WHP Cruise Summary Information

WOCE section designation	P17E/P19S
Expedition designation (EXPOCODE)	316N138_10 (a.k.a. JUNO Leg 2)
Chief Scientist(s) and their affiliation	Jim Swift, SIO
Dates	1992.12.04–1993.01.22
Ship	KNORR
Ports of call	Papeete, Tahiti, F.P., to Punta Arenas, Chile
Number of stations	106
Geographic boundaries of the stations	51°06.91"S 134°59.89"W 087°53.46"W 69°15.72"S
Floats and drifters deployed	see below
Moorings deployed or recovered	none
Contributing Authors (in order of appearance)	B.J. Nisly M.C. Johnson F.M. Delahoyde R.T. Williams R.M. Key A. Mantyla B. Millard

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
Description of parameters sampled	
Bottle depth distributions (figure)	Salinity
Floats and drifters deployed	Oxygen
Moorings deployed or recovered	Nutrients
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

WHP Ref. No.: P17E/P19S
Last updated: 3 March 1993

CRUISE REPORT

A. CRUISE NARRATIVE

A.1 HIGHLIGHTS

A.1.a	WOCE designation	P17E and P19S
A.1.b	EXPOCODE	316N138_10
A.1.c	Chief Scientist	James H. Swift Scripps Institution of Oceanography La Jolla, CA 92093-0230
A.1.d	Ship	R/V Knorr
A.1.e	Ports of call	Papeete, Tahiti, F.P., to Punta Arenas, Chile
A.1.f	Cruise dates	4 December 1992 - 22 January 1993

A.2 CRUISE SUMMARY INFORMATION

A.2.a Geographic boundaries

The cruise track included WHP stations beginning at 52°30'S, 135°W on 13 December, 1992, continuing east along ca. 52°30'S (P17E) at 30 nautical mile intervals. At 126°W the track turned south, and south of 61°S, station spacing was increased to 40 nautical miles. The planned southern terminus of the P17E line at 67°S was covered by sea ice. The farthest south station occupied on this line was located at ca. 66 20°S, 126°W on 25 December. Sampling resumed on the P17E line at 52°S on 29 December, and stations were occupied at 30 and 40 nautical mile intervals roughly eastward to 54°S, 88°W (10 January, 1993), except that the western end of the line ran northeast from 52°30'S 126°W to ca. 51°S 125°W before turning 'east' in order to cross the axis of the East Pacific Rise at closer to a right angle and away from known fracture zones. From 54°S, 88°W, WOCE sampling along line P19S continued south to ca. 69°16'S (18 January) at 30 nautical mile spacing to 61°S and 40 nautical mile spacing south of there, except for the final two stations, which were at ca. 32 and 23 mile spacing. (Cruise track shown in Figure 1.)

A.2.b Stations occupied

There were 106 CTD/rosette stations, each close to the bottom. 79 stations are along P17E and 27 are along P19S. Seven included one deep and one intermediate depth large volume cast. There were several casts carried out for tests and other non-WOCE purposes. No reportable data were collected at test stations and they are not tabulated in the WOCE .SUM file.

A.2.c Floats and drifters deployed

ALACE floats were deployed at 6 locations between 51°S and 61°30'S along 126°W (P17E) and 6 locations between 54°S and 62°30'S along 88°W (P19S).

A.2.d Moorings deployed or recovered

None

A.3 List of Principal Investigators

Name	Measurement responsibility	Institution
R. Davis	ALACE floats	SIO
E. Firing & P. Hacker	ADCP	Univ. of Hawaii
L. Gordon	nutrients (tech support)	OSU
W. Jenkins	helium (van support)	WHOI
C. Keeling	CO_2 (shore)	SIO
R. Key	LVS ^{14}C, AMS ^{14}C, surface $^{226}Ra/^{228}Ra$, alkalinity, underway surface T & pCO_2	Princeton
J. Lupton	helium	PMEL/Newport
G. Rau	^{13}C, ^{15}N (surface)	NASA/AMES
J. Reid & J. Swift	CTD/O_2/nutrients	SIO
P. Schlosser	helium/tritium	LDGO
W. Smethie	CFCs, CCl_4	LDGO
S. Smith	bathymetry	SIO
T.Takahashi & D.Chipman	CO_2 (shipboard), surface pCO_2 (underway)	LDGO
R. Weiss	CFCs, surface CFC/T/pCO_2 (underway)	SIO
B. Walden	IMET meteorology Thermosalinograph	WHOI

A.4 Scientific Programme and Methods

R/V *Knorr* expedition 138/10 (also known as JUNO, Leg 2) took place from Papeete, Tahiti, French Polynesia, to Punta Arenas, Chile, 4 December 1992 - 22 January 1993. Chief Scientist was James Swift (SIO). Scientific work for the P17 portion of Leg 2 was proposed by Joseph Reid (SIO) and Swift, and the P19 portion by Swift at an earlier time. (The work for the two proposals was partially merged in response to the rescheduling of the US WHP Pacific Basin study engendered by the delays in the refit of R/V *Knorr*.) The overall purpose was to contribute to a multi-cruise examination of the meridional circulation and water mass transitions in the Pacific Ocean for the WOCE Hydrographic Program, in this case emphasizing the subpolar regimes of the Southeast Pacific.

R/V *Knorr* departed Papeete, Tahiti, on 4 December, 1992, and headed toward the first WOCE station. On the afternoons of 5, 6, and 7 December the vessel stopped for station tests and training. No reportable data were collected. WHP stations began at 52°30'S, 135°W on 13 December (local date) and continued on the planned track until the Antarctic ice edge was reached at 6°20'S, 126°W on 25 December. After a three day run north to 5°2'S, 12°38'W, P17E stations resumed on 29 December on a track slightly south of the originally planned line, ending at 54°S 88°W on 9 January. At this point the track turned south to follow the originally planned P19S line south to ca. 6°16'S, 8°W, when station work was terminated short of the ice edge due to the need to begin the run into port, exceeding, however, the planned minimum southward goal of 67°S, which was the latitude of the *Ioffe* crossing of the S4 line. The vessel arrived in port on schedule 22 January 1993. The total number of station was slightly less than planned, but a preliminary examination of the isopleths suggests no serious data loss was generated by the use of 40 mile spacing over three 'deep basin' portions of the expedition.

The principal sampling program consisted of full-depth CTDO profiles with a maximum of 36 small-volume water samples per cast. Water samples were collected for salinity, dissolved oxygen, silicate, phosphate, nitrate, and nitrite from all sampled levels at all stations, and for CFC- 11, CFC-12, CFC-113, CCl_4, ^{3}He, tritium, AMS ^{14}C, and CO_2 system parameters (pCO_2, TCO_2, alkalinity) at selected levels and stations. Large volume sampling for ^{14}C was carried out at seven stations with 270-liter Gerard barrels, with up to 18 samples per station in two casts. Check samples for salinity and silicate were analyzed from the Gerard barrels and their piggyback Niskin bottles. Separate surface water samples were taken approximately one each day for analyses of ^{226}Ra and ^{228}Ra. Separate surface samples were filtered at each station for shore analyses of ^{13}C and ^{15}N.

Rosette water samples were collected by the Scripps Oceanographic Data Facility (ODF) from ODF-constructed 10-liter sample bottles mounted on an ODF-constructed 36-bottle rosette sampler which used General Oceanics 24- and 12-place pylons. The rosette was equipped with an ODF-modified NBIS Mark IIIb CTD for *in-situ* measurement of conductivity, temperature, pressure, and dissolved oxygen. A transmissometer belonging to Dr. Wilf Gardner, TAMU, was installed on the rosette and used at every station. A short-range (ca. 100 meter) altimeter was mounted on the rosette frame and its data fed into the CTD data stream. A pinger on the rosette frame gave height above bottom (via a PDR in the CTD console area) throughout the water column. In every case the bottles were closed at selected depths during the up cast, after the winch had stopped at that depth. There were 106 CTD/rosette stations, each close to the bottom. Seven included one deep and one intermediate depth cast with Gerard barrels.

While on station and underway a shipboard ADCP system was operated. Underway surface measurements were also obtained – temperature, pCO_2, and atmospheric CFCs. Sonic depth and position were recorded at five minute intervals between most stations and along selected portions of the long runs. Routine weather observations were collected at four hour intervals by the ship's officers, and an IMET system was operated by the Knorr's resident technician. The sea work was occasionally affected by sea and swell generated by low pressure cells in the region.

NOTES ON THE CONTENTS OF THE ".DOC" AND ".SUM" FILES

Note regarding position accuracy: Positions for ROS and LVS casts are reported here to the WHPO specification of the nearest hundredth of a minute (ca. 20 meters). However, elementary consideration shows that the position of the underwater equipment is difficult enough to know to tenths of a minute. One should also note that the net RMS system accuracy of the GPS at its current degradation was ±100 meters of absolute planetary position. Hence the reported ROS and LVS positions are not reliable to the precision required by the WHPO.

The ".SUM" file follows the format of the reference document except as follows:

"Uncorrected Bottom Depths" are in almost every case actual raw readings in meters read manually from the trace on the ship's PDR, copied from the ODF "Console Operation Log" sheets. These are uncorrected for the depth of the transducer below waterline, which was about 4 - 5 meters (depending on fuel remaining) for this cruise. Note that ODF "Station/Cast Description" files for this cruise contain bottom depths corrected from raw readings via Carter Tables. (This methodology matches that used to obtain the depths recorded every five minutes by the underway bathymetry group, and hence make for easier 'fits' for scientists preparing sections with realistic bathymetry between stations.) Hence future ODF data releases may show different bottom depths than the ".SUM" file from the Chief Scientist.

"Height Above Bottom" was determined for most ROS casts both from an altimeter on the rosette which returned altitude above bottom through the CTD data stream, and also from a pinger on the rosette frame used with the ship's PDR. In the ".SUM" file, priority in reported height above bottom was usually given to altimeter data when available. In the ODF "Station/Cast Description" file, the height above bottom is usually, but not always, the PDR reading. In any event, the two numbers were usually within 1-2 meters of each other. ODF also kept a record of PDR height above bottom at the time the mercury thermometers on the second bottle were reversed, in order to provide comparison with data from the unprotected thermometer. These data are available from ODF.

The "Meter Wheel" readings are the actual maximum wire out as recorded on the winch operator's display (and the repeater on the CTD computer). Cast-start winch readings are nominally adjusted at the surface by the winch operators; however this was not verified on a cast by cast basis by the scientists on watch.

"Maximum Pressure" is for ROS casts the preliminary corrected CTD pressure at the time of tripping the first (deepest) rosette bottle and for LVS casts the pressure calculated for the deepest LVS sampler from the thermometers on its piggyback Niskin bottle. The data acquisition system used for the CTD data on this cruise records and reports preliminary corrected pressures in real time, hence it was decided after consultation with the WHPO not to report in the ".SUM" file raw CTD pressures which do not correspond to expedition records distributed to participants.

The "Number of Bottles" is the maximum number attempted each cast, not the number returned to deck with sample-able water inside. This distinction was not discussed in the WHPO reference manual, which calls for the "number of bottles used" during a cast, and so we made our own decision, which bears comment: If a rosette bottle came up open or otherwise unsample-able, or if it came up full, but was later – on examination of the chemical data – found to be faulty, it did count in the tally shown. This does not necessarily make sense from the standpoint of the chemistry groups, because their tallies keep track of the number of bottles sampled for the parameters of interest, and rosette bottles known absolutely to be faulty (for example top cap open or bottle empty) are not sampled. Another problem is that the CTD data acquisition system prepared a file (containing CTD pressure, temperature, conductivity, oxygen, and other parameters) for each attempt to close a rosette bottle (including some bogus "double-trips" which had nothing to do with pylon tripping). Because of all these factors, some versions of the CTD rosette trip files from this expedition may show different numbers of bottles than in this column.

Should CTD data be reported from attempted bottle trips which produced no bottle data? The reason to do this is that it helps fill out the vertical profiles for T, S, and O_2 for those who primarily use bottle data. (Generally speaking, the CTD console operators attempt to close rosette bottles at key or interesting places in the water column.) A gap will make representation of that layer impossible from only the bottle data file. The reason not to do this is that there are no bottle data at those depths. This difference between the number of bottles attempted and the number sampled should perhaps be addressed by the WHPO in a future version of the reference document.

During cruise 138/10, pCO_2 and total CO_2 measurements were made from water taken from the shallowest rosette bottle at every station, and pCO_2 and total CO_2 profiles from a full rosette cast were collected and analyzed approximately once each day. The WHPO Requirements for Data Reporting manual lists sample codes for fugacity of CO_2 and total carbonate. A chemist consulted on this matter stated that fugacity of CO_2 was different from the partial pressure of CO_2 and that total carbonate was different than total CO_2. Hence new parameter codes were created for the carbon system parameters actually measured on Knorr 138/10. There were four other parameters routinely measured on 138/10 that did not have listed WHPO parameter codes: ^{13}C, ^{15}N, CFC-113, and CCl_4. These were assigned new numbers also, as per the instructions in the data reporting manual.

A.5 Major Problems and Goals not Achieved

The *Knorr* left Tahiti one day late due to a problem with the ship's radar not discovered until the originally-intended sailing day. The ODF electronics technician repaired the radar before scheduled departure time, but because the crew had been released, it was not possible to depart until the following morning. Eighteen hours were lost due to this. The CTD cable was occasionally damaged near the rosette due to the combined action of wave and ship motion. New end terminations were carried out on 15 (twice) and 21 December, and 4 and 8 January, with a total time loss of about 14 hours. Cable reterminations usually coincided with weather delays. Additional delays of about 36 hours were generated waiting out seas and weather too severe for rosette operations. At times when sea state was marginal for rosette casts, twelve of the rosette bottles were removed to reduce drag. These 24-level profiles are bracketed by 36-level profiles, and kept CTD operations active in somewhat rougher conditions than recommended for the 36-place configuration.

The expedition plan required three long steams (ca. 2180, 880, and 1200 miles). Pre-cruise information from the vessel operator for planning had been that in good weather the vessel would do 12-13 knots underway on long steams. Therefore the cruise was planned at 10 knots, with no weather allowance, but in effect with a multi-day allowance generated by the expected higher speed on long steams. (We also knew that in good weather we could carry out CTD casts in about 80% of the time used in the planning document.) However, cruising speed on the critical long first run proved to be only 10 knots (due to fuel consumption considerations). This meant the loss of about two days time. Steaming speed at night was reduced to 4 knots during most of the run south along 126°W; it was not until the farthest south portion of the line that sea surface temperatures dropped below zero or any growlers were sighted not immediately associated with icebergs. With this experience in hand, the run south along 88°W incurred fewer night-time steaming delays. Additional time was lost when the Chileans refused to supply a pilot for the most direct route to Punta Arenas (via the Cockburn Channel), forcing a detour northward to use the Straits of Magellan. (This was known approximately 2-3 weeks ahead of time.)

The sum of the various delays and lost time, plus the extension of the 126°W line to 66°40'S to better meet the *Ioffe* S4 line, made it necessary to expand station spacing over some deep basin portions of the track to 40 nautical miles. The Chief Scientist must seek adequate time (and funds) for an expedition, and so the responsibility for widening the spacing lies there, not with the vessel operator or any other factor. (As a result of this experience the vessel operator instituted new guidelines for cruise and fuel planning.)

A.6 Other Incidents of Note

The CTD and rosette bottles worked especially well during the expedition. There were the fewest problems with bottle leaks in the Chief Scientist's experience. Despite continual expert maintenance, the General Oceanics 24-place rosette pylons were troublesome. The most common problem was 'trip throughs', where the rotor advances, but fails to release the lanyard at one level, and then releases two lanyards at the next level. Fortunately, over much of the water column vertical gradients were high enough to sort these out. At two stations where over 5000 meters of CTD wire was played out, two of the deep rosette trips failed to release the lanyards (those bottles came up open). This was tracked and investigated by the electronics technician, and after several adjustments, the problem did not reoccur.

There are property differences between JUNO Leg 2 stations and IOFFE S4 stations reoccupied during JUNO. There were also property differences between JUNO Leg 1 Station 80 and its JUNO Leg 2 reoccupation (Station 128). For example, the JUNO 1/2 deep temperatures suggested that Leg 2 measurements at the same levels were 0.02°C colder than during Leg 1. Secondary PRT and mercury thermometer differences over Leg 1 and Leg 2 show no visible trends over time, and certainly no 0.02° shift. These and other property differences will be documented in the final cruise report.

We carried out tests of three new rosette bottle designs, all with external springs: a stock General Oceanics 'Lever Action' Niskin Bottle, a 'lever action' bottle modified by General Oceanics to include a 'floater' type top cap, and a similar bottle constructed by ODF. (The floater caps hold a buoyant disk slightly smaller than the bottle barrel. The disk is held in place by the air vent, which is relocated to the top lid. When the air vent is opened, it releases the floating disk, which, at least in theory, reduces gas exchange between the sample and the air in the headspace.) The ODF version leaked heavily on its first try, then broke at a weakly supported glue joint on its cocking for its second station. It was obvious it would just break again, so it was retired to shore for modifications. The General Oceanics floater bottle leaked badly (top cap was not sealing well enough, though bottom cap was doing O.K.), and had a cable on it that was wearing out very quickly. However, if the top cap was manually seated when the rosette came out of the water, it would retain its seal. An oxygen draw down test – with an ODF standard 10-liter bottle as the 'control' – showed no significant contamination reduction with the floater. However, this test was not definitive, and further development and tests must proceed before a conclusion is drawn. The stock General Oceanics external spring model without floater work well enough. On its own, however, it does not solve the head space gas exchange problem.

On 9 January, R.Streib found a deep water pelagic snail in the oxygen sample flask from 1000 meters at station 205. It was preserved in alcohol for return to shore, though deteriorated when it was placed in alcohol.

A.7 List of Cruise Participants

Name	Responsibility on cruise	Institution or affiliation
Baker, Linda	CO_2	LDGO
Boennisch, Gerhard	helium/tritium	LDGO
Bos, David	chief nutrient analyst	SIO/ODF
Delahoyde, Frank	CTD data, computer systems	SIO/ODF
Guffy, Dennis	nutrients	TAMU
Handley, William	resident technician; ALACE	WHOI
Harrison, Kathleen	CM operations, science assistant	SIO/PORD
Key, Robert	^{14}C, LVS operations, surface sampling, underway systems, co-chief scientist	Princeton
Klas, Millie	CO_2	LDGO
Lyons, John	dock, salinity	SIO/ODF
Lyons, Michelle	ADCP, CTD operations, science assistant	SIO/PORD
Mathieu, Guy	CFCs, CCl_4	LDGO
Mattson, Carl	electronics	SIO/ODF
Muus, David	chief marine technician, deck, data analyst	SIO/ODF
Patrick, Ron	deck (2nd watch leader), O_2	SIO/ODF
Pillard, Gent	dock, salinity	SIO/ODF
Rubin, Stephany	chief CO_2 analyst	WOO
Salameh, Peter	CFCs, underway systems	SIO/GRD
Streib, Rebecca	deck, O_2	SIO/ODF
Swift, Jim	chief scientist	SIO/PORD/ODF
Tedesco, Kathy	helium/tritium, science assistance	UCSB

B. Underway Measurements

B.1 Navigation and bathymetry

B.2 Acoustic Doppler Current Profiler (ADCP)

B.3 Thermosalinograph and underway dissolved oxygen, etc

B.4 XBT and XCTD

B.5 Meteorological observations

B.6 Atmospheric chemistry

WOCE P17E/P19S

(EXPOCODE 316N138/10)

Calibrated Pressure-Series CTD Data Processing Summary and Comments

April 10. 1996

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1. Introduction

This document describes the CTD and dissolved oxygen data acquisition, processing, corrections, and laboratory calibrations used for WOCE P17E/P19S, also known as Knorr 138/10 and JUNO2. This cruise was on the R/V Knorr from December 4, 1992 - January 22, 1993.

2. CTD Setup and Processing Summary

106 CTD casts were done during JUNO2. The rosette used was a 36-bottle system that was designed at ODF. The system consisted of a 12-bottle ring nested inside a 24-bottle ring. Two General Oceanic pylons were mounted inside the smaller ring: one 12-place and one 24-place. Ten liter ODF and Niskin bottles were used. The CTD, altimeter, pinger, and transmissometer were mounted to the bottom of the rosette frame. A modified Neil Brown Instrument Systems Mark IIIB CTD (ODF #1) was used the entire leg. At the outset, the CTD was equipped with these four sensors: a Rosemount primary platinum resistance thermometer, a Falmouth Scientific secondary PRT, a Rosemount pressure sensor, and a Sensormedics oxygen sensor. Later, a Falmouth Scientific pressure sensor was deployed in the place of the secondary PRT. One winch and one transmissometer were used the entire leg. Table 1 shows the configurations of the rosette as it was deployed. Deep sea reversing thermometers were deployed on 96 casts. Additionally, factory-calibrated digital DSRTs were deployed on approximately half of the casts.

The CTD data stream consisted of pressure, temperature, conductivity, dissolved oxygen, secondary temperature, four CTD voltages, trip confirmation, transmissometer, altimeter, and elapsed time. The raw FSK CTD signal was DC decoupled, demodulated, and converted to an RS-232 signal by a deck unit that was designed and fabricated at ODF. The decoupled FSK CTD signal was recorded on VHS videotape. The RS-232 signal was sent to a Sun SPARCstation 2 which acquired and displayed the data in real time using software developed at ODF. The data were recorded on hard disk as were the bottle trip levels. A 3- to 4-second average of the CTD data was stored for each detected bottle trip. These data were then used to verify the CTD temperature calibration and to derive CTD conductivity and oxygen corrections.

CTD data processing steps are as follows:

- Data are acquired from the deck unit and assembled into consecutive 0.04-second frames containing all data channels. The data are converted to scientific units.
- The raw pressure, temperature and conductivity data are passed through broad absolute value and gradient filters to eliminate noise (see Table 2). The entire frame of raw data is omitted if any one of the filters is exceeded. The filters may be adjusted as needed for each cast.
- Pressure and conductivity are phase-adjusted to match temperature. This is necessary because the temperature sensor response time lags the response times of the pressure and conductivity sensors. Conductivity data are corrected for ceramic compressibility in accordance with the NBIS Mark IIIB Reference Manual.
- The data are averaged into 0.5-second blocks. For each channel, data falling outside four standard deviations from the mean are rejected and the average is recalculated. Then data falling outside two standard deviations from the new mean are rejected, and the average is again recalculated. The resulting averages, minus secondary temperature and CTD voltages, are reported as the 0.5-second time-series data. Secondary temperature data are used to verify the stability of the primary temperature channel calibration. Secondary temperature data are only reported if the primary thermometer malfunctions.
- Corrections are applied to the data. The pressure data are corrected using laboratory calibration data with the procedure described in Appendix A, "Improving the Measurement of Pressure in the NBIS Mark III CTD," by F. Delahoyde and R. Williams. Temperature corrections are based on laboratory calibrations and are typically quadratic functions of temperature. Conductivity and oxygen corrections are calculated from water sample data. Conductivity corrections are typically linear functions of conductivity. Oxygen data are corrected on an individual cast basis by correcting pressure-series CTD oxygen data to match the up-cast discrete oxygen values at common isopycnals. This technique is described in Appendix B, "CTD Dissolved Oxygen Data Processing," by F. Delahoyde.
- A down-cast pressure-series data set is created from the time-series data by applying a ship-roll filter to the down- cast time-series data, then averaging the data within 2-decibar pressure intervals centered on the reported pressure. The ship-roll filter disallows pressure reversals. The first few seconds of data for each cast are excluded from the averages to allow the sensors to adjust. Pressure intervals without time-series data are filled by double-parabolic interpolation. When the down-cast CTD data have

excessive noise, gaps, or offsets, the up-cast data are used instead. Down- and up-cast data are not reported together because they do not represent identical water columns due to ship movement, internal waves, and wire angle.

The CTD time-series data is the definitive record for the pressure, conductivity and temperature channels. The final CTD and dissolved oxygen pressure-series data are reported to the principal investigator and to the WOCE Hydrographic Programme Office. Uncorrected time-series transmissometer data are forwarded to Texas A&M University for final processing and reporting.

Table 1: JUNO2 CTD Sensor Configuration

Stations	Pressure	Temperature PRT-1	Temperature PRT-2	Conductivity	Oxygen
128-183	131910	14304	FSI-T1320	5902-F117	2-6-9
184-205					2-6-10
206-233			FSI-Pressure†		

†NOTE: An FSI pressure sensor was deployed instead of the secondary temperature sensor.

Table 2: JUNO2 Raw Data Filters

Raw Data Channel	Minimum	Maximum	Frame-to-Frame Gradient
Pressure	-40	6400	2 decibars
Temperature	-8	32.7	0.2°C
Conductivity	0	64.355	0.3 mmho
Oxygen	(no filter was used)		

3. CTD Laboratory Calibrations

3.1 Pressure Sensor Calibration

The CTD #1 pressure transducer was calibrated in a temperature-controlled bath with a Ruska Instrument Corporation Model 2400 dead weight gage. The mechanical hysteresis loading and unloading curves were measured both pre- and post-cruise at cold temperature (-2.0 to -1.4°C bath) to a maximum of 8830 psi. The warm temperature (29.1 to 30.0°C bath) hysteresis curves were measured to a pre-cruise maximum of 2030 psi and a post-cruise maximum of 4030 psi. The post-cruise calibration included an additional measurement to 4030 psi in a 10.3°C bath.

The transient thermal response of the pressure sensor was also quantified with thermal shock tests. The CTD was subjected to a step change in temperature from warm air to cold water at stable pressure in the laboratory, while the pressure and temperature were measured over a period of 1 hour. The cold-to- warm thermal shock response was also measured; that response was roughly the mirror image of the warm-to-cold response.

Thermal shock tests for CTD #1 were done from warm air to cold water, and later from cold water to warm air, during the post-cruise calibration. Further testing was done in

October '93 to get a proper cold-to-warm response measurement by going from cold water to warm water.

CTD #1 pre- and post-cruise pressure calibrations are summarized in Figures 1a, 1b, 1c, 2a, and 2b.

3.2 Temperature Sensor Calibration

Both primary and secondary PRT were calibrated in a temperature-controlled bath with a Rosemount Model 162CE standard PRT as measured by a NBIS Automatic Temperature Bridge Model 1250 resistance bridge. Eight calibration temperatures, spaced across the range of 0 to 31.3C, were measured both pre- and post-cruise. The standard PRT was monitored for drift with a water triple- point cell and a gallium cell.

CTD #1 pre- and post-cruise temperature calibrations, referenced to the ITS-90 standard, are summarized in Figures 3a and 3b. Temperature calibration coefficients were converted to the IPTS-68 standard. CTD temperature data were corrected to the IPTS-68 standard because calculated parameters, including salinity and density, are currently defined in terms of that standard only. After final corrections were applied, IPTS-68 data were converted back to the ITS-90 standard.

4. CTD Data Processing

4.1 CTD Pressure Corrections[1]

CTD #1 pre- and post-cruise pressure calibrations were compared (Figures 1a and 1b). The warm/shallow and cold/deep calibration curves both shifted at the surface by about 2.5 to 3 decibars from pre- to post-cruise. The cold/deep pressure calibration curves had similar slopes in the top 2400 decibars, then diverged an additional 2 decibars between 2400 and 6100 decibars. The post-cruise cold/up-cast curve was 1 decibar closer to the downcast than pre-cruise. The warm/shallow slope was less steep post-cruise, and the surface points were 0.5 decibar further from the cold curve than they were during the pre-cruise calibration. The post-cruise down-cast pressure calibrations had similar slopes at all 3 temperatures, whereas the pre-cruise warm calibration curve was steeper than the cold calibration curve.

Because of the pre- and post-cruise slope inconsistencies, laboratory calibrations from December '91, May '92, and October '93 were also examined for trends over time. The cold/deep correction curve slopes have gone more negative and the warm/cold surface offsets have drifted apart with time. Only the August '92 pre-cruise calibration contradicts these trends; the May '93 post-cruise pressure calibrations are much more consistent with the history of the instrument. The post-cruise pressure calibrations were used to correct the CTD #1 station data, with an additional offset applied to account for the shift in the calibration curves over time. No slope change was applied to the May '93 data, since

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[1] Refer to Appendix A, "Improving the Measurement of Pressure in the NBIS Mark III CTD" for details on the ODF pressure model and its application.

there was less than a 1 decibar in 6000 decibars slope change between May '92 and May '93 laboratory calibrations.

The additional offset to the pressure calibration was determined by examining raw CTD pressure versus temperature data from the laboratory temperature calibrations and comparable shipboard data. Raw CTD pressure versus temperature data from just before the CTD entered the water on each cast were tabulated. The CTD readings were fairly stable, with atmospheric pressures and stable ambient temperatures around the CTD for 30 or more minutes prior to each cast. These conditions were similar to conditions during the laboratory calibrations. The May '93 post-cruise pressure calibration curves were shifted by the +2.0-decibar average difference between the laboratory and cast data; the resulting data were used to correct JUNO2 CTD #1 pressure data (Figure 1c).

Post-cruise warm-to-cold thermal shock data (Figure 2a) were fit to determine the time constants and temperature coefficients which model the pressure response to rapid temperature change. May 91 and May '93 post-cruise data were compared and the results were similar in magnitude and response time. A thermal shock test from cold-to-warm water was done in October '93 (Figure 2b). The results were similar in magnitude but mirror-image to the warm-to-cold shock tests from May '93. The May '93 time constants and temperature coefficients were used to correct the JUNO2 CTD #1 pressure data (Table 3). The pressure correction applied to up-cast data for the thermal response used a modification of the down-cast correction to achieve the mirror- image effect seen in the laboratory.

DSRTs were used on 96 casts to measure thermometric pressure at depth. Additional data were collected at 1-3 intermediate-to- deep levels using factory-calibrated digital DSRTs. The only shift observed in thermometric and CTD pressure differences, between stations 188 and 189, could be attributed to a change in the DSRT used to measure the thermometric values.

The shifted May '93 post-cruise calibration curve (Figure 1c) was used in conjunction with the May '93 thermal shock results (Figure 2a) to correct the pressure for all JUNO2 CTD #1 casts. Any residual offset was compensated for automatically at each station: as the CTD entered the water, the corrected pressure was adjusted to 0 decibar.

Table 3: Thermal Response Coefficients for CTD #1 Pressure †

Short Time Constant (secs) Tau1	Temp. Coeff. for Tau1 k1	Long Time Constant (secs) Tau2	Temp. Coeff. for Tau2 k2
82.1826	+0.306253	384.176	-0.26423

†See Appendix A, Section 2.

4.2. CTD Temperature Corrections

CTD #1 was equipped with two PRT sensors: the primary thermometer (PRT-1) and the secondary thermometer (PRT-2). PRT-1 was calibrated pre- and post-cruise. Different secondary thermometers were connected to CTD #1 during the pre- and post- cruise calibrations.

PRT-2 was used to monitor any PRT-1 drift during the cruise. PRT-1 versus PRT-2 data showed consistent differences throughout JUNO2. Temperatures were measured with the DSRTs during 96 casts; they also indicated no PRT-1 shift occurred during the leg.

A comparison of the pre- and post-cruise laboratory CTD #1 PRT-1 temperature sensor calibrations (Figures 3a and 3b) showed two curves with nearly identical slopes and a +.001°C shift in the temperature correction over the range of 0 to 32°C. An average of the pre- and post-cruise temperature corrections was used for the final temperature corrections. The corrections were converted to the IPTS-68 standard and then applied to the CTD temperature data.

4.3. CTD Conductivity Corrections

In order to calibrate CTD conductivity, check-sample conductivities were calculated from the bottle salinities using CTD pressures and temperatures. For each cast, the differences between sample and CTD conductivities at all pressures were fit to CTD conductivity using a linear least-squares fit. Values greater than two standard deviations from the fits were rejected. On JUNO2, CTD conductivity slopes were steady, except for some scatter in high-latitude stations with small conductivity ranges. An average of the conductivity slopes was applied to all JUNO2 casts. Conductivity slope as a function of conductivity was plotted to ensure that no residual slope remained.

After applying the conductivity slope corrections, conductivity differences were calculated for each cast. Residual conductivity offsets were computed for each cast. Smoothed offsets were determined by groups based on common temperature and conductivity sensor combinations and applied to the data.

Offsets smoothed with a first-order fit were applied to CTD conductivities for stations 128-133 for a total shift of 0.002 mmho over 6 casts. This is typical at the start of a leg where the CTD has not been used for several days. An average offset was applied to stations 134-205, with a smooth transition between stations 133 and 134 offsets. The average offset for stations 206-218 shifted 0.0015 mmho lower than the previous group after a salinity offset during station 206 down cast. There were numerous mid-cast conductivity offsets, presumably caused by biological matter, during stations 206-218. Then a more permanent shift of +.0035 mmho occurred during station 219. Offsets smoothed with a first-order fit were applied to stations 219-233 shifting a total of -.003 mmho over the 15 casts. Some offsets were manually re-adjusted to account for discontinuous shifts in the conductivity transducer response, or to insure a consistent deep theta-salinity relationship from station to station.

Figures 4a and 4b show plots of the final JUNO2 conductivity slopes and offsets. The JUNO2 calibrated bottle-minus-CTD conductivity statistics include salinity values with quality 3 or 4. There is approximately a one-to-one correspondence between conductivity and salinity residual differences. Figure 5a is a plot of the differences at all pressures and

Figure 5b is a plot of those differences below 1500 decibars. Table 4 shows the statistical results of the final bottle data set and the corrected up-cast CTD data.

Table 4: JUNO2 Final Bottle-CTD Conductivity Statistics

Pressure Range (decibars)	Mean Conductivity Difference (mmho)	Standard Deviation (mmho)	Sample Size
all pressures	-0.000240‡	0.00214	3652
all pressures (filtered)†	-0.000154	0.00098	3419
pressures < 1500	-0.000318	0.00269	2164
pressures < 1500 (filtered)†	-0.000227	0.00126	2020
pressures > 1500	-0.000126‡	0.00084	1488
pressures > 1500 (filtered)†	-0.000067	0.00063	1398

†These data were passed through a 4/2 rejection filter.

‡Figures 5a and 5b are plots of these differences.

4.4. CTD Dissolved Oxygen Corrections[2]

Dissolved oxygen data were acquired using two Sensormedics dissolved oxygen sensors. The second sensor was used after station 183.

CTD oxygen data were corrected after pressure, temperature and conductivity corrections were determined. CTD raw oxygen data were extracted from the down-cast pressure-series data at isopycnals corresponding to the up-cast check samples. Down-cast oxygen data are typically smoother than up-cast data because of the flow-dependence problems occurring at up-cast bottle stops. These problems also occur when the winch is slowed, as often happens during bottom approaches.

The CTD oxygen correction coefficients were determined by applying a modified Levenberg-Marquardt nonlinear least-squares fitting procedure to residual differences between CTD and bottle oxygen values. These bottle oxygen values included data with quality codes of 3 or 4. Bottle oxygen values were weighted as required to optimize the fitting of CTD oxygen to discrete bottle samples. Some bottle levels were omitted from a fit because of large pressure differences between down- and up-cast CTD data at isopycnals. Deep levels were often weighted more heavily than shallow levels due to the higher density of shallow samples on a typical 36-bottle sampling scheme. Residual oxygen differences from these fits are shown in Table 5.

4.5. Additional Processing

A software filter was used on 26 casts to remove conductivity or temperature spiking problems. Pressure did not require filtering. Oxygen spikes were filtered out of 8 casts.

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[2] Refer to Appendix B, "CTD Dissolved Oxygen Data Processing" for details on ODF CTD oxygen processing.

Table 5: JUNO2 Final Bottle-CTD Oxygen Statistics

Pressure Range (decibars)	Mean Oxygen Difference (ml/l)	Standard Deviation (ml/l)	Sample Size
all pressures	-0.0325‡	0.776	3544
all pressures (filtered)†	-0.0012	0.088	3386
pressure < 1500	-0.0574	1.004	2114
pressure < 1500 (filtered)†	-0.0163	0.143	2016
pressure > 1500	0.0042‡	0.028	1430
pressure > 1500 (filtered)†	0.0039	0.021	1338

†These data were passed through a 4/2 rejection filter.

‡Figures 6a and 6b are plots of these differences.

The remaining density inversions in high-gradient regions cannot be accounted for by a mis-match of pressure, temperature and conductivity sensor response. Detailed examination of the raw data shows significant mixing occurring in these areas because of ship roll. The ship-roll filter resulted in a reduction in the amount and size of density inversions.

5. General Comments and Problems

There is one pressure-sequenced CTD data set, to near the ocean floor, for each of 106 casts at 106 station locations. There were two additional equipment test casts which were neither processed nor reported. Most of the data were reported from down casts. The data from the following casts were reported from up casts: 194/01, 206/02, 211/01, 217/01, 219/01, and 229/02.

The CTD oxygen sensor requires several seconds in the water to acclimate before responding properly; this is manifested as erratic CTD oxygen values at the start of some casts. The nature of the oxygen sensor is such that it consumes oxygen at the seawater interface and therefore is highly sensitive to flow rate. Flow-dependence problems occur when the CTD is slowed or stopped. Usually this happens during bottom approaches, at the cast bottom, or at bottle stops. The CTD oxygen sensor took longer than usual to acclimate in the freezing conditions that were encountered. Because of this, all casts have the upper 100 decibars of CTD oxygen data labeled as questionable. Table 6 shows casts that had more levels labeled as questionable. Cast 182/01 had sensor stability problems from 0-908 decibars. Cast 196/01 had sensor drift problems from 4000-4662 decibars. Casts 184/01, 185/01, 186/01, and 187/02 have no CTD oxygen data reported because the data were either not salvageable or non- existent.

Table 6: Questionable CTD Oxygen Levels Below 100 Decibars

Casts	Levels (decibars)
141/01, 142/01, 146/02, 157/02	0-150
155/01, 202/01	0-200
182/01	0-908
196/01	4000-4662

The 0-4 decibar levels of some casts were extrapolated using a quadratic fit through the next three deeper levels. Recorded surface values were rejected only when it appeared that the drift was caused by sensors adjusting to the air/water transition. Otherwise, the original data were reported. Extrapolated surface levels are identified by a count of "1" in the *NUMBER OBS* field reported with each data record. The pressures for extrapolated data frames as well as other cast-by-cast shipboard or processing comments are listed in Table 6 in Appendix D. Significant delays during the casts are documented in Table 7 in Appendix D. Appendix D contains other tables related to processing also.

World Ocean Circulation Experiment (WOCE) P17E/P19A
Knorr 138 Leg 10
Expocode: 316N138/10
4 Dec 1992 - 22 Jan 1993
Papeete, Tahiti to Punta Arenas, Chile

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C. DESCRIPTION OF MEASUREMENT TECHNIQUES AND CALIBRATIONS

ODF CTD/rosette casts were carried out with a 36 bottle rosette sampler of ODF manufacture using General Oceanics pylons. An ODF-modified NBIS Mark 3 CTD, a Benthos altimeter, a SensorMedics oxygen sensor and a SeaTech transmissometer provided by Texas A&M University (TAMU) were mounted on the rosette frame. A FSI temperature sensor was used on most stations as a check on CTD temperature. Seawater samples were collected in 10-liter PVC Niskin and ODF bottles mounted on the rosette frame. A Benthos pinger was mounted separately on the rosette frame; its signal was displayed on the precision depth recorder (PDR) in the ship's laboratory. The rosette/CTD was suspended from a three-conductor EM cable which provided power to the CTD and relayed the CTD signal to the laboratory.

Each CTD cast extended to within approximately 10 meters of the bottom unless the bottom returns from both the pinger and the altimeter were extremely poor. The bottles were numbered 1 through 36. When one of these 36 bottles needed servicing and repairs could not be accomplished by the next cast, the replacement bottle was given a new number. Subsets of CTD data taken at the time of water sample collection were transmitted to the bottle data files immediately after each cast to provide pressure and temperature at the sampling depth, and to facilitate the examination and quality control of the bottle data as the laboratory analyses were completed. The CTD data and documentation are submitted separately.

After each rosette cast was brought on board, water samples were drawn in the following order: Freon (CFC-11 and CFC-12), Helium-3, Oxygen, Total CO_2, Alkalinity, and AMS ^{14}C. Tritium, Nutrients (silicate, phosphate, nitrate and nitrite), and Salinity are drawn next and could be sampled in arbitrary order. The identifiers of the sample containers and the numbers of the ODF or Niskin samplers from which the samples were drawn were recorded on the Sample Log sheet. Normal ODF sampling practice is to open the drain valve before opening the air vent to see if water escapes, indicating the presence of a small air leak in the sampler. This observation ("air leak"), and other comments ("lanyard caught in lid", "valve left open", etc.) which may indicate some doubt about the integrity of the water samples were also noted on the Sample Log sheets. These comments are included in this documentation with investigative comments and results.

Tripping problems were experienced at the beginning of the leg until all the lanyards were fine-tuned. There were also numerous tripping problems occurring with 24-place pylons. Most were "double trips", with one bottle not closing at the intended level but then closing at the next level up, along with the bottle intended to trip at that level. Some of these actually sometimes tripped up 1 further level, ending up with 3 bottles tripping at the same depth. Attempts were repeatedly made to find a solution to the problems by swapping out the 2 24-place pylons. At one point some bent release pins were straightened but most of the effort was in seeking the exactly correct alignment position for each pin.

Large Volume Sampling (LVS) was also performed on this expedition. These commonly referred to as Gerard casts were carried out with ~270 liter stainless steel Gerard barrels on which were mounted 2-liter Niskin bottles with reversing thermometers. Samples for salinity, silicate and ^{14}C were obtained from the Gerard barrels; samples for salinity and silicate were drawn from the piggyback Niskin bottles. The Gerard barrels were numbered 81 through 93 and the piggyback bottles were numbered 41 through 49. The salinity and silicate samples from the piggyback bottle were used for comparison with the Gerard barrel salinities and silicates to verify the integrity of the Gerard sample.

LVS casts experienced an annoying number of pre-trips. Lowering the casts at 30 meters/min gave significantly fewer tripping problems than the former method of lowering at 50 meters/min.

The discrete hydrographic data were entered into the shipboard data system and processed as the analyses were completed. The bottle data were brought to a usable, though not final, state at sea. ODF data checking procedures included verification that the sample was assigned to the correct depth. This was accomplished by checking the raw data sheets, which included the raw data value and the water sample bottle, versus the sample log sheets. The oxygen and nutrient data were compared by ODF with those from adjacent stations. Any comments regarding the water samples were investigated. The raw data computer files were also checked for entry errors that could have been made on the station number, bottle number and/or flask number (as would be the case for oxygens). The salinity and oxygen values were transmitted from PC's attached to either the salinometer or oxygen titration system. Nutrients were manually entered into the computer; therefore these values were double checked for data entry errors.

Investigation of data included comparison of bottle salinity and oxygen with CTD data, and review of data plots of the station profile alone and compared to nearby stations. If a data value did not either agree satisfactorily with the CTD or with other nearby data, then analysis and sampling notes, plots, and nearby data were reviewed. If any problem was indicated, the data value was flagged. Section E, the Quality Comments, includes comments regarding missing samples and investigative remarks for comments made on the Sample Log sheets, as well as all flagged (WOCE coded) data values.

The WOCE codes were assigned to the water data using the criteria:

code 1 = Sample for this measurement was drawn from water bottle, but results of analysis not received.
code 2 = Acceptable measurement.
code 3 = Questionable measurement. Does not fit station profile or adjoining station comparisons. No notes from analyst indicating a problem. Datum could be real, but the decision as to whether it is acceptable will be made by a scientist rather than ODF's technicians.
code 4 = Bad measurement. Does not fit station profile and/or adjoining station comparisons. There are analytical notes indicating a problem, but data values are reported. ODF recommends deletion of these data values. Analytical notes for salinity and/or oxygen may include large differences between the water sample and CTD profiles. Sampling errors are also coded 4.
code 9 = Sample for this measurement not drawn.
code P = This code is only used on the LVS pressure. If the Gerard and/or piggyback bottle pre or post-tripped, and a determination was made as to at what pressure the bottles actually tripped within ~50m a P will be assigned to the pressure.

Quality flags assigned to parameter BTLNBR (bottle number) as defined in the WOCE Operations manual are further clarified as follows:

code 4 = If the bottle tripped at a different level than planned, ODF assigned it a code 4. If there is a 4 code on the bottle, and 2 codes on the salinity, oxygen and nutrients then the pressure assignment was probably correct.
code 3 = An air leak large enough to produce an observable effect on a sample is identified by a 3 code on the bottle and 4 code on the oxygen. (Small air leaks may have no observable effect, or may only affect gas samples).

The following table shows the number of ODF samples drawn and the number of times each WOCE sample code was assigned.

Rosette Samples

	Rosette Samples Stations 128-233						
	Reported levels	WHP Quality Codes 1	2	3	4	5	9
Bottle	3753	0	3608	7	125	0	13
CTD Salt	3753	0	3752	0	1	0	0
CTD Oxy	3609	0	3189	419	1	144	0
Salinity	3739	0	3651	68	20	1	13
Oxygen	3733	0	3614	106	13	5	15
Silicate	3739	0	3717	11	11	1	13
Nitrate	3739	0	3526	146	67	1	13
Nitrite	3739	0	3725	4	10	1	13
Phosphate	3737	0	3689	36	12	3	13

Large Volume Samples

Stations 146-229

	Reported	Bottle Codes				Water Sample Codes						
	levels	2	3	4	9	1	2	3	4	5	9	P
	246	239	1	1	5							
Salinity	240					0	228	12	0	0	6	
Silicate	240					0	224	16	0	0	6	
Temperature	228					0	236	0	1	0	9	
Pressure	246					0	246	0	0	0	0	0

C.1. Pressure and Temperature

All pressures and temperatures for the bottle data tabulations on the rosette casts were obtained by averaging CTD data for a brief interval at the time the bottle was closed on the rosette.

LVS pressures and temperatures were calculated from deep-sea reversing thermometer (DSRT) readings. Each DSRT rack normally held 2 protected (temperature) thermometers and 1 unprotected (pressure) thermometer. Thermometers were read by two people, each attempting to read a precision equal to one tenth of the thermometer etching interval. Thus, a thermometer etched at 0.05 degree intervals would be read to the nearest 0.005 degrees.

