Northwest Atlantic Fisheries Organization

2024 and 2025 Oceanographic Conditions in the Labrador Sea in the Annual-to-Multidecadal Variability Context

Fisheries and Oceans Canada | Pêches et Océans Canada

Bedford Institute of Oceanography

Deep-Ocean Observation and Research Synthesis

DEEP-OCEAN OBSERVATION DOORS AND RESEARCH SYNTHESIS

Objective:

(1) The recent oceanographic developments in the Labrador Sea, this time without focusing on the mechanism of thermal and freshwater forcings, which can be found in the recent Labrador Sea paper, and extensive 2003 and 2024+2025 NAFO reports;

(2) The sea level changes, and why in the subpolar regions we need to worry about it more than anywhere else.

The oceanographic compilations, analyses and results presented here are based on:

(1) **1908-1991** Historical Nansen, Amundsen and other bottle data,

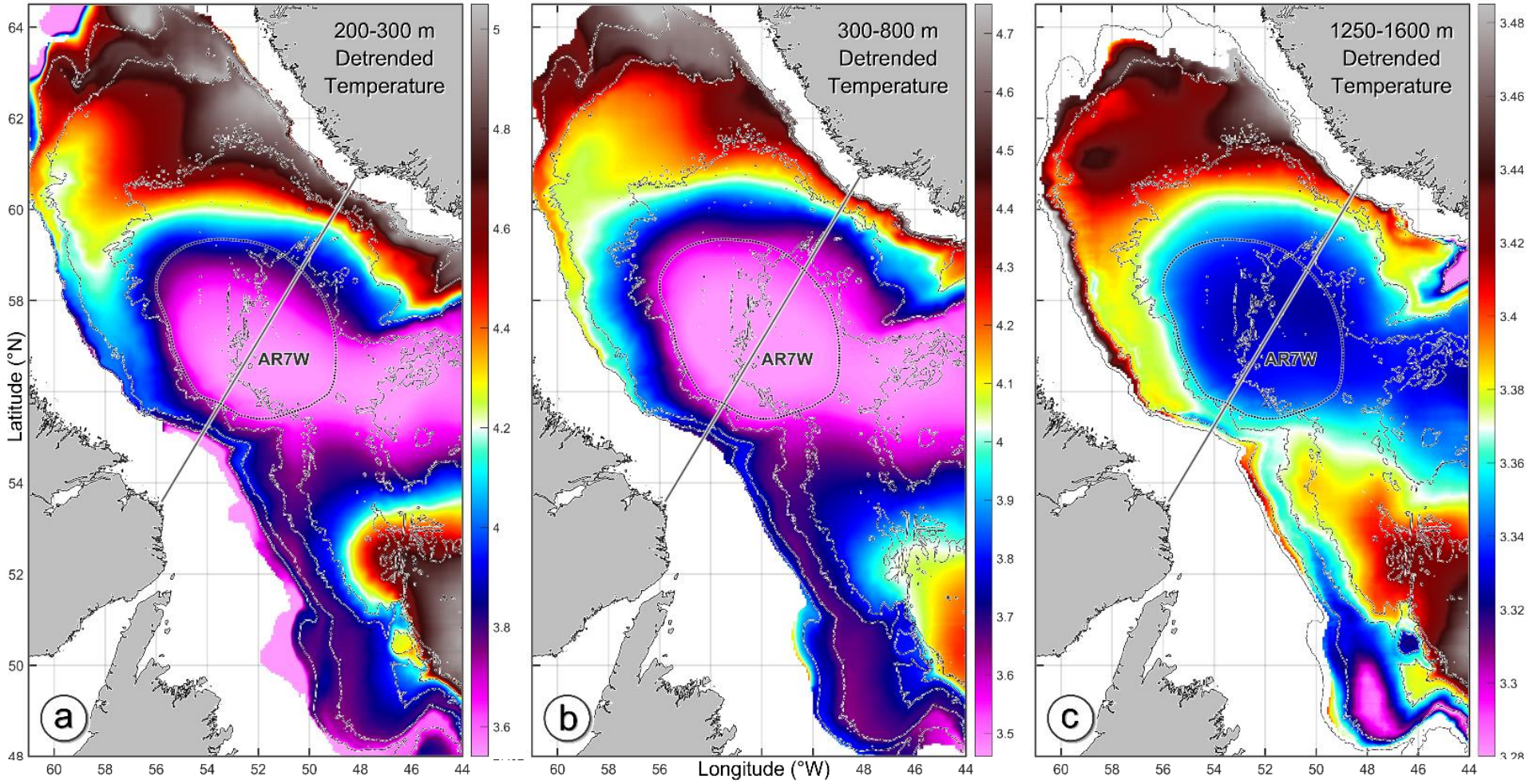
(2) Exclusively over the period of **1990-2019**: thoroughly checked, cleaned and calibrated high-accuracy shipboard measurements,

(3) **2002-2025** profiling Argo and Deep Argo float data,

(4) **1987-2024** Random uncontrolled international shipboard observations.

First, we introduce
the general oceanographic features
of the Labrador Sea

2002-2024 Multiplatform Vertically-Averaged Temperature Climatology

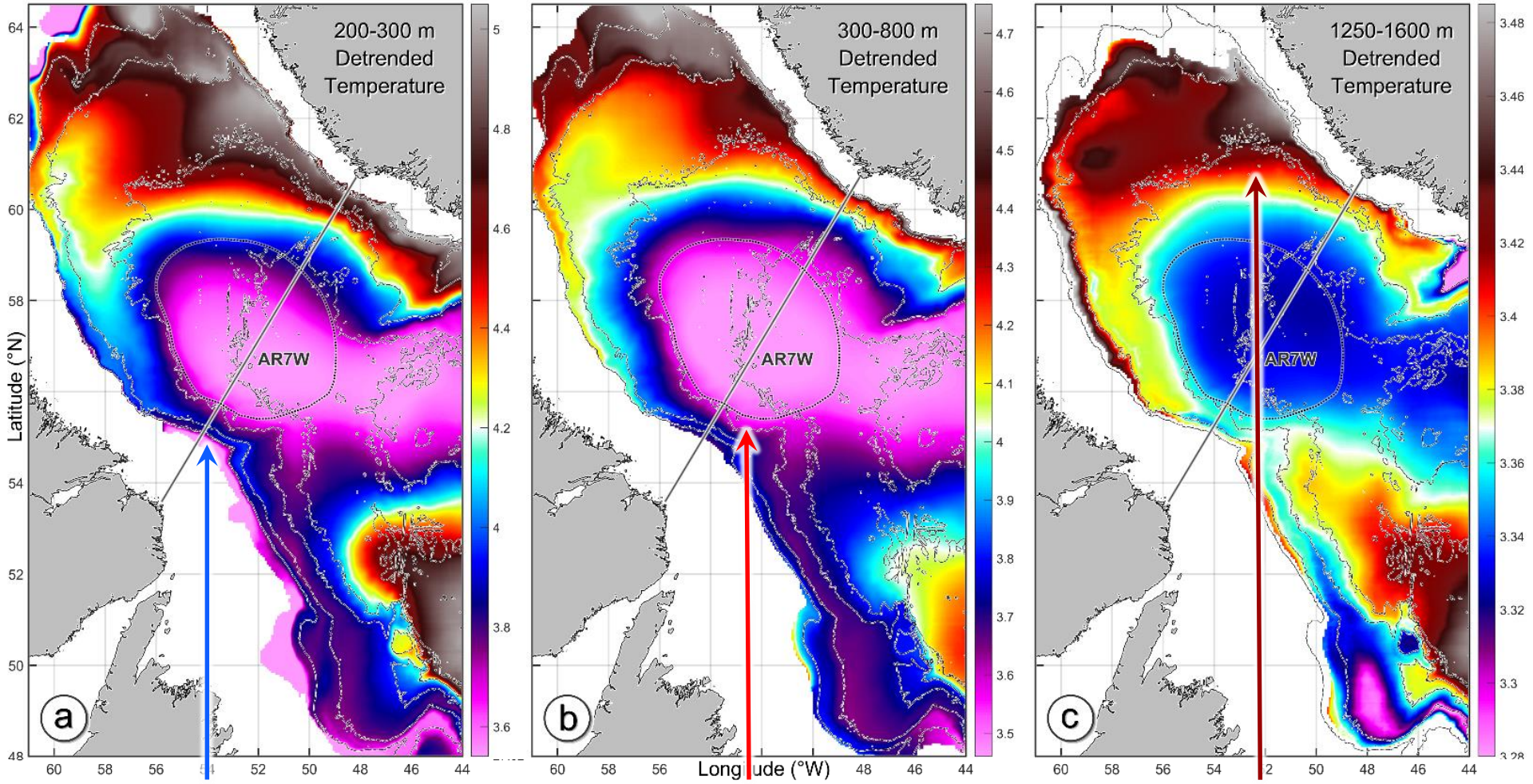


Hydrographic measurements from all platforms (*e.g., profiling floats, ships*) pass thorough multistep quality control, problem (*e.g., sensor drift*) detection and correction.

Seasonal and interannual signals removed before spatial gridding.

Here, 2002-2023 was chosen because of spatiotemporal uniformity of data.

2002-2024 Multiplatform Vertically-Averaged Temperature Climatology

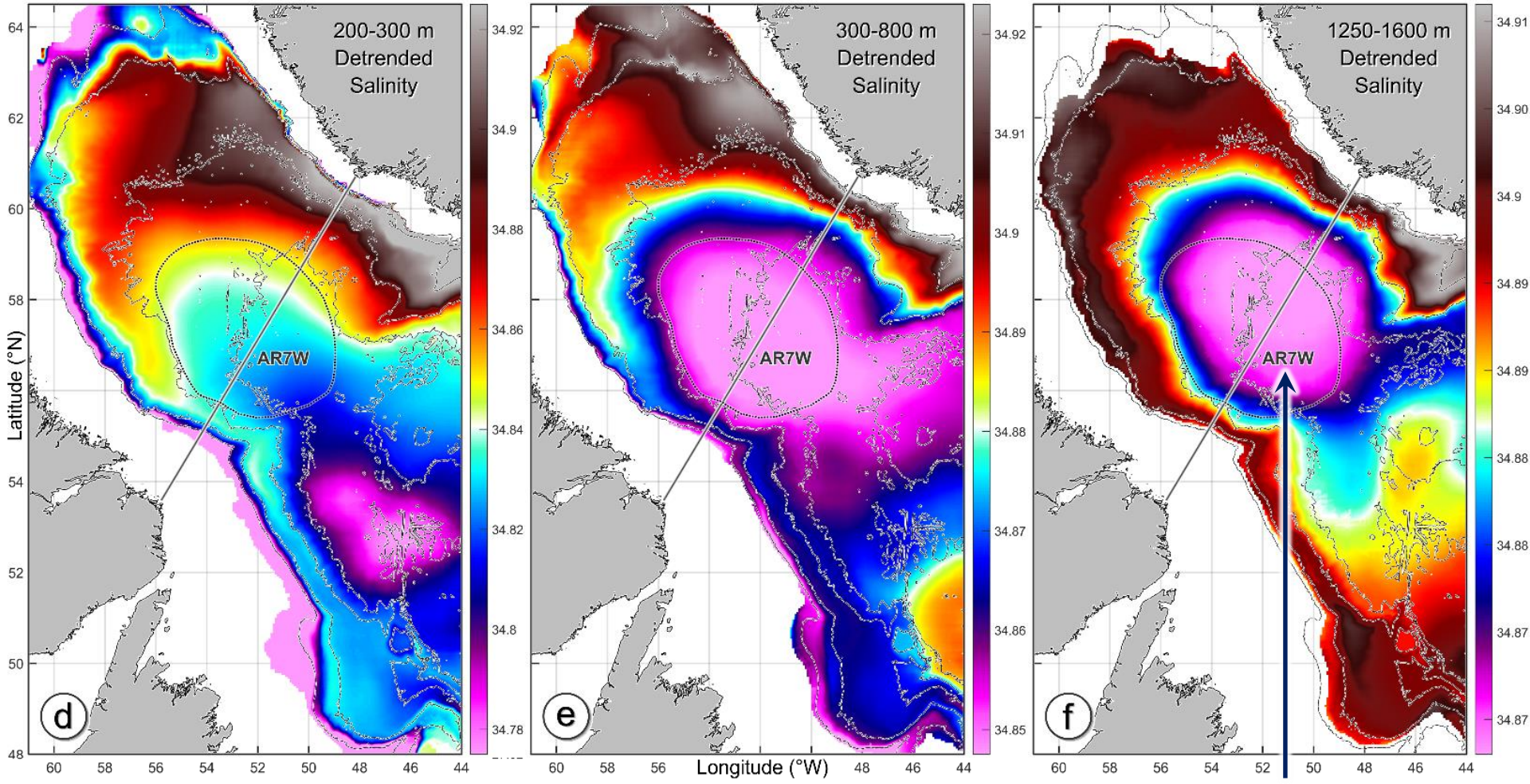


AR7W Atlantic Repeat hydrography line 7-West (1990-2019 used here)

Central Labrador Sea (**CLS**)

