The Surface-Forced Overturning of the North Atlantic: Estimates from Modern Era Atmospheric Reanalysis Datasets

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Outline

1. The Surface-Forced Overturning and the AMOC
2. Estimates of the Mean Surface-Forced Overturning
3. Estimates of the Time Varying Surface-Forced Overturning

Surface-Forced Overturning

Marsh (2000) described (but did not test) a method that might allow ‘the meridional stream function to be largely inferred from surface fluxes alone”.

We’ve examined this possibility using output from:

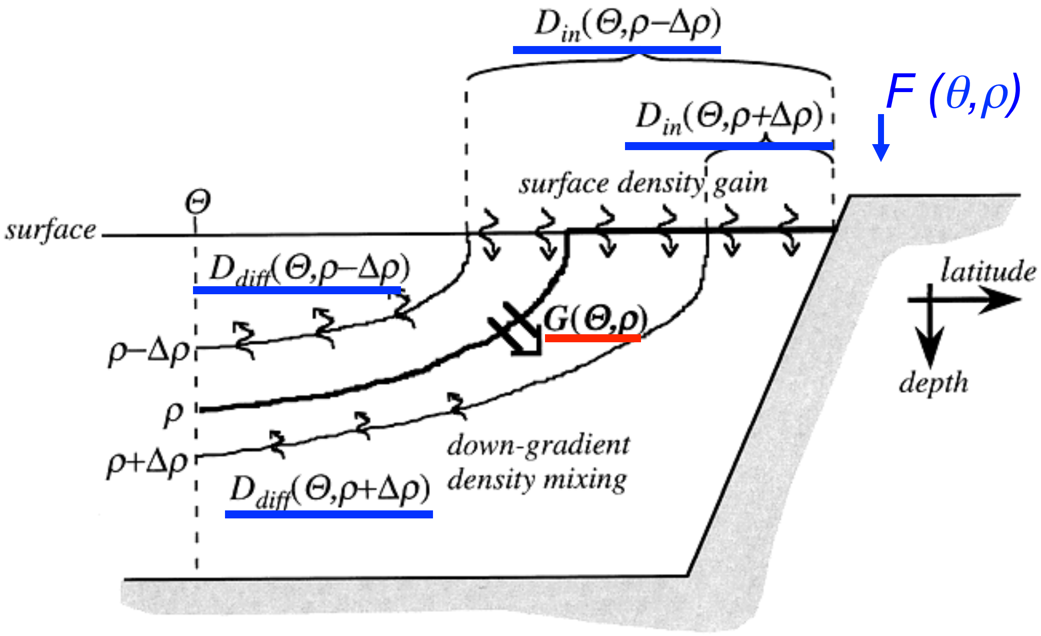
1) Three IPCC coupled climate models. (100-400 years of GFDL2.1, BCM, HadCM3) (Grist et al. *J. Climate* 2009; Josey et al. 2009).

2) Eddy-permitting (1/4 º) ocean only model (88 years of ORCA-025, ‘NEMO’) (Grist et al., *JGR-Oceans* 2012).

Surface-Forced Overturning

Walin (1982), Nurser et al. (1999), Marsh (2000)

Net diapycnal volume flux, G (Θ,ρ) and Diapycnal density fluxes D (Θ,ρ) in an idealized North Atlantic.



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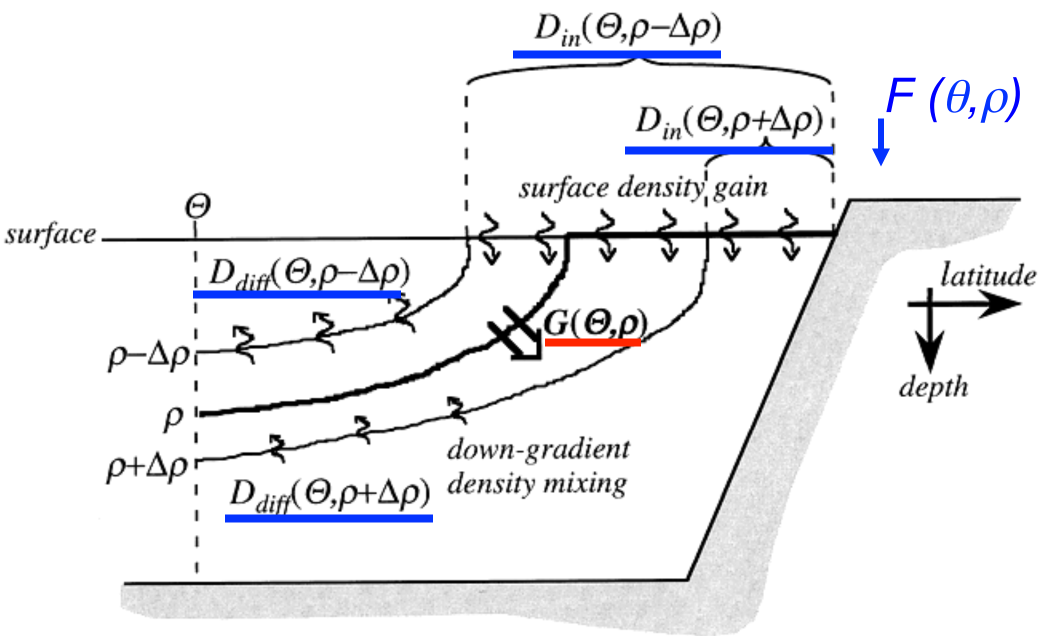

$$G(\Theta,\rho) = F(\Theta,\rho) - \frac{\partial D_{diff}(\Theta,\rho)}{\partial \rho} + C(\Theta,\rho)$$

