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SWIR/VIS Reflectance Ratio Over Korea for Aerosol Retrieval

Kwon Ho Lee*†, Zhangqing Li*, Young Joon Kim**

*Earth System Science Interdisciplinary Center (ESSIC), University of Maryland (UMD), MD, USA kwonlee@umd.edu, zli@atmos.umd.edu

**Advanced Environmental Monitoring Research Center (ADEMRC), Gwangju Institute of Science & Technology (GIST), Gwangju, Korea, yjkim@gist.ac.kr

Abstract : Relatively simplified method for determination of surface reflectance has been used by using the ratio between SWIR and VIS band reflectance over land surface. The surface reflectance ratios (SWIR/VIS) were estimated over land in Korea from Terra Moderate Resolution Imaging Spectro-radiometer (MODIS) L1 data. The ratios by using the minimum reflectance technique were lower than those by MODIS operational aerosol retrieval algorithm. Although the comparison between MODIS and sunphotometer Aerosol Optical Thickness (AOT) has a good correlation coefficient (R=0.84), slightly overestimated MODIS AOTs were shown with a slope of linear regression line of 0.89. The comparison between the ratio and AOT clearly exhibit that the error of MODIS AOT could be originated from the underestimated surface reflectances by MODIS operational algorithm.

Key Words : SWIR/VIS, Surface reflectance, Ratio, MODIS, AOT.

1. Introduction

Determination of aerosol property from satellite data in visible wavelength region is complex due to the large variability of surface properties. For the sufficiently small ground reflectance, the most contribution to the satellite receiving radiance would be the atmospheric signal under very low surface reflectance. Since typical vegetation are dark in the red (~0.66μm) and blue (~0.47μm) wavelengths it is reasonable to use the dark pixels for aerosol retrieval. However, the surface reflectance by the dark vegetation has large uncertainty for vegetation type. Moreover land cover has many bright surfaces like some soils, urban area, desert, etc.

In order to overcome this difficulty, one of the surface reflectance determination methods for aerosol retrieval has been introduced; called as the band correlation method (Kaufman *et al.*, 1997). The idea is that the visible reflectance can be determined from the linear correlation slope between visible and SWIR (2.12 μm) band reflectance. The usefulness of SWIR reflectance is negligible atmospheric extinction (atmospheric molecule and aerosol). The empirical ratios between SWIR/blue=4 and SWIR/red=2 were suggested by Kaufman *et al.* (1997a) and those ratios

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† Corresponding Author: K. – H. Lee (kwonlee@umd.edu)

has been used for retrieval of MODIS operational aerosol products by NASA since 1999. Lee *et al.* (2006) also used these ratios for aerosol retrieval over Seoul, Korea using MODIS and HYPERION data.

However, this relationship is highly dependent on land cover type and temporal variation of vegetation. Karnieli *et al.* (2001) found the ratios were 4.35 and 1.92 over Brazil. Levy *et al.* (2005) found 3.03 and 1.54 during the CLAMS experiment. Moreover BRDF effect can change the ratios. Gatebe *et al.* (2001) and Remer *et al.* (2001) noted that the ratios are the function of scattering geometry. Lee *et al.* (2006) showed the real surface refrectance ratios were lower than Kaufman's values over Korea. Thus, the fixed single ratios used by operational MODIS algorithm cannot be directly applied for local region.

In this paper, we attempt to estimate the SWIR/VIS surface reflectance ratios over Korea using Terra MODIS L1 data. MODIS retrieved AOT data have also been validated by comparing with ground based sunphotometer measurement.

2. Methodology

MODIS data are very useful for aerosol retrieval since it has 36 spectral bands, between the range 0.405 and 14.385μm, with three different spatial resolutions: 250m, 500m and 1000m, respectively. In this analysis, 1-year (2005) TERRA/MODIS L1 data has been obtained from NASA Goddard Earth Sciences Distributed Active Archive Center (GES/DAAC) for surface reflectance calculation over land. Study area is rectangular area (124~131°E, 32~44°N) containing Korean peninsular.

