CTD Calibration Report
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Cruise summary

Ship: USCGC *Healy*
Project Name: DBO-NCIS
Dates: 16 August – 15 September, 2017
Ports: Dutch Harbor, AK – Dutch Harbor, AK

Data files included as part of this distribution

HLY1702_CTD_Calibration_Report.pdf
This document in pdf format

HLY1702_*.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. All CTD salinity data have been post-calibrated using bottle salinity measurements.

HLY1702_*.cbot_s***
One file per station following the WOCE format specifications for cruise bottle data. The final .cbot_s files contain fully calibrated pressure, temperature, salinity, oxygen, fluorescence, and turbidity data at the location of each bottle sample.

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

141 casts were performed using a SeaBird 911plus CTD and deck unit configured to measure pressure, temperature, conductivity, oxygen current, 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	0639	Sea-Bird	16-Nov-16	1-141
Temperature 1	2945	Sea-Bird	08-Nov-16	1-141
Temperature 2	1459	Sea-Bird	08-Nov-16	1-141
Conductivity 1	2545	Sea-Bird	08-Nov-16	1-141
Conductivity 2	2575	Sea-Bird	08-Nov-16	1-141
Oxygen 1	0456	Sea-Bird	04-Nov-16	1-141
Transmissometer	390DR	WET Labs C-Star	03-Mar-17	1-141
Fluorescence	flrtd-073	WET Labs ECO-AFL/FL	27-Jan-17	1-141

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. The following table

summarizes the processing routines used together with SeaBird-recommended parameters for the sensor configuration used.

SeaBird processing routines

SeaBird Module	Description (SeaBird, Version 7.22.0)
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 1 dbar pressure bins
DERIVE sal	Compute salinity
STRIP	Extract columns of data from .cnv files
SPLIT	Split .cnv file into upcast and downcast files

Post-processing conductivity calibrations

Procedure:

HLY1702 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. As such, a simplified 0-order correction was used in post-calibrating the primary and secondary CTD conductivity measurements. The 0-order, or constant offset, correction was defined by using in-situ salinity bottle measurements. Differences between upcast CTD conductivity readings and salinity bottle measurements were used to define an average offset from what should be a zero difference.

Salinity bottle samples were originally taken at the bottom of every cast for HLY1702. After analyzing the first batches of samples, it became clear that obtaining a high-quality salinity measurement was difficult for samples taken shallower than 500 m, due to the high salinity variability in the upper 500 m. Because of this, only salinity bottle samples taken at a depth of 500 m or deeper were used in defining the 0-order correction for the conductivity sensors. Additionally, any CTD and bottle differences that were larger than one standard deviation of all differences considered were not used. This was done as a precaution to avoid aliasing by “fly away” salinity measurements.

Figures 1-4 in Appendix B. help to summarize the final calibration applied to the conductivity sensors. In all, 22 salinity bottle samples were chosen to produce a calibration (of a total of 136). While a small number, these measurements, which represent close to all stations that sampled salinity deeper than 500 m, show a very consistent and small offset for both primary and secondary conductivity sensors.

The following table summarizes the final salinity offset applied to both primary and secondary conductivity sensors, together with the resulting standard deviation of CTD and bottle differences used.

Sensor	0-order correction	Final standard deviation of all differences
Primary (2545)	+ 0.002157	0.0015 psu
Secondary (2575)	+ 0.002213	0.0017 psu

Salinity water sample measurements

Summary

136water samples were collected from most stations occupied during the HLY1702 cruise. Samples were analyzed for concentrations and used to post-calibrate the CTD 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 21˚C, they were analyzed for salinity using a Guildline Salinometer model 8400 B. The salinometer's bath temperature was set to 21˚C and was standardized before and after each run using IAPSO Standard Seawater. Accuracies of salinity measurements were ±0.002 psu. Bottle salinities were assigned a quality control flag based upon the difference between CTD salinity (calibrated) at the same pressure and/or at the same potential temperature.

Appendix A.

Instrument configuration file: HLY1702_000.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 : 2945
Calibrated on : 08-Nov-16
G : 4.36611378e-003
H : 6.45889930e-004
I : 2.32097492e-005
J : 2.17793343e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 2545
Calibrated on : 08-Nov-16
G : -1.00077190e+001
H : 1.53989403e+000
I : -1.38599941e-003
J : 1.89909259e-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-Nov-16
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 : 0.99957647
Offset : -0.16560
AD590M : 1.275510e-002
AD590B : -9.091326e+000

