AR60 CTD Calibration Report

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Cruise summary

Ship: RV *ARMSTRONG*
Project Name: OOI Irminger Sea 8 Deployment
Dates: August 3 – 26, 2021
Ports: Woods Hole, MA – Reykjavik, Iceland

Data files included as part of this distribution

AR60_CTD_Calibration_Report.pdf
This document in pdf format

*AR60_****.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, and salinity data at the location of each bottle sample.

*AR60_****.dcc*
One 24 Hz file per station following WOCE format specifications for CTD data. Final .dcc files contain CTD sensor pressure, time, temperature, salinity, oxygen, 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. These files have been provided for the purposes of SBE Microcat calibration. *Bottle-calibrated CTD oxygen data are not included in these files.*

Variable definitions

Final .dcc variable definitions

Pres	Binned pressure (db)
T90(1)	Calibrated temperature (°C)
Sal(1)	Calibrated salinity (psu)
OxCur	Oxygen Current (V)
OXYG	Dissolved Oxygen (ml/l)
wocecode	WOCE quality word for each variable

Final .cbot_s variable definitions

CTD Bottle Number	CTD rosette trigger position (Niskin number)
CTD Pres	CTD pressure (db)
CTD T1	Calibrated temperature (°C)
CTD TH1	Calculated potential temperature (°C)
CTD Sal1	Calibrated salinity (psu)
CTD OXY	CTD Dissolved Oxygen (ml/l)
Meas SAL	Bottle salinity (psu)
QUAL	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

12 casts were performed using a SeaBird 911plus CTD and deck unit configured to measure pressure, temperature, conductivity, and oxygen current. 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 a number of parameters including salinity and dissolved oxygen. 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 manufacture before the cruise. A listing of sensors and calibration dates are presented in the following table.

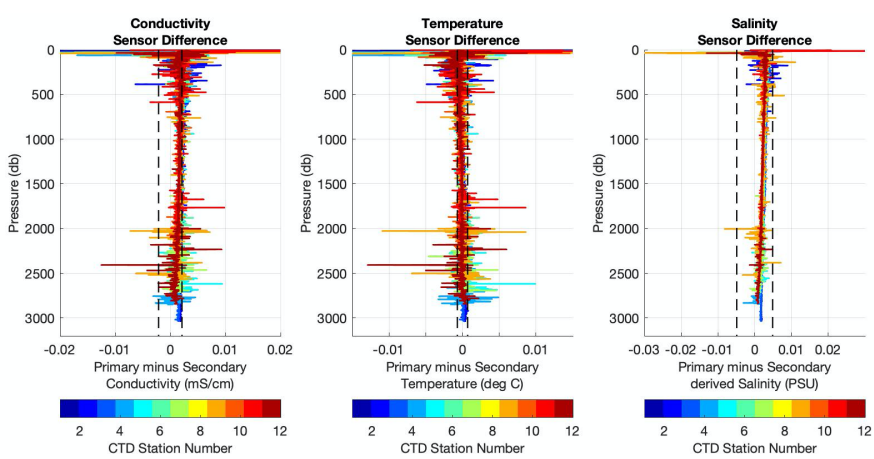
CTD sensor calibration dates

Sensor Type	Sensor Number	Manufacturer	Calibration Dates	Stations Used
Pressure	0383	Sea-Bird	14-Jul-21	1-12
Temperature 1	4973	Sea-Bird	11-May-19	1-12
Temperature 2	5045	Sea-Bird	25-Jul-20	1-12
Conductivity 1	3522	Sea-Bird	14-May-19	1-12
Conductivity 2	4698	Sea-Bird	15-May-19	1-12
Oxygen	0444	Sea-Bird	08-Jul-21	1-12
Fluorometer	FLNTURT-969	WET Labs	09-May-2019	1-12
Turbidity	FLNTURT-969	WET Labs	09-May-2019	1-12
Transmissometer	CST-1116	WET Labs	15-July-2021	1-12

