Geophysical Research Abstracts
Vol. 17, EGU2015-15506, 2015
EGU General Assembly 2015

Threshold exceedance risk assessment in complex space-time systems

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Environmental and health impact risk assessment studies most often involve analysis and characterization of complex spatio-temporal dynamics. Recent developments in this context are addressed, among other objectives, to proper representation of structural heterogeneities, heavy-tailed processes, long-range dependence, intermittency, scaling behavior, etc. Extremal behaviour related to spatial threshold exceedances can be described in terms of geometrical characteristics and distribution patterns of excursion sets, which are the basis for construction of risk-related quantities, such as in the case of evolutionary study of ‘hotspots’ and long-term indicators of occurrence of extremal episodes. Derivation of flexible techniques, suitable for both the application under general conditions and the interpretation on singularities, is important for practice.

Modern risk theory, a developing discipline motivated by the need to establish solid general mathematical-probabilistic foundations for rigorous definition and characterization of risk measures, has led to the introduction of a variety of classes and families, ranging from some conceptually inspired by specific fields of applications, to some intended to provide generality and flexibility to risk analysts under parametric specifications, etc. Quantile-based risk measures, such as Value-at-Risk (VaR), Average Value-at-Risk (AVaR), and generalization to spectral measures, are of particular interest for assessment under very general conditions.

In this work, we study the application of quantile-based risk measures in the spatio-temporal context in relation to certain geometrical characteristics of spatial threshold exceedance sets. In particular, we establish a closed-form relationship between VaR, AVaR, and the expected value of threshold exceedance areas and excess volumes. Conditional simulation allows us, by means of empirical global and local spatial cumulative distributions, the derivation of various statistics of practical interest, and subsequent construction of dynamic risk maps. Further, we study the implementation of static and dynamic spatial deformation under this setup, meaningful, among other aspects, for incorporation of heterogeneities and/or covariate effects, or consideration of external factors for risk measurement.

We illustrate this approach though Environment and Health applications.

This work is partially supported by grant MTM2012-32666 of the Spanish Ministry of Economy and Competitiveness (co-financed by FEDER).