

# The role of the Russian Shelf in seasonal & interannual variability of Arctic **Sea Surface Salinity** & **Freshwater Content**



**Michael Steele**  
*University of Washington*



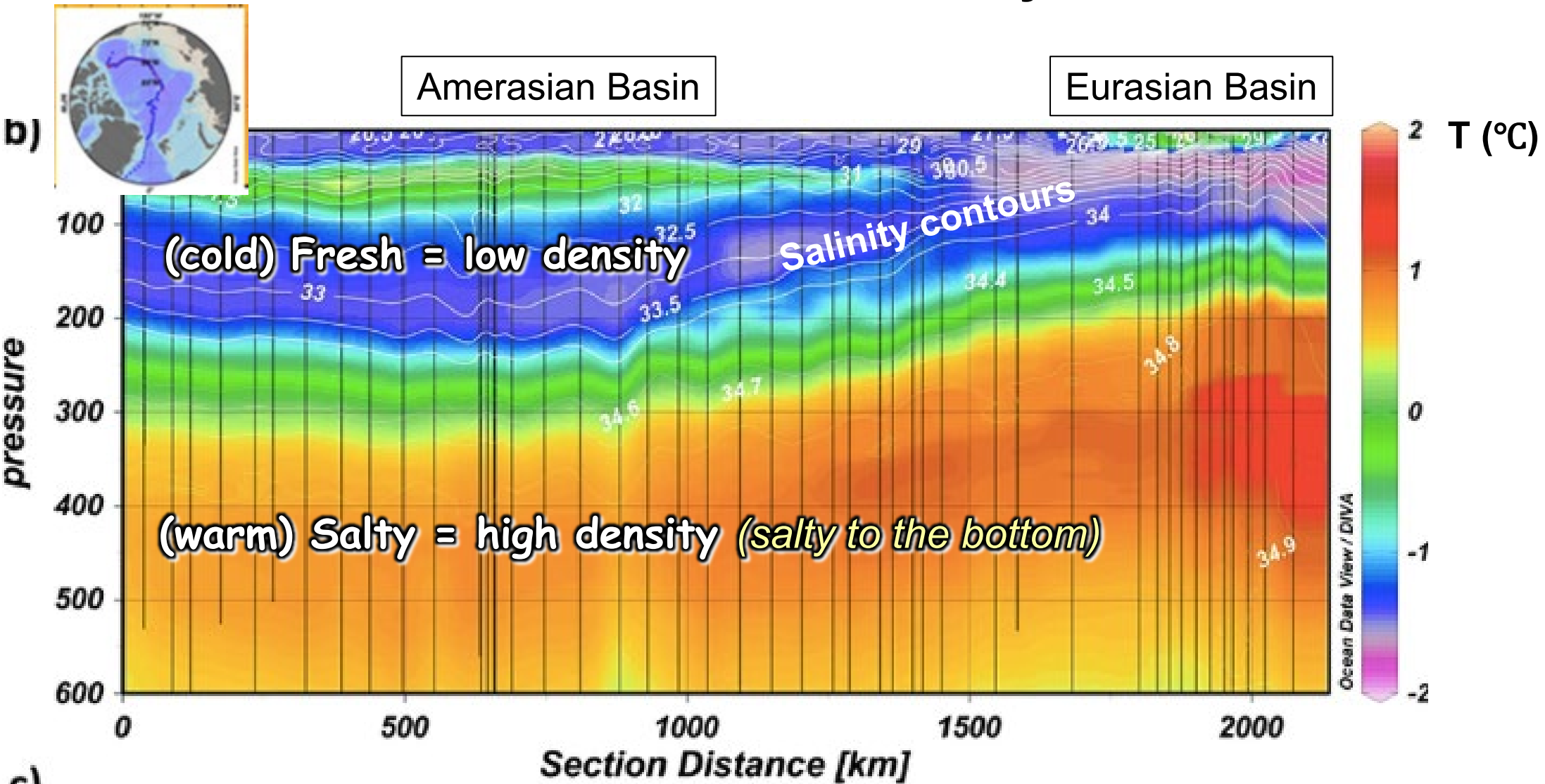
**Sarah Hall**  
*University of South Carolina*



**Subra Busulu**  
*University of South Carolina*

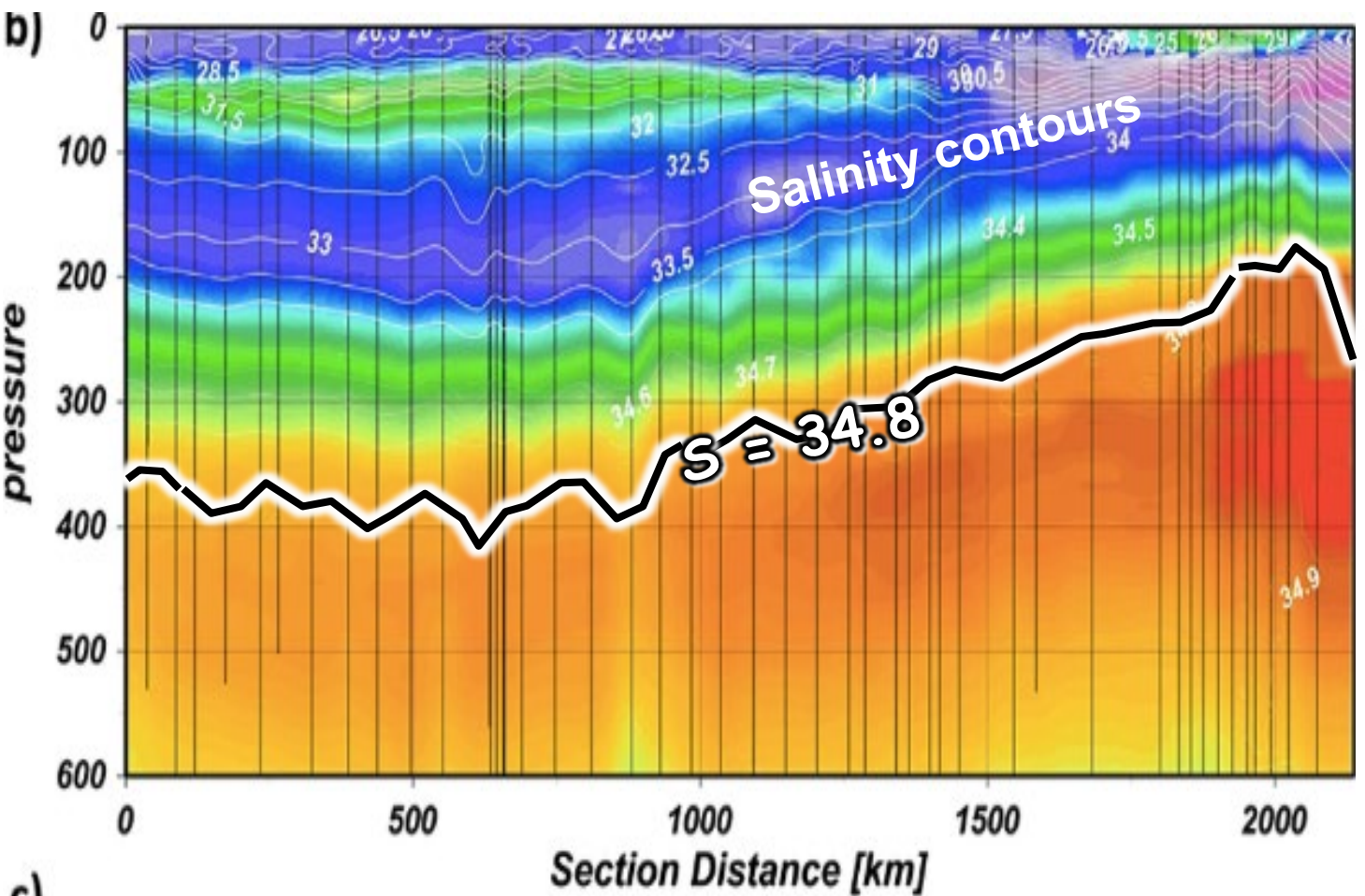
*Hall et al. (in review, JGR, 2022)*

# The Arctic Ocean is very stratified



Carmack et al. (JGR, 2015)

Amerasian Basin                      Eurasian Basin



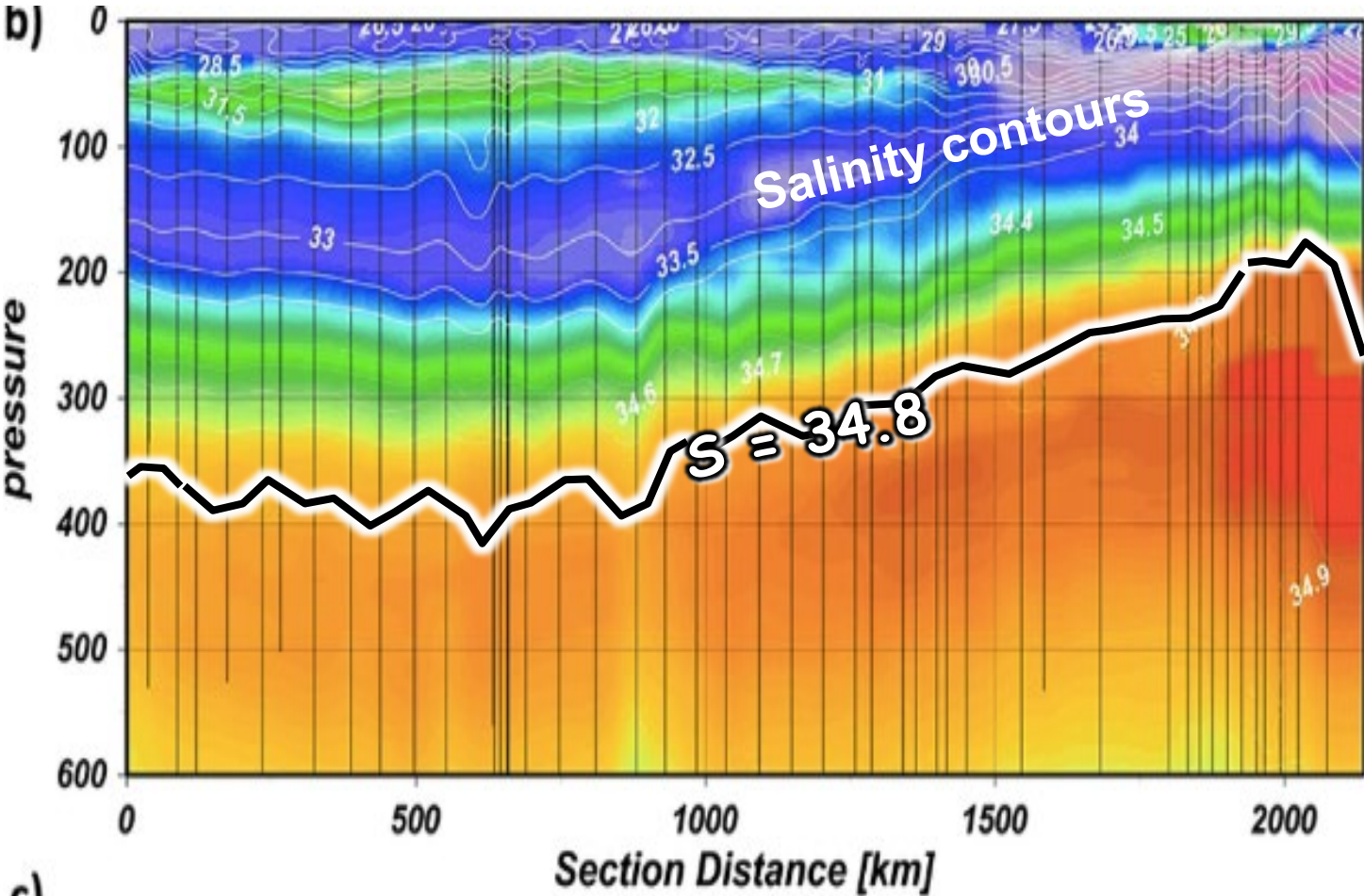
## Freshwater Content (FWC)

$$FWC = \int_{z(S=S_{ref})}^{z_0} \frac{S_{ref} - S}{S_{ref}} \cdot dz$$

$$S_{ref} = S_{ave} = 34.8 \text{ psu}$$

Amerasian Basin

Eurasian Basin



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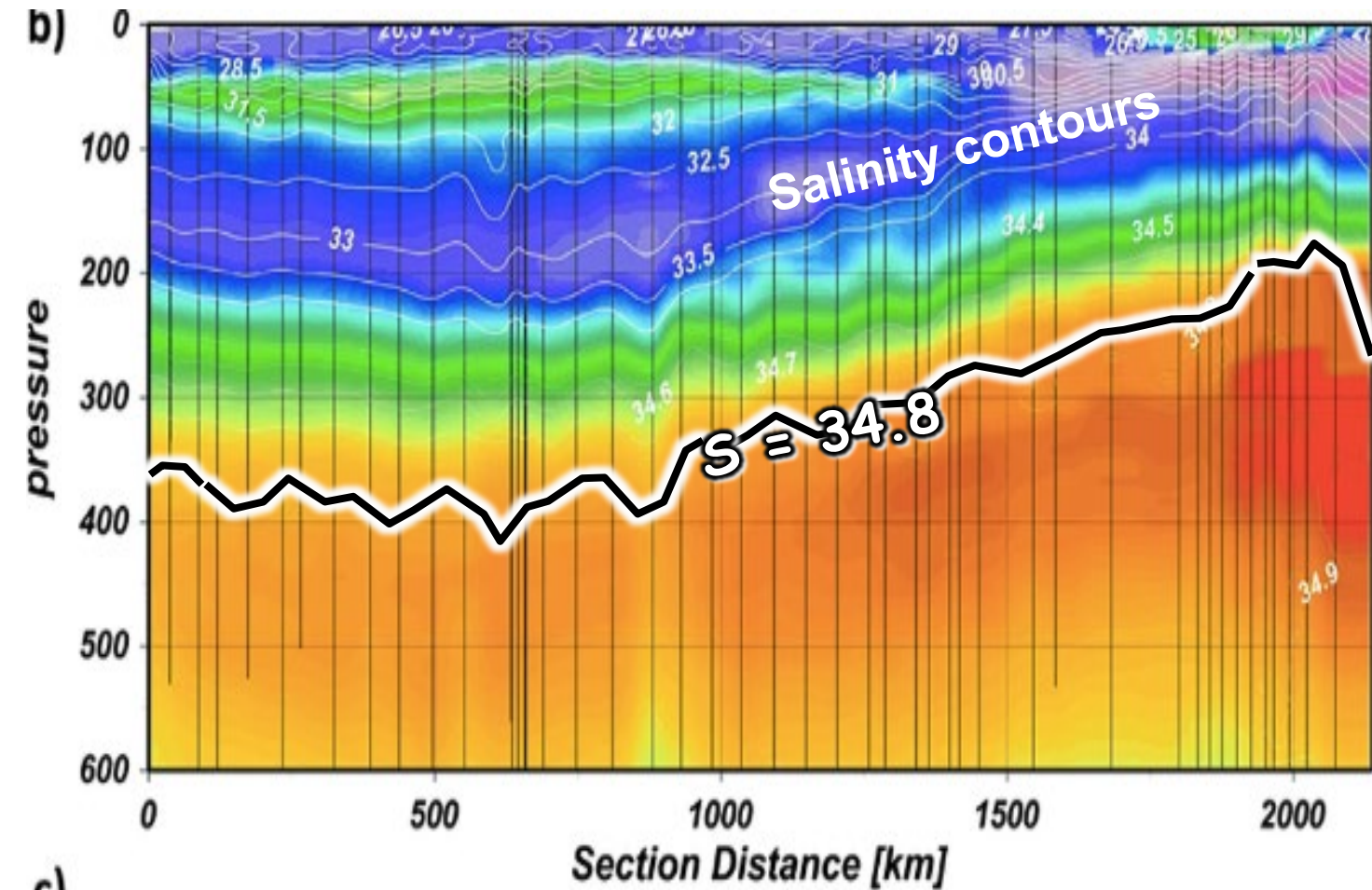
FWC = function of upper layer:

