A NEW METHOD TO ESTIMATE THE VISIBLE REFLECTANCE FROM SHORT WAVE INFRARED WAVELENGTH

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ABSTRACT:

This article mainly discussed how to estimate surface reflectance of the visible wavelength which are affected by the atmosphere from surface reflectance at 2.1μm which are almost transparent in common conditions, especially in brighter area where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, where $NDVI_{SWIR}$ is an alternative of NDVI, and defined by MODIS channel 5 and channel 7. Based on the research of others, further analyze is imposed on the effects of $NDVI_{SWIR}$ as a parameter used to calculate surface reflectance in the visible band, and propose a new equation to estimate the surface reflectance of the visible band from both the surface reflectance at 2.1μm and $NDVI_{SWIR}$. The method proposed in this article gets a better result.

1. INTRODUCTION

For the surface reflectance in the visible is great affected by the atmosphere, it is difficult but important to obtain the visible wavelength reflectance from the satellite image, especially in the research on the atmospheric parameters (such as aerosol optical thickness) deriving over land with the complex structure. To solve this problem, Kaufman et al[1] studied the relationship of the visible wavelengths, which are affected by the atmosphere, and the SWIR wavelengths, which are almost transparent in common condition, and found that surface reflectance in the 0.46um and 0.66 um can be assumed to be one-quarter and one-half, respectively, of the surface reflectance in the 2.1um. The relationships have been popular used in the land aerosol optical depth (AOD) retrieval, which are called DDV algorithm. Remer[2] found that the ratio between visible and short wave infrared was affected by forward scattering angle. After eliminating the effect of forward scattering angle, more accurate surface reflectance in the visible band was gotten, and so does the precision of aerosol optical depth.

At the same time, Remer found that the Normalized Difference Vegetation Index (NDVI) can also affect the precision of surface reflectance in the visible band, but more detailed analysis was not given. In article [3], $NDVI_{SWIR}$ was used as an alternative of NDVI to calculate the surface reflectance in the visible. But all these methods mentioned above are only suitable for the area with low surface reflectance, for the area with higher surface reflectance, the error in estimating aerosol optical depth was large. Later, Remer[4] et al extended the DDV algorithm to the area which the surface reflectance in the SWIR lower than 0.25. Lin Sun[5] et al mainly researched aerosol retrieval in sparse vegetation area, and found effect of humidity of soil in estimating the surface reflectance from SWIR, the precision of surface reflectance in the visible calculated from SWIR reached 0.015 after taking the humidity of soil into account.

Based on the research mentioned above, in this article, MODIS Terra surface reflectance 8-day product in 500 meters is used as the research data, the data was collected in the summer semi-year from 2000 to 2005, in cloud free area. Further analysis is imposed on the effect of $NDVI_{SWIR}$ on the relationship of surface reflectance in the visible and that in the SWIR, especially the brighter area where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, and propose a new equation to describe the relationship between surface reflectance in the visible and that in the SWIR.

2. AFFECTION OF $NDVI_{SWIR}$

According to the Remer's research, the relationship of $\rho_{0.466}$, $\rho_{0.644}$ and $\rho_{2.1}$ was affected by NDVI. In order to further analyze the relationship of the three bands, we choose the MODIS Terra Surface Reflectance 8-day product as the research data $\rho_{0.466}$, $\rho_{0.644}$ and $\rho_{2.1}$ represent MODIS channel 3, channel 1, and channel 7 respectively.

Because the NDVI can be heavily influenced by aerosol, an alternative is the $NDVI_{SWIR}$ [3], defined as:

$$NDVI_{SWIR} = (\rho_{1.24} - \rho_{2.1}) / (\rho_{1.24} + \rho_{2.1}) \quad (1)$$

Where $\rho_{1.24}$ is the MODIS-measured reflectance of the 1.24 μm channel (MODIS channel 5), both $\rho_{1.24}$ and $\rho_{2.1}$ are much less influenced by aerosol (except for heavy aerosol or dusts). In aerosol free conditions $NDVI_{SWIR}$ is highly correlated with regular NDVI. A value of $NDVI_{SWIR} > 0.6$ is a highly vegetated area, whereas $NDVI_{SWIR} < 0.2$ is representative of sparse vegetation.

According to the experiment, in the area where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, when $\alpha \times NDVI_{SWIR}$ ($\alpha < 0$) is subtracted from the SWIR, a higher correlation will be get between the surface reflectance in the visible and that in the SWIR. This is shown in figure 1 and figure 2.

