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The Impact on Simulated Storm Structure and Intensity of Variations in the Lifted Condensation Level and the Level of Free Convection

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ABSTRACT

The sensitivities of convective storm structure and intensity to changes in the altitudes of the prestorm environmental lifted condensation level and level of free convection are studied using a full-physics three-dimensional cloud model. Matrices of simulations are conducted for a range of LCL=LFC altitudes, using a single moderately-sheared curved hodograph trace in conjunction with convective available potential energy values of either 800 or 2000 J kg^{-1}, with the matrices consisting of all four combinations of two distinct choices of buoyancy and shear profile shape. For each value of CAPE, the LCL=LFC altitudes are also allowed to vary in a series of simulations based on the most highly compressed buoyancy and shear profiles for that CAPE, with the environmental buoyancy profile shape, subcloud equivalent potential temperature, subcloud lapse rates of temperature and moisture, and wind profile held fixed. For each CAPE, one final simulation is conducted using a near optimal LFC, but a lowered LCL, with a neutrally buoyant environmental thermal profile specified in between.

Results show that, for the buoyancy-starved small-CAPE environments, the simulated storms are supercells and are generally largest and most intense when LCL=LFC altitudes lie in the approximate range 1.5-2.5 km above the surface. The simulations show similar trends for the shear-starved large-CAPE environments, except that conversion from supercell to multicell morphology frequently occurs when the LCL is high. For choices of LCL=LFC height within the optimal 1.5-2.5 km range, peak storm updraft overturning efficiency may approaches unity relative to parcel theory, while for lower LCL=LFC heights, overturning efficiency is reduced significantly. The enhancements of overturning efficiency and updraft diameter with increasing LFC height are shown to be the result of systematic increases in the mean equivalent potential temperature of the updraft at cloud base. For the shear-starved environments, the tendency for outflow dominance is eliminated, but a large overturning efficiency maintained, when a low LCL is used in conjunction with a high LFC. The

result regarding outflow dominance at high LCL is consistent with expectations, but the beneficial effect of a high LFC on convective overturning efficiency has not previously been widely recognized. The simulation findings here also appear to be consistent with statistics from previous severe storm environment climatologies, but provide a new framework for interpreting those statistics.

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