

Thinning of the cold halocline in the Beaufort Gyre

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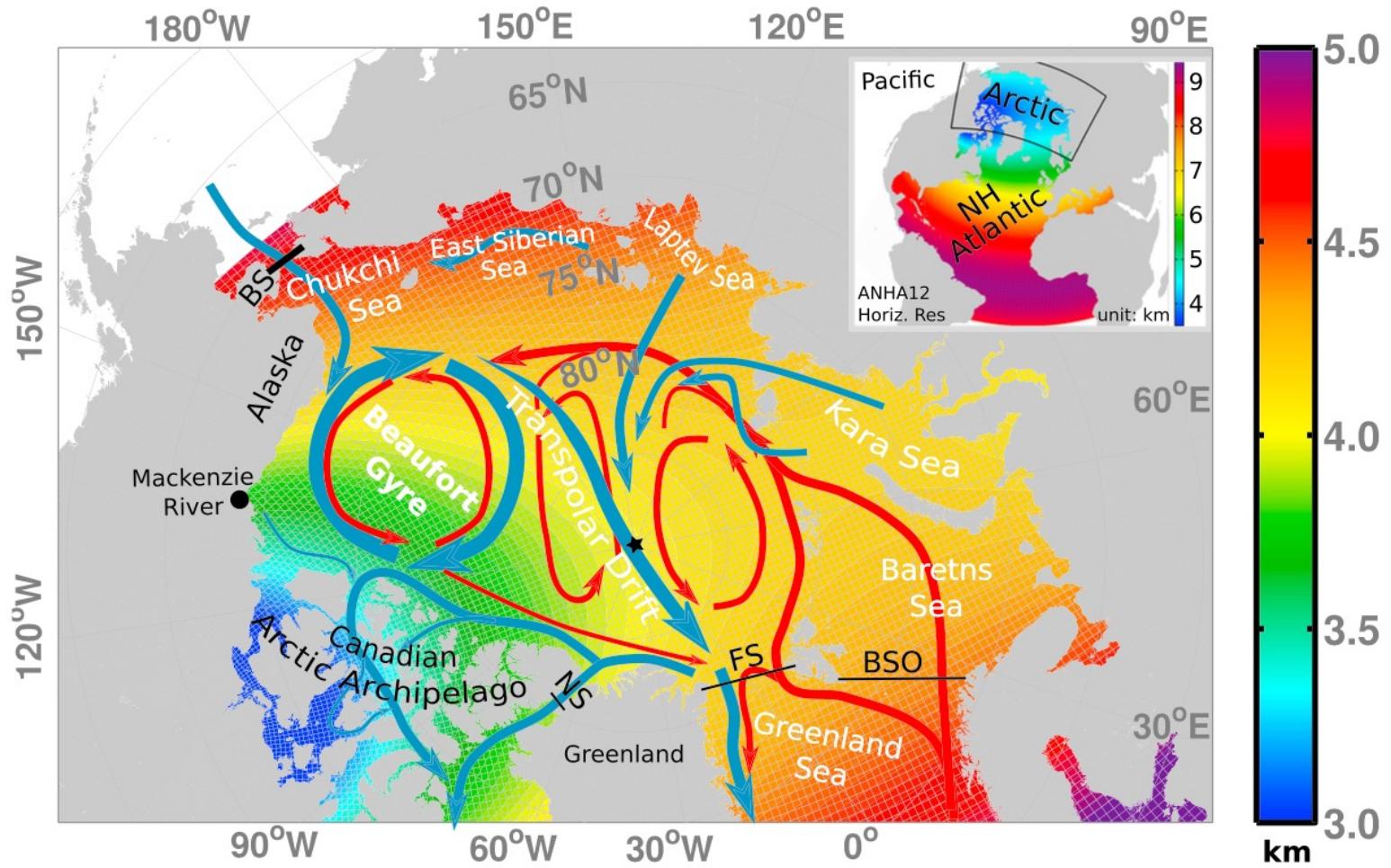


Outline

- 1. Overview of the Beaufort Gyre
- 2. Long-term trend of the Beaufort Gyre
- 3. Causes of the thinning cold halocline layer in the gyre region.



1. Beaufort Gyre



Hu et al., 2019



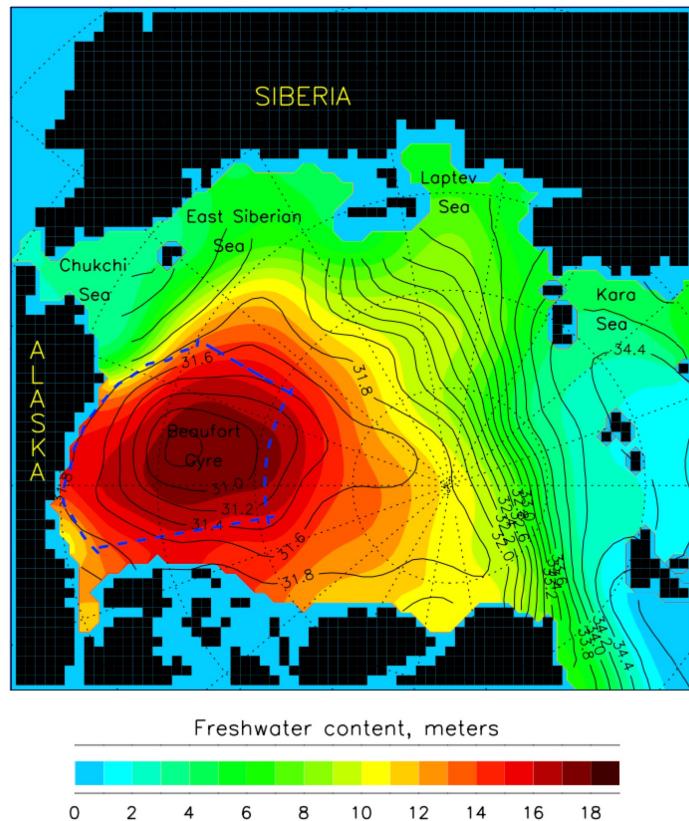
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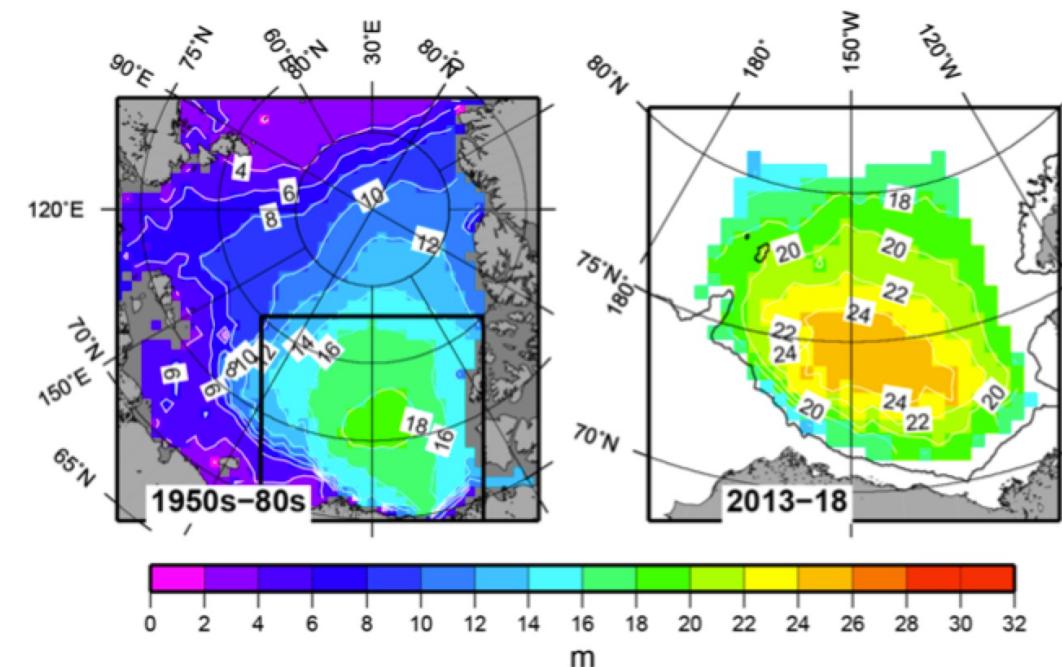
1. Beaufort Gyre

Largest freshwater reservoir in the Arctic



Proshutinsky et al., 2009

Freshwater content



Proshutinsky et al., 2019a

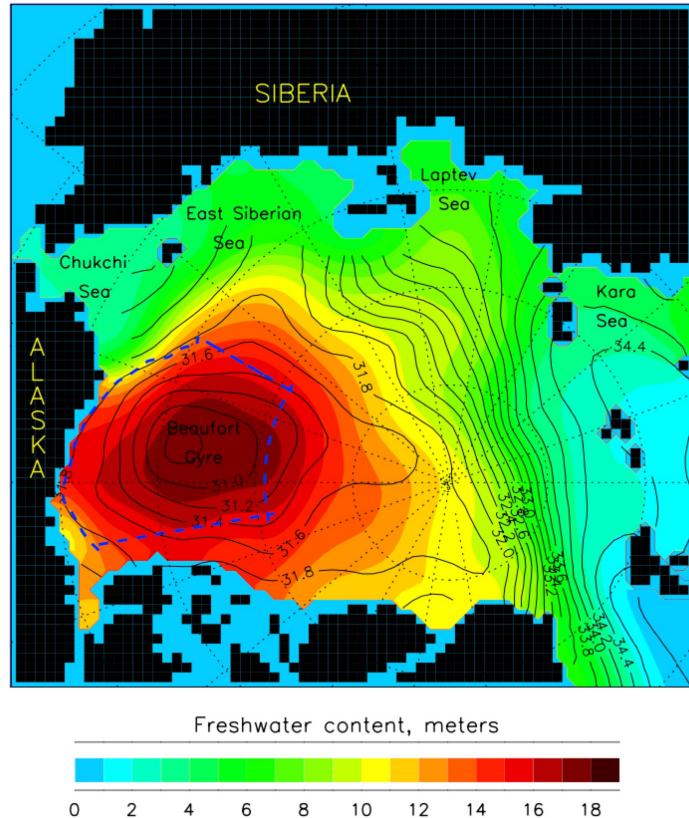


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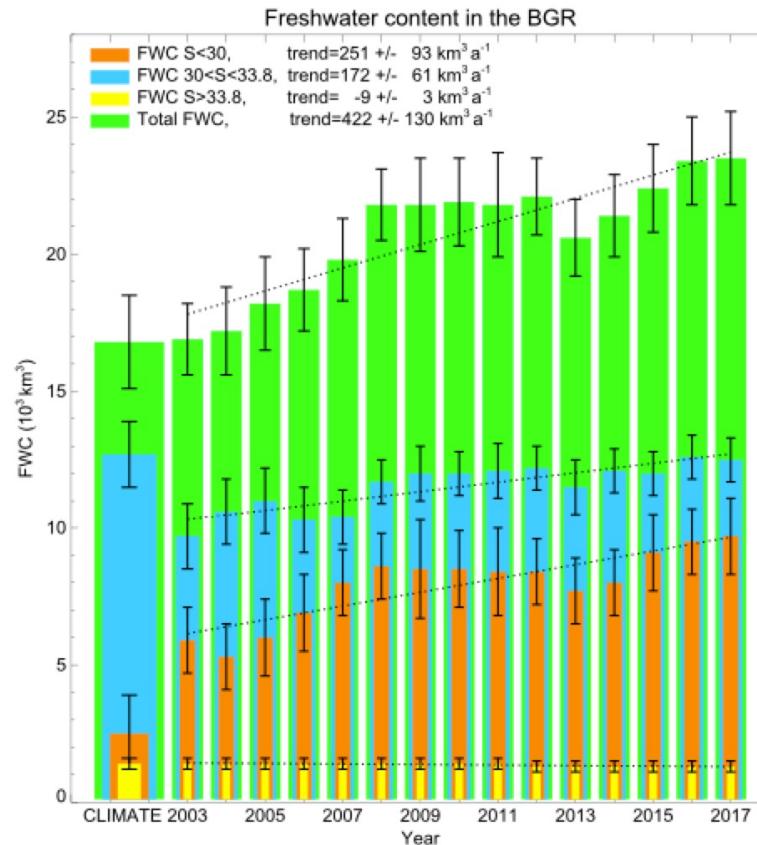
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1. Beaufort Gyre