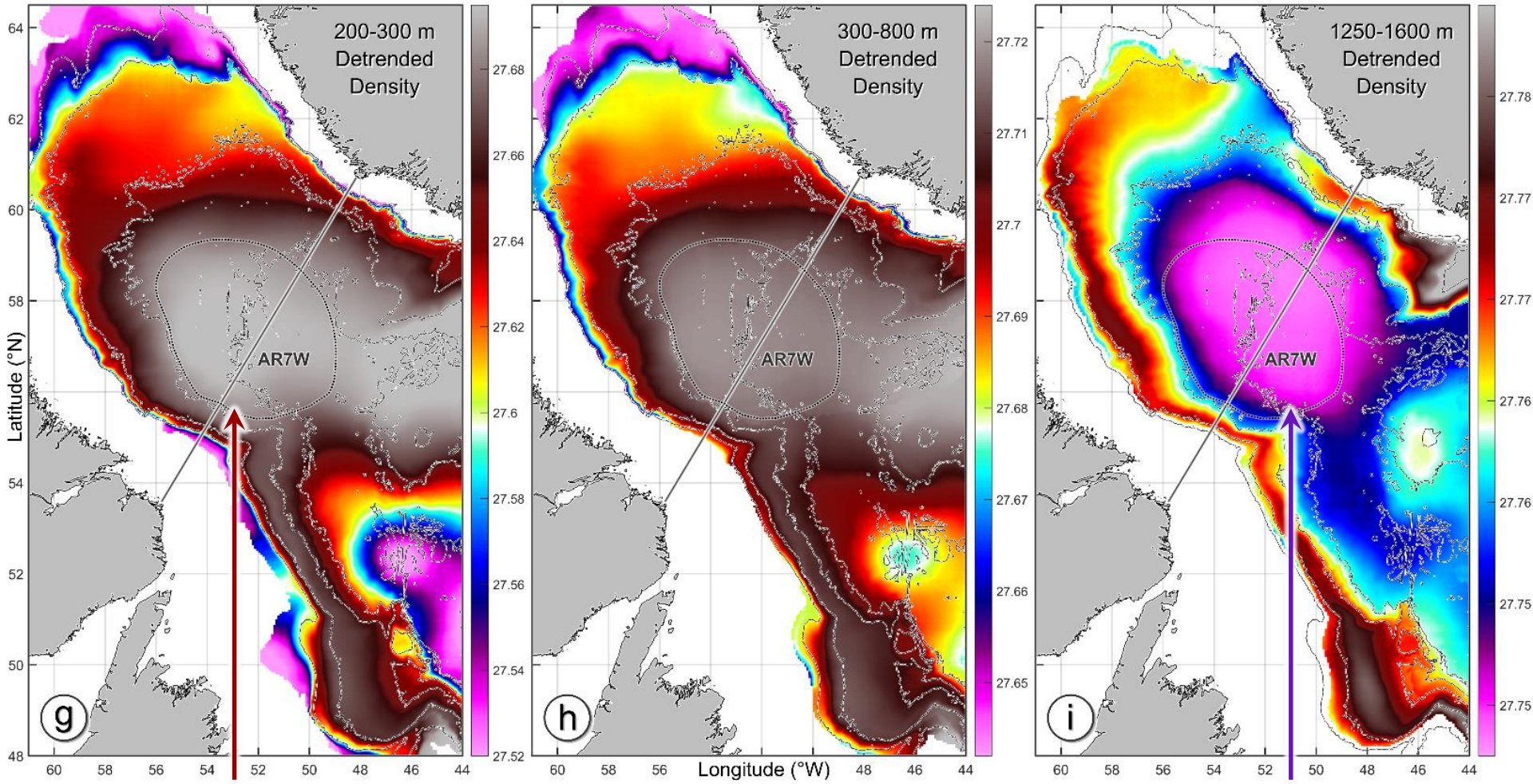
A reservoir of warm Atlantic Water in the northern Labrador Sea

2002-2024 Multiplatform Vertically-Averaged Salinity Climatology



Here freshwater and gases sink deeper than anywhere else in the subpolar North Atlantic

2002-2024 Multiplatform Vertically-Averaged Density Climatology



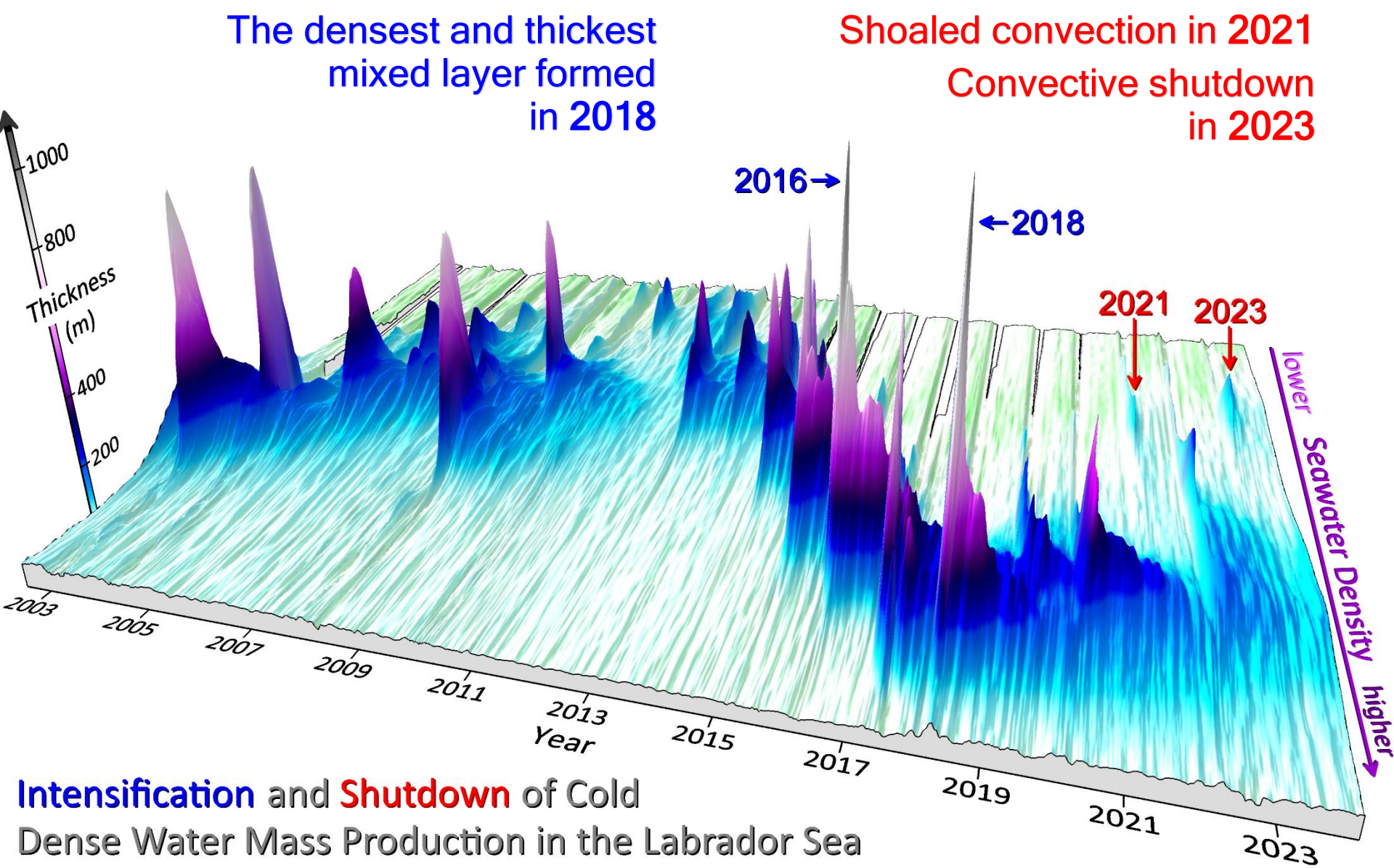
In the top 1000 m, the densest water is found in the center

Below 1000 m, the central Labrador Sea showcases a density minimum, explaining low stratification of the 200-1600 m layer.

This means that salinity dominates density at depth.

The second stop in our
Labrador Sea Magical Mystery Tour
is the state-of-the-art high-resolution
record of environmental conditions.
There are three major points
to be taken from there.

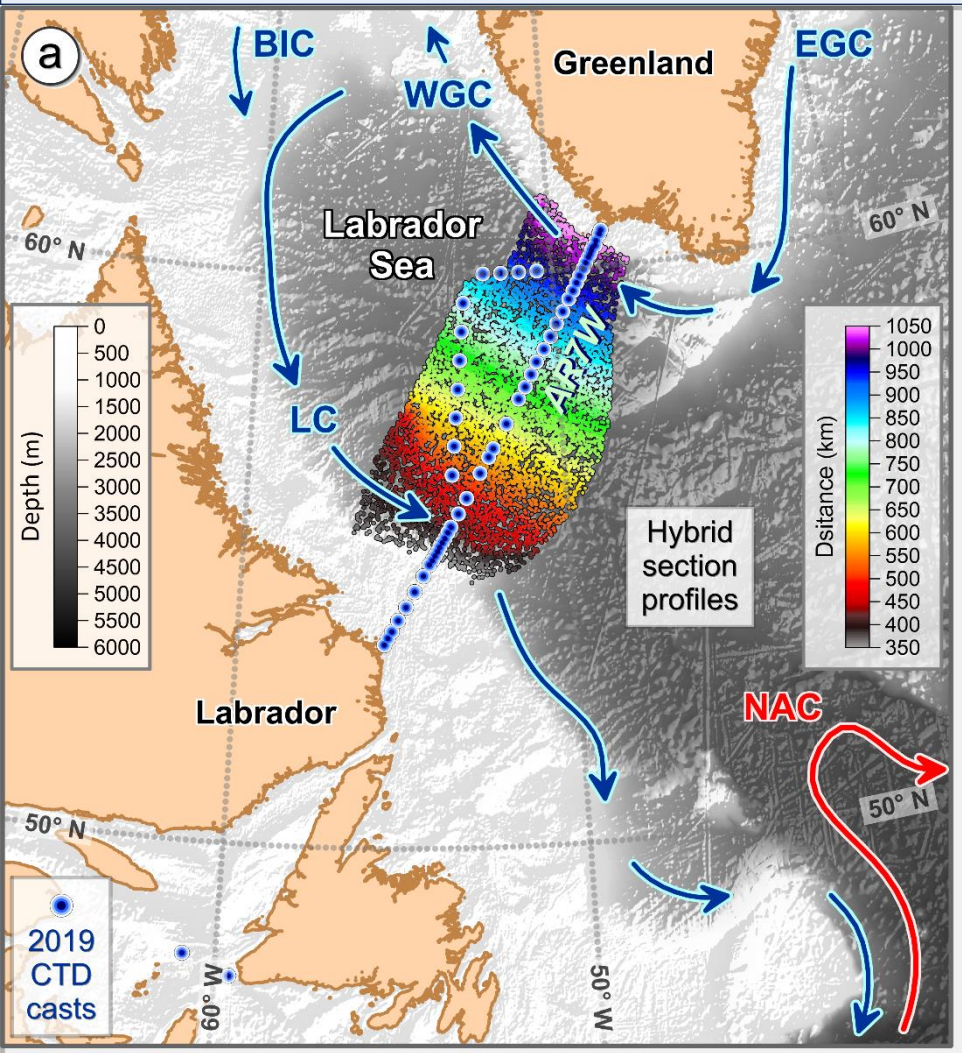
These features could only be discovered with Argo!

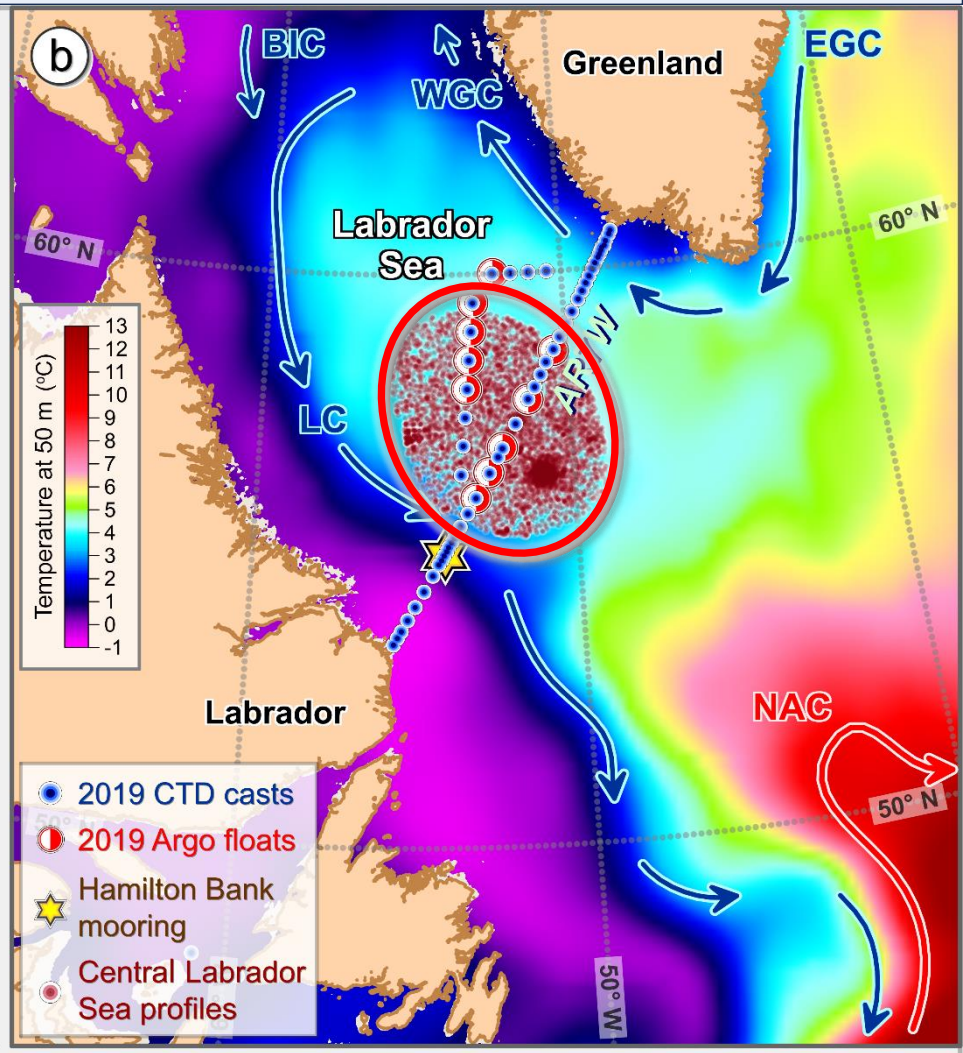


Intensification and **Shutdown** of Cold Dense Water Mass Production in the Labrador Sea

