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Improvements to OOI Irminger Sea Array shipboard hydrographic data

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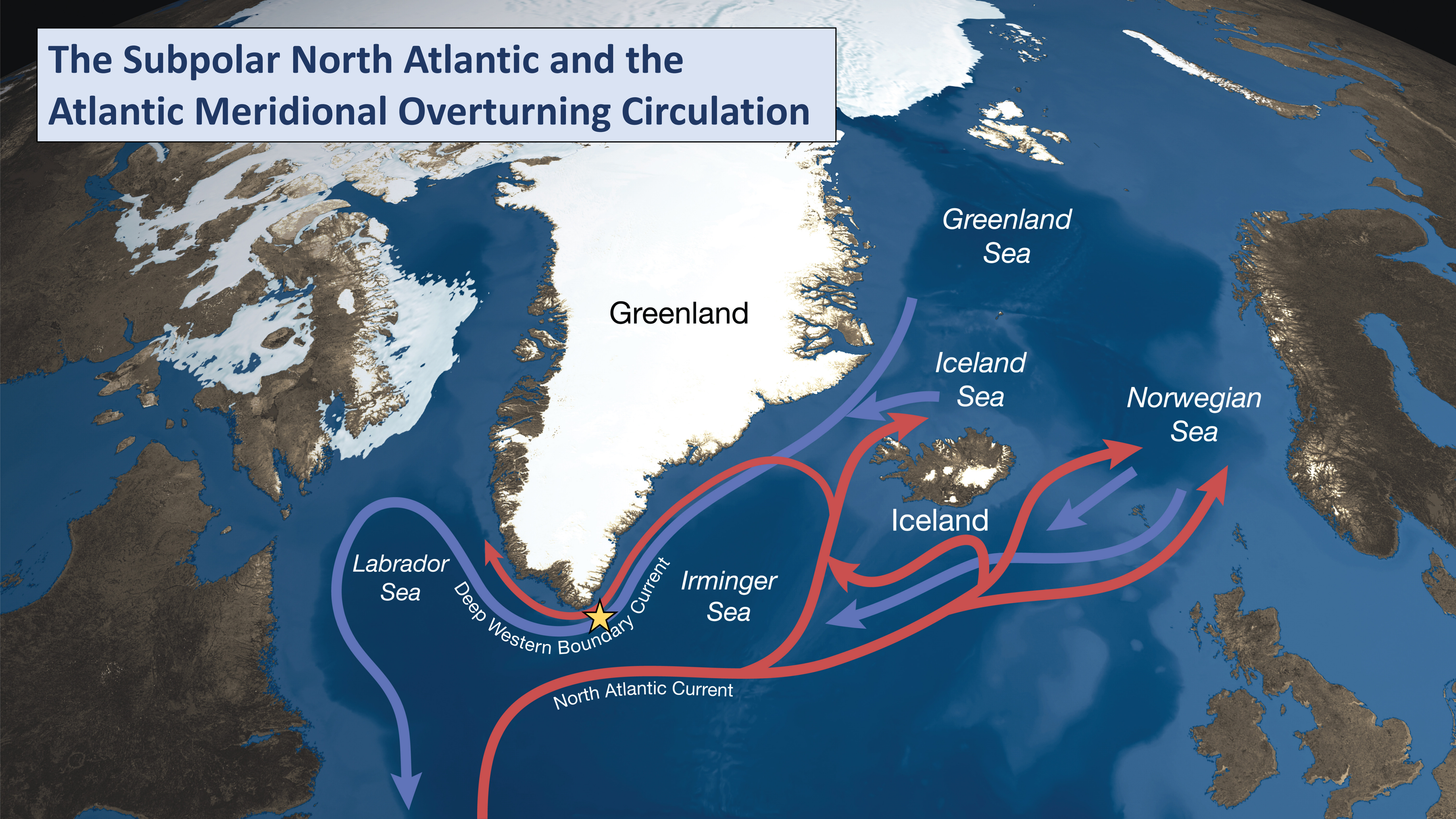
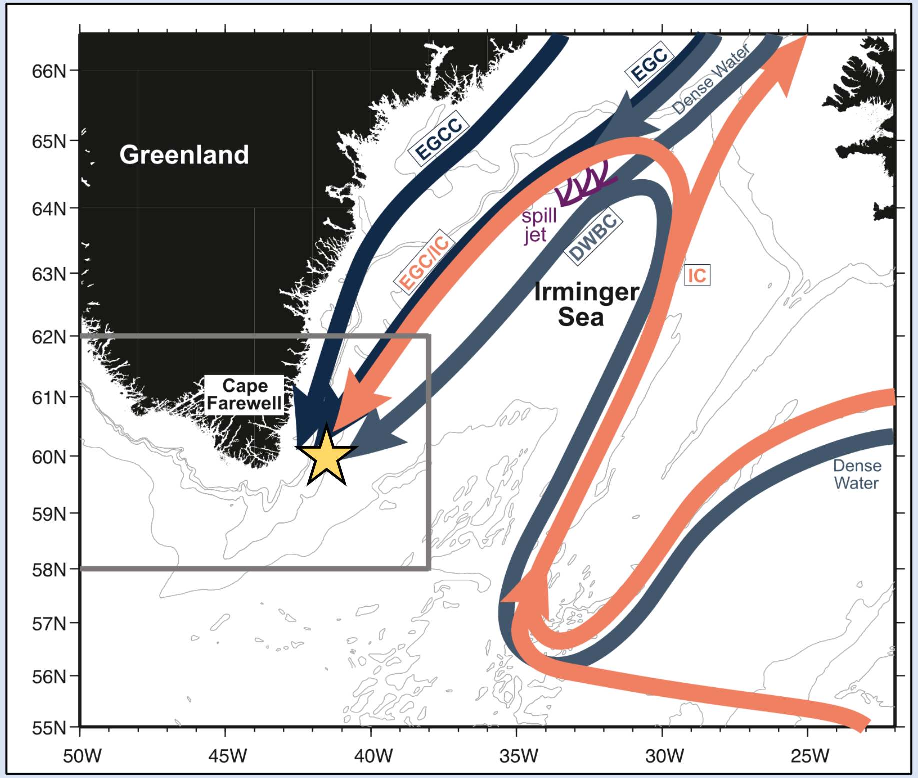
Photo: Captain Kent Sheasley

The Subpolar North Atlantic and the Atlantic Meridional Overturning Circulation

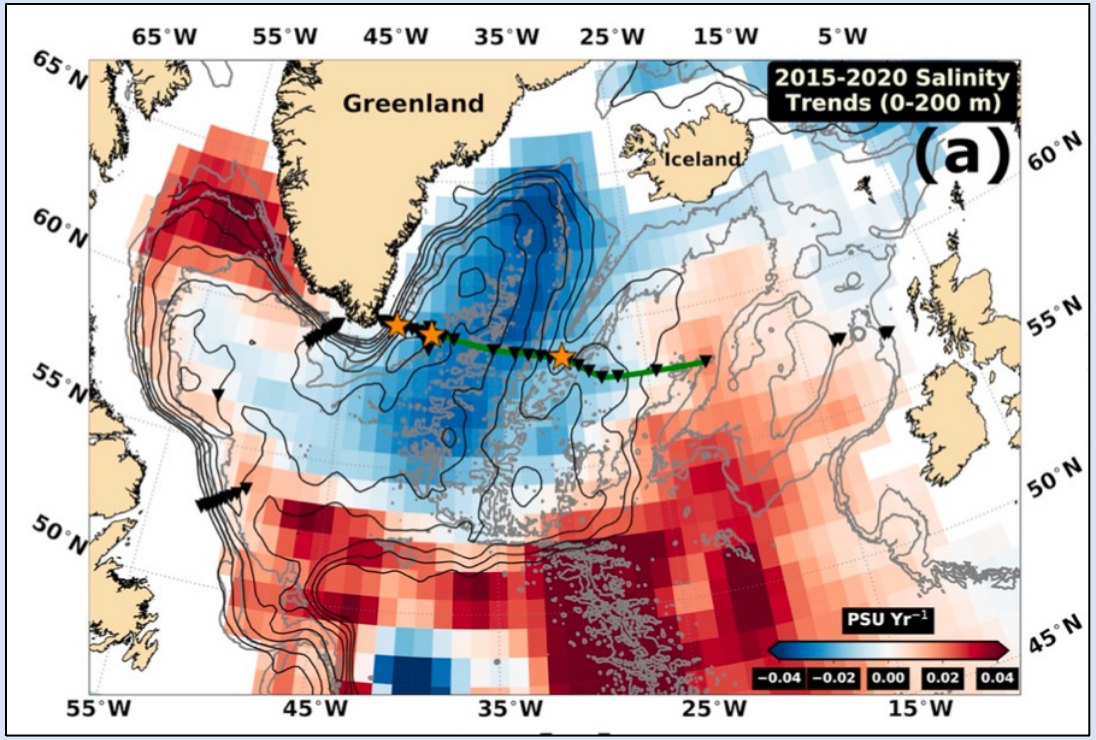


The Subpolar North Atlantic and the OOI Irminger Array

- Several currents meet near the array where they are exposed to the windiest conditions of the world ocean
- Deep convection is a primary mechanism for deep water formation and sequestration of carbon
- A recent salinity anomaly led to a rapid freshening of the Irminger Sea between 2015 and 2020
- Salinity anomalies reduce dense water formation and weaken the vertical transport of carbon into the ocean



