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A space-time multifractal analysis on radar rainfall sequences from central Poland

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Rainfall downscaling belongs to most important tasks of modern hydrology. Especially from the perspective of urban hydrology there is real need for development of practical tools for possible rainfall scenarios generation. Rainfall scenarios of fine temporal scale reaching single minutes are indispensable as inputs for hydrological models. Assumption of probabilistic philosophy of drainage systems design and functioning leads to widespread application of hydrodynamic models in engineering practice. However models like these covering large areas could not be supplied with only uncorrelated point-rainfall time series. They should be rather supplied with space time rainfall scenarios displaying statistical properties of local natural rainfall fields.
Implementation of a Space-Time Rainfall (STRAIN) model for hydrometeorological applications in Polish conditions, such as rainfall downscaling from the large scales of meteorological models to the scale of interest for rainfall-runoff processes is the long-distance aim of our research. As an introduction part of our study we verify the veracity of the following STRAIN model assumptions: rainfall fields are isotropic and statistically homogeneous in space; self-similarity holds (so that, after having rescaled the time by the advection velocity, rainfall is a fully homogeneous and isotropic process in the space-time domain); statistical properties of rainfall are characterized by an “a priori” known multifractal behavior.
We conduct a space-time multifractal analysis on radar rainfall sequences selected from the Polish national radar system POLRAD. Radar rainfall sequences covering the area of 256 km x 256 km of original 2 km x 2 km spatial resolution and 15 minutes temporal resolution are used as study material. Attention is mainly focused on most severe summer convective rainfalls. It is shown that space-time rainfall can be considered with a good approximation to be a self-similar multifractal process. Multifractal analysis is carried out assuming Taylor’s hypothesis to hold and the advection velocity needed to rescale the time dimension is assumed to be equal about 16 km/h. This assumption is verified by the analysis of autocorrelation functions along the x and y directions of “rainfall cubes” and along the time axis rescaled with assumed advection velocity. In general for analyzed rainfall sequences scaling is observed for spatial scales ranging from 4 to 256 km and for timescales from 15 min to 16 hours. However in most cases scaling break is identified for spatial scales between 4 and 8, corresponding to spatial dimensions of 16 km to 32 km. It is assumed that the scaling break occurrence at these particular scales in central Poland conditions could be at least partly explained by the rainfall mesoscale gap (on the edge of meso-gamma, storm-scale and meso-beta scale).