Labrador Sea Cardiogram – Measuring Heartbeat of the Sea

The Labrador Sea Deep-Ocean Observation and Research Synthesis (DOORS)
Oceanographic data uptake, quality control, analysis and synthesis platform

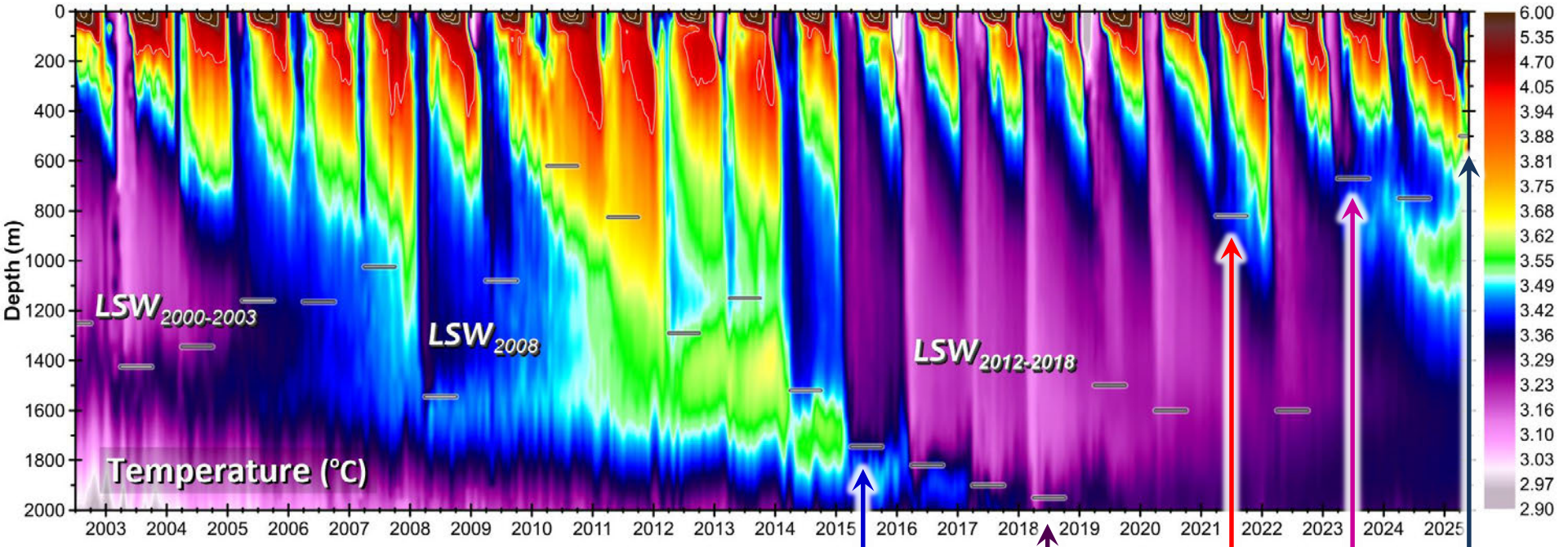




EGC - East-Greenland Current | **WGC** - West-Greenland Current | **LC** - Labrador Current | **BIC** - Baffin Island Current | **NAC** - North Atlantic Current

Distance color-coded locations of profiles used to construct the composite sections

Locations of the central Labrador Sea (CLS) profiles



2002 June – 2025 April

Temporal averaging is limited to maximum of two weeks, nominally – one week.

This is why the seasonality is resolved from surface to bottom in all years.

The ship-based data alone do not resolve the seasonal and interannual changes in the top 700 m layer.

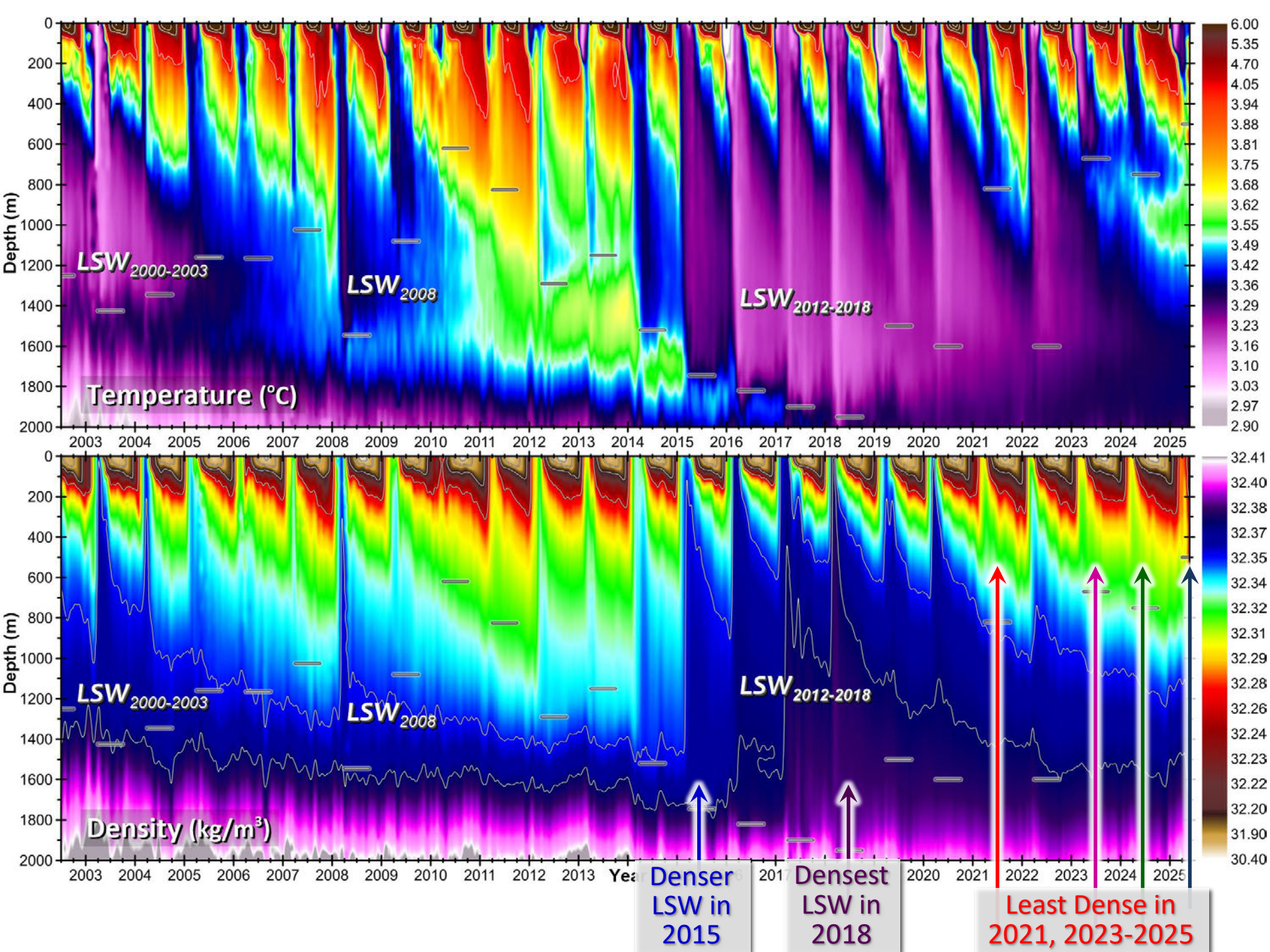
Strongest Cooling in 2015

Deepest Mixing in 2018

Rapid Warming in 2021

Shallow but Cold Mixed Layer in 2023

Record Shallow Mixed Layer in 2025


Depth (m)
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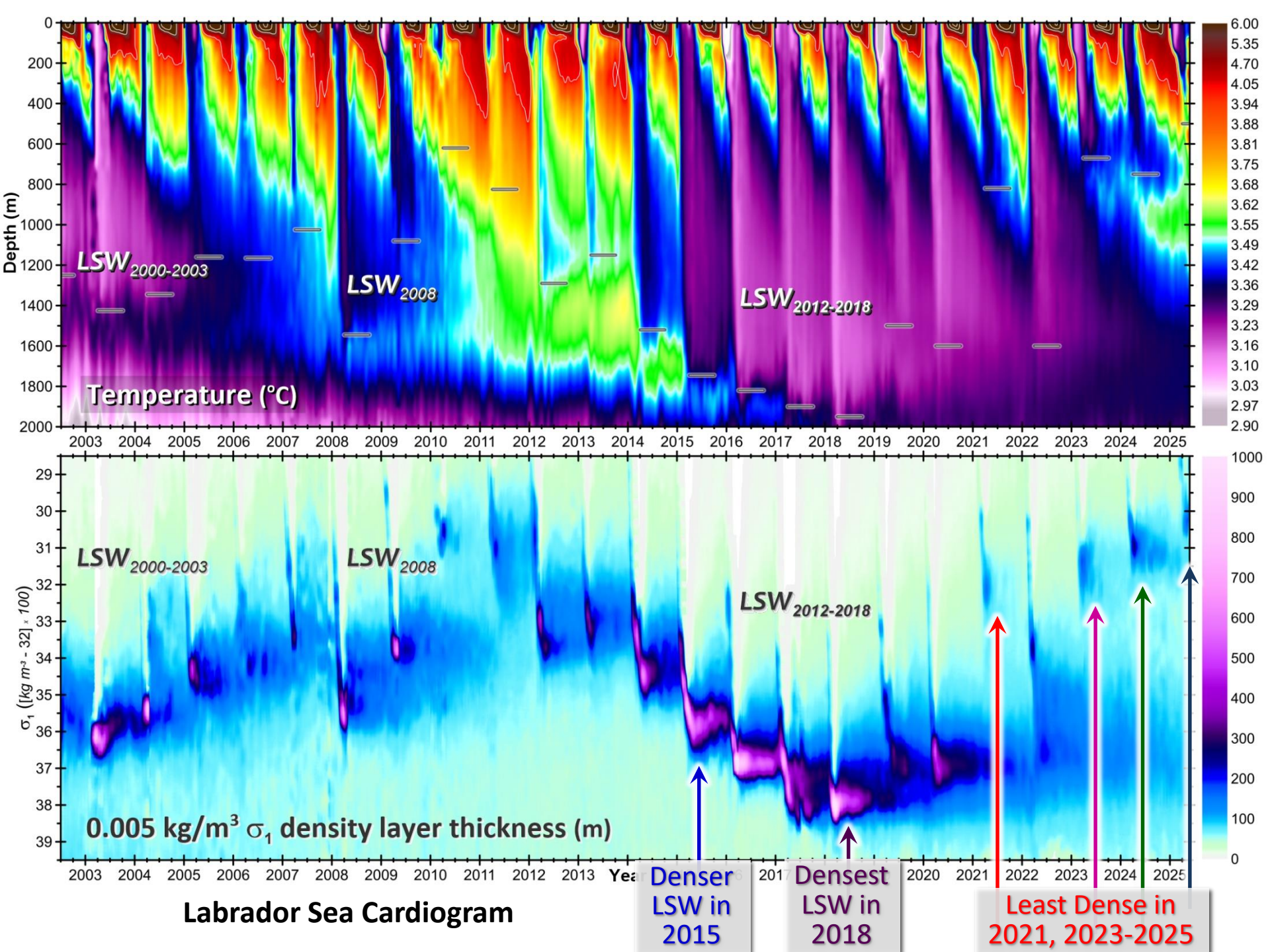
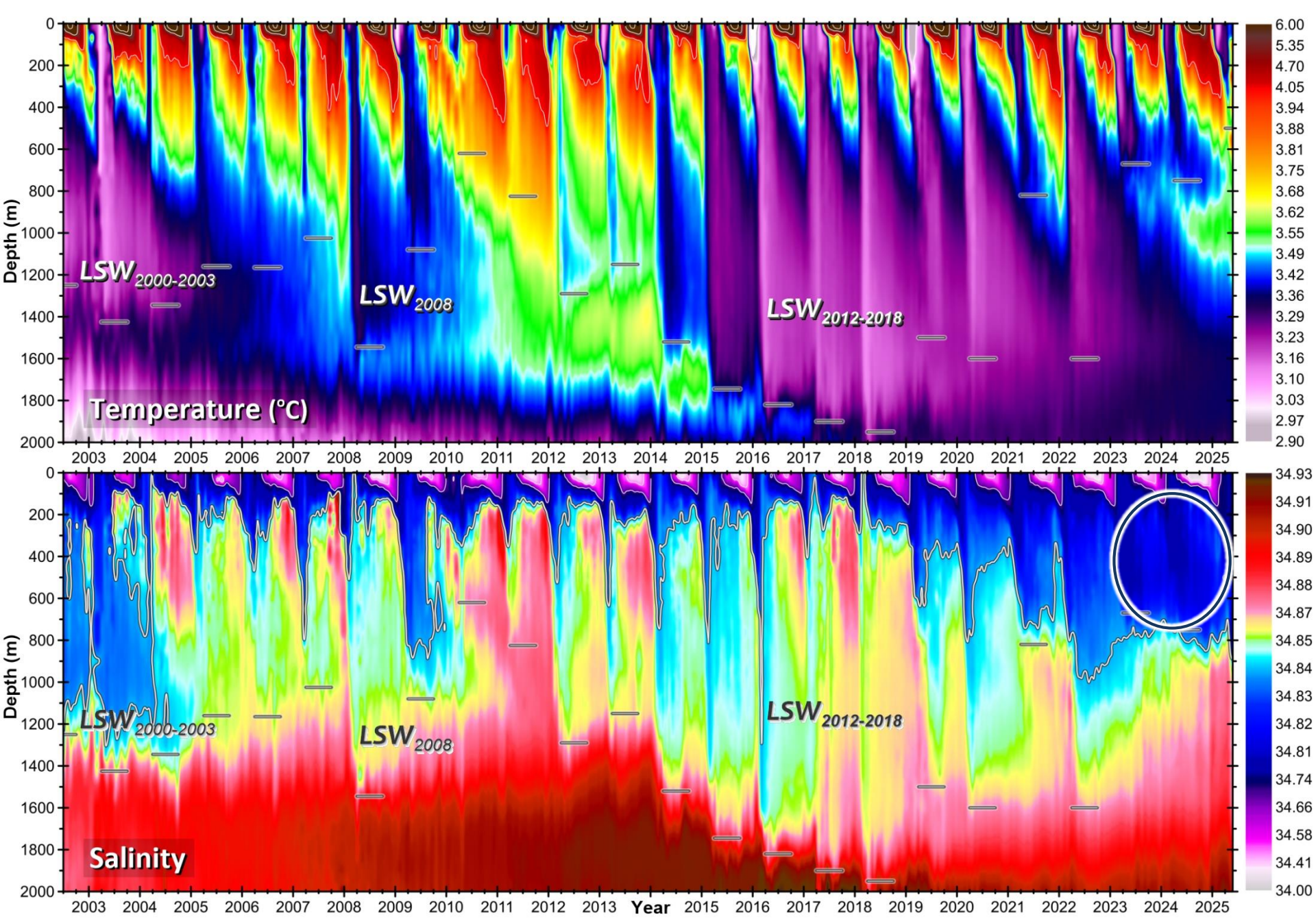
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
LSW2000-2003
LSW2008
LSW2012-2018
Temperature (°C)
6.00
5.35
4.70
4.05
3.94
3.88
3.81
3.75
3.68
3.62
3.55
3.49
3.42
3.36
3.29
3.23
3.16
3.10
3.03
2.97
2.90
Density (kg/m³)
32.41
32.40
32.38
32.37
32.35
32.34
32.32
32.31
32.29
32.28
32.26
32.24
32.23
32.22
32.20
31.90
30.40
Denser LSW in 2015
Densest LSW in 2018
Least Dense in 2021, 2023-2025