All reported CTD data are calibrated and processed with the methodology described in the documentation accompanying the CTD data submission.

Each temperature value reported on the LVS casts is calculated from the average of four readings provided both protected thermometers function normally. The pressure is verified by comparison with the calculation of pressure determined by wireout. The pressure from the thermometer is fitted by a polynomial equation which incorporates the wireout and wire angle.

Documentation of CTD calibration is included with the CTD data.

Calibration of the thermometers are performed in ODF's calibration facility depending on the age of the thermometer and not more than two years of the expedition.

The temperatures are based on the International Temperature Scale of 1990.

C.2. Salinity

A single ODF-modified Guildline Autosal Model 8400A salinometer (Serial Number 57-396), located in a temperature-controlled laboratory, was used to measure salinities. Analyses and data acquisition were controlled by a small computer through an interface board designed by ODF. The salinometer cell was flushed until successive readings met software criteria, then two successive measurements were made and averaged for a final result.

Salinity samples were analyzed for the rosette casts and the Large Volume casts from both the piggyback bottle and the Gerard barrel. Salinity samples were drawn into 200 ml Kimax high alumina borosilicate bottles, after 3 rinses, and were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. If loose inserts were found, they were replaced to ensure an airtight seal. Salinity was determined after sample equilibration to laboratory temperature, usually within 8-36 hours of collection. Salinity was calculated according to the equations of the Practical Salinity Scale of 1978 (UNESCO, 1981).

Salinity samples were compared with CTD data and significant differences were investigated.

The salinometer was standardized for each cast with IAPSO Standard Seawater (SSW) Batch P-120, using at least one fresh vial per cast.

There were some problems with lab temperature control throughout cruise; the Autosal bath temperature was adjusted accordingly. Salinities were generally considered good for the expedition despite the lab temperature problem.

The estimated accuracy of bottle salinities run at sea is usually better than 0.002 psu relative to the particular Standard Seawater batch used. Although laboratory precision of the Autosal can be as small as 0.0002 psu when running replicate samples under ideal conditions, at sea the expected precision is about 0.001 psu under normal conditions, with a stable lab temperature.

C.3. Oxygen

Dissolved oxygen analyses were performed with an SIO-designed automated oxygen titrator using photometric end-point detection based on the absorption of 365 nm wavelength ultra-violet light. Thiosulfate was dispensed by a Dosimat 665 buret driver fitted with a 1.0 ml buret. ODF uses a whole-bottle Winkler titration following the technique of Carpenter (1965) with modifications by Culberson et al. (1991), but with higher concentrations of potassium iodate standard (approximately 0.012N) and thiosulfate solution (50 gm/l). Standard solutions prepared from pre- weighed potassium iodate crystals were run at the beginning of each session of analyses, which typically included from 1 to 3 stations. Several standards were made up during the cruise and compared to assure that the results were reproducible, and to preclude the possibility of a weighing error. Reagent/distilled water blanks were determined to account for oxidizing or reducing materials in the reagents. The auto-titrator generally performed very well. A decrease in voltage output led to changing the UV source lamp during the cruise.

Samples were collected for dissolved oxygen analyses soon after the rosette sampler was brought on board and after CFC and helium were drawn. Nominal 125 ml volume-calibrated iodine flasks were rinsed twice with minimal agitation, then filled via a drawing tube, and allowed to overflow for at least 3 flask volumes. The sample temperature was measured with a small platinum resistance thermometer embedded in the drawing tube. Reagents were added to fix the oxygen before stoppering. The flasks were shaken twice; immediately after drawing, and then again after 20 minutes, to assure thorough dispersion of the $MnO(OH)_2$ precipitate. The samples were analyzed within 4-36 hours of collection.

Draw temperatures were very useful in detecting possible bad trips even as samples were being drawn. The data were logged by the PC control software and then transferred to the Sun (the main computer) and calculated.

Blanks, and thiosulfate normalities corrected to 20°C, calculated from each standardization, were plotted versus time, and were reviewed for possible problems. New thiosulfate normalities were recalculated after the blanks had been smoothed. These normalities were then smoothed, and the oxygen data was recalculated.

Oxygens were converted from milliliters per liter to micromoles per kilogram using the in-situ temperature. Ideally, for whole-bottle titrations, the conversion temperature should be the temperature of the water issuing from the Niskin bottle spigot. The sample temperatures were measured at the time the samples were drawn from the bottle, but were not used in the conversion from milliliters per liter to micromoles per kilogram because the software is not available. Aberrant temperatures provided an additional flag indicating that a bottle may not have tripped properly. Measured sample temperatures from mid-deep water samples were about 4-7°C warmer than in-situ temperature. Had the conversion with the measured sample temperature been made, converted oxygen values, would be about 0.08% higher for a 6°C warming (or about 0.2µmol/kg for a 250µmol/kg sample).

Oxygen flasks were calibrated gravimetrically with degassed deionized water (DIW) to determine flask volumes at ODF's chemistry laboratory. This is done once before using flasks for the first time and periodically thereafter when a suspect bottle volume is detected. All volumetric glassware used in preparing standards is calibrated as well as the 10ml Dosimat buret used to dispense standard Iodate solution.

Even though laboratory and sample temperatures were recorded, these temperatures were not used in the calculation of oxygen. Therefore, these temperatures are not reported in the data submission to ensure that the data user does not use these temperatures.

Iodate standards are pre-weighed in ODF's chemistry laboratory to a nominal weight of 0.44xx grams and exact normality calculated at sea.

Potassium Iodate (KIO_3) is obtained from Johnson Matthey Chemical Co. and is reported by the suppliers to be > 99.4% pure. All other reagents are "reagent grade" and are tested for high levels of oxidizing and reducing impurities prior to use.

C.4. Nutrients

Nutrient analyses (phosphate, silicate, nitrate and nitrite) were performed on an ODF-modified AutoAnalyzer II, generally within a few hours of the cast, although some samples may have been refrigerated at 2 to 6°C for a maximum of 12 hours. The procedures used are described in Gordon et al. (1992).

Silicate is analyzed using the basic method of Armstrong et al. (1967). Ammonium molybdate is added to a seawater sample to produce silicomolybdic acid which is then reduced to silicomolybdous acid (a blue compound) following the addition of stannous chloride. The sample is passed through a 15mm flowcell and measured at 820nm. This response is known to be non-linear at high silicate concentrations; this non-linearity is included in ODF's software.

A modification of the Armstrong et al. (1967) procedure is used for the analysis of nitrate and nitrite. For nitrate analysis, a seawater sample is passed through a cadmium column where the nitrate is reduced to nitrite. This nitrite is then diazotized with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form an azo dye. The sample is then passed through a 15mm flowcell and measured at 540nm. A 50mm flowcell is required for nitrite (NO_2). The procedure is the same for the nitrite analysis less the cadmium column.

Phosphate is analyzed using a modification of the Bernhardt and Wilhelms (1967) method. Ammonium molybdate is added to a seawater sample to produce phosphomolybdic acid, which is then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The sample is passed through a 50mm flowcell and measured at 820nm.

Besides running rosette cast samples, LVS cast samples for both Gerard barrels and piggyback Niskins were analyzed for silicate as an added check (with salinity) on barrel sample integrity.

Nutrient samples were drawn into 45 ml high density polypropylene, narrow mouth, screw-capped centrifuge tubes which were rinsed three times before filling. Standardizations were performed at the beginning and end of each group of analyses (one cast, usually 36 samples) with a set of an intermediate concentration standard prepared for each run from secondary standards. These secondary standards were in turn prepared aboard ship by dilution from dry, pre-weighed standards. Sets of 4-6 different concentrations of shipboard standards were analyzed periodically to determine the deviation from linearity as a function of concentration for each nutrient.

All peaks were logged manually, and all the runs were re-read to check for possible reading errors.

Temperature regulation problems in the analytical lab did not appear to significantly affect the results, which were generally very good. ODF first attempted to control the temperature in the lab during the previous leg by rigging up a ceramic heater and fan, under the control of a thermistor and in conjunction with the ship's cooling. This worked well on this leg, providing about plus or minus 0.5°C stability, except when outside temperatures were too warm in the tropics, or when it became too cold and the ship's heating system was erratically controlled. Depending on the ship's heading, the wind would sometimes blow directly into either the lab's ventilation shaft or the vent for the hood. In these extreme cold conditions, the vent covers (up on the exterior 02 level) were closed by the analysts after first checking with the ship's engineering staff.

Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at zero pressure, in-situ salinity, and an assumed laboratory temperature of 25°C.

Silicate standard is obtained from Fischer Scientific and is reported by the supplier to be >98% pure. Nitrate, nitrite and phosphate standards are obtained from Johnson Matthey Chemical Co. and the supplier reports a purity of 99.999%, 97%, and 99.999%, respectively.

D. REFERENCES AND UNCITED SUPPORTING DOCUMENTATION

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E. Quality Comments

Remarks for deleted samples, missing samples, and WOCE codes other than 2 from JUNO-2 - WOCE P17E/P19A. Investigation of data may include comparison of bottle salinity and oxygen data with CTD data, review of data plots of the station profile and adjoining stations, and rereading of charts (i.e., nutrients). Comments from the Sample Logs and the results of ODF's investigations are included in this report. Units stated in these comments are milliliters per liter for oxygen and micromoles per liter for Silicate, Nitrate, and Phosphate, unless otherwise noted. The first number before the comment is the cast number (CASTNO) times 100 plus the bottle number (BTLNBR).

Station 128

136	Sample Log: "air bubble for oxygen." Oxygen appears about.01 high Not sure what happened here, why wasn't oxygen redrawn. Silicate appears ~.1 high, other samples appear to be okay. Footnote oxygen bad, silicate questionable.
124	Delta-s .005 high at 2118db. Calc ok. High CTD T grad, small CTD S bump. No notes. Footnote salinity questionable.
117	Sample Log: "valve stem sucks." O2 and salinity agree with CTD and adjoining stations. Other samples appear reasonable.
114	Salinity appears high compared with CTD, oxygen appears low. Nutrients appear high compared with adjoining stations. Footnote bottle leaking and samples questionable.
101-104	CTD Processor: "CTD O2 questionable, 0 - 100 db."
101	Sample Log: "didn't close top." Samples appear to be okay.

Station 129

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 130

136 PO4 appears .1 high at 4478db (10m above bottom). Calc ok. Poor peak. Footnote po4 bad. ODF recommends deletion.
131-136 NO3 appears high vs. adjoining stations. See NO3 101-115 comment. Footnote NO3 bad.
131 PO4 appears .04 high at 3528db. Calc & peak ok. No notes. Other water samples ok. Footnote po4 questionable.
127 PO4 appears .04 high at 2703db. Calc & peak ok. No notes. Other water samples ok. Footnote po4 questionable.
120 Delta-S .004 low at 1296db. Calc ok. No notes. Smooth CTD T & S gradients. Footnote salinity questionable.
101-115 NO3 appears low, plotted vs. ptotemp. Remaining profile (except 131-136) agrees with adjacent stations (128-131); slightly high compared with station 132, but acceptable. Footnote NO3 bad.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 131

134 PO4 appears .02 high at 4279db. Calc & peak ok. Footnote po4 questionable.
132 PO4 appears .05 high at 3768db. Calc & peak ok. Footnote po4 questionable.
131 PO4 appears .03 high at 3560db. Calc & peak ok. Footnote po4 questionable.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 132

134 Delta-S .003 high at 3918db. Calc ok. Smooth CTD S gradient. No notes. Footnote salinity questionable.
131 Delta-S .004 high at 3347db. Calc ok. Smooth CTD S gradient. Possible dupe draw from NB30. Footnote salinity bad.
122-136 See 121 NO3 comment. Footnote NO3 questionable.
121 NO3 appears low compared to adjacent stations. Calc ok. First station after odd F1s on Stations 130 & 131. See Station 130 comments. Footnote no3 questionable.
105 Water samples indicate bottom end cap probably closed about 550db vs 125db as intended. Footnote bottle leaking, did not trip as scheduled, footnote samples bad, ODF recommends deletion of all water samples.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 133

Cast 1 Sample Log: "Approximately 3 of the inner rosette [bottles]were opened during rosette separation, bottle numbers unknown." Samples appear to be okay, except as noted, bottle 10 could be suspect, but will leave as okay.

111 Sample Log: "dripping from bottom." Samples appear to be okay.
105 Water samples indicate NB5 closed early. Lanyard too long. Shortened after this station. Footnote bottle did not trip as scheduled, footnote all samples bad. ODF recommends deletion of all water samples.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 134

131 NB31, intended to trip at 3228db, water samples same as NB30 at 3011db. Delta-S .005 high Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled. Samples appear to be okay as reassigned pressure.
126 NB26, intended to trip at 2187db, water samples same as NB25 at 2000db. Delta-S .032 high Used NB25 CTD trip data for NB26. Footnote bottle did not trip as scheduled. Samples appear to be okay at reassigned pressure.
121 Sample Log: "leaks at the valve stem when opened." Samples appear to be okay.
117 Sample Log: "leaks at the valve when opened." Samples appear to be okay.
111 Sample Log: "Slow drip from valve stem when open." Samples appear to be okay.
110 Sample Log: "has no water." Footnote no samples from NB10.
106 Delta-S .017 high at 170db. Took 6 Autosal tries to get agreement; probably salt crystal fell in sample when cap opened. Smooth CTD S gradient. Calc ok. Footnote salinity bad, ODF recommends deletion.
105 Sample Log: "Possible valve stem leak." Samples appear to be okay.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 135

135 Flask broke during titration. No hydro o2. Footnote oxygen lost.
131 NB31, intended to trip at 3020db, water samples same as NB30 at 2821db. Delta-S .004 high. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled. Samples appear to be okay at reassigned pressure.
110 No water samples, bottom end cap hung up on pinger. Footnote bottle no samples taken.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 136

131 Intended to trip at 2855db, water sample same as NB30 at 2648db. Delta-S .000 but no CTD S gradient. Hydro o2 & silicate have gradient this level but have same value as NB30. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
128 Delta-S .018 high at 2238db. Calc ok. Same value as 129 salinity. Other water samples ok. Probably dupe draw from NB29. Smooth CTD trace. Footnote salinity bad, ODF recommends deletion.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 137

132 Sample Log: "drips from valve stem after vented." Samples appear to be okay.
131 Intended to trip at 2908db, water samples same as NB30 at 2704db. Delta-S .003 high. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled. Samples appear to be okay at reassigned pressure.
125 Sample Log: "drips from valve stem when opened and vented. "Samples appear to be okay.
121 Sample Log: "leaks from valve stem when opened and vented. "Samples appear to be okay.
117 Sample Log: "valve stem leaks and slips when opened and vented." Samples appear to be okay.
111 Sample Log: "leaks at valve stem when opened and vented. "Samples appear to be okay.
105 Sample Log: "Valve stem leaks when opened and vented. "Samples appear to be okay.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 138

134 Sample Log: "top cap was a little loose." Samples appear to be okay.
114 Sample Log: "Spigot was in." Samples appear to be okay.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 139

131 Intended to trip at 2911d, water samples same as NB30 at 2704db. Delta-S .000 but no CTD S gradient. Hydro o2 &silicate have gradient but same values as NB30. Used NB30CTD trip data for NB31. Footnote bottle did not trip as scheduled. Samples appear to be okay at reassigned pressure.
111 Sample log: "air leak - vent not closed tight enough. "Samples appear to be okay.
106 Sample log: "Vent not closed." Delta-S .000 at 165db. Other water samples also look ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 140

131 All water samples except silicate indicate NB31 closed at level above with NB30. Silicate has poor peak which could be interpreted as same as NB30 silicate value. Salinity, NO3 & PO4 have no gradient, but o2 does. Assume tripped at NB30 based on o2 and results for NB31 on adjacent stations. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled. Silicate value appears high for both intended NB31 level and NB30 as indicated by other water samples. Footnote silicate bad.
127 Sample Log: "dripping from bottom cap." Samples appear to be okay.
126 Sample Log: "possible leak from bottom cap." Samples appear to be okay.

124 Salinity: "Unable to get agreement after 3 attempts. Possible salt crystal contamination." Footnote salinity lost.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 141

133 PO4 appears .08 high at 3286db. Other water samples ok. Poor peak but definitely high. Footnote po4 bad.
131 Intended to trip at 2867db, water samples same as NB30 at 2661db. Delta-S .000 but no CTD S gradient. Hydro o2 and silicate have gradient but values same as NB30. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
116 Hydro o2 appears high. Calc ok. CTDO has corresponding bump this level. Other water samples ok. Oxygen acceptable.
102-136 See NO3 comment. Footnote NO3 questionable.
102 Sample Log: "leaks before vented." Salinity and oxygen appear to be okay.
101-104 CTD Processor: "CTD O2 questionable, 0 - 150 db."
101 All NO3 values a little high (.4). Calc ok. No apparent problems with AA run. Footnote no3 questionable.

Station 142

121 Oxygen appears .15 high. Calc ok. Smooth CTDO gradient. Same value as NB20 above. Possible dupe draw. Footnote oxygen bad.
101-106 CTD Processor: "CTD O2 questionable, 0 - 150 db."

Station 143

135 Intended to trip at 3537db, water samples & DSRTs same as NB34 at 3406db. Used NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled, samples acceptable.
130 Sample Log: "vent open." Salinity appears to be okay.
129-136 See 128 O2 comment. Footnote oxygen questionable.
128 Sample Log: "oxygen sample bottles NB36 through NB28, possibly off, immediately after watch switch realized we were off by 1 bottle, re-sampled bottles NB26 and NB27." O2 values not in close agreement with adjacent stations. OXY values questionable.
124 Sample Log: "vent pushed in." Salinity and oxygen appear to be okay.
123 Sample Log: "vent not closed tight enough." Salinity and oxygen appear to be okay.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 144

135 Intended to trip at 3573db, water samples & DSRTs same as NB34 values. Used NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled, footnote samples as acceptable. NO3 agreement is slightly off, but OK.

112 Sample Log: "Bottle leaking, vent not closed tight enough. "Salinity agrees with CTD, oxygen appears a little high, but agrees with adjoining stations, there does appear to be an oxygen feature in CTDO.

105 O2 value 3ml/L low. "error" noted on data sheet. Footnote oxygen bad, ODF recommends deletion.

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 145

129 Oxygen: "Power went out, lost sample." Footnote oxygen lost.

124 Delta-S .003 low at 1413db. Calc ok. Smooth CTD S gradient. Footnote salinity questionable.

123 O2 appears .07 high at 1261db. Calc ok. no notes. Smooth CTDO gradient. Footnote oxygen questionable.

108 Sample Log: "Lanyard Clip Broken on NB8." Salinity .004high, oxygen agrees with Station 144 profile. Other samples appear to be okay.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 146

235 Intended to trip at 4239db, water samples & DSRT values same as NB34 at 3958db. Used NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled.

231 Bottom didn't close. No water samples.

212 Sample Log: "vent not closed tightly." All water samples appear to be consistent with adjoining stations and CTD data.

208 Sample Log: "has an air leak, draining w/o opening air vent." All water samples appear to be consistent with adjoining stations and CTD data.

201-205 CTD Processor: "CTD O2 questionable, 0 - 150 db."

Station 147

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 148

133 Intended to trip at 3635db, water samples same as NB32 at 3427db. Used NB32 CTD trip data for NB33. Footnote bottle did not trip as scheduled.

130 Sample log: "Did not close". No water samples.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 149

124 Sample Log: "Valve stem on All samples appear to be consistent with adjoining stations and CTD values.

114 Sample Log: "appears to be dripping from the bottom." All samples appear to be consistent with adjoining stations and CTD values.

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 150

131 Intended to trip at 3963db, water samples same as NB30 at 3759db. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
125 Intended to trip at 2734db, water samples same as NB24 at 2531db. Used NB24 CTD trip data for NB25. Footnote bottle did not trip as scheduled.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 151

132 Delta-S .003 high at 4121db. Calc & Autosal runs ok. Smooth CTD traces this level. Same value as level above, NB35 & test level-arm Niskins. Possible dupe draw. Footnote salinity bad.
131 Intended to trip at 3656db, water samples same as NB30 at 3451db. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
127 Delta-S .019 high at 2834db. Calc ok. No notes. First 2 Autosal runs agreed. Other water samples ok. Footnote salinity bad. ODF recommends deletion of salinity.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 152

135 Unprotected DSRT wrong break.
131 Intended to trip at 4021db, water samples same as NB30 at 3764db. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
125 Intended to trip at 2633db, water samples same as NB24 at 2430db. Used NB24 CTD trip data for NB25. Footnote bottle did not trip as scheduled.
114 Sample Log: "leaks - occasional swoosh." all samples appear to be consistent with adjoining stations and ctd values.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 Sample Log: "vent was open." all samples appear to be consistent with adjoining stations and ctd values.

Station 153

135 Intended to trip at 4661db, water samples & DSRT values same as NB34 at 4371db. Oxygen appears ok but had note on data sheet re poor UV end point. Used NB34 CTD trip data for NB34. Footnote bottle did not trip as scheduled. Titrator noted UV end point problem. Voltage was 1.10 vs 1.06 for other samples. See 133 comment.
133 Intended to trip at 4070db, water samples same as NB32 at 3810db. Used NB32 CTD trip data for NB33. Footnote bottle did not trip as scheduled.
113-114 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 154

131 oxygen appears ~.01 high, but it could be that 32-46 are low. Footnote OXY questionable.

114-136 See 113 PO4 comment. Footnote PO4 questionable.
113-114 CTD Processor: "CTD O2 questionable, 0 - 100 db."
113 All values appear high compared to adjacent stations and P-N plot. Calc & peaks ok. Standard values normal. Footnote po4 questionable.

Station 155

135 Intended to trip at 4595db, water samples & DSRT values same as NB34 at 4445db. Used NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled.
134 Delta-S .005 high at 4445db. 7 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives better value. Footnote salinity questionable. O2appears .01 to .02 low. Note on Sample log: "too much MnCl2 on 1227 on bottle 34" Footnote salinity and oxygen questionable.
125 Delta-S .002 high at 2305db. 6 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives better value. Footnote salinity questionable.
119 Note on nutrient data sheet: "Sample spilled" Footnote nutrients lost.
114 Sample Log: "is leaking from bottom cap. - needs new gasket?" all samples are consistent with adjoining stations and CTD values.
113 Delta-S .006 high at 457db. 8 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives better value. Footnote salinity questionable.
112 Delta-S .007 high at 367db. 7 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives better value. Footnote salinity questionable.
110 Sample Log: "leaked at spigot prior to venting." All samples are consistent with adjoining stations and CTD values.
106 Delta-S .000 high at 166db. 11 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives worse Delta-S (-.012) but in area of high T&S gradient and T inversion. Use first fill to be consistent with other samples this station with same problem. Footnote salinity questionable.
104 Sample Log: "Valve is pushed in." All samples appear to be consistent with adjoining stations and CTD values.
101-107 CTD Processor: "CTD O2 questionable, 0 - 200 db."
101 Delta-S .006 high at 3db. 6 Autosal fills to get agreement. Possible salt crystal contamination. First fill gives better value. Footnote salinity questionable.

Station 156

132 Intended to trip at 4048db, water samples same as NB31 at 3790db. Used NB31 CTD trip data for NB32. Footnote bottle did not trip as scheduled.
124 PO4 appears .06 high. Peak fair, calc ok. Other water samples ok. Footnote po4 questionable.
123 O2 appears .07 high. Calc ok. No notes. Smooth CTDO trace. Other water samples ok. Footnote oxygen questionable.
114 Intended to trip at 547db, water samples same as NB13 at 450db. Delta-S .054 low. Used NB13 CTD trip data for NB14. Footnote bottle did not trip as scheduled.
110 Sample Log: "Bottle dripping from the spigot." Samples appear to be consistent with adjoining stations and CTD values.
102-136 See 101 NO3 comments. Footnote NO3 questionable.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 All NO3 appear high compared to adjacent station and P-N plot. Calc ok, end standard factor (F1B) high compared to adjacent station but no obvious cause. Footnote NO3 questionable.

Station 157

232 Delta-S .008 high at 4326db. Smooth CTD S trace. 8 Autosal tries to get agreement. First Autosal run gives better Delta-S (.002) for both 4326db & 4069db (See note below). Intended to trip at 4326, water samples except salinity (see above) same as NB31. Used NB31 CTD trip data for NB32. Footnote bottle did not trip as scheduled.
225 Intended to trip at 2536db, water samples same as NB24. Used NB24 CTD trip data for NB25. Footnote bottle did not trip as scheduled.
214 Sample Log: "Salt Bottle had a loose plastic insert-replaced." Salinity value consistent with CTD and adjoining stations.
212 Delta-S .007 high at 482db. Smooth CTD S trace. 4 Autosal tries to get agreement. First Autosal run gives better Delta-S (.001). Footnote salinity questionable.
201-205 CTD Processor: "CTD O2 questionable, 0 - 150 db."

Station 158

132 Intended to trip at 4580db, water samples same as NB31 at 4322db. Used NB31 CTD trip data for NB32. Footnote bottle did not trip as scheduled.
128 Intended to trip at 3809db, water samples same as NB27 at 3556db. Used NB27 CTD trip data for NB28. Footnote bottle did not trip as scheduled.
126 Intended to trip at 3041db, water samples same as NB25 at 2785db. Delta-S .004 high. Used NB25 CTD trip data for NB26. Footnote bottle did not trip as scheduled.
113 May be slightly high, no problems noted. Footnote oxygen questionable.
110 Sample Log: "spigot dripping." Oxygen may be slightly high. Could be an air leak. If gas investigators indicate a problem, then would recommend footnoting bottle as having an air leak, if there were such a footnote. Footnote oxygen questionable.
105 Sample Log: "spigot accidentally popped open during rosette separation." Samples appear to be consistent with adjoining stations and CTD values.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 159

132 Intended to trip at 4440db, water samples same as NB31 at 4183db. Used NB31 CTD trip data for NB32. Footnote bottle did not trip as scheduled.
130 Appears .06 low at 3924db. Calc ok. Other water samples ok. Possible dupe draw from NB29. Footnote oxygen bad.
129 Appears .002 low at 3670db. Calc ok. First 2 Autosal runs agreed. No notes. Other water samples ok. Footnote salinity questionable.

125 Intended to trip at 2621db, water samples same as NB25 at 2379db. Delta-S .005 high. Used NB24 trip data for NB25. Footnote bottle did not trip as scheduled.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 160

130 Intended to trip at 4042db, water samples same as NB29 at 3784db. Used NB29 CTD trip data for NB30. Footnote bottle did not trip as scheduled.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 Sample Log: "Surface Radium collected"

Station 161

114 Sample Log: "bottom cap leaks." Parameter values are consistent with the rest of the cast and adjacent stations.
113-115 CTD Processor: "CTD O2 questionable, 0 - 100 db."
110 Sample Log: "dripping." Parameter values are consistent with the rest of the cast and adjacent stations.
105 Sample Log: "loose vent." Parameter values are consistent with the rest of the cast and adjacent stations.
102-136 See 101 bottle tripping comment.
101 Tripped inner bottles (12-1) first and outer bottles (36-13) last, to check bottle tripping problems in higher gradient and to check freon values of NBs 1-12 in deep water. All bottles and both DSRT racks tripped as intended. Sample Log: "lanyard broke - not sure if bottle tripped correctly. "Parameter values are consistent with the rest of the cast and adjacent stations.

Station 162

133 Intended to trip at 4592db, water samples and DSRT values same as NB32 at 4331db. Loose bungee on NB33 therm rack mount was replace with SS gerard barrel spring prior this station. Used NB32 CTD trip data for NB33. Footnote bottle did not trip as scheduled.
130 Intended to trip at 3797db, water samples same as NB29 at 3559db. Used NB29 CTD trip data for NB30. Footnote bottle did trip as scheduled.
123 Bottle didn't close. Pylon pin bent and didn't release lanyard. No water samples.
114 Sample Log: "dripping at bottom." Sample parameters appear to be ok.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 163

133 Intended to trip at 4274db, water samples & DSRT values same as NB32 at 4020db. Used NB32 CTD trip data for NB33. Footnote bottle did not trip as scheduled.
127 Intended to trip at 2743db, water samples same as NB26 values at 2488db. Used NB26 CTD trip data for NB27. Footnote bottle did not trip as scheduled.
114 Sample Log: "Bottom Cap is still leaking." Sample parameters appear to be ok.
101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 164

133 Intended to trip at 4066db, water samples & DSRT values same as NB32 values at 3810db. Used NB32 CTD trip data for NB33. Footnote bottle did not trip as scheduled.

131 Intended to trip at 3554db, water samples same as NB30 at 3299db. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.

127 Intended to trip at 2534db, water samples same as NB26 at 2279db. Delta-S .005 high. Used NB26 CTD trip data for NB27. Footnote bottle did trip as scheduled.

101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

101 Found cap off salt sample bottle when ready for Autosal run. Reason unknown. Delta-S .022 high in thin mixed layer. Footnote salinity bad. ODF recommends deletion of salinity.

Station 165

121 Sample Log: "leaks from spigot." Oxygen appears to be okay, plotted vs. potemp as well as pressure and CTDO. Other samples also okay.

114 Sample Log: "leaks from bottom." Oxygen appears to be okay, plotted vs. potemp as well as pressure and CTDO. Other samples also okay.

113 NO2 .25 high, no analytical problem noted. Rechecked peak, appears to be okay (clean peak). NO3 peak is a little low. Footnote no2 questionable, no analytical problem, but value appears unlikely.

106 Delta-S .018 high at 159db. Calc ok. 6 Autosal runs to get agreement Smooth CTD S trace. First Autosal run gives Delta-S .008 high. Used first Autosal run for now. Footnote salinity bad.

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 166

115 Delta-S .026 high at 831db. Calc ok. Bumpy CTD T & S this level but high compared to up CTD S trace. Same value as NB16. Assume dupe draw. Footnote salinity bad. ODF recommends deletion of salinity.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 167

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

101 Sample Log: "leaks out of bottom after venting." All samples appear to be consistent with adjoining stations.

Station 168

135 Intended to trip at 3600db, water samples & DSRT values same as NB34 at 3367db. Used NB34 trip values for NB25.Footnote bottle did not trip as scheduled.

108 Sample log: "Lanyard in top end cap. Air leak." Footnote bottle leaking. Delta-S .001 high at 205db. Other water samples also look ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 Sample log: "leaking from bottom." Samples are consistent with adjoining stations and CTD values.

Station 169

127 Intended to trip at 2024db, water samples same as NB26 at 1822db. Used NB26 CTD trip data for NB27. Footnote bottle did not trip as scheduled.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 170

123 Sample log: "leaking from bottom after air vent opened. "Samples are consistent with adjoining stations and CTD values.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 171

127 Intended to trip at 1869db, water samples same as NB26 at 1717db. Used NB26 CTD trip data for NB27. Footnote bottle did not trip as scheduled.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 172

127 Intended to trip at 1816db, water samples same as NB26 at 1714db. Used NB26 CTD trip data for NB27. Footnote bottle did not trip as scheduled.
102 Sample log: "leaks before venting." Sample values are consistent with CTD and adjoining stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 173

127 Intended to trip at 1512db, water samples same as NB26 at 1310db. Used NB26 CTD trip data for NB27. Footnote bottle did not trip as scheduled.
121 Sample log: "leaking e spigot." Sample values are consistent with CTD and adjoining stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 174

111 Delta-S .018 high at 325db. Calc ok. Smooth CTD gradient down & up. Sigma theta higher sample below. Same value as NB10 at level above. Hydro o2 agrees well with CTDO gradient (inversion). NO3, PO4 & SIL same as NB10 but may be feature associated with o2 inversion. NO2 has normal gradient. Assume salt is dupe draw. Footnote salinity bad. ODF recommends deletion of salt value.

101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 175

114 Sample log: "leaks a little bit through bottom after venting." Sample values look ok.
108 Sample log: "Air vent open" Delta-S .001 low at 230db. Other water samples also ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 176

134 Sample log: "Air leak, top not seated". Delta-S .000 at 2593db. Other water samples also ok.
129 Delta-S .004 high at 1948db. Calc & Autosal run ok. Smooth CTD T & S gradients. Other water samples ok. Footnote salinity questionable.
120 Sample log: "bad set up -no water- lanyard hook on 1 strand only." Footnote no samples drawn.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 Sample log: "Air vent open" Delta-S .000 at 2db. Other water samples also look ok.

Station 177

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 178

132 Sample log: "Thermometer lanyard caught in top, leaking. "Sample values agree with CTD and adjoining stations.
121 Sample log: "dripping from spigot." Sample values agree with CTD and adjoining stations.
117 Sample log: "dripping slightly from O ring around spigot."O2 and salt values track feature displayed by CTDO and CTD plot. Nutrient values also ok.
111 Sample log: "vent not closed, (flowed before venting), also leaks from spigot." Sample values agree with CTD and adjoining stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 179

129 Sample log: "leaking from base of spigot when spigot is open." Sample values are consistent with CTD and adjoining stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 180

134 Sample log: "has major venting leak - top cap leaking -coming out spigot." Sample values are consistent with CTD data and values from adjoining stations.

130 Sample log: "no water... bottom cap hung up on pinger. "Footnote no samples drawn.
129 Sample log: "leaks from spigot area after being vented heavily." Sample values are consistent with CTD data and values from adjoining stations.
127 Delta-S .002 high at 2113db. Used 2nd & 3rd Autosal run. First Autosal run gives Delta-S .000. Dupe level with NB26. Footnote salinity questionable.
124 Delta-S .005 low at 1816db. Calc & Autosal run ok. High gradient. Other water samples ok. Footnote salinity questionable.
123 Delta-S .005 low at 1713db. Calc & Autosal run ok. Small CTD S bump. High gradient. Other water samples ok. Footnote salinity questionable.
102-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 (No Pressure) Surface bottle tripped without stopping because of ship's roll. Tripped in air. No samples drawn.

Station 181

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 182

127 Sample log: "dripping from spigot after vented." NB27 and NB26 tripped at same level in area of a steep gradient, yet values look acceptably similar.
121 Sample log: "Leaking a lot from spigot" Doesn't say if before or after air vent opened. Footnote bottle leaking. Delta-S .001 high at 880db. Sample values are consistent with CTD and adjacent station.
111 Sample log: "leaking from spigot." Data plots look suspicious, however adjacent station 181 has very similar structure between 175db & 400db. Sample values ok.
109 Sample log: "slight drip from spigot." Data plots look suspicious, however adjacent station 181 has very similar structure between 175db & 400db. Sample values ok.
101-121 CTD Processor: "CTD O2 questionable, 0 - 908 db."

Station 183

134 Sample log: "leaked from spigot before being vented." Plot of oxy vs. deg theta very similar to station 184 at this depth. Other sample values also consistent.
130 Delta-S .016 high at 2589db. Calc & Autosal run ok. Other water samples ok. No notes. Footnote salinity bad. ODF recommends deletion of salinity value.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 184

Cast 1 CTD Processor: "CTD O2 not reported for this station -various O2 sensor problems."
102-136 See 101 O2 comment. Footnote O2 questionable.
102 Sample log: "leaks before being vented--top cap not seated. "Except for oxy, Sample values are consistent with CTD and adjacent stations.

101 Analyst indicates problems with titrator which may have affected all of station 184 & 185. Plots are not consistent with adjacent stations. Footnote O2 questionable.

Station 185

Cast 1 CTD Processor: "CTD O2 not reported for this station -various O2 sensor problems."
134 Intended to trip at 3478db, water samples same as NB33 at 3325db. Delta-S .000 and CTDO o2 values very similar at both levels. Probably would not be questioned if obvious trip problems these bottles had not occurred on subsequent stations. Used NB33 CTD trip data for NB34. Footnote bottle did not trip as scheduled.
124 Sample log: "needs O ring on bottom." Sample values consistent with CTD and Adjacent stations.
102-136 See 101 O2 comment. Footnote O2 questionable.

Station 186

Cast 1 CTD Processor: "CTD O2 not reported for this station - various O2 sensor problems."
134 Sample log: "leaks after venting from spigot," water samples same as NB33 as 3644db. Delta-S .004 high, other samples also have gradient that show mistrip clearly. Used NB33 CTD trip data for NB34. Footnote bottle did not trip as scheduled.
125 Sample log: "dripping from spigot after venting." Sample values consistent with CTD and adjacent stations.
121 Sample log: "leaking from spigot after venting." Sample values consistent with CTD and adjacent stations.
117 Sample log: "dripping from spigot after venting." Sample values consistent with CTD and adjacent stations.
112 Sample log: "Vent not closed" Delta-S .000 at 423db. Other water samples also ok.
111 Sample log: "dripping from spigot after venting." Sample values consistent with CTD and adjacent stations.
109 Sample log: "slight drip from spigot after venting." Sample values consistent with CTD and adjacent stations.
104 Spigot broken during sampling. No gases drawn.
101 Sample log: "spigot in open position." Sample values consistent with CTD and adjacent stations.

Station 187

Cast 2 CTD Processor: "CTD O2 not reported for this station - various O2 sensor problems."
234 Intended to trip at 3834db, water samples same as NB33 at 3692db. Delta-S .003 high. Therm rack lanyard from NB35 in top cap NB34 and o2 .03 lower than NB33 o2. Salinity & nutrients same as NB33. Used NB33 CTD trip data for

NB34. Footnote bottle did not trip as scheduled. Sample log: "NB34 top cap is jammed open by NB35 therm rack" Sample log: "lanyard--both therms a tangled mess." ODF recommends deletion of all bottle values for NB34. All bottle sample parameters bad.

Station 188

128 Delta-S .004 high at 2837db. Calc ok but took 4 Autosal runs to get agreement. No note re original 2 CR. CTD S & O2 have bump this level. Hydro o2 matches CTDO up trace well. Nutrient & salinity values similar to NB30 values, but hydro & CTDO o2 show good gradient. Footnote salinity questionable.

114 Sample log: "Lanyard caught in bottom end cap, leaking vigorously-leaked dry." No samples drawn.

111 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 189

135 Both original and rerun peaks were bad (off scale &erratic). Other nutrients ok. Footnote po4 lost.

113-114 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 190

133 Sample log: "Drip from btm cap after air vent open." Sample values are consistent with CTD and adjacent stations.

122 Did not trip. Pylon pin not released as ramp shaft passed through. No water samples. Removed and inspected pylon (Nr.2803) and could find no problem. OK next stations.

121 Sample log: "Small leak when air vent opened." Sample values are consistent with CTD and adjacent stations.

113-114 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 191

134 Sample log: "leaked before venting." O2 and Salt values are consistent with CTD and adjacent stations.

111 Sample log: "drips from spigot after venting." O2 and salt values are consistent with CTD and adjacent stations.

110 Bottom end cap hung up on pinger. No water samples.

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 192

117 Sample log: "dripping from bottom cap." O2 and Salinity values are consistent with CTD and adjacent stations.

110 Bottom end cap hung up on pinger. No water samples.
108 Sample log: "Leaked before venting, appears that I.D. tag was caught in upper lid." Delta-S .005 low at 207db. CTD up trace shows T & S inversions not seen on down trace. This sample in very high salinity & temp gradient. Bottle data looks good.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 193

116 Sample log: "leaks a little bit after venting." Sample values consistent with CTD and adjacent stations.
106 Delta-S .022 low at 145db. Calc ok but had computer problem on this Autosal run and had to record 2 CR reading by hand and they disagreed by .002 PSU. Sample log: "Very erratic putting out water" Assume flow problem thru spigot. Could find nothing wrong with spigot after sampling and no problems adjacent stations. Very high T & S gradients on CTD down & up traces this level. Other water samples look ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 194

127 Sample log: "has little drip from spigot after venting. "Salinity and o2 plots are consistent with CTD and adjacent stations.
121 Delta-S .002 low at 1599db. Calc & Autosal run ok. High gradient Sample log: "has little drip from spigot after venting." Salinity and o2 plots are consistent with CTD and adjacent stations.
111 Sample log: "leaks after venting." Salinity and o2 plots are consistent with CTD and adjacent stations.
110 Sample log note: "Leaks before venting." Doesn't say from where but probably from open spigot-air leak. Delta-S .001high high at 366db. Other water samples also ok.
109 Sample log: "leaks after venting little bit." Salinity and o2 plots are consistent with CTD and adjacent stations.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 195

101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 196

134-136 CTD Processor: "CTD O2 questionable, 4000 - 4662 db."
110 Sample log: "leaks before venting." Salinity and o2 plots are consistent with CTD and adjacent stations.
108 Sample log: "is a slow drip before venting." Salinity and o2 plots are consistent with CTD and adjacent stations.

106 Sample log: "is a very slow drip before venting." Salinity and o2 plots are consistent with CTD and adjacent stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 197

102-136 See 101 NO3 comment. Footnote NO3 bad.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 Shallow samples low, deep samples higher than adjacent stations. New cadmium column not stable during original run. Remainder of samples were rerun after system appeared stable but still had large change between beginning and end standards. Footnote no3 bad. Re-read original data sheets and re-did calculations without finding any large mistakes. ODF recommends deletion of no3 values.

Station 198

136 Flask broken before analysis. Footnote oxygen lost.
127 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
125 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
124 Hydro o2 appears .1 high at 1878db (o2 min) compared to adjacent stations. Calc ok. Same value as NB25 below. Possibly drawn from NB25 in error. Footnote oxygen questionable.
123 Pylon pin did not release. Bottle didn't close. Footnote no samples drawn.
121 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
117 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
114 Sample log: "dripping from bottom cap after venting." Sample values look ok compared to CTD and adjacent stations.
111 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
105 Sample log: "dripping from spigot after venting." Sample values look ok compared to CTD and adjacent stations.
102 See 101 salinity comment. Footnote salinity bad.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 End Wormley standard indicates .003 PSU drift. Second vial not run to confirm. Initial standard dial reading same as previous and subsequent stations, so assume end Wormley is bad. Delta-Ss confirm. Footnote salinity bad.

Station 199

123 See 122 salinity comment. Footnote salinity questionable.
122 Calc & Autosal runs ok. Smooth CTD gradient although fairly high for deep water (1818-2017db). Other water samples look ok. Footnote salinity questionable.

118 Nutrients same value as NB19. Salinity & o2 have normal gradient. Assume mistakenly drawn from NB119. Footnote no3 & no2 bad, ODF recommends deletion. Footnote po4 bad, ODF recommends deletion. Footnote sil bad, ODF recommends deletion.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 200

136 Sample log: "air bubble in sample 36 o2." O2 value consistent with CTDO & station 201 value. Sample log: "wrong Flask 36 >> 1122." O2 flask number originally entered incorrectly on Sample Log as 1126. Corrected to1122 at a later time.

110 Sample log: "is a drip before venting." Sample values look good compared to CTD and adjacent stations.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 201

136 One good confirmation on trip box, 7 computer confirmations in B-file. Raw data file indicates no trip at deepest level (5763db). Water samples same as adjacent levels. Used CTD trip data at next level up (5639db) for NB36 but could have tripped at NB35 level as well. Footnote bottle did not trip as scheduled.

135 DSRTs indicate NB35 tripped one level higher than intended, 5427db vs 5639db. Water samples same as adjacent levels. Used intended NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled.

134 Uncertain whether NB34 closed one or two levels higher than intended (see 133 & 135 notes.) Raw CTD data indicates confirmations at both 5164 & 4905dbs, but Therm racks indicate NB35 tripped at 5427db (level below) and NB33 tripped at 4653db (level above). Water sample values too similar at these levels to distinguish which of the two levels is correct. Arbitrarily chose 5164db CTD trip data for NB34. Footnote bottle did not trip as scheduled.

133 SIS digital thermometers and pressure sensor indicate NB33 tripped 2 levels higher than intended, 4653db vs 5427db. Water samples same as adjacent levels. Used intended NB29 CTD trip data for NB31. Footnote bottle did not trip as scheduled.

132 Hydro o2 & sil indicate bottles tripped two levels higher than intended. Other water samples same as adjacent levels. Used CTD trip data for two levels higher. Footnote bottle did not trip as scheduled.

131 SIS digital thermometers and pressure sensor, together with all water samples indicate NB31 tripped 2 levels higher than intended. 4125db vs 4653db. Used intended NB29 CTD trip data for NB31. Footnote bottle did not trip as scheduled.

115-130 Sample log: "pylon stopped at bottle 15." Water samples indicate bottles tripped two levels higher than intended. Used CTD trip data for two levels higher. Footnote bottle did not trip as scheduled.

113-114 (No Pressure) Neither NB13 nor NB14 closed. Ramp shaft stopped at 15 although 24 confirmations indicated on trip box. See 136 note. Footnote no samples drawn.

103 Delta-S .014 high at 56db. Other water samples also indicate NB3 closed deeper than intended. ODF recommends deletion of all water samples, footnote bottle leaking, samples bad.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 202

121 Sample log: "is leaking from spigot a lot." Oxy and Salinity values are good when plotted against CTD and adjacent stations. Other values also good.
110 Sample log: "still dripping." Oxy value may be .1 ml/L too high when plotted against CTDO and adjacent stations. Other values look ok. Footnote oxygen questionable.
102 Sample log: "is leaking before venting through spigot." Sample values are consistent with CTD and adjacent stations.
101-107 CTD Processor: "CTD O2 questionable, 0 - 200 db."

Station 203

122 Delta-S .004 low at 1717db. Calc & Autosal run ok. Smooth CTD trace but high gradient. Other water samples ok.
120 Delta-S .004 low at 1365db. Calc & Autosal run ok. Smooth CTD trace but high gradient. Other water samples ok.
103 Sample log: "O2 number 3 is 1017."
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 204

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 205

127 Sample log: "found NUT tubes empty and upright--took NUT samples from salts bottle." Samples not affected; ODF data acceptable.
118 Sample log: "animal taken from 18" Sample values are consistent with CTD and adjacent stations.
113 Sample log: "found NUT tubes empty and upright--took NUT samples from salts bottle." Samples not affected; ODF data acceptable.
112 Sample log: "found NUT tubes empty and upright--took NUT samples from salts bottle." Nutrient values are consistent with adjacent stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 206

236 One good confirmation on trip box, 7 computer confirmation sin B-file. Raw data file indicates no trip at deepest level (5143db). Water samples same as adjacent levels. Used CTD trip data at next level up (4991db) for NB36 but could have tripped at NB35 level as well. Footnote bottle did not trip as scheduled.

235 DSRTs indicate NB35 tripped one level higher than intended, 4787db vs 4991db. Water samples same as adjacent levels. Used intended NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled.

