The Role of Initial Cloud Condensation Nuclei Concentration in Hail Using the WRF NSSL 2-moment Microphysics Scheme

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Introduction

- Atmospheric aerosol particles can serve as cloud condensation nuclei (CCN) in the formation of cloud droplets. More CCN in a given sounding environment generally result in reduced cloud particle size and then may affect the amount and type of precipitation (rain or hail) and thus affect the development of convective cloud.
- There is a significant decreasing in hail day frequency during 1961-2010 in the Inner Mongolia Autonomous Region in northern China, where the typical hail storm sounding is weak and haze occurred more in recent years. The long-term trend of hail day frequency may be affected by aerosols, and it is not fully understood in this area.

Methods

- WRF REAL TEST: Simulate the hail process to get an sounding with NSSL 2-moment scheme.

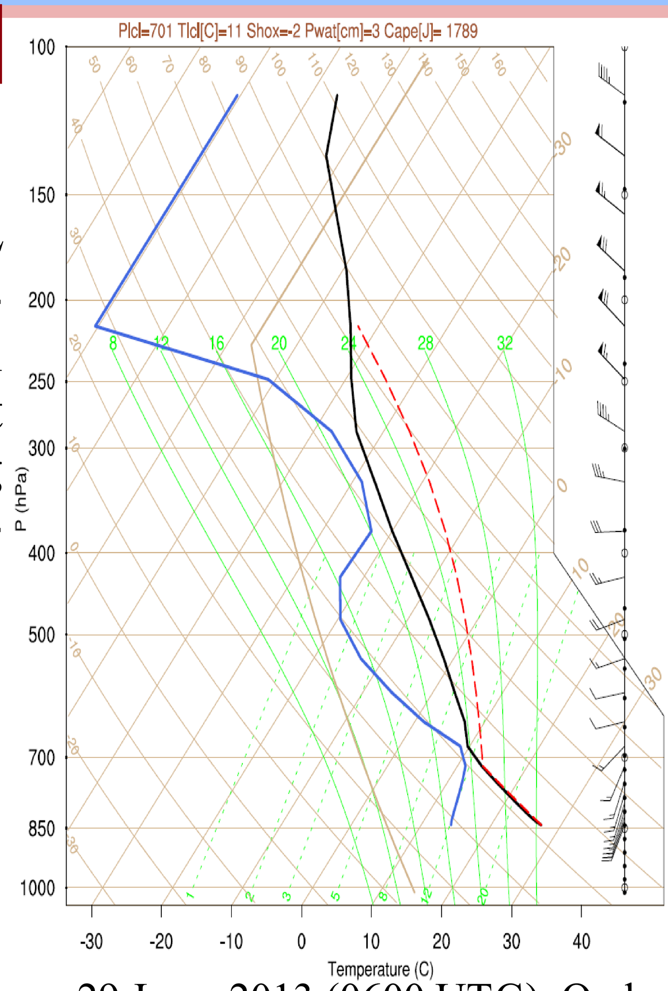

Fig. 1. Sounding on 29 June 2013 (0600 UTC), Ordos, China.

- WRF IDEALIZED TEST: Design 6 experiences by changing the value of the CCN concentration (CCNC) from 100 to 3000 mg^{-1}. To make it a well-mixed boundary-layer, the CCNC in unit of mg^{-1} is set to a constant below 2 km and decreasing exponentially from the 2 km height.