$$F(\Theta,\rho) = \frac{\partial D_{in}(\Theta,\rho)}{\partial \rho}$$

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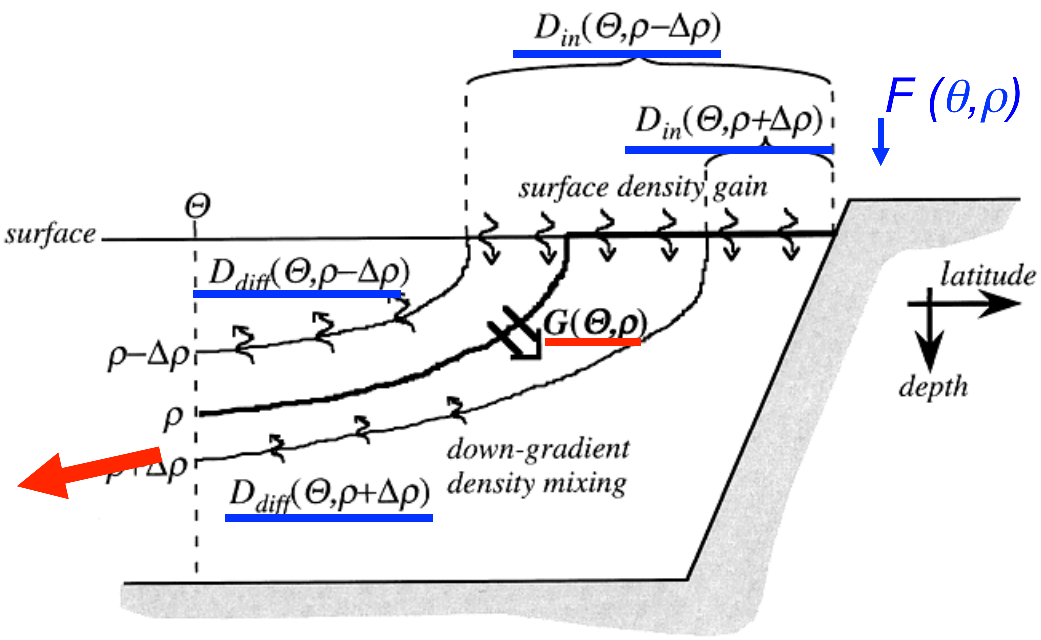

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$\psi\ (\Theta,\rho) = G\ (\Theta,\rho)$

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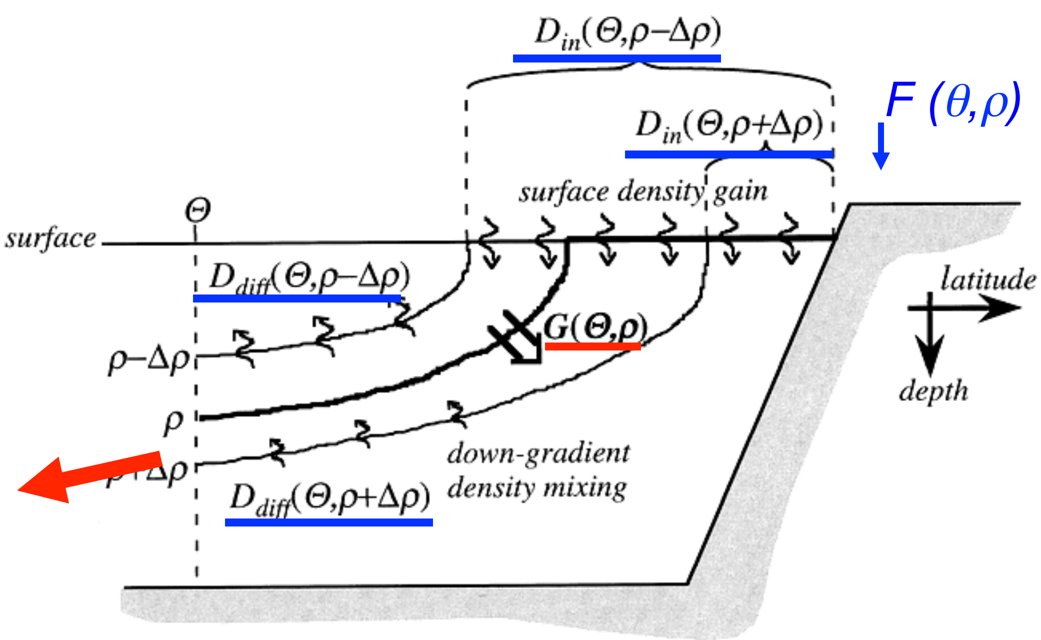

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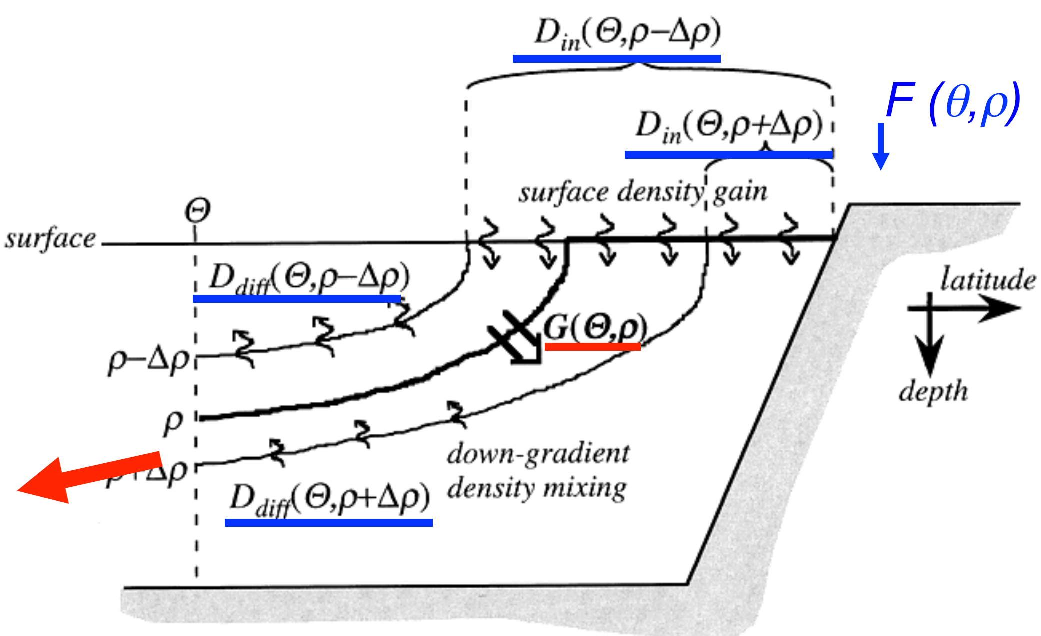

