CALIBRATION OF BRDF EFFECTS IN PADDY FIELD REFLECTANCE FROM TEMPORAL MODIS IMAGES

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ABSTRACT:

Moderate Resolution Imaging Spectroradiometer (MODIS) has a potential for more detailed daily monitoring of land covers and their change than ever because two bands, red and near-infrared bands, have 250m spatial resolutions. On the other hand, the use of MODIS data requires attention to Bidirectional Reflectance Distribution Function (BRDF) effect, which is one of the most important factors to calibrate reflectance obtained from remotely sensed data. In order to examine the possibility of BRDF estimation from MODIS data and BRDF calibration, firstly Bidirectional Reflectance Factor (BRF) data in paddy fields were measured on the ground during three months. Then, parameters of BRDF model were estimated using the ground data. Finally, parameters of BRDF model were estimated by using temporally successive sixteen-day MODIS images, and both BRDFs were compared. The experimental results reveal that while the ground BRDF and MODIS BRDF are similar, the degree of the BRDF curvature is different. Therefore, it is concluded that further research is required to apply the ground BRDF for the estimation of MODIS BRDF.

1. INTRODUCTION

Spaceborne and airborne remotely sensed data are observed from varying viewing angles. This difference affects the Earth's surface reflectance and is expressed as the BRDF. The BRDF can be used to calibrate reflectance into the reflectance at nadir, which leads to the normalization of reflectance and enables comparison of data observed from different angles (Kimes *et al.*, 1985) (Pinty *et al.*, 1991) (Roujean *et al.*, 1992). Therefore, the BRDF effect is one of the most important factors in the utilization of satellite data and the derivation of biophysical information from the ground surface (Chopping, 2000) (Wanner *et al.*, 1995).

BRDF models are roughly divided into three categories; empirical model, semiempirical model and physical model. Semiempirical BRDF models are regarded as robust models. A kernel-driven BRDF model is one of the traditional semiempirical models, and is applicable to any kind of land cover type (Hu *et al.*, 1997). The kernel in the model is a function determined by viewing and illumination geometries . The kernel-driven model was adopted for BRDF/albedo standard product of MODIS sensor onboard the Terra satellite, launched on Dec. 1999 (Strahler *et al.*, 1999). This model selects the most suitable kernels for volume and geometric scattering, respectively. In estimating parameters of kernel-driven BRDF models, robustness and reliability are of quite importance. In order to achieve the robustness, Li *et al.* have discussed the importance of a priori knowledge accumulation and its application to linear BRDF model inversion (Li *et al.*, 2001). Moreover, Gao *et al.* has reported a multikernel least-variance approach to retrieve and evaluate the albedos from limited bidirectional measurements in order to avoid a biased estimation (Gao *et al*., 2001).

In various analyses of biophysical dynamics on land, atmospherically corrected surface reflectance data are inevitable. MODIS level 1B radiances are corrected for atmospheric effects to generate the surface reflectance, i.e. MOD09 product. Atmospheric correction requires inputs that describe the variable constituents that influence the signal at the top of the atmosphere and a correct modeling of the atmosphere scattering and absorption. In order to generate MOD09, MODIS atmospheric products (MOD04:aerosols, MOD05:water vapor, MOD07:ozone, MOD35:cloud mask) and ancillary data sets (Digital Elevation Model, Atmospheric Pressure) are necessary as input data. A correction for atmospheric/BRDF coupling can be achieved if there are a-priori estimate of the surface BRDF (Strahler *et al*., 1999).

In this research, we examined the possibility of BRDF estimation from MODIS data and BRDF calibration. Firstly, BRDF data measured in paddy fields during three months were used for the estimation of BRDF model parameters. Then, temporal MODIS data observed during the period when the ground measurement was conducted were used for the estimation of BRDF model. Finally, we compared both the BRDF estimated from ground measurement data and the BRDF estimated from MODIS data, and examined the possibility of the calibration MODIS data using the data obtained by the ground measurements.

2. BRDF ESTIMATION

We used BRF data collected on the ground and MODIS data in order to validate the difference between BRDF model from the ground data and BRDF model from MODIS data. Considering that the importance of paddy fields in terms of food production and planning in Asian countries, we focused on paddy fields for the validation.

BRF data measurements were conducted for paddy fields at Yohkaichiba in Chiba, Japan, from June to August 2002. The fields were harvested at the end of August. The site is a flat area having more than 2 km^2 homogeneity. We used a car to which a controllable arm was attached in order to measure BRF data. A spectroradiometer was attached to the rotatable platform at the edge of the arm. The height of the spectroradiometer was 3.5 to 4.0 meters away from the ground, and the instantaneous field of view (IFOV) of the spectroradiometer was approximately 21 degrees. The view azimuth and zenith angles of the platform were controlled via software run on a PC from the ground. The spectroradiometer can measure both sample and reference simultaneously. Thus, both data were used to calculate the reflectance of the paddy fields.

On the other hand, Tokyo University of Information Sciences has been receiving MODIS data since November 19, 2000. In the daily processing, not only level 1B data but also higher-level products, e.g. MOD09 (reflectance) and MOD11 (land surface temperature), are processed. In this research, we used MOD09. In June and July, Japan has rainy season, then just few MODIS reflectance data are available during the period. However, in August 2002, there were many clear-sky days. Examining data obtained during the period around August 9, 2002, when ground measurement was conducted, several-day data are found to be available, shown in Table 1. Table 1 also represents 1km-resolution band 1 and 2 reflectances, sensor zenith, sensor azimuth, solar zenith and solar azimuth angles using 1km-resolution MOD09 and MOD03 data.

