

Satellite-informed Reconstruction of Upper-Ocean Freshwater Content Variability in the Barents Sea

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ARCFRESH

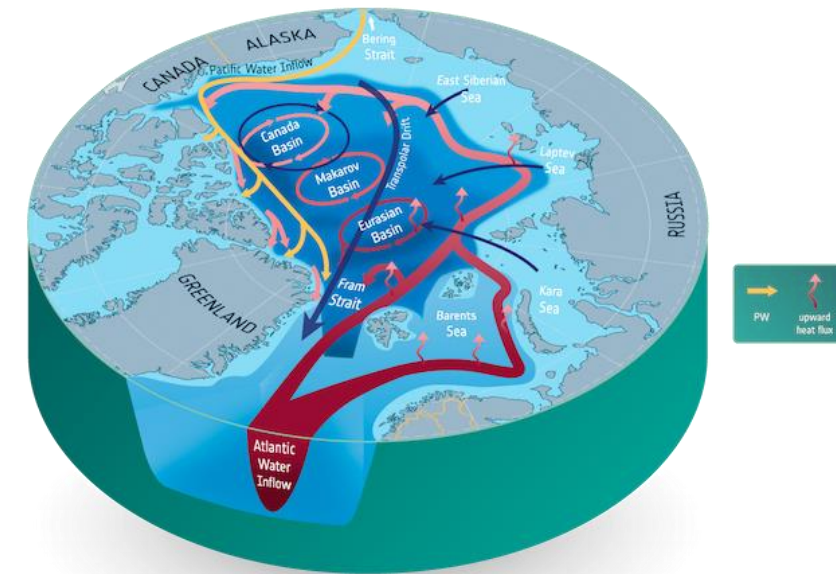
The Arctic Freshwater Budget (ARCFRESH) project aims to enhance knowledge of Arctic freshwater processes by maximising the use of EO-derived datasets from the ESA Climate Change Initiative

Helpdesk



Pan-Arctic Freshwater System is changing

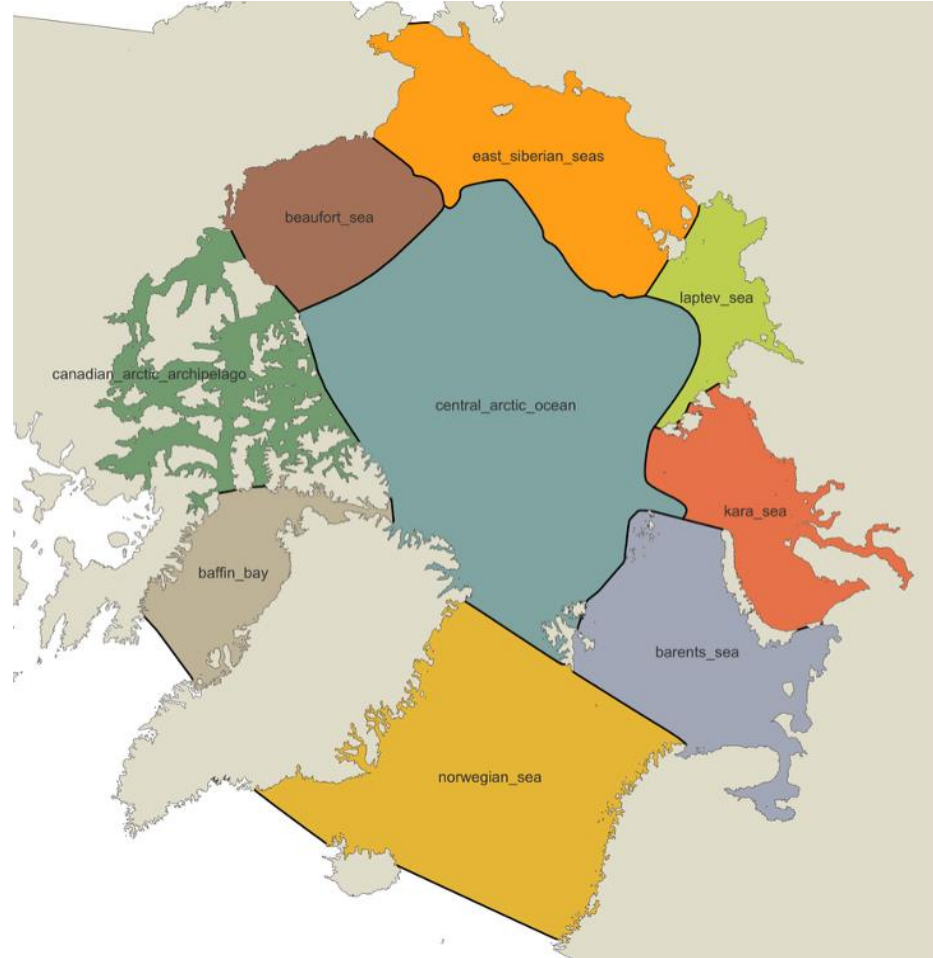
- **Long-term & short-term Shift Post-2010:** The robust freshening of the Arctic upper layer observed in the early 2000s has transitioned into a more complex, less clear signal after 2010
- **Freshwater redistribution:** Freshwater is redistributed within the Arctic basin, likely impacting regional circulation
- **The "hidden" inputs:** A significant portion of the freshwater budget—notably groundwater and river discharge—remains poorly constrained in current models
- **The Halocline Change:** Increased vertical mixing and the subsequent weakening of the halocline present a direct risk to the stability of the Arctic sea ice cover and ocean-atmosphere heat exchange



Insufficient Temporal Coverage in In-Situ Records

$$FWC = \int_{z_1}^{z_2} \left(\frac{S_{ref} - S(z)}{S_{ref}} \right) dz$$

$S_{ref} = 34.8 \text{ pss}$



Major Basin	Total Profiles since 2010
Beaufort	~10000
Siberian	~2000
Eurasian	~400
Barents	~4000

*CORA + UDASH

Surface Salinity as a proxy ?