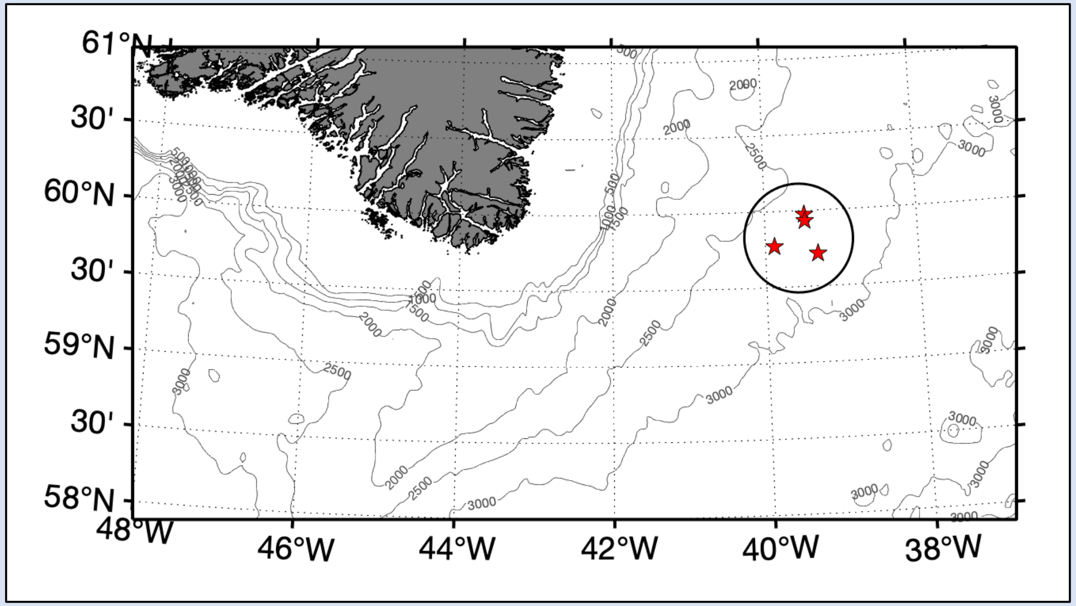
Pacini et al., DOI: 10.1175/JPO-D-20-0086.1

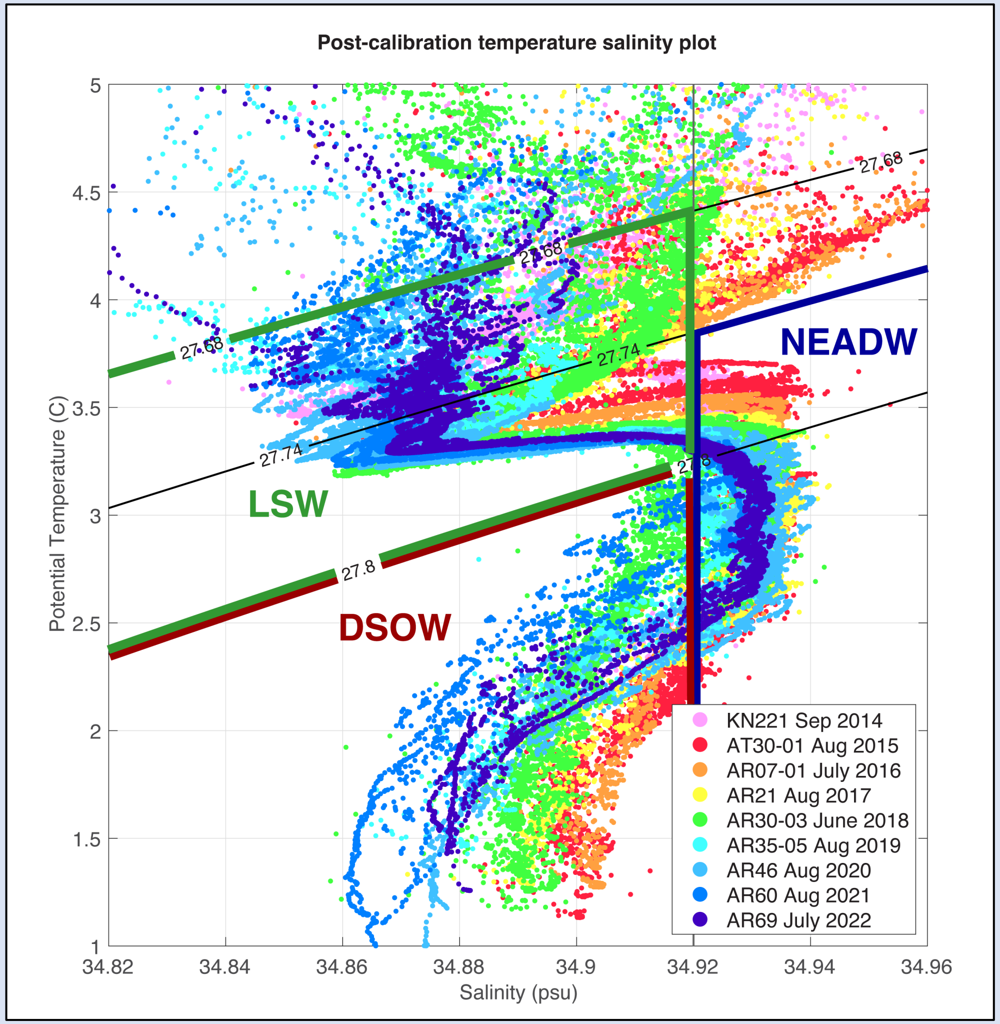


Biló et al., DOI: 10.1029/2022GL098857

Water masses near the OOI Irminger Array

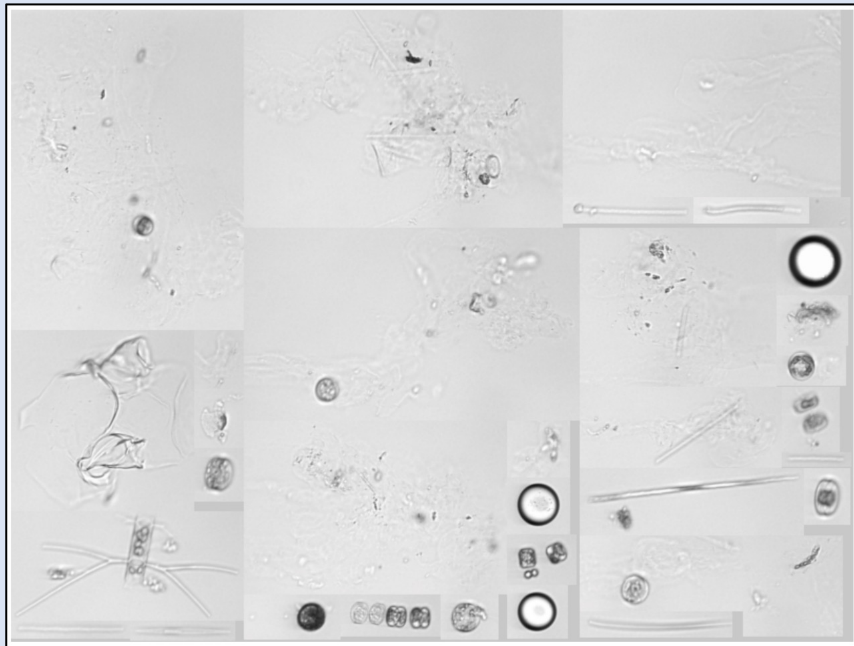
- **Labrador Sea Water (LSW)** is formed in the Labrador and Irminger Seas via deep wintertime convection
- **Denmark Strait Overflow Water (DSOW)** is formed in the Nordic Seas and contains very dense water that helps to form the Deep Western Boundary Current
- **Northeast Atlantic Deep Water (NEADW)** is a complex of several water masses





High-latitude CTD sensors and plumbing are exposed to harsh environmental conditions

Image credit: Fisheries and Oceans Canada and Woods Hole Oceanographic Institution



Extreme temperatures, windchills, ice particles, and elevated sea state can lead to accelerated sensor drifts and sensor damage from freezing

- CTD conductivity sensors are brittle and prone to cracking

High levels of biological activity can lead to clogged CTD ducting and biofouled sensors

- This can lead to physically inconsistent measurements

Photo: Rachel Fletcher

Photo: Isabela Le Bras

Photo: Isabela Le Bras

Temperature and salinity accuracies and drifts

Example range of CTD end uses:

- **Hydrographic profile measurements**
  - High-accuracy calculation of in situ physical parameters, for example density, salinity, and sound speed velocity
- **Complementary profile measurements**
  - Calculation of physical values from auxiliary sensors, for example dissolved oxygen
- **Physics-dependent discrete water sample analysis**
  - Water sample analysis requiring in situ measurements, e.g. DIC and dissolved oxygen sample analysis
- **In situ and density-referenced sensor validation and calibration**
  - Sensors attached to CTD frame or deployed on other platforms (e.g. gliders, floats, and moorings) requiring validation or calibration
- **Matching discrete water sample measurements to water masses and physical properties**

Parameter	Initial Accuracy	Stability	Maximum anticipated drift for 1 year deployment
SBE3 Temperature	±0.001 °C	<0.001 °C over 6 months	±0.002 °C
SBE4 Conductivity	±0.0003 S/m (±0.003 mS/cm)	0.0003 S/m (0.003 mS/cm) per month	±0.0039 S/m (±0.039 mS/cm)
Derived salinity*	±0.004 psu		±0.050 psu
Derived density*	±0.002 kg/m^3		±0.041 kg/m^3

