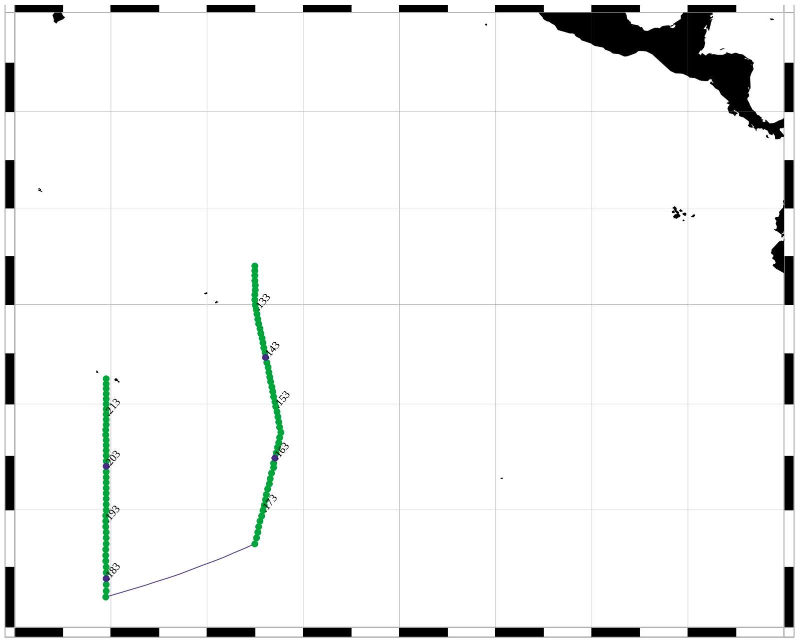
A. Cruise Narrative: **P16S and P17S** (Tunes 2)



A.1. Highlights

WHP Cruise Summary Information

WOCE line designation	**P16S and P17S**	
Expedition designation (ExpoCode)	**31WTTUNES_2**	
Chief scientist and affiliation	**James H. Swift/SIO***	
Ship	R/V Thomas Washington	
Cruise dates	1991.JUL.16 1991.AUG.25	
Ports of call	Papeete, Tahiti, French Polynesia	
Number of stations	P16S	41 CTD/rosette stations, (4 with Gerard casts)
	P17S	56 CTD/rosette stations, (6 with Gerard casts)
Geographic boundaries	4° 0.0' S 151° 0.0' W 137° 0.0' W 38° 0.0' S	
Floats and drifters deployed	12 ALACE floats deployed	
	12 "Niiler" type surface drifters deployed	
Moorings deployed or recovered	0	

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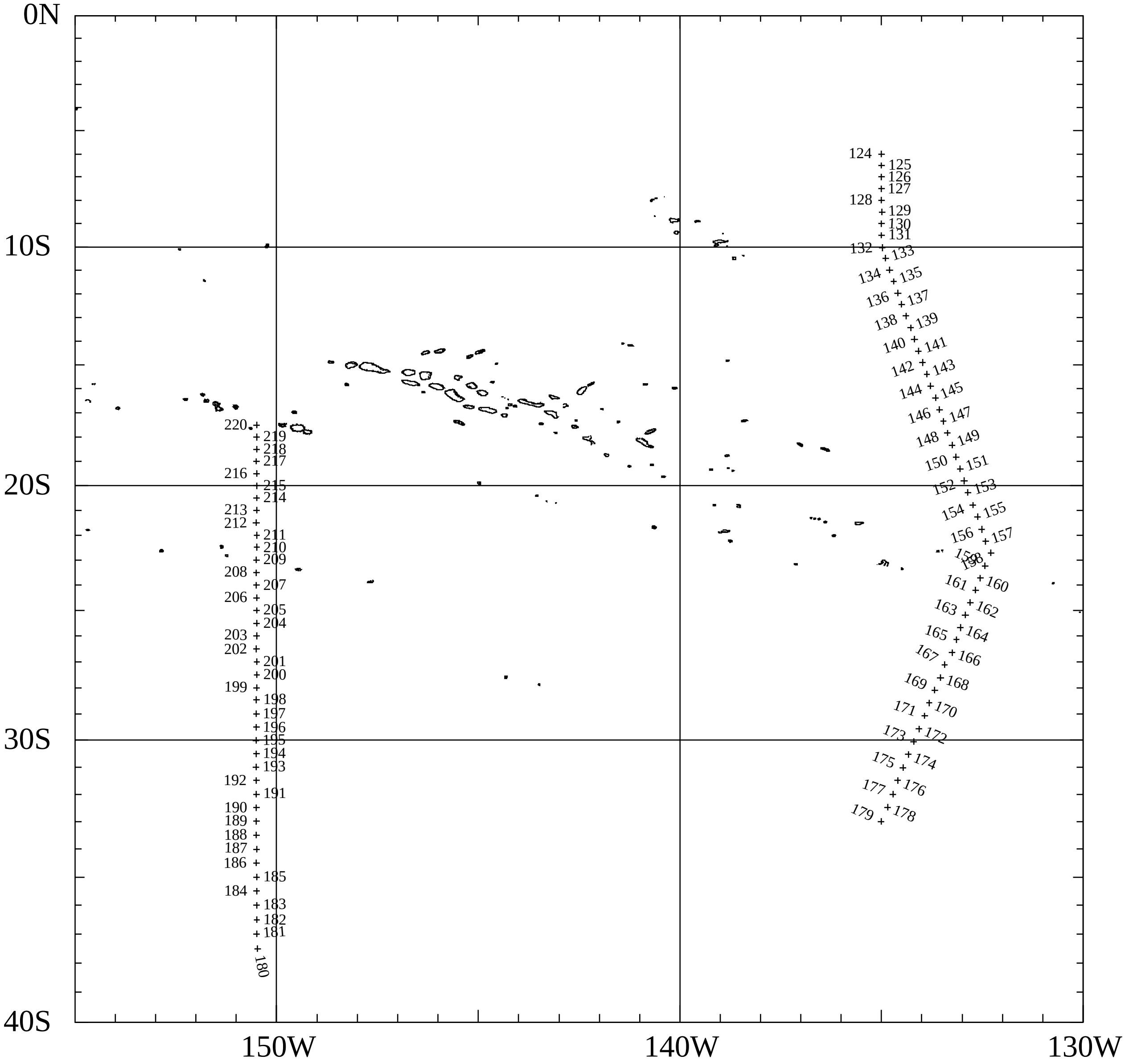
WHP Cruise and Data Information

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

Cruise Summary Information	Hydrographic Measurements
Description of scientific program	CTD general
	CTD pressure
Geographic boundaries of the survey	CTD temperature
Cruise track (figure) PI WHPO	CTD conductivity/salinity
Description of stations	CTD dissolved oxygen
Description of parameters sampled	**Bottle**
Bottle depth distributions (figure)	Salinity
Floats and drifters deployed	Oxygen
	Nutrients
	CFCs
Principal Investigators for all measurements	**Large Volume Samples**
Cruise Participants	Preliminary Report
	Final Report
Problems and goals not achieved	Pres/Tmp Salinity
	Nutrients C14

Underway Data Information	DQE Reports
Navigation	CTD
Bathymetry	S/O_2/nutrients
Acoustic Doppler Current Profiler (ADCP)	CFCs Report 1 Final
Thermosalinograph & related measurements	14C AMS
XBT and/or XCTD	
Meteorological observations	
Atmospheric chemistry data	

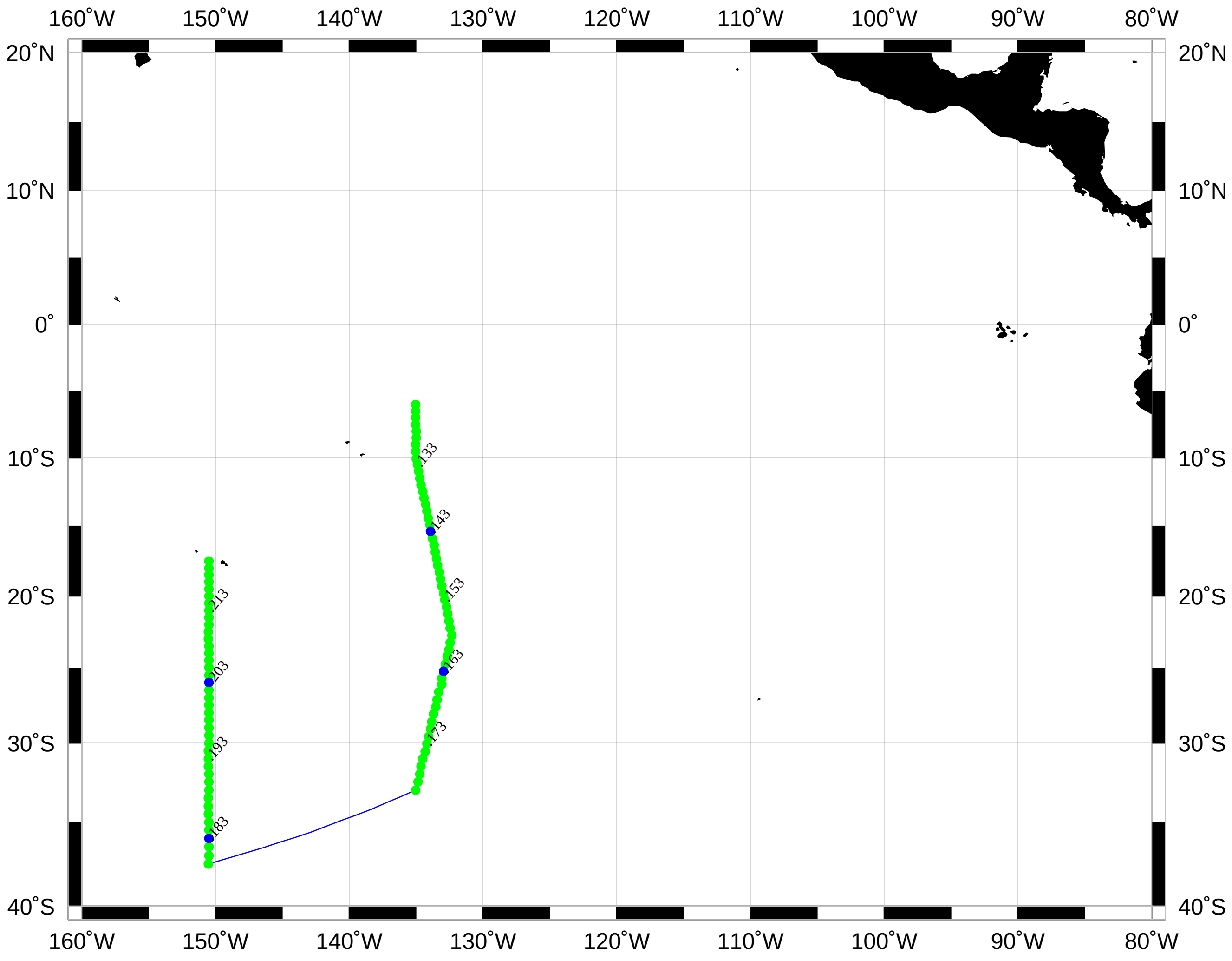
References	Acknowledgments	Data Processing Notes
CTD	CTD	
BTL		
Large Volume		
14C AMS		



WOCE Pacific 91 P17, P16 R/V Thomas Washington

Mercator Projection

P16S_P17S Station Positions



Produced from .sum file by WHPO-SIO

A.2. Floats

ALACE floats were deployed on behalf of Russ Davis (SIO) by the Resident Technician at stations 129, 137, 146, 154, 165, 173, 180, 183, 192, 199, 207, and 215. No problems were encountered. Information on ALACE floats may be obtained from the WOCE float DAC.

ID #	latitude	longitude	date
42	08 30.1S	134 59.7W	7/23/91
50	12 27.4S	134 29.4W	7/26/91
81	16 52.1S	133 34.1W	7/29/91
67	20 47.5S	132 44.2W	7/31/91
77	26 08.7S	133 09.9W	8/3/91
75	30 03.0S	134 12.3W	8/6/91
87	37 30.7S	150 25.3W	8/12/91
78	35 59.9S	150 29.5W	8/13/91
79	31 30.4S	150 32.1W	8/17/91
57	27 59.7S	150 29.8W	8/19/91
30	24 00.1S	150 30.0W	8/21/91
56	20 01.6S	150 30.4W	8/24/91

"Niiler" type surface drifters were deployed on behalf of Laurence Sombardier (SIO) by the Resident Technician at stations 132, 143, 153, 158, 163, 173, 179, 185, 192, 195, 205, and 215. No problems were encountered. Information on the surface drifters may be obtained from the WOCE drifter DAC.

ID#	latitude	longitude	date
15101	10 00.1S	135 00.1W	7/24/91
15119	15 22.3S	133 55.5W	7/28/91
15033	20 14.6S	132 51.3W	7/31/91
15112	22 42.5S	132 17.1W	8/1/91
15036	25 14.0S	132 55.6W	8/2/91
15118	30 02.8S	134 12.2W	8/6/91
15024	33 00.7S	135 01.1W	8/8/91
15129	35 00.0S	150 29.9W	8/14/91
15120	31 30.4S	150 32.0W	8/17/91
15032	30 00.9S	150 27.4W	8/18/91
15020	24 57.7S	150 29.2W	8/21/91
15044	20 01.5S	150 30.5W	8/24/91

There were no moorings deployed or recovered.

A.3. List of Principal Investigators

Name	Institution	Measurement responsibility	Funding Source
Dr. David Chipman (for data see Takahashi)	LDEO	CO_2 (shipboard)	(Takahashi)
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Dr. Russ Davis	UCSD/SIO	ALACE floats	NSF OCE-9017744
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Dr. Rana Fine	RSMAS	CFCs	NSF OCE-9104721
4600 Rickenbacker Causeway • Miami, FL 33149 • (305) 361-4722			
Dr. Louis I. Gordon (no data responsibility)	OSU	nutrients (tech support)	NSF OCE-9002474
COAS • Oceanography Admin. Bldg 104 • Corvallis, OR 97331-5503 • (503) 737-2161			
Dr. Catherine Goyet	WHOI	alkalinity (shore)	DOE: DE-FGO$_2$-ER60980
Woods Hole, MA 02543 • (508) 457-2000 x2552			
Dr. Peter W. Hacker (for data see Firing)	U. Hawaii	ADCP	NSF OCE-9015429
JIMAR • 1000 Pope Rd., MSB 312 • Honolulu, HI 96822 • (808) 956-8689			
Dr. Willliam Jenkins	WHOI	helium (upper), tritium	P17: NOAA: NA16RC0413-01 P16: NSF: OCE-8902480
Chemistry Dept., Clark 4 • Woods Hole, MA 02543 • (508) 457-2000 x2554			
Dr. Charles D. Keeling	UCSD/SIO	CO_2 (shore)	DOE: DE-FG03-90ER60982
9500 Gilman Drive • GRD, 0220 • La Jolla, CA 92093-0220 • (619) 534-4230			
Dr. Robert Key	Princeton U	^{14}C, $^{226}Ra/^{228}Ra$, Ba*	NSF OCE-9002485 (with NOAA supplement)
(* Ba samples were given to J. Bishop, LDEO) Geology Dept. • Princeton University • Princeton, NJ 08544 • (609) 258-3595			
Dr. Pearn P. Niiler	UCSD/SIO	drifters	NSF OCE-8918731
9500 Gilman Drive • PORD, 0230 • La Jolla, CA 92093-0230 • (619) 534-4100			
Stuart M. Smith	UCSD/SIO	SeaBeam (bathymetry)	NSF OCE-8911587
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Dr. James H. Swift	UCSD/SIO	CTD/O_2/nutrients (P16)	NSF OCE-9002483 and NSF OCE-8918961
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Name	Institution	Measurement responsibility	Funding Source
Dr. Taro Takahashi	LDEO	CO_2 (shipboard)	DOE: DE FG02-90ER60983
Geochemistry Dept. • Columbia University • Palisades, NY 10964 • (914) 359-2900 x537			
Dr. Lynne D. Talley (for data see Swift)	UCSD/SIO	CTD/O_2/nutrients (P17) surface T/S (underway)	NSF OCE-8918961
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Dr. Mizuki Tsuchiya (for data see Swift)	UCSD/SIO	CTD/O_2/nutrients (P17)	NSF OCE-8918961
9500 Gilman Drive • MRD, 0230 • La Jolla, CA 92093-0230 • (619) 534-3236			
Dr. Ray F. Weiss	UCSD/SIO	pCO_2 (underway)	DOE: DE-FG03-90ER60981
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Abbreviations:

COAS	College of Oceanic & Atmospheric Sciences
GDC	Geological Data Center
GRD	Geo-Sciences Research Division
LDEO	Lamont-Doherty Earth Observatory
MRD	Marine Research Division
OSU	Oregon State University
PORD	Physical Oceanography Research Division
Princeton U	Princeton University
RSMAS	Rosenstiel School of Marine and Atmospheric Science
U. Hawaii	University of Hawaii
UCSD/SIO	University of California, San Diego / Scripps Institution of Oceanography
WHOI	Woods Hole Oceanographic Institute

A.4. Scientific Program and Methods

A.4.a Narrative

Cruise track

R/V ***Thomas Washington*** expedition TUNES Leg 2, roundtrip from/to Papeete, Tahiti, French Polynesia, was carried out during 16 July 25 August 1991. Chief Scientist was James Swift (SIO); Captain was A. Arsenault. Scientific work for the first portion of Leg 2 was proposed by Lynne Talley and Mizuki Tsuchiya (SIO) and the second portion by James Swift. The overall purpose of both was to contribute to a planned 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 central subtropical gyres of the North and South Pacific. TUNES Leg 2 included a section of full depth CTD and water sample profiles at 30 nmile spacing and Gerard barrel profiles at nominal 300 nmile spacing along a line from 6°S to 33°S along ca. 135°W (WHP line P17), and from 37°30'S to 17° 30'S along 150° 30'W (WHP line P16). Over the ridge extending from the East Pacific Rise to the Tuamotu Islands the P17 track was shifted slightly to the east and back in order to cross the rise at a saddle. (See track in Figure 1.)

The Scripps Oceanographic Data Facility (ODF) carried out full-depth CTDO profiles with a maximum of 36 small-volume water samples per cast and deep and intermediate-depth Gerard barrel casts of up to 9 270-liter Gerard water samplers each. ODF technicians led deck operations and the overall sea program, carried out CTDO profiling and processing, oxygen, nutrient, and salinity sampling, analyses, and processing from the water samples, and record keeping for CTD casts and water sampling. Other groups carried out complementary programs for CFC's, helium/ tritium, CO_2, and ^{14}C.

Stations occupied

There were 97 CTD/rosette stations, in all but one case each close to the bottom. Nine included large volume casts, usually including one deep and one intermediate depth cast with Gerard barrels, often with a brief one-barrel surface cast in addition. Rosette water samples were collected from Niskin and ODF-constructed 10-liter sample bottles mounted on an ODF-constructed 36-bottle rosette sampler which used General Oceanics 24and 12-place pylons. The rosette was equipped with — at various times — ODF CTD's #1, 2, and 10 (modified NBIS Mark III) 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, except for some of the large-volume stations, when the rosette was used without a pinger. In every case the bottles were closed at selected depths during the up cast, after the winch had stopped at that depth.

CTD preliminary data processing was carried out at sea during and after the casts. Subsets of CTD data comparable to the water samples were provided to the bottle data files immediately after each station in order to facilitate examination and quality control of the bottle data as the laboratory analyses were completed. The subsequent "preliminary bottle data reports" were used as part of the at-sea scientific and quality control analyses. At sea the data were examined as a suite for consistency and evidence of errors. Shore processing included preparation and distribution of preliminary data tapes, re-calibration of CTD sensors, a lengthy review of all ODF bottle data, CTDO processing, and completion of the documentation suite.

ODF equipment was prepared and loaded on the ***Washington*** in San Diego. ODF technicians on Leg 1 used the equipment and left it in excellent condition for Leg 2.

The ***Washington*** left Papeete, Tahiti, F.P., on schedule at 1600, 16 July, and headed toward the first station, at 6°S 135°W, in light seas. A watch list was drawn up for two scientific watches, 0000-1200 and 1200-2400. Most personnel were assigned to one watch or the other, with only a few positions "floating" due to the nature of the task involved (see watch list). On the morning of 18 July the vessel stopped for two hours for station tests and training. The first WOCE station (124) began on 21 July and went well. CTD #1 was used. This was the primary instrument used on TUNES Leg 1.

Scientific Party Watch List

Noon-midnight		**Midnight-noon**	
Name	Task	Name	Task
Swift, Jim	console ops, data	Peterson, Ray	console ops, data
Lewis, Diana	data assistant	Orsi, Alex	ADCP, data assistant
Boaz, John	deck leader, R.T.	Williams, Bob	deck leader, data
Delahoyde, Frank	CTD processing	Streib, Rebecca	deck, salts
Schmitt, Jim	electronics, salts	Patrick, Ron	deck, oxygens
Masten, Doug	LVS, deck, oxygens	Bouchard, George	salts, computer tech
Guffy, Dennis	nutrients	Williams, Nadya	nutrients
Maillet, Kevin	CFCs	Mathieu, Guy	CFCs
Rubin, Stephany	CO_2	Goddard, John	CO_2

"Floaters"

Name	Task
Rotter, Rich	LVS, C^{14} extraction
Birdwhistell, Scot	Helium/tritium
Tedesco, Kathy	Helium/tritium, CO_2

WOCE stations continued according to the advance scientific plan, and the routines were quickly established: soon station times were down to about 3 hours for a 4500 meter cast.

The planned southern terminus of the P17 line was reached with out major incident on 8 August, and the vessel steamed for 83 hours to the southern end of the P16 line. In this case, the southernmost attainable point (37°30'S) was set by back-calculation from the planned end port arrival date/time.

The P16 line was beset by somewhat more serious instrument problems (in terms of potential effect on CTD data quality — see the ODF section on CTD data processing), but managed to complete every planned station and head into port on schedule.

The weather was mostly quite good during this period. Overnight on 25 July rain squalls and steady light rain drove inner rosette sampling indoors for the only time during Leg 2. The wind began coming up during 30 July, but caused few problems other than slowing of vessel. The weather began to be more wintery: cooler, cloudy, grey, some rain squalls, winds to over 25 knots by 1 August. But we soon came under the benign influence of a strong subtropical high pressure zone, so the local weather improved and rarely again became a negative factor in Leg 2. On our return to the tropics in late August, winds rose somewhat, but did not interfere with operations. Long period swell influenced over-the-side operations at times, especially on the southern ends of the legs. Still, the weather was remarkably favorable considering that operations were being carried out during the middle of the austral winter.

At the completion of this expedition leg in Papeete, most ODF data acquisition and analysis services were taken over for Leg 3 by WHOI and OSU groups, so most ODF equipment — except for the rosettes, Gerard barrels, nutrient autoanalyzer, and radiocarbon extraction equipment — was unloaded in Papeete and returned to San Diego.

Rosette casts:

In conditions of low ship roll it was possible to prepare the rosette before coming onto station. 30 minutes before the station the scientific deck watch (2-3 persons) and winch operator met at the rosette area. The technicians cocked and checked the inner rosette, which between stations was held suspended at sampling height by the opposing tension of the CTD cable and four fitted ropes attached to vertical posts on the rosette frame and anchored to eyebolts on the rosette cart rails. When it was time to mate the rosette rings, the deck crew was joined by others at hand to make a 5 person party on deck. With one person on each post of the inner rosette and a fifth standing by at the rosette cart controls, the winch operator then lowered the inner rosette to the deck or — if there was very little roll — to knee height. The bottom ring (which stabilizes the inner rosette in air) and the four ropes were removed. With one person still on each leg, the winch operator raised the inner rosette above the height of the outer rosette, and the cart operator utilized an air tugger to bring the cart out underneath the suspended inner ring. The inner ring was then carefully lowered into the outer, safety pins inserted and guard rails assembled, the electrical and safety cables were connected, and the deck crew cocked and inspected the outer rosette. [The mating procedure was carried out on station if ship roll underway prohibited safe control.] The scientist on duty in the laboratory meanwhile verified pre-station entries in the console operations log, prepared tapes and computer peripherals, and, when the rosette was fully assembled and the ship was coming on station, powered up the CTD and verified its on deck performance from the deck unit (or its surrogate on the data acquisition computer).

When the mate on watch had secured the vessel on station and activated the after steering station, he gave permission for rosette launch. The deck leader removed sensor covers, activated the pinger, and verified permission to launch from the CTD computer operator (who, at that point, completed the final keystroke of the computer initialization sequence, turned on the VCR recorder, and noted cast start data on the console operations log). Three persons from the scientific party were required to actually launch the rosette. In good weather, two operated tag lines and the third operated the hydraulic controls for the boom. In conditions of heavier roll, the third person also handled a (third) tag line. [There was no room for more than three people to handle lines.] On signal from the deck leader, the winch operator raised the rosette above the rail, the boom operator swung the boom outward to cast position, and, at a propitious moment, the deck leader signaled the winch operator to lower away. The winch operator lowered the rosette through the sea surface and continued lowering at about 15-20 meters/minute until the rosette was at 15 meters. He engaged the heave compensator system (ca. 2 minutes), and then asked the computer operator for permission to lower away.

In general, once the cruise had progressed to the point where the winch operators knew well the safe operating conditions and limitations of this winch-compensator-cable-rosette system, they were free to select any safe lowering speed up to a maximum of 60 meters/minute. Typically, this meant starting at 20 meters/minute until about 100 meters of wire were out, and slowly increasing to 60 meters per minute by about 250-300 meters out. At ca. 400 meters of wire out, a small block — used to make certain that the CTD cable could not jump the first sheave at low cable tensions — was removed by the winch operator (and re-engaged on the up cast at about that depth). Meanwhile, in the laboratory, the scientist on watch monitored the PDR and deck unit, engaged various on-screen real-time plots — updating the scales, parameters, and ranges as needed (the computer was capable of post-dating plots after changes with the data from earlier in the cast) — and chose sampling depths for the up cast.

Bottom approach and cast turn-around were easy: With the deck leader monitoring the PDR as a back-up, the scientist monitoring the CTD computer (with its altimeter output) guided the winch operator to a final depth 10-15 meters above the bottom.

The final 50-100 meters of lowering were always accomplished at reduced winch speed. As soon as the winch stopped, a simple button push and a three-second wait were all that were required before raising the rosette to the next stop depth, and so time near bottom was kept to the absolute minimum. The CTD console operator was responsible for manually writing key back-up information on the console operations log at cast start, bottom, each rosette trip, and at the surface, although all of that information except depth information from the PDR was also logged automatically by the CTD computer.

Recovery and disassembly were virtually mirror images of assembly and launch in terms of procedures and personnel required, although, because of the added mass to the inner rosette ring, it was disassembled only on station; i.e., the vessel never left station until all was secure in the rosette area.

After each rosette cast was brought on board, analysts drew water samples from each bottle for various parameters. Sample drawing order was set at: CFC, helium, oxygen, CO_2, tritium, AMS ^{14}C, nutrients, salinity, and alkalinity. The only routine violation was that the nutrient and salinity samplers were allowed to preceed the AMS ^{14}C sampler if little water had previously been drawn from a bottle. In general, an attempt was made to collect gas samples in sequence as soon as possible after the air vent was opened. Hence, on some casts oxygen sampling began in the upper layers, following CFC sampling. In other cases — the norm — bottles were sampled in the order deepest to shallowest.

Rosette water sampling was often very busy, and for almost every rosette cast — except some rosette casts during large-volume stations — a "sample cop" armed with sample log sheet and pencil enforced sampling order, maintained records of the serial number of sample containers and the Niskin bottle each was filled from, and helped guide samplers to available rosette bottles. Sampling took as little as 65-70 minutes if only CFC, O_2, nutrients, and salinities were drawn (the minimum set every station), and well over two hours when enough sampling programs coincided. However, in no case did sampling from the last station prevent the next station from beginning on schedule (just barely).

At the completion of sampling, the samplers ensured that their samples were properly stored and labled, the sample cop placed the sample log sheet in the folder reserved for unregistered data sheets, and the water was emptied from the rosette.

Gerard barrel casts:

Gerard barrels (LVS) casts were carried out usually with five from the scientific party for deployment and six for recovery, not including the trawl winch operator. Space limitations dictated stern LVS casts on this cruise. A heavy cable was fed from the trawl winch below decks with a long fairlead from the forward/amidships portion of the fantail over a large sheave on the after A-frame. Due to the large amount of equipment and vans stored on the ***Washington's*** decks, it was not possible to site the small crane used for LVS handling on the same side of the vessel as the LVS samplers. Hence the trawl wire itself interfered with crane operation, forcing the crane operator during each transfer of a barrel between the stern and the barrel storage area to set down the barrel, move the crane "over" the trawl wire, and pick up the barrel again. During this time, it was necessary to have 2-4 tag/anchor lines on the LVS sampler to keep it upright. It was partly this requirement for stabilizing the samplers that brought about such a heavy personnel requirement for LVS operations on the ***Washington***.

Casts themselves went smoothly enough, with the principal problem being the effects of surge, which caused various tripping/closure problems. As has been noted on other expeditions, the work load was very heavy when a Gerard cast followed a rosette cast because a full rosette sampling crew is required in addition to the Gerard cast deployment crew. This never posed any special problem, and in fact the intensity and coordination required for these operations helped promote a certain 'group spirit' in the scientific party.

Additional information, and LVS-related data, may be obtained from Dr. Robert Key, Princeton University.

Surface radium and barium:

Bags with ion exchange filters designed to collect the isotopes radium-226, radium-228 and barium were soaked at the sea surface and collected for shore analysis by Richard Rotter (Princeton), on behalf of Robert Key (Princeton) at many Leg 2 stations (see .SUM file). (Barium samples were transfered later to J. Bishop, LDEO.) Information on this program may be obtained from Key.

Problems and comments:

At station 129 the rosette hit the side of the ship fairly hard and was brought back on board with damage to two bottles, several weight hangers, and the clamp that holds the end cap on the CTD pressure case, but we lost only 70 minutes due to these problems.

The first LVS station (#132) began on 23 July. The first cast (deep) failed to yield confirmation of bottom bottle trip (double ping from pinger). The recovery crew found six good closures, with the seventh bottle failing to trip or release. This turned out to be a typical problem in Gerard casts from the fantail in conditions when surge from ship pitch could be quite pronouced (Gerard barrel casts are notoriously sensitive to surge).

The CTD cast at #133 showed small conductivity high spikes on downward sensor motion, no spikes on upward. We decided to replace the CTD conductivity sensor on CTD #1, with the new sensor beginning on station 134. By station 137 continued conductivity problems (of the same type) on CTD #1 forced a switch to CTD #2.

We had to switch to CTD #10 on 29 July after the main PRT on CTD #2 went bad. CTD #10 needed adjustment for two-pylon use, but after that worked fine. On 2 August the rosette crashed into the ship, breaking 4 inner-ring bottles, loosening weights, etc.

During the transit from lines P17 to P16 (8-11 August), we cut off the end of the CTD cable and reterminated it, because wear had weakened the armor.

On the night of 10 August there was an interesting event: The mate and seaman on watch saw two red flares on the far horizon somewhat to port of ship track. They altered course toward the sighting. 12-14 miles later a weak radar return was noted. Finally a light was seen. No radio response at first, but then radio contact was established. It was a USSR vessel "practicing" with their flares. It turned out we saw their flares from 24 miles.

A CTD software problem arose at the first P16 station (#180, 12 August), the deepest station in the cruise, causing greatly distorted corrected pressures for most of the up cast. Several stations later (continued quite deep) this was diagnosed as a novel coincidence of CTD calibration data with a term in the hysteresis correction program and was easily corrected.

On station 182, at ca. 100 meters wire out, the signal stopped from the CTD (#10). On inspection it was found partially flooded (through the second thermometer turret, although the O-rings looked good). We switched to CTD #1, after applying additional shielding to a circuit board suspected of interfering with the conductivity channel. But the problems with conductivity noise (very specifically-characterized noise) on the down cast continued. We aborted #182 at 2000 meters wire out, tripping 24 bottles on the up cast, in order to get the CTD into repair. The suspect board was removed, but the CTD could still not be made to work properly. We chose to go next to CTD #2, substituting the backup PRT for main temperature channel. This worked reasonably well, although the physical separation of the backup PRT from the conductivity sensor made for more difficult salinity calculations, introducing noise typical of mismatched sensors.

On down cast at #189 near 300 meters CTD #2 froze up in T and C, but not P. Problem went away when hauled up. Inspection and changes provided no improvement on cast #2, i.e. same problem reappeared. New repairs did not fully fix things, but gave the CTD technicians enough new information to decide to construct a hybrid CTD out of working parts from #1 and #2. This worked out fairly well, except that the conductivity noise problem from CTD #1 was transferred to the hybrid instrument. Also, the oxygen channel had been noisy prior to this repair, so the sensor was replaced, but the oxygen profiles then were "flat".

During subsequent stations systematic card substitutions were made to the hybrid CTD, but failed to fix the conductivity problem. Tests with this CTD pointed toward some other type of problem than the internal electronics. The raw data showed a good correlation of conductivity jumps with package acceleration as judged via ship roll, increasing at higher winch speeds, suggesting a mechanical/electrical problem such as a stressed or loose connection or connector. Meanwhile, the old oxygen sensor was re-installed, with a new cable, and this fixed that channel. Finally on 18 August the roots of the CTD problems were identified: combination of mechanical troubles including loose bulkhead port seals (fortunate that CTD was not flooded), and loose coating on conductivity sensor guard. These were quite literally fixed with a crescent wrench and a pocket knife.

The hybrid CTD was used for the remainder of the cruise without further incident.

On 22 August we lost 1 hour with minor electrical problems (with slip ring plugs, as it turned out), and the restart was aborted when the CTD was launched without telling lab.

At station 211 the rosette hit the side of the ship on recovery. Broke FSI bag along seam (but not bottle) and Niskin #2, and lost one lead weight.

The conductivity (salinity) channel of the underway surface measurement system ceased to function early during Leg 2 due to failure of the conductivity cell. Underway temperature and pCO_2 were unaffected.

Other equipment problems arose during the cruise but had little ot no effect on the data. These include failure of both temperature-instrumented sampling tubes for O_2 sampling, reduction of the active pinger complement usually to one instrument, and failure of two power boards on the nutrient autoanalyzer. The air pumps used for radiocarbon extraction and the underway system (same model) experienced heavy wear, and most of the replacement parts were found to be defective. The Gerard barrels required continued maintenance to remain operational, but this is not unusual. Various terminals and serial ports went out, but no special problems were generated. Wear and tear on the double-rosette was evident from the gradually-increasing "looseness" of its frame. The inner ring design does not adequately support the Niskin bottles, causing wear on the attachment blocks and pins. With the launch/recovery set-up on the Washington, occasional accidents were inevitable, and several occurred, causing additional damage.

The ship's power was an occasional problem during the cruise. Serious brown-outs occurred three times when failure of the main generator voltage regulator drove the generator off-line. These power interruptions had a serious effect on the computers and peripherals, and probably on other electrical equipment. While little permanent damage seems to have occurred, various software glitches are probably traceable to these events.

Communications with shore facilities were a disappointment during Leg 2. The INMARSAT antenna mechanism did not function properly, and for the most part voice, data, and electronic mail through that service was lost, or at best were sporadic. Voice communications via ATS were also occasionally weak. Radioteletype messages were relayed daily via SIO radio station WWD and formed the principal vehicle for communications.

Leg 2 involved operations during the austral winter, at latitudes to 37° 30'S, and though the weather was mostly excellent for winter, long period swell generally prevailed. Scientific operations with the WOCE rosette and Gerard barrels are sensitive to ship motion, hence equipment wear and tear played a more prominent role than desired during this leg. Adding to this, the heavy cast schedule — itself a major contributor to extra wear — provided very little time for maintenance.

The R/V ***Thomas Washington*** (now the Chilean naval oceanographic vessel ***Vidal Gormaz***) was in advance of this expedition thought to be a marginally suitable vessel for US WHP operations. Negative aspects with respect to WOCE needs included small free laboratory space, marginal scientific party capacity (22 berths, with three of these quite poor), limited range and stores capacity, small scientific hold space, and excessive ship roll. But the vessel was prepared for TUNES by an agressive and capable marine department (SIO/MARFAC), who created space for three 20-foot laboratory vans, an 11-foot nutrient van, and a trash van, and built a first-class rosette sampling room and radiocarbon extraction room on the fantail while still leaving room for the Gerard barrels, extraction tanks, trawl wire, and cranes. The vessel was already fitted with a feedback-controlled hydraulic ram line tensioner. It appeared to reduce roll-induced upward package motion and resultant CTD data artifacts during down CTD casts, and greatly reduced line tension fluctuations. Probably the most important positive factor was the excellent quality of the ship's personnel complement and their helpful, always-friendly attitude. The only ways in which the size of the vessel impacted operations were (1) with Gerard barrels deployed from the stern, even moderate pitch created enough surge to make tripping the barrels uncertain; and (2) the lack of space/capability to deploy a weight underneath the rosette made rosette deployment and recovery more hazardous to the equipment — and somewhat more hazardous to the scientific personnel — than would otherwise have been the case.

The LDGO CO_2 work on Leg 2 was intensive, plus there was the unique situation for TUNES Leg 2 of the CO_2 group being asked to obtain shore samples for two other labs (WHOI and SIO). Hence on Leg 2 the CO_2 group needed sampling assistance. The CTD station rate was close to 4 36-level casts per day, which kept the non-CO_2 scientific party busy, and left little time for volunteer activities, especially technically exacting ones such as drawing the SIO shore samples. The two nutrient technicians agreed that on a time-available basis they would draw the SIO samples, and other assistance was occasionally provided, and so the CO_2 program achieved its goals. As a result of this experience, it was recommended to the US JGOFS CO_2 consortium that on future WOCE cruises the CO_2 groups prepare self-contained sampling and analytical programs within the limitations of the laboratory and bunk space available to the CO_2 program as a whole.

FSI water sampling bottle:

We experimented with a prototype "Fougere" bottle from Falmouth Scientific, which used a flushed bag-like liner to capture and isolate a ca. 6-liter water sample from gas exchange even during sampling. The first problem was mounting it on the ODF outer rosette frame, which does not accept General Oceanics-type block mounts (for which the FSI bottle was equipped). A suitable mount was constructed and adjusted for the sampler. Only three casts were completed with this arrangement before the sampler closed in air, incurring heavy damage. Later, after repairs, additional casts were made. In general, there were continuing mechanical problems with the design, although it did function, especially in good weather. (The FSI bottle suffered an exaggerated form of one of the main mechanical weaknesses of Niskin bottles in that the center of mass is held well away from the attachment block, leading to high risk of material failure at the attachment point during routine mechanical stress.) The bag holder/closure was always clumsy to use, though re-engineering might produce improvement.

Comparison water sample data showed that the bags sent out were contaminated with CFC. (This was not unexpected, and was one of the leading reserrvations regarding bag-like sampling for other water sampler designs.) One bag was baked extensively by the shipboard CFC group (to reduce CFC contamination), and it did show lower CFC levels, though still far above those from the ODF bottles. Salinity and nutrient samples from intact bags showed no real differences from samples drawn from 10-liter ODF bottles. Dissolved oxygens were always slightly (0.01 ml/l) lower than those from an ODF bottle, and the good news was that analyzed oxygen levels exhibited very little change when the bag literally hung out on deck an hour or two and was resampled. (In a similar situation, oxygen concentrations in water held in an opened Niskin-type bottle would have increased far beyond WOCE specifications during the hold time.) The temperature of the water in an FSI bag at the time of sample drawing was much warmer than the corresponding Niskin or ODF bottle, indicative of the lack of insulation in the FSI bottle. On this cruise we were not able to test the behavior in deep high oxygen cold water, where the warming of the contained water would result in a sample supersaturated in oxygen at the time of drawing.

A tentative conclusion was that though the mechanical design of this early version of the FSI sampler needed improvement, the general concept of the bag-type sampler did have promise, if delayed sampling for gas samples were an expedition requirement, and with the caveat that the CFC contamination issue would require close attention.

Data Notes:

Reports on the methodology and related information for all TUNES Leg 2 measurement programs will be added to the documentation as they come available from the participating investigators. For example, ODF has submitted reports on the bottle data pressure, temperature, salinity, oxygen, and nutrient data, and on the CTD data, and Rana Fine's group has a report on CFC measurements.

The ".SUM", ".SEA", and ".CTD" files for 31WTTUNES/2 were prepared according to the specifications and model files published in Joyce et al (1991). ODF created the original ".SEA" file (for pressure, temperature, salinity, oxygen, nitrate, nitrite, phosphate, and silicate only) and the ".CTD" file, and J. Swift created the ".SUM" file. Parameters, formats, units, and other related matters for the WHPO data files are as specified in Joyce et al (1991). Comments:

> Station numbers are consecutive from the beginning to end of the cruise, without interruption, as assigned by the Chief Scientist, continuing the TUNES Leg 1 sequence except for unreported test stations.
>
> Cast numbers are consecutive at each station, including aborted casts.
>
> The WHPO does not include meteorological data in header files. However, we intend that the NODC "Master File" SD2 format version of the routine hydrographic data, when available, will contain weather information collected by the ship's officers and copied by hand from the Washington's Bridge Log. Other meteorological data were reported by the ship to collection agencies as per standard practice.
>
> Positions for ROS and LVS casts were recorded by the ODF to 0.1 minutes, not the hundredths of a minute required by the WHPO. We have thus padded the

hundredths place with meaningless zeros. We also note that the position of the underwater equipment was difficult enough to know to tenths.

"Uncorrected Bottom Depths" are in almost every case actual raw readings in meters read manually from the trace on the ship's PDR plus the depth of the transducer below waterline, which we took to be an average of about 2 meters for this cruise. When there were multiple bottom returns, the Watch Leader chose a "most likely depth" from the information at hand. Occasionally only corrected bottom depths were available in the cruise files, in which cases these were back-calculated to raw depths using the appropriate tables and algorithms. Corrected depths will be issued by the WHPO.

Bottom depths were not recorded at cast ends and so are not reported in the .SUM file.

"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. Priority in reported height above bottom was given to altimeter data when available.

The "Meter Wheel" readings are the wire out as recorded on the winch operator's display (and the repeater in the ship's laboratory). 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. Meter wheel readings at bottle trip time were not recorded for one-barrel LVS surface casts.

"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 not the maximum number attempted each cast, but the number returned to deck with sampleable water inside. This distinction was not discussed in the WHPO reference manual, and so we made our own decision, which bears comment: If a rosette bottle came up open or otherwise unsampleable, it did not count in the tally in this column; 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 makes sense from the standpoint of the chemistry groups, because their tallies keep track of the number of bottles sampled for the parameters of interest. The 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), and so 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.

Three groups carried out CO_2 system sampling during TUNES Leg 2: A group from LDEO (PI's were Chipman and Takahashi) carried out on-board analyses for pCO_2 and TCO_2. Samples for alkalinity were returned to shore for analyses by Goyet (WHOI), and samples for TCO_2 were returned to shore for analyses by Keeling (SIO). At the time this report was written it is not yet known how the WHPO will report multiple observations of the same parameter (TCO_2) by different groups. (It is also possible that there will be some overlap in the helium program, which was carried out by two groups. Again, it is not yet known how the WHPO will report these multiple observations.)

The parameter codes listed in Joyce et al (1991) for CO_2 sampling are for total carbon, alkalinity, and fugacity of CO_2. The parameters measured during TUNES Leg 2 were total inorganic carbon (also called total CO_2, which combines total dissolved CO_2 with carbonate and bicarbonate, but does not include organic carbon), alkalinity, and partial pressure of CO_2. The parameter code for total carbon ("23") is here used for total CO_2 and similarly for fugacity/pCO_2 ("25").

No WHPO sample code existed for the IO_3 profiles carried out on TUNES Leg 2. Hence, according to the instructions on pp. 24-25 of Joyce et al (1991), code "26" was temporarily assigned for IO_3. Similarly no WHPO sample code existed for the Barium surface samples and so code "27" was temporarily assigned for these.

Note that the Radium isotope (code "18" and "19") and Barium (code "27") sampling programs took place only from surface samples (fiber-filled bags with ion exchange resins suspended in the water on a line thrown over the side of the vessel).

Note that while profiles for TCO_2 and pCO_2 were made at about one station each day, at most other stations samples for these parameters were collected from the near-surface bottles and so the relevant parameter codes ("23" and "25") show up at almost every station.

TUNES Leg 2 was originally proposed in a different configuration: the P17 portion of the work was to be part of a long "P17C" expedition proposed by Talley and Tsuchiya and the P16 portion was part of an Antarctica-to-Tahiti "P16S" line in a P19S/P16S plan proposed by Swift. The original cruises were delayed by difficulties with the refit of the intended vessel (R/V ***Knorr***), so the lines were restructured and rescheduled. The P17 portion of the cruise was known before and during the expedition as "P17C" and since the P16 portion completed was mostly in the subtropics, it, too, was called P16C by the participants. However, Joyce et al (1991) state that line designations must match that of the WOCE Implementation Plan. In the published international version of the plan, this would be simply P17 and P16, but the WHPO (personal communication) has renamed these lines "P17S" and "P16S". We have tried to change "P17C" to "P17S", etc., in this and all other submitted final documentation.

Reversing thermometer measurements were made at many of the CTD stations. Results were used only for data processing and are not reported in the .SUM" and .SEA" files.

WHPO Parameter Codes used in the .SUM file for TUNES Leg 2:

1	salinity	8	CFC-12	19	radium^{226}
2	oxygen	9	tritium	23	total CO_2
3	silicate	10	helium	24	alkalinity
4	nitrate	11	del helium^{3}	25	pCO_2
5	nitrite	12	del carbon^{14}	26	IO_3
6	phosphate	18	radium^{228}	27	barium
7	CFC-11				

One of the appendices to this report contains a complete listing of all TUNES Leg 2 bottles where the reported data quality code for the routine hydrographic parameters is not "22222222", sorted by the type of error or problem.

Data files in other formats:

Although the TUNES Leg 2 CTD and routine hydrographic data were prepared in WHPO format (".SUM", ".SEA", and ".CTD" files), some investigators may find other formats useful, especially for the water sample data, which in WHPO format contain known bad values (although these are always indicated by the appropriate quality flags). Acting on the belief that persons closest to the data collection are best qualified to prepare "clean" bottle data sets, we plan to prepare water sample data files in the following alternative formats:

NODC SD2: This is a standard transmission format and is compatible with the NODC Master Files, therefore when this file is submitted to NODC, it should be accessible under the search and retreival system in use in 1993. Headers will be based on the .SUM file created by the Chief Scientist, but will hopefully also contain other information, such as meteorological data on station, not recorded in the WHPO-format headers. The format requires that oxygen and nutrient data be in volume units. It would have been most convenient to use the original source data from the analyses, which were in these units before being converted to mass units for the WHPO format version of the data, but this would not have permitted use during translation of the WHPO codes, required here because the ODF file from which the WHPO .SEA file was made contains the bad values. We used ***in situ*** temperature to back-convert the oxygen concentrations and a laboratory temperature of 25°C to back-convert the nutrients. In addition to the formatting, we substituted CTD salinities for bad bottle salinities in order to preserve density field information. Note that temperature, salinity, and oxygen data were degraded somewhat to fit NODC requirements.

ASCII flat file report: We plan to prepare ASCII electronic data reports based on the version of the data in the NODC SD2 file, adding calculated parameters (depth, potential temperature, density referred to 0, 2000, and 4000 decibars, oxygen percent saturation, dynamic height, and stability), and also standard ODF cast/sample numbers.

OceanAtlas for Macintosh: We will prepare a binary Macintosh data file from the version of the data in the NODC SD2 file, in "OceanAtlas for Macintosh" format, for use in that application.

Data Distribution:

TUNES Leg 2 hydrographic and CTD data and headers will be sent to the WHP Office in Woods Hole. The WHPO will create an evolving documentation file (".DOC") from various records.

Merging of TUNES Leg 2 CTD/hydrographic data in WHPO format with CFC, helium, tritium, radiocarbon, and other data is a continual exercise. The WHPO will submit assembled data files and all documentation to the WOCE Hydrographic Program Special Analysis Center in Hamburg, Germany. Data tracking for all TUNES Leg 2 data will be provided during WOCE by the WOCE Data Information Unit.

The WHP SAC will act as an intermediary data distribution point. The SAC will prepare a final data report in mixed print/electronic form, and will submit data and complete documentation (metadata) to the appropriate long-term archives. According to tentative agreements, the WDC-A will hold the TUNES Leg 2 data and all documentation in a WOCE program archive yet to be established.

Warning: TUNES Leg 2 "Level 1" or originator data were supplied to the WOCE Hydrographic Program Office in "WHPO" format, which contains, as required, the complete hydrographic data listing, ***including known bad values***. Each datum in the principal water sample listings is accompanied by a quality code byte (see Joyce et al, 1991). Additional documentation supplied with these data lists the reason for every degraded quality code. (The documentation also includes much additional detail, such as remarks about data initially thought suspicious but assigned "good" codes during data processing.) The following "filtering" is highly recommended to anyone using the TUNES Leg 2 ".SEA" file:

Discard all salinity, oxygen, or nutrient data reported with a "4" quality byte. Note that this does not include the ***bottle*** quality byte.

Seriously consider discarding salinity, oxygen, or nutrient data reported with a "3" quality byte. These data have some sort of discrepancy compared to other data, but cannot be unambiguously proven "bad". Examine the bottle data comment documentation, and make your own choice. We plan to delete code "3" salinity, oxygen, and nutrient data from our version of the NODC SD2 file and its subsequent derivatives.

Discard all bottle data, for any parameter, where the *bottle* quality byte is "3" and all other water sample codes are "4".

Discard all <u>gas</u> sample data (oxygen, helium, CFC, and maybe CO_2) **for any bottle where the bottle quality byte is "3"** (leaking) **and the oxygen quality byte is "4"** (the leak affected a gas sample, so probably all gas samples from the bottle are bad).

If the bottle quality byte is "3", the accompanying water sample data may or may not be reliable. Check the additional text documentation for guidance. (Sometimes leaks are reported by the deck crew, but are later found to have no discernible effect on the reported water sample data.) For example, the bottle code may be "3", and the oxygen code "4", but the salinity and nutrients may be coded "2" meaning that they have been investigated and found reliable. In our version of the NODC SD2 file and its subsequent derivatives we kept code "2" salinity and nutrient data from water samples with code "3" bottles and code "4" oxygens.

A bottle quality byte of "4" ("did not trip correctly") is not of itself an indicator of the reliability of the water samples from that bottle. Instead, this might mean only that the bottle did not close at the level intended by the operator of the cast. If the actual closure level was determined in later processing, the water sample data may be fully recoverable, though at a different depth than noted on the original operator's log sheet. For example, if the rosette pylon fails to release a lanyard at the intended level, but subsequently releases two lanyards at the next intended level, the quality byte on the mistripped bottle will be "4", but all the water sample data may be perfectly valid, but reported at the depth where it tripped with the other bottle. We will not delete code "2" water samples from code "4" bottles in our NODC SD2 file and its subsequent derivatives.

Data Assembly and Distribution Centers:

WHP Data Assembly Center:	WHP Special Analysis Center:
WOCE Hydrographic Program Office Scripps Institution of Oceanography 9500 Gilman Drive • MS 0214 La Jolla CA 92093-0214 • USA ***contacts***: Dr. James H. Swift phone: 858-534-3387 internet:jswift@ucsd.edu Mr. Steve C. Diggs phone: 858-534-1108 fax: 858-534-7383 internet:sdiggs@ucsd.edu	WHP Special Analysis Center Bundesamt fur Seeschiffahrt und Hydrographie (BSH) Deutsches Ozeanographisches Datenzentrum Postfach 30 12 20 • D-20305 Hamburg • Germany ***contact***: Mr. Kai Jancke phone: 49-40-3190-3536 fax: 49-40-3190-5000 telex: 215448 HYDRO H omnet: WOCE.WHP.SAC internet: kai.jancke@m5.hamburg.bsh.dbp.de

Files with positions and depths every five minutes (in time) are held at:

National Geophysical Data Center
NOAA, Code E/GC
325 Broadway
Boulder, CO 80303-3328

Contact : Ms. Robin R. Warnken
Phone: (303) 497-6338
fax: (303) 497-6513)
Internet email: rrw@mail.ngdc.noaa.gov.

A.4.b Comparisons with Previous Data

We compared TUNES Leg 2 water sample data with those from the Scorpio 28°S section (SIO; 1967) and with preliminary/proprietary data from TUNES Leg 1 (ODF; 1991; M. Tsuchiya, Chief Scientist), TUNES Leg 3 (WHOI/OSU; 1991; L. Talley, Chief Scientist), the P6 section (WHOI/OSU; 1992; M.McCartney, Chief Scientist), and from JUNO Leg 1, (ODF; 1992; J. Reid, Chief Scientist). Water sample results were compared with reference to potential temperature. All comparisons were restricted to the range _ ≤ 2.5 °C, or approximately the waters deeper than 1500 meters, because in the deep waters most property gradients are relatively small.

Plots of bottle salinity, oxygen, nitrate, phosphate, and silicate against potential temperature for each comparison exercise are shown in the accompanying figures, along with tables summarizing the offsets and scatter (visually/arbitrarily judged) **along isotherms**. In the plots, the TUNES Leg 2 data are always shown with solid lines connecting data points whereas the comparison cruise data are always shown as triangles.

We summarize the findings below:

General:

The most disturbing differences may well be those with TUNES Leg 3, which was run following TUNES 2 with different technical groups. There are large differences in all nutrients (TUNES 2 is higher by 1.1% for NO3, 3.5% for PO4, and 2.5% for SiO3), and disturbing differences in salinity. At this writing there is no conclusive explanation for these differences.

Salinity:

TUNES salinities (both Legs 1 and 2) are lower than other expedition salinities by about 0.002, including the ODF JUNO expedition 14 months later, TUNES Leg 3, and the Scorpio expedition in 1967. No problems were experienced with the TUNES salinometers or measurements and there were no discrepancies of this magnitude with the IAPSO standard seawater. There is thus no known cause for these differences, which are larger than would be expected. Scatter (apparent precision) of the TUNES 2 data is about 0.001. The implied accuracy is on the edge of the WOCE specification and the precision is within specification.

Oxygen:

TUNES Leg 2 oxygens agree to within 0.01 ml/l with those from TUNES Leg 1, P6, and JUNO. Scatter of the TUNES 2 data is about 0.01 ml/l. The modern comparisons and scatter are well within WOCE specifications. The TUNES Leg 2 values are 0.06-0.09 ml/l lower than those from the Scorpio 28°S section.

Silicate:

TUNES Leg 2 silicate values are about 1-3 µm/l higher than those from other recent expeditions. The differences are smaller (1-2 µm/l) with ODF expeditions and larger (2-3 µm/l) with OSU expeditions. The latter agrees with Talley's recent findings. Scatter of the TUNES 2 data is about 0.5-1 µm/l, though this is uncertain due to effects of natural variability.

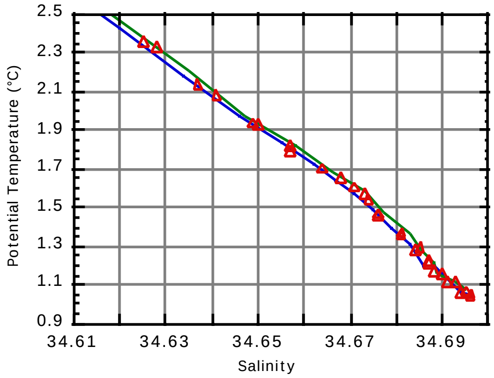
Nitrate:

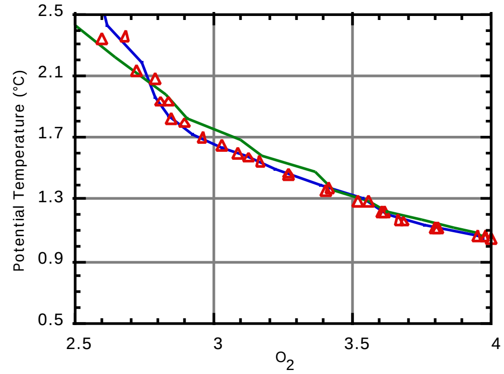
TUNES Leg 2 nitrate values are occasionally 0.2-0.3 µm/l lower than those from other recent expeditions, with a difference at the comparison station of 0.08 µm/l from TUNES Leg 1. Scatter of the TUNES Leg 2 data is about 0.2 µm/l. The TUNES 1/2 comparison may be influenced by problems during TUNES Leg 1. TUNES 3 is lower than TUNES 2 by 0.4 µm/l and this is as yet unexplained. Nitrate methodology in 1967 was inferior to that in use today, so comparisons with Scorpio serve no point.

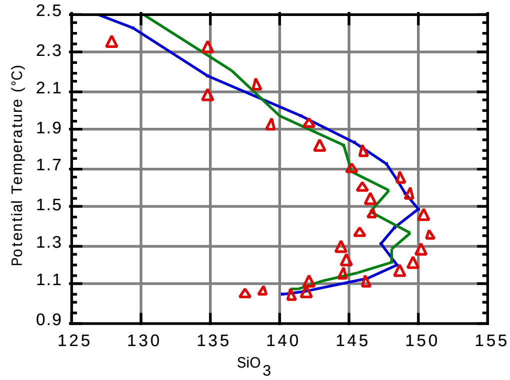
Phosphate:

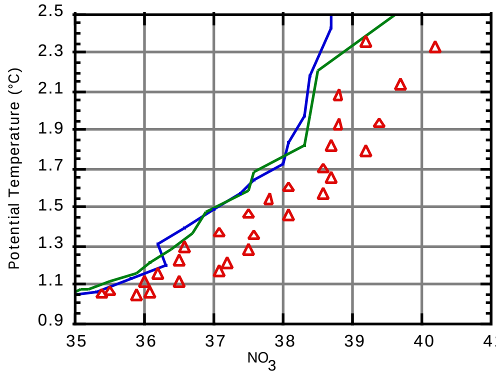
TUNES Leg 2 phosphate values are never lower than those from other recent expeditions, and occasionally about 0.02 µm/l higher, and in the case of TUNES 3, they are 0.09 µm/l higher. Scatter of the TUNES Leg 2 data is about 0.2 µm/l. Bad values (code 4) at station 124 disort the TUNES 1/2 comparison. TUNES Leg 2 phosphates are 4% lower (0.07-0.12 µm/l) than those from Scorpio.

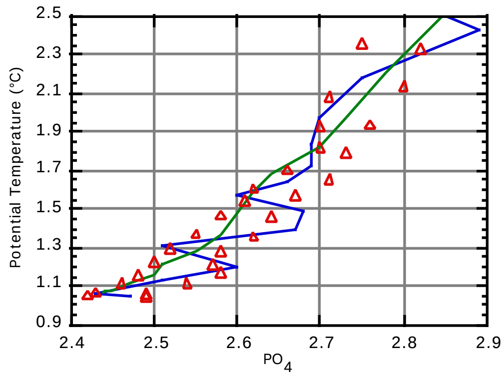
P17: TUNES Legs 1 & 2 comparison







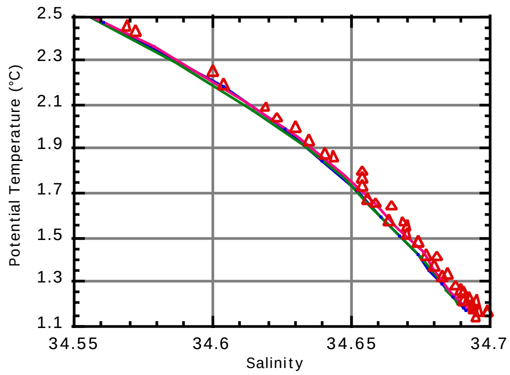


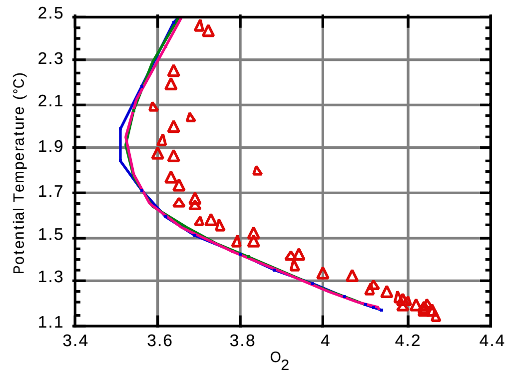


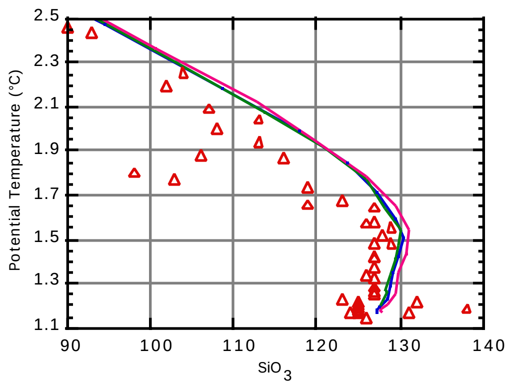
TUNES 2 (124, 125) and TUNES 1 (122, 123) 6°S, 135°W			
Property	Offset: T2 minus T1	TUNES 2 scatter	TUNES 1 scatter
S	0.000	0.001	0.001
O2 (ml/l)	0.00	0-0.02	<0.01
SiO3	1-2	1-3	2-5
NO3	-0.8	0-0.2	0.6-0.8
PO4	0?	0.02-0.08	0.06

Discussion:
There is an unusual amount of nutrient noise for two consecutive legs of the same expedition (run by the same technical group), and a small (<1%) silicate offset and a larger (2%) nitrate offset. TUNES 2 phosphates shown include known bad values, plus TUNES 1 station 122 reported high values possibly associated with an instrument problem, leaving this parameter noisy but with no obvious offset. Salinity and oxygen noise and differences are small.

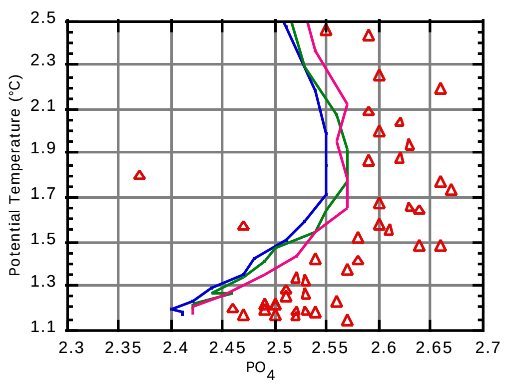
P17: TUNES Leg 2 and Scorpio comparison







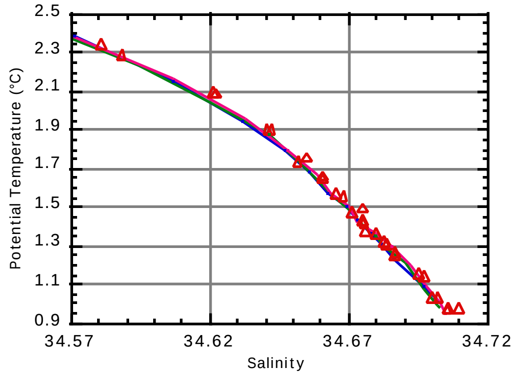
(Nitrate methodology in use during Scorpio significantly lower quality than that used during TUNES.)

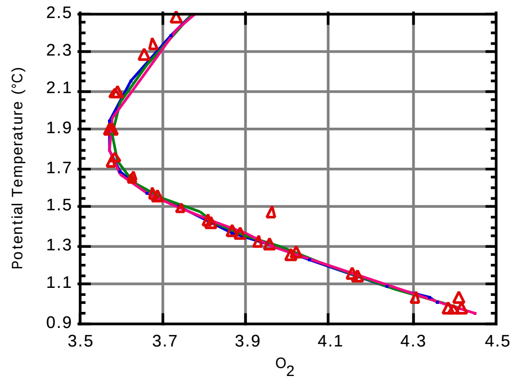


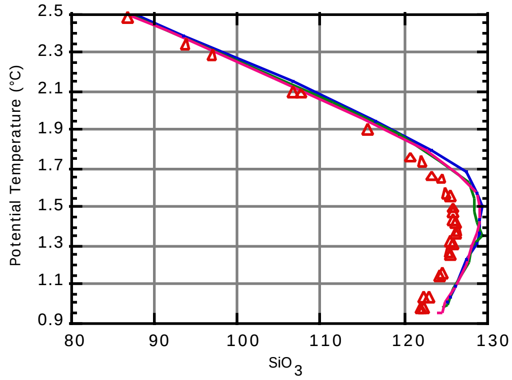
TUNES 2 (169-171) and Scorpio (123-125) ca. 28°S, 134°W			
Property	Offset: T2 minus Scorpio	TUNES 2 scatter	Scorpio scatter
S	-0.004	<0.001	0.003
O2 (ml/l)	-0.09	0.01	0.04
SiO3	ca. 4	0.5	2-10+
NO3	na		
PO4	-0.07	0.02	0.04-0.08+

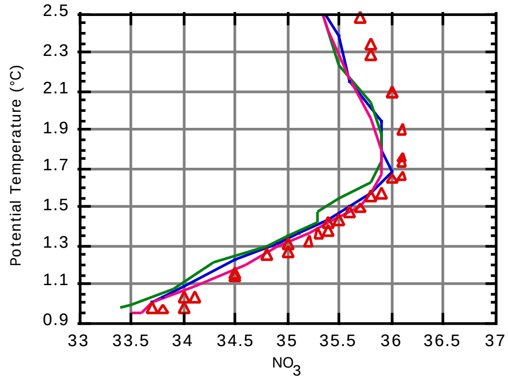
Discussion:
Correction of Scorpio IAPSO standard seawater to modern raises values by about 0.002, at least half the difference, and probably to within WOCE tolerances. Oxygen difference is -2%, silicate is 3%, and phosphate is -3%, all higher than WOCE accuracy tolerances. Apparent noise in TUNES data is within WOCE precision tolerances.

