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Multifractality of a high-resolution rainfall time series and assessment of the zero rain rate effect from standard and weighted analysis procedures

Sebastien Verrier, Laurent Barthès, and Cécile Mallet
Université Versailles Saint-Quentin; CNRS/INSU; LATMOS-IPSL, Guyancourt, France (verrier@latmos.ipsl.fr)

Rainfall processes have highly nonlinear and complex dynamics. A pertinent approach for their description is based on the scaling and multifractal properties exhibited by such processes. From a number of literature results, the Universal Multifractal Model (UMM) can be a good candidate for representing rainfall. This model is a generic three-parameter stochastic multiplicative cascade model, characterized by an index of multifractality α, an inhomogeneity parameter C1, and a nonconservativity parameter H. However, some issues remain open: in particular, the numerous zeros present in the rainfall series are expected to bias multifractal analysis results in some way. Moreover, we cannot easily distinguish between 'true' zeros and those due to instrumental limitations. Another issue, in the time domain, is a problem of resolution for most available time series: most studies concerning scaling were based on daily or hourly data, and very few information is available about smaller scales. Such datasets may provide partially inadequate information since the structure of short rain events (that contain extreme peaks, that of critical importance!) is washed out due to insufficient resolution. Coarse scale data may even artificially mix short and strong events with dry periods preceding or following them. In this study, spectral and multifractal analysis techniques are applied to an original dataset, consisting in a rain rate time series collected by the means of a dual-beam spectropluviometer in Palaiseau, France. The series have a 15-s resolution and cover a duration of 2 years, i.e. from summer 2008 to summer 2010. Whereas the largest scales (> 1 week) are associated to an almost flat spectrum, smaller scales show evidence of scaling, in separate regimes. The spectrum shows evidence of a sharp transition between scaling regimes at 30-min timescales, which is likely to correspond to the average rainfall event duration. The transition occurs between scales dominated by rain event internal variability and those dominated by event-to-event variability. Therefore, a small-scale (30 min -15s) and a large-scale (3 days - 1-3 h) regimes should be distinguished due to different scaling properties. The large-scale regime is characterized by multifractal variability with UMM exponents α=0.6, C1=0.4, H=0, which are similar to most literature results at such scales. On the contrary, at the smallest scales (<30 min), rain events exhibit a nonconservative multifractal behavior with UMM parameters α=1.8, C1=0.1, H=0.45. The zero rain rates represent 96% of the point values of the dataset and generally occur outside short continuous rain events. Since coarse-scale rain rate estimates mainly consist in averages of zeros and of true rain, it is expected that the large-scale UMM parameter estimates are biased. In order to remove at least part of this bias, a modified multifractal analysis technique, adapted from Gires et al. (2009, 2010), is applied to the data. Namely, a procedure of estimation of weighted empirical moments is defined in order to overweight nonzero values. The weighted moments of the series show a scaling behavior from 32-min timescale up to 2 weeks. It is shown that large-scale parameters estimated from this procedure are noticeably different from the previous ones, and much closer to small-scale UMM parameters, i.e. α=1.4, C1=0.15. The upper limit of the latter scaling range could be interpreted in terms of a 'synoptic maximum' associated with planetary scale atmospheric structures.

References:

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