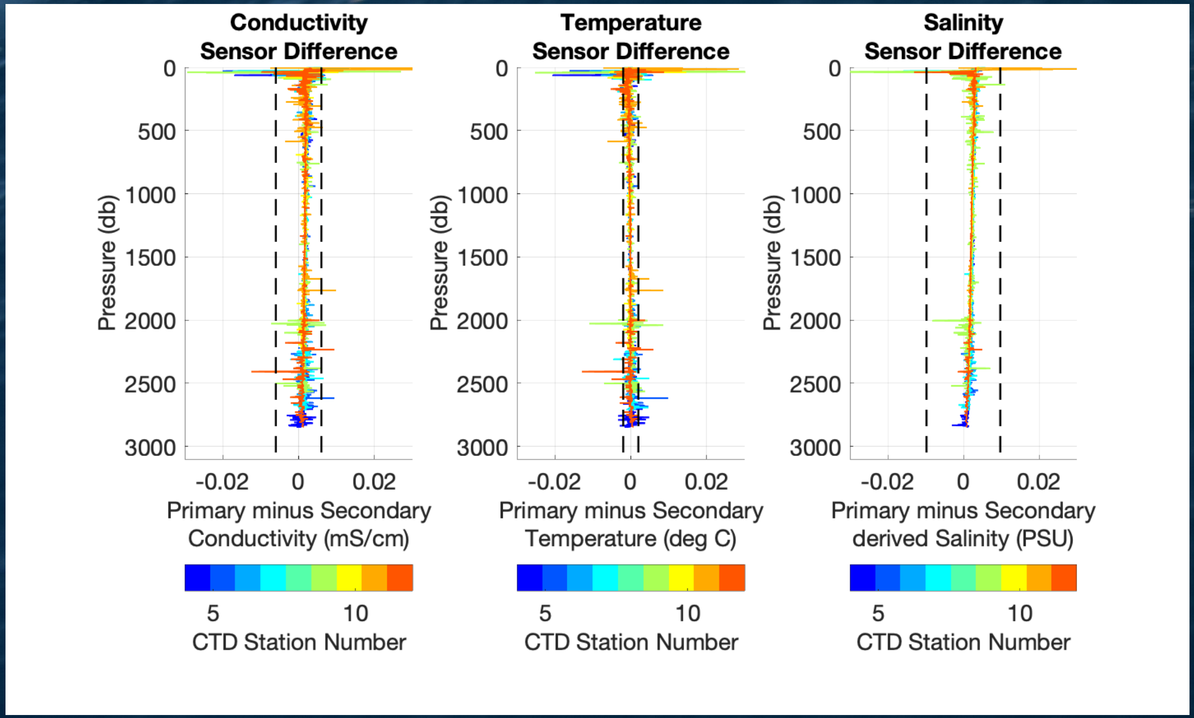
* approx. for ranges -1-10 °C and 25-35 mS/cm

Visualizing anticipated sensor accuracies: Difference plots

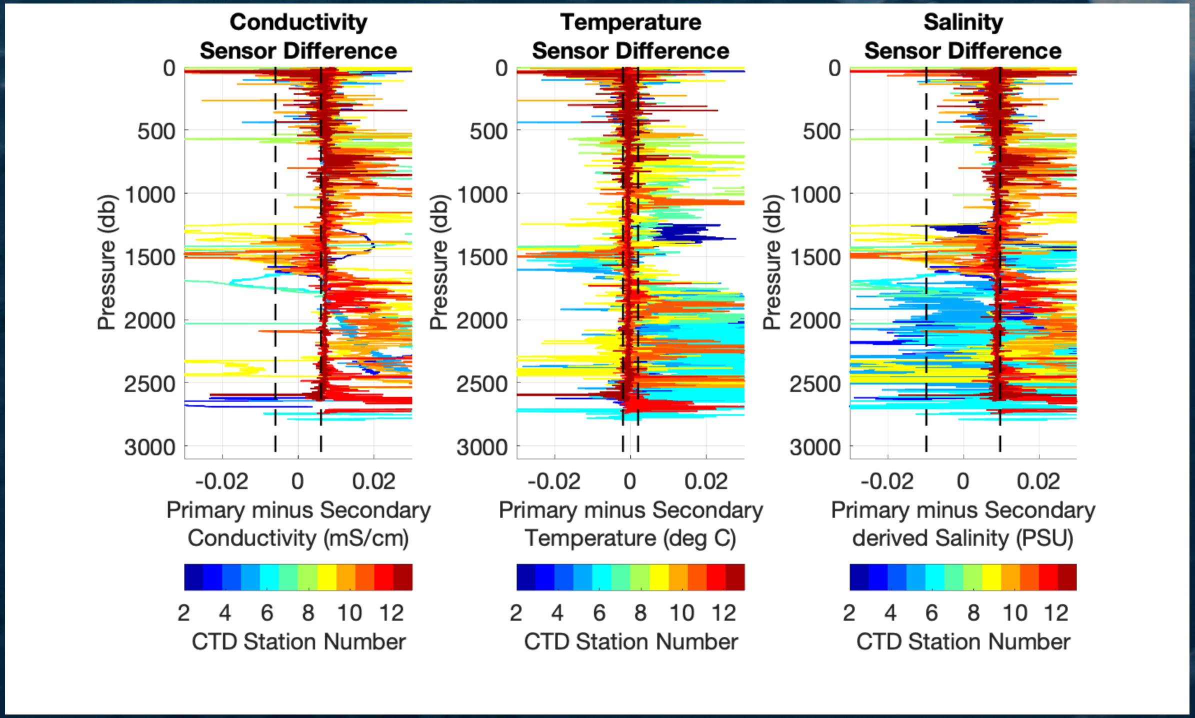
These plots provide a relative comparison, making them suitable for detecting changes that occur suddenly or at a rate faster than anticipated sensor drifts

Parameter	Initial Accuracy	Maximum anticipated drift for 1 year deployment
SBE3 Temperature	±0.001 °C	±0.002 °C
SBE4 Conductivity	±0.0003 S/m (±0.003 mS/cm)	±0.0039 S/m (±0.039 mS/cm)
Derived salinity*	±0.004 psu	±0.050 psu

2021 (AR60-01)



2019 (AR35-05)



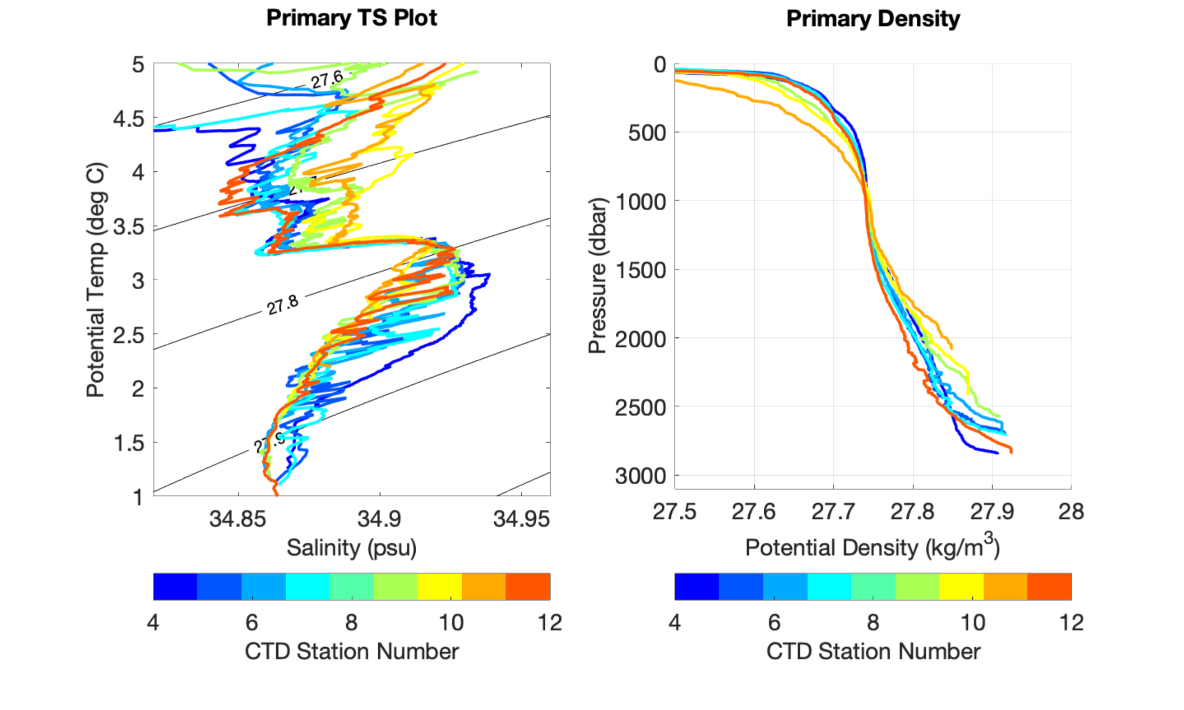
Visualizing anticipated sensor accuracies: Density plots

