WHP Cruise Summary Information

WOCE section designation	P18 (N and S)
Expedition designation (EXPOCODE)	31DSCG94_2-3
Chief Scientist(s) and their affiliation	Bruce Taft, NOAA/PMEL (leg 2); Gregory Johnson, NOAA/PMEL (leg 3)
Dates	1994.02.22–1994.03.24 (leg 2) 1994.03.29–1994.04.27 (leg 3)
Ship	DISCOVERER
Ports of call	Punta Arenas, Chile to Easter Island, Chile to San Diego, California, USA
Number of stations	78 (leg 2), 107 (leg 3)
Geographic boundaries of the stations	22°51.10''N 102°57.00''W 90°10.89''W 66°59.90''S
Floats and drifters deployed	12 (leg 2) and 13 ALACE Floats (leg 3)
Moorings deployed or recovered	none

Contributing Authors

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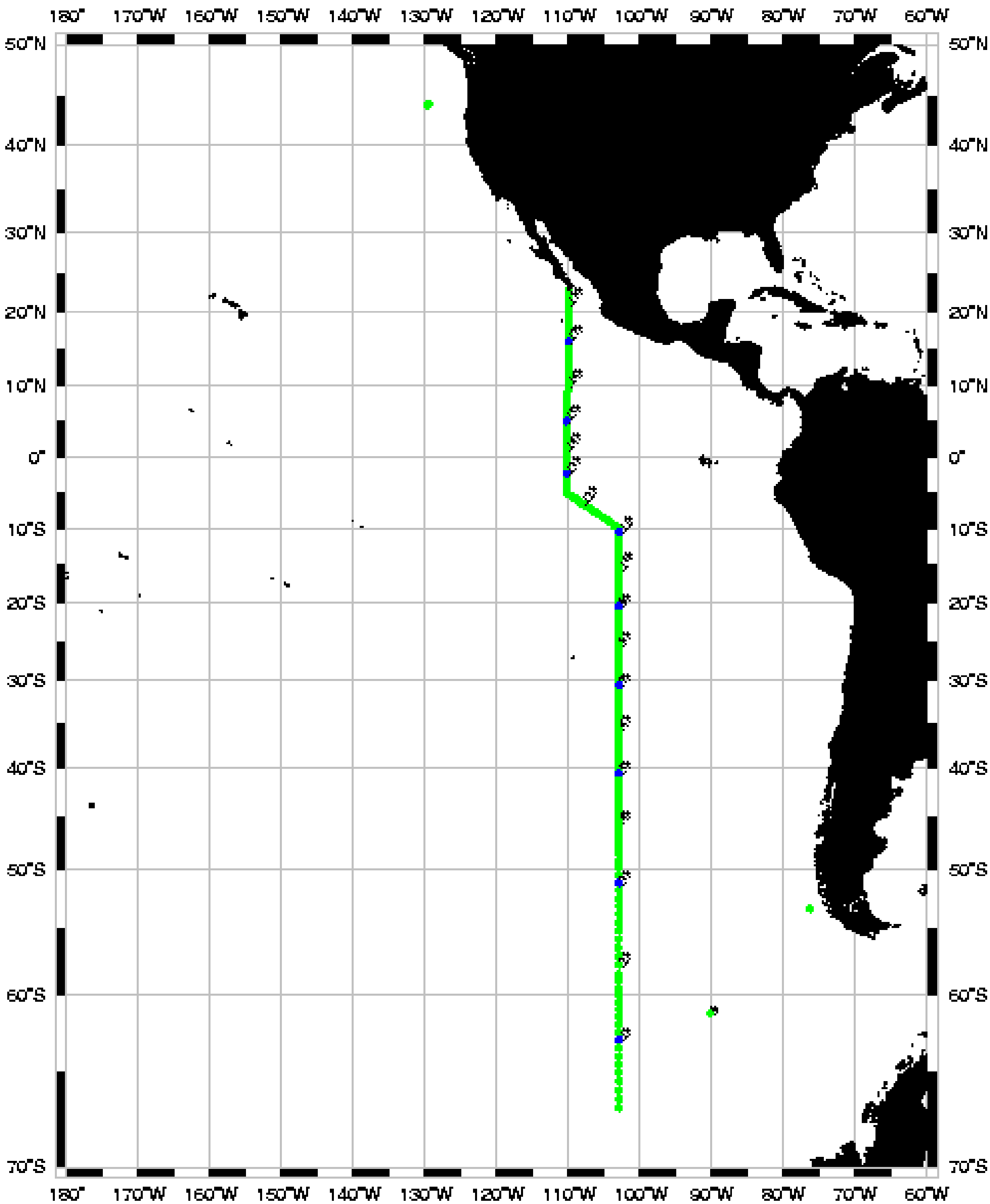
WHP Cruise and Data Information

Instructions: Click on items below 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
	Salinity
Floats and drifters deployed	Oxygen
Moorings deployed or recovered	Nutrients
	CFCs
Principal Investigators for all measurements	
Cruise Participants	
Problems and goals not achieved	
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	
	Data Status Notes

Station locations for P18



(Produced from .SUM files by WHPO)

A. Cruise Narrative

A.1 Highlights

A.1.a	WOCE designation	P18S P18N
A.1.b	EXPOCODE	P18S: 31DSCG94/2 P18N: 31DSCG94/3
A.1.c	P18S:	
	Chief Scientist	Dr. Bruce Taft (retired)
	Co-Chief Scientist	Dr. John Bullister Phone: 206-526-6741 Fax: 206-526-6744 Internet: bullister@pmel.noaa.gov
	P18N:	
	Chief Scientist	Dr. Gregory Johnson Phone: 206-526-6806 Fax: 206-526-6744 Internet: gjohnson@pmel.noaa.gov
	Co-Chief Scientist	Dr. Richard Feely Tel: (206)526-6214 Fax: (206)526-6744 Internet: feely@pmel.noaa.gov
	All at:	
		National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory (NOAA-PMEL) 7600 Sand Point Way NE Seattle WA 98115 USA
A.1.d	Ship	R/V Discoverer
A.1.e	Ports of Call	P18S: Punta Arenas to Easter Island P18N: Easter Island to San Diego
A.1.f	Cruise dates	P18S: Feb 22 - March 24 1994 P18N: March 29 - April 27 1994

A.2 Cruise Summary Information

WOCE Hydrographic Section P18 was completed on the NOAA Ship Discoverer in early 1994 by NOAA and academic researchers measuring a wide suite of physical, chemical, and biological processes. The P18 section started north from 67°S, 103°W to 10°S, 103°W. From there the section crossed the East Pacific Rise in a northwesterly direction to 5°S, 110°20'W. The northward course was then resumed to 8°N, 110°20'W, where slight adjustments in longitude were made to bring the section to 110°W at 10°N. From there a northward course was followed to the final station, in less than 200 m of water off the southern cape of Baja California at 22°51.2'N, 110°W. Nominal station spacing was 30 nm, reduced to 20 nm from 3°S to 3°N and less from 22 30N to the section end. Station spacing was increased to 40 nm from 58°30' to 48°30'S, from 10° to 5°S, and from 10° to 14°N, to make up for delays owing to heavy weather and winch level-wind problems.

A.2.a Geographic boundaries 23 N
110 W 103 W
67 S

A.2.b Stations Occupied

A total of 185 full water column CTD/water sample stations were made along the section from 67°S 103°W to 23°N 110°W. Of these, 158 stations were made using a 36-position, 10-liter bottle frame with a lowered Acoustic Doppler Current Profiler (ADCP) and a transmissometer. The other 27 stations were made using a 24-position, four-liter bottle frame deployed primarily during heavy weather. A Sea-Bird Electronics 911plus CTD was mounted in each frame. In addition to a set of temperature and conductivity sensors resident on each CTD, a single set of mobile temperature, conductivity, and dissolved oxygen sensors was used at every station for quality control and continuity of temperature and conductivity measurements while keeping each CTD mounted in its own frame.

Water samples were collected at every station for analyses of salt, dissolved oxygen and dissolved nutrients (i.e., silicate, nitrate, nitrite and phosphate). Samples were drawn at selected locations for analysis of CFC-11, CFC-12, dissolved inorganic carbon (DIC), total alkalinity, pH, pCO_2, ^{3}He, tritium, dissolved organic carbon, carbon isotopes, oxygen isotopes, and other variables. Daily shallow casts were made for assessment of various biological parameters, including productivity. A total of 25 ALACE (Autonomous Lagrangian Circulation Explorer) floats were deployed during the cruise. Nineteen XCTDs were successfully launched between CTD/O_2 stations from 1-9.5 N. Underway measurements included ADCP data, meteorological variables, bottom depth, pH, pCO_2, atmospheric CFCs, nitrate, and chlorophyll.

Sampling accomplished:
194 Stations were completed, including 9 on the transit to the start of the P18 section (Sta 1-9)

Approximately number of water samples analysed: 6147 salinity, 6042 oxygen, 5999 nutrients, 2960 chlorofluorocarbons (CFCs), 3147 Total CO_2, 2998 pCO_2, 4365 pH, 1006 DOC, 314 DON

Approximate number of water samples collected for shore-based analysis: 1002 helium-3, 587 tritium, 938 AMS radiocarbon (C-14) and C-13

Lowered ADCP profiles were obtained at about 158 stations using a rosette mounted lowered ADCP instrument.

Continuous underway ADCP measurements were made along the cruise track.

Measurents of surface-layer dissolved gases and atmospheric trace gases including nitrous oxide and halocarbons) were made along the transit leg (Leg 1). These results have been presented in the technical report: Lobert, J.M.., J.H. Butler, L.S. Geller, S.A. Yvon, S.A. Montzka, R.C. Myers, A.D. Clarke, and J.W. Elkins. BLAST94: Bromine Latitudinal Air/Sea Transect 1994 report on oceanic measurements on methyl bromide and other compounds. NOAA Technical Memorandum ERL CMDL-10, 39 pp. (1996).

A.2.c Floats and drifters deployed

ALACE Floats were launched at 25 locations listed in Table 1. Twelve ALACE floats were released on Leg 2 and thirteen on Leg 3.

Table 1: Time and location of ALACE float deployments

Date	Time	Latitude	Longitude
022494	0756	55°50.17'S	80°22.34'W
022494	1636	56°39.64'S	81°46.87'W
022494	2130	57°30.02'S	83°17.12'W
022594	0228	58°19.87'S	84°45.79'W
022594	0725	59°09.26'S	86°18.96'W
022594	1210	59°59.90'S	87°51.50'W
030894	1025	55°10.40'S	103°01.09'W
031094	2028	49°49.28'S	103°00.10'W
031394	0637	44°58.99'S	103°00.25'W
031594	0117	40°00.99'S	103°00.55'W
031894	1200	35°00.40'S	103°00.74'W
032094	0739	30°00.15'S	103°01.53'W
032994	1341	25°00.24'S	103°00.05'W
033194	2011	20°29.51'S	102°59.98'W
040494	0005	14°59.70'S	103°00.01'W
040694	1917	9°59.76'S	103°00.70'W
040994	1441	6°09.09'S	108°38.61'W
041094	2307	3°59.28'S	110°19.78'W
041294	1838	1°20.27'S	110°19.94'W
041494	1443	1°00.38'N	110°19.96'W
041694	1431	3°59.69'N	110°19.93'W
041794	1731	5°59.90'N	110°20.30'W
041994	1956	10°00.78'S	110°00.19'W
042194	1819	14°29.77'S	110°00.03'W
042394	2246	18°59.93'S	109°59.80'W

A.2.d Moorings deployed or recovered

A.3 Principal Investigators

Table 2: List of Principal Investigators

Measurement	Principal Investigator	Institution
CTD/O2	B. Taft, G. Johnson	PMEL
Chlorofluorocarbons (CFCs)	J. Bullister	PMEL
C-14 (AMS radiocarbon), C-13	P. Quay	UW
Nutrients	K. Krogsland	UW
Dissolved Oxygen	J. Bullister	PMEL
Helium/tritium	W. Jenkins	WHOI
CO2 (alkalinity)	F. Millero	UM
Total CO2 (coulometry), pCO2	R. Feely	PMEL
pH	R. Byrne	USF
ADCP	P. Hacker	UH
ALACE floats	R. Davis	SIO
Underway atmospheric/surface halocarbons, nitrous oxide	J. Butler	CMDL
Productivity	F. Chavez	MBARI
Bathymetry	Ship personnel	
Underway thermosalinograph	Ship personnel	

Participating Institutions:

NOAA/PMEL	National Oceanic and Atmospheric Adminstration Pacific Marine Environmental Laboratory
USF	University of South Florida
MBARI	Monterey Bay Aquarium Research Institute
SIO	Scripps Institution of Oceanography
UM	University of Miami
UW	University of Washington
UH	University of Hawaii
WHOI	Woods Hole Oceanographic Institution
CMDL	NOAA Climate Modelling and Diagnostics Laboratory

A.4 Scientific Programme and Methods

The long term objective of the Climate and Global Change Program is to provide reliable predictions of climate change and associated regional implications on time scales ranging from seasons to a century or more. In support of NOAA's Climate Program, PMEL scientists have been measuring the growing burden of greenhouse gases in the Pacific Ocean and the overlying atmosphere since 1980. The NOAA Office of Global Programs (OGP) sponsored Ocean Tracers and Hydrography Program and Ocean-Atmosphere Carbon Exchange Study (OACES) studies ocean circulation, mixing processes, and the rate at which CO_2 and chlorofluorocarbons (CFCs) are taken up and released by the oceans. Work on this cruise was cooperative with the World Ocean Circulation Experiment (WOCE) and the U.S. Joint Global Ocean Flux Study (JGOFS). The research was designed to (1) describe water properties and relate them to circulation processes throughout the water column in the eastern Pacific Ocean; (2) determine the sources and sinks of carbon dioxide along 103-110°W; (3) study the invasion of CFCs in the ocean; and (4) provide a high quality set of baseline measurements for the continuing evaluation of changes in ocean content of dissolved gasses, water properties, and circulation. This section fills a gap in the eastern Pacific between WOCE Hydrographic Programme (WHP) meridional sections P19 (along 90°W) and P17 (along 135°W). The southern end of this section intersects WHP S4, an E-W section along 67°S occupied in 1992.

During the transit (leg 1) from Seattle, Washington to Punta Arenas, Chile, a test station was occupied in the Puget Sound to evaluate the CTD/rosette system. This profile was not processed and is not included in this data report. In response to significant volcanic activity detected by the VENTS monitoring system at the East Blanco Depression (44°12'N, 129°42'W), 6 stations were occupied in this area during leg 1. The NOAA/PMEL VENTS program focuses research on determining the oceanic impacts and consequences of submarine hydrothermal venting. This event was particularly interesting as the area is a pull-apart basin in a transform zone, possibly the site of early ridge formation.

Occupation of WOCE section P18 began with station 10 of leg 2, after two test casts were completed enroute to 67°S, 103°W from Punta Arenas, Chile. Seventy-eight full water column hydrographic stations were occupied east of the Pacific Rise along 103°W from 67°S to 27°S. Stations were spaced at 30 nm intervals except from 58°30'S to 48°S where spacing was increased to 40 nm intervals to make up time lost from bad weather and winch level wind problems. Features sampled during leg 2 included the Polar and Subantarctic Fronts of the Antarctic Circumpolar Current, the Subtropical Front, the Subantarctic Mode Water, the Antarctic Intermediate Water, the Circumpolar Deep Water spreading to the northern reaches of the Southeast Pacific Basin, and currents along the Sala y Gomez Fracture Zone.

During leg 3 stations continued northward along 103°W to 10°S at 30 nm intervals. The section turned northwestward from 10°S to 5°S with 40 nm station spacing to cross the East Pacific Rise in a perpendicular fashion. The 30 nm spacing was resumed from 5S to 3°S northward along 110°20'W. From 3°S to 3°N stations were occupied every 20 nm along the same longitude. From 3°N to 22 30°N stations were occupied at 30 nm intervals, except from 12°N to 16°N, where the spacing was again increased to 40 nm to make up for time lost to winch level wind problems. A gradual shift in the longitude from 110°20'W to 110°W was made between 8°N and 10°N. North of 22°30'N station spacing was reduced to as little as 3 nm over the rapidly shoaling bathymetry approaching Cabo San Lucas. The line was completed in 200 m of water at 22°51'N, 110°W. During leg 3, 107 full water column hydrographic stations were occupied sampling the deep waters of the Bauer Basin, currents associated with the flanks of the East Pacific Rise, tropical water masses and currents over the full water column, the northern mid-depth helium-3 plume, and the oxygen depleted layer of the tropical Eastern Pacific.

Full water column CTD/O_2 profiles were collected at all stations. Lowered Acoustic Doppler Current Profiler (ADCP) measurements were also collected on most casts. In addition, underway salinity, temperature, and CO_2 measurements were taken along the cruise track. Shallow productivity casts were made daily, ALACE floats were launched at predetermined locations, and XCTDs were successfully dropped in a high-resolution survey from 1°N to 9.5°N. Water samples were analyzed for a suite of anthropogenic and natural tracers including salinity, dissolved oxygen, inorganic nutrients, CFCs, pCO_2, total CO_2, pH, total alkalinity, helium, tritium, C-13, C-14, O-18, dissolved organic carbon, and dissolved organic nitrogen. Samples were collected from productivity casts for chlorophyll and primary productivity.

Leg 1 (Seattle, Washington to Punta Arenas, Chile)

This leg was a transit leg with a test station occupied in the Puget Sound to evaluate the CTD/rosette system. This profile was not processed and is not included in this data report. In response to significant volcanic activity detected by the VENTS monitoring system at the East Blanco Depression (44°12'N, 129°42'W), 6 stations were occupied in this area during leg 1.

Leg 2 (Punta Arenas - Easter Island).

This leg consisted of 78 stations along 103°W; the first station on the WOCE Line P18 (#10) was occupied at 67°00'S 103°00'W on 26 February 1994 and the final station at 26°00'S 103°00'W on 23 March 1994. Except for 10 degrees of latitude span (58°30'S - 48°30'S), the station spacing was 30 miles. The station spacing was increased to 40 miles in the above mentioned latitudinal band because of time lost to heavy weather and slower than normal retrieval rates of the CTD package due to problems with the winch level wind. All CTD stations were full depth (nominally 10 m above the bottom). Two CTD/rosette packages were used: a 24 position 4 l bottle rosette (21 stations) and a 36 position 10 l bottle rosette (57 stations). The choice between the two systems was usually dictated by the severity of the weather. On stations where the large rosette was used, a LADCP was attached to the rosette frame which reduced the number of bottle positions from 36 to 33. Shallow (200 m) productivity bottle casts with light transmission profiles were made at 23 stations. Twelve ALACE floats were released at predetermined locations along the section and on the transit to the first station.

Leg 3 (Easter Island - San Diego).

A similar observational program was carried out on this leg (107 stations) with the following changes from the nominal 30-mile station spacing. Stations were occupied at 40 mile intervals along a dog-leg section across the East Pacific Rise from 10°S 103°W to 5°S 110°20'W. Thirty-mile spacing was resumed between 5°S and 3°S and then reduced to 20 miles between 3°S and 3°N. From 3°N to 22°30'N stations were occupied at 30 mile intervals except between 12°N and 16°N, where spacing was again relaxed to 40 miles. Between 8°N and 10°N a gradual shift in longitude from 110°20'W to 110°00'W was made. As the ship approached Cabo San Lucas, at the end of the section, spacing was reduced to as little as 3 miles over the steeply shoaling bathymetry. Only on six stations, during reterminations of the CTD cable, was the 24 bottle rosette used.

Discussion:

The basic goals of the cruise were accomplished. All casts were made to the bottom. Station spacing only occasionally was increased to 40 miles from the nominal WOCE interval of 30 miles. There were no significant gaps in sampling any of the variables. Preliminary analysis of the Seabird CTD measurements and bottle data indicate that they will meet the WOCE standards.

A.5 Major Problems and Goals not Achieved

Some time was lost on the southern end of leg 2 due to weather. We encountered a number of problems with the level-wind mechanism on the winch, which led to bad wraps on the drum. A number of attempts were made to re-tension the wire on the drum at sea by removing the CTD/rosette package, attaching a weight to the wire, and spooling the full length of the wire (except the last full wrap on the drum) out behind the ship while underway. These problems persisted throughout the cruise, and resulted in slower than anticipated average winch speeds and some loss of time. Some time was lost on station due to conducting cable and wire termination problems.

A.6 Other Incidents of Note

A.7 List of Cruise Participants

A list of cruise participants is found in Table 3.

Table 3: Cruise Participants

Program	Inst.	Leg 1	Leg 2	Leg 3
Chief Scientist	PMEL	*John Bullister	Bruce Taft	Gregory Johnson
Co-Chief Scientist	PMEL	*Gregory Johnson	John Bullister	Richard Feely
CTD	PMEL	*K. McTaggart	K. McTaggart	K. McTaggart
	Sea-Bird		Nordeen Larson	
CFC	PMEL	*David Wisegarver	David Wisegarver	David Wisegarver
	PMEL		C.J. Beegle	Kirk Hargreaves
Salinity	PMEL		Gregg Thomas	Gregg Thomas
helium, tritium	WHOI		Joshua Curtice	Scott Birdwhistell
oxygen	PMEL	*Kirk Hargreaves	Kirk Hargreaves	David Jones
nutrients	UW		K. Krogslund	K. Krogslund
	UW		Calvin Mordy	Calvin Mordy
ADCP	UH		Craig Huhta	Claude Lumpkin
trace gases	CMDL	J. Lobert		
	CMDL	M. Nowich		
	CMDL	L. Geller		
	CMDL	*J. Butler		

	CMDL	*S. Montzka		
productivity	MBARI		Kurt Buck	Kurt Buck
			Gregory Morris	Raphael Kudela
			Thomas Hayden	
DOC	Miami		Dennis Hansell	Rhonda Kelly
alkalinity	Miami		J. Zhang	Essa Peltola
			Sonya Olivella	Michael De Alessi
			Bernardo Vargas	Mary Roche
Underway pH	SIO	A. Dickson		
pH	USF		Robert Byrne	Huining Zhang
	USF		Renate Bernstein	Sean McElligott
	USF		Huining Zhang	Frederick Stengard
pCO2	PMEL		Dana Greeley	Dana Greeley
	PMEL	Kerry Jones	Catherine Cosca	Matthew Steckley
TCO2	PMEL	*Marilyn Roberts	Kerry Jones	Marilyn Roberts
	PMEL		Thomas Lantry	Thomas Lantry
C-13, C-14	UW		James Green	Elizabeth Houzel
Vents	CIMRS	*L. Evans		
	PMEL	*D. Taylor		
		*V. Anderson		
CTD	PMEL	*H. Milburn		
Mexican Observer	Texas A&M			Diego Lopez-Veneroni
				Humberto Perez-Ortiz
Chilean Observer	SHOA		Dante Gutierrez-Besa	
Electronics Technician		J. Payseur	J. Payseur	S. Macri

* Disembarked in San Francisco on Leg 1

B.1 Navigation and bathymetry

SeaBeam multibeam sonar was used continuously for bathymetry during both legs. Navigation was by means of the Global Positioning System (GPS).

B.2 Acoustic Doppler Current Profiler (ADCP)

Shipboard ADCP measurements, along with global position system (GPS) data, were collected continuously along the track to measure the velocity profile in the upper 500 m.

B.3 Thermosalinograph and underway dissolved oxygen, etc

A thermosalinograph was operated continuously on both legs.

pCO_2 and pH were measured while underway together with photosynthetically active radiation, nitrate and chlorophyll concentrations.

B.4 XBT and XCTD

Nineteen XCTDs were dropped along 110°20'W between 1°10'N and 9°45'N at locations halfway between successive CTD stations on Leg 3. Times and positions of each deployment are shown in Table 4.

Table 4: Deployment times and locations for XCTD casts

Date	Time	Latitude	Longitude
012994	0355	44°12.97'N	129°37.08'W
030294	1916	62°27.85'S	102°58.45'W
030394	0941	61°25.90'S	102°58.90'W
031094	0556	51°09.50'S	103°00.60'W
041494	1540	1°10.01'N	110°19.87'W
041494	2208	1°30.10'N	110°19.60'W
041594	0340	1°50.30'N	110°19.70'W
041594	0933	2°10.10'N	110°20.00'W
041594	1455	2°30.00'N	110°19.80'W
041594	2116	2°50.00'N	110°19.90'W
041694	0250	3°15.00'N	110°19.90'W
041694	0942	3°45.00'N	110°19.40'W
041694	1546	4°15.00'N	110°19.80'W
041694	2313	4°45.00'N	110°20.00'W
041794	0536	5°16.28'N	110°19.77'W
041794	1227	5°45.00'N	110°20.00'W
041794	1845	6°15.03'N	110°20.46'W
041894	0038	6°45.00'N	110°20.60'W
041894	0659	7°15.00'N	110°20.61'W
041894	1307	7°45.00'N	110°19.90'W
041894	2011	8°15.00'N	110°17.74'W
041894	0159	8°45.10'N	110°12.50'W
041994	0822	9°15.00'N	110°07.60'W

B.5 Meteorological observations

B.6 Atmospheric chemistry

3/8" O.D. Dekaron air sampling lines (reinforced plastic tubing) was run from the CFC van to the bow and stern and air was analyzed continuously for: CFC-11 CFC-12 CFC-113 Carbon tetrachloride Methyl chloroform

C. Hydrographic Measurements

C.1. CTD/O_2 Measurements and Calibrations
(K.E. McTaggart, G.C. Johnson, and B.A. Taft)

C.1.1. STANDARDS AND PRE-CRUISE CALIBRATIONS

The CTD system is a real time data system with the CTD data from a Sea-Bird Electronics, Inc. (SBE) 9plus underwater unit transmitted via a conducting cable to the

SBE 11plus deck unit. The serial data from the underwater unit is sent to the deck unit in RS-232 NRZ format using a 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK) telemetry link. The deck unit decodes the serial data and sends it to a personal computer for display and storage in a disk file using Sea-Bird SEASOFT software.

The SBE 911plus system transmits data from primary and auxiliary sensors in the form of binary number equivalents of the frequency or voltage outputs from those sensors. The calculations required to convert from raw data to engineering units of the parameters being measured are performed by software, either in real-time, or after the data has been stored in a disk file.

The SBE 911plus system is electrically and mechanically compatible with standard, unmodified rosette water samplers made by General Oceanics (GO), including the 1016 36-position sampler. An optional modem and rosette interface allows the 911plus system to control the operation of the rosette directly, and without interrupting the data from the CTD, eliminating the need for a rosette deck unit.

The SBE 9plus underwater unit uses Sea-Bird's standard modular temperature (SBE 3) and conductivity (SBE 4) sensors which are mounted with a single clamp and "L" bracket to the lower end cap. The conductivity cell entrance is co-planar with the tip of the temperature sensor's protective steel sheath. The pressure sensor is mounted inside the underwater unit main housing and is ported to outside pressure through the oil-filled plastic capillary tube seen protruding from the main housing bottom end cap. A compact, modular unit consisting of a centrifugal pump head and a brushless DC ball bearing motor contained in an aluminum underwater housing pump flushes water through sensor tubing at a constant rate independent of the CTD's motion. This improves dynamic performance. Motor speed and pumping rate (3000 rpm) remain nearly constant over the entire input voltage range of 12-18 volts DC.

The SBE 11plus deck unit is a rack-mountable interface which supplies DC power to the underwater unit, decodes the serial data stream, formats the data under microprocessor control, and passes the data to a companion computer. It provides access to the modem channel and control of the rosette interface. Output data is in RS-232 (serial) format.

C.1.1.a. Conductivity

The flow-through conductivity sensing element is a glass tube (cell) with three platinum electrodes. The resistance measured between the center electrode and end electrode pair is determined by the cell geometry and the specific conductance of the fluid within the cell, and controls the output frequency of a Wien Bridge circuit. The sensor has a frequency output of approximately 3 to 12 kHz corresponding to conductivity from 0 to 7 S/m (0 to 70 mmho/cm). The SBE 4 has a typical accuracy/stability of ± 0.0003 S/m/month; resolution of 0.00004 S/m at 24 samples per second; and 6800 meter anodized aluminum housing depth rating.

Pre-cruise sensor calibrations were performed at Sea-Bird Electronics, Inc. in Bellevue, Washington. The following coefficients were entered into SEASOFT using software module SEASON:

S/N 1177 September 22, 1993	S/N 1247 January 21, 1994
a = 2.28847772e-05	a = 1.76162580e-05
b = 5.58250114e-01	b = 5.50791410e-01
c = -4.14341657e+00	c = -4.07804361e+00
d = -9.59251789e-05	d = -9.32262258e-06
m = 4.1	m = 4.2

Conductivity calibration certificates show an equation containing the appropriate pressure-dependent correction term to account for the effect of hydrostatic loading (pressure) on the conductivity cell:

$$C\ (S/m) = (af^{m} + bf^{2} + c + dt)\ /\ [10\ (1 - 9.57e^{-8}\ p)]$$

where a, b, c, d, and m are the calibration coefficients above, f is the instrument frequency (kHz), t is the water temperature (C), and p is the water pressure (decibars). SEASOFT automatically implements this equation.

C.1.1.b. Temperature

The temperature sensing element is a glass-coated thermistor bead, pressure-protected by a stainless steel tube. The sensor output frequency ranges from approximately 5 to 13 kHz corresponding to temperature from -5 to 35°C. The output frequency is inversly proportional to the square root of the thermistor resistance which controls the output of a patented Wien Bridge circuit. The thermistor resistance is exponentially related to temperature. The SBE 3 thermometer has a typical accuracy/stability of ± 0.004°C per year; and resolution of 0.0003°C at 24 samples per second. The SBE 3 thermometer has a fast response time of 70 milliseconds. It's anodized aluminum housing provides a depth rating of 6800 meters.

Pre-cruise sensor calibrations were performed at Sea-Bird Electronics, Inc. in Bellevue, Washington. The following coefficients were entered into SEASOFT using software module SEASON:

S/N 1455 January 13, 1994	S/N 1461 February 11, 1994
a = 3.68103063e-03	a = 3.68110418e-03
b = 6.03073078e-04	b = 6.00486851e-04
c = 1.51707342e-05	c = 1.48701147e-05
d = 2.20648879e-06	d = 1.99797919e-06
f0 = 6228.23	f0 = 6212.56

Temperature (IPTS-68) is computed according to

$$T\ (°C) = 1/\{a+b[\ln(f0/f)]+c[\ln^2(f0/f)]+d[\ln^3(f0/f)]\}-273.15$$

where a, b, c, d, and f0 are the calibration coefficients above and f is the instrument frequency (kHz). SEASOFT automatically implements this equation.

C.1.1.c. Pressure

The Paroscientific series 4000 Digiquartz high pressure transducer uses a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress measuring changes in pressure as small as 0.01 parts per million with an absolute range of 0 to 10,000 psia (0 to 6885 decibars). Also, a quartz crystal temperature signal is used to compensate for a wide range of temperature changes. Repeatability, hysteresis, and pressure conformance are 0.005% FS. The nominal pressure frequency (0 to full scale) is 34 to 38 kHz. The nominal temperature frequency is 172 kHz + 50 ppm/°C.

Pre-cruise sensor calibrations were performed at Sea-Bird Electronics, Inc. in Bellevue, Washington. The following coefficients were entered into SEASOFT using software module SEASON:

S/N 53960 August 4, 1993	S/N 53586 October 29, 1993
c1 = -43150.48	c1 = -39204.51
c2 = 4.54280e-01	c2 = 6.23456e-01
c3 = 1.34438e-02	c3 = 1.35057e-02
d1 = 0.037952	d1 = 0.038943
d2 = 0.0	d2 = 0.0
t1 = 30.34230	t1 = 30.46303
t2 = -1.80938e-04	t2 = -9.018862e-05
t3 = 4.61615e-06	t3 = 4.52889e-06
t4 = 2.08422e-09	t4 = 3.30959e-09
t5 = 0.0	t5 = 0.0

Pressure coefficients are first formulated into

c = c1 + c2*U + c3*U^2
d = d1 + d2*U
t0 = t1 + t2*U + t3*U^2 + t4*U^3 + t5*U^4

where U is temperature in degrees Celsius. Then pressure is computed according to

$$P\ (psia) = c * [1 - (t0^2/t^2)] * \{1 - d[1 - (t0^2/t^2)]\}$$

where t is pressure period (microsec). SEASOFT automatically implements this equation.

C.1.1.d. Oxygen

The SBE 13 dissolved oxygen sensor uses a Beckman polarographic element to provide in-situ measurements at depths up to 6800 meters. This auxiliary sensor is also included in the path of pumped sea water. Oxygen sensors determine the dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through a membrane. By knowing the flux of oxygen and the geometry of the diffusion path the concentration of oxygen can be computed. The permeability of the membrane to oxygen is a function of temperature and ambient pressure. The interface electronics outputs voltages proportional to membrane current (oxygen current) and membrane temperature (oxygen temperature). Oxygen temperature is used for internal temperature compensation. Computation of dissolved oxygen in engineering units is done in the software. The range for dissolved oxygen is 0 to 15 ml/l; accuracy is 0.1 ml/l; resolution is 0.01 ml/l. Response times are 2 seconds at 25°C and 5 seconds at 0°C.

The following oxygen calibrations were entered into SEASOFT using SEACON:

S/N 130309 September 7, 1993
m = 2.4544 e-7
b = -4.6633 e-10
k = 8.9224
c = -6.9788

The use of these constants in linear equations of the form I = mV + b and T = kV + c will yield sensor membrane current and temperature (with a maximum error of about 0.5°C) as a function of sensor output voltage. These scaled values of oxygen current and oxygen temperature were carried through the SEASOFT processing stream unaltered.

C.1.2. DATA ACQUISITION

CTD measurements were made using one of two Seabird 9plus CTDs each equipped with a fixed pumped temperature-conductivity (TC) sensor pair. A mobile pumped TC pair with dissolved oxygen sensor was mounted on whichever CTD was in use so that dual TC measurements and dissolved oxygen measurements were always collected. The TC pairs were monitored for calibration drift and shifts by examining the differences between the two pairs on each CTD and comparing CTD salinities with bottle salinity measurements.

PMEL's Sea-Bird 9plus CTD/O2 S/N 09P8431-0315 (sampling rate 24 Hz) was mounted in a 36-position frame and employed as the primary package. Auxiliary sensors included a lowered ADCP, Metrox load cell, Benthos altimeter, and SeaTech transmissometer. Water samples were collected using a General Oceanics 36-bottle rosette and 10-liter Nisken bottles. The primary package was used for the majority of 194 casts.

PMEL's Sea-Bird 9plus CTD/O2 S/N 329053-0209 (sampling rate 24 Hz) was mounted in a 24-position frame and employed as the backup package. Auxiliary sensors included a Metrox load cell and Benthos altimeter. Water samples were collected using a Sea-Bird 24-bottle rosette, and 4-liter Niskin bottles. There were 29 bad weather stations made using the smaller backup package.

The package entered the water from the stern of the ship and was held 5-20 m beneath the surface for one minute in order to activate the pump and attach tag lines for package recovery. Under ideal conditions the package was lowered at a rate of 30 m/min to 50 m, 45 m/min to 200 m, and 60 m/min to depth. Ship roll often caused substantial variation about these mean lowering rates, especially at southern ocean stations. Load cell values were monitored in real-time during each cast. The position of the package relative to the bottom was monitored on the ship's Precision Depth Recorder (PDR). A bottom depth was estimated from bathymetric charts and the PDR ran during the bottom 1000 m of the cast. Fig. 2 shows the depths of bottle closures during the upcast.

Upon completion of the cast, sensors were flushed with deionized water and stored with a dilute Triton-X solution in the plumbing. Niskin bottles were sampled for salinity, dissolved oxygen, inorganic nutrients, CFCs, total CO_2, pCO_2, pH, C-13, C-14, O-18, helium, tritium, total alkalinity, dissolved organic carbon, and dissolved organic nitrogen. Sample protocols conformed to those specified by the WOCE Hydrographic Programme.

A Sea-Bird 11plus deck unit received the data signal from the CTD. The analog data stream was recorded onto video cassette tape as a backup. Digitized data were forwarded to a 286-AT personal computer equipped with SEASOFT acquisition and processing software version 4.201. Temperature, salinity, and oxygen profiles were displayed in real-time. Raw data files were transferred to a 486 personal computer using Laplink version 3 and backed up onto 1/4" cartridge tapes using a Microsolutions Backpack QIC-80 external tape drive.

C.1.2.a. Data Acquisition Problems

During leg 2, station spacing increased to 40 nm between 58.5°S and 48°S owing to a delay in departure from Punta Arenas, delays owing to winch problems for some casts, and bad weather. About 36 hours were lost waiting for the weather to moderate at 58S. Other problems included poor level winding of the winch resulting in non-uniform lays on the drum and high tension crossing and snapping of the cable, compromised chemistry samples owing to contamination from the ship's stack output, and difficulties associated with doing CTDs from the stern of the ship in heavy to moderate seas at high latitudes.

Stations 8 and 9 test casts were very noisy. Modulo errors persisted through cast 14. Station 11 cast 1 did not sample the upper 800 meters and so a second cast was performed at this station for these bottles. Station 11 cast 2 CTD data was not processed. Station 111 stopcocks and vents were left open therefore no samples were collected. At station 120, upcast water sampling was skipped from 800 to 400 db while a fishing vessel cleared it's net out of the water. Prior to station 123, the cable was reterminated after cutting off 2500 m of cable to get below bad wraps. At station 131 the package sat on the bottom for several minutes. The upcast CTD data were bad. Uptrace pressures were matched to downtrace pressures for bottle sample CTD data. Station 160 had increasing modulo errors during the downcast and was aborted. Water was found in the ground wire at the termination. No samples collected at station 160. There was no sample from station 190 bottle 11 owing to a stuck lanyard.

