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GORDON AND BETTY MOORE FOUNDATION

SMART CABLES

SMART Cable Observing System Simulation Experiments in the North Atlantic

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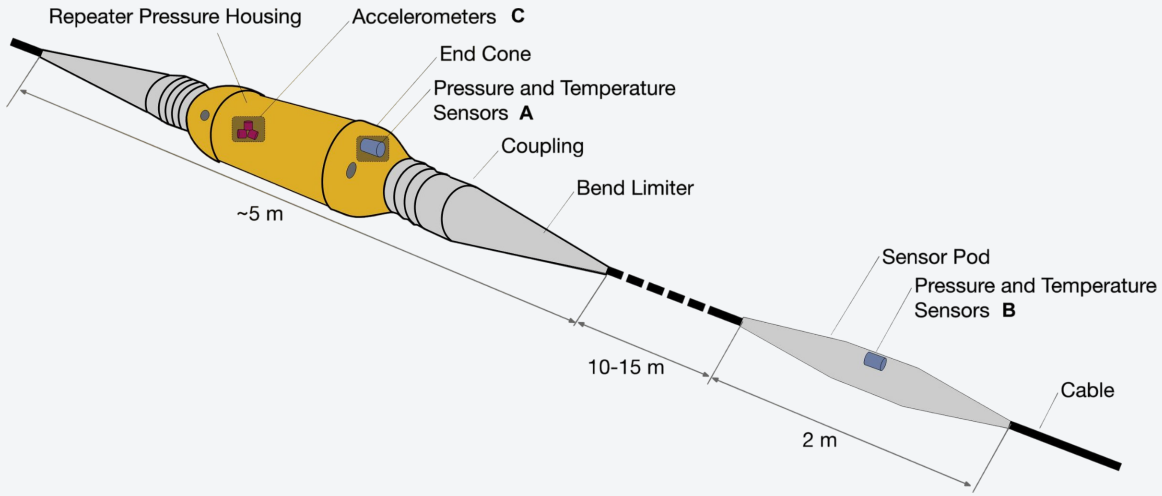
Context

Science Monitoring and Reliable Telecommunications **(SMART)**

Integrate scientific sensors (temperature, pressure, seismic acceleration) into newly deployed subsea fiber optic cables



SMART repeater housing (Howe et al. 2019)

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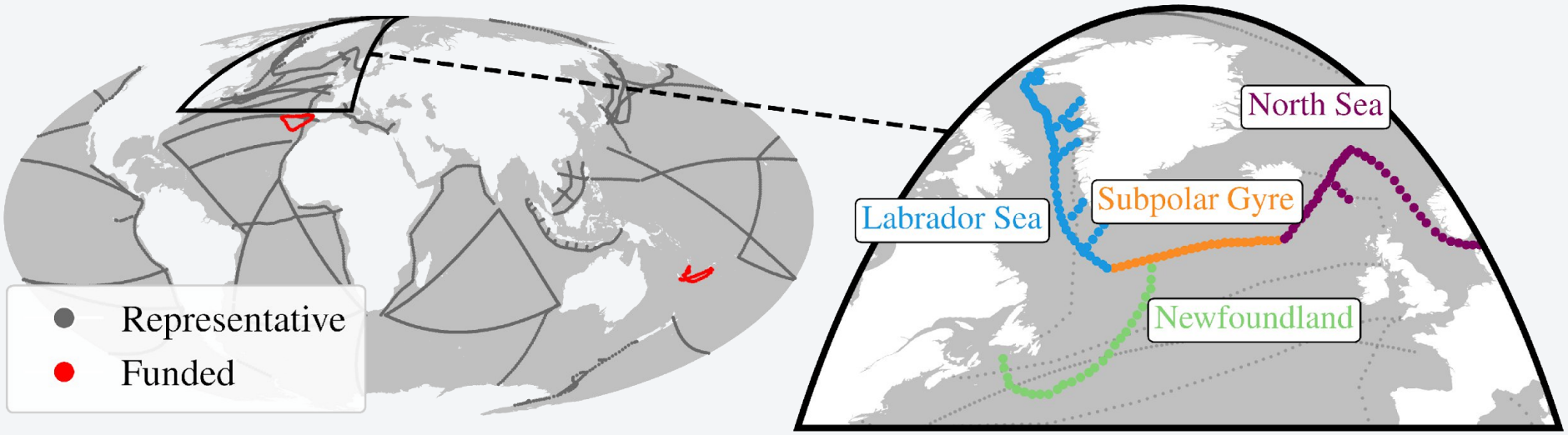
Motivation

Simulation experiments pre-assess SMART's value towards reducing uncertainty in

- **Ocean bottom pressure** (OBP) anomaly
- Barotropic, i.e. depth-integrated velocities
- Atlantic-Arctic freshwater exchange