Calculated seawater density, in general, increases as a function of depth

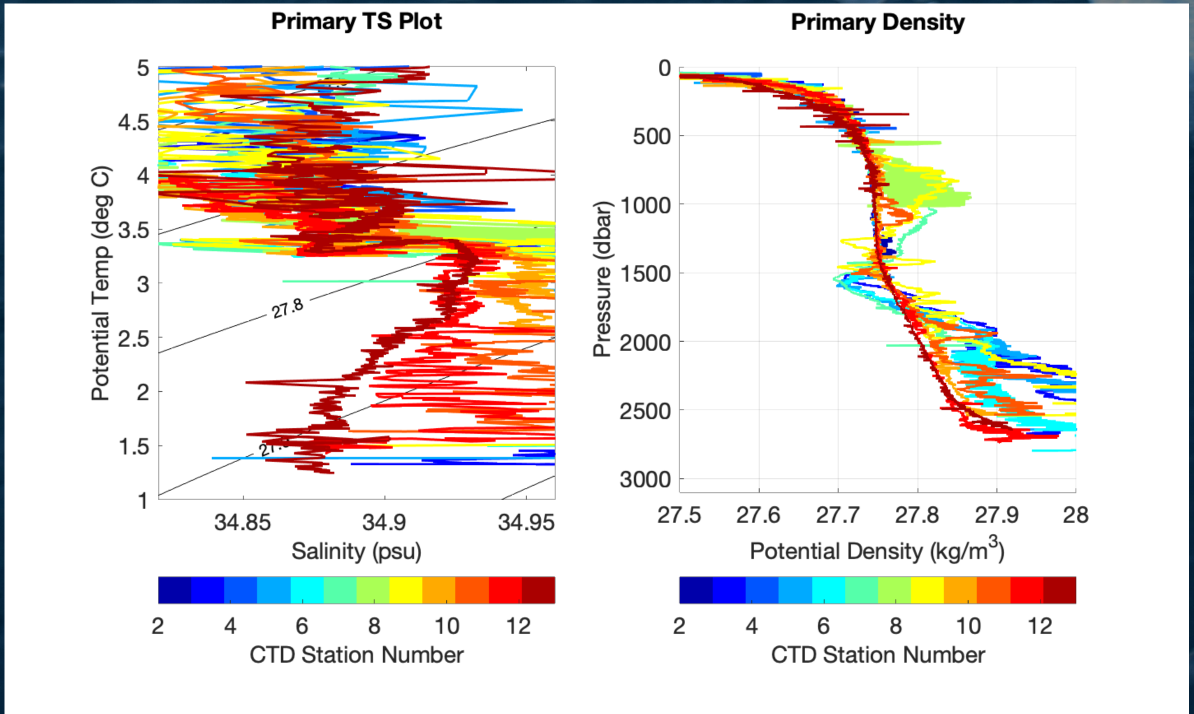
Parameter	Initial Accuracy	Maximum anticipated drift for 1 year deployment
Derived density*	±0.002 kg/m³	±0.041 kg/m³

*approx. for ranges -1-10 °C and 25-35 mS/cm

2021 (AR60-01)



2019 (AR35-05)



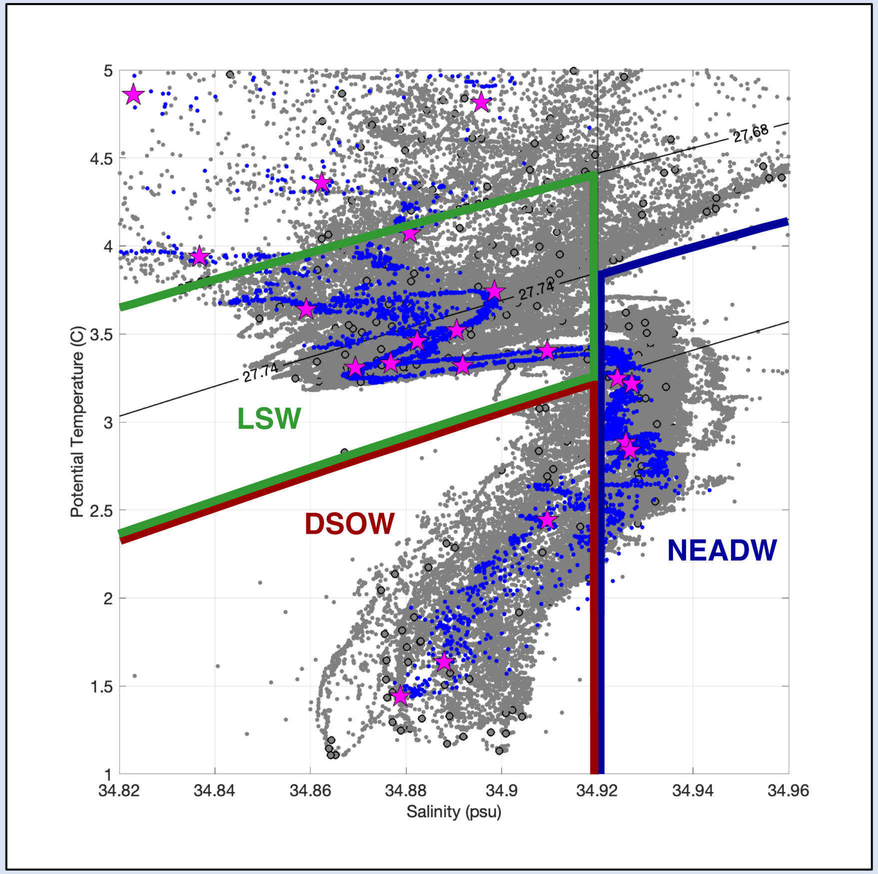
Understanding risk to CTD data and objectives

For a baseline validation: differences between bottle and CTD data values should have a standard deviation at, or better than, the manufacturer-stated accuracies

- With this we can verify consistent density data
- Can advise primary vs. secondary data
- Samples within deep water masses are valuable

In 2019 we almost didn't get deep bottle data!

- Old OOI CTD sampling plan: of 5 sites, only the profiler mooring location collected samples within DSOW
- In 2019, only two stations returned physical data and one was at the profiler mooring location!



Two consistent sources of risk for OOI Irminger CTD data:

1. Contamination/biofouling
2. Insufficient data coverage

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Impact of biofouling		mild		80% return	mild	**22% return**		mild	mild
#NEADW samples	**3**	12	12	**0**	6	**4**	8	5	8
#DSOW samples	**1**	5	**2**	**1**	9	**3**	5	7	8

A multithreaded approach with a continuing impact!

Prevent, diagnose, and treat biofouling of CTD system

Worked with SSSGs and WHOI experts to present the issue and establish a more robust procedure

Modify CTD sampling:

OSNAP, OCP, and BGC-Argo PIs met to strategize

Coordinate with OOI

What was the OOI team able to support?

- Advocate for CTD system
- Cleaning protocols
- Updated CTD priorities and bottle sample plans
- Visualization support
- *Leah floating in the ether!*

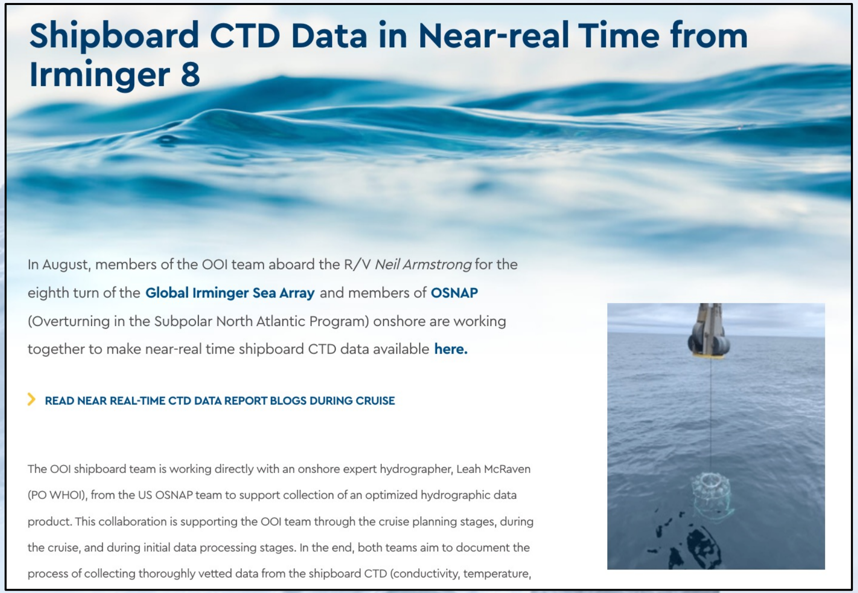
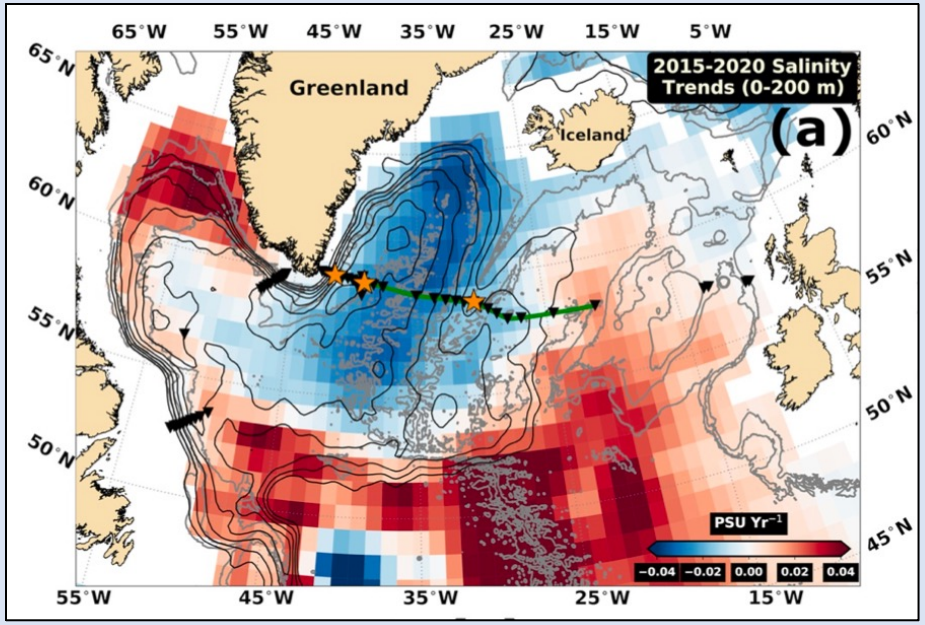


