Spatially and Temporally Complete Surface Albedo Product Over the ARM SGP Area for 2000-2003 Period

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Introduction

Spatially and temporally complete surface albedo product over the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) area has been generated using data from two Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on Terra and Aqua satellites. In order to retrieve the albedo which is a hemispheric integral of directional reflectance, the bi-directional reflectance distribution function (BRDF) has to be known for the surface anisotropic reflecting properties. A landcover-based algorithm is developed in this paper to derive the BRDF model parameters. The approach employs a landcover map and multi-day clear-sky composites of directional surface reflectance. The landcover map is derived from the Landsat TM 30-meter data set, and the surface reflectances are from MODIS 8-day, 500m-resolution clear-sky composite data products (MOD09). The MOD09 data are re-arranged into 10-day intervals for compatibility with other satellite products, such as those from the NOVA/AVHRR and SPOT/VGT sensors. Separate datasets for MODIS on Terra and Aqua as well as the combined data product are generated at 500-meter spatial resolution and every 10-day since March 2000 and July 2002, respectively. To fill the data gaps due to cloud presence, various interpolation procedures are applied based on a multi-year observation database and referring to results from other locations with similar landcover property. Special seasonal smoothing procedure is also applied to remove outliers and artifacts in data series. Surface anisotropic properties derived from MODIS, which is a cross-track scanning instrument, are compared with the along-track multi-angular observations from Multiangle Imaging Spectro-Radiometer (MISR) system. Generally, the results compare quite favorably with MISR. For example, the correlation coefficients are between 0.7-0.95 for albedo. The biases are 0.01 on average and standard deviations are 0.02. Selected datasets are currently available at CCRS ftp site: ftp://ftp.ccrs.nrcan.gc.ca/ftp/ad/CCRS_ARM/Satellites. Entire dataset for the period 2000- 2003 will be placed into the ARM archive soon.

Landcover-Based Fitting Approach for BRDF

The landcover based fitting (LBF) approach assumes a similarity of the BRDF properties for the same landcover type with a similar biophysical condition within the same climatic region. It is to use a multi-day clear-sky composite of surface reflectance dataset for a certain area, and to group the pixels in that area according to the landcover types, in addition, to group the intraclass pixels by their green biomass levels (e.g., characterized by the Normalized Difference Vegetation Index [NDVI]). With these grouped data, which may include observations at various geometric illuminations, i.e., solar zenith angle (SZA), view zenith angle (VZA) and Sun-satellite relative azimuth angle (RAA), the BRDF model parameters can be fitted optimally for each landcover type with certain biomass level. The particular BRDF for each pixel is then determined through the adjusting of the general landcover-grouped BRDF parameters to the observed reflectances corresponding to that pixel. This approach overcomes the major limitation of pixel-based fitting approach which is based on a certain period (e.g., 16 days) of accumulation of observations for a pixel and is currently used in the MODIS official albedo product (MOD43), which may be associated with small or insufficient number of observations (Schaaf et al. 2002, Jin et al. 2003).

The region selected for our study covers a $8° \times 10°$ latitude/longitude area centered at the ARM SGP Central Facility (CF) located in North Oklahoma. The National Land Cover Dataset is used as the initial map of landcover types, which is compiled from the Landsat TM imagery with a spatial resolution of 30 m and supplemented by various ancillary data (http://landcover.usgs.gov/natllandcover.asp). In this paper it is aggregated to 500 meter and re-mapped into the ARM-SGP area. The landcover map can be viewed elsewhere in this issue of the proceeding (Trishchenko et al. 2004).

For the BRDF the RossThick-LiSparse reciprocal model is used for its good performance for data with limited angular distributions, and for its computational efficiency and linear structure (Wanner et al. 1995). The model is expressed as a sum of several theoretically constructed kernel functions

$$\rho_\lambda(\theta_s,\theta_v,\phi) = a_0 + a_1 f_1(\theta_s,\theta_v,\phi) + a_2 f_2(\theta_s,\theta_v,\phi) \qquad (1)$$

among them θ_s, θ_v and ϕ are SZA, VZA and RAA, respectively. $f1$ is called as RossThick kernel representing scattering from a dense leaf canopy based on a single-scattering approximation of radiative transfer theory. $f2$ is LiSparse kernel which is derived, assuming a sparse ensemble of surface objects, from the geometric-optical mutual shadowing model. Parameters a_0, a_1, and a_2 are coefficients of the kernels and related to isotropic, volumetric and geometric reflectances, respectively.

