Prelimnary Data report
may 15, 1995

A. Cruise Narrative

A.1 Highlights

A.1.a WOCE designation: PR6
A.1.b Expedition designation: 18999105/1
A.1.c Chief Scientist: Ron Bellegay
A.1.d Ship: Endeavor
A.1.e Ports of Call: Esquimalt, B.C., Canada
A.1.f Cruise Dates: Oct. 17 to Nov. 1, 1991

A.2 Cruise Summary

A.2.a Geographic boundaries
A.2.b Total number of stations

Table 1: Stations by type

Sample type	No. stations	Max. depth (m)
CTD casts	36	1500
Bottle casts	7	4200
Bucket samples	36	surface
Sed. Trap Moorings	2	4200

A.2.c Floats and drifters deployed

No floats or drifters deployed

A.2.d Moorings deployed or recovered

At station AG, sediment trap moorings were recovered and redeployed. At St. P, a trap mooring was lost and a new mooring deployed. Near MP20, two current meter moorings were recovered.

A.3 List of Principal Investigators for All Measurements

A.4 Scientific Programme and Methods

This was the first WOCE designated cruise along Line RP5, although this section has been covered for over 30 years. After delaying for the time necessary to repair the desalinization system on the ship, the cruise set sail from Esquimalt harbor on Thursday, October 17, 1991 on board the Canadian Naval Auxiliary Vessel ENDEAVOR. Participating organizations were the Institute of Ocean Sciences(Pat Bay) and the University of British Columbia. In order to meet the objective of recovering two sediment trap moorings before any infelicity could occur, the ship sailed directly to Station P, 50 N, 145 W, without taking any measurements. Mooring recovery and redeployment were completed at Station P. The ship then immediately sailed north to Station AG, 55 N, 145 W to recover and redeploy the second sediment trap mooring. Bottle casts were done at Station AG together with a CTD comparison. CTD casts were completed on 46 stations along the return track to Station P and along Line P. Bottle reversing thermometer casts were done at Stations P (MP26), MP20, MP18, MP16, MP06, and MP04. Near station MP20, two current meter moorings were recovered for the Quiet Eddy Program. The ship docked in Esquimalt harbor on the morning of Nov 1.

The cruise began in moderate seas following a fall storm and enjoyed good weather and low sea state for the balance of the time.

Most post-cruise effort has gone into inspection of T/S data quality. Routines have been revised for correcting CTD profiles, eliminating most of the error from instrument drift. Comparisons of bottle cast and CTD data show a slight but significant temperature offset between the two sampling procedures that demands closer inspection. Inspection of oxygen data show that we must use larger Niskin samplers to increase the flushing time of sample bottles, as an initial step in improving this data. We will also be checking flask calibrations to see if these are changing with time.

A.5 Major Problems and Goals not Achieved

The cruise was delayed to allow temporary repairs to the freshwater generating system which had been damaged by corrosion and continued to threaten to limit the endurance of the cruise. Under the limitations imposed by this problem, the cruise did well to achieve the major objectives of the program.

On Oct. 21, a sediment trap mooring was released and partially recovered when a kevlar splice parted and the instruments and acoustic release sank to the bottom. A further recovery attempt using a ROV is under consideration.

Nutrient samples were frozen because analytical instrumentation did not return to Victoria soon enough to be put aboard the ship. Consequently, data quality will be reduced.

The calibration thermistor case attached to the CTD started leaking during the first cast sending one thermistor off scale and affecting the second thermistor at about 1000 m. As a result there was only a partial check on in-situ temperatures which indicated a temperature .002 higher than the final calibrated temperature for that cast.

The thermistors were removed and the connector was insulated from the seawater. Subsequent inspection showed a micro-hole in a solder joint. Since the case was being flooded at the time this information was not deemed reliable enough to be used except as a rough indication of agreement between the CTD and the thermistors. In future, this sensor unit, which had never been under pressure before, will be pressure tested before a cruise.

Goals achieved
Line PR6 was completed.
Not achieved
Line PR5 was not occupied .