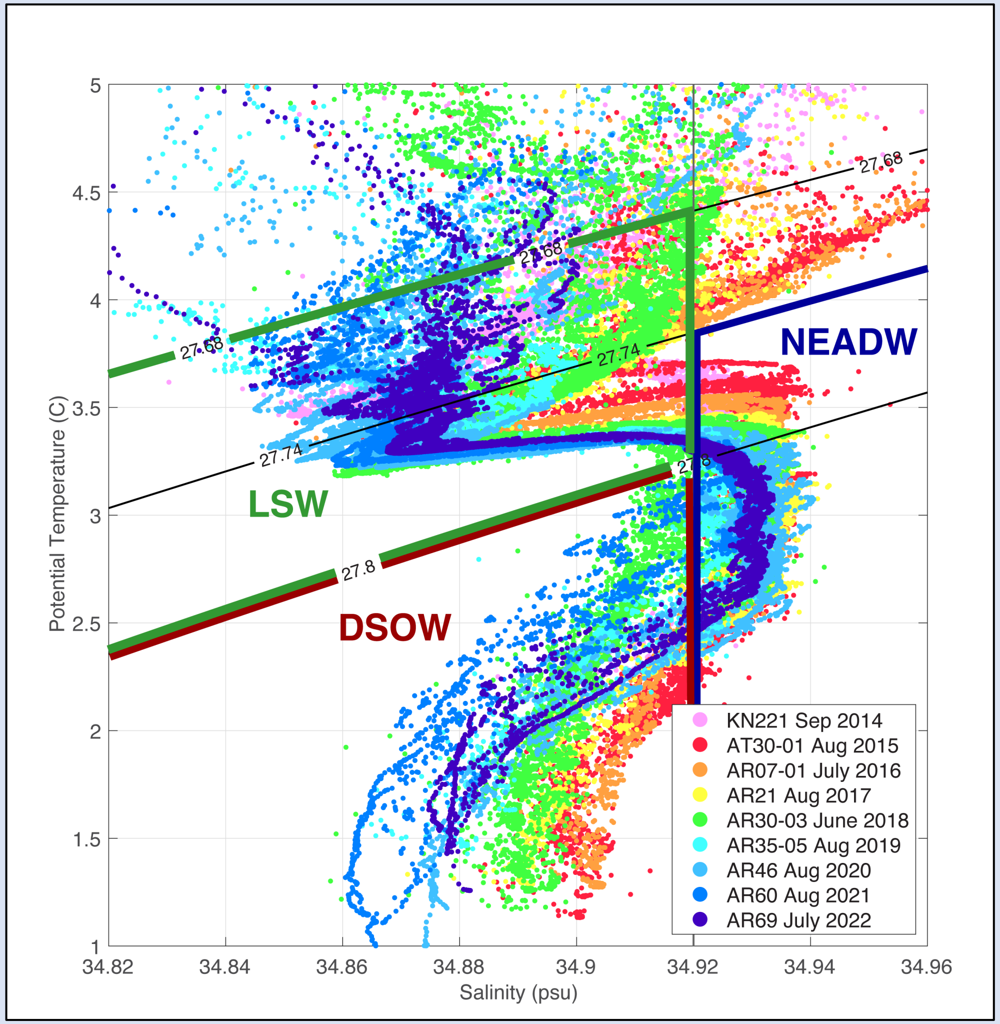
Photo: Isabela Le Bras

What scientific questions can be addressed with CTD T and S?

Consider 9 years of CTD data collected near the OOI Irminger mooring array:

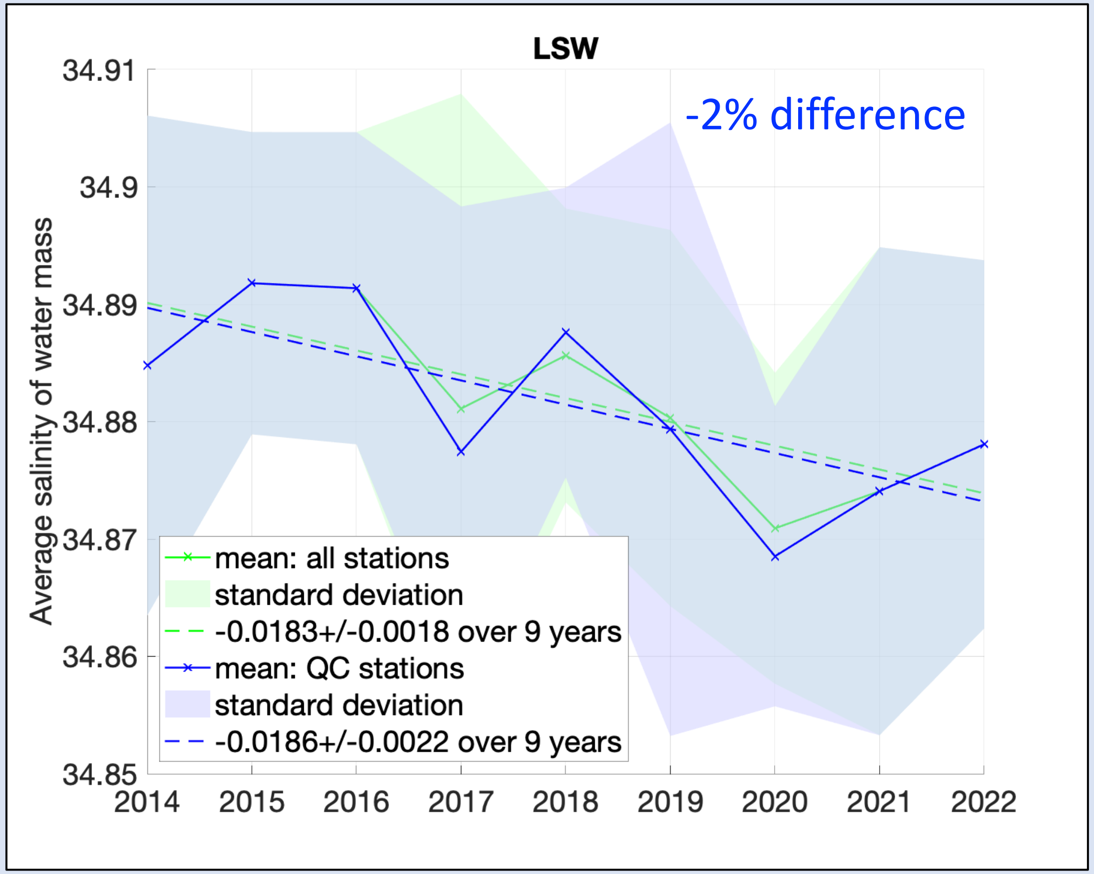
- **How robust are water mass characterizations?**
- **Can we detect any significant salinity trends?**
    1. Use duplicate T, S, and density profiles to identify physical profiles
    2. Use bottle data to further calibrate CTD salinity





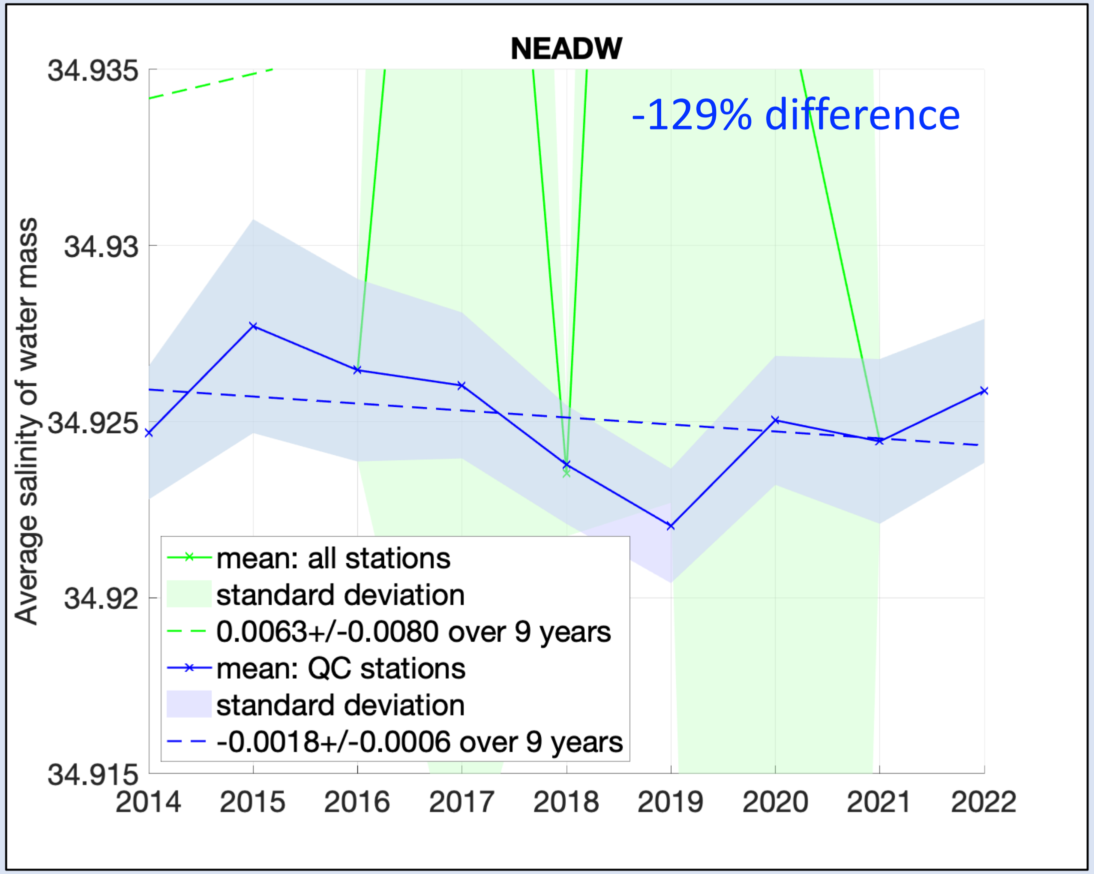
Impact of excluding contaminated profiles

Best-case scenario CTD salinity accuracy of ± 0.004 psu



To quantify 9 years of freshening of LSW:

This is a very large signal compared to CTD sensor accuracy!

