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CTD MEASUREMENTS COLLECTED ON A CLIMATE AND GLOBAL CHANGE CRUISE ALONG 170°W DURING FEBRUARY-APRIL 1990

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CONTENTS

PAGE

FIGURES

TABLES

CTD Measurements Collected on a Climate and Global Change Cruise
Along 170°W During February-April 1990

K. McTaggart[1], D. Wilson[2], and L. Mangum

ABSTRACT.

Summaries of Nell Brown Instrument System CTD measurements and hydrographic data acquired on a Climate and Global Change (CGC) cruise during the spring of 1990 aboard the NOAA ship ***Malcolm Baldrige*** are presented. The majority of these data were collected along 170°W from 5°N to 60°S. Additional data collected along a trackline from 60°S, 170°W to 46.3°S, 179.5°E, and along 32.5°S from 179°W to 170°W are also presented. Data acquisition and processing systems are described and calibration techniques are discussed. Station location, meteorological conditions, abbreviated CTD data listings, profiles, and potential temperature-salinity diagrams are shown for each cast. Section plots of oceanographic variables and hydrographic data listings are also given.

1. INTRODUCTION

In support of NOAA's Climate Program, PMEL scientists have been measuring the growing burden of greenhouse gases in the thermocline waters of the Pacific Ocean and the overlying atmosphere since 1980. During leg I of this cruise, hydrographic and chemical measurements were made in a detailed section along 170°W in the southwestern Pacific Ocean. Goals included the assessment of the change in inventory of CFC- 11, CFC- 12, and anthropogenic CO_2 since the first observations in the southwestern Pacific during 1984; observation of freons and other tracers in several crossings of the Deep Western Boundary Current; and observation of tracers in the bottom waters of the deep basin of the southwestern Pacific. During leg 2 of this cruise, measurements were made in the deep passages between the North and South Pacific Basins, across the Deep Western Boundary Current at 32.5°S, and across the equator. Figures I and 2 show the cruise track and station locations. In Figure 2, leg I stations are indicated by a circle and leg 2 stations are marked by a triangle. Table I provides a summary of cast information.

2. STANDARDS AND PRE-CRUISE CALIBRATIONS

The Neil Brown Mark IIIb CTD profiler is designed to make precise, high resolution measurements of conductivity, temperature, and pressure in the ocean environment. Electrical conductivity of sea water is obtained using a miniature four-electrode ceramic cell and highly precise and stable interface electronics; temperature is determined using a platinum resistance thermometer. Pressure is determined using a high performance strain gage pressure transducer. A thermistor within the pressure sensor housing corrects pressure values for the effects of temperature changes on the sensor itself.

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Data from the underwater unit is transmitted in real time to a shipboard data terminal through a 3-conductor electro-mechanical cable. The data is in TELETYPE (TTY) format and uses a frequency shift key (FSK) modulated signal superimposed on the DC power supplied to the underwater unit.

The EG&G conductivity sensor has a range of I to 65 mmho, an accuracy of ±0.005 mmho, resolution of 0.001 mmho, and stability of 0.003 mmho/month. The Rosemount platinum thermometer has a range of -32 to 32°C, an accuracy of ±0.005°C (-3 to 32°C), resolution of 0.0005°C, and stability of 0.001°C/month. The Paine pressure sensor has a range of 0 to 6500 db, an accuracy of ±6.5 db, resolution of 0.1 db, and stability of 0.1%/month.

Pre-cruise calibrations were done at Northwest Regional Calibration Center (NRCC) in Bellevue, Washington. The CTD was placed in a temperature controlled bath and compared against a calibration standard at nine different temperatures ranging from 0 to 30°C. A linear fit was calculated for the platinum thermometer. A calibrated piston gauge was used to determine separate third-order fits for the pressure sensor at four temperatures for increasing pressure (a range of seven pressure values from 0 to 6300 db) and decreasing pressure (a range of six values from 6300 to 0 db). Temperature and pressure calibrations were crudely checked at sea by comparing values with those from deep reversing thermometers, but the stability of the temperature and pressure sensors is such that the sensors are more accurate than the reversing thermometers. The conductivity sensor, on the other hand, is not as stable relative to water sample values and is more accurately calibrated using water sample salinities. Immediately prior to tripping the rosette, values of pressure, temperature, and conductivity were recorded from the CTD deck unit. These upcast CTD values were used for comparison with the water sample values.

3. DATA ACQUISITION

The CTD was deployed off the starboard platform of the ***Malcolm Baldrige*** using an Interocean winch throughout both legs of the cruise. A total of 64 CTD profiles were collected at 36 stations on leg I along 170°W from 15°S to 60°S, and along a trackline from 60°S, 170°W to 46.3°S, 179.5°E, including 21 deep casts to within 50 db of the bottom and 6 test/freon calibration casts. Cast 63 and 64 were freon calibration casts. CTD data from cast 63 is included in the data set although no bottle salts were drawn, but CTD data from cast 64 was not processed. A total of 46 CTD profiles were collected during leg 2 along 32.5°S from 178.8°W to 171.5°W, and along 170°W from 30°S to 5°N, including 13 deep casts to within 50 db of the bottom.

PMEL's Nell Brown CTD/02 S/N 2044 (sampling rate 31 Hz) and a General Oceanics 24-bottle rosette were used for casts 0-10. Eight-hundred pounds of lead weight were attached to the frame to reduce the effects of surging. AOML's Neil Brown CTD S/N 2043 (sampling rate 31 Hz) and a General Oceanics 12-bottle rosette with 400 pounds of lead weight were used for casts 11-64 of leg I and throughout leg 2. Casts to within 50 meters of the bottom were made using a Benthos acoustic pinger mounted low and opposite the CTD sensor arm on the frame. The position of the package relative to the bottom was monitored on the ship's Precision Depth Recorder. Ten-liter Niskin bottles were used to collect water samples for salinity, oxygen, nutrients, CFC, helium, total CO, alkalinity, and dissolved inorganic carbon. Reversing thermometers were mounted on several Niskin bottles on each cast and were used to verify rosette trip sequence and monitor the CTD temperature sensor for calibration shifts.

The package entered the water and was lowered at a rate of 30 m/min for the first 50 meters. To reduce the chance of contamination in the bottles, the package was not stopped just beneath the surface on its descent. Speed was increased at 50 meters to 45 m/min, and increased again at 200 meters to 60 m/min. Ship roll sometimes caused substantial variation about these mean lowering rates.

A Neil Brown Mark III deck unit received the FSK signal from the CTD and displayed pressure, temperature, and conductivity values. An analog signal was forwarded from the deck unit to an XYY' recorder which monitored the data acquisition in real-time for signal spiking and problems with the electrical termination. An audio signal was forwarded to a video cassette recorder as a backup. The digitized data were forwarded to a microVAX and written directly to a disk file. Digitized data were also recorded on 9-track magnetic tape as an additional backup. The acquisition microVAX was equipped with Scientific Computer System (SCS) data acquisition software modified from PMEL/AOML source code. The disk files were transferred to a processing microVAX where PMEL's standard processing and plotting software were installed. Plots were generated after each cast to check for problems and monitor sensor drift. Backups of the raw and processed data were made on TK50 cartridge tapes and returned to PMEL.

3.1 Data Acquisition Problems

Early into leg 1, patches of deteriorated cable were identified from near-surface to greater than 5000 meters. Efforts were made to reinforce damaged areas in order to continue with CTD operations.

