Validation of OMI UV measurements against ground-based UV measurements in Kampala, Uganda

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Abstract

We present solar ultraviolet (UV) irradiance data measured with a NILU-UV instrument at a ground site in Kampala (0.31° N, 32.58° E), Uganda for the period 2005 - 2014. We retrieved UV index values from OMI UV irradiances and validated them against the ground-based UV index values obtained from the NILU-UV measurements. The UV index values were found to follow a seasonal pattern with maximum values in March and October, and minimum values in June-July and November. OMI inferred UV index values were overestimated with a mean bias of about 28% under all-sky conditions, but the mean bias was reduced to about 8% under clear-sky conditions when only days with radiation modification factor (RMF) greater or equal to 65% were considered. However, when days with RMF greater or equal to 70, 75, and 80% were considered, the mean bias between the ground-based and OMI inferred UV index values was reduced to 5, 3, and 1%, respectively. In the validation we identified clouds/aerosols, which were present in 88% of the measurements, as the main cause of OMI overestimation of the UV index.

Methodology

For a given biological action spectrum A(λ), the UV dose rate dD/dt, is defined as

$$\frac{dD}{dt}=\int_0^\infty A(\lambda)F(\lambda)\,d\lambda\approx\sum_{i=1}^{m}A_iF_i\Delta\lambda_i \qquad (1)$$

where m is the number of instrument channels. The action spectrum A(λ) for erythema is the widely used CIE action spectrum (McKinlay and Diffey, 1987). The NILU-UV instrument has five UV channels and the CIE weighted UV dose rate may be calculated by requiring that

$$\sum_{i=1}^{5}a_iV_i=\sum_{i=1}^{m}A_iF_i\Delta\lambda_i \qquad (2)$$

where a_i are coefficients that are determined by using a radiative transfer model to compute the spectra necessary to solve Eq. (2) (Dahlback, 1996).
The UV index is obtained by dividing the CIE weighted UV dose rates (in Wm^{-2}) by 25×10^{-3} Wm^{-2} and is a unit less quantity (WHO, 2002).

The change in UV levels caused by surface reflections and presence of clouds and aerosols can be expressed by the radiation modification factor defined as

$$RMF=\left(\frac{V_i(\theta)_{meas}}{V_i(\theta)_{cal}}\right)\times100\% \qquad (3)$$

where $V_i(\theta)_{meas}$ is the measured irradiance at a certain wavelength λ and solar zenith angle θ, and $V_i(\theta)_{cal}$ is the corresponding irradiance calculated for clear-sky conditions and zero surface albedo at the site altitude using a radiative transfer model (Lindfors and Arola, 2008).

Results

Fig 1: Site Location (Kampala, Uganda). (Courtesy of http://www.nationsonline.org/oneworld/map/uganda-map.htm)

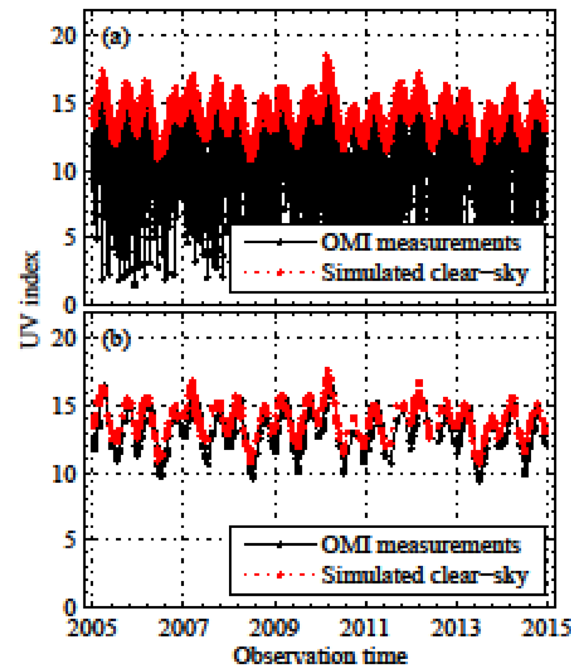

Fig. 2: (a) Time series of the simulated clear-sky noon UV index and the OMI overpass UV index. (b) Time series of the simulated clear-sky noon UV index and the OMI overpass UV index under clear-sky conditions. Only days with reflectivity less than 10% were considered in (b).