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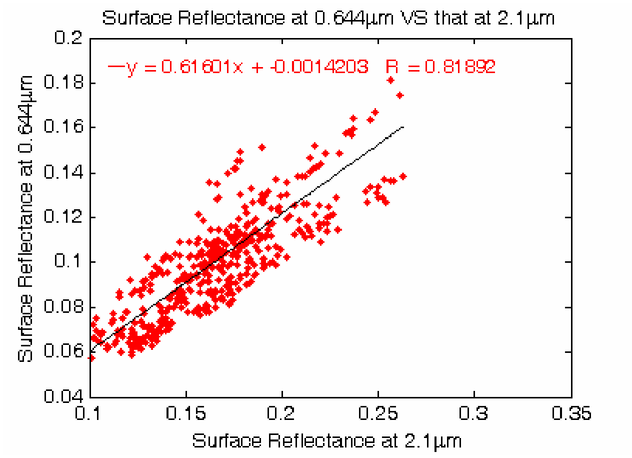

Fig. 1 Scattering points between $\rho_{0.644}$ and $\rho_{2.1}$ when α = 0, in the figure x represent $\rho_{2.1}$

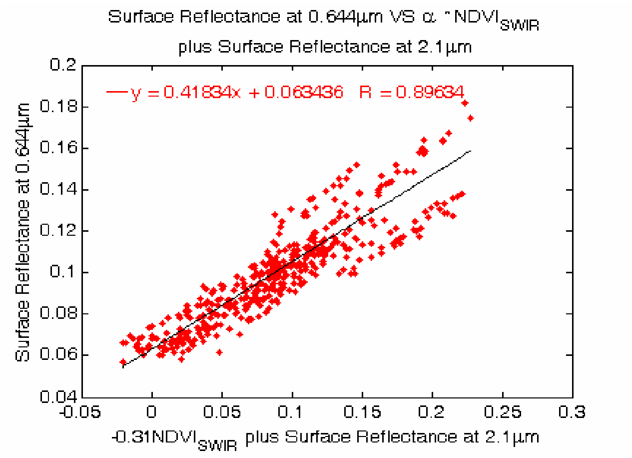

Fig. 2 Scattering points between $\rho_{0.644}$ and $\rho_{2.1}$ when α = -0.31. x represent $\rho_{2.1} - 0.31NDVI_{SWIR}$

MODIS image NO.	**Slope**		**α**		**Offset**	
	$\lambda = 0.466$ μm	$\lambda = 0.644$ μm	$\lambda = 0.466$ μm	$\lambda = 0.644$ μm	$\lambda = 0.466$ μm	$\lambda = 0.644$ μm
2000209	0.24010	0.49877	-0.2800	-0.2400	0.026916	0.043523
2001193	0.24054	0.46168	-0.2000	-0.2100	0.018494	0.039010
2001217	0.20413	0.41834	-0.3600	-0.3100	0.036140	0.063436
2002241	0.21554	0.34952	-0.3000	-0.3900	0.035972	0.080373
2002257	0.24915	0.48178	-0.2000	-0.1900	0.025099	0.046928
2003185	0.24618	0.40712	-0.1700	-0.1600	0.032847	0.061267
2003249	0.23729	0.37615	-0.2300	-0.2900	0.029287	0.069517
2003257	0.26154	0.42095	-0.1800	-0.1600	0.020539	0.047645
2004185	0.27903	0.32730	-0.1400	-0.3500	0.022462	0.079974
2004273	0.17945	0.28617	-0.3400	-0.4900	0.034314	0.082040
2005193	0.21636	0.37771	-0.3300	-0.3600	0.043671	0.084223
2005209	0.22262	0.36866	-0.3900	-0.4500	0.041653	0.089484
2005225	0.27201	0.49759	-0.0900	-0.0800	0.023664	0.046145
2005241	0.29814	0.52570	-0.1300	-0.1100	0.236260	0.060087
2005273	0.21596	0.38739	-0.2400	-0.3100	0.029145	0.067220
Average	0.23854	0.41232	-0.2387	-0.2733	0.043764	0.064058
Std. Division	0.0310	0.0692	0.0913	0.1225	0.0538	0.0167

Tab. 1 The number 2000 in the image 2000209 mean 2000 years and 209 mean the number of days from Jan 1. The data collected in this table were all located in the mid-east part of china, and $NDVI_{SWIR}$ in this area is limited to [0.1, 0.4].