234 Uncertain whether NB34 closed one or two levels higher than intended (see 133 & 135 notes.) Raw CTD data indicates confirmations at both 4538 & 4284dbs, but Therm racks indicate NB35 tripped at 4787db (level below) and NB33 tripped at 4030db (level above). Water sample values too similar at these levels to distinguish which of the two levels is correct. Arbitrarily chose 4538db CTD trip data for NB34. Footnote bottle did not trip as scheduled.

233 SIS digital thermometers and pressure sensor indicate NB33 tripped 2 levels higher than intended, 4030db vs 4538db. Water samples same as adjacent levels. Used intended NB29 CTD trip data for NB31. Footnote bottle did not trip as scheduled.

232 Hydro o2 & sil indicate bottles tripped two levels higher than intended. Other water samples same as adjacent levels. Used CTD trip data for two levels higher. Footnote bottle did not trip as scheduled.

231 SIS digital thermometers and pressure sensor, together with all water samples indicate NB31 tripped 2 levels higher than intended. 3526db vs 4030db. Used intended NB29 CTD trip data for NB31. Footnote bottle did not trip as scheduled.

227 Sample log: "drips slightly from spigot after venting. "Sample values are consistent with CTD and adjacent stations.

221 Sample log: "drips slightly from spigot after venting. "Sample values are consistent with CTD and adjacent stations.

217 Sample log: "drips slightly from spigot after venting. "Sample values are consistent with CTD and adjacent stations.

215-230 Water samples indicate bottles tripped two levels higher than intended. Used CTD trip data for two levels higher. Footnote bottle did not trip as scheduled.

213-214 (No Pressure) Neither NB13 nor NB14 closed. Ramp shaft stopped at 15 although 24 confirmations indicated on trip box. See 136 note. No samples drawn.

211 Sample log: "drips slightly from spigot after venting. "Sample values are consistent with CTD and adjacent stations.

201-204 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 207

136 Sample log: "bottle is in sunlight." Sample values are consistent with Ctd and adjacent stations.

134 Sample log: "NB34 O2 is 1096." Titration problem on this sample. No OXY value to report.

114 Sample log: "Bottom of lid leaks after venting." Sample values are consistent with Ctd and adjacent stations.

113 Sample log: "bottles are in sunlight." Sample values are consistent with CTD and adjacent stations.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 208

136	Delta-S .004 high at 4890db. Took 7 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .000 high. Assume salt crystal contamination. Footnote salinity questionable.
124	Delta-S .004 high at 1920db. Took 8 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .000 high. Assume salt crystal contamination. Footnote salinity questionable.
121	Sample log: "vent was open." Sample values are consistent with CTD and adjacent stations.
119	Delta-S .006 high at 1065db. Took 5 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .002 high. Assume salt crystal contamination. Footnote salinity questionable. Sample log: "Slow drip before venting from spigot." Sample values are consistent with CTD & adjacent stations.
118	Delta-S .006 high at 914db. Took 5 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .001 high. Assume salt crystal contamination. Footnote salinity questionable.
117	Sample log: "leaks before venting through spigot" Sample values are consistent with CTD and adjacent stations.
115	Delta-S .006 high at 691db. Took 6 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .000 high. Assume salt crystal contamination. Footnote salinity questionable.
114-136	Thermometers & water samples indicate all bottle trippe done level higher than intended. Confirmations on trip box and computer ok at deepest level but capacitor did not charge as much as usual. (5077db, intended NB36 level). Used CTD trip data one level higher than intended with no water samples at 5077db. Samples acceptable after correction.
114	Sample log: "leaking through bottom cap." Plots of nutrient values & OXY are consistent with CTD & adjacent stations. Delta-S .005 high at 629db. Took 4 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .001 high. Assume salt crystal contamination. Footnote salinity questionable.
113	(No Pressure) Sample log: "did not close." NB13 not tripped. Ramp shaft stopped at NB14.
110	Sample log: "leaks before venting." Sample values are consistent with CTD and adjacent stations.
108	Sample log: "slow drip before venting." Sample values are consistent with CTD and adjacent stations.
105	Delta-S .004 high at 129db. Took 5 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .000 high. Assume salt crystal contamination. Footnote salinity questionable.
104	Sample log: "leaks before venting." Sample values are consistent with CTD and adjacent stations.
102	Sample log: "leaks before venting." Sample values are consistent with CTD and adjacent stations.
101-104	CTD Processor: "CTD O2 questionable, 0 - 100 db."
101	Delta-S .004 high at 3db. Took 5 Autosal runs to get 2 consecutive runs to agree. First run after rinses gives Delta-S .001 high. Assume salt crystal contamination.

Footnote salinity questionable. Sample log: "vent didn't close." Other than salinity, sample values are consistent with CTD and adjacent stations.

Station 209

135 Intended to trip at 5113db, water samples and DSRTs same as NB34 water samples and CTD T & P at 4910db. Used NB34 CTD trip data for NB35. Footnote bottle did not trip as scheduled.

128 Intended to trip at 3382db, water samples same as NB27 at 3129db. Delta-S .002 high. o2 & silicate have good gradients and show trip problem clearly. Used NB27 trip data for NB28 also. Footnote bottle did not trip as scheduled. NB28 and NB27 tripped at same level and have close agreement for all sample values.

127 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

125 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

121 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

119-136 See 118 NO3 comment. Footnote NO3 questionable.

118 Deep no3 1 uM/L low. Calc & peaks ok. Only note is: "new imidazole". Footnote NO3 questionable.

117 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

112 Sample log: "vent open." Sample values are consistent with CTD and adjacent stations.

111 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

109 Air vent open. Delta-S .003 low at 355db. Other water samples do not indicate leak. Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

105 Sample log: "slight drip from spigot after venting." Sample values are consistent with CTD and adjacent stations.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 210

134 Sample log: "thermometer lanyard caught in top cap, leaked before venting." Air leak. Therm rack lanyard caught in top end cap. Delta-S .000 at 4447db. Other water samples also look ok. Check final CTDO, if no problem, then this bottle did not leak. O2 plot very close to plots of previous station & CTDO. Bottle did not leak.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 211

136 Hydro o2 appears .05 high at 5585db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples

this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

135 Hydro o2 appears .06 high at 5455db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 1 helium sample drawn before o2. Similar problem on other samples this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

133 Hydro o2 appears .2 high at 4990db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

131 Hydro o2 appears .05 high at 4478db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 1 helium sample drawn before o2. Similar problem on other samples this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

130 Hydro o2 appears .02 high at 4220db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 1 helium sample drawn before o2. Similar problem on other samples this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

128 Hydro o2 appears .02 high at 3708db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 221 & 225 when many samples taken before o2. Footnote OXY questionable.

123 See 122 nutrient comments. Footnote nutrients questionable.

122 NBs 22 & 23 nutrients same at 2332db & 2560db. Possibly drawn from same bottle but adjacent stations show some nutrient features this level. o2, S & T have normal gradients. Footnote nutrients questionable.

119-136 See 118 NO3 comment. Footnote NO3 questionable.

118 Deep NO3 1 uM/L high. Note on data sheet: "Cd column refurbished" Next station (212) no3 also high then back to normal on Station 213. Calc & peaks ok. Footnote NO3 questionable.

114 Sample log: "leaking from bottom cap after venting." Sample values are consistent with CTD and adjacent stations.

113 o2 flask broken before analysis. Footnote OXY lost.

103 Sample log: "O2 NB3 is 869."

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

101 Sample log: "leaks a little through bottom cap after venting." Sample values are consistent with CTD and adjacent stations.

Station 212

127 Sample log: "dripping from spigot after venting." Plots of sample values, except as noted, look ok.

125 Sample log: "dripping from spigot after venting." Plots of sample values, except as noted, look ok.

121 Sample log: "dripping from spigot after venting." Plots of sample values look ok, except as noted.

119-136 See 118 NO3 comment. Footnote NO3 questionable.

118 Deep no3 1 uM/L high. Note on Sta 211 data sheet: "Cd column refurbished" Station 211 had high no3 also. back to normal on Station 213. Calc & peaks ok. Read standards, blanks, peaks and did calculations; everything looks ok. May be real. Footnote NO3 questionable.
111 Sample log: "dripping from spigot after venting." Plots of sample values, except as noted, look ok.
110 Sample log: "drips before venting spigot." Plots of sample values, except as noted, look ok.
102-136 See 101 salinity comment. Footnote salinity questionable.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 0.007 PSU drift on Autosal run. Room temp went from 24.0 to 24.9 during run. Bath temp 24C. Delta-Ss look ok. Std dial same as previous station. 2 end vials confirm. Footnote salinity questionable.

Station 213

136 Delta-S .004 high at 5393db. 5 Autosal runs. 1st run after rinses gives Delta-S .000. Footnote salinity questionable.
121 Sample log: "dripping from spigot after venting." Sample values are consistent with CTD and adjacent stations.
114 Sample log: "bottom lid leaks after venting." Sample value sare consistent with CTD and adjacent stations.
103 Sample log: "potential mix-up during O2 sampling, e NB4,NB3, in sampling order most likely correct. Note if unusual sampling results." Plots of o2 values are consistent with CTDO and adjacent stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 214

121 Sample log: "dripping at spigot after venting." Sample values are consistent with CTD and adjacent stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 215

130 Sample log: "Slow drip on spigot after venting." Sample values are consistent with CTD and adjacent station 216.
114 Sample log: "leak after venting through bottom cap." O2 and salinity values look ok. Nutrients for NB14 have same value as NB15. Other water samples and adjacent stations have normal gradients. Apparently 114 nutrient sample drawn from NB15. Footnote no3, po4, sil, and no2 as bad, ODF recommends deletion.
113 Sample log: "leak after venting through bottom cap. "Compared to CTD data, O2 appears .2 ml/l low and salinity appears steep gradients. Sample values ok.
101-103 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 216

134 Sample log: "drips very slowly from open spigot before venting and from closed spigot after venting." Sample values are consistent with CTD and adjacent stations.
133 Sample log: "possible skip of NB33--have off 1 number. "Drawing error-No oxygen sample drawn. Other samples ok.
112 Sample log: "drips before venting spigot." Sample values are consistent with CTD and adjacent stations.
110 Sample log: "drips from closed spigot before venting, not popped." Sample values are consistent with CTD and adjacent stations.
108 Sample log: "drips from spigot before venting." Sample values are consistent with CTD and adjacent stations.
101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 217

134 Sample log: "leaks from spigot before venting." Sample values are consistent with CTD and adjacent station.
132 Sample log: "Helium 32 (one failed)."
117 Sample log: "bottle NB17- ran out of H20 during sample collection - potential bubbles in sample." Sample log: "O2 NB27 is 1086." Sample log comments refer to alkalinity, the last sample drawn.
111 Sample log: "spigot dripping after venting." Sample values are consistent with CTD and adjacent station.
109 Sample log: "spigot dripping after venting." O2 value in agreement with CTDO and station 218. Delta-S is high at .007. However, bottle data in close agreement with up-trace in this high gradient depth range.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."
101 o2 titrated in two parts. 1st titration stopped for unknown reason. Did a 2nd titration and added the 2 raw titers for calculation. Surface value looks 0.1 to 0.2 high compared to adjacent stations. Footnote o2 bad. ODF recommends deletion of oxygen.

Station 218

228 Sample log: "O2 started sampling at 28, then switched to 36 after 19."
219 Sample log: "Bottom Cap Leak on doesn't reseat." Sample values are consistent with CTD and adjacent stations.
212 Sample log: "Small leak from spigot on opened, not popped." Sample values are consistent with CTD and adjacent stations.
205 PO4 appears .2 high at 100db. Other nutrients and water samples ok. Same value as 204 which is also high. Contamination? Footnote PO4 questionable.
204 PO4 appears .3 high at 80db. Other nutrients and water samples ok. Same value as 205 which is also high. Contamination? Footnote PO4 questionable.
201-204 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 219

125 Sample log: "cleaned MnCl pump after bottle NB25, MnCl pump cleaned and greased after bottle NB17." Sample values are consistent with CTD and adjacent station.
120-121 Sample log: "syringes for bottles NB20 + NB21 reversed, (first collected has rubber band on it)." This comment would not affect ODF samples.
119 Sample log: "leaks from bottom cap after venting." Sample values are consistent with CTD and adjacent station.
108 Sample log note: "Number tab caught in top cap" Footnote bottle leaking. Delta-S .000 at 260db. Other water samples also look ok.
106 Sample log: "Flask 1057 on bottle 6, got an air bubble in it during pickling w/MgCl." O2 value compares well to CTDO and value on previous station.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 220

124 Sample log: "small spigot leak after air vent opened." Sample values are consistent with CTD and adjacent stations.
111 Delta-S .116 high at 434db. Other water samples also indicate bottle closed deeper. Footnote did not trip as scheduled, and all water samples bad. ODF recommends deletion of all water samples, not sure exactly where this bottle tripped.
109 Delta-S .058 low at 308db. Calc & Autosal run ok. Large CTD T & S spike on up trace at trip level. All water samples look ok.
108 Sample log: "Lanyard tab in top end cap" Footnote bottle leaking. Delta-S .008 low at 257db but small CTD spike on up trace (See 109). Hydro salt and other water samples look ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 221

136 Hydro o2 appears .05 high at 4944db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 225 when many samples taken before o2. Footnote oxygen questionable.
132 Hydro o2 appears .07 high at 4108db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 1 helium sample drawn before o2. Similar problem on other samples this station and Stations 211 & 225 when many samples taken before o2. Footnote oxygen questionable.
125 Sample log: "O2 NB25 is 699."
122 PO4 appears .04 high at 1905db. Peak fair, definitely high. Footnote po4 questionable.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 222

132 Sample log: "Slight drip before venting on 32 - air leak. "Sample values look ok on plots.
111 Delta-S .035 high at 537db. Calc & Autosal runs ok. Other water samples also indicate bottle closed early, just after start up from previous bottle. Same problem sample 110. Reason unknown. Footnote bottle did not trip as scheduled, footnote all water samples bad. ODF recommends deletion of all samples.
110 Delta-S .043 high at 462db. Calc & Autosal runs ok. Other water samples also indicate bottle closed early, just after start up from previous bottle. Same problem sample 111. Reason unknown. Footnote bottle did not trip as scheduled, footnote all water samples bad. ODF recommends deletion of all samples.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 223

121 Sample log: "leaking from spigot after venting." Plots of sample values are consistent with CTD and adjacent station.
108 Delta-S .026 high at 280db. CTD up T very different from down T. Other water samples ok.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 224

116 No water, bottom end cap apparently hung up & closed as rosette came out of water. Footnote no samples drawn.
111 Sample log: "leak from spigot after venting." Sample values are consistent with CTD and adjacent station.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 225

136 Hydro o2 appears .1 high at 4821db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.
135 Hydro o2 appears .07 high at 4636db. Calc & titration ok. No notes. 1 freon, 1 CCl4, & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.
134 Hydro o2 appears .02 high at 4405db. Calc & titration ok. No notes. 1 freon & 1 CCl4 sample drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.
133 Hydro o2 appears .03 high at 4197db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 1 helium sample drawn before o2. Similar problem on other samples this

station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.

131 Hydro o2 appears .03 high at 3812db. Calc & titration ok. No notes. 1 freon & 1 CCl4 sample drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.

129 Hydro o2 appears .02 high at 3440db. Calc & titration ok. No notes. 1 freon & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.

128 Hydro o2 appears .02 high at 3244db. Calc & titration ok. No notes. 1 freon & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.

126 Hydro o2 appears .02 high at 2849db. Calc & titration ok. No notes. 1 freon, 1 CCl4 & 2 helium samples drawn before o2. Similar problem on other samples this station and Stations 211 & 221 when many samples taken before o2. Footnote oxygen questionable.

110 Delta-S .240 high at 429db. Other water sample also from deeper levels. Possibly bottom end cap closed early. Similar problem this bottle last station. Adjusted bottom lanyard next station. Footnote bottle did not trip as scheduled, footnote all water samples bad. ODF recommends deletion of all water samples.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 226

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 227

126 Sample log: "O2 bottle remove flask lid from bottle, replace with 1065."

125 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

121 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

111 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

109 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

107 Sample log: "drips from spigot after venting." Sample values are consistent with CTD and adjacent stations.

101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 228

129-133 See 128 SIL comment. Footnote silicate questionable.

128 Appear 1 to 3 uM/L low. Calc & peaks ok. Footnote silicate questionable.

120 Intended to trip at 1448db, water samples same as NB19 at 1240db. Used NB19 CTD trip data for NB20. Footnote bottle did not trip as scheduled.
108 No po4. Note on data sheet: "sample spilled, not enough for run." Other nutrients look ok. Footnote PO4 lost.
107 Delta-S .040 low at 182db. Calc & Autosal run ok. Much noise on CTD up trace at this level. All water samples look ok. Footnote CTD salinity bad. CTDO is coded bad because the CTD salinity is coded bad.
101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 229

236 No trip confirmation. All water samples same as NBs 35 & 34 tripped 35db above. Silicate is only property with gradient this level. NB36 may have tripped 35db above intended level of 4467db.
230 Delta-S .005 high at 3462db. 6 Autosal runs to get agreement. First run after rinse gives Delta-S .000. Footnote salinity questionable.
227 Sample log: "drips from around spigot." Sample values are consistent with CTD and adjacent stations.
225 Sample log: "drips from around spigot." Sample values are consistent with CTD and adjacent stations.
222 Sample log: "Major leak through top end cap" Assume air leak. Delta-S .000 at 1741db, other water samples also ok.
221 Sample log: "drips from around spigot." Sample values are consistent with CTD and adjacent stations.
220 Intended to trip at 1341db, water samples same as NB19 at 1196db. Used NB19 CTD trip data for NB20. Footnote bottle did not trip as scheduled. Delta-S at new level .002 high .4 Autosal runs to get agreement. First run after rinse gives Delta-S .000 at NB19 level. Footnote salinity questionable.
217 Sample log: "NB117 has small spigot leak." Sample values are consistent with CTD and adjacent stations.
211 Sample log: "drips from around spigot." Sample values are consistent with CTD and adjacent stations.
201-236 Sample log: "rotor on 24-place pylon advanced one place. "Sample plots look ok. No affect on data.
201-204 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 230

135 Intended to trip at 4216db, water samples & DSRT values same as NB34 at 4065db. Used NB35 CTD trip data for NB36. Footnote bottle did not trip as scheduled. Delta-S .003 high for both intended & new levels. 4 Autosal runs to get agreement. First run after rinse gives Delta-S .000. Footnote salinity questionable.
131 Intended to trip at 3453db, water samples and DSRT values same as NB30 at 3248db. Used NB30 CTD trip data for NB31. Footnote bottle did not trip as scheduled.
120 Intended to trip at 1210db, water samples same NB19 at 1027db. Used NB19 CTD trip data for NB20. Footnote bottle did not trip as scheduled.

102 Delta-S .012 high at 25db. Autosal run ok. High gradient. Sample log: "leaks before venting." Oxygen agrees with adjoining stations.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 231

134 Sample log: "leaks - air leak though top cap - does not reseat." Sample values agree with adjacent station and CTD.
101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 232

134 Sample log: "slow drip before venting - air leak." Drip does not affect data.
133 Sample log: "slow drip before venting - air leak." Drip does not affect data.
131 Sample log: "slow drip before venting w/ spigot closed." Drip does not affect data.
125 Sample log: "has small drip from spigot after venting." Drip does not affect data.
121 Sample log: "slow drip before venting w/ spigot closed." Sample log: "has small drip from spigot after venting." Drip does not affect data.
117 Sample log: "small drip from spigot after venting." Drip does not affect data.
112 Sample log: "slow drip before venting - air leak." Drip does not affect data.
111 Sample log: "small drip from spigot after venting." Drip does not affect data.
110 Sample log: "squirts once, then seals from spigot." Sample log: "not popped." Drip does not affect data.
109 Sample log: "small drip from spigot after venting." Drip does not affect data.
105 Sample log: "small drip from spigot after venting." Delta-S.025 high at 102db. Autosal run ok. High gradient. Drip does not affect data.
104 SIL appears 6 uM/L high at 76db. Peak fair but definitely high. Other nutrients ok. Footnote SIL questionable.
101-104 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Station 233

110 Sample log: "leaking from spigot when coming on board." Samples appear to be okay.
101-105 CTD Processor: "CTD O2 questionable, 0 - 100 db."

Quality Comments

Remarks for missing samples, and WOCE codes other than 2 from JUNO - WOCE P16A/P17A Large Volume Samples. Investigation of data may include comparison of bottle salinity and silicate data from piggy-back and Gerard with CTD cast data, review of data plots of the station profile and adjoining stations, and rereading of charts (i.e., nutrients). Comments from the Sample Logs and the results of ODF's investigations are included in this report.

Station 146

347 @2111db Left protected & middle protected therms both malfunction, no temperature readings.
389 @2111db See thermometer failure on NB347.
141 @2557db Delta-S (n-g) at 2557db is 0.0059, salinity is 34.732. Salinities in gerard (81) & niskin (41) are equally off when compared with rosette cast. No indication of any problems in sample log. Footnote salinity uncertain. Silicate values slightly low, but within precision of measurement.
181 @2558db Footnote salinity uncertain. Other gerard sample integrity to be determined by PI.
144 @3156db Delta-S (n-g) at 3156db is 0.0031, salinity is 34.722. Values from NB44 are OK. See comments for GER 84.
184 @3156db Salinity and silicate low compared with NB44 & rosette. Footnote salinity uncertain.
145 @3356db Delta-S (n-g) at 3356db is 0.0026, salinity is 34.719. Gerard salinity & silicate acceptable.

Station 157

347 @2164db Both left protected & middle protected therms malfunctioned. No temperature.
389 @2165db See therm failure on NB347.
141 @2778db Therm Sheet:"41 Nis no trip, therm OK". No samples from NB 141. Samples from GER 181 are OK.
187 @4045db Therm Sheet:"87 did not drop messenger". Samples from both Ger 187 and piggy-back Nis 146 are OK. However, Ger's 189, 190, 193 and piggy-back Niskins did not close.

Station 164

347 @2114db Sample log: "Therm ok, bottle no trip." No water samples from this bottle.
241 @2690db Delta-S (n-g) at 2690db is 0.0045, salinity is 34.712. Ger 81 salinity value closer to rosette value than Nis 41. Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote Salinity & Silicate uncertain.
281 @2691db See 241 salinity and silicate values.
242 @2945db Delta-S (n-g) at 2945db is 0.0057, salinity is 34.711. Ger 82 salinity value closer to rosette value than Nis 42. Silicate value about 3 UMOL/KG higher

than associated Ger. Ger value close to rosette value. Footnote salinity & silicate uncertain.

282 @2945db See 241 salinity and silicate values.

243 @3199db Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.

283 @3200db See 243 silicate value.

244 @3454db Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.

284 @3454db See 244 silicate value.

245 @3708db Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.

285 @3708db See 245 silicate value.

246 @3962db Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.

287 @3963db See 246 silicate value.

247 @4217db Silicate value about 3 UMOL/KG higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain. Footnote silicate uncertain.

289 @4217db See 247 silicate value.

248 @4420db Silicate value about 3 UMOL/KG higher than associated Ger. Nis value closer to rosette value than Ger 90.

290 @4420db See 248 silicate value.

Station 187

341 @ 749db Niskin 41 not tripped. Niskin trip arm on Gerard 81 not down far enough. No Niskin samples. Gerard salt & silicate agree well with Rosette data.

348 @1808db N-G .003 low at 1808db. Calc & Autosal runs ok. Leave for now. 930111/dm Nis 48 piggy-back on Ger 90.

390 @1809db See 348 salinity comment.

149 @2105db Niskin 49 not tripped. Niskin trip arm on Gerard 81 not down far enough. No Niskin samples. Nisken 41 normally on this Gerard so thought bottle mismatch was problem. Gerard salt & silicate agree well with Rosette data.

189 @3483db N-G .048 high. Gerard salinity and silicate both appear to be from higher in water column. Footnote salinity and silicate bad.

142 @3713db Nis 42 is bottle associated with Ger 90.

190 @3714db N-G .005 high at 3714db. Gerard silicate also a little lower (1.5) than the Niskin silicate indicating a possible small leak in Gerard sample. Footnote silicate and salinity uncertain.

Station 206

341 @1257db N-G .005 high at 1257db. Took 4 Autosal runs to get 2 runs to agree. Probably salt crystal contamination. First Autosal run after rinses gives N-G .001 low. Gerard salt and silicates good.

346 @2012db N-G .006 high at 2012db. Took 7 Autosal runs to get 2 runs to agree. Probably salt crystal contamination. First Autosal run after rinses gives N-G .0004 low. Gerard salt and silicates good.

Station 218

341 @1500db N-G salt .005 high at 1500db. 4 Autosal runs to get agreement. First run after rinses gives N-G .000. Used first run. 930114/dm

142 @3164db Sample Log: "Tube (plastic) in upper lid." No samples.

147 @4558db Sample Log: "Lanyard hung up". No samples.

Station 229

383 (No Pressure) Gerard Barrel 83 failed to trip on cast 3. Messenger was on trip arm with latch not pushed quite far enough to close lid. Messenger not released. Re-lowered untripped barrels to shallower terminal reading as cast 4.

449 @1909db DSRTs not shaken down from previous cast. Same readings as NB49 on Cast 1. Footnote bad thermometer readings.

D. Acknowledgments

This expedition represents the sum cooperative efforts of a great many talented and dedicated people. Captain Swanson, his officers, and crew deserve a 'hats off' for their enthusiasm and expertise, countless efforts to improve and maintain the Knorr's performance, and careful work. The scientific group, assembled from several institutions, treated the expedition not as a grab bag of diverse measurements, but as one program, the WOCE program. Their dedication and skill show in the exceptional quality of these data. And none of this would have been possible without the advice and generous support received from the National Science Foundation, which supported this work via grant NSF OCE93-00648.

E. References

Unesco, 1983. International Oceanographic tables. Unesco Technical Papers in Marine Science, No. 44.

Unesco, 1991. Processing of Oceanographic Station Data. Unesco memorgraph By JPOTS editorial panel.

F. WHPO Summary

Several data files are associated with this report. They are the 316N138_10.sum, 316N138_10.hyd, 316N138_10.csl and *.wct files. The 316N138_10.sum file contains a summary of the location, time, type of parameters sampled, and other pertinent information regarding each hydrographic station. The 316N138_10.hyd file contains the bottle data. The *.wct files are the ctd data for each station. The *.wct files are zipped into one file called 316N138_10.wct.zip. The 316N138_10.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 316N138_10.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.

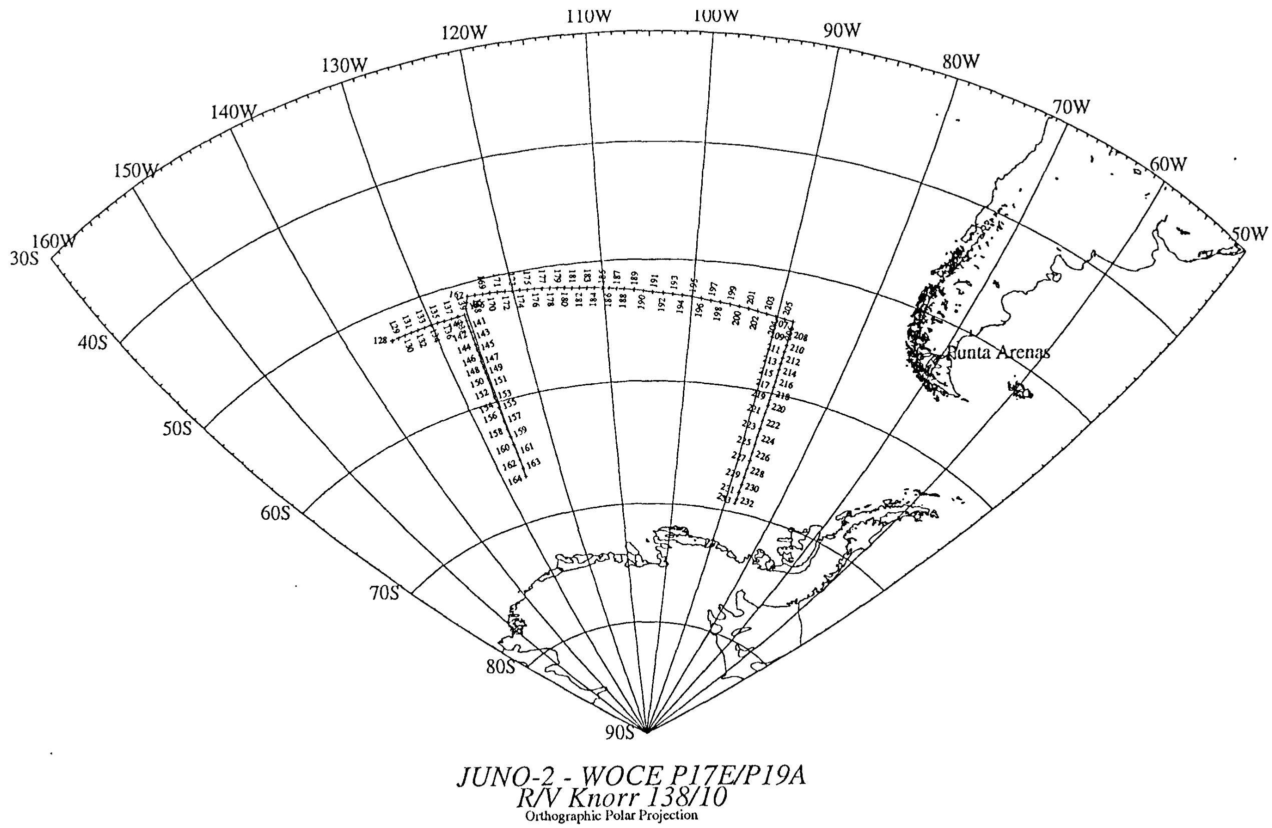
Potential Vorticity (POT-V: 1/ms 10-11) is calculated as the vertical component ignoring contributions due to relative vorticity, i.e. pv=fN2/g, where f is the coriolius parameter, N is the buoyancy frequency (data expressed as radius/sec), and g is the local acceleration of gravity.

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.

G. Data Quality Evaluation

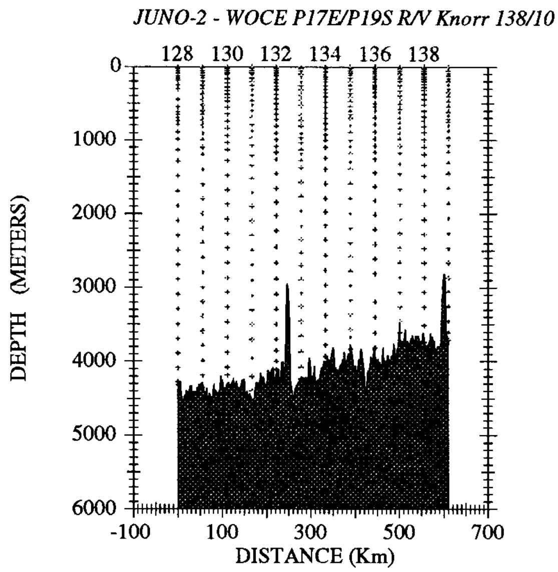


30S
40S
50S
60S
70S
80S
90S
160W
150W
140W
130W
120W
110W
100W
90W
80W
70W
60W
50W
Punta Arenas
JUNO-2 - WOCE P17E/P19A
R/V Knorr 138/10
Orthographic Polar Projection

Figure 1

BOTTLE DEPTH DISTRIBUTIONS:

Rosette Stations



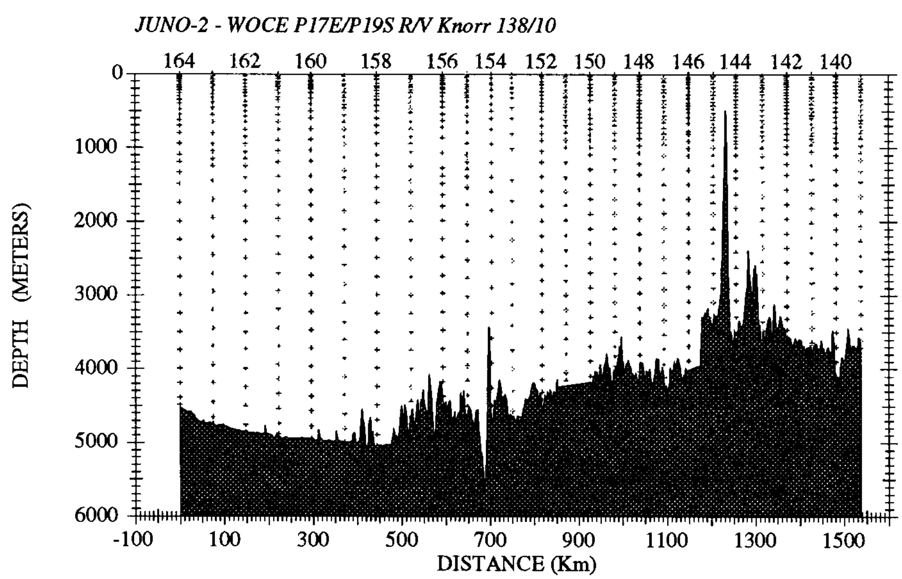
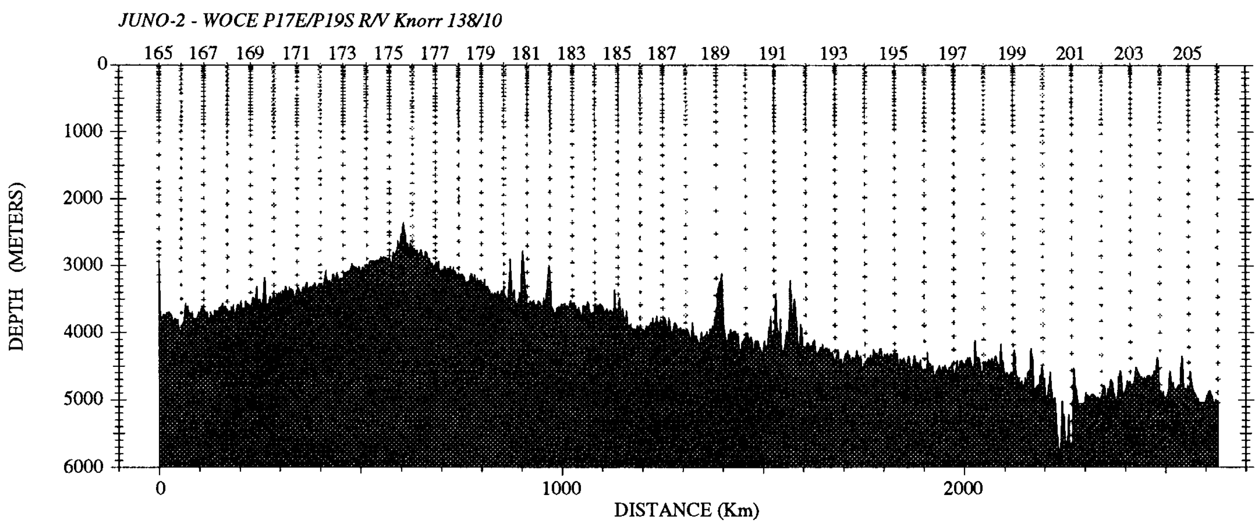


Figure 2

Rosette Stations



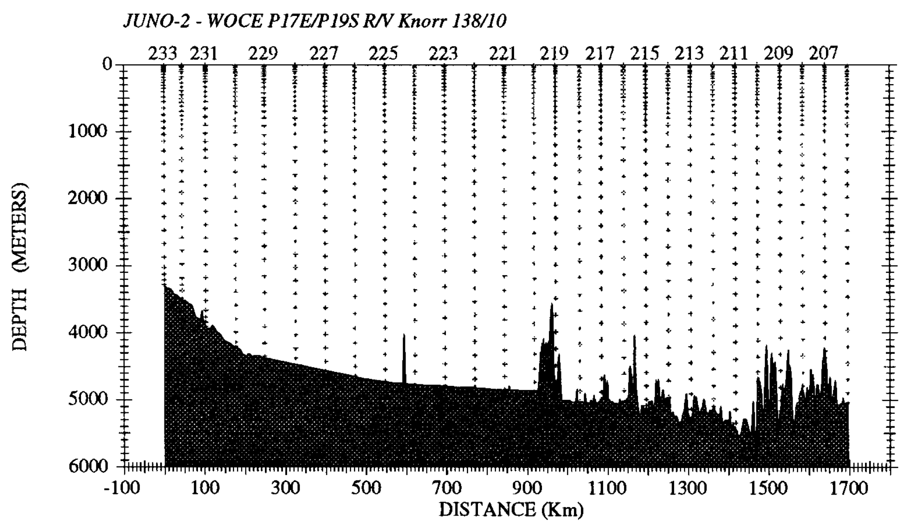
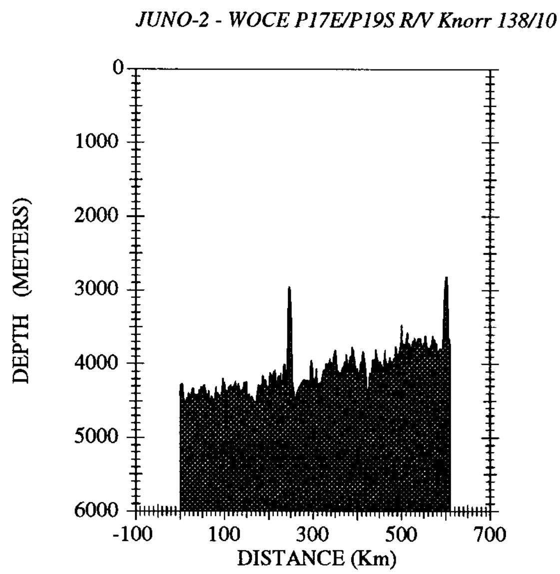


Figure 3

Large Volume Stations



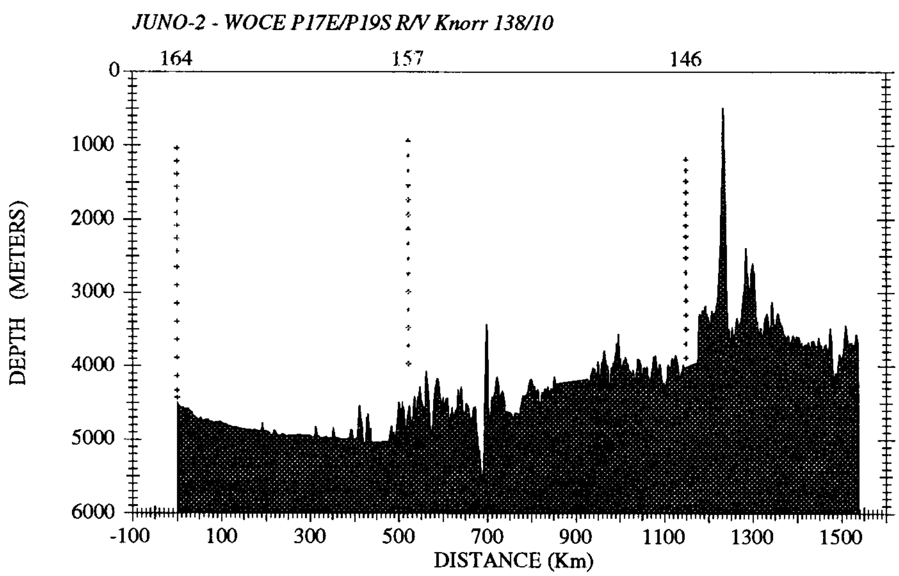
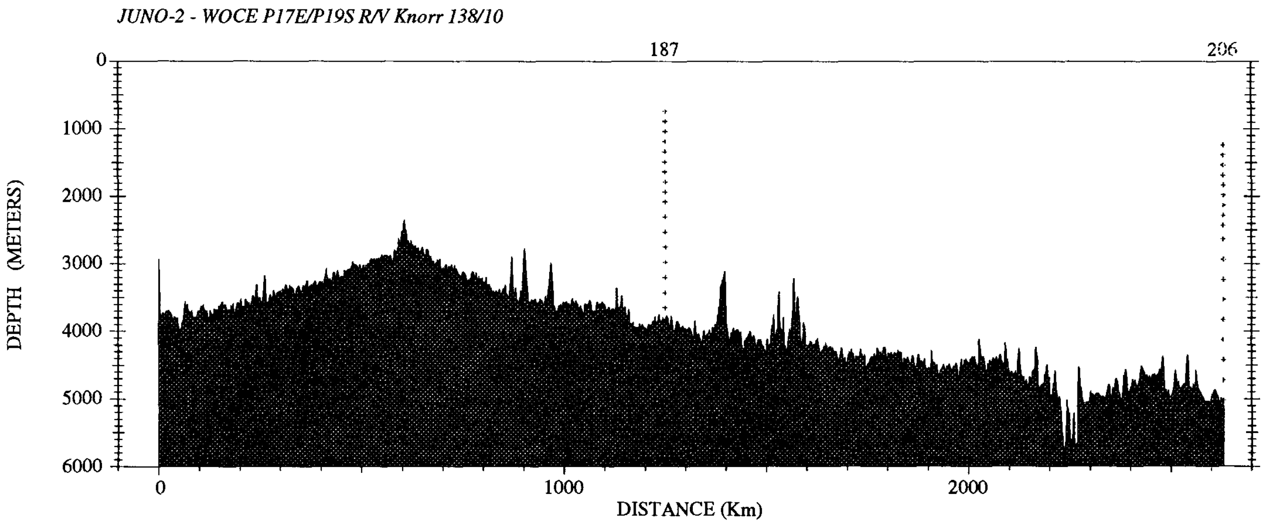


Figure 4

Large Volume Stations



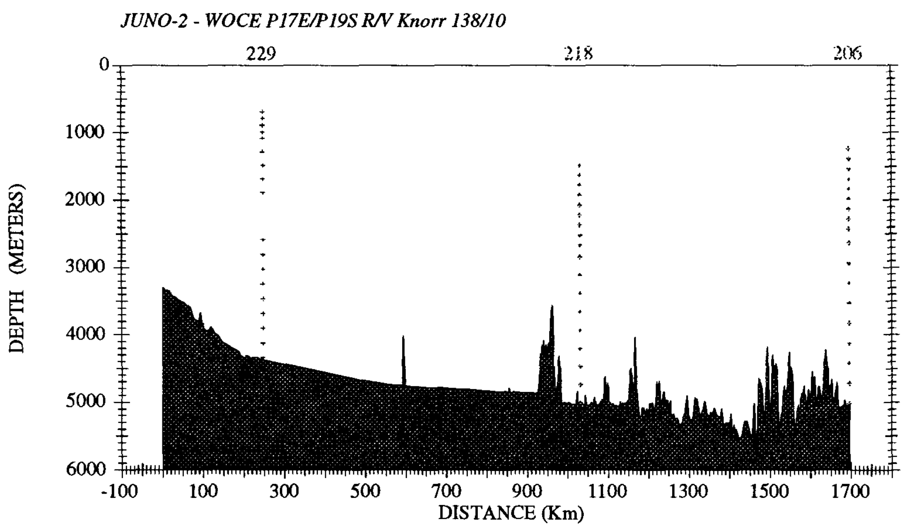


Figure 5

Appendix A:

Improving the Measurement of Pressure in the NBIS Mark III CTD

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ABSTRACT

A software model for correcting the dynamic response of the Paine Instruments stainless steel strain-gauge pressure transducer used in the NBIS Mark IIIB CTD is described. Laboratory calibration techniques and the response characteristics of strain-gauge transducers are discussed. Experimental data supporting the model are presented.

August 23, 1994
Preliminary Draft

1. Introduction

The NBIS Mark IIIB CTD uses a stainless steel strain-gauge pressure transducer to measure pressure. The early models contained sensors produced by Standard Controls. Later versions contain sensors from Paine Instruments, with no significant differences in their characteristics. These sensors have proven to be reliable and of adequate sensitivity and stability for oceanographic profiling applications. Their accuracy depends upon careful and frequent calibration, with attention paid to their response characteristics. With an understanding of these characteristics, and applying an appropriate correction model, pressure accuracy of 2 db or better can be consistently attained. This level of pressure accuracy is necessary to insure the accuracy of parameters calculated from pressure; a 4 db error in pressure can result in a 0.002 PSU error in calculated salinity. The manufacturer's specifications are shown in Table 1 and have been found to be generally conservative.

Pressure range	0-8850 psi (0-6100 db)
Compensated temperature range	-32 to 151°C
Thermal zero shift	0.01 %F.S./°F (1.10 db/°C)
Thermal sensitivity shift	0.005% F.S./°F (0.55 db/°C)
Non-linearity and hysteresis	±0.25% F.S. (±15.25 db)
Shock, vibration, acceleration	0.01% F.S./G (0.61 db/G)
Repeatability	±0.05 %F.S. (±3.05 db)

Table 1.
Specifications of Paine Instruments Model 211-35-090-05 strain-gauge pressure transducer.

Most pressure calibration methods have concentrated on measuring steady-state responses. A dead-weight tester is used to measure non-linearity and hysteresis in the pressure response. Used in conjunction with a temperature-controlled bath, thermal zero and sensitivity shift can be measured. A response characteristic that varies with time before it reaches a steady-state is a dynamic response. For oceanographic applications where both pressure and temperature are changing, dynamic response characteristics become important.

The Mark III CTD Strain-gauge has a thermal response-time several orders of magnitude greater than the pressure response-time, due to the physical location of the sensor. The transducer is threaded into a port drilled through the CTD pressure case endcap, and located on the inside face. Most of the sensor is inside the pressure case, surrounded by a substantial mass of low thermal conductivity stainless steel. The strain-gauge is insulated from the ambient temperature by water filling the port and the material encasing the sensing element. Thermal response-time constants on the order of 400 seconds are not unusual. In the ocean, the sensor can be responding to temperatures differing from the ambient by more than 20°C, depending on profiling velocity and temperature gradients.

Non-linearity and hysteresis are characteristics of the sensor's response to pressure. The amount of hysteresis is dependent upon the maximum pressure applied to the sensor. Typical pressure response-times are less than 40 milli-seconds.

Stability is a measure of how often a sensor must be calibrated to insure some criteria for accuracy. This depends on how frequently the sensor is used, how it is employed, and the required accuracy. Typical stability metrics for 2 db pressure accuracy are on the order of months, and it is usually sufficient to calibrate Mark III pressure sensors immediately before and after 1-2 month expeditions.