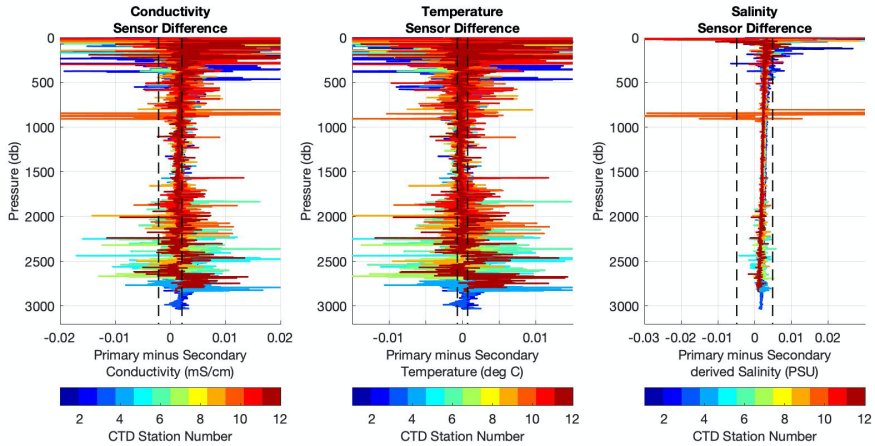
Summary of CTD performance, events, and problems

Stations 1-12: There existed no evidence of temperature or conductivity sensor drift throughout the cruise based on primary and secondary differences. Below figures summarize sensor difference <u>prior</u> to bottle calibration for all downcast data and all upcast data.

Downcast sensor differences:



Upcast sensor differences:



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 2 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
BOTTLESUM	Writes out a summary of the bottle data to a file with a .btl extension
ALIGNCTD	Advance oxygen by 3.5 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 (0.25 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 2 db pressure bins
SPLIT	Split .cnv file into upcast and downcast files

Post-processing conductivity calibrations

Basic fitting procedure

CTD salinity data were further calibrated by utilizing water sample salinity measurements. WHOI post-processing fitting procedures are modeled after methods used in Millard and Yang, 1993. CTD conductivity and water sample salinity differences were characterized as a function of pressure and time. One fit was created by grouping together data from all CTD stations occupied. The group was fit for a slope and bias adjustment using only water sample data that were within a defined physical range of CTD values. The slope term is a polynomial function of the station number based upon chronological station collection order. 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 [db]*
m - *conductivity slope*
b - *conductivity bias [mS/cm]*
β - *linear pressure term [mS/cm/db]*

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

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

Results

The polynomial functions determined for both primary and secondary sensor data are presented in the following table. Stations were fit in a single grouping for determining post-calibration values. Once calibrated, the overall standard deviation of the primary CTD conductivity measurements (s/n 3522) and water sample differences is **0.0019 psu**. The overall standard deviation of the secondary CTD conductivity measurements (s/n 4698) and water sample differences is **0.0018 psu**. Figures that summarize conductivity calibrations are included in **Appendix A**.

Final CTD conductivity calibration parameters

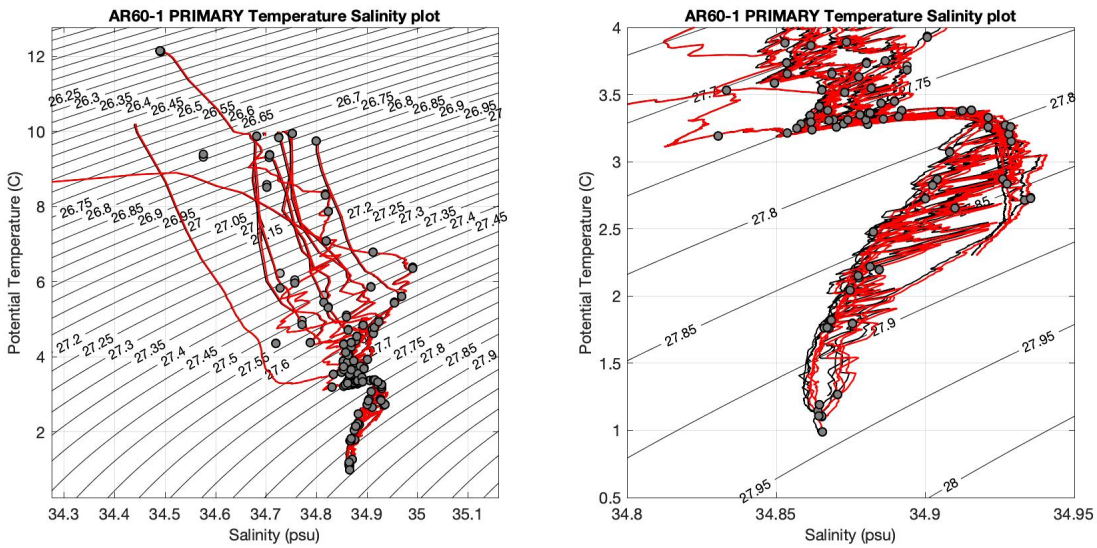
Sensor	**Stations**	**Bias**	**Slope (min/max)**	**Beta**	**Final standard deviation**
Primary					
3522	1-12	-0.01010563	1.00029451/1.00034557	2.76639106e-07	0.0019
Secondary					
4698	1-12	-0.01281884	1.00045190/1.00050406	-1.05070957e-07	0.0018

