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# Turbulent compound Poisson / multifractal processes for modeling precipitation and the nature of the zeroes

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Longstanding observer's problems in rain include the transition from a particle description of rain at small scales to a field description at larger scales, and the problem of the nature of the support of the rain process (those regions where the rain rate is nonzero). In this talk, we show how both can be solved with the help of scaling, turbulence based stochastic (multifractal) processes.

At the small scales, the HYDROP (stereophotography) experiment has allowed a first direct connection to be made with classical turbulence laws: it was found that the liquid density field ($\rho$) follows the Corrsin-Obukov (passive scalar) $k^{-5/3}$ spectrum down to an inner "relaxation scale" of the order of 30-50cm where the drops effectively decouple from the turbulent wind field. By considering the turbulent drop coalescence equation, we show that the $\rho$, $n$ fields define different quadratic invariants leading to a $k^{-2}$ (rather than $k^{-5/3}$) spectrum for the drop number density field. Combined, the two laws can be used to construct a compound Poisson multifractal processes in which individual drops are distributed in a manner that satisfies the observed scaling statistics as well as the turbulent phenomenology. At large scales, this model can approximated by a thresholded cascade process; the threshold arises naturally since when the number density is sufficiently low, the inner scale of the rain process effectively becomes quite large.

At the large (5km-20,000km) scales, we use satellite radar reflectivities from the 10 year Tropical Rainfall Monitoring Mission (TRMM) to show how this model can be used to reproduce the reflectivity statistics over the range 5-20000km. First, even without explicitly considering the radar's relative high background noise (minimum detectable signal), which affects the low order moments of the reflectivity ($Z$), we find that the theoretically predicted multiscaling holds remarkably well. Indeed, over the observed range 5-20000km, the moments $<\mathrm{Z}_{\lambda}^{q}>\approx \lambda^{K(q)}$ for $0.5<q<2$ are predicted to within a maximum deviation of ±6% where $\lambda=\mathrm{L}_{eff}/\mathrm{L}_{res}$ $\mathrm{L}_{res}$, is the resolution of the reflectivities and $\mathrm{L}_{eff}$ is the effective outer scale of the cascade. We find $\mathrm{L}_{eff} \approx$ 40000km indicating that at planetary scales (20000km), there is residual variability from interactions with other meteorological fields/processes. We show that the scaling moment function $K(q)$ is well reproduced by a theoretically predicted two parameter ("universal") form, with co-dimension of the mean field $C_1 \approx 0.63$ and Levy index $\alpha$ (characterizing the degree of multifractality) $\approx 1.5$. In order to explain the small deviations from scaling for the low order moments which are sensitive to the minimum radar detection limit, we use multifractal models which we threshold. We find that zeroing all the regions below roughly one half the climatological reflectivity, that the slight deviations in the scaling of the low order moments can be explained to within 7%. It is noteworthy that the support (nonzero rain rate regions) do not need to be explicitly modeled, they are determined by the satellite's minimum detectable signal.