CTD Calibration Report for R/V Oceanus 371-1
prepared by Deborah West-Mack
Woods Hole Oceanographic Institution

I.1 Cruise Summary

Ship: R/V Oceanus 371-1
Project Name: Site W
Dates: October 4, 2001 – October 6, 2001
Ports: Woods Hole – Woods Hole

5 CTD stations
Rosette salts and dissolved oxygen (but all oxygen values were deemed unusable for this cruise)

I.2 Digital data files included as part of this distribution:

2001oct_ctd_proc.doc This document in MS-Word format.
2001oct_ctd_proc.pdf This document in pdf format.

2001oct.whp_btl This file follows WOCE specifications for bottle data. Salt and oxygen quality words have been entered.

2001oct.sum The SUM file contains the CTD station information using WOCE format.

2001oct_*.ctd One 2db averaged file per station following the WOCE format specification for CTD profiles. All CTD salt and oxygen has been calibrated to the bottle salt and oxygen. CTD temperature based on pre-cruise calibrations. CTD pressure are based on pre-cruise calibrations.

II. Finalized Description of Measurements

II.1 CTD Measurements

5 casts were made using a SeaBird 911plus CTD measuring pressure, temperature, conductivity, and oxygen current. Station locations are shown in Figure 1. For each cast, water samples were collected at discrete intervals and analyzed for salinity and dissolved oxygen – primarily for the purpose of calibrating the CTD sensors. All casts were full water column.

II.1.a Difficulties Encountered

All oxygen data (water samples and CTD) were deemed of poor quality and therefore unusable in the post-processing assessment phase.

II.1.b Equipment Configuration

A SeaBird 911plus CTD was used throughout the cruise. It was provided with a pressure transducer S/N 0462, two temperature sensors S/N 4035 and S/N 2774, two conductivity sensors S/N 2645 and S/N 2362, and one SBE43 oxygen sensor S/N 0072. Calibrations were performed by the manufacturer before the cruise. All sensors appeared to work well throughout the entire cruise. There were no equipment or sensor changes.

The pylon was controlled through a dedicated personal computer using SeaBird's software SEASOFT.

A rosette frame was provided for the cruise. The frame held 24 4-liter bottles produced at WHOI.

II.1.c Acquisition and Processing Methods

Data from the CTD were acquired at 24 hz. The CTD data was acquired by a SBE Model 11 plus CTD Deck Unit providing demodulated data to a personal computer running SeaBird software. SEASAVE version 4.249 CTD acquisition software (SeaBird, 2001) provided graphical data to the screen. Bottom approach was controlled by following the pinger direct and bottom return signals on the ship-provided PDR trace.

After each station, the CTD data was run through SeaBird data conversion software listed in Table 2. The data was first-differenced, lag corrected, pressure sorted and centered into 2 decibar bins for final data quality control and analysis, including fitting to water sample salinity and oxygen results. WHOI post-processing software after Millard and Yang, 1993.

Table 2. SeaBird Processing Software

SeaBird Module	Description (SeaBird, 2001)
DATCNV	Convert the raw data to pressure, temperature, conductivity, and dissolved oxygen current.
ROSSUM	Reads in a .ROS file created by DATCNV and writes out a summary of the bottle data to a file with a .BTL extension.
ALIGNCTD	Advance conductivity approximately 0.073 seconds relative to pressure.
WILDEDIT	Checks for and marks and 'wild' data points: first pass 2.0 standard deviations; second pass 20 standard deviations.
CELLTM	Conductivity cell thermal mass correction alpha = 0.03 and 1/beta = 7.0.
FILTER	Low pass filter conductivity with a time constant of approximately 0.03 seconds. Filter pressure with a time constant of 0.15 seconds to increase pressure resolution for LOOPEDIT.
LOOPEDIT	Mark scans where the CTD is moving less than the minimum velocity (0.1 m/s) or traveling backwards due to ship roll.
DERIVE oxy.cfg	Compute oxygen from oxygen current, temperature, and pressure.
BINAVG	Average data into the 2 dbar pressure bins.
DERIVE sal.cfg	Compute salinity.
STRIP	Extract columns of data from .CNV files.
TRANS	Change .CNV file format from ASCII to binary.
SPLIT	Split .CNV file into upcast and downcast files.

