CTD Calibration Report
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Cruise summary

Ship: USCGC *Healy*
Project Name: DBO NCIS ECO-FOCI
Dates: 7 – 24 August 2018
Ports: Nome, AK

Data files included as part of this distribution

HLY1801_CTD_Calibration_Report.pdf
This document in pdf format

HLY1801_*.dcc***
One 1 dB pressure-averaged file per station following WOCE format specifications for CTD data. Final .dcc files contain primary and secondary sensor pressure, temperature, salinity, oxygen, fluorescence, turbidity, and altimeter data. CTD temperatures, pressures, and conductivities have been scaled with pre-cruise calibrations from the sensor manufacturer.

HLY1801_*.bot_s***
One file per station (when available) following the WOCE format specifications for cruise bottle data. The final .bot_s files contain pressure, temperatures, and conductivities at the location of each bottle stop that have been scaled with pre-cruise calibrations from the sensor manufacturer.

Variable definitions

Final .dcc variable definitions

Pres	Binned pressure (dB)
T90(1)	Calibrated primary temperature (°C)
T90(2)	Calibrated secondary temperature (°C)
Sal(1)	Calibrated primary salinity (psu)
Sal(2)	Calibrated secondary salinity (psu)
OxCur	Oxygen Current (V)
OXYG	Dissolved Oxygen (ml/l)
Trans	Beam Transmission (%)
Flur	Fluorescence (mg/m^3)
Altimeter	Bottom-finding altimeter reading (m)
wocecode	WOCE quality word for each variable

Final .cnut_qc variable definitions

CTD Bottle Number	CTD rosette trigger position (Niskin number)
CTD Pres	CTD pressure (dB)
CTD T1	Calibrated primary temperature (°C)
CTD T2	Calibrated secondary temperature (°C)
CTD TH1	Calculated primary potential temperature (°C)
CTD TH2	Calculated secondary potential temperature (°C)

CTD Sal1	Calibrated primary salinity (psu)
CTD Sal2	Calibrated secondary salinity (psu)
CTD OXY	CTD Dissolved Oxygen (ml/l)
CTD FLUR	CTD Fluorescence (mg/m^3)
CTD TRAN	CTD Beam Transmission (%)
Meas SAL	Bottle salinity (psu)
wocecode	WOCE quality word for each variable

WOCE quality word definitions:
1 = Not calibrated with water samples
2 = Acceptable measurement
3 = Questionable measurement
4 = Bad measurement
9 = not sampled

CTD configuration

General

142 casts were performed using a SeaBird 911plus CTD and deck unit configured to measure pressure, temperature, conductivity, oxygen, beam transmission, and fluorescence. Data from the CTD were acquired at 24 Hz. The CTD data were acquired by an SBE Model 11 plus V2 CTD Deck Unit providing demodulated data to a personal computer running SEASAVE (SeaBird). Bottom approach was controlled by real time altimeter data and ship provided ocean depth information. For each cast, water samples were collected at up to 24 discrete intervals and analyzed for salinity. A rosette frame holding 24 10 L Niskin bottles was used for collecting water samples.

CTD calibrations

Calibrations for CTD sensors were performed by the manufacturer before the cruise. A listing of sensors and calibration dates are presented in the following table. The configuration report file for the SBE 911plus containing sensor calibration coefficients can be found in appendix A.

CTD sensor calibration dates

Sensor Type	Sensor Number	Manufacturer	Calibration Dates	Stations Used
Pressure A	0638	Sea-Bird	21-Dec-17	1
Temperature 1 A	2796	Sea-Bird	06-Dec-17	1
Temperature 2 A	2945	Sea-Bird	06-Dec-17	1
Conductivity 1 A	2568	Sea-Bird	05-Dec-17	1
Conductivity 2 A	2575	Sea-Bird	05-Dec-17	1
Pressure B	0639	Sea-Bird	16-Jan-18	2-142
Temperature 1 B	2855	Sea-Bird	05-Dec-17	2-142
Temperature 2 B	2824	Sea-Bird	02-Dec-17	2-142
Conductivity 1 B	2545	Sea-Bird	05-Dec-17	2-142
Conductivity 2 B	2561	Sea-Bird	05-Dec-17	2-142
Oxygen 1	0459	Sea-Bird	05-Dec-17	1-142
Oxygen 2	0456	Sea-Bird	05-Dec-17	1-142
Transmissometer	CST-390DR	WET Labs C-Star	26-Mar-18	1-142
Fluorescence	flrtd-074	WET Labs ECO-AFL/FL	21-Mar-18	1-142

