Journal of Quantitative Spectroscopy & Radiative Transfer 144 (2014) 117–122

Contents lists available at ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

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

Analysis of polarization characteristics of plant canopies using ground-based remote sensing measurements

A.F. Sid'ko*, I.Yu. Botvich, T.I. Pisman, A.P. Shevyrnogov

Institute of Biophysics of the Siberian Branch of RAS, Siberian Federal University, 50-50 Akademgorodok, Krasnoyarsk, Russia

A R T I C L E I N F O

Article history:
Received 2 December 2013
Received in revised form
29 March 2014
Accepted 31 March 2014
Available online 8 April 2014

Keywords:
Spectral brightness coefficients
Degree of polarization
Polarized component of spectral brightness coefficients
Farm crop
Coniferous and broadleaf forests

A B S T R A C T

The paper presents results and analysis of a study on polarized characteristics of the reflectance factor of different plant canopies under field conditions, using optical remote sensing techniques. Polarization characteristics were recorded from the elevated work platform at heights of 10–18 m in June and July. Measurements were performed using a double-beam spectrophotometer with a polarized light filter attachment, within the spectral range from 400 to 820 nm. The viewing zenith angle was below 20 degree. Birch (*Betila pubescens*), pine (*Pinus sylvestris L.*), wheat (*Triticum acstivum*) [L.] crops, corn (*Zea mays* L. ssp. *mays*) crops, and various grass canopies were used in this study. The following polarization characteristics were studied: the reflectance factor of the canopy with the polarizer adjusted to transmit the maximum and minimum amounts of light (R_{max} and R_{min}), polarized component of the reflectance factor (R_q), and the degree of polarization (P). Wheat, corn, and grass canopies have higher R_{max} and R_{min} values than forest plants. The R_q and P values are higher for the birch than for the pine within the wavelength range between 430 and 740 nm. The study shows that polarization characteristics of plant canopies may be used as an effective means of decoding remote sensing data.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

To develop satellite technology for monitoring of terrestrial plant canopies and ground-based optical remote sensing techniques, one should employ new approaches to identify farmlands, determine the plant species composition, and study the morpho-physiological traits of plants [1,2]. A change in the reflectance spectra of the light reflected from the plant canopies characterizes changes in plant optical properties through the season. Having determined the relationship between the morpho-physiological state of the plants and their spectral reflection properties, researchers will be able to use aerospace data for mapping and identification of the vegetation types [2]. The well-known Fresnel equations suggest that the light reflected by the smooth leaf surfaces is polarized light. The value of the polarized component is determined by the incidence angle of light on the leaf surface, the indices of refraction of the leaf waxy coating, and the roughness of its surface [3,4]. Authors of earlier studies investigated different parameters of polarization of scattered light by plant parts (leaves and needles) at Brewster's angle [5–7]. Several authors reported studies of polarized characteristics of reflected and scattered light in the visible radiation range [6–12]. Then imaging polarimetry became available to investigate reflection–polarization characteristics of plant surfaces [8]. In 1993, Ghosh et al. wrote: "The amount of linearly polarized light reflected by a wheat canopy was measured using a polarizing filter attached to a radiometer at two wavelengths (478 nm and 668 nm) and three view zenith angles (60°, 70°, 80°). Measurements were carried out in the anti-solar direction in the principal plane, with relative azimuth between Sun and view directions

* Corresponding author. Tel.: +7 8391 249 44 55.
E-mail address: Sidko@ibp.krasn.ru (A.F. Sid'ko).

http://dx.doi.org/10.1016/j.jqsrt.2014.03.031
0022-4073/© 2014 Elsevier Ltd. All rights reserved.

being 180°. It is found that the degree of polarization (DOP) and mean polarized radiance (R_Q) between stages is statistically significant at view zenith angles of 70° and 80°, in the blue region. It is concluded that DOP and R_Q are better indicators of the onset of heading stage" [9]. Several authors reported studies of spectral and polarization properties of the light reflected from the leaves of plants subject to unfavorable environmental conditions [10–12]. Other studies focused on polarized properties of reflected and scattered light in the visible light region for wheat canopy [13,14]. The degree of linear polarization of wheat was plotted as a function of wavelength and view direction for two crop development stages. Investigations of plant leaves showed that the main mechanism that determines polarization of scattered light is specular reflection from the outer surface of the leaf [15]. Herman and Vanderbilt [16] investigated the typical polarization features of aerosols, cloud droplets, and plant canopies, as observed by ground based and airborne sensors, and addressed the question of polarization measurements from space.

