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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Comparison of total ozone and erythemal UV data from OMI with ground-based measurements at Rome station" *by* I. Ialongo et al.

**I. Ialongo et al.**

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"Comparison of total ozone and erythemal UV data from OMI with ground-based measurements at Rome station" by Ialongo et al.

*Author comments are in italic*

*Reviewer 2*

*We thank reviewer 2 for the positive judgement and the comments. The manuscript was rewritten as suggested by the referee. Each point of the referee comment will be discussed.*

1) The interpretation of the OMI bias in erythemal radiation intensity as caused by absorbing aerosols is however not supported by any experimental or modelling evidence. The study would be more interesting and informative if this hypothesis was further investigated. If experimental aerosol information is available for the site, it could be examined if the OMI/ground difference is correlated with the aerosol absorption optical depth.

*The role of aerosols was investigated by means of AOD at 320.1 nm derived from Brewer measurements. In the section 2.1 (P2386 L20) the following statements will be included in the revised manuscript: "Aerosol Optical Depth (AOD) retrievals from Brewer spectrophotometer were obtained using the Langley plot method as described in Sellitto et al. (2006). AODs at 320.1 nm determined at noon during cloudless days from September 2004 to July 2006, will be used to analyse the causes of the difference between OMI and ground-based UV data."*

*The new reference "Sellitto, P., di Sarra, A. G., and Siani, A. M.: An improved algorithm for the determination of aerosol optical depth in the ultraviolet spectral range from Brewer spectrophotometer observations, J. Opt. A: Pure Appl. Opt., 8, 849-855, doi:10.1088/1464-4258/8/10/005, 2006" will be included.*

*In section 2.3 the statement at page 2389 L9 will be modified as follows: "The values of (yi-xi)/xi were analysed as a function of the AOD at 320.1 nm at different Solar Zenith Angle (SZA)."*

*The discussion of the comparison between OMI and ground-based UV data taking into account the AOD is reported in the section 3 of the revised manuscript (see at the end of the answers).*

*The conclusions on the comparison between OMI and ground-based UV data taking into account the AOD is reported in the section 4 of the revised manuscript (see at the end of the answers).*



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*The modified figures 6 and 7 (now figures 4 and 5, respectively), including the relative difference between OMI and ground-based EDR as a function of AOD, will be reported in the revised manuscript.*

2) A fundamental difference between a ground measurement and a satellite-derived irradiance is that the former measures the irradiance at a point while the latter is by nature an average over a certain area (the satellite product pixel). Because of this, other factors than aerosols can lead to systematic differences such as cloudiness, altitude or albedo for which the conditions at the measurement site may not be representative of the pixel area. For instance, a systematic difference between the cloudiness over land and sea can a priori lead to a bias if the pixel containing Rome also includes a fraction of sea. A detailed analysis would probably be complex but I think this point should be at least briefly discussed. In this regard, more information on the spatial resolution at which the OMI UV products are generated would be desirable. Possibly related to this aspect, there is a sentence at page 2389: Otherwise, the comparison does not show any significant dependence on the distance pixel-GB. This should be explained. Does the variability of the distance pixel-GB result from the swath drift? How much does it vary?

*The discussion about the role of OMI pixel on satellite estimates will be reported in the sessions 3 and 4 in the revised manuscript (see at the end of the answers).*

3) I regret that all figures on the UV comparisons are restricted to clear sky days. My opinion is that figures that would show the results for all days would advantageously replace figures 1 and 2, which do not bring essential information to the study topic.

*As suggested by the referee 2, in the section 3 the Figures 1 and 2 will be removed and the comparison between ground and OMI UV data taking into account all sky conditions and only clear sky days will be included in the revised manuscript as follows:*

*In section 2.1: "The Figure 1 shows the comparison between Brewer and YES EDRs at local noon under clear sky (light blue circle) and under all sky (black circle) conditions.*



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*During clear sky days the correlation coefficient r is 0.97 and the bias is -2% . The value of r increases to 0.95 and the bias becomes -3% when all conditions were considered. The absolute value of the bias is lower than the estimated accuracy of the Brewer 067 UV irradiance (about 5%). Both Brewer and YES datasets were used for OMI validation exercise."*

*In section 2.3 the paragraph at page 2389 L3 will be modified as follows: "Ground-based Brewer daily mean total ozone measurements were compared with both OMI-TOMS and OMI-DOAS ozone data. Brewer EDRs at local noon were compared with OMI EDRs, under clear sky and all sky conditions. Furthermore, EDRs at noon and EDDs from YES radiometer were compared with OMI satellite-derived data, in both clear sky and all sky conditions."*

*The results of the comparison between OMI and ground-based UV data taking into account both clear sky and all sky conditions days will be reported in the modified section 3 in the revised manuscript (see at the end of the answers).*

