Optimal Atmospheric Excitation of AMOC as Estimated via Application of the FDT

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(Simplified, Quasi-gaussian) Fluctuation Dissipation Theorem

(Leith, 1975; Deker&Haake, 1975; Risken, 1984)

Suppose have a discretized dynamical system with noise and a F-P eqn with unique solutions. Also assume gradients of the system PDF are well approximated by a Gaussian fit. Then the PDF-averaged response to weak forcing f is

$$r(t) = \int_{t_0}^{t} C(t-\tau)C^{-1}(0)f(\tau)\,d\tau$$

$$\text{for } C(\tau) = \text{lag}-\tau \text{ cov matrix}$$

Sufficient data to find *C*

Atmospheric applications:

* *Gritsun, Branstator (2007)*
* *Gritsun, Branstator, Majda (2008)*
* *Liu et al. (2012)*

CCSM4

T31, 3deg 8000 year control

$$\begin{bmatrix} T(t) \\ S(t) \\ u(t) \\ v(t) \end{bmatrix} = r(t) = \mathbf{M}_t \bar{f} = \mathbf{M}_t \begin{bmatrix} \dot{T} \\ \dot{S} \\ \dot{u} \\ \dot{v} \end{bmatrix}$$

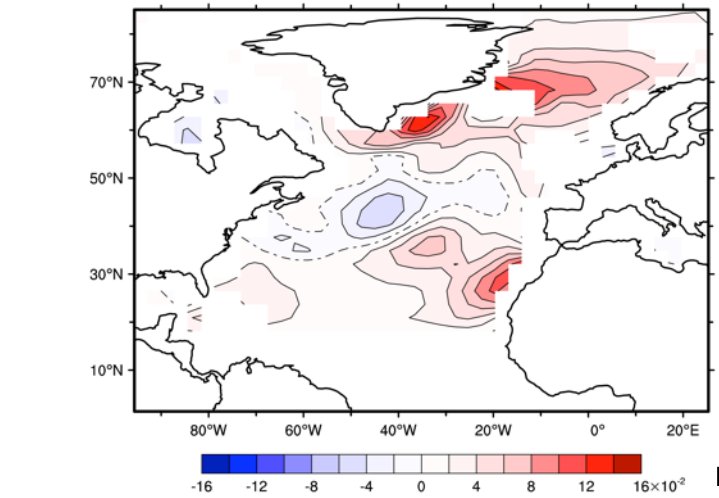
state of multivariate 3D fields
is represented by 675 EOFs

