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On data-based analysis of extreme events in multidimensional non-stationary meteorological systems: Based on advanced time series analysis methods and general extreme value theory

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Given an observed series of extreme events we are interested to capture the significant trend in the underlying dynamics. Since the character of such systems is strongly non-linear and non-stationary, the detection of significant characteristics and their attribution is a complex task. A standard tool in statistics to describe the probability distribution of extreme events is the General Extreme Value Theory (GEV). While the univariate stationary GEV distribution is well studied and results in fitting the data to the model parameters using Likelihood Techniques and Bayesian Methods (Coles,'01; Davison, Rames, '00), analysis of non-stationary extremes is based on the a priori assumption about the trend behavior (e.g linear combination of external factors/polynomials (Coles,'01)). Additionally, analysis of multivariate, non-stationary extreme events remains still a strong challenge, since analysis without strong a priori assumptions is limited to low dimensional cases (Nychka, Cooley,'09).

We introduce FEM-GEV approach, which is based on GEV and advanced Finite Element time series analysis Methods (FEM) (Horenko,'10-11). The main idea of the FEM framework is to interpolate adaptively the corresponding non-stationary model parameters by a linear convex combination of K local stationary models and a switching process between them. To apply FEM framework to a time series of extremes we extend FEM by defining the model parameters wrt GEV distribution, as external factors we consider global atmospheric patterns. The optimal number of local models K and the best combination of external factors is estimated using Akaike Information Criteria. FEM-GEV approach allows to study the non-stationary dynamics of GEV parameters without a priori assumptions on the trend behavior and also captures the non-linear, non-stationary dependence on external factors.

The series of extremes has by definition no connection to real time scale, for this reason the results of FEM-GEV can be only used to predict the return period and level of extremes. For the purpose of real time prediction we define an other discrete process, jumping between 3 states: positive extremes, mean value, negative extremes. The dynamic of this discrete process can be analyzed with FEM-Markov approach (Horenko,'11), FEM-Markov decides if the jumping process has a non-stationary/stationary markovian or bernoulli behavior. The resulting model can predict the next occurrence of an either positive or negative extreme event on real time scale. This interaction, between FEM-Markov for the discrete jump process and FEM-GEV, allows making prediction of the mean intensity of extremes on real time scale. The proposed framework was exemplified on practical examples (test cases and real datasets).