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Application of linear dynamical mode decomposition to ensembles of climate simulations

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An analysis of the climate system is usually complicated by its very high dimensionality and its nonlinearity which impedes spatial and time scale separation. An even more difficult problem is to obtain separate estimates of the climate system's response to external forcing (e.g. anthropogenic emissions of greenhouse gases and aerosols) and the contribution of the climate system's internal variability into recent climate trends. Identification of spatiotemporal climatic patterns representing forced signals and internal variability in global climate models (GCMs) would make it possible to characterize these patterns in the observed data and to analyze dynamical relationships between these two types of climate variability.

In contrast with real climate observations, many GCMs are able to provide ensembles of many climate realizations under the same external forcing, with relatively independent initial conditions (e.g. LENS [1], MPI-GE [2], CMIP ensembles of 20th century climate). In this report, a recently developed method of empirical spatio-temporal data decomposition into linear dynamical modes (LDMs) [3] based on Bayesian approach, is modified to address the problem of self-consistent separation of the climate system internal variability modes and the forced response signals in such ensembles. The LDM method provides the time series of principal components and corresponding spatial patterns; in application to an ensemble of realizations, it determines both time series of the internal variability modes of current realization and the time series of forced response (defined as signal shared by all realizations). The advantage of LDMs is the ability to take into account the time scales of the system evolution better than some other linear techniques, e.g. traditional empirical orthogonal function decomposition. Furthermore, the modified ensemble LDM (E-LDM) method is designed to determine the optimal number of principal components and to distinguish their time scales for both internal variability modes and forced response signals.

The technique and results of applying LDM method to different GCM ensemble realizations will be presented and discussed. This research was supported by the Russian Science Foundation (Grant No. 18-12-00231).

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