Optimal N Atlantic Salinity Forcing of AMOC

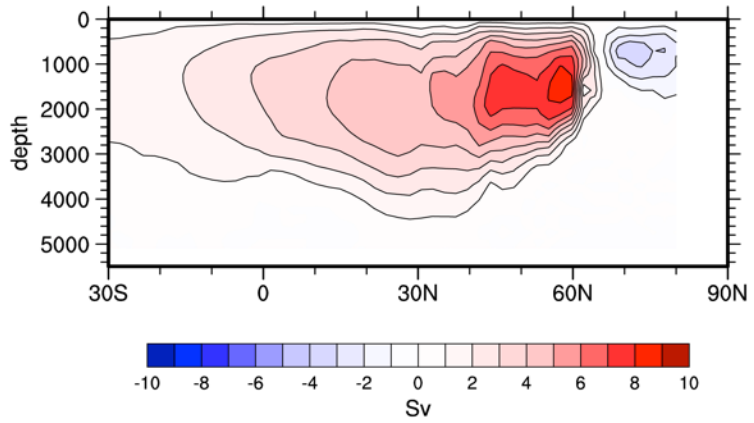
5 year forcing; year 5 response

force 0-100m

SV1 35x



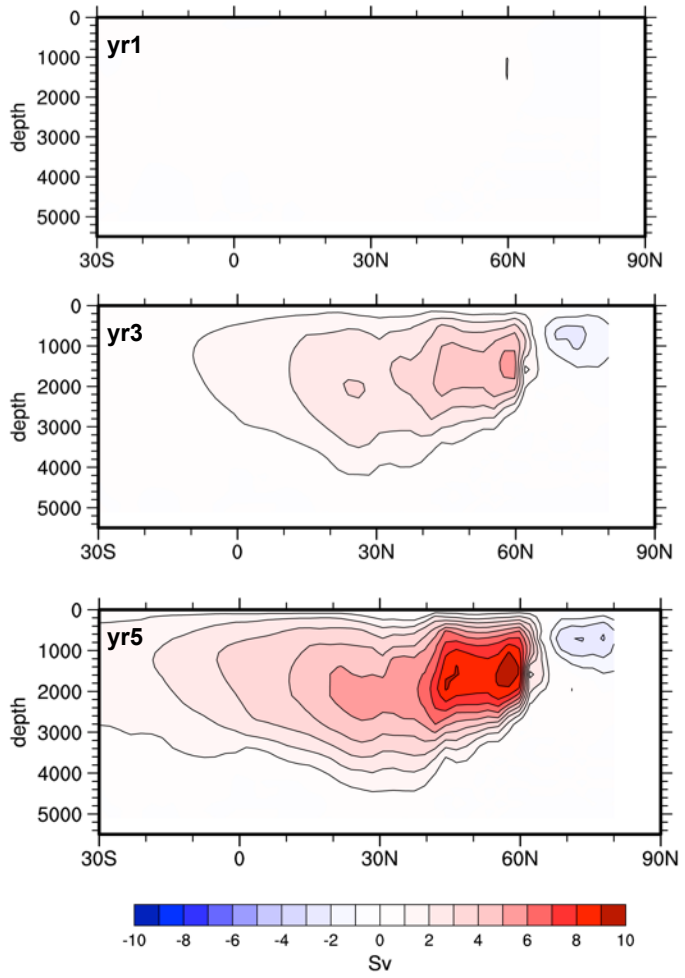
PSU/mon



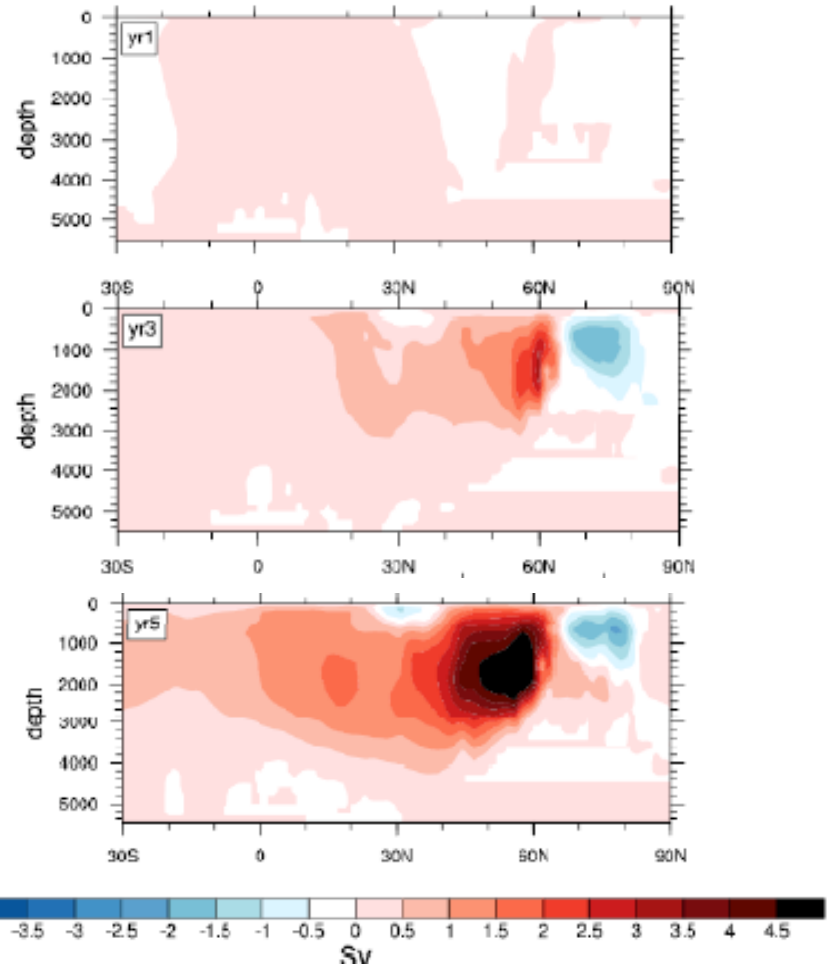
Optimal & CCSM4 Response of AMOC to Salinity Forcing

