Geophysical Research Abstracts, Vol. 9, 11001, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-11001

The scale dependence of rain: from raindrop stereophotography to global TRMM orbits

S. Lovejoy (1), D. Schertzer (2), V. Allaire (1)

(1) Physics dept., McGill U., 3600 University st., Montréal, Canada (lovejoy@physics.mcgill.ca (2) CEREVE, Ecole Nationale des Ponts et Chaussées, 6-8, avenue Blaise Pascal, Cité Descartes, 77455 MARNE-LA-VALLEE Cedex, (1) Physics dept., McGill U., 3600 University st., Montréal, Canada (lovejoy@physics.mcgill.ca/1-514-398-6537)

Rain is a highly turbulent process over enormous ranges of scale. The stereophotography of rain drops directly demonstrates that rain is strongly coupled with the wind field down to a "relaxation" scale of the order 30-50cm below which drop inertia makes them free. Using the results of this "HYDROP" experiment, we show that while the liquid water density (ρ) follows a multifractal generalization of the classical Corrsin-Obukov passive scalar law; $\Delta\rho \approx l^{1/3}$, on the contrary, the drop number density (n) follows the new law Δn$\approx l^{1/2}$. We show how both laws can be derived from dimensional analysis using appropriate turbulent fluxes.

The HYDROP experiment only determines the statistical properties of precipitation over the range of scales 3cm to 2m; for larger but intermediate scales ($\approx$3m- 5km), we use lidar and radar data which also show scaling of the backscatter cross-section and radar reflectivity factors respectively. To extend this up to planetary scales (5 - 20,000km), we use 3 months (1166 orbits) of the TRMM (Tropical Rainfall Monitoring Mission) satellite radar data at heights 250m above the surface. This global data set (over the region $\pm 38^o$ latitude) is remarkable for it's relatively complete and uniform coverage over a range of $\approx$4,000 in scale; it is also nearly free of the range dependent biases which plague ground based radar data. Ignoring for the moment the statistics from the weak reflectivities (which are biased due to the rather higher minimum detectable signal), we find that over the observed range 5-20000km, the moments $<Z_\lambda^q>$ for 0.5<q<2 follow the theoretically predicted form $<Z_\lambda^q> \approx \lambda^{K(q)}$ to within a maximum deviation of $\pm$6% where λ=L_{eff}/L_{res} L_{res}, is the resolution of the reflec-

tivities and L_{eff} is the effective outer scale of the cascade. We find $L_{eff} \approx 40000$km indicating that at planetary scales (20000km), there is residual variability from other interactions. Analyzing the exponent K(q) we show that it is well reproduced by a theoretically predicted two parameter ("universal") form, with codimension of the mean field $C_1 \approx 0.63$ and Levy index α (characterizing the degree of multifractality) ≈ 1.5. Finally over the range 20,000 - 5km using multifractal simulations we show that if the minimum detectable signal is ≈ 0.5 times the mean, then the slight deviations in the scaling of the low order moments ($q<0.5$) are explained to within $\pm 7\%$.

These findings allow us to make stochastic precipitation models which reproduce these isotropic statistics over huge ranges of scale. On the one hand, we can make compound Poisson / multifractal/ models of the distribution of individual drops which respect the basic turbulence laws, on the other hand, the same model can be used at much larger scales to accurately model the TRMM reflectivities.