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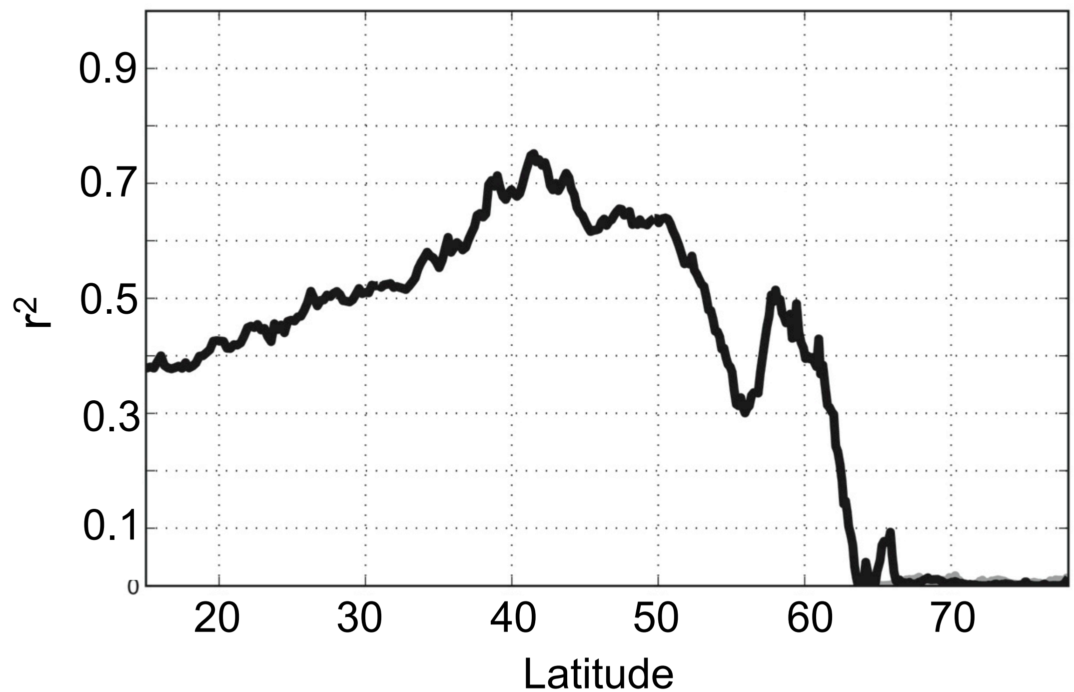
$\psi\ (\Theta,\rho)$ *lags* $G\ (\Theta,\rho)$

Greatest agreement if *AMOC related to average Surface Forced signal over previous 10 years.*

Grist et al. (J. Climate, 2009; JGR-Oceans, 2012)

Fraction AMOC(σ) Explained by Surface-Forced Overturning: ¼º NEMO Ocean Model



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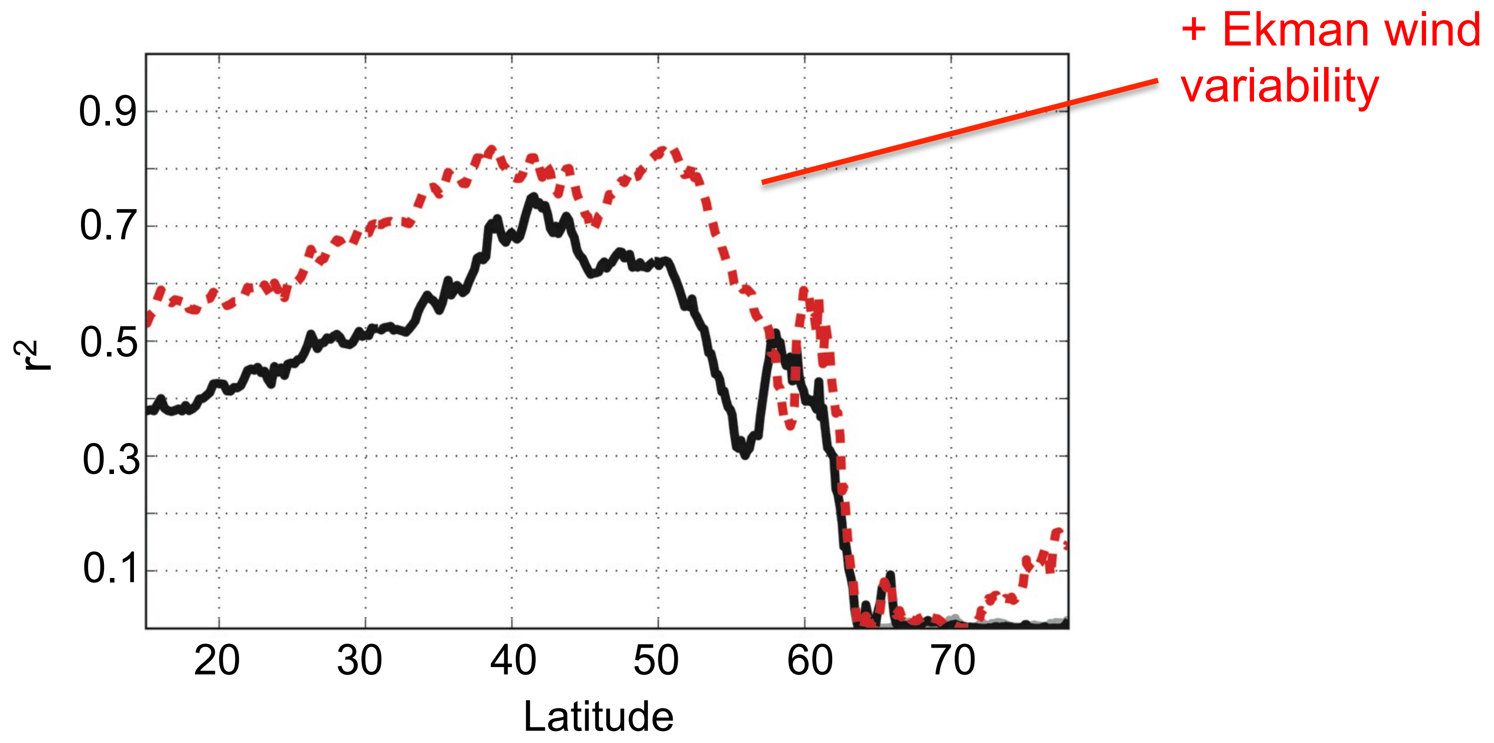

