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CTD/O_2 MEASUREMENTS COLLECTED ON A CLIMATE AND GLOBAL CHANGE CRUISE (WOCE SECTIONS P14S AND P15S) DURING JANUARY–MARCH, 1996

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CTD/O_2 Measurements Collected on a Climate and Global Change Cruise (WOCE Sections P14S and P15S) During January–March, 1996

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ABSTRACT. Summaries of CTD/O_2 measurements and hydrographic data acquired on a Climate and Global Change cruise during the austral summer of 1996 aboard the NOAA ship *Discoverer* are presented. The majority of these data were collected along WOCE section P14S from 53°S, 170°E to 66°S, 171°E and WOCE section P15S from 67°S, 170°W to 0°, 169°W. Also presented are data collected along a short section across the Samoan Passage. Data acquisition and processing systems are described and calibration procedures are documented. Station location, meteorological conditions, CTD/O_2 summary data listings, profiles, and potential temperature-salinity diagrams are included for each cast. Section plots of oceanographic variables and hydrographic data listings are also given.

1. Introduction

The long-term objective of the Climate and Global Change Program is to provide reliable predictions of climate change and associated regional implications on time scales ranging from seasons to centuries. In support of NOAA's Climate Program, PMEL scientists have been measuring the growing burden of greenhouse gases in the Pacific Ocean and the overlying atmosphere since 1980. The NOAA Office of Global Programs (OGP) sponsors the Ocean Tracers and Hydrography Program and Ocean-Atmosphere Carbon Exchange Study (OACES) to study ocean circulation, mixing processes, and the rate at which CO_2 and chlorofluorocarbons (CFCs) are taken up and released by the oceans. Work on this cruise was cooperative with the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). Data from this cruise will allow quantification of the zonal currents and meridional distribution of water masses throughout the full water column in the southwestern Pacific. Tracer measurements will be used to study the rates of mass formation and transport processes throughout the water column.

For all sections sampled on this cruise, stations were occupied at a nominal spacing of 30 nm, closer over steeply sloped bathymetry, and never more distant than 60 nm. Stations 1–3 were test stations occupied to evaluate the CTD/O_2 and rosette systems on the transit from Hobart, Australia to the start of P14S. These profiles were not processed and are not included in this data report. The cruise was broken up into two legs of roughly 1-month duration each by a port stop in Wellington, New Zealand after station 93. Station 94 was a reoccupation of station 93 to evaluate temporal variations that occurred during the port stop.

Full water column CTD/O_2 profiles were collected at all stations. Lowered Acoustic Doppler Current Profiler (ADCP) measurements were also collected on most casts of leg 1. In addition, underway salinity, temperature, and CO_2 measurements were taken along the cruise track. Shallow productivity casts were made daily, and ALACE floats were deployed during the cruise. Water samples were analyzed for a suite of natural and anthropogenic tracers including salinity, dissolved oxygen, inorganic nutrients, CFCs, carbon tetrachloride, dissolved inorganic carbon, total alkalinity, pH, pCO_2, dissolved organic carbon, dissolved organic nitrogen, carbon isotopes, and oxygen isotopes. Samples were collected from productivity casts for chlorophyll and primary productivity. Figure 1 shows station locations. Table 1 provides a summary of cast information.

WOCE section P14S began with station 4 at 53°S, 170°E in 200 m of water on the south edge of the Campbell Plateau and ended with station 32 at 66°S, 171°E, intersecting the zonal WHP section S4 occupied nominally along 67°S in 1992. The section consisted of 29 stations. It sampled the entire Antarctic Circumpolar Current between the edge of the Campbell Plateau and the crest of the Pacific-Antarctic Ridge. At the ridge crest it explored a deep passage between the Ross Sea and the Southwest Pacific Basin. South of the ridge crest, it entered the north side of the Ross Sea Gyre.

WOCE section P15S began with station 33 at 67°S, 170°W, again intersecting the zonal WHP section S4 occupied nominally along 67°S in 1992. It proceeded north to station 72 at 47.5°S, 170°W, whereupon it followed a diagonal in towards the Chatham Rise until station 85 at 43.25°S, 175°E. From there it moved back away from the rise towards 170°W along a diagonal to station 104 at 36°S, 170°W. It then resumed north to station 154 at 10.5°S, 170°W, whereupon it shifted longitudes slightly to follow the axis of the Samoan Passage until station 164 at 7.5°S, 168.75°W. From there it continued north to station 174 at the equator, 168.75°W. Station 175 and 176 were added to the section to improve meridional resolution in the vicinity of the Samoan Passage. From 15°S to the equator the section overlapped WHP section P15N, occupied in 1994. The section consisted of 143 stations, discounting the duplication after the Wellington port stop. It sampled the north end of the Ross Sea Gyre, the Antarctic Circumpolar Current, the Deep Western Boundary Current system on both flanks of the Chatham Rise, the Subtropical Gyre, and the Tropical Regime up to the equator.

Stations 177 to 182 were taken after the completion of P15S but prior to the final port stop in Pago Pago, American Samoa. These profiles constitute a short, nearly zonal, section near 10°S across the Samoan Passage. These stations were taken to investigate deep water-mass and transport variability there.

2. Standards and Pre-Cruise Calibrations

The CTD/O_2 system is a real-time data system with the data from a Sea-Bird Electronics, Inc. (SBE) 9plus underwater unit transmitted via a conducting cable to the SBE 11plus deck unit. The serial data from the underwater unit is sent to the deck unit in RS-232 NRZ format using a 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK) telemetry link. The deck unit decodes the serial data and sends it to a personal computer for display and storage in a disk file using Sea-Bird SEASOFT software.

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

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

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

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

2.1 Conductivity

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

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

S/N 748	S/N 1561	S/N 1562
December 14, 1995	December 14, 1995	December 14, 1995
g = –4.13299236	g = –4.09205330	g = –4.16899749
h = 4.36576287e–01	h = 5.28538155e–01	h = 5.53740992e–01
i = –1.39236118e–04	i = –1.56949585e–04	i = –5.94323544e–05
j = 2.59599092e–05	j = 3.46776288e–05	j = 3.11836344e–05
ctcor = 3.2500e–06	ctcor = 3.2500e–06	ctcor = 3.2500e–06
cpcor = –9.5700e–08	cpcor = –9.5700e–08	cpcor = –9.5700e–08

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

$$C\ (\mathrm{S/m}) = (g + hf^2 + if^3 + jf^4) / [10\ (1 + ctcor\ \ t + cpcor\ \ p)]$$

where g, h, i, j, $ctcor$, and $cpcor$ are the calibration coefficients above, f is the instrument frequency (kHz), t is the water temperature (C), and p is the water pressure (dbar). SEASOFT automatically implements this equation.

2.2 Temperature

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

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

S/N 1370	S/N 2038	S/N 2037
November 22, 1995	December 14, 1995	December 14, 1995
g = 4.84042876e–03	g = 4.11396861e–03	g = 4.13135090e–03
h = 6.74974915e–04	h = 6.20923913e–04	h = 6.33482482e–04
i = 2.38622986e–05	i = 1.98024796e–05	i = 2.11340704e–05
j = 1.66698127e–06	j = 1.99224715e–06	j = 2.16252937e–06
f0 = 1000.0	f0 = 1000.0	f0 = 1000.0

Temperature (ITS-90) is computed according to

$$T\ (°C) = 1/\{g+h[\ln(f0/f)] + i[\ln^2(f0/f)] + j[\ln^3(f0/f)]\} - 273.15$$

where g, h, i, j, and $f0$ are the calibration coefficients above and f is the instrument frequency (kHz). SEASOFT automatically implements this equation, and converts between ITS-90 and IPTS-68 temperature scales when selected.

2.3 Pressure

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

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

S/N 53960 April 11, 1995	S/N 53586 October 29, 1993
c1 = –4.315048e+04	c1 = –3.920451e+04
c2 = 4.542800e–01	c2 = 6.234560e–01
c3 = 1.344380e–02	c3 = 1.350570e–02
d1 = 3.795200e–02	d1 = 3.894300e–02
d2 = 0.0	d2 = 0.0
t1 = 3.034230e+01	t1 = 3.046303e+01
t2 = –1.809380e–04	t2 = –9.018862e–05
t3 = 4.616150e–06	t3 = 4.528890e–06
t4 = 2.084220e–09	t4 = 3.309590e–09

Pressure coefficients are first formulated into

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

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

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

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

2.4 Oxygen

The SBE 13 dissolved oxygen sensor uses a Beckman polarographic element to provide in-situ measurements at depths up to 6800 meters. This auxiliary sensor is also included in the path of pumped sea water. Oxygen sensors determine the dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through a membrane. By knowing the flux of oxygen and the geometry of the diffusion path the concentration of oxygen can be computed. The permeability of the membrane to oxygen is a function of temperature and ambient pressure. The interface electronics outputs voltages proportional to membrane current (oxygen current) and membrane temperature (oxygen temperature). Oxygen temperature is used for internal temperature compensation. Computation of dissolved oxygen in engineering units is done in the software. The range for dissolved oxygen is 0 to 650 µmol/kg; nominal accuracy is 4 µmol/kg; resolution is 0.4 µmol/kg. Response times are 2 s at 25°C and 5 s at 0°C.

The following oxygen calibrations were entered into SEASOFT using SEACON:

S/N 130309
September 28, 1995

m = 2.4544 e–07
b = –4.6633 e–10
soc = 2.6721
boc = –0.0178
tcor = –3.3e–02
pcor = 1.5e–04
tau = 2.0
wt = 0.67
k = 8.9224
c = –6.9788

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

3. Data Acquisition

CTD/O_2 measurements were made using one of two SBE 9plus CTDs each equipped with a fixed pumped temperature-conductivity (TC) sensor pair. A mobile pumped TC pair with dissolved oxygen sensor was mounted on whichever CTD was in use so that dual TC measurements and dissolved oxygen measurements were always collected. The TC pairs were monitored for calibration drift and shifts by examining the differences between the two pairs on each CTD and comparing CTD salinities with bottle salinity measurements.

PMEL's SBE 9plus CTD/O2 S/N 09P8431-0315 (sampling rate 24 Hz) was mounted in a 36-position frame and employed as the primary package. Auxiliary sensors included a lowered

ADCP, Metrox load cell, and Benthos altimeter. Water samples were collected using a GO 36-bottle rosette and 10-liter Niskin bottles. The primary package was used for the majority of 182 casts.

PMEL's SBE 9plus CTD/O2 S/N 329053-0209 (sampling rate 24 Hz) was mounted in a 24-position frame and employed as the backup package. Auxiliary sensors included a Metrox load cell and Benthos altimeter. Water samples were collected using a SBE 32 24-bottle rosette, and 4-liter Niskin bottles. One test cast and 22 bad-weather casts were made using the smaller backup package.

