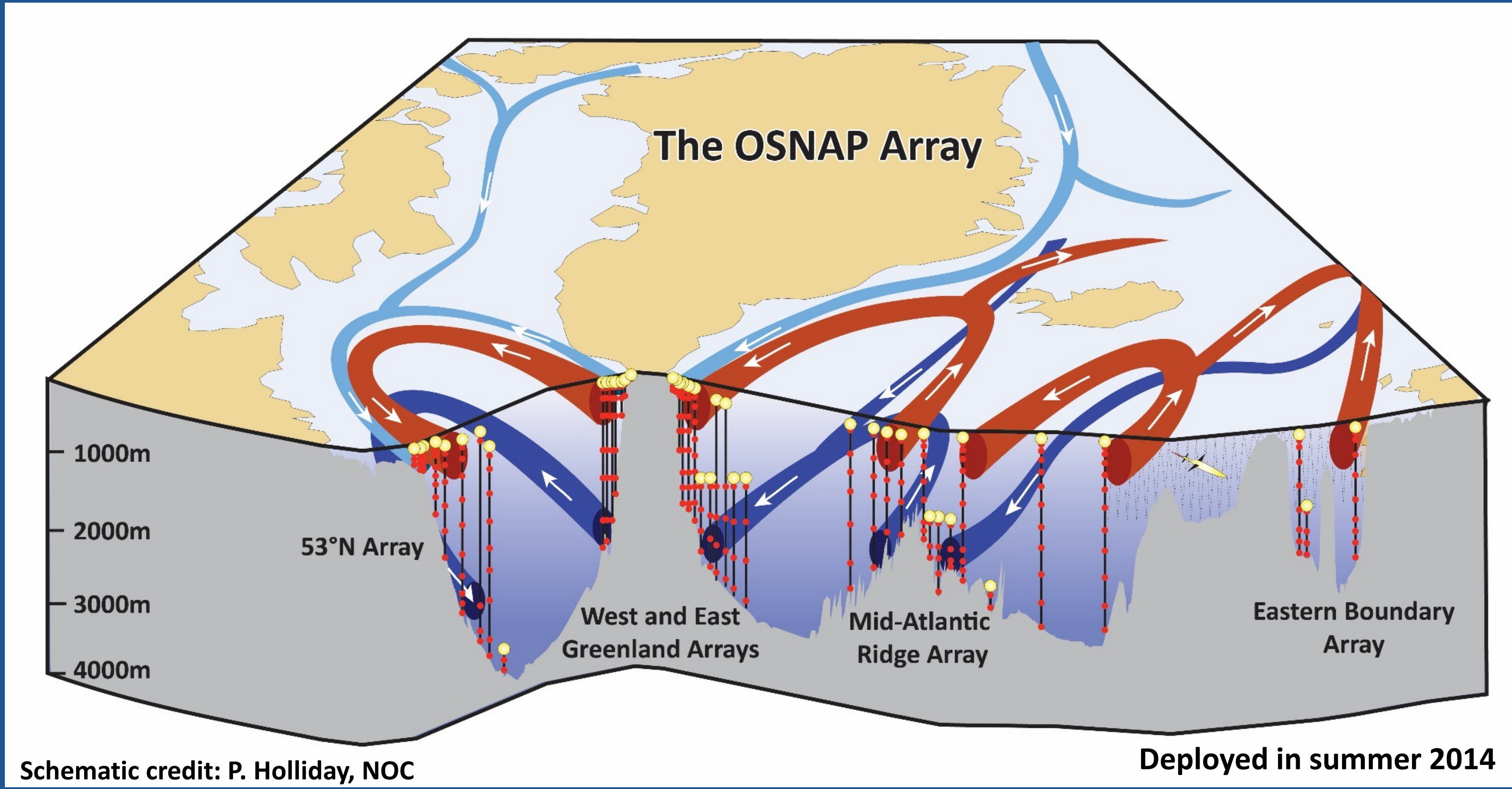
Overturning in the Subpolar North Atlantic

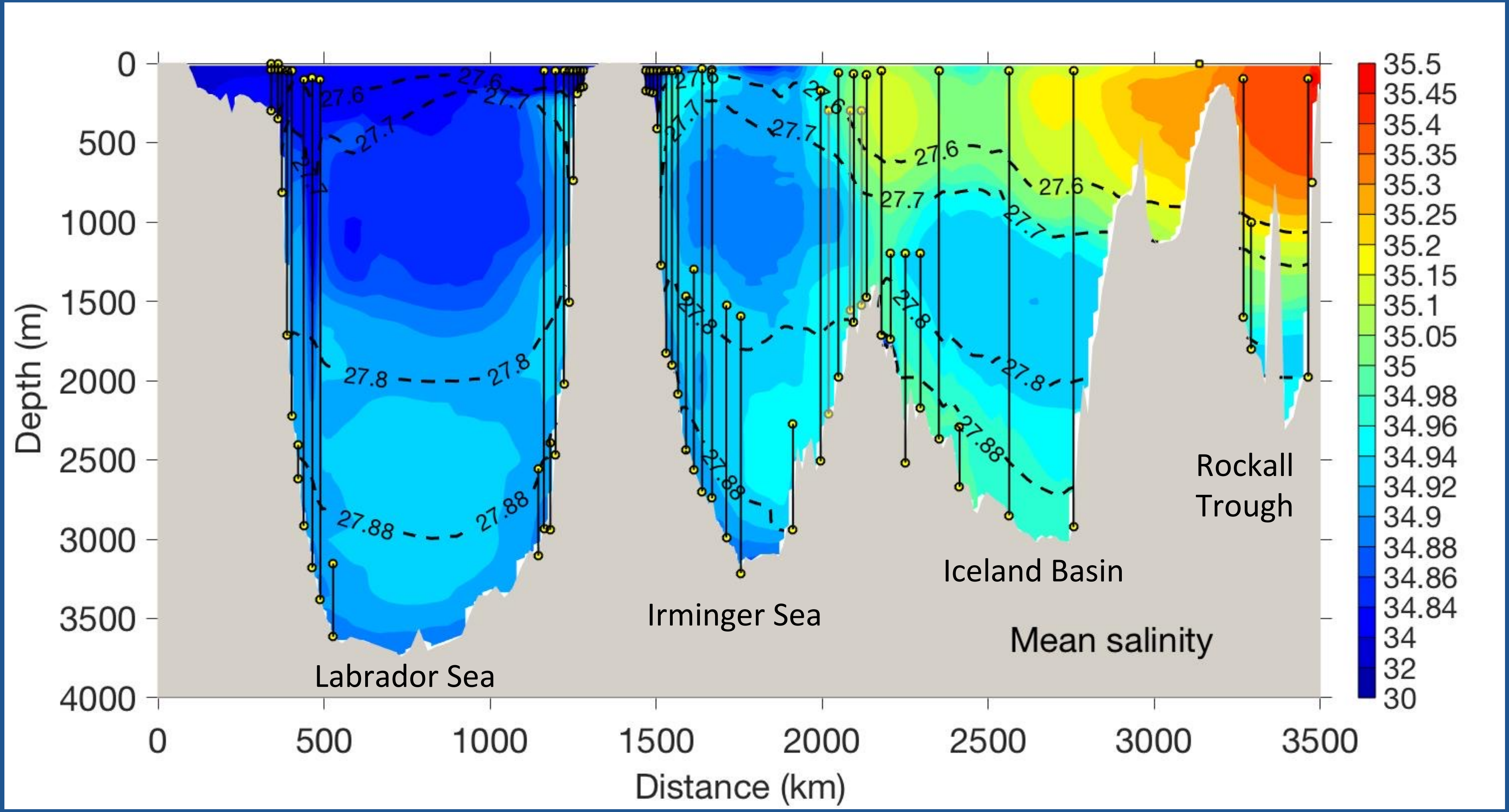
What we have learned and what we have yet to learn