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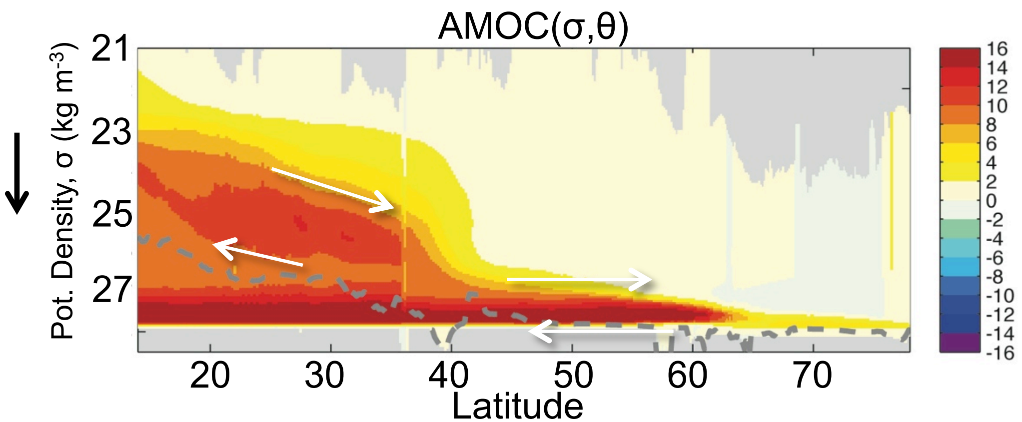
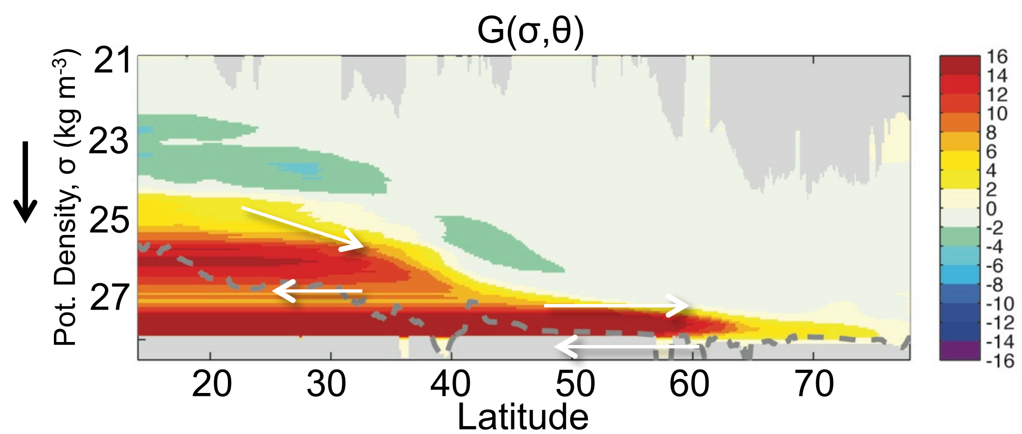
Mean Surface-Forced Overturning:
¼º NEMO





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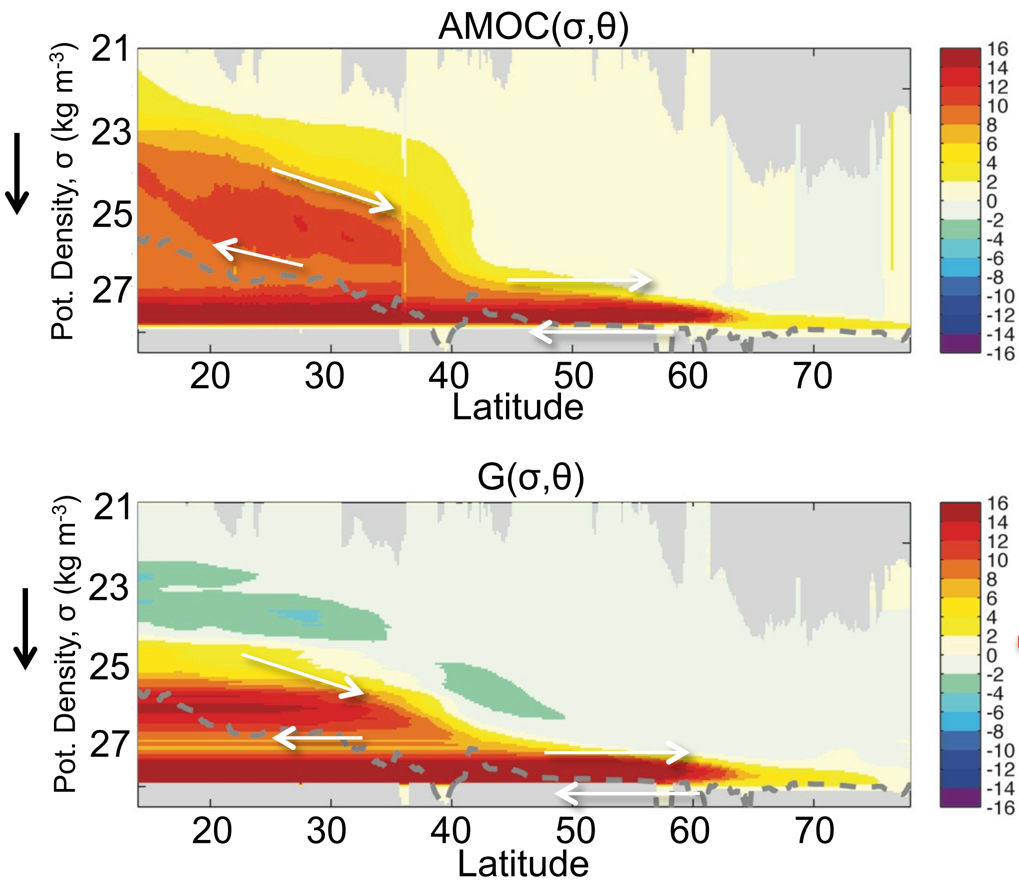
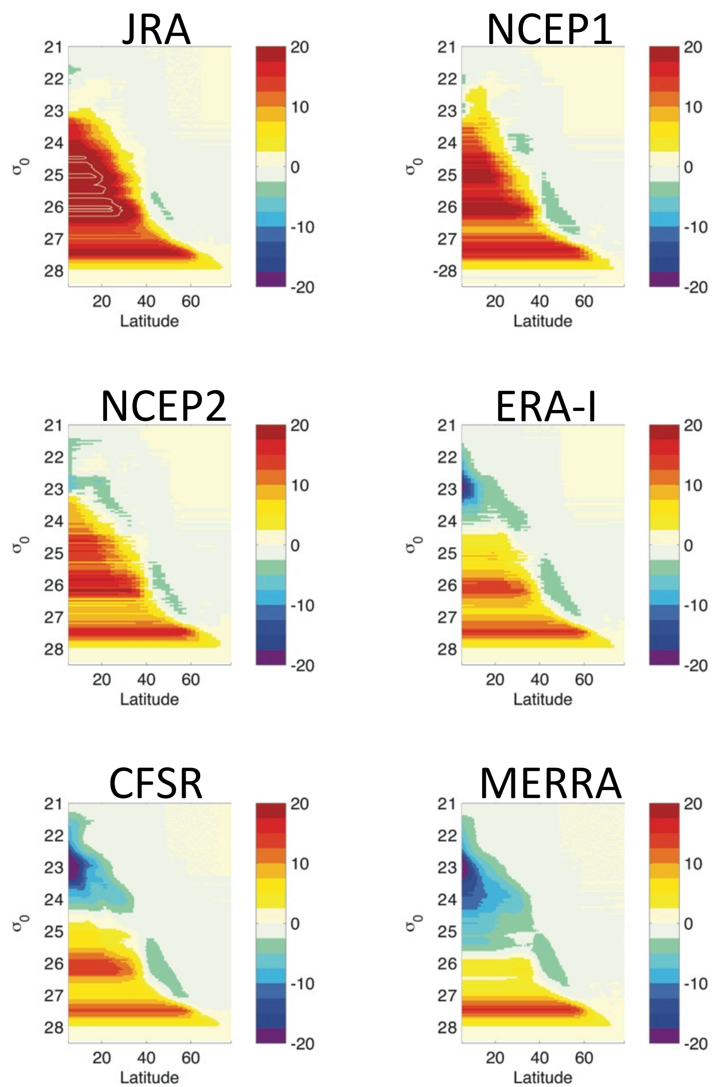


