Aerosol Effects in a Simulated Supercell Thunderstorm

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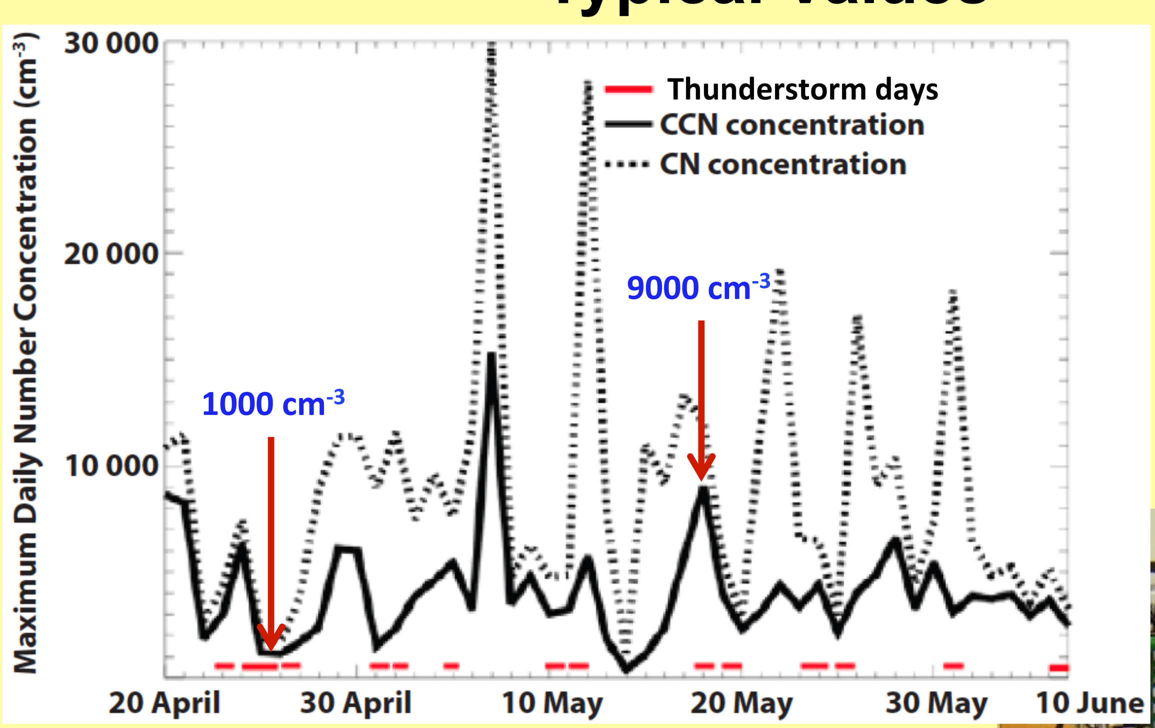
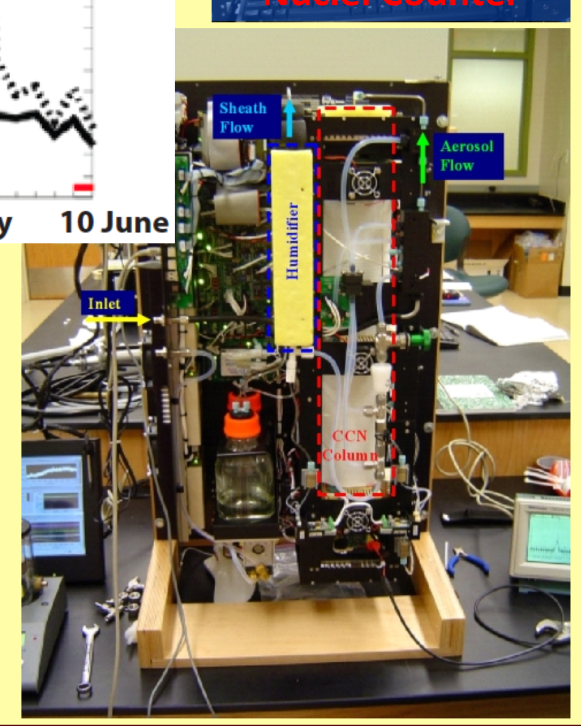
1. Motivation

1. How do the microphysical processes in a supercell thunderstorm change across the range of aerosol concentrations observed in our atmosphere?
2. How do aerosol-induced changes in the microphysical processes affect the cold pool and the spatial distribution of precipitation?
3. Do these changes increase monotonically with increases in aerosol concentration, or are there nonlinear effects?

