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## Submission Read Me

**Submission title:** Salinity-calibrated Conductivity Temperature Depth (CTD) data from the 2020 Ocean Observations Initiative (OOI) Irminger Sea 7 and Overturning in the Subpolar North Atlantic Program – Greenland Deep Western Boundary Current (ONSAP GDWBC) cruise (AR46).

### Summary:

**Cruise:** AR46, DOI: <https://doi.org/10.7284/908990>

**Dates:** 8 August 2020 – 5 September 2020

**Start Port:** Woods Hole, MA

**End Port:** Woods Hole, MA

### Description:

This submission contains salinity-calibrated Conductivity Temperature Depth (CTD) data from the 2020 Ocean Observations Initiative (OOI) Irminger Sea 7 and Overturning in the Subpolar North Atlantic Program – Greenland Deep Western Boundary Current (ONSAP GDWBC) cruise (AR46). 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 7 cruise (AR46). 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.

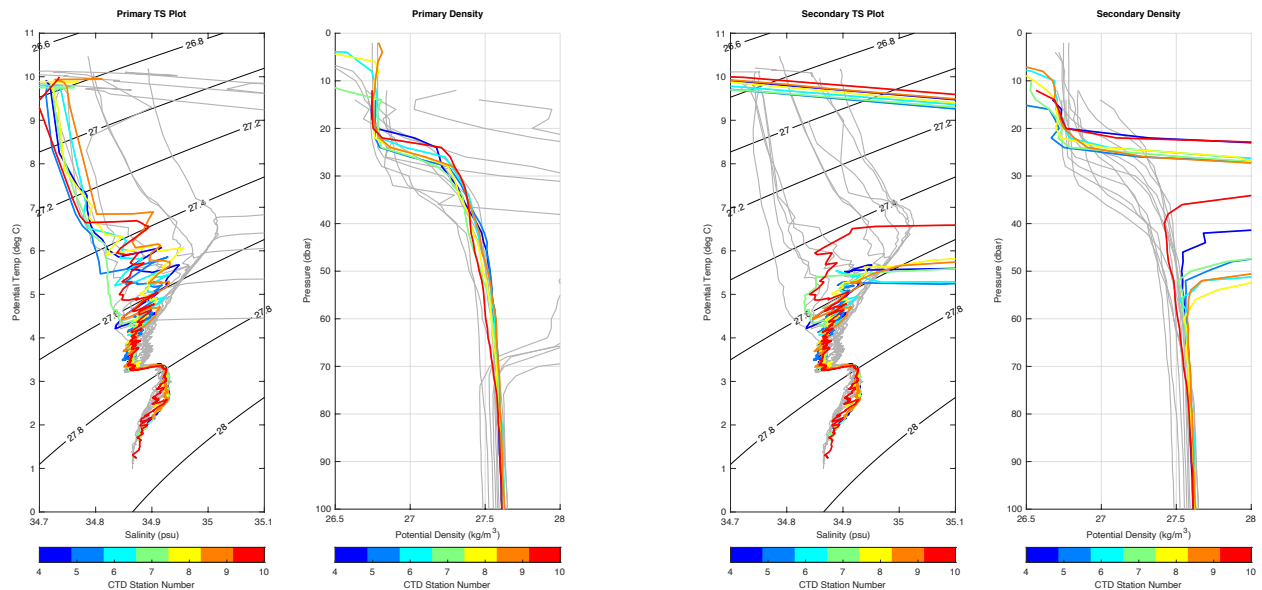
Table 1: SeaBird data processing module inputs