- salinity
- thickness



Amerasian Basin

Eurasian Basin



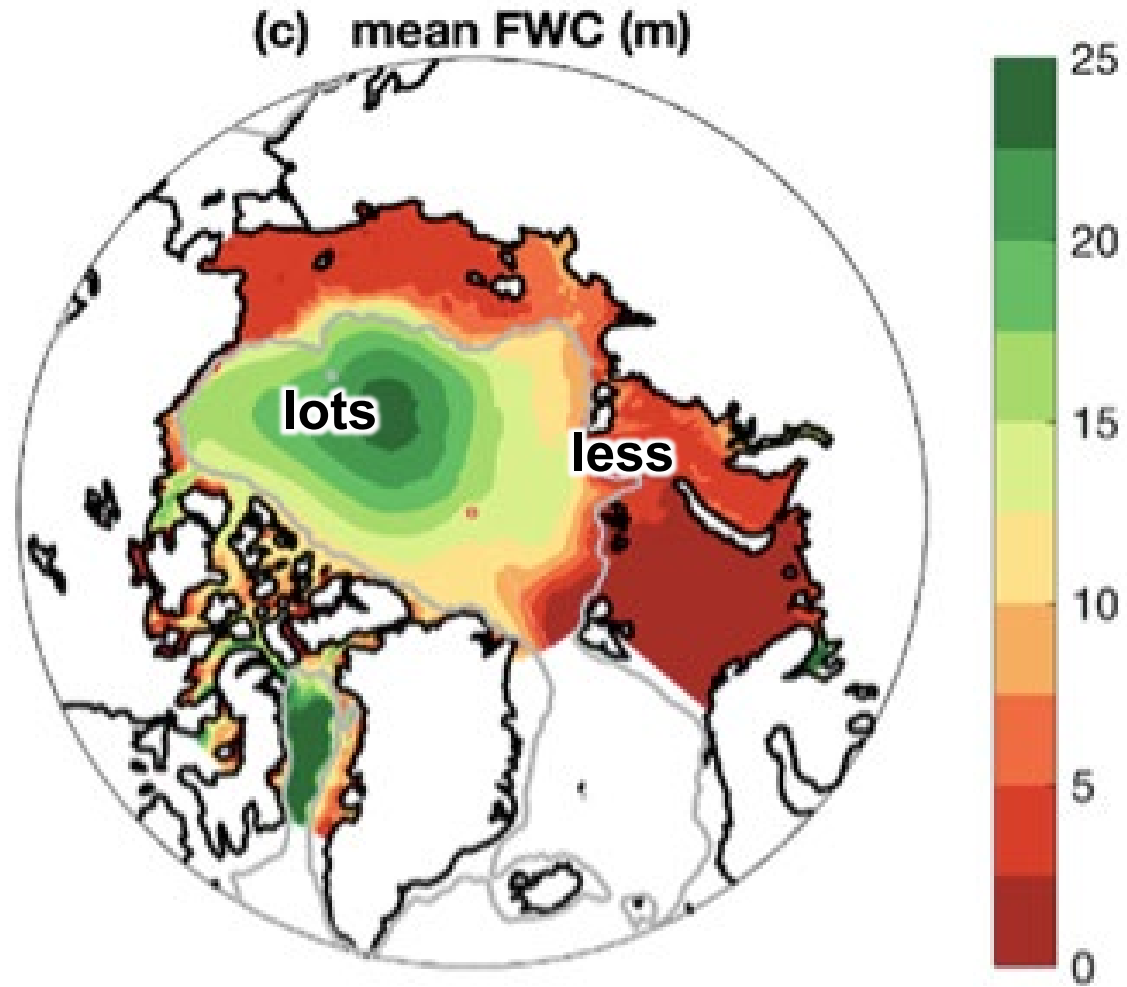
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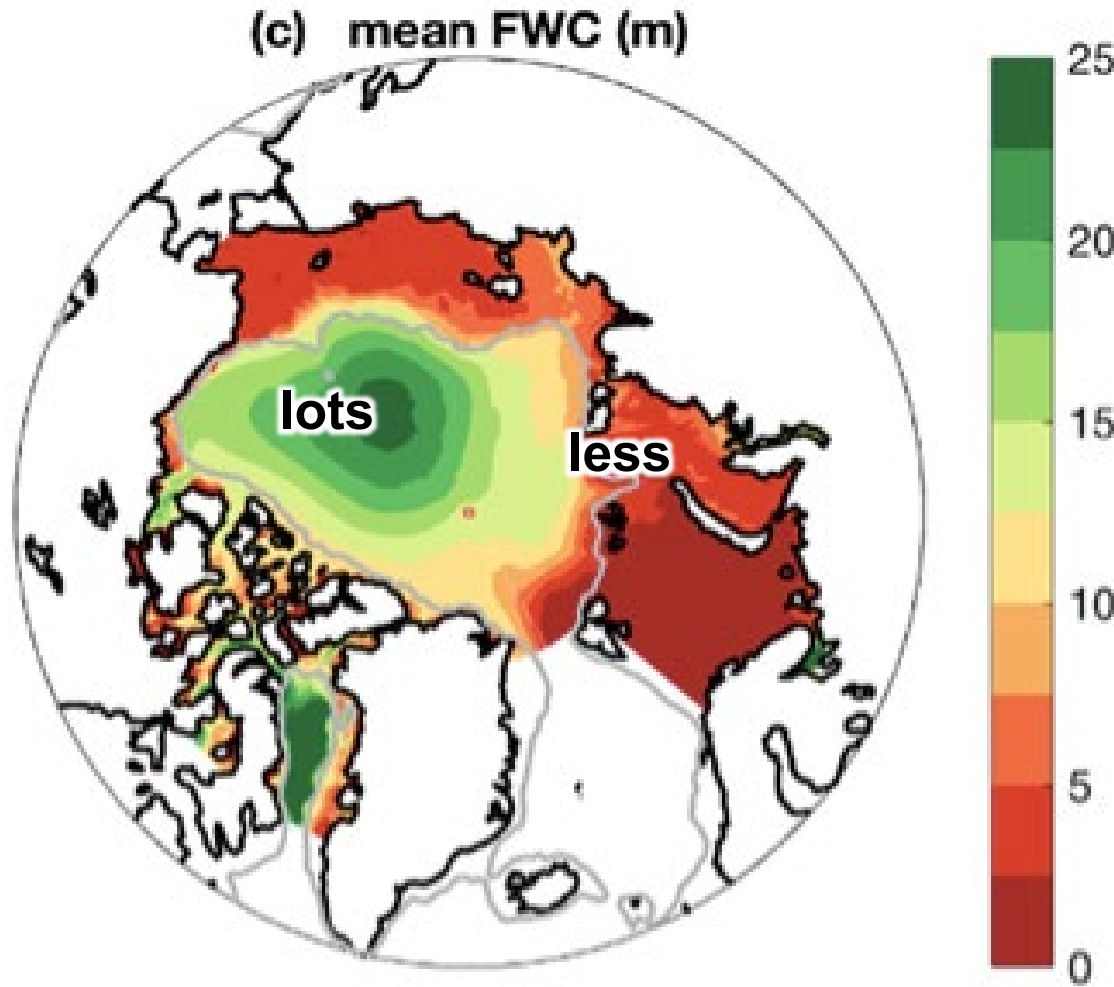
**Units = "meters of freshwater"**

# Arctic Freshwater Content (m)



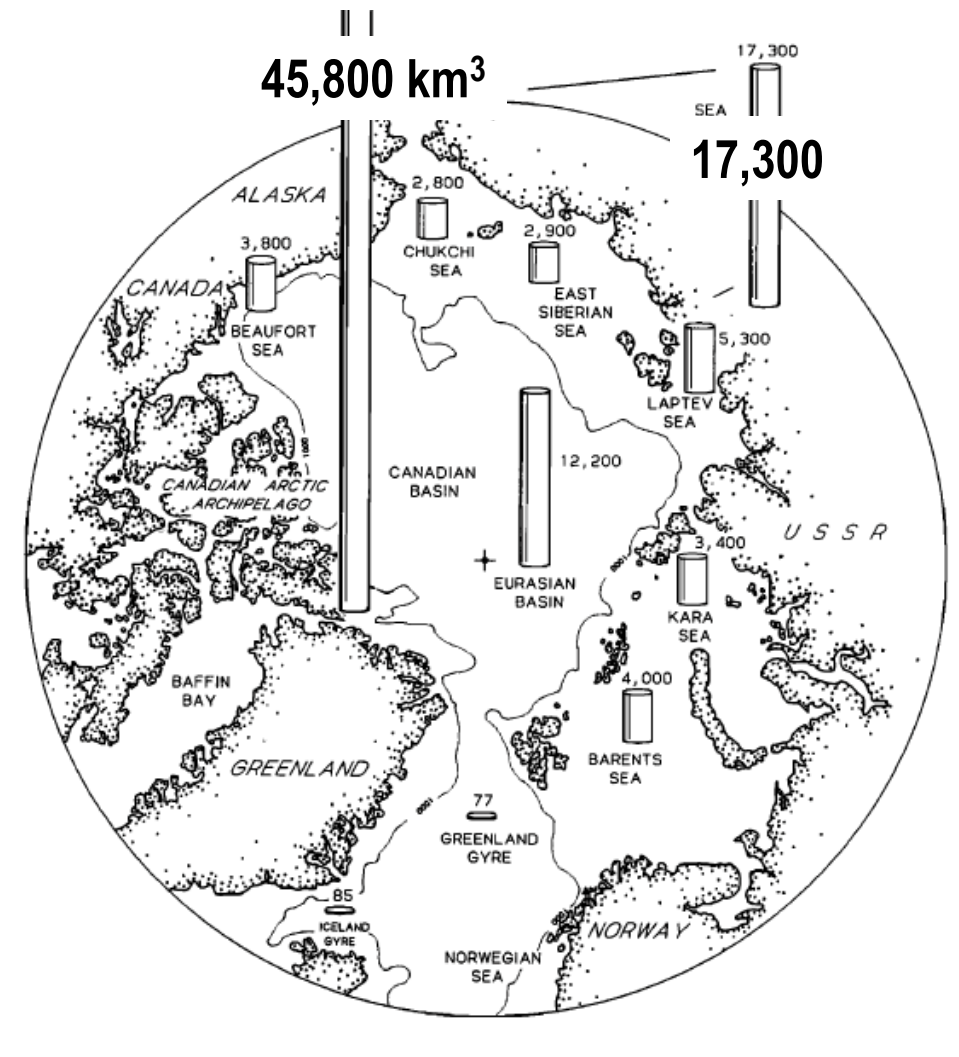
*Johnson et al. (GRL, 2018): model analysis*

# Arctic Freshwater Content (m)



Johnson et al. (GRL, 2018): model analysis

# Arctic Freshwater Volume (km<sup>3</sup>)



Aagaard & Carmack (JGR, 1989): in situ obs

# Arctic Freshwater Content/Volume: *So many papers...*

Google Scholar

arctic ocean freshwater

## [HTML] Changing arctic ocean freshwater pathways

[J Morison](#), [R Kwok](#), [C Peralta-Ferriz](#), [M Alkire](#), I Rigor... - Nature, 2012 - nature.com

... The **freshwater** changes were due to a cyclonic (anticlockwise) shift in the **ocean** pathway of Eurasian runoff forced by strengthening of the west-to-east Northern ...

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## Rapid change in freshwater content of the Arctic Ocean

[MG McPhee](#), [A Proshutinsky](#)... - Geophysical ..., 2009 - Wiley Online Library

... **Arctic** sea ice extent in recent years has been accompanied by surprising changes in the thermohaline structure of the **Arctic Ocean**, with ... circulation of the world **ocean**. Extensive aerial ...

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## Projected changes in Arctic Ocean freshwater budgets

[MM Holland](#), [J Finnis](#), [AP Barrett](#)... - Journal of Geophysical ..., 2007 - Wiley Online Library

... [33] This paper has analyzed the **Arctic Ocean freshwater** budgets from 10 climate ... **freshwater** storage in the **Arctic Ocean** as liquid and sea ice and the fluxes of **freshwater** to the **Arctic** in ...

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## [HTML] An assessment of Arctic Ocean freshwater content changes from the 1990s to the 2006–2008 period

[B Rabe](#), [M Karcher](#), [U Schauer](#), [JM Toole](#)... - Deep Sea Research ..., 2011 - Elsevier

... **freshwater** (LFW) inventories in the **Arctic Ocean** ... **Arctic Ocean** (water depth greater than 500 m). This is close to the annual export of **freshwater** (liquid and solid) from the **Arctic Ocean** ...

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## [HTML] The Arctic ocean estuary

[JW McClelland](#), [RM Holmes](#), [KH Dunton](#)... - Estuaries and ..., 2012 - Springer

... Large **freshwater** contributions to the **Arctic Ocean** from a variety of sources combine in what ... **Arctic Ocean** more fully, including the importance of **freshwater** export from the **Arctic Ocean** ...

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## [HTML] Arctic Ocean freshwater changes over the past 100 years and their causes

[IV Polyakov](#), [VA Alexeev](#), [GI Belchansky](#)... - Journal of ..., 2008 - journals.ametsoc.org

... 30s and in recent decades when the central **Arctic Ocean** was saltier, and two periods in the ... central **Arctic Ocean** salinification suggests that the FWC anomalies generated on **Arctic** ...

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## [HTML] Freshwater in the arctic ocean 2010–2019

[A Solomon](#), [C Heuzé](#), [B Rabe](#), [S Bacon](#)... - Ocean ..., 2021 - os.copernicus.org

... We show that the trend in **Arctic freshwater** content in the 2010s has stabilized relative to ... **freshwater** in the rest of the **Arctic Ocean**. However, large inter-model spread across the **ocean** ...

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## Freshwater balance and the sources of deep and bottom waters in the Arctic Ocean inferred from the distribution of H218O

[D Bauch](#), [P Schlosser](#), [RG Fairbanks](#) - Progress in Oceanography, 1995 - Elsevier

... **Arctic Ocean** occupied in 1987 and 1991 are used to derive information on the **freshwater** balance of the **Arctic Ocean** ... in the upper waters of the **Arctic Ocean** and infer pathways of the ...

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## Freshwater content variability in the Arctic Ocean

[S Häkkinen](#), [A Proshutinsky](#) - ... of Geophysical Research: Oceans, 2004 - Wiley Online Library

... the **Arctic Ocean** as a whole. To display the magnitude and variability of the simulated **Arctic Ocean freshwater** anomalies... **freshwater** anomaly referenced to the monthly climatology. The ...