A response-correction model for Mark III CTD pressure based on these sensor characteristics must describe the pressure response as functions of pressure, maximum pressure, temperature, and time.

One such model, together with appropriate calibration techniques, was developed by the authors and has been in use for several years. This method interpolates the pressure correction, using the sensor pressure signal and an estimate of the sensor temperature, from tables of calibration values measured at two or more temperatures. The number of calibration temperatures and pressures are selected such that the response of the transducer is adequately defined. In practice, pressure calibrations are performed to low (25% F.S.) and full-scale pressures at each of two widely-spaced temperatures, typically 0 and 25°C. An estimate of the sensor thermal response-time is made by plunging the thermally-equilibrated instrument into an ice-bath, generating a thermal step-change. Corrections are derived by linear interpolation between calibration points selected from the tables using the uncalibrated sensor pressure and a temperature modeled for the thermal response of the sensor.

This technique can be applied to other types of pressure transducers, where non-linear response characteristics make simpler models impractical. It has the advantage of operating directly from the pressure calibration data.

2. Temperature Effects

The response of a Mark III pressure transducer to a step-change in temperature can be modeled as the sum of at least two different responses with different response-times.

The faster thermal response is due to internal strain-gauge temperature compensation. The manufacturer uses a resistive temperature-compensating element in the transducer that ideally would exhibit the same thermal response-time as the strain-gauge, exactly canceling the temperature response. In practice this is not readily achieved, as the compensating element must be exactly matched to an individual sensor. The temperature compensation is adequate to bring the response to within the manufacturer's specifications, but typically introduces a second temperature response due to mismatches of the magnitude and response-time of the compensation. Figure 1.0 (not included) illustrates typical Mark III pressure response to a temperature step-change.

The original Mark III CTD design further complicates the pressure response by an additional attempt at temperature compensation using a thermister attached to the transducer. The response-time of the thermister is grossly mismatched to the transducer, and its placement is such that it does not measure the transducer temperature. The correction techniques discussed in this paper assume that this compensation has been removed.

The pressure signal can be corrected for thermal response by

$$P_{corrected}=P_{raw}+k_1T_{lagged1}+k_2T_{lagged2} \quad (1.0)$$

Where:

k_1 is the temperature coefficient (db/°C) associated with the first thermal response;
$T_{lagged1}$ is the lagged temperature associated with the first thermal response;
k_2 is the temperature coefficient (db/°C) associated with the second thermal response; and
$T_{lagged2}$ is the lagged temperature associated with the second thermal response.

The lagged temperatures can be modeled satisfactorily as a simple exponential decay with no initial delay. They are modeled from the in-situ temperature using response-time constants determined experimentally:

$$T_{lagged}=e^{-dt/\tau}T_p+(1-e^{-dt/\tau})T \quad (2.0)$$

Where:

dt is the measurement period in seconds;
τ is the temperature response-time constant in seconds;
T_p is the previous lagged temperature;
T is the in-situ temperature.

Figure 1.0 (not included) illustrates Mark III CTD pressure response to a step change in temperature, together with a 2 term exponential model of the response.

One problem with modeling a sensor temperature from the in-situ temperature is the choice of an appropriate initialization value. Using the out-of-water CTD pressure and the pressure calibration, a reasonably-accurate initial temperature can be calculated. Because of the long response-time associated with the thermal response, care should be taken to insure the CTD is reasonably equilibrated with the ambient temperature and does not heat up from exposure to the sun.

3. Pressure Response

Strain-gauge transducers typically exhibit a non-linear pressure response. Correcting the response is complicated by hysteresis. This hysteresis is reproducible, and is dependent on the maximum pressure applied to the sensor. Figure 2.0 (not included) illustrates the pressure correction curves obtained from a Mark III CTD calibrated to several maximum pressures at two different temperatures. To correct for hysteresis, it is necessary to construct an unloading correction curve based on the maximum pressure applied to the sensor.

4. Pressure Hysteresis Correction

A simple method for approximating the unloading curve correction uses the ratio of the observed maximum pressure to the calibration maximum pressure to scale the amount of hysteresis measured in the calibration (see Figure 3.0; not included):

1. A pressure calibration is performed to some maximum calibration pressure (the "loading" calibration), then back to zero pressure (the "unloading" calibration). Sufficient calibration points are taken to clearly define the response curve. The calibration is then used to correct sensor response.
2. The sensor response is corrected using the temperature correction and the loading calibration correction until the pressure decreases (begins unloading). The corrected maximum loading pressure P_{max} and the maximum calibration pressure P_{cal} are noted.
3. The proportion P_{max}/P_{cal} is calculated. The amount of hysteresis (the difference between loading and unloading calibration curves) at 0 decibars is scaled by P_{max}/P_{cal} to give H_0. The amount of hysteresis at P_{max} gives H_{max}.
4. The slope and intercept of the line between H_0 and H_{max} is calculated.
5. At any pressure less than P_{max}, the difference between this line and the original unloading curve represents the amount of hysteresis at that pressure. This difference, when subtracted from the original loading curve, generates the unloading curve.

Complications to this technique are introduced when repeated raising and lowering of the CTD (a "yo-yo" cast) is necessary. The correction scheme must provide a mechanism for returning along the unloading curve to the loading curve when the original maximum pressure is exceeded, and the construction of a new unloading curve based on the most recent maximum pressure.

ODF Pressure Calibration for Transducer 131910

Calibration Date: 5 May 1993
Calibrated by: rp

Temperature Response Time Constants = 58.2487 426.765
Temperature Response Coefficients = 0.251782 -0.360534
Temperature Response Offset = 0.0
Lagged Temperature Initialization Range = 1.000000 50.000000
Initial Pressure Offset = 0.0
Raw Pressure Offset = 0.0
Conductivity Limit = 15.0
Surface Atmospheric Pressure = 0.0
Minimum Unloading Curve Interpolation Pressure = 50.0
Unloading State Pressure Threshold = 3.0
Sampling Period = 0.5

Calibration Pressures:

Loading:

0.00	20.81	89.65	158.48	227.32	296.17	364.98	502.66
640.34	709.18	846.86	1053.36	1397.62	1741.82	2086.07	2430.27
2774.53	3118.75	3463.04	4151.57	4840.11	5528.67	6079.51	

Unloading:

0.00	20.81	89.65	158.48	227.32	296.17	364.98	502.66
640.34	709.18	846.86	1053.36	1397.62	1741.82	2086.07	2430.27
2774.53							

Unloading:

0.00	20.81	89.65	158.48	227.32	296.17	364.98	502.66
640.34	709.18	846.86	1053.36	1397.62	1741.82	2086.07	2430.27
2774.53	3118.75	3463.04	4151.57	4840.11	5528.67	6079.51	

Calibration Temperature = 0.01

Loading:

16.99	37.71	106.33	174.94	243.58	312.29	380.99	518.57
656.29	725.20	863.10	1069.79	1415.04	1760.28	2105.36	2450.08
2794.53	3138.57	3482.50	4170.12	4857.54	5544.99	6095.17	

Unloading:

17.02	37.86	107.19	176.16	245.79	315.14	384.20	522.67
661.58	730.84	869.26	1076.73	1421.61	1765.70	2109.16	2452.07
2794.53							

Unloading:

16.21	37.07	106.33	175.69	245.03	314.38	383.42	522.17
661.13	730.46	869.06	1076.69	1422.21	1766.93	2111.18	2454.98
2798.53	3141.86	3485.13	4171.59	4858.27	5545.20	6095.17	

Calibration Temperature = 11.74

Loading:

17.93	38.77	107.38	176.01	244.69	313.40	382.10	519.86
657.60	726.54	864.52	1071.17	1416.68	1762.02	2107.18	2451.97
2796.38	3140.42	3484.36	4171.97	4859.39	5546.85	6097.02	

Unloading:

17.96	38.93	108.25	177.24	246.91	316.25	385.31	523.96
662.89	732.18	870.68	1078.12	1423.25	1767.45	2110.99	2453.95
2796.38							

Unloading:

17.15	38.14	107.39	176.77	246.14	315.49	384.53	523.46
662.44	731.80	870.48	1078.07	1423.85	1768.67	2113.00	2456.87
2800.39	3143.72	3486.98	4173.44	4860.13	5547.06	6097.02	

Calibration Temperature = 31.22

Loading:

20.80	41.64	110.29	178.95	247.68	316.45	385.23	522.98
660.90	729.95	868.01	1075.05	1420.40	1765.71	2110.83	2455.59
2800.04	3144.07	3488.01	4175.63	4863.04	5550.50	6100.67	

Unloading:

20.99	41.94	111.26	180.32	250.01	319.36	388.60	526.92
666.04	735.31	873.88	1081.32	1426.48	1770.75	2114.40	2457.41
2800.04							

Unloading:

20.03	41.01	110.30	179.70	249.13	318.54	387.65	526.58
665.74	735.21	873.97	1081.95	1427.57	1772.36	2116.65	2460.49
2804.04	3147.37	3490.64	4177.10	4863.78	5550.71	6100.67	

Figure 4.0.
Calibration data for the correction interpolation model.

5. Correction Interpolation Model

The correction interpolation model for pressure developed by the authors combines the modeled thermal response-correction and unloading curve interpolation techniques previously described with tables of calibration data (Figure 4.0). The calibration data are organized into tables at different calibration temperatures (stored in ascending temperature sequence). The first table contains the calibration pressures for the loading curve, followed by calibration pressures for each of the measured unloading curves (stored from shallowest to deepest maximum pressures). The pressures are stored in ascending sequence for each curve. Subsequent tables, at each calibration temperature, contain the raw pressure measurement corresponding to the calibration pressure at the calibration temperature. Each table has the same number of points as its corresponding calibration pressures table. The number of temperatures and unloading curves are only limited by the amount of calibration information necessary to properly correct the response of a particular sensor to the required degree of accuracy.

The model uses the current raw pressure and a sensor temperature modeled from the in-situ temperature to look-up the corrected pressures of adjacent calibration points from the calibration tables. The corrected pressure is then calculated by linear interpolation of the adjacent calibration points.

The model is initialized when in-situ conductivity exceeds a previously-established "in-water" value. A pressure correction (known pressure minus observed pressure) is interpolated from the calibration data loading curves bracketing the current sensor temperature. An offset is calculated (the correction still required to bring the pressure to 0.0 db after the correction interpolated from the loading curves is applied). This offset is applied to the first loading curve interval. The model is now in the "loading" state.

The model continues in the "loading" state as long as pressure does not decrease. Calibrated pressures are interpolated from four adjacent loading curve points: two higher-pressure points and two lower-pressure points at two adjacent temperatures.

When pressure decreases, the model enters the "unloading" state. Unloading curves are calculated for the two adjacent temperature calibration tables, using the differences between loading and unloading curves. In this model, the possibility of multiple calibration unloading curves permits the construction of an unloading curve from the shallowest calibration curve that originates at a pressure deeper than the maximum observed pressure. Using the sensor temperature, a correction is interpolated from the two calculated unloading curves. If the CTD is again lowered, the calculated unloading curves are followed until the original maximum pressure is reached. The model then reverts to the "loading" state.

The pressure correction is extrapolated if the CTD pressure exceeds the maximum calibration pressure. As the maximum calibration pressure is typically close to full-scale, the practice of exceeding this pressure should be restricted.

The model also extrapolates corrections for temperatures outside the range of available calibration information. This is reasonable behavior for Mark III pressure transducers, which generally exhibit linear temperature response. Certain types of pressure sensors (e.g., piezo-electric quartz transducers) that exhibit nonlinear temperature response would necessarily be calibrated at more temperatures to adequately define the temperature response. Any new or unknown pressure sensor should be calibrated at several temperatures to insure the thermal response is adequately defined. Subsequent recalibrations can be at fewer temperatures if the response is linear.

A graphical representation of the ODF interpolation model is presented in Figure 5.0.

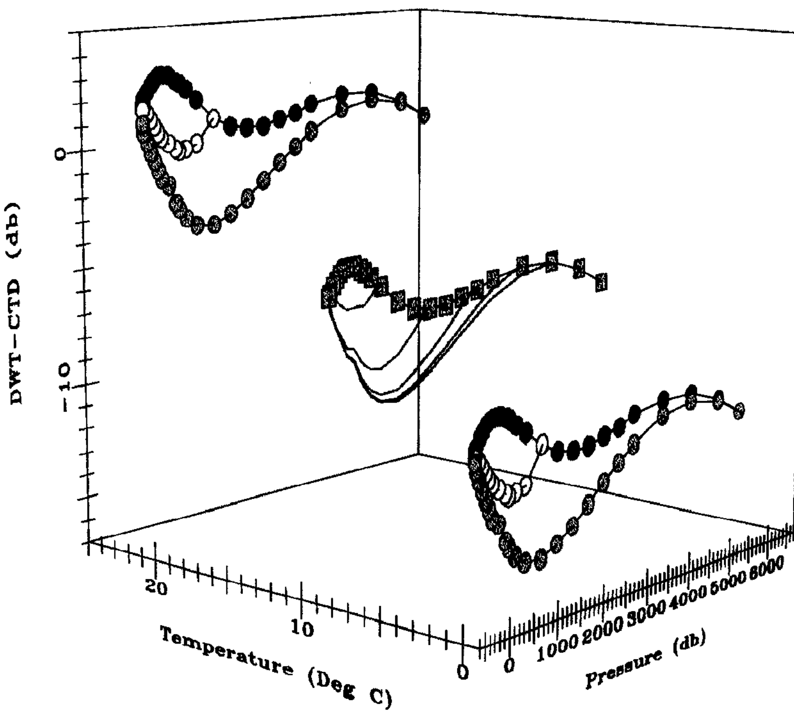

Figure 5.0.

A graphic representation of the ODF interpolation method of pressure correction. The left and right hysteresis curves were measured at 22.75°C and 0.9°C, respectively. The black circles are the loading curve points and the grey circles two unloading curves: from 6080db and from 1398db. The center hysteresis curve is interpolated by a computer model at 10.0°C with unloading curves at 1000, 2000, 3000, 4000 and 5000db.

6. Further Information

WOCE participants interested in implementing either model, or who have further questions can contact the authors at the Oceanographic Data Facility.

Appendix B:

CTD Dissolved Oxygen Data Processing

F.M. Delahoyde

Oceanographic Data Facility
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ABSTRACT

This paper describes the techniques used at the Oceanographic Data Facility (ODF) for processing CTD dissolved oxygen data acquired from NBIS Mark III instruments, employing Sensormedics[1] dissolved oxygen sensors. The response characteristics of the sensors are discussed and deployment methods examined. An algorithm for converting the measured oxygen current, pressure, temperature and salinity to dissolved oxygen concentration is presented. The determination of calibration coefficients from Winkler titration check-sample data is discussed. Results from the application of the algorithm to some recently-collected data sets are examined.

August 31, 1993
Preliminary Draft

1. Introduction

The Oceanographic Data Facility (ODF) at SIO has been making CTD measurements since the early 1970s, primarily using NBIS instrumentation. These instruments employ Sensormedics sensors to effect dissolved O_2 measurement.

Correcting the non-linear response characteristics of these sensors has driven the evolution of a series of sensor models. Early attempts at laboratory calibration had proven futile, due to poor sensor stability and a lack of data on dynamic response characteristics. A practical field calibration technique proved to be fitting sensor model coefficients to differences between modified Winkler titration check-sample data and the sensor measurements. Refinements in this technique has led to a better understanding of the secondary and dynamic responses inherent in these sensors.

The check-sample and sensor data are collected with a 24 or 36-place rosette system containing a CTD. A conducting wire is used to lower and raise the package, transmit check-sample trip signals to the rosette, and transmit CTD data to the ship for real-time analysis. O_2 check-samples are normally drawn from all bottles. At routine profiling velocities of 50-80 m/min, the processed CTD data provide 1-2 meters of vertical

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[1] Formerly Beckman.

resolution in temperature and salinity structure, and 10-15 meters in dissolved O_2 structure.

2. The Sensor and Sensor Interface

The Sensormedics sensor is a membrane-covered polarographic detector consisting of a 0.5 mil thick FEP Teflon membrane covering a layer of KCl gel. A gold cathode is the sensing electrode, and a silver electrode serves as both the anode and the reference. A 0.8 volt potential applied across the two electrodes results in a current proportional to the activity of O_2 diffusing through the membrane and gel, and reducing at the cathode:

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The NBIS interface to the Sensormedics sensor employs a current to frequency converter with a sample period of 1.024 seconds. The sensor frequency is resolved to 11-bits, with a full-scale value corresponding to 2.047 µamps. The NBIS interface also provides for an 8-bit digitized O_2 membrane temperature, which is not used by ODF. The interface electronics are contained within the CTD pressure case. The sensor is mounted in an ODF-designed pressure-compensating holder, which is typically attached to the rosette frame in proximity to the CTD end-cap. The sensor assembly plugs into a bulkhead connector in the end-cap through an underwater cable, providing easy servicing and sensor replacement.

3. Deployment and Maintenance

The Teflon membrane is extremely vulnerable to petroleum distillates, such as diesel oil. Care is taken to deploy the package through clean water.

Between casts, an air-tight plexi-glass cover is fixed over the sensor. The cover contains an absorbent tissue moistened with distilled water. The sensor membrane is periodically examined for any obvious external damage or contamination.

4. Sensor Response Characteristics

4.1. O_2 Response

The O_2 response of the sensor depends upon the O_2 activity at the sensor cathode. The selectivity of the reaction is generally guaranteed by the relatively anodic value for its equilibrium potential[1]. However, a network of reactions can occur at the cathode, depending upon the exact state and ionic species present. H_2O_2 can appear as a stable reaction intermediate and is reduced[2], aliasing the O_2 signal.

The sensitivity of the O_2 response is determined by the O_2 diffusion-rate through the membrane diffusion layer. This is determined by temperature and pressure.

4.2. Temperature Response

The rate of O_2 diffusion through the Teflon membrane is primarily determined by temperature. The diffusion rate can be characterized:

$$Q_d = (P_0/b)e^{-Ep/RT} \qquad (4.2.0)$$

where P_0 is a constant for FEP Teflon, b is the membrane thickness, Ep is the activation energy for permeation, R is the gas constant and T is temperature. Changes in temperature affect the sensitivity of the O_2 response.

Secondary temperature effects include changes in sensor geometry due to thermal expansion or compression (changing membrane tension), and thermal sensitivity of the interface electronics.

4.3. Pressure Response

The crystalline structure of FEP Teflon changes with pressure. This affects the membrane permeability, and sensitivity of the sensor[3].

4.4. Flow-dependence

When the flow rate across the sensor membrane decreases below a certain level, depletion of dissolved O_2 in seawater adjacent to the membrane occurs. The sensor current drops as the membrane diffusion layer thickness is effectively increased. Sensormedics recommends a minimum profiling velocity of 17 m/min.

4.5. Response Time

The time constant for the response of the sensor to an O_2 step-change at 20°C in surface seawater is nominally 2 seconds. This is the optimal case, and is beyond the Nyquist frequency of the sampling electronics. At lower temperatures and higher pressures, the time constant can exceed 15 seconds.

5. Calibration

Repeated exposures to low temperatures and high pressures adversely affects the stability of the sensor, making laboratory calibration unfeasible. Calibration to Winkler titration check-samples insures the prompt detection of sensor malfunctions.

The Winkler titration measures dissolved O_2 concentration. In contrast, the polarographic O_2 sensor measures O_2 activity. It is necessary to correct for salinity, temperature, and pressure effects when calculating concentrations from activity[4,5].

ODF normally collects at least 12 check-samples per cast. The oxygens are generally titrated within 6 hours of the cast. Modeling coefficients and time-constants are then fit to the check-samples.

6. The Model

The general form of the ODF O_2 conversion equation follows WHOI[6,7] and NBIS[8]:

$$O_2=[c_1O_c+c_2]f_{sat}(T,S)\ e^{(c3P+c4Tm)} \qquad (6.0)$$

where:

O_2 is the dissolved O_2 concentration;
O_c is the sensor current, in µamps;
$f_{sat}(S,T,P)$ is the O_2 saturation concentration at T,S in ml/l;
S is the salinity, in PSUs;
T is the temperature, in °C;
P is the pressure at O_2 response-time, in decibars;
T_m is the temperature of the sensor membrane, in °C.
c_1, c_2, c_3 and c_4 are coefficients to be determined through check-sample comparison.

Tm is derived by NBIS from the digitized O_2 temperature. ODF instead models a membrane temperature by low-pass filtering the PRT temperature. *In situ* pressure and temperature are filtered to match the sensor response. Time-constants for the pressure response τ_p, and two temperature responses τ_{Ts} and τ_{Tf} are fitting parameters. The O_c gradient is approximated by low-pass filtering 1st-order O_c differences. This term attempts to correct for reduction of species other than O_2 at the cathode. The time-constant for this filter, τ_{og}, is a fitting parameter. Oxygen partial-pressure is then calculated:

$$O_{pp}=[c_1O_c+c_2]\ f_{sat}(S,T,P)\ e^{(c3Pl+c4Tf+c5Ts+c6\ (dOc/dt))} \qquad (6.1)$$

where:

O_{pp} is the dissolved O_2 partial-pressure in atmospheres;
O_c is the sensor current, in µamps;
$f_{sat}(S,T,P)$ is the O_2 saturation partial-pressure at S,T,P in atmospheres;
S is the salinity at O_2 response-time, in PSUs;
T is the temperature at O_2 response-time, in °C;
P is the pressure at O_2 response-time, in decibars;
P_l is the low-pass filtered pressure, in decibars;
T_f is the fast low-pass filtered temperature, in °C;
T_s is the slow low-pass filtered temperature, in °C;
dO_c/dt is the sensor current gradient.

c_1, c_2, c_3, c_4, c_5 and c_6 are coefficients determined by applying a modified Levenberg-Marquardt non-linear least-squares fitting procedure[2] to differences from the Winkler titration check-sample data.

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[2] Procedure snls1 from the Stanford SLATEC math library.

CTD O_2 current values used for the fit are normally extracted from the down-cast at iso-pycnals corresponding to the actual up-cast check-sample points. This is done to avoid the flow-dependence problems occurring at bottle stops.

The response time-constants τ_{Ts} and τ_P (slow temperature and pressure) are typically determined once for a cruise. The other two time-constants τ_{og} and τ_{Tf} (O_2 current gradient and fast temperature) show some variability and are determined for each sensor deployment. The remaining modeling coefficients are determined for each sensor deployment.

7. Results

8. Summary

References

[1] Hitchman, M.L., *Measurement of Dissolved Oxygen*, John Wiley & Sons, Inc. and Orbisphere Corp., 1978.

[2] Damjanovic, A., in *Modern Aspects of Electrochemistry*, (J. O'M. Bockris and B.E. Conway, Eds.), No. 5, Butterworths, London, 1969.

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[6] Millard, R.C. Jr., "CTD calibration and data processing techniques at WHOI using the practical salinity scale", *Proc. Int. STD Conference and Workshop*, La Jolla, Mar. Tech. Soc., 19pp. (1982).

[7] Owens, W.B. and Millard, R.C. Jr., "A new algorithm for CTD oxygen calibration", *Journ. of Am. Meteorological Soc*., **15**, 621 (1985).

[8] Brown, N.L. and Morrison, G.K., "WHOI/Brown conductivity, temperature and depth microprofiler", *Woods Hole Oceanographic Institution Technical Report No. 78-23*, 1978.

Appendix C

Calibration Figures

NOTE: Some data may fall outside of the plotted limits.

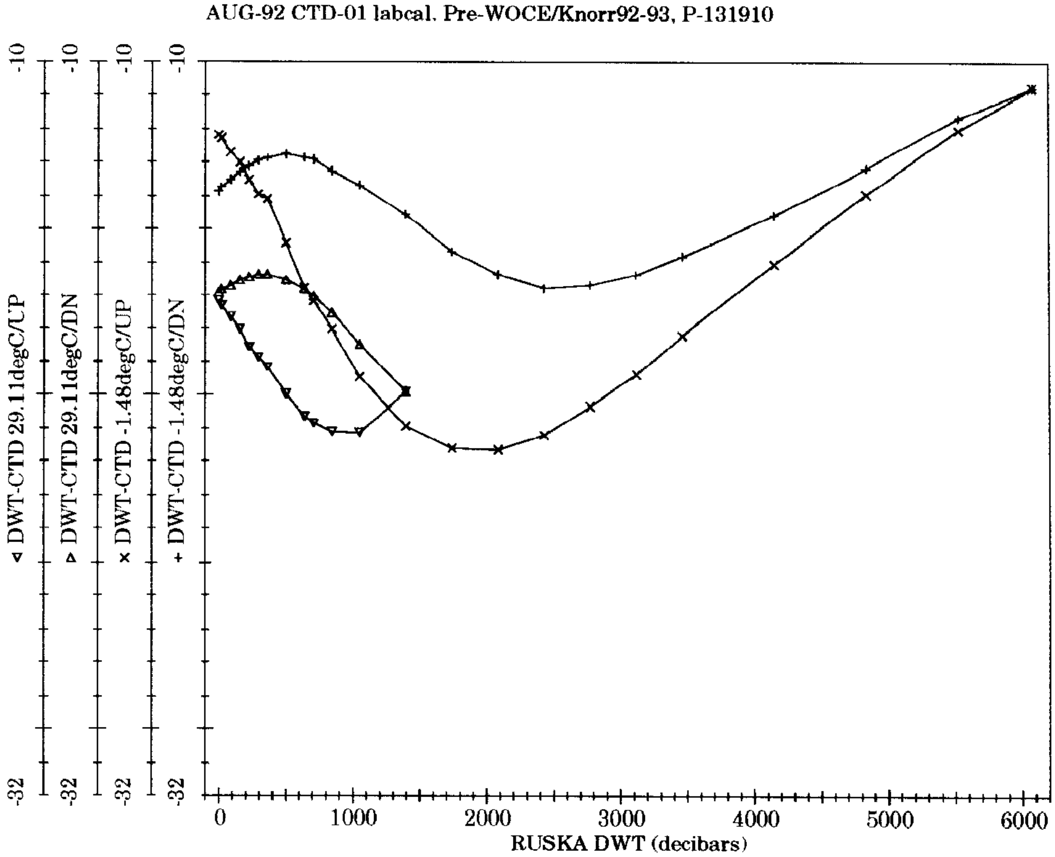

Figure 1a: CTD #1 Pre-cruise Pressure Calibration

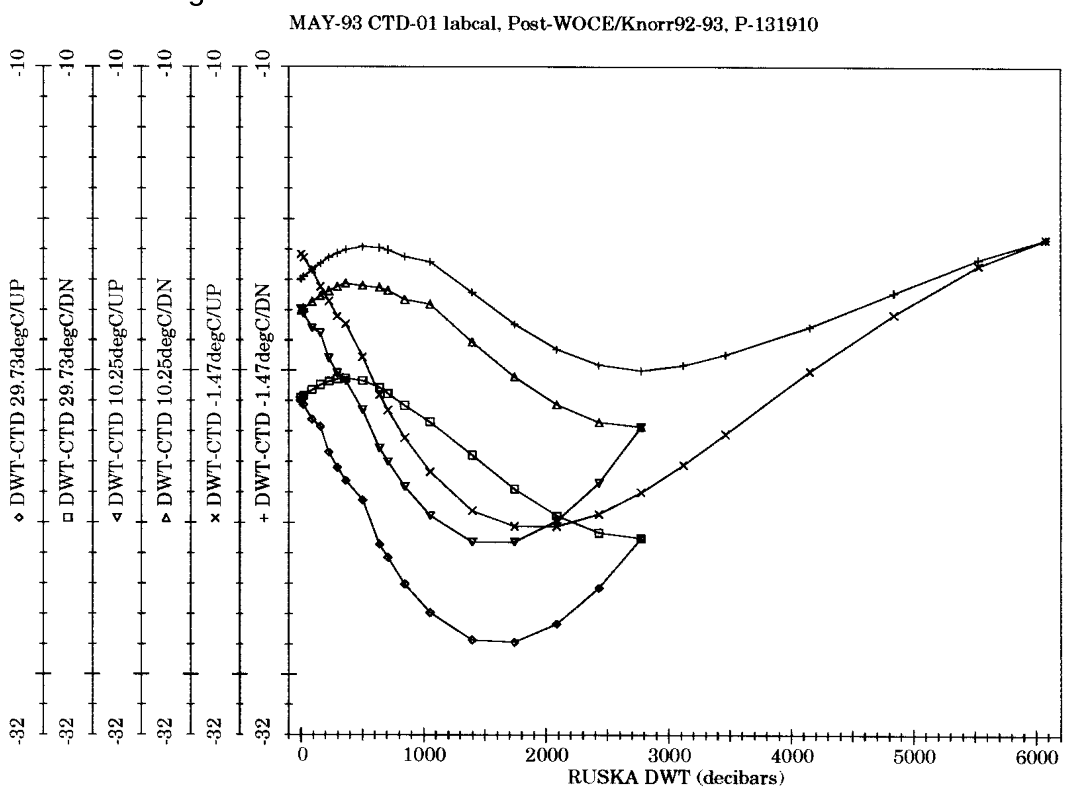

Figure 1b: CTD #1 Post-cruise Pressure Calibration

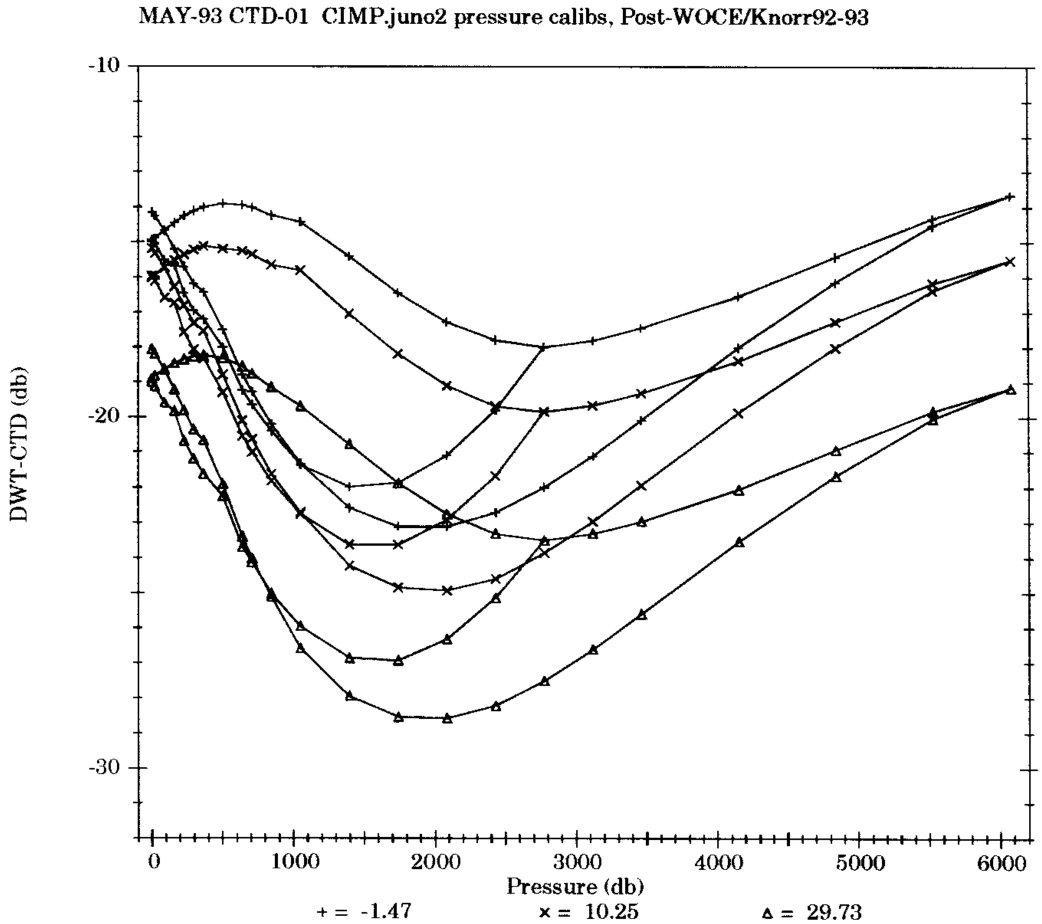

Figure 1c: CTD #1 Averaged Pressure Calibration plus Offset used for JUNO2

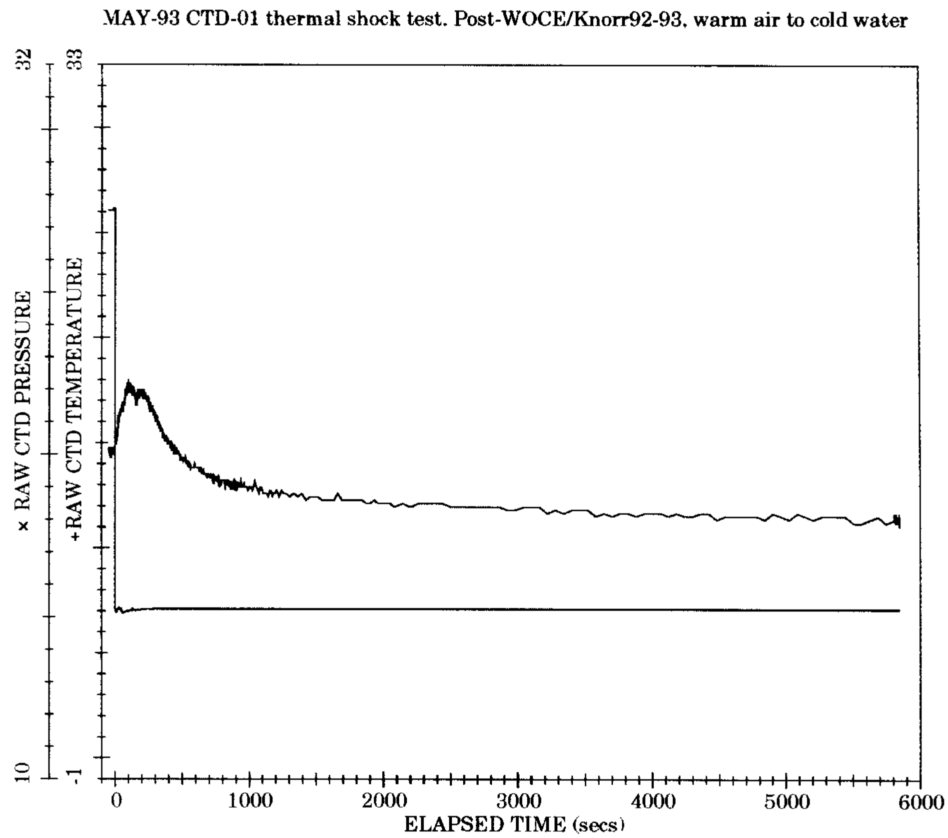

Figure 2a: CTD #1 Warm-to-Cold Thermal Shock Data

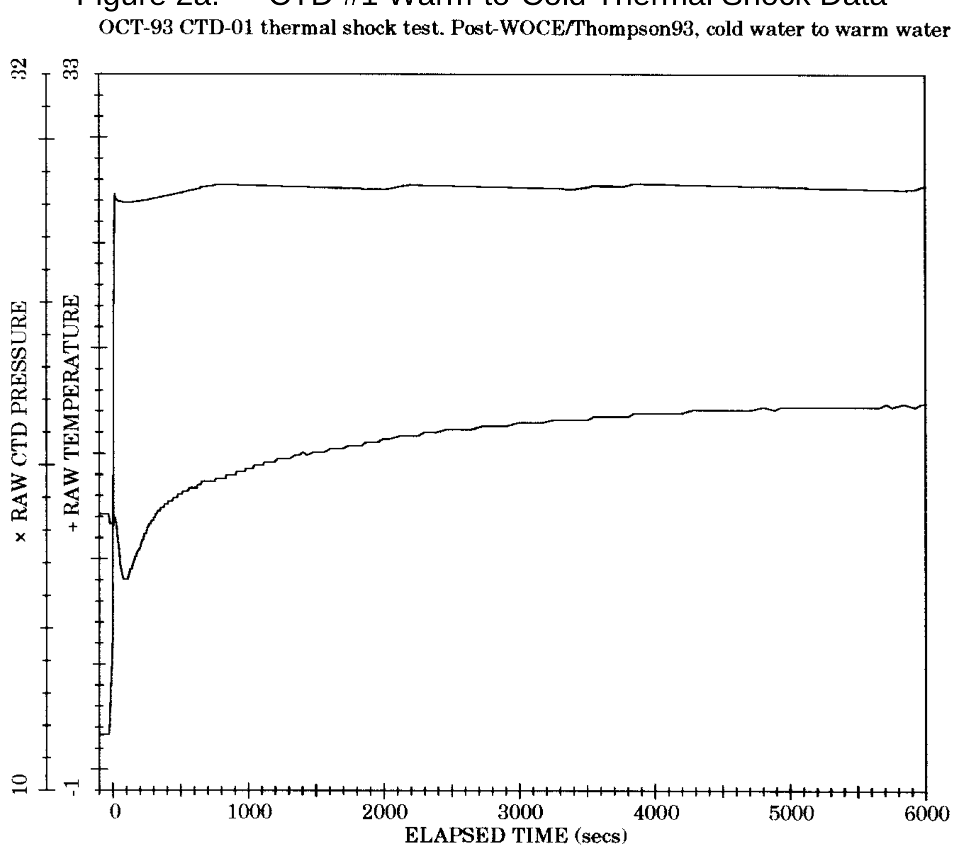

Figure 2b: CTD #1 Cold-to-Warm Thermal Shock Data

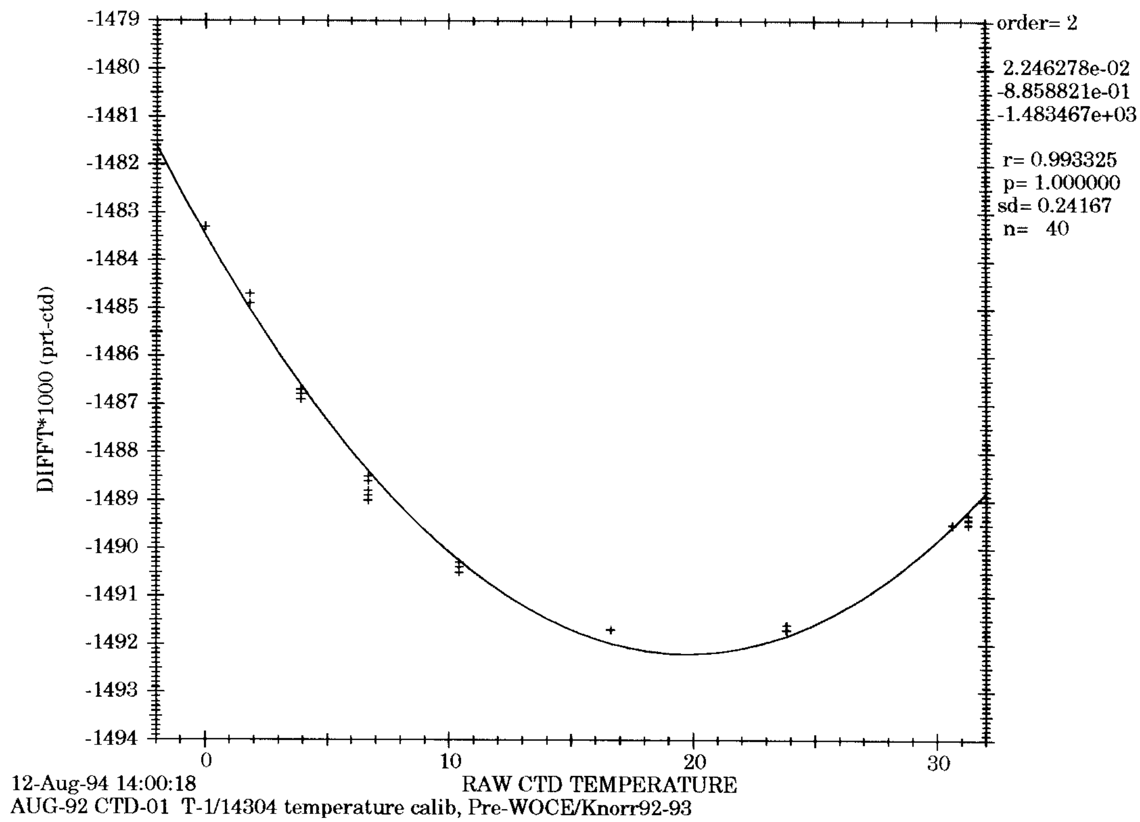

Figure 3a: CTD #1 Pre-cruise PRT-1 Temperature Calibration (ITS-90)

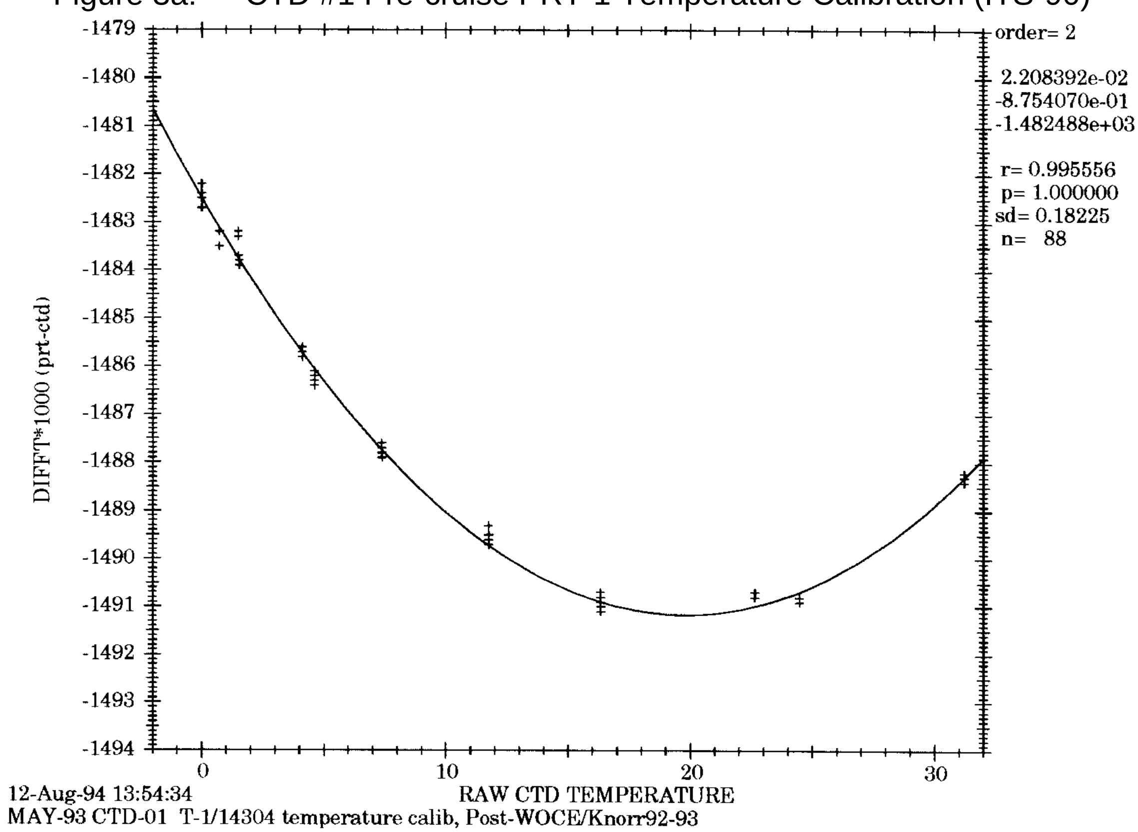

Figure 3b: CTD #1 Post-cruise PRT-1 Temperature Calibration (ITS-90)