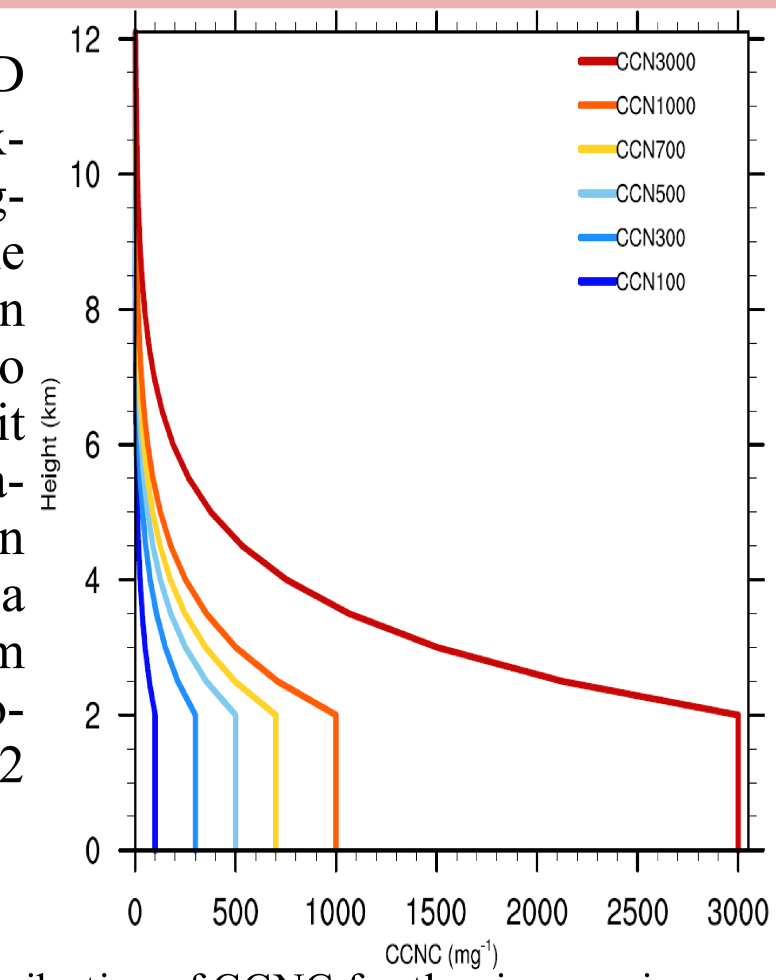

Fig. 2. Vertical distribution of CCNC for the six experiences.

Results

- There is a **threshold** of the CCNC impact on hail both in clouds and at the surface.