C.1.2.b. Salinity Analyses

Bottle salinity analyses were performed in a temperature-controlled van using two Guildline Model 8400A inductive autosalinometers standardized with IAPSO Standard Seawater batch P114. The autosalinometer in use was standardized before each run and either at the end of each run or after no more than 48 samples. The drift between standardizations was monitored and the individual samples were corrected for that drift by linear interpolation. Duplicate samples taken from the deepest bottle on each cast were analyzed on a subsequent day. Bottle salinities were compared with preliminary CTD salinities to aid in identification of leaking bottles as well as to monitor the CTD conductivity cells' performance and drift.

The expected precision of the autosalinometer with an accomplished operator is 0.001 pss, with an accuracy of 0.003. To assess the precision of discrete salinity measurements on this cruise, a comparison was made for data from the instances in which two bottles were tripped within 10 dbar of each other at the same station below a depth of 2000 dbar. For the 138 instances in which both bottles of the pair have acceptable salinity measurements, the standard deviation of the differences is 0.0012 pss. This value is very close to the expected precision.

Calibrated CTD salinities replace missing bottle salinities in the hydrographic data listing and are indicated by an asterisk.

C.1.3. POST-CRUISE CALIBRATIONS

Post-cruise sensor calibrations were done at Sea-Bird Electronics, Inc. during May 1994. For stations 2-8, temperature sensor T1455 (with pre-cruise calibration coefficients dated January 1994) and conductivity sensor C1177 (with pre-cruise calibration coefficients dated September 1993) were selected as the best source of data. Post-cruise calibrations showed T1455 had drifted (offset only) by approximately -0.0015; C1177 displayed a change in slope. For stations 9-194, sensor T1461 (with pre-cruise calibration coefficients dated January 1994) and C1247 (with pre-cruise calibration coefficients dated January 1994) were selected for final data reduction since they were used on both packages. Post-cruise calibrations showed T1461 to be drifting (offset only) by approximately -0.006°C. C1247 had drifted (slope and offset) by approximately -0.0009 S/m.

At sea monitoring and post-cruise calibration of redundant TC pair T1460/C1180 showed T1460 had jumped by 0.002°C, warranting repair. Redundant TC pair

T1072/C748 post-cruise calibration showed T1072 had drifted to an offset of -0.004°C. These TC pairs were not included in the final processing.

C.1.3.a. Conductivity

SEASOFT module ALIGNCTD was used to align conductivity measurements in time relative to pressure. Measurements can be misaligned due to the inherent time delay of the sensor response, the water water transit time delay in the pumped plumbing line, and the sensors being physically misaligned in depth. Because SBE 3 temperature response is fast (0.06 seconds), it is not necessary to advance temperature relative to pressure. When measurements are properly aligned, salinity spiking and density errors are minimized.

For a SBE 9 CTD with ducted TC sensors and a 3000 rpm pump the typical net advance of conductivity relative to temperature is 0.073 seconds. The SBE 11 deck units advanced primary conductivity 0.073 seconds but do not advance secondary conductivity. Therefore when C1177 or C1247 conductivity data came from a secondary sensor channel the alignment was much larger, typically 0.06 seconds versus coming from a primary sensor channel, typically 0.02 seconds.

Conductivity slope and bias, along with a pressure fudge term (beta) were computed by a least-squares minimization of CTD and bottle conductivity differences. The function minimized was

$$BC - m * CC - b - beta * CP$$

where BC is bottle conductivity (S/m), CC is pre-cruise calibrated CTD conductivity (S/m), CP is the CTD pressure (dbar), m is the conductivity slope, b is the bias (S/m), and beta is the pressure fudge term (S/m/dbar). The final CTD conductivity (S/m) is

$$m * CC + b + beta * CP$$

The slope term m is a fourth-order polynomial function of station number to allow the entire cruise to be fit at once with a smoothly-varying station- dependent slope correction. For each sensor a series of fits were made, each fit throwing out bottle values for locations having a residual between CTD and bottle conductivities of greater than three standard deviations. This procedure was repeated with the remaining bottle values until no more bottle values were thrown out.

For C1177, the slope correction ranged from 1.00014254 to 1.00014262, the bias applied was $-3.8e^{-4}$, and the beta term was $-5.69e^{-9}$. Of 5040 bottles, the percentage of bottles retained in the fit was 84.9 with a standard deviation of CTD versus bottle conductivity differences of $1.19e^{-4}$ S/m. For C1247, the slope correction ranged from 1.00021478 to 1.00044972, the bias applied was $-7.2e^{-4}$, and the beta term was $-1.29e^{-8}$. Of 5797 bottles, the percentage of bottles retained in the fit was 83.4 with a standard deviation of $0.87e^{-4}$ S/m. The slope and bias were applied in SEACON. The beta-fudge term was applied after SEASOFT post-processing in PMEL program POSTCAL.

CTD-bottle conductivity differences used for the final fits are plotted against cast number to show the stability of the calibrated CTD conductivities relative to the bottle conductivities. The entire set of CTD-bottle conductivity differences are plotted against pressure to show the tight fit below 1000 m and the increasing scatter above 1000 m.

C.1.3.b. Temperature

In SEACON, adjustments were made to the bias of the thermistors as deviations from the pre-cruise calibrations on a station by station basis. These deviations were obtained from a linear fit of the pre-cruise and post-cruise temperature residuals from the pre-cruise calibration versus time. Deep temperature differences between primary and secondary sensors were less than 0.001°C.

Also, a uniform correction for heating of the thermistor owing to viscous effects was applied to the bias in SEACON. This correction was obtained using the formula:

$$\text{error[C]} = B * \text{sqrt(nu)*U*U}$$

where B=0.692, U=1.02 m/s, and nu=$1.7279e^{-6}$ m^2/s. The value for viscosity nu is that for the peak in the distribution of the temperature and salinity bottle values (te=1.8°C, sa=34.67 pss). Error[C] = $0.9464e^{-3}$°C. All the thermistors read high by this amount and were adjusted down accordingly. The adjustment is near the maximum viscous heating for the encountered temperature and salinity range. Thermistors will read about $0.66e^{-3}$°C high near the surface in the tropics (te=30°C, sa=34.5 pss) causing an overadjustment of $0.29e^{-3}$°C. For deep values (te=0°C, sa=37 pss) where gradients are small, thermistors will read about $0.97e^{-3}$°C high and so will be underadjusted by $0.2e^{-3}$°C.

C.1.3.c. Oxygen

In situ oxygen samples collected during CTD profiles are used for post-measurement calibration. SEASOFT bottle files were merged and bottle oxygen values flagged as 'good' were appended to the data records. Because the dissolved oxygen sensor has an obvious hysteresis, PMEL program OXDWNP replaced up-profile water sample data with corresponding down-profile CTD/O_2 data at common pressure levels. Oxygen saturation values were computed according to Benson and Krause (1984) in units of µmol/kg.

The algorithm used for converting oxygen sensor current and probe temperature measurements to oxygen as described by Owens and Millard (1985) requires a non-linear least squares regression technique in order to determine the best fit coefficients of the model for oxygen sensor behavior to the water sample observations. WHOI program OXFITMR uses Numerical REcipes (Press et al., 1986) Fortran routines MRQMIN, MRQCOF, GAUSSJ, and COVSRT to perform non-linear least squares regression using Levenberg-Marquardt method. A Fortran subroutine FOXY describes the oxygen model with the derivatives of the model with respect to six coefficients in the following order: oxygen current slope, temperature correction, pressure correction, weight, oxygen current bias, and oxygen current lag.

Program OXFITMR reads the data for a group of stations. The time rate of change of oxygen current is computed using a least squares estimate over 15 second intervals. The data are editted to remove spurious points where values are less than zero or greater than 1.2 times the saturation value. The routine varies the six (or fewer) parameters of the model in such a way as to produce the minimum sum of squares in the difference between the calibration oxygens and the computed values. Individual differences between the calibration oxygens and the computed oxygen values (residuals) are then compared with the standard deviation of the residuals. Any residual exceeding an edit factor of 2.8 standard deviations is rejected. A factor of 2.8 will have a 0.5% chance of rejecting a valid oxygen value for a normally distributed set of residuals. The iterative fitting process is continued until none of the data fail the edit criteria. The best fit to the oxygen probe model coefficients is then determined. Coefficents were applied by PMEL program CALOX2W and CTD oxygen was computed using subroutine OXY6W.

By plotting the oxygen residuals versus station, appropriate station groupings for further refinements of fitting were obtained by looking for abrupt station to station changes in the residuals. Sometimes it was necessary to fix values of some oxygen algorithm parameters to keep those parameters within a reasonable range. Final coefficients were applied by PMEL program EPSBE94.

C.1.4. POST-CRUISE PROCESSING

SEASOFT consists of modular menu driven routines for acquisition, display, processing, and archiving of oceanographic data acquired with Sea-Bird equipment and is designed to work with an IBM or compatible personal computer. Raw data is acquired from the instruments and is stored as unmodified data. The conversion module DATCNV uses the instrument configuration and calibration coefficients to create a converted engineering unit data file that is operated on by all SEASOFT post processing modules. Each SEASOFT module that modifies the converted data file adds information to the header of the converted file permitting tracking of how the various oceanographic parameters were obtained. The converted data is stored in either rows and columns of ascii numbers or as a binary data stream with each value stored as a 4 byte binary floating point number. The last data column is a flag field used to mark scans as good or bad.

The following are the SEASOFT processing module sequence and specifications used in the reduction of P18 CTD/O2 data.

DATCNV converted the raw data to pressure, temperature, conductivity, oxygen current, oxygen temperature, and transmissometer voltage. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition.

ROSSUM created a summary of the bottle data. Bottle position, date, and time were output as the first two columns. Pressure, temperature, conductivity, oxygen current, oxygen temperature, and transmissometer voltage were averaged over a two-second interval (48 scans). For the primary package, the time interval was from five to three seconds prior to the confirm bit in order to avoid spikes in conductivity and oxygen current owing to minor incompatibilities between the Sea-Bird 911plus CTD system and General Oceanics 1016 rosette. Bottle data from the backup package were averaged from one second prior to the confirm bit to 1 second after the confirm bit in the data stream.

WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 200 scans. Data greater than two standard deviations were flagged. The second pass computed a standard deviation over the same 200 scans excluding the flagged values. Values greater than 16 standard deviations were marked bad.

SPLIT removed decreasing pressure records from the data files leaving only the downcast.

FILTER performed a low pass filter on pressure with a time constant of 0.15 seconds. In order to produce zero phase (no time shift) the filter first runs forward through the file and then runs backwards through the file.

ALIGNCTD aligned conductivity in time relative to pressure to ensure that all calculations were made using measurements from the same parcel of water. Alignment between stations was checked every time the CTD configuration changed between primary and secondary underwater packages or every ten stations, whichever was less.

CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. Typical values were used for thermal anomaly amplitude (alpha=0.03) and the time constant (1/beta=9.0).

DERIVE was used to compute fall rate (m/s) with a time window size for fall rate and acceleration of 2.0 seconds.

LOOPEDIT marked scans where the CTD was moving less than the minimum velocity of 0.2 m/s or travelling backwards due to ship roll.

BINAVG averaged the data into 1 db pressure bins starting at 1 db with no surface bin. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value ± half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record exists every decibar.

STRIP removed scan number and fall rate from the data files.

TRANS converted the data file format from binary to ascii.

Following the SEASOFT processing modules, PMEL program POSTCAL corrected conductivity with respect to pressure using an additional beta term,

beta = $-1.29e^{-8}$ for C1247
beta = $-5.69e^{-8}$ for C1177
c2(i) = (c1(i)*10) + beta * p(i)

computed salinity,

s(i) = SAL78(c2(i)/42.914,t1(i),p(i),0)

corrected temperature due to instrument calibration error,

t2(i) = 1.00008961734348 * t1(i) - 9.924374518041036e-4

and backed out final conductivity values.

c3(i) = SAL78(s(i),t2(i),p(i),1)
c3(i) = c3(i) * 42.914

Also, POSTCAL interpolated temperature, conductivity, oxygen current, oxygen temperature, and transmissometer voltage where values were bad as flagged by SEASOFT before the above corrections and repeated to the surface the first good record input interactively by the user.

PMEL program EPSBE94 followed POSTCAL and computed doxc/dt, calibrated CTD oxygens, and computed ITS-90 temperature, potential temperature, sigma-t, sigma-theta, and dynamic height. EPSBE94 also introduced the WOCE quality flag associated with pressure, temperature, salinity, and CTD oxygen. Quality flag definitions can be found in the WOCE Operations Manual (1994). 1 db data were output in EPIC format (Soreide, 1995). Processed data were despiked and values linearly interpolated. WOCE flags were ammended to reflect these changes.

D. Acknowledgments

The assistance of the officers, crew, and survey department of the NOAA ship DISCOVERER is gratefully acknowledged. Funds for the CTD/O_2 program were provided to PMEL by the Climate and Global Change program under NOAA's Office of Global Programs.

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F. WHPO Summary

Several data files are associated with this report. They are the 31DSCG94_2.sum and 31DSCG94_3.sum, 31DSCG94_2.hyd and 31DSCG94_3.hyd, 31DSCG94_2.csl and 31DSCG94_3.csl and *.wct files. The *.sum file contains a summary of the location, time, type of parameters sampled, and other pertinent information regarding each hydrographic station. The *.hyd file contains the bottle data. The *.wct files are the ctd data for each station. When submitted to the SAC, the *.wct files are zipped into one file called *wct.zip. The *.csl file is a listing of ctd and calculated values at standard levels.

The following is a description of how the standard levels and calculated values were derived for the *.csl file:

Salinity, Temperature and Pressure: These three values were smoothed from the individual CTD files over the N uniformly increasing pressure levels.

using the following binomial filter-

$$t(j) = 0.25ti(j-1) + 0.5ti(j) + 0.25ti(j+1) \quad j=2....N-1$$

When a pressure level is represented in the *.csl file that is not contained within the ctd values, the value was linearly interpolated to the desired level after applying the binomial filtering.

Sigma-theta(SIG-TH:KG/M3), Sigma-2 (SIG-2: KG/M3), and Sigma-4(SIG-4: KG/M3): These values are calculated using the practical salinity scale (PSS-78) and the international equation of state for seawater (EOS-80) as described in the Unesco publication 44 at reference pressures of the surface for SIG-TH; 2000 dbars for Sigma-2; and 4000 dbars for Sigma-4.

Gradient Potential Temperature (GRD-PT: C/DB 10-3) is calculated as the least squares slope between two levels, where the standard level is the center of the interval. The interval being the smallest of the two differences between the standard level and the two closest values. The slope is first determined using CTD temperature and then the adiabatic lapse rate is subtracted to obtain the gradient potential temperature. Equations and Fortran routines are described in Unesco publication 44.

Gradient Salinity (GRD-S: 1/DB 10-3) is calculated as the least squares slope between two levels, where the standard level is the center of the standard level and the two closes values. Equations and Fortran routines are described in Unesco publication 44.

Potential Vorticity (POT-V: 1/ms 10-11) is calculated as the vertical component ignoring contributions due to relative vorticity, i.e. pv=fN2/g, where f is the coriolius parameter, N is the buoyancy frequency (data expressed as radius/sec), and g is the local acceleration of gravity.

Buoyancy Frequency (B-V: cph) is calculated using the adiabatic leveling method, Fofonoff (1985) and Millard, Owens and Fofonoff (1990). Equations and Fortran routines are described in Unesco publication 44.

Potential Energy (PE: J/M2: 10-5) and Dynamic Height (DYN-HT: M) are calculated by integrating from 0 to the level of interest. Equations and Fortran routines are described in Unesco publication 44.

Neutral Density (GAMMA-N: KG/M3) is calculated with the program GAMMA-N (Jackett and McDougall) version 1.3 Nov. 94.

P18
Final Report
for AMS ^{14}C Samples

Robert M. Key and Paul D. Quay

August 26, 1998

1.0 General Information

WOCE cruise P18 was s carried out aboard the R/V Discoverer in the southeastern Pacific Ocean. The WHPO designation for this cruise was 31DSCG94/2,3. Bruce Taft and John Bullister, were the chief scientists for leg 2 and Gregory Johnson and Richard Feely for leg 3 (all from NOAA-PMEL). Leg 2 (P18S) departed Punta Arenas, Chile on February 22, 1994 and ended on March 2, 1994 at Easter Island. The next leg, P18N, departed Easter Island March 27, 1994 and ended at San Diego, CA on April 3, 1994. Together the two legs made a meridional section approximately along 106°W from approximately 67°S to 24°N. The reader is referred to cruise documentation provided by the chief scientists as the primary source for cruise information. This report covers details of the small volume radiocarbon samples. The AMS station locations are shown in Figure 1 and summarized in Table 1. A total of 882 $\Delta^{14}C$ samples were collected at 33 stations.

Table 1: P18 Station AMS ^{14}C Locations

Station	Date	Latitude	Longitude	Bottom Depth (m)
10	2/27/1994	-66.995	-103.007	4746
16	3/01/1994	-63.989	-102.987	5018
22	3/03/1994	-61.017	-103.000	4970
28	3/05/1994	-57.818	-103.002	4591
33	3/08/1994	-54.501	-103.001	4086
37	3/09/1994	-51.834	-103.002	4000
41	3/11/1994	-49.163	-103.003	4203
47	3/12/1994	-45.993	-102.999	3907
53	3/14/1994	-43.003	-102.998	3827
59	3/15/1994	-40.003	-102.980	4053
67	3/17/1994	-35.994	-102.992	3700
71	3/18/1994	-34.007	-103.002	3667
77	3/20/1994	-31.000	-103.000	3504
83	3/22/1994	-28.000	-103.000	3352
89	3/29/1994	-24.988	-103.001	3833
101	4/01/1994	-19.000	-103.002	4085
105	4/02/1994	-16.998	-102.995	3928
113	4/05/1994	-13.010	-103.008	4252
117	4/06/1994	-11.000	-103.013	4248
126	4/08/1994	-7.312	-106.944	3175
134	4/10/1994	-4.003	-110.329	3841
138	4/11/1994	-2.333	-110.334	3987

Station	Date	Latitude	Longitude	Bottom Depth (m)
142	4/13/1994	-1.0017	-110.328	4070
145	4/13/1994	-0.000	-110.334	3785
148	4/14/1994	1.001	-110.333	3675
152	4/15/1994	2.333	-110.333	3701
156	4/16/1994	4.002	-110.335	3868
163	4/18/1994	7.498	-110.335	3939
168	4/19/1994	10.000	-110.000	3310
174	4/21/1994	14.002	-109.998	3275
178	4/22/1994	16.002	-110.000	3307
182	4/23/1994	17.998	-110.000	3269
190	4/25/1994	21.998	-110.000	3165

2.0 Personnel

^{14}C sampling for this cruise was carried out by J. Green and E. Houzel from U. Washington. ^{14}C analyses were performed at the National Ocean Sciences AMS Facility (NOSAMS) at Woods Hole Oceanographic Institution. G. Thomas (AOML) analyzed salinity; K. Hargraves and D. Jones (PMEL) analyzed oxygen. Nutrients were analyzed by K. Krogslund (UW) and C. Mordy (PMEL). ^{13}C analyses were run in P. Quay's lab (U. Washington). Key collected the data from the originators, merged the files, assigned quality control flags to the ^{14}C and submitted the data files to the WOCE office (8/98). Paul Quay is P.I. for the ^{13}C and ^{14}C data.

3.0 Results

This 14C data set and any changes or additions supersedes any prior release.

3.1 Hydrography

Hydrography from this leg has been submitted to the WOCE office by the chief scientist and described in the hydrographic report.

3.2 ^{14}C

The $\Delta^{14}C$ values reported here were originally distributed in a NOSAMS data report (NOSAMS, 1998), June 19, 1998. That reports included preliminary results which had not been through the WOCE quality control procedures. This report supersedes that data distribution.

All of the AMS samples from this cruise have been measured. Replicate measurements were made on 14 water samples. These replicate analyses are tabulated in Table 2. The table shows the error weighted mean and uncertainty for each set of replicates. Uncertainty is defined here as the larger of the standard deviation and the error weighted standard deviation of the mean. For these replicates, the simple average of the normal standard deviations for the replicates is 4.9‰. This precision estimate is approximately correct for the time frame over which these samples were measured (Aug. 1996 - Apr. 1998). Note that the errors given for individual measurements in the final data report (with the exception of the replicates) include only counting errors, and errors due to blanks and backgrounds. The uncertainty obtained for replicate analyses is a better estimate of the true error which includes errors due to sample collection, sample degassing, *etc*. For a detailed discussion of this see Key (1996).

Table 2: Summary of Replicate Analyses

Sta-Cast-Bottle	$\Delta^{14}C$	Err	E.W.Mean[a]	Uncertainty[b]
16-1-29	-107.0	4.3	-100.8	6.1
	-98.4	2.7		
28-1-30	-52.6	3.5	-54.9	2.9
	-56.6	2.9		
33-2-33	37.0	4.1	31.9	7.4
	26.5	4.3		
33-2-21	-5.1	3.8	-4.6	3.3
	-2.9	6.7		
41-1- 7	44.0	5.4	36.9	6.7
	34.6	3.1		
47-1-18	-31.3	4.5	-35.4	4.3
	-37.3	3.1		
71-1-19	-20.5	5.1	-20.5	5.1
	15.0[c]	5.1		
83-1-28	130.7	3.8	128.8	4.4
	124.5	5.6		
113-1-23	-90.3	3.8	-94.2	5.8
	-98.6	4.1		
126-2- 2	-219.3	2.9	-223.8	8.1
	-230.7	3.6		
134-1-21	-108.4	2.8	-107.0	2.0
	-105.6	2.7		
163-1-18	-170.1	2.3	-174.9	8.4
	-181.9	2.8		
168-3-17	-206.9[d]	2.4	-188.8	3.6
	-188.8	3.6		
182-1-23	-108.1	3.0	-106.9	1.8
	-106.2	2.2		

a. Error weighted mean reported with data set
b. Larger of the standard deviation and the error weighted standard deviation of the mean.
c. Results not used
d. Results not used

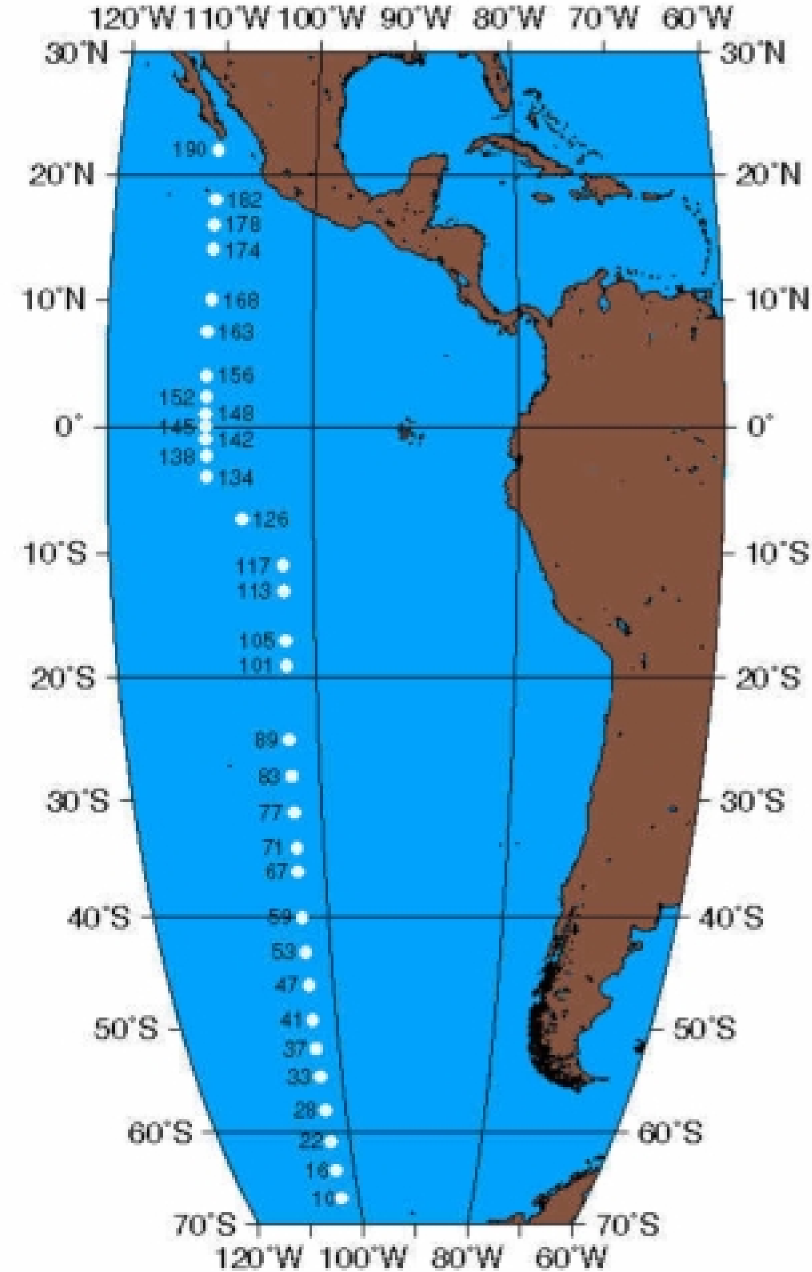

Figure 1: AMS ^{14}C station locations for WOCE P18.

4.0 Quality Control Flag Assignment

Quality flag values were assigned to all $\Delta^{14}C$ measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev. 2 section 4.5.2. (Joyce, *et al.*, 1994). Measurement flags values of 2, 3, 4, 5 and 6 have been assigned. The choice between values 2 (good), 3 (questionable) or 4 (bad) involves some interpretation. There is little overlap between this data set and any existing ^{14}C data, so that type of comparison was difficult. In general the lack of other data for comparison led to a more lenient grading on the ^{14}C data.

When using this data set for scientific application, any ^{14}C datum which is flagged with a "3" should be carefully considered. My subjective opinion is that any datum flagged "4" should be disregarded. When flagging ^{14}C data, the measurement error was taken into consideration. That is, approximately one-third of the ^{14}C measurements are expected to deviate from the true value by more than the measurement precision (~4.9‰). No measured values have been removed from this data set, therefore a flag value of 5 implies that the sample was totally lost somewhere between collection and analysis. Table 3 summarizes the quality control flags assigned to this data set. For a detailed description of the flagging procedure see Key, *et al.* (1996).

Table 3: Summary of Assigned Quality Control Flags

Flag	Number
2	742
3	4
4	8
5	30
6	11

5.0 Data Summary

Figures 2-5 summarize the $\Delta^{14}C$ data collected on this leg. Only $\Delta^{14}C$ measurements with a quality flag value of 2 ("good") or 6 ("replicate") are included in each figure. Figure 2 shows the $\Delta^{14}C$ values with 2σ error bars plotted as a function of pressure. The mid depth $\Delta^{14}C$ minimum which normally occurs around 2500 meters in most of the Pacific is absent in this section except at the northern end and it is weak there. In the main thermocline the results cluster into two distinct bands. The band with higher concentration result from ventilation *via* mode and intermediate waters. Figure 3 shows the $\Delta^{14}C$ values plotted against silicate.The straight line shown in the figure is the least squares regression relationship derived by Broecker *et al*. (1995) based on the GEOSECS global data set. According to their analysis, this line ($\Delta^{14}C$ = -70 - Si) represents the relationship between naturally occurring radiocarbon and silicate for most of the ocean. They interpret deviations in $\Delta^{14}C$ above this line to be due to input of bomb-produced radiocarbon, however, they note that the interpretation can be problematic at high latitudes. The points falling above the line with silicate concentrations greater than 100 μm/kg clearly illustrate the departure for waters from the Southern Ocean. Samples collected from shallow depths show an upward curving trend with decreasing silicate values reflecting the addition of bomb produced ^{14}C.

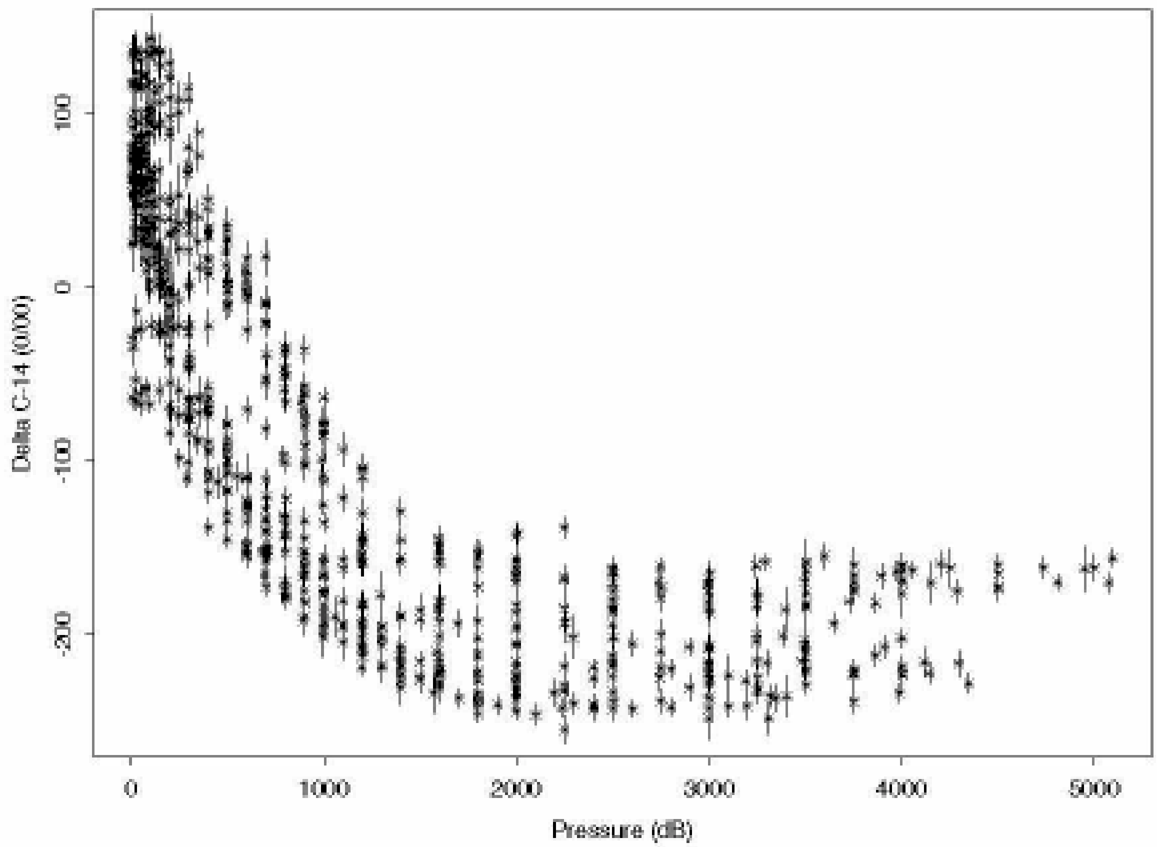

Figure 2: $\Delta^{14}C$ results for P18 stations shown with 2σ error bars. Only those measurements having a quality control flag value of 2 or 6 are plotted.

Figure 4 compares the surface $\Delta^{14}C$ values for P18 to those from the southeastern Pacific GEOSECS data set. The greatest change in concentration is in the 30°S to 45°S latitude range and at 20°N where the $\Delta^{14}C$ levels decreased by approximately 50‰. The low latitude region shows essentially no change since GEOSECS.

Figure 5 shows contoured sections of the $\Delta^{14}C$ distribution along the cruise track. The "A" portion shows the upper kilometer of the section and "B" the remainder of the water column. The data were gridded using the "loess" methods described in Chambers *et al*. (1983), Chambers and Hastie (1991), Cleveland (1979) and Cleveland and Devlin (1988). Figure 6 shows the same data as Figure 5A except the section is plotted in potential density (σ_θ) - latitude space. For this section, the maximum $\Delta^{14}C$ concentration was found at the surface except for a few stations between 20°S and 5°S. Both Figure 5A and Figure 6 clearly indicate those surfaces which are being directly ventilated by contact with the surface.

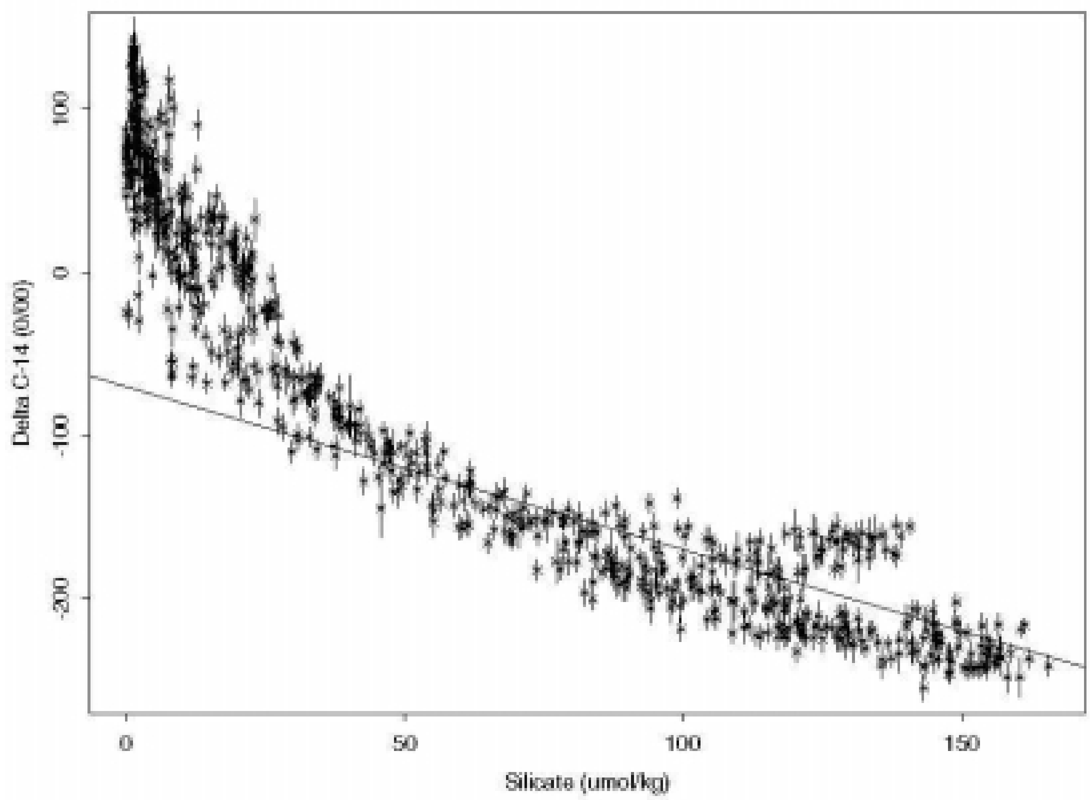

Figure 3: $\Delta^{14}C$ as a function of silicate for P18 AMS samples. The straight line shows the relationship proposed by Broecker, *et al.*, 1995 (Δ14C=-70 - Si with radiocarbon in ‰ and silicate in μmol/kg).

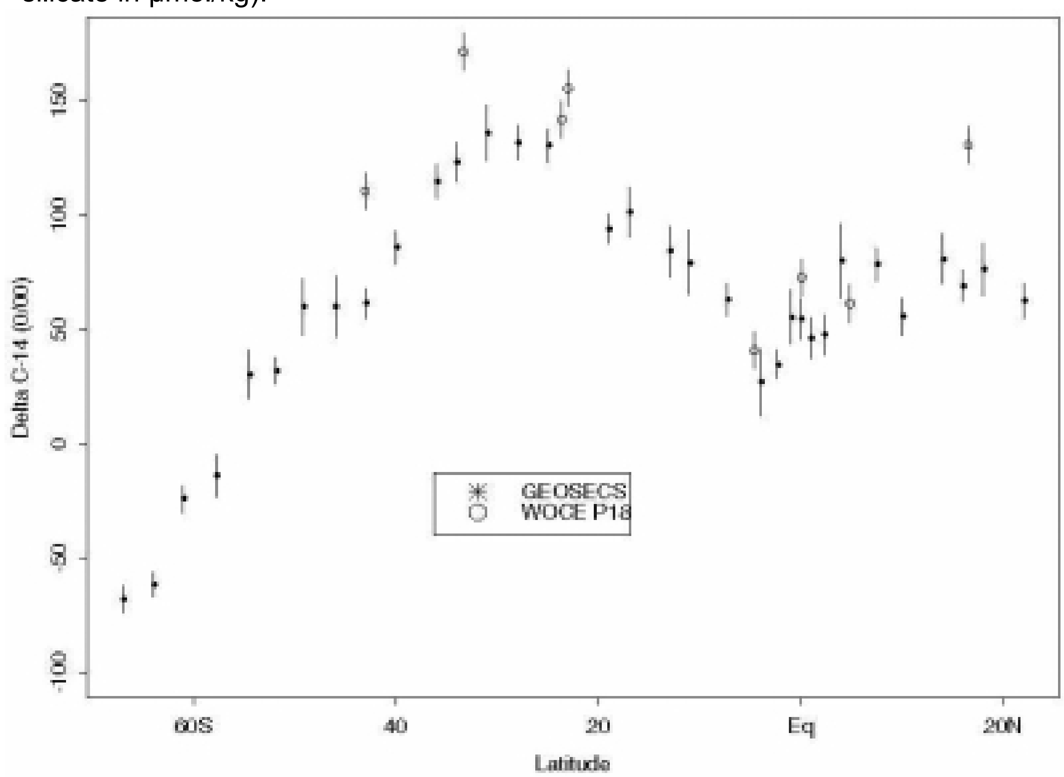

Figure 4: Surface distribution of Δ14C along WOCE section P18. For comparison the GEOSECS data from the southeastern Pacific are also plotted. Both data sets are shown with 2σ error bars.

