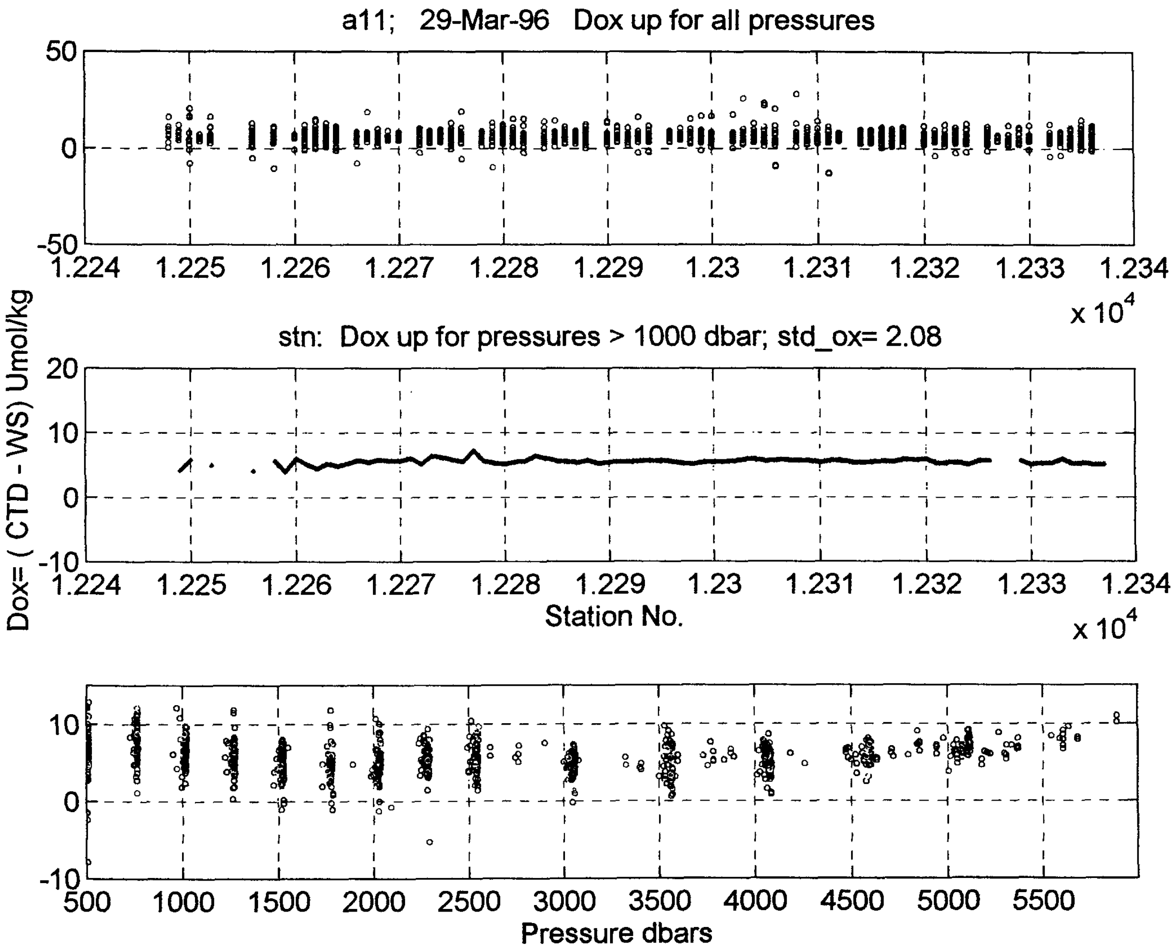
Figure 2



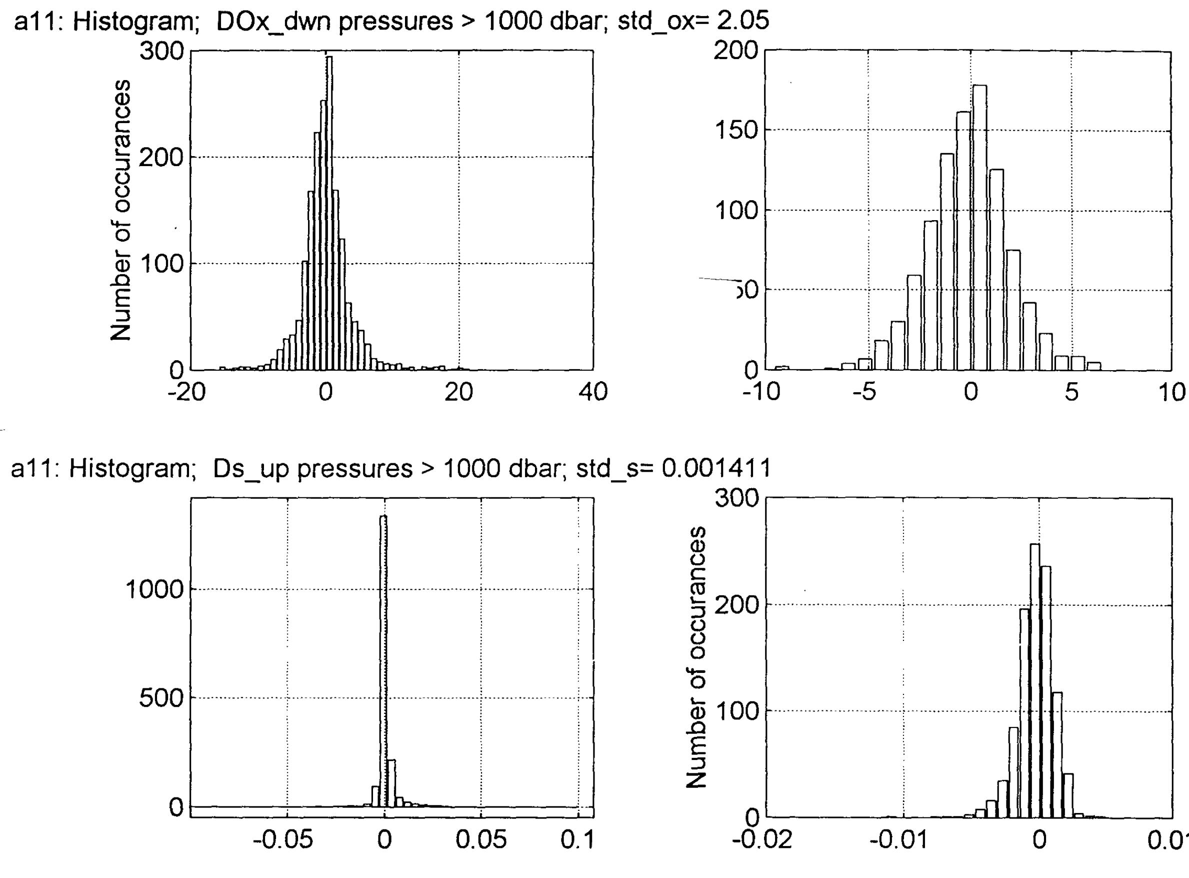
Figures 3a, 3b and 3c



Figures 4a, 4b and 4c



Figures 5a, 5b and 5c



Figures 6a, 6b (top), 6c and 6d (bottom)

