Fractal property in horizontal geometry of tropical clouds from high-resolution observation and simulation

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In the tropics, deep convection spontaneously organizes over a variety of spatiotemporal scales, characterized by hierarchical structure of cloud clusters. Cloud-resolving models, which explicitly calculate individual clouds, have been developed for the purpose of understanding the effect of cumulus convection on large-scale circulation. There has been an increasing need for quantitative index for geometry of cloud clusters to validate observations and cloud-resolving simulations. As a measure, previous works have addressed fractal analyses (Lovejoy, 1982). Yet, it is unclear if the results of those fractal analyses have any valuable implications for the dynamics of convection. Thus, the science of fractal has not been properly incorporated into meteorology. Here we newly formulate a version of fractal dimension as a function of horizontal scale. From satellite observations, we find a self-similarity that is confined to certain range of scales instead of ideal fractal. We show that there is a typical length scale at about 30 km, which characterizes the scale separation of cumulus convection. On the other hand, a simulation with Non-hydrostatic Icosahedral Atmospheric Model displays a different self-similarity. These findings illustrate that even a cloud-resolving model with sub-kilometer resolution cannot fully reproduce the geometrical features of tropical clouds. The characteristic length scale at 30 km mostly corresponds to that of precipitative cold pools (Haerter et al., 2019), implying a relation between formation of convections and collision of cold pools. Since the horizontal distribution of clouds have a significant effect on the Earth's radiation balance, fractal properties must be incorporated into cloud-resolving models to simulate convective extremes and their effect on climate more realistically.

Key words: Fractal, HIMAWARI-8, NICAM

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