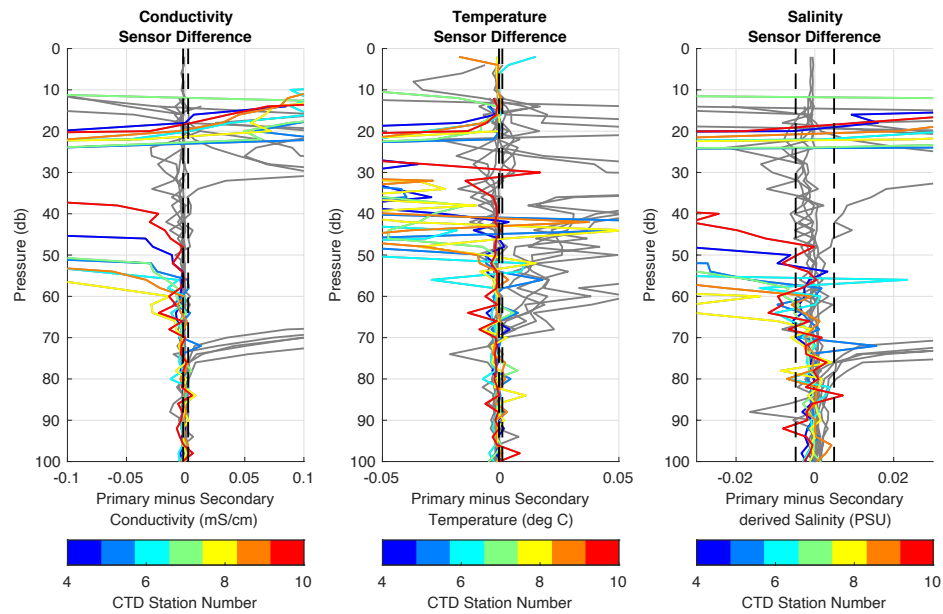
SeaBird Module	Description (SeaBird, Version 7.22.0)
DATCNV	Convert the raw data to pressure, temperature, conductivity, and dissolved oxygen
BOTTLESUM	Writes out a summary of the bottle data to a file with a .btl extension
ALIGNCTD	Advance oxygen by 3.5 seconds relative to pressure
WILDEDIT	Checks for 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

## Summary of CTD performance, events, and problems

### Stations 4 – 10:

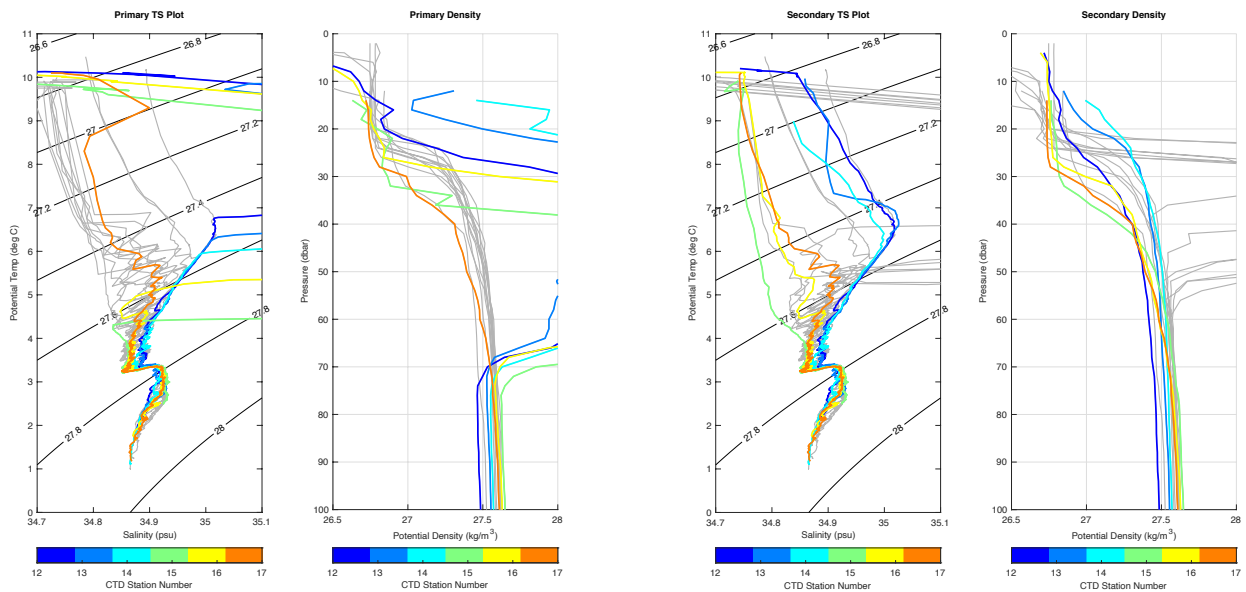
Throughout stations 4 – 10 there existed unphysical secondary temperature and conductivity data within approximately the upper 60 meters. Unphysical data resulted in large density inversions and unusable data in the secondary sensor suite. The cause was most likely related to biofouling of only the secondary line. Primary temperature and conductivity do not appear to have been affected.