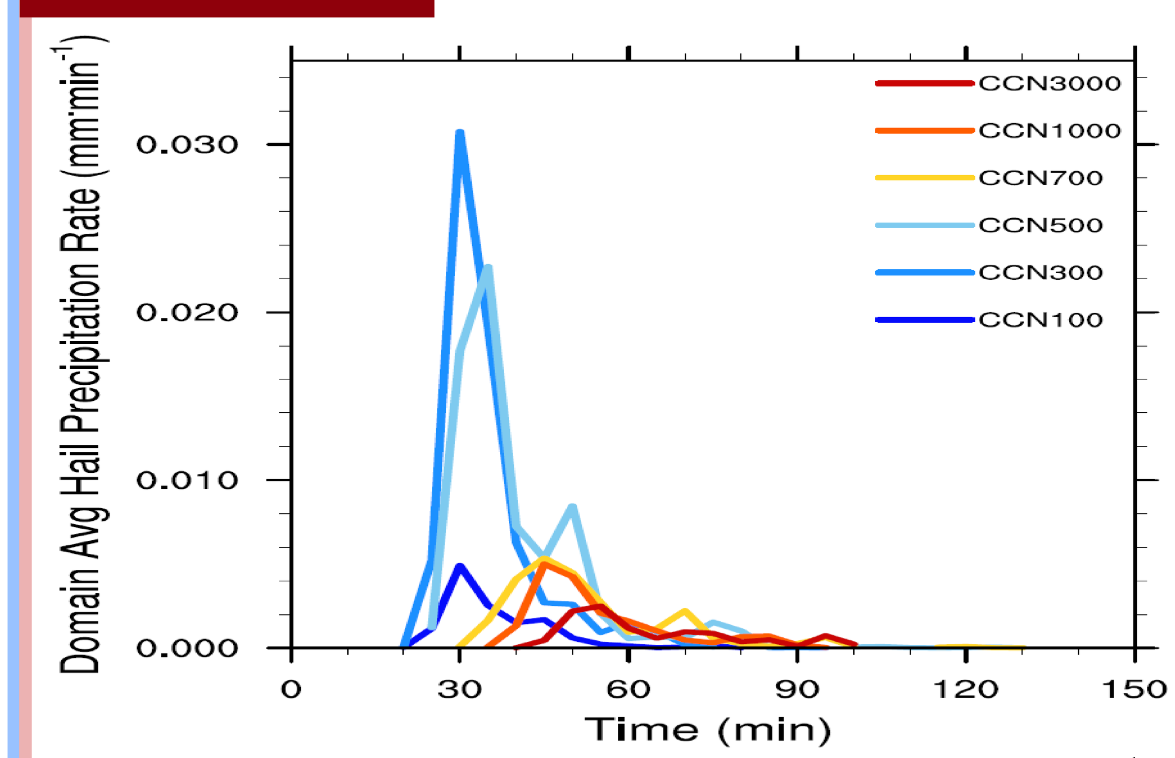

Fig. 3. Time series of avg hail precipitation rate in mm·min^{-1}.

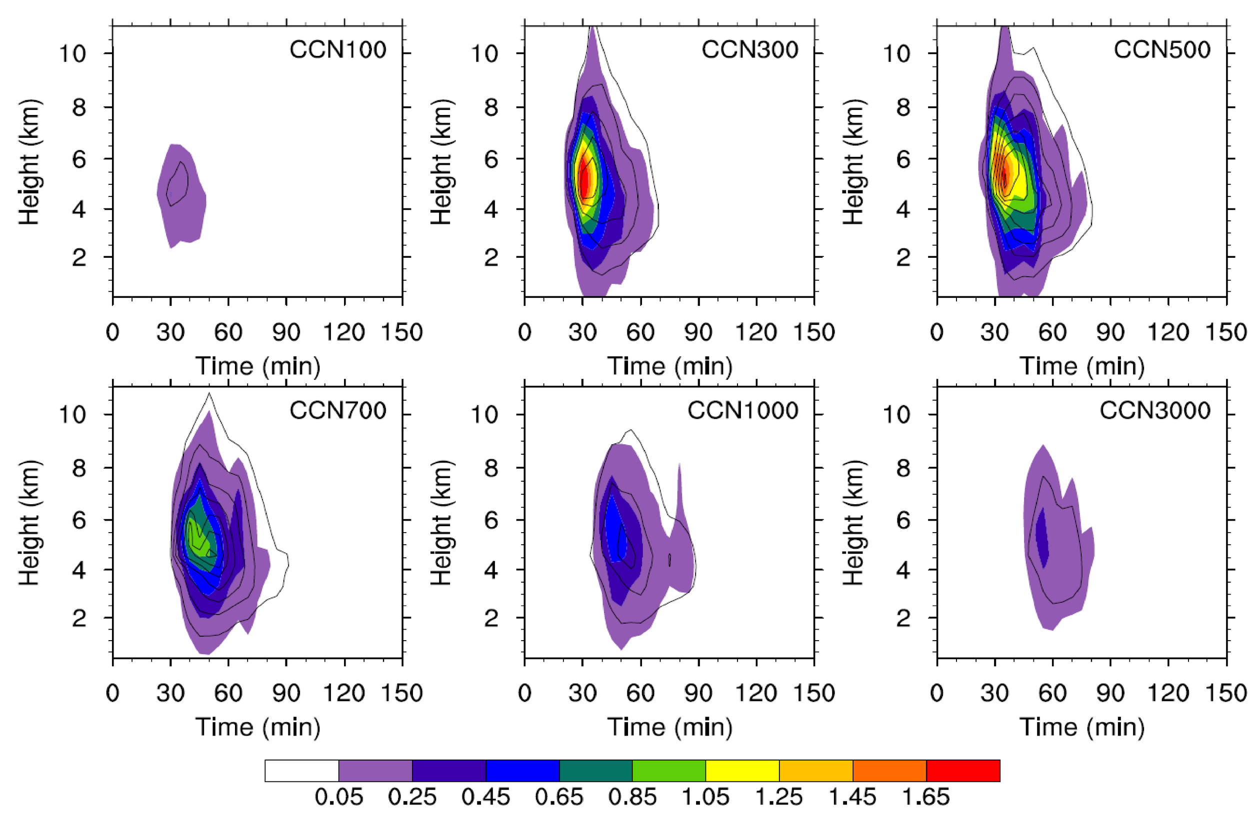

Fig. 4. Time–height contours of domain-averaged hail mixing ratio in mg·kg^{-1} and number concentration in 10^{-3}kg^{-1} (black contours from 5 to 75 by 10).