Largest freshwater reservoir in the Arctic



Proshutinsky et al., 2009



Proshutinsky et al., 2019a



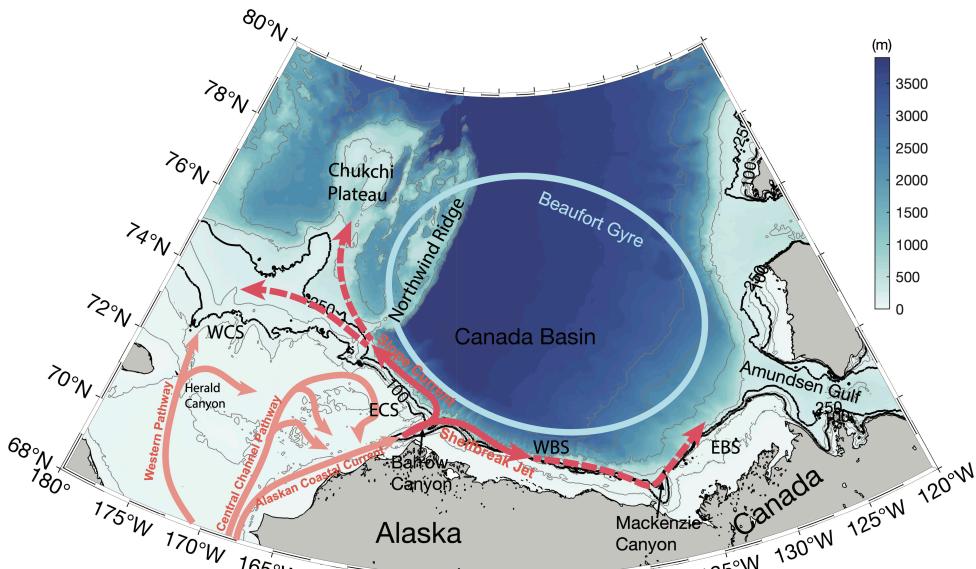
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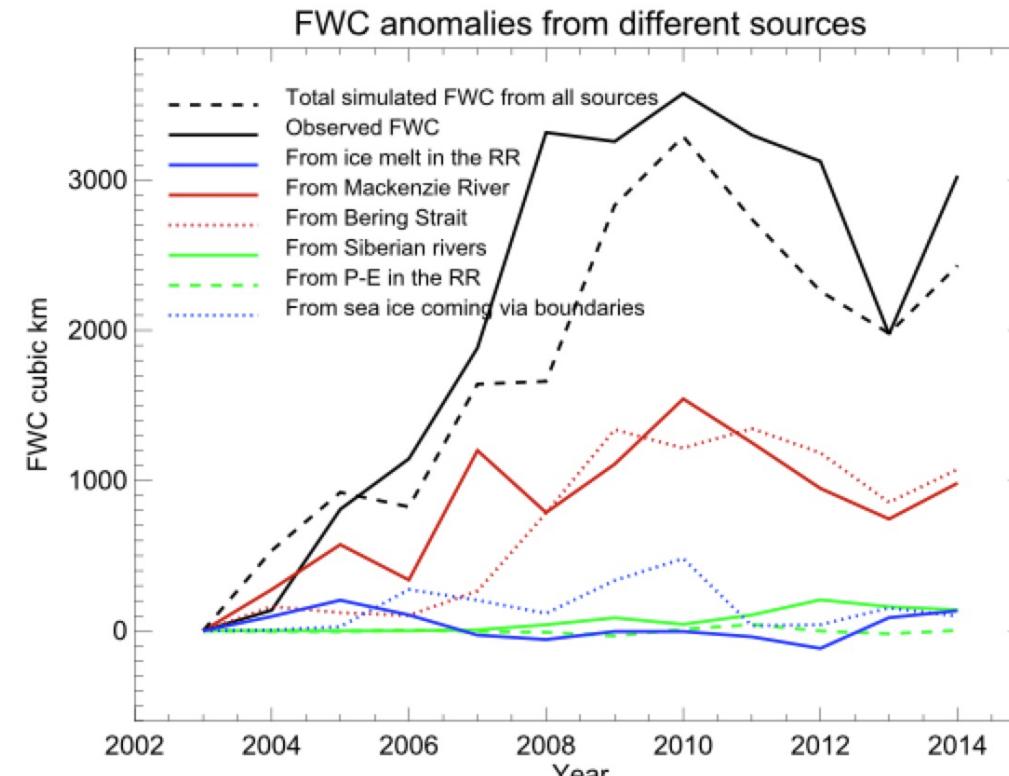
1. Beaufort Gyre

Freshwater sources:

1. Pacific-origin Water



Lin et al. 2021



Proshutinsky et al., 2019b



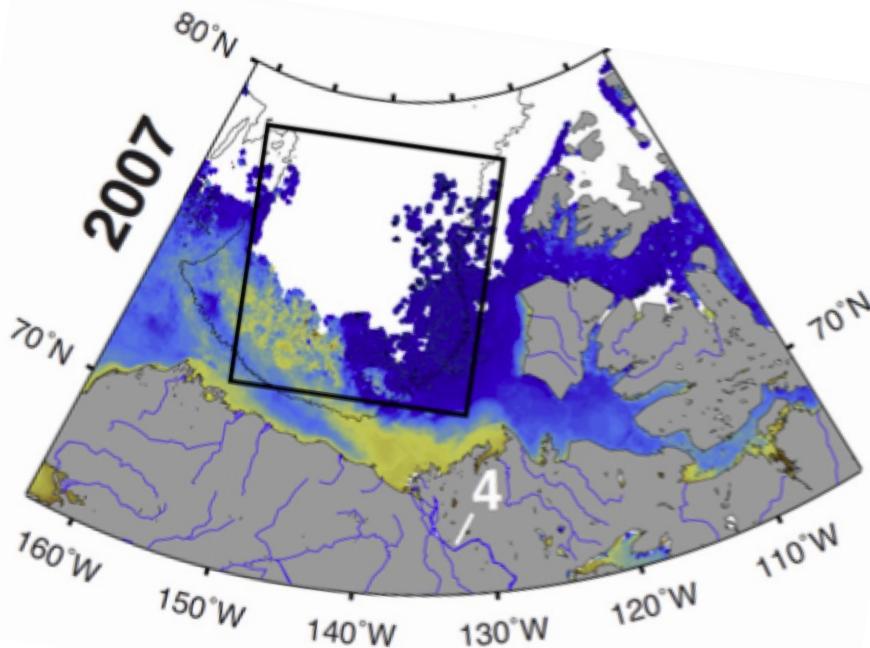
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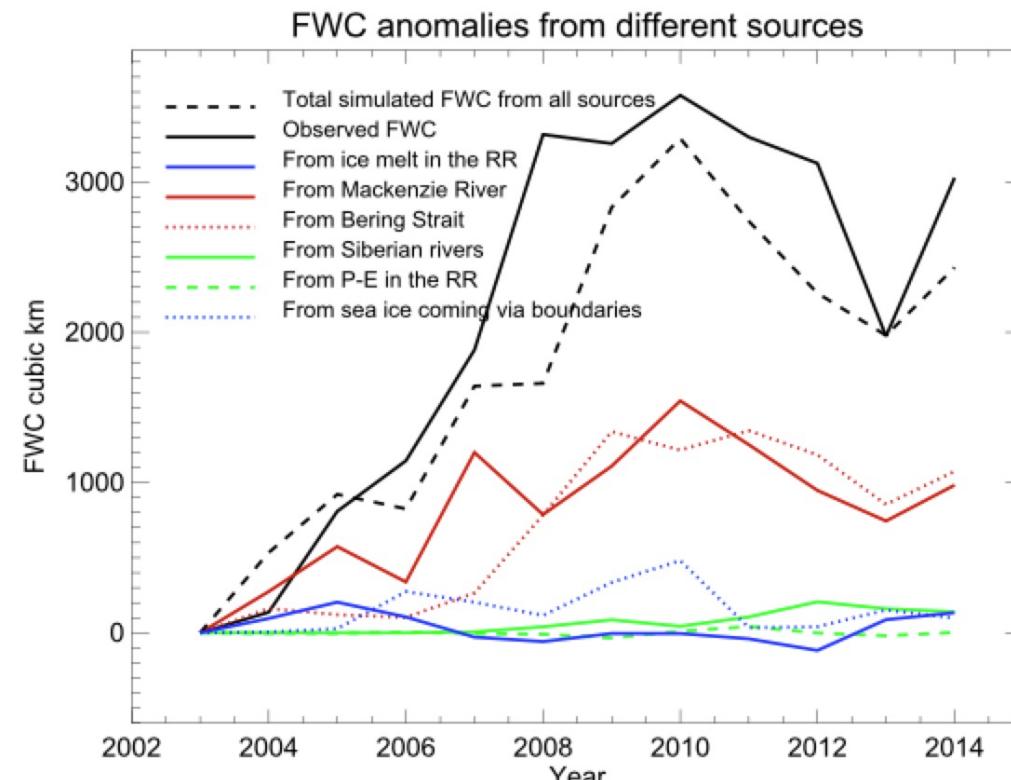
1. Beaufort Gyre

Freshwater sources:

1. Pacific-origin Water
2. Mackenzie River runoff



Fichot et al., 2013



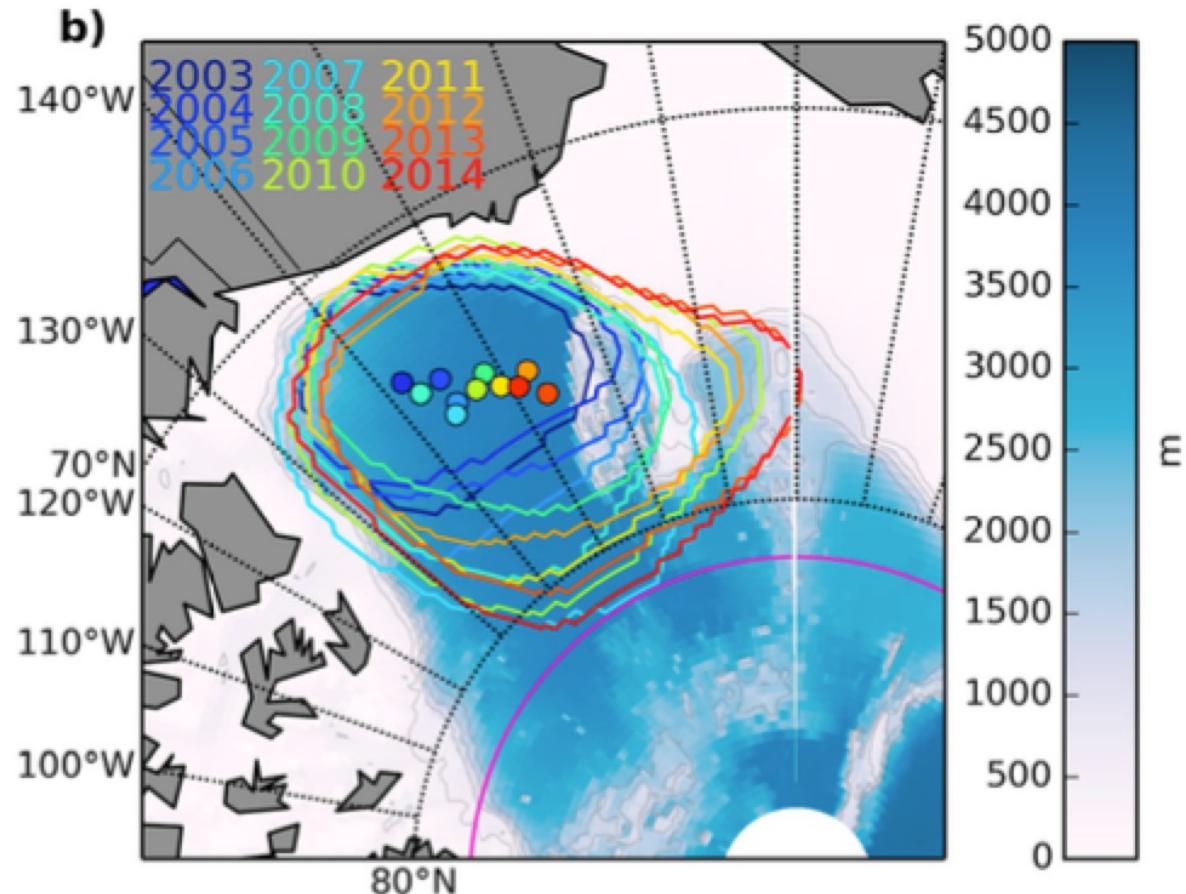
Proshutinsky et al., 2019b



1. Beaufort Gyre

Northwestward shifting of the Beaufort Gyre.