force 0-100m

FDT response
SV1



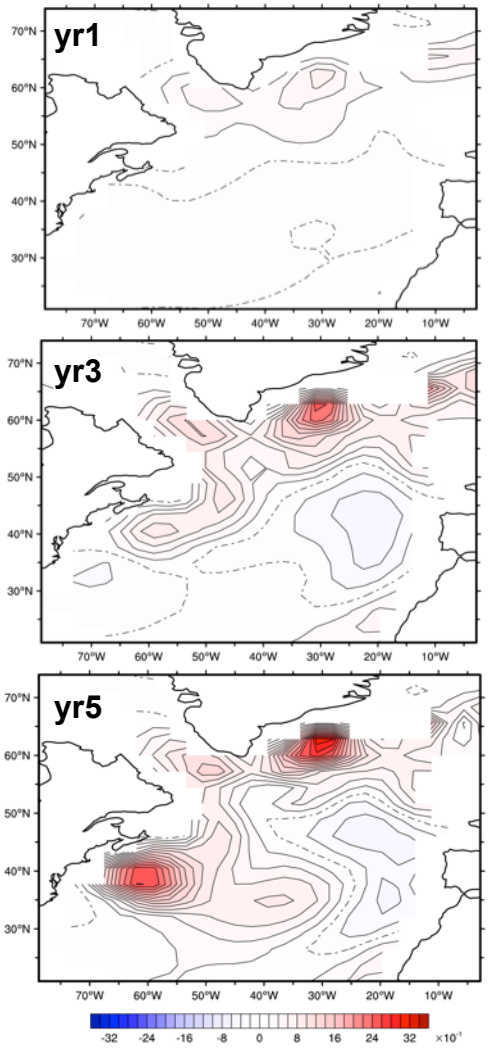
difference of two
20 member CCSM4 ensembles



FDT & CCSM4 SST Response to Optimal Salinity Forcing of AMOC

force 0-100m

FDT response



difference of two
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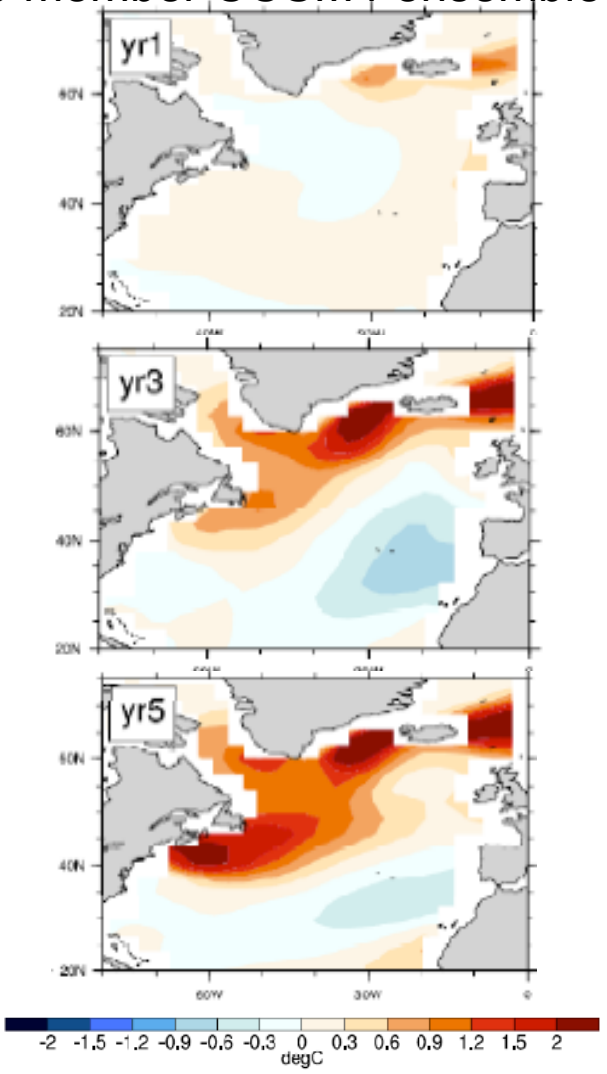


Remember

- FDT can be used to systematically study ocean response

- The leading patterns of AMOC variability do not depend on the existence of special atmospheric structures

