WHP Cruise Summary Information

WOCE section designation	I02EW
Expedition designation (EXPOCODE)	316N145_14-15
Chief Scientist(s) and their affiliation	Gregory Johnson, NOAA/PMEL Bruce Warren, WHOI
Dates	1995.12.02 - 1996.01.22
Ship	KNORR
Ports of call	Singapore to Mombasa, Kenya to Diego Garcia
Number of stations	168
Geographic boundaries of the stations	2˚30.00''S 39°49.50"E 105°38.18''E 12°21.33''S
Floats and drifters deployed	27 Floats and 20 Drifters
Moorings deployed or recovered	none
Contributing Authors	none listed

WHP Cruise and Data Information

Instructions: Click on any highlighted item to locate primary reference(s) or use navigation tools above.

Cruise Summary Information	Hydrographic Measurements
Description of scientific program	CTD - general
	CTD - pressure
Geographic boundaries of the survey	CTD - temperature
Cruise track (figure)	CTD - conductivity/salinity
Description of stations	CTD - dissolved oxygen
Description of parameters sampled	
Bottle depth distributions (figure)	Salinity
Floats and drifters deployed	Oxygen
Moorings deployed or recovered	Nutrients
	CFCs
Principal Investigators for all measurements	Helium
Cruise Participants	Tritium
	Radiocarbon
Problems and goals not achieved	CO2 system parameters
Other incidents of note	Other parameters
Underway Data Information	**Acknowledgments**
Navigation	**References**
Bathymetry	
Acoustic Doppler Current Profiler (ADCP)	**DQE Reports**
Thermosalinograph and related measurements	
XBT and/or XCTD	CTD
Meteorological observations	S/O2/nutrients
Atmospheric chemistry data	CFCs
	14C
	Data Status Notes

Station locations for I02E (JOHNSON)

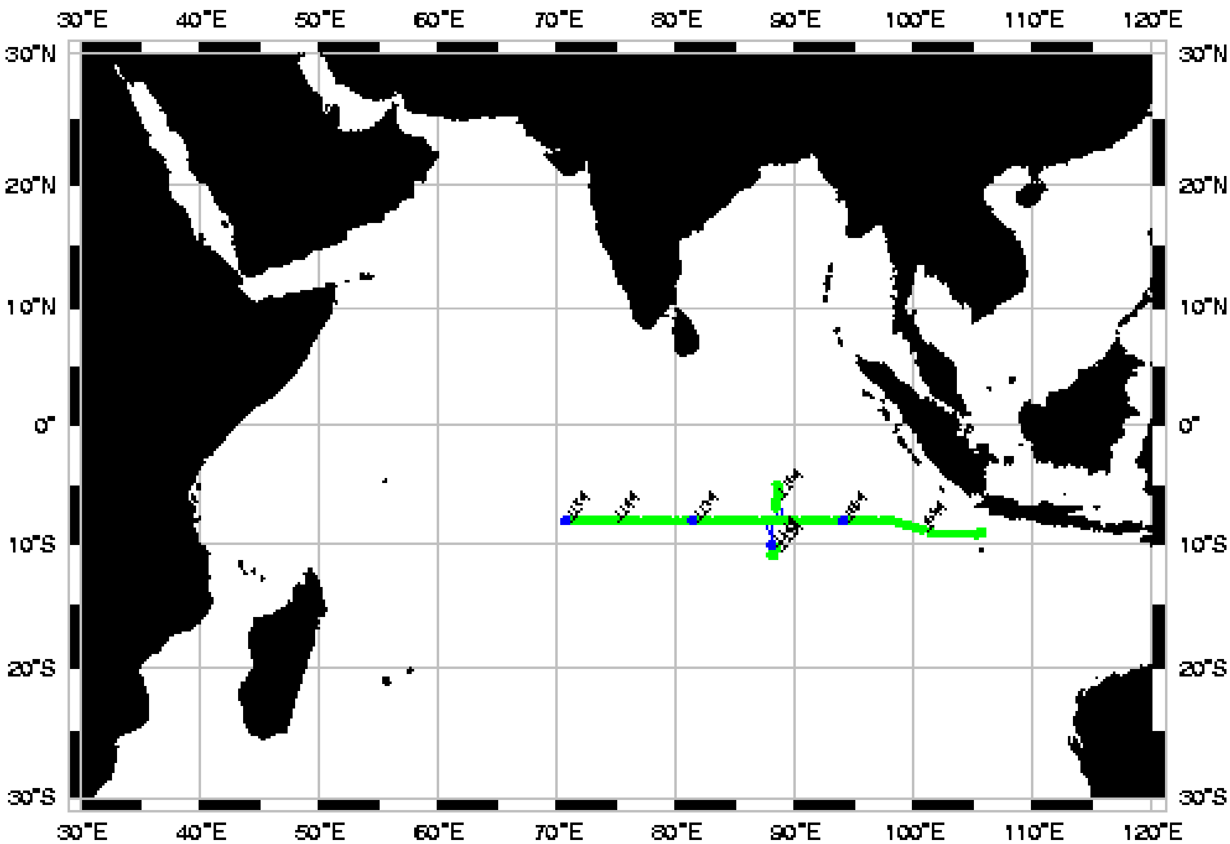


Figure 1a) (Produced from.SUM files by WHPO)

Station locations for I02W (JOHNSON)

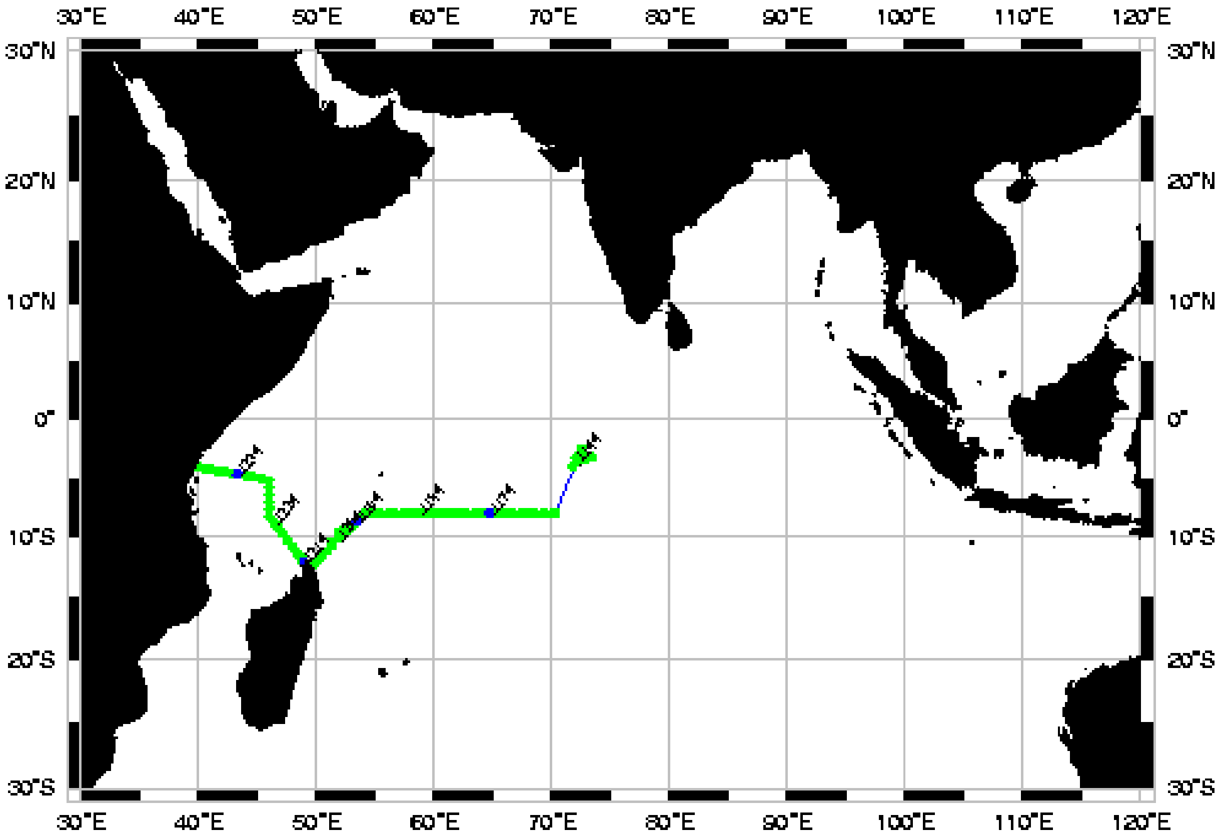


Figure 1b) WOCE I02W Cruise Track (produced by .SUM files by WHPO)

Draft Cruise Report
World Ocean Circulation Experiment
Indian Ocean Hydrographic Program Section I02
R/V KNORR Voyage 145-14
2 December 1995 - 22 January 1996

A. Cruise Narrative

A.1. Highlights

WOCE Hydrographic Program Section I02 (EXPCODE 316N145/14) was carried out aboard the R/V KNORR on voyage 145-14. This voyage began in Singapore on 2 December 1995 and ended in Mombasa, Kenya on 22 January 1996 with an intermediate port call in Diego Garcia from 28 to 30 December 1995. The chief scientist from Singapore to Diego Garcia was Gregory Johnson: NOAA/Pacific Marine Environmental Laboratory, Ocean Climate Research Division, 7600 Sand Point Way NE Bldg. 3, Seattle WA 98115, USA, gjohnson@pmel.noaa.gov. The chief scientist from Diego Garcia to Mombasa, Kenya was Bruce Warren: Woods Hole Oceanographic Institution, Department of Physical Oceanography, Woods Hole MA 02543, USA, bwarren@whoi.edu.

A.2. Cruise Summary

The work done during this cruise comprised WOCE Hydrographic Program Section I02, a transindian ocean section along nominal latitude 8˚S, and three diversions to nearby gaps in ridges to explore possible avenues for flow of deep and bottom water between various deep basins. During the cruise a total of 168 CTD/O2 stations were occupied within 10 m of the bottom with a 36 position 10-l bottle frame equipped with a lowered ADCP. Discounting one test station, 139 of these stations were occupied along the I02 section. The nominal station spacing along the I02 section is 40 nm in the interior, reduced near boundaries, mid-ocean ridges, and other places where narrow currents might exist. The average station spacing along the section is 32 nm. The positions of the CTD stations are plotted in Fig. 1, and the distribution of points along the main section at which water samples were drawn is plotted in Fig. 2.

Special attention was given to the bottom topography in laying out the station positions because of the opportunity offered for the exploration of the three major deep flows in the South Indian Ocean. The deep western boundary current of the eastern Indian Ocean, flowing northward along the Ninety east Ridge, had never been observed north of 18˚S. The central deep boundary current had been inferred to divide near 15˚S, with ill- defined branches flowing northward along the Chagos-Laccadive Ridge, Central Indian Ridge, and Mascarene Plateau. In the west the major deep and mid-depth flows between the Mascarene and Somali Basins could be documented on a complete section from the Mascarene Plateau to Madagascar.

Three diversions were made from the main section to investigate flow of bottom water through deep gaps in mid-ocean ridges. The first diversion, 7 stations from 6˚50'S to 5˚S around a mean longitude of 88˚28'E, mapped a westward flow of bottom water from the West Australian Basin to the Central Indian Basin across a deep gap in the Ninety east Ridge at 5˚S. The second diversion consisted of 11 stations between 11˚S - 10˚S and 88˚E - 88˚25'E to investigate a similar flow across a gap in the ridge at 10˚S. The third diversion consisted of 10 stations between 4˚00'S - 2˚30'S and 71˚45'E - 73˚20'E, placed within and on the western flank of a deep gap in the Chagos-Laccadive Ridge. This diversion explored, for the first time, suspected flow of bottom water through this gap between the Central Indian Basin and the Arabian Basin.

The ship left Singapore at 0900L on 2 December 1995 without the Indonesian observers, who had elected not to participate since clearance to work within the Indonesian Exclusive Economic Zone was not obtained. After a roughly 3 day steam, stations 1077 and 1078 were occupied at the location of station 1075, occupied ten days earlier during I10, at 9˚S, 105˚38'E; these served as test stations for equipment and personnel. Stations 1079 though 1084 went from 105˚10'E to 102˚E along 9˚7.5'S. By station 1090 the line reached 8˚S at 98˚E, after skirting the offshore edge of the Indonesian Exclusive Economic Zone (EEZ). The ship crossed the Ninety-east Ridge at station 1105, and the Chagos-Laccadive Ridge at 1154. Stations 1106-1112 and 1116-1126 comprised the first two diversions from the main section along 8˚S. The cruise broke off after station 1156 for a 48 hour port call in Diego Garcia, where Gregory Johnson departed to join another cruise and the two Kenyan observers joined the ship. After departing Diego Garcia at 0900L 30 Dec 1995 the ship steamed north for the third diversion, at the Chagos-Laccadive gap, stations 1157-1166. Returning to the 8˚S line, it passed the crest of the Central Indian Ridge at station 1172, and that of the Mascarene Plateau at station 1185. At station 1194 at 54˚E, the ship's course turned southwestward to cross the Amirante Passage (stations 1199-1201 in the Amirante Trench proper) and reached the northern tip of Madagascar at station 1215. After rounding the tip, the ship resumed stations heading northwestward toward Africa, taking a dog-leg track with turns at stations 1227 and 1232 to avoid the Tanzanian EEZ, and arriving in Mombasa on 22 January 1996 after completing station 1244.

Twenty-seven Autonomous Lagrangian Circulation Explorer (ALACE) floats and twenty surface drifters were deployed during the course of the cruise. Serial numbers, launch dates, launch times, positions, and CTD station numbers corresponding to launch sites are listed in Tables 1 and 2, respectively. An underway program of meteorological, sea surface, and hull-mounted ADCP measurements was carried out along the entire cruise track outside the Indonesian EEZ. For a non-WOCE, adjunct project, 25-ml samples for barium analysis ashore were drawn from every Niskin bottle on alternate stations, and stored for shipment to the U.S.

Table 1.

WOCE-I02 ALACE Float Deployment Log.

