Global statistics of cloud top ice microphysical and optical properties

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The evolution of ice crystal size and shape depends on temperature and supersaturation, as well as on other processes that may lead to various coexisting complex shapes in natural ice clouds. To improve representation of ice clouds in global climate models, observations on the global variation of crystal shape and size are crucial. It has been extensively shown that multi-angle polarization measurements contain information on ice crystal shape and in turn their scattering properties. However, such observations are not substantially sensitive to ice crystal macro scale (i.e., 'habit') but are dominated by aspect ratios of hexagonal components of complex crystals and the microscale distortion of the crystals. This is the basis of the algorithm that we developed and evaluated (e.g., [1,2]), which focusses on inferring aspect ratios and distortion parameters of individual hexagonal ice columns and plates that serve as proxies for more complex shapes and aggregates. Using over 84 million POLDER pixel-level retrievals, we present a global assessment of shape characteristics and asymmetry parameters of ice crystals at the tops of optically thick clouds, which are collocated with MODIS particle size retrievals. The results indicate systematic covariations of ice size, shape and distortion, as well as variations with temperature that show a remarkable agreement with simplified ice crystal growth theory and in situ and laboratory data. This simplicity may be viewed as somewhat surprising given the many processes that govern ice crystal properties and might be attributable to the temperature dependence of cloud top ice size and shapes commonly being dominated by vapor growth. We also find that, contrary to commonly used models, but in agreement with recent laboratory measurements, ice scattering asymmetry parameters decrease with increasing effective radius, reducing sensitivity of cloud reflectance to particle size.

References

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[2] Van Diedenhoven, B., A. S. Ackerman, A. M. Fridlind, and B. Cairns, 2016: On averaging aspect ratios and distortion parameters over ice crystal population ensembles for estimating effective scattering properties. *J. Atmos. Sci*. **73**, 775–787.

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