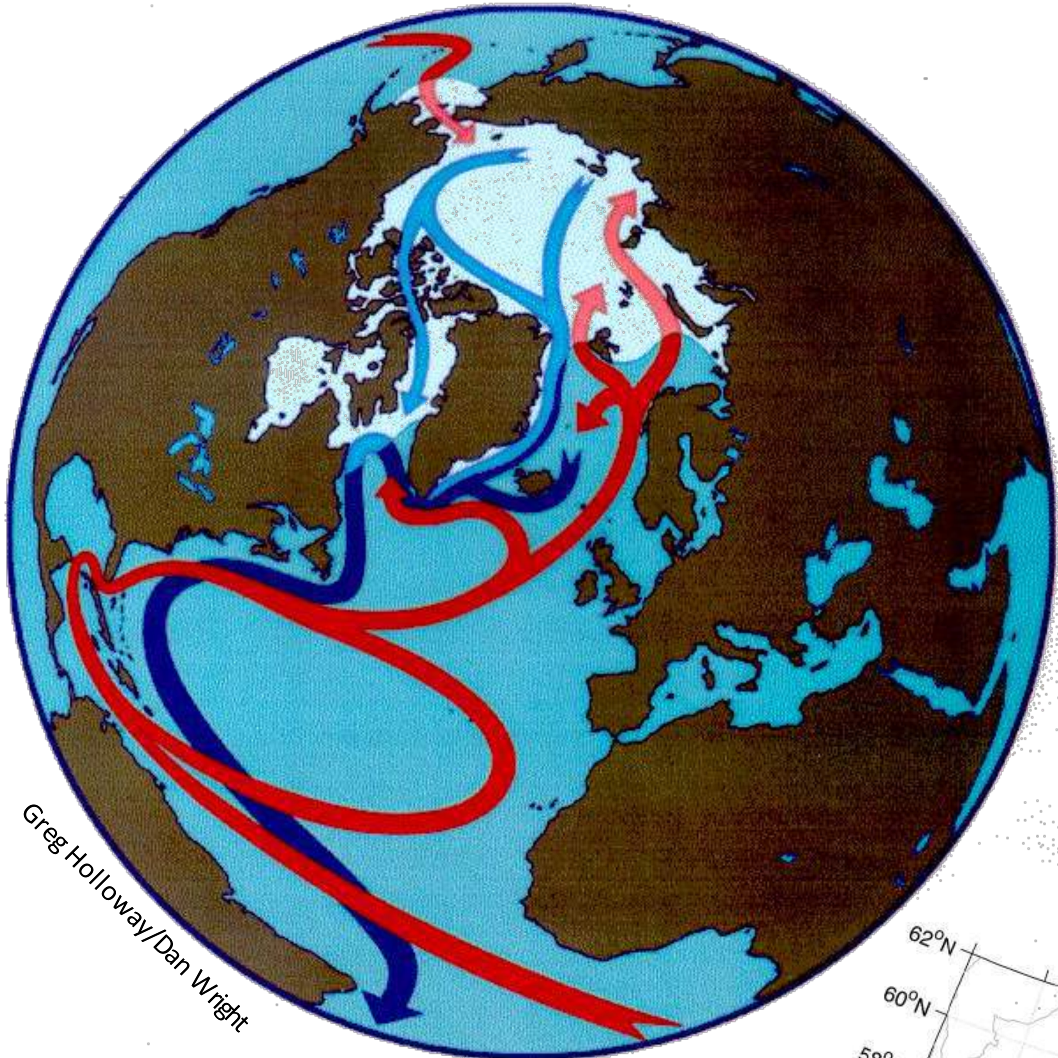


Greg Holloway/Dan Wright

Attribution of subpolar versus subtropical Atlantic overturning variability

Yavor Kostov

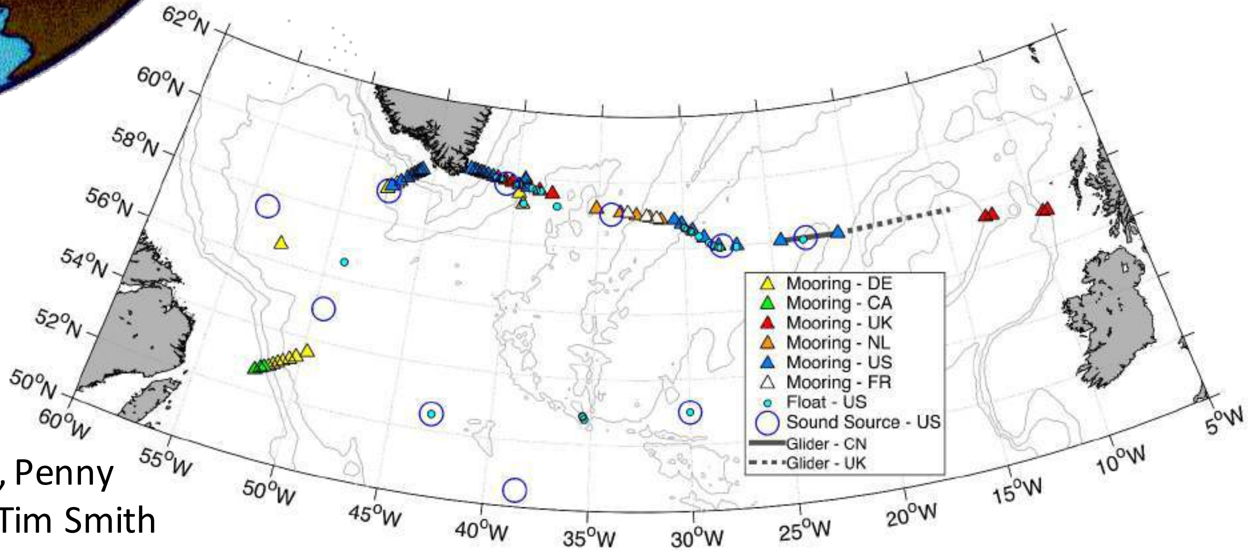
with