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# Arctic Freshwater Content/Volume: *So many papers...*

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arctic ocean freshwater

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... **Arctic** sea ice export of **freshwater** from the **Arctic Ocean** ... thermohaline structure ...

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In situ obs, models, & satellites

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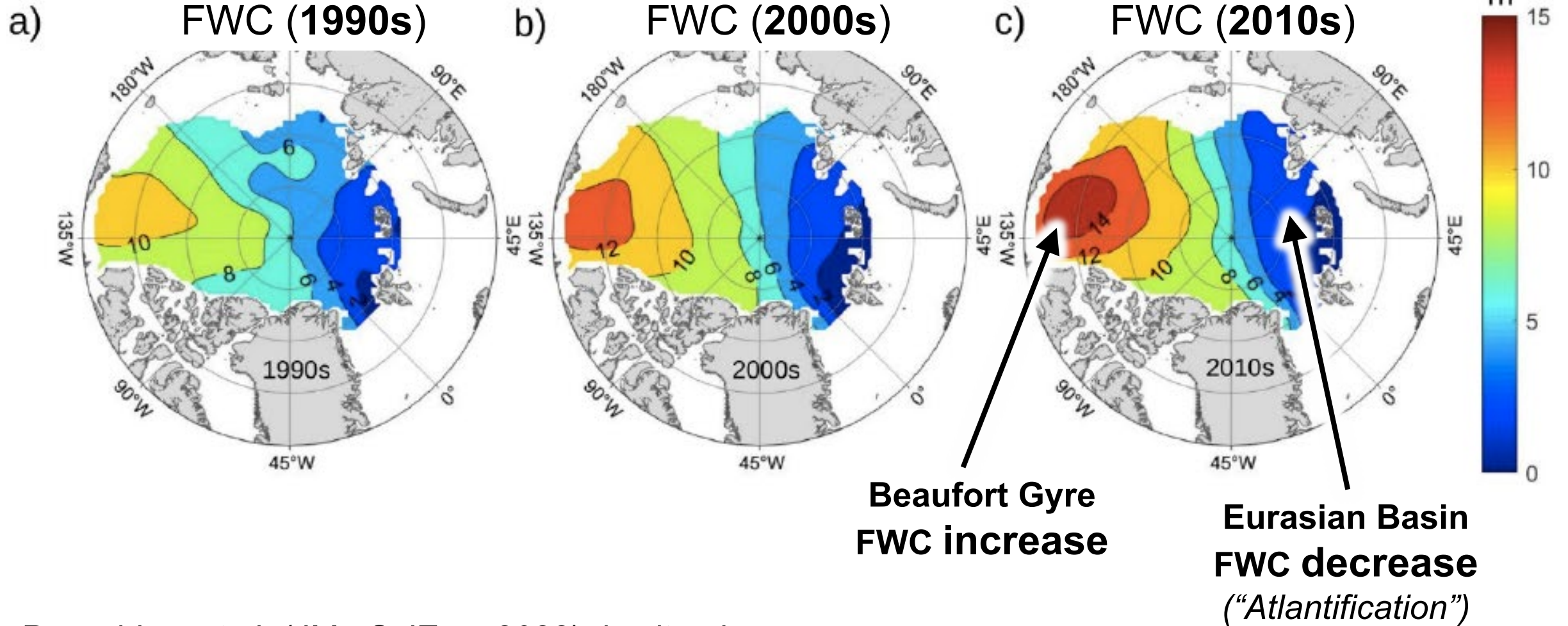
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# A typical FWC study: in situ obs

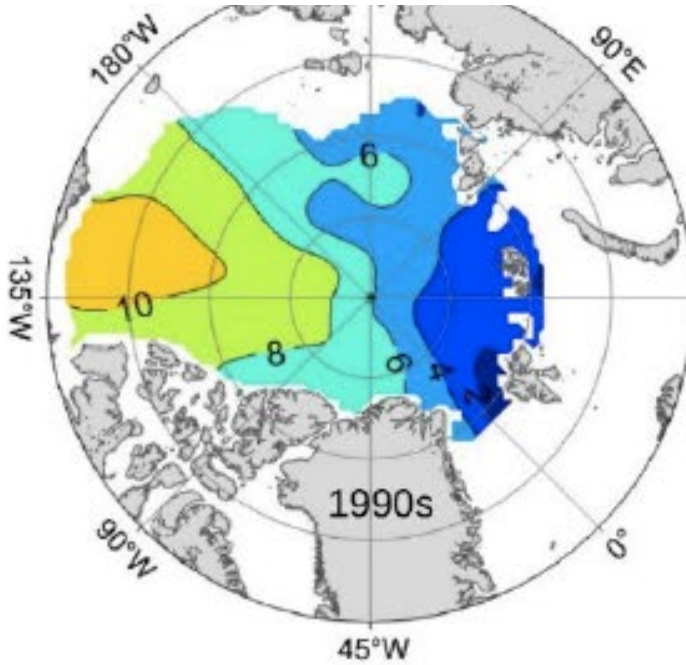


*Pnyushkov et al. (JMarSciEng, 2022): in situ obs*

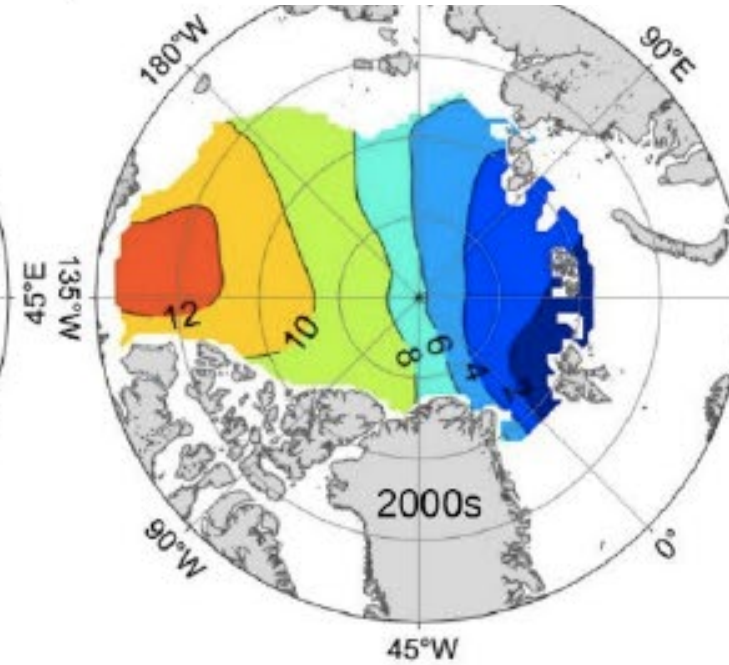
# A typical FWC study: in situ obs

But...where's the Russian shelf?!

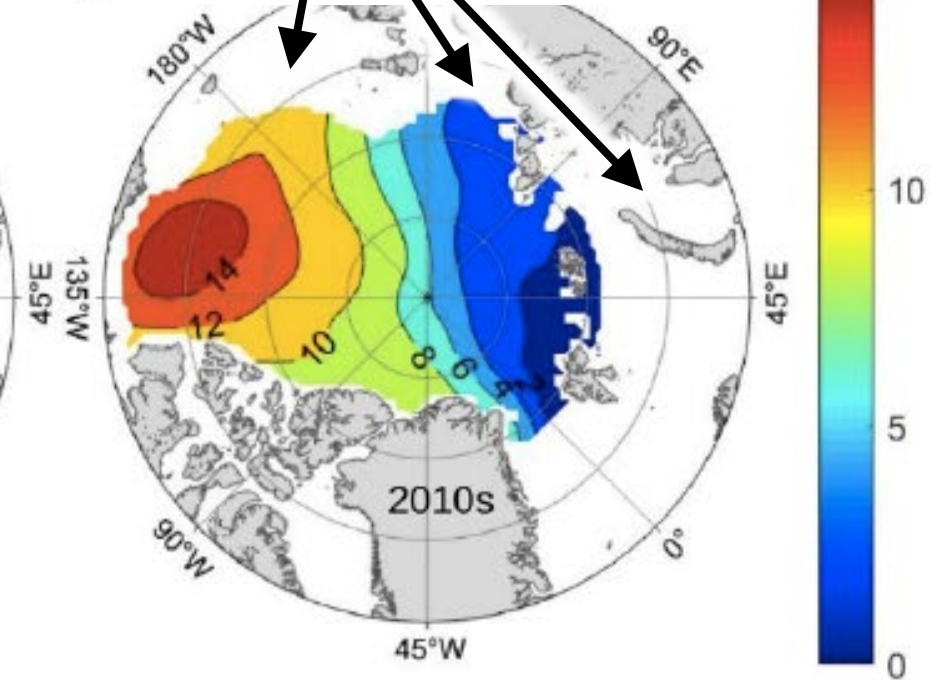
a) FWC (1990s)



b) FWC (2000s)



c) FWC (2010s)

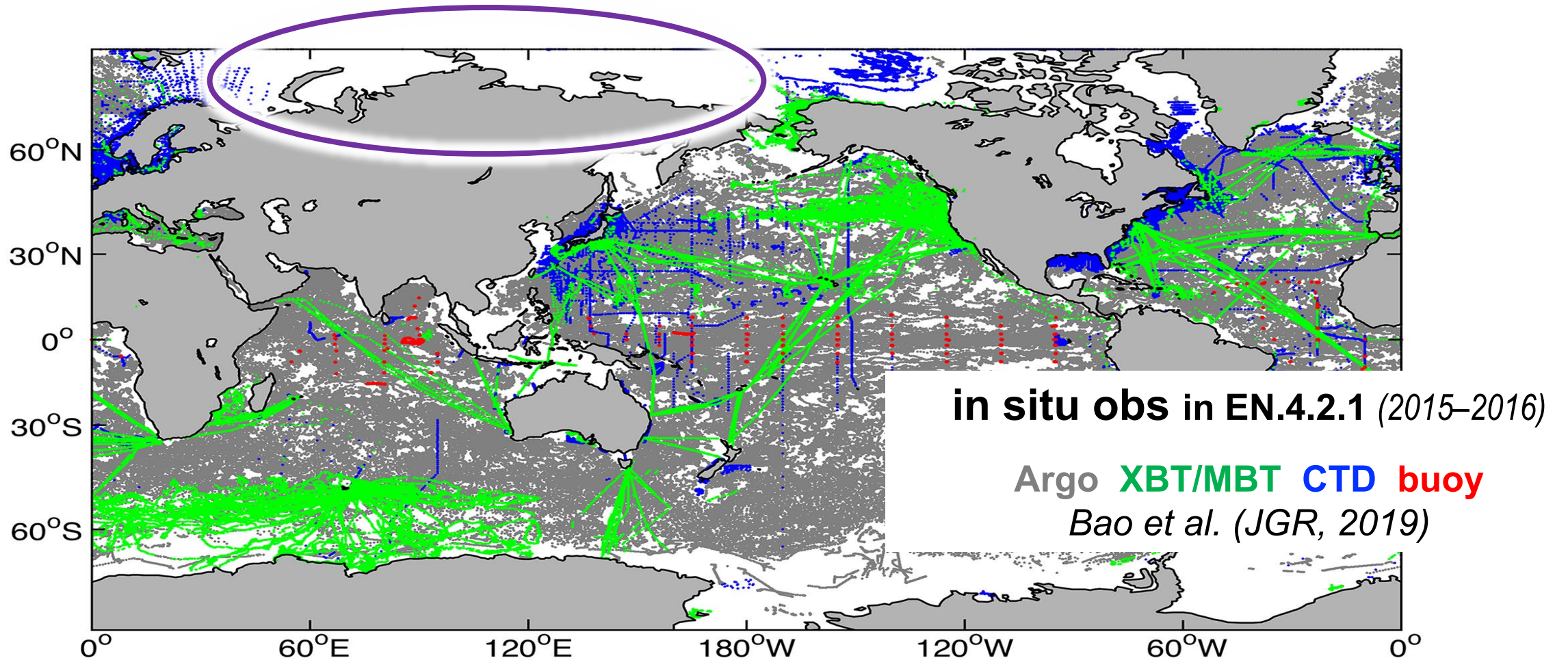




# A typical FWC study: in situ obs

Answer: *Lack of in situ obs*

But...where's the Russian shelf?!

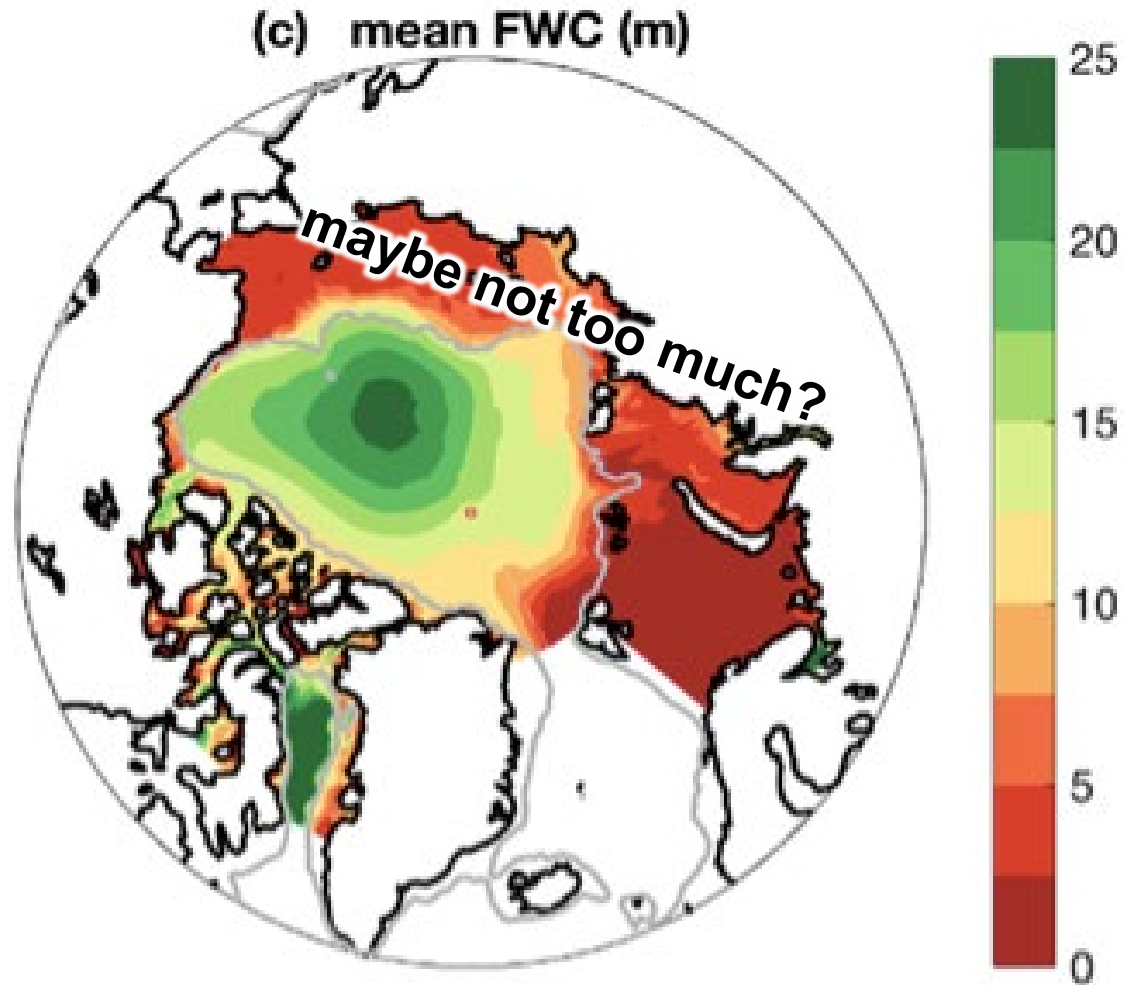






Our question:

