CTD Calibration Report for R/V Oceanus 401-1
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I.1 Cruise Summary

Ship: R/V Oceanus 401-1
Project Name: Site W
Dates: 28 April 2004 – 07 May 2004
Ports: Woods Hole – Woods Hole

18 CTD stations
Rosette salts and dissolved oxygen

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

2004may_ctd_proc.doc This document in MS-Word format.
2004may_ctd_proc.pdf This document in pdf format.

2004may.whp_btl This file follows WOCE specifications for bottle data. Salt and oxygen quality words have been entered.

2004may.sum The SUM file contains the CTD station information using WOCE format.

2004may_*.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 are based on pre-cruise calibrations. CTD pressure are based on pre-cruise calibrations.

II. Finalized Description of Measurements

II.1 CTD Measurements

18 casts were made using a SeaBird 911plus CTD measuring pressure, temperature, conductivity, and oxygen current. 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

- ✍ CTD stations 1-18 were not collected in chronologicial order.
  The CTD operations schedule was adjusted to allow mooring operations to occur during daylight hours and calm weather conditions.
  CTD stations were collected in the following order :
  [12, 11, 9, 8, 7, 6, 5, 4, 3, 2, 1, 10, 13, 14, 15, 16, 17, 18]
  This order defines a transect incrementing from station 1 at the continental shelf to station 18 at the furthest extent southeast on the site W line.
  (Note: In the ship's log stations are numbered chronologically and sequentially 1:18)
- ✍ The secondary conductivity cell (S/N 2362) intermittently behaved badly below 1000 db after the collection of station 11. It was replaced by conductivity cell

(S/N 2707) before station 10. Primary conductivity (S/N 2147) and primary temperature (S/N 4148) were used to calibrate the entire cruise since both perfomed well and without incident.

- ✍ There are no water sample salinities for station 8 as bottles were inadvertently reused before being analyzed.
- ✍ All water sample oxyens for station 5 are clearly bad.

II.1.b Equipment Configuration

A SeaBird 911plus CTD was used throughout the cruise. It was provided with a Digiquartz with TC pressure transducer S/N 69685, two temperature sensors S/N 4148 and S/N 2271, two conductivity sensors S/N 2147 and S/N 2362, and one SBE43 oxygen sensor S/N 0264. Calibrations for all CTD sensors were performed by the manufacturer before the cruise. The CTD was also provided with a Wetlab ECO-AFL/FL flourometer (S/N 013), a Chelsea/Seatech/Wetlab Cstar transmissometer (S/N 537DR), an OBS Seapoint Turbidity meter (S/N 1661), and an altimeter (S/N 639).

Primary conductivity sensor S/N 2362 was used for the entire cruise.

Secondary conductivity sensor S/N 2362 deteriorated during the first part of the cruise and was replaced by conductivity sensor S/N 2707. Stations 1 through 9, 11 and 12 (which occurred during the first part of the cruise) were collected with secondary conductivity sensor S/N 2362 . Stations 10 and 13 through 18 (which occurred during the latter part of the cruise) were collected with secondary conductivity sensor S/N 2707.

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 were acquired by an SBE Model 11 plus CTD Deck Unit providing demodulated data to a personal computer running SeaBird software. SEASAVE version 5.30b CTD acquisition software (SeaBird) provided graphical data to the screen. Bottom approach was controlled by real time altimeter data and ship provided ocean depth information.

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
69685	pressure	Paroscientific/Sea-Bird	18 Dec 2002
4148	temperature	Sea-Bird	10 Jan 2004
2271	temperature	Sea-Bird	18 Oct 2003
2147	conductivity	Sea-Bird	01 Nov 2003
2362	conductivity	Sea-Bird	01 Nov 2003
2707	conductivity	Sea-Bird	27 Feb 2003
0264	SBE43 dissolved oxygen	Sea-Bird	04 Mar 2004

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 primary conductivity sensor data was fit to the water sample conductivity. All stations (except station 8 which had no rosette water sample salinity data) were grouped together in chronological order to find the best fit. The group was fit for slope and bias. A linear pressure term (modified beta) was applied to conductivity slopes using a least-squares minimization of CTD and bottle conductivity differences. The function minimized was:

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

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]
? - linear pressure term [mS/cm/dbar]

The slope term is a polynomial function of the station numberbased upon chronological station collection order. 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 2147. Fits to primary conductivity and temperature were applied to the final data.