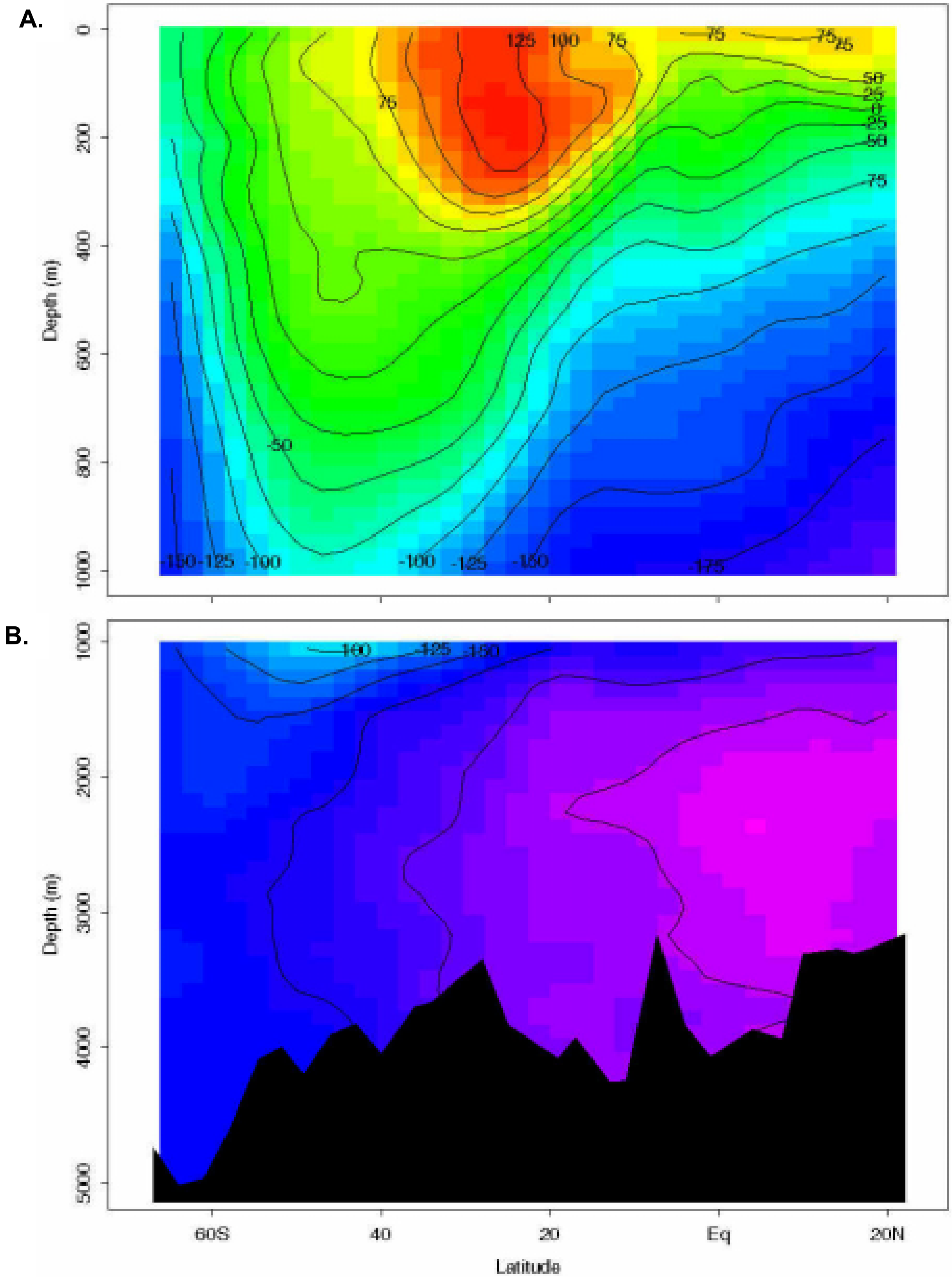

Figure 5: $\Delta^{14}C$ sections for WOCE P18 along 165°E. The section shown in two parts to allow more detail. See text for gridding method. The bottom topography in B is taken from cruise data, but only using those stations on which $\Delta^{14}C$ was measured.

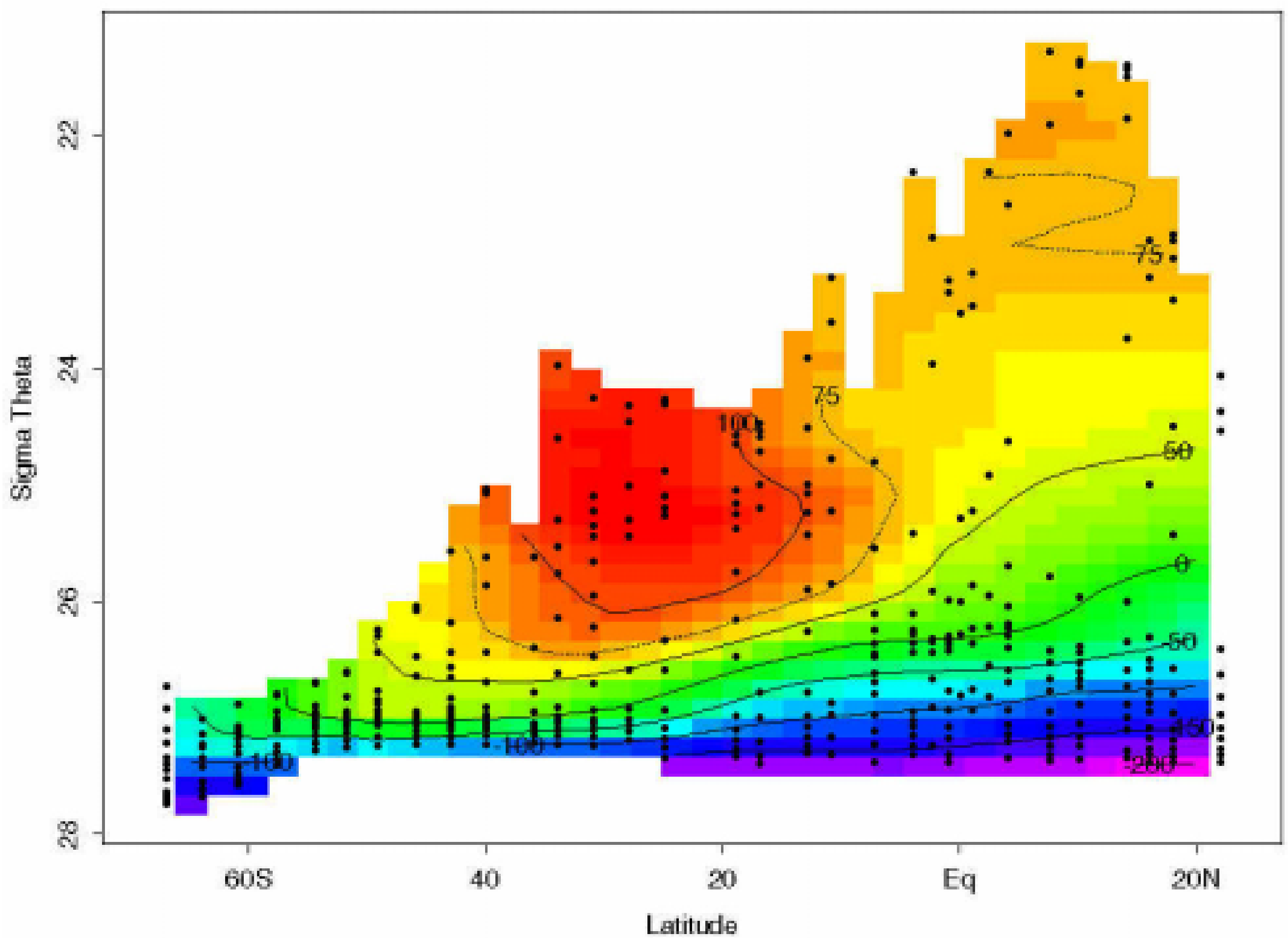

Figure 6: $\Delta^{14}C$ along WOCE section P18 plotted in potential density (σ_θ) - latitude space for the upper kilometer of the water column. Colors and contours contain the same information.

5.1 References and Supporting Documentation

Broecker, W.S., S. Sutherland and W. Smethie, Oceanic radiocarbon: Separation of the natural and bomb components, *Global Biogeochemical Cycles, 9(2),* 263-288, 1995.

Chambers, J.M. and Hastie, T.J., 1991, Statistical Models in S, Wadsworth & Brooks, Cole Computer Science Series, Pacific Grove, CA, 608pp.

Chambers, J.M., Cleveland, W.S., Kleiner, B., and Tukey, P.A., 1983, Graphical Methods for Data Analysis, Wadsworth, Belmont, CA.

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots, J. Amer. Statistical Assoc., 74, 829-836.

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Joyce, T., and Corry, C., *eds*., Corry, C., Dessier, A., Dickson, A., Joyce, T., Kenny, M., Key, R., Legler, D., Millard, R., Onken, R., Saunders, P., Stalcup, M., *contrib*., Requirements for WOCE Hydrographic Programme Data Reporting, WHPO Pub. 90-1 Rev. 2, 145pp., 1994.

Key, R.M., WOCE Pacific Ocean radiocarbon program, *Radiocarbon, 38(3),* 415-423, 1996.

Key, R.M., P.D. Quay, G.A. Jones, A.P. McNichol, K.F. Von Reden and R.J. Schneider, WOCE AMS Radiocarbon I: Pacific Ocean results; P6, P16 & P17, *Radiocarbon, 38(3),* 425-518, 1996.

NOSAMS, National Ocean Sciences AMS Facility Data Report #97-023, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, 1997.

Cruise Report: WHP Line P18
(Draft prepared by John Bullister, NOAA-PMEL, 18 June 2000)

The following appendices are included in this file:

Expedition: CGC94 (WOCE section P18)
EXPOCODE:31DICG94/1 31DICG94/2 31DICG94/3
Ship: NOAA Research Vessel DISCOVERER

Leg 1: Transit from Seattle- Punta Arenas Chile
26 January 1994 - 18 February 1994
(Stations 1-7: Not part of P18 section)
Leg 2: Punta Arenas- Easter Island
22 February 1994 - 24 March 1994
(Stations 8-87)
Leg 3: Easter Island- San Diego
29 March 1994 - 27 April 1994
(Stations 88-194)

Cruise Track: The station locations are listed in Appendix 1 and in the P18.sum file.

Additional details on the measurement techniques used on this expedition are given in:

McTaggart, K.E., G.C. Johnson, and B.A. Taft (1996): CTD/O_2 measurements collected on a Climate and Global Change Cruise (WOCE Section P18) along 110°W during January-April, 1994. NOAA Data Report ERL PMEL-59, 519 pp.

Lamb, M. F., J. L. Bullister, R. A. Feely, , G. C. Johnson, D. P. Wisegarver, B. Taft, R. Wanninkhof, K. E. McTaggart, K. A. Krogslund, C. Mordy, K. Hargreaves, D. Greeley, T. Lantry, H. Chen, B. Huss, F. J. Millero, R. H. Byrne, D. A. Hansell, F. P. Chavez, P.

D. Quay, P. R. Guenther, J.-Z. Zhang, W. D. Gardner, M. J. Richardson, and T.-H. Peng. Chemical and hydrographic measurements in the eastern Pacific during the CGC94 expedition (WOCE section P18). NOAA Data Report ERL PMEL-61, 1997.

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APPENDIX 1. CTD/Rosette Station Locations on P18 (CGC94)

CGC94 LEG1:

STATION NUMBER	Latitude	Longitude	Date
1	47 43.4 N	122 24.6 W	26 Jan 94
2	44 14.1 N	129 40.5 W	28 Jan 94
3	44 12.0 N	129 43.0 W	28 Jan 94
4	44 16.6 N	129 44.9 W	28 Jan 94
5	44 09.8 N	129 44.9 W	28 Jan 94
6	44 12.3 N	129 37.3 W	29 Jan 94
7	44 18.0 N	129 35.3 W	29 Jan 94

CGC94 LEG2:

STATION NUMBER	Latitude	Longitude	Date
8	53 22.9 S	076 22.0 W	23 Feb 94
9	61 13.2 S	090 10.9 W	25 Feb 94
10	66 59.7 S	103 00.4 W	27 Feb 94
11	66 29.8 S	103 00.6 W	28 Feb 94
12	66 00.0 S	102 59.8 W	28 Feb 94
13	65 30.0 S	102 60.0 W	28 Feb 94
14	65 00.0 S	102 59.4 W	28 Feb 94
15	64 29.9 S	102 59.2 W	1 Mar 94
16	63 59.3 S	102 59.2 W	1 Mar 94
17	63 30.0 S	102 59.6 W	2 Mar 94
18	63 00.0 S	102 58.0 W	2 Mar 94
19	62 30.0 S	103 00.0 W	2 Mar 94
20	61 59.9 S	103 00.1 W	2 Mar 94
21	61 27.0 S	102 59.0 W	3 Mar 94
22	61 01.0 S	103 00.0 W	3 Mar 94
23	60 30.9 S	102 57.1 W	3 Mar 94

24	60 00.0 S	103 06.4 W	4 Mar 94
25	59 31.6 S	103 01.0 W	4 Mar 94
26	58 59.8 S	103 01.2 W	4 Mar 94
27	58 30.5 S	102 59.3 W	5 Mar 94
28	57 49.1 S	103 00.1 W	5 Mar 94
29	57 10.3 S	103 00.1 W	6 Mar 94
30	56 31.6 S	103 04.0 W	7 Mar 94
31	55 49.6 S	102 59.4 W	7 Mar 94
32	55 10.0 S	103 00.0 W	8 Mar 94
33	54 30.1 S	103 00.1 W	8 Mar 94
34	53 50.0 S	102 59.9 W	8 Mar 94
35	53 10.0 S	103 03.0 W	9 Mar 94
36	52 30.2 S	103 00.6 W	9 Mar 94
37	51 50.0 S	103 00.1 W	9 Mar 94
38	51 10.0 S	103 00.0 W	10 Mar 94
39	50 30.0 S	103 00.0 W	10 Mar 94
40	49 50.0 S	102 60.0 W	10 Mar 94
41	49 09.8 S	103 00.2 W	11 Mar 94
42	48 29.0 S	103 00.0 W	11 Mar 94
43	47 59.8 S	103 00.4 W	11 Mar 94
44	47 30.0 S	103 00.1 W	11 Mar 94
45	46 59.9 S	102 59.9 W	12 Mar 94
46	46 30.0 S	103 00.0 W	12 Mar 94
47	45 59.6 S	102 60.0 W	12 Mar 94
48	45 28.9 S	102 58.3 W	12 Mar 94
49	45 00.5 S	102 59.6 W	13 Mar 94
50	44 29.0 S	103 00.0 W	13 Mar 94
51	43 59.1 S	102 59.8 W	13 Mar 94
52	43 30.0 S	103 00.8 W	13 Mar 94
53	43 00.2 S	102 59.9 W	14 Mar 94
54	42 29.0 S	103 00.0 W	14 Mar 94
55	42 00.0 S	103 00.0 W	14 Mar 94
56	41 29.6 S	102 59.5 W	15 Mar 94
57	41 01.0 S	103 00.0 W	15 Mar 94
58	40 30.2 S	102 59.2 W	15 Mar 94
59	40 00.2 S	102 58.8 W	15 Mar 94
60	39 29.9 S	102 59.9 W	16 Mar 94
61	39 00.0 S	103 00.0 W	16 Mar 94
62	38 30.3 S	102 59.8 W	16 Mar 94
63	37 59.9 S	102 59.9 W	16 Mar 94
64	37 29.9 S	102 59.0 W	17 Mar 94
65	37 00.0 S	103 00.0 W	17 Mar 94
66	36 30.0 S	103 00.0 W	17 Mar 94
67	35 59.6 S	102 59.5 W	17 Mar 94
68	35 30.0 S	102 59.9 W	18 Mar 94
69	35 00.0 S	103 00.0 W	18 Mar 94
70	34 31.0 S	103 00.0 W	18 Mar 94

71	34 00.4 S	103 00.1 W	18 Mar 94
72	33 29.7 S	102 59.9 W	19 Mar 94
73	33 00.0 S	103 00.0 W	19 Mar 94
74	32 30.0 S	103 00.0 W	19 Mar 94
75	31 59.8 S	102 58.8 W	19 Mar 94
76	31 29.5 S	103 00.0 W	20 Mar 94
77	31 00.0 S	103 00.0 W	20 Mar 94
78	30 30.3 S	103 00.0 W	20 Mar 94
79	30 00.0 S	103 00.0 W	21 Mar 94
80	29 29.0 S	103 00.0 W	21 Mar 94
81	29 00.1 S	103 00.8 W	21 Mar 94
82	28 29.7 S	102 59.8 W	22 Mar 94
83	28 00.0 S	103 00.0 W	22 Mar 94
84	27 30.1 S	103 01.1 W	22 Mar 94
85	26 55.2 S	103 00.6 W	22 Mar 94
86	26 29.7 S	103 00.0 W	23 Mar 94
87	26 00.0 S	103 00.0 W	23 Mar 94

CGC94 LEG3:

STATION NUMBER	Latitude	Longitude	Date
88	25 29.9 S	103 00.0 W	29 Mar 94
89	24 59.3 S	103 00.0 W	29 Mar 94
90	24 30.1 S	102 59.8 W	29 Mar 94
91	23 59.9 S	103 00.1 W	29 Mar 94
92	23 29.7 S	102 59.7 W	30 Mar 94
93	23 00.1 S	102 59.8 W	30 Mar 94
94	22 29.9 S	102 59.9 W	30 Mar 94
95	21 59.6 S	102 59.4 W	30 Mar 94
96	21 30.0 S	102 59.9 W	31 Mar 94
97	20 59.9 S	103 00.1 W	31 Mar 94
98	20 30.1 S	103 00.0 W	31 Mar 94
99	20 00.0 S	103 00.0 W	1 Apr 94
100	19 30.1 S	102 59.5 W	1 Apr 94
101	19 00.0 S	103 00.1 W	1 Apr 94
102	18 29.7 S	103 00.1 W	2 Apr 94
103	17 59.9 S	103 00.2 W	2 Apr 94
104	17 30.0 S	103 00.4 W	2 Apr 94
105	16 59.9 S	102 59.7 W	2 Apr 94
106	16 29.9 S	102 59.9 W	3 Apr 94
107	16 00.0 S	103 00.0 W	3 Apr 94
108	15 30.1 S	103 00.0 W	3 Apr 94
109	14 60.0 S	102 60.0 W	3 Apr 94
110	14 30.2 S	102 59.3 W	4 Apr 94
111	14 00.0 S	102 59.7 W	4 Apr 94
112	13 30.0 S	103 00.2 W	4 Apr 94
113	13 00.6 S	103 00.5 W	5 Apr 94
114	12 30.1 S	103 00.1 W	5 Apr 94

115	12 00.1 S	103 00.1 W	5 Apr 94
116	11 30.3 S	103 00.0 W	5 Apr 94
117	11 00.0 S	103 00.8 W	6 Apr 94
118	10 30.4 S	103 00.1 W	6 Apr 94
119	10 00.2 S	102 60.0 W	6 Apr 94
120	09 37.1 S	103 34.0 W	6 Apr 94
121	09 14.1 S	104 08.1 W	7 Apr 94
122	08 51.2 S	104 41.7 W	7 Apr 94
123	08 27.8 S	105 15.6 W	7 Apr 94
124	08 04.7 S	105 49.7 W	8 Apr 94
125	07 42.0 S	106 23.0 W	8 Apr 94
126	07 18.7 S	106 56.6 W	8 Apr 94
127	06 56.4 S	107 30.7 W	9 Apr 94
128	06 33.7 S	108 04.4 W	9 Apr 94
129	06 09.3 S	108 38.5 W	9 Apr 94
130	05 46.4 S	109 12.2 W	9 Apr 94
131	05 23.5 S	109 46.0 W	10 Apr 94
132	05 00.1 S	110 20.1 W	10 Apr 94
133	04 29.7 S	110 19.6 W	10 Apr 94
134	04 00.2 S	110 19.7 W	10 Apr 94
135	03 29.9 S	110 20.0 W	11 Apr 94
136	03 00.0 S	110 20.0 W	11 Apr 94
137	02 40.0 S	110 19.9 W	11 Apr 94
138	02 20.0 S	110 20.1 W	11 Apr 94
139	02 00.7 S	110 20.4 W	12 Apr 94
140	01 40.0 S	110 19.9 W	12 Apr 94
141	01 20.0 S	110 20.1 W	12 Apr 94
142	01 00.1 S	110 19.7 W	13 Apr 94
143	00 41.0 S	110 20.0 W	14 Apr 94
144	00 20.1 S	110 19.6 W	14 Apr 94
145	00 00.0 S	110 20.0 W	13 Apr 94
146	00 20.1 N	110 20.0 W	14 Apr 94
147	00 39.9 N	110 20.2 W	14 Apr 94
148	01 00.0 N	110 20.0 W	14 Apr 94
149	01 20.0 N	110 20.0 W	14 Apr 94
150	01 40.6 N	110 20.2 W	15 Apr 94
151	02 00.0 N	110 20.1 W	15 Apr 94
152	02 20.0 N	110 20.0 W	15 Apr 94
153	02 40.0 N	110 20.0 W	15 Apr 94
154	03 00.0 N	110 20.0 W	15 Apr 94
155	03 30.0 N	110 20.0 W	16 Apr 94
156	04 00.1 N	110 20.1 W	16 Apr 94
157	04 30.0 N	110 20.0 W	16 Apr 94
158	04 59.7 N	110 20.1 W	17 Apr 94
159	05 30.0 N	110 20.1 W	17 Apr 94
160	06 00.0 N	110 20.0 W	17 Apr 94
161	06 29.9 N	110 20.0 W	17 Apr 94

162	07 00.0 N	110 20.4 W	18 Apr 94
163	07 29.9 N	110 20.1 W	18 Apr 94
164	07 59.9 N	110 20.2 W	18 Apr 94
165	08 30.1 N	110 15.1 W	18 Apr 94
166	09 00.1 N	110 10.0 W	19 Apr 94
167	09 30.1 N	110 05.2 W	19 Apr 94
168	10 00.0 N	110 00.0 W	19 Apr 94
169	10 40.0 N	109 60.0 W	20 Apr 94
170	11 20.0 N	110 00.0 W	20 Apr 94
171	12 00.1 N	110 00.0 W	20 Apr 94
172	12 40.0 N	110 00.0 W	20 Apr 94
173	13 20.0 N	109 59.7 W	21 Apr 94
174	14 00.1 N	109 59.9 W	21 Apr 94
175	14 29.9 N	109 59.9 W	21 Apr 94
176	15 00.0 N	110 00.0 W	21 Apr 94
177	15 29.9 N	109 59.7 W	22 Apr 94
178	16 00.1 N	110 00.0 W	22 Apr 94
179	16 30.0 N	110 00.1 W	22 Apr 94
180	17 00.0 N	110 00.0 W	22 Apr 94
181	17 30.1 N	109 59.8 W	23 Apr 94
182	17 59.9 N	110 00.0 W	23 Apr 94
183	18 30.0 N	110 00.0 W	23 Apr 94
184	19 00.0 N	110 00.0 W	23 Apr 94
185	19 30.0 N	109 59.9 W	24 Apr 94
186	20 00.1 N	109 59.9 W	24 Apr 94
187	20 29.9 N	110 00.0 W	24 Apr 94
188	21 00.0 N	110 00.0 W	24 Apr 94
189	21 29.9 N	110 00.1 W	24 Apr 94
190	21 59.9 N	110 00.0 W	25 Apr 94
191	22 29.8 N	109 59.7 W	25 Apr 94
192	22 43.9 N	110 00.4 W	25 Apr 94
193	22 47.9 N	110 00.3 W	25 Apr 94
194	22 51.1 N	109 59.9 W	25 Apr 94

APPENDIX 2. ALACE Float Deployment Locations on P18 (CGC94) (in .sum format)

31DICG94/2	1	FLT	022494	0756	DE	55 50.17 S	80 22.34 W GPS
31DICG94/2	1	FLT	022494	1636	DE	56 39.64 S	81 46.87 W GPS
31DICG94/2	1	FLT	022494	2130	DE	57 30.02 S	83 17.12 W GPS
31DICG94/2	1	FLT	022594	0228	DE	58 19.87 S	84 45.79 W GPS
31DICG94/2	1	FLT	022594	0725	DE	59 09.26 S	86 18.96 W GPS
31DICG94/2	1	FLT	022594	1210	DE	59 59.90 S	87 51.50 W GPS
31DICG94/2 P18	1	FLT	030894	1025	DE	55 10.40 S	103 01.09 W GPS
31DICG94/2 P18	1	FLT	031094	2028	DE	49 49.28 S	103 00.10 W GPS
31DICG94/2 P18	1	FLT	031394	0637	DE	44 58.99 S	103 00.25 W GPS
31DICG94/2 P18	1	FLT	031594	0117	DE	40 00.99 S	103 00.55 W GPS
31DICG94/2 P18	1	FLT	031894	1200	DE	35 00.40 S	103 00.74 W GPS

31DICG94/2	P18	1	FLT	032094	0739	DE	30 00.15 S	103 01.53 W	GPS
31DICG94/3	P18	1	FLT	032994	1341	DE	25 00.24 S	103 00.05 W	GPS
31DICG94/3	P18	1	FLT	033194	2011	DE	20 29.51 S	102 59.98 W	GPS
31DICG94/3	P18	1	FLT	040494	0005	DE	14 59.70 S	103 00.01 W	GPS
31DICG94/3	P18	1	FLT	040694	1917	DE	9 59.76 S	103 00.70 W	GPS
31DICG94/3	P18	1	FLT	040994	1441	DE	6 09.09 S	108 38.61 W	GPS
31DICG94/3	P18	1	FLT	041094	2307	DE	3 59.28 S	110 19.78 W	GPS
31DICG94/3	P18	1	FLT	041294	1838	DE	1 20.27 S	110 19.94 W	GPS
31DICG94/3	P18	1	FLT	041494	1443	DE	1 00.38 N	110 19.96 W	GPS
31DICG94/3	P18	1	FLT	041694	1431	DE	3 59.69 N	110 19.93 W	GPS
31DICG94/3	P18	1	FLT	041794	1731	DE	5 59.90 N	110 20.30 W	GPS
31DICG94/3	P18	1	FLT	041994	1956	DE	10 00.78 S	110 00.19 W	GPS
31DICG94/3	P18	1	FLT	042194	1819	DE	14 29.77 S	110 00.03 W	GPS
31DICG94/3	P18	1	FLT	042394	2246	DE	18 59.93 S	109 59.80 W	GPS

APPENDIX 3. XCTD deployments Locations on P18 (CGC94) (in .sum format)

31DICG94/1		XCTD	012994	0355	DE	44 12.97 N	129 37.08 W	GPS
31DICG94/2	P18	XCTD	030294	1916	DE	62 27.85 S	102 58.45 W	GPS
31DICG94/2	P18	XCTD	030394	0941	DE	61 25.90 S	102 58.90 W	GPS
31DICG94/2	P18	XCTD	031094	0556	DE	51 09.50 S	103 00.60 W	GPS
31DICG94/3	P18	XCTD	041494	1540	DE	1 10.01 N	110 19.87 W	GPS
31DICG94/3	P18	XCTD	041494	2208	DE	1 30.10 N	110 19.60 W	GPS
31DICG94/3	P18	XCTD	041594	0340	DE	1 50.30 N	110 19.70 W	GPS
31DICG94/3	P18	XCTD	041594	0933	DE	2 10.10 N	110 20.00 W	GPS
31DICG94/3	P18	XCTD	041594	1455	DE	2 30.00 N	110 19.80 W	GPS
31DICG94/3	P18	XCTD	041594	2116	DE	2 50.00 N	110 19.90 W	GPS
31DICG94/3	P18	XCTD	041694	0250	DE	3 15.00 N	110 19.90 W	GPS
31DICG94/3	P18	XCTD	041694	0942	DE	3 45.00 N	110 19.40 W	GPS
31DICG94/3	P18	XCTD	041694	1546	DE	4 15.00 N	110 19.80 W	GPS
31DICG94/3	P18	XCTD	041694	2313	DE	4 45.00 N	110 20.00 W	GPS
31DICG94/3	P18	XCTD	041794	0536	DE	5 16.28 N	110 19.77 W	GPS
31DICG94/3	P18	XCTD	041794	1227	DE	5 45.00 N	110 20.00 W	GPS
31DICG94/3	P18	XCTD	041794	1845	DE	6 15.03 N	110 20.46 W	GPS
31DICG94/3	P18	XCTD	041894	0038	DE	6 45.00 N	110 20.60 W	GPS
31DICG94/3	P18	XCTD	041894	0659	DE	7 15.00 N	110 20.61 W	GPS
31DICG94/3	P18	XCTD	041894	1307	DE	7 45.00 N	110 19.90 W	GPS
31DICG94/3	P18	XCTD	041894	2011	DE	8 15.00 N	110 17.74 W	GPS
31DICG94/3	P18	XCTD	041894	0159	DE	8 45.10 N	110 12.50 W	GPS
31DICG94/3	P18	XCTD	041994	0822	DE	9 15.00 N	110 07.60 W	GPS

APPENDIX 4. Productivity and Shallow Biological Cast Locations on P18 (CGC94) (in .sum format)

31DICG94/2	8	2	BIO	022394	1824	EN	53 23.88 S	76 21.54 W	GPS
31DICG94/2	9	1	BIO	022594	1910	BE	61 12.44 S	90 11.49 W	GPS
31DICG94/2	9	1	BIO	022594	1913	BO	61 12.52 S	90 11.45 W	GPS

31DICG94/2		9	1	BIO	022594	1916	EN	61	12.52	S	90	11.45	W	GPS	
31DICG94/2		9	2	BIO	022594	1920	BE	61	12.55	S	90	11.43	W	GPS	
31DICG94/2		9	2	BIO	022594	1932	BO	61	12.71	S	90	11.29	W	GPS	
31DICG94/2		9	2	BIO	022594	1940	EN	61	12.83	S	90	10.93	W	GPS	
31DICG94/2	P18	10	1	BIO	022794	1407	BE	67	00.02	S	102	59.46	W	GPS	
31DICG94/2	P18	10	1	BIO	022794	1416	BO	67	00.01	S	102	59.21	W	GPS	
31DICG94/2	P18	10	1	BIO	022794	1420	EN	66	59.98	S	102	59.13	W	GPS	
31DICG94/2	P18	10	2	BIO	022794	1424	BE	67	00.00	S	102	59.00	W	GPS	SECHI?
31DICG94/2	P18	10	2	BIO	022794	1429	MR	67	00.01	S	102	59.00	W	GPS	
31DICG94/2	P18	10	2	BIO	022794	1442	MR	67	00.06	S	102	59.01	W	GPS	
31DICG94/2	P18	10	2	BIO	022794	1451	EN	67	00.11	S	102	59.00	W	GPS	
31DICG94/2	P18	13	2	BIO	022894	1819	BE	65	30.27	S	102	59.91	W	GPS	
31DICG94/2	P18	13	2	BIO	022894	1859	BO	65	31.33	S	102	59.27	W	GPS	
31DICG94/2	P18	13	2	BIO	022894	1914	EN	65	31.38	S	102	59.28	W	GPS	
31DICG94/2	P18	14	2	BIO	030194	0223	BE	65	00.24	S	103	00.39	W	GPS	
31DICG94/2	P18	14	2	BIO	030194	0235	EN	65	00.39	S	103	00.56	W	GPS	
31DICG94/2	P18	16	2	BIO	030194	1710	BE	63	57.71	S	103	02.14	W	GPS	
31DICG94/2	P18	16	2	BIO	030194	1716	BO	63	57.71	S	103	02.15	W	GPS	
31DICG94/2	P18	16	2	BIO	030194	1719	EN	63	57.67	S	103	02.29	W	GPS	
31DICG94/2	P18	16	3	BIO	030194	1735	BE	63	57.39	S	103	02.35	W	GPS	
31DICG94/2	P18	16	3	BIO	030194	1747	BO	63	57.19	S	103	02.78	W	GPS	
31DICG94/2	P18	16	3	BIO	030194	1753	EN	63	57.17	S	103	02.67	W	GPS	
31DICG94/2	P18	19	2	BIO	030294	1822	BE	62	29.22	S	102	59.05	W	GPS	
31DICG94/2	P18	19	2	BIO	030294	1829	BO	62	29.23	S	102	58.99	W	GPS	
31DICG94/2	P18	19	2	BIO	030294	1858	EN	62	29.88	S	102	58.88	W	GPS	
31DICG94/2	P18	23	1	BIO	030394	1843	BE	60	29.57	S	103	00.22	W	GPS	
31DICG94/2	P18	23	1	BIO	030394	1850	BO	60	29.65	S	102	59.92	W	GPS	
31DICG94/2	P18	23	1	BIO	030394	1853	EN	60	29.70	S	102	59.86	W	GPS	
31DICG94/2	P18	23	2	BIO	030394	1859	BE	60	29.78	S	102	59.60	W	GPS	
31DICG94/2	P18	23	2	BIO	030394	1912	BO	60	29.96	S	102	59.21	W	GPS	
31DICG94/2	P18	23	2	BIO	030394	1920	EN	60	30.07	S	102	58.96	W	GPS	
31DICG94/2	P18	26	1	BIO	030494	1732	BE	58	59.20	S	102	59.95	W	GPS	
31DICG94/2	P18	26	1	BIO	030494	1747	BO	58	59.30	S	102	59.60	W	GPS	
31DICG94/2	P18	26	1	BIO	030494	1800	EN	58	59.40	S	102	59.20	W	GPS	
31DICG94/2	P18	27	2	BIO	030594	1546	BE	58	30.45	S	102	59.03	W	GPS	
31DICG94/2	P18	27	2	BIO	030594	1555	EN	58	30.36	S	102	59.89	W	GPS	
31DICG94/2	P18	27	3	BIO	030594	1604	BE	58	30.31	S	102	58.63	W	GPS	SECHI
31DICG94/2	P18	27	3	BIO	030594	1635	EN	58	29.91	S	102	57.86	W	GPS	
31DICG94/2	P18	28	2	BIO	030694	0033	BE	57	50.93	S	103	02.65	W	GPS	
31DICG94/2	P18	28	2	BIO	030694	0038	MR	57	50.91	S	103	02.72	W	GPS	
31DICG94/2	P18	28	2	BIO	030694	0044	EN	57	50.82	S	103	03.04	W	GPS	
31DICG94/2	P18	33	1	BIO	030894	1401	BE	54	29.63	S	102	59.47	W	GPS	
31DICG94/2	P18	33	1	BIO	030894	1426	EN	54	29.68	S	102	58.81	W	GPS	
31DICG94/2	P18	33	3	BIO	030894	1840	BE	54	29.97	S	102	59.97	W	GPS	
31DICG94/2	P18	33	3	BIO	030894	1843	BO	54	29.97	S	102	59.95	W	GPS	
31DICG94/2	P18	33	3	BIO	030894	1847	EN	54	29.92	S	102	59.93	W	GPS	
31DICG94/2	P18	36	2	BIO	030994	1516	BE	52	29.86	S	103	00.49	W	GPS	

