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Using cascade models to understand TRMM space-time satellite precipitation reflectivities from 20000 to 4km, from days to years

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

(1) Physics dept., McGill U., 3600 University st., Montréal, Canada (lovejoy@physics.mcgill.ca/1-514-398-6537) (2) CEREVE, Ecole Nationale des Ponts et Chaussées, 6-8, avenue Blaise Pascal, Cité Descartes, 77455 MARNE-LA-VALLEE Cedex (3) NOAA, Earth System Research Laboratory R/CSD6, 325 Broadway, Boulder CO 80305-3337, USA.

The advent of space borne precipitation radar has opened up the possibility of studying the variability of global precipitation over huge ranges of scale while avoiding many of the calibration and sparse network problems which plague ground based rain gage and radar networks. We studied 1176 consecutive orbits of attenuation-corrected near surface reflectivity measurements from the TRMM satellite PR instrument. We find that for well-measured statistical moments (orders $0 < q < 2$) corresponding to dB$Z < 57$ and probabilities $>10^{-6}$, that the residuals with respect to a pure scaling (power law) variability are remarkably low: ±6.4% over the range 20,000 km down to 4.3 km. We argue that higher order moments are biased due to inadequately corrected attenuation effects. When a stochastic three - parameter universal multifractal cascade model is used to model both the reflectivity and the minimum detectable signal of the radar (which was about twice the mean), we find that we can explain all the same statistics to within ±4.6% over the same range. The effective outer scale of the variability was found to be 32,000 ± 2000 km. The fact that this is somewhat larger than the planetary scale (20,000 km) is a consequence of the residual variability of precipitation at the planetary scales. With the help of numerical simulations we were able to estimate the three fundamental parameters as αg $\approx$ 1.5, C_1 = 0.63±0.02 and H = 0.00±0.01 (the multifractal index, the codimension of the mean and the noncon-

servation parameter respectively). There was no error estimate on α since although α = 1.5 was roughly the optimum value, this conclusion depended on assumptions about the instrument at both low and high reflectivities. The value $H = 0$ means that the reflectivity can be modeled as a pure multiplicative process, i.e. that the reflectivity is conserved from scale to scale. We show that by extending the model down to the inner "relaxation scale" where the turbulence and rain decouple (in light rain, typically about 40 cm), that even without an explicit threshold, the model gives quite reasonable predictions about the frequency of occurrence of perceptible precipitation rates.

While our basic findings (the scaling, outer scale) are almost exactly as predicted twenty years on the basis on ground based radar and the theory of anisotropic (stratified) cascades, they are incompatible with classical turbulence approaches which require at least two isotropic turbulence regimes. They are also incompatible with classical meteorological phenomenology which identifies morphology with mechanism and breaks up the observed range 4 km - 20 000km into several subranges each dominated by different mechanisms. Finally, since the model specifies the variability over huge ranges, it shows promise for resolving long standing problems in rain measurement from both (typically sparse) rain gage networks and radars.