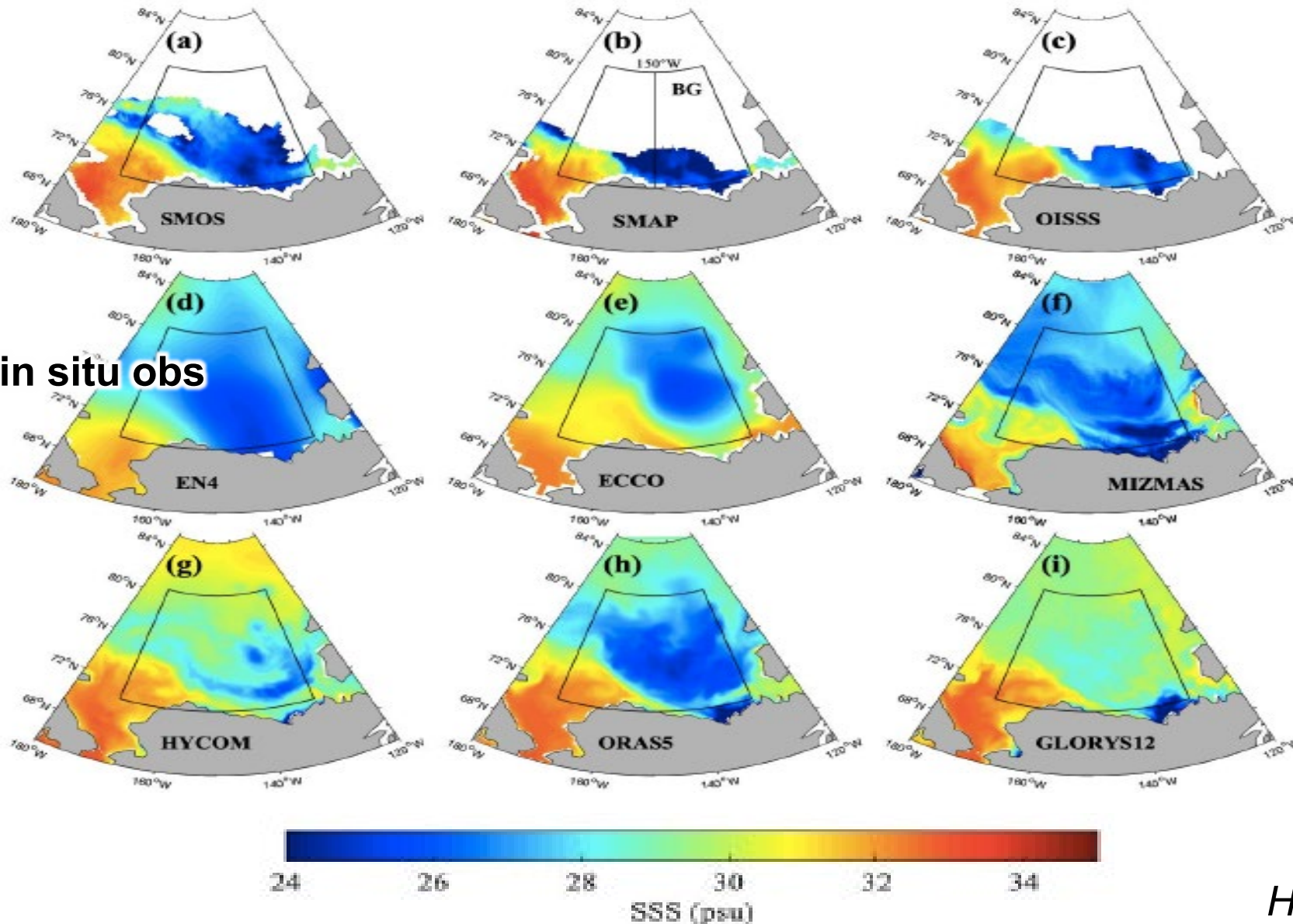
# 👉 What are we missing when we neglect the Russian Shelves?



*Johnson et al. (GRL, 2018): model analysis*

# Tools

## Chukchi & Beaufort

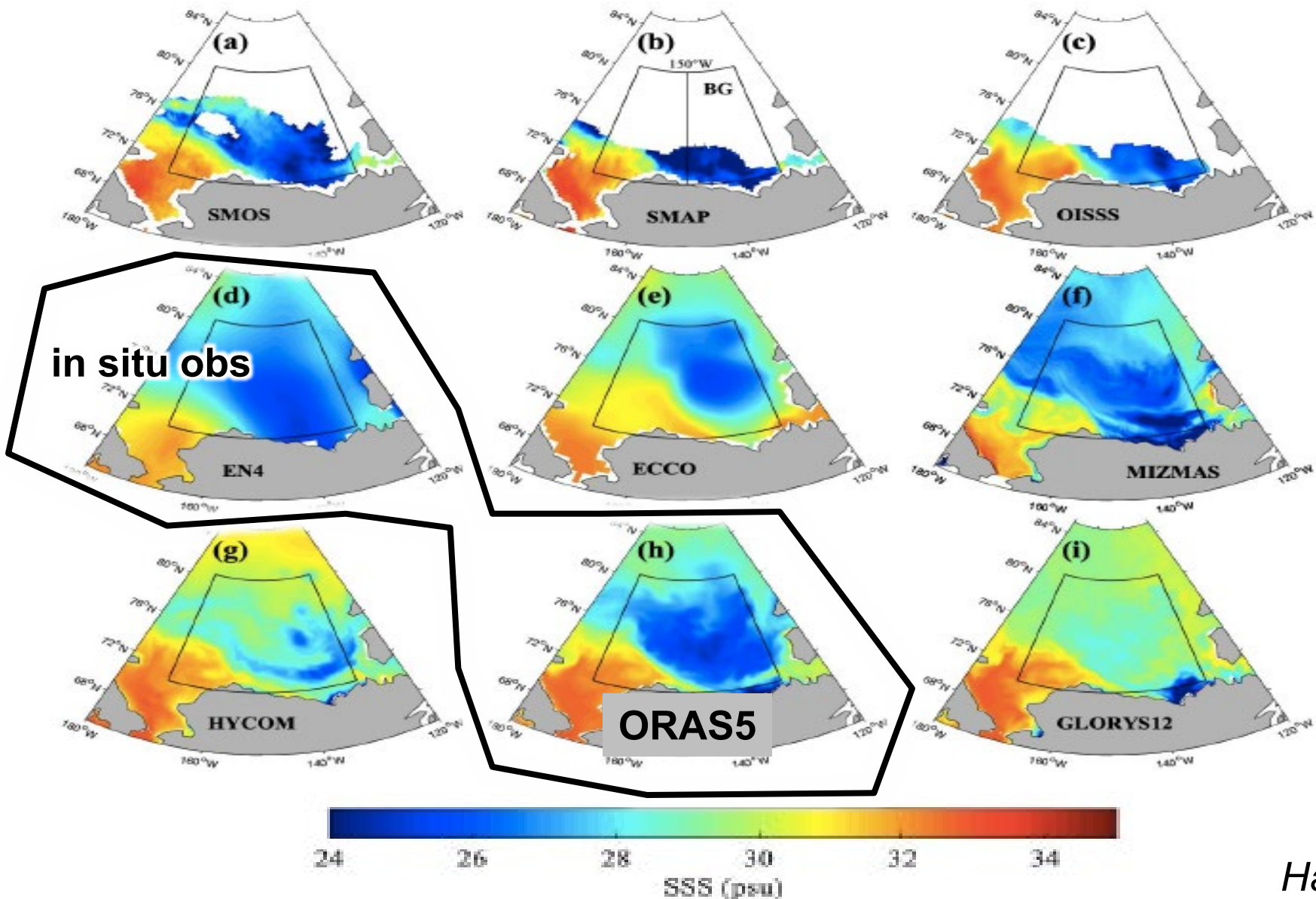


(1)  
Satellite  
Sea Surface Salinity

(2)  
“Reanalysis” =  
Model + obs blend

# Tools

## Chukchi & Beaufort



(1)  
Satellite  
Sea Surface Salinity

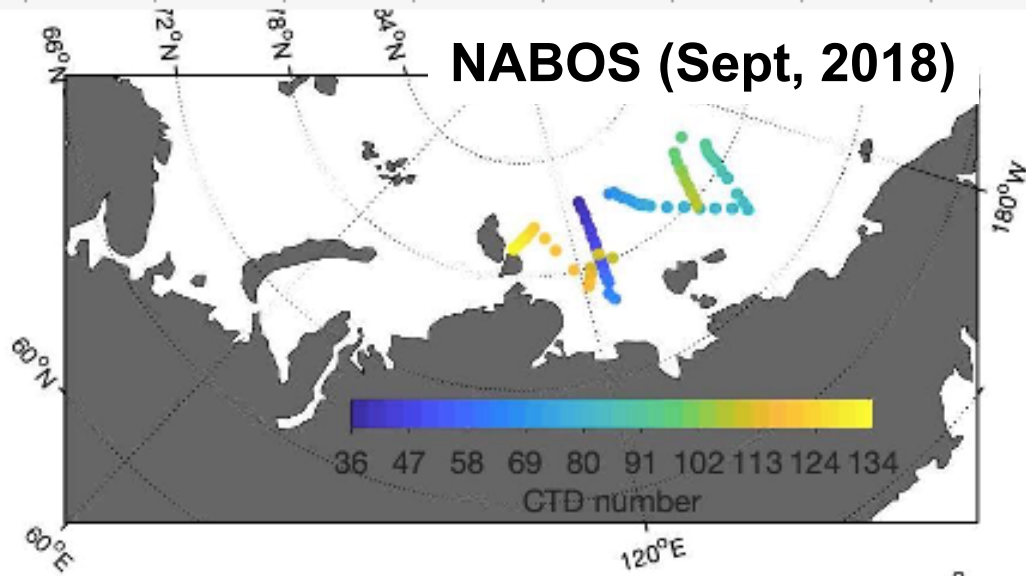
(2)  
“Reanalysis” =  
Model + obs blend

Conclusion:  
**ORAS5 best**

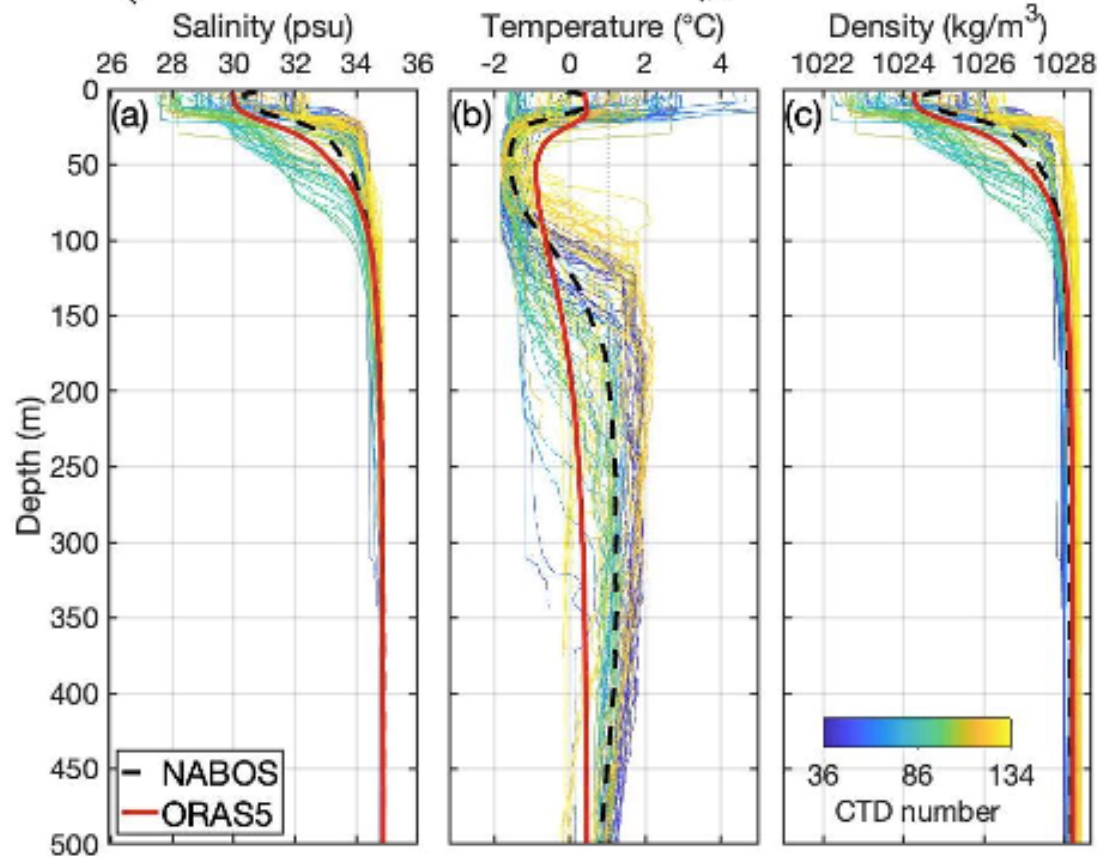
Hall et al. (Rem. Sens., 2021)



