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Normalized Difference Vegetation Index with Atmospheric Correction for Satellite Images

Chien-Hui Liu

Abstract—**Monitoring of vegetation using remote sensing is usually hampered by atmosphere. Therefore, in order to determine accurate NDVI, atmospheric correction (AC) is an essential work. Error in NDVI occurs when AC is omitted. In the paper, error of NDVI due to neglect of AC is estimated. A SPOT image covering Taoyuan, Taiwan is used. Mean NDVI of the image with AC, can increase to 0.39 using surface reflectance from 0.30 using top-of-atmosphere reflectance (without AC). Error can be up to 0.095 NDVI unit. Hence, the error can be up to 32% when AC is neglected.**

Index Terms—**NDVI, Atmospheric Correction, Surface Reflectance, Remote Sensing.**

I. Introduction

Vegetation index (VI) is important to monitor regional and global changes in terrestrial vegetation. Normalized Difference Vegetation Index (NDVI), the most commonly used VI, can be applied in estimation of land surface biophysical variables such as leaf area index and biomass [1]–[3]. Remote sensing is the best tool to monitor vegetation change. Atmospheric effect of remote sensing images can cause deviation of true surface reflectance due to the scattering and absorption of both molecules and aerosol. Atmospheric effect usually reduces the contrast of satellite imagery, whereby brightening the dark targets and darkening the bright targets. It can also intrinsically cause errors in the classification, when surface reflectances for classes are considered in the classification scheme. To accurately derive NDVI remotely sensed data, atmospheric correction (AC) is needed. Surface reflectance can be derived, since AC can correct the atmospheric effect of remotely sensed images. However, AC of satellite image is so complex that raw image is used to derive NDVI instead of using surface reflectance. Hence error in NDVI can be induced.

This study illustrates the procedure of NDVI computation from AC and accounts for the error of NDVI, if AC is omitted.

II. Methodology

A. Aerosol optical depth retrieval

The first step in AC is to derive AOD by image itself. Radiative transfer model (RTM) is usually used with assumptions of aerosol model and dark target reflectance [4]. In this study, AOD retrieval algorithm with darkest pixel as dark target is used. Vector-based 6S is selected as RTM. Maritime aerosol model is considered as a suitable aerosol model in northern Taiwan. Retrieval of AOD from top-of-atmosphere is based on assumption of dark target reflectance of 0.01 at red band. However, the algorithm is confined to cloudless images with uniform atmospheric effect.

Chien-Hui Liu, Department of Digital Media and Product Design, Transworld University, Douliu, Taiwan, R.O.C.

B. Atmospheric correction algorithm

As in AOD retrieval, vector-based 6S is used as RTM to derive surface reflectance from top-of-atmosphere (TOA) reflectance [5]. Tropic atmosphere is assumed as the atmospheric profile. Maritime aerosol and retrieved AOD are used. Then simulation of TOA reflectance is performed among the range of surface reflectance [0, 1] to build the lookup table (LUT). This LUT is then used to derive surface reflectance, i.e. perform atmospheric correction, from TOA reflectance for every pixel [6], [7]. According to RMSE of retrieved AOD, accuracy of AC can be estimated as 0.015, since an error of 0.01 in assumed surface reflectance can cause error of 0.1 in retrieved AOD [4], [8].

C. Normalized Difference Vegetation Index

The most commonly used VI is the Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{\rho(NIR) - \rho(RED)}{\rho(NIR) + \rho(RED)}, \qquad (1)$$

where ρ(NIR) and ρ (RED) are the near-infrared and red surface reflectances, respectively. However, it is very often that digital count of raw image is used. Sometimes, TOA reflectance is used instead of surface reflectance, derived from AC of raw image. Hence, error can exit because of the neglect of atmospheric effect.

III. Results and Discussion

Fig. 1 shows TOA reflectance images of SPOT satellite for Taoyuan test site without enhancement. This image covers Zhongli city, Taoyuan and taken on 2007/01/29. Raw image is influenced by atmospheric effect and not visually clarified (Fig. 1). The whole test covers mainly with vegetation and urban area covers on the right side of the image.

After atmospheric correction of the raw image, surface reflectance can be obtained (Fig. 2). With proper enhancement, it can be helpful for visual interpretation. Fig. 3 illustrates histogram of NDVI computed with TOA reflectance and surface reflectance after AC. One can also see that the dynamic range of NDVI computed with surface reflectance increases after AC, as compared with that computed with TOA reflectance before AC, which indicating the advantage of AC.

In fact, mean TOA reflectances are 0.11 and 0.096 and are reduced to 0.083 and 0.086 for surface reflectances at green and red bands, respectively as listed in Table 1. This is because atmospheric effect mainly due to atmospheric scattering is corrected after AC. Surface reflectance is increased to 0.201 after AC, as compared to TOA reflectance of 0.181 at near-infrared (NIR) band. It is because of the correction of atmospheric absorption after AC. These also shows the advantage of AC as mentioned above.

Usually, raw image is used to determine NDVI. Fig. 4 illustrates NDVI using TOA reflectance; and fig. 5 shows NDVI using surface reflectance. Mean NDVI for TOA reflectance is 0.297 and is increased to 0.392 for surface reflectance. Hence, error is up to 0.095 NDVI unit. This indicates NDVI computed by surface reflectance after AC is increased by 32% as compared with NDVI with TOA reflectance, indicating again the importance of AC for NDVI determination.

IV. Conclusion

Remotely-sensed image is influenced by atmospheric effect. Hence, AC is essential in order to determine NDVI. In this paper, the error of NDVI due to neglect of AC is estimated. Mean NDVI of the whole test image determined by surface reflectance, i.e. with AC, can increase to 0.392 from 0.297 determined by TOA reflectance, i.e. without AC. Error can be up to 0.095 NDVI unit. Hence, the error can be up to 32% when AC is neglected.

