ASIAN DUST CATEGORIZATION BY MODIS DUST INDICES

Izumi Nagatani[a,b] and Jun-ichi Kudoh[a]

[a]GSIS Tohoku University,6-3-09 Aramaki aza Aoba, Aobaku Sendai, Japan,
E-mail: Nagatani@affrc.go.jp and E-mail: Kudoh@cneas.tohoku.ac.jp

[b]Agriculture, Forestry and Fisheries Research Information Technology Center,2-1-9 Kannondai, Tsukuba, Ibaraki 305-8601, Japan;Tel: +81-29-838-7341 E-mail: Nagatani@affrc.go.jp

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Abstract: Asian dust storm monitoring is essential for daily meteorological forecasting. Heavy Asian dusts are occasionally carried by strong winds to Korea, Japan, even to North America and cause respiratory disease, transportation disturbances, and other disruptions of social and economical activities. Remote sensing technique is useful for detecting and monitoring such heavy Asian dusts.
In our previous study, a methodology for retrieving an Asian dust cluster from the MODIS three indices was developed. At that time, three stages of Asian dust behavior were confirmed as 1) initial stage, 2) transported stage, and 3) diffusion stage. In this study, to understand Gobi-desert origin dust behavior from MODIS data, we developed a new dust index for more appropriate dust detection than conventional way of Brightness Temperature Difference (BTD) and Normalized Dust Difference Index (NDDI). Then, a new methodology for Asian dust categorization using MODIS was developed. This dust categorization was demonstrated with MODIS data of 2010 and 2011 dust storms.

1. INTRODUCTION

Asian dust storm monitoring is essential for daily meteorological forecast. Heavy Asian dusts carried by strong winds are observed in Korea, Japan, even North America. In Japan, Gobi-desert origin dust is observed frequently. Remote sensing technique is useful for detecting and monitoring such heavy Asian dusts.

Terra/Aqua MODIS true color image is commonly used for identifying dust transport direction and MODIS dust indices such as Brightness Temperature Difference (BTD) (Ackerman, 1997) and Normalized Difference Dust Index (NDDI) (Qu, 2006) are used for analyzing dust intensity. However, it is difficult for non-expert to understand the real intensity from these indices, because these indices include a lot of noises such as ground surface influence. To avoid unnecessary information, dust extraction process is required. And also easily comprehensible index is required.

In our previous study, a methodology for retrieving an Asian dust cluster from the MODIS three indices was developed (Nagatani, 2011). At that time, three stages of Asian dust behavior were confirmed as 1) initial stage, 2) transported stage, and 3) diffusion stage. It seemed that these dust stages were useful information for understanding dust monitoring.

In this study, we developed new dust index and categorization methodology which are Asian Dust Index (ADI) and Asian dust categorization. The ADI shows blowing dust intensity and identify dust more accurately than BTD and NDDI. The Asian dust categorization is performed with NDDI and ADI. The categories mean three stages: 1) dust storm stage, 2) blowing dust stage, and 3) diffusing stage. The first stage shows dust storm outbreaks on the ground. The second stage is dust transported stage in the air. The third stage shows spreading and floating dust. These categories are understandable easily.

2. METHODOLOGY

Asian dust index (ADI)

The Asian dust index (ADI) is derived from BTD and NDDI. The BTD and NDDI are common indices for Asian dust detection. These indices indicate dust intensity. However the BTD has a problem of showing low value even at higher density dust. On the other hand, the NDDI properly indicates dust concentration but it has a difficulty of discriminating dust from desert or arid land. Therefore, the ADI was developed to indicate dust intensity more accurately. The BTD and NDDI functions are shown in Eq. 1.

