Geophysical Research Abstracts, Vol. 9, 09373, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-09373

The $l^{1/2}$ particle number law in rain

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The stereophotography of rain drops 10m^3 volumes (the “HYDROP” experiment ....[*Desaulniers-Soucy., et al.*, 2001]) has for the first time made it possible to empirically determine both the scaling properties and small scale scaling limits of both the liquid water density (ρ) and particle number density fields (n). In previous work, these data established that –due to the coupling of the drops and turbulence, that for scales larger than 30-50cm, the large scale density fluctuations were multifractal. In this paper, we show that the decoupling scale is (as expected) the relaxation scale for the drops and that at larger scales, the spectra are indeed close to those predicted for passive scalars by Corrsin-Obukhov theory (corresponding to density fluctuations $\Delta\rho \approx l^{1/3}$i.e. to a classical $k^{-5/3}$ spectrum for ρ) which assumes that the passive scalar variance of liquid water density is conserved from scale to scale. This is the first direct link between precipitation and passive scalar turbulence theory of which we are aware. However, the key link between turbulence and precipitation is via the particle number density (n). We show that since drop coalescence processes conserve particle mass but not number densities, that the number density flux is also a turbulent quadratic invariant but with a transfer time scale which is different than for the liquid water variance flux. From dimensional analysis, we theoretically predict a new Δn$\approx l^{1/2}$for fluctuations in n over a distance l corresponding to a k^{-2} spectrum for n which we confirm is close to observations.

Finally, we show how to model these number density and liquid density statistics using coupled multifractal cascade processes. These in turn can control a multifractal compound Poisson process which models the positions and volumes of individual rain drops. Numerical simulations spanning the range 1cm to 1000km can be readily

produced. These simulations can be used for simulating radar reflectivity factors, effective radar reflectivity factors; extensions of the model can be used to simulate rain rates and rain gauges. These models can thus potentially solve various precipitation observer problems.