SeaBird processing

As per manufacturer recommendations, CTD data were processed using SeaBird data processing software (ver. 7.22.0). The raw CTD data were converted from HEX to ASCII, lag corrected, edited for large spikes, smoothed according to sensor, and pressure averaged into 1 dB bins for final data quality control and analysis. Given that HLY1801 took place in a region with strong vertical gradients in both temperature and salinity, special care was taken to choose the best values for the ALIGNCTD module so as to minimize unphysical spikes in derived salinity values. In addition, special care was taken to cut out data prior to and during the surface soak in the DATCNV module. This together with LOOPEDIT ensures that only data from the CTD once equilibrated to the ocean temperature and salinity was included in the final pressure binned data (CTD sensors took roughly 1 min to equilibrate once deployed).

The following table summarizes the processing routines used together with SeaBird-recommended parameters for the sensor configuration used. Additional information regarding SeaBird processing can be found in the lengthy header of each .cdn downcast file.

SeaBird processing routines

SeaBird Module	Description (SeaBird, Version 7.22.0)
DATCNV	Convert the raw data to pressure, temperature, conductivity, and dissolved oxygen
BOTTLESUM	Writes out a summary of the bottle data to a file with a .btl extension
ALIGNCTD	Delaying conductivity by 0.05 seconds relative to pressure minimized salinity spikes through sharp gradients
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 sal	Compute salinity
DERIVE oxy	Compute oxygen from oxygen current (filtered), temperature, and pressure
BINAVG	Average data into the 1 dbar pressure bins
SPLIT	Split .cnv file into upcast and downcast files

CTD sensor performance

General:

After the first CTD station, it was determined that the CTD pressure sensor required replacement. The core CTD unit that contains the pressure sensor also contains the primary and secondary temperature and conductivity sensors. As such, after the first station, the pressure sensor, primary and secondary temperature, and primary and secondary conductivity were all swapped with replacement sensors. All sensors showed normal performance after the swap took place.

Roughly after CTD station 84 the CTD was re-terminated due to a loss in connection with the instrument. Normal CTD functionality continued for the remainder of the cruise.

Manual data edits:
Upon completion of Seabird processing, each CTD profile was assessed for quality of data. Using primary and secondary temperature and conductivity data, density was calculated and inspected for spikes and inversions with respect to pressure. Temperature and conductivity data that resulted in spikes and density inversions were consequently interpolated as a function of pressure.

Additionally, 7 CTD stations were manually edited due to poor data quality in either the primary or secondary sensor suits. The table below summarizes edits made.

CTD Station	Manual Edits
14	Secondary temperature and conductivity suspect, replaced with primary values and recalculated secondary salinity.
15	Secondary temperature and conductivity suspect, replaced with primary values and recalculated secondary salinity.
23	Secondary temperature and conductivity suspect, replaced with primary values and recalculated secondary salinity.
29	Secondary temperature and conductivity suspect, replaced with primary values and recalculated secondary salinity.
40	Secondary temperature and conductivity suspect, replaced with primary values and recalculated secondary salinity.
51	Primary temperature and conductivity suspect, replaced with secondary values and recalculated primary salinity.
110	Primary temperature and conductivity suspect, replaced with secondary values and recalculated primary salinity.

Conductivity sensor performance:
HLY1801 took place in a region with very shallow bottom depths, strong vertical gradients in both temperature and salinity, and large spatial variability in both temperature and salinity. Throughout the cruise a small number of salinity bottle measurements were made as a precautionary effort to monitor CTD conductivity performance. In contrast to the 2017 DNO-NCIS cruise, there were only two CTD casts that exceeded 300 dB, and only 10 CTD stations where salinity bottle data were collected. It is not recommended that a conductivity calibration be performed using the bottle data for the given dataset based on the criteria for creating a statistically meaningful characterization of sensors detailed in reports such as Millard and Yang, 1993, and McTargget et al. 2010.