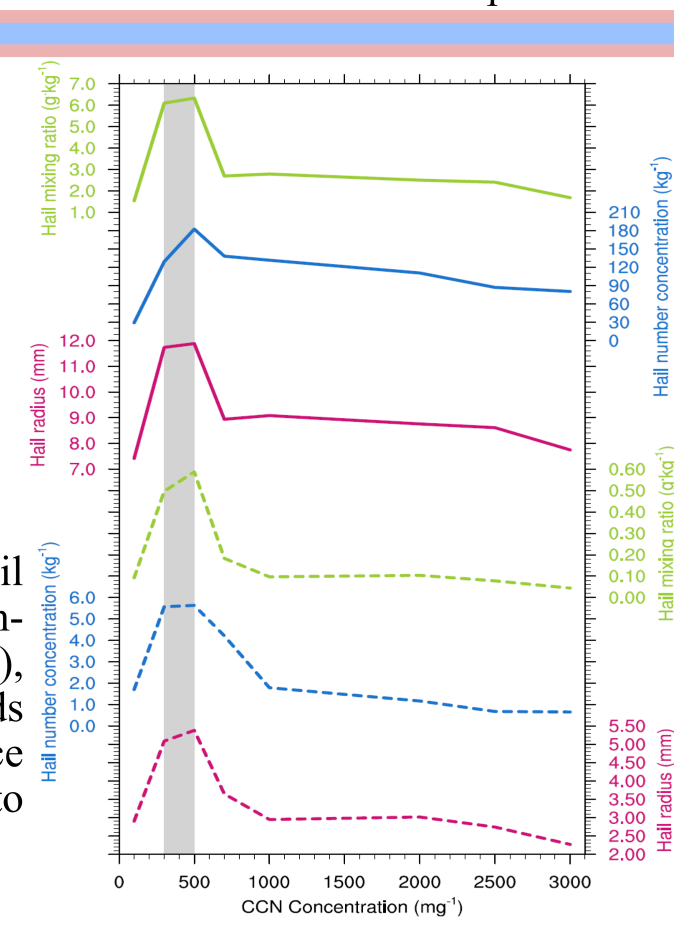

Fig. 5. Maximum hail mixing ratio (green), number concentration (blue), and radius (red) in clouds (solid) and at the surface (dashed) with respect to the CCNC.

- CCN effect on **thermodynamics**.

