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Suitability of the Twentieth Century Reanalysis for climate change assessment

Craig R. Ferguson (1) and Gabriele Villarini (2)

(1) The University of Tokyo Institute of Industrial Science, Tokyo, Japan (cferguso@rainbow.iis.u-tokyo.ac.jp), (2) The University of Iowa, Iowa City, Iowa, USA (gabriele-villarini@uiowa.edu)

The ever-growing demand for applications in climate science, and particularly in the realm of climate change attribution has triggered a paradigm shift in reanalysis production towards so-called "climate-quality" reanalyses. Climate-quality reanalyses seek to ameliorate the issue of unphysical time-varying biases through the assimilation of only those few data streams that are stable over long periods of time. The first attempt at such a reanalysis is the National Oceanic and Atmospheric Administration (NOAA) - Cooperative Institute for Research in Environmental Sciences (CIRES) Twentieth Century Reanalysis (20CR), which spans a period of 140-years (1871-2010)- more than doubling the pre-existing reanalysis record length.

The 20R assimilates only synoptic surface and sea level pressure observations and uses monthly sea surface temperature and sea ice extent observations as boundary forcing. If its record can be shown to be homogenous, then it constitutes the first reanalysis suitable for long-term trend assessments. On the other hand, if discontinuities exist, then their presence will confound the detection and attribution of a possible climate change signal, making accounting for them a critical step in improving the applicability of these products in climate research.

In previous work, we applied three statistical breakpoint methods (Pettitt and Bai-Perron tests and segmented regression) to evaluate the homogeneity of nine hydrometeorological variables in 20CR over the central U.S. We were able to show, through joint analyses of 20CR's ensemble spread and assimilated observation counts and inter-comparison with independent gridded datasets, that the quintupling of 20CR's assimilated observation counts was the primary cause of inhomogeneities for that region.

In this study, we extend the same analysis methodology globally. We rigorously evaluate series homogeneity at regional, seasonal, inter-variable, and intra-ensemble scales. We analyze the metadata (assimilated observation counts and ensemble spread), boundary forcing (HadISST v1.1), and representative inputs (HadSLP2) of 20CR for change points in the same manner. We produce a quantitative characterization of 20CR's inhomogeneities that is unprecedented in its level of detail. We demonstrate with objective techniques how far we can (or can't) go in attributing variability to various mechanisms of natural or anthropogenic origin. We place the results in context with other global observational time series and a number of other reanalyses covering shorter periods.

We show that the effect of observational shocks is not isolated to the central U.S. but applies more broadly. In fact, changes in the observing system or boundary forcing account for 27% and 30% of inhomogeneities in the temperature and precipitation, respectively. Before definitive attribution of the shifts (to either natural or unphysical sources) in 20CR can proceed, the inhomogeneities of its boundary forcing and assimilated pressure observations must first be addressed.