In order to quantify CTD conductivity performance for the HLY1801 cruise, the primary and secondary conductivity sensors have been regressed against one another. Figures 1-2 in Appendix B. summarize the regression and general performance of sensors. The final slope, bias, standard deviations, and percent error are reported in the table below. The standard deviations reported are defined by the scatter about the fit line and are meant to be an estimate of relative sensor precision. In addition, a calculation of percent error, defined as [(fit – CTD values)/fit] * 100, is given as a relative estimate of sensor accuracy. Overall, a slope of 1.00003 and bias of 0.00194 relate the two conductivity

sensors. The standard deviation about this fit is 0.0333 with an average absolute value in percent error of 0.01676%.

Conductivity 2 vs. Conductivity 1 Regression

Slope	Bias	Standard deviation about fit	Standard deviation when pressure < 400 dB	Standard deviation when pressure > 400 dB
1.00003	0.00194	0.0333 (using 18137 data points)	0.03424 (using 17156 data points)	0.00038 (using 981 data points)

Conductivity 2 vs. Conductivity 1 Percent Error

Average absolute value of percent error	Average absolute value of percent error when pressure < 400 dB	Average absolute value of percent error when pressure > 400 dB
0.02676% (using 18137 data points)	0.02825% (using 17156 data points)	0.00076% (using 981 data points)

Salinity water sample measurements

Summary

69 water samples were collected from 10 stations occupied during the HLY1801 cruise. Samples were analyzed for concentrations and not used to post-calibrate the CTD sensors. Figures 1-2 in Appendix C. show a comparison of CTD temperature-salinity profiles with bottle values for both primary and secondary sensors.

Methods

Water was collected in 200 ml glass bottles. The bottles were rinsed three times, and then filled to the neck. After the samples reached the lab temperature of approximately 24˚C, they were analyzed for salinity using a Guildline Salinometer model 8400 B. The salinometer's bath temperature was set to 24˚C and was standardized before and after each run using IAPSO Standard Seawater. Accuracies of salinity measurements were ±0.002 psu.

References

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. OCE-91-14465.

McTaggart K.E., G.C. Johnson, M.C. Johnson, F.M. Delahoyde, and J.H. Swift. 2010. The GO-SHIP Repeat Hydrography Manual: A collection of Expert Reports and Guidelines, Notes on CTD/O2 data acquisition and processing using Sea-Bird hardware and software. IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1, 2010.

Knapp, G.P., M. Stalcup, and R.J. Stanley. 1990. Automated Oxygen Titration and Salinity Determination. WHOI Technical Report, WHOI-90-35, 25 pp.

Appendix A.

Instrument configuration file: HLY1801_001.XMLCON
Configuration report for SBE 911plus/917plus CTD

```
Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : Yes
NMEA device connected to      : PC
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 2796
   Calibrated on : 06-Dec-17
   G             : 4.30515074e-003
   H             : 6.40946016e-004
   I             : 2.21867494e-005
   J             : 2.03914397e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

2) Frequency 1, Conductivity

   Serial number : 2568
   Calibrated on : 05-Dec-17
   G             : -9.83278292e+000
   H             : 1.50839759e+000
   I             : -2.56797410e-003
   J             : 2.81806946e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0638
   Calibrated on : 21-Dec-17
   C1            : -4.129335e+004
   C2            : 2.366132e-001
   C3            : 1.120910e-002
   D1            : 3.246900e-002
   D2            : 0.000000e+000
   T1            : 3.014179e+001
   T2            : 1.666793e-004
   T3            : 3.283910e-006
```

```
   T4              : 5.609600e-009
   T5              : 0.000000e+000
   Slope           : 0.99939709
   Offset          : -12.88384
   AD590M          : 1.279590e-002
   AD590B          : -9.206300e+000

4) Frequency 3, Temperature, 2

   Serial number : 2945
   Calibrated on : 06-Dec-17
   G             : 4.36606911e-003
   H             : 6.45750216e-004
   I             : 2.31028413e-005
   J             : 2.15338537e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0000

5) Frequency 4, Conductivity, 2

   Serial number : 2575
   Calibrated on : 05-Dec-17
   G             : -1.03058795e+001
   H             : 1.52915137e+000
   I             : 3.13111211e-004
   J             : 7.07729614e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00000000
   Offset        : 0.00000
```