In order to separate aerosol signal from other contribution, satellite measured top-of-atmosphere (TOA) reflectance in a cloud-free pixel should be separated from Rayleigh scattering and surface reflectance.

$$\rho_{TOA}(\lambda) = \rho_{Ray}(\lambda) + \rho_{Aer}(\lambda) + \frac{T_0 \cdot T_S \cdot \rho_S(\lambda)}{1 - s \cdot \rho_S(\lambda)} \quad (1)$$

Where ρ_{TOA} = reflectance at TOA

ρ_{Ray} = reflectance by Rayleigh scattering

ρ_{Aer} = reflectance by aerosol scattering

$T_0 \cdot T_S$ = downward and upward transmittance

ρ_S = surface reflectance

s = hemispheric albedo

From Eq (1) (Kaufman *et al.*, 1997b), s is negligible under clear sky condition since atmospheric contribution is smaller than others. Rayleigh scattering can calculate by standard model atmosphere and USGS GTOPO30 digital elevation map (DEM).

In order to find extremely clear sky condition, the minimum reflectance technique (*e.g.* select clearest value during each season for a given location) has been employed. Detail processes are shown in flowchart in Figure 1. For the first step, 1km resolution MODIS L1 data has been corrected by Rayleigh scattering calculation result after cloud screening. Then the minimum reflectance pixel could be selected as 0.2×0.2 degree spatial resolution. For minimize BRDF effects, high scattering angle pixels were also screened.

3. Results and Discussion

1) SWIR/VIS Ratio

The SWIR/VIS ratios for currently used MODIS operational aerosol retrieval algorithm over land surface are 4 (blue: 0.47μm) and 2 (red: 0.66μm), respectively. This band correlation method is a useful method for retrieving the aerosol parameters over lands. However, this ratio could be affected by surface cover type and temporal variation.

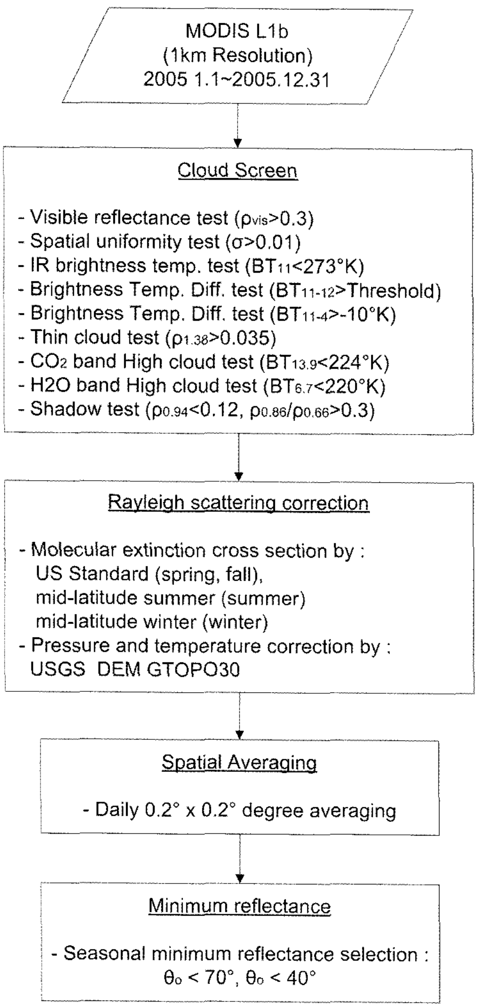

Figure 1. Flow chart of aerosol detection algorithm.

Furthermore, large aerosol particle could be affected on 2.1 micron reflectance. Therefore regional variation in the SWIR/VIS ratio can not expressed as simple fixed values.