The package entered the water from the stern of the ship and was held 5–15 m beneath the surface for 1 minute in order to activate the pump and attach tag lines for package recovery. Under ideal conditions the package was lowered at a rate of 30 m/min to 50 m, 45 m/min to 200 m, and 60 m/min to depth. Ship heave often caused substantial variation about these mean lowering rates, especially in the Southern Ocean. Load cell values were monitored in real time during each cast. The position of the package relative to the bottom was monitored by the ship's Precision Depth Recorder (PDR) and an altimeter. A bottom depth was estimated from bathymetric charts and the PDR ran during the bottom 1000 m of the cast. Casts were generally made to within 10 m of the bottom, sometimes farther away in heavy weather. Figure 2 shows the depths of bottle closures during the upcast.

Upon completion of the cast, sensors were flushed with deionized water and stored with a dilute Triton-X solution in the plumbing. Niskin bottles were then sampled for various water properties detailed in the introduction. Sample protocols conformed to those specified by the WOCE Hydrographic Programme.

A SBE 11plus deck unit received the data signal from the CTD. The analog data stream was recorded onto video cassette tape as a backup. Digitized data were forwarded to a 286-AT personal computer equipped with SEASOFT acquisition and processing software version 4.216. Temperature, salinity, and oxygen profiles were displayed in real time. Raw data files were transferred to a 486 personal computer using Laplink version 3 and backed up to optical disk.

3.1 Data Acquisition Problems

Some time was lost at the beginning of leg 1 owing to level-wind problems on the primary winch. The sea cable was retensioned on the drum at sea by removing the CTD/rosette package, attaching a weight to the cable, and spooling the full length of cable behind the ship while underway to within the last full wrap on the drum. Level-wind problems were much reduced after this procedure.

No useful data from the secondary TC pair and dissolved oxygen sensor were collected during station 12 owing to biological fouling of the mobile sensors. Data from the primary TC pair were processed for station 12, as well as for stations 69, 78, 79, 128, 130, 131, and 159 owing to noise. No oxygen data are available for stations 132, 133, 134, and 144 during which problems with the dissolved oxygen sensor were being diagnosed and repaired.

3.2 Salinity Analyses

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

The expected precision of the autosalinometer with an accomplished operator is 0.001 PSS, with an accuracy of 0.003. To assess the precision of discrete salinity measurements on this cruise, a comparison was made for data from the instances in which two bottles were tripped within 10 dbar of each other at the same station below a depth of 2000 dbar. For the 124 instances in which both bottles of the pair have acceptable salinity measurements, the standard deviation of the differences is 0.0008 PSS. This value is below the expected precision.

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

4. At-Sea Processing

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

The following is the SEASOFT processing module sequence and specifications used in the reduction of P14S/P15S CTD/O2 data:

- DATCNV converted the raw data to pressure, temperature, conductivity, oxygen current, and oxygen temperature; and computed salinity and the time rate of change of oxygen current. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition.
- ROSSUM created a summary of the bottle data. Bottle position, date, and time were output as the first two columns. Pressure, temperature, conductivity, salinity, oxygen current, oxygen temperature, and time rate of change of oxygen current were averaged over a 2-s interval (48

scans). For the primary package, the time interval was from 5 to 3 s prior to the confirm bit in order to avoid spikes in conductivity and oxygen current owing to minor incompatibilities between the SBE 911plus CTD/O_2 system and GO 1016 rosette. Bottle data from the backup package were averaged from 1 s prior to the confirm bit to 1 s after the confirm bit in the data stream. ROSSUM computed CTD oxygen, potential temperature, and sigma-theta.

- WILDEDIT marked extreme outliers in the data files. The first pass of WILDEDIT obtained an accurate estimate of the true standard deviation of the data. The data were read in blocks of 200 scans. Data greater than two standard deviations were flagged. The second pass computed a standard deviation over the same 200 scans excluding the flagged values. Values greater than 16 standard deviations were marked bad.
- SPLIT removed decreasing pressure records from the data files, leaving only the downcast.
- FILTER performed a low pass filter on pressure with a time constant of 0.15 s. In order to produce zero phase (no time shift) the filter first runs forward through the file and then runs backwards through the file.
- ALIGNCTD aligned conductivity in time relative to pressure to ensure that all calculations were made using measurements from the same parcel of water. Conductivity for the primary sensor on the 36-bottle package was advanced by –0.020 s. Conductivity for the primary sensor on the 24-bottle package was advanced by –0.010 s. Conductivity for the secondary, mobile sensor on either package was advanced 0.055 s.
- CELLTM used a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. For C748 with an epoxy coating, the thermal anomaly amplitude (alpha = 0.03) and the time constant (1/beta = 9.0) were higher than for C1561 and C1562 with no coating (alpha = 0.02, 1/beta = 7.0).
- DERIVE was used to compute fall rate (m/s) with a time window size for fall rate and acceleration of 2.0 seconds.
- LOOPEDIT marked scans where the CTD was moving less than the minimum velocity of 0.25 m/s or traveling backwards due to ship heave.
- BINAVG averaged the data into 1-dbar pressure bins starting at 1 dbar with no surface bin. The center value of the first bin was set equal to the bin size. The bin minimum and maximum values are the center value ± half the bin size. Scans with pressures greater than the minimum and less than or equal to the maximum were averaged. Scans were interpolated so that a data record exists every decibar.
- STRIP removed scan number and fall rate from the data files.
- TRANS converted the data file format from binary to ASCII.

5. Post-Cruise Calibrations

Post-cruise sensor calibrations were done at Sea-Bird Electronics, Inc. during May 1996. Mobile, secondary sensor pair T1370 and C748 were selected for final data reduction for all stations except 12, 69, 128, 130, 131, and 159. Post-cruise calibrations showed T1370 to have drifted by 0.43e–03°C over the 3.2 months between calibrations. Station 12 data are from sensors T2037 and C1562. Post-cruise calibrations showed T2037 to have drifted by –0.28e–03°C over the 3.2 months between calibrations. The remaining station data are from sensors T2038 and C1561. Post-cruise calibrations showed T2038 to have drifted by 0.11e–03°C over the 3.3 months between calibrations.

5.1 Conductivity

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

For a SBE 9 CTD with ducted TC sensors and a 3000 rpm pump the typical net advance of conductivity relative to temperature is 0.073 s. The SBE 11 deck unit advances primary conductivity by 0.073 s but does not advance secondary conductivity. Therefore the alignment of C748 conductivity data, which was from the secondary sensor channel (except for stations 78 and 79), was much larger, typically 0.06 s versus coming from a primary sensor channel, typically 0.02 s.

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

$$\mathrm{BC} - m * \mathrm{CC} - b - \mathrm{beta} * \mathrm{CP}$$

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

$$m * \mathrm{CC} + b + \mathrm{beta} * \mathrm{CP}$$

The slope term *m* is a fourth-order polynomial function of station number to allow the entire cruise to be fit at once with a smoothly-varying station-dependent slope correction. For sensors C748 and C1561 a series of fits were made, each fit throwing out bottle values for locations having a residual between CTD and bottle conductivity greater than three standard deviations. This procedure was repeated with the remaining bottle values until no more bottle values were thrown out.

For C748, the slope correction ranged from 1.0000501 to 1.0001274, the bias applied was –7.5e–04 S/m, and the beta term was –9.01e–09 S/m/dbar. Of 5680 bottles, the percentage of bottles retained in the fit was 85.2 with a standard deviation of CTD versus bottle conductivity differences of 9.88e–05 S/m. For C1561, the slope correction ranged from 1.0001481 to 1.0002849, the bias applied was –3.8e–04 S/m, and the beta term was –3.16e–09 S/m/dbar. Of 5118 bottles, the percentage of bottles retained in the fit was 88.1 with a standard deviation of 9.93e–05 S/m.

For station 12, station 13 calibrated secondary salinity data was used as a reference. A slope, bias, and pressure correction was determined that matched station 13 uncalibrated primary salinity (C1562, T2037) to station 13 calibrated secondary salinity (C748, T1370). These coefficients (slope = 1.004, bias = –0.0011 S/m, beta = –2.49e–08 S/m/dbar) were used to calibrate station 12 primary salinity (C1562, T2037).

CTD-bottle conductivity differences are plotted against station number to show the stability of the calibrated CTD conductivities relative to the bottle conductivities (Fig. 3, upper panel). CTD-bottle conductivity differences are plotted against pressure to show the tight fit below 500 m and the increasing scatter above 500 m (Fig. 3, lower panel).

5.2 Temperature

Adjustments were made to the bias of the thermistors as deviations from the pre-cruise calibrations on a station-by-station basis. These deviations were obtained from a linear fit of the pre-cruise and post-cruise temperature residuals from the pre-cruise calibration versus time.

A pressure correction was then applied to each sensor such that

$$CT = CT * pcor * CP$$

where CT is CTD temperature (°C) with the bias adjustment, pcor is the pressure correction (dbar) for each sensor, and CP is CTD pressure (dbar).

$$pcor1370 = –2.6e–03/9000 \text{ dbar} = –2.8889e–007 \text{ 1/dbar}$$
$$pcor2037 = –2.3e–03/9000 \text{ dbar} = –2.5556e–007 \text{ 1/dbar}$$
$$pcor2038 = –1.7e–03/9000 \text{ dbar} = –1.8889e–007 \text{ 1/dbar}$$

Also, a uniform correction was applied for heating of the thermistor owing to viscous effects. All the thermistors were biased high by this effect and were adjusted down accordingly. An adjustment of 0.6e–03°C results in errors of no more than ±0.15°C from this effect for the full range of oceanographic temperature and salinity.

Post-cruise temperature and conductivity calibrations were applied to all sensor pairs using PMEL program CALCTD (STA12CAL for station 12). Surface values were filled using PMEL program FILLSFC. FILLSFC copied the first good value of salinity and potential temperature back to the surface and then back-calculated temperature and conductivity. Primary and secondary sensor differences were examined. Data from the secondary sensor pair (T1370/C748) were chosen for all stations except 12, 69, 78, 79, 128, 130, 131, and 159. Primary sensor data chosen for these 8 stations were within .001 PSS of the secondary sensor data of the surrounding stations. All profiles were despiked and data linearly interpolated using PMEL program DESPIKE.

Package slowdowns and reversals owing to ships heave can move mixed water in tow to in front of the CTD sensors and obscure measurements. In addition to SEASOFT module LOOPEDIT (see section 4), PMEL program DELOOP computed values of density locally referenced between every 1 dbar of pressure to compute $N^2 = (-g/\text{rho})(d\text{rho}/dz)$ and linearly interpolated over those records where $N^2 \leq -1.0\text{e}{-05}\ \text{s}^{-2}$.

Post-cruise calibrations were applied to CTD data associated with bottle data using PMEL program CALMSTR. CALMSTR also amended WOCE quality flags associated with CTD and bottle salinities. Eighteen CTD salinities were flagged as bad during station 78 likely owing to clogged plumbing of the primary sensors during the upcast. Of the 5640 bottle salinities, 0.33% were flagged as bad and 2.68% were flagged as questionable.