The number of pixels for a landcover class (e.g., grasslands) is very large, and their distribution with respect to VZA and RAA is irregular. Unequal weights for different angles may lead biasing the fitting results toward most frequently observed data points and ignoring valuable but less frequent data. To address this problem, all data points of a certain landcover class are sorted into small 4-dimension bins with three angular plus the NDVI intervals, e.g., 5°, 5°, 10° and 0.1 for SZA, VZA, RAA and NDVI, respectively. Data collected within each data bin are statistically processed to eliminate outliers and reduce noises. An example of such pre-processed data for grasslands is given in Figure 1, i.e., the polar plots of Terra and Aqua MODIS surface reflectances of three spectral bands for May of 2003 in the ARM SGP area. The radius of the polar plot represents the VZA, and the polar angle is the RAA.

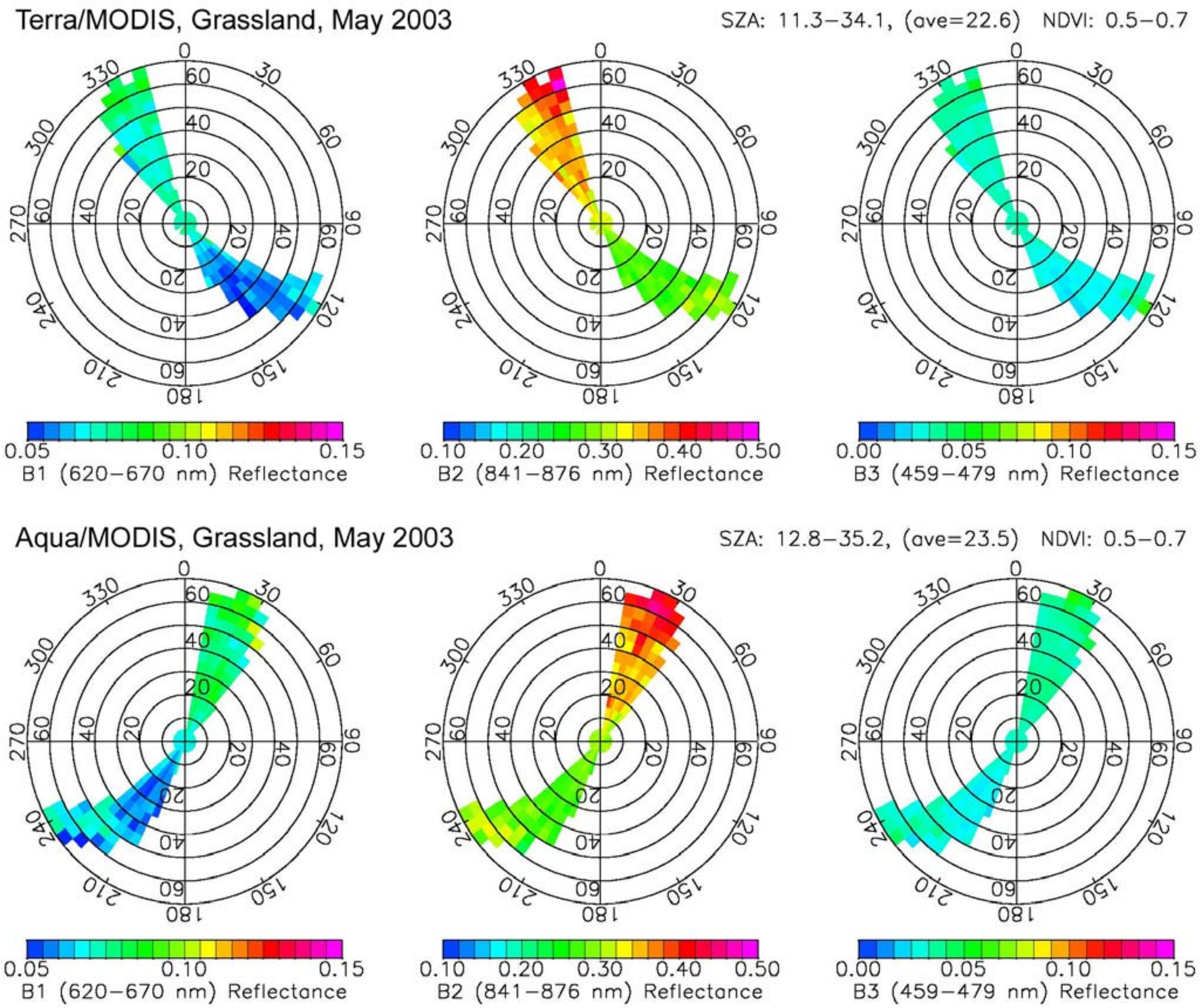

Figure 1. Polar plots of surface reflectance for 3 spectral bands for grasslands in the ARM SGP area from Terra and Aqua MODIS observations in May of 2003. The solar zenith angle (SZA) range and its average for each month as well as the NDVI intervals used for collecting data are indicated at the top. The radius of the polar plot represents the viewing zenith angle (VZA), and the polar angle is the relative azimuth angle (RAA) between the Sun and viewer.

Results of BRDF and Albedo Retrievals

The fitting results of MODIS reflectances by Ross-Li model with the LBF approach are shown, with selected examples, in Figure 2. The reflectances are plotted against the VZA. The Aqua/MODIS red and NIR bands are shown for two major landcover types (grasslands and croplands) at various NDVI levels. Each black square represents one binned MODIS reflectance obtained at the pre-processing step. The red triangles show fitting results of the Ross-Li BRDF model.