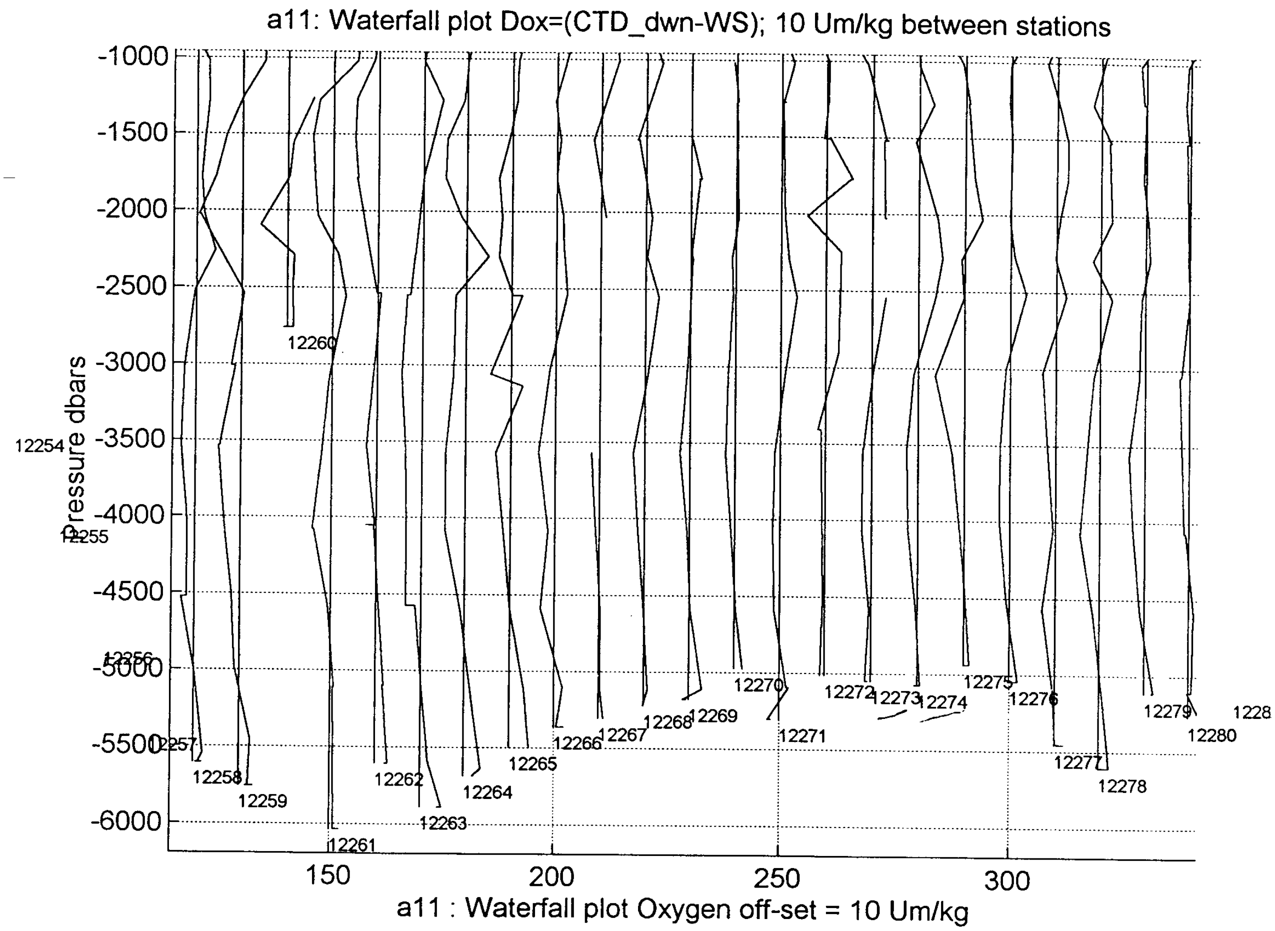
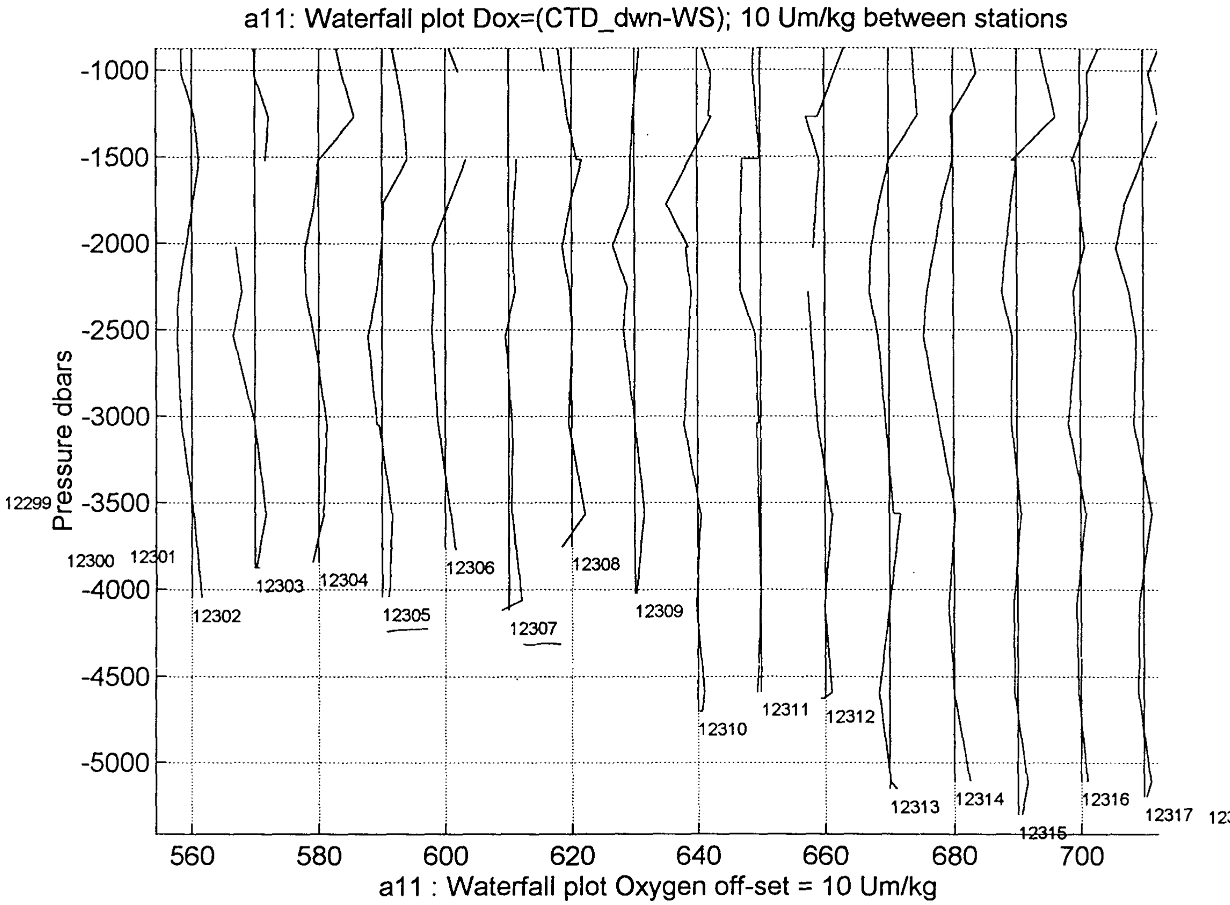
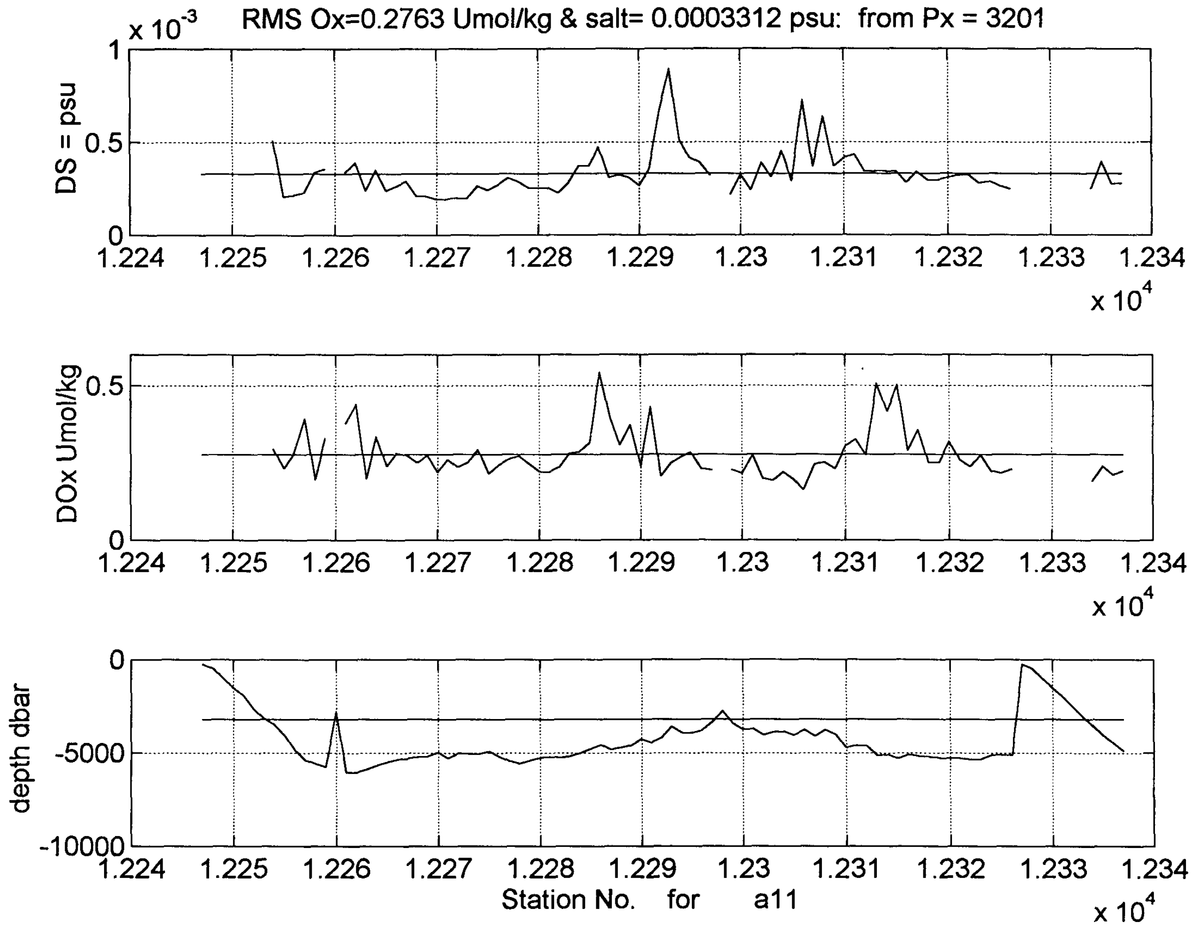

