AR69-01 CTD Calibration Report
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Cruise summary

Ship: RV *ARMSTRONG*
Project Name: OOI Irminger Sea 9 Deployment
Dates: 20 June – 17 July 2022
Ports: Woods Hole, MA – Reykjavik, Iceland

Data files included as part of this distribution

AR69-01_CTD_Calibration_Report.pdf
This document in pdf format

*AR69-01_****.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.

*AR69-01_****.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

23 casts were performed using a SeaBird 911plus CTD and V2 deck unit providing demodulated data to a computer running SEASAVE (SeaBird) at sea. Data from the CTD were acquired at 24 Hz. 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 Name	Serial Num	Cal Date
Temperature	4491	30-Jul-21
Conductivity	3009	30-Jul-21
Pressure, Digiquartz with TC	0383	14-Jul-21
Temperature, 2	4492	30-Jul-21
Conductivity, 2	3521	29-Jul-21
Altimeter	VA500-46506	2018
Oxygen, SBE 43	1960	31-Jul-21
Fluorometer, WET Labs ECO-AFL/FL	FLNTURT-969	2019-05-09
Turbidity Meter, WET Labs, ECO-NTU	FLTURT-969	2019-May-19
Transmissometer, WET Labs C-Star	CST-1116	2021-July-15
Fluorometer, WET Labs ECO CDOM	FLCDRTD-1964	20161118

Summary of CTD performance, events, and problems

21 June 2022

CTD test casts 1 and 2 were performed during the first day of transit from Woods Hole to test a new altimeter. Very unphysical data were recorded.

