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The Multi-Model Large Ensemble Archive as a climate noise generator: opportunities and outlooks for Observational Large Ensemble construction

Anna L. Merrifield¹, Flavio Lehner^{2,3}, Ruth Lorenz¹, and Reto Knutti¹

¹Institute for Atmosphere and Climate, D-USYS, ETH Zurich, Zurich, Switzerland

²Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, USA

³Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, USA

The Multi-Model Large Ensemble Archive (MMLEA) is a collection of CMIP5-generation single model initial condition large ensembles (SMILEs) and thus provides estimates of internal variability from several independently developed coupled climate models. Work is underway to determine whether these simulations provide a range of historical regional climate variability suitable for statistically increasing the observed temperature sample. Alternative sequences of historical temperature can be constructed by combining a forced signal with estimates of internal climate noise; prior studies have used the forced response from one SMILE in concert with observational noise resampling to form an “observational large ensemble” (McKinnon et al. 2018). Analogous to a SMILE, an observational large ensemble can be used to statistically contextualize monthly to half-yearly extreme events, such as the persistently mild Siberian winter of 2020, and to develop additional extended hot or cold spell storylines to explore in future projections of regional climate.

In this study, an alternative approach to constructing an observational large ensemble of European surface air temperature over the historical period (1950-2014), made possible by the MMLEA, is explored. Rather than relying on forced response and internal variability, components not well-defined in the single realization of observed climate, the constructed circulation analogue method of dynamical adjustment is employed to separate temperature anomalies related to atmospheric circulation (“dynamic noise”) from a more thermodynamically driven residual signal. The approach is advantageous because it can be applied in a similar manner to single realizations from both models and observations. Here, dynamic noise is computed by dividing each of the seven CMIP5-generation SMILEs in half and empirically estimating the component of temperature associated with interannual sea level pressure variability in one half of the SMILE using circulation analogues from members in the other half. Because ensemble means can be computed in SMILEs, it is possible to use the relationship between unforced temperature and unforced sea level pressure anomalies to construct dynamic noise. In observations, weekly-averaged analogues are assessed as a means to increase the size of the analogue pool such that the separation between dynamic noise and thermodynamic residual signal occurs in a manner more similar to that computed in the SMILEs.

The extent to which dynamic noise fields from different SMILEs are distinguishable from each other and from observational estimates is determined via spectral and spatial pattern analyses. To avoid introducing regional model bias into dynamic noise estimates, a mosaic approach will be taken; noise estimates from different models are mosaiced such that observed statistical properties are maintained at each grid point of the European domain. Upon validation, SMILE-derived dynamic noise and observational thermodynamic residual signal estimates are combined into a 50-member European observational large ensemble and evaluated via a multi-month extreme temperature frequency metric against the observational large ensemble developed by McKinnon et al. (2018). Anomalously persistent hot and cold spells found in the European observational large ensemble are further compared to events in out-of-sample future projections of climate from the CMIP6 archive.