The strength and location of the gyre are associated with intensity of the surface forcing and location of the Beaufort High, respectively (e.g., Proshutinsky et al., 2009; Zhang et al., 2016; Regan et al., 2019).



Regan et al., 2019



1. Beaufort Gyre

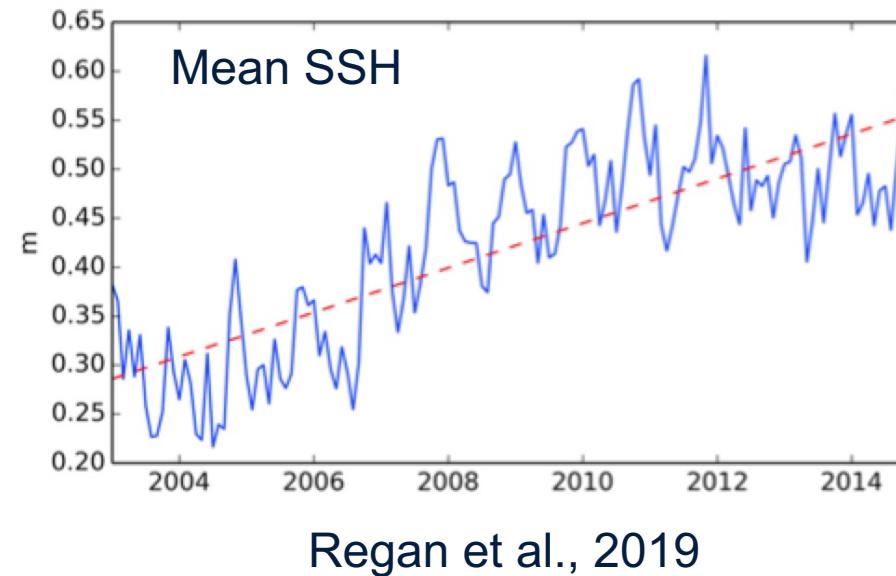
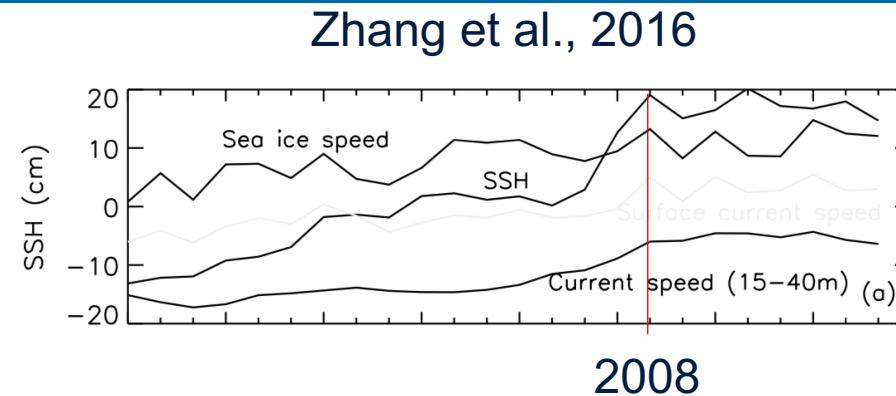
Beaufort Gyre is potentially stabilizing in recent years.

1. Change of the surface forcing

(Meneghelli et al., 2017, 2018; Zhong et al., 2018)

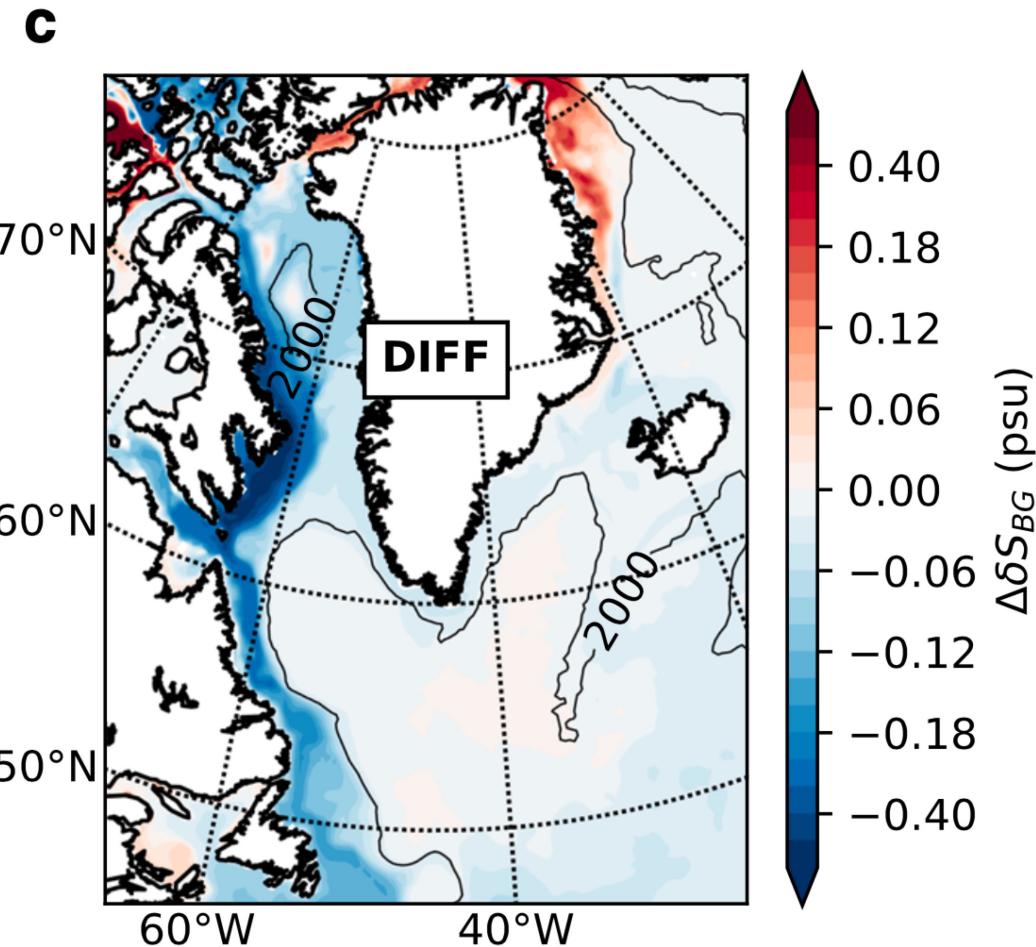
2. Eddy dissipation

(Manucharyan and Spall, 2016; Armitage et al., 2021)



1. Beaufort Gyre

If released within a short period, the excess freshwater could potentially impact the large-scale ocean circulation by freshening the upper subpolar North Atlantic.



Zhang et al., 2021



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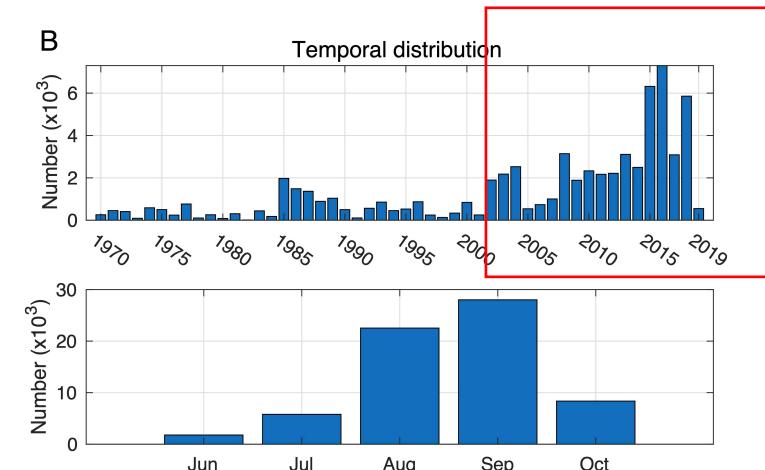
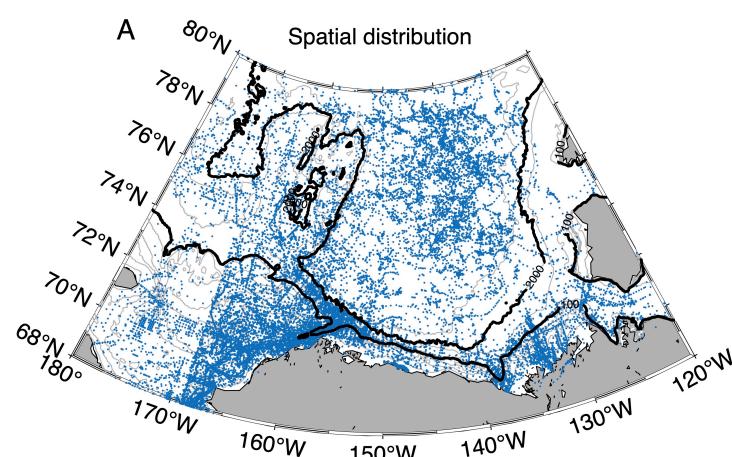
Questions

- Whether the Beaufort Gyre is continuously stabilizing in the recent decade?
- How does the water column respond to the changes?



Data and Methods

Hydrographic profiles

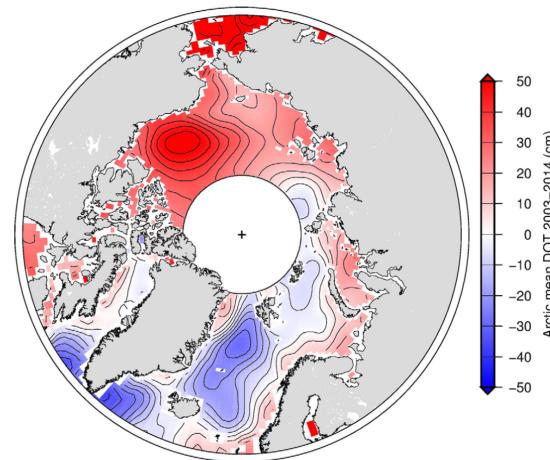


2003-2019

Lin et al., 2021

DOT data

1. 2003-2014 (Armitage et al., 2016)
2. 2011-2019 (Heorton & Tsamados)



