Atmospheric origins of variability in the South Atlantic meridional overturning circulation

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Motivation

- South Atlantic hosts complex water mass exchanges, review: [Garzoli and Matano, 2011]
- SAMOC variability impacts severity of summer monsoon [Lopez et al., 2016]
- What mechanisms control variability in the SAMOC?

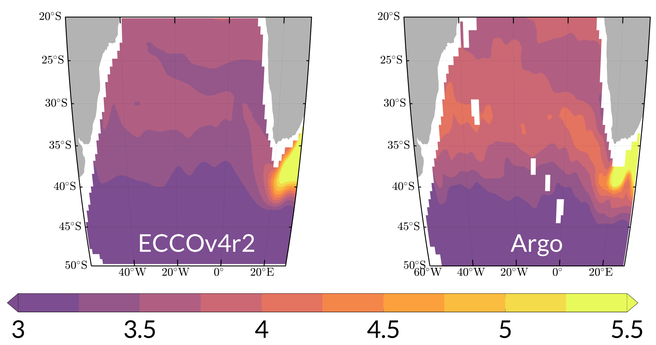
Goal

Attribute seasonal to interannual variability in the SAMOC at 34°S to its geographical origins as atmospheric perturbations.

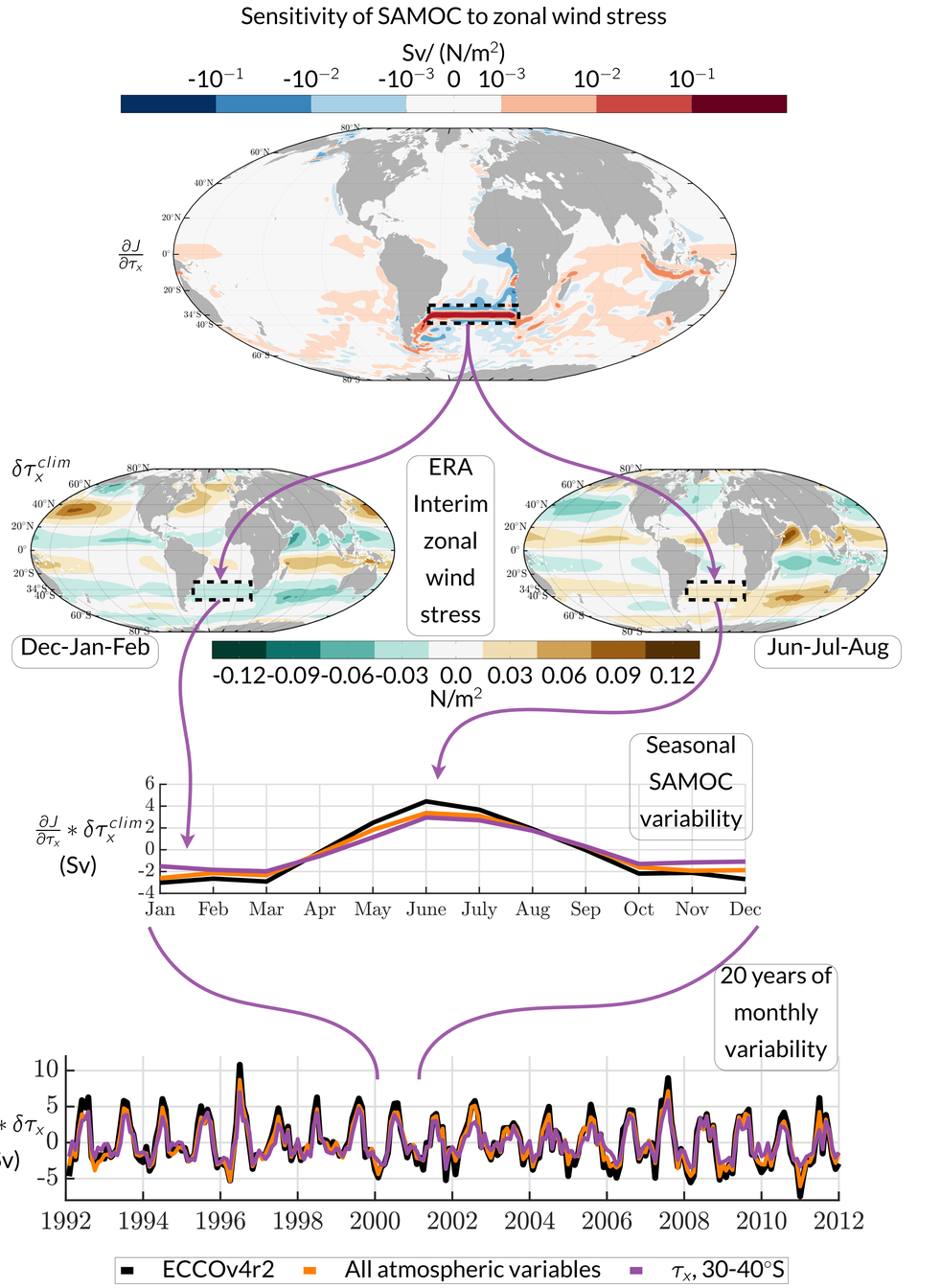
ECCOv4 state estimate

- represents observations [Forget et al., 2015]
- provides a physically consistent, 4D picture of the ocean state
- equipped with model adjoint for sensitivity analysis

Comparison to observations



Time mean temperature at 1000m depth (°C)
Gridded Argo data from [Roemmich and Gilson, 2009].
For model-data comparisons, cf. [Dong et al., 2014].



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Sensitivity analysis

- Define $J :=$ monthly mean SAMOC at 34°S
- Seek **sensitivity** to atmospheric forcing: $\partial J/\partial \mathbf{F}$
- **Adjoint:** computationally tractable means to compute $\partial J/\partial \mathbf{F}$

Attribution