OSNAP: An international program: US, Canada, UK, Germany, Netherlands, France and China

Susan Lozier, US AMOC Meeting 04.25.22

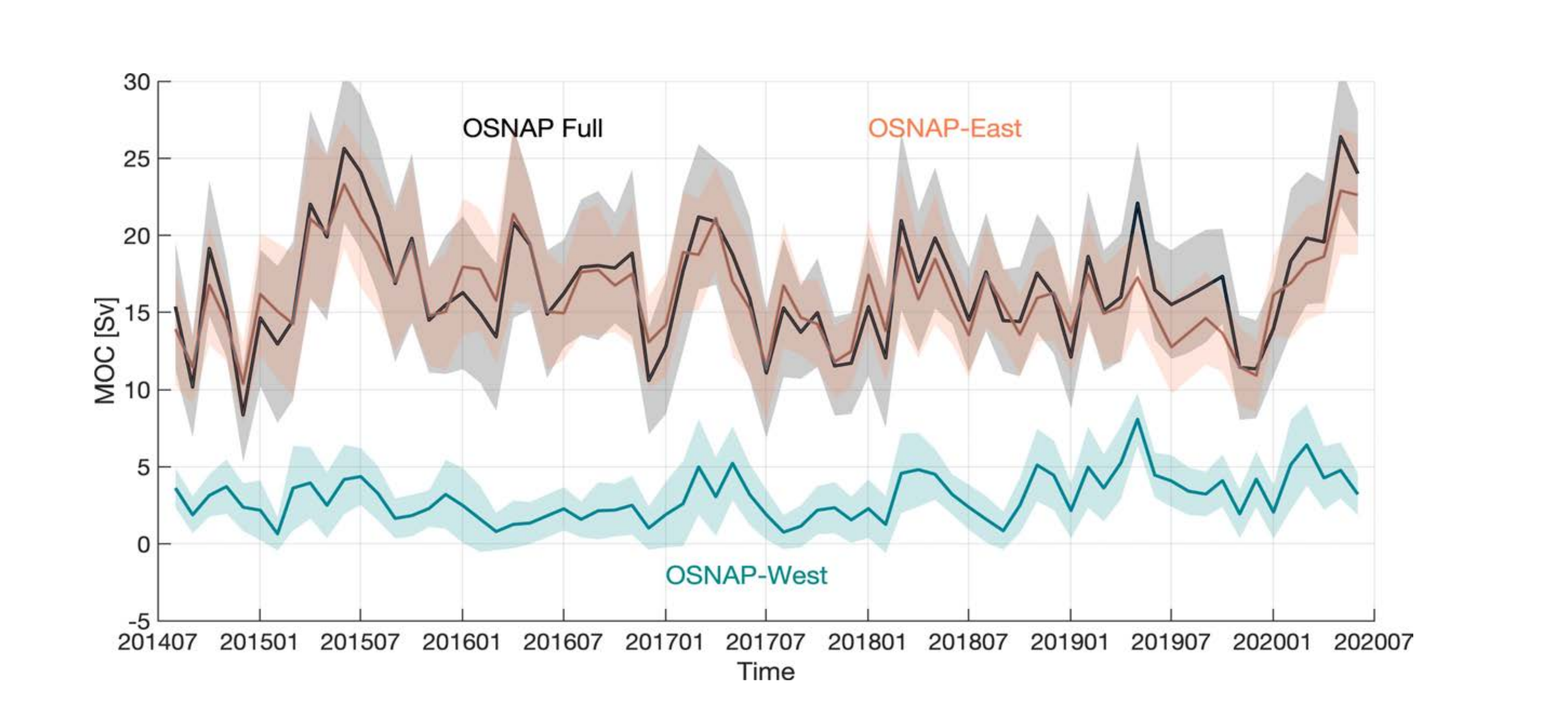
Mean salinity across OSNAP West and East