# NABOS (Sept, 2018)

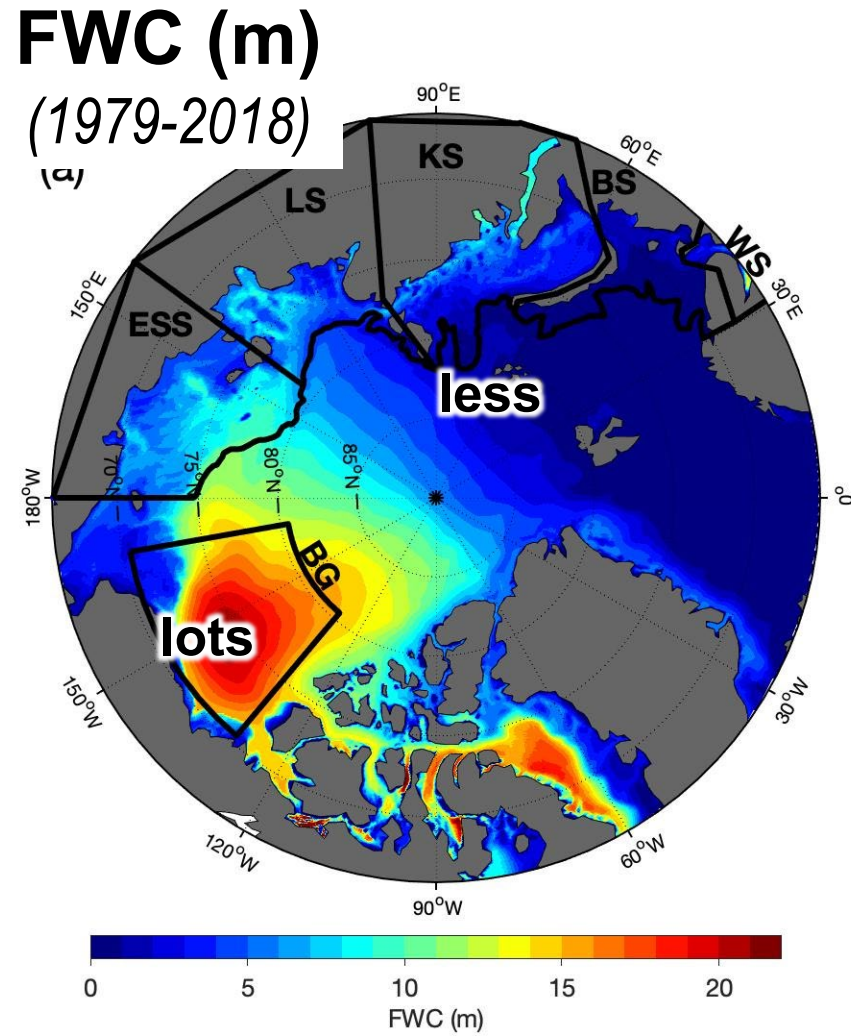


**ORAS5 not bad  
in the Laptev**

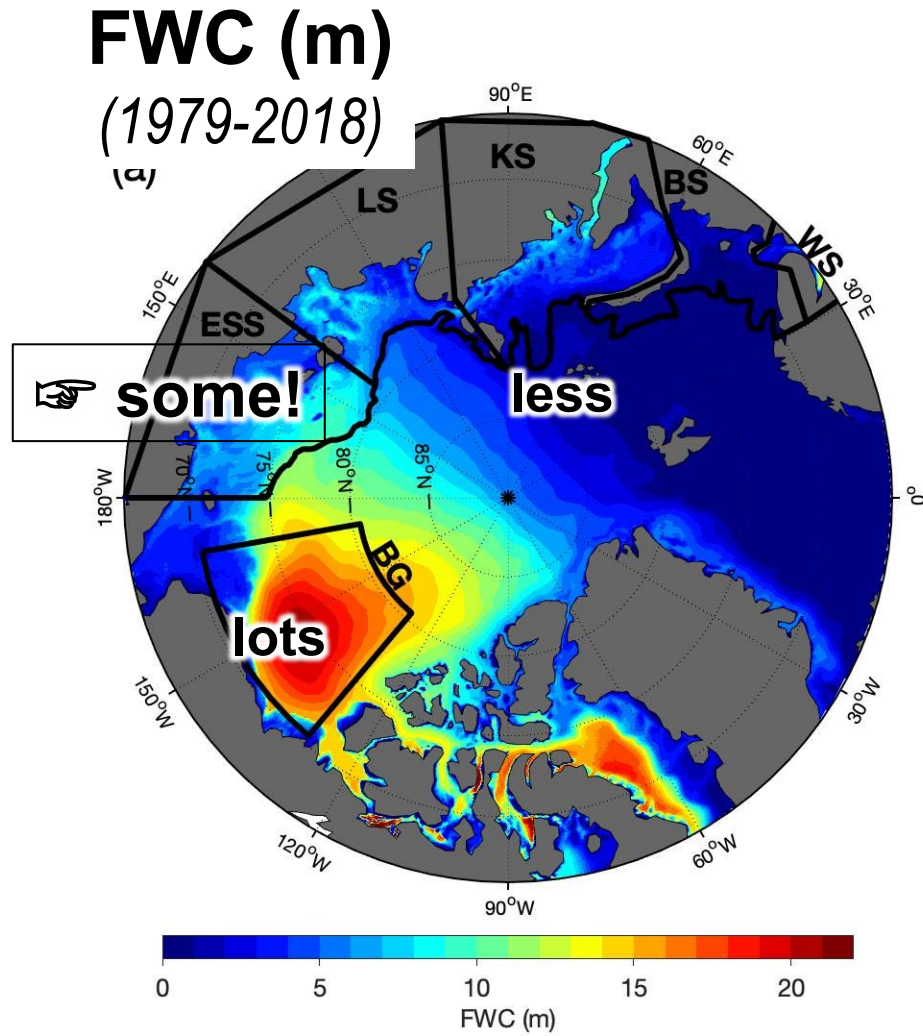




# ORAS5 Reanalysis FWC

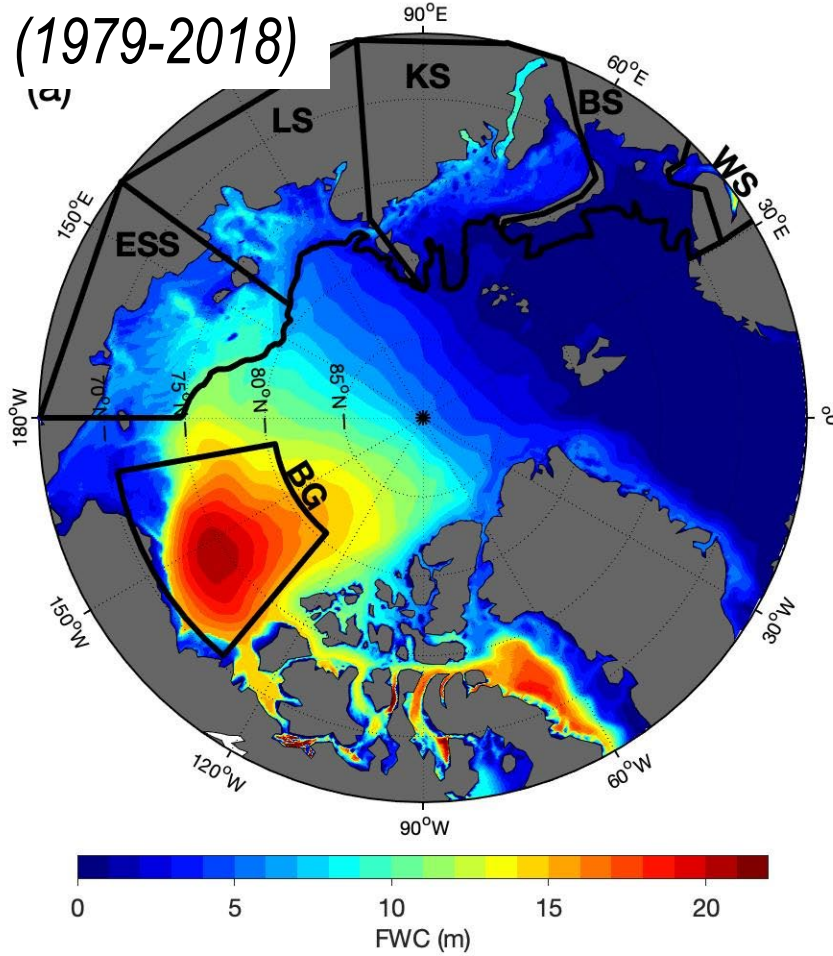


# ORAS5 Reanalysis FWC

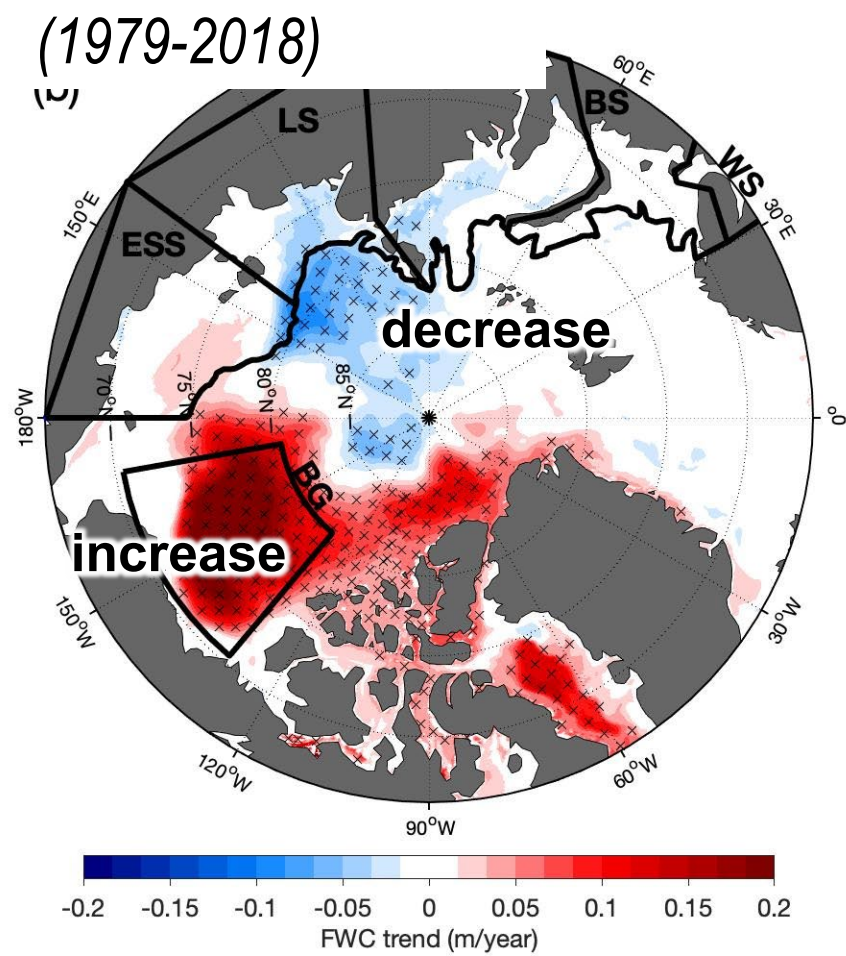


# ORAS5 Reanalysis FWC

**FWC (m)**  
(1979-2018)



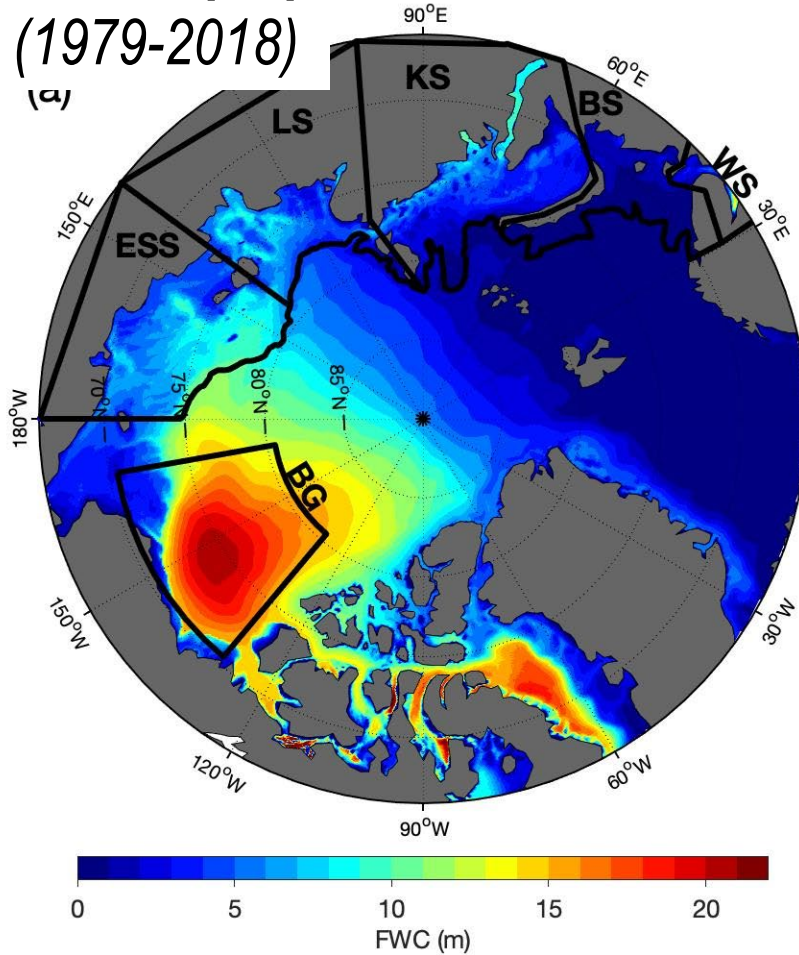
**FWC trend (m/year)**  
(1979-2018)



