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Retrieving Aerosol Characteristics from FORMOSAT-2 RSI Images

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***Abstract*—Aerosol characteristics vary with locations due to its composition. Dependent on the abundance, dark target also varies with locations. In this study, the optimal aerosol model and assumed dark target surface reflectance in AOD retrieval from FORMOSAT-2 RSI data are determined for Tainan test site, Taiwan. AERONET data are used to assess the accuracy of retrieved AOD. The results show that optimal aerosol model is determined to be desert aerosol model, which is different from maritime aerosol in Taoyuan, Taiwan. Assumed dark target reflectance at red band is determined to be 0.005, which is smaller as compared to 0.01 in Taoyuan. RMSEs in retrieved AOD in both cases are 0.11 (Tainan) and 012 (Taoyuan), respectively.**

***Index Terms*—Aerosol Optical Depth, Aerosol Model, FORMOSAT-2, Dark Target.**

I. Introduction

Aerosol is a key factor when global change, radiative energy and air pollution is considered [1], [2]. Remote sensing has the advantages on earth monitoring, because of its repetitive and economic monitoring ability of aerosol characteristics. Currently, there are many global aerosol products available from different satellite instruments, such as Moderate Resolution Imaging Spectroradiometer (MODIS) [3]. Aerosol is also the most uncertain factor, when surface reflectance derived from the process of atmospheric correction of satellite images [4], [5].

FORMOSAT-2 (formerly known as ROCSAT-2) satellite was launched in 2004 by National Space Program Office of Taiwan (NSPO). It has the capability of daily revisit [6] and contains Remote Sensing Instrument (RSI) onboard with eight meter spatial resolution in four visible and NIR bands. It has been widely applied to various fields, including coastal monitoring [7], urban heat balance [8], rice straw open burning [9], monitoring glacier movements and disaster surveillance [10], [11]. In-flight calibration has also been carried out to assure the radiometric accuracy of RSI [12], [13].

Retrieval of aerosol optical depth (AOD) using dark target (DT) is considered to be most popular method for satellite remote sensing [14]. It is because of its stable and low reflectance, only small error of retrieved AOD can be produced. Aerosol model is usually fixed, when radiative transfer model such as vector based 6S (6SV) [15], is applied in the process of retrieval. However, aerosol model varies with location based on the aerosol composition, such as dust-like, water-soluble, oceanic and soot [15]. DT reflectance needs to be assumed along with the chosen aerosol model for different location. Assumed DT reflectance is based on the extent of abundance on the study area. Hence both aerosol model and assumed DT reflectance may vary at different locations.

Recent study has found that the most suitable aerosol model is maritime using SPOT satellite images to monitor AOD, over Taoyuan, Taiwan [16]. Following the previous study, this paper uses similar approaches in Tainan test site in Taiwan for FORMOSAT-2 RSI data. Aerosol Robotic Network (AERONET) data are used to assess the accuracy of retrieved AOD.

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II. Methodology

A. Data

Experiments are conducted over Tainan (NCKU). Total of 21 FORMOSAT-2 RSI images are acquired from Center for Space and Remote Sensing Research (CSRSR), National Central University (NCU). The temporal ranges of these images in three sites are 2005/01~2011/02. Images with only cloudless and uniform atmospheric effect, which are determined by visual interpretation, are acquired. Each test areas cover spatial range with 12 km x 12 km. Fig. 1 shows FORMOSAT-2 RSI images for Taoyuan, taken on 2005/1/23.

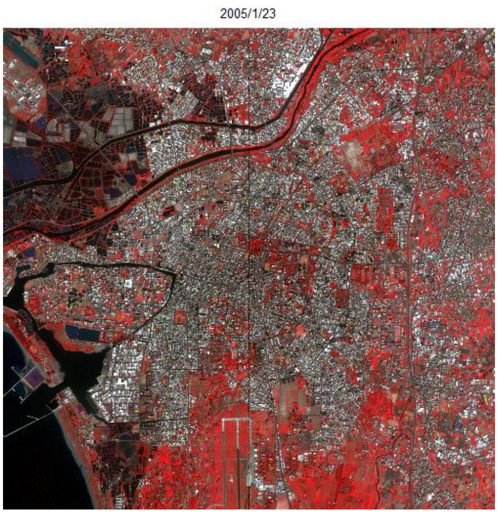

Fig. 1. FORMOSAT-2 RSI image over Tainan test site with false-color band combinations: near infrared (red), red (green) and green (blue).

Ground-measurement AOD data are obtained from Aerosol Robotic Network (AERONET) developed USA/NASA [17]. Sunphotometer data over Chen-Kung_Univ station corresponding to Tainan area is used to verify that the accuracy of AOD inversion from the

FORMOSAT-2 RSI images [17]. Sunphotometer-measured AOD data within 30 minutes of FORMOSAT-2 satellite overpass time are averaged and used to validate the AOD retrieval algorithm.

B. Aerosol Optical Depth Retrieval

When aerosol optical depth is retrieved by a radiative transfer model, top-of-atmosphere (TOA) reflectance ρ^{TOA} should be simulated at first. 6SV radiative transfer model is applied in this study [18].

