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# A systematic analysis of scaling properties of meteorological analyses, numerical models, and atmospheric fields

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Between the outer planetary scale and inner (viscous) dissipation scale, the basic equations of the atmosphere have no characteristic lengths. Therefore, we expect that both the atmosphere and the corresponding numerical (weather/climate) models should be scaling; i.e., that their statistics (such as spectra) are power law functions of space/time scales. This expectation has been repeatedly confirmed by empirical observations, and including the recent systematic analysis of TRMM satellite data. While the temporal scaling properties of climate models have been occasionally studied, the model spatial resolutions have been too low to allow systematic study of their spatial scaling properties. However, in the last few years, the models have come to contain a wide enough range of spatial scales (close to 1000) so that their spatial scaling properties can be reasonably well determined using a variety of analysis techniques. We investigate this problem by considering the temporal spatial scaling in the ERA-40 (ECMWF reanalysis) as well as various numerical prediction and general circulation climate models.

Our most remarkable conclusion is that the horizontal wind and temperate seem to follow the predictions of cascade theories very closely between the planetary scale and a scale corresponding to a couple of pixels of the being analysed model (&#8776;300km). We observe scale invariance at different altitudes, as well. The horizontal spectrum for both east/west (U) wind and temperature fields has at lower altitudes a slope of -11/5 corresponding to the Bolgiano-Obukhov law, which corresponds to the spectrum being dominated by the buoyancy force flux, and it steepens with in-

creasing altitude for both.

These results demonstrate that the apparent complexity of models actually implies simplicity in their scale-by-scale behaviour. One possible application is creating new sub-grid parameterizations with these results. A more immediate application is the possibility of evaluating models using stochastic methods in lieu of comparing a model realization and an atmospheric "snapshot", thereby overcoming many of the problems of inadequate data. Finally, by systematically comparing the scaling characteristics of the empirical data, the analyses, and then the model integrations with each other, we can examine the "stochastic coherence" of the data assimilation and model system.