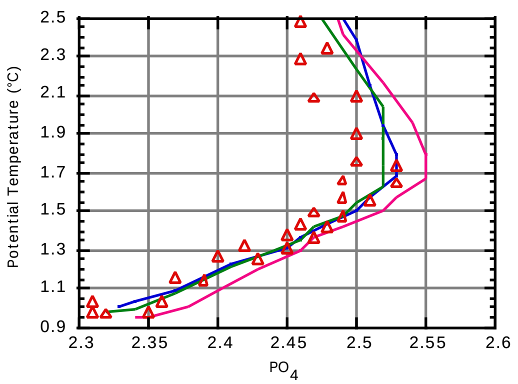
P17: Tunes Leg 2 and P6 comparison







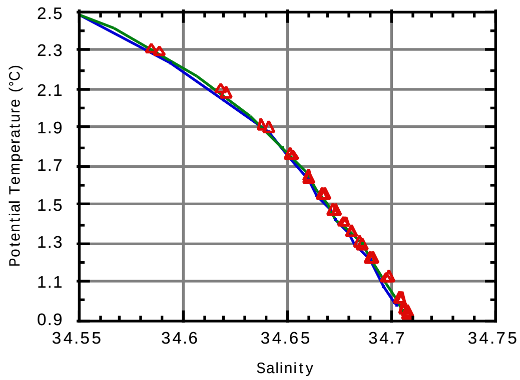


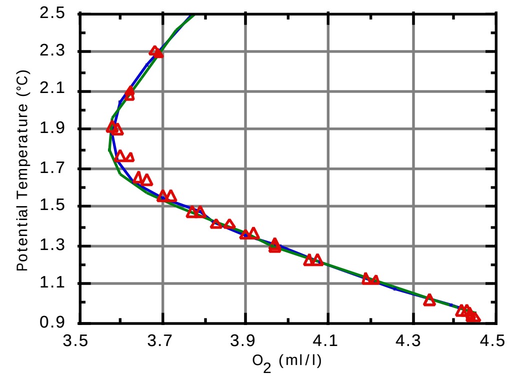


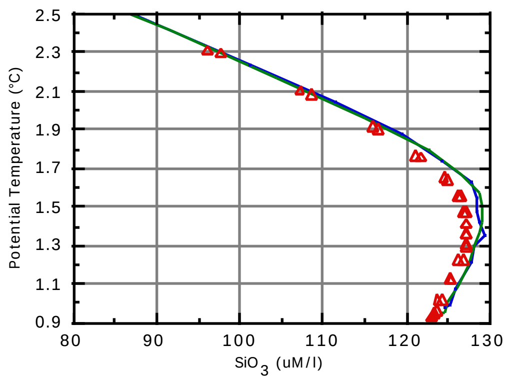
TUNES 2 (177-179) and Knorr P6 (107, 108) ca. 32.5°S, 135°W			
Property	Offset: T2 minus P6	TUNES 2 scatter	P6 scatter
S	-0.002	0.001	0.002
O2 (ml/l)	0.00	0.00-0.02	0.01-0.02
SiO3	2	1-2	1-2
NO3	-0.3	0.1-0.2	0.1-0.2
PO4	0.02	0.02-0.03	0.02-0.03

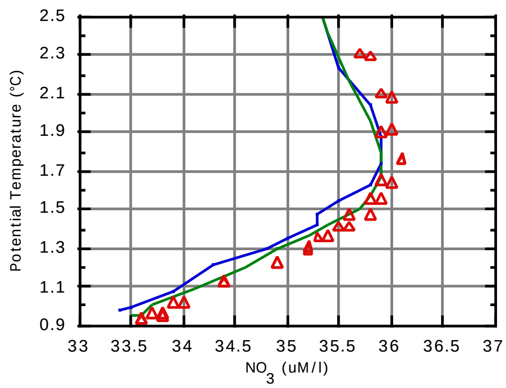
Discussion:
Salinity offset of -0.002 is at edge of WOCE accuracy tolerance, silcate offset (2%) over tolerance but nitrate and phosphate within WOCE 1% level. Scatter is acceptable for all parameters. (P6 data are preliminary.)

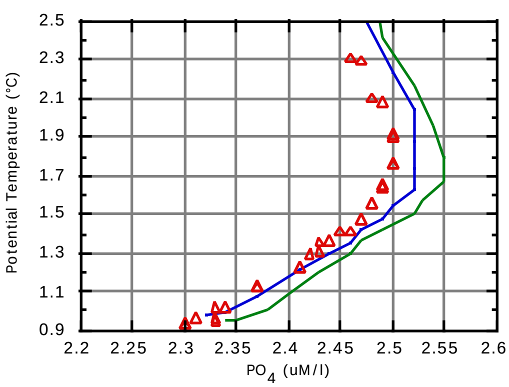
P17: TUNES Leg 1 & JUNO Leg1 comparison









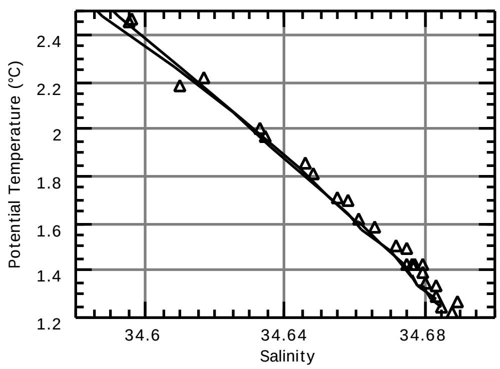


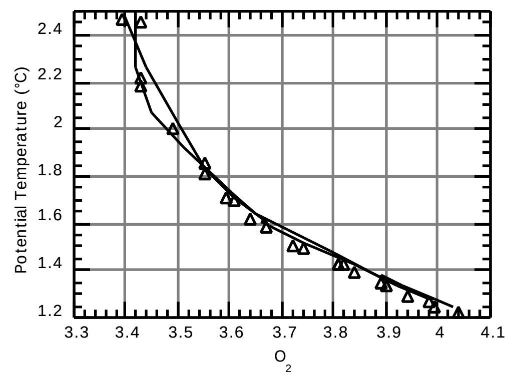
TUNES 2 (178, 179) and JUNO 1 (118, 119) ca. 33°S, 135°W			
Property	Offset: T2 minus JUNO 1	TUNES 2 scatter	JUNO 1 scatter
S	-0.003	0.001	0.001
O2 (ml/l)	0.00	0.01	0.01
SiO3	1-2	0.5	0.5
NO3	-0.2-0.3	0.1-0.2	0.1
PO4	0.03	0.01-0.03	0.01

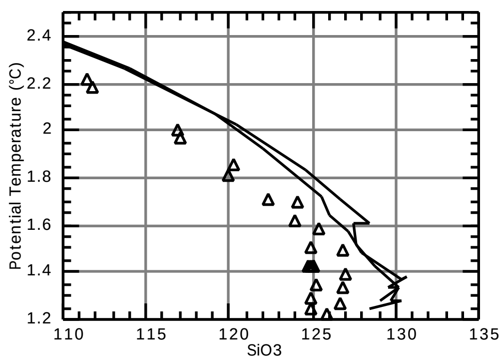
Discussion:

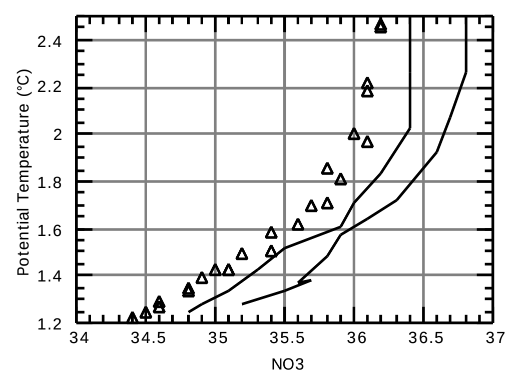
Salinity difference exceeds WOCE accuracy tolerance. All other differences and scatter are within WOCE accuracy and precision tolerances. Some indications of a north-south property gradient which may bias these comparisons. (JUNO data are preliminary.)

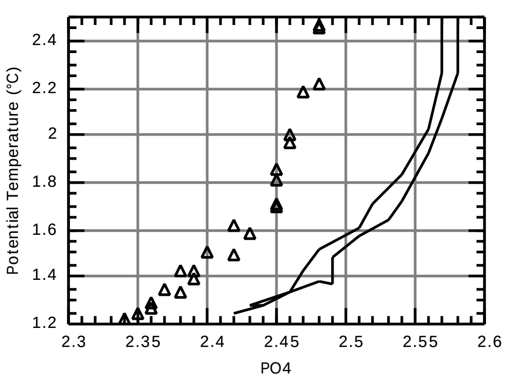
P16: TUNES Legs 2 & 3 comparison







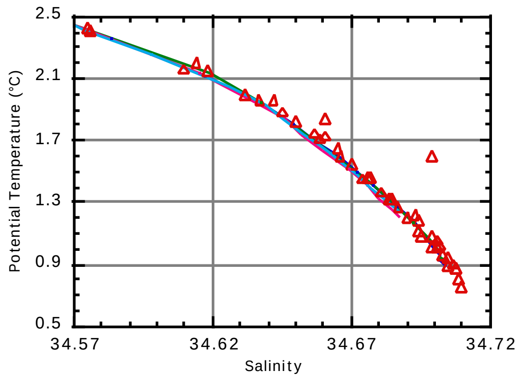


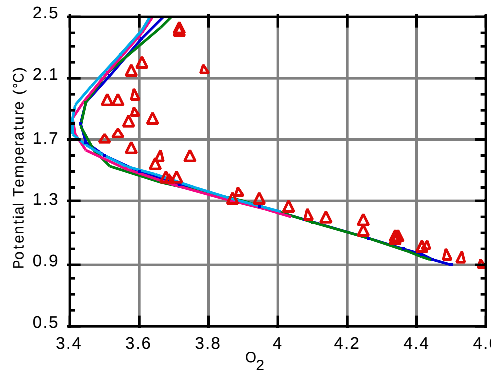


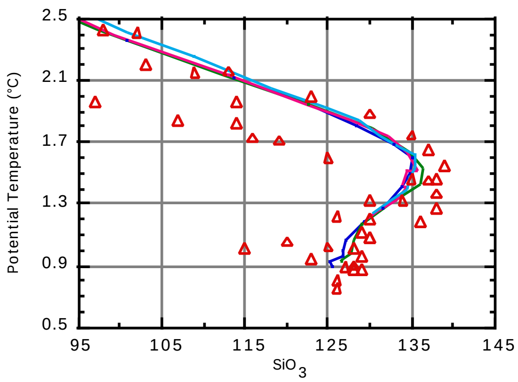
TUNES 2 (219, 220) and TUNES 3 (221,222) ca. 17.5°S, 150.5°W			
Property	Offset: T2 minus T3	TUNES 2 scatter	TUNES 3 scatter
S	-0.004	0.001	0.002
O_2 (ml/l)	<0.02	0.01	0.01
SiO_3	3	0.3-1	1-2
NO_3	0.4	0.3	0.1
PO_4	0.09	0.01	0.01

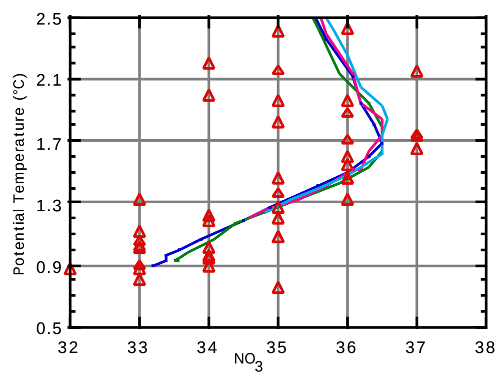
Discussion:
There are baffling differences between these two legs, run on the same vessel but by different technical groups. All the salinities were standardized to the same batch IAPSO SSW. The same nutrient autoanalyzer was used (though with some methodological differences). Oxygen methodology differed. The questions raised here bear much further examination.

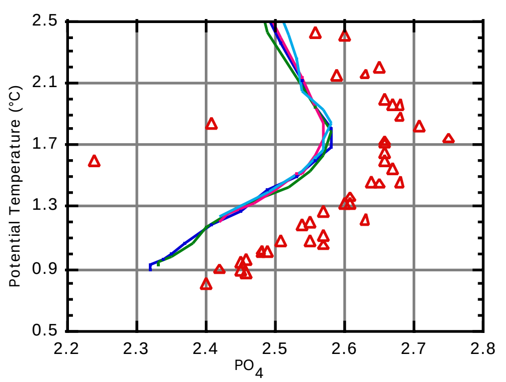
P16: Tunes Leg 2 and Scorpio comparison









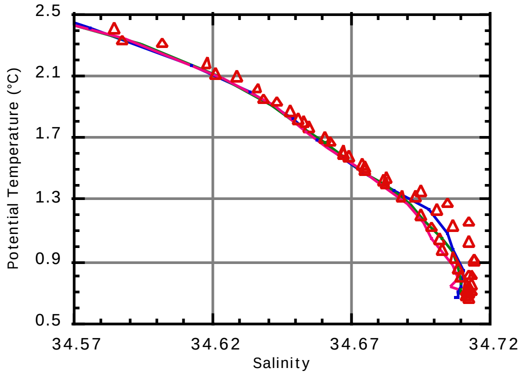


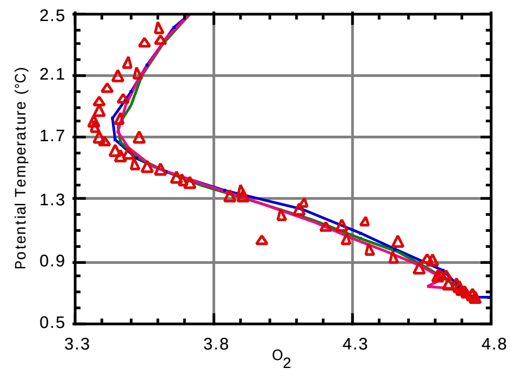
TUNES 2 (197-200) and Scorpio (132-134) ca. 28°S, 150.5°W			
Property	Offset: T2 minus Scorpio	TUNES 2 scatter	Scorpio scatter
S	-0.003	0.001-0.002	0.002-0.005
O_2 (ml/l)	-0.06	0.00-0.02	0.02-0.10
SiO_3	0?	0.5-1.0	ca. 10
NO_3	na	0.2	(2)
PO_4	-0.1-.12	0.01-0.02	0.04

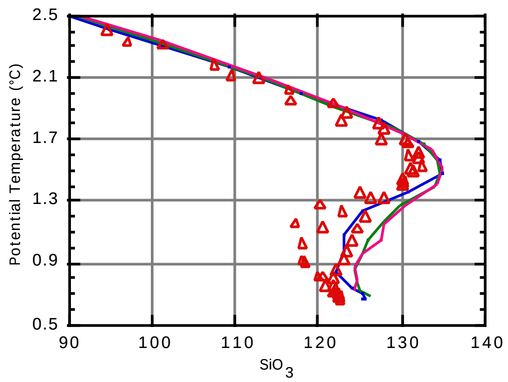
Discussion:

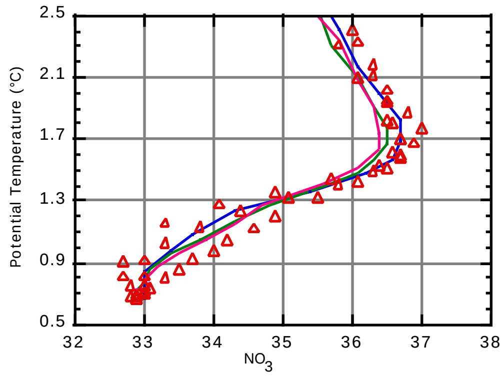
Most of salt difference is accounted for by 0.002 correction of Scorpio salts to modern IAPSO standard seawater. Oxygen difference (-1.5%) and phosphate difference (-4%) exceed WOCE accuracy standards. Precision of TUNES 2 data within WOCE tolerances. Scorpio nutrients, and perhaps some of oxygens, well off WOCE precision tolerances. (Nitrate comparison shown only to illustrate improved quality with modern autoanalyzer methodology.)

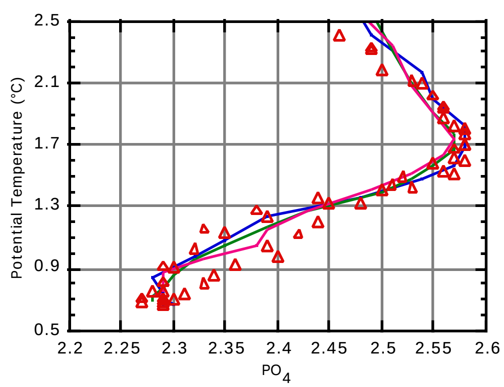
P16: TUNES Leg 2 and P6 comparison







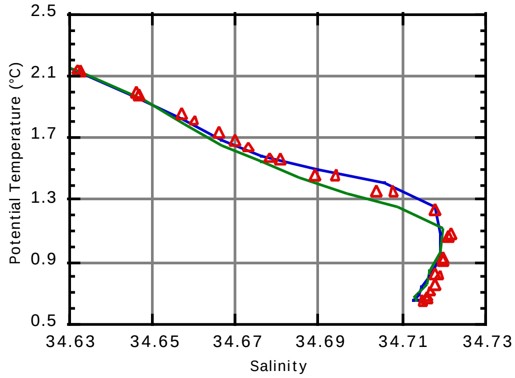


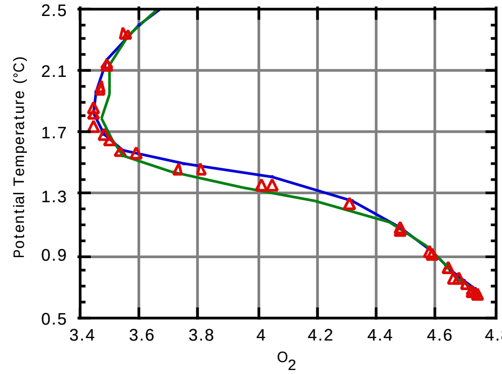


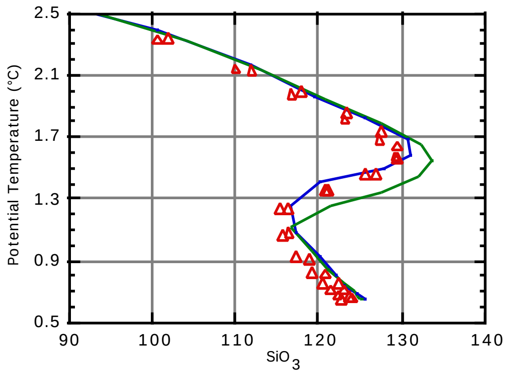
TUNES 2 (189-191) and Knorr P6 (127-129) ca. 32.5°S, 150.5°W			
Property	Offset: T2 minus P6	TUNES 2 scatter (wm?)	P6 scatter (wm?)
S	-0.003	0.001-0.004	0.002-0.010
O2 (ml/l)	0?	0.01-0.03	0.02-0.10
SiO3	2-3	0.5-2.0	1-6
NO3	0.0-0.2	0.2	0.2-0.4+
PO4	0?	0.02	0.02-0.06+

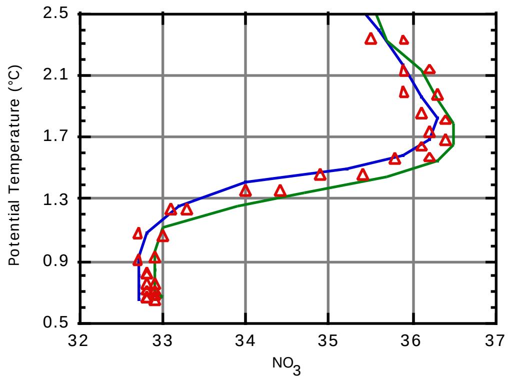
Discussion:
Comparisons difficult due to possible natural (watermass) variability. Salinity difference of -0.003 and silicate difference of 2-3 are slightly outside WOCE accuracy tolerances. Precision comparisons suggest slightly lower apparent noise in the TUNES 2 data, but this could be influenced by shape of natural gradients. (P6 data are preliminary.)

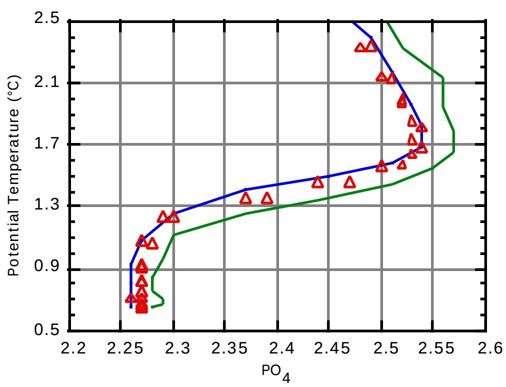
P16: TUNES Leg 1 & JUNO Leg 1 comparison











effects of natural variability

TUNES 2 (180, 181) and JUNO 1 (3, 4) ca. 37.5°S, 150.5°W			
Property	Offset: T2 minus JUNO 1	TUNES 2 scatter (wm?)	JUNO 1 scatter (wm?)
S	-0.002	0.001-0.005	0.001-0.003
O2 (ml/l)	0.01	0.00-0.05+	0.00-0.03
SiO3	1-2	0-3	1-2
NO3	0.0	0.2	0.2-0.4
PO4	0.00-0.02	0.02-0.03	0.01-0.02

Discussion:

Comparisons may be complicated by natural (watermass) variability. Salinity difference of -0.002 and silicate difference of 1-2 are on edge of WOCE accuracy tolerance. Estimated precision in both data sets looks to be within WOCE tolerances; that is, if natural variability accounts for the station-to-station differences.

A.4.c Vertical Sections along the Ship's Track

Figures 2 and 4 show the distribution of small volume (10-liter) water samples on the P17 and P16 portions of TUNES Leg 2, and Figures 3 and 5 show the sectional distribution of large volume (Gerard) water samples. Note that in the upper ca. 1000 meters, small volume water samples were collected for radiocarbon analyses, hence the general absence of LVS samples in that layer.
and Tsuchiya (1993)".

A.5. Major Problems and Goals Not Achieved

None of the problems noted in the "narrative" section resulted in serious loss or degradation of data. The areal and property coverage of TUNES Leg 2 was exactly as planned.

A.6. Other Incidents of Note

The "narrative" section covers the entire scope of this cruise.

A.7. List of Cruise Participants

Name	Group	Institution
Birdwhistell, Scot	Helium (upper)	WHOI
Boaz, John	resident technician	SIO/STS
Bouchard, George	computer technician & ODF	SIO/SCG
Delahoyde, Frank	CTD system	SIO/ODF
Goddard, John	CO_2	LDGO
Guffy, Dennis	nutrients	TAMU
Lewis, Diana	physical oceanography (student)	SIO
Maillet, Kevin	CFC	U of Miami
Masten, Doug	LVS/C^{14}	SIO/ODF
Mathieu, Guy	CFC	LDGO
Orsi, Alex	ADCP	TAMU
Patrick, Ron	marine tech	SIO/ODF
Peterson, Ray	physical oceanography	SIO/PORD
Rotter, Rich	LVS/AMS/C^{14}	Princeton
Rubin, Stephany	CO_2	LDGO
Schmitt, Jim	electronics	SIO/ODF
Streib, Rebecca	marine tech	SIO/ODF
Swift, James	physical oceanography	SIO/PORD/ODF
Tedesco, Kathy	helium (deep)	UCSB
Williams, Nadya	nutrients	SIO/ODF
Williams, Robert	marine tech/data	SIO/ODF

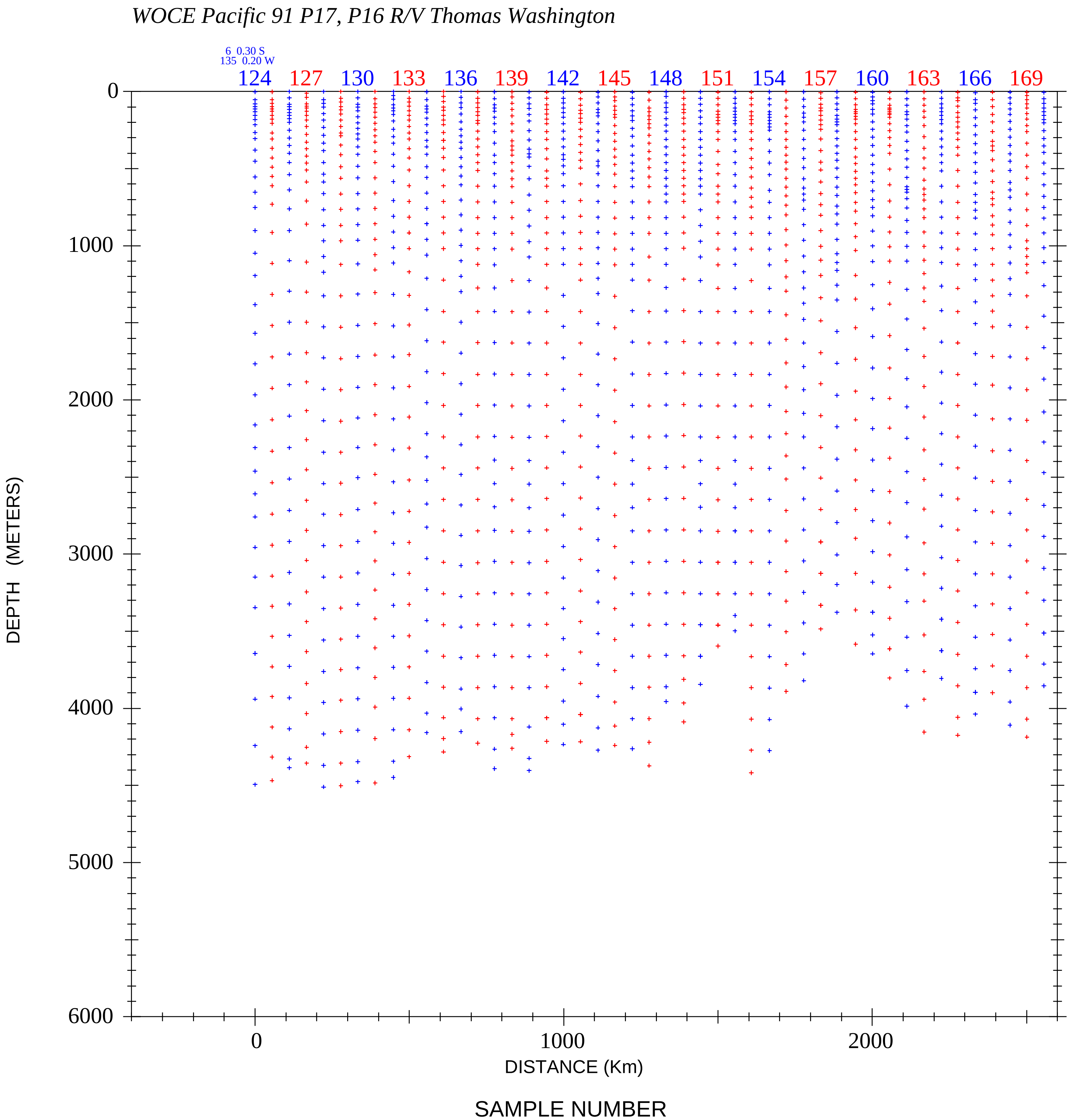
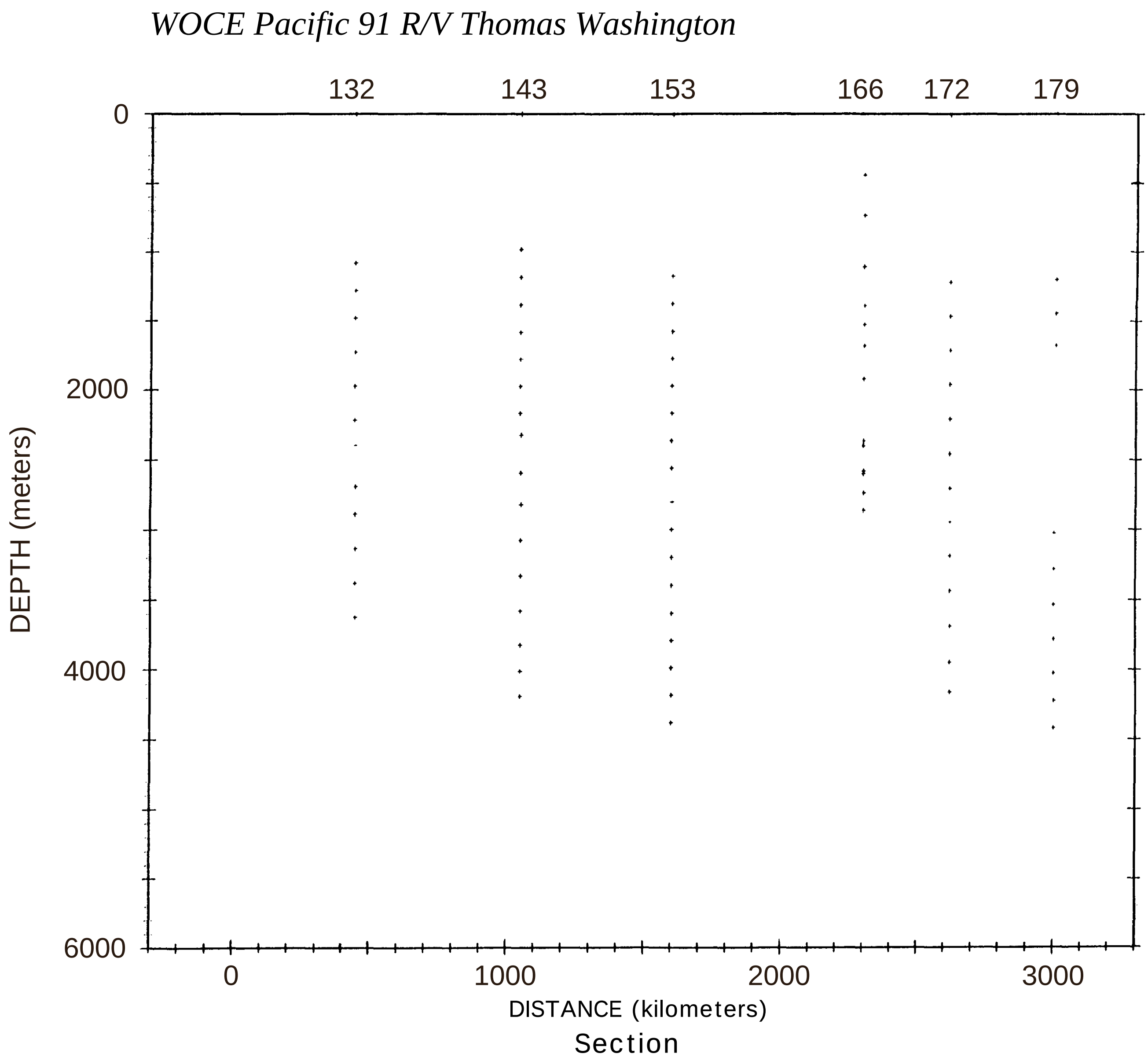
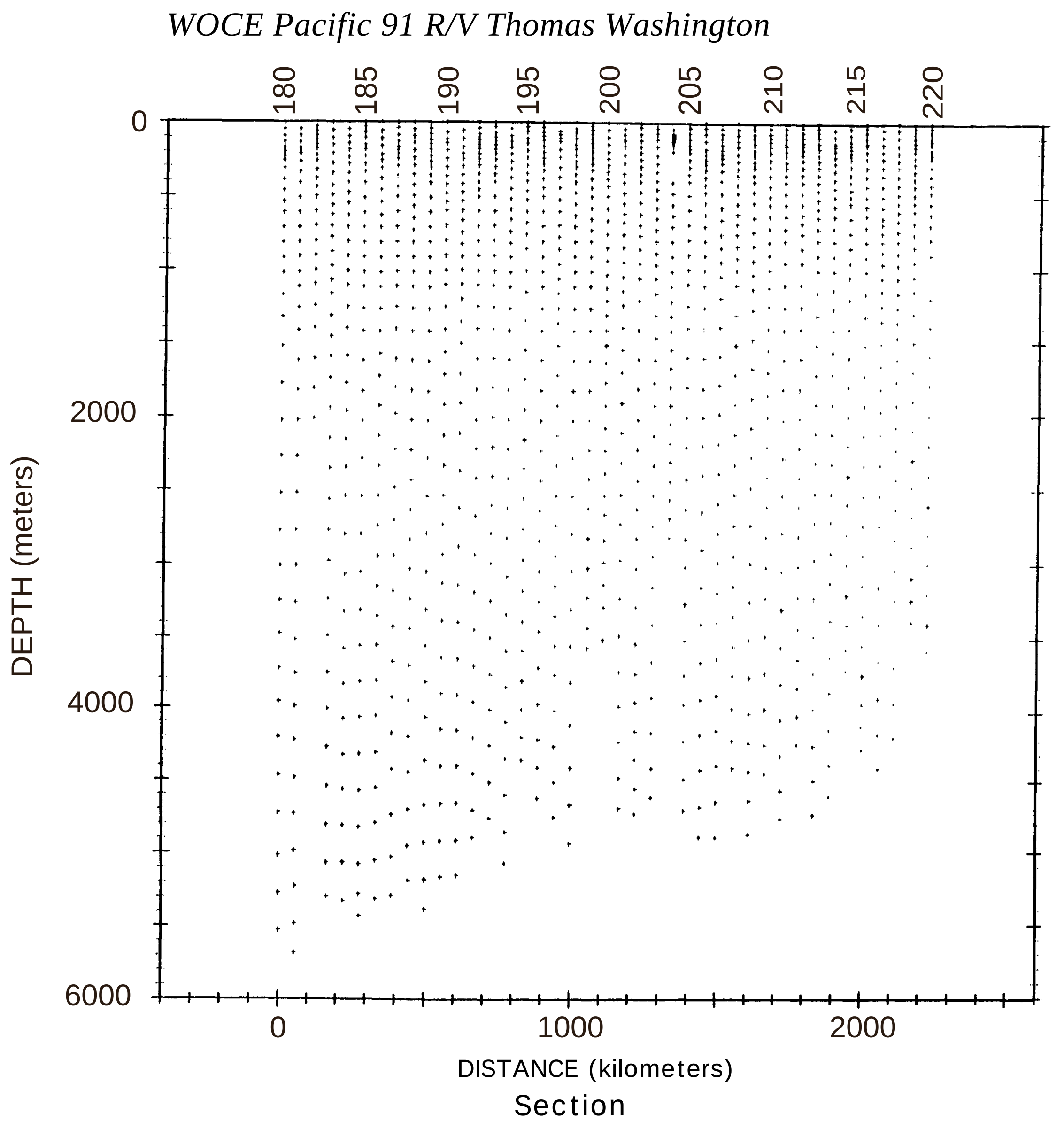

WOCE Pacific 91 P17, P16 R/V Thomas Washington
6 0.30 S
135 0.20 W
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
0
1000
2000
3000
4000
5000
6000
DEPTH (METERS)
0
1000
2000
DISTANCE (Km)
SAMPLE NUMBER

Figure 2


WOCE Pacific 91 R/V Thomas Washington
132
143
153
166
172
179
0
2000
4000
6000
DEPTH (meters)
0
1000
2000
3000
DISTANCE (kilometers)
Section
Figure 3


WOCE Pacific 91 R/V Thomas Washington
180
185
190
195
200
205
210
215
220
0
2000
4000
6000
DEPTH (meters)
0
1000
2000
DISTANCE (kilometers)
Section
Figure 4

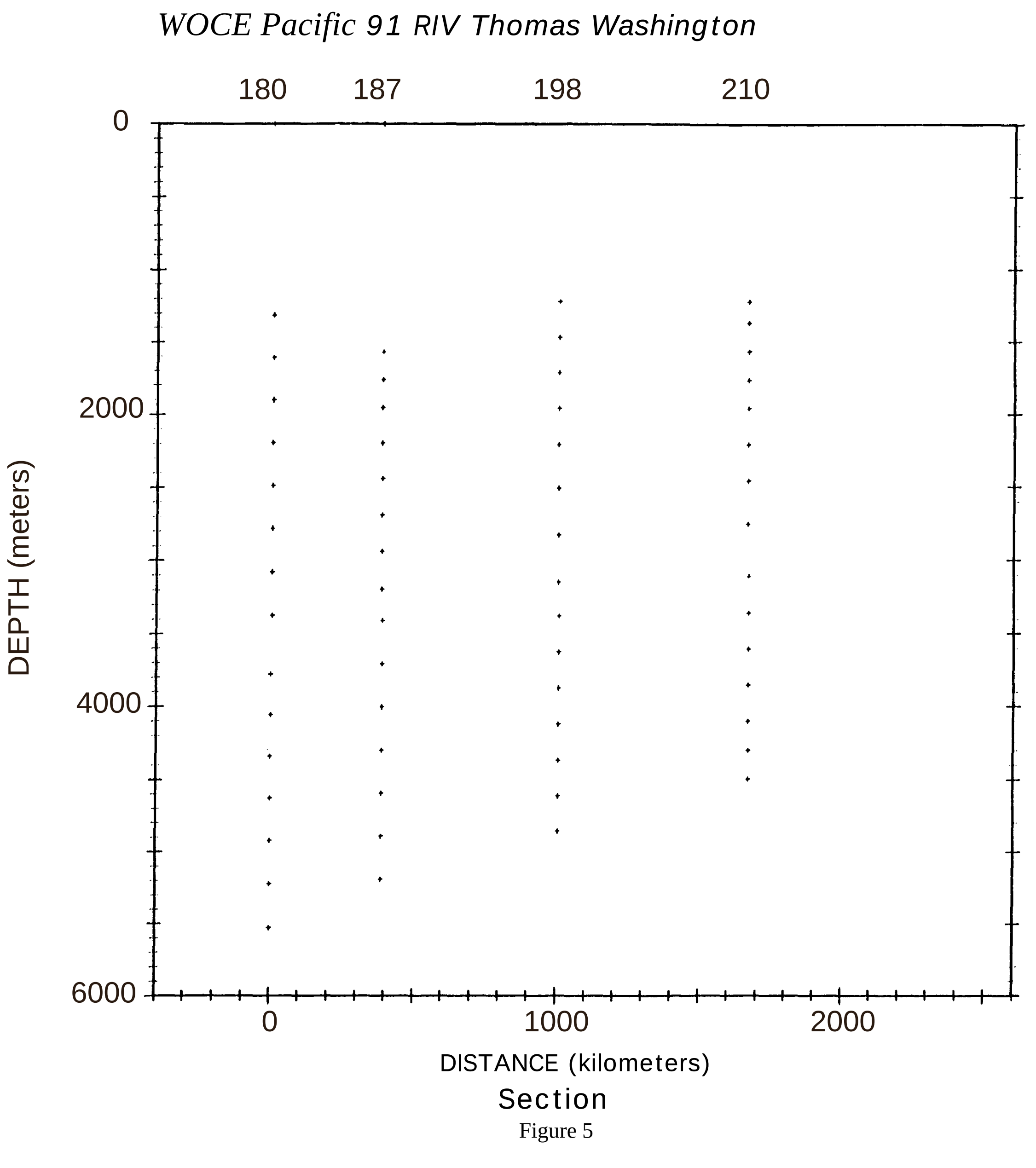

WOCE Pacific 91 R/V Thomas Washington
180
187
198
210
0
2000
4000
6000
DEPTH (meters)
0
1000
2000
DISTANCE (kilometers)
Section

Figure 5

B. Underway Measurements

B.1. Navigation and Bathymetry

Navigation information was provided by the SIO Shipboard Computer Group and relayed to the ODF data acquisition displays and computers. Methodology was solely GPS, with net RMS system accuracy during the cruise of ±100 meters of absolute planetary position, i.e. the performance level available in mid-1991 without classified equipment.

Multi-beam bathymetric observations were recorded continuously underway by the SeaBeam system on the vessel. This was operated and overseen by George Bouchard, acting on behalf of Christopher DeMoustier (SIO). There are several data gaps due to power failures or a secondary operator forgetting to turn the system back on after a CTD station, but, in general, the system worked well for the voyage. A data file with center-track bottom depths and positions every five minutes is available in MGD77 exchange format from S. Smith (SIO) or the National Geophysical Data Center (see PI listing).

B.2. Acoustic Doppler Current Profiler (ADCP)

An Acoustic Doppler Current Profiler was operated by Alex Orsi (TAMU; on behalf of Peter Hacker and Eric Firing, University of Hawaii). The system appeared to perform well over the balance of the expedition. No data are held by the Chief Scientist and the quality and utility of these measurements is unknown to the Chief Scientist. Information on this program should be obtained from the investigators.

B.3. Thermosalinograph and Underway Dissolved Oxygen, Fluorometer, etc.

A system to determine underway sea surface temperature and salinity was operated by Bob Williams (SIO; on behalf of Lynne Talley, SIO). The conductivity sensor ceased functioning normally shortly into Leg 2, but the temperature channel functioned acceptably for the balance of the leg, with short periods off line for various reasons. No data are held by the Chief Scientist and the quality and utility of these measurements is unknown to the Chief Scientist. Information on this program should be obtained from the investigator.

B.4. XBT and XCTD

There were no XBT or XCTD profiles taken during TUNES Leg 2.

B.5. Meteorological Observations

The ship's officers collected and recorded routine weather observations at two-hour intervals. These will form the basis of on-station weather observations if any appear with the NODC SD2 format version of the hydrographic data. (The WHPO does not record station weather data in its header format.) Weather data were reported as per standard ship operations and are also available (copies of logs) from the Marine Facility at SIO. No further information on the scope or quality of these data is held by the Chief Scientist.

B.6. Atmospheric Chemistry

A system to determine underway pCO_2 was operated by Guy Mathieu (LDGO; on behalf of Ray Weiss, SIO). No data are held by the Chief Scientist and the quality and utility of these measurements is unknown to the Chief Scientist. Information on this program should be obtained from the investigator.

C. Description of Measurement Techniques and Calibrations

C.1. Bottle Data Collection, Analyses, and Processing
(Kristin Sanborn and James Swift)

ODF CTD/rosette casts were carried out with a 24/12 double-ring 36-bottle rosette sampler of ODF manufacture using General Oceanics pylons. An ODF-modified NBIS Mark 3 CTD, a Benthos altimeter and a SeaTech transmissometer provided by Texas A&M University (TAMU) were mounted on the rosette frame. Seawater samples were collected in 10-liter PVC Niskin and ODF bottles mounted on the rosette frame. A Benthos pinger with a self-contained battery pack 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 wire 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. The replacement bottles were numbered 37 through 39, 61, 62, 64, and 68 through 70. 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.

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, AMS 14C, Tritium, Nutrients (silicate, phosphate, nitrate and nitrite), and Salinity. The samples and the ODF or Niskin sampler they were drawn from were recorded on the Sample Log sheet. Comments regarding validity of the water sample (valve open, lanyard caught in lid, etc.) were also noted on the Sample Log sheets.

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 and 14C were obtained from the Gerard barrels. The Gerard barrels were numbered 81 through 94 and the piggy-back Niskin bottles were numbered 41 through 50 and 71. Salinity check samples were always drawn from the piggy-back bottles for comparison with the Gerard barrel salinities to verify the integrity of the Gerard sample.

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 useable, though not final, state at sea. ODF data checking procedures included verification that the sample was assigned to the correct level. 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. Any comments regarding the water samples were investigated. The raw data computer files were also checked for 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.

The oxygen and nutrient data were compared by ODF with those from adjacent stations. Dr. Mizuki Tsuchiya, Dr. James Swift, and Dr. Ray Peterson did comparisons with historical data sets.

Historically, most failures to return a validated water sample can be traced to the rosette pylon, with ship's wire and CTD cable end termination the next most frequent leading cause. However, on this expedition the pylons and wire worked nearly perfectly, and the leading cause of failure to return a reportable water sample was miscellaneous mechanical problems with the rosette bottles, i.e., a lanyard hanging up in a lid, open spigot and/or vent, etc.

If a data value did not either agree satisfactorily with the CTD or with other nearby data, then analyst and sampling notes, plots, and nearby data were reviewed. If any problem was indicated, the data value was flagged. ODF preserved all bottle data values. The Bottle Data Processing Notes include comments regarding miss.ascii 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 5 Data value deleted. Value did not fit station profile or adjoining station data comparison. Comments were made that clearly indicated a leak and contamination of the samples.

code 4 Does not fit station profile and/or adjoining station comparisons. There are analytical notes indicating a problem, but data values were 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 3 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 2 Acceptable measurement.

code 1 Sample for this measurement was drawn from water bottle, but results of analysis not received.

The quality flags assigned to the bottle as defined in the WOCE Operations manual are further clarified as follows: If the bottle tripped at a different level than planned, ODF assigned it a code 4. If the bottle tripped between the scheduled trip and the next trip, as indicated by the water sample data, ODF coded these bottles 3. 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. An air leak is identified by a 3 code on the bottle and 4 code on the oxygen. Air leaks affect only the gas samples.

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

Stations 124-220

	Reported levels	Bottle Codes				Water Sample Codes					
		2	3	4	9	1	2	3	4	5	9
	3468	3427	28	0	13						
Salinity	3453					4	3417	4	28	0	15
Oxygen	3450					2	3413	1	34	0	18
Silicate	3454					0	3430	2	22	0	14
Nitrate	3454					0	3434	0	20	0	14
Nitrite	3454					0	3434	0	20	0	14
Phosphate	3454					0	3413	12	29	0	14

Replicate Sampling Program:

ODF carried out a replicate Niskin sampling program during Leg 2 at the direction of the Chief Scientist. At stations where the distributions of characteristics and maximum depth permitted, at some convenient level (or levels) two rosette bottles were tripped (within 10 seconds). In most cases the two bottles were tripped below 2000 meters. (Four Niskin bottle pairs were collected above 2000 meters.) The samples were drawn and analyzed exactly as if the samples had come from different depths. (In almost all cases, the technicians were unaware that the bottles were from the same depth.) These might thus be called "operational replicates", because they evaluate the overall capacity to collect, draw, and analyze water samples.

TUNES Leg 2 Replicate Sample Summary

sta. #	depth meters	salt #1 psu	O_2 #1 ml/l	NO_3 1 µM/l	PO_4 1 µM/l	SiO_3 1 µM/l	Δ S psu	Δ O_2 ml/l	Δ NO_3 µM/l	Δ PO_4 µM/l	Δ SiO_3 µM/l
133	916	34.532	2.10	40.7	2.91	75.6	0.002	0.01	0.2	0.00	0.1
134	856	34.527	1.80	41.1	2.90	68.7	0.001	0.02	0.0	0.01	0.0
135	314	34.712	0.77	27.8	2.46	21.6	0.002	0.00	0.1	0.01	0.4
141	4061	34.689	3.93	35.1	2.46	136.4	0.002	0.01	0.0	0.00	0.8
143	4040	34.687	3.90	35.1	2.47	135.3	0.001	0.01	0.1	0.00	0.2
151	3053	34.676	3.79	35.3	2.48	130.8	0.000	0.00	0.0	0.01	0.3
151	3256	34.678	3.81	35.3	2.47	131.3	0.000	0.00	0.1	0.01	0.8
151	3459	34.680	3.83	35.2	2.47	133.0	0.001	0.00	0.2	0.00	0.1
157	2920	34.670	3.76	35.4	2.48	126.8	0.001	0.02	0.0	0.00	0.1
157	3124	34.673	3.85	35.4	2.48	127.2	0.000	0.02	0.2	0.00	0.4
157	3330	34.675	3.89	35.0	2.47	127.6	0.002	0.01	0.1	0.02	0.4
160	3375	34.680	3.93	35.3	2.46	127.8	0.001	0.00	0.1	0.01	0.4
161	3614	34.683	3.98	35.1	2.45	128.8	0.001	0.00	0.0	0.01	0.0
164	3421	34.685	3.98	35.0	2.45	128.3	0.000	0.00	0.1	0.01	0.0
164	3625	34.686	4.01	35.0	2.45	128.3	0.001	0.00	0.2	0.01	0.1
165	1630	34.589	3.54	35.5	2.50	101.5	0.007	0.02	0.7	0.06	2.5
166	3895	34.688	4.06	34.6	2.41	128.2	0.000	0.01	0.1	0.00	0.6
170	3510	34.685	3.98	34.8	2.44	128.3	0.001	0.00	0.0	0.02	0.3
177	3860	34.697	4.23	34.0	2.37	126.1	0.000	0.00	0.0	0.00	0.0
195	2163	34.643	3.46	36.3	2.54	123.8	0.000	0.00	0.0	0.00	0.0
195	3806	34.699	4.26	34.0	2.35	127.9	0.001	0.00	0.1	0.01	0.7
199	2829	34.669	3.56	36.2	2.54	135.7	0.000	0.00	0.1	0.01	1.1
199	3028	34.676	3.70	35.7	2.50	133.7	0.000	0.00	0.0	0.00	0.7
215	2404	34.652	3.57	35.9	2.54	125.4	0.000	0.00	0.1	0.00	0.9
215	3209	34.676	3.86	35.1	2.46	128.4	0.000	0.01	0.0	0.01	0.4
216	3753	34.686	4.04	34.7	2.44	128.1	0.001	0.00	0.0	0.01	0.0
219	2297	34.652	3.60	36.3	2.54	125.5	0.000	0.00	0.0	0.00	0.0
219	3092	34.676	3.88	35.6	2.49	130.4	0.000	0.00	0.1	0.01	0.3
219	3240	34.678	3.92	35.5	2.46	129.5	0.001	0.00	0.0	0.00	0.7
220	2609	34.660	3.66	35.9	2.51	128.5	0.001	0.00	0.0	0.00	1.0
220	3407	34.683	3.98	34.9	2.43	129.7	0.001	0.00	0.0	0.01	0.7
avg.		34.666	3.63	35.4	2.50	121.2	0.0009	0.005	0.08	0.008	0.45
as %	conc.							0.12%	0.24%	0.31%	0.37%
>2000	m avg.	34.677	3.87	35.2	2.47	129.3	0.0006	0.003	0.06	0.006	0.41
as %	conc.							0.09%	0.17%	0.24%	0.32%

Thirty-one pairs of same-depth replicates (salinity, oxygen, and nutrients) were collected. The results are tabulated above. The average difference in salinity was 0.0009 psu, the average difference in oxygen was 0.005 ml/l (0.12% average net difference with respect to concentration), the average nitrate difference was 0.08 µm/l (0.24%), the average phosphate difference was 0.008 µm/l (0.31%), and the average silicate difference was 0.45 µm/l (0.37%). The differences were slightly smaller for the 27 sample pairs collected below 2000 meters (see table).

The small size of these differences suggests that on this expedition the net capability of drawing and analyzing a routine hydrochemistry sample from a given depth meets WOCE repeatability specifications. The frequency of replicates was under 1% (there were over 3000 water samples), well below the frequency recommended in general laboratory manuals. However the relative station-to-station homogeneity of the deep waters provides a much more frequent type of near-replicate sampling, and this is utilized — more than same-depth or same-bottle replicates — by the seagoing technicians during data quality examination.

C.1.a Pressure and Temperature

(Kristin Sanborn)

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

Gerard 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. Each temperature value is therefore calculated from the average of four readings provided both protected thermometers function normally.

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

C.1.b Salinity

(Kristin Sanborn and James Swift)

Salinity samples were drawn into 200ml Kimax high alumina borosilicate bottles with custom-made plastic insert thimbles and Nalgene screw caps. This assembly provides very low container dissolution and sample evaporation. Salinity bottles were rinsed three times before filling. Salinity was determined after sample equilibration to laboratory temperature, usually within about 8-36 hours of collection. Salinometers were located in a temperature-controlled laboratory van designed, constructed, and loaned for this purpose by the Woods Hole Oceanographic Institution. Only one salinometer was used for TUNES Leg 2 salinity samples.

Salinity has been calculated according to the equations of the Practical Salinity Scale of 1978 (UNESCO, 1981). This calculation uses the conductivity ratio determined from bottle samples analyzed (minimum of two recorded analyses per sample bottle after flushing) with an ODF-modified Guildline Autosal Model 8400A salinometer. The initial plan was to calibrate against a single batch of Wormley IAPSO standard seawater, P-114, with at least one fresh vial opened per cast. However, while the latter part of this procedure was used, it was necessary to use two batches because upon opening one of the boxes marked P-114 it was found to contain P-108. Hence salinities for stations 124-140 are standardized against batch P-114, and those from stations 141-220 against batch P-108. A single comparison at sea during TUNES Leg 2 yielded a salinity value for P-114 ca. 0.002 higher than that of P-108, when standardized against P-108.

Accuracy estimates of bottle salinities run at sea are usually better than 0.002 psu relative to the specified batch of standard. 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.

Supplementary documentation:

Bottle salinities for stations 124-140 were standardized against IAPSO Standard Seawater batch P-114, while those from stations 141-220 were standardized against batch P-108. A single comparison at sea during TUNES Leg 2 yielded a salinity value for P-114 ca. 0.002 higher than that of P-108, when standardized against P-108. On its own, such a difference is meaningless. It is the difference in ***measured***-salinity-of-standard versus ***labeled***-salinity-of-standard that is important. Laboratory tests of P-108 had been performed earlier by two groups (Mantyla, personal communication). These showed that P-108 was about 0.0003-0.0004 higher than the labelled value. In 1993, careful laboratory tests at ODF on both batches showed that P-114 was about 0.0001 lower than labelled. These very small errors are insignificant at the 0.001 level. However, if one wishes to correct for these this means that all salinities standardized against batch P-114 should have 0.0001 psu subtracted from them and all salinities standardized against batch P-108 should have 0.0003 psu added to them to be statistically compatible with Mantyla's overall modern reference (based on studies of batches 91-110). However, no batch-to-batch corrections have been made to the data, which are reported relative only to the standard seawater batch used in the original analyses.

The repeatability of replicate determinations by the Autosal 8400A of standard seawater in an environmentally-controlled shore laboratory is about 0.0002 psu.

Because a small droplet of fresh water, or the residue from a small evaporated droplet of seawater, can affect a bottle salinity in the third decimal place, and because the Autosal salinometer is sensitive to temperature, electrical, and EMF fluctuations, salinities from bottle samples have a lower true precision under field conditions than in the laboratory.

Salinometer performance during TUNES Leg 2 was excellent, except as usual during ship's radio operations. (This was easily worked around by establishing mutually exclusive routine schedules for both operations.) There were small problems with bath overflow during ship roll, but these did not affect the measurements. There was no problem with readings drifting up and down during ship roll. Temperature control was adequate in the van where the salinity analysis occurred. ODF flagged the bottle salinity whenever there was any question regarding its validity.

Examination of bottle salinity profiles from relatively low gradient portions of the water column suggests that on this cruise, salinity precision was typically about ±0.001 psu. Because each profile is typically cross-checked to at least two vials of IAPSO Standard Seawater, accuracies with respect to the batch used should be nearly the same as precision. This is because there are normally no vial-to-vial differences in standard seawater observable from correctly manufactured and stored vials of standard seawater (from the same batch) under seagoing conditions, and the occasional defective vial is usually obvious in the cross-checking procedure used by ODF.

C.1.c Oxygen

(Kristin Sanborn and James Swift)

Samples were collected for dissolved oxygen analyses soon after the rosette sampler was brought on board and after CFC and helium were drawn. Nominal 100 or 125 ml volume iodine flasks were rinsed carefully with minimal agitation, then filled via a drawing tube, and allowed to overflow for at least 2 flask volumes. 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 Mn(OH)2 precipitate. The samples were analyzed within 4-36 hours.

Dissolved oxygen analyses, reportable in both milliliters per liter and micromoles per kilogram, were performed via titration in the volume-calibrated iodine flasks with a 1 ml microburet, using the whole-bottle Winkler titration following the technique of Carpenter (1965) with modifications by Culberson et al. (1991). Standardizations were performed with 0.01N potassium iodate solutions prepared from preweighed potassium iodate crystals. Standards were run at the beginning of each session of analyses, which typically included from 1 to 3 stations. Several standards were made up and compared to assure that the results were reproducible, and to preclude basing the entire cruise on one standard, with the possibility of a weighing error. A correction was made for the amount of oxygen added with the reagents. Combined reagent/distilled water blanks were determined to account for oxidizing or reducing materials in the reagents. (***Note***: This was the first ODF cruise to adopt the WOCE recommendation for distilled water blanks.)

The data processor and/or analyst plotted the oxygen standards and blanks and have reviewed the data for possible problems with standards and/or blanks.

Oxygens were converted from milliliters per liter to micro-moles 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 temperature of the samples was measured at the time the sample was drawn from the bottle, but were not used in the conversion from milliliters per liter to micromoles per kilogram because the software was 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 degree C warmer than in-situ temperature. Converted oxygen values, if this conversion with the measured sample temperature were made, would be about 0.08% higher for a 6 degree C warming (or about 0.2um/kg for a 250um/kg sample).

Supplementary documentation:

The iodine determination flasks with ground glass stoppers are used by ODF because they have steeply sloped sides and a flared mouth, and thus tiny bubbles are easier to eliminate during sampling, and because the large volume theoretically reduces the effects of a given volume of contaminant. The oxygen error from post-pickling introduction of a tiny amount of oxygenated water into the flask is much lower than that from an equivalent volume of air. With oxygen samples run soon after collection, and with the flared-top iodine determination flasks, so long as there is water in the top, above the stopper, air cannot be drawn in.

The reagent concentrations followed the Carpenter modifications of the Winkler method.

For over 20 years with several different chemical suppliers ODF has seen a measurable reagent blank, even if small, and so ODF included a blank determination, measured approximately 2-3 times each week. This was done because the size of the oxygen blank is observed to vary from batch to batch of the pickling reagents and also to drift from an initially higher value toward zero within a given batch.

Multiple and overlapping KIO_3 standards (pre-weighed amounts) were used in order to help identify, isolate, and quantify the effects of standard weighing errors, if any. As a result of this overlapping application of standard, ODF in post-cruise processing fit the oxygens overall to an improved estimate of the standard, i.e., "smoothed" out any batch-to-batch variations. The actual technique varies somewhat with the circumstances, but is documented for each expedition leg. (The word "batch" in this paragraph means one unit of weighed KIO_3. This does not refer to manufacturer's batch number, which is the same over the expedition.)

The quality of the KIO_3 is the ultimate limitation on the accuracy of this methodology. The assay value bandwidth of the KIO_3 used by ODF is 0.1% (i.e., ±0.05%), and so this is the absolute accuracy limit of the methodology. The thiosulfate is known to change over time, for example via the action of bacteria and evaporation and condensation. This in itself is no problem because its normality is continually checked against KIO_3.

The true limit in the quality of the bottle oxygen data probably lies in the practical limitations of the present sampling and analytic methodology, from the time the rosette bottle is closed through calculation of oxygen concentration from titration data. We do not really measure oxygen, but instead measure iodine equivalents in seawater, most of which is oxygen. Sampling presents problems. On a deep cast into cold bottom waters, the deep samples on this cruise (which used rapid profiling) typically sat in the bottle about two hours before the oxygen sample was drawn. During this time it is passed through layers of much warmer water, the bottles may be exposed to direct sunlight and warm air temperatures (however the rosette is soon moved into a sheltered area), and on this expedition the oxygen sampling technician usually waited for the CFC and helium sampling technicians. However, some comparison experiments with rapid bottle retrieval and immediate oxygen sample drawing on other expeditions suggest that the oxygen concentration in the rosette bottle stays intact during this time. Of course, the technique of drawing the sample must be absolutely correct or else the data suffer visibly. The net effect of these common errors can go beyond those introduced by careful laboratory procedures.

Iodate /blank profiles:

Several times during this expedition Robert T. Williams (SIO/ODF) collected and analyzed samples of the seawater blank (mostly natural iodate) which contributes to measured oxygen values. The resulting profiles strongly resemble those for nutrients. Ultimately, this information may contribute to a more accurate determination of dissolved oxygen in seawater than that permitted by the distilled water blank technique recommended for WOCE in 1991. Any further information on this activity must be obtained directly from Williams.

(Note that for some of the ***preliminary*** data reported from this cruise leg, a generic seawater blank was applied to the ODF oxygen data. Though this correction is potentially more accurate than the WOCE methodology recommended by Culbertson, it also contains the uncertainty of the spatial variability of the seawater blank, whereas oxygen data corrected for distilled water blanks, as now recommended, ***and as done for the final data***, can at least in theory be converted at some later date once the natural vartiability of the seawater blank is better understood.)

Automatic oxygen titrator:

The ODF UV oxygen autotitration system was tested extensively during this expedition. Though never used to provide reported data, agreements with ODF manual titrations were typically ±0.002 ml/l. This was the final development phase for the autotitrator, and it was put into service on subsequent ODF WOCE cruises with good results.

C.1.c Nutrients

(Kristin Sanborn and James Swift)

Nutrients (phosphate, silicate, nitrate, and nitrite) analyses, reported in micromoles/kilogram, were performed on a Technicon AutoAnalyzer(R). The procedures used are described in Hager ***et al*** (1972) and Atlas ***et al*** (1971). Standardizations were performed with solutions prepared aboard ship from preweighed standards; these solutions were used as working standards before and after each cast (approximately 36 samples) to correct for instrumental drift during analyses. Sets of 4-6 different concentrations of shipboard standards were analyzed periodically to determine the linearity of colorimeter response and the resulting correction factors. Phosphate was analyzed using hydrazine reduction of phosphomolybdic acid as described by Bernhardt & Wilhelms (1967). Silicate was analyzed using stannous chloride reduction of silicomolybdic acid. Nitrite was analyzed using diazotization and coupling to form dye; nitrate was reduced by copperized cadmium and then analyzed as nitrite. These three analyses use the methods of Armstrong ***et al*** (1967).

Samples were drawn into 45 cc high density polyethylene, narrow mouth, screw-capped bottles which were rinsed twice before filling. The samples may have been refrigerated at 2 to 6 degree C for a maximum of 15 hours.

Nutrients were converted from micromoles per liter to micromoles per kilogram by dividing by sample density calculated at an assumed laboratory temperature of 25 degree C.

Nutrient sample storage tests:

Nadya Williams, chief nutrient analyst, acting on direction from the Chief Scientist, carried out two nutrient sample storage tests:

In the first, a duplicate 36-place tray of nutrients was drawn at station 137, with special care not to fill beyond the shoulder of the tube. The tray was then placed in a freezer in the science hold (cold enough to keep ice cream hard frozen, i.e., ca. -17°C), on a horizontal shelf (so that no ice could form near the caps). These were left for 20 days, then thawed quickly by partial immersion in water at laboratory temperature, shaken twice, and run at once. Results are tabulated below. In short, the differences from the samples run fresh exceeded WOCE specifications. While this is not a comprehensive test, even a single such failure — when no unknown thawing occurred — indicates that freezing of nutrient samples is probably not a viable option for WOCE work.

Nutrient replicates, fresh-minus-frozen

parameter	minimum difference	maximum difference	number of points	mean difference	standard deviation	avg. difference as % of avg. concentration
SiO_3	-9.4	-0.5	36	-3.8	±3.0	-6.3%
PO_4	-0.02	0.29	36	0.05	±0.08	2.9%
NO_3	0	7.3	36	1.4	±2.1	5.8%

The second nutrient test was more germane to US WOCE as it is now configured: we experimented three times drawing two sets of nutrients from bottles, running one set at once, while the other was stored in the laboratory refrigerator for 8-10 hours, then warmed in air for one hour (to lab temperature), then run, with all analyses completed within 10-14 hours after drawing. In every case, the differences were very small (see below), near the expected difference of replicate samples run fresh, and within WOCE repeatability standards. Hence it is our preliminary judgement that the overnight storage methodology as practiced by ODF — and used on many ODF cruises but not this one — remains a valid option for US WOCE.