		Date and time shown in GMT.						After
		SELF TEST		DEPLOYMENT				CTD
	S/N	Date	Time	Date	Time	Lat	Lon	Stn#
1.	560	951206	1158	951206	1407	9°07.70'S	103°20.10'E	1082
2.	561	951208	1107	951208	1124	8°22.42'S	98°20.01'E	1088
3.	573	951212	1008	951212	1326	7°59.91'S	91°20.20'E	1100
4.	574	951214	2004	951214	2155	5°00.22'S	88°28.25'E	1109
5.	568	951216	1206	951216	1510	8°00.14'S	87°59.85'E	1115
6.	567	951218	0001	951218	0154	11°00.06'S	88°01.93'E	1120
7.	563	951221	1600	951221	1900	8°00.06'S	83°19.57'E	1133
8.	549	951223	0419	951223	0618	8°00.31'S	79°59.84'E	1138
9.	562	951225	0007	951225	0207	7°59.92'S	75°59.90'E	1144
10.	495	951226	1423	951226	1618	7°59.88'S	72°49.56'E	1150
11.	535	951227	1335	951227	1532	7°59.71'S	70°39.20'E	1156
12.	538	960104	1935	960104	2048	8°00.06'S	67°19.93'E	1172
13.	570	960106	1517	960106	1742	8°00.28'S	62°39.77'E	1179
14.	569	960107	0450	960107	0628	8°00.45'S	61°27.08'E	1181
15.	550	960107	2327	960108	0035	7°59.96'S	59°19.99'E	1185
16.	557	960109	1501	960109	1752	8°00.10'S	55°19.57'E	1192
17.	555	960111	0705	960111	1008	8°56.92'S	53°02.88'E	1200
18.	558	960112	0914	960112	1227	9°32.84'S	51°54.29'E	1205
19.	556	960113	1125	960113	1436	11°12.53'S	50°47.23'E	1209
20.	553	960114	0707	960114	0946	12°12.24'S	49°47.87'E	1213
21.	571	960114	2209	960115	0158	11°54.06'S	48°44.03'E	1218
22.	554	960116	0149	960116	0412	10°16.80'S	47°30.30'E	1223
23.	572	960117	0010	960117	0137	8°44.88'S	46°20.50'E	1226
24.	552	960117	2028	960117	2103	7°00.47'S	45°57.29'E	1229
25.	564	960119	0046	960119	0355	5°02.51'S	45°16.75'E	1233
26.	565	960120	0605	960120	0852	4°33.47'S	42°41.33'E	1237
27.	551	960121	0036	960121	0206	4°15.63'S	40°58.22'E	1240

Table 2.

WOCE I02 Surface Drifter Deployment Log.

		Date and time shown in GMT.				After
		DEPLOYMENT				CTD
	S/N	**Date**	**Time**	**Lat**	**Lon**	**Stn #**
1.	21904	120595	1508	9°07.98'S	105°09.99'E	1079
2.	21903	120895	0346	8°33.77'S	99°59.65'E	1087
3.	21933	121095	1709	8°00.41'S	95°20.26'E	1094
4.	21932	121395	0254	7°59.96'S	89°59.84'E	1102
5.	21870	121495	0533	6°00.10'S	88°28.56'E	1106
6.	21871	121495	2200	5°00.36'S	88°28.49'E	1109
7.	21905	121695	1511	8°00.20'S	87°59.84'E	1115
8.	21901	121795	0520	10°02.88'S	87°59.98'E	1116
9.	21912	121895	1557	10°59.99'S	88°01.93'E	1120
10.	21913	122095	2148	7°59.97'S	85°19.97'E	1130
11.	21921	122395	0620	8°00.33'S	79°59.81'E	1138
12.	21920	122595	0918	7°59.97'S	75°19.88'E	1145
13.	21926	010196	0029	2°30.30'S	72°32.24'E	1160
14.	21928	010396	1956	7°59.84'S	69°59.86'E	1168
15.	21929	010596	1653	7°59.95'S	65°19.75'E	1175
16.	21927	010796	1724	7°59.90'S	60°09.62'E	1183
17.	21952	010996	1753	8°00.10'S	55°19.33'E	1192
18.	21951	011596	2134	10°46.69'S	47°52.15'E	1222
19.	21923	011796	2205	7°00.40'S	45°57.26'E	1229
20.	21922	012096	1515	4°27.84'S	42°06.66'E	1238

A.3. Principal Investigators

1. Gregory Johnson Salinity Oxygen CTD/O2
NOAA/Pacific Marine Environmental Laboratory, Ocean Climate Research Division,
7600 Sand Point Way NE Bldg. 3, Seattle WA 98115-0070, USA,
gjohnson@pmel.noaa.gov
2. Bruce Warren Salinity Oxygen CTD/O2
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
bwarren@whoi.edu
3. John Toole Salinity Oxygen CTD/O2
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
jtoole@whoi.edu
4. Louis Gordon Nutrients
Oregon State University, College of Ocean and Atmospheric Sciences,
104 Ocean Administration Building, Corvallis OR 97331-5503, USA,
lgordon@oce.orst.edu
5. John Bullister CFCs (F11, F12) & Air Chemistry
NOAA/Pacific Marine Environmental Laboratory, Ocean Climate Research Division,
7600 Sand Point Way NE Bldg. 3, Seattle WA 98115-0070, USA,
bullister@pmel.noaa.gov
6. William Jenkins Shallow Helium/tritium
Woods Hole Oceanographic Institution, Chemistry Department,
Woods Hole MA 02543, USA,
wjenkins@whoi.edu
7. Peter Schlosser Deep Helium
Lamont Doherty Earth Observatory, Columbia University,
Pallisades NY 10964,
peters@ldeo.columbia.edu
8. Robert Key AMS C14 & Radium
Princeton University, Geology Department,
Guyot Hall, Princeton NJ 08544, USA,
key@wiggler.princeton.edu
9. Kelly Falkner Barium
Oregon State University, College of Ocean and Atmospheric Sciences,
104 Ocean Administration Building, Corvallis OR 97331-5503, USA,
kfalkner@oce.orst.edu
10. Chris Winn Total Carbon & Alkalinity
Scripps Institution of Oceanography, Marine Physical Laboratory 0902,
University of California at San Diego,
9500 Gilman Drive, La Jolla CA 92037, USA,
cwinn@chiton.ucsd.edu

11. Douglass Wallace Total Carbon & Alkalinity
Brookhaven National Laboratory,
Building 318, Upton NY 11973, USA,
wallace@bnl.gov
12. Peter Hacker ADCP & LADCP
University of Hawaii, Joint Institute for Marine and Atmospheric Research,
1000 Pope Road, Honolulu HI 96882, USA,
hacker@soest.hawaii.edu
13. Eric Firing ADCP & LADCP
University of Hawaii, Joint Institute for Marine and Atmospheric Research,
1000 Pope Road, Honolulu HI 96882, USA,
efiring@soest.hawaii.edu
14. Barrie Walden Meteorology
Woods Hole Oceanographic Institution, Woods Hole MA 02543, USA,
bwalden@whoi.edu
15. Russ Davis ALACE Floats
Scripps Institution of Oceanography, University of California at San Diego,
9500 Gilman Drive 0230, La Jolla CA 92093-0230, USA,
davis@nemo.ucsd.edu
16. Mark Bushnell Surface Drifters
NOAA/Atlantic Oceanographic Marine Laboratory,
4301 Rickenbacker Causeway, Miami FL 33149, USA,
bushnell@aoml.noaa.gov

A.4. List of Cruise Participants

1. Gregory Johnson* chief scientist
NOAA/Pacific Marine Environmental Laboratory, Ocean Climate Research Division,
7600 Sand Point Way NE Bldg. 3, Seattle WA 98115-0070, USA,
gjohnson@pmel.noaa.gov
2. Bruce Warrren** co-chief scientist
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
bwarren@whoi.edu
3. Sara Zimmermann CTD data processor
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
szimmermann@whoi.edu
4. George Knapp oxygen analyst
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
gknapp@whoi.edu
5. Toshiko Turner (WHOI) salinity analyst
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
tturner@whoi.edu

6. H. Marshall Swartz CTD electronics technician & CTD watch leader
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
mswartz@whoi.edu
7. Laura Goepfert CTD watch leader
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
lgoepfert@whoi.edu
8. Paul Bennett CTD watch stander
Woods Hole Oceanographic Institution,
110 High Park Place, Pittsburgh PA 15266, USA
9. Steven Jayne CTD watch stander
Woods Hole Oceanographic Institution, Department of Physical Oceanography,
Woods Hole MA 02543, USA,
sjayne@whoi.edu
10. Arthur Voorhis CTD watch stander
Woods Hole Oceanographic Institution,
54 Whitman Road, Woods Hole MA 02543, USA
11. Mela Swapp CTD watch stander
University of Washington,
P.O. Box 8231, Kirkland WA 98034, USA,
swapp@pmel.noaa.gov
12. Deborah LeBel CTD watch stander
University of Washington, School of Oceanography,
Box 357940, Seattle WA 98195-7940,
lebel@ocean.washington.edu
13. Stanley Moore Nutrient analyst
Oregon State University, College of Ocean and Atmospheric Sciences,
104 Ocean Administration Building, Corvallis OR 97331-5503, USA,
moores@ucs.orst.edu
14. Consuelo Carbonell-Moore Nutrient analyst
Oregon State University, College of Ocean and Atmospheric Sciences,
104 Ocean Administration Building, Corvallis OR 97331-5503, USA,
carbonec@oce.orst.edu
15. Elodie Kestenare ADCP & LADCP watch leader
University of Hawaii, Joint Institute for Marine and Atmospheric Research,
1000 Pope Road, Honolulu HI 96882, USA,
elodie@soest.hawaii.edu
16. Mark Majodina ADCP & LADCP watch stander
University of Cape Town, Oceanography Department,
Rondebosch 7700, SOUTH AFRICA,
majodina@physci.uct.ac.za,
17. Frederick Menzia CFC analyst
NOAA/Pacific Marine Environmental Laboratory, Ocean Climate Research Division,
7600 Sand Point Way NE Bldg. 3, Seattle WA 98115-0070, USA,
menzia@pmel.noaa.gov

18. Bing-Sun Lee CFC analyst
University of Washington, School of Oceanography,
Box 357940, Seattle WA 98195-7940,
blee@pmel.noaa.gov
19. Art Dorety C-14 and Radium analyst
Princeton University, Geology Department,
Guyot Hall, Princeton NJ 08544, USA,
key@wiggler.princeton.edu
20. Dan Smith Deep Helium-3 analyst
Lamont Doherty Earth Observatory, Columbia University,
Palisades NY 10964,
dansmith@lamont.ldgo.columbia.edu
21. Scot Birdwhistell Tritium/Helium-3 analyst
Woods Hole Oceanographic Institution, Chemistry Department,
Woods Hole MA 02543, USA,
sbirdwhistell@whoi.edu
22. Rolf Schottle TCO2/Alkalinity analyst
Scripps Institution of Oceanography, Marine Physical Laboratory,
University of California at San Diego,
9500 Gilman Drive 0902, La Jolla CA 92037, USA,
rolfs@chiton.ucsd.edu
23. Jennifer Phillips TCO2/Alkalinity analyst
University of Hawaii at Hilo, Department of Marine Science.
200 West Kawili St, Hilo HI 96720,
jphillip@hawaii.edu
24. Angela Adams TCO2/Alkalinity analyst
University of Hawaii, Department of Oceanography,
1000 Pope Road, Honolulu HI 96822,
aadams@soest.hawaii.edu
25. Cathy Cipolla TCO2/Alkalinity analyst
University of Rhode Island, Graduate School of Oceanography,
Equipment Development Laboratory,
South Ferry Road - Box 60, Narragnasett RI 02882-1197, USA,
seabiz@gsosun1.gso.uri.edu
26. Stanley Rosenblad Resident Technician
Woods Hole Oceanographic Institution,
Woods Hole MA 02543, USA,
srosenblad@whoi.edu
27. Michael Mutua Nguli*** Kenyan scientist
Kenya Marine and Fisheries Research Institute,
P.O. box 81651, Mobassa, KENYA,
modido@main.bib.uia.ac.be
28. Mika Oduor Odido*** Kenyan scientist
Kenya Marine and Fisheries Research Institute,
P.O. box 81651, Mobassa, KENYA,
modido@main.bib.uia.ac.be

* Departed Ship in Diego Garcia
** Chief Scientist from Diego Garcia to Mombasa
*** Joined ship in Diego Garcia

A.5. Special Notes

Extraordinary time and effort were expended by the chief scientist and Indonesian scientists from the Bogor Agricultural University in an attempt to gain clearance to occupy hydrographic stations within the Indonesian EEZ as part of WOCE Section I02.Formal clearance was never granted. Late on 30 November 1995 one of the Indonesian scientists involved called the Chief Scientist saying that he had obtained clearance. He requested a three day delay in the start of I02 to accommodate the schedules of the Indonesian military observers. The stations to be allowed started 19 nm from the Indonesian coast at about2000 m depth. After a brief consideration weighing the experience gained in Indonesian clearance procedure from the preceding cruise, WOCE Section I10, a decision was made to start the cruise on time and abandon hope of working within the Indonesian EEZ. This lack of clearance was most unfortunate as measurement of the South Java Current, most likely flowing southeastward along Indonesia, had to be omitted from the program.

B. Underway Measurements

B.1. Navigation and Bathymetry

To obtain bathymetric data, uncorrected sonic depths and times were logged manually from the 12 khz PDR every 5 minutes by the CTD watch. These depths were then merged by time with the navigation data.

B.2. Meteorological Observations

The IMET system was calibrated prior to the departure of the Knorr and extra sensors were aboard. The data were automatically recorded once per minute on the ship's computer. Variables measured included computer time, ship's heading (Gyro syncro),ship's speed (EDO Speed log), sea surface conductivity (mmho/cm), sea surface temperature (˚C), port GPS 200 time & position, stbd GPS 200 time &position, GPS course over ground, GPS speed over ground, GPS time & position, air temperature (˚C),barometric pressure (millibars), relative humidity (percent), precipitation(millimeters),short wave radiation (watts/sq m), compass reading (degrees), wind direction (ship relative), and wind speed (m/s, ship relative). The quality of the wind records may have been degraded sometimes when red-footed boobies (Sula sula) sat on the sensors.

B.3. Acoustic Doppler Current Profilers

Ocean velocity observations were taken using two acoustic Doppler current profiler(ADCP) systems and accurate navigation data. The two systems are the hull-mounted ADCP and a lowered ADCP mounted on the rosette with the CTD. The purpose of the observations was to document the upper ocean horizontal velocity structure along the cruise track, and to measure vertical profiles of the horizontal velocity components at the individual hydrographic stations. The observations provide absolute velocity estimates including the ageostrophic component of the flow.

B.3.1. Hull-mounted ADCP

The hull-mounted ADCP is part of the ship's equipment aboard the KNORR. The ADCP is a 150 kHz unit manufactured by RD Instruments. The instrument pings about once per second, and for most of the cruise the data were stored as 5-minute averages or ensembles. The user-exit program, ue4, receives and stores the ADCP data along with both the P-code navigation data from the ship's Magnavox receiver and the Ashtech gps receiver positions. The P-code data are used as navigation for the ADCP processing. The ship gyro provides heading information for vector averaging the ADCP data over the 5- minute ensembles. The user-exit program calculates and stores the heading offset based on the difference between the heading determination from the Ashtech receiver and from the ship gyro. The ADCP transducer is mounted at a depth of about 5 meters below the sea surface.

