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Effect of Atmospheric Haziness to the Error of Normalized Difference Vegetation Index for Satellite Images

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***Abstract*—In this study, atmospheric haziness effect to the error of NDVI using top-of-atmosphere reflectance, is analyzed. SPOT satellite images are used. Ground measured AOD data are implemented to characterize the atmospheric haziness. The results show that when aerosol optical depth at 550 nm increases to 0.8, the mean error of NDVI image can up to 0.25 in NDVI units. Corresponding relative error of NDVI can up to 50%. The relationships between error of NDVI and relative error of NDVI to ground measured AOD are also studied to further emphasize the importance of AC in NDVI determination.**

***Index Terms*—NDVI, Atmospheric Haziness, Aerosol Optical Depth, Surface Reflectance, Remote Sensing.**

I. Introduction

Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation index used to derive vegetation ecological parameter [1]. Satellite remote sensing has the advantage to monitor regional and global changes in terrestrial vegetation, because of its periodic and wide area scanning ability. NDVI can be derived from remotely sensed data [2]. Vegetation canopy PAR absorption can be also derived by NDVI [3], [4]. Atmospheric effect hampers the monitoring vegetation using remotely sensed data. Remotely sensed NDVI from top-of-atmosphere (TOA) signal can be deviated due to the gas and aerosol absorption as well as molecular and aerosols scattering. Aerosol is the most uncertain factor, when correction of atmospheric in remote sensing data is performed [5]. Hence, it's important to study the effect of atmospheric haziness to the remotely sensed NDVI.

Atmospheric correction (AC) is needed, when NDVI derived from surface by remotely sensed data. Surface reflectance can be retrieved using AC to correct the atmospheric effect of remotely sensed images. However, NDVI using raw data is usually used in quantitative analysis of remote sensing, since AC is complex. Hence error in NDVI can be induced.

Recently, mean error of NDVI in a test image due to the neglection of AC is studied [6]. The error can be up to 0.095 NDVI unit; relative error is up to 32%. This study illustrates the different atmospheric haziness to the error of NDVI, when AC is neglected for SPOT satellite images.

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II. Methodology

A. Data

Taoyuan test site in Taiwan is selected, which is the same used in previous study [7]. To be complete in context, data are briefly stated here. SPOT satellite images of total 37 images are acquired from Center for Space and Remote Sensing Research (CSRSR), National Central University (NCU). Because the limitation of the atmospheric correction model, only cloudless and uniform atmospheric effect. Test area is 12 km x 12 km [7].

Aerosol Robotic Network (AERONET) data over EPA_NCU station are used as ground-measured AOD data [7]. Sun-photometer measured AOD550 is determined and interpolated with AOD of nearest wavelengths [8]. AOD550 data within 30 minutes of SPOT satellite overpass time are averaged to denote the different atmospheric haziness in this study. They are also used in AC in order to derive surface NDVI.

B. AOD retrieval and Atmospheric Correction

The methods in AOD retrieval and the follow-on AC for SPOT satellite images are similar to the previous study [6]. It is briefly mentioned here.

To account the radiative transfer of atmospheric effect for SPOT satellite image, vector-based 6S radiative transfer model (RTM) is used. Assumptions of aerosol model and dark target (DT) reflectance are made. Maritime aerosol model is considered. Darkest pixel is used as dark target. Retrieval of AOD can then be made from 6SV run on the assumed DT reflectance at red band. Surface reflectance image can be derived based on the retrieved AOD using the lookup table (LUT) built by multiple simulations of top-of-atmosphere (TOA) reflectance. Surface reflectance images can be derived from AC. It is reported that an error of 0.01 in assumed surface reflectance can cause error of 0.1 in retrieved AOD [9], [10].

C. Effect Analysis

Effect of NDVI due to atmospheric haziness is performed. The error of NDVI is computed by the mean error in every image, as similar to [6]. Error of NDVI in two SPOT images with different haziness are compared. Relationship between relative error of NDVI and ground-measured AOD550 is then analyzed for all data. In the analysis, TOA NDVI and surface NDVI are both computed using TOA reflectance and surface reflectance derived after AC.