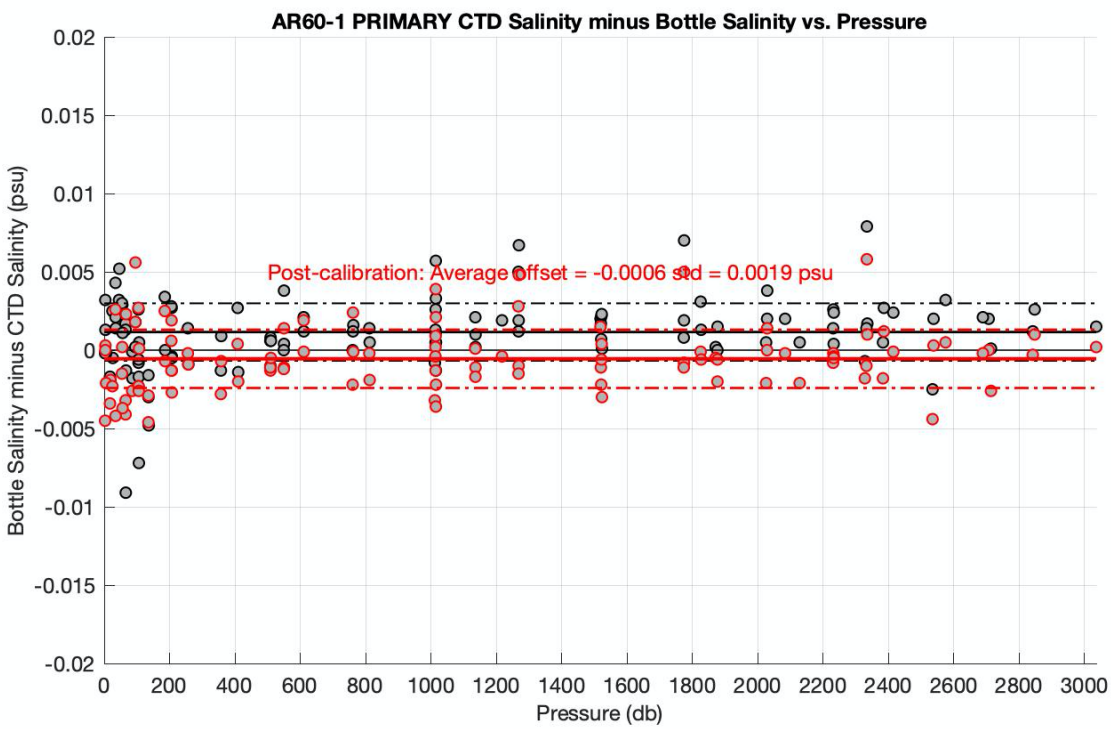
CTD data usage recommendations

Overall, data from both the primary and secondary sensors were of good quality and reflected manufacturer expectations. Apparent in both the SBE calibration sheet as well as the bottle calibration fits, the secondary sensor had drifted in calibration more than the primary sensor. Hence, it is recommended that data from the primary CTD channel are used for hydrographic and instrument calibration purposes.

Appendix A

Primary conductivity post-calibration summary. Black indicates CTD data before bottle calibration, red indicates CTD values after CTD calibration.





Secondary conductivity post-calibration summary. Black indicates CTD data before bottle calibration, blue indicates CTD values after CTD calibration.