Journal of Quantitative Spectroscopy & Radiative Transfer 133 (2014) 1–12

Contents lists available at ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

Particle size effects on the reflectance and negative polarization of light backscattered from natural surface particulate medium: Soil and sand

Zhongqiu Sun *, Jiquang Zhang, Zhijun Tong, Yunsheng Zhao

College of Urban and Environmental Sciences, Northeast Normal University, Changchun 130024, China

ARTICLE INFO

Article history:
Received 21 December 2012
Received in revised form
20 March 2013
Accepted 21 March 2013
Available online 6 April 2013

Keywords:
Polarization
Scattering
Surface reflectance
Spectrometry

ABSTRACT

Many remote sensing applications rely on the knowledge of light scattering by particulate surface. We present results of photometric and polarimetric laboratory measurements of natural particulate surface at a scattering angle range from 140° to 172° in the principal plane. Fifteen samples with different particle size, which is much larger than the wavelength of incident radiation, have been measured in visible and near infrared (350–2500 nm). Each sample displays the prominent phenomena of both opposition surge and negative polarized branch. We can find that the particulate surfaces with small radius show brighter reflectance than those of large radius. For overall samples, the absolute values of negative polarized branch increase with an increase in particle size. Simultaneously, there is a particular case that the particle-size dependence of the negative polarization becomes more obvious for low reflectance particulate surface than for high reflectance particulate surface. The differences in the spectral behavior of degree of polarization of particle surface are found. These results are useful to better understand the scattering property of surface layer with large particles.

Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.

1. Introduction

Many astrophysical, biophysical and other areas of science and engineering applications rely on the scattering property of light by particulate surface. It is of particular importance in remote sensing research because the visible surface of most objects in the Solar System are made up of particles, either in the form of regoliths [1,2,74].

The phenomenon of the brightness opposition spike and accompanying negative polarization at the backscattering direction, which is widely used in remote sensing and laboratory characterization of several objects, can be ubiquitous for particulate surfaces (e.g., atmosphereless solar-system objects and natural Earth land surfaces). The coherent backscattering mechanism, whose general formulation has been put forward by Mishchenko [3], as the explanation of both phenomenon has gained widespread attention from several scientists [4–10].

As the possibility of deducing particulate surface properties from photopolarimetric measurements and reproducing the sharp reflectance increase close to the backscattering direction (or small phase angle) is of great interest in remote sensing techniques and radiative transfer field. A quantity of significant experimental measurement data, numerical and theoretical results base on coherent backscattering mechanism have been obtained [1,6–8,11–14], though several suggestion showing that other mechanisms may also contribute to negative polarization and opposition peak [15–17,75]. In the interpretation of observations of the opposition effect, the near-field effect must be invoked, especially for densely packed scatters comparable to the wavelength in size [75,77]. The observation of negative polarization with double-minima has been found

* Corresponding author. Tel.: +86 138 94897391.
E-mail addresses: sunzq465@nenu.edu.cn (Z. Sun), Zhangjqo22@nenu.edu.com (J. Zhang), gis@nenu.edu.com (Z. Tong), Zhaoys975@hotmail.com (Y. Zhao).

0022-4073/$ - see front matter Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jqsrt.2013.03.013

for satellites of Jupiter by Rosenbush et al. [1] and for Saturn's rings by Dollfus [76]: the narrow polarization opposition effect (POE) and the wider negative polarization branch (NPB). In the case of particulate surfaces, these two branches appear to be dominated by coherent backscattering as well as the single scattering by particles, respectively [18]. Subsequently, measurements of the phase-angle dependence of the linear polarization from a wide variety of natural mineral samples surfaces and particles in air have been reported in several works, these results may be summarized that the negative polarization branch of particulate surfaces can be a remnant of the negative polarization of single scattering by the particles which composing the surfaces [19–22].

However, the practical particles with a wide size ranging in the atmospheres and on the surfaces of various objects (including earth surface) are non-spherical, irregular and internally inhomogeneous. All these make it very difficult to perform a theoretical study of scattering property of particles. For particles whose radii are comparable to the incident wavelength T-matrix method and the discrete-dipole approximation (DDA) have been used to compute non-spherical particles optical parameters even though the former is limited to simple geometries [8,23–27,79–81]. Moreover, if the regolith particles are larger than the wavelength, geometrical optics can be used to investigate the variation of the photometry and polarimetry consequences for media of different physical properties of composing particles [28–33].

