Alternatives to NAO driving of AMOC variability in CCSM4

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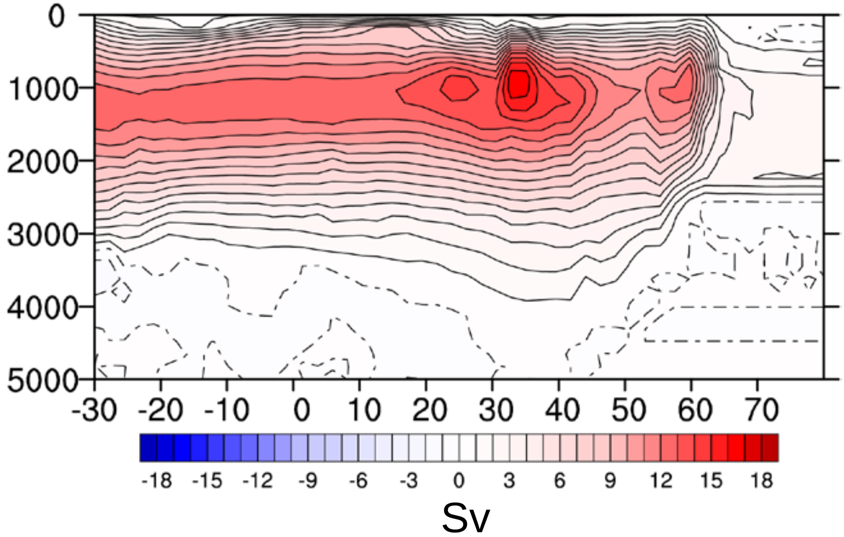
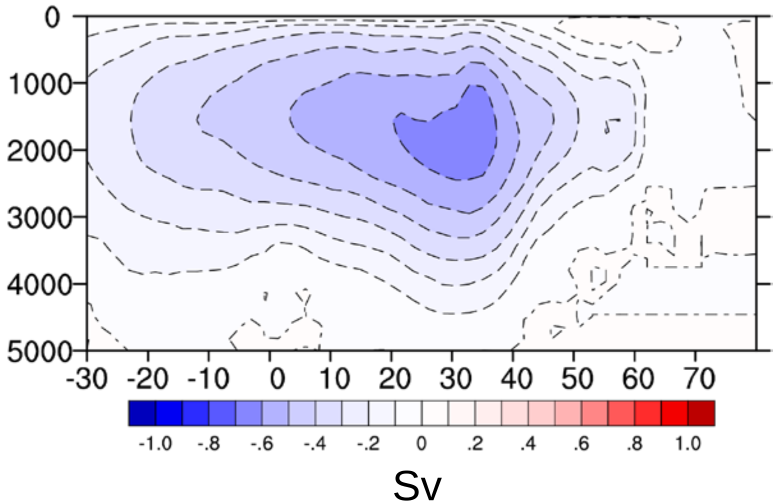
CCSM4 T31, 3° *Shields et al. (2012)*
17200 year control