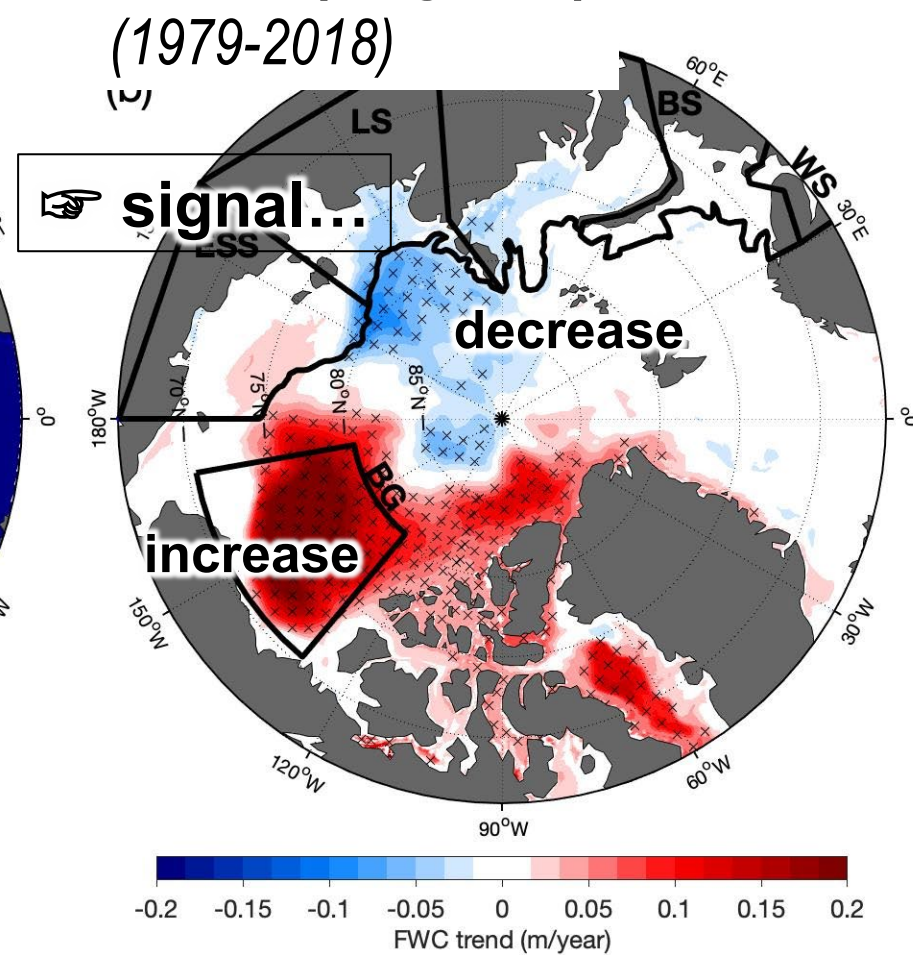


# ORAS5 Reanalysis FWC

**FWC (m)**  
(1979-2018)

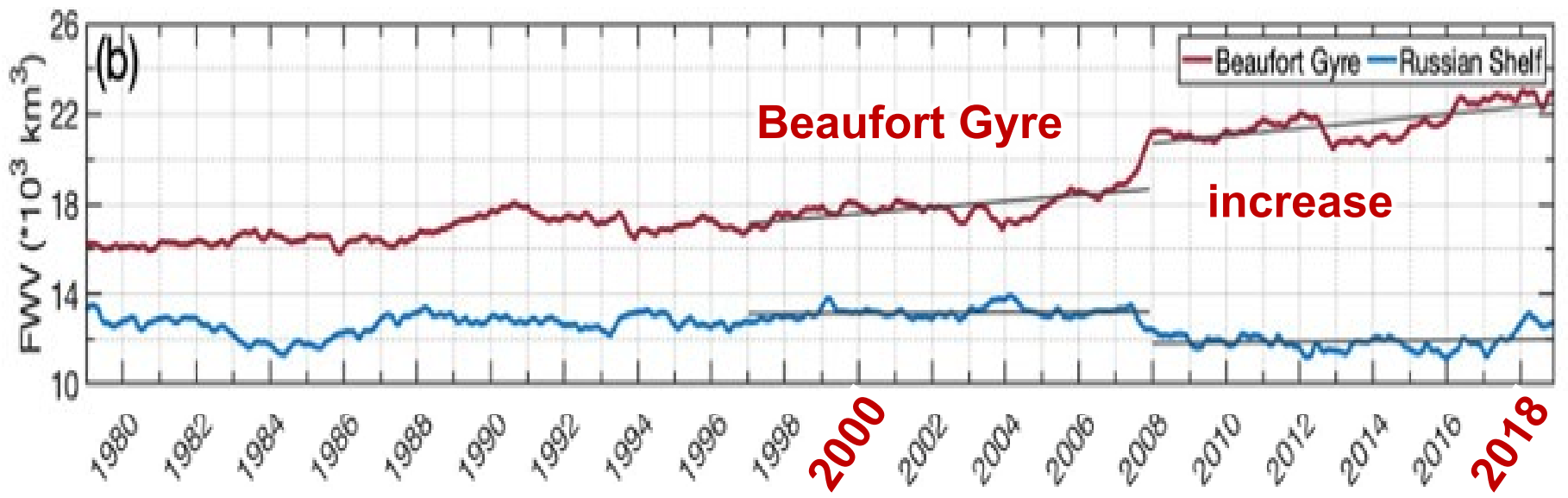


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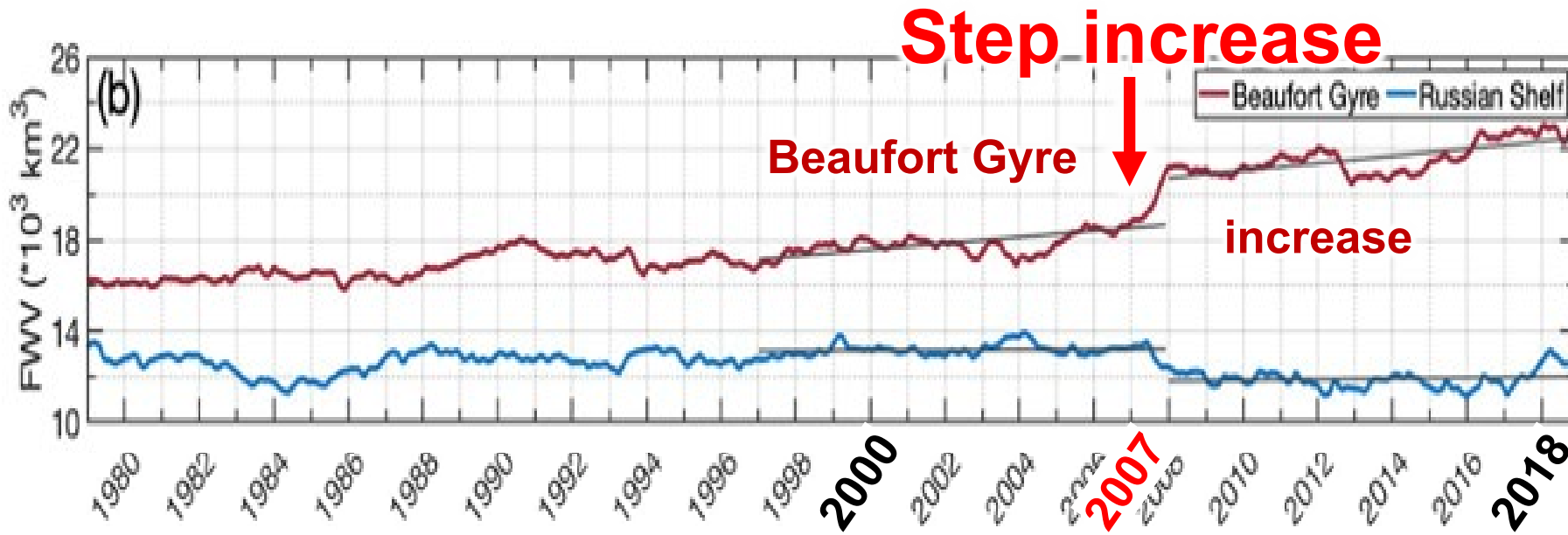




# ORAS5 Reanalysis FWV (deseasoned)



# ORAS5 Reanalysis FWV (deseasoned)



Zhong, W., Zhang, J., Steele, M., Zhao, J., & Wang, T.

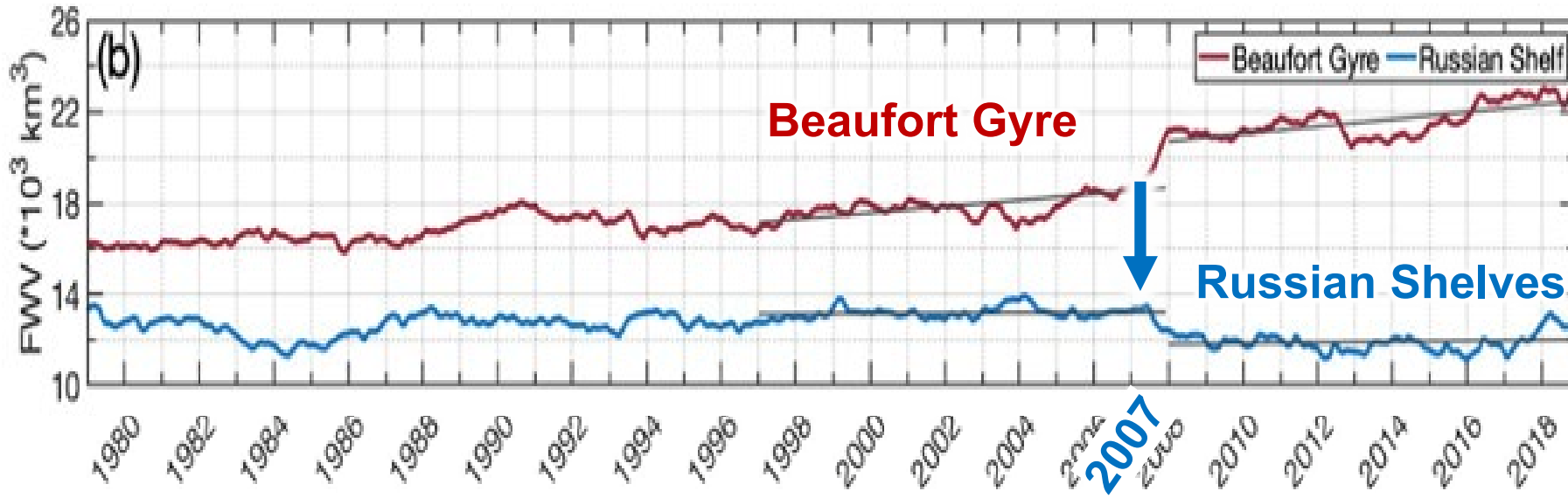
**“Episodic** extrema of surface stress energy input to the western Arctic Ocean  
contributed to step changes of freshwater content in the Beaufort Gyre”

GRL (2019)

see also: Moore, Steele, et al. (Nature Comm. E&E, 2022)

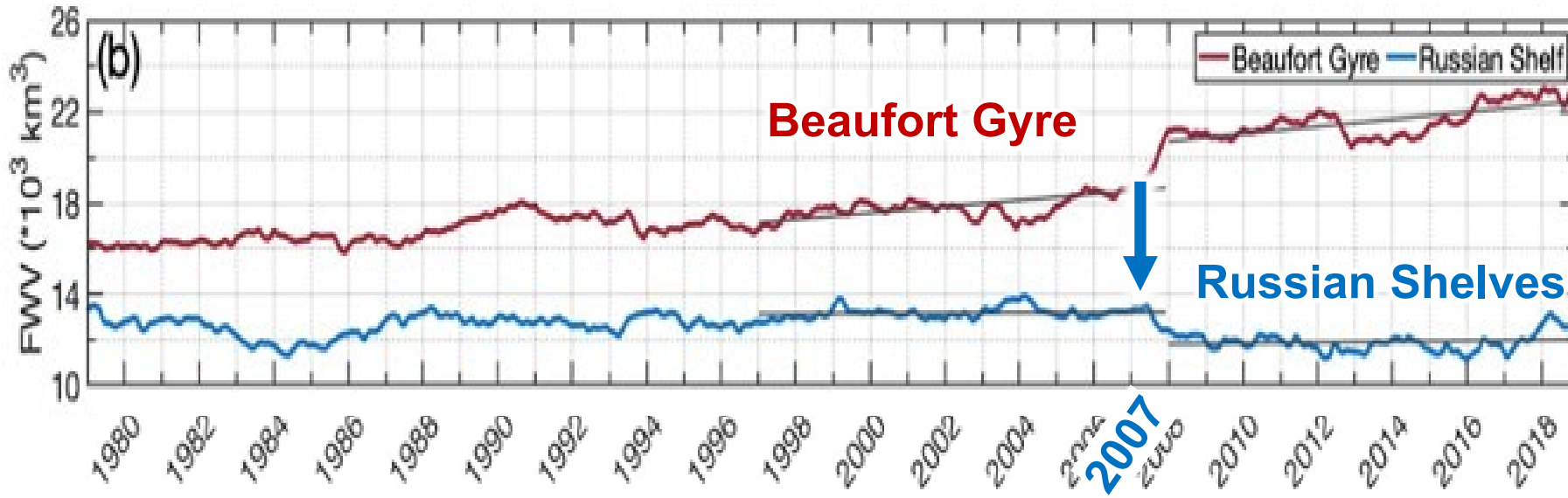
Hall et al. (in review, JGR, 2022)

# ORAS5 Reanalysis FWV (deseasoned)



**Step decrease** ...mostly from ESS & Laptev

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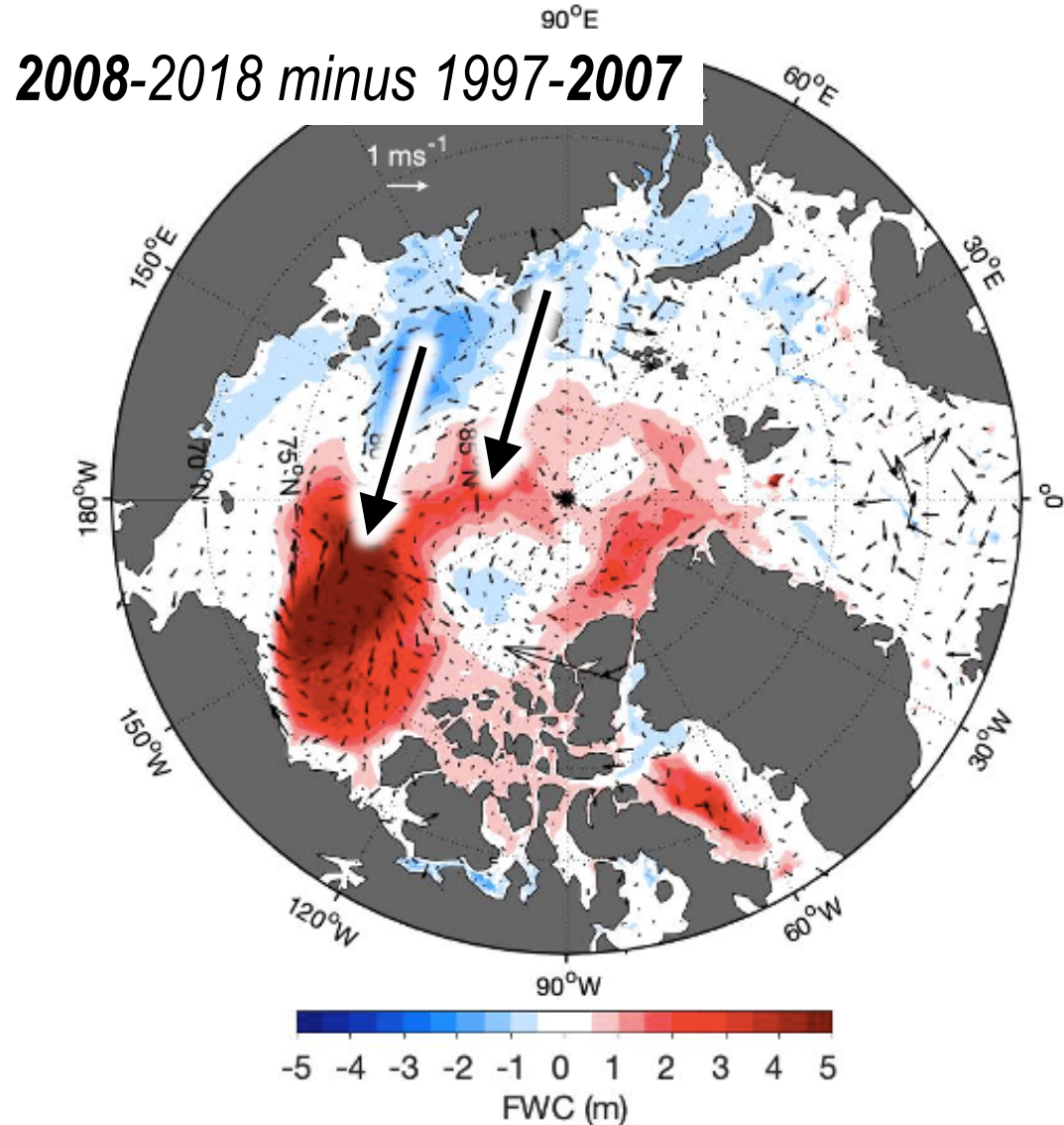
**Step decrease** ...mostly from ESS & Laptev

