A Collaborative Multi-Model Study: Understanding AMOC Variability Mechanisms and Their Impacts on Decadal Prediction

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This collaborative project is aimed at advancing our understanding of simulated AMOC variability, the impact of that variability on the atmosphere and climate, and the relevance of that variability to our ability to make decadal climate predictions. Our specific goals include improving understanding of how particular physical processes and climate state information may give rise to predictive skill related to AMOC variability and evaluating how model differences in simulating AMOC variability affect related decadal predictability. During the first year of this proposal, work has begun towards accomplishing our goals. We summarize some of our recent progress below and note that several manuscripts are in preparation covering this work.

Recent results

Yeager and Danabasoglu (2014) have shown that buoyancy forcing over the Labrador Sea (LS) explains most of the decadal AMOC variability in a forced ocean–sea ice hindcast simulation. The simulation is forced with the Coordinated Ocean-ice Reference Experiments inter-annually varying atmospheric datasets, i.e., CORE-II. The study also shows that interannual buoyancy forcing perturbations, *not* wind forcing perturbations, explain most of the high latitude variations in barotropic circulation. Yeager (2014) investigates how topographic coupling between the large-scale overturning and gyre circulations explains buoyancy-driven gyre flow and momentum-driven overturning in similarly forced hindcast simulations. This analysis highlights the importance of abyssal flow interaction with spatially-varying bottom topography – quantified as the bottom pressure torque term (BPT) of the vertically-integrated vorticity balance – in determining both the mean large-scale Atlantic circulation as well as its response to surface forcing changes. For example, the hindcast simulation (CONTROL) exhibits large decadal variations in the high latitude AMOC, which are largely recovered in a sensitivity experiment (B) in which only buoyancy fluxes are allowed to vary interannually (Figure 1, panels a, f, and g). Composite differences between years of high and low buoyancy-driven AMOC show that there is a significant enhancement of cyclonic subpolar gyre circulation, as well as anti-cyclonic subtropical gyre circulation, in both CONTROL and B. In B, this gyre response can only be attributable to changes in BPT, because the experiment lacks any wind stress curl variability. Much, but not all, of the gyre response in CONTROL is also associated with this BPT effect. This highlights the profound importance of abyssal flow in understanding Atlantic circulation variability.

At WHOI, an analysis of AMOC both in depth and density coordinates has been completed. Specifically, Kwon and Frankignoul (2014) further explain the mechanism of the strong 20-year AMOC variability in the present-day control integration of the Community Climate System Model version 3 (CCSM3). The AMOC in density coordinate is shown to better represent the variability associated with the water mass transformation in the subpolar gyre, thus better correlated with the Atlantic meridional heat transport (AMHT) in the North Atlantic subpolar gyre (Figure 2). The figure shows that the density coordinate AMOC is closely correlated with AMHT at all latitudes without any lag, while the depth coordinate AMOC substantially leads AMHT in the subpolar gyre. Therefore, AMOC in density space reflects AMHT better at a given latitude, while AMOC in depth space may provide some predictive skill for AMHT. Further analysis for the relationship between the depth and