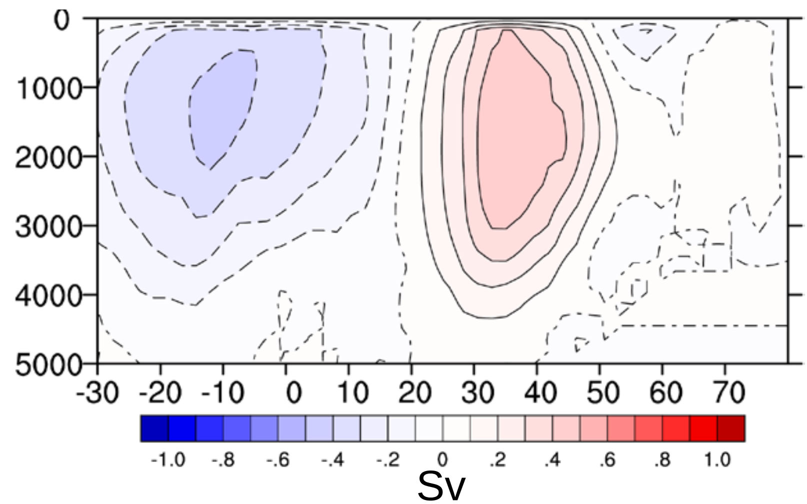
Mean AMOC



EOF1 35.6%

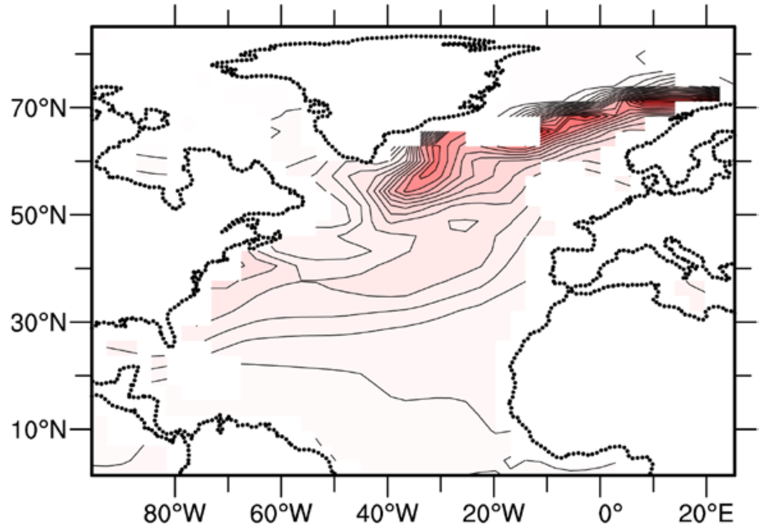


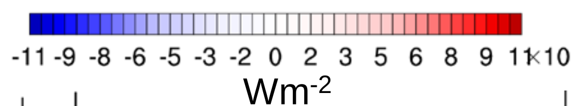
EOF2 19.5%



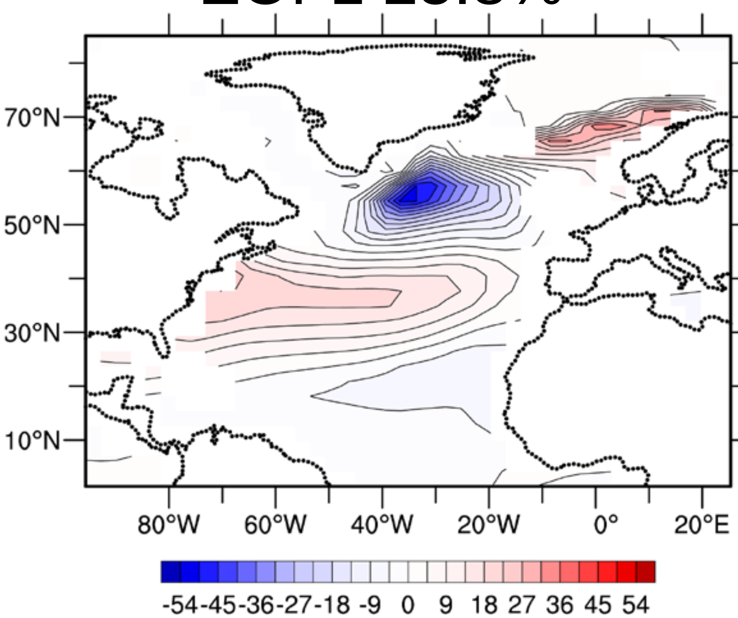
CCSM4 DJFM 1yr mean SHF

Std dev

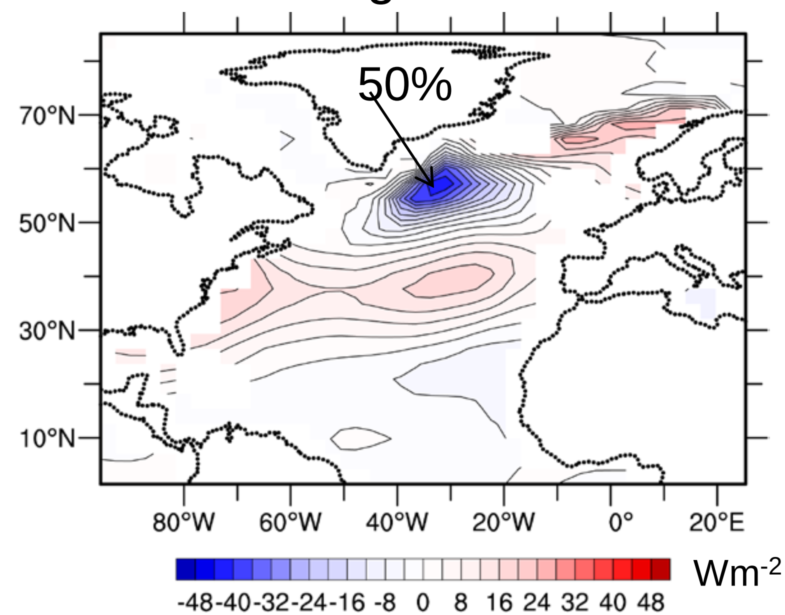




EOF1 25.8%



SHF regressed from NAO



Suppose have linear forced system,

$$\frac{\partial X}{\partial t} + \mathbf{L}X = R$$

Assume steady,

$$\mathbf{L}X = R$$

Say have complete set of eigenvectors

$$\mathbf{L}E_j = \sigma_j E_j$$

$$X = \sum_j s_j E_j$$

$$R = \sum_j r_j E_j$$

Then

$$X = \sum_j \frac{r_j}{\sigma_j} E_j$$

(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 R is

$$X(t) = \int_{t_0}^{t} \mathbf{C}(t-\tau)\mathbf{C}^{-1}(0)R(\tau)\,d\tau$$

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

For steady forcing

$$X(t) = \left[\int_{0}^{t} \mathbf{C}(t-\tau)\mathbf{C}^{-1}(0)\,d\tau\right] R_0$$

Sufficient data to find *C*

Atmospheric applications:

** Gritsun, Branstator (2007)*

** Gritsun, Branstator, Majda (2008)*

T31, 3deg CCSM4

$$\left[AMOC(t)\right] = \hat{X}(t) = \hat{\mathbf{M}}_t R = \hat{\mathbf{M}}_t \begin{bmatrix} \dot{T} \\ \dot{S} \\ \dot{u} \\ \dot{v} \end{bmatrix}$$