Barrow Canyon moorings
GLORYS12 reanalysis
ERA5



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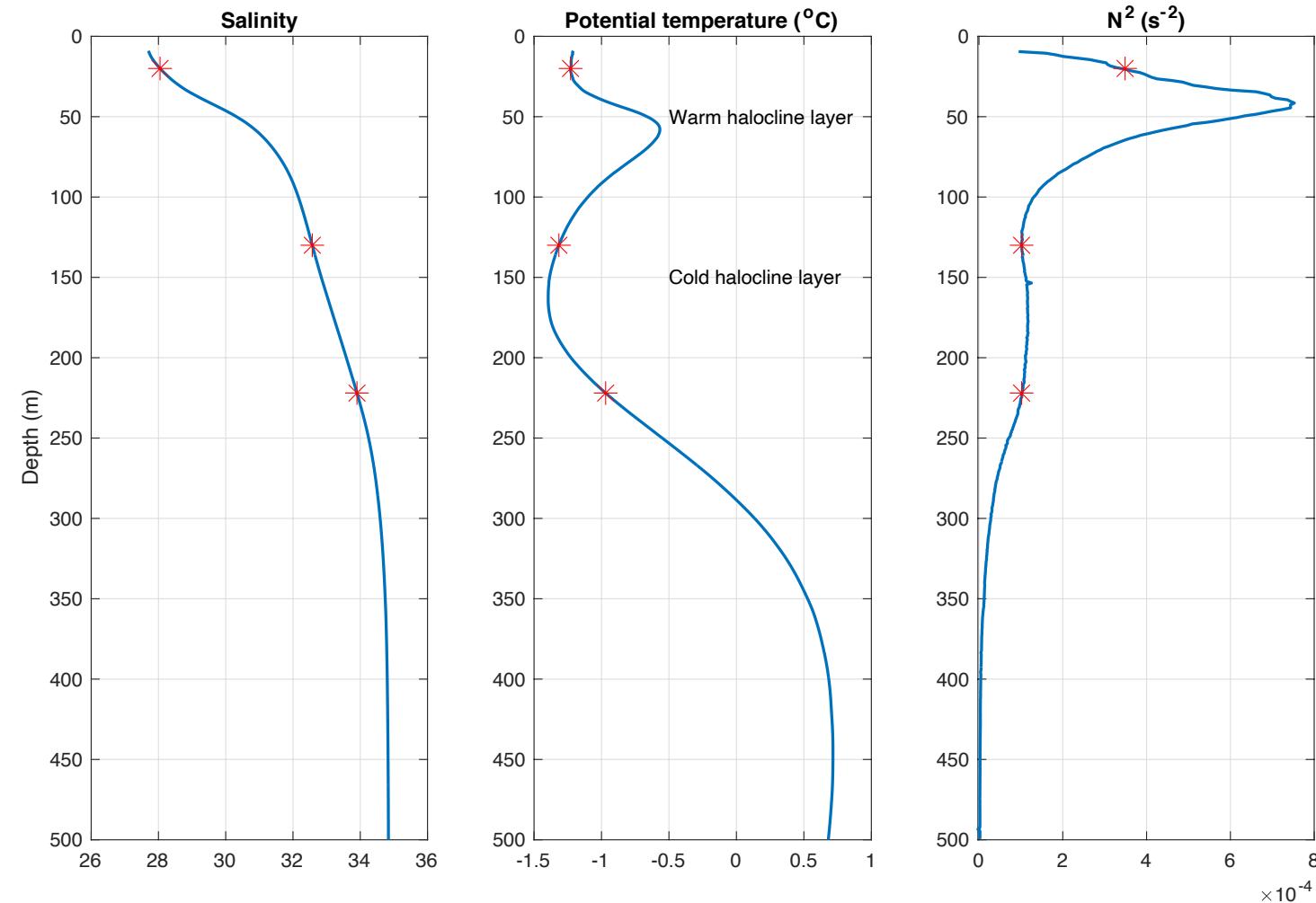
Data and Methods

Base of cold halocline layer (CHL)

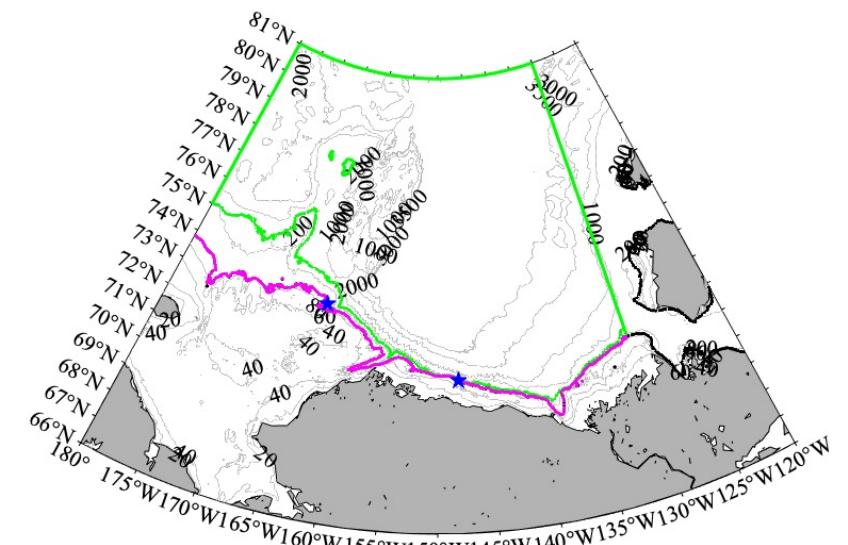
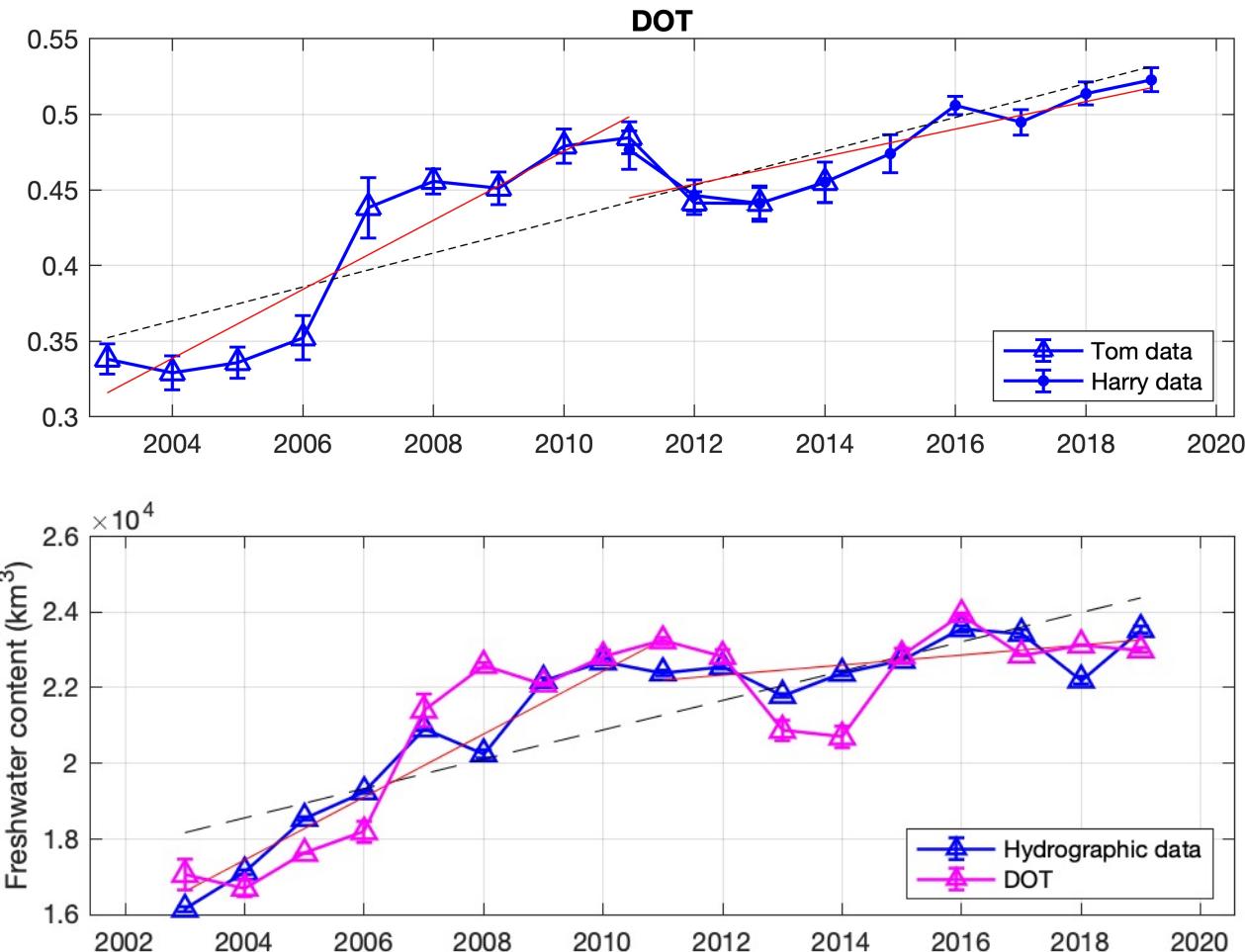
A ratio of density gradient due to temperature versus the density gradient due to salinity.
(Bourgain and Gascard, 2011)

$$R = \alpha \Delta T / \beta \Delta S, = 0.05$$

Salinity of CHL is 32.6 to 34.



2. Long-term trend of the BG

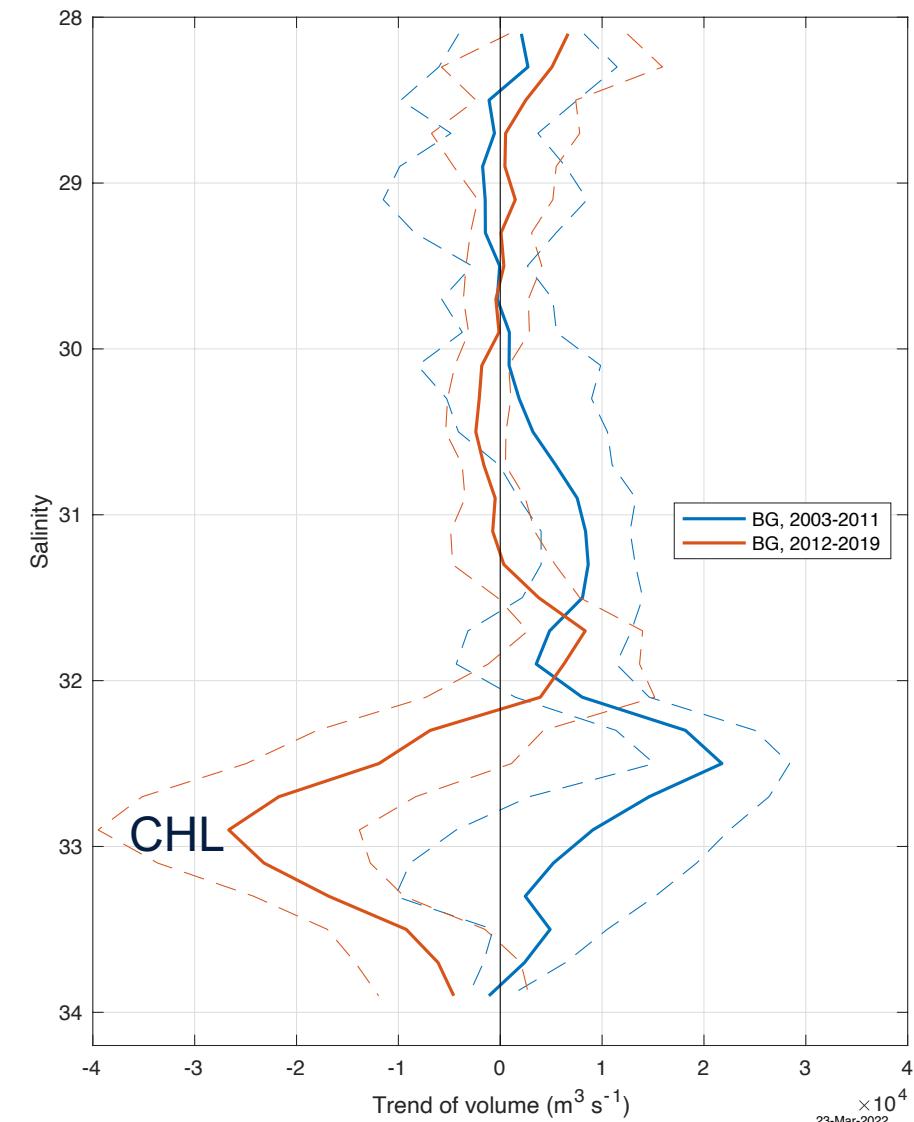
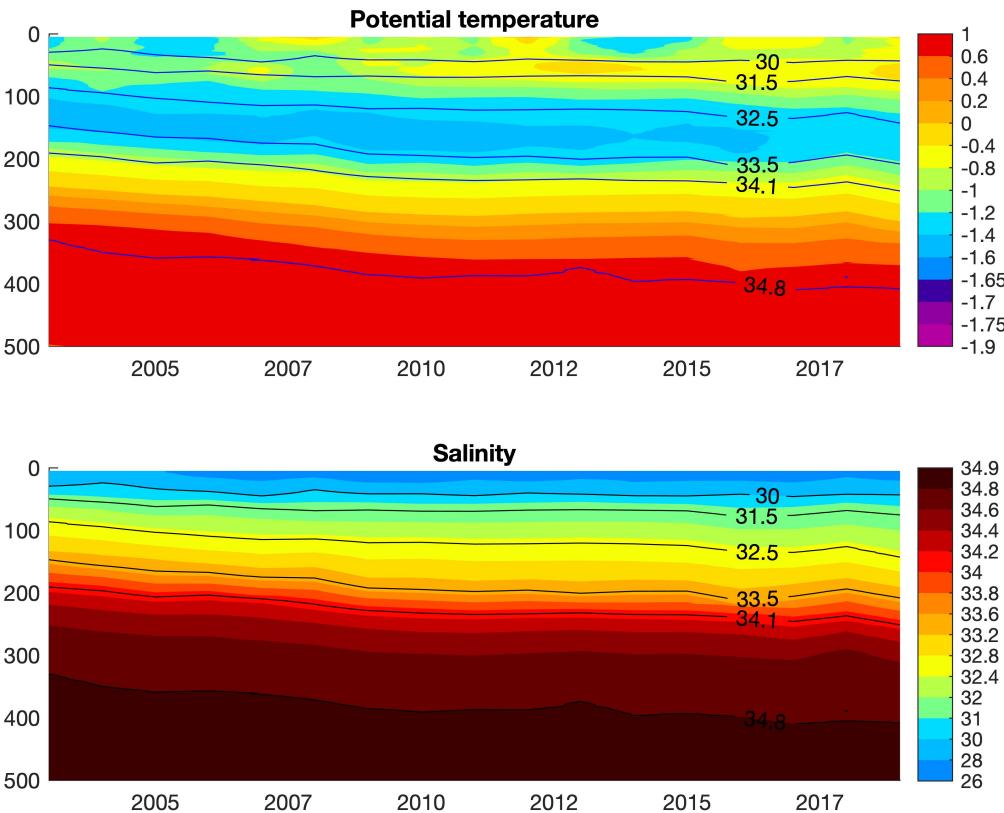