Nutrient replicates, fresh-minus-refrigerated

parameter	minimum difference	maximum difference	number of points	mean difference	standard deviation	avg. difference as % of avg. concentration
SiO_3	-1.6	1.0	36	-0.2	±0.5	-0.3%
	-0.6	0.6	36	0.1	±0.3	0.2%
	-1.3	0.7	35	-0.1	±0.4	-0.2%
PO_4	-0.01	0.02	36	0.00	±0.01	0%
	-0.01	0.02	36	0.00	±0.01	0%
	-0.05	0.03	35	0.00	±0.01	0%
NO_3	-0.4	0.1	36	-0.1	±0.2	-0.4%
	-0.2	0.4	36	0.1	±0.1	0.4%
	-0.2	0.5	35	0.2	±0.1	0.8%

C.1.d CFC Measurements

(Kevin A. Maillet and Kevin F. Sullivan)

Concentrations of the dissolved atmospheric cholorfluorocarbons (CFCs) F-11 and F-12 were measured by shipboard electron-capture gas chromatography according to the methods described by Bullister and Weiss (1988). The measurements were carried out by the group at the University of Miami under the direction of Dr. Rana A. Fine with the assistance of a technician from LDEO, Columbia University. A total of 1847 water analyses were carried out, 23 of which were duplicate analyses as tabulated in Table 1. The mean value of duplicate analyses are reported in the data file and are assigned a quality byte of 6.

Occasional problems with the analytical system resulted in the loss of a sample. In accordance with WHP protocol, the value for these analyses has been reported as -9.000 and they have been assigned a quality byte of 5.

On a number of occasions, the CFC analysis appeared routine yet the values obtained were clearly inappropriate based on the depth at which the Niskin was tripped. Upon further inspection it was noticed that there appeared to be problems with other measured quantities from these bottles as well and in many cases, the quality byte assigned to the bottle itself had been set to 4 to indicate a problem with that bottle. In these situations, we are reporting the data as measured and have assigned a data qulity flag of 4 to the quality byte for that measurement.

Situations where this occurred were:

Station	Niskin
126	6
133	6
136	6
137	11
138	11

The following analyses are suspect in relation to the surrounding values and have been flagged as questionable data (quality byte 3):

Station	Niskin	Parameter(s)
127	17	F11
212	19	F12
217	17	F11 & F12

A combination bottle and handling blank was used to correct for contamination from the Niskin bottles and from the collection and storage of the samples. This blank was estimated by analyzing samples from Niskins after they were tripped in what is believed to be CFC-free water. The bottle blanks were low throughout the cruise. In cases where the bottle/handling blank is greater than the measured concentration, a negative concentration is reported in the data file. A list of all Niskins and their bottle-handling blanks over the entire cruise is included in Table 2.

Measurements of the atmospheric concentration of F-11 and F-12 were carried out regularly during the cruise. Air samples were pumped through a Decabond tubing air line run along the railing of the ship and up the mast at the bow. Air measurements were usually carried out while on station when the bow of the ship was heading into the wind to avoid contamination from the stack. Usually, three to six air measurements were carried out in sequence. The mean values of replicate air analyses are tabulated in Table 3.

Table 1. Duplicate analyses from TUNES 2 cruise on R/V Thomas Washington, 7/8 1991

(duplicate syringes drawn on same niskin)

Station #	Niskin	Depth	pM12/kg	pM11/kg	Avg F12 Stdev F12	Avg F11 Stdev F11
999	11	400	0.111	0.189	0.1108	0.1904
999	11	400	0.111	0.192	0.0003	0.0013
999	12	400	0.117	0.209	0.1173	0.2087
999	12	400	0.118	0.208	0.0006	0.0003
999	13	400	0.117	0.209	0.1155	0.2079
999	13	400	0.114	0.207	0.0018	0.0007
132	2	25	0.884	1.702	0.8789	1.7036
132	2	25	0.874	1.705	0.0050	0.0012
132	4	85	0.911	1.709	0.9076	1.7093
132	4	85	0.904	1.709	0.0036	0.0000
132	6	125	0.960	1.879	0.9627	1.8809
132	6	125	0.966	1.883	0.0031	0.0022
132	8	190	0.987	2.028	0.9887	2.0176
132	8	190	0.991	2.007	0.0019	0.0102
133	2	40	0.877	1.645	0.8753	1.6505
133	2	40	0.873	1.656	0.0020	0.0051
133	5	120	1.002	1.831	0.9961	1.8349
133	5	120	0.990	1.839	0.0060	0.0038
135	11	310	0.164	0.305	0.1667	0.3004
135	11	310	0.169	0.296	0.0025	0.0047
173	61	1	1.262	2.479	1.2605	2.4710
173	61	1	1.259	2.463	0.0010	0.0081
175	2	40	1.297	2.581	1.2996	2.5584
175	2	40	1.302	2.535	0.0024	0.0229

(duplicate syringes drawn on same niskin)

Station #	Niskin	Depth	pM12/kg	pM11/kg	Avg F12 Stdev F12	Avg F11 Stdev F11
184	61	1	1.432	2.924	1.4320	2.9374
184	1	1	1.432	2.951	0.0004	0.0133
184	2	45	1.453	2.917	1.4417	2.9280
184	2	45	1.430	2.939	0.0113	0.0112
190	68	360	0.923	1.972	0.9212	1.9471
190	68	360	0.920	1.922	0.0015	0.0250
191	69	420	0.884	1.856	0.8788	1.8553
191	69	420	0.873	1.855	0.0053	0.0003
197	6	180	1.256	2.409	1.2511	2.4079
197	6	180	1.246	2.406	0.0047	0.0016
197	69	370	0.648	1.296	0.6510	1.2955
197	69	370	0.654	1.295	0.0027	0.0006
197	70	440	0.570	1.088	0.5587	1.0826
197	70	440	0.548	1.077	0.0108	0.0051
198	2	40	1.174	2.261	1.1657	2.2618
198	2	40	1.157	2.263	0.0084	0.0012
198	64	110	1.215	2.366	1.2113	2.3734
198	64	110	1.207	2.381	0.0042	0.0077
198	6	180	1.190	2.341	1.1965	2.3472
198	6	180	1.203	2.354	0.0064	0.0064
199	6	140	1.185	2.331	1.1786	2.3400
199	6	140	1.172	2.349	0.0061	0.0093
199	11	320	0.789	1.586	0.7887	1.5844
199	11	320	0.788	1.582	0.0003	0.0021

(duplicate niskins at same depth or duplicate analyses from the same syringe)

Station#	Niskin	Depth	c'pM12/kg	c'pM11/kg	Avg F12 Stdev F12	Avg F11 Stdev F11
133	17	900	0.005	0.002	0.0052	0.0052
133	18	900	0.005	0.008	0.0003	0.0033
134	16	850	0.002	0.002	0.0043	0.0039
134	17	850	0.006	0.006	0.0019	0.0024
204	6	100	1.132	2.250	1.1334	2.2541
204	7	100	1.135	2.258	0.0013	0.0036
193	61	1	1.253	2.493	1.2432	2.5116
193	61	1	1.233	2.530	0.0101	0.0183

Table 2. Bottle/handling blanks applied to TUNES2 water analyses

CFC 11 — TUNES 2

Niskin	pmol/kg
1	0.003
2	0.005
3	0.003
4	0.004
5	0.003
6	0.002
7	0.003
8	0.004
9	0.002
10	0.005
11	0.005
12	0.002
13	0.002
14	0.002

Niskin	pmol/kg
15	0.002
16	0.002
17	0.002
18	0.002
19	0.002
20	0.003
21	0.002
22	0.002
23	0.002
24	0.002
25	0.002
26	0.002
27	0.002
28	0.002
29	0.002

Niskin	pmol/kg
30	0.002
31	0.004
32	0.003
33	0.003
34	0.002
35	0.002
36	0.003
37	0.002
38	0.002
61	0.002
64	0.003
68	0.003
69	0.003
70	0.003

CFC 12 — TUNES 2

Niskin	pmol/kg
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0.002
14	0.002

Niskin	pmol/kg
15	0.002
16	0.003
17	0.002
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0

Niskin	pmol/kg
29	0
30	0
31	0
32	0
33	0
34	0
35	0
36	0
37	0.002
38	0
61	0
64	0
68	0
69	0
70	0

Table 3. Air analyses carried out during TUNES2

6.0 S	482	270
12.5	486	262
15.4 S	480	266

20.3	475	255
37.0 S	476	231

Reference

Bullister, J.L. and R.F. Weiss. (1988) Determination of CC13F and CC12F2 in seawater and air. Deep-Sea Research, 35, 839-853

C.2.a Description of LVS Measurement Techniques and Calibrations

Large Volume Sampling (LVS) was 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 2.2-liter Niskin bottles (Piggyback bottles) with reversing thermometers.

There were 11 large volume stations, with at least one deep cast (2500db to the bottom), and either or both an intermediate (1000db to 2500db) and/or a shallow cast (surface to 1000db). There were 29 casts total, 2 of which were redeployments to complete the complement of 9 levels. The cast was relowered if the complement of 9 levels was not achieved due to pretrips or failure of one Gerard barrel releasing it's messenger thereby tripping the rest of the string of barrels. The Gerard barrel platform, as set up in port prior to the cruise, did not allow enough clearance for barrel during deployment & recovery. The Chief Engineer cut the platform loose and rewelded it to the deck about one foot forward. The spring-loaded trapping-pin was no longer usable so a chain was shackled to one forward corner of the platform, passed aft of the wire then hooked to the other forward corner to hold the trawl wire in the platform "V" while the barrels were being attached and detached. Limited fantail space and the low trawl wire lead required that the crane work over the wire to move barrels from racks to near the centerline just forward of the platform, then the barrel was unhooked and the crane moved to the other side of the wire and rehooked to move the barrel to the attachment position. This procedure was reversed for recovery. Working Gerards off the stern went well in good weather but, as expected, pitching in moderate seas (15-20 knots wind) caused tripping problems. Slowing down the lowering rate to less than 50 meters/minute seemed to help.

Samples for salinity, silicate and 14C were obtained from the Gerard barrels; samples for salinity were drawn from the piggyback bottles and at station 172 PO_4, NO_3, NO_2 and Silicate were sampled. The salinity and silicate samples from the piggyback bottle were used for comparison with the Gerard barrel salinities to verify the integrity of the Gerard sample. The identifiers of the sample containers and the numbers of the ODF or Piggyback 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.

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 salinity 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 sample container number. The salinity values were transmitted from a PC attached to the salinometer system.

Investigation of data included comparison of piggyback salinities and silicates versus Gerard salinities and silicates, and review of data plots of the station rosette data profile. If any problem was indicated, the data value was flagged. 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 other than 2, an acceptable measurement.

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 yet 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 may include large differences between the piggyback and Gerard sample. Sampling errors are also coded 4.

code 5 = Not reported.

code 9 = Sample for this measurement not drawn.

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).

code 2 = Acceptable measurement.

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

Large Volume Samples

Stations 132-210

		WHP Quality Codes								
	Reported levels	1	2	3	4	5	6	7	8	9
BTLNBR	306	0	271	9	23	0	0	0	0	3
SALNTY	303	0	292	0	11	0	0	0	0	3
SILCAT	303	0	290	0	13	0	0	0	0	3
NITRAT	177	0	0	0	177	0	0	0	0	129
NITRIT	177	0	0	0	177	0	0	0	0	129
PHSPHT	176	0	0	0	176	1	0	0	0	129
REVPRS	306	0	306	0	0	0	0	0	0	0
REVTMP	276	0	274	0	2	10	0	0	0	20

Pressure and Temperature

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.

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.

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.

Salinity Analysis

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 airtight 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.

A single Guildline Autosal Model 8400A salinometer (Serial Number 57-396) located in a temperature-controlled laboratory was used to measure salinities. The salinometer was modified by ODF and contained interfaces for computer-aided measurement. A computer (PC) prompted the analyst for control functions (changing sample, flushing) while it made continuous measurements and logged results. The salinometer cell was flushed until successive readings met software criteria for consistency, then two successive measurements were made and averaged for a final result.

The salinometer was standardized for each cast with IAPSO Standard Seawater (SSW) Batch P-114 on Stations 124 through 140, and P-108 on stations 141 through 220. 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.

303 salinity measurements were made and 18 vials of standard water were used. The temperature stability of the laboratory used to make the measurements was good. Salinities were generally considered good for the expedition. Salinity samples were analyzed for the Large Volume casts from both the piggyback bottle and the Gerard barrel.

Nutrient Analysis

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 station, usually 18 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 primary standards. Sets of 5-6 different concentrations of shipboard standards were analyzed periodically to determine the deviation from linearity as a function of concentration for each nutrient.

Nutrient analyses (phosphate, silicate, nitrate and nitrite) were performed on an ODF-modified 4 channel Technicon AutoAnalyzer II, generally within one hour of the cast. However, on LVS cast, samples for the Gerard barrels were analyzed for silicate only as an added check (with salinity) on barrel sample integrity. Occasionally some samples were refrigerated at 2 to 6 degree 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 is analyzed using the technique of Armstrong et al. (Armstrong 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. Tartaric acid is also added to impede PO4 contamination. The sample is passed through a 15 mm flowcell and the absorbence measured at 820nm. ODF's methodology is known to be non-linear at high silicate concentrations (>120 uM); a correction for this non-linearity is applied in ODF's software.

Modifications of the Armstrong et al. (1967) techniques for nitrate and nitrite analysis are also used. The seawater sample for nitrate analysis is passed through a cadmium column where the nitrate is reduced to nitrite. Sulfanilamide is introduced, reacting with the nitrite, then N-(1-naphthyl)ethylenediamine dihydrochloride which couples to form a red azo dye. The reaction product is then passed through a 15 mm flowcell and the absorbence measured at 540 nm. The same technique is employed for nitrite analysis, except the cadmium column is not present, and a 50 mm flowcell is used.

Phosphate is analyzed using a modification of the Bernhardt and Wilhelms (1967) technique. Ammonium molybdate is added to the sample to produce phosphomolybdic acid, then reduced to phosphomolybdous acid (a blue compound) following the addition of dihydrazine sulfate. The reaction product is heated to 55 degree C to enhance color development, then passed through a 50 mm flowcell and the absorbence measured at 820 nm.

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 degree C.

Na2SiF6, the silicate primary standard, is obtained from Fluka Chemical Company and Fischer Scientific and is reported by the suppliers to be >98% pure. Primary standards for nitrate KNO3, nitrite NaNO2, and phosphate KH2PO4, are obtained from Johnson Matthey Chemical Co. and the supplier reports purities of 99.999%, 97%, and 99.999%, respectively.

303 nutrient (Silicate) analyses were performed. Phosphate, Nitrate and Nitrite were analyzed starting with station 172, however, these samples are coded as bad and should only be used if there is an unresolved problem of gerard barrel integrity. No major problems were encountered with the measurements.

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Quality Comments

Remarks for missing samples, and WOCE codes other than 2 from WOCE P17, P16 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. Units stated in these comments are micromoles per liter for Silicate unless otherwise noted. The first number before the comment is the cast number (CASTNO) times 100 plus the bottle number (BTLNBR). PB refers to the bottle that is attached to the Gerard.

STATION 132

385 @ 1489db	Sample log: "Air leak before vent." Gerard looks ok. PB (45) @1489db.
348 @ 2950db	Pretripped ~1000m (1150m) shallower than scheduled. Delta- S (PB-G) is 0.013 and silicate is high, gerard appears to be okay at reassigned pressure. Code bottle did not trip as scheduled, silicate and salinity bad. Gerard (93) pretripped.
393 @ 2950db	Pretripped ~1000m (1150m) shallower than scheduled (4000m). Samples appear to be okay. PB (48) pretripped @2950db.
144 @ 3179db	Sample log: "Niskin open. No samples. No therms." Gerard (85) is okay.
185 @ 3180db	Sample log: "Air leak before vent." Gerard looks ok, no temperature. PB (44) @3179db had no samples.
349 @ 3470db	Pretripped ~1000m (930m) shallower than scheduled (4300m). Samples appear to be okay. Gerard (94). Delta-S(PB-G) at 3470db is 0.003, salinity is 34.686.
394 @ 3470db	Pretripped ~1000m (930m) shallower than scheduled (4300m). Samples appear to be okay. PB (49) @3470db.

STATION 143	
485 @ 1194db	Sample log: "Air leak when vented." PB (43); Gerard looks ok.
142 @ 2631db	Delta-S(PB-G) at 2631db is 0.03, salinity is 34.701. Silicate is low. Suspect niskin leaked, Gerard (83) is okay.
183 @ 2632db	Sample log: "Did not drop messenger." PB (42). Cast 2 performed for seven gerards that did not trip.
243 @ 2856db	Gerard (84). Delta-S(PB-G) at 2856db is -0.003, salinity is 34.673.
245 @ 3108db	Gerard (85) appears to be okay.
285 @ 3109db	Sample log: "Air leak when vented." PB (45); Gerard looks ok.
244 @ 3361db	Looks like Niskin did not close. No samples drawn. Therms: Malfunction. Temps way off. Temperature not reported. Gerard (87) is okay.
287 @ 3362db	Temperature not reported, see PB (44) comments.
294 @ 4276db	Sample log: "Air entered top vent during drain, gerard empty before barrel filled." PB (49); Gerard looks ok.
STATION 153	
349 @ 7db	Surface bbl. No therms. No temperature, Gerard (81). Delta-S(PB-G) at 7db is 0.024, salinity is 36.450.
381 @ 7db	No temperature, see PB (49) comment.
385 @ 1595db	Sample log: "Small leak when vented." PB (43); Gerard looks ok.
142 @ 3046db	Delta-S(PB-G) at 3046db is 0.003, salinity is 34.674. Salinity difference is a little high, but suspect drawing rather than a problem with Gerard. Gerard (83) is okay.
183 @ 3046db	See PB (42) salinity comment.
143 @ 3248db	Delta-S(PB-G) at 3248db is -0.014, salinity is 34.670. Footnote bottle leaking, and salinity and silicate bad. Temperature also appears low, footnote temperature bad. Gerard (84) leaked or mistripped.
184 @ 3248db	Sample log: "Top vent cracked open." Footnote Gerard leaked and salinity and silicate bad. PB (43) also leaked or mistripped.
185 @ 3450db	Sample log: "Small leak when vented." PB (45); Gerard looks ok.
187 @ 3653db	Sample log: "Leaking from loose bolt on bottom when retrieved, also top vent cracked open." PB (44); Gerard looks ok.
150 @ 4054db	Delta-S(PB-G) at 4054db is 0.064, salinity is 34.743. Salinity high, silicate low. Footnote bottle leaking, samples bad. Gerard (90) is okay.
190 @ 4055db	Sample log: "Small leak when vented." Gerard appears to be okay. PB (50) leaked.
STATION 165	Cast 1: Sample log: "Cast no good, 100% pretrip." No shore-based data taken.

STATION 166	Cast 1: Therms: "No double ping - appeared on way up. Will use samples."
449 @ 4db	Surface barrel. No therms. Gerard (81). Delta-S(PB-G) at 4db is 0.002, salinity is 35.549.
481 @ 5db	Surface barrel. No therms. PB (49).
147 @ 449db	Delta-S(PB-G) at 449db is -0.024, salinity is 34.460. Footnote as pretrip, but Gerard also has a leaking problem. Gerard (85) leaked.
185 @ 449db	Sample log: "Small leak when vented." Gerard and niskin appear to have pretripped. Water appears to be 50-150m deeper. Footnote as pretrip, but Gerard also has a leaking problem. Footnote salinity and silicate bad. PB (47) pretripped, Gerard (85) leaked.
144 @ 744db	Pretripped. Salinity and silicate are acceptable at reassigned pressure. See Gerard (87) comment. Delta-S(PB- G) at 744db is -0.005, salinity is 34.316.
187 @ 744db	Pretripped. Salinity and silicate are acceptable at reassigned pressure. PB (44).
145 @ 1121db	Niskin pretripped, gerard also pretripped but appears to have leaked. Gerard (89) pretripped and leaked.

STATION 166	
189 @ 1121db	Sample log: "Major leak when vented-pressure leak did not allow C14 barrel to fill." Delta-S (PB-G) is -.0290. Footnote as leaking. Footnote bottle did not trip as scheduled, samples bad. PB (45) also pretripped.
342 @ 1545db	Footnote bottle did not trip as scheduled. See Gerard (87) posttrip comments.
387 @ 1546db	Sample log: "Pre- or posttrip." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (42).
341 @ 2399db	Footnote bottle did not trip as scheduled. See Gerard (90) post trip comments. Delta-S(PB-G) at 2399db is 0.002, salinity is 34.654.
390 @ 2399db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (41).
143 @ 2434db	Footnote bottle did not trip as scheduled. See Gerard (90) posttrip comments. Gerard (90) appears to be okay at reassigned pressure. Delta-S(PB-G) at 2434db is -0.003, salinity is 34.652.
190 @ 2435db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure, PB (43).
350 @ 2619db	Footnote bottle did not trip as scheduled. See Gerard (93) posttrip comments.

STATION 166	
393 @ 2619db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (50).
142 @ 2637db	Footnote bottle did not trip as scheduled. See Gerard (93) posttrip comments.
193 @ 2638db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (42).
141 @ 2777db	Footnote bottle did not trip as scheduled. See Gerard (94) posttrip comments.
194 @ 2778db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (41).
348 @ 2907db	Footnote bottle did not trip as scheduled. See Gerard (94) posttrip comments.
394 @ 2907db	Sample log: "Posttripped when retrieving first bottle." Footnote posttripped, samples appear to be okay at reassigned pressure. PB (48).
STATION 172	
449 @ 4db	Surface barrel. No therms. Gerard (90) leaked.
490 @ 5db	Surface barrel. No therms. Delta-S (PB-G) is 1.970, gerard silicate is 1.0 high. Difficult to explain where the extremely low salinity water came from. Footnote Gerard as leaking, salinity and silicate bad. PB (49).
350 @ 1239db	Sample log: "Hangup. No sample." Gerard (85) looks okay.
385 @ 1239db	Sample log: "Small leak when vented." PB (50); no temperature, Gerard looks ok
341 @ 1488db	Gerard (81) appears to be okay.
381 @ 1488db	Sample log: "Air leak when vented, top valve loose." PB (41); Gerard looks ok.
345 @ 2239db	Gerard (87) appears to be okay.
387 @ 2240db	Sample log: "Air leak when vented, top valve loose." PB (45); Gerard appears to be okay.
142 @ 3505db	Nutrients: "PO4 value impossibly high - contamination suspected." Therms way off. Wrong break. Temperature not reported. Gerard (87). No po4.
187 @ 3506db	Temperature not reported, see PB (42) comments.
148 @ 4235db	Gerard (94) is okay.
194 @ 4235db	Sample log: "Significant air leak at lid when vented." Sample looks ok. PB (48).

STATION 179	Cast 3: Sample log: "No double ping."
342 (No Pressure)	Gerard (94) posttripped. Salinity, nutrients sampled, no C-14. Samples not reported.
394 (No Pressure)	Sample Log: "Post-tripped @1500m." Salinity, nutrients sampled, no C-14. Samples not reported.
343 (No Pressure)	See Gerard (93) comment, no samples.
393 (No Pressure)	Sample Log: "Tripped near surface, no sample." PB (43), no samples.
341 (No Pressure)	See Gerard (89) comment, no samples.
389 (No Pressure)	Sample Log: "Tripped near surface, no sample." PB (41).
350 (No Pressure)	Salinity apparently sampled, salinity not reported. No C-14 or nutrients.
387 (No Pressure)	Sample Log: "Did not trip, no sample." PB (50).
449 @ 3db	Surface barrel. No therms. Gerard (90) is okay.
490 @ 4db	See PB (49) comment, no temperature.
344 @ 1467db	Footnote bottle leaking, and no3, po4, sio3, no2, salinity bad. Delta-S (PB-G) is 0.4041. Looks like niskin leaked. Gerard (83) is okay.
383 @ 1467db	Gerard po4 slightly high compared with CTD cast. PB (44) leaked.
345 @ 1700db	Gerard (84) is okay.
384 @ 1700db	Sample log: "Did not drop messenger." PB (45); Gerard is okay.
144 @ 4094db	Gerard (89) leaked.

STATION 179	Cast 3: Sample log: "No double ping."
189 @ 4094db	Delta-S(PB-G) at 4099db is 0.017, salinity is 34.702. Silicate is ~3.5 low. Looks like gerard leaked. Footnote bottle leaking and samples bad. PB (44).
148 @ 4495db	Gerard (94) leaked.
194 @ 4496db	Delta-S(PB-G) at 4497db is 0.0217, salinity is 34.705. Silicate is ~5.0 low. Footnote bottle leaking and samples bad. PB (48).

STATION 180	
471 @ 3db	Surface barrel. No therms. Gerard (90) is okay.
490 @ 4db	No temperature, see PB (71) comment; Gerard is okay.
348 @ 3426db	Gerard (85) is okay.
385 @ 3427db	Sample log: "Small leak when vented." Gerard data looks ok. PB (48); Gerard is okay.
141 @ 4432db	Temps bad, salt, sil ok. Temperature not reported, rubber on rack reversal may be bad. Gerard (84) is okay.
184 @ 4432db	Temperature not reported, see PB (41) comment; Gerard is okay.
145 @ 5011db	Temps bad, salt, sil ok. Temperature not reported, rubber on rack reversal may be bad. Gerard (89) is okay.
189 @ 5012db	Temperature not reported, see PB (45) comment; Gerard is okay.

STATION 187	Cast 1: Sample log: Pinger started double ping, short in wire brought it up and changed switch. Barrels are ok. Looks like comment refers to start of cast before barrels were hung.
471 @ 3db	Sample log: "Surface sample, no therms." Gerard (90) is okay.
490 @ 4db	No temperature, see PB (71) comment.
348 @ 1591db	Therms: "Wrong break. No therms." Temperature not reported, Gerard (81) is okay.
381 @ 1592db	Temperature not reported, see PB (48) comment.
350 @ 2472db	Gerard (89) silicate is low.
389 @ 2473db	Silicate is 1.6 low, footnote silicate bad. Salt looks ok. PB (50).
341 @ 2726db	Silicate is 1.9 low, footnote silicate bad. Salt looks ok. Gerard (93) is okay.
393 @ 2727db	PB (41) silicate is bad.
342 @ 3244db	Gerard (85) is okay.
385 @ 3245db	Sample log: "Small leak when vented." Gerard data looks ok. PB (42).
STATION 198	
471 @ 3db	Surface barrel. No therms. Gerard (90) is okay. Delta- S(PB-G) at 3db is 0.006, salinity is 35.571.
490 @ 4db	No temperature, see PB (71) comment.
341 @ 1736db	Gerard (84) is okay.
384 @ 1737db	Sample log: "Leaking around bottom valve." PB (41); Gerard appears to be okay.
345 @ 2237db	Gerard (89) is okay.
389 @ 2237db	Salt too high, looks like drawn from gerard 93 (next bottle down), or salt analyst made an error in numbering. On this same cast, the salt for 93 was missing on the salt form, but was redrawn from ext barrel by rtw and rotter and found to agree with niskin, suggesting that the salt run for 89 was in fact that for 93, and 89's salt was not recorded, although drawn and run. Nuts look fine on 89, probably no leak. Since shipboard data processor states that a salinity sample was redrawn and it agreed with niskin value will use niskin value for gerard, in order for current programs to calculate kg units on nutrients. PB (45).
STATION 210	Cast 3: Sample log: "No double ping, put 90 on for surface sample before start-up." Called 90 cast 4.
471 @ 3db	Surface barrel. No therms. Gerard (90) is okay.
490 @ 4db	No temperature, see PB (71) comment.
345 @ 1985db	Gerard (89) is okay.
389 @ 1986db	Sample log: Closed but not latched. Did not leak when vented. Gerard data looks ok. PB (45).

C.2.b P16S17S TUNES-2 Final Report for Large Volume Samples

(Robert M. Key)

July 3, 1996

1.0 General Information

WOCE section P16S17S was the second in a series of three cruise legs collectively referred to as "TUNES" (expedition designation 31WTTUNES/2). The cruise was carried out aboard R/V Thomas Washington during the period July 16 - August 25, 1992. The cruise began and ended in Papeete, Tahiti. 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 final cruise report prepared by Swift as the primary source for cruise information. Portions of this report were taken from that data report.

Ten large volume (LV) stations were occupied on this leg. The cruise plan called for 2 Gerard casts of 9 barrels each at each LV station. The planned sampling density was 1 station every 5° of latitude (~300nmi). Each station included at least 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. 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.

All LV casts for the TUNES cruises were done using the stern A-frame on the R/V Thomas Washington. As is generally the case, the combination of a small vessel with working off the stern led to an elevated failure rate for the LV work relative to working off the side of a larger vessel. This problem is a result of accelerations on the trawl wire caused by ship motion and sea state. Slowing the lowering rate to 50 meters per minute or less reduced the failure rate. For several of the stations the number of Gerards per cast was reduced to 7 or 8 in an effort to reduce pretrip problems. On these stations a third cast with one bottle was used to collect the surface sample. The Gerard barrel platform, as set up in port prior to the cruise, did not allow enough clearance for barrel deployment and recovery. The Chief Engineer cut the platform loose and rewelded it to the deck about one foot forward. The spring-loaded trapping-pin was no longer usable so a chain was shackled to one forward corner of the platform, passed aft of the wire then hooked to the other forward corner to hold the trawl wire in the platform "V" while the barrels were being attached and detached. Limited fantail space and the low trawl wire lead required that the crane work over the wire to move barrels from racks to near the center-line just forward of the platform, then the barrel was unhooked and the crane moved to the other side of the wire and re-hooked to move the barrel to the attachment position. This procedure was reversed for recovery. Problems were minimized by the exceptional effort and capability of the Washington's crew. Table 1 summarizes the LV sampling and Figure 1 shows the LV station locations.

TABLE 1. LV Sampling Summary

Station	Cast	South Latitude	West Longitude	No. Ger. Samples
132	1	10.030	134.982	9
	3	10.000	134.967	9
143	1	15.385	133.877	2
	2	15.387	133.867	7
	4	15.365	133.918	8
153	1	20.273	132.860	9
	3	20.262	132.848	8
166	1	26.650	133.250	6
	3	26.667	133.260	8
	4	26.667	133.800	1
172	1	29.567	134.070	7
	3	29.550	134.058	7
	4	29.550	134.058	1
179	1	32.998	135.013	7
	3	33.053	135.022	7
	4	33.053	135.022	1
180	1	37.513	150.470	7
	3	37.533	150.517	8
	4	37.533	150.517	1
187	1	34.008	150.497	7
	3	34.030	150.545	8
	4	34.030	150.545	1
198	1	28.460	150.502	7
	3	28.482	150.502	8
210	1	22.485	150.493	7
	3	22.512	150.522	9
Total	26			160

Each Gerard barrel was equipped with a piggyback 5 liter Niskin bottle which 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. Approximate-

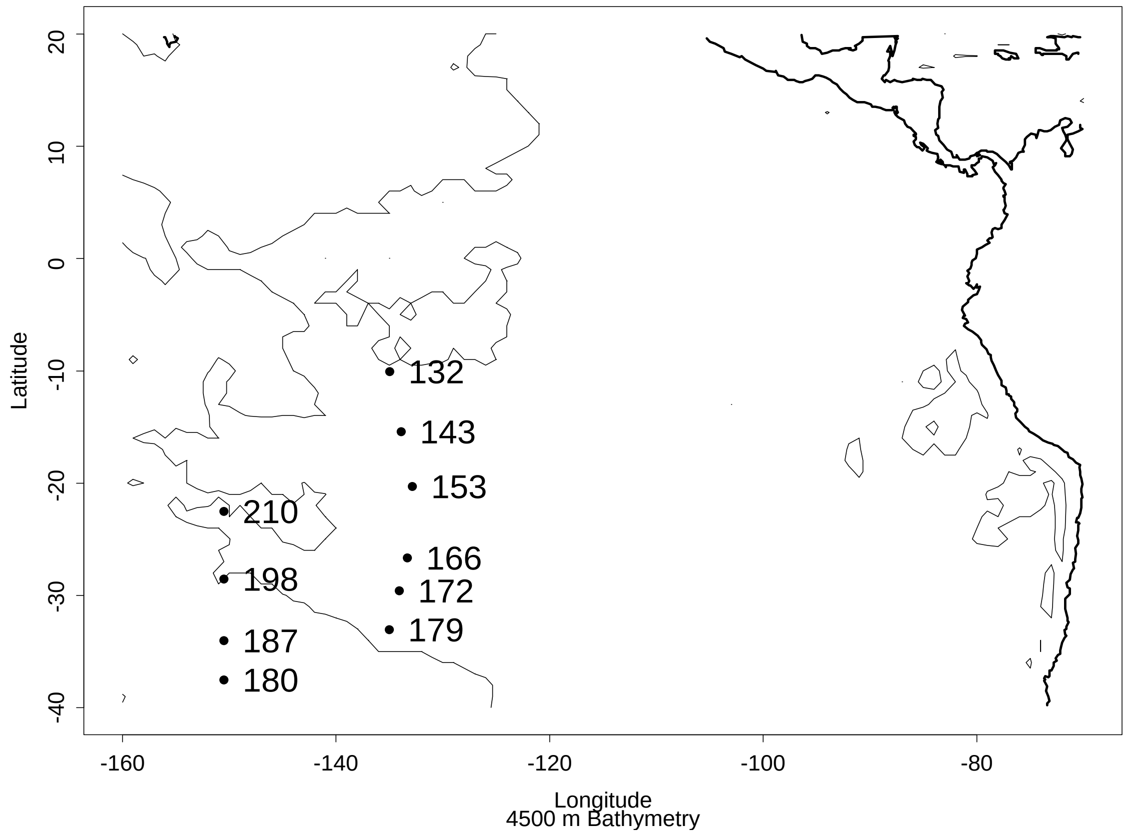

Figure 1: P16S17S large volume station locations.

ly half of the Gerard-Niskin pairs were sampled for other nutrients (nitrate, nitrite and phosphate) Additionally, each Gerard was sampled for radiocarbon. The salinity and silicate samples from the piggyback bottle were used for comparison with the Gerard barrel values to verify the Gerard sample integrity. As samples were collected, the information was recorded on a log sheet. Any abnormalities with sampler or sample collection were also noted. 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 included verification that the sample was assigned the correct depth. Salinity and nutrient data were compared by ODF with values 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.

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 Rich Rotter (Princeton). Deck work and reading thermometers was done by the SIO CTD group with assistance from many of the scientific party. Salinities and nutrients were analyzed ODF/SIO personnel with assistance from Dennis Guffy (TAMU). ^{14}C analyses were split between Göte Östlund's laboratory (U. Miami, R.S.M.A.S.) and Minze Stuiver's laboratory (U. Washington). 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 81-94.

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. Reported temperatures were calculated from the average of four readings provided that all protected thermometers function 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 (1500m to bottom). Rosette data from the same stations and depth ranges are shown as connected small filled squares. The agreement is excellent for almost all data.

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

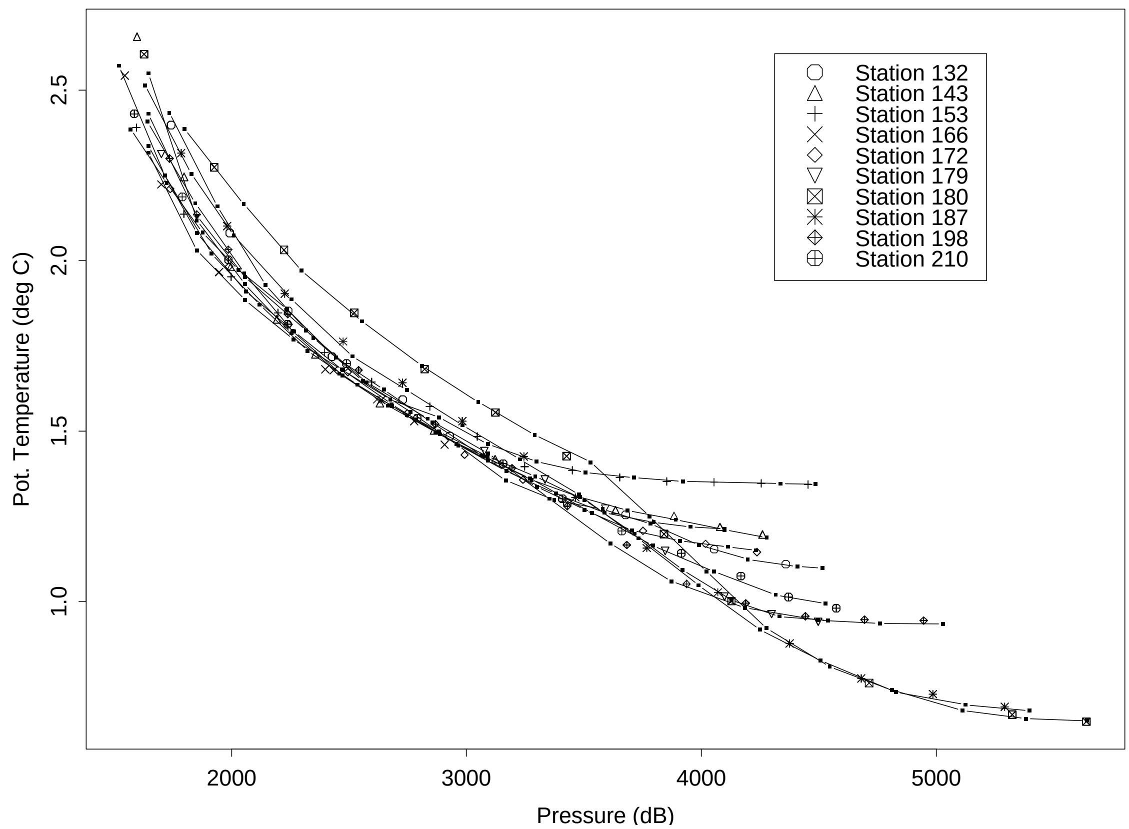

Figure 2: Large symbols are from Gerard casts (1500m - bottom only). CTD data for same stations and pressure range is shown as small filled connected squares.

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 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 airtight 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.

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-114 (Stations 124-140) and Batch P-108 (Stations 141-220), 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 and the use of two batches of SSW. Figure 3 shows potential temperature *vs.* salinity for the Gerard casts (1500m - bottom only). For comparison the CTD/Rosette data for the same stations and pressure range are plotted as connected small filled squares. In general the agreement between the Gerard-piggyback Niskin pairs is excellent as is agreement between the LV and CTD/Rosette casts.

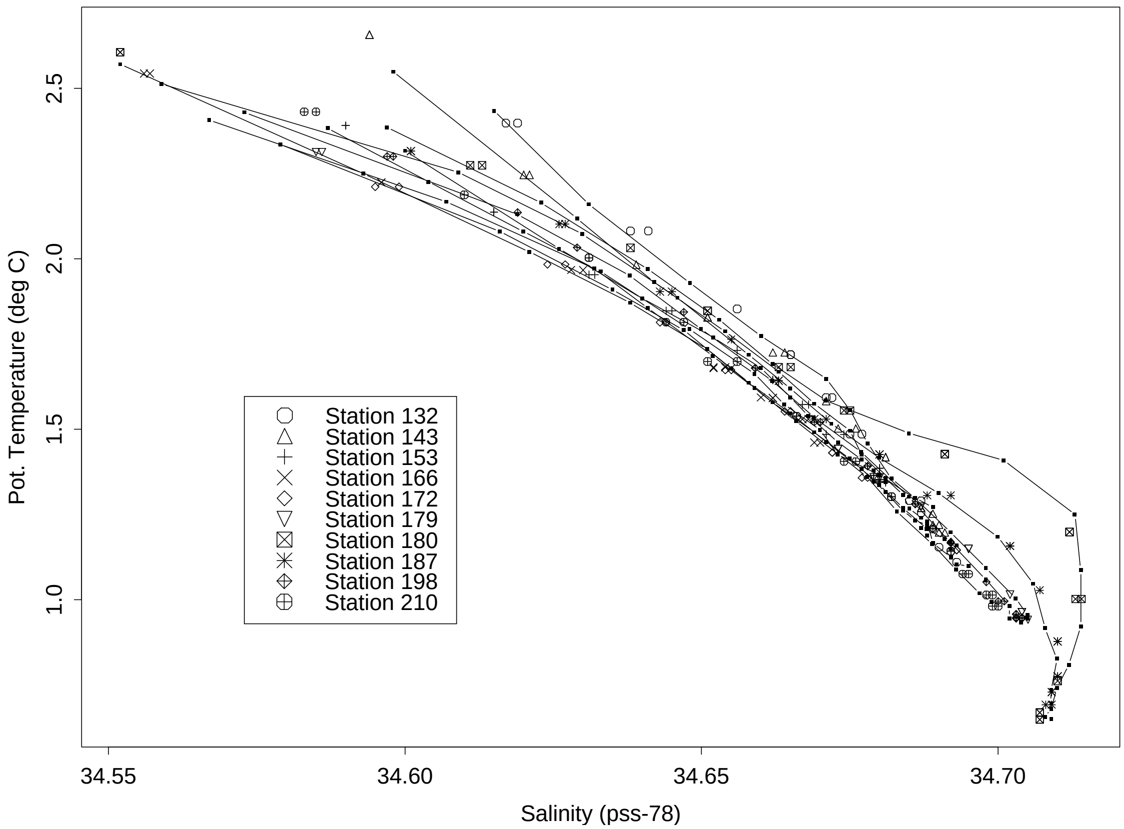

Figure 3: Theta *vs.* salinity for LV casts. CTD/Rosette data from the same stations and pressure range is overlain as small filled connected squares.

3.3 Nutrients

Nutrient samples were collected from Gerard casts. On this leg silicate values were measured on all samples and phosphate and nitrate on selected 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.

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 preweighed 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 a 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.

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. 258 silicate analyses were performed. No major problems were encountered with the measurements. Figure 4 shows the LV cast silicate values plotted against potential temperature (1500m - bottom only). The Rosette cast measurements from the same stations and depth range are overlain as small filled connected squares. In general the agreement is good. The difference between most Gerard - Niskin pairs is approximately half the systematic LV - Rosette offset which is turn is approximately 2 μmol/kg.

3.4 14C

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

All Gerard samples deemed to be "OK" on initial inspection were extracted for ^{14}C analysis using the technique described by Key (1991). The extracted $^{14}CO_2$/NaOH

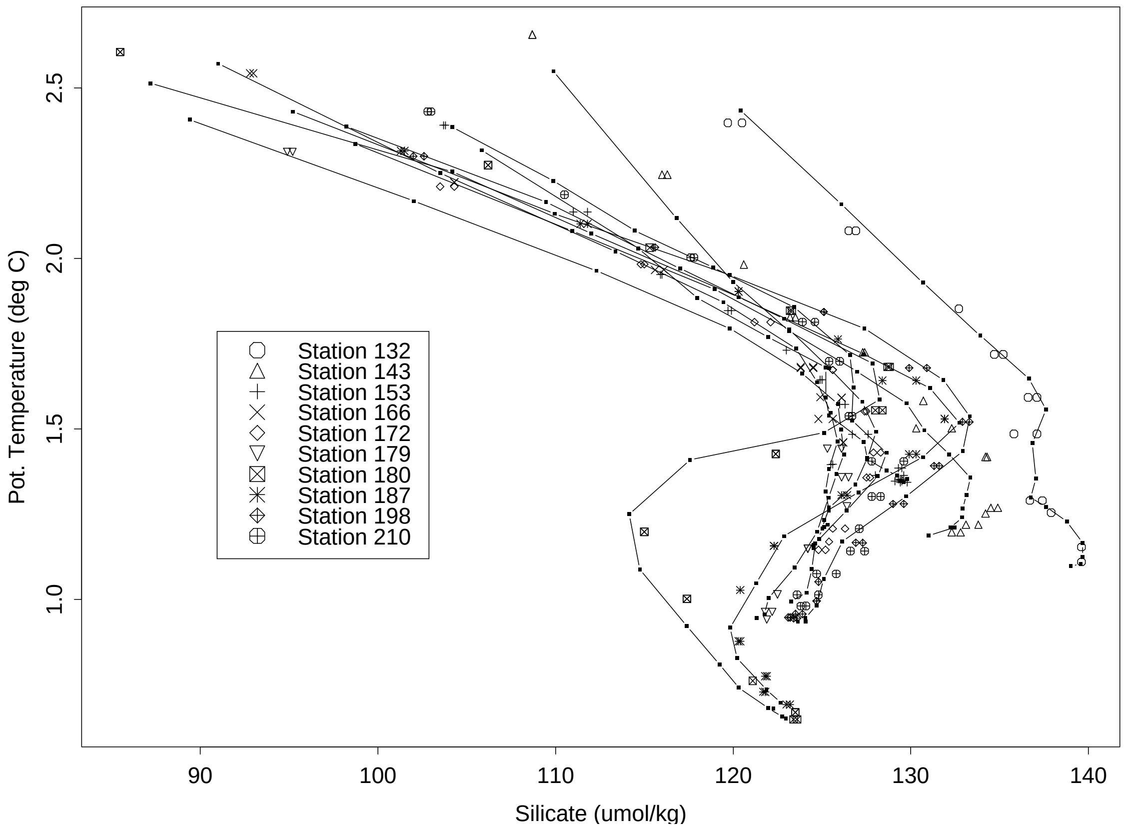

Figure 4: Silicate *vs.* potential temperature for LV casts (1500m - bottom only). Rosette measurements from the same stations and depth ranges are shown as small filled connected squares.

samples were returned to the Ocean Tracer Lab at Princeton and subsequently shipped to Östlund's lab in Miami. Östlund kept the P17S samples for analysis in his lab and forwarded those from P16S to Stuiver. Both ^{13}C and ^{14}C measurements are performed on the same CO_2 gas extracted from the large volume samples. All ^{13}C analyses were done in Stuiver's lab. 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). Östlund's lab reports a precision of 4‰ for each measurement based on a long term average of counting statistics. Stuiver reports individual errors for each measurement based on counting statistics.

Of the 160 Gerard samples collected, ^{14}C has been measured on 152 (95%). 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 GEOSECS measurements and neighboring WOCE measurements. Comparison of these data sets indicates that they are in agreement to the precision of the measurements.

4.0 Data Summary

Figures 5-8 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 (1000m - bottom only). One sigma error bars are shown. The most noticeable characteristic is the strong minimum in the 2000-2600dB range for all stations. Figure 6 shows $\Delta^{14}C$ values plotted against measured Gerard barrel

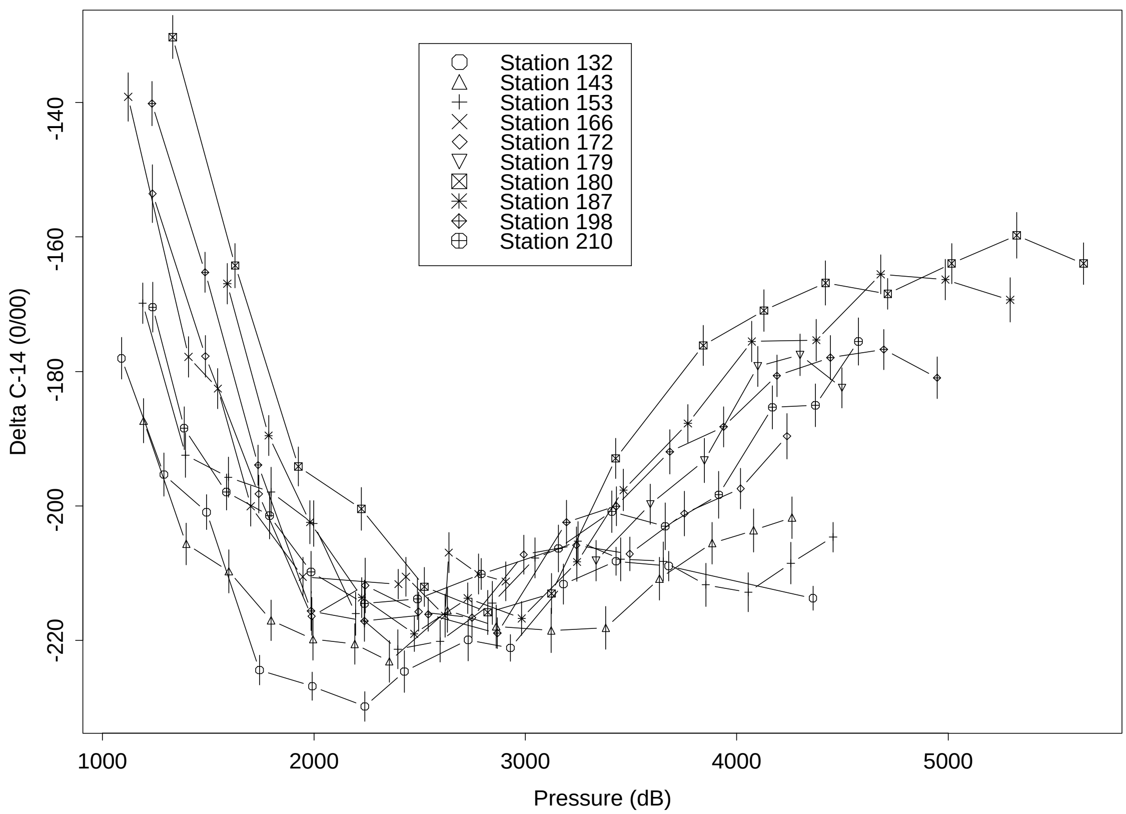

Figure 5: LV $\Delta^{14}C$ *vs.* pressure for Gerard samples collected at depths below 1000dB. Vertical bars indicate 1σ standard deviations.

silicate values. The backward checkmark shape is typical of other profiles measured in the South Pacific. Figure 7 is a coarse resolution machine contoured section of the ^{14}C distribution in the deep and bottom waters for the P16 portion of this leg (155°W). The minimum increases in depth to the south, but otherwise the section is rather monotonous. The squiggle in the -170‰ near bottom contour is an artifact of the gridding (there are two few data for reasonable objective section gridding). Figure 8 is an objectively gridded section for the samples collected along the P17 portion of this leg. Additional AMS $\Delta^{14}C$ results

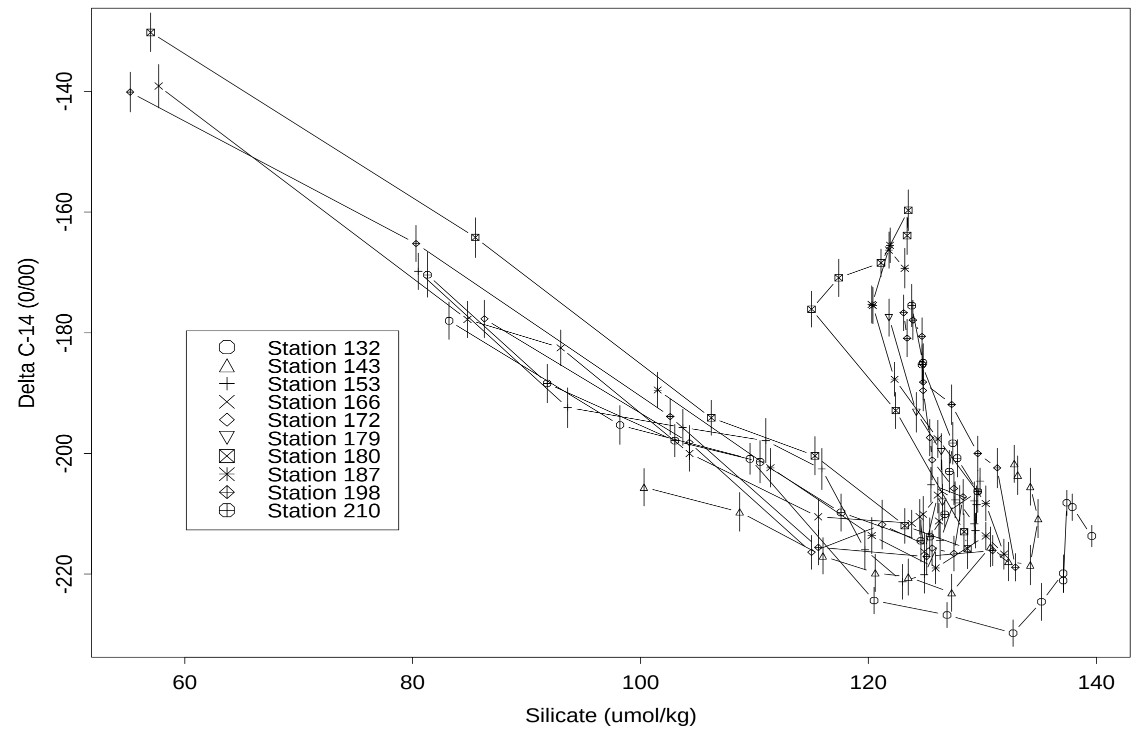

Figure 6: $\Delta^{14}C$ *vs.* silicate for LV samples collected at pressures greater than 1000dB. The backwards checkmark shape is typical for the South Pacific in areas north of the circumpolar circulation.

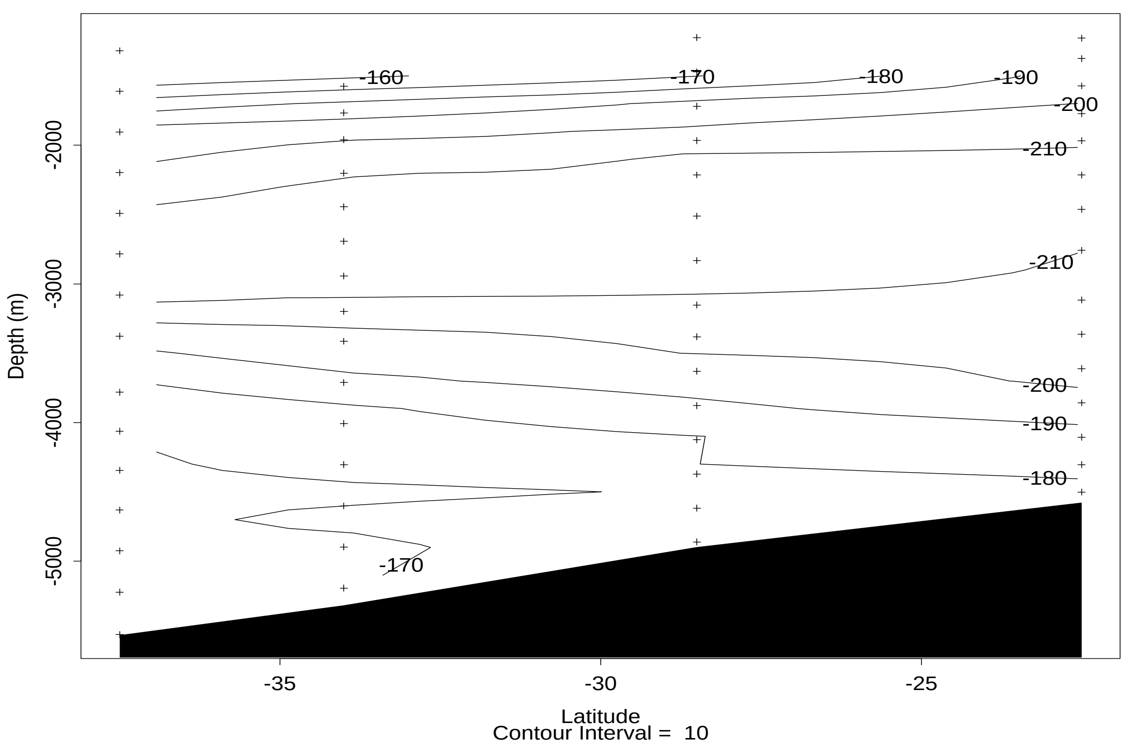

Figure 7: $\Delta^{14}C$ section for LV samples collected along P16 (~155°W). Due to the low number of data points on this section, a linear gridding scheme was rather than an objective technique. The squiggle in the -170‰ near bottom contour is erroneous and due to the gridding method.

were used in preparing this section, but the data points are omitted from the figure. The minimum along this longitude (135°W) appears to be lower and slightly shallower than was seen for the P16C section. The near bottom values along P17 are somewhat lower than for P16, but most of this difference is probably due simply to bottom depth differences.

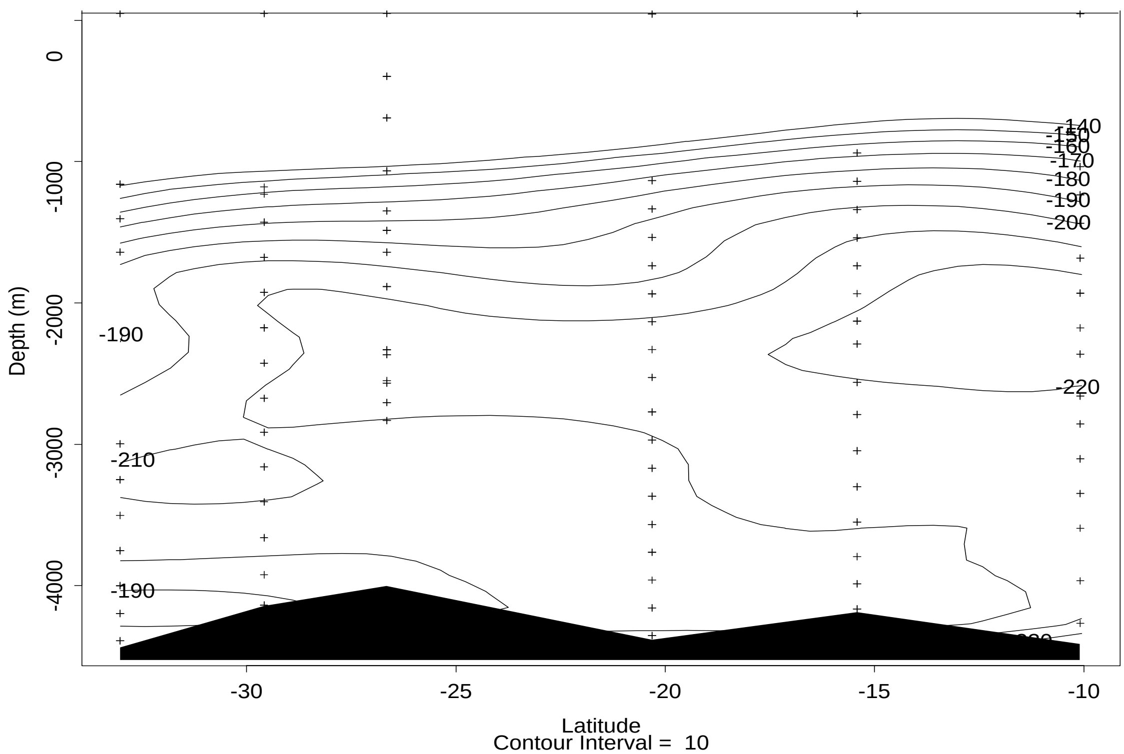

Figure 8: $\Delta^{14}C$ section for LV samples collected along P17 (~135°W). In addition to the LV data shown, AMS samples collected along this track were used in preparing this objectively gridded section (AMS data not shown).

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, 5 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”. 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 using this data set for scientific application, any ^{14}C datum which is flagged with a “3” should be carefully considered. My 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 of ~4‰.

No measured values have been removed from this data set. When using this data set, it is advised that the nutrient data (with the exception of silicate) 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. Note that there may be some errors between assignment of flag value 5 (not reported) and flag value 9 (no sample collected).

TABLE 2. P16S17S LV Quality Code Summary

	Reported	WHP Quality Codes								
	Levels	1	2	3	4	5	6	7	8	9
BTLNBR	284	0	284	3	12	0	0	0	0	0
SALNTY	284	0	272	5	3	4	0	0	0	0
SILCAT	284	0	255	1	2	26	0	0	0	154
NITRAT	150	0	150	0	0	0	0	0	0	134
NITRIT	150	0	150	0	0	0	0	0	0	134
PHSPHT	150	0	150	0	9	0	0	0	0	134
REVPRS	284	0	284	0	0	0	0	0	0	0
REVTMP	284	0	258	0	3	23	0	0	0	10
DELC14	152	0	147	0	5	0	0	0	0	132[a]

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

6.0 References and Supporting Documentation

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D. Calibrated Pressure-Series CTD Data Processing Summary and Comments

(Mary C. Johnson/ODF CTD Group)
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Notes:

- A single CTD processing file was produced for TUNES Legs 1 and 2. An ASCII version is shown here as received from the author. We are aware that the WHP Office requires reformatting of methodology reports to match that required by the office. However, in this case such a massive reformatting is simply not justified. A PostScript version of the CTD report was also prepared, but cannot be inserted into this report.

- The CTD processing document refers to four appendices (A-D). These do not fit the numbering scheme used by the WHPO for appendices. However, they are attached to this report in their original letter-order due to the frequent references in this document. The ASCII versions attached to this document are inferior to the PostScript version, which contains electronically-imbedded figures.

D.1. Introduction

In this document we discuss CTDO data acquisition, calibration, corrections, and other processing for the TUNES cruise, Legs 1 and 2, on the R/V Thomas Washington. At various times during these legs, the CTD instruments and sensors exhibited more than the usual share of noise, drifts or other problems, making CTD data processing more challenging than usual. We believe that we have greatly reduced the uncertainty in the final reported values via careful examination and application of the preand post-cruise calibrations, and by comparison of CTD data with the water sample and thermometric data collected during the CTD casts. Our techniques and calibration data are discussed below.

D.2. CTD Acquisition and Processing Summary

221 CTD casts and 4 test casts were completed during TUNES Legs 1 and 2. The rosette used was an ODF-designed 36-bottle system with a ring of twelve 10-liter bottles and 12and 24-place General Oceanics pylons nested inside a ring of twenty-four 10-liter

bottles. A CTD, altimeter, pinger and transmissometer were mounted on the bottom of the frame. ODF CTDs #1 and #2 (modified NBIS Mark III-B instruments) were used during both Legs 1 and 2. CTD #10 was used on Leg 2 only.

Each ODF CTD acquired data at a maximum rate of 25 Hz. The data consisted of pressure, temperature, conductivity, dissolved oxygen, second temperature, four CTD voltages, trip confirmation, transmissometer, altimeter and elapsed time. Power to the CTD was optimized by applying the minimum current to attain the CTD voltages required to maintain sensor stability. These voltages were monitored throughout the cast.

An ODF-designed deck unit demodulated the FSK CTD signal to an RS-232 interface. The raw CTD data server allowed the data to be split into three different paths: to be logged in raw digitized form, to be monitored in real time as raw data, and to be processed and plotted. During the TUNES expedition, an Integrated Solutions Inc. (ISI) Optimum V computer served as the real-time data acquisition processor. Additionally, Sun SPARC computers were used during postcruise processing.

The raw CTD audio signal was recorded on VHS videotape as an ultimate back-up, and all raw binary data were logged on a hard disk and then backed up to magnetic cartridge tape. In addition, all intermediate versions of processed data were backed up to magnetic cartridge tape.

CTD data processing consists of a sequence of steps which is modified as needed. Data can be re-processed from any point in this sequence after the raw data are acquired from the sea cable and recorded on videotape and/or hard disk. Each CTD cast is assigned a correction file, and while the corrections are usually determined for groups of stations, it is possible to fine tune the parameters for even a single station. The acquisition and processing steps are as follows:

- Data are acquired from the CTD sea cable and assembled into consecutive .04-second frames containing all data channels. The data are converted to engineering units.

- The raw pressure, temperature and conductivity data are passed through broad absolute value and gradient filters to eliminate noisy data. The entire frame of raw data is omitted, as opposed to interpolating bad points, if any one of the filters is exceeded. The filters may be adjusted as needed for each cast.

TYPICAL TUNES RAW DATA FILTERS

Raw Data Channel	Minimum	Maximum	Frame-to-Frame Gradient
Pressure	-40	6400	2.0 dbar
Temperature	-8	32.7	.2 to .6 deg.C
Conductivity	0	64.355	.3 to .6 mmho

- Pressure and conductivity are phase-adjusted to match the temperature response, since the temperature sensor responds more slowly to change. Conductivity data are corrected for ceramic compressibility in accordance with the NBIS Mark III-B Reference Manual.

- The data are averaged into 0.5-second blocks. During this step, 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 data are re-averaged. The resulting averages, minus second temperature and CTD voltages, are reported as the 0.5-second time series. Secondary temperature data are used to verify the stability of the primary temperature channel calibration. Secondary temperature data are only filtered, averaged and reported with the time-series data when they are used in place of the primary temperature data due to a sensor malfunction.

- Corrections are applied to the data. The pressure data are corrected using laboratory calibration data. Temperature corrections, typically a quadratic correction as a function of temperature, are based on laboratory calibrations. Conductivity and oxygen corrections are derived from water sample data. Conductivity corrections are typically a linear fit as a function of conductivity. Oxygen data are corrected on an individual cast basis. Uncorrected time-series transmissometer data are forwarded to TAMU for final processing and reporting.