2. Atmospheric Aerosol Concentration: Typical Values



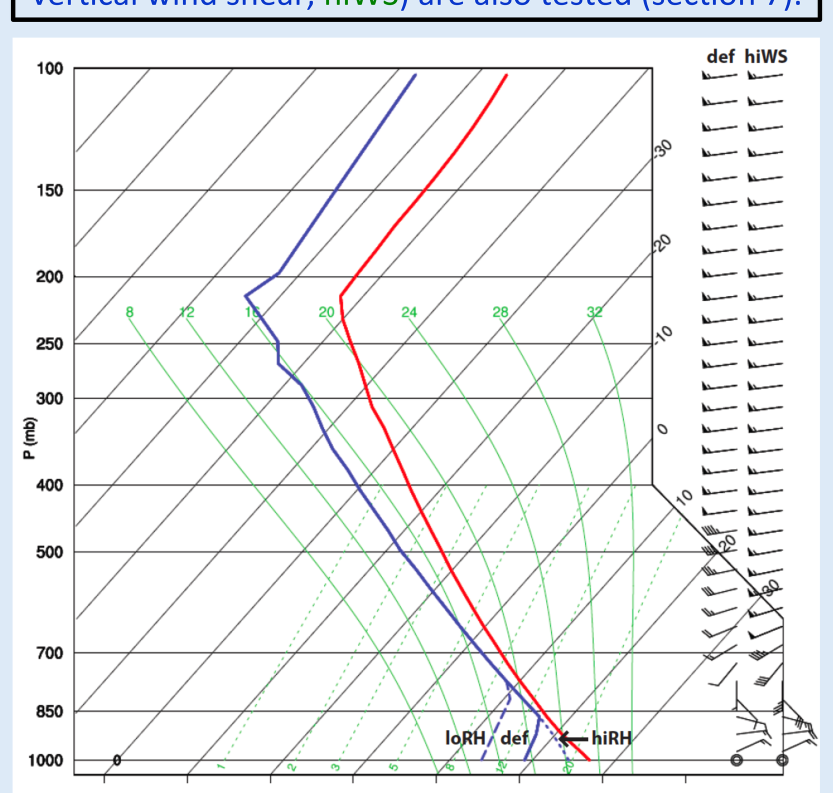


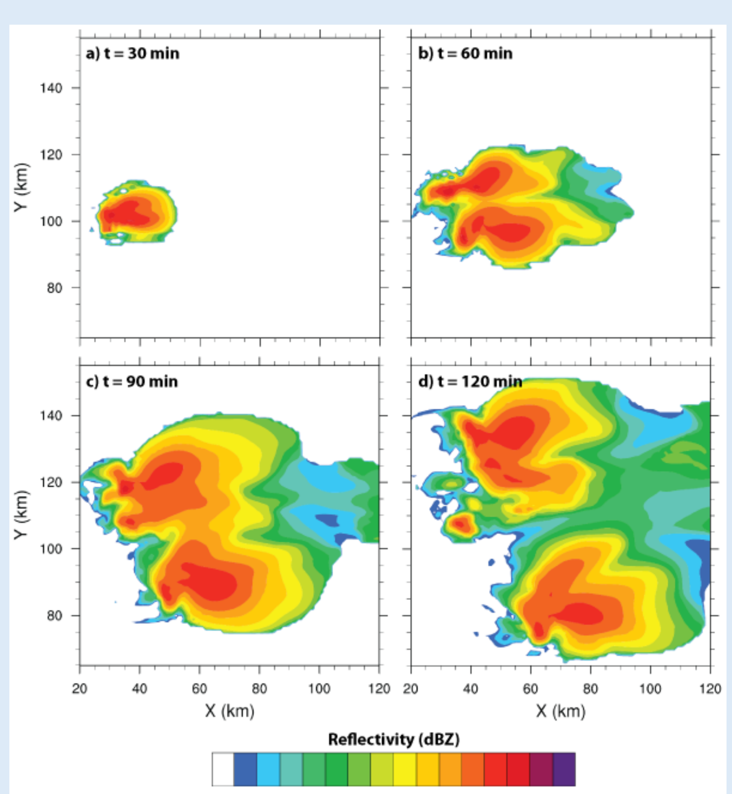
Above: Observations from the Southern Great Plains (Lamont, OK)

