ATMOSPHERIC SCIENCES
TEXAS A&M UNIVERSITY

Idealized Simulations of Supercells in Environments with Varying LCLs

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Background

Motivated by studies that suggested that the height of the Lifted Condensation Level (LCL) can affect tornadogenesis and cold pool intensities in supercell thunderstorms, idealized simulations were run to investigate the influence of LCL heights on supercells and their development. Several studies have noted that a more intense cold pool may inhibit tornadogenesis, since the air that comprises the pre-tornadic near-ground circulation would be more negatively buoyant and harder to intensify via vorticity stretching (Markowski and Richardson 2009). In order to evaluate whether supercells with lower LCLs are more likely to produce tornadoes, we performed three idealized numerical simulations of isolated supercell thunderstorms in environments with varying LCLs. Each horizontally homogeneous environment is thermodynamically and kinematically similar but for the addition of a successively deeper boundary layer with a lapse rate that is nearly dry adiabatic. Corrections to the surface pressure were made to maintain near constant CAPE and CIN among the simulations. It is our expectation that weaker vertical vorticity will be present at the surface in simulations with higher LCLs due to the production of stronger, more negatively buoyant cold pools.

Model Specifications

- Cloud Model 1 (CM1), version 18.3 – A 3D, time-dependent, non-hydrostatic model
- 500 meter grid spacing on a 250 km by 250 km grid
- 37 vertical levels with a vertically stretched grid
- 5th order velocity and scalar advection schemes
- 6th order diffusion scheme
- Klemp-Wilhelmson time splitting, vertically implicit pressure solver
- Morrison double-moment moisture scheme
- Warm Bubble Initialization
    - 1400 meters AGL
    - 4 K maximum potential temperature perturbation

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References and Acknowledgments

