

The AOD Sensitivity Comparison between MODIS Multi-Angle Implementation of Atmospheric Correction (MAIAC) and Standard MODIS Surface Reflectance

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Abstract

This study compares the Multi-Angle Implementation of Atmospheric Correction (MAIAC) and standard MODIS surface reflectance (SR) products (MOD09) for various aerosol optical depth (AOD) levels. Data from one MODIS tile in northern China for the whole year 2018 is compared. The results reveal that MAIAC SR has good stability for the full range of AOD for which SR is reported, whereas MOD09 SR shows increasing high bias with AOD increases. The cross-comparison of spectral characteristics between MAIAC SR and MOD09 SR shows a systematic MAIAC-MOD09 difference increasing from NIR to Blue. This pattern is consistent with the bias caused by Lambertian assumption used in MOD09 SR algorithm.

1. Introduction

The Multi-Angle Implementation of Atmospheric Correction (MAIAC) is an advanced algorithm which uses time series analysis and a combination of pixel- and image-based processing to improve accuracy of cloud detection, aerosol retrievals and atmospheric correction (Lyapustin et al., 2011a,b; 2012; 2018). MAIAC MODIS Collection 6 suite of products MCD19, offering an interdisciplinary suite of products such as cloud/snow mask over land, high

spatial resolution (1km) aerosol optical depth (AOD) and type, surface reflectance (SR), bi-directional reflectance distribution function (BRDF) and Albedo, and snow grain size and sub-pixel snow fraction for the snow-covered regions, has been available since May 2018. Since its introduction in 2011-2012, MAIAC SR product has been extensively used in land related science applications, in particular over highly cloudy tropical regions where MAIAC offers a significant accuracy improvement for vegetation trend and change analysis (Hilker et al., 2012; 2014; 2015; Guan et al., 2015; Bi et al., 2015; 2016; Saleska et al., 2016; Chen et al., 2017; Petri and Galvão, 2019). Although these studies have shown improved results in their particular applications by introducing MAIAC products, direct comparison of MAIAC SR and current MODIS SR (MOD09) under different AOD conditions has been missing.

One fundamental difference between MAIAC SR and MOD09 SR is that MOD09 SR is based on Lambertian surface assumption (Vermote & Vermeulen, 1999) whereas MCD19 uses a physical atmosphere-surface model where the model parameters are defined from measurements with minimal assumptions (Lyapustin et al., 2011a,b; 2012a,b). The Lambertian assumption can

dramatically reduce the complexity, time cost and storage needs of the algorithm, however, it has been proved that uncompensated atmospheric scattering caused by this approximation systematically biases the results (Wang et al. 2010). The magnitude of the bias depends on the amount of scattering in the atmosphere, i.e. the aerosol loading in the atmosphere.

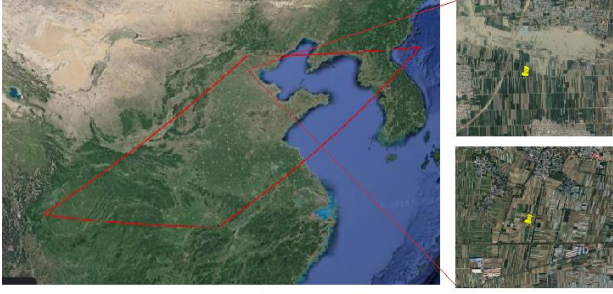


Figure 1. The Northern China study area. Two 5x5km² sample boxes are illustrated on the right.

In this study, we will compare MCD19 SR and MOD09 SR under different AOD conditions to access the AOD sensitivities of the two products. We will present the method and data used in section 2, followed by results (section 3) and conclusion (section 4).

2. Data and Method

We select North China region as our study area (Figure 1). This area has periodic very high AOD variations from clear to extremely opaque in a matter of 7-10 days when surface properties remain relatively stable, makes it ideal to study the accuracy of SR as a function of AOD.