The oxygen sensor on CTD SiN 2044 started losing sensitivity before the cap was inadvertently left on during a deep cast which ruptured the sensor's membrane. Before the sensor could be replaced, the entire underwater package was lost during cast 10 when the cable parted with approximately 600 meters of cable out. An additional 4100 meters of cable was discarded and operations continued with the 12-bottle package. Multiple casts were made at selected stations to adequately sample the water column. CTD oxygen data were not processed.

Problems existed throughout the cruise with the rosettes and the rosette deck units of both packages. Several deck units were tried. A strip chart recorder connected to the rosette deck units to monitor the signal voltages was helpful in determining misfires. Bottle salinity, oxygen and nutrient data were also used in an effort to determine the actual depth of each bottle fired. No bottles closed during cast 63 owing to a nicked connector.

3.2 Salinity Analyses

Bottle salinity analyses were performed by survey personnel in a climate-controlled van using two Guildline Autosal Model 8400A inductive salinometers and IAPSO Standard Seawater from Wormley batch P 112. The commonly accepted precision of the Autosal is 0.001 psu, with an accuracy of 0.003 psu. The Autosals were standardized before each run and either at the end of each run or after no more than 48 samples. The drift during each run was monitored and individual samples were corrected for the drift during each run by linear interpolation. Bottle salinities were compared with computed CTD salinities to identify leaking bottles, as well as to monitor the conductivity sensor performance and drift.

Problems developed with both autosals midway through the cruise but were fixed by ship's personnel. Generally, there was good agreement between preliminary CTD data and bottle salinities, with a standard error near .005 psu. Calibrated CTD salinities replace problem bottle salinities in the hydrographic data listing and are indicated by an asterisk.

4. POST-CRUISE CALIBRATIONS

Pressure and temperature values for both CTDs were corrected using pre-cruise calibration coefficients. Reversing thermometer data showed no shifts in temperature and pressure calibrations within the resolution of these measurements. The new International Temperature Scale of 1990 (ITS-90) was not applied to the temperature values of this data set.

Final calibrations for conductivity were determined by reading uncalibrated CTD upcast and sample salinity data and calculating a least squares linear fit between CTD and water sample conductivity, weighting all data equally. When the difference between CTD and water sample conductivity exceeded 2.8 times the standard deviation of the calculated fit, the calibration pair was thrown out. Another fit was then calculated with these points omitted and the process repeated until no calibration pairs are discarded. This cruise was separated into three groups:

	BIAS	SLOPE	MAXIMUM RESIDUAL	STANDARD DEVIATION
Casts 0-10:	-2.0077199E-02	0.9993219	-0.019	0.0068 mmho/cm
Casts 11-63:	-0.7075790E-02	0.9987081	-0.010	0.0038 mmho/cm
Casts 65-110:	-1.4587455E-02	0.9986109	-0.010	0.0039 mmho/cm
Casts 0-10:	16 values were discarded from a total of 122 in 6 repetitions.			
Casts 11-63:	36 values were discarded from a total of 555 in 8 repetitions.			
Casts 65-110:	49 values were discarded from a total of 510 in 7 repetitions.			

Deep potential temperature- salinity diagrams for each cast were used to check the quality of the fits. Where leg I stations were revisited on leg 2 (32.5°S, 30°S, 25°S, 20°S, and 15°S), overplots were generated. At reoccupied stations on leg 2, deep potential temperature- s ali ni ty diagrams of CTD and bottle data showed good correlation, however there was a difference of approximately 0.002 psu at two of the five reoccupied stations, 25°S and 30°S.

Historical data from 1967 Scorpio, 1987 TEW, and 1974 GEOSECS cruises were examined and there also existed differences between these cruises in salinity of the deepest water masses of about 0.002 psu. Comparing the 1990 data set with these historical data, leg I salinity data was within this 0.002 psu difference. Therefore leg 2 data at stations 25°S and 30°S along 170°W (casts 77-84) were corrected. This was done by regridding leg I and leg 2 data at these two stations according to potential temperature. The range of potential temperature was around 0.6 to 0.8°C, with a grid size of 0.01°C. The mean difference in salinity between leg I and leg 2 casts was computed. For the station at 25°S, this value was 0.0018 psu; for the station at 30°S, it was 0.0021 psu. For each regridded scan of leg 2 data, a new conductivity was calculated using the value of salinity plus delta-salinity. The differences between the old and new conductivities were averaged (25°S = 0.0014 mmho/cm, 30°S = 0.0018 mmho/cm) and added to the conductivity calibration bias applied. Corrections were linearly interpolated over casts 77-84.

5. PROCESSING

Raw CTD data files were restored from TK50 cartridge tapes and processed on PMEL microVAX node NBVAX. In order to eliminate anomalous excursions in the raw temperature and conductivity data associated with reversals in the direction of movement of the CTD package, as well as when the package decelerates due to ship roll, program DPDNB was used to read the SCS LOGGER raw data files and compute a fall rate every 60 scans (about 2 seconds). Fall rate was then carried along with the original unprocessed data.

Program DLAGAV read the raw data files with fall rates and applied pre-cruise calibrations. Window outliers (acceptable ranges were -12 to 6500 db for pressure, -2 to 33°C for temperature, and 24 to 68 mmho/cm for conductivity) and first-differencing outliers (acceptable differences between scans were 1.0 db for pressure, 0.07°C for temperature, and 0. 1 mmho/cm for conductivity) were removed. Gaps in the data were filled by linear interpolation. DLAGAV lagged conductivity, edited data exceeding the fall rate criteria (minimum fall rate acceptable was 0.5 db/60 scans or about 15 meters per minute and pressure interval to skip beyond the point of failure was 1.2 db as determined at sea), and computed 1-decibar data files.

First-differencing outliers were tentatively flagged if the differences between two scans were greater than the above mentioned preset values. If the difference between the next scan and the last good scan exceeded twice the allowable difference between scans, it too was flagged. If five scans in a row failed in this manner it was assumed that there was a gap in the data record and all scans were retained. Or if the next, third, fourth or fifth scan had values close enough to the last good scan, then the flagged scans were rejected.

The filter applied to conductivity to account for the response time difference between the conductivity sensor and the slower platinum thermometer is described in Fofonoff et al. (1974). The conductivity is lagged as follows:

$$C(n) = (I-A)\, CM(n) + A \bullet C(n-1)$$

where C is the lagged conductivity, CM is the measured conductivity, n is the scan number, and A is a constant empirically determined (Home and Toole, 1980) to best match temperature and conductivity (A = 0.87).

Program EPCTD read calibrated pressure, calibrated temperature, and raw conductivity data output from DLAGAV. EPCTD corrected raw conductivity for thermal and pressure effects, applied conductivity calibrations, and computed salinity using the 1978 Practical Salinity Scale (UNESCO, 1981). Single-point spikes were eliminated using maximum allowable gradients of 0.05°C for temperature and 0.025 psu for salinity above 200 db, and 0.01°C for temperature and 0.0 1 psu for salinity below 200 db. Additional salinity spikes were omitted from casts 12, 24, 5 1, 58, 70, and 95 as specified by the processor. Missing data were filled by linear interpolation for a value to exist every whole decibar. Final conductivity values were recomputed from salinity.

The conductivity cell dependence on temperature and pressure was corrected using the following (Fofonof et al., 1974):

$$C = CR \bullet (1-ALPHA \bullet (T-15.) + BETA \bullet (P/3.))$$

where CR is lagged conductivity, ALPHA is 6.5E-06, and BETA is 1.5E-08.