4) Frequency 3, Temperature, 2
Serial number : 1459
Calibrated on : 08-Nov-16
G : 4.82305797e-003
H : 6.67584156e-004
I : 2.45025392e-005
J : 1.88767582e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 2575
Calibrated on : 08-Nov-16
G : -1.03107109e+001
H : 1.53086616e+000
I : -1.51812741e-004
J : 1.01780838e-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 : 0456
Calibrated on : 04-Nov-16
Equation : Sea-Bird
Soc : 5.41440e-001
Offset : -5.24000e-001
A : -3.55230e-003
B : 1.33460e-004
C : -1.83830e-006
E : 3.60000e-002
Tau20 : 9.90000e-001
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, Free

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

Serial number : 390DR
Calibrated on : 3-3-17
M : 21.6630
B : -1.5337
Path length : 0.250

9) A/D voltage 3, Fluorometer, WET Labs ECO-AFL/FL
Serial number : flrtd-073
Calibrated on : 1-27-17
Dark output : 0.0420
Scale factor : 2.50000000e+000

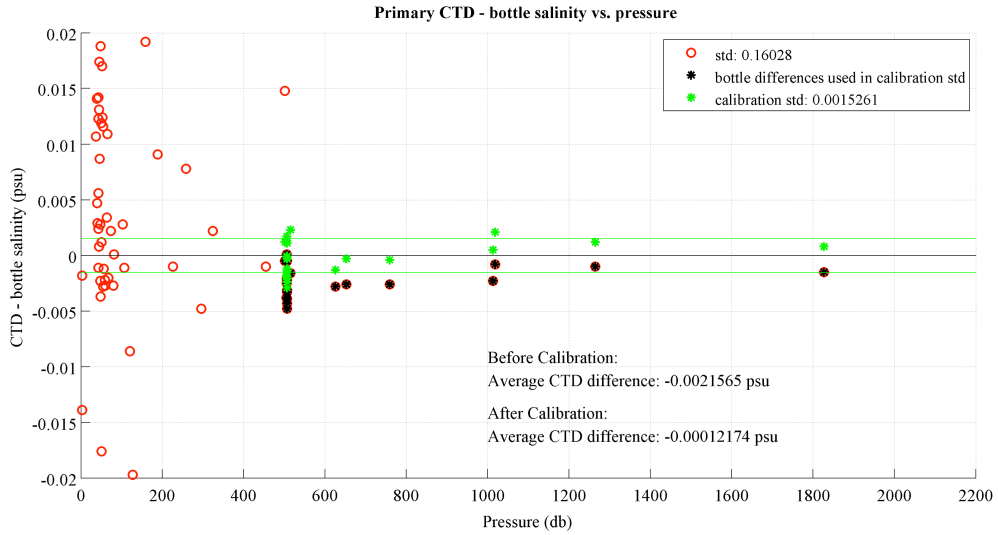
10) A/D voltage 4, Altimeter
Serial number :
Calibrated on :
Scale factor : 15.000
Offset : 0.000

