Detection of Asian dust aerosol over land using SeaWiFS data

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Abstract

We propose a simple method of detecting dust-loaded airmass over the land area, which is based on the difference between Rayleigh-corrected reflectances at 412 nm and 443 nm bands of SeaWiFS data. The method, together with multi-band based cloud masking algorithm, is applied to '98 April SeaWiFS images of continental China, when a major dust event occurred. The resulted "dust aerosol index" imageries are compared with dust amount distribution predicted by a dust transport model, showing good general agreement. The correlation of the satellite-derived index and the predicted dust amount is discussed from the viewpoint of difference in the land cover.

Introduction

Mineral dust-rich aerosol, such as with Saharan dust or Asian dust particles, is important in terms of its effect on radiation budget as well as its role as a source of micro-nutrient in the oceanic phytoplankton ecosystem. To know the spatial distribution and its temporal variability, satellite observation of dust aerosol is of great importance.

There have been many works in satellite remote sensing of aerosol (King *et al.*, 1999, for example), where typical observation bands are mid-visible to near-infrared or short wave infrared. An exceptional case is Herman *et al.* (1997) who used UV observation data of Total Ozone Mapping System (TOMS) to derive Aerosol Index (AI), but there seems to be no attempt to use short wavelength visible band data, which may be useful in observing absorptive aerosol.

In this paper we study the possibility of using "blue" bands of Sea Wide Field-of-View Scanner (SeaWiFS) to detect the Asian dust-loaded aerosol over the land area. One of the differences between ocean and land in terms of satellite remote sensing of aerosol is the variability in the spectral reflectance of the surface. While the oceanic water is almost black at near infrared bands where most of the signal comes from aerosol, the land surface changes its spectral response over wide range of visible through near-infrared region, largely depending on its land cover category. Hence, we should take the difference in land cover into consideration although the analysis was not made at full strength in the present study.

In this paper, we define a simple empirical formula of "dust veil index over land (LDVI)" which is derived from the 412 and the 443 nm band data of SeaWiFS. Then, a series of "one day composite" imagery of the dust veil index over 11 days in April, 1998 is compared with the columnar mass of dust particles predicted by a dust transport model calculation developed by one of the authors. Comparison is also made with the contemporaneous TOMS Aerosol Index (AI) images. We also discuss the effect of different land cover category, using an existing land cover data base (Tateishi *et al.*, 1999).

Dust veil index over land (LDVI) for SeaWiFS data

Definition of LDVI

We first define the elevation-corrected Rayleigh radiance L_{CR} as the radiance that the satellite would observe at the pixel location when the atmosphere consists of air molecules only. In calculating this, we assume that the Rayleigh radiance is proportional to the surface pressure which, in tern, is a simple function of the elevation at the location.

Then, the empirical dust veil index over land LDVI is defined as

$$LDVI = \{L_T(443) - L_{CR}(443)\} - \{L_T(412) - L_{CR}(412)\}$$

where $L_T(\lambda)$ stands for the total radiance observed by SeaWiFS in λ [nm] band.

The rationale for this is formula as follows. Firstly, $L_T - L_{CR}$ is modeled as the sum of the radiance due to aerosol and the radiance due to the ground. Since the pair of the selected bands (412nm and 443nm) is located so close that we can anticipate minimum difference in the surface reflectance. Meanwhile, when we have dust aerosol, the aerosol radiance in 412nm band will be more diminished than in 443nm band due to the enhanced absorption effect that arises from larger value of imaginary part of refractive index of dust particles. This effect is also enhanced from the larger interaction between dust particles and air molecules due to the thicker Rayleigh optical thickness. Hence, we anticipate larger LDVI value when aerosol is more absorptive.

SeaWiFS data processing

SeaWiFS Level–1 GAC data that covers 80 – 150°E range were collected to form daily composites of LDVI images over the period of April 15 – 25 in 1998. The "cloud" pixel is masked when the following criteria were met at the same time.