EPCTD then calculated potential temperature, sigma-t, and sigma-theta using the 1980 equation of state algorithms described by Fofonoff and Millard (1983). Dynamic height in dynamic meters was calculated by integrating from the sea surface. When the uppermost pressure was not equal to 0 db, surface values of temperature and salinity were filled with the values associated with the shallowest pressure for which values did exist (provided this pressure was less than 10 db). EPCTD output finalized CTD data in PMEL's Equatorial Pacific Information Collection (EPIC) format (Soreide and Hayes, 1988).

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). Tables 2-6 define the abbreviations and units used in the CTD data summary listings. Plots and summary listings of the CTD data follow for each cast. Hydrographic bottledata at discrete depths are listed in the final section.

7. PERSONNEL

		Leg I	Leg 2
John Bullister, NOAA Pacific Marine Environmental Laboratory (PMEL)	CFC	x	
David Wisegarver, (Chief Scientist, legs I and 2), PMEL	CFC	x	x
Fred Menzia, PMEL	CFC	x	x
Jeff Benson, PMEL	CTD	x	
Dana Greeley, PMEL	C02/CTD	x	x
Paulette Murphy, PMEL	C02	x	x
Marilyn Roberts, PMEL	C02	x	x
Linda Mangum, PMEL	CTD	x	
Kristy McTaggart, PMEL	CTD	x	
Lloyd Moore, NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML)	Nutrients	x	x
Rick Van Woy, Scripps Institute of Oceanography	CFC	x	
Gary Wick, University of Colorado	SST	x	x
Mike Behrenfeld, Western Washington University (WWU)	UV-b	x	
Andrew Hanneman, WWU	UV-b	x	
Michael Mathewson, Woods Hole Oceanographic Institute	Helium	x	
Bob Byrnes, University of Southern Florida (USF)	pH	x	
Tanya Clayton, USF	pH	x	
Doug Wilson, AOML	ADCP	x	
Rick Cole, USF	Moorings		x
Margie McCarty, PMEL	CTD		x
Lt. Cliff Wilson, PMEL	Moorings		x
Rolf Beck, Ocean Science Institute, University of Sydney	CFC	x	
Jeff Donavan, USF	Moorings		x

8. ACKNOWLEDGMENTS

The assistance of the officers and crew of the NOAA ship ***Malcolm Baldrige*** is gratefully acknowledged. The survey department (Dennis Sweeney and Tom Lantry), under the supervision of Chief Survey Technician Robert Hopkins, provided valuable assistance in operations during this cruise.

We wish to thank Margie McCarty for the acquisition and preliminary calibration of leg 2 CTD data, as well as Jeff Benson and Dana Greeley for their help with the rosette, bottles, and CTD operations.

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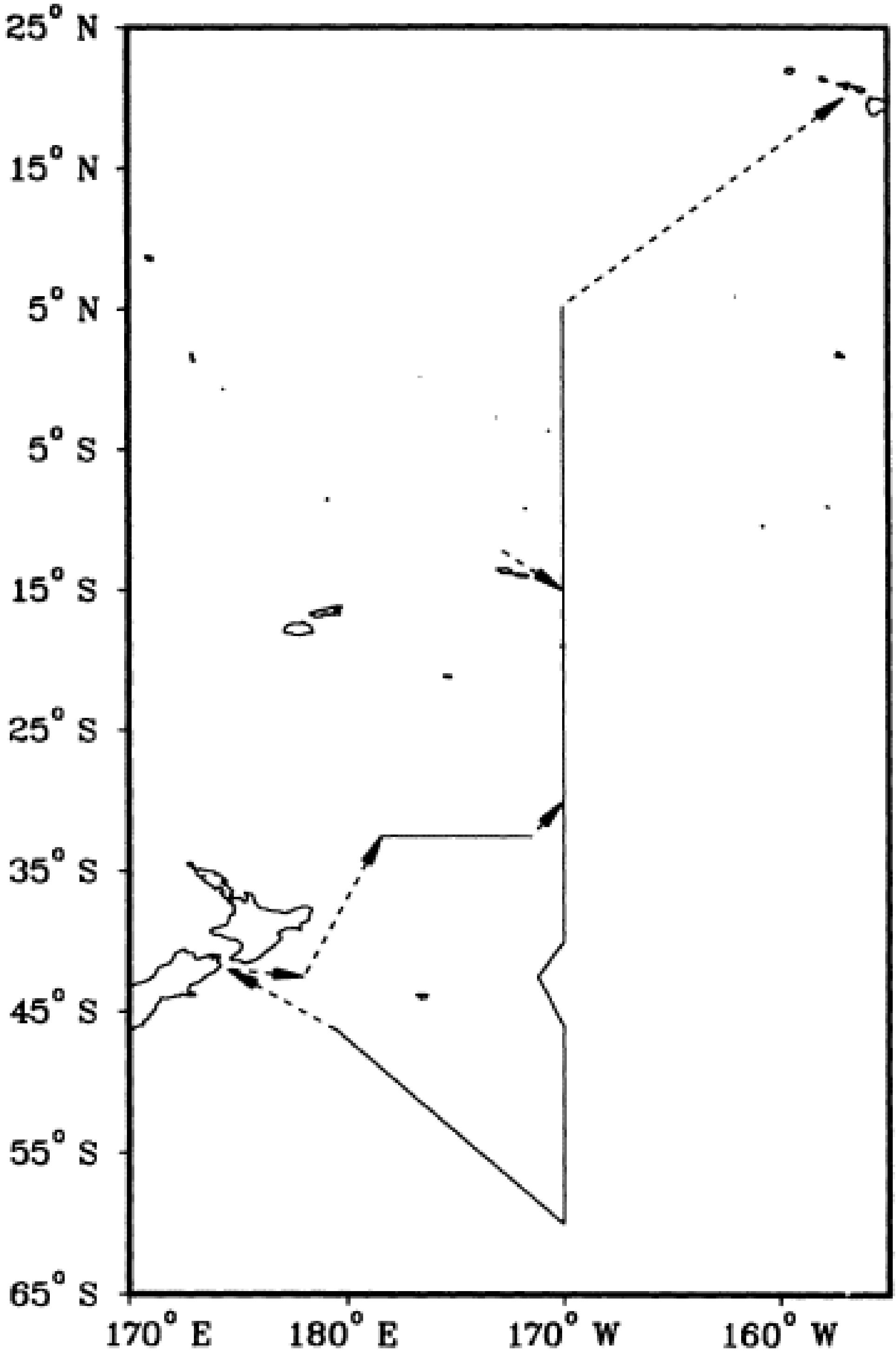
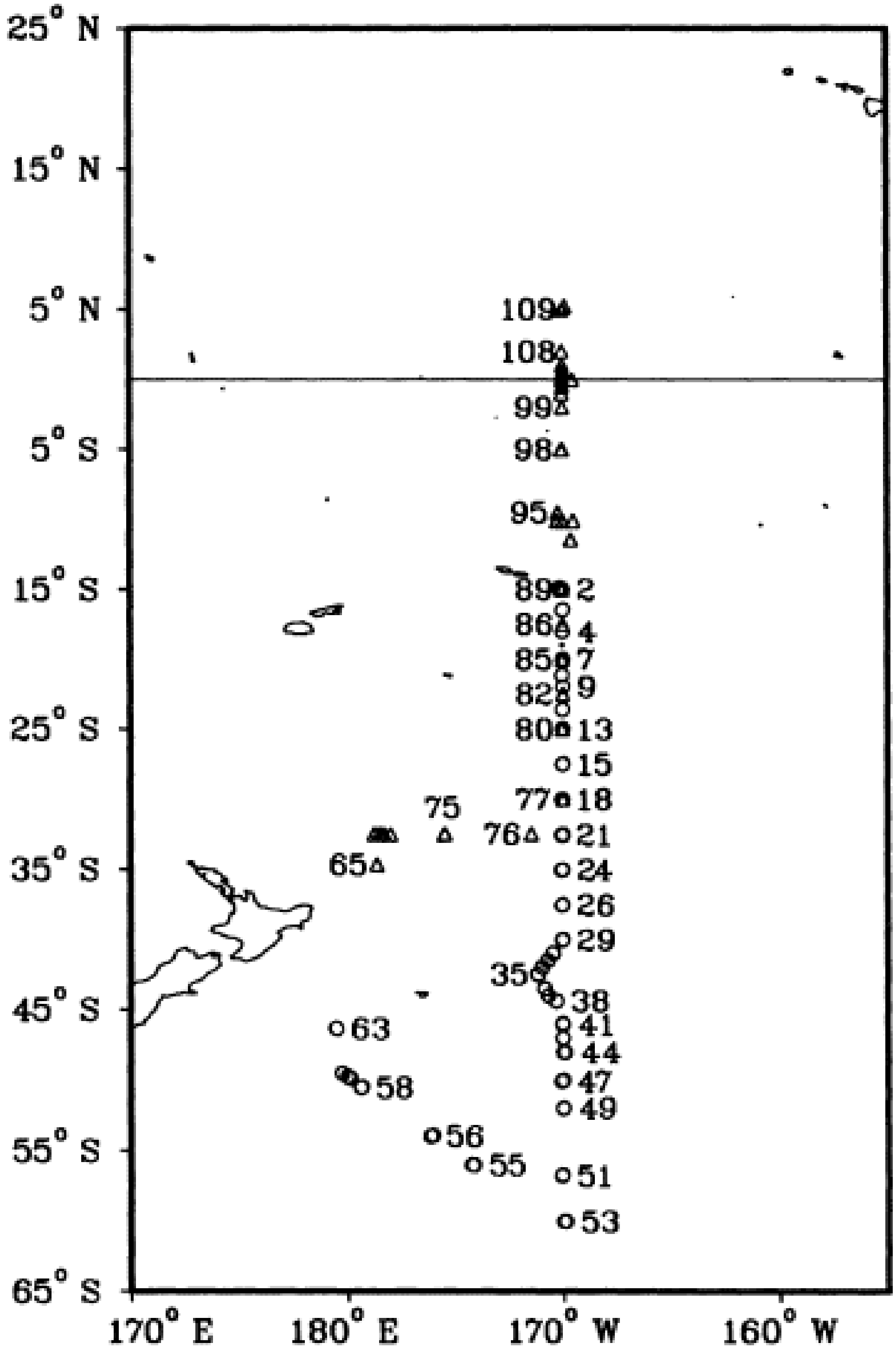
UNESCO Technical Papers in Marine Science, No. 37, 144 pp.



