CTD Calibration Report

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Cruise Summary

Ship: R/V Atlantic Explorer
Cruise ID: AE1213
Project Name: DynAMITE
Dates: 28 May – 6 June 2012
Ports: Bermuda – Bermuda

Data Files Included as part of this distribution

AE1213_CTDprocessing.pdf
This document in pdf format.

AE1213.sea
This file follows WOCE specifications for bottle data. S and oxygen quality words have been entered.

AE1213.sum
The SUM file contains the CTD station information using WOCE format.

*AE1213_***.ctd*
One 2db averaged file per station following the WOCE format specification for CTD profiles. The final *.ctd files contain primary sensor temperature, conductivity and oxygen data. CTD temperatures, pressures, and conductivities have been scaled with pre-cruise calibrations from the sensor manufacturer. All CTD salt and oxygen data have been post-calibrated using the bottle salt and oxygen data.

Sensor Configuration and Manufacturer Calibrations

CTD measurements and water samples

18 casts were performed using a SeaBird 911plus CTD configured to measure pressure, temperature, conductivity, and oxygen current. For each cast, water samples were collected at 24 discrete intervals and analyzed for salinity and dissolved oxygen – primarily for the purpose of performing additional sensor calibrations. All casts spanned the full water column.

CTD Sensors and manufacturer calibrations

A SBE 911plus/917plus CTD was used throughout the cruise.
Pressure sensor: Digiquartz TC pressure transducer, s/n 91377
Primary temperature sensor: SBE 03-02/F, s/n 030876
Secondary temperature sensor: SBE 03-02/F, s/n 031079
Primary conductivity sensor: SBE 04-02/0, s/n 041345
Secondary conductivity sensor: SBE 04-02/0, s/n 043880
Primary dissolved oxygen sensor: SBE 43, s/n 0905
Secondary dissolved oxygen sensor: SBE 43, s/n 0909
Calibrations for these CTD sensors were performed by the manufacturer before the cruise. The CTD was also provided with an SPAR/Surface Irradiance sensor (s/n 20399) and an altimeter (s/n PSA 916 54062). CTD data from both conductivity sensors and oxygen sensor were calibrated using bottle data for the entire cruise. The

unit was controlled through a dedicated personal computer using SeaBird's software SEASOFT version 7.21a for windows. A rosette frame holding 24 12 L Niskin bottles was used for collecting water samples.

All sensors were calibrated by the manufacturer prior to the cruise. A listing of sensors and calibration dates are presented in Table 1.

Table 1. Sensor Calibration Dates

Sensor Number	Sensor Type	Manufacturer	Calibration Dates
91377	Pressure	Sea-Bird	26 February 2010
030876	Temperature	Sea-Bird	30 December 2011
031079	Temperature	Sea-Bird	27 April 2011
041345	Conductivity	Sea-Bird	30 December 2011
043880	Conductivity	Sea-Bird	21 September 2011
0905	SBE43 dissolved oxygen	Sea-Bird	17 September 2011
0909	SBE43 dissolved oxygen	Sea-Bird	17 September 2011

Acquisition and Seabird 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 7.21a 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 processing software listed in Table 2. The data was converted from HEX to ASCII, lag corrected, edited for large spikes, smoothed according to sensor, and pressure averaged into 2 decibar bins for final data quality control and analysis.

Table 2. SeaBird Processing Software

SeaBird Module	Description (SeaBird, Version 7.21a)
DATCNV	Convert the raw data to pressure, temperature, conductivity, and dissolved oxygen current
BOTTLESUM	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 '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 pressure and depth 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	Compute oxygen from oxygen current (filtered), temperature, and pressure
BINAVG	Average data into the 2 dbar pressure bins
DERIVE sal	Compute salinity
STRIP	Extract columns of data from .cnv files
SPLIT	Split .cnv file into upcast and downcast files

