ASSESSMENT OF BIASES IN MODIS SURFACE REFLECTANCE DUE TO LAMBERTIAN APPROXIMATION

Yujie Wang[1,2], Alexei Lyapustin[1,2]

[1]GEST center, University of Maryland Baltimore County

[2]NASA Goddard Space Flight Center

1. INTRODUCTION

Surface reflectance is an important component of the Earth Observing System (EOS) program and the National Polar Orbiting Environmental Satellite System (NPOESS) programs. Successful application of satellite-derived surface reflectance to vegetation studies requires its uncertainty be well defined. The process of establishing the accuracy of environmental data products on regional and global scales is called validation. However, validation of the moderate resolution (~1km) surface reflectance products at global scales with field measurements is challenging because they usually involve significant resources, are subject to weather uncertainties, and are strongly limited in temporal and spatial coverage.

Recently, we developed an AERONET-based Surface Reflectance Validation Network (ASRVN) as an alternative validation approach. ASRVN is an automated data collection and processing system [1] which receives 50×50 km^2 subsets of MODIS L1B data from MODIS adaptive processing system (MODAPS) and Aerosol Robotic Network (AERONET) [2] aerosol and water vapor information and performs atmospheric correction for about 100 AERONET sites based on accurate radiative transfer theory with complex quality control of the input data. The ASRVN algorithm uses a high accuracy semi-analytical Green's function solution [3]. In combination with the Ross-Thick Li-Sparse (RTLS) BRDF model [4], this solution provides an explicit parameterization of TOA reflectance in terms of three surface RTLS model parameters. The ASRVN algorithm derives RTLS coefficients directly by fitting the radiative transfer solution to the measured TOA reflectance accumulated over a 4-16 day period and creating a sensor-specific record of spectral BRF, albedo and derivative products. In this paper, a multi-year ASRVN data record is used to assess biases in the MODIS surface reflectance due to Lambertian approximation used in the MODIS atmospheric correction algorithm [5].

2. DATA ANALYSIS

The Lambertian assumption largely simplifies the radiative transfer model, reduces the size of the look-up tables and creates faster algorithm which is important in the operational processing. At the same time, it creates systematic angle-dependent biases in derived surface reflectance reducing anisotropy of reflectance. The Lambertian assumption re-distributes reflected energy between all directions, reducing reflectance where BRF is high and enhancing it where BRF is low [5, 6]. For example, for a typical bowl-shaped bidirectional reflectance distribution function (BRDF), the derived reflectance is underestimated at high solar or view zenith angles, where BRDF is high, and is overestimated at low zenith angles where BRDF is low. The magnitude of biases grows with the amount of scattering in the atmosphere, i.e. at shorter wavelengths and at higher aerosol concentration.

To demonstrate the impact of Lambertian assumption, we simulated this effect by using the ASRVN framework and real MODIS measurements. A Lambertian reflectance (ρ_{Lamb}) from a given MODIS observation was computed (using reduced algorithm with Lambertian assumption) for every grid cell in addition to standard ASRVN products. Comparing these values will allow us to make a direct assessment of biases due to Lambertian assumption. Because the errors depend on the view geometry (mainly solar and view zenith angles), atmospheric opacity and wavelength, we stratified the input (MODIS measurements) into four categories resulting from low ($<45^o$) and high ($\geq 45^o$) sun/view zenith angles and low and high values of aerosol optical thickness (AOT<0.3 or AOT≥0.3). Here, AOT pertains to the measured AERONET value at wavelength 0.44 μm. As expected, the results show that the slope of regression ρ_{Lamb} vs BRF is the highest and close to 1 when both zenith angles and AOT are low. This case corresponds to least amount of atmospheric scattering and maximal direct transmittance. The slope progressively decreases when optical path through the atmosphere increases at higher solar/view zenith angles, higher AOT, and shorter wavelength. For example, the slope decreases from 0.94 (ZA<45^o, AOT<0.3) to 0.83 (ZA≥45^o, AOT≥0.3) in the red band, and from 0.85 to 0.64 in the green band.

In the next step, we compared MODIS daily surface reflectance (MOD09GA) with ASRVN data, conducted similar analysis stratified by solar/view zenith angles and AOT, as described above. The results for Konza EDC site are shown in Figure 1. These results are very similar in the pattern and in magnitude to that of the ASRVN simulation. The slope of regression decreases (bias grows) for higher zenith angles and AOT. For this site, the slope ranges from 0.96 (ZA<45^o, AOT<0.3) to 0.81 (ZA≥45^o,