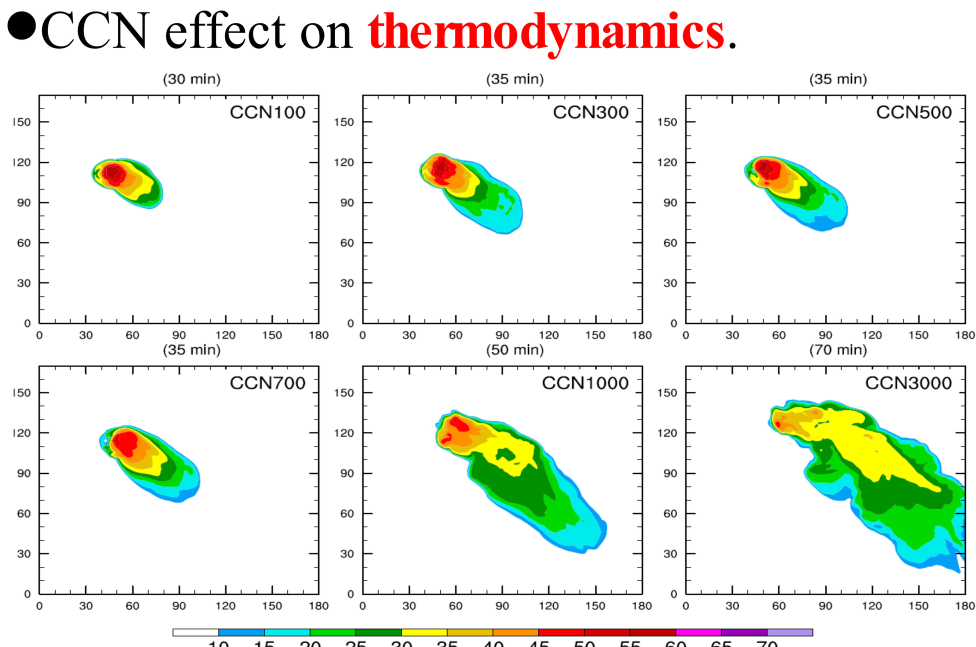

Fig. 6. Simulated domain maximum equivalent radar composite reflectivity factor in dBZ, with simulation times.

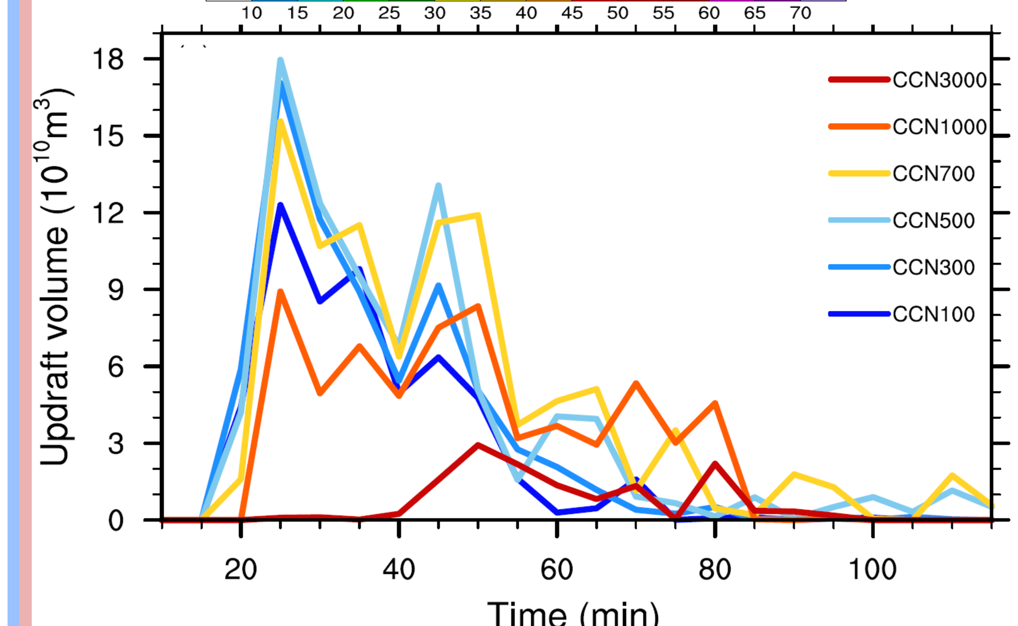

Fig. 7. Time series of updraft volume (updraft speed > 10 m·s^{-1}, radar reflectivity > 35 dBZ and temperature < 0 ℃) in 10^{10} m^3.

- The effect of CCN on **microphysics**.