12 Estimates:
6 Reanalysis products
2 Salinity Products
(WOA & EN3)

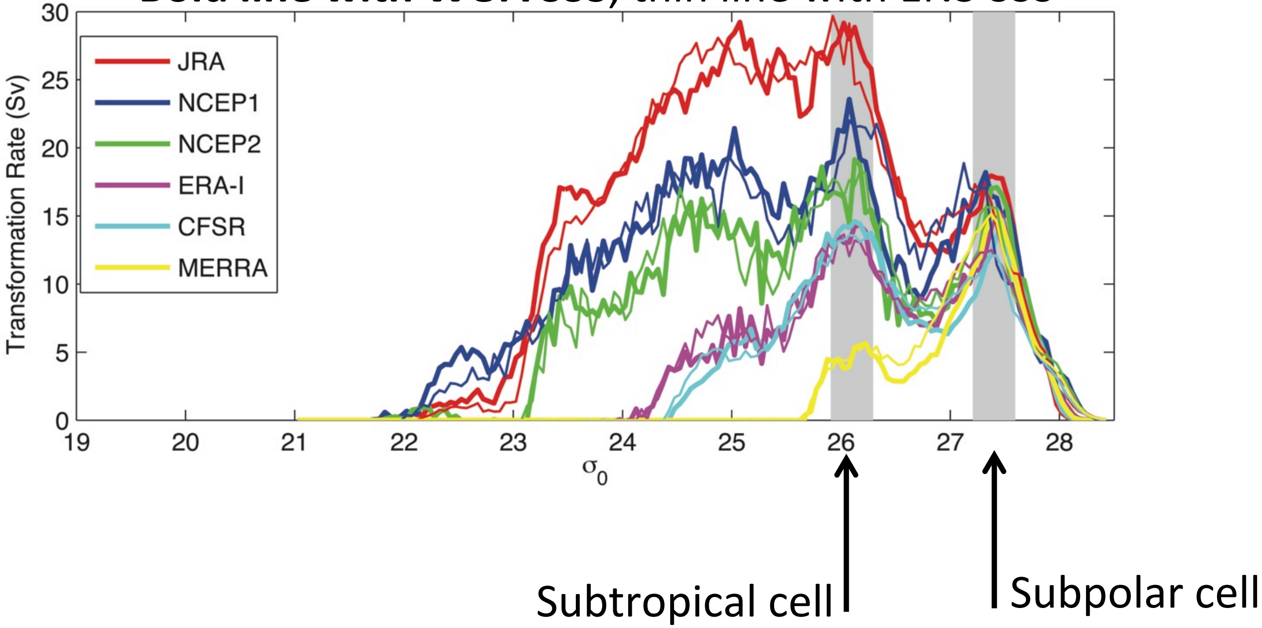
Mean Surface-Forced Overturning:
Atmospheric Reanalysis Products

1979-2007
SSS from WOA

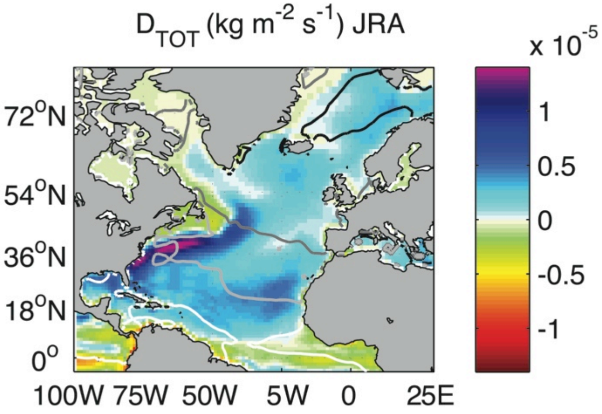


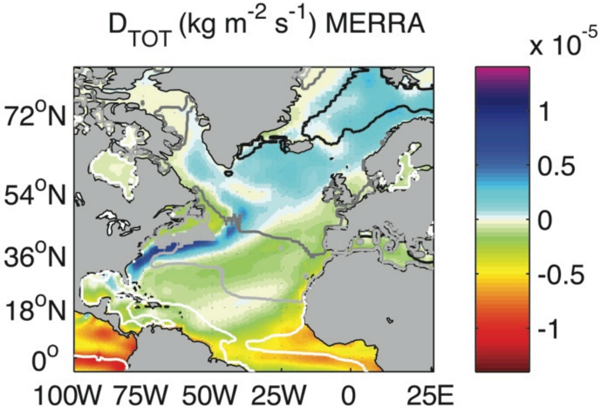
Mean Surface-Forced Overturning: Atmospheric Reanalysis Products