a11: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
150
200
250
300
a11 : Waterfall plot Oxygen off-set = 10 Um/kg
12254
12255
12256
12257
12258
12259
12260
12261
12262
12263
12264
12265
12266
12267
12268
12269
12270
12271
12272
12273
12274
12275
12276
12277
12278
12279
12280
1228

Figure 7a

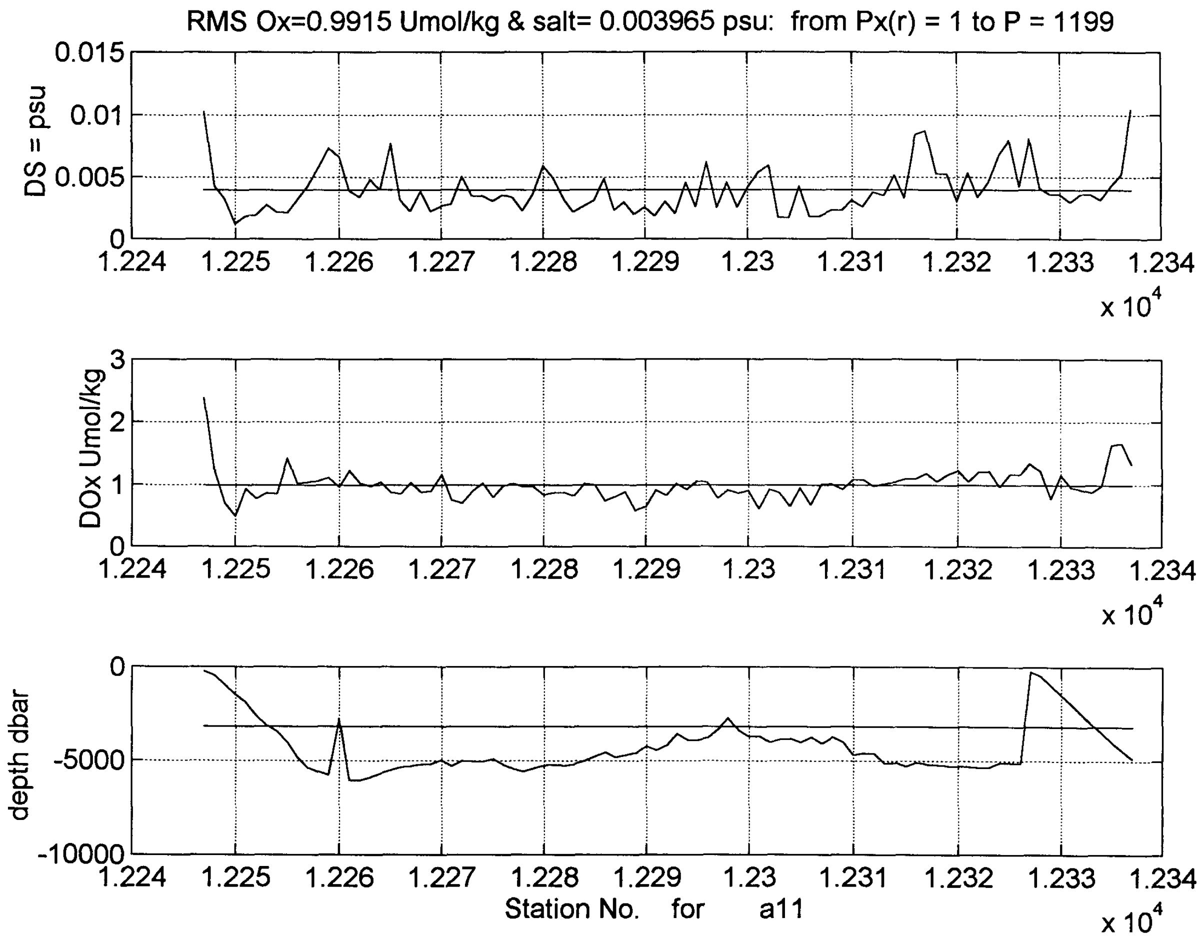


a11: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
12299
12300
12301
12302
12303
12304
12305
12306
12307
12308
12309
12310
12311
12312
12313
12314
12315
12316
12317
123
560
580
600
620
640
660
680
700
a11 : Waterfall plot Oxygen off-set = 10 Um/kg