The setup parameters were a blanking interval of 4 meters, a vertical pulse length of 16 meters, and a vertical bin size of 8 meters. We used a 5 minute sampling interval for the entire cruise.

Bottom tracking was activated during the shallow water transits near Diego Garcia Atoll, and along the coasts of Madagascar and Mombasa. For the processing of the ADCP data aboard ship, we used a rotation amplitude of 1.0085, a rotation angle of -0.06 degrees (added to the gyro minus gps heading), and a time filter width of 0.0104 days (15 minutes). Final editing and calibration of the ADCP data has not yet been done.

A couple of days before arriving at Diego Garcia, the performance of beam 4 became poorer than usual. During the second leg (Diego Garcia - Mombasa), the beam 4 failed and the three other beams were going slowly worse and worse. Several tests have been done: the results confirm that the main electronics works well but a problem occurs inside the transducers. We suspect that beam 4 (and maybe the three others) has flooded.

A complete set of preliminary plots was generated during the cruise. The plots consist of: vector plots with velocity averaged over several depth intervals, and over a tenth or a twentieth of degrees in spatial grid; and contour plots of u (positive east) and v (positive north) typically averaged over 0.1 degree of longitude or latitude, depending on the track. The velocity was measured from a depth of 21 m to a depth of about 300 to 400 m, typically during the first leg and about 200 to 300 m during the second leg since a beam failed.

B.3.2. Lowered ADCP

The second ADCP system is the lowered ADCP (LADCP), which was mounted to the rosette system with the CTD. The LADCP yields vertical profiles of horizontal velocity components from near the ocean surface to near the bottom. Two LADCP were available: Teresa Chereskin's (Scripps Institution of Oceanography - SIO) and Eric Firing & Peter Hacker's (University of Hawaii - UH). Both units are a broadband, self-contained 150 kHz system manufactured by RD Instruments.

The SIO instrument, used with an asynchronous signal (with alternating sampling intervals of about 1.2 and 1.8 seconds), allows one to decrease the number of samples contaminated by bottom interference. We used single ping ensembles. Vertical shear of horizontal velocity was obtained from each ping. These shear estimates were vertically binned and averaged for each cast. By combining the measured velocity of the ocean with respect to the instrument, the measured vertical shear, and accurate shipboard navigation at the start and end of the station, absolute velocity profiles are obtained (Fisher and Visbeck, 1993). Depth is obtained by integrating the vertical velocity component; a better estimate of the depth coordinate will be available after final processing of the data together with the CTD profile data. The shipboard processing results in vertical profiles of u and v velocity components, from a depth of 60 m to near the ocean bottom in 16-m intervals. These data have been computer contoured to produce preliminary plots for analysis and diagnosis (see enclosed figures).

The SIO (newest) LADCP was used between CTD stations 1077 and 1094. The very poor performance of the instrument below 3000 m and then below 2000 m during these first 18 stations is due to a low transmit current inside the instrument (the HP module failed). The UH LADCP was used from station 1095 until the end of the cruise.

Five stations (1015, 1118 - 1121) were missed owing to the use of an improper configuration file. One command required for proper LADCP operation with the new resistor (changed July 95) was not included correctly in the initial file. Also, the LADCP was not deployed during station 1215, because of shallow water (around 300 m). The deep casts often have noise problems below 3000 m or so owing to poor instrument range and interference from the return of the previous ping.

B.3.3. Navigation

The ship used a Trimble precision code (P-code) receiver for navigation, with data coming in once per second. These one-second data were stored for the entire cruise.

The Ashtech receiver uses a four antennae array to measure position and attitude. The heading estimate was used with the gyro to provide a heading correction for the ADCP ensembles. The Ashtech data were stored by the ADCP user-exit program along with the ADCP data.

B.4. Thermosalinograph

Surface temperature and salinity from an FSI thermosalinograph were recorded on the ship's computer. The thermosalinograph was not calibrated prior to the departure of the Knorr from Woods Hole and will require station calibrations with the CTD/rosette system to obtain correct salinity data.

B.5. Atmospheric Chemistry

The CFC group ran 3/8" O.D. Dekaron air sampling lines (reinforced plastic tubing) from the CFC van to the bow and stern and their personell periodically analysed air for: CFC-11, CFC-12, CFC-113, carbon tetrachloride, and methyl chloroform.

B.6. pCO2

Equilibrated seawater and surface air were monitored underway for pCO2 by the TCO2 and Total Alkalinity personell. Two separate systems were continuously monitoring pCO2. One system uses a shower type equilibrator and gas chromatographic detection. The other system uses a rotating disk equilibrator and infra-red detection. Sample analyses were typically completed within 12 hours of sample collection for discrete samples (TCO2 and Total Alkalinity).

C. Hydrographic Measurements

C.1. Water Sampling (Rosette) Equipment

2 SIO/ODF 36 position/10-liter frame with LADCP mounts.
1 WHOI/Bullister 25 position/4-liter frame.
1 WHOI 24 position/1.2 liter frame.

80 SIO/ODF 10-liter bottles with spares.
32 WHOI/Bullister 4-liter bottles with spares.
28 Bullister 4-liter bottles with spares.
36 WHOI/GO 1.2 liter bottles with spares.

3 GO 36-position pylons model 1016-36.
2 GO 24-position pylons model 1015-24.
2 GO 36-position surface control interfaces.
2 GO 24-position pylon deck units.
1 GO GO-FIRE external tonefire system for 36-position pylons.

C.2. CTD Data acquisition and processing

C.2.1. CTD Equipment

3 WHOI-modified EG&G Mk-IIIb CTD/O2 system with WHOI titanium pressure transducer and pressure temperature channel.
2 WHOI/FSI ICTD/O2 systems with separate fast temperature channels.
5 WHOI/FSI Ocean Temperature Modules (external platinum resistance thermometers) for redundancy on Mk-IIIb.
2 WHOI/FSI Ocean Conductivity Module for redundancy on Mk-IIIb.

C.2.2. CTD Equipment Configuration

Equipment used aboard Knorr for WOCE section I02 has been provided by both Woods Hole Oceanographic Institution CTD Operations, and the Scripps Institution of Oceanography's Shipboard Technical Services/ Ocean Data Facility (SIO STS/ODF). A total of 168 stations were taken during the cruise, which includes two test stations to check instrument performance.

The underwater equipment was attached to an ODF-provided aluminum frame, capable of mounting thirty-six 10-liter bottles and a range of electronics. For this cruise two CTDs were usually used, along with a 36-position pylon, pinger, independent temperature modules and a lowered acoustic doppler current profiler (LADCP).

Nearly all CTD data came from CTD-9, a WHOI-modified Neil Brown Mk-3b sampling at 23.8Hz, and incorporating a Sensormedics oxygen sensor assembly and a titanium pressure transducer with temperature sensor. Two early stations were taken with CTD-8, a General Oceanics-upgraded Mk3-c CTD.

On most stations, one of two Falmouth Scientific (FSI) ICTDs were used in memory mode to provide an independent CTD trace. Both of the ICTDs provide 26Hz scan rate and Sensormedics oxygen sensors. Either can be configured for use in FSK mode to send data up the cable or in memory mode to internally record data and dump it at the end of a cast. Additionally, an FSI Ocean Temperature Module (OTM) was attached to each of the Mk-3 and ICTDs to give further temperature benchmarks.

A General Oceanics (GO) model 1016-36 pylon and thirty-six ODF 10-liter bottles mounted in two concentric circles on the frame were provided by ODF. Also clamped into the frame were an Ocean Instrument Systems pinger for bottom-finding and an RDI LADCP and battery pack (see separate LADCP discussion).

The underwater system was lowered from the Knorr's starboard Markey winch spooled with approximately 10,000 meters of Rochester 0.322 inch 3-conductor electromechanical cable. Standard lowering rates were 30 meters per minute to 200 meters wire out, and then 60 meters per minute to the target depth, as well as 60 meters per minute on the upcast.

Significant backup equipment was available aboard but not used, including one spare 36-position frame complete with bottles from ODF, a WHOI-owned 25-position 4-liter bottle frame, two GO 1016-36 pylons, three GO 1015-24 pylons and two pingers.

C.2.3. CTD Equipment Performance

Of the 168 stations, 166 were taken with CTD-9, and two with CTD-8. The two FSI ICTDs took data on 137 stations, configured for internal recording and mounted on the frame at the same height as the Mk-3 to provide an independent CTD data set. ICTD-1338 was used for 67 stations, and ICTD-1344 provided 70 stations.

CTD-8 was not used further because of jumps in the multiplexed data channels, which resulted in unfittable data in the oxygen and pressure temperature channels.

OTM data were integrated directly into the CTD data streams at the regular scan rate for that CTD. One OTM was replaced when it developed an intermittent output. Preliminary reviews have shown no obvious temperature shifts comparing the OTMs with either of the CTDs' temperature data.

ICTD data were downloaded from the ICTD at the end of each station. Early problems maintaining connection to the downloading computer were traced to a faulty cable from the ICTD to the lab, and a replacement provided satisfactory performance.

CTDs and OTMs used during the cruise are being returned to WHOI for post-cruise calibrations in WHOI's CTD Calibration Laboratory during early 1996.

Power was maintained to the CTDs and pylon at all times to assure warm up conditions. Each of the three conductors of the sea cable were used, one providing power and signal to/from the pylon, one for power and signal to/from the FSK mode CTD, and one providing power to the memory-mode CTD. The memory mode CTD was also provided with a backup battery in a pressure case to minimize the possibility of logging mode shutdown in the event of a power dropout.

The starboard winch, wire and boom arrangement worked flawlessly. The sea cable was reterminated approximately every 25 stations to avoid fatigue and corrosion failure, but in every case the wire was observed in apparently good to excellent shape at the termination. Retermination was not needed because of any cable problems. It should be noted that sea conditions were calm to moderate during the cruise. Winch operators were well-trained, attentive and proactive, making the CTD watch significantly smoother.

Equipment provided by Scripps STS/ODF was in well maintained condition, and performed reliably during the cruise. There were occasional communications errors with the pylon traced to cross-talk from the CTD and pylon telemetry, but these were minor inconveniences. Special thanks go to the ODF group for their technical and logistics assistance and equipment support to WHOI in conducting this section as well as the I8S/I9S and I1 sections.

C.2.4. CTD Data Acquisition and Processing Methods

CTD data were acquired using a Neil Brown Instrument Systems Mk-III deck unit/display providing demodulated data to two personal computers running EG&G CTD acquisition software version 5.2 rev 2 (EG&G, Oceansoft acquisition manual, 1990). One computer provided graphical data to screen and plotter, the other provided a listing output. Two more personal computers were used, one for pylon control and one for recovering the data from the internal-recording ICTD. The pylon was driven by an ODF-provided pylon control system. Bottom approach of the CTD package was monitored by following the attached pinger's direct and bottom return signals on the ship-provided PDR trace.

Following each station, the CTD data were forwarded to another set of personal computers running both EG&G CTD post-processing 5.2 rev 2 software and custom software from WHOI (Millard and Yang, 1993). The raw data were edited, pressure sorted, scaled and pressure centered into 2 decibar bins for final data quality control and analysis. A first pass fit of CTD salinity and oxygen to water sample salinity and oxygen was performed.

C.2.5. CTD Calibration Summary

C.2.5.1.Pre-cruise Laboratory Calibration:

The pressure, temperature, and conductivity sensors of CTD-9, CTD-8, ICTD-1338 and ICTD-1344 were calibrated at the Woods Hole Oceanographic Institution's CTD Calibration Laboratory in November 1995 directly before the I02 cruise began. OTMs used during the cruise were also calibrated at that time.

PRESSURE AND TEMPERATURE CALIBRATIONS:

The pressure, temperature, and conductivity sensors of CTD-9, CTD-8, ICTD-1344 and ICTD-1338 were calibrated at the Woods Hole Oceanographic Institution's CTD Calibration Laboratory in November 1995 directly before the I02 cruise began. OTMs used during the cruise were also calibrated at that time. Post cruise calibrations for all instruments were performed in April and May 1996. There was a strong case for applying pre-cruise calibrations to this data as they were considerably closer in time than the post-cruise calibrations to this cruise.

Only calibrations of instruments used in the final data set are included here. Calibration runs for all instruments are available from the WHOI CTD group. Laboratory calibrations of the conductivity and oxygen cells are not included in this section as multiple regression fits of the ctd data to the rosette data yeilding more accurate descriptions of the data are discussed later.

Special Notes on Primary Instrument CTD 9:

Pressure calibrations:

Pre-cruise laboratory calibrations were used for the final data load for stations collected with ctd 9. There was a .33 to .5 db shift over the 0-7000db range between the pre and post calibrations.

Different from other cruises, a single pressure bias term was used for the entire cruise for CTD 9. This term was set equal to the mean of a regression fit to all of the on deck pressure bias data and the original pre-cruise laboratory pressure bias term.

Pressure Sensor Issues:

The pressure reading of CTD 9 before each station varied from 0.5 to 1.5 dbars on deck and 5.0 to 6.5 when back on deck. It was discovered, post cruise, that there was, in fact, a real pressure historesis of the CTD 9 pressure cell induced by a huge temperature gradient characteristic of this part of the ocean.

Pressure historesis: This problem took us through many an iteration during the processing of the ctd data. At sea, the pre-to-post cast pressure bias differential was attributed to a malfunction of the pressure sensor specific to the last 100m or so of the upcast during warming. In fact, the CTD was measuring 2db too shallow at depth as well as 4.5 db too deep back at the surface! It was particularly evident when overplotting with ictd 1344 showed the discrepancy. Finally, the solution was to apply a C1(D1) and an S1(S2) term to the pressure temperature sensor calibrations as described by Millard, Bond and Toole 1993. These additional terms, although part of the original equation for scaling pressure temperature, have not previously contributed significant adjustments to pressure data. However, we encountered an especially steep pressure/temperature gradient during this cruise and the application of these terms proved to be the solution.

The values of these terms were worked out from a post-cruise laboratory dunk test of the ctd from a warm bath directly to a cold bath and visa versa. The C1(D1) term accommodates the lag associated with the thermal propagations from the end cap into the interior of the pressure temperature transducer.

Implementing these terms reduced the down/up historesis of the pressure term to less than 1 db.

Temperature Sensor Issues:

Stations 1075 from the previous leg and station 1077 from this leg were collected in the same geographic location with two different CTD's. Comparison of these data show that station 1077, the first station on this cruise, was .002 degrees colder in the deep water. The consensus, after many comparisons of ictd, otm, and ctd calibration data was that the .002 difference could be real. Since there is virtually no difference between CTD 9 pre and post temperature calibrations, and since comparisons of all other simultaneously used profiling instruments vary within that .002 spectrum, it was decided to load the data with the original pre-cruise temperature calibrations.