Depth (m)
LSW2000-2003
LSW2008
LSW2012-2018
Temperature (°C)
σ1 ([kg m-3 - 32] x 100)
0.005 kg/m3 σ1 density layer thickness (m)
Year
Denser LSW in 2015
Densest LSW in 2018
Least Dense in 2021, 2023-2025
Labrador Sea Cardiogram


Depth (m)
0
200
400
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800
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3.49
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3.36
3.29
3.23
3.16
3.10
3.03
2.97
2.90
2003
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2015
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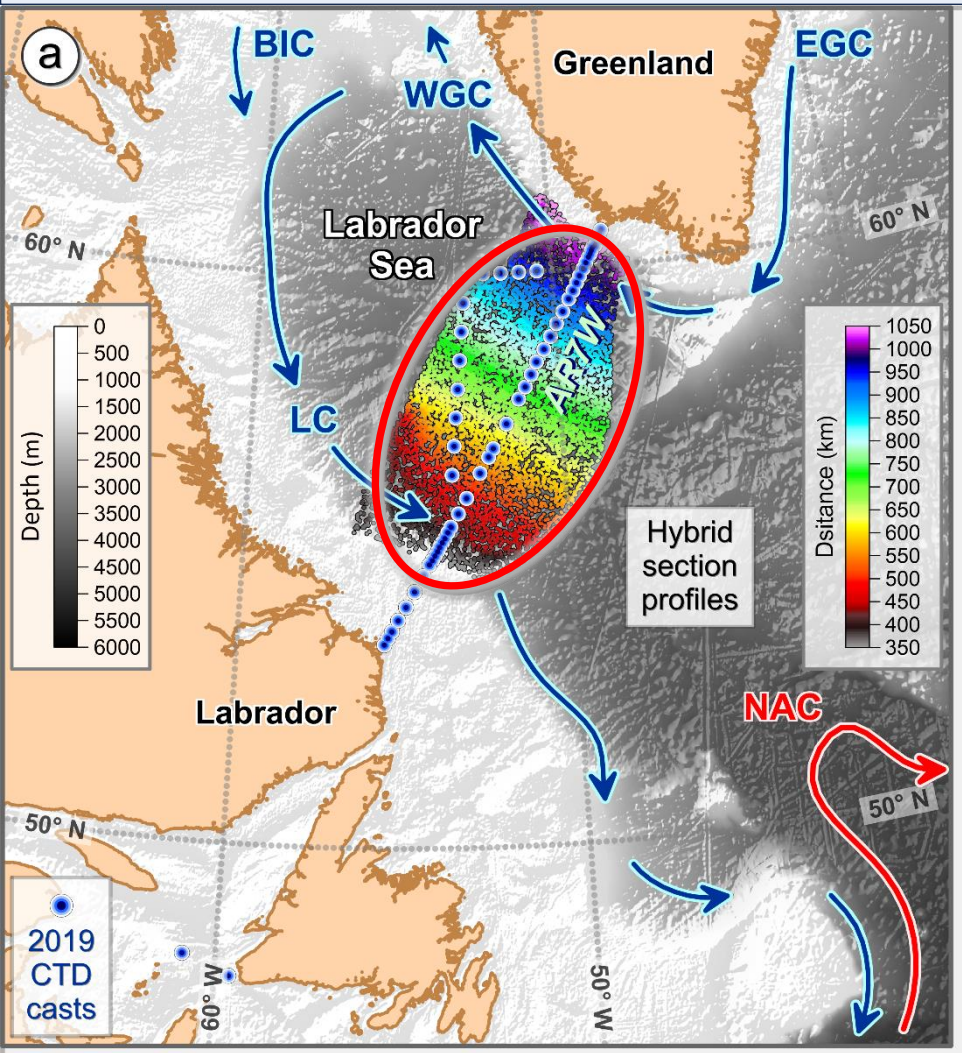
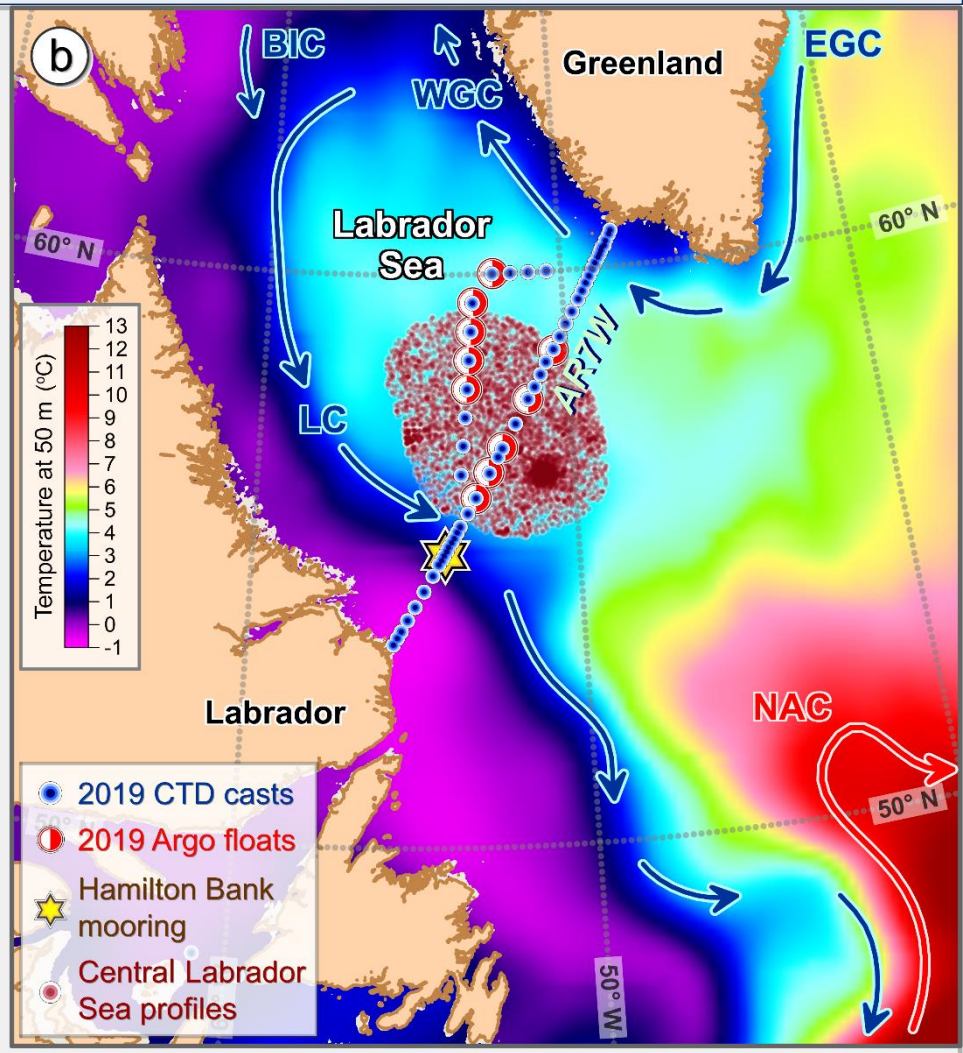
2017
2018
2019
2020
2021
2022
2023
2024
2025
Depth (m)
LSW2000-2003
LSW2008
LSW2012-2018
Salinity
34.93
34.91
34.90
34.89
34.88
34.87
34.85
34.84
34.83
34.82
34.81
34.74
34.66
34.58
34.41
34.00
Year

Next, we cross-examine annual April-August composite AR7W section plots for the period of 2018-2024

The Labrador Sea Deep-Ocean Observation and Research Synthesis (DOORS)
Oceanographic data uptake, quality control, analysis and synthesis platform





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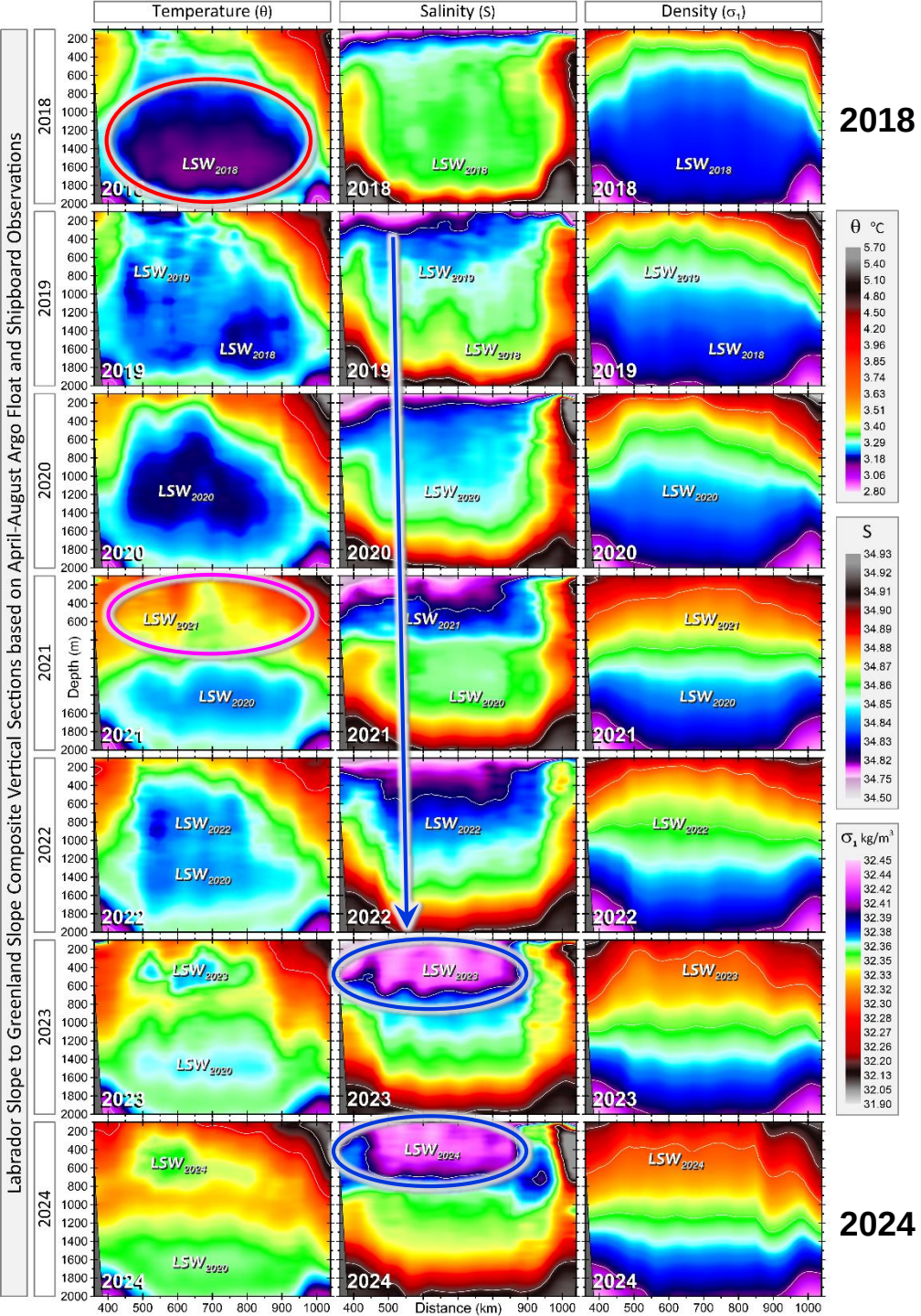