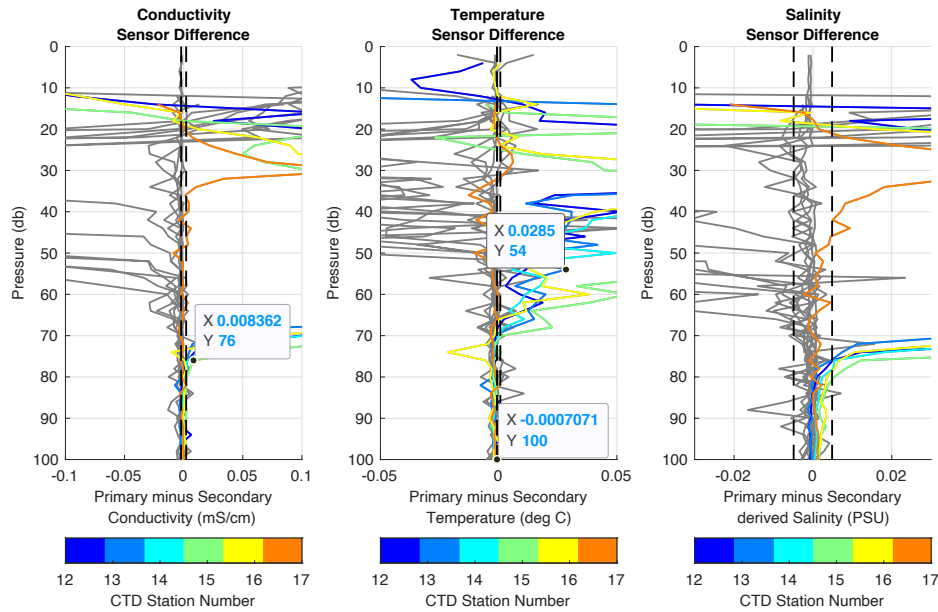




### *Stations 12 – 17:*

Throughout stations 12 – 17 there existed unphysical primary temperature and conductivity data within approximately the upper 70 meters. Unphysical data resulted in large density inversions and unusable data in the primary sensor suite. The cause was most likely related to biofouling of only the primary line. Secondary temperature and conductivity do not appear to have been affected.





## 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:

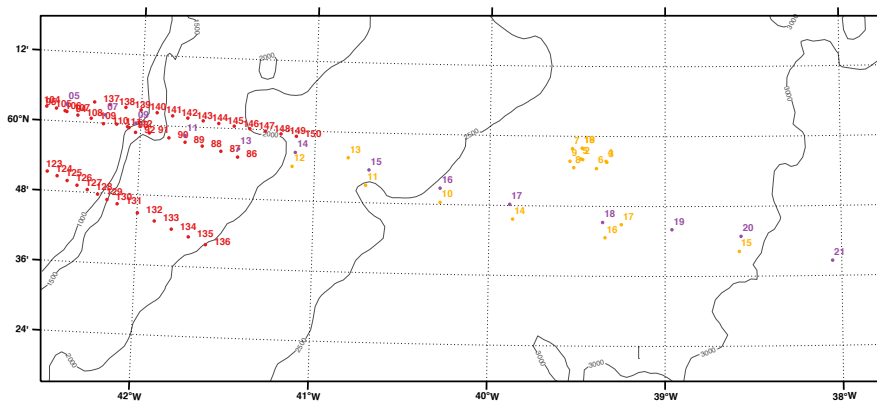
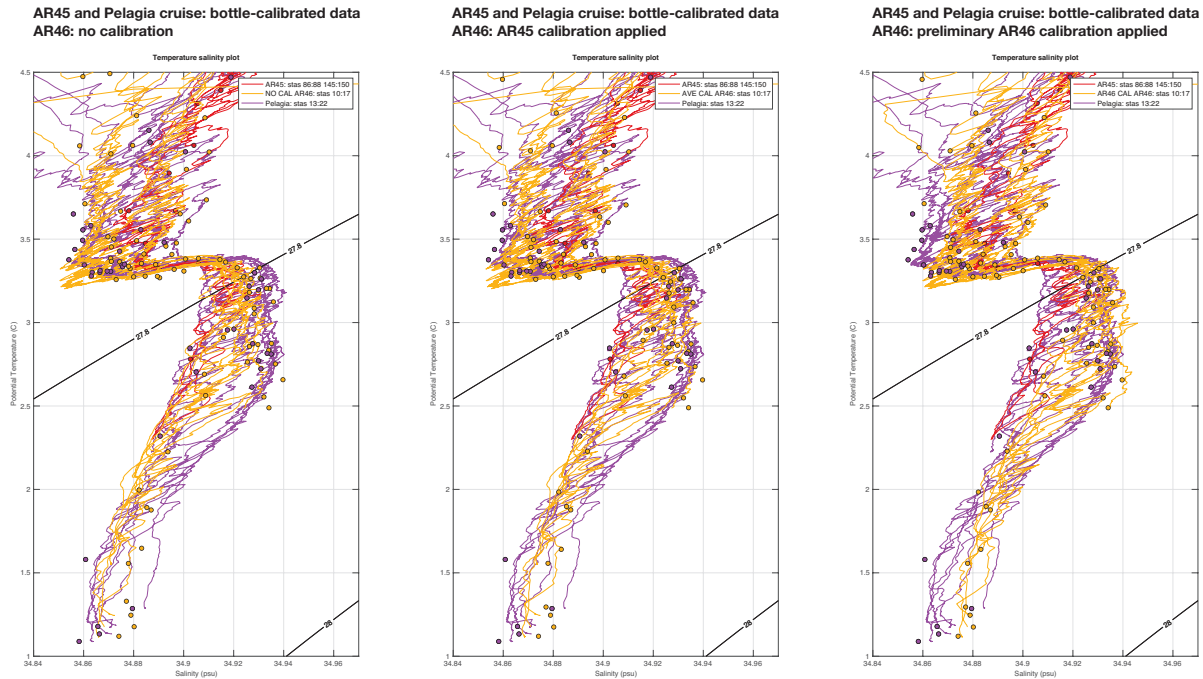
$$FC = m * CC + b + \beta * CP$$