Other authors gave detailed reports of measuring directional reflectance factors and degrees and azimuth of polarization of radiation from leaves [17,18]. Data obtained by remote sensing of polarized characteristics of different plant species in the northern areas were reported in great detail by Suomalainen et al. [19]. Remote polarized measurements of the plant canopy may be a source of useful information, but they have mainly been performed on different plant parts so far [6,7]. Very few studies have addressed polarization properties of the reflectance factor of different vegetation types (forest plants and farm crops) in a certain stage of their development.

The purpose of this study was to analyze results of ground-based remote sensing measurements and potential information value of polarization characteristics of the reflectance factor (polarization component and degree of polarization) obtained in investigations of light reflected from different kinds of plant canopies (forest stands and farm crops), using ground-based remote measurements.

2. Instruments and measurement practices

Polarization properties of the plant canopy reflectance factor were determined using field measurements of reflectance spectra of coniferous and broadleaf forests and different farm crops and grass canopies. The procedure of evaluating polarized light reflected by plant canopies was a modification of the procedure described elsewhere [20–23]. Determination of plant canopy polarized characteristics and their analysis is the next stage of the study published in the Journal of Quantitative Spectroscopy and Radiative Transfer 2013 [24]. Birch (*Betila pubescens*), pine (*Pinus sylvestris L.*), wheat (*Triticum acstivum*) crops, corn (*Zea mays* L. ssp. *mays*) crops, and various grass canopies were used in this study. The area of measurement was 0.7–0.8 m^2 for coniferous and broadleaf forests and 1.2–1.3 m^2 for farm crops and grass canopies. The study of wheat was conducted in the stooling stage and the study of corn was conducted in the stage of 10–12 leaves. Wheat leaves have a linear shape, and corn leaves have a wide shape. These are the most common vegetation types in the Krasnoyarskii Krai. The area of each site measured photometrically was 200 ha or greater. Polarization properties of the plant canopy reflectance factors were recorded from the elevated work platform at heights of 10–18 m under sunny conditions, using a PDSP double-beam spectrophotometer, in late June and in July (Fig. 1). The double-beam differential spectrophotometer (PDSP) was designed by the authors. It records the differential reflectance factor of the object studied and the reference surface, coated with magnesium oxide (MgO) [25].

The scanning rate in the spectral range from 400 to 820 nm was 60 s. In order to obtain the polarization component of the reflectance factor of plants, we attached a polarizer onto the measuring channel, which could be rotated 360° in 2° increments, in accordance with the method described elsewhere [20–23]. A polarizing filter of class 2 (OST 3.4-414-42, Russia) was used as a polarizer. The reflectance factor was measured with a spectral resolution of ±2 nm. Values R_{max} and R_{min} correspond to the reflectance factor of the canopy with the polarizer adjusted to transmit the maximum and minimum amounts of light. Orientation of the polarizer for a maximum light transmittance was determined experimentally. This position of the polarizer was defined as the zero point of measurements (the angle of the polarizer rotated was 0°). Then the polarizer was turned 90°, making it possible to measure the reflectance factor with minimum intensity of light transmittance. Values R_{max} and R_{min} are the basis for the calculation of the polarization component of the reflectance

Fig. 1. Remote sensing measurements of the reflection factor of plant canopies using a spectrophotometer installed on the elevated work platform.

Download English Version:

https://daneshyari.com/en/article/5428199

Download Persian Version:

https://daneshyari.com/article/5428199

Daneshyari.com