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Simulating the shortwave direct radiative effects of dust using optical properties of spherical and spheroidal model particles

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Mineral dust aerosols, which primarily originate from desert and semi-arid regions but, can be transported by wind far away from the source areas, are considered to play an important role in Earth's climate system through their direct and indirect effects. These particles do not have any preferential shape, but they are exclusively irregular. It has been shown in several studies that light scattering by real dust particles differs significantly from that based on spherical model particles. However, in radiative transfer simulations and remote sensing applications, these particles are still often described as spheres and this can cause substantial errors. A number of studies have shown that model particles as simple as spheroids reproduce the optical properties of dust particles clearly better than spheres. In particular shape distributions of spheroids that give more weight to the aspect ratios that deviate strongly from the sphere describe the laboratory-measured scattering matrixes of dust better than the often used equiprobable shape distribution, and one such distribution is recommended in a recent study (Merikallio et al., 2011) to be used in climate simulations.

The sensitivity of direct shortwave radiative effect of dust (DRE) to assumed particle shape distribution is investigated. The radiative transfer simulations are conducted using optical properties of either spheres or different shape distributions of spheroids. Two cases of mass-equivalent spheroids are considered: one where the number concentration and hence the total mass is the same as for spheres (mass-conserving case) and another where the number concentration is adjusted so as to obtain the same mid-visible optical thickness as for spheres (τ-conserving case). The optical properties of dust are obtained from the database by Dubovik et al. (2006). Impacts of particle shape on DRE are investigated for different dust particle effective radii, optical thickness, solar zenith angle, and surface albedo (ocean, grass, and desert) with the libRadtran radiative transfer model.

It is found that the impacts of dust particle shape on the SW direct radiative effects of dust are non-systematic. Results for the different distributions of spheroids may deviate more from each other than from those for spheres. In addition, the effects of non-sphericity largely depend on whether the mass- or τ-conserving case is considered. For example, when using a shape distribution of spheroids that favors strongly elongated spheroids, the DRE at the surface differs at most 5% from that for spherical particles in the mass-conserving case. This stems from compensating shape related effects on optical thickness, asymmetry parameter, and single-scattering albedo. However, in the τ-conserving case, the DRE at the surface can be up to 15% smaller for spheroids than spheres.

References

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