

## **General comments**

The paper by Czerwińska et al provides useful information regarding the effect of an urban agglomeration on the levels of the solar UV irradiance. It highlights the importance of the aerosol optical properties for the determination of the UV irradiance that reaches the earth surface and has the potential to contribute in the better understanding of the complex interactions between aerosols, clouds, surface albedo and UV radiation in an urban environment. The authors compare the erythemal and UV-A1 (340-400 nm) doses measured by the Brewer spectrophotometers in Warsaw (52.3°N, 21.0°E) and Belsk (51.8°N, 20.8°E) and are trying to quantify the effects of differences in surface albedo, cloudiness, aerosol optical depth and aerosol single scattering albedo.

However, the main problem in the data analysis is that the effect of different latitude (thus of different SZAs for the measured UV doses) has not been removed (or quantified) properly leading to biases in the quantification of the effect of other factors (such as the aerosol SSA and the cloudiness). The effect of different latitude changes periodically in the year and is more pronounced in winter (higher SZAs, which means that the difference of 0.5° becomes more important). The authors considered the effect of different SZAs to be invariant during the year which is not correct. Thus, I suggest to re-analyze the data and either quantify the effect of different latitude properly (e.g. with the use of a radiative transfer model) or perform the comparison for standard SZAs.

The second important issue that has to be solved prior to publication in ACP is the large number of editorial, grammatical and linguistic errors in the manuscript. The authors have to try hard to improve the manuscript. If possible, I suggest that the manuscript should be edited by a native English speaker.

Additionally, I suggest reorganizing sections 3 and 4 as follows: 3.1. Comparison between measurements at Belsk, 3.2. Comparison between measurements at Belsk and Warsaw, 3.3. Quantification of the factors which are responsible for the differences, 3.4. Long-term change of the erythemal irradiance at Belsk. In section 3.3 you can include the numerical simulations (now section 3.3) and part of the discussion from section 4 (e.g. the results reported in P8, L15 – 31 regarding the effects of cloudiness). I also suggest moving figure 8 (and the relative discussion) in section 3.4 and expand the discussion. This way, I believe that it will be easier for the reader to follow the discussion.

The effect of different SZA (presented in paragraph 3.2) should be initially studied for UV-A1. Then, the combined effect of SZA and TO3 could be studied for the erythemal dose. Although the effect of SZA is stronger for lower wavelengths (due to stronger Rayleigh scattering and increased absorption by TO3 for larger SZAs) and the effects of SZA and TO3 on erythemal irradiance are not independent to each other, this way you could get a quantitative estimation regarding the effect of differences in TO3. However, the most effective way to quantify the effect of different TO3 is to study the ratios of UV-A1 and erythemal irradiance for specific SZAs (or small SZA intervals).

## **Specific comments**

Please define a specific acronym to use in the document for each Brewer. For example, Brewer with Serial Number 207 is referred as BS No. 207, BS 207 and BS207 (without defining what the number 207

is) at different points of the document. Please choose a single acronym and use it everywhere (in the manuscript and the figures). E.g. you could define at the beginning of the methodology section that each BS with serial number xxx will be referred as BSxxx and then refer to each Brewer the same way.

### **Abstract**

P1, L7-8: replace “well-know” with “well-known”

P1, L8: replace “cleaner” with “less polluted”

P1, L9-11: replace the sentence:

“The present study focuses on differences in the erythemal and UV-A1 (340-400 nm) doses measured by the Brewer spectrophotometers in Warsaw (52.3°N, 21.0°E) and at Belsk (51.8°N, 20.8°E), which is located in a rural region at a distance of about 60 km in the south-west direction from the city.”

With

“The present study focuses on differences between the erythemal and UV-A1 (340-400 nm) doses measured by the Brewer spectrophotometers in Warsaw (52.3°N, 21.0°E) and Belsk (51.8°N, 20.8°E). The latter is a rural region at a distance of about 60 km south-west of the city of Warsaw.”

