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Multifractal constraints on cloud and precipitation structure in LES

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Coarse-gridded atmospheric models often account for subgrid-scale variability by specifying probability distribution functions (PDFs) of process rate inputs such as cloud and rain water mixing ratios (q_c and q_r, respectively). PDF parameters can be obtained from numerous sources: in situ observations, ground- or space-based remote sensing, or fine-scale modeling such as large eddy simulation (LES). LES is appealing to constrain PDFs because it generates large sample sizes, can simulate a variety of cloud regimes/case studies, and is not subject to the ambiguities of observations. However, despite the appeal of using model output for parameterization development, it has not been demonstrated that LES satisfactorily reproduces the observed spatial structure of microphysical fields. In this study, the structure of observed and modeled microphysical fields are compared by applying bifractal analysis, an approach that quantifies variability across spatial scales, to simulations of a drizzling stratocumulus field that span a range of domain sizes, drop concentrations (a proxy for mesoscale organization), and microphysics schemes (bulk and bin). Simulated q_c closely matches observed estimates of bifractal parameters that measure smoothness and intermittency. There are major discrepancies between observed and simulated q_r properties, though, with bulk simulated q_r consistently displaying the bifractal properties of observed clouds (smooth, minimally intermittent) while bin simulations produce q_r that is appropriately intermittent but too smooth. These results suggest fundamental limitations of bulk and bin schemes to produce sufficiently intermittent and rough precipitation, further implying that simulations of warm rain with Eulerian microphysics schemes are likely unable to reproduce higher-order spatial statistics of precipitation. We end by proposing a framework for development of stochastic microphysical parameterizations.

Authors: WITTE, Mikael (Naval Postgraduate School); Dr MORRISON, Hugh (NCAR)

Presenter: WITTE, Mikael (Naval Postgraduate School)

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