Satellite Monitoring of Smoke Aerosol Plume during the Russian Fire Episode of May 2003 over Northeast Asia

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Abstract: The large amount of smoke produced near Lake Baikal was transported to Northeast Asia with high AOT (Aerosol Optical Thickness) as seen in satellite images. Aerosol retrieval using a separation technique was applied to MODIS (Moderate Imaging Spectroradiometer) and SeaWiFS (Sea-viewing Wide Field-of-view Sensor) data observed during 14-22 May 2003. Large AOT, 2.0~5.0 was observed on 20 May 2003 over Korea due to the influence of the long range transport of smoke aerosol plume from the Russian fires, resulting in high PM10 concentration was observed at the surface.
Keywords: AOT, smoke, MODIS, SeaWiFS

1. Introduction

Atmospheric aerosols interact with sunlight and affect the global radiation balance, causing climate change through direct and indirect radiative effects. It is known that atmospheric aerosols affect climate not only directly [*Charson et al.*, 1991] by scattering and absorbing visible and infrared energy, but also indirectly by modifying the properties of clouds and lifetime [*Twomey*, 1991]. Biomass burning produces a complex mixture of aerosol particles including soot, soluble organic compounds, sulphates and nitrates. Due to the high soot content, this aerosol can absorb solar radiation significantly. The absorption of solar radiation can also heat the atmosphere and alter the cloud formation. Recently, it has become evident by estimates from satellite remote sensing data that biomass burning play important role in regional air quality and atmospheric chemistry. Wildfire affects about 12-15 million Ha of closed boreal forest annually, most of it in Eurasia. Extensive fire activity occurred across the border in Russia, particularly east of Lake Baikal between the Amur and Lena rivers in May 2003. Biomass burning releases large amounts of particulates and gases into the atmosphere, resulting in adverse effects on regional air quality and the global budgets of radiation. Smoke pollution from the Russian forest fires was transported to Northeast Asia through Mongolia, eastern China, and Korea.

In this paper, we present the results of compositing aerosol optical thickness maps using MODIS and SeaWiFS data. To retrieve AOT over the ocean and land, Look-up table constructed from the 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) code was used with a biomass burning aerosol model.

2. Methodology

Table 1. shows the dataset used in this study. The separation technique [*von Hoyningen et al.*, 2003] was used in order to retrieve AOT from satellite data. The TOA reflectance can be affected by many factors including solar and observation geometry, Rayleigh and aerosol scattering, atmospheric transmittance, and surface reflectance, and etc. Therefore, in order to separate aerosol reflectance from TOA reflectance, other contributors such as Rayleigh scattering and surface reflectance should be removed from it. Aerosol reflectance, r_a can be expressed as

$$r_a = r_{TOA} - r_{Ray}(l, q, p(z), M_0, M_S) - w_0(l) \cdot t_R(l, M_S) \cdot r_{Surf}(l, z_0, z_S) \quad (1)$$

where, $r_{Ray}(l, q, p, M_0, M_S)$ is the normalized Rayleigh path reflectance inclusive multiple scattering for the scattering angle q, the pressure p, the air mass factor for illumination M_0 and satellite M_S, $w_0(l)$ is the single scattering albedo, t_R is the transmission for Rayleigh atmosphere for zenith distance of satellite z_S from sun z_0, and $r_{Surf}(l, z_0, z_S)$ is the surface reflectance for sun and satellite geometry. $p(z)$ is the pressure at elevation z km.

In case of separation of the surface reflectance from TOA reflectance over land, a linear mixing model of the spectral reflection of ‘green vegetation’ and ‘bare soil’ was used to determine the land surface reflectance. The Normalized Differential Vegetation Index (NDVI) was

Table 1. Characteristics of satellite sensors for this study.

Sensor	Application	Bands	Swath
MODIS	Active Fire, Aerosol	36	2330km

SeaWiFS	Aerosol	8	2800km

used to estimate green vegetation cover from the aerosol corrected reflectance of the channels 6 (670nm) and 8 (865nm) for SeaWiFS and the channels 1 (660nm) and 2 (870nm) for MODIS.