From these two figures, when α = 0, the correlation value between $\rho_{0.644}$ and $\rho_{2.1}$ is 0.81892, while α =-0.31, the correlation value between the two reaches to 0.89634. The correlation improved a lot. This improvement also appears between $\rho_{0.466}$ and $\rho_{2.1}$. But the correlation will not always improve as the absolute value of α increasing, if | α | is very high the correlation will also decrease as | α | increasing. So it is import to confirm the exact value of α, when the visible and SWIR bands get the best correlation. Table 1 shows a series of slope, α and offset of regression equation between the visible and SWIR, when the correlation value reaches its best value in each dataset.

According to the table, we can get the regression equation between the visible and SWIR:

$$\rho_{0.466} = 0.23854(\rho_{2.1} - 0.2387NDVI_{SWIR}) + 0.043764 \qquad (2)$$

$$\rho_{0.644} = 0.41232(\rho_{2.1} - 0.2733NDVI_{SWIR}) + 0.064058 \qquad (3)$$

Where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$.

Only part of surface reflectance in the visible can be estimated by equation 2 and 3, in the area with $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, the surface reflectance in the SWIR drop into 0.1~0.3. When retrieving aerosol optical depth, surface reflectance in the visible bands in the area $NDVI_{SWIR} > 0.4$ is estimated by equation 4 and 5.

$$\rho_{0.466} = 0.25\rho_{2.1} \qquad (4)$$

$$\rho_{0.644} = 0.50\rho_{2.1} \qquad (5)$$

3. PRECISION OF THE ESTIMATION

In order to check the precision of the estimation, we compare with the method mentioned in article [3], we call it levy's method. The equations are as follows:

$$\rho^{s}_{0.66} = \rho^{s}_{2.12} * slope_{0.66/2.12} + y\mathrm{int}_{0.66/2.12} \qquad (5)$$

$$\rho^{s}_{0.47} = \rho^{s}_{0.66} * slope_{0.47/0.66} + y\mathrm{int}_{0.47/0.66} \qquad (6)$$

where

$$slope_{0.66/2.12} = slope^{NDVI_{SWIR}}_{0.66/2.12} + 0.002\Theta - 0.27$$

$$y\mathrm{int}_{0.66/2.12} = 0.00025\Theta + 0.033$$

$$slope_{0.47/0.66} = 0.49, and \;\; y\mathrm{int}_{0.47/0.66} = 0.005$$

where in turn

$$slope^{NDVI_{SWIR}}_{0.66/2.12} = 0.48; NDVI_{SWIR} < 0.25$$

$$slope^{NDVI_{SWIR}}_{0.66/2.12} = 0.58; NDVI_{SWIR} > 0.75$$

$$slope^{NDVI_{SWIR}}_{0.66/2.12} = 0.48 + 0.2(NDVI_{SWIR} - 0.25) \;;$$

and $0.25 \le NDVI_{SWIR} \le 0.75$

Θ is scattering angle, defined as:

$$\Theta = \cos^{-1}(-\cos\theta_0 \cos\theta + \sin\theta_0 \sin\theta \cos\phi) \qquad (6)$$

where θ_0, θ and ϕ are the solar zenith, sensor view zenith and relative azimuth angle, respectively.

We use one SWIR band of MODIS reflectance dataset that was not under atmosphere correction in cloud free area to estimate the surface reflectance in the visible, and compared with atmosphere corrected daily MODIS surface reflectance product (MOD09) in the visible band.

In figure 3, x axis stand for atmosphere corrected surface reflectance in the visible, y axis stand for surface reflectance in the visible estimated form SWIR. So, the test relationship of the two axes is *y = x*, and the correlation value is 1. For the red band, the correlation value in figure b is 0.76336 which is better than the correlation value 0.76115 in figure a. At the same time, equation *y = 0.74103x + 0.020513* in figure b is closer to *y = x* than *y = 0.66183x + 0.086616* in figure a. For the blue band, although the correlation value 0.70462 in figure d is lower than the value 0.77242 in figure c, equation *y = 0.62589x + 0.029668* in figure d is closer to *y = x* than *y = 0.54455x + 0.049406* in figure c.