Before synthesizing BTD and NDDI, scale matching is performed by linear functions (Eq. 2). Then, ADI is derived from the scaled BTD (SBTD) and scaled NDDI (SNDDI) by normalize difference function (Eq. 3).

$$BTD = BT12 - BT11 + C \qquad \begin{cases} C = 0.0 & land \\ C = 0.5 & ocean \end{cases} \qquad \text{(Eq. 1)}$$

$$NDDI = (b7 - b3)/(b7 + b3)$$

$$SBTD = (1.0/2.0) * BTD$$
$$SNDDI = (1.0/3.0) * NDDI + 0.2 \qquad \text{(Eq. 2)}$$

$$ADI = (SBTD - SNDDI)/(SBTD + SNDDI) \qquad \text{(Eq. 3)}$$

where, the *BT11* and *BT12* is the brightness temperature of 11μm and 12μm wavelength, respectively. The *b3* and *b7* is the top of atmosphere (TOA) reflectance of MODIS band 3 (459-479nm), and band 7 (2,105-2,155nm), respectively. The C is a constant value for BTD matching BTD between land and ocean.

The ADI which is normalize difference between SBTD and SNDDI shows blowing or floating dust intensity based on the SNDDI. This index is superior for detecting weak dust floating over ocean. Figure 2 shows comparison of Asian dust detection between (b) SBTD, (c) SNDDI, and (d) ADI. In the yellow circle is the target dust storm. This result shows that the SBTD and SNDDI detected ground surface (orange circles) that are obviously errors. The ADI detected Asian dust perfectly. However cloud existing become the error source for the ADI (e.g. blue circle). This means cloud masking is required for ADI analysis.

Asian dust categorization

Gobi-desert origin dust is characterized into three stages: 1) dust storm stage, 2) blowing dust stage, and 3) diffusing dust stage. The thresholds of the stage categories are tentatively set here as follows: the first stage is NDDI>=0.4, ADI>0.0 and ADI<0.4. The second stage is NDDI>=0.05. The third stage is NDDI<0.05. These thresholds should be improved in the future work.

CASE STUDY

In the case study, we processed MODIS data of Asian dust in 2010 and 2011. Aqua-MODIS Level 1b products were collected from the NASA LAADS site, (http://ladsweb.nascom.nasa.gov/). The atmosphere corrected reflectance and brightness temperature datasets were prepared using CREFL and MOD14 software packages distributed by the NASA Direct Readout Laboratory, (http://directreadout.sci.gsfc.nasa.gov/) and two indices of BTD and NDDI were created. These images were re-sampled and mosaiced to latitude-longitude map coordination covering from Gobi-desert to Japan (30.0˚-50.0˚N, 100.0˚-150.0˚E) (Figure 1). ADI and categorized images were generated.

Table 1. MODIS data in the case study

Date of data	Satellite
Nov. 10, 2010	Aqua
Nov. 11, 2010	Aqua
Nov. 12, 2010	Aqua
Apr. 29, 2011	Aqua
Apr. 30, 2011	Aqua
May. 1, 2011	Aqua

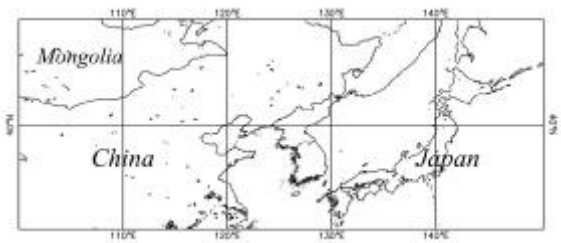

Figure 1: Study area

3. RESULTS AND DISCUSSIONS

Figure 3 shows the results of Asian dust categorization. The left are original MODIS true color images and the right are categorized result images. Yellow circles in each image show the target dust storms. Though there are some misidentified pixels, overall accuracy was satisfactory. The red pixels show dust storm stage which are mainly shown in Mongolia. The orange pixels are blowing dust stage. The yellow pixels show the diffusing dust stage which are shown over sea. These figures prove that the ADI detects Asian dust properly and shows floating or blowing dust intensity for each pixel. Unlike BTD and NDDI, the ADI is not influenced by ground surface. However, some cloud pixels are misidentified. To avoid this error, cloud masking is required.

