Preliminary Report
may 15, 1995

A. Cruise Narrative
A.1. Highlights
A.1.a WOCE designation: PR16
A.1.b EXPOCODE: 31DSEP390/2
A.1.c Chief Scientist: Ben Moore
National Oceanic and Atmospheric Administration
Pacific Marine Environmental Laboratory

A.1.d Ship Name: NOAA R/V DISCOVERER R-102.

A.1.e Ports of Call

A.1.f Cruise Dates: November 26 - December 6, 1990

A.2 Cruise Summary

A.2.a Geographic boundaries

Location: Along 110W from 5S to 16N and along the equator from 125W to 110W.

A.2.b Total number of stations Occupied

A.2.c Floats and drifters deployed

A.2.d Moorings deployed or recovered

A.3 List of Principal Investigators

Principal Investigator: Stanley P. Hayes
National Oceanic and Atmospheric Administration
Pacific Marine Environmental Laboratory

A.4 Scientific Programme and Methods

A meridional hydrographic section along 110W from 5S to 16N was made on leg 2 of the fall EPOCS (Equatorial Pacific Ocean Climate Studies) cruise in the Eastern Tropical Pacific. Also during this leg, a zonal hydrographic section was made along the equator from 125W to 110W. Operations took place aboard the NOAA research vessel DISCOVERER R-102.

Underway operations included continuous determination of sea surface temperature (SST) and meteorological parameters, Acoustic Doppler Current Profiler (ADCP) measurements, intermittent XBT casts and water samples for bucket temperatures, sea bird and marine mammal observations during daylight hours, and sea surface gravity and bathymetry. Although the primary objective of the cruise was the recovery and deployment of moored temperature buoys, there were also drifting buoy deployments, an inverted echo sounder (IES) recovery, two current meter mooring recovery and deployments, and 31 "small volume" CTD/rosette casts with on-board seawater analyses of salinity. (Analyses of nutrients, productivity, and nitrogen uptake were cancelled at the last minute.)

A Neil Brown MKIII CTD, serial number 1111, was used throughout leg2. There was no oxygen sensor added to this fish, and the fast response temperature sensor had been disabled. Because of time gained during mooring operations, extra CTD casts were added along 110W for a total of 27 casts along this section beginning at 5S, spaced every one degree of latitude with half-degree spacing equatorward of 2 degrees to 16N. Three casts were made along the equator every 5 degrees of longitude from 125W to 115W, and a single test cast was made at 7N, 140W. Out of a total of 31 casts, 6 were deep casts, 23 were taken to a depth of 1000 meters, and 2 were taken to a depth of 500 meters. Because the ship's pingers caused sever spiking in the pressure channel near the end of leg 1, no pinger was mounted during leg 2 and the packaged was kept 200 meters off the bottom during deep casts. (The bottom depth was provided by the ship's seabeam.)

The NOAA-sponsored EPOCS research program is an ongoing research effort that began in 1979 and is designed to further understanding of the role of the tropical ocean in modifying the world's climate. EPOCS contributes to the WOCE Hydrographic Program's efforts to describe and understand the global ocean circulation, its decadal changes, and its influence on climate.

A.5 Major Problems and Goals not achieved

A.6 Other Incidents of Note

A.7 List of Cruise Participants

Table 1: List of Cruise Participants

Name	Institution	Responsiblity
Ben Moore (Chief Scientist)	PMEL	temperature buoy recovery and deployment
Kevin Kinsey	PMEL	temperature buoy recovery and deployment
Julia Nichols	PMEL	temperature buoy recovery and deployment
Doug Fenton	PMEL	Current Meter recovery and deployment
Kristy McTaggart	PMEL	CTD acquisition and on-board processing
Larry Speak	PRBO	Bird and marine mammal observations
Steve Howell	PRBO	Bird and marine mammal observations
Nina Karnovsky	PRBO	Bird and marine mammal observations
Sophie Webb	PRBO	Bird and marine mammal observations

The principal investigator responsible for sample and CTD analysis and interpretation is Dr. Stanley P. Hayes of the National Oceanic and Atmospheric Administration Pacific Marine Environmental Laboratory.