Conductivity Sensor Issues:

CTD 9 exhibited a subtle, yet distinct, conductivity sensor historesis which is discussed in detail in the conductivity fitting section of the documentation. Even after compensating both for this and the pressure historesis, it was impossible to compensate for a digitizer problem which the conductivity cell also displayed. Final calibrated data still shows a mismatch in the down/up salinity that is at the +/- 1 conductivity digitizer unit level.

KB45 - I02 - Instrument calibrations:

CTD9

PRESSURE:

* pre-cruise 1.8¯C -.123343E+02 0.999335E-01 0.262451E-10
  stdev=0.520752
  (pr09d018.fit ... 12-02-95)   meandev=-0.468648E-4
post-cruise 30.3C -.781314E+01 0.999537E-01 0.368139E-10
  stdev=0.413239
  (pr09d001.fit ... 04-23-96)   meandev=-0.530802E-4
* actual bias used: -.118000E+02

PRESSURE TEMPERATURE:

S1   T0   BIAS   SLOPE
* pre-cruise 2.9980E-07 1.8 .374183E02 -.917955E-02
  stdev=.103365
  (te09d002.fit ... 12-02-95)   meandev=.101896E-5
* The D1 and S2 terms were derived from post-cruise laboratory dunk test!
  S2=0.1067 D1(C1)=-290.15

TEMPERATURE:

* pre-cruise -.179140E+01 .496259E-03 .473093E-11
  stdev=.319748E-03
  (te09d002.fit ... 12-02-95)   meandev=.371819E-06
A temperature lag of 0.150 was used for all CTD9 stations.
post-cruise -.179157E+01 .496325E-03 .382716E-11
  stdev=.277972E-03
  (te09d010.fit ... 05-08-96)   meandev=.720932E-06

CTD8

PRESSURE:

* pre-cruise 1.5¯C -55.9266 0.107747 -.230898E-08
  stdev=.582264
  (pr08d001.fit ... 9-09-95 really post mw95)

PRESSURE TEMPERATURE:

S1 S2 T0 BIAS SLOPE
* pre-cruise 4.0859E-07 -0.35786 1.5 .121813E+03 -.268788E-02
  stdev=.175228
  (te08d001.fit ... 12-12-95)

(note that a portion of station 1078 was loaded with bias of .135813E+03 to compensate for pressure/temp drop at 865 db. This correction altered calculated pressure by 5 db.)

TEMPERATURE:

* pre-cruise -.571426E-01 .499145E-03 .207133E-11
  stdev=.374120E-03
  (te08d002.fit ... 12-02-95) meandev=.867638E-06

A temperature lag of 0.240 seconds was used for all CTD 8 stations.

post-cruise

FAST TEMPERATURE:

pre-cruise -.255953 .524715e-03 -.136373e-08 .145946E-13
stdev=.200573E-02
(te08d002.fit ... 12-02-95) meandev=.261125E-06

ICTD 1344

PRESSURE:

pre-cruise 1.8¯C 1.926020 .100003 -.201953E-08 .199206E-13
stdev=.500850
(pr44d001.fit ... 11-19-95) meandev=-.517319E-04
post-cruise 30.3C 0.170542E+01 0.999827E-01 -.141189E-08 0.148897E-13
stdev=.399364
(pr44d001.fit ... 05-09-96) meandev=.226782E-04

TEMPERATURE:

pre-cruise -.863030E-02 .500618E-03 -.224525E-10 .220719E-15
stdev=.364214E-03
(te44d002.fit ... 11-19-95) meandev=.169501E-06
post-cruise -.107943E-01 0.500615E-03 -.235938E-10 0.233805E-15
stdev=.490960E-03
(te44d010.fit ... 05-06-96) meandev=.295274E-06

A temperature lag of 0.50 seconds was used for ICTD 1344.

Fast Temp -.169302E-01 .523736E-03 -.113775E-08 .125944E-1
stdev=.167868E-02
(te44d002.fit ... 11-19-95) meandev=.718449E-07

A temperature lag of 0.250 seconds was used for this sensor.

2nd Temp -.715269E-02 .500605E-03 -.246339E-10 .257380E-15
stdev=.397759E-03
(te44d002.fit ... 11-19-95) meandev=.362196E-06
post-cruise -.704266E-02 0.500570E-03 -.244250E-10 0.256205E-15
stdev=.678849E-03
(te44d010.fit ... 05-06-96) meandev=.242432E-06

A temperature lag of 0.40 seconds was used for this sensor.

C.2.5.2.At-sea Pressure Correction:

The pressure reading of the CTD before each station varied from 0.5 to 1.5 dbars on deck. To correct for this bias, the amount was subtracted from the pressure bias term so the calculated pressure read zero at the sea surface at the start of each station.

C.2.5.3.At-sea Conductivity Calibration:

The CTD conductivity data were fit to the water sample conductivity as described in Millard and Yang, 1993. CTD-9's conductivity sensor appeared quite stable. The sensor drifted 0.003 pss over the first 140 stations.

Conductivity Calibration Difficulties:

The I02 data was processed many times with various methods in an effort to compensate for three very subtle issues which begged to be addressed:

1) historesis in conductivity sensor (discussed here)
2) historesis in the pressure transducer (discussed earlier)
3) problem with the digitizer of the conductivity cell

Well into the processing of this data set it became evident that CTD 9, the primary instrument, had a problem with conductivity historesis. Multiple regression fits of the uptrace ctd data to the rosette salts, when applied to the downtrace ctd data, yielded a subtle, yet consistent, .001 discrepancy between the ctd and the rosette data between theta 1,3 and 3.0. This difference is not evident when applying the results of these fits to the uptrace ctd data. There is a subtle historesis in the conductivity sensor.

In an effort to properly calibrate both the uptrace ctd salinity data in the rosette file and the downtrace ctd salinity profiles, different fits were used for each case. The calibrations for ctd salinities in the rosette file were derived from multiple regression fits of the uptrace ctd data to the rosette salts. The calibrations for ctd downtrace salinities were derived from multiple regression fits of downtrace ctd data to the rosette salts.

Beyond this problem, was a problem with the digitizer of the ctd 9 conductivities. Final calibrated data still exibits a mismatch in the down/up salinity that is at the +/- 1 conductivity digitizer unit level which could not be compensated for.

Brief summary of Conductivity Calibration Iterations:

The CTD conductivity data were initially fit to the water sample conductivities as described in Millard and Yang, 1993. Primary CTD 9 stations (166 of 168) were initially treated as a single group. A multiple regression fit of CTD uptrace conductivity data to rosette salt data yielded an initial set of station groupings to use for conductivity calibrations.

Fits to initial groupings yielded a data set with a distinct pressure dependence of the delta (ctd-ws) conductivities. Setting the beta term to 0 resolved most of that issue.

Next, we discovered the pressure historesis problem and reloaded the data with the new D1 and S2 pressure temperature terms as well as the new mean pressure bias. We refit for conductivities with beta=0 and then discovered the subtle conductivity historesis. These fits to the uptrace data, however, with beta=0 are the conductivity calibrations which were applied to the final hydrographic water sample file.

It was necessary, then, to extract down profile ctd conductivities to replace uptrace conductivities in the rosette file for doing new multiple regression fits specific to the downtrace data. When we did this, we discovered that with this new method, there was no pressure dependence of the delta conductivities, and that setting beta equal to zero was like compensating for a problem which did not exist in the downtrace ctd conductivity data. Once again, we refit our station groups with beta back to normal, fitting uptrace rosette data to downtrace ctd data. Results here, except for individual station adjustments, are the final conductivity calibrations applied to the downtrace ctd profiles.

Initially, when processing this data, all processing was done in the PC DOS environment with existing programs. As questions arose and more involved details needed addressing, MATLAB procedures proved valuable for looking at the data. In the end, MATLAB was used to determine conductivity calibrations for this data set allowing comparisons of uptrace and downtrace ctd data in a single working environment. Development of these MATLAB procedures, however, required time and testing.

In summary, fits to the uptrace conductivities were applied to the final SEA file, and fits of extracted downtrace conductivities to the water sample conductivities were applied to the downtrace ctd profiles. This is non-standard processing, but has provided the best information available for both the ctd profiles and final rosette file.

A note about shallow stations 151-158. These stations appear not to match their rosette data as well as surrounding stations. However, the station group used to determine calibrations for these was 134-223 and stations before and after this group match with their rosette data and this data very well. Rather than force the ctd to match the rosette data for these stations, we put faith in the fact that the ctd remained constant and consistent across this shallow group of stations.

RESULTS OF CONDUCTIVITY FITS:

CTD #8: see special note on ctd 8 stations below:

a)

78	-.351557E-01	0.100452E-02	(then add .002 psu)
79	-.351557E-01	0.100452E-02	

CTD #9: primary instrument

Fits of downtrace ctd data to uptrace rosette data applied to down profiles:
Conductivity bias for all ctd 9 stations is -.013 determined from a multiple regression fit to all of the CTD9 data.

a) fit stations 80 slope > 2000 st.dev.=.0007487

77	-.130000E-01	0.997904E-03
80	-.130000E-01	0.997904E-03

b) fit stations 81-109 slope > 2000 st.dev.=.0008664

81	-.130000E-01	0.997904E-03	
82	-.130000E-01	0.997904E-03	
83	-.130000E-01	0.997950E-03	(adj +.0015 add 4.6E-8)
84	-.130000E-01	0.997904E-03	
85	-.130000E-01	0.997904E-03	
86	-.130000E-01	0.997904E-03	
87	-.130000E-01	0.997904E-03	
88	-.130000E-01	0.997904E-03	
89	-.130000E-01	0.997904E-03	
90	-.130000E-01	0.997904E-03	
91	-.130000E-01	0.997904E-03	
92	-.130000E-01	0.997904E-03	

93	-.130000E-01	0.997904E-03	
94	-.130000E-01	0.997904E-03	
95	-.130000E-01	0.997904E-03	
96	-.130000E-01	0.997904E-03	
97	-.130000E-01	0.997904E-03	
98	-.130000E-01	0.997904E-03	
99	-.130000E-01	0.997904E-03	
100	-.130000E-01	0.997904E-03	
101	-.130000E-01	0.997904E-03	
102	-.130000E-01	0.997904E-03	
103	-.130000E-01	0.997904E-03	
104	-.130000E-01	0.997904E-03	
105	-.130000E-01	0.997904E-03	
106	-.130000E-01	0.997904E-03	
107	-.130000E-01	0.997904E-03	
108	-.130000E-01	0.997934E-03	(adj +.001 add 3E-8)
109	-.130000E-01	0.997934E-03	(adj +.001 add 3E-8)

c) fit station 110 slope > 2000 st.dev.=.0007355

110	-.130000E-01	0.998058E-03

d) fit stations 111-135 slope > 2000 st.dev.=,000812

111	-.130000E-01	0.997925E-03	(adj +.001 add 3E-8)
112	-.130000E-01	0.997895E-03	
113	-.130000E-01	0.997895E-03	
114	-.130000E-01	0.997895E-03	
115	-.130000E-01	0.997895E-03	
116	-.130000E-01	0.997895E-03	
117	-.130000E-01	0.997895E-03	
118	-.130000E-01	0.997895E-03	
119	-.130000E-01	0.997895E-03	
120	-.130000E-01	0.997895E-03	
121	-.130000E-01	0.997895E-03	
122	-.130000E-01	0.997895E-03	
123	-.130000E-01	0.997895E-03	
124	-.130000E-01	0.997895E-03	
125	-.130000E-01	0.997895E-03	
126	-.130000E-01	0.997895E-03	
127	-.130000E-01	0.997895E-03	
128	-.130000E-01	0.997895E-03	
129	-.130000E-01	0.997895E-03	
130	-.130000E-01	0.997895E-03	
131	-.130000E-01	0.997895E-03	
132	-.130000E-01	0.997895E-03	

133	-.130000E-01	0.997895E-03
134	-.130000E-01	0.997895E-03
135	-.130000E-01	0.997895E-03

e) fit stations 136-223 st.dep. slope > 2000 st.dev.=0009773

136	-.130000E-01	0.997922E-03
137	-.130000E-01	0.997872E-03
138	-.130000E-01	0.997873E-03
139	-.130000E-01	0.997924E-03
140	-.130000E-01	0.997924E-03
141	-.130000E-01	0.997925E-03
142	-.130000E-01	0.997926E-03
143	-.130000E-01	0.997926E-03
144	-.130000E-01	0.997927E-03
145	-.130000E-01	0.997928E-03
146	-.130000E-01	0.997929E-03
147	-.130000E-01	0.997929E-03
148	-.130000E-01	0.997930E-03
149	-.130000E-01	0.997931E-03
150	-.130000E-01	0.997931E-03
151	-.130000E-01	0.997932E-03
152	-.130000E-01	0.997933E-03
153	-.130000E-01	0.997933E-03
154	-.130000E-01	0.997934E-03
155	-.130000E-01	0.997935E-03
156	-.130000E-01	0.997936E-03
157	-.130000E-01	0.997936E-03
158	-.130000E-01	0.997937E-03
159	-.130000E-01	0.997938E-03
160	-.130000E-01	0.997938E-03
161	-.130000E-01	0.997939E-03
162	-.130000E-01	0.997940E-03
163	-.130000E-01	0.997940E-03
164	-.130000E-01	0.997941E-03
165	-.130000E-01	0.997942E-03
166	-.130000E-01	0.997942E-03
167	-.130000E-01	0.997943E-03
168	-.130000E-01	0.997944E-03
169	-.130000E-01	0.997945E-03
170	-.130000E-01	0.997945E-03
171	-.130000E-01	0.997946E-03
172	-.130000E-01	0.997947E-03
173	-.130000E-01	0.997947E-03
174	-.130000E-01	0.997948E-03

175	-.130000E-01	0.997949E-03	
176	-.130000E-01	0.997949E-03	
177	-.130000E-01	0.997950E-03	
178	-.130000E-01	0.997951E-03	
179	-.130000E-01	0.997952E-03	
180	-.130000E-01	0.997952E-03	
181	-.130000E-01	0.997953E-03	
182	-.130000E-01	0.997954E-03	
183	-.130000E-01	0.997954E-03	
184	-.130000E-01	0.997955E-03	
185	-.130000E-01	0.997956E-03	
186	-.130000E-01	0.997956E-03	
187	-.130000E-01	0.997957E-03	
188	-.669766E-02	1.000345E-03	ictd 1344
189	-.130000E-01	0.997958E-03	
190	-.130000E-01	0.997959E-03	

f) re-fit stations 191-198 slope > 2000 st.dev.=.0007966

191	-.130000E-01	0.997938E-03
192	-.130000E-01	0.997938E-03
193	-.130000E-01	0.997938E-03
194	-.130000E-01	0.997938E-03
195	-.130000E-01	0.997938E-03
196	-.130000E-01	0.997938E-03
197	-.130000E-01	0.997938E-03
198	-.130000E-01	0.997938E-03

