

Features of Yellow Sand in SeaWiFS Data and Their Implication for Atmospheric Correction

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Abstract

Yellow sand event has been studied using SeaWiFS data in order to examine the aerosol optical characteristics in the Yellow Sea and their influences on the atmospheric correction for the ocean color remote sensing. Two SeaWiFS images of April 18 and April 25, 1998, representing Yellow Sand event and clear-sky case respectively, are selected for emphasizing the impact of high aerosol concentration on the ocean color remote sensing. It was shown that NASA's standard atmospheric correction algorithm treats yellow sand area as either too high radiance or cloud area, in which ocean color information is not generated. SeaWiFS aerosol optical thickness is compared with nearby ground-based sun photometer measurements and also is compared with radiative transfer simulation in conjunction with yellow sand model, examining the performance of NASA's atmospheric correction algorithm in case of the heavy dust event.

1. Introduction

Remote sensing of ocean color has been providing valuable information on the marine environment and its bio-geo-chemical and physical processes from which environmental changes of our planet can be studied. Following the success of scientific investigation using the data from Coastal Zone Color Scanner (CZCS) which was on board the Nimbus 7 satellite from late 1978 and 1986, recent missions such as the Ocean Color and Temperature Scanner (OCTS) and the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) provide ample opportunities for advent scientific investigation and application for examining our environmental changes.

It has been known that the yellow sand (Asian dust) is the heavy dust originated from the desert areas of North China and its significant portion is transported to the North Pacific Ocean (Uematsu et al., 1983). In particular, during the spring time, the yellow sand event results in poor visibility in East Asia. Many attempts have been made to examine the optical and chemical characteristics as well as long-range transport issues (Tanaka et al., 1989 among many others). Fukushima and Ishizaka (1993) studied the influence of the yellow sand on the remote sensing of pigment concentration over the East Sea (Japan Sea) using CZCS data.

In this research, we examine the optical characteristics of the yellow sand using the SeaWiFS data and compare ground-based optical parameters of aerosol for validating the satellite method. We also show the impact of the heavy dust on ocean color remote sensing by presenting that the current NASA's standard atmospheric correction algorithm does not work when it applies to East Asia area where occasional heavy dust events occur, in particular, during the spring time.

2. Data Set and Analysis

The SeaWiFS is an ocean color sensor launched in 1997. It consists of 8 spectral bands; 412, 443, 490, 510, 555, 670, 765, and 865 nm. The last two near-infrared channels are used for determining atmospheric aerosol and thus for atmospheric correction. Nominal spatial resolution is about 1km at the nadir view. Detailed sensor characteristics are found in Gregg et al. (1994). In this research, the reduced resolution Global Area Coverage (GAC) data from the high resolution local area coverage (LAC) data generated by scanner are used.

Analyses were performed on two cases of April 18 and 25, selected for contrasting the signal of yellow sand aerosol to the background aerosol. Figure 1(a) and (b) are SeaWiFS imagery for April 18 and 25, respectively. Considering the spatial scale and pattern of imagery there is a clear indication of yellow sand aerosol spread over the East China Sea and across the Korean peninsula on April 18. By contrast April 25 appears to be clear sky with background aerosol since most oceans are dark.

The atmospheric correction algorithm employed in the SeaWiFS data processing has two different aspects from CZCS algorithm, i.e.: to consider multiple scattering and to employ aerosol models. Since there is a near-linear relationship between aerosol multiple scattering and single scattering it is possible to calculate multiple scattering using single scattering effect with an aid of near-linear relationship between them (Gordon and Wang, 1994). SeaWiFS algorithm consists of 12 aerosol models, i.e.: maritime, coastal and tropospheric models varying with 4 classes of relative humidity of 50, 70, 90 and 99%. The algorithm can be summarized as