1. Tremendous variation in CCN concentration: 100 cm^{-3} - 15 000 cm^{-3}
2. Peak concentration is smaller on thunderstorm days: 9000 cm^{-3}
3. We therefore test 15 different CCN concentrations: 100 - 10 000 cm^{-3}

3. Configuration of the <u>W</u>eather <u>R</u>esearch and <u>F</u>orecasting (WRF) Model

Model is initialized with the default (def) sounding shown below. Different soundings (low relative humidity, loRH; high relative humidity, hiRH; and high vertical wind shear, hiWS) are also tested (section 7).

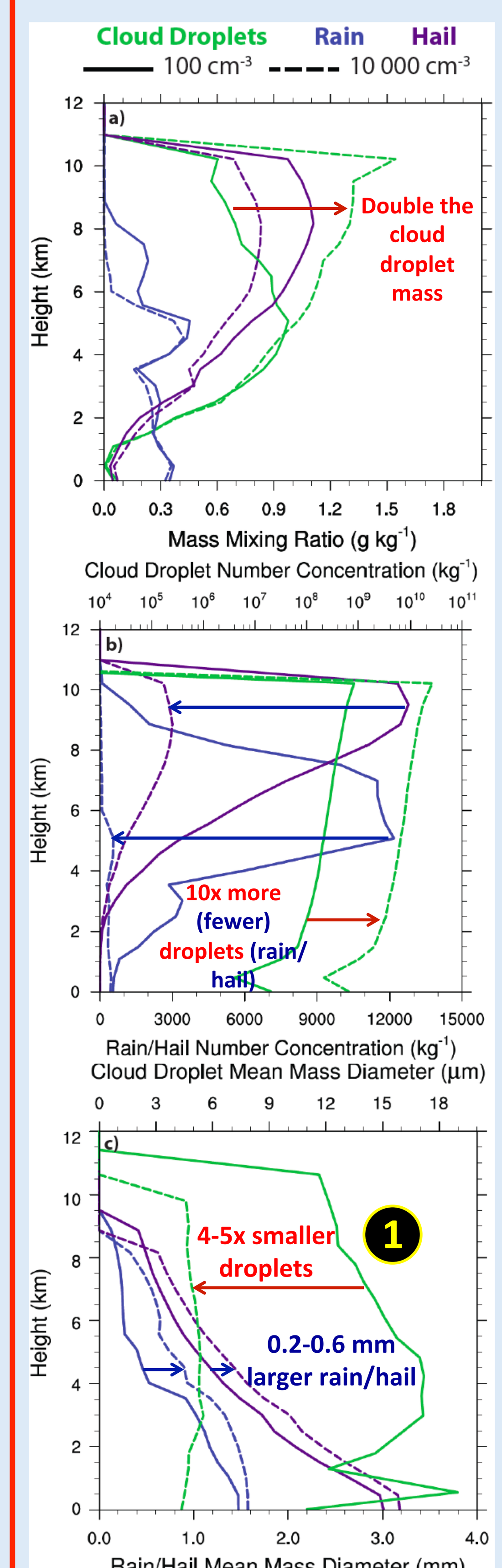




Idealized supercell thunderstorm with Morrison microphysics (double moment: cloud droplets, ice crystals, rain, snow, and hail). All other physics packages turned off. Δx = 1 km