Figure 7b



Figures 8a, 8b and 8c



Figures 9a, 9b and 9c

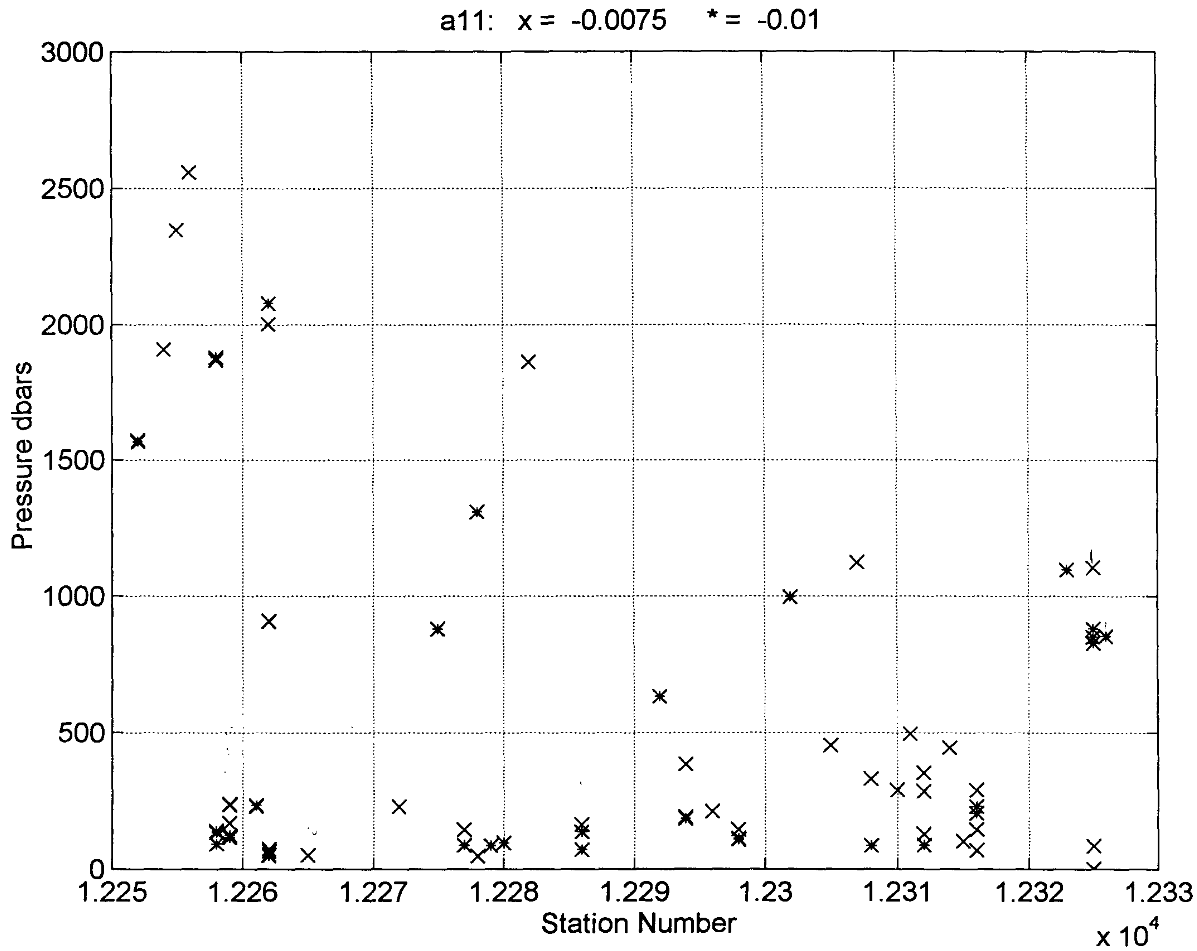
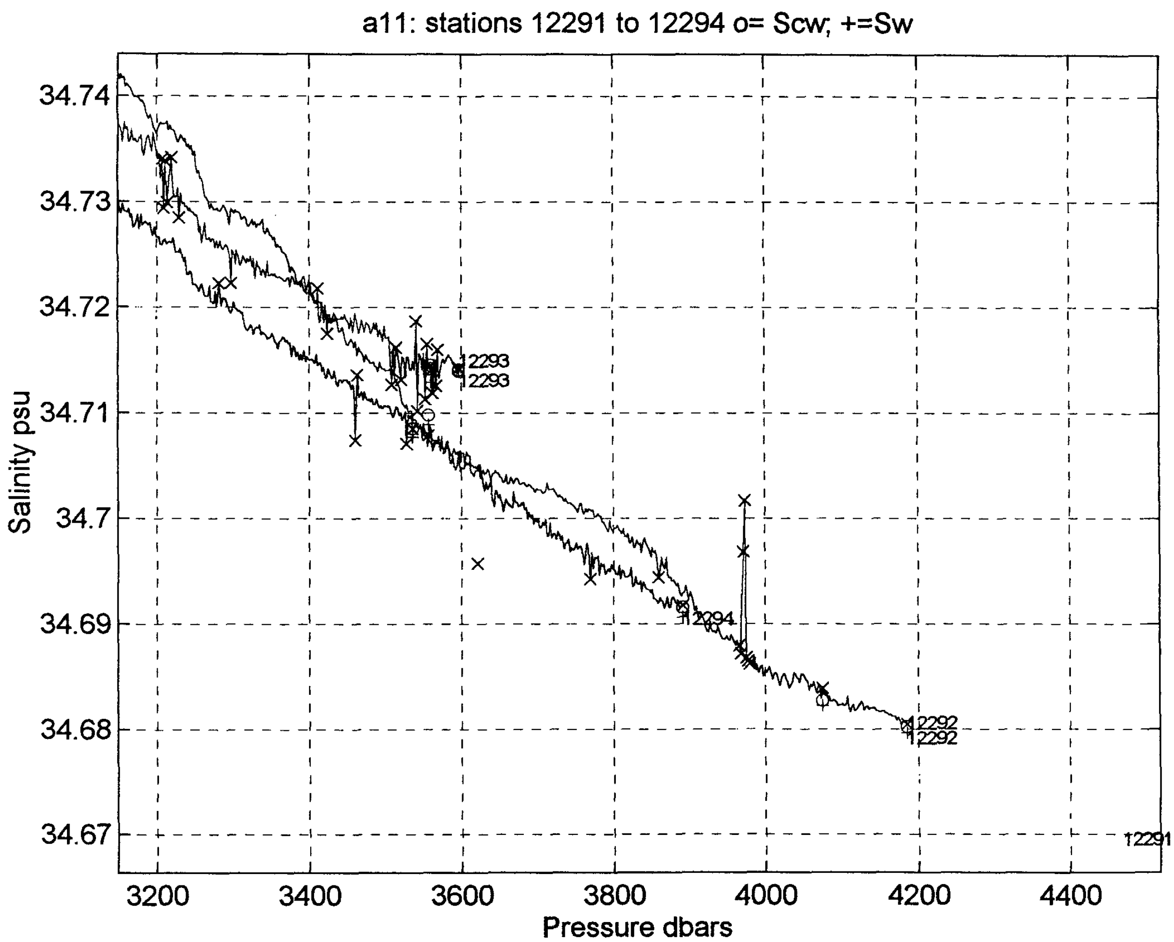

a11: x = -0.0075 * = -0.01
3000
2500
2000
1500
1000
500
0
Pressure dbars
1.225
1.226
1.227
1.228
1.229
1.23
1.231
1.232
1.233
Station Number
x 10^4