5.3 Oxygen

In situ oxygen samples collected during CTD/O_2 profiles are used for post-measurement calibration. Calibrated CTD/O_2 data associated with bottle data were merged with bottle oxygen data flagged as "good." Because the dissolved oxygen sensor has an obvious hysteresis, PMEL program OXDWNP replaced up-profile water sample data with corresponding down-profile CTD/O_2 data at common pressure levels. The time rate of change of oxygen current was computed using 2-s intervals in SEASOFT and smoothed using a median filter of width 5 dbar prior to OXDWNP. Oxygen saturation values were computed according to Benson and Krause (1984) in units of µmol/kg.

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

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

By plotting the oxygen residuals versus station, appropriate station groupings for further refinements of fitting are obtained by looking for abrupt station-to-station changes in the residuals. For each grouping, two sets of coefficients were determined, one fitting all the bottles and a second fitting only bottles deeper than just above the median bottle oxygen minimum. Sometimes it was necessary to fix values of some oxygen algorithm parameters to keep those parameters within a reasonable range (noted by asterisks in Table 2). Final coefficients were applied to downcast data using PMEL program OXYCALC; and to bottle data using OXYCALB. The two sets of coefficients were blended at the oxygen minimum using a set of hyperbolic tangent functions with 250-dbar decay scales.

CTD oxygen values were despiked using PMEL program CLEANOX. Bad CTD oxygen data were flagged for all of station 12 owing to clogged plumbing, parts of stations 127–131 where the dissolved oxygen module failed in the deep water (the dissolved oxygen module was replaced prior to station 135), and stations 177–182 above 2850 dbar where no shallow bottle data were available to calibrate the sensor.

CTD-bottle oxygen differences are plotted against station number to show the stability of the calibrated CTD oxygens relative to the bottle oxygens (Fig. 4, upper panel). Note that the residuals are well below the nominal accuracy quoted for the oxygen sensor. CTD-bottle oxygen differences are plotted against pressure to show the tight fit below 1200 m and the increasing scatter above 1200 m (Fig. 4, lower panel).

PMEL program P15_EPIC converted finalized CTD/O_2 data files into EPIC format (Soreide, 1995), and computed ITS-90 temperature, ITS-90 potential temperature, and dynamic height. EPIC datafiles contain a WOCE quality flag parameter associated with pressure, temperature, CTD salinity, and CTD oxygen. Quality flag definitions can be found in the WOCE Operations Manual (1994).

6. Data Presentation

The final calibrated data in EPIC format were used to produce the plots and listings which follow. The majority of the plots were produced using Plot Plus Scientific Graphics System (Denbo, 1992). Vertical sections of potential temperature, CTD salinity, potential density, and CTD oxygen are contoured with pressure as the vertical axis and latitude as the horizontal axis (Figs. 5–8). Nominal vertical exaggerations are 1000:1 below 1000 dbar (lower panels) and 2500:1 above 1000 dbar (upper panels). Plots and summary listings of the CTD/O_2 data follow for each cast. Tables 3–7 define the abbreviations and units used in the CTD/O_2 data summary listings. Hydrographic bottle data at discrete depths are listed in the final section.

The hydrographic listings presented include two-digit WOCE quality flags. The numeric digits are associated with bottle salinity and bottle oxygen. Quality flag definitions can be found in the WOCE Operations Manual (1994).

7. Participating Institutions/Personnel

NOAA Pacific Marine Environmental Laboratory (PMEL)
NOAA Atlantic Oceanographic and Meterological Laboratory (AOML)
Bermuda Biological Station for Research (BBSR)
Monterey Bay Aquarium Research Institute (MBARI)
Scripps Institution of Oceanography (SIO)
University of Tennessee (UT)
University of Hawaii (UH)
University of Washington (UW)
University of Miami (UM)
University of South Florida (USF)
University of Charleston, South Carolina (UCSC)

Measurement	Principal Investigator	Institution
CTD/O_2, salinity	G. Johnson	PMEL
Chlorofluorocarbons (CFCs)	J. Bullister	PMEL
Total CO_2 (DIC), pCO_2	R. Feely	PMEL
C-14 (AMS radiocarbon), C-13	P. Quay	UW
Nutrients	C. Mordy	PMEL
	Z. Zhang	AOML
Dissolved Oxygen	J. Bullister	PMEL
Total alkalinity	F. Millero	UM
pH	R. Byrne	USF
Underway pH/DIC	A. Dickson	SIO
DOC/DON	D. Hansell	BBSR
ADCP	P. Hacker/E. Firing	UH
ALACE floats	R. Davis	SIO
Primary productivity	J. DiTullio	UCSC
	W. Smith	UT
Underway chlorophyll	F. Chavez	MBARI

		Leg 1	Leg 2
John Bullister, PMEL	Chief Scientist	x	
Greg Johnson, PMEL	Co-Chief Scientist	x	
Dick Feely, PMEL	Chief Scientist		x
Marilyn Roberts, PMEL	Co-Chief Scientist		x
Kristy McTaggart, PMEL	CTD	x	x
Norge Larson, Sea-Bird	CTD	x	
John Love, IOS	CTD	x	
Jim Richman, OSU	CTD		x
Gregg Thomas, AOML	salinity	x	x
Dave Wisegarver, PMEL	CFC	x	x
Craig Neill, PMEL	CFC	x	x

Wenlin Huang, PMEL	CFC	x	
Kirk Hargreaves, PMEL	oxygen	x	x
Carol Stewart, IOS	oxygen/CFC	x	x
Calvin Mordy, PMEL	nutrients	x	x
Zia-Zhong Zhang, AOML	nutrients	x	x
Tom Lantry, AOML	DIC	x	x
Marilyn Roberts, PMEL	DIC	x	
Kim Currie, IOS	DIC		x
Cathy Cosca, PMEL	underway pCO_2	x	
Dana Greeley, PMEL	pCO_2	x	x
Hua Chen, AOML	pCO_2	x	
Rhonda Kelly, BBSR	pCO_2		x
Jamie Goen, RSMAS	alkalinity	x	x
David Purkinson, RSMAS	alkalinity	x	
Mary Roche, RSMAS	alkalinity		x
Chris Edwards, RSMAS	alkalinity	x	
Xiarong Zhu, RSMAS	alkalinity		x
Sean McElligott, USF	pH	x	x
Wensheng Yao, USF	pH	x	x
Johan Schijf, USF	pH	x	
Xeuwu Liu, USF	pH		x
Eric Firing, UH	ADCP	x	
Susan Becker, BBSR	DOC	x	x
Rachel Parsons, BBSR	DOC	x	x
Brian Kleinhaus, UW	C-13, C-14	x	
Tanya Westby, UW	C-13, C-14		x
Kendra Daly, UTK	productivity	x	x
David Jones, UCSC	productivity	x	x
Peter Walz, MBARI	productivity	x	
Tim Pennington, MBARI	productivity		x

8. Acknowledgments

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FIGURES AND TABLES

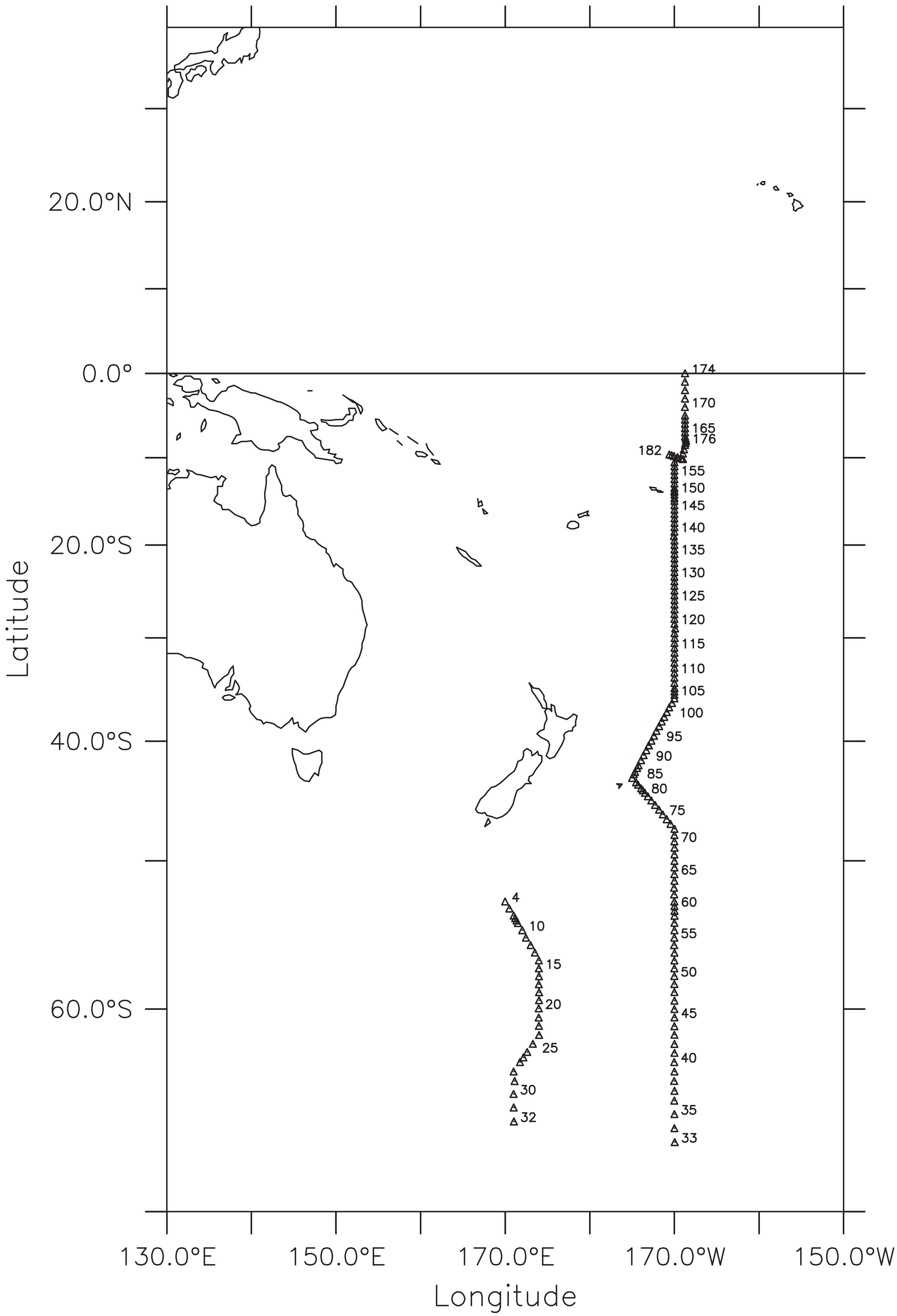


Fig. 1. CTD station locations made on the R/V *Discoverer* from January 9 to March 9, 1996.

Table 1. CTD cast summary.