$L_T(412) - L_{CR}(412) \geqq 8$,

$L_T(443) - L_{CR}(443) \geqq 10$, and

$L_T(670) - L_{CR}(670) \geqq 10$ (μW/cm^2/nm/sr).

Comparisons with other dust indices

Image comparisons

The resulted dust veil index images are shown in figure 1, together with ONLT model–predicted columnar amount (center) and TOMS Aerosol Index images (right). On–line dust transport (ONLT) model was implemented into Regional Atmospheric Modeling System (RAMS), to simulate the transportation of dust particles which originate desert areas in China (Uno *et. al.*, in press). The original data of TOMS AI are taken from the TOMS home page (http://toms.gsfc.nasa.gov/TOMSmain.html). Looking the dust images in a day by day basis, there is general agreement in "dust distribution" pattern among the three different imageries. The LDVI images show good correlation with the ONLT–predicted dust distribution, although it seems to fail in depicting "extreme dust load" in dust source area. In comparison with the LDVI and ONLT images, TOMS AI imagery shows significant difference in the magnitude of the index. It is not so sensitive for heavy dust load in the source areas whereas it shows high sensitivity in the areas far from the sources where the dust concentration is much lowered. This may indicate relative insensitivity to the near–surface dust events.

Consideration on different land cover

Although we assumed that the spectral reflectance of the surface observed in 412 and 443 nm bands are close and the effect of the variability in land surface reflectance is minimum, the LDVI values may be affected by different land cover. To see the variability due to that aspect, we used AARS Asian land cover data set (Tateishi *et al.*, 1999) to compare with the imageries. We show a part of our analysis below.

Figure 2 shows a scatter diagram of the subsampled LDVI and ONLT dust amount for April 20, 1998. At each sample location, the land cover is checked and, for this figure, the sample point is masked if the land cover is one of "water" categories or urban area. Hence, the points in the figure covers wide range of land cover classes, including vegetation, forests, grasslands, paddy/wheat fields, and even those non-vegetative areas such as bare ground, sand or rock. Although the scatter in figure 2 is not small, we see positive correlation of the index with the model-predicted dust amount.

We also conducted similar analysis on TOMS data whose result is shown in figure 3. Note that the diagram has more variability than the one in the previous figure, reflecting different response of TOMS AI over "source area" and "far area".

Figures 4 and 5 show examples of LDVI-ONLT relationship over different classes of land cover. In figure 4, we restricted samples to those with categories 10 through 132 of the land cover data set that corresponds to general vegetation area. This clearly shows better correlation in contrast to the result in figure 5 where the samples were taken from a set of categories which consists of paddy/wheat fields and other typical desert-type land cover such as sand, rock or bare ground.

Conclusion

We have introduced a simple index for dust-loaded aerosol based on the SeaWiFS short wavelength visible band data and conducted initial evaluation using a model-predicted dust amount and TOMS Aerosol Index over 11 day period in April, 1998 when major series of dust events occurred. From the results, our dust veil index (LDVI) shows significantly high correlation with ONLT model-predicted dust amount, which seems to be better than TOMS AI. At the same time, LDVI obviously has dependency on land cover, which necessitates further investigation.

Acknowledgement

This work was supported by the Ministry of Education, Science and Culture. The part of this work was also supported by National Space Development Agency of Japan.

