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ORIGINAL ARTICLE

Stochastic transfer of polarized radiation in finite cloudy atmospheric media with reflective boundaries

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Abstract The problem of monoenergetic radiative transfer in a finite planar stochastic atmospheric medium with polarized (vector) Rayleigh scattering is proposed. The solution is presented for an arbitrary absorption and scattering cross sections. The extinction function of the medium is assumed to be a continuous random function of position, with fluctuations about the mean taken as Gaussian distributed. The joint probability distribution function of these Gaussian random variables is used to calculate the ensemble-averaged quantities, such as reflectivity and transmissivity, for an arbitrary correlation function. A modified Gaussian probability distribution function is also used to average the solution in order to exclude the probable negative values of the optical variable. Pomraning-Eddington approximation is used, at first, to obtain the deterministic analytical solution for both the total intensity and the difference function used to describe the polarized radiation. The problem is treated with specular reflecting boundaries and angular-dependent externally incident flux upon the medium from one side and with no flux from the other side. For the sake of comparison, two different forms of the weight function, which introduced to force the boundary conditions to be fulfilled, are used. Numerical results of the average reflectivity and average transmissivity are obtained for both Gaussian and modified Gaussian probability density functions at the different degrees of polarization.

Keywords Polarization · Stochastic radiative transfer · Finite cloudy atmospheric medium

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1 Introduction

The study of radiative transfer of polarized radiation in stochastic random media is of great interest for the investigation of planetary atmosphere. It is well known that the scattering by particles (aerosols, cloud drops, crystals, molecules and atoms) induces polarization in the incident unpolarized light beam or modifies the initial polarization. Hence, an exact treatment of the problem of light propagation in a medium composed of such scattering particles must include the complete state of polarization of light before and after scattering. The first formulation of such problem allowing polarization was developed by Chandrasekhar (1960) which describe the spatial variation of the four Stokes parameters $\mathcal{I}$, $\mathcal{K}$, $\mathcal{U}$, and $\mathcal{V}$.

There has been an increasing interest in the use of polarization in imaging through cluttered media (random media). Optical imaging through clouds and fog, imaging in biological media, and microwave detection in clutter can benefit from the additional information provided by the polarization characteristics (Ishimaru et al. 2001). Polarization pulse propagation in random media has also received attention; most of those studies were based on Monte Carlo calculations (Lewis et al. 1999; Kim et al. 2001; Bruscaglioni et al. 1993). Also, the observations of polarization of radiation give considerable valuable information about stars with large gaseous and dust envelopes (Berdyugin and Piirola 2002; Polyakova 2003; Raveendran 2002; Sengupta 2003), reflection nebulae of different kinds (King et al. 2002; Rodrigues et al. 2003), interstellar medium (Leonard et al. 2002), active galaxies (Hagen-Thorn et al. 2002), etc. (see Freimanis 2005). Due to the importance of studying atmospheric polarization, computer modeling of light scattering by aggregates and their light scattering characteristics, specifically polarization, change with phase an-

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