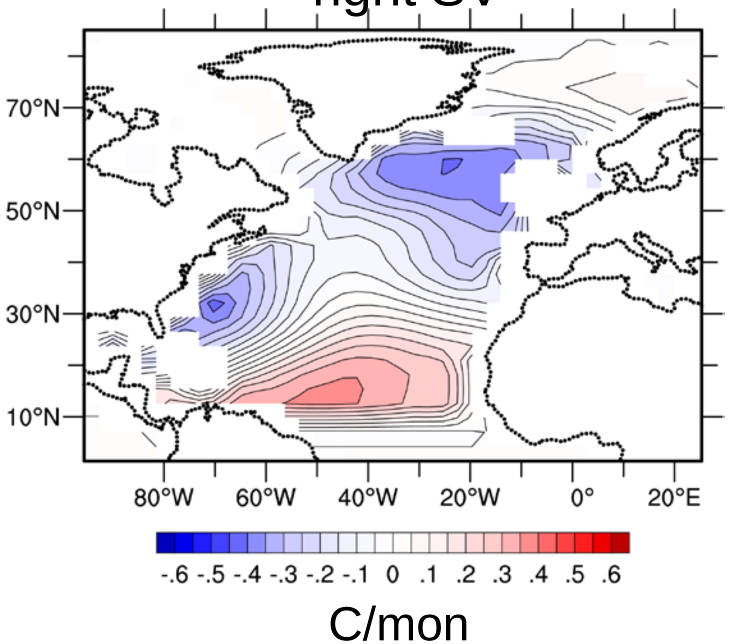
t = 5 yrs

singular value decomposition

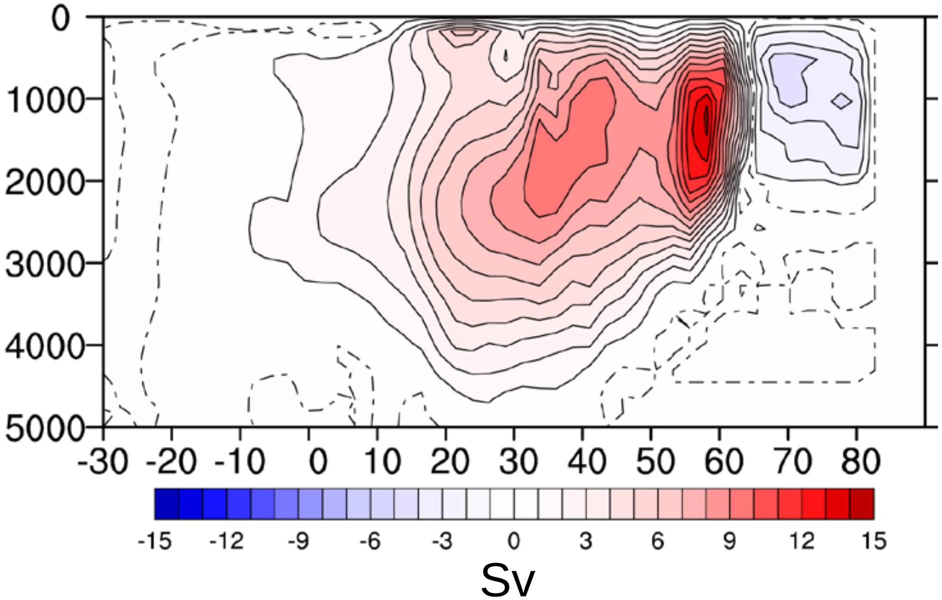
SV1 for thermal forcing in top 110m

maximizing yr 5 response

right SV

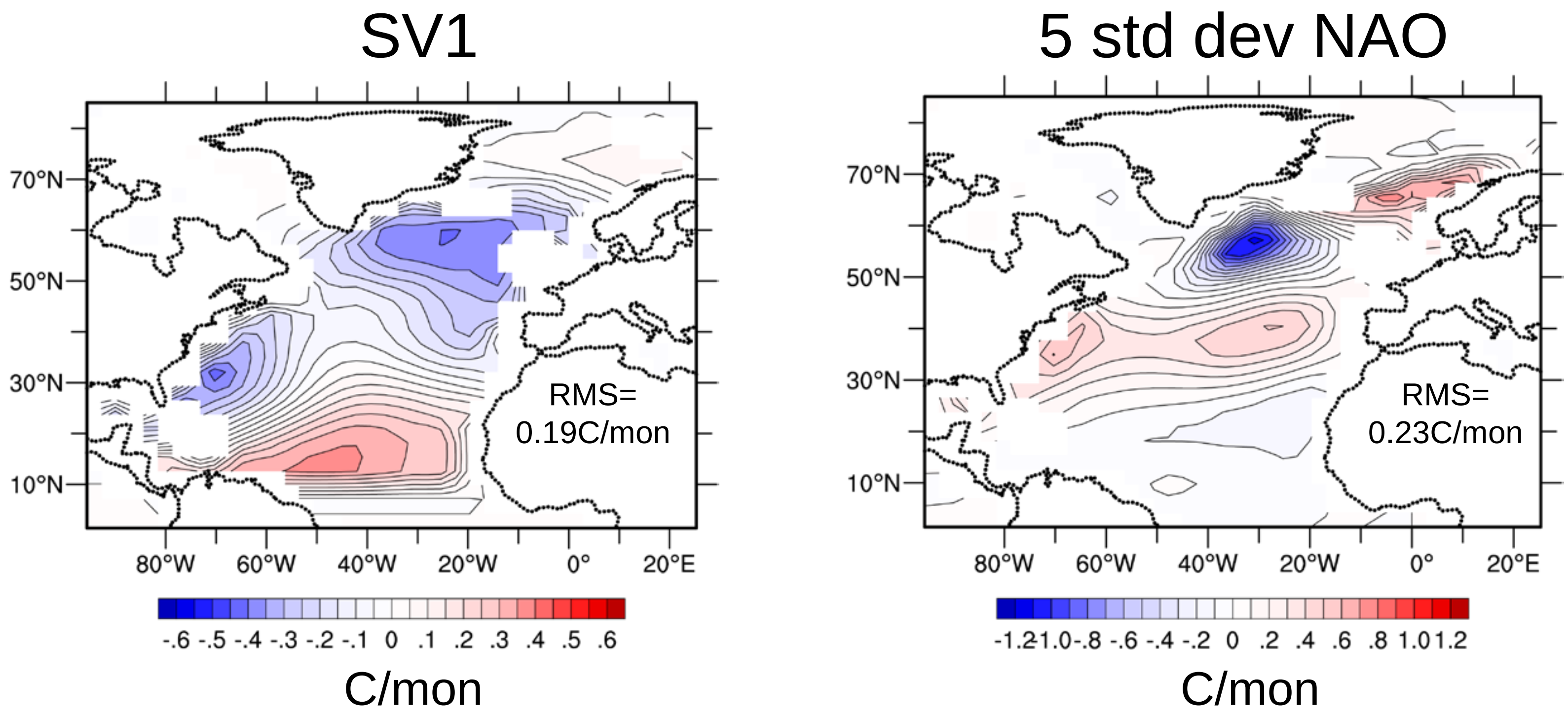


left SV