MCD19 data is generated on MODIS standard Sinusoid grid. We selected one 1200x1200 km² tile (h25v07) in this study. All MCD19 data (daily MCD19A1 surface products, MCD19A2

Atmospheric products and 8-day MCD19A3 BRDF products) for this tile in year 2018 is downloaded via NASA's Level 1 and Atmosphere Archive and Distribution System (LAADS). In each MCD19 daily file, MAIAC algorithm keeps all the available orbits as difference data layers, hence make it easy to compare with swath form L2 granules.

We use original L2 MOD09 swath products for comparison. All the granules that overlaps with tile h25v07 in year 2018 are downloaded from LAADS. To avoid the possible calibration bias caused by Terra MODIS degradation (Lyapustin et al. 2014), the better quality MODIS Aqua data (MYD09) for 2018 were used in this study.

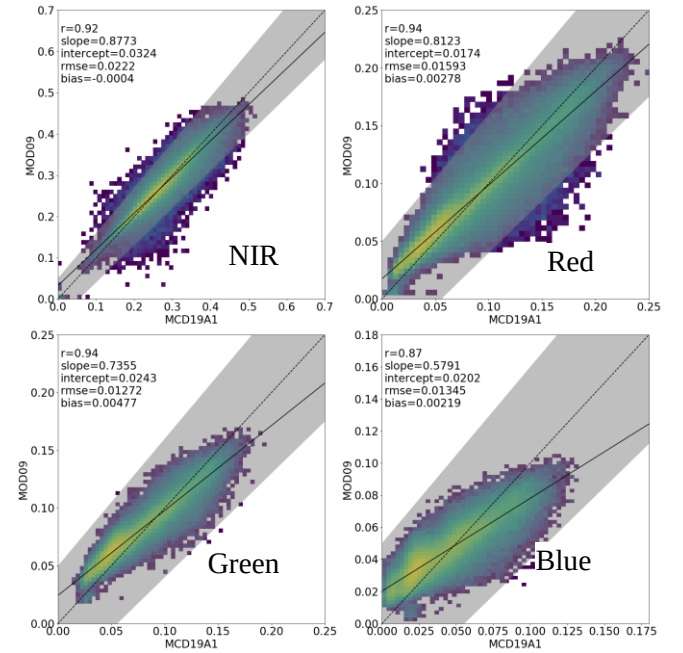


Figure 2. Scatter plot for MCD19 SR vs. MOD09 SR for NIR, red, blue and green bands.

The MYD09 granules are reprojected to sinusoid grid to match with MCD19 SR. Both SR dataset are QA filtered (Samanta et al., 2010; Lyapustin et al. 2018). To avoid the gridding error, both MCD19 SR and

MYD09 SR are aggregated into 5x5km² boxes, only boxes with best quality data coverage over 50% are used. Four most commonly used land bands are compared: Blue (0.47), Green(0.55), Red(0.65) and NIR (0.86).

3. Results

The scatter plots of MCD19 SR vs. MYD09 SR for the selected four bands are shown in Figure 2. Both slopes and correlations are decreasing from longer wavelength NIR band to short wavelength blue band. This pattern is consistent with the bias of Lambertian approximation which grows with the amount of scattering lights in the atmosphere (Wang et al. 2010). Since the general AOD level is high in this region, this bias can even be seen in NIR band.

For the two selected 5x5 km² sample area (illustrated in Figure 1), we draw the time series of MCD19 SR (black dots) and MYD09 SR (green dots) for year 2018 (Figure 3). The red line represents MAIAC-retrieved AOD at 0.47μm displaying very high variations during the entire year. In order to minimize the BRDF effect, both SRs are angular normalized to SZA = 45 degree and nadir view, using MCD19A3 B R D F parameters (https://modis-land.gsfc.nasa.gov/pdf/MCD19_UserGuide_final_Feb-6-2018.pdf). One can see that MCD19 SR is much more stable with AOD variations compared to MYD09 SR which shows high outliers correlated with AOD. Figure 4 shows the normalized SR difference (MAIAC – MOD09) as a function of AOD for larger statistics (49 sampled locations). As in our earlier analysis, the MYD09 SR bias is positive at high AODs and grows with AOD by 2-3% in absolute

reflectance. It strongly increases from NIR to Red, although further increase towards Blue is rather minor.