Mean from Aug 2014 to May 2016

Lozier et al. 2019

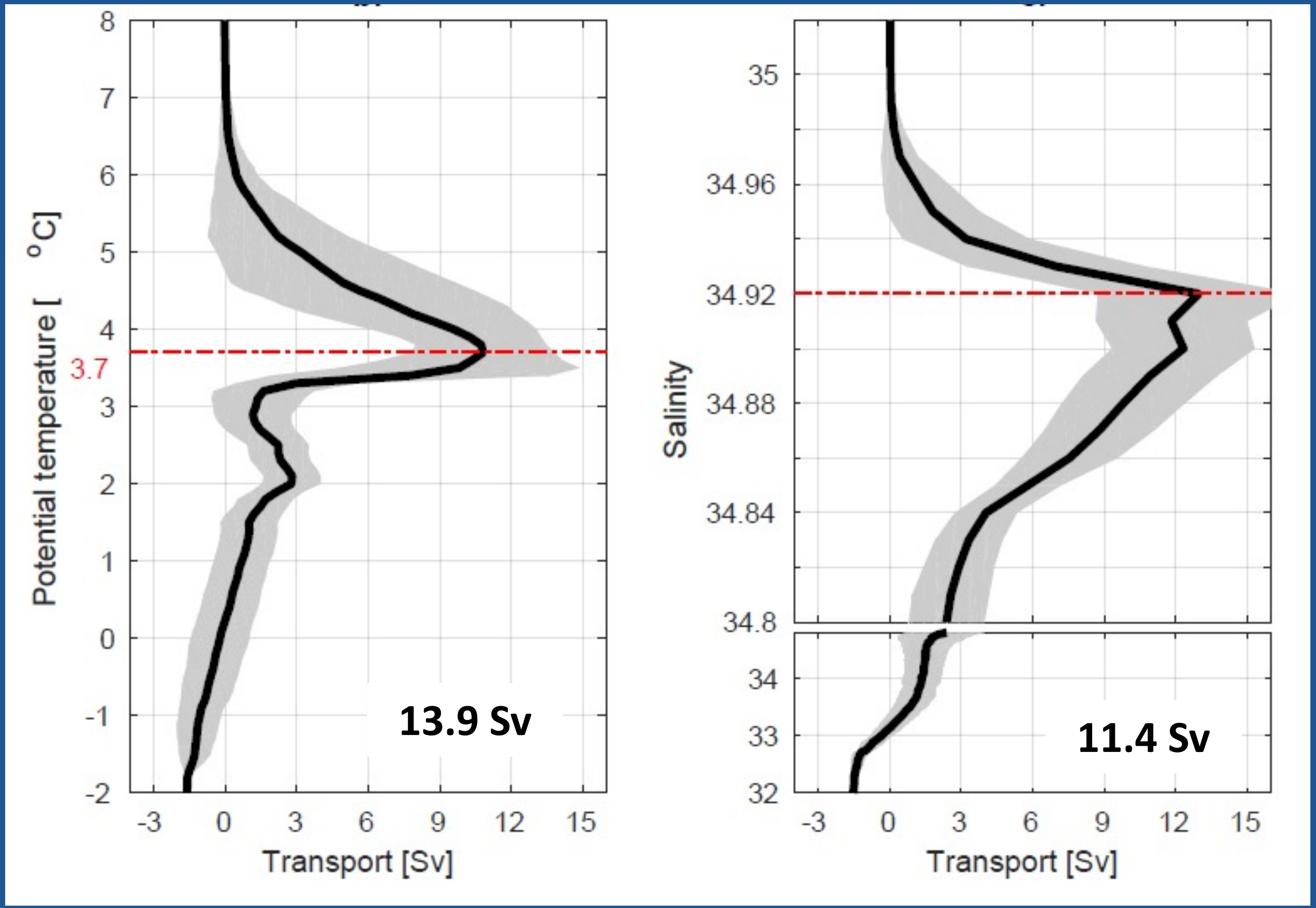
Maximum of the overturning streamfunction in density space



Shading indicates uncertainty in 30-day means obtained w/ Monte Carlo runs.

Fu et al., in prep

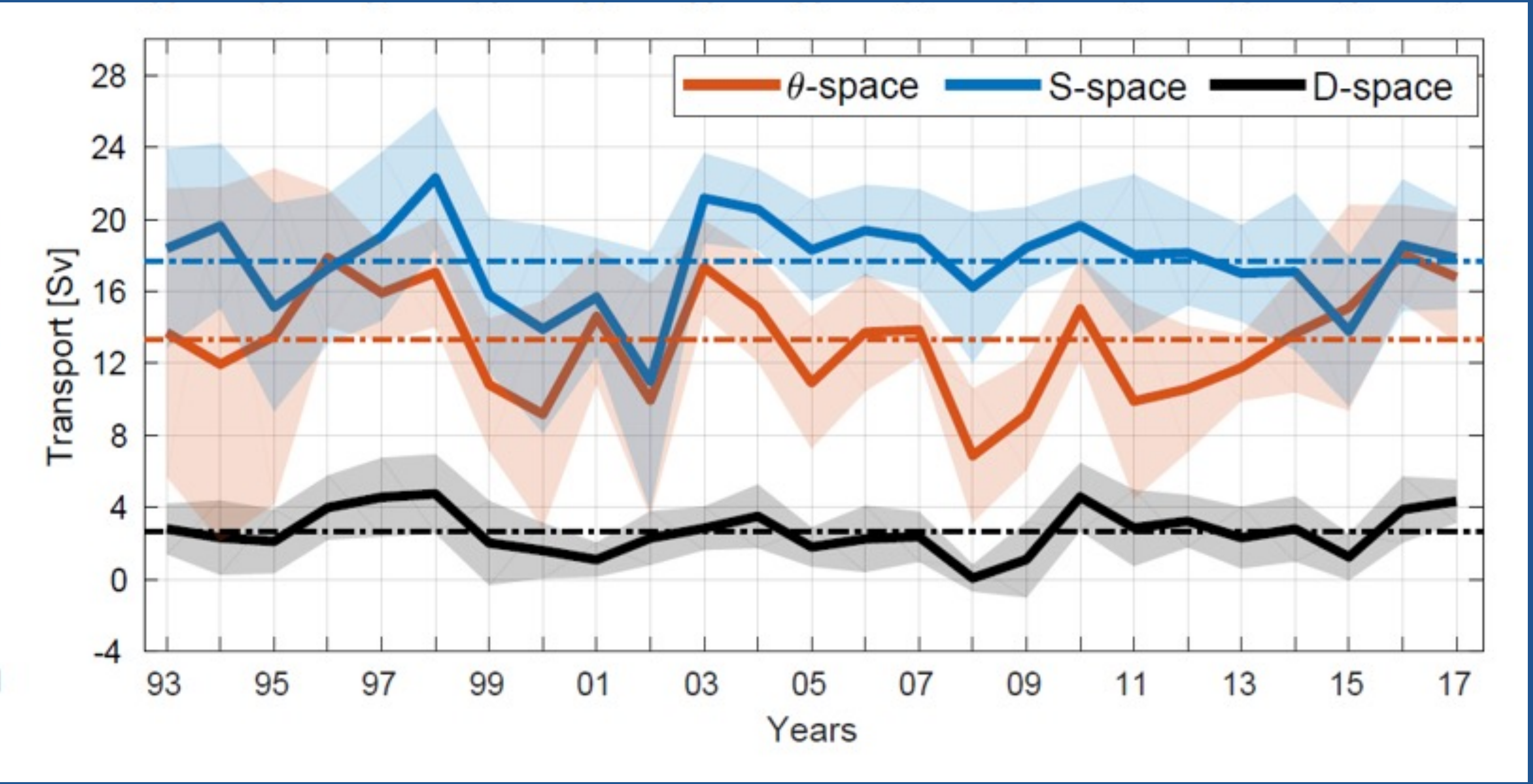
Alternative overturning measures across OSNAP West (Labrador Sea)