199	-.130000E-01	0.997965E-03
200	-.130000E-01	0.997966E-03
201	-.130000E-01	0.997967E-03
202	-.130000E-01	0.997967E-03
203	-.130000E-01	0.997968E-03
204	-.130000E-01	0.997969E-03
205	-.130000E-01	0.997970E-03
206	-.130000E-01	0.997970E-03
207	-.130000E-01	0.997971E-03
208	-.130000E-01	0.997972E-03
209	-.130000E-01	0.997972E-03
210	-.130000E-01	0.997973E-03
211	-.130000E-01	0.997974E-03
212	-.130000E-01	0.997974E-03
213	-.130000E-01	0.997975E-03
214	-.130000E-01	0.997976E-03

215	-.130000E-01	0.997977E-03
216	-.130000E-01	0.997977E-03
217	-.130000E-01	0.997978E-03
218	-.130000E-01	0.997979E-03
219	-.130000E-01	0.997979E-03
220	-.130000E-01	0.997980E-03
221	-.130000E-01	0.997981E-03
222	-.130000E-01	0.997981E-03
223	-.130000E-01	0.997982E-03

g) fit stations 224-226 slope > 2000 st.dev.=0008161

224	-.130000E-01	0.997945E-03
225	-.130000E-01	0.997945E-03
226	-.130000E-01	0.997945E-03

h) fit stations 227-244 st.dep. slope > 2000 st.dev.=.000925

227	-.130000E-01	0.998018E-03	
228	-.130000E-01	0.998015E-03	
229	-.130000E-01	0.998012E-03	
230	-.130000E-01	0.998009E-03	
231	-.130000E-01	0.998006E-03	
232	-.130000E-01	0.998049E-03	(adj +.0015 ad 4.5E-8)
233	-.130000E-01	0.998001E-03	
234	-.130000E-01	0.997998E-03	
235	-.130000E-01	0.997995E-03	
236	-.130000E-01	0.997992E-03	
237	-.130000E-01	0.997989E-03	
238	-.130000E-01	0.997986E-03	
239	-.130000E-01	0.997984E-03	
240	-.130000E-01	0.997981E-03	
241	-.130000E-01	0.997978E-03	
242	-.130000E-01	0.997975E-03	
243	-.130000E-01	0.997972E-03	
244	-.130000E-01	0.997969E-03	

Fits of uptrace ctd data to uptrace rosette data applied to SEA file.

CTD #8:

78	-.351557E-01	0.100452E-02	(then add .002 psu)
79	-.351557E-01	0.100452E-02	

CTD #9:

8/24/97 fitting of stations 80-111

a) fit stations 80-83 slope & bias all / st.dep. slope > 1500

77	-.97646495E-02	0.99780168E-03	
80	-.97646495E-02	0.99780168E-03	st. dev. = .000715
81	-.97646495E-02	0.99782430E-03	
82	-.97646495E-02	0.99784693E-03	
83	-.97646495E-02	0.99786955E-03	

sta 84-92 fit full profile for bias & 99-103 station dep slope > 1500 st. dev. = .000715

b1) fit stations 84-92 99-103 slope & bias all / st.dep. slope > 1500

84	-.72365110E-02	0.99773304E-03
85	-.72365110E-02	0.99773458E-03
86	-.72365110E-02	0.99773613E-03
87	-.72365110E-02	0.99773768E-03
88	-.72365110E-02	0.99773923E-03
89	-.72365110E-02	0.99774078E-03
90	-.72365110E-02	0.99774233E-03
91	-.72365110E-02	0.99774387E-03
92	-.72365110E-02	0.99774542E-03

b2) fit stations 84-92 99-103 slope & bias all / st.dep. slope > 1500

99	-.72365110E-02	0.99775626E-03
100	-.72365110E-02	0.99775781E-03
101	-.72365110E-02	0.99775935E-03
102	-.72365110E-02	0.99776090E-03
103	-.72365110E-02	0.99776245E-03

c) fit stations 93-98 slope and bias all / slope > 1500

93	-.59222312E-02	0.99770399E-03	st. dev. = .000662
94	-.59222312E-02	0.99770399E-03	
95	-.59222312E-02	0.99770399E-03	
96	-.59222312E-02	0.99770399E-03	
97	-.59222312E-02	0.99770399E-03	
98	-.59222312E-02	0.99770399E-03	

d) fit stations 104-105 slope and bias all / slope > 1500

104	-.60349899E-02	0.99770400E-03	st. dev. = .000584
105	-.60349899E-02	0.99770400E-03	

e) fit stations 106-109 slope and bias all / st.dep.slope > 1500 (and apply fit of station 109 to 110 and 111)

106	-.22696049E-02	0.99755894E-03	st. dev. = .000756
107	-.22696049E-02	0.99757846E-03	
108	-.22696049E-02	0.99759798E-03	
109	-.22696049E-02	0.99761750E-03	
110	-.22696049E-02	0.99761750E-03	
111	-.22696049E-02	0.99761750E-03	

sta 112-127 fit full profile for bias ; fit slope > 1500

112	-.633288E-02	0.997708E-03	st. dev. = .000786
113	-.633288E-02	0.997708E-03	
114	-.633288E-02	0.997708E-03	
115	-.633288E-02	0.997708E-03	
116	-.633288E-02	0.997708E-03	
117	-.633288E-02	0.997708E-03	
118	-.633288E-02	0.997708E-03	
119	-.633288E-02	0.997708E-03	
120	-.633288E-02	0.997708E-03	
121	-.633288E-02	0.997708E-03	
122	-.633288E-02	0.997708E-03	
123	-.633288E-02	0.997708E-03	
124	-.633288E-02	0.997708E-03	
125	-.633288E-02	0.997708E-03	
126	-.633288E-02	0.997708E-03	
127	-.633288E-02	0.997708E-03	

10 July 1997
sta 137-151 fit full profile for bias
station dep slope > 1500
stations 128-137 take cals of 137!

128	0.282178E-03	0.997512E-03	st. dev. = .000702
129	0.282178E-03	0.997512E-03	
130	0.282178E-03	0.997512E-03	
131	0.282178E-03	0.997512E-03	
132	0.282178E-03	0.997512E-03	
133	0.282178E-03	0.997512E-03	
134	0.282178E-03	0.997512E-03	

135	0.282178E-03	0.997512E-03
136	0.282178E-03	0.997512E-03
137	0.282178E-03	0.997512E-03
138	0.282178E-03	0.997515E-03
139	0.282178E-03	0.997518E-03
140	0.282178E-03	0.997521E-03
141	0.282178E-03	0.997524E-03
142	0.282178E-03	0.997528E-03
143	0.282178E-03	0.997531E-03
144	0.282178E-03	0.997534E-03
145	0.282178E-03	0.997537E-03
146	0.282178E-03	0.997540E-03
147	0.282178E-03	0.997543E-03
148	0.282178E-03	0.997546E-03
149	0.282178E-03	0.997550E-03
150	0.282178E-03	0.997553E-03

September 1997:
sta 151-158 fit full profile for bias
station dep slope > 1500

151	-.469850E-02	0.997714E-03	st. dev. = .000683
152	-.469850E-02	0.997708E-03	
153	-.469850E-02	0.997702E-03	
154	-.469850E-02	0.997697E-03	
155	-.469850E-02	0.997691E-03	
156	-.469850E-02	0.997685E-03	
157	-.469850E-02	0.997680E-03	
158	-.469850E-02	0.997674E-03	

sta 159-166 fit full profile for bias
station dep slope > 1500

159	0.660155E-03	0.997536E-03	st. dev. = .000679
160	0.660155E-03	0.997536E-03	
161	0.660155E-03	0.997536E-03	
162	0.660155E-03	0.997536E-03	
163	0.660155E-03	0.997536E-03	
164	0.660155E-03	0.997536E-03	
165	0.660155E-03	0.997536E-03	
166	0.660155E-03	0.997536E-03	

sta 167-171 fit full profile for bias
station dep slope > 1500

167	-.774001E-02	0.997788E-03	st. dev. = .000831
168	-.774001E-02	0.997780E-03	
169	-.774001E-02	0.997773E-03	
170	-.774001E-02	0.997765E-03	
171	-.774001E-02	0.997757E-03	

sta 171-178 fit full profile for bias
station dep slope > 1500
apply to stations 172-177!

172	-.318309E-03	0.997545E-03	st. dev. = .000741
173	-.318309E-03	0.997552E-03	
174	-.318309E-03	0.997559E-03	
175	-.318309E-03	0.997565E-03	
176	-.318309E-03	0.997572E-03	
177	-.318309E-03	0.997579E-03	

sta 178-186 fit full profile for bias
station dep slope > 1500
apply to stations 178-182!

178	-.415914E-02	0.997709E-03	st. dev. = .000777
179	-.415914E-02	0.997701E-03	
180	-.415914E-02	0.997694E-03	
181	-.415914E-02	0.997686E-03	
182	-.415914E-02	0.997678E-03	

sta 186-206 fit full profile for bias
station dep slope > 1500
station 183-185 extend station dependence backward from 186!

183	-.615559E-02	0.997685E-03	st. dev. = .000727
184	-.615559E-02	0.997690E-03	
185	-.615559E-02	0.997695E-03	
186	-.615559E-02	0.997700E-03	
187	-.615559E-02	0.997705E-03	
188	-.669766E-02	1.000345E-03	ictd 1344
189	-.615559E-02	0.997715E-03	
190	-.615559E-02	0.997720E-03	
191	-.615559E-02	0.997725E-03	
192	-.615559E-02	0.997730E-03	

193	-.615559E-02	0.997735E-03
194	-.615559E-02	0.997740E-03
195	-.615559E-02	0.997745E-03
196	-.615559E-02	0.997751E-03
197	-.615559E-02	0.997756E-03
198	-.615559E-02	0.997761E-03
199	-.615559E-02	0.997766E-03
200	-.615559E-02	0.997771E-03
201	-.615559E-02	0.997776E-03
202	-.615559E-02	0.997781E-03
203	-.615559E-02	0.997786E-03
204	-.615559E-02	0.997791E-03
205	-.615559E-02	0.997796E-03
206	-.615559E-02	0.997801E-03
207	-.615559E-02	0.997801E-03

sta 208-215 fit full profile for bias
fit slope > 1500

208	-.655756E-02	0.997758E-03	st. dev. = .000787
209	-.655756E-02	0.997758E-03	
210	-.655756E-02	0.997758E-03	
211	-.655756E-02	0.997758E-03	
212	-.655756E-02	0.997758E-03	
213	-.655756E-02	0.997758E-03	
214	-.655756E-02	0.997758E-03	
215	-.655756E-02	0.997758E-03	

sta 115-232 fit full profile for bias
station dep slope > 1500
apply to 216-230 (except 224 & 225)

216	-.669768E-02	0.997767E-03	st. dev. = .000684
217	-.669768E-02	0.997772E-03	
218	-.669768E-02	0.997777E-03	
219	-.669768E-02	0.997781E-03	
220	-.669768E-02	0.997786E-03	
221	-.669768E-02	0.997791E-03	
222	-.669768E-02	0.997795E-03	
223	-.669768E-02	0.997800E-03	
226	-.669768E-02	0.997814E-03	
227	-.669768E-02	0.997819E-03	
228	-.669768E-02	0.997824E-03	
229	-.669768E-02	0.997828E-03	
230	-.669768E-02	0.997833E-03	

sta 224-225 fit full profile for bias
fit slope > 1500

224	-.889504E-02	0.997814E-03	st. dev. = .000501
225	-.889504E-02	0.997814E-03	

sta 231-240 fit full profile for bias
station dep slope > 1500
station 241-244 set to same as 240

231	-.629043E-02	0.997846E-03	st. dev. = .001842
232	-.629043E-02	0.997835E-03	
233	-.629043E-02	0.997823E-03	
234	-.629043E-02	0.997812E-03	
235	-.629043E-02	0.997800E-03	
236	-.629043E-02	0.997789E-03	
237	-.629043E-02	0.997778E-03	
238	-.629043E-02	0.997766E-03	
239	-.629043E-02	0.997755E-03	
240	-.629043E-02	0.997743E-03	
241	-.629043E-02	0.997743E-03	
242	-.629043E-02	0.997743E-03	
243	-.629043E-02	0.997743E-03	
244	-.629043E-02	0.997743E-03	

Special Cases for stations 78, 79 and 188:

CTD #8:

Theta/S plots of CTD 8 stations 78 and 79 are comparable to surrounding CTD 9 stations. These CTD #8 stations were processed at sea. These stations are as they were at cruise end.

78	-.351557E-01	0.100452E-02	(then add .002 psu)
79	-.351557E-01	0.100452E-02	

STA 1078 has two pres/temp bias cals applied and salt manually adjusted. The alternate pres/temp bias is to compensate for a 14 degpres/temp drop at 865 db.. It also, however, alters the calculated pressure by 5 db.

.121813E+03 (c01 bias)
.135813E+03 (c02 bias)

The down profile was scaled with each cal file (C01 and C02). It was then cut and pasted to make one whole file. Up cast is scaled with the second cal (C02); no cut and paste needed. However, resulting salt was too low. We manually add +.002 psu to .ctp .prs and .scl files which became standard input for the final data set.

ICTD 1344: Station 188

Station 188 was processed from the ICTD 1344 data since the sensor caps were left on during CTD 9 sta 188. Scans in the rosette file for sta 188 were also extracted from the ictd. Conductivity calibrations were derived from a fit to the station 188 rosette data.

WATER SAMPLE SALINITY AND OXYGEN DATA:

A complete description of the water sample dissolved oxygen and salinity measurement techniques used during this cruise is presented by Knapp et al. (1990). As described in this report, samples were collected for the analysis of dissolved oxygen and salinity from each of the 24 ten-liter bottles tripped on the upcast of each CTD station, in accordance with the recommendations of the WOCE Hydrographic Office. The vertical distribution of these samples was a compromise between the need to obtain deep samples for the calibration of the CTD conductivity and oxygen sensors and the requirement to define the characteristics of the water masses by the distributions of the various measured parameters.

C.2.5.4. At-sea Oxygen Calibrations:

The CTD oxygen data were fit to the water sample oxygens to determine the six parameters of the oxygen algorithm (Millard and Yang, 1993). As with conductivity, the stations were fit when excessive drift in the sensor was noted. CTD-9's oxygen data, using the same six parameters to calculate oxygen show a drift of only 0.1 ml/l over the first 140 stations.

C.2.6. Quality Control Notes For 2 Decibar CTD Data and .SEA Files

Pressure difference:

On deck difference in CTD-9's pressure between the start and end of cast was consistently close to 4.5 dbars. Comparing the pressure data with the ICTD logging in memory mode, it appears the 4.5 dbar change is occurring as the CTD is warming on the uptrace in the last few hundred meters.