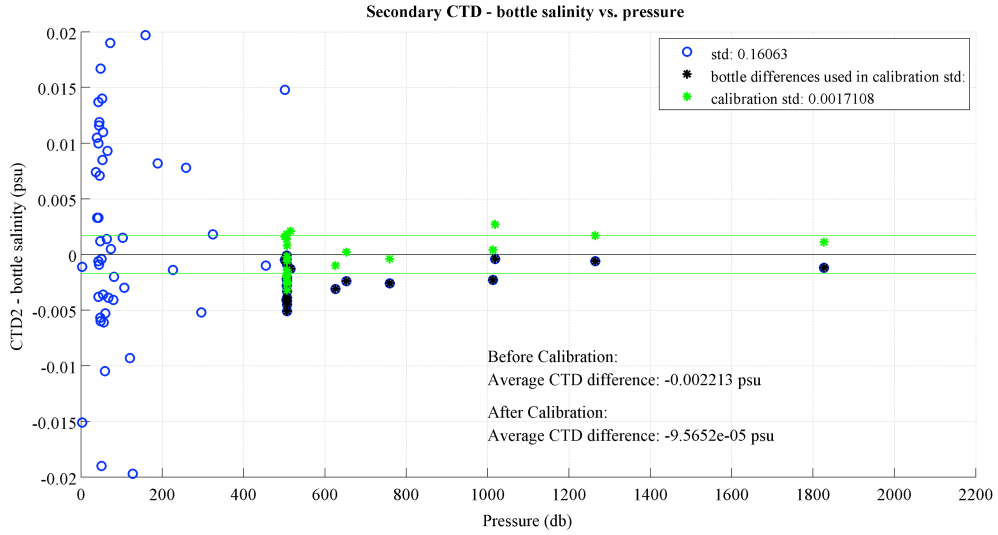
11) A/D voltage 5, Free

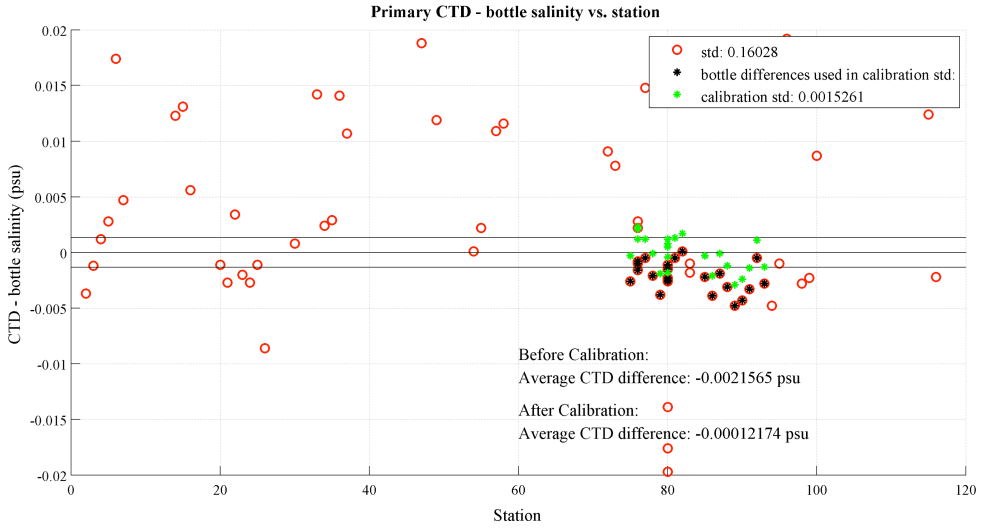
12) A/D voltage 6, PAR/Irradiance, Biospherical/Licor
Serial number : 70112
Calibrated on : 1/26/17
M : 1.00000000
B : 0.00000000
Calibration constant : 11312217194.57000000
Multiplier : 1.00000000
Offset : -0.08864868

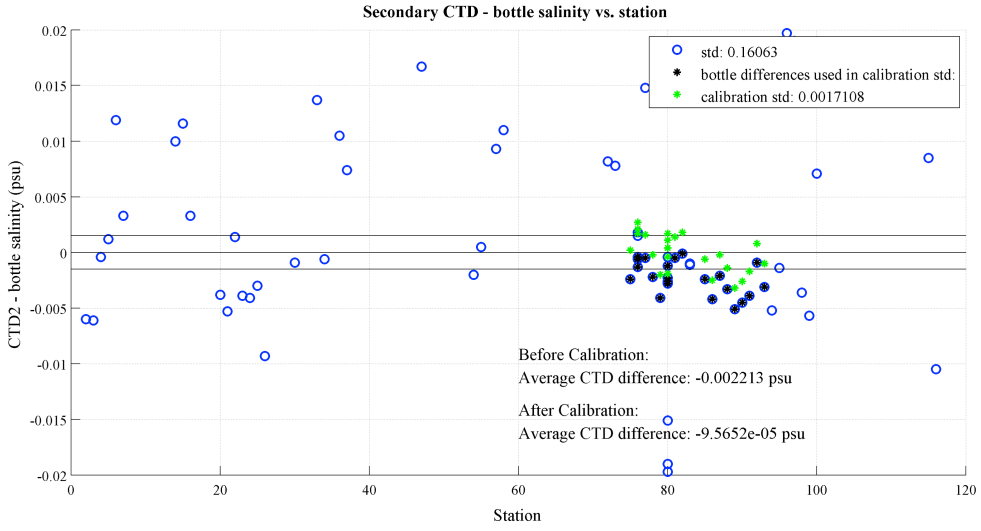
13) A/D voltage 7, Free
Scan length : 41

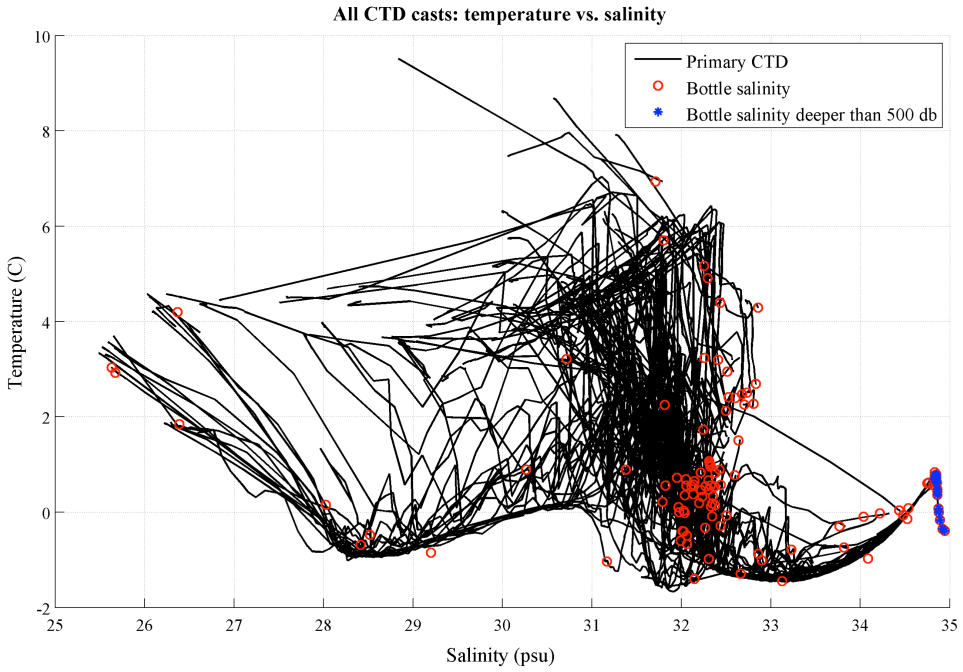
Appendix B.