B. Underway Measurements

B.1 Navigation and bathymetry
B.2 Acoustic Doppler Current Profiler (ADCP)
B.3 Thermosalinograph and underway dissolved oxygen, fluorometer
B.4 XBT and XCTD
B.5 Meteorological observations
B.6 Atmospheric chemistry

C. Hydrographic Measurements

VERTICAL SECTIONS

Note that stations north of 10N are not on the 110W line but along the cruise track from 10N, 110W to 16N, 113W. The bottle depth distribution for the small volume samples were approximately as follows with an extra bottle (a PMEL prototype) tripped at one of the deeper stops.

DEEP CASTS	1000m CASTS
bottom-200	1000
4000	900
3750	800
3500	700
3000	500

2000	250
1000	100
500	sfc
100	
sfc*	

ACQUISITION:

A Neil Brown Mark III CTD, serial number 1111, was used throughout leg two of the fall 1990 EPOCS cruise measuring pressure, temperature, and conductivity (no oxygen sensor). Because of time gained during mooring operations, extra CTD casts were added to the project at every degree of latitude along 110W from 5N to 16N for a total of 27 casts along this section beginning at 5S. Three additional casts were made along the equator every 5 degrees of longitude from 125W to 115W, and a single test/calibration cast was made at 7N, 140W. Out of a total of 31 casts, 6 were deep casts, 23 were taken to a depth of 1000 meters, and 2 were taken to a depth of 500 meters. Because the ship's pingers were shown in the real-time analog plots of temperature and conductivity verses pressure to interfere with the CTD data stream causing severe spiking in the pressure channel, there was no pinger mounted during the deep casts and the package was kept 200 meters off the bottom. (The bottom depth was provided by the ship's Seabeam.)

The CTD data stream was passed through a Neil Brown Mark III deck unit. An analog signal was displayed on an XYY' plotter to monitor the quality of the transmission in real-time; an audio signal was recorded onto tape as a backup; and digitized data was sent to a Zenith personal computer equipped with EG&G CTD acquisition software where it was calibrated and displayed in listing and graphical forms in real-time, as well as documented and stored in raw form onto the hard disk. All equipment performed well and there were no signs of misfires associated with the General Oceanics rosette sampling system. Shipboard processing was done using programs generated at PMEL on a shipboard microVAX system. Preliminary analysis of cast profiles showed the data to be of good quality.

Also, a prototype water sampling bottle produced at PMEL was tested on each cast. This bottle was tripped at the same depth as a ship's Niskin bottle and their salinities compared. These numbers showed the prototype to be of equal quality.

SALINITIES:

Salinity was the only analysis performed on the water samples collected. Guildline Autosal 56.118, last calibrated at NRCC 1/9/90, was used to run salinities for all casts by CST Murray. IAPSO standard seawater used was lot #P110. Operating temperature was 24C. Drift corrections were applied by survey before being transcribed to the CTD cast logs.

A second sample from one of the deeper bottles from each cast was run on a subsequent day to check the Autosal and it's drift. These numbers showed the salinometer to have worked well throughout the cruise. Also, reversing thermometer temperature and thermometric depths were reasonable.

CONDUCTIVITY CALIBRATIONS:

CALIB.DAT precruise calibrations for CTD 1111:

1111   6 380

-19.3940	.9960320	0.190816E-5	-0.2018487E-09	P DN	S/N 1111	JUL 90
-21.3632	.9937291	0.302192E-5	-0.3140824E-09	P UP	S/N 1111	JUL 90
0.0498	1.0007090	0.000000E-6	0.0000000E-10	T 68	S/N 1111	JUL 90
0.0010	0.9999194	0.000000E-6	0.0000000E-10	C	S/N 1111	JUL 90

LINCALW was run on the whole and a cast break was seen between casts 10 and 11. Linear fit coefficients used in EPCTDW and CALMSTRW for casts 1-10 were