CTD-9 temperature and OTM-1326 difference:

Difference in temperature at depth appears to have remained constant between these two instruments indicating there has been no temperature shift greater than 0.002˚C since the OTM began collecting data on station 1090.

Station 1078, CTD-8:

The oxygen sensor assembly failed during downtrace at 875 dbar. Water had leaked into the assembly molding. Pressure temperature dropped 14˚C, also at 875 dbars. While the oxygen data were not recoverable, the pressure temperature data were corrected by increasing the temperature after the drop by 14˚C. The resulting corrected pressure temperature changed the calculated pressure by 5 dbars.

Station 1079, CTD-8:

The oxygen assembly from ICTD-1344 was put on to CTD-8, however oxygen current and oxygen temperature still did not look good. The oxygen data were unusable. Pressure temperature dropped again just at completion of the station. CTD-8 was removed from the package and replaced with CTD-9.

Station 1090, CTD-9:

OTM-1326 was connected to CTD-9 and successfully collected data through the end of the cruise.

Stations 1100, 1101, 1102, CTD-9:

Conductivity jumped low by 0.008 mmho during downtrace, most noticeably below 2.5˚C potential temperature. Uptrace appeared fine.

Station 1110, CTD-9:

Conductivity drifted low by 0.005 mmho during downtrace, most noticeably below 2.5˚C potential temperature.

Station 1111 to 1174, ICTD-1338:

ICTD-1338 was attached to package and successfully recorded and downloaded data from its internal memory.

Station 1175 to end of cruise, ICTD-1344:

ICTD-1338 was taken off package and replaced with ICTD-1344 and OTM-1372 before station 1175 and used for the remainder of the cruise.

C.3. Bottle Salinity Analysis

A complete description of the salinity measurement techniques used during this cruise is presented in Knapp et al (1990). All measurements were made in a temperature controlled (23˚C) van.

The water sample salinities were collected by one of the CTD watch standers in 200 ml bottles with removable polyethylene inserts and caps. Bottles were rinsed three times, filled to the shoulder and securely capped. Samples were then allowed to reach laboratory temperature, and then measured with a Guildline Autosal Model 8400B salinometer (WHOI no. 11) that was standardized daily with IAPSO Standard Sea Water Batch P-128, dated 18 July 1995. Daily fluctuations of the Autosal standardization were usually less than 0.0002. Long-term drift of the instrument, from the beginning to the end of the cruise was approximately 0.001. The salinity measurements have an accuracy of 0.002.

Jan 7 '96

s77t156.sea — salts, oxygen, (sta 1077 to 1156)
nutrients (sta 1077 to 1156)
cfc (sta 1078 to 1156) (duplicates have mistakenly been labeled bad)
co2 without quality word (sta 1078 to 1156) (sta 1126 corrected)
File does not include final CTD salt and oxygen

Sta 1077 has been reordered from shallowest to deepest.
Sta 1077 does not have the cfcs or co2 merged in.
Sta 1078 CTD pressure has been corrected.
The merging program insists the files being used be ordered from deep to shallow. When reordering is necessary, the whole line of bottle and ctd data is swapped, not just part of it thereby keeping the bottle, and ctd data in tact.
Sta 1104 put bottles 3 and 4 in reverse order so that pressure is decreasing.
Sta 1107 put bottles 5 and 6 in reverse order so that pressure is decreasing.
Sta 1127 had pylon problems. Bottle 22 was tripped at 900db and bottles 23 to 31 are believed to have tripped at 900 as well. It is not clear where the remaining bottles tripped and two of them were leakers. Bottles 32 to 36 were removed from data set. Tags were added to the file for the extra 8 bottles at 900db. The tags are copies of the bottle #22's tag with a .1db change in pressure for each tag to keep each tag distinct.

Jan 19 '96

s157t199.sea — salts, oxygen, (sta 1157 to 1199)
nutrients (sta 1157 to 1199)
cfc (sta 1157 to 1199)
co2 without quality word (sta 1157 to 1199)
File does not include final CTD salt and oxygen

Jan 22 '96

s200t244.sea	salts, oxygen, (sta 1200 to 1244) nutrients (sta 1200 to 1244) cfc (sta 1200 to 1244) co2 without quality word (sta 1200 to 1244) File does not include final CTD salt and oxygen

Jan 22 '96

I2.sea	all the above sea files appended into one file AND the station numbers have been changed to their true numbers (from 77 through 244 to 1077 through 1244)

C.4. Dissolved Oxygen Analysis

A complete description of the dissolved oxygen measurement techniques used during this cruise is presented in Knapp et al (1990). All measurements were made in a temperature controlled (23˚C) van.

Dissolved oxygen samples were also collected by a designated CTD watch stander from each watch. Aliquots of these samples were titrated within fourteen hours of collection. All oxygen reagents were prepared at WHOI in August, 1994, and loaded on the ship when she sailed from Woods Hole. A single batch of sodium bi-iodate standard was also prepared and loaded on the ship at that time. Post-cruise comparison of this standard will be made with a freshly prepared standard when the equipment returns to Woods Hole in March 1996, but based on comparisons made with oxygens measured on earlier legs of the expedition, it does not appear that this standard (17 months old at the end of the cruise) has deteriorated. Accuracy of these dissolved oxygen measurements is 0.5%.

RESULTS OF OXYGEN FITS:

Oxygens were fit in station groupings according to similar characteristics. Groupings were derived from a plot of delta oxygen (ctd-ws) vs. station number where all stations were scaled to a single set of calibrations. The standard deviation of this plot for data below 1000db was 0.0556.Regression fits were typically done to 2.8 standard deviations unless a tighter criteria was required to obtain acceptable results. After arriving at valid oxygen calibration terms, the lag term for all stations was increased to 10 seconds in an attempt to accommodate an incredibly steep temperature gradient in the shallow water.

High quality oxygen profiles were collected for all but 3 stations on this cruise.

CTD 8 stations 77 and 78 have no oxygen data. The oxygen sensor assembly failed on station 77 during downtrace at 875 dbar. Water had leaked into the assembly molding. Pressure temperature dropped 14 deg. C, also at 875 dbars. While the oxygen data were not recoverable, the pressure temperature data were corrected by increasing the temperature after the drop by 14 degrees. The resulting corrected pressure temperature changed the calculated pressure by 5 dbars. On station 79, the oxygen assembly from ICTD-1344 was put on to CTD-8. However oxygen current and oxygen temperature still looked ominous and the oxygen data were unusable. Pressure temperature dropped again just at completion of station 79. CTD-8 was no longer used.

Station 188 (whose profile was processed from ICTD 1344 instead of CTD 9) has no oxygen data. The standard deviation of calibrated CTD oxygens minus water sample oxygens below 1000 db for the entire cruise was 0.0365 (ml/l). There is no overall pressure dependent shape to the delta oxygen (ctd-ws) plot.

Station groupings and fitting results are as follows:

a) fit stations 80-106 to 2.8 st. deviations using 833/949 pts std=.029205 apply to 77,80-106

sta	bias	slope	pcor	tcor	wt	lag
77	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
80	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
81	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
82	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
83	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
84	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
85	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
86	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
87	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
88	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
89	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
90	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
91	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
92	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
93	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
94	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
95	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
96	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
97	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
98	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
99	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
100	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02

101	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
102	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
103	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
104	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
105	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02
106	-.900000E-02	0.139400E-02	0.146500E-03	-.294000E-01	0.620000E+00	0.100000E+02

b) fit stations 107-110 to 2.8 st. deviations using 127/139 pts std=.02262

sta	bias	slope	pcor	tcor	wt	lag
107	-.600000E-02	0.137900E-02	0.146100E-03	-.303000E-01	0.530000E+00	0.100000E+02
108	-.600000E-02	0.137900E-02	0.146100E-03	-.303000E-01	0.530000E+00	0.100000E+02
109	-.600000E-02	0.137900E-02	0.146100E-03	-.303000E-01	0.530000E+00	0.100000E+02
110	-.600000E-02	0.137900E-02	0.146100E-03	-.303000E-01	0.530000E+00	0.100000E+02

c) fit stations 111-114 to 2.5 st. deviations using 128/140 pts std=.02342

sta	bias	slope	pcor	tcor	wt	lag
111	-.900000E-02	0.141000E-02	0.144100E-03	-.296000E-01	0.670000E+00	0.100000E+02
112	-.900000E-02	0.141000E-02	0.144100E-03	-.296000E-01	0.670000E+00	0.100000E+02
113	-.900000E-02	0.141000E-02	0.144100E-03	-.296000E-01	0.670000E+00	0.100000E+02
114	-.900000E-02	0.141000E-02	0.144100E-03	-.296000E-01	0.670000E+00	0.100000E+02
115	-.900000E-02	0.141000E-02	0.144100E-03	-.296000E-01	0.670000E+00	0.100000E+02

d) fit stations 116-121 to 2.8 st. deviations using 177/202 pts std=.01996 fitting for station dependent bias term.

sta	bias	slope	pcor	tcor	wt	lag
116	-.250000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02
117	-.220000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02
118	-.200000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02
119	-.170000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02
120	-.150000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02
121	-.120000E-02	0.139500E-02	0.143400E-03	-.291000E-01	0.680000E+00	0.100000E+02

e) fit stations 122-126 to 2.0 st. deviations using 135/169 pts std=.01400

sta	bias	slope	pcor	tcor	wt	lag
122	-.400000E-02	0.140100E-02	0.144500E-03	-.292000E-01	0.700000E+00	0.100000E+02
123	-.400000E-02	0.140100E-02	0.144500E-03	-.292000E-01	0.700000E+00	0.100000E+02
124	-.400000E-02	0.140100E-02	0.144500E-03	-.292000E-01	0.700000E+00	0.100000E+02
125	-.400000E-02	0.140100E-02	0.144500E-03	-.292000E-01	0.700000E+00	0.100000E+02
126	-.400000E-02	0.140100E-02	0.144500E-03	-.292000E-01	0.700000E+00	0.100000E+02

f) fit stations 127-138 to 2.5 st. deviations using 355/414 pts std=.01936

sta	bias	slope	pcor	tcor	wt	lag
127	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
128	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
129	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
130	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
131	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
132	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
133	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
134	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
135	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
136	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
137	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02
138	-.300000E-02	0.138600E-02	0.144200E-03	-.287000E-01	0.690000E+00	0.100000E+02

g) fit stations 139-144 to 2.5 st. deviations using 178/208 pts std=.02282

sta	bias	slope	pcor	tcor	wt	lag
139	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02
140	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02
141	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02
142	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02
143	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02
144	-.500000E-02	0.141200E-02	0.144100E-03	-.286000E-01	0.720000E+00	0.100000E+02

h) fit stations 145-155 to 2.5 st. deviations using 255/324 pts std=.02000

sta	bias	slope	pcor	tcor	wt	lag
145	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
146	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
147	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
148	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
149	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
150	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
151	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
152	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
153	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
154	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02
155	-.700000E-02	0.144100E-02	0.142900E-03	-.295000E-01	0.670000E+00	0.100000E+02

i) fit stations 156-191 to 2.5 st. deviations using 897/1085 pts std=.02957

sta	bias	slope	pcor	tcor	wt	lag
156	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
157	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
158	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
159	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
160	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
161	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
162	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
163	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
164	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
165	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
166	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
167	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
168	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
169	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
170	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
171	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
172	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
173	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
174	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
175	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
176	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
177	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
178	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
179	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
180	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
181	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
182	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
183	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
184	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
185	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
186	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
187	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
189	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
190	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02
191	-.800000E-02	0.143700E-02	0.142600E-03	-.294000E-01	0.730000E+00	0.100000E+02

j) fit stations 192-197 to 2.0 st. deviations using 116/181 pts std=.02331

sta	bias	slope	pcor	tcor	wt	lag
192	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02
193	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02
194	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02
195	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02
196	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02
197	-.140000E-01	0.142800E-02	0.148100E-03	-.288000E-01	0.760000E+00	0.100000E+02

k) fit stations 198-214 to 2.5 st. deviations using 413/547 pts std=.03565

sta	bias	slope	pcor	tcor	wt	lag
198	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
199	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
200	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
201	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
202	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
203	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
204	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
205	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
206	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
207	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
208	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
209	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
210	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
211	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
212	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
213	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02
214	-.600000E-02	0.139500E-02	0.146800E-03	-.289000E-01	0.670000E+00	0.100000E+02

l) fit stations 215-223 to 2.5 st. deviations using 175/226 pts std=.04467

sta	bias	slope	pcor	tcor	wt	lag
215	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
216	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
217	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
218	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
219	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
220	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
221	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
222	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02
223	0.200000E-02	0.136800E-02	0.145200E-03	-.287000E-01	0.680000E+00	0.100000E+02

m) fit stations 224-231 to 2.5 st. deviations using 228/275 pts std=.04144

sta	bias	slope	pcor	tcor	wt	lag
224	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
225	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
226	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
227	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
228	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
229	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
230	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
231	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
232	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
233	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
234	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
235	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
236	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
237	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
238	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
239	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
240	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
241	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
242	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
243	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02
244	-.140000E-01	0.146300E-02	0.143500E-03	-.292000E-01	0.770000E+00	0.100000E+02

C.6. Nutrient Analyses

C.6.1. Equipment and Techniques

The analyses were performed using a Technicon AutoAnalyzer II (AAII) which is the property of Scripps Institution of Oceanography's Oceanographic Data Facility (ODF). This AutoAnalyzer has been used throughout the Indian Ocean WOCE Programme. A Keithley model 575 data acquisition system was used in parallel with analog stripchart recorders to acquire the absorbance data. The software used to process the nutrient data was developed at OSU. All of the reagent and standard materials were provided by OSU. The analytical methods are described in Gordon et al (1994).

C.6.2. Sampling Procedures:

Nutrient samples were drawn from all CTD/rosette casts at stations 1077 to 1244. High density polyethylene (HDPE) centrifuge tubes of approximately 50 mL volume were used as sample containers, and these same tubes were positioned directly in the autosampler tray. These sample tubes were routinely rinsed at least 3 times with one half to full volume of sample before filling. Sample tubes were rinsed twice with deionized water after sample runs, and were soaked in 10% HCl every other day. The nutrient samples were drawn following those for CFCs, helium, tritium, dissolved oxygen, carbon dioxide, alkalinity and salinity. At most stations, the AAII sample run was started before sampling was completed to reduce delay and minimize possible changes in nutrient concentration due to biological processes.

C.6.3. Calibration and Standardization:

Calibration standards for the nutrient analyses were prepared from high purity preweighed crystalline standard materials. The materials used were:

Phosphate standard: J.T. Baker potassium di-hydrogen phosphate lot 3246.