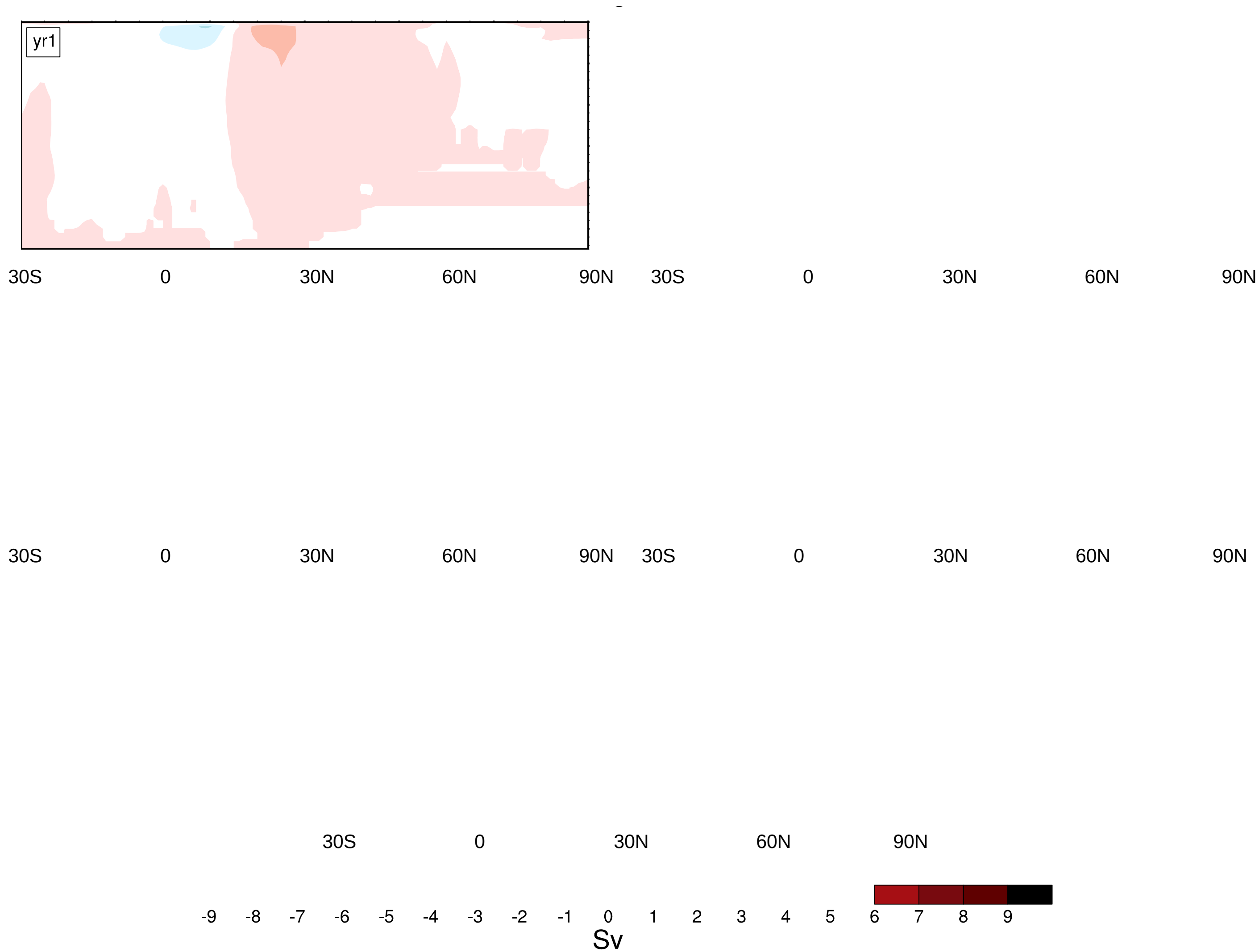


8 times average response to random forcing

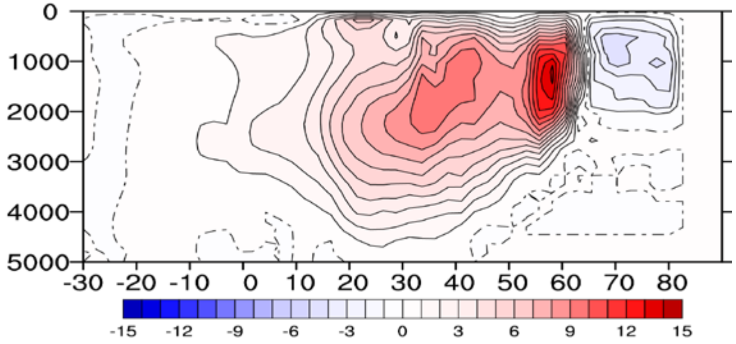
Thermal forcing in top 110m



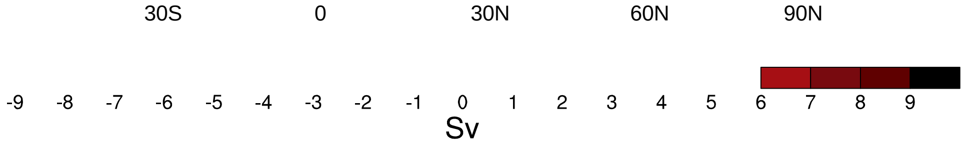
CESM AMOC response to thermal SV1



FDT yr 5 response to SV1temp