II.1.d Summary of manufacture CTD Calibrations

All sensors were calibrated by the manufacturer. A listing of sensors and calibration dates are presented in Table 3.

Table 3. Sensor Calibration Dates.

Sensor Number	Sensor Type	Manufacturer	Calibration Dates
0462	pressure	Paroscientific/Sea-Bird	Nov. 30, 2000
4035	temperature	Sea-Bird	Jun. 28, 2001
2774	temperature	Sea-Bird	Mar. 6, 2001
2645	conductivity	Sea-Bird	Aug. 10, 2001
2362	conductivity	Sea-Bird	Mar. 3, 2001
0072	SBE43 dissolved oxygen	Sea-Bird	Jul. 6, 2001

II.1.e Summary of CTD Calibrations

PRESSURE CALIBRATION
The pressure bias of the CTD at the sea surface was monitored at the beginning of each station to make sure there was no significant drift in the calibration.

CONDUCTIVITY CALIBRATION
Basic fitting procedure

The CTD conductivity sensor data was fit to the water sample conductivity. For each sensor all stations were grouped together to find the best fit due to the limited number of stations. The group was fit for slope and bias, along with a linear pressure term (modified beta) using a least-squares minimization of CTD and bottle conductivity differences. The function minimized was:

$$BC - m * CC - b - \beta * CP$$

where BC - bottle conductivity [mS/cm]
CC - pre-cruise calibrated CTD conductivity [mS/cm]
CP - CTD pressure [dbar]
m - conductivity slope
b - conductivity bias [mS/cm]
β - linear pressure term [mS/cm/dbar]

The slope term is a polynomial function of the station number. The polynomial function which provided the lowest standard deviation for a group of samples along with the corresponding bias were determined for each station grouping. A series of fits were made, each fit removing outliers having a residual greater than three standard deviations. This procedure was repeated with the remaining bottle values until no more outliers occurred. The best fit coefficients for each station grouping are presented in Table 4a for sensor 2645 and Table 4b for sensor 2362.

The final conductivity, FC [mS/cm] is:

$$FC = m * CC + b + \beta * CP$$

Data Quality

Calibrated, the overall standard deviation of the CTD and the water sample differences for S/N2645 was 0.0037 and S/N2362 was 0.0043 psu.

Table 4a. Best Fit Conductivity Coefficients for Conductivity S/N 2645.

Stations	Type	#pts used	total #pts	std dev (mS/cm)	bias	slope min	slope max	beta
1-5	calcos4	84	94	0.0037	-0.00339	1.00014	1.00036	--

Table 4b. Best Fit Conductivity Coefficients for Conductivity S/N 2362.

Stations	Type	#pts used	total #pts	std dev (mS/cm)	bias	slope min	slope max	beta
1-5	calcop2	85	94	0.0043	0.00206	0.99994	1.00010	-3.1808e-7

OXYGEN CALIBRATION

Basic fitting procedure

The CTD oxygen sensor variables were fit to water sample oxygen data to determine the six parameters of the oxygen algorithm (Millard and Yang, 1993). The oxygen calibration was performed after temperature and conductivity calibrations due to its weak dependence on the CTD pressure, temperature, and conductivity (salinity). A FORTRAN program oxfitmrx.exe developed by Millard and Yang (1993) was used for determining the oxygen calibration coefficients. The program uses the following algorithm developed by Owens and Millard (1985) for converting oxygen sensor current and temperature measurements with the time rate of change of oxygen current measurements to oxygen concentration. The weight was set to 0 as the new SBE43 oxygen sensor temperature is not measured and is assumed to be the same as the in situ temperature. The lag was set to 0 as per manufacturer recommendation.

$$Oxm = \left[slope * \left(Oc + lag * \tfrac{dOc}{dt}\right) + bias\right] * Oxsat * \exp\left(tcor * \left[T + wt * \left(T_o - T\right)\right] + pcor * P\right)$$

where
- Oxm - oxygen concentration [ml/l]
- Oc - oxygen current [uA/s]
- Oxsat - oxygen saturation []
- P - CTD pressure [dbar]
- T - CTD temperature [°C]
- T_o - oxygen sensor temperature [°C]
- S - salinity [PSS-78, psu]
- slope - oxygen current slope []
- lag - oxygen sensor lag [s]
- bias - oxygen current bias []
- tcor - membrane temperature correction []
- wt - weight, membrane temperature sensitivity adjustment []
- pcor - correction for hydrostatic pressure effects

The stations were calibrated as one group as indicated in the oxygen coefficients table (see Table 5). The oxfitmrx program was run with wt=0.0 and lag=0.0 held constant and allowing for the calibration or bias, slope, pcor, and tcor.