STN #	LATITUDE	LONGITUDE	DATE	TIME	W/D T	W/S (kts)	DEPTH† (m)	HAB* (m)	CAST (db)
4	53 0.1S	169 59.3E	9 JAN 96	13	270	5	195	12	185
5	53 29.9S	170 29.6E	9 JAN 96	342	275	8	732	10	733
6	53 59.9S	171 0.1E	9 JAN 96	736	275	10	1159	10	1172
7	54 10.2S	171 10.9E	9 JAN 96	1022	320	9	1346	10	1368
8	54 19.8S	171 20.2E	9 JAN 96	1338	315	15	2583	11	2582
9	54 30.3S	171 29.8E	9 JAN 96	1852	355	16	4373	9	4503
10	54 59.7S	172 0.7E	10 JAN 96	203	260	19	5350	5	5469
11	55 30.4S	172 27.0E	10 JAN 96	904	250	38		10	5453
12	55 59.8S	173 0.6E	10 JAN 96	1750	240	27	5448	10	5544
13	56 29.2S	173 30.2E	11 JAN 96	42	220	20	5350	0	5466
14	56 59.7S	173 58.6E	11 JAN 96	908	230	17	5437	10	5549
15	57 30.3S	173 58.5E	11 JAN 96	1731	275	23	5368	11	5425
16	58 0.2S	173 59.5E	12 JAN 96	1	300	18	5206	16	5308
17	58 30.3S	173 58.2E	12 JAN 96	641	315	21	5043	5	5108
18	58 59.8S	174 0.0E	13 JAN 96	1344	265	25	5109	8	5216
19	59 28.7S	173 59.7E	13 JAN 96	2208	280	30	4998	18	5077
20	59 57.9S	173 57.9E	13 JAN 96	530	270	34		40	4419
21	60 30.3S	173 57.8E	13 JAN 96	1958	285	25	5016	22	5107
22	60 59.1S	173 58.8E	14 JAN 96	257	315	19	4692	9	4774
23	61 30.0S	174 0.2E	14 JAN 96	856	340	27	5025	10	5134
24	62 0.0S	173 16.1E	14 JAN 96	1631	330	23	4450	10	4538
25	62 26.9S	172 35.2E	14 JAN 96	2249	305	26	4414	12	4499
26	62 44.7S	172 9.0E	15 JAN 96	424	270	30	4425	39	4052
27	63 0.0S	171 44.9E	15 JAN 96	1135	295	23		10	2644
28	63 30.1S	170 59.6E	15 JAN 96	1744	5	16	2374	12	2391
29	63 59.8S	171 6.6E	16 JAN 96	29	10	26	2551	25	2534
30	64 40.6S	170 58.6E	16 JAN 96	737	330	24	3430	10	3457
31	65 20.2S	171 0.0E	16 JAN 96	1459	35	14	3403	6	3461
32	66 0.9S	171 1.6E	17 JAN 96	11	355	12	3103	7	3159
33	66 59.6S	170 0.0W	18 JAN 96	1150	340	18	3587	10	3668
34	66 20.3S	170 0.0W	18 JAN 96	1930	325	12	3384	10	3431
35	65 39.8S	170 0.3W	19 JAN 96	114	305	17	3142	7	3190
36	64 59.6S	170 0.9W	19 JAN 96	815	265	23		6	2905
37	64 30.1S	169 59.9W	19 JAN 96	1333	230	32	2332	11	2357
38	63 59.7S	170 2.0W	19 JAN 96	1858	240	28	2744	19	2922
39	63 30.1S	170 0.3W	20 JAN 96	57	280	23	2766	12	2842
40	62 59.7S	170 1.4W	20 JAN 96	630	255	17	3046	12	3064
41	62 30.0S	169 59.8W	20 JAN 96	1206	310	15		17	2473
42	62 0.2S	169 59.9W	20 JAN 96	1806	330	28	3384	11	3431
43	61 29.5S	170 0.0W	21 JAN 96	37	315	33	3463	12	3434
44	61 0.1S	170 0.3W	21 JAN 96	2105	300	15	4169	30	4190
45	60 29.7S	169 59.6W	22 JAN 96	410	280	34	3926	10	4013
46	60 0.3S	170 0.3W	22 JAN 96	1030	310	17	3702	12	3747
47	59 30.2S	169 59.9W	22 JAN 96	1702	315	20	4007	10	4104
48	58 59.9S	170 0.2W	22 JAN 96	2311	310	18	4771	10	4860
49	58 29.6S	170 0.8W	23 JAN 96	547	315	17	5188	10	5295
50	57 59.7S	170 0.8W	23 JAN 96	1212	290	13	4119	8	4492
51	57 30.1S	170 0.4W	23 JAN 96	1858	240	9	4998	7	5110
52	57 0.2S	170 0.2W	24 JAN 96	122	250	14	5165	8	5261
53	56 29.9S	169 59.8W	24 JAN 96	751	250	21	5052	9	5159

Table 1. (continued).

STN #	LATITUDE	LONGITUDE	DATE	TIME	W/DT	W/S (kts)	DEPTH† (m)	HAB* (m)	CAST (db)
54	56 0.0S	170 1.8W	24 JAN 96	1352	220	20	5157	7	5236
55	55 29.9S	170 0.0W	24 JAN 96	2050	240	5	4945	9	5049
56	54 59.8S	170 0.0W	25 JAN 96	307	285	11	4812	7	4916
57	54 29.4S	170 0.1W	25 JAN 96	900	285	13	4811	3	4929
58	54 0.1S	169 59.3W	25 JAN 96	1545	290	16	5009	8	5138
59	53 39.9S	169 59.4W	25 JAN 96	2122	270	17	5131	5	5253
60	53 19.9S	169 59.6W	26 JAN 96	320	280	22	5286	8	5459
61	53 0.0S	170 0.5W	26 JAN 96	925	275	22	5193	9	5298
62	52 29.9S	170 1.8W	26 JAN 96	1643	270	27	5070	7	5173
63	52 0.1S	170 7.8W	26 JAN 96	2325	275	26	4970	10	5067
64	51 30.0S	170 0.2W	27 JAN 96	606	270	26	4754	20	4876
65	51 0.2S	170 0.4W	27 JAN 96	1221	250	20	5249	12	5321
66	50 29.9S	169 59.6W	27 JAN 96	1937	220	10	5052	15	5129
67	50 0.4S	169 59.9W	28 JAN 96	225	210	11	5361	8	5479
68	49 30.3S	170 0.9W	28 JAN 96	917	265	15	5217	15	5337
69	48 59.6S	169 59.4W	28 JAN 96	1633	270	18	5253	10	5340
70	48 30.0S	170 0.2W	28 JAN 96	2248	310	10	5303	5	5409
71	47 59.8S	170 0.3W	29 JAN 96	531	340	10	5293	10	5400
72	47 30.3S	169 59.8W	29 JAN 96	1148	45	13	5309	5	5474
73	47 6.5S	170 27.7W	29 JAN 96	1902	70	6	5391	8	5500
74	46 43.4S	170 54.7W	30 JAN 96	124	45	6	5292	9	5387
75	46 20.0S	171 22.2W	30 JAN 96	743	50	10	5101	8	5196
76	45 57.0S	171 49.5W	30 JAN 96	1446	100	15	5156	9	5250
77	45 33.6S	172 16.7W	30 JAN 96	2127	110	9	4968	7	5057
78	45 10.6S	172 44.2W	31 JAN 96	443	180	10	4660	10	4738
79	44 50.1S	173 8.2W	31 JAN 96	1035	230	15	3832	10	3869
80	44 31.8S	173 29.4W	31 JAN 96	1707	230	16	3397	10	3452
81	44 19.2S	173 44.7W	31 JAN 96	2119	225	10	3077	9	3115
82	44 9.4S	173 56.3W	1 FEB 96	106	280	5	1897	10	1911
83	43 50.9S	174 17.7W	1 FEB 96	434	250	11	946	10	959
84	43 38.8S	174 32.2W	1 FEB 96	710	0	0	790	10	789
85	43 15.2S	174 59.9W	1 FEB 96	1023	280	9	788	12	785
86	42 55.9S	174 47.2W	1 FEB 96	1328	270	5	1054	10	1055
87	42 44.8S	174 39.3W	1 FEB 96	1627	300	4	1581	9	1595
88	42 24.1S	174 24.4W	1 FEB 96	2014	315	7	2654	10	2677
89	42 10.1S	174 15.0W	2 FEB 96	6	350	10	2862	7	2889
90	41 42.8S	173 56.5W	2 FEB 96	520	330	12	3118	6	3162
91	41 16.0S	173 38.7W	2 FEB 96	1014	325	12	3319	6	3353
92	40 49.5S	173 19.5W	2 FEB 96	1545	330	14	4169	6	4239
93	40 23.6S	173 2.0W	2 FEB 96	2056	345	18	4574	9	4652
94	40 23.5S	173 1.7W	13 FEB 96	2049	130	15	4574	4	4658
95	39 57.7S	172 42.2W	14 FEB 96	326	150	22	4738	8	4823
96	39 31.0S	172 25.2W	14 FEB 96	937	190	23	4761	8	4848
97	39 4.3S	172 7.7W	14 FEB 96	1612	160	18	4835	10	4929
98	38 37.8S	171 48.6W	14 FEB 96	2202	140	12	4914	10	5003
99	38 11.4S	171 30.2W	15 FEB 96	423	140	8	4932	10	5031
100	37 45.8S	171 12.0W	15 FEB 96	1033	130	14	4997	7	5119
101	37 18.6S	170 53.7W	15 FEB 96	1727	145	14	5130	5	5230
102	36 52.3S	170 37.0W	15 FEB 96	2306	210	12	5278	6	5384
103	36 27.0S	170 17.2W	16 FEB 96	513	220	15	5122	8	5219

Table 1. (continued).

