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Comparison of spectral ultraviolet irradiance measured from satellite and ground-based instrument at Nakhon Pathom province

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Abstract. In this study, comparisons of spectral ultraviolet irradiance at 305, 310, 324 and 380 nm at the overpass time retrieved from OMI/AURA satellite with that from ground-based measurements were performed at Nakhon Pathom (13.82ºN,100.04ºE), Thailand. The analyzed data period comprised from 1 January 2010 to 31 December 2015. The comparison results clearly showed the overestimation of satellite data with root mean square difference (RMSD) between 22.9 and 48.9%, and mean bias difference (MBD) between 5.3 and 39.8% for all sky conditions, and reduced to 10.6-40.5% and 0.18-34.9% for clear sky conditions. Further results showed that the differences between the two datasets depend on atmospheric aerosol loads and clouds.

1. Introduction

The solar ultraviolet (UV) radiation is a small part of electromagnetic radiation which its wavelength ranges from 100-400 nm. Due to the biological effect, the UV radiation can be divided into three types; UV-A (315-400 nm), UV-B (280-315 nm) and UV-C (100-280 nm). Only UV-A and UV-B can reach the earth surface while UV-C is mostly absorbed by stratospheric ozone and cannot incident the surface. UV-A and UV-B have both positive and negative impacts on human life, animals and plants. For example, UV-B can synthesis vitamin D in human skin and by contrast, it can cause skin cancer. For these reasons, surface UV irradiance data is very important. This data can be retrieved from ground-based and satellite measurements. Although the ground-based measurement is the most accurate solution for obtaining UV radiation data, ground-based measurement is very scarce as it is costly. Therefore, satellite data is an alternative approach as it can provide the data globally. The validation of satellite data have been performed in several studies. For example, the validation of the daily erythemal UV doses from satellite products [1] and spectral UV radiation [2] were carried out in Europe. For Thailand, the differences of the UV index [3] and also erythemal UV doses [4] were presented. Thus, in this study, spectral UV irradiance at 305, 310, 324 and 380 nm from ground-based measurement and Ozone Monitoring Instrument (OMI) product in a tropical environmental of Thailand were compared. In addition, effects of cloud and aerosol on the difference of the two datasets were also analyzed.

2. Measurement and Data

2.1. Ground-based data

The ground-based spectral UV irradiance data used in this study were measured by a spectroradiometer (Bentham, model DMc150) installed at Faculty of Science, Silpakorn University, Nakhon Pathom (13.82°N, 100.04°E), Thailand, as shown in figure 1. This instrument was used to measure the spectral irradiance from 260-420 nm with a resolution of 1 nm.

Figure 1. The Bentham spectroradiometer installed at Faculty of Science, Silpakorn University, Nakhon Pathom, Thailand.

The signal retrieved every 10 minute was recorded by using a PC. The signal was then converted into spectral UV irradiance using its sensitivity as follows:

$$I_{\lambda} = \frac{c_{\lambda}}{s_{\lambda}} \tag{1}$$

where I_{λ} is spectral UV irradiance (mW/m^2/nm), c_{λ} is signal at each wavelength (nA) and S_{λ} is sensitivity of each wavelength (nA/nm/mW/m^2). The spectral UV data at 305, 310, 324 and 380 nm matching the OMI/AURA satellite product were averaged within ±30 minute of the OMI overpass time during 1 January 2010 to 31 December 2015.

Apart from the spectral UV data, aerosol optical depth (AOD) at 340 nm measured using a sunphotometer (Cimel, model CE318) installed at the site was collected from the Aerosol Robotic Network (AERONET) website. Cloud transmission factor (CLT) was also calculated as follows:

$$CLT = \frac{UV_{measured}}{UV_{clear}} \tag{2}$$

where $UV_{measured}$ is UV irradiance at 340 nm measured by the Bentham spectroradiometer under actual sky conditions and UV_{clear} is UV irradiance at 340 nm under clear sky condition calculated from UVSPEC radiative transfer model. In addition, sky conditions were classified by using sky images taken by a sky view (Prede, model PSV100) installed at the site during the five year period.

2.2. Satellite data

OMI is one of instruments onboard the NASA EOS/AURA satellite which is a sun-synchronous polar orbit. It measures reflected and backscattered solar radiation in the range of 270-500 nm, with a spatial resolution of 13 km×24 km at nadir. One of the OMI/AURA products is overpass time spectral irradiances at 305, 310, 324 and 380 nm, which is around 1 pm - 3 pm (local time) of the studied site. These data from 1 January 2010 to 31 December 2015 were retrieved and used to compare with the ground-based data.

3. Methodology

To validate the OMI spectral UV product, the OMI overpass time data at 305, 310, 324 and 380 nm were plotted against those from the ground-based data under clear sky and all sky conditions. Then root mean square difference (RMSD) and mean bias difference (MBD) were calculated to determine the differences between the two datasets.

For the study of the influences of the atmospheric parameters, the ratios of the ground-based data to the satellite data for the four wavelengths were calculated. If the ratio equals 1, it means that the satellite data is equal to the ground-based data. Then the ratio were plotted with the aerosol optical depth for clear sky conditions and with the cloud transmission factor for all sky conditions. Finally, the changes of the ratios for each atmospheric parameter were analyzed.

4. Result and discussion

The comparisons between the spectral UV at the four wavelengths from OMI and ground-based measurements were shown in figure 2. It can be seen that the OMI data overestimated the ground-based data for all wavelengths with the RMSD ranging from 22.9-48.9% and MBD from 5.3-39.8% for all sky conditions, and 10.6-40.5% and 0.18-34.9% for clear sky conditions.

