Initial Value Predictability of Intrinsic Modes and Implications for Decadal Prediction over North America

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The objective of this project is quantification of the predictability characteristics of the climate system as simulated by comprehensive climate models on decadal timescales. The focus is on the predictability of prominent or highly predictable patterns, and to determine whether the identified decadal predictability has a signature over North America.

Recent results

During the early stages of this project we focused on predictability characteristics of coupled models that resulted from initializing them. Overall, we found that initialization, on average, had the potential to have a positive impact on the skill of predictions of AMOC and heat content for roughly a decade, but that this limiting range varied substantially from model-to-model as well as depending on the region one was predicting and whether annual or multi-year averages were being predicted. Of particular interest was the finding that there were special anomalous structures whose predictability was much higher than that of typical anomalies.

As a means of understanding some of the physical processes that might control the behavior of these special structures, we have focused on a new stage in this project that considers mechanisms by which the atmosphere may be involved in the production of high amplitude, long-lasting (and thus possibly highly predictable) ocean anomalies. To do this, we have developed a novel tool for efficiently determining the oceanic response of a coupled model to surface buoyancy and momentum fluxes of arbitrary structure. Using this tool we are able to find the most efficient geographical distribution of fluxes for producing a large AMOC or heat content response at a given range. The theoretical basis for developing this tool is the fluctuation dissipation theorem, which is an idea borrowed from statistical physics. The theorem states that the response of dynamical systems with certain reasonable properties can be found by simple matrix multiplication of a (sufficiently weak) forcing vector times a linear response operator whose elements depend only on lag-covariance statistics of the undisturbed system.

In the past year, we have extensively tested the fluctuation dissipation theorem when it is applied to a low-resolution version of CCSM4 and found that it can be used to make good estimates of the GCM's oceanic response to salinity, temperature, and momentum near-surface forcing. Given this success, we have then used it to find the most efficient way to force anomalous AMOC circulations. An example is given in Figure 1, which shows the salinity-forcing pattern (left panel) that produces the strongest AMOC response (right panel) after the forcing has been applied for five years. The structure of this optimal response pattern is very similar to the leading EOF of multi-year AMOC variability. Optimal patterns of temperature and momentum forcing also produce a similar AMOC response. For both forms of buoyancy forcing the regions that are most efficient at exciting AMOC are also the regions in the Nordic Seas where deep convection is most common in this version of CCSM4. Our previous results indicate that this same pattern of AMOC variability is highly predictable, and the current results indicate forcing by the atmosphere may be involved in the initiation of these highly predictable events. Also of interest is that this pattern is so much easier to excite than are typical

AMOC anomalies that no special atmospheric patterns (e.g. the NAO) are necessary to explain its prominence. Even random fluxes produced by random atmospheric variability would produce the amount of AMOC EOF1 variability observed in CCSM4.

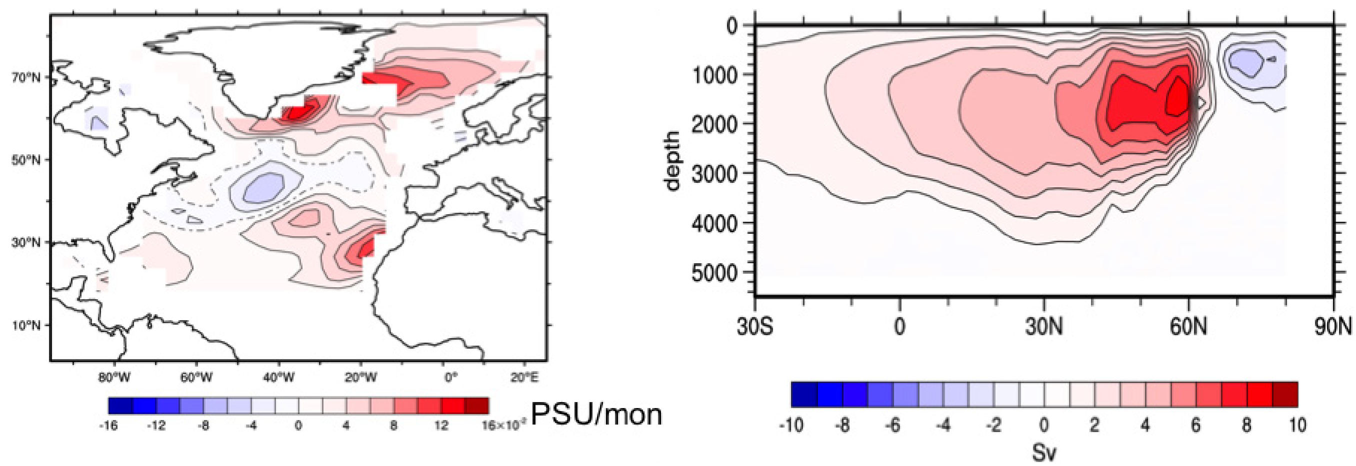

Figure 1. Salinity forcing (left) that produces the maximum AMOC response (right) when applied for 5 years to the near surface layer of CCSM4, as calculated using the fluctuation dissipation theorem.