Frequency-domain analysis of AMOC processes

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The dynamics of the Atlantic Meridional Overturning Circulation (AMOC) vary considerably between different CMIP5 models: some models show clear peaks in the power spectra, while others do not. In order to better understand these model differences, we turn to the frequency domain and introduce transfer functions, to estimate the frequency-dependent process dynamics between any pair of input and output variables. This approach is borrowed from control engineering, which is concerned with the analysis of feedbacks in complex systems, and has already been successfully applied to diagnose model errors in the study of ENSO. For AMOC variability, we evaluate processes in 8 different models, and focus particular attention on GFDL CM2.1, and NCAR CCSM4 which span the range of observed power spectra. We explore the dynamic relationship between the AMOC index and a number of surface fields: temperature, salinity, fresh-water forcing, wind stress magnitude, and air-sea heat flux. In general, there is little agreement between models for any of the pairs of variables we consider, suggesting that there remains considerable uncertainty in accurately capturing AMOC in current GCMs. However, there are several processes that illuminate differences between those models that do have spectral peaks in AMOC and those that don't, such as a stronger MOC response to high-latitude wind stress perturbations of particular periods. While much detective work remains, we expect that frequency-domain analysis of underlying process dynamics will prove to be a valuable diagnostic tool for model intercomparison.