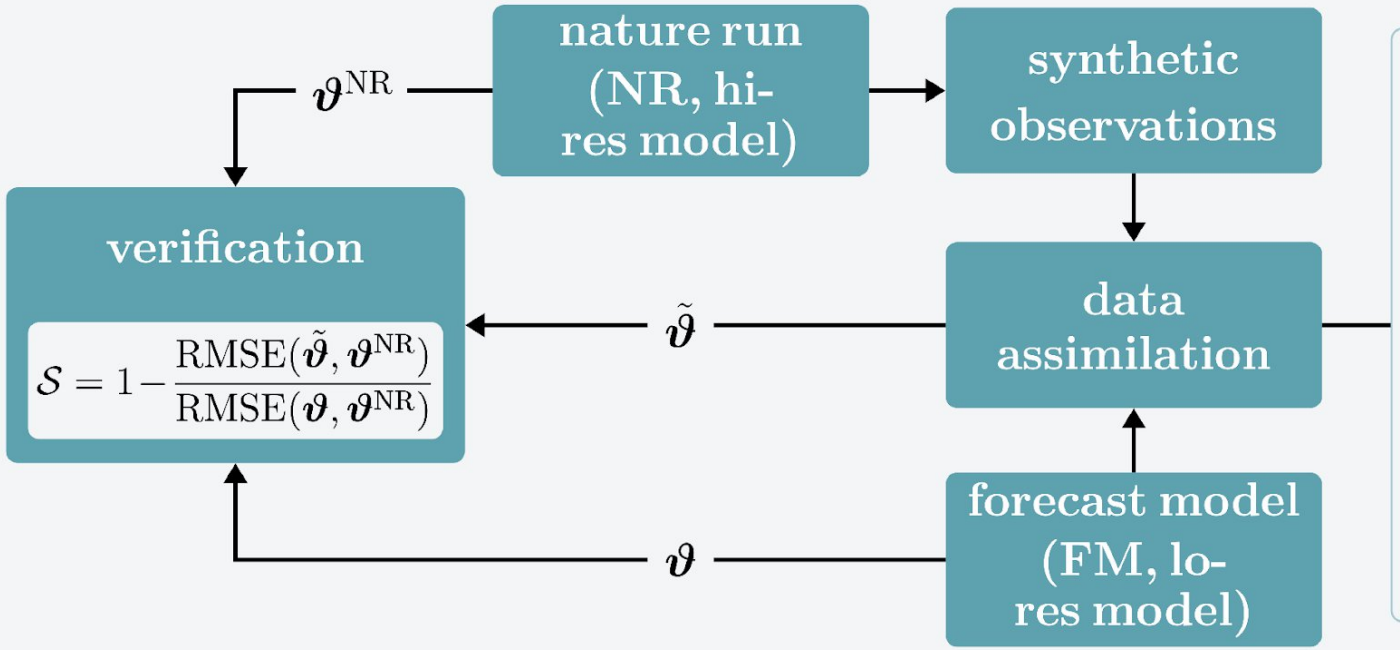
SMART OBP complements satellite gravimetry (GRACE)

- Hourly temporal frequency drastically higher than GRACE's monthly
- No aliasing error



Observing System Simulation Experiments (OSSEs)

Nature Run (NR) – high resolution "true Earth" model, source of synthetic SMART data
Forecast Model (FM) – lower resolution model into which NR data is assimilated



Compute:

$$\mathbf{u}_{\min} = \min_{\mathbf{u}} J(\mathbf{u})$$

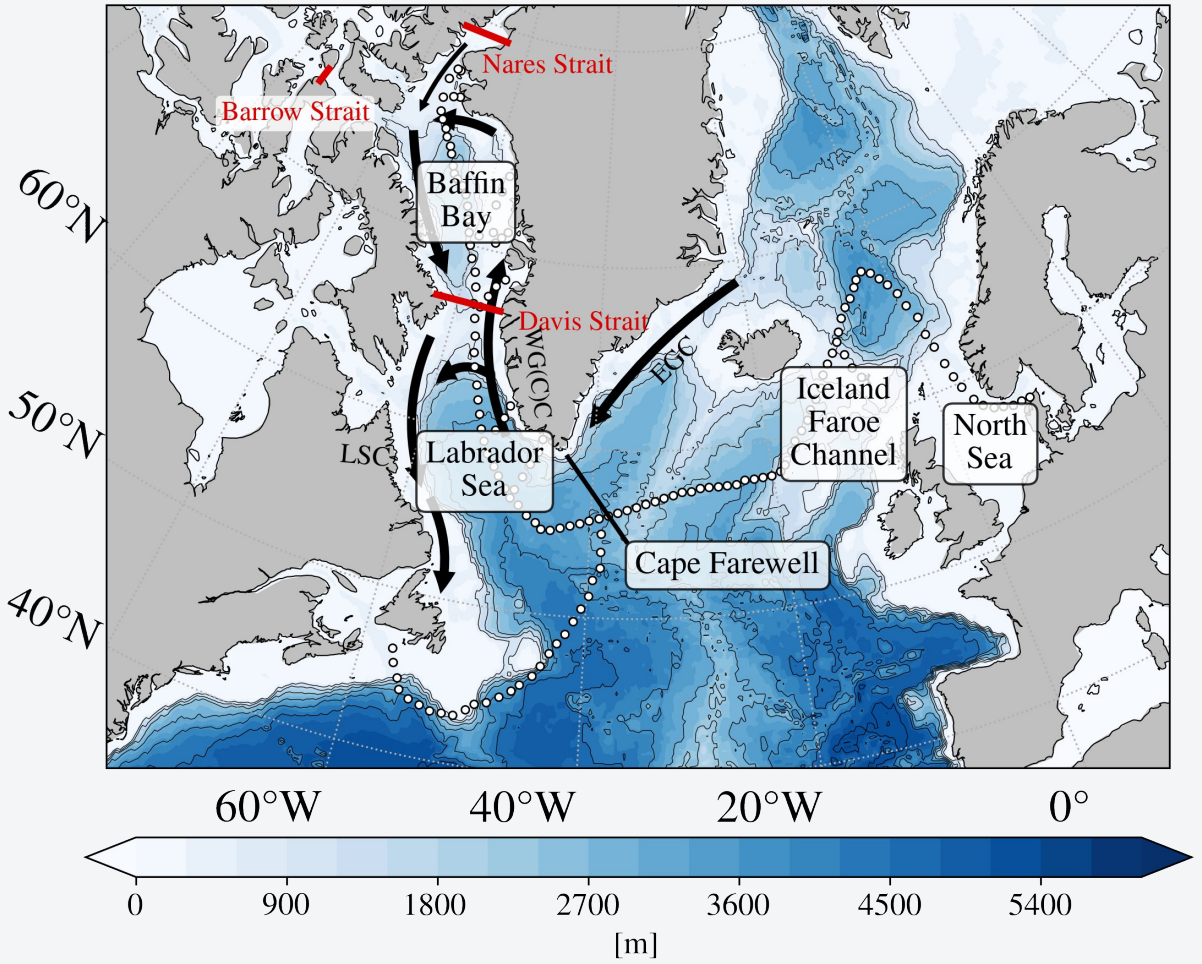
for cost function

$$J(\mathbf{u}) = \underbrace{\tfrac{1}{2}(\mathbf{y} - \hat{\mathbf{y}})^{\mathrm{T}}(\mathbf{\Gamma}_{\mathrm{obs}})^{-1}(\mathbf{y} - \hat{\mathbf{y}})}_{J_{\mathrm{misfit}}(\mathbf{u})} + \underbrace{\tfrac{1}{2}(\mathbf{u}_{\mathrm{BC}} - \mathbf{u}^0_{\mathrm{BC}})^{\mathrm{T}}(\mathbf{\Gamma}_{\mathrm{BC}})^{-1}(\mathbf{u}_{\mathrm{BC}} - \mathbf{u}^0_{\mathrm{BC}})}_{J_{\mathrm{BC}}(\mathbf{u})}.$$