Data Quality

Calibrated, the overall standard deviation of the CTD and water samples differences was 0.106 ml/l. Examination of the water sample oxygen values relative to historical values, shows them to be unrealistic and unusable. Repeated attempts to fit the CTD oxygen profiles did not produce satisfactory results. All oxygen data for this cruise are considered poor quality.

Table 5. Best Fit Coefficients for Oxygen Sensor 13053.

Stations	bias	slope	pcor	tcor	wt	lag	std err (ml/L)
1-5	-0.177	0.3376	0.0001621	0.0066	0	0	0.106

II.1.f Other notable data acquisition/processing issues

At-sea logs were kept for CTD data acquisition. They include anything of note regarding each station: equipment changes, instrument behavior, equipment or operational problems.

II.2 Salinity and Dissolved Oxygen Measurements

contributed by George Tupper and Marshall Swartz

II.2.a Summary

Water samples were collected from virtually every bottle during this cruise for the determination of salinity and dissolved oxygen. The primary purpose of these measurements were to accurately calibrate the sensors on the CTD.

II.2.b Salinity

Water was collected in 200 ml glass bottles. The bottles were rinsed twice, and then filled to the neck. Samples were transferred to the shore based laboratory for analysis. Samples were analyzed within 30 days of collection. After the samples reached the lab temperature of 22°C, they were analyzed for salinity using a Guildline Autosal Model 8400B (WHOI#12) salinometer. The salinometer was standardized once a day using IAPSO Standard Seawater Batch P-140 (dated 10-Nov-00). The Autosal worked flawlessly and showed virtually no drift during the entire analysis. Conductivity readings were logged automatically to a computer, salinity was calculated and merged with the CTD data, and finally used to update the CTD calibrations. Accuracies of salinity measurements were ±0.002 psu.

II.2.c. Dissolved Oxygen

Measurements were made using a modified Winkler technique similar to that described by Strickland and Parsons (1972). Each seawater sample was collected in a 150 ml brown glass Tincture bottle. When reagents were added to the sample, iodine was liberated which is proportional to the dissolved oxygen in the sample. Samples where then transferred to the shore based laboratory for analysis. Samples were analyzed within 5 days of collection. A carefully measured 50-ml aliquot was collected from the prepared oxygen sample and titrated for total iodine content. Titration was automated using a PC controller and a Metrohm Model 665 Dosimat buret. The titration endpoint was determined amperometrically using a dual plate platinum electrode, with a resolution better than 0.001 ml. Accuracy was about 0.02 ml/l, with a standard deviation of replicate samples of 0.005. This technique is described more thoroughly by Knapp et al (1990). Calculated oxygen was merged with the CTD data, and used to update the CTD calibrations. Standardization of the sodium thiosulphate titrant was performed before analysis. The titration apparatus worked flawlessly, and no unusual problems were noted.

However, compared to climatological oxygen profiles in this locale, the water samples were determined to be of poor quality and unusable.

III. References

Knapp, G.P., M. Stalcup, and R.J. Stanley. 1990. Automated Oxygen Titration and Salinity Determination. WHOI Technical Report, WHOI-90-35, 25 pp.

Millard, R.C. and K. Yang. 1993. CTD Calibration and Processing Methods used at Woods Hole Oceanographic Institute. WHOI Technical Report, WHOI-93-44, 96 pp.

Owens, Brechner W. and Robert C. Millard, Jr. 1985. A New Algorithm for CTD Oxygen Calibrations. J. Phys. Oc. 15:621-631.

SeaBird Electronics, Inc. 2001. CTD Data Acquisition Software Seasoft Version 4.249 Manual.