Maximum overturning (Sv) for density range:
Bold line with WOA SSS, thin line with EN3 SSS

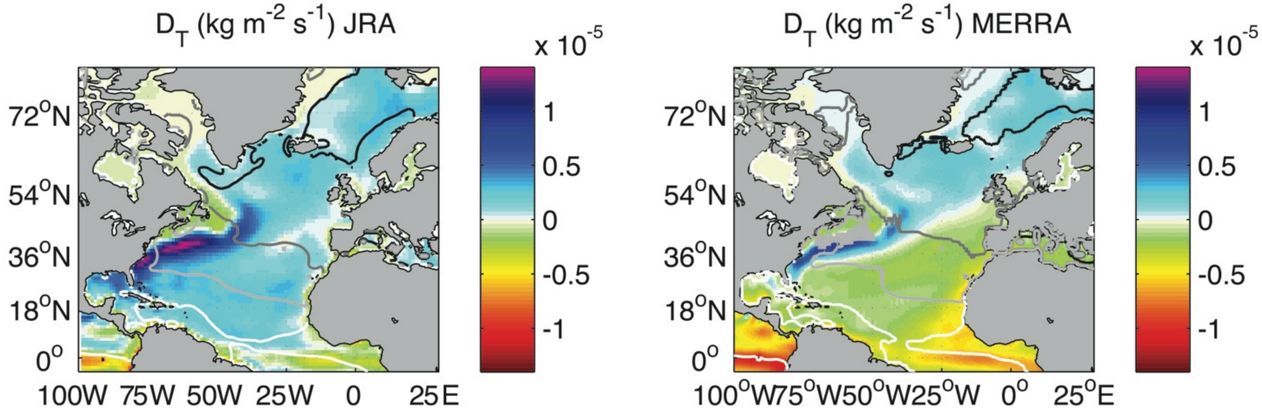


Mean Surface-Forced Overturning:
Estimates of Total Surface Density Flux

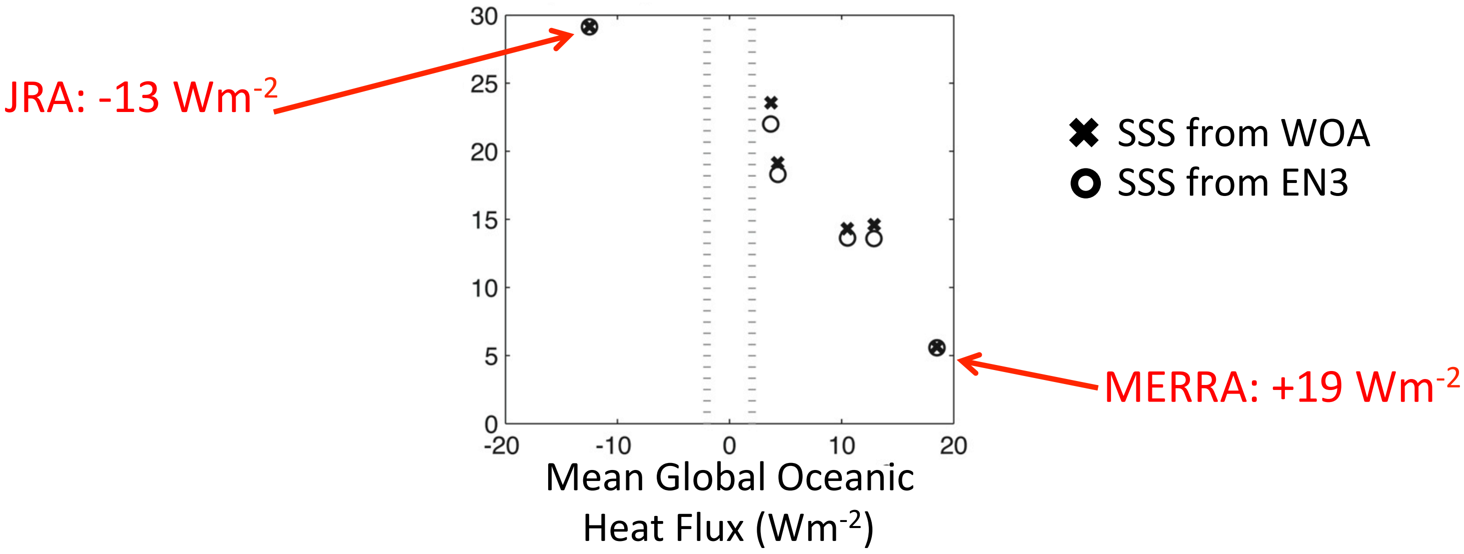




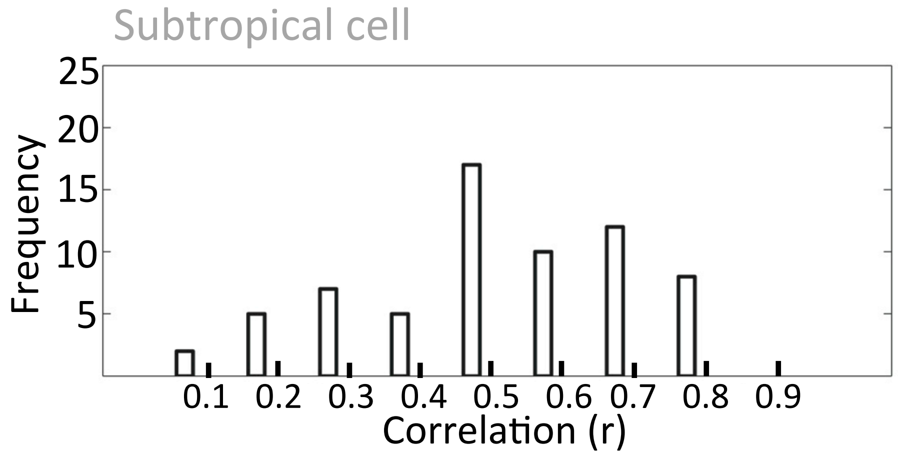
Mean Surface-Forced Overturning:
Estimates of Thermal Surface Density Flux



