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Direct modeling of multiple electromagnetic scattering by particulate media: A review

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While it is recognized that the Maxwell equations (MEs) control the transport of electromagnetic energy in particulate media (clouds, soil and snow/ice surfaces, vegetation), direct solutions of the MEs for such media had been impracticable until quite recently. This has led to the widespread use of the radiative transfer (RT) equation in situations when its very applicability is questionable. This situation has now changed owing to the development of efficient computer solvers of the MEs applicable to macroscopic multi-particle groups. In fact, a new branch of statistical optics emerged in 2006–07 wherein multiple scattering of light (and other electromagnetic radiation) by particulate media is modeled directly by using numerically exact computer solutions of the MEs without invoking any assumptions underlying the RT theory.

This review talk is intended to summarize this profound recent development. We describe the application of the numerically exact superposition T-matrix method to extensive computations of electromagnetic scattering by 3D volumes filled with randomly distributed wavelength-sized particles. These computations are used to simulate and analyze the effect of randomness of particle positions as well as the onset and evolution of various multiple-scattering effects with increasing number of particles in a statistically homogeneous volume of discrete random medium. These exact results illustrate and substantiate the methodology underlying the approximate microphysical theories of RT and coherent backscattering and quantify the range of particle packing densities beyond which both theories break. We show that even in densely packed media, the light multiply scattered along strings of widely separated particles still provides a significant contribution to the total scattered signal and thereby makes quite pronounced the classical RT and coherent backscattering effects. Numerical experiments with Gaussian laser beams provide a vivid demonstration of the robustness of the RT methodology.