1. The DOT of the BG continuously increases with a smaller rate.
2. Freshwater content has a similar trend.



2. Long-term trend of the BG

Changes in different layers



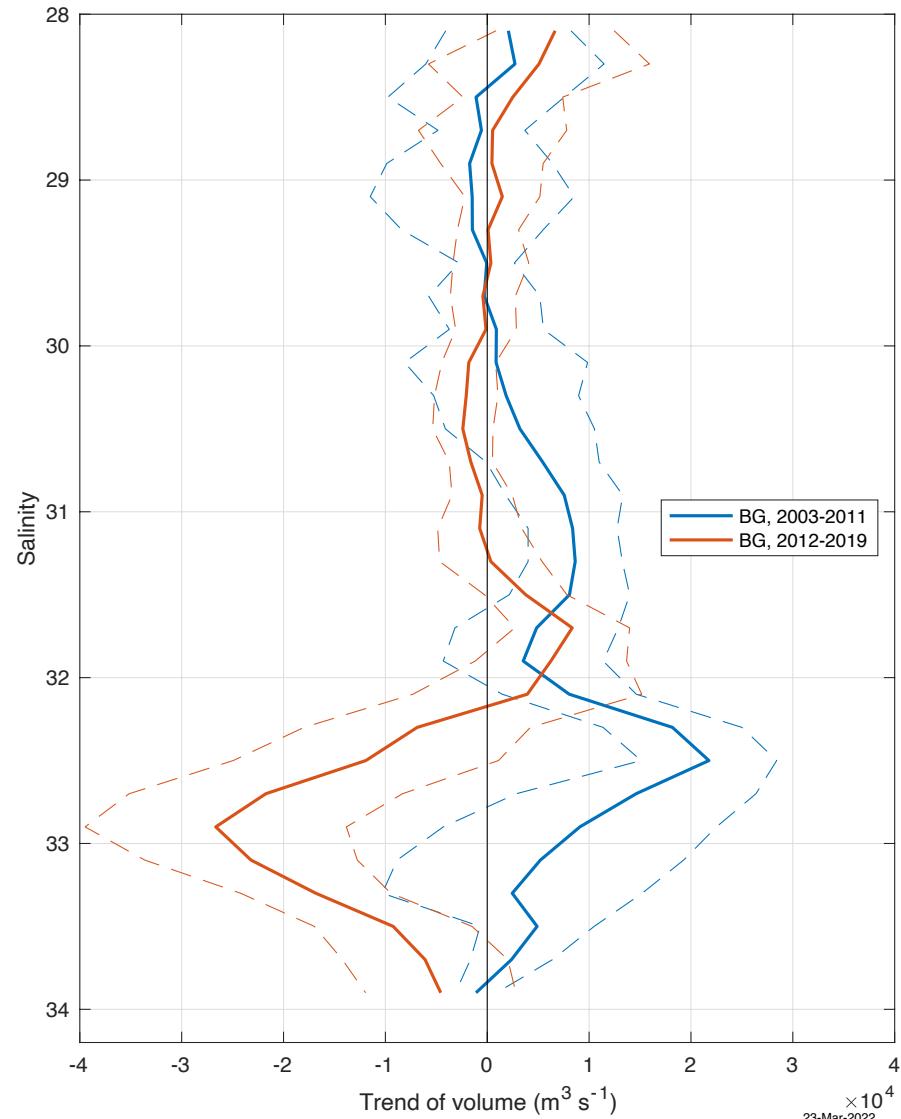
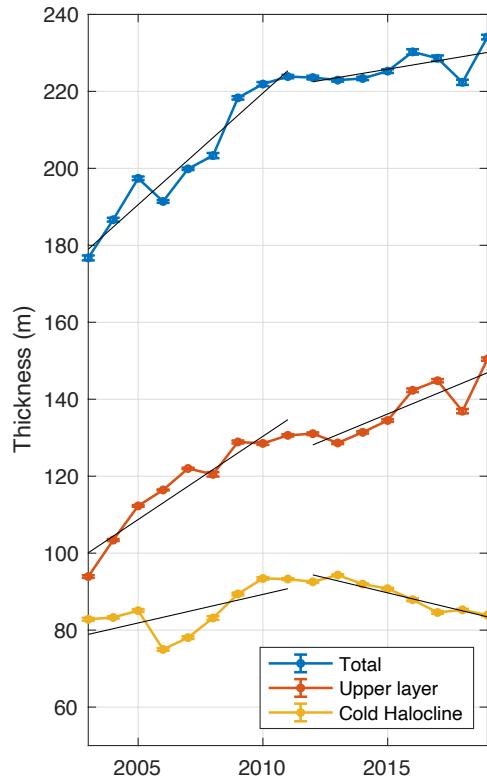
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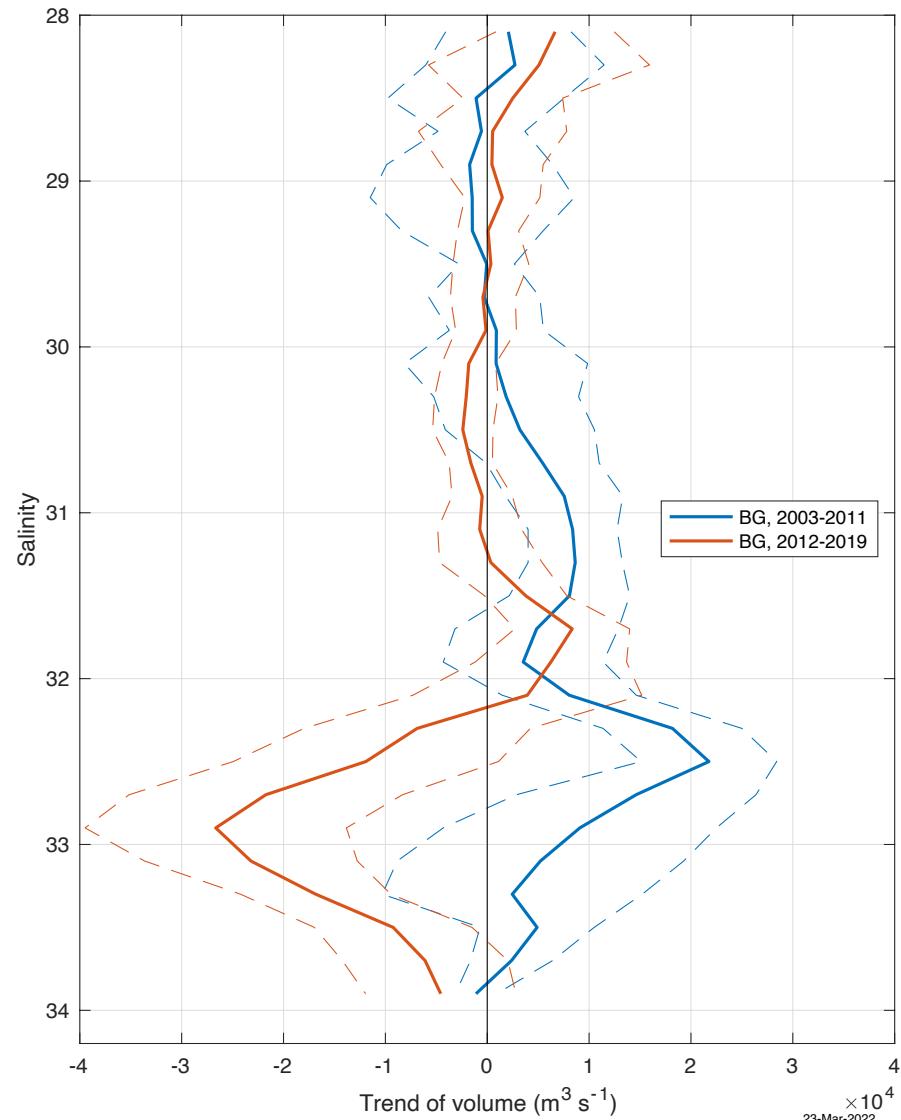
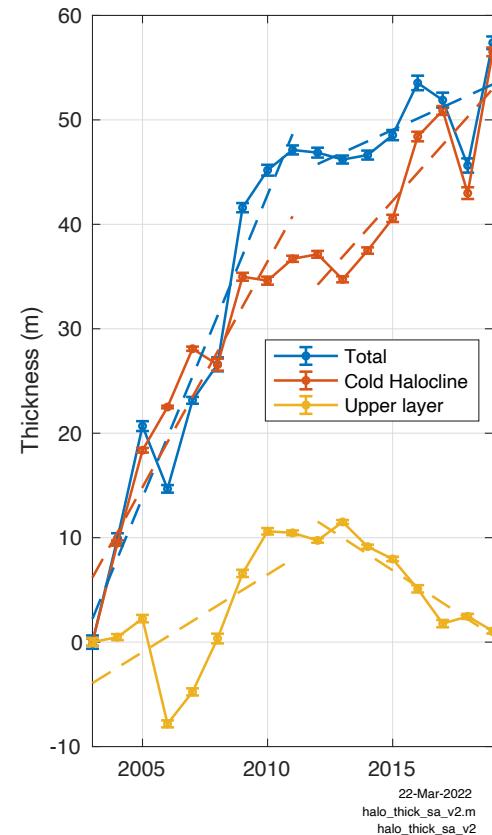
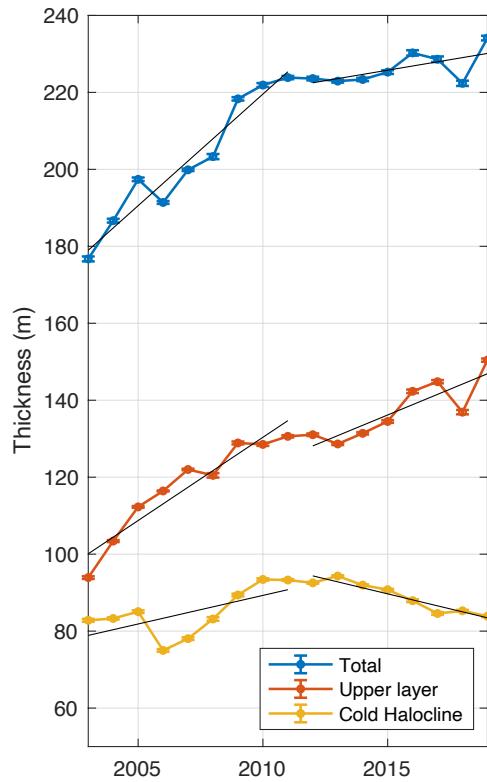
2. Long-term trend of the BG

