AEROSOL MAPS OVER THE OCEAN OF THE SOUTHEAST ASIAN REIGON

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Abstract: In this paper, we present the results of compositing aerosol optical thickness maps using 12 days of data from the MODerate-resolution Imaging Spectrometer (MODIS) onboard the Terra satellite. Two ocean viewing bands namely, band 15 (743- 753 nm) and band 16 (862 – 877 nm) are used to retrieve the optical thickness over the ocean , assuming a maritime model using a Look-up table constructed from the 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) code.

1. INTRODUCTION

Aerosols play an important part in the global energy budget of the earth and contributes to the path radiance in optical remote sensing images. Useful information from the surface of the earth are obscured by the absorbing and scattering properties of aerosols. Properties of aerosols can be obtained either from ground based measurements or via remote sensing techniques. Remote sensing methods provide good temporal and spatial information on the properties of aerosols in the atmosphere. The Moderate-resolution Imaging Spectrometer (MODIS) on-board the TERRA Satellite offers a good coverage of the South East Asian region, with approximately two daytime passes daily.

We used the 1-km resolution ocean-colour bands of MODIS to retrieve the aerosol optical properties over the seas in the Southeast Asian region. In optical remote sensing images, the surface radiance interferes with the atmospheric path radiance causing difficulty in the retrieval of aerosol properties from the images. However, over the sea waters far from the coast, the water leaving radiance in the near-infrared (NIR) region is typically low, so the detected radiance over the ocean is predominantly due to the atmospheric path radiance (Gordon et.al, 1999). Two MODIS NIR bands (band 15, 743-753 nm and band 16, 862-877 nm) are used where the water leaving radiance of the sea is assumed to be zero and the contribution to the reflectance at the top of the atmosphere ρ_{TOA}, is mainly due to scattering by molecular (i.e. Rayleigh scattering) and aerosol. The top of the atmosphere reflectance is first corrected for water vapor absorption. The corrected ρ_{TOA} was then used for retrieval of the aerosol thickness at band 15 and 16. The retrieval is based on a look-up table (LUT) constructed from the 6S radiative transfer code. The aerosol optical thickness is then extrapolated to 550nm using the Angstrom turbidity Law (Ångström ,1961).

2. AEROSOL RETRIEVAL ALGORITHM

The top of the atmosphere reflectance detected by the sensor can be modeled as

$$\rho_{TOA} = T(\rho_{ral+aero} + \rho_w) \tag{1}$$

where $\rho_{ral+aero}$ is the path reflectance due to aerosol and Rayleigh scattering, ρ_w is the water leaving radiance and T is the transmission term due to gaseous absorption. In our case, only water vapour absorption is considered. In the NIR region, the water leaving radiance ρ_w can be assumed to be zero, such that the top of the atmosphere reflectance can be considered as the atmospheric path reflectance. The path radiance due to aerosol and rayleigh scattering is not simply the sum of the individual components due to the presence of an interaction term (Vermote et al. ,1997). The 6S code employs a model where aerosol is mixed with the gaseous molecules for the computation of the atmospheric path radiance. Atmospheric transmission maps due to water vapour absorption for bands 15 and 16 are generated and used to correct for water vapour absorption in the MODIS NIR bands (Lim et al. 2002).

The direct-broadcast MODIS Level 1b data downlinked at the CRISP ground station are first processed to filter off clouds (Chang et. al 2002) and sun glint pixels. The retrieval of aerosol optical thickness is based on the LUT constructed from 6S, assuming the maritime model (Vermote et al. 1997). The 6S code uses the SOS (Successive Order of Scattering) algorithm for the computation of the atmospheric path radiance, in which mixing of aerosol and gaseous molecules was taken into account. The atmospheric path radiance depends on the imaging conditions (sun angles and sensor viewing angles) and the aerosol optical thickness. Molecular scattering is assumed to be invariant. For each set of imaging condition (i.e. solar zenith angle θ_s, sensor view angle θ_v and difference of the solar and sensor azimuthal angles $\Delta\phi$) the path reflectance (i.e. the TOA reflectance over the dark ocean) is computed for several values of the aerosol optical thickness ranging from 0 to 1. For ease of retrieval, the set of (, ρ_{TOA}) values for each imaging condition is fitted to a cubic equation,

$$\tau = a_0 + a_1\rho_{TOA} + a_2\rho_{TOA}^2 + a_3\rho_{TOA}^3 \tag{2}$$

and only the four coefficients are stored in the LUT. The LUT is constructed by stepping through each of the three imaging geometry parameters at an angular interval of 2.5^o. For the retrieval phase, given the NIR ρ_{TOA} at a pixel location, the aerosol optical thickness is interpolated from the LUT using the cubic convolution algorithm.

Given the aerosol optical thickness at the two NIR bands, the optical thickness at any wavelength in the visible region can be extrapolated using the the Angstrom Turpidity Law (Anders Ångström ,1964)

$$\tau(\lambda) = \tau_o\left(\frac{\lambda}{\lambda_o}\right)^{-\alpha} \tag{3}$$

where τ_0 is the optical thickness at a reference wavelength λ_0 and is known as the Angstrom exponent which can be computed from

$$\alpha = -\frac{\ln\left(\frac{\tau_1}{\tau_2}\right)}{\ln\left(\frac{\lambda_1}{\lambda_2}\right)} \qquad (4)$$

where $_1$ and $_2$ are the optical thickness retrieved from the NIR bands with wavelengths $_1$ and respectively. With this value of , the aerosol optical thickness at a reference wavelength of 550 nm can be computed using equation (3).