Nevertheless, our ability to model scattering by individual particles and many geophysical scattering media are composed of densely packed particles which are much larger than the wavelength constituting the surfaces is limited [34,35]. For the later case, typical examples are the natural Earth land surfaces or artificial objects which differ by their physical, optical, geometrical properties. Models and measurements of scattering property of these targets can be used for retrieval of surface properties [36–38]. There are several scientists have paid more attention to investigate the reflectance and polarization characteristics of surfaces with large particles, e.g. soil, snow and sand which are widely distributed and are illuminated directly by the Sun on the Earth [17–22,37,39–59,60–68]. However, for particle is much larger than the incident wavelength, there is little investigation relate both reflectance and polarization of particulate surface to surface properties characterization, e.g. particles size, especially in the backward direction.

The study described in this paper is an optical experiment investigating the reflectance and negative polarization of light backscattered from natural surface particulate medium: soil and sand in laboratory. We will place emphasis in the backscattering direction in order to link simultaneously the negative polarization branch and brightness opposition spike produced by scattering from soil and sand surfaces to understand both phenomena in a wide particle size rage. The knowledge of scattering-angle dependence can be useful to relate in both phenomena to changes in surfaces conditions, such as particle size. We also provide spectrally resolved measurement data of soil and sand surfaces in order to quantify in detail the polarization features.

2. Samples and measurements

2.1. Samples

The choice of bare soil (black soil) and sand is dictated by the requirement that both of them are widely distributed on the land surface. We have used 15 samples in this study. The soil samples were form Three River Plain in the Northeast of China, whose site located at 47°08′33″N, 130°42′05″E. Two types of sand samples were used: one was from desert pavement; the other was from a dune in China; the sites located at 45°02′50″N, 121°49′12″E nearby. All these samples were taken from the surface layer, which is not much deeper than 2 cm.

Fig. 1 presents all the surfaces with a wide variety of particle. Before measuring the reflectance and polarization of these samples in the backward direction, we separated them through a series of sieves after drying undisturbed for a week at room temperature. For the samples of black soil and sand from desert pavement (represent as S1), they were prepared so that six different size distributions were obtained. These samples were subsequently sieved with two 900 , 450 μm and 300 μm sieves, producing six different size distributions designated as “a”, “b”, “c” (with black soil particles diameter equal to 900 μm, 450 μm, 300 μm, respectively); “d”, “e”, “f” (with black soil particles range in the 450–900 μm, 300–450 μm, smaller than 300 μm, respectively); “g”, “h”, “i” (with S1 particles diameter equal to 900 μm, 450 μm, 300 μm, respectively), “j”, “k”, “l” (with S1 particles range in the 450–900 μm, 300–450 μm, smaller than 300 μm, respectively). However, the sieving procedure can not remove all particles with diameter larger than 450 μm from sand from a dune (represent as S2), because the S2 samples were relative fine compare with the samples of S1 and black soil. We sieved them with a 450 μm and two 300 μm sieves, three different size distributions designated as “m”, “o”, “n” (with S2 particles diameter range in 300–450 μm, smaller than 300 μm, and equal to 300 μm, respectively).

Subsequently, each sample was filled in the columnar container, which has a diameter of 15 cm and a height of 10 cm. The containers were lightly shaken to allow for depositing. In order to mimic theirs natural condition on the land surface as closely as practical, theirs surfaces were not pressed or scraped in any way and no attempt was made to pack the samples. Our motivation in selecting these samples is that we are studying here structural analogs of natural particulate surface rather than compositional analogs. We are focusing here on the scattering property of samples with different size, which is much larger than the wavelength of incident radiation, so that we may better understand the nature of the negative polarization and brightness spike in the backward direction. In the paper, we assume that the particles constituting the surface can be considered as Gaussian particles in Fig. 2, which has been used in recent research for large dust particles [61].

2.2. Measurement system

The measurement system consists of a goniometer, a lamp and an ASD FS3 (Analytical Spectral Devices Field-Spec 3) spectroradiometer. It is used to detect the

Download English Version:

https://daneshyari.com/en/article/5428537

Download Persian Version:

https://daneshyari.com/article/5428537

Daneshyari.com