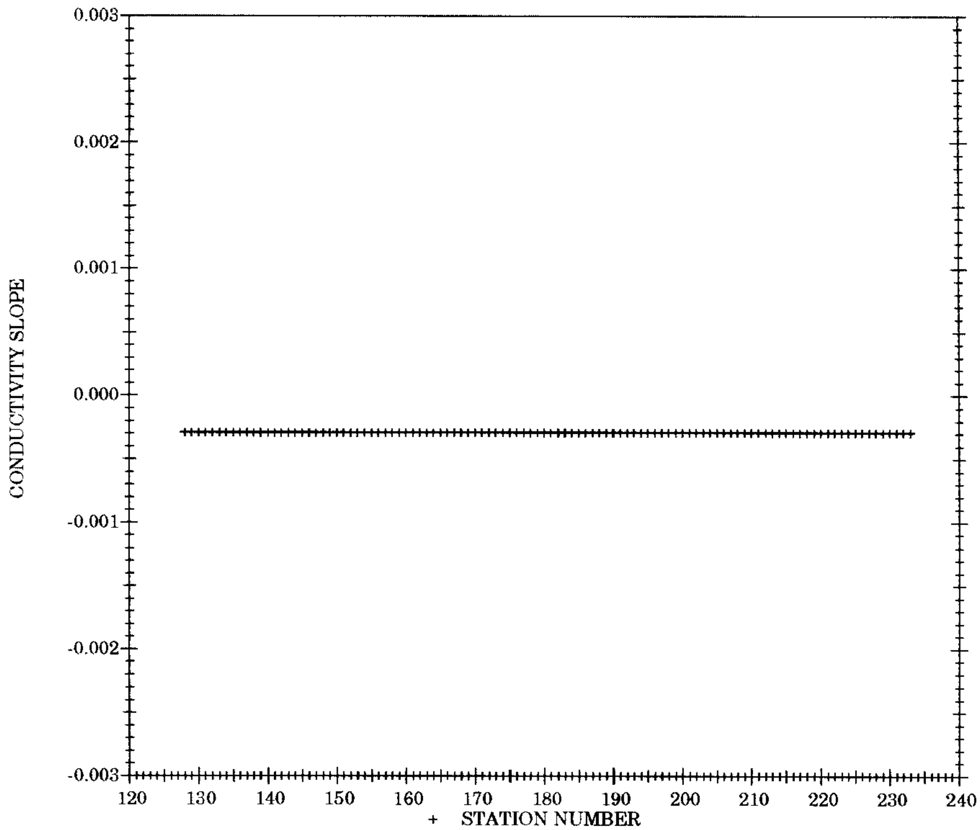

Figure 4a: JUNO2 Conductivity Slopes

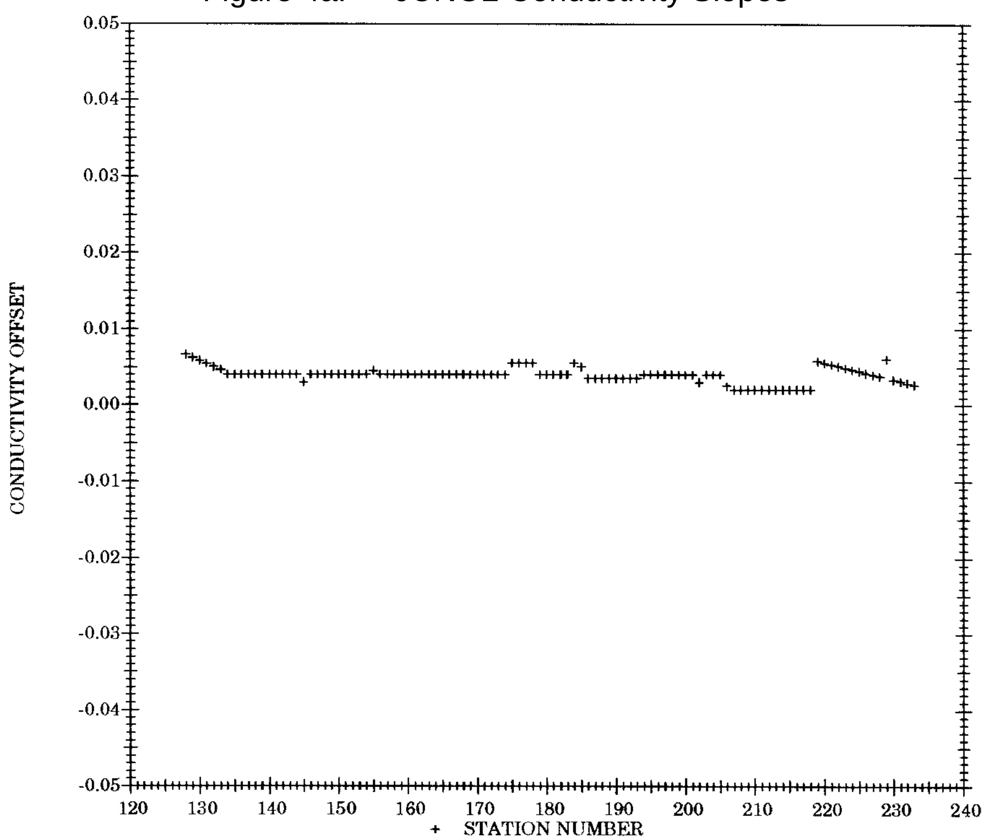

Figure 4b: JUNO2 Conductivity Offsets

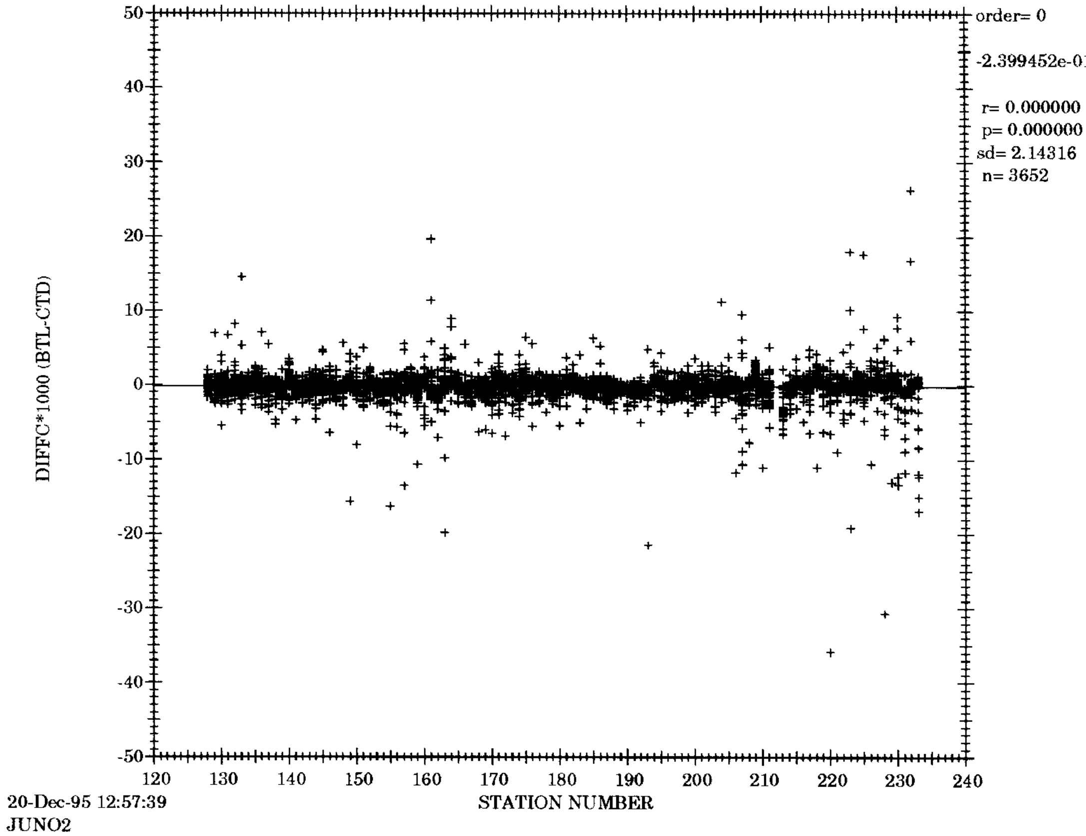

Figure 5a: JUNO2 Residual Conductivity Differences (Bottle-CTD) - All Pressures

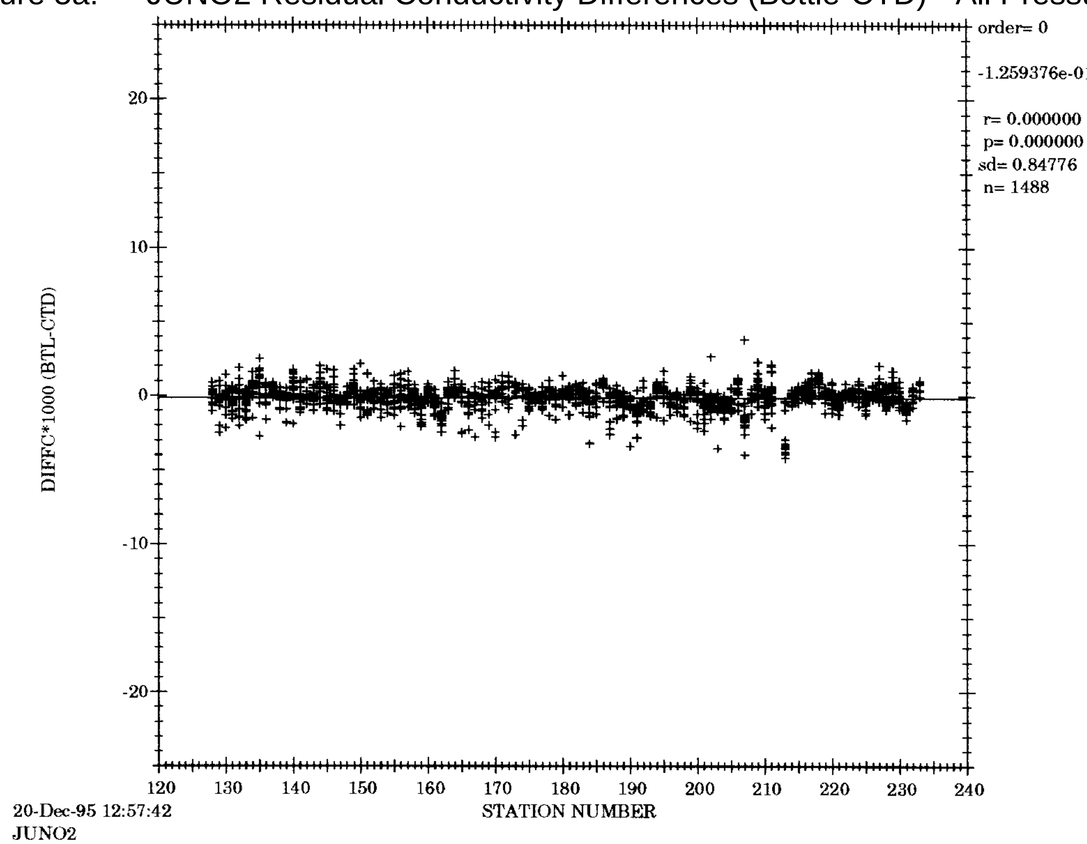

Figure 5b: JUNO2 Residual Conductivity Differences (Bottle-CTD) - Pressure>1500dbar

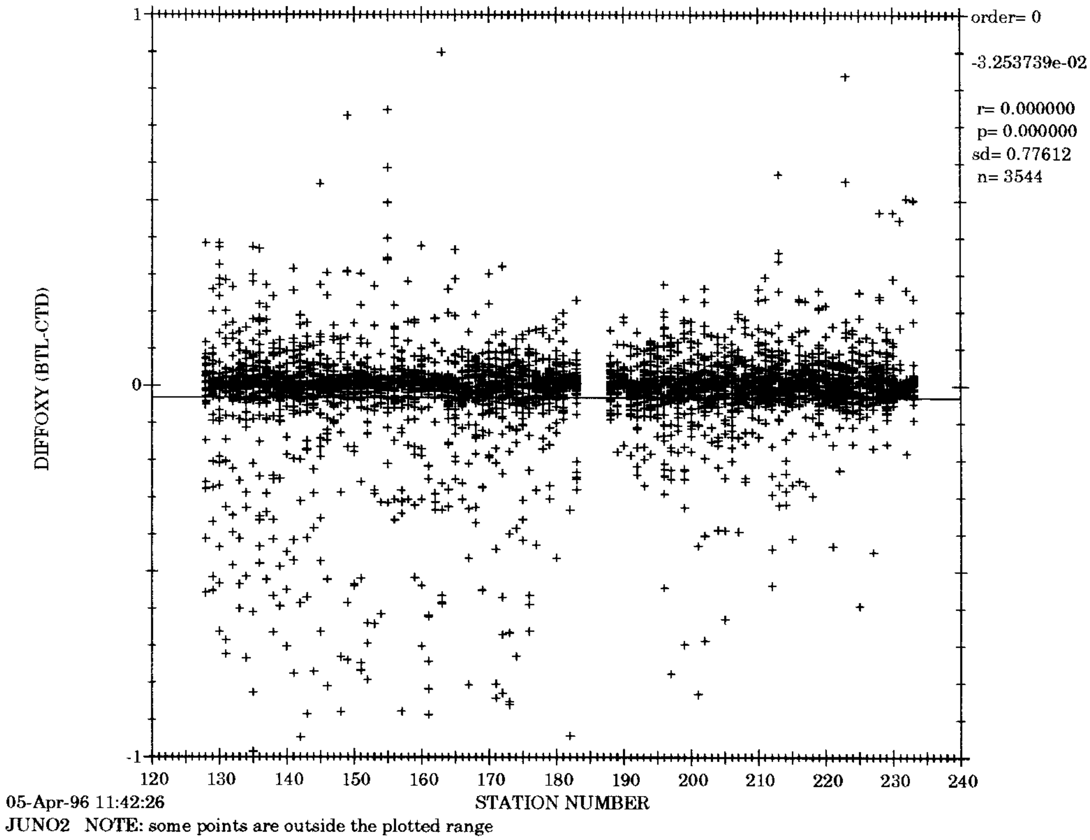

Figure 6a: JUNO2 Residual Dissolved Oxygen Differences (UpBottle-DownCTD) - All Pressures

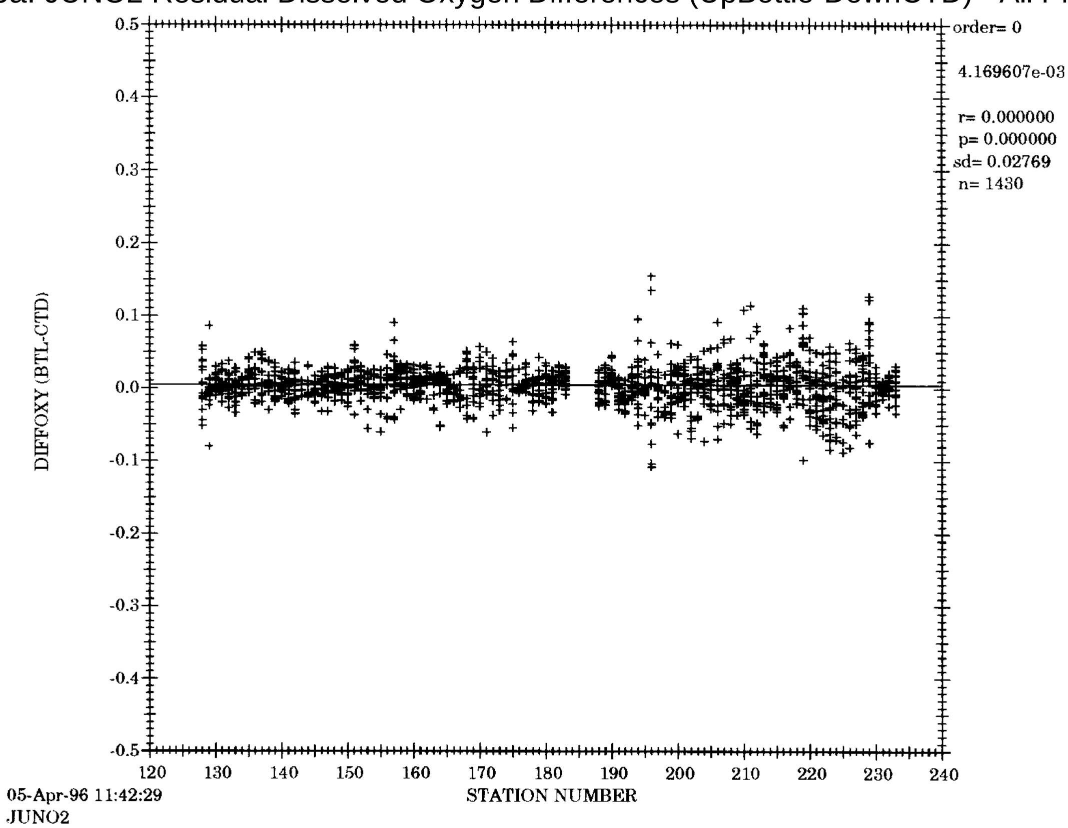

Figure 6b: JUNO2 Residual Dissolved Oxygen Differences (UpBottle-DownCTD) - Pressure>1500dbar

Appendix D

Tables of Processing Notes

Table 6: CTD Shipboard and Processing Comments

Station/cast	Comments
128/01	0-2 dbar level extrapolated; vcr stopped prematurely, not noticed until cast end.
129/01	0 dbar level extrapolated.
130/01	0-2 dbar level extrapolated; xmiss might be working improperly.
131/01	0-2 dbar level extrapolated.
132/01	0 dbar level extrapolated.
133/01	0-2 dbar level extrapolated; rough seas/long station.
134/01	0-4 dbar level extrapolated; new end termination and 24-place pylon change prior to cast; bad weather.
135/01	0 dbar level extrapolated.
136/01	
137/01	
138/01	0 dbar level extrapolated; data acqsn started incorrectly; restart in air.
139/01	0 dbar level extrapolated; corner station; dbl computer confirm at btl 2.
140/01	0 dbar level extrapolated.
141/01	0-4 dbar level extrapolated.
142/01	0-2 dbar level extrapolated; 24-plc pylon repaired prior to cast; cast terminated abnormally.
143/01	0 dbar level extrapolated.
144/01	0-4 dbar level extrapolated.
145/01	0 dbar level extrapolated.
146/02	0 dbar level extrapolated; winch not zeroed prior to cast or meter slipping.
147/01	0 dbar level extrapolated.
148/01	0 dbar level extrapolated.
149/01	0-2 dbar level extrapolated.
150/01	0 dbar level extrapolated; altimeter erratic at btm apprch; dbl computer confirm at btl. 30.
151/01	0-2 dbar level extrapolated.
152/01	0 dbar level extrapolated; btl test: 3 btls tripped at next to btm level.
153/01	0-2 dbar level extrapolated; 24 btls only, cast delayed by weather.
154/01	0 dbar level extrapolated; 24 btls due to bad weather.
155/01	0 dbar level extrapolated; new end termination prior to cast.
156/01	0 dbar level extrapolated; 2 btls tripped at next to btm level.
157/02	0 dbar level extrapolated; 2 btls tripped at next to btm level; cast terminated abnormally.
158/01	0 dbar level extrapolated.
159/01	0-2 dbar level extrapolated.
160/01	0 dbar level extrapolated.
161/01	0-2 dbar level extrapolated; trip inner pylon first for freons.
162/01	0 dbar level extrapolated.
163/01	0-2 dbar level extrapolated.
164/01	0-2 dbar level extrapolated; southernmost P17S station; long lead time in raw ctd - ice delayed launch.
165/01	0 dbar level extrapolated.

Station/cast	Comments
166/01	0-2 dbar level extrapolated.
167/01	0 dbar level extrapolated.
168/01	0-2 dbar level extrapolated.
169/01	0 dbar level extrapolated.
170/01	0-2 dbar level extrapolated.
171/01	0 dbar level extrapolated.
172/01	0-2 dbar level extrapolated.
173/01	0-2 dbar level extrapolated.
174/01	0-2 dbar level extrapolated.
175/01	0 dbar level extrapolated.
176/01	0 dbar level extrapolated; first station E of E. Pac. Rise.
177/01	0 dbar level extrapolated.
178/01	0 dbar level extrapolated.
179/01	0-4 dbar level extrapolated.
180/01	0-2 dbar level extrapolated; problems w/voltage 3x during cast; 24v->12v; fiddled w/ 'DCMilli' to incrs. Apparent -0.003 TS shift at bottom (1.7 deg theta, 3000db) of downcast; seems to return at 1950db on upcast.
181/01	0-118 dbar level extrapolated; O2 sensor Dot working at cast start (20 uamps); ok 150m+. -0.01 salt spike at 1.75 deg theta on downcast (maybe biological).
182/01	0-4 dbar level extrapolated; No O2 signal at start (0 uamps); on at 250m but not working properly.
183/01	0-2 dbar level extrapolated; Bad O2 signal top 200m of down cast.
184/01	0-2 dbar level extrapolated; O2 sensor changed from 2-6-9 to 2-6-10; reads 0 uamps in water; hard launch.
185/01	0-2 dbar level extrapolated; O2 sensor started a little high; lots of noise.
186/01	0-2 dbar level extrapolated; O2 sensor screwy after 80m; 4 computer confirms at btl 33.
187/02	0-2 dbar level extrapolated; FMD: various O2 sensor problems since 182 seem to be fixed, not sure what Carl did; console operator: no O2 rdgs (on same co log); srfc sampled while package moving.
188/01	0-2 dbar level extrapolated; some O2 noise.
189/01	0-4 dbar level extrapolated; initial CTD launch aborted due to green water over side - several lanyards/spigots broken on outer rosette. CTD brought inside hangar for repairs, removed inner rosette prior to re-launch.
190/01	0-4 dbar level extrapolated; srfc sampled while package moving.
191/01	0-4 dbar level extrapolated; new end termination; moved off orig. station position due to seamount.
192/01	0-2 dbar level extrapolated.
193/01	0 dbar level extrapolated.
194/01	0 dbar level extrapolated; -0.005 salt shift at 1.55 deg theta (2730-60db) on downcast. Seems to return on upcast. Maybe biological. UP
195/01	0 dbar level extrapolated.
196/01	
197/01	0 dbar level extrapolated.

Station/cast	Comments
198/01	0 dbar level extrapolated.
199/01	0-2 dbar level extrapolated.
200/01	0-2 dbar level extrapolated; winch zeroed about 10m in; 2 computer confirms at btl 18.
201/01	0 dbar level extrapolated; wind about 30 knots; 5 computer confirms/no DU confirm at btm btl.
202/01	0-2 dbar level extrapolated; new end termination prior to cast; dbl computer confirm at btl 33.
203/01	0-2 dbar level extrapolated.
204/01	0-2 dbar level extrapolated.
205/01	
206/02	5 computer confirms at btm btl, no DU confirm. Elapsed time problem fixed, PRT-2 replaced by FSI Pressure; -0.004 salt shift at 2350db on downcast. Seems to wash off. UP
207/01	0 dbar level extrapolated; 6 minute NIW at cast start.
208/01	0-2 dbar level extrapolated; vcr turned on 7 minutes after cast in water; CTD-id on DU apparently switched from 1 to 9 before btm approach thru abt 3500db up.
209/01	new 24-place pylon #2810 this cast; btl 11/531db tripped on the fly. no DU confirm/5 computer confirms at btls 28 and 35; xmiss out at 4130db/back again at 5200db (down or up?),
210/01	0-2 dbar level extrapolated; FMD: strange xmiss signal 1720-3760 down, not on upcast.
211/01	0 dbar level extrapolated; xmiss out at 2800, back at 4300db down; -0.003 salt shift at 1.2 deg theta on downcast. Returns at 0.4 deg theta on upcast. UP
212/01	0 dbar level extrapolated; changed pylon before this cast.
213/01	0 dbar level extrapolated; +0.004 salt shift at .22 deg theta on upcast (trip #5, bottle 32). Looks like it stays.
214/01	0 dbar level extrapolated; xmiss signal weak/gone 2600-3800m. down, A on up.
215/01	0 dbar level extrapolated; xmiss up to 17490 at 2430db, back at 2830db.
216/01	0-2 dbar level extrapolated; changed pylon prior to cast (now 2803); vcr started at 475m/10 mins. down.
217/01	0 dbar level extrapolated; btl 34 tripped on the fly; 3x-0.002 salt drops at 2400db on downcast. Probably biological. UP
218/02	0-2 dbar level extrapolated; short voltage drop at 70m down; xmiss out at 2236-2733.
219/01	0 dbar level extrapolated; new pylon #2810; sm. seamount shifted station location; vcr started 20 mins. late; -0.003 salt shift at 1.6 deg theta (2040db) on downcast; looks like it stays. UP
220/01	0 dbar level extrapolated.
221/01	0 dbar level extrapolated; xmiss looks ok.
222/01	
223/01	0 dbar level extrapolated.
224/01	0-4 dbar level extrapolated.
225/01	0 dbar level extrapolated-

Station/cast	Comments
226/01	0 dbar level extrapolated.
227/01	0 dbar level extrapolated.
228/01	0 dbar level extrapolated.
229/02	0 dbar level extrapolated; 5xcomputer confirms/no DU confirm at btm. btl; some comment about 2 try trips at btls 13/12 (pylon change); odd trip/smpl# in computer for btl 3; vcr started after 4 minutes of cast. UP
230/01	0 dbar level extrapolated; no DU confirm/5 computer confirms at ban btl.
231/01	0-2 dbar level extrapolated; change to pylon 2805 prior to cast; dbl computer confirm at btl 23.
232/01	0 dbar level extrapolated; wind 17 knots; air -0.5 deg.C.
233/01	3 trips at lvl above btm for O2 draw test.

Table 7: Cast Stops Longer Than One Minute

station /cast	down /up	minutes stopped	average pressure (decibars)	pressure range (decibars)
133/01	DOWN	1.1	12	(10 - 14)
140/01	DOWN	1.1	6	(4 - 8)
146/02	DOWN	1.1	78	(76 - 80)
149/01	DOWN	2.0	46	(44 - 48)
150/01	DOWN	1.3	4248	(4246 - 4250)
166/01	DOWN	2.7	4137	(4132 - 4142)
182/01	DOWN	1.6	3052	(3048 - 3056)
206/02	DOWN	1.2	5144	(5142 - 5146)
208/01	DOWN	2.1	5010	(5008 - 5012)
210/01	DOWN	6.1	1	(0 - 2)

Table 8: CTD Temperature and Conductivity Corrections Summary

Station/ Cast	PRT Response Time (seconds)	Temperature Coefficients ($T_{cor} = t_2T^2 + t_1T + t_0$) t_2	t_1	t_0	Conductivity Coefficients ($C_{cor} = c_1C + c_0$) c_1	c_0
128/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00664
129/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00624
130/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00584
131/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00544
132/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00504
133/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00464
134/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
135/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
136/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
137/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
138/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
139/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
140/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
141/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
142/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
143/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
144/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
145/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00302
146/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
147/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
148/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
149/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
150/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
151/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
152/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
153/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
154/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
155/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00452
156/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
157/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
158/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
159/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
160/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
161/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
162/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
163/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
164/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
165/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
166/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
167/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
168/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
169/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
170/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402

Station/ Cast	PRT Response Time (seconds)	Temperature Coefficients ($T_{cor} = t_2T^2 + t_1T + t_0$)			Conductivity Coefficients ($C_{cor} = c_1C + c_0$)	
		t_2	t_1	t_0	c_1	c_0
171/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
172/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
173/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
174/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
175/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00552
176/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00552
177/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00552
178/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00552
179/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
180/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
181/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
182/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
183/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
184/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00552
185/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00502
186/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
187/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
188/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
189/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
190/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
191/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
192/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
193/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00352
194/01	.30	2.22788e-05	-8.80861e4)4	-1.48332	-2.92177e-04	0.00402
195/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
196/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
197/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
198/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
199/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
200/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
201/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
202/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00302
203/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
204/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
205/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00402
206/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00254
207/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
208/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
209/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
210/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
211/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
212/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
213/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
214/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204

Station/ Cast	PRT Response Time (seconds)	Temperature Coefficients ($T_{cor} = t_2T^2 + t_1T + t_0$) t_2	t_1	t_0	Conductivity Coefficients ($C_{cor} = c_1C + c_0$) c_1	c_0
215/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
216/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
217/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
218/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00204
219/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00578
220/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00556
221/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00534
222/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00512
223/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00490
224/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00469
225/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00447
226/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00425
227/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00403
228/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00381
229/02	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00609
230/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00337
231/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00315
232/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00293
233/01	.30	2.22788e-05	-8.80861e-04	-1.48332	-2.92177e-04	0.00272

Table 9: CTD Oxygen Time Constants

Pressure τ_P	Temperature τ_{Tf}	τ_{Ts}	O_2 Gradient τ_{og}
19.4	32.0	363.0	60.0

Table 10: CTD Oxygen Levenberg-Marquardt Non-linear Least-Squares-Fit Coefficients

Station/ Cast	c_1 Slope	c_2 Offset	c_3 Pressure	c_4 Temperature (fast)	c_5 Temperature (slow)	c_6 Gradient
128/01	1.32274e-03	6.41484e-02	1.18899e-04	3.99009e-02	-6.47692e-02	-3.54384e-04
129/01	1.47047e-03	1.69524e-03	1.44619e-04	-2.27546e-02	-2.10247e-02	-1.83009e-04
130/01	1.53160e-03	-5.92498e-03	1.42950e-04	-3.89309e-02	-1.51618e-02	-2.18198e-04
131/01	1.60595e-03	-3.00755e-02	1.47005e-04	-1.03190e-02	-3.90786e-02	-1.70724e-04
132/01	1.47387e-03	4.09383e-03	1.48803e-04	-1.38448e-02	-2.66836e-02	-8.76100e-05
133/01	1.47295e-03	-7.07102e-03	1.50251e-04	-2.49232e-02	-1.57646e-02	-1.18012e-04
134/01	1.52824e-03	-1.25122e-02	1.47817e-04	-3.27657e-02	-1.56857e-02	-1.73410e-04
135/01	1.65170e-03	-5.67306e-02	1.59692e-04	1.85105e-04	-4.89594e-02	-1.48090e-04
136/01	1.20346e-03	8.83890e-02	1.22391e-04	3.30748e-03	-2.82772e-02	-9.35620e-05
137/01	1.01483e-03	1.01523e-01	1.41301e-04	-2.69214e-02	1.79594e-02	-8.46960e-05
138/01	1.49520e-03	-3.52892e-03	1.46074e-04	-2.79107e-02	-1.85991e-02	-1.34791e-04
139/01	1.27732e-03	4.86021e-02	1.40285e-04	-2.53128e-02	-5.64545e-03	-1.37420e-04
140/01	1.63320e-03	-2.25205e-02	1.39393e-04	-1.86389e-02	-3.85086e-02	-8.95440e-04
141/01	1.80093e-03	-7.61090e-02	1.54262e-04	-2.89706e-02	-3.86470e-02	-1.17178e-04
142/01	1.35535e-03	2.36302e-02	1.48523e-04	-2.59237e-02	-1.00538e-02	-1.81584e-04

Station/ Cast	c_1 Slope	c_2 Offset	c_3 Pressure	c_4 Temperature (fast)	c_5 Temperature (slow)	c_6 Gradient
143/01	1.62340e-03	-3.13264e-02	1.47264e-04	-1.33178e-02	-3.81114e-02	-1.54760e-04
144/01	1.52185e-03	-3.95454e-03	1.40741e-04	2.50477e-03	-4.50158e-02	-1.20048e-04
145/01	1.33821e-03	4.97285e-02	1.34225e-04	1.54387e-02	-4.77534e-02	-3.47318e-04
146/02	1.44620e-03	3.03548e-02	1.29366e-04	9.72231e-03	-5.31710e-02	-2.94929e-04
147/01	1.42040e-03	3.30141e-02	1.32533e-04	-1.82464e-03	-4.29825e-02	1.04796e-05
148/01	1.52143e-03	4.54982e-03	1.36972e-04	1.44680e-02	-6.09740e-02	-1.39547e-04
149/01	2.04093e-03	-2.25055e-03	8.33706e-05	1.00584e-01	-2.20971e-01	-1.83555e-04
150/01	1.71767e-03	-5.47089e-03	1.18525e-04	-6.54671e-02	-2.63931e-02	-1.11969e-04
151/01	1.75480e-03	8.96957e-02	6.75646e-05	-3.22419e-02	-9.89582e-02	-1.76157e-04
152/01	1.71534e-03	6.24454e-02	8.48531e-05	1.32564e-02	-1.21093e-01	-1.33489e-04
153/01	1.50783e-03	4.38289e-02	1.15589e-04	-3.46881e-02	-3.85157e-02	-1.16455e-04
154/01	1.22985e-03	1.07574e-01	1.11498e-04	-7.09190e-02	2.48097e-02	-1.03809e-04
155/01	7.65209e-04	3.40937e-01	4.84840e-05	-7.57064e-02	2.89606e-03	-2.56664e-02
156/01	1.37176e-03	1.08602e-01	9.55996e-05	-4.88818e-02	-3.42515e-02	9.92672e-05
157/02	1.31261e-03	1.14785e-01	9.94186e-05	-5.81724e-02	-1.58517e-02	-3.22279e-03
158/01	1.28435e-03	1.06625e-01	1.05997e-04	-6.73229e-02	6.43001e-03	-1.43741e-05
159/01	1.29063e-03	1.28667e-01	9.56821e-05	-5.41292e-02	-2.20236e-02	-9.49253e-05
160/01	1.09287e-03	1.71724e-01	9.36947e-05	-1.15978e-01	6.14165e-02	-1.23883e-04
161/01	1.35100e-03	8.35100e-02	1.12668e-04	-5.73305e-02	-6.09134e-03	-6.53362e-03
162/01	1.18085e-03	1.57362e-01	9.23950e-05	-6.11699e-02	-3.61270e-03	-6.56609e-05
163/01	9.66954e-04	2.32399e-01	7.85504e-05	-6.09003e-02	2.36460e-03	-1.37845e-03
164/01	1.61146e-03	-2.06343e-01	3.09999e-04	1.08193e-01	-3.04070e-02	-1.00074e-04
165/01	1.20420e-03	4.19849e-02	1.58463e-04	-1.36015e-02	-3.84333e-03	-4.28509e-05
166/01	1.36547e-03	3.10701e-02	1.38234e-04	2.79167e-03	-3.25557e-02	1.76958e-05
167/01	7.94688e-04	1.30193e-01	1.50093e-04	-1.68831e-02	3.61796e-02	-1.00496e-04
168/01	6.06415e-04	1.96321e-01	1.22350e-04	4.48651e-02	-2.28515e-03	-1.04291e-03
169/01	1.08080e-03	9.98814e-02	1.28765e-04	1.61049e-02	-2.34577e-02	-5.09434e-04
170/01	1.24831e-03	4.01477e-02	1.53778e-04	-4.94506e-02	1.95436e-02	4.72373e-05
171/01	1.30518e-03	3.94273e-02	1.44623e-04	-2.70912e-02	-6.05209e-03	-5.66360e-04
172/01	1.60026e-03	4.87778e-02	1.71556e-04	-4.48133e-02	-9.66119e-03	-1.44141e-04
173/01	1.76786e-03	-4.86630e-02	1.42516e-04	1.22928e-04	-6.22424e-02	-1.27851e-04
174/01	1.43074e-03	2.69346e-03	1.57401e-04	-4.99663e-02	4.54527e-03	-2.54365e-05
175/01	1.06123e-03	9.35980e-02	1.40966e-04	-2.55265e-02	1.70800e-02	-7.08518e-05
176/01	1.48485e-03	8.35991e-03	1.44874e-04	1.20898e-02	-5.49532e-02	-9.02097e-05
177/01	1.30458e-03	4.22093e-02	1.44453e-04	-2.12087e-02	-1.05403e-02	-7.90242e-05
178/01	1.30128e-03	2.61648e-02	1.56407e-04	-3.91859e-02	1.06808e-02	-1.75976e-05
179/01	1.05883e-03	1.02973e-01	1.31824e-04	1.61426e-03	-9.28807e-03	-5.41197e-05
180/01	2.50704e-03	-2.28698e-01	1.53160e-04	1.90096e-02	-1.12517e-01	-2.78905e-04
181/01	5.35896e-04	2.00350e-01	1.29668e-04	1.44141e-02	3.51862e-02	3.16627e-05
182/01	2.51658e-03	-2.03203e-01	1.37025e-04	1.51898e-04	-1.03889e-01	-3.62385e-03
183/01	6.66380e-04	1.73299e-01	1.33526e-04	1.54610e-02	1.94780e-02	4.24976e-03
184/01	8.09220e-04	-1.25915e-01	1.05854e-04	4.55990e-02	-5.71646e-02	1.41267e-02
185/01	-3.65760e-03	1.11902e+00	5.71379e-04	-8.19884e-01	-2.74670e-01	1.16944e-02
186/01	-1.38436e-03	7.49511e-01	2.59175e-05	1.16284e-01	1.84425e-01	1.64110e-02
187/02	1.00000e-03	0.00000e+00	1.50000e-04	0.00000e+00	-3.00000e-02	-3.00000e-02
188/01	2.40499e-04	1.96536e-01	1.71383e-04	2.43468e-02	8.16150e-02	1.26636e-05

Station/ Cast	c_1 Slope	c_2 Offset	c_3 Pressure	c_4 Temperature (fast)	c_5 Temperature (slow)	c_6 Gradient
189/01	2.97625e-04	1.78999e-01	1.76573e-04	1.11978e-02	8.22347e-02	-9.86010e-07
190/01	1.16341e-03	2.05553e-02	1.40411e-04	1.10475e-03	-3.51682e-02	1.69456e-05
191/01	6.73384e-04	1.28664e-01	1.47798e-04	-1.18349e-02	3.12575e-02	-2.03076e-05
192/01	4.76989e-04	1.67504e-01	1.54666e-04	4.56198e-03	4.80909e-02	-2.52192e-05
193/01	1.02030e-03	5.38218e-02	1.41462e-04	-8.45487e-03	-1.21482e-02	-3.70134e-05
194/01	1.56446e-03	-5.54520e-02	1.26125e-04	-7.37437e-03	-5.17468e-02	-5.11035e-03
195/01	1.08241e-03	3.86020e-02	1.40541e-04	-6.42746e-03	-2.10030e-02	-2.21297e-05
196/01	7.77304e-04	4.79018e-02	1.79461e-04	-1.79061e-02	2.23086e-02	-7.47284e-05
197/01	6.72600e-04	9.06029e-02	1.64669e-04	-3.61449e-02	5.01406e-02	-8.68229e-05
198/01	9.25434e-04	9.34218e-02	1.28511e-04	-3.91881e-03	-1.53597e-02	-3.40619e-05
199/01	7.45315e-04	6.10575e-02	1.74482e-04	-4.32649e-02	4.45163e-02	-9.64643e-05
200/01	1.23777e-03	-3.67289e-02	1.55265e-04	3.37256e-03	-4.78104e-02	-2.72637e-05
201/01	1.26775e-03	-5.61717e-02	1.63052e-04	4.96858e-02	-9.17816e-02	-1.65994e-04
202/01	1.13257e-03	-4.19666e-02	1.66125e-04	1.81419e-02	-4.91592e-02	-1.79678e-04
203/01	1.07992e-03	-2.23047e-02	1.79480e-04	-8.58426e-03	-1.89110e-02	-4.61580e-06
204/01	1.19188e-03	-1.98465e-02	1.58137e-04	-1.20112e-02	-3.14890e-02	-6.46903e-05
205/01	1.30427e-03	-6.58933e-02	1.72185e-04	-5.52030e-03	-4.60638e-02	-8.15280e-05
206/02	1.26548e-03	-8.48809e-02	1.73555e-04	-1.64139e-02	-3.01714e-02	-7.26468e-05
207/01	1.24572e-03	-9.85550e-02	2.02978e-04	-7.84835e-03	-3.27355e-02	-5.07499e-05
208/01	1.80047e-03	-2.00269e-01	1.75473e-04	9.85630e-04	-9.26587e-02	-3.79948e-05
209/01	1.21508e-03	1.46787e-03	1.39317e-04	1.79174e-02	-5.83694e-02	-1.15916e-05
210/01	1.03896e-03	-1.48976e-02	1.75134e-04	-5.28453e-02	2.04362e-02	2.38630e-04
211/01	1.37921e-03	-2.01437e-02	1.32461e-04	-2.66205e-02	-2.03715e-02	-3.03677e-03
212/01	1.08239e-03	-3.48856e-02	1.83517e-04	-5.25931e-03	-2.39519e-02	-6.75494e-05
213/01	9.75730e-04	1.47312e-02	1.68616e-04	-1.30436e-01	8.92381e-02	8.05287e-05
214/01	7.13489e-04	1.35307e-01	1.27753e-04	-5.58071e-02	4.69213e-02	-2.90880e-05
215/01	1.16329e-03	-6.04951e-02	1.92254e-04	-2.47305e-02	-1.28801e-02	-3.56344e-05
216/01	1.14497e-03	-5.27313e-02	1.88445e-04	-2.65868e-02	-8.09393e-03	4.36303e-05
217/01	1.40938e-03	-5.94384e-02	1.48763e-04	-8.44928e-03	-3.08021e-02	-1.14773e-04
218/02	1.03718e-03	2.18459e-02	1.42477e-04	-2.83981e-02	4.82055e-03	-1.35934e-06
219/01	1.06732e-03	4.77032e-02	1.30474e-04	-3.54010e-02	2.21703e-02	-2.53021e-03
220/01	1.30401e-03	-7.37985e-02	1.76257e-04	7.72411e-03	-7.07816e-02	1.04970e-07
221/01	9.08167e-04	4.56561e-02	1.61375e-04	-1.84142e-02	6.33392e-03	2.36243e-05
222/01	9.50214e-04	2.48886e-02	1.67554e-04	-3.34525e-02	2.14865e-02	-2.82781e-05
223/01	1.07917e-03	-6.23855e-03	1.65786e-04	2.03891e-03	-3.26455e-02	1.93457e-04
224/01	1.04585e-03	1.14037e-02	1.58948e-04	-1.71851e-02	-1.63058e-02	5.37781e-05
225/01	9.94097e-04	6.86713e-02	1.36212e-04	-2.15705e-02	-3.42346e-02	2.01281e-04
226/01	1.08018e-03	-1.33324e-02	1.71803e-04	-1.00280e-02	-2.62160e-02	2.36765e-05
227/01	1.10951e-03	2.90095e-02	1.39900e-04	-3.27465e-02	-3.74694e-02	-7.48011e-04
228/01	9.73280e-04	5.53297e-02	1.44674e-04	-1.87504e-02	-2.22699e-02	6.53409e-05
229/02	1.13230e-03	-5.12981e-02	1.83721e-04	-1.13226e-02	5.55479e-02	-1.08293e-02
230/01	9.73731e-04	5.85127e-02	1.33795e-04	-1.64368e-02	-1.02325e-02	7.34064e-05
231/01	9.13531e-05	5.56219e-01	1.76574e-05	-1.04840e-01	5.20686e-02	6.04796e-04
232/01	3.79238e-04	3.91036e-01	5.41522e-05	-8.41642e-02	5.15125e-02	6.12875e-04
233/01	9.61367e-04	6.87781e-02	1.44768e-04	-1.19995e-02	3.13506e-03	1.77288e-04

P17E19S
Final Report
for Large Volume Samples and $\Delta^{14}C$ Measurements

Robert M. Key
July 8, 1996

1.0 General Information

WOCE cruise P17E19S was the second of three legs carried out aboard the R/V Knorr in the south central and southeastern Pacific Ocean. The WHPO designation for this leg was 316N138/10 (A.K.A. Juno-2). Jim Swift of SIO was chief scientist for this leg. This report covers details of data collection and analysis for the large volume Gerard samples. The reader is referred to the ODF Final Report (1994) for general information (World Ocean Circulation Experiment (WOCE) P17E/P19A Knorr 138 Leg 10; 12/12/94). The detailed sampling notes from that report regarding Gerard casts are reproduced here as an appendix. The cruise departed Papeete, Tahiti on December 4, 1992 and ended at Punta Arenas, Chile on January 22, 1993.

Seven large volume (LV) stations were occupied on this leg. The planned sampling density was 1 station every 5° of latitude (~300nmi). Each station included one deep cast (2500db to the bottom), and an intermediate (1000db to 2500db) cast. In the event of mistripped Gerard sampler(s), casts were repeated as time allowed in an attempt to collect the full suite of samples. All LV casts for the Juno cruises were done using the starboard-aft crane and coring cable on the R/V Knorr. This arrangement was far superior to that used on the R/V Thomas Washington for the TUNES cruises. The purpose of these casts was to collect samples for ^{14}C analysis. ^{14}C coverage for the upper water column was done *via* small volume AMS sampling from the Rosette.

Table 1 summarizes the LV sampling and Figure 1 shows the station positions for leg P17E19S.

Table 1: Station/Cast Summary

Station	Cast	South Latitude	West Longitude	# LV Samples
146	1	56.002	125.930	9
	3	56.035	125.924	9
157	1	61.638	126.041	6
	3	61.654	125.971	9
164	2	66.331	126.098	9
	3	66.350	126.152	9
187	1	52.394	108.538	9
	3	52.389	108.550	9
206	1	54.002	88.000	9
	3	54.031	87.995	9
218	1	59.978	87.956	9
	3	59.994	87.905	9

229	1	67.028	87.988	9
	3	67.073	87.986	2
	4	67.096	87.976	7

Each Gerard barrel was equipped with a piggyback 5 liter Niskin bottle which, in turn, had a full set of high precision reversing thermometers to determine sampling pressure and temperature. Both Gerard and Niskin were sampled for salinity and silicate. Additionally, each Gerard was sampled for radiocarbon. The salinity samples from the piggyback bottle were used for comparison with the Gerard barrel salinities to verify the integrity of the Gerard sample. As samples were collected, information was recorded on a sample log sheet. Normal sampling practice was to open the drain valve before opening the air vent to see if water escapes, indicating the presence of a small air leak in the sampler. This observation ("air leak"), and other comments ("lanyard caught in lid", "valve left open", etc.) which may indicate some doubt about the integrity of the water samples were noted on the sample log sheets. The discrete hydrographic data were entered into the shipboard data system and processed as the analyses were completed. The bottle data were brought to a usable, though not final, state at sea. Data checking procedures included verification that the sample was assigned to the correct depth. The salinity and nutrient data were compared with those from adjacent stations and with the rosette cast data from the same station. Any comments regarding the water samples were investigated. The raw data computer files were also checked for entry errors that could have been made on the station number, bottle number and/or sample container number.

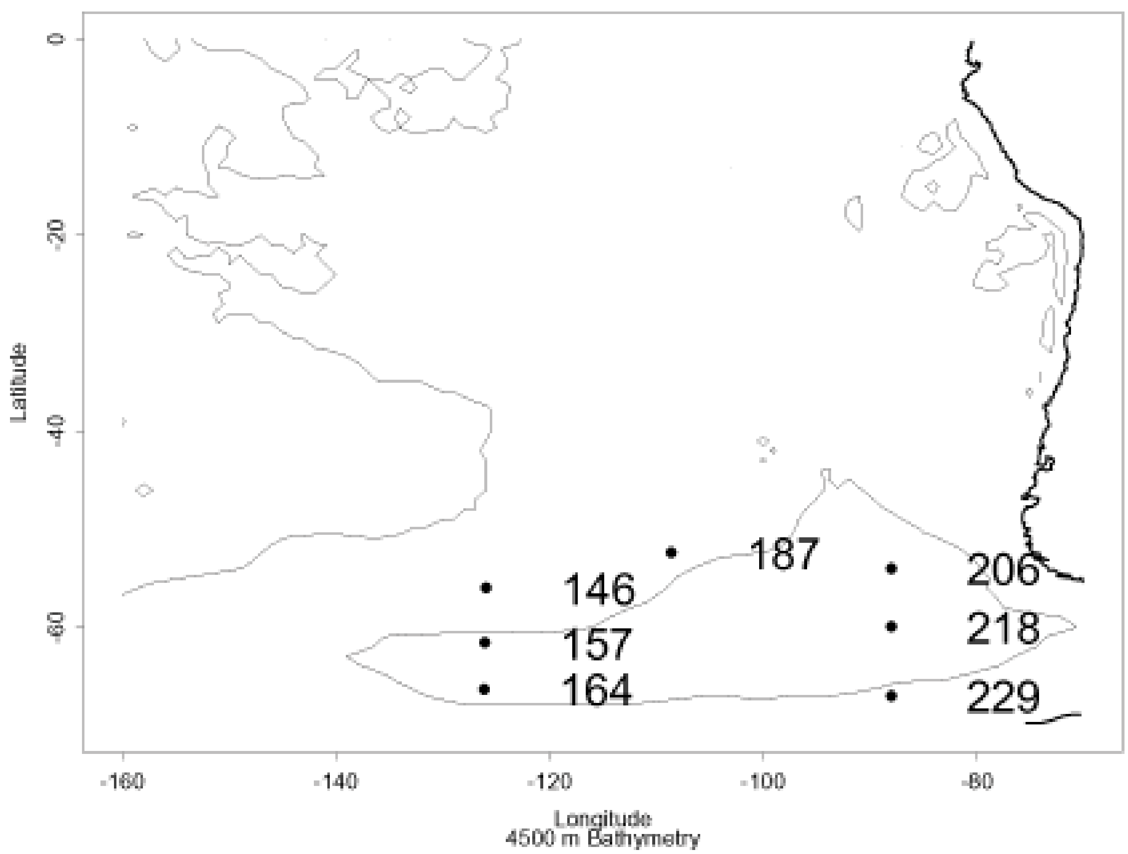

Figure 1: Large volume station locations for WOCE cruise P17E19S.

