CTD Calibration Report for R/V Oceanus 432-1

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I.1 Cruise Summary

Ship: R/V Oceanus432
Project Name: Line W
Dates: 19 October 2006 – 26 October 2006
Ports: Woods Hole – Woods Hole

21 CTD stations
Rosette salts and dissolved oxygen

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

32OC432_docfile.doc This document in MS-Word format.
32OC432.pdf *T*his document in pdf format.

OC432_CTD_stationlog.doc At sea station by station event log

32OC432.SEA This file follows WOCE specifications for bottle data.
Salt and oxygen quality words have been entered.

32OC432.SUM The SUM file contains the CTD station information using WOCE format.

**.CTD* One 2db averaged file per station following the WOCE format specification for CTD profiles. The final *.CTD files contain primary conductivity and primary oxygen data. All CTD salt and oxygen data have been calibrated to the bottle salt and oxygen data. CTD temperatures have been scaled with pre-cruise calibrations. CTD pressures have been scaled with pre-cruise calibrations.

II. Finalized Description of Measurements

II.1 CTD Measurements

Twenty one casts were made using a SeaBird 911plus CTD configured to measure 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

Weather conditions limited the number of stations collected during this cruise. Twenty one out of twenty six anticipated stations were successfully collected. Quality of the ctd oxygen sensor data progressively deteriorated from stations one through fourteen, at which point the sensor was replaced. Deep oxygen data for stations eleven through fourteen have been replaced with 2db interpolated rosette data. Secondary conductivity and temperature consistently dropped out during casts somewhere in the ~600-2000db range. Station 4 has no rosette data.

II.1.b Equipment Configuration

A SeaBird 911plus CTD (serial number 9785) was used throughout the cruise. It was provided with a Digiquartz TC pressure transducer S/N 94763, two temperature sensors S/N 04491 and S/N 04492, two conductivity sensors S/N 02186 and S/N 03009, and one SBE43 oxygen sensors S/N 0113 which was replaced with oxygen sensor S/N 0723 after station fourteen. 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 0304), a Chelsea/Seatech/Wetlab Cstar Transmissometer (S/N 0854), a SPAR/Surface Irradiance sensor (S/N 6294), an altimeter (S/N 997), and a 3psi rosette tension meter.

CTD data from both the primary conductivity and oxygen sensors, and secondary conductivity sensor, were calibrated for the entire cruise. Primary conductivity and oxygen were chosen for the final WOCE format *.CTD data files due to their superior performance.

The pylon was controlled through a dedicated personal computer using SeaBird's software SEASOFT version 5.33 for windows. A rosette frame was provided for the cruise. The frame held 21 10-liter bottles some of which were produced at WHOI and some which were borrowed from Scripts Institute of Oceanography.

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 5.33 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 raw CTD data was run through the 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.

Table 2. SeaBird Processing Software

SeaBird Module	Description (SeaBird, Version 5.33)
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.

Standard final output included the following variables:

name 0 = prDM: Pressure, Digiquartz [db]
name 1 = t090C: Temperature [ITS-90, deg C]
name 2 = t190C: Temperature, 2 [ITS-90, deg C]
name 3 = c0mS/cm: Conductivity [mS/cm]
name 4 = c1mS/cm: Conductivity, 2 [mS/cm]
name 5 = sbeox0V: Oxygen Voltage, SBE 43
name 6 = sbeox0dOC/dT: Oxygen, SBE 43 [doc/dt]
name 7 = sbeox0ML/L: Oxygen, SBE 43 [ml/l]
name 8 = scan: Scan Count
name 9 = nbin: number of scans per bin
name 10 = sal00: Salinity [PSU]
name 11 = sal11: Salinity, 2 [PSU]
name 12 = flag: flag

CTD salinity and oxygen data were then calibrated by fitting the data to water sample salinity and oxygen data. WHOI post-processing fitting procedures are modelled after Millard and Yang, 1993.

A second set of CTD data files used for LADCP processing were created using a subset of the Seabird data conversion software listed in Table 2. Standard final output included the following variables:

name 0 = timeS: Time, Elapsed [seconds]
name 1 = prDM: Pressure, Digiquartz [db]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = svCM: Sound Velocity [Chen-Millero, m/s]
name 4 = timeJ: Julian Days
name 5 = latitude: Latitude [deg]
name 6 = longitude: Longitude [deg]
name 7 = scan: Scan Count
name 8 = c0mS/cm: Conductivity [mS/cm]
name 9 = c1mS/cm: Conductivity, 2 [mS/cm]
name 10 = t190C: Temperature, 2 [ITS-90, deg C]
name 11 = nbin: Scans Per Bin
name 12 = sal00: Salinity [PSU]
name 13 = sal11: Salinity, 2 [PSU]
name 14 = flag:

A third set of CTD data files containing transmissometer data were also created using a subset of the Seabird data conversion software listed in Table 2. Standard final output included the following variables:

```
# name 0 = timeS: Time, Elapsed [seconds]
# name 1 = prDM: Pressure, Digiquartz [db]
# name 2 = t090C: Temperature [ITS-90, deg C]
# name 3 = timeJ: Julian Days
# name 4 = latitude: Latitude [deg]
# name 5 = longitude: Longitude [deg]
# name 6 = sal00: Salinity [PSU]
# name 7 = scan: Scan Count
# name 8 = c0mS/cm: Conductivity [mS/cm]
# name 9 = flECO-AFL: Fluorescence, Wetlab ECO-AFL/FL [mg/m^3]
# name 10 = upoly0: Upoly 0, Upoly 0, Turbidity
# name 11 = xmiss: Beam Transmission, Chelsea/Seatech/Wetlab CStar [%]
# name 12 = nbin: Scans Per Bin
# name 13 = flag:
```

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
94763	pressure	Paroscientific/Sea-Bird	12 May 2004
4491	temperature	Sea-Bird	31 March 2006
4492	temperature	Sea-Bird	04 April 2006
2186	conductivity	Sea-Bird	31 March 2006
3009	conductivity	Sea-Bird	31 March 2006
0113	SBE43 dissolved oxygen	Sea-Bird	30 March 2006
723	SBE43 dissolved oxygen	Sea-Bird	19 April 2006

II.1.e Summary of CTD Calibrations

PRESSURE CALIBRATION

The pressure bias of the CTD at the sea surface was monitored at the completion of each station to make sure there was no significant drift in the calibration. On deck pressure bias ranged from -0.2 to -0.4 decibars.

CONDUCTIVITY CALIBRATION

Basic fitting procedure:

The CTD primary and secondary conductivity sensor data were fit to the water sample conductivity. All stations 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:

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

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

The slope term is a polynomial function of the station number based 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 primary sensor 2186 and secondary sensor 3009. Fits to primary conductivity and temperature were applied to the final data.

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

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

Data Quality

Calibrated, the overall standard deviation of the CTD conductivity and the water sample differences for primary sensor (S/N 2186) is **0.0007012**. The overall standard deviation for secondary conductivity sensor (S/N 3009) and the water sample differences is **0.0008073.**

Table 4a. Best Fit Conductivity Coefficients for Primary Conductivity S/N 2186

Stations	#pts used	total #pts	std dev (mS/cm)	Slope	Bias	Beta
Fit as a group in chronological order [1:3 5:21]	200	210	.0007012	Pressure Dependent Coefficients		
1				1.00024747	-0.00753783	-1.42443916e-007
2				1.00025835	-0.00753783	-1.42443916e-007
3				1.00026777	-0.00753783	-1.42443916e-007
4 (interp btwn 3 & 5)				1.00027178	-0.00753783	-1.42443916e-007
5				1.00027578	-0.00753783	-1.42443916e-007
6				1.00028245	-0.00753783	-1.42443916e-007
7				1.00028784	-0.00753783	-1.42443916e-007
8				1.00029203	-0.00753783	-1.42443916e-007
9				1.00029507	-0.00753783	-1.42443916e-007
10				1.00029703	-0.00753783	-1.42443916e-007
11				1.00029797	-0.00753783	-1.42443916e-007

12				1.00029796	-0.00753783	-1.42443916e-007
13				1.00029707	-0.00753783	-1.42443916e-007
14				1.00029535	-0.00753783	-1.42443916e-007
15				1.00029287	-0.00753783	-1.42443916e-007
16				1.00028970	-0.00753783	-1.42443916e-007
17				1.00028590	-0.00753783	-1.42443916e-007
18				1.00028154	-0.00753783	-1.42443916e-007
19				1.00027667	-0.00753783	-1.42443916e-007
20				1.00027138	-0.00753783	-1.42443916e-007
21				1.00026571	-0.00753783	-1.42443916e-007

Table 4b. Best Fit Conductivity Coefficients for Secondary Conductivity S/N 3009

Stations	**#pts used**	**total #pts**	**std dev (mS/cm)**	**Slope**	**Bias**	**Beta**
Fit as a group in chronological order [1:3 5:21]	184	205	.0008073	Pressure Independent Coefficients		
1				0.99965962	0.01253773	0.00000000e+000
2				0.99966387	0.01253773	0.00000000e+000
3				0.99966749	0.01253773	0.00000000e+000
4 (interp btwn 3 & 5)				0.99966899	0.01253773	0.00000000e+000
5				0.99967050	0.01253773	0.00000000e+000
6				0.99967289	0.01253773	0.00000000e+000
7				0.99967466	0.01253773	0.00000000e+000
8				0.99967581	0.01253773	0.00000000e+000
9				0.99967635	0.01253773	0.00000000e+000
10				0.99967626	0.01253773	0.00000000e+000
11				0.99967556	0.01253773	0.00000000e+000
12				0.99967424	0.01253773	0.00000000e+000
13				0.99967230	0.01253773	0.00000000e+000
14				0.99966975	0.01253773	0.00000000e+000
15				0.99966657	0.01253773	0.00000000e+000
16				0.99966278	0.01253773	0.00000000e+000
17				0.99965837	0.01253773	0.00000000e+000
18				0.99965334	0.01253773	0.00000000e+000
19				0.99964770	0.01253773	0.00000000e+000
20				0.99964143	0.01253773	0.00000000e+000
21				0.99963455	0.01253773	0.00000000e+000

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 calibrating temperature and conductivity 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. The following matlab mfiles created by Jane Dunworth were used for determining and applying the oxygen calibration coefficients using Millard's routines: make_oxygile.m, oxycal_SBE.m, plot_caloxy.m, claoxy_dco.m, plot_thetaso.m, dco2ctd.m, cal_nut.m, cnut_2_sea.m. These programs used 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

Data from all stations and both oxygen sensors were calibrated according to the groups indicated in the oxygen coefficients tables (see Table 5a and Table 5b).