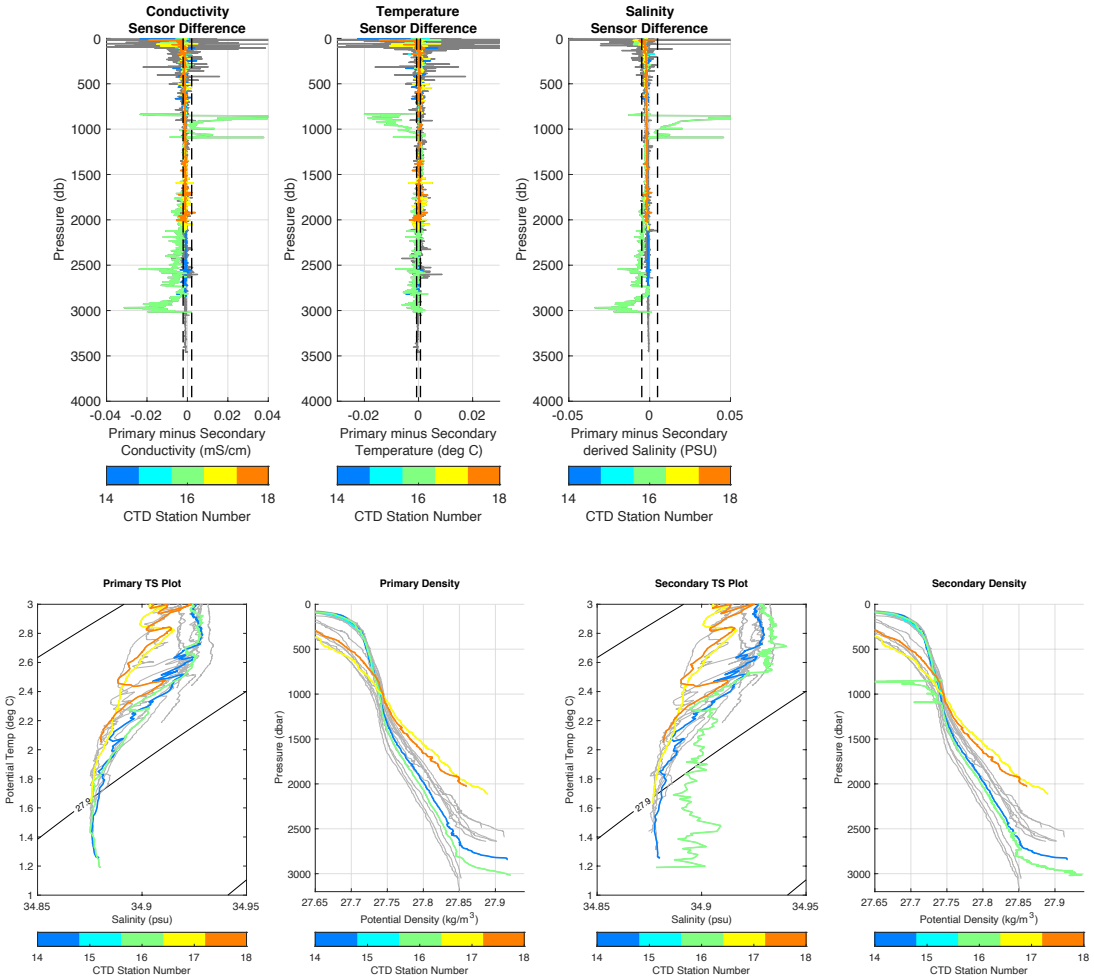
25 June 2022

CTD station 3 was a test cast to 1000 m. During CTD station 4 (microcat calibration cast #1), communication with the CTD failed at 1800 m during the downcast. Communication was reestablished during the upcast near 450 m. The CTD was then lowered back down to 600 m to test for communication loss by SSSG. A small number of salinity samples were taken on this cast.

An old CTD fish was tested during station 5 in the event it was needed. A problem with the ‘Y’ cable was identified and the new fish was installed back on the CTD package. This sensor configuration was used for the remainder of the cruise

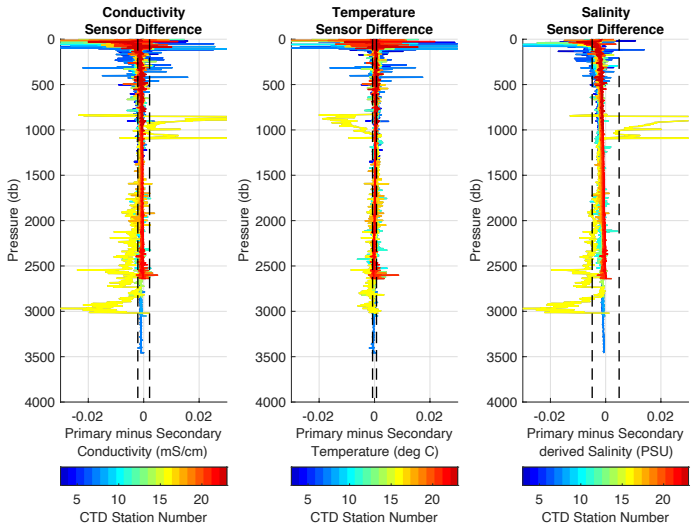
4 July 2022

During cast 16, biofouling occurred near 700 m during the downcast. Data in the secondary sensor channel were impacted. The problem persisted until the completion of the cast and impacted the entire upcast. The problem was fixed with sensor flushing and there were no more issues on the next cast. Summary figures below.

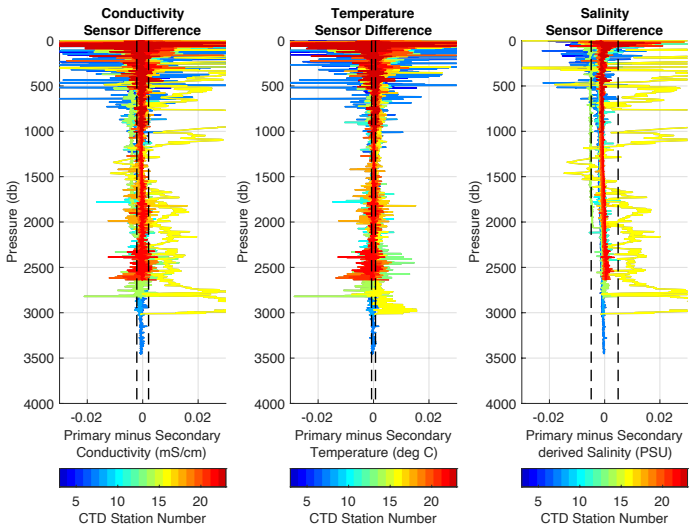


Stations 3-23: Except for station 16, there existed no evidence of temperature or conductivity sensor drift throughout the cruise based on primary and secondary differences. Below figures summarize sensor difference <u>prior</u> to bottle calibration for all downcast data and all upcast data.

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. SeaBird processing routines used are reported in **Appendix A**.

