MODIS 가시 채널을 사용한 SMAC 계수 개선
An adjustment of coefficients for SMAC using MODIS red band

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Abstract

In this study, Simplified Method for the Atmospheric Correction (SMAC) radiative transfer model (RTM) used to retrieve surface reflectance from MODIS Top Of Atmosphere (TOA) reflectance (MOD02). SMAC code provides coefficients which were previously yielded by Second Simulation of the Satellite Signal in the Solar Spectrum (6S) for each satellite sensor. We conducted error analysis of SMAC RTM using MOD02 over comparison with MODIS surface reflectance (MOD09) which was provided from 6S. It showed that low accuracy values such as, R^2 : 0.6196, Root Means Square Error (RMSE) : 0.00031, bias : - 0.0859. Thus sensitivity analysis of input parameters and coefficients was conducted to searching error sources. Coefficients about τ_p (average AOD) are more influence than any other coefficients of τ_{a550} (Aerosol Optical Depth at 550nm) from sensitivity test. Calibrated coefficients of τ_p from regression analysis were used to surface reflectance which showed that improve accuracy of surface reflectance (R^2 : 0.827, RMSE : 0.00672, bias : - 0.000762).

1. Introduction

Remotely sensed imageries observed by satellites are mostly contaminated by gases (i.e., H_2O, O_3, O_2 etc) and aerosol in atmosphere. Although many multi spectral sensors designed to avoiding atmospheric effect using atmospheric windows, attenuation by atmosphere is indispensableness.

Trace gases in atmosphere function reflectance, absorption, and scattering for solar illumination. In order to accurate estimating reflectance, atmospheric correction which remove atmospheric effects is one of the key steps to obtain surface reflectance from space borne optical instruments operating in the visible and near-infrared domain (Hagolle et al., 2008).

There are several methods to retrieving

truly surface reflectance from satellite Top Of Atmosphere (TOA) reflectance. Simplified Method for the Atmospheric Correction (SMAC) is based on 6S code. SMAC provided coefficients which was previously yielded for various sensors. The main advantage of SMAC is that it is several hundred times faster than more detailed radiative transfer codes like 6S and it does not require precalculated Look Up Table (H. Rahman and G. Dedieu, 1994).

In this study, surface reflectance using SMAC was compared with MOD09 (MODIS surface reflectance) for error analysis. After comparison, sensitivity test was conducted according to each input parameter for finding error sources. This study aims to detected error sources and to improve accuracy of surface reflectance using SMAC.

2. Data

2.1. MODIS TOA reflectance and surface reflectance

The MODIS TOA reflectance (MOD02 product) from Terra/MODIS were used for estimated surface reflectance.

The MOD09 GA product (MODIS surface reflectance) that were obtained from Land Process Distributed Active Archive Center (LP DAAS) used for validation. Several MODIS atmospheric products (MOD04: aerosols, MOD05: water vapour, MOD07: ozone, MOD35: cloud mask) were used to estimating surface reflectance and ancillary data (Digital Elevation Model, Atmospheric Pressure) as an input parameters to the atmospheric correction (Vermote and Vermeulen, 1999).

2.2. Ancillary data

Several product were used to atmospheric correction as ancillary data (aerosol optical depth, water vapour contents, ozone field data, geolocation data, cloud status information). The MOD03 product is geolocation product which includes geometric information between sun and surface and satellite. Several level 2 product were used as input parameters; aerosol optical depth, water vapour, and ozone data in individual days using SCIAMACHY sensor for atmospheric correction method. MODIS cloud (MOD35) product was used to detecting cloud in satellite images.

3. Method

MODIS red channel data extracted and separated land/sea and cloud area using MOD 35 product. Only cloud free and inland pixels were selected for estimated surface reflectance using SMAC code. After estimation using SMAC, it was compared with MOD09 and detected factor of difference between MOD09 and estimated surface reflectance. Each input parameter was extracted from corresponding product.

3.1. SMAC

SMAC is simple and fast atmospheric correction method and suitable for correction, because it employs coefficients that specified each sensor in several satellites. Each coefficient pre-yields for each sensor using 6S RTM. MODIS coefficients was used to estimate surface reflectance using SMAC in this study. SMAC is based on the parameterization of the equations describing radiative transfer in the atmosphere (Rahman and Dedieu, 1994).

4. Result & Analysis

4.1. Retrieval Surface reflectance

Estimated surface reflectance (ρ_{sfc}) was compared with MODIS TOA reflectance (ρ_{TA}) . Accuracy of estimated ρ_{sfc} (Figure 1 (a)) using SMAC evaluated over calculating of Root Means Square Error (RMSE), R^2 and bias values from comparison with MODIS ρ_{sfc} (Figure 1 (b)). Result of comparison (Figure 2) between estimated ρ_{sfc} and MODIS ρ_{sfc} showed R^2 : 0.617, RMSE : 0.00775, bias : -0.859 and negative bias in general.