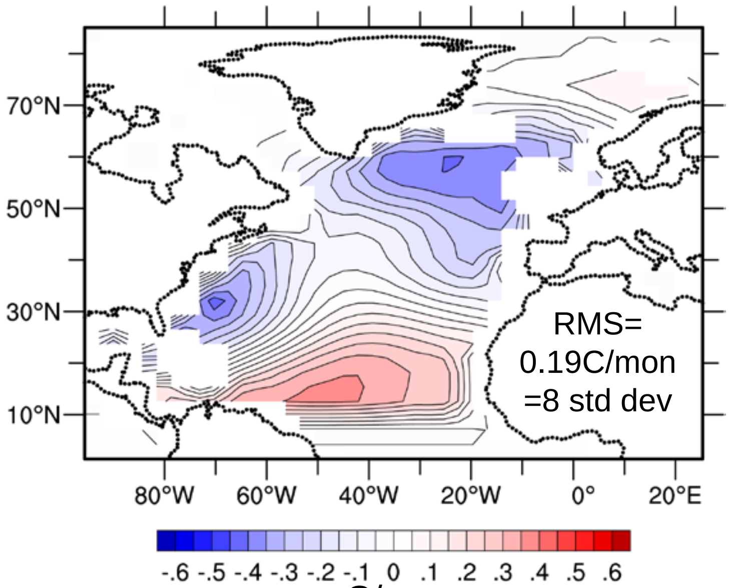


CESM yr 5 response to thermal SV1

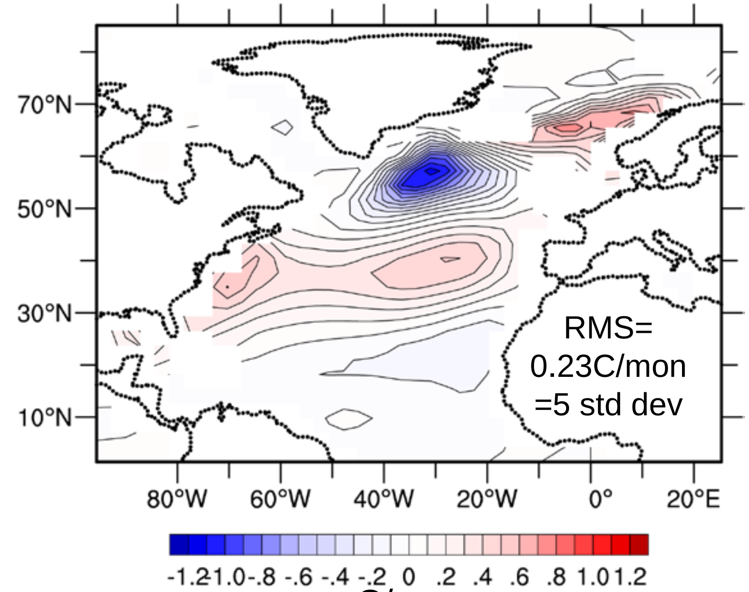


Thermal forcing in top 110m

SV1



NAO



CESM yr 5 AMOC response

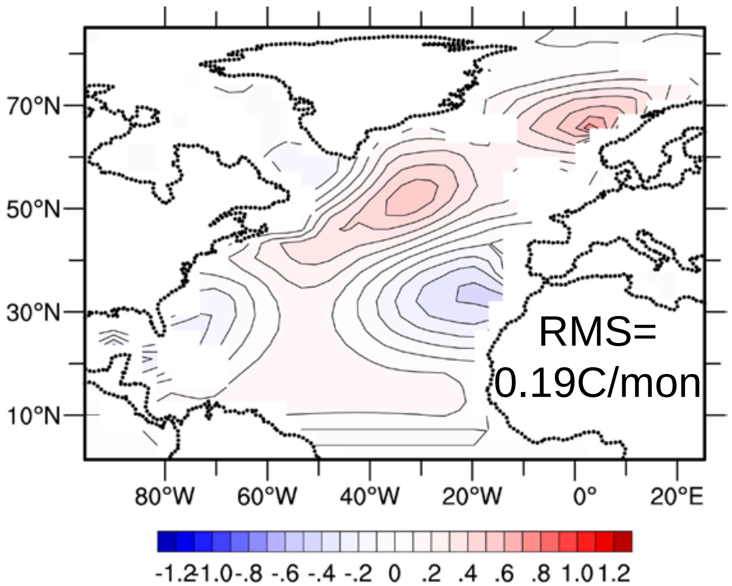
7Sv

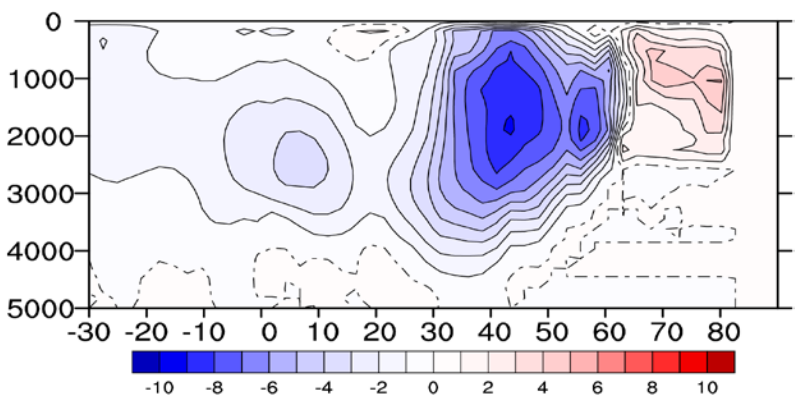