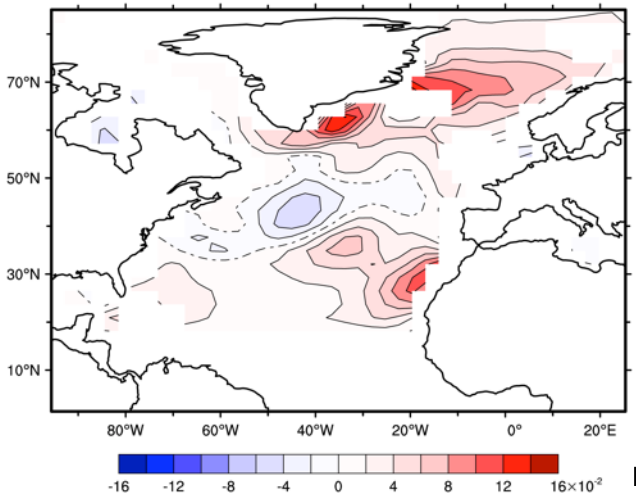
- The effect of a given atmospheric pattern on AMOC depends sensitively on details of its structure and of ocean dynamics

Optimal Salinity Forcing of AMOC

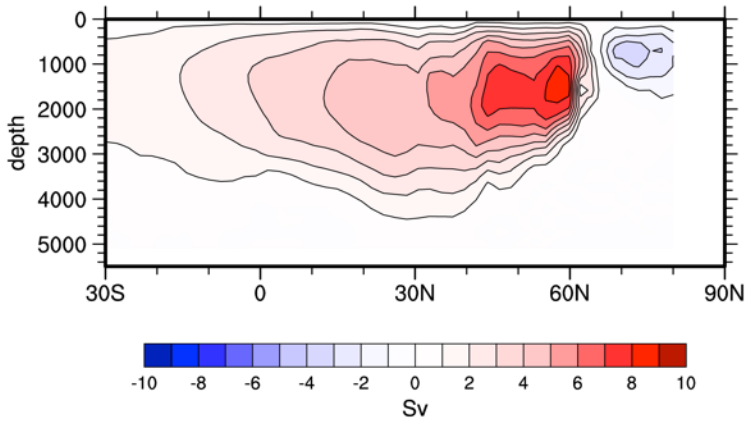
5 year forcing; year 5 response

force 0-100m

SV1 35x 62%

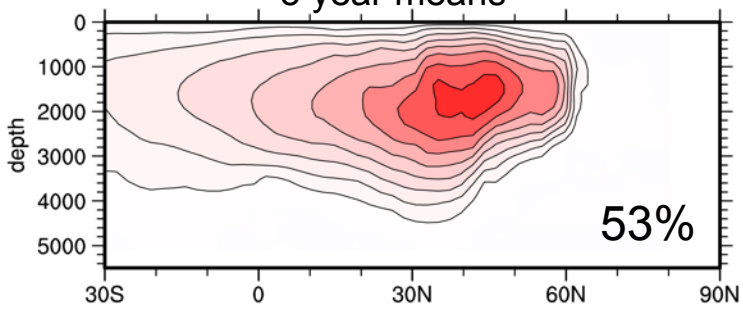


PSU/mon



CCSM4 EOF1

5 year means

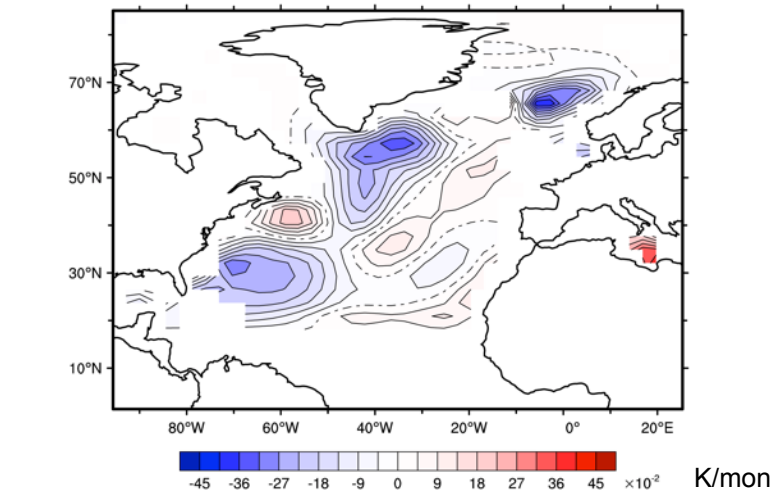