JGR Oceans

RESEARCH ARTICLE
10.1029/2020JC016110

Sea Surface Salinity as a Proxy for Arctic Ocean Freshwater Changes

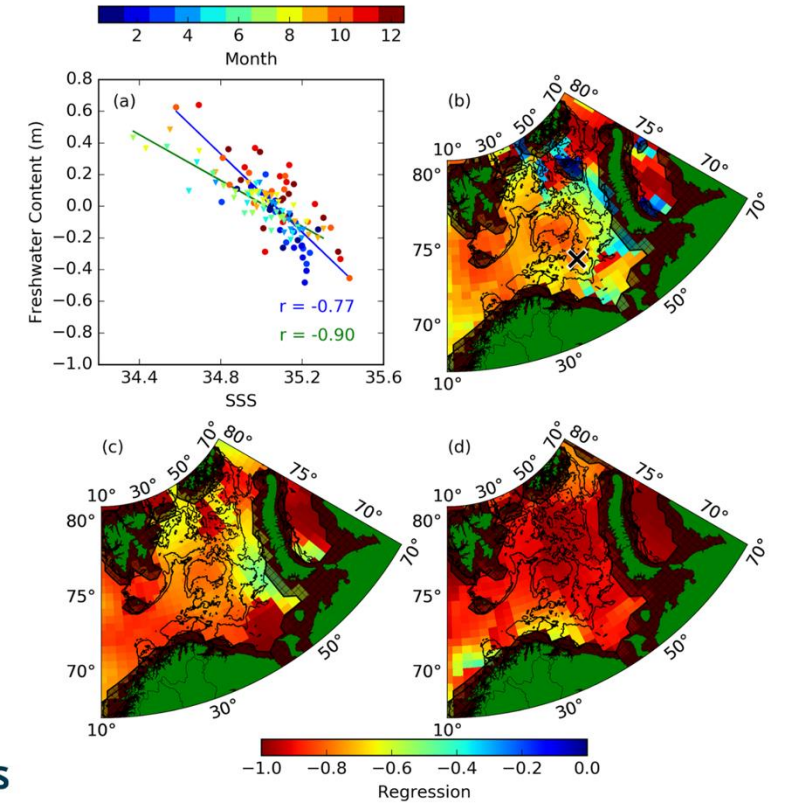
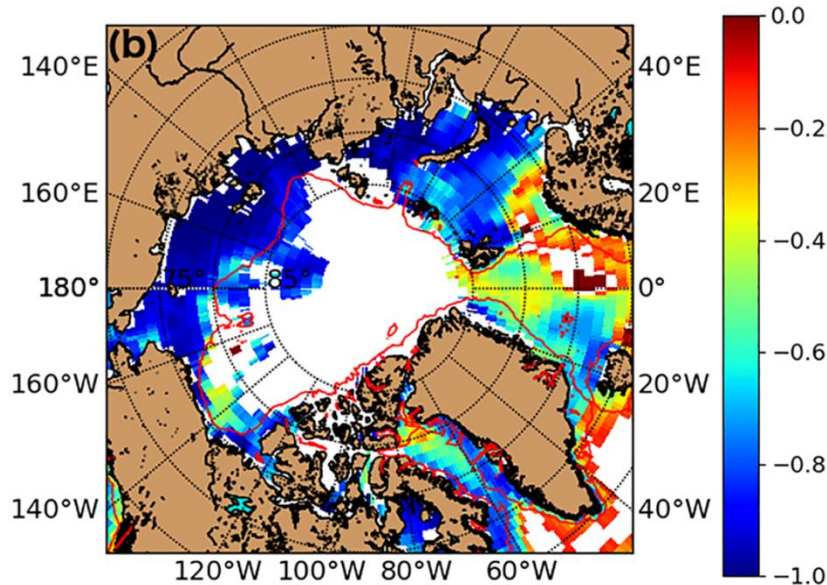
Special Section:
The Arctic: An AGU Joint
Special Collection

Séverine Fournier¹, Tong Lee¹, Xiaochun Wang², Thomas W. K. Armitage³, Ou Wang¹, Ichiro Fukumori¹, and Ron Kwok¹

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Key Points:

- Sea surface salinity (SSS) is found to be a good proxy for characterizing fresher changes in much of the



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RESEARCH ARTICLE
10.1029/2019JC015449

Water Mass Properties Derived From Satellite Observations in the Barents Sea

Key Points:

- Satellite data are combined in novel ways to infer steric height in the Barents Sea
- Heat and freshwater contents are estimated from satellite and in situ

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²School of Ocean Sciences, Bangor University, Bangor, UK, ³National Oceanography Centre, Liverpool, UK

Existing Challenges

Challenges	Physical Impact	Resulting Error
Stratification	Surface is decoupled from the deep	Over/underestimation of total FWC variability
Alpha vs. Beta	Temperature influences sea level	Misattribution of SLA to freshwater
Vertical Mixing	Weakening halocline	SSS stays fresh while deeper layers saltify

...

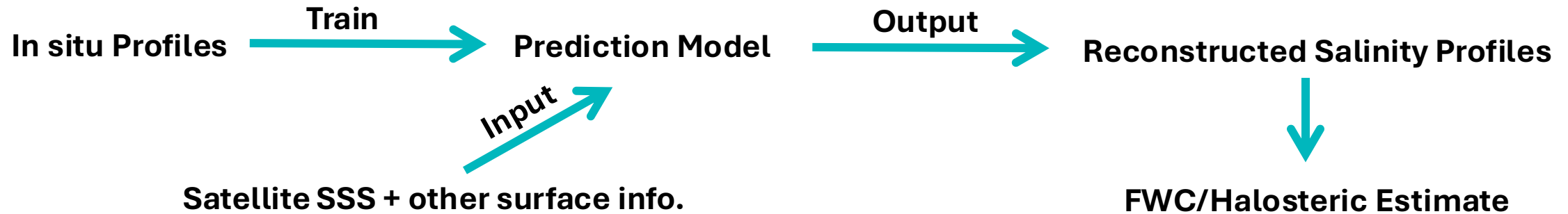
How can satellite SSS be better integrated with subsurface data to improve estimate of FWC variability?

