Differences Between Multidecadal Climate Variability in the GFDL CM3 Model and Reanalyses

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The bulk of our understanding about causes of 20th century climate change comes from simulations using numerical global climate models. Some of these models seemingly reproduce the observed nonuniform global warming, with periods of faster warming in 1910–1940 and 1970–2000, and a pause in between. However, closer inspection reveals differences between the observations and model simulations. Here we show that observed multidecadal variations of surface climate exhibit a coherent global-scale signal characterized by a pair of patterns, one of which evolved in sync with multidecadal swings of the global temperature, and the other in quadrature with them. In contrast, simulations of a global climate model are dominated by the stationary — single pattern — forced signal somewhat reminiscent of the observed "in-sync" pattern most pronounced in the Pacific. While simulating well the amplitude of the largest-scale — Pacific and hemispheric — multidecadal variability in surface temperature, the model underestimates variability in the North Atlantic and atmospheric indices.

Comments:

Methodologically, we considered collective behavior of a network of climate indices and decomposed the 20th century climate variability into the linear trend, multidecadal and residual components using an objective multivariate filtering technique (Multichannel Singular Spectrum Analysis: M-SSA). Our network is 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 5 independent 20th century climate realizations of the GFDL CM3 model.

We found that spatiotemporal structure of the simulated multidecadal variability is fundamentally different from that diagnosed in the reanalysis data sets (see Fig. 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 (see Fig.

2). For further information, see the authors' preprint of the paper and supplemental materials available from Sergey Kravtsov website —

Main text:

https://people.uwm.edu/kravtsov/files/2016/12/KWCT2014_main_FINAL-t4f0rj.pdf

Supplemental materials:

https://people.uwm.edu/kravtsov/files/2016/12/KWCT2014_supportinginfo-ubicbg.pdf

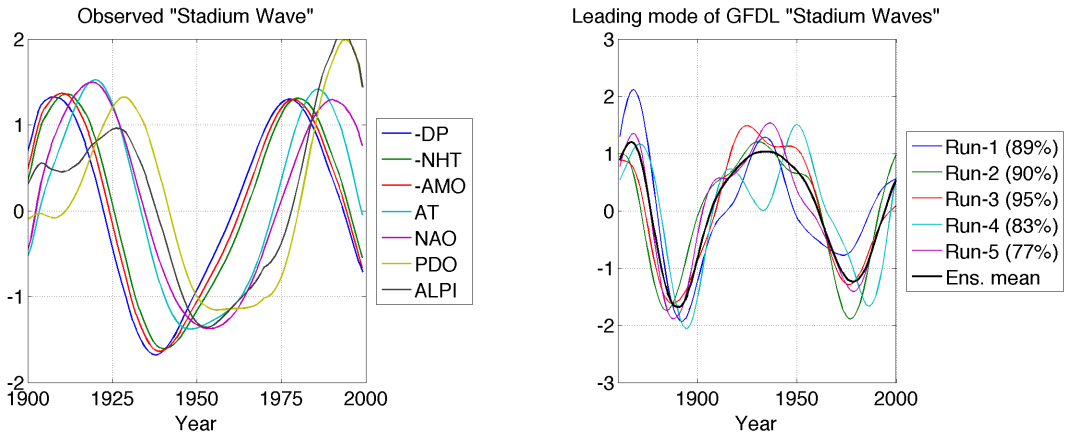

Figure 1: Leading mode of multidecadal variability (dubbed "stadium wave") in the observed (left) and GFDL CM3 simulated (right) network of climate indices (see the left panel for the list of indices used). The observed NAO and ALPI indices in the left panel were based on the 20th century reanalysis (20CR) data set. Note a shared time scale and substantial phase spread among the observed indices. 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 5 individual 20th century GFDL runs considered.

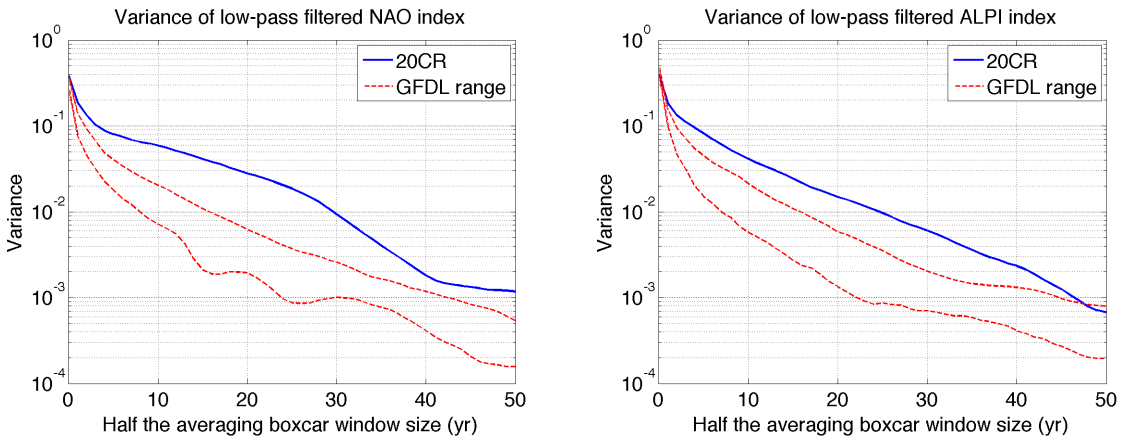

Figure 2: Spectra of the observed and GFDL simulated atmospheric indices. The spectra are defined here as the variance of the running-mean averaged time series for different window sizes. The abscissa on all plots shows half the window size in units of years, with 0 corresponding to no averaging (raw annual data), 1 — to 3-yr boxcar averages, 2 — to 5-yr boxcar averages and so on. The blue line shows the observed spectra based on the 20th-century reanalysis indices, and the red dashed lines show the range of spectral estimates over those for 5 individual 20th century runs. Index names are listed in the caption of each panel. Note the logarithmic scale on *y*-axis: while the level of interannual variability is essentially the same in models and observations, the simulated *multidecadal variability* is up to an order of magnitude weaker than the observed variability.