# The Sensitivity of Convective Initiation to the Lapse Rate of the Active Cloud-Bearing Layer

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ABSTRACT

Numerical experiments are conducted using an idealized cloud-resolving model to explore the sensitivity of deep convective initiation (DCI) to the lapse rate of the active cloud-bearing layer [ACBL; the atmospheric layer above the level of free convection (LFC)]. Clouds are initiated using a new technique that involves a preexisting airmass boundary initialized such that the (unrealistic) adjustment of the model state variables to the imposed boundary is disassociated from the simulation of convection. Reference state environments used in the experiment suite have identical mixed layer values of convective inhibition, CAPE, and LFC as well as identical profiles of relative humidity and wind. Of the six simulations conducted for the experiment set, only the three environments with the largest ACBL lapse rates support DCI. The simulated deep convection is initiated from elevated sources (parcels in the convective clouds originate near 1300 m) despite the presence of a surface-based boundary. Thermal instability release is found to be more likely in the experiments with larger ACBL lapse rates because the forced ascent at the preexisting boundary is stronger (despite nearly identical boundary depths) and because the parcels' LFCs are lower, irrespective of parcel dilution. In one experiment without deep convection, DCI failure occurs even though thermal instability is released. Results from this experiment along with the results from a heuristic Lagrangian model reveal the existence of two convective regimes dependent on the environmental lapse rate: a supercritical state capable of supporting DCI and a subcritical state that is unlikely to support DCI. Under supercritical conditions the rate of increase in buoyancy due to parcel ascent exceeds the reduction in buoyancy due to dilution. Under subcritical conditions, the rate of increase in buoyancy due to parcel ascent is outpaced by the rate of reduction in buoyancy from dilution. Overall, results demonstrate that the lapse rate of the ACBL is useful in diagnosing and/or predicting DCI.

## 1. Introduction

The initiation of deep convection requires (at a minimum) conditional instability (a vertical profile of temperature that can yield the release of thermal instability given parcel saturation) and a trigger (the initial upward motion that releases the thermal instability). A localized trigger for deep convective initiation (DCI) would be unnecessary if the atmosphere was absolutely unstable, but this is usually not the case and more often the atmosphere is characterized by a layer of potentially warm air above the surface [quantified as convective inhibition (CIN)] that inhibits the spontaneous release of thermal instability. However, in situations for which atmospheric preconditioning (Johnson and Mapes 2001) has removed CIN, DCI is still not assured since the dilution of individual air parcels ascending toward the level of free convection (LFC) can increase the actual inhibition of each parcel (Ziegler and Rasmussen 1998). This increase in inhibition typically manifests itself as a cooling of cloudy parcels produced when dilution/entrainment reduces parcel moisture, thereby promoting evaporation. Assessing the dilution of individual air parcels requires relaxing parcel theory, which specifically excludes mixing. In doing so, the parcel LFC becomes a time-dependent quantity that increases with increasing parcel dilution (a parcel cooled

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