Mean Surface-Forced Overturning:
Sub-Tropical Transformation Rate vs Bias in Global Ocean Heat Budget



Surface-Forced Overturning:
Correlation (r) Between Time Series from Different Reanalysis Estimates



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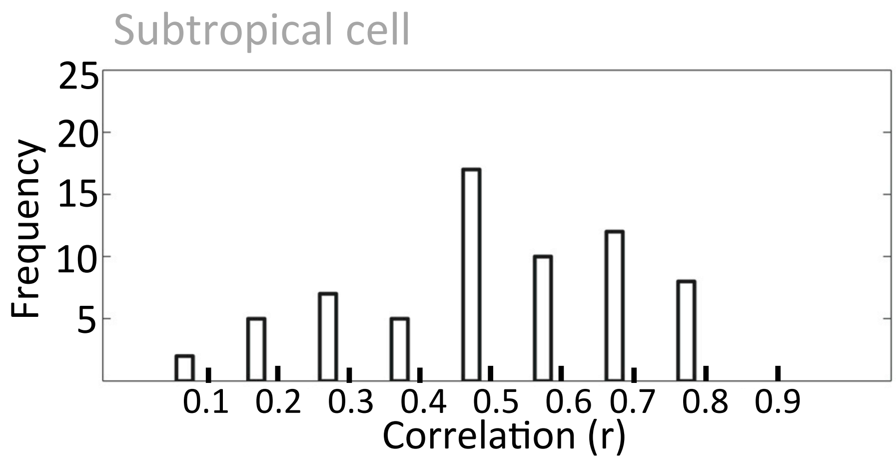
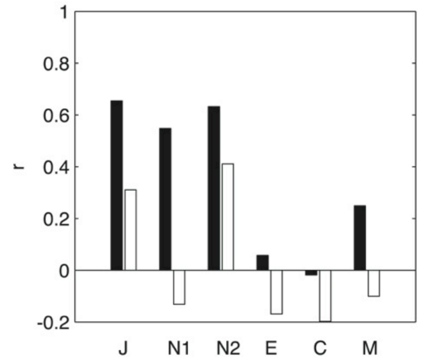


- Estimate STMW Formation Rate
- Inferred change STMW Volume
- Compared to Observations



Only 2 estimates significantly Correlated with observations.

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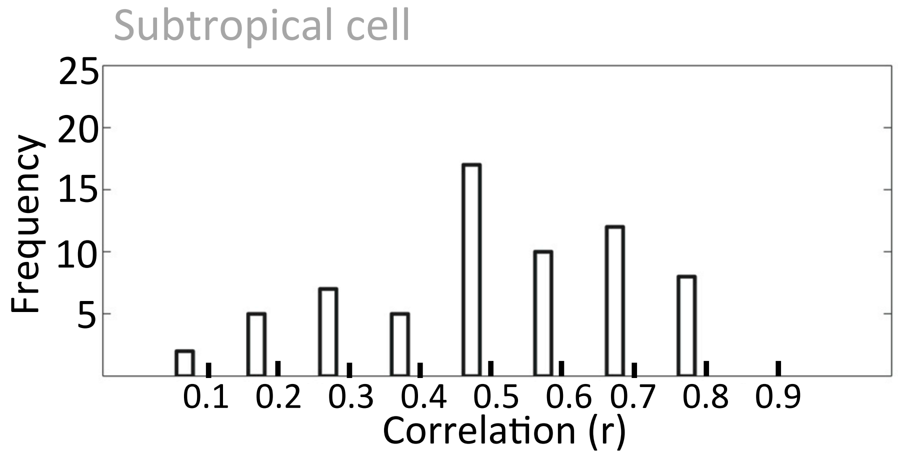

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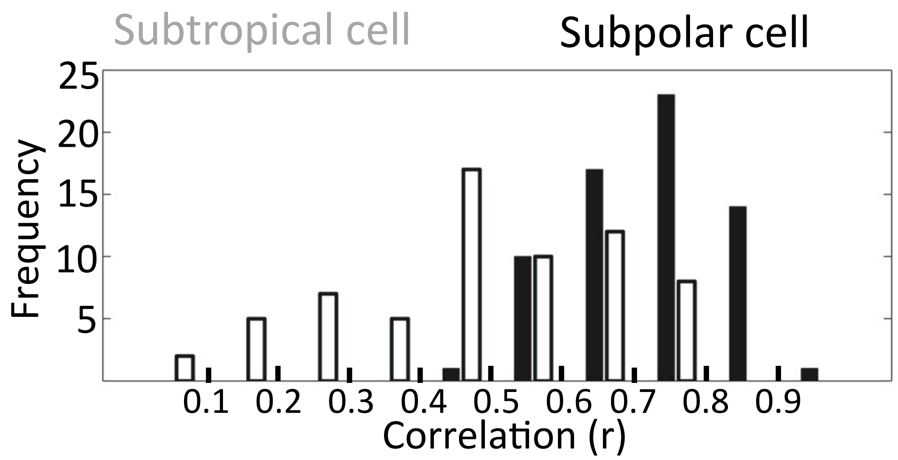
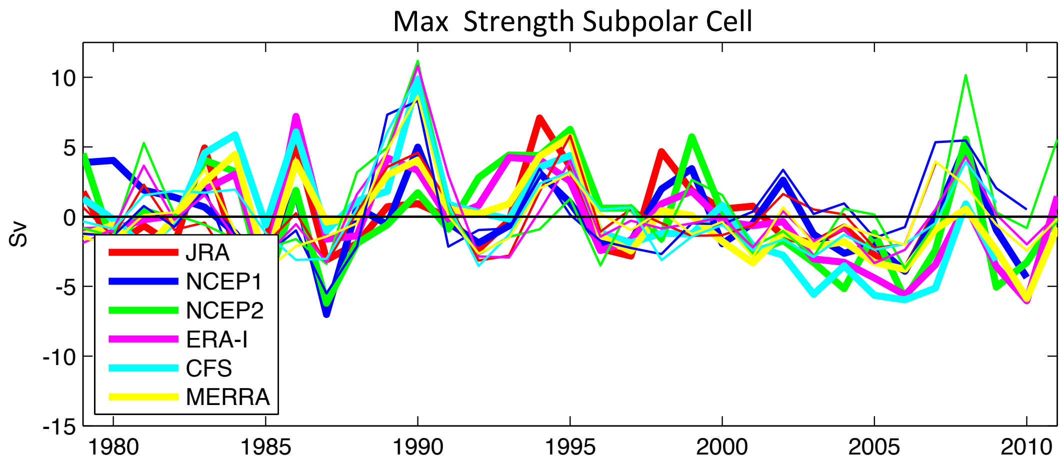