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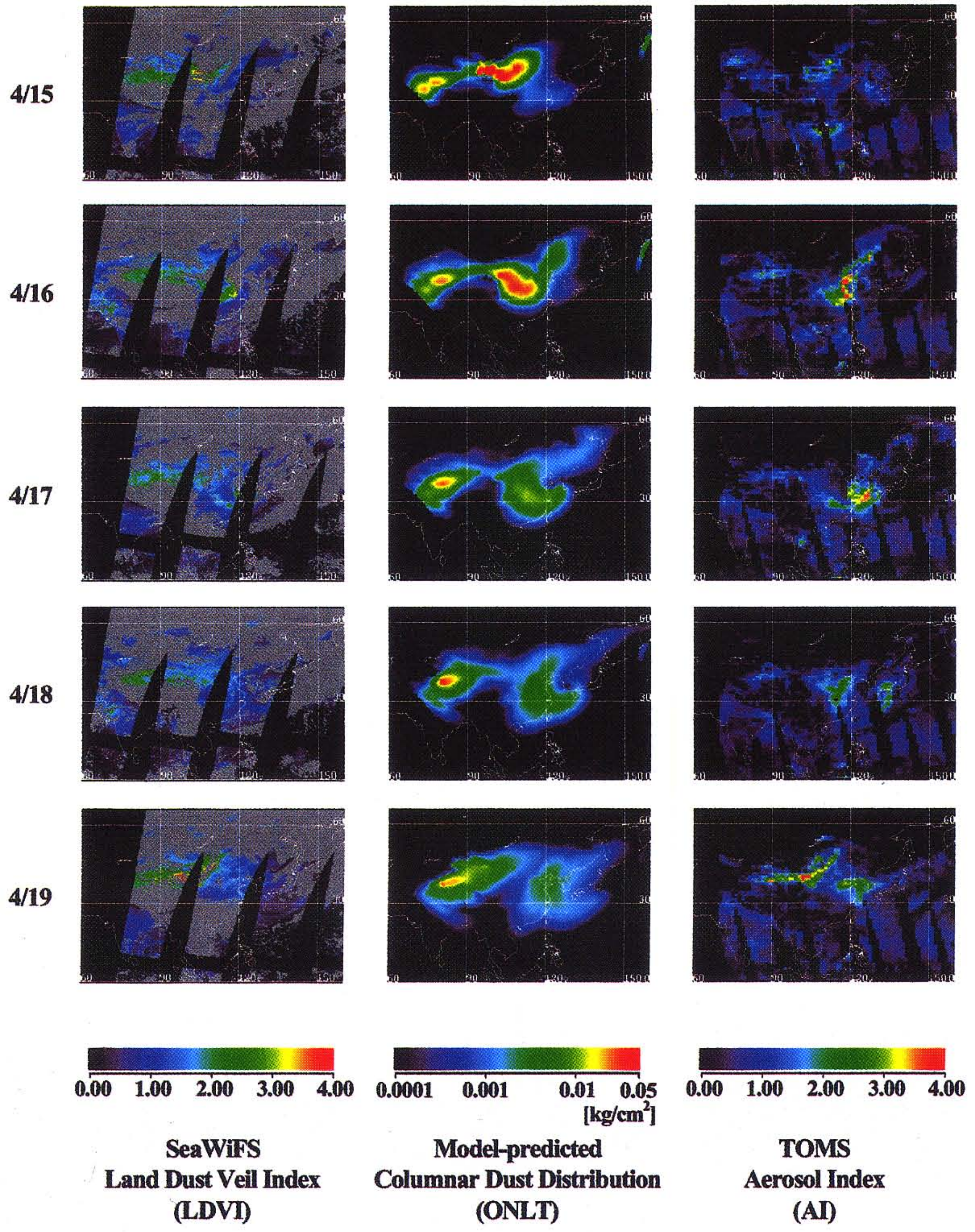


Figure 1. Comparisons of dust imageries over April 15 – 19, 1998. SeaWiFS-derived dust veil index for land (LDVI) proposed in this study, ONLT model-predicted columnar dust amount, and TOMS Aerosol Index taken from the TOMS home page.