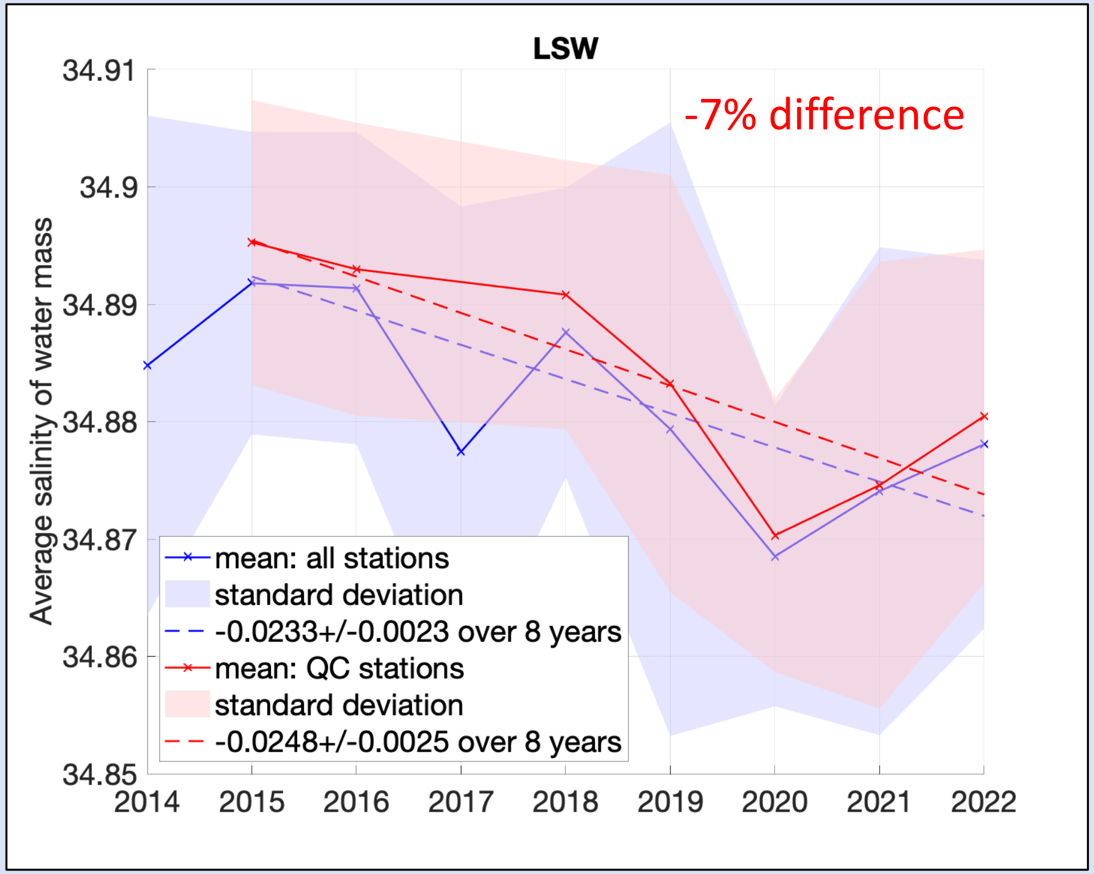


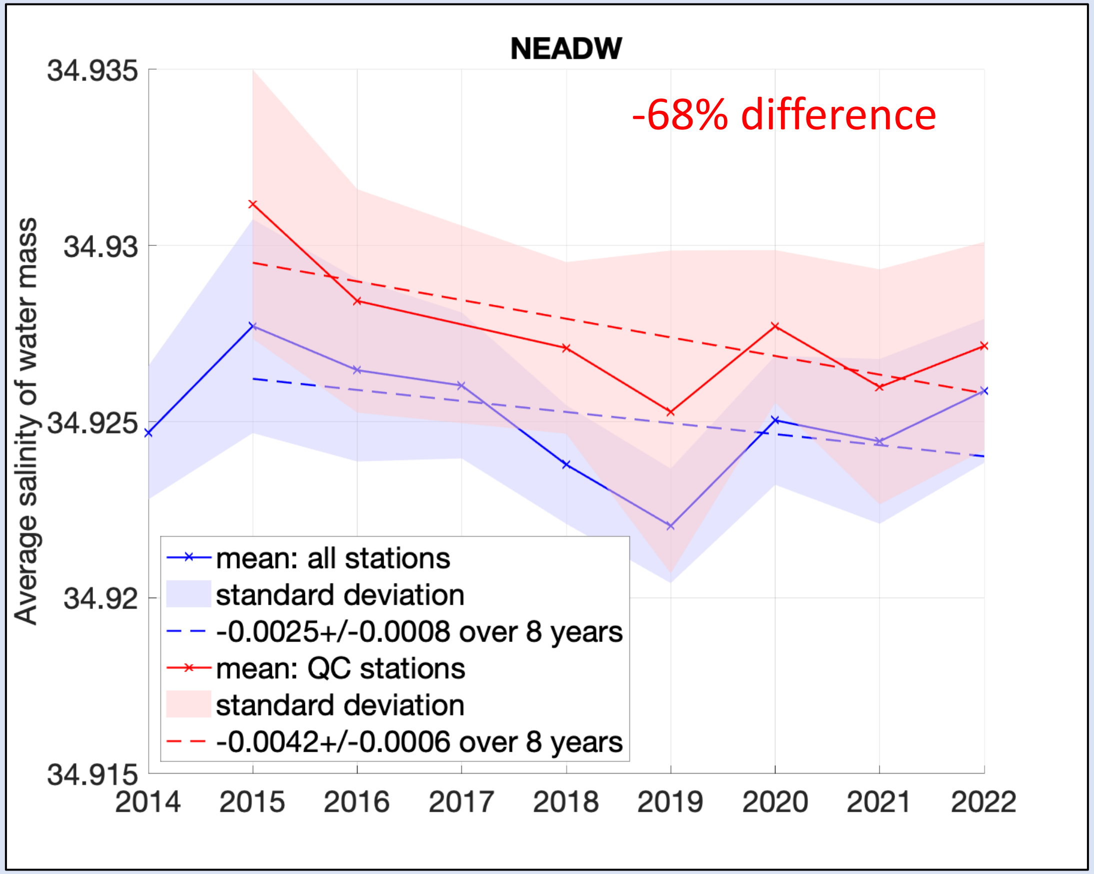
To quantify 9 years of freshening of NEADW:

There are some particularly problematic years that are remedied by using QC cutoffs

Impact of post calibration using salinity bottle data

Best-case scenario post-calibration accuracy is ± 0.0002 psu





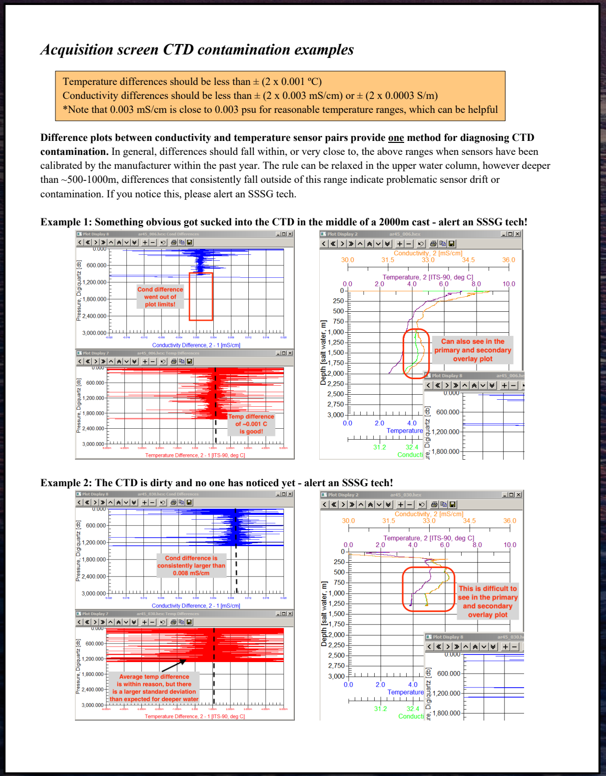
To quantify *8 years of freshening of DSOW:

With a long enough timeseries, CTD bottle calibration may not be needed

To quantify *8 years of freshening of NEADW:

CTD bottle validation or post-calibration is necessary, freshening rate and post-calibration 0-order correction are close to the accuracy of the CTD