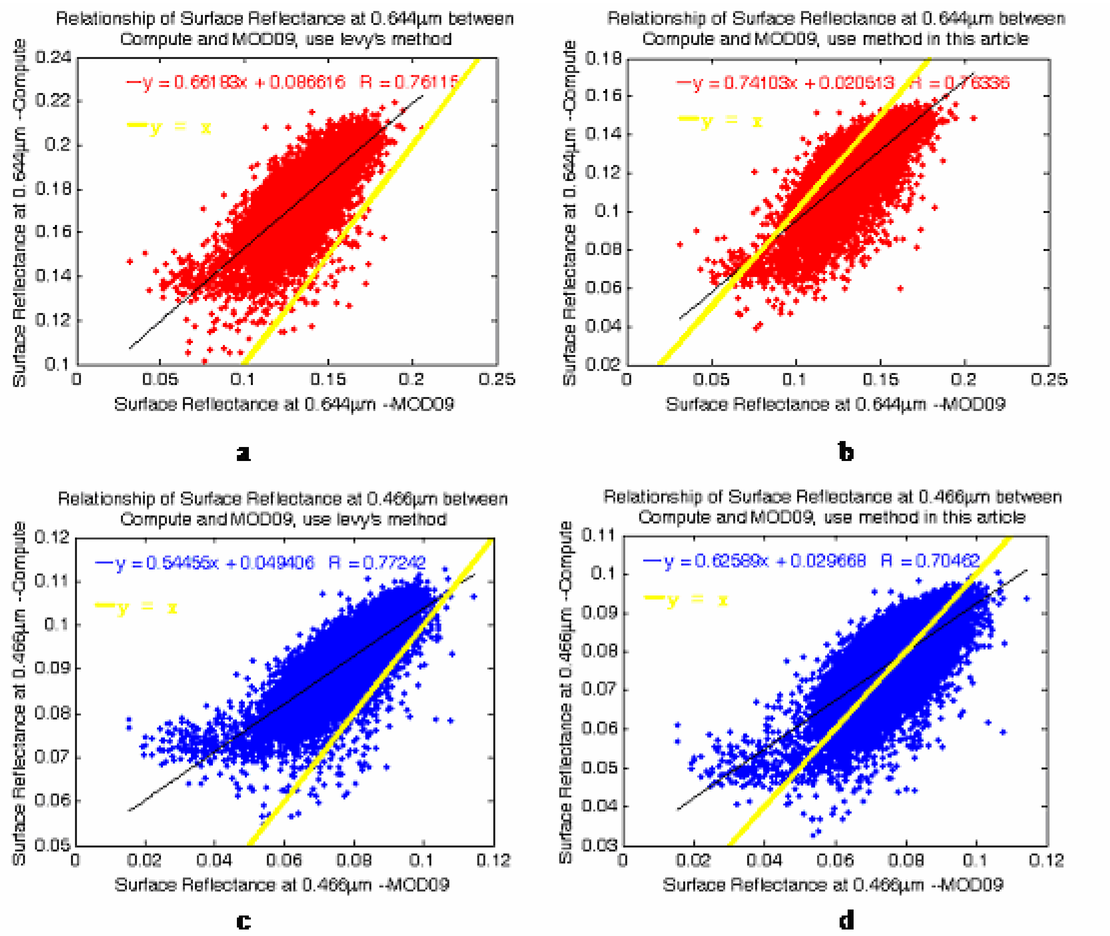

Fig. 3 Comparison of Surface Reflectance of the visible band between estimated and MOD09

	$abs(\rho_{0.466-compute}-\rho_{0.466-MOD09})$		$abs(\rho_{0.644-compute}-\rho_{0.644-MOD09})$	
	Levy's method	Method in this article	Levy's method	Method in this article
Average	0.0155	0.0056	0.0422	0.0142
Standard division	0.0057	0.0042	0.0099	0.0094

Tab. 2. Average Errors and Standard division of the two methods.

We also calculate averages and standard division of the absolute value of the difference between the surface reflectance estimated and that under atmosphere corrected in the visible band. This is shown in table 2.

According to table 2, in the area where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, both the average error and standard division of method in this article are better than levy's method.

4. CONCLUSIONS

Based on the data collected from the brighter area where $0.1 \leqslant NDVI_{SWIR} \leqslant 0.4$, we analyze the influence of the $NDVI_{SWIR}$ on the estimating of surface reflectance in the visible, proposed a equation based on SWIR and $NDVI_{SWIR}$. Surface reflectance estimated by this method is better than levy's method in brighter area. This can be used to retrieve aerosol optical depth in brighter area.

The method used in this article is based on empirical, and the data used is collected in the summer semi-year, so it only suitable for the summer semi-year. If more factors are taken into account, such as the type of soil, geometry conditions, and higher precision will be get.

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