Temperature space **Salinity space**

Zou et al. 2020

Variability of overturning transports using GloSea5

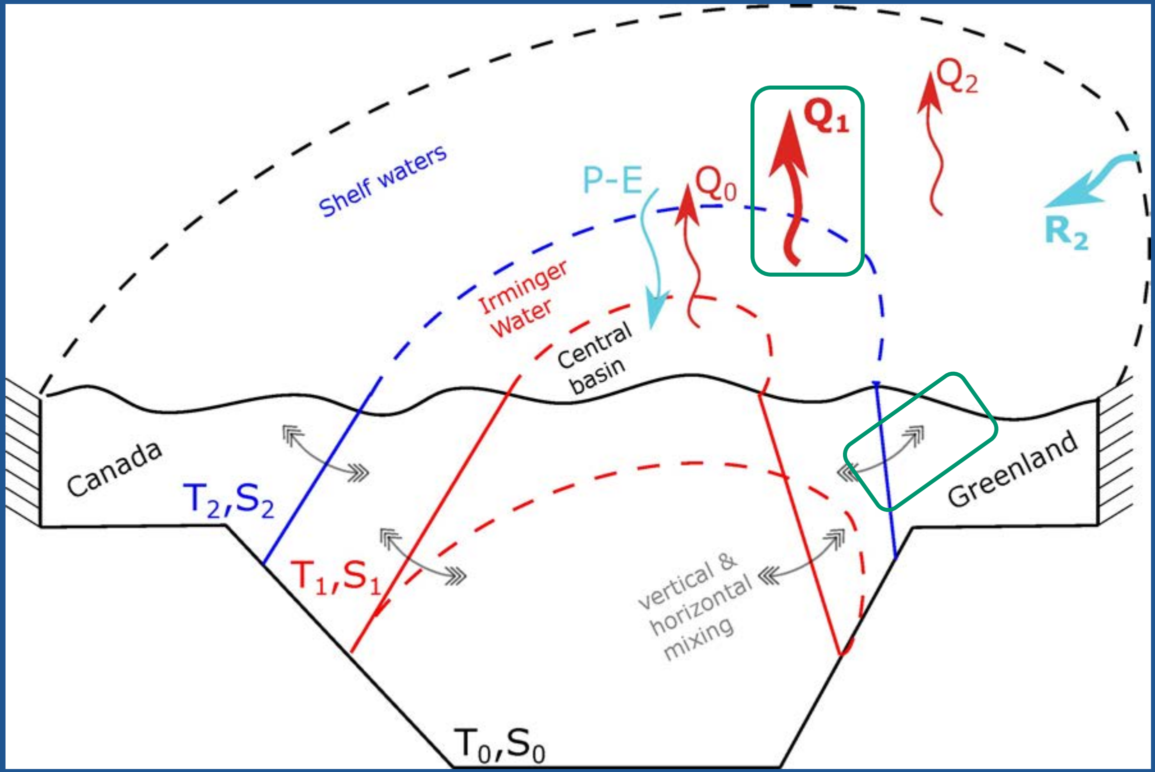


Simulated annual time series of MOC_{θ} (orange), MOC_{S} (blue), and MOC. Color shading indicates monthly standard deviation for each year. All time series have been detrended.