Concept

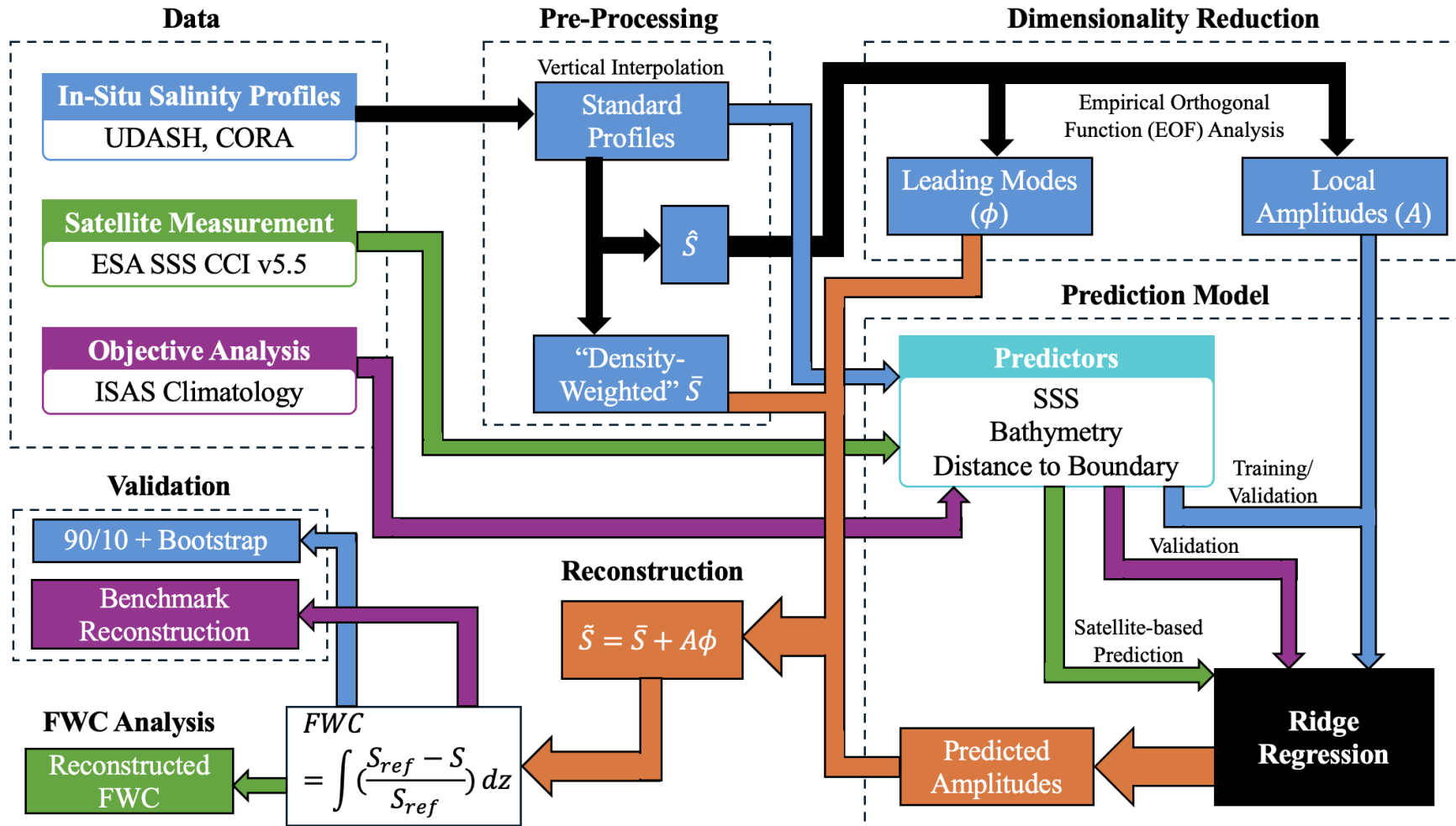
SSS $\xrightarrow{\text{Correlation}}$ FWC/Halosteric



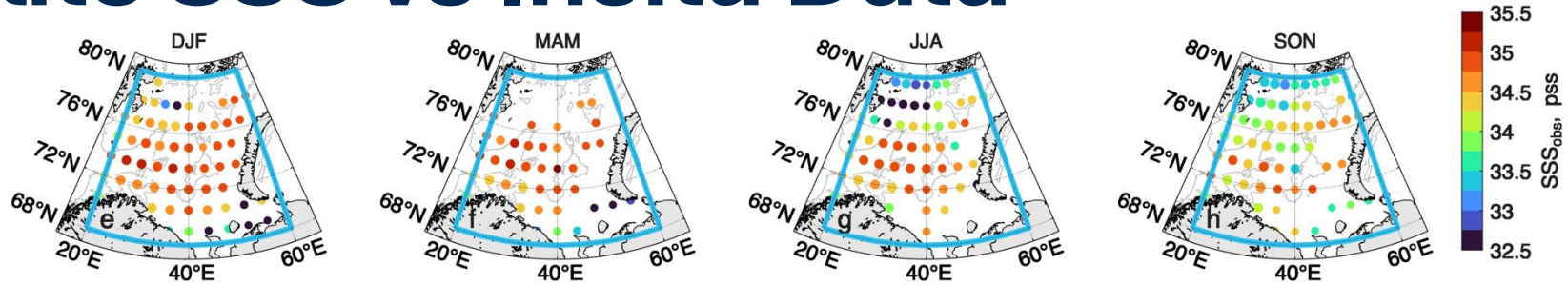
Surface info. $\xrightarrow{\text{Predictability}}$ Subsurface Structure



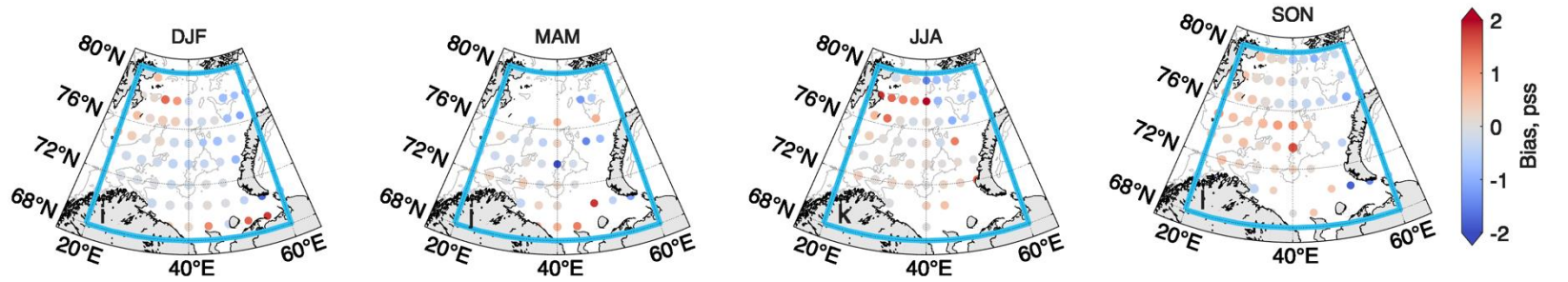
Predicting Vertical Structure from Surface