## Calibration Results

During the summer of 2020, there were four OSNAP cruises that took place: A cruise on R/V Pelagia of the Netherlands, and AR45, AR46, and AR47 on R/V Armstrong. After comparison with three additional 2020 cruises in the OSNAP region, OSNAP PIs determined that salinity bottle data collected and processed at sea during AR46 were not acceptable for use in post-calibration of AR46 CTD data. OSNAP cruises AR45 and AR47 bracketed the AR46 cruise and determined comparable post-calibrations for conductivity sensors used in the Armstrong CTD setup. The AR45 and AR46 operational areas had the

most overlap, and as such AR45 calibration coefficients were used to calibrate the AR46 CTD conductivity data.

Below is a summary figure comparing three post-calibration results for primary AR46 data. In all panels, AR46 data are compared to final Pelagia and AR45 data for nearby stations (station locations indicated in the map below). From left to right, the panels show AR46 CTD data with 1) no post-calibration, 2) post-calibration based on AR45 data, and 3) post-calibration using the AR46 bottle data. Final calibrations shown in the center panel were chosen for the AR46 CTD data and are summarized in the table below.



Final CTD conductivity calibration parameters (based on fits from the AR45 and AR47 cruises)

Sensor	Stations	Bias	Slope (min/max)	Beta	Final standard deviation
<b>Primary</b>					<b>N/A</b>
1860	1 – 19	-0.01789966	-0.01789966/1.00061112	2.48717738e-07	
<b>Secondary</b>					<b>N/A</b>
3089	1 – 19	-0.01278871	1.00045204 /1.00053466	3.93250840e-08	

## 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/m <sup>3</sup> )
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

Given CTD issues experienced during this cruise, certain CTD profiles should not be considered for scientific use or instrument calibration purposes. The following is a summary list of recommended sensors for all stations completed.

AR46 CTD Station	Recommended temperature and calibrated conductivity/salinity data for scientific use
1	Primary and Secondary
2	Primary and Secondary
3	Primary and Secondary
4	Primary only
5	Primary only
6	Primary only
7	Primary only
8	Primary only
9	Primary only
10	Primary only
11	Primary and Secondary
12	Secondary only
13	Secondary only
14	Secondary only
15	Secondary only
16	Secondary only
17	Secondary only
18	Primary and Secondary
19	Primary and Secondary

*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.