CGC-90-MB CRUISE TRACK
February 22 - April 16,1990
Pago Pago, Samoa - Wellington, NZ - Honolulu, HI

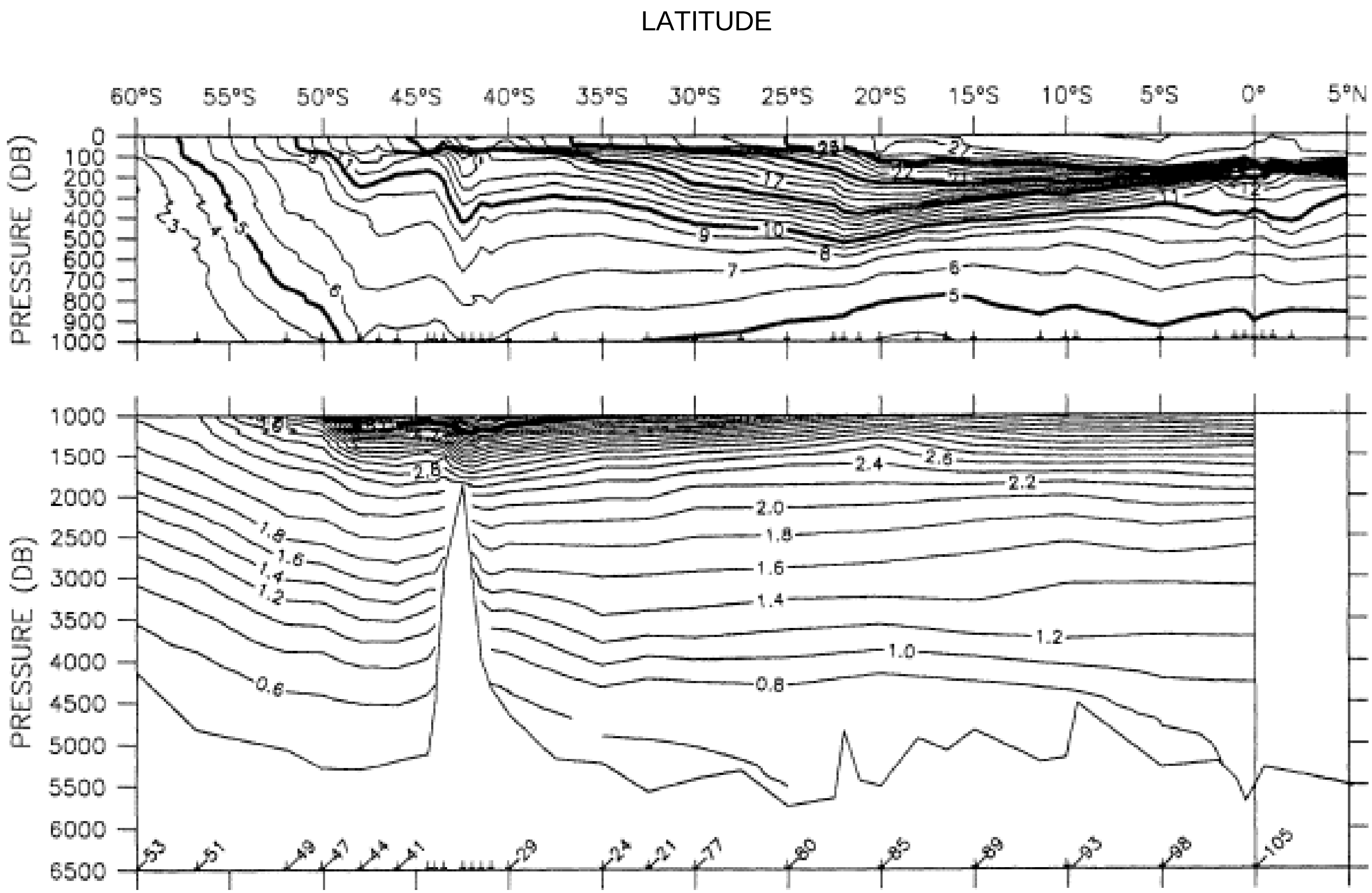
Figure 1. CGC-90-MB cruise track.



