ROLE OF ATMOSPHERE-OCEAN INTERACTION IN THE MIDLATITUDE NORTH ATLANTIC ON INTERANNUAL CLIMATE VARIABILITY

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Abstract

The primary mode of observed interannual variability in the North Atlantic is characterized by a north-south oriented dipole pattern in anomalies of surface air temperature and sea surface temperature (SST). The atmospheric circulation associated with the dipole mode of variability is consistent with the notion of the atmosphere forcing the ocean. The impact of air-sea interaction on the dipole-like mode of variability is examined using a mixed layer model (MLM) of the upper ocean in the North Atlantic between 20-60˚N coupled to the NCAR Community Climate Model (CCM1). The climatology of the MLM ocean temperature is adjusted to be consistent with the SSTs that form the lower boundary conditions for CCM1 by including heat flux corrections in the net forcing of the ocean. Heat and salt flux corrections are calculated in a series of uncoupled simulations where the MLM is forced with CCM1 surface fluxes. This research focuses on interannual variability in the North Atlantic during the northern autumn and winter months of September to March.

The natural variability in a 31-year integration of the MLM in the North Atlantic coupled to CCM1 is compared to a CCM1 control simulation of similar length with SSTs specified to have the same climatological annual cycle as in the coupled integration. The mean December to February (DJF) climatology (e.g. air temperature, winds, 500mb heights) is essentially unchanged with the inclusion of midlatitude air-sea interaction. However, air-sea interaction leads to significant increases in the persistence of air temperature anomalies on interannual as well as monthly time scales.

In the model subpolar North Atlantic, air and ocean temperature anomalies are significantly autocorrelated (0.4 to 0.6) from one winter to the following winter. These autocorrelations are consistent with the ‘Re-emergence’ mechanism (Namias and Born, 1970).

Deep ocean temperature anomalies, present at the end of one winter, remained sequestered below the shallow summer mixed layer. As the mixed layer deepens during the following fall, ocean temperature anomalies from the previous winter are reincorporated into the surface layer. February mixed layer ocean temperatures are strongly correlated with sub-mixed layer ocean temperatures during the following summer and surface ocean temperature anomalies the following winter. An uncoupled sensitivity experiment is performed, in which the MLM is forced with heat, momentum, and freshwater fluxes from the coupled simulation, and anomalies are supressed in mixed layer depth and entrainment heating. The sensitivity experiment finds that the autocorrelations from one winter to the next in ocean temperature are weak when anomalies in entrainment heating or mixed layer depths are supressed. The 'Re-emergence' mechanism does not play an important role in the subtropical model domain. Observed air and ocean temperature autocorrelations from one winter to the next are strong (weak) in the northern (southern) part of the North Atlantic basin, in agreement with model results.

Air temperature anomalies decay more slowly as a result of air-sea interaction. Short-term autocorrelations of air temperature are statistically significant up to 1-2 and 3-4 months in the control and coupled simulations, respectively. When air temperatures are not affected by SST anomalies as in the control simulation, the turbulent heat fluxes act to strongly damp air temperature anomalies (Frankignoul, 1985). With the inclusion of variable ocean temperatures, the 'thermal damping' of atmospheric temperature anomalies is weaker. Consistent with these findings, the variance of air temperature increases and of total heat flux decreases as a result of coupling.