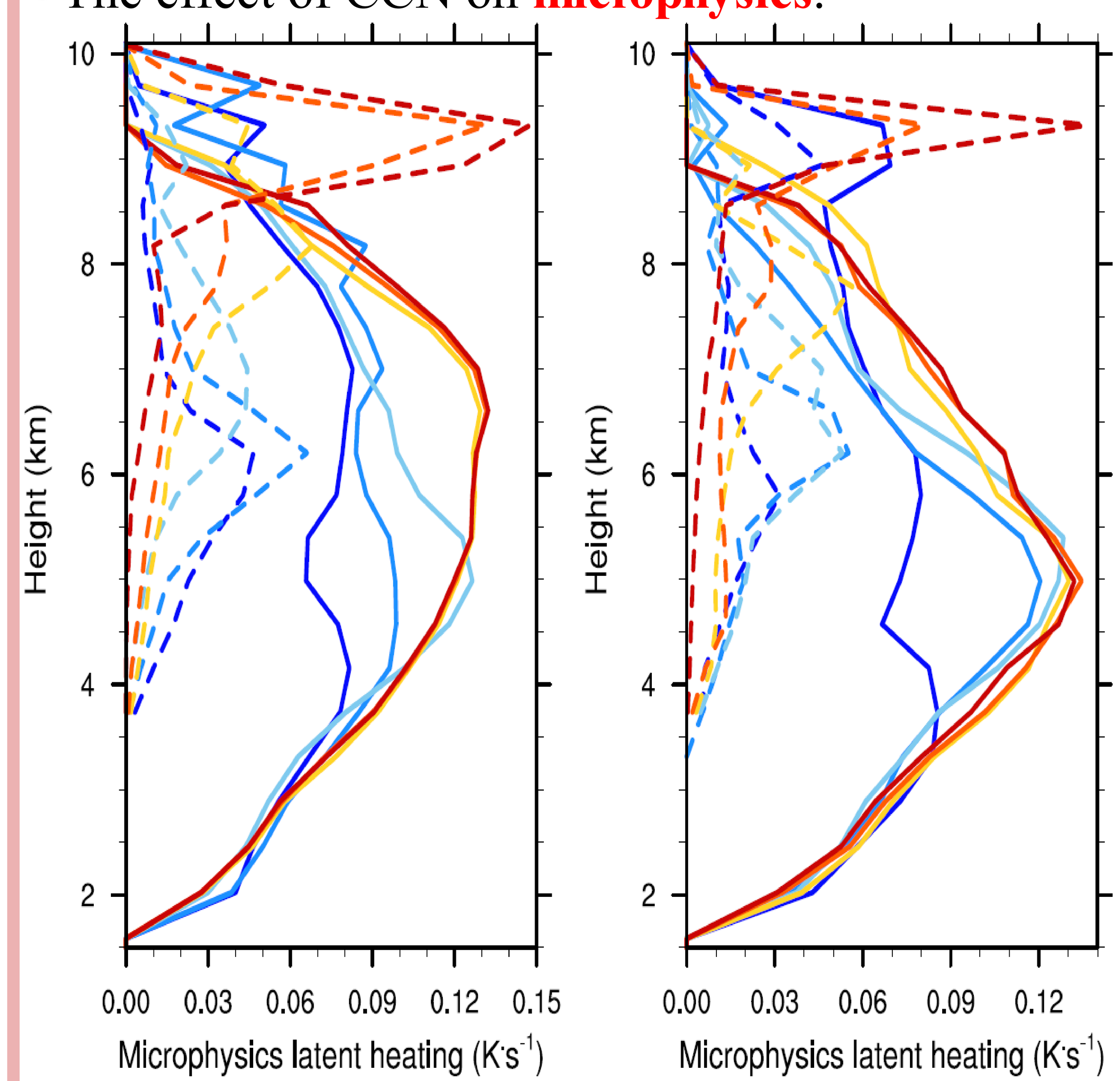

Fig. 8. Maximum condensation (solid) and frozen (dashed) heating in K·s^{-1} from 10-30 min (left) and 35-55 min (right).

