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Single-scattering properties of small atmospheric ice crystals at absorbing wavelengths: Dependence on idealized models.

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Cirrus, located in the upper troposphere and lower stratosphere, occur at very cold temperatures and are mainly composed of ice crystals. Cirrus spatial coverage, temporal frequency, microphysical and scattering properties have large impacts on how cirrus affects radiation. Despite the importance of cirrus, its representation in small and large-scale models has large uncertainties mainly due to the lack of knowledge on what controls the shapes and sizes of non-spherical ice crystals. Thus, its role in modulating the Earth-radiation balance has not been well established.

A conventional method for representing the scattering properties of cirrus in numerical models and satellite and ground-based retrieval algorithms is to combine distributions of ice crystal shape and size measured by aircraft during field campaigns with pre-calculated single-scattering libraries of different shapes and sizes of ice crystals. These methods depend heavily on the assumed size and shape distributions and on the single-scattering properties of the ice crystals.

To calculate the single-scattering properties of different shapes of ice crystals, idealized models representing the shapes of real ice crystals are needed. Such models have been developed using images of ice crystals obtained by probes installed on aircraft flying through clouds. However, it is difficult to identify the detailed shapes of small ice crystals (hereafter those with maximum dimensions < 100 μm) using state-of-the-art cloud probes because the probe resolutions are insufficient to resolve the fine structure of small ice crystals.

High-resolution images of small ice crystals obtained by a Cloud Particle Imager (CPI) during the Tropical Warm Pool International Cloud Experiment (TWP-ICE) and other cirrus experiments appear mainly quasi-spherical. Corresponding idealized models (e.g., the droxtal, Chebyshev particle, Gaussian random sphere, and budding Bucky ball) have thus been developed to describe their shapes using varying quasi-spherical models. There is significant discrepancy in the shapes of these idealized models that have been used to describe small ice crystals. Previously, we showed that single-scattering properties of small ice crystals at non-absorbing wavelength (λ=0.55 μm) depend heavily on the choice of the idealized model and the area ratio used to characterize the small ice crystals.

Here, previous studies are extended to absorbing wavelengths to quantify the dependence of the single-scattering properties and absorption characteristics of the different idealized models representing small ice crystals on crystal shape and size. The scattering and absorption efficiency, the single-scattering albedo, asymmetry parameter, and Mueller Matrix of the droxtal, Chebyshev particle, Gaussian random sphere, and budding Bucky ball are calculated at three different infrared wavelengths (λ=2.13, 3.78, and 11 μm) using a discrete dipole method. The size dependence of the single-scattering properties is determined and the sensitivity of the bulk scattering properties computed using the size and shape distributions measured during TWP-ICE to the choice of idealized model at these absorbing wavelengths is discussed. Potential problems of currently used methods for calculating bulk scattering properties of cirrus are discussed either.