Comparing Hyperspectral BRDF Data of Grass Derived from Three Different Laboratory- and Field-Goniometer Systems

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Abstract -- The study compares hyperspectral BRDF data of grass vegetation acquired in the laboratory and field with three different goniometric systems. Reflectance measurements of relatively sparse prairie grass were comparable to measurements taken over a dense grass lawn surface only after correction for the soil influences determined by the canopy gap probability function. Nadir-normalized BRDF data consistently revealed a strong wavelength dependence. In addition, a distinctive relationship between BRDF effects and the canopy reflectance signature was observed in all three grass canopies. These phenomena are due to multiple scattering effects which occur within the grass canopy. Since the canopy structure and multiple scattering effects are ultimately related, the potential for deriving canopy architecture parameters from hyperspectral BRDF data is suggested.

INTRODUCTION

With the advent of NASA's Earth Observation System and other satellites with multidirectional viewing capability and high spectral resolution, hyperspectral Bidirectional Reflectance Distribution Function (BRDF) ground reference data will become increasingly important for remote sensing applications and BRDF-model validation efforts. Much of the BRDF data available today, however, lack high spectral resolution and thus do not explicitly address the spectral characteristics of BRDF effects. This study focuses on the wavelength dependence of reflectance anisotropy in vegetation canopies and on the effects of multiple scattering in hyperspectral BRDF data.

EXPERIMENT

A hyperspectral BRDF data set of a perennial ryegrass surface (Lolium perenne) taken under controlled laboratory conditions at the European Goniometric facility (EGO) of the Joint Research Center in Ispra, Italy [1] is compared to corresponding measurements of the same grass species acquired with the Field-Goniometer System (FIGOS) of the Remote Sensing Laboratories at the University of Zurich, Switzerland [2]. Both, the EGO and FIGOS data, were measured with a GER-3700 spectroradiometer with hyperspectral resolution and a 3° field-of-view. In both goniometers, the sensor is pointing to the same central target area within a 2m radius hemisphere defined by a superstructure on which the sensor is mounted. The data were acquired under a source zenith angle of 35° with view zenith angles ranging from +75° to -75° at increments of 15° and 5° in the FIGOS and EGO data, respectively. Also included in the comparison are bidirectional data of tallgrass prairie dominated by big bluestem (Andropogon gerardi) and Indiangrass (Sorghastrum nutans), acquired with an SE-590 spectroradiometer in the First ISLSCP Field Experiment (FIFE) at site 916 (plot 3) on 8/8/89 under a solar zenith angle of 34° and view zenith angles ±50°, ±35°, ±20°, and 0° in the principal plane [3] [4]. All field data were obtained under clear-sky conditions. In contrast to the EGO and FIGOS measurements, the SE-590 data were taken with a sensor field-of-view of 15° and from a distance of 3.4m. The FIFE prairie grass exhibited a moderately heterogeneous and sparse canopy with a mean leaf area index (LAI) of 2.1 and a height of 34cm, whereas the grass lawn canopies measured with EGO and FIGOS were very dense and uniform with heights of 7cm and 3.5cm, respectively. Thus, the FIFE SE-590 data are more strongly influenced by the soil/background whereas the EGO and FIGOS data are dominated by the vegetation canopy itself.

![Figure 1: Bidirectional reflectance at 600nm of soil and grass taken in the principal plane in three different campaigns under a source zenith angle of 34° (a to c) and 35° (d). Curve (c) shows data of the FIFE prairie grass (b) reduced by the soil reflectance (a).](image-url)
METHODOLOGY

In order to elucidate spectral BRDF effects, the data were normalized to nadir reflectance. In addition, the FIFE data were corrected for the soil/background impact. Based on the leaf angle distribution (LAD) of big bluestem and Indiangrass [4], the bidirectional gap probability (p) of the canopy is derived using a dual-parameter elliptical function [5] which takes the canopy gap fractions in illumination and viewing directions into account. Since FIFE site 916 was burned in previous years, litter accumulation on the ground was limited. Consequently, bidirectional reflectance measurements for the background was obtained for an adjacent bare soil plot that was prepared using a weed trimmer to remove surface vegetation and leave root systems intact [3]. We assumed that the total canopy reflectance (R\textsubscript{Total}) at each wavelength is dominated by sunlit soil (R\textsubscript{Soil}) and grass (R\textsubscript{Veg}) reflectances, neglecting contributions from the shadowed soil:

\begin{equation}
R\textsubscript{Veg} = \frac{R\textsubscript{Total} - p \cdot R\textsubscript{Soil}}{1 - p}
\end{equation}