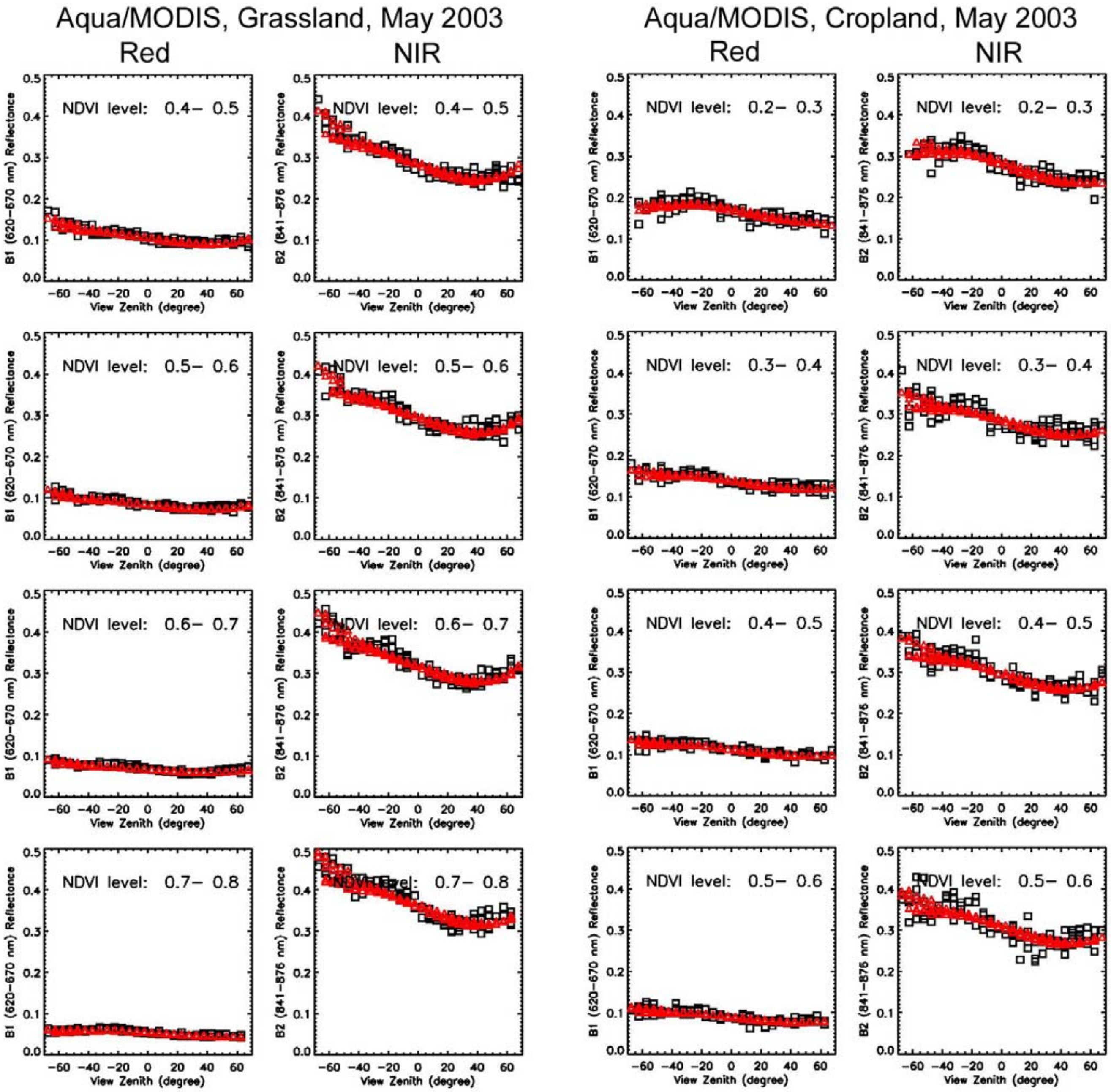

Figure 2. Aqua/MODIS reflectances at red and NIR bands against viewing zenith angles (VZA) for different NDVI levels. The black squares are observed values. The red symbols are correspondingly fitted values based on RossThick-LiSparse BRDF model. The main landcover types (grasslands, croplands) for May 2003 are displayed.

For theoretical modeling kernels the weights a_0, a_1 and a_2 are considered being functions of surface structural parameters, optical properties of canopy elements and Leaf Area Index (LAI). Figure 3 shows these three parameters for the red and NIR channels for May 1-10, 2003, which are derived based on combined Terra and Aqua MODIS datasets.