31DICG94/2	P18	36	2	BIO	030994	1529	BO	52	29.90	S	103	00.23	W	GPS
31DICG94/2	P18	36	2	BIO	030994	1540	EN	52	29.95	S	103	00.15	W	GPS
31DICG94/2	P18	37	1	BIO	030994	1827	BE	51	49.63	S	102	59.38	W	GPS
31DICG94/2	P18	37	1	BIO	030994	1838	BO	51	49.51	S	102	59.19	W	GPS
31DICG94/2	P18	37	1	BIO	030994	1842	EN	51	49.49	S	102	59.14	W	GPS
31DICG94/2	P18	38	1	BIO	031094	0047	BE	51	10.24	S	102	59.55	W	GPS
31DICG94/2	P18	38	1	BIO	031094	0055	EN	51	10.24	S	102	59.46	W	GPS
31DICG94/2	P18	40	1	BIO	031094	1537	BE	49	50.03	S	102	59.90	W	GPS
31DICG94/2	P18	40	1	BIO	031094	1545	EN	49	50.05	S	102	59.87	W	GPS
31DICG94/2	P18	40	2	BIO	031094	1605	BE	49	50.14	S	102	59.75	W	GPS
31DICG94/2	P18	40	2	BIO	031094	1620	BO	49	50.20	S	102	59.71	W	GPS
31DICG94/2	P18	40	2	BIO	031094	1629	EN	49	50.21	S	102	59.70	W	GPS
31DICG94/2	P18	43	2	BIO	031194	1530	BE	47	59.82	S	103	00.90	W	GPS
31DICG94/2	P18	43	2	BIO	031194	1538	EN	47	59.84	S	103	01.04	W	GPS
31DICG94/2	P18	43	3	BIO	031194	1544	BE	47	59.88	S	103	01.15	W	GPS
31DICG94/2	P18	43	3	BIO	031194	1601	EN	48	00.02	S	103	01.37	W	GPS
31DICG94/2	P18	47	2	BIO	031294	1516	BE	45	59.26	S	102	59.38	W	GPS
31DICG94/2	P18	47	2	BIO	031294	1537	EN	45	59.26	S	102	59.69	W	GPS
31DICG94/2	P18	51	1	BIO	031394	1521	BE	44	00.30	S	102	59.82	W	GPS
31DICG94/2	P18	51	1	BIO	031394	1529	EN	44	00.23	S	102	59.85	W	GPS
31DICG94/2	P18	51	2	BIO	031394	1533	BE	44	00.22	S	102	59.86	W	GPS
31DICG94/2	P18	51	2	BIO	031394	1615	EN	44	00.19	S	103	00.13	W	GPS
31DICG94/2	P18	51	4	BIO	031394	1925	BE	43	57.49	S	102	59.78	W	GPS
31DICG94/2	P18	51	4	BIO	031394	1937	BO	43	57.40	S	102	59.95	W	GPS
31DICG94/2	P18	51	4	BIO	031394	1949	EN	43	57.31	S	103	00.14	W	GPS
31DICG94/2	P18	55	1	BIO	031494	1609	BE	42	00.18	S	103	00.09	W	GPS
31DICG94/2	P18	55	1	BIO	031494	1616	EN	42	00.15	S	103	00.16	W	GPS
31DICG94/2	P18	55	2	BIO	031494	1621	BE	42	00.12	S	103	00.21	W	GPS
31DICG94/2	P18	55	2	BIO	031494	1648	EN	42	00.12	S	103	00.52	W	GPS
31DICG94/2	P18	56	1	BIO	031494	2359	BE	41	30.78	S	103	00.02	W	GPS
31DICG94/2	P18	56	1	BIO	031594	0007	BO	41	30.86	S	103	00.03	W	GPS
31DICG94/2	P18	56	1	BIO	031594	0014	EN	41	30.90	S	103	00.08	W	GPS
31DICG94/2	P18	58	1	BIO	031594	1553	BE	40	30.07	S	103	00.05	W	GPS
31DICG94/2	P18	58	1	BIO	031594	1602	EN	40	30.15	S	103	00.05	W	GPS
31DICG94/2	P18	58	2	BIO	031594	1609	BE	40	30.20	S	103	00.00	W	GPS
31DICG94/2	P18	58	2	BIO	031594	1639	EN	40	30.38	S	102	59.61	W	GPS
31DICG94/2	P18	62	1	BIO	031694	1505	BE	38	29.99	S	102	59.95	W	GPS
31DICG94/2	P18	62	1	BIO	031694	1524	EN	38	30.15	S	102	59.96	W	GPS
31DICG94/2	P18	62	2	BIO	031694	1534	BE	38	30.19	S	102	59.97	W	GPS
31DICG94/2	P18	62	2	BIO	031694	1557	EN	38	30.44	S	102	59.89	W	GPS
31DICG94/2	P18	66	1	BIO	031794	1538	BE	36	29.92	S	102	59.74	W	GPS
31DICG94/2	P18	66	1	BIO	031794	1558	EN	36	29.97	S	102	59.73	W	GPS
31DICG94/2	P18	70	2	BIO	031794	1742	BE	34	30.25	S	102	59.01	W	GPS
31DICG94/2	P18	70	2	BIO	031894	1745	BO	34	30.30	S	102	59.10	W	GPS
31DICG94/2	P18	70	2	BIO	031794	1749	EN	34	30.33	S	102	59.05	W	GPS
31DICG94/2	P18	70	3	BIO	031794	1757	BE	34	30.33	S	102	59.02	W	GPS
31DICG94/2	P18	70	3	BIO	031894	1814	BO	34	30.33	S	102	59.02	W	GPS

31DICG94/2	P18	70	3	BIO	031794	1824	EN	34	30.46	S	102	58.94	W	GPS
31DICG94/2	P18	74	2	BIO	031994	1607	BE	32	30.10	S	103	00.13	W	GPS
31DICG94/2	P18	74	2	BIO	031994	1615	EN	32	30.09	S	103	00.13	W	GPS
31DICG94/2	P18	74	3	BIO	031994	1622	BE	32	30.11	S	103	00.19	W	GPS
31DICG94/2	P18	74	3	BIO	031994	1650	EN	32	30.05	S	103	00.09	W	GPS
31DICG94/2	P18	78	2	BIO	032094	1546	BE	30	29.17	S	103	00.39	W	GPS
31DICG94/2	P18	78	2	BIO	032094	1618	EN	30	29.15	S	103	00.60	W	GPS
31DICG94/2	P18	81	1	BIO	032194	1604	BE	28	59.98	S	102	59.80	W	GPS
31DICG94/2	P18	81	1	BIO	032194	1612	EN	28	59.92	S	102	59.83	W	GPS
31DICG94/2	P18	81	2	BIO	032194	1618	BE	28	59.82	S	102	59.83	W	GPS
31DICG94/2	P18	81	2	BIO	032194	1652	EN	28	59.58	S	102	59.91	W	GPS
31DICG94/2	P18	84	2	BIO	032294	1610	BE	27	30.04	S	103	03.67	W	GPS
31DICG94/2	P18	84	2	BIO	032294	1623	EN	27	29.87	S	103	03.85	W	GPS
31DICG94/2	P18	84	3	BIO	032294	1631	BE	27	29.81	S	103	03.91	W	GPS
31DICG94/2	P18	84	3	BIO	032294	1709	EN	27	29.38	S	103	04.32	W	GPS
31DICG94/3	P18	90	1	BIO	032994	1557	BE	24	29.72	S	103	00.13	W	GPS
31DICG94/3	P18	90	1	BIO	032994	1607	EN	24	29.64	S	103	00.13	W	GPS
31DICG94/3	P18	90	2	BIO	032994	1612	BE	24	29.59	S	103	00.17	W	GPS
31DICG94/3	P18	90	2	BIO	032994	1643	EN	24	29.29	S	103	00.23	W	GPS
31DICG94/3	P18	94	1	BIO	033094	1507	BE	22	29.92	S	103	00.08	W	GPS
31DICG94/3	P18	94	1	BIO	033094	1516	EN	22	29.89	S	103	00.11	W	GPS
31DICG94/3	P18	94	2	BIO	033094	1519	BE	22	29.88	S	103	00.12	W	GPS
31DICG94/3	P18	94	2	BIO	033094	1546	EN	22	29.74	S	103	00.14	W	GPS
31DICG94/3	P18	98	1	BIO	033194	1548	BE	20	30.19	S	102	59.04	W	GPS
31DICG94/3	P18	98	1	BIO	033194	1551	EN	20	30.16	S	102	59.04	W	GPS
31DICG94/3	P18	98	2	BIO	033194	1615	BE	20	30.17	S	102	59.02	W	GPS
31DICG94/3	P18	98	2	BIO	033194	1625	EN	20	30.10	S	102	58.92	W	GPS
31DICG94/3	P18	101	1	BIO	040194	1827	BE	18	53.70	S	103	08.66	W	GPS
31DICG94/3	P18	101	1	BIO	040194	1836	EN	18	53.68	S	103	08.64	W	GPS
31DICG94/3	P18	101	2	BIO	040194	1843	BE	18	53.65	S	103	08.63	W	GPS
31DICG94/3	P18	101	2	BIO	040194	1919	EN	18	53.68	S	103	08.50	W	GPS
31DICG94/3	P18	104	2	BIO	040294	1729	BE	17	29.78	S	103	00.15	W	GPS
31DICG94/3	P18	104	2	BIO	040294	1758	EN	17	29.74	S	103	00.11	W	GPS
31DICG94/3	P18	104	3	BIO	040294	1805	BE	17	29.82	S	103	00.13	W	GPS
31DICG94/3	P18	104	3	BIO	040294	1813	EN	17	29.84	S	103	00.17	W	GPS
31DICG94/3	P18	108	2	BIO	040394	1743	BE	15	30.03	S	102	59.89	W	GPS
31DICG94/3	P18	108	2	BIO	040394	1812	EN	15	30.02	S	102	59.83	W	GPS
31DICG94/3	P18	112	2	BIO	040494	1838	BE	13	30.19	S	103	00.50	W	GPS
31DICG94/3	P18	112	2	BIO	040494	1849	EN	13	30.14	S	103	00.61	W	GPS
31DICG94/3	P18	112	3	BIO	040494	1853	BE	13	30.08	S	103	00.72	W	GPS
31DICG94/3	P18	112	3	BIO	040494	1919	EN	13	29.86	S	103	01.19	W	GPS
31DICG94/3	P18	115	2	BIO	040594	1618	BE	11	59.79	S	103	00.38	W	GPS
31DICG94/3	P18	115	2	BIO	040594	1624	EN	11	59.80	S	103	00.44	W	GPS
31DICG94/3	P18	115	3	BIO	040594	1627	BE	11	59.78	S	103	00.48	W	GPS
31DICG94/3	P18	115	3	BIO	040594	1650	EN	11	59.80	S	103	00.66	W	GPS
31DICG94/3	P18	119	2	BIO	040694	1836	BE	9	59.94	S	103	00.21	W	GPS
31DICG94/3	P18	119	2	BIO	040694	1848	EN	9	59.94	S	103	00.27	W	GPS

31DICG94/3	P18	119	3	BIO	040694	1852	BE	9	59.95	S	103	00.32	W	GPS
31DICG94/3	P18	119	3	BIO	040694	1915	EN	9	59.83	S	103	00.61	W	GPS
31DICG94/3	P18	122	2	BIO	040794	1729	BE	8	51.63	S	104	41.64	W	GPS
31DICG94/3	P18	122	2	BIO	040794	1747	EN	8	51.49	S	104	41.67	W	GPS
31DICG94/3	P18	123	1	BIO	040794	2048	BE	8	27.66	S	105	15.50	W	GPS
31DICG94/3	P18	123	1	BIO	040794	2056	EN	8	27.69	S	105	15.55	W	GPS
31DICG94/3	P18	126	1	BIO	040894	1530	BE	7	18.64	S	106	56.98	W	GPS
31DICG94/3	P18	126	1	BIO	040894	1600	EN	7	18.75	S	106	57.36	W	GPS
31DICG94/3	P18	130	1	BIO	040994	1735	BE	5	46.32	S	109	12.38	W	GPS
31DICG94/3	P18	130	1	BIO	040994	1745	EN	5	46.38	S	109	12.41	W	GPS
31DICG94/3	P18	130	2	BIO	040994	1749	BE	5	46.42	S	109	12.45	W	GPS
31DICG94/3	P18	130	2	BIO	040994	1817	EN	5	46.54	S	109	12.66	W	GPS
31DICG94/3	P18	133	2	BIO	041094	1649	BE	4	29.53	S	110	20.25	W	GPS
31DICG94/3	P18	133	2	BIO	041094	1659	EN	4	29.42	S	110	20.19	W	GPS
31DICG94/3	P18	133	3	BIO	041094	1708	BE	4	29.40	S	110	20.20	W	GPS
31DICG94/3	P18	133	3	BIO	041094	1726	EN	4	28.90	S	110	20.29	W	GPS
31DICG94/3	P18	137	2	BIO	041194	1556	BE	2	39.92	S	110	19.57	W	GPS
31DICG94/3	P18	137	2	BIO	041194	1603	EN	2	39.91	S	110	19.58	W	GPS
31DICG94/3	P18	137	3	BIO	041194	1607	BE	2	39.90	S	110	19.62	W	GPS
31DICG94/3	P18	137	3	BIO	041194	1628	EN	2	39.78	S	110	10.60	W	GPS
31DICG94/3	P18	141	2	BIO	041294	1752	BE	1	20.12	S	110	19.94	W	GPS
31DICG94/3	P18	141	2	BIO	041294	1800	EN	1	20.16	S	110	19.95	W	GPS
31DICG94/3	P18	141	3	BIO	041294	1804	BE	1	20.82	S	110	19.86	W	GPS
31DICG94/3	P18	141	3	BIO	041294	1833	EN	1	20.24	S	110	19.87	W	GPS
31DICG94/3	P18	145	1	BIO	041394	1730	BE	0	00.08	S	110	19.93	W	GPS
31DICG94/3	P18	145	1	BIO	041394	1737	EN	0	00.18	S	110	19.93	W	GPS
31DICG94/3	P18	145	2	BIO	041394	1742	BE	0	00.20	S	110	19.97	W	GPS
31DICG94/3	P18	145	2	BIO	041394	1802	EN	0	00.34	S	110	19.91	W	GPS
31DICG94/3	P18	149	1	BIO	041494	1635	BE	1	20.01	N	110	20.05	W	GPS
31DICG94/3	P18	149	1	BIO	041494	1657	EN	1	19.98	N	110	19.97	W	GPS
31DICG94/3	P18	153	1	BIO	041594	1552	BE	2	40.10	N	110	20.13	W	GPS
31DICG94/3	P18	153	1	BIO	041594	1600	EN	2	40.16	N	110	20.27	W	GPS
31DICG94/3	P18	153	2	BIO	041594	1605	BE	2	40.20	N	110	20.34	W	GPS
31DICG94/3	P18	153	2	BIO	041594	1626	EN	2	40.35	N	110	20.59	W	GPS
31DICG94/3	P18	157	1	BIO	041694	1705	BE	4	30.14	N	110	20.16	W	GPS
31DICG94/3	P18	157	1	BIO	041694	1711	EN	4	30.11	N	110	20.14	W	GPS
31DICG94/3	P18	157	2	BIO	041694	1715	BE	4	30.08	N	110	20.13	W	GPS
31DICG94/3	P18	157	2	BIO	041694	1740	EN	4	30.10	N	110	20.29	W	GPS
31DICG94/3	P18	160	2	BIO	041794	1656	BE	5	59.96	N	110	20.09	W	GPS
31DICG94/3	P18	160	2	BIO	041794	1703	EN	5	59.94	N	110	20.16	W	GPS
31DICG94/3	P18	160	3	BIO	041794	1706	BE	5	59.91	N	110	20.19	W	GPS
31DICG94/3	P18	160	3	BIO	041794	1728	EN	5	59.90	N	110	20.29	W	GPS
31DICG94/3	P18	164	2	BIO	041894	1829	BE	8	00.37	N	110	20.18	W	GPS
31DICG94/3	P18	164	2	BIO	041894	1833	EN	8	00.46	N	110	20.31	W	GPS
31DICG94/3	P18	164	3	BIO	041894	1842	BE	8	00.50	N	110	20.34	W	GPS
31DICG94/3	P18	164	3	BIO	041894	1906	EN	8	00.89	N	110	20.76	W	GPS
31DICG94/3	P18	168	1	BIO	041994	1545	BE	10	00.04	N	110	00.07	W	GPS

31DICG94/3	P18	168	1	BIO	041994	1552	EN	10	00.04	N	110	00.16	W	GPS
31DICG94/3	P18	168	2	BIO	041994	1555	BE	10	00.04	N	110	00.19	W	GPS
31DICG94/3	P18	168	2	BIO	041994	1616	EN	10	00.09	N	110	00.37	W	GPS
31DICG94/3	P18	172	1	BIO	042094	1718	BE	12	40.11	N	109	59.98	W	GPS
31DICG94/3	P18	172	1	BIO	042094	1724	EN	12	40.13	N	109	59.99	W	GPS
31DICG94/3	P18	172	2	BIO	042094	1728	BE	12	40.13	N	110	00.00	W	GPS
31DICG94/3	P18	172	2	BIO	042094	1754	EN	12	40.36	N	109	59.91	W	GPS
31DICG94/3	P18	175	2	BIO	042194	1743	BE	14	29.81	N	110	00.10	W	GPS
31DICG94/3	P18	175	2	BIO	042194	1751	EN	14	29.74	N	110	00.09	W	GPS
31DICG94/3	P18	175	3	BIO	042194	1754	BE	14	29.69	N	110	00.09	W	GPS
31DICG94/3	P18	175	3	BIO	042194	1814	EN	14	29.67	N	110	00.05	W	GPS
31DICG94/3	P18	179	2	BIO	042294	1736	BE	16	29.87	N	109	59.93	W	GPS
31DICG94/3	P18	179	2	BIO	042294	1738	EN	16	29.81	N	109	59.90	W	GPS
31DICG94/3	P18	179	3	BIO	042294	1741	BE	16	29.79	N	109	59.91	W	GPS
31DICG94/3	P18	179	3	BIO	042294	1800	EN	16	29.64	N	109	59.93	W	GPS
31DICG94/3	P18	183	2	BIO	042394	1627	BE	18	29.98	N	109	59.99	W	GPS
31DICG94/3	P18	183	2	BIO	042394	1636	EN	18	29.89	N	109	59.99	W	GPS
31DICG94/3	P18	183	3	BIO	042394	1640	BE	18	29.87	N	109	59.99	W	GPS
31DICG94/3	P18	183	3	BIO	042394	1701	EN	18	29.74	N	109	59.98	W	GPS
31DICG94/3	P18	188	1	BIO	042494	1644	BE	20	59.85	N	109	59.94	W	GPS
31DICG94/3	P18	188	1	BIO	042494	1653	EN	20	59.78	N	109	59.96	W	GPS
31DICG94/3	P18	188	2	BIO	042494	1656	BE	20	59.76	N	110	00.01	W	GPS
31DICG94/3	P18	188	2	BIO	042494	1728	EN	20	59.52	N	110	00.17	W	GPS
31DICG94/3	P18	192	2	BIO	042594	1602	BE	22	44.24	N	110	00.22	W	GPS
31DICG94/3	P18	192	2	BIO	042594	1607	EN	22	44.17	N	110	00.29	W	GPS
31DICG94/3	P18	192	3	BIO	042594	1610	BE	22	44.09	N	110	00.29	W	GPS
31DICG94/3	P18	192	3	BIO	042594	1627	EN	22	43.80	N	110	00.51	W	GPS

APPENDIX 5a.: CFC-11 and CFC-12 Measurements on WOCE P18 (CGC94)

(Following discussion provided by J. Bullister, PMEL)

CFC Sampling Procedures and Data Processing

CFCs were usually the first water sample collected from the 10 liter bottles. Care was taken to co-ordinate the sampling of CFCs with other gas samples to minimize the time between the initial opening of each bottle and the completion of sample drawing. In most cases, helium, tritium, dissolved oxygen, total CO_2, alkalinity and pH samples were collected within several minutes of the initial opening of each bottle. CFC samples were collected in 100 ml precision glass syringes, and held immersed in a water bath until processing.

The CFC analytical system functioned relatively well during this expedition. The CFC system was installed in a specially designed laboratory van located on deck, and was isolated from possible contamination from high levels of CFCs which are sometimes present in air inside ship laboratories. Concentration of CFCs in air inside this van were usually close to those of clean marine air.

Concentrations of CFC-11 and CFC-12 in air samples, seawater and gas standards on the cruise were measured by shipboard electron capture gas chromatography, according to the methods described by Bullister and Weiss (1988). The concentrations of CFC-11 and CFC-12 in air, seawater samples and gas standards are reported relative to the SIO 1993 calibration scale. CFC concentrations in air and standard gas are reported in units of mole fraction CFC in dry gas, and are typically in parts-per-trillion (ppt) range. Dissolved CFC concentrations are given in unit of picomole CFC per kg seawater (pmol/kg). CFC concentrations in air and seawater samples were determined by fitting their chromatographic peak areas to multi-point calibration curves, generated by injecting known volumes of gas from a CFC working standard (PMEL cylinder 71489) into the analytical instrument. This concentrations of CFC-11 and CFC-12 in this working standard were calibrated versus a primary CFC standard (CC36743) before and after the cruise. No measurable drift in the working standard could be detected during this interval. Full range calibration curves were run at 1 to 2 day intervals. Single injections of a fixed volume of standard gas were run much more frequently (at intervals of 1 to 2 hours) to monitor short term changes in detector sensitivity. The estimated reproducibility of the calibrations is about 1.3% for CFC-11 and 0.5% for CFC-12. We estimate a precision (1 standard deviation) for dissolved CFC measurements of about 1%, or 0.005 pmol/kg, whichever is greater (see listing of replicate samples).

Sample loops filled with CFC-free gas, and syringe samples of CFC-free water (degassed in a specially designed glass chamber) were run to check sampling and analytical blanks. CFC-11 and CFC-12 were present throughout the water column south of about 50°S. CFC concentrations measured in deep samples (>2000 m) along the section north of 40°S were typically in the range of 0 to 0.010 pmol/kg, near the detection limit of the analytical system (~0.004 pmol/kg). Previous studies (Wisegarver et al, et al 1993) of time-dependent tracers in this region of the Pacific indicate that waters at densities sigma0>27.4 should have CFC concentrations near zero at present. We attribute the low level CFC signal present in some deep samples along the northern end of the section to the slow release of CFC from the walls and O-rings of the 10 liter bottles into the seawater sample during storage, and to contamination during the transfer and storage of the seawater samples in glass syringes prior to analysis. Based on the median concentrations observed in deep water samples along northern end of the section, a CFC-11 blank correction of 0.0086 pmol/kg has been applied to the CFC-11 data on Leg 2 (Sta 8-87) and 0.0048 pmol/kg for Leg 3 (Sta 88-194). A CFC-12 blank correction of 0.0025 pmol/kg has been applied to the CFC-12 data on Leg 2 (Sta 9-87) and 0.0024 for Leg 3 (Sta 89-194). As a result of these blank corrections, some concentrations reported for deep samples are negative.

A number of water samples had anomously high CFC-11 and/or CFC-12 concentrations relative to adjacent samples. These high values appeared to occur more or less randomly, and were not clearly associated with other features in the water column (eg. elevated oxygen concentrations, salinity features, etc). In most cases, only one of the 2 CFCs measured showed these anomolously high levels. This suggests that the high values were due to analytical variability or isolated low-level contamination events. These samples are included in this report and are flagged as either 3 (questionable) or 4 (bad) measurements. Approximately 40 analyses of CFC-11 were assigned a flag of 3 and 161

CFC-11 samples assigned a flag of 4. Approximately 14 analyses of CFC-12 were assigned a flag of 3 and 61 CFC-12 samples assigned a flag of 4.

A number of samples were analysed for CFC-113 and carbon tetrachloride during the cruise. Because of calibration standard uncertainties and analytical problems, the processing of these data have not yet been finalized. These samples are flagged as "5" (not reported). Those interested in these data should contact the John Bullister for updates on the status of the CFC-113 and carbon tetrachloride data processing.

References:

Bullister, J.L. and R.F. Weiss, Determination of CCl_3F and CCl_2F_2 in seawater and air. Deep-Sea Research, 35 (5), 839-853, 1988.

Wisegarver, D.P., J.L. Bullister, R.H. Gammon, F.A. Menzia, and K.C. Kelly (1993): NOAA chlorofluorocarbon tracer program air and seawater measurements: 1986-1989. NOAA Data Report ERL PMEL-43.

APPENDIX 5b. CFC Air Measurements on P18 (CGC94)

Leg 2

Date	Time (hhmm)	Latitude	Longitude	F11 PPT	F12 PPT
24 Feb 94	0912	55 18.3 S	079 29.3 W	261.3	503.9
24 Feb 94	0923	55 18.3 S	079 29.3 W	260.8	502.5
24 Feb 94	0933	55 18.3 S	079 29.3 W	261.5	502.5
25 Feb 94	0913	59 27.4 S	086 51.7 W	259.8	508.2
25 Feb 94	0923	59 27.4 S	086 51.7 W	260.0	506.9
25 Feb 94	0933	59 27.4 S	086 51.7 W	259.6	509.2
25 Feb 94	0944	59 27.4 S	086 51.7 W	260.2	508.6
26 Feb 94	0355	67 00.0 S	095 00.0 W	259.4	508.0
26 Feb 94	0405	67 00.0 S	095 00.0 W	260.4	509.9
26 Feb 94	0415	67 00.0 S	095 00.0 W	259.1	508.8
26 Feb 94	0425	67 00.0 S	095 00.0 W	259.7	508.0
27 Feb 94	1743	66 59.7 S	103 00.0 W	259.4	506.9
27 Feb 94	1807	66 59.7 S	103 00.0 W	259.0	504.8
27 Feb 94	1819	66 59.7 S	103 00.0 W	259.0	504.1
27 Feb 94	1839	66 59.7 S	103 00.0 W	259.5	503.5
28 Feb 94	0902	66 00.1 S	102 59.9 W	259.3	506.9
28 Feb 94	0912	66 00.1 S	102 59.9 W	259.8	509.0
28 Feb 94	0922	66 00.1 S	102 59.9 W	259.5	506.8
28 Feb 94	0932	66 00.1 S	102 59.9 W	259.6	508.4
1 Mar 94	1611	63 58.4 S	103 00.3 W	259.5	508.3
1 Mar 94	1621	63 58.4 S	103 00.3 W	259.4	506.6
1 Mar 94	1632	63 58.4 S	103 00.3 W	258.5	507.3
3 Mar 94	0844	61 26.7 S	102 59.3 W	259.4	-9.0
3 Mar 94	0854	61 26.7 S	102 59.3 W	260.0	515.4
3 Mar 94	0906	61 26.7 S	102 59.3 W	263.1	518.3

3 Mar 94	0944	61 26.7 S	102 59.3 W	260.1	-9.0
4 Mar 94	0742	60 00.0 S	103 00.0 W	262.5	515.1
4 Mar 94	0752	60 00.0 S	103 00.0 W	260.8	511.1
4 Mar 94	0802	60 00.0 S	103 00.0 W	260.4	522.5
4 Mar 94	0812	60 00.0 S	103 00.0 W	260.4	519.9
6 Mar 94	1904	56 31.2 S	103 09.8 W	259.9	507.8
6 Mar 94	1916	56 31.2 S	103 09.8 W	260.2	508.5
6 Mar 94	1926	56 31.2 S	103 09.8 W	261.1	508.1
6 Mar 94	1938	56 31.2 S	103 09.8 W	259.4	506.2
8 Mar 94	0314	55 40.0 S	103 00.0 W	260.9	505.3
8 Mar 94	0324	55 40.0 S	103 00.0 W	260.5	505.3
8 Mar 94	0334	55 40.0 S	103 00.0 W	260.4	506.1
8 Mar 94	0344	55 40.0 S	103 00.0 W	260.5	506.6
10 Mar 94	0252	51 09.9 S	102 59.9 W	260.8	507.6
10 Mar 94	0305	51 09.9 S	102 59.9 W	260.7	508.0
10 Mar 94	0315	51 09.9 S	102 59.9 W	260.5	504.0
12 Mar 94	0443	47 30.0 S	103 00.0 W	260.3	508.8
12 Mar 94	0453	47 30.0 S	103 00.0 W	259.8	509.8
12 Mar 94	0503	47 30.0 S	103 00.0 W	260.6	509.0
12 Mar 94	0513	47 30.0 S	103 00.0 W	259.6	509.9
14 Mar 94	0816	43 00.0 S	103 00.0 W	261.0	511.4
14 Mar 94	0826	43 00.0 S	103 00.0 W	260.3	510.5
14 Mar 94	0836	43 00.0 S	103 00.0 W	260.9	507.7
14 Mar 94	0846	43 00.0 S	103 00.0 W	259.8	505.1
18 Mar 94	1155	35 00.0 S	103 00.0 W	260.0	506.0
18 Mar 94	1206	35 00.0 S	103 00.0 W	259.2	506.9
18 Mar 94	1217	35 00.0 S	103 00.0 W	259.3	507.6
18 Mar 94	1228	35 00.0 S	103 00.0 W	259.1	509.3
20 Mar 94	0337	31 30.0 S	103 00.0 W	261.2	509.8
20 Mar 94	0347	31 30.0 S	103 00.0 W	261.8	507.1
20 Mar 94	0357	31 30.0 S	103 00.0 W	261.6	508.6
20 Mar 94	0407	31 30.0 S	103 00.0 W	261.7	508.9
21 Mar 94	2234	28 47.4 S	103 01.3 W	262.2	509.1
21 Mar 94	2244	28 47.4 S	103 01.3 W	261.0	508.9
21 Mar 94	2258	28 47.4 S	103 01.3 W	260.6	510.4
23 Mar 94	2308	26 47.8 S	106 13.2 W	261.7	510.4
23 Mar 94	2319	26 47.8 S	106 13.2 W	260.7	509.8
23 Mar 94	2333	26 47.8 S	106 13.2 W	261.5	511.2

Leg 3

Date	Time (hhmm)	Latitude	Longitude	F11 PPT	F12 PPT
29 Mar 94	1415	25 00.0 S	103 00.0 W	260.9	510.3
29 Mar 94	1426	25 00.0 S	103 00.0 W	260.9	510.0
29 Mar 94	1437	25 00.0 S	103 00.0 W	260.1	509.1
29 Mar 94	1448	25 00.0 S	103 00.0 W	259.5	510.6
30 Mar 94	1329	23 00.0 S	103 00.0 W	260.9	500.1
30 Mar 94	1339	23 00.0 S	103 00.0 W	262.0	504.4

30 Mar 94	1349	23 00.0 S	103 00.0 W	262.3	500.3
30 Mar 94	1359	23 00.0 S	103 00.0 W	260.8	505.7
31 Mar 94	1345	21 00.0 S	103 00.0 W	261.2	504.3
31 Mar 94	1355	21 00.0 S	103 00.0 W	262.7	503.9
31 Mar 94	1405	21 00.0 S	103 00.0 W	261.2	502.4
31 Mar 94	1415	21 00.0 S	103 00.0 W	260.6	502.3
2 Apr 94	0226	18 29.8 S	103 00.1 W	261.5	512.4
2 Apr 94	0237	18 29.8 S	103 00.1 W	262.3	510.5
2 Apr 94	0248	18 29.8 S	103 00.1 W	261.4	510.7
3 Apr 94	0215	16 54.7 S	103 00.0 W	261.0	509.7
3 Apr 94	0225	16 54.7 S	103 00.0 W	261.6	513.1
3 Apr 94	0235	16 54.7 S	103 00.0 W	261.9	511.1
3 Apr 94	0245	16 54.7 S	103 00.0 W	261.3	511.5
4 Apr 94	0605	14 30.2 S	102 59.9 W	262.2	511.7
4 Apr 94	0616	14 30.2 S	102 59.9 W	262.9	514.6
4 Apr 94	0627	14 30.2 S	102 59.9 W	262.2	511.0
5 Apr 94	0610	12 30.1 S	103 00.0 W	261.6	510.4
5 Apr 94	0621	12 30.1 S	103 00.0 W	262.9	505.9
5 Apr 94	0632	12 30.1 S	103 00.0 W	262.1	504.0
6 Apr 94	0538	11 00.4 S	103 00.9 W	261.4	-9.0
6 Apr 94	0549	11 00.4 S	103 00.9 W	262.1	510.5
6 Apr 94	0600	11 00.4 S	103 00.9 W	262.1	512.3
7 Apr 94	0310	09 38.9 S	103 36.4 W	264.6	-9.0
7 Apr 94	0321	09 38.9 S	103 36.4 W	263.3	-9.0
7 Apr 94	0332	09 38.9 S	103 36.4 W	263.5	516.8
7 Apr 94	1729	08 51.7 S	104 41.8 W	263.3	510.0
7 Apr 94	1740	08 51.7 S	104 41.8 W	262.3	511.2
7 Apr 94	1751	08 51.7 S	104 41.8 W	262.9	515.2
8 Apr 94	1135	07 42.0 S	106 22.9 W	262.3	513.7
8 Apr 94	1146	07 42.0 S	106 22.9 W	262.4	511.2
8 Apr 94	1157	07 42.0 S	106 22.9 W	263.4	513.5
8 Apr 94	1208	07 42.0 S	106 22.9 W	263.8	513.0
10 Apr 94	1608	04 30.0 S	110 00.0 W	261.1	518.2
10 Apr 94	1619	04 30.0 S	110 00.0 W	264.0	-9.0
10 Apr 94	1630	04 30.0 S	110 00.0 W	261.6	-9.0
10 Apr 94	1641	04 30.0 S	110 00.0 W	261.4	514.0
11 Apr 94	0654	03 00.0 S	110 20.0 W	261.6	513.2
11 Apr 94	0705	03 00.0 S	110 20.0 W	261.1	513.9
11 Apr 94	0716	03 00.0 S	110 20.0 W	260.9	515.5
11 Apr 94	1619	02 40.0 S	110 20.0 W	264.0	517.0
11 Apr 94	1630	02 40.0 S	110 20.0 W	263.7	517.8
11 Apr 94	1641	02 40.0 S	110 20.0 W	264.7	514.8
11 Apr 94	1652	02 40.0 S	110 20.0 W	263.1	519.5
13 Apr 94	1008	00 40.0 S	110 20.0 W	264.5	520.3
13 Apr 94	1019	00 40.0 S	110 20.0 W	263.9	519.4
13 Apr 94	1030	00 40.0 S	110 20.0 W	264.4	521.5
14 Apr 94	1013	00 20.0 N	110 20.0 W	263.7	-9.0

14 Apr 94	1024	00 20.0 N	110 20.0 W	262.7	523.2
16 Apr 94	0854	03 30.0 N	110 20.0 E	264.0	517.9
16 Apr 94	0905	03 30.0 N	110 20.0 E	263.3	518.7
16 Apr 94	0916	03 30.0 N	110 20.0 E	263.2	521.0
17 Apr 94	0436	05 00.0 N	110 20.0 W	265.9	520.7
17 Apr 94	0447	05 00.0 N	110 20.0 W	265.6	519.1
17 Apr 94	0458	05 00.0 N	110 20.0 W	265.1	521.3
19 Apr 94	1923	10 00.0 N	110 20.0 W	266.0	516.7
19 Apr 94	1934	10 00.0 N	110 20.0 W	265.8	519.1
19 Apr 94	1945	10 00.0 N	110 20.0 W	265.4	519.5
19 Apr 94	1956	10 00.0 N	110 20.0 W	264.6	519.4
22 Apr 94	0758	15 48.0 N	110 00.0 W	265.5	525.1
22 Apr 94	0809	15 48.0 N	110 00.0 W	265.4	522.1
22 Apr 94	0820	15 48.0 N	110 00.0 W	265.3	519.9
23 Apr 94	0627	17 43.0 N	110 00.0 W	264.7	522.6
23 Apr 94	0638	17 43.0 N	110 00.0 W	264.7	522.5
23 Apr 94	0649	17 43.0 N	110 00.0 W	264.7	525.0
24 Apr 94	0905	20 00.0 N	110 00.0 W	266.3	525.3
24 Apr 94	0916	20 00.0 N	110 00.0 W	266.6	521.4
24 Apr 94	0927	20 00.0 N	110 00.0 W	265.2	522.0
26 Apr 94	1159	24 30.4 N	113 47.4 W	266.7	528.2
26 Apr 94	1210	24 30.4 N	113 47.4 W	266.0	526.6
26 Apr 94	1221	24 30.4 N	113 47.4 W	266.6	526.0
26 Apr 94	1232	24 30.4 N	113 47.4 W	265.6	526.0

APPENDIX 5c. CFC Air Measurements on P18 (CGC96) (interpolated to station locations)

STATION NUMBER	Latitude	Longitude	Date	F11 PPT	F12 PPT
1	47 43.4 N	122 24.6 W	26 Jan 94	272.0	515.0
2	44 14.1 N	129 40.5 W	28 Jan 94	272.0	515.0
3	44 12.0 N	129 43.0 W	28 Jan 94	272.0	515.0
4	44 16.6 N	129 44.9 W	28 Jan 94	272.0	515.0
5	44 09.8 N	129 44.9 W	28 Jan 94	272.0	515.0
6	44 12.3 N	129 37.3 W	29 Jan 94	272.0	515.0
7	44 18.0 N	129 35.3 W	29 Jan 94	272.0	515.0
8	53 22.9 S	076 22.0 W	23 Feb 94	260.4	506.0
9	61 13.2 S	090 10.9 W	25 Feb 94	260.1	509.9
10	66 59.7 S	103 00.4 W	27 Feb 94	259.4	506.3
11	66 29.8 S	103 00.6 W	28 Feb 94	259.4	506.3
12	66 00.0 S	102 59.8 W	28 Feb 94	259.4	506.3
13	65 30.0 S	102 60.0 W	28 Feb 94	259.3	506.6
14	65 00.0 S	102 59.4 W	28 Feb 94	259.3	506.6
15	64 29.9 S	102 59.2 W	1 Mar 94	259.4	507.6
16	63 59.3 S	102 59.2 W	1 Mar 94	259.9	509.7
17	63 30.0 S	102 59.6 W	2 Mar 94	259.9	509.7
18	63 00.0 S	102 58.0 W	2 Mar 94	260.0	510.3