The averaged data are recorded on hard disk and sent to the realtime display system, where the averaged data can be reported and plotted during a cast. The averaging system also communicates with the CTD acquisition computer for detection of bottle trips, almost always occurring during the up casts. A 3to 4-second average of the CTD data is stored for each detected bottle trip.

A down-cast pressure-series data set is created from the time series by applying a ship-roll filter to the down-cast time-series data, then averaging the data within 2-dbar pressure intervals centered on the reported pressure. The first few seconds of data for each cast are generally excluded from the averages due to sensor adjustment or bubbles during the in-water transition. Pressure intervals with no time-series data can optionally be filled by doubleparabolic interpolation. When the down-cast CTD data have excessive noise, gaps or offsets, the up-cast data are used instead. CTD data from down and up casts are not mixed together in the pressure-series data because they do not represent identical water columns (due to ship movement, wire angles, etc.).

The CTD time series is always the primary CTD data record for the pressure, conductivity and temperature channels. The final corrections to the CTD oxygen data are made by correcting pressure-series CTD oxygen data to match the up-cast oxygen water samples at common isopycnals. The final CTDO pressure-series data are the data reported to the principal investigator and to the WHP Office.

Subsequent sections of this document discuss the laboratory calibrations, data processing and corrections for each CTD used during TUNES Legs 1 and 2.

D.3. CTD Laboratory Calibrations

D.3.a Pressure Transducer Calibration

Each CTD pressure transducer was calibrated in a temperaturecontrolled bath to the ODF Ruska deadweight-tester (DWT) pressure standards. The mechanical hysteresis loading and unloading curves were measured both preand post-cruise at cold temperature (-1.0 to 0.1 degrees C bath) to a maximum of 8830 psi, and at warm temperature (29.4-30.2 degrees C bath) to a maximum of 1730-2030 psi. The CTD-1 pre-cruise calibration also included a cold calibration to 2030 psi as well as a warm calibration to 8830 psi.

CTD #10 was not calibrated post-cruise because it flooded during Leg 2 and was modified during repair. CTD #1 and CTD #2 had parts interchanged during Leg 2; these were put back in their original configurations before their post-cruise calibrations.

CTD preand post-cruise pressure calibrations are summarized in Figures 1, 2 and 3.

D.3.b PRT Temperature Calibration

All CTD PRT temperature transducers were calibrated in a temperature-controlled bath. CTD temperatures were compared with temperatures calculated from the resistance of a standard platinum resistance thermometer (SPRT) as measured by a NBIS ATB-1250 resistance bridge. The ultimate temperature standards at ODF are water and diphenyl ether triple-point cells and a gallium cell. Six or more calibration temperatures, spaced across the range of -2.0 to 30.2 degrees C, were measured both preand post-cruise.

CTD preand post-cruise temperature calibrations are summarized in Figures 4, 5 and 6.

D.4. CTD Data Processing

D.4.a Pressure, Temperature and Conductivity/Salinity Corrections

A maximum of 36 salinity and oxygen check samples were collected during each CTD cast. Thermometric temperature data were also measured at 1 or 2 levels per cast for stations 183 through 220 on Leg 2. No thermometric pressure data were collected.

A 3- to 4-second average of the CTD time-series data was calculated for each sample. The resulting data were then used to verify the preand post-cruise temperature calibrations, and to derive CTD conductivity/salinity and oxygen corrections.

Two CTDs were traded off during the equatorial section of Leg 1 so that 11-bottle rosette casts with LADCP could alternate with 36-bottle rosette casts. During Leg 2, there were numerous CTD problems and repair attempts that resulted in various sensors and interfaces being shifted from one instrument to another. The following chart clarifies which sensors were being used for any given cast on Leg 1 or Leg 2:

SUMMARY OF CTD SENSORS[@] USED ON EACH PROCESSED TUNES CAST

CTD	Press.	Temp.	Cond.	STATIONS
1	1	1/PRT-1	1	Leg1: 1-75,84-96even,98/2,100-116even,118-123
				Leg2: 124-133,182,189,193-220
1	1	1s/PRT-1	1	Leg1: 76-80,82
1	1	1/PRT-1	1s	Leg2: 134-136
1	1	1/PRT-1	1.2	Leg2: 190-192
2	2	2/PRT-1	2	Leg1: 81-97odd,98/4,99-117odd
				Leg2: 137-147
2	2	2/PRT-2	2	Leg2: 148-150,183-188
10	10	10/PRT-1	10	Leg2: 151-181

[@] Exact Sensor Serial numbers appear below:

CTD ID#	Pressure	Temperature		Conductivity
		PRT-1	PRT-2	
1	131910	14304	FSI1319	5902-F117
1s			FSI1320	spare (ser.no.unknown)
1.2				5902-F117 + CTD-2 Cond.interface
2	110188	15766	10680	2172-G147
10	55504	16185	16188	2932-H137

D.4.a.1 CTD Pressure Corrections

CTD #1

CTD #1 preand post-cruise pressure calibrations, Figures 1a/b and 1c, were compared. The warm/shallow and cold/deep calibration curves both shifted by about 3 decibars from preto post-cruise. The slopes of the warm/shallow pressure calibration curves were nearly identical. The slopes of the cold/deep curves were slightly different: shallower points were 1 decibar closer than deeper points from the two calibrations. Thermometric pressures were not measured during either leg.

An average of the preand post-cruise pressure calibrations, Figure 1d, was calculated and applied to the CTD #1 pressure data from both legs.

CTD #2

CTD #2 preand post-cruise pressure calibrations, Figures 2a and 2b, were compared. The warm/shallow and cold/deep calibration curves both shifted by about 8 decibars from preto post-cruise. The slopes of the 2 sets of pressure calibration curves differed by a maximum of 1 decibar over 6000 decibars. Thermometric pressures were not measured during either leg.

CTD #2 surface raw pressure data were compared over the course of both legs to determine when the 8-decibar shift might have occurred. CTD #2 was used on Leg 1 for each LADCP cast: every other station from 81 through 117. There was no apparent shift in the surface raw pressures during this time: all values, down or up cast, were within 1 decibar of each other at equatorial surface temperatures. These raw pressures were approximately halfway between the preand post-cruise laboratory calibration values at similar temperatures.

The Leg 2 CTD #2 casts, stations 137-150 and 183-188, were also checked. Down and up cast raw pressures were consistent and an average 2 decibars lower than the Leg 1 values, closer to the precruise calibration than Leg 1. There was no shift in raw pressure values between stations 150 and 183.

The pre-cruise calibration was left in place for the CTD #2 pressure data on both legs because of negligible slope differences between preand post-cruise calibrations. Any residual offset was compensated for automatically at each station: as the CTD enters the water, the corrected pressure is adjusted to 0 decibars.

CTD #10

CTD #10 could not be calibrated post-cruise: the instrument flooded during the first/aborted cast at station 182 and was subjected to major repairs and adjustments after the cruise. Any calibration data collected after this repair would not apply to the TUNES cruises.

Thermometric pressures were not measured during Leg 2. The precruise pressure calibration, Figure 3, remained in effect for the CTD #10 data on Leg 2.

D.4.a.2 CTD Temperature Corrections

CTD #1

CTD #1 had two temperature sensors: PRT-1 was calibrated preand post-cruise; PRT-2 was only calibrated pre-cruise and was used to check for PRT-1 drift during the cruise. A comparison of the preand post-cruise laboratory CTD #1 PRT-1 temperature transducer calibrations, Figures 4a and 4b, showed two curves with nearly identical slopes and a +.0025 deg.C temperature shift in the range of 0 to 32 deg.C. An average of the two laboratory calibrations, Figure 4c, was applied to the CTD #1 temperature data.

Thermometric temperature data from Leg 2, stations 189 through 220, were compared to the calibrated CTD #1 temperature data. The average difference between thermometric data and final calibrated CTD data was 0+/-.0005 deg.C, in good agreement with the average laboratory calibration used.

CTD #2

CTD #2 also had two temperature sensors, each calibrated preand post-cruise, Figures 5a/b (PRT-1) and 5c/d (PRT-2). PRT-1, the primary sensor, shifted an average +.044 deg.C between calibrations; PRT-2, the secondary sensor, shifted an average -.011 deg.C. The slopes also shifted by about .004 deg.C each over the 30 deg.C temperature range of the calibrations. The PRT-1 minus PRT-2 difference changed by +.055 deg.C between calibrations at both cold and warm temperatures.

CTD #2 Laboratory Temperature Calibrations

CTD #2 Sensor	Lab. Calib. Temp.	Std.-CTD Pre-crs	T (deg.C) Post-crs	Change in Corrxn	Avg. Change In CTD T
PRT-1	0 degC	-1.486	-1.528	-.042	
	30 degC	-1.496	-1.542	-.046	+.044
PRT-2	0 degC	-1.497	-1.484	+.013	
	30 degC	-1.495	-1.486	+.009	-.011

PRT-1 drifting was first noticed during Leg 2, station 149, as a possible conductivity problem; PRT-1 temperature offsets as large as +.7 deg. C were noted during station 150. After CTD #10 flooded and CTD #1 was under repair for continuing conductivity noise problems, CTD #2 was used again for stations 183-188. The secondary sensor was used for CTD temperature data during these casts, and DSRT thermometer data were collected to monitor any PRT-2 sensor drifting problems.

The two PRTs were monitored shipboard to check for drifting or other problems. At first glance, PRT-1 appeared to be stable throughout the Leg 1 casts for which it was used; but PRT-1 minus PRT-2 differences had already shifted by approximately +.007 deg.C compared to the pre-cruise calibration. Either sensor could have shifted in its preto post-cruise direction to cause this change, which was 3 times the WOCE standard.

The two PRTs were compared by lagging the faster PRT-1 raw temperature data by .15 seconds to match the PRT-2 raw data. PRT-1 minus PRT-2 differences were tabulated for Leg 1 and Leg 2 CTD #2 casts to determine when temperature shifts occurred. The PRT-1 data was too unstable to use for the comparison beginning with station 148. The results of the comparison are as follows:

CTD #2 PRT-1 vs PRT-2 Comparisons

Stations	Avg. PRT-1 Warm/27°C	minus PRT-2 Cold/1.5°C	Avg.Change
Pre-crs calib.	+.001	-.011	-
Leg1,81-117	+.0075	-.0035	+.0070
Leg2,137-147	+.0285	+.0185	+.0215
Post-crs calib.	+.056	+.044	+.0265

The above comparison is only helpful if it can be determined when each PRT shifted. Two thermometric temperature points per cast were measured on stations 183-188 as a calibration check for PRT-2. The DSRT vs. PRT-2 comparisons indicate agreement with the post-cruise PRT-2 calibration. The average residual DSRT-CTD difference after applying the post-cruise calibration is +.0034 deg.C, the closest difference possible using either of the lab calibrations, or even a combination of the two.

PRT-2 had clearly shifted to the post-cruise temperature calibration by stations 183-188, and corrections were applied accordingly. The rest of the temperature corrections were determined from this information, combined with clues provided by an apparently stable CTD #2 conductivity sensor.

In an attempt to clarify when each sensor shifted, the CTD #2 data from Leg 1 and Leg 2 were block-averaged two ways: using PRT-1 or PRT-2 temperature data to calculate CTD salinity. PRT-2-based salinity corrections for stations 150/183 were comparable using the post-cruise temperature calibration. Using this same PRT-2 calibration for stations 137-150 also showed a smooth salinity picture, indicating that PRT-2 had shifted to its post-cruise calibration by the start of Leg 2.

PRT-2 was used for the primary temperature data for stations 148-150 based on major shifts in conductivity slopes from 147 to 148 when PRT-1 temperature data were used, and because of PRT-1 temperature shifts observed during stations 149-150. PRT-2 was not located as near to the conductivity sensor as PRT-1, so it generated noisier CTD salinity data: it was measuring slightly different water and could not be matched properly to the conductivity sensor response. Because of this, PRT-1 was used for all CTD #2 data prior to station 148, before it began to malfunction.

The PRT-1 minus PRT-2 difference was used to determine the Leg 2 PRT-1 calibration for stations 137-147. The pre-cruise calibration was used, with an offset, because the strange behavior of PRT-1 beginning at station 148 could have affected the post-cruise calibration slope and it would not apply to earlier casts. The average preto post-cruise calibration drift for PRT-2 was -.011 deg.C; the average PRT-1 minus PRT-2 change from pre-cruise to stations 137-147, for cold or warm temperatures, was .0285 deg.C. As PRT-2 drifted lower, increasing the difference by .011, PRT-1 had to drift higher; so the PRT-1 pre-cruise calibration curve was decreased by -.0175 deg.C for stations 137-147. A smooth salinity correction for the PRT-1/PRT-2 transition at stations 147-148 verified this decision.

The Leg 1 PRT-1 minus PRT-2 differences shifted an average +.0075 deg.C, cold or warm, compared to the pre-cruise calibrations. No thermometer data was collected during this leg to verify which PRT(s) had changed since the pre-cruise calibration. Salinity differences from the last CTD #2 casts of Leg 1 and the first CTD #2 casts from Leg 2 were compared. When the Leg 1 PRT-1 temperatures were corrected with the pre-cruise calibration and a -.0075 deg.C offset, the Leg 1/Leg 2 salinity differences were within .003 psu, a normal shift after any CTD has been on-deck and sitting idle for several weeks. This PRT-1 correction, which assumes that PRT-2 did its entire shift between Legs 1 and 2, was used for all CTD #2 casts on Leg 1.

After Leg 2 conductivity/salinity corrections were calculated, there was up to a +.005 psu residual surface salinity offset for stations 143-147, indicative of an earlier PRT-1 problem than previously thought. Two options were considered: use PRT-2 for temperature or use PRT-1 with an additional first-order T correction. Because of the noisy salt signal that results from using PRT-2, it was decided to use the added first-order T correction to PRT-1 for stations 143-147. This gave the best deep T/S data while pulling in the surface differences. A summary of the origin and correction of CTD #2 temperature data is listed below:

CTD #2 Temperature Correction Summary

Leg #	Stations	CTD #2 PRT#	Laboratory Calib. Used	Calibration Adjustment
1	81-117odd + 98-4	PRT-1	Pre-cruise	-.0075 offset
2	137-142	PRT-1	Pre-cruise	-.0175 offset
2	143-147	PRT-1	Pre-cruise	-.0175 offset + 1st-order T(T) corrxn
2	148-150 + 183-188	PRT-2	Post-cruise	None

CTD #10

CTD #10 had two temperature sensors, both calibrated pre-cruise only. CTD #10 could not be calibrated post-cruise: the instrument flooded during the first/aborted cast at station 182 and was subjected to major repairs and adjustments after the cruise. Any calibration data collected after this repair would not apply to the TUNES cruises.

No thermometric temperatures were measured for this CTD. The PRT-1 minus PRT-2 difference shifted -.002 deg.C from the pre-cruise laboratory calibration, Figures 6a/b, to the first TUNES CTD #10 cast. The PRT difference changed by a maximum -.002 deg.C from the first to the last CTD #10 cast (stations 151-181). The conductivity correction shifted by more than .04 psu during this same time, a change 20 times greater than the PRT differences could account for. The pre-cruise calibration notes for CTD #10 indicated that PRT-2 was unstable, so it was assumed that any shift in the PRT difference was due to changes in PRT-2. The pre-cruise PRT-1 temperature calibration, Figure 6a, remained in effect for the CTD #10 data on Leg 2.

D.4.a.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 2 standard deviations from the fits were rejected. The resulting conductivity correction slopes were plotted as a function of station number. The conductivity slopes were grouped by stations, based on common PRT and conductivity sensor combinations, and then fit as a function of station number to generate smoothed slopes for each group. These smoothed slopes were either averages of the slopes in the station group (0-order) or changing by a fixed amount from station to station (1st-order).

Conductivity differences were then calculated for each cast after applying the preliminary conductivity slope corrections. Residual conductivity offsets were computed for each cast and fit to station number. Smoothed offsets were determined by groups as above, based on common PRT and conductivity sensor combinations. The resulting smoothed offsets were then applied to the data. Then conductivity slope as a function of conductivity was re-checked: no changes were warranted.

Some offsets were manually adjusted to account for discontinuous shifts in the conductivity transducer response, or to insure a consistent deep T-S relationship from station to station.

Leg 1

CTD #1 and #2 were both used on Leg 1 without any apparent conductivity problems. They were mounted on different rosettes and used for opposite casts during the equatorial stations to allow for adequate sampling time on the larger rosette without loss of ship time. CTD #1 was on the 36-place rosette, while CTD #2 was on a 12-place rosette with the LADCP. Plots of the final Leg 1 conductivity slopes and offsets can be found in Figures 7a and 8a.

Leg 1 Conductivity Correction Summary

Stations	CTD#	Cond.Slopes	Cond.Offsets@
1-3	1	+3.4450e-4	+9.337e-3
4-9	1	+3.4450e-4	+1.0837e-2
9-30	1	+3.4450e-4	-2.2706e-4*sta +1.3643e-2
31-67	1	+3.4450e-4	+4.9702e-5*sta +3.0220e-3
68-96 even, 98/2, 100-116 even, 118-123	1	+3.4450e-4	+7.7941e-3
81-117 odd, 98/4	2	-1.12e-5*sta +1.7936e-3	+3.6617e-4*sta -7.2150e-2

@ individual stations were adjusted after this for conductivity sensor shifting or to insure a consistent deep T-S relationship from cast to cast.

Leg 2

During Leg 2, the CTD #1 conductivity sensor had downcast noise problems of .005 psu or larger beginning with station 133. The conductivity sensor was switched out for a spare before station 134, but the problem continued and actually tripled in size by station 136. Other CTDs were used until CTD #2's PRT problems and CTD #10's flooding problems required trying CTD #1 again, with its original conductivity sensor, at station 182; the noise problem continued. CTD #2 was again used for several stations until it locked up.

CTD #1 was brought back on line at station 189 as a mixture of parts from CTDs #1 and #2. Following numerous repair attempts and part switching, the culprit was discovered to be a coating on the PRT/Conductivity sensor guard that was flaking off and flapping in front of the sensor on the downcasts. The coating was removed and there were no more noise problems beginning with station 197. Because of severe conductivity noise problems on their downcasts, the upcasts were used for stations 133-136, 182, and 189-196. Plots of the final Leg 2 conductivity slopes and offsets can be found in Figures 7b and 8b.

Leg 2 Conductivity Correction Summary

Stations	Conduct. Sensor ID	Conductivity Slopes	Conductivity Offsets@
124-133	1	+2.2324e-4	+4.2845e-4*sta -4.8951e-2
134-136	1s	-1.8377e-4*sta -1.3375e-2	+6.5794e-3*sta -8.7711e-1
137-147	2	-2.5674e-5*sta +3.7912e-3	+1.4006e-3*sta -2.1403e-1
148-150,	2	+2.9952e-6*sta -1.0495e-4	-1.0969e-4*sta -1.9537e-3
183-188			
151-181	10	-1.1894e-5*sta +2.2683e-3	+2.0299e-4*sta -3.1279e-2
182,189,	1	+1.6366e-5*sta -3.7327e-3	-5.0723e-4*sta +1.1454e-1
193-196			
190-192	1.2	+2.0127e-4*sta +1.0515e-2	-6.59775e-3*sta +1.2534
197-220	1	-6.5218e-4	+8.19092e-3

@ individual stations were adjusted after this for conductivity sensor shifting or to insure a consistent deep T-S relationship from cast to cast.

D.4.b Bottle vs. CTD Conductivity Statistical Summary

The TUNES calibrated bottle-minus-CTD conductivity statistics include bottle salinity values with quality 3 or 4. There is approximately a 1:1 correspondence between conductivity and salinity residual differences. The following statistical results were generated from the final bottle data set and the final corrected CTD data:

TUNES Final Bottle-CTD Conductivity Statistics

cruise leg	pressure range (dbars)	Mean conductivity difference (bottle-CTD mmho/cm)	standard deviation	#values in mean
TUNES-1	All pressures	-.00053@@	.01357	3819
	Allp (4,2rej)@	.00033	.00365	3566
	Press < 1500	-.00077	.01741	2230
	p<1500(4,2rej)@	.00040	.00609	2081
	Press > 1500	-.00019@@@	.00412	1589
	p>1500(4,2rej)@	.00012	.00128	1527
TUNES-2	All pressures	.00013@@	.03991	3449
	Allp (4,2rej)@	.00003	.00355	3310
	Press < 1500	.00016	.05191	2036
	p<1500(4,2rej)@	-.00012	.00566	1953
	Press > 1500	.00007@@@	.00242	1413
	p>1500(4,2rej)@	-.00010	.00084	1359

@ "4,2rej" means a 4,2 standard-deviation rejection filter was applied to the differences before generating the results.
@@ Plots of these differences can be found in Figures 9a and 9b.
@@@ Plots of these differences can be found in Figures 10a and 10b.

D.4.c. CTD Dissolved Oxygen Data

D.4.c.1 CTD Oxygen Corrections

Dissolved oxygen data were acquired using Sensormedics dissolved oxygen sensors. During TUNES Legs 1 and 2, two oxygen sensors were used. Sensor A was used with all CTDs for every station except 188-192, where it was temporarily replaced with sensor B because of oxygen signal problems.

CTD oxygen data are corrected after pressure, temperature and conductivity corrections have been determined. CTD raw oxygen currents were extracted from the pressure-series data at isopycnals corresponding to the up-cast check samples. Most pressure-series data were from the down casts, where oxygen data are usually smoother than up-cast data because of the more constant lowering rate, avoiding the flow-dependence problems occurring at up-cast bottle stops. However, the TUNES CTD oxygen data were affected with flow-dependence problems, down or up cast, each time a cast was stopped for several minutes around 20 decibars to activate/de-activate the heave compensator.

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. 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 downand up-cast CTD data at isopycnals. Deep data points were often weighted more heavily than shallower data due to the higher density of shallow sampling on a typical 36-bottle sampling scheme.

The TUNES surface oxygen data fitting was adversely affected by the long heave compensator stop which, combined with the typical going-in-water bubbles/noise, made it difficult to fit CTD oxygens to the bottle data in the surface mixed layer of many casts.

Bottle vs. CTD Oxygen Statistical Summary

The CTD oxygens are generated by fitting up cast oxygen bottle data to down cast CTD raw oxygen (microamps) measurements along isopycnals. Residual oxygen differences are not generated from these comparisons, so no comparison statistics are shown in this report.

D.4.d Additional Processing

A software filter was used on 36 Leg1 casts and 40 Leg2 casts to remove conductivity or temperature spiking problems in about 0.1% of the time-series data frames. Pressure did not require filtering. A fourth of the T/C spiking problems occurred in station 182, and another fourth were concentrated in the CTD-2/PRT-2 casts, where the distance between the secondary PRT and the conductivity sensor resulted in poor signal matchup in high-gradient areas.

Oxygen spikes were filtered out of 2 Leg1 casts and 91 Leg2 casts; software improvements prior to the Leg2 oxygen processing enabled this large difference in oxygen filtering. The filtered oxygen levels affected approximately 2.5% of the time-series data frames. 76% of the filtered oxygen data were shallower than 100 dbars and could be directly related to the stop at the heave compensator activation/de-activation, or bubbles trapped during the going-in-water transition.

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.

After filtering, the down cast (or up cast see table below) portion of each time-series was pressure-sequenced into 2-decibar pressure intervals. A ship-roll filter was applied to each cast during pressure sequencing to disallow pressure reversals. The heave compensator installed on the R/V Washington decreased the magnitude of shiproll effects to a level comparable to Melville/Knorr CTD casts.

D.4.e General Comments/Problems

There is one pressure-sequenced CTD data set, to near the ocean floor, for each of 221 casts at 220 station locations. There was an extra CTD cast at station 98, the equator station for Leg 1, to collect LADCP data. There were four additional equipment test casts, plus four casts aborted because of various CTD problems; these were neither processed nor reported. Another CTD cast was done immediately after any aborted cast at the same location.

The data reported is from down casts, excepting the stations listed below:

UP-CAST PRESSURE-SERIES DATA REPORTED

Leg#	Station(s)	Problem with Down Cast Data
1	16	VCR-operator error 800-1100 dbar down, data not recorded/lost; up ok
2	133-136,182,189-196	Conductivity sensor guard coating flaking off, causing noisy conductivity signal on down casts, much less noise on up casts. Problem resolved before station 197.

The 0-2 decibar level(s) 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 in-water transition; if there were any question that the that the surface values might be real, the original data was reported. Extrapolated surface levels are identified by a count of "1" in the "Number of Raw Frames in Average" reported with each data record on the tapes.

Several shipboard time-series data sets had areas of missing or noisy data. These casts were recovered by re-digitizing the raw signal from analog tape. The top 8 db of one Leg1 cast and 4 nonsurface data levels in 2 Leg2 casts were interpolated. The pressures for these interpolated data frames as well as other cast-by-cast shipboard or processing comments are listed in the "CTD Processing Comments" in Appendix D. All interpolated data levels have a count of "1" in the "Number of Raw Frames in Average" column in the data files.

In addition, missing data values, such as CTD oxygens in casts where the sensor failed, are represented as "-9" in the data files. There were two casts (stations 183-184) where the oxygen signal failed only during the top 200 decibars; these are not reported as "-9", but the affected pressures are listed in Appendix D.

The CTD oxygen sensor often requires several seconds in the water before being wet enough to respond properly; this is manifested as low or high CTD oxygen values at the start of some casts. Flow-dependence problems occur when the lowering rate varies, or when the CTD is stopped, as at the cast bottom, bottle trips or the heave-compensator activation, where depletion of oxygen at the sensor causes lower oxygen readings. Station 133 oxygen data demonstrate a typical oxygen depletion effect at each bottle stop. Delays and yoyos during the casts are documented in Appendix D.

D.4.f Assignment of WHPO Quality Bytes for CTDO data
(Lynne Talley and Jeff Bytof)

1. Pressure:
   All are flagged 2, even though very very few reversing thermometers were used so there was no ***in situ*** calibration against bottles. The assumption is that this flag really means quality of the lab calibration.

1. Temperature:
   All good values are flagged 2, as per comment 1. Despiking was accomplished on the time series and not on the pressure series. Therefore interpolations through spikes typically affected only a portion of a 2 dbar pressure bin, or portions of adjacent bins. Since the only flagging which is suggested for use is either "correct" or "interpolated", we have flagged all pressure bins in which despiking was done as "6", for interpolated. It should be noted though that there may be many good frames of data in the interpolated values.

1. Salinity:
   Same comment with regard to interpolation. If a temperature was despiked, then salinity was flagged as interpolated, "6". Then the additional levels for which conducitivity was despiked were flagged as interpolated, "6". There are no "bad" values, only interpolated.

1. Oxygen:
   A. Because a heave compensator was used for the top 18-20 dbar of each cast, at the end of which there was an extensive wait while the compensator was being turned off, all oxygens above this pressure are flagged as "3" (questionable).

   B. The oxygen sensor cut out on stations 125, 183 and 184. These values are flagged as "4" (bad). The sensor continued to cause problems on subsequent stations (noise flagged 3). There are no recorded oxygens for stations 189-192.

sta 183:	0-118 120-140	flag 4 flag 3
sta 184:	0-78	flag 4
sta 186:	1190-1544	flag 3 (noisy)
sta 187:	0-1658	flag 3 (noisy)
sta 188:	900-1550	flag 3 (noisy)
sta 189-192:		-9 for all O_2

   C. Any other oxygens which were indicated as having been despiked were flagged as "6" (interpolated). except on 186,187,188 where all despikes were flagged "3" because of general problems with the sensor.

D.4.g Acknowledgements

The collection of high quality data at sea rests upon the united capabilities and actions of too many people to individually acknowledge. Special note must be made of the high quality, professionalism, and enthusiasm of Captain Arsenault, his officers, and crew. Their accomplishments were made possible the extraordinary support for this expedition provided by the SIO Marine Facitities Group. With this combination, the success of this expedition was assured. The scientific party was a joy to work with, and each program owes part of its success to the comradie and selfless assistance provided by others. I am grateful to my program officers at the National Science Foundation not only for their support, supplied for the principal physical oceanography program via grants OCE-9002483 and OCE-8918961, but also for their advice, encouragement, and patience. Additional support was received from other agencies, and is listed in the investigator list. This report was prepared with much assistance from Kristin Sanborn, Ben Crane, and Kim Coles.

D.4.h References and Uncited Supporting Documentation

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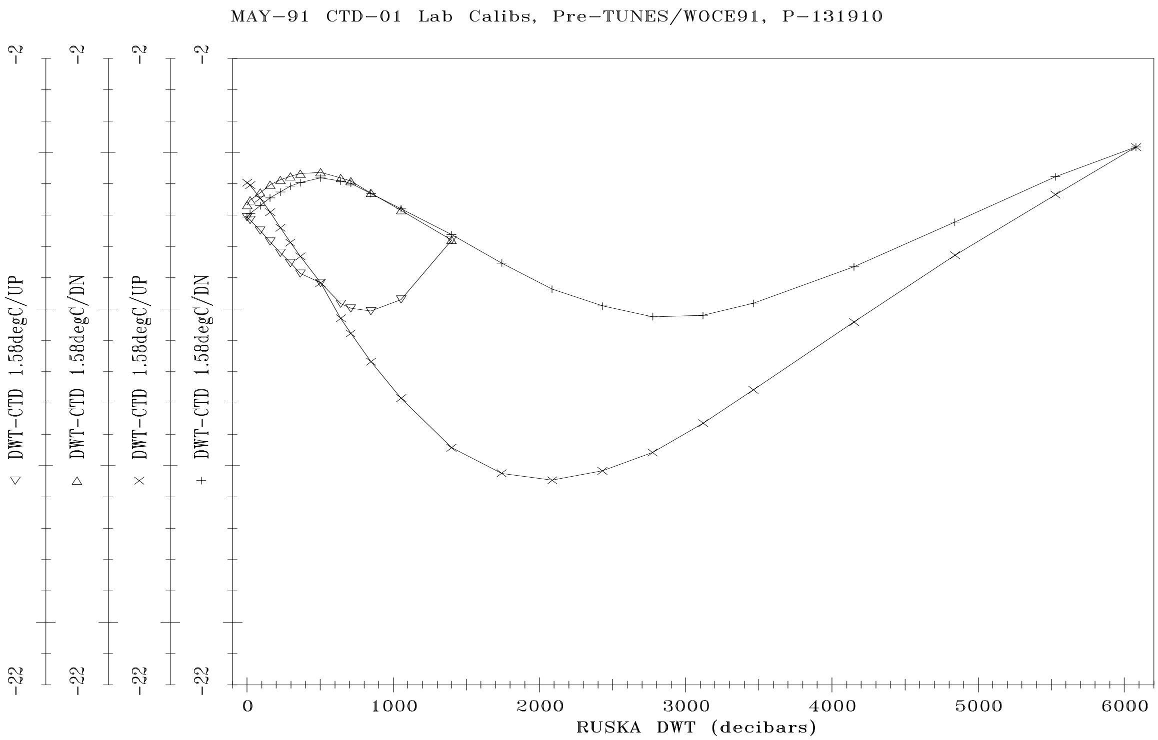