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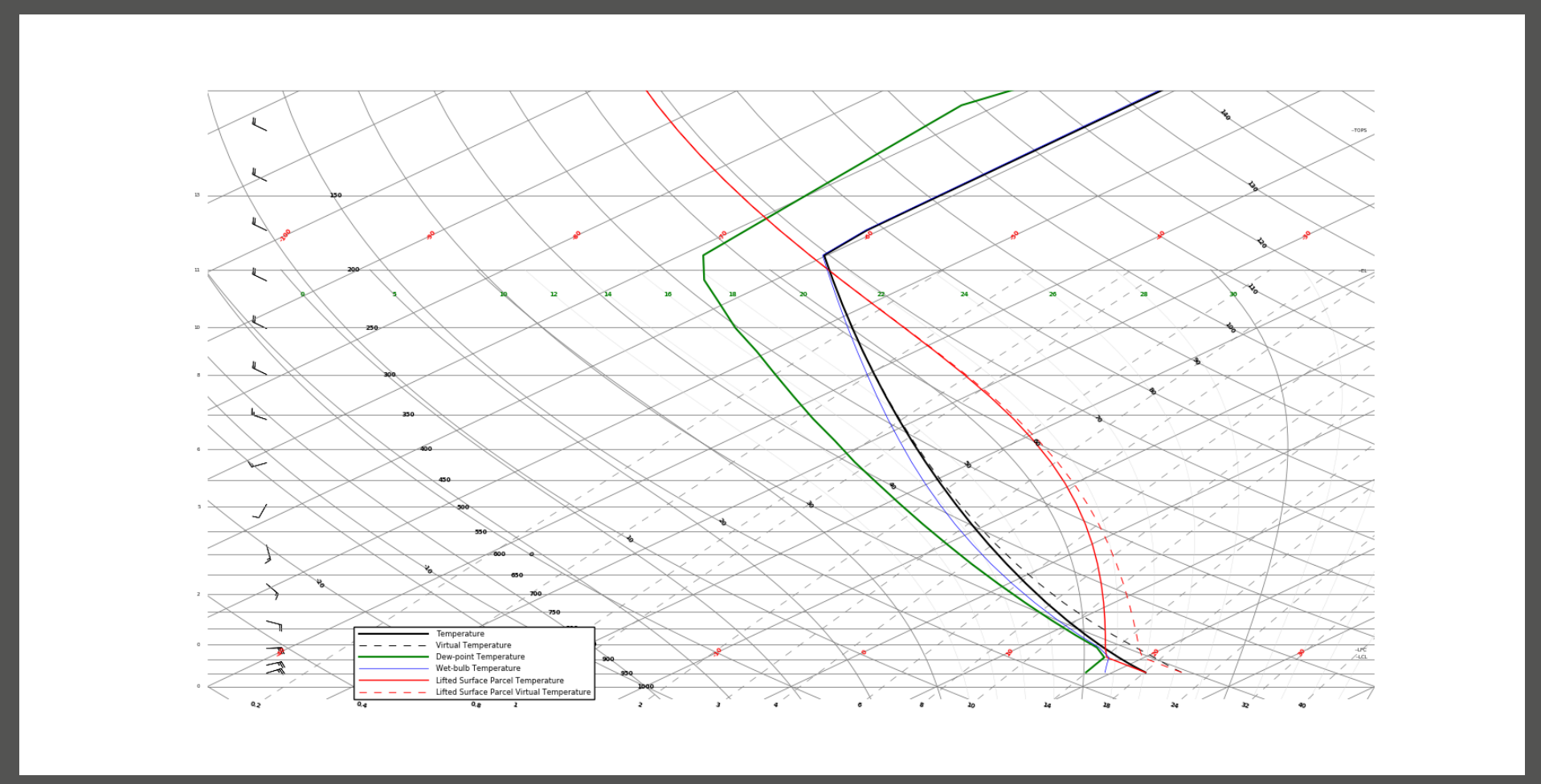
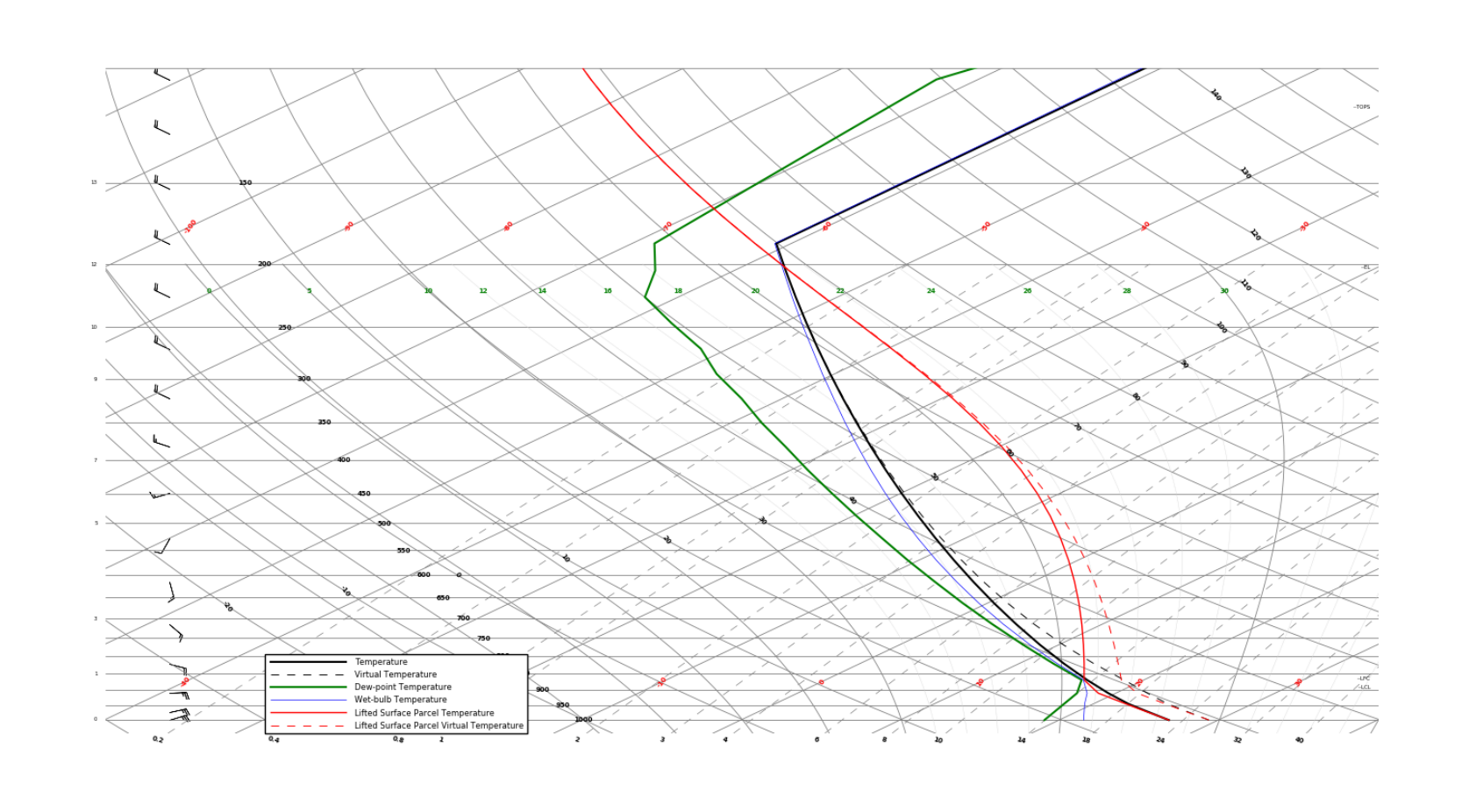
Marskowski, P.M., and Richardson, Y.P., 2009: Tornadogenesis: Our current understanding, forecasting considerations, and questions to guide future research. *Atmospheric Research,* **93**, 3-10, doi: 10.1016/j.atmosres.2008.09.015