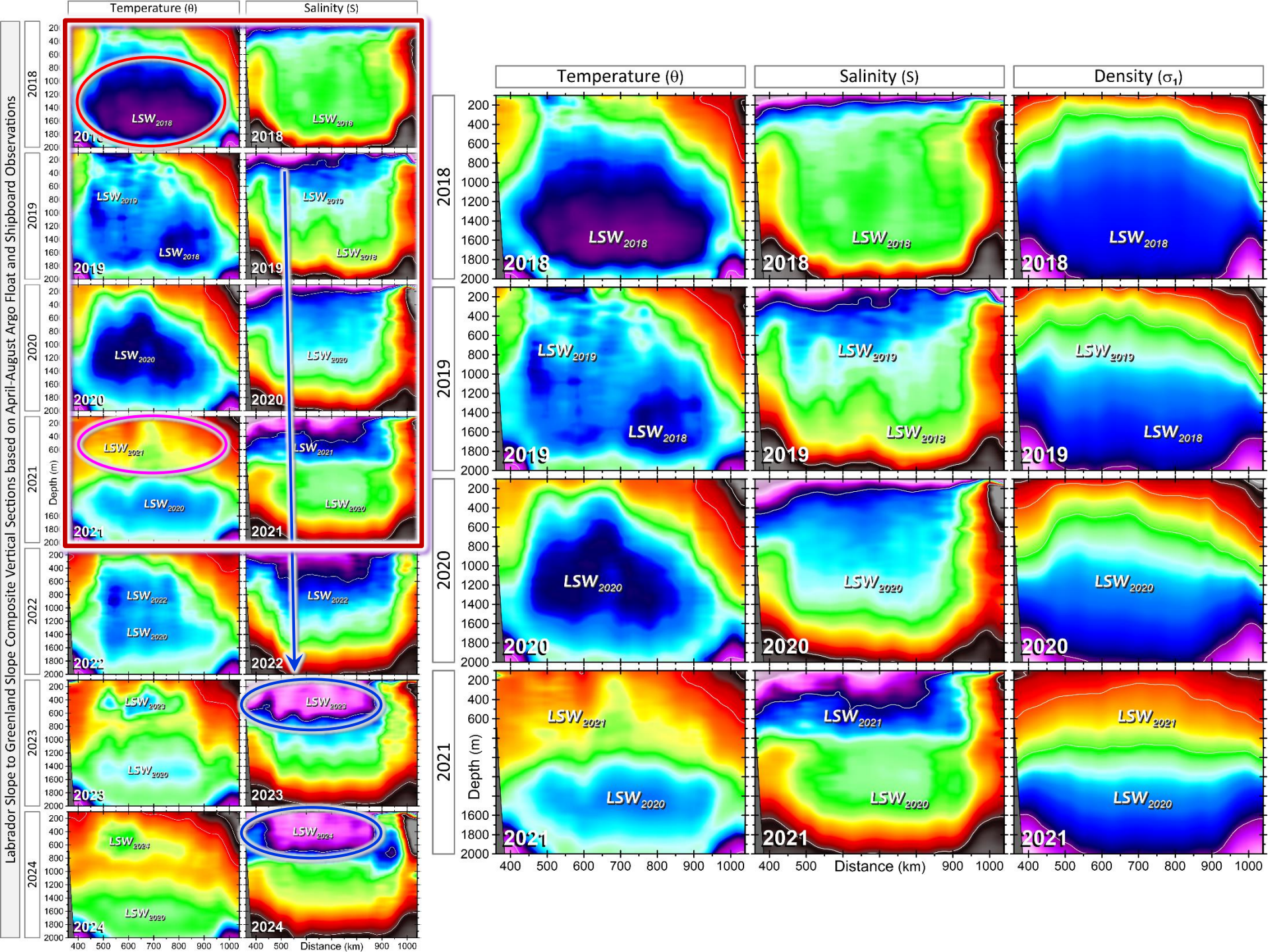
April-August Temperature, Salinity and Density on AR7W from Multiplatform Observations

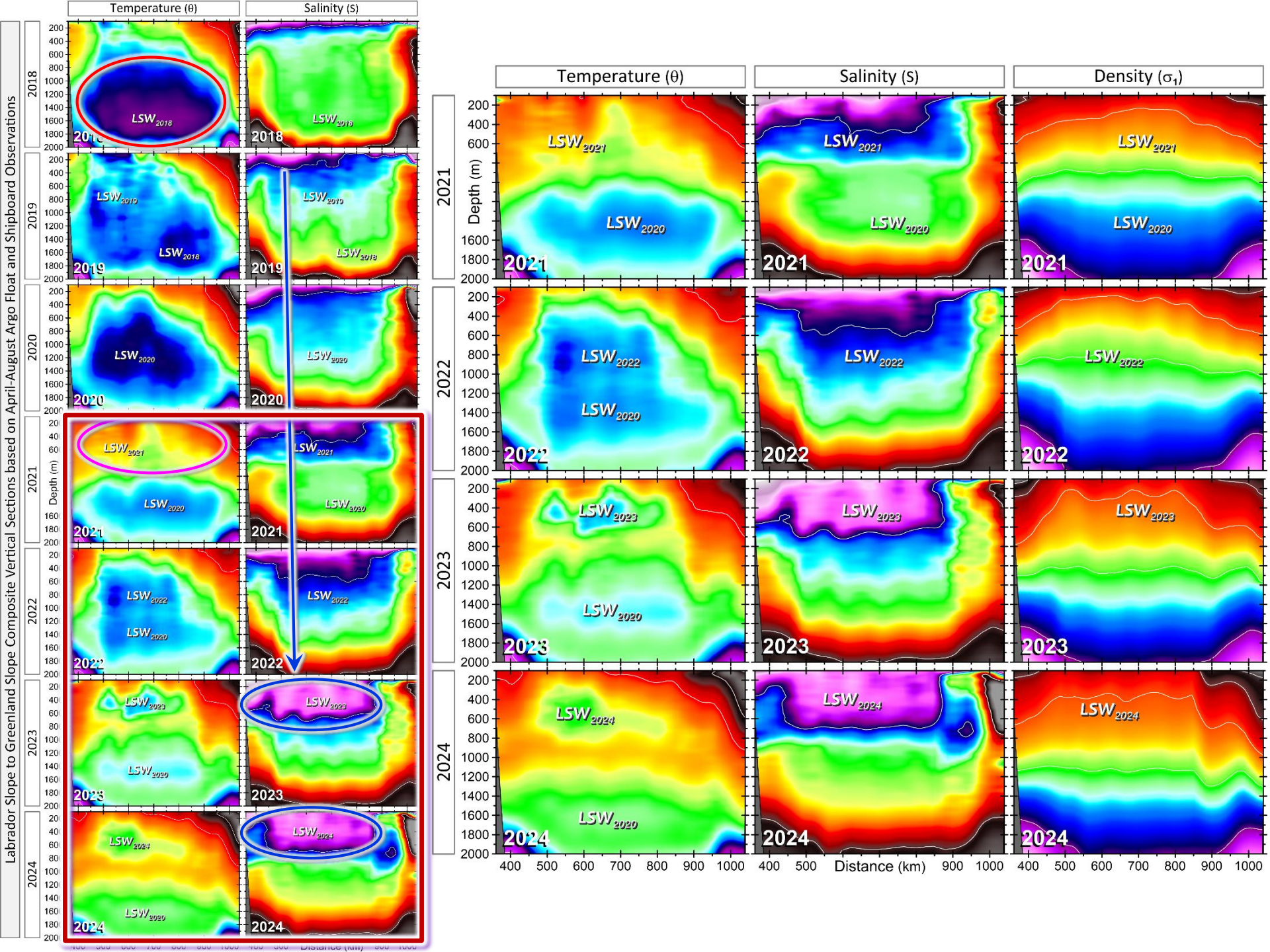
The sections were constructed using the hybrid coordinate method.

In the first year in this series, 2018, convection (large cold blob - **LSW_{2018}**) reached 2000 m.

LSW_{2018} was still present in 2019, when convection was much shallower, making the sea more stratified.

Most remarkable changes occurred in 2021 and 2023: **warm fresh low-density 800 m deep layer in 2021**, and **massive layer of fresher colder low-density water in 2023**.


Temperature (θ)
Salinity (S)
Density (σ1)
Labrador Slope to Greenland Slope Composite Vertical Sections based on April-August Argo Float and Shipboard Observations
2018
2019
2020
2021
2022
2023
2024
Depth (m)
Distance (km)
LSW2018
LSW2019
LSW2020
LSW2021
LSW2022
LSW2023
LSW2024


Labrador Slope to Greenland Slope Composite Vertical Sections based on April-August Argo Float and Shipboard Observations
Temperature (θ)
Salinity (S)
Density (σ1)
Depth (m)
Distance (km)
2018
2019
2020
2021
2022
2023
2024
LSW2018
LSW2019
LSW2020
LSW2021
LSW2022
LSW2023
LSW2024

The Labrador Sea oceanographic record contains water sample, reversing thermometer, CTD and Argo float data

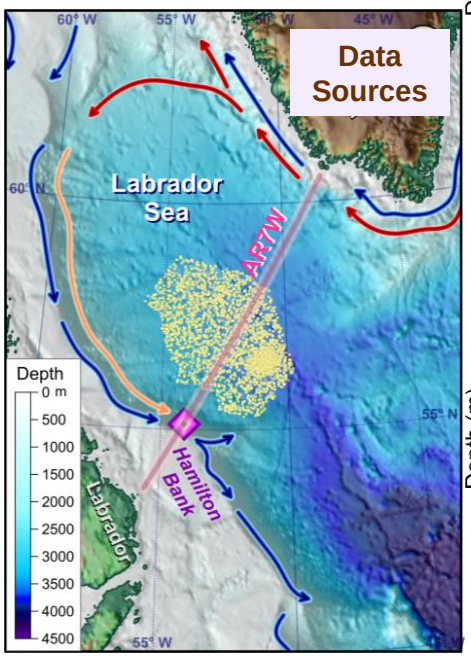
Vertical profile averaging:

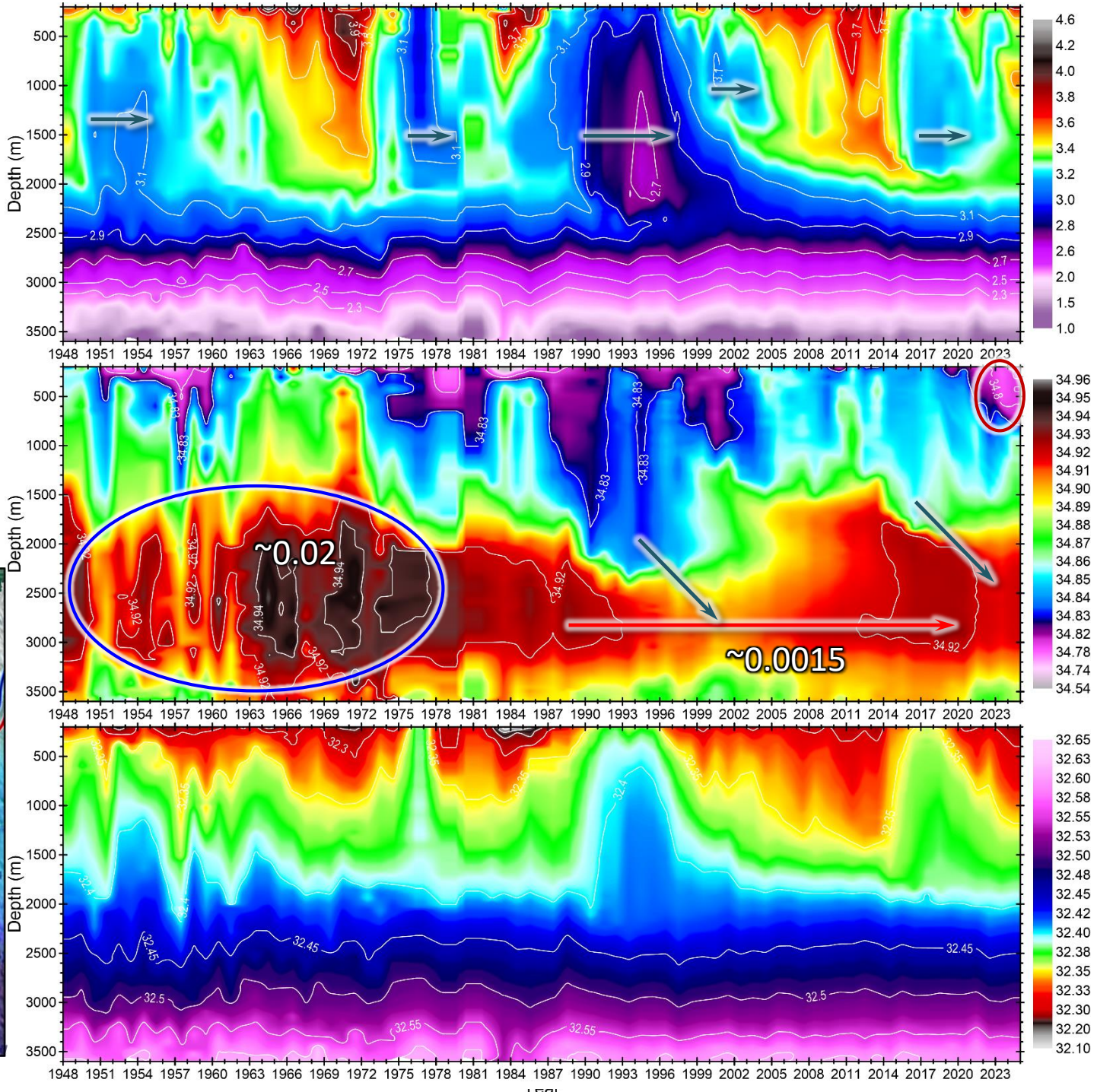
Early years – isobaric;

