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Revisiting Multifractal of High-resolution Temporal Rainfall Using a Wavelet-based Formalism

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Rainfall modeling and the characterization of its scale-invariant properties have been approached based on concepts and methodologies used in turbulence, e.g., multifractal analysis and multiplicative cascade models. Unfortunately, very much like what was done in the early studies of turbulence data, the techniques used to perform multifractal analysis of rainfall data, namely box-counting and structure function techniques, were shown to have intrinsic insufficiencies that might lead to partial and/or misleading estimates of the multifractal spectra.

In this work, we re-examine the scaling structure of high resolution temporal rainfall using a methodology, based on the continuous wavelet transform, which offers important advantages as compared to the more traditional multifractal approaches. The method amounts to computing partition functions from the wavelet transform modulus maxima (WTMM). The scaling exponent curve, $\tau(q)$, is extracted from the power law behavior of these partition functions and, from its ($\tau(q)$) Legendre transform, we obtain the singularity spectrum $D(h)$. We have applied the WTMM method to several midlatitude convective storms sampled every 5 seconds over several hours (Iowa storms). The $\tau(q)$ spectrum so-obtained is definitely nonlinear, the hallmark of multifractal scaling. Moreover, according to our limited statistical sample and the experimental uncertainty, these $\tau(q)$ curves are well fitted by a parabola $\tau(q) = c_1 q - c_2 q^2$ as expected for log-normal statistics. The quantitative estimates of the coefficients $c_1 = \langle h \rangle = 0.48 \pm 0.03$ and $c_2 = \langle h^2 \rangle - \langle h \rangle^2 = 0.18 \pm 0.05$ have been corroborated by alternatively computing the cumulants of the logarithm of the WTMM (also called the magnitude) which provide an independent estimate of c_1 and c_2, respectively. The robustness of these results has been tested by reproducing the multifractal analysis

with analyzing wavelets of increasing order; this study reveals that in order to get reliable estimates of the multifractal spectra of rainfall, one needs to use wavelets that have at least two vanishing moments. We also report preliminary results of 2-point statistical analysis of temporal rainfall data that reveal the existence of long-range correlations as characterized by a very slow logarithmic decrease of the magnitude correlation versus the time separation. The observation that the intermittency coefficient c_2 actually controls this logarithmic decay is a strong indication of the existence of an underlying multiplicative process. The experimental demonstration of the actual pertinence of the log-normal cascading picture (or lack thereof) for temporal rainfall data would require a richer statistical sample.