P1, L18: replace “by larger aerosol absorption” with “mainly by larger aerosol absorption over Warsaw”

P1, L18-19: The meaning of the phrase: “It appears that a slightly increased optical depth of the urban aerosols and properties of clouds generated over Warsaw are less important for the UV attenuation.” is not clear at this point. I would suggest replacing with something like:

“Differences between the aerosol optical depth and cloud optical properties over the two sites are found to be less important.”

P1, L19-20: replace “In this work we are showing that the higher city surface albedo compensates for the solar UV attenuation caused by urban aerosol load in the city of Warsaw.”

With something like:

“We show that the higher surface albedo in Warsaw compensates for the stronger attenuation of the solar UV radiation by the urban aerosols.”

### **Introduction**

P2, L5: add appropriate references

P2, L6: add appropriate references

P2, L8: replace “depended” with “dependent”

P2, L11: replace “surface UV attenuation” with “attenuation of the solar UV radiation”

P2, L10-12: add references to support your statement that “The absorption by SO<sub>2</sub> (in the UV-B range) and NO<sub>2</sub> (mostly in the UV-A range) is important for the surface UV attenuation only in extreme concentrations of such gases.”

P2, L12: Replace “surface intensity of UV” with “intensity of the solar UV radiation at the earth surface”. Furthermore, in addition to the properties, the amount of aerosols and clouds also affect UV radiation.

P2, L12-14: Change the phrase: “The negative trends in these variables, found over many of the northern hemisphere mid-latitude sites in the 1980s and 1990s, lead to increases of both the UV-B and UV-A irradiance”

With

“Increases of both the UV-B and UV-A irradiance have been reported over several mid-latitude sites of the northern hemisphere since the beginning of the 1990s, which have been mainly attributed to decreasing attenuation by aerosols and clouds.”

P2, L15: Replace “An” with “The”.

P2, L15: Replace “the large urban agglomeration” with “large urban agglomerations”.

P2, L17: Replace “UV cloudless sky irradiances” with “cloudless-sky UV irradiances”. Also replace “its suburbs” with “a sub-urban area near Athens”.

P2, L19: Replace “The erythemal irradiance at the centre of Athens was 30% lower than at the suburbs with similar values of total ozone (TO<sub>3</sub>) for days with increased pollution in the air.”

With

“The erythemal irradiance at the centre of Athens was up to 30% lower than at the outskirt site during days with increased air pollution over Athens basin and similar values of total ozone (TO<sub>3</sub>) over the two sites.”

P2, L20-21: What you write here is not clear. Please be more specific. Do you mean differences from the measurements or differences by corresponding simulations over the Athens basin?

P2, L23: Delete “the” before “winter” and “summer”. Replace “Mexico” with “Mexico City”.

P2, L23-24: Are 9% and 21% the differences between the annual mean levels for winter and summer? Please be more precise.

P2, L24-25: “Corr et al. (2009) ... 0.7 – 0.85”. This sentence is not clear. Please rephrase.

P2, L26: Delete “atmospheric”

P2, L30: Delete “of aerosols”

P3, L3-8: Notice that for a typical Angström parameter of  $\sim 1.5$ , the differences in AOD becomes  $\sim 2$  times larger for UV-B wavelengths. I suggest that you should provide quantitative estimations of the changes in UV irradiance due to the reported differences in AOD (e.g. for a low SSA = 0.85) at this point, to prove that the reported differences in AOD do not induce large differences in UV irradiance. That can be easily achieved by performing modeling simulations. Furthermore, it should be mentioned that for organic particles, the absorption in the UV range may be even larger than that predicted by interpolating using the Angström parameter for the visible range of the spectrum (e.g. see Bais et al. (2015)\* and references therein).

\* Bais, A. F., R. L. McKenzie, G. Bernhard, P. J. Aucamp, M. Ilyas, S. Madronich, and K. Tourpali (2015), Ozone depletion and climate change: impacts on UV radiation, *Photochemical & Photobiological Sciences*, 14(1), 19-52, doi:10.1039/c4pp90032d.

P3, L4: Remove “,” after “stated”.