Craven, J.P., Brooks, H.E., and Hart, J.A., 2002: Baseline climatology of sounding derived parameters associated with deep moist convection. *21st Conference on Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., 643-646, [Available online at http://www.spc.noaa.gov/publications/craven/baseclim.pdf]

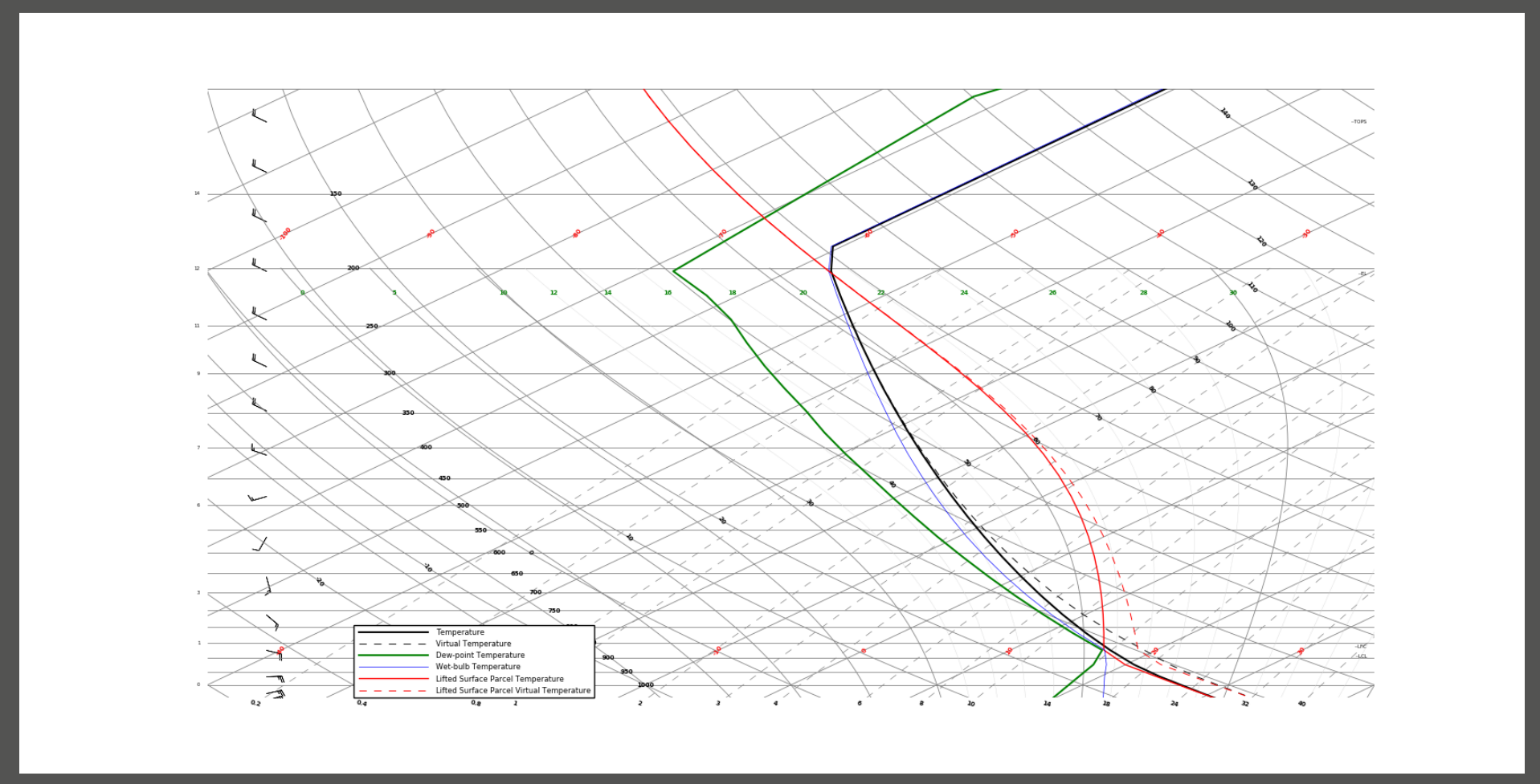
Soundings



Low LCL
- SFC-CAPE: 2444.2 J/kg
- SFC-CIN: 10.1 J/kg
- SFC-LCL: 557.3 m

