Dynamical Attribution of AMOC Variability at the Mouth of the South Atlantic

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Interest in the South Atlantic

- South Atlantic plays active role in exchanging water masses from neighboring ocean basins. Review: [Garzoli and Matano, 2011]
- Understand origins of AMOC variability
- NOAA's SAMOC initiative: South Atlantic MOC Basin-wide Array (SAMBA) to study variability at 34.5°S [Meinen et al., 2013]

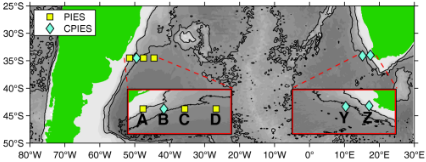

Figure: Preliminary SAMOC observations at 34.5°S. Figure from [Meinen et al., 2013].

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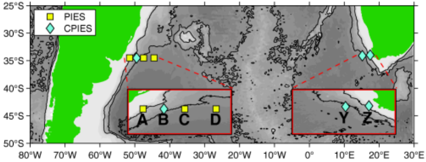


Figure: Preliminary SAMOC observations at 34.5°S. Figure from [Meinen et al., 2013].

Goal: attribute monthly to interannual variability to surface forcing from the atmosphere.

An Inverse Modeling Perspective

Consider linear perturbations of $\mathcal{J} \equiv$ AMOC @ 34°S:

$$\mathcal{J}(u(x,y,t)) = \mathcal{J}_0 + \frac{\partial \mathcal{J}}{\partial u}(x,y,t)\delta u(x,y,t)$$

Quantity of interest:

$$\delta\mathcal{J}(u(x,y,t)) \equiv \text{Monthly AMOC Anomaly @ 34°S}$$

"controlled" by:

$$\delta u(x,y,t) \equiv \text{Surface Atm. Forcing Perturbations}$$

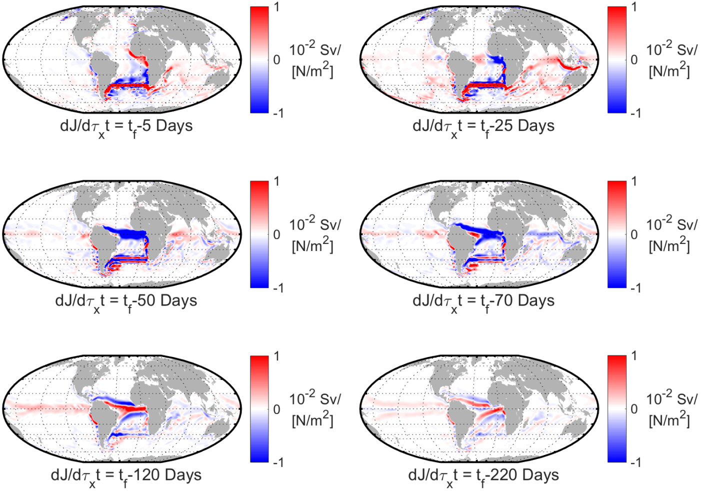
through (assumed) linear dynamics described by:

$$\frac{\partial \mathcal{J}}{\partial u}(x,y,t) \equiv \text{Sensitivity}$$

ECCOv4 release 2 state estimate [Forget et al., 2015]

- Forward model MITgcm fit to observation data from 1992-2011
- Generic inverse modeling framework for determining $\frac{\partial \mathcal{J}}{\partial u}$

AMOC Sensitivity



For animations, contact Tim Smith: tsmith@ices.utexas.edu

AMOC Reconstruction

With sensitivities and atmospheric state data, we can reconstruct the AMOC via the integral:

$$
\begin{aligned}
\delta\mathcal{J}(t) &= \sum_{k}^{N_{atm}} \delta\mathcal{J}_k(t) \\
&= \sum_{k}^{N_{atm}} \int_{t_0}^{t} \int_x \int_y \frac{\partial \mathcal{J}}{\partial u_k}(x, y, \tau - t_f)\, \delta u_k(x, y, \tau)\, dxdyd\tau
\end{aligned}
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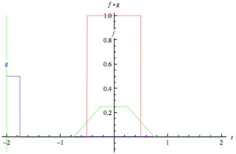
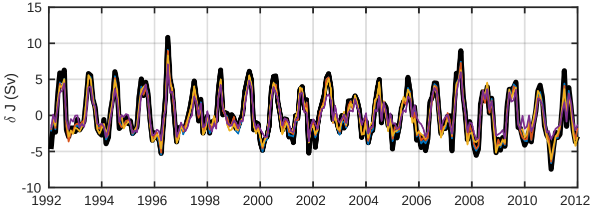
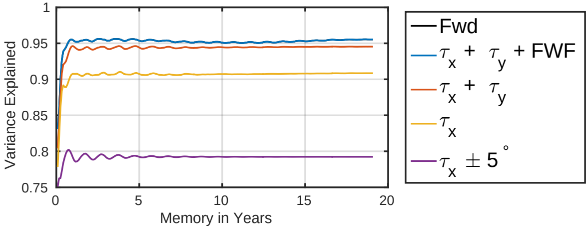