Before inverting AOD550 from ρ^{TOA} based on dark target, both aerosol model and DT surface reflectance ρ_{DT} have to be assumed [16]. Built-in aerosol models of 6SV contain several options, such as continental, maritime, urban, desert and biomass-burning types. Because the aerosol compositions, such as dust-like, water-soluble, oceanic and soot, vary with different location, aerosol model selected in 6SV may vary thereafter [15]. Assumed dark target reflectance ρ_{DT} is considered to range from 0.0 to 0.03 in 6SV run.

Because of smaller error in retrieved AOD from TOA when compared with other targets, DT is selected. Dense dark vegetation (DDV) has stable and low reflectance at blue and red bands. In this study, DDV is used as DT to retrieve AOD from satellite. DDV is defined as the target which has lowest radiance at near-infrared band chosen from f1 fraction of highest NDVI [19]. f1 is set to 0.2 here. RMSEs at wide range of ρ_{DT} are computed by comparing retrieved AOD and ground-measurement AOD data from AERONET for every considered aerosol model. Both of the optimal aerosol model and assumed ρ_{DT} are determined at the minimum RMSE. The current algorithm is confined to cloudless images with uniform atmospheric effect.

III. Results and Discussion

Table 1 depicts the sensitivity of RMSE of retrieved AOD from FORMOSAT-2 RSI data using different aerosol models and assumed ρ_{DT}. Only maritime and desert aerosol model cases are listed. As shown in table 1, the optimized aerosol model is desert type. Most suitable DDV reflectances at red band (assumed ρ_{DT}) is 0.005, resulting RMSE of 0.11. Interestingly, RMSE is 0.12 when maritime aerosol and assumed ρ_{DT} of 0.01 is considered in the AOD retrieval in this data set.

Fig. 2 illustrates the relationship between retrieved AOD and ground-measured AOD550 over Tainan. The optimal aerosol model, i.e. desert and assumed ρ_{DT}, i.e. 0.005, is applied. The assumed ρ_{DT} lies at the lower bound of the suggested DDV reflectances at red band 0.02 ± 0.01 [19]. Considering the abundance of vegetation as shown in Fig. 1, determined DDV reflectances at red band are quite rational. High coefficient of determination R^2 is obtained: 0.81 (Table 1).

To be summarized, the optimized aerosol model in AOD retrieval is desert type in Tainan for this study. This is different from maritime aerosol model in Taoyuan, Taiwan determined by SPOT images [16]. This may be due to varying aerosol composition in Taoyuan and Tainan. The assumed DT reflectance at red band is assumed to be 0.01 in Taoyuan [16], as compared with 0.005 in Tainan. RMSE of retrieved AOD of 0.11 in this study is comparable to that in Tainan (0.12).

IV. Conclusion

This study determines the optimal aerosol model and assumed dark target surface reflectance in AOD retrieval from FORMOSAT-2 RSI data. Test site Tainan in Taiwan is selected. AERONET data are used to assess the accuracy of retrieved AOD. The results show that optimal aerosol model is determined to be desert aerosol model. Most suitable DDV reflectance at red band is determined to be 0.005. RMSEs in retrieved AOD is 0.11. Comparison with previous results in Taoyuan case, has been also discussed. The algorithm is confined to cloudless images with uniform atmospheric effect.

Table 1 Sensitivity of RMSE of retrieved AOD using maritime and desert aerosol model and assumed dark target reflectance ρ_{DT} ranging from 0.0 to 0.03. * denotes the optimized aerosol model and ρ_{DT}.

Aerosol Model	ρ_{DT}.	RMSE
Maritime	0.000	0.17
Maritime	0.005	0.13
Maritime	0.010	0.12
Maritime	0.015	0.14
Maritime	0.020	0.19
Maritime	0.025	0.26
Maritime	0.030	0.34
Desert	0.000	0.12
Desert	0.005	0.11*
Desert	0.010	0.12
Desert	0.015	0.15
Desert	0.020	0.20
Desert	0.025	0.25
Desert	0.030	0.32

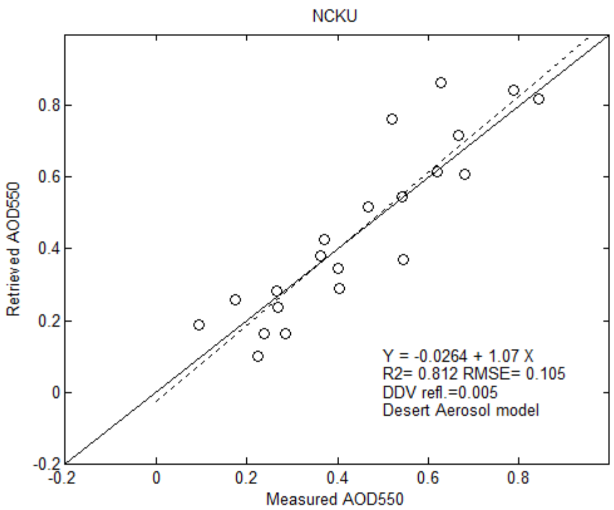

Fig. 2. Relationship between retrieved FORMOSAT-2 RSI retrieved AOD and ground-measured AOD over Tainan (NCKU) site using optimized aerosol model and ρ_{DT} depicted in table 1.

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