The linear correlation results between visible and SWIR channel reflectances from the minimum reflectance pixels over Korea are listed in Table 1. The linear regression line slopes are quite smaller than operational ratios. These smaller ratio values mean the visible surface reflectances over study region are larger than those by operational ratios. That means MODIS operational surface reflectances

Table 1. Linear regression ($y = ax + b$, x: ρ_{VIS}, y: ρ_{SWIR}, R: correlation coefficient) results between visible and 2.12 μm channel surface reflectances in each season.

	0.47μm			0.66μm		
	a	*b*	*R*	*a*	*b*	*R*
Spring	2.78	-0.023	0.78	1.45	0.013	0.91
Summer	1.32	0.015	0.73	1.09	0.021	0.90
Fall	2.07	0.010	0.69	1.28	0.016	0.90
Winter	3.2	0.008	0.61	1.13	0.007	0.89

are smaller than real surface reflectances by using the high ratio values. The under-estimated surface reflectance could lead to overestimated aerosol signal. In addition, correlation coefficients in blue channel reflectance are much smaller than red channel's in Table 1. Since blue channel does not correlated with SWIR channel, the uncertainty of aerosol signal would increase.

Figure 2 shows the seasonal mean differences between SWIR/VIS ratios by minimum reflectances and MODIS operational ratios (4-SWIR/blue and 2-SWIR/red). The differences are higher in blue channel and their spatial distributions are quite variable. Therefore, single fixed ratio values are not an answer for surface reflectance determination.

2) Validation of the MODIS aerosol products

Figure 3 shows the correlation between MODIS AOT and CIMEL sunphotometer-derived AOT at GIST (126.167°E, 33.226°N), Gwangju, Korea. For the comparison, MODIS data (3×3 pixels) close to ground station were selected while sunphotometer data within ±30 minute of TERRA satellite over-passing time were taken. These spatially averaged MODIS AOTs and temporally averaged sunpotometer AOTs were used for validation of MODIS L2 aerosol product. Although there was good agreement with a correlation coefficient (R) of 0.84, slightly overestimated MODIS AOTs are shown.

In order to estimate surface reflectance effects on error of AOT, ratio differences and AOT differences