**Why?**



# 2007 freshwater flux:

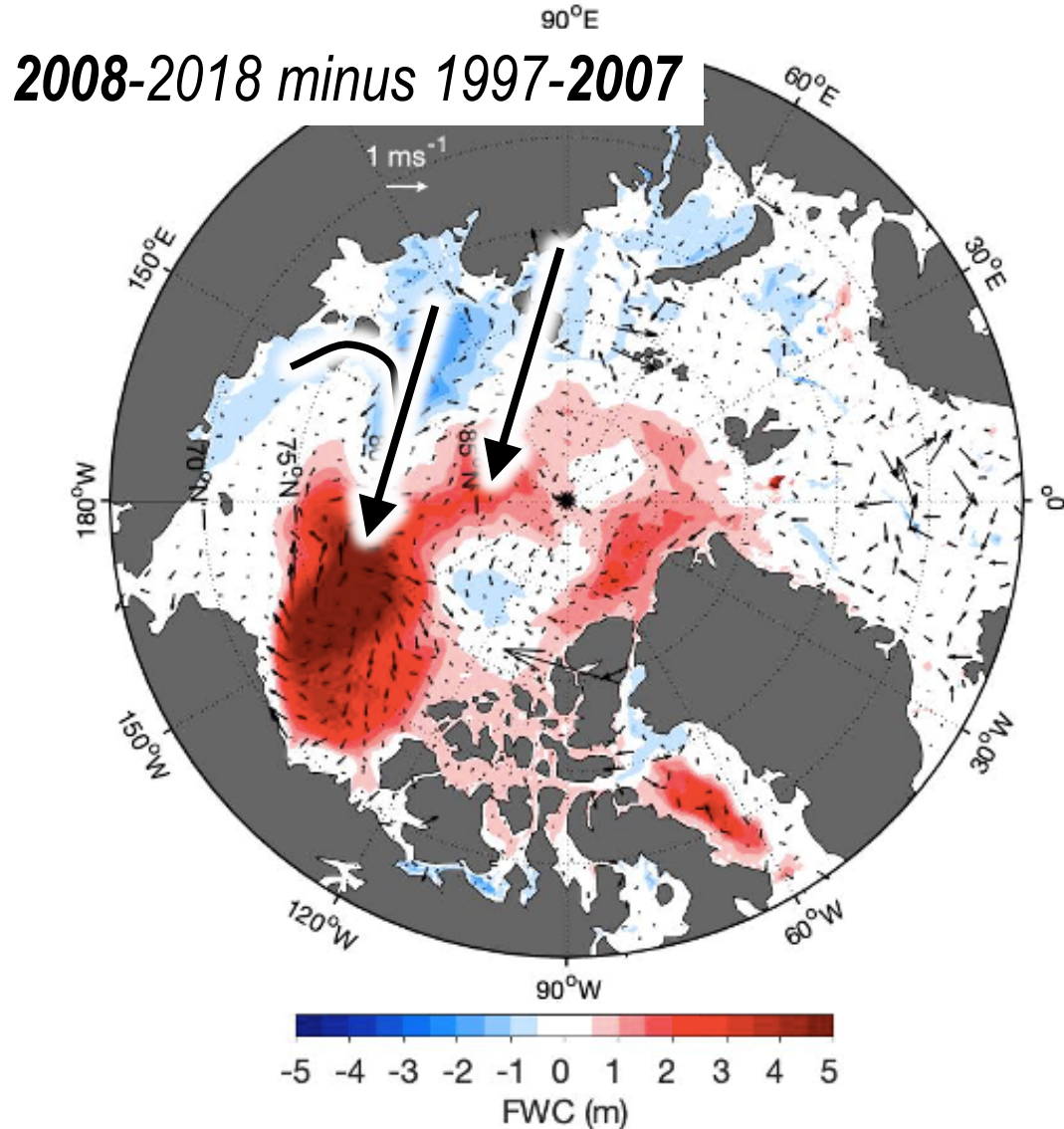
*Eurasian Basin* → *Amerasian Basin*



*Hall et al. (in review, JGR, 2022)*

# 2007 freshwater flux:

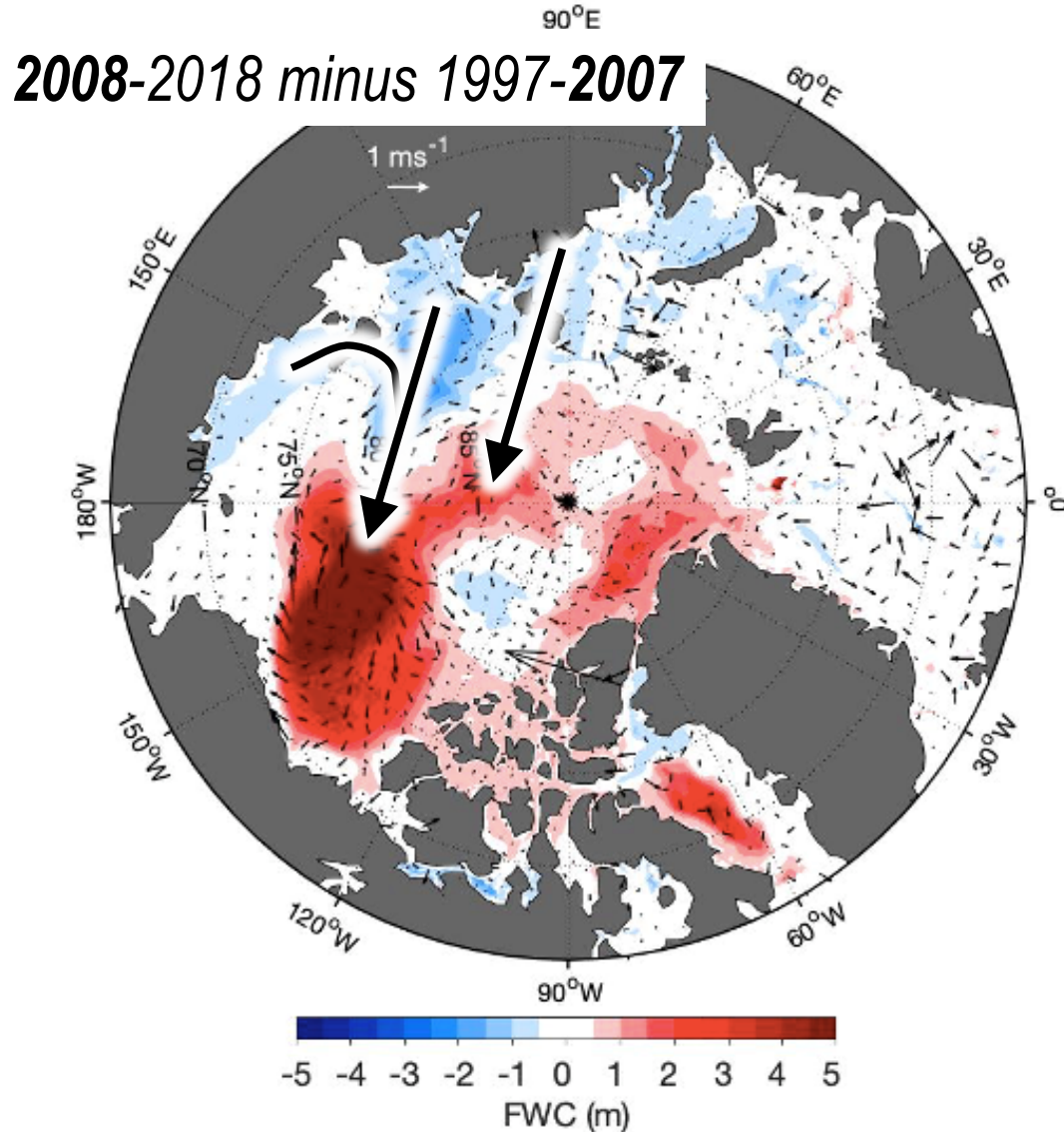
*Eurasian Basin + Russian Shelves* → *Amerasian Basin*



**EB → AB flux has a “root”  
on the Russian Shelf**

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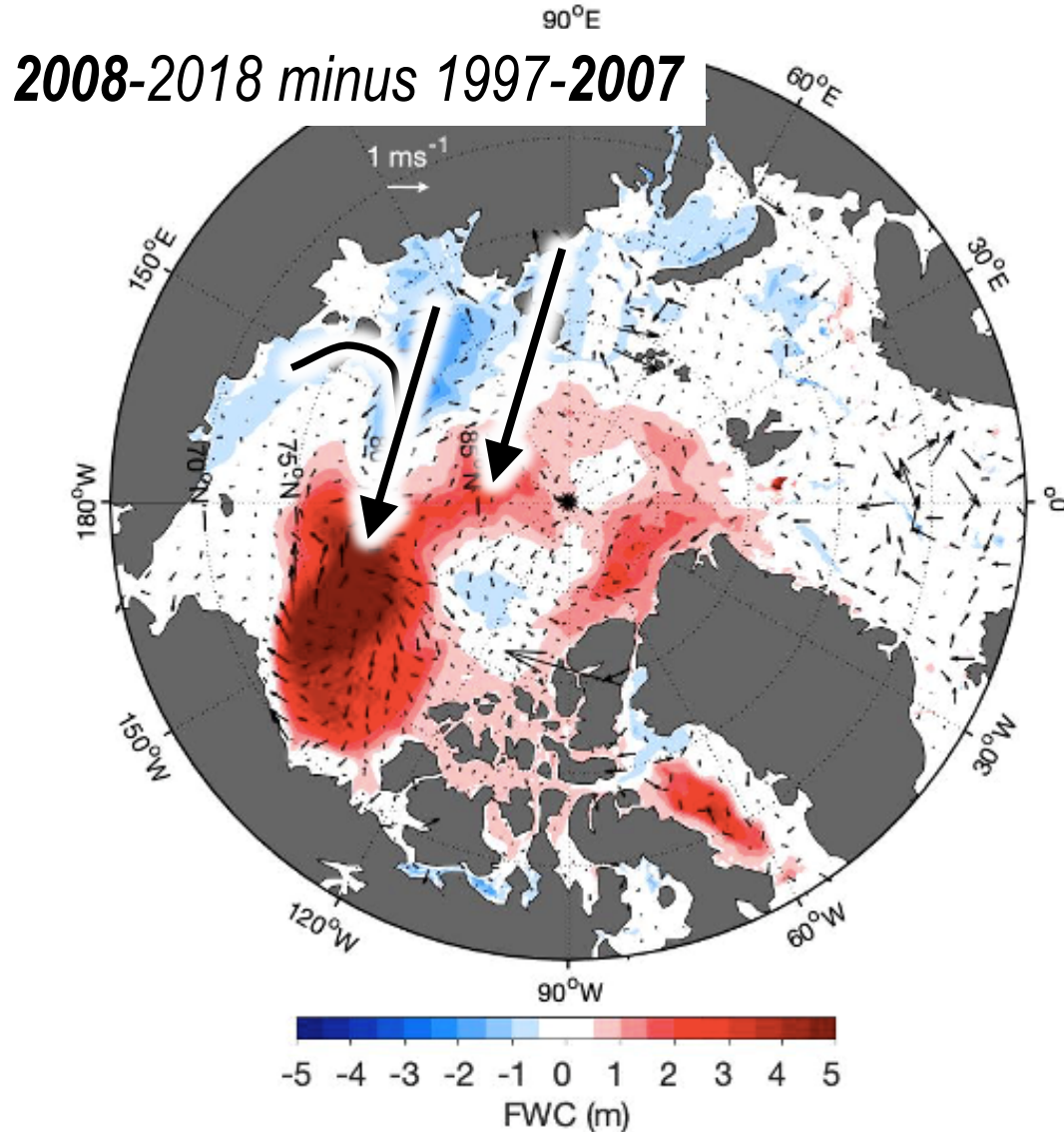
**Neglect of Russian Shelf:**

**Unrealistic 2007 Arctic Ocean  
FWC increase by ~ 25%**



# 2007 freshwater flux:

*Eurasian Basin + Russian Shelves* → *Amerasian Basin*



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**Unrealistic 2007 Arctic Ocean  
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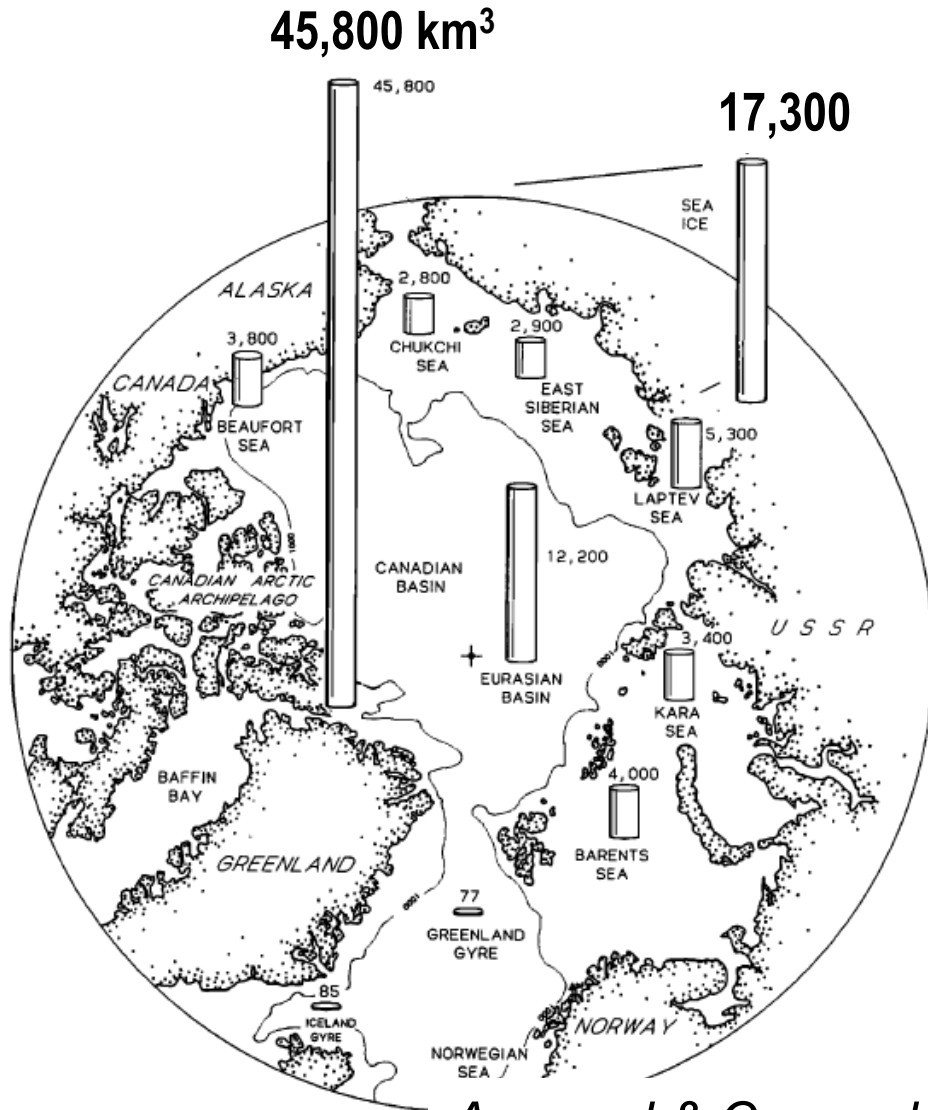
# Thank You

*Hall et al. (in review, JGR, 2022)*





# Arctic Freshwater Volume



Aagaard & Carmack (JGR, 1989)

$$FWV = \int \int \int_{z(S=S_{ref})}^{z_0} \frac{S_{ref} - S}{S_{ref}} \cdot dz \cdot dx \cdot dy$$

