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## Submission Read Me

**Submission title:** Salinity-calibrated Conductivity Temperature Depth (CTD) data from the 2021 Ocean Observations Initiative (OOI) Irminger Sea 8 cruise (AR60-01).

### Summary:

**Cruise:** AR60-01, DOI: <https://doi.org/10.7284/909249>

**Dates:** 3 August, 2021 – 26 August, 2021

**Start Port:** Woods Hole, MA, USA

**End Port:** Reykjavík, Iceland

### Description:

This submission contains salinity-calibrated Conductivity Temperature Depth (CTD) data from the 2021 Ocean Observations Initiative (OOI) Irminger Sea 8 cruise (AR60-01). Data quality control methods have been used to assess performance of the CTD instrument. Resulting high-quality profiles were then used together with salinity bottle data analyzed at sea to create a post-cruise salinity-calibrated CTD product.

This submission has been produced as part of an ongoing effort to more fully utilize CTD data collected by OOI Irminger cruises, which have been taking place annually since 2014. The hydrographic data collection facilitated by OOI in the Irminger Sea currently supports science for not only OOI end users, but also international oceanographic research projects, including the Overturning in the Subpolar North Atlantic Program (<https://www.o-snap.org/>), Atlantic Meridional Overturning Circulation Program (<https://usclivar.org/amoc>) and BioGeoChemical Array for Real-time Geostrophic Oceanography program (<https://biogeochemical-argo.org/index.php>). Such programs require a higher-level data product than what OOI provides through its standard data dissemination, and hence a quality controlled, salinity-calibrated data product has been produced.

This submission contains calibrated data from the OOI Irminger 8 cruise (AR60-01). Funding for data collection has been supported by “Ocean Observatories Initiative, NSF OCE-1743430.” Additional support for data processing and submission efforts was provided by the Burke OOI Innovation Fund (via Woods Hole Oceanographic Institution), and “Overturning in the Subpolar North Atlantic Program, NSF OCE-1948505 and OCE-1756363.”

### Methods:

#### Data collection

CTD casts were performed using a ship-provided Sea Bird 911plus CTD and deck unit (<http://www.seabird.com//sbe911plus-ctd>) configured to measure pressure, temperature, conductivity, oxygen current, and other variables. The CTD data were acquired by an SBE Deck Unit providing demodulated data to a personal computer running SEASAVE (<http://www.seabird.com/software/seasave-v7>) acquisition software. Calibrations for CTD sensors were performed by the manufacturer before the cruise.

#### SeaBird processing

As per manufacturer recommendations, CTD data are processed using SeaBird data processing software. The raw 24 Hz CTD data are converted from HEX to ASCII, lag corrected, edited for large spikes,

smoothed according to sensor, and pressure averaged for final data quality control and analysis. Below is a summary of inputs used for each module applied.

Table 1: SeaBird data processing module inputs

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 are 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 are characterized as a function of pressure and time. A fit is created by grouping together data from CTD stations. The group is fit for a slope and bias adjustment using only water sample data that was 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 [dbar]

$m$  - conductivity slope

$b$  - conductivity bias [mS/cm]

$\beta$  - linear pressure term [mS/cm/dbar]

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

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

## Calibration 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**.

Table 2: Final CTD conductivity calibration parameters

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

## Final data:

### Format descriptions

The .dcc and .ucc file format (ASCII file) is commonly used at Woods Hole Oceanographic Institution for CTD data that have received a higher level of data processing than normally provided through standard practices. Each dcc and ucc file contains (downcast and upcast data, respectively) pressure-averaged data for one CTD station following the World Ocean Circulation Experiment (<https://www.osti.gov/biblio/149787-world-ocean-circulation-experiment-woce-operations-manual-volume-observational-programme-section-woce-hydrographic-programme-part-whp-operations-methods-revision>) format and quality specifications for CTD 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.

### Final file 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)
uOXY	Dissolved Oxygen (µm/kg)
Trans	Beam Transmission (%)
Flur	Fluorescence (mg/m3)
Altimeter	Bottom-finding altimeter reading (m)
nscans	Number of CTD scans used in pressure bin-averaging
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

The cbot\_s file format is used at Woods Hole Oceanographic Institution for CTD bottle data that have received a higher level of data processing than normally provided through standard practices. Each cbot\_s file contains fully calibrated in-situ CTD values at bottle stop pressures together with water sample measurements of salinity.