19	62 30.0 S	103 00.0 W	2 Mar 94	260.4	513.8
20	61 59.9 S	103 00.1 W	2 Mar 94	260.4	513.8
21	61 27.0 S	102 59.0 W	3 Mar 94	260.9	517.0
22	61 01.0 S	103 00.0 W	3 Mar 94	260.9	517.0
23	60 30.9 S	102 57.1 W	3 Mar 94	260.9	517.0
24	60 00.0 S	103 06.4 W	4 Mar 94	260.9	517.0
25	59 31.6 S	103 01.0 W	4 Mar 94	260.9	517.0
26	58 59.8 S	103 01.2 W	4 Mar 94	260.6	513.3
27	58 30.5 S	102 59.3 W	5 Mar 94	260.6	512.4
28	57 49.1 S	103 00.1 W	5 Mar 94	260.6	510.2
29	57 10.3 S	103 00.1 W	6 Mar 94	260.4	506.7
30	56 31.6 S	103 04.0 W	7 Mar 94	260.4	506.7
31	55 49.6 S	102 59.4 W	7 Mar 94	260.4	506.7
32	55 10.0 S	103 00.0 W	8 Mar 94	260.4	506.7
33	54 30.1 S	103 00.1 W	8 Mar 94	260.4	506.7
34	53 50.0 S	102 59.9 W	8 Mar 94	260.4	506.7
35	53 10.0 S	103 03.0 W	9 Mar 94	260.6	506.1
36	52 30.2 S	103 00.6 W	9 Mar 94	260.6	506.1
37	51 50.0 S	103 00.1 W	9 Mar 94	260.6	506.1
38	51 10.0 S	103 00.0 W	10 Mar 94	260.3	508.2
39	50 30.0 S	103 00.0 W	10 Mar 94	260.3	508.2
40	49 50.0 S	102 60.0 W	10 Mar 94	260.3	508.2
41	49 09.8 S	103 00.2 W	11 Mar 94	260.3	508.2
42	48 29.0 S	103 00.0 W	11 Mar 94	260.3	508.2
43	47 59.8 S	103 00.4 W	11 Mar 94	260.3	508.2
44	47 30.0 S	103 00.1 W	11 Mar 94	260.3	508.2
45	46 59.9 S	102 59.9 W	12 Mar 94	260.3	509.0
46	46 30.0 S	103 00.0 W	12 Mar 94	260.3	509.0
47	45 59.6 S	102 60.0 W	12 Mar 94	260.3	509.0
48	45 28.9 S	102 58.3 W	12 Mar 94	260.3	509.0
49	45 00.5 S	102 59.6 W	13 Mar 94	260.3	509.0
50	44 29.0 S	103 00.0 W	13 Mar 94	260.3	509.0
51	43 59.1 S	102 59.8 W	13 Mar 94	260.3	509.0
52	43 30.0 S	103 00.8 W	13 Mar 94	260.3	509.0
53	43 00.2 S	102 59.9 W	14 Mar 94	260.3	509.0
54	42 29.0 S	103 00.0 W	14 Mar 94	260.3	509.0
55	42 00.0 S	103 00.0 W	14 Mar 94	260.3	509.0
56	41 29.6 S	102 59.5 W	15 Mar 94	260.0	508.5
57	41 01.0 S	103 00.0 W	15 Mar 94	260.0	508.5
58	40 30.2 S	102 59.2 W	15 Mar 94	259.9	508.1
59	40 00.2 S	102 58.8 W	15 Mar 94	259.9	508.1
60	39 29.9 S	102 59.9 W	16 Mar 94	259.9	508.1
61	39 00.0 S	103 00.0 W	16 Mar 94	259.9	508.1
62	38 30.3 S	102 59.8 W	16 Mar 94	259.9	508.1
63	37 59.9 S	102 59.9 W	16 Mar 94	259.9	508.1
64	37 29.9 S	102 59.0 W	17 Mar 94	260.5	508.3
65	37 00.0 S	103 00.0 W	17 Mar 94	260.5	508.3

66	36 30.0 S	103 00.0 W	17 Mar 94	260.5	508.0
67	35 59.6 S	102 59.5 W	17 Mar 94	260.5	508.0
68	35 30.0 S	102 59.9 W	18 Mar 94	260.5	508.0
69	35 00.0 S	103 00.0 W	18 Mar 94	260.5	508.0
70	34 31.0 S	103 00.0 W	18 Mar 94	260.5	508.0
71	34 00.4 S	103 00.1 W	18 Mar 94	260.5	508.0
72	33 29.7 S	102 59.9 W	19 Mar 94	260.5	508.0
73	33 00.0 S	103 00.0 W	19 Mar 94	260.5	508.0
74	32 30.0 S	103 00.0 W	19 Mar 94	260.5	508.0
75	31 59.8 S	102 58.8 W	19 Mar 94	260.7	508.4
76	31 29.5 S	103 00.0 W	20 Mar 94	261.4	509.0
77	31 00.0 S	103 00.0 W	20 Mar 94	261.4	509.0
78	30 30.3 S	103 00.0 W	20 Mar 94	261.4	509.0
79	30 00.0 S	103 00.0 W	21 Mar 94	261.4	509.0
80	29 29.0 S	103 00.0 W	21 Mar 94	261.4	509.0
81	29 00.1 S	103 00.8 W	21 Mar 94	261.4	509.0
82	28 29.7 S	102 59.8 W	22 Mar 94	261.4	509.4
83	28 00.0 S	103 00.0 W	22 Mar 94	261.4	509.4
84	27 30.1 S	103 01.1 W	22 Mar 94	261.3	510.0
85	26 55.2 S	103 00.6 W	22 Mar 94	261.3	510.0
86	26 29.7 S	103 00.0 W	23 Mar 94	261.3	510.0
87	26 00.0 S	103 00.0 W	23 Mar 94	261.3	510.0
88	25 29.9 S	103 00.0 W	29 Mar 94	260.9	506.3
89	24 59.3 S	103 00.0 W	29 Mar 94	260.9	506.3
90	24 30.1 S	102 59.8 W	29 Mar 94	260.9	506.3
91	23 59.9 S	103 00.1 W	29 Mar 94	260.9	506.3
92	23 29.7 S	102 59.7 W	30 Mar 94	260.9	506.3
93	23 00.1 S	102 59.8 W	30 Mar 94	260.9	506.3
94	22 29.9 S	102 59.9 W	30 Mar 94	261.5	502.9
95	21 59.6 S	102 59.4 W	30 Mar 94	261.5	502.9
96	21 30.0 S	102 59.9 W	31 Mar 94	261.5	502.9
97	20 59.9 S	103 00.1 W	31 Mar 94	261.5	505.2
98	20 30.1 S	103 00.0 W	31 Mar 94	261.5	505.2
99	20 00.0 S	103 00.0 W	1 Apr 94	261.5	506.6
100	19 30.1 S	102 59.5 W	1 Apr 94	261.5	506.6
101	19 00.0 S	103 00.1 W	1 Apr 94	261.5	508.4
102	18 29.7 S	103 00.1 W	2 Apr 94	261.6	511.3
103	17 59.9 S	103 00.2 W	2 Apr 94	261.6	511.3
104	17 30.0 S	103 00.4 W	2 Apr 94	261.6	511.3
105	16 59.9 S	102 59.7 W	2 Apr 94	261.6	511.3
106	16 29.9 S	102 59.9 W	3 Apr 94	261.8	511.6
107	16 00.0 S	103 00.0 W	3 Apr 94	261.9	511.8
108	15 30.1 S	103 00.0 W	3 Apr 94	261.9	511.8
109	14 60.0 S	102 60.0 W	3 Apr 94	261.9	511.8
110	14 30.2 S	102 59.3 W	4 Apr 94	262.0	510.3
111	14 00.0 S	102 59.7 W	4 Apr 94	262.3	509.6
112	13 30.0 S	103 00.2 W	4 Apr 94	262.3	509.6

113	13 00.6 S	103 00.5 W	5 Apr 94	262.3	509.6
114	12 30.1 S	103 00.1 W	5 Apr 94	262.6	510.8
115	12 00.1 S	103 00.1 W	5 Apr 94	262.6	510.8
116	11 30.3 S	103 00.0 W	5 Apr 94	262.6	510.0
117	11 00.0 S	103 00.8 W	6 Apr 94	262.6	510.0
118	10 30.4 S	103 00.1 W	6 Apr 94	262.6	510.0
119	10 00.2 S	102 60.0 W	6 Apr 94	262.7	510.7
120	09 37.1 S	103 34.0 W	6 Apr 94	262.8	512.7
121	09 14.1 S	104 08.1 W	7 Apr 94	262.9	512.8
122	08 51.2 S	104 41.7 W	7 Apr 94	262.9	512.8
123	08 27.8 S	105 15.6 W	7 Apr 94	262.9	512.6
124	08 04.7 S	105 49.7 W	8 Apr 94	262.9	512.6
125	07 42.0 S	106 23.0 W	8 Apr 94	262.9	512.6
126	07 18.7 S	106 56.6 W	8 Apr 94	262.9	512.6
127	06 56.4 S	107 30.7 W	9 Apr 94	262.6	513.3
128	06 33.7 S	108 04.4 W	9 Apr 94	262.5	513.9
129	06 09.3 S	108 38.5 W	9 Apr 94	262.5	513.9
130	05 46.4 S	109 12.2 W	9 Apr 94	262.6	515.0
131	05 23.5 S	109 46.0 W	10 Apr 94	262.5	516.0
132	05 00.1 S	110 20.1 W	10 Apr 94	262.5	516.0
133	04 29.7 S	110 19.6 W	10 Apr 94	262.5	516.0
134	04 00.2 S	110 19.7 W	10 Apr 94	262.5	516.0
135	03 29.9 S	110 20.0 W	11 Apr 94	262.7	516.0
136	03 00.0 S	110 20.0 W	11 Apr 94	262.7	516.0
137	02 40.0 S	110 19.9 W	11 Apr 94	262.7	516.0
138	02 20.0 S	110 20.1 W	11 Apr 94	262.7	516.0
139	02 00.7 S	110 20.4 W	12 Apr 94	262.7	516.0
140	01 40.0 S	110 19.9 W	12 Apr 94	263.2	517.3
141	01 20.0 S	110 20.1 W	12 Apr 94	263.2	517.8
142	01 00.1 S	110 19.7 W	13 Apr 94	263.2	517.8
143	00 41.0 S	110 20.0 W	14 Apr 94	263.8	519.2
144	00 20.1 S	110 19.6 W	14 Apr 94	263.2	517.8
145	00 00.0 S	110 20.0 W	13 Apr 94	263.2	517.8
146	00 20.1 N	110 20.0 W	14 Apr 94	263.2	517.8
147	00 39.9 N	110 20.2 W	14 Apr 94	263.2	517.8
148	01 00.0 N	110 20.0 W	14 Apr 94	264.3	519.5
149	01 20.0 N	110 20.0 W	14 Apr 94	264.3	519.5
150	01 40.6 N	110 20.2 W	15 Apr 94	264.5	520.8
151	02 00.0 N	110 20.1 W	15 Apr 94	264.5	520.8
152	02 20.0 N	110 20.0 W	15 Apr 94	264.5	520.8
153	02 40.0 N	110 20.0 W	15 Apr 94	264.5	520.8
154	03 00.0 N	110 20.0 W	15 Apr 94	264.5	520.8
155	03 30.0 N	110 20.0 W	16 Apr 94	264.5	520.8
156	04 00.1 N	110 20.1 W	16 Apr 94	264.5	520.8
157	04 30.0 N	110 20.0 W	16 Apr 94	264.8	520.0
158	04 59.7 N	110 20.1 W	17 Apr 94	264.8	520.0
159	05 30.0 N	110 20.1 W	17 Apr 94	265.5	519.4

160	06 00.0 N	110 20.0 W	17 Apr 94	265.5	519.4
161	06 29.9 N	110 20.0 W	17 Apr 94	265.5	519.4
162	07 00.0 N	110 20.4 W	18 Apr 94	265.5	519.4
163	07 29.9 N	110 20.1 W	18 Apr 94	265.5	519.4
164	07 59.9 N	110 20.2 W	18 Apr 94	265.5	519.4
165	08 30.1 N	110 15.1 W	18 Apr 94	265.5	519.4
166	09 00.1 N	110 10.0 W	19 Apr 94	265.5	519.4
167	09 30.1 N	110 05.2 W	19 Apr 94	265.5	519.4
168	10 00.0 N	110 00.0 W	19 Apr 94	265.5	520.3
169	10 40.0 N	109 60.0 W	20 Apr 94	265.5	520.3
170	11 20.0 N	110 00.0 W	20 Apr 94	265.4	520.2
171	12 00.1 N	110 00.0 W	20 Apr 94	265.4	520.2
172	12 40.0 N	110 00.0 W	20 Apr 94	265.4	520.2
173	13 20.0 N	109 59.7 W	21 Apr 94	265.4	520.2
174	14 00.1 N	109 59.9 W	21 Apr 94	265.0	522.9
175	14 29.9 N	109 59.9 W	21 Apr 94	265.0	522.9
176	15 00.0 N	110 00.0 W	21 Apr 94	265.0	522.9
177	15 29.9 N	109 59.7 W	22 Apr 94	265.0	522.9
178	16 00.1 N	110 00.0 W	22 Apr 94	265.0	522.9
179	16 30.0 N	110 00.1 W	22 Apr 94	265.0	522.9
180	17 00.0 N	110 00.0 W	22 Apr 94	265.0	522.9
181	17 30.1 N	109 59.8 W	23 Apr 94	265.0	522.9
182	17 59.9 N	110 00.0 W	23 Apr 94	265.4	522.9
183	18 30.0 N	110 00.0 W	23 Apr 94	265.3	523.1
184	19 00.0 N	110 00.0 W	23 Apr 94	265.3	523.1
185	19 30.0 N	109 59.9 W	24 Apr 94	265.3	523.1
186	20 00.1 N	109 59.9 W	24 Apr 94	265.3	523.1
187	20 29.9 N	110 00.0 W	24 Apr 94	265.3	523.1
188	21 00.0 N	110 00.0 W	24 Apr 94	265.3	523.1
189	21 29.9 N	110 00.1 W	24 Apr 94	265.3	523.1
190	21 59.9 N	110 00.0 W	25 Apr 94	265.7	524.6
191	22 29.8 N	109 59.7 W	25 Apr 94	265.7	524.6
192	22 43.9 N	110 00.4 W	25 Apr 94	266.1	525.1
193	22 47.9 N	110 00.3 W	25 Apr 94	266.1	525.1
194	22 51.1 N	109 59.9 W	25 Apr 94	266.1	525.1

APPENDIX 5d. Replicate CFC-11 measurements on P18 (CGC94)

STATION NUMBER	SAMP NO.	F11 pM/kg	F11 Stdev	STATION NUMBER	SAMP NO.	F11 pM/kg	F11 Stdev
8	313	0.062	0.021	107	123	0.070	0.006
8	319	0.115	0.008	107	128	2.316	0.012
8	323	0.110	0.009	107	131	2.138	0.004
10	304	0.090	0.004	109	128	1.402	0.005
10	307	0.057	0.003	109	131	2.152	0.011
10	313	0.049	0.003	110	121	0.002	0.002
10	334	6.818	0.048	112	123	0.010	0.003

12	101	0.100	0.001	112	126	0.058	0.000
12	107	0.066	0.005	112	131	2.090	0.005
12	132	6.960	0.037	113	122	0.001	0.001
14	101	0.136	0.009	113	126	0.130	0.000
14	113	0.047	0.008	113	131	2.135	0.067
16	135	5.766	0.130	113	135	1.845	0.003
20	101	0.130	0.002	114	129	0.902	0.007
22	101	0.083	0.006	114	131	2.278	0.003
22	106	0.050	0.004	115	123	0.008	0.009
22	111	0.038	0.000	115	131	2.274	0.004
22	132	5.349	0.013	116	123	0.034	0.005
24	101	0.075	0.000	116	126	0.135	0.004
24	107	0.083	0.005	116	132	2.233	0.008
24	134	4.777	0.014	117	123	0.004	0.001
27	110	0.188	0.007	117	127	0.067	0.002
28	104	0.059	0.008	117	135	1.762	0.008
28	106	0.052	0.008	118	129	0.288	0.004
28	130	4.286	0.147	119	127	0.061	0.000
33	203	0.031	0.024	119	129	0.580	0.003
33	206	0.016	0.001	119	132	2.162	0.011
33	212	0.131	0.002	120	126	0.097	0.003
33	218	2.015	0.003	120	131	2.153	0.082
33	223	3.854	0.010	121	129	1.349	0.001
33	226	3.993	0.008	121	133	1.959	0.013
33	229	4.180	0.013	122	125	0.124	0.006
35	119	2.652	0.022	122	128	0.274	0.001
36	101	-0.000	0.001	122	132	2.151	0.009
36	107	0.004	0.007	125	115	-0.001	0.002
37	225	4.012	0.124	126	223	0.057	0.000
40	301	-0.001	0.002	126	226	0.260	0.000
40	321	2.778	0.004	126	232	1.905	0.002
40	329	3.898	0.009	127	123	0.138	0.005
41	103	-0.000	0.009	127	133	1.699	0.009
42	103	0.006	0.003	128	122	0.017	0.002
42	127	3.723	0.033	129	126	0.130	0.001
42	132	4.217	0.291	129	132	1.798	0.002
44	103	-0.001	0.006	129	136	1.694	0.004
46	103	-0.001	0.003	133	123	0.132	0.001
46	123	3.057	0.034	133	128	0.417	0.005
47	111	0.030	0.003	133	132	0.692	0.003
47	116	0.904	0.028	134	122	0.058	0.002
47	123	3.116	0.075	134	125	0.265	0.009
47	127	3.590	0.091	134	132	0.756	0.004
53	103	-0.003	0.002	135	125	0.481	0.001
53	107	-0.001	0.001	135	129	0.632	0.009
53	135	3.253	0.019	135	133	0.920	0.007
55	313	0.021	0.001	137	126	0.238	0.002

55	317	0.641	0.007	137	128	0.518	0.004
55	325	3.022	0.011	137	132	0.713	0.003
55	331	3.970	0.018	138	129	0.536	0.001
59	103	0.002	0.003	139	123	0.122	0.002
59	109	0.000	0.006	139	127	0.465	0.005
59	111	0.005	0.002	139	131	0.733	0.002
59	113	0.005	0.001	141	125	0.169	0.003
59	119	1.532	0.000	141	127	0.388	0.000
59	128	3.065	0.028	141	132	0.785	0.002
59	134	3.420	0.054	142	127	0.586	0.007
61	112	-0.003	0.003	142	131	0.752	0.006
61	114	0.004	0.006	143	127	0.590	0.003
61	131	3.424	0.072	143	131	0.813	0.002
61	132	3.400	0.002	143	135	1.720	0.020
61	133	3.270	0.014	147	129	0.777	0.005
63	116	0.132	0.004	147	133	1.239	0.001
63	118	0.700	0.005	148	121	0.020	0.003
68	116	0.124	0.002	148	132	0.843	0.017
68	118	0.641	0.006	149	232	0.872	0.002
68	132	3.509	0.081	151	123	0.109	0.000
69	117	0.254	0.002	151	127	0.433	0.004
69	126	2.274	0.008	151	133	0.956	0.003
71	123	1.770	0.006	152	136	1.809	0.009
73	118	0.766	0.120	154	125	0.189	0.002
73	119	1.268	0.006	154	129	0.553	0.001
73	128	2.532	0.015	154	133	0.983	0.009
73	133	2.592	0.008	155	129	0.651	0.005
74	118	0.601	0.023	155	131	0.861	NaN
74	126	1.993	0.004	156	122	0.020	0.000
77	118	0.536	0.001	156	126	0.304	0.001
77	127	2.336	0.006	156	132	0.865	0.026
77	132	2.432	0.007	157	325	0.213	0.001
79	117	0.169	0.002	157	333	0.978	0.000
79	121	1.296	0.029	158	127	0.253	0.003
79	129	2.582	0.004	158	133	1.381	0.172
79	132	2.616	0.017	158	135	1.668	0.002
81	301	-0.000	0.001	159	126	0.096	0.002
81	320	0.902	0.010	159	130	0.318	0.003
81	322	1.689	0.004	161	123	0.058	0.027
81	325	2.223	0.017	161	129	0.391	0.002
81	330	2.652	0.051	163	123	0.037	0.000
81	332	2.478	0.018	163	126	0.183	0.001
82	124	2.253	0.026	163	132	0.569	0.001
83	118	0.139	0.014	163	136	1.637	0.002
83	126	2.463	0.094	164	132	0.646	0.005
83	127	2.477	0.011	165	125	0.210	0.000
83	132	2.346	0.001	165	129	0.389	0.001

84	126	2.419	0.016	165	133	0.985	0.001
84	130	2.385	0.013	167	125	0.156	0.001
85	118	0.338	0.002	167	131	0.743	0.004
85	120	0.950	0.013	168	325	0.091	0.000
85	122	1.110	0.003	168	331	0.567	0.004
85	125	1.970	0.005	169	123	0.045	0.002
85	131	2.335	0.002	169	131	0.624	0.016
87	119	0.278	0.002	169	135	1.636	0.006
88	106	0.002	0.000	170	127	0.291	0.066
88	119	0.073	0.009	170	133	1.638	0.015
88	131	2.274	0.001	172	331	1.674	0.002
89	119	0.037	0.002	174	122	0.020	0.001
89	126	2.008	0.005	174	125	0.091	0.009
90	321	0.881	0.001	174	131	1.529	0.002
91	120	0.093	0.000	176	123	0.017	0.000
91	127	2.240	0.011	176	129	0.313	0.000
92	122	0.469	0.000	176	135	1.722	0.001
93	115	-0.002	0.001	178	122	0.021	0.001
93	119	0.008	0.024	178	125	0.078	0.004
93	126	1.596	0.007	178	131	2.012	0.002
93	132	2.182	0.006	180	121	0.002	0.001
93	135	1.927	0.007	180	125	0.050	0.003
95	119	0.002	0.000	180	133	1.998	0.008
95	126	1.352	0.013	181	127	0.145	0.004
95	132	2.115	0.019	181	135	1.870	0.011
95	135	1.935	0.056	182	122	0.032	0.008
97	120	0.009	0.013	182	125	0.056	0.001
97	125	0.467	0.004	182	131	2.221	0.005
97	128	2.329	0.003	183	132	2.193	0.012
97	132	2.164	0.008	184	122	0.047	0.001
97	135	1.921	0.028	184	125	0.127	0.007
99	120	0.030	0.015	184	131	1.045	0.002
99	127	2.393	0.002	186	123	0.037	0.006
99	132	2.152	0.015	186	129	0.353	0.031
101	325	0.940	0.000	186	133	2.154	0.007
101	329	2.329	0.028	188	322	0.045	0.014
103	121	0.022	0.006	188	325	0.084	0.003
103	125	0.668	0.000	188	331	1.130	0.001
103	128	2.315	0.005	188	336	2.201	0.007
103	131	2.117	0.001	190	125	0.089	0.003
103	133	1.976	0.002	190	129	0.472	0.001
103	135	1.953	0.001	190	133	2.535	0.006
105	123	0.053	0.001	191	123	1.512	0.003
105	127	1.472	0.005	193	103	0.010	0.003
105	130	2.204	0.010	193	106	0.049	0.002
105	134	1.957	0.003	193	109	0.187	0.001
106	120	-0.000	0.001	193	111	0.367	0.001

106	132	1.969	0.021	193	113	0.911	0.009
107	121	0.012	0.005	193	117	2.214	0.014

APPENDIX 5e. Replicate CFC-12 measurements on P18 (CGC94)

STATION NUMBER	SAMP NO.	F12 pM/kg	F12 Stdev	STATION NUMBER	SAMP NO.	F12 pM/kg	F12 Stdev
2	113	0.011	0.003	103	131	1.170	0.012
8	311	0.015	0.001	103	133	1.102	0.014
8	313	0.017	0.002	103	135	1.086	NaN
8	319	0.058	0.010	105	123	0.031	0.003
8	323	0.053	0.005	105	127	0.756	0.009
10	301	0.059	0.001	105	130	1.203	0.007
10	304	0.038	0.007	105	134	1.137	0.039
10	307	0.026	0.002	106	120	0.001	0.000
10	313	0.021	0.001	106	132	1.106	0.022
10	334	3.130	0.007	107	121	0.003	0.000
12	101	0.054	0.002	107	123	0.042	0.002
12	107	0.022	0.002	107	128	1.241	0.011
12	113	0.014	0.003	107	131	1.165	0.009
12	115	0.031	0.013	109	121	-0.000	0.003
12	119	0.059	0.001	109	128	0.741	0.005
12	125	0.134	0.002	109	131	1.185	0.001
12	127	0.288	0.000	110	121	0.001	0.000
12	129	0.719	0.009	112	123	0.005	0.001
12	132	3.193	0.029	112	126	0.036	0.002
14	101	0.065	0.003	112	131	1.149	0.004
14	106	0.030	0.002	113	122	0.001	0.002
14	113	0.017	0.001	113	126	0.076	0.002
14	118	0.049	0.000	113	131	1.236	0.079
16	103	0.042	0.008	113	135	1.027	0.014
16	118	0.057	0.000	114	129	0.491	0.007
16	135	2.764	0.016	114	131	1.233	0.013
20	101	0.061	0.002	115	123	0.003	0.008
22	101	0.041	0.004	115	131	1.233	0.015
22	106	0.026	0.003	116	123	0.023	0.004
22	111	0.017	0.002	116	126	0.077	0.002
22	132	2.527	0.000	116	132	1.220	0.009
24	101	0.035	0.005	117	123	-0.000	0.003
24	128	2.004	0.011	117	127	0.039	0.002
24	134	2.322	0.017	117	135	1.009	0.002
27	110	0.079	0.003	118	129	0.162	0.002
28	101	0.030	0.003	119	127	0.033	0.001
28	104	0.025	0.006	119	129	0.320	0.007
28	106	0.021	0.001	119	132	1.198	0.006
28	118	0.160	0.001	120	126	0.056	0.001
28	127	1.408	0.018	120	131	1.187	0.033

28	130	2.176	0.009	121	129	0.725	0.005
28	135	2.241	0.142	121	133	1.093	0.013
33	201	0.012	0.005	122	125	0.070	0.004
33	203	0.014	0.010	122	128	0.158	0.000
33	206	0.005	0.003	122	132	1.199	0.005
33	212	0.061	0.000	125	115	-0.002	0.000
33	218	0.951	0.005	126	223	0.032	0.002
33	223	1.927	0.021	126	226	0.150	0.001
33	229	2.105	0.008	126	232	1.025	0.008
35	119	1.251	0.028	127	123	0.079	0.001
36	101	0.001	0.001	127	133	0.979	0.006
36	107	-0.001	0.001	128	122	0.018	0.001
37	225	1.913	0.006	129	126	0.083	0.006
40	301	0.000	0.000	129	132	0.971	0.005
40	303	-0.000	0.000	129	136	1.002	0.027
40	321	1.333	0.007	133	123	0.082	0.002
40	329	1.946	0.011	133	128	0.232	0.002
41	103	-0.000	0.000	133	132	0.380	0.002
42	103	0.003	0.004	134	122	0.030	0.003
42	127	1.833	0.004	134	125	0.150	0.002
42	132	2.150	0.117	134	132	0.420	0.002
44	103	-0.002	0.001	135	125	0.267	0.001
46	103	-0.001	0.001	135	129	0.353	0.001
46	123	1.479	0.012	135	133	0.505	0.002
47	111	0.010	0.003	137	126	0.139	0.004
47	116	0.430	0.012	137	128	0.296	0.002
47	123	1.497	0.027	137	132	0.402	0.004
47	127	1.755	0.021	138	129	0.303	0.000
53	103	0.002	0.001	139	123	0.072	0.002
53	107	0.001	0.002	139	131	0.400	0.003
53	135	1.678	0.043	141	125	0.095	0.003
55	313	0.011	0.000	141	127	0.223	0.001
55	317	0.332	0.001	141	132	0.429	0.000
55	325	1.478	0.006	142	127	0.321	0.003
55	331	1.993	0.002	142	131	0.410	0.001
59	103	-0.001	0.001	143	131	0.439	0.001
59	109	-0.000	0.000	143	135	0.939	0.030
59	111	-0.000	0.002	147	129	0.421	0.005
59	113	-0.002	0.003	147	133	0.669	0.003
59	119	0.787	0.004	148	121	0.006	0.001
59	128	1.482	0.027	148	132	0.454	0.010
59	134	1.750	0.007	149	228	0.283	0.004
61	112	-0.002	0.001	149	232	0.469	0.003
61	114	0.004	0.006	151	123	0.064	0.001
61	131	1.730	0.016	151	127	0.240	0.002
61	132	1.745	0.020	151	133	0.517	0.007
61	133	1.699	0.024	152	136	0.964	0.006

63	116	0.080	0.003	154	125	0.100	0.001
63	118	0.367	0.003	154	129	0.308	0.001
68	116	0.074	0.002	154	133	0.529	0.008
68	118	0.338	0.001	155	129	0.350	0.007
68	132	1.753	0.109	155	131	0.453	0.006
69	117	0.145	0.001	156	122	0.007	0.001
69	126	1.098	0.005	156	132	0.455	0.019
71	123	0.845	0.001	157	325	0.116	0.001
73	118	0.397	0.055	157	333	0.513	0.001
73	119	0.640	0.014	158	127	0.140	0.003
73	128	1.278	0.006	158	133	0.746	0.122
73	133	1.397	0.004	158	135	0.962	0.004
74	118	0.316	0.001	159	126	0.051	0.003
74	126	0.973	0.002	159	130	0.173	0.003
77	118	0.318	0.044	161	123	0.035	0.013
77	127	1.175	0.006	161	129	0.215	0.001
77	132	1.308	0.003	163	123	0.021	0.002
79	117	0.101	0.005	163	126	0.100	0.001
79	121	0.646	0.007	163	132	0.310	0.003
79	129	1.343	0.001	164	132	0.353	0.002
79	132	1.402	0.009	165	125	0.120	0.003
81	301	-0.002	0.000	165	129	0.220	0.007
81	320	0.465	0.022	165	133	0.545	0.003
81	322	0.834	0.001	167	125	0.095	0.011
81	325	1.112	0.015	168	325	0.052	0.003
81	330	1.396	0.009	168	331	0.317	0.003
82	124	1.117	0.044	169	123	0.028	0.002
83	118	0.079	0.001	169	131	0.348	0.004
83	126	1.274	0.037	169	135	0.962	0.004
83	127	1.310	0.006	170	127	0.166	0.033
83	132	1.278	0.020	170	133	0.959	0.015
84	126	1.280	0.003	171	120	0.002	0.000
84	130	1.280	0.003	172	331	0.968	0.004
85	118	0.184	0.008	174	122	0.012	0.001
85	120	0.483	0.001	174	125	0.061	0.018
85	122	0.551	0.000	174	131	0.859	0.006
85	125	0.988	0.009	176	123	0.018	0.004
85	131	1.264	0.005	176	129	0.191	0.002
87	119	0.163	0.004	176	135	0.995	0.011
87	125	0.676	0.007	178	122	0.010	0.000
88	106	0.001	0.000	178	125	0.045	0.000
88	119	0.048	0.001	178	131	1.055	0.007
88	131	1.258	0.012	180	121	-0.000	0.000
89	119	0.025	0.002	180	125	0.030	0.001
89	126	1.025	0.003	180	133	1.130	0.001
90	321	0.450	0.002	181	127	0.086	0.001
91	120	0.058	0.000	181	135	1.063	0.002

91	127	1.154	0.001	182	122	0.007	0.001
92	122	0.262	0.006	182	125	0.028	0.003
93	115	0.001	0.002	182	131	1.178	0.019
93	119	0.003	0.008	183	132	1.162	0.011
93	126	0.809	0.009	184	122	0.025	0.000
93	132	1.204	0.000	184	125	0.069	0.000
93	135	1.073	0.005	184	131	0.559	0.001
95	119	0.003	0.000	186	123	0.020	0.000
95	126	0.691	0.008	186	129	0.198	0.002
95	132	1.183	0.005	186	133	1.135	0.000
95	135	1.058	0.019	188	322	0.015	0.000
97	120	0.002	0.002	188	325	0.044	0.002
97	125	0.247	0.003	188	331	0.597	NaN
97	128	1.238	0.002	188	336	1.228	0.017
97	132	1.216	0.016	190	125	0.046	0.002
97	135	1.086	0.009	190	129	0.257	0.004
99	120	0.025	0.012	190	133	1.351	0.012
99	127	1.253	0.008	191	123	0.790	0.006
99	132	1.192	0.014	193	103	-0.000	0.001
101	320	-0.001	0.001	193	106	0.018	0.001
101	325	0.493	0.002	193	109	0.103	0.003
103	121	0.013	0.001	193	111	0.206	0.008
103	125	0.358	0.000	193	113	0.487	0.002
103	128	1.234	0.006	193	117	1.196	0.010

APPENDIX 6a. Oxygen Measurement techniques on WOCE P18 (CGC94)

Summary of Oxygen Data for CGC94
Kirk Hargreaves
18 April 1996

1.1 Oxygen
1.1.1 Overview

Oxygen samples were drawn from every bottle for every station (except for some of the test casts). A total of 6191 samples were drawn, including 450 duplicates. Five different people drew oxygen samples and four people were involved with running samples. The estimated accuracy is 0.3% plus an estimated precision of 0.3 µmol/kg. Note that precision is sampler dependent and was as good as 0.2 µmol/kg for some samplers. All samples for station 89 are flagged as bad because of bad sampling.

Samples were titrated using Carpenter's whole bottle technique (Carpenter, 1969). An auto-titrator based on a design by Gernot Friederich (Friederich, 1991) and using a modified version of Friederich's software was used to titrate the samples. The titrator consists of a Kloehn 50100 Syringe Drive with a 5 ml syringe, a home-built photometer, and a computer. Post- processing software was used to add in temperature corrections and to analyze data.

1.1.2 Sampling and pickling

Oxygen sampled immediately after CFC's and Helium. Samples were drawn in calibrated 125 ml nominal volume iodine determination flasks (Corning 5400-125).

The sampling tube was inserted into the flask, allowed to flow freely and tapped to removed bubbles, and then inverted. The tube was pinched to reduce flow and allow water in the flask to drain. A water sheet was formed on the inside of the flask, the sampling tube pinched off, the flask drained, and then put right side up. The sampling tube was slowly released to prevent turbulent flow and the flask allowd to fill. Using a watch, the fill time was measured and used to ensure at least two flask volumes overflow. (Typical fill time was 7 seconds). During this time, the temperature of the water was recorded using an uncalibrated Pt-RTD. However, these temperatures are not used in the final data processing.

Reagents were introduced quicky after sampling using Brinckmann 1.0 ml Fixed Volume Dispensette repipets. The tips of the repipets were lengthened using clear polyolefin shrink tubing. How reagents were introduced varied. My preferred method was adding $MnCl_2$ at the bottom of the flask, and NaOH/NaI at the mid-point. The repipet tips were inserted into the flask and then the repipets were filled and dispensed. This had the problem that on the upstroke, sometimes seawater (~5 uL) was aspirated up the tube. In later cruises, the upstroke should take place outside of the flask. All reagents were prepared according to WOCE specifications.

Flasks were capped at this point and shaken until the reagents were well mixed. The flask was inverted and checked for bubbles. Distilled water, or later, seawater, was added to the collar of the flask and the flask stowed. At least 20 minutes after sampling was finished, flasks were reshaken.

1.1.3 Analysis

Samples were analyzed no earlier than 20 minutes and no later than 8 hours after remixing. Liquid from the flask collar was aspirated with a transfer pipette and the stopper removed. ~1ml of 10N sulfuric acid and a rinsed stir bar were added. (Note - the stir bars had short lengths of Tygon on them to improve their stirring characteristics. Stir bars without pivot rings have since been found to work better.) The flask was wiped dry and placed in the titrator and titrated with 0.05 N sodium thiosulfate. After titration, the sample was poured out and the flask rinsed with hot tap water.

1.1.4 Standardization

Titrant was standardized with 0.01N potassium iodate solution which was mixd before the cruise and stored in air tight bottle. Standard was dispensed using a spare Kloehn 50100 with a calibrated 5 ml buret. The measured accuracy of the dispensed standards is 0.6 uL and 2.3 uL for volumes below and above 5 mL, respectively. Standards all were within 0.1% of each their calculated values when intercompared after the cruise.

1.2 Oxygen References

Culberson, C.H., "Dissolved Oxygen", WHP Operations and Methods, WHP Office Report WHPO 91-1, July 1992.

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Friederich, G.E., Codispoti, L.A., and Sakamoto, C.M., "An Easy-to-Construct Automated Winkler Titration System", MBARI Technical Report 91-6, August 1991.

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T., Numerical Recipies in C, Cambridge University Press, Cambridge, 1988.

