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Optical modeling of irregularly shaped ice particles in convective cirrus

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Estimating the light-scattering properties of ice particles that form cirrus clouds is an important issue in the study of atmospheric radiation and satellite/ground-based cloud remote sensing. In tropical anvil cirrus, ice particles with very complex and irregular shapes have been observed. This complexity of particle shape is expected, given the greater amount of moisture for deposition and mixing and turbulence associated with vertical motions. Furthermore, ice aggregates in convective cirrus often appear fractal in the relation between the size and the mass. In contrast, regular ice particle shapes, such as columns, plates, and bullet rosettes, are dominant in synoptically generated cirrus. In this work, we focus on highly complex ice particles that observed in the convective cirrus. A database of light-scattering properties for complex ice aggregates as a component of cirrus clouds would be useful for advanced cloud remote sensing.

A model of irregularly shaped ice particles for convective clouds was proposed. The modeled particles are aggregates with a cell-type structure which are created by using spatial Poisson-Voronoi tessellations. Moreover, the reported mass-dimensional and area ratio-dimensional relationships for the measured cirrus particles were taken into account for the determination of the particle model. The single-scattering properties of the randomly oriented Voronoi aggregates (VA) at visible and infrared wavelengths were investigated using the Finite Difference Time Domain (FDTD) method and Geometrical Optics Integral Equation (GOIE) method.

The results of the numerical calculations showed that the VA model had scattering properties that were similar to those obtained by analyses of polar nephelometer and LIDAR measurements at visible wavelength. The VA model had no halos in the forward-scattering direction and a flat angular dependence from the side-to-backscattering directions of the phase functions, asymmetry factors 0.73∼0.78, and values of 0.13∼0.24 for the backscattering phase function. These VA scattering features were maintained over a wide size parameter range in geometrical optics regime.