A(0) = -1.6119338E-03
A(1) = 0.9999725
standard deviation = 1.6040863E-03

Coefficients for casts 11-31 were

A(0) = 1.4693985E-03
A(1) = 0.9998032
standard deviation = 1.6934872E-03

DEEPCTD plots with the above calibrations applied showed poor correlation between deep CTD traces and deep bottle salinities. A linear fit was applied to (a) only deep EP390 CTD and bottle conductivity pairs for group 1 and 2, (b) deep EP390 CTD and mean historical bottle conductivity pairs for group 1 and 2, and (c) deep EP390 CTD and mean historical bottle conductivity for each deep cast. As a whole, EP390 CTD and bottle data looked a bit fresher than historical data in the deep water. Calibrating the CTD to just the deep bottles, or to historical bottle data didn't improve the discrency consistently for all deep casts. So the data was submitted to WHPO with the original fit coefficients listed above. Further investigation may take place at a later date.

CONDUCTIVITY CALIBRATION PROGRAMS & PPLUS COMMAND FILES:

CALDSKW - creates .CAL uncalibrated data file on SCS system
CALMSTRW - inputs .CAL uncalibrated data file
- outputs .CLB calibrated data file (from .COM), and .SEA calibrated WOCE data file (edit quality bytes)
LINCALW - inputs .CAL uncalibrated data file (may be broken into groups), applies a linear fit to the data and throws out any points greater than 2.8 times the standard deviation, iterates through the program until no points are thrown out outputs .COEF file containing linear fit coefficients and .LOG file of fit iterations
CALMCONW.PPC - reads .CLB calibrated bottle data file and makes five separate scatter plots: P, T, C, S, and cast number vs. delta-C (CTD-bottle). These are examined for cast breaks and drifts in the CTD.
CALMDEEPW.PPC - reads .CLB calibrated bottle data file and makes two separate scatter plots: CTD salinity and bottle salinity vs. potential temperature from theta=0.6 to 2.2 C.
DEEPCTD.PPC - reads .CTD EPIC pointer file and .BOT EPIC pointer file of deep casts only and overplots the bottle salinity data and CTD salintiy trace from theta=.8 to 2.4 C for each deep cast.

PROCESSING:

Processing with precruise calibrations were done at sea on a microVAX II computer system. During the last week of the cruise, parity errors began to increase and processing was halted. Data files were restored in the lab from TK50 tape.

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DPDNZ - inputs EG&G .EDT raw data file
      - outputs .DPZ binary file including computed fall rates and
           .RECZ ASCII file to choose downcast record range from
DLAGZ - inputs .DPZ binary file, applies precruise calibrations from
        CALIB.DAT, edits data for window outliers (according to
        WINDOW.DAT) and first differencing outliers, fills gaps by
        linear interpolation, lags conductivity, edits data exceeding
        fall rate criteria (according to .INP created by DLAGAVZ.COM;
        default minimum fall rate acceptable is .8 db/60 scans (25
        meters per minute) and pressure interval of 1.5 db; doesn't
        fill these gaps), computes 1-meter averages, and applies cell
        dependence to final conductivity values
        - outputs CTDERR.DAT file of outlier flags, interpolated values,
        and fall rate criteria failures, and an ASCII .CTD data file
        including computed salinity
EPCTDW - inputs .CTD calibrated P, T, OXC, OXT, and raw conductivity;
       applies any additional P and T cals (in EPCTDW_SHIP.COM),
       corrects raw C for cell factor, and applies C cals from

EPCTDW_SHIP.COM; computes salinity; deals with oxygen if
         there was a sensor; eliminates 1-point spikes according to
         the gradients hardwired into the source code; omits any
         values for manual despiking; fills by linear interpolation
         for a value to exist every whole meter; recomputes C from
         S; and calculates other EPIC variables.
         - outputs final .CTD data file in EPIC format, and a .LOG
         file listing editted and filled data points