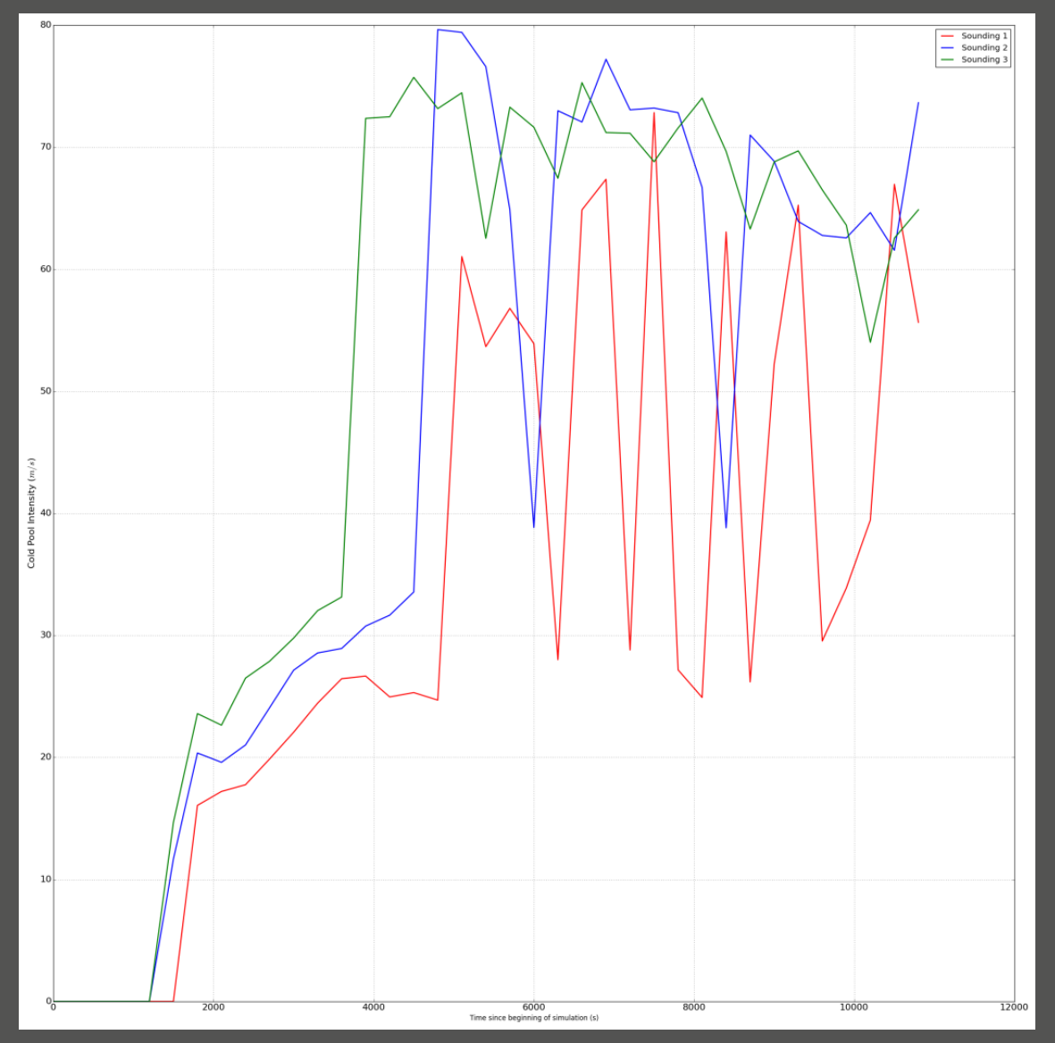


Mid LCL
- SFC-CAPE: 2415.8 J/kg
- SFC-CIN: 11.4 J/kg
- SFC-LCL: 1026.5 m



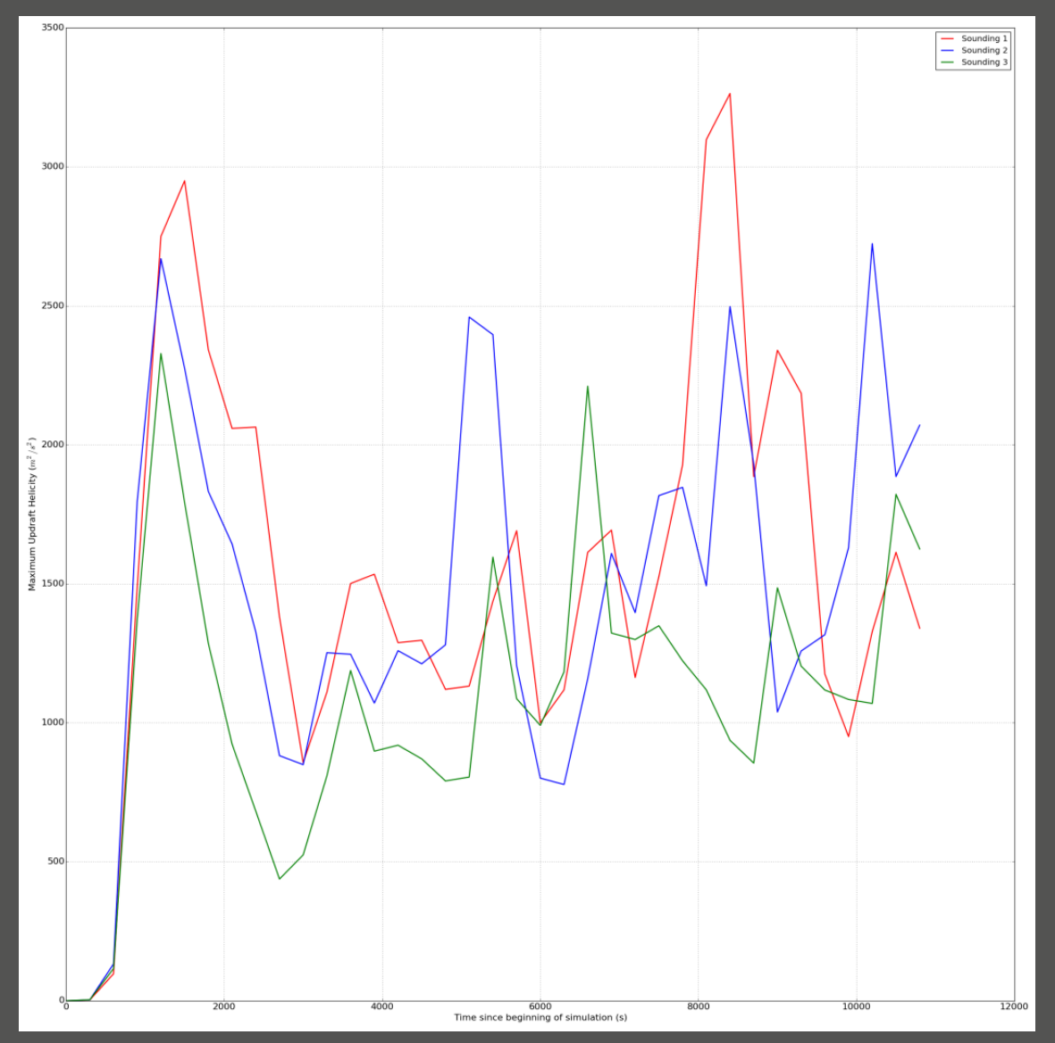
High LCL
- SFC-CAPE: 2350.2 J/kg
- SFC-CIN: 18.4 J/kg
- SFC-LCL: 1616.4 m