In the ADI images of (c) November 12, 2010, the weak floating dusts over sea are well detected. Additionally, the ADI has a capability of monitoring Asian dust with discriminating artificial smoke or air pollutions. This is useful for Asian dust and air pollution study.

4. CONCLUSIONS

To monitor Gobi-desert origin dust by Terra/Aqua MODIS, we developed a new dust index, Asian Dust Index (ADI) which is derived from BTD and NDDI. This has a capability of dust detection more accurately than conventional ways of BTD and NDDI. In the new dust categorization, Asian dusts are categorized into three dust stages: 1) dust storm stage, 2) blowing dust stage, and 3) diffusing dust stage. These categories are helpful to understand dust storm behavior. We will continue to improve accuracy of categorization method by adjusting categories thresholds.

ACKNOWLEDGMENT

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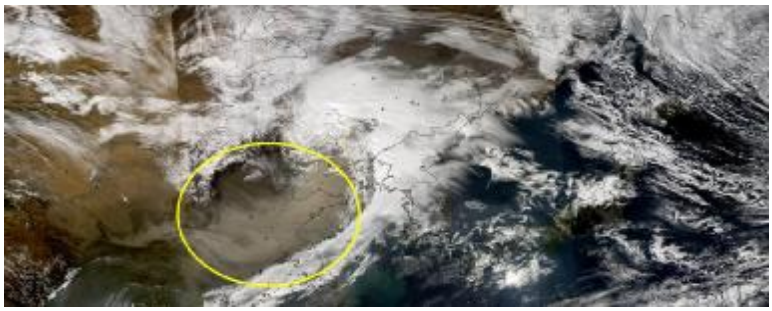
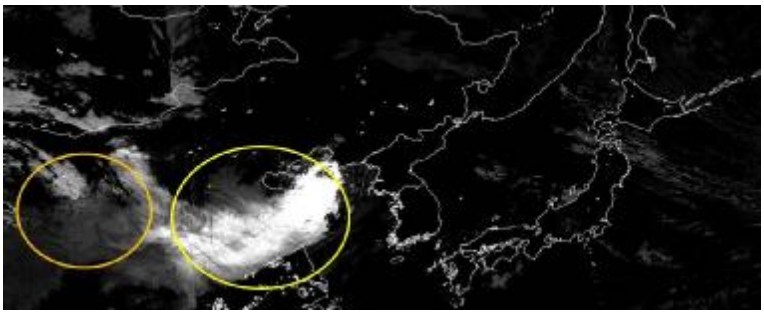


(a)



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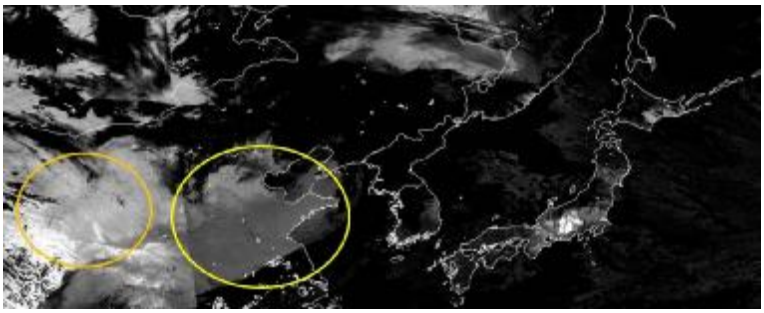