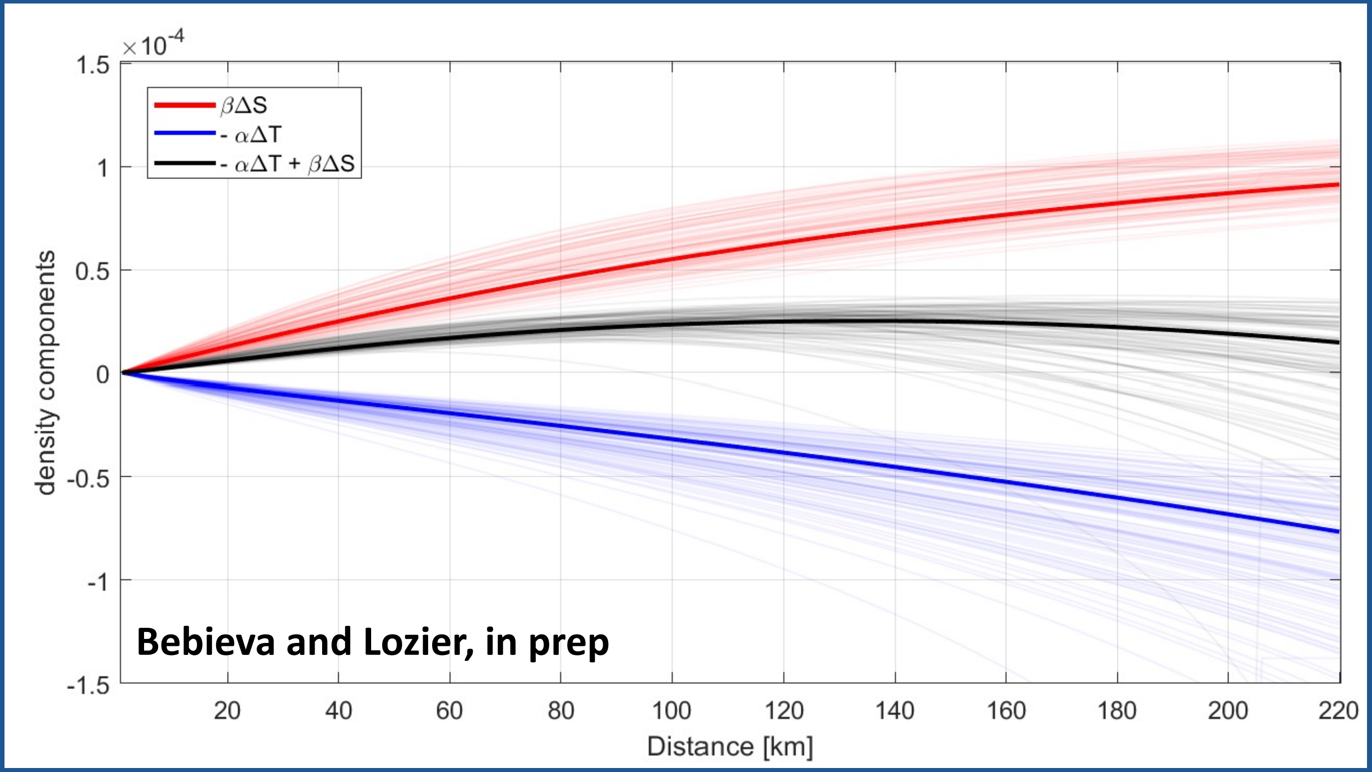
Zou et al. 2020

Mechanism of Density Compensation in the Labrador Sea

Extension of a 2-layer model by Straneo (2006)

