Integration of optimal habit selection with DDA and SSRGA models for improved microwave radiative transfer simulations

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Abstract

For applications of spaceborne microwave brightness temperatures (TBs), such as cloud-precipitation retrieval algorithms and data assimilation, solving the forward problem through reliable radiative transfer (RT) simulations is essential. Particularly, accurately representing scattering signatures from nonspherical frozen hydrometeors remains a major challenge for reliable RT simulations. To address this issue, particle scattering models that explicitly account for nonspherical particle shapes —such as the Discrete Dipole Approximation (DDA; Draine and Flatau, 1994) and the Self-Similar Rayleigh-Gans Approximation (SSRGA; Hogan et al., 2017) models —have been incorporated into RT simulations. However, these approaches introduce the so-called “one-shape-fits-all” problem, arising from the subjective selection of a single particle habit applied uniformly across varying atmospheric conditions. This practice can induce substantial uncertainty, primarily due to inconsistencies in density assumptions throughout the simulation framework.

This study proposes a method that integrates the optimal habit selection approach of Kim *et al.* (2024) with DDA and SSRGA scattering models. For the calculation of scattering from nonspherical frozen hydrometeors, the method selects an optimal DDA- or SSRGA-based particle habit that best corresponds to the given riming conditions. This framework enables flexible assignment of nonspherical particle habits across atmospheric fields, thereby better representing the natural inhomogeneity of frozen hydrometeors within precipitating clouds and their growth processes. RT simulation results demonstrate the promising performance of the proposed methods. Particularly, the combination of optimal habit selection with SSRGA particle scattering models effectively reconciles microphysical consistency and physical realism within the RT simulation framework.

This study further discusses potential directions to enhance the feasibility of the proposed methods for improved RT simulations, including the application of machine-learning techniques and simplified nonspherical density parameterizations.

References

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