CGC-90-MB CTD STATIONS
February 22 - April 16,1990
Pago Pago, Samoa - Wellington, NZ - Honolulu, HI

Figure 2. Location of stations occupied during CGC-90-MB. Leg I stations are indicated by a circle, leg 2 stations are shown with a triangle.

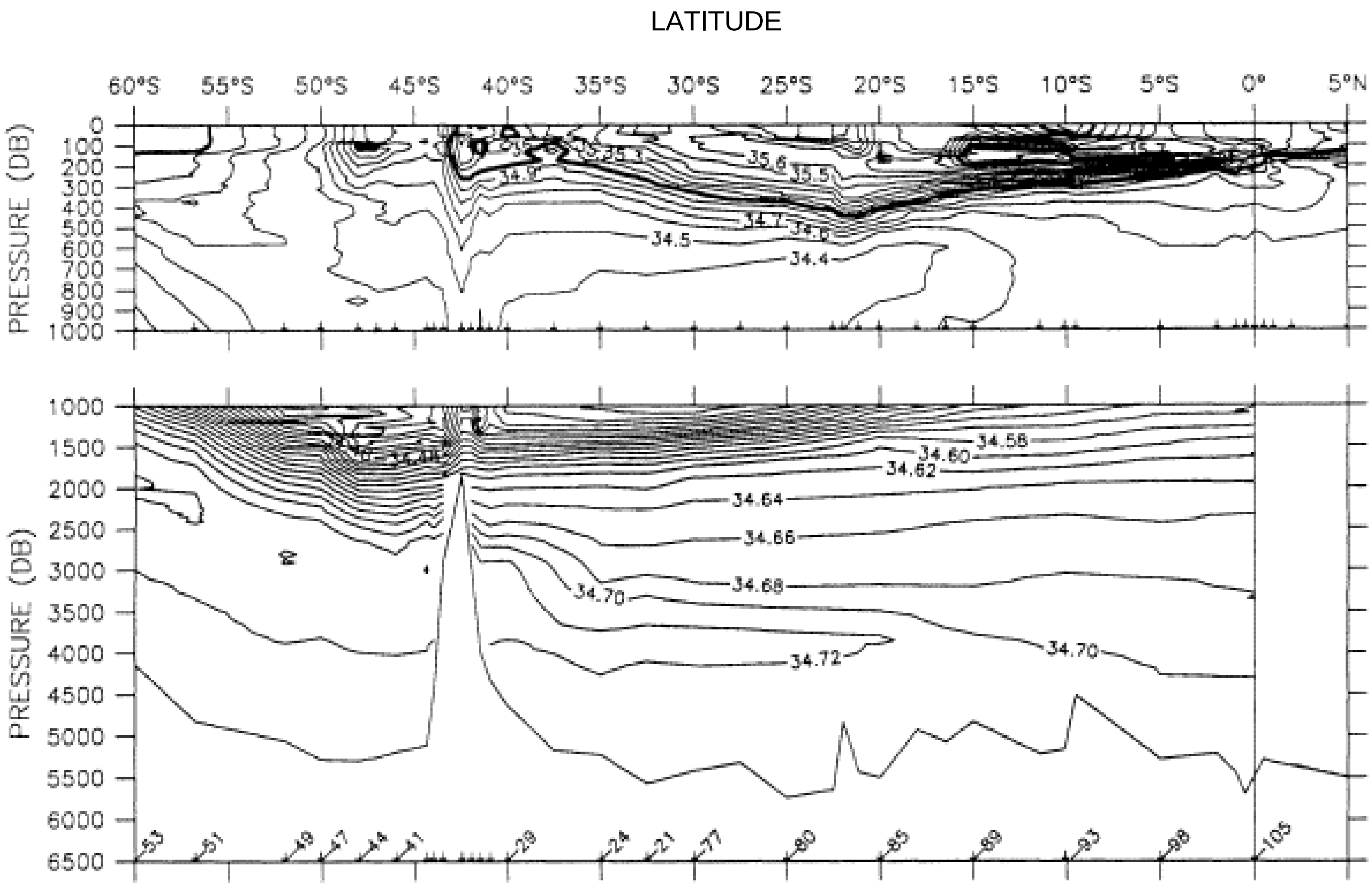
170°W POTENTIAL TEMPERATURE (C)
February 24 - April 12, 1990



C.I. = 1 lt 1000 db, .2 gt 1000 db

Figure 3. CGC-90-MB upper ocean and deep water potential temperature (°C) sections along 170°W.

170°W SALINITY (PSU)
February 24 - April 12, 1990



C.I. = .1 lt 1000 db, .02 gt 1000 db

Figure 4. CGC-90-MB upper ocean and deep water salinity (psu) sections along 170°W.

