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Nonlinear dynamical modes of climate variability: from curves to manifolds

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The necessity of efficient dimensionality reduction methods capturing dynamical properties of the system from observed data is evident. Recent study shows that nonlinear dynamical mode (NDM) expansion is able to solve this problem and provide adequate phase variables in climate data analysis [1].
A single NDM is logical extension of linear spatio-temporal structure (like empirical orthogonal function pattern): it is constructed as nonlinear transformation of hidden scalar time series to the space of observed variables, i. e. projection of observed dataset onto a nonlinear curve. Both the hidden time series and the parameters of the curve are learned simultaneously using Bayesian approach. The only prior information about the hidden signal is the assumption of its smoothness. The optimal nonlinearity degree and smoothness are found using Bayesian evidence technique.
In this work we do further extension and look for vector hidden signals instead of scalar with the same smoothness restriction. As a result we resolve multidimensional manifolds instead of sum of curves. The dimension of the hidden manifold is optimized using also Bayesian evidence. The efficiency of the extension is demonstrated on model examples. Results of application to climate data are demonstrated and discussed.
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1. Mukhin, D., Gavrilov, A., Feigin, A., Loskutov, E., & Kurths, J. (2015). Principal nonlinear dynamical modes of climate variability. Scientific Reports, 5, 15510. http://doi.org/10.1038/srep15510