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

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

Data Quality

Calibrated, the overall standard deviation of the CTD and the water sample differences for S/N2147 was .0008932. Fits to the two secondary conductivity sensors were not used because the quality of the primary sensor data was excellent and that of the first of the two secondary conductivity sensors was so poor.

Table 4a. Best Fit Conductivity Coefficients for Conductivity S/N 2147

Stations	#pts used	total #pts	std dev (mS/cm)	Slope	Bias	Beta
Fit as a group in chronological order [12 11 9:1 10 13:18]	260	324	0.0037			
1				1.00018641	-0.00805375	2.44516274e-07

2				1.00018332	-0.00805375	2.44516274e-07
3				1.00018007	-0.00805375	2.44516274e-07
4				1.00017665	-0.00805375	2.44516274e-07
5				1.00017306	-0.00805375	2.44516274e-07
6				1.00016930	-0.00805375	2.44516274e-07
7				1.00016537	-0.00805375	2.44516274e-07
8				1.00016128	-0.00805375	2.44516274e-07
9				1.00015701	-0.00805375	2.44516274e-07
10				1.00018932	-0.00805375	2.44516274e-07
11				1.00015258	-0.00805375	2.44516274e-07
12				1.00014798	-000.805375	2.44516274e-07
13				1.00019207	-0.00805375	2.44516274e-07
14				1.00019465	-0.00805375	2.44516274e-07
15				1.00019706	-0.00805375	2.44516274e-07
16				1.00019930	-0.00805375	2.44516274e-07
17				1.00020137	-0.00805375	2.44516274e-07
18				1.00020328	-0.00805375	2.44516274e-07

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 encorporated into matlab routines by Millard (2004) for use in processing ctd oxygens using matlab. Matlab mfiles created by Jane Dunworth were used for determining the oxygen calibration coefficients using Millard's routines. 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.

$$Oxm = \left[slope \cdot \left(Oc + lag \cdot \frac{dOc}{dt} \right) + bias \right] \cdot Oxsat \cdot \exp\left(tcor \cdot \left[T + wt \cdot \left(T_o - T \right) \right] + \right.$$

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 in two groups (A & B) 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. Group A stations (chronologically) [12 11 9:1] were fit for BI, SL, Pcor and Tcor. Group B stations (chronologically) [13:18] were fit for BI and SL after applying the Pcor and Tcor of a fit to groups A and B together for BI, SL, Pcor and Tcor.

Data Quality

Calibrated, the overall standard deviation of the CTD and water samples differences for Group A was 0.0294 ml/l. The overall standard deviation for Group B was 0.0485ml/l.

Table 5. Best Fit Coefficients for Oxygen Sensor 0264.

Stations	bias	slope	pcor	tcor	wt	lag	std err (ml/L)
[12 11 9:-1:1]	-0.4951693	0.38128662	1.3799823e-4	1.29496e-4	0	0	0.0294
[10 13:18]	-0.5462132	0.38523893	1.4428868e-4	1.87969e-3	0	0	0.0485

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 Dave Wellwood

II.2.a Summary

Water samples were collected from 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 at sea within 24 hrs of collection. After the samples reached the lab temperature of 22°C, they were analyzed for salinity using a Guildline Autosal Model 8400B (WHOI#__) salinometer. The salinometer was standardized once a day using IAPSO Standard Seawater Batch P-143 (dated _________). 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 were analyzed within 24 hours 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.

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.

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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.

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