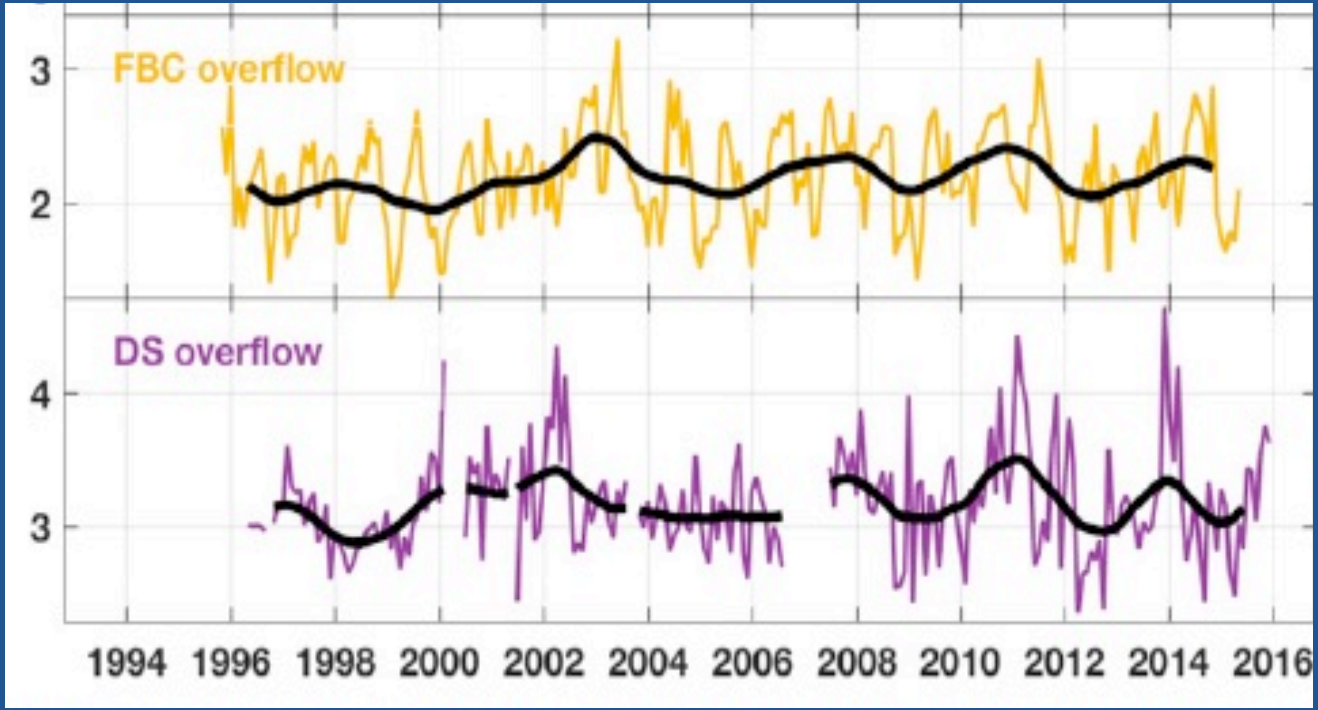


Density compensation as function of path length



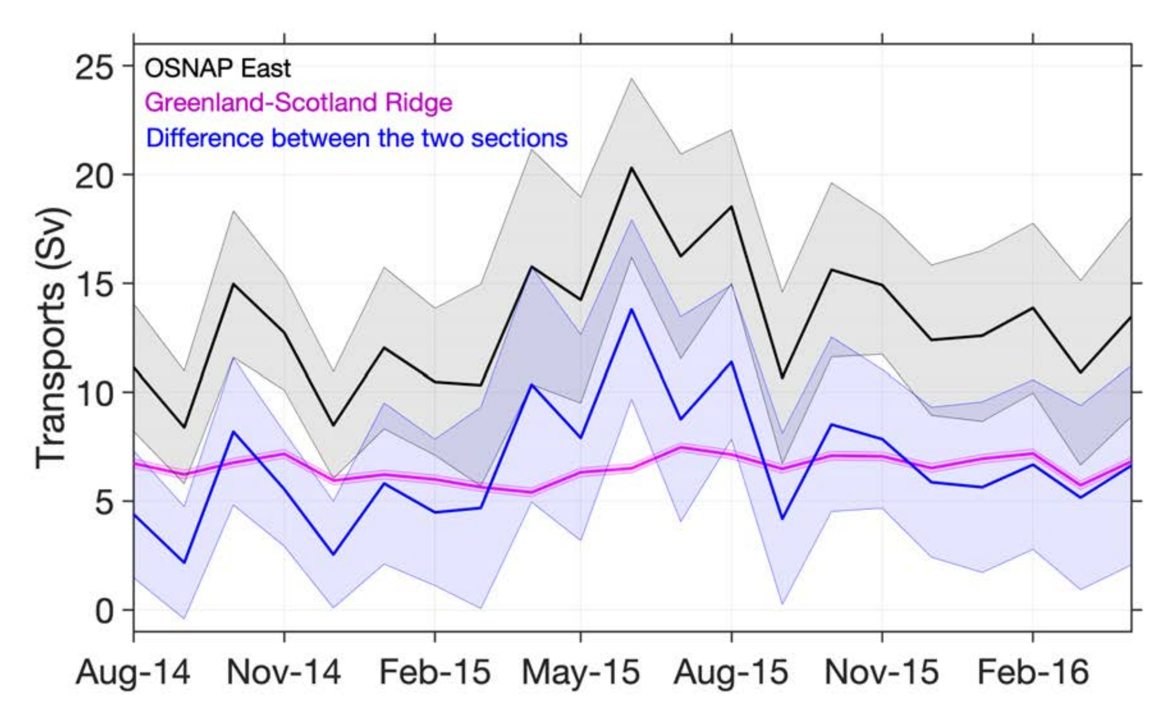
Take-away: The density-compensating water mass transformation in the boundary current can be largely attributed to the combined effect of direct atmospheric cooling of the relatively warm boundary current and freshening due to interaction with the fresh waters derived from the Greenland meltwater discharge and Arctic Ocean inflow.

GSR overflow and OSNAP East variability



Current-meter-based monthly time series of volume transports across GSR. All values are in Sv. Black line shows time series with 25-month triangular filter.

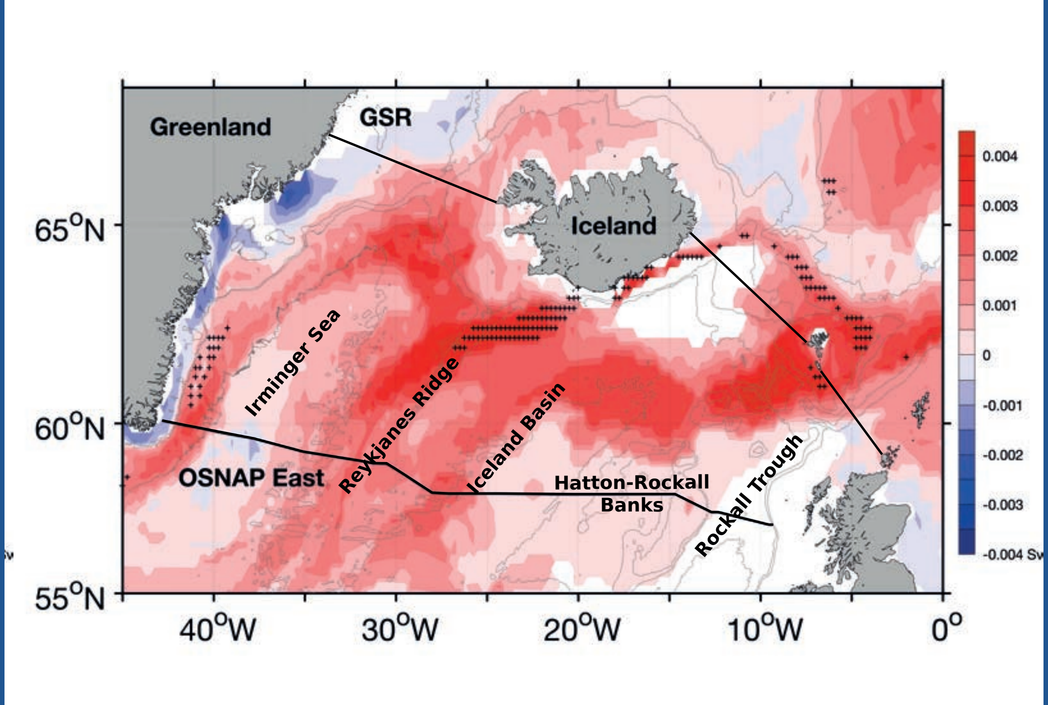
Bringedal et al. 2018



30-day mean transports for the lower layer at OSNAP East (black line) and GSR (magenta line), and their difference (blue line). Shading indicates uncertainty. Layers are separated by the isopycnal of the AMOC at OSNAP East, σ_{MOC}.