Figure 10



a11: stations 12291 to 12294 o= Scw; +=Sw
34.74
34.73
34.72
34.71
34.7
34.69
34.68
34.67
Salinity psu
3200
3400
3600
3800
4000
4200
4400
Pressure dbars
12293
12293
12294
12292
12292
12291

Figure 11

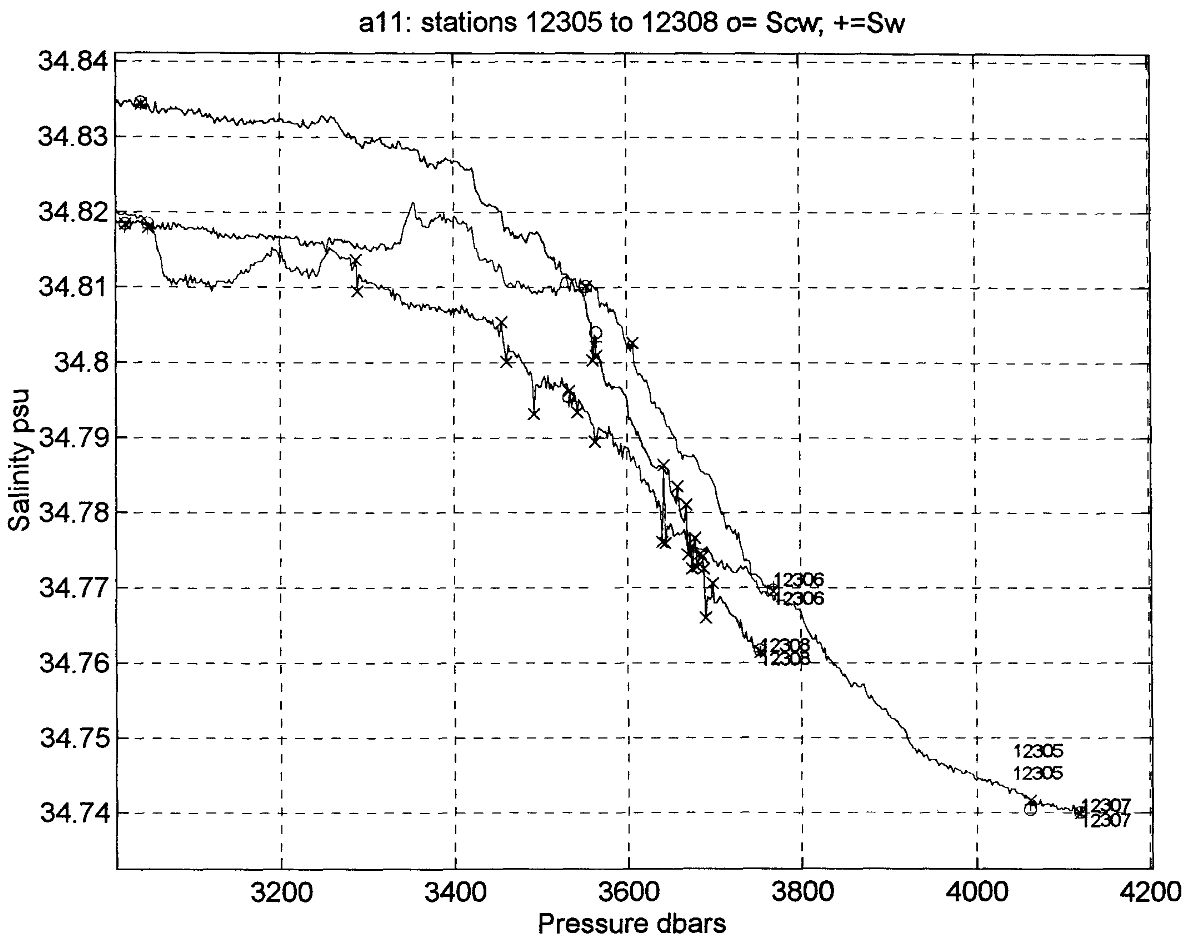

a11: stations 12305 to 12308 o= Scw; +=Sw
34.84
34.83
34.82
34.81
34.8
34.79
34.78
34.77
34.76
34.75
34.74
Salinity psu
3200
3400
3600
3800
4000
4200
Pressure dbars
12306
12306
12308
12308
12305
12305
12307
12307

