A METHOD FOR DERIVING AEROSOL OPTICAL DEPTH FROM METEOROLOGICAL SATELLITE DATA

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ABSTRACT

Aerosols are important agent of radiative forcing and climate disturbance, especially in a polluted environment. In general, the impact of aerosol on the climate depends on aerosol optical properties. One of important aerosol optical properties is aerosol optical depth (AOD). In general, AOD can be measured using ground-based sunphotometers. However, it is costly to deploy such instruments over a large area. Due to a lack of comprehensive measurement on a global scale, retrieval of aerosol information from some instruments on board satellites (e.g. MODIS and POLDER) has been developed. However, aerosol information from such satellites has relatively short historical records. In addition, such information is available only once or twice a day. Therefore, in this work, we propose a method for deriving AOD from meteorological geostationary satellite data. This is because geostationary satellites have advantage that they have longer historical data and their data are available on the hourly basis. According to the proposed method, a radiative transfer model, namely 6S, was used to construct series of look up tables (LUT) which contained pre-computed datasets including earth-atmospheric reflectivity, aerosol information and surface albedo. The satellite images in a visible channel were used to calculate the earth-atmospheric reflectivity data and these data were later employed as the main input of the method. In addition, the infrared images from the satellite were also used to identify cloud scene over the area. The value of AOD, which makes the value of the earth-atmospheric reflectivity from the LUT matching to the earth-atmospheric reflectivity obtained from the satellite data, will be considered as the true AOD. For the validation, the calculated AOD from this method was compared with the ground-based AOD measurements from NASA-AERONET. It was found that the measured and calculated AOD were in reasonable agreement.

Keywords: aerosol optical depth, radiative transfer, satellite data.

1 INTRODUCTION

Aerosols are small solid or liquid particles in suspension in the atmosphere [1]. Aerosols play very important role in the atmospheric stability and can affect solar radiation reaching the earth's surface. One of important aerosol optical properties is aerosol optical depth (AOD). The depletion of solar radiation due to aerosols depends on AOD. This property is known to be highly variable in space and time, which impacts on the change of solar radiation [2]. Although, AOD can be measured using ground-based instruments such as sunphotometers and spectroradiometer, but the spatial distribution of aerosol data is still limited because there are no dense network measurements over the large region.

In this work, we propose a method for deriving AOD from meteorological geostationary satellite data. This technique based on a radiative transfer model 6S which used the atmospheric constituents as input parameters and stored these values in a look-up table (LUT). Visible and infrared satellite imageries collected from MTSAT satellite for the period of 2011–2015 were used as the main inputs to the algorithm. The AOD from this method was validated with that from the NASA-Aerosol Robotic Network (NASA-AERONET) measurement at 4 meteorological monitoring stations in Thailand.

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2 METHODOLOGY

2.1 Descriptions of the proposed method

For estimating the aerosol optical depth, a radiative transfer program called 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) [3] was utilized to generate a library of pre-computed earth-atmosphere reflectivity and brightness temperature seen by satellites. These earth-atmosphere reflectivity and brightness temperature represent the signals in visible and infrared bands observed by the satellite. The data calculated from the 6S were stored in a look-up table (LUT). The inputs involved in the LUT calculations consist of atmospheric parameters namely solar zenith angle, surface albedo, aerosols optical depth (AOD) and aerosol types.

It is almost impossible to evaluate AOD using satellite observation over the cloud layers, therefore only cloud free images are used in this estimation. Cloudless pixels were identified by observing the darker pixels of the visible images. In combination with the values of cloud top temperature identified by using brightness temperature data obtained from the infrared channel, the cloudless pixels were all determined as resulting images.

To obtain AOD, all input parameters such as solar zenith angle, surface albedo, the satellite-derived reflectivity including aerosol properties over the given pixels have to be

