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The Detection of Yellow Sand with Satellite Infrared bands

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Abstract : An algorithm for detection of yellow sand aerosols has been developed with infrared bands. This algorithm is a hybrid algorithm that has used two methods combined. The first method used the differential absorption in brightness temperature difference between 11μm and 12μm (BTD1). The radiation at 11μm is absorbed more than at 12μm when yellow sand is loaded in the atmosphere, whereas it will be the other way around when cloud is present. The second method uses the brightness temperature difference between 3.7μm and 11μm (BTD2). This technique is sensitive to dust loading, which the BTD2 is enhanced by reflection of 3.7μm solar radiation. First the Principle Component Analysis (PCA), a form of eigenvector statistical analysis from the two methods, is performed and the aerosol pixel with the lowest 10% of the eigenvalue is eliminated. Then the aerosol index (AI) from the combination of BTD 1 and 2 is derived. We applied this method to Multi-functional Transport Satellite-1 Replacement (MTSAT-1R) data and obtained that the derived AI showed remarkably good agreements with Ozone Mapping Instrument (OMI) AI and Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol optical depth.

Key Words : Brightness Temperature Difference, MODIS, MTSAT-1R, Principle Component Analysis, Aerosol Index.

1. Introduction

Yellow sand is well-known phenomena during the springtime in Korean peninsula. The sources of the yellow sand are from the deserts of Mongolia and China [Zheng *et al.*, 1998]. The travelling low-pressure systems accompanied with strong winds behind the associated cold fronts cause to raise dust into the atmosphere. Aerosols, such as the yellow sand, are air pollution that is harmful to human health, ecosystem, industry activity, and production of goods. In addition, aerosols affect the radiation budget of the Earth-atmosphere system directly by scattering and absorption of solar and thermal radiation, and have the indirect effects by modifying the optical properties and lifetimes of clouds as a role of the cloud condensation nuclei. Therefore, the measurement of aerosols is crucial to understand its impact on human-earth system.

Ground-based aerosol remote sensing using wide angular and spectral measurements of solar and sky radiation is suited to reliably and continuously derive the detailed aerosol optical properties in key locations, but it does not provide global coverage. On the other hand, satellite remote sensing is adequate to investigate the global impact of aerosols.

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Detection of yellow sand aerosol using satellite observation has been utilized from various bands from ultraviolet to infrared channels. Though infrared band has shown a weakness in detecting aerosols due to relatively high error to shortwave bands it has an advantage of detecting aerosols over high reflecting surface and during nighttime. In this study, we have studied a possibility of improving aerosol detection with infrared bands of 3.7, 11, and 12μm.

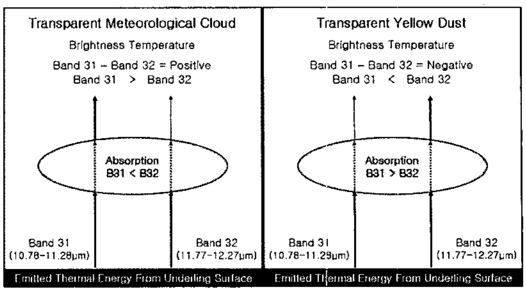

Fig. 1. Schematic diagram showing how two band thermal IR transmission through meteorological and yellow sand is different. Bands 31 and 32 refer to MODIS detectors [Gu and Rose, 2003].

2. Data and Methodologies

1) Data

For the application of our developed algorithm, we have selected infrared bands of 3.7, 11, and 12μm from MTSAT-1R for the period of March and April in 2005 and 2006 when the yellow sand loading was frequently observed. For the comparison, Aerosol Index from Ozone Monitoring Instrument (OMI), which has good sensitivity in monitoring mineral dust and biomass burning aerosol, has been used.

2) Methodologies

(1) BTD1 (11 - 12μm)

A thermal infrared remote sensing algorithm is originally developed to detect volcanic cloud. Later *Wen and Rose* [1994] applied this method to detect aerosol over northeast Asia. This algorithm takes an advantage that upwelling thermal infrared radiation of 11 and 12μm from the earth's surface is selectively scattered and absorbed with respect to the various airborne particles. Ice and liquid water particles preferentially absorb longer wavelengths, whereas dust particles preferentially absorb shorter wavelengths. In laboratory experiments, *Vickers and Lyon* [1967] found that the emissivity of siliceous the principal ingredient of yellow sand has minimum between 8.0 and 9.7μm, and then increases with longer wavelength, becomes maximum around 12-13μm. This can cause the brightness temperature difference between 11 and 12μm (hereafter BTD1) to be negative for dust particles and positive for water particles (Fig. 1).

Based on this founding, *Gu and Rose* [2003] applied the brightness temperature difference between 11 and 12μm to MODIS for derivation of sandstorm over northern China. This study defined the BTD1 threshold value of 0 as a criterion between aerosols and clouds. We have studied how the threshold values vary with respect to satellite spectral response function, satellite zenith angle, surface temperature, and surface emissivity with the radiative transfer model, Rstar5b, developed by Nakajima.

Fig. 2 shows how the variation of BTD1 threshold varies with these parameters. We found the threshold value varies significantly in the range between -3°K and 2°K. The wide range of the threshold can cause a significant error as much as about 100% for aerosol detection. Therefore, in order to apply this method for detection of aerosol, it is required to be filter out the aerosol pixel without aerosol, which is caused by a change in threshold value.

(2) BTD2 (3.7 - 11μm)

The Brightness Temperature Difference between 3.7 and 11μm (hereafter BTD2) also investigated for a possible method for aerosols detection by Ackerman (1989). The BTD2 method shows an ability to enhance a strong signal due to solar reflectance during daytime.