As a surrogate measurement for reflectance anisotropy, an anisotropy index (anix) at each wavelength is defined as the ratio of the maximum and minimum bidirectional reflectance factor in the principal plane:

\begin{equation}
anix = \frac{R\textsubscript{max}}{R\textsubscript{min}}
\end{equation}

RESULTS AND DISCUSSION

Fig. 1 shows the bidirectional reflectance factors in the principal plane at a wavelength of 600nm for FIFE soil (a) and prairie grass, before (b) and after (c) correction for the soil impact, and for ryegrass acquired with FIGOS (d). The soil clearly shows non-Lambertian reflectance characteristics and is rather bright due to the dry conditions at the time of data acquisition. Elimination of the soil influence on total canopy reflectance (b) using (1) reduced canopy reflectance while slightly enhancing reflectance anisotropy (c). The FIGOS data reveal a dominant hot spot which is not observable in the SE-590 measurements due to its much larger field-of-view of $15^\circ$ which is strongly affected by the instrument shadow in the hot spot direction. Distinctive forward and backscatter characteristics are also pronounced in the FIGOS data (and EGO measurements not shown) since they include extreme view zenith angles of up to $\pm75^\circ$.

The nadir-normalized reflectance data of the grass surface acquired under laboratory conditions with EGO (Fig. 2a) and in the field with FIGOS (Fig. 2b) both reveal a strong wavelength dependence of the BRDF effect especially in the spectra from backscatter angles. These data also exhibit the

\begin{figure*}[h]
\centering
\includegraphics[width=\textwidth]{fig2.png}
\caption{Nadir normalized reflectance data of (a) perennial ryegrass acquired in the EGO laboratory, and (b) in the field with the FIGOS goniometer under $35^\circ$ source zenith angle, and of (c) bluestem/Indiangrass acquired during FIFE under a solar zenith angle of $34^\circ$. Figure (d) corresponds to (c), but is corrected for the soil impact on the grass reflectance measurements.}
\end{figure*}
highest reflectance in the backscatter direction and lowest values close to nadir in the forward scatter direction. The BRDF effects in the original FIFE SE-590 reflectance data (Fig. 2c) also exhibit a similar reflectance anisotropy pattern, but a much weaker wavelength dependence. However, after correcting for the soil impact using (1), a strong wavelength dependence of reflectance anisotropy is also evident. In all three datasets, EGO, FIGOS and the corrected SE-590 measurements, reflectance anisotropy is most pronounced in the blue and red chlorophyll absorption bands which exhibit relatively low reflectance. However, reflectance anisotropy is particularly low, especially in backscatter spectra, for the much more highly reflective near-infrared range. Reduced anisotropy under highly reflective conditions can be explained by enhanced multiple scattering which reduces the contrast between sunlit and shadowed canopy components. As a result, reflectance anisotropy of vegetated surfaces is low in high reflectance bands and more pronounced for low reflectances. Fig. 3 illustrates this relationship by showing anisotropy index (anix) data versus nadir reflectance. Since the role of multiple scattering on reflectance anisotropy is dependent on the gap probability of the canopy, we believe that structural parameters of a vegetation canopy are preserved in hyperspectral BRDF data and might be derived from functions as given in Fig. 3. According to the gradients in Fig. 3, the EGO grass sample (d) apparently exhibits the most erectophile canopy followed by the FIFE (c) and the FIGOS grass surfaces (e). The relatively fine grained soil of the FIFE site (a), however, seems to have low sensitivity to multiple scattering effects and reveals an anisotropy which is nearly independent of nadir reflectance (Fig. 3). Thus, the relationship between anix and nadir reflectance in the uncorrected data of FIFE (b) are strongly biased by the soil.

CONCLUSIONS

Hyperspectral BRDF data of grass canopies acquired in the laboratory and in the field with three considerably different experimental configurations consistently showed a strong wavelength dependence of BRDF effects in vegetation canopies. Spectral BRDF effects are highly correlated with the spectral canopy reflectance signature since spectral anisotropy is inversely related to multiple scattering. For the relatively sparse FIFE grass canopy, this relationship could only be fully expressed after a correction of the soil influence on the grass reflectance measurements. Since the effect of multiple scattering on spectral reflectance anisotropy characteristics is dependent on the canopy architecture, canopy structure parameters may be derived from hyperspectral BRDF data.

REFERENCES


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