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Modeling deep moist atmospheric convection

W. Skamarock and G. Bryan
National Center for Atmospheric Research, Boulder, Colorado, USA [skamaroc@ucar.edu]

In the past decade, numerous studies have demonstrated that numerical simulations of deep moist atmospheric convection are not statistically converged until grid spacings are of order 100 meters or less, consistent with Large Eddy Simulation (LES) theory. Simulations using LES resolutions possess statistics consistent with theory and observations for 3d turbulence and convection, including a k**(-5/3) inertial subrange in the kinetic energy spectra, exponential behavior of the vertical mass fluxes, and strong kurtosis, in addition to having converged statistics for quantities of critical importance in climate and weather prediction such as surface precipitation and net vertical transport of water substance.

Neither climate nor weather models can be run at LES resolutions, and while it is well known that parameterizations for large-scale models have serious deficiencies, we find that simulations using cloud resolving models (CRMs) with grid spacings of a few kilometers also contain serious errors. Hence even when using CRMs significant sub-grid parameterization problems exist. We will briefly review our LES and CRM simulation results and illustrate the errors encountered in simulations using horizontal grid-spacings of a few kilometers, and we will consider approaches for parameterizing the sub-grid component of deep convection at these grid spacings. Parameterization at these scales is a difficult problem for which there is no existing theory in contrast to the parameterization problem for the large scale, where it is assumed that an ensemble of convective cells exists within a grid volume, or for the LES scale, where it is assumed that the large eddies responsible for most of the mixing in convective cells are resolved and that mixing associated with the sub-grid eddies can be modeled based on correlations with the resolved scales. Current research involves either extending these existing approaches, or exploring alternatives such as using stochastic backscatter.