The SeaWiFS Level 1A data from HRPT station and MODIS Level 1A data from the Korea Aerospace Research Institute (KARI) ground station were first processed to produce TOA reflectance. Then the retrieval of aerosol optical thickness is based on the LUT constructed from 6S, assuming the biomass burning aerosol model (Vermote et al. 1997).

3. Results

Fig. 1. shows a MODIS RGB image over study area on 20 May 2003. This image shows also active fires marked with red dots which are produced from MODIS fire product (MOD14). Satellite images show hundreds of wildfires burning out of control. The Russian forest fires are producing severe smoke plume which extends far to the south into Korea and is transporting to the Pacific Ocean.The thick smoke plume completely obscures the land and ocean surface over study area. This was largely due to the abundance of biomass burning aerosol from the forest fires in Russia.

A composite AOT map was produced using SeaWiFS and MODIS L1B data on 20 May 2003. Spectral AOT was retrieved from the cloud-free pixels of the region having a spatial resolution of 1 ㎞×1 ㎞. The AOT composite is shown in Fig. 2. The optical thickness was relatively high over Northeast China and Korea, indicating a higher aerosol concentration. The optical thickness over these regions was about 2 to 5 and the Angstrom exponent ranges from 1 to 1.8. The Angstrom exponent also tends to be higher near fire positions, indicating the presence of finer aerosol particles.

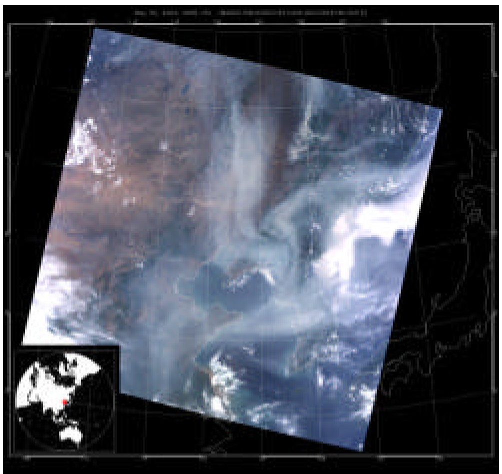

Fig. 1. MODIS RGB image(Ch.1,4,3) with hot spot on 20 May 2003.

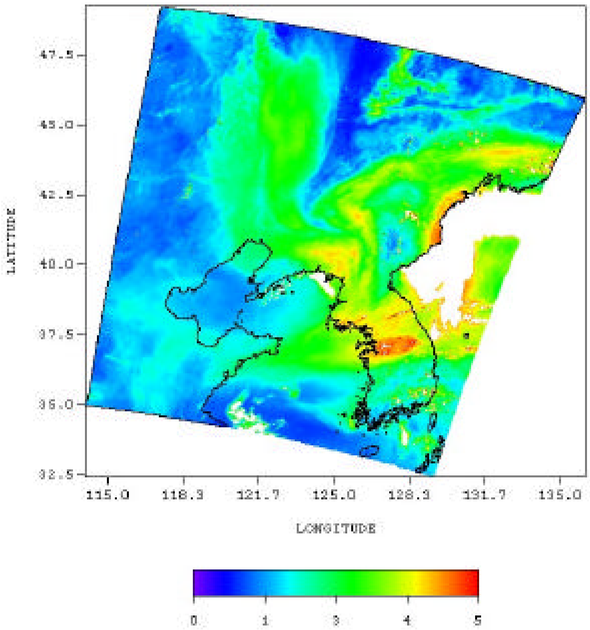

Fig. 2. Regional composite of MODIS AOT at 465nm for 20 May 2003 at 1㎞×1㎞ resolution.

4. Conclusions

Smoke aerosol plume from the Russian forest fires was analyzed using satellite data to estimate the impacts on air quality and radiation. The Russian forest fires produced thick smoke plume transporting to Korea. This smoke aerosol obscures the land and ocean surface over study area. Large AOT, 2.0~5.0 was observed on 20 May 2003 over Korea due to the influence of the long range transport of smoke aerosol plume from the Russian fires. This results show that satellite can be capable of detecting smoke aerosol based on our retrieval method.

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