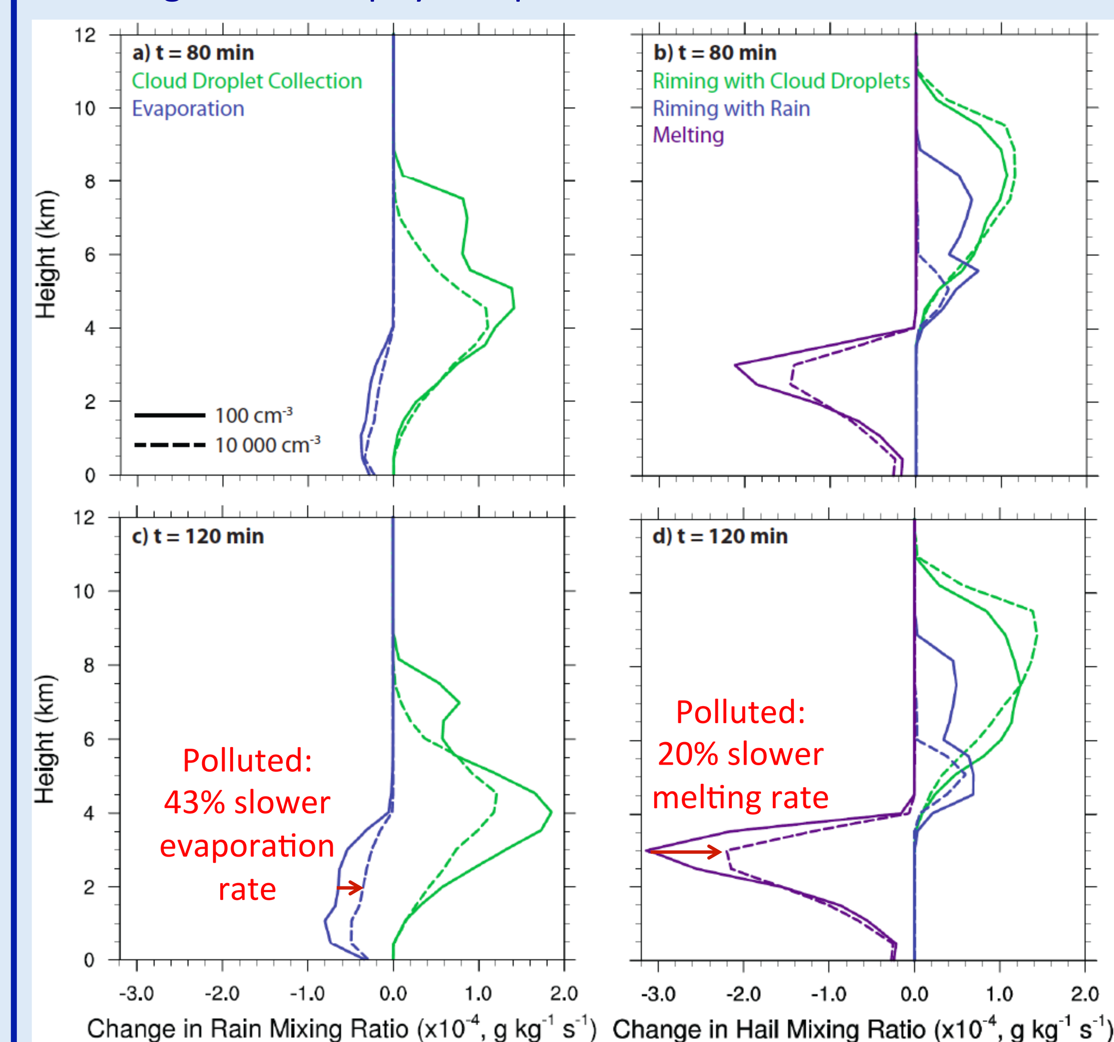
4. Results: Aerosol Effect on Cloud Microphysics