Helen Johnson and David Marshall

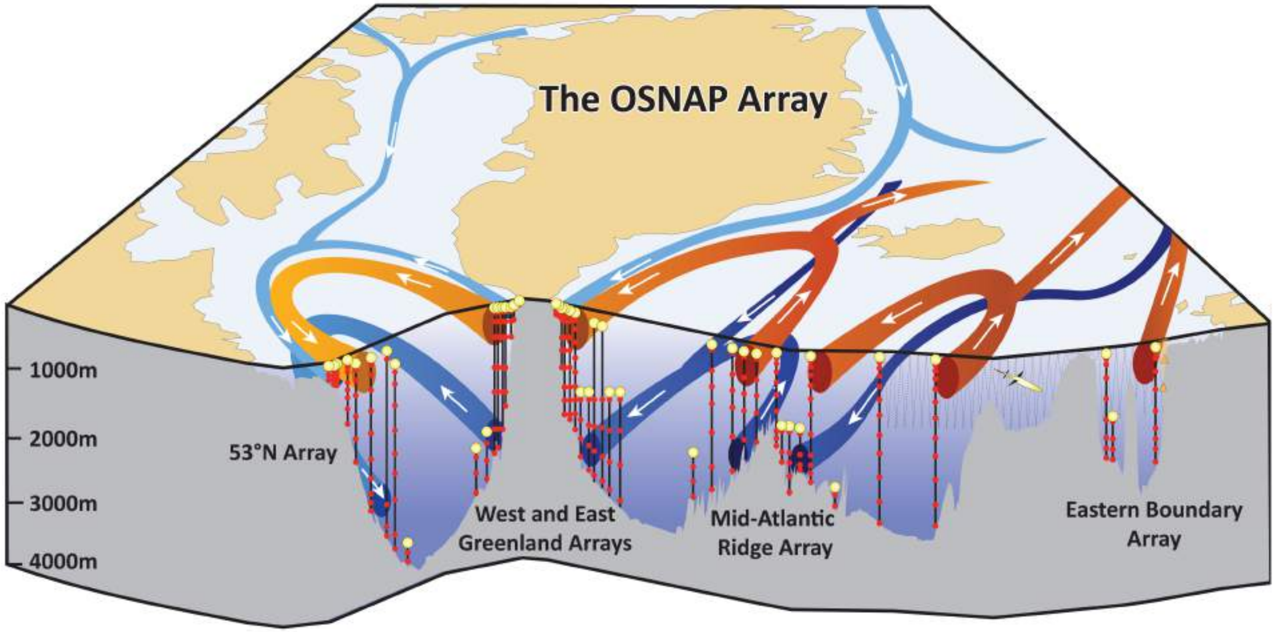
University of Oxford, UK

OSNAP

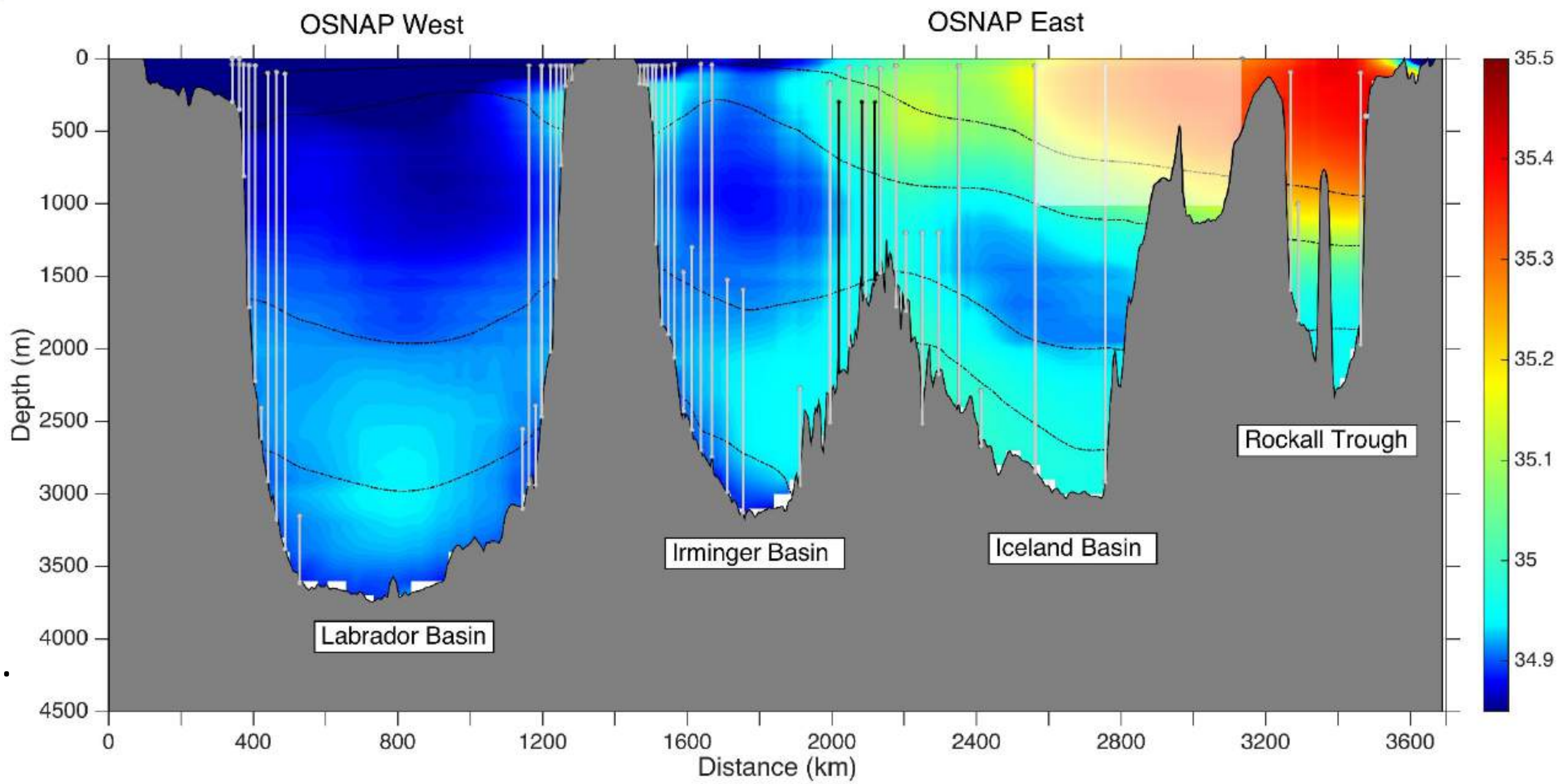
OVERTURNING IN THE SUBPOLAR NORTH ATLANTIC PROGRAM