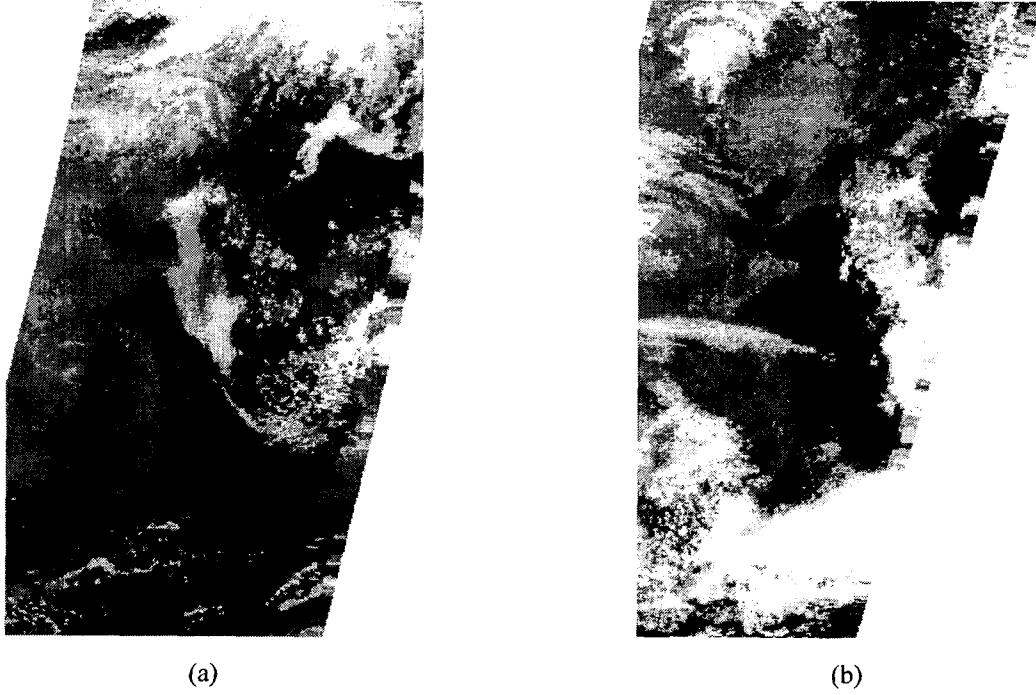


Figure 1: Combined image of SeaWiFS channel 1, 5, 6 measurements for (a) April 18, and (b) April 25.

follows :

$$t\rho_w(\lambda) = \rho_t(\lambda) - \rho_r(\lambda) - [\rho_a(\lambda) + \rho_{ra}(\lambda)] \quad (1)$$

$$\varepsilon(765,865) = \frac{1}{12} \sum_{j=1}^{12} \varepsilon_j(765,865) \quad (2)$$

$$\rho_t(765) - \rho_r(765) \quad \text{and} \quad \rho_t(865) - \rho_r(865) \xrightarrow{12 \text{ Models}} \varepsilon(765,865) \Rightarrow \text{select 2 models} \quad (3)$$

$$\varepsilon(765,865) \xrightarrow{2 \text{ Models}} \varepsilon(\lambda,865) \quad (4)$$

$$\rho_{as}(865) \xrightarrow{\varepsilon(\lambda,865)} \rho_{as}(\lambda) \quad (5)$$

$$\rho_{as}(\lambda) \xrightarrow{2 \text{ Models}} \rho_a(\lambda) + \rho_{ra}(\lambda) \quad (6)$$

In these equations we followed symbols used in Gordon and Wang (1994). Because water leaving radiance in near IR region (765 and 865 nm for SeaWiFS channels) is nearly zero, we can compute aerosol effect by removing Rayleigh scattering, ozone absorption, and multiple scattering from the total reflectance, as in Eq. (1). Because Rayleigh scattering and ozone absorption are relatively easy to compute, the problem of calculating water leaving radiance comes down to how we calculate aerosol influences.

SeaWiFS algorithm calculates average $\varepsilon(765,865)$ from 12 aerosol models and selects two aerosol models having nearest $\varepsilon(765,865)$ as in Eq. (3). Assuming in situ aerosol effect can be expressed by these two aerosol models, we can calculate aerosol single scattering effect and thus multiple scattering effect.

We calculated aerosol optical thickness at 510 nm as well as 865nm. Due to the criteria of the reflected radiance at the top of the atmosphere to be masked or flagged, optical thickness for the yellow sand case (April 18) was produced only in small region over the East Sea of the Korean peninsular and in the middle of the Yellow Sea. The typical value of the aerosol optical thickness in Figure 2 is between 0.2 and 0.3. On the other hand, the optical thickness of background aerosol (April 25 case) shows values smaller than 0.2 over much of the Yellow Sea and East Sea surrounding the Korean peninsular. It seems that SEADAS software performs data processing when the aerosol optical thickness at 510 nm is smaller than 0.3. These background aerosol optical thickness at 510 nm are in good agreement with ground observations. We measured direct and diffuse solar radiation at the background atmosphere monitoring site (36.517°N, 126.317°E) in Anmyon Do which is on the west coast of the Korean peninsular. Detailed descriptions of these measurements and results are found in