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 using data from stations 17-22, which were all deep stations that collected water samples evenly throughout the water column. This fit was then used to calibrate stations 6-23. Once calibrated, the overall standard deviation of the primary CTD conductivity measurements (s/n 3009) and water sample differences is **0.002 psu**. The overall standard deviation of the secondary CTD conductivity measurements (s/n 3521) and water sample differences is **0.002 psu**. Figures that summarize conductivity calibrations are included in **Appendix B**.

Final CTD conductivity calibration parameters

Sensor	**Stations**	**Bias**	**Slope (min/max)**	**Beta**	**Final standard deviation**
Primary					
3009	6-23	-0.01476735	1.00054808/1.00055523	-1.03574467e-07	0.002
Secondary					
3521	6-23	-0.00792895	1.00028750/1.00031534	2.74622887e-07	0.002

CTD data usage recommendations

Summary of CTD sites:

- Stations 3-8 performed during transit through Labrador Sea (stations 1-5 are not included in the final data)
- Stations 9:22 were all within the OOI/OSNAP operational region
    - Stations 9, 12, 13, 14, 15, 19-22 within vicinity of OOI array and glider deployment
    - Station 10 near OSNAP M3
    - Station 11: near OSNAP M2
    - Station 16: near OSNAP M4 (use primary data only)
    - Station 17-18: near OSNAP M1
- Microcat caldip stations: 7 (redo of station 4), 8, 18, 20, 21, 22
- LADCP test at station 23 during the transit to Iceland

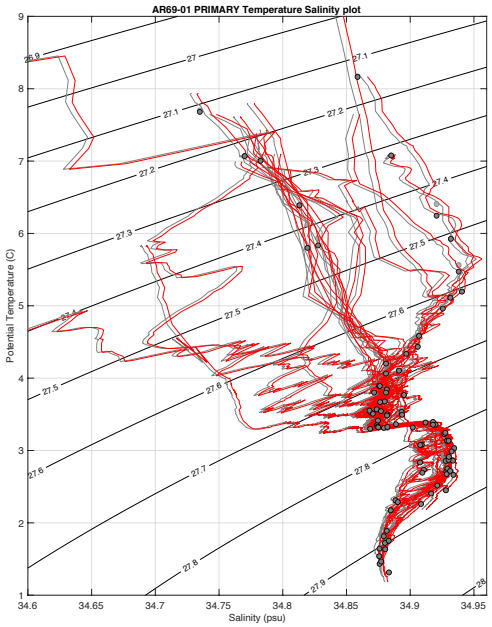
Overall, data from both the primary and secondary sensors were of good quality and reflected manufacturer expectations once hardware issues were sorted out (by cast 6). Except for cast 16, both primary and secondary data are suitable for instrument calibration and validation purposes. Primary data only should be used for cast 16 as biofouling impacted both the downcast and upcast.