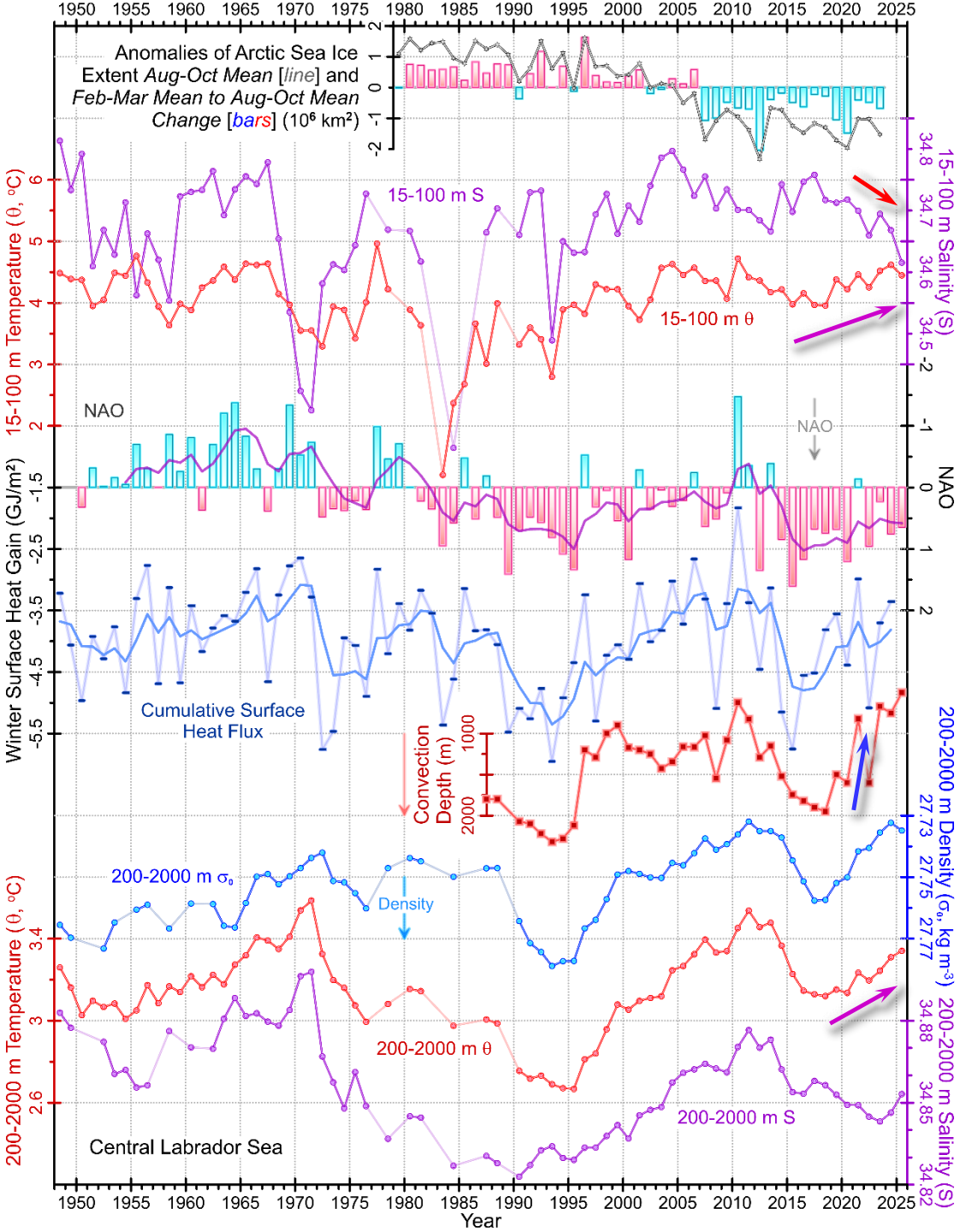
1948-1975 – isobaric-isopycnic hybrid;

1976-2023 – isopycnic;

Argo-only – isobaric 2017 & 2021







Yearly-Averaged Key Oceanographic Metrics of the Labrador Sea updated through 2025

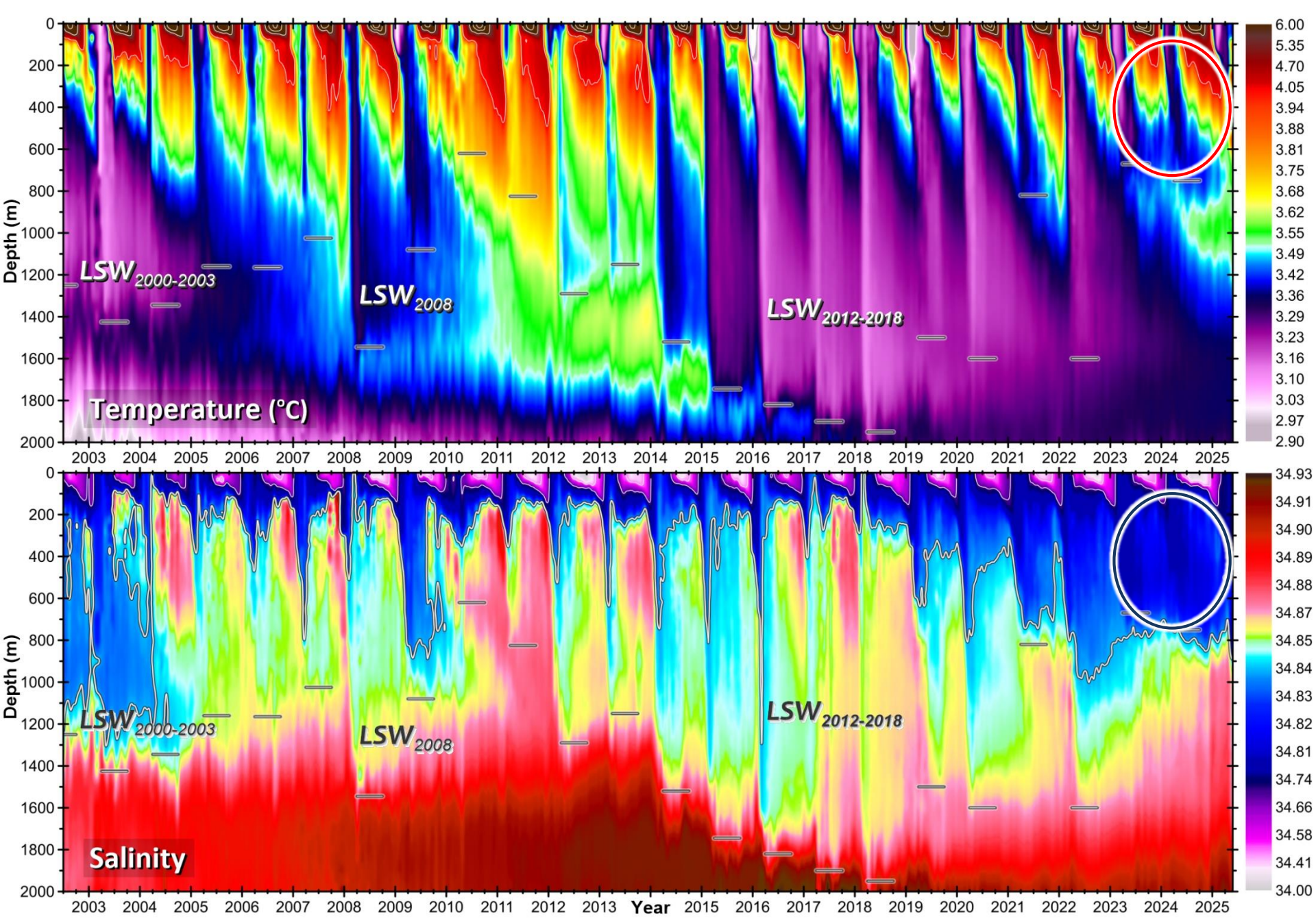
Extreme freshening of the upper, 15-100 m, layer in 2022 and 2025.

Persistent warming of the upper and intermediate layers.

Shoaling of winter convection after 2018. Record shallow convection in 2025.

Please download the report (*having the same name as this presentation*) featuring year-by-year changing seasonalities, anomalies and other cool metrics of the upper layer.

Let’s revisit our striking time series,
and ask ourselves one question …


Depth (m)
0
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LSW2000-2003
LSW2008
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Depth (m)
LSW2000-2003
LSW2008
LSW2012-2018
Salinity
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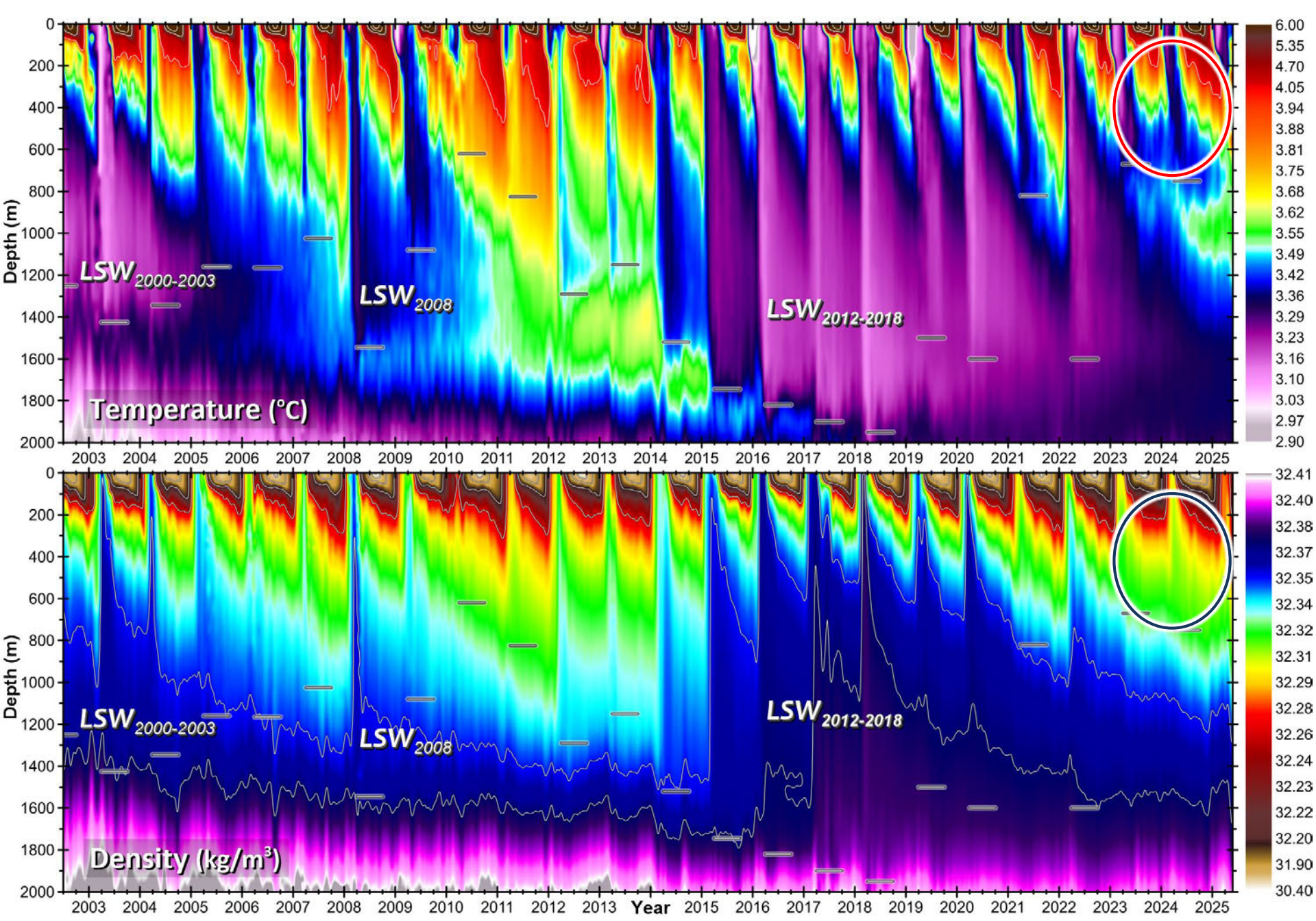
34.87
34.85
34.84
34.83
34.82
34.81
34.74
34.66
34.58
34.41
34.00
Year