With thanks to Patrick Heimbach, Gael Forget, Penny Holiday, Susan Lozier, Feili Li, Helen Pillar and Tim Smith

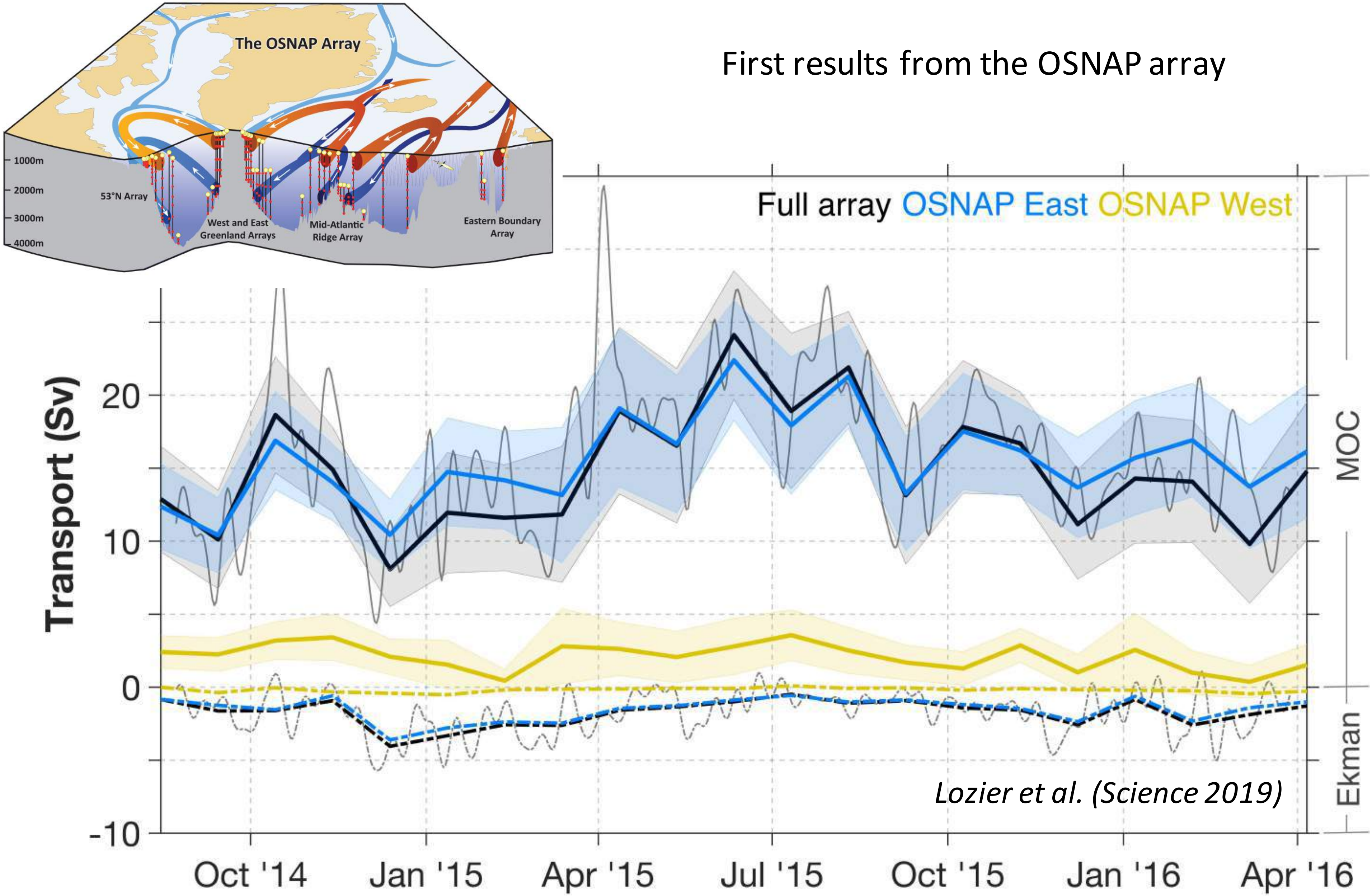


At subpolar latitudes isopycnals slope steeply across the basin and much of the watermass transformation is associated with the horizontal circulation.



Need to calculate the overturning circulation in density space.

First results from the OSNAP array



OSNAP East dominates the overturning and its variability.