Optimal North Atlantic Temperature Forcing of AMOC

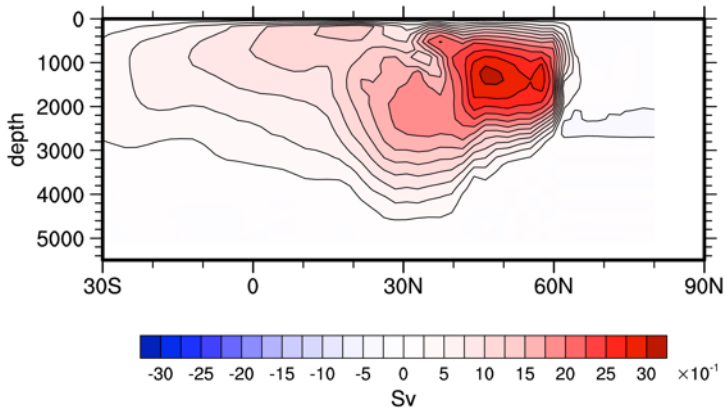
5 year forcing; year 5 response

force 0-100m

SV1 34x



K/mon

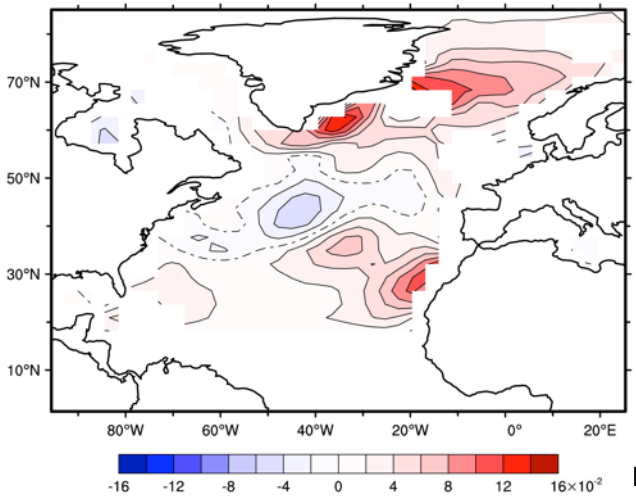


Optimal Salinity & Temperature Forcing of AMOC

5 year forcing; year 5 response

force 0-100m

SV1 35x



PSU/mon

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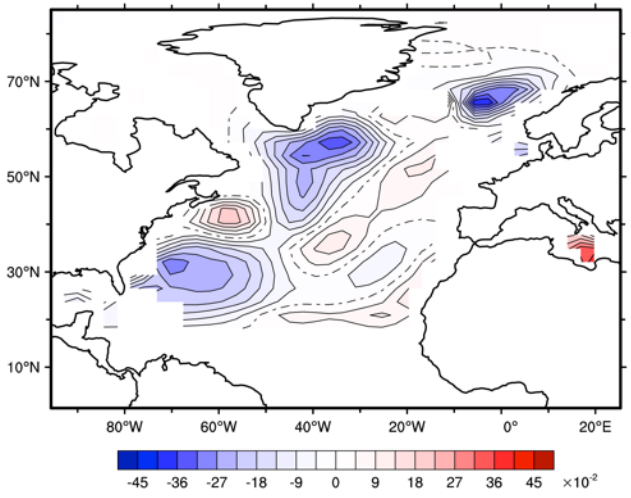
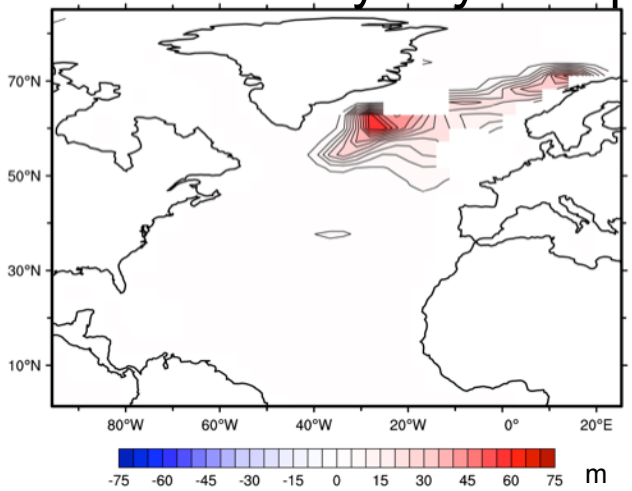


