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Decomposition of the complex system into nonlinear spatio-temporal modes: algorithm and application to climate data mining

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Proper decomposition of the complex system into well separated "modes" is a way to reveal and understand the mechanisms governing the system behaviour as well as discover essential feedbacks and nonlinearities. The decomposition is also natural procedure that provides to construct adequate and concurrently simplest models of both corresponding sub-systems, and of the system in whole.

In recent works two new methods of decomposition of the Earth's climate system into well separated modes were discussed. The first method [1-3] is based on the MSSA (Multichannel Singular Spectral Analysis) [4] for linear expanding vector (space-distributed) time series and makes allowance delayed correlations of the processes recorded in spatially separated points. The second one [5-7] allows to construct nonlinear dynamic modes, but neglects delay of correlations. It was demonstrated [1-3] that first method provides effective separation of different time scales, but prevent from correct reduction of data dimension: slope of variance spectrum of spatio-temporal empirical orthogonal functions that are "structural material" for linear spatio-temporal modes, is too flat. The second method overcomes this problem: variance spectrum of nonlinear modes falls essentially sharply [5-7]. However neglecting time-lag correlations brings error of mode selection that is uncontrolled and increases with growth of mode time scale.

In the report we combine these two methods in such a way that the developed algorithm allows constructing nonlinear spatio-temporal modes. The algorithm is applied for decomposition of (i) multi hundreds years globally distributed data generated by the INM RAS Coupled Climate Model [8], and (ii) 156 years time series of SST anomalies distributed over the globe [9]. We compare efficiency of different methods of decomposition and discuss the abilities of nonlinear spatio-temporal modes for construction of adequate and concurrently simplest ("optimal") models of climate systems.

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