STN #	LATITUDE	LONGITUDE	DATE	TIME	W/D T	W/S (kts)	DEPTH† (m)	HAB* (m)	CAST (db)
104	36 0.2S	170 0.3W	16 FEB 96	1135	200	19	5069	8	5156
105	35 40.3S	170 0.9W	16 FEB 96	1727	205	24	4292	5	4329
106	35 20.0S	170 0.1W	16 FEB 96	2233	170	21	4895	7	4981
107	35 0.5S	169 59.6W	17 FEB 96	415	140	19	5250	5	5348
108	34 30.3S	170 0.2W	17 FEB 96	1137	160	20	5487	6	5591
109	33 59.8S	170 0.0W	17 FEB 96	1849	150	16	5533	6	5640
110	33 29.9S	170 0.1W	18 FEB 96	119	150	10	5416	6	5509
111	33 0.1S	170 0.1W	18 FEB 96	736	115	10	5582	10	5677
112	32 30.1S	170 0.1W	18 FEB 96	1404	115	8	5533	7	5651
113	31 59.8S	169 59.8W	18 FEB 96	2055	140	6	5677	7	5790
114	31 30.0S	169 59.3W	19 FEB 96	330	90	7	5526	8	5645
115	31 0.4S	169 59.7W	19 FEB 96	951	80	15	5606	7	5725
116	30 30.3S	169 59.8W	19 FEB 96	1640	90	14	5537	9	5640
117	30 0.2S	169 59.8W	19 FEB 96	2259	80	12	5413	7	5514
118	29 30.2S	169 59.8W	20 FEB 96	503	90	15	5148	12	5190
119	29 0.8S	169 59.9W	20 FEB 96	1113	70	18	5596	15	5684
120	28 30.5S	169 59.8W	20 FEB 96	1809	90	10	5459	9	5555
121	28 0.3S	169 59.6W	21 FEB 96	10	90	13	4907	10	4966
122	27 30.1S	170 0.1W	21 FEB 96	600	100	20	5349	7	5485
123	27 0.3S	169 59.5W	21 FEB 96	1202	95	13	5241	7	5331
124	26 29.7S	169 59.4W	21 FEB 96	1906	110	24	5613	8	5710
125	26 0.3S	169 59.7W	22 FEB 96	321	100	20	5601	9	5695
126	25 30.0S	170 0.0W	22 FEB 96	1005	105	17	5833	9	5944
127	25 0.1S	169 59.9W	22 FEB 96	1734	100	20	5640	3	5818
128	24 30.0S	170 0.1W	23 FEB 96	16	90	16	5650	10	5757
129	23 59.8S	170 0.1W	23 FEB 96	720	80	16	5678	10	5780
130	23 30.1S	170 0.1W	23 FEB 96	1404	100	18	5666	7	5781
131	22 59.8S	169 59.7W	23 FEB 96	2139	120	9	5691	9	5799
132	22 30.0S	169 59.9W	24 FEB 96	448	120	13	5649	7	5752
133	22 0.0S	169 59.9W	24 FEB 96	1127	160	12	5626	8	5731
134	21 30.4S	170 0.1W	24 FEB 96	1837	150	7	5421	6	5514
135	20 59.7S	169 59.6W	25 FEB 96	107	160	5	5461	4	5566
136	20 29.9S	170 0.1W	25 FEB 96	739	175	5	5598	40	5722
137	20 0.0S	170 0.1W	25 FEB 96	1354	170	6	5315	7	5429
138	19 29.9S	170 0.1W	25 FEB 96	2023	80	4	4904	8	4982
139	19 0.1S	170 3.4W	26 FEB 96	159	350	5	2991	10	3047
140	18 30.3S	170 0.1W	26 FEB 96	730	330	9	5260	3	5343
141	18 0.0S	170 0.0W	26 FEB 96	1324	350	3	4912	9	4991
142	17 30.1S	170 0.0W	26 FEB 96	1948	65	5	5024	8	5097
143	17 0.1S	169 59.8W	27 FEB 96	156	80	12	4974	7	5081
144	16 30.3S	169 59.9W	27 FEB 96	746	80	17	5134	6	5208
145	16 0.2S	169 59.9W	27 FEB 96	1343	90	13	5145	5	5233
146	15 29.8S	170 0.1W	27 FEB 96	2028	70	10	5087	8	5172
147	15 0.2S	170 0.0W	28 FEB 96	250	0	10	4820	8	4884
148	14 40.0S	169 59.9W	28 FEB 96	800	80	14	3315	8	3365
149	14 16.9S	169 59.8W	28 FEB 96	1225	20	10	3535	8	3578
150	13 58.3S	170 0.0W	28 FEB 96	1648	355	11	2938	9	2986
151	13 49.1S	170 0.1W	28 FEB 96	2111	40	7	4303	7	4367
152	13 30.1S	170 0.0W	29 FEB 96	231	280	6	4878	8	4952
153	12 59.9S	170 0.0W	29 FEB 96	821	95	11	4969	10	5047

Table 1. (continued).

STN #	LATITUDE	LONGITUDE	DATE	TIME	W/D T	W/S (kts)	DEPTH† (m)	HAB* (m)	CAST (db)
154	12 29.9S	169 59.9W	29 FEB 96	1403	20	7	5000	5	5084
155	12 0.1S	170 0.1W	29 FEB 96	2018	310	11	5078	9	5016
156	11 30.0S	170 0.0W	1 MAR 96	217	330	13	5057	9	5138
157	11 0.1S	170 0.0W	1 MAR 96	807	20	9	5124	10	5205
158	10 30.1S	169 59.8W	1 MAR 96	1345	350	7	4876	5	4964
159	9 55.5S	169 37.7W	1 MAR 96	2112	20	20	5205	10	5285
160	9 30.1S	168 59.9W	2 MAR 96	429	60	18	5340	5	5432
161	9 0.0S	168 52.6W	2 MAR 96	1036	70	19	4866	9	4973
162	8 29.9S	168 44.9W	2 MAR 96	1726	40	10	5154	6	5243
163	8 0.0S	168 37.0W	2 MAR 96	2343	40	5	5164	8	5260
164	7 30.0S	168 45.0W	3 MAR 96	542	70	10	5273	7	5364
165	7 0.0S	168 44.9W	3 MAR 96	1141	100	10	5670	8	5767
166	6 30.1S	168 44.9W	3 MAR 96	1854	70	10	5535	10	5646
167	6 0.0S	168 45.0W	4 MAR 96	123	30	10	5671	8	5769
168	5 30.1S	168 45.0W	4 MAR 96	803	50	10	5379	8	5522
169	5 0.0S	168 45.0W	4 MAR 96	1441	50	9	5572	10	5666
170	4 0.0S	168 45.1W	4 MAR 96	2242	40	14	5208	8	5290
171	3 0.0S	168 45.0W	5 MAR 96	712	30	20	5379	4	5467
172	2 0.1S	168 45.0W	5 MAR 96	1555	40	17	3285	10	3447
173	1 0.1S	168 45.2W	6 MAR 96	12	80	17	5786	8	5891
174	0 0.1S	168 45.0W	6 MAR 96	828	70	16	5581	10	5683
175	7 44.8S	168 40.2W	8 MAR 96	14	80	14	5319	3	5414
176	8 15.1S	168 41.3W	8 MAR 96	549	75	10	4964	6	5051
177	10 8.7S	168 58.8W	8 MAR 96	1642	100	12	4640	8	4709
178	10 4.1S	169 12.7W	8 MAR 96	2108	100	10	5254	10	5336
179	9 55.2S	169 37.7W	9 MAR 96	248	70	11	5215	4	5306
180	9 47.0S	170 3.5W	9 MAR 96	1024	95	7	5014	8	5097
181	9 41.6S	170 19.5W	9 MAR 96	1459	30	6	4293	8	4372
182	9 35.7S	170 36.1W	9 MAR 96	1900	90	9	4038	7	4090

* height above bottom
† corrected water depth

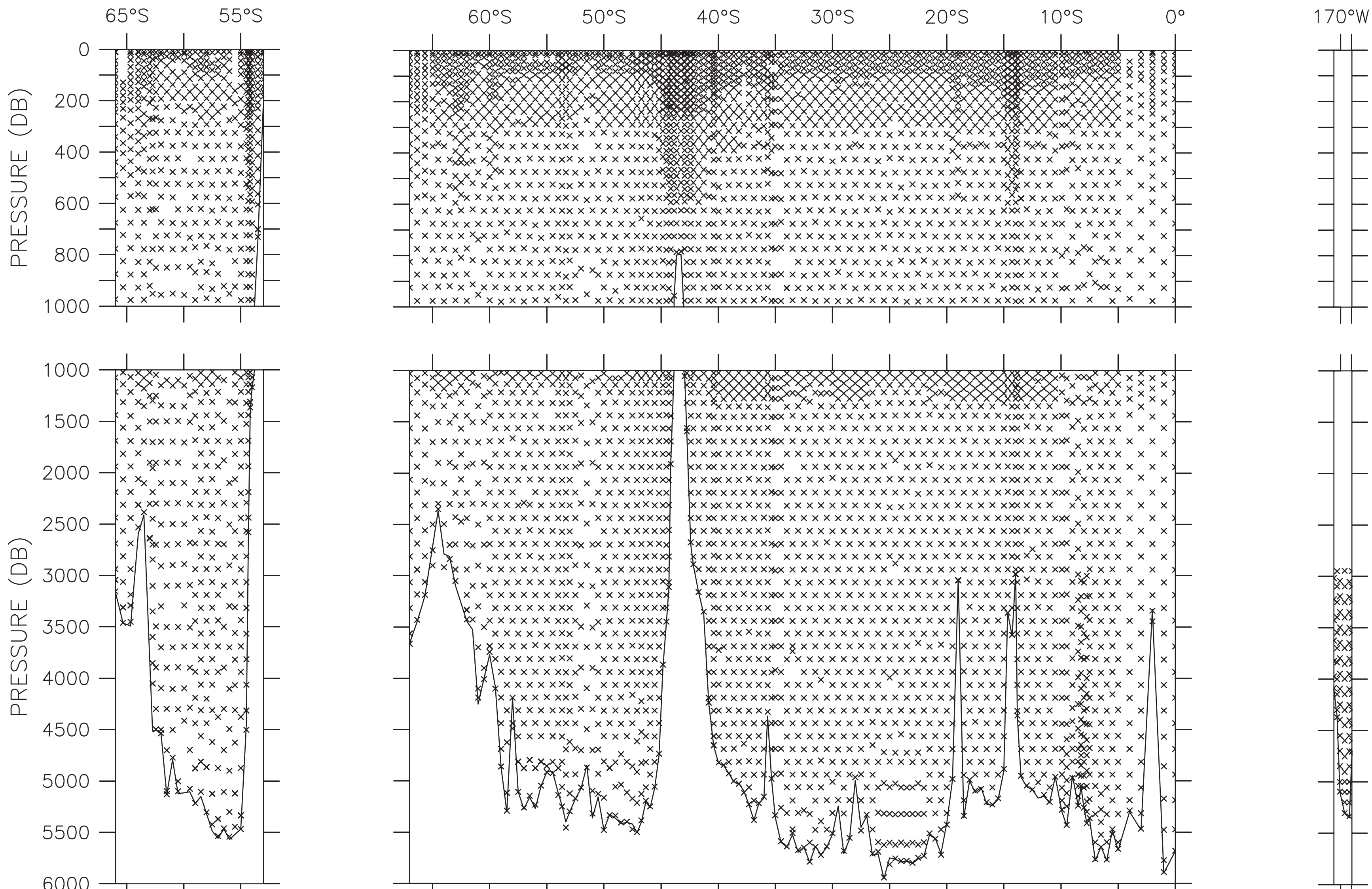


Fig. 2. Pressures of bottle closures at each station.