III. Results and Discussion

Fig. 1 demonstrate SPOT satellite for Taoyuan test site. It is shown with false-color band combinations and enhanced for better visual interpretation. Image is taken on 2006/08/19. AOD550 is 0.64. NDVI images computed by TOA reflectance and surface reflectance are shown in Fig. 2 and Fig. 3, respectively. These two images are shown without image enhancement. Surface NDVI image shows much brighter than TOA NDVI, indicating NDVI is increased when atmospheric effect is corrected. It could be also shown in Fig. 4. Fig. 4 illustrates histogram of NDVI computed with TOA reflectance and surface reflectance after AC. Dynamic range of surface NDVI increases after AC, as compared with that computed with TOA reflectance before AC. This indicates the advantage of AC. To further validate, error of NDVI image defined as TOA NDVI – Surface NDVI, is shown (Fig. 5). One can see that most pixels shown as colors in green, yellow and red colors. This means the most errors of NDVI are less than -0.3 in NDVI unit. However, some pixels show in cyan color are with error about -0.4 in NDVI unit. Compared with error (0.095) in previous study [6], errors are higher. These pixels correspond to water (pond). This is because water body is less reflective and its TOA reflectance is dominated by atmospheric scattering in visible bands. When AC is performed on water target, water surface reflectance is much less than water TOA reflectance, thus causing error of NDVI for water pixels are higher than other targets, such as vegetation or urban targets.

Fig. 6 shows error of NDVI for SPOT image taken on 2006/09/27. AOD550 is 0.16 which is less than that on that shown in Fig.4 (0.64). Most pixels are in red color, indicating much error is less than -0.2. This is because less atmospheric scattering effect on TOA reflectance, when aerosol concentration reduces.

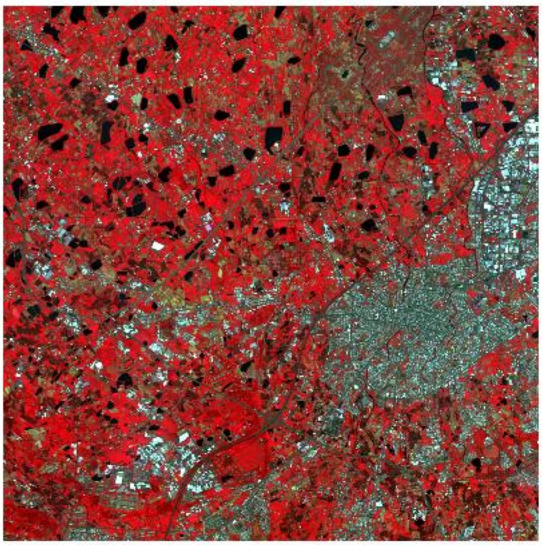

Fig. 1 SPOT satellite image over Taoyuan test site with false-color band combinations: near infrared (red), red (green) and green (blue). Image is taken on 2006/08/19. AOD550 is 0.64.

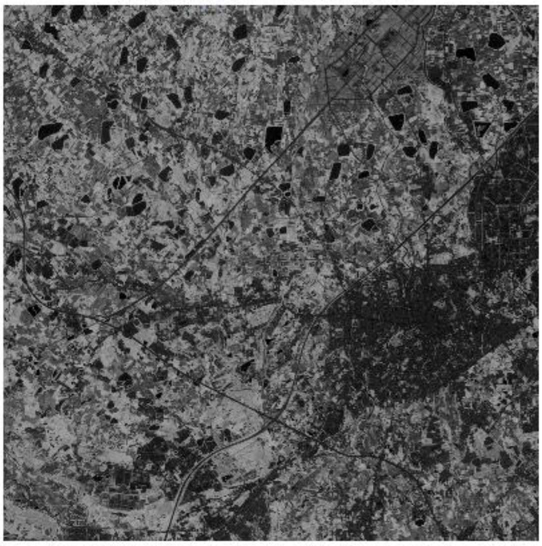

Fig. 2 Similar to Fig. 1, except top-of-atmosphere reflectance image.