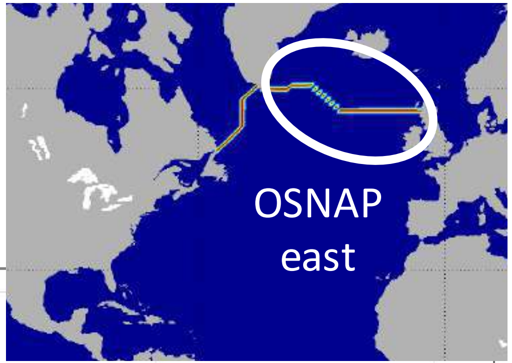
Reconstructing and attributing OSNAP east overturning variability

For linear perturbations:

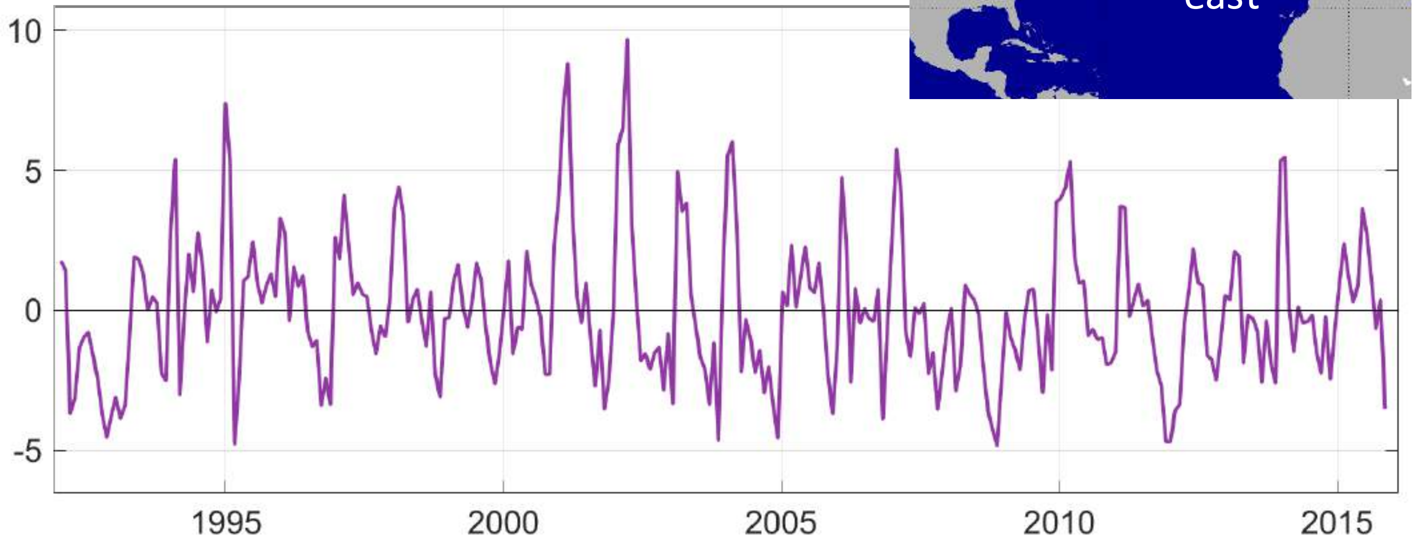
$$\text{Response} = \sum \begin{array}{c}\text{sensitivity to} \\ \text{winds, SST and SSS}\end{array} \times \begin{array}{c}\text{anomalies in} \\ \text{winds, SST and SSS}\end{array}$$

ECCO version 4 configuration of the MITgcm

- ECCO: combines the MITgcm with observations to obtain a time-evolving global ocean state estimate (1992-2015).
- Roughly $1^{o} \times 1^{o}$ resolution on a lat-lon-cap grid.
- Eddy and vertical mixing schemes with optimized parameters.
- Optimized surface fluxes (no restoring) and ocean state.



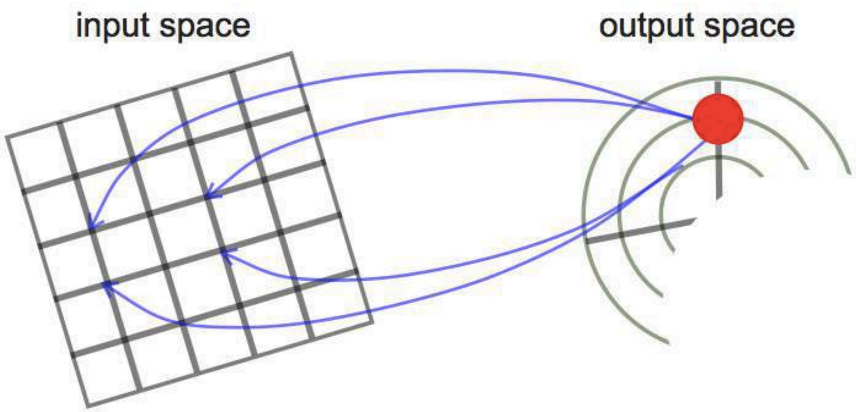
Overturning in density space across OSNAP East in ECCO:



Large variability with an irregular seasonal cycle.

