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The space-time cascade structure of TRMM and MTSAT precipitation and thermal infrared radiances

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Up until now, attempts to systematically understand the space-time statistical structure of the atmosphere (including precipitation) have been hampered by both inappropriate theoretical frameworks and inadequate, problematic data. On the one hand, the theories have concentrated on classical turbulent fluxes especially the energy and enstrophy fluxes which are only justified with strong but unrealistic isotropy assumptions: on the contrary, the real atmosphere is strongly anisotropic (stratified) but nevertheless scaling. On the other hand, if we restrict our attention to the wind, temperature and other standard meteorological fields, then only very narrow ranges of space-time scales are empirically accessible.

If the stratification is scaling, then atmospheric dynamics can be governed by anisotropic cascades of nonstandard turbulent fluxes. In this generalized scaling framework we expect scaling relations of the (generalized) Kolmogorov form to hold:

F(L) = e(L) L**H

where F(L) is the fluctuation in a field at scale L and H is a scaling exponent and e(L) is the underlying resolution L flux. We use this approach to estimate e(L) and then to systematically degrade it to lower and lower resolutions. The cascade hypothesis predicts that

<e(L)**q> = (Louter/L)**K(q)

where here L is the resolution of the flux, Louter is the outer scale of the cascade (where it starts) and K(q) is a scaling exponent function describing all the statistical properties as a function of scale.

In order to exploit the space-time data with highest resolution possible, we analyse satellite radar and radiance data spanning the visible, infra red, and microwave regions of the spectrum from the TRMM and MTSAT satellites over the region ±40o latitude. The temporal resolutions are respectively 2 -4 days and 1 hour and both have spatial resolutions of 5km. We analysed the spatial properties over all these radiance channels and found that scaling behaviour is obeyed to within about ±1% from planetary scales down to the smallest available.

Since the dynamical (velocity) field is strongly coupled to the radiances (via the cloud field), and the velocity couples the spatial and temporal statistics, we expect that the radiances will also be scaling in time. We therefore determined the statistical lifetime-size relation for structures defined by the various fields. Up to about 20-30 days (the lifetime of planetary size structures), we found that the relation is quite with an effective velocity of about 6 m/s. For longer (climate scale) periods there seems to be another scaling regime with outer scale around 1200 days with corresponding characteristic velocity of about 0.5 m/s. This apparently corresponds to the temporal precipitation cascade as shown by space-time analyses of the TRMM precipitation radar data. We discuss the implications for measuring and modeling atmospheric fields especially precipitation.