3Sv

30S 0 30N 60N 90N

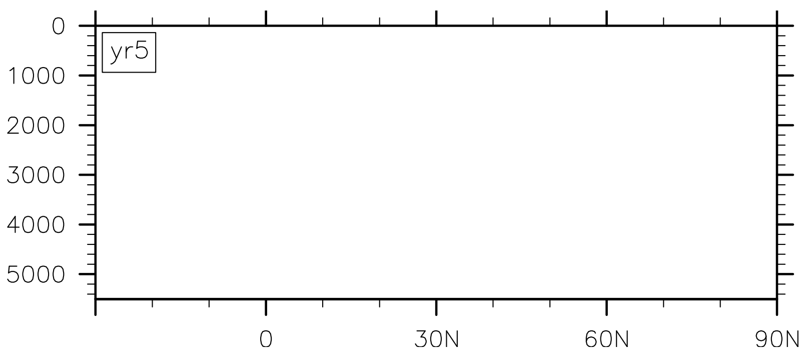
Thermal forcing in top 110m

SV2



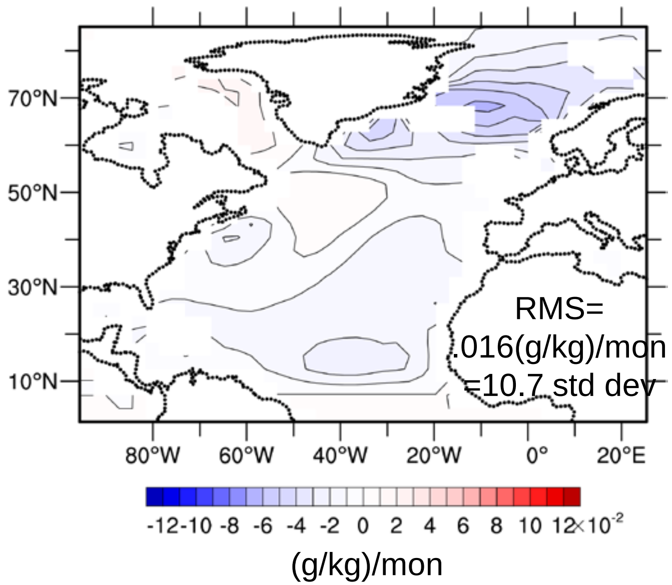


CESM yr 5 AMOC response

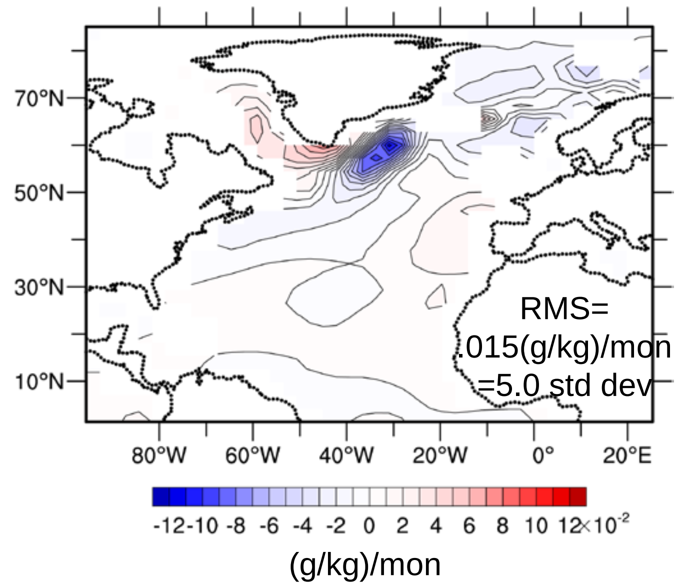


Salinity Forcing

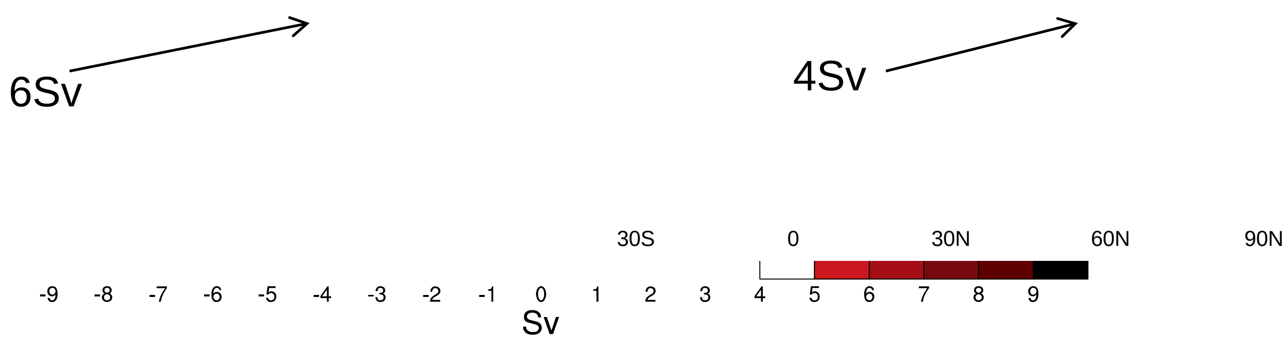
