BRDF calibration of natural samples in support of remote sensing

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The monitoring of land surface is a major science objective in Earth remote sensing. A major goal is to identify major biomes and to map and distinguish the changes in their composition introduced by anthropogenic and climatic factors. Currently, deforestation and desertification are the most important land cover area processes of scientific interest. These processes play a major role in climate variation particularly with respect to clouds and rainfall. Given known anthropogenic influences on climate, air, and water quality, biome mapping has clearly become a research priority. Understanding the spatial characteristics of the properties of biomes will help in the formulation of site-specific management plans over the globe. Changes in chemistry and dynamics of land and sea are directly connected with Earth geophysical processes, which include the circulation of the major air and sea currents, the type, concentration and distribution of atmospheric aerosols, and the formation of clouds. The modeling of the processes will help predict the changes in major Earth biomes and their impact on climate variation.

Significant efforts have been invested in the study of the Earth’s major biomes. For example, King et al.1, have developed an airborne, multi-wavelength scanning Cloud Absorption Radiometer (CAR) that has been used to measure surface anisotropy, which is characterized with bidirectional reflectance distribution function (BRDF), for different surfaces and ecosystem in many parts of the world, Gatebe et al.2.

The BRDF describes the spatial and spectral interaction of light on a sample’s surface as a function of the incident and scatter angles and wavelength. The BRDF is particularly important in the characterization of reflective and transmissive diffusers used in the pre-flight and on-orbit radiance and reflectance calibrations of Earth remote sensing instruments3. Satellite BRDF measurements of Earth scenes can be used as a sensitive tool for early detection of changes occurring in vegetation canopies, soils, or the oceans.

In this study, we present laboratory BRDF measurements of leaf samples as effort to understand the role of spatial and spectral variability of the natural biome. The samples measured in the laboratory included leaf litter, predominantly from acacia trees collected from the savanna biome of Skukuza, South Africa, and fresh and dry leaves from poplar tree (Liriodendron tulipifera) and acacia (Acacia greggii). The poplar and acacia leaves were also crushed and separated using standard sieves in order to address the scaling of remote sensing airborne observations. Three different size litter samples were created between 4 and 4.75 mm, 1.7 and 2 mm, and 75 and 90 nm. Their BRDF was measured using the scatterometer located in the Diffuser Calibration Facility (DCaF) of NASA’s Goddard Space Flight Center. The samples were measured at both in-plane and out-of-plane geometries and at a number of incident angles and wavelengths. The light source used was a short-arc Xenon lamp - monochromator assembly producing an incoherent, tunable light with a well-defined spectral bandpass. The scatterometer can perform in-plane and out-of-plane BRDF measurements with typical measurement uncertainties of 1 % (k = 1), where k is the coverage factor. The results presented here are traceable to the National Institute of Standards and Technology’s (NIST’s) Special Tri-function Automated Reference Reflectometer (STARR)4. The NASA’s DCaF scatterometer was used to measure the BRDF with different source and detector angular configurations. The facility has participated in several round-robin measurement campaigns with domestic and foreign calibration institutions in support of Earth and space satellite validation programs5.

BRDF was measured at incident angles of 0, and 67° chosen to cover the wide range of solar zenith angles associated with CAR field measurements. The detector was positioned at scatter zenith angles from 0-
to 80° with data acquired in steps of 5. Scatter azimuth angles of 0° and 180° correspond to the in-the-principal plane measurement geometry. Scatter azimuth angles of 45°, 90°, and 135° correspond to out-of-plane measurement geometries. The wavelengths were 340 nm, 470 nm and 870 nm again chosen after the CAR instrument. The tops and bottoms of the leaves were measured to account for structural differences such as smoothness and glossiness.

The BRDF of a fresh green leaf measured in-plane at normal incidence increases with increasing wavelength and decreases with increasing scatter zenith angle for 870 nm. However at 340 and 470 nm the BRDF decreases for scatter zenith angles from 5° to 45°, while increases from 45° to 80°. The reason can be attributed to leaf biochemical composition, nitrogen, water, and lignin and cellulose. The leaves exhibit forward scattering at all wavelengths. The out-of-plane BRDF at normal incidence behaves the same way as in-plane showing that the leaves exhibit the same scattering in all directions. The BRDF of a dry green leaf in-plane at normal incidence is also proportional to the scatter zenith angle for 870 nm. Similar to the fresh leaves, the BRDF of the dry leaves decreases for scatter zenith angles 5° to 40° and increases from 40° to 80° at 340 and 470 nm. At a scattering zenith angle of 70° the BRDF seems to be affected by surface roughness. The out-of-plane BRDF at normal incidence shows smooth scatter distribution up to 30° scatter azimuth angle, which is similar to the fresh leaves. The leaves exhibit forward scattering at all wavelengths. The BRDF at larger scatter zenith angles shows a dependence upon the scatter azimuth angles, mainly due to surface roughness. The BRDF of poplar tree leaves is also presented. Both whole leaves and cut leaves were measured and their BRDF compared. It is shown how the BRDF depends on the light incident and scatter angles. The shapes of the BRDF curves strongly depend on the nature of the sample (i.e. crushed versus whole leaf) and the angle of incidence. The dry leaves exhibited lower BRDF values at small scatter angles compared to fresh leaves.

This work is intended to describe more completely the BRDF of different leaf samples measured in a laboratory environment. The data recorded at field campaigns present the scatter of land surface with trees, grass and bare soil. However we believe the lab results are going to be of great help to the remote sensing community at their modeling and correction efforts of airborne data.

REFERENCES