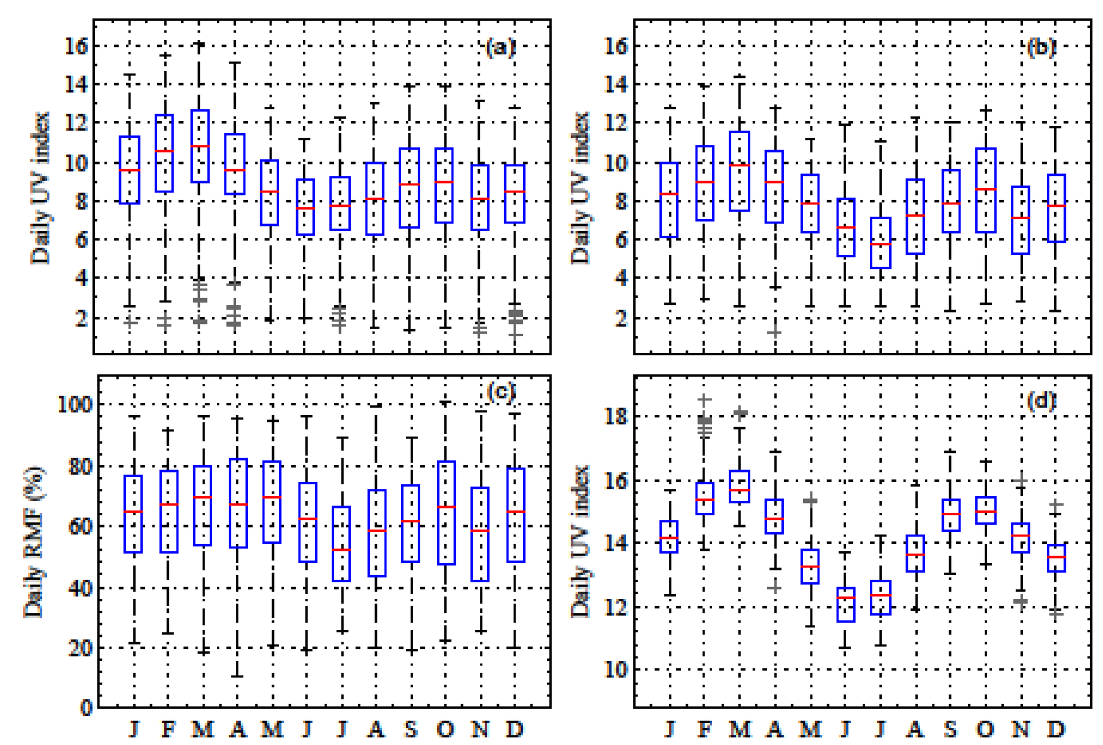

Fig. 3: Box-and-whisker plots of daily (a) OMI overpass UV index values, (b) ground-based UV index values averaged over a half-hour period starting 15 minutes before the OMI overpass time, (c) RMF values, and (d) simulated solar noon clear-sky UV index values.

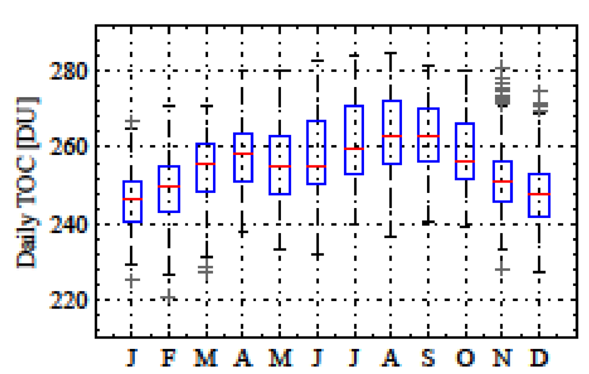

Fig. 4: Box-and-whisker plots showing daily total ozone column values inferred from OMI measurements over Kampala.