SV1



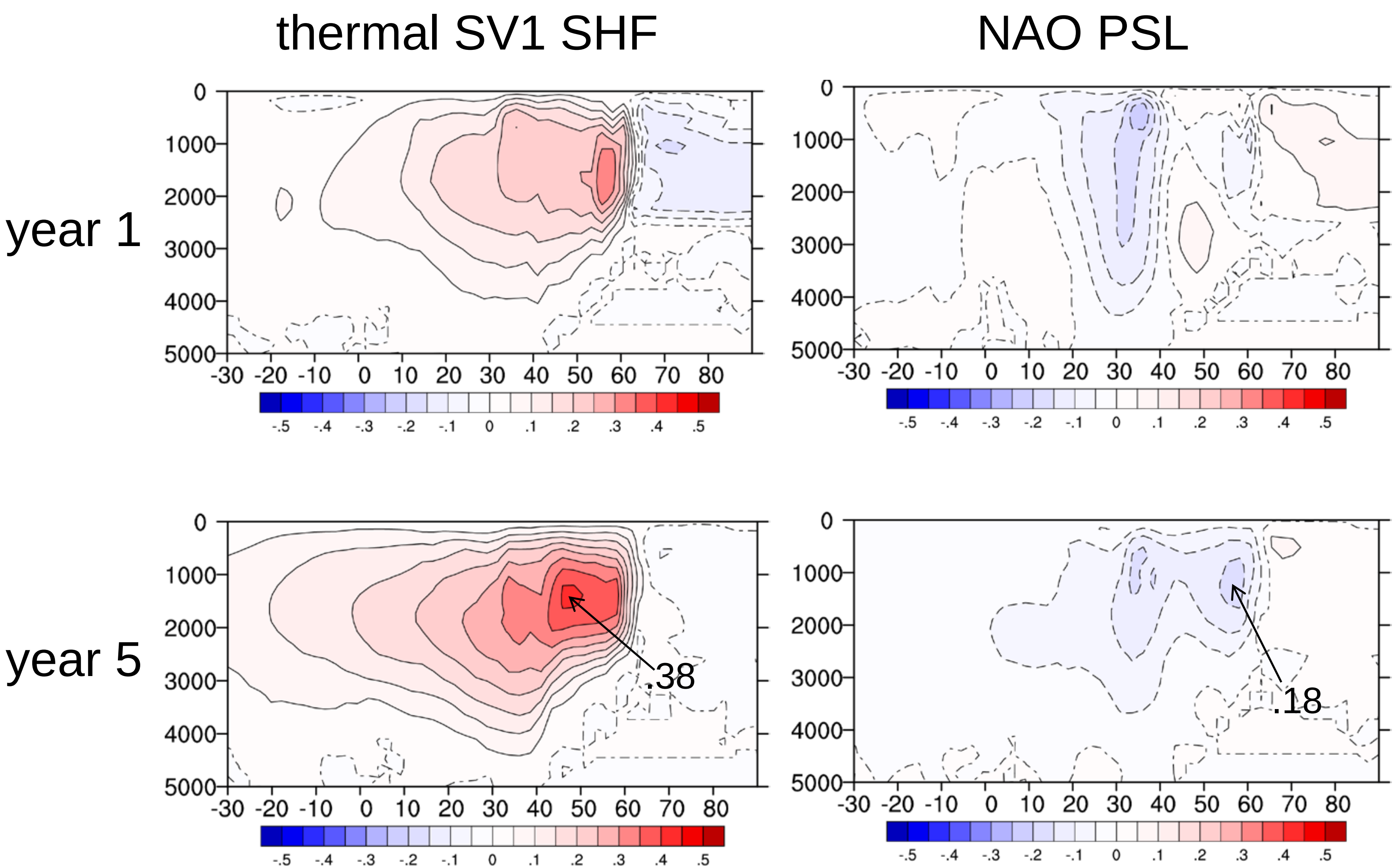
NAO



CCSM4 5yr AMOC response



AMOC after 5yr mean surface events



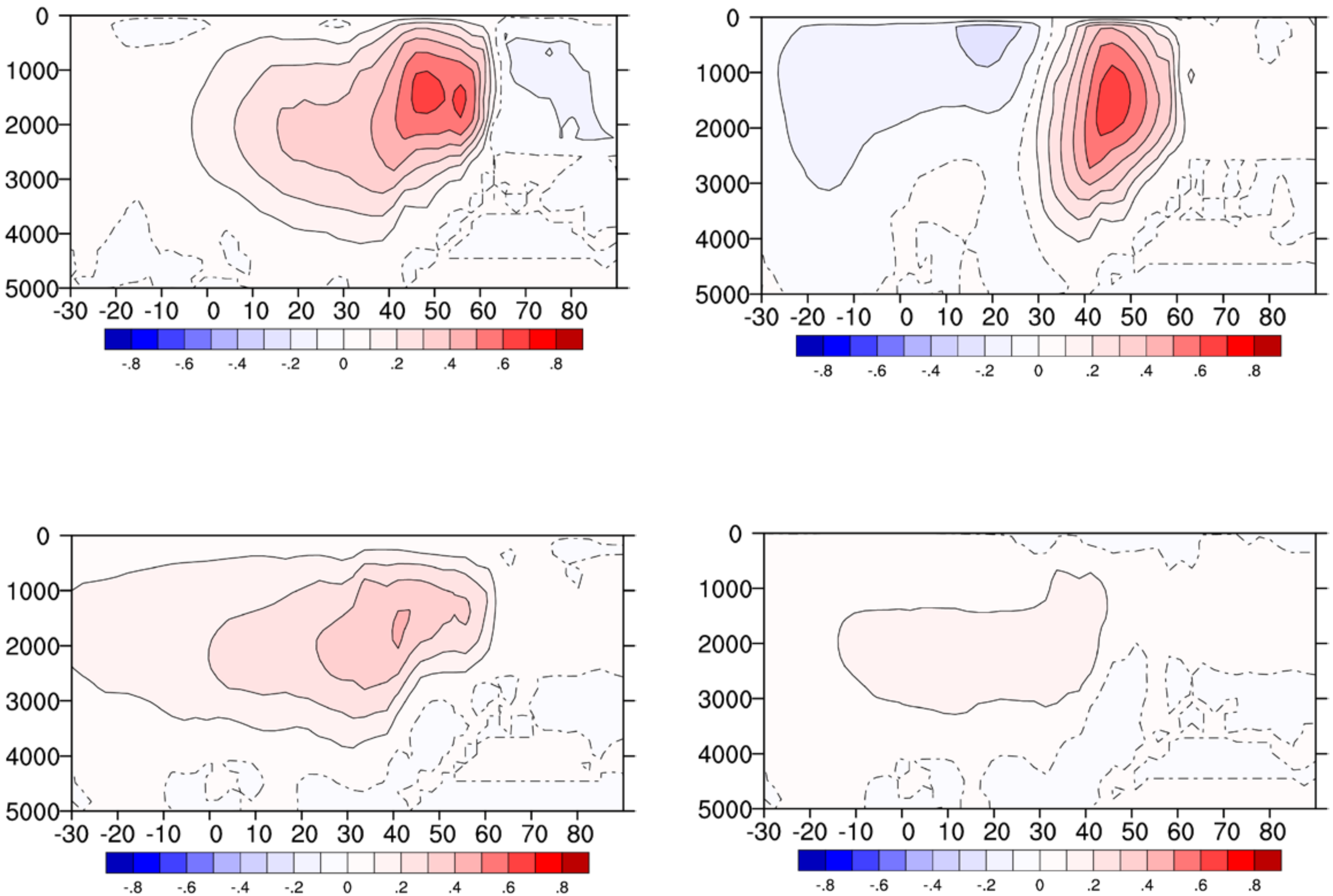
Persistence of response patterns

thermal SV1 response pattern

NAO SHF response pattern

lag 0

lag 5



- **Alternatives to NAO exist for driving AMOC variability in CCSM4**

- **Modest changes in surface flux structure can have substantial impacts on AMOC variability**

- **The most effective surface fluxes excite intrinsically long lasting patterns**