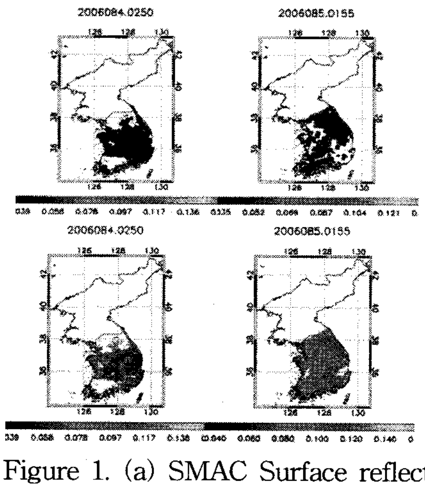

Figure 1. (a) SMAC Surface reflectance, (b) MODIS surface reflectance

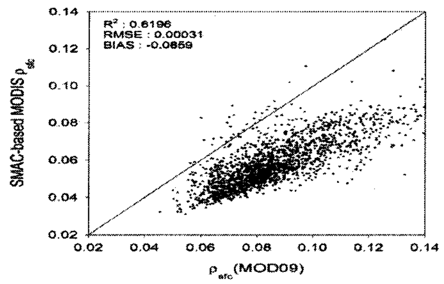

Figure 2. Scatter plot between MODIS ρ_{sfc} and estimated ρ_{sfc}e using SMAC

4.2. Analysis

4.2.1. Sensitivity test

The test conducted sensitivity analysis for input parameters (aerosol optical depth, water vapour, ozone) to finding error sources. According to analysis result, the most effective input parameter is τ_{a550} (Aerosol Optical Depth at 550nm) as you see in figure 3. Variation of τ_{a550} is major cause for reflectance variation among the parameters variation.

Plots represent estimated surface reflectance according to solar zenith angle(SZA) and each input parameter value, such as τ_{a550}, H_2O, and O_3. In figure 3 (a) showed that variation of calculated reflectance increases as τ_{a550} value increases. Sensitivity test of H_2O showed increase of reflectance to SZA 30° and decrease over 30° in figure 3 (b) and O_3 showed increase of reflectance in section of O_3 value more than 1.5. Both graphs have little and constant variation in reflectance. Particularly, estimated reflectance has drastic variation in τ_{a550} value greater than 1.6. In case of τ_{a550}

value greater than 1.0 and SZA greater 30°, estimated reflectance becomes negative value.

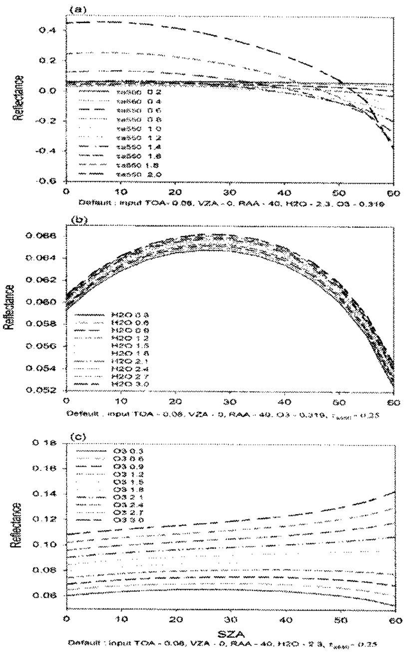

Figure 3. Scatter plot of input parameters and SZA at VZA(viewing zenith angle 0° (a - τ_{a550}, b - H_2O, c - O_3)

But τ_{a550} value was used in many part in calculation of SMAC code, such as up and downward total atmospheric transmission (τ_{ta}) , atmospheric spheric albedo (A_s), and average optical depth for a given band of aerosol scattering (τ_p) from atmospheric reflectance. The sensitivity test was conducted about τ_{a550} part (A_s, τ_p, and τ_{ta}) in SMAC again (Figure 4). A_s had the least effect on surface reflectance any other parameters in figure 4. Both graph of τ_p and τ_{ta} showed that reflectance decreases as input parameter value increase.

Figure 4 showed that τ_p is most influent parameter to truly estimated surface reflectance in calculation about τ_{a550}. Only graph of τ_p showed negative reflectance in sensitivity analysis. The τ_{a550} value was used to calculate A_s and τ_{ta} and τ_p among the atmospheric correction processes. The data set was created for polynomial regression analysis.

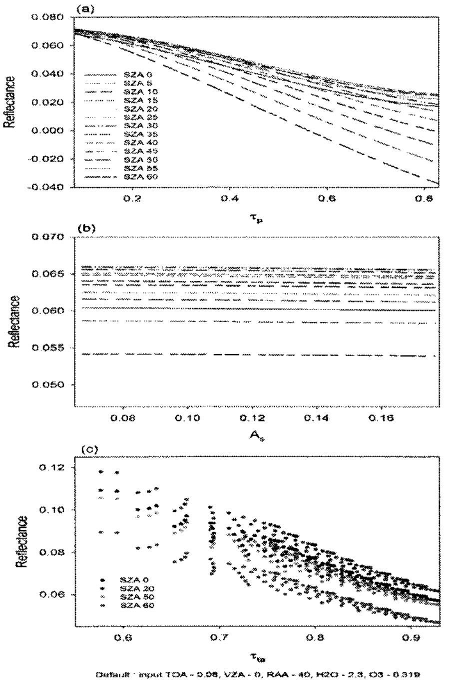

Figure 4. Scatter plot of parameters about τ_{a550} versus reflectance at VZA 0° (a - τ_p, b - A_s, c - τ_{ta})

4.3. Calibration coefficients about τ_p

The τ_p was simulated using MODIS ρ_{sfc} that value makes calculate truly reflectance. Data set for regression analysis was created including geometric information, τ_p of SMAC, and each ρ_{sfc}.

