The Detection of Yellow Sand Using MTSAT-1R Infrared bands

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ABSTRACT:

An algorithm for detection of yellow sand aerosols has been developed with infrared bands from Moderate Resolution Imaging Spectroradiometer (MODIS) and Multi-functional Transport Satellite-1 Replacement (MTSAT-1R) data. The algorithm is the hybrid algorithm that has used two methods combined together. The first method used the differential absorption in brightness temperature difference between 11μm and 12μm (BTD1). The radiation at 11 ㎛ is absorbed more than at 12 ㎛ 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). The technique would be most sensitive to dust loading during the day when the BTD2 is enhanced by reflection of 3.7μm solar radiation. We have applied the three methods to MTSAT-1R for derivation of the yellow sand dust and in conjunction with the Principle Component Analysis (PCA), a form of eigenvector statistical analysis. As produced Principle Component Image (PCI) through the PCA is the correlation between BTD1 and BTD2, errors of about 10% that have a low correlation are eliminated for aerosol detection. For the region of aerosol detection, aerosol index (AI) is produced to the scale of BTD1 and BTD2 values over land and ocean respectively. AI shows better results for yellow sand detection in comparison with the results from individual method. The comparison between AI and OMI aerosol index (AI) shows remarkable good correlations during daytime and relatively good correlations over the land.

KEY WORDS: Brightness Temperature Difference, MODIS, MTSAT-1R, Principle Component Analysis, Aerosol Index

1. INTRODUCTION

A sandstorm that is affecting the Korean peninsula occurs frequently in the spring season in the arid and semi-arid area of sand deserts in the Asian continent. The area of Asian dust source regions covers most of northern China and Mongolia. The travelling low-pressure systems accompanied with strong winds behind the associated cold fronts cause to raise dust into the atmosphere (Yellow sand). Aerosols 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 observation provides high quality of data, but it provides only limited spatial and temporal coverage. Therefore, satellite measurement is adequate to investigate the global impact of aerosols.

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 order to detect yellow dust we have developed the Hybrid method using Infrared bands of 3.7, 11, and 12μm.

2. DATA AND METHODOLOGIES

2.1 Data

For the application of our developed algorithm, we have selected MTSAT-1R data for March and April of 2005 and 2006 when the yellow sand loading was frequently observed. MTSAT-1R, launched on February 26, 2005 provides imagery coverage over the Asia-Pacific region. The meteorological mission includes an imager giving nominal hourly full earth disk images like those from GOES-9 (and GMS-5), and in 5 spectral bands. The bands that have used for this study are band 4(3.7μm), band 1(11μm), band 2(12μm).

The sensor used verifying is Ozone Monitoring Instrument (OMI). OMI was launched mid-2003 on NASA's EOS-Aura satellite. OMI sensor measure ozone columns and profiles, aerosols, clouds, Methodologies, etc. Therefore, aerosol data of OMI will be good validation data.

2.2 Methodologies

2.2.1 BTD1 (11 - 12μm)

A thermal infrared remote sensing retrieval method developed by ***Wen and Rose***[1994], which retrieves particle sizes, optical depth, and total masses of silicate particles in the volcanic cloud. Upwelling thermal infrared radiation between 11 and 12μm from the earth's surface is selectively scattered and absorbed by airborne particles. Ice and liquid water particles preferentially absorb longer wavelengths while aerosol particles preferentially absorb shorter wavelengths. Therefore it cause a negative brightness temperature difference (BTD1<0, Fig. 1). In laboratory experiments, ***Vickers and Lyon***[1967] found that the emissivity of siliceous the principal ingredient of yellow sand has a minimum value between 8.0 and 9.7μm, which then increase with longer wavelength, becoming a maximum around 12-13μm. Based on this theory, ***Gu and Rose***[2003] was applied the algorithm to determine the sandstorm over northern China, using MODIS . This study defined the BTD1 threshold as a criterion between aerosols and clouds. The BTD1 threshold depends on satellite measurements with the spectral response function, satellite zenith angle, surface temperature, and surface emissivity.