Figure 1a: CTD #1 Pre-cruise Cold Pressure Calibration

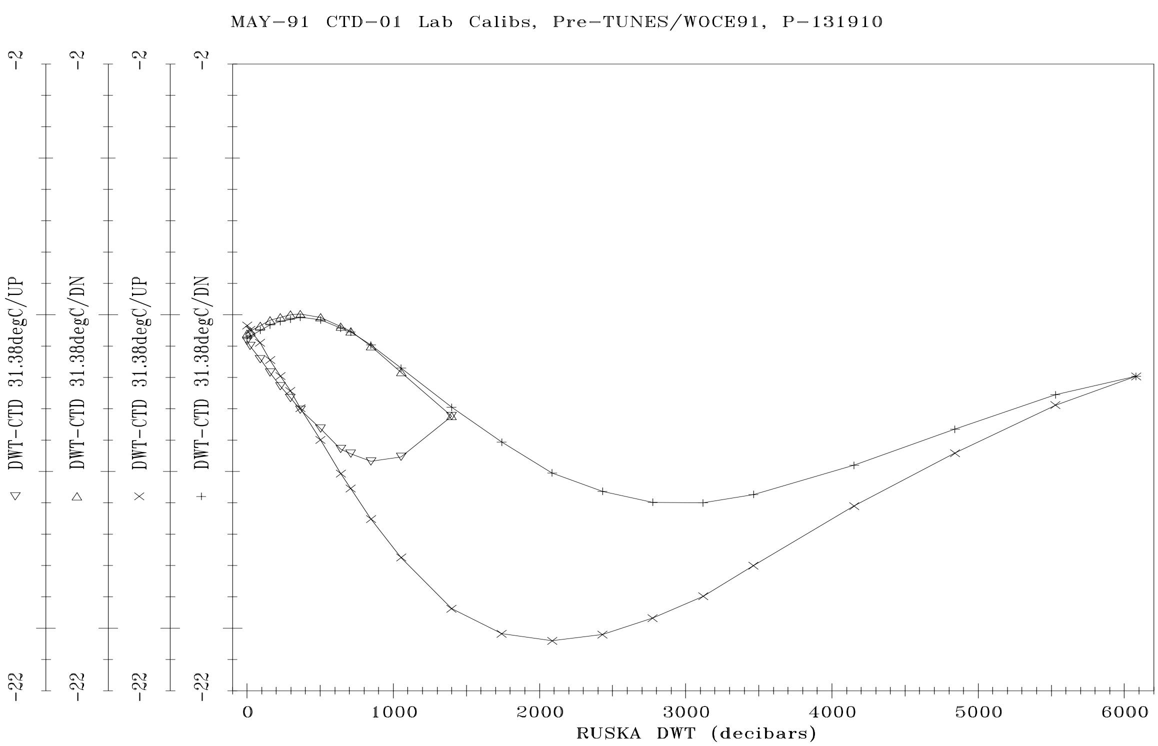


Figure 1b: CTD #1 Pre-cruise Warm Pressure Calibration

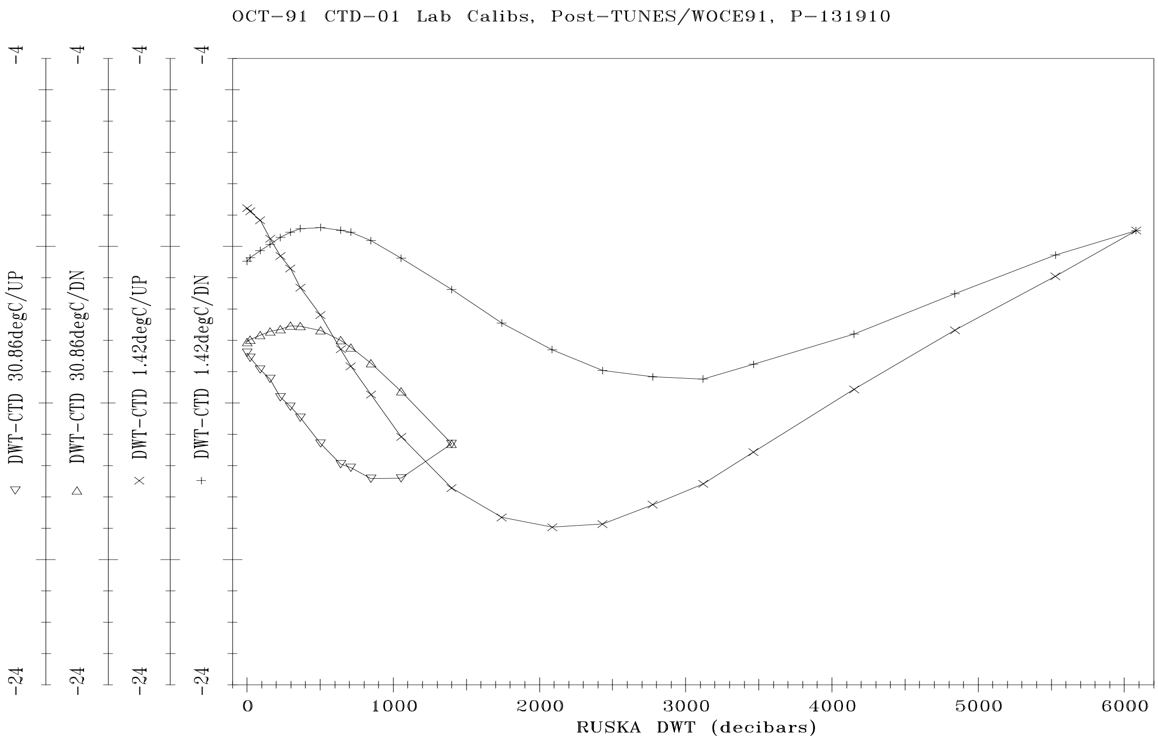


Figure 1c: CTD #1 Post-cruise Pressure Calibration

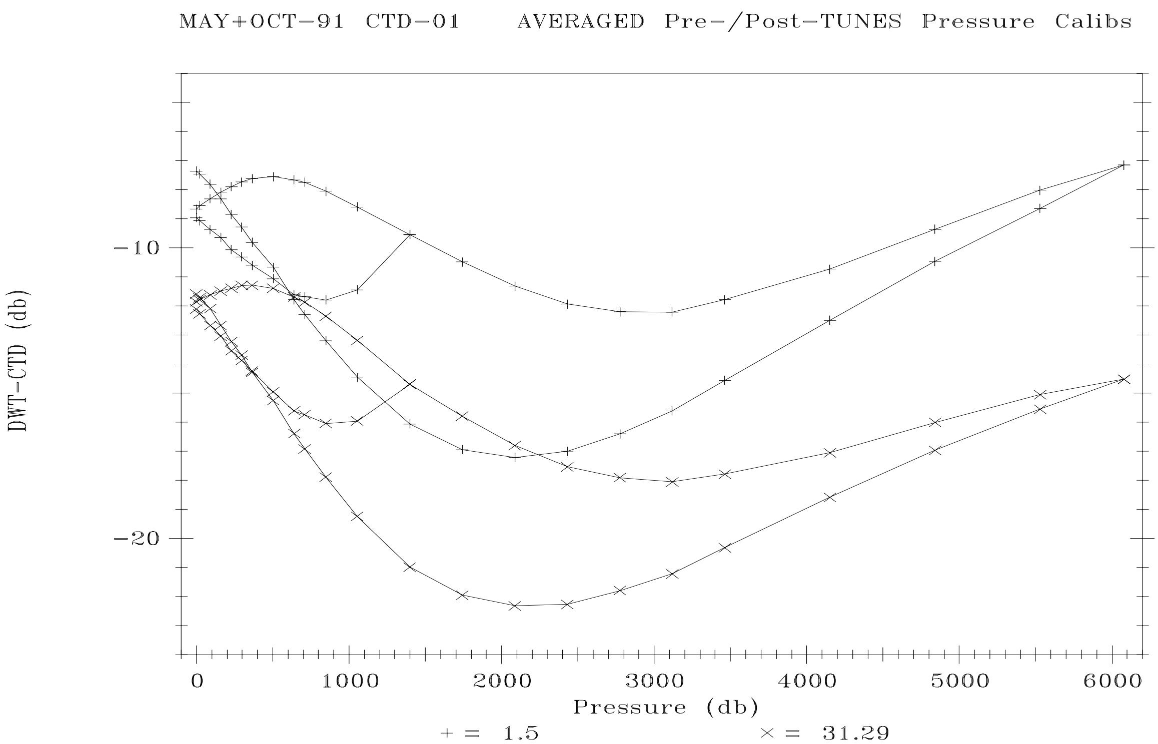


Figure 1d: CTD #1 Averaged Pre-/Post-cruise Pressure Calibration

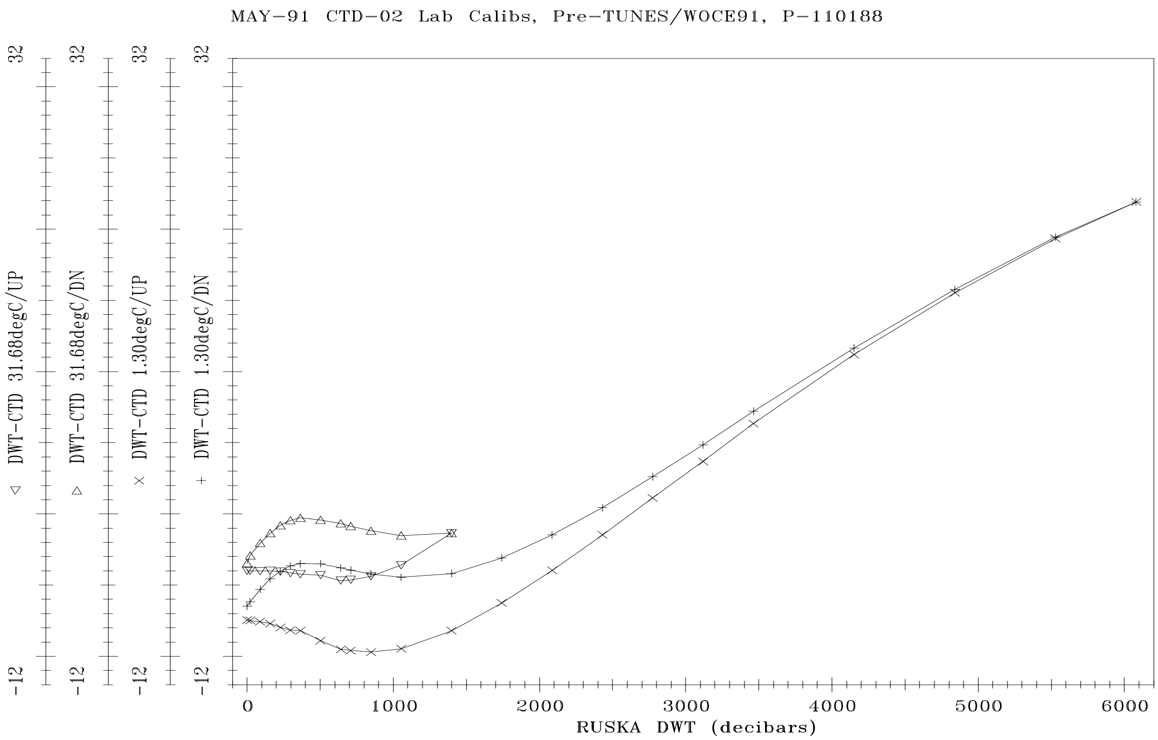


Figure 2a: CTD #2 Pre-cruise Pressure Calibration

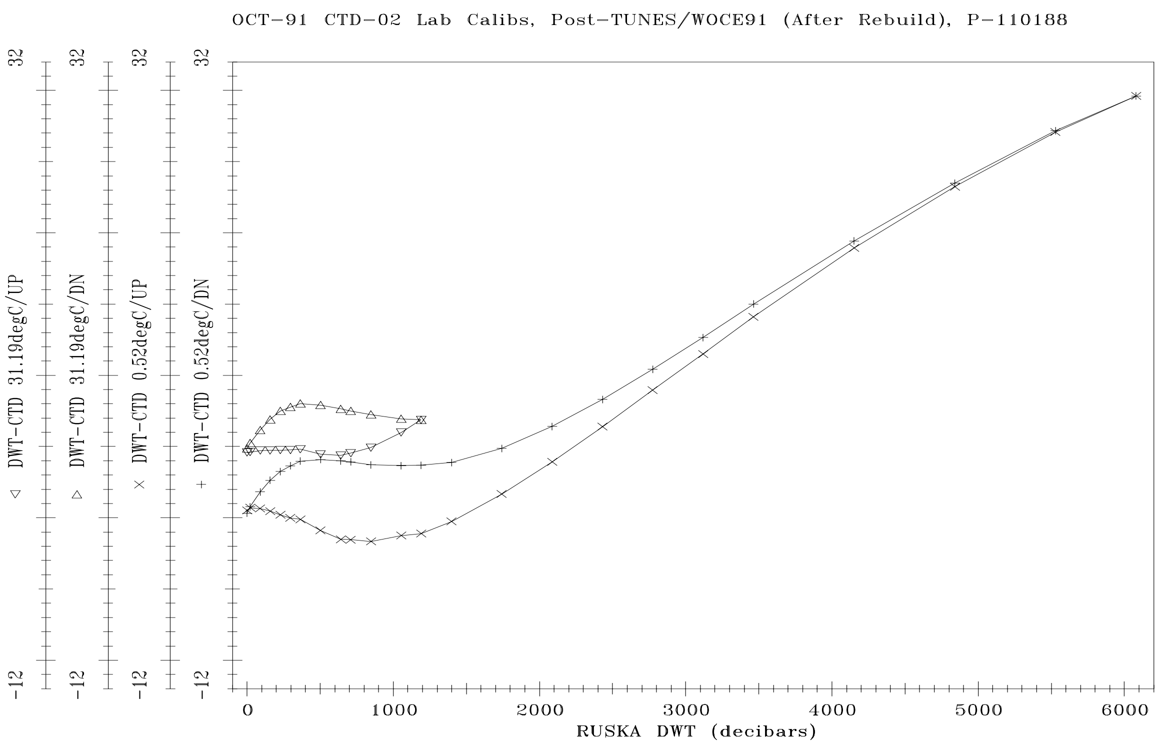


Figure 2b: CTD #2 Post-cruise Pressure Calibration

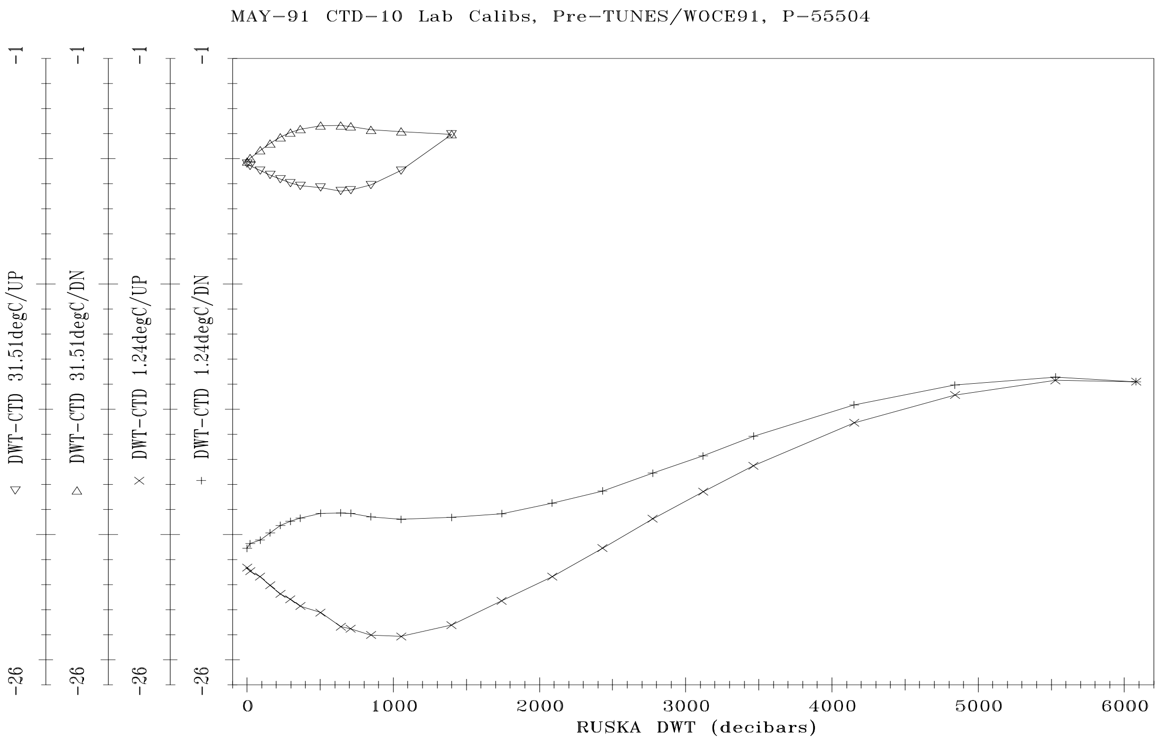


Figure 3: CTD #10 Pre-cruise Pressure Calibration

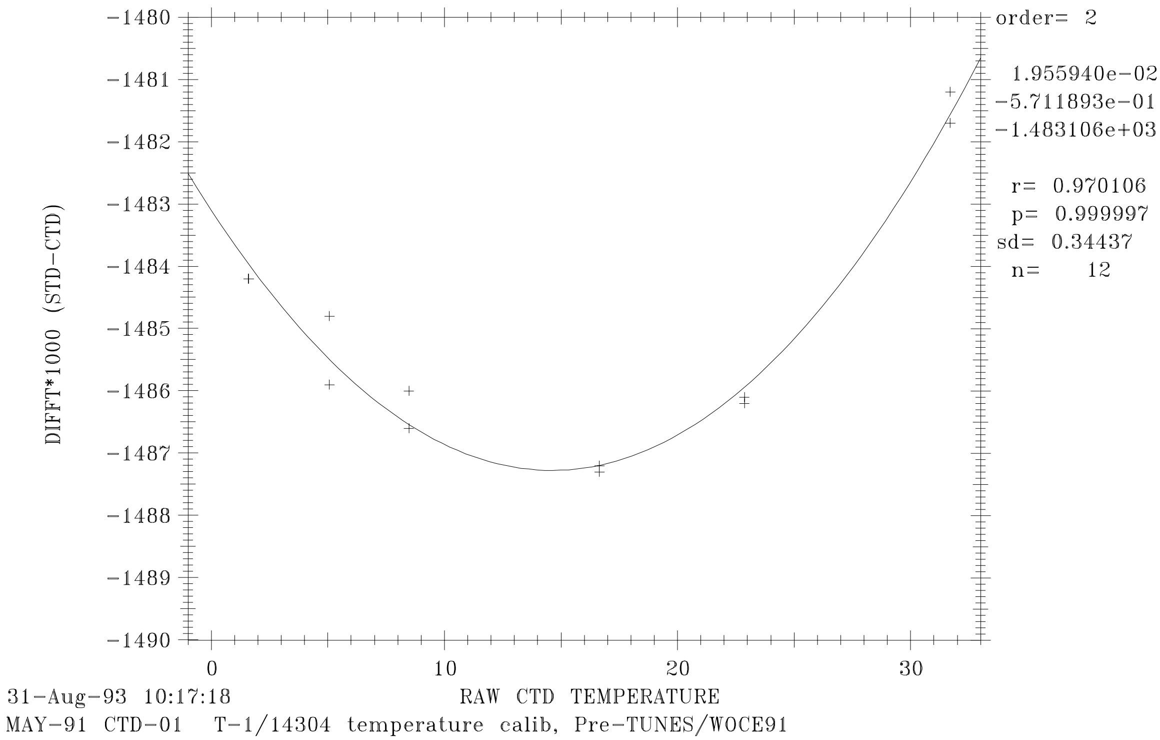


Figure 4a: CTD #1 Pre-cruise PRT-1 Temperature Calibration

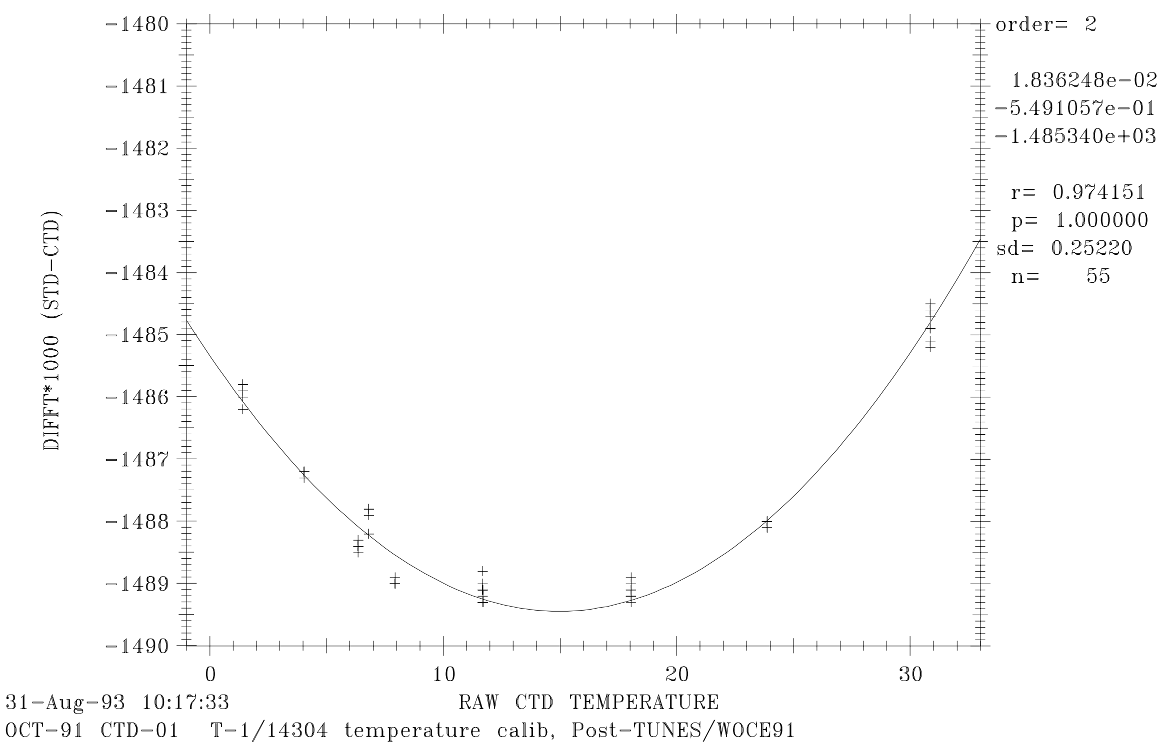


Figure 4b: CTD #1 Post-cruise PRT-1 Temperature Calibration

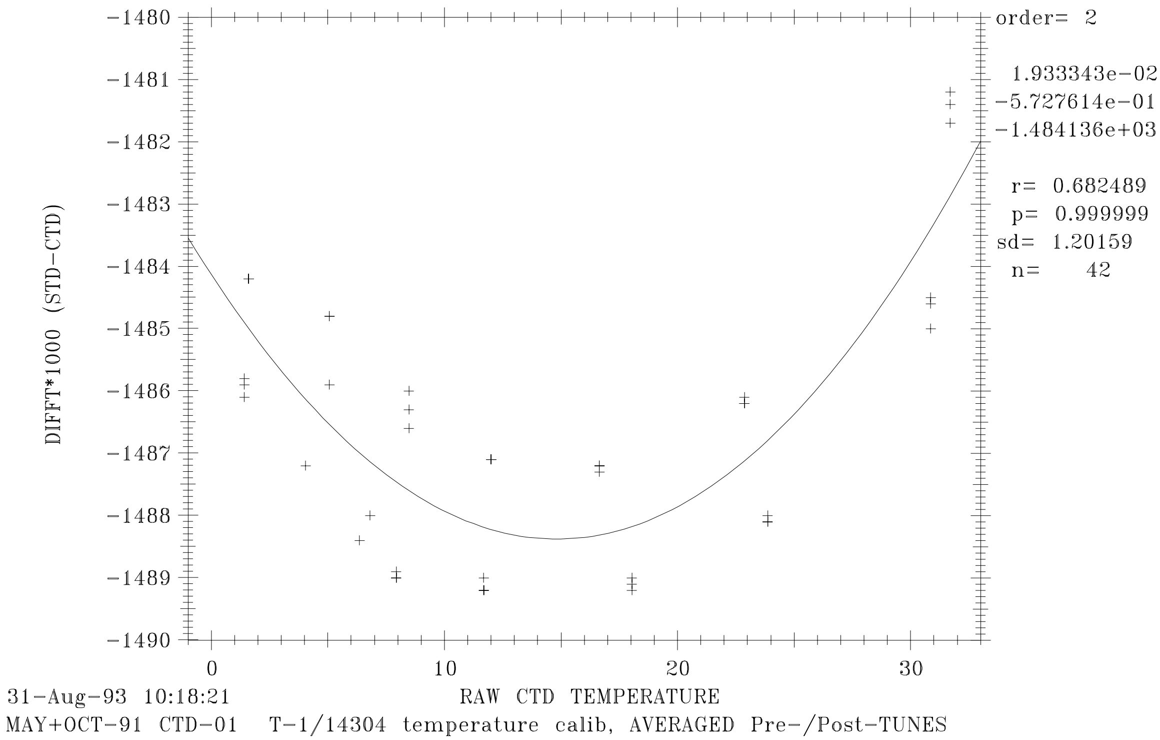


Figure 4c: CTD #1 Averaged Pre-/Post-cruise PRT-1 Temperature Calibration

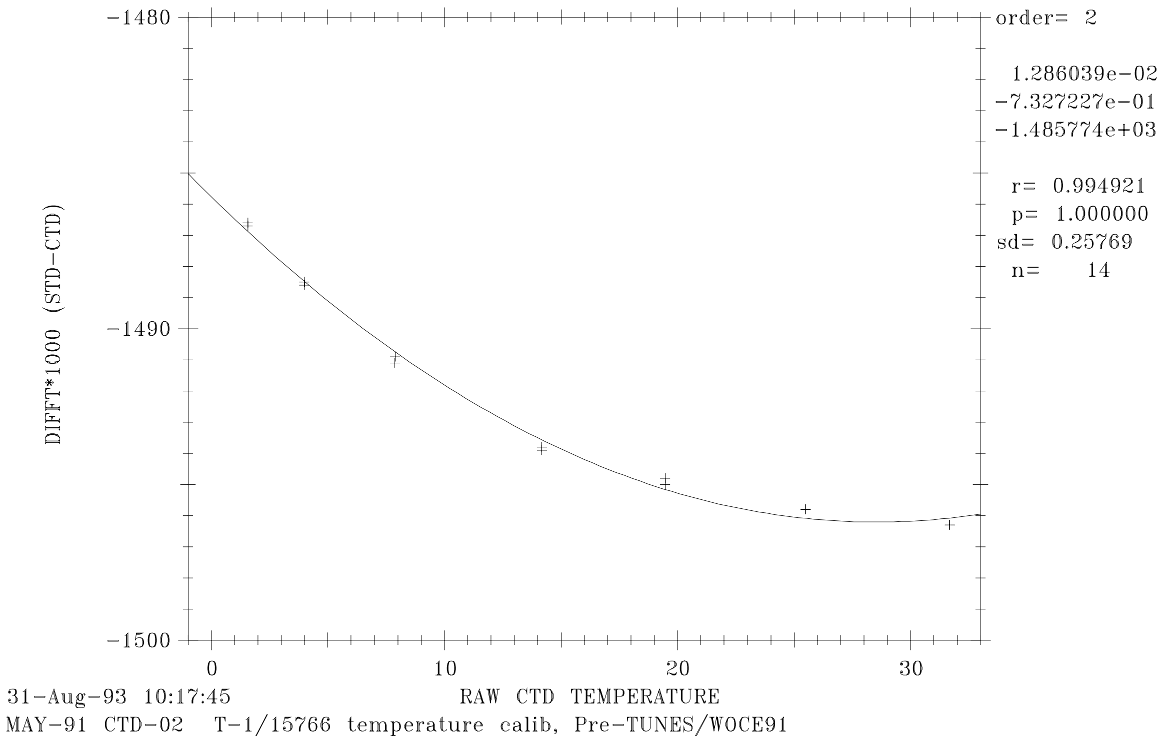


Figure 5a: CTD #2 Pre-cruise PRT-1 Temperature Calibration

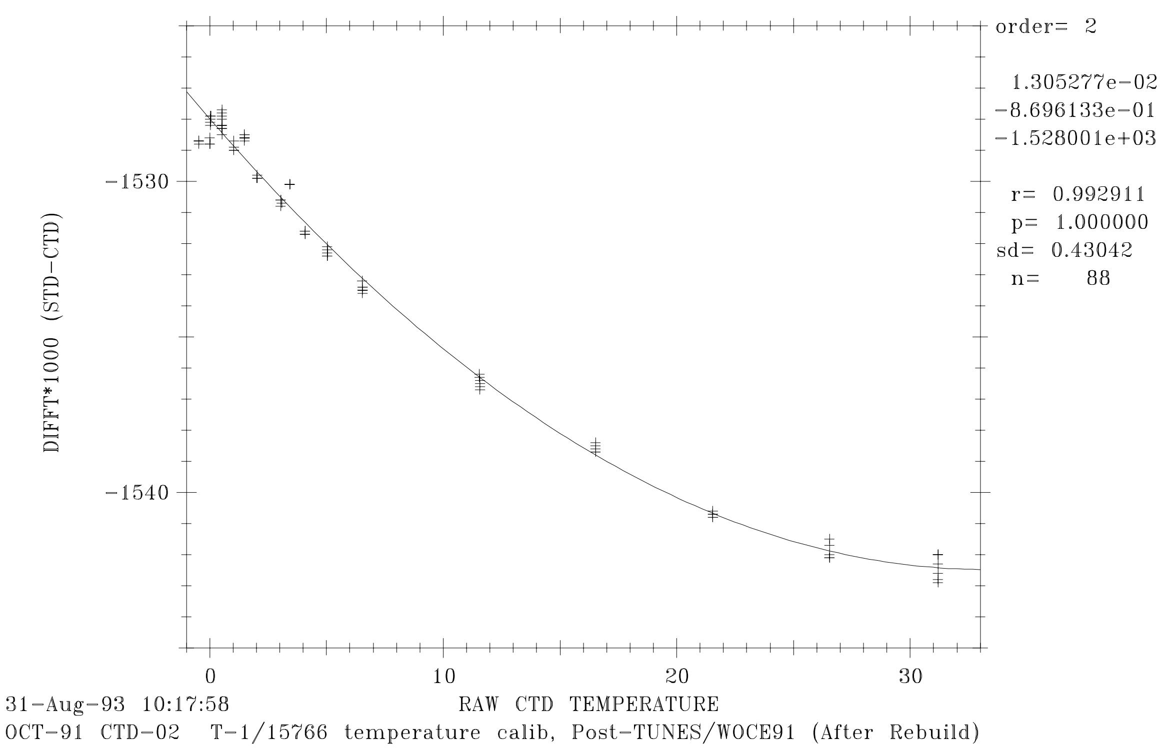


Figure 5b: CTD #2 Post-cruise PRT-1 Temperature Calibration

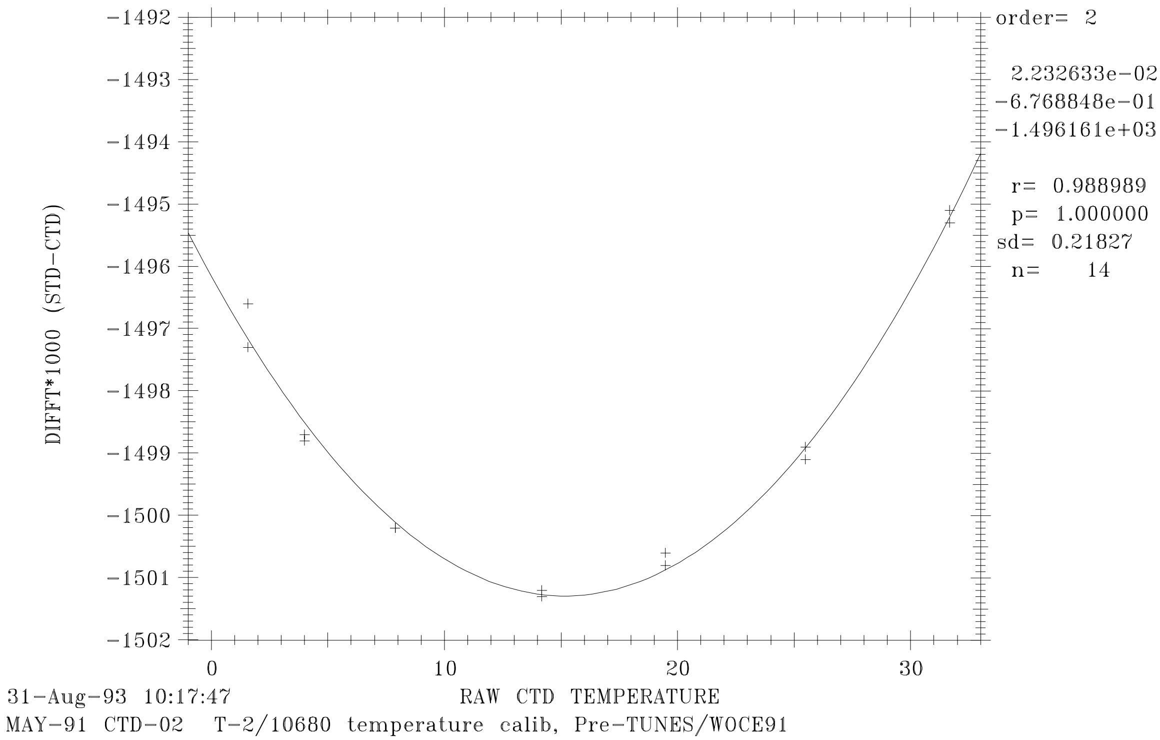


Figure 5c: CTD #2 Pre-cruise PRT-2 Temperature Calibration

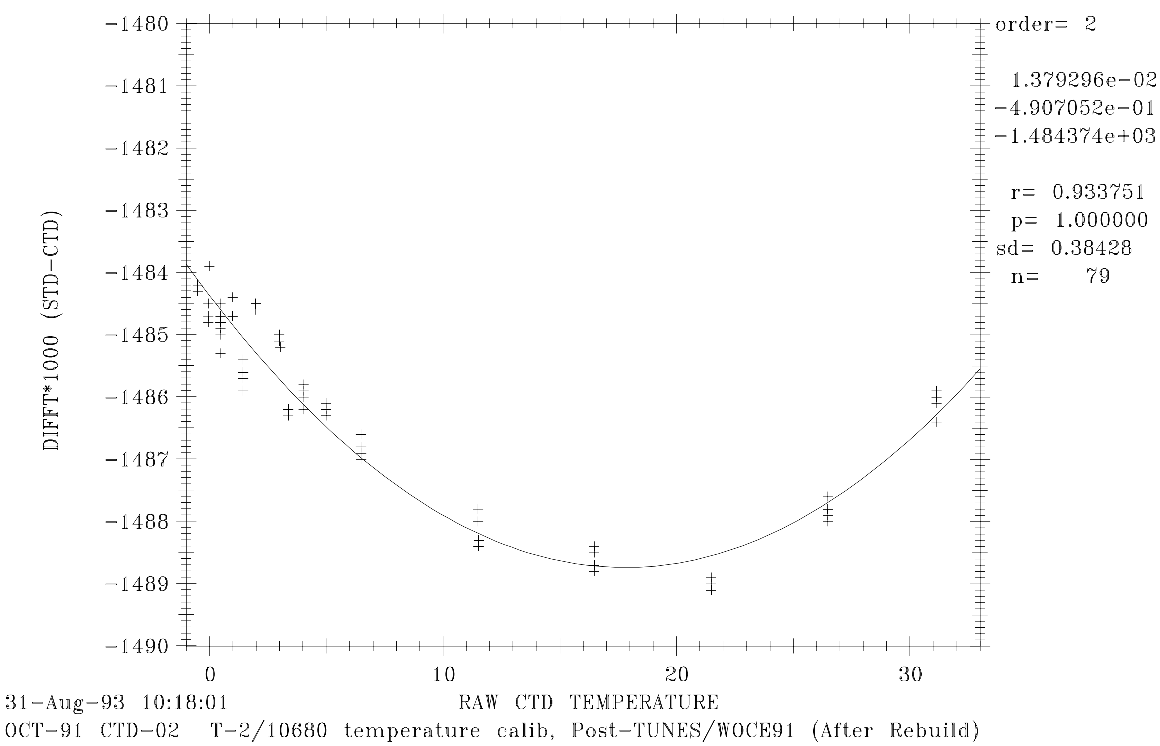


Figure 5d: CTD #2 Post-cruise PRT-2 Temperature Calibration

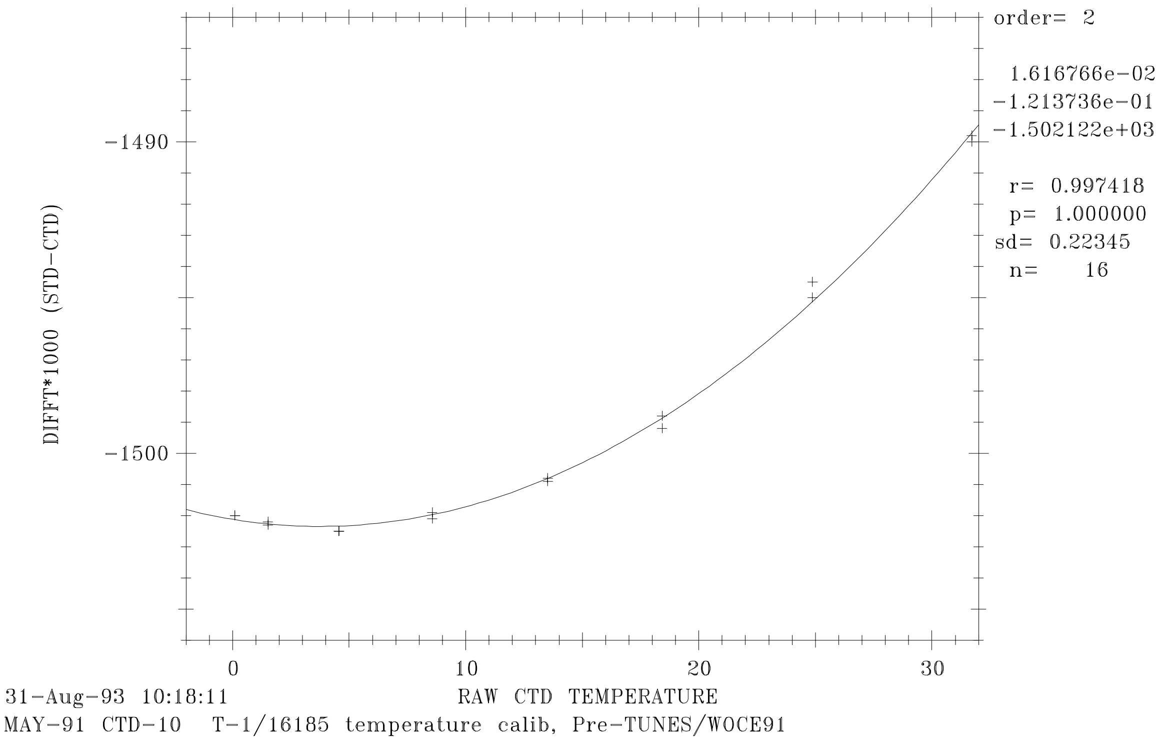


Figure 6a: CTD #10 Pre-cruise PRT-1 Temperature Calibration

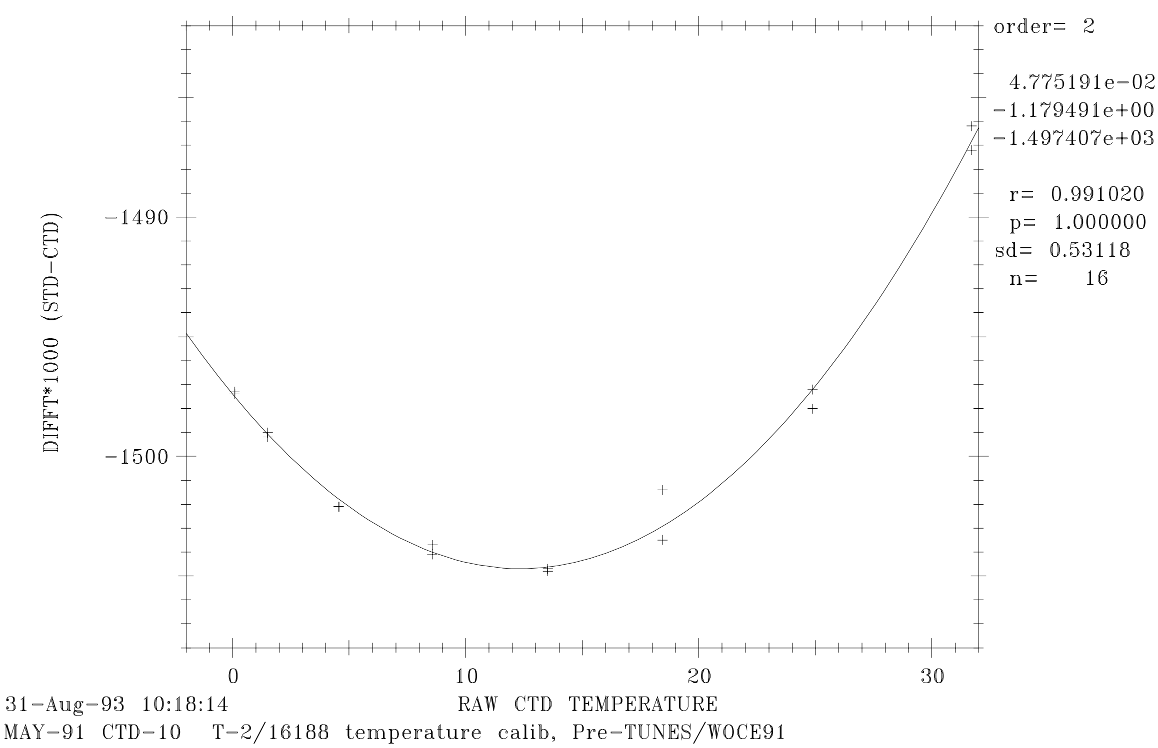


Figure 6b: CTD #10 Pre-cruise PRT-2 Temperature Calibration

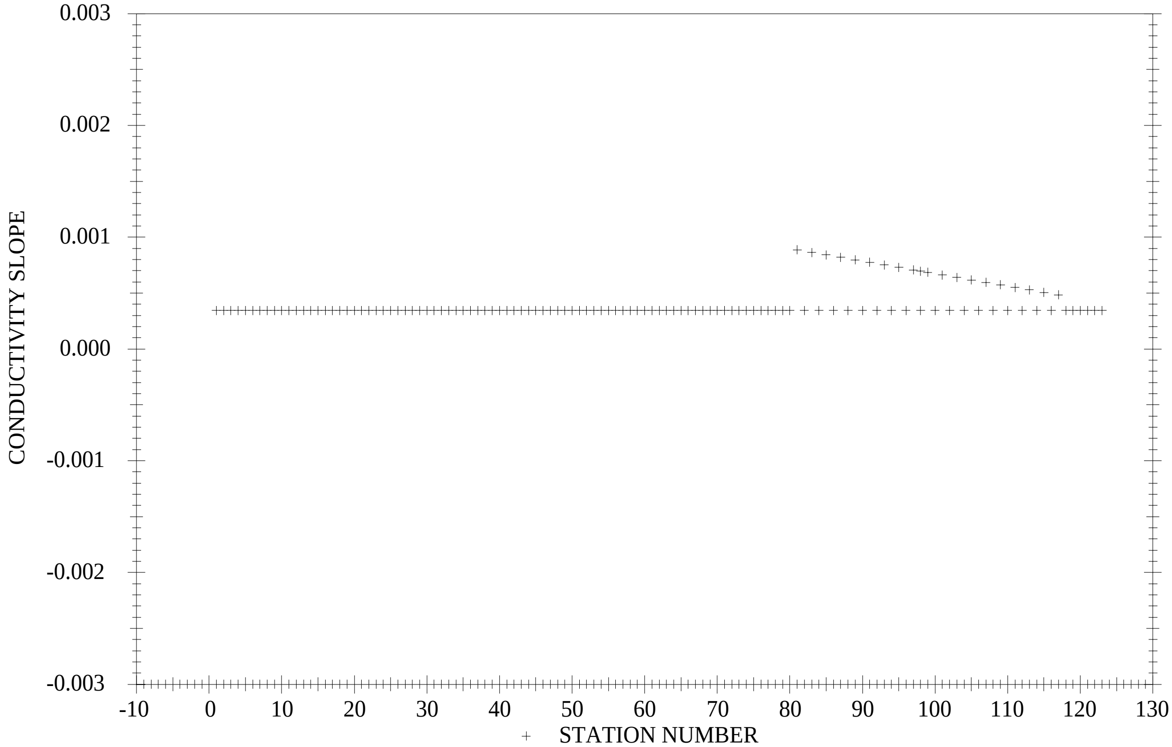


Figure 7a: TUNES-1 Conductivity Slopes, All CTDs

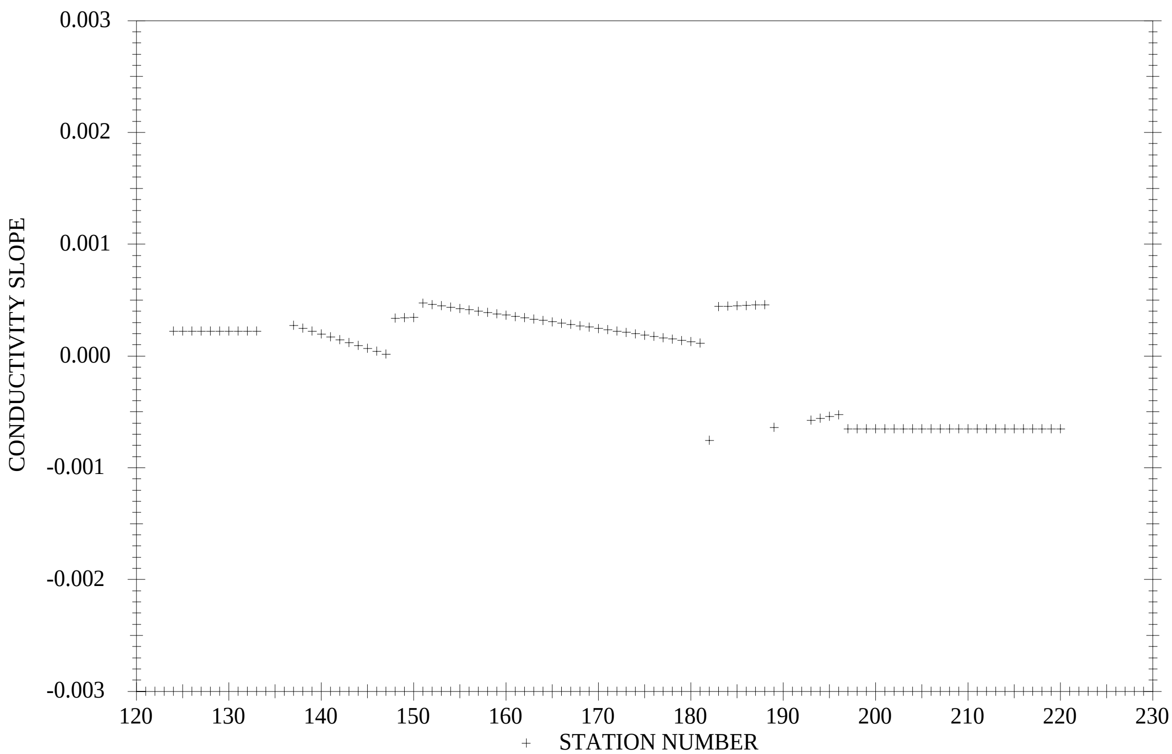


Figure 7b: TUNES-2 Conductivity Slopes, All CTDs

NOTE: Stas 133-136 and 190-192 Cond. Slopes are Off-Scale

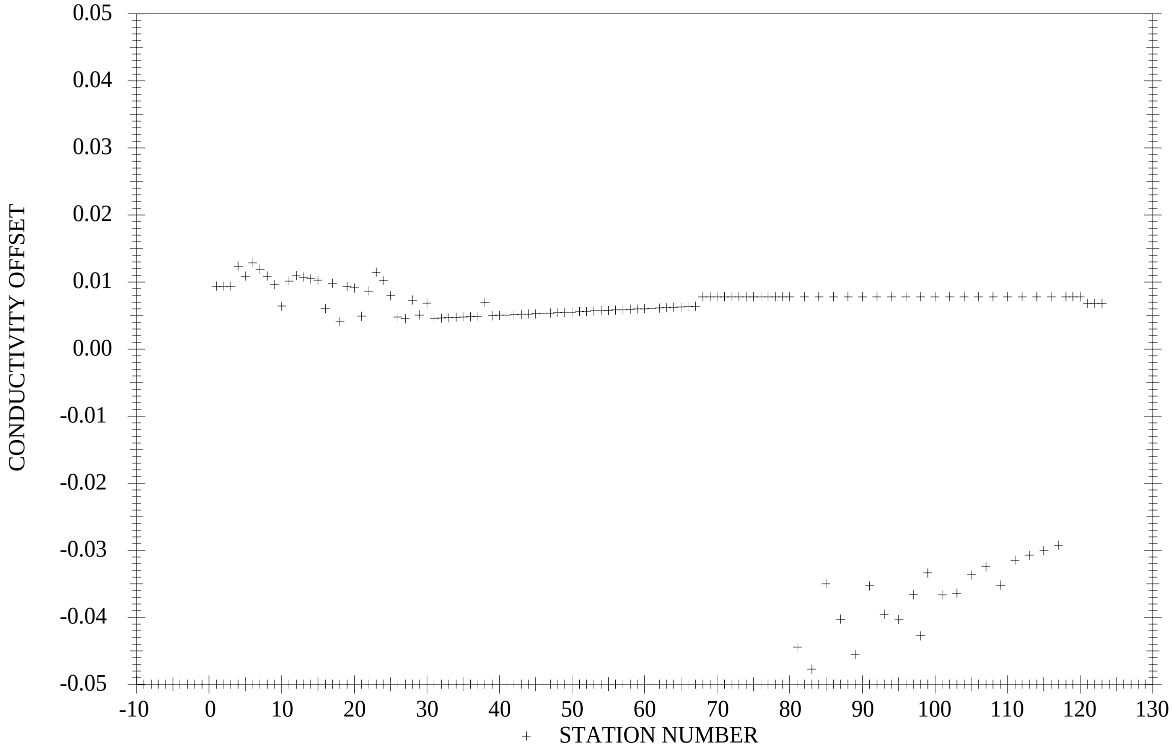


Figure 8a: TUNES-1 Conductivity Offsets, All CTDs

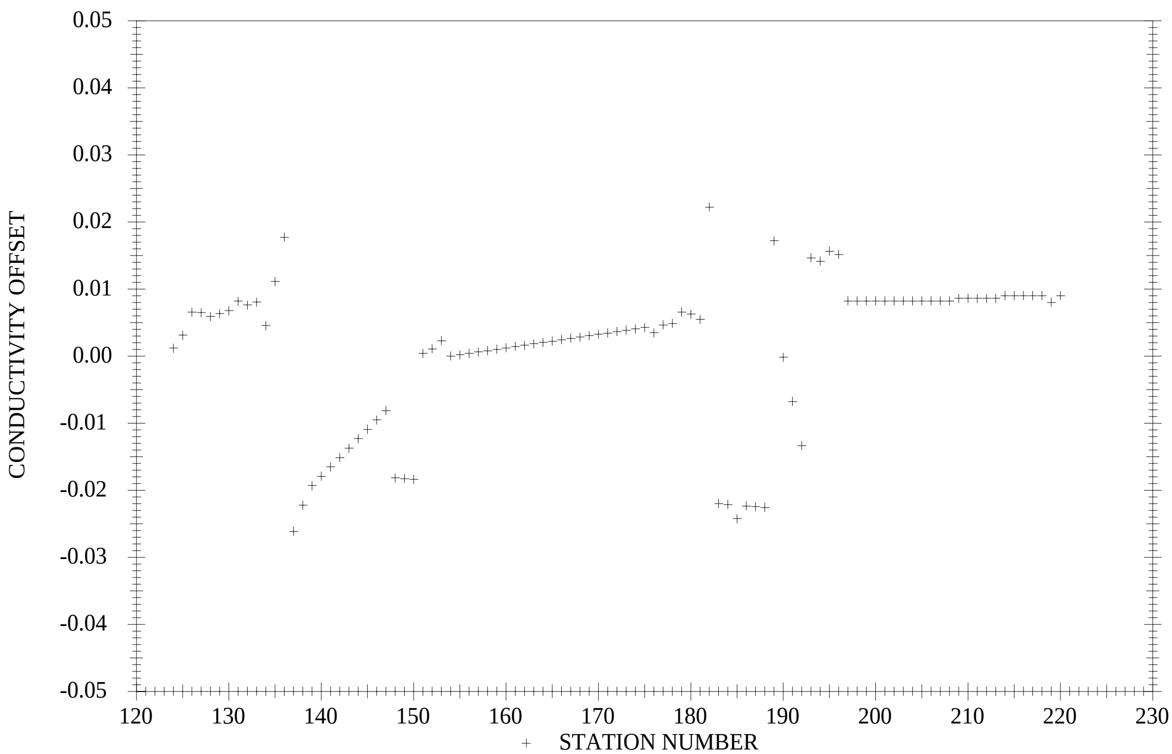


Figure 8b: TUNES-2 Conductivity Offsets, All CTDs

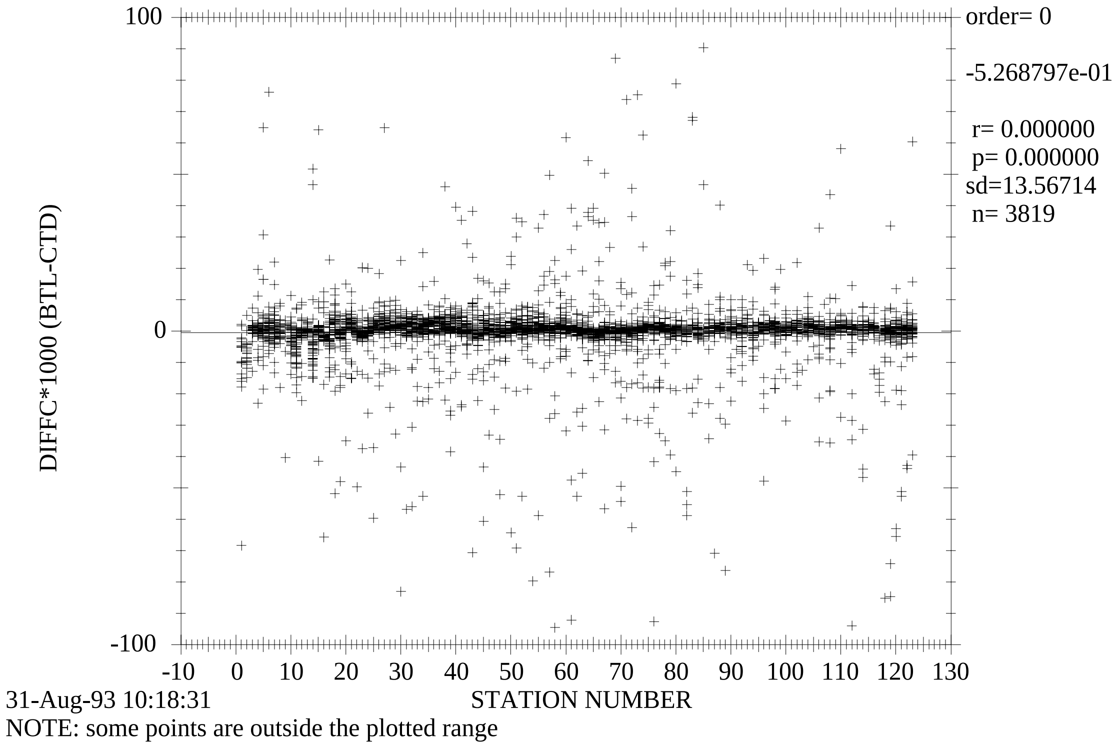


Figure 9a: TUNES-1 Residual Conductivity Bottle-CTD Differences - All Pressures

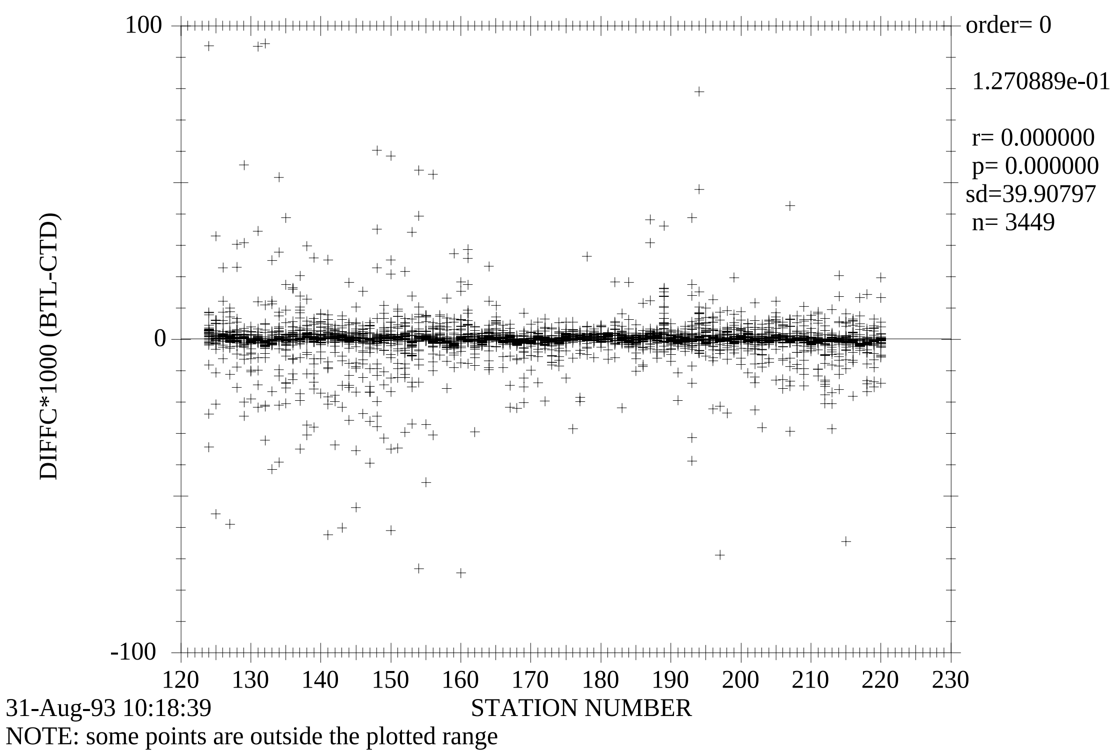


Figure 9b: TUNES-2 Residual Conductivity Bottle-CTD Differences - All Pressures

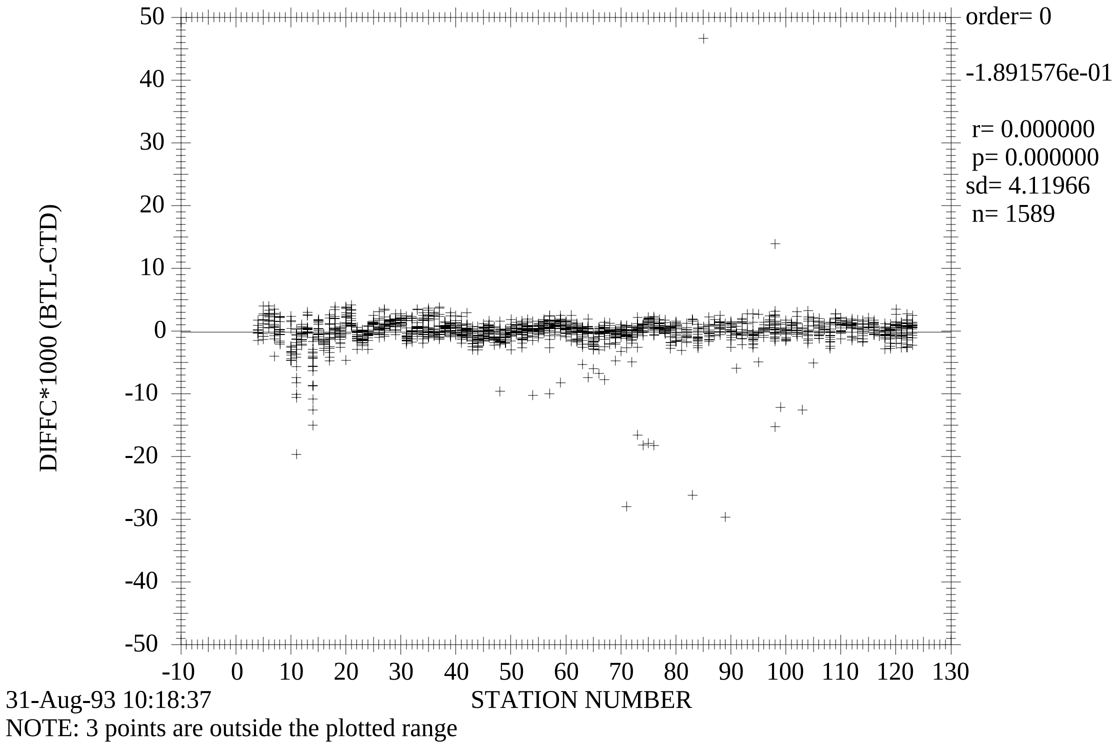


Figure 10a: TUNES-1 Residual Conductivity Bottle-CTD Differences - Prs>1500dbar

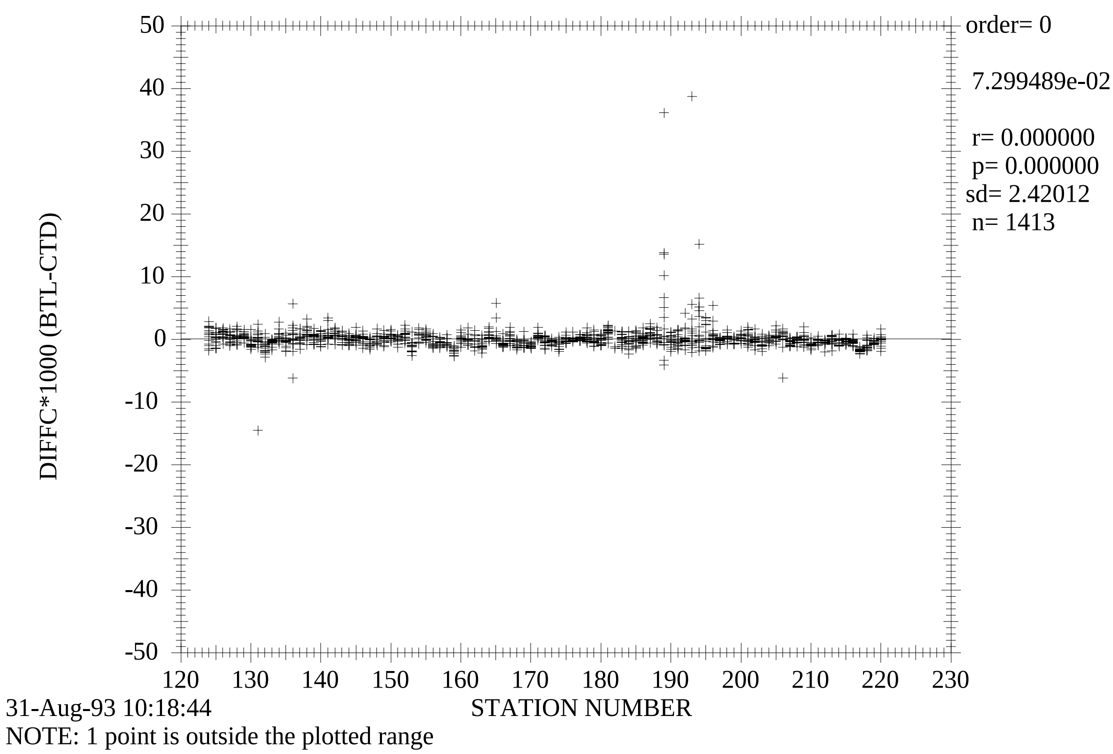


Figure 10b: TUNES-2 Residual Conductivity Bottle-CTD Differences - Prs>1500dbar

Appendices

Appendix 1: DATA COMMENTS (routine hydrography)
(Kristin Sanborn, SIO/ODF)

Remarks for deleted or missing samples from WOCE Pacific 91 P17S, P16S: Investigation of data may include comparison of bottle salinity and oxygen with CTD data, review of data plots of station profile and adjoining stations, rereading of charts (ie. nutrients). Comments from the Sample Logs and ODF's results of investigation are included in this report. Each station number is shown as a header, with concatenated cast/sample number (i.e., 101 = cast 1, bottle 01) for each comment.

STATION 124	
1all	Nutrients: Bubbles were coming through NO_2 and PO4, either a valve was partly stopped-up or a leak in the NO_2 sample tube.
101 @ 1db	Sample log: "Top valve not closed." Samples appear to be okay.
108 @ 181db	Sample log: "Leaking, open end top and bottom leaked." Samples appear to be okay.
113 @ 454db	Sample log: "Top valve leak." PO4 low see 1all comment. Other samples appear to be okay. Footnote po4 bad, rerun of po4 agrees with original -.01.
120 @ 1392db	PO4 unreasonably low. See 1all Nutrients comment. Footnote po4 bad, ODF recommends deletion.
121 @ 1581db	PO4 unreasonably low. See 1all Nutrients comment. Footnote po4 bad, ODF recommends deletion.
129 @ 2989db	PO4 unreasonably high. See 1all Nutrients comment. Footnote po4 bad, ODF recommends deletion. Rerun of po4 agrees with original -.02.
130 @ 3185db	PO4 unreasonably high. See 1all Nutrients comment. Footnote po4 bad, ODF recommends deletion. Rerun of po4 agrees with original -.02.
132 @ 3692db	Sample log: "No samples drawn." No samples drawn, reason not in sample log.
133 @ 3692db	PO4 unreasonably high. See 1all Nutrients comment. Footnote po4 bad, ODF recommends deletion.
135 @ 4305db	Sample log: "Cracked stopcock." Samples agree with CTD profile and adjoining station.
136 @ 4562db	Sample log: "Small stopcock leak." Samples agree with CTD profile and adjoining station.
STATION 125	
101 @ 0db	Sample log: "Missed top valve; leaked." Salinity and oxygen agree with CTD, other samples appear to be okay.
128 @ 2976db	Salt missing. Sample depleted while experiencing radio interference.

STATION 126	
106 @ 137db	All hydro data bad, leak or hangup Footnote salinity, oxygen, and nuts bad, ODF recommends deletion.
116 @ 640db	Sample log: "stopcock leaked." Oxygen high vs. CTDO, but samples all agree with adjoining station.
135 @ 4394db	Sample log: "oxygen was taken before helium."
136 @ 4452db	Sample log: "small air leak." Oxygen appears a little high, salinity slightly low (.0013) so samples may have been affected. Footnote oxygen bad, bottle leak may only affect gas samples. Footnote bottle leaking.
STATION 127	
130 @ 3285db	Tsuchiya: "Verify the decrease in sil level (by ~5µm/l) from the previous station. This is probably real; see the sil level on next station." No analytical problem noted.
131 @ 3482db	Tsuchiya: "See 130 comment."
132 @ 3680db	Tsuchiya: "See 130 comment."
133 @ 3892db	Tsuchiya: "See 130 comment."
STATION 128	
125 @ 2364db	No oxygen, forgot to record Manostat. Footnote oxygen lost.
STATION 129	
209 @ 268db	All hydro data bad, leak or hangup Footnote salinity, oxygen, and nuts bad, footnote bottle leaking, ODF recommends deletion.
217 @ 872db	Sample log: "dripping from valve." Samples appear to be okay.
229 @ 3186db	No water, lanyard hangup Sample log: "didn't trip; top lanyard was stuck."
231 @ 3598db	Tsuchiya: "Max in O_2 and minima in all three nuts. Are these real?" No analytical problems noted, oxygen agrees with CTDO and samples agree with next station.
234 @ 4211db	Sample log: "bottom lanyard." No water, lanyard hangup
STATION 130	
101 @ 0db	Sample log: "top was left open." All samples appear to be okay.
111 @ 359db	Sample log: "Bottle open." No samples taken
113 @ 486db	Sample log: "Spring leaks." All samples appear to be okay.
135 @ 4412db	Sample log: "stop cock leaked." All samples appear to be okay, oxygen agrees with CTDO.
136 @ 4545db	Sample log: "maybe an air leak." All samples appear to be okay, oxygen is a little low compared with CTDO but agrees with adjoining station.

STATION 131	
101 @ 0db	Sample log: "leaks again; top not tight." Oxygen slightly high compared to CTDO. Leave as is.
105 @ 135db	Tsuchiya: "O_2 minimum real? Check against CTD O_2." Oxygen looks low compared with CTDO and adjoining stations. Footnote oxygen bad.
112 @ 462db	Sample log: "Drain valve broke off, nuts, salt only." Oxygen not drawn.
113 @ 562db	Sample log: "leaky; bottom end cap." Oxygen looks okay.
115 @ 762db	Tsuchiya: "PO4 and NO3 appear to be too high, but may be real because O_2 shows correspondingly low values." No analytical problem noted.
123 @ 1918db	Delta-S is -0.0177. Salt same as 122, all else ok. Suspect duplicate draw with 122, footnote salinity bad, ODF recommends deletion of salinity.
126 @ 2507db	Sample log: "dripping from spigot." Samples look okay.
137 @ 662db	Tsuchiya: "PO4 and NO3 appear to be too high, but may be real because O_2 shows correspondingly low values." No analytical problem noted.
STATION 133	
106 @ 154db	Bottle leaked or hung, all bad. Footnote salinity, oxygen and nuts bad, ODF recommends deletion.
117 @ 922db	Sample log: "vent not closed." Salinity and oxygen agree with CTD. Samples look good.
STATION 134	
133 @ 3679db	Tsuchiya: "The sudden decrease in near bottom SiO3 from Sta. 133 to 134 real? (Sta. 135 on shows the same level of low Sio3)." 133-136 No analytical problems noted. Samples look okay.
134 @ 3884db	Tsuchiya: "See 133 comment."
135 @ 4090db	Tsuchiya: "See 133 comment."
136 @ 4219db	Tsuchiya: "See 133 comment." Sample log: "air leak; water shooting out from spigot without top open." Samples look okay compared with adjoining station.
STATION 135	
101 @ 0db	Delta-S at 0db is -0.1998 No analytical problem, po4 high. The computer did take two tries to get the first conductivity. Next station's salinity also appears low. Station 137-139 indicates this bottle had a problem. Footnote bottle leaking and samples as bad.
127 @ 2675db	Tsuchiya: "O_2 looks too low." No analytical problems noted. Agrees with CTDO.
136 @ 4346db	Sample log: "air band loose" Samples look okay compared with CTD and adjoining station.

STATION 136

101 @ 0db	Delta-S at 0db is 0.132 No analytical problem, other samples look okay. The computer did take two tries to get the first conductivity. Previous station's salinity also appears low. Station 137-139 indicates this bottle had a problem. Footnote bottle leaking, salinity bad, and oxygen and nutrients as bad.
106 @ 196db	Bottle leaked or hung, all bad. Footnote salinity, oxygen and nuts bad, footnote bottle leaking, ODF recommends deletion.
123 @ 1710db	Delta-S at 1710db is -0.0076 No analytical problem. Footnote salinity uncertain.
135 @ 4061db	Sample log: "stopcock leaked." Samples agree with adjoining stations.
136 @ 4212db	Delta-S at 4212db is 0.0072 No analytical problem, other samples look okay. Footnote salinity uncertain.

STATION 137

101 @ 1db	Sample log: "look at top!! ok bottom lid." Samples appear to be okay agree with adjoining stations and CTD profile.
111 @ 360db	Sample log: "post trip? thermo? Lower lid hung on marmon clamp." Footnote salinity, oxygen, and nuts bad, bottle leaking, ODF recommends deletion.
117 @ 821db	Sample log: "top valve not closed." Oxygen agrees with CTD profile and previous station.
134 @ 3920db	Nutrients: Ran out of hydrazine samples 34-36. The po4 sample may be .02 high. See comments on 135, footnote po4 bad.
135 @ 4127db	Tsuchiya: "PO4 slightly too high?" The bottom 2 po4 are about .02 high, analyst reran samples after stds. Unfortunately, there appears to be a drift on the reruns, but we can't change the data based on no3, footnote po4 bad.
136 @ 4289db	Tsuchiya: "PO4 slightly too high?" See comments for 134-135, footnote po4 bad.

STATION 138

101 @ 2db	Sample log: "leaks." Samples appear to be okay.
111 @ 464db	Lower lid hung on marmon clamp. Footnote salinity, oxygen and nuts bad, bottle leaking, ODF recommends deletion.
121 @ 1642db	Salinity lost, no reason noted, the system tried 9 times to get a reading.
131 @ 3499db	Raw oxygen sheet has order of 30 and 31 reversed. Oxygen agrees with CTD profile and adjoining station. Other samples except salinity appear to be okay. Delta-S at 3499db is 0.0037 No analytical problem, footnote salinity uncertain.

STATION 139	
101 @ 2db	Sample log: "little leak." Samples agree with adjoining station.
111 @ 412db	Sample log: "has air because bottle hose clamp of the CTD had to be rotated. Oxygen seems high compared to adjoining station and CTDO. Other samples look okay. Footnote oxygen uncertain, bottle leak that may only affect gas samples.
127 @ 2676db	Tsuchiya: "Verify that the decrease (by 3-4 µm/l) in sil from Sta 138 to 139 is not a measurement error 127-129." No analytical problems noted.
128 @ 2884db	Tsuchiya: See comments 127.
129 @ 3091db	Tsuchiya: See comments 127.
136 @ 4324db	Sample log: "leaked." Oxygen appears slightly high. Check with CTDO. Other samples appear okay.
STATION 140	
113 @ 569db	Sample log: "bottom cap leaked." Samples appear to be okay.
131 @ 3506db	Sample log: "slow spigot leak." Samples appear to be okay.
STATION 141	
101 @ 3db	Sample log: "still weak" Oxygen appears to be okay as are other samples. Not sure what sample log comment refers to.
117 @ 924db	Sample log: "top not closed." Oxygen and other data appears to be okay.
130 @ 3292db	Delta-S at 3292db is 0.0036 No analytical problem, other samples appear okay. Footnote salinity uncertain.
STATION 142	
112 @ 4298db	Tsuchiya: "Bottom po4 and no3 slightly higher than those at Stas. 141 and 143." No analytical problems noted.
113 @ 1db	Sample log: "oxygen was run before helium."
117 @ 135db	Sample log: "small leak." Samples look good for shallow water.
135 @ 1744db	Sample log: "bottom leaked." Samples look okay.
136 @ 1950db	Sample log: "leaking when opened." Oxygen looks slightly high compared with CTDO and adjoining station. Footnote oxygen bad, bottle leak, but may have only affected gas samples.
STATION 143	
306 @ 173db	All parameters indicate leak or lid hangup. Footnote salinity, oxygen and nuts bad, bottle leaking, ODF recommends deletion.
311 @ 397db	Sample log: "bottom cap bumped open." Oxygen agrees with CTDO, other samples appear to be okay.
336 @ 4279db	Sample log: "vent leaked." Samples look okay.

STATION 144	
135 @ 4187db	Sample log: "small top leak." Tsuchiya: "no3 slightly too high?" No analytical problems noted.
136 @ 4336db	Sample log: "major air leak." Tsuchiya: "all three nutrients too high?" No analytical problems noted.
STATION 145	
111 @ 374db	Sample log: "top vent not closed." Samples look okay.
STATION 146	
117 @ 925db	Sample log: "leaks with top valve closed." Samples look okay. Oxygen agrees with CTDO. Salt values lost: radio interference.
124 @ 2056db	PO4 bottles 24-34 appears to be high by about 0.05 µm/l. No math errors, and no obvious way to correct. Leave as is, footnote po4 uncertain.
125 @ 2262db	See 124 po4 comment, footnote po4 uncertain.
126 @ 2417db	See 124 po4 comment, footnote po4 uncertain.
127 @ 2573db	See 124 po4 comment, footnote po4 uncertain.
128 @ 2728db	See 124 po4 comment, footnote po4 uncertain.
129 @ 2883db	See 124 po4 comment, footnote po4 uncertain.
130 @ 3091db	See 124 po4 comment, footnote po4 uncertain.
131 @ 3298db	See 124 po4 comment, footnote po4 uncertain.
132 @ 3507db	See 124 po4 comment, footnote po4 uncertain.
133 @ 3713db	See 124 po4 comment, footnote po4 uncertain.
134 @ 3921db	See 124 po4 comment, footnote po4 uncertain.
136 @ 4326db	Sample log: "leaky with top valve closed." Samples agree with adjoining stations.
STATION 148	
136 @ 4013db	Sample log: "major air leaking." Salt & no3 okay, sil & po4 low, oxy high. Footnote bottle leaking, oxygen, silicate and po4 bad.
STATION 150	
130 @ 3090db	Tsuchiya: "sil minimum real? (or sil max at 129 real?" No analytical problems noted.
131 @ 3297db	Tsuchiya: "O_2 maximum real?" No analytical problems noted. O_2 agrees with CTDO.
134 @ 3712db	No water samples, no reason in sample log
STATION 151	
101 @ 3db	Oxygens may be slightly low, footnote oxygen bad. Oxygen: "Bubble in O_2 flask, may have pulled air in when brought into van colder than insitu temperature. $_{O2}$ may be slightly high."
102 @ 44db	See 101 oxygen comment, footnote oxygen bad.

STATION 152	
101 @ 2db	Sample log: "top was left open." Samples look okay. Oxygen: "Bubble in O_2 flask, may have pulled air in when brought into van colder than insitu temperature. O_2 may be slightly high."
119 @ 1028db	Sample log: "helium had to be re-run." Samples look okay
130 @ 2884db	Sample log: "helium had to be re-run." Samples look okay
STATION 153	
227 @ 2676db	Tsuchiya: "All nuts look too low (bottom 9 bottles) 227-238. Oxygen is higher and no3 is lower than Sta 152,154." No analytical problems. Therefore, features are probably real.
228 @ 2884db	Tsuchiya: "See 227 comments."
229 @ 3091db	Tsuchiya: "See 227 comments."
230 @ 3299db	Tsuchiya: "See 227 comments."
231 @ 3506db	Tsuchiya: "See 227 comments."
232 @ 3714db	Tsuchiya: "See 227 comments."
233 @ 3921db	Tsuchiya: "See 227 comments."
234 @ 4129db	Sample log: "lanyard to bottom cap hung up; no sample."
235 @ 4337db	Tsuchiya: "See 227 comments." Sample log: "bottom cap leak when vent opened." Delta-S at 4337db is -0.0034 Salinity difference is not unreasonable just not to ODF standards, no analytical problems. Oxygen appears to be okay as well as other samples.
238 @ 4487db	Tsuchiya: "See 227 comments."
STATION 154	
116 @ 722db	Delta-S at 722db is 0.0442 Salinity analyst got out of sequence with samples. It is difficult to understand the pattern, however, this seems to have the same value as 17 and does not agree with CTD or adjoining stations. Footnote salinity bad, ODF recommends deletion.
138 @ 4340db	S high, nuts low, O_2 ok(!) Footnote salinity, oxygen and nuts as bad, ODF recommends deletion. S and nuts impossible. Correct O_2 could be artifact of leakage in both low and high O_2 regions above. Sample log "leaking; vent was open."
STATION 156	
117 @ 870db	Sample log: "top vent not closed." Oxygen agrees with adjoining station and CTDO. Other samples look okay.

STATION 157	
128 @ 2534db	Tsuchiya: "sil looks low relative to neighboring stations 128-138." Low compared with previous group of stations, but agree with next group of stations to Station 166. Oxygen goes up at station 157 also, feature appears real.
129 @ 2741db	Tsuchiya: "See 128 comments."
130 @ 2956db	Tsuchiya: "See 128 comments."
131 @ 2956db	Tsuchiya: "See 128 comments."
132 @ 3165db	Tsuchiya: "See 128 comments."
133 @ 3165db	Tsuchiya: "See 128 comments."
134 @ 3377db	Tsuchiya: "See 128 comments."
135 @ 3375db	Tsuchiya: "See 128 comments."
138 @ 3534db	Tsuchiya: "See 128 comments."
STATION 158	
106 @ 178db	Sample log: "Nutrients were drawn before oxygens." Oxygen agrees with adjoining stations and CTDO.
STATION 159	
135 @ 3406db	Sample log: "bottom leaked." Delta-S at 3406db is -0.0032 Salinity is just within accuracy of measurement, 0ther samples appear to be okay.
STATION 161	
113 @ 350db	Sample log: "spigot leaks (o-ring?)" Salinity and oxygen agree with CTD and adjoining stations. Other samples also look okay.
116 @ 607db	Delta-S at 607db is 0.0318 Tsuchiya: "Salinity too high?" Salinity minimum gradient area, agrees with adjoining stations.
126 @ 2009db	Sample log: "spigot broken; missing collar on spigot." Salinity and oxygen agree with CTD and adjoining stations. Other samples also look okay.
127 @ 2205db	Sample log: "spigot leaks (o-ring?)." Salinity and oxygen agree with CTD and adjoining stations. Other samples also look okay.
STATION 162	
116 @ 655db	Sample log: "Bottom lid stuck open." No water drawn
117 @ 697db	Sample log: "little leak." Salinity and oxygen agree with CTD and adjoining stations. Other samples also appear okay.
135 @ 3809db	Sample log: "bottom leak." Salinity and oxygen agree with CTD and adjoining stations. Other samples also appear okay.
137 @ 622db	Delta-S is 0.2185. Salt high, no obvious error, nuts, O_2 ok Footnote salinity bad, ODF recommends deletion.

STATION 163	
101 @ 2db	Sample log: "bottle open." Rosette hit ship on recovery, breaking bottles 1,8,9,10, and opening drain valves on bottle 12. Nuts obtained on all bottles by recovering water between drain valve and lower lid. Salts missed on 1 and 9. O_2 missed on 1, 9, 10, Salinity not drawn. Oxygen not drawn. Samples appear to be okay.
108 @ 370db	Sample log: "bottle broken; see 101." Samples agree with CTD and adjoining station. Leave as is.
109 @ 434db	Sample log: "bottle open." Bottle broken; see 101. Oxygen and salinity not drawn. Samples appear to be okay.
110 @ 501db	Sample log: "bottle broken; see 101." Oxygen not drawn. Samples appear to be okay.
112 @ 636db	Sample log: "bottle open." Drain valve opened by hitting ship; see 101. Samples agree with CTD and adjoining station. Leave as is.
130 @ 2965db	Sample log: "major air leak." O_2 high, perhaps from air leakage at impact. Footnote oxygen bad, bottle leak which may have only affected gas samples, ODF recommends deletion of oxygen.
131 @ 3168db	O_2 high, perhaps from air leakage at impact. Footnote oxygen bad,bottle leak which may have only affected gas samples, ODF recommends deletion of oxygen.
135 @ 4001db	O_2 high, perhaps from air leakage at impact. Footnote oxygen bad, bottle leak which may have only affected gas samples, ODF recommends deletion of oxygen.
STATION 164	
135 @ 3677db	Sample log: "bottom cap leak (spring?)" Delta-S is .0021, all other deep salinities are no more than .0010. This was a duplicate trip with bottle 34. Suspect that there is slight leakage. Footnote bottle leaking, oxygen and salinity bad. See comment on Station 163, rosette hit side of ship.
STATION 165	
235 @ 1645db	Delta-S at 1645db is 0.0071 This is a duplicate trip with bottle 34 and samples do not agree. Suspect that there is slight leakage. See comment on Station 163, rosette hit side of ship. Footnote salinity, oxygen and nuts bad, bottle leaking, ODF recommends deletion.
STATION 166	
213 @ 672db	Sample log: "small bottom cap leak." Salinity and oxygen agree with CTD and adjoining stations. Other samples also look okay.
234 @ 3954db	Sil .6 µm/l low, peak looks good, no analytical error. Duplicate level with bottle 35. Footnote sil uncertain.

STATION 167	
106 @ 261db	Delta-S is -0.1847. Salt low, probable draw from 107 Footnote salinity bad, ODF recommends deletion.
111 @ 517db	Sample log: "tritium was drawn before CO_2."
113 @ 659db	Sample log: "tritium was drawn before CO_2."
119 @ 1028db	Sample log: "lanyard was caught in bottom cap." No water drawn
169 @ 384db	Sample log: "tritium was drawn before CO_2."
170 @ 445db	Sample log: "tritium was drawn before CO_2."
STATION 168	
168 @ 296db	Delta-S is 0.2607. Salt high, probable draw from 106 Footnote salinity bad, ODF recommends deletion.
STATION 169	
104 @ 81db	Tsuchiya: "Check if weak temperature inversion is real." Final CTD data indicates inversion is real.
117 @ 976db	Sample log: "top vent not tight." Samples appear to be okay, salinity and oxygen agree with CTD and adjoining stations.
STATION 170	
119 @ 924db	Sample log: "lanyard in bottom cap" No water drawn
1deep.	Tsuchiya: "Deep po4 (>1500m) increases at this station and remains high as far as Sta 174. Verify the increase because no3 does not show such an increase." Station 170 looked okay, 169 seemed low. Correction was made to ending F1 on Station 169
STATION 171	
107 @ 279db	Sample log: "bottle leaked." Salinity and oxygen agree with CTD and adjoining stations as do the other samples.
135 @ 4116db	Sample log: "slight leak in the bottom." Salinity and oxygen agree with CTD and adjoining stations as do the other samples.
137 @ 635db	Bottle salt drawn but not run, no reason. Salinometer log indicates there are only 35 samples. Footnote salinity lost.
STATION 172	
268 @ 211db	Sample log: "vent open." Salinity and oxygen agree with CTD and adjoining stations other samples also appear okay.

STATION 173	
113 @ 439db	Sample log: "leak in bottom." Salinity and oxygen agree with CTD and adjoining stations, other samples also appear okay.
115 @ 592db	Tsuchiya: "O_2 lower than neighboring stations." No analytical problem noted.
116 @ 669db	Tsuchiya: "O_2 lower than neighboring stations." No analytical problem noted.
117 @ 771db	Sample log: "was leaking (pushed in)." Samples appear to be okay.
137 @ 516db	Tsuchiya: "O_2 lower than neighboring stations." No analytical problem noted.
STATION 174	
102 @ 36db	Sample log: "Bottles were in the sun." Samples appear to be okay.
103 @ 72db	Sample log: "Bottles were in the sun." Samples appear to be okay.
104 @ 107db	Sample log: "Bottles were in the sun." Samples appear to be okay.
105 @ 138db	Sample log: "Bottles were in the sun." Samples appear to be okay.
125 @ 1532db	Tsuchiya: "O_2 too high? maximum seems questionable." O_2 does not agree with CTDO or adjoining stations. Other samples look good. No problems noted, footnote oxygen bad.
161 @ 4db	Sample log: "Bottles were in the sun." Samples appear to be okay.
STATION 175	
111 @ 534db	Tsuchiya: "O_2 looks too high; po4 and no3 look slightly low." There was what looked like a bubble after sample 11 in po4 and nO_2. However, the shipboard results seemed to be handled correctly. If this were a leaky bottle, O_2 would be low not high. Therefore, we will leave this level as is. Oxygen agrees with CTDO.
117 @ 979db	Sample log: "top vent not closed." Samples look okay.
128 @ 2279db	Sample log: "air got in niskin." Tsuchiya: "O_2 looks too high." Oxygen high compared with CTDO. Other samples okay. Footnote oxygen as bad, bottle leak which may only affect gas samples, ODF recommends deletion of oxygen.
135 @ 3991db	Sample log: "bottom cap leak." Samples look okay.
STATION 179	
206 @ 191db	O_2 high, S high, nuts low, CTD diff high Looks like bottle 6 leak or lid hangup Footnote bottle leaking, salinity, oxygen and nuts as bad, ODF recommends deletion.

STATION 181	
131 @ 4565db	Sample log: "small air leak." Samples look okay.
STATION 183	
106 @ 283db	Sample log: "bottle didn't close; lower lid hangup." no sample
111 @ 636db	Sample log: "bottle leaked." Samples look okay.
135 @ 5164db	Sample log: "bottom leaked." Samples look okay.
STATION 184	
138 @ 5439db	Sample log: "bottom end cap leak (o-ring?)." Samples look okay.
STATION 185	
117 @ 1130db	Sample log: "vent open." Samples look okay.
135 @ 5389db	Sample log: "bottom end cap leak." Samples look okay.
138 @ 5547db	Sample log: "top vent open." Oxygen appears low compared with Sta 181. Check with final CTDO. Footnote oxygen bad, bottle leak which may only affect gas samples. Footnote bottle leaking.
STATION 186	
115 @ 1030db	Tsuchiya: "Deep po4 is lower by .02 µm/l than stations 185 and 187." No analytical problems, other nutrients reflect this same feature.
STATION 187	
235 @ 5125db	Sample log: "bottom leak when air valve opened." Samples look okay compared with adjoining stations.
238 @ 5398db	Tsuchiya: "sil slightly too low." No analytical problems, other nutrients reflect this same feature.
STATION 189	
312 @ 516db	No nuts, not sampled, no reason. Nutrients: Failed to take samples.
364 @ 121db	Tsuchiya: "Verify the salinity minimum and O_2 maximum against CTD." The down and up CTD trace is very different, O_2 is not much help. Salinity agrees with CTD.
STATION 190	
116 @ 1016db	Sample log: "leaking from valve." Samples look okay compared with adjoining station.
STATION 191	
139 @ 5013db	Delta-S is -.0023 which is within accuracy of measurement, but does not fit adjoining station profiles. Leave as is. Bottle leaked or closed late. Footnote bottle leaking, salinity, oxygen and nuts bad, ODF recommends deletion.

STATION 192	
106 @ 186db	Delta-S at 186db is 0.0914 No analytical problem noted. Footnote salinity bad measurement. Footnote nutrients bad measurement. Footnote oxygen bad measurement. Suspect this bottle had a late closure. Footnote bottle leaking. ODF recommends deletion of all water samples.
113 @ 513db	Sample log: "small bottom end cap leak." Samples appear to be okay. This bottle may have been a problem throughout the cruise. See Station 193, 202 and intermittent stations before and after these have comments on this bottle.
134 @ 4545db	Delta-S at 4545db is 0.0052 Does not agree with adjoining stations or CTD. Footnote salinity bad, ODF recommends deletion.
STATION 193	
113 @ 511db	Delta-S at 511db is -0.0415 JS: "Double trip with 137? CFC values approx. equal." Salinity too low. Nutrients too high. Oxygen slightly low. Bottle appears to have leaked. Footnote bottle as leaking, Oxygen and nuts as bad, ODF recommends deletion.
STATION 194	
311 @ 527db	Sample log: "the ring came of the spigot." Salinity and oxygen agree with CTD and adjoining stations. Other samples also appear to be okay.
313 @ 668db	Sample log: "top came off; loose." Salinity and oxygen agree with CTD and adjoining stations. Other samples also appear to be okay.
STATION 195	
128 @ 3015db	Tsuchiya: "Sil slightly too high." Sil peak not very good, footnote sil as bad.
STATION 197	
1all	Sample log: "oxygens were drawn out of order." Oxygens look a little noisy. Not sure exactly what comment refers to.
118 @ 1179db	Delta-S at 1179db is -0.0807. Sample log indicates some kind of salinity drawing problem, there is no bottle 20 listed, but it was drawn. Could be a drawing problem and drawn at bottle 15. Footnote salinity bad, ODF recommends deletion.
131 @ 3609db	Sample log: "small leak." Samples look good compared to adjoining stations.
STATION 198	
239 @ 4760db	Sample log: "small bottom cap leak when air vent opened." Samples look okay compared with previous station.

STATION 201	
106 @ 224db	Sample log: "top valve not closed." Samples look okay compared with adjoining station.
161 @ 1db	Sample log: "top valve not closed." Samples look okay compared with adjoining station.
STATION 202	
113 @ 675db	Delta-S at 635db is -0.0247 JS: "Tripping trouble? See Sta 193. This station is slightly" more subtle but has same "double trip" signature. CFC also almost identical." This bottle and 37 tripped sequentially on the fly at about 675db. This makes all the sample bad at this pressure (635).
117 @ 973db	Sample log: "vent not closed." Samples look okay compared with adjoining station.
137 @ 675db	Delta-S at 708db is 0.0166 See 113 tripping problem. This bottle and 13 tripped sequentially on the fly at about 675db. This makes all the sample bad at this pressure (708).
STATION 203	
117 @ 982db	Sample log: "small leak." Samples look okay compared with adjoining station.
122 @ 1638db	Nuts look like drawn from 121 Footnote nuts bad, ODF recommends deletion.
125 @ 2157db	Oxygen appears high. po4 & sil slightly low. Salinity and no3 look okay. Footnote oxygen as uncertain, as well as po4 and sil.
139 @ 4495db	Sample log: "was leaking from the bottom." Samples look okay compared with adjoining station.
STATION 204	
130 @ 2079db	Tsuchiya: "Deep sil looks too low relative to adjoining stations." No analytical problem, peak looks good.
STATION 205	
125 @ 2458db	Low O_2, no calc. error. Does not agree with CTDO. Footnote oxygen bad, ODF recommends deletion.
STATION 206	
126 @ 2430db	Delta-S at 2430db is -0.0071 Looks like drawing error. Footnote salinity bad, ODF recommends deletion.
129 @ 3195db	Sample log: "bottle did not close; lanyard ball caught in frame."
168 @ 288db	JS: "Samples do not fit profiles (may just be unusual water)." Oxygen agrees with CTDO.
STATION 207	
117 @ 961db	Delta-S is 0.0494. Salt off, same as 118, prob bad draw. Footnote salinity bad, ODF recommends deletion.

STATION 209	
111 @ 405db	Sample log: "leaking from stopcock even when vent was closed." Samples look okay.
128 @ 3037db	Tsuchiya: "Verify that the sudden decrease in sil concentrations near the sil max (~3000m) from Sta 208 to Sta 209 is real (~136 µm/l at Sta 208 and ~132 um/l at Sta 209. There are similar decreases in po4 and no3 at about the same depth range." No analytical problems.
STATION 210	
206 @ 162db	Sample log: "No water, lower lid held open by lanyard (lanyard was too tight)."
STATION 211	
102 @ 36db	Sample log: "Bottle broke on recovery, rosette hit ship." No oxygen drawn.
111 @ 359db	Sample log: "small bottom end cap leak." Oxygen agrees with CTDO.
118 @ 969db	Tsuchiya: "verify the decrease in deep po4 (theta < 5 deg) from Station 210 to 211." No analytical problems noted.
STATION 212	
121 @ 1270db	Sample log: "lanyard broke; no sample."
124 @ 1833db	Oxygen: Flask broke when opened. Footnote oxygen lost.
139 @ 4102db	Late closure on bottle. Nuts high, oxygen and salts low. Footnote bottle leaking, all water samples bad, ODF recommends deletion.
STATION 213	
113 @ 531db	Sample log: "leaked." Samples look okay compared with adjoining station.
STATION 214	
111 @ 449db	Sample log: "leaked." Samples look okay.
STATION 216	
162 @ 33db	Sample log: "loose spigot." Samples look okay compared with adjoining station.
STATION 217	
131 @ 3193db	Sample log: "slight leak." Samples look okay.
169 @ 437db	Sample log: "tritium was drawn before oxygen." Oxygen looks slightly high compared with adjoining station and CTDO, footnote oxygen bad.

STATION 219	
119 @ 956db	Looks like sampling error for nutrients. Footnote po4, no3, sil, nO_2 bad, ODF recommends deletion.
162 @ 32db	Sample log: "vent not closed." Samples look okay compared with adjoining stations.
STATION 220	
113	Sample log: "did not trip; no sample." Pylon was switched before bottle 13, so it was missed (not tripped).
134	Sample log: "Samples not needed, so do not sample -JHS"
138 @ 3636db	Sample log: "leaked from bottom end cap." Samples look okay.
139	Sample log: "Samples not needed, so do not sample -JHS"

APPENDIX 2: **Routine hydrographic data not having "2" quality codes**
(Kristin Sanborn, SIO/ODF)

BOTTLES WHERE QUALITY CODES WERE NOT "22222222", SORTED BY ERROR/PROBLEM TYPE

EXPOCODE: 31WTTUNES_2
WHP-ID: P17S, P16S
CRUISE DATES: 16 July 25 August 1991

Quality code bytes in the original SIO/ODF .SEA file are in the following order:

BTLNBR	CTDSAL	SALNTY	OXYGEN	SILCAT	NITRAT	NITRIT	PHSPHT
	PSS-78	PSS-78	UMOL/KG	UMOL/KG	UMOL/KG	UMOL/KG	UMOL/KG

(each record is listed as station, cast/bottle number, quality code)

SLT lost

125	128	22122222
138	121	22122222
146	117	22122222
171	137	22122222

OXY lost

128	125	22212222
212	124	22212222

PO4 uncertain

146	124	22222223
146	125	22222223
146	126	22222223
146	127	22222223
146	128	22222223
146	129	22222223
146	130	22222223
146	131	22222223
146	132	22222223
146	133	22222223
146	134	22222223

PO4 bad

124	113	22222224
124	120	22222224
124	121	22222224
124	129	22222224
124	130	22222224
137	134	22222224
137	135	22222224
137	136	22222224

SIL uncertain

166	234	22223222

SIL bad

195	128	22224222

SIL bad, NO3 bad, NO2 bad, PO4 bad

203	122	22224444
219	119	22224444

SIL not drawn, NO3 not drawn, NO2 not drawn, PO4 not drawn

189	312	22229999

OXY uncertain, NO3 uncertain, PO4 uncertain

203	125	22233223

OXY bad

131	105	22242222
151	101	22242222
151	102	22242222
174	125	22242222
205	125	22242222
217	169	22242222

OXY not drawn

131	112	22292222
163	110	22292222
211	102	22292222

SLT uncertain

136	123	22322222
136	136	22322222
138	131	22322222
141	130	22322222

SLT bad

131	123	22422222
154	116	22422222
162	137	22422222
167	106	22422222
168	168	22422222
192	134	22422222
197	118	22422222
206	126	22422222
207	117	22422222

SLT not drawn, OXY not drawn

163	101	22992222
163	109	22992222

BTL leaking, OXY bad

126	136	32242222
139	111	32242222
142	136	32242222
163	130	32242222
163	131	32242222
163	135	32242222
175	128	32242222
185	138	32242222

BTL leaking, SLT bad, OXY bad, SIL bad, NO3 bad, NO2 bad, PO4 bad

126	106	32444444
129	209	32444444
133	106	32444444
135	101	32444444
136	101	32444444
136	106	32444444
137	111	32444444
138	111	32444444
143	306	32444444
154	138	32444444
165	235	32444444
179	206	32444444
191	139	32444444
192	106	32444444
193	113	32444444
202	113	32444444
202	137	32444444
212	139	32444444

BTL leaking, OXY bad, SIL bad, PO4 bad

148	136	32244224

BTL leaking, SLT bad, OXY bad

164	135	32442222

BTL samples not drawn

124	132	92999999
129	229	92999999
129	234	92999999
130	111	92999999
150	134	92999999
153	234	92999999
162	116	92999999
167	119	92999999
170	119	92999999
183	106	92999999
206	129	92999999
210	206	92999999
212	121	92999999

Appendix C: TUNES Calibration Figures

NOTE: some differences fall outside of the plotted limits.
Please refer to the bottle data quality codes.