2.0 Personnel

LV sampling for this cruise was under the direction of the principal investigator, Robert M. Key (Princeton). All LV ^{14}C extractions at sea were done by Key. In addition to Key, deck work was done by the SIO CTD group (primarily Ron Patrick and David Muus) with assistance from the scientific party. Muus, Patrick and Key were responsible for reading thermometers. Salinities and nutrients were analyzed by SIO-ODF with assistance from Dennis Guffy (Texas A&M Univ.). ^{14}C analyses were performed at Göte Östlund's laboratory (U. Miami, R.S.M.A.S.). Minze Stuiver made the ^{13}C measurements which are necessary to correct the ^{14}C values for fractionation effects. Key collected the data from the originators, merged the files, assigned quality control flags to the ^{14}C, rechecked the flags assigned by ODF and submitted the data files to the WOCE office (7/96).

3.0 Results

This data set and any changes or additions supersedes any prior release. In this data set Gerard samples can be differentiated from Niskin samples by the bottle number. Niskin bottle numbers are in the range 41-49 while Gerards are in the range 81-93.

3.1 Pressure and Temperature

Pressure and temperature for the LV casts are determined by reversing thermometers mounted on the piggyback Niskin bottle. Each bottle was equipped with the standard set of 2 protected and 1 unprotected thermometer. Each temperature value reported on the LV casts was calculated from the average of four readings, provided both protected thermometers functioned normally. The temperatures are based on the International Temperature Scale of 1990. All thermometers, calibrations and calculations were provided by SIO-ODF. Reported temperatures for samples in the thermocline are believed to be accurate to 0.01°C and for deep samples 0.005°C. Pressures were calculated using standard techniques combining wire out with unprotected thermometer data. In cases where the thermometers failed, pressures were estimated by thermometer data from adjacent bottles combined with wire out data. Because of the inherent error in pressure calculations and the finite flushing time required for the Gerard barrels, the assigned pressures have an uncertainty of approximately 10 dB. The pressures recorded in the data set for each Gerard-Niskin pair generally differ by approximately 0.5 dB with the Gerard pressure being the greater. This is because the Niskin is hung near the upper end of the Gerard. Figure 2 shows potential temperature vs. pressure for the LV casts. CTD values from the same stations and pressure ranges are indicated on the plot (small filled squares).

3.2 Salinity

Salinity samples were collected from each Gerard barrel and each piggyback Niskin bottle. Analyses were performed by the same personnel who ran the salt samples collected from the Rosette bottles so the analytical precision should be the same for LV salts and Rosette salt samples. When both Gerard and Niskin trip properly, the difference between the two salt measurements should be within the range 0.000 - 0.003 on the PSU scale. Somewhat larger differences can occur if the sea state is very calm and the cast is not "yoyo'ed" once the terminal wire out is reached. This difference is due to the flushing time required for the Gerard barrels and the degree of difference is a function of the salinity gradient where the sample was collected. In addition to providing primary hydrographic data for the LV casts, measured salinity values help confirm that the barrels closed at the desired depth. For the area covered by this leg, deep nutrient values (especially silicate) are as useful for trip confirmation as salt measurements due to the very low salt gradients.

Salinity samples were drawn into 200 ml Kimax high alumina borosilicate bottles after 3 rinses, and were sealed with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. As loose inserts were found, they were replaced to ensure a continued air-tight seal. Salinity was determined after a box of samples had equilibrated to laboratory temperature, usually within 8-12 hours of collection. The draw time and equilibration time, as well as per-sample analysis time and temperature were logged.

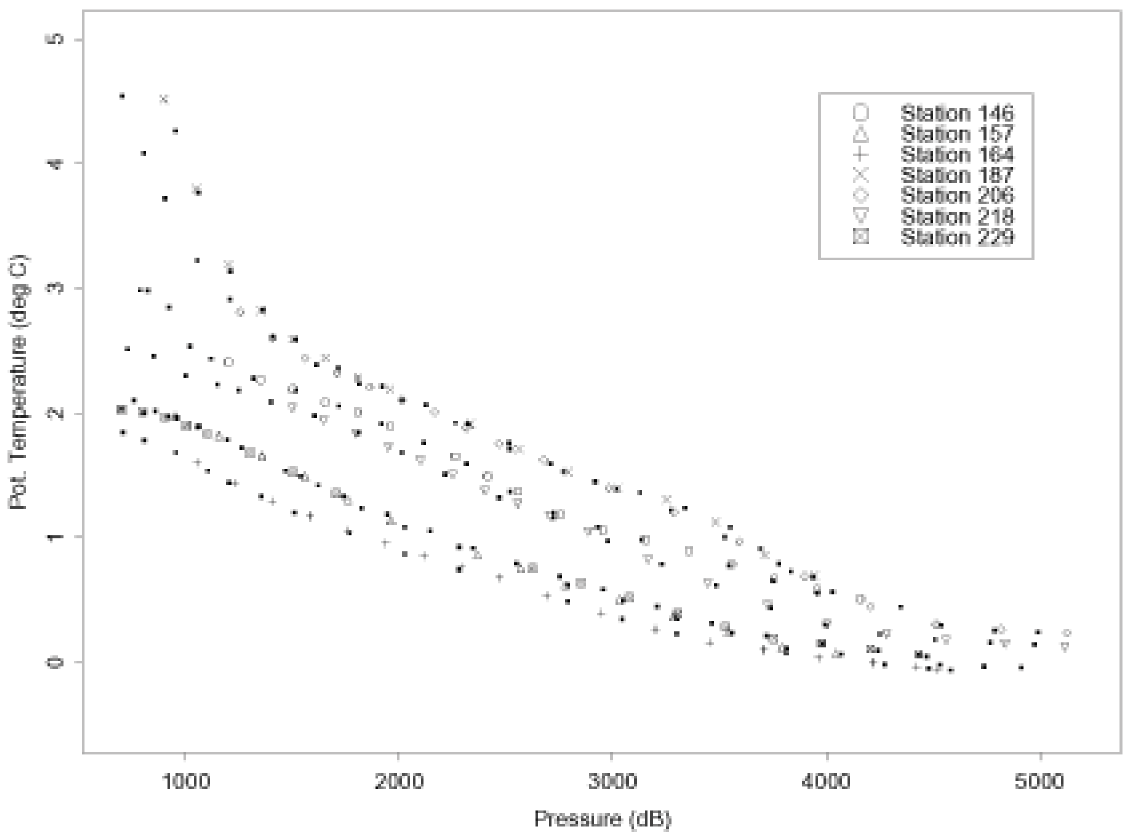

Figure 2: Potential temperature from DSRT on LV casts vs. pressure. CTD data from the same stations and depth ranges are indicated by small filled squares.

A single Guildline Autosal Model 8400A salinometer located in a temperature controlled laboratory was used to measure salinities. The salinometer was standardized for each cast with IAPSO Standard Seawater (SSW) Batch P-120, using at least one fresh vial per cast. The estimated accuracy of bottle salinities run at sea is usually better than 0.002 PSU relative to the particular Standard Seawater batch used. PSS-78 salinity (UNESCO 1981) was then calculated for each sample from the measured conductivity ratios, and the results merged with the cruise database. There were some problems with lab temperature control throughout cruise; the Autosal bath temperature was adjusted accordingly. Salinities were generally considered good for the expedition despite the lab temperature problem. The quality of the temperature and salinity is demonstrated by Figure 3 which shows data from all of the large volume samples overlain by CTD/Rosette data from the same stations. Each Gerard-Niskin pair is assigned the same temperature which allows direct comparison of many of the paired salinity values on the figure.

3.3 Nutrients

Nutrient samples were collected from Gerard samples. On this leg silicate values were measured on all samples. LV nutrients were measured along with Rosette nutrients so the analytical precision for Gerard samples should be the same as Rosette samples. Nutrients collected from LV casts are frequently subject to systematic offsets from samples taken from Rosette bottles. For this reason it is recommended that these data be viewed primarily as a means of checking sample integrity (*i.e.* trip confirmation). The Rosette-Gerard discrepancy is frequently less for silicate than for other nutrients.

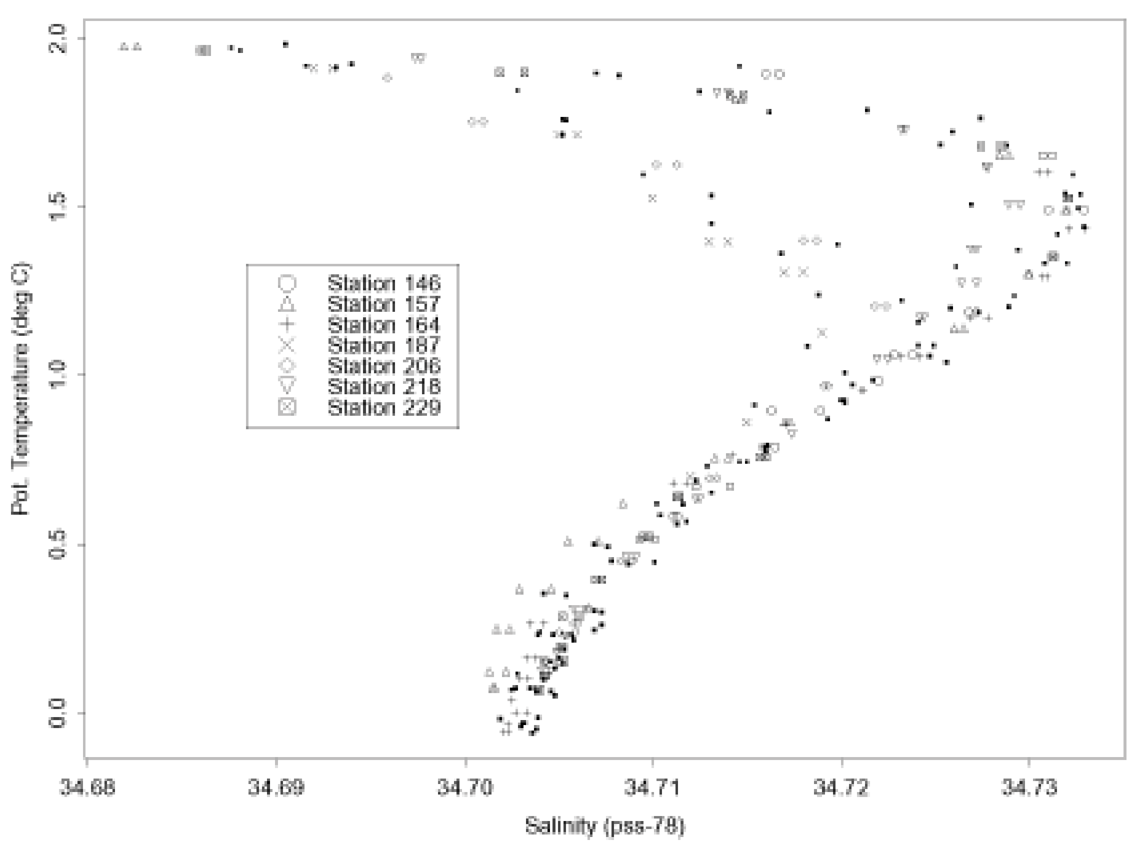

Figure 3: Theta-salinity for all of the large volume cast data with a QC flag of 2 for both temperature and salinity. CTD theta values with Rosette bottle salinities (small filled squares) are overlain for comparison.

Nutrient samples were drawn into 45 ml high density polypropylene, narrow mouth, screw-capped centrifuge tubes which were rinsed three times before filling. Standardizations were performed with solutions prepared aboard ship from pre-weighed chemicals; these solutions were used as working standards before and after each cast to correct for instrumental drift during analysis. Sets of 4-6 different concentrations of shipboard standards were analyzed periodically to determine the linearity of colorimeter response and the resulting correction factors.

Nutrient analyses were performed on an ODF-modified 4 channel Technicon AutoAnalyzer II, generally within one hour of the cast. Occasionally some samples were refrigerated at 2 to 6°C for a maximum of 4 hours. The methods used are described by Gordon *et al*. (1992), Atlas *et al*. (1971), and Hager *et al*. (1972). All peaks were logged manually, and all the runs were re-read to check for possible reading errors.

Silicate was analyzed using the technique of Armstrong *et al.* (1967). ODF''s methodology is known to be non-linear at high silicate concentrations (>120 µM); a correction for this non-linearity was applied. Phosphate was analyzed using a modification of the Bernhardt and Wilhelms (1967) technique.

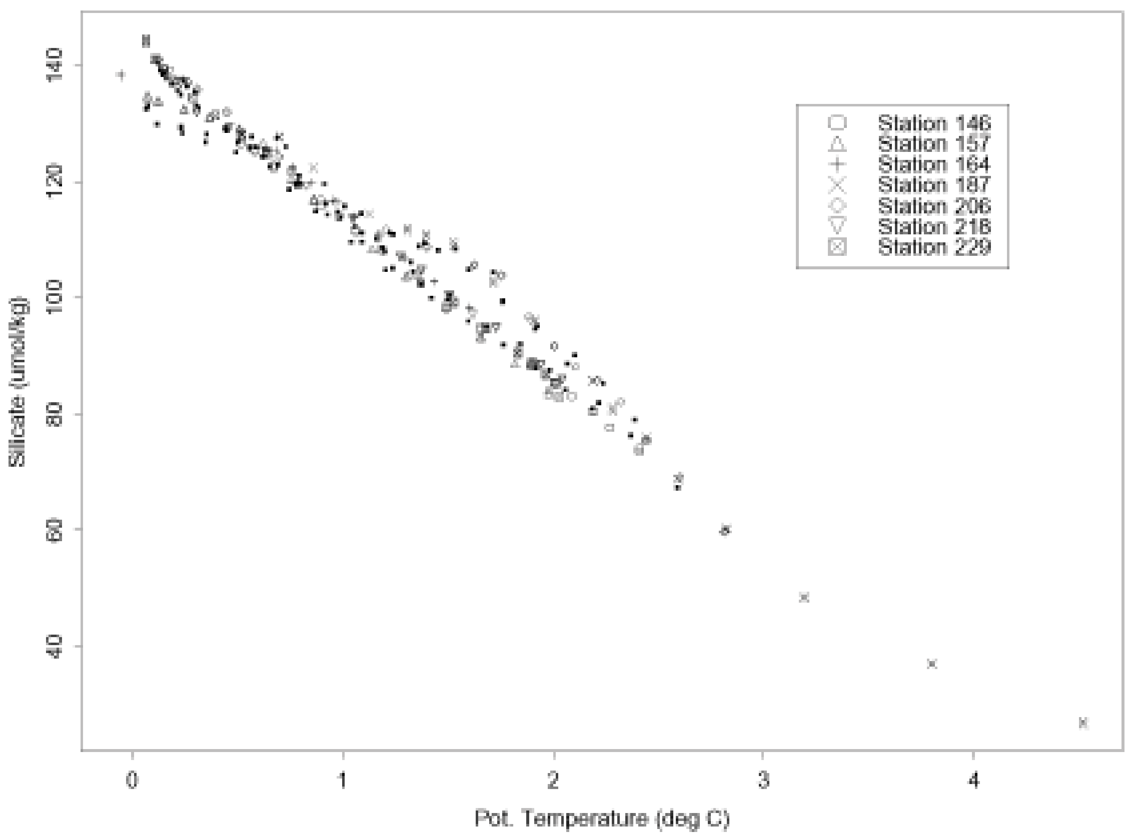

Figure 4: Plot includes silicate data from both Gerard and piggyback Niskin samples. Rosette/CTD data from the same stations and depth ranges are overlain (small filled squares).

Na_2SiF_6, the silicate primary standard, was obtained from Fluka Chemical Company and Fischer Scientific and is reported by the suppliers to be >98% pure. Primary standards for phosphate, KH_2PO_4, were obtained from Johnson Matthey Chemical Co. and the supplier reports purity of 99.999%. Nutrients, reported in micromoles per kilogram, were converted from micromoles per liter by dividing by sample density calculated at zero pressure, *in-situ* salinity, and an assumed laboratory temperature of 25°C. The overall quality of the silicate data for this cruise is demonstrated in Figure 4 which shows both Gerard and piggyback Niskin silicate values as a function of potential temperature. Overlain on the plot (small filled squares) are the Rosette measurements for the same stations and depth ranges.

3.4 ^{14}C

Some of the $\Delta^{14}C$ values reported here have been distributed in data reports produced by Östlund (1994, 1995). Those reports included preliminary hydrographic data and are superseded by this submission.

All Gerard samples deemed to be "OK" on initial inspection at sea were extracted for ^{14}C analysis using the technique described by Key (1991). The extracted $^{14}CO_2$/NaOH samples were returned to the Ocean Tracer Lab at Princeton and subsequently shipped to Ostlund's lab in Miami. Both ^{13}C and ^{14}C measurements are performed on the same CO_2 gas extracted from the large volume samples. The standard for the ^{14}C measurements is the NBS oxalic acid standard for radiocarbon dating. R-value is the ratio between the measured specific activity of the sample CO_2 to that of CO_2 prepared from the standard, the latter number corrected to a $\delta^{13}C$ value of -19 ‰ and age corrected from today to AD1950 all according to the international agreement. $\Delta^{14}C$ is the deviation in ‰ from unity, of the activity ratio, isotope corrected to a sample $\delta^{13}C$ value of -25 ‰. For further information of these calculations and procedures see Broecker and Olson (1981), Stuiver and Robinson (1974) and Stuiver (1980). Ostlund's lab reports a precision of 4 ‰ for each measurement based on a long term average of counting statistics. Of the 123 Gerard samples collected, ^{14}C has been measured on 102 (83%). This exceeds the rate funded for this work (80%). Existing ^{14}C data for the area sampled on this cruise is limited to a few GEO-SECS measurements. Comparison of these two data sets indicates that they are in agreement to the precision of the measurements.

4.0 Data Summary

Figures 4 & 5 summarize the large volume ^{14}C data collected on this leg. All $\Delta^{14}C$ measurements with a quality flag value of 2 are included in each figure. Figure 5 shows the $\Delta^{14}C$ values plotted as a function of pressure. One sigma error bars (±4 0/00) are shown with each datum. The most noticeable characteristic is the fact that there is little or no gradient for values collected at pressure greater than 2000dB. Figure 6 shows the $\Delta^{14}C$ values plotted against measured Gerard barrel silicate values. Essentially no correlation between $\Delta^{14}C$ and silicate is indicated by this data. The angled heavy line is the relationship suggested by Broecker *et al*. (1995) to be representative of the mean global pre-bomb $\Delta^{14}C$ -silicate correlation. As was pointed out in that paper, and as is evident with this data set, the relationship does not hold for high latitude southern waters.

5.0 Quality Control Flag Assignment

Quality flag values were assigned to all bottles and all measurements using the code defined in Tables 0.1 and 0.2 of WHP Office Report WHPO 91-1 Rev. 2 sections 4.5.1 and 4.5.2 respectively. In this report the only bottle flag values used were 2, 3, 4 and 9.

For the measurement flags values of 2, 3, 4 or 9 were assigned. The interpretation of measurement flag 9 is unambiguous, however the choice between values 2, 3 or 4 is involves some interpretation. For this data set, the salt and nutrient values were checked by plotting them over the same parameters taken from the rosette at the same station. Points which were clearly outliers were flagged "4". Points which were somewhat outside the envelop of the other points were flagged "3". In cases where the entire cast seemed to be shifted to higher or lower concentrations (in nutrient values), but the values formed a smooth profile, the data was flagged as "2". A few of the large volume flag values have been changed from those given in the ODF final report. Once the nutrient and salt data had been flagged, these results were considered in flagging the ^{14}C data. There is very little overlap between this data set and any existing ^{14}C data, so that type of comparison was impractical. In general the lack of other data for comparison led to a more lenient grading on the ^{14}C data. 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 of ~4 ‰. All of the $\Delta^{14}C$ values reported for this cruise were flagged "2".

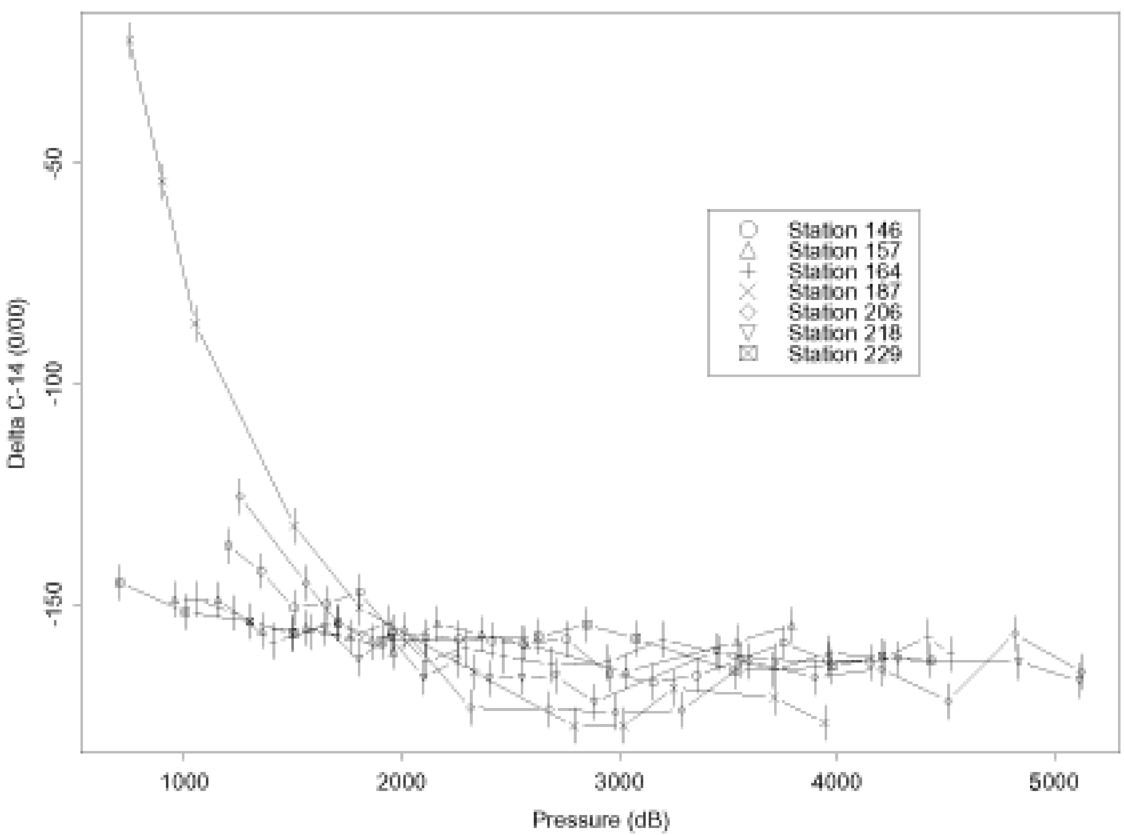

Figure 5: All LV $\Delta^{14}C$ values as a function of pressure. Vertical bars indicate one sigma (4 ‰) errors.

No measured values have been removed from this data set. When using this data set, it is advised that the nutrient data only be considered as a tool for judging the quality of the ^{14}C data regardless of the quality code value. A summary of all flags is provided in Table 2.

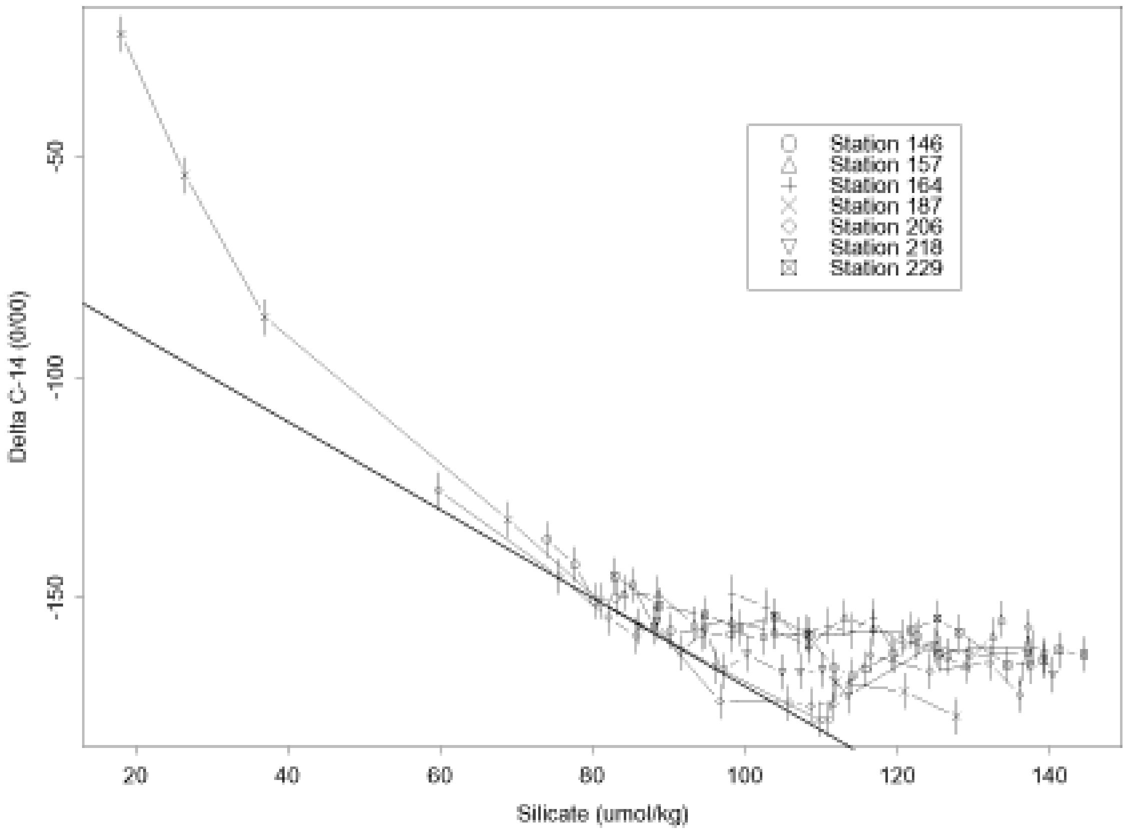

Figure 6: All LV Δ^{14}C measurements having a quality control flag value of 2 or 6 are plotted. Vertical bars are one sigma errors. The heavy line is that suggested by Broecker, *et al*. (1995) to be representative of the global relationship between pre-bomb ^{14}C and silicate.

TABLE 2. Quality Code Summary

		WHP Quality Codes								
	Levels	1	2	3	4	5	6	7	8	9
BTLNBR	246	0	239	1	1	0	0	0	0	5
SALNTY	240	0	227	12	1	0	0	0	0	6
SILCAT	240	0	223	16	1	0	0	0	0	6
REVPRS	246	0	246	0	0	0	0	0	0	0
REVTMP	238	0	235	1	1	0	0	0	0	9
DELC14[a]	123	0	102	0	0	21	0	0	0	0

a. ^{14}C large volume samples can not be collected from piggyback Niskin bottles

6.0 References and Supporting Documentation

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7.0 Appendix

Quality Comments

Remarks for missing samples, and WOCE codes other than 2 from JUNO - WOCE P16A/P17A Large Volume Samples. Investigation of data may include comparison of bottle salinity and silicate data from piggyback and Gerard with CTD cast data, review of data plots of the station profile and adjoining stations, and rereading of charts (i.e., nutrients). Comments from the Sample Logs and the results of ODF's investigations are included in this report.

Station 146

347 @2111db Left protected and middle protected therms both malfunction, no temperature readings.

389 @2111db See thermometer failure on NB347.
141 @2557db Delta-S (n-g) at 2557db is 0.0059, salinity is 34.732. Salinities in gerard(81) and niskin(41) are equally off when compared with rosette cast. No indication of any problems in sample log. Footnote salinity uncertain. Silicate values slightly low, but within precision of measurement.
181 @2558db Footnote salinity uncertain. Other gerard sample integrity to be determined by PI.
144 @3156db Delta-S (n-g) at 3156db is 0.0031, salinity is 34.722. Values from NB44 are OK. See comments for GER 84.
184 @3156db Salinity and silicate low compared with NB44 and rosette. Footnote salinity uncertain.
145 @3356db Delta-S (n-g) at 3356db is 0.0026, salinity is 34.719. Gerard salinity and silicate acceptable.

Station 157

347 @2164db Both left protected and middle protected therms malfunctioned. No temperature.
389 @2165db See therm failure on NB347.
141 @2778db Therm Sheet: "41 Nis no trip, therm OK". No samples from NB141. Samples from GER 181 are OK.
187 @4045db Therm Sheet: "87 did not drop messenger". Samples from both Ger 187 and piggyback Nis 146 are OK. However, Ger's 189, 190, 193 and piggyback Niskins did not close.

Station 164

347 @2114db Sample log: "Therm ok, bottle no trip." No water samples from this bottle.
241 @2690db Delta-S (n-g) at 2690db is 0.0045, salinity is 34.712. Ger 81 salinity value closer to rosette value than Nis 41. Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote Salinity and Silicate uncertain.
281 @2691db See 241 salinity and silicate values.
242 @2945db Delta-S (n-g) at 2945db is 0.0057, salinity is 34.711. Ger 82 salinity value closer to rosette value than Nis 42. Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote salinity and silicate uncertain.
282 @2945db See 241 salinity and silicate values.
243 @3199db Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.
283 @3200db See 243 silicate value.
244 @3454db Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.
284 @3454db See 244 silicate value.
245 @3708db Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.
285 @3708db See 245 silicate value.
246 @3962db Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain.
287 @3963db See 246 silicate value.

247 @4217db Silicate value about 3 µmol/kg higher than associated Ger. Ger value close to rosette value. Footnote silicate uncertain. Footnote silicate uncertain.
289 @4217db See 247 silicate value.
248 @4420db Silicate value about 3 µmol/kg higher than associated Ger. Nis value closer to rosette value than Ger 90.
290 @4420db See 248 silicate value.

Station 187

341 @ 749db Niskin 41 not tripped. Niskin trip arm on Gerard 81 not down far enough. No Niskin samples. Gerard salt & silicate agree well with Rosette data.
348 @1808db (N-G) 0.003 low at 1808db. Calc & Autosal runs ok. Leave for now. 930111/dm Nis 48 piggyback on Ger 90.
390 @1809db See 348 salinity comment.
149 @2105db Niskin 49 not tripped. Niskin trip arm on Gerard 81 not down far enough. No Niskin samples. Niskin 41 normally on this Gerard so thought bottle mismatch was problem. Gerard salt & silicate agree well with Rosette data.
189 @3483db (N-G) 0.048 high. Gerard salinity and silicate both appear to be from higher in water column. Leave for now to indicate Gerard sample problem. 930111/dm
142 @3713db Nis 42 is bottle associated with Ger 90.
190 @3714db (N-G) 0.005 high at 3714db. Gerard silicate also a little lower(1.5) than the Niskin silicate indicating a possible small leak in Gerard sample. Footnote silicate and salinity uncertain.

Station 206

341 @1257db (N-G) 0.005 high at 1257db. Took 4 Autosal runs to get 2 runs to agree. Probably salt crystal contamination. First Autosal run after rinses gives (N-G) 0.001 low. Gerard salt and silicates good.
346 @2012db (N-G) 0.006 high at 2012db. Took 7 Autosal runs to get 2 runs to agree. Probably salt crystal contamination. First Autosal run after rinses gives (N-G) 0.0004 low. Gerard salt and silicates good.

Station 218

341 @1500db (N-G) salt 0.005 high at 1500db. 4 Autosal runs to get agreement. First run after rinses gives (N-G) 0.000. Used first run. 930114/dm
142 @3164db Sample Log: "Tube (plastic) in upper lid". No samples.
147 @4558db Sample Log: "Lanyard hung up". No samples.

Station 229

383 (No Pressure) Gerard Barrel 83 failed to trip on cast 3. Messenger was on trip arm with latch not pushed quite far enough close lid. Messenger not released. Lowered remaining barrels to shallower terminal reading as cast 4.
449 @1909db DSRTs not shaken down from previous cast. Same readings as NB49 on Cast 1. Footnote bad thermometer readings.

P17E19S
Final Report for AMS ^{14}C Samples

Robert M. Key
March 3, 1997

1.0 General Information

WOCE P17E19S (WHPO 316N138/10) consisted of two meridional sections and one zonal section in the far southeastern Pacific Ocean. The cruise departed Papeete, Tahiti on December 4, 1992 and ended on January 22, 1993 at Puenta Arenas, Chile. The reader is referred to cruise documentation provided by the chief scientist, James H. Swift, 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 480 samples were collected at the 28 stations sampled for $\Delta^{14}C$. Seven of the stations were also sampled using the large volume technique. The results of the large volume sampling program were reported by Key (1996).

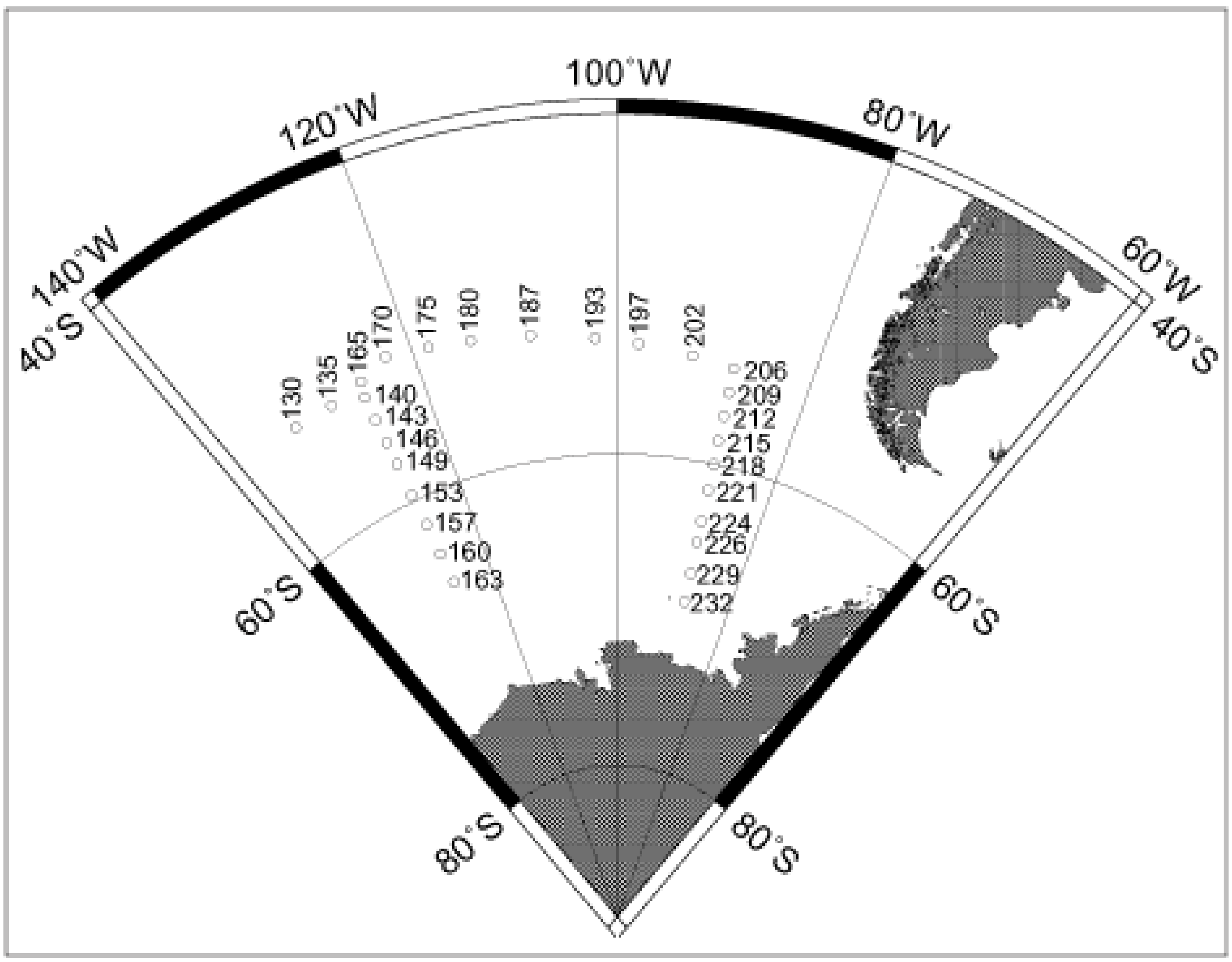


Figure 1: AMS ^{14}C station locations for WOCE P17E19S.

Table 1: Radiocarbon station summary

Station	Date	Latitude	Longitude	Bottom Depth (m)
130	12/14	-52.504	-133.350	4402
135	12/16	-52.510	-129.275	3840
140	12/17	-53.004	-125.998	4385
143	12/18	-54.477	-125.982	3637
146	12/19	-56.002	-125.975	4273
149	12/20	-57.492	-126.001	4060
153	12/22	-59.604	-126.053	4809
157	12/23	-61.659	-125.991	4818
160	12/24	-63.681	-126.005	4968
163	12/25	-65.660	-126.031	4772
165	12/29	-52.042	-125.622	3256
170	12/30	-51.299	-122.517	3440
175	12/31	-51.654	-118.376	2972
180	1/1	-51.956	-114.296	3364
187	1/3	-52.389	-108.538	3890
193	1/5	-52.900	-102.238	4510
197	1/7	-53.245	-97.879	4638
202	1/8	-53.672	-92.383	4910
206	1/10	-54.016	-87.986	5041
209	1/11	-55.509	-88.019	5170
212	1/12	-56.995	-87.996	5097
215	1/12	-58.504	-88.009	5087
218	1/13	-60.000	-87.982	5022
221	1/14	-61.656	-87.964	4867
224	1/15	-63.678	-87.973	4790
226	1/16	-65.005	-87.983	4673
229	1/17	-67.019	-87.994	4417
232	1/17	-68.871	-87.976	3534

2.0 Personnel

^{14}C sampling for this cruise was carried out by R. Key from Princeton U. ^{14}C analyses were performed at the National Ocean Sciences AMS Facility (NOSAMS) at Woods Hole Oceanographic Institution. Salinities and nutrients were analyzed by the SIO CTD group. 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 (3/97). Key is P.I. for these ^{14}C data.

3.0 Results

This ^{14}C 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 final hydrographic reports.

3.2 ^{14}C

The $\Delta^{14}C$ values reported here were originally distributed in a data report (NOSAMS, Jan.15, 1997). That report included preliminary hydrographic data and ^{14}C results which had not been through the WOCE quality control procedures. This report supersedes that data distributions.

All of the AMS samples from this cruise have been measured. Replicate measurements were made on 14 of the water samples. These replicate analyses are tabulated in Table 2. The table shows the error weighted mean and uncertainty for each set of replicates. The uncertainty is defined here as the larger of the standard deviation and the error weighted standard deviation of the mean. For these samples, the average standard deviations is 4.3 ‰. This precision estimate is approximately correct for the time frame over which these samples were measured (Feb. - Dec. 1996, but primarily the latter half of the year). For a summary of the improvement in precision with time at NOSAMS, see Key, *et al*. (1996). Note that the errors given in the final data report include only counting errors, and errors due to blanks and backgrounds. The uncertainty obtained for replicate analysis is an estimate of the true error which includes errors due to sample collection, sample degassing, *etc*.

Table 2: Summary of Replicate Analyses

Sta-Cast-Bottle	$\Delta^{14}C$	Err	Mean[a]	Uncertainty[b]
160-1-12	-142.1	3.1	-144.6	3.4
	-146.9	2.9		
160-1-13	-146.3	3.4	-147.0	3.2
	-149.2	3.2		
175-1-35	-191.8	2.8	-195.4	8.7
	-204.1	4.3		
180-1-24	-156.2	3.1	-160.1	5.0
	-163.3	2.8		
180-1-29	-169.9	2.8	-172.3	4.2
	-175.9	3.4		
202-1-15	-20.2	3.4	-23.8	4.6
	-26.7	3.0		
206-2-20	-94.3	3.1	-97.7	4.2
	-100.2	2.7		
209-1-13	-15.8	5.2	-17.3	2.3
	-17.7	2.6		
212-1-1	31.0	3.4	33.6	4.9
	38.0	4.5		
226-1-15	-143.4	3.2	-144.3	2.2
	-144.9	2.9		

Sta-Cast-Bottle	$\Delta^{14}C$	Err	Mean[a]	Uncertainty[b]
232-1-8	-141.9	2.5	-144.6	9.0
	-154.7	4.8		
232-1-11	-156.5	6.0	-158.6	2.5
	-159.1	2.7		
232-1-16	-143.7	2.3	-147.0	5.5
	-151.5	2.7		
232-1-28	-167.1	3.3	-169.2	2.8
	-171.0	3.1		

a. Error weighted mean reported with data set
b. Larger of the standard deviation and the error weighted standard deviation of the mean.

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 no 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 (~4.3 ‰). No measured values have been removed from this data set. 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	455
3	5
4	3
5	3
6	14

5.0 Data Summary

Figures 2-5 summarize the AMS ^{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 data density in this figure demonstrates the scheme for the small volume sampling - AMS samples were used to cover the surface and thermocline waters while large volume samples covered deep and bottom waters (at a significantly decreased density). The deep AMS samples collected on this leg were primarily substitutes for large volume sample when the weather was too harsh to allow Gerard bottle casts. The most outstanding things to note in Figure 2 are the very old near surface values, the lack of a mid-depth minimum and the large spread in the near surface. The old near surface values are due to the large vertical mixing known to occur in this region. The large spread in the near surface waters is due to the fact that the cruise track crossed two frontal regions. The stations taken north of the northernmost front have the highest ("youngest) near surface values.

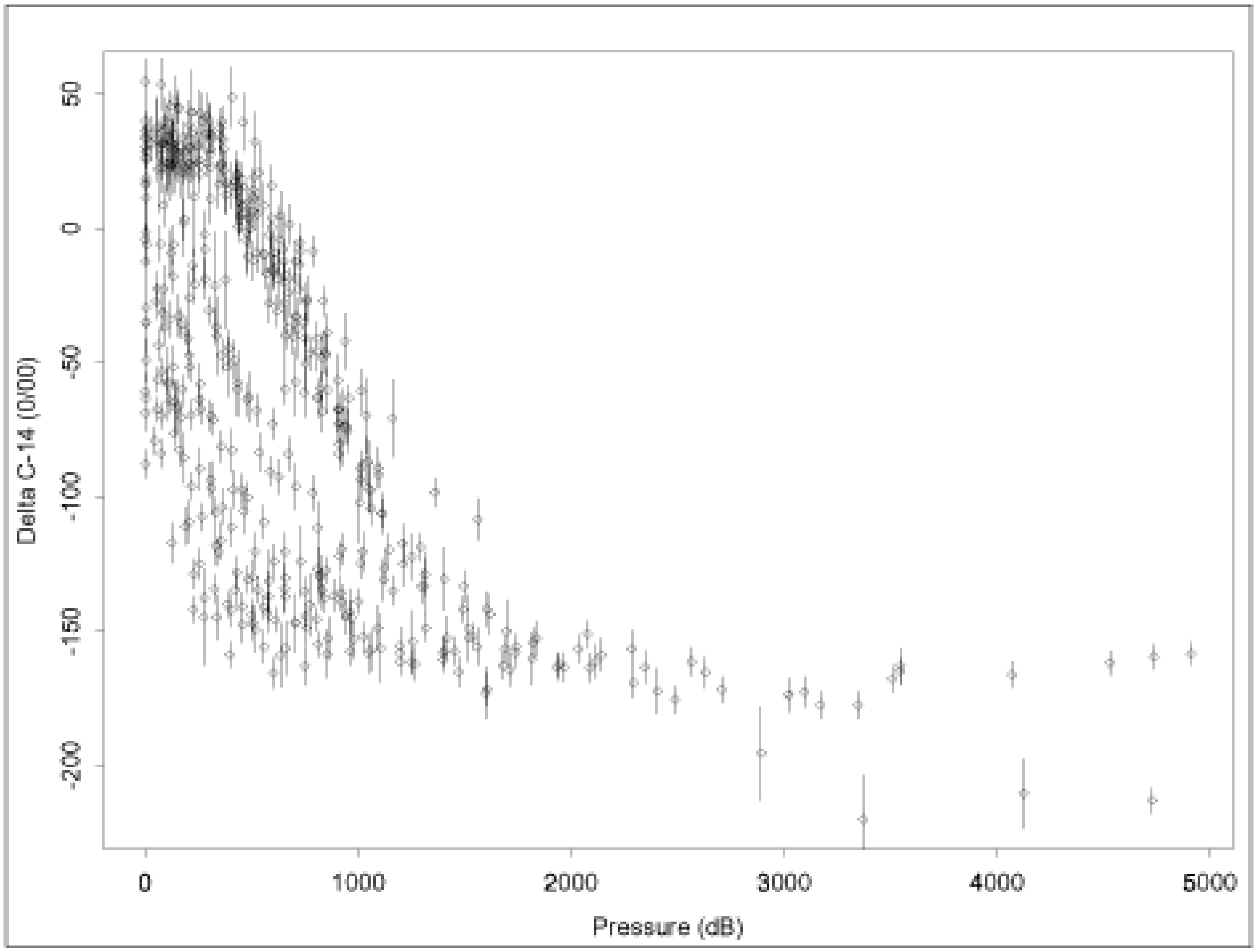


Figure 2: AMS $\Delta^{14}C$ results for P17E19S stations shown with 2σ error bars. Only those measurements having a quality control flag value of 2 are plotted.