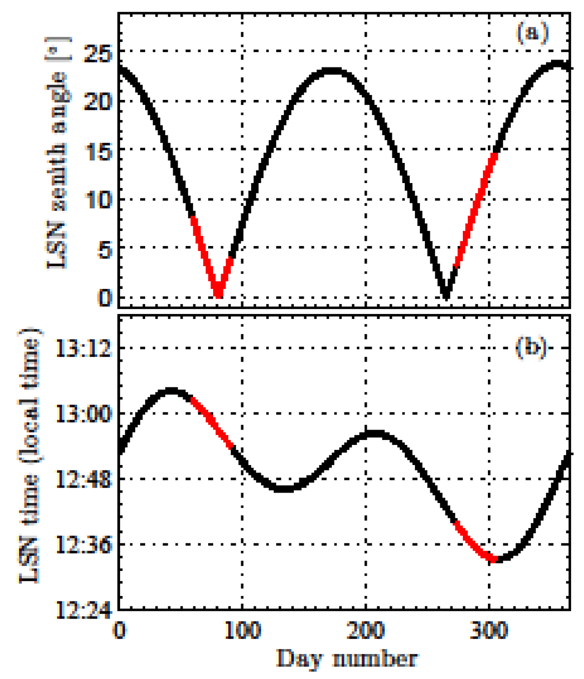

Fig. 5: Variation of (a) local solar noon (LSN) zenith angle and (b) LSN time (local time) during the year in Kampala. The red parts show the results for day 60 to day 90 (March) and day 274 to day 304 (October). The OMI overpass time was at about 13:45 local time.

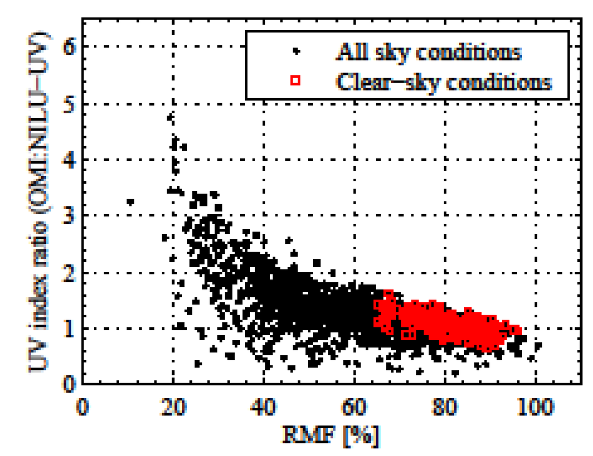

Fig. 6: The ratio of OMI overpass UV index to ground-based UV index against radiation modification factor (RMF) retrieved from NILU-UV measurements.