APPENDIX 6b Replicate Oxygen Measurements on WOCE P18 (CGC94) File gives station, sample, mean of replicate oxygen measurements (in µmol/kg), standard deviation of replicate measurements (sO_2), and range of values for replicate samples:

#Sta	Sta	O_2	sO_2	HighO_2	LowO_2
11	107	209.67	0.02	209.68	209.66
11	117	186.14	0.43	186.45	185.84
11	209	345.22	0.51	345.58	344.85
12	127	175.44	0.22	175.60	175.29
12	121	176.42	0.12	176.51	176.34
13	101	216.31	0.11	216.39	216.23
13	102	217.23	0.06	217.27	217.19
13	103	216.30	0.19	216.43	216.16
15	119	175.82	0.18	175.96	175.69
15	129	229.91	0.06	229.95	229.87
16	102	216.79	0.46	217.11	216.46
20	102	216.53	0.02	216.54	216.52
20	103	216.01	0.25	216.19	215.83
21	106	210.65	0.17	210.77	210.53
21	119	171.54	0.07	171.59	171.49
22	110	199.45	0.34	199.69	199.21
22	121	175.68	0.01	175.68	175.67
23	307	206.03	0.02	206.05	206.01
23	311	195.09	0.23	195.25	194.93
24	117	171.52	0.05	171.55	171.48
24	130	295.04	0.13	295.13	294.95
28	107	205.58	0.25	205.76	205.41
28	113	187.73	0.27	187.92	187.54
33	207	185.03	0.04	185.06	185.00
33	219	247.23	0.01	247.23	247.23
33	230	281.77	0.68	282.25	281.29
34	107	180.58	0.13	180.68	180.49
34	109	174.59	0.38	174.86	174.32
35	106	189.68	0.22	189.84	189.53
35	115	192.85	0.11	192.93	192.77

35	123	270.72	0.02	270.74	270.71
36	112	169.65	0.03	169.67	169.62
36	114	179.01	0.06	179.06	178.97
37	204	199.09	0.19	199.22	198.95
37	208	179.84	0.18	179.96	179.71
37	210	172.80	0.38	173.07	172.53
39	107	171.13	0.33	171.37	170.90
40	309	173.90	0.81	174.47	173.33
41	108	175.82	0.11	175.89	175.74
41	109	172.81	0.03	172.83	172.79
42	110	167.63	0.01	167.63	167.63
42	114	169.13	0.04	169.15	169.10
44	104	195.74	0.23	195.90	195.57
44	106	182.61	0.73	183.13	182.09
44	108	173.48	0.44	173.79	173.17
45	106	183.05	0.18	183.18	182.92
45	108	173.78	0.19	173.92	173.65
45	110	170.46	0.28	170.65	170.26
46	102	195.21	0.09	195.28	195.15
46	104	188.23	0.03	188.25	188.21
46	108	169.24	0.05	169.27	169.20
47	103	192.84	0.05	192.87	192.80
47	105	182.38	0.08	182.43	182.33
47	108	170.38	0.25	170.55	170.20
52	103	186.60	0.23	186.76	186.44
52	104	180.77	0.62	181.21	180.33
52	106	171.92	0.35	172.17	171.67
53	109	171.94	0.35	172.19	171.69
53	112	160.98	0.10	161.05	160.91
53	115	179.58	0.01	179.58	179.57
54	121	264.28	0.27	264.47	264.09
54	125	261.39	0.08	261.44	261.34
54	130	281.11	0.03	281.13	281.09
55	318	234.36	0.25	234.54	234.19
55	321	261.12	0.05	261.16	261.09
55	323	262.03	0.02	262.05	262.02
58	307	168.45	0.84	169.05	167.85
58	308	167.11	0.23	167.27	166.95
58	310	161.99	0.15	162.10	161.88
59	105	176.76	0.05	176.80	176.72
59	107	166.76	1.08	167.52	165.99
59	109	159.83	0.50	160.19	159.48
60	110	150.61	0.07	150.66	150.56
60	115	184.42	0.06	184.47	184.38
60	134	252.09	0.01	252.10	252.08
61	102	191.62	0.03	191.65	191.60
61	106	171.19	0.09	171.25	171.13

61	108	164.85	0.06	164.89	164.81
62	307	166.44	0.09	166.50	166.38
62	308	164.68	0.57	165.09	164.28
62	309	158.67	0.51	159.03	158.31
63	103	192.86	0.02	192.87	192.84
63	105	182.16	0.01	182.17	182.16
63	107	169.09	0.12	169.18	169.01
64	106	164.47	0.05	164.50	164.43
64	110	131.87	0.02	131.88	131.86
64	115	180.47	0.10	180.54	180.40
68	110	134.88	0.08	134.93	134.82
68	115	169.60	0.07	169.66	169.55
68	121	250.94	0.16	251.05	250.83
69	110	144.05	0.02	144.06	144.03
70	125	243.94	0.40	244.23	243.66
70	131	247.40	0.09	247.47	247.34
70	128	219.68	0.39	219.96	219.41
71	109	160.54	0.42	160.84	160.25
71	111	146.48	1.42	147.48	145.47
71	113	128.59	0.14	128.69	128.50
72	103	166.95	0.22	167.10	166.79
72	104	167.31	0.10	167.37	167.24
72	105	167.07	0.22	167.23	166.91
73	110	149.25	0.14	149.35	149.15
73	126	219.79	0.06	219.83	219.74
73	128	212.61	0.07	212.65	212.56
73	130	240.28	0.12	240.37	240.20
74	104	165.61	2.03	167.04	164.18
74	109	156.57	0.07	156.62	156.52
74	127	217.55	0.01	217.55	217.54
75	104	166.85	0.10	166.92	166.78
75	110	149.98	0.23	150.14	149.82
75	116	188.08	0.16	188.20	187.97
76	103	165.58	0.22	165.74	165.43
76	105	164.80	0.01	164.81	164.79
76	107	160.34	0.02	160.36	160.33
77	104	164.98	0.03	165.00	164.96
77	115	153.46	0.04	153.49	153.43
77	125	208.50	0.03	208.52	208.47
78	101	167.04	1.98	168.44	165.64
78	105	163.18	0.09	163.24	163.12
78	123	216.78	0.33	217.02	216.55
79	104	164.85	0.08	164.91	164.79
79	129	216.58	0.11	216.66	216.50
79	133	246.76	2.06	248.22	245.30
80	101	165.18	0.10	165.25	165.11
80	105	161.33	0.03	161.35	161.31

80	131	245.09	0.13	245.19	245.00
81	304	163.74	0.35	163.98	163.49
82	104	162.15	0.69	162.63	161.66
82	108	153.90	0.08	153.96	153.84
83	104	161.35	0.14	161.45	161.25
83	133	236.37	0.01	236.37	236.36
83	135	213.12	0.13	213.21	213.03
84	102	160.90	0.67	161.37	160.43
84	104	158.34	0.12	158.43	158.26
85	105	158.32	0.37	158.58	158.06
85	113	131.08	0.24	131.25	130.91
86	104	157.62	0.10	157.69	157.55
86	107	156.61	0.17	156.73	156.48
86	115	127.98	0.11	128.06	127.90
87	105	156.46	0.02	156.48	156.45
87	119	197.14	0.15	197.24	197.03
88	111	153.96	1.23	154.83	153.09
88	125	181.28	4.13	184.20	178.36
88	136	211.11	0.11	211.19	211.03
90	317	166.69	0.07	166.74	166.64
90	318	196.02	0.06	196.06	195.98
90	319	207.76	1.82	209.05	206.47
91	115	131.89	0.02	131.90	131.88
91	119	131.22	0.24	131.39	131.04
91	122	206.45	0.50	206.80	206.10
92	116	132.08	0.09	132.15	132.02
92	125	147.64	0.06	147.69	147.60
92	130	226.63	0.61	227.06	226.20
93	110	156.20	0.84	156.80	155.61
93	120	132.78	2.27	134.38	131.18
93	130	221.07	0.10	221.14	221.00
94	311	152.31	0.19	152.45	152.18
94	312	147.91	0.28	148.10	147.71
94	313	140.15	0.23	140.31	139.98
95	108	156.01	0.22	156.16	155.85
95	112	120.29	0.02	120.30	120.28
95	136	208.92	0.73	209.44	208.40
96	110	146.82	0.01	146.83	146.81
96	113	115.67	0.02	115.69	115.66
96	135	210.62	0.20	210.76	210.47
97	121	142.87	0.12	142.95	142.78
97	122	159.96	0.00	159.96	159.96
97	123	119.08	0.21	119.22	118.93
98	309	153.85	0.19	153.99	153.72
98	320	94.96	0.09	95.03	94.90
98	321	113.87	0.06	113.92	113.83
99	109	153.89	0.40	154.17	153.61

99	115	93.03	0.41	93.32	92.74
99	129	221.48	0.06	221.52	221.44
100	121	91.10	0.29	91.31	90.89
100	122	114.49	0.10	114.55	114.42
100	123	112.25	0.19	112.39	112.12
101	305	149.58	0.38	149.85	149.31
101	311	128.00	0.37	128.26	127.73
101	319	78.30	0.03	78.32	78.28
102	109	151.10	0.47	151.43	150.77
102	111	128.72	0.05	128.75	128.68
102	136	209.50	0.17	209.62	209.38
103	109	149.23	0.16	149.34	149.11
103	120	77.86	0.29	78.06	77.65
103	131	220.21	0.02	220.22	220.19
104	117	86.09	1.54	87.17	85.00
104	118	83.34	1.85	84.65	82.04
104	119	78.41	2.17	79.95	76.88
105	103	147.69	0.34	147.93	147.44
105	109	146.42	0.09	146.48	146.36
105	135	210.15	0.16	210.27	210.04
106	115	72.99	0.17	73.11	72.88
106	117	64.39	0.16	64.50	64.28
106	123	50.35	0.26	50.54	50.17
107	107	145.67	0.37	145.93	145.40
107	118	58.62	0.75	59.15	58.09
107	129	203.57	0.19	203.70	203.43
108	117	72.62	0.49	72.96	72.27
108	122	58.74	0.00	58.74	58.74
108	133	219.89	1.06	220.64	219.14
109	107	140.24	0.17	140.36	140.12
109	111	132.06	0.08	132.12	132.01
109	125	12.77	0.02	12.78	12.75
109	127	15.16	1.49	16.22	14.11
110	109	139.47	0.11	139.55	139.39
110	115	79.75	0.04	79.78	79.72
110	133	214.66	0.02	214.67	214.65
112	101	136.78	0.03	136.80	136.76
112	111	140.39	0.44	140.70	140.07
112	133	209.84	0.05	209.88	209.81
113	112	114.83	0.03	114.85	114.81
113	119	52.82	0.57	53.22	52.41
113	133	213.31	0.06	213.35	213.27
114	101	137.04	0.22	137.20	136.88
114	107	138.81	0.08	138.87	138.75
114	121	42.27	0.24	42.44	42.10
115	107	136.45	0.32	136.68	136.23
115	118	49.74	0.52	50.11	49.37

115	129	132.66	0.18	132.79	132.54
116	109	134.98	0.02	134.99	134.97
116	115	77.13	0.05	77.17	77.10
116	130	124.04	0.09	124.11	123.98
116	136	207.06	1.37	208.02	206.09
117	105	136.14	0.11	136.22	136.06
117	113	105.25	1.82	106.53	103.96
117	119	54.59	0.17	54.71	54.47
118	106	137.60	0.00	137.60	137.60
118	119	52.60	0.26	52.79	52.42
118	134	206.36	0.26	206.54	206.17
119	107	136.94	0.12	137.02	136.86
119	118	90.47	0.09	90.54	90.41
119	132	193.18	0.55	193.57	192.79
120	105	136.64	0.44	136.94	136.33
120	107	135.77	0.09	135.84	135.71
120	109	130.14	0.08	130.19	130.08
121	101	138.41	0.30	138.63	138.20
121	112	111.18	0.14	111.28	111.08
122	107	125.29	0.22	125.45	125.14
122	114	90.48	0.18	90.61	90.35
122	123	10.41	0.24	10.58	10.24
123	209	95.67	0.17	95.79	95.56
123	216	8.92	0.28	9.11	8.72
123	224	203.08	0.71	203.58	202.58
124	105	125.81	0.26	125.99	125.63
126	208	113.04	0.09	113.11	112.98
126	210	102.76	0.04	102.79	102.74
126	223	4.22	0.21	4.37	4.07
127	105	126.80	0.41	127.09	126.51
127	115	86.39	0.07	86.45	86.34
127	128	7.06	0.14	7.16	6.96
128	105	135.76	0.13	135.85	135.66
128	111	95.18	0.26	95.36	95.00
128	115	89.43	0.05	89.47	89.39
129	109	105.27	0.23	105.43	105.11
129	117	77.52	0.16	77.63	77.41
129	120	35.31	0.00	35.31	35.31
133	102	154.55	0.56	154.94	154.15
133	110	115.75	0.34	115.99	115.51
133	131	47.79	0.13	47.88	47.70
134	101	156.60	0.27	156.79	156.41
134	120	26.66	0.21	26.81	26.51
134	132	61.31	0.03	61.34	61.29
135	101	155.87	0.02	155.89	155.86
135	102	157.09	1.08	157.86	156.33
135	103	157.20	0.32	157.42	156.97

135	104	154.09	0.01	154.09	154.08
135	105	148.16	0.45	148.48	147.84
135	106	140.24	0.69	140.73	139.75
136	107	133.07	0.11	133.14	132.99
136	109	110.19	0.11	110.27	110.12
136	111	97.37	0.12	97.46	97.29
136	120	50.33	0.15	50.43	50.23
136	121	33.92	0.06	33.96	33.88
136	136	202.37	0.04	202.40	202.34
137	101	157.86	0.11	157.94	157.78
137	105	148.59	0.22	148.74	148.44
137	109	125.80	0.19	125.93	125.66
138	102	157.78	0.45	158.10	157.46
138	113	98.16	0.03	98.18	98.14
138	115	90.77	0.13	90.86	90.67
139	101	158.81	0.76	159.34	158.27
139	105	144.00	0.25	144.18	143.83
139	109	111.72	0.12	111.81	111.64
139	113	86.59	0.27	86.78	86.40
139	119	62.59	0.05	62.63	62.55
139	136	201.29	0.44	201.61	200.98
140	107	131.26	1.43	132.27	130.25
140	109	115.10	0.22	115.26	114.95
140	133	120.92	1.38	121.89	119.94
141	103	148.77	0.14	148.87	148.67
141	109	119.49	0.19	119.62	119.36
141	136	200.72	0.06	200.76	200.68
142	129	81.65	0.72	82.16	81.14
142	130	91.69	0.24	91.86	91.52
142	131	97.46	0.16	97.57	97.35
142	132	100.44	0.49	100.78	100.09
142	133	59.42	1.42	60.42	58.42
142	134	85.26	0.98	85.95	84.57
142	135	195.33	0.79	195.89	194.77
142	136	203.50	7.76	208.99	198.02
143	105	145.13	0.06	145.17	145.09
143	135	174.56	0.03	174.58	174.53
143	136	194.56	0.26	194.74	194.37
144	103	154.84	0.14	154.94	154.74
144	135	163.18	0.11	163.26	163.10
144	136	188.09	0.11	188.17	188.02
146	126	18.98	0.83	19.56	18.39
146	128	70.91	0.16	71.02	70.79
146	130	103.51	0.91	104.15	102.86
146	132	107.10	0.29	107.31	106.90
146	133	112.44	0.01	112.45	112.44
146	134	134.44	0.07	134.48	134.39

146	135	180.08	0.32	180.31	179.86
146	136	184.97	0.11	185.04	184.89
147	123	24.22	0.52	24.59	23.85
147	134	187.23	0.01	187.23	187.22
147	136	191.99	0.16	192.10	191.87
148	126	26.72	0.05	26.76	26.69
148	128	53.43	0.01	53.44	53.42
148	130	62.78	0.08	62.83	62.72
148	132	64.65	0.15	64.75	64.54
148	134	103.40	0.01	103.41	103.40
148	135	187.27	0.04	187.30	187.25
148	136	194.12	0.15	194.23	194.02
149	209	116.29	0.25	116.47	116.11
149	221	47.99	0.05	48.03	47.96
149	236	200.25	0.01	200.26	200.25
150	101	147.88	0.08	147.94	147.83
150	119	46.98	1.26	47.88	46.09
150	136	202.01	0.12	202.10	201.93
151	136	203.53	0.18	203.66	203.40
152	117	52.88	0.19	53.01	52.74
152	119	52.44	0.12	52.52	52.35
152	129	47.72	0.30	47.93	47.51
153	309	99.22	0.06	99.26	99.17
153	311	85.23	0.09	85.29	85.17
153	336	202.78	0.04	202.81	202.75
154	101	148.89	0.31	149.11	148.67
154	117	62.92	1.07	63.68	62.16
154	136	203.26	0.06	203.30	203.22
155	111	92.69	0.08	92.75	92.64
155	123	29.02	0.66	29.48	28.55
155	136	202.17	0.05	202.20	202.13
156	103	148.21	0.24	148.37	148.04
156	111	90.56	0.04	90.59	90.54
156	136	205.51	0.11	205.59	205.43
157	301	149.32	0.51	149.68	148.96
157	305	133.26	0.27	133.45	133.07
157	331	60.76	0.10	60.84	60.69
158	101	148.52	0.56	148.92	148.13
158	109	112.57	0.06	112.61	112.53
158	136	198.82	0.02	198.83	198.81
159	115	63.75	0.07	63.80	63.69
159	123	2.89	0.14	2.99	2.79
159	127	34.83	0.05	34.87	34.80
161	101	137.12	0.45	137.45	136.80
161	121	1.45	0.32	1.68	1.22
161	135	197.56	0.04	197.59	197.54
162	105	130.14	0.15	130.24	130.03

162	119	8.17	0.08	8.22	8.11
162	130	10.82	0.41	11.11	10.53
163	103	140.70	0.11	140.78	140.62
163	113	81.49	0.52	81.86	81.12
163	129	30.66	0.04	30.70	30.63
164	105	130.53	0.05	130.56	130.50
164	113	55.49	0.06	55.53	55.45
164	127	27.49	0.29	27.69	27.28
165	107	117.18	0.09	117.24	117.12
165	111	97.59	0.04	97.62	97.56
165	133	41.69	0.29	41.90	41.49
166	107	108.03	0.11	108.11	107.95
166	111	68.51	0.32	68.74	68.28
166	136	198.18	0.03	198.19	198.16
167	103	130.15	0.13	130.24	130.06
167	121	6.17	0.22	6.32	6.01
167	131	14.55	0.01	14.56	14.55
168	305	115.46	0.09	115.53	115.40
168	315	36.08	0.10	36.16	36.01
168	331	5.35	0.04	5.38	5.33
169	103	128.09	0.06	128.13	128.05
169	109	85.41	0.18	85.53	85.28
169	113	51.20	0.20	51.34	51.06
170	105	114.24	0.50	114.59	113.88
170	107	98.85	0.60	99.27	98.43
170	135	197.79	0.13	197.88	197.70
171	107	96.57	0.03	96.59	96.55
171	122	2.72	0.10	2.79	2.65
171	131	154.06	0.09	154.13	154.00
172	303	137.35	0.10	137.42	137.28
172	309	113.58	0.27	113.77	113.38
172	335	198.28	0.20	198.42	198.14
173	103	132.63	0.10	132.70	132.56
173	105	125.30	0.01	125.31	125.30
173	135	198.77	0.14	198.87	198.67
174	110	71.57	0.06	71.62	71.53
174	121	5.16	0.06	5.20	5.11
174	123	1.30	0.04	1.32	1.27
175	106	117.08	0.04	117.11	117.05
175	123	0.93	0.13	1.03	0.84
175	131	8.54	0.13	8.63	8.45
176	105	125.69	0.04	125.72	125.67
176	109	100.47	0.14	100.56	100.37
176	135	203.14	0.09	203.20	203.07
177	103	127.93	0.04	127.95	127.90
177	105	121.02	0.13	121.11	120.93
177	115	23.51	0.07	23.56	23.46

178	111	62.90	0.22	63.06	62.74
178	121	0.55	0.15	0.65	0.44
179	102	121.45	0.12	121.53	121.36
179	107	111.53	0.64	111.98	111.08
179	126	0.50	0.00	0.50	0.50
180	101	122.62	0.05	122.66	122.59
180	121	0.74	0.28	0.94	0.54
180	131	42.70	0.17	42.82	42.58
181	111	75.05	0.43	75.36	74.75
181	115	24.91	0.16	25.03	24.80
181	129	0.61	0.26	0.79	0.42
182	106	108.51	0.12	108.60	108.43
182	114	32.66	0.14	32.76	32.56
182	132	214.37	0.01	214.38	214.36
183	107	108.97	0.17	109.09	108.85
183	123	1.34	0.29	1.54	1.14
184	102	119.24	0.01	119.25	119.23
184	122	0.86	0.42	1.16	0.56
184	134	222.53	0.11	222.61	222.46
185	105	115.62	0.01	115.62	115.61
185	115	17.86	0.20	18.00	17.72
185	135	214.99	0.47	215.32	214.66
186	109	71.19	0.07	71.24	71.15
186	135	223.33	0.04	223.36	223.30
187	115	17.60	0.02	17.62	17.58
187	129	3.54	0.06	3.59	3.50
188	309	82.56	0.08	82.61	82.50
188	317	10.89	0.13	10.98	10.79
188	331	27.36	0.02	27.37	27.35
189	105	112.91	0.45	113.23	112.59
189	115	22.57	0.13	22.66	22.48
189	125	1.38	0.42	1.67	1.08
190	101	115.69	0.15	115.79	115.59
190	121	4.19	0.03	4.21	4.17
191	107	64.78	0.11	64.85	64.70
191	115	1.43	0.01	1.44	1.42
192	103	61.19	1.11	61.98	60.41
192	111	10.17	0.19	10.31	10.04
192	123	21.75	0.06	21.79	21.70
193	101	11.38	0.17	11.50	11.26
193	109	1.21	0.05	1.25	1.18
193	115	51.30	0.30	51.51	51.09
194	105	25.13	0.33	25.36	24.90
194	109	153.84	1.47	154.82	152.15

APPENDIX 7. Bottle Salinity Measurement techniques on WOCE P18 (CGC94)

Bottle salinity measurements on section P18 were made by Gregg Thomas (NOAA-AOML). The salinity analysis was accomplished using two Guildline Model 8400A inductive autosalinimoters standardized with IAPSO Standard Seawater batch P114. The instruments were located in a temperature controlled van. The autosalinometer in use was standardized before each run and either at the end of each run or after no more than 48 samples. The drift between standardizations was monitored and the individual samples were corrected for that drift by linear interpolation. Duplicate samples taken from the deepest bottle on each cast were analyzedon a subsequent day. Bottle salinities were compared with preliminary CTD salinities to aid in identification of leaking bottles as well as to monitor the CTD conductivity cells' performance and drift.

The expected precision of the autosalinometer with an accomplished operator is 0.001 pss, with an accuracy of 0.003. To assess the precision of discrete salinity measurements on this cruise, a comparison is made for data from the instances in which two bottles were tripped within 10 dbar of each other at the same station below a depth of 2000 dbar. For the 138 instances in which both bottles of the pair have acceptable salinity measurements, the standard deviation of the differences is 0.0012 pss. This value is very close to the expected precision.

APPENDIX 8. Nutrient Measurement techniques on WOCE P18 (CGC94)

Nutrients
by K.A. Krogslund and C.W. Mordy (8 May, 1996)

Equipment and Analytical Methods

An Alpkem RFA/2(trademark) autoanalyzer was used to determine dissolved concentrations of silicate ($Si(OH)_4$), phosphate ($HPO_4{}^{-3}$) nitrate ($NO_3{}^{-}$) and nitrite ($NO_2{}^{-}$). Measurements were made in a temperature controlled laboratory which was maintained at 21(±)1°C. The following analytical methods were employed:

Silicate was converted to silicomolybdic acid and reduced with stannous chloride to form silicomolybdous acid or molybdenum blue (Armstrong, 1967).

Phosphate was converted to phosphomolybdic acid and reduced with ascorbic acid to form phosphomolybdous acid in a reaction stream heated to 37°C (Bernhardt and Wilhelms, 1967).

Nitrite was diazotized with sulfanilamide and coupled with NEDA to from a red azo dye.

Nitrate+Nitrite was measured by first reducing nitrate to nitrite in a copperized cadmium coil, and then analyzing for nitrite. Nitrate was determined from the difference of nitrate+nitrite and nitrite (Armstrong, 1967).

Sampling Procedures

Nutrient samples were collected from 10-liter Niskin bottles in aged 20 ml high density polyethylene scintillation vials closed with teflon lined polyethylene caps. All vials and caps were rinsed with 10% HCl and deionized water prior to each station, and rinsed at least three times with sample before filling. Samples were usually analyzed immediately after collection; however, some samples were stored for up to 12 hours at 4-6°C.

Calibrations and Standards

Standard material for dissolved silicate was sodium fluorosilicate which had been referenced against a fused-quartz standard. Primary standards were prepared by dissolving standard material in deionized water, and working standards were prepared in low nutrient seawater. At each station, seven concentrations of working standard were freshly prepared and analyzed prior to sample analysis, and the highest standard was again analyzed after the last sample. This allowed for regular monitoring of the response, drift and linearity of each chemistry. All analysis were within the linear range of the instrument. Concentrations were converted to µmoles/kg by calculating sample densities using the laboratory temperature of 21°C and the practical salinity scale (UNESCO, 1981).

Precision

Analytical precision was determined by replicate measurements (usually 4-5 measurements) on 46 samples from depths greater than 100 m. The average standard deviations of these precision tests were (micromoles/kg) 1.1 silicate, 0.015 phosphate, and 0.22 nitrate; and the average percent deviations were 0.56% silicate, 0.84% phosphate, and 0.59% nitrate.

References

Armstrong, FAJ, Stearns, CR, Strickland, JDH (1967) The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment. Deep-Sea Res 14: 381-389.

Bernhardt H, Wilhelms, A (1967) The continuous determination of low level iron, soluble phosphate and total phosphate with the AutoAnalyzer. Technicon Symposia, Vol I, 385-389. UNESCO (1981)

The practical salinity scale 1978 and the international equation of state of seawater 1980. Tenth report of the Joint Panel on Oceanographic Tables and Standards. UNESCO Technical Papers in Marine Science, No. 36, 144 p.

APPENDIX 9a. Responses to WOCE DQE of CTD data

Dear Mark,

Thank you for your DQE evaluation of CTD data collected along WOCE section P18. We considered each of your suggestions and the following is an itemized explanation of what we did or didn't change in our data files, as well as answers to your questions.

Kristy McTaggart and Greg Johnson

****

STATION SUMMARY FILE (.sum)

.sum files here were ammended to contain the same maximum pressure values for stations 25, 27, 32, 46, 61, and 78 as you listed.

The PDR sound speed used for sounder readings was 1500 m/s. The readings were not corrected for transducer depth below the waterline. The depth of the transducer would've been about 5.5 ± 0.6 m. We would prefer to use the PDR depths as listed and correct them using Carter's tables so that they serve as independent measurements and can be used as a check on CTD pressure.

SALINITY

Regarding suspicious CTD salinity data listed in Table 4:

station 24	2-6 dbar	flags not changed to 3
station 51	84 dbar	flag changed to 3
station 52	74 dbar	flag changed to 3
station 53	70 dbar	flag changed to 3
station 55		flags not changed to 3
station 67	46 dbar	flag changed to 3

'Scatter of salinity residuals'

There is an incompatibility between the General Oceanics rosette sampler and the Sea-Bird 911plus CTD system that generates a spike in the data stream at the moment a bottle is confirmed as tripped. Because of this, upcast CTD burst data had to be averaged prior to the bottle confirm bit. Two-second averages were chosen over a longer interval because the CTD operators did not always let the package sit at bottle depth for at least 10 seconds before firing the rosette. Hence no changes were made.

'Biasing of CTD salinity data for individual stations'

Of course one can seemingly make a (very slight) improvement in the CTD-bottle residual statistics by allowing more degrees of freedom in the fit as the DQE has suggested (that is, breaking up the fit into small station groupings). One could get the best statistics by individually fitting each station to its bottles, but most experts would argue that this would be a bad choice, because one would not be taking advantage of the CTD calibration as a way to average out station-to-station bottle salinity noise.

We believe that the SBE-9/11 CTD conductivity slope drifts gradually, and is actually more stable than the day-to-day fluctuations in the autosal- inometer salinities owing to small temperature drifts in the laboratory and the fact that severe budgetary constraints on these cruises forced us to economize even on such things as standard sea water. We suspect that the "biasing of the CTD salinity data" mentioned in the DQE evaluations is actually noise in the bottle data. Somewhat suspicious is that the station groupings recommended by the DQE of the correct size (most often 3-5 stations per group) that they could easily be owing to daily drift problems in the autosalinometer. For our original calibrations we deliberately chose to model the conductivity slope adjustments of the entire data sets for P14S/P15S and P18 using 4th-order polynomial functions of station number to average out bottle salinity noise. We did this because we saw no obvious jumps in the CTD calibration for either cruise, just gradual drifts.

Statistical support for our philosophy over that of the DQE is given by the following exercise: The 2°C potential isotherm is well within the oldest Pacific Deep Water, and has some of the tightest Theta-S relation- ships in the Pacific Ocean (and probably the world). For both P18 and P14S/P15S, we looked at the absolute values of station-to-station changes in CTD salinity on Theta=2.0°C (Figure 1) for our original calibration, creating a histogram of station-to-station differences for each cruise in 0.001 bins. We then applied the DQE's suggested ad-hoc calibrations for smaller station groupings to the data and conducted the same analysis. When the histograms are differenced (Figure 2), one can see that the Theta-S relations at 2°C after the DQE's corrections are noisier for both cruises. For P18, after the DQE's suggested correction there are four less station pairs in the 0.000 difference bin and one less in the 0.001 difference bin whereas there are three more in the 0.002 difference bin and two more in the 0.003 difference bin. For P15S/P15S there are four less stations in the 0.000 difference bin after the DQE's suggested correction, with one more in the 0.001 difference bin and three more in the 0.002 difference bin. Since the DQE's "corrections" actually introduce more noise in the CTD Theta-S relation at 2°C than our original calibration, we decline application of them. The small groups do not improve the calibraiton, they degrade, perhaps by introducing auto-salinometer drift noise.

OXYGEN

Rankings for stations as listed in Table 6 were complied with except for station 160, which is closer to a rating of 2 than 1 and was flagged as 3 not 4. A cutoff of 3750 dbar was used to reflag the deep data of stations 21 and 22; 3400 dbar for station 65; 3200 dbar for station 67; and 2200 dbar for station 85. Note all flags of 6, 7, or 8 were preserved in the reflagging.

Poor oxygen data were owing to poor sensor performance not to the data processing or curve fitting. A few worst case groupings were reexamined using two sets of fit coefficients blended near the oxygen minimum as was done for P14S/P15S. However, there was no significant improvement. Unfortunately, only one oxygen module was available for this cruise due to severe budgetary constraints, and it was not a good one.

Suspicious oxygen data listed in Table 5 were examined and near surface data were reflagged as 3 as suggested. Note that data files submitted before and after the DQE evaluation are 1 dbar averages, not the 2 dbar averages referenced. For suspicious oxygen data deeper in the water column, these were interpolated over and flagged as 6 (stations 30, 69, 70, 71-74, 128, 153, and 180). The shift in oxygen data between 2084 and 2384 dbar for station 188 was flagged as 3 and not interpolated over. Again, all flags of 6, 7, or 8 were preserved in the reflagging.

Stations 26, 89 and 160 were viewed with adjacent profiles and their bottles. Station 26 and 89 oxygen profiles were flagged as 4 as suggested in Table 6. Station 160, however, looked to be closer to a rating of 2 than 1 and was flagged as 3 not 4.

CTDOXY flags in the .sea file were changed to 4 for all the station samples you listed. Also, CTDOXY flags were changed to 4 where profiles were recently interpolated as a result of DQE suggestions:

station	30	sample	121
	70		107
	73		108
	180		111

TEMPERATURE

There is a typo in the data report. The value of the drift for temperature sensor T1461 is -0.0006 C. Temperature calibrations were applied to the data using Seasoft processing module DATCNV which reads the sensor's .con file for coefficients.

DESPIKING, INTERPOLATION AND FLAGS

The flag value of 8 used near the surface in the .ctd files represent data that were continued to the surface from the first assumed good value. For P14S/P15S we used 7. For P18, this procedure was done in program POSTCAL where temp, cond, oxc and oxt were copied back and flagged as 8, then salinity was recomputed and flagged as 2 in most cases. Despiking done after POSTCAL changed some flags to 6. Flags of 8 were left in the data files for this cruise.

As for the large blocks of interpolated data (mostly oxygen) listed in Table 2, we maintain that this is the best way to deal with these data from a poor and failing sensor. Flags of 6 (as well as 7 and 8) have been preserved even when reflagging the entire oxygen profile as suggested in Table 6.

DENSITY INVERSIONS

Original data submitted for P18 were not examined for small density inversions. In response to the DQE evaluation, program DELOOP, as applied to P14S/P15S, with an N^2 criteria of -3x10e-6 was applied to P18 profiles. Over 82% of the density inversions listed in Table 7 were interpolated over. Delooped 1 dbar averaged data files with all the changes noted above are resubmitted along with this reply to the DQE.

DOCUMENTATION

Again, the PDR sound speed was 1500 m/s, and the readings have not been corrected for transducer depth (5.5 ± 0.6 m) below the waterline.

Station groupings used for oxygen calibrations and final values of fit parameters are given in a separate oxygen calibration table.

Oxygen calibration problems were owing to poor sensor performance.

Temperature pre- and post-cruise calibration difference for sensor T1461 was a typo in the documentation and should read -0.0006°C.

More frequent flagging of surface temperatures compared to surface salinities is explained in the previous section, DESPIKING, INTERPOLATION AND FLAGS.

Data files submitted to the WOCE office were 1 dbar averages, not 2 dbar.

APPENDIX 9b. Responses to WOCE DQE of nutrient data

P18 Data Quality Control: Nutrients

C.W. Mordy response to Mantyla Evaluation

Edits Resulting from Mantyla's Comments:

Sta 23: Silicates flagged as uncertain. Same and Mantyla

Sta 86 & 87: Deep PO_4s and NO_3s are higher than surrounding stations (85 & 88). Flagged Sta 87 bottles 101-119 PO_4 & NO_3 as uncertain, flagged Sta 86 bottles 101-118 PO_4 & NO_3 as uncertain. Mantyla suggested deep PO_4s be flagged 3.

Sta 88: Nitrates flagged as "ok" except for bottles 117 & 101. Same as Mantyla.

Sta 148: Bottle 126 NO_2 flagged as uncertain, same as Mantyla.

Sta 191: Bottle 113 NO_2 flagged as uncertain, same as Mantyla.

Zero Silicates: ND would be perhaps more appropriate. Note that P4, P21 and P6 all have zero values in the region. P17E has values of 2-3 uM near the crossing while P18 data has lots of scatter. 99 bottles with zero silicates were given an uncertain flag.

Other edits:

Silicic Acid
The following were flagged as uncertain in agreement with Mantyla: 8:303, 11:118, 18:103, 31:116, 32:121-124, 113:135, 117:104, 189:103.

Nitrate
The following were flagged as uncertain in agreement with Mantyla: 8:303, 10:323, 12:123, 13:117, 21:113, 31:116, 75:102-103, 91:102, 95:136, 107:106, 120:104, 140:101, 156:106, 179:111, 180:114, 186:113, 188:303, 190:113, 190:103.
The suggestion to flag Sta 163:107 as uncertain was not taken as the measurement was within the scatter of the profile.

Phosphate
The following were flagged as uncertain in agreement with Mantyla: 8:303, 18:102, 26:317, 31:122 & 116, 35:102, 56:209, 79:101-116, 83:101-119, 86:103, 94:301-318, 95:136, 135:119, 140:101-118, 144:112, 155:114, 156:106, 166:123 & 131, 179:106-116, 190:113.
The following suggested changes from flag 2 to 3 were not taken: 31:116, 56:209, 83:120, 117:101, 132:101, 166:132.

Nitrite
The following were flagged as uncertain in agreement with Mantyla: 8:303, 11:116, 88:18-101.
Sta 49:107, 55:335, 117:109, 125:107, 142:119, 148:126, 191:114 were flagged as 4 (in agreement with all other nuts).

APPENDIX 9c. Responses to WOCE DQE of oxygen data

All of the flag changes and sample changes suggested by A. Mantyla were accepted.

For station 169, samples 105 to 108 were shifted to one depth shallower, samples 108 and 109 averaged and sample 105 set to -9, flagged as 5.

SO, for station 169
- sample 108 averaged with 109 as sample 109
- sample 107 becomes sample 108,
- sample 106 becomes sample 107,
- sample 105 becomes sample 106,
- sample 105 is set to -9, flag = 5.

For station 192:
no sample for # 104, samples 105 to 107 should be one bottle deeper and no listing for sample 107,

SO, for station 192

sample 105 becomes sample 104,
sample 106 becomes sample 105,
sample 107 becomes sample 106,
sample 107 is set to -9, flag = 5.

In addition, the following flags were changed:

sta	samp	oldflag	newflag
16	104	2	3
22	105	2	3
90	304	2	3
92	115	2	3
93	117	2	3
95	102	2	3
96	109	2	3
96	107	2	3
103	135	2	3
115	135	2	3
116	108	2	3
119	111	2	3
126	226	3	2
148	126	6	3
152	113	2	3
152	110	2	3
155	101	2	3
157	303	2	3
163	107	2	3
164	111	3	2
191	114	2	3

DQE Evaluation of CTD data for RV Discoverer Cruise along WOCE Section P18 (S and N) Expocode 31DSCG94_2 and 31DSCG94_3

Mark Rosenberg, November 1998

This report contains a data quality evaluation of the CTD data files for the Pacific sector cruise along WOCE meridional section P18 (S and N) (Figure 1) on the RV Discoverer in February to April, 1994. Bottle data are evaluated by Arnold Mantyla in a separate report. The data provide a useful contiguous meridional section from Antarctic through to tropical waters.

P18 (1994) and P14S/P15S (1996) CTD data were collected by the same group, and several of the problems noted here are shared with the 1996 cruise, and are already described in the P14S/P15S DQE report (most notably the biasing of salinity data for whole stations). Some of the problems found in the P18 data are much improved in the later P14S/P15S cruise data (most notably CTD oxygen data quality).

2 dbar CTD data were examined for stations 10 to 194. CTD files for stations 2 to 7 from the East Blanco Depression were not available. Upcast CTD burst data in the .sea file were examined for all stations. In general, salinity data are of good quality, while CTD oxygen data quality is mixed.

Station Summary File (.sum)

- The maximum pressure value for several stations was missing in the .sum file. The following values were obtained from the .ctd files, and inserted into the .sum file:

station	max press
25	4648
27	4832
32	4608
46	3914
61	3866
78	3410

- Sound speed and transducer depth information for the ship's sounder were not provided in the documentation. "Corrected depth" (.sum file) was therefore calculated from the CTD at the bottom of the cast i.e. altimeter reading + maximum CTD pressure recalculated in meters (using the method of Saunders and Fofonoff, 1976). For stations with no altimeter reading, no corrected depth was calculated. These corrected depth values are in an ascii file corrdepth.dat, and have not been merged into the .sum file.