Changes in different layers



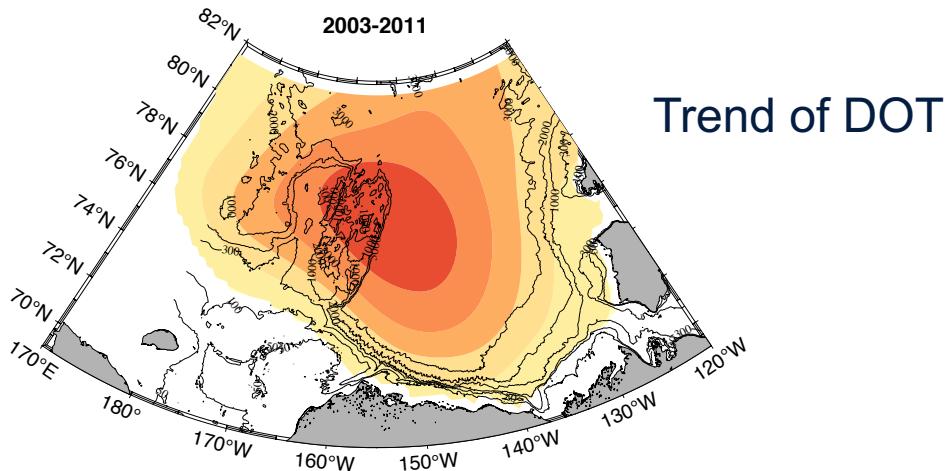
2. Long-term trend of the BG

Changes in different layers



2. Long-term trend of the BG

Spatial changes



Trend of DOT



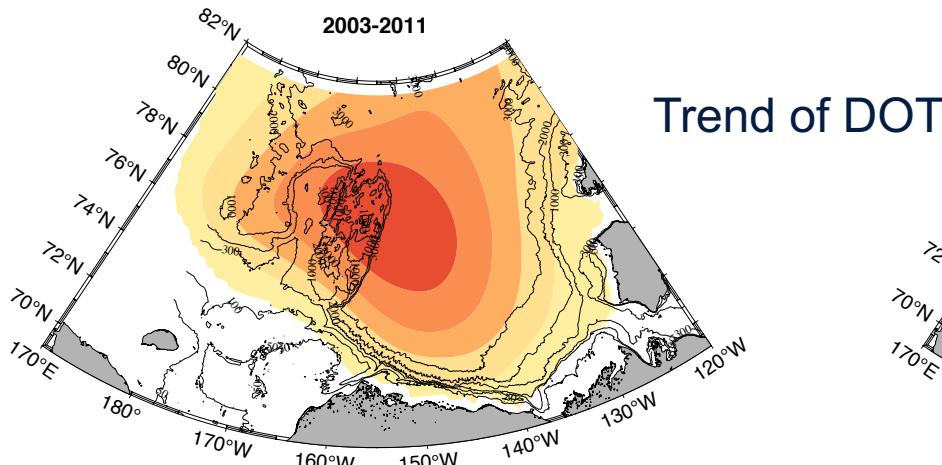
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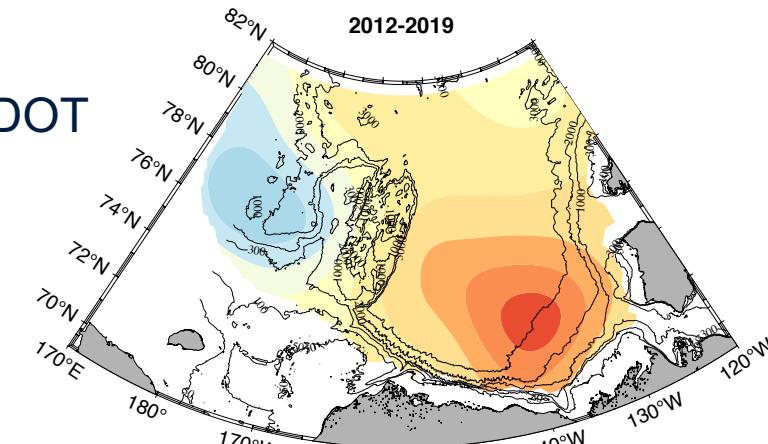
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2. Long-term trend of the BG

Spatial changes

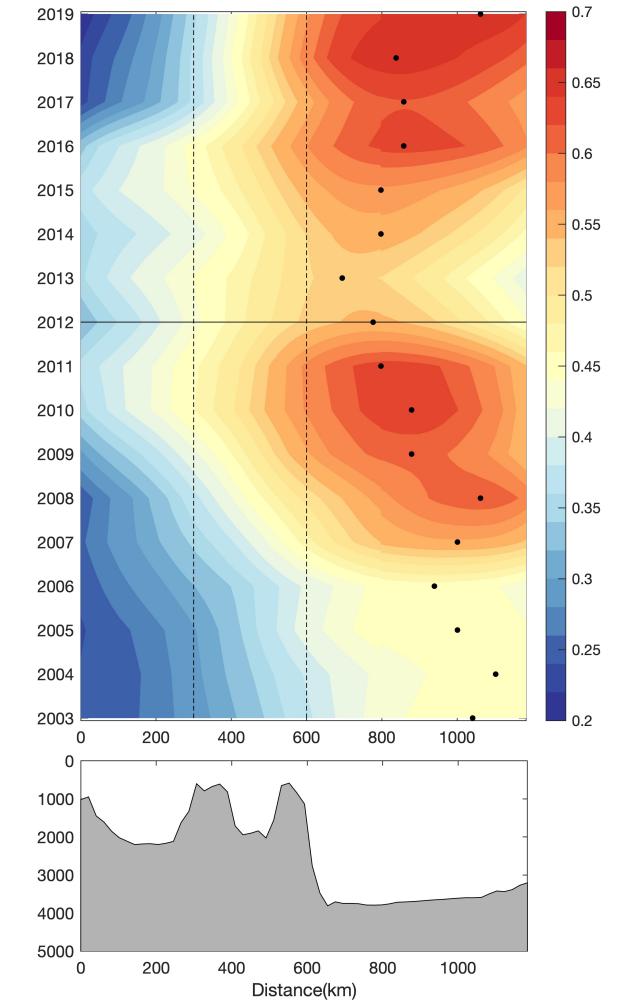
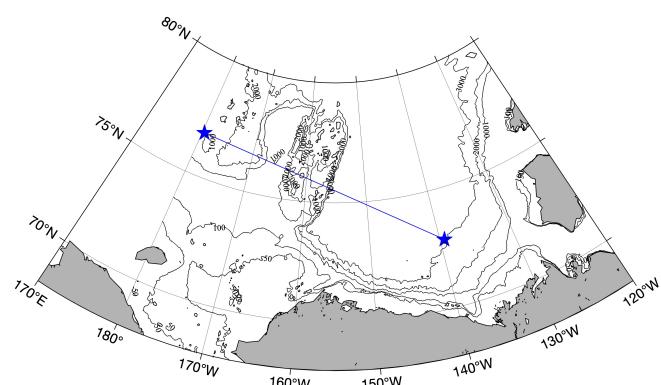


Trend of DOT



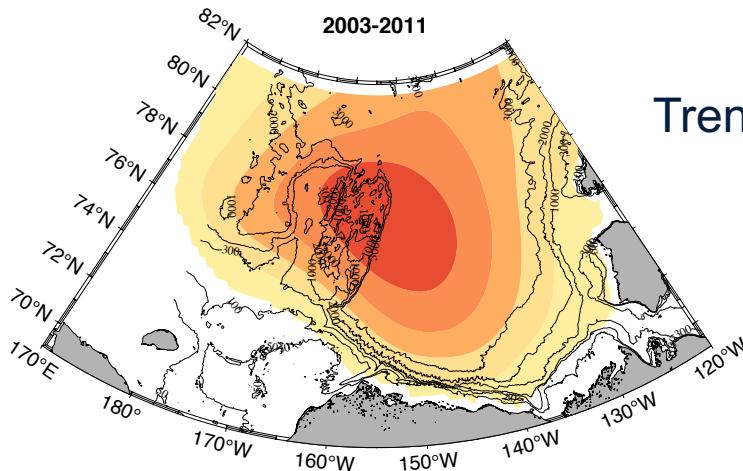
(m yr^{-1})

-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
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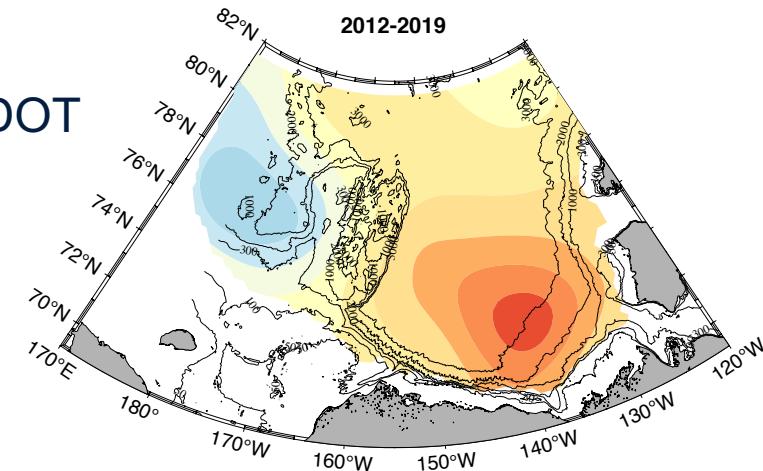


2. Long-term trend of the BG

Spatial changes



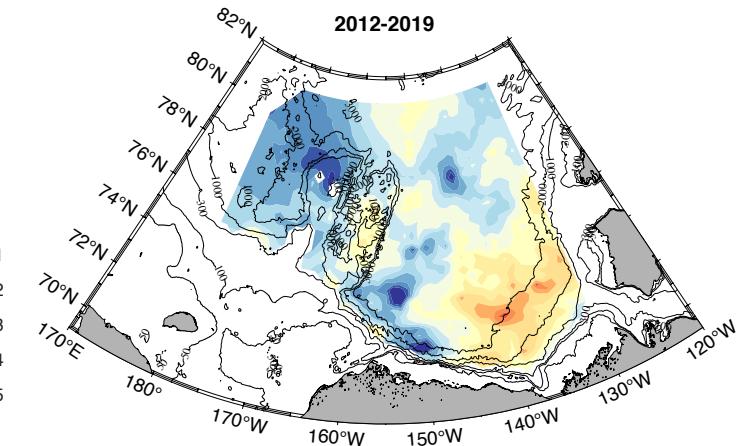
Trend of DOT



(m yr^{-1})

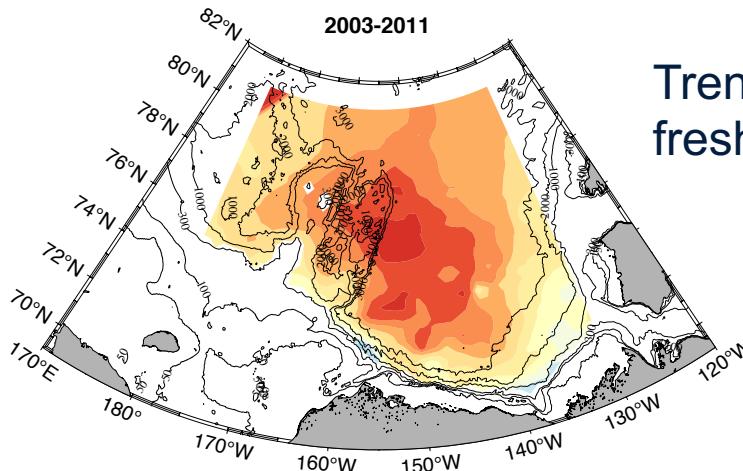
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05