A. Changes in hydrometeor mass mixing ratio, number concentration, and diameter



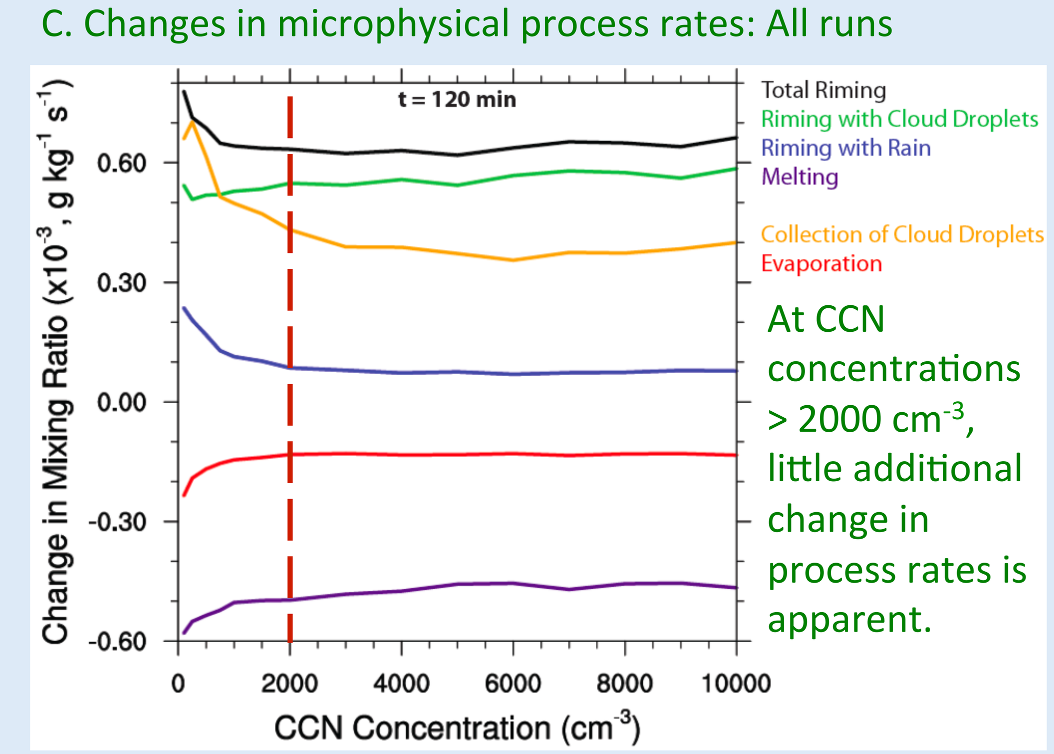
More CCN lead to smaller, more numerous cloud droplets and larger, more sparse rain and hail particles.

B. Changes in microphysical process rates: Polluted vs. clean



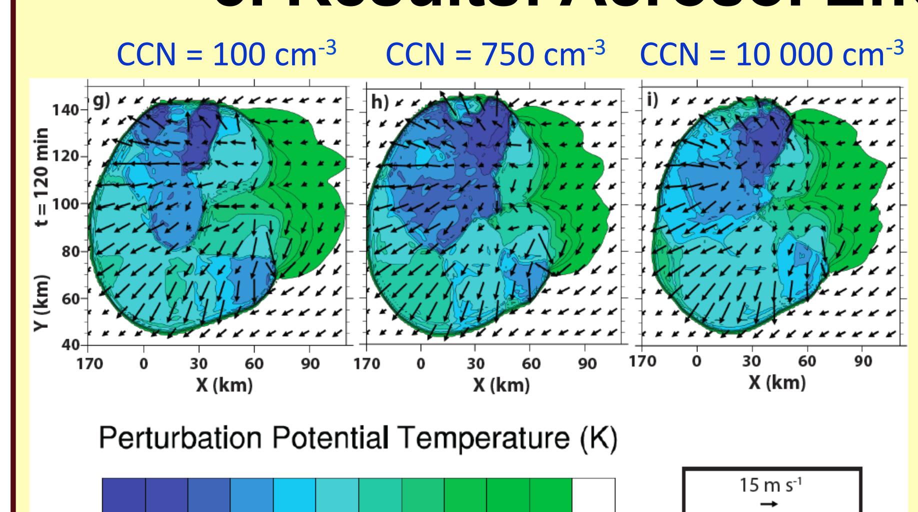
At larger CCN concentrations, evaporation and melting are reduced. Riming of hail with cloud droplets is increased.

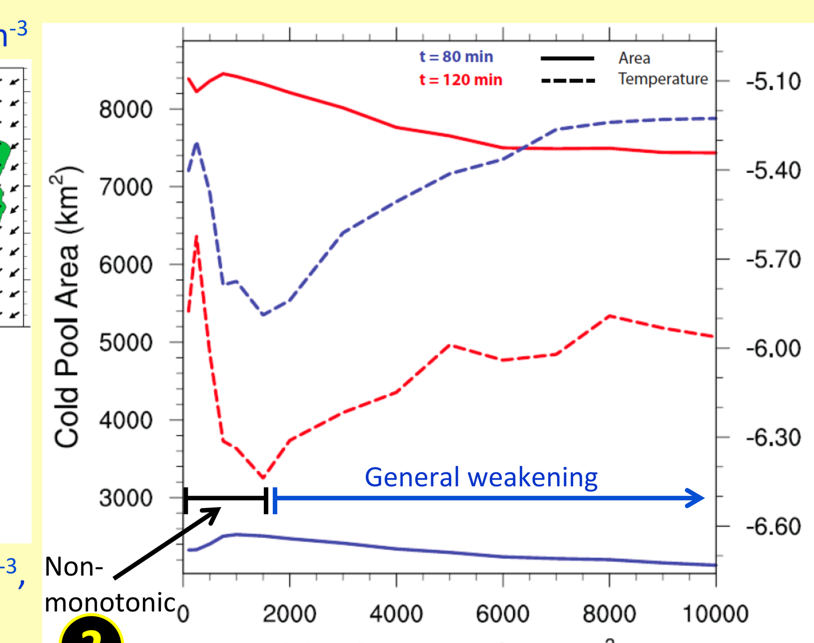
C. Changes in microphysical process rates: All runs