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. It is unlikely that the points falling above the line with silicate concentrations greater than 100 mm/kg are elevated due to the addition of bomb-produced $\Delta^{14}C$. If the

GEOSECS Pacific data from the same latitude range were added to Figure 3, the points would fall within the envelop of the WOCE data.

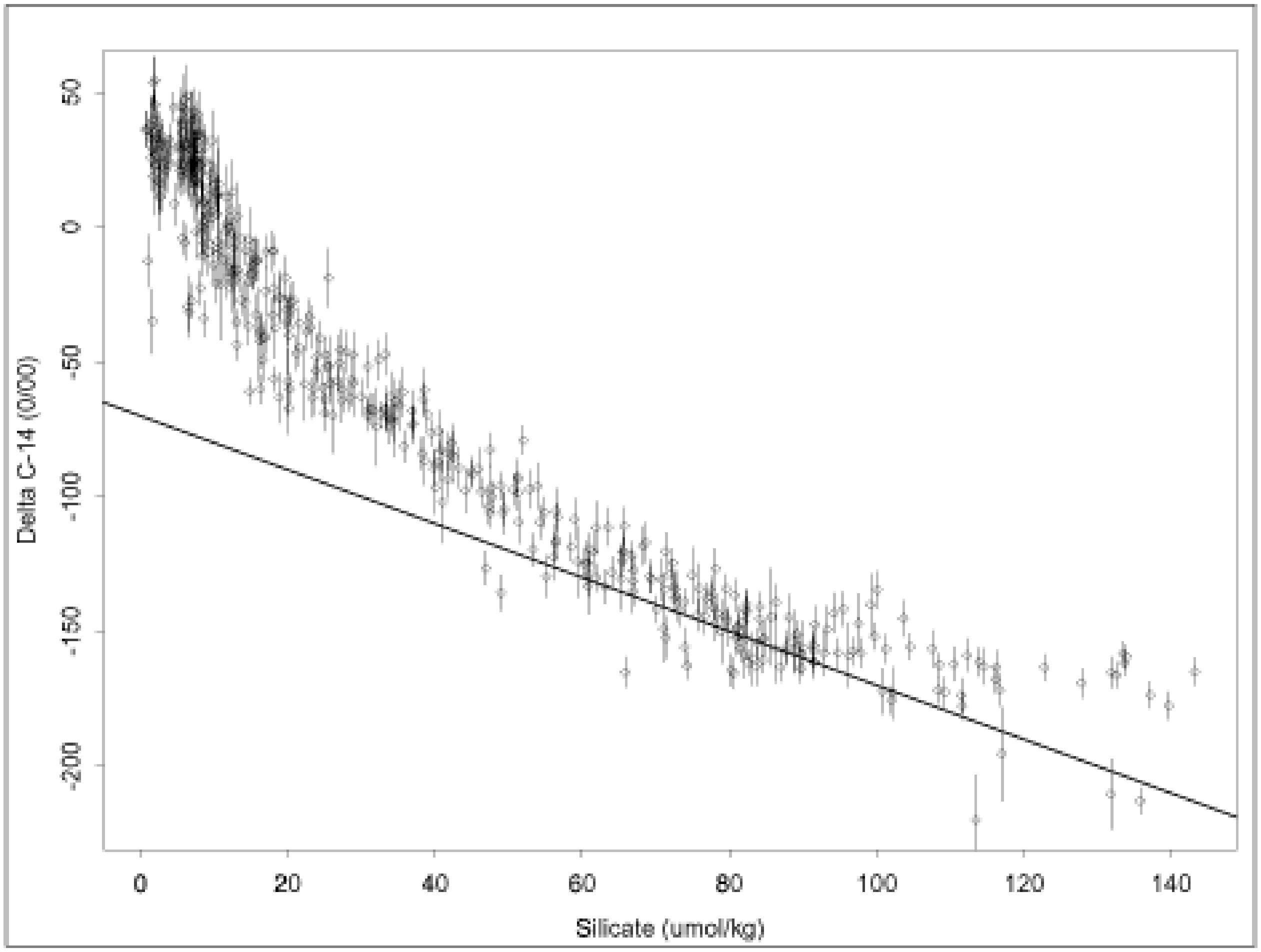


Figure 3: $\Delta^{14}C$ as a function of silicate for P17E19S AMS samples. The straight line shows the relationship proposed by Broecker, et al., 1995 ($\Delta^{14}C$ = -70 - Si with radiocarbon in ‰ and silicate in µmol/kg).

Figure 4, Figure 5 and Figure 6 show contoured sections of the $\Delta^{14}C$ distribution for the upper 1.5 kilometer of the water column. The data in these sections were girded using the "loess" methods described in Chambers *et al*. (1983), Chambers and Hastie (1991), Cleveland (1979) and Cleveland and Devlin (1988). Figure 4 shows the zonal section which runs approximately along 52°S, but trends slightly south of east. All of the stations on this section were taken north of the Subantarctic Front, however, most of the waviness in the contour lines in this section is probably due to meanders in the general circumpolar circulation. This is implied by the lower portion of Figure 4 in which the same data is plotted against potential density (σ_θ).

Figure 5 and Figure 6 show $\Delta^{14}C$ for the meridional sections along 125°W and 88°W, respectively. The data included in each section was limited to samples collected in the upper 1500dB of the water column. The lower portion of each figure shows the same data used in the upper portion, but plotted in potential density space rather than pressure space. In each figure the same isopycnals appear to outcrop ($\Delta^{14}C$ => -60 0/00), however, each of these isolines on the 88°W section outcrops further to the south and at a lighter density than on the 125°W section.

5.1 References and Supporting Documentation

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.

Cleveland, W.S. and S.J. Devlin, 1988, Locally-weighted regression: An approach to regression analysis by local fitting, J. Am. Statist. Assoc, 83:596-610.

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., P17E19S Final report for large volume samples and $\Delta^{14}C$ measurements, Ocean Tracer Laboratory Tech. Rep. # 96-8, 15pp, 7/8/96.

Key, R.M., WOCE Pacific Ocean radiocarbon program, *Radiocarbon*, *38, in press*, 1996.

Key, R.M., P.D. Quay and NOSAMS, WOCE AMS Radiocarbon I: Pacific Ocean results; P6, P16 & P17, *Radiocarbon, 38, in press*, 1996.

NOSAMS, National Ocean Sciences AMS Facility Data Report #97-001, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, 1997.

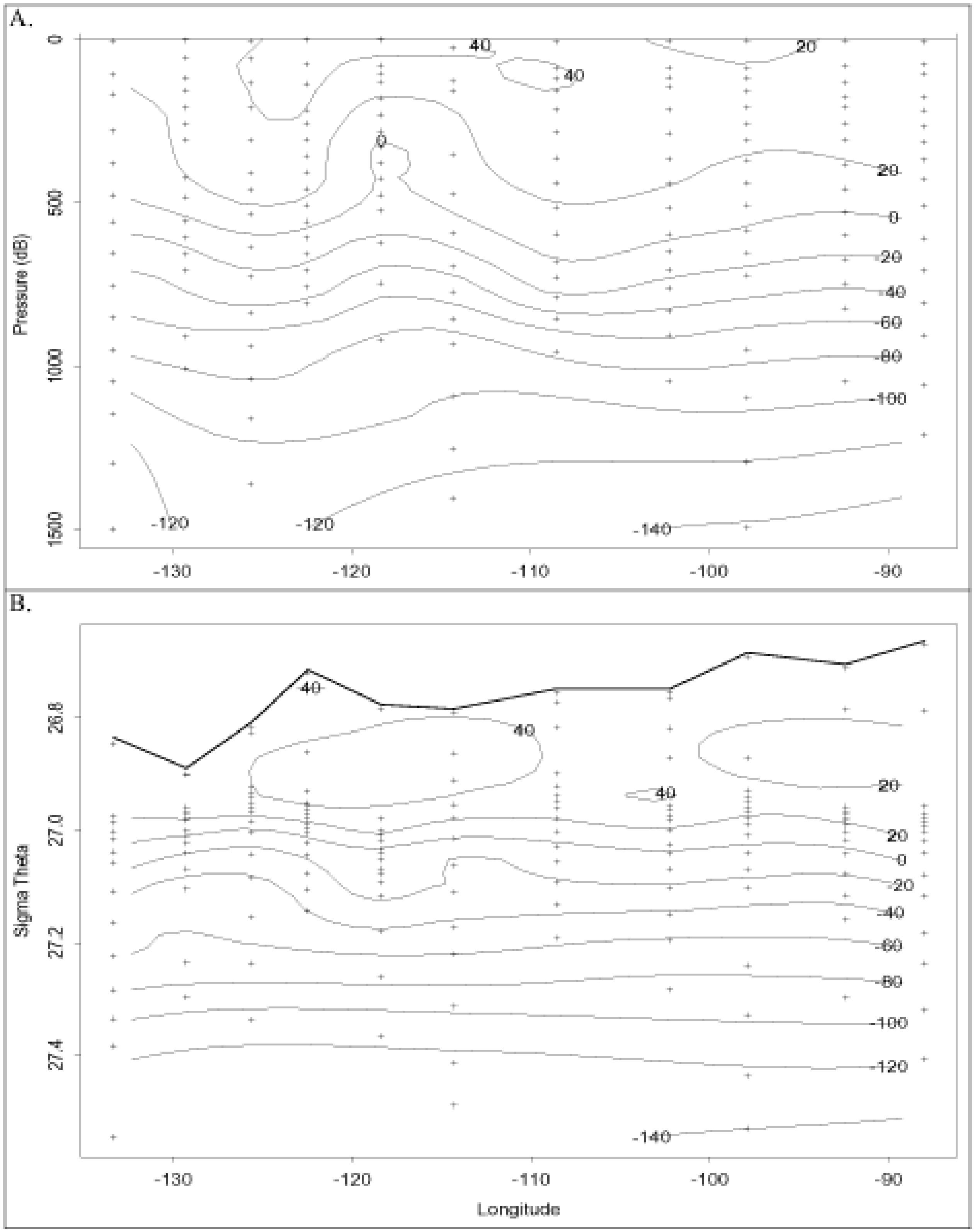


Figure 4: $\Delta^{14}C$ in the upper 1500dB of Juno-2 (WOCE line P17E19S) along 52°S. Gridding done using a loess method (references given in text). All of the samples were measured using the AMS technique. In B. the heavy line indicates the ocean surface. The waviness in the pressure section (A) is due to meanders in the Antarctic Circumpolar Current.

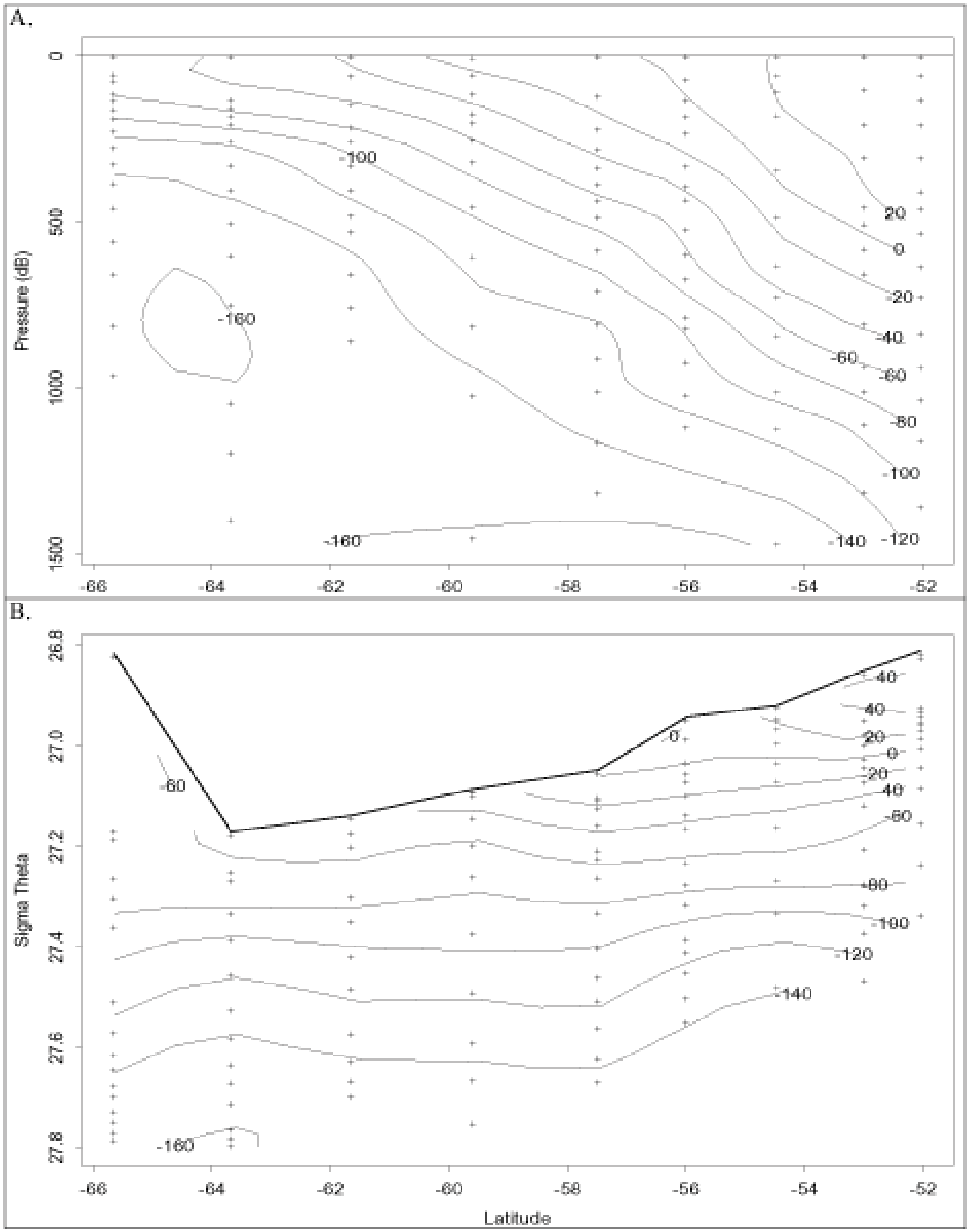


Figure 5: $\Delta^{14}C$ in the upper 1500dB of Juno-2 (WOCE line P17E19S) along 125°W. Gridding done using the loess method (references in text). All of the samples were measured using the AMS technique. In B. the heavy line indicates the ocean surface.

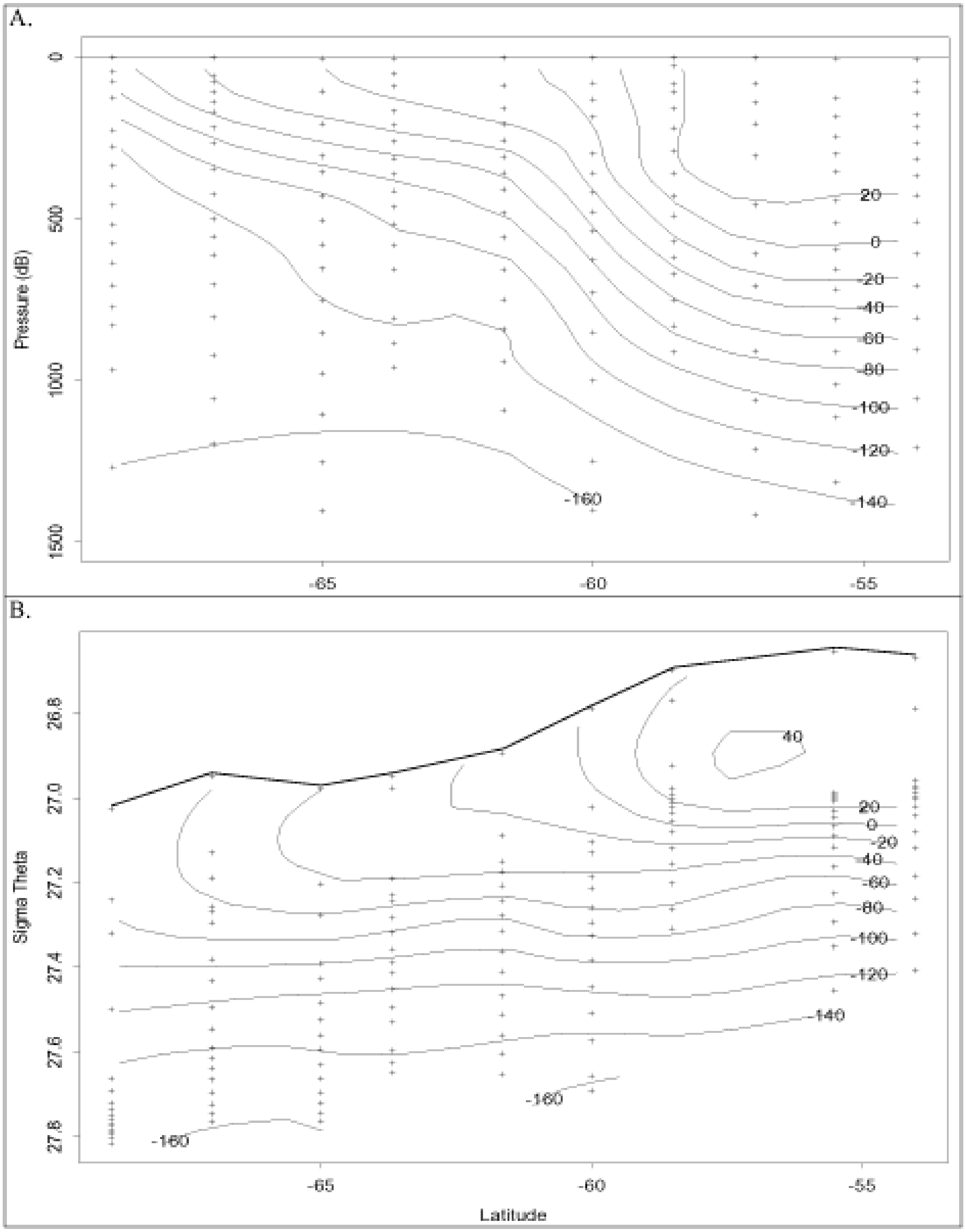


Figure 6: $\Delta^{14}C$ in the upper 1500dB of Juno-2 (WOCE line P17E19S) along 88°W. Gridding done using the loess method (references in text). All of the samples were measured using the AMS technique. In B. the heavy line indicates the ocean surface.

4 September 1996

DQ Evaluation of JUNO II (Knorr Cr. 138/10) P17E/P19A Hydrographic Data
A. Mantyla

This second Antarctic leg of Juno suffered from many rosette trip problems, although with less serious data loss compared to the first leg. For the most part, the trip depth uncertainties have been resolved satisfactorily. I've noted a few stations below that may need another look and possible adjustment of a few depths. Data density was also less than desired on the few stations where the normal 36 place rosette casts were replaced by 24 bottle casts, and in regions south of 61S where station spacing was increased from the usual 30 nautical mile intervals to 40 nautical miles.

The data originators have done a thorough job in evaluating the data, and in resolving inadvertent shifts in rosette bottle tripping sequences that result from mis-fires, hang-ups, or double-trips. In some cases the data originators flagged bottle codes "4" to indicate that the bottle did not trip where planned, although all of the water sample data is okay and confirmed by CTD salinity and oxygen comparisons. For the most part, I have changed those codes to "2" because the data really is okay, even though the CTD operators did not initially know which bottle they were tripping. Because many data users automatically discard any data flagged 3 or 4, it would be a shame to have data not used that is really okay. Station 201, 206, and 208 are good examples.

I have softened many of the originators codes from "data uncertain" to "data okay" and from "data bad" to "data uncertain"; they seemed over zealous in rejecting data that in many cases were within WOCE precision targets. Also, the "bad" code should not be used for data that appears to be only slightly off of the "normal" profile. The "bad" code should be reserved for known problems or truly impossible results.

The nutrient data, particularly the nitrates, were not as sharp as they were on the last leg. The nitrate profiles shifted from station to station, independent of any change in phosphate profiles. Several nitrate profiles were flagged uncertain, and many other profiles could have been flagged. Most offsets are less than 0.5 mm, so even the "doubtful" data is substantially better than any nearby historical data. This cruise could have benefited by a more careful evaluation of the nitrate standard factors and blanks, along with analyses of group PO_4 - NO_3 scatter plots to refine the nitrate results into a more acceptably consistent pattern.

The CTD oxygen data, taken from the down cast, were considered to be poor at the start of the cast, so all of the CTD O_2 data in the top 100m were arbitrarily flagged uncertain by the data originators. However, many agree quite well with the titration data, so I've changed some of those flags to okay. A few of the mixed layer O_2 analytical results were not in very good agreement, usually the surface value seemed to be in error and have been flagged uncertain. That was also true of some surface salinities (unstable). First sample analytical problems may occur when the equipment is not sufficiently cleared of a very different previous sample (low salinity surface sample run immediately after the high salinity Wormly Water Standard, for example). Deeper O_2 data that appeared to be off by only .02 - .03 ml/l, or less than 1%, I prefer to accept since that is still better than the CTD O_2 data or no data at all, so I've changed some flags to okay accordingly.

There was discussion in the cruise report on whether or not to report CTD trip data for depths where the rosette bottle failed and did not get any water samples from those depths. My own strong preference would be to report the CTD data in those instances, they really help to flesh out the density profile and pinpoint salinity extrema that were meant to be sampled.

Sta. 134 BE - date is wrong, the day and month were transposed. It is in order originally listed by the data originators, rather than in the order preferred by the U.S. WOCE Office.

Sta. 176 BO and EN - day, month and year are incorrect. That date and time occurred back on sta. 172.

Sta. 151 - bottles 35 and 32 would look better moved up one depth shallower to the omitted trip depth of 3656db and the listed depth of 3859db, leaving just CTD info at 4121db. (Mis-trips started at 2nd bottle up on sta. 153 and here.)

Sta. 152 - As on sta. 151, move the 2nd and 3rd bottles up from the bottom to one depth shallower, to the unlisted depth of 4021db and to 4222db, leaving just the CTD info at 4391db. As on sta. 153, mis-trip likely started at the 2nd bottle up.

Sta's. 156-159 - bottles 31 and 32 listed at identical depths, would look better at the next deeper (unlisted) depth, particularly for the oxygen and silicate profiles. Salinity gradients are weak, so salt check not definitive at these depths.

Sta's. 162-164 - bottle 34 would fit better at next planned trip depth up, suggest change and correct the data.

Sta's. 184-185 - all O_2's "u"'d, but profiles look as good as any. No CTD O_2's either. Would prefer to keep this data rather than have no data at all, there isn't any good historical data in this region at all.

Sta. 212 - all salts flagged uncertain, CTD comparison indicates that a salinometer drift correction of zero at the surface to .005 at the bottom should be applied to the bottle data. If that were done the mean CTD minus bottle salinity difference would be .0007 ± .0013 standard deviation and the bottle salts would be okay, confirmed by the composite CTD data.

Sta. 228 - 5 near bottom silicates were flagged questionable. There really wasn't any basis to do so, other than they seemed to be a couple of micromoles low compared to adjacent (but not nearby) stations. I haven't changed the flags, but I recommend keeping the data as okay.

All in all, this is a very valuable data set from a sparsely sampled part of the ocean. It would have been nice to have had stations up the Antarctic continental slope on to the shelf, but I'm sure time constraints did not allow that. None the less, combined with the next Juno leg, the section is reasonably complete from the Antarctic slope to North America. I look forward to seeing the sections.

December 11, 1996

Bob Millard

Data Quality Evaluation Report for WOCE legs P17E and p19S

Two WOCE hydrographic sections P17E and p19S are examined in this report. The data were collected southeast of Tahiti; zonally along 52°S from 135°W to 88W together with two meridional sections south of 52°S approaching the Antarctic continent along 126°W and 88°W. The overall potential temperature versus salinity plot of figure 1 shows the range of potential temperature variation from below -1.8 to 9°C while the salinity varies from 33 to 34.74 psu. Valid oxygens range from 170 to 370 Umol/kg, as indicated on the potential temperature versus oxygen plots of figure 2. All of the 2 decibar CTD temperature, salinity and oxygen observations are displayed in figures 1 and 2 along with all good water sample and CTD observations from the bottle file. The CTD data pre generally well calibrated to the water samples and for the most part free of spurious observations. There are a few odd oxygen values found in the upper layer seen in these overall plots which will be examined later.

The cruise report is informative. It contains a good description of the instrument calibration methods both in the laboratory and during the cruise. The CTD data processing methods applied to this data set and the processing approach to obtain the 2 decibar profiles are also described in detail; following similar descriptions of other Scripps cruise reports. The laboratory calibration description for pressure has some standards pressure values expressed in psi while the CTD measurements are in decibars. I would suggest changing the reporting of all pressures to units of decibars.

The cruise report sections on processing methods and calibration techniques makes a good start towards a technical report describing the method CTD calibration and processing carried out at Scripps. Such a report would allow parts of the current cruise report material to be reduced to references with only the adaptations of procedures discussed in the cruise report along with the problems encountered with processing the particular data set (which this cruise report does a good job of addressing).

The station varying CTD conductivity calibration technique used for this data set differs from the approach we use at WHOI for handling a station varying conductivity calibration. At WHOI we model the conductivity drift from station to station with the conductivity slope variation while the changes described in this report were handled by adjusting the conductivity bias. A conductivity slope change from station to station models the effect of a conductivity sensor output variations associated with a coating or ablation process occurring within the conductivity cell. This cruise report describes applying a smoothed station to station varying bias. Has this been found to adequately model the conductivity cells behavior under all profiling conditions? I do not expect the difference between adjusting the conductivity values using a bias versus a slope to effect the results of this data set as the range of conductivity variations is fairly small but generally the shallow conductivity magnitude of mid-latitude profiles is nearly twice the deep values which will lead to observable differences between using a conductivity bias versus a slope term for the adjustment.

A check of the CTD salinity calibrations for up-profile bottle file samples is given in figure 3a, b, and c. Figure 3a shows salinities differences (all differences are CTD-Water Sample [WS] value) for those WS data marked good in the quality word of the bottle file all pressure levels. Only a few salinity values of stations in the upper 150's and early 160's 205-210 and last few stations 220-233 appear to have excessively large salinity differences. Further checking shows all of these occur in high salt gradient regions where large differences might be expected. Figure 3b shows the good salinities differences below 1000 decibars with a station average (solid line). The scatter (standard deviation) for all the good deep water (pressures greater than 1000 dbars) salinity differences is a low value equal to 0.0011 psu. Only a few stations (159, 162, 191, 193, 207, 209 and 213) appear to have possible deep salinity calibration problems and they will be examined more closely in the vertical using potential temperature versus salinity plots. Figure 3c, the plot of salinity differences versus pressure, shows the CTD salinity data for both P17E and P19S WOCE legs are very well calibrated in the vertical with not even a suggestion of a calibration problem in the vertical.

Waterfall plots of salinity differences versus pressure offset and labelled with station numbers are shown in figure 4 for stations groups around the station 213 that appeared questionable earlier. This plot reinforce the possibility of a salinity calibration error in the CTD but difference plots can't sort out whether the CTD or bottle salinity is in error. Figure 5 plots potential temperature versus salinity for stations around 213 and it is clear that the CTD salinity in the bottle file is salty but the 2 decibar down profile salinities are well calibrated. A potential temperature salinity plot for stations around 159 through 162 (figure 6) shows that some of the deep bottle salts of station 162 are fresh below .6 C while the CTD salts in the bottle file are too salty for station 159. The water sample salts for station 191, see figure 7a, appear low compared to both the down & up CTD salts and finally the water sample salinities of station 207 are fresh compared to the CTD station of 207 and neighboring stations. All salinity calibrations problems appear to be limited to the water sample file data and the quality flags of this file should be checked over. The 2-dbar down-profile CTD salinities appear well calibrated.

Overall and deep water (pressures greater than 1000 dbars) histograms of salinity and oxygen differences (CTD-WS) are shown in figure 8. The salinity differences below 1000 dbars has a very low standard deviation (0.0011 psu) and a mean difference of 0.0003 psu both indicate careful bottle salinity quality control and CTD calibration. The oxygen differences below 1000 dbars shows a standard deviation of 1.29 Umol/kg which is some what larger than the earlier

P16A P17A cruise value of .78 Umol/kg. The oxygen mean difference is 0.13 Umol/kg. The mean and standard deviation of water sample versus CTD oxygen differences indicates careful bottle oxygen quality control and calibration of the CTD oxygen data. The overall histograms for both salinity and oxygen were edited to remove outlyers greater than ± .05 psu and ± 40 Umol/kg respectively. There were no salinity differences exceeding the criteria and the oxygen differences were edited from the histogram are given in table I below. All oxygen differences are shallow and are attributed to down/up mismatches associated with larger vertical oxygen gradient regions.

Table I

sta.	P	Dox	Ox (WS)	Ox CTD
159	254.5	-53.0	235.7	288.7
161	164.1	-56.8	251.0	308.0
161	194.6	-53.0	232.2	285.2

A comparison of the station to station CTD oxygen calibrations to the bottle oxygens (CTD-WS Umol/kg) is shown in figures 9a and b. Oxygen differences at depths greater than 1000 decibars are extremely tight around the zero line with no stations standing out except for the missing stations 184 through 187. The vertical calibration of the CTD oxygens appears well behaved as indicated in figure 9c. The overall potential temperature versus oxygen plot given in figure 2 suggested that a few CTD profiles have some odd oxygen values. The 2- dbars CTD data for stations 184-187 are correctly marked with a missing oxygen flag in the O2 quality word "9". Stations 182, 196 and 227 appear to have odd looking upper section of the 2-dbar CTD profiles as is also noted in the cruise report. The CTD oxygens for station 182 are shown together with neighboring stations in figure 10. The oxygens are flagged as questionable ("3") in the 2 dbar data file. I would assign a quality code of bad "N" to the upper 900 decibars of station 182 since the oxygens are clearly not reasonable as they range from -26. to over 1100 Umol/kg. Station 196 displays oddly low oxygens from 4000 dbars to the bottom (figure 11) which are flagged as questionable "3" in the quality word. Station 196's CTD oxygens appear high from 3000 to 4000 decibars both versus pressure and versus potential temperature but are flagged as good ("2"). Station 201 (figure 11) also shows a drop in oxygen in the bottom 100 meters that looks suspect. Station 208, plotted in figure 11 b shows a marked decrease in oxygen in the bottom 100 dbars. The low oxygens in Both stations 201 and 208 are perhaps associated with decreased lower rate near the bottom.

Noise Checks for spurious salinity and oxygen values:

This section makes an evaluation of the CTD salinity and oxygen noise levels with checks for spurious data values. To check for spurious salinity and oxygen observations in the 2 decibar CTD data the standard deviation of the high-pass filtered oxygen and salinity with wavelengths between 4 and 25 decibars is summarized in the deep water depth ranges to the cast bottom. The standard deviation is plotted versus station for several depth intervals from the bottom to the surface but only the deepest (3000 dbar) interval is shown. Figure 12a, & b shows the standard deviation of salinity (12a) and oxygen (12b) from 3000 dbars to the bottom of the cast. The station bottom pressure is shown in figure 12c. Note some station don't go to 3000 dbars and the are left blank in the plots. The average salinity scatter (0.00020 psu) is indicated on the plot and includes stations with up to 50 percent larger levels of scatter (stations 131-134, 165, 169, 171, 189, and 219) which upon closer examination represent real variations associated with salinity fine structure in the deep waters. The salinity noise level is estimated from stations with a minimum deep water salinity variance to be approximately 0.00018 psu (see stations 145 and 215) which falls in the middle of observed CTD noise levels from other data sets examined (0.0001 to 0.0003 psu). The average oxygen standard deviation (figure 12b) is 0.23 Umol/kg which is about twice the observed oxygen noise level (minimum) of roughly 0.12 Umol/kg. The minimum variance is observed around station 160 (see figure 12b). The oxygen minimum falls at the lower end of observed CTD oxygen noise from other data sets (0.08 Umol/kg to 0.35 Umol/kg). The excessive oxygen scatter seen in figure 12b for stations 164, 180, 190 and 207 and 208 in some cases is twice the average oxygen scatter value and appears on closer examination to be associated with enhanced instrumental/processing noise as discussed next.

Figure 13a shows that station 164 CTD oxygens are clearly somewhat noisy than neighboring stations and also has an odd near bottom oxygen decrease seen earlier for stations 201 and 208. Figure 13b shows the same noisy behavior compared to its neighboring stations for station 180 with a clear oxygen glitch (low) around 3010 dbars. Again, station 190 (figure 13c) again shows excessive short wavelength oxygen variations compared with neighboring stations. Finally stations 208 discussed earlier and station 207 (both plotted on figure 11 b) also show elevated noise levels compared to neighboring stations. Although the elevated oxygen noise levels of these stations should be noted some where, I would not set the data quality flag to questionable.

The extremes values of the high-passed filtered salinities and oxygens are shown in figures 14a & c with the pressure level that they occur shown in figure 14b. Only one extreme value was found to be a data problem, the bad near surface oxygen values for station 182 as shown in figure 10 and marked as questionable in the 2-dbar data file. The extreme surface salinity at station 164 (south most station along 126W) is real.

Vertical stability checks:

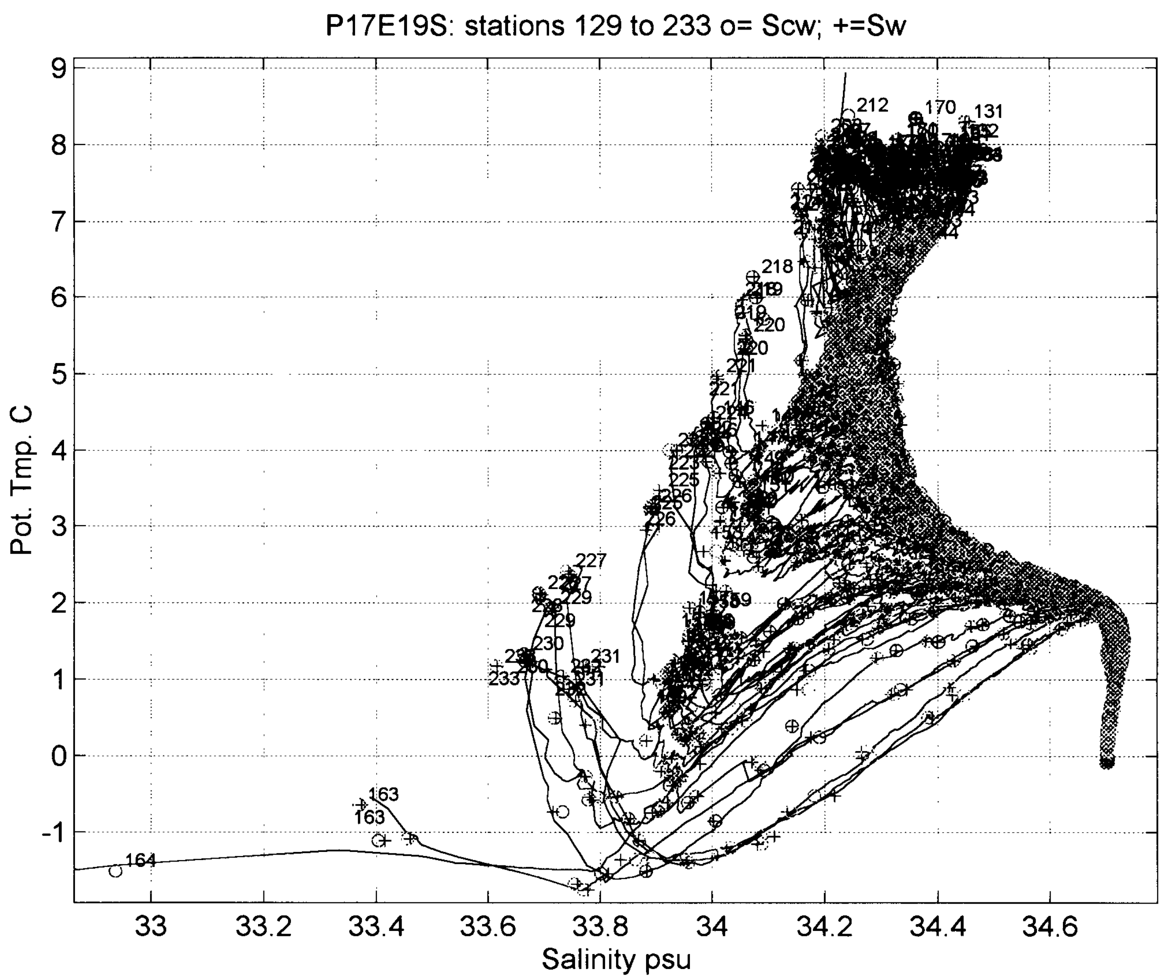
A check for density inversions provides additional information about spurious salinity and/or temperature values particularly in the near surface region where this method provides a more sensitive test than looking at the high wave number salinity variability. The vertical gradient of potential density (determined by computing the first difference of density) is calculated and checked for decreases in density with depth exceeding one of two thresholds: -0.005 and -0.0075 kg/m3. The P17E and 19S CTD data has very few questionable data by the vertical stability criteria compared with other data sets reviewed. A plot of the 4 points flagged are given in figure 15 All are in the higher gradient region of the upper 125 decibars. Table II is a list of the density inversion values plotted on figure 15 together with station number and pressure.

Table II
Density inversions: 2 decibar CTD data
Dsg/Dp < -0.005 kg/dbar

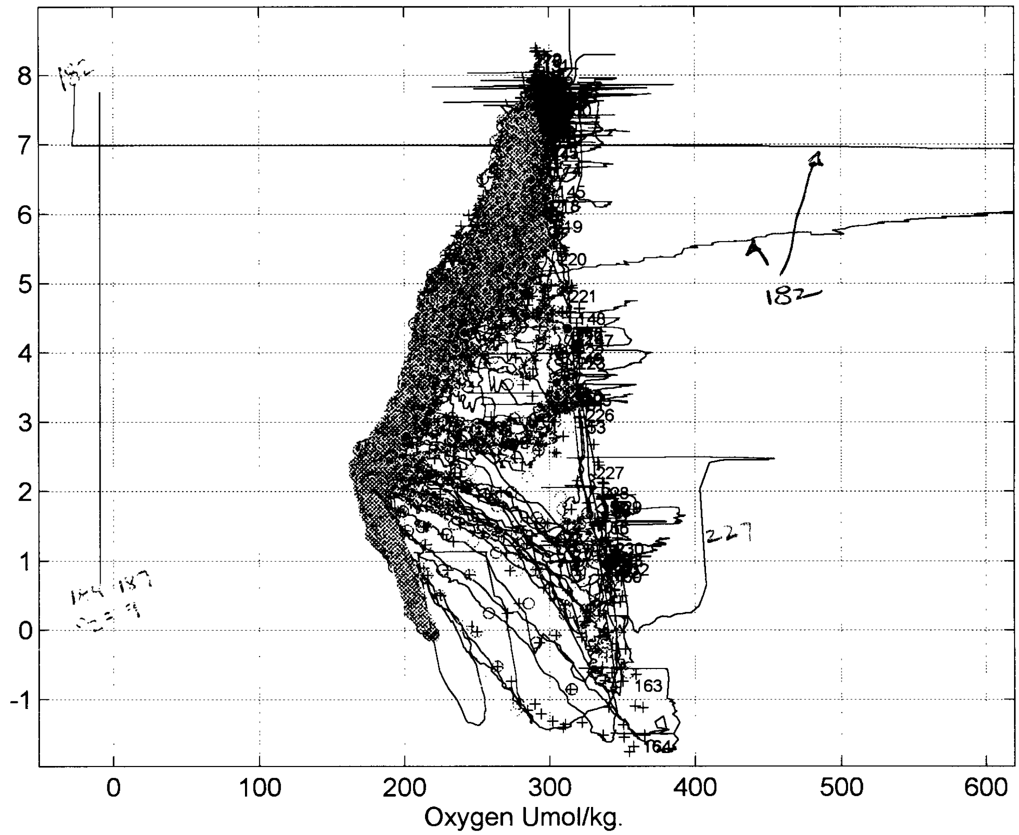
Dsg/Dp	station	pressure dbars
-6.7571326e-003	1.8100000e+002	0.0000000e+000
-5.8722514e-003	1.9400000e+002	9.4000000e+001
-5.1537654e-003	2.1000000e+002	1.1600000e+002
-7.8537612e-003	2.1100000e+002	9.0000000e+001

Dsg/Dp < -0.0075 kg/dbar

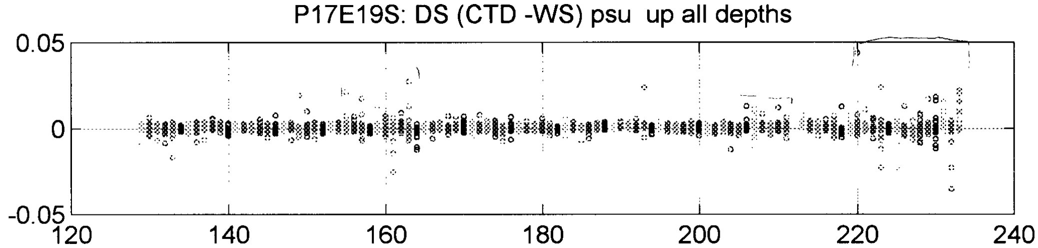
Dsg/Dp	station	pressure dbars
-7.8537612e-003	2.1100000e+002	9.0000000e+001



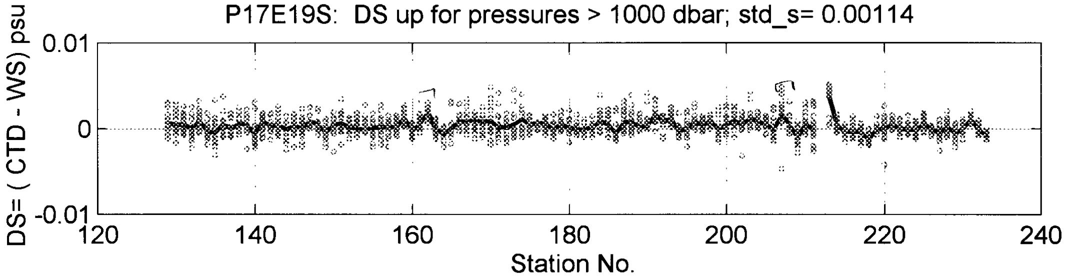
P17E19S: stations 129 to 233 o= Oxcw; +=Oxw