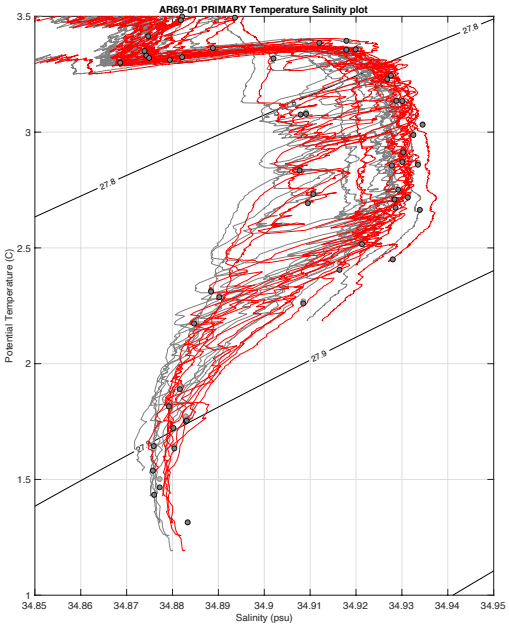
Appendix A

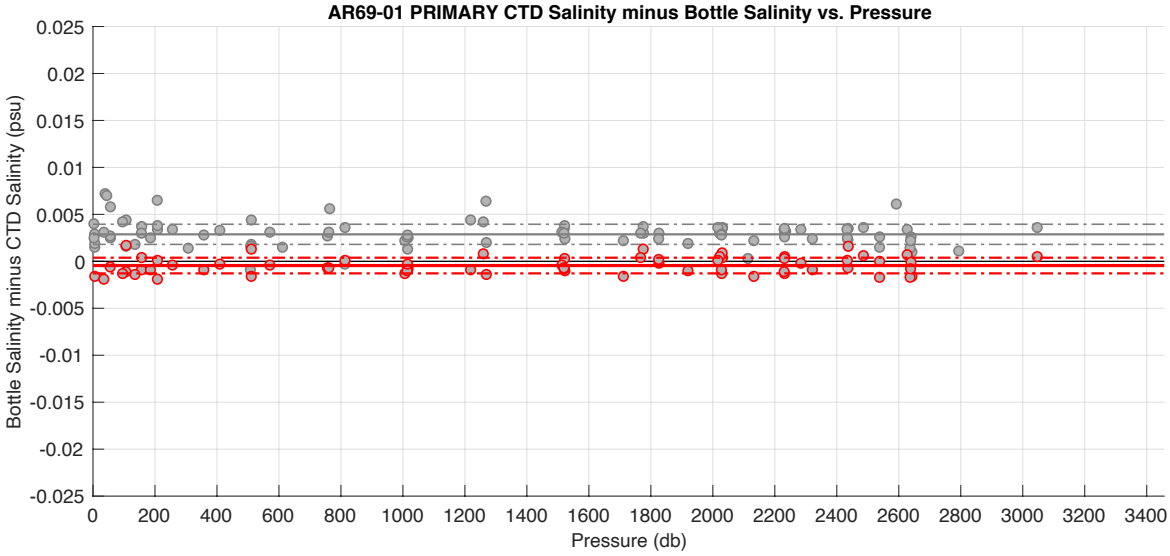
```
# datcnv_date = Aug 16 2022 15:22:19, 7.26.7.129 [datcnv_vars = 17]
# datcnv_in = C:\data\ctd\OOI\AR69-01\raw\ar69-01_019.hex C:\data\ctd\OOI\AR69-01\raw\ar69-
01_019.XMLCON
# datcnv_skipover = 486
# datcnv_ox_hysteresis_correction = no
# datcnv_ox_tau_correction = no
# wildedit_date = Aug 16 2022 15:22:28, 7.26.7.129
# wildedit_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# wildedit_pass1_nstd = 2.0
# wildedit_pass2_nstd = 20.0
# wildedit_pass2_mindelta = 1.000e-003
# wildedit_npoint = 100
# wildedit_vars = prDM depSM t090C t190C c0mS/cm c1mS/cm flECO-AFL CStarTr0 svCM altM sbeox0V
sal00 sal11 sbeox0ML/L sbox0Mm/Kg
# wildedit_excl_bad_scans = yes
# celltm_date = Aug 16 2022 15:22:34, 7.26.7.129
# celltm_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# celltm_alpha = 0.0300, 0.0300
# celltm_tau = 7.0000, 7.0000
# celltm_temp_sensor_use_for_cond = primary, secondary
# filter_date = Aug 16 2022 15:22:41, 7.26.7.129
# filter_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# filter_low_pass_tc_A = 0.300
# filter_low_pass_tc_B = 0.150
# filter_low_pass_A_vars = prDM depSM
# filter_low_pass_B_vars = svCM
# loopedit_date = Aug 16 2022 15:22:54, 7.26.7.129
# loopedit_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# loopedit_minVelocity = 0.000
# loopedit_surfaceSoak: minDepth = 5.0, maxDepth = 20, useDeckPress = 0
# loopedit_excl_bad_scans = yes
# Derive_date = Aug 16 2022 15:23:06, 7.26.7.129 [derive_vars = 4]
# Derive_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv C:\data\ctd\OOI\AR69-01\processed\ar69-
01_019.XMLCON
# derive_time_window_docdt = seconds: 2
# derive_ox_tau_correction = no
# binavg_date = Aug 16 2022 15:23:15, 7.26.7.129
# binavg_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# binavg_bintype = decibars
# binavg_binsize = 2
# binavg_excl_bad_scans = yes
# binavg_skipover = 0
# binavg_omit = 0
# binavg_min_scans_bin = 1
# binavg_max_scans_bin = 2147483647
# binavg_surface_bin = no, min = 0.000, max = 0.000, value = 0.000
# split_date = Aug 16 2022 15:23:22, 7.26.7.129
# split_in = C:\data\ctd\OOI\AR69-01\processed\ar69-01_019.cnv
# split_excl_bad_scans = yes
```

Appendix B

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.