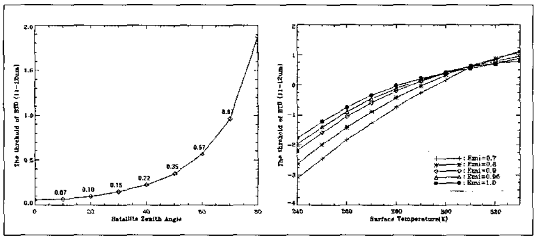

Fig. 2. The variation of BTD1 threshold as a function of satellite zenith angle (left), surface temperature, and emissivity(right).

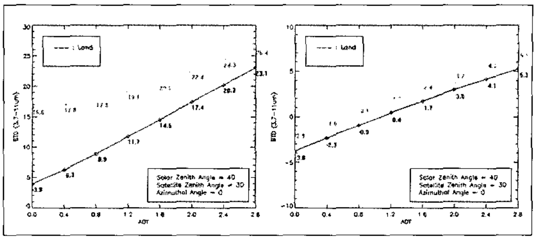

Fig. 3. Radiative temperature difference (3.7-11μm) as a function of AOT for a satellite viewing angle of 30° and a solar zenith angle of 40°. Left figure represent a day case while right figure represent a night case.

This results in a positive value in BTD2 when aerosol loading is presented. A problem in using this method is that the positive value is also obtained in the presence of clouds. Therefore, in order to use this method, we have to distinguish aerosols from clouds.

Fig. 3 illustrates how BTD2 varies with respect to various conditions as of BTD1. BTD2 values vary according to satellite and solar zenith angle, and the magnitude of the change is larger over ocean than land, which suggests that BTD2 is sensitive over ocean than land as well as during daytime than night. Application of BTD2 for aerosols detection in night will suffer a significant error.

(3) Hybrid Method

In order to eliminate the mistaken aerosol pixels without aerosols due to the error associated with either BTD1 or 2, we compare all aerosol pixels derived from both BTD1 and 2, and provide a value depending on the degree of possibility for aerosol existence. The process has been done with the principal component analyses (PCA) from Empirical Orthogonal Function. The advantage of this analysis help technique combine common signal and separates the noisy. The first component (PCA-1 image) contains the most significant from the two methods. The second and subsequent PCA images contain information not explained by previous components.

We have performed by separating the analysis over the land and ocean first after screening the cloud contaminated pixel.

3. Application and Results

The threshold value distinguishing between mineral dust and cloud is defined as zero for BTD1. Generally, the range of BTD1 in the presence of mineral dust is between -3°K and 0°K. The threshold between mineral dust and clouds is defined as 40°K for BTD2. The lowest aerosol loading corresponding to 0°K for two cases. Fig. 4 is the brightness temperature difference of MTSAT-1R derived from BTD1 and 2. Then the PCA analysis has been performed with the data from BTD1 and 2. The lower 10% of the derived eigenvalues is discarded. The BTD values in a pixel defined as an aerosol existence is converted to 0 for 0°K, and 100 for -3°K in BTD1 and 40°K for BTD2, and defined as an Aerosol Index.

Because BTD 1 and 2 are sensitive to aerosol over land and ocean, respectively, aerosol index is determined from BTD 1 over land and BTD 2 over ocean. The right column in Fig. 5 shows the derived aerosol index from the hybrid method.

To evaluate the results, we have compared those with OMI AI and obtained remarkable good agreement between them.

4. Conclusions

Using satellite infrared band for aerosol detection has been widely used in comparison with visible and ultraviolet band because of a significant error

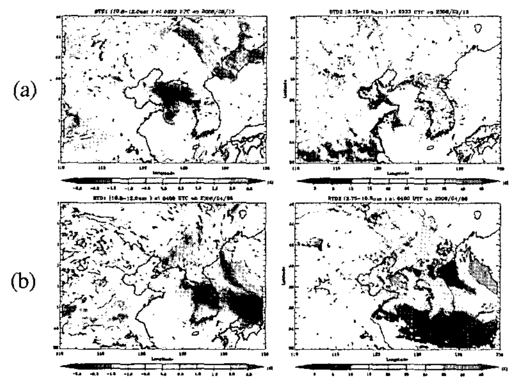

Fig. 4. Brightness Temperature Difference of the MTSAT-1R between 11μm and 12μm channels (left side), between 3.7μm and 11μm channels (right side) for March 13, 2006 (03:33UTC, a) and April 8, 2006 (04UTC, b).

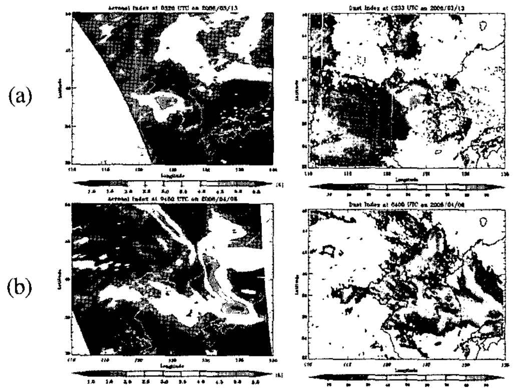

Fig. 5. Aerosol Index of the OMI (left side), and aerosol index (right side) for March 13, 2006 (03:33UTC, a) and April 8, 2006 (04UTC, b).

associated with aerosol retrieval from infrared bands. This study examines the possibility of detection of mineral dust aerosol and seeks a way to overcome the problems associated with aerosol retrieval with the infrared bands. We have shown that mistaken aerosol pixels with no aerosol derived from IR methods can be eliminated with PCA analysis and this approach will result in reducing the error associated with IR method.

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