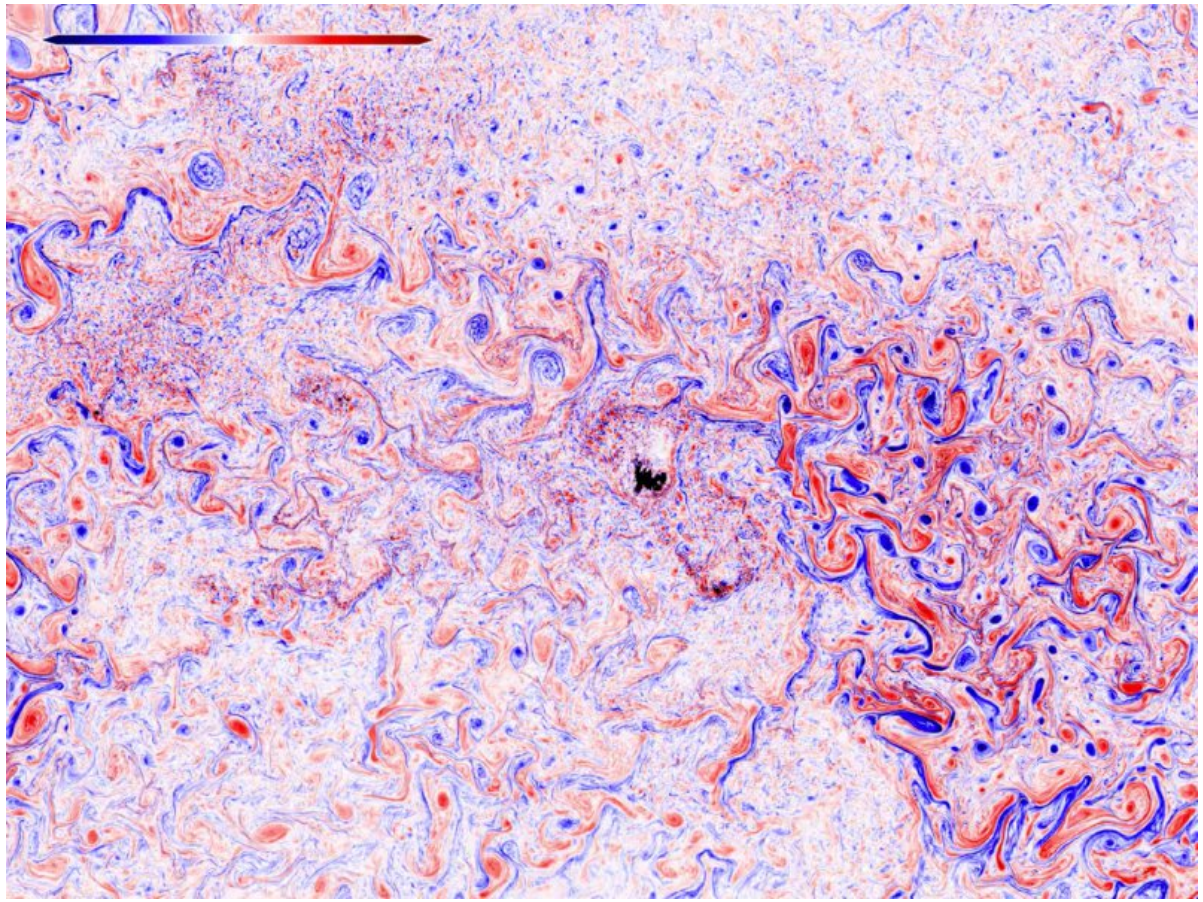
subject to

[hydrostatic primitive equations]

Forecast Model: ASTEr1



Nature Run: LLC4320



LLC4320 Relative Vorticity in the Indian Ocean Sector of the Southern Ocean (Jinbo Wang, NASA JPL, 2019)

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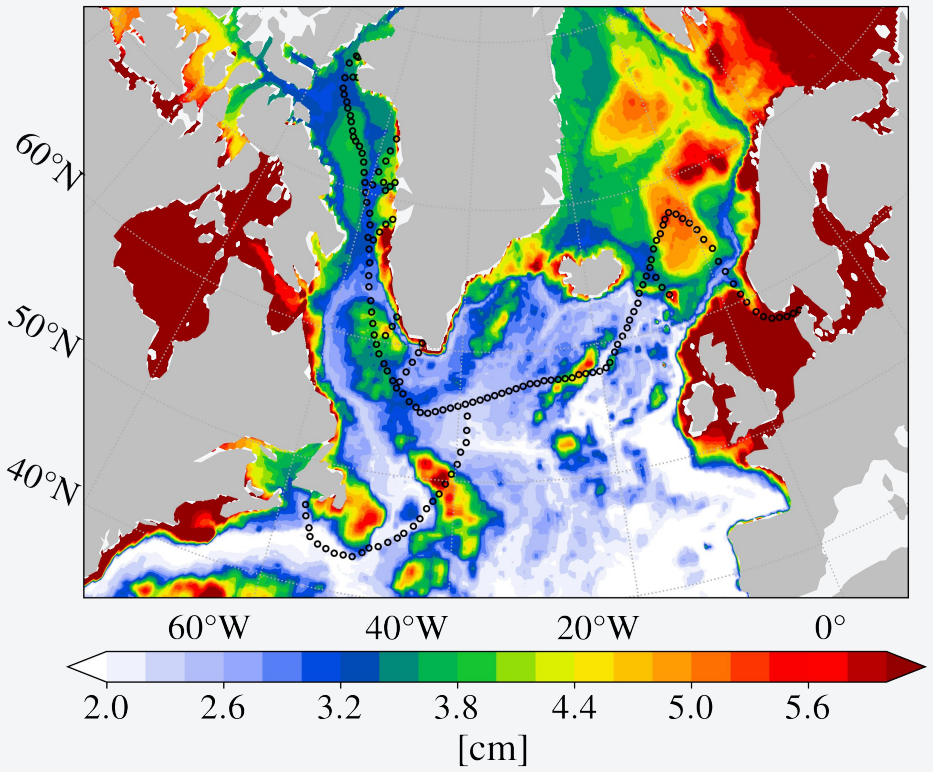
Data Assimilation