P3, L6: “the difference” instead of “it”

P3, L11: Delete “a specific”

P3, L14: Delete “at”

### **Methodology**

P3,L23: Replace “at Belsk (51.8°N, 20.8°E, 190 m amsl), which is located in a rural region” with “Belsk (51.8°N, 20.8°E, 190 m amsl). The latter is a rural region”

P3, L25: Replace “the area” with “an area”

P3, L28: Replace “spectra accuracy” with “spectral accuracy”

P4, L3: Please provide reference(s) regarding the fact that the estimated uncertainty in the erythemal irradiance is 5%.

P4, L8: In this section you describe how each Brewer (207 and 64) is calibrated. Was the calibration procedure for the two Brewers the same before and after BS207 was moved to Warsaw? Is BS207 also calibrated against BS017? Please add some more information to convince the reader that the changes in the ratio are not due to a change in the calibration procedure or due to change of the BS207 characteristics during transportation from the one site to the other.

P4, L11: Replace “The erythemal action spectrum follows CIE (1987)” with “The erythemal action spectrum is that suggested by the Commission internationale de l'éclairage (CIE) (CIE, 1987)”

P4, L13: Were there any criteria for the selection of the partly daily doses used for the comparison between Belsk and Warsaw? Is there a minimum amount of measurements (or measurements per 1 or 2 hours) below which the data are rejected? Calculation of the integral from only a small number of measurements and/or large gaps in the 3- or 6-hour period may lead to large differences between the

integrals for the two sites. If not already done, I would suggest using a filter (e.g. use only time intervals with at least one measurement per 1 - 2 hours).

P4, L15: How confident are you for your cloud detection method? Are there cloudy cases that cannot be detected? Can you estimate if, and in what extent, they affect your results?

P4, L23-30: The specific paragraph is carelessly written. Please try to re-write it more carefully.

## **Results**

Figure 1: Add some more information in the manuscript for LOWESS filter and/or proper references.

P5, L8-9: I think that the phrase “The most of the differences lie within  $\pm 5\%$  range” is not necessary here since in the previous paragraph the  $1\sigma$  uncertainty (which by the way is 7%) is given.

Figure 2a: In the specific figure there are two data points near 0.9. Is there any explanation for this large difference between the results from the two instruments for the particular days?

P5, L22: Please specify that the higher latitude of the site at Warsaw means that for the same time, the solar zenith angle over Warsaw is always lower by  $\sim 0.5^\circ$  compared to Belsk.

P5, L23: replace “surface albedo” with “different surface albedo”

P5, L25: replace “in” with “to perform”

P5, L27: Replace the phrase “prescribed values of surface albedo equal to 0.03 at Belsk and a set {0.03, 0.06, 0.12} in Warsaw” with “standard values of surface albedo equal to 0.03 for Belsk and 0.03, 0.06 and 0.12 for Warsaw”

P5, L28: Replace “of” before  $\text{TO}_3$  with “between” and delete “in”

P5, L30: Do you mean “coincidence” instead of “correspondence”? In this case it is for the entire range of the  $\text{TO}_3$  variability of both sites and not only of Belsk.

P6, L1: “assuming that” instead of “assuming”

Figure 4: There is an obvious annual cycle of the ratio. I suppose that this is due to the stronger effect of the  $0.5^\circ$  difference in SZAs in winter, when the SZAs are larger. Thus, the effect of larger albedo compensates for the effect of different latitude only for a specific period of the year. The same annual cycle is obvious in Figure 5, possibly due to the remaining effect of the difference in SZA. Given that in Figure 4 there are no results for December and January, when the effect of SZA is expected to be even larger, while in Figure 5 there are results for the particular months, I believe that the deviation of the mean ratio from unity is partially due to the effect of different SZAs. I suggest that you should either quantify the remaining effect due to different SZAs and take it into account in the discussion of the results presented in Figures 5 and 6, or alternatively compare the irradiances for specific SZAs (thus slightly different time).