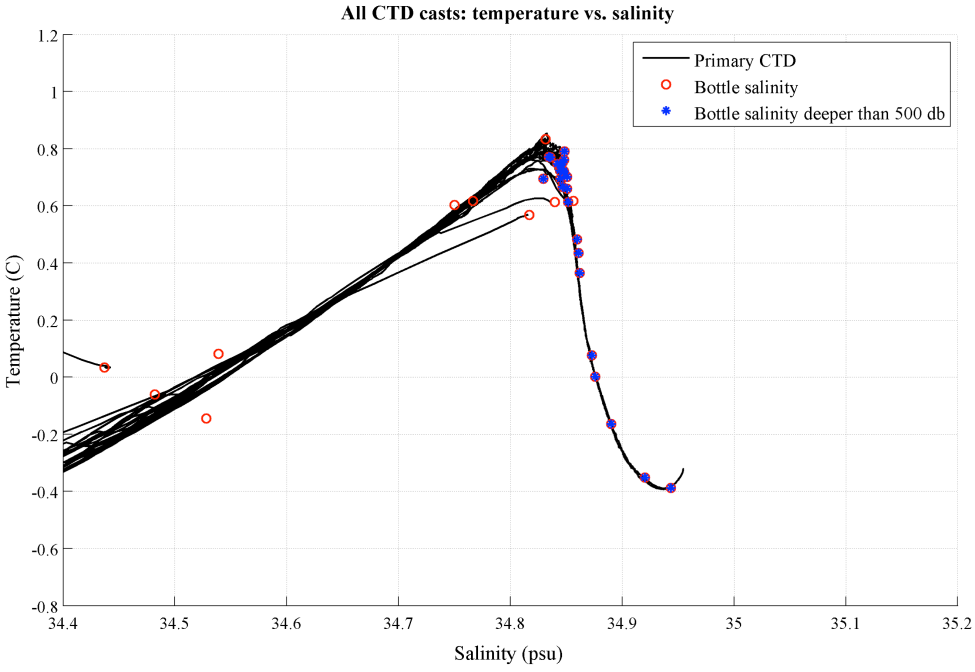

Primary CTD - bottle salinity vs. pressure
std: 0.16028
bottle differences used in calibration std
calibration std: 0.0015261
Before Calibration:
Average CTD difference: -0.0021565 psu
After Calibration:
Average CTD difference: -0.00012174 psu
CTD - bottle salinity (psu)
Pressure (db)


Secondary CTD - bottle salinity vs. pressure
std: 0.16063
bottle differences used in calibration std:
calibration std: 0.0017108
Before Calibration:
Average CTD difference: -0.002213 psu
After Calibration:
Average CTD difference: -9.5652e-05 psu
CTD2 - bottle salinity (psu)
Pressure (db)


Primary CTD - bottle salinity vs. station
std: 0.16028
bottle differences used in calibration std:
calibration std: 0.0015261
Before Calibration:
Average CTD difference: -0.0021565 psu
After Calibration:
Average CTD difference: -0.00012174 psu
CTD - bottle salinity (psu)
Station


Secondary CTD - bottle salinity vs. station
std: 0.16063
bottle differences used in calibration std:
calibration std: 0.0017108
Before Calibration:
Average CTD difference: -0.002213 psu
After Calibration:
Average CTD difference: -9.5652e-05 psu
CTD2 - bottle salinity (psu)
Station


All CTD casts: temperature vs. salinity
Primary CTD
Bottle salinity
Bottle salinity deeper than 500 db
Temperature (C)
Salinity (psu)
10
8
6
4
2
0
-2
25
26
27
28
29
30
31
32
33
34
35


All CTD casts: temperature vs. salinity
Primary CTD
Bottle salinity
Bottle salinity deeper than 500 db
Temperature (C)
Salinity (psu)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
34.4
34.5
34.6
34.7
34.8
34.9
35
35.1
35.2