Synthetic data uncertainty



	controls
1	Air temperature
2	Precipitation
3	Downward shortwave radiation
4	Downward longwave radiation
5	Specific humidity
6	**Zonal wind speed**
7	**Meridional wind speed**
8	**Atmospheric pressure**

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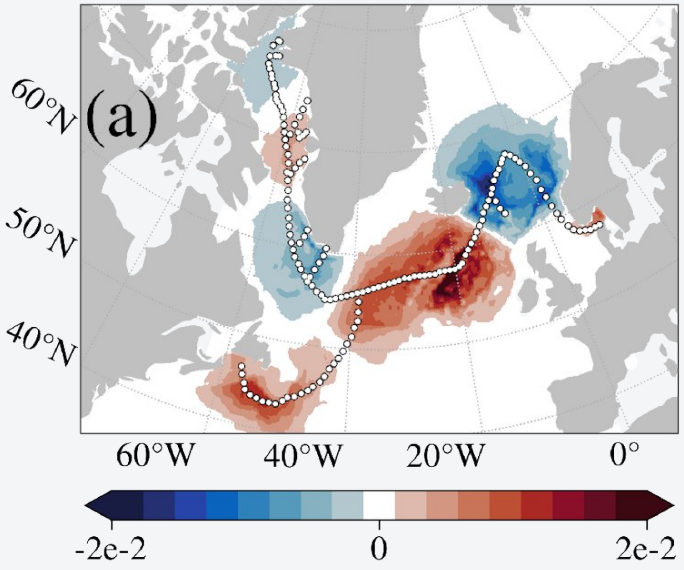
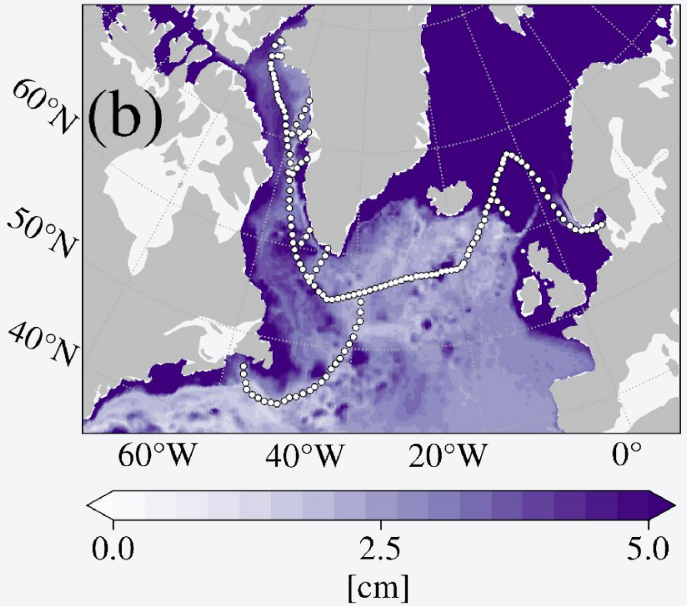
Results: improved p_b model representation

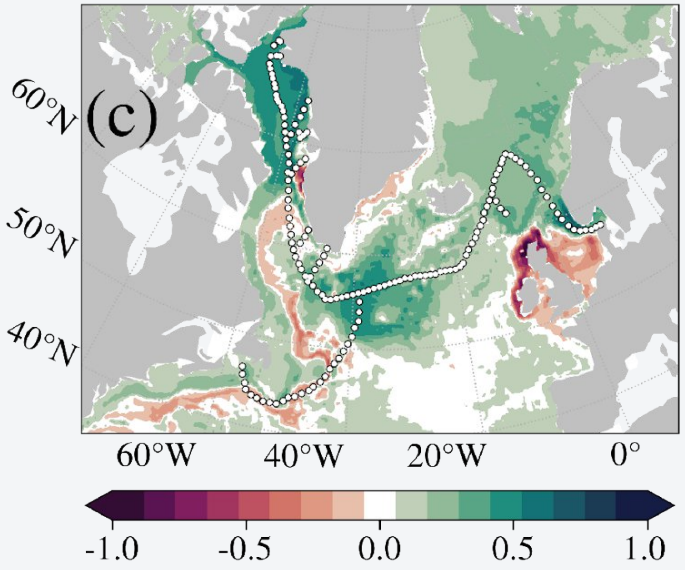
p_b model-data misfit



RMSE($\widetilde{p_b}$, p_b^{NR})



