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Effects of dust non-sphericity in a global aerosol-climate model

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In climate model radiation schemes and most remote sensing applications, the single-scattering properties of atmospheric aerosols are based on the Mie theory, which assumes spherical and internally homogeneous particles. Yet it is well known that mineral dust, which is one of the most radiatively important atmospheric aerosol types, consists exclusively of irregular non-spherical particles.

We test the impact of dust particle non-sphericity in the ECHAM5.5-HAM2 global aerosol-climate model (Stier et al. 2005; Zhang et al. 2012). The optical properties of dust are modelled using an ensemble of spheroids, which has been previously shown to reproduce the optical properties of dust-like aerosols significantly better than spheres. Based on a comparison with laboratory measurements of light scattering (Merikallio et al. 2011), the "n=3" shape distribution of spheroids is adopted that gives a relatively large weight to spheroids with large aspect ratios. The optical properties of spheroids (extinction cross section, single-scattering albedo and asymmetry parameter) are based on Dubovik et al. (2006).

The ECHAM5.5 atmospheric GCM was run at a horizontal resolution of T42 ($\approx$300 km) with 19 levels in the vertical. The aerosol model HAM2 represents the size distribution of aerosols through a superposition of seven log-normal modes. Aerosols are treated as spheroids in the shortwave radiation calculations for those two modes in which dust appears as the only chemical component, i.e., the accumulation insoluble mode and the coarse insoluble mode. The effects of non-sphericity on longwave radiation are ignored.

First, the effect of dust non-sphericity on solar radiative fluxes was evaluated diagnostically. When non-spherical dust particles were modeled as mass-equivalent spheroids, the shortwave direct radiative effect (DRE) of insoluble dust at the surface and at the top of the atmosphere was slightly smaller (by 3-4 %) for spheroidal than spherical dust particles, with a fairly uniform geographical distribution of the differences. This rather small difference stems from compensating non-sphericity effects on dust optical depth, single-scattering albedo and asymmetry parameter. The compensation was demonstrated in another experiment, in which dust mid-visible (550 nm) optical depth was "retuned" to that of spheres, while keeping the single-scattering albedo, asymmetry parameter, and wavelength dependence of optical depth for spheroids. In this case, the non-sphericity effect becomes larger, the shortwave DRE of insoluble dust being $\approx$ 16% smaller than that for spheres, mainly because spheroids feature a larger asymmetry parameter (i.e., less backward scattering) than spheres.

Subsequently, we tested the impact of dust non-sphericity interactively, coupling ECHAM5.5-HAM2 with a mixed-layer ocean model. Consistent with the fairly small radiative effects, there were only minor differences in simulated climate to a model run assuming spherical dust particles. Thus, especially considering other uncertainties related to the representation of dust in aerosol-climate models, it appears justified to ignore the effects of dust non-sphericity.

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