A.6 Other Incidents of Note

A.7 List of Cruise Participants

Table 2: List of Cruise Participants

Name	Responsibility	Affiliation*
R.D. Bellegay	Moorings/sampling	IOS
R.G. Perkin	CTD	IOS
B.G. Minkley	T/S/O	IOS
L.A.F. Spearing	Moorings/CTD casts	IOS
T.J. Soutar	Electronics	IOS
J. Wu	C & N isotopes	DOUBC
R. Mugo	Trace metals	DOUBC
H. McLean	Trace metals	DOUBC
M. Dempsey	Moorings	Oceanetics

*See Table 3 for list of Institutions

Table 3: List of Institutions

Abbreviations	Address
IOS	Institute of Ocean Sciences 9860 West Saanich Road, Sidney, B.C. Canada, V8L 4B2
DOUBC	Department of Oceanography University of B.C., Vancouver, B.C.
Oceanetics	Oceanetics Measurements Inc. Sidney, B.C.

B. Underway Measurements

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

C. Hydrographic Measurements

Water sampling

Niskin samplers (1.7 L) were used for all hydro casts. Water samples were collected in the order O2, TCO2 (not on every cast), nutrients and salinity. Oxygen samples were immediately pickled with standard reagents (Carpenter, 1966) and the temperature of the sample recorded using a Guildline Model 2175A digital thermometer. TCO2 samples were pickled with HgCl2, and cool stored for future analysis. Nutrients were only sampled to 500 m and were frozen for future analysis, since our Autoanalyzer had not returned from a joint program with USSR. Salinity samples were drawn into borosilicate bottles for analysis onboard ship. Rinses for gas samples are likely insufficient, due to the limited amount of water available in 1.7 L Niskins. Future cruises will employ 10 L Niskins.

Hydro cast temperature and depth

Reversing thermometers were used to record temperature and provide correct depths on all hydro casts. Protected thermometers were used in pairs, and an average value recorded, unless there was a discrepancy greater than 0.04o C. Then thermometers were cross checked with those that were known to be consistent. This ongoing process removed thermometers that were not properly working or were in need of recalibration. Unprotected thermometers were used to estimate the bottle depths.

Oxygen

The micro-Winkler procedure of Carpenter (1966) with a starch end-point titration was used. After the first 3 hydro casts, the sulfuric acid concentration was increased from 280 mL/L acid, to 420 mL/L to improve the dissolution of the precipitate. Duplicate samples drawn from the same bottle did not show good agreement.

Depth Range(m)	Conc. Range (uM/kg)	Sp of pairs	(k = no. of pairs)
500 to 1500	10 to 35	0.53	(k=6)
2000 to 4000	55 to 130	1.00	(k=12)

The major source of error is likely in sample drawing. Also flask calibrations need to be verified.

Standards were prepared as outlined in WOCE Report 73/91.

Nutrients
Since frozen samples provide poor results at high concentrations (especially for silicate, see Macdonald and McLaughlin, 198), samples were only collected to 500m and frozen. Analyses will be done by standard Technicon procedures, for NO3 & NO2, PO4 and dissolved Si.

Salinity

A Guildline Model 2400 Autosal (SN 40.364) was used onboard ship to analyze all samples except for those from the last hydro cast. Because the instrument became unstable near the end of the trip, samples from station MP04 were analyzed at IOS using a Guildline Model 2410 Salinometer (SN 58879). IAPSO Standard Seawater batch P115 was used for daily calibrations.

Duplicate samples from 2000 to 3800 m, run in sequence, had a standard deviation Sp = 0.001 (k=9), confirming that sampling and analyses are precise, and that Niskin bottles were not leaking (since a salinity gradient is evident in leaking bottles).

CTD

CTD casts were done using one of two Guildline instruments with intercomparisons at stations with bottle casts. CTD-5 (an Arctic version of Guildline Model 8705) was equipped with a 3-bottle Rosette triggered electronically from the surface without interrupting the cast; It also had a pair of narrow range thermistors to verify the main temperature sensor. Calibration samples from the rosette were transferred into borosilicate bottles provided by the Standard Seawater Service and analyzed for salinity using an Autosal salinometer either aboard the ship or shortly after landing at Esquimalt. A summary of the bottle calibrations is given in Table 4,5,6. Both CTD's were recalibrated in a lab shortly after returning to IOS.

Calibrations and Standards
The digital CTD(Model 8706 and 8715) probes used during this cruise are made by Guildline Instruments of Smiths Falls, Ontario, Canada. Their resolution and accuracy are given in the following table.

Table 4. Oxygen: standard deviation of pairs

Sp = {(sum d2)/2k}1/2, d is difference between pairs, and k is the number of pairs.

Variable	Accuracy	Resolution	Stability
Conductivity	.005 psu	.001 psu	.002 psu/6 months
Temperature	.005	.001	.002/30 days
Pressure	.15% FS	.01% FS	FS = 1500 dbar

Pre-cruise calibrations for CTD-5 were as follows

Table 5 Guildline CTD specifications.