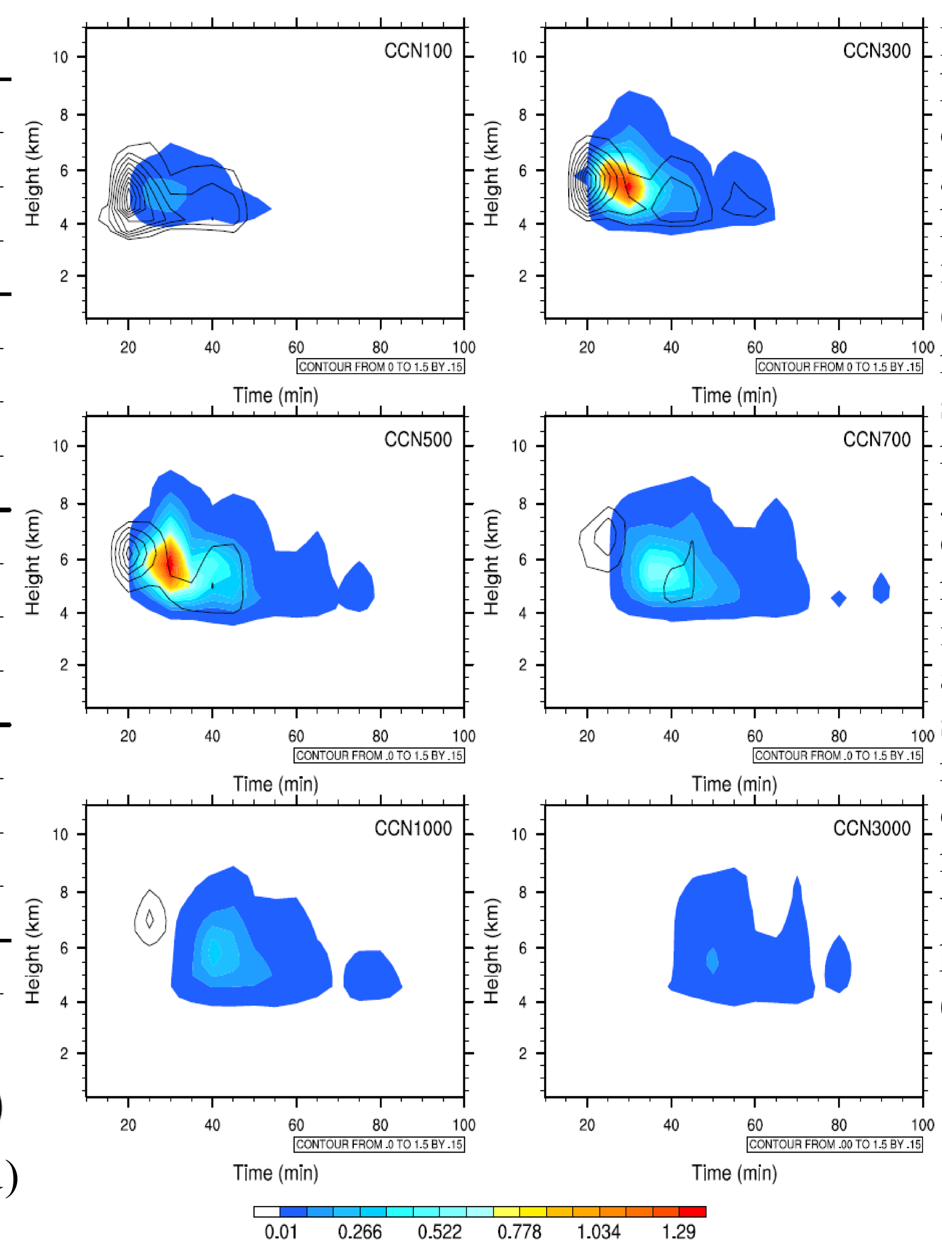

Fig. 9. Time–height contours of the domain-averaged net hail riming rate in mg·kg-1·s-1 (color fill) and mixing ratio of supercooled rain water in g·kg-1 (black contours). The net riming rate is calculated by acc+acr-shr and supercooled rain water is defined as the rain water where air temperature below 0 ℃.

Results

- An increasing CCNC is conducive (suppressive) to the amount of surface hail precipitation below (above) the CCNC threshold. The non-monotonic effects were due to both the thermodynamics and microphysics.
- Below the CCNC threshold, the cloud droplets and ice crystals increased dramatically with the increasing CCNC, resulting in more latent heat released from condensation and frozen between 4 and 8 km and intensified updraft volume. The extent of the riming process, which is the primary process for hail production, increased dramatically.
- Above the CCNC threshold, the mixing ratio of cloud droplets and ice crystals increased continuously, but the maximum updraft volume was weakened because of reduced frozen latent heating at low level. The smaller ice crystals reduced the formation of hail and smaller clouds, with decreased rain water reducing riming efficiency so that graupel and hail also decreased with increasing CCNC, which is unfavorable for hail growth.

Reference

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