CTD Data Calibration Report for R/V Endeavor 466
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I.1 Cruise Summary

Ship: R/V Endeavor 466 **Project Name**: Line W
Dates:31 August – 10 September 2009 **Por**t: Narragansett, RI
Chief Scientist: Terrence Joyce
CTD data processor: Jane Dunworth-Baker
Hydrographer: George Tupper

26 CTD stations
Rosette salts and dissolved oxygen plus, CFCs, SF-6, I-129

I.2 Final Data Files

32EV466_ctdproc.doc
2009sep.whp_btl (bottle data in WOCE format)
2009sep.sum (station information in WOCE format)
2009sep_ctd.zip (collection of individual CTD data files)

*.*CTD* One 2db averaged file per station following the WOCE format specification for CTD profiles. The final *.CTD files derive from the secondary conductivity and primary oxygen sensor data. All CTD salt and oxygen data have been calibrated to the bottle salt and (adjusted) oxygen data. CTD temperature and pressure has been scaled with pre-cruise calibrations.

II.1 CTD Measurements

Twenty six 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, and cfc's. All casts were full water column.

II.2 Difficulties Encountered

Systemic problems were found in the bottle oxygen data, and 35% of the bottles were flagged as bad or questionable. The reagent dispensers were suspected to be the source of these problems. Oxygen bubbles were visible in the dispenser tubes, which were changed. Attempts were made to clear the dispensers before adding the reagents to the sample bottles but, the problem still existed.

II.3 Equipment Configuration

A SeaBird 911plus/917 plus CTD was used throughout the cruise. It was equiped with a Digiquartz TC pressure transducer S/N 80016, two temperature sensors S/N 4130 and S/N 4126, three conductivity sensors S/N 3220 and S/N 2469/2459(sta 22-end), and two SBE43 oxygen sensors S/N 1648 and 0343. Calibrations for all CTD sensors were performed by the manufacturer before the cruise. The CTD also contained a Chelsea/Seatech/Wetlab Cstar Transmissometer (S/N 969DR), and an altimeter (S/N 1017). CTD data from both the primary conductivity and oxygen sensors, and secondary conductivity sensor, were calibrated for the entire cruise. While the primary and secondary conductivity sensors were consistant throughout most of the cruise, the primary was chosen for the final data product .

The pylon was controlled through a dedicated personal computer using SeaBird's software SEASAVE version 7.18c for windows. A rosette frame was provided for the cruise. The frame held 22 10-liter bottles , the ladcp took up 2 bottle positions.

II.4 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 7.18c 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 were run through the SeaBird data conversion software listed in Table 2. 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.

Table 2. SeaBird Processing Software

SeaBird Module	Description (SeaBird, Version 7.18d)
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 BINAVG	Compute oxygen from oxygen current, temperature, and pressure. 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 output nominally scaled CTD data files, used as input for final CTD calibrations, 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
#name 8 = scan: Scan Count
name 9 = nbin: number of scans per bin
name 10 = sal10: Salinity [PSU]
name 11 = sal11: Salinity, 2 [PSU]
name 12 = flag: flag

A second set of CTD data files used for LADCP processing were created with 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:

II.5 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. No adjustments were applied to the CTD pressure data apart from the pre-cruise laboratory calibrations.

CONDUCTIVITY CALIBRATION

Basic fitting procedure:

Locally written calibration routines ('CTD_GUI") were used to fit primary and secondary conductivity sensor data to the water sample conductivity data. All stations were grouped together in chronological order to find the best fit. Five cal groups were determined, all groups had pressure independant coefficients and a station dependant fit. Station 7 did not fit with any surrounding stations and was cal'd by itself. A linear pressure term (modified beta) was applied to conductivity slopes using a least-squares minimization of CTD and bottle conductivity differences.

