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Finite element techniques in computational time series analysis of turbulent flows

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In recent years there has been considerable increase of interest in the mathematical modeling and analysis of complex systems that undergo transitions between several phases or regimes. Such systems can be found, e.g., in weather forecast (transitions between weather conditions), climate research (ice and warm ages), computational drug design (conformational transitions) and in econometrics (e.g., transitions between different phases of the market). In all cases, the accumulation of sufficiently detailed time series has led to the formation of huge databases, containing enormous but still undiscovered treasures of information. However, the extraction of essential dynamics and identification of the phases is usually hindered by the multidimensional nature of the signal, i.e., the information is "hidden" in the time series. The standard filtering approaches (like f.ẽ. wavelets-based spectral methods) have in general unfeasible numerical complexity in high-dimensions, other standard methods (like f.ẽ. Kalman-filter, MVAR, ARCH/GARCH etc.) impose some strong assumptions about the type of the underlying dynamics.

Approach based on optimization of the specially constructed regularized functional (describing the quality of data description in terms of the certain amount of specified models) will be introduced.
Based on this approach, several new adaptive mathematical methods for simultaneous EOF/SSA-like data-based dimension reduction and identification of hidden phases in high-dimensional time series will be presented.
The methods exploit the topological structure of the analysed data an do not impose severe assumptions on the underlying dynamics.
Special emphasis will be done on the mathematical assumptions and numerical cost of the constructed methods.

The application of the presented methods will be first demonstrated on a toy example and the results will be compared with the ones obtained by standard approaches. The importance of accounting for the mathematical assumptions used in the analysis will be pointed up in this example. Finally, applications to analysis of meteorological and climate data will be presented.