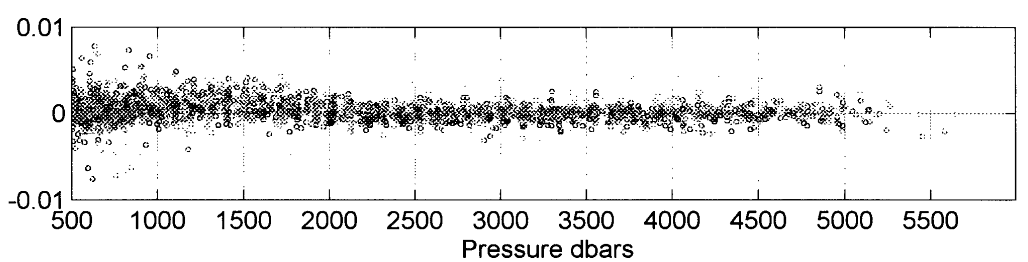


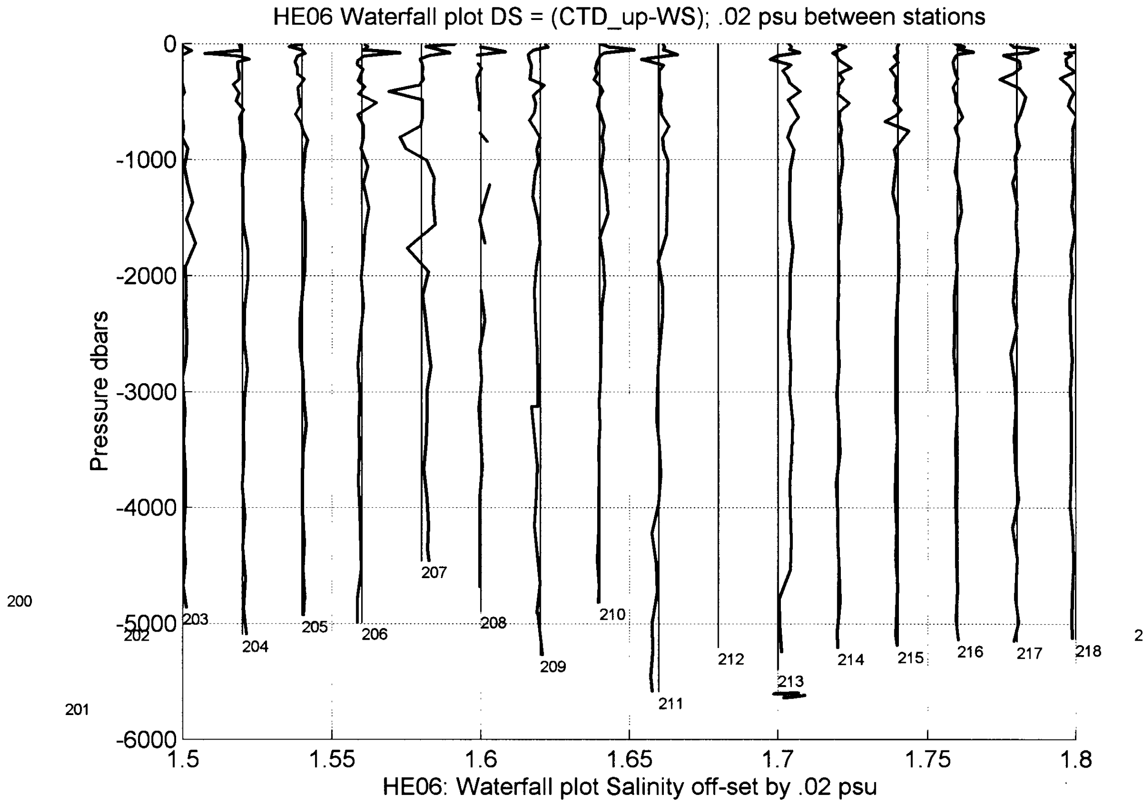
P17E19S: DS (CTD -WS) psu up all depths

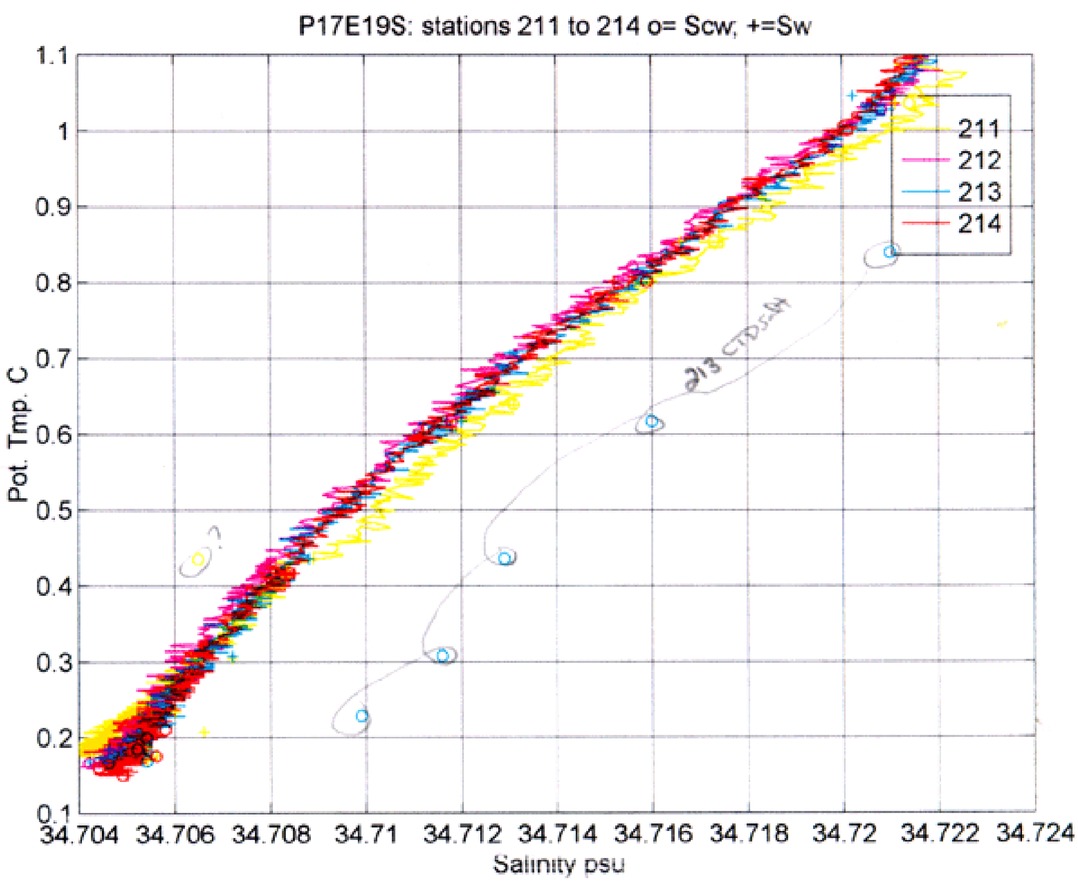


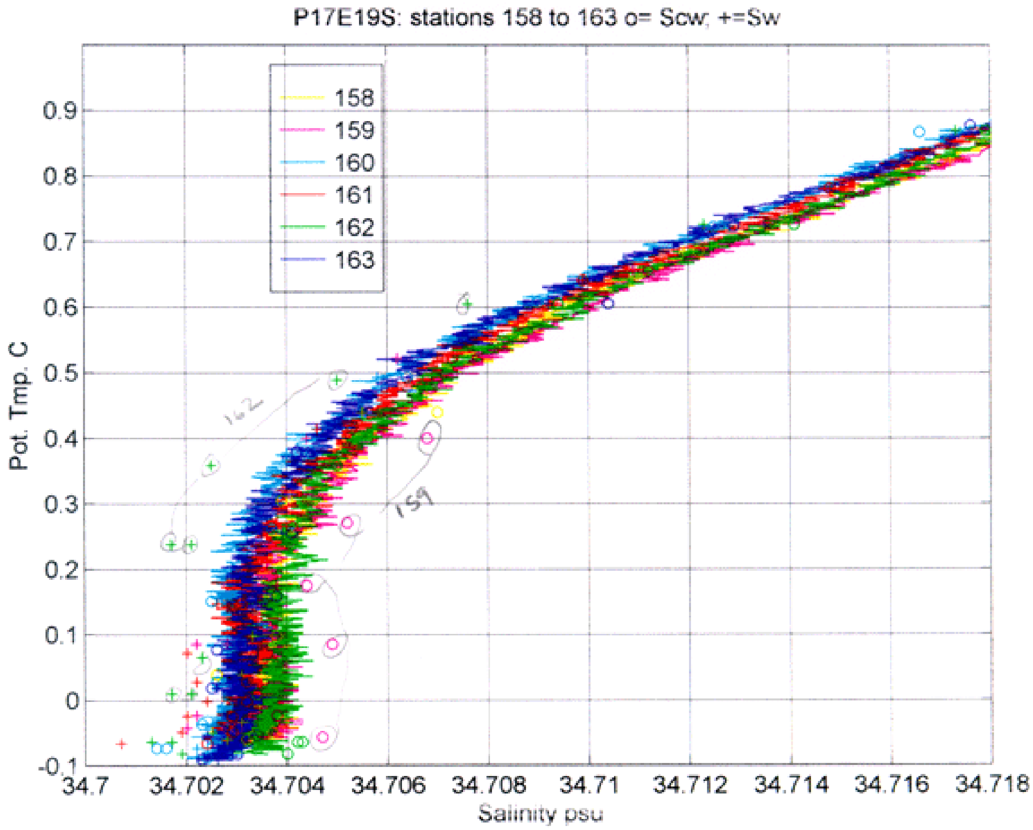
P17E19S: DS up for pressures > 1000 dbar; std_s= 0.00114



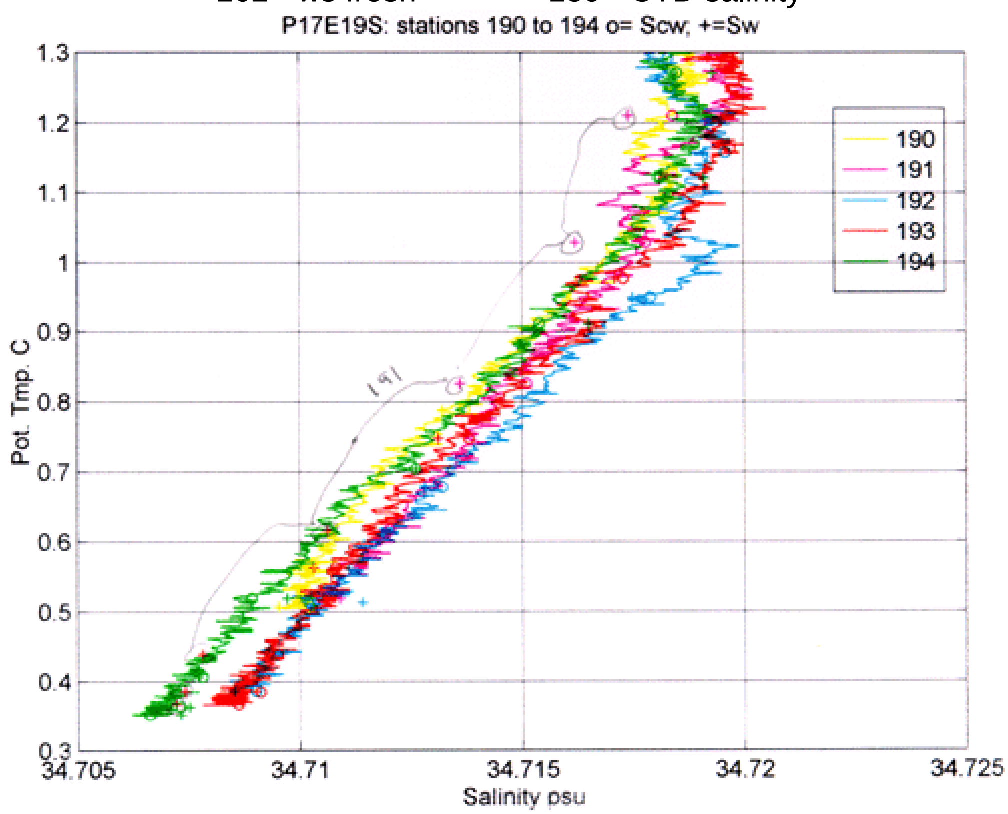



HE06 Waterfall plot DS = (CTD_up-WS); .02 psu between stations
Pressure dbars
HE06: Waterfall plot Salinity off-set by .02 psu
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
2

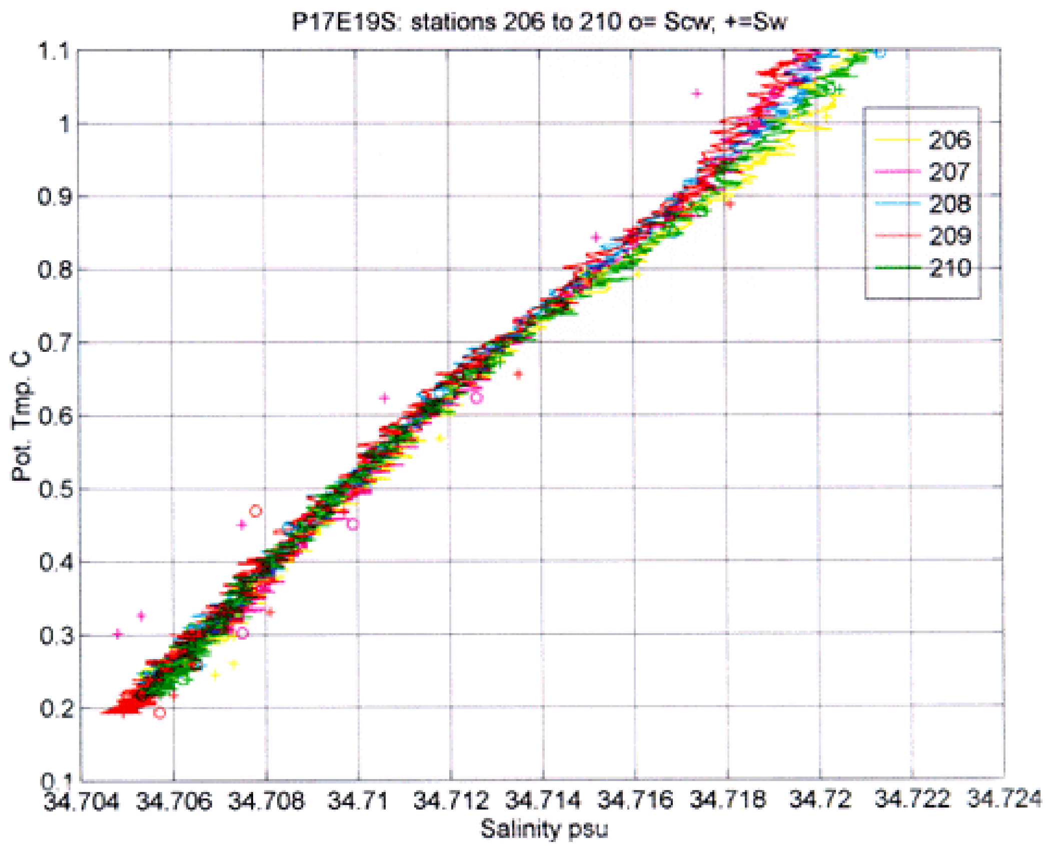

P17E19S: stations 211 to 214 o= Scw; +=Sw
Pot. Tmp. C
Salinity psu
211
212
213
214
213 CTDsal



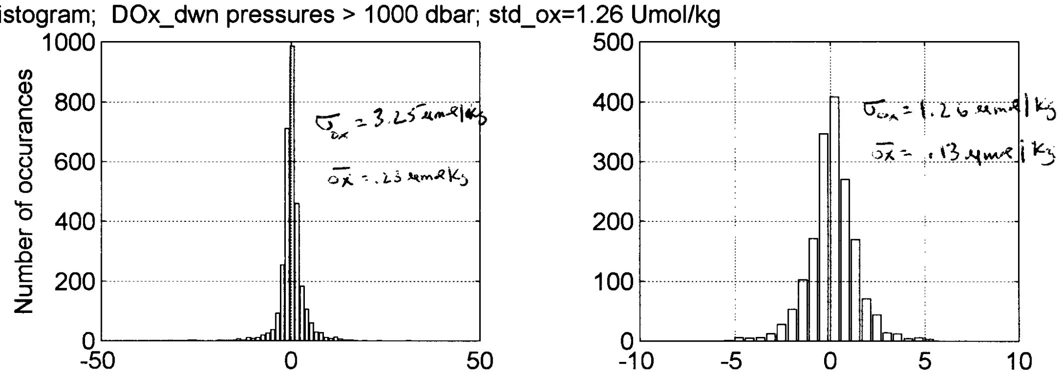
162 - ws fresh 159 - CTD salinity



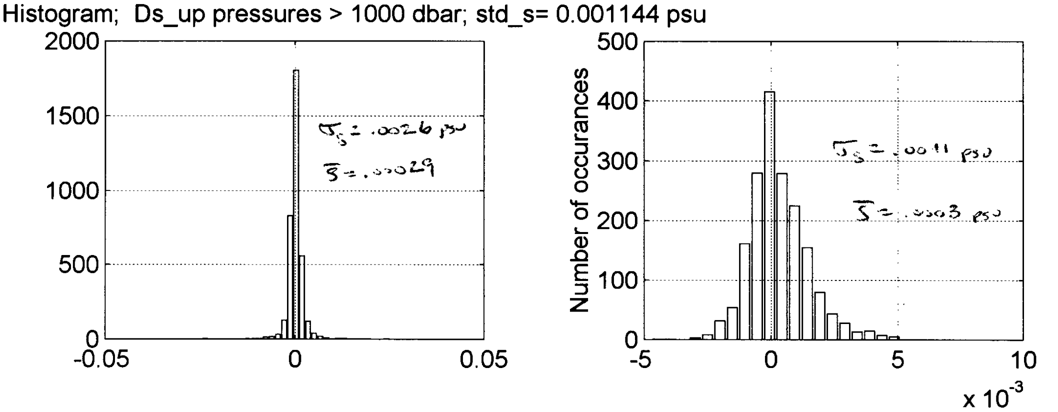
191 - ws fresh .002

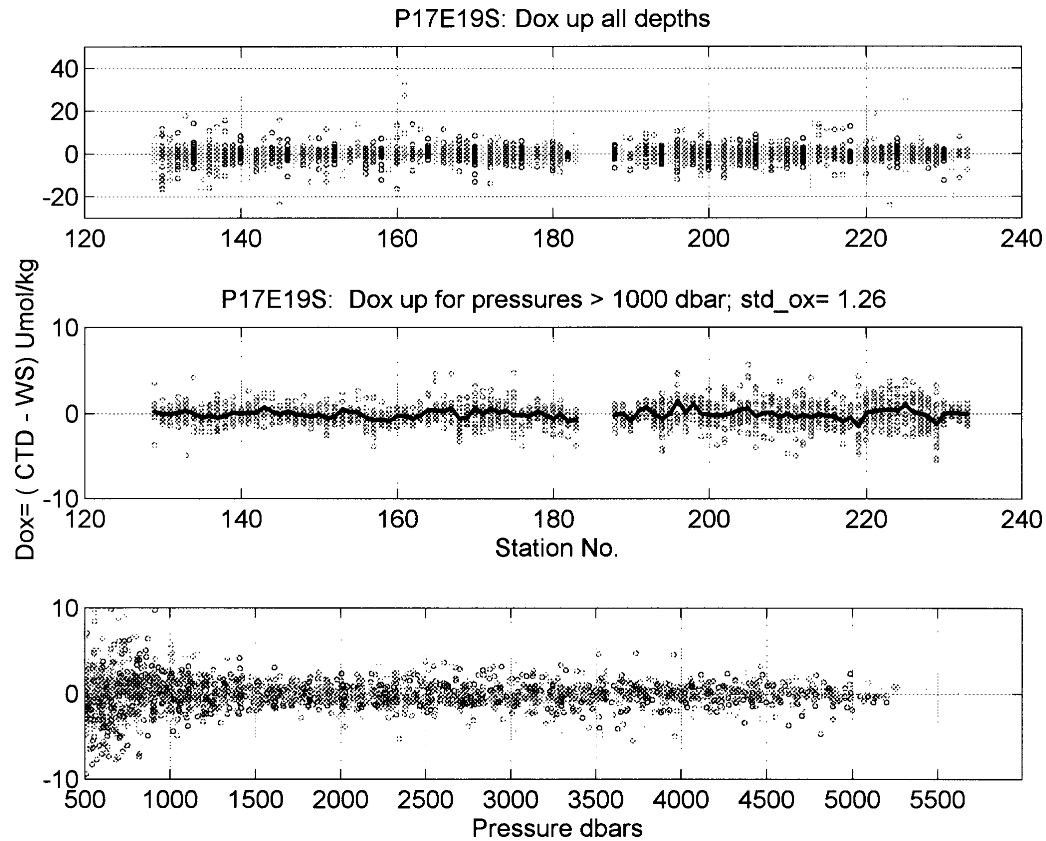


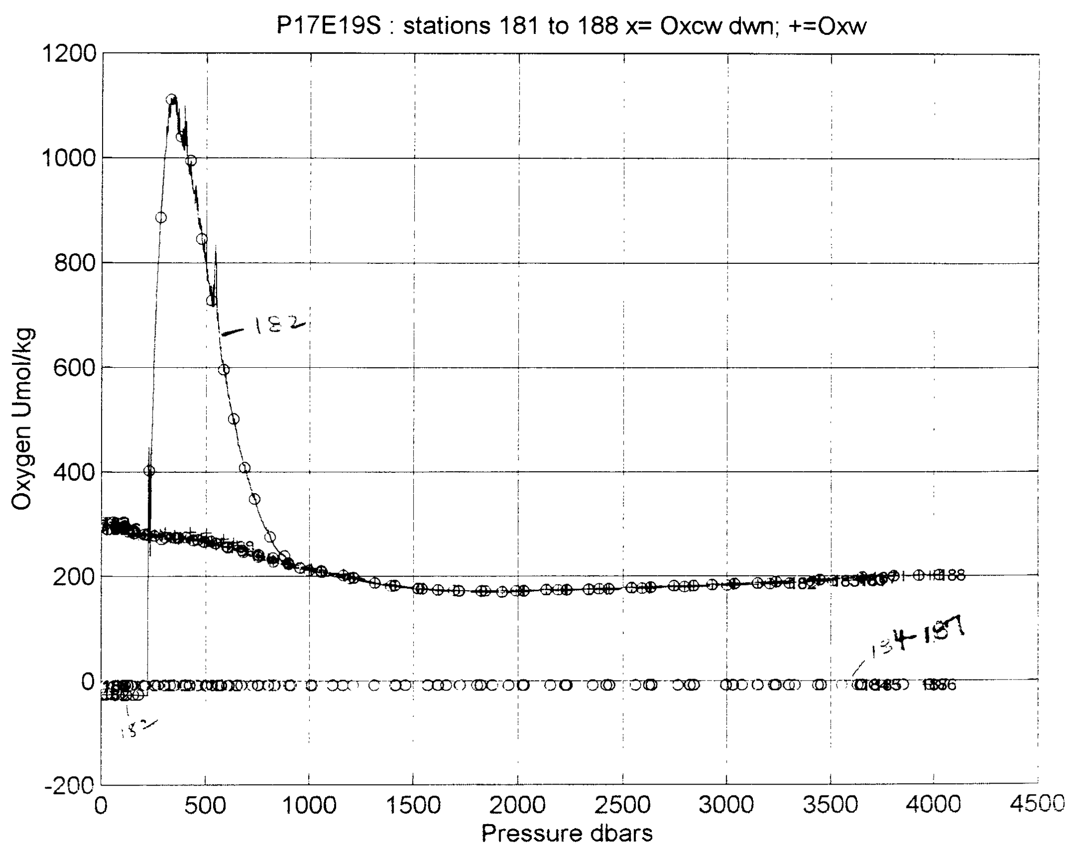
19S: Histogram; DOx_dwn pressures > 1000 dbar; std_ox=1.26 Umol/kg

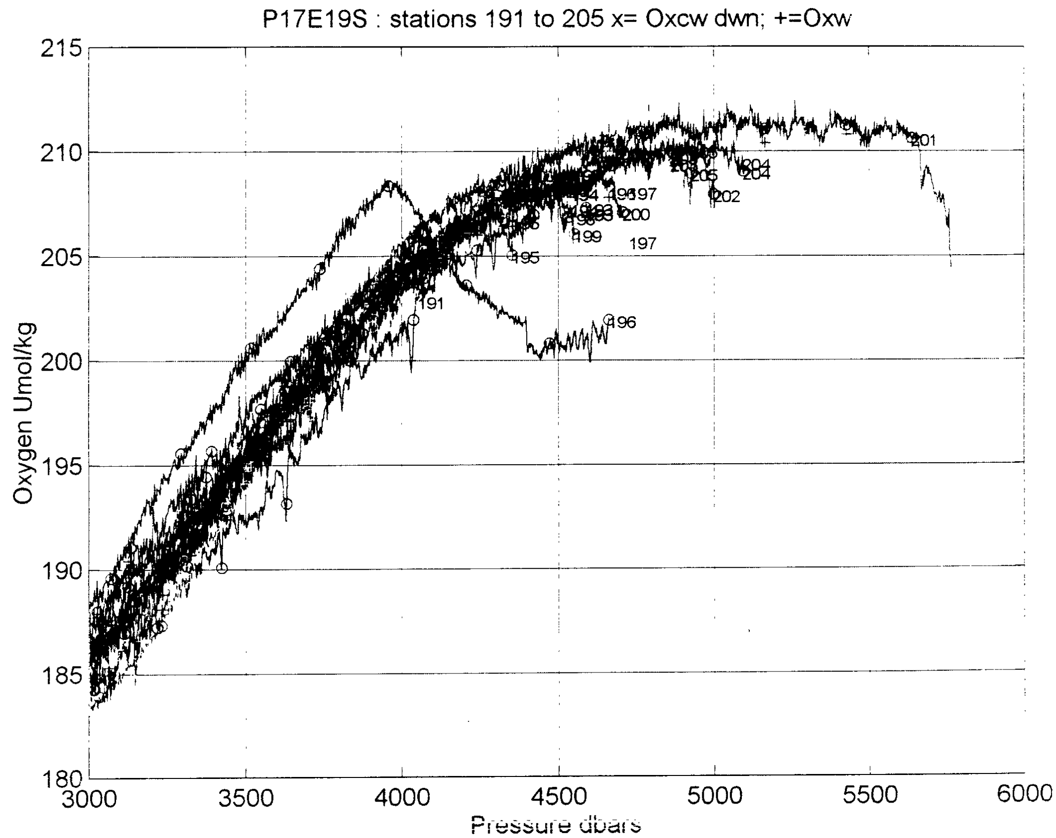


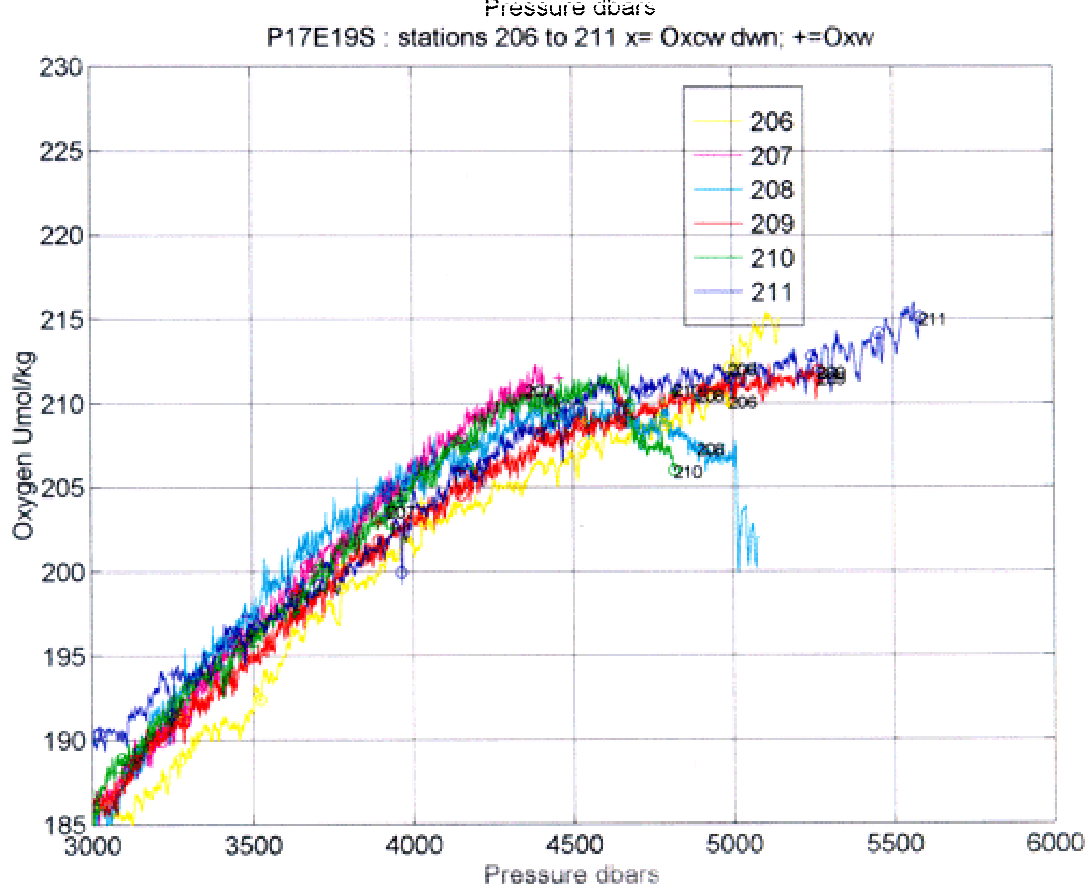
E19S: Histogram; Ds_up pressures > 1000 dbar; std_s= 0.001144 psu

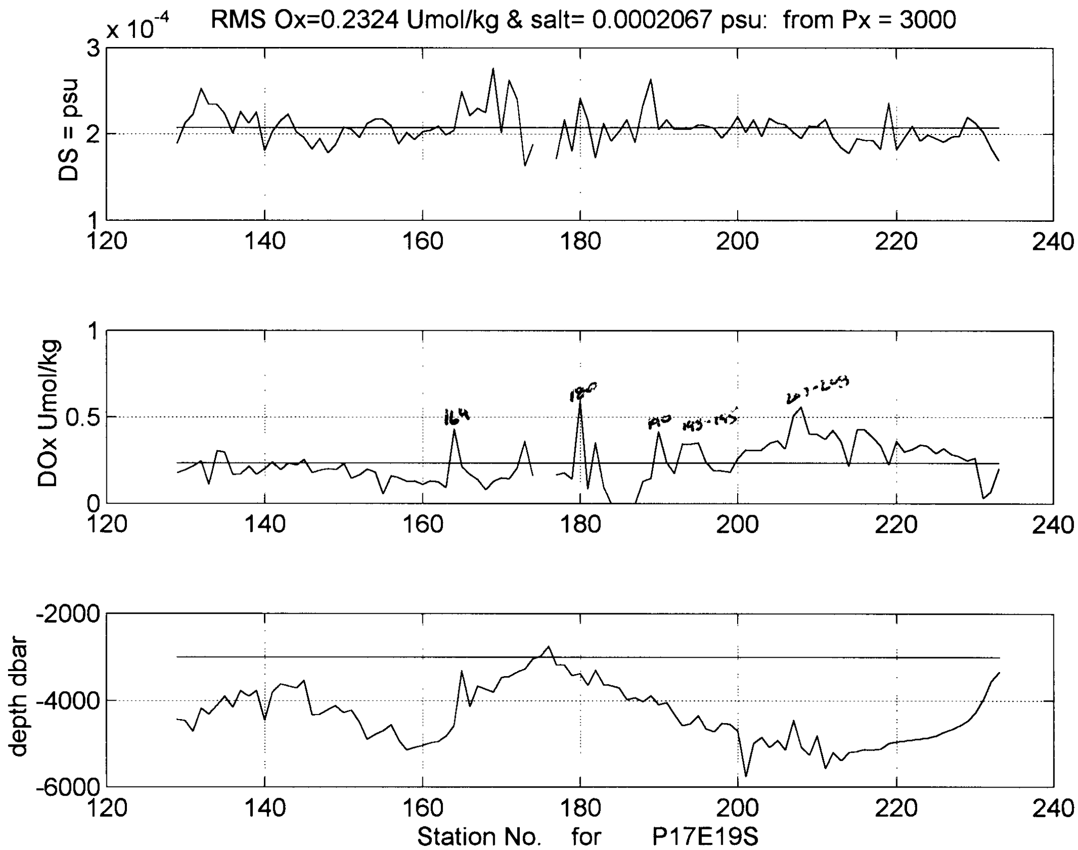


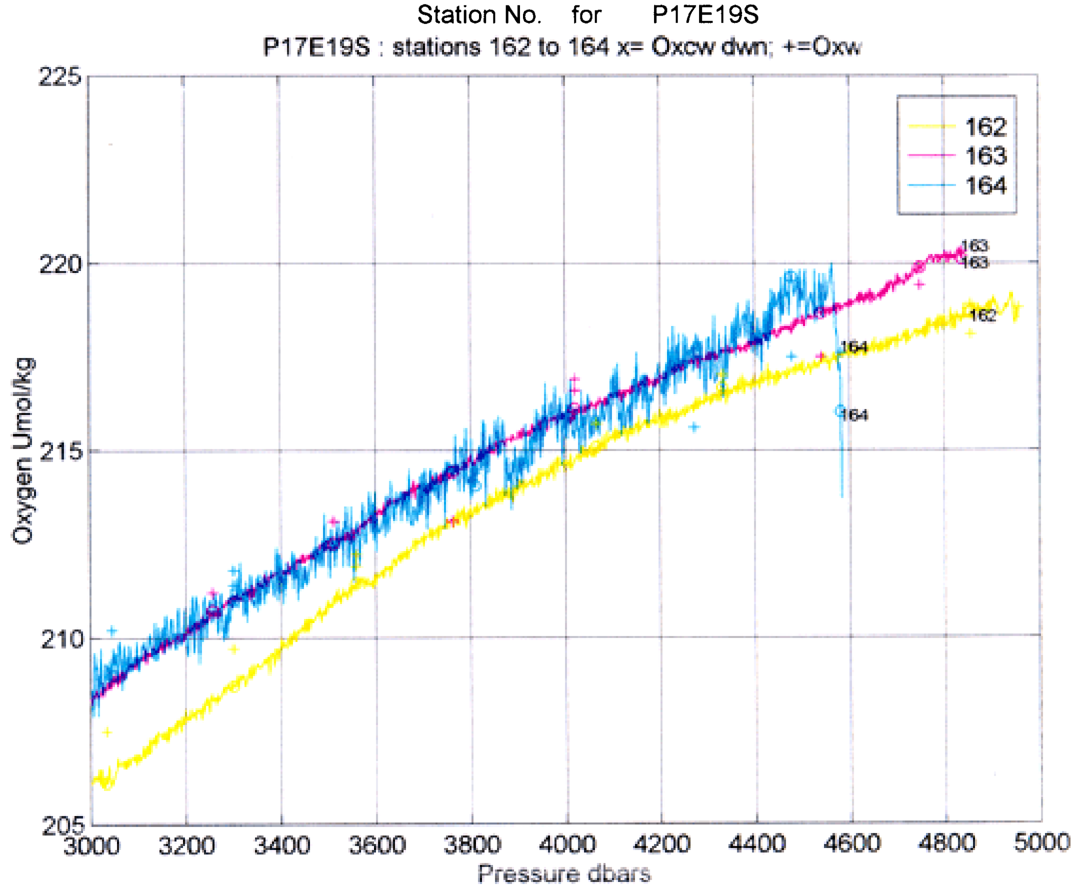

P17E19S: Dox up all depths
P17E19S: Dox up for pressures > 1000 dbar; std_ox= 1.26
Dox= (CTD - WS) Umol/kg
Station No.
Pressure dbars

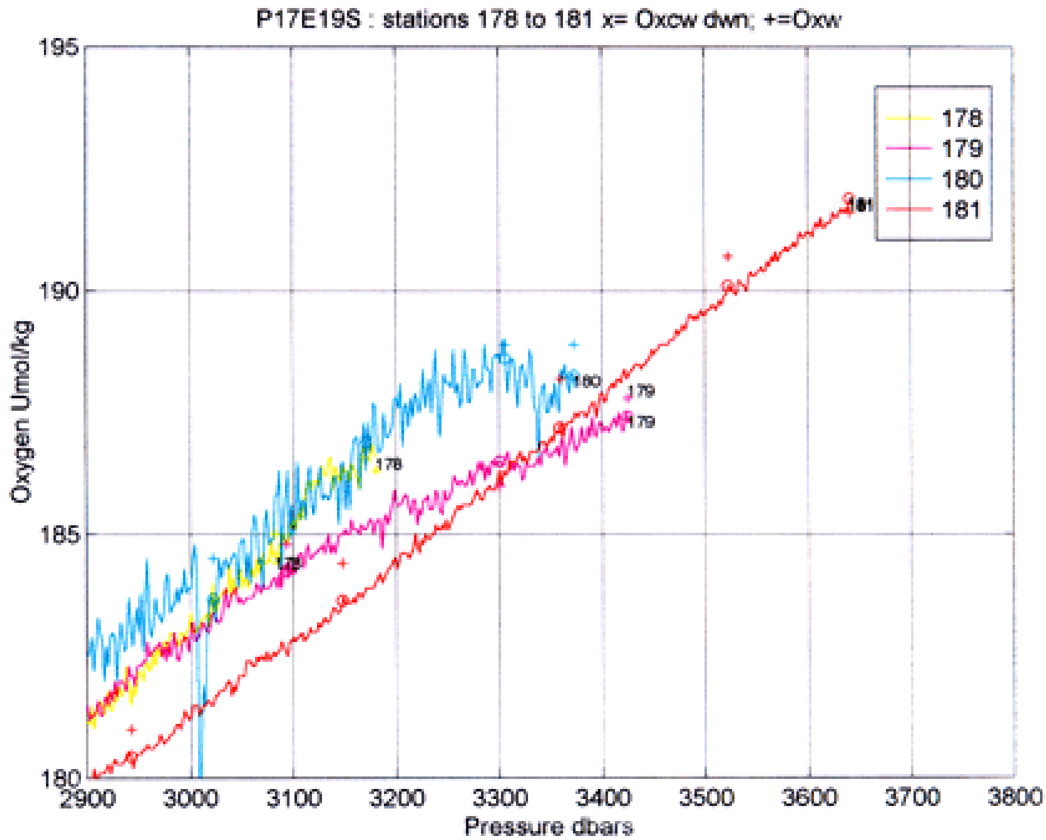

P17E19S : stations 181 to 188 x= Oxcw dwn; +=Oxw
Oxygen Umol/kg
Pressure dbars
182
184-187

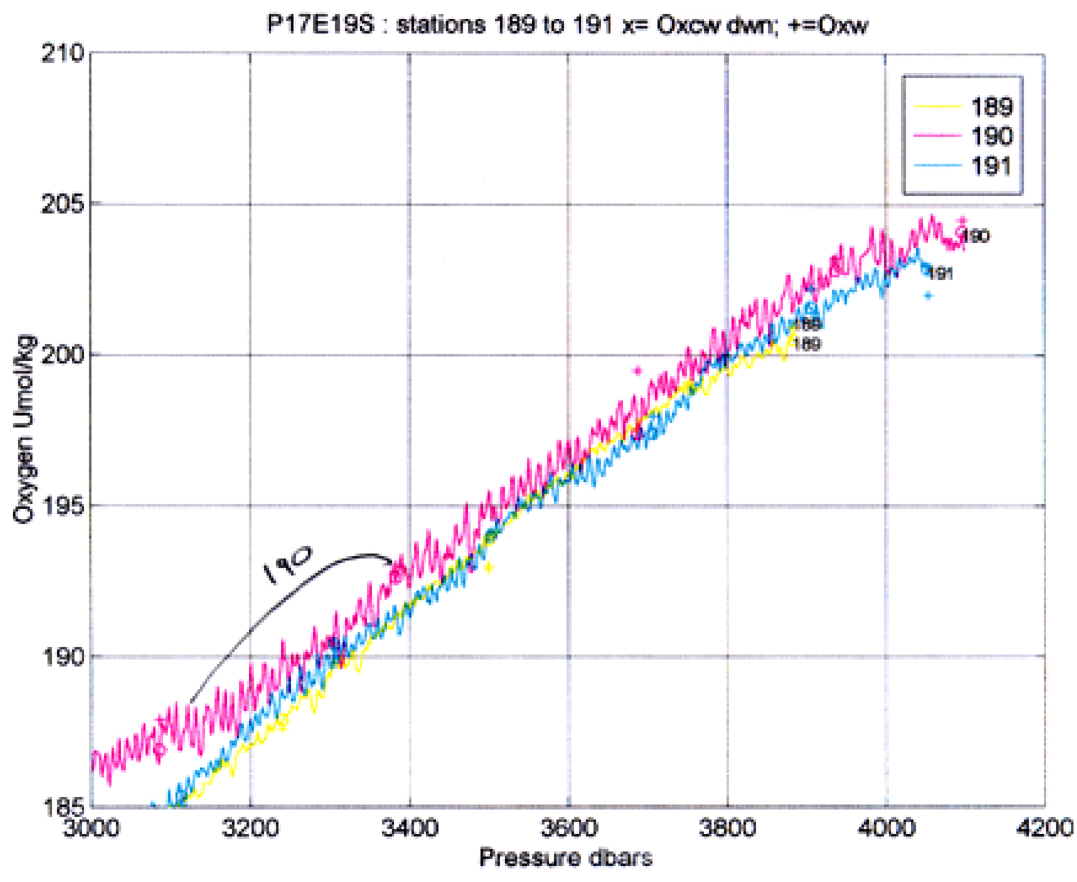

P17E19S : stations 191 to 205 x= Oxcw dwn; +=Oxw
Oxygen Umol/kg
Pressure dbars
201
204
205
202
197
200
199
195
191
196

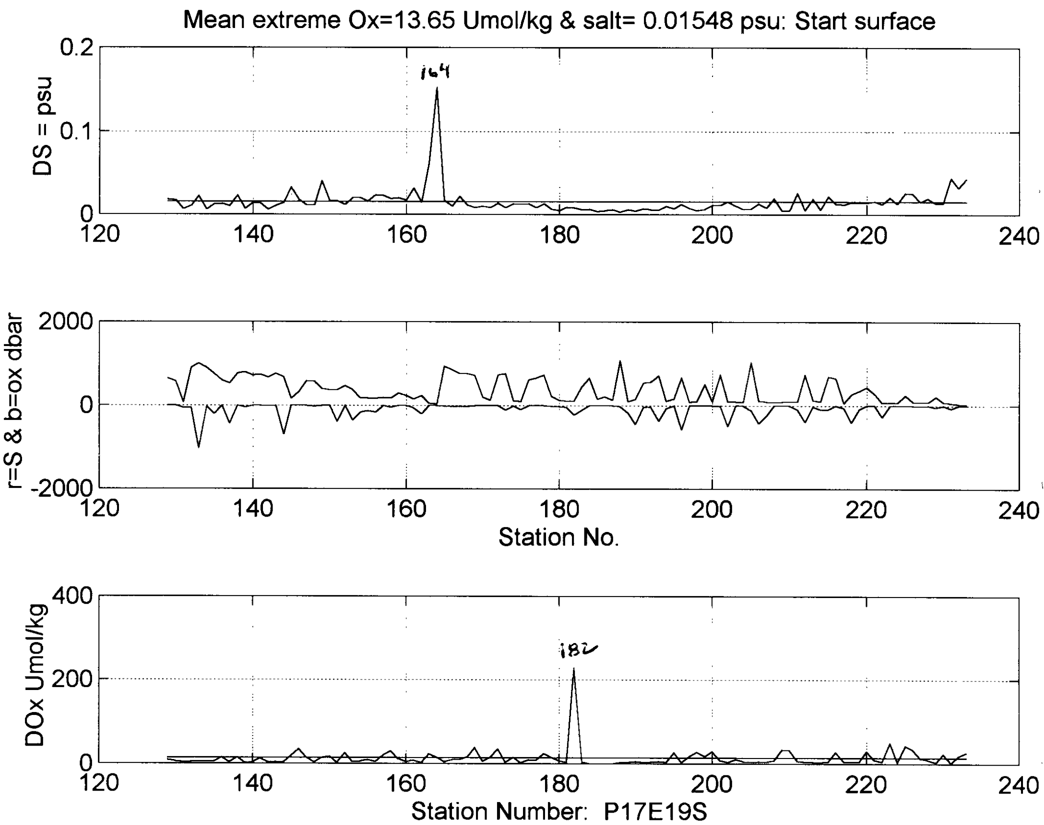

P17E19S : stations 206 to 211 x= Oxcw dwn; +=Oxw
206
207
208
209
210
211
Oxygen Umol/kg
Pressure dbars

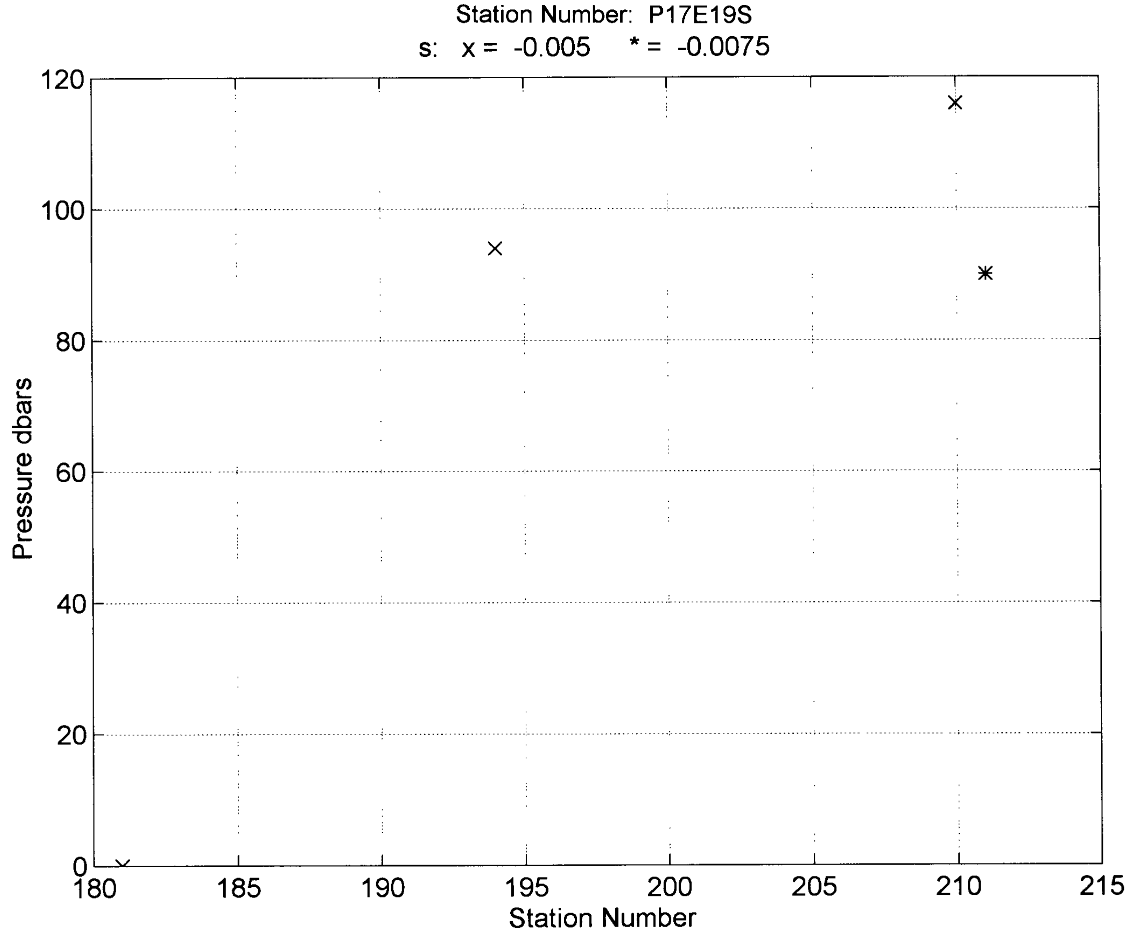

RMS Ox=0.2324 Umol/kg & salt= 0.0002067 psu: from Px = 3000
x 10^-4
DS = psu
DOx Umol/kg
164
180
depth dbar
Station No. for P17E19S


P17E19S : stations 162 to 164 x= Oxcw dwn; +=Oxw
162
163
164
Oxygen Umol/kg
Pressure dbars


P17E19S : stations 178 to 181 x= Oxcw dwn; +=Oxw
178
179
180
181
Oxygen Umol/kg
Pressure dbars


P17E19S : stations 189 to 191 x= Oxcw dwn; +=Oxw
189
190
191
Oxygen Umol/kg
Pressure dbars
190


Mean extreme Ox=13.65 Umol/kg & salt= 0.01548 psu: Start surface
DS = psu
164
r=S & b=ox dbar
Station No.
DOx Umol/kg
182
Station Number: P17E19S


s: x = -0.005 * = -0.0075
Pressure dbars
Station Number

DATA STATUS NOTES

1999.05.10 DMB: I have merged total carbon, pco2, and pco2tmp into the p17e_p19s bottle file. The data are from Alex Kozyr and are public. I have replaced the file in the data directory and updated the public table to reflect the file change.

HeNe NOTES

EXPOCODE: 316N138/10

1. Column: STNNBR
2. Column: CAST
3. Column: BOTTLE
4. Column: DELHE3 [%]
5. Column: ERR. DELHE3 [%]
6. Column: FLAG DELHE3 [%]
7. Column: HELIUM [NMOL/KG]
8. Column: ERR. HELIUM [NMOL/KG]
9. Column: FLAG HELIUM
10. Column: NEON [NMOL/KG]
11. Column: ERR. NEON [NMOL/KG]
12. Column: FLAG NEON