Figure 12

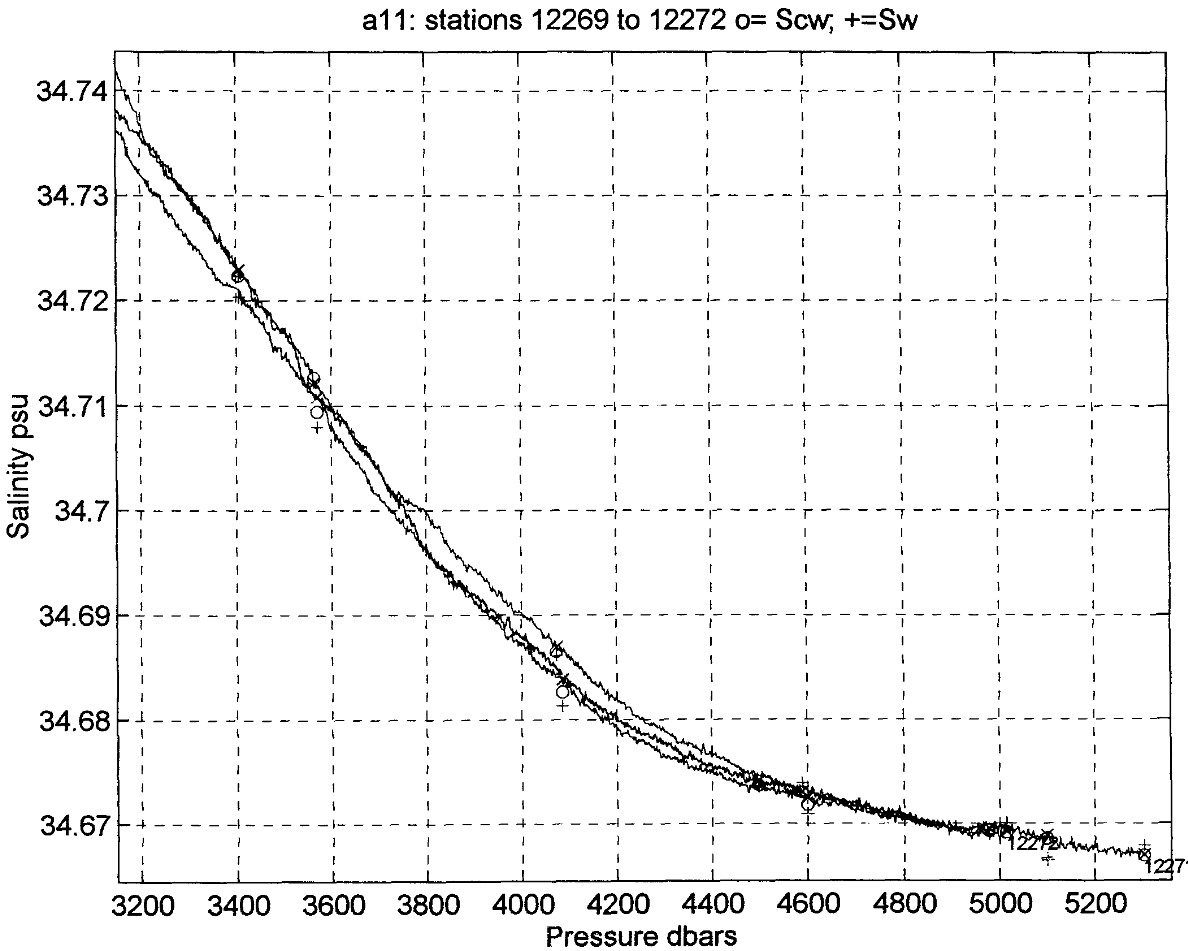
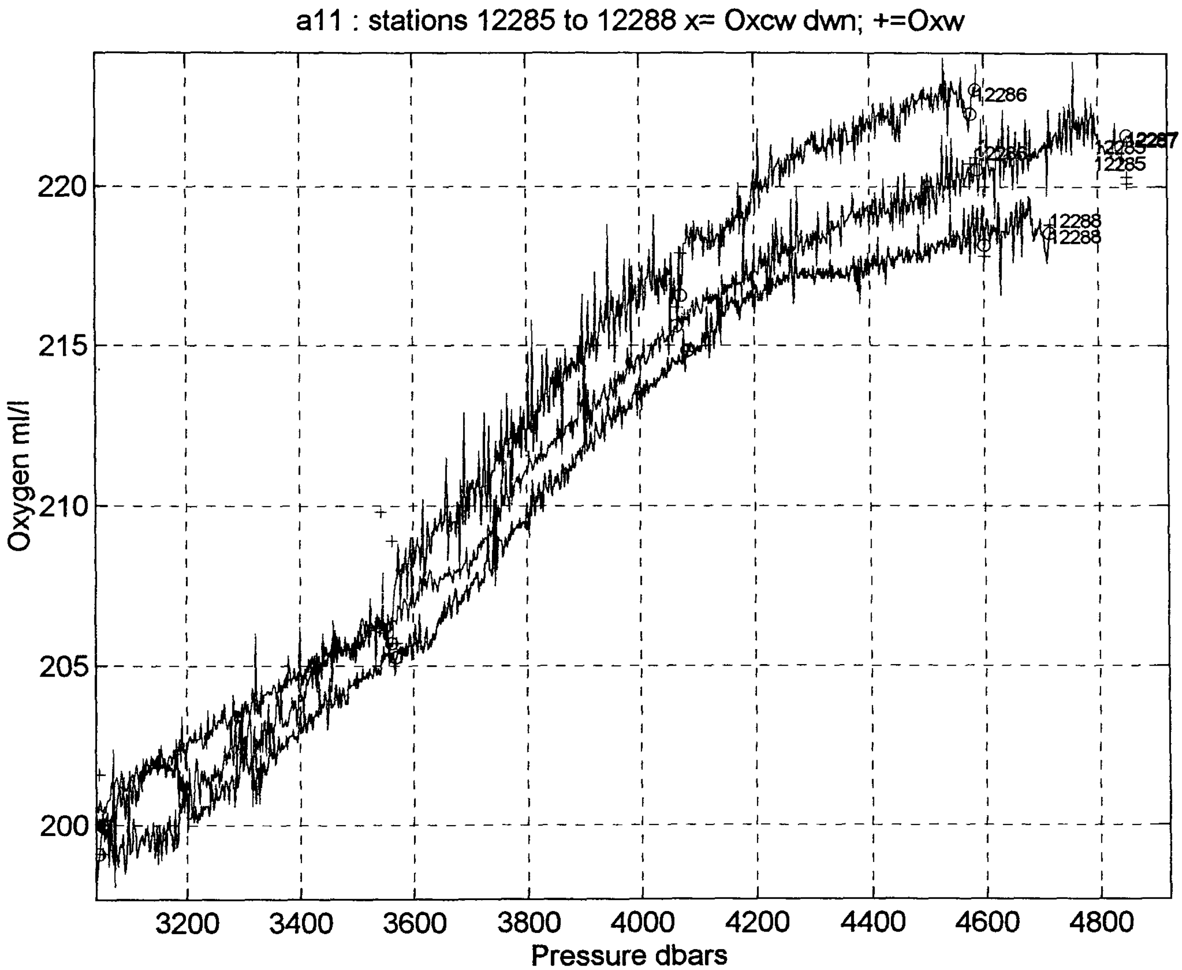
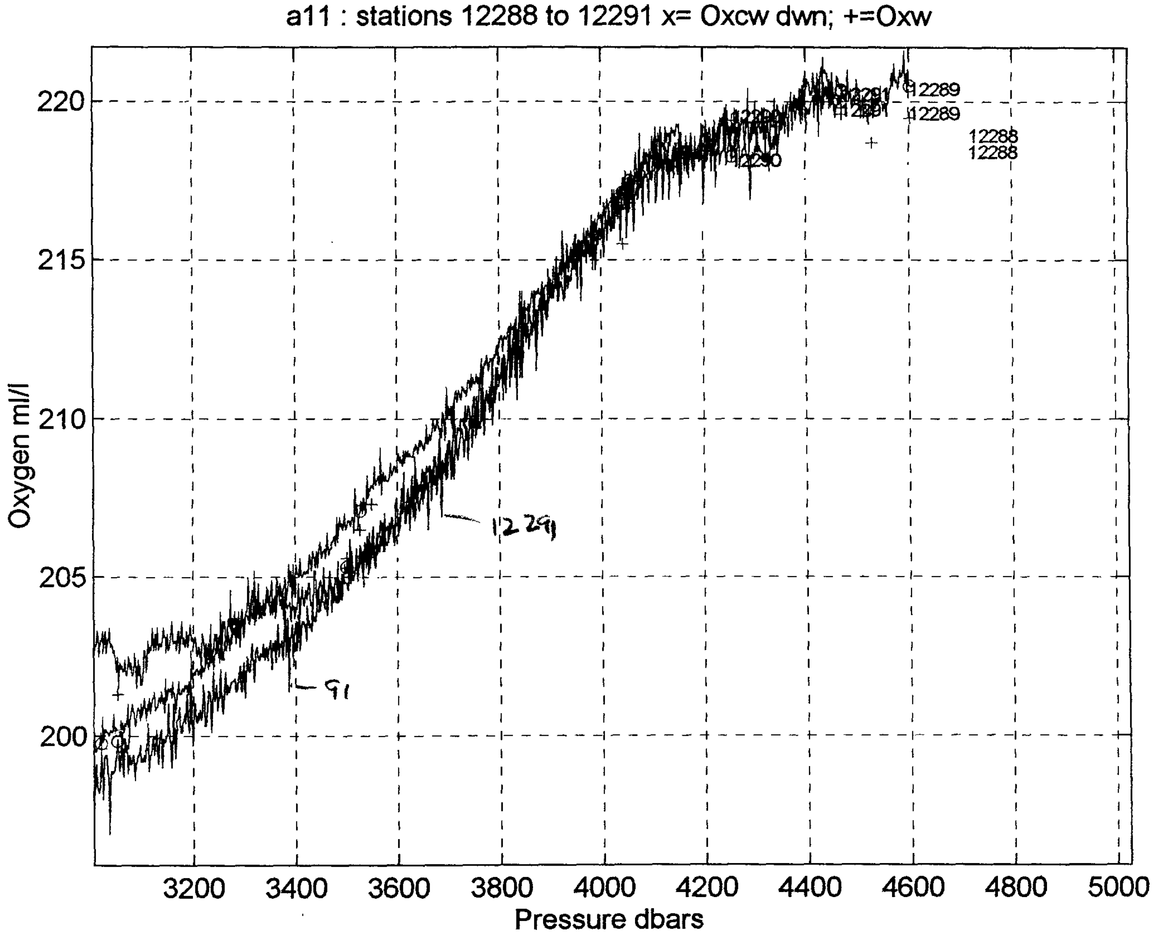

a11: stations 12269 to 12272 o= Scw; +=Sw
Salinity psu
34.74
34.73
34.72
34.71
34.7
34.69
34.68
34.67
Pressure dbars
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
12272
12271