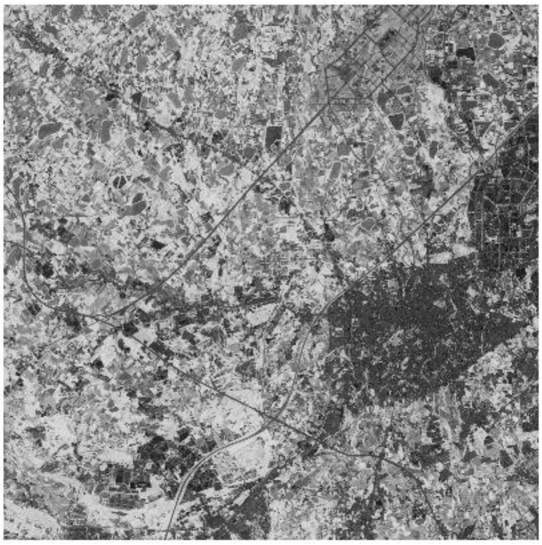

Fig. 3 Similar to Fig. 1, except surface reflectance image after atmospheric correction.

Relationship between error of NDVI and ground-measured AOD550 is shown in Fig. 7. Error of NDVI is computed from the whole image. Total 37 SPOT images and their corresponding AERONET measurements are considered. Ground-measured AOD550 ranges from 0.1 to 0.8, indicating the different haziness considered in this study. The error of NDVI can up to 0.25 in NDVI units when AOD550 increases up to 0.8. This error is computed by mean value of the whole image considered in this Taoyuan dataset. Linear regression fit is computed. The determination coefficient R^2 is 0.48, meaning that 48% of the variation in the error of NDVI is predictable from AOD550. Relationship between relative error of NDVI (%) and ground-measured AOD550 is also shown (Fig. 8). Relative error of NDVI can up to 50% when AOD550 increases up to 0.8. R^2 is 0.51, which is larger than that between error in NDVI vs. ground measured AOD550. R^2 can further increase to 0.69, when linear regression fit of ratio of TOA NDVI to Surface NDVI is considered.

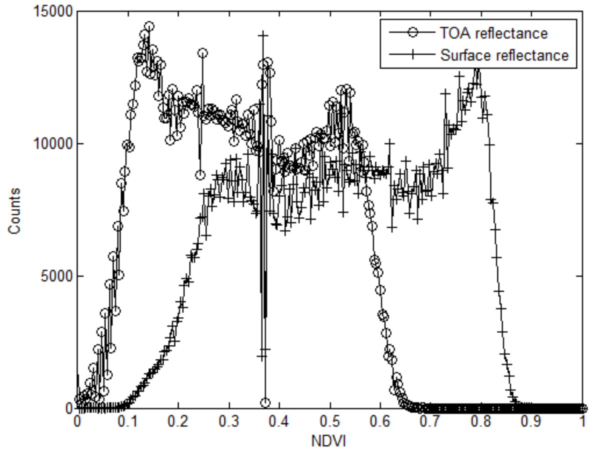

Fig. 4 Histogram of NDVI computed with TOA reflectance and surface reflectance(AC)

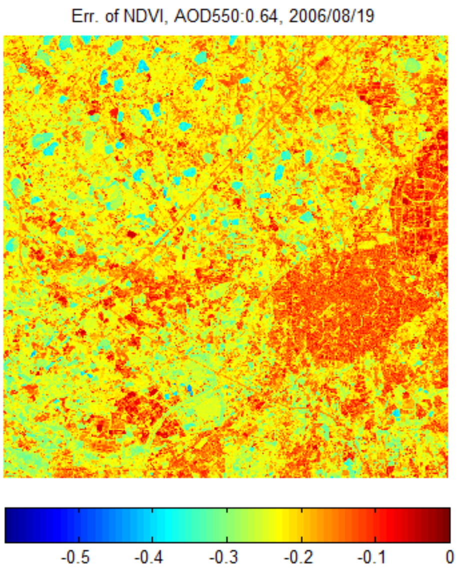

Fig. 5 Error of NDVI image over Taoyuan test site, as computed by TOA NDVI – Surface NDVI. AOD550 is 0.64.