Linear sensitivity estimated using the adjoint to the MITgcm

ADJOINT
LINEAR
SENSITIVITY



Sensitivity of one output to all inputs (time-varying spatial maps of sensitivity)

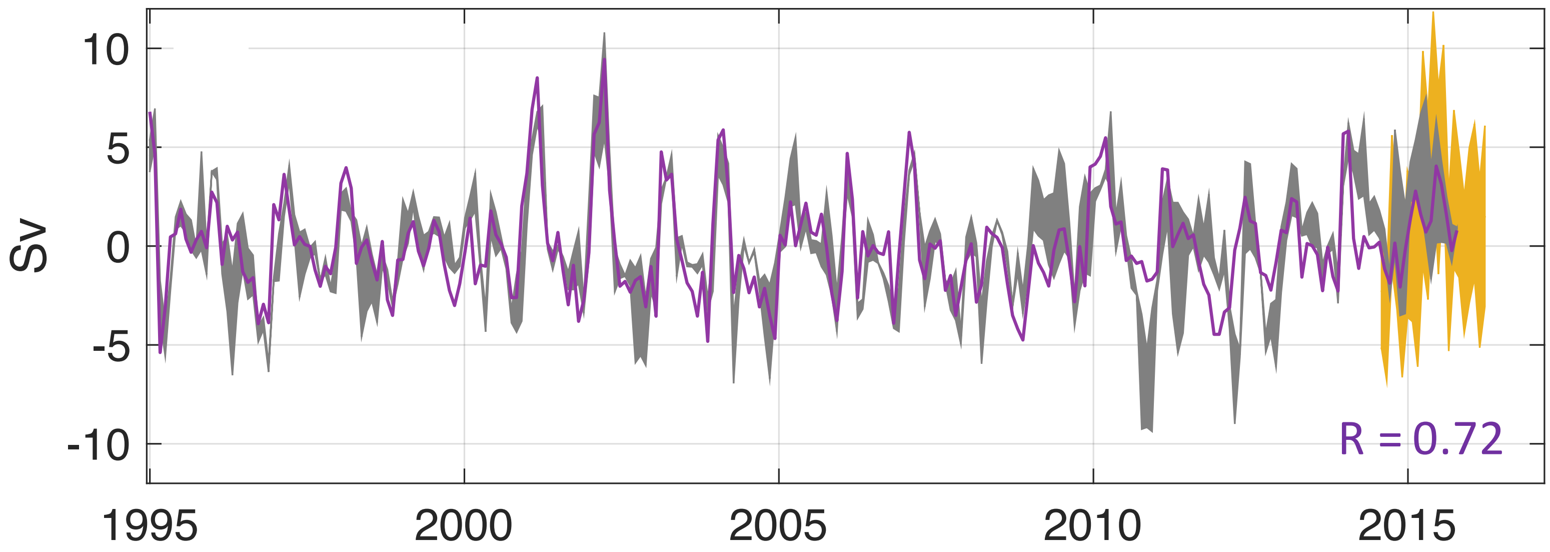
- Quantity of interest
  = monthly mean maximum overturning across OSNAP east in density space (ψ)
- Controls = surface wind stress (τ^x, τ^y), sea surface temperature (SST) and salinity (SSS)
- Adjoint analysis yields time-varying spatial maps of

$$\frac{\partial\psi}{\partial\tau^x} \quad \frac{\partial\psi}{\partial\tau^y} \quad \frac{\partial\psi}{\partial SST} \quad \frac{\partial\psi}{\partial SSS}$$

- Adjoint code generated by algorithmic differentiation (Giering and Kaminski 1998)

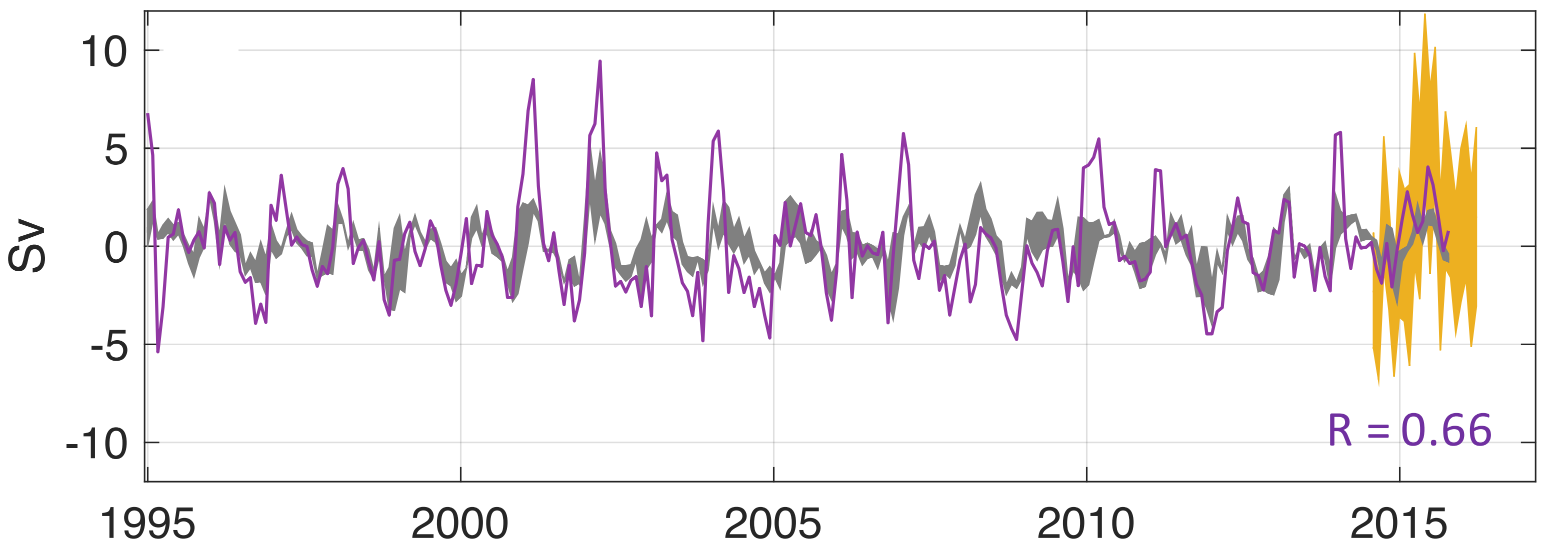
Then convolve linear sensitivities with control variable anomalies to reconstruct overturning variability.

Reconstruction of OSNAP East overturning variability in ECCO and OSNAP East observations
using wind, SST and SSS and known seasonal cycle.