Standard final output included the following variables:

name 0 = prDM: Pressure, Digiquartz [db]
name 1 = depSM: Depth [salt water, m]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = t190C: Temperature, 2 [ITS-90, deg C]
name 4 = c0mS/cm: Conductivity [mS/cm]
name 5 = c1mS/cm: Conductivity, 2 [mS/cm]
name 6 = sbeox0V: Oxygen raw, SBE 43 [V]
name 7 = spar: SPAR/Surface Irradiance
name 8 = altM: Altimeter [m]
name 9 = scan: Scan Count
name 10 = sbeox1V: Oxygen raw, SBE 43, 2 [V]
name 11 = sbeox0ML/L: Oxygen, SBE 43 [ml/l], WS = 2
name 12 = sbeox0dOV/dT: Oxygen, SBE 43 [dov/dt], WS = 2
name 13 = sbeox1ML/L: Oxygen, SBE 43, 2 [ml/l], WS = 2
name 14 = sbeox1dOV/dT: Oxygen, SBE 43, 2 [dov/dt], WS = 2
name 15 = nbin: number of scans per bin
name 16 = sal00: Salinity, Practical [PSU]
name 17 = sal11: Salinity, Practical, 2 [PSU]
name 18 = flag: flag

Post-Processing Conductivity Calibrations

Basic fitting procedure:

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

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

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 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 3 for primary sensor (s/n 041345) and secondary sensor (s/n 043880).

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

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

Fitting results

Once calibrated, the overall standard deviation of the CTD conductivity and the water sample differences for the primary conductivity sensor (s/n 041345) is **0.001012**. The overall standard deviation for the secondary conductivity sensor (s/n 043880) and the water sample differences is **0.000957.**

Table 3a. Best Fit Conductivity Coefficients for Primary Conductivity S/N 1345

Stations	#pts used	total #pts	std dev (mS/cm)	Slope (min/max)	Bias	Beta
Fit as a group in chronological order [1:18]	337	430	.001012	1.00023/1.00023	-0.0049448	-8.7658e-07

Table 3b. Best Fit Conductivity Coefficients for Secondary Conductivity S/N 3880

Stations	#pts used	total #pts	std dev (mS/cm)	Slope (min/max)	Bias	Beta
Fit as a group in chronological order [1:18]	338	430	.000957	1.00028/1.00028	-0.0059449	-6.7628e-07

Post-Processing Oxygen Calibrations

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 slight 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_oxyfile.m, oxycal_SBE.m, plot_caloxy.m, caloxy_dco.m, dco2ctd.m, cal_nut.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 [ ]*

Fitting results

Once calibrated, the overall standard deviation of the CTD oxygen and the water sample differences for the primary conductivity sensor (s/n 0905) is **0.0266**. Data from all stations were calibrated together in one group for the primary sensor.
The oxygen calibration file with the coefficients used can be found in appendix A as AE1213_1_18.par

Other notable data acquisition

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

Salinity and Dissolved Oxygen Measurements

Contributed by David Wellwood and George Tupper

Summary

Water samples collected during this cruise were analyzed for concentrations of salinity and dissolved oxygen. These measurements were used to calibrate the CTD sensors.

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 of approximately 25˚C, they were analyzed for salinity using a Guildline Portable Salinometer model 8410A (WHOI #P3, s/n 65735). The salinometer's bath temperature was set to 26˚C and was standardized once a day using IAPSO Standard Seawater Batch P-153 (use by date: March 2014). 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 ±0.003 psu. Bottle salinities were assigned a quality control flag based upon the difference between upcast CTD salinity (calibrated) at the same pressure and/or at the same potential temperature.

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.

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.

Appendix A: AE1213_1_18.par

```
% bias slope pcor tcor stn   from: AE1213_oxy1_18.fit
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      1
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      2
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      3
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      4
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      5
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      6
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      7
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      8
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588      9
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     10
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     11
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     12
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     13
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     14
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     15
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     16
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     17
-0.7268802366 0.3956301184  0.000148693622759 -0.0009063588     18
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