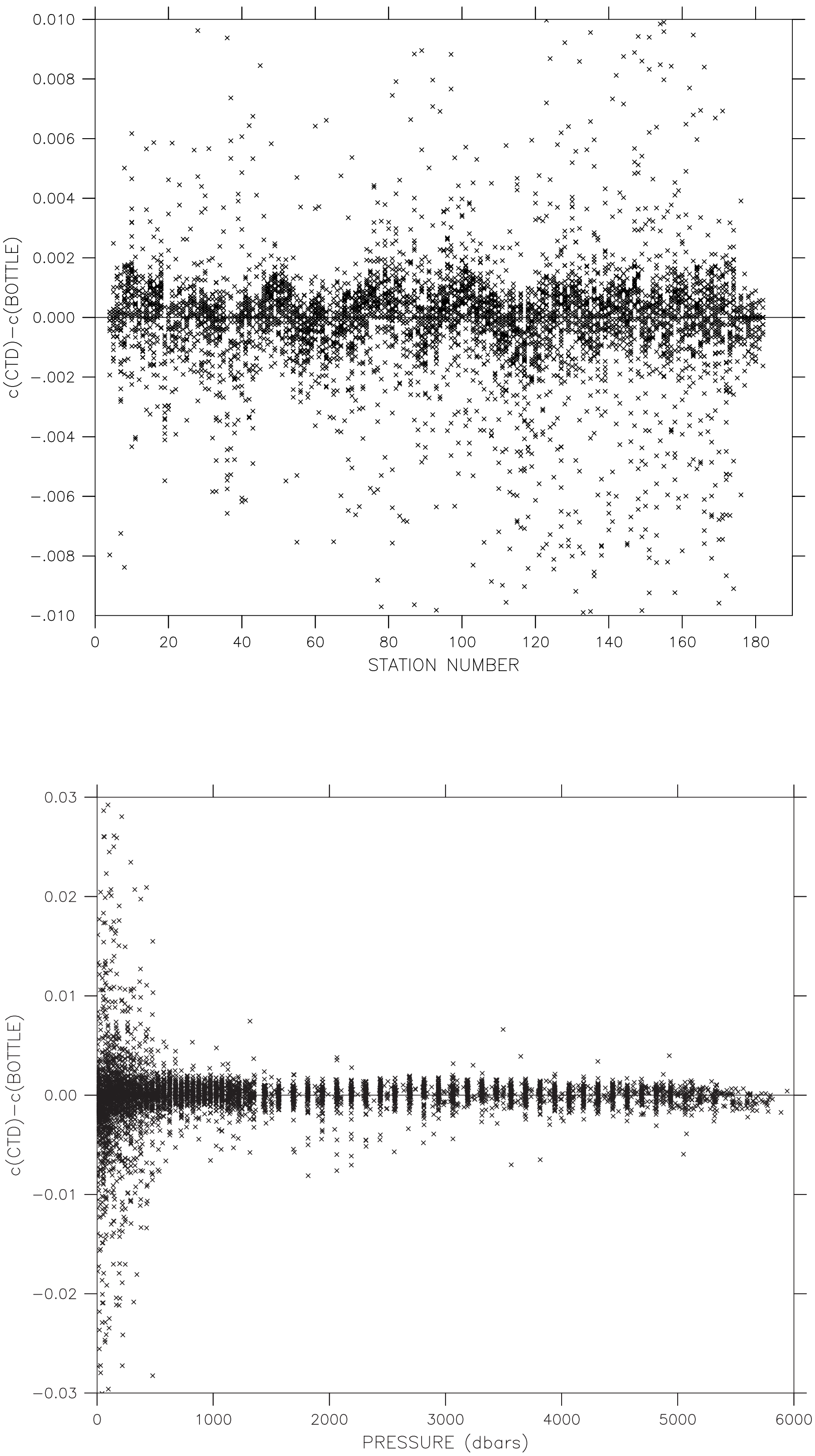


Fig. 3. Calibrated CTD-bottle conductivity differences (mS/cm) plotted against station number (upper panel). Calibrated CTD-bottle conductivity differences (mS/cm) plotted against pressure (lower panel).

Table 2a. Full water column station groupings for CTD oxygen algorithm parameters.

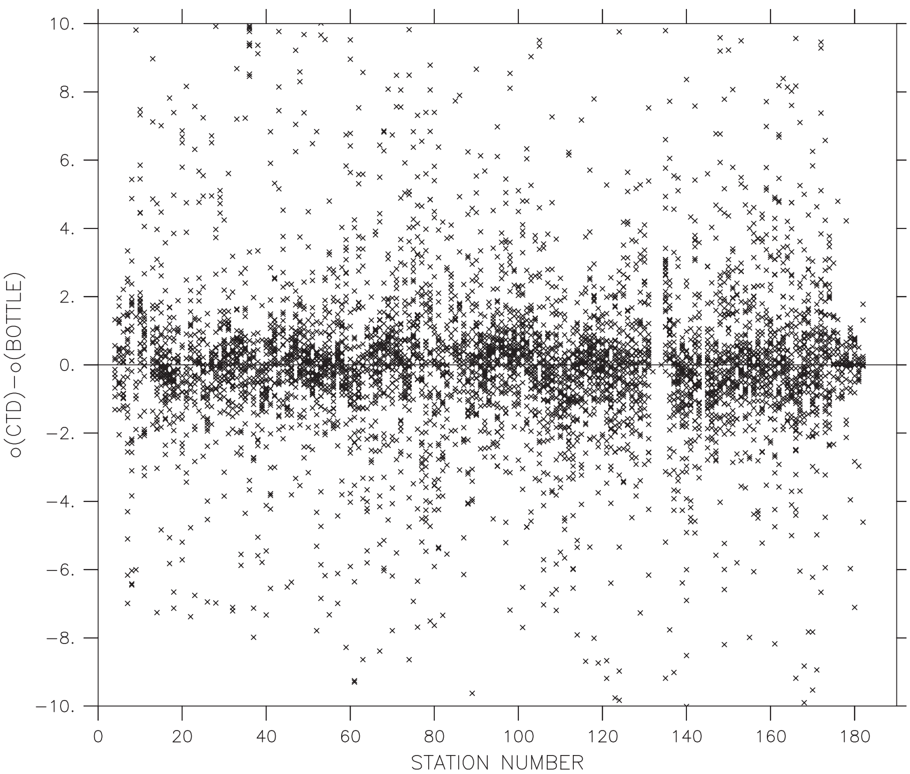
Station	StdDev	#Obs	2.8*sd	1:Bias	2:Slope	3:Pcor	4:Tcor	5: Wt	6: Lag
4-9	0.1351E+01	96	3.782	0.014	0.3616E-02	0.1350E-03*	-0.3149E-01	0.8702E+00*	0.3275E+01*
10-13	0.1732E+01	73	4.849	0.026	0.3561E-02	0.1350E-03*	-0.3003E-01	0.8702E+00*	0.3275E+01*
14-18	0.9219E+00	145	2.581	0.007	0.3815E-02	0.1350E-03*	-0.3797E-01	0.8702E+00*	0.3275E+01*
19-24	0.1207E+01	108	3.380	0.020	0.3702E-02	0.1350E-03*	-0.3494E-01	0.8702E+00*	0.3275E+01*
25-31	0.8802E+00	149	2.465	0.019	0.3738E-02	0.1350E-03*	-0.3822E-01	0.8702E+00*	0.3275E+01*
32-45	0.1088E+01	322	3.045	0.017	0.3772E-02	0.1338E-03	-0.3540E-01	0.6807E+00	0.7588E+01
46-53	0.9705E+00	237	2.718	0.023	0.3676E-02	0.1345E-03	-0.3174E-01	0.6084E+00	0.6309E+01
54-62	0.1516E+01	273	4.244	0.021	0.3675E-02	0.1361E-03	-0.3032E-01	0.8185E+00	0.1341E+01
63-77	0.2001E+01	430	5.603	0.045	0.3481E-02	0.1310E-03	-0.2757E-01	0.8358E+00	0.2439E+01
78-87	0.2184E+01	231	6.114	0.044	0.3320E-02	0.1449E-03	-0.2536E-01	0.7788E+00	0.2021E+01
88-95	0.1724E+01	255	4.827	0.050	0.3271E-02	0.1409E-03	-0.2511E-01	0.7474E+00	0.2745E+01
96-113	0.1770E+01	574	4.956	0.034	0.3472E-02	0.1389E-03	-0.2739E-01	0.8249E+00	0.2537E+01
114-131	0.1687E+01	587	4.724	0.034	0.3479E-02	0.1390E-03	-0.2703E-01	0.8737E+00	0.3543E+01
135-154	0.1714E+01	624	4.800	0.045	0.2938E-02	0.1476E-03	-0.2465E-01	0.8803E+00	0.5267E-01
155-171	0.1929E+01	558	5.402	0.009	0.3289E-02	0.1508E-03	-0.2794E-01	0.8965E+00	0.1374E-01
172-176	0.1494E+01	124	4.182	-0.006	0.3554E-02	0.1474E-03	-0.3070E-01	0.7925E+00	0.0000E+00*
177	0.4873E+00	13	1.364	0.021	0.3213E-02	0.1474E-03*	-0.4386E-01	0.7925E+00*	0.0000E+00*
178	0.8195E+00	16	2.295	-0.009	0.3443E-02	0.1474E-03*	-0.8431E-01	0.7925E+00*	0.0000E+00*
179	0.5936E+00	15	1.662	-0.019	0.3316E-02	0.1474E-03*	-0.9472E-01	0.7925E+00*	0.0000E+00*
180	0.5059E+00	13	1.416	-0.040	0.3283E-02	0.1474E-03*	-0.1163E+00	0.7925E+00*	0.0000E+00*
181	0.3037E+00	10	0.850	-0.041	0.3268E-02	0.1474E-03*	-0.1508E+00	0.7925E+00*	0.0000E+00*
182	0.1928E+01	7	5.398	-0.098	0.3711E-02	0.1474E-03*	-0.1875E+00	0.7925E+00*	0.0000E+00*

* fixed parameter

Table 2b. Deep water column station groupings for CTD oxygen algorithm parameters.