K/mon

Std Dev Boundary Layer Depth

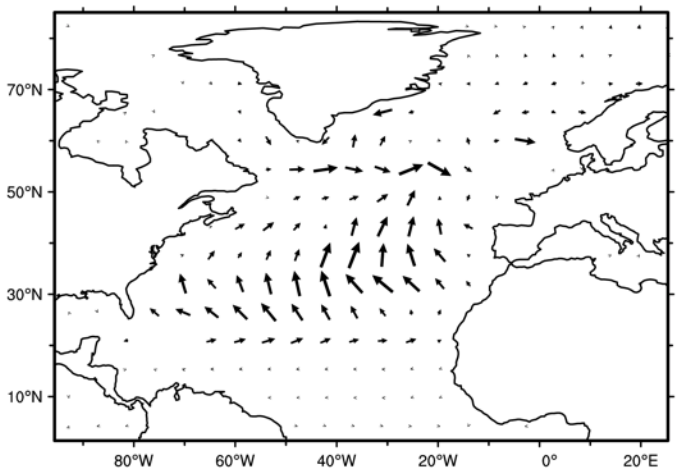


m

Optimal Excitation of AMOC by Currents in the North Atlantic

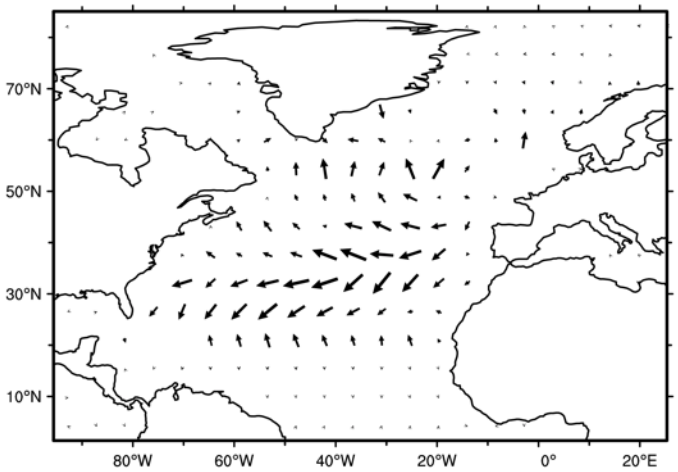
SV1 35x

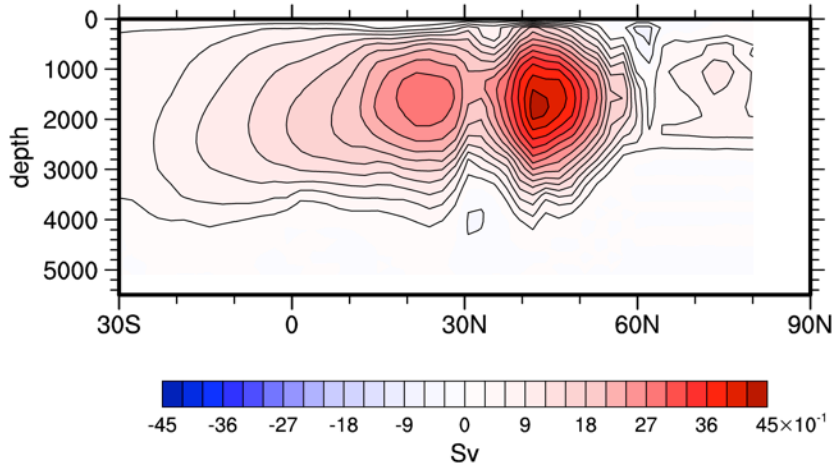
forcing of 0-100m currents



=7.2 cm s^{-1}/mon

wind stress





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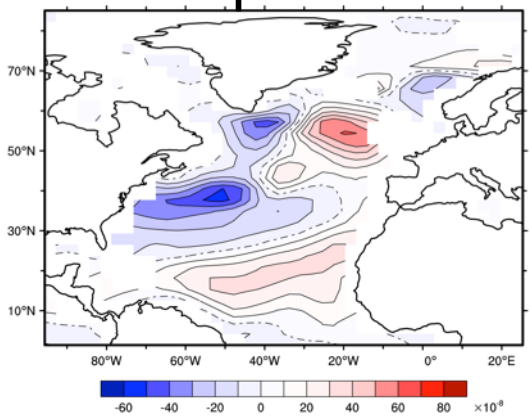
Comparing NAO Fluxes & Optimal Forcing