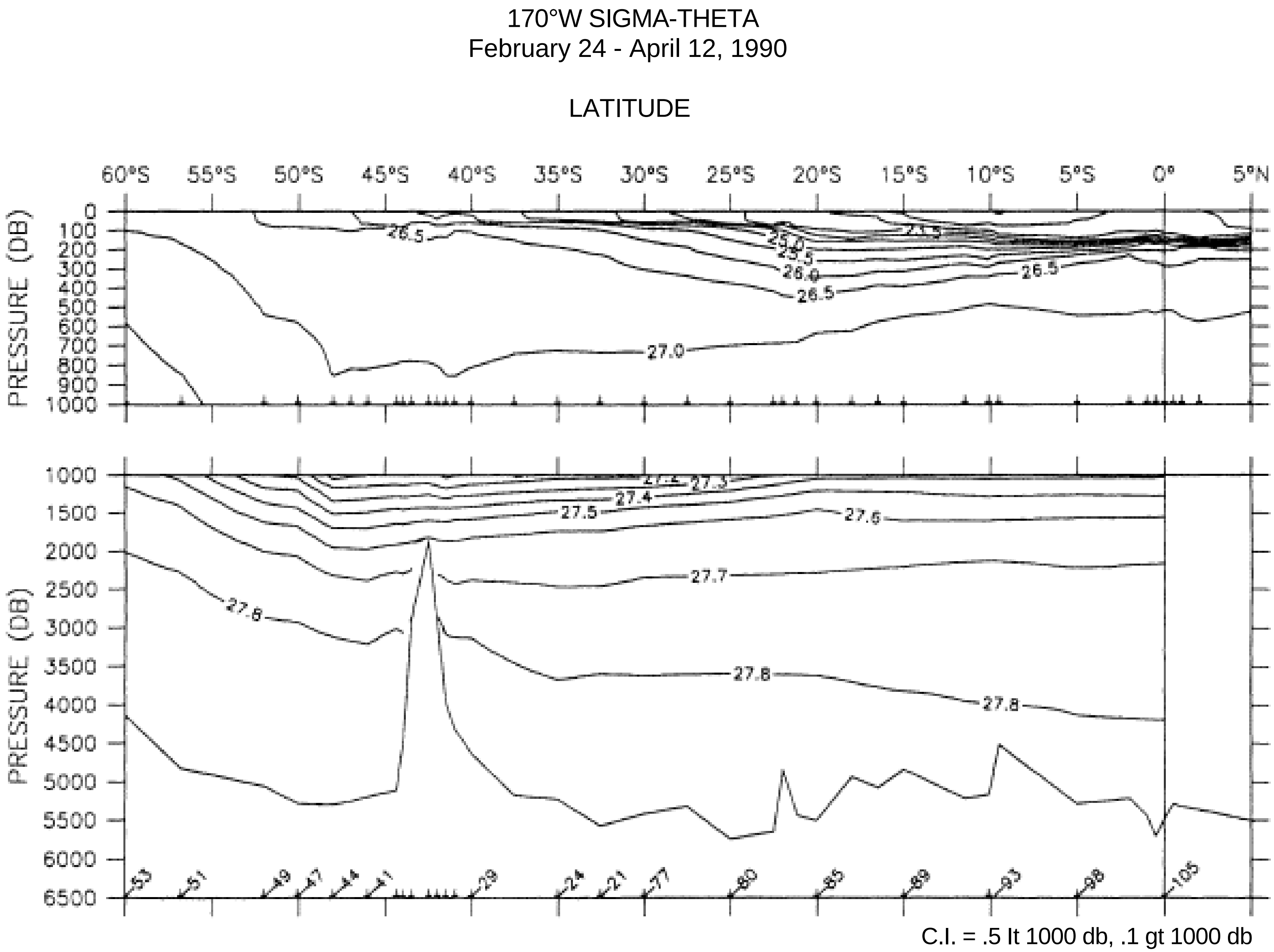


Figure 5. CGC-90-MB upper ocean and deep water potential density (kg/m 3) sections along 170°W.

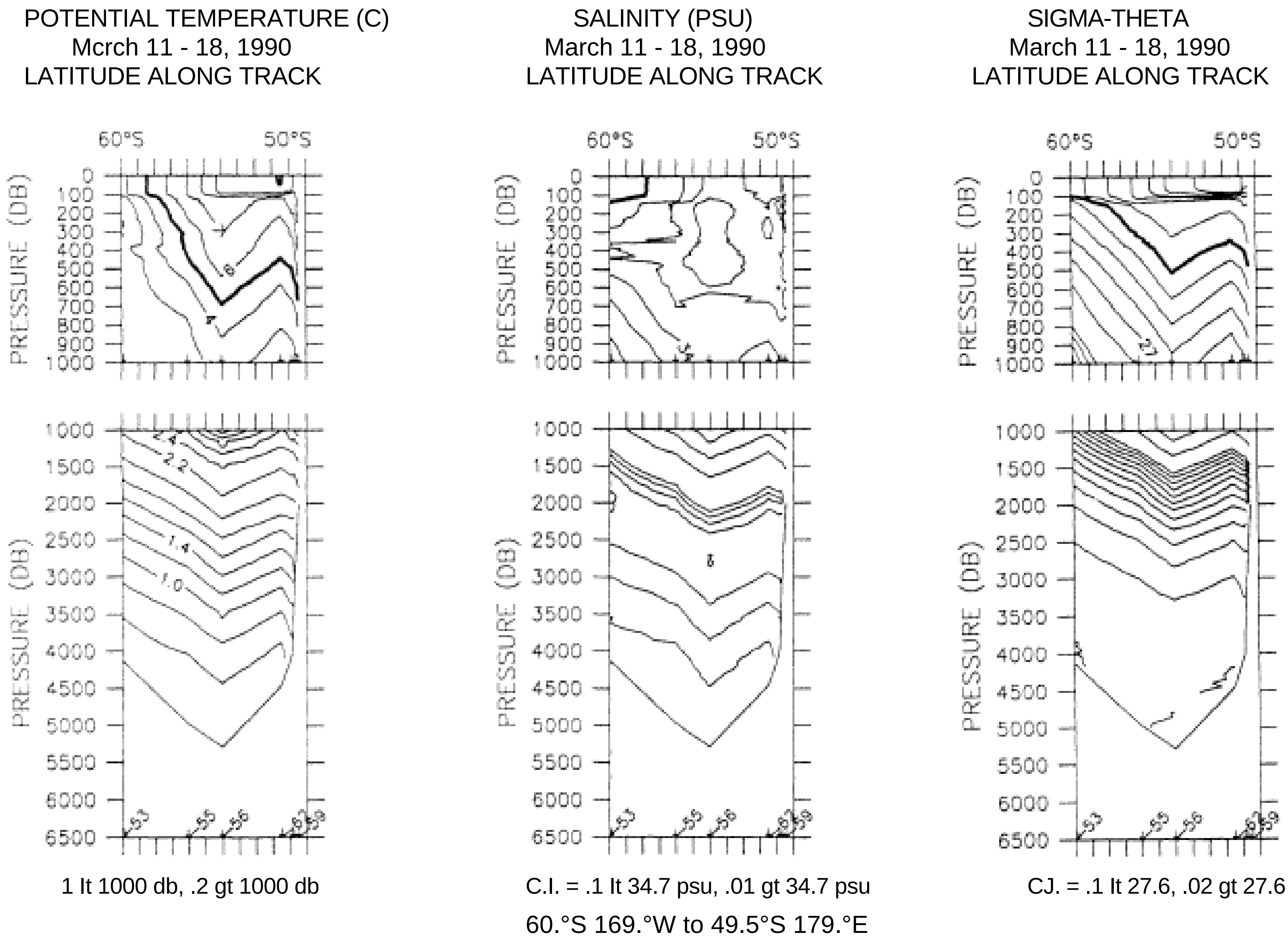
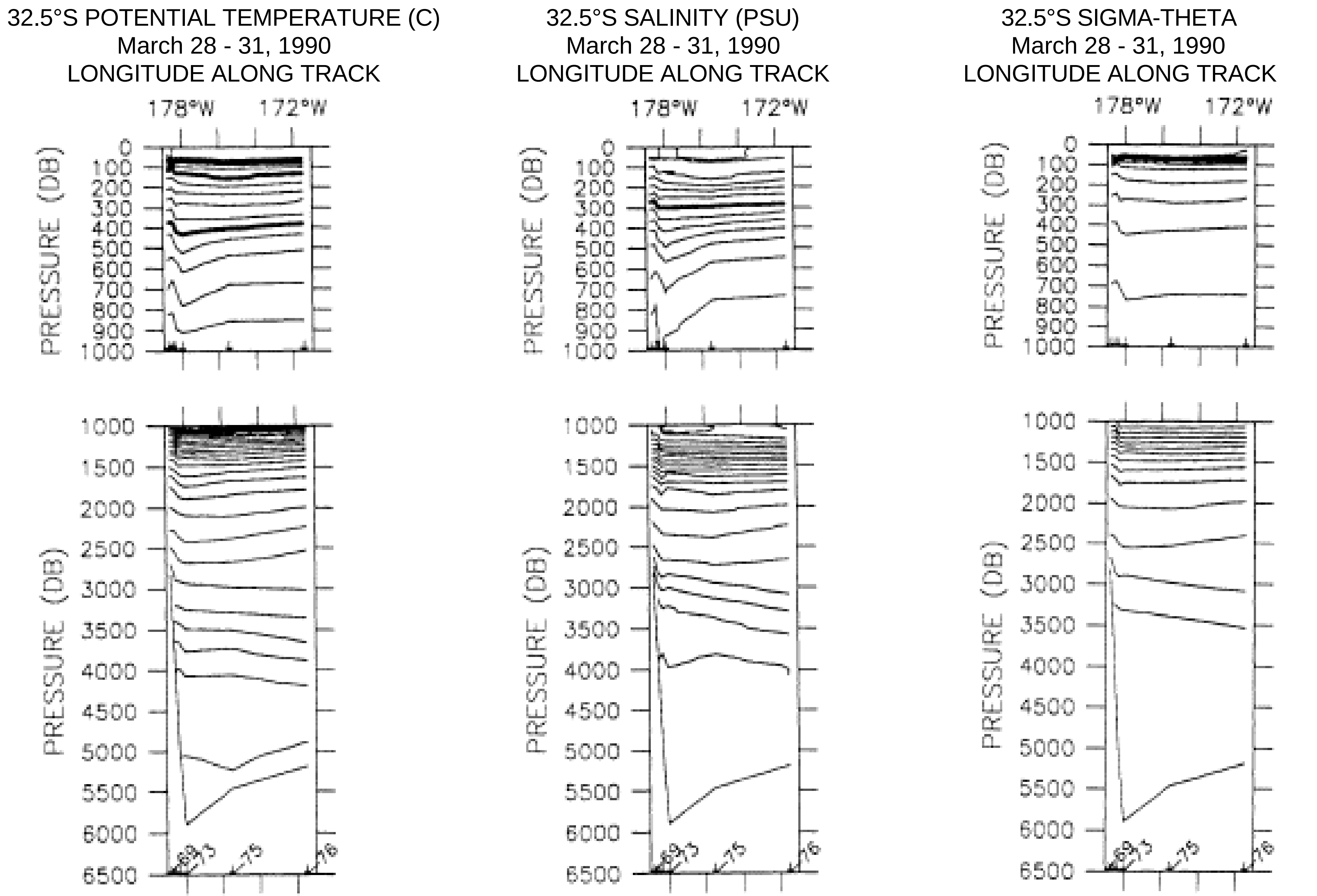