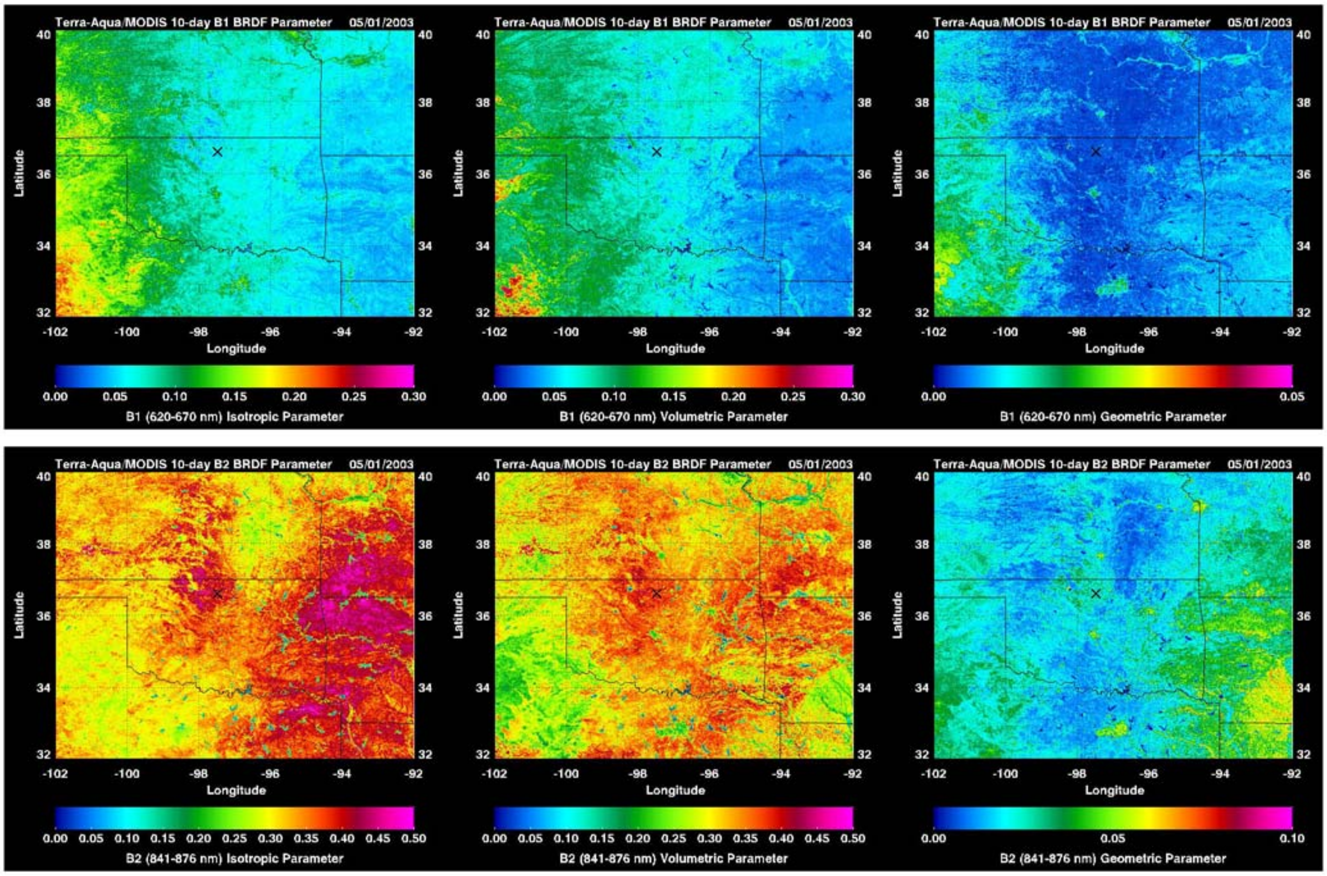

Figure 3. Derived three RossThick-LiSparse BRDF parameters, i.e., isotropic, volumetric, and geometric parameters for the red and NIR bands for the period of May 1-10, 2003.

When the BRDF model parameters are available, they can be used to compute the hemispheric reflectance, i.e., albedo. The direct albedo is defined as albedo of the surface illuminated by a parallel beam of radiation. The diffuse albedo is defined as albedo of the surface when downward radiance field is fully isotropic. For a liner BRDF model such as the Ross-Li, both types of albedo can be computed either by using look-up table of pre-computed kernel integrals or through the analytical approximations expressing albedo as function of BRDF parameters and SZAs (Lucht et al. 2000). Figure 4 displays the direct albedo maps computed at local solar noon for the red and NIR bands for May of 2003, when an aerosol IOP was conducted around ARM-SGP Central Facility (CF). Albedo maps in three 10-day intervals are derived based on MODIS 10-day clear-sky composite datasets. The three MODIS maps clearly show significant variation of surface albedo with time; namely, the decreasing of albedo in NIR band around CF (with a cross symbol) indicates a fast change of vegetated canopy during this season (i.e., wheat ripening). Figure 4 also emphasizes the advantage of the LBF approach for mapping rapid

