Aerosol Sensitivities in Idealized Simulations of VORTEX-2 and VORTEX-SE Supercells

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Motivation

- Aerosol cloud condensation nuclei (CCN) types and concentrations are known to affect many different aspects of deep convective storms
- Recent studies have shown substantial sensitivity of supercell properties, such as cold pool intensity and tornadogenesis potential, to changes in initial CCN concentrations (Lerach et al. 2008; Lerach and Cotton 2012)
- One objective of the VORTEX-SE field program is to characterize microphysical and thermodynamic processes in low-CAPE Southeast-U.S. supercells and how they differ from storms in higher-CAPE environments more typical of the U.S. Great Plains

Main research questions:

- Are sensitivities to CCN concentrations different between these two environments for various storm properties? Why or why not?
- What are the implications for tornadogenesis potential?

Methods and Objectives

- Perform high-resolution (250-m horizontal grid spacing) idealized, horizontally homogeneous simulations of VORTEX-SE and VORTEX2 supercells initialized with proximity soundings (Fig. 1)
- Simulations are stratified by the initial constant background CCN concentration spanning values associated with "clean" environments (0.1 x 10^9 m^{-3}; 100 cm^{-3} to "highly polluted" (3.0 x 10^9 m^{-3}; 3000 cm^{-3}).
- We utilize the triple-moment version of the NSSL bulk microphysics scheme with variable density graupel and hail and prognostic CCN (Mansell et al. 2010; Dawson et al. 2014).
- Initial objective is to characterize the sensitivity of overall storm organization and cold pool properties.

Case Overview

- Two cases from VORTEX-SE (31 March 2016 and 30 April 2016) and one case from VORTEX-2 (5 June 2009).
- VORTEX-SE cases characterized by relatively modest SBCAPE (~1300 and ~800 J kg^{-1}, respectively), and relatively deep moisture
- VORTEX-2 case characterized by high CAPE (~2800 J kg^{-1}) and a well-mixed boundary layer capped by a dry EML.

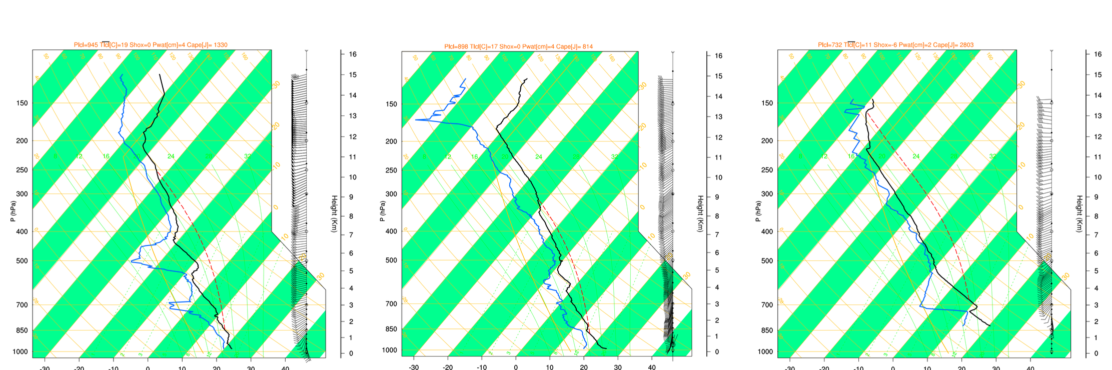

Fig. 1. Skew-T plots of soundings used for idealized simulations. (Left) 31 March 2016. (Middle) 30 April 2016. (Right) 5 June 2009.