p_b skill



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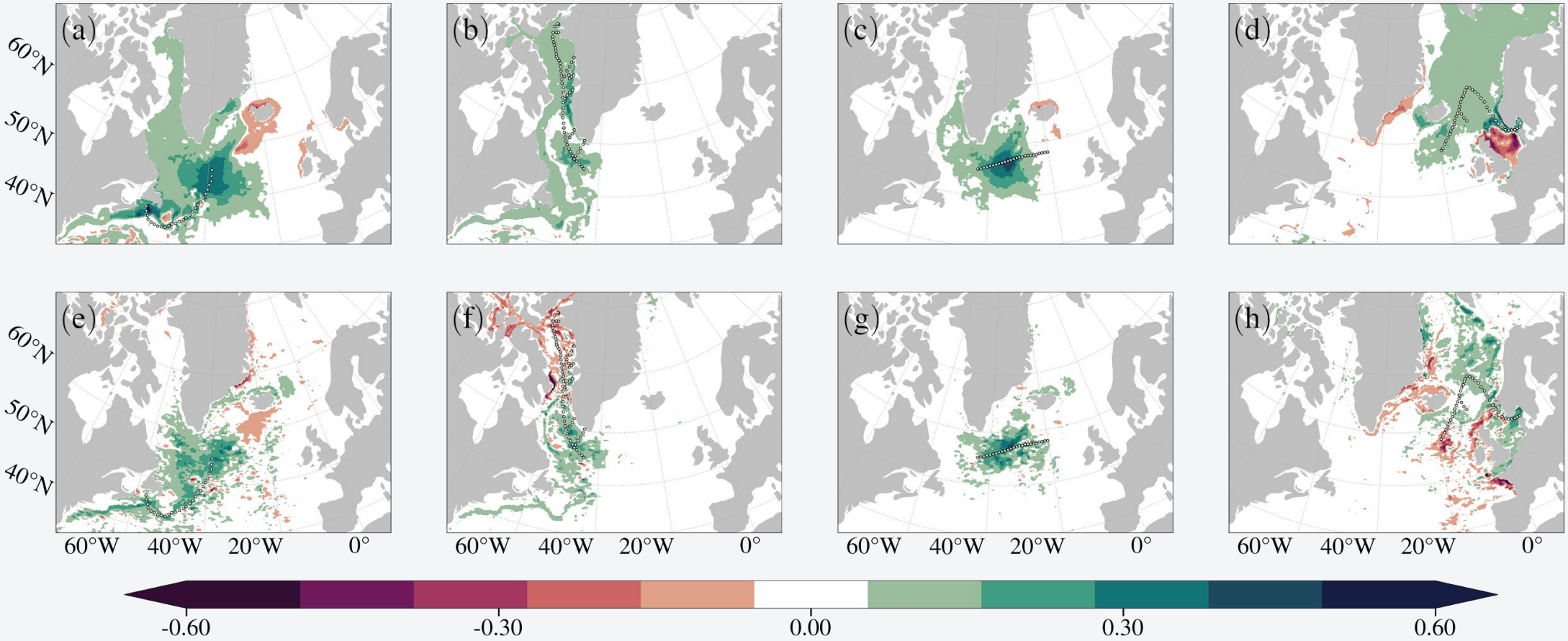
Barotropic velocity skill



"Partial cable" OSSEs daily skills for month of Jan 2012. Top row: p_b skill. Bottom row: zonal barotropic velocity skill

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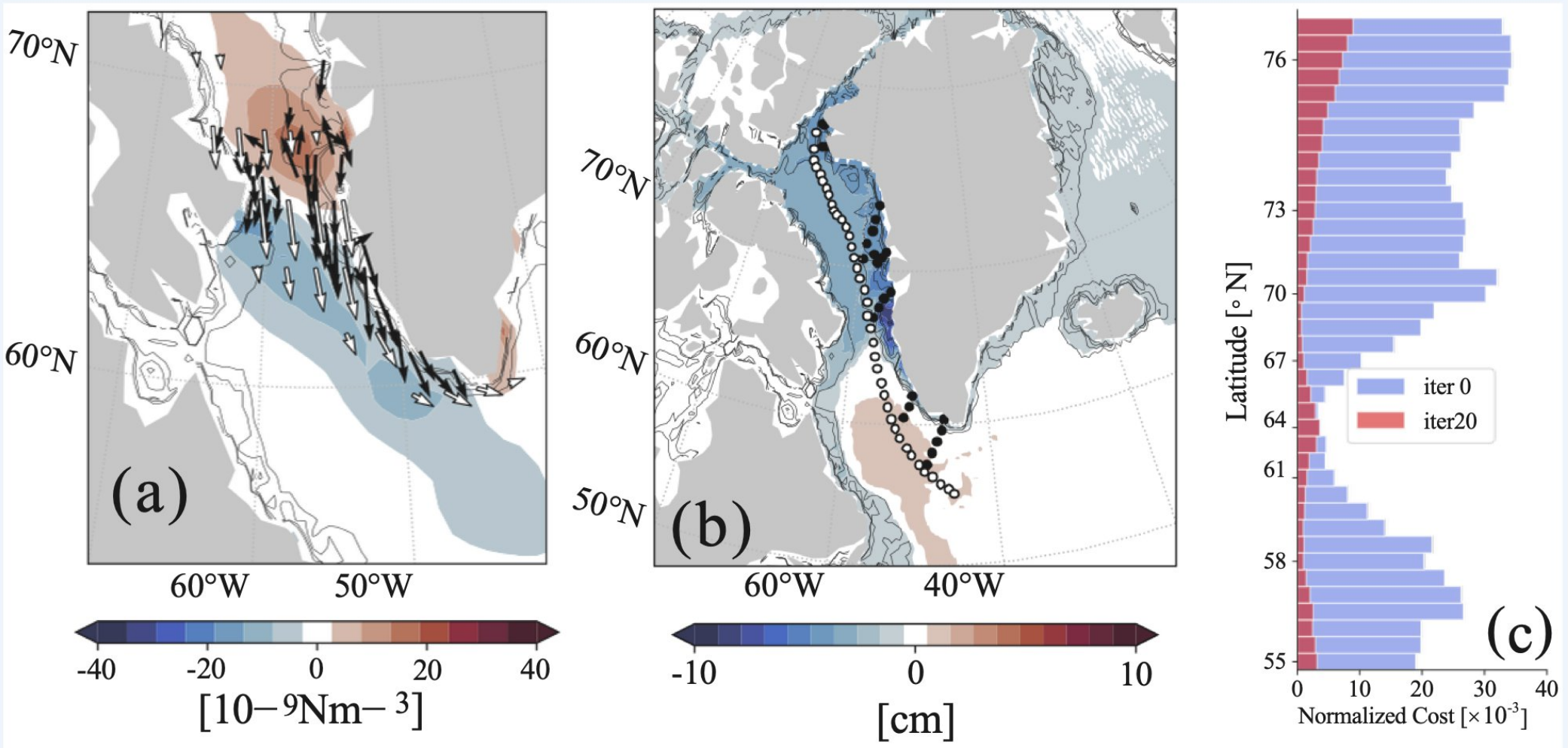
Arctic-Atlantic freshwater export