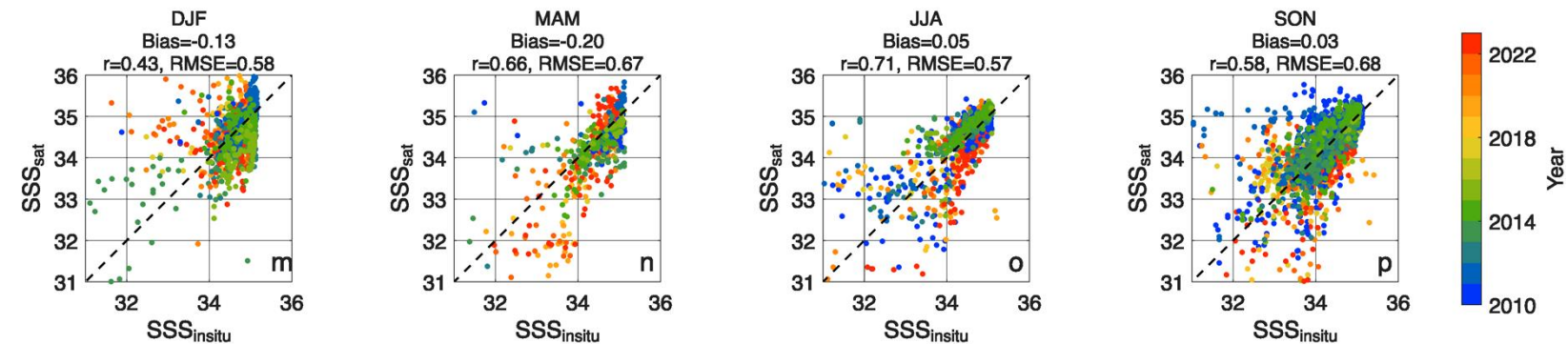
Satellite SSS vs Insitu Data



In situ SSS

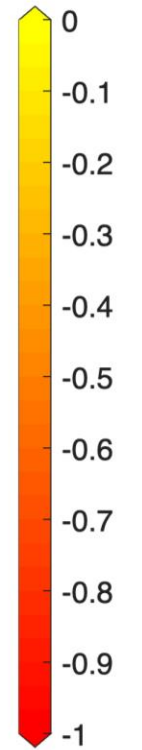
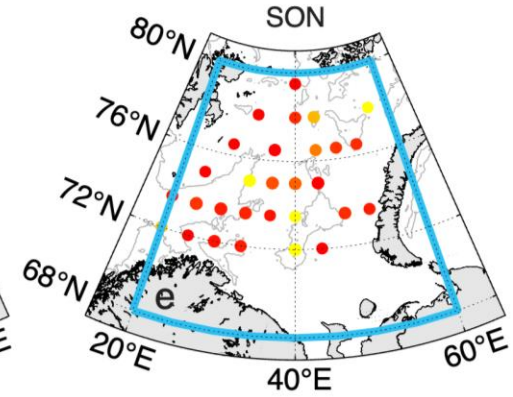
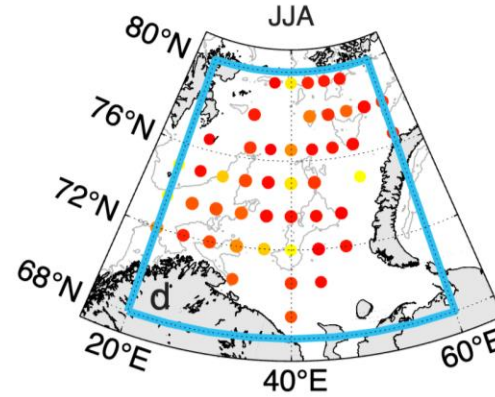
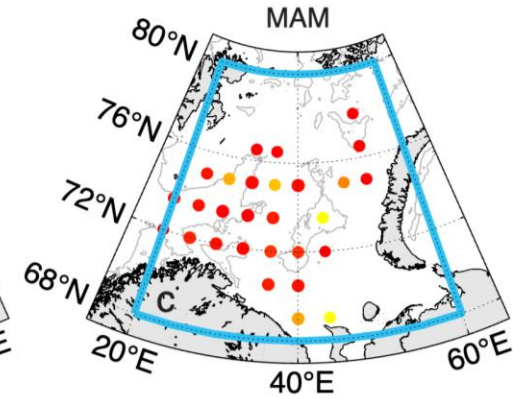
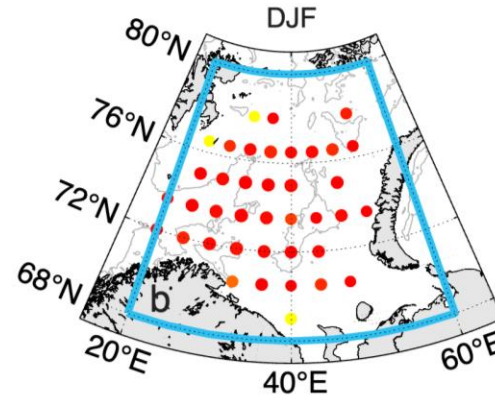
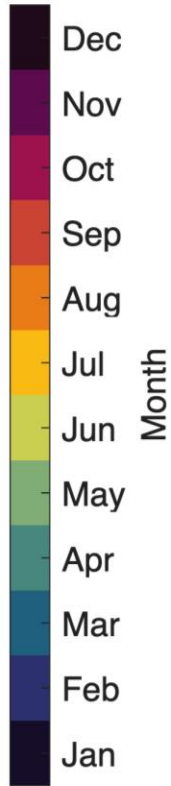
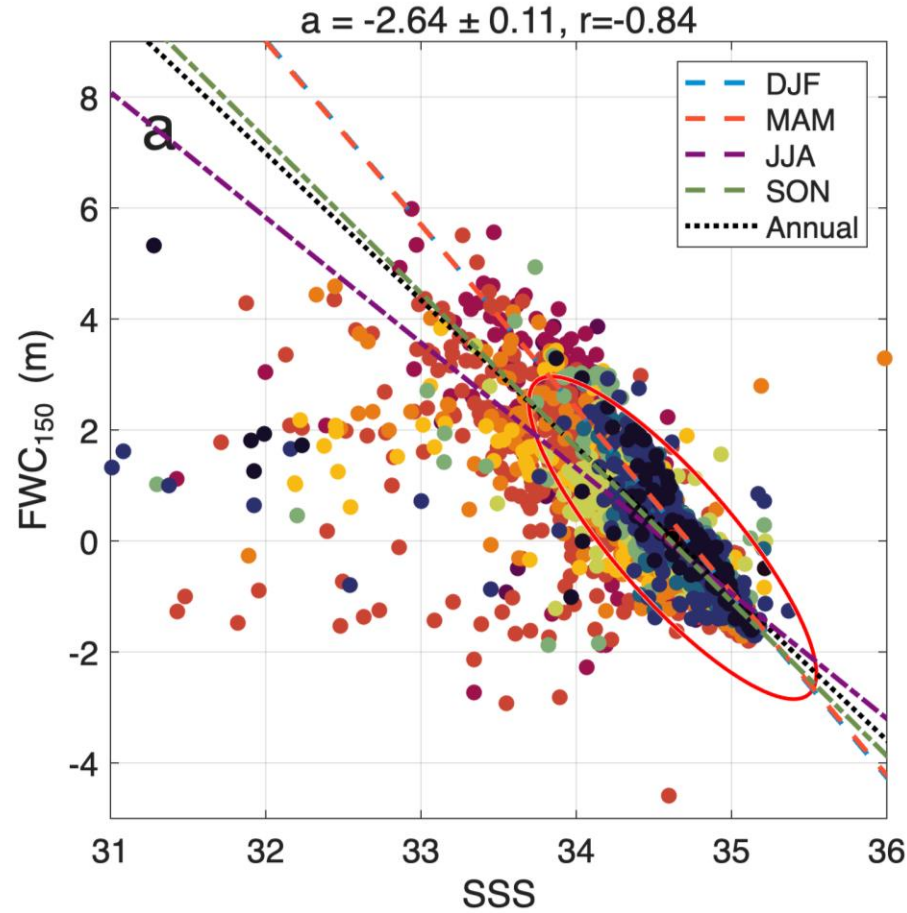