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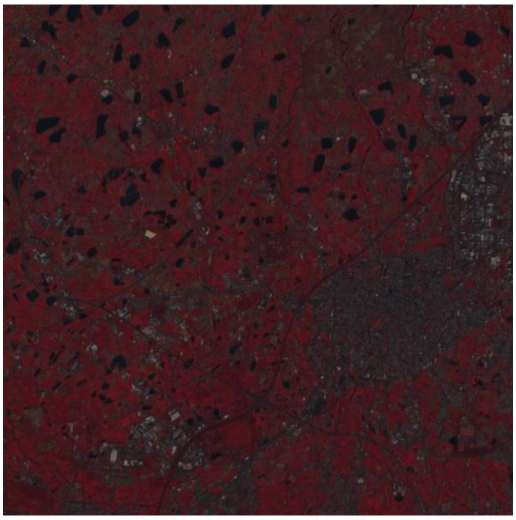

Fig. 1 Top-of-Atmospherie reflectance images of SPOT satellite for Taoyuan test site without enhancement.

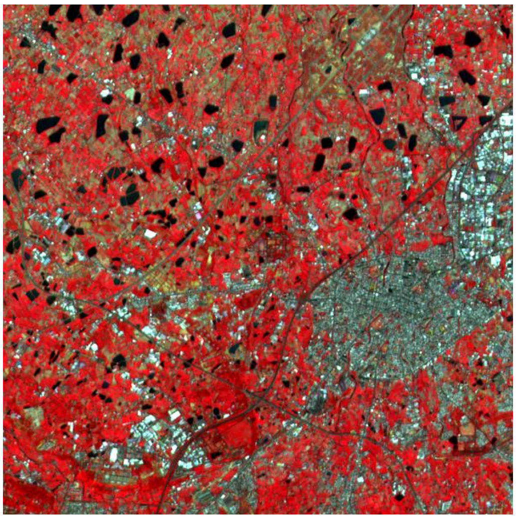

Fig. 2 Similar to Fig. 1, except surface reflectance image after atmospheric correction. Image is enhanced.

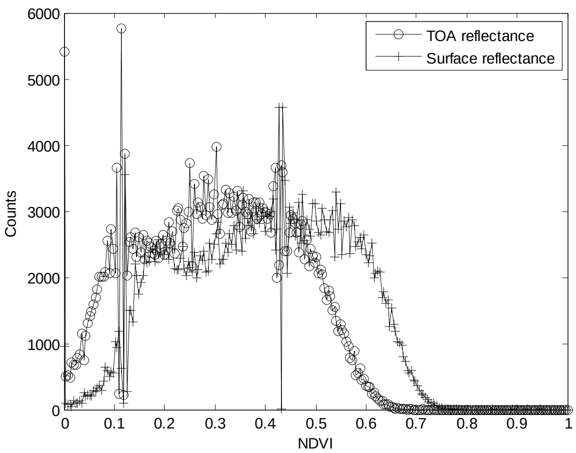

Fig. 3 Histogram of NDVI computed with TOA reflectance,Surface reflectance(AC)

Table 1. Mean and standard deviation of TOA reflectance and surface reflectance of the whole image as well as those using NDVI of these two data.

Band / NDVI	**TOA reflectance**		**Surface Reflectance**	
	mean	***std***	***mean***	***std***
Green	0.11	0.022	0.083	0.026
Red	0.096	0.026	0.086	0.030
NIR	0.181	0.047	0.201	0.054
NDVI	0.297	0.151	0.392	0.160

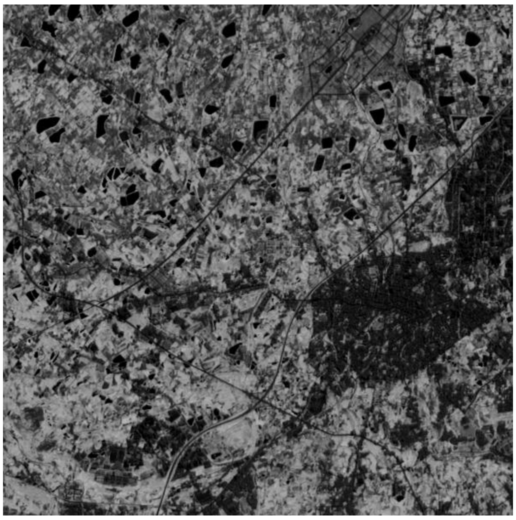

Fig. 4 Similar to Fig. 1, except NDV image derived by Top-of-Atmospherie reflectance image.

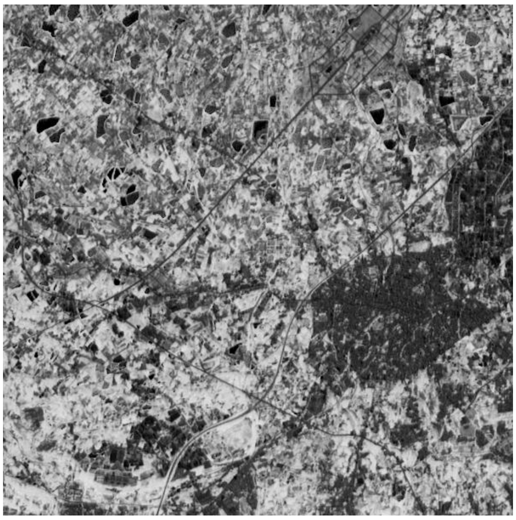

Fig. 5 Similar to Fig. 1, except NDV image derived by surface reflectance image.