Appendix D: TUNES Processing Notes

TUNES-2 / WOCE-P17S/P16S CTD Shipboard and Processing Comments

sta/cast	Comments
998/01	using CTD-1 from beginning of cruise. TEST cast: btls 20-36 all tripped at 1000m; 3 additional btls tripped at 400m
124/01	repeat station 123 from leg 1
125/01	
126/01	
127/01	
128/01	-.1 mmho/cm cond. spike at 148-152 db down; despiked/ok now
129/01	ABORT at 150m: sensor caps on/pinger off; data not saved
129/02	1-hr deploymt delay when rosette hit ship hard at initial launch: weights knocked loose, CTD end clamp broken, other misc.breakage. No cast# assigned to 2-minute first launch/data not used.
130/01	brief yoyo on down (15 to 12m) at base of T mixed-layer
131/01	
132/02	
133/01	frequent/high cond. noise (not drop-outs) on down from 810-1300 db, again 1985-bottom; yoyo 50m back down after 2544 db trip to check sensor response: problem occurs when P increases cracked cell? yoyo from 2546-2598 db up; 436,448,478 db levels interpolated: cutouts in raw data signal.
134/01	replaced cond. cell with new spare prior to cast.
135/01	cond. problem may still be here, but smaller amplitude
136/01	cond. problem still here: maybe FSI temp board?
137/01	switch to CTD-2 beginning this cast
138/01	
139/01	
140/01	
141/01	
142/01	dipped into water before sensor covers removed/pinger on; trip inner rosette first for freons
143/03	
144/01	
145/01	
146/01	xmiss cleaned at start of cast
147/01	

sta/cast	Comments
148/01	used PRT-1 for primary temperature during cast; used PRT-2 for final data see station 150 PRT comments
149/01	used PRT-1 for primary temperature during cast; used PRT-2 for final data see station 150 PRT comments
150/01	PRT-1 T offsets: +.7 deg at 528 db down and two smaller offsets. PRT-1 definitely sick; used PRT-2 for final data
151/01	CTD-10 starting here; trip detect only sees outer pylon: CTD data for top 12 trips extracted manually
152/01	
153/02	
154/01	
155/01	
156/01	
157/01	
158/01	
159/01	pauses at 2549/2742 db trips for winch operator work
160/01	
161/01	
162/01	
163/01	
164/01	
165/02	inner pylon tripped first for freons
166/02	
167/01	
168/01	no well-defined mixed layer
169/01	
170/01	stop at 1812 db down: winch trouble
171/01	
172/02	
173/01	
174/01	
175/01	
176/01	
177/01	
178/01	
179/02	cast start delayed 10 mins. after rosette hit side of ship: one lanyard broken/repaired, no other damage noted.
180/02	xmiss check (before or after cast?)
181/01	
182/01	ABORT at 100m down: complete signal loss; CTD-10 flooded
182/02	back to CTD-1 w/orig. C-sensor, changed shielding around PRT-2 temperature interface. Cond. problem worse: shorten cast to 2000m/24 btls. Cond. noise has pressure-direction (down) dependence, up much cleaner. -.2 mmho/cm cond. spike 252-254 db up: despiked/ok now. Multiple spikes on up cast, most despiked/ok now. Some smaller cond. noise still remains. Yoyo from 294-330 db up.

sta/cast	Comments
183/01	back to CTD-2 using PRT-2 for primary temperature. No inner-pylon detect circuit in: CTD data for top 12 trips extracted manually. Ctdoxy signal cutouts top 120 db. Two DSRTs added to each cast from here to end of cruise to monitor PRT drifting problems.
184/01	still no inner-pylon detect, CTD data for top 12 trips extracted manually; ctdoxy signal cutouts top 70 db
185/01	pylon detect for inner pylon installed; ctdoxy problem fixed: sensor interconnect cable problem.
186/01	
187/02	ctdoxy probe acting up till 1900 db down
188/01	new oxygen sensor; PRT-2 jumped; cond. seems ok
189/01	ABORT at 300m: CTD-2/PRT-2 + cond. jumping; PRT-1 locked up at 32767 (raw data)
189/02	ABORT at 300m similar problems to cast 1
189/03	rebuilt CTD-2: CTD-2 card cage in CTD-1 Pressure case w/turret, PRT, endcaps, A/D, digitizer, mmux, P/T/orig.C sensors from CTD-1: still cond. noise: low-side S noise from CTD-1 moved to CTD-2? Ctdoxy sensor malfunctioning, reads 20% of normal values; ctdoxy data not usable. Delay 27 minutes at 15m down: computer problems.
190/01	CTD-2 cond. sensor interface board swapped in, ctdoxy sensor wires swapped; using CTD-1 tty/fsk card; ctdoxy still not working see cast 189/03. Cast delayed 15 minutes for cable/connector repairs. Yoyo from 2968-2978 db up.
191/01	CTD oxygen useless again: see cast 189/03
192/01	CTD oxygen useless again: see cast 189/03; pinger died near bottom
193/01	delay cast start 40 mins.: replaced CTD-1 cond sensor interface. Replaced ctdoxy sensor w/old one: ok. Yoyo from 2632-2642 db up.
194/01	TEST cast to <600m using CTD-2 P-sensor interface: no effect.
194/02	TEST cast to <600m using CTD-10 T-sensor interface: no effect.
194/03	CTD-1 P/T sensor interfaces. Same cond. noise as before.
195/01	experiments w/winch speed vs. cond. noise on downcast
196/01	found loose FSI-T bulkhead connector, tightened it: changed, but did not eliminate, cond. noise: some stable cond. areas.
197/01	replaced FSI bulkhead/cleaned cond. sensor guard: coating on PRT/cond. guard peeling off: large sheet still attached to top of guard: apparently flapped over cond. cell going down, flapped out of the way going up. Removed coating from guard: no more cond. problem!
198/02	
199/01	
200/01	
201/01	

sta/cast	Comments
202/01	
203/01	rosette lowered into bottom (+8m after btm trip): winch went the wrong way; no damage, but bottom cond. spike cut off in p-series. 1418 db level interpolated: cutout in raw data signal.
204/01	NEW END TERMINATION prior to cast; steep btm/side of seamount
205/01	problem w/winch or heave compensator from 15m to 2233m
206/01	
207/01	steep bottom
208/01	yoyo from 17-4 db down
209/01	-.5 mmho/cm cond. spike (seasnot?) 1056-1070 db down: despiked/ok now
210/02	
211/01	1-hr delay at cast start: dead signal in-water, immed. back out: slip ring plug slipped/plugged back in and insulation repaired. Second false-start when cast resumed before computer ready. Data from false starts not saved.
212/01	heave-compensator disabled 15-260m down as a test
213/01	bad/high ctdoxy rdgs up: water leaked into sensor
214/01	
215/01	
216/01	
217/01	rosette briefly out of water before srfc btl closed; lowered back in
218/01	
219/01	
220/01	descent delayed 5 mins. due to heave compensator

TUNES-2: CAST STOPS LONGER THAN 1-MINUTE

station /cast	down /up	#minutes stopped	avg.pressure (decibars)	pressure range
124/01	DOWN	2.3	18	(16 20)
125/01	DOWN	1.9	18	(16 20)
126/01	DOWN	7.7	2	(0 4)
		2.1	18	(16 20)
127/01	DOWN	3.5	18	(16 20)
128/01	DOWN	5.0	18	(16 20)
129/02	DOWN	1.9	18	(16 20)
130/01	DOWN	1.1	8	(6 10)
		2.8	18	(16 20)
131/01	DOWN	5.1	18	(16 20)
132/02	DOWN	4.0	16	(14 18)
133/01	UP	1.6	16	(14 18)
		2.7	2545	(2544 2546)
134/01	UP	2.0	16	(14 18)
135/01	UP	1.6	1	(0 2)
		4.7	14	(12 16)
		1.5	368	(366 370)
136/01	UP	1.8	18	(16 20)
		1.7	2308	(2306 2310)
137/01	DOWN	2.3	17	(16 18)
138/01	DOWN	6.0	18	(16 20)
139/01	DOWN	1.9	20	(18 22)
140/01	DOWN	2.8	20	(18 22)
141/01	DOWN	2.0	18	(16 20)
142/01	DOWN	4.6	2	(0 4)
		1.9	16	(14 18)
143/03	DOWN	1.4	4	(0 8)
		2.4	21	(20 22)
144/01	DOWN	2.5	18	(16 20)
145/01	DOWN	1.8	20	(18 22)
146/01	DOWN	2.1	18	(16 20)
147/01	DOWN	1.9	20	(18 22)
148/01	DOWN	2.9	18	(16 20)
149/01	DOWN	1.6	20	(18 22)
150/01	DOWN	2.6	18	(16 20)
151/01	DOWN	1.8	19	(18 20)
152/01	DOWN	2.0	20	(18 22)
153/02	DOWN	2.9	18	(16 20)
154/01	DOWN	1.9	20	(18 22)
155/01	DOWN	2.0	22	(20 24)
156/01	DOWN	3.0	20	(18 22)
157/01	DOWN	2.1	20	(18 22)
158/01	DOWN	1.8	19	(18 20)
159/01	DOWN	2.2	22	(20 24)
160/01	DOWN	4.2	12	(10 14)
161/01	DOWN	2.3	22	(20 24)
		2.2	503	(500 506)
162/01	DOWN	3.1	22	(20 24)
		2.0	406	(404 408)
163/01	DOWN	1.8	22	(20 24)
		1.3	498	(496 500)
164/01	DOWN	1.9	20	(18 22)
		2.2	415	(412 418)

station /cast	down /up	#minutes stopped	avg.pressure (decibars)	pressure range
165/02	DOWN	2.3	20	(18 22)
166/02	DOWN	2.1	22	(20 24)
		1.6	410	(408 412)
167/01	DOWN	1.7	21	(20 22)
		1.2	410	(408 412)
168/01	DOWN	1.9	26	(24 28)
		1.6	410	(408 412)
169/01	DOWN	2.2	20	(18 22)
		1.2	547	(544 550)
170/01	DOWN	2.1	20	(18 22)
		9.6	1822	(1820 1824)
171/01	DOWN	2.5	20	(18 22)
172/02	DOWN	2.0	20	(18 22)
		1.2	426	(424 428)
173/01	DOWN	2.0	18	(16 20)
174/01	DOWN	2.5	22	(20 24)
175/01	DOWN	2.2	20	(18 22)
		1.0	409	(408 410)
176/01	DOWN	1.9	20	(18 22)
177/01	DOWN	2.5	22	(20 24)
178/01	DOWN	1.7	22	(20 24)
		1.3	412	(410 414)
179/02	DOWN	1.4	8	(6 10)
		2.0	24	(22 26)
180/02	DOWN	1.3	19	(18 20)
		1.1	442	(440 444)
181/01	DOWN	1.8	22	(20 24)
		1.8	405	(402 408)
		1.1	5801	(5798 5804)
182/02	UP	1.4	2	(0 4)
		2.0	16	(14 18)
		2.6	293	(292 294)
		1.8	510	(508 512)
		1.5	2042	(2040 2044)
183/01	DOWN	2.1	20	(18 22)
184/01	DOWN	2.6	18	(16 20)
185/01	DOWN	2.0	22	(20 24)
		1.4	515	(512 518)
186/01	DOWN	2.7	20	(18 22)
		1.4	612	(610 614)
187/02	DOWN	2.1	18	(16 20)
		1.1	394	(392 396)
188/01	DOWN	3.0	20	(18 22)
		1.5	512	(510 514)
189/03	UP@	1.2	2	(0 4)
		1.3	20	(18 22)
		1.1	516	(514 518)
		5.6	3094	(3092 3096)
		5.4	4442	(4440 4444)
190/01	UP@	2.1	22	(20 24)
		1.5	428	(426 430)
		5.6	2968	(2966 2970)
		5.5	4224	(4220 4228)
191/01	UP@	2.2	2	(0 4)
		2.4	18	(16 20)

station /cast	down /up	#minutes stopped	avg.pressure (decibars)	pressure range
		1.7	362	(360 364)
		5.2	2924	(2920 2928)
		5.4	4226	(4224 4228)
192/01	UP@	2.2	18	(16 20)
		1.4	44	(42 46)
		2.2	410	(408 412)
		5.1	2717	(2714 2720)
		5.4	4022	(4020 4024)
193/01	UP@	1.1	2	(0 4)
		2.0	18	(16 20)
		1.4	410	(408 412)
		5.7	2632	(2630 2634)
		1.7	3294	(3292 3296)
		5.2	3818	(3816 3820)
194/03	UP@	2.2	20	(18 22)
		1.3	526	(524 528)
		1.1	1432	(1430 1434)
		5.4	2862	(2860 2864)
		5.4	4164	(4162 4166)
195/01	UP@	1.2	1	(0 2)
		1.9	18	(16 20)
		1.9	404	(402 406)
		3.4	2184	(2182 2186)
		5.5	2800	(2796 2804)
		7.0	3385	(3382 3388)
		3.3	3439	(3438 3440)
		5.8	3861	(3858 3864)
196/01	UP@	2.3	18	(16 20)
		1.2	450	(448 452)
		5.3	2674	(2672 2676)
		5.3	3766	(3764 3768)
197/01	DOWN	4.3	18	(16 20)
		1.1	410	(408 412)
198/02	DOWN	2.3	18	(16 20)
		1.3	1657	(1654 1660)
199/01	DOWN	2.5	18	(16 20)
200/01	DOWN	1.8	18	(16 20)
		1.0	512	(510 514)
201/01	DOWN	2.4	18	(16 20)
		1.4	416	(414 418)
202/01	DOWN	1.7	18	(16 20)
203/01	DOWN	2.1	18	(16 20)
204/01	DOWN	4.8	24	(22 26)
205/01	DOWN	12.2	19	(16 22)
		1.3	396	(394 398)
206/01	DOWN	1.6	18	(16 20)
207/01	DOWN	2.0	18	(16 20)
208/01	DOWN	2.1	18	(16 20)
209/01	DOWN	2.9	18	(16 20)
210/02	DOWN	1.8	16	(14 18)
		1.2	408	(406 410)
211/01	DOWN	3.0	22	(20 24)
212/01	DOWN	6.5	17	(14 20)
213/01	DOWN	2.0	18	(16 20)
		1.1	400	(398 402)

station /cast	down /up	#minutes stopped	avg.pressure (decibars)	pressure range
214/01	DOWN	1.8	18	(16 20)
215/01	DOWN	1.0	19	(18 20)
		1.1	415	(414 416)
216/01	DOWN	2.2	18	(16 20)
		1.1	444	(442 446)
217/01	DOWN	2.2	17	(16 18)
218/01	DOWN	2.8	16	(14 18)
219/01	DOWN	2.1	20	(18 22)
220/01	DOWN	6.2	18	(16 20)
		1.2	420	(418 422)

@NOTE: two 5-minute therm soaks on each UP CAST, stas. 183-220

TUNES-2: CTD Temperature and Conductivity Corrections Summary

Sta/ Cast	PRT Response Time (secs)	Temperature Coefficients corT = t2*T2 + t1*T + t0			Conductivity Coefficients corC = c1*C + c0	
		t2	t1	t0	c1	c0
124/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0012
125/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0031
126/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0065
127/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0065
128/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0059
129/02	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0063
130/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0067
131/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0082
132/02	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0076
133/01	.325	1.93330e-05	-5.72760e-04	-1.4841	2.23244e-04	0.0080
134/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-3.80005e-02	0.0045
135/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-3.81843e-02	0.0111
136/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-3.83681e-02	0.0177
137/01	.360	1.28600e-05	-7.32720e-04	-1.5035	2.73821e-04	-0.0261
138/01	.360	1.28600e-05	-7.32720e-04	-1.5035	2.48147e-04	-0.0222
139/01	.360	1.28600e-05	-7.32720e-04	-1.5035	2.22472e-04	-0.0193
140/01	.360	1.28600e-05	-7.32720e-04	-1.5035	1.96798e-04	-0.0179
141/01	.360	1.28600e-05	-7.32720e-04	-1.5035	1.71124e-04	-0.0165
142/01	.360	1.28600e-05	-8.92720e-04	-1.5030	1.45449e-04	-0.0151
143/03	.360	1.28600e-05	-1.01272e-03	-1.5027	1.19775e-04	-0.0137
144/01	.360	1.28600e-05	-1.01272e-03	-1.5027	9.41008e-05	-0.0123
145/01	.360	1.28600e-05	-1.01272e-03	-1.5027	6.84265e-05	-0.0109
146/01	.360	1.28600e-05	-1.01272e-03	-1.5027	4.27522e-05	-0.0095
147/01	.360	1.28600e-05	-1.07272e-03	-1.5025	1.70779e-05	-0.0081
148/01	.500	1.37930e-05	-4.90710e-04	-1.4844	3.38337e-04	-0.0182
149/01	.500	1.37930e-05	-4.90710e-04	-1.4844	3.41332e-04	-0.0183
150/01	.500	1.37930e-05	-4.90710e-04	-1.4844	3.44328e-04	-0.0184
151/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.72316e-04	0.0004
152/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.60423e-04	0.0011
153/02	.240	1.61680e-05	-1.21370e-04	-1.5021	4.48529e-04	0.0023
154/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.36636e-04	-0.0000
155/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.24742e-04	0.0002
156/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.12848e-04	0.0004
157/01	.240	1.61680e-05	-1.21370e-04	-1.5021	4.00955e-04	0.0006
158/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.89061e-04	0.0008
159/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.77168e-04	0.0010
160/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.65274e-04	0.0012
161/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.53380e-04	0.0014
162/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.41487e-04	0.0016
163/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.29593e-04	0.0018
164/01	.240	1.61680e-05	-1.21370e-04	-1.5021	3.17700e-04	0.0020

Sta/ Cast	PRT Response Time (secs)	Temperature Coefficients corT = t2*T2 + t1*T + t0 t2	t1	t0	Conductivity Coefficients corC = c1*C + c0 c1	c0
165/02	.240	1.61680e-05	-1.21370e-04	-1.5021	3.05806e-04	0.0022
166/02	.240	1.61680e-05	-1.21370e-04	-1.5021	2.93912e-04	0.0024
167/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.82019e-04	0.0026
168/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.70125e-04	0.0028
169/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.58232e-04	0.0030
170/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.46338e-04	0.0032
171/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.34444e-04	0.0034
172/02	.240	1.61680e-05	-1.21370e-04	-1.5021	2.22551e-04	0.0036
173/01	.240	1.61680e-05	-1.21370e-04	-1.5021	2.10657e-04	0.0038
174/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.98764e-04	0.0040
175/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.86870e-04	0.0042
176/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.74976e-04	0.0034
177/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.63083e-04	0.0046
178/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.51189e-04	0.0049
179/02	.240	1.61680e-05	-1.21370e-04	-1.5021	1.39296e-04	0.0066
180/02	.240	1.61680e-05	-1.21370e-04	-1.5021	1.27402e-04	0.0063
181/01	.240	1.61680e-05	-1.21370e-04	-1.5021	1.15508e-04	0.0055
182/02	.325	1.93330e-05	-5.72760e-04	-1.4841	-7.54052e-04	0.0222
183/01	.500	1.37930e-05	-4.90710e-04	-1.4844	4.43169e-04	-0.0220
184/01	.500	1.37930e-05	-4.90710e-04	-1.4844	4.46165e-04	-0.0221
185/01	.500	1.37930e-05	-4.90710e-04	-1.4844	4.49160e-04	-0.0242
186/01	.500	1.37930e-05	-4.90710e-04	-1.4844	4.52155e-04	-0.0224
187/02	.500	1.37930e-05	-4.90710e-04	-1.4844	4.55150e-04	-0.0225
188/01	.500	1.37930e-05	-4.90710e-04	-1.4844	4.58145e-04	-0.0226
189/03	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.39488e-04	0.0172
190/01	.325	1.93330e-05	-5.72760e-04	-1.4841	4.87559e-02	-0.0002
191/01	.325	1.93330e-05	-5.72760e-04	-1.4841	4.89572e-02	-0.0068
192/01	.325	1.93330e-05	-5.72760e-04	-1.4841	4.91585e-02	-0.0134
193/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-5.74023e-04	0.0146
194/03	.325	1.93330e-05	-5.72760e-04	-1.4841	-5.57657e-04	0.0141
195/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-5.41291e-04	0.0156
196/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-5.24925e-04	0.0151
197/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
198/02	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
199/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
200/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
201/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
202/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
203/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
204/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
205/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
206/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
207/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082

Sta/ Cast	PRT Response Time (secs)	Temperature Coefficients corT = t2*T2 + t1*T + t0 t2	t1	t0	Conductivity Coefficients corC = c1*C + c0 c1	c0
208/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0082
209/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0086
210/02	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0086
211/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0086
212/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0086
213/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0086
214/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090
215/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090
216/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090
217/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090
218/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090
219/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0080
220/01	.325	1.93330e-05	-5.72760e-04	-1.4841	-6.52178e-04	0.0090

SUMMARY OF TUNES CTD OXYGEN TIME CONSTANTS

Oxygen Sensor	Casts Used	Temperature Fast(tauTF)	Temperature Slow(tauTS)	Press. (tauP)	O_2 Grad. (tauOG)
A	Leg1	32.0	363.0	19.4	60.0
A/B	Leg2/Downs	32.0	363.0	19.4	60.0
A	Leg2/Ups@	16.0	450.0	13.5	150.0

@ NOTE: pressure-series upcasts had an inverted elapsed time: 0 dbar times were re-defined as 0, and other times were generated by subtracting averaged time from averaged surface time. This required calculating entirely new taus in order to fit the data.

TUNES-2 CTD Oxygen: Levenberg-Marquardt Non-linear Least-Squares-Fit Coefficients

Sta/ Cast	Slope (c1)	Offset (c2)	Pcoeff (c3)	TFcoeff (c4/fast)	TScoeff (c5/slow)	OGcoeff (c6)
124/01	9.74036e-04	2.74161e-02	1.38260e-04	1.13660e-02	-3.74159e-02	1.35937e-04
125/01	9.88555e-04	1.42946e-02	1.46805e-04	-8.23080e-04	-2.42034e-02	2.32403e-03
126/01	9.64627e-04	2.19085e-02	1.46160e-04	1.56478e-03	-2.69694e-02	1.39288e-03
127/01	7.20499e-04	9.55390e-02	1.36654e-04	2.30895e-02	-3.92416e-02	-8.73076e-04
128/01	7.85126e-04	8.58324e-02	1.29759e-04	1.87087e-02	-3.71071e-02	5.77933e-04
129/02	9.74450e-04	2.45606e-02	1.40970e-04	-2.42716e-03	-2.34322e-02	4.75858e-04
130/01	9.72792e-04	1.21977e-02	1.51431e-04	-3.75316e-03	-1.88455e-02	6.11484e-03
131/01	9.46839e-04	2.20674e-02	1.49447e-04	2.02056e-03	-2.41925e-02	7.48703e-03
132/02	8.69841e-04	5.28195e-02	1.40260e-04	4.57305e-03	-2.52919e-02	8.28663e-04
133/01	1.23075e-03	-3.70209e-02	1.38253e-04	-3.38737e-02	3.77030e-03	-4.45136e-03
134/01	1.16423e-03	-2.22803e-02	1.41353e-04	-3.17152e-02	3.43710e-03	-7.22666e-03
135/01	1.13587e-03	-2.13681e-02	1.45314e-04	-4.15103e-02	1.36212e-02	-1.44598e-03
136/01	1.14442e-03	-5.48818e-03	1.30485e-04	-2.21766e-02	-5.84958e-03	-4.89250e-03
137/01	8.04538e-04	8.80899e-02	1.30294e-04	1.79691e-02	-3.71009e-02	-3.46420e-04
138/01	9.27807e-04	4.47543e-02	1.39047e-04	5.78485e-03	-2.93921e-02	5.83201e-04
139/01	9.26000e-04	5.28698e-02	1.31956e-04	5.99761e-03	-2.90277e-02	-3.67244e-04
140/01	9.72469e-04	3.33778e-02	1.39136e-04	7.93609e-03	-3.19523e-02	4.51678e-04
141/01	1.02034e-03	2.82425e-02	1.32970e-04	8.15073e-03	-3.45033e-02	-6.18173e-04
142/01	8.78143e-04	6.32930e-02	1.34683e-04	1.31040e-02	-3.30647e-02	1.90743e-03
143/03	9.70027e-04	3.39855e-02	1.38869e-04	6.13234e-03	-3.17918e-02	-5.63932e-04
144/01	9.97689e-04	2.77420e-02	1.37296e-04	9.77747e-03	-3.55768e-02	-1.82198e-04
145/01	1.00357e-03	2.01629e-02	1.43201e-04	7.79951e-03	-3.12180e-02	7.34854e-03
146/01	1.00234e-03	2.37381e-02	1.41278e-04	8.35470e-03	-3.40002e-02	-3.19773e-03
147/01	9.25596e-04	4.63474e-02	1.39812e-04	5.32981e-03	-2.65962e-02	6.16987e-03
148/01	9.43262e-04	4.94159e-02	1.32288e-04	1.36087e-02	-3.74967e-02	-9.84955e-04
149/01	9.08413e-04	6.01087e-02	1.31258e-04	7.29372e-03	-2.96914e-02	3.04312e-04
150/01	1.13607e-03	-2.16355e-02	1.49687e-04	9.08542e-03	-3.85515e-02	-9.85967e-04
151/01	9.86250e-04	2.35871e-02	1.45587e-04	5.27522e-03	-3.14749e-02	-2.00609e-03
152/01	9.79475e-04	3.37289e-02	1.35609e-04	4.46854e-03	-2.88005e-02	8.63516e-04
153/02	1.01440e-03	2.98860e-02	1.30338e-04	4.92377e-03	-3.21539e-02	1.42977e-03
154/01	9.56233e-04	3.86116e-02	1.36852e-04	1.91465e-03	-2.75336e-02	1.62430e-03
155/01	8.43446e-04	8.20899e-02	1.25023e-04	7.79834e-04	-2.26916e-02	1.00613e-03
156/01	8.94453e-04	6.14941e-02	1.32899e-04	-9.68918e-04	-2.36078e-02	5.26077e-04
157/01	9.83516e-04	3.12903e-02	1.37690e-04	1.28305e-03	-2.82337e-02	1.61909e-03
158/01	9.50178e-04	2.48023e-02	1.52902e-04	-2.84830e-03	-2.22188e-02	5.00782e-03
159/01	1.10911e-03	-1.57433e-02	1.45069e-04	4.34918e-03	-3.42891e-02	6.99069e-04
160/01	9.15838e-04	5.65461e-02	1.31994e-04	-2.82383e-03	-2.23812e-02	1.50998e-03
161/01	9.76541e-04	3.67686e-02	1.35698e-04	3.52564e-03	-3.03183e-02	2.38863e-04
162/01	1.00913e-03	2.18993e-02	1.39440e-04	-4.99025e-04	-2.78230e-02	5.73047e-04
163/01	9.92499e-04	2.25870e-02	1.44242e-04	-3.10614e-04	-2.63406e-02	1.92347e-03
164/01	1.01372e-03	2.01795e-02	1.43503e-04	-1.18380e-03	-2.71355e-02	-2.37808e-05

Sta/ Cast	Slope (c1)	Offset (c2)	Pcoeff (c3)	TFcoeff (c4/fast)	TScoeff (c5/slow)	OGcoeff (c6)
165/02	9.47497e-04	4.61054e-02	1.34169e-04	-1.32815e-03	-2.50594e-02	-4.23704e-04
166/02	1.01222e-03	1.16514e-02	1.47535e-04	-3.01877e-03	-2.72148e-02	-1.62388e-04
167/01	9.65490e-04	3.07138e-02	1.43549e-04	-2.94021e-03	-2.46337e-02	1.54298e-03
168/01	1.01952e-03	9.38912e-03	1.47524e-04	-3.31298e-03	-2.56856e-02	9.19736e-05
169/01	9.92975e-04	2.15173e-02	1.45156e-04	-1.27772e-03	-2.66347e-02	-5.56928e-05
170/01	1.09682e-03	-4.67248e-03	1.43783e-04	4.33293e-03	-3.61059e-02	4.13626e-04
171/01	1.03991e-03	1.51834e-02	1.41128e-04	5.82635e-03	-3.48170e-02	-1.11327e-03
172/02	9.65464e-04	2.88758e-02	1.45327e-04	-1.07821e-02	-1.90955e-02	1.17278e-04
173/01	9.92514e-04	2.54707e-02	1.43603e-04	-1.35774e-03	-2.64658e-02	-3.90692e-04
174/01	1.02221e-03	1.61930e-02	1.44875e-04	6.18773e-03	-3.37413e-02	1.07993e-04
175/01	9.70707e-04	3.81207e-02	1.40143e-04	-2.35929e-03	-2.45734e-02	-3.91433e-05
176/01	1.02346e-03	1.71879e-02	1.43864e-04	1.61324e-03	-2.90824e-02	4.25191e-04
177/01	1.00907e-03	2.90049e-02	1.38135e-04	-1.01364e-03	-2.58912e-02	3.42700e-03
178/01	1.04821e-03	1.43697e-02	1.41951e-04	4.73295e-03	-3.23759e-02	2.37301e-04
179/02	1.03618e-03	1.08475e-02	1.47259e-04	-1.65927e-03	-2.70478e-02	1.12468e-03
180/02	1.02725e-03	8.05786e-03	1.45292e-04	-2.51802e-03	-2.88875e-02	-5.86707e-04
181/01	9.83335e-04	2.96404e-02	1.39107e-04	4.05513e-03	-3.04371e-02	-6.92337e-06
182/02	1.16887e-03	7.62552e-03	8.78018e-05	-2.61066e-02	-9.76593e-03	-3.77702e-03
183/01	1.00920e-03	2.06813e-02	1.43375e-04	-2.72462e-02	-8.78713e-03	-4.85355e-04
184/01	1.01351e-03	1.73297e-02	1.45849e-04	-2.66070e-02	-8.54734e-03	-1.03444e-03
185/01	9.39419e-04	4.11220e-02	1.41664e-04	-6.73055e-03	-1.73737e-02	3.85836e-03
186/01	9.85708e-04	2.94156e-02	1.43114e-04	-5.15553e-03	-2.17635e-02	1.91419e-04
187/02	9.93422e-04	3.03151e-02	1.40169e-04	1.81920e-03	-2.85360e-02	2.29725e-03
188/01	9.92379e-04	1.83591e-02	1.47224e-04	3.31433e-03	-3.26159e-02	-4.28132e-06
193/01	8.56067e-04	7.41068e-02	1.31170e-04	-3.48618e-02	1.45682e-02	-2.31530e-03
194/03	1.01673e-03	3.30716e-02	1.31019e-04	-2.48869e-02	-1.50489e-03	-6.41632e-03
195/01	1.03338e-03	2.20898e-02	1.36240e-04	-2.84714e-02	-8.76995e-06	-9.26474e-03
196/01	8.56847e-04	8.00897e-02	1.28120e-04	-3.22148e-02	1.33820e-02	-1.04290e-03
197/01	9.98900e-04	1.96720e-02	1.45111e-04	9.30220e-03	-3.71486e-02	-4.30105e-04
198/02	9.63034e-04	3.00695e-02	1.45933e-04	-1.22247e-03	-2.79709e-02	-1.23479e-03
199/01	8.90092e-04	4.50071e-02	1.53063e-04	6.98631e-04	-2.34627e-02	1.49480e-03
200/01	9.55612e-04	1.96937e-02	1.63588e-04	6.05485e-03	-3.01778e-02	-3.26536e-04
201/01	9.61216e-04	3.64178e-02	1.44177e-04	2.86506e-03	-2.95201e-02	-9.88325e-04
202/01	9.68779e-04	3.78174e-02	1.42125e-04	2.10321e-03	-3.06230e-02	-2.12457e-03
203/01	9.75186e-04	3.20391e-02	1.46398e-04	1.19479e-03	-2.91412e-02	8.22370e-04
204/01	1.02167e-03	2.29675e-02	1.45919e-04	4.17063e-03	-3.38061e-02	-1.29569e-03
205/01	8.53594e-04	8.25995e-02	1.33500e-04	-1.40165e-03	-2.17228e-02	6.54864e-04
206/01	9.03648e-04	5.93182e-02	1.39662e-04	-2.76579e-03	-2.20259e-02	1.93567e-03
207/01	9.40520e-04	5.16192e-02	1.37779e-04	1.53863e-03	-2.76990e-02	-1.30542e-03
208/01	9.43210e-04	4.38431e-02	1.46352e-04	1.69443e-03	-2.78140e-02	-3.41290e-03
209/01	8.57270e-04	8.25120e-02	1.32823e-04	-2.07116e-03	-2.15492e-02	1.16307e-03
210/02	1.14233e-03	-1.64812e-02	1.49065e-04	1.36421e-02	-4.58470e-02	-5.32877e-03
211/01	1.02694e-03	2.00706e-02	1.45605e-04	8.83728e-04	-3.02670e-02	-7.39584e-04
212/01	1.00621e-03	2.79678e-02	1.44059e-04	6.48505e-03	-3.36940e-02	-1.57985e-04
213/01	8.38116e-04	9.23205e-02	1.27497e-04	1.33727e-03	-2.28328e-02	5.04368e-04
214/01	6.87475e-04	1.37463e-01	1.24238e-04	-1.92717e-03	-1.42103e-02	7.51458e-04
215/01	9.26096e-04	4.83288e-02	1.47684e-04	-9.00041e-04	-2.46545e-02	-1.05974e-03
216/01	1.11954e-03	-1.04200e-02	1.54310e-04	9.97415e-03	-3.95453e-02	-1.27928e-03
217/01	1.02024e-03	3.49490e-02	1.42072e-04	5.76715e-03	-3.22223e-02	5.60629e-04
218/01	1.13903e-03	-1.62749e-02	1.55528e-04	3.12347e-03	-3.42289e-02	-7.74700e-04
219/01	7.96293e-04	1.09757e-01	1.29044e-04	-1.49413e-03	-2.03201e-02	4.02498e-05
220/01	1.00456e-03	3.96412e-02	1.38775e-04	4.36451e-03	-3.09871e-02	-7.55432e-04

E. Data Quality Evaluations

E.1. CTD Data Quality Control Report for WOCE cruises P16S and P17S

(Bob Millard)
April 9, 1996

The range of variation of potential temperature is from below zero to 27°C while the salinity varies from 34.3 to 36.3 psu as the potential temperature versus salinity plot of figure 1 illustrates. The oxygen values range widely, from near zero to 270 µmol/kg, as shown in the potential temperature versus oxygen plot of figure 2. These two plots contain all 2 decibar observations Plus the water sample salinities and oxygens. To the plotting resolution, the salinity, oxygen and temperature data are well behaved.

The evaluation of the CTD data of WOCE cruises P16S and P17S examines the following two CTD data sets: individual 2 decibar down-profile data (a total of 97 station files) and the subset of the up-profile CTD observations stored in the bottle file together with the water sample oxygens and salinities. The CTD processing documentation is pretty comprehensive, covering the laboratory and in situ calibrations along with problems encountered with the various instrument combinations used during this cruise. The documentation has good bit of detail to help explain problems identified in the data set. Both the CTD salinity and oxygen data in the bottle file (P16s17s.HYD) and the individual 2-decibar down-profiles for WOCE cruises P16S and P17S are found to be well matched to water sample data and generally free of spurious observations. The CTD data set is a credit to the personnel responsible for processing these data as creating such a consistent and good quality data set from three instruments with several conductivity and temperature sensor combinations is not an easy undertaking.

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

Calibration checks

CTD and Water Sample Salinity and Oxygens:

Checks involve both the individual 2 decibar profiles and the bottle file CTD subset. The calibration checks are divided into an assessments at all depths and then just the deeper layer (i.e. pressures greater than 1000 decibars). The calibration checks of salinity and oxygen involved looking at the differences of the CTD minus the water sample values both the down and up-profile CTD salinity and oxygen data were examined against bottle values. The salinity differences presented are formed using the bottle file CTD data while oxygen differences presented are created by interpolating the down-profile 2-decibar profiles CTD oxygens at the bottle depths. The interpolated down-profile CTD oxygens found to be nearly identical to those in the water sample file with only differences occurring in the upper 500 decibars.

Check for Spurious Salinity and Oxygens Values Deep:

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

Vertical Stability Check:

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

Salinity Calibration:

The bottle file salinity differences are plotted versus station number, first at all pressures (figure 3a) and then the subset below 1000 decibars with a station average value indicated by the solid line in figure 3b. The third panel, figure 3c, is a plot of salinity differences versus pressure below 500 decibars. Both plots versus station (3a and 3b) show the CTD salinity (conductivity) to be well matched to the water sample salts, the only evidence of a station off-set are stations 159 and 189. Station 189 has a few unflagged questionable deep water sample file CTD salts that create this apparent mis-calibration. The down-profile interpolated salinity differences below 1000 decibars (not shown) reinforce station 159 to be 0.0015 psu fresh and also doesn't indicate station 189 to be mis-calibrated suggesting the CTD salinities in the water sample file are incorrect. Figure 3c begins at 500 decibars to permit an expanded salinity range and suggestions that the CTD salinity is well calibrated in the vertical. The few large salinity differences below 1000 dbars all occur between stations 189-195 (see figure 3b). A histogram of salinity differences is shown for all pressures in figures 5c and below 1000 dbars in figure 5d. The standard deviation of the salinity differences below 1000 decibars is 0.0024 psu but reduces to 0.0017 psu when a few questionable differences greater than +/-0.02 psu are removed. Most of the large salinity differences are due to erroneous CTD salinities in the water sample file of stations 181 and 189.

A series of waterfall plots of up-profile CTD salinity minus up water sample differences DS= (Sctd_up - WS) psu are given in figures 7 a-d. Again, questionable salts are observed in stations 159, 181, and 189. For Station 189, the large salinity differences occur only with the up-profile CTD salinities and the down-profile salinities look fine. This is the case for station 181 as well where it appears the CTD may have lift the bottom! So only station 159 seems to require further adjustment as the pot. temp. versus salinity plot indicates.

Oxygen Calibration:

Figures 4 a,b,c show the down-profile oxygen differences versus station, overall and deep, and versus pressure. The plots of the up-profile oxygen differences were examined but plots are not included as they are identical except shallow and do not change any conclusions concerning oxygen calibrations. Figure 4c begins at 500 decibars to permit an expanded oxygen range and suggests that the CTD oxygen might be systematically underestimated by 1 to 2 µmol/kg (the same was seen in the bottle file comparisons) in the depth range of around 4000 decibars. Figure 4a indicates that there are a few large oxygen differences between stations 177 & 183. The station average oxygen difference below 1000 decibars (figure 4b) suggest that the CTD oxygens match the deeper water samples, except perhaps stations 135, 193, 194 and 207 which are examined more closely in the Delta-oxygen waterfall plots. A histogram of oxygen differences for all pressure levels figure 5a and below 1000 dbars figure 5b. The oxygen differences below 1000 dbars appear normally distributed with a standard deviation of 1.29 µmol/kg.

A series of waterfall plots consisting of down-profile CTD oxygen minus up water sample differences Dox= (OXctd_dwn - WS) µmol/kg versus station are given in figures 6 a-d. Each station is labeled and the separation between profiles is 10 µmol/kg. Again stations 135, 193, 194 and perhaps 207 appear to be anomalous. The deeper CTD oxygens of these stations read low compared to the water samples, which was noticed previously in the plot of all oxygen differences versus pressure (figure 4c).

Spurious Salinities and Oxygens:

The standard deviation of the high-pass filtered salinity (between vertical wavelengths of 4 and 25 decibars) from 2500 decibars to the bottom is shown in figure 8a. The standard deviation of the high-pass filtered salinity below 2500 decibars is shown in figure 8a. The bottom pressure is plotted versus station number in figure 8c. The average RMS CTD salinity scatter over the cruise of 0.00021 psu becomes as low as 0.00017 psu (stations 140-147) which is consistent with the salinity noise level found for other cruises. Figure 8a indicates that the first seven stations (stations 124-130) have an elevated noise level 50 percent higher than most of the remainder of the cruise. Stations 189, 194 and 196 are also anomalously high and this is traced to some spurious salinity values that need to be flagged, perhaps because they are upcasts. The station averaged RMS oxygen noise level is twice as large as the best cruises examined (~0.1 µmol/kg) and is probably set by the oxygen current quantizing. Stations 207, 209 and 211 stand out as having abnormally large RMS oxygen scatter which seem to be traceable to regions of spurious oxygen variability as indicated in figure 8b. A second plot of the standard deviation of the high-pass filtered salinity and oxygen between 1198 and 2500 decibars is shown in figure 9a and b. There arc two station groups which are considerably above the background salinity variability: stations 148-150 and stations 183-189. Both of these groups of stations were collected with CTD #2 using PRT-2. The report notes additional salinity noise for the first group of stations due to a larger physical separation between T/C sensors, but I could not find any reference to problems with salinity for stations 183 to 188.

The stability of all 2 decibar CTD data is checked by looking at potential density differences that exceed one of two thresholds. A plot of the pressure levels at which these instabilities occur (table 1) is shown in figure 10 with potential density differences exceeding -0.0075 kg/m3/dbar, marked with an (x), and -0.01 kg/m3/dbar, marked with a (*). A tabular listing of these 40 points with negative density gradients exceeding -.0075 kg/m3/dbar is given below. The data set has only 4 levels exceeding -.01 kg/m3/dbar. The instabilities are in the shallow depths regions less than 500 decibars that have the largest temperature and salinity gradients.

Detailed comments on individual or groups of stations

Stations 133- 136:

- CTD Oxygens (O_2 drifts low at bottle stops). The 2 decibar station is from the up-profile and the O_2 depletion is noted in the data report! May want to flag in quality word. See figure 11.

Oxygen calibration (see figure 4)

- Station 135 low below 1500 dbars;
- Station 193 CTD O_2 low below 3000;
- Station 194 CTD O_2 low below 3000;
- Station 207 CTD O_2 low below 3200 dbars
- Stations 183-184 surface oxygens had. The quality word for O_2 is set to bad but perhaps should also set CTD O_2 = -9 since the O_2's are not useful?

Stations 193-196:

- CTD Oxygens (O_2 drifts low what appear to be bottle stops). Data report notes that the CTD profiles 189-196 are from the up-cast!
- CTD deep oxygens are noisy for stations 207, 209 and 211 as suggested earlier in RMS plot. Perhaps filter or mark quality word? See figures 12, 13, & 14.

Stations 148-150:

- salinity noisy: see salinity minimum in figure 15. There are density inversion of up to -0.004 kg/m3. Requires documentation and perhaps should be flagged in data files. Station 183-188
- salinity noisy: see salinity minimum in figure 16. There are density inversion of up to -0.004 kg/m3. Requires documentation and perhaps should be flagged in data files.
- Salinities noisy for stations 189. 193. 194, 195, 196. Only station 189 has clearly identified salt spikes (figure 17) while stations 193-196 fewer salt spikes but a generally higher salinity noise, perhaps due to data being collected on the upcast. Suggest Flagging salinity spikes in quality word.

Station 159

- CTD salinity high .0015 psu. See theta/S figure 18

Stations 181 & 189

- low CTD salinities in water sample file: Need to be flagged in the quality word.

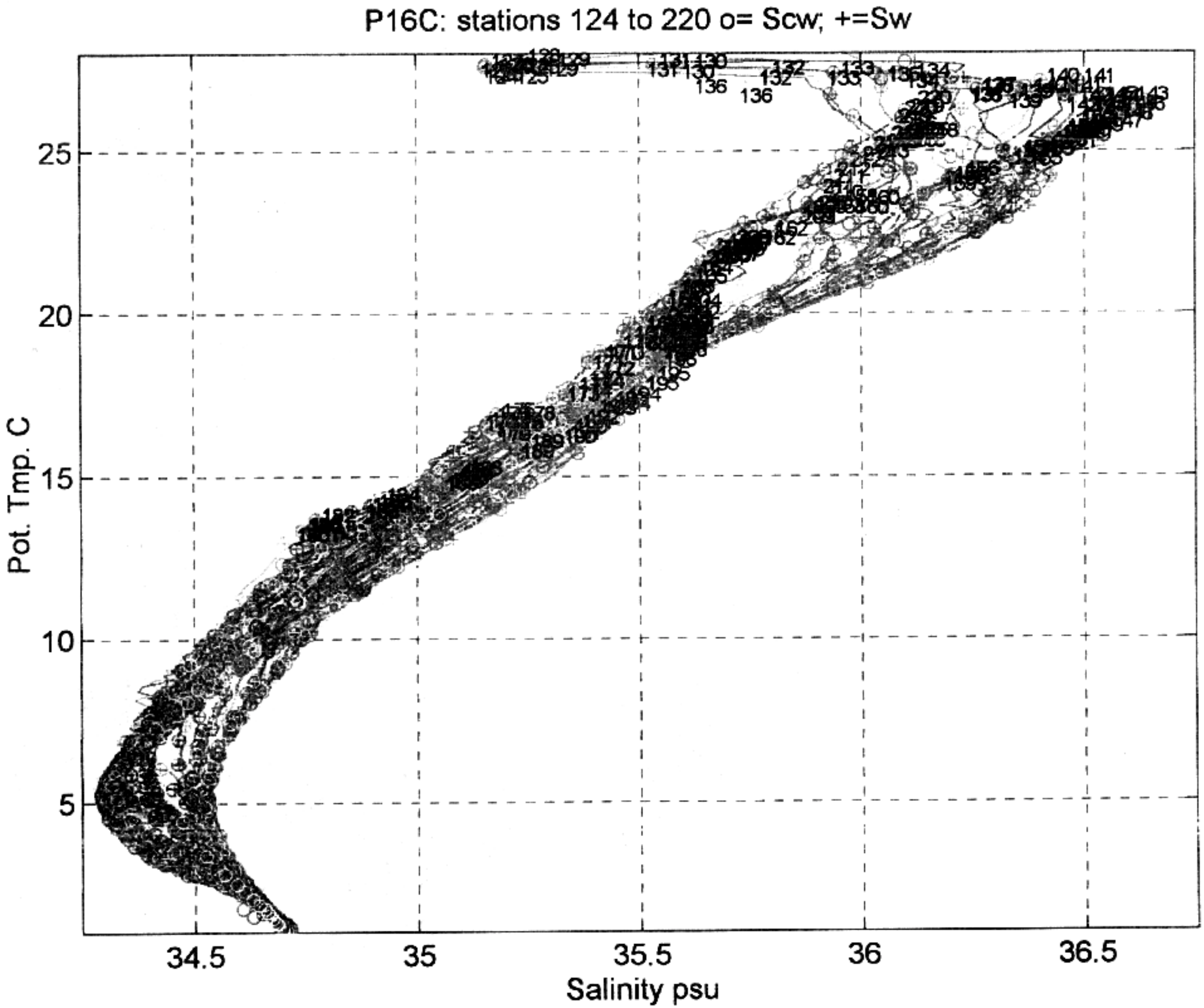
Table 1: dsg/dp > -.0075 kg/m3/dbar

dsg/dp	station #	Prs dbars
-7.8641805e-003	1.2800000e+002	1.4000000e+002
-8.8297845e-003	1.3600000e+002	1.7000000e+002
-9.7508236e-003	1.3700000e+002	2.7400000e+002
-8.3715948e-003	1.3700000e+002	3.1000000e+002
-7.6583882e-003	1.3800000e+002	2.1200000e+002
-8.6767688e-003	1.4100000e+002	3.2600000e+002
-7.8341546e-003	1.4200000e+002	2.8800000e+00?
-8.0255380e-003	1.4300000e+002	3.3400000e+002
-8.4706133e-003	1.4400000e+002	1.2800000e+002
-7.9266174e-003	1.4400000e+002	3.4400000e+002
-7.9858524e-003	1.4800000e+002	2.3800000e+002
-7.5826407e-003	1.4800000e+002	2.6000000e+002
-1.0002281e-002	1.4800000e+002	3.0800000e+002
-9.8196501e-003	1.4800000e+002	3.1600000e+002
-1.0194750e-002	1.4800000e+002	3.2400000e+002
-7.6654652e-003	1.4900000e+002	1.3200000e+002
-9.8661496e-003	1.4900000e+002	2.4000000e+002
-9.4343715e-003	1.4900000e+002	3.0000000e+002
-9.7408253e-003	1.4900000e+002	3.3400000e+002
-9.2506939e-003	1.4900000e+002	3.7000000e+002
-8.0809873e-003	1.5000000e+002	2.2400000e+002
-7.7992862e-003	1.5000000e+002	3.0800000e+002
-8.4964802e-003	1.5000000e+002	4.5400000e+002
-8.9271953e-003	1.5100000e+002	3.7400000e+002
-7.7591976e-003	1.5100000e+002	4.3000000e+002
-7.9234132e-003	1.5100000e+002	4.3800000e+002
-8.0958725e-003	1.6500000e+002	1.8800000e+002
-8.0027661e-003	1.7000000e+002	4.02000000+002
-1.0618018e-002	1.8200000e+002	1.52000000+002
-7.7939928e-003	1.8300000e+002	2.1600000e+002
-9.1669738e-003	1.8300000e+002	3.1600000e+002
-8.3398096e-003	1.8300000e+002	3.2200000e+002
-9.1135829e-O03	1.8500000e+002	3.6000000e+002
-1.0028792e-002	1.8500000e+002	3.7000000e+002
-8.8489481e-003	1.8600000e+002	2.0000000e+002
-8.5536518e-003	1.8700000e+002	2.5600000e+002
-9.3649987e-003	1.8700000e+002	3.0200000e+002
-8.7831869e-O03	1.8800000e+002	3.1600000e+002
-8.0227023e-003	1.9300000e+002	3.3200000e+002
-8.8509689e-003	2.1200000e+002	2.2400000e+002

Table2: dsg/dp>-.01kg/m3/dbar

dsg/dp	station #	Prs dbars	comments
-1.0002281e-002	1.4800000e+002	3.0800000e+002	fix S at 306
-1.0194750e-002	1.4800000e+002	3.2400000e+002	ok qual. wd
-1.0618018e-002	1.8200000e+002	1.5200000e+002	ok qual. wd
-1.0028792e-002	1.8500000e+002	3.7000000e+002	ok qual. wd

Figure 1



P16C: stations 124 to 220 o= Scw; +=Sw
Pot. Tmp. C
Salinity psu
25
20
15
10
5
34.5
35
35.5
36
36.5

Figure 2

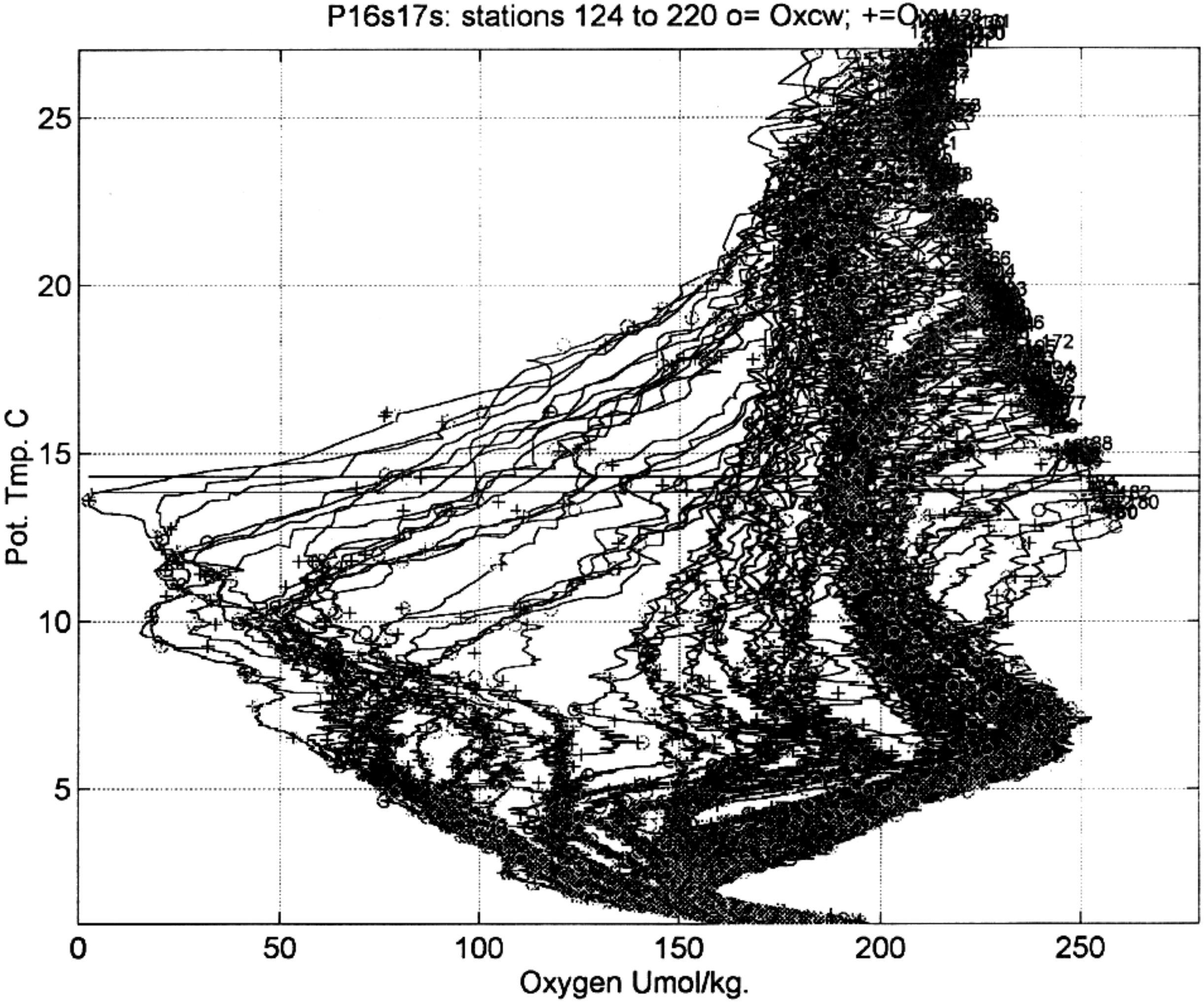
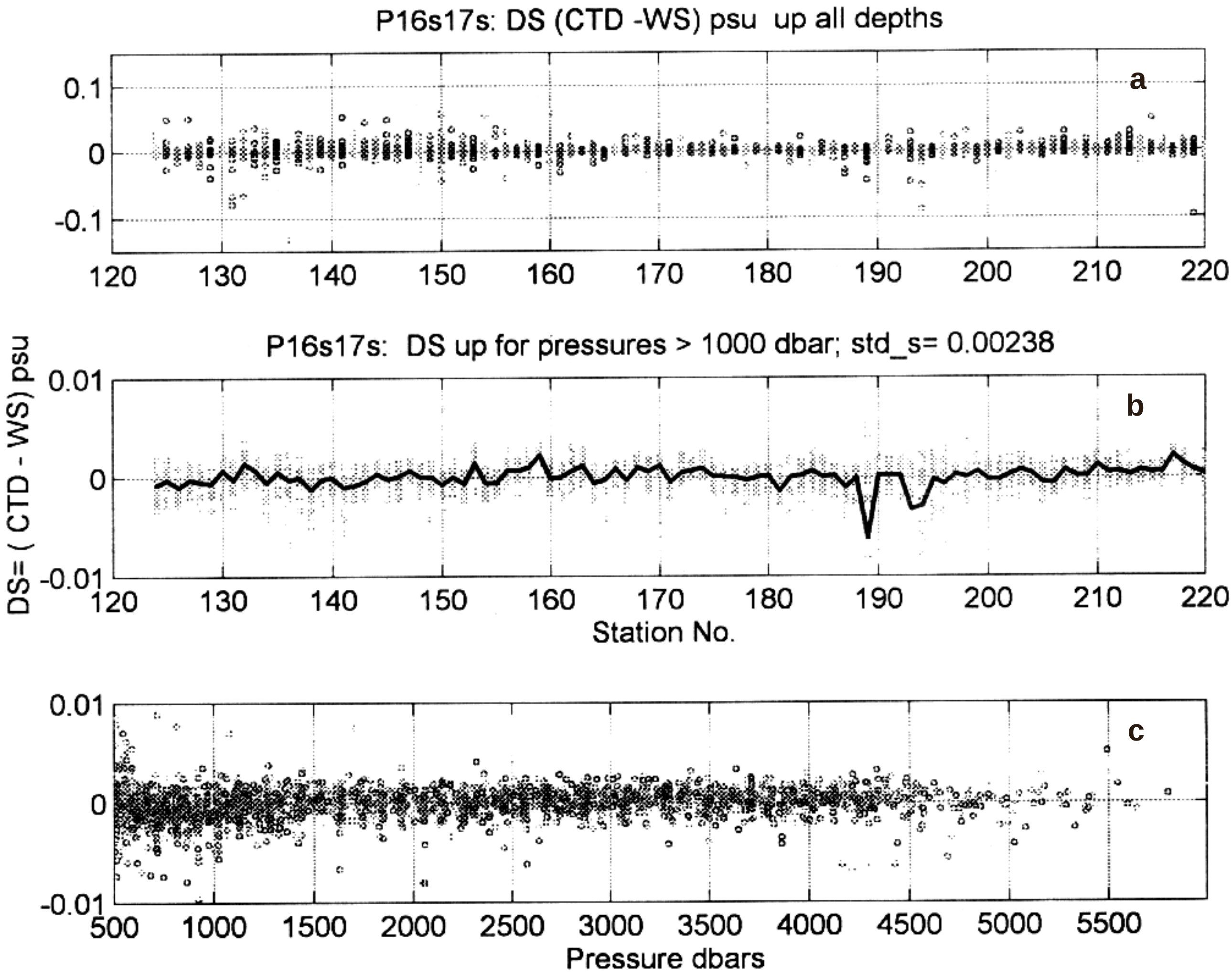

P16s17s: stations 124 to 220 o= Oxcw; +=Oxw
Pot. Tmp. C
Oxygen Umol/kg.
25
20
15
10
5
0
50
100
150
200
250

Figure 3



P16s17s: DS (CTD -WS) psu up all depths
a
0.1
0
-0.1
120
130
140
150
160
170
180
190
200
210
220
P16s17s: DS up for pressures > 1000 dbar; std_s= 0.00238
b
DS= (CTD - WS) psu
0.01
0
-0.01
Station No.
c
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Pressure dbars

Figure 4

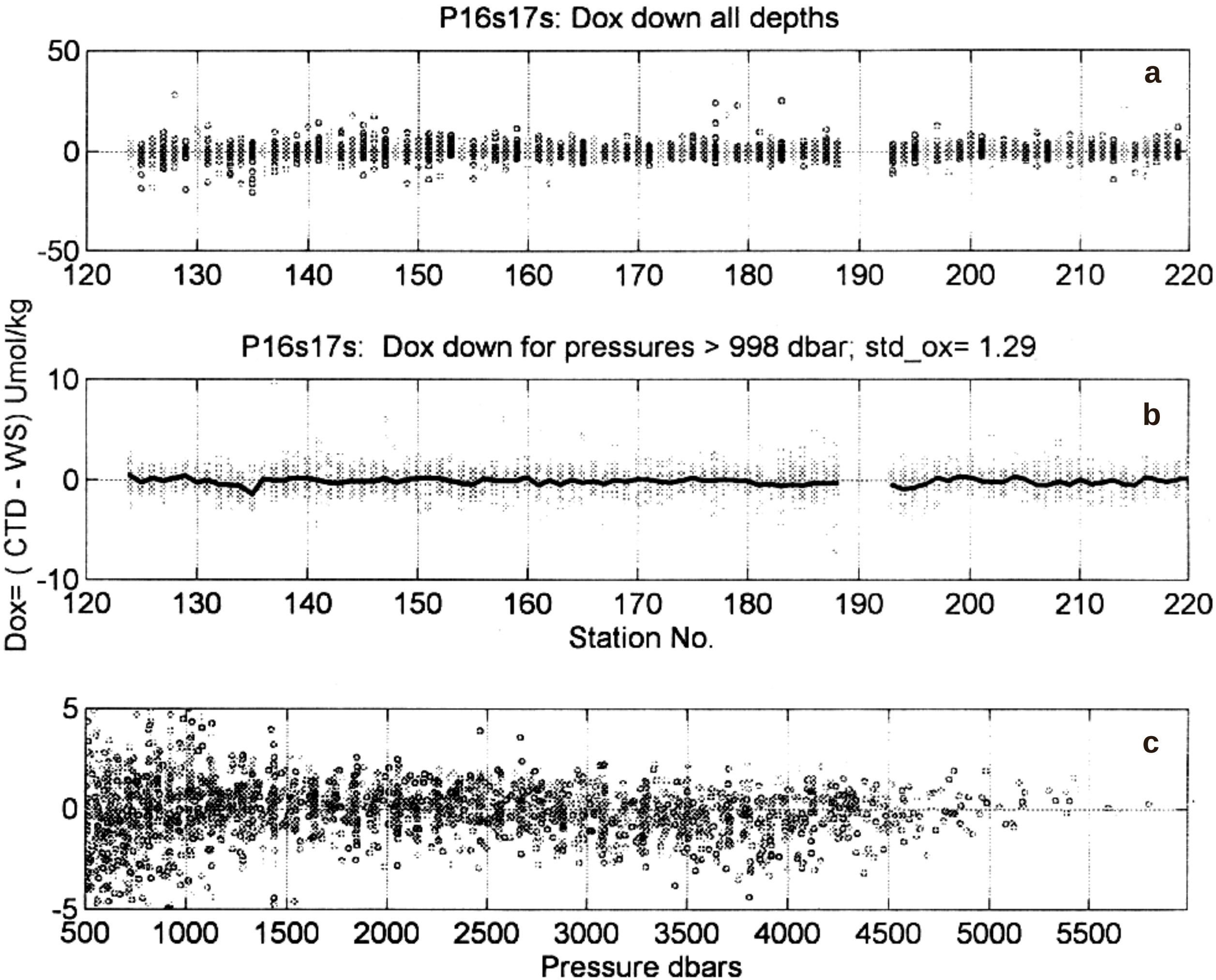

P16s17s: Dox down all depths
a
50
0
-50
120
130
140
150
160
170
180
190
200
210
220
P16s17s: Dox down for pressures > 998 dbar; std_ox= 1.29
b
10
0
-10
Station No.
Dox= (CTD - WS) Umol/kg
c
5
0
-5
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Pressure dbars