Reconstruction captures >50% of variability

Reconstruction of OSNAP East overturning variability in ECCO and OSNAP East observations
using only direct sensitivity to wind stress.

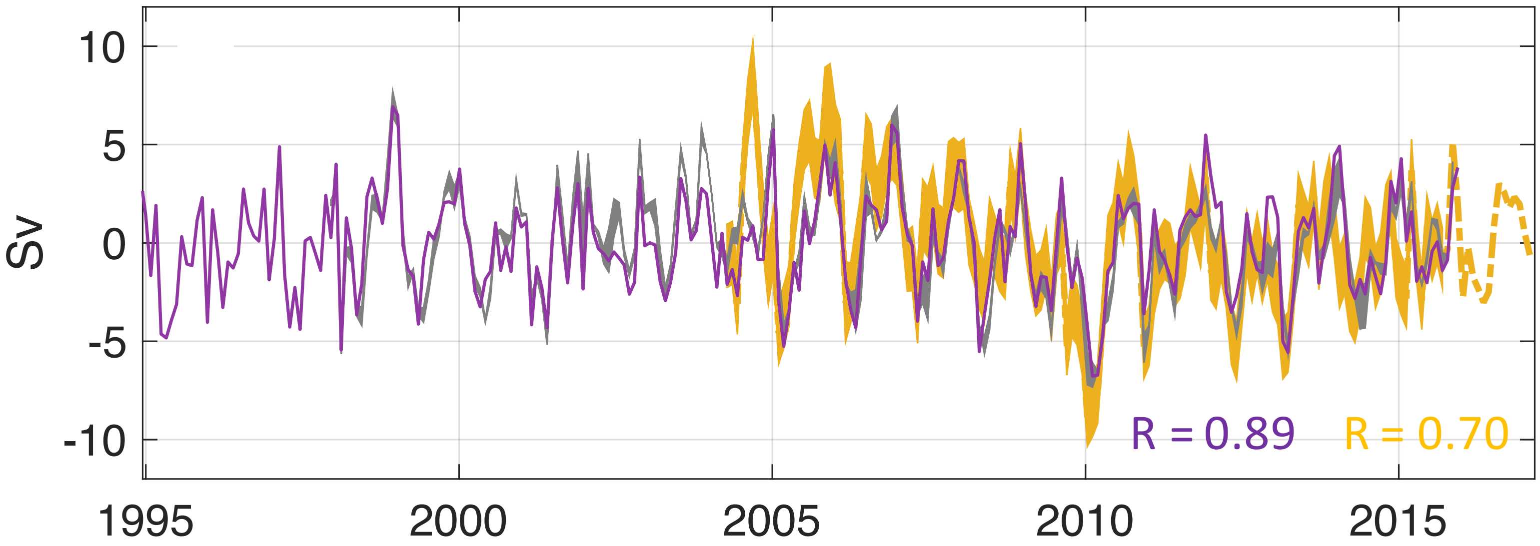


Skill doesn't come just from wind

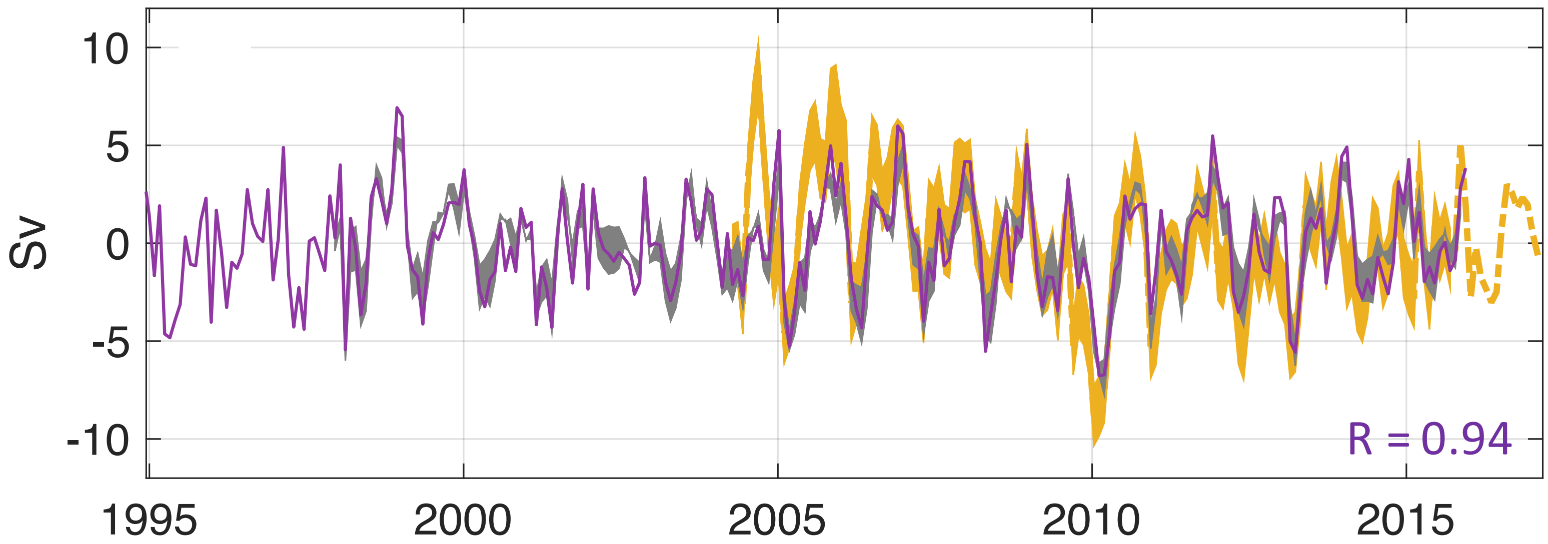
Kostov et al. (2020, submitted)

Contrast with subtropical overturning variability!