*Table 1 will be modified in the revised manuscript by also including the bias and r coefficient for all sky conditions.*

*The modified figures 3,6,7 and 8 (now figures 1,4,5 and 6, respectively), including data under all sky and only clear sky conditions, will be reported in the revised manuscript.*

*The conclusions about the comparison between OMI and ground-based UV data taking into account both clear sky and all sky conditions days will be updated in the section 4 of the revised manuscript (see at the end of the answers).*

4) The bias dependence on the solar zenith angle would support the absorbing aerosols attenuation hypothesis. It is apparent with respect to the Brewer dose rates but practically absent when comparing with the YES data. Is there a difference in the two instruments characteristics that would explain this? In this situation, I think that the SZA dependency of the OMI bias can only be ascertained if there is a reason to



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believe that the Brewer measurements are more reliable.

*In section 3 the figures showing the dependence of OMI/Brewer and OMI/YES EDRs on SZA will be replaced with the figures showing the dependence on AOD taking into account data with SZA>55° (Figures 4 and 5 in the revised manuscript). All changes are included in the modified sections 3 and 4 of the revised manuscript (see at the end of the answers).*

5) At page 2389, the authors state "Furthermore, the difference can be related to the fact that the time of overpass and conditions during overpass do not correspond to time and conditions at solar noon (Weihs et al., 2006)." In order to contribute to the bias, the difference in the conditions between noon and the overpass time must have a systematic nature. Can the authors comment on what it could be, apart from the direct effect of solar zenith angle, which I imagine is corrected for in the OMI product.

*In order to estimate the uncertainties due to the difference between the OMI overpass time and solar noon the optical depth measurements were used to analyse the magnitude of changes in atmospheric transmittance during the time period between solar noon and OMI overpass.*

*The discussion of the uncertainty due to the difference between the OMI overpass time and the local solar noon will be reported in the modified sections 3 and 4 of the revised manuscript (see at the end of the answers).*

Minor remarks: Absorbing aerosols (e.g. organic carbon, smoke and dust) or trace gases (e.g. NO2, SO2) are known to lead an overestimation of the surface UV irradiance (Krotkov et al., 1998; Arola et al., 2005); It is neglecting the effects of absorbing aerosols and trace gases that leads to the overestimation.

*This sentence (Page 2387 L23) will be modified as follows: "Krotkov et al. (1998) showed that absorbing aerosols can lead to an overestimation in the satellite-derived UV flux ranging from a few percent to 50%; Arola et al. (2005) found that the positive*



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*bias between TOMS and Brewer UV irradiances can be reduced by more than 15%, if an absorbing aerosol correction is applied."*

p 2382 ecosistem => ecosystems; p 2383 continous => continuous

*It will be done*

p 2384 Antartic => Antarctic;

p 2387 tecnique => technique;

p 2389 sistematically => systematically;

p 2389 slighly => slightly;

*It will be done*

If the publishing language is UK English: *The language is UK English*

p 2386 behavior => behaviour

*It will be replaced.*

Section 3 from page 2388 L13 will be modified in the revised manuscript as follows:

"The validation results are summarized in Table 1 in terms of bias and correlation coefficient (r). The daily means of Brewer total ozone measurements were compared with OMI-TOMS ozone (Fig.2) from September 2004 to December 2006 and OMI-DOAS ozone (Fig.3) from October 2005 to December 2006, for all sky days. OMI ozone slightly underestimates ground-based ozone with a negative bias around -1.8% for OMI-TOMS and -0.7% for OMI-DOAS. Balis et al. (2006) showed that OMI-DOAS comparisons exhibit a solar zenith angle dependence; in this study, any significant dependence on SZA was observed.

Figure 4 (upper panel) shows the comparison between Brewer and OMI EDRs at local noon taking into account all sky (black circle) and clear sky (light blue circle) conditions from September 2004 to July 2006. It can be noticed a positive bias larger in case of all



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sky conditions (33%) than in cloudless conditions (28%). The correlation coefficient (r) of 0.96 in all sky conditions, increases to 0.99 when clear sky days were selected. The comparison with OMI using EDRs at local noon from YES radiometer (Figure 5 upper panel) shows a bias of 30% and r=0.91 under all sky conditions (black circle). When the analysis was restricted to cloudless skies the bias becomes 23% and r=0.99 (light blue circle).

The OMI overestimation of ground-based UV measurements may be partly explained with the fact that satellite instruments do not probe well the lower atmospheric layers of urban sites where aerosols play an important role. Because of this, the OMI UV retrievals were compared to ground-based data looking at the aerosol effect. Figures 4 and 5 (lower panels) show the relative difference between ground UV data (Brewer and YES EDRs, respectively) and OMI EDRs as a function of AOD at 320.1 nm for clear sky days. Only data at large SZA (>55°) showed a moderate (r=0.44 for Brewer) or large (r=0.57 for YES radiometer) correlations, according to Cohen (1988). Looking at EDDs for all selected days (Fig. 6 black circle) the bias was 23% and r=0.97; a small reduction in the bias value (21%) under cloudless conditions was observed (Fig.6 light blue circle).