Figure 5

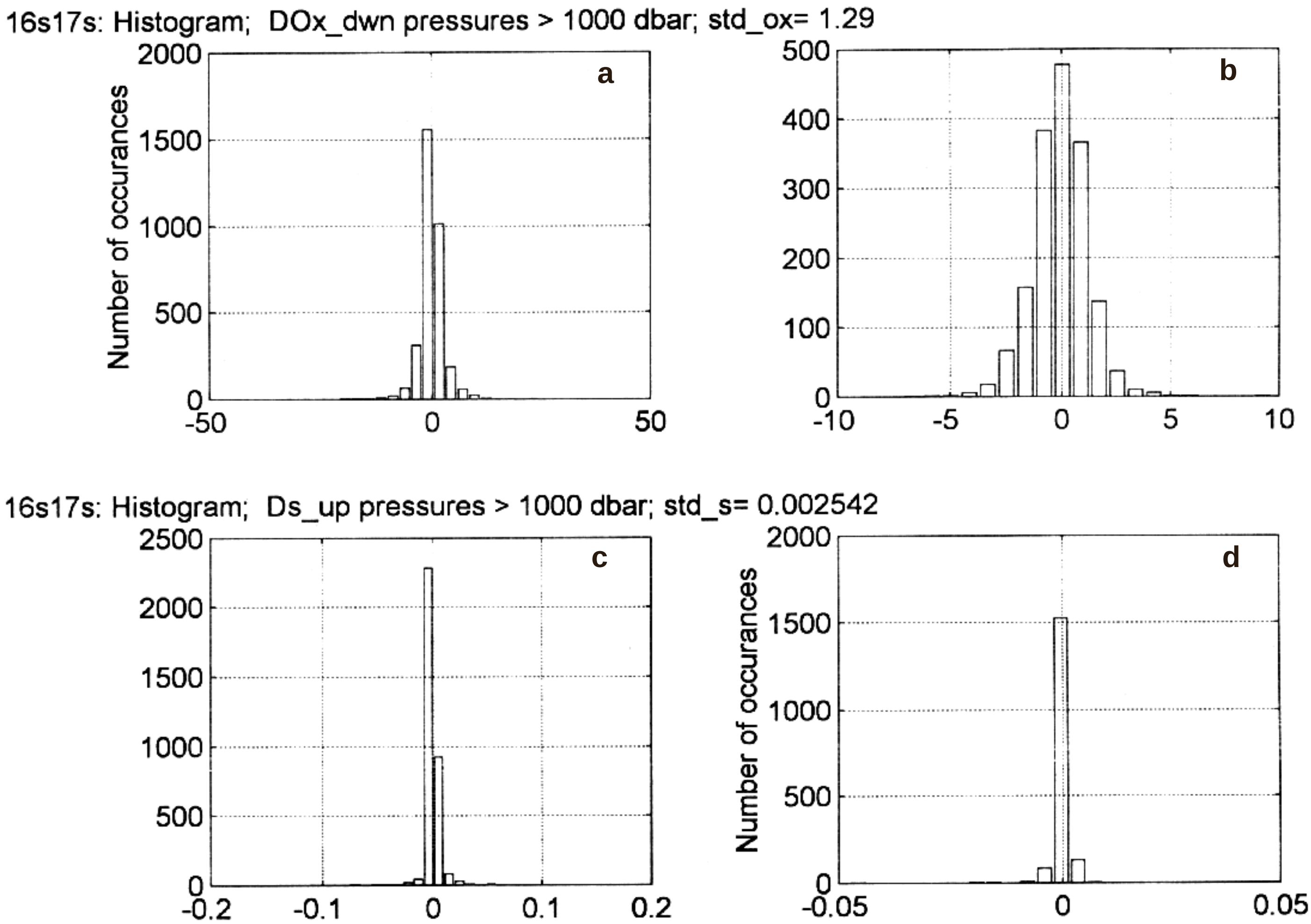
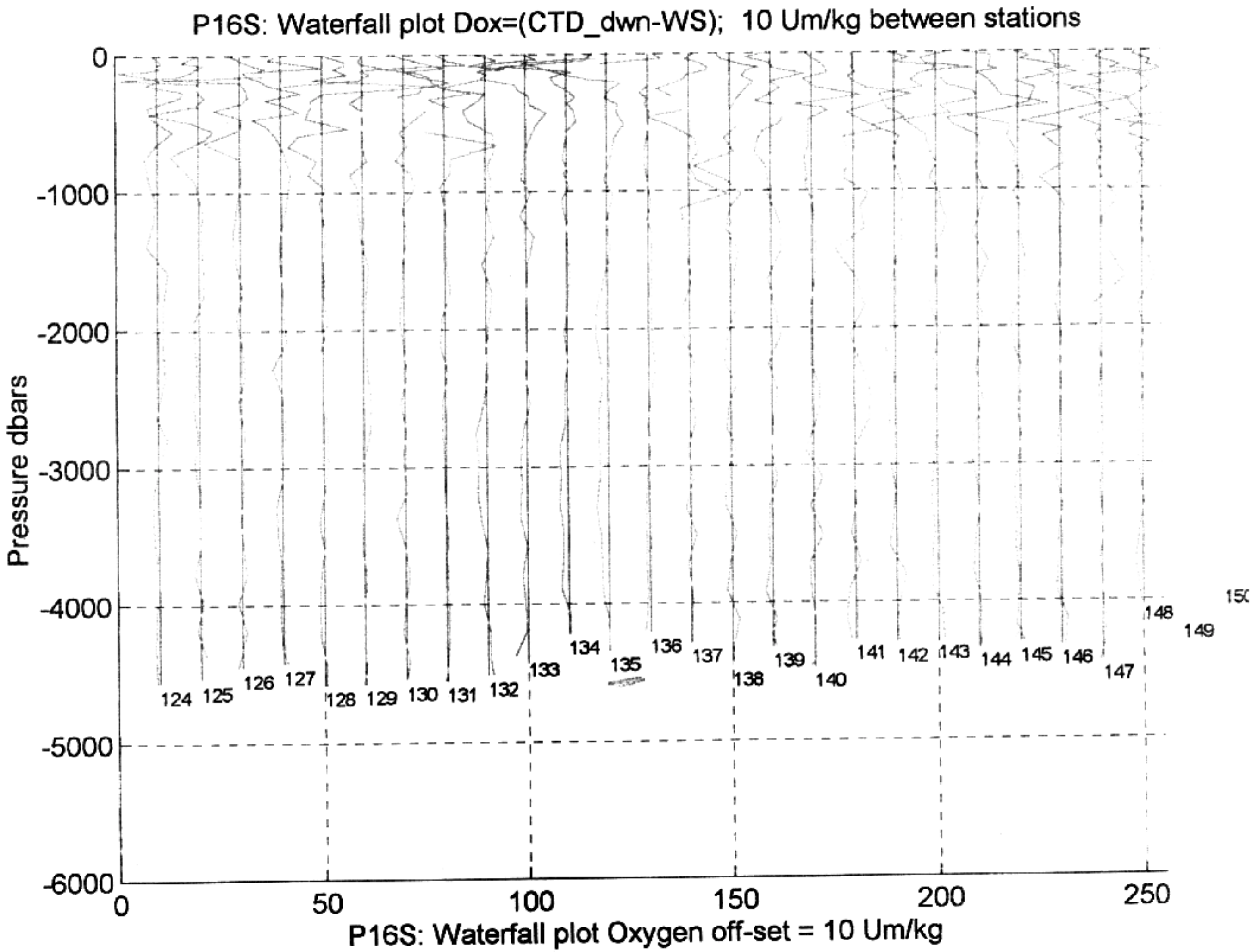

16s17s: Histogram; DOx_dwn pressures > 1000 dbar; std_ox= 1.29
Number of occurances
a
b
16s17s: Histogram; Ds_up pressures > 1000 dbar; std_s= 0.002542
Number of occurances
c
d

Figure 6a



P16S: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
0
50
100
150
200
250
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149
P16S: Waterfall plot Oxygen off-set = 10 Um/kg

Figure 6b

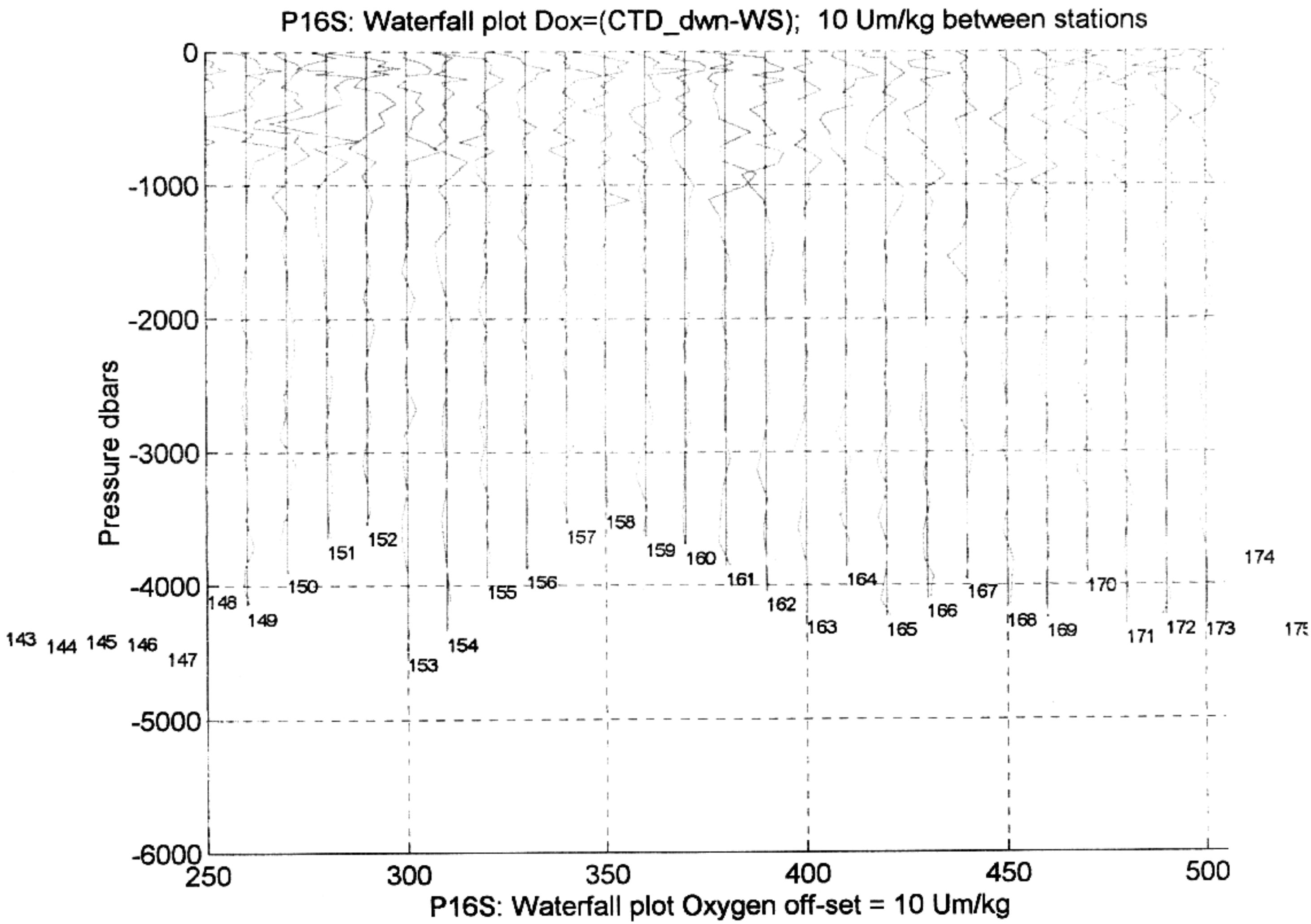
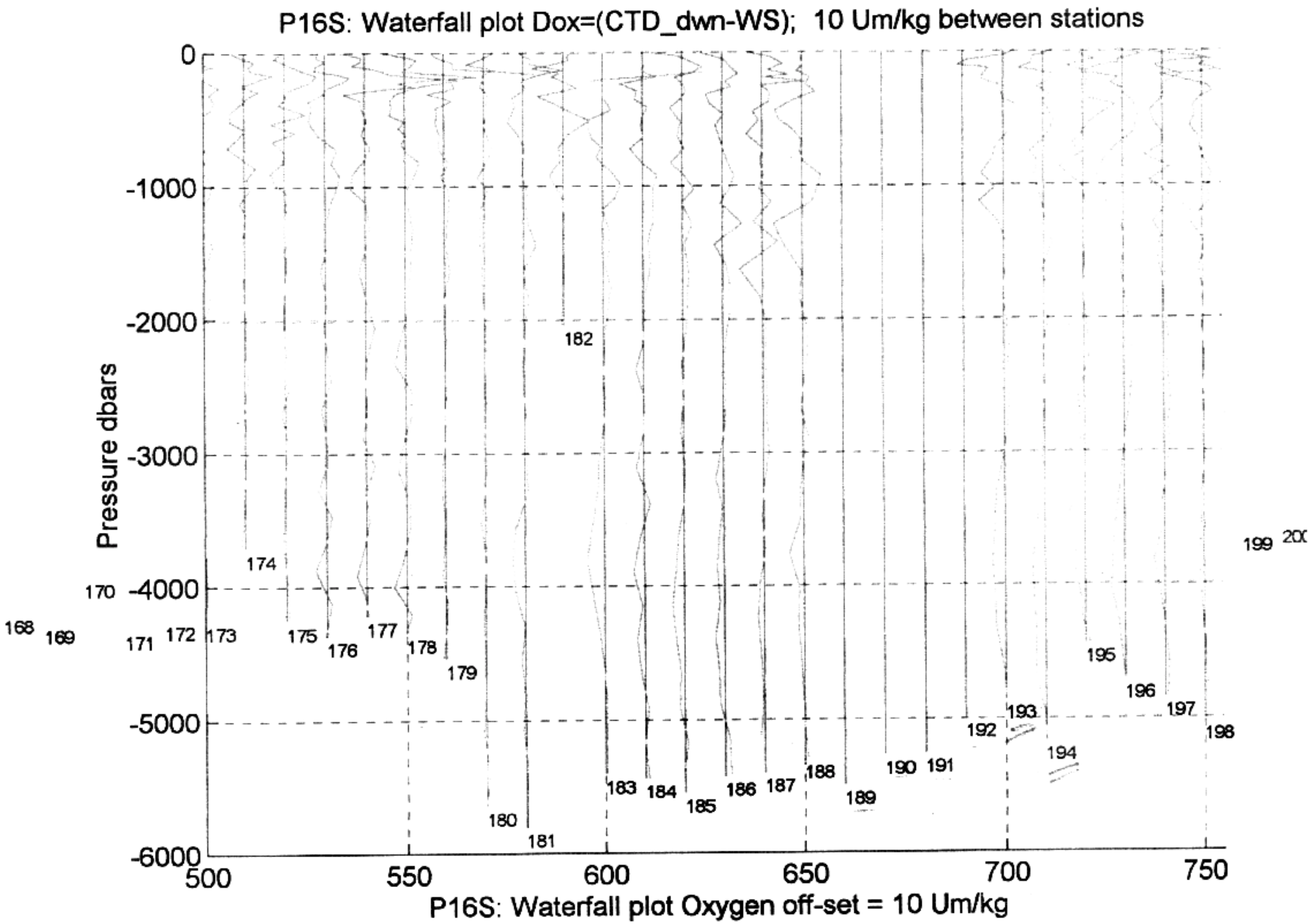

P16S: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
250
300
350
400
450
500
P16S: Waterfall plot Oxygen off-set = 10 Um/kg
143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174

Figure 6c



P16S: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
500
550
600
650
700
750
168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 20
P16S: Waterfall plot Oxygen off-set = 10 Um/kg

Figure 6d

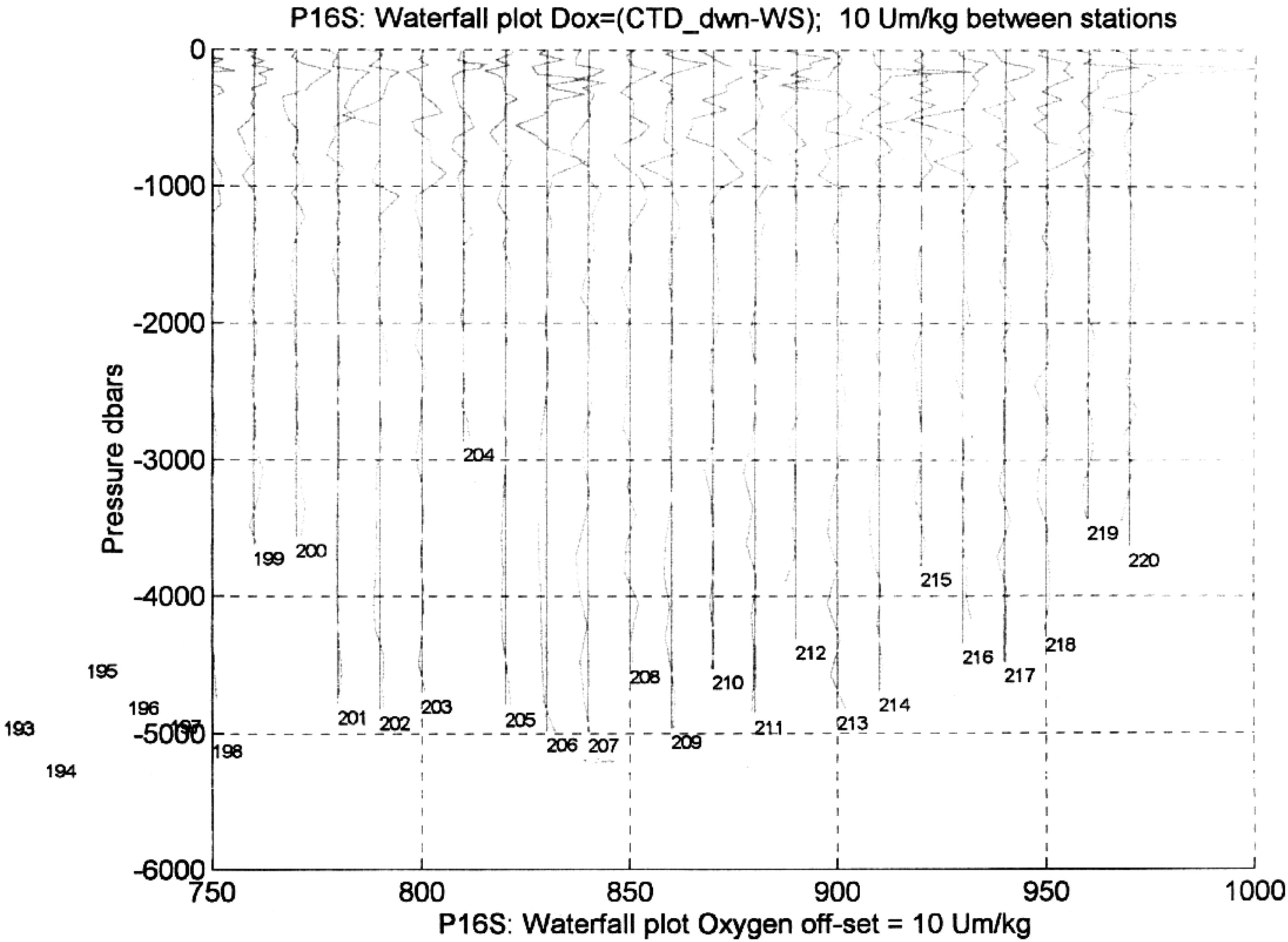

P16S: Waterfall plot Dox=(CTD_dwn-WS); 10 Um/kg between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
750
800
850
900
950
1000
P16S: Waterfall plot Oxygen off-set = 10 Um/kg
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220

Figure 7a

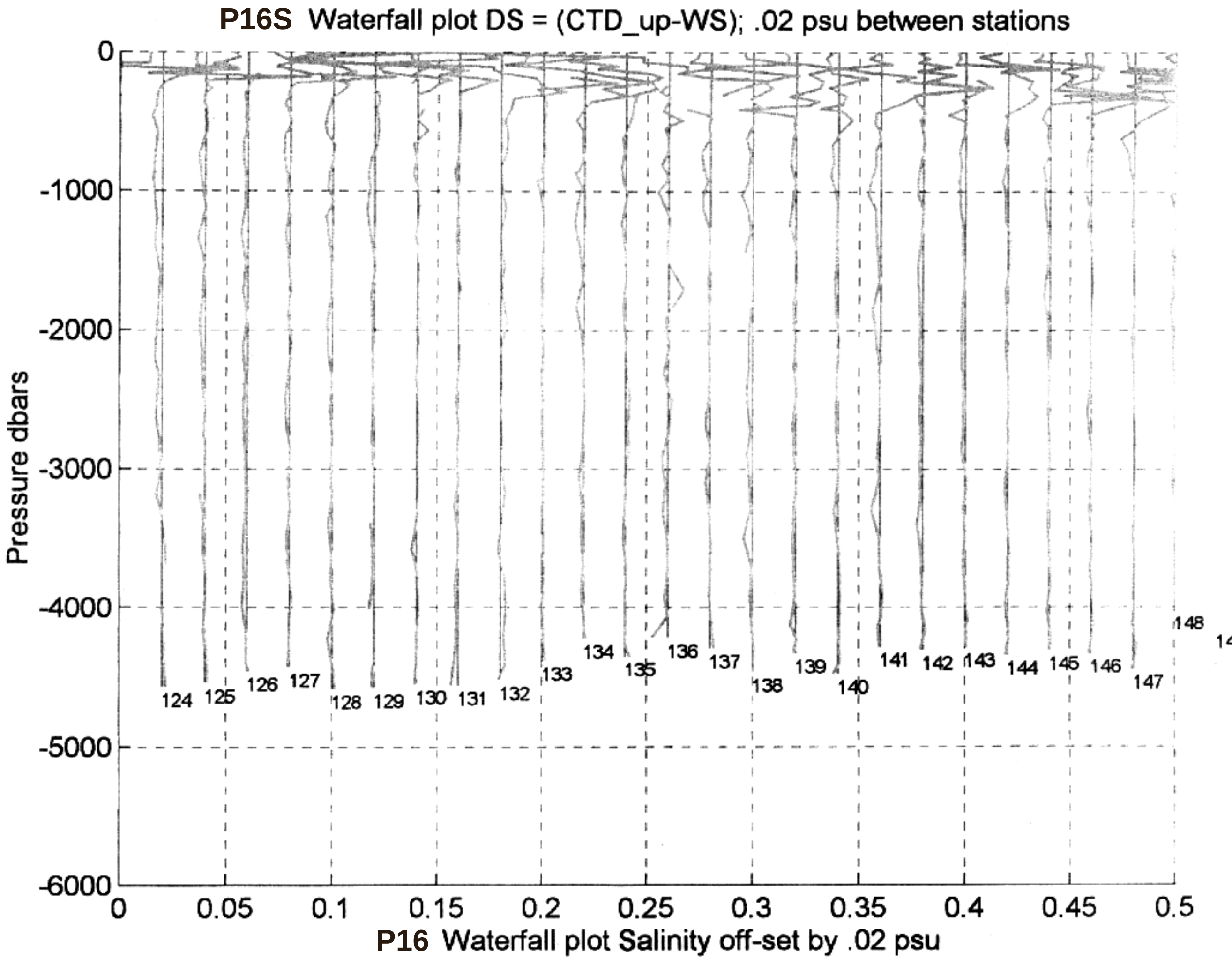

P16S Waterfall plot DS = (CTD_up-WS); .02 psu between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149
P16 Waterfall plot Salinity off-set by .02 psu

Figure 7b

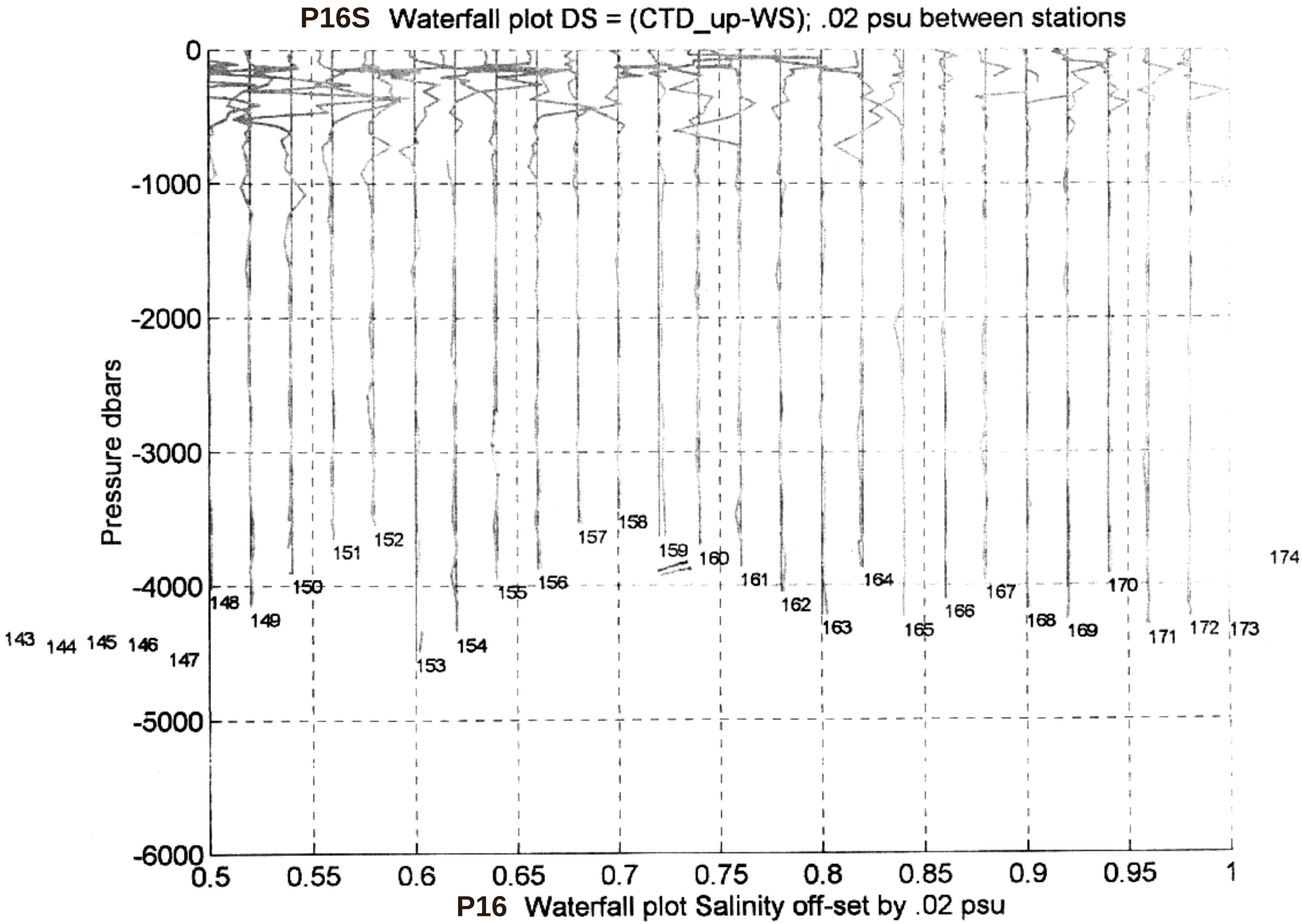

P16S Waterfall plot DS = (CTD_up-WS); .02 psu between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
P16 Waterfall plot Salinity off-set by .02 psu
143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174

Figure 7c

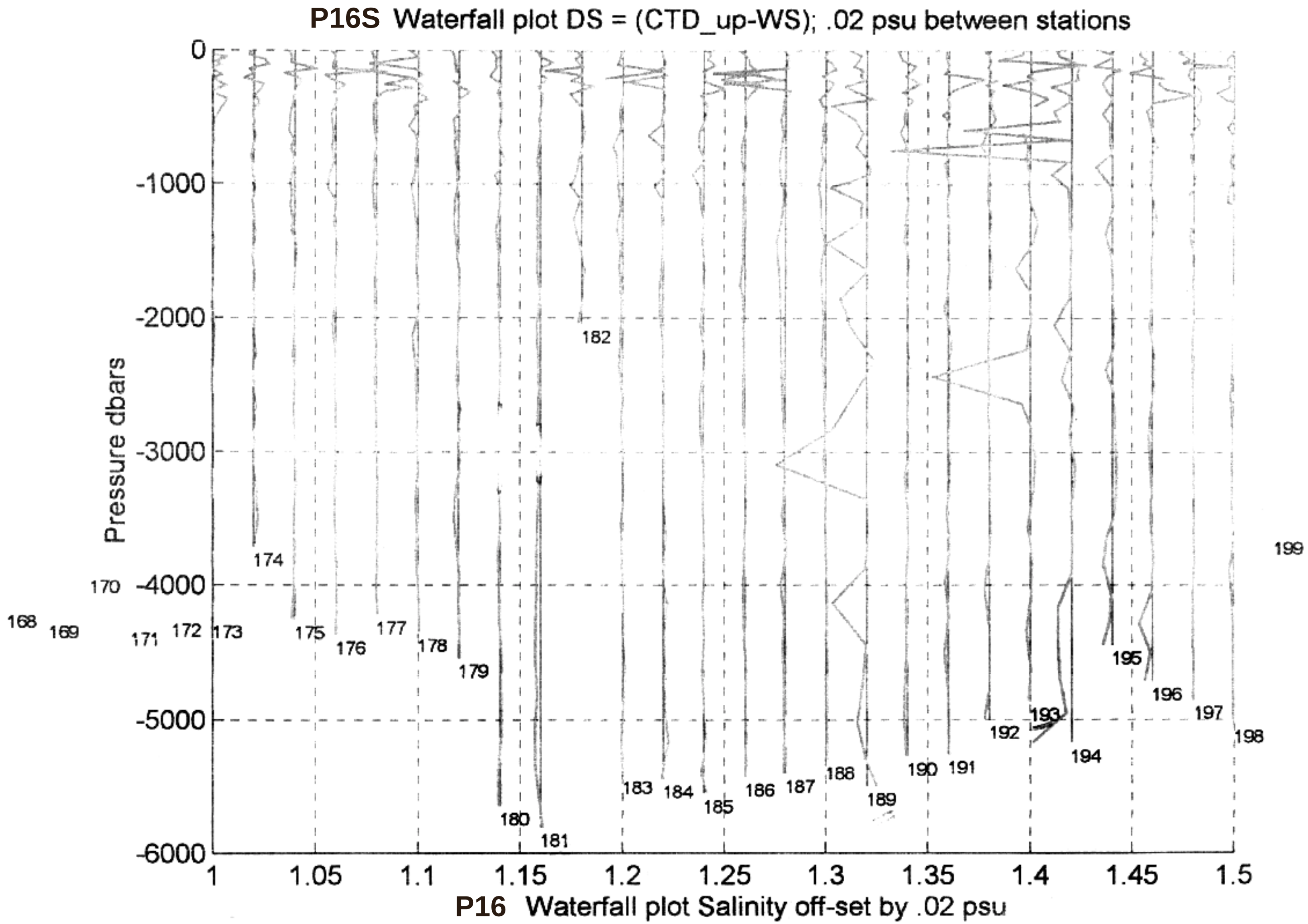

P16S Waterfall plot DS = (CTD_up-WS); .02 psu between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
P16 Waterfall plot Salinity off-set by .02 psu

Figure 7d

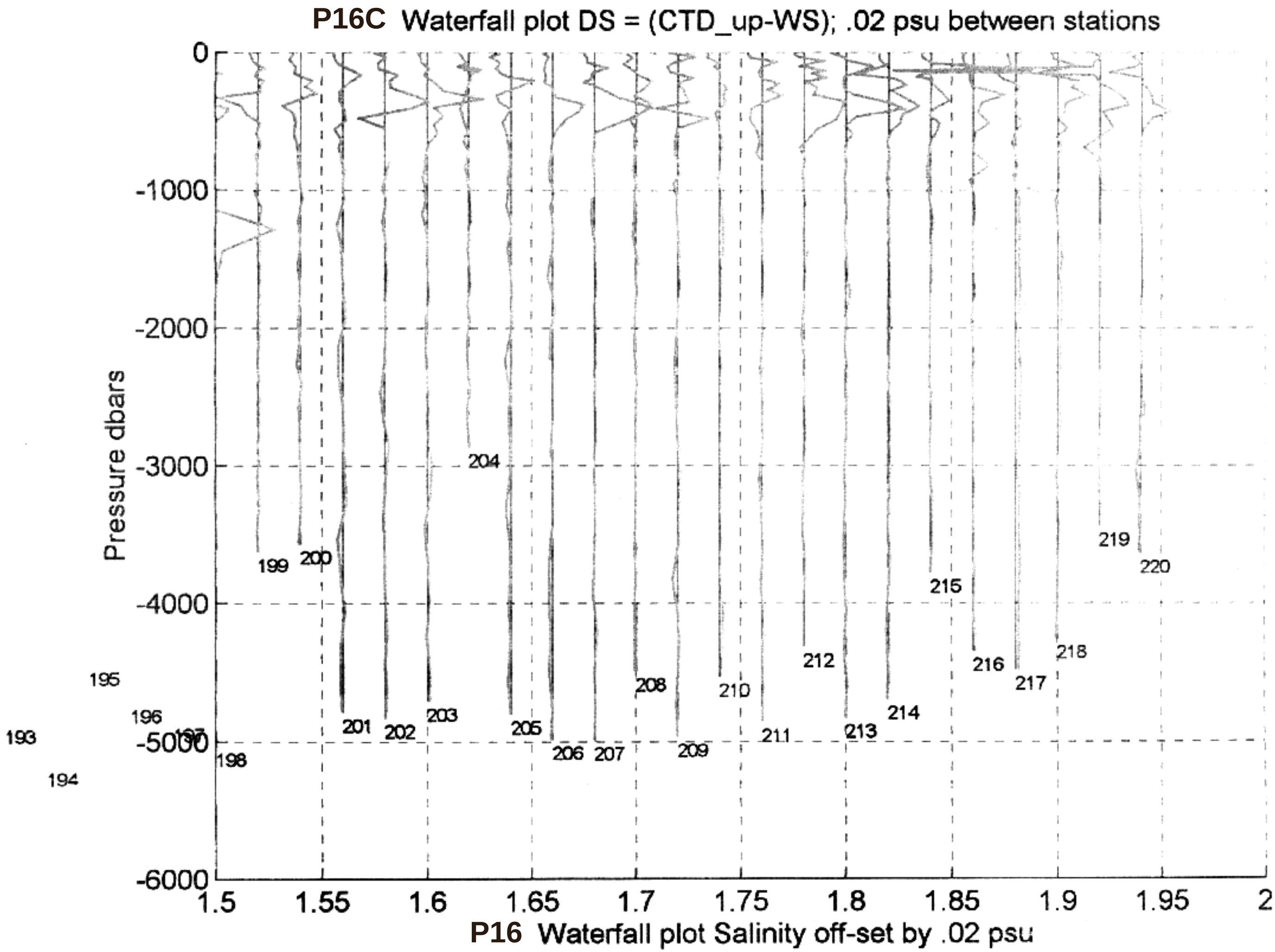
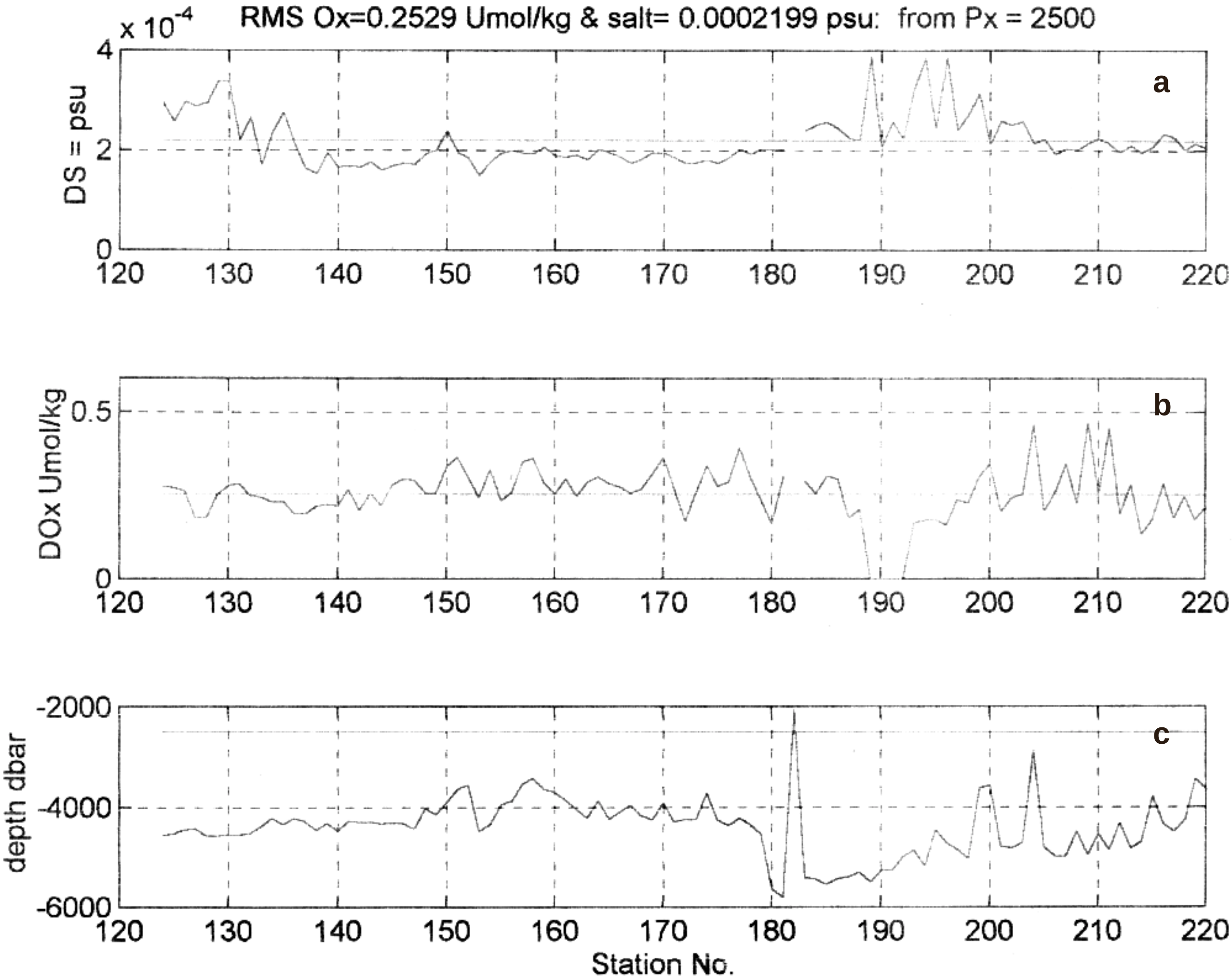
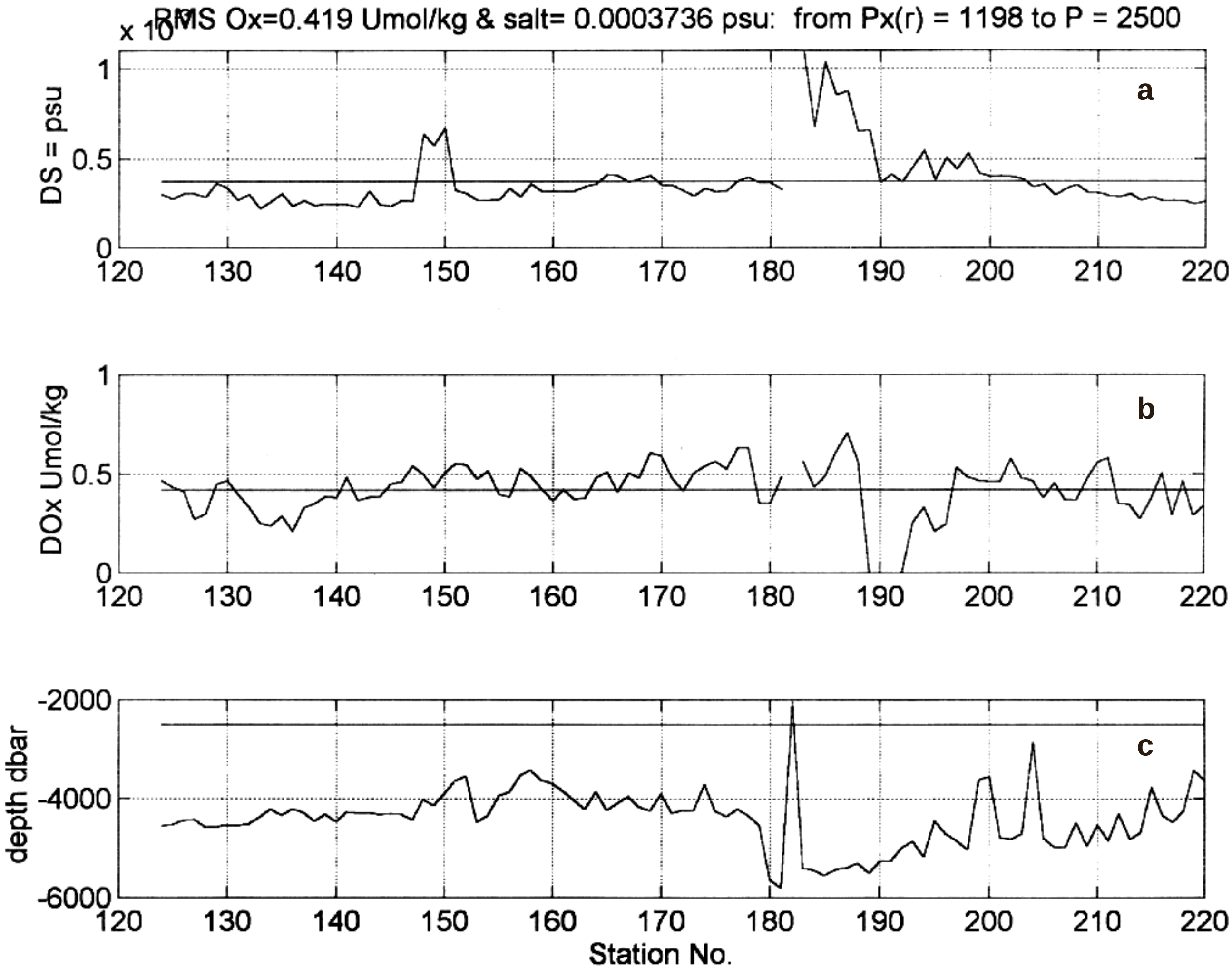

P16C Waterfall plot DS = (CTD_up-WS); .02 psu between stations
Pressure dbars
0
-1000
-2000
-3000
-4000
-5000
-6000
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
2
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
P16 Waterfall plot Salinity off-set by .02 psu

Figure 8



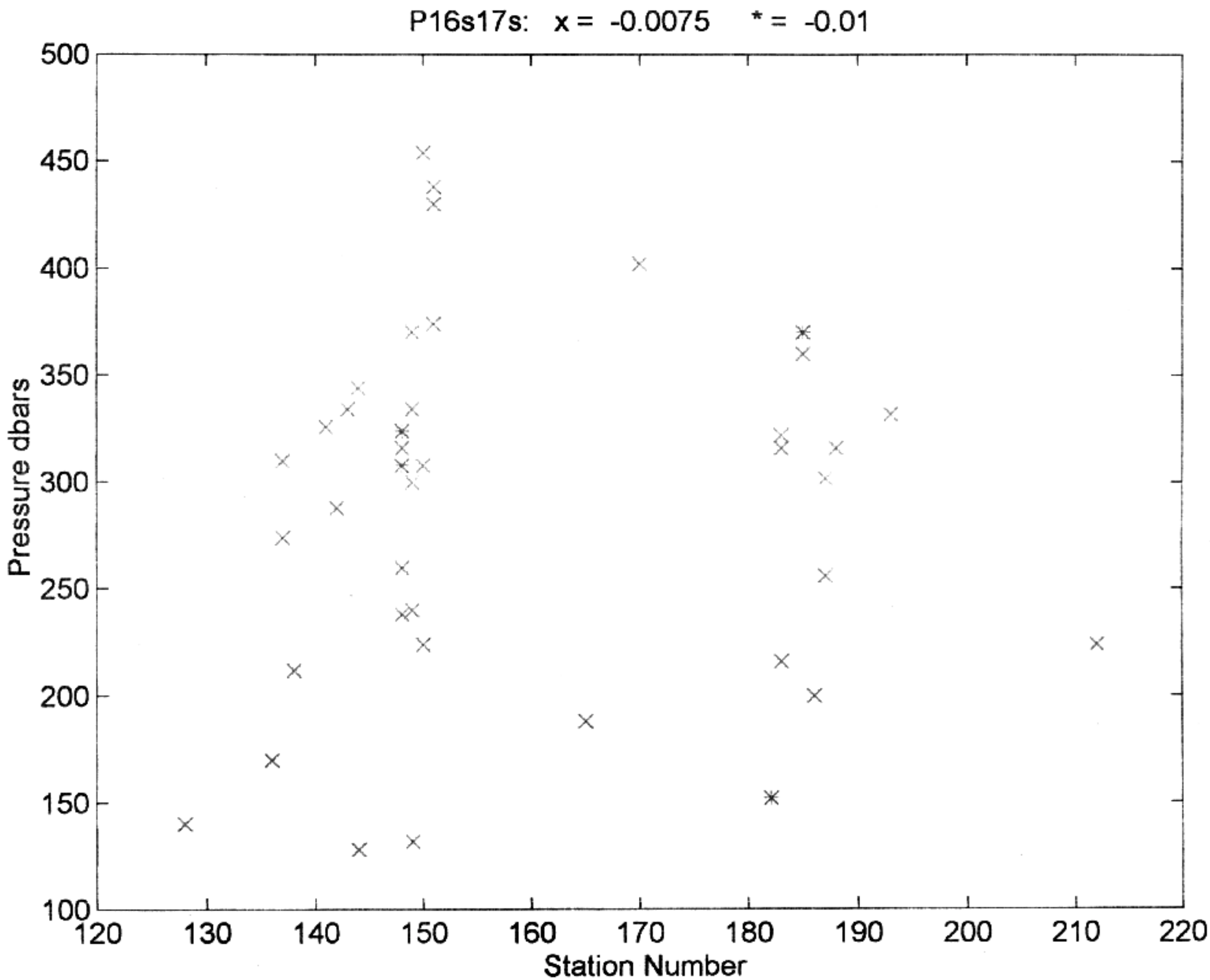
RMS Ox=0.2529 Umol/kg & salt= 0.0002199 psu: from Px = 2500
x 10^-4
DS = psu
4
2
0
a
DOx Umol/kg
0.5
0
b
depth dbar
-2000
-4000
-6000
c
120
130
140
150
160
170
180
190
200
210
220
Station No.

Figure 9



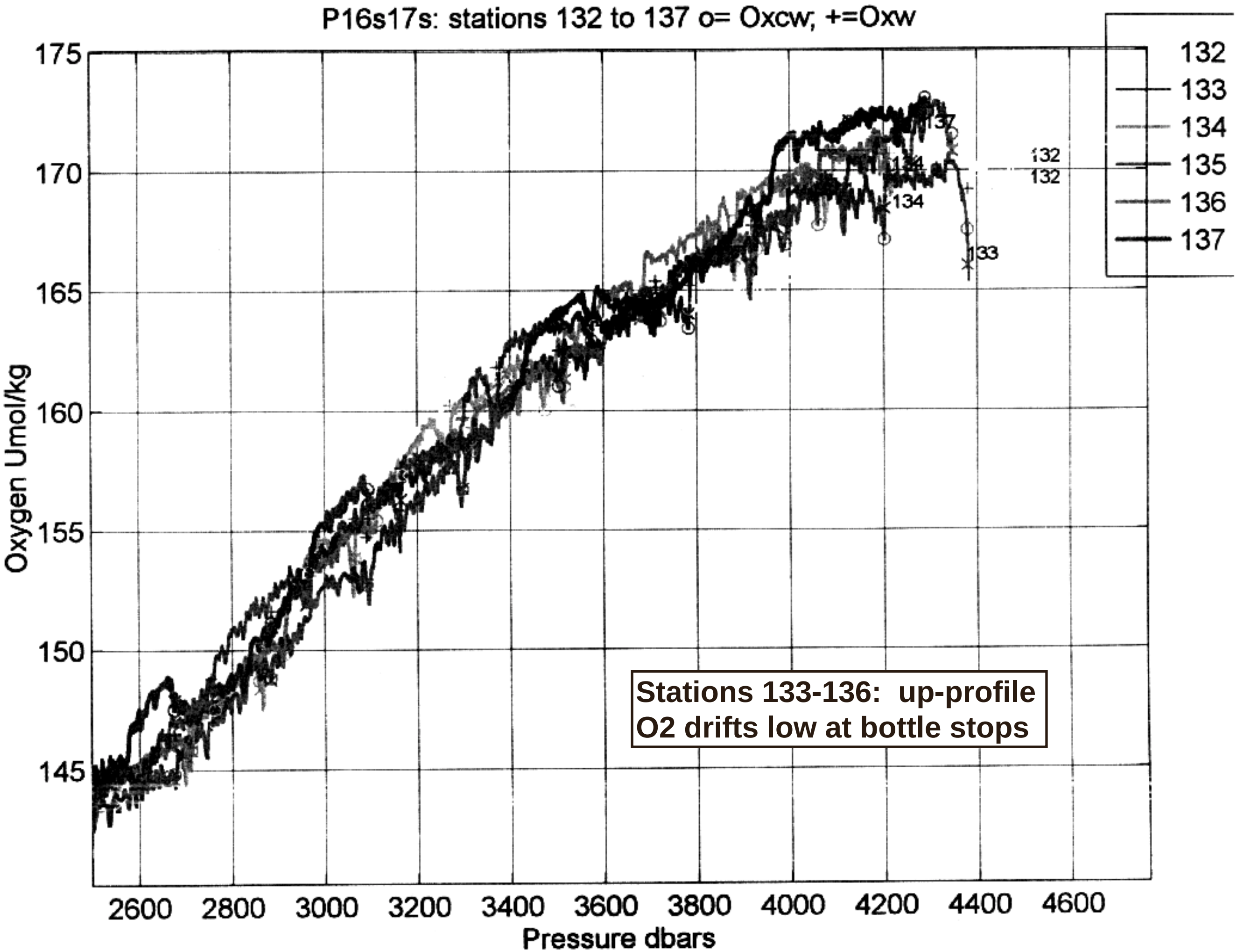
RMS Ox=0.419 Umol/kg & salt= 0.0003736 psu: from Px(r) = 1198 to P = 2500
x 10
DS = psu
a
DOx Umol/kg
b
depth dbar
c
Station No.

Figure 10



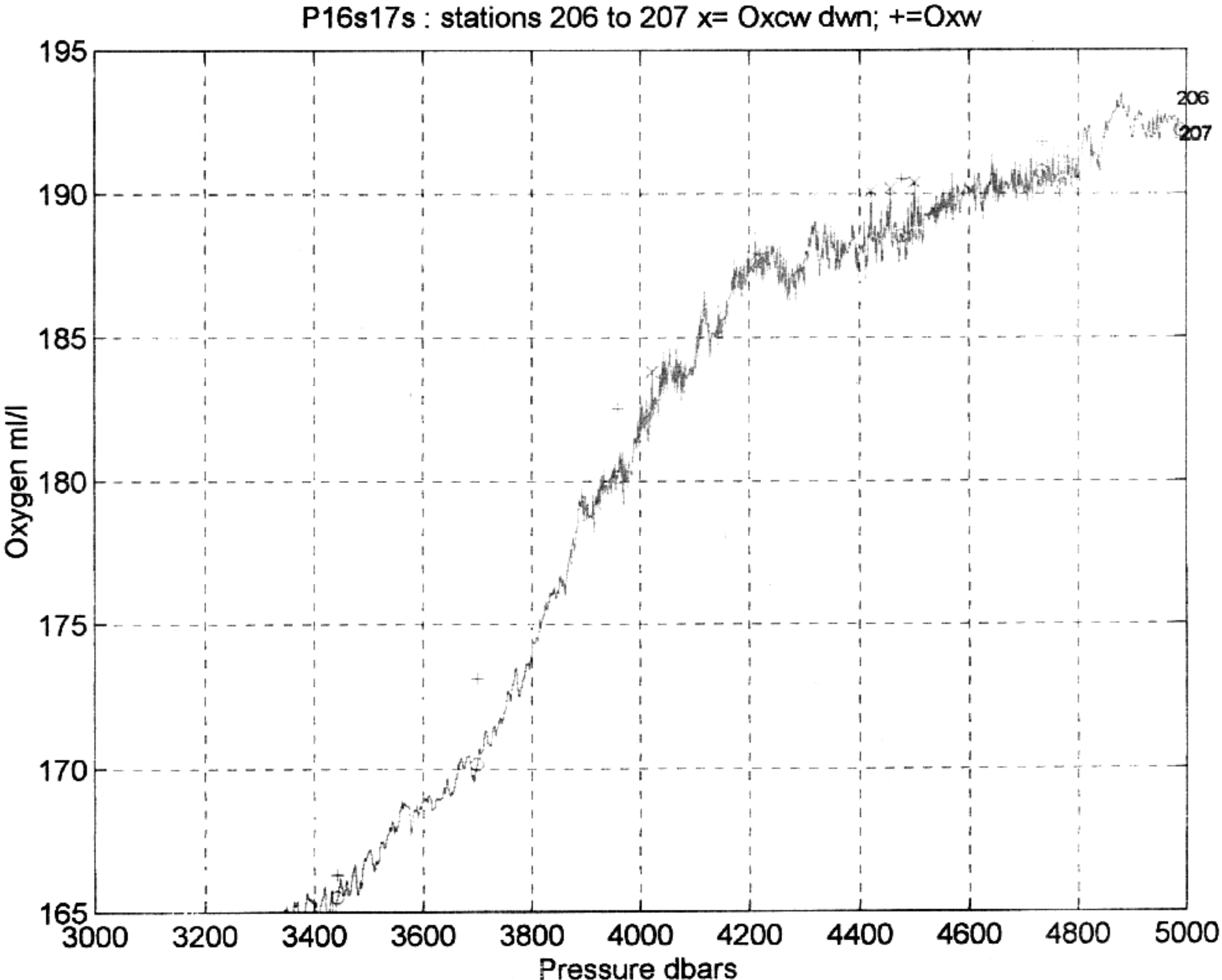
P16s17s: x = -0.0075 * = -0.01
500
450
400
350
300
250
200
150
100
Pressure dbars
120
130
140
150
160
170
180
190
200
210
220
Station Number

Figure 11



P16s17s: stations 132 to 137 o= Oxcw; +=Oxw
Oxygen Umol/kg
Pressure dbars
175
170
165
160
155
150
145
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
132
133
134
135
136
137
Stations 133-136: up-profile O2 drifts low at bottle stops

Figure 12



206

Figure 13

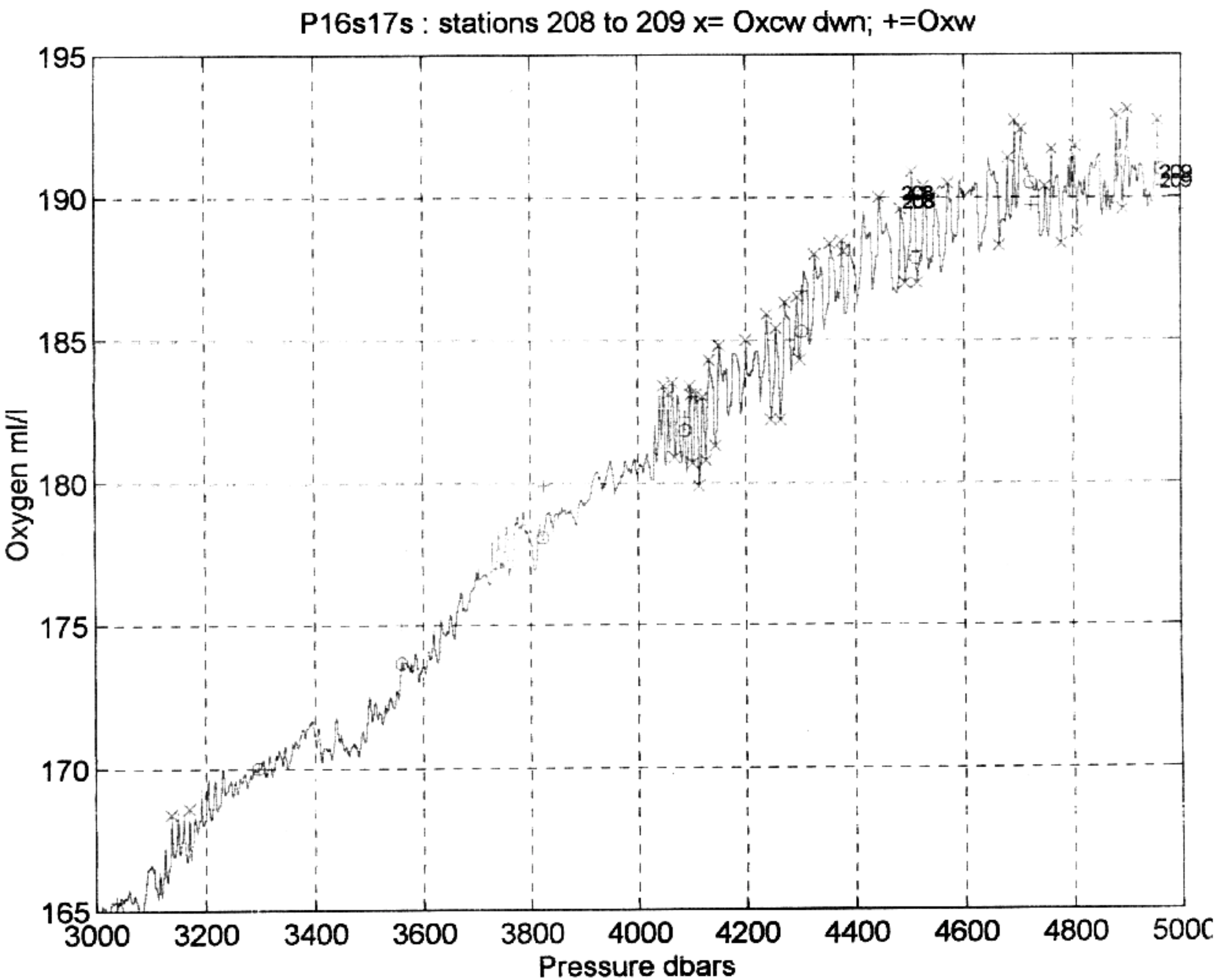

P16s17s : stations 208 to 209 x= Oxcw dwn; +=Oxw
Oxygen ml/l
195
190
185
180
175
170
165
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
Pressure dbars
208
209

Figure 14

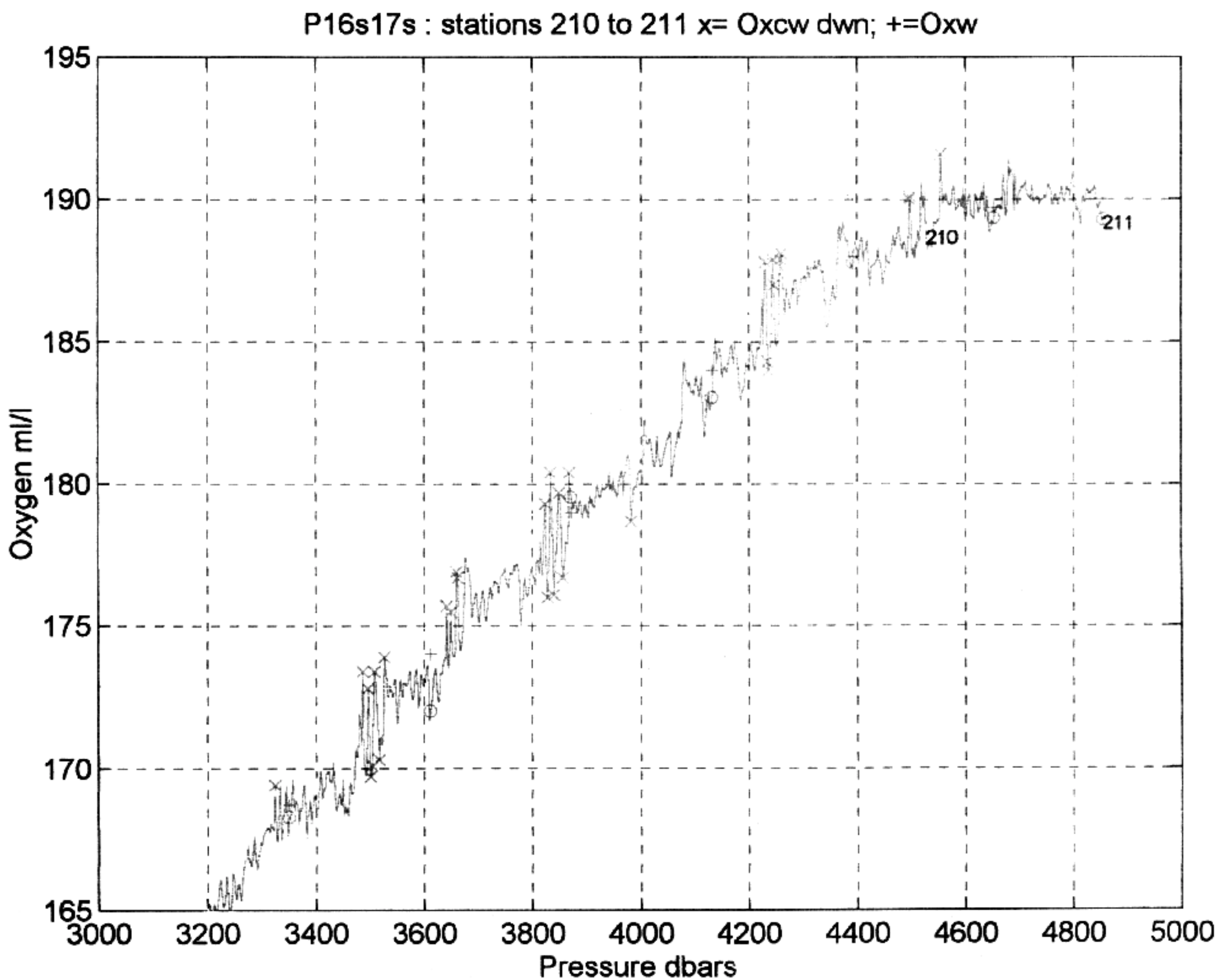
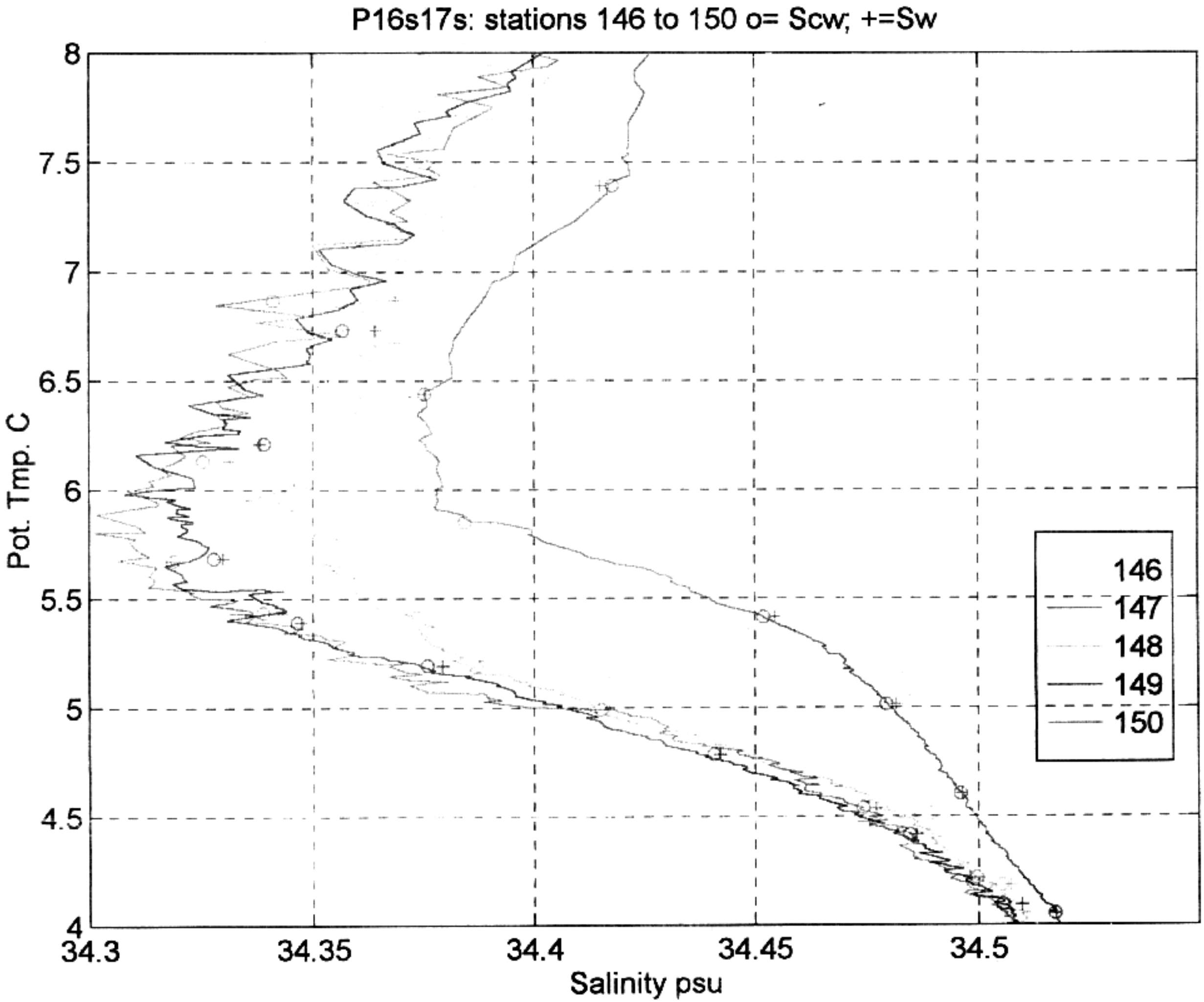

