CTD Data Calibration Report for R/V Oceanus 421
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I.1 Cruise Summary

Ship: R/V Oceanus 421 **Project Name**: Line W
Dates:5 – 9 April 2006 **Port**: Woods Hole,MA
Chief Scientist: John Toole
CTD data processor: Jane Dunworth-Baker
Hydrographer: Dave Wellwood

17 CTD stations
Rosette salts, dissolved oxygen, cfc's,
CTD and LADCP

I.2 Final Data Files

2006apr_ctd_proc.doc
2006apr.whp_btl
2006apr.sum
2006apr_ctd.zip

**.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

Seventeen 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

This was a combination ctd/mooring recovery cruise, so after the initial 6 stations, ctd cast were done
at night, when mooring work is not possible. The ctd work was hampered by bad weather and strong currents.
There were deck unit issues on sta 8, ie no bottle firing confirmations. Bottle table ok, not sure how fixed,
but sta 9 was ok. Stations 1:6 had a leaky niskin bottle #2, until the o-ring was replaced

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 94763, two temperature sensors S/N 4502 and S/N 4507, two conductivity sensors
S/N 3089 and S/N 3093, and one SBE43 oxygen sensors S/N 0772. Calibrations for all CTD sensors were performed by the manufacturer before the cruise. The CTD also contained a Wetlab ECO-AFL/FL Flourometer (S/N 0304), a Chelsea/Seatech/Wetlab Cstar Transmissometer (S/N 0854), an altimeter (S/N 997). 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 chosed 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 23 10-liter bottles and 1 4-liter bottle to allow room for the ladcp..

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 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 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 7.18c)
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:

A third set of CTD data files of transmisometer data contained 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 = scan: Scan Count
name 7 = c0mS/cm: Conductivity [mS/cm]
name 8 = flECO-AFL: Fluorescence, Wetlab ECO-AFL/FL [mg/m^3]
name 9 = par: PAR/Irradiance, Biospherical/Licor
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 = sal00: Salinity [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:

Deb West-Mack's calibration gui 'ctd_gui' was 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. Two cal groups were determined, both groups had pressure dependant coefficients and a station dependant fit. A linear pressure term (modified beta) was applied to conductivity slopes using a least-squares minimization of CTD and bottle conductivity differences.

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Site W -  OC421 Conductivity Coefficient File for Sensor S/N 3089
          sta-dep fit, stdev=.00105
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Station	Slope	Bias	Beta
1	1.00028342	-0.00911984	-1.04799093e-007
2	1.00028342	-0.00911984	-1.04799093e-007
3	1.00028342	-0.00911984	-1.04799093e-007
4	1.00028342	-0.00911984	-1.04799093e-007
5	1.00030852	-0.00911984	-1.04799093e-007
6	1.00030870	-0.00911984	-1.04799093e-007
7	1.00030104	-0.00911984	-1.04799093e-007
8	1.00029655	-0.00911984	-1.04799093e-007
9	1.00030012	-0.00911984	-1.04799093e-007
10	1.00031051	-0.00911984	-1.04799093e-007
11	1.00032040	-0.00911984	-1.04799093e-007
12	1.00031636	-0.00911984	-1.04799093e-007

Site W - OC421 Conductivity Coefficient File for Sensor S/N 3089
sta-dep fit, stdev=.0005122

Station	Slope	Bias	Beta
13	1.00001987	-0.00186142	3.10150728e-008
14	1.00003041	-0.00186142	3.10150728e-008
15	1.00005319	-0.00186142	3.10150728e-008
16	1.00006453	-0.00186142	3.10150728e-008
17	1.00006961	-0.00186142	3.10150728e-008

Data Quality

Water sample data for salinity appears to be of good quality. The oxygen samples were generally ok,
except for stations 7 & 8, where bottle data was too low.

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:

% bias slope pcor tcor stn from: oc421oxy1_17.fit

bias	slope	pcor	tcor	stn
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	1
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	2
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	3
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	4
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	5
-0.5272171547	0.4278449415	0.000138096468968	0.0022233422	6
-0.5406605006	0.4257199875	0.00013502412437	0.0040987568	7
-0.5369098986	0.4257199875	0.00013502412437	0.0040987568	8
-0.5609825062	0.4338712731	0.000137240885263	0.0037395168	9
-0.5600763119	0.4338712731	0.000137240885263	0.0037395168	10
-0.5566472265	0.4338712731	0.000137240885263	0.0037395168	11
-0.5371646355	0.4353852685	0.000133194323033	0.0028018694	12
-0.5333417222	0.4353852685	0.000133194323033	0.0028018694	13
-0.5327850679	0.4353852685	0.000133194323033	0.0028018694	14
-0.5032926979	0.4324966957	0.000130724014525	0.0025386645	15
-0.4993788956	0.4324966957	0.000130724014525	0.0025386645	16
-0.4990090054	0.4324966957	0.000130724014525	0.0025386645	17

Data Quality and Processing issues

Because of the mooring work, stations were not occupied in any geographical order. Calibration
groups are affected by water masses and time, so care had to be taken.

Station	Std Location	Station	Std Location
1	9001	10	9011
2	9002	11	9007
3	9003	12	9008
4	9004	13	9015
5	9005	14	9016
6	9006	15	9017
7	9014	16	9010
8	9013	17	9009
9	9012		

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 locations 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.

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.