Instrument configuration file: HLY1801_002.XMLCON
Configuration report for SBE 911plus/917plus CTD

```
Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : Yes
NMEA device connected to      : PC
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 2855
   Calibrated on : 05-Dec-17
   G             : 4.30491115e-003
```

H : 6.34269541e-004
I : 2.27106936e-005
J : 2.28060077e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 2545
Calibrated on : 05-Dec-17
G : -1.00066601e+001
H : 1.53902177e+000
I : -1.07704693e-003
J : 1.72679815e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 0639
Calibrated on : 16-Jan-18
C1 : -3.840384e+004
C2 : -2.736111e-001
C3 : 1.081720e-002
D1 : 3.215400e-002
D2 : 0.000000e+000
T1 : 3.019013e+001
T2 : -1.599643e-004
T3 : 3.601120e-006
T4 : 4.889920e-009
T5 : 0.000000e+000
Slope : 0.99961448
Offset : 0.17048
AD590M : 1.275510e-002
AD590B : -9.091326e+000

4) Frequency 3, Temperature, 2

Serial number : 2824
Calibrated on : 02-Dec-17
G : 4.32195007e-003
H : 6.36481029e-004
I : 2.14885818e-005
J : 1.93986208e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 2561
Calibrated on : 05-Dec-17

G : -1.07729798e+001
H : 1.67073234e+000
I : -1.54320863e-003
J : 2.32289466e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 0458
Calibrated on : 05-Dec-17
Equation : Sea-Bird
Soc : 5.00550e-001
Offset : -4.90300e-001
A : -2.95760e-003
B : 1.48040e-004
C : -2.32490e-006
E : 3.60000e-002
Tau20 : 1.32000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Oxygen, SBE 43, 2

Serial number : 0456
Calibrated on : 05-Dec-17
Equation : Sea-Bird
Soc : 5.41240e-001
Offset : -5.08800e-001
A : -3.29380e-003
B : 1.63260e-004
C : -2.86990e-006
E : 3.60000e-002
Tau20 : 1.06000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

8) A/D voltage 2, Transmissometer, WET Labs C-Star

Serial number : CST-390DR
Calibrated on : 26Mar2018
M : 21.6798
B : -1.2704
Path length : 0.250

9) A/D voltage 3, Fluorometer, WET Labs ECO-AFL/FL

Serial number : FLRTD-073
Calibrated on : 21Mar2018
Dark output : 0.0360
Scale factor : 2.30000000e+001

10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor

Serial number : 70682
Calibrated on : 15Jan2018
M : 1.00000000
B : 0.00000000
Calibration constant : 10504201680.67000000
Multiplier : 1.00000000
Offset : -0.09572755

11) A/D voltage 5, Altimeter

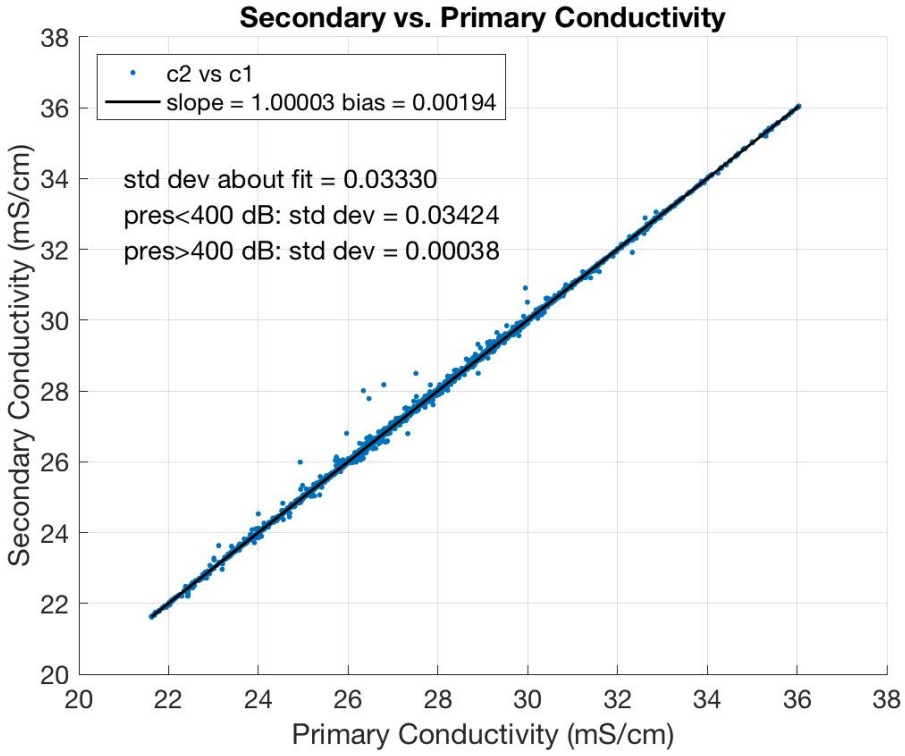
Serial number : 60362
Calibrated on :
Scale factor : 15.000
Offset : 0.000