Sensor	#Slope	Offset	Date	Standards
Conductivity	1.00032	-.00021	June 19,1991	Batch No.P106

Temperature	.999762	.0055	Oct. 15, 1991	NRC of Canada*
Pressure(@15oC) F.S.=1500 dbars	1.001566	.55	Oct. 15,1991	Ashcroft 1305B deadweight Tester: .1% of F.S.
Pressure(@8oC)	1.003943	-.93	Oct. 15,1991	Ashcroft 1305B deadweight Tester: .1% of F.S.
Thermistor #810	1.0000	0.000	Oct. 15, 1991	NRC of Canada*
Thermistor #811	1.0000	0.000	Oct. 15, 1991	NRC of Canada*

* Temperature calibrations traceable to the Temperature Standards Lab. of the National Research Council of Canada: accuracy = .002 C and are maintained with triple point cells. Corrected variable = Measured variable*Slope+Offset

Post-cruise calibrations for CTD-5 were as follows:

Table 6 Pre-cruise calibrations.

Sensor	Slope	Offset	Date	Standards
Conductivity	1.00009	-.00021	Nov. 12,1991	Batch N0. P106,
Temperature	.999762	.0072	Nov. 12, 1991	NRC of Canada*

The temperature correction was averaged between the pre and post cast values. The difference of .00170 in the calibrations is at the estimated limit of accuracy of the calibration bath system.

The pressure sensor was not recalibrated.

The conductivity sensor was calibrated using the salinities from the rosette samples. Table 7 gives a summary of the computed cell constants normalized to the pre-cruise value. These are plotted in Fig. 3 and show a systematic change over the first 4 casts amounting to .014 in salinity equivalent. The cell constant remained constant for the remaining casts and rebounded marginally for the post-cruise calibration. Additional checks with the hydro-casts and comparisons with the other CTD remain to be done.

Near the end of the cruise the Autosal showed signs of increasing drift at the .001 level of salinity equivalent. Post-cruise checks could find no problem with the electronics or mechanical parts however, a thorough cleaning of the cell returned the Autosal to its previous stability.

Fig. 2 shows the CTD/rosette with a bumper attached to the bottom of the pressure case for added weight and protection. The performance of this system was tested by triggering three bottles through strong salinity/temperature gradients in the presence of moderate wave action. The bottles could be made to agree with the CTD only after applying a 5.5 m long running mean to the CTD data. This suggests that the bumper was causing a significant wake which interfered with the flushing of the bottles. Because of the low gradients in the deeper water, this effect was significant at only one of the calibration bottles and the filter was applied bringing this salinity into line. Modifications are under consideration to eliminate this wake effect.

Some samples were lost because of the dislodging of O-rings when the rosette bottles were triggered. O-rings with greater stretch are being installed for future cruises.

Carpenter, J.H. 1965. The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnol. Oceanogr., 10: 141-143.

Macdonald, R.W. and McLaughlin, F.A. 1982. The effect of storage by freezing on dissolved inorganic phosphate, nitrate and reactive silicate for samples from coastal and estuarine waters. Water Res. 1: 95-104.