Retrieval regression equation calculated τ_p with MODIS ρ_{TA}. ρ_{sfc} using calibrated τ_p was validated through comparison with MODIS ρ_{sfc}.

4.3.1. Simulation τ_p

The equation of τ_p uses two coefficients (Equation 1). One is coefficient of τ_{a550} and another is constant. Extracted information and MODIS ρ_{sfc} were used to simulated τ_p. Regression analysis was conducted to find relationship between simulated τ_p and τ_{a550} with same location. At first, calculating τ_p was tried to using inversion equation which altered from SMAC code with MODIS ρ_{sfc}. Nevertheless, It was used in many equations, such as residual of 6S, residual of aerosol, and aerosol reflectance.

$$\tau_p = a0 + a1 \cdot \tau_{a550} \quad (1)$$

where $a0$ is constant and $a1$ is coefficient about τ_{a550}.

Equation of retrieval τ_{a550} is too complex to alter using equation in SMAC code. Simulated coefficients of τ_p were calculated that every value in τ_p range was inputted in SMAC code. The value was determined as simulated τ_p which calculated nearest value to MODIS ρ_{sfc} value.

4.3.2. Stepwise regression analysis

To retrieve coefficient of τ_p, regression analysis was conducted. In order to polynomial regression analysis, dataset was created including τ_{a550} value, SZA, VZA, SMAC τ_p, simulated τ_p , MODIS ρ_{sfc}, MODIS ρ_{TA} and estimated ρ_{sfc} using coefficients of simulated τ_p.

Each stage analysis performed like as table 1. Result of analysis showed VZA has little influence. As SZA added, accuracy was improved 0.074 in R^2 and 0.0932 in standard deviation. In case of added VZA, result of analysis only improved 0.002 in R^2 and 0.00002 in standard deviation.

Table 1. Result of stepwise multiple regression analysis.

Input parameters	R	R^2	Standard Deviation
AOD	0.814	0.663	0.10109
AOD, SZA	0.859	0.737	0.00893
AOD, SZA, VZA	0.860	0.739	0.00889

Each retrieval regression equation for estimating τ_p from stepwise regression analysis same as following:

$$\text{Model1}: \tau_p^{est} = a + b_0 \cdot AOD \quad (2)$$

$$\text{Model2}: \tau_p^{est} = a + b_0 \cdot AOD + b_1 \cdot SZA \quad (3)$$

$$\text{Model3}: \tau_p^{est} = a + b_0 \cdot AOD + b_1 \cdot SZA + b_2 \cdot VZA \quad (4)$$

5. Conclusions

ρ_{sfc} was estimated with MODIS ρ_{TA}. Comparison between MODIS ρ_{sfc} and estimated ρ_{sfc} using SMAC showed high RMSE, bias and low R^2 value. Sensitivity test was conducted about input parameters. It showed that τ_{a550} value is most influential parameter than any other parameters. τ_{a550} value was used several part of SMAC code. Sensitivity analysis was conducted about three part involved in τ_{a550} value again. Result of analysis, τ_p is the most effective factor to estimate ρ_{sfc} among the calculations using τ_{a550}.

Regression analysis yielded a constant and coefficients of τ_{a550}, SZA, while VZA excluded due to little influence. τ_p equation yielded using polynomial regression analysis.

In this study aims to improve accuracy of SMAC, and calibration of coefficient conducted using polynomial regression. Newly coefficients that account for τ_{a550}, and SZA were proposed for accurate ρ_{sfc} using SMAC code. ρ_{sfc} was estimated with calibrated coefficients that showed high accuracy than ρ_{sfc} using SMAC coefficients. Calibrated coefficients in this study will be contributed to estimating accurate ρ_{sfc}.

Acknowledgments

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Reference

Hagolle, O., G. Dedieu, B. Mougenot, V. Debaecker, B. Duchemin and A. Meygret, 2008, Correction of aerosol effects on multi-temporal images acquired with constant viewing angles: Application to Formosat-2 images, Remote Sensing of Environment, Vol112(4), pp1689-1701.

Rahman, H. and G. Dedieu, 1994, SMAC: a simplified method for the atmospheric correction of satellite measurements in the solar spectrum, International Journal of Remote Sensing, Vol 15(1), pp123-143.

Vermote, E. F. and A. Vermeulen, 1999, MODIS Algorithm Technical Background Document, ATMOSPHERIC CORRE CTION ALGORITHM: SPECTRAL REFLECTANCES (MOD09) Version 4.0, April 1999, pp 107.