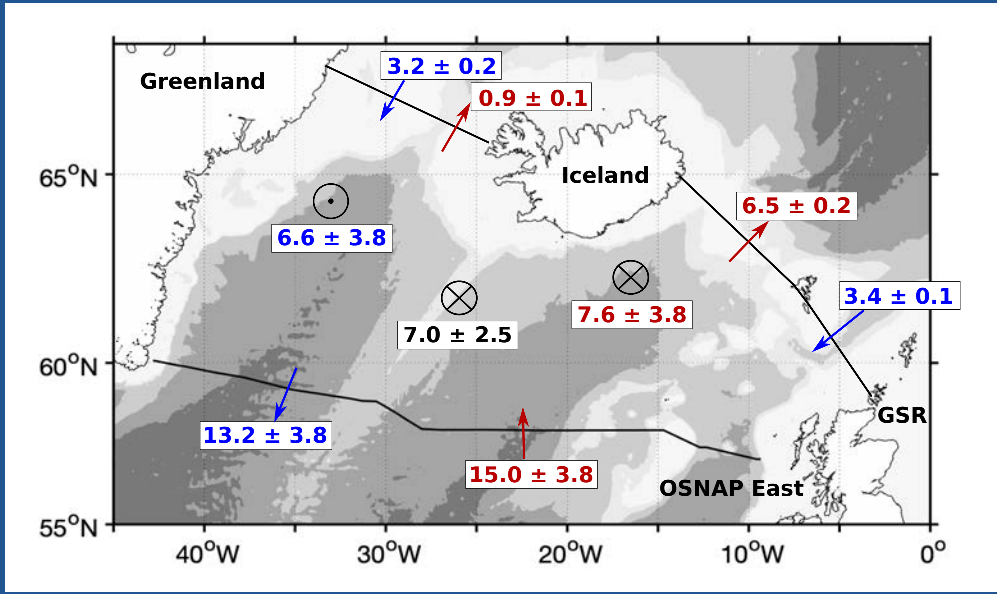
Petit et al. 2020

OSNAP East transformation and volume budget



Transformation to σ_{MOC} (27.55 kg m^{-3}), derived from averaged heat and freshwater fluxes of ERA5 and NCEP.

Petit et al. 2020



Volume budget of upper (red) and lower (blue) layers between GSR and OSNAP East

Blue circle: volume of water from upper layer to lower layer estimated from volume budget of lower layer.

Red circle: Volume of water from upper layer to lower layer estimated from volume budget of upper layer.

Black circle: volume of water from upper layer to lower layer estimated from averaged transformation across σ_{MOC}.

OSNAP East volume budget using ocean reanalyses

Elements of lower limb budget:

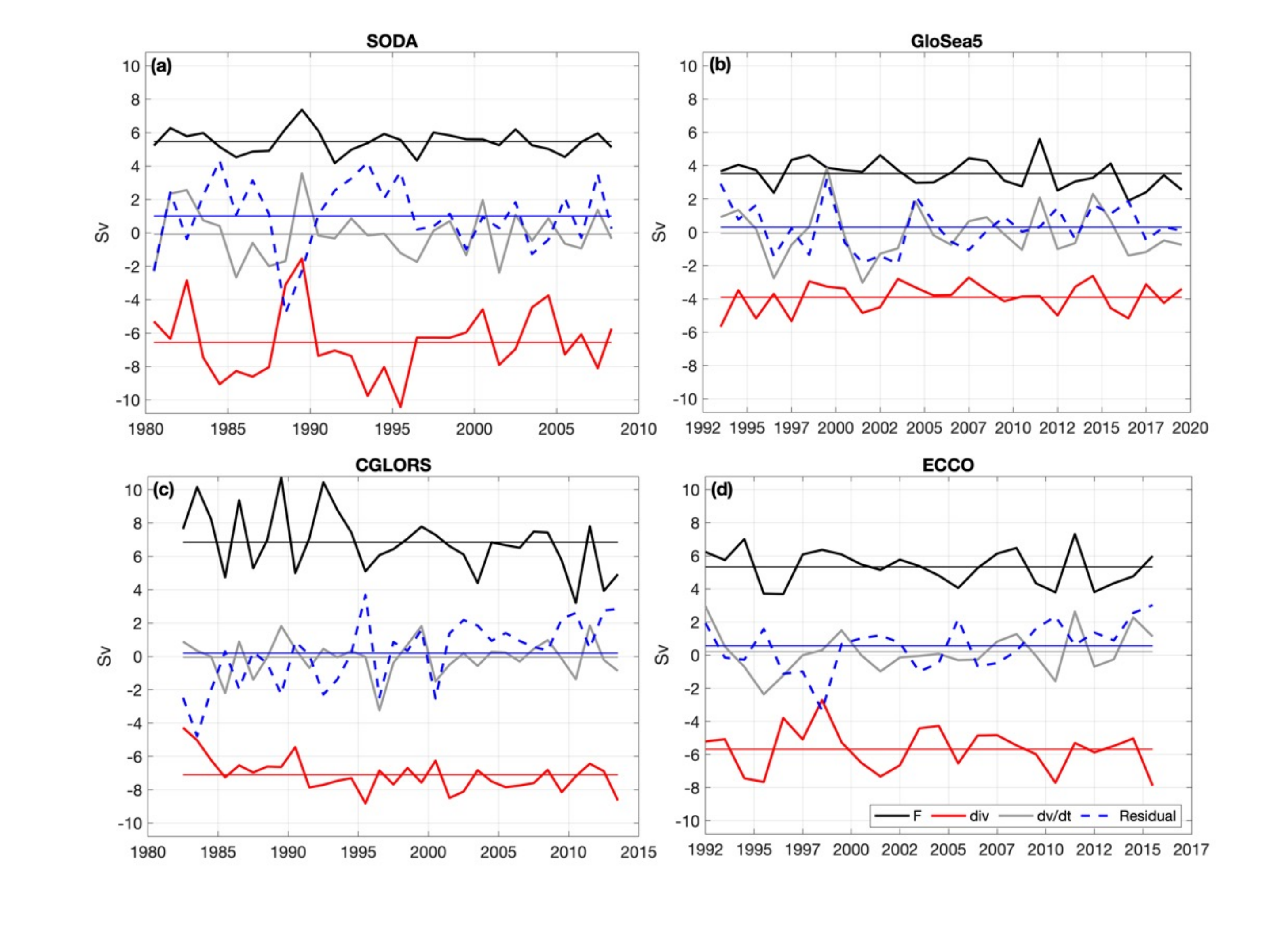
Gray: d(volume)/dt of lower limb

Black: Transformation to σ_{MOC} from surface buoyancy forcing

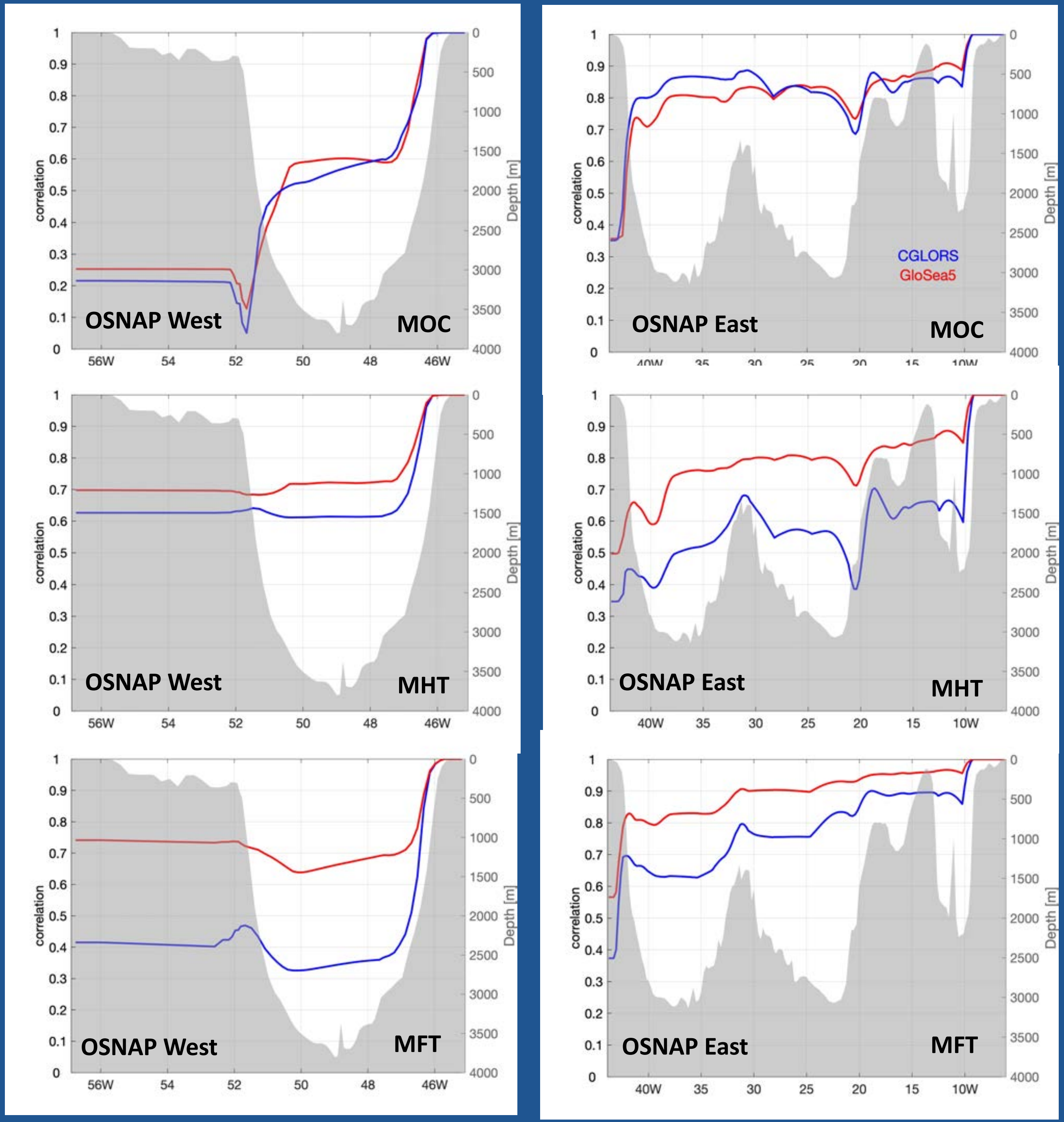
Red: Divergence of lower limb (OSNAP East minus overflow across GSR)

Blue: Residual

Take-away: In the mean,the difference between surface-forced transformation and net outflow is < 1 Sv.



Majumder and Lozier, in prep



Toward the optimization of the OSNAP array

Correlations between MOC/MHT/MFT and their reconstructions estimated adding time-varying volume/heat/freshwater fluxes sequentially from west to east, while other variables in the array are kept at monthly climatological means.

Take-aways so far:

1. **OSNAP West needs both boundary arrays for MOC, MHT and MFT.**
2. **OSNAP East MOC can be captured fairly well by the array along East Greenland.**
3. **Capturing temporal variability of the NAC across OSNAP East is critical to measuring MHT and, to some extent, MFT.**

Majumder, Lozier and Li in prep

Summary

• OSNAP shows dominance of overturning from Greenland to Scotland, rather than overturning across the Labrador Sea, over the six years of observations.

• Density compensation in the Labrador Sea is compatible with weak overturning, and highlights the importance of freshwater forcing in that basin. Idealized modeling study suggests that compensation is due to the offset of surface cooling by input of fresh coastal waters.

• Overturning in the Irminger and Iceland basins is a major contributor to the AMOC and can be accounted for in the mean by surface transformation. Storage of newly formed deep waters shows sizeable interannual variability.

• Spread of DSOW and ISOW are remarkably different in the subpolar North Atlantic. ISOW spreads southward along multiple pathways, including those to the east of the Mid-Atlantic Ridge.

• Study of OSNAP optimization is ongoing. Array design depends on whether MOC, MHT and/or MFT is prioritized.

Summary, continued

• Anomalies in a single boundary current do not capture a meaningful amount of AMOC variability, particularly in the Labrador Sea. See Li et al. 2021.

• The link between convection in the interior and boundary current anomalies is not straightforward. Anomalies found in the boundary current can be imported from upstream, created due to exchange w/ the interior and formed in the boundary current. See Li et al. 2021 and Menary et al. 2020.

• Transformation of surface waters in the Iceland and Irminger basins depends upon surface outcrop area and buoyancy forcing, with the former playing a larger role in setting interannual to decadal variability. See Petit et al. 2021.

Note: Please see Yao Fu's poster on the OSNAP MOC, MHT and MFT seasonality.

What we (actually, I) don't know

- Is the ~ 6 yr OSNAP period representative of MOC , MHT and MOC variability on longer time scales?

- How will ice/glacial melt impact overturning in the subpolar North Atlantic in the years and decades ahead? What might its differential impact be for OSNAP East and West?

- How quickly will changes in deep water formation be communicated downstream to lower latitudes? [We still don't know the time scale for meridional coherence based on observations.]

- How will changes in the AMOC impact the uptake of anthropogenic CO_2?

- Why is there (still) such a spread in the AMOC response among climate models?