Figure 6. CGC-90-MB upper ocean and deep water potential temperature (°C), salinity (psu), and potential density (kg/M3) sections along track from 60°S, 169.9°W to 49.5°S, 179.7°E.



C.I. = 1 lt 1000 db, .2 gt 1000 db

C.I. = .1 it 1000 db, .02 gt 1000 db

C.I. = .2 lt 1000 db, .05 gt 1000 db

Figure 7.CGC-90-MB upper ocean and deep water potential temperature (°C), salinity (psu), and potential density (kg/m 3) sections along 32.5°S.

TABLE 1. CTD Cast Summary

STN #	Cast #	Latitude	Longitude	Date (GMT)	Time (°T)	W/D (kts)	W/S (m)	Depth (°C)	SST (db)	Cast
0	0	14 53.2 S	170 8.5 W	23 FEB 90	1742	-	-	4541	28.1	3013
1	1	14 59.5 S	170 0.6 W	23 FEB 90	2146	51	4	4806	28.2	200
2	2	15 0.1 S	170 0.3 W	24 FEB 90	151	-	-	4817	28.8	4847
3	3	16 28.3 S	169 59.6 W	24 FEB 90	1238	-	-	5073	28.6	2000
4	4	18 0.2 S	170 0.4 W	24 FEB 90	2149	148	7	4929	27.6	2001
5	5	20 0.2 S	169 59.6 W	25 FEB 90	816	180	8	5320	27.0	202
5	6	20 2.1 S	169 59.9 W	25 FEB 90	1100	-	-	5361	27.0	2152
5	7	20 0.7 S	169 59.6 W	25 FEB 90	2049	116	10	5320	27.0	5427
6	8	21 9.1 S	170 1.7 W	26 FEB 90	657	120	10	5433	26.7	2501
7	9	21 59.5 S	169 59.8 W	26 FEB 90	1300	103	10	4839	26.0	2004
8	10	23 37.2 S	170 0.3 W	26 FEB 90	2310	98	18	5660	25.8	600
9	11	24 59.9 S	170 1.4 W	27 FEB 90	1157	90	20	5753	24.7	2501
9	12	25 0.4 S	170 0.5 W	27 FEB 90	1509	100	18	5702	24.6	600
9	13	25 1.3 S	170 0.9 W	27 FEB 90	1837	25	5	5712	24.6	5055
10	14	27 30.2 S	170 0.3 W	28 FEB 90	727	116	14	5223	24.1	352
10	15	27 30.8 S	170 0.9 W	28 FEB 90	952	114	10	5316	24.1	2500
11	16	30 0.3 S	170 0.8 W	28 FEB 90	2215	85	19	5417	23.7	304
11	17	30 1.1 S	170 1.5 W	1 MAR 90	16	67	18	5415	23.8	1512
11	18	30 0.3 S	170 2.6 W	1 MAR 90	441	60	16	5429	23.9	5178
12	19	32 31.0 S	169 59.9 W	1 MAR 90	1825	45	22	5588	22.1	351
12	20	32 34.2 S	169 59.9 W	1 MAR 90	2032	68	24	5577	22.0	1504
12	21	32 33.2 S	170 3.1 W	2 MAR 90	30	63	20	5568	22.0	5300
13	22	35 2.0 S	170 3.3 W	2 MAR 90	1514	15	18	5172	20.7	352
13	23	35 2.0 S	170 3.4 W	2 MAR 90	1719	15	18	5128	20.7	1503
13	24	35 1.4 S	170 0.6 W	2 MAR 90	2115	355	17	5225	20.7	5278
14	25	37 30.6 S	170 1.1 W	3 MAR 90	1037	55	12	5149	19.7	400
14	26	37 32.6 S	170 2.2 W	3 MAR 90	1252	40	18	5170	19.6	2504
15	27	40 0.0 S	170 0.2 W	4 MAR 90	52	38	14	4626	17.2	398
15	28	40 0.8 S	170 0.1 W	4 MAR 90	306	40	10	4626	17.6	2301
15	29	40 1.7 S	170 1.7 W	4 MAR 90	706	168	5	4626	17.6	4678
16	30	40 59.8 S	170 28.8 W	4 MAR 90	1535	192	10	4248	17.6	2005
16	31	40 58.1 S	170 29.0 W	4 MAR 90	1908	195	14	4323	17.5	4346
17	32	41 29.4 S	170 43.4 W	5 MAR 90	41	185	14	3984	18.0	3405
18	33	41 58.9 S	170 59.0 W	5 MAR 90	554	157	18	2974	18.2	2978
19	34	42 29.5 S	171 12.2 W	5 MAR 90	1016	161	10	1826	17.8	502
19	35	42 28.7 S	171 12.5 W	5 MAR 90	1225	155	6	1857	17.8	1845
20	36	43 30.1 S	170 51.2 W	5 MAR 90	1902	97	9	2904	15.6	2923
21	37	43 59.1 S	170 41.6 W	6 MAR 90	54	58	8	4473	16.0	4648
22	38	44 22.2 S	170 19.7 W	6 MAR 90	641	43	12	5108	15.8	5186
23	39	45 58.6 S	170 0.7 W	6 MAR 90	1612	25	8	5225	14.7	352
23	40	46 3.2 S	170 0.6 W	6 MAR 90	1819	25	20	5173	14.6	1752
23	41	46 2.7 S	170 0.1 W	6 MAR 90	2207	23	21	5190	14.6	5272
24	42	47 0.4 S	170 0.8 W	7 MAR 90	538	15	14	5252	13.4	3000
25	43	48 0.3 S	169 59.5 W	7 MAR 90	1133	8	14	5307	13.7	1000
25	44	48 1.3 S	169 54.9 W	7 MAR 90	1509	30	8	5294	13.7	5205
26	45	50 0.2 S	169 59.8 W	8 MAR 90	213	358	14	5340	12.5	404
26	46	50 0.3 S	170 1.5 W	8 MAR 90	434	315	10	5340	12.6	2402
26	47	50 4.0 S	170 4.2 W	8 MAR 90	844	321	25	5279	11.6	5305
27	48	51 59.6 S	169 59.2 W	8 MAR 90	2113	256	21	4981	9.5	1003
27	49	51 58.0 S	169 59.1 W	9 MAR 90	27	266	18	5054	9.4	5130
28	50	56 42.1 S	170 3.4 W	10 MAR 90	231	345	20	4883	5.5	1000
28	51	56 46.1 S	170 4.1 W	10 MAR 90	612	12	26	4822	5.5	4769

