Understanding Changes in the Atlantic Meridional Overturning Circulation During the 20th Century Using IPCC AR5 Model Ensembles

PIs: P. Chang[1], S. Yeager[2], and G. Danabasoglu[2]
[1]Texas A&M University, College Station, TX
[2]National Center for Atmospheric Research, Boulder, CO

The objectives of this collaborative research between TAMU and NCAR are i) to understand the dominant ocean – atmosphere processes controlling the long-term AMOC changes over the 20th century and examine how these processes are represented in the models contributing to the IPCC AR5 (Inter-governmental Panel on Climate Change Fifth Assessment Report) and ii) to determine plausible causes of differences in long-term AMOC changes simulated by coupled climate models and forced ocean—sea ice models during the late 20th century. The proposed research consists of a comprehensive inter-model comparison analysis of IPCC AR5 coupled climate model simulations and ocean—sea ice model simulations of the 20th century climate and a set of ocean—sea ice model sensitivity experiments to assess the sensitivity of long-term AMOC changes to a variety of alternative atmospheric state choices.

Recent results

We have compared the representation of the Atlantic Multidecadal Variability (AMV) over the 20th century in the 30-member Community Earth System Model Large Ensemble (CESM-LE) simulations to that simulated in a forced ocean—sea ice simulation (Figure 1). The latter experiment is forced with the Coordinated Ocean-ice Reference Experiments inter-annually varying atmospheric data sets (CORE-II) for the 1948-2007 period (Danabasoglu et al., 2014) and is referred to as the CORE-II POP (Parallel Ocean Program). The forced simulation shows excellent agreement with observations (HADISST; Rayner et al. 2003) over the latter half of the 20th century, and we find that the CESM-LE ensemble-mean AMV also exhibits a reasonable reproduction of relatively warm conditions around mid-century and in the 1990s, with relatively cool conditions in the 1960s and 1970s. The existence of such a decadal AMV signal in the CESM-LE ensemble-mean, which is consistent with observations, suggests an important role for external forcing in the AMV variations of the 20th century. However, analysis of surface heat fluxes, averaged over the North Atlantic, indicates that the CESM-LE AMV signal is largely driven by net shortwave and longwave downwelling radiation. This stands in contrast to the CORE-II POP in which ocean circulation changes linked to AMOC play a dominant role in the decadal sea surface temperature (SST) variability in the Atlantic (Yeager and Danabasoglu 2014). The pattern of late 20th century SST warming in CESM-LE is broadly distributed over the whole Atlantic, whereas in the observations and forced hindcast, the warming is concentrated in the North Atlantic along the Gulf Stream and its extension into the subpolar gyre (Figure 2). The CESM-LE warming in Figure 2 is associated with a large and uniform increase in downwelling longwave radiation (not shown), but we find that the realistic AMV signal in CORE-II POP is almost identically reproduced even when the radiative surface heat fluxes are replaced with climatology (Figure 3, experiment POPTurb). Thus, the correspondence between the AMV signal in CESM-LE and the observed AMV appears to be coincidental with different mechanisms at work in CESM-LE than in CORE-II POP. In particular, heat flux appears to be the dominant AMV driving mechanism in CESM-LE whereas AMOC is the key driver in CORE-II POP. Work is ongoing to partition AMV mechanisms in the individual ensemble members of CESM-LE.

In other collaborative work, we are investigating the sudden onset of the 2007/8 deep convection in the Labrador Sea (LS), which has been hypothesized to be related to the intensified winter storm activity in the region (Vage et al. 2009). To test this hypothesis, a series of CORE-II forced ocean—sea ice sensitivity