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Transient Scaling Behavior and Predictability of Atmospheric Moisture, Clouds and Precipitation

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The stochastic scaling behavior of clouds and rainfall observations exhibits transient behavior consistent with the temporal and spatial evolution of atmospheric dynamics at all scales. In mountainous regions, and regions of well-defined, spatially stationary modes of land-atmosphere interactions, analysis of remote-sensing and ground-based observations shows ubiquitous co-organization of landform, clouds and precipitation with seasonal and inter-annual variability consistent with regional climate. Recent work using both idealized and realistic model simulations of atmospheric dynamics (Nogueira and Barros, 2014; Nogueira et al., 2013) shows that transient scaling behavior at regional scales can be strictly interpreted in the light of moist processes, and in particular atmospheric stability regimes as defined by CAPE, Richardson number and normalized Brunt-Vaisala frequency among others. Furthermore, a sharp transition scaling parameters between non-convective and convective conditions is found that explains different scaling regimes reported in the literature for atmospheric wind, temperature and moisture observations. Spectral slopes around 2-2.3 arise under non-convective or very weak convective conditions, tightly related to the scaling behavior of the underlying topography. In convective situations the transient scaling exponents remain under 5/3 in agreement with the Kolmogorov turbulent regime accounting for the intermittency correction. The non-convective/convective transition is also unambiguously captured by the temporal evolution of the multifractal intermittency parameter. These findings indicate that the transient stochastic scaling of clouds and precipitation is an emergent property of complex moist processes with important implications for predictability: predictability in space conditional on landform and land-atmosphere interactions at local to regional scales, and predictability in time conditional on atmospheric dynamics, and convective activity in particular. This has direct impact for stochastic downscaling generally, an in practice for the implementation of stochastic sub-grid scale parameterizations using fractal methods in atmospheric models. For instance, results obtained by imposing the 2.1 or 5/3 scaling in the fractal interpolation algorithm as a first approximation to the transient scaling parameters, depending on whether the downscaled field is respectively stratiform or convective, capture the sub-grid scale statistics of cloud fields well. Specifically, it is shown that, based on scaling arguments and atmospheric stability conditions, time-varying sub-grid scale probability distributions of atmospheric moisture, clouds and precipitation in particular, can be obtained from the coarse resolution information alone. Previous research has focused on horizontal and volume scaling analysis. Here, we present for the first time new results on vertical scaling analysis of high resolution numerical simulations that allow us to explore the fingerprints of stratification and vertical organization in the atmosphere.

Nogueira, M., and Barros, A.P., 2014: The non-convective/convective structural transition in stochastic scaling of atmospheric fields. J. Geophys. Res- Atmos., 119, DOI:10.1002/2014JD022548.

Nogueira, M., Barros, A.P., Miranda, P., 2013: Multifractal properties of embedded convective structures in orographic precipitation: toward subgrid-scale predictability. Nonlinear Processes in Geophysics, 20, 1-17, DOI:10.5194/npg-20-1-2013.