«Оптика атмосферы и океана», **23**, № 4 (2010)

ОПТИКА КЛАСТЕРОВ, АЭРОЗОЛЕЙ И ГИДРОЗОЛЕЙ

УДК 519.216.24, 519.6

Monte Carlo simulation of angular characteristics for polarized radiation in water-drop and crystal clouds

Sergey M. Prigarin[1], Ulrich G. Oppel[2]

[1] *Institute of Comp. Mathematics and Math. Geophysics, SB RAS,*
pr. Academician Lavrentyev, 6, Novosibirsk, 630090, Russia
Novosibirsk State University, Pirogova str., 2, Novosibirsk, 630090, Russia
[2] *Institute of Mathematics, Ludwig-Maximilian University of Munich,*
Theresienstr., 39, Д80333, Munich, Germany

Поступила в редакцию 20.12.2009 г.

In the paper we present the results of computational experiments aimed to define the angular distributions for the polarized radiation scattered in a cloudy layer. The angular distributions for Stokes parameters were computed by Monte Carlo method for different optical models of water-drop and crystal clouds. The ulterior objective of the research is to develop effective techniques to study the particles shape and size by measuring angular characteristics of the scattered radiation emanating from clouds.

Key words: polarized radiation transfer, water-drop and crystal clouds, Monte Carlo simulation, angular distributions, particle shape and size.

Introduction

The role of clouds in the global climate system is important but not well studied. Cloud feedbacks are the largest source of uncertainty in estimates of radiation balance and climate sensitivity, therefore a better understanding and representation of radiation transfer processes in clouds is of paramount importance for climate science. On the other hand, the adequate optical models of clouds are necessary to investigate properties of cloudiness by active and passive optical remote sensing. Our paper deals with numerical modeling of the solar radiation transfer in the atmosphere clouds taking into account specific features caused by polarization of light. By computational experiments we studied angular distributions for the polarized radiation scattered upward and downward by water-drop and crystal clouds. The angular distributions were computed for the Stokes parameters, degree of polarization, and direction of preferable polarization. For computations we used Monte Carlo method and several optical models of clouds. The ultimate aim of the research is to develop effective techniques to study phase structure of clouds, shape and size of particles by measuring characteristics of the scattered radiation.

1. Mathematical model and Monte Carlo algorithms

Assume that an optically isotropic scattering medium consists of particles randomly oriented in space, extinction coefficient and single scattering albedo in the medium does not depend on light polarization, and a field of reference-vectors $\rho(\omega)$ is fixed, i.e. for every direction $\omega \in \Omega = \{(a, b, c) \in R^3: a^2 + b^2 + c^2 = 1\}$ there is defined a unit vector $\rho(\omega)$ orthogonal to ω. Then the process of stationary polarized radiation transfer in the scattering medium may be described by integral equations of the second kind with the generalized kernel

$$S[\rho](r, \omega) = \int_\Omega \int_{R^3} \frac{e^{-\tau(r',r)}}{\|r-r'\|^2} q(r')\sigma(r') M[\rho',\rho](\omega',\omega,r') \times$$

$$\times S'[\rho'](r',\omega')\delta\left(\omega - \frac{r-r'}{\|r-r'\|}\right) dr' d\omega' + S_0[\rho](r,\omega),$$

$$r', r \in R^3, \ \omega', \omega \in \Omega, \ \rho = \rho(\omega), \ \rho' = \rho(\omega'). \quad (1)$$

Here $S[\rho](r, \omega)$ is the Stokes vector (we shall consider Stokes vectors of the type (I,Q,U,V)) with respect to the reference vector $\rho = \rho(\omega)$ for the radiation at the point r spreading in the direction ω, $q(r')$ is the single scattering albedo at the point r', $\sigma(r')$ is the extinction coefficient at the point r', δ is the delta-function, $S_0[\rho](r,\omega)$ is the Stokes vector of the source at the point r in the direction ω, $\tau(r', r) = \int_0^l \sigma(r(s),\omega) ds$ is the optical length of the segment $[r', r]$, $r(s) = r' + s(r - r')/l$, $l = \|r - r'\|$, $M[\rho', \rho](\omega', \omega, r')$ is the 4×4-phase matrix of the medium at the point r' (ω' is the direction before scattering, and ω is the direction after scattering):

$$M[\rho',\rho](\omega',\omega,r') = L[\rho,\rho^*]^{-1} M(\omega',\omega,r')\, L[\rho',\rho^*],$$