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The senstivity of convection initiation to the wind shear, lapse rate, and relative humidity in the active cloud-bearing layer

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A suite of 3D cloud-resolving numerical simulations have been conducted in order to explore the sensitivity of convection initiation to the active cloud-bearing layer (ACBL) lapse rate (LR), relative humidity (RH), and vertical wind shear. An analytic sounding generation technique is used so that ML-CIN, ML-CAPE, and ML-LFC are the same across all environments considered. The initiation of deep convection is achieved using an initially slab-symmetric (2D) preexisting airmass boundary whose symmetry is broken through the prescription of a wave-like temperature perturbation on the cool-side of the boundary.

All 64 of the 3D cloud-resolving simulations that composed the parameter space mapped by the combinations of four values of the ACBL parameters resulted in the release of gravitational instability but only 25 supported CI, defined according to the simulation of appreciable rainwater and hail at the surface. Consistent with prior work, simulated CI is more likely for larger ACBL LR and higher ACBL RH. A consistent relationship between CI and vertical shear is not reflected in all LR-RH combinations (for many combinations, CI either occurs or does not occur for all vertical shear values considered), but for those combinations that exhibit both CI and no CI (across the set of vertical shear values) the trend is clear: the likelihood of CI scales directly with the vertical shear. This behavior would seem to be inconsistent with the increased turbulence and mixing that would be expected in larger shear (lower Ri) environments. Analysis reveals that vertical shear impacts CI through upstream (relative to the eastward gust front motion) advection of high equivalent potential temperature air that has detrained from downstream shallow convection. Shallow convection developing within this detrained air will experience less deleterious entrainment and will therefore have an increased likelihood of becoming deep. Moreover, the presence of residual positive buoyancy in this detrained air can increase the upward vertical perturbation pressure gradient force owing to the buoyant component of pressure.