Reconstruction of 26°N overturning variability in ECCO and RAPID-MOCHA observations
using wind, SST and SSS and known seasonal cycle.



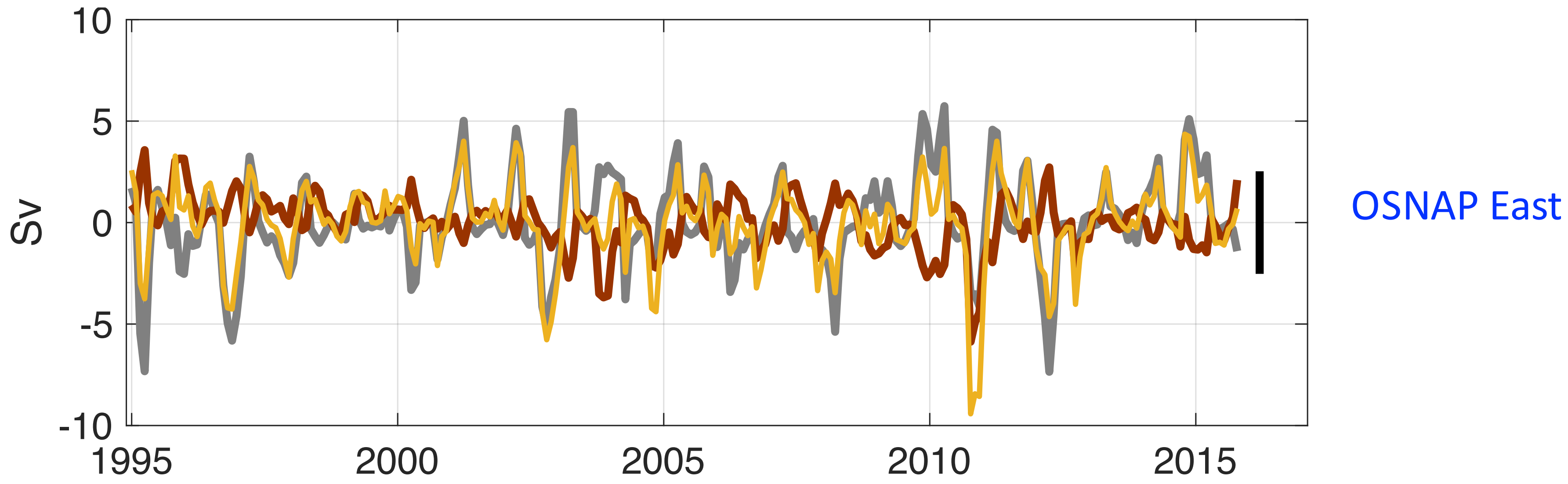
Reconstruction of 26°N overturning variability in ECCO and RAPID-MOCHA observations
using only direct sensitivity to wind stress.

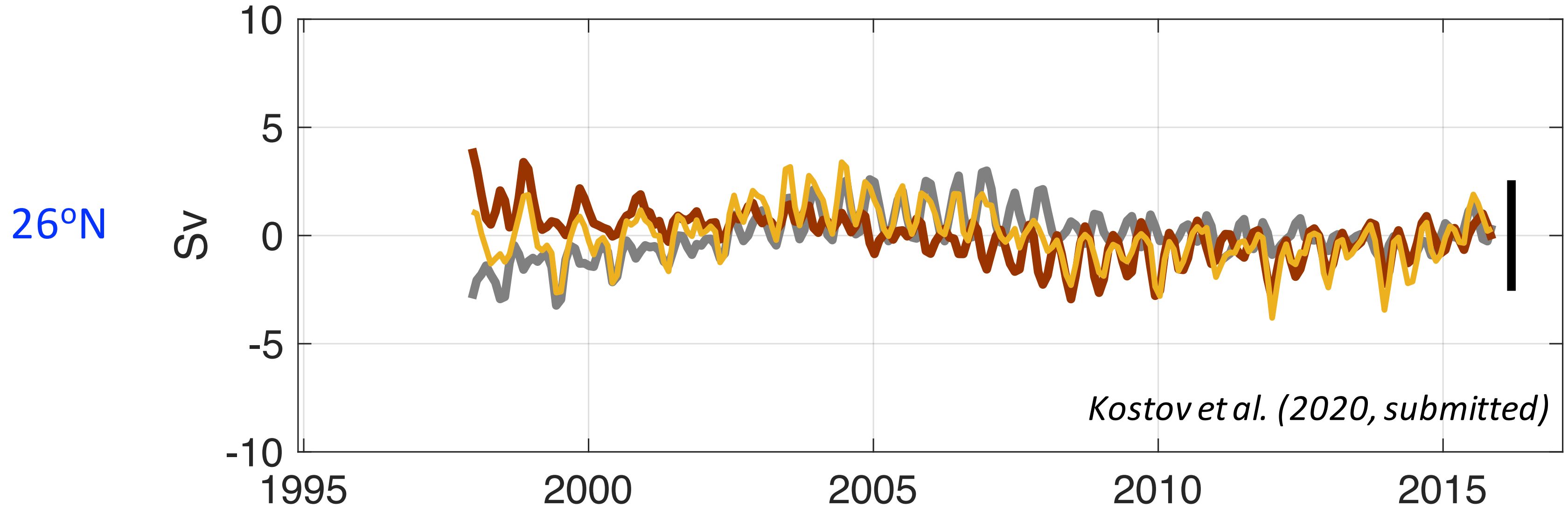


Variability almost all wind-forced at 26°N

Kostov et al. (2020, submitted)

