Decadal Variability of Interacting Climate Subsystems in the Northern Hemisphere

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In this project, we study the Northern Hemisphere climate's decadal variability using data output from a suite of current-generation coupled climate models. Our primary approach is to examine networks of climate indices that generally represent coupled climate subsystems. Conceptually, we hypothesize that decadal climate shifts — defined as abrupt changes in the climates long-term state and variability that tend to happen with decadal frequency— arise as a result of collective behavior of climate subsystems due to interplay between occurrences of synchronized states and variable coupling strength within the climate network. This mechanism, which is consistent with the theory of synchronized chaos, appears to be a very robust mechanism operating in the climate system. It has been found in instrumental records, in forced and unforced climate simulations, as well as in proxy records spanning several centuries. The tendency for the climate subsystems to synchronize/couple their intra-seasonal "beats" appears to be enhanced in certain phases of the slowly varying Meridional Overturning Circulation in the Atlantic,which is, of course, dominated by the decadal time scales.

During 2014, we concentrated on identifying and comparing the properties of climatic teleconnections operating on decadal time scale in observations and simulations performed within the Coupled Model Intercomparison Project, phase 5 (CMIP5). For such a comparison, we followed the general framework developed by Wyatt et al. (2012). This framework is based on applying an objective filtering method — Multi-channel Singular Spectrum Analysis (M-SSA; Ghil et al. 2002) — to highlight the dominant multidecadal variability in a network of climate indices. Our network was comprised of indices based on surface temperature (Northern Hemisphere average temperature (NHT), Pacific Decadal Oscillation index (PDO), Atlantic Multidecadal Oscillation index (AMO), among others) and indices based on sea-level pressure (SLP), in particular the North Atlantic Oscillation (NAO) and the Aleutian Low-Pressure Index (ALPI). A variety of reanalysis data sources were used, including the 20th century reanalysis (20CR). The reanalysis-derived networks were compared to networks derived from the virtual climates produced in five independent 20th century climate realizations of the GFDL CM3 model (Kravtsov et al. 2014).

Recent results

We found that spatiotemporal structure of the simulated multidecadal variability is fundamentally different from that diagnosed in the reanalysis data sets (Figure 1). We hypothesize that these differences stem from the apparent lack of atmospheric sensitivity to multidecadal variations of surface climate in the GFDL CM3 runs, as manifested in a striking deficit of decadal-to-multidecadal variance in the NAO and SLP spectra (Figure 2).

Figure 1 notes a shared time scale and substantial phase spread among the observed indices; the latter propagation in the phase space of the observed indices is dubbed 'stadium wave.' In contrast, the GFDL simulations are characterized by the in-phase 'stadium wave' well described by the single pattern and its associated time series shown on the right for the five individual 20th century GFDL runs considered. Figure 2 shows that the simulated *multidecadal variability* is up to an order of magnitude weaker than the observed variability, while the level of interannual variability is essentially the same in models and observations,

In general, the GFDL CM3 model simulates well the amplitude of the largest-scale — Pacific and hemispheric — multidecadal variability in surface temperature, but underestimates multidecadal variability in the North Atlantic and atmospheric indices.