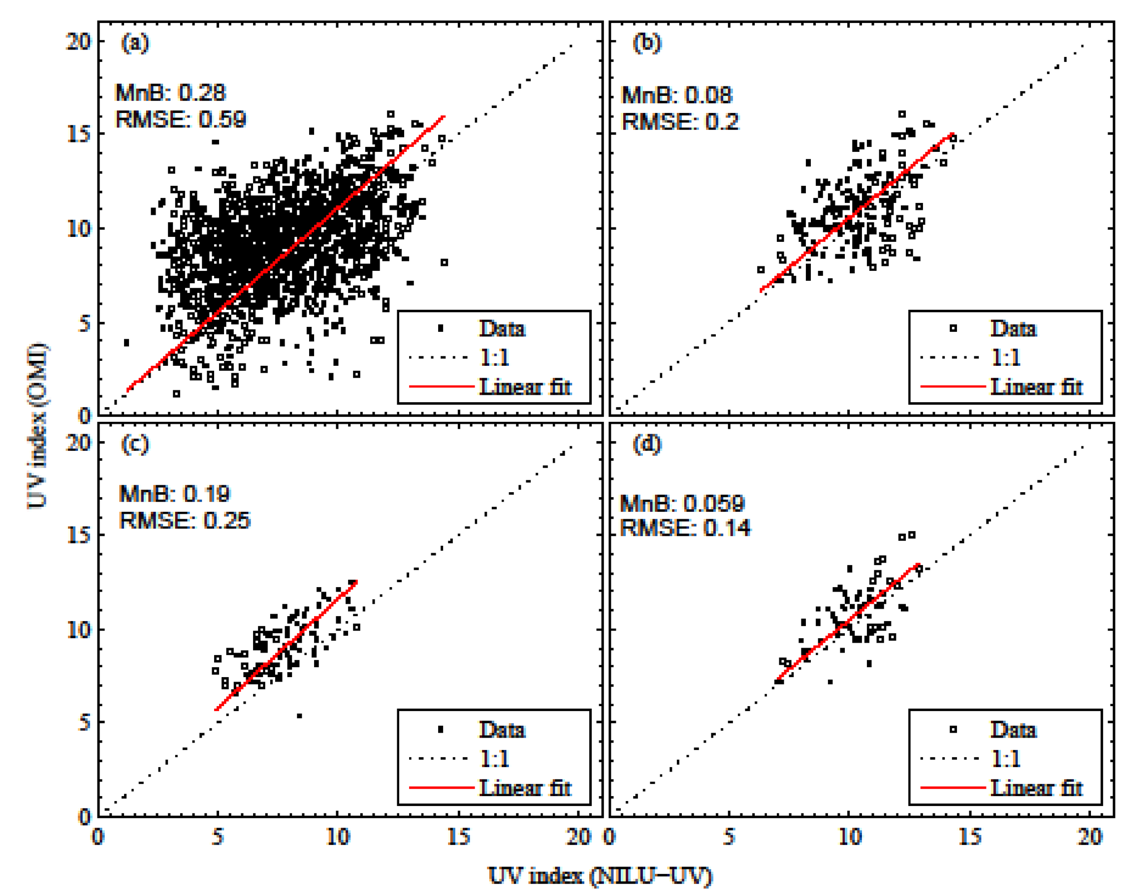

Fig. 7: Scatter plots of OMI overpass UV index versus ground-based UV index; (a) under all-sky conditions, (b) under clear-sky conditions, (c) monthly average under all-sky conditions, and (d) monthly average under clear-sky conditions.

Conclusions

The UV index values were found to follow a seasonal pattern with maximum values in March and October, and minimum values in June-July and November. The seasonal variation of the UV index was attributed to a corresponding seasonal variation in the local solar noon (LSN) zenith angle, which led to peak UV index values in March and October, and to variation in the Sun-Earth distance, which led to the difference between the minimum UV index values in June-July and November-January.
The seasonal variation in the Sun-Earth distance partly accounted for a higher peak UV index value in March than in October.
The seasonal variations in the total ozone column value, RMF, and OMI overpass time relative to the LSN time, were found to account for the rest of the observed seasonal variation of the UV index.

We found that the OMI retrieval algorithm overestimates the UV index with a mean bias of about 28% under all-sky conditions, which reduces to 8% under clear-sky conditions (with RMF values greater or equal to 65%). When days with RMF values greater or equal to 70, 75, and 80% were considered, the mean bias agreement between OMI overpass and ground-based UV index values was found to be 5, 3, and 1%, respectively.

Clouds and aerosols were identified to be the main cause of the overestimation of the UV index by the OMI retrieval algorithm. Among all measurement days in Kampala, only about 12% were clear-sky days (with RMF values greater or equal to 65%).

Acknowledgement

We acknowledge the efforts of the scientists who made The Ozone Monitoring Instrument (OMI) Project a success. This work was supported by the Norwegian Research Council and the Norwegian Programme for Development, Research and Education (NUFU) through the project number 33/02.

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