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North Atlantic decadal climate variability in a very large ensemble of CGCM runs

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Very large ensembles of simulations with the MPI Earth System Model were analyzed with focus on the North Atlantic sector. The set of runs consists of a 2000-year climatologically forced control run, a 100-member ensemble with historical (observed) radiative forcings and a 68-member ensemble with 1%/yr CO_2 increase.

Our main objectives were to understand and quantify the influence of external forcing on different ocean indices, and to achieve a better understanding of the link between large-scale Sea Surface Temperature in the North Atlantic and the ocean circulation to determine possible implications for the predictability of multi-annual to decadal climate variability in this region.

The high number of ensemble members allows us to perform statistical analysis and thereby to make robust estimates of what influences the different indices of ocean variability and possible links between them: Comparison of the ensemble mean and the intra-ensemble spread of the indices allows us to distinguish externally-forced or physically generated internal modes from randomly-generated differences between the individual ensemble members. Comparing the historical ensemble and the 2000-year long climatologically forced control simulation allows us to separate externally forced features of variability from internally generated modes of the system. As one example, a noticeable part of the AMV shows common features in the individual members of the historical ensemble and therefore can be interpreted as being externally forced. With respect to the historical simulations, the 1% simulations show strong changes to the ocean mean state. Beyond this, the ensemble spread of the AMOC is highly reduced towards the end of the simulations with strongly increased radiative forcing, indicating a weakened internal variability related to the forcing.

A lead-lag cross-correlation analysis shows a qualitatively robust link between AMV, AMOC and subpolar gyre variability. However, the strength of the correlation between AMOC and AMV is varying between different periods in the control run and has some spread within the historical ensemble. Probably related to the reduced AMOC variability under strong radiative forcing, the cross-correlation between AMOC and AMV is decreased in the 1% simulations.