IRS2012-198
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Quantifying and reducing uncertainty in observed sizes, shapes and concentrations of small ice crystals: implications for derived scattering properties at visible wavelengths

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At a microphysical level, the bulk ice water content, bulk extinction and single-scattering radiative 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, 2011 Instrument Development and Education in Airborne Sciences 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. Ice analogues grown from sodium fluorosilicate solution on glass substrates, with several columns emanating from a common center of mass, are also quasi-circular when imaged by the state-of-the-art cloud particle imager. An idealized model, called the budding Bucky ball (3B) that resembles the small ice analogue shape, has thus also been developed to characterize small crystal shapes. Comparing its single-scattering properties (scattering phase function and asymmetry parameter) against those of the other models shows 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 in the aforementioned campaigns; uncertainties in the mean scattering properties are derived by considering uncertainties in both the idealized shape model and concentration of small ice crystals. Future efforts underway to better constrain the concentrations and shapes of small crystals are discussed.