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Multi-fractal modelling the hydrological and environmental systems with using the empirical orthogonal function decomposition: Spectral hierarchy and self-scaling

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The multi-fractal approach (MFA) gives an opportunity to describe extremely compactly different hydrological and meteorological processes and systems. In the applied hydrology and oceanology the MFA for description of various objects and processes develops actively. A set of most inportant results is as follows: a concept of scale self-similarity for the topography of Earth's surface (Mandelbrot, 1967; Menabde et al.,2001), the hydraulic-geometric similarity of river system and floods forced by the heavy rain (Lovejoy-Schertzer, 1992; Burlando-Rosso,1996), Deidda et al.,1998), optimal version of the MFA for the non-stationary time series (Kantelhardt et al., 2002) etc. Here a generalized version of the MFA to modelling general hydrological and environmental systems is developed and numerically realized (Loboda-Glushkov,2003,2004). Specifically, we investigate the annual runoff for the Ukrainian and Moldavia's rivers and reveal scale invariance for distribution of this variable by using statistical parameters such as arithmetic average, coefficients of variation, skewness, and auto-correlation. Investigations of the annual runoff for indicated rivers using standard fluctuation analysis show that both in spatial distribution and in time one of the runoff's characteristics the self-affine scaling behaviours exist. The fractal dimension d = 1.72 for long-term annual runoff and d= 1.63 for variation coefficient. Spatial correlation between these parameters is found at distance up to 400 and 200 km respectively. If distance increases ($s = L$) then these characteristics become uncorrelated. The statistical parameters such as the skewness C and the auto correlation coefficient r have a randomicity of distribution in the space; a "satiation" of spatial structure function occurs at very short S. We may recommend a zoning for the spatial

generalization of C and r. The use of multifractal approach to the first component of decomposition on the empirical orthogonal functions for annual runoff has an advantage over the use of observational time series. First component of decomposition and its components represent large-scale forcing of generating process for the annual runoff. At the same time the influence of water-related activities and surface factors are eliminated. Furthermore, the time components (amplitude functions) are general for all hydrological objects, i.e. they characterize the fluctuation of runoff in time. In addition, this fluctuation is averaged for whole territory. The time part of first component describes most general patterns for the annual runoff fluctuations of rivers. Namely this variable is subject to the fractal analysis. Here the variational function $F(s) \sim s*(H)$is used as a property of spatial-time variation for the annual runoff (H is the exponent of scaling identical with the fractal dimension). It is determined that H = 0.77 and this agrees to the hypothesis of Hurst's universal exponent.

References:

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