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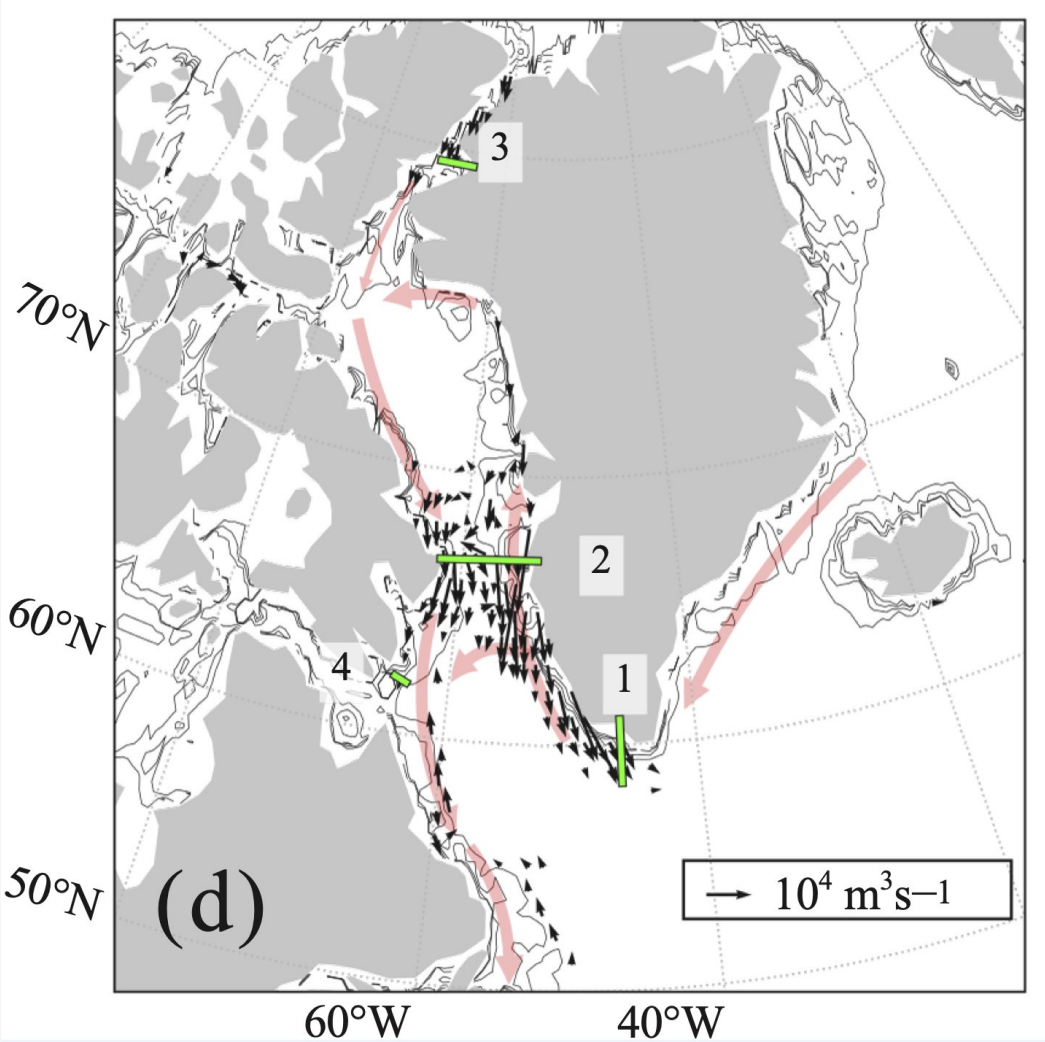
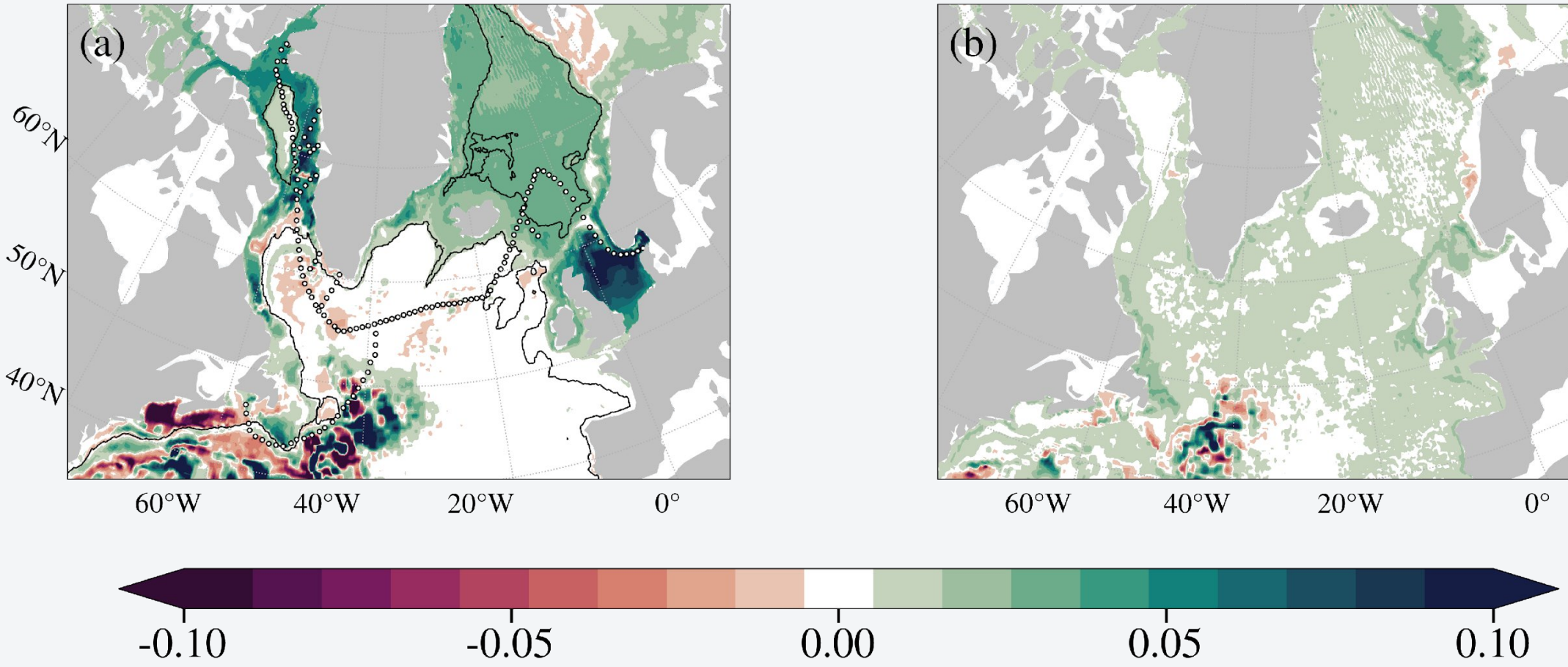
Arctic-Atlantic freshwater export