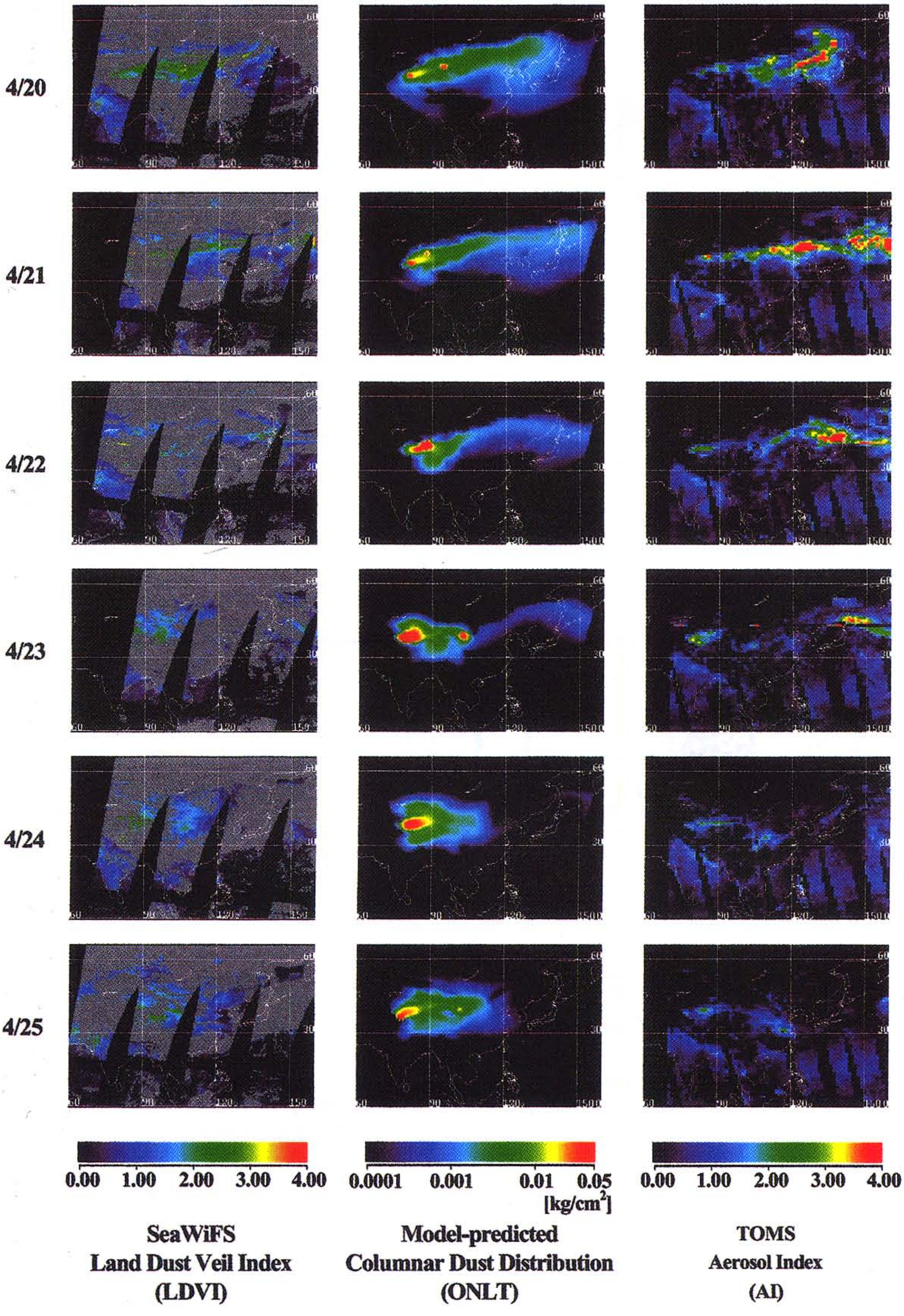
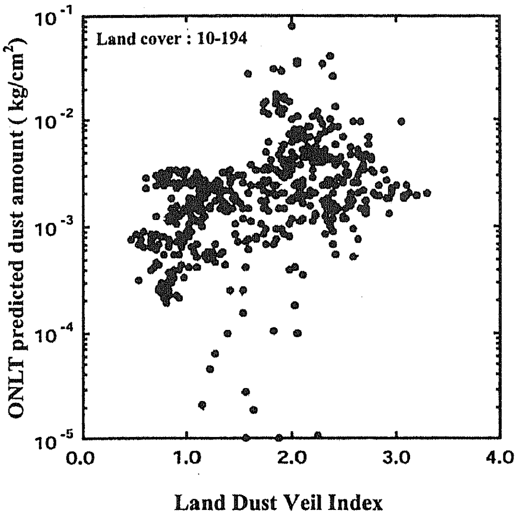


Figure 1. (continued) Comparisons of dust imageries over April 20 – 25, 1998.