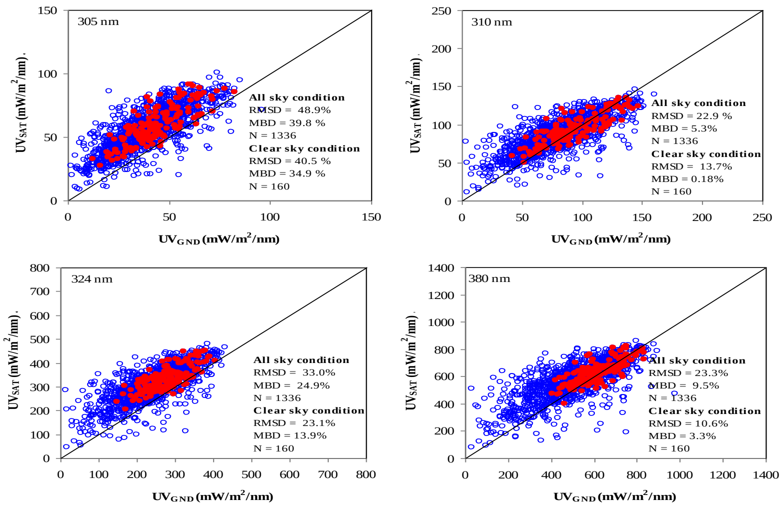

Figure 2. Comparison between the satellite-based (UV_{SAT}) and ground-based (UV_{GND}) overpass time spectral UV under clear sky (•) and all sky conditions (o).

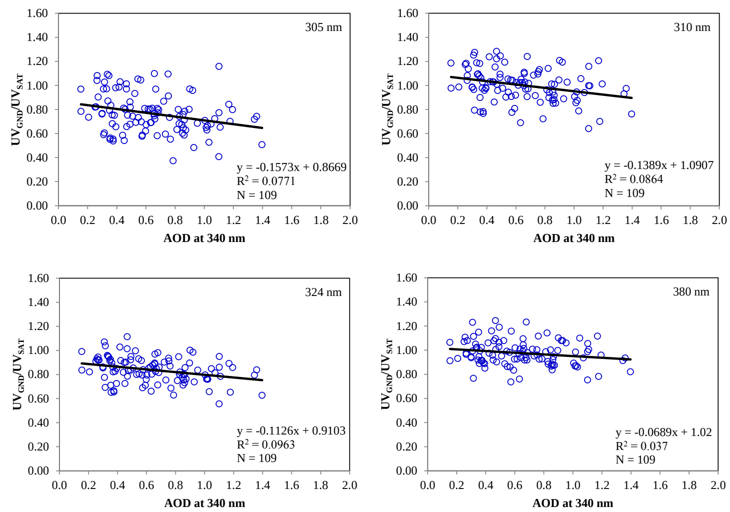

Figure 3. Relationship between the ratio of ground-based (UV_{GND}) to satellite (UV_{SAT}) spectral UV at overpass time and the aerosol optical depth.

These differences may be caused by the mismatches of time and space of the two datasets. In addition, the overestimation of the satellite data can be obtained as a result of cloud and aerosol contamination which can be seen in figure 3 and figure 4. The relationship between the ratio of the ground-based data to the OMI data and the aerosol optical depth for each wavelength under clear sky conditions was shown in figure 3. The ratio decreases from 1 to 0.5 when the atmospheric aerosol increases especially for shorter wavelengths. For the influence of cloud, figure 4 presented that when it is no cloud (CLT equals one), the OMI data is equal to the ground-based data, while the ground-based data is almost half of the OMI data when it is overcast

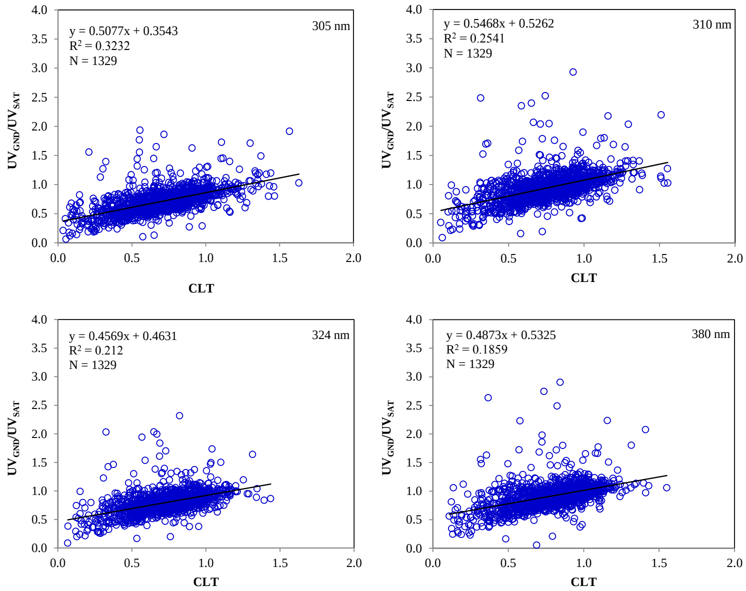

Figure 4. Relationship between the ratio of ground-based to (UV_{GND}) satellite (UV_{SAT}) spectral UV at overpass time and the cloud transmission factor.

5. Conclusion

The comparisons of overpass time spectral UV at 305, 310, 324 and 380 nm from OMI/AURA satellite and the Bentham spectroradiometer at Nakhon Pathom, Thailand were analyzed. The results showed the overestimation of the OMI data for all wavelengths, even under clear sky conditions. Thus, in order to correct the satellite-derived UV data, the influences of aerosols and clouds on the UV data should be examined. Finally, The linear relationships between the ratio of the satellite-derived to measured UV and aerosols and clouds were obtained as a result.

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