Thank you for your support!
Deliverables related to this work…



Acquisition screen CTD contamination examples

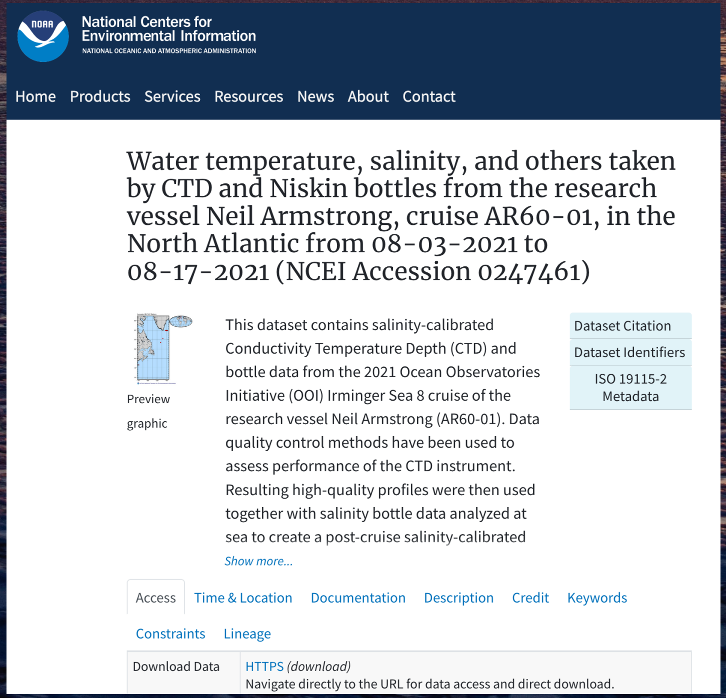
Temperature differences should be less than ± (2 x 0.001 ºC)
Conductivity differences should be less than ± (2 x 0.003 mS/cm) or ± (2 x 0.0003 S/m)
*Note that 0.003 mS/cm is close to 0.003 psu for reasonable temperature ranges, which can be helpful

Difference plots between conductivity and temperature sensor pairs provide <u>one</u> method for diagnosing CTD contamination. In general, differences should fall within, or very close to, the above ranges when sensors have been calibrated by the manufacturer within the past year. The rule can be relaxed in the upper water column, however deeper than ~500-1000m, differences that consistently fall outside of this range indicate problematic sensor drift or contamination. If you notice this, please alert an SSSG tech.

Example 1: Something obvious got sucked into the CTD in the middle of a 2000m cast - alert an SSSG tech!

Example 2: The CTD is dirty and no one has noticed yet - alert an SSSG tech!

At sea support toolkit



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Water temperature, salinity, and others taken by CTD and Niskin bottles from the research vessel Neil Armstrong, cruise AR60-01, in the North Atlantic from 08-03-2021 to 08-17-2021 (NCEI Accession 0247461)

Preview graphic

This dataset contains salinity-calibrated Conductivity Temperature Depth (CTD) and bottle data from the 2021 Ocean Observatories Initiative (OOI) Irminger Sea 8 cruise of the research vessel Neil Armstrong (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

Show more…

Dataset Citation
Dataset Identifiers
ISO 19115-2 Metadata

Access | Time & Location | Documentation | Description | Credit | Keywords | Constraints | Lineage

Download Data | HTTPS *(download)* Navigate directly to the URL for data access and direct download.

Post-calibrated CTD data and collaboration between groups

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Ocean best practices

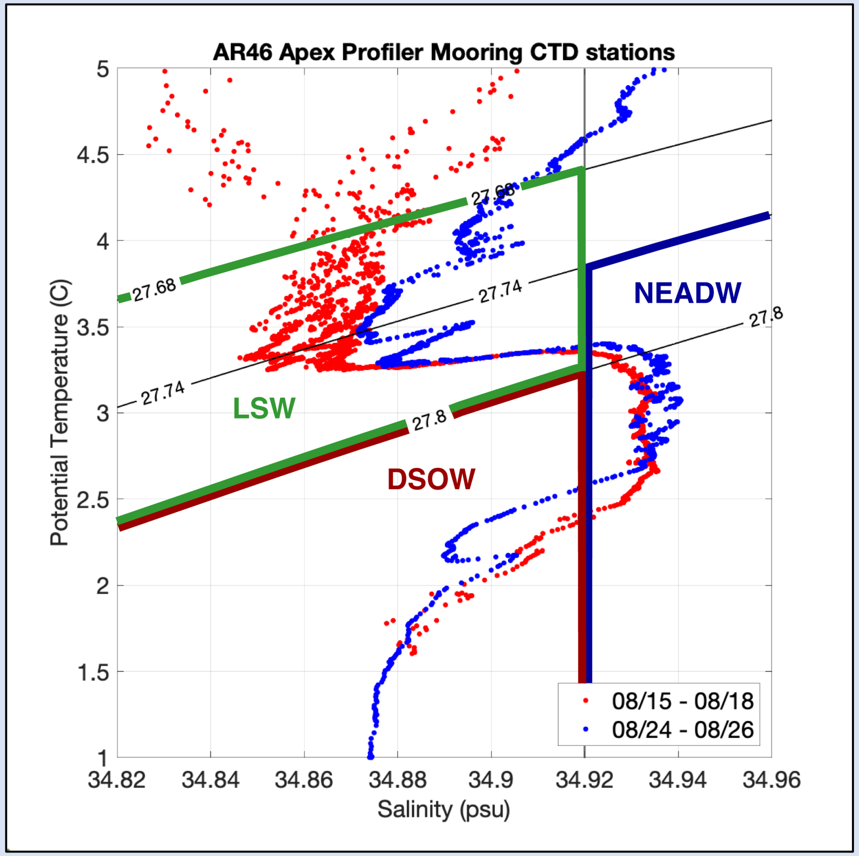
SEA-BIRD SCIENTIFIC

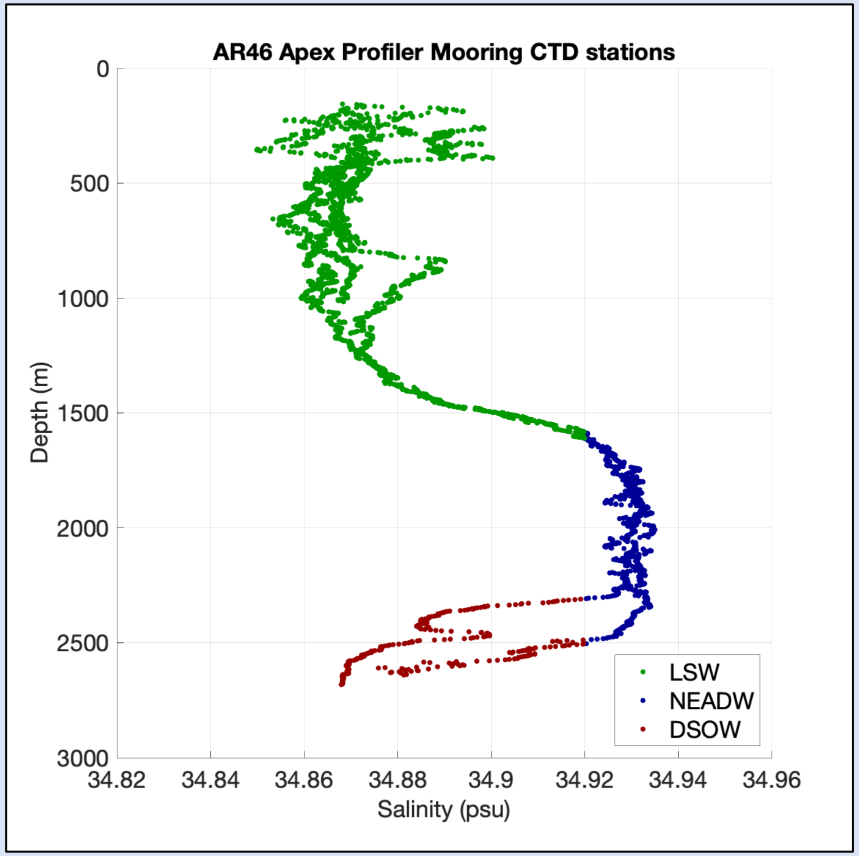
A continuing conversation with the technical community

