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Long-term memory in forced and unforced climate models

Bo Christiansen and Peter Thejll
Danish Meteorological Institute, Climate and Arctic Research, Copenhagen, Denmark (boc@dmi.dk)

The detection of long-term memory in the climate system could have serious consequences for the evaluation of the statistical significance of, e.g., trends and changes in the occurrence of extreme events. However, the estimation of long-term memory is troublesome; long time-series are needed for significant estimations and the chosen method may produce false positives by responding to, e.g., forced regime change. In this paper we evaluate long-term memory in the geographically distributed near-surface temperature in coupled climate simulations from CMIP5. Long experiments (1000 years) both without forcings (piControl) and including natural forcings (past1000) are considered. We use two different methods to estimate the long-term memory; fitting the parameters of ARFIMA processes by Whittle estimation (yielding the fractional dimension) and detrended fluctuation analysis (yielding the Hurst exponent). The ARFIMA method allows confidence levels to be estimated by a Bayesian approach.

We find the same geographical patterns of the fractional dimension and the Hurst exponent. In the experiments with natural forcings significant long-term memory is found in regions of the tropics, the Arctic, and the Southern Ocean. However, the long-term memory is almost totally absent in the unforced experiments. Additional analysis will be performed to understand the role of the natural forcings such as solar variations and volcanic aerosols. This analysis will include simple toy models as well as attempts to remove the parts from the model output congruent with the applied forcings.