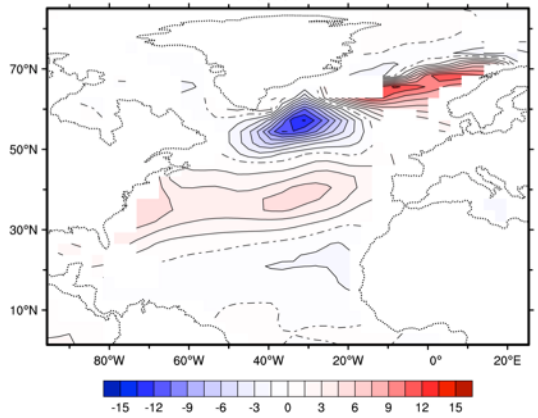
5 year forcing; year 5 response

NAO

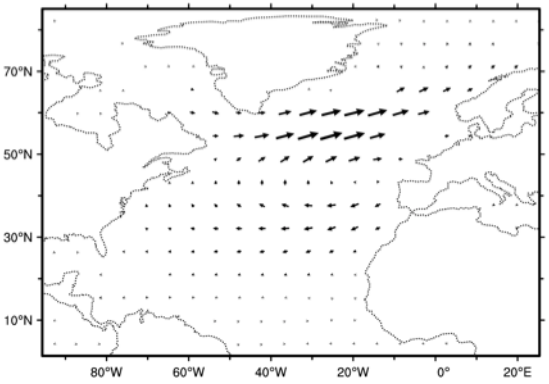
Evaporation



Surface heat flux

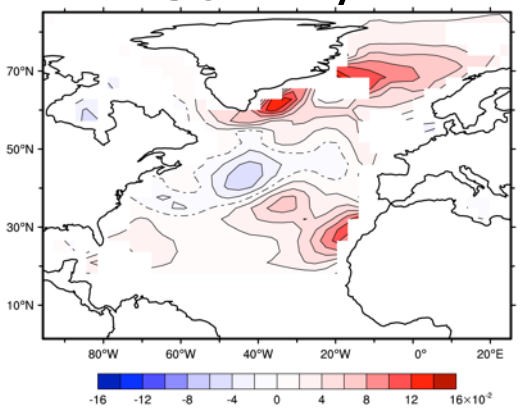


Wind stress

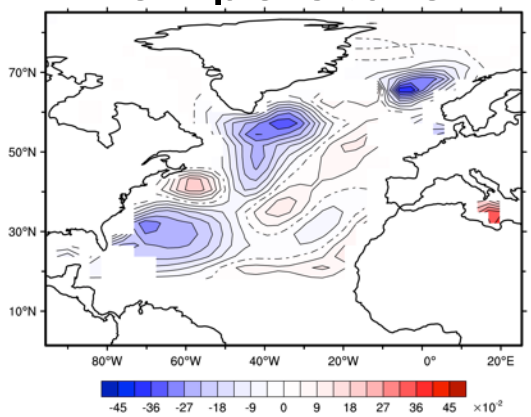


Optimal forcing
force 0-100m

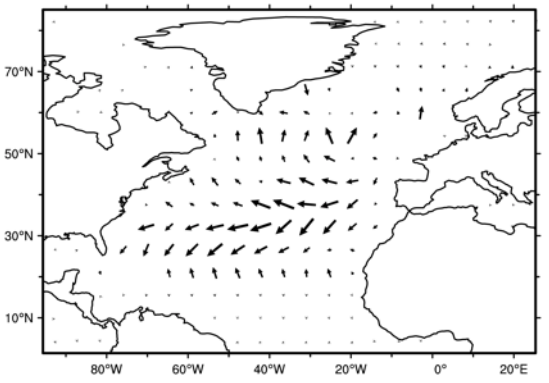
Salinity



Temperature



Wind stress



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