Satellite - In situ



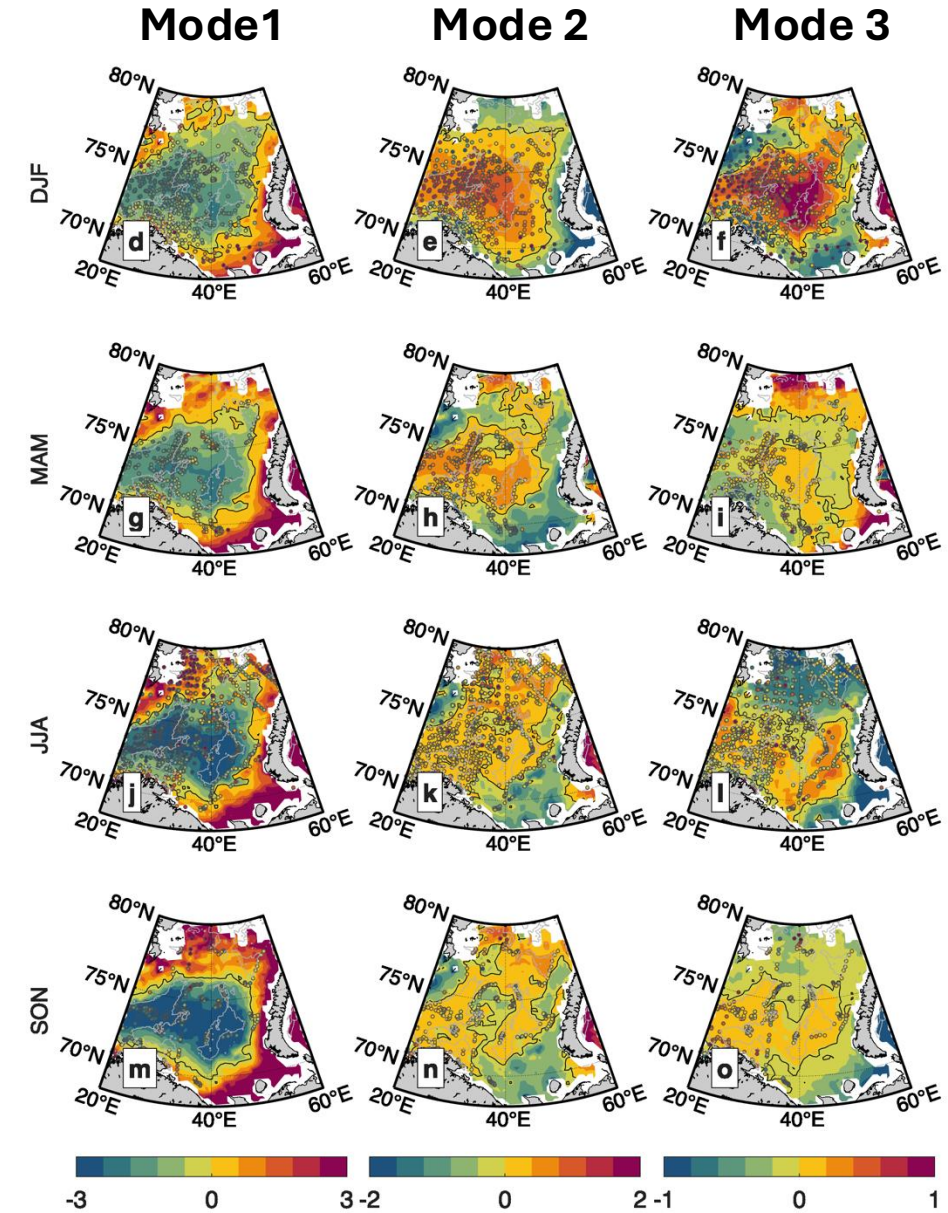
Satellite vs. In situ

SSS & FWC relationship

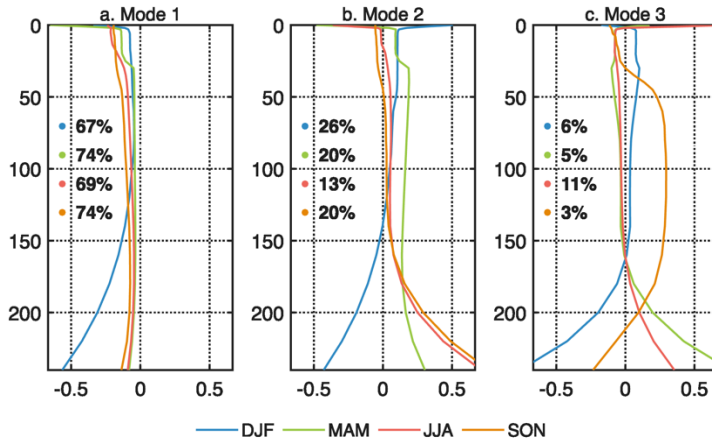


Decomposition & Prediction

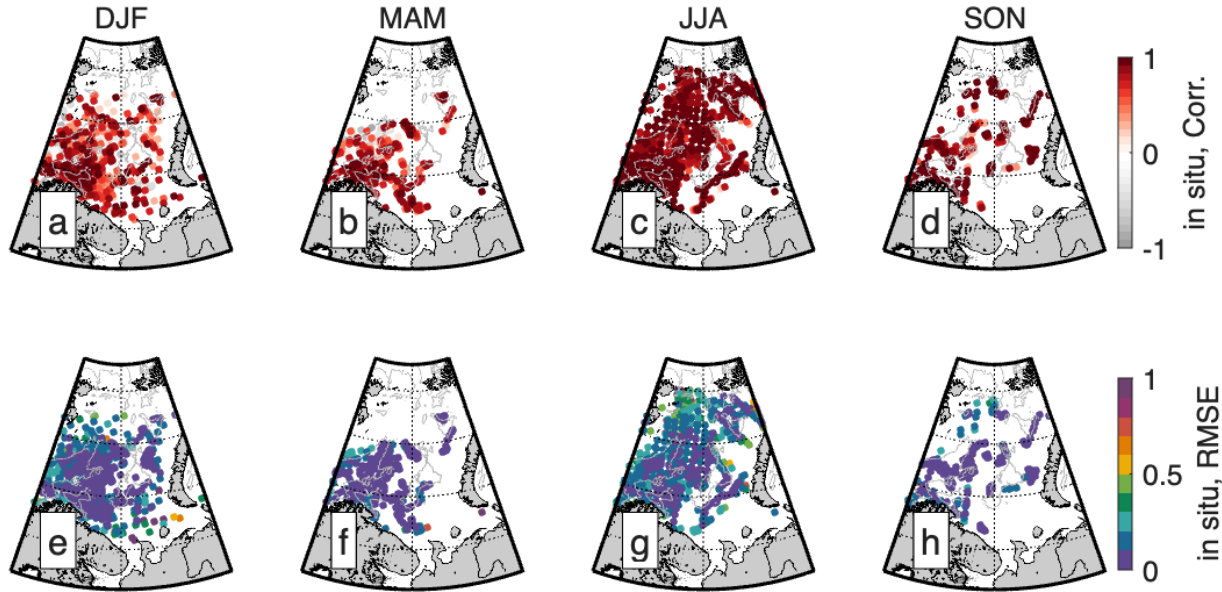
Local Amplitudes of in situ profiles
& predicted amplitudes using satellite SSS →