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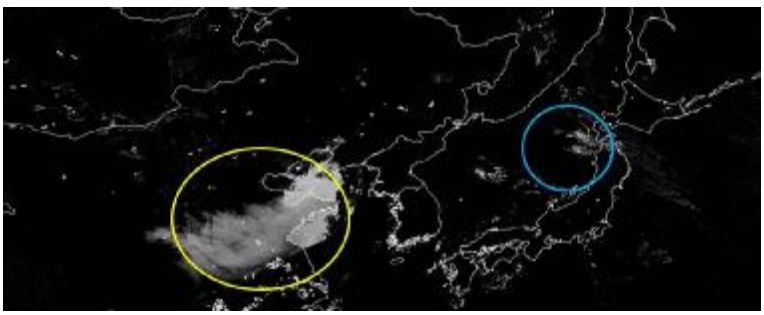
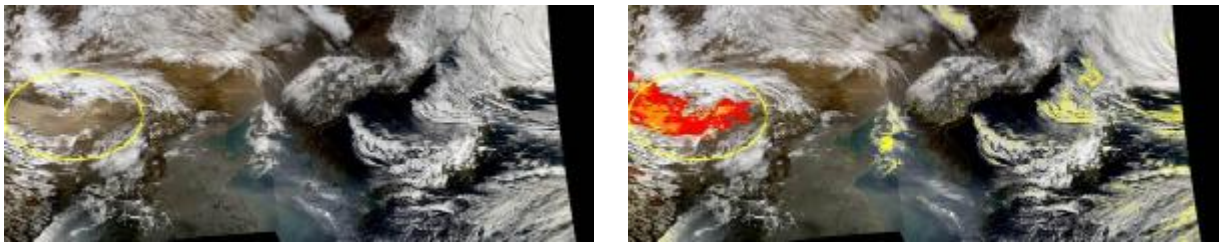
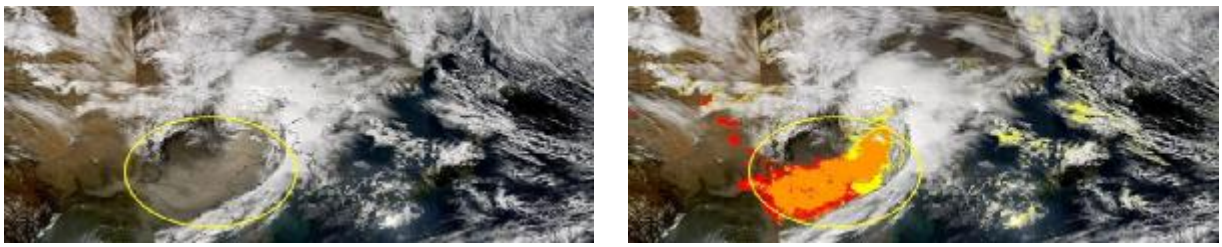


(d)

Figure 2. Comparison of Asian dust detection between three indices. (a) Original MODIS true color image, (b) Scaled BTD image (SBTD), (c) Scaled NDDI image (SNDDI), and (d) ADI image. Yellow circles show Asian dust storm. Orange show ground surface, and Blue shows cloud.



(a)



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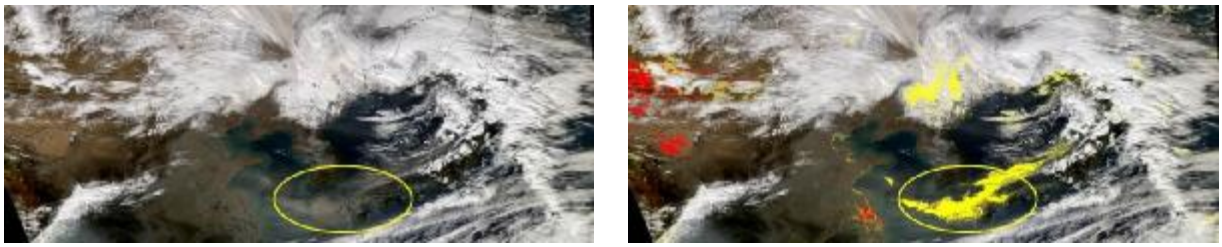

(c)

Figure 3. Original MODIS true color image (left) and Asian dust categorized results (right) of (a) November 10, 2010, (b) November 11, 2010, and (c) November 12, 2010. Red shows dust storm stage. Orange shows blowing dust stage. Yellow shows diffusing dust stage. Yellow circles show Asian dust storm.