in the linearized setting

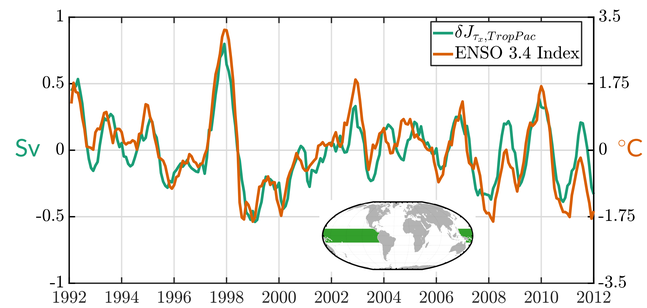
$$J(t) = \underbrace{J_0}_{20\,year\ mean} + \delta J(t)$$

$$\delta J_{Rec}(t) = \sum_k \int_{t-\tau_{mem}}^{t} \int_x \int_y \frac{\partial J}{\partial F_k}(x, y, s-t)\, \delta F_k(x, y, s)\, dx\, dy\, ds$$

requires two ingredients:

- $\delta\mathbf{F}$:= atmospheric forcing from ERA Interim with ECCOv4r2 adjustments [Dee et al., 2011, Forget et al., 2015]
- $\frac{\partial J}{\partial \mathbf{F}}$:= sensitivity of SAMOC to atmospheric forcing

ENSO fingerprint



Interannual SAMOC variability attributed to tropical Pacific zonal wind anomalies, communicated via Kelvin wave dynamics

Conclusions

- Zonal wind generates most seasonal SAMOC variability in ECCOv4r2
- Interannual variability has more remote and complex origins
- ENSO can generate variability with similar amplitude as local forcing
- Is this signal observable?

Smith & Heimbach, J. Clim. (2019)

References

[Dee et al., 2011] doi: 10.1002/qj.828
[Dong et al., 2014] doi: 10.1002/2014GL060428
[Forget et al., 2015] doi: 10.5194/gmd-8-3071-2015
[Garzoli and Matano, 2011] doi: 10.1016/j.dsr2.2010.10.063
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[Roemmich and Gilson, 2009] doi: 10.1016/j.pocean.2009.03.004