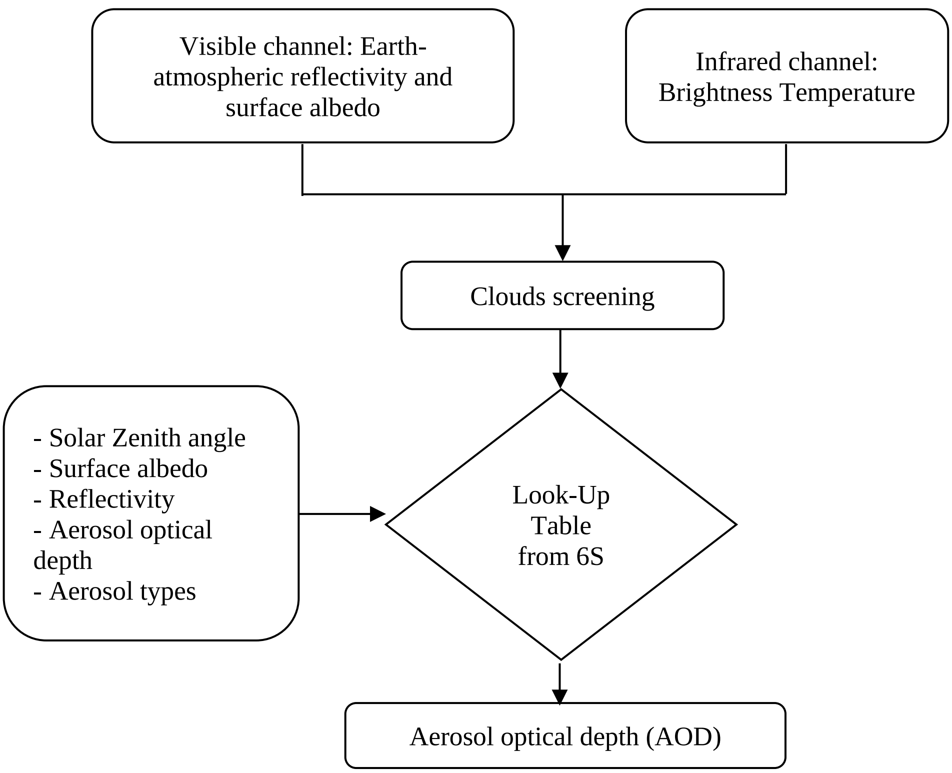

Figure 1: Schematic diagram of the method for estimating the AOD.

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provided at the first step. The value of AOD, which makes the value of the earth-atmospheric reflectivity from the LUT matching to the earth-atmospheric reflectivity obtained from the satellite data, will be considered as the true AOD. The schematic diagram for deriving AOD is shown in Fig. 1.

2.2 Processing of satellite data

The satellite data used in this work are hourly geostationary satellite images in both visible and infrared channels from Multifunctional Transport Satellites (MTSAT) satellite from January 2011 to December 2015. The visible satellite images contains pixels. Each pixel has information in the form of grey level. The value of the grey level is quantified in term of 8-bit digital counts which represent a combination of 256 values ranging between 0 and 255. Each pixel from the visible channel has a spatial resolution of 3 km × 3 km, whereas the infrared images contain 10-bit digital counts with a spatial resolution of 5 km × 5 km. Both visible and infrared satellite images were converted into earth-atmospheric reflectivity and brightness temperature, respectively, using calibration tables provided by a satellite data agency.

2.3 Validation

The AOD values estimated from this method were compared with the ground-based AOD measurements by NASA-AERONET [4] at 4 sites in Thailand namely, Chiang Mai (18.78°N, 98.98°E), Ubon Ratchathani (15.25°N, 104.87°E), Nakhon Pathom (13.82°N, 100.04°E) and Songkhla (7.2°N, 100.60°E). The data processing and quality control were performed daily at the central processing facility of NASA-AERONET [5].

3 RESULTS AND DISCUSSION

The validation between monthly average AOD obtained from this method with those from the measurements gave a reasonable agreement, with root mean square difference (RMSD) of 26%. After the validation, the method was used to calculate AOD over Thailand from a six-year period (2011–2015) of the MTSAT data. The results are displayed as long-term monthly average maps representing spatial distribution of AOD as shown in Fig. 2.

From the monthly maps, it can be seen that the feature of high AOD exhibits in dry period (December–April), while the values of low AOD presents mostly during rainy period (June–September) of Thailand. It is also observed that the feature of high aerosol loads can be obviously seen mainly in the northern part of the country due to intensive biomass burning in this region. A decrease in the AOD distribution begins from June and continues toward this wet season is mainly due to rains and during the monsoon season, washing out aerosols from the atmosphere.