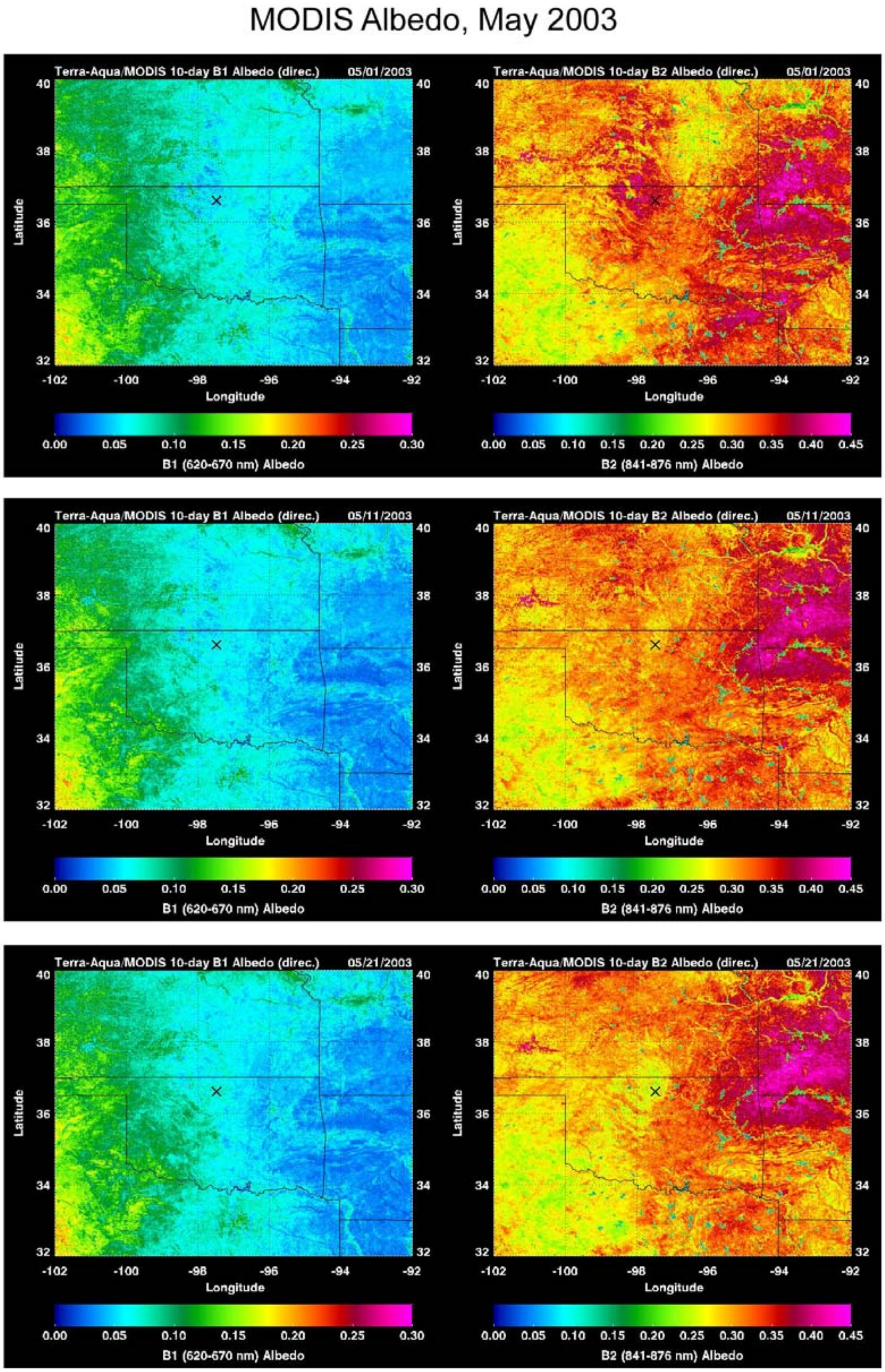

Figure 4. Direct albedo (local noon) for the red and NIR bands over the ARM-SGP area. The MODIS albedo maps are based on the LBF algorithm and are of three 10-day intervals for May of 2003.

changes in surface properties over short-time intervals. To inspect the detail behaviors around the CF (marked by a cross symbol in Figure 4) in May of 2003, the spectral albedo in a small area of 12.5 x 12.5 km2 centered at the CF are shown in Figure 5. Dominated by ripening wheat fields in that season, the surface albedo decreases in the NIR band and increases in the visible band through the month.

