How much is enough? The convergence of finite sample scattering properties to those of infinite media

A. Penttilä[1,*], J. Markkanen[1,2], T. Väisänen[1], J. Räbinä[1,3], M.A. Yurkin[4,5], and K. Muinonen[1,6]

[1] *Department Physics, University of Helsinki, Finland.*
[2] *Max Planck Institute for Solar System Research, Göttingen, Germany.*
[3] *Faculty of Information Technology, University of Jyväskylä, Finland.*
[4] *Voevodsky Institute of Chemical Kinetics and Combustion, SB RAS, Novosibirsk, Russia.*
[5] *Novosibirsk State University, Russia.*
[6] *Finnish Geospatial Research Institute FGI, National Land Survey, Kirkkonummi, Finland.*
[*] *corresponding author's e-mail: antti.i.penttila@helsinki.fi*

Introduction

We study the scattering properties of a cloud of particles. The particles are spherical, close to the incident wavelength in size, have a high albedo, and are randomly packed to 20 % volume density. We show, using both numerically exact methods for solving the Maxwell equations and radiative-transfer-approximation methods, that the scattering properties of the cloud converge after about ten million particles in the system. After that, the backward-scattered properties of the system should estimate the properties of a macroscopic, practically infinite system.

Results

According to our results, it seems that for this particular problem, the scattering properties of the system start to converge at about 10^7 particles or at the circumscribing volume size parameter of 650, see Fig. 1. On one hand, this result is unique to this particular scattering target. On the other hand, the individual particles are close to the wavelength size ($x = 1.76$), which means that they are efficient scatterers. Furthermore, there is almost no absorption in the system, the single-scattering albedo of the single sphere in the system is $\varpi = 0.999374$. Thus, one can expect excessive multiple scattering for this system. With less multiple scattering or with smaller single-scattering albedos, the convergence might be achieved earlier. That is why we conclude that a system with 10 million particles with sizes in the wavelength range can be considered to have the scattering properties in the backward-reflected hemisphere of a macroscopic system. The full results can be found from Penttilä et al. (2021) [1].

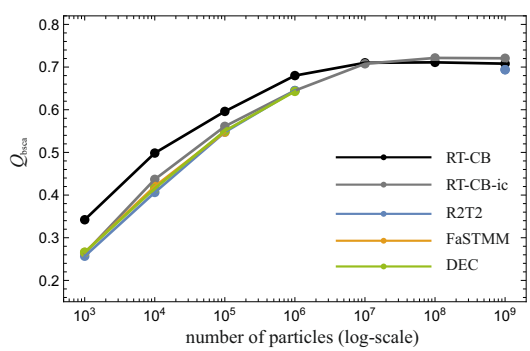

Figure 1: The backscattering hemisphere scattering efficiency Q_{bcsa} as a function of the target size, expressed as the number of the particles in the cloud. The Q_{bcsa} is shown here for five methods, of which the FaSTMM and DEC rigorously solve the macroscopic Maxwell equations, and the RT-CB, RT-CB-ic, and $\mathrm{R^2T^2}$ are based on the radiative transfer approximation.

References

[1] A. Penttilä, J. Markkanen, T. Väisänen, J. Räbinä, M. A. Yurkin, and K. Muinonen *How much is enough? The convergence of finite sample scattering properties to those of infinite media.* J. Quant. Spectrosc. Radiat. Transfer, 262, 2021.