Decomposed Vertical Structures
for each season

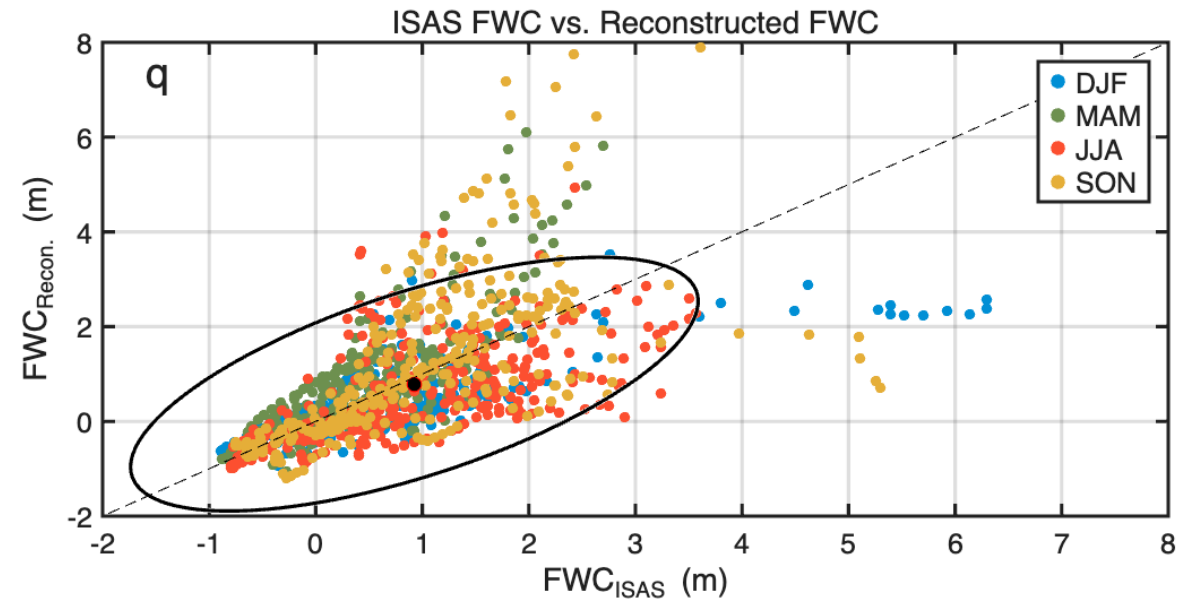


Validation & Benchmark

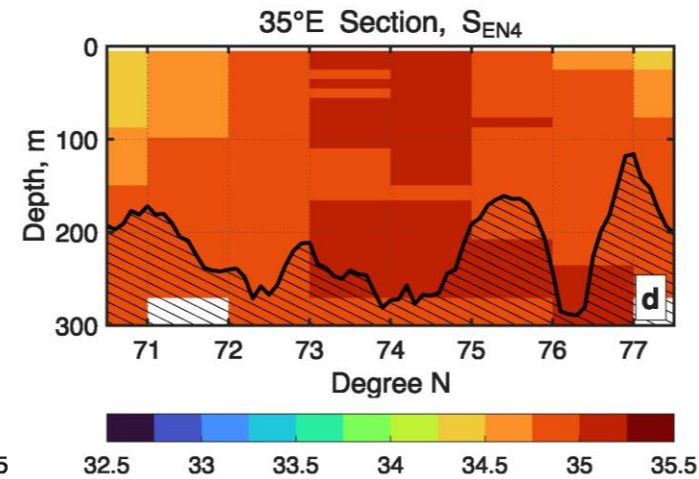
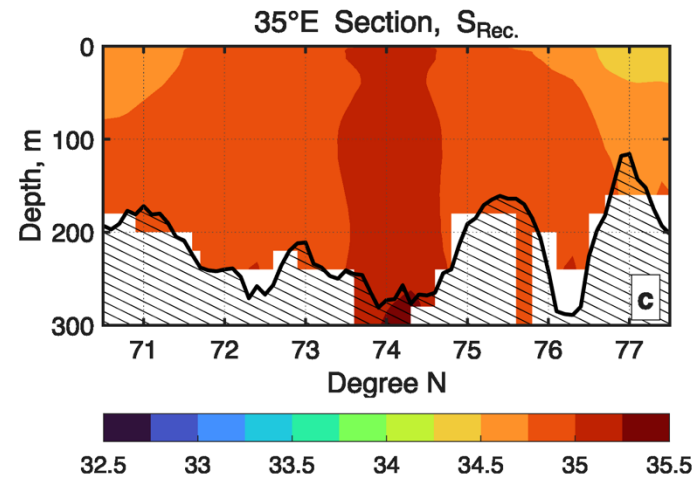
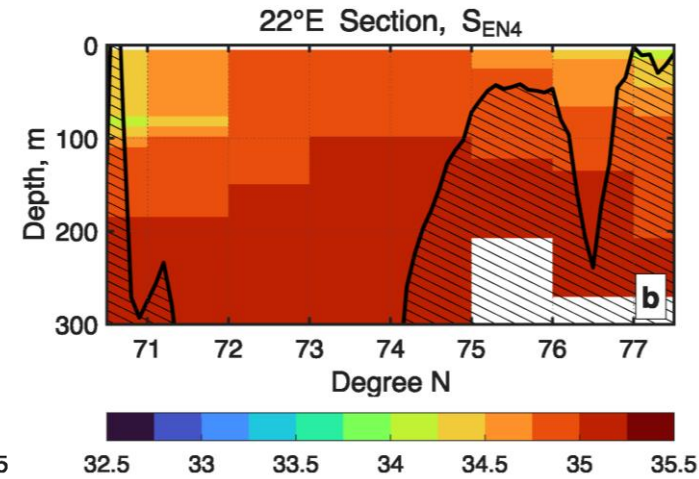
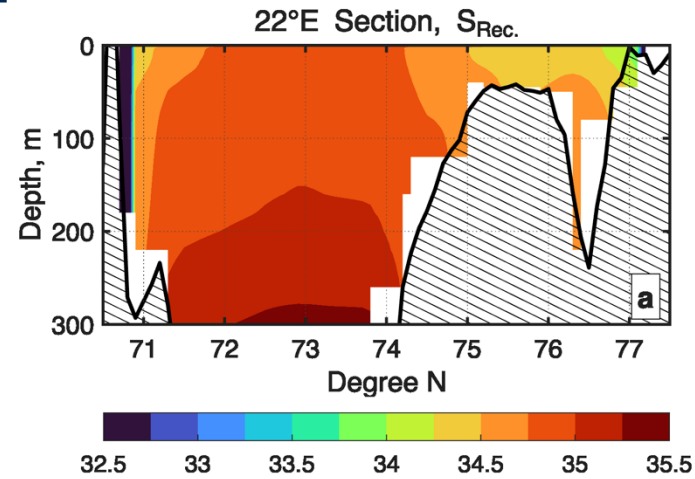
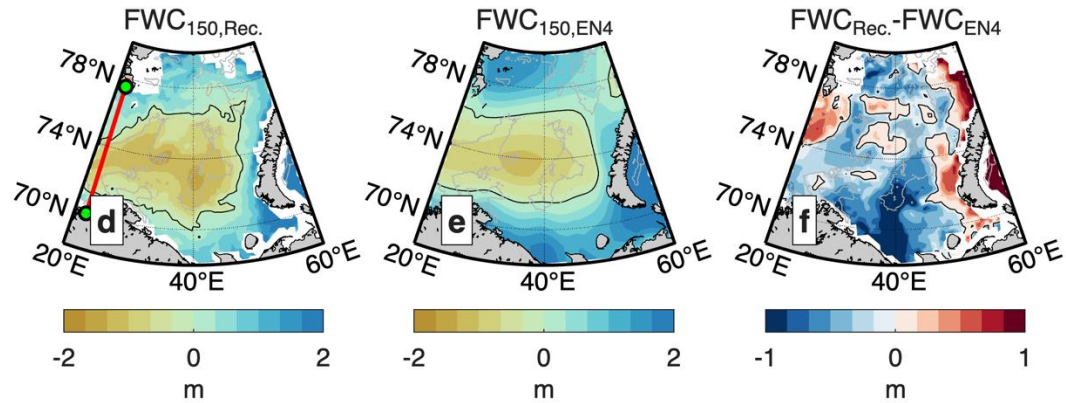
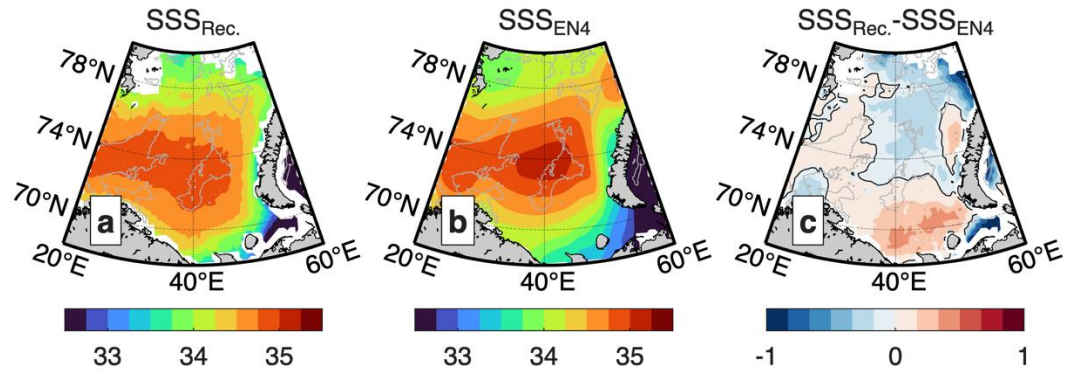