At CCN concentrations > 2000 cm^{-3}, little additional change in process rates is apparent.

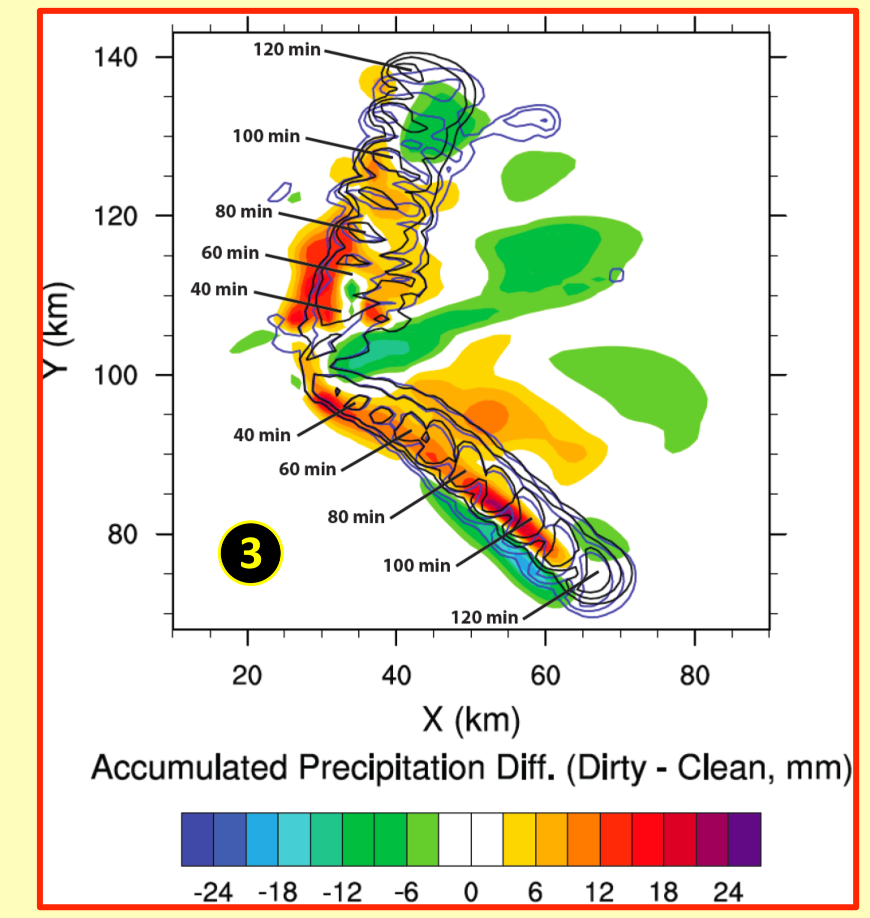
5. Results: Aerosol Effect on the Cold Pool