Salinity

In the following discussion, only CTD and bottle values with a quality flag of 2 are considered (i.e. QUALT1=2 for CTDSAL and SALNTY in the .sea file). See Table 4 for a station by station summary of salinity data problems.

Scatter of salinity residuals

The salinity residual data ΔS (where ΔS = bottle – CTD salinity difference) for all depths is shown in Figure 2. Outliers were rejected iteratively by the data processors, as described in the cruise report. Below 500 dbar, scatter of ΔS is greatly reduced (Figure 3). In steep gradients above 500 dbar, the sign of the residual appears to be consistent in most cases with the salinity gradient direction (assuming CTD sensors are below the bottles on the rosette package). As for P14S/P15S, I recommend increasing the averaging period for CTD burst data to 10 seconds. Obviously there will still be a residual in the steepest gradients, however the increased averaging period may help decrease residuals in less dramatic gradients when the ship is rolling during bottle stops.

Biasing of CTD salinity data for individual stations

Standard deviations for ΔS for the whole cruise were calculated from data in the .sea file ("uncorrected data" in Table 1). The value of 0.0017, calculated using all sampling depths and $|\Delta S| \leq 0.008$, is a reasonable estimate of the salinity accuracy for the cruise. The same biasing problem for individual stations exists as described in the P14S/P15S DQE report. When the cruise is viewed as a whole, the salinity accuracy meets WOCE requirements and ΔS varies about a mean of zero (Figures 2 and 3). However when individual stations are examined, there is a clear biasing of CTD salinity data (e.g. stations 113 to 115 in Figure 3, where ΔS clearly negative). This biasing is a direct result of the conductivity calibration method, where the whole cruise is fitted in one group and the fourth order station dependent slope correction fails to fully track the variation of conductivity sensor behaviour over the cruise. Breaking down the stations into smaller calibration groups is strongly recommended – this would allow the station dependent slope correction to remove the bias for individual stations.

I've repeated the exercise performed on the P14S/P15S data, doing an extra fit to the ΔS data to demonstrate the advantages of refining station grouping for the conductivity calibration – see the P14S/P15S DQE report for the method. The resulting $S_{btl} - S_{cor}$ residuals for depths below 500 dbar are plotted in Figure 4. Standard deviation calculations for these "corrected" data are shown in Table 1.

There is only a small improvement to standard deviations calculated for the whole cruise (Table 1), however there is a marked improvement to the biasing of individual stations (Figure 5 shows some examples). Clearly, breaking down a cruise into smaller station groups for the calibration of CTD conductivity significantly improves the calibration. As for P14S/P15S, the correction done here is only a rough version – for a real calibration on selected station groups, groups would be selected with a linear variation of station mean ΔS, allowing the station dependent slope correction to take effect within each group and giving even better calibration results.

Table 1: Standard deviations for salinity residuals ΔS (using only bottle and CTD data for which the quality flag=2), where "uncorrected data" are as submitted to WHPO, and corrected data are with additional ΔS fit applied.

data	standard deviation of ΔS, uncorrected data	standard deviation of ΔS, corrected data
all depths	0.0034	0.0033
deeper than 500 dbar	0.0010	0.0009
all depths, $\lvert\Delta S\rvert \leq 0.008$	0.0017	0.0016

Deepwater θ-S curves

Comparing adjacent stations on deepwater θ-S curves, no outlying stations were found.

Oxygen

Oxygen residual data (i.e. bottle – CTD oxygen difference) are plotted in Figure 6, noting that large outliers lie beyond the axis limits on the graph. CTD oxygen data quality is in general not good, particularly when compared with the excellent quality for P14S/P15S. From examination of oxygen residual profiles for all stations, the calibration is acceptable for only ~40% of stations. The curve-fitting results are often poor when compared to bottle profiles, and constant offsets also occur. In many cases oxygen features which persist in the bottle data for a number of consecutive stations are not well described by the CTD oxygen traces e.g. the feature around 2000 dbar for stations 125 to 148; and the feature around 2500 dbar for stations 184 to 191 (Figure 7 shows examples). Table 6 ranks the calibration quality of each station on a scale from 1 (bad) to 5 (good). I suggest the following flagging for the entire CTD oxygen data in the .ctd files:

- stations ranked 5 or 4 are acceptable (accurate to within ~1%)
- stations ranked 3 or 2 should be flagged as 3 (accurate to within ~2.5%)
- stations ranked 1 should be flagged as 4

It is hard to tell from the data set whether the poor CTD oxygen data quality is due to poor oxygen sensor performance, or else due to the data processing and curve fitting. From the data report, the processing methodology appears simpler than for the later P14S/P15S cruise – notably, there isn’t the blending of 2 sets of fit coefficients as for P14S/P15S. I’d be interested in a comment from the data processors about the source of the problem.

Other relevant notes are as follows:

- The near surface (top ~100 dbar) CTD oxygen data is often unreliable; the top ~40 dbar should be treated with particular caution.
- Many stations appear to have suspicious oxygen data for the top few bins, due to transient sensor errors as the instrument enters the water and the pump winds up. Stations where these errors are greater than ~4 µmol/kg, and where there is no matching T/S feature, are

summarised in Table 5. The table also includes suspicious data from deeper down, and a flag of 3 is recommended where these glitches are greater than ~4 µmol/kg.

- For stations 168 to 189, the oxygen sensor has trouble responding to the rapid fall of oxygen concentration towards zero below the thermocline, a problem common to membrane type sensors in the oxygen depleted layer.
- Stations 26, 89, 111 and 160 have no oxygen bottle samples. CTD oxygen data does not compare well with surrounding stations for 26, 89 and 160, and a flag 4 is recommended for the entire CTD oxygen profile; surprisingly, station 111 does compare well with surrounding stations.
- In some cases where CTD oxygen data have been “despiked” in the .ctd file, the unspiked data have been transferred to the CTDOXY value in the .sea file. This occurs for the following samples:

station	sample	station	sample
15	128	171	136
13	136	172	336,335
20	129,128,126	173	136
22	127	184	136
35	136	185	136,135
48	124	190	136,133
166	136		
167	136,135		
168	336		
169	108,107,106,105		
170	136,135		

CTDOXY values for these samples should all be flagged as 4 in the .sea file.

Temperature

The data report states that data from temperature sensor T1461 were used for stations 9-194, and that “post-cruise calibrations showed T1461 to be drifting (offset only) by approximately -0.006°C”. I am confused about this statement, as the report goes on to say that “T1460 had jumped by 0.002°C, warranting repair”. If the pre and post cruise calibrations for sensor T1461 indeed differ by .006°, this is of great concern: is this the correction done by the program POSTCAL? I’d appreciate if the data processors would clarify this.

Despiking, Interpolation and Flags

A flag value of 8 has often been used near the surface in the .ctd files. This is an unassigned value. I assume that this was supposed to be the “despiking” flag 7, akin to the flag used for near surface data in the P14S/P15S data, where data has been continued to the surface from the first assumed good value. Note that for P18 data, this occurs more often for temperature than for salinity data (vice versa for P14S/P15S) – I’d be interested in a comment from the data processors here i.e. I would have expected both parameters to be simultaneously flagged out in most cases.

Large blocks of interpolated data (flag 6 in the .ctd files) occur, often in steep gradients, and over intervals up to 200 dbar. Linear interpolation is really only justified over small vertical intervals, and preferrably not in steep gradients. The worst instances are listed in Table 2 below. In all the cases listed, it's better to either leave a data gap and flag as 5 (my recommendation), or else leave the bad data in and flag as bad.

Table 2: Linear interpolations over large vertical blocks, or over large spans of parameter value.

station	parameter	pressure interval (dbar)	comment
13	T	90-96,100-118, 130-156	
13	O	352-422	large gap
18	O	314-512	large gap
20	O	102-308	large gap
22	O	374-558	large gap
81	O	274-432	large gap
90	O	376-420	large gap
175	O	128-152	large data span, ~90µmol/kg
178	O	86-102	large data span, ~60µmol/kg
179	O	70-94	large data span, ~60µmol/kg
180	O	82-110	large data span, ~100µmol/kg
180	O	116-136	large data span, ~90µmol/kg
183	O	82-110	large data span, ~70µmol/kg
183	O	116-140	large data span, ~60µmol/kg
184	O	90-118	large data span, ~90µmol/kg
185	O	78-88	large data span, ~100µmol/kg
186	O	62-94	large data span, ~100µmol/kg
190	O	74-86	large data span, ~80µmol/kg
193	O	8-24	large data span, ~80µmol/kg

Density Inversions

Locations of unstable vertical density gradients are shown in Figure 8; only gradients more unstable than -0.003 kg/m^3/dbar are shown. Density gradient values for these instabilities are summarised in Table 7. The vertical profiles were inspected for the 5 worst cases (more unstable than -0.015 kg/m^3/dbar): in these cases, the instabilities are due to wake water from the package passing the sensors. Many of the smaller instabilities may be due to the same effect.

Comparisons with Other Cruises

Deepwater θ-S and θ-oxygen curves were compared for P18 stations coincident with other cruise data sets (Table 3), as follows. Note that only a limited number of stations occur at the crossovers. In general, θ-S agreement lies within the expected inter-cruise accuracy of 0.002. Oxygen agreement is within 2% of deepwater oxygen values.

Table 3: Stations from different cruises used for comparison with P18.

P18 stn	P18 approx. position	other cruise stn	other cruise approx. position
167	9.5°N 110.08°W	P4E 182	9.5°N 110.33°W
		P4E 183	9.5°N 109.5°W
105	17°S 103°W	P21 76	16.75°S 102.67°W
106	16.5°S 103°W	P21 77	16.75°S 103.33°W
74	32.5°S 103°W	P6E 57	32.5°S 102.67°W
		P6E 58	32.5°S 103.33°W
35	53.17°S 103°W	P17E 192	52.8°S 103.33°W
36	52.5°S 103°W	P17E 193	52.88°S 102.25°W
10	67°S 103°W	S4P 712	67°S 103.5°W

P18N and P4E (P.I. H. Bryden on eastern leg) (Figure 9)

P4E salinity is higher than P18 by ~0.0015
Oxygen data compare well below θ=2.2°

P18N and P21 (P.I. M. McCartney on eastern leg) (Figure 9)

P21 salinity is higher than P18 by ~0.002.
Oxygen data compare well below θ=2.2° for the two P21 stations and one of the P18 stations; the second P18 station is lower by ~3 µmol/kg above θ=1.55°, and agrees below this.

P18S and P6E (P.I. H. Bryden on eastern leg) (Figure 9)

P6E salinity is lower than P18 by ~0.001.
Oxygen comparison is inconclusive: P6E is ~2.5 µmol/kg higher than P18, but converges at the bottom.

P18S and P17E (P.I. J. Swift) (Figure 10)

P17E salinity is higher than P18 by ~0.001 to 0.002 below the deepwater salinity maximum. Oxgen data compare fairly well below θ=1.3°

P18S and S4P (P.I Koshlyakov) (Figure 10)

S4P salinity is lower than P18 by ~0.002.
Oxygen data for S4P at the crossover is too noisy for a fair comparison.

Documentation

CTD data processing methodology is in general well described. It would be useful to add the following information:

- sound speeds used for sounder readings, and whether or not readings have been corrected for transducer depth below the waterline;
- station groupings used for oxygen calibration, and final values of fit parameters.

Comments on the following would be appreciated, as discussed in previous sections:

- oxygen calibration problem (i.e. sensor, or fitting problem);
- temperature pre and post cruise calibration difference for sensor T1461;

- more frequent flagging of surface T data compared to surface S data (opposite to cruise P14S/P15S).

Lastly, the methodology in the report discusses 1 dbar averaging. Are the 2 dbar data submitted to the WOCE office derived from the same raw data level, or are they somehow extracted from 1 dbar data?

Reference

Saunders, P.M. and Fofonoff, N.P., 1976. Conversion of pressure to depth in the ocean. Deep Sea Research, 23:109-111.

Table 4: Suspicious CTD salinity (S_{ctd}) data. *Indicates calibration improved by additional correction described in the text (i.e. using smaller station groupings).

station	comment	recommendation
3	S_{ctd} high by ~0.003 below 1500 dbar	
4	S_{ctd} high by ~0.002 below 1200 dbar	
*6	S_{ctd} high by ~0.002 below 2000 dbar	use smaller station groupings
*9	S_{ctd} low by ~0.0015 at surface	use smaller station groupings
*11	S_{ctd} high by ~0.001 for whole profile	use smaller station groupings
12	S_{ctd} high by ~0.001 below 2500 dbar	
*13	S_{ctd} high by ~0.001 below 2000 dbar	use smaller station groupings
*14	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*15	S_{ctd} high by ~0.001 200-2200 dbar, high by ~0.002 below 2200 dbar	use smaller station groupings
*16	S_{ctd} high by ~0.002 below 200 dbar	use smaller station groupings
*17	S_{ctd} high by ~0.001 for whole profile	use smaller station groupings
*18	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*20	S_{ctd} low by ~0.001 above 1000 dbar, high by ~0.001 below 1000 dbar	use smaller station groupings
*21	S_{ctd} high by ~0.001 below 500 dbar	use smaller station groupings
*22	S_{ctd} low by ~0.001 at surface, high by ~0.001 below 1000 dbar, high by ~0.002 below 4000 dbar	use smaller station groupings
*23	S_{ctd} mostly high by ~0.001 below 3000 dbar	use smaller station groupings
*24	S_{ctd} high by ~0.001 below 800 dbar suspicious S feature at 2 to 6 dbar	use smaller station groupings flag as 3 in .ctd file
*25	S_{ctd} low by ~0.001 above 1000 dbar	use smaller station groupings
28	S_{ctd} low by ~0.001 above 1000 dbar	
30	S_{ctd} low by ~0.001 for whole profile	
*31	S_{ctd} low by ~0.002 above 1000 dbar	use smaller station groupings
*33	S_{ctd} high by ~0.001 below 500 dbar	use smaller station groupings
*34	S_{ctd} high by ~0.002 below 1000 dbar	use smaller station groupings
*35	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*36	S_{ctd} mostly high by ~0.0015 for whole profile	use smaller station groupings
*37	S_{ctd} high by ~0.0015 below 2000 dbar	use smaller station groupings
*39	S_{ctd} high by ~0.0015 below 1500 dbar	use smaller station groupings

*41 to 43	S_{ctd} high by ~0.0015 below 1000 dbar	use smaller station groupings
*45 to 48	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
51,52,53,55	S glitch between 50 and 100 dbar, due to spiking in steep T gradient	
*52	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*54 to 55	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
57	S_{ctd} high by ~0.0008 below 1000 dbar	
*58	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*60 to 62	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*63	S_{ctd} high by ~0.0015 below 500 dbar	use smaller station groupings
*64	S_{ctd} high by ~0.001 below 1300 dbar	use smaller station groupings
*66	S_{ctd} low by ~0.002 near surface	use smaller station groupings
67	large S spike at 46 dbar	flag as 3 in .ctd file
*69 to 72	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
74	S_{ctd} high by ~0.002 below 1000 dbar	
75	S_{ctd} high by ~0.001 below 2000 dbar	
76	S_{ctd} high by ~0.0015 below 1000 dbar	
78	S_{ctd} high by ~0.002 below 1000 dbar	
79	S_{ctd} high by ~0.001 below 1000 dbar	
80	S_{ctd} high by ~0.0015 below 1000 dbar	
*85	S_{ctd} low by ~0.0015 below 1500 dbar	use smaller station groupings
90	S_{ctd} high by ~0.002 below 500 dbar	
*92	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*94	S_{ctd} high by ~0.001 for whole profile	use smaller station groupings
104	S_{ctd} high by ~0.001 for 1000 to 3800 dbar	
*105	S_{ctd} low by ~0.001 below 1000 dbar	use smaller station groupings
107	S_{ctd} low by ~0.001 below 1000 dbar	
*108	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
*110	S_{ctd} high by ~0.001 below 1000 dbar	use smaller station groupings
111	no bottles, but compares well with surrounding stations	
*112	S_{ctd} high by ~0.001 below 200 dbar	use smaller station groupings
*113	S_{ctd} high by ~0.0015 for whole profile	use smaller station groupings
*114	S_{ctd} high by ~0.001 for whole profile	use smaller station groupings
*115	S_{ctd} high by ~0.0015 for whole profile	use smaller station groupings
116	S_{ctd} high by ~0.001 for 500 to 3500 dbar	
*121	S_{ctd} low by ~0.001 below 1000 dbar	use smaller station grouping
*123	S_{ctd} high by ~0.001 for whole profile	use smaller station groupings
*125	S_{ctd} low by ~0.001 below 1500 dbar	use smaller station grouping
132	S_{ctd} low by ~0.001 below 500 dbar	
*133	S_{ctd} low by ~0.0008 below 1000 dbar	use smaller station grouping
*144	S_{ctd} high by ~0.001 below 500 dbar	use smaller station grouping
*146	S_{ctd} high by ~0.0008 for whole profile	use smaller station grouping
*148	S_{ctd} high by ~0.001 below 500 dbar	use smaller station grouping
*149	S_{ctd} high by ~0.001 for whole profile	use smaller station grouping
152	S_{ctd} high by ~0.001 above 3000 dbar	
155	S_{ctd} high by ~0.001 for whole profile	

*169	S_{ctd} high by ~0.001 below 200 dbar	use smaller station grouping
*172	S_{ctd} high by ~0.0008 below 500 dbar	use smaller station grouping
*182	S_{ctd} low by ~0.001 below 750 dbar	use smaller station grouping
*185	S_{ctd} low by ~0.001 below 500 dbar	use smaller station grouping
*187	S_{ctd} high by ~0.001 for whole profile	use smaller station grouping
*188 to 189	S_{ctd} high by ~0.001 below 100 dbar	use smaller station grouping
*191	S_{ctd} high by ~0.001 below 500 dbar	use smaller station grouping
*192	S_{ctd} high by ~0.001 above 1500 dbar	use smaller station grouping

Table 5: Suspicious CTD oxygen data. For recommended flag changes, original flags in data are 2 unless specified otherwise.

station	comment	recommendation	comment
15	little step from 4226 to ~4400 dbar		
18	little step at 4412 dbar		
25	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	
30	100 to 108 dbar oxygen spike	flag as 3 in .ctd file	
52	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	
66	0 to 12 dbar transient/despiking error	flag as 3 in .ctd file	
68	~2245 dbar small oxygen glitch		
69	2360 to 2374 dbar small oxygen glitch	flag as 3 in .ctd file	
70	0 to 12 dbar transient/despiking error	flag as 3 in .ctd file	
70	2236 to 2246 dbar small oxygen glitch	flag as 3 in .ctd file	
71	0 to 12 dbar transient/despiking error	flag as 3 in .ctd file	
71	2378 to 2392 dbar small oxygen glitch	flag as 3 in .ctd file	
72	2348 to 2366 dbar small oxygen glitch	flag as 3 in .ctd file	
73	2244 to 2260 dbar small oxygen glitch	flag as 3 in .ctd file	
74	2300 to 2316 dbar small oxygen glitch	flag as 3 in .ctd file	
75	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	
75	~2070 dbar small oxygen glitch		
76	0 to 12 dbar transient/despiking error	flag as 3 in .ctd file	
76	~2355 dbar small oxygen glitch		
77	2362 to 2380 dbar small oxygen glitch	flag as 3 in .ctd file	
78	~2650 dbar small oxygen glitch		
79	much noisier over top 1200 dbar than surrounding stations		
80	~2360 dbar small oxygen glitch		
91	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	0-6 dbar currently flag 8
92	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	
94	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	0-4 dbar currently flag 8
97	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	4-6 dbar currently flag 6
98	0 to 12 dbar transient/despiking error	flag as 3 in .ctd file	6 dbar currently flag 7 12 dbar currently flag 6
99	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	
100	~4100 dbar small oxygen glitch		
103	0 dbar transient/despiking error	flag as 3 in .ctd file	
107	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	6 dbar currently flag 7
113	0 to 4 dbar transient/despiking error	flag as 3 in .ctd file	

118	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	2-6 dbar currently flag 6
123	0 dbar transient/despiking error	flag as 3 in .ctd file	
124	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	6 dbar currently flag 7
125	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	6 dbar currently flag 7
128	1720 to 1726 dbar oxygen spike	flag as 3 in .ctd file	
140	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	
141	0 to 4 dbar transient/despiking error	flag as 3 in .ctd file	
142	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	
144	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	
145	0 to 10 dbar transient/despiking error	flag as 3 in .ctd file	0-2 dbar currently flag 8 4-10 dbar currently flag 6
153	40 dbar oxygen spike	flag as 3 in .ctd file	
160	0 to 8 dbar transient/despiking error	flag as 3 in .ctd file	
163	0 to 4 dbar transient/despiking error	flag as 3 in .ctd file	
170	0 to 16 dbar transient/despiking error	flag as 3 in .ctd file	0-14 dbar currently flag 8
174	0 to10 dbar transient/despiking error	flag as 3 in .ctd file	4,10 dbar currently flag 6 6 dbar currently flag 7
177	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	2 dbar currently flag 6 6 dbar currently flag 7
180	1792 to 1800 dbar oxygen spike	flag as 3 in .ctd file	
182	0 to 6 dbar transient/despiking error	flag as 3 in .ctd file	6 dbar currently flag 7
184	0 dbar transient/despiking error	flag as 3 in .ctd file	
188	2084 to 2384 oxygen glitch	flag as 3 in .ctd file	
190	0 to 14 dbar transient/despiking error	flag as 3 in .ctd file	0 dbar currently flag 8 2-14 dbar currently flag 6
193	0 to 4 dbar transient/despiking error	flag as 3 in .ctd file	2 dbar currently flag 7

Table 6: CTD oxygen data calibrations. Quality of calibration is rated from 1 (bad) to 5 (good) as follows: 5=good
4=moderately good (residual < 2μmol/kg)
3=a bit poor (residual up to 3 μmol/kg, or a constant small bias)
2=fairly poor (residual up to 6 μmol/kg)
1=poor (residual >6 μmol/kg)

stn	calibration rating	stn	calibration rating	stn	calibration rating
10	1 above 3000 dbar	50-56	5	111	4
11	2	57	3	112-113	3
12	3	58	4	114	2
13	5	59	5	115	5
14	3	60-62	4	116	4
15	5	63	3; 2 at bottom	117-118	5
16	1	64	4	119-120	3
17	2	65	4; 3 at bottom	121-122	2
18	5; 3 above 1000 dbar	66	4	123	3
19	2	67	5; 3 at bottom	124	2
20	3	68-69	3	125	1 below 1300 dbar
21	5; 2 at bottom	70	2	126-137	1
22	5; 2 at bottom	71-72	3	138-139	2

23	5	73-75	5	140	1
24	2	76	1	141-152	2
25	4	77-78	4	153-155	3
26	1	79-82	5	156	5
27	5	83-84	3	157	3
28	3	85	5; 1 at bottom	158	5
29	5	86-87	4	159	4
30	3	88	2	160	1
31	3	89	1	161	2
32	5	90-91	2	162-163	3
33	3	92-93	5	164	4
34	5	94	4	165-171	3
35	5; 1 above 400 dbar	95	5	172	2
36	4	96	3	173-178	3
37	5	97-100	5	179-180	2
38	5	101	3	181	3
39	4	102	4	182	2
40-44	5	103-106	5	183-184	3
45	3	107	4	185-191	2
46-48	5	108	5	192	3
49	1	109-110	3	193-194	5

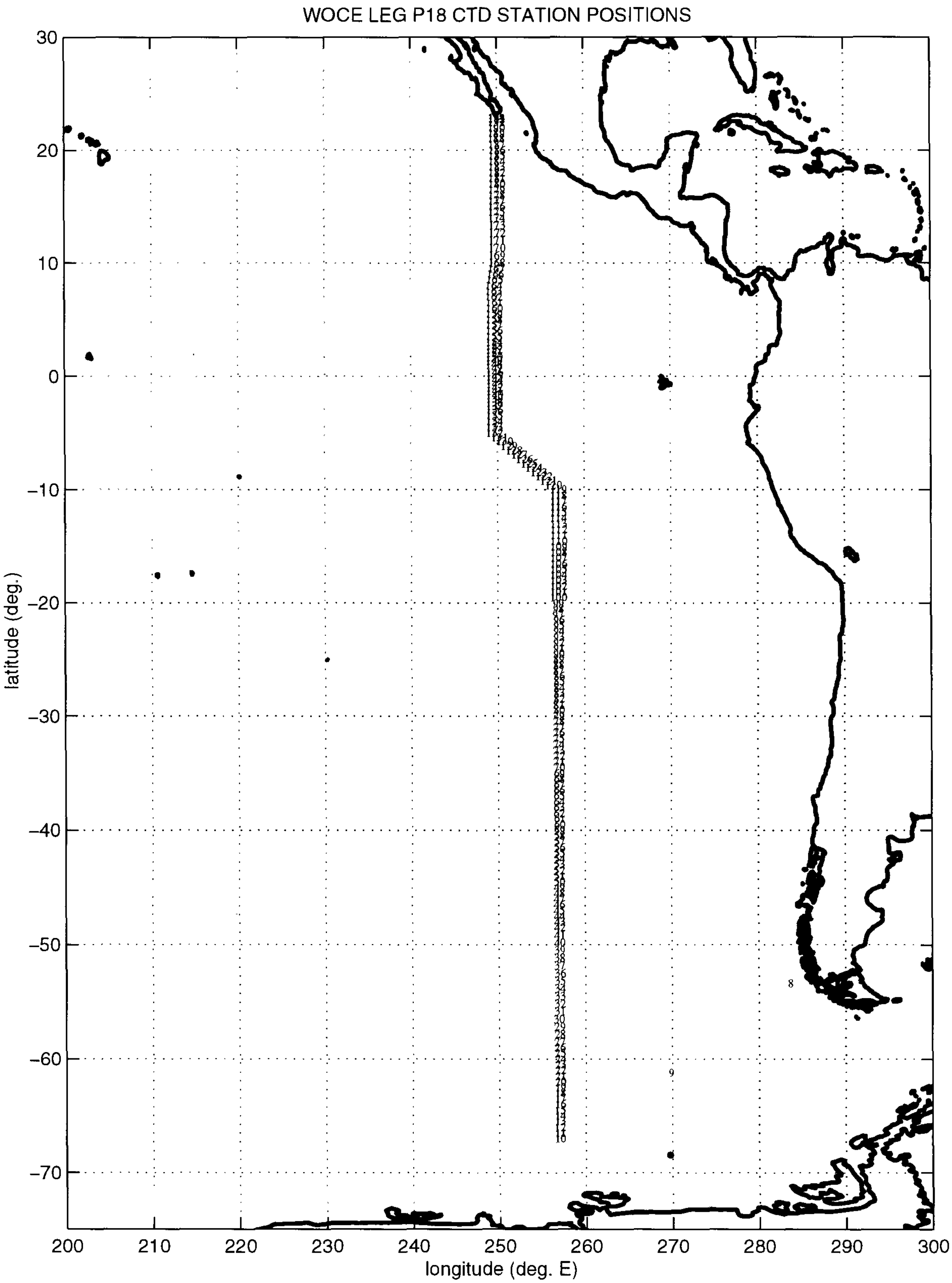
Table 7: Density inversions < -0.003 kg/m^3/dbar, and quality flag for salinity in .ctd file for the pressure bin.

stn	pressure (dbar)	density gradient	sal. flag	stn	pressure (dbar)	density gradient	sal. flag	stn	pressure (dbar)	density gradient	sal. flag
10	6	-0.0067	2	77	460	-0.0041	2	107	98	-0.0037	2
13	112	-0.0046	2	78	58	-0.0097	2	110	6	-0.0059	2
13	114	-0.0059	2	78	92	-0.0089	2	116	80	-0.0110	2
13	154	-0.0031	2	78	98	-0.0031	2	118	6	-0.0034	2
16	6	-0.0038	2	78	160	-0.0050	2	118	152	-0.0131	2
30	106	-0.0074	2	78	166	-0.0031	2	121	6	-0.0078	2
32	8	-0.0044	2	78	194	-0.0122	2	122	200	-0.0039	2
32	702	-0.0038	2	78	266	-0.0077	2	126	170	-0.0044	2
34	114	-0.0345	2	78	276	-0.0102	2	126	578	-0.0037	2
34	118	-0.0256	2	78	364	-0.0039	2	126	602	-0.0036	2
40	14	-0.0031	2	79	110	-0.0065	2	126	688	-0.0031	2
40	16	-0.0077	2	79	116	-0.0077	2	127	62	-0.0033	2
43	6	-0.0037	2	79	130	-0.0050	2	127	72	-0.0114	2
49	10	-0.0031	2	79	200	-0.0084	2	127	122	-0.0039	2
53	6	-0.0030	8	79	258	-0.0070	2	128	140	-0.0127	2
54	6	-0.0041	2	79	284	-0.0042	2	129	38	-0.0043	2
54	54	-0.0031	2	79	328	-0.0033	2	129	64	-0.0258	2
55	74	-0.0077	2	79	472	-0.0031	2	129	442	-0.0037	2
56	82	-0.0069	2	82	302	-0.0040	2	130	152	-0.0032	2
56	182	-0.0053	2	82	380	-0.0039	2	133	348	-0.0048	2
56	188	-0.0054	2	83	6	-0.0071	2	134	318	-0.0095	2

58	98	-0.0081	2	84	134	-0.0054	2	134	430	-0.0048	2
58	104	-0.0070	2	84	164	-0.0033	2	136	6	-0.0039	2
58	132	-0.0047	2	88	288	-0.0037	2	136	66	-0.0170	2
58	146	-0.0061	2	88	390	-0.0032	2	136	326	-0.0033	2
58	156	-0.0082	2	88	406	-0.0073	2	142	8	-0.0035	2
58	166	-0.0102	2	90	262	-0.0044	2	144	10	-0.0043	2
58	170	-0.0070	2	90	326	-0.0055	2	146	8	-0.0048	2
58	206	-0.0046	2	91	198	-0.0031	2	152	6	-0.0083	2
60	84	-0.0086	2	91	422	-0.0041	2	155	66	-0.0105	2
62	136	-0.0090	2	92	144	-0.0053	2	157	6	-0.0100	2
62	226	-0.0052	2	92	208	-0.0067	2	159	62	-0.0104	2
62	286	-0.0033	2	92	216	-0.0054	2	163	6	-0.0046	2
64	226	-0.0034	2	93	66	-0.0076	2	164	136	-0.0039	2
75	272	-0.0040	2	93	316	-0.0085	2	174	10	-0.0033	2
77	8	-0.0046	2	93	322	-0.0051	2	174	12	-0.0115	2
77	56	-0.0082	2	94	218	-0.0035	2	175	170	-0.0045	2
77	64	-0.0204	2	94	270	-0.0040	2	176	130	-0.0067	2
77	116	-0.0047	2	96	6	-0.0045	2	177	10	-0.0061	2
77	214	-0.0055	2	100	6	-0.0068	2	178	6	-0.0051	2
77	232	-0.0049	2	102	12	-0.0042	2	183	6	-0.0094	2
77	332	-0.0113	2	104	6	-0.0032	2	184	10	-0.0065	2
77	344	-0.0065	2	104	84	-0.0057	2	188	86	-0.0055	2
77	352	-0.0082	2	105	116	-0.0041	2	191	8	-0.0067	2
				105	232	-0.0043	2	193	14	-0.0036	2
				107	68	-0.0048	2	194	10	-0.0050	6

Table 8: Summary of flag and other changes recommended.

station	parameter	recommendation
96	T,S,O at 0 dbar	remove bad first data line with 0's in .ctd file (done) and change number of records to 2003 in header
25,72,32, 46,61,78	maximum pressure	add value into .sum file (done)
24,67	S	flag changes in .ctd files recommended in Table 4
numerous	O	flag changes in .ctd files recommended in Table 5
numerous	O	reflag oxygen data in .ctd files according to calibration ranking in Table 6: reflag as 3 for ranking of 2 or 3 reflag as 4 for ranking of 1
numerous	O	change CTDOXY flags to 4 in .sea file for samples listed in the section on oxygen.
all	T,S,O	change all 8 flags to 7
13	T	remove blocks of interpolated data listed in Table 2, and change flags from 6 to 5
numerous	O	remove blocks of interpolated data listed in Table 2, and change flags from 6 to 5



WOCE LEG P18 CTD STATION POSITIONS
latitude (deg.)
longitude (deg. E)
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
200
210
220
230
240
250
260
270
280
290
300

Figure 1

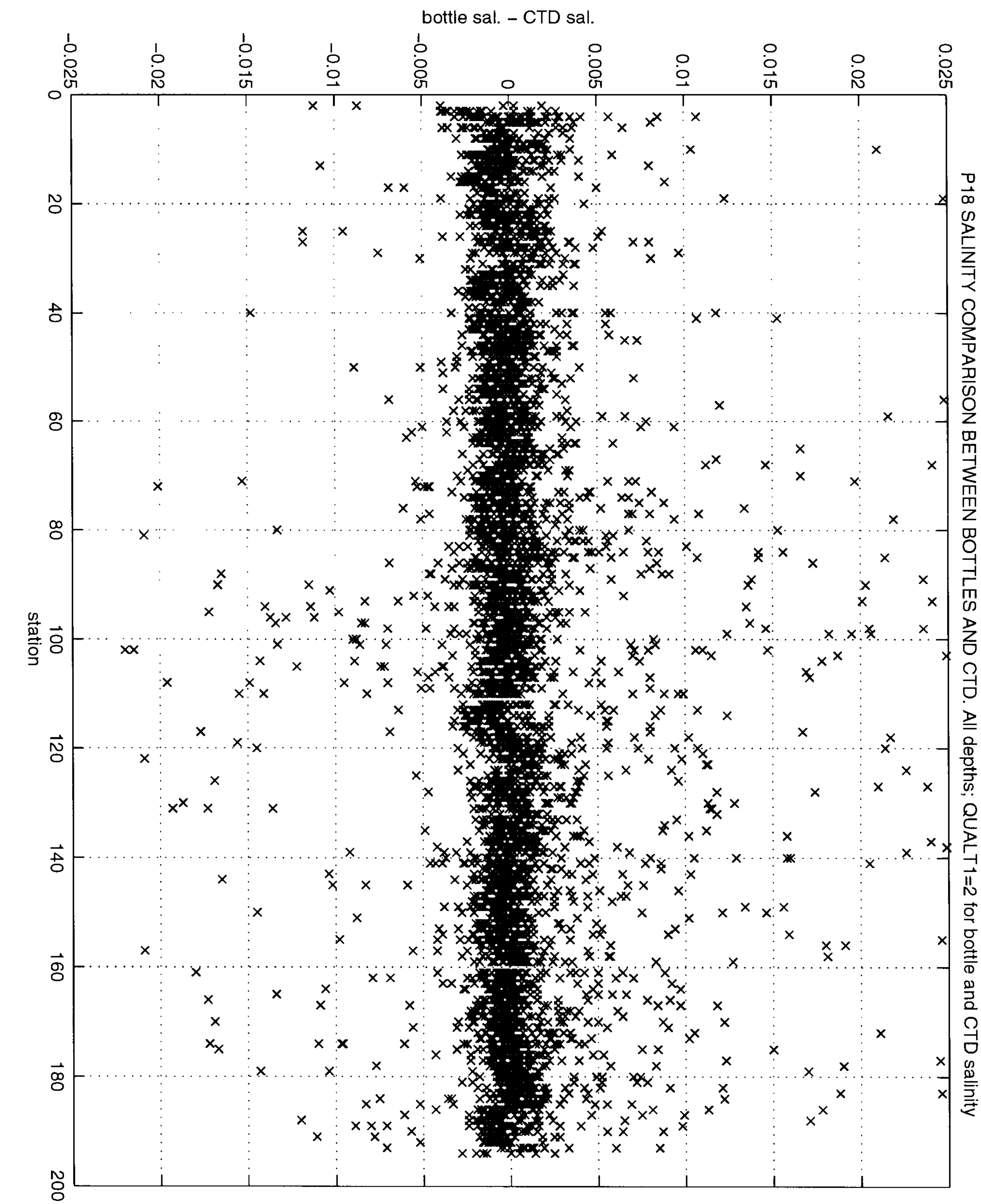

P18 SALINITY COMPARISON BETWEEN BOTTLES AND CTD. All depths; QUALT1=2 for bottle and CTD salinity
bottle sal. − CTD sal.
station
−0.025
−0.02
−0.015
−0.01
−0.005
0
0.005
0.01
0.015
0.02
0.025
0
20
40
60
80
100
120
140
160
180
200