EPICBOMSTRW - inputs .CLB calibrated bottle data file and
            .CTD EPIC data files (for header information)
            - outputs .BOT bottle data files in EPIC format
TSPLTEP.PPC - reads .CTD EPIC pointer file and .BOT EPIC pointer file
             and overplots full water column bottle salinity and CTD
             trace as well as sigma-t lines (from SIGMAT.DAT). Use
           TSPLTB.PPC to include oxygen data.
TEXTNOX - inputs .CTD EPIC pointer file and constructs PPLUS subcommand
          files
        - outputs TXT*.PPC files containing %label commands for table
          listings for each cast
3PLTNOX.PPC - reads TXT*.PPC subcommand files and .CTD EPIC pointer
                file and overplots vertical profiles of temperature,
            salinity, and sigma-t vs. pressure to 1000 db on left-
            hand side of page; and lists data in table form on
            right-hand side of page.  Use 4PLT1DB.PPC to include
            oxygen data.
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DLAGZ was run with default minimum fall rate and pressure interval criteria. EPCTDW was run without gradient despiking except in the case of cast 4 where the original raw data was lost due to an operator error and the 1000 meter cast had to be replayed from audio tape on the Akai reel-to-reel tape recorder. The tapes had been reused repeatedly from cruise to cruise and some oxidation had occurred making the replay very noisy. Also, unfortunately, the recording levels had dropped during cast 4 and was not noticed by the operator. Only the first 500 meters of the cast was recoverable.

TSPLTEP and DEEPCTD plots were looked at for any spiking that needed to be removed manually (i.e. using the NOMIT subroutine in EPCTDW). Spikes were removed from casts nearly every cast except for casts 1, 10, 13, 15, 17, 19, 30, and 31; and data was replaced by linear interpolation.

Final CTD and bottle files were moved to DISK$HAYES and included in the RIM data management tables on November 7, 1991.

WOCE SUBMISSION:

Because EP390 collected data along 110W, WOCE repeat line PR16, a cruise plan was submitted prior to the cruise and a cruise report was submitted afterwards on January 30, 1991. In July 1991, a revised WHP manual of hydrographic data reporting requirements was distributed. CTD data files and bottle data .SEA file were finalized for submission according to these new specifications on November 11, 1991. A new .SUM file was not submitted.

In the .SEA file, BTLNBR, CTDSAL, and SALNTY were assigned quality flags as follows.

BTLNBR: Not all of the bottles are accounted for here. If a sample was not drawn from a bottle, it was ommitted from this file instead of given a quality byte value of 9. The definitions for byte values used were 2 'no problems noted', 3 'leaking' (as noted on the sampling sheets and CTD cast logs), and 4 'did not trip correctly' (given if the nominal depth at which the bottle was supposed to have been tripped differed from the actual depth).

CTDSAL: All CTD salinity values in this file were considered acceptable.

SALNTY: An in-house criteria was set up to distinguish between acceptable, questionable, and bad quality byte values for bottle salinity measurements. For the highly variable upper water column (0-1000 db), if the difference between the CTD salinity and bottle salinity was greater than .04 psu, SALNTY was assigned a byte value of 4 'bad'; if the difference was between .01 and .04 psu, SALNTY was assigned a byte value of 3 'questionable'; and if the difference was less than .01, it was considered an acceptable bottle salinity. For the more stable deep water (potential temperature less than 2.4 C), SALNTY was considered bad if the difference in salinities was greater than .008 psu, questionable if delta-S was between .003 and .008 psu, and acceptable if less than .003 psu. For mid-column water, the assignment of byte values was subjective.

D. Acknowledgments

E. References

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

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

F. WHPO Summary

Several data files are associated with this report. They are the ep390.sum, ep390.hyd, ep390.csl and *.wct files. The ep390.sum file contains a summary of the location, time, type of parameters sampled, and other pertient information regarding each hydrographic station. The ep390.hyd file contains the bottle data. The *.wct files are the ctd data for each station. The *.wct files are zipped into one file called ep390.wct.zip. The ep390.csl file is a listing of ctd and calculated values at standard levels.

The following is a description of how the standard levels and calculated values were derived for the ep390.csl file:

Salinity, Temperature and Pressure: These three values were smoothed from the individual CTD files over the N uniformly increasing pressure levels using the following binomial filter-

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

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

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

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

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

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

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

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

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

G. Data Quality Evaulations