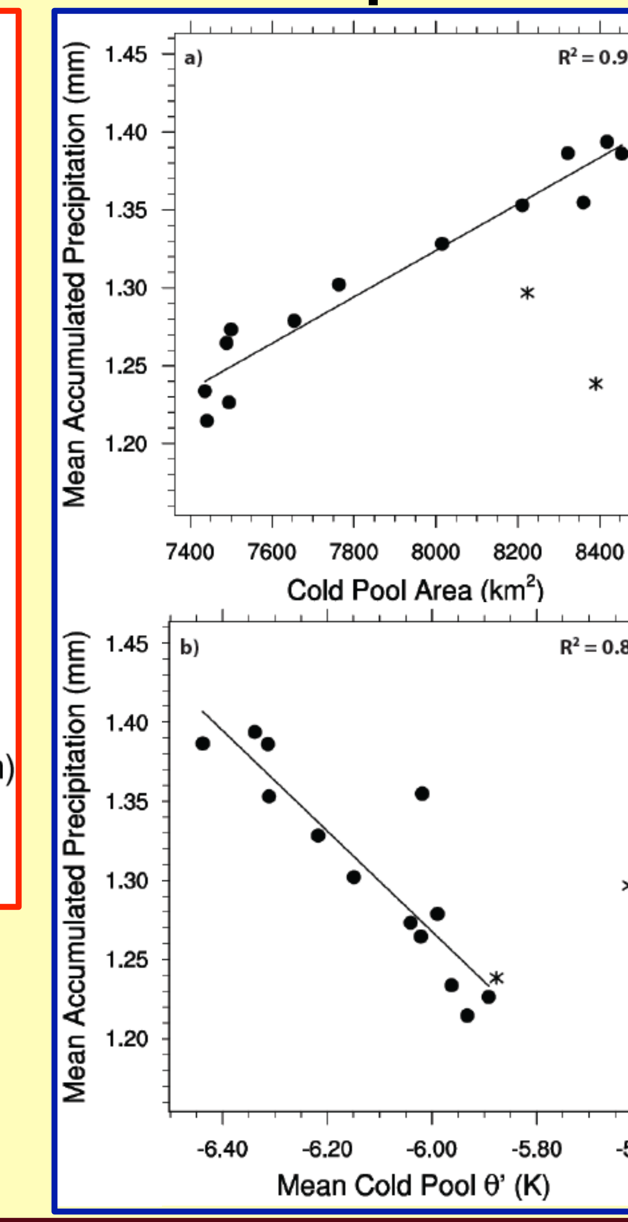




Non-monotonic effects are apparent: Up to CCN = 750 cm^{-3}, larger CCN concentrations strengthen the cold pool. After CCN = 1500 cm^{-3}, the cold pool weakens.