STN #	Cast #	Latitude	Longitude	Date (GMT)	Time (°T)	W/D (kts)	W/S (m)	Depth (°C)	SST (db)	Cast
29	52	60 0.7 S	169 57.3 W	11 MAR 90	138	314	26	4139	3.8	1005
29	53	60 0.6 S	169 53.0 W	11 MAR 90	502	265	16	4139	3.8	4177
30	54	55 59.5 S	174 14.2 W	12 MAR 90	1825	155	10	5011	7.0	1001
30	55	55 59.8 S	174 10.1 W	12 MAR 90	2212	171	12	4970	7.0	5030
31	56	53 56.9 S	176 9.5 W	13 MAR 90	1304	270	24	5289	9.3	5025
31	57	53 54.2 S	176 3.3 W	13 MAR 90	1643	280	22	5310	9.2	1250
32	58	50 30.3 S	179 23.7 W	15 MAR 90	620	270	18	4448	10.2	1753
33	59	49 29.9 S	179 44.7 E	15 MAR 90	1420	337	18	2012	8.8	1987
34	60	49 43.5 S	179 59.9 W	16 MAR 90	724	267	16	3111	8.5	3088
35	61	49 50.9 S	179 52.7 W	16 MAR 90	1146	284	21	4030	9.8	4056
36	62	50 29.0 S	179 21.4 W	18 MAR 90	704	285	22	4458	10.0	4531
37	63	46 20.0 S	179 28.9 E	20 MAR 90	5	145	14	3317	15.0	3004
38	65	34 38.9 S	178 38.2 W	29 MAR 90	948	144	23	6556	21.2	3000
39	66	32 29.8 S	178 18.8 W	28 MAR 90	2141	124	20	4994	21.9	5061
40	67	32 30.6 S	178 31.4 W	29 MAR 90	237	94	7	-	22.1	4219
41	68	32 29.8 S	178 44.6 W	29 MAR 90	704	93	10	3080	22.1	999
41	69	32 29.3 S	178 46.0 W	29 MAR 90	1000	100	11	2828	22.1	2973
42	70	32 29.0 S	178 30.1 W	29 MAR 90	1257	123	8	4211	22.0	1498
43	71	32 29.6 S	178 17.8 W	29 MAR 90	1554	157	8	5004	22.2	1500
44	72	32 29.5 S	178 0.2 W	29 MAR 90	2008	114	8	5722	21.9	1499
44	73	32 30.6 S	177 59.9 W	30 MAR 90	29	155	6	5898	22.0	5975
45	74	32 29.0 S	175 29.0 W	30 MAR 90	1229	125	4	5574	22.2	1498
45	75	32 29.4 S	175 30.1 W	30 MAR 90	1642	-	-	5462	22.3	5526
46	76	32 28.8 S	171 28.7 W	31 MAR 90	1104	218	3	5182	21.6	5229
47	77	30 0.0 S	170 0.4 W	1 APR 90	233	134	12	5414	24.1	5502
48	78	24 58.6 S	170 1.3 W	2 APR 90	206	114	24	5689	25.4	399
48	79	24 58.9 S	170 1.0 W	2 APR 90	506	100	20	5784	25.4	2253
48	80	25 1.2 S	170 1.8 W	2 APR 90	857	122	21	5740	25.3	5804
49	81	22 29.8 S	170 0.4 W	2 APR 90	2222	135	25	5468	25.4	500
49	82	22 30.4 S	170 0.5 W	3 APR 90	42	126	20	5645	25.4	2999
50	83	20 0.4 S	170 0.4 W	3 APR 90	1333	125	22	5320	27.0	400
50	84	20 0.9 S	170 0.0 W	3 APR 90	1548	120	18	5351	27.2	2249
50	85	20 1.5 S	170 0.8 W	3 APR 90	1926	132	24	5502	27.2	5472
51	86	17 29.5 S	170 0.3 W	4 APR 90	841	117	25	4848	27.6	600
52	87	15 0.2 S	170 0.6 W	4 APR 90	2202	168	8	4686	28.5	399
52	88	14 58.7 S	170 2.9 W	5 APR 90	12	85	4	4771	28.5	2016
52	89	15 0.3 S	170 0.4 W	5 APR 90	438	105	14	4833	28.5	4873
53	90	11 26.4 S	169 36.5 W	5 APR 90	2237	329	10	5216	28.8	1250
54	91	10 6.1 S	169 30.2 W	6 APR 90	700	38	14	5249	28.9	5302
55	92	10 5.4 S	169 59.5 W	6 APR 90	1137	53	6	5161	28.8	1500
55	93	10 5.5 S	170 0.0 W	6 APR 90	1546	60	8	5163	28.7	5230
56	94	10 5.3 S	170 14.9 W	6 APR 90	2053	56	14	5929	28.7	5111
57	95	9 29.5 S	170 12.8 W	7 APR 90	238	75	16	4515	29.0	1499
58	96	5 0.1 S	170 0.8 W	7 APR 90	2307	64	20	5413	29.1	400
58	97	5 1.5 S	170 3.7 W	8 APR 90	139	93	19	5436	29.2	1998
58	98	5 0.8 S	170 1.2 W	8 APR 90	526	80	18	5280	29.2	5481
59	99	2 0.3 S	170 0.4 W	8 APR 90	2116	66	21	5214	28.4	998
60	100	0 59.7 S	170 1.2 W	9 APR 90	244	80	18	5435	28.3	1001
61	101	0 29.9 S	170 0.4 W	9 APR 90	605	90	16	5698	28.3	999
62	102	0 0.0 S	170 1.2 W	9 APR 90	931	78	15	5342	28.1	1999
62	103	0 0.7 N	170 0.3 W	9 APR 90	1149	69	10	5324	27.8	399
63	104	0 2.0 S	169 32.3 W	11 APR 90	916	72	13	5181	28.0	501
64	105	0 0.0 S	170 0.2 W	11 APR 90	1400	105	12	-	27.9	5582
65	106	0 30.0 N	170 0.3 W	11 APR 90	1837	104	14	5285	27.8	1002

STN #	Cast #	Latitude	Longitude	Date (GMT)	Time (°T)	W/D (kts)	W/S (m)	Depth (°C)	SST (db)	Cast
66	107	1 0. 1 N	170 0.3 W	11 APR 90	2145	117	16	5316	27.8	999
67	108	2 0.3 N	170 0.9 W	12 APR 90	308	96	14	5357	27.8	1001
68	109	5 0.1 N	170 0.6 W	12 APR 90	1655	90	22	7161	28.0	1005
69	110	5 13.7 N	169 52.4 W	12 APR 90	1923	60	20	5496	28.2	1249

TABLE 2. Weather condition code used to describe each set of CTD measurements.

Code	Weather Condition
0	Clear (no cloud)
I	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 3. 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 4. 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 5. Cloud type.

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

TABLE 6. 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