Trend of CHL thickness

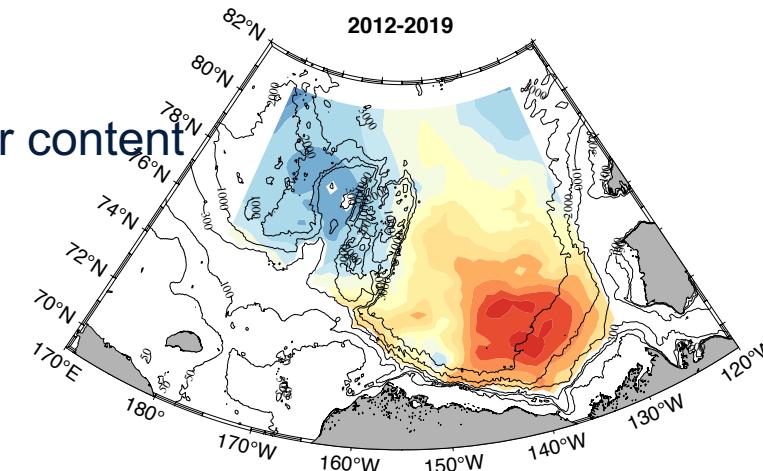


(m yr^{-1})

6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6

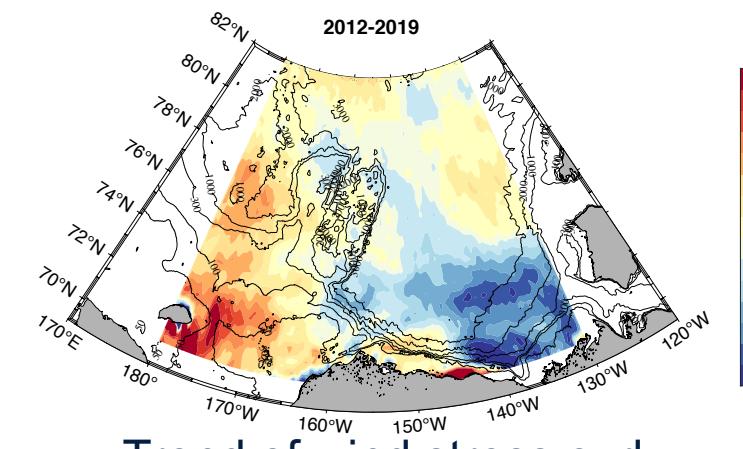


Trend of
freshwater content



($\text{m} \cdot \text{yr}^{-1}$)

-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.6



($\text{N} \cdot \text{m}^3 \cdot \text{yr}^{-1}$)

20
10
0
-10
-20

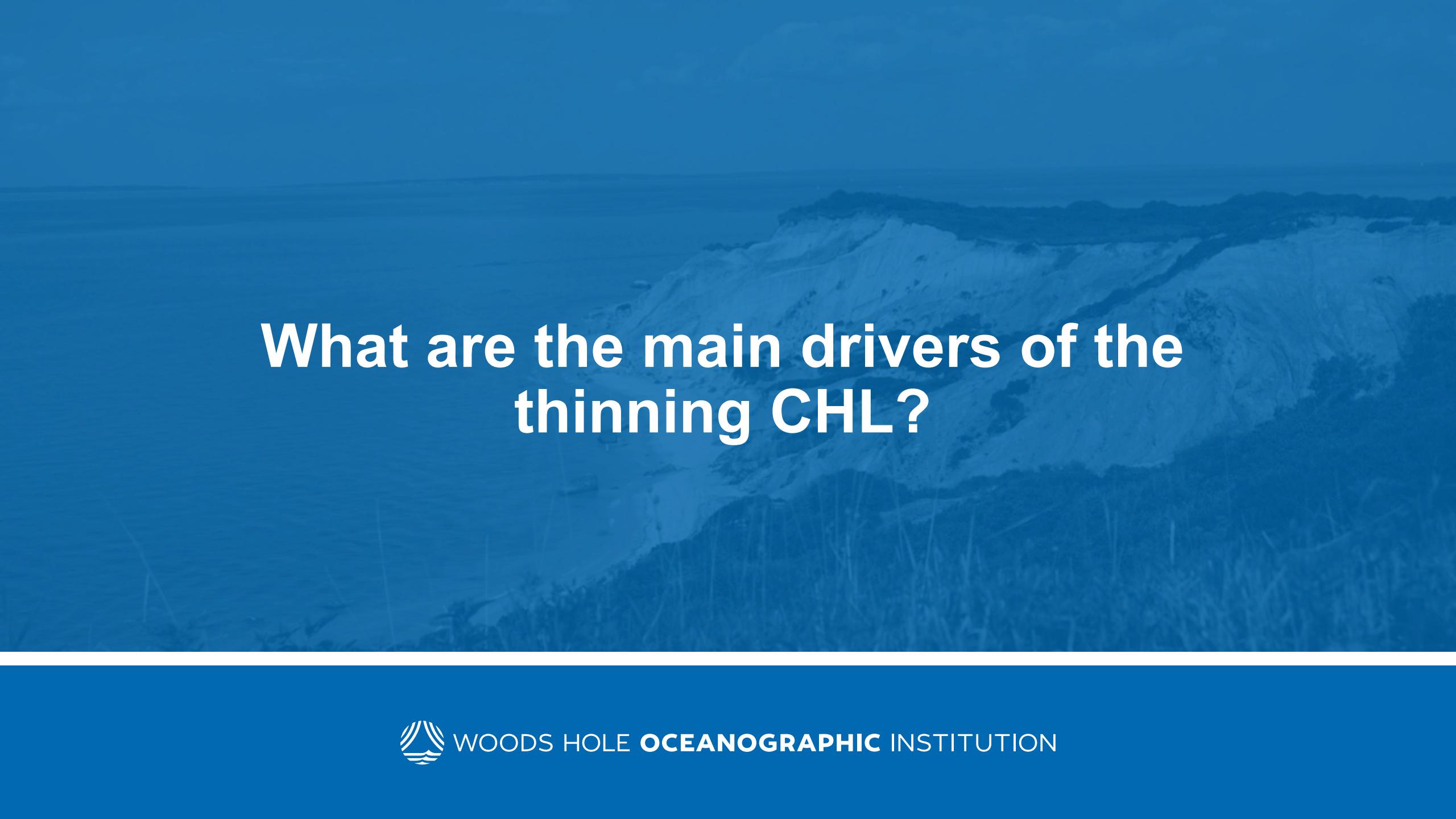
Trend of wind stress curl

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A blue-tinted photograph of a coastal landscape. In the foreground, there are sandy dunes with some low-lying vegetation. The ocean is visible in the background with small, white-capped waves. The overall color palette is dominated by shades of blue and teal.

What are the main drivers of the thinning CHL?

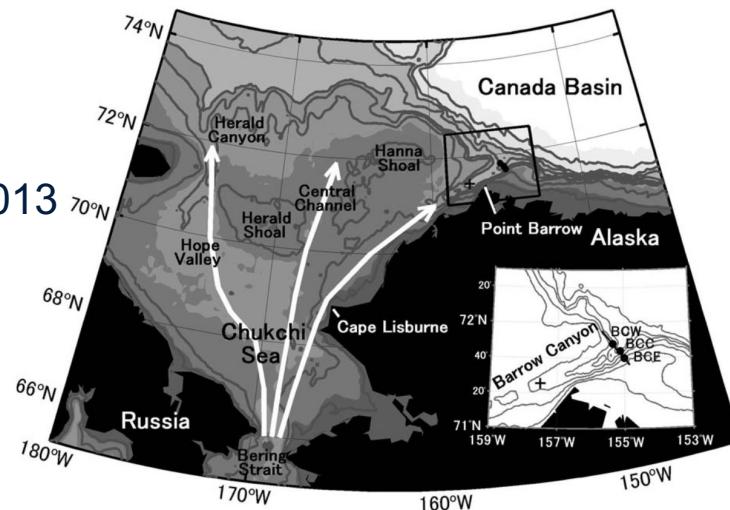


WOODS HOLE **OCEANOGRAPHIC** INSTITUTION

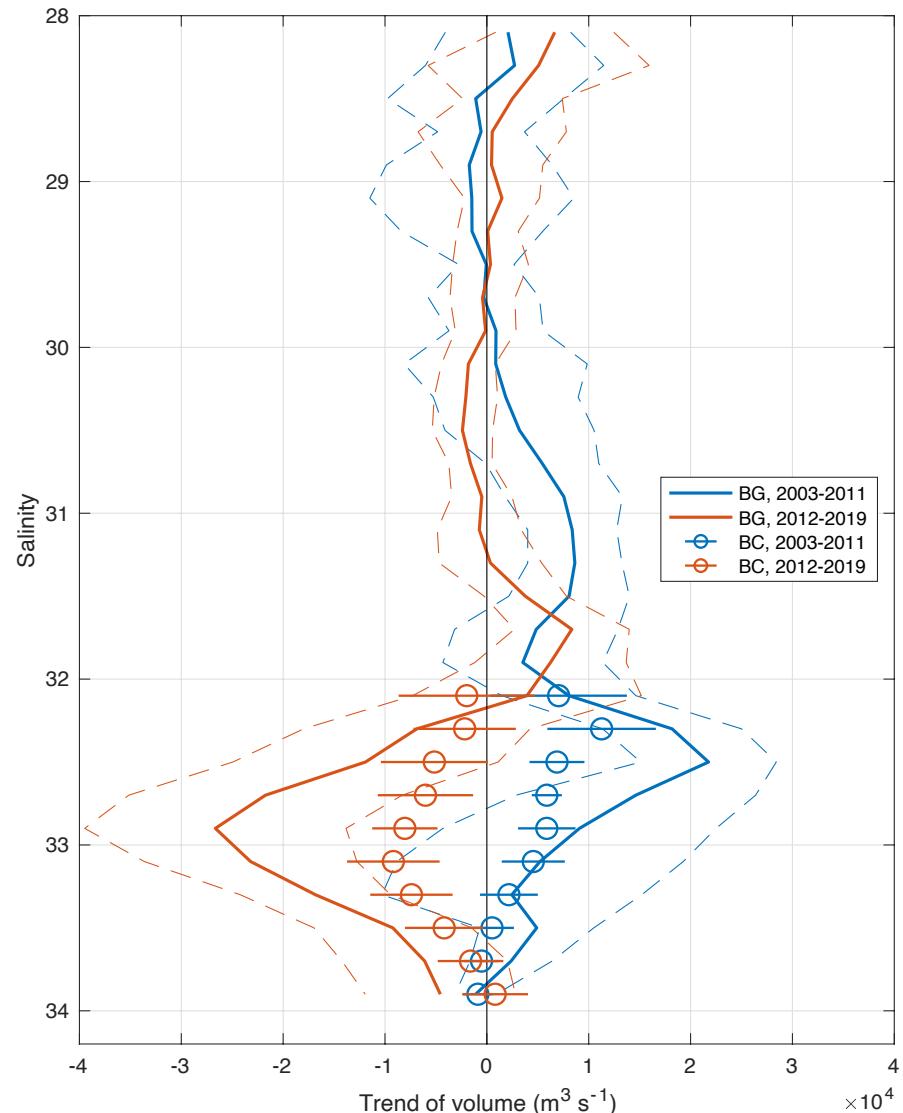
3. Causes of the thinning CHL

1. Pacific-origin Water

Itoh et al., 2013



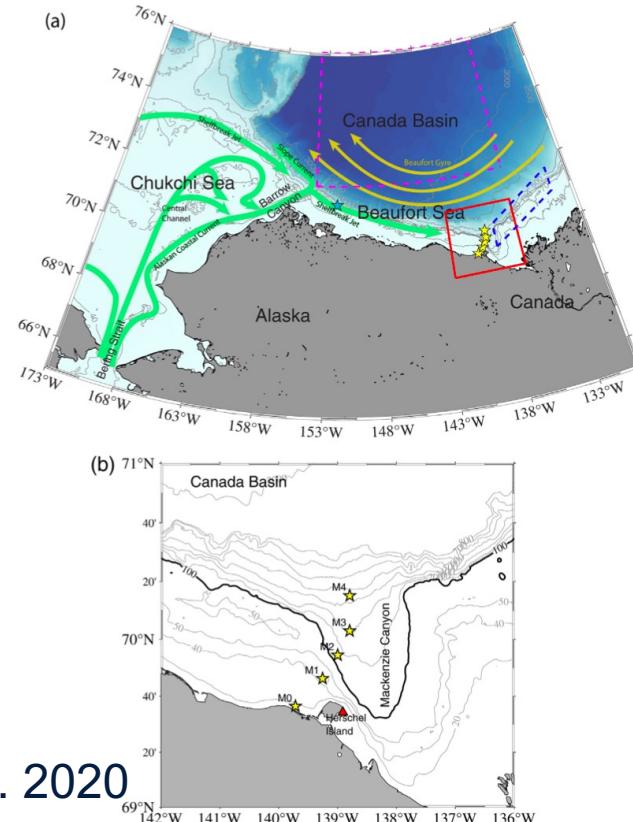
1. The PW has a similar trend shape.
2. The trend of PW is less in the magnitude, particularly in the recent years.