Surface-Forced Overturning: Subpolar Time Series from Different Reanalysis Estimates



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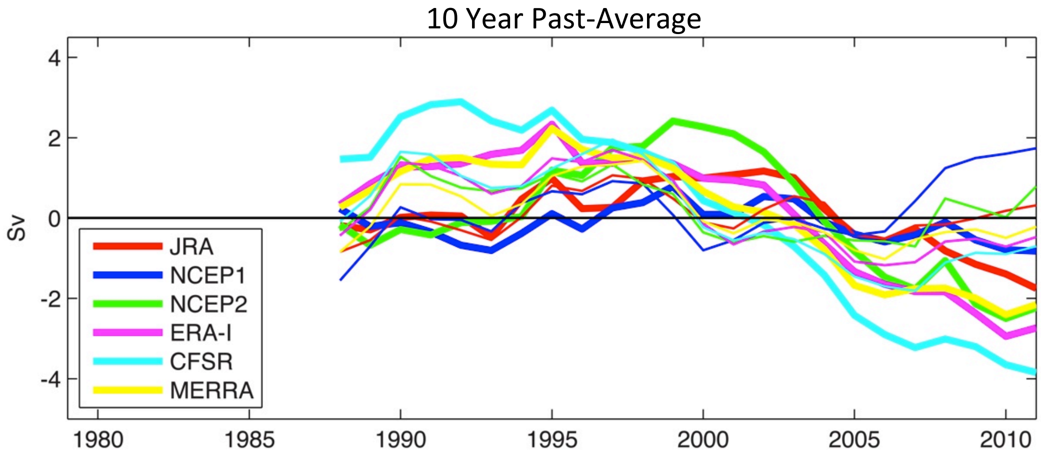

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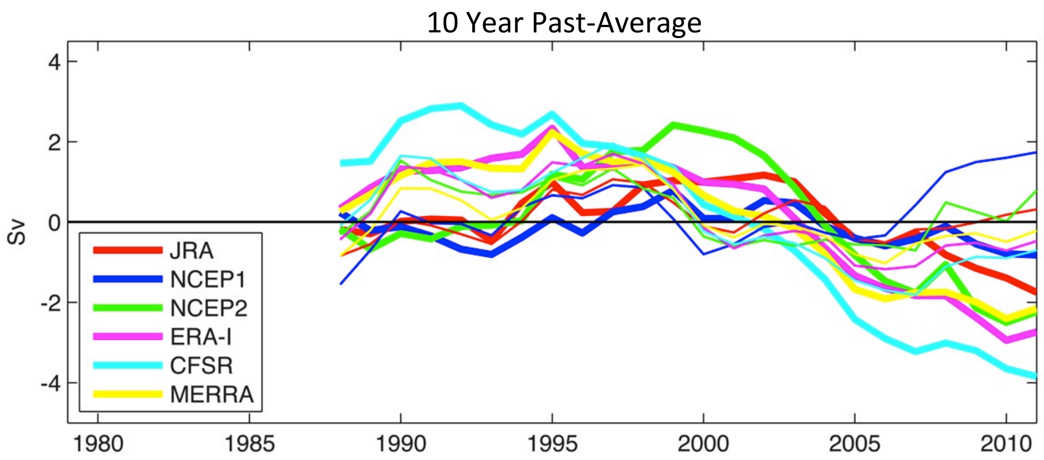

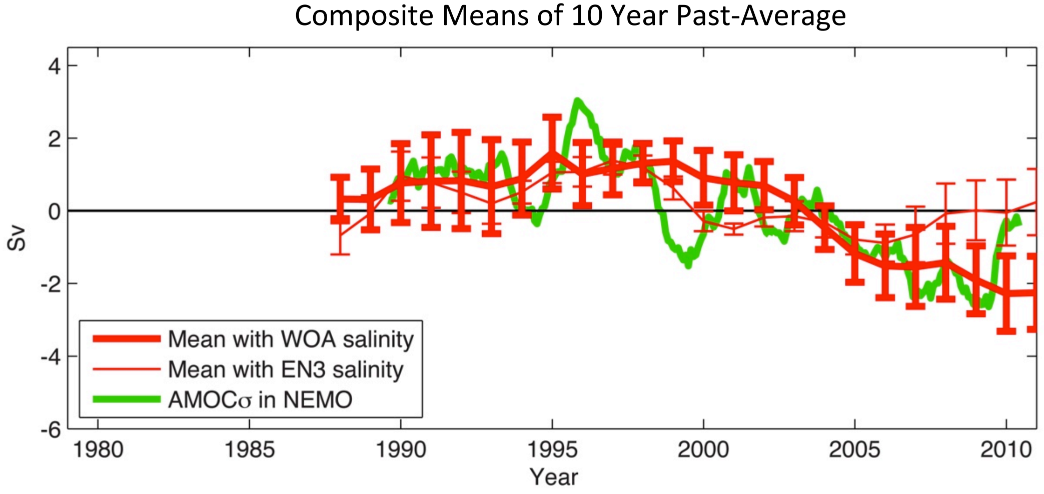

Summary

- In ¼º NEMO ocean model, the water mass transformation method can be used to estimate AMOC variability.
- The method shows greatest potential between 33ºN and 54ºN where 70-84% of the AMOC (σ) variance is explained.
- As the method relies only on surface observations, estimates of AMOC variability can be made for the reanalysis era.
- *Sub-tropics:* *Reanalyses yield a large range in transformation rates. Influenced by biases in Global Ocean heat budget.*
- *Some estimates poorly correlated with each other. Only 2 capture significant fraction of observed STMW variability.*
- *Sub-polar region:* *Reanalysis products show mean surface-forced sub-polar overturning 12-18 Sv.*
- *Better temporal agreement than in sub-tropics: Common features of inferred AMOC change: High 1990s, low or normal since 2005.*
- *Grist et al. 2013 (submitted to J. Climate).*