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Light scattering by irregular particles much larger than the wavelength with wavelength-scale surface roughness

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Natural particles like atmospheric aerosols, powder constituents, cosmic dust, etc., demonstrate great variety of sizes, shapes and morphologies. If the size parameter $X = \pi d/\lambda$, where d is the particle size and λ is the wavelength, exceeds several tens accurate simulations of light scattering by realistic geometries require significant computer resources. The only efficient approach here is to apply geometrical optics (GO) approximation. This implies, however, ignoring small-scale surface roughness and, correspondingly, wave effects.

In this work we study optical properties of faceted irregular smooth and rough particles with size parameter X=200 (diameter of the circumscribing sphere) generated by means of the Gaussian Random field method in the wave optics regime. In the first case an irregular shape is formed by relatively small number of triangular facets (200-300), which creates large planar areas on the surfaces of particles. In the second case a two-scale geometry is considered. Large facets are subdivided into smaller elements with characteristic dimensions comparable with the wavelength. Next, all vertices are randomly displaced with increments that are normally distributed with zero average and root mean square equal to 1 in size parameter units. In this way surface roughness is formed preserving morphology of the initial shape. The Discontinuous Galerkin Time Domain method is applied to simulate wave propagation and to calculate the light scattering quantities.

We report that with size parameter X=200 the problem approaches the GO regime if surface topography of GRF particles is formed by flat facets that are larger than the wavelength. We compare wave-optics and conventional ray tracing calculations and obtain good agreement for intensity and polarisation in the entire range of scattering angles with exception of forward scattering diffraction peak which is very narrow at X=200. Introducing surface roughness of the scale of the wavelength leads to an expected tendency. Due to diffuse scattering from the rough surface Fresnel reflection and refraction are not valid any more. This results in smoothing out features in the curves for all non-zero scattering matrix elements.