SST-induced, SSS-induced and total buoyancy-induced overturning variability

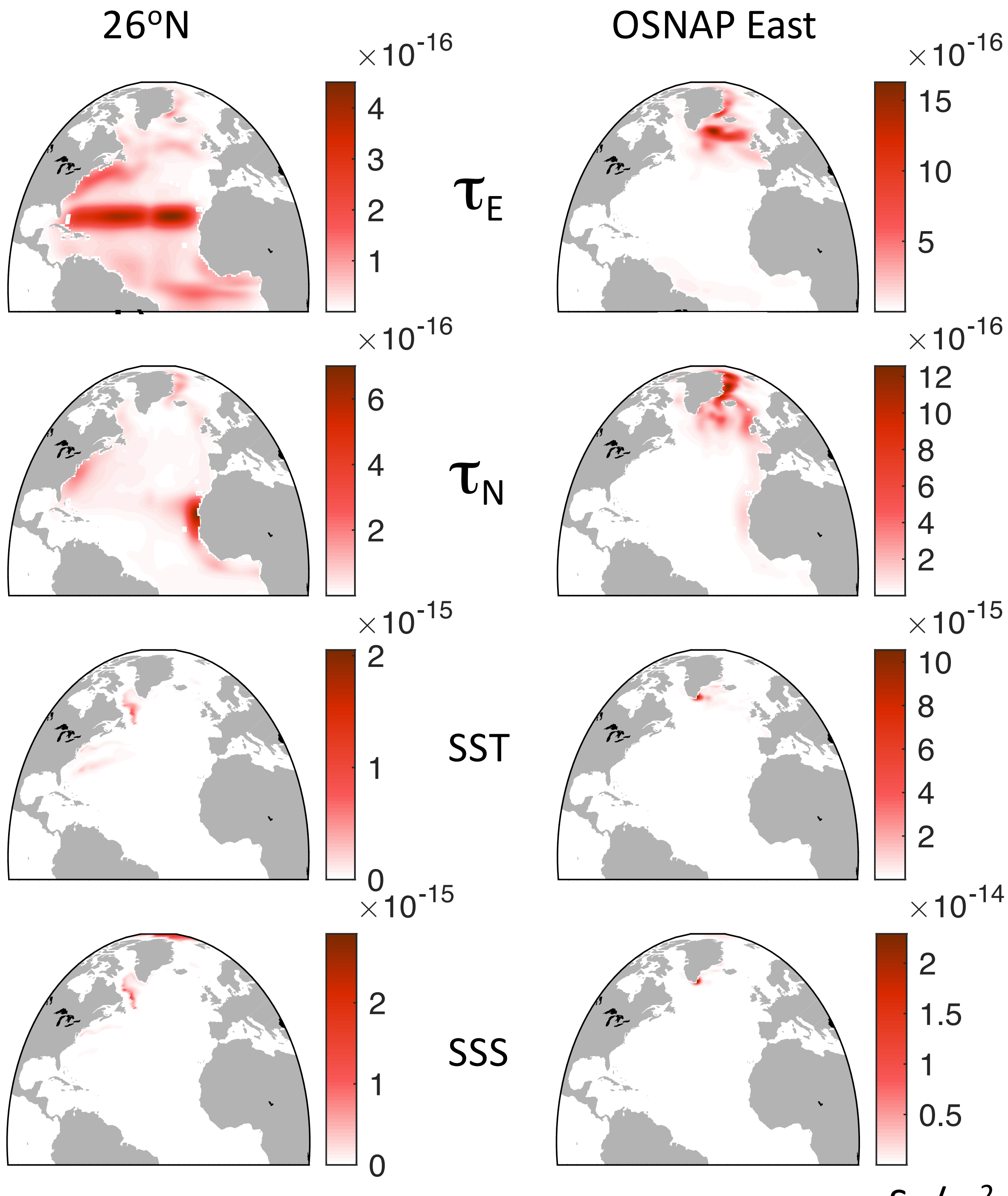




Contributions are anti-correlated, with SSS dominating at OSNAP East.

No SSS-induced contribution to overturning variability at 26°N in 2008-2013.

Spatial origins of variability in overturning



Root-mean-square contribution per unit area to the reconstructed overturning variability over 1992-2015

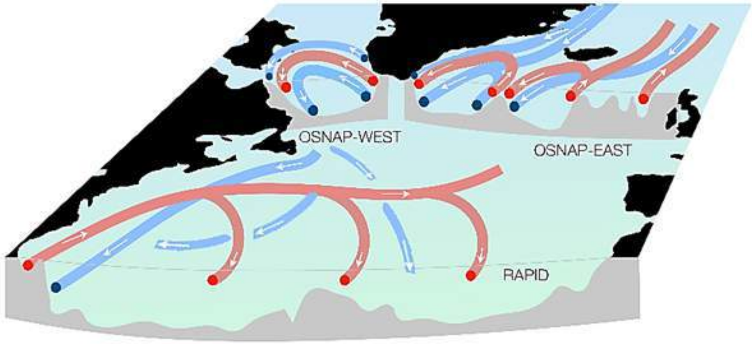
Kostov et al. (2020, submitted)

Conclusions

- The overturning and its variability at the OSNAP array are dominated by watermass transformation east of Greenland.
- Wind alone cannot explain the large seasonal-interannual variability in OSNAP east overturning in ECCO. We can reconstruct 50% of the variability from winds, SST and SSS.
- This contrasts with RAPID, where interannual variability is entirely wind-driven.
- SSS and SST contributions compensate (with SSS dominating).
- Important role for local SSS and SST variations off SE Greenland and subtropical winds.

Ongoing

- Can we attribute the *observed* variability across OSNAP East to specific anomalies in wind, SST and SSS (in space and time)?
- Is there any useful predictability?
- What are the mechanisms governing the variability?
- How does subpolar overturning variability relate to that in the subtropics?



Kostov et al. (2020, submitted)