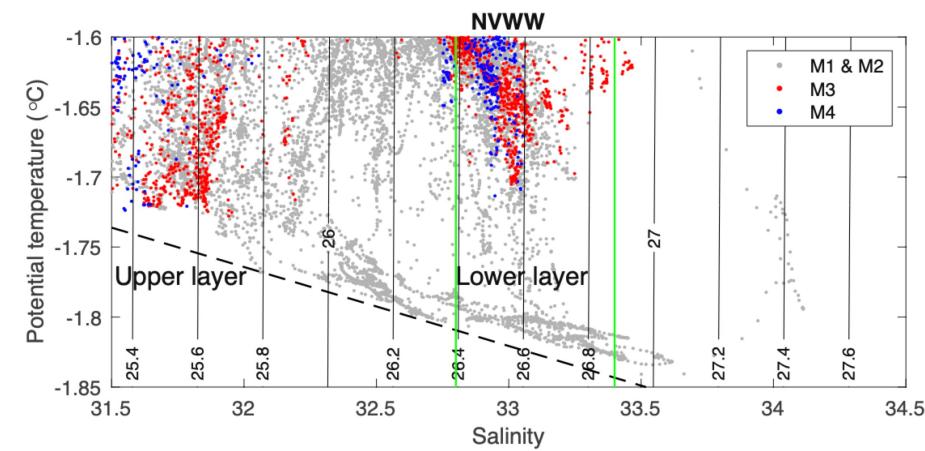
3. Causes of the thinning CHL

1. Pacific-origin Water

2. Local-formed water in Eastern Beaufort Sea



Lin et al. 2020



Lin et al., 2021

How does this contribute to the thinning CHL?



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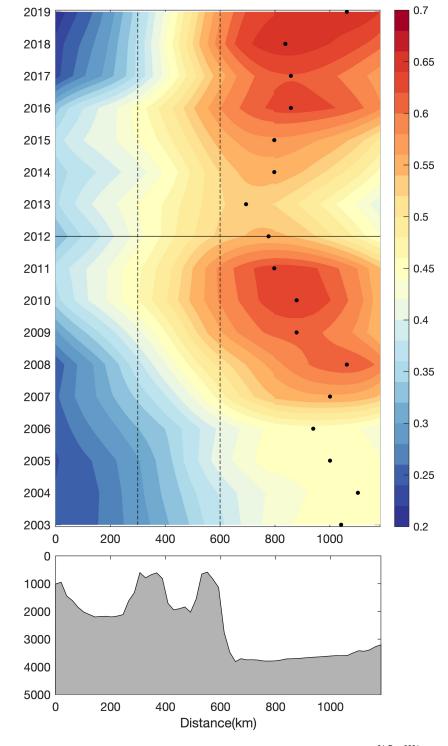
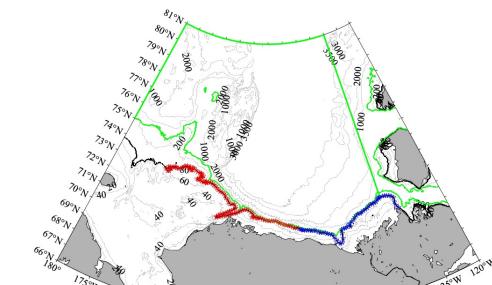
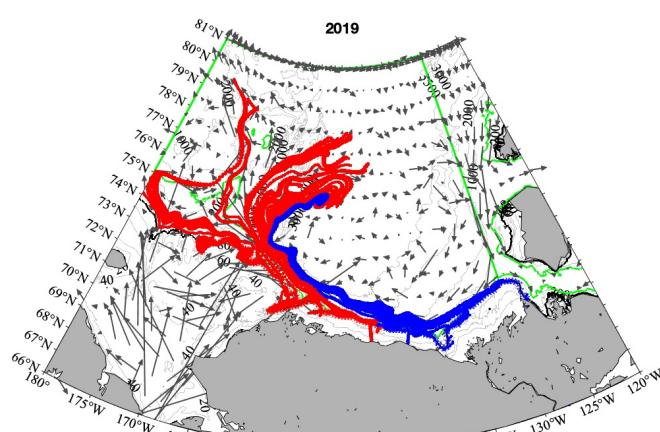
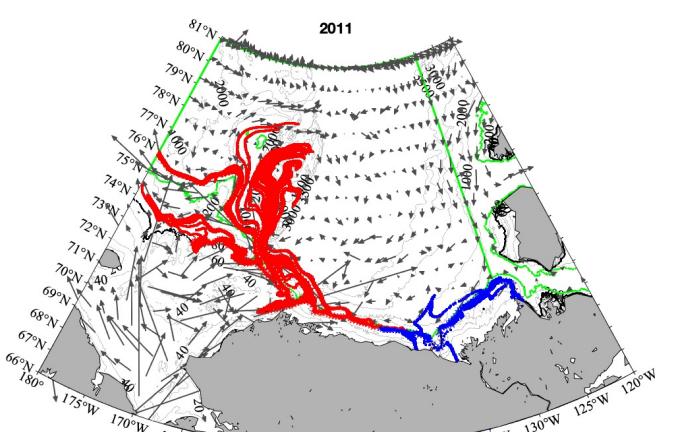
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3. Causes of the thinning CHL

1. Pacific-origin Water

2. Local-formed water in Eastern Beaufort Sea



Percentage of tracers into the BG

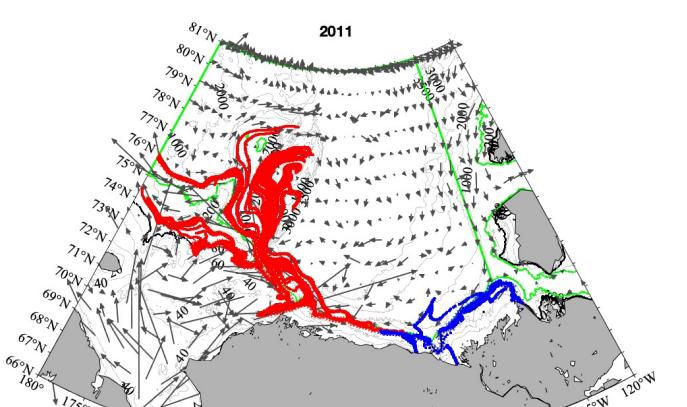
	BC
2011	90%
2019	84%



3. Causes of the thinning CHL

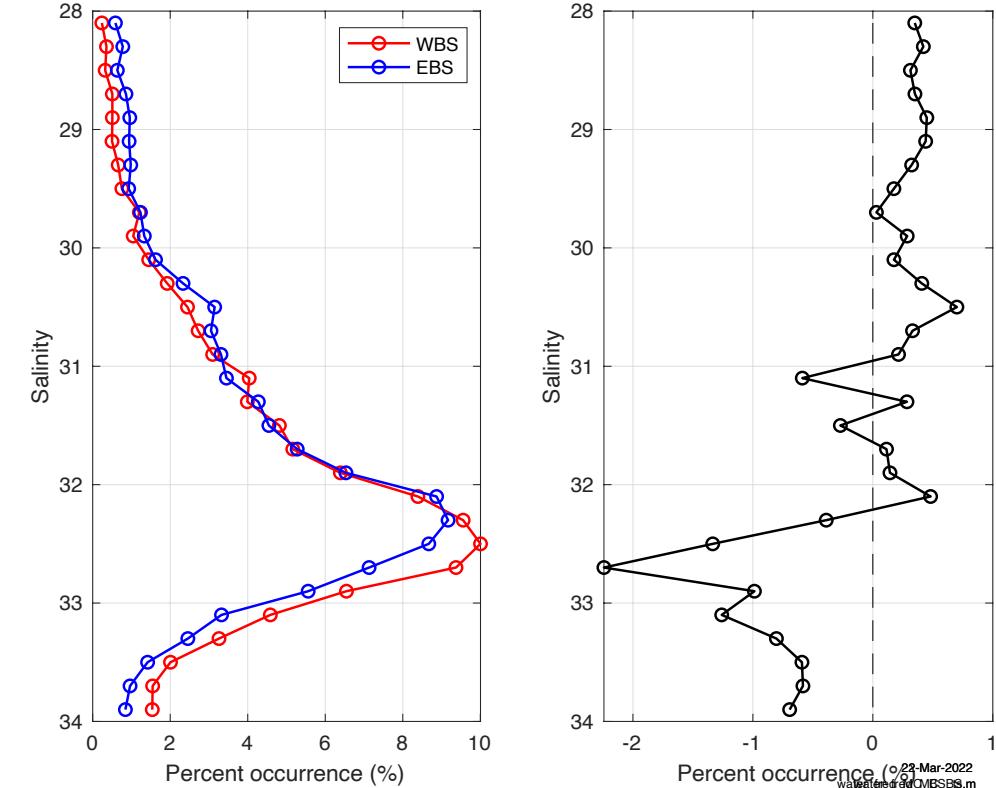
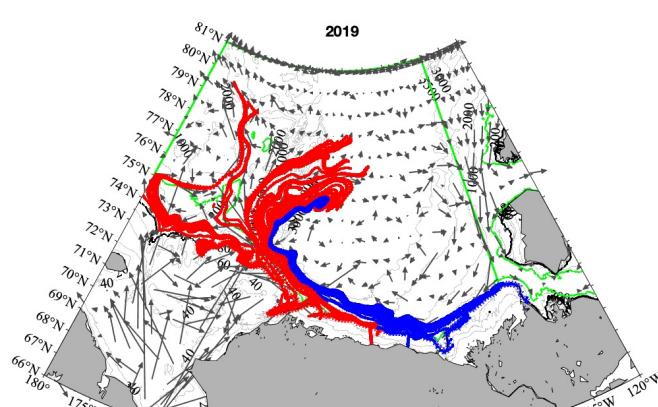
1. Pacific-origin Water

2. Local-formed water in Eastern Beaufort Sea



Percentage of tracers into the BG

	BC	EBS
2011	90%	15%
2019	84%	73%
2018	89%	54%



More **fresher** water from EBS can be trapped into the Beaufort Gyre when the gyre shifts to the southeast.



3. Conclusions

- In the recent decade, the DOT and freshwater content of the BG continuously increase with a smaller rate. Spatially, the BG is shifting to the southeast of the basin, controlled by the change of the basin-scale atmospheric forcing.
- These long-term trends are mainly due to the thinning cold halocline layer ($S=32.6-34$).
- There are two main drivers of the thinning cold halocline: 1) the less input of the cold halocline water from Pacific and Chukchi Sea; 2) More fresher water from Eastern Beaufort Sea contributes to the basin due to the southeastward-shift BG.



A wide-angle photograph of a massive glacier in a fjord. The glacier is a massive wall of ice, its surface a mix of white and deep blue. It stretches across the middle ground, framed by towering mountains on either side. These mountains are heavily covered in snow, with some rocky peaks visible through the white. The sky above is a clear, pale blue, with a few wispy clouds near the horizon. In the foreground, the dark blue water of the fjord is visible, with small, white-capped icebergs floating on its surface.

Thank you!