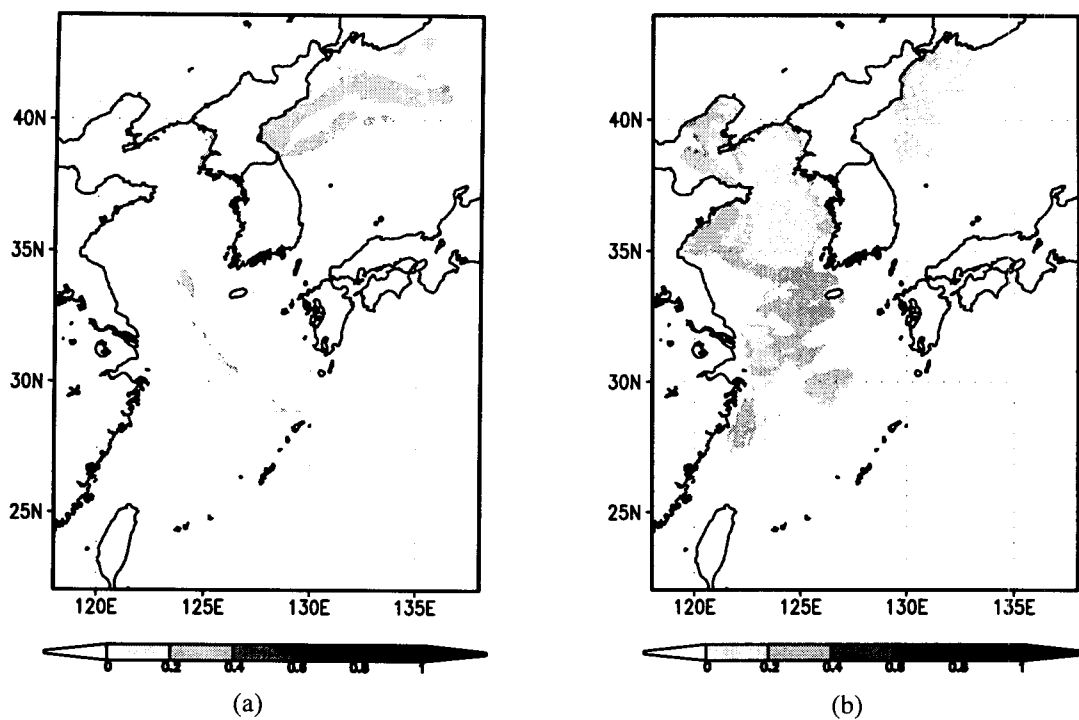


Figure 2: Aerosol optical thickness at 510 nm for (a) April 18, and (b) April 25.

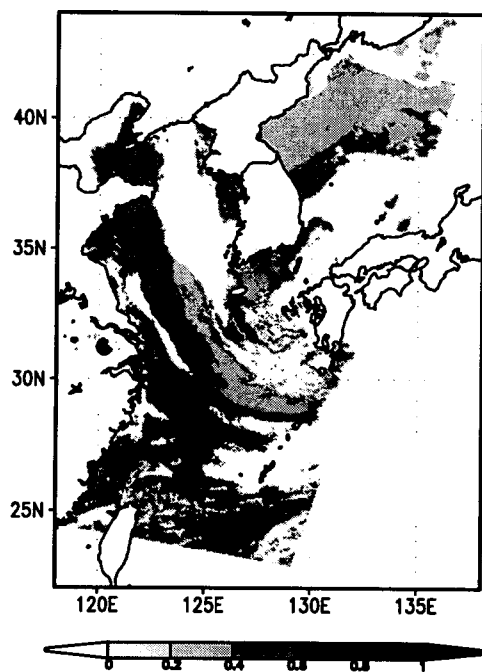


Figure 3: Aerosol optical thickness at 510 nm for April 18 obtained after removing flag or mask information that is set for the pixel having high value of reflectance during the SEADAS data process.