P6, L11: remove “of”

P6, L11: remove “in”

P6, L15: replace

“in the periods symmetrical around local noon for 6h for all-sky and 3h before noon for cloudless sky conditions”

with

“for 6h symmetrical periods around local noon for all-skies, and 3h periods before local noon for cloudless skies”

P6, L17: Delete “previously”

P6,L19: Replace “The” with “A”

P6,L23: It seems to me that the ratio oscillates around  $\sim 1.05$  and not 1. As already commented, I believe that part of the spread in the calculated ratios is due to the remaining effect of the difference in the latitude of the two sites.

Figure 5: I suppose that the slightly different pattern of the temporal evolution of the ratios for the erythemal doses and the UV-A1 doses are again because of the effect of the different SZA. The effect of different SZAs is stronger for lower wavelengths, being partially responsible for the larger ratios of the erythemal doses compared to those of the UV-A1 doses.

P7, L6: “attenuates” instead of “attenuate”

P7, L10: “emissions” instead of “emission”

P7, L11: add references to support your statement that “causing numerous cases over the EU air quality threshold”

P7, L12: what do you mean with the phrase “makes specific boundary layer”? Please explain (e.g. is the upper limit of the boundary layer higher compared to the nearby rural areas?).

P7, L12-13: Add references

P7, L15: “higher AOD at 500 nm over Warsaw” instead of “higher Warsaw AOD values at 500 nm”

P7, L16: “similar differences” instead of “similar values”

P7, L21: “ $\sim 2\%$  more attenuation” is more accurate than “ $\sim 2\%$  attenuation”.

P7, L21-24: Again, these numbers may change after re-evaluation of the effect of the SZA.

P7, L30-31: “An Indirect method for BS has been proposed by Bais et al. (2005)” instead of “Indirect method for BS has been proposed (Bais et al., 2005)”

P8, L2: add appropriate reference to support that the typical SSA for rural sites is 0.92.

P8, L2-4: Since the overall difference is 6% and AOD difference is responsible for 2% (according to what is written in the previous paragraph) then SSA differences should compensate for 4% - and not 5% - of the difference. However, this might be different if you take into account the effect of the SZA.

P8, L5-7: I suggest moving the sentence “Kazadzis et al. (2009b) ... quality there” to P7, L27, after “... to SSA changes.”

P8, L6: “in Thessaloniki” instead of “in the Thessaloniki”

P8, L20 – 31: As already commented, the effect of difference in SZA is more pronounced during the cold period (larger SZAs) and less pronounced during the warm period (smaller SZAs). The effect of different SZAs has to be removed – or taken into account - properly, so that you can get more accurate conclusions.

Figure 8: I recommend adding a paragraph (e.g. 3.4) and expand the discussion relative to Figure 8. Furthermore, the discussion regarding the agreement of your results with the results of other recent studies (e.g. Zerefos et al. (2012), de Bock et al. (2014), Fountoulakis et al. (2016)), as well as the reasons for this agreement could be expanded.

P8, L24 - 26: “Thus, it seems possible that increased cloudiness over urban areas does not necessarily mean increased attenuation of solar radiation, since modification of the cloud structure and properties by the urban aerosols may lead to the formation of clouds which attenuate the solar radiation less effectively”

instead of

“Thus it seems possible that even higher cloudiness over urban areas does not mean higher attenuation of solar radiation, because the urban aerosols modify the cloud structure compensating the effect of increased cloud cover there”

P8, L27: “the” instead of “an”

P8, L32: “level” instead of “levels” and “higher than in the past” instead of “high”

P8, L33: Zerefos et al. (2012) discuss the trends of the UVR after the mid-1990s. Thus, in the particular study they do not discuss the increase of the UVR due to the decrease of ozone until the mid-1990s.

P9, L2-3: Add proper reference to support your statement that that the environmental pollution was enormous in the mid-1970 and early-1980. Furthermore, the UV increases because aerosol and clouds decrease relative to the past – not because they were high in the past.

P9, L6: I do not think that 5-8% is “slightly” lower. I suggest removing the phrase “only slightly”.

P9, L8: "parts" instead of "part"