P16s17s : stations 210 to 211 x= Oxcw dwn; +=Oxw
195
190
185
180
175
170
165
Oxygen ml/l
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
Pressure dbars
210
211

Figure 15



P16s17s: stations 146 to 150 o= Scw; +=Sw
Pot. Tmp. C
Salinity psu
8
7.5
7
6.5
6
5.5
5
4.5
4
34.3
34.35
34.4
34.45
34.5
146
147
148
149
150

Figure 16

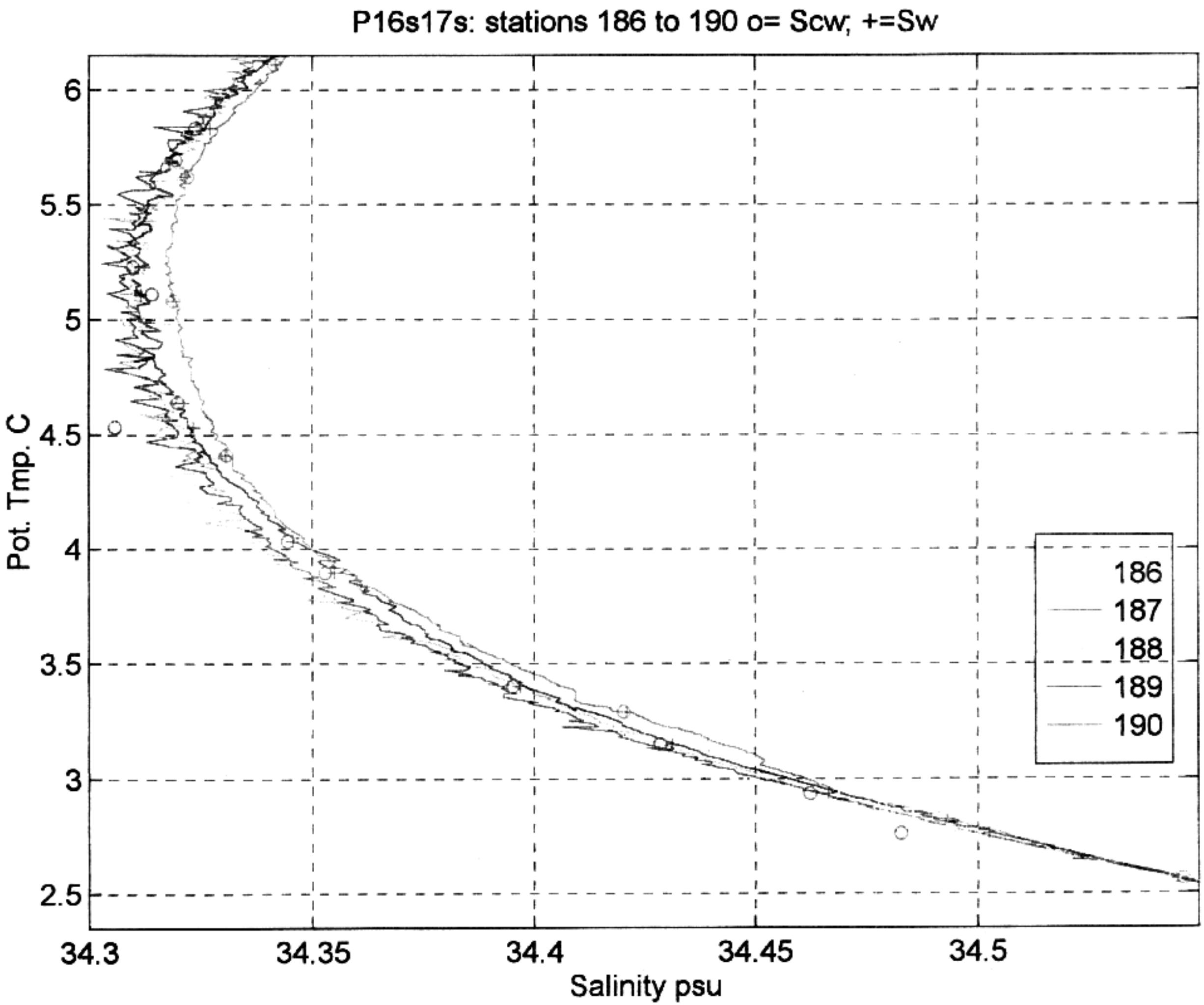
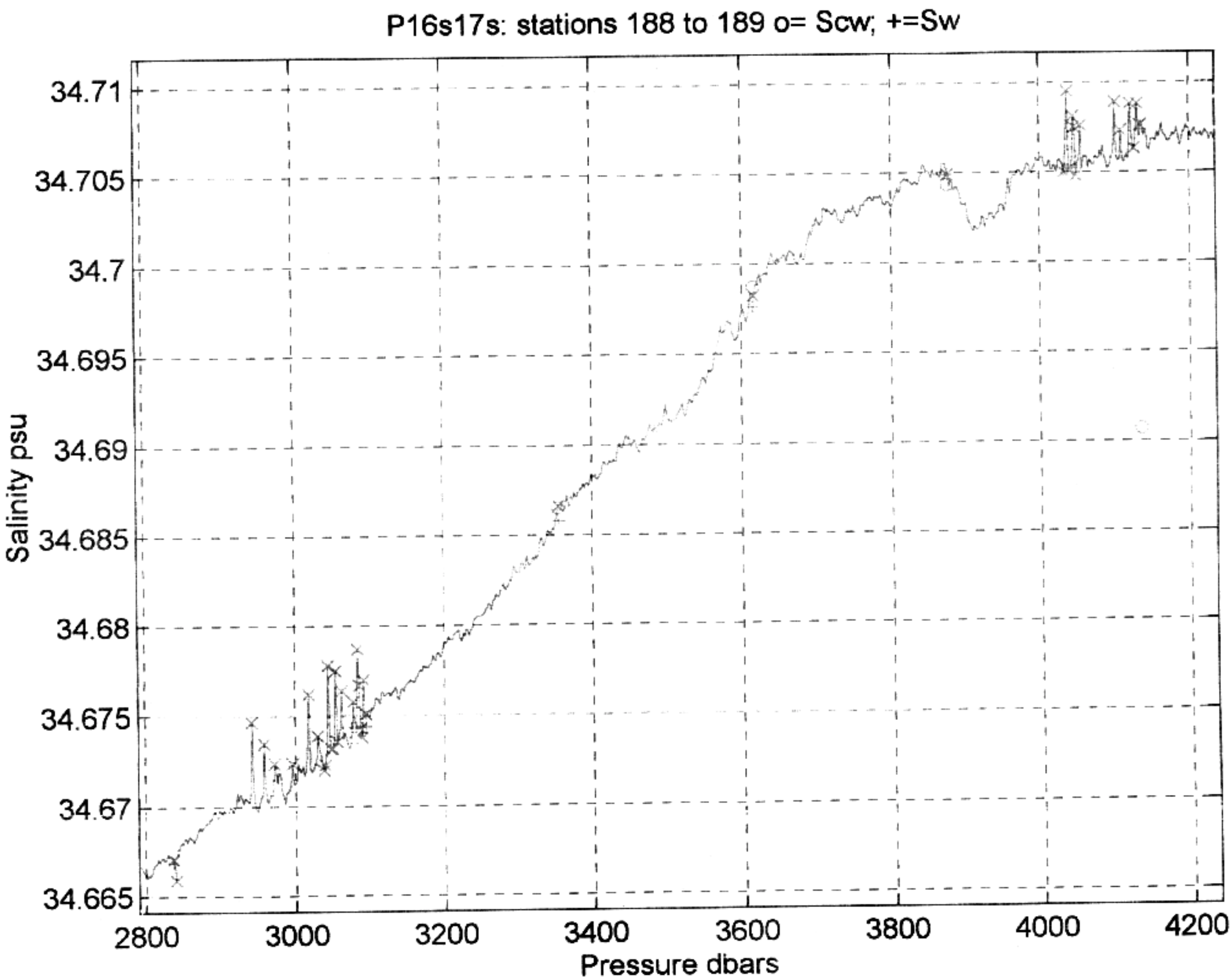
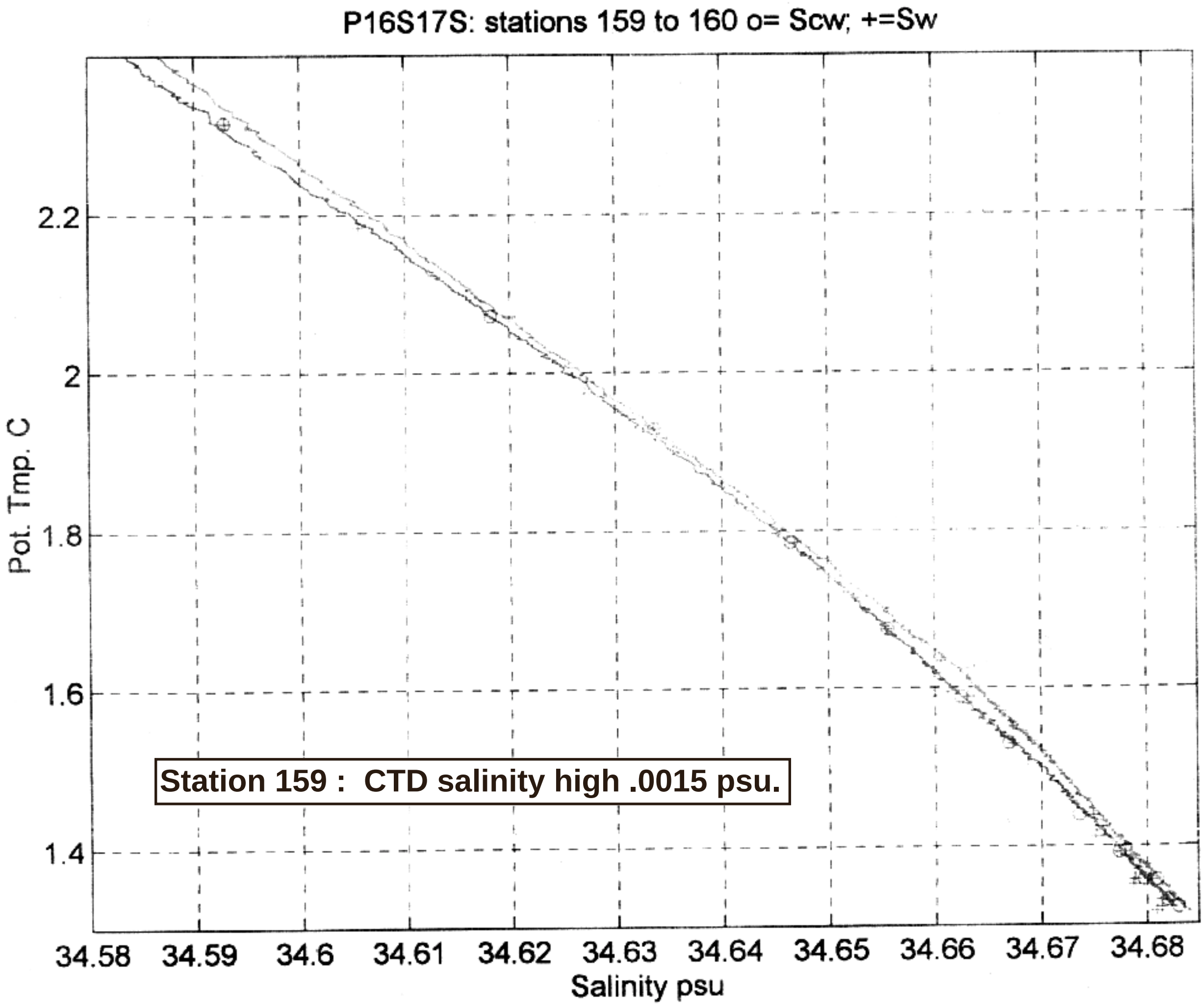

P16s17s: stations 186 to 190 o= Scw; +=Sw
Pot. Tmp. C
6
5.5
5
4.5
4
3.5
3
2.5
34.3
34.35
34.4
34.45
34.5
Salinity psu
186
187
188
189
190

Figure 17



P16s17s: stations 188 to 189 o= Scw; +=Sw
34.71
34.705
34.7
34.695
34.69
34.685
34.68
34.675
34.67
34.665
Salinity psu
2800
3000
3200
3400
3600
3800
4000
4200
Pressure dbars

Figure 18



P16S17S: stations 159 to 160 o= Scw; +=Sw
2.2
2
1.8
1.6
1.4
Pot. Tmp. C
34.58
34.59
34.6
34.61
34.62
34.63
34.64
34.65
34.66
34.67
34.68
Salinity psu
Station 159 : CTD salinity high .0015 psu.

E.2. Data Quality Evaluation of TUNES Leg II (P17S/P16S) Hydrographic Data

(A. Mantyla)
4 January 1994

The TUNES II cruise has produced a very good data set for the data sparse region of the central Pacific. The cruise P.I.s have made a detailed comparison of the TUNES II data with other near-by WOCE legs and with the old SCORPIO expedition; and have shown the results of the comparisons in the final cruise report submitted with the data. The agreement in dissolved oxygen among the recent cruises was excellent, salinity agreement good; and nutrient differences somewhat greater than hoped for in the WOCE guidelines. WOCE cruise nutrients have not met expectations elsewhere on other cruises, so the guidelines may be overly optimistic.

There were far fewer rosette trip malfunctions on this leg compared to the first leg, aside from the occasional lanyard hang-ups that nearly always occur on CTD-rosette cruises. However, there were problems with the CTDs, a CTD had to be assembled from two cannibalized CTDs. The results were not entirely satisfactory, as several of the CTD salinities listed for the bottle trips were clearly questionable; use of the listed CTD salinity would result in an instability, while use of the bottle salinity results in a smooth and stable profile. None of the CTD data were flagged as a problem by the data originators, but I have flagged several CTD salinities as questionable, particularly near stations 189-193. There were the typical spread of differences between the CTD and bottle salinities in the main pycnocline, probably due to "quick" trips before the rosette bottle could flush out enough to collect a water sample representative of the intended sampling depths. Few, if any of those levels were flagged since it is a common problem and one recognizes that rosette water samples tend to be smeared out a bit.

The CTD oxygen data at the bottle trip levels were not supplied; they would have been useful to confirm the considerable oxygen structure seen in the bottle data. The cruise report indicates the sample drawing temperature was recorded, but not used in the concentration calculation. The potential error could be as large as 0.2mM, an amount that is negligible compared to the reagent/seawater blank uncertainty. From the cruise report, it is not clear which reagent blank was used for this cruise. WOCE procedures specify distilled water reagent blanks, and page 40 of the cruise report states that was what was used; however page 25 of the report states "a generic seawater blank was applied to the ODF oxygen data." The cruise report should be corrected to reflect what was actually done on the cruise.

As on TUNES I, the data on this leg have been looked over very carefully by the originators. I have some qualms about accepting some of the originators "bad data" flags for points that only appear to be slightly off for no known reason and are within expected accuracy limits, or for oxygen data that looks fine, but has a sample log sheet comment "air leak". If an air leak does not appear to affect the sample, the comment is not sufficient reason to flag the oxygen as "bad". I have changed some of the "4" flags to "3", or even "2" based on comparisons with nearby stations at the same potential temperature.

The following are some specific problems that should be looked at:

Station 136

0db: Water sample data was flagged bad on the basis of a large CTD/bottle salinity difference. However, there is a greater than 0.5 salinity gradient between 0db and 34db, and comparisons usually do not agree well in strong haloclines. O_2 and nutrients particularly NO_2, confirm the water samples are ok. Also, at 4212db, the CTD salinity is questionable, bottle salinity is ok, based on adjacent station THETA - S profiles.

Station 148

4013db: O_2, Sil and PO_4 flagged "bad". However, note sharp drop in THETA. The data is the same as on adjacent stations "at the same potential temperature", a benthic front effect. The data is most likely ok. Also, CTD salt at 33db is questionable (unstable), bottle salt (stable) confirms CTD salt unlikely.

Station 158; mixed layer

39db and 82db: data nearly identical in all properties; 2db temperature .017C COLDER and more saline, thus unstable. CTD temperature would have to be much warmer to be stable. If CTD temperature is ok, suggest flag bottle salt and O_2 questionable.

Station 197

64db: O_2 and nutrients look like water is from deeper in the water column, perhaps near 200m. Salinity could be slightly off also. Leaker? NO_2 verifies data definitely not from 64db. Suggest flag data doubtful.

Station 202

675db: samples 113 and 137: Both listed at 675db, but the two CTD temperatures differ by 0.6C, they are probably the CTD temperatures at the original intended trip depths at 635db and 708db. List 675db temperature for both. The close agreement of the water sample data from the 2 bottles, and the large +/- CTD/bottle salinity differences at the intended depths led the data originators to assume both tripped "on the fly" at about 675db. The water samples were clearly wrong for the originally planned depths, and are flagged "bad", but they look ok at 675db. The oxygen data in particular agree to 0.1mM and are at a local maximum, similar to adjacent stations. This is an important level, so I would suggest: Flag the two bottles "4" (did not trip correctly), accept the water samples as ok, and list the correct CTD temperature and salinity for 675db.

STNNBR	CASTNO	SAMPNO	CTDPRS	CTDSAL ***********	SALNTY ***********	OXYGEN ***********	SILCAT ***********	NITRAT ***********	NITRIT **********	PHSPHT ***********	QUALT1	QUALT2
124	1	13	454.3							2.56	~~~~~~4	~~~~~~3
124	1	20	1392.4							2.70	~~~~~~4	~~~~~~2
124	1	21	1581.0							2.68	~~~~~~4	~~~~~~2
124	1	22	1780.0							2.82	~~~~~~2	~~~~~~3
124	1	29	2989.4							2.62	~~~~~~4	~~~~~~3
124	1	30	3185.2							2.61	~~~~~~4	~~~~~~3
124	1	33	3691.7							2.54	~~~~~~4	~~~~~~3
126	1	16	640.4			76.1					~~2~~~~	~~3~~~
126	1	36	4451.6			171.9					~~4~~~~	~~2~~~
131	1	5	134.5			181.4					~~4~~~~	~~3~~~
136	1	1	0.2		35.7454	214.0	1.38	1.85	0.03	0.36	~444444	~222222
136	1	36	4212.1	34.6838	34.6906						23~~~~~	32~~~~
137	1	34	3919.8							2.43	~~~~~~4	~~~~~~3
137	1	35	4127.2							2.42	~~~~~~4	~~~~~~3
137	1	36	4289.0							2.43	~~~~~~4	~~~~~~3
148	1	2	32.7	36.4731							2~~~~~~	3~~~~~
148	1	36	4012.8			171.0	132.72			2.40	~~44~~4	~~22~~2
151	1	1	2.7			204.8					~~4~~~~	~~3~~~
151	1	2	44.3			204.9					~~4~~~~	~~3~~~~
161	1	1	4.1		35.7044						~2~~~~~	~3~~~~
161	1	33	3462.1		34.6848						~2~~~~~	~3~~~~
163	1	30	2964.9			167.5					~~4~~~~	~~2~~~
164	1	35	3677.3		34.6873	175.0					~44~~~~	~22~~~
177	1	61	2.7			244.7					~~2~~~~	~~3~~~
189	3	26	2836.6	34.6501							2~~~~~~	3~~~~~
189	3	31	4135.5	34.6907							2~~~~~~	3~~~~~
189	3	38	5494.0	34.7130							2~~~~~~	3~~~~~
193	1	3	74.5	35.4213							2~~~~~~	3~~~~~
193	1	26	2440.2	34.6079							2~~~~~~	3~~~~~
194	3	12	597.6	34.3478							2~~~~~~	3~~~~~
194	3	37	749.8	34.2438							2~~~~~~	3~~~~~
194	3	32	4166.5	34.6949							2~~~~~~	3~~~~~
194	3	33	4429.8	34.6969							2~~~~~~	3~~~~~

STNNBR	CASTNO	SAMPNO	CTDPRS	CTDSAL ***********	SALNTY ***********	OXYGEN ***********	SILCAT ***********	NITRAT ***********	NITRIT **********	PHSPHT ***********	QUALT1	QUALT2
194	3	34	4691.3	34.6996							2~~~~~~	3~~~~~
194	3	38	5171.2	34.6881							2~~~~~~	3~~~~~
195	1	28	3015.2				132.66				~~~4~~~	~~~3~~
196	1	34	4290.1	34.6956							2~~~~~~	3~~~~~
197	1	2	64.3		35.5434	217.3	1.47	0.59	0.04	0.16	~222222	~333333
198	2	20	1284.3		34.4182						~2~~~~~	~3~~~~
202	1	13	675.0	34.3752							2~~~~~~	3~~~~~
202	1	37	675.0	34.3632							2~~~~~~	3~~~~~
203	1	25	2157.2							2.49	~~~~~~3	~~~~~~2
217	1	69	437.4			171.1					~~4~~~~	~~3~~~
219	1	5	132.9	35.8746							2~~~~~~	3~~~~~

E.3.a Data Quality Evaluation of CFC Data

(F.A. Van Woy)
January 13, 1995

We recently ftp'd the quality word changes that I made for Tunes leg2, PI6S_P17S. I believe that a reasonable assessment has been done. If the data originator wishes that I reconsider my choices, I will need to be provided with the following:

1) CFC air concentrations for each station
2) Calibration curves used for calculations
3) Chromatograms
4) Sample blanks applied and how determined
5) Stripper efficiency results
6) Contour plots

It is recommended on future cruises that the observer draw and run more replicate samples along with running more deep "blank" samples to assess the sample blank more thoroughly.

I believe that a reasonable quality assessment of the data has been done without the above items and any additional effort would take a fairly intensive involvement from this laboratory.

NBR	CASTNO	SAMPNO	CTDPRS	CFC-11	CFC-12	QUALT1	QUALT2
				**********	**********		
124	1	5	114.0	1.768	0.993	28	33
124	1	36	4562.4	0.008		8~	3~
125	1	3	77.8		0.943	~2	~3
125	1	10	267.7		0.100	~2	~3
126	1	1	0.2		0.916	~8	~3
126	1	2	42.0		0.902	~8	~3
126	1	3	82.4		0.929	~2	~3
126	1	4	96.9		0.950	~2	~3
126	1	5	116.7		1.010	~8	~3
126	1	14	461.5		0.026	~2	~3
126	1	16	640.4	0.050	0.032	22	33
127	1	1	10.3	1.866	0.891	28	33
127	1	2	37.9		0.906	~2	~3
127	1	3	78.5		0.917	~8	~3
127	1	4	93.3		0.955	~2	~3
127	1	5	107.2		0.985	~8	~3
128	1	2	52.5		0.908	~8	~3
128	1	3	75.9		0.886	~8	~3
128	1	5	143.8		1.064	~2	~3
128	1	6	185.6		1.165	~2	~3
128	1	7	231.8		0.549	~2	~3

NBR	CASTNO	SAMPNO	CTDPRS	CFC-11	CFC-12	QUALT1	QUALT2
				**********	**********		
128	1	8	283.5		0.116	~2	~3
128	1	9	334.3		0.049	~2	~3
128	1	10	384.7		0.035	~2	~3
129	2	17	871.9	0.007	0.009	22	33
129	2	28	2979.9	0.095		4~	3~
130	1	10	308.6		0.091	~2	~3
131	1	20	1313.4	0.008	0.009	22	33
132	2	11	336.8		0.078	~2	~3
132	2	12	407.4		0.031	~2	~3
132	2	20	1326.0	0.000	0.011	88	23
133	1	18	921.3	0.009	0.005	27	32
143	3	6	172.8	1.714	0.921	22	33
144	1	11	453.8		0.051	~2	~3
146	1	11	464.9		0.102	~2	~3
146	1	12	515.4		0.067	~2	~3
148	1	37	565.2		0.064	~2	~3
149	1	12	463.4		0.000	~2	~4
152	1	5	127.2	1.746		2~	3~
153	2	6	182.7	1.614	0.986	28	33
154	1	1	1.9	1.425		2~	3~
155	1	8	363.5	1.414	0.790	22	33
157	1	16	737.6	0.087	0.061	22	33
158	1	18	746.8	0.085	0.062	22	33
158	1	19	798.7	0.031	0.032	22	33
159	1	21	863.5		0.035	~2	~3
164	1	18	921.4		0.034	~2	~3
165	2	2	2264.7	0.020		2~	3~
166	2	21	1375.8	0.011		2~	3~
167	1	15	738.9	0.261	0.297	82	33
167	1	18	934.6	0.095	0.071	22	33
171	1	16	733.6	0.337	0.219	22	33
173	1	7	158.3	2.061	1.174	22	33
173	1	37	515.6	1.036	0.568	22	33
173	1	20	1079.6		0.049	~2	~3
173	1	21	1232.8		0.022	~2	~3
180	2	38	5641.6	0.023		2~	3~
182	2	34	1628.4	0.022		8~	3~
185	1	68	288.8	2.017	1.076	22	33
185	1	11	520.0	1.283	0.803	22	33
186	1	37	927.1	0.255	0.153	22	33
199	1	20	1023.7		0.047	~2	~3
206	1	37	635.1		0.301	~2	~3
207	1	12	493.1		0.458	~2	~3
212	1	17	764.5		0.100	~2	~3
214	1	3	95.3	1.754	0.968	22	33
214	1	68	278.7	1.949	0.907	22	33

NBR	CASTNO	SAMPNO	CTDPRS	CFC-11	CFC-12	QUALT1	QUALT2
				**********	**********		
214	1	69	328.7	1.837	0.837	22	33
214	1	70	388.9	1.529	0.658	22	33
214	1	11	449.1	1.041	0.450	22	33
214	1	12	511.7	0.716	0.298	22	33
214	1	13	574.9	0.450	0.188	22	33
214	1	37	646.7	0.198	0.089	22	33
215	1	61	1.5	1.680	0.950	22	33
215	1	62	33.1	1.660	0.931	22	33
215	1	3	78.2	1.681	0.933	22	33
215	1	64	123.9	1.677	0.943	22	33
215	1	5	153.7	1.672	0.943	22	33
215	1	6	177.7	1.671	0.926	22	33
215	1	7	201.5	1.674	0.912	22	33
215	1	68	223.9	1.573	0.890	22	33
215	1	69	247.6	1.602	0.870	22	33
215	1	70	296.4	1.467	0.806	22	33
216	1	61	2.8	1.692	0.921	22	33
216	1	62	32.6	1.630	0.905	22	33
216	1	3	62.0	1.677	0.928	22	33
216	1	64	102.8	1.703	0.922	22	33

E.3.b Final CFC Data Quality Evaluation (DQE) Comments on P17S_P16S.

(David Wisegarver)
Dec 2000

During the initial DQE review of the CFC data, a small number of samples were given QUALT2 flags which differed from the initial QUALT1 flags assigned by the PI. After discussion, the PI concurred with the DQE assigned flags and updated the QUAL1 flags for these samples.

The CFC concentrations have been adjusted to the SIO98 calibration Scale (Prinn et al. 2000) so that all of the Pacific WOCE CFC data will be on a common calibration scale.

For further information, comments or questions, please, contact the CFC PI for this section

R. Fine (rfine@rsmas.miami.edu)
or
David Wisegarver (wise@pmel.noaa.gov).

Additional information on WOCE CFC synthesis may be available at: http://www.pmel.noaa.gov/cfc

Prinn, R. G., R. F. Weiss, P. J. Fraser, P. G. Simmonds, D. M. Cunnold, F. N. Alyea, S. O'Doherty, P. Salameh, B. R. Miller, J. Huang, R. H. J. Wang, D. E. Hartley, C. Harth, L. P. Steele, G. Sturrock, P. M. Midgley, and A. McCulloch, A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE. Journal of Geophysical Research, 105, 17,751-17,792, 2000.

E.4. P16S17S TUNES-2 Final Report for AMS14C Samples

(Robert M. Key)

July 5, 1996

1.0 General Information

WOCE section P16S17S was the second in a series of three cruise legs referred to as "TUNES". Jim Swift of SIO was chief scientist for this leg. This report covers details of data collection and analysis for the small volume (AMS) radiocarbon samples. The reader is referred to "Documentation for WOCE Hydrographic Program section P16S17" by J. Swift as the primary source for cruise information. Of 97 stations, 25 were sampled for radiocarbon. The AMS station locations are shown in Figure 1 and summarized in Table 1

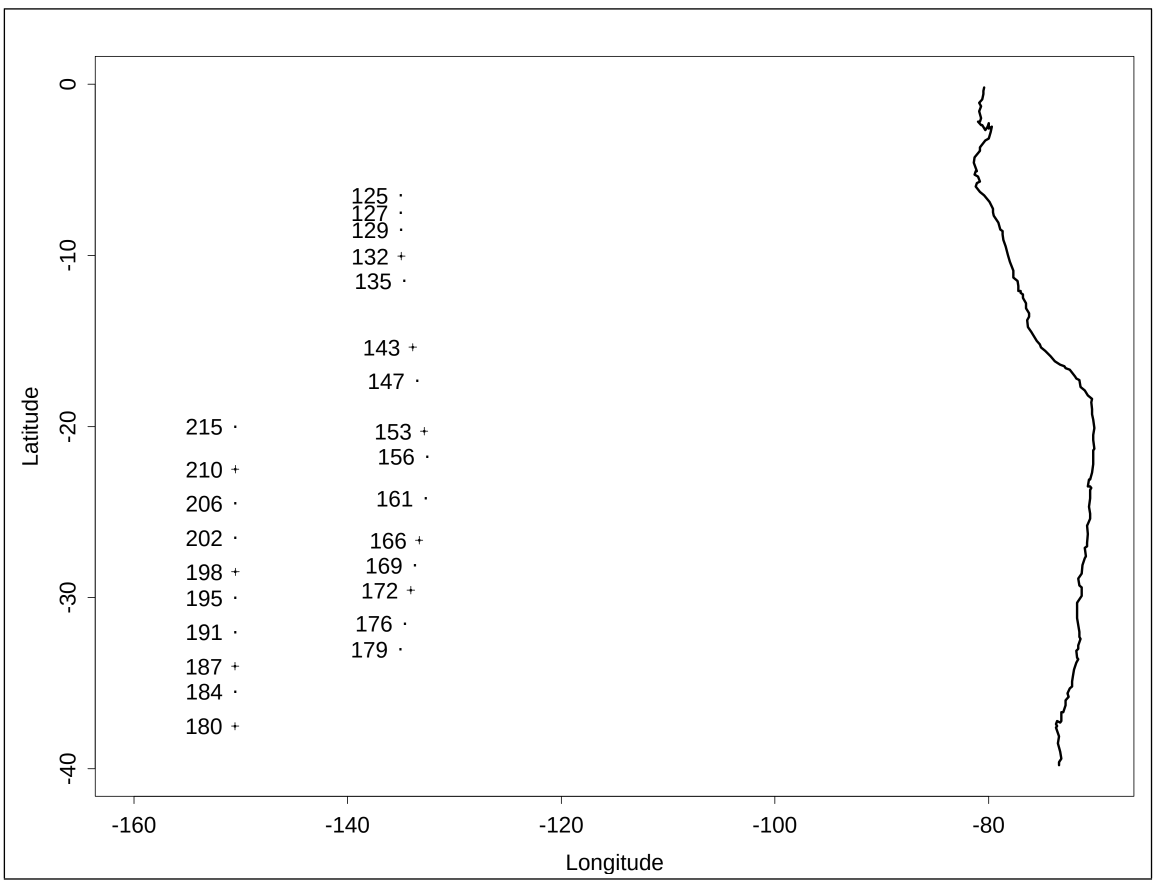


Figure 1: ^{14}C station locations for WOCE P16S17 (TUNES-2). Stations indicated by a dot were sampled only in the thermocline using the AMS technique. Stations indicated by a + were sampled over the entire water column using AMS to the thermocline and large volume sampling for deep and bottom waters.

^{14}C samples were additionally collected for measurement by the large volume

Table 1: P16S17 Station Data

Station	Date 1991	Latitude	Longitude	Bottom Depth (m)
125	7/22	-6.512	-135.012	4474
127	7/22	-7.522	-135.003	4387
129	7/23	-8.513	-134.982	4507
132	7/24	-10.055	-134.957	4444
135	7/25	-11.487	-134.700	4277
143	7/28	-15.377	-133.893	4221
147	7/29	-17.348	-133.470	4384
153	7/30	-20.282	-132.827	4414
156	7/31	-21.768	-132.532	3822
161	8/2	-24.212	-132.675	3810
166	8/3	-26.643	-133.295	4037
169	8/5	-28.102	-133.680	4192
172	8/5	-29.560	-134.065	4177
176	8/7	-31.510	-134.617	4303
179	8/8	-33.015	-135.028	4468
180	8/12	-37.513	-150.517	5527
184	8/13	-35.485	-150.508	5372
187	8/15	-34.008	-150.522	5303
191	8/16	-31.997	-150.500	5167
195	8/16	-30.013	-150.487	4412
198	8/18	-28.497	-150.497	4948
202	8/20	-26.510	-150.497	4739
206	8/21	-24.495	-150.485	4917
210	8/22	-22.503	-150.513	4463
215	8/24	-20.008	-150.505	3729

technique on 9 stations (132, 143, 153, 166, 172, 180, 187, 198 and 210). For information on the large volume samples, the reader is referred to the data report by Key (1996). AMS sampling was used for the upper thermocline and large volume sampling for the deep and bottom waters.

2.0 Personnel

^{14}C sampling for this cruise was carried out by Rich Rotter (Princeton). ^{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 and the Oregon State Univ. group respectively. R. Key (Princeton) 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 (7/96).

3.0 Results

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

3.1 Hydrography

Hydrography from this leg have been submitted to the WOCE office by the chief scientist and described in the previously mentioned report.

3.2 14C

Most of the $\Delta^{14}C$ values reported here have been distributed in two data reports (NOSAMS, 1995, 1996). Those reports included preliminary hydrographic data and ^{14}C results which had not been through the WOCE quality control procedures. This report supersedes any previous ^{14}C data distributions.

At this time 472 of 529 samples collected have been measured and reported. Replicate measurements were made on 13 of the samples. These replicate analyses are tabulated in Table 2. The table shows the mean and standard deviation for each set of duplicates. For

Table 2: Summary of Replicate Analyses

Sta-Cast-Bottle	$\Delta^{14}C$	Err	Mean[a]	Standard Deviation[b]
215-1-13	17.5	2.7	16.7	1.1
	15.9	3.3		
215-1-15[c]	-21.5	3.1	-14.4	10.1
	-7.2	2.8		
215-1-16	-75.9	2.6	-71.4	6.4
	-66.9	2.8		
215-1-17	-100.6	2.9	-99.2	2.0
	-97.8	2.5		
215-1-18	-146.9	4.5	-140.1	9.7
	-133.2	2.5		
215-1-20	-168.6	3.2	-164.2	6.2
	-159.8	2.7		
215-1-21	-186.9	2.7	-184.8	3.0
	-182.6	2.6		
215-1-22	-201.1	2.1	206.0	6.9
	-210.8	2.1		
215-1-24	-217.4	3.4	-219.9	3.5
	-222.4	2.4		

Table 2: Summary of Replicate Analyses

Sta-Cast-Bottle	$\Delta^{14}C$	Err	Mean[a]	Standard Deviation[b]
215-1-37	-6.9	2.7	-11.9	7.0
	-16.8	2.9		
215-1-61	102.5	3.0	106.7	5.9
	110.8	3.2		
215-1-64	119.7	4.2	112.0	10.9
	104.3	3.2		
215-1-68	130.8	3.5	130.0	1.1
	129.2	3.0		

a. Error weighted mean reported with data set

b. Error weighted standard deviation of the mean reported with data set.

c. Only first run retained for data set

these few samples, the average standard deviation is 5.7‰. This precision estimate is approximately correct for the time frame over which these samples were measured. For a summary of the improvement in precision with time at NOSAMS, see Key, *et al*. (1996). In the final data reported to the WOCE office, the error weighted mean and error weighted standard deviation of the mean are given for replicate analyses (WOCE QC code 6).

4.0 Quality Control Flag Assignment

Quality flag values were assigned to all ^{14}C measurements using the code defined in Table 0.2 of WHP Office Report WHPO 91-1 Rev. 2 section 4.5.2. Measurement flags values of 2, 3, 4, 6 and 9 have been assigned to date. Approximately 50 samples remain to be measured. With a few exceptions, these samples will be completed. Currently, the unmeasured samples are incorrectly coded with a flag value of 9 (no sample collected) rather than 1 (sample collected) or 5 (no result reported). The choice between values 2 (good), 3 (questionable) or 4 (bad) is involves some interpretation. There is very little overlap between this data set and any existing ^{14}C data, so that type of comparison was difficult. In general the lack of other data for comparison led to a more lenient grading on the ^{14}C data.

When using this data set for scientific application, any ^{14}C datum which is flagged with a “3” should be carefully considered. My subjective opinion is that any datum flagged “4” should be disregarded. When flagging ^{14}C data, the measurement error was taken into consideration. That is, approximately one-third of the ^{14}C measurements are expected to deviate from the true value by more than the measurement precision. 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). As more of the Pacific

Table 3: Summary of Assigned Quality Control Flags

Flag	Number
2	443
3	11
4	5
6	13

data set becomes available, it is possible that some of these flag values may be modified. Any additional data received for this leg will be reported to the WOCE office as they become available.

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 are included in the figures. Figure 2 shows the $\Delta^{14}C$ values with 2σ error bars plotted as a function of pressure for the upper two kilometers of the water column. This figure clearly demonstrates the sampling strategy used during the TUNES legs. That is, AMS sampling was almost totally limited to the upper 1500 meters of the water column. Large volume Gerard barrel sampling was used to cover the deep and bottom waters. This strategy was chosen primarily because the collection cost for AMS ^{14}C samples is significantly less than for the Gerard technique. At the time of this cruise, it was known that the AMS technique was less precise than the large volume technique, however Figure 2 clearly demonstrates that AMS precision is easily sufficient to resolve the vertical gradients in $\Delta^{14}C$, at least in the upper kilometer. The data in Figure 2 fall into two fairly distinct groups in the 250-1000 meter depth range. The stations included in the group with the lower $\Delta^{14}C$ values for a given depth are those which are equatorward of 16°S (Stations 125-143). The stations south of station 147 tend to group together at somewhat higher values for a given depth, regardless of the longitude (to first order). This separation is due to a doming of the $\Delta^{14}C$ isopleths to shallower depths toward the Equator.

Figure 3 shows the $\Delta^{14}C$ values plotted against silicate for samples from the upper 2 kilometers of the water column. 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. Clearly, this relationship is not ideal for the P16S17 data set. The data points having sili-

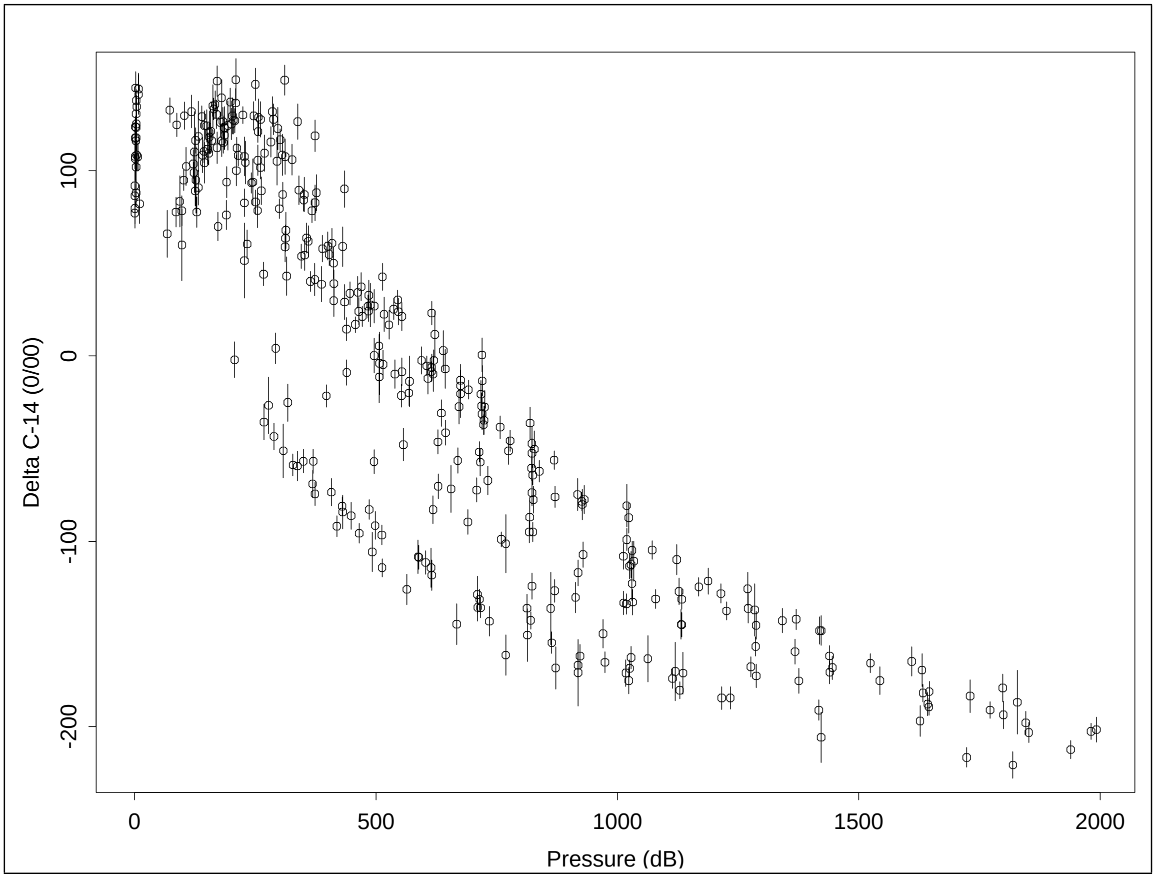


Figure 2: AMS $\Delta^{14}C$ results for P16S17 stations shown with 2σ error bars.Only those measurements having a quality control flag value of 2 are plotted. The lower grouping of data points is from stations north of 16°S.

cate values greater than or equal to 60 µmol/kg almost certainly have no bomb-radiocarbon component and should therefore lie on, rather than below, the line as seen in Figure 3. For these data the slope of the line needs to be steeper or/and the intercept needs to be lower. A least squares fit of the data from samples between 1 and 2 km depth (n=73; R^2=.92) gives an intercept of -69±3 which is easily within error of Broecker's -70, but the intercept value of -1.26±.04 is significantly steeper than the -1. calculated for the GEOSECS global data set.

Figure 4 and Figure 5 are objectively contoured sections (LeTraon, 1990) of the $\Delta^{14}C$ distribution for the upper kilometer of the water column (Station 125-179 and 180-215, respectively). Obvious in Figure 4 is the doming of the isopleths toward the Equator and the subsurface location of the maximum $\Delta^{14}C$ concentration for most of the section. In both sections, from the southern end to approximately 25°S and a depth of approximately 600m to the bottom on the section is thermostad region referred to by McCartney (1977, 1982) and Tsuchiya and Talley (1996) as Subantarctic Mode Water. Within this tongue of relatively low salinity water, the $\Delta^{14}C$ isopleths are parallel to the isopycnals (Key, *et al*., 1996).

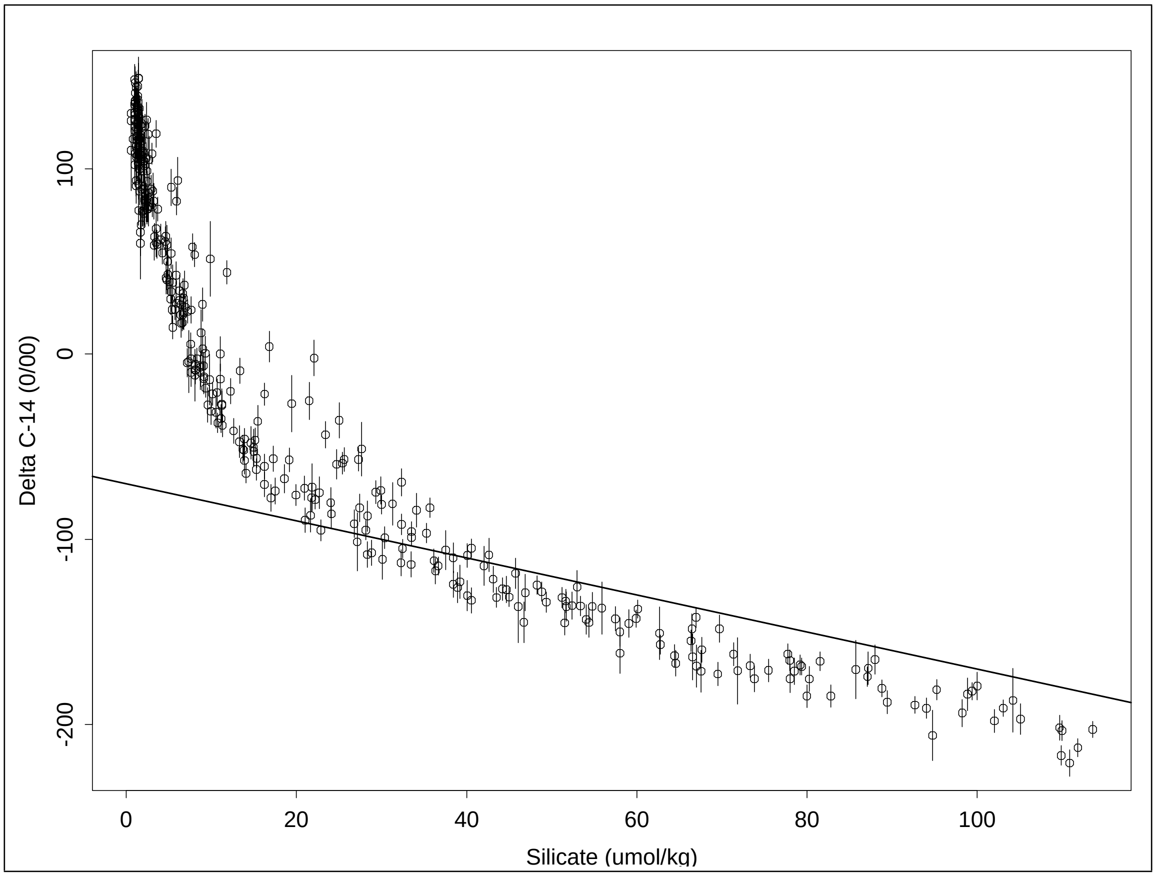


Figure 3: $\Delta^{14}C$ as a function of silicate for P16S17 AMS samples. The straight line shows the relationship proposed by Broecker, *et al.*, 1995 ($\Delta^{14}C$ = -70 - Si with radiocarbon in ‰ and silicate in μmol/kg).

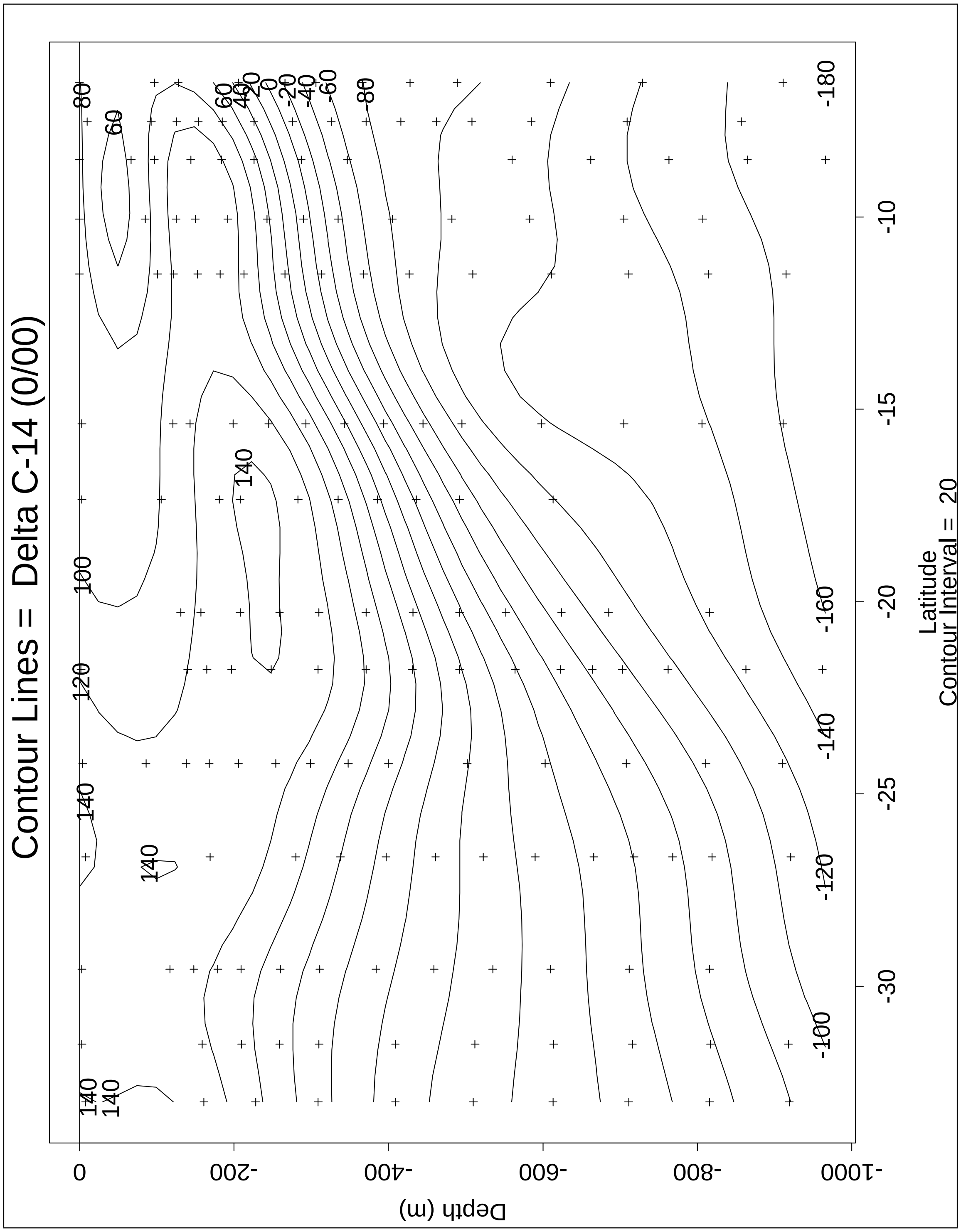


Figure 4: $\Delta^{14}C$ concentration in the upper kilometer of the meridional portion of TUNES leg 2(Stations 125-179; WOCE line P17C) along 135°W. Gridding done using the method of Letraon (1990); all samples measured using the AMS technique (Key, 1996a,b; Key, *et al*., 1996). For most of the section the maximum concentration is found below the surface.

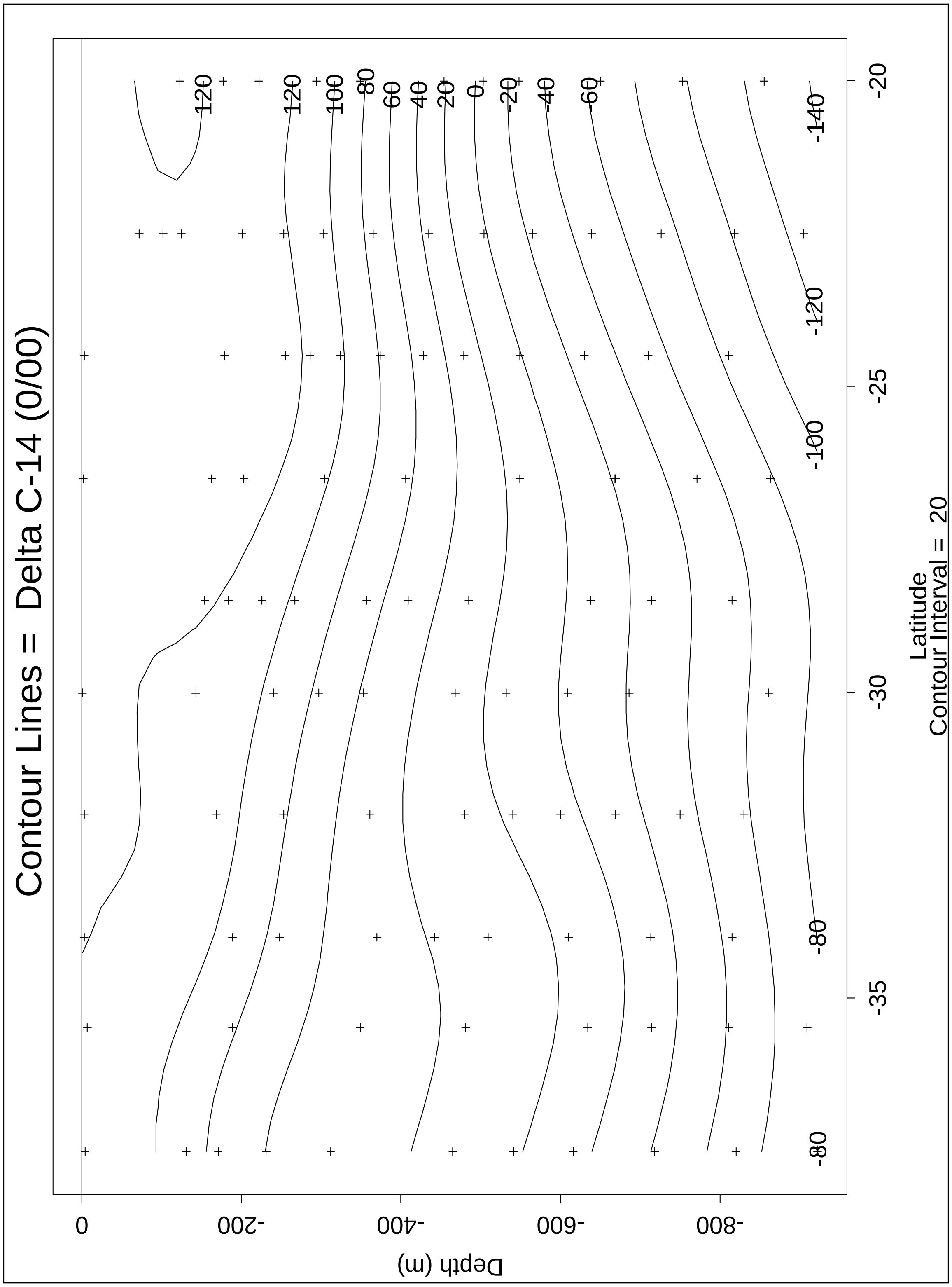


Figure 5: $\Delta^{14}C$ concentration in the upper kilometer of the meridional portion of TUNES leg 2 (Stations 180-215; WOCE line P17C) along 155°W. Gridding done using the method of Letraon (1990); all samples measured using the AMS technique (Key, 1996a,b; Key, *et al.*, 1996). For the northern portion of the section the maximum concentration is found below the surface

6.0 References and Supporting Documentation

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LeTraon, P.Y., A method for optimal analysis of fields with spatially variable mean, *J. Geophys. Res., 95*, 13543-13547, 1990.

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Peng, T.-H., R. M. Key and H. G. Östlund, Temporal variations of bomb radiocarbon inventory in the Pacific Ocean, *Marine Chem., submitted,* 1996.

Swift, J., “Documentation for WOCE Hydrographic Program section P17C”, unpublished WHP manuscript.

Tsuchiya, M., and L.D. Talley, Water-property distributions along an eastern Pacific hydrographic section at 135°W, *J. Mar. Res., 54(3),* 1996.

Data Processing Notes

Date	Contact	Data Type	Data Status Summary
01/04/94	Mantyla	NUTs/S/O	DQE Report rcvd @ WHPO
40/09/96	Millard	CTD	DQE Report rcvd @ WHPO
07/07/98	Lupton	HELIUM	Submitted for DQE
07/07/98	Lupton	HELIUM	Submitted for DQE
01/19/99	Willey	CFCs	Data rcvd @ WHPO

I received the CFC-11/12 datasets for the following WHP lines:

EXPOCODE	31WTTUNES/2	WHP-ID	P17S,P16S
EXPOCODE	31WTTUNES/1	WHP-ID	P17C
EXPOCODE	316N138/12	WHP-ID	P19C
EXPOCODE	318MWEST_4_5	WHP-ID	P21E/W
EXPOCODE	316N138/3	WHP-ID	P6E

Each file looks fine and has been placed in the proper archived directory on our machine so that they can be merged in with the rest of the values.
-Steve Diggs

I just ftp'd our cfc files to the /INCOMING/RFine_cfcs directory. The files named *.sea are hydro files with our final cfc values and quality bytes merged in. The files named *_cfcs.dat are files that include station, cast, bottle, CFCs and quality bytes. Please let me know if you have any problems and I'll let you know if we have any changes (hopefully not...).

Date	Contact	Data Type	Data Status Summary
02/17/99	Bartolacci	CFCs	Data Merged/OnLine

P16s(31WTTUNES_2), p17c(31WTTUNES_1), and p19c(316N138_12) have all had cfc data from Rana Fine merged and updated into them. The tables and files have been updated to reflect this change. Data are public.

Date	Contact	Data Type	Data Status Summary
04/29/99	Bartolacci	DELC13	Data and/or Status info

Requested from P. Quay

Date	Contact	Data Type	Data Status Summary
10/08/99	Evans	DELHE3	Submitted for DQE
10/20/99	Willey	CFCs	Final Data Rcvd @ WHPO

This is a follow-up to last month's message requesting that all of our Pacific and Indian Ocean CFCs be made accessible to the public. Our cruises are; (Pacific) P17C, P1716S, P06E, P19C, P17N, P21E, and (Indian) I09N, I05W/I04, I07N, I10.

Date	Contact	Data Type	Data Status Summary
01/18/00	Key	DELC14 LV	Final Data Rcvd @ WHPO
02/04/00	Kozyr	ALKALI/PCO2/TCARBN	Final Data Rcvd @ WHPO

(DQE Complete)

Date	Contact	Data Type	Data Status Summary
06/21/00	Bartolacci	helium/delhe3	Data Updated

not yet merged into btl file

Date	Contact	Data Type	Data Status Summary
07/12/00	Buck	CFCs	Data Merged

Moved RFine_cfcs_p1716s.sea and RFine_cfcs_p1716s_cfcs.dat from /usr/export/ftp-incoming.2000.02.14/RFine_cfcs

The RFine files are different from the FINE_WILLEY files. The RFine files look newer. I ran Bren's code on it and the data from the RFine_cfcs_p1716s_cfcs.dat file has been merged into p16shy.txt.

07/25/00	Johnson	DOC	ODF Report rcvd @ WHPO

I transferred files over to the ftp-incoming directory the easy way (for me)... You will find the following "new" directories in /usr/export/ftp-incoming on whpo:

p16a_p17a p17c_p17s_p16s p17e_p19s

I already gave you p19c (which I see is in P19Cdoc). I thought it was redundant to put long names in every filename, so I made the directory name with the cruise lines, and the files are all the same. The figs files are all figxx.ps (where xx should indicate the figure numbers referenced in the documentation). I also included ps and ascii versions of the original documentation and applicable appendices. (appendix a and b will be missing - they are outdated now and shouldn't be included in anything.)

10/02/00	Anfuso	HELIUM	Website Updated

Data merged into online Bottle file: (helium, delhe3)

Helium data from L. Evans merged into hyd file. Updated file on line. Note: Some helium data from the Evan's group replaced data values that preexisted in the hyd file. These preexisting data were duplicate samples drawn by a different helium group.

11/21/00	Uribe	DOC	Submitted

2000.11.21 KJU
File contained here is CRUISE SUMMARIES and NOT sumfiles. Files listed below should be considered WHP DOC files. Documentation is online.

2000.10.11 KJU
Files were found in incoming directory under whp_reports. This directory was zipped, files were separated and placed under proper cruise. All of them are sumfiles. Received 1997 August 15th.

02/06/01	Stuart	DELC13	Submitted

06/22/01	Uribe	CTD/BTL	Website Updated: CSV File Added

CTD and Bottle files in exchange format have been put online.

11/16/01	Bartolacci	CFCs	Data Ready to be Merged

Updated CFCs ready to be merged I have placed the updated CFC data file sent by Wisegarver into the P16s original directory in a subdirectory called 2001.07.09_P16SP17S_CFC_UPDT_WISEGARVER This directory contains data, and several copies of documentation and readme files (because multiple submissions were attempted, files appear to be duplicates). data are ready for merging

01/08/02	Uribe	CTD	Website Updated: CSV File Added

CTD has been converted to exchange using the new code and put online.

01/22/02	Hajrasuliha	CTD/BTL	Internal DQE completed

created .ps files, check with gs viewer. Created *check.txt file

04/17/02	Anderson	BTL/SUM	Data Reformatted

SUM file reformatted, lvs file from Key reformatted: salnty, oxygen, silcat, nitrat, nitrit, phspht, revprs, revtmp, delc14, delc13, c14err

Reformatted the .sum file to conform with the accepted WHP format. Put online. Reformatted the .lvs file from Key. This needs to be linked to the web site.

Reformatted .lvs file p16s17slv.data from Key found in: .../onetime/pacific/p16/p16s/original/2000.01.18_KEY_C14-LV.dir Data file a cast 4 for stations 198 and 210. The .sum file does not have a cast 4. This needs to be resolved.

05/06/02	Muus	DELC13	Data Merged into BTL file

Data merged into online file, new csv file online P17S DELC13 merged into bottle file and put on line together with new exchange file. Removed "1" flags from QUALT words.

Notes on P16S/P17S merging May 6, 2002 D.Muus

1. Merged P17S DELC13 from: /usr/export/html-public/data/onetime/pacific/p17/original/20010206_C13_P17_STUART.e mail into bottle file (p16shy.txt 19990216WHPOSIODMB)
2. Only sample reference in C13 data file is station, cast and niskin. SAMPNO appears same as BTLNBR in bottle file so no apparent problem.
3. Changed quality flag "1"s in QUALT1 to "9"s. Copied QUALT1 to QUALT2 after checking that no QUALT2 flags differed from QUALT1 other than being "1"s or "9"s.
4. Arnold Mantyla DQE recommendations were in QUALT1 except for:

Sta	Ca	Sample	
158	1	1	1.8db
202	1	13	675.0db
202	1	37	675.0db

   which require CTD processing expertise.
   1) Is 158/1/1 CTD temp ok?
   2) Calculate corrected Sta 202 up-cast CTD temp and salinity at 675db.
   Left these flags unchanged.
5. No DELC13 data for the P16S stations.
6. Made new exchange file for Bottle data.
7. Checked new bottle file with Java Ocean Atlas.

05/24/02	Anderson	DELC13	Data Merged into BTL file

Data merged into online file, new CSV file created Merged DELC13 into online file p16shy.txt (20020502WHPOSIODM). The DELC13 data was retrieved from Bob Key's ftp site in May of 2001. Dana Stuart sent a new file May 24, 2002. A quick comparison indicates that the values are the same.

Made a new exchange file.

Notes:

- Merged DELC13 into online file p16shy.txt (20020502WHPOSIODM).
- File with DELC13 was retrieved from Bob Key's ftp site in May of 2001.
- Key's file contained both P16S and P17S DELC13 data. I did not merge the DELC13 from Key's file into the P17S part since Dave Muus had already done that using a file sent by Dana Stuart 20010206 which contained only P17S DELC13 data.
- Compared Key's file with file received from Dana Stuart on May 24, 2002. Values appear to be the same.

06/28/02	Uribe	LVS	LVS data linked to website

06/28/02	Anderson	LVS	Data Updated

Corrections made, file needs to be linked to web site.

Reformatted lvs file p16s17slv.data from Key found in p16s/original/2000.01.18 _KEY_C14-LV.dir. This file needs to be linked to the web site.

09/23/02	Kappa	DOC	Cruise Reports Updated, OnLine

Added to both the Text version of the Cruise Report and the new PDF Version:

- Report on Large Volume Samples (R. Key);
- Report on AMS 14C (R Key);
- DQE Reports on CTD, BTL and CFC data;
- these Data Processing Notes

PDF Version also has:

- links from the table of contents to appropriate text,
- links from figure and table references in the text to the appropriate figures and tables.

Deleted Appendices A & B as per M. Johnson's instructions that they are both out of date. (7/25/00)