Station	StdDev	#Obs	2.8*sd	1:Bias	2:Slope	3:Pcor	4:Tcor	5: Wt	6: Lag
10-18	0.8233E+00	119	2.305	0.000	0.3918E-02	0.1350E-03*	-0.4539E-01	0.8702E+00*	0.3275E+01*
19-31	0.8240E+00	187	2.307	0.016	0.3754E-02	0.1350E-03*	-0.3740E-01	0.8702E+00*	0.3275E+01*
32-45	0.8000E+00	237	2.240	0.021	0.3735E-02	0.1338E-03*	-0.3460E-01	0.6807E+00*	0.7588E+01*
46-53	0.5762E+00	131	1.613	0.010	0.3846E-02	0.1345E-03*	-0.3893E-01	0.6084E+00*	0.6309E+01*
54-62	0.4671E+00	139	1.308	-0.001	0.3939E-02	0.1361E-03*	-0.3908E-01	0.8185E+00*	0.1341E+01*
63-77	0.5677E+00	190	1.590	0.008	0.3972E-02	0.1310E-03*	-0.4515E-01	0.8358E+00*	0.2439E+01*
78-95	0.8477E+00	90	2.374	-0.011	0.3991E-02	0.1409E-03*	-0.3776E-01	0.7474E+00*	0.2745E+01*
96-113	0.7719E+00	196	2.161	-0.001	0.3901E-02	0.1389E-03*	-0.3079E-01	0.8249E+00*	0.2537E+01*
114-131	0.7562E+00	213	2.117	-0.008	0.4008E-02	0.1390E-03*	-0.3101E-01	0.8737E+00*	0.3543E+01*
135-154	0.8193E+00	180	2.294	-0.003	0.3476E-02	0.1476E-03*	-0.2547E-01	0.8803E+00*	0.5267E-01*
155-171	0.8459E+00	225	2.368	-0.013	0.3480E-02	0.1508E-03*	-0.6254E-02	0.8965E+00*	0.1374E-01*
172-176	0.1120E+01	64	3.135	-0.009	0.3524E-02	0.1474E-03*	-0.1246E-01	0.7500E+00*	0.0000E+00*

* fixed parameter



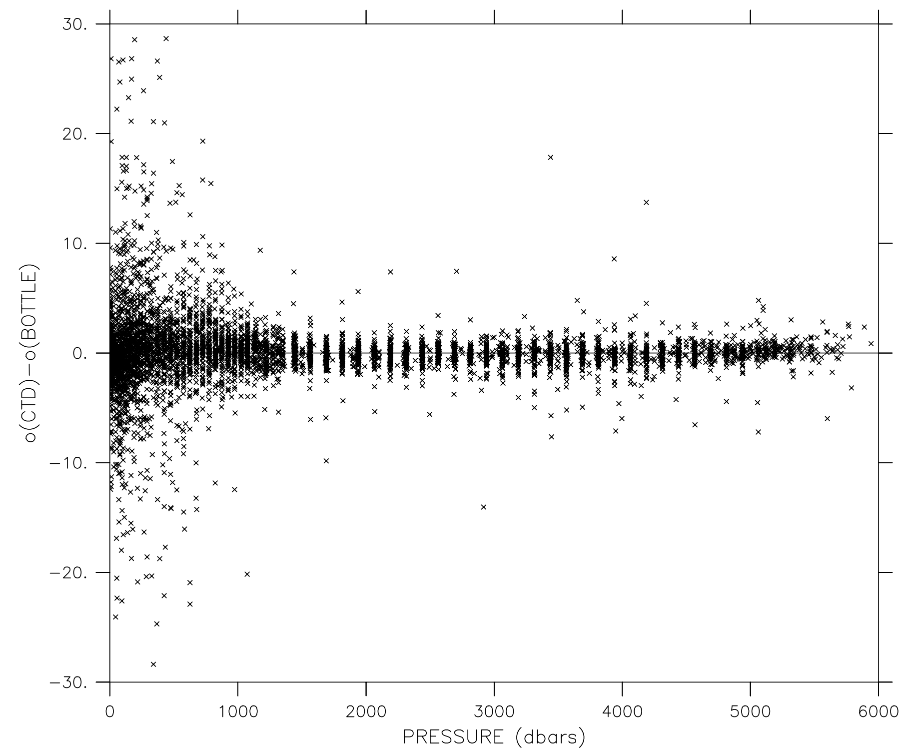


Fig. 4. Calibrated CTD-bottle oxygen differences (µmol/kg) plotted against station number (upper panel). Calibrated CTD-bottle oxygen differences (µmol/kg) plotted against pressure (lower panel).

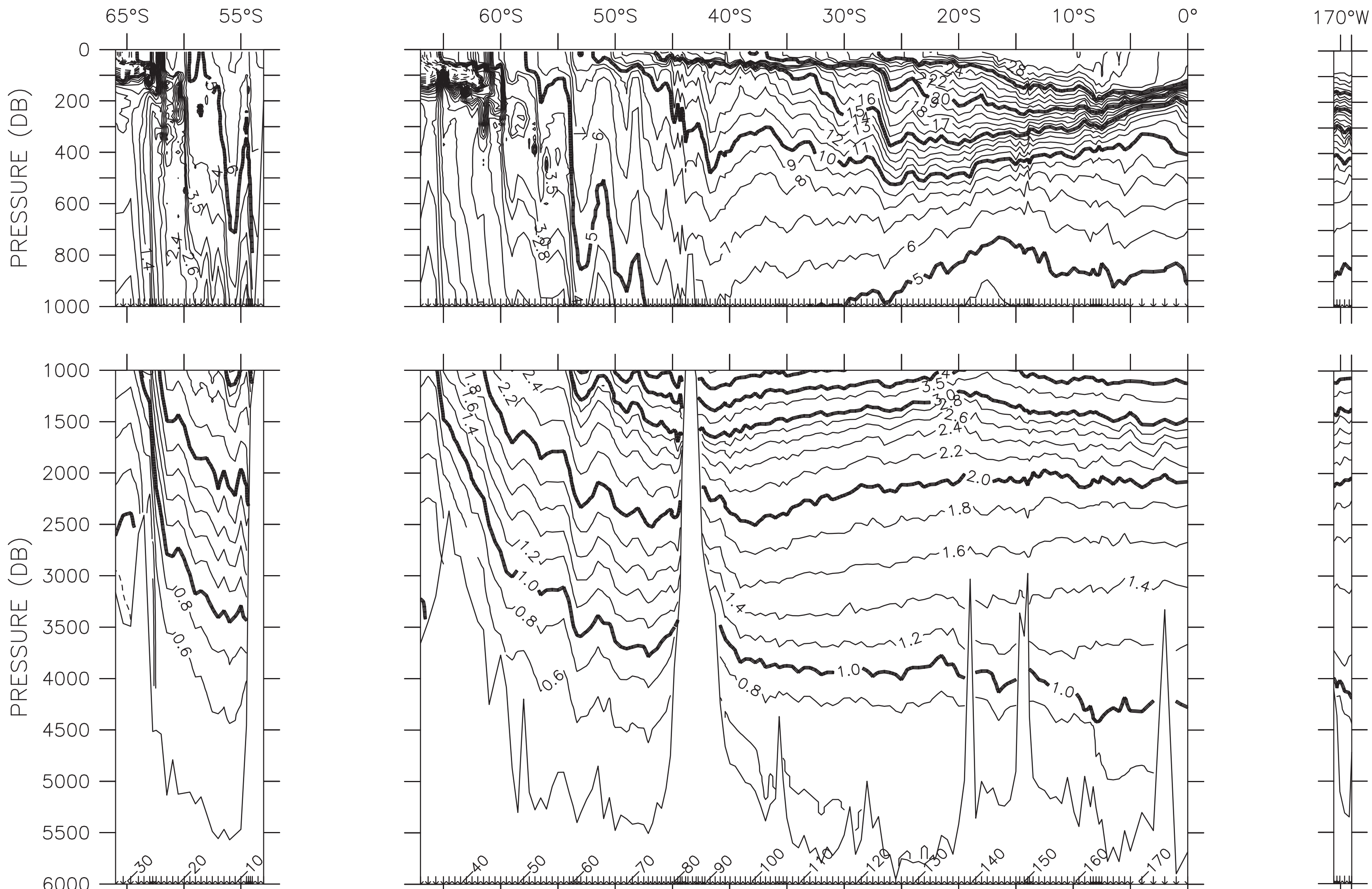


Fig. 5. Potential temperature (°C) sections along P14S, P15S, and across the Samoan Passage. Contour intervals are 0.2 from –2–3°C, 0.5 from 3–4°C, and 1 from 4–35°C.

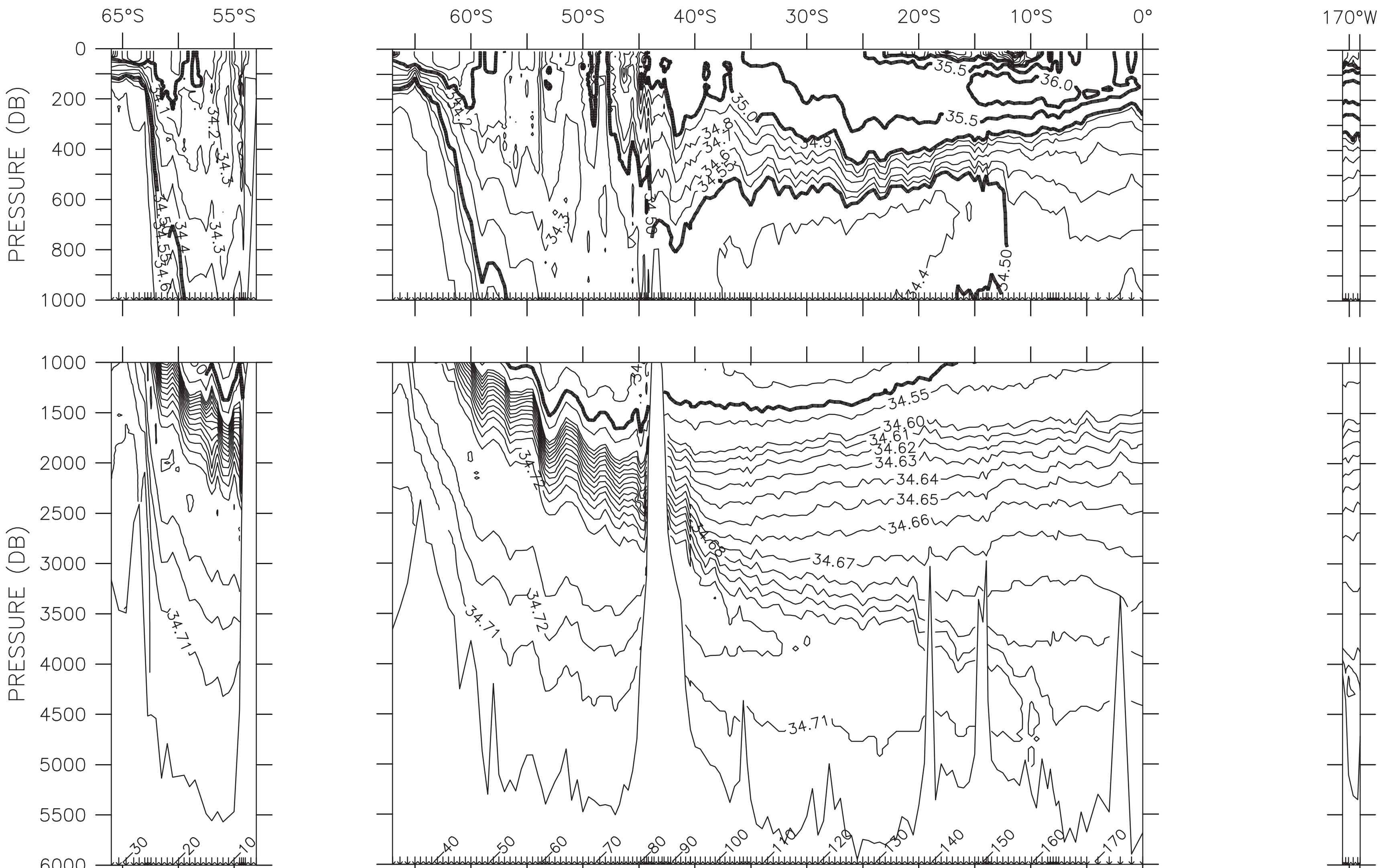


Fig. 6. Salinity (PSS) sections along P14S, P15S, and across the Samoan Passage. Contour intervals are 0.1 from 32–34.5 PSS, 0.05 from 34.5–34.6 PSS, 0.1 from 34.6–35 PSS, 0.5 from 35–37 PSS in the upper panel. Contour intervals are 0.1 from 32–34.5 PSS, 0.05 from 34.5–34.6 PSS, and 0.01 from 34.6–34.8 PSS, 0.1 from 34.8–35, and 1.0 from 35–37 PSS in the lower panel.