Figure 13



a11 : stations 12285 to 12288 x= Oxcw dwn; +=Oxw
Oxygen ml/l
Pressure dbars
220
215
210
205
200
3200
3400
3600
3800
4000
4200
4400
4600
4800
12286
12286
12285
12285
12288
12288

Figure 14



a11 : stations 12288 to 12291 x= Oxcw dwn; +=Oxw
Oxygen ml/l
Pressure dbars
220
215
210
205
200
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
12289
12289
12288
12288
12290
12291

Figure 15

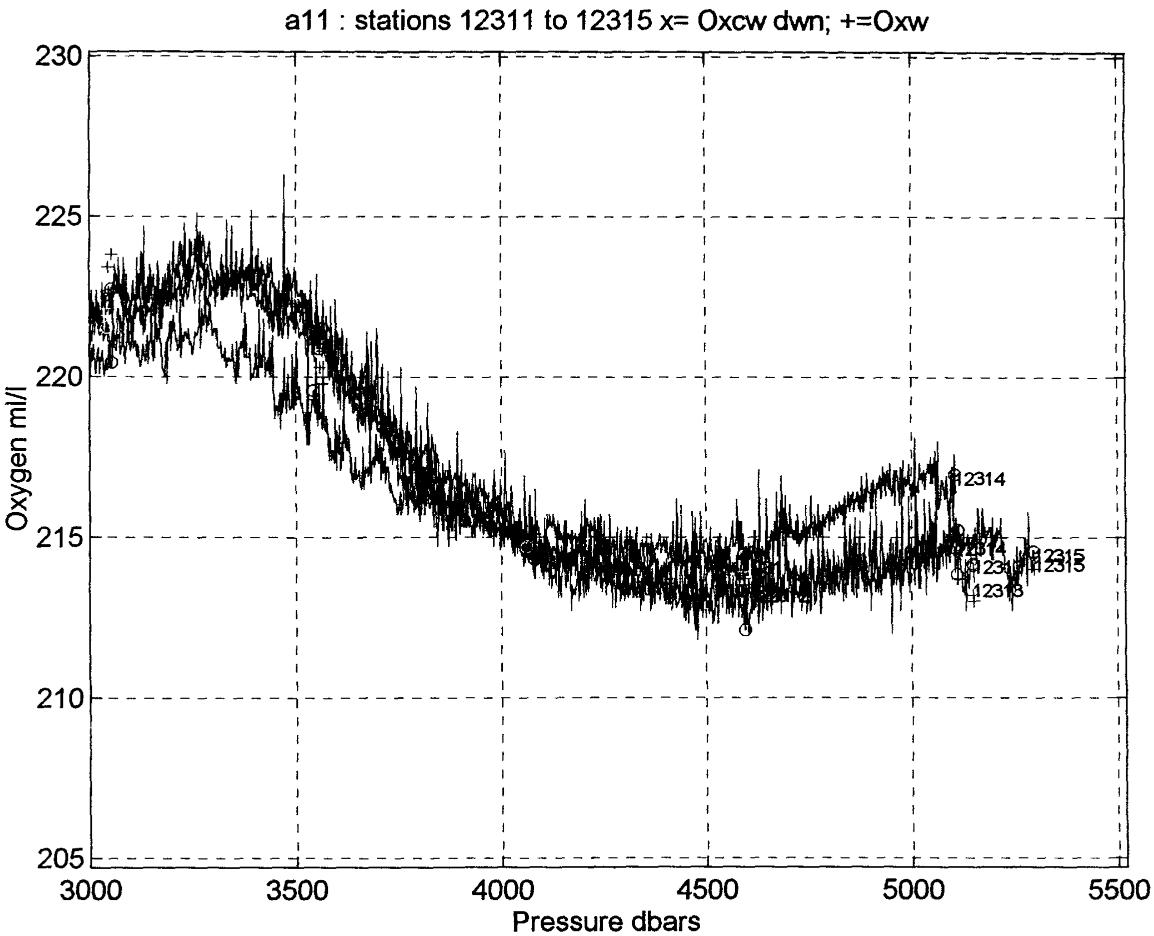
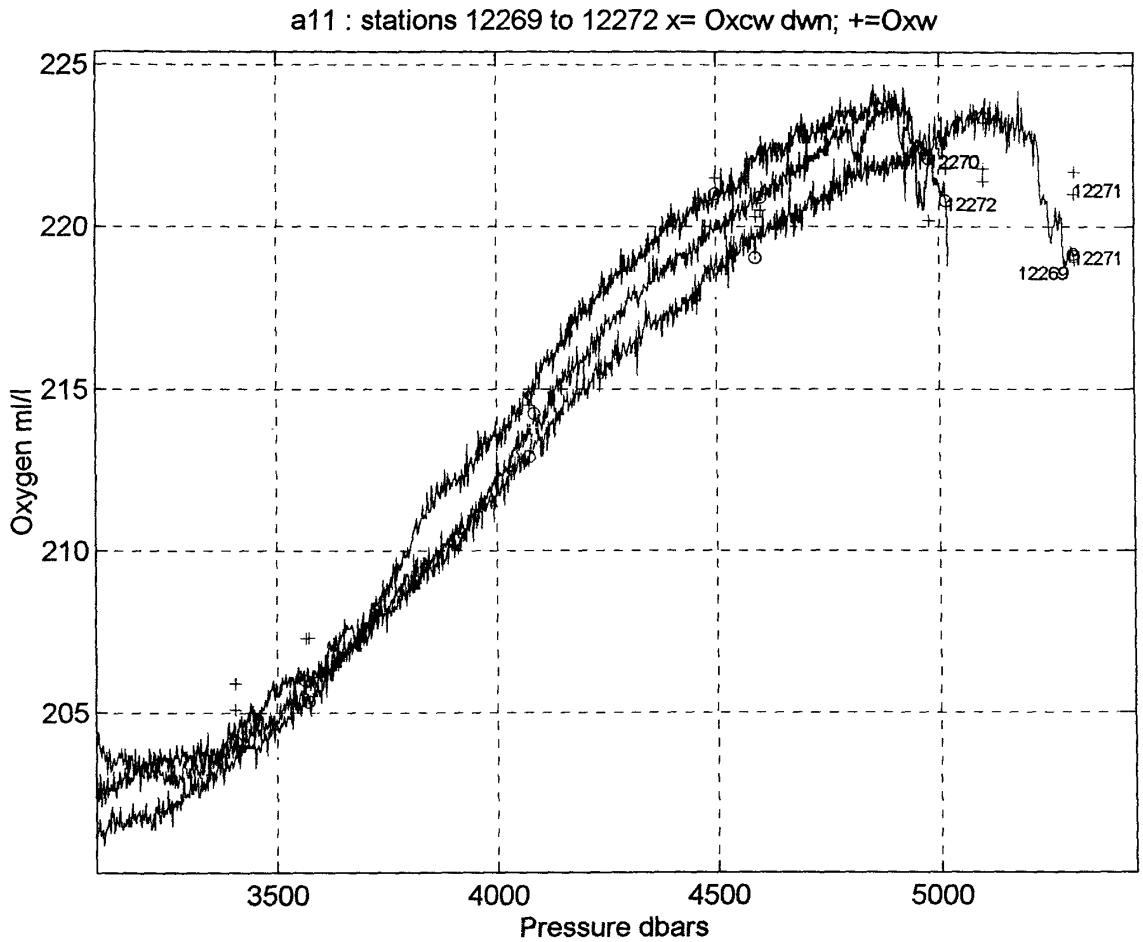

a11 : stations 12311 to 12315 x= Oxcw dwn; +=Oxw
Oxygen ml/l
Pressure dbars
230
225
220
215
210
205
3000
3500
4000
4500
5000
5500
12314
12315
12313