Depth (m)
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Depth (m)
LSW2000-2003
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Density (kg/m³)
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32.32
32.31
32.29
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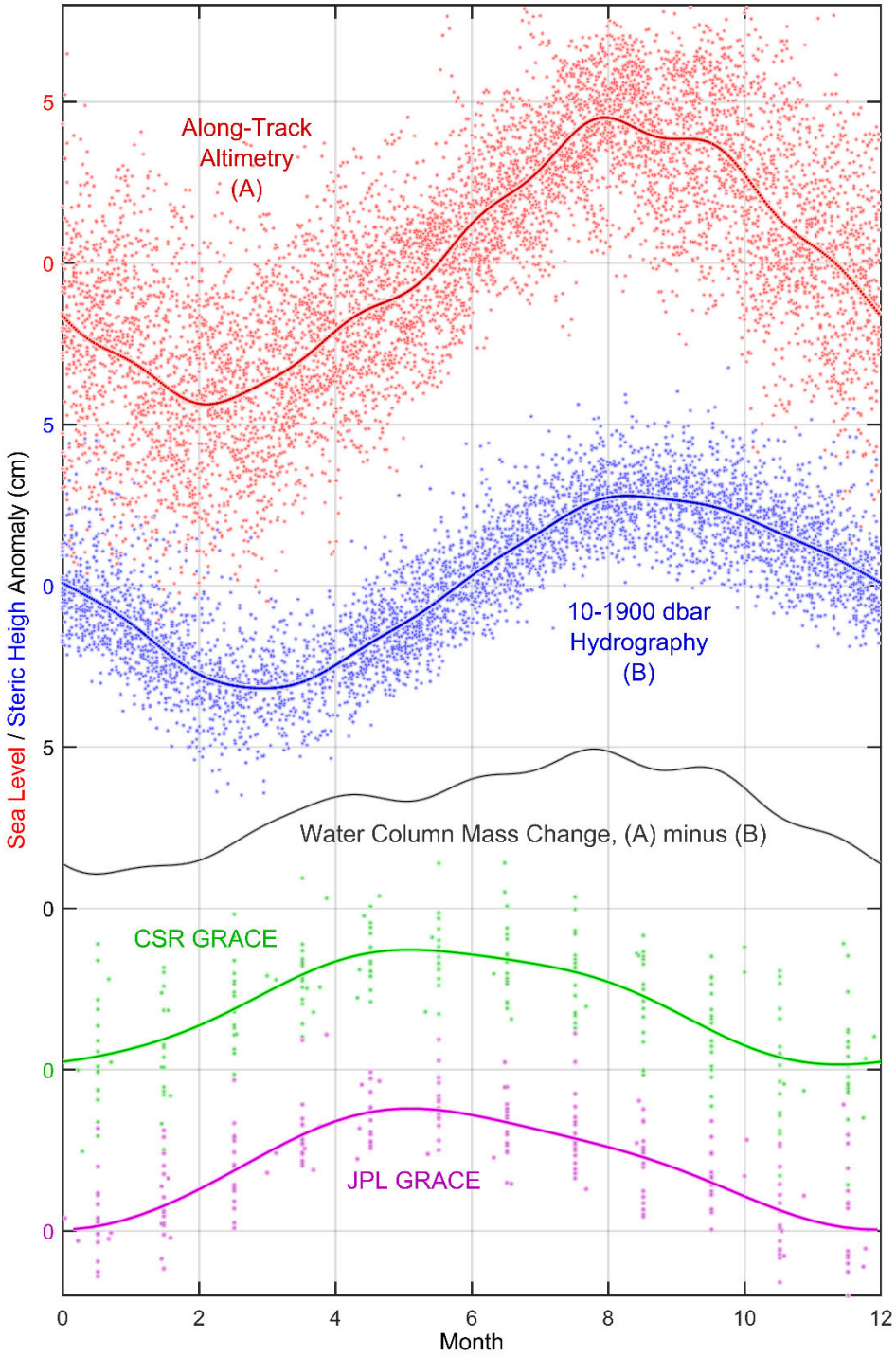
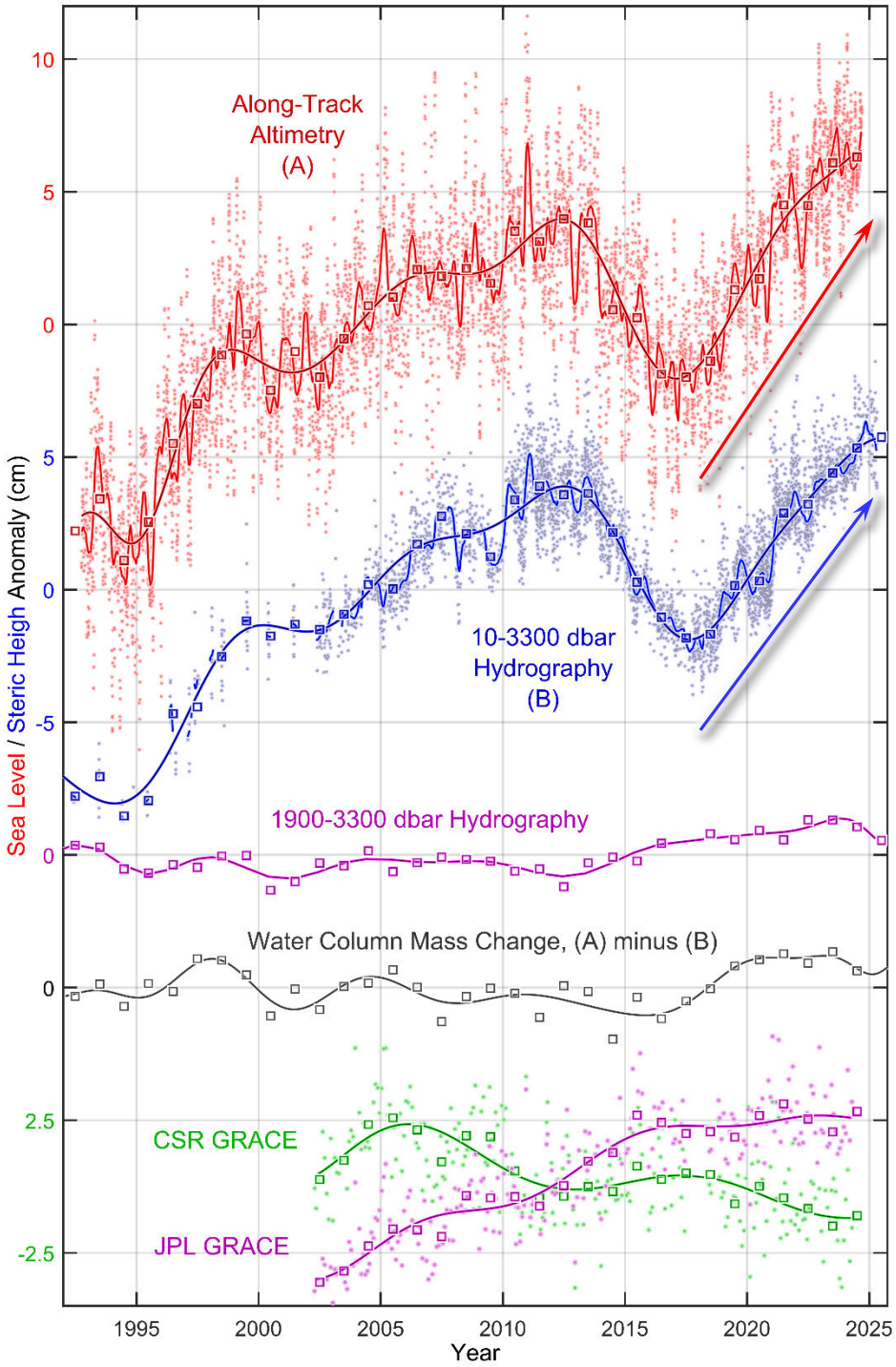
32.24
32.23
32.22
32.20
31.90
30.40
Year

How do the concurrent warming and freshening of the Labrador Sea affect the sea level?



Total Variance
=
Interannual
+
Regular
Seasonal
+
Irregular
Seasonal
+
MesoSynopitc
+
High-Frequency
+
Noise

Igor Yashayaev
& Yang Zhang,
in revision for
Nature
Communications



Total Variance
=
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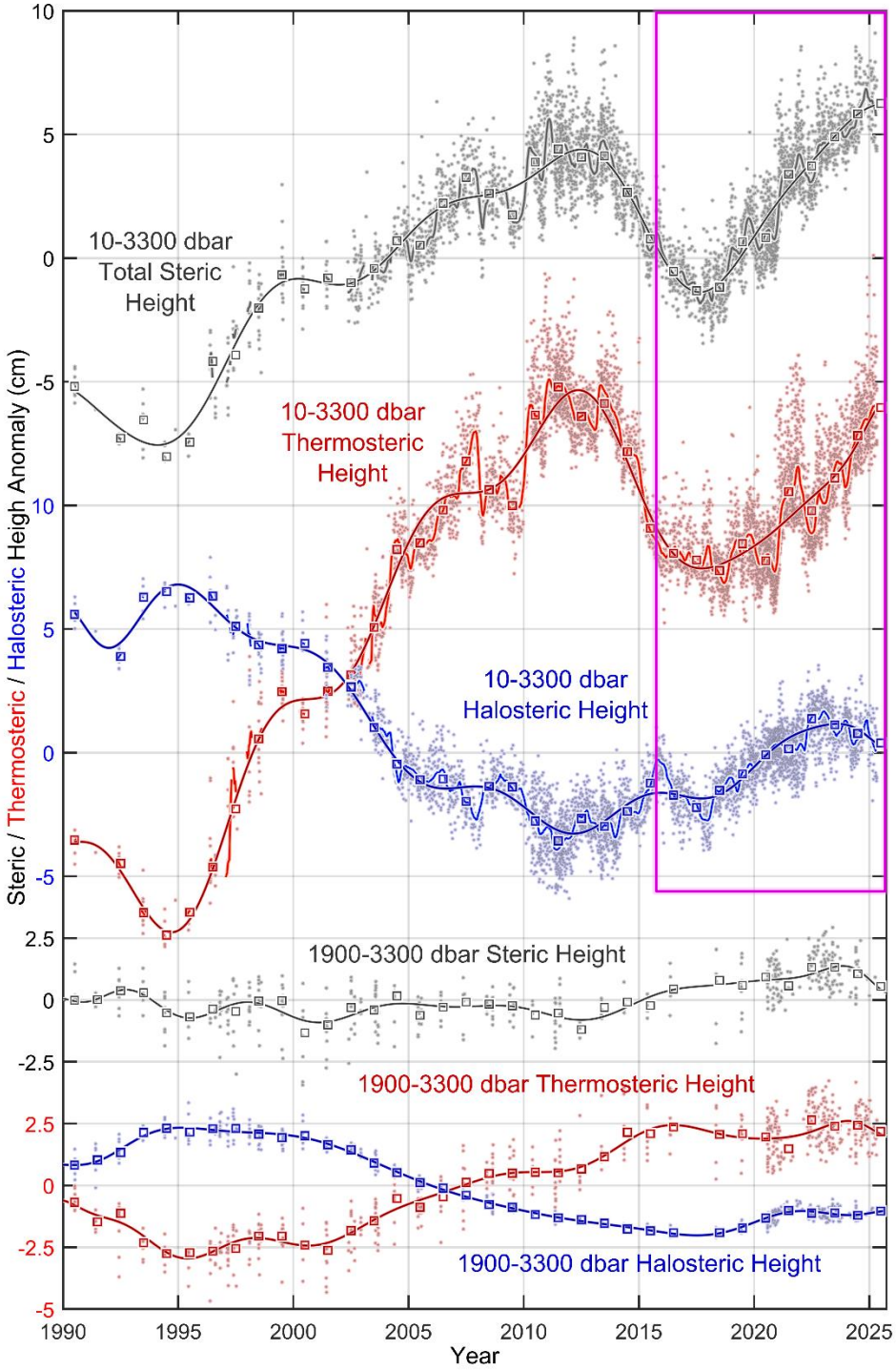
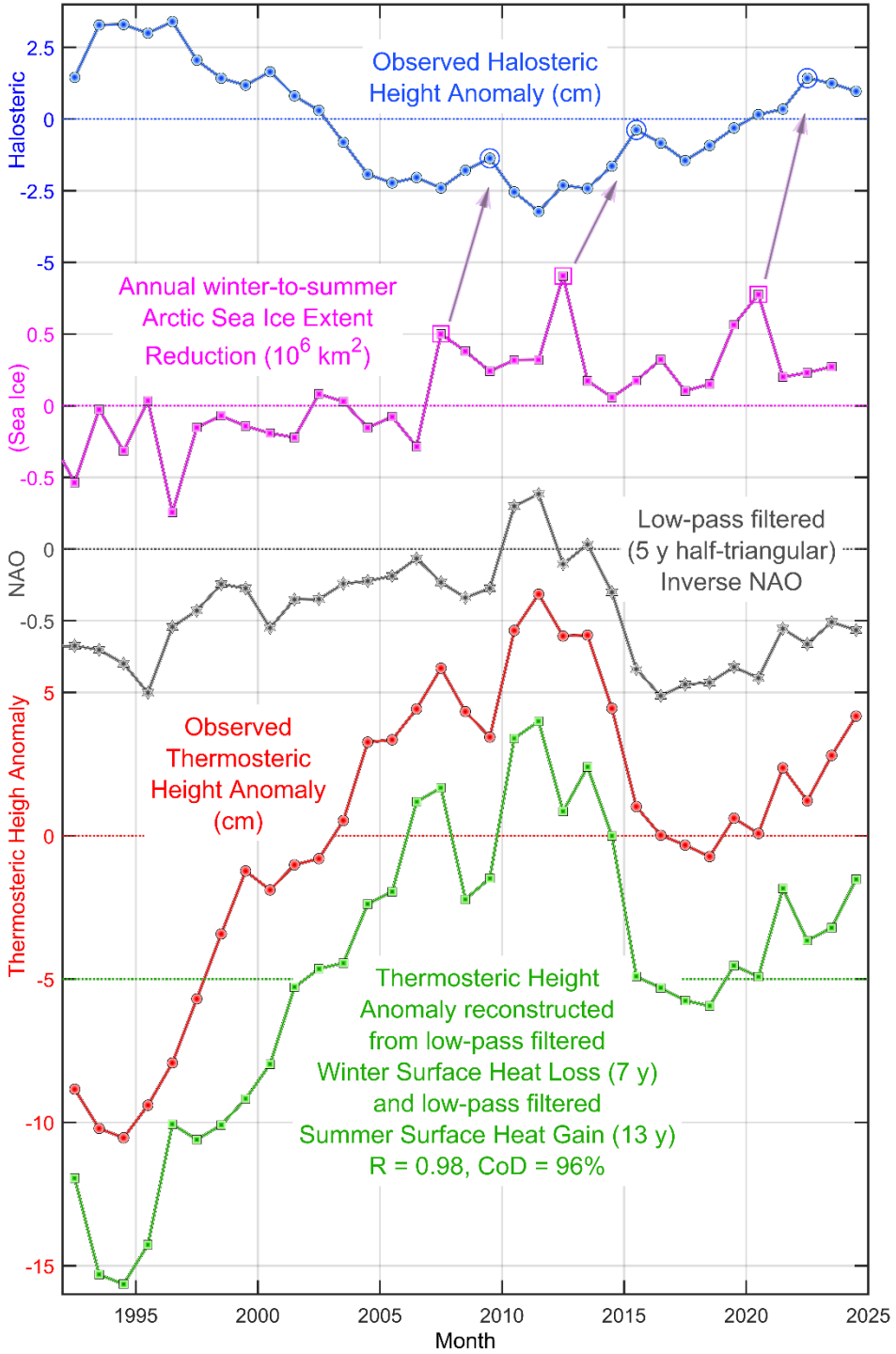


After 2015, temperature and salinity add concurrently to sea level rise.