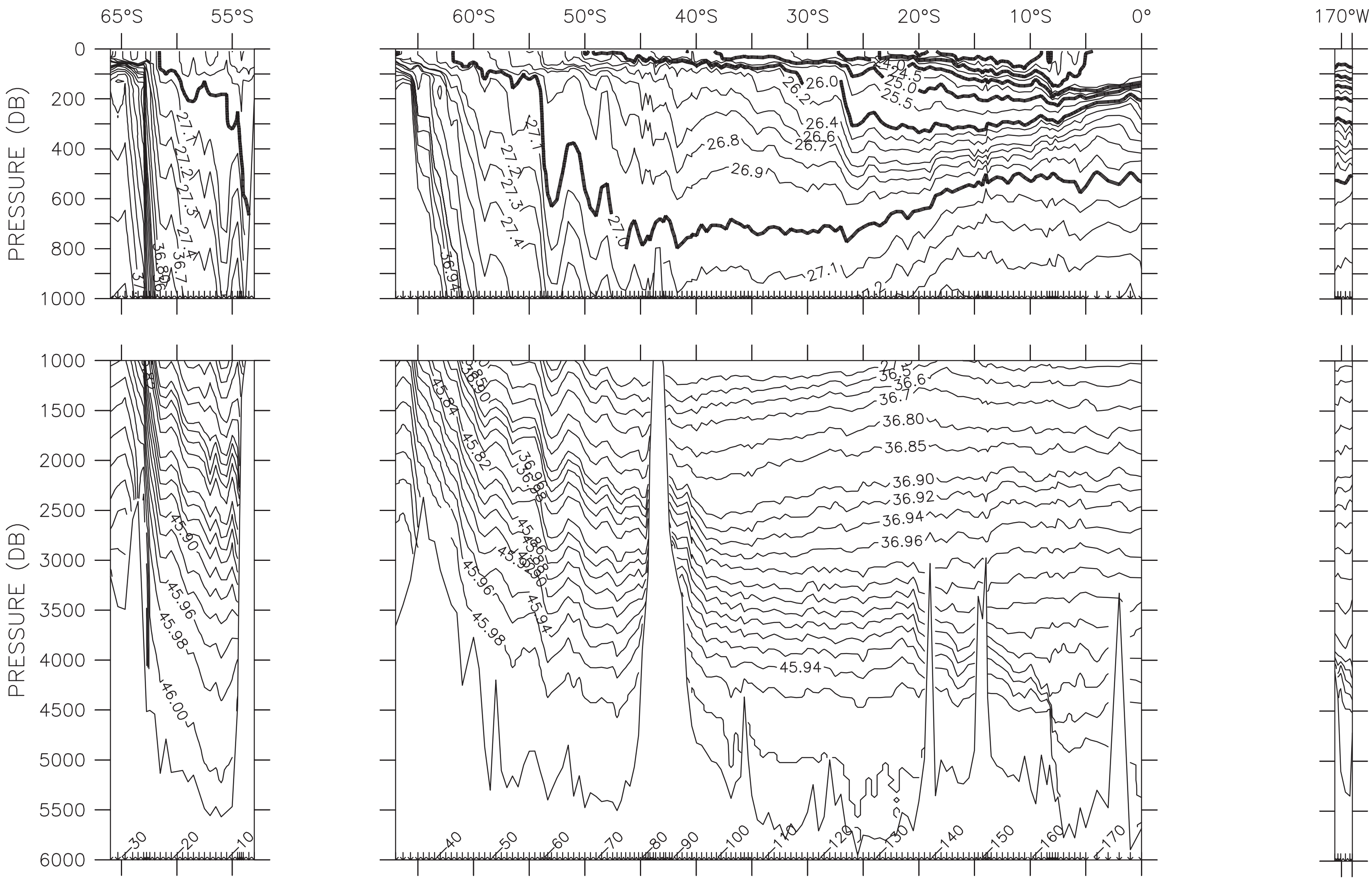


Fig. 7. Potential density (kg/m^3) sections along P14S, P15S, and across the Samoan Passage. Sigma-theta contour intervals are 0.5 from 22–26, 0.2 from 26–26.6, and 0.1 from 26.6–27.4. Sigma-2 contour intervals are 0.1 from 36.7–36.8, 0.05 from 36.8–36.9, and 0.02 from 36.9–37. Sigma-4 contour intervals are 0.02 from 45.82–48.

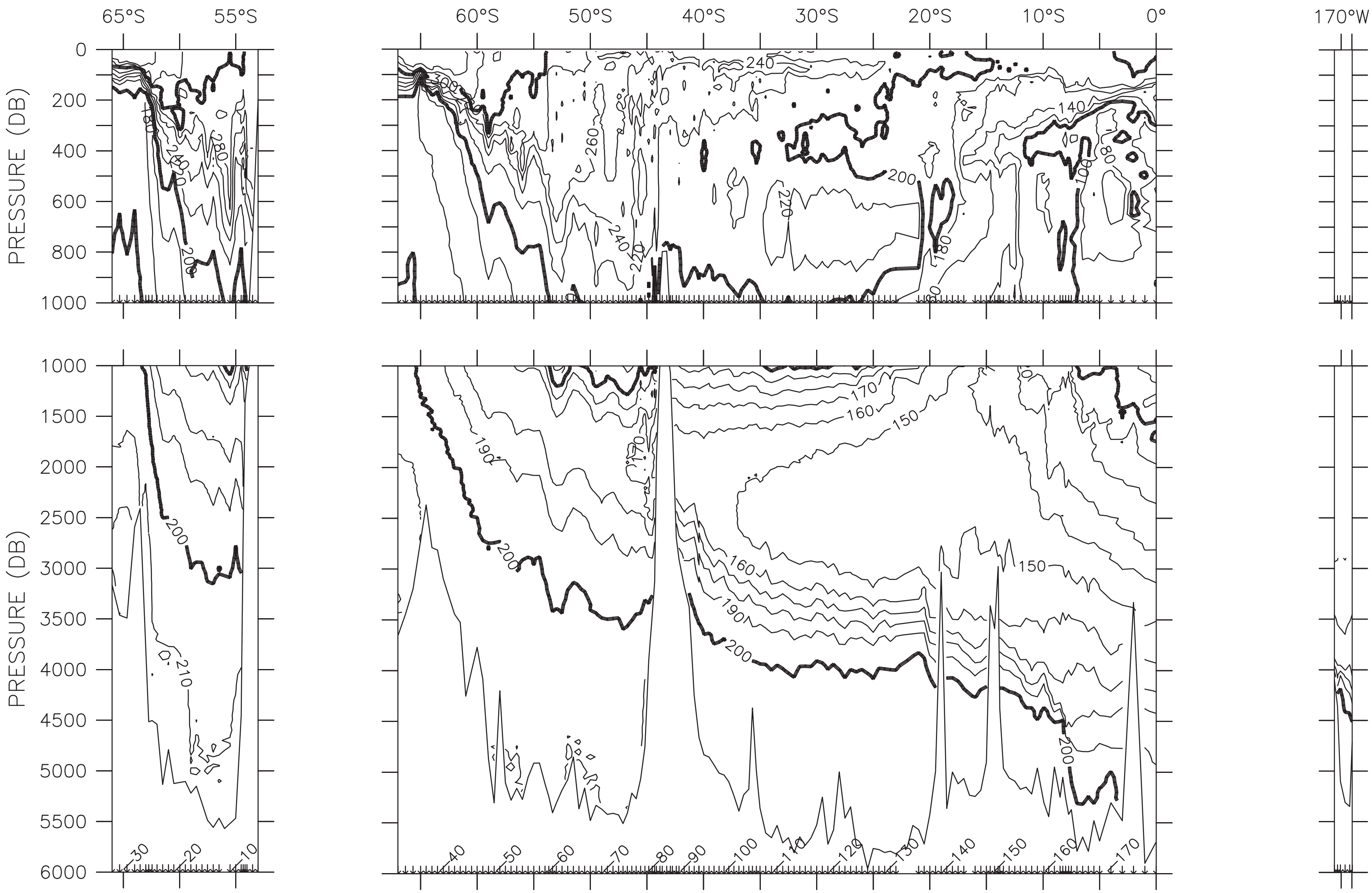


Fig. 8. CTD oxygen (µmol/kg) sections along P14S, P15S, and across the Samoan Passage. Contour intervals are 5 from 0–20 µmol/kg and 20 from 20–400 µmol/kg.

Table 3. Weather condition code used to describe each set of CTD measurements.

Code	Weather Condition
0	Clear (no cloud)
1	Partly cloudy
2	Continuous layer(s) of cloud(s)
3	Sandstorm, dust storm, or blowing snow
4	Fog, thick dust or haze
5	Drizzle
6	Rain
7	Snow, or rain and snow mixed
8	Shower(s)
9	Thunderstorms

Table 4. Sea state code used to describe each set of CTD measurements.

Code	Height (meters)	Description
0	0	Calm-glassy
1	0–0.1	Calm-rippled
2	0.1–0.5	Smooth-wavelet
3	0.5–1.25	Slight
4	1.25–2.5	Moderate
5	2.5–4	Rough
6	4–6	Very rough
7	6–9	High
8	9–14	Very high
9	>14	Phenomenal

Table 5. Visibility code used to describe each set of CTD measurements.

Code	Visibility
0	<50 meters
1	50–200 meters
2	200–500 meters
3	500–1,000 meters
4	1–2 km
5	2–4 km
6	4–10 km
7	10–20 km
8	20–50 km
9	50 km or more

Table 6. Cloud type.

Code	Cloud Types
0	Cirrus
1	Cirrocumulus
2	Cirrostratus
3	Altocumulus
4	Altostratus
5	Nimbostratus
6	Stratocumulus
7	Stratus
8	Cumulus
9	Cumulonimbus
X	Clouds not visible

Table 7. Cloud amount.

Code	Cloud Amount
0	0
1	1/10 or less but not zero
2	2/10–3/10
3	4/10
4	5/10
5	6/10
6	7/10–8/10
7	9/10
8	10/10
9	Sky obscured or not determined

All CTD and Hydrographic Data can be obtained by contacting K.E. McTaggart at kem@pmel.noaa.gov.