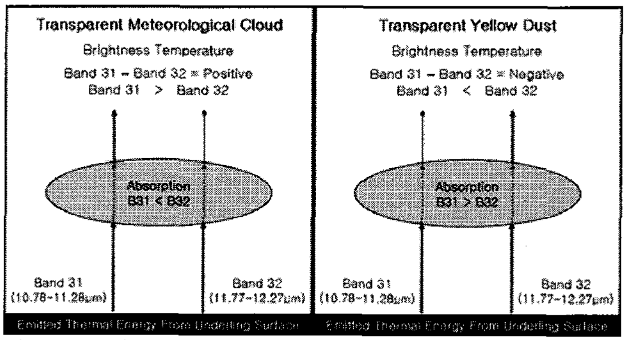

Figure 1. Schematic diagram showing how two band thermal IR transmission through meteorological and yellow sand is different. Bands 31 and 32 refer to MODIS detectors [Gu and Rose, 2003].

Therefore, prior to apply hybrid method, we have investigated the BTD1 threshold according to satellite zenith angle, surface temperature, and surface emissivity using radiative transfer model, Rstar5b. The variation of BTD1 threshold is shown in Fig 2. The BTD1 threshold range from -3°K to 2°K, which are mentioned above. The difference may be caused by an error about 100% in aerosol detection. Therefore, based on analysis of BTD1 threshold, we need to correction about satellite zenith angle, surface temperature, and emissivity.

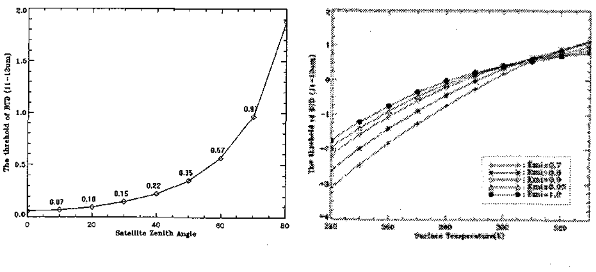

Figure 2. The variation of BTD1 threshold as a function of satellite zenith angle(left), surface temperature, and emissivity(right).

2.2.2 BTD2 (3.7 - 11μm)

The Brightness Temperature Difference between 3.7 and 11μm (BTD2) was investigated as a possible method for aerosols detection [Ackerman, 1989]. The BTD2 method shows an ability to enhance a strong signal from daytime solar reflectance, which results in a positive value in BTD2. However, it has a disadvantage that does not distinguish the aerosols from meteorological clouds because the aerosols reflectivity is about the same as of clouds. Therefore, it is required to remove clouds from aerosols scene.

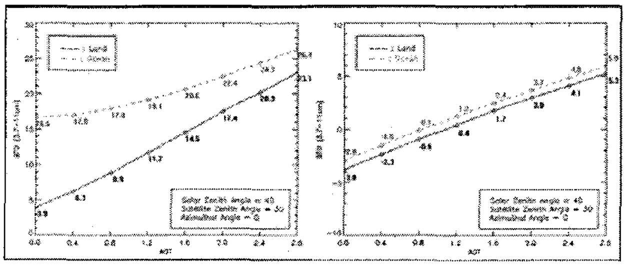

Figure 3. Radiative temperature difference (3.7-11μm) as a function of AOT for a satellite viewing angle of 30° and a solar zenith angle of 40° . Left figure represent a day case while right figure represent a night case.

The Radiative Transfer model analyses with the assumption of uniformly mixed layer between 3-5km, spherical particle shape, and the uniform size distribution indicate the positive values of the BTD2. The differences between the two brightness temperatures are shown in Fig.3 as a function of optical thickness over land and ocean and during night and daytime. BTD2 values change according to satellite and solar zenith angle, and the magnitude of BTD2 is larger over ocean than over land. This technique appears to work better during the day than night. The application of this method for night time measurements is valid, but less sensitive.

2.2.3 Hybrid Method

In order to combine the aerosols indexes from two methods, the principal component analyses from EOF is adapted. 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 all the 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 after screening the cloud interference.