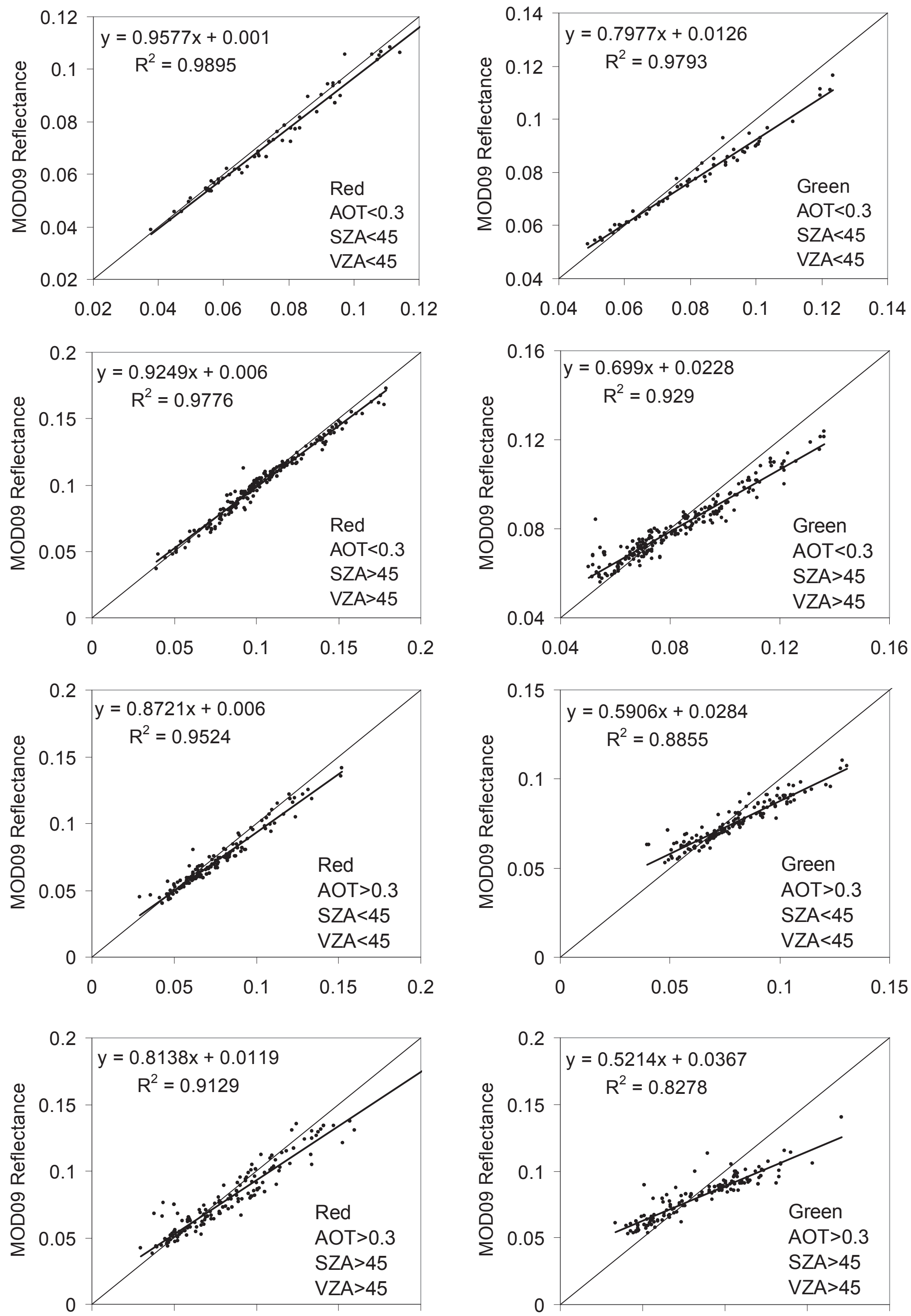

Figure 1. Comparison of MOD09 daily reflectance with ASRVN BRF in red (left) and green (right) bands for Konza EDC site for 2000-2008. To avoid geolocation differences, the data were averaged over 10×10 km^2. Data are stratified into four categories according to AOT and solar/view zenith angles.

AOT≥0.3) in red band, and from 0.8 to 0.52 in green band. These numbers are very close to that of the ASRVN simulation, which indicates that the major error of the MODIS surface reflectance may come from lambertian approximation for this site.

3. CONCLUSION

This paper investigated errors in the surface reflectance retrievals caused by the Lambertian approximation which is used in the MODIS atmospheric correction algorithm. We have demonstrated these errors using the ASRVN framework and the comparison of MODIS surface reflectance products (MOD09) with ASRVN retrievals. Both the internal ASRVN analysis with and without Lambertian assumption, and comparison between ASRVN and MOD09 show uncompensated effect of atmospheric scattering which increases at shorter wavelengths, higher AOT and higher zenith angles. In both cases, the slopes of regression are very similar, which indicates that the major error of MOD09 data may come from the lambertian approximation in the studied sites.

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