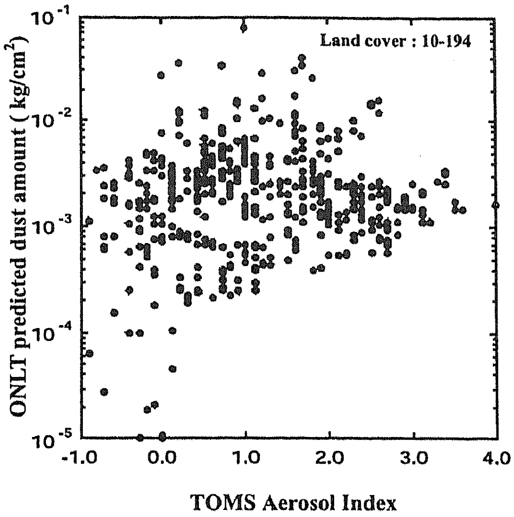
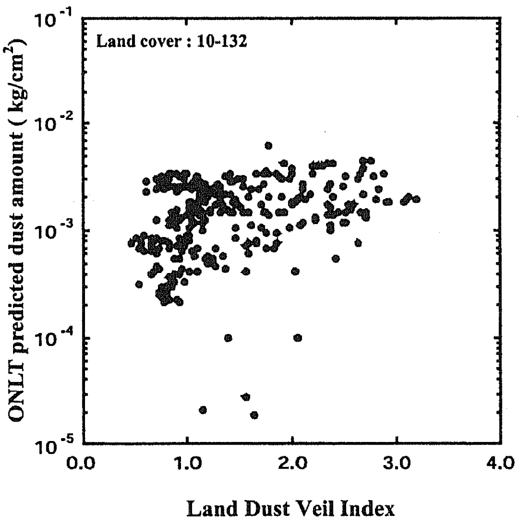


Figure 2. Scatter diagram of the SeaWiFS-derived dust veil index for land (LDVI) and the ONLT model-predicted columnar mass of the dust particles on April 20, 1998. Points are sampled with about 1-degree grid spacing over 30°-50°N and 75°-135° E areas. Land cover categories of 10-194 are considered.

Figure 3. Scatter diagram of TOMS Aerosol Index and the ONLT model-predicted columnar mass of the dust particles on April 20, 1998. Points were sampled in the same way as Figure 2.



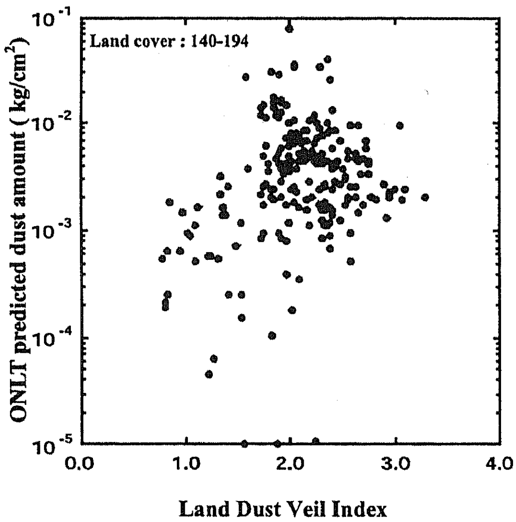


Figure 4. Same as Figure 2 but samples are limited to the land cover categories 10-132, which are mostly vegetation and grassland.

Figure 5. Same as Figure 2 but samples are limited to the land cover categories 140-194, which include paddy, wheat, bare ground and rock.