4 CONCLUSION

A method for deriving aerosol optical depth (AOD) from visible and infrared imageries has been proposed. This approach is based the look-up table obtained from the 6S radiative transfer model. The comparison between the estimated and measured AOD is in reasonable agreement, with root mean square difference of 26%. Long-term average AOD maps over Thailand were generated using this method. The feature of high AOD was observed over northern region of Thailand during the dry period due to biomass burning, while low AOD presented throughout the country in the wet season.

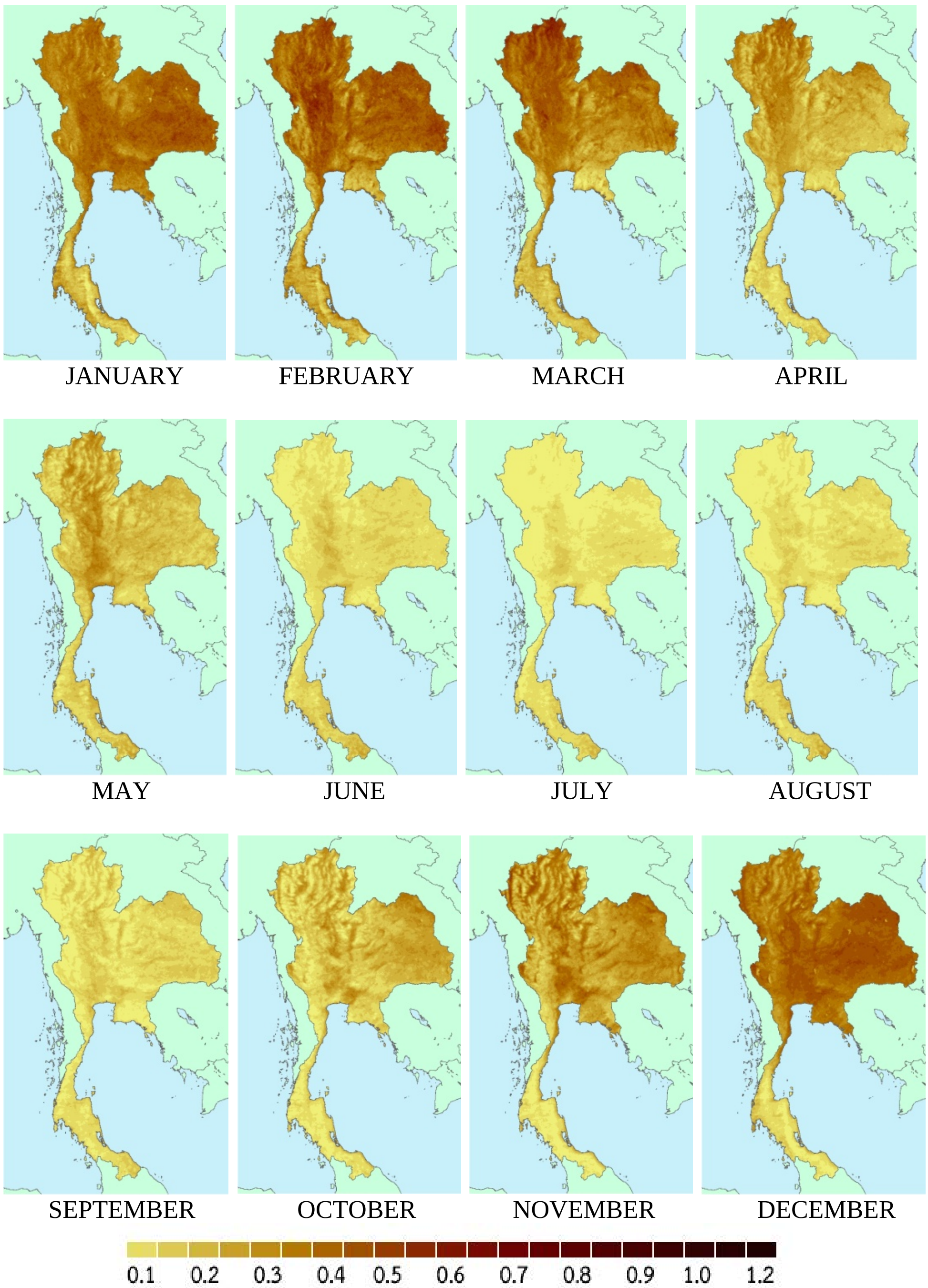

Figure 2: Long-term monthly average of AOD over Thailand.

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