Time Series



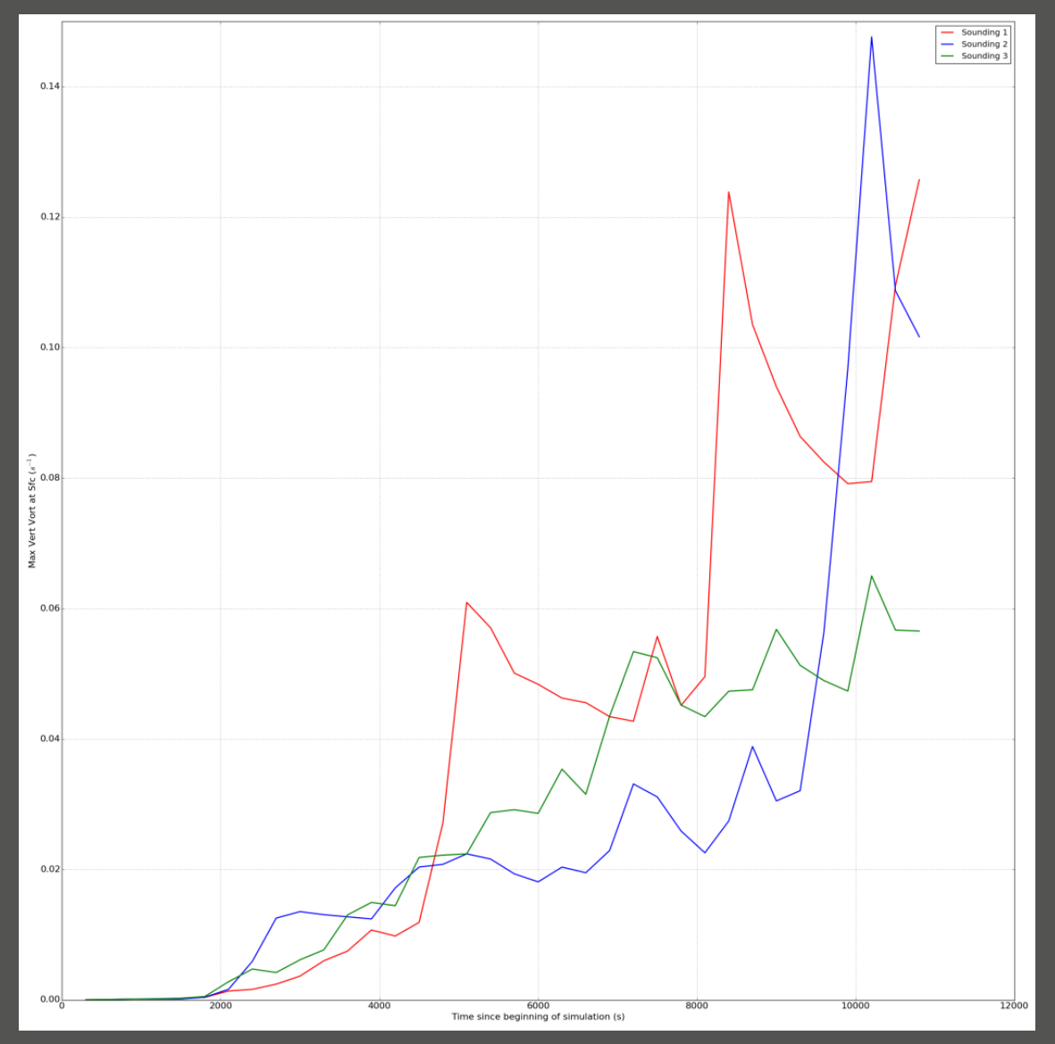
Cold Pool Intensity

- The lowest LCL sounding reaches its first maximum at the latest time, and never reaches higher intensity levels. Additionally, the CPI drops significantly at five different times.
- The middle LCL sounding reaches its maximum CPI, the highest of all three soundings, at a slightly earlier time than the lowest LCL sounding. CPI values drop significantly only twice.
- The highest LCL sounding reaches its highest CPI values the earliest of the three soundings, and does not see any significant drops.
- Generally, the higher the LCL, the larger the cold pool intensity