Table 7. IOS (Pat Bay) Cruise 91-15: Summary of CTD calibration bottle data

1503	270.00	O-ring rolled							
1503	505.60	3.606	0.739864	34.1828	0.739790	0.999901	0.999909	34.1832	-0.0003
1503	706.50	3.235	0.736276	34.2821	0.736211	0.999912	0.999909	34.2819	0.0001
1503	706.50	3.235	0.736276	34.2821	0.736211	0.999912	0.999909	34.2819	0.0001
1504	253.40	3.762	0.736357	33.9677	0.736157	0.999728	0.999827	33.9678	0.0001
1504	253.40	3.762	0.736357	33.9675	0.736153	0.999723	0.999827	33.9678	-0.0003
1504	1007.20	2.741	0.731674	34.4039	0.731538	0.999815	0.999827	34.4044	-0.0005
1504	1007.20	2.741	0.731674	34.4043	0.731546	0.999825	0.999827	34.4044	-0.0001
1504	1494.30	2.220	0.728098	34.5205	0.727980	0.999838	0.999827	34.5201	0.0004
1504	1494.30	2.220	0.728098	34.5203	0.727976	0.999833	0.999827	34.5201	0.0002
1516	649.80	3.673	0.743084	34.1973	0.742908	0.999763	0.999778	34.1979	-0.0006
1516	649.80	3.673	0.743084	34.1971	0.742904	0.999758	0.999778	34.1979	-0.0008
1516	1000.00	O-ring rolled							
1516	1519.00	2.342	0.730424	34.4976	0.730258	0.999773	0.999778	34.4977	-0.0002
1516	1519.00	2.342	0.730424	34.4993	0.730292	0.999819	0.999778	34.4977	0.0016
1526	597.60	3.768	0.743252	34.1313	0.743028	0.999698	0.999648	34.1294	0.0019
1526	597.60	3.768	0.743252	34.1309	0.743020	0.999688	0.999648	34.1294	0.0015
1526	997.60	3.001	0.735975	34.3539	0.735768	0.999719	0.999648	34.3512	0.0027
1526	997.60	3.001	0.735975	34.3535	0.735761	0.999709	0.999648	34.3512	0.0023
1526	1500.00	O-ring rolled							
1531	500.00	O-ring rolled							
1531	1000.64	3.038	0.736826	34.3543	0.736553	0.99963	0.999648	34.3550	-0.0007
1531	1000.64	3.038	0.736826	34.3539	0.736545	0.999619	0.999648	34.3550	-0.0011
1531	1500.48	2.358	0.730580	34.4911	0.730275	0.999583	0.999648	34.4936	-0.0025
1531	1500.48	2.358	0.730580	34.4936	0.730324	0.99965	0.999648	34.4936	0.0001
1538	1000.98	3.257	0.741252	34.3511	0.740956	0.9996	0.999648	34.3530	-0.0018
1538	1000.98	3.257	0.741252	34.3513	0.740960	0.999605	0.999648	34.3530	-0.0016
1538	1492.65	2.404	0.731586	34.4987	0.731278	0.999579	0.999648	34.5014	-0.0027

1538 1492.65 2.404 0.731586 34.4999 0.731301 0.99961 0.999648 34.5014   -
0.0015

Nov. 1, 1991
1538 499.51 4.606 0.758158 34.0653 0.757869 0.99962 0.999648 34.0664   -
0.0011
1544 498.49 5.010 0.766610 34.0753 0.766367 0.999683 0.999648 34.0739
0.0013
1544 998.78 3.503 0.746260 34.3556 0.746044 0.999711 0.999648 34.3533
0.0024
1544 998.78 3.503 0.746260 34.3580 0.746090 0.999772 0.999648 34.3533
0.0047
1544 1497.48 2.444 0.732624 34.5097 0.732346 0.999619 0.999648 34.5108   -
0.0011
1544 1497.48 2.444 0.732624 34.5115 0.732379 0.999665 0.999648 34.5108
0.0007
1546 533.67 4.849 0.764445 34.1138 0.764189 0.999666 0.999648 34.1131
0.0007
1546 533.67 4.849 0.764445 34.1117 0.764146 0.999609 0.999648 34.1131   -
0.0015
1546 798.32 4.042 0.754001 34.2885 0.753752 0.99967 0.999648 34.2876
0.0008
1546 798.32 4.042 0.754001 34.2886 0.753756 0.999675 0.999648 34.2876
0.0010
1546 997.61 3.524 0.747389 34.3872 0.747088 0.999598 0.999648 34.3891   -
0.0019
1546 997.61 3.524 0.747389 34.3866 0.747077 0.999582 0.999648 34.3891   -
0.0025
RMS   0.0016

BOTTLES TRIGGERED IN UPPER 50 M IN A STRONG GRADIENT(not used for calibration)

1548   39.71 9.294 0.815481 32.4259 0.814533 0.998838 0.999648 32.2750 0.1509
1548   39.71 9.294 0.815481 32.4244 0.814498 0.998795 0.999648 32.2750 0.1494
1548   46.29 8.429 0.798776 32.4758 0.798004 0.999035 0.999648 32.4782 -0.0024
1548   46.29 8.429 0.798776 32.4778 0.798047 0.999088 0.999648 32.4782 -0.0004
1548   50.29 8.130 0.793064 32.5046 0.792587 0.999399 0.999648 32.5050 -0.0004
1548   50.29 8.130 0.793064 32.5055 0.792609 0.999426 0.999648 32.5050 0.0005

Comments: Cast No 1504,1548 were filtered, Cast No. 1526 triggers missing
for cast

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 en9105.sum, en9105.hyd, en9105.csl and *.wct files. The en9105.sum file contains a summary of the location, time, type of parameters sampled, and other pertient information regarding each hydrographic station. The en9105.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 en9105.wct.zip. The en9105.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 en9105.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