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Identification of forced response and internal climate variability using ensemble linear dynamical modes

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The problem of accurate detection of climate response to slow external forcing in 19-21 centuries is complicated by the presence of internal climate variability, which can also exhibit slow (decadal and multidecadal) large-scale dynamics, and also by the fact that there is only one observed climate realization available. At the same time, state-of-the-art Earth system models (ESMs) exhibit different spatiotemporal content on slow time scales, and their ability to estimate forced and internal climate variability needs further verification, especially given a relatively poor (short) observational statistics with respect to slow time scales.

Here we present a method called ensemble linear dynamical mode (E-LDM) decomposition [1] which addresses the problem of forced signal and internal variability detection from small ensembles of ESM simulations. The method is based on the general assumption that the forced response is the same in all ensemble members and the internal variability is uncorrelated, while both of them can be essentially represented by a low-dimensional set of spatial patterns and corresponding forced and internal time series with certain time scales; the patterns, the time series and their time scales are optimized via the Bayesian framework. We compare the E-LDM method with other state-of-the-art methods of forced signal detection on synthetic and ESM-simulated data, and also discuss its applicability to the problem of intercomparison of ESMs and their verification with respect to real data.

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1. Gavrilov, A., Kravtsov, S., Buyanova, M., Mukhin, D., Loskutov, E., & Feigin, A. (2023). Forced response and internal variability in ensembles of climate simulations: identification and analysis using linear dynamical mode decomposition. Climate Dynamics, 1–28. https://doi.org/10.1007/S00382-023-06995-1.