Halosteric effect reversal

Igor Yashayaev & Yang Zhang, in revision for *Nature Communications*

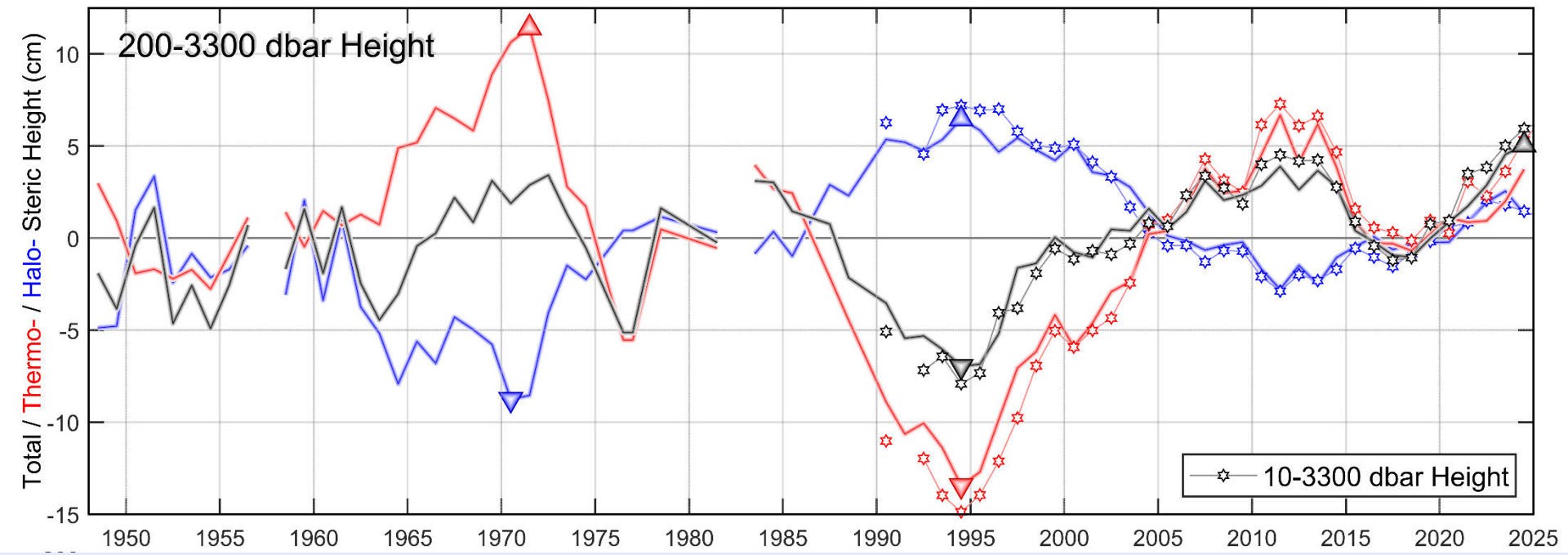


Igor Yashayaev
& Yang Zhang,
in revision for
Nature
Communications

Now, an important question is
if a similar team-play of temperature
and salinity happened in the past.

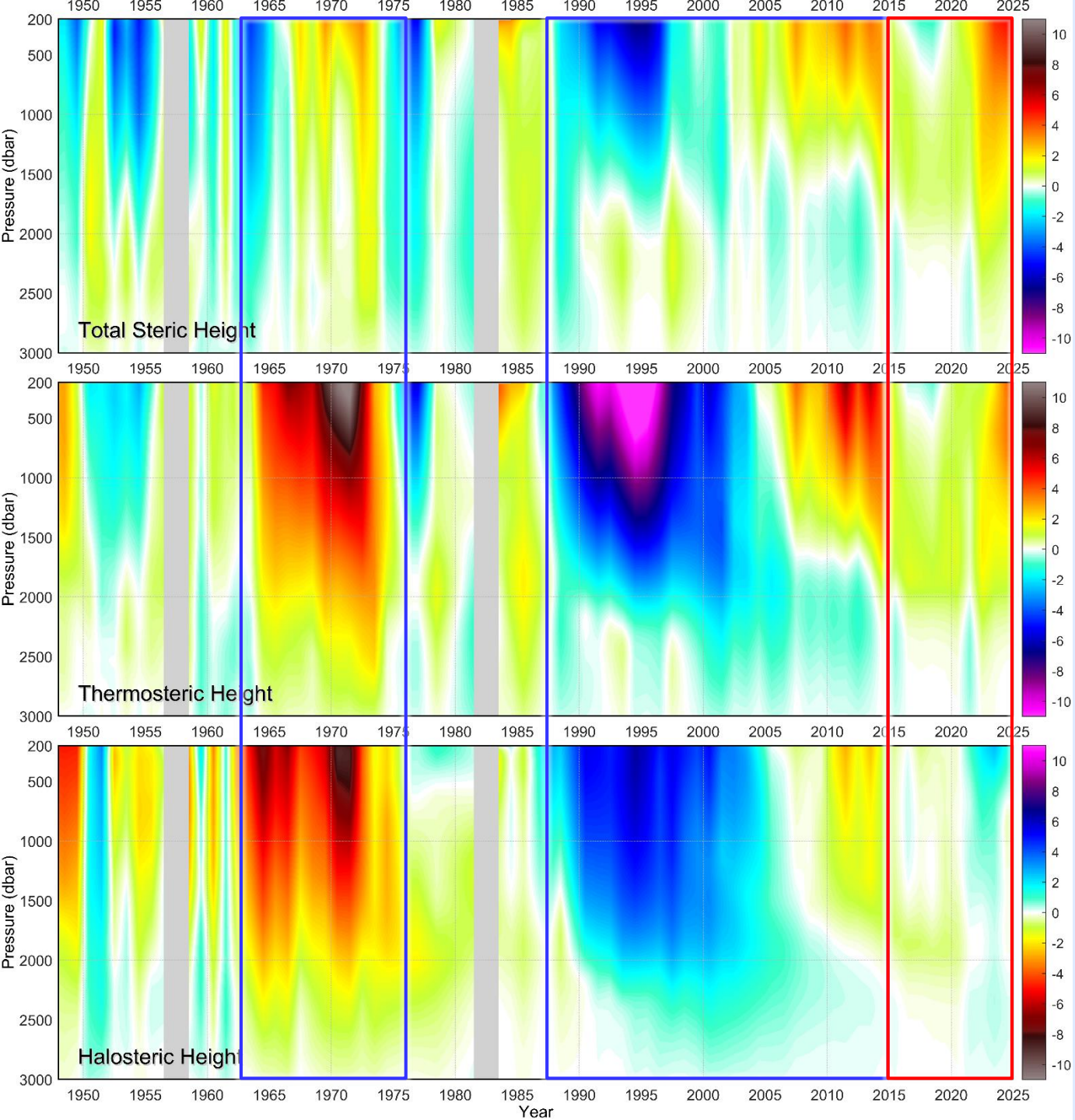
Starting from 2002, we are fully geared to resolve and interpret seasonal and interannual variability from surface-to-bottom. In the past, we only had a relatively small number of ship-based observations scattered between years and seasons. So, we need to remove the top 200 m layer for any proper analysis of the past changes.

What do we lose in the steric signals by chopping the top 200 m thick part off?



The test passed – the top 200 m layer does not change the overall trend in the steric heigh and its components.

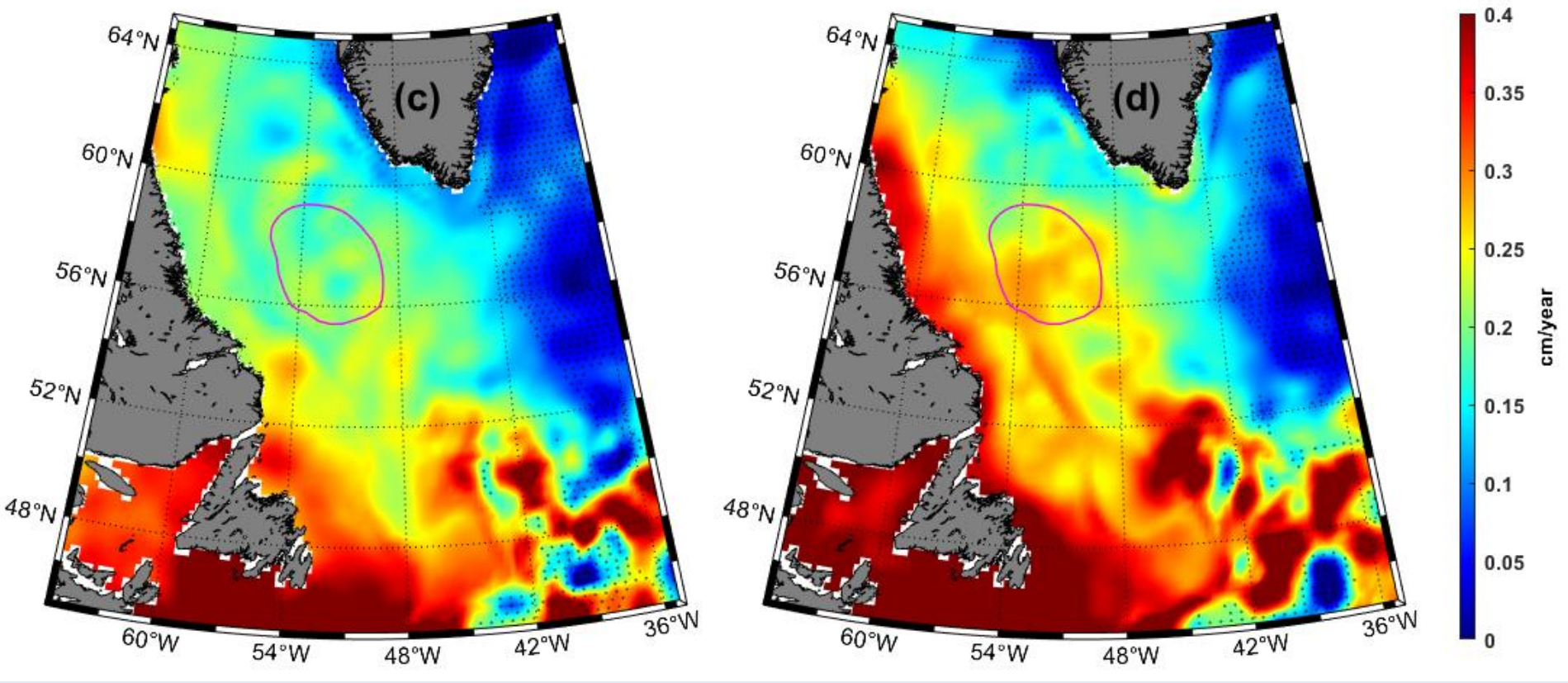
However, there is a small reduction in magnitude, if the top is removed.



Halosteric effect reversal

Note that for easier comparison of counterbalancing effects the halosteric colours are flipped upside-down.

Why do we need to pay attention to sea level?



Winter (left) and summer (right) sea level trends (cm/year).

Amplification in the coastal area due to melt.

Change in the spatial gradient (tilt) of the sea surface affects circulation.

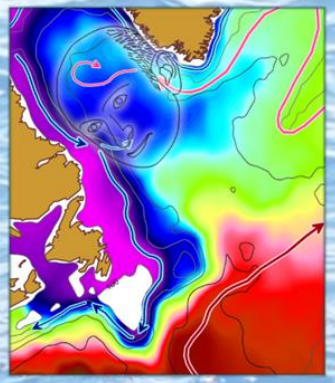
Igor Yashayaev & Yang Zhang, in revision for *Nature Communications*

Conclusions:

Record strong freshening, record shallow convection and record high sea level in the Labrador Sea throughout 2023-2025

A switch from the halosteric compensation of the thermosteric contribution to the sea level rise to the halosteric enforcement after 2015

Thermosteric and halosteric height changes are predictable



Igor Yashayaev

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Source:

Yashayaev, I. 2025. 2024 and 2025 Oceanographic Conditions in the Labrador Sea in the Context of Seasonal-to-Multidecadal Variability. Scientific Council Research Documents, SCR 25/13.