3. RESULTS AND CONCLUSIONS

A composite aerosol optical thickness map was produced using MODIS L1B data from 27 September to 8 October 2002. Aerosol optical thickness and Angstrom exponent were retrieved from the cloud-free and non-glint pixels for each pass. The composite map was produced by geolocating the pixels from the optical thickness map derive from each individual pass onto a pre-fixed map of the region having a spatial resolution of 0.05 of a deg. The nearest neighbour method was used in spatial interpolation and for pixels that were oversampled, the mean values of the overlapping pixels were used. The aerosol optical thickness and the Angstrom exponent composite maps are shown in figure 1 and 2.

From the two composited maps, it is apparent that there are missing holes in the maps. This was largely due to the abundance of cloud and sun glint pixels. Nevertheless, the two maps shows a hint of the recent forest fires over the region. The optical thickness was relatively high near to Sumatra and Kalimantan where the fires occurred, indicating a higher aerosol particleulate concentration. The optical thickness over these regions was about 0.25 to 0.7 and the Angstrom exponent á ranges from 0.3 to 1.0. The Angstrom exponent also tends to be higher near Sumatra and Kalimantan, indicating the presence of finer aerosol particles. However, this observation has not been validated by ground measurements. Comparison with aerosol maps from TOMS and Level2 and Level3 Products from NASA MODIS processing facility could be done. The problem of missing holes could be overcome by compositing more scenes, however this would result in some loss of the temporal information.

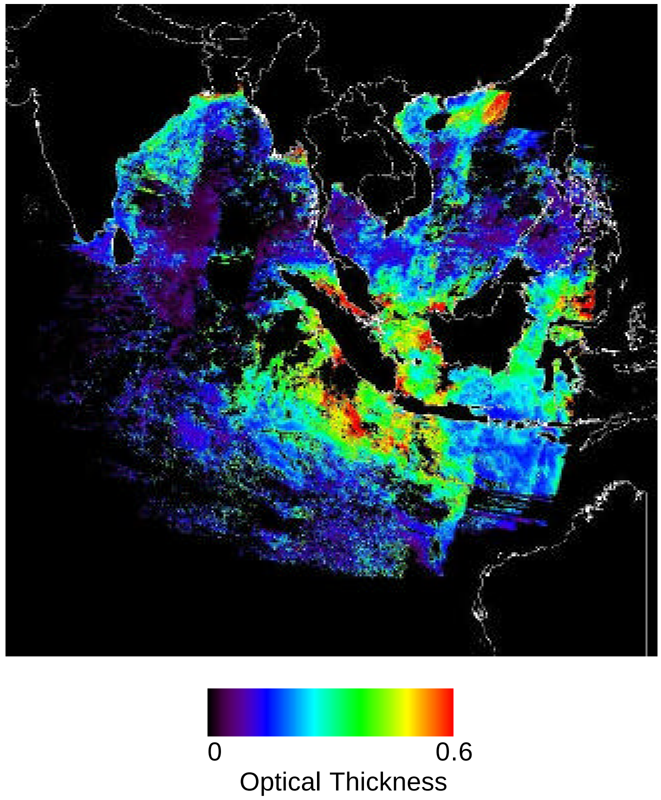

Figure 1 . Compsite map of aerosol optical thickness

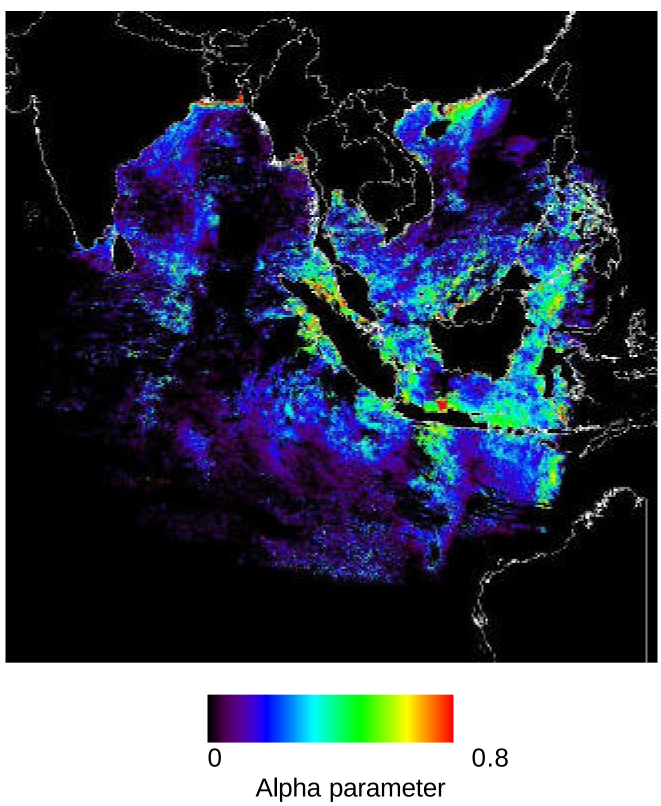

Figure 2 . Compsite map of alpha parameter

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