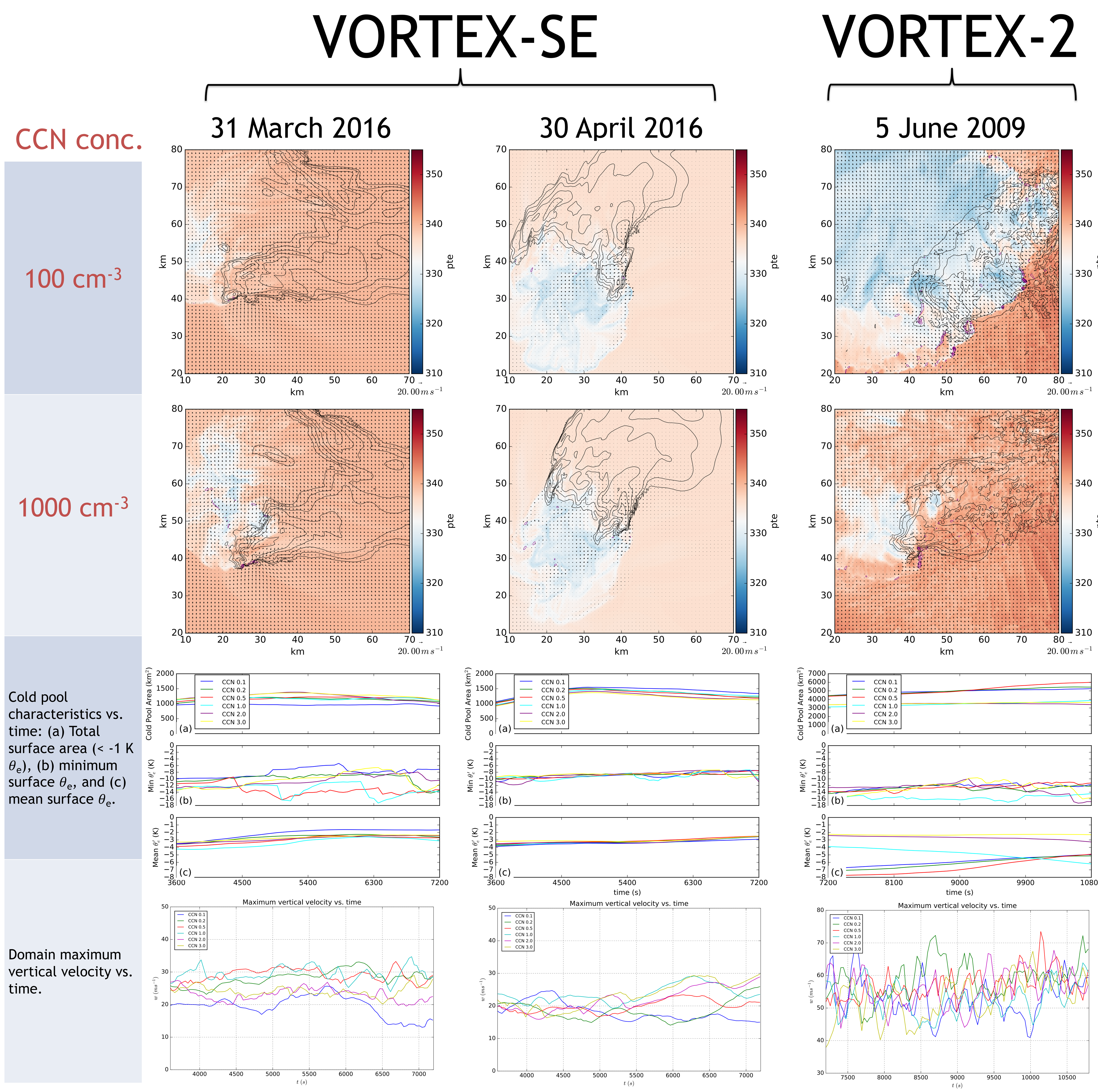

Fig. 2. (Top color-filled plots): surface equivalent potential temperature θ_e (color fill), radar reflectivity (black contours; 10 dBZ increment and surface wind vectors (every 1 km) for (left to right) 31 March 2016, 30 April 2016, and 5 June 2009, respectively and (top) 100 cm-3 and (bottom) 1000 cm-3 CCN concentration respectively. Plots are shown at 3600 s for the 31 March and 30 April cases, and 7200 s for the 5 June case. (Bottom line plots): Cold pool characteristics and domain maximum vertical velocity for the various CCN concentrations (x 10^3 cm^{-3}).

Discussion and Preliminary Conclusions

- Overall storm behavior and morphology is reasonably well captured by idealized simulations in each case (Fig. 2)
- Overall trend for storm organization to improve with increasing CCN concentration, especially between 0.1 and 1.0 x 10^9 m^{-3}.
- The two VORTEX-SE cases show relatively little trend in cold pool characteristics with increasing CCN concentration; there appears to be a slight increase (decrease) in cold pool size and intensity for the 31 March (30 April) cases.
- In contrast, the 5 June 2009 VORTEX2 case exhibits much stronger sensitivity, with a substantial increase in both area and intensity, especially between 500 and 1000 cm^{-3}.
- These results are broadly consistent with those of Lerach et al. (2008), Lerach and Cotton (2012), and Kalina et al. (2014).
- **Big questions:** why the abrupt change in cold pool intensity and size in the VORTEX-2 case, but not in the VORTEX-SE case? Is this difference repeatable?

Next Steps

- This analysis is still very preliminary. Immediate plans are for adding more cases and testing sensitivity to initial conditions (i.e. different soundings from each case, different configurations of initial forcing regions, etc.)
- Analysis of microphysical processes responsible for storm organization and cold pool intensity differences
- Higher-resolution simulations to examine sensitivity of tornadogenesis, intensity, and longevity
- Current simulations utilize free-slip lower boundary conditions. Ongoing work is testing a new balancing technique to test the sensitivity of cold pool and tornado behavior to the presence of surface friction without modifying the initial background wind profile.

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