Effect of aerosols on freezing drops, hail and precipitation in a mid-latitude storm

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Hailstorms pose a serious threat to agriculture and property in many places around the world. Observational studies showed that large hail forms in the presence of a significant amount of supercooled water. Since increase in the concentration of cloud condensational nuclei (CCN) increases the supercooled mass of liquid droplets, significant effects of aerosols on hail mass and hail size can be expected. In the present study, a mid-latitude hail storm was simulated using a new version of the spectral bin microphysics Hebrew University Cloud Model (HUCM) with a detailed description of time-dependent melting and freezing. In addition to size distributions of drops, plate-, columnar- and branch-type ice crystals, snow, graupel and hail, new distributions for freezing drops as well as for liquid water mass within precipitating ice particles were implemented to describe time-dependent freezing and wet growth of hail, graupel and freezing drops (Phillips et al. 2015; Ilotoviz et al. 2015).

Results

Simulations carried out using different aerosol loadings show that an increase in aerosol concentrations leads to a decrease in the total mass of hail, but to a substantial increase in the maximum size of hailstones. Fig.1 shows the field of mean volume radii in simulations with (a) high (2500 cm^{-3}) and (b) low (100 cm^{-3})

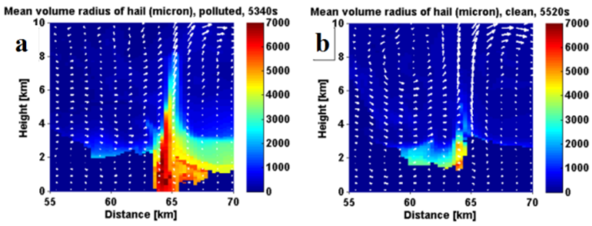

Figure 1. The fields of mean volume radii in cases of high and low CCN concentrations.

CCN concentrations at developed stage of the storm. One can see that size of hail in the polluted case is substantially larger. The maximum diameter of hail falling to the surface is about 5 cm in case of polluted air and does not exceed 2 cm in clean air. Analysis shows that hail grows in the course of recycling within the area of cloud updrafts as is demonstrated in the scheme in Figure 2. Raindrops begin freezing, thus producing freezing drops (black ellipses). Total freezing of liquid within freezing drops leads to formation of hail (red circles). Large particles fall along cloud edges and some of them penetrate updrafts and grow in the zone of high CWC (recycling). The largest hail falls to the surface.

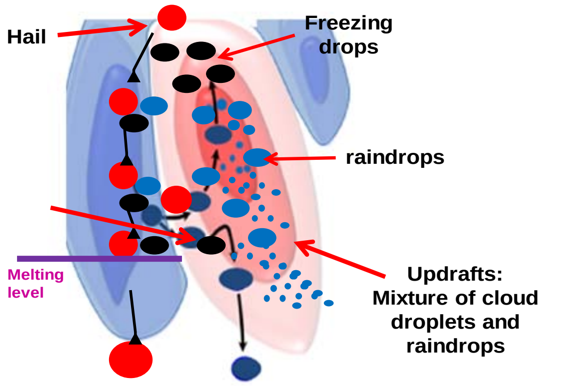

Figure 2. Conceptual model of the hail growth in the updraft-downward cloud zones. The zone of updraft is marked by red; the zone of downdrafts at cloud edge is marked by blue. In updrafts, small droplets (small blue circles) ascend to higher levels, leading to raindrop formation (large blue ellipses).

The main effect of the increase in the aerosol concentration is the increase in the supercooled cloud water content. Accordingly, at high aerosol concentration the hail grows largely by accretion of cloud droplets in the course of recycling in the cloud updraft zone. The main mechanism of hail formation in case of low aerosol concentration is freezing of comparatively small raindrops (Ilotoviz et al., 2015).

Cumulative rain strongly increases with an increase in aerosol concentration from 100 cm^{-3} to about 1000 cm^{-3}. At higher CCN concentrations, the sensitivity of hailstones' size and surface precipitation to aerosols decreases.

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