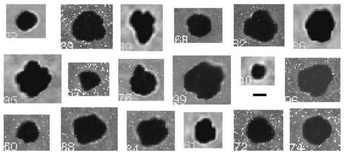
Small Irregular Ice Crystals in Tropical Cirrus

Research Highlight

Images of crystals from high-resolution Cloud Particle Imagers (CPI) installed on aircraft flying through ice clouds in many field campaigns have shown that small ice crystals, with maximum dimensions smaller than 100 micrometers, appear quasi-spherical. However, there have hitherto been no studies that investigated whether the detailed shape characteristics of these quasi-spherical particles vary in different geographical locations. There have also been no assessments as to whether the shattering of large crystals on the surfaces of Cloud Particle Imagers might artificially generate small crystals that are in turn imaged by the probe. In this study, a statistical shape model developed using images acquired by a CPI installed on the Scaled Composites Proteus aircraft flying through tropical cirrus during the Tropical Warm Pool-International Cloud Experiment (TWP-ICE) is compared against a similar model previously developed using images acquired in mid-latitude cirrus. Potential contributions of artificially generated small ice crystals to the total numbers of crystals imaged are also assessed.

The infrequent occurrence of multiple particles in single CPI frames suggests that most crystals imaged were natural ice crystals rather than artifacts produced by shattering. Thus, a subset of 1,143 small ice crystal images was used to describe the observed ice crystal silhouettes. A corresponding covariance function was then used in conjunction with the Gaussian random sphere geometry to generate three-dimensional model ice particles that were used in ray-optics simulations to compute the single-scattering properties at the 550-nm wavelength. Compared to the crystal shapes and single-scattering properties obtained by the same methodology for mid-latitude cirrus sampled over Oklahoma, the small tropical ice crystals were closer to spherical than their mid-latitude counterparts. Consequently, their asymmetry parameters, g, were larger, but the differences are not significant from the standpoint of the accuracy needed for climate studies. Additional sensitivity studies examined how uncertainties in crystal shape affected the scattering properties: introducing a convex hull transformation increased g from 0.785 to 0.808; modifying the covariance function to promote six-fold symmetry in the model crystals increased g to 0.818; and introducing internal scatterers, such as air bubbles, decreased g by up to tens of percent, depending on the amount and characteristics of the scatterers. Unfortunately, no data are available to determine realistic values for the internal scatterers to assess their likely actual impact.

For tropical cirrus conditions sampled during TWP-ICE, imaged ice crystals correspond to naturally occurring particles rather than shattered artifacts. The shape characteristics and derived single-scattering properties of the small quasi-spherical ice crystals did not differ from those in mid-latitude cirrus to an extent that would be significant for climate studies. This has important implications for the development of model and remote sensing representations of ice crystal radiative properties. Further work still needs to determine why calculated asymmetry properties are larger than those determined from direct radiative observations; sensitivity studies suggest that the introduction of internal scatterers in the modeled crystals could significantly lower the asymmetry parameters.



Examples of small quasi-spherical ice crystals observed in tropical cirrus. The black scale bar in the image is 11 pixels or about 25 micrometers long.

Reference(s)

Nousiainen T, H Lindqvist, GM McFarquhar, and J Um. 2011. "Small irregular ice crystals in tropical cirrus." Journal of the Atmospheric Sciences, 68(11), doi:10.1175/2011JAS3733.1.

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