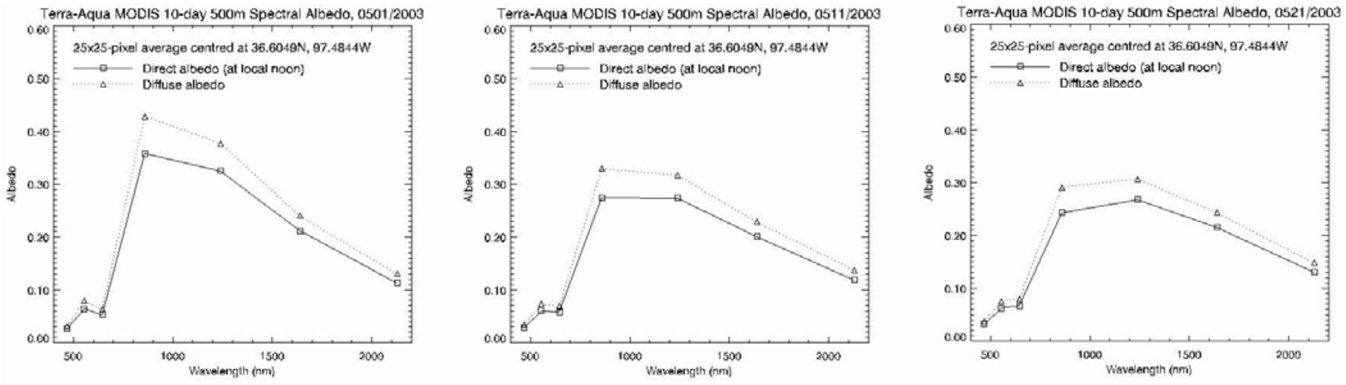

Figure 5. Spectral albedo for three 10-day intervals of May of 2003 in an area of 12.5 x 12.5 km2 centered at the ARM-SGP CF.

Pixel-by-pixel comparisons between MISR and MODIS LBF albedo for the red and NIR bands are presented in Figure 6 for April 2001. Pixels are grouped by five major landcover types in the ARM SGP area. Considering the significant short-term variability shown in Figures 4 and 5, the MODIS albedo for each pixel is selected from one of three composites whose date is closest to that of the MISR pixel data.