Nitrate standard: Alfa potassium nitrate lot 121881.

Silicic acid standard: J. T. Baker sodium silicofluoride lot 21078 10A.

Nitrite standard: MCB sodium nitrite lot 4205.

The volumetric flasks and pipettors used to prepare standards were gravimetrically calibrated prior to the cruise. The Eppendorf Maxipettor adjustable pipettors used to prepare mixed standards typically have a standard deviation of less than 0.002 mL on repeated deliveries of 10 mL volumes. High concentration mixed standards containing nitrate, phosphate, and silicic acid were prepared at intervals of 7 to 10 days and kept refrigerated in HDPE bottles. For almost every station, a fresh "working standard" was prepared by adding aliquots of the high concentration mixed standard to low nutrient seawater. This working standard has nutrient concentrations similar to those found in Deep and Bottom waters. A separate nitrite standard solution was also added to these working standards. Corrections for the actual volumes of the flasks and pipettors were included in the preliminary data. The WOCE Operations Manual calls for nutrient concentrations to be reported in units of micromole/Kg. Because the salinity information required to compute density is not usually available at the time of initial computation of the nutrient concentrations, our concentrations are always originally computed as micromole/L. This unit conversion will be made using the corrected salinity data when it is available. Due to some problems with the nitrite analysis (see below), the nitrate values from station 1168 on reported in the .nut files include also nitrite. These values will be replaced later on after the appropriate correction is applied.

C.6.4. Measurement of Precision and Bias:

C.6.4.1.Short Term Precision and Bias:

Throughout the cruise, replicate samples drawn in different sample tubes from the same Niskin bottle were analyzed to assess the precision of the AAII analyses. These replicate samples were analyzed both as adjacent samples (one after the other) and also at the beginning and end of sample runs to monitor deterioration in the samples or uncompensated instrumental drift. When the post cruise QC work is completed, these replicate analyses will be used to estimate short term precision and instrumental drift.

C.6.4.2. Longer Term Precision:

On most of the sample runs during I02, an "old" working standard from the previous station was run with the "new" working standard which had been freshly prepared. The "old" standards were kept refrigerated in plastic bottles. The average age of the "old" standards when reanalyzed was four to eight hours. The differences between these standards will be analyzed to assess the precision of standard preparation and handling and inter-station precision.

C.6.5. Comparison with other data, long term precision and bias:.

There were several crossings of other Indian Ocean WOCE lines along the I02 cruise track. Detailed comparisons with the nutrient data from these sections will be made after the post cruise QC work is complete.

C.6.6. Nutrient Quality Control Notes:

During the I02 cruise, no flagging of the nutrient data was performed, except for those bottles that were obvious leakers and for bottles whose values are average of two replicates. It is expected that during the post cruise QC work, questionable data can be corrected. In some stations the silicate analysis showed abnormally high values. These were due to an aberrant increase in the difference of the absorbance between the matrix (we use low nutrient seawater and distilled water, 25:1) and the distilled water reagent blank. The cause of this increase appears related to the presence of the surfactant used to decrease the noise in the absorbances and the sampler valving system. This actual process of this phenomenon is not clearly understood. However, it is possible to quantify the increase in values so a correction may be applied. There is an "ideal" LNSW-DDW value of ca. 12 absorbance units rather than the aberrant 20-40 we infrequently encountered. The nitrite analysis also showed problems. Beginning with station 1168, no nitrite values were reported. Artificially high values through the entire water column were obtained. Because those values do not really exist except for a couple near the surface, the subtraction of these values from the nitrite+nitrate analysis in order to get nitrate values would result in lower nitrate than the actual values. The nitrite correction will be reviewed at OSU and will be applied accordingly.

C.7. CFC-11 and CFC-12 Analyses

The transient tracers CFC-11 and CFC-12 were measured as a part of the overall program of measurements on WOCE leg I02. The technique to use CFC's to help describe ocean circulation is described in Gammon et al. (1981) and Bullister and Weiss (1983).

C.7.1. Sample Collection

Samples were collected at depth using 10 liter Niskin bottles. Aliquots of seawater were transferred to 100 cm^3 precision ground-glass syringes for the CFC analysis. Owing to the short length of time between legs I-10 and I-2 (3 days), cleaning of the Niskin bottles and o-rings was not necessary. All the 36 bottles in use remained outside on deck throughout the cruise. None of them showed CFC contamination during the cruise.

C.7.2. Equipment and Methods

Chlorofluorocarbons CFC-11 and CFC-12 were measured on a total of 158 stations. The analytical procedure is described by Bullister and Weiss (1988). Trapping is done on a length of 1/8 in. o.d. ss tubing packed with 5cm of Porasil C (80/100 mesh) and 5cm 0f Porapak T (80/100 mesh) cooled to -30˚C using an ethanol bath cooled by a Neslab Cryocool. The trapped sample is desorbed using a 100˚C water bath. A Shimadzu Mini-II GC is used to analyze the samples. It contains a 15cm precolumn and a 3m analytical column, both are 1/8 in o.d. stainless steel and are packed with 80/1 00 mesh Porasil C. Water samples are stored for analysis in a flow-through bath under clean sea water, after being drawn from the Niskin bottles. The analyses were completed typically within 5-10 hours of the sample collection, which is immediately after the CTD and rosette are brought on board. Air samples were run every 2 or 3 days from an air intake high up on the foremast and pumped from there to the lab van through a single length of Dekoron tubing using an Air Cadet diaphragm pump.

C.7.3. Calibration

Calibration curves used for determining CFC concentrations in air and water samples are generated by injection of various known volumes of standard gas. The calibration curves spanned the range of CFC concentrations in both the air and water samples. The standard is "clean" compressed air collected in the marine boundary layer and stored in Scott Aculife cylinders. The gas standard was calibrated at PMEL in Seattle WA. Intercalibrations of our standards have been carried out with other labs involved in WOCE.

C.7.4. Data

Data were reported as specified in the WOCE Operations Manual, WHP Office Report WHPO 91-1. Data were compared to historical data whenever possible. Historical data as well as real time observations were used as a guide for developing sampling strategies.

C.8. Helium and Tritium Sampling

During the I02 leg of WOCE Indian Ocean 370 helium/tritium sample pairs, one each helium and tritium taken from same bottle, were taken on 32 stations. The station spacing was approximately every 5 degrees of longitude along the 8˚S line. The spacing was reduced to approximately every 1.5 degrees on the eastern and western boundaries and on the two short meridional lines near 88˚ & 72˚E. These last two lines were sampled to further augment the overall spatial distribution of helium/tritium in the upper water column. The vertical distribution of the sampling was as follows: one station of 16 bottles sampled down to 1000m depth, followed by 8 bottle sampling down to a depth of 500m on the next helium/tritium station. On these same stations the deep helium sampling started where shallow helium/tritium ended to give complete helium profiles. This pattern of alternating 500m them 1000m samplings was carried out the whole length of the 8˚S line including boundaries. The processing of the helium and tritium samples was carried out on board using "standard" high vacuum techniques. Both the helium extraction and the tritium degassing procedures involved using rotary mechanical pumps to achieve rough vacuum followed by diffusion pumping. The Varian pumps were charged with a poly phenyl ether based oil (Santovac 5), in conjunction with a cryogenic trapping of the water vapor. This procedure achieves pressures in the low to mid x10^-7 torr range. Once this starting pressure was reached on the all stainless steel vacuum system the samples were introduced into the system. The helium extraction was carried out using water vapor pumping as the means to strip and contain the helium sample until it could be sealed in a glass ampoule for storage. The tritum degassing system uses the same principle, water vapor pumping of the head space above the sample, stripping it of all gases, then shaking of the water sample to reequilibrate the head space. This procedure of stripping and reequilibration is repeated until head space pressure are in the low x10^-6 torr range. At this point the remaining degassed water sample is sealed in a glass bulb for storage. The helium and tritium samples are then transported back to the Helium Isotope Laboratory at the Woods Hole Oceanographic Institution for analysis by mass spectrometry.

C.9. Deep Helium Sampling Report

C.9.1 Sampling

Eight hundred and sixteen deep helium samples were collected from Niskin bottles in stainless steel cylinders which are approximately 40 ml in volume. A total of 53 stations were sampled, spaced two degrees apart, with one degree spacing across spreading zones and through flow areas. Sixteen samples were taken at each station in an array between 1000 meters depth and the bottom of the cast. In some cases the sea floor was too shallow to permit sixteen samples, so all bottles fired in the given interval were sampled.

C.9.2 Sample preparation methods

Each water sample was stripped of dissolved gases using both high and ultra high vacuum technologies. A rotary pump was used to create the initial high vacuum (approximately 5.0 E-3 torr) and an oil diffusion pump using Santovac 5 (pentaphenyl ether) was used to create the ultra high vacuum (approximately 5.0 E-7 torr). A "water vapor pump" was created by applying a temperature gradient of 100 degrees across the evacuated space. The dissolved gases were pumped into glass ampoules and held there by the resulting pressure gradient until the ampoules were closed by flame sealing. The ampoules are being shipped back to the Lamont-Doherty Earth Observatory for analysis by mass spectrometer.

C.10. Radiocarbon Sampling

The Princeton University Ocean Tracers Lab was responsible for collecting samples for carbon 14 analysis on WOCE line I02. The data from this line together with data from the far western Pacific and other WOCE Indian Ocean lines will be used to characterize the water masses at particular points of interest. Such points include mapping the through flow of the deep boundary current along the 90˚E Ridge, the deep flow around 3o 00'S across the Chagos-Laccadive Ridge and a mapping of the northern branch of the South Equatorial Current. This was a detailed leg and other locations were documented as well. Six hundred and fifty five samples were collected at 29 stations on this line. Full water profiles were collected at 14 stations; shallow profiles, 1800m or less, were collected at 15 stations. The samples will be analyzed at a later date in the land based Atomic Mass Spectrometry lab at Woods Hole Oceanographic Institution.

C.11. Radium Sampling

As a side project the Princeton University Ocean Tracers Lab has been collecting surface samples at various stations along the I02 track for analysis of radium 226 and 228. Samples are collected on stations of depths greater than 2500m to give the fiber, for 228 measurement, time to soak. Samples are collected about once a day if they are deep enough. The method for collection is as follows. For the surface soak, fiber is placed in a flow through, netted, cloth bag and cast over the side attached to a string on the ship. It soaks for the duration of the station and is then brought up, placed in a baggie, which is labeled and stored for shipment back to the Ocean Tracers Lab for processing and analysis. This is a large volume sample. Small volume samples are placed in 7 x 3/4 inch clear plastic tubes. A 25 liter jug with a spigot is then filled with surface water collected with a bucket cast over the side. The fiber tube is attached to the spigot with a flexible tube and the water in the jug is trickled through the fiber over an 8 to 12 hour period. When this is done this sample is also placed in a baggie, labeled and stored for shipment back to the lab. For LV (large volume) samples the fiber is leached and formed into a precipitate which is put into a small tube and measured in a gamma counter. SV samples are measured on a radon board by forcing gas through and measuring decay counts in special cells with photaic properties. The fiber is actually acrylic fiber that has been "cooked" at 100o C in potassium permanganate. The radium attaches to the manganate, and thus the reason long soaking times are needed. About 30 samples each of SV and LV were collected on I02 for later analysis back at Princeton.

C.12. Total CO2 and Alkalinity Analyses

C.12.1 Overall Objective:

Documentation of the CO2 partial pressure, total inorganic carbon content and alkalinity of the ocean to discern the forces modulating rise in atmospheric CO2. These parameters were measured in conjunction with the overall program of measurements for the WOCE I02 leg.

C.12.2 Sample Collection:

Documentation of the CO2 partial pressure, total inorganic carbon content and alkalinity of the ocean to discern the forces modulating rise in atmospheric CO2. These parameters were measured in conjunction with the overall program of measurements for the WOCE I02 leg.

C.12.3 Equipment and Methods:

Total inorganic carbon (TCO2) and total alkalinity (TA) were measured on a total of 166 stations (75 full profiles/91 surface). A total of 3001 samples were analyzed for TCO2 (including replicates). A total of 3070 samples were analyzed for TA (including replicates). The analytical techniques employed are described in Dickson and Goyet (1994). A short description is as follows:

TCO2- A known amount of seawater is dispensed into a stripping chamber, where it is acidified and purged with an inert gas. This gas stream is coulometrically titrated and compared to known amounts of CO2 gas. The final concentration is expressed in micromole/Kg of seawater.

TA- A known amount of seawater is placed in a closed, thermostated, titration cell and titrated with a solution of hydrochloric acid. The titration is monitored by using a glass electrode/reference electrode and a non-linear least squares approach is applied to the resultant e.m.f. data. The final concentration is expressed in micromole/kg of seawater.

C.12.4Data:

Data were reported as specified in the WOCE Operations Manual, WHP Office Report WHPO 91-1. Internal Data Quality Indicators incorporated into the sampling plan included field replicates and Certified Reference Materials. Review of these data indicated that the instrumentation performed within acceptable control limits throughout the cruise. The few minor instrumentation difficulties encountered during the cruise were quickly fixed and did not impact our ability to adhere to our original sampling/analysis scheme.

D. Acknowledgments

We are indebted to the officers and crew of R/V Knorr for their good-natured and unflagging support for the scientific work on the I02 leg of the WOCE Hydrographic Program Indian Ocean Expedition. The good spirit of the entire ship's company throughout this long voyage contributed greatly to making it such a pleasant and successful one.

E. References

Bullister, J. L. and R. F. Weiss. 1983. Anthropogenic chlorofluoromethanes in the Greenland and Norwegian Seas. Science, Vol. 221, pp. 265-268.

Bullister, J. L. and R. F. Weiss. 1988. Determination of CCl3F and CCl2F2 in sea water and air. Deep-Sea Research, Vol. 35, No. 5, pp. 839-853.

Dickson, A.G. and C. Goyet. 1994. Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water, Ver.2. DOE.

Fisher, J. and M. Visbeck. 1993. Deep velocity profiling with self-contained ADCPs. J. Atmos. Oceanic Technol., 10, 764-773.

Gammon, R. H., J. D. Cline and D. P. Wisegarver. 1981. Chlorofluoromethanes in the Northeast Pacific Ocean: measured vertical distributions and application as transient tracers of upper ocean mixing. Journal of Geophysical Research, Vol. 87, pp. 9441-9454.

Gordon, L. I., J. C. Jennings, Jr., A. A. Ross and J. M. Krest. 1994. A suggested protocol for continuous flow automated analysis of seawater nutrients (phosphate, nitrate, nitrite and silicic acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study. In WOCE Operations Manual, WOCE Report No. 68/91. Revision 1, 1994.

Knapp, G. P., M.C. Stalcup & R.J. Stanley. 1990. Automated Oxygen Titration and Salinity Determination. Woods Hole Oceanographic Institution Tech. Rep. WHOI-90-33, 25 pages.