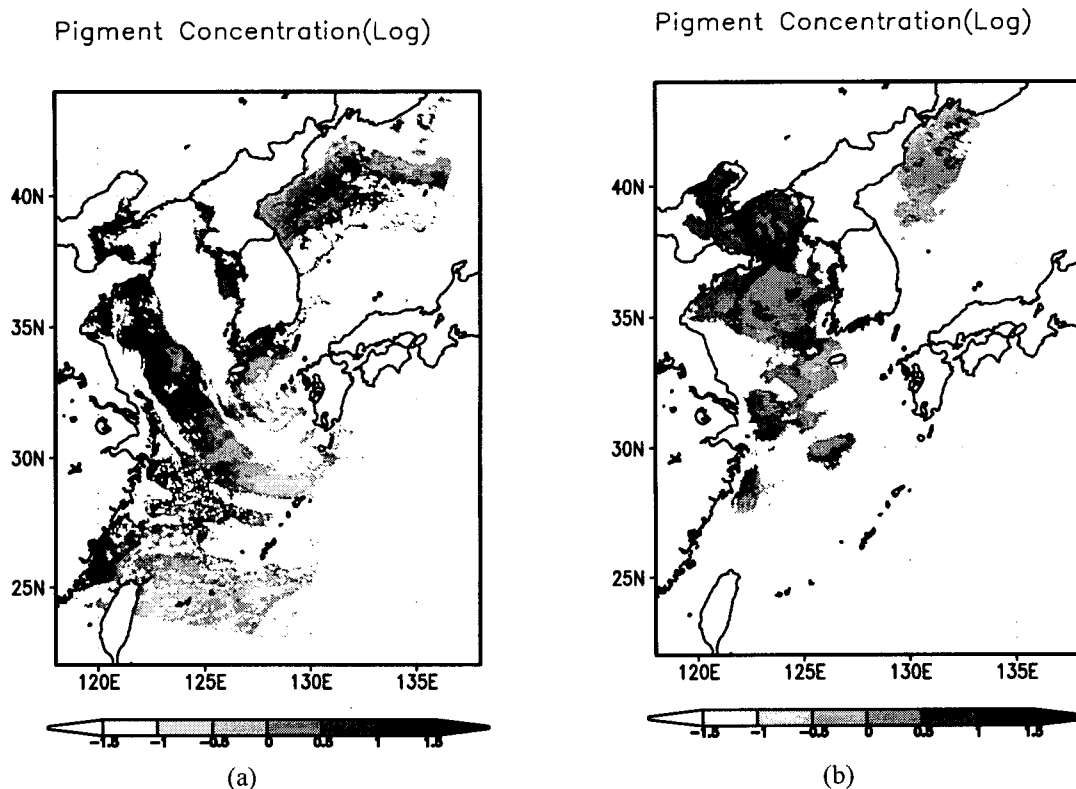


Figure 4: CZCS type pigment concentration obtained by applying SeaWiFS atmospheric correction algorithm for (a) April 18, and (b) April 25. In (a), values are obtained by removing flag or mask information that is set for the pixel having high value of reflectance during the SEADAS data process.

another paper by Sohn et al. (1998) in this preprint volume.

In order to see if the NASA's SeaWiFS algorithm is also applicable to the yellow sand case, aerosol optical thickness was obtained by removing mask or flag information assigned during the normal data processing. Results are given in Figure 3. The optical thickness over the yellow sand area over the East China Sea is ranging from 0.6 to 1.0, which are also comparable to ground observation made at Anmyon Do where heavy yellow sand aerosols are observed in the following day (April 19). Therefore the NASA algorithm seems to be applicable even for the computation of optical thickness of yellow sand aerosol. However, the distribution of CZCS type pigment concentration shows very erroneous results, compared to those of background aerosol case measured seven days later (April 25) -- see Figure 4. For example, pigment concentration around 10 $\mu\text{g/liter}$ is found over the yellow sand area between Yangtze basin and Cheju island whereas 3-4 $\mu\text{g/liter}$ of the concentration is found in the same area. These results suggest that a new scheme resolving the influence of yellow sand for processing the Asian dust-laden SeaWiFS scene. The inclusion of the Asian dust in the OCTS algorithm developed by Fukushima et al. (1997) may also help SeaWiFS data produce more realistic results even in the case of yellow sand event.

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4. References

- Gregg, W.W., F.S. Patt, R.H. Woodward, 1994: The simulated SeaWiFS data set, Version 2. *NASA Technical Memorandum* 104566, Vol. 15, 42pp.
- Fukushima, H., T. Noguchi, H. Tabata, and M. Toratani, 1997: Evaluation of OCTS atmospheric correction and possible improvement. *Proceeding of International Symposium on Remote Sensing*, Korean Society of Remote Sensing and EMSEA, Nov. 5-7, 1997, Pusan, 262-268.
- Fukushima, H., and J. Ishijaka, 1993: Special features and applications of CZCS data in Asian waters. *Ocean colour: Theory and applications in a decade of CZCS experience*. Ed. by V. Barale and P.M. Schlittenhardt, Kluwer Academic Publishers, 213-236.

- Sohn, B.J., D.S. Shin, and S.S. Lee, 1998: Optical Characteristics of Yellow Sand from Ground-Based Solar Radiation Measurements near the Yellow Sea. *Proceeding of International Symposium on Remote Sensing*, Korean Society of Remote Sensing and EMSEA, Sep. 16-18, 1998, Kwangju
- Tanaka, M., T. Nakajima, M. Shiobara, M. Yamano, and K. Arao, 1989: Aerosol optical characteristics in the yellow sand events observed in May, 1982 at Nagasaki - Part I Observations. *J. Meteor. Soc. Japan*, **67**, 267-278.
- Uematsu, M., R. Duce, J.M. Prospero, L. Chen, and J.T. Merrill, and R.L. McDonald, 1983: Transport of mineral aerosol from Asia over the North Pacific ocean. *J. Geophys. Res.*, **88**, 5343-5352.
- Gordon, H. R., and M. Wang, 1994: Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS : A preliminary algorithm, *App. Opt.*, **33**, 443-452