Final cbot\_s file variable definitions

CTD Bottle number	Trigger location of Niskin bottle
CTD Pres.	CTD pressure (db)
CTD T1(90)	Calibrated CTD primary temperature (°C)
CTD T2(90)	Calibrated CTD secondary temperature (°C)
CTD TH1(68)	Derived CTD primary potential temperature (°C)
CTD TH2(68)	Derived CTD secondary potential temperature (°C)
CTD SAL1	Calibrated CTD primary salinity (psu)
CTD SAL2	Calibrated CTD secondary salinity (psu)
CTD OXY	Dissolved oxygen (ml/l)
CTD OXYu	Dissolved oxygen (µm/kg)
Meas SAL	Bottle sample salinity (psu)
QUAL	WOCE quality code as detailed above

### 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.

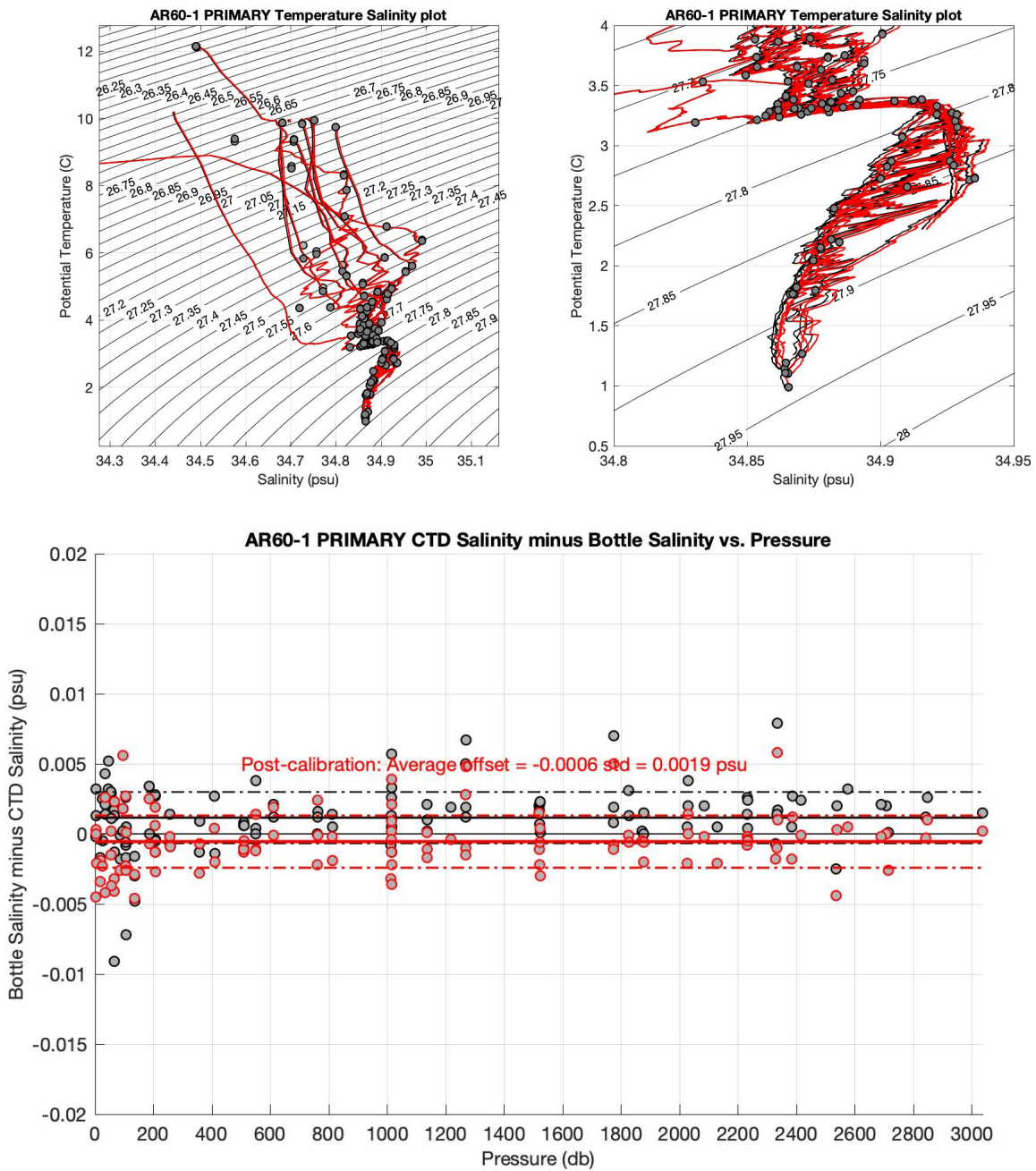
*For more information pertaining to this dataset, please contact the distributors.*

### 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

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.