Figure 2

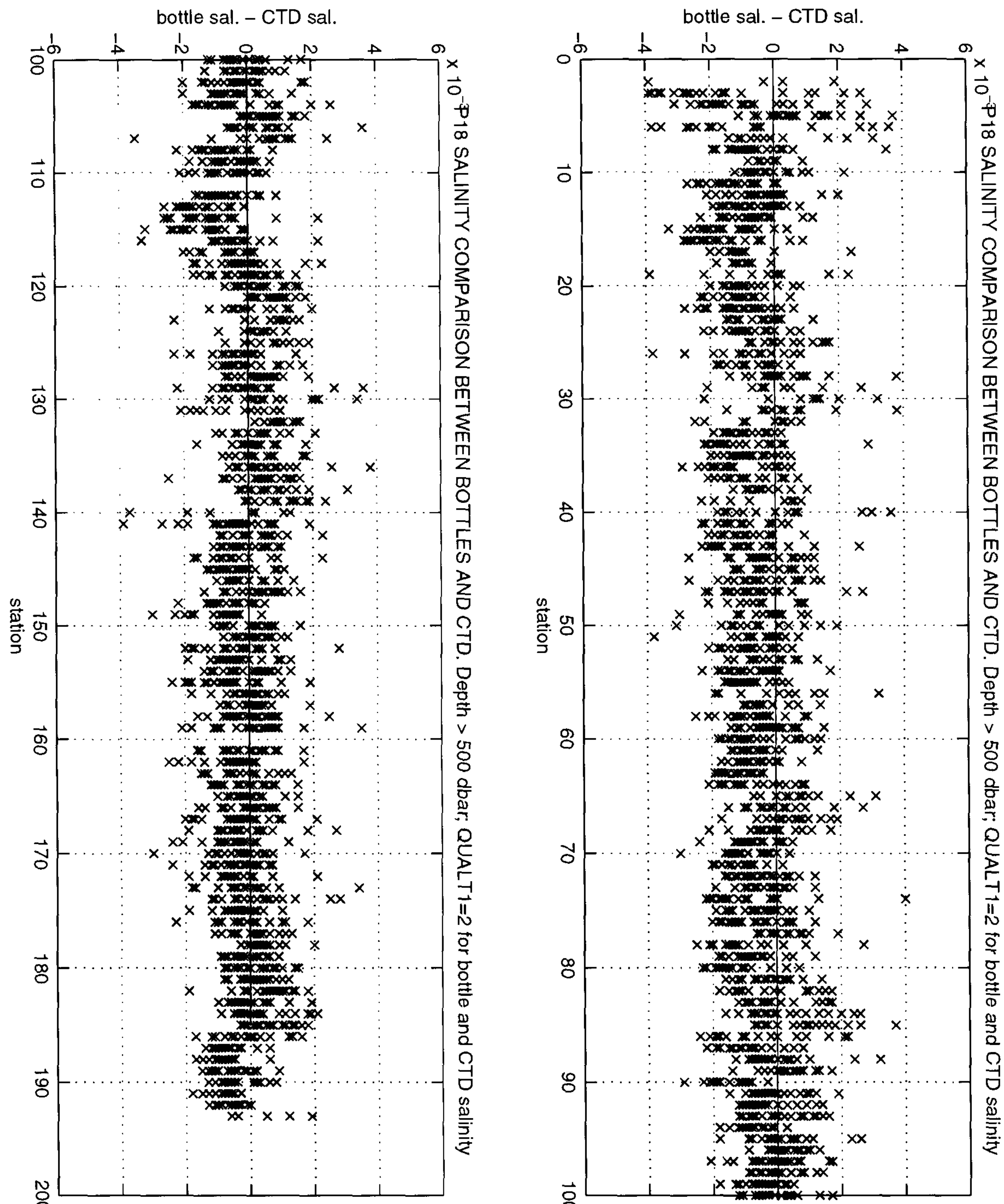

P18 SALINITY COMPARISON BETWEEN BOTTLES AND CTD. Depth > 500 dbar; QUALT1=2 for bottle and CTD salinity
x 10^-3
bottle sal. – CTD sal.
station
P18 SALINITY COMPARISON BETWEEN BOTTLES AND CTD. Depth > 500 dbar; QUALT1=2 for bottle and CTD salinity
x 10^-3
bottle sal. – CTD sal.
station

Figure 3

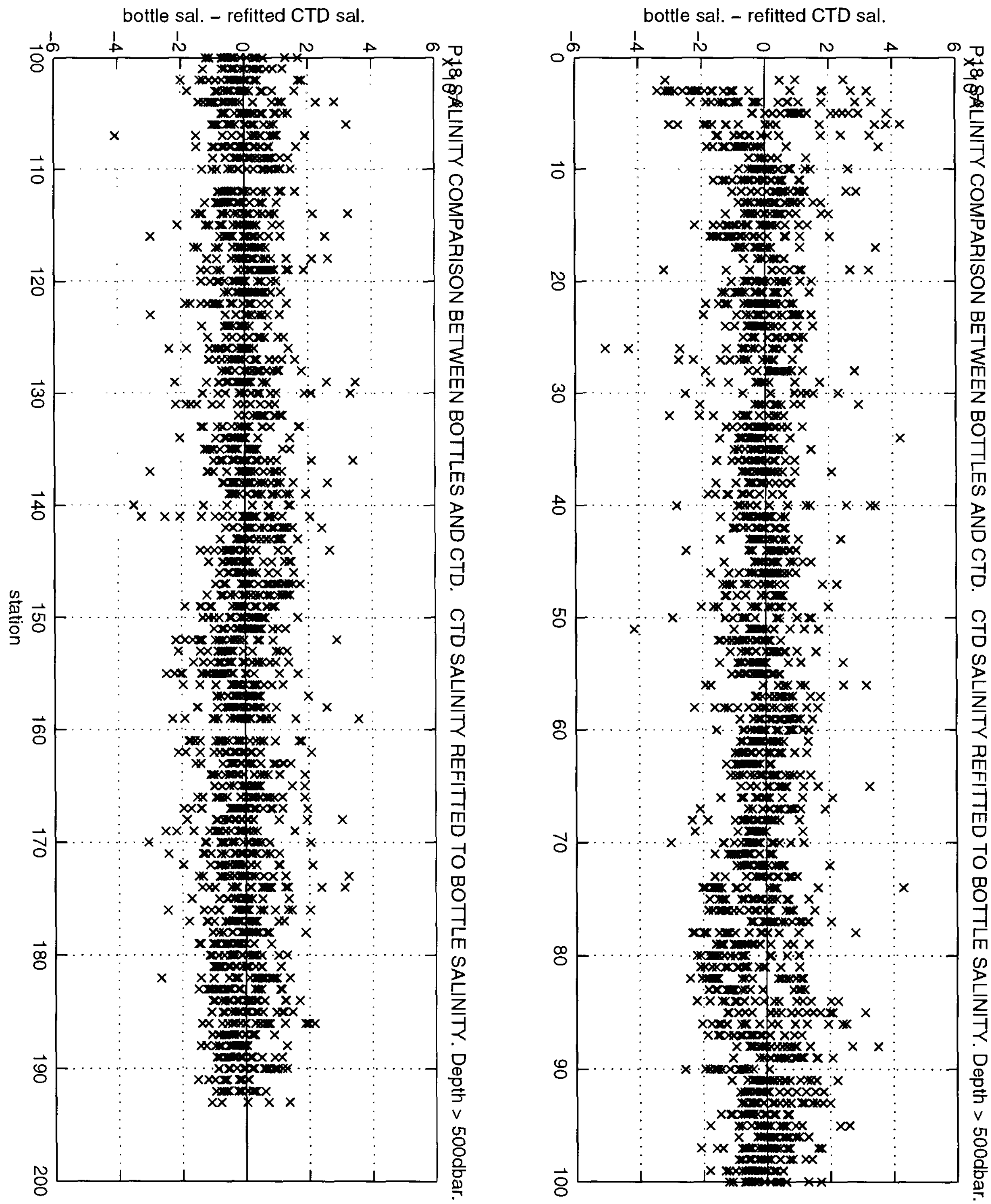
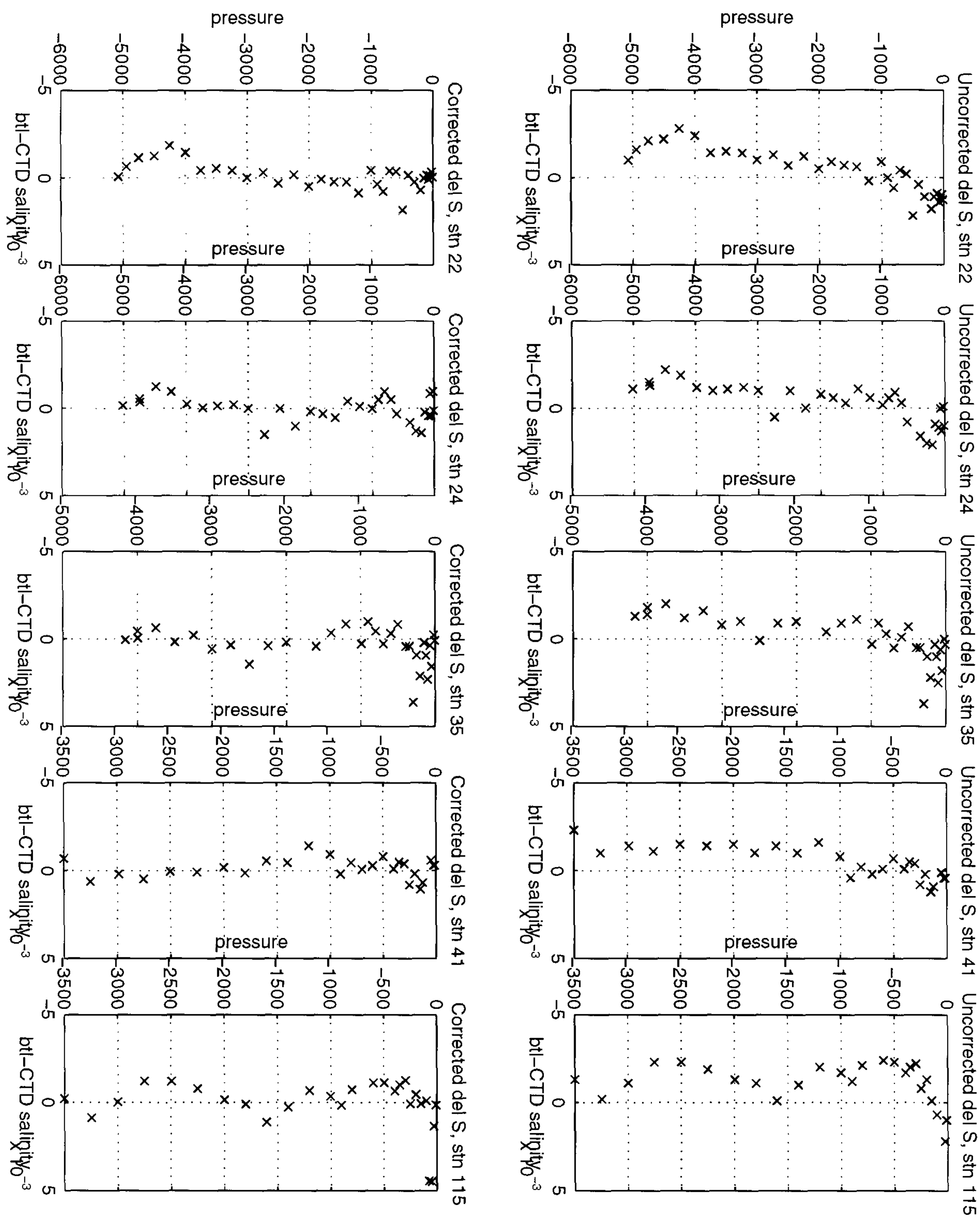


Figure 4: "Corrected" salinities



Uncorrected del S, stn 22
Uncorrected del S, stn 24
Uncorrected del S, stn 35
Uncorrected del S, stn 41
Uncorrected del S, stn 115
Corrected del S, stn 22
Corrected del S, stn 24
Corrected del S, stn 35
Corrected del S, stn 41
Corrected del S, stn 115
pressure
btl−CTD salinity x10^-3

Figure 5

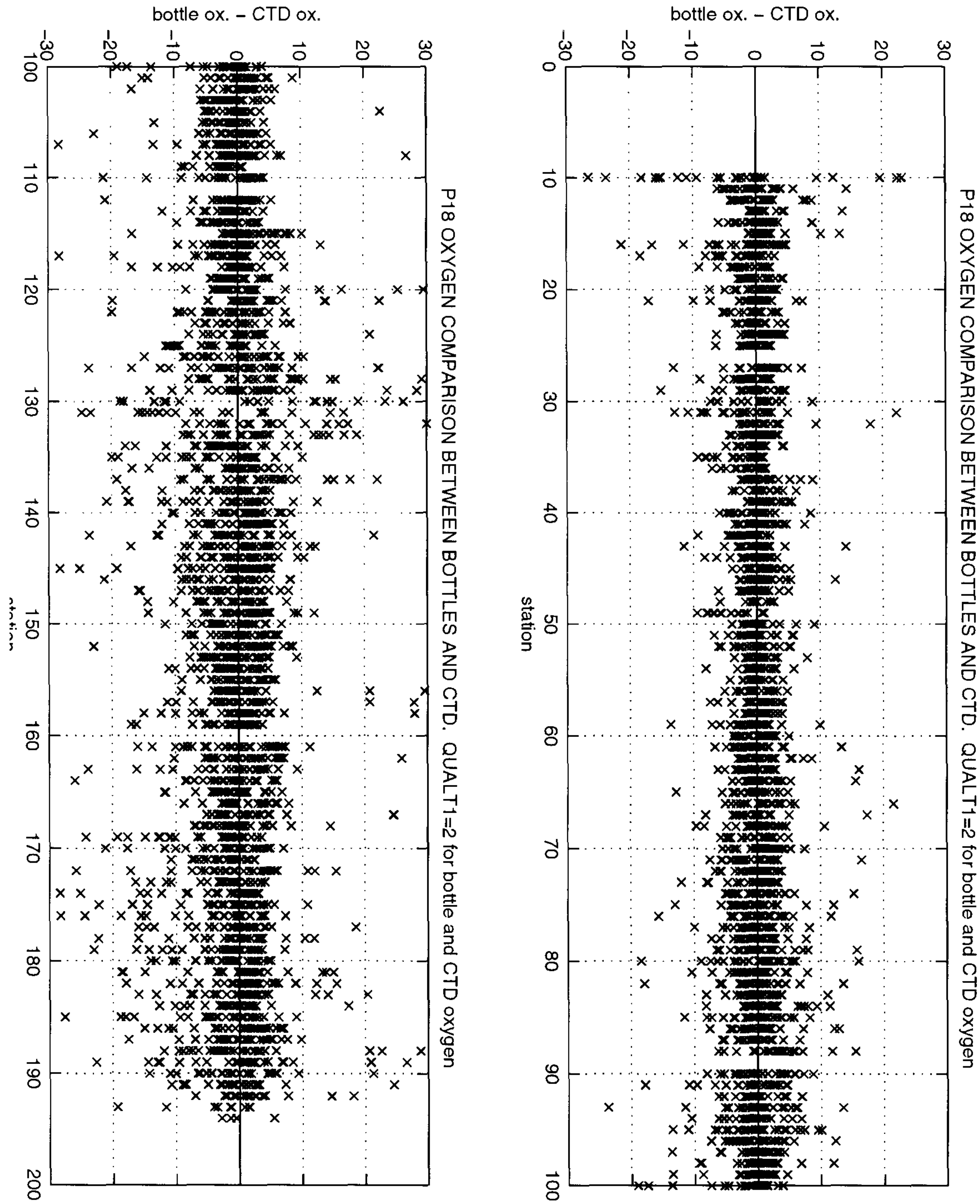

P18 OXYGEN COMPARISON BETWEEN BOTTLES AND CTD. QUALT1=2 for bottle and CTD oxygen
bottle ox. - CTD ox.
station
P18 OXYGEN COMPARISON BETWEEN BOTTLES AND CTD. QUALT1=2 for bottle and CTD oxygen
bottle ox. - CTD ox.

Figure 6

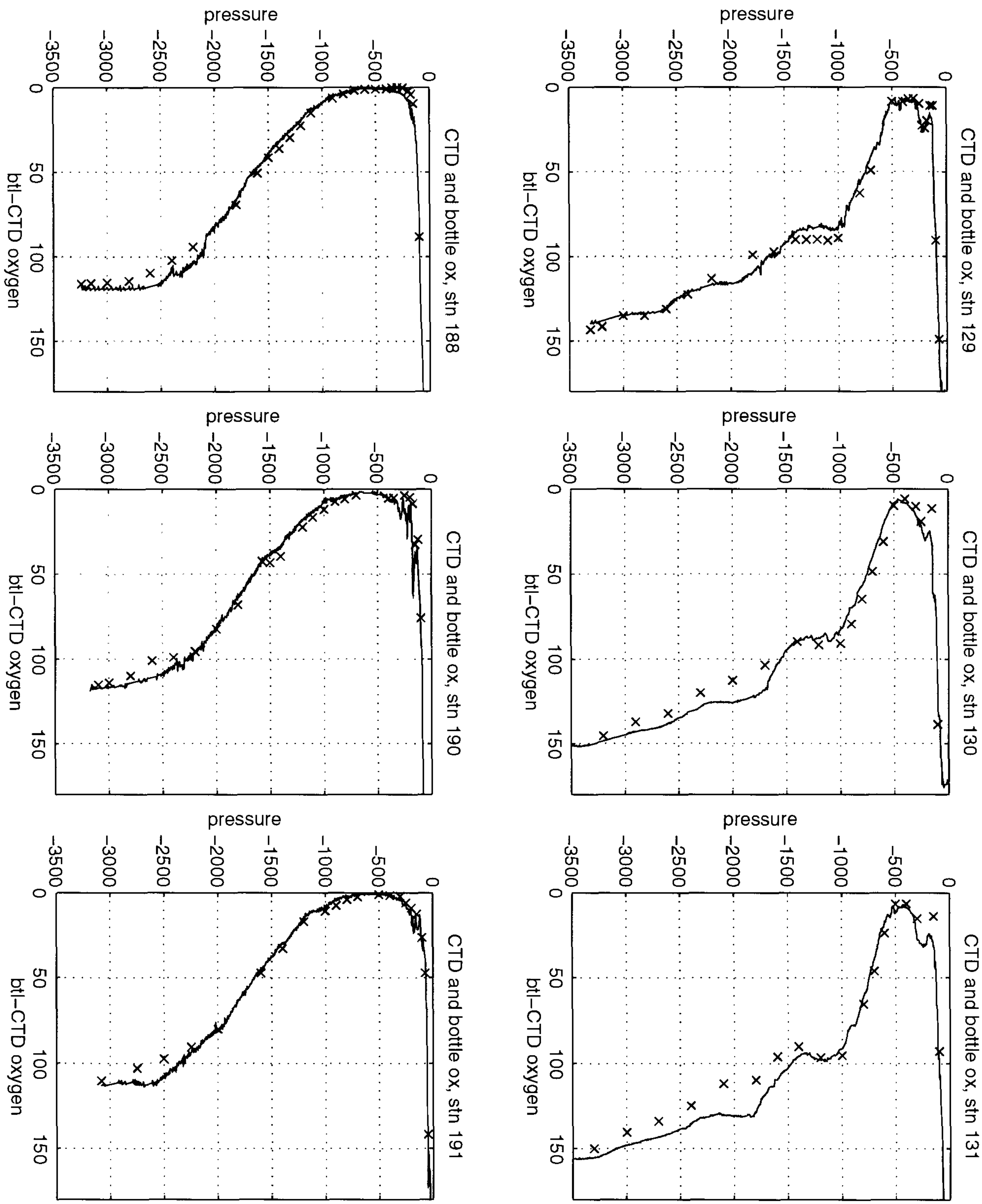

CTD and bottle ox, stn 129
CTD and bottle ox, stn 130
CTD and bottle ox, stn 131
CTD and bottle ox, stn 188
CTD and bottle ox, stn 190
CTD and bottle ox, stn 191
pressure
btl−CTD oxygen

Figure 7

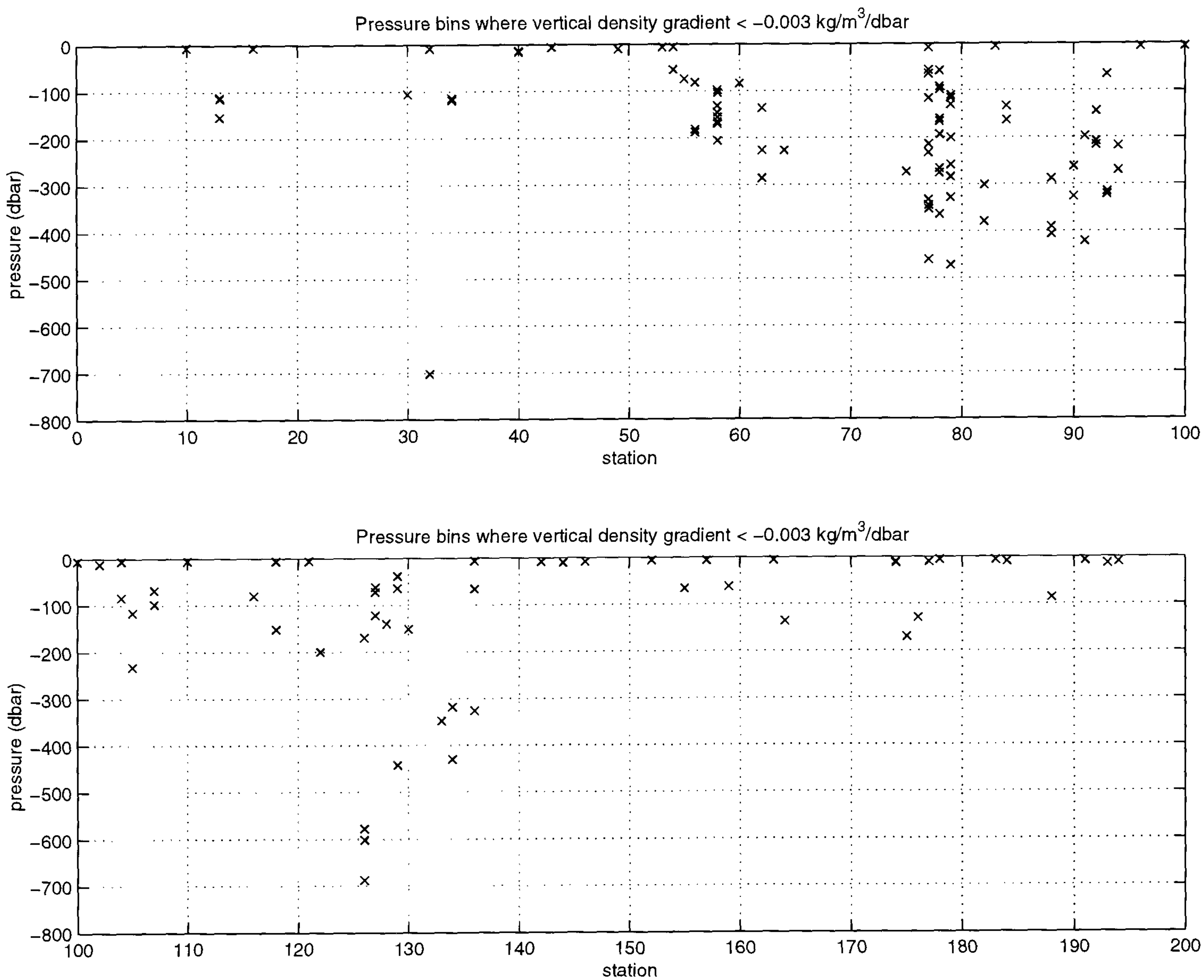
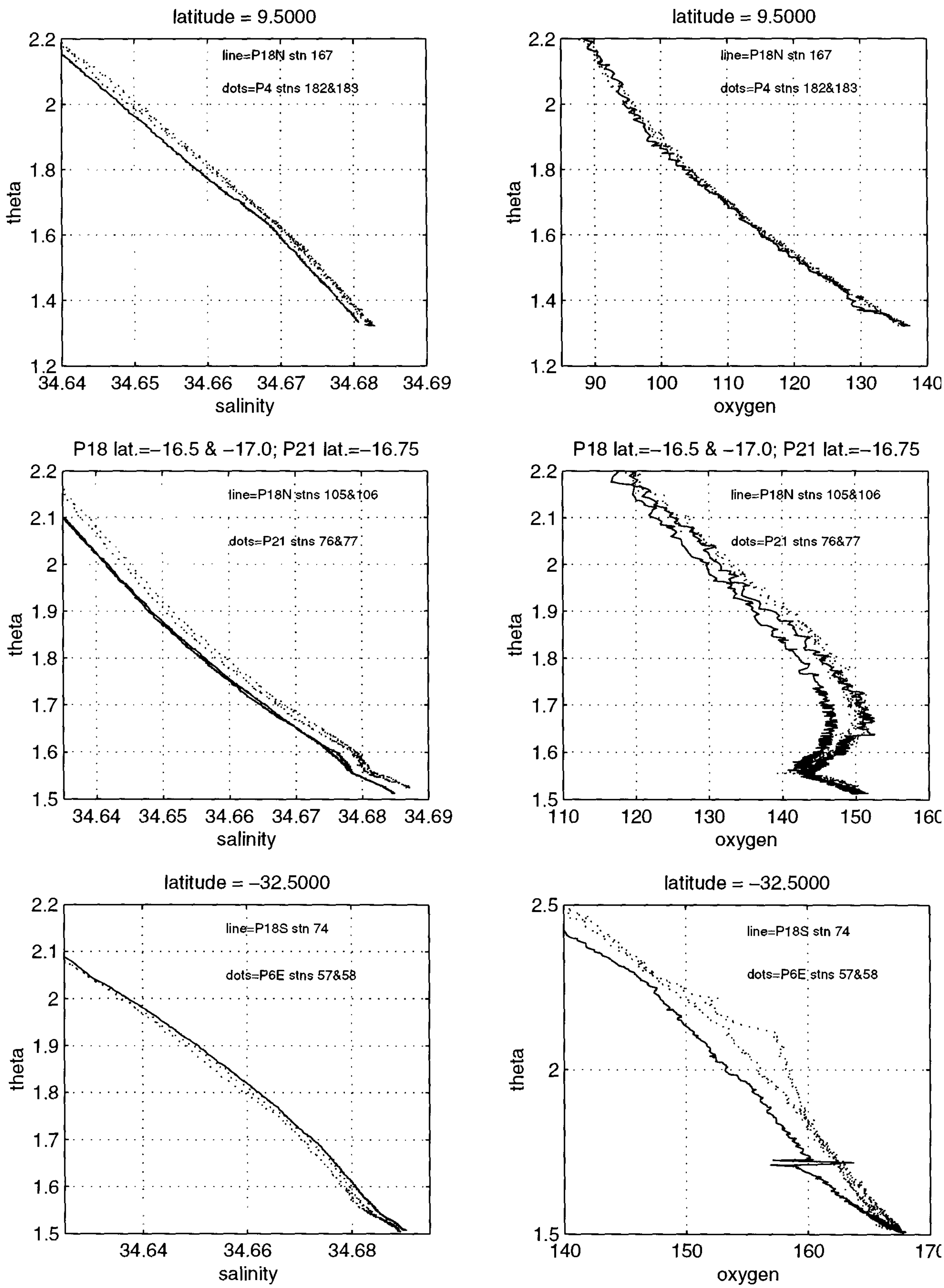

Pressure bins where vertical density gradient < −0.003 kg/m^3/dbar
pressure (dbar)
0
−100
−200
−300
−400
−500
−600
−700
−800
station
0
10
20
30
40
50
60
70
80
90
100
Pressure bins where vertical density gradient < −0.003 kg/m^3/dbar
pressure (dbar)
station
100
110
120
130
140
150
160
170
180
190
200

Figure 8



latitude = 9.5000
line=P18N stn 167
dots=P4 stns 182&183
theta
salinity
oxygen
P18 lat.=−16.5 & −17.0; P21 lat.=−16.75
line=P18N stns 105&106
dots=P21 stns 76&77
latitude = −32.5000
line=P18S stn 74
dots=P6E stns 57&58

Figure 9

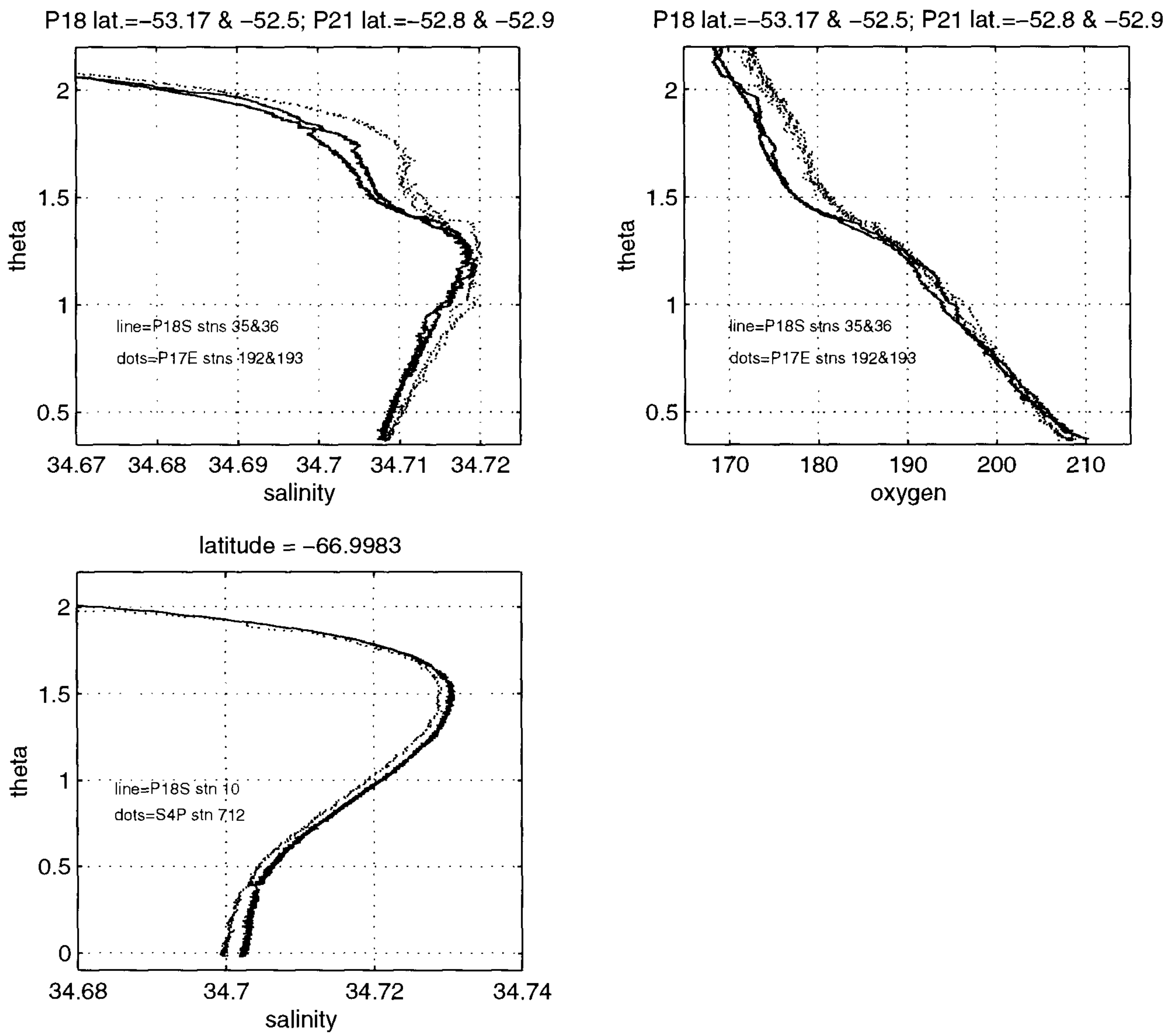


Figure 10: Comparison of P18 with P17E and S4P

DQ Evaluation of WOCE P18S and P18N hydrographic data

Arnold W. Mantyla

WOCE line P18 began in the southern Amundson Basin at the same latitude as WOCE line S04 and then extended northward, mostly along the eastern flank of the East Pacific Rise, ending near Cabo San Lucas at the tip of Baja California, Mexico. The cruise resulted in an excellent section across the frontal zones of the Antarctic Circumpolar Current and through the very low oxygen minimum zones of the Eastern Pacific on both sides of the equator. About 85% of the 185 stations from the two legs (P18S and P18N) were done with a 35 place rosette that provided good full water column water sample coverage. Except for one station where no water samples were recovered, the rest were done with a 24 place rosette system, usually at times of rough weather. The latter stations had a higher data loss than the fair weather stations done with the larger system.

The cruise track crossed 5 other WOCE lines: S04, P17E, P06, P21, and P04, as well as the two classical Scorpio lines. Comparison of data at the crossings indicated the P18 cruise tended to be slightly lower in salinity, oxygen, silicate, phosphate, and nitrate than the other WOCE cruises, but the differences were within the combined expected precision of the cruise pairs.

Overall, the data looks quite good, and the data originators have done a thorough job in checking the data. However, some of the data rejection may have been overly zealous, particularly with the salinity flags. About a third of the doubtful salinities were clearly due to sample collection errors, usually off by one depth. These were not rosette trip errors, as revealed by the oxygen and nutrient profiles. They would be ok if shifted to their CTD verified depths. Of the remaining questioned salinities, about 40% were within one depth of the primary nitrite maximum in the upper thermocline (the secondary NO2 max is associated with the deeper very low O2's). The primary NO2 max is usually in the maximum stability zone, or in the strongest density gradient below the surface layer. Both temperature and salinity can also have strong vertical gradients there and it is in that area that the CTD and the water samples often have trouble in seeing the same answer, for a variety of reasons. The fact that the two measurements often differ does not mean that either is bad and some judgement should be used before rejecting data that in all likelihood is ok. I have changed a few of the flags to ok, but for the most part have left the flags as done by the data originators. Also, water samples collected near a sharp salinity minimum or maximum at times seemed to be more extreme than the CTD and therefore flagged questionable, but I believe that they shouldn't be flagged, so I changed some of the flags to ok.

There appears to be a small CTD salinity bias that varied with depth, the surface CTD being about .001 too low at the surface, and about .001 too high at the bottom. Mark Rosenberg has noted the problem in his CTD DQE evaluation, so the CTD salinities should be corrected at the rosette trip levels also.

Five stations had sample collection errors by being off one level for part of the sample drawing of the salinities (sta.'s 107, 112, and 140), O2 (sta. 169), and nutrients (sta. 23).

Since the CTD verifies the correct depths for the salinity and oxygen samples, I can't see why the samples couldn't be shifted to the correct depths, as long as that was noted in the cruise report. The nutrient offset is apparent from comparison with the nutrient vs density profile on the adjacent stations.

Many stations had surface layer silicates listed as zero, unlike any in the bracketing WOCE lines P17E and P19, or most other recent expeditions. I flagged the first station (32) zero silicates uncertain, but did not flag any of the other 27 stations that had unlikely zero surface silicate values. It seems the autoanalizer baseline correction may have been too large on many stations, or perhaps there was a problem with low level detection. I don't believe the zero values, but have decided to let them go as is.

There were a number of curious isolated depths where only oxygen was listed, but no salinity or nutrients. Salinities should always be collected and listed, as that is the essential sample in verification of the correct tripping of the rosette bottle.

The following are comments on specific stations with problems that should be looked into:

Sta. 23: 1995-4740db - silicates are higher than adjacent stations at the same density, it looks like they belong one depth deeper. Phosphate and nitrate gradients are too weak to tell, they would look ok at wither depth. Suspect a sample drawing error similar to those later (S and O2) verified by the CTD. As listed, the silicates should be flagged "uncertain", they would look ok if listed one depth deeper.

Sta. 40: 9-363db - Water sample salinity and oxygen data compared to the CTD indicate that samples 326-335 belong one depth deeper. Looks like samples 326 and 325 both tripped at 363db, with subsequent trips then one depth deeper than intended, and then only one trip at 9db (sample 336) instead of a double trip there. Suggest re-list the data with the correct pressures and temperatures and change the questionable salinity flags to data ok flags.

Sta.'s 85-88 PO4's: The deep phosphate for the last two stations of P18S appear high compared to station 85 and to the first station on P18N (sta. 88) The calculations should be checked, and if ok I recommend that stas 86 and 87 deep PO4's be flagged uncertain. Also, the deep nitrites on sta. 88 were flagged "bad", but they look OK, so I changed the flags to OK, except for two slightly high values which were flagged uncertain.

Sta. 107: 200-1303db - The salinity samples from bottles 114 to 128 clearly belong one depth shallower. Numerous salinities were flagged "bad", but if moved up one level (and average 128 and 129), the data would be all ok. This is a clear sample collection error, as the O2 and nutrients confirm they were not a mis-trip.

Sta 112: 1800-2200db - Salinity samples 113 and 114 clearly belong one depth deeper, the missing salinity should be at 1801db, rather than at 2201db. Data would be ok if moved. Oxygen confirms not a mis-trip.

Sta 117: 123db - Salinity listed as .0000, should change it to -9.000.

Sta. 140: 602-3748db - As on sta. 107, many salts flagged either questionable or bad. The CTD verifies that samples 103 to 119 are from one depth shallower and both 119 and 120 are from 602db. If moved, all of the salts would be ok. Not a mis-trip, per O2 data.

Sta. 148: 301db - This level is clearly a mis-trip or a leaker, and the water did not come from here. Therefore, the oxygen and nitrite should also be flagged uncertain, even though they would seem to "fit" at this depth.

Sta. 169: 1998-3001db - Clear oxygen sampling error, samples 105 to 108 belong one depth shallower (108 and 109 are both from 1998db), as confirmed by the CTD. If moved, the data would be ok, otherwise they are clearly "bad".

Sta. 190: 99 and 1800db - It looks like the salinity samples 110 and 132 belong in reverse order, but I don't have a clue how that error could have happened.

Sta. 191: 699db - A clear mis-trip or leaker, so O2 and NO2 must be flagged uncertain also. The samples are not from this depth.

Sta. 192: 100-1601db - There is no oxygen listed form sample 104 at 1601db; the CTD verifies that samples 105 to 107 belong one depth deeper, and no O2 listed for sample 107. If moved, the data would be ok.