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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Proposal of a new erythemal UV radiation amplification factor" *by* A. Serrano et al.

A. Serrano et al.

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"Proposal of a new erythemal UV radiation amplification factor" by A. Serrano, M. Antón, M.L. Cancillo, and J.A. García

Item-by-item response to referee #2

Referee's comments: -)

Responses: *)

(NOTE: The numbers of page and lines referred in this response correspond to the former version prior to the revision.)

(NOTE: Figures 3 and 6 have been improved.)

-) General comments. The paper aims to the quantification of changes of erythemal

ultraviolet irradiance derived from changes in total ozone amounts using the Radiation Amplification Factor (RAF). This parameter is calculated without any limitation on the variability of solar zenith angles and it is analyzed taking into account changes in total ozone and cloudiness. The title reflects the contents of paper and the abstract well summarizes the study. The topic is of scientific relevance and the paper would be of considerable interest to the readers of ACP and it is suitable for publication on ACP with the revisions outlined in more details below.

The language is some sessions is not fluent and precise and it requires a revision.

*) The text has been completely revised and the language has been improved.

-) Specific comments. The authors use UVER (ultraviolet erythemal radiation) in the text. This radiometric quantity should be better specified and replaced by the more appropriate "erythemal ultraviolet irradiance between 280 and 400 nm, i.e. the dose rate"

*) According to the referee's comment, UVER has been specified as "erythemal ultraviolet irradiance between 280 and 400 nm" in the abstract. Also it has been defined in the introduction as follows:

"In order to also account for the effect of the ultraviolet radiation on the human skin, the radiometric quantity UVER is used. It is defined as the erythemal ultraviolet irradiance between 280 and 400 nm, i.e. the dose rate."

-) What does "ozone slant" mean? Is it the "slant ozone column" (ratio of the total ozone column and the cosine of the solar zenith angle)?

*) Yes, we referred to the "slant ozone column". The right term "slant ozone column" has been used along the text and it has been defined in page 1096, line 22 as follows:

"Also the ozone amount was divided by the cosine of the solar zenith angle, resulting in the so-called slant ozone column."

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-) Although Mckenzie (1991) derived the RAF taking into account the erythemally effective UV radiation, a wider definition of RAF, without specifying the biological process is provided and suggested: "The Radiation Amplification Factor (RAF) is defined as the percentage increase in the biologically effective UV irradiance that would result from a 1% decrease in the column amount of atmospheric ozone" (Madronich et al... J. Photochem. and Photobiol. B: Biology 46, 1998, 5-9). It could be more appropriate to define the RAF as an useful parameter and not as "standard index" because there is not any scale. Values of RAF for various biological processes are reported in Madronich et al. (1998)

*) According to the suggestions given by the referee, the wider definition of the RAF is provided and some sentences are rewritten as follows (page 1091, lines 25-30):

The impact of ozone depletion on the UV radiation is frequently expressed by means of the Radiation Amplification Factor (RAF) defined as the percentage increase in the biollogically effective UV irradiance that would result from a 1% decrease in the atmospheric ozone (Madronich et al. 1998). Values of RAF for different biological processes can be found in Madronich et al. (1998). This paper focuses on the erythemally effective UV radiation, and RAF will refer to UVER RAF. This variable has become a useful parameter during the last years (McKenzie, 1991; Madronich, 1993; Bodhaine et al., 1997; Madronich et al., 1998; Dubrovsky, 2000; Zerefos, 2002).

-) The authors should pay attention when they use stratospheric ozone instead of total ozone as they should use.

*) According to this comment and the second comment from referee #1, stratospheric ozone has been replaced by total ozone when necessary.

-) Abstract. Results of analysis taking into account cloudiness changes should also be included.

*) Results of analysis of the effect of cloudiness changes have been included in the

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abstract as follows:

"Results indicate that the new RAF increases as clearness decreases, ranging from 1.41 for clear sky cases to 1.79 when all cases are considered. This behaviour could be attributed to the multireflection effect through Rayleigh scattering and cloud reflection, enhancing the effect of any variation in ozone."

-) Introduction More updated references should be included. Page 1090, 25: The authors should include some references about "the reduction in ozone and consequences in UV increases" (see for example Diffey BL. Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. Phys Med Bio 2004; 49: R1-R11).

*) The suggested and the following two references have been included:

Fioletov, V.E., L. McArthur, J.E. Kerr and D.I. Wardle, 2001: Long-term variations of UV-B irradiance over Canada estimated from Brewer observations and derived from ozone and pyranometer measurements. J. Geophys. Res., 106, 2309?2307.

Frederick, JE; Manner, VW; Booth, CR, 2001: Interannual variability in solar ultraviolet irradiance over decadal time scales at latitude 55 degrees South, Photochem. Photobiol., 74, 771-779.

-) Page 1091, 5: The authors should cite that "Several short and long term health diseases deriving from UV radiation can be found in WHO (World Health Organization) Public Health and the Environment 'Solar Ultraviolet Radiation. Global burden of disease from solar ultraviolet radiation' Environmental Burden of Disease Series, No. 13-R. Lucas, T. McMichael, W. Smith, B. Armstrong. Editors A. Prüss-Üstün, H. Zeeb, C. Mathers, M. Repacholi 2006; and in Gallaghera R.P., T.K. Leea, Adverse effects of ultraviolet radiation: A brief review, Prog Biophys Mol Bio 92, 119-131, 2006.

*) Both references have been included.

-) Page 1091,1-3: The authors should include the new findings reported in