3. APPLICATION AND RESULTS

The BTD1 with less than zero is defined as yellow sand and the BTD1 with more than zero is defined as cloud. This threshold separates the yellow sand aerosols in case of marginal difference of brightness temperature over land and ocean. BTD1 values range from -3°K to 0°K in the presence of yellow sand, but BTD threshold varies according to satellite zenith angle, surface temperature, and surface emissivity. Radiative transfer model analysis shows a negative value when sea salt particles exist over ocean (not shown). This error occurs when yellow sand aerosols are at high altitude or with clouds. Therefore, the BTD1 values may be contained the uncertainties due to components, which are mentioned above.

The threshold between 0° and 40°in BTD2 is related to and yellow sand signal over land and ocean. The brightness temperature difference from BTD2 is larger than from BTD1, and thereby efficient for yellow sand detection both over land and ocean. However, the 3.7μm band produces an error over highly reflecting surface as of most visible and near IR channels.

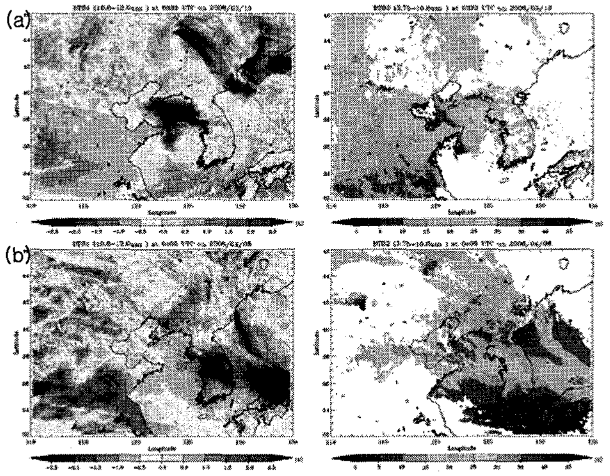

Figure 4. Brightness Temperature Difference of the MTSAT-1R between 11μm and 12μm channels (left side), between 3.75μm and 11μm channels (right side) for March 13, 2006(03:33UTC, a) and April 8, 2006 (04UTC, b).

In order to optimize merits from two methods, the principle components analysis from EOF is adapted, and we eliminated the noisy. BTD1 and BTD2 methods are applied for the land and ocean, respectively. After scaling, we have computed the Dust Index (DI). DI can be useful index because, from general public to experts, it can be decided yellow sand area by scaling from 0 to 100%. To verification, we have compared with calculated DI and OMI AI. DI shows good correspond with OMI AI more than BTD1 and BTD2. Therefore, the hybrid method can be a powerful technique for yellow sand detection.

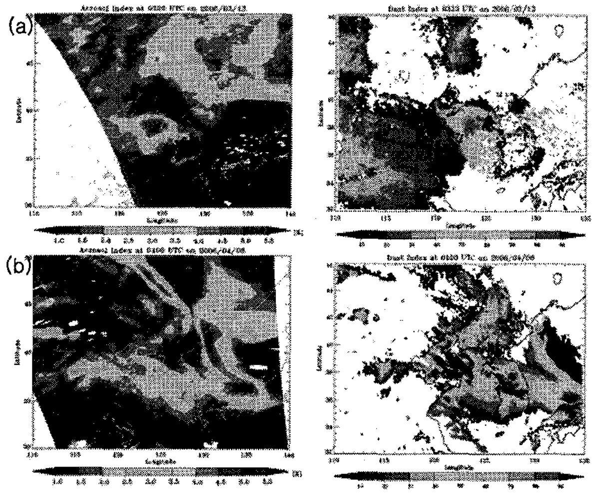

Figure 5. Aerosol Index of the OMI (left side), and dust index (right side) for March 13, 2006(03:33UTC, a) and April 8, 2006 (04UTC, b).

4. CONCLUSIONS

Yellow sand detection BTD with 3.7, 11, and 12μm bands of MTSAT-1R obtains both strength and weakness in all methods. However, the hybrid of the two methods shows elevated yellow sand aerosols signal and proves a strong potential of detecting aerosols.

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