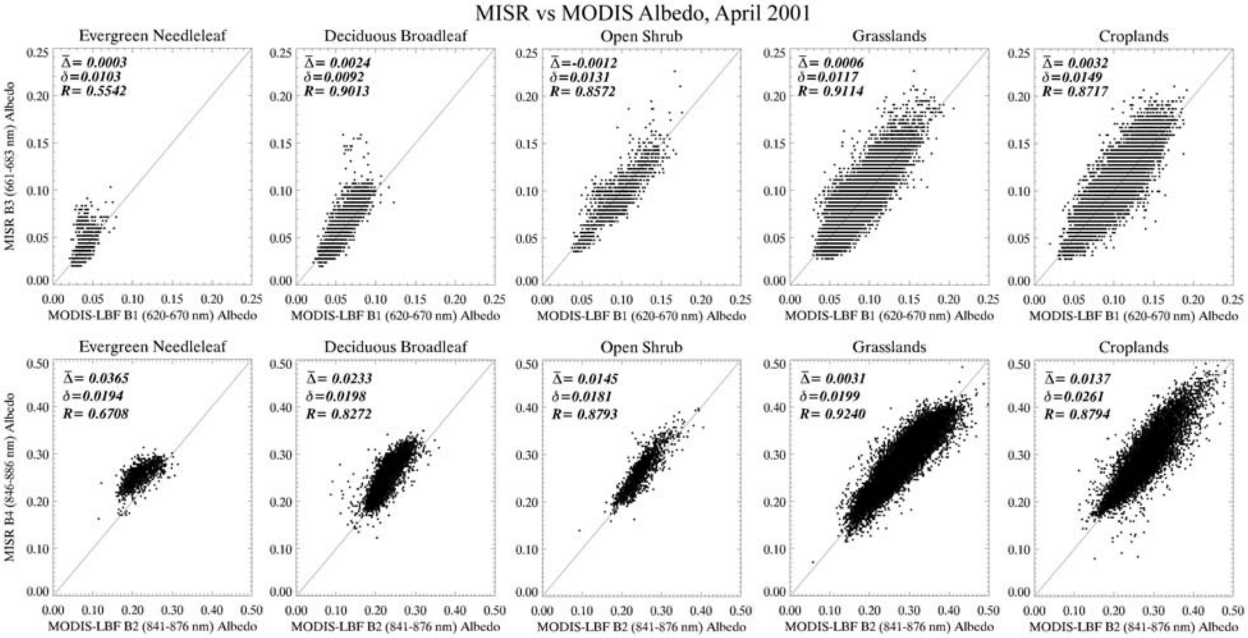

Figure 6. Scatter plots of MISR direct albedo against MODIS albedo derived by the landcover-based fitting algorithm for April 2001.

It should be noted that some additional noise in this comparison might be caused by the difference in the spectral response function between the two systems (Trishchenko et al. 2002) and also due to the re-projection and spatial mismatch between two independent products. Despite these facts, in most cases the data points fall around the line with slope equal to one. The correlation coefficients (R) are normally larger than 0.80. Mean biases ($\overline{\Delta}$) are usually small, and standard deviations (δ) are at the level of 0.01 or 0.02 for red and NIR bands.

Summary

1. The purpose of this work is to develop an approach suitable for generating surface BRDF/Albedo product using multi-day composite datasets obtained from satellite observations.

2. The proposed LBF approach has several advantages with respect to pixel-based method. It increases the number of samples used in BRDF fitting procedure and thus makes retrieval of the BRDF shape more reliable. It performs data binning process which reduces noise or outliers and prevents biasing due to uneven distribution of observational conditions. It can generate albedo based on short time interval composite and capture the rapid variations of the surface properties.

3. The LBF approach can be easily applied for joint data processing of multi-day clear-sky composite data assembled from multiple platforms. Spectral correction procedure has to be implemented to merge data from similar but not identical sensors to reduce spectral response function effect.

4. The potential limitation of this approach is that it may not always capture subtle spatial differences in the BRDF behavior within the same landcover class.

5. Results shown in this poster are based on our primary studies. Further validation and comparison among different sensors and with ground measurements, and possible improvements are in process.

6. Generated BRDF model parameters and albedo has been released through the CCRS ftp site: ftp://ftp.ccrs.nrcan.gc.ca/ftp/ad/CCRS_ARM/Satellites/.

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