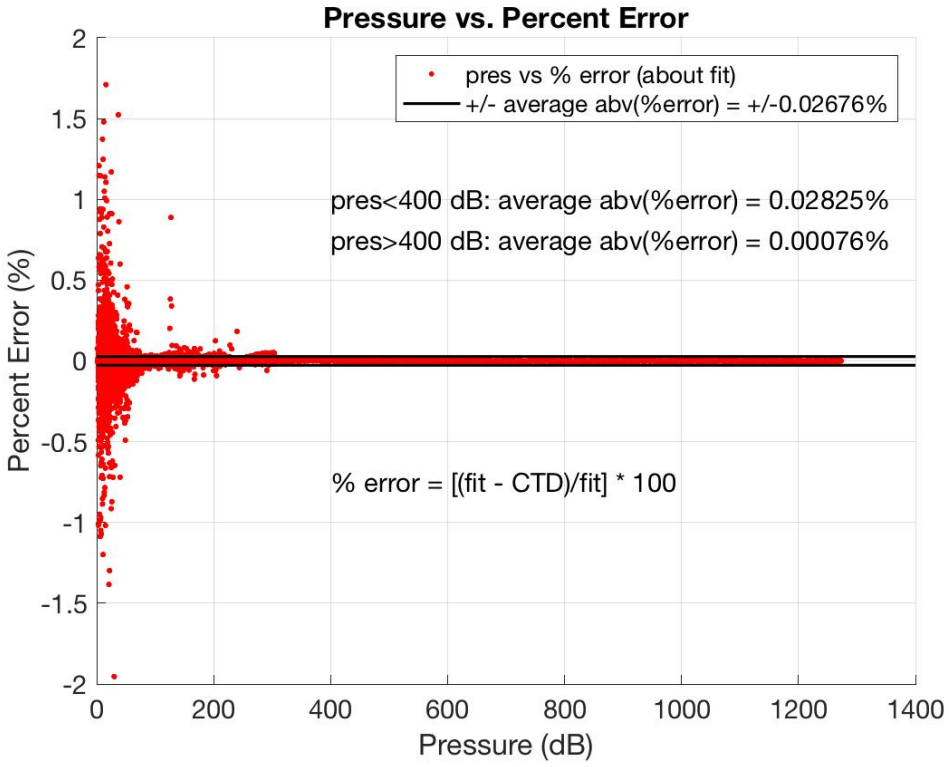
12) A/D voltage 6, Free

13) A/D voltage 7, Free

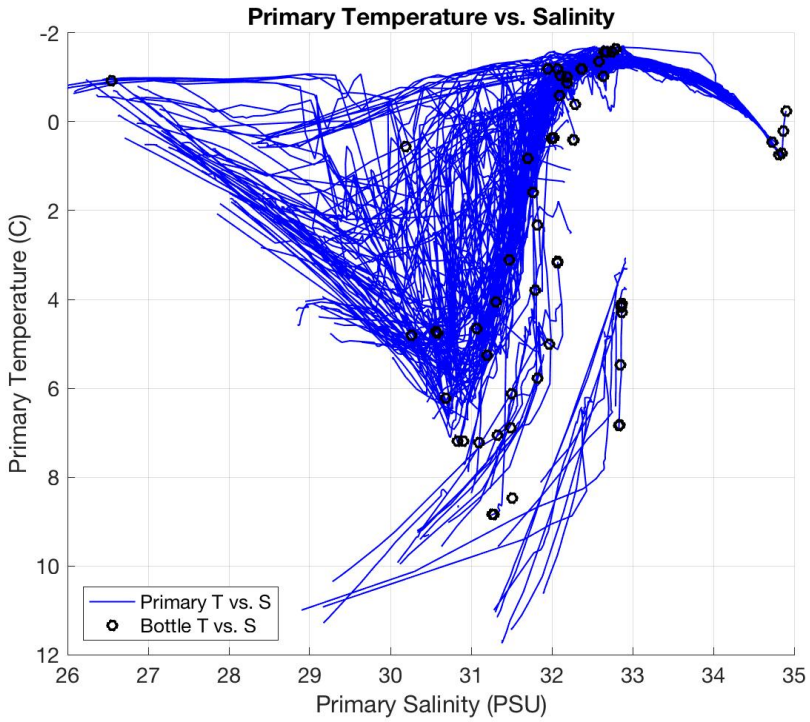
Scan length : 41

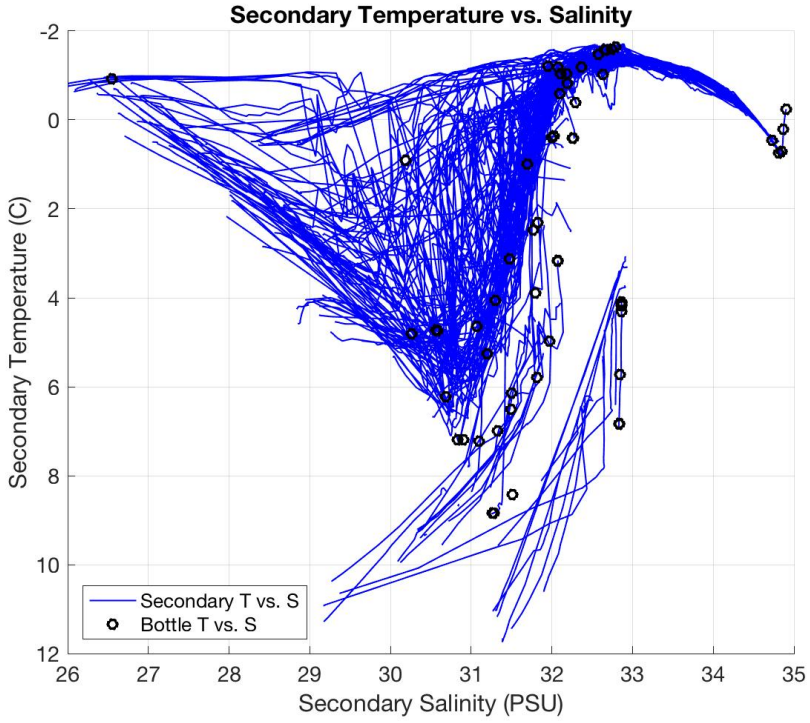
Appendix B.


Secondary vs. Primary Conductivity
c2 vs c1
slope = 1.00003 bias = 0.00194
std dev about fit = 0.03330
pres<400 dB: std dev = 0.03424
pres>400 dB: std dev = 0.00038
Secondary Conductivity (mS/cm)
Primary Conductivity (mS/cm)
20
22
24
26
28
30
32
34
36
38


Pressure vs. Percent Error
pres vs % error (about fit)
+/- average abv(%error) = +/-0.02676%
pres<400 dB: average abv(%error) = 0.02825%
pres>400 dB: average abv(%error) = 0.00076%
% error = [(fit - CTD)/fit] * 100
Percent Error (%)
Pressure (dB)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
200
400
600
800
1000
1200
1400

Appendix C.


Primary Temperature vs. Salinity
Primary Temperature (C)
Primary Salinity (PSU)
Primary T vs. S
Bottle T vs. S
-2
0
2
4
6
8
10
12
26
27
28
29
30
31
32
33
34
35


Secondary Temperature vs. Salinity
Secondary Temperature (C)
Secondary Salinity (PSU)
Secondary T vs. S
Bottle T vs. S
-2
0
2
4
6
8
10
12
26
27
28
29
30
31
32
33
34
35