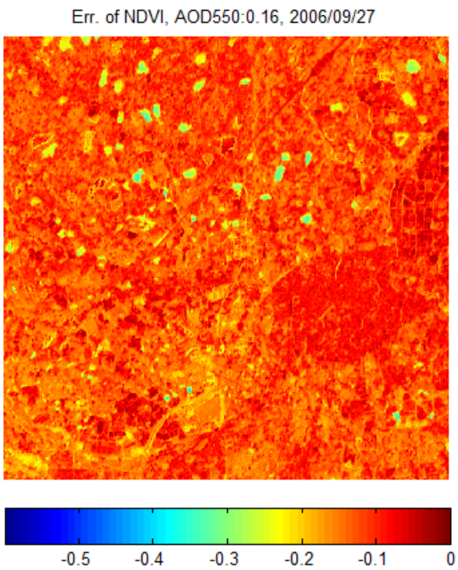

Fig. 6 Similar to Fig. 5, except for SPOT image taken on 2006/09/27. AOD550 is 0.16.

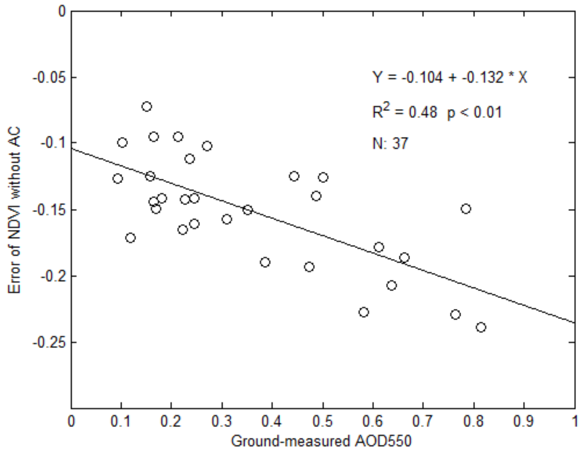

Fig. 7 Relationship between error of NDVI and ground-measured AOD550.

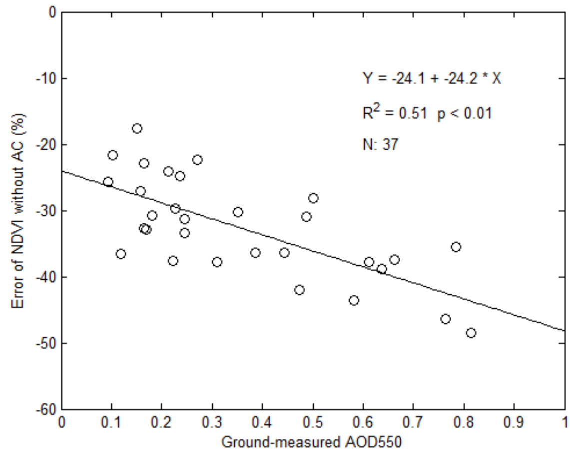

Fig. 8 Similar to Fig. 7, except for relative error of NDVI (%) vs. ground-measured AOD550.

IV. Conclusion

In this study, atmospheric haziness effect to the error of NDVI, when AC is neglected, is analyzed. SPOT satellite images are used. Ground measured AOD data are implemented to characterize the atmospheric haziness. Ground-measured AOD550 ranges from 0.1 to 0.8. The results show that the mean error of NDVI image can up to 0.25 in NDVI units when AOD550 increases up to 0.8; relative error of NDVI can up to 50%. Coefficients of determination of the linear regression are 0.48 and 0.51, when relationships between error of NDVI and relative error of NDVI to ground measured AOD are computed. These further emphasize the importance of AC in NDVI determination and the atmospheric haziness to NDVI error.

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