Benchmark using ISAS SSS to reconstruct FWC →

← **Random 90/10 train-test splits using in situ input**

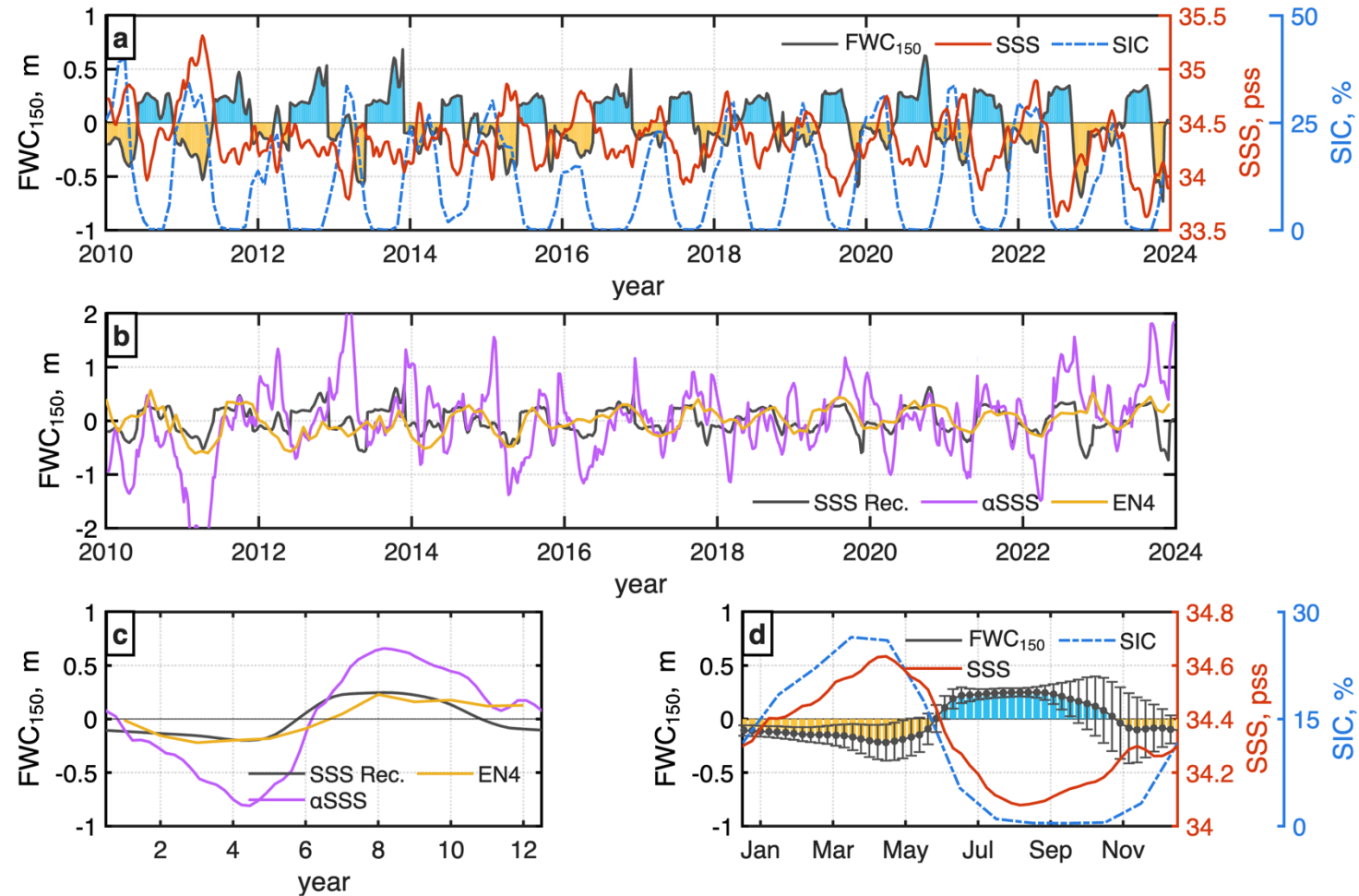


Comparison with EN4



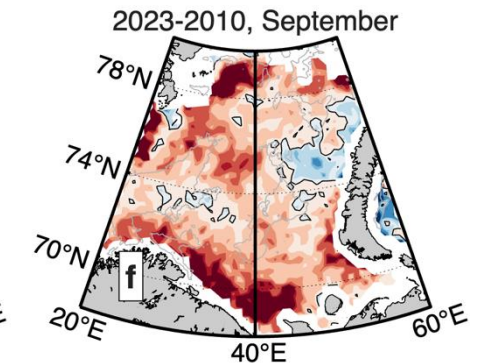
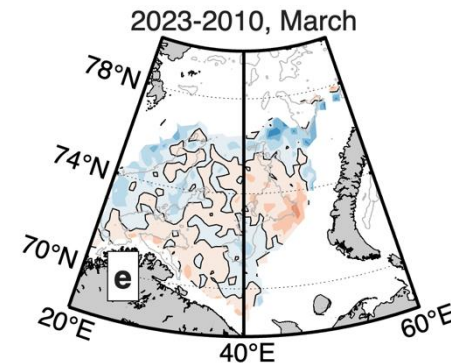
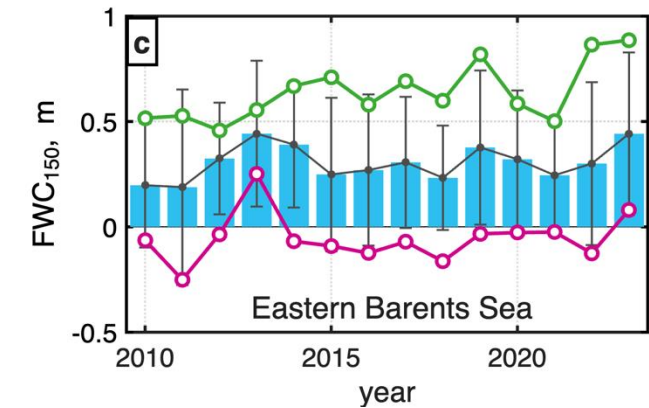
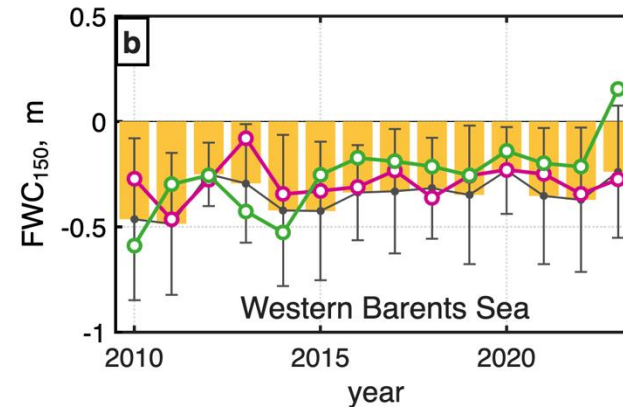
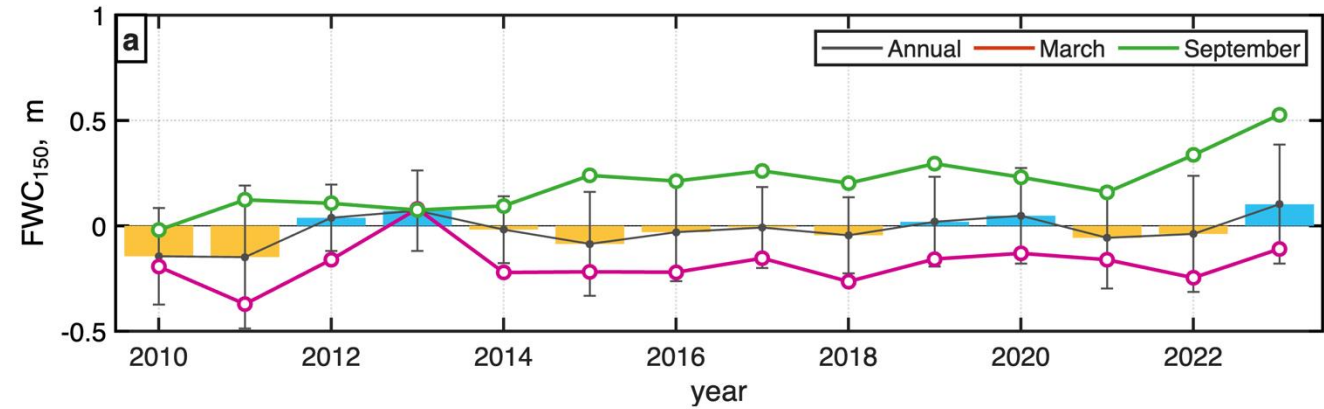
Variability of FWC

- Reconstructed FWC tracks SSS/SIC variability
- Anomalies remain in phase with EN4-derived FWC
- Demonstrates the model's ability to "decouple" surface and deep-layer signals
- Higher variability captured during peak melting and freezing seasons



Variability of FWC

- The annual mean freshwater content remains relatively stable
- Spatial Contrast: Western → Negative, Eastern → Positive
- Seasonal Contrast: increase in September and "calm" in March
- In September, the increasing trend is geographically coherent with hotspots near the boundaries



Take Home Messages

- **Preservation of Vertical Structure:** By utilizing in-situ profile data for model training, the reconstruction successfully preserves the vertical salinity structure and inherent subsurface variability.
- **Optimized Machine Learning Framework:** A robust yet computationally efficient approach was employed to maximize predictive skill despite the limited number of available Arctic profiles.
- **Enhanced Spatial Resolution:** The model captures sharper spatial gradients compared to EN4 and provides more precise definitions of the bottom boundary layers.
- **Future Outlook:** While the current method demonstrates strong potential, future iterations will focus on improving intraseasonal consistency and ability to capture complex non-linear terms.

Thank you!