Figure 16



a11 : stations 12269 to 12272 x= Oxcw dwn; +=Oxw
225
220
215
210
205
Oxygen ml/l
3500
4000
4500
5000
Pressure dbars
12270
12272
12271
12269
12271

Figure 17

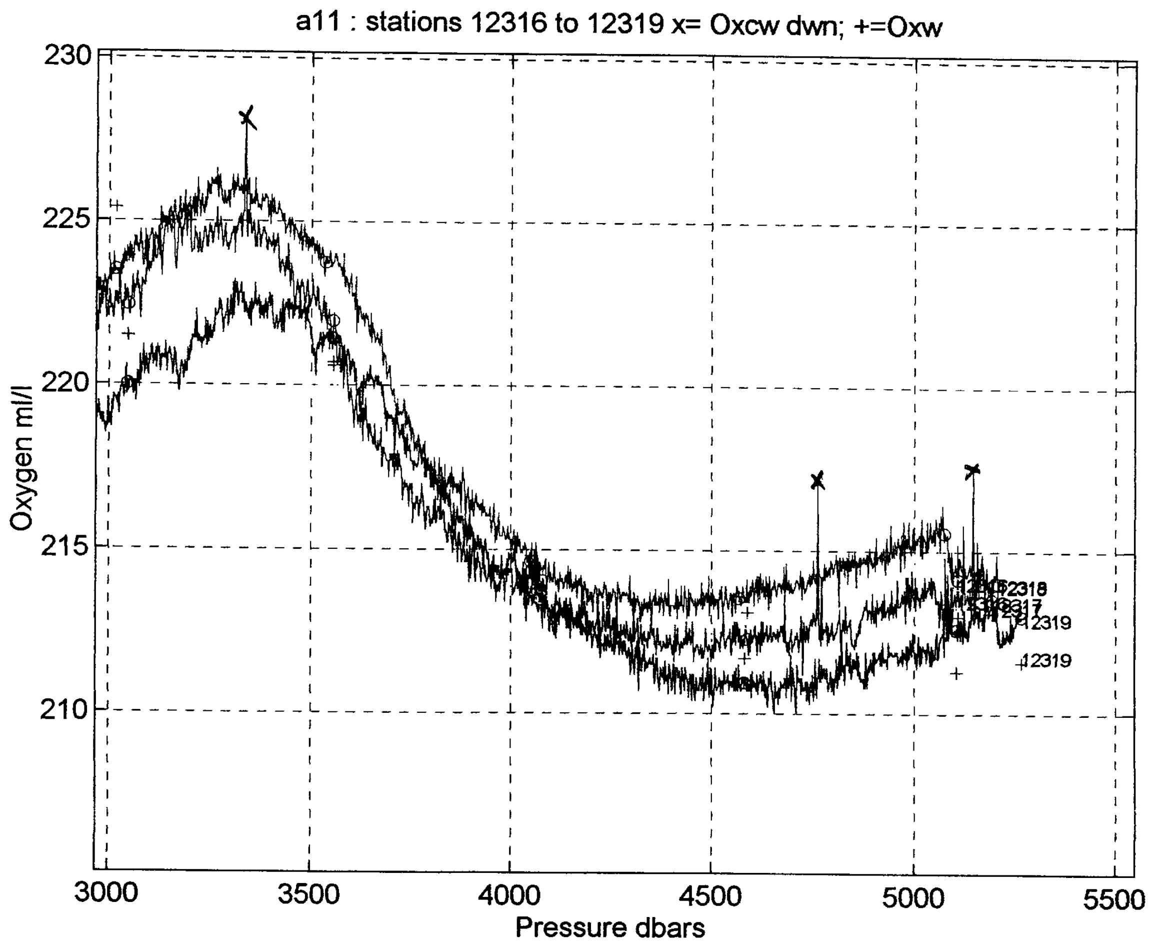

a11 : stations 12316 to 12319 x= Oxcw dwn; +=Oxw
Oxygen ml/l
Pressure dbars
230
225
220
215
210
3000
3500
4000
4500
5000
5500
12318
12319
12319

Figure 18

16 August 1996

All DQE notes:

Overall, the nutrient data appear to be of very good quality. Most of the data points which were outside of regional nutrient/theta trends had been flagged by the data originator. Specific bottles which had problems noted by either the data originator or the WOCE DQE evaluator are listed below.

Station	Bottle	Problem	Q1	Q2
12257	25701	Low P	222	223
12257	25702	Low P	222	223
12257	25703	Low P	222	223
12257	25704	Low P	222	223
12257	25705	Low P	222	223
12259	25920	High Sil	333	333
12261	26112	N & P a bit high	222	233
12261	26119	P high	222	223
12262	26204	N high	222	232
12264	26424	High Sil	444	333
12284	28405	Low Sil	444	333
12283	28324	All nuts high	444	333
12288	28802	N low	222	232
12288	28804	N low	222	232
12288	28805	N low	222	232
12293	29320	N and P high	333	333
12302	30211	High P	222	223
12306	30619	Low P	223	223
12306	30618	Low P	223	223
12319	31906	High P	222	223
12319	31914	High P	222	223
12322	32224	Q1 flagged, theta high, could be real	444	333
12323	32324	Sil and P a bit high	444	333
12329	32905	Sil high, O2 low	333	333
12331	33109	Sil high	333	333

INPUT FILE: A11.JCJ
THE DATE TODAY IS: 21-AUG-96

STNNBR	CASTNO	SAMPNO	CTDPRS	SILCAT	NO2+NO3	PHSPHT	QUALT1	QUALT2
12257	1	25705	3528.0			2.03	~~2	~~3
12257	1	25704	4043.8			2.07	~~2	~~3
12257	1	25703	4558.6			2.10	~~2	~~3
12257	1	25701	5397.3			2.10	~~2	~~3
12261	1	26112	2553.3		28.96	1.92	~22	~33
12262	1	26204	5099.3		33.92		~2~	~3~
12264	1	26424	11.7	2.75	10.66	0.66	444	333
12283	1	28324	16.3	14.72	21.09	1.38	444	333
12284	1	28405	3018.2	76.66			4~~	3~~
12302	1	30211	760.9			2.12	~~2	~~3
12319	1	31906	3045.5			1.78	~~2	~~3
12322	1	32224	11.5	3.35	4.03	0.39	444	333
12323	1	32324	10.6	2.46	3.64	0.37	444	333