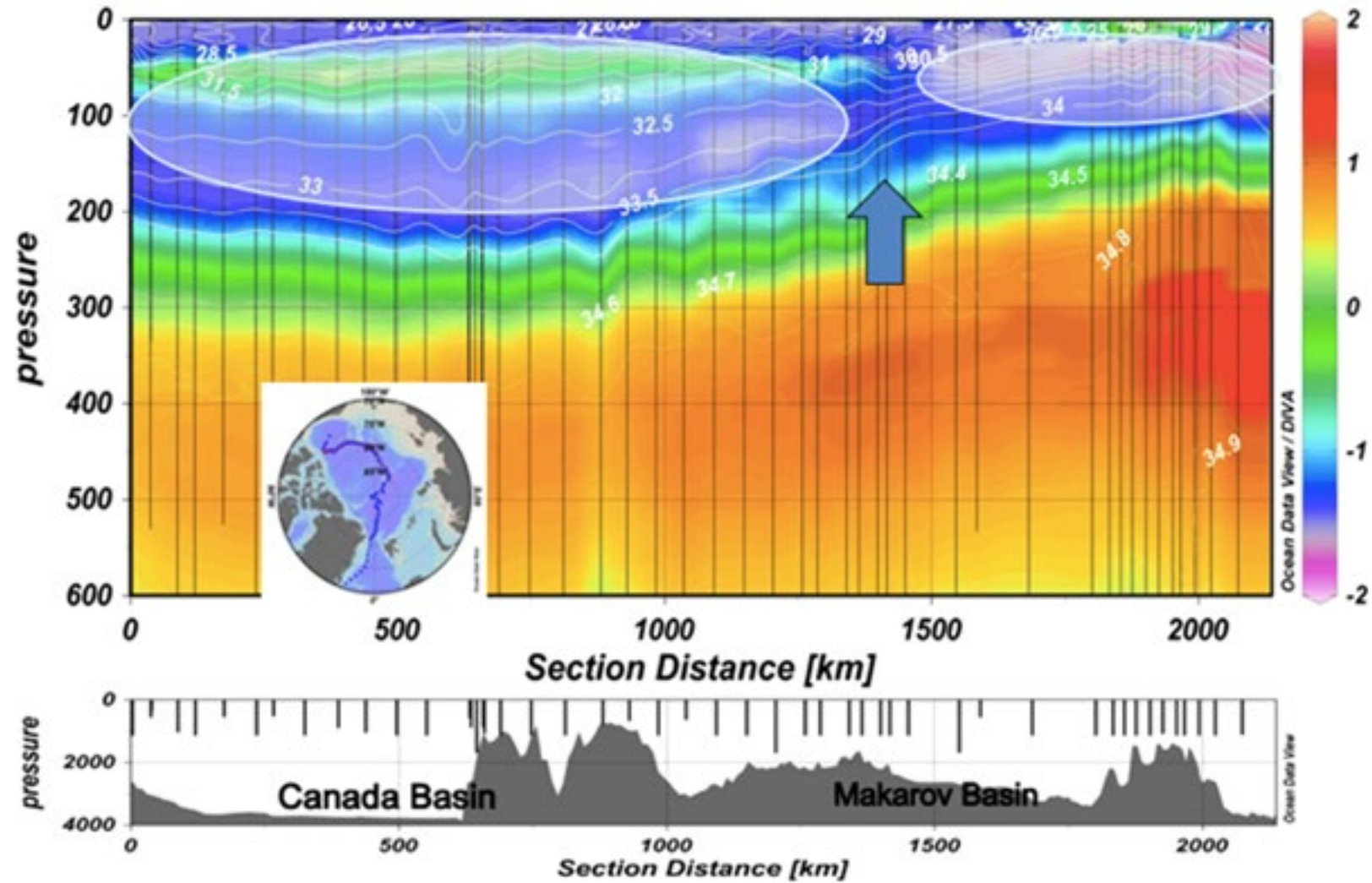
**FWC x area = FWV**

“content”

“volume”

# Arctic Freshwater Content: *So many papers...*

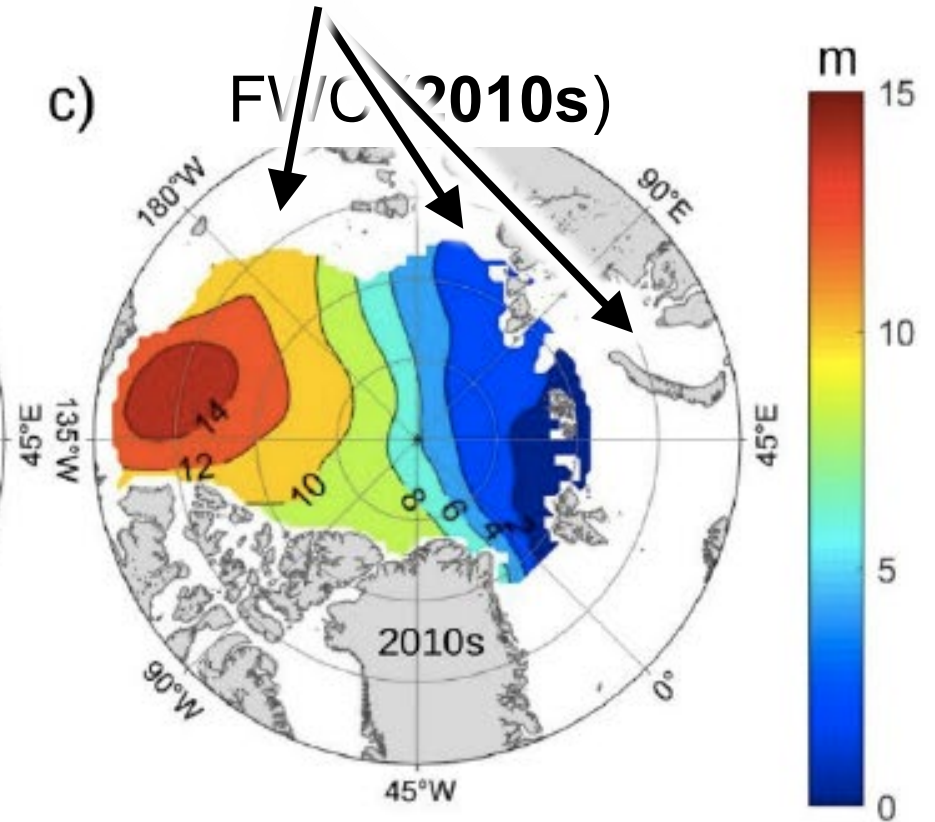
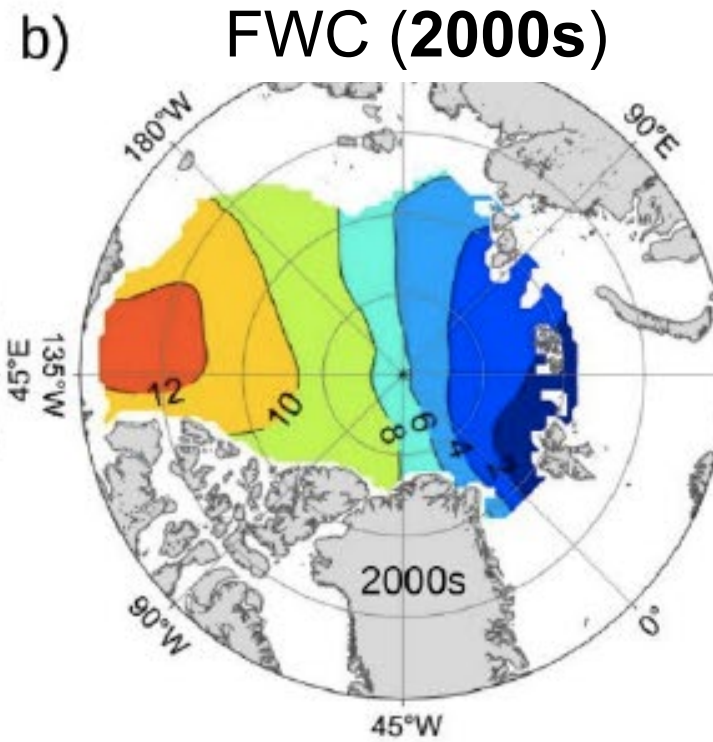
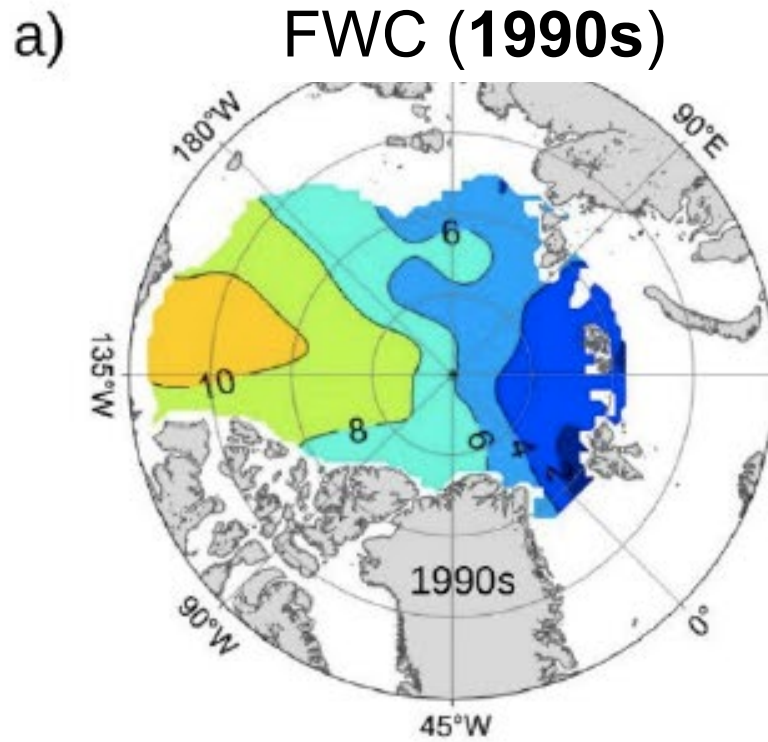
Aagaard



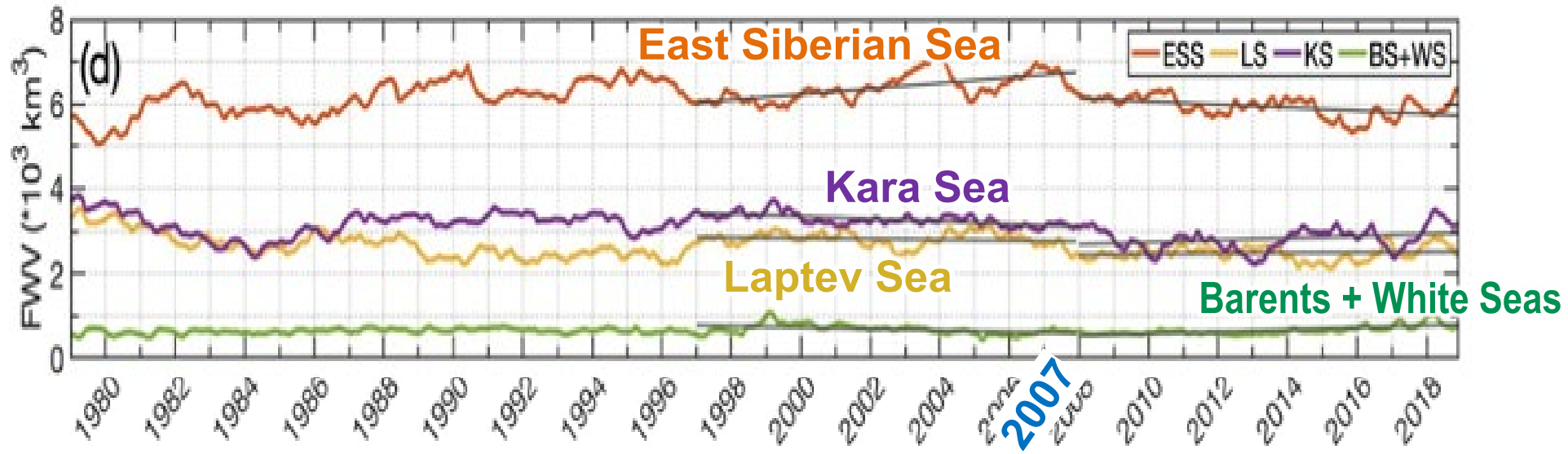
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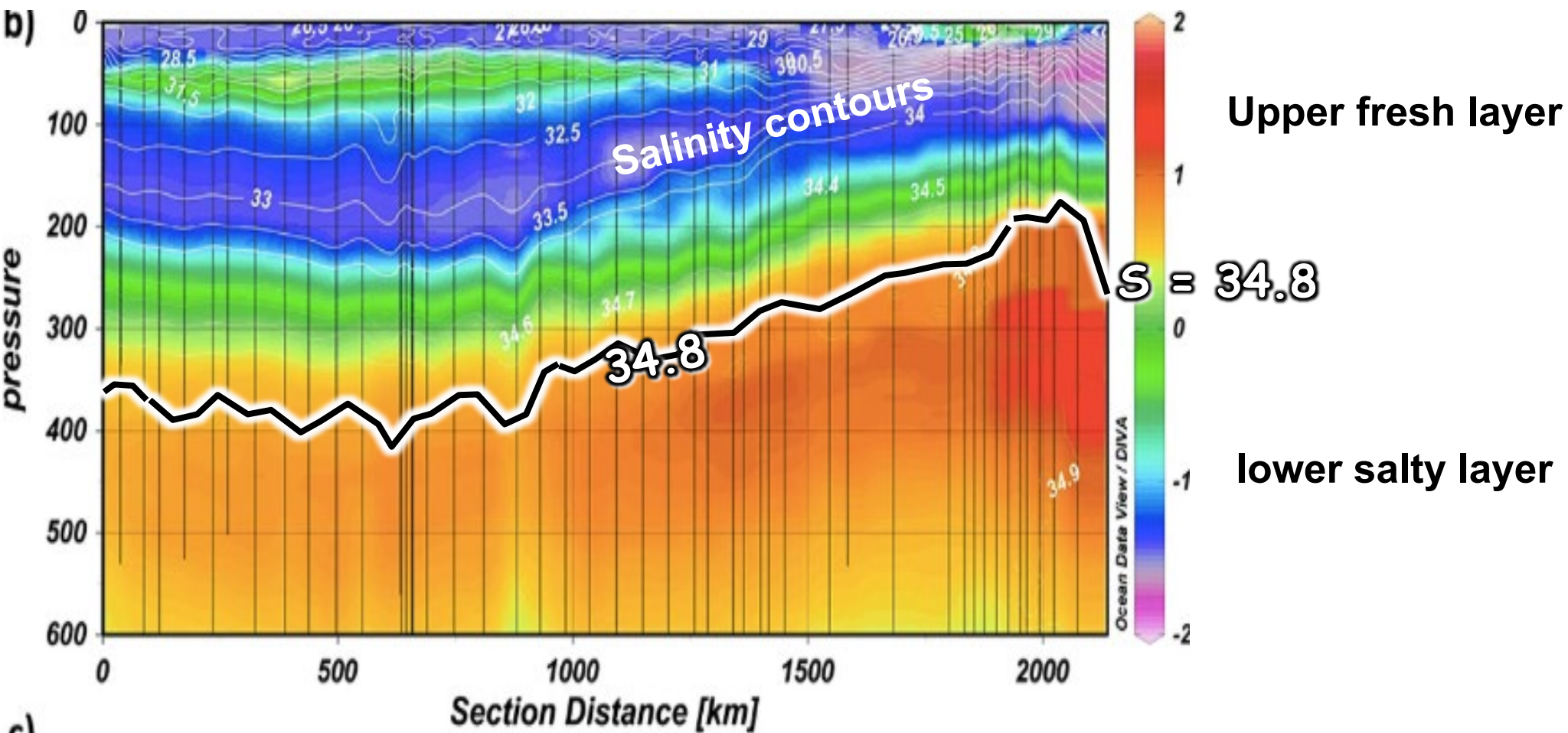




# The Arctic Ocean is ~ a “2-layer fluid”

Amerasian Basin

Eurasian Basin



Carmack et al. (JGR, 2015)