6. Results: Aerosol Effect on Precipitation

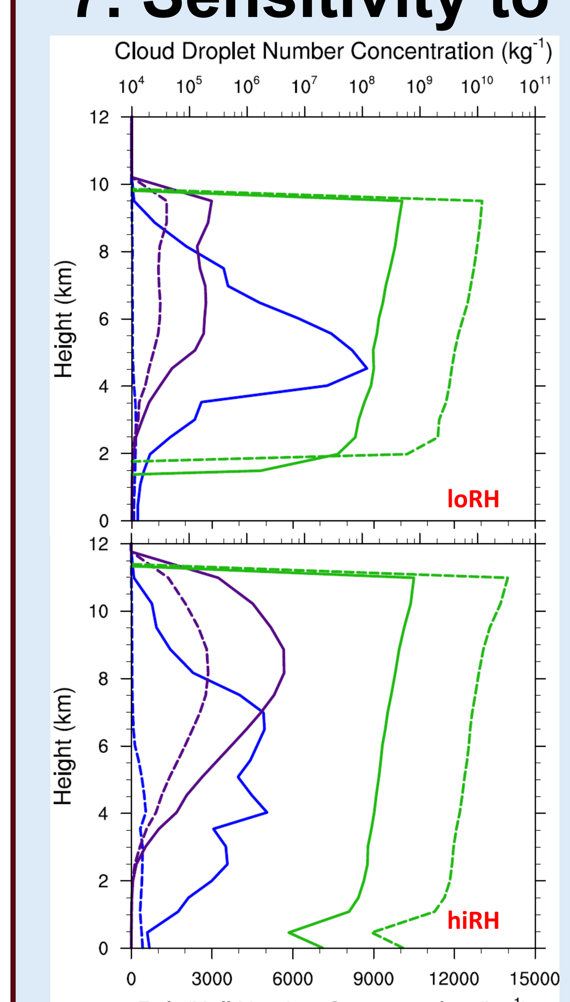


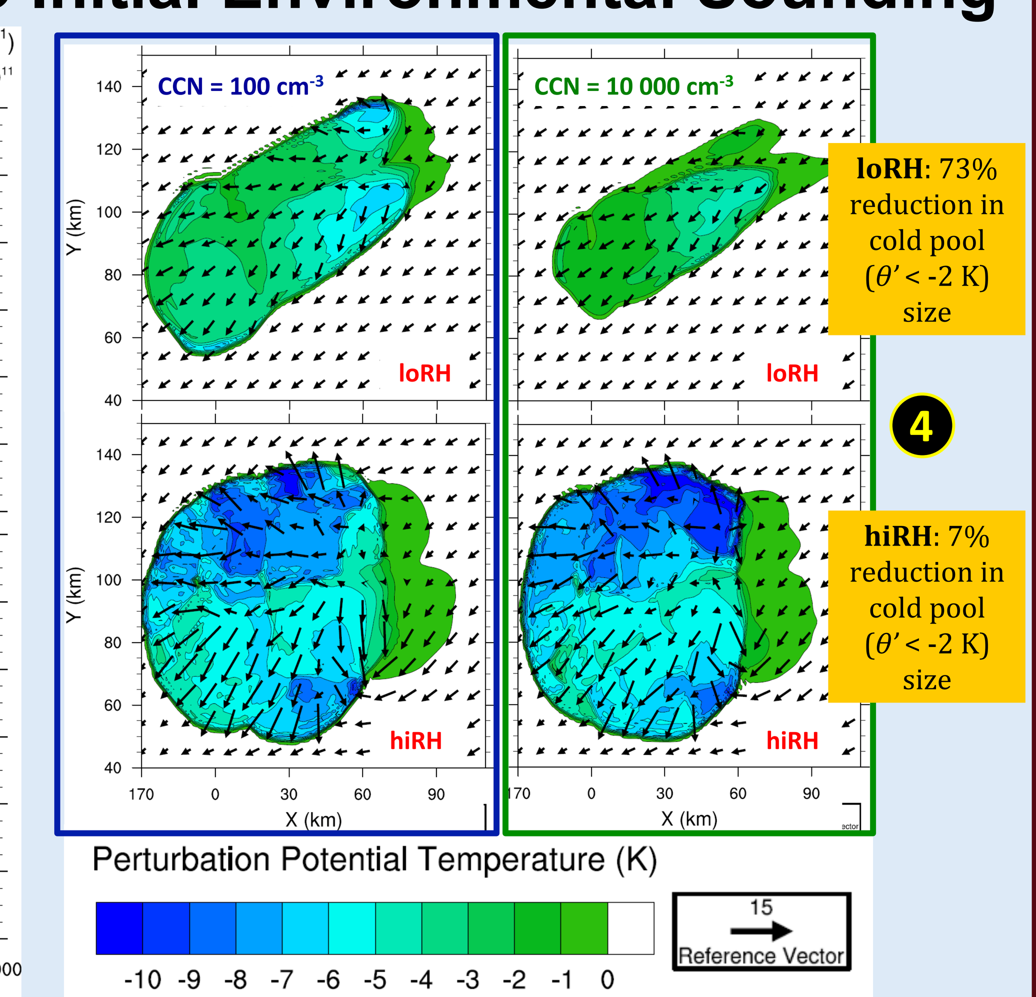


<u>Above</u>: In the most polluted run, accumulated precipitation along the left- and right-moving updraft tracks is up to 24 mm larger.

<u>Right</u>: The domain-averaged precipitation is strongly correlated with the cold pool characteristics (size: R^2 = 0.94; temperature: R^2 = 0.80).

7. Sensitivity to Initial Environmental Sounding





loRH: 73% reduction in cold pool (θ' < -2 K) size

hiRH: 7% reduction in cold pool (θ' < -2 K) size

8. Conclusions

1. The dirtiest simulation (CCN = 10 000 cm^{-3}) has smaller, more numerous cloud droplets and larger, less numerous rain and hail particles than the cleanest simulation (CCN = 100 cm^{-3}).
2. The size and temperature of the cold pool display non-monotonic responses to changes in the CCN concentration, with maxima in cold pool area and temperature deficit at CCN = 750 cm^{-3} and CCN = 1500 cm^{-3}, respectively.
3. Compared to the cleanest run, precipitation is increased (by up to 24 mm) along the tracks of the left- and right-moving updrafts in the most polluted run. In addition, the track of the right-mover has shifted to the northeast.
4. The magnitude of the aerosol effect is sensitive to the initial sounding, especially with respect to the low-level relative humidity.

Acknowledgements

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