Millard, R. C. and K. Yang. 1993. CTD Calibration and Processing Methods Used At Woods Hole Oceanographic Institution. Woods Hole Oceanographic Institution Tech. Rep. WHOI-93-44, 96 pages.

Oceansoft MKIII/SCTD Acquisition Software Manual. 1990. P/N Manual 10239. EG&G Marine Instruments.

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

F. Figure Captions

Figure 1. WOCE Hydrographic Program Section I02 station locations (dots) with the 3000m isobath. Every fifth station number is shown for clarity.

Figure 2. Vertical section of bottle positions for WOCE Hydrographic Program Section I02. Vertical exaggeration is 750:1. the longitude locations (˚E) are plotted parametrically along the bottom axis. The station locations are plotted parametrically along the top axis. the bathymetry is plotted only at station locations.

8 July 1997

I02 QC Report: Nutrients

I Methods

The analysts, from Oregon State University (OSU) used an analytical system based upon the Technicon Industrial AutoAnalyzer II (AAII). The Oceanographic Data Facility (ODF) of the Scripps Institution of Oceanography furnished the system. It contained an autosampler developed and constructed at ODF. A Keithley data acquisition system (DAS), model 575, digitized the analog absorbance data. OSU's software, DATABEEP, controlled the DAS and stored the data in digital format. The absorbance data were converted to concentrations using OSU's NUTCALC software. The OSU group supplied all calibration standards, chemical reagents and other consumables. Gordon et al. (1994) described the protocols used.

The nutrient analysts sampled all CTD/rosette casts at stations 1077 to 1244 using nominal 50 ml HDPE centrifuge tubes after rinsing at least three times with at least 20 ml of sample. Without any additional transfers these tubes were placed in the ODF autosampler. Nutrient sampling followed that for CFC, helium, tritium, dissolved oxygen, carbon dioxide, alkalinity and, in some cases, salinity. When possible the analysts started the AAII system before sampling to keep sample degradation to a minimum. In many cases difficulties with the silicate analysis delayed the actual beginning of the analytical run by more than an hour. (See "Problems" section, this document). Following analysis the sample tubes were rinsed twice with deionized water (DIW) and soaked every other day in 10% hydrochloric acid.

II. Instrument calibration

For reagent blanks the analysts used DIW prepared using a Barnstead Nanopure deionizer with feed water from the ship's evaporator. The NUTCALC program applied corrections for the difference in refractive index between DIW and seawater. The calibration standards were prepared in a matrix solution consisting of aged, low-nutrient surface seawater and appropriate aliquots of primary and secondary calibration solutions. The OSU calibration protocols followed those of Gordon et al. (1994) including comparison with "matrix solutions." The matrix solutions consisted of the same natural, low-nutrient seawater, filtered and aged, as used to make up the working, calibration standard solutions but to which no nutrient stock standards were added. To prepare the primary calibration solutions the analysts used high purity dried and pre-weighed, crystalline standard materials. They employed the sequence of sequential, stock, calibration solutions as outlined in the protocol by Gordon et al. (1994). The crystalline materials can be traced to US-NIST, primary standard materials. The silicate standard material can be traced to ultra-high purity, silicon dioxide used in the semiconductor industry and to an ultra-high purity silicon metal sample provided by Dr. Shier Berman, Director of Environmental Measurement

Science, National Research Council, Canada. The analysts used the following, specific materials:

Phosphate standard: J.T. Baker potassium di-hydrogen phosphate lot 3246.
Nitrate standard: Alfa potassium nitrate lot 121881.
Silicic acid standard: J. T. Baker sodium silicofluoride lot 21078 10A.
Nitrite standard: MCB sodium nitrite lot 4205.

Eppendorf Maxipettors were used to make up the calibration standards and all volumetric ware had been gravimetrically calibrated prior to the expedition. The primary calibration solutions contained nitrate, phosphate and silicate (silicic acid) at concentrations designed to approximate deep-water concentrations in the final, working calibration solutions. The analysts added aliquots of nitrite primary solutions directly to the final, working calibration solutions. They prepared the working calibration solutions immediately before analyzing each station's samples in almost all cases. They stored the primary and intermediate calibration solutions in the refrigerator when not in use.

The data supplied to the WOCE Hydrographic Programme Office are in units of micromoles per liter. They must be converted to micromoles per kg when the salinity data can be used, together with the laboratory temperature of 25 Ò3C to calculate the sample densities needed.

III. Precision and bias

The analysts drew replicate samples at each cast for measurement of short-term precision on the order of minutes to one or two hours). They placed the replicates both adjacent to each other and separated by the rest of the samples of each run.

As a quality control measure to monitor the stability of working-standard, calibration solutions they kept the preparation left over after most stations to compare with that prepared for the next. Typical time lags between preparations amounted to four to eight hours.

The analysts achieved the WOCE specifications for precision for phosphate and nitrate in virtually all cases. Only a very few cases as noted later exceeded these specifications. Instrumental problems introduced very severe problems into the silicate and nitrite analyses for many stations throughout the leg. Because of its low concentrations most of the time, the nitrite problems presented only relatively minor challenges to evaluate and correct the errors.

The silicate problems affected as many as 30% of the stations. The magnitude of the errors was typically 1 - 4 % and required a great deal of post-cruise data workup to evaluate and correct the data. When finished, for the most part, we achieved between station precision in the deep-water values of ca. one per cent. We were able to salvage most of the data and note where this was possible and where not. Although there are no WOCE specifications for accuracy in the nutrient analyses, we urge users of this data set to be cautious in use of the silicate data! We are available to consult with users of these data on the problems and probable errors.

Following the post cruise data editing we computed estimates of short-term (within station) precision by examining a random subset of the replicate sample determinations. These estimates are given below for phosphate, nitrate and silicate. They report the absolute mean difference between deep water samples run at the beginning of a sample run and rerun again at the end in units of micro moles per liter.

Analysis:	phosphate	nitrate	silicate
Mean difference	0.0148	0.123	0.44
Stnd deviation	0.0090	0.093	0.26

For nitrite, we estimate the precision for stations 1077 - 1166 to be ca. 0.003 micromoles per liter.

IV. Problems

There were no major equipment failures in the AAII system, but there were two significant analytical problems with the silicic acid and nitrite data. The analysts at sea were aware of these problems but were unable to resolve them satisfactorily during the cruise. The problems and the post-cruise treatment of the data follow.

A. Silicate:

The silicate problem resulted from an anomalous response when the AAII was switched from deionized water to seawater, with the initial seawater absorbance being unusually high and tapering off over time. This occurred at the beginning of the sample run for many stations. Our calibration standards were prepared in low nutrient seawater and corrected for the absorbance due to the seawater alone, leading to the standards being over corrected. The computed sample concentrations were then erroneously high. The magnitude of the error was ca. 1 to 4 (M. We have attempted to reproduce this problem in the lab, but have been unable to do so; the cause remains unknown.

To correct the problem, we chose and objective approach based on our experience of the constancy of nutrient concentrations in aged LNSW. The silicate concentration of LNSW should be quite constant over time, yet in the affected stations it was apparently changing within the time span of a sample run (< 2hours). We plotted the seawater (LNSW) absorbance minus deionized water (DIW) absorbance at the start and finish of each sample run. Normally, this absorbance arises from small amounts of silicate present in the LNSW and from optical effects; it should be constant for any given batch of LNSW. For stations where the apparent LNSW silicate concentration was more than 1.0 (M too large, we corrected the LNSW absorbances to equal the mean low values for the appropriate batch of LNSW. This lowered the calculated silicate concentrations at the questionable stations and resulted in much improved grouping of theta/silicate plots.

Fifty-one stations were recalculated after editing to correct the anomalous LNSW readings in the silicate channel.

B. Nitrite

The second significant analytical problem involved apparent shifts in the response of the nitrite channel, usually following the calibration standards run at the start of each sample run. These shifts led to anomalously high apparent nitrite concentrations in the deep water, often accompanied by obvious and non-linear drift in the absorbance signal. The analysts at sea recognized the problem but were unable to eliminate the drift, so they elected to cease reporting nitrite concentrations following station 1166.

Post cruise inspection of the AAII stripchart recordings showed that the deep-water nitrite samples all had essentially the same absorbance. Since deep-water nitrite concentrations are expected to be essentially zero, the wandering nature of the deepwater absorbance peaks is obviously erroneous. Therefore we edited all deep-water concentrations to zero for stations 1166 - 1244. Where primary and secondary nitrite maxima clearly appeared, at shallower depths, we calculated nitrite concentrations using the differences in absorbances of these peaks from the apparent seawater background of the adjacent samples. Our acceptance criterion for "zero" nitrite concentration was 0.1 ÊM.

V. References

Gordon, L. I., J. C. Jennings, Jr., A. A. Ross and J. M. Krest. 1994. A suggested protocol for continuous flow automated analysis of seawater nutrients (phosphate, nitrate, nitrite and silicic acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study. In WOCE Operations Manual, WOCE Report No. 68/91. Revision 1, 1994.

VI. Post cruise data editing:

Silicate concentrations were recalculated for the following stations after editing anomalous LNSW responses described previously in this document, and for station 1166 for a problem unrelated to the LNSW response

1077	1078	1079
1080	1081	1084
1093	1103	1108
1109	1110	1115
1116	1122	1123
1131	1134	1135
1144	1145	1146
1147	1148	1157

1158	1160	1162
1163	1164	1165
1180	1181	1182
1183	1187	1188
1190	1191	1192
1201	1202	1211
1224	1226	1228
1229	1230	1231
1236	1237	1238

Nitrate concentrations were recalculated for the following stations. The problems were mostly due to inconsistent (noisy) readings by the data acquisition system.

1102	1113	1115
1119	1127	1135
1136	1139	1144
1157	1159	1163
1165	1200	1205
1206	1210	1213

1224 1225

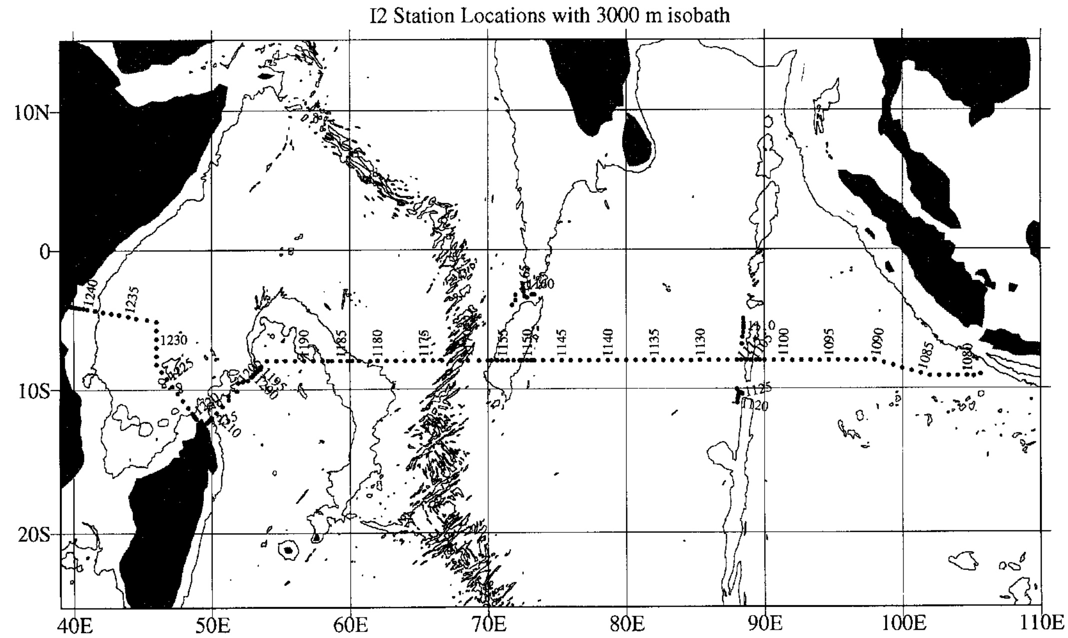
Phosphate concentrations were recalculated at the following stations.

1136	1142	1143
1144	1175	1179

1180 1190

In addition to the nitrite problems described earlier, the following stations were recalculated with minor editing after the cruise.

1144	1163	1164



I2 Station Locations with 3000 m isobath
10N
0
10S
20S
40E
50E
60E
70E
80E
90E
100E
110E

Figure 1

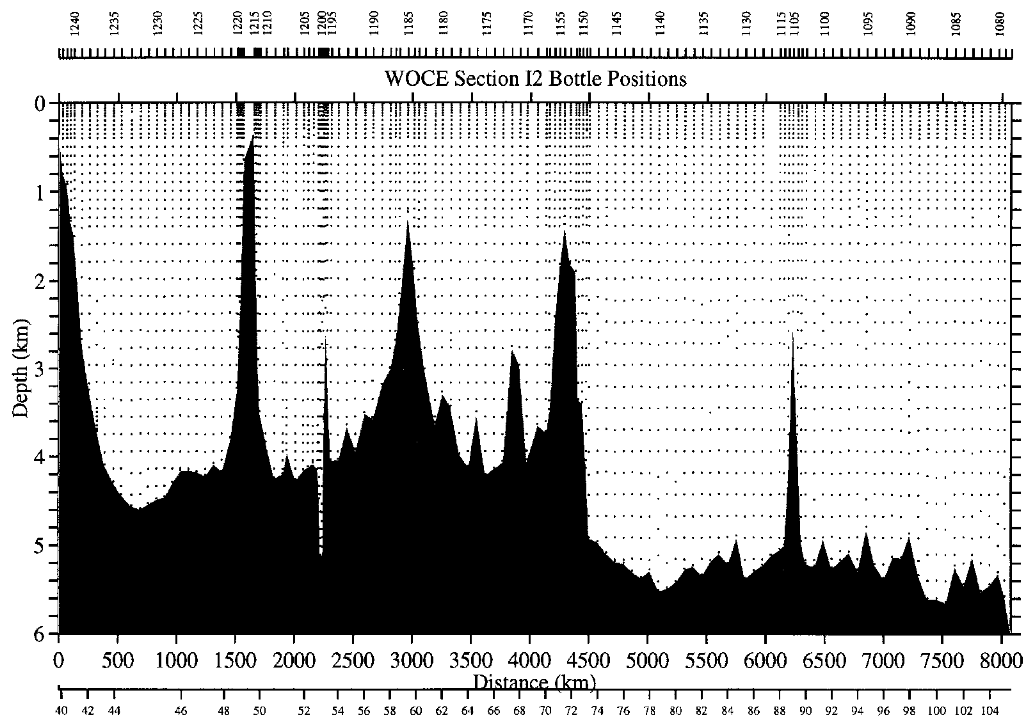


Figure 2