In the experiments, MOD09 band 2 (841-876nm) reflectance data and the measured near-infrared wavelength (841-876nm) data were used. As kernels of kernel-driven BRDF model, RossThin and LiDense kernels were selected. The parameters required in the model were set as h/b = 2.0 and b/r =1.0. In Figures, (1) and (2), the reflectances measured on the ground are expressed as crosses. The result obtained by substituting 20-degree solar zenith angle into the ground BRDF is represented as a dash line. Correspondingly, the result obtained by substituting 20-degree solar zenith angle into the MODIS BRDF is represented as a solid line.

3. DISCUSSIONS

In Figure (1), it is shown that the ground BRDF and MODIS BRDF have a similar curve, a larger reflectance as a sensor zenith angle becomes larger. However, the degree of the curvature is different. While MODIS BRDF in Figure (2) shows the same curve as the ground BRDF, which has the lowest reflectance at nadir, the MODIS BRDF in Figure (2) seems like a flat line. It is that the angle dependence cannot be shown in MODIS BRDF as much as the ground BRDF.

The BRDF/albedo product of the MODIS data is produced from the data collected over sixteen successive days (Strahler *et al*., 1999), and can be plotted at approximately the same plane as the cross-principal plane. We cannot expect to utilize all sixteen data for the product because of cloud contamination. In fact, previously mentioned, available MODIS data during the periods around ground measurements in June and July are just two-day data respectively. It is reported by Chopping (Chopping, 2000) and Li *et al*. (Li *et al*., 2001) that parameter estimation using a limited angular data sets can cause results that differ from those obtained using a sufficient angular data sets. The sampling problem should be also considered for the further research of MODIS BRDF estimation.

4. CONCLUSIONS

In the present paper, it is revealed that while the ground BRDF and MODIS BRDF have similar characteristics in their shapes, the degree of the BRDF curvature is different. Therefore, it is concluded that further research is required to apply the ground BRDF for the estimation of MODIS BRDF. In addition, we examine to apply the ground BRDF for the estimation of MODIS BRDF on condition that there are limited available MODIS data.

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Table 1. Band1 and 2 reflectances, sensor zenith, sensor azimuth, solar zenith and solar azimuth angles using 1km-resolution MOD09 and MOD03 data. The angle unit is degree.

Observation date-time (GMT)	Band1 reflectance	Band2 reflectance	Sensor zenith angle	Sensor azimuth angle	Solar zenith angle	Solar azimuth angle
20020807-005805	0.0830	0.4287	46.44	96.28	29.28	124.54
20020808-014201	0.0359	0.3877	26.97	-77.52	23.21	143.56
20020809-004559	0.0605	0.4304	57.95	94.01	31.74	121.29
20020810-012933	0.0489	0.3899	4.49	-78.42	25.21	138.38
20020814-010413	0.0761	0.4153	38.85	96.95	29.64	129.96
20020815-014834	0.0762	0.3936	36.41	-76.74	24.24	149.86

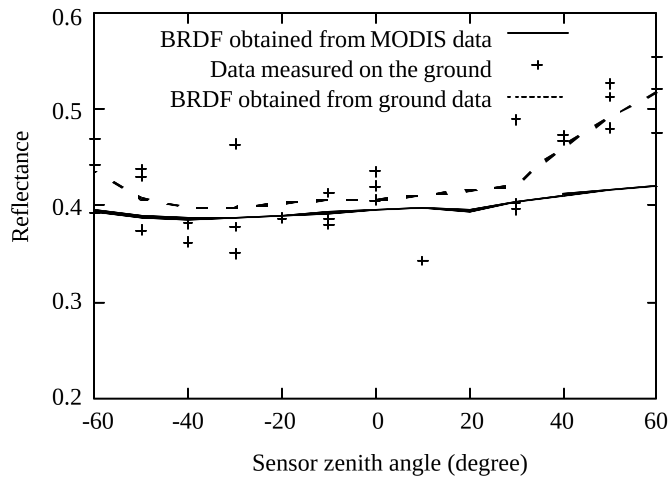

Figure 1. BRDF for near-infrared band data (841-876nm) in the principal plane. The reflectances measured on the ground are expressed as crosses. The result obtained by substituting 20-degree solar zenith angle into the ground BRDF is represented as a dash line. Correspondingly, the result obtained by substituting 20-degree solar zenith angle into the MODIS BRDF is represented as a solid line.

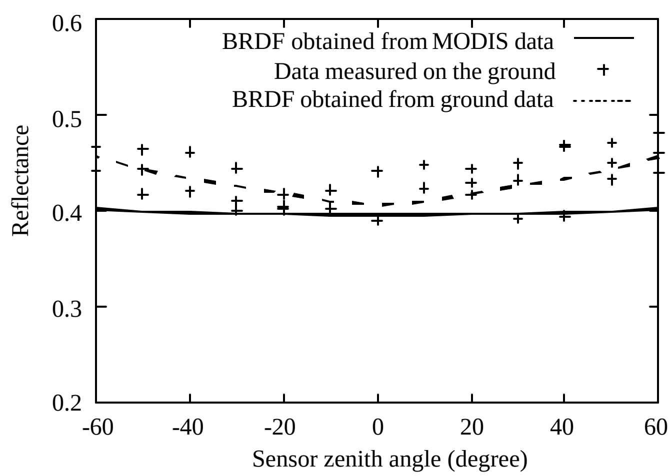

Figure 2. BRDF for near-infrared band data (841-876nm) in the cross-principal plane. The reflectances measured on the ground are expressed as crosses. The result obtained by substituting 20-degree solar zenith angle into the ground BRDF is represented as a dash line. Correspondingly, the result obtained by substituting 20-degree solar zenith angle into the MODIS BRDF is represented as a solid line.