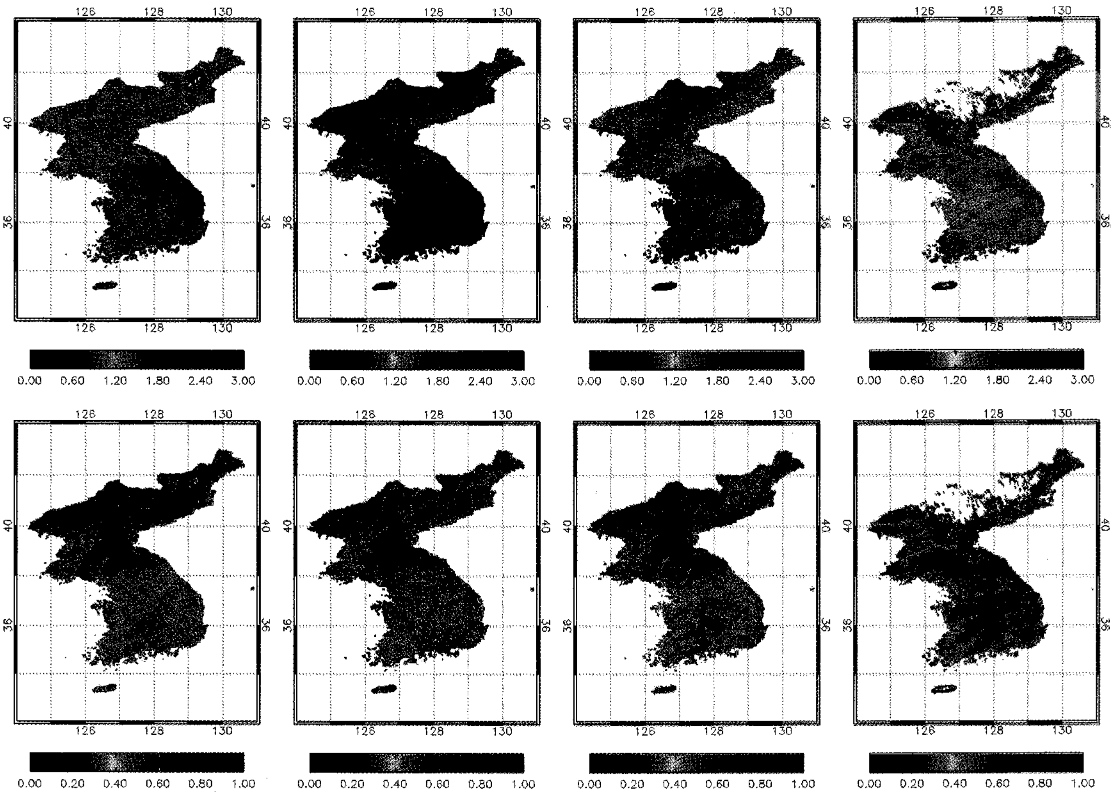

Figure 2. Differences of SWIR/VIS ratio from the ratios (top: 0.47μm and bottom: 0.66μm) by MODIS Ver.4 operational aerosol retrieval algorithm in four seasons (MAM, JJA, SON, and DJF) in Korea.

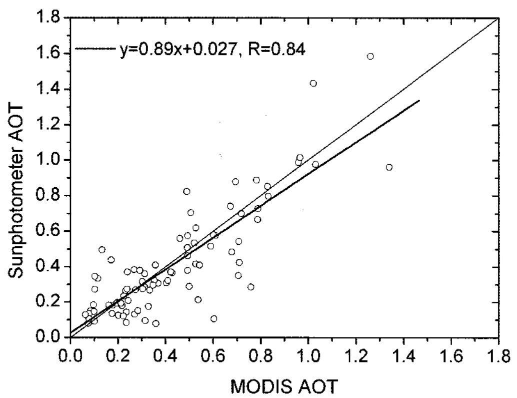

Figure 3. Comparison between MODIS retrieved AOT and CIMEL sunphotometer AOT at Gwangju, Korea.

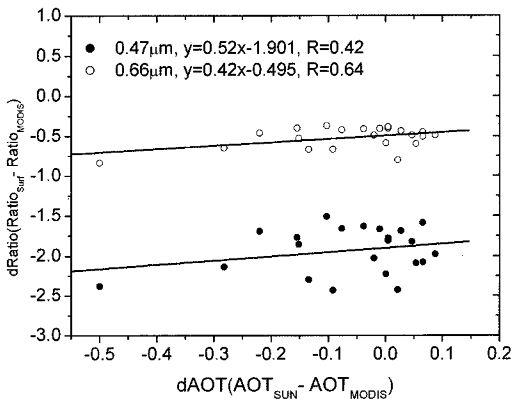

Figure 4. MODIS retrieved AOT and CIMEL sunphotometer AOT under relatively aerosol free conditions (sunphotometer AOT<0.2).

were compared under relatively clear day condition (sunphotometer AOT<0.2). Figure 4 shows a correlation between the ratio and AOT differences in blue and red channels. The linear regression results support that the underestimated surface reflectances by large ratios have correlated to increased error of AOTs.

4. Summary

SWIR/VIS ratios for aerosol retrieval over Korea have been estimated in this study. Under clear sky condition, SWIR/VIS ratios over land surface in Korea indicate that MODIS operational ratios are not appropriate for aerosol retrieval. The ratios determined from the minimum reflectance technique were smaller than operational values because of temporal and spatial variations of surface cover. Large ratios mean underestimated visible channel surface reflectances and could increase atmospheric contribution to satellite receiving radiance. In fact, the MODIS AOT showed higher valued than ground-based sunphotometer AOT. Those underestimated surface reflectances also have well correlated with error of MODIS retrieved AOT. Therefore surface reflectance determination should have more accuracy for acquisition of aerosol only signal. Although SWIR/VIS correlation method is simple and useful, its variation in terms of various surface conditions should be known for aerosol retrieval.

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