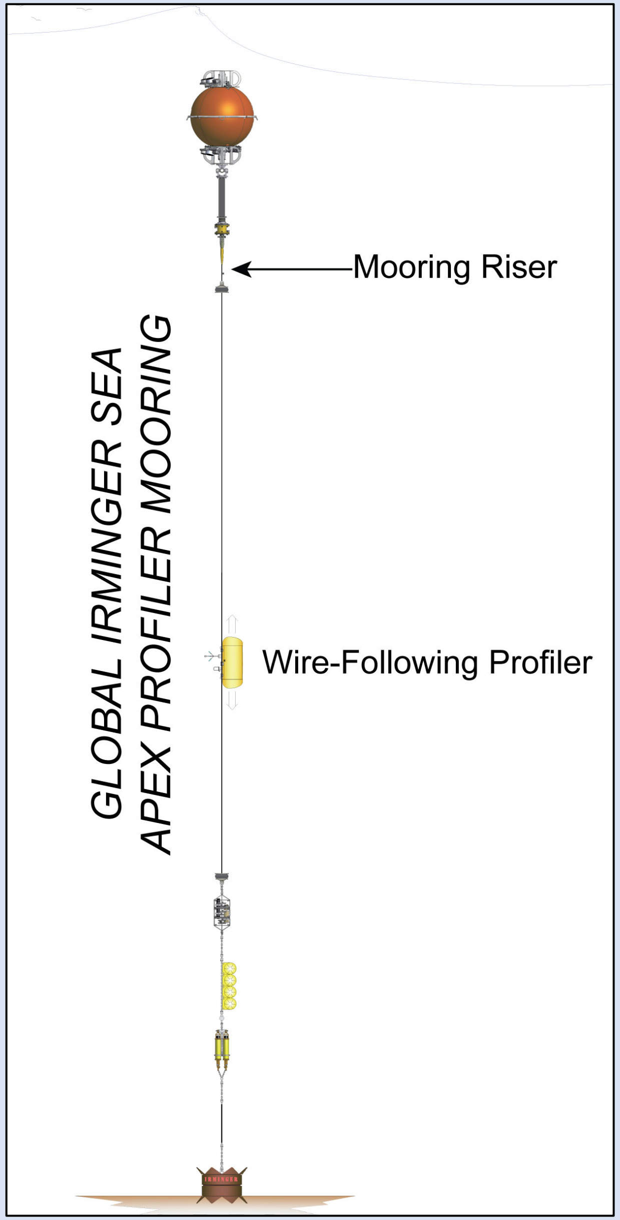
Photo: Laurie Juranek

Water masses near the OOI Irminger Array

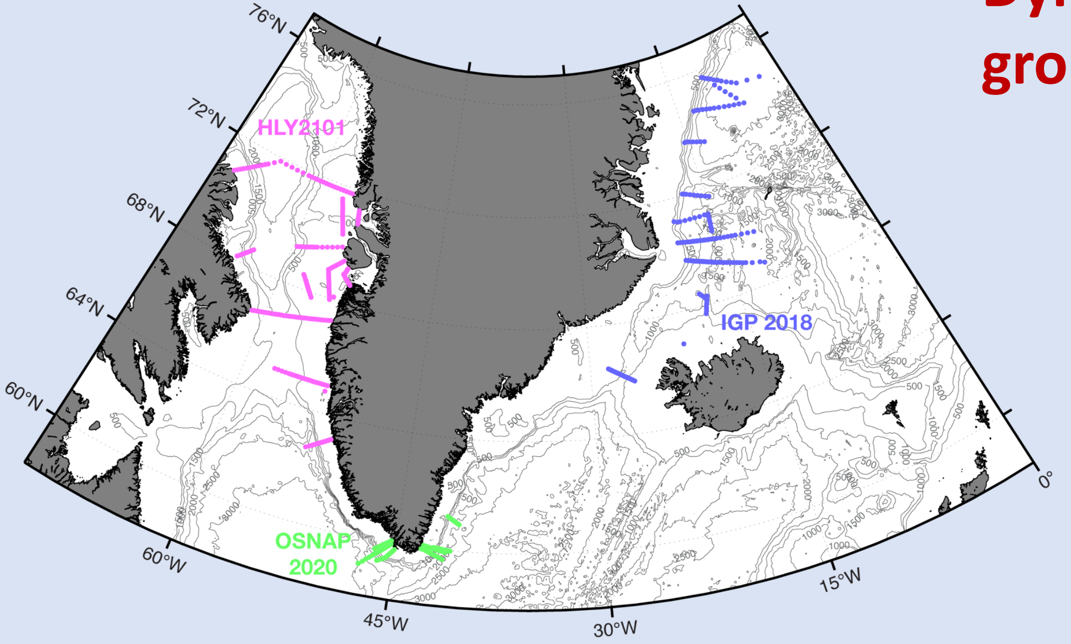
- **The water in this region is extremely dynamic in properties**





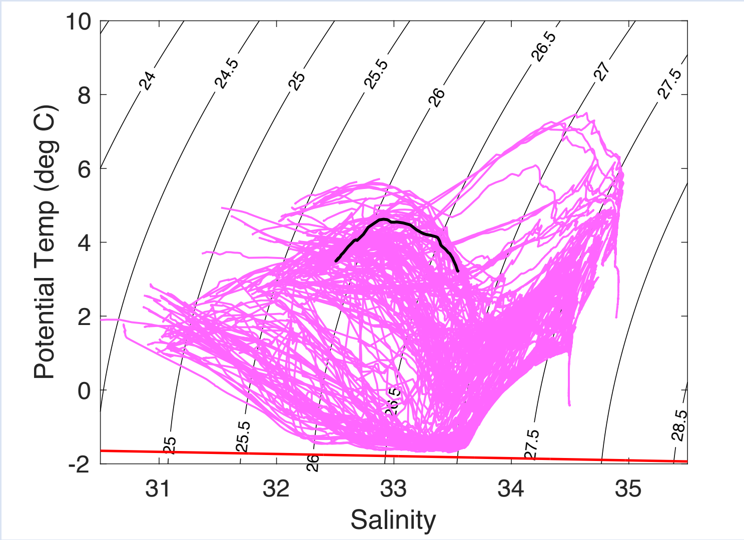


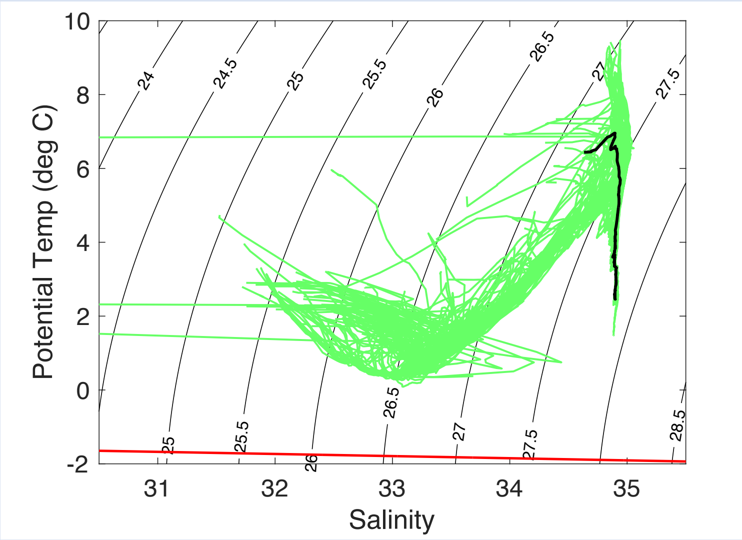
Dynamic water column structure can make ground truthing measurements very difficult

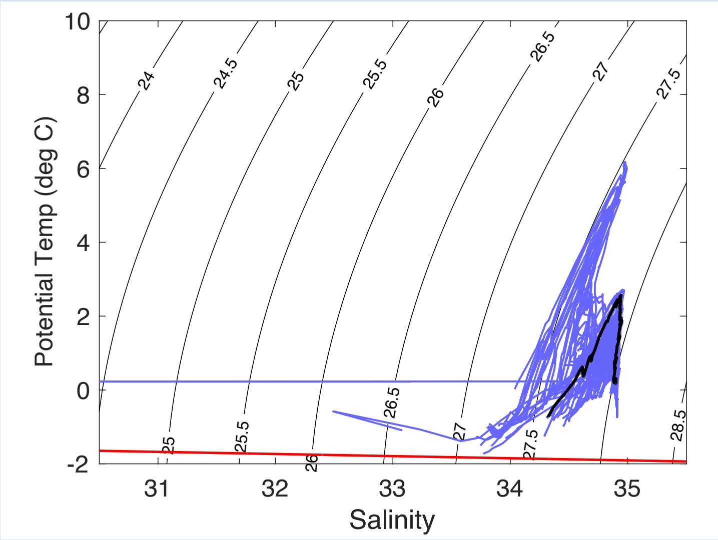


Summary temperature-salinity plots from three locations around Greenland illustrate:

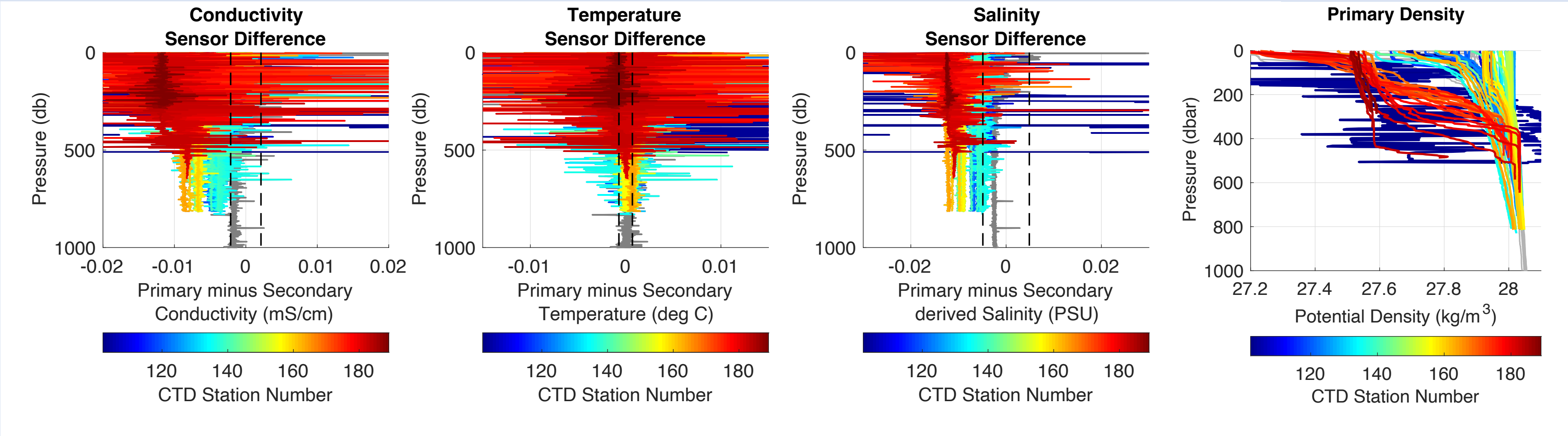
- Widely varying temperature and salinity values compared to other places in the world ocean
- Very sharp gradients in both temperature and salinity
- This is a region where sensors are more vulnerable and it's harder to identify problems







Why bottle data are critical



- Near station 140 we experienced windchills colder than -10 °C
- A sudden and large offset occurred (~0.01 psu over about a day)
- The bottle data characterized the event very well!