Updraft Helicity

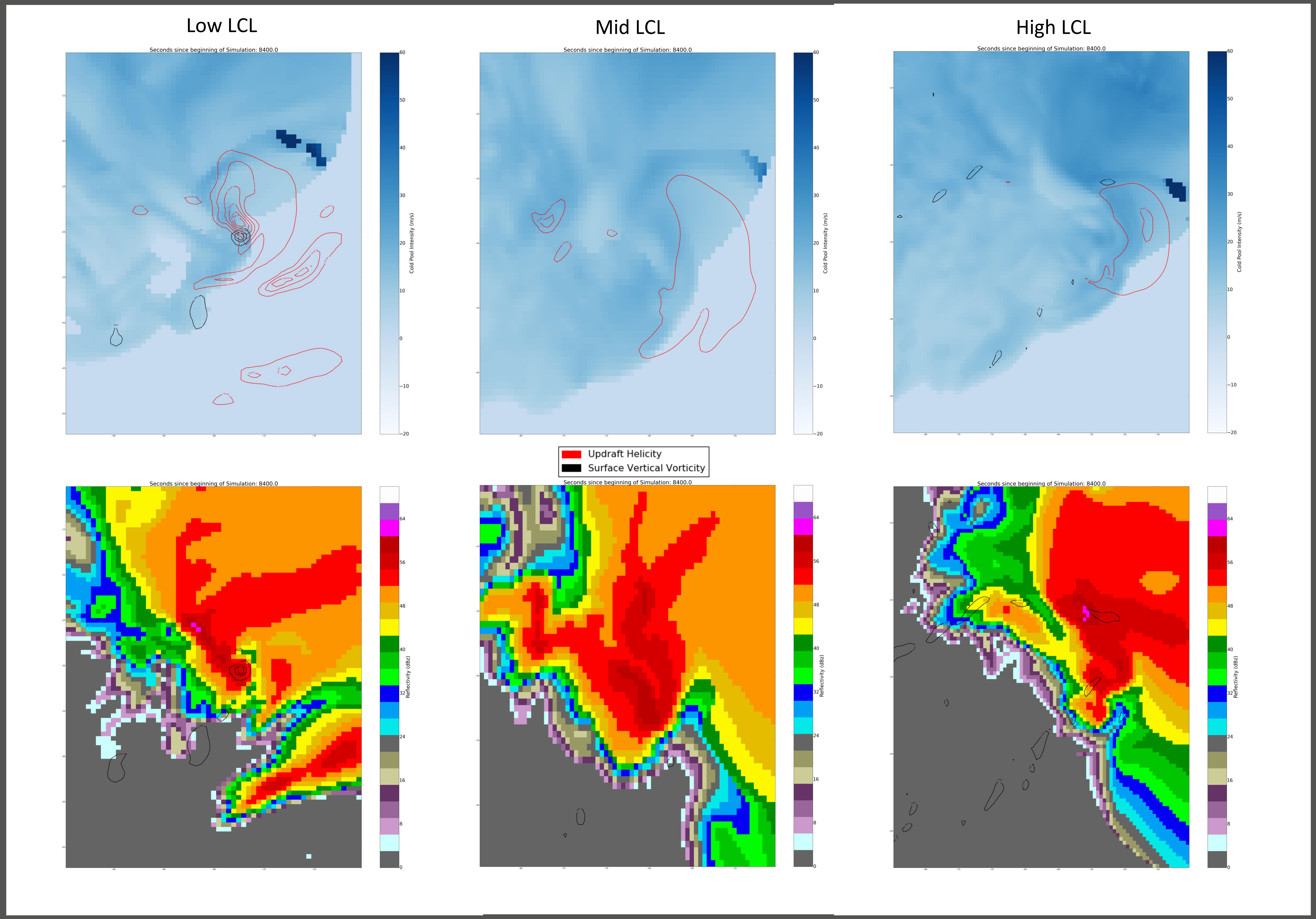
- The lowest LCL sounding has two notable maxima at 1500 and 8400 seconds, reaching the highest values of any three of the simulations
- The middle LCL sounding reaches a slightly weaker maximum before the low LCL sounding, at 1200 seconds, but has three more distinct peaks at 5100, 8400, and 10200 seconds.
- The highest LCL sounding also reaches a weak maximum at 1200 seconds, but only reaches one other significant maximum at 6600 seconds.
- These results suggest that higher LCL heights may lead to suppressed updraft helicity values in supercell thunderstorms



Surface Vertical Vorticity

- The lowest LCL sounding reaches two notable maxima at 5100 and 8400 seconds, and generally has the highest values throughout the simulation
- The middle LCL sounding shows significant suppression of vertical vorticity, reaching its maximum at 10200 seconds
- While having a higher surface vertical vorticity than the middle LCL sounding from 4800 to 9600 seconds, the highest LCL sounding shows a definite suppression in the surface vertical vorticity, never reaching a value greater than 0.07 s^{-1}
- These results suggest the higher the LCL, the more suppressed the surface vertical vorticity

Comparison at 8400 seconds



- Significantly higher values of updraft helicity in the Low LCL case, and the amount of updraft helicity decreases during this time step as LCL height decreases
- Low LCL simulation shows a significant amount of surface vertical vorticity very near the maximum amount of updraft helicity.
- Little to no significant surface vertical vorticity found in the Mid and High LCL cases
- High LCL case has the largest and most intense cold pool, and both the size and intensity tend to decrease as the LCL is lowered
- Low LCL simulated reflectivity shows another cell developing in the updraft region of the main cell
- Mid LCL simulated reflectivity shows a storm of less defined shape, and the High LCL storm appears to be organized more like the Low LCL case

Conclusions

- Simulation results suggest that lower LCL heights correspond well with higher values of surface vertical vorticity and updraft helicity, and that the values of both decrease as the LCL height is raised.
- As the LCL is increased, cold pool size and intensities tend to increase as well.
- This implies that the stretching of the near-ground circulation is easier in the case of a low LCL. This could be a result of less negatively buoyant air in the circulation (less intense cold pool due to less evaporation in the boundary layer), or a stronger mid-level mesocyclone.