Strickland, J.D.H. and T.R. Parsons. 1972. The Practical Handbook of Seawater Analyiss. Bulletin 167, Fisheries Research Board of Canada, 310 pp.

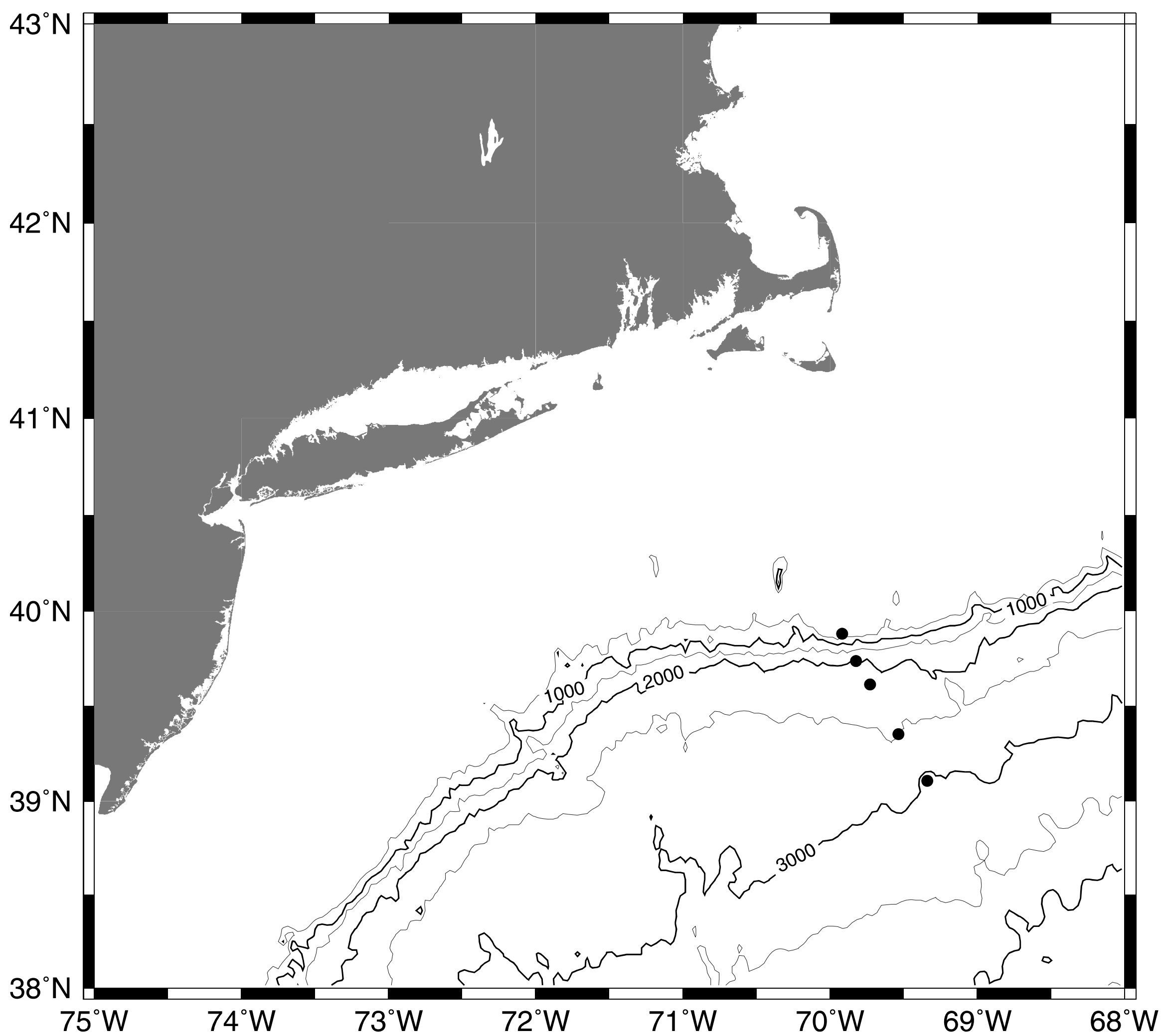

Figure 1. Station Location for Site W – R/V Oceanus Cruise Number 371 Leg 1.