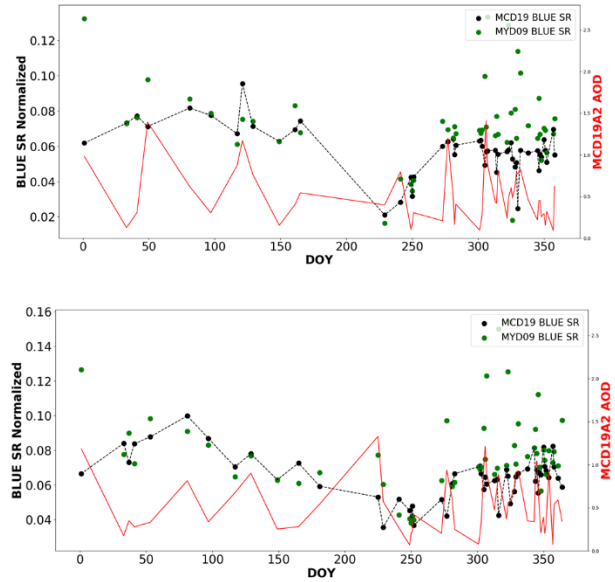


Figure 3. Time series of Normalized MAIAC SR (black dots) and MYD09 SR (green dots), as well as MAIAC AOD (red line) for two selected 5x5km² sample boxes.

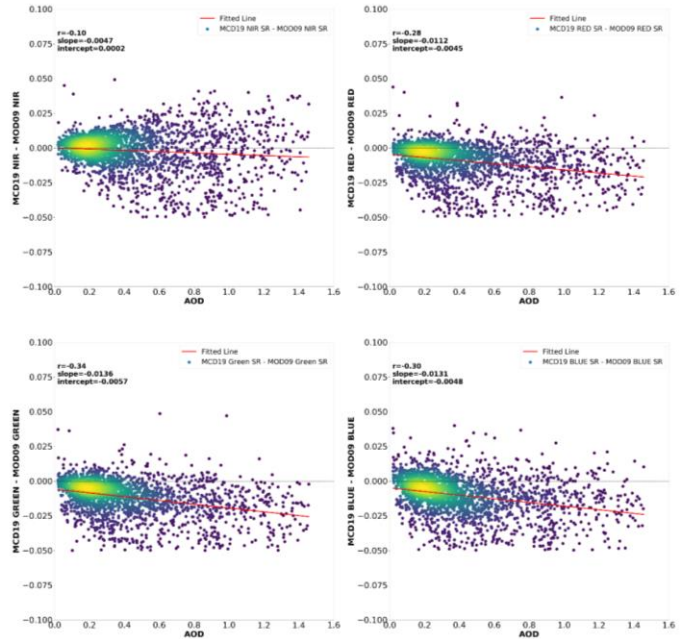


Figure 4. MAIAC – MYD09 difference for NIR, red, green and blue bands. Outliers above ± 0.05 is filtered to avoid cloud leak.

4. Conclusion

We have compared the MAIAC SR and standard MODIS MOD09 SR and tested their sensitivities as a function of AOD level. The results show that MAIAC SR has good stabilities in the full range of AOD variations ($AOD_{0.47} < 1.5$) for which MAIAC SR is reported, whereas MOD09 SR often shows high outliers at high AOD levels. Cross-comparison of spectral characteristics between MCD19 SR and MOD09 SR shows that the MAIAC-MOD09 difference is lowest in the NIR, and consistently increases towards blue band. This pattern is consistent with the bias caused by Lambertian assumption. This study also found that MOD09 SR bias increases with AOD, and reaches largest in blue band where Rayleigh scattering is the strongest.

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