The results of the comparison are summarized in Table 1: the positive values of bias show that OMI data overestimate ground-based measurements. Although for YES UV data the bias values are slightly smaller with respect to Brewer UV data, the difference between OMI and ground-based UV data is still large (bias>20%).

Similar results were found by Weihs et al. (2006) with UV measurements performed at Villeneuve d'Ascq (France) station (near urban site). Furthermore, Bais et al. (2007) confirmed that OMI-derived EDDs overestimate ground-based data by between 20% and 30% at three sites in Greece. Due to the lack of OMI UV data at the overpass time (13:45 Local Time) the comparison at noon can be affected by actual atmospheric conditions at the overpass time. AOD values during the time interval between solar noon and the OMI overpass time were taken into account in order to analyse the magnitude of changes in atmospheric transmittance. The mean relative difference between AOD at overpass time and AOD at local noon is -4% with a high variability (standard deviation larger than 50%). This result show that the difference in atmospheric conditions between local noon and OMI overpass time can affect the comparison between OMI and ground-based UV data.

Furthermore, a difference between ground-based (GB) and satellite UV irradiances is that ground-based instruments measure the irradiance at a single point while satellite products are an average over a given area (satellite pixel). Because of this, in addition to aerosols, variations of cloudiness, of altitude and of surface albedo within the pixel area can lead to a significant difference between ground-based and OMI UV data. The OMI pixel covers an area of 13 x 24 $km^2$ and the distance between the centre of the pixel and the station can vary from 1.7 km to 61.6 km; thus, the atmospheric conditions in an urban site as Rome may not be representative of the pixel area.

Finally, the OMI bias can also be due to the fact that OMI surface UV algorithm does not account for the effect of absorbing aerosols in the boundary layer, where the absorption by the aerosols can be important, mainly in an urban site (Krotkov, 1998; Arola, 2005)."

Section 4 from page 2388 L3 will be modified in the revised manuscript as follows:

"The results of OMI total ozone and erythemal UV data validation by using ground-based high quality measurements at Rome site were shown for all sky conditions.

The comparison of OMI retrieved ozone data with the daily mean ozone values from Brewer spectrophotometer 067 showed a good agreement for both OMI-TOMS (bias=-1.8%) and OMI-DOAS (bias=-0.7%) algorithms. In both cases, comparisons do not show any significant dependence on SZA. EDRs at local noon and EDDs retrieved from YES UVB-1 radiometer were derived from 2000 to 2006 at Rome site in all sky conditions. Noontime EDR retrievals from YES radiometer and Brewer 067 were compared showing a good agreement (bias=-2% for clear skies and bias=-3% for all skies).



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The comparisons between OMI and ground-based UV data (both Brewer and YES radiometer data) showed that, on average, OMI UV products exceed ground-based UV measurements by more than 20%. The comparison between OMI and Brewer EDRs at local noon showed a positive bias, larger in case of all sky conditions (33%) than in cloudless conditions (28%). Concerning YES radiometer EDRs, the bias is 30% under all sky conditions and 23% for clear sky days; a small reduction in the bias can be observed taking into account EDD data from YES radiometer (23% and 21% for all sky and clear sky days, respectively).

This discrepancy may be partly attributed to the fact that the satellite instrument does not effectively probe the extinction by the aerosols which can be important in the boundary layer, mainly in an urban site as Rome. It was observed that the correlation between the relative difference between ground-based and OMI EDRs and AOD at 320.1 nm taking into account data at SZA larger than 55° is moderate (r=0.44 for Brewer) or large (r=0.57 for YES radiometer).

The difference between OMI and ground-based instruments could also be due to the different atmospheric conditions between solar noon and overpass time. In this regard, the magnitude of changes in atmospheric transmittance was estimated to be -4% with a variability larger than 50%. In addition, the OMI spatial resolution (the distance pixel centre-GB station ranging from 1.7 to 61.6 km) may be insufficient to fully characterize the urban area of Rome.

Further investigations on satellite-derived OMI spectral UV data are required to give hints about the possible sources of uncertainty. Furthermore, EDRs at actual satellite overpass time will be compared with ground-based measurements, in order to decrease the uncertainty of satellite UV retrievals. Finally, the role of absorbing aerosols on OMI UV estimates is under investigation by means of the absorbing aerosol optical depth retrievals derived from Brewer UV irradiances and radiative transfer modelling."

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 2381, 2008.