Introduction:

- The representation of the Atlantic Meridional Overturning Circulation (AMOC) differs greatly among individual coupled General Circulation Models (GCMs). Physical reasons for these differences are still poorly understood.
- We consider two such GCMs, ESM2M and CCSM4, and their simulation of the AMOC as defined by the anomalous streamfunction minus the Ekman component ($\psi_{\text{NoEk}}$; see depth-latitude slices below). For this study, we use annually averaged model output.
- In particular, we investigate what role, if any, surface fresh water flux (FW: see latitude-longitude plots below) and surface heat flux (HF) in the same geographical area as FW (see plots below), play in the interannual evolution of the AMOC.

Comparison of ESM2M and CCS4 when $x$ consists only of $\psi_{\text{NoEk}}$:

- ESM2M: This initial condition evolves into this pattern in 3 years. $\psi_{\text{NoEk}}$ variance increases by a factor of 3.0.
- CCSM4: This initial condition evolves into this pattern in 1 year. $\psi_{\text{NoEk}}$ variance here increases by a factor of 2.9.

Comparison of ESM2M and CCSM4 when $x$ consists of ($\psi_{\text{NoEk}}$, FW, HF):

- ESM2M: The three-component (left column) initial condition below causes $\psi_{\text{NoEk}}$ to evolve into this pattern in three years, with an amplification factor of 2.9.
- CCSM4: The three-component (left column) initial condition below causes $\psi_{\text{NoEk}}$ to evolve into this pattern in one year with an amplification factor of 2.6/67 or 3.9.

Methodology:

- For each model, we consider two classes of state vector $x$, consisting either of the 10 leading Principal Components (PCs) of $\psi_{\text{NoEk}}$ alone, or of the 10 leading PCs of each field, ($\psi_{\text{NoEk}},$ FW, HF), normalized so that the 30 time series are about the same size but the relative variance of the PCs within any single field is preserved. We apply Linear Inverse Modeling (LIM) to these fields. That is, we use lagged and contemporaneous statistics to derive the best fit linear model of the form

$$\frac{dx}{dt} = Lx + \xi$$

where $L$ is a constant matrix and $\xi$ is a vector of white noise. With this ansatz, the most probable prediction of $x(t+\tau)$ given $x(t)$ is $G(\tau)x(t)$, where $G(\tau) = \exp(L\tau)$. Further, the initial condition evolving during time $\tau$ into the pattern having the largest possible amplitude of, say, $\psi_{\text{NoEk}}$, is the leading eigenvector of $G(\tau)WG(\tau)$, called the optimal structure. $W$ is a weighting matrix ensuring that the amplitude of $\psi_{\text{NoEk}}$ is what is maximized. If $x$ consists of $\psi_{\text{NoEk}}$ only, then $W$ is the identity matrix.

Conclusions

- Evolution of $\psi_{\text{NoEk}}$ in ESM2M appears to be due to an internal oscillation. Only 5 eigenvectors of $L$ (i.e., “modes”), including a resolved (decay time > 1yr) oscillating pair, project significantly (>) 1 on the $\psi_{\text{NoEk}}$ optimal structure. The 3-year optimal growth interval is consistent with an oscillation of 12-17 years.

- Evolution of $\psi_{\text{NoEk}}$ in CCSM4 appears to depend heavily on interactions with FW and HF. The $\psi_{\text{NoEk}}$ optimal structure significantly projects onto a large number of modes, most of them with decay times less than the output resolution (1yr).
- Unresolved (and, therefore, highly biased) modes project most strongly onto the $\psi_{\text{NoEk}}$ optimal structure. We defer analysis of modes themselves to subsequent work with monthly model output.
- These results are consistent with Transfer Function Analysis (talk with D. MacMartin).

Future work

- Develop verification method based on data
- Use monthly output to identify stochastic forcing
- Analyze other GCMs