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Quantifying and reducing uncertainty in observed shapes and concentrations of small ice crystals: implications for derived scattering properties

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At a microphysical level, the bulk water content, bulk extinction and single-scattering properties are most important for determining how ice clouds impact radiation. Accurate observations of the sizes, shapes, and concentrations of ice crystals are required to derive these quantities. However, recent studies have suggested that many observations of small ice particles may be the consequence of larger particles impacting on probe tips or inlets and breaking up into smaller fragments; the contribution of such shattered particles to measured concentrations are uncertain. Further the limited resolution of state-of-the-art cloud particle imagers means there are also large uncertainties in small crystal shapes.

Small crystal concentrations were measured by several versions of forward scattering probes, including those with tips designed to reduce large crystal shattering, during previous field campaigns in the mid-latitudes (2010 Profiling of Winter Storms campaign), Arctic (2008 Indirect and Semi-Direct Aerosol Campaign), and Tropics (2006 Tropical Warm Pool International Cloud Experiment. Data from these probes are compared for varying large crystal concentrations to assess how varying probe designs affect measurements of small crystal concentrations; closure studies where bulk mass measured by evaporator probes is compared against mass derived from the size distributions offers additional insight on the uncertainties associated with the measurements.

Small crystals appear quasi-circular in shape. Thus, idealized quasi-spherical shapes, like Chebyshev particles, Gaussian random spheres, and droxtals, have been constructed to calculate their single-scattering properties. Recently, an ice analogue grown from sodium fluorosilicate solution on a glass substrate, with several columns emanating from a common center of mass, was shown to be quasi-circular when imaged by a state-of-the-art cloud particle imager. A new idealized model, called the budding Bucky ball (3B) that resembles the small ice analogue shape, is thus developed. Its single-scattering properties (scattering phase function and asymmetry parameter) are computed by a ray-tracing code and compared with previously used models. The results show that small crystal scattering properties depend on the idealized model and the area ratio used to characterize the small ice crystal. Mean scattering properties are derived by weighting the scattering properties of different sizes and shapes of ice crystals according to their measured concentrations; uncertainties in the mean scattering properties are derived by considering uncertainties in both the scattering model and concentration of small ice crystals. Future efforts underway to better constrain the concentrations and shapes of small crystals are discussed.