Site W - EN466 FINAL Conductivity Coefficient for Sensor S/N 3220

Station	Slope	Bias	Beta
1	1.00015376	0.00211851	0.00000000e+000
2	1.00011676	0.00211851	0.00000000e+000
3	1.00007976	0.00211851	0.00000000e+000
4	1.00004276	0.00211851	0.00000000e+000
5	1.00000576	0.00211851	0.00000000e+000
6	0.99996876	0.00211851	0.00000000e+000
7	0.99932521	0.02749442	0.00000000e+000
8	1.00011425	-0.00094402	0.00000000e+000
9	1.00011278	-0.00094402	0.00000000e+000
10	1.00011880	-0.00094402	0.00000000e+000
11	1.00013231	-0.00094402	0.00000000e+000
12	1.00008205	0.00185503	0.00000000e+000
13	1.00007214	0.00185503	0.00000000e+000
14	1.00006598	0.00185503	0.00000000e+000
15	1.00006356	0.00185503	0.00000000e+000
16	1.00006488	0.00185503	0.00000000e+000
17	1.00006995	0.00185503	0.00000000e+000
18	1.00007877	0.00185503	0.00000000e+000
19	1.00009134	0.00185503	0.00000000e+000
20	1.00006096	0.00111293	0.00000000e+000
21	1.00005295	0.00111293	0.00000000e+000
22	1.00004493	0.00111293	0.00000000e+000
23	1.00003692	0.00111293	0.00000000e+000

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24      1.00002891      0.00111293      0.00000000e+000
25      1.00002090      0.00111293      0.00000000e+000
26      1.00001289      0.00111293      0.00000000e+000
```

Data Quality

Water sample data for salinity appears to be of good quality. The oxygen samples were not up to our standards of quality: ~35% of samples were flagged as questionable or bad, 58% compared reasonably with the CTD (after calibration). A faulty dispenser for the chemical reagents was suspected. Good as well as questionable oxygen bottles were used to arrive at reasonable oxygen fits, and historical profiles from earlier Line W cruises were used to validate these fits. The questionable samples were later flagged '3'.

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 to account for the (weak) dependence of oxygen on the CTD pressure, temperature, and conductivity (salinity).

An oxygen calibration package, oxycal_SBE , (was used to arrive at final oxygen calibrations. The package calls three fitting routines that use an 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
Final CALS:

```
% dec 7, 2009 final
% bias slope pcor tcor stn   from: en466oxy1_26.fit
-0.5242167296 0.5149493490  0.000138730017147 0.0019018861      1
-0.5235312028 0.5149493490  0.000138730017147 0.0019018861      2
-0.5229712215 0.5149493490  0.000138730017147 0.0019018861      3
-0.5225682851 0.5149493490  0.000138730017147 0.0019018861      4
-0.5219508061 0.5149493490  0.000138730017147 0.0019018861      5
-0.5211082344 0.5149493490  0.000138730017147 0.0019018861      6
-0.5187742631 0.5149493490  0.000138730017147 0.0019018861      7
-0.5176282268 0.5149493490  0.000138730017147 0.0019018861      8
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225      9
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     10
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     11
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     12
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     13
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     14
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     15
-0.5022668831 0.5188578049  0.00013282556663 -0.0006282225     16
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     17
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     18
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     19
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     20
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     21
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     22
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     23
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     24
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     25
-0.5113804726 0.5206353487  0.000134097834824 0.0024302976     26
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Data Quality and Processing issues

Stations were occupied North to South along the line, 1=9001 and 26=9026. Oxygen data were cal'd using the limited good bottle oxygen that was available. They appear to be consistant

with the historical data. Station 6 watersample file appears to have bad ctdsalnty and were replaced with interpolated values from the .ctd file The qbyte is '6' in the sea files for station 6.

Bill Smethie sent his final cfc data in July 2010. The data were inserted into the sea file using add_cfcdata. The routine had to be modified to include the SF-6 data. The I-129 data were not sent.

III Sampling Methods

Water samples were collected from virtually every bottle during this cruise for the determination of salinity and dissolved oxygen. The purpose of these measurements were to calibrate the sensors on the CTD, and to create a clean sample file (sea) containing bottle salts, bottle oxygen, cfc-11,cfc-12 cfc-113, and calibrated ctdsalt and ctdoxy. A small number of SF-6 and I-129 samples were collected at location chosen by Bill Smethie.

III.1 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 URI's Portasal Salimometer. 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-144. The accuracy of salinity measurements is ±0.004 psu.

III.2 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 is believed to be 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). Standardization of the sodium thiosulphate titrant was performed daily.

IV. 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.

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