	Gateway	ADV_{fw} skill %
1	Cape Farewall	4.04
2	Davis Strait	10.07
3	Nares Strait	-4.12
4	West Labrador Sea	5.35

Comparison to GRACE



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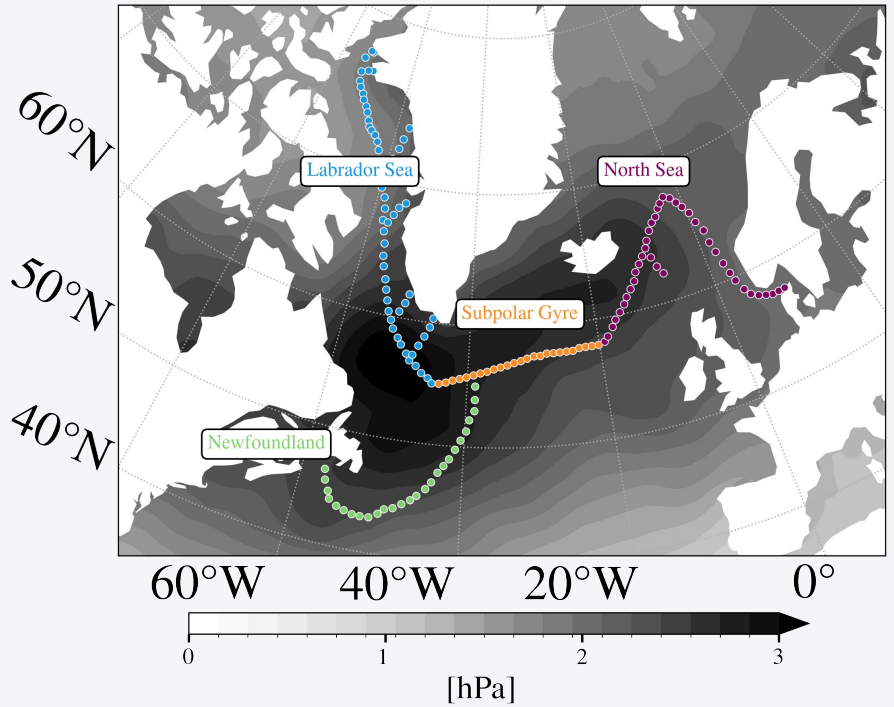
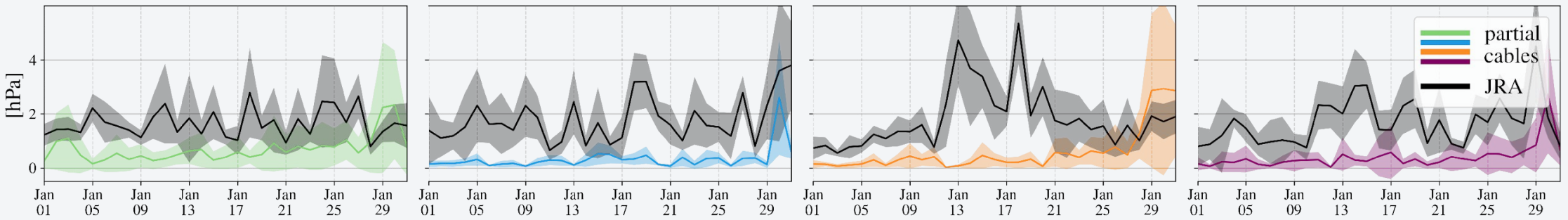
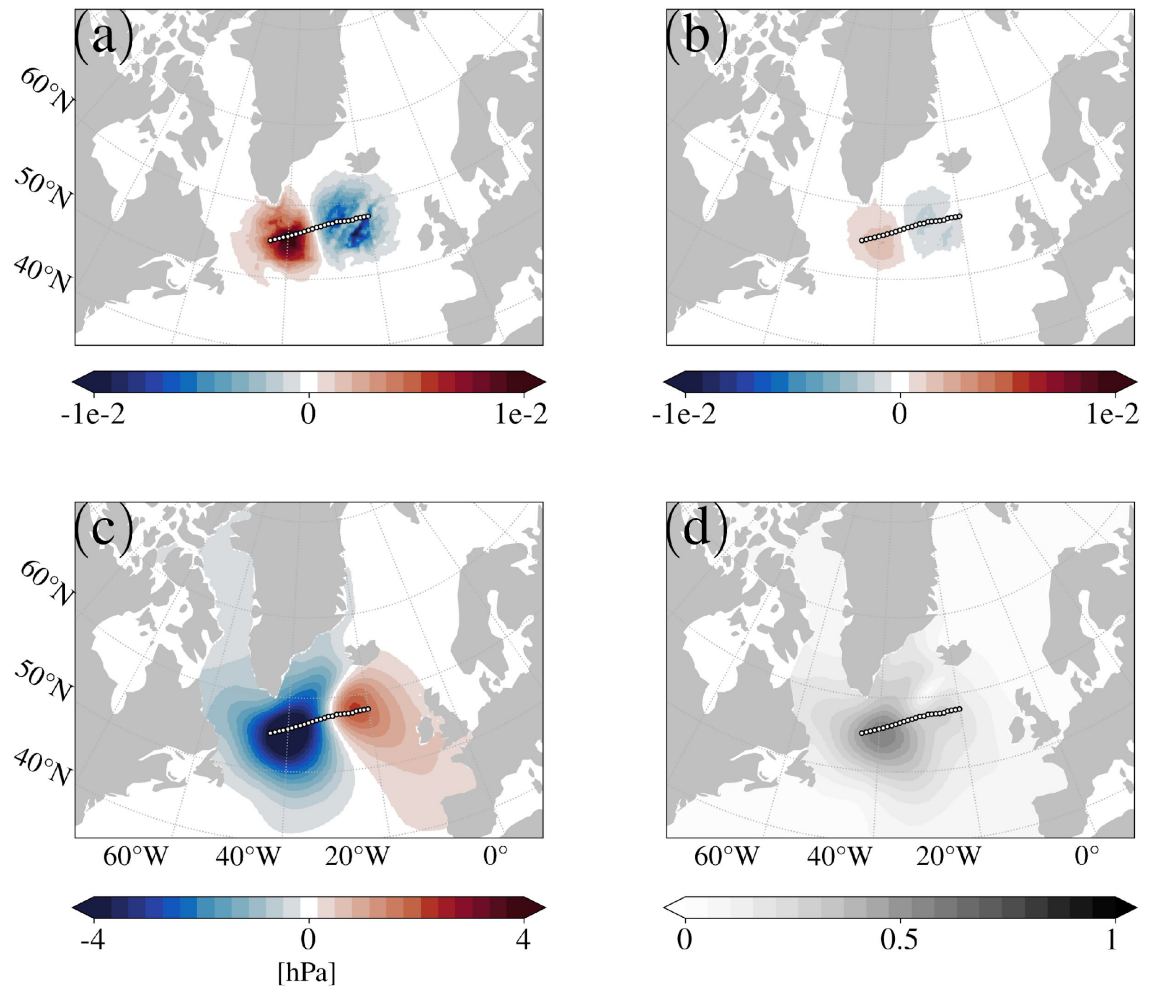
p_{atm} control adjustments

