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Retrieval of dust particle refractive index using ellipsoids

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Ellipsoid and spheroid ensembles are commonly used as proxies when computing the single-scattering properties of mineral dust. Many studies show how these shape models can be used to closely reproduce, e.g., laboratory-measured scattering matrices of real dust particles. Considering how widely used these shape models currently are, e.g., in retrieval algorithms of different Earth observation methods, it is surprising how little effort has been put to validating their performance in such inversion problems.

In this work we investigate how well the refractive index of irregularly shaped particles, such as dust grains, can be retrieved from the angular dependence of their scattering matrix elements using ellipsoids. As target particles, we use real-like model dust particles whose shapes have been derived through stereogrammetry, and assign them with a refractive index to be retrieved. The angle-dependent scattering matrices are computed using the ADDA implementation of the discrete-dipole approximation. The scattering matrices for different ellipsoids are obtained from the database by Meng et al., for a predefined set of refractive indices that includes also the correct value. The refractive index is then inverted by searching the refractive index of ellipsoids that provides the best fit with the target particles' scattering matrix. The fits are evaluated separately for different scattering matrix elements and their combination. Two cases are considered for ellipsoids: first, a case where the fitting algorithm can search for the optimal shape distribution of ellipsoids for each refractive index tested, and second, a case where a predefined (equiprobable) shape distribution of ellipsoids is assumed.

The results show that the ellipsoid ensembles with correct refractive indices generally mimic reasonably well the scattering matrices of the target particles. However, in each case studied, even better matches are obtained with a wrong refractive index. The outcome is the same both with the predefined and optimized (fitted) shape distributions for the ellipsoids. These findings suggest that ellipsoids are neither a reliable nor an accurate model for retrieving the refractive index of irregular particles such as dust particles. It may be that the outcome can be generalized for any set of model particles that do not represent sufficiently well the intended target particles, but this remains to be verified. The study also showed that, when using the retrieved refractive indices in radiative transfer simulations, errors in computed radiative fluxes were often quite substantial.