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The resolution dependence of explicitly modeled convection

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In a number of studies over the past decade, researchers have concluded that cloud resolving models (CRMs) can often successfully simulate moist unstable atmospheric convection when using horizontal gridspacings of a few kilometers or less. These modeling-based studies have focused primarily on reproducing the observed convective structures and evolutions in a gross sense, for example, simulating the evolution of a squall line from a downshear to an upshear tilt in a weakly sheared environment. Comparisons of observations with simulations show, however, that CRMs do not reproduce well many aspects of convection, including hydrometeor distributions, surface precipitation and cold pool temperatures, and even gross convective structure in some environments. Additionally, different models show significant variations in convective realizations, including transport.

The simulation errors arise from problems both internal and external to the CRMs. As one step towards improving CRMs, we have performed simulations to determine at what gridspacing the CRM solutions statistically converge (with respect to structure and transport properties) for a range of convective environments and initial states. We find that the gridspacings necessary for convergence are consistent with Large Eddy Simulation (LES) experience, that is, gridspacings must generally be two orders of magnitude smaller than the length scales of the energeticaly dominent structures in the CRM simulations. For most convective simulations, this suggests that gridspacings need to be of order 100 meters or less. These results point to the turbulence parameterization as being one of the critical CRM components, and the design of turbulence parameterizations for commonly used gridspacings (of order 1 km) as being a critically important research question.