Microphysical Characteristics of Frozen Droplet Aggregates from Deep Convective Clouds

Abstract. During the 2012 Deep Convective Clouds and Chemistry (DC3) experiment the National Science Foundation/National Center for Atmospheric Research Gulfstream-V (G-V) aircraft sampled the upper anvils of two storms that developed in eastern Colorado on 6 June 2012. A cloud particle imager (CPI) mounted on the G-V aircraft recorded images of ice crystals at altitudes of 12.0 – 12.4 km and T= –61 – –55 °C. A total of 22,393 CPI crystal images were analyzed, all with maximum dimension D_{max} < 433 μm with an average D_{max} of 80.7±45.4 μm. The occurrence of well-defined pristine crystals (e.g., columns and plates) was less than 0.04% by number. Single frozen droplets and frozen droplet aggregates (FDAs) were the dominant habits with fractions of 73.0% (by number) and 46.3% (by projected area), respectively. The relative frequency of occurrence of single frozen droplets and FDAs depended on temperature and position within the anvil cloud.

A new algorithm that uses the circle Hough transform technique was developed to automatically identify the number, size, and relative position of element frozen droplets within FDAs. Of the FDAs, 42.0% had two element frozen droplets with an average of 4.7±5.0 element frozen droplets. The occurrence frequency gradually decreased with the number of element frozen droplets. Based on the number, size, and relative position of the element frozen droplets within the FDAs, possible three-dimensional (3-D) realizations of FDAs were generated and characterized by two different shape parameters, the aggregation index (AI) and the fractal dimension (D_f), that describe 3-D shapes and link to scattering properties with an assumption of spherical shape of element frozen droplets. The AI of FDAs decreased with an increase in the number of element frozen droplets, with larger FDAs with more element frozen droplets having more compact shapes. The D_f of FDAs was about 1.20–1.43 smaller than that of black carbon (BC) aggregates (1.53–1.85) determined in previous studies. Such smaller D_f of FDAs indicates that FDAs have more linear chain-like branched shapes than the compact shapes of BC aggregates. Determined morphological characteristics of FDAs along with the proposed reconstructed 3-D representations of FDAs in this study have important implication to improve the calculations of the microphysical (e.g., fall velocity) and radiative (e.g., asymmetry parameter) properties of ice crystals in upper anvil clouds.