Data Quality

The standard deviation of the differences between the CTD and rosette oxygen data stations 1-14 (oxygen sensor S/N 0113) scaled with precruise oxygen calibrations were poor due to the poor performance of the sensor below 1000db (st.dev = 0.597). The standard deviation of the differences between the CTD and rosette oxygen data for stations 15-21 (oxygen sensor S/N 723) were significantly better (st. dev=0.184). For all stations, calibration coefficients were fine tuned according to station groupings to produce final WOCE format CTD data.. Irrecoverable deep water oxygen data for stations 11-14 final data were replaced with 2db interpolated water sample oxygen data.

Oxygen Sensor S/N 0113 was used for station 1-14 final data.
Mfile: make_oxyfile was used to create file: oc432oxy1_14.fit
Mfile: oxycal_sbe was used for the following fits:
.... fit stations [1:3] station dependent
.... fit stations [5:14] each independently BI,SL,Pcor,Tcor
... apply station 5 calibrations to station 4 which has no rosette data

Table 5a. Best Fit Coefficients for Original Oxygen Sensor 113 used for final data.

Bias	Slope	Pcor	Tcor	St. Dev	Sta
0.8139351075	0.2405420611	-0.00162284343385	0.0055050880	0.0568	1
0.8066494396	0.2405420611	-0.00162284343385	0.0055050880	0.0568	2
0.8009681584	0.2405420611	-0.00162284343385	0.0055050880	0.0568	3
-0.6641650596	0.3492062895	0.000215426295419	0.0077109923	=sta 5	4
-0.6641650596	0.3492062895	0.000215426295419	0.0077109923	0.1400	5
-0.7844635238	0.4266377134	9.5817905388e-005	0.0022705228	0.0282	6
-0.7714906947	0.4282371300	8.70013318802e-005	-0.0031376881	0.0293	7
-0.8754364244	0.4506578589	8.65935626863e-005	-0.0012067471	0.0465	8
-0.8960361161	0.4281026786	0.000103581437766	0.0026807278	0.0278	9
-1.1563200245	0.4246471878	0.00014299716506	0.0344958565	0.0227	10
-0.8602405374	0.4220904605	0.000103712411847	0.0039139385	0.0468	11
-0.7747383787	0.4413809384	3.35819394857e-005	-0.0062200215	0.0743	12
-0.6578944011	0.3757480993	6.26123340004e-005	0.0048246376	0.1440	13
-0.8029236255	0.4823005371	-0.000103028118508	-0.0023063187	0.1450	14

Oxygen Sensor S/N 723 data were used for station 15-21 final data.
Mfile: make_oxyfile was used to create file: oc432oxy15_21.fit
Mfile: oxycal_sbe was used for the following fits:
.... fit stations [15:16] each independently BI,SL,Pcor,Tcor
.... fit stations [17:19] station dependent
.... fit stations [20:21] station dependent

Table 5b. Best Fit Coefficients for Second Oxygen Sensor 723 used for final data.

Bias	Slope	Pcor	Tcor	St. Dev	Sta
-0.4805842405	0.5593140490	0.000130661682148	0.0013343591	0.0422	15
-0.5688850885	0.6439740214	0.000134859081936	-0.0022270177	0.0396	16
-0.5463983297	0.6468405930	0.000133842423175	-0.0019909293	0.0363	17
-0.5403952883	0.6468405930	0.000133842423175	-0.0019909293	0.0363	18
-0.5374607342	0.6468405930	0.000133842423175	-0.0019909293	0.0363	19
-0.5271964928	0.6398051659	0.00013202800699	0.0014484992	0.0755	20
-0.5209798298	0.6398051659	0.00013202800699	0.0014484992	0.0755	21

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. LADCP station logs were also kept for LADCP data collected during each station. An at-sea station event log was also kept during the cruise to point summarize notable information about each CTD station collected.

II.2 Salinity and Dissolved Oxygen Measurements

contributed by David Wellwood

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. After the samples reached the lab temperature, they were analyzed for salinity using a Guildline Autosal Model 8400B salinometer (WHOI #11, serial #59210). The salinometer's bath temperature was set to either 24C or 27C, depending on the ship's ambient lab temperature, and was standardized once a day using IAPSO Standard Seawater Batch P-146 (dated May-2005). 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. 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 daily.

III. References

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