Figure from http://mathworld.wolfram.com/Convolution.html

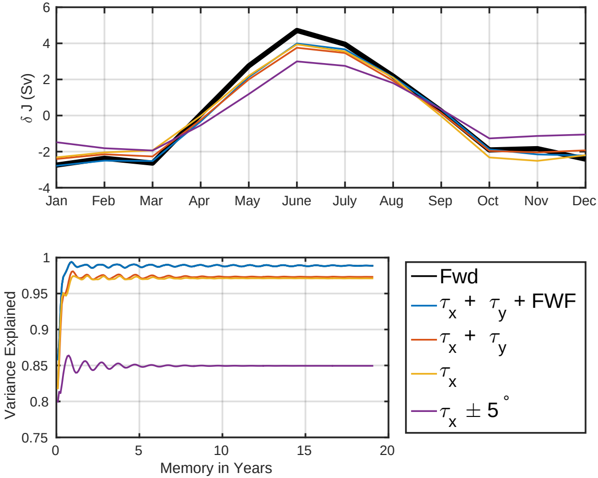
SAMOC Reconstruction





$$\text{Variance Explained} = 1 - \frac{var(Fwd - Rec)}{var(Fwd)}$$

Reconstructing the SAMOC Climatology



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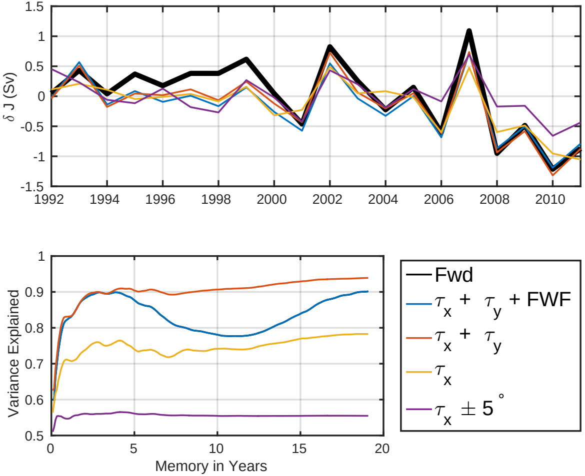
Attribution of Interannual Variability



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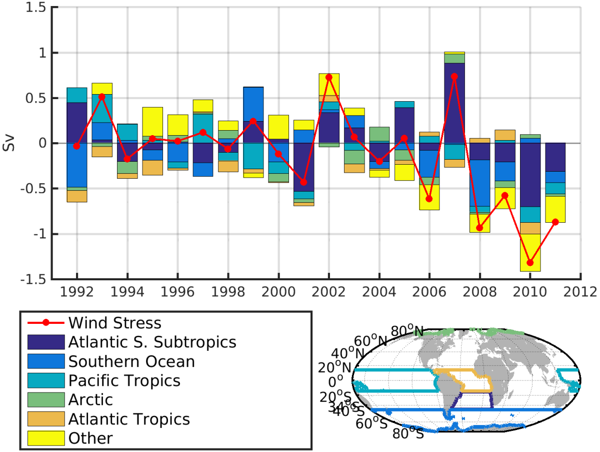
Attribution of Interannual Variability



Conclusions

- Monthly AMOC variability can be explained by linear dynamics propagating atmospheric perturbations to 34°S
- Large domain of influence through sensitivity maps unique to South Atlantic
- Zonal wind stress, particularly from local forcing, dominates variability on seasonal timescales
- Interannual variability has a more complex dependence on remote forcing from neighboring ocean basins, local forcing plays much smaller role

Outlook:

- Dissect and analyze remote contributions to interannual variability
- Consider Ekman and geostrophic transport as separate objective functions for correspondance with observations

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