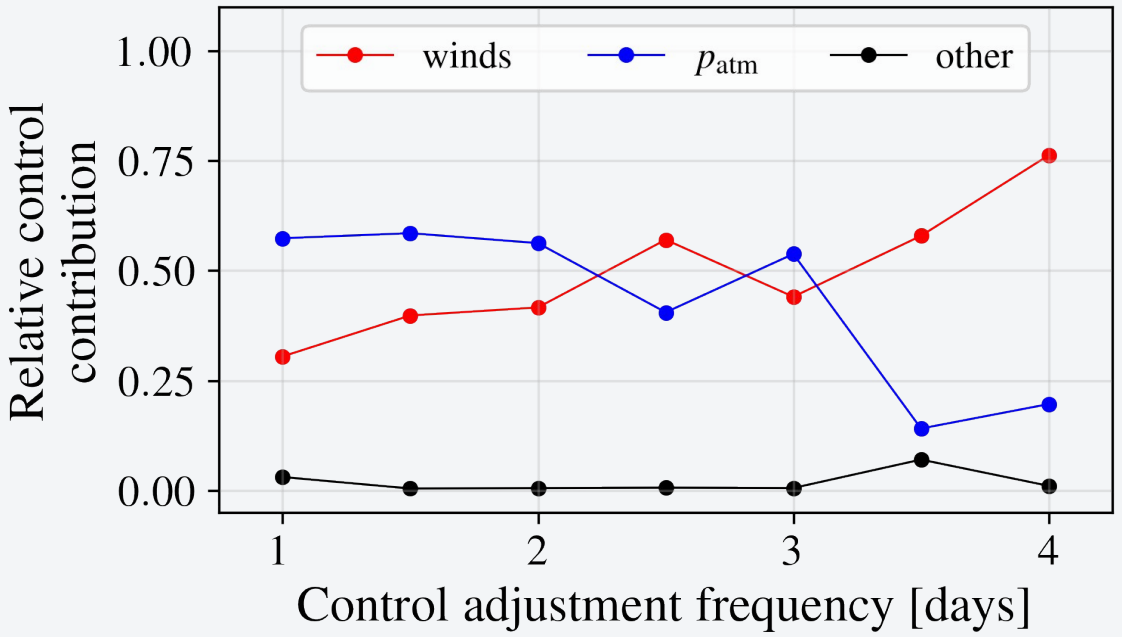




Misfit Reduction



Role of “inverted barometer” effect



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Conclusion

SMART p_b assimilation **reduces uncertainty** in daily…

- OBP local to and remote from the cable
- Barotropic velocities
- Advective freshwater flux

SMART p_b **complements GRACE**, yielding higher monthly p_b skill along **barotropic pathways**

Introduced **atmospheric pressure** control into ECCO framework

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Future work

Improved representation of synthetic OBP (sensor drift)

Explore p_b skill on **annual to interannual timescales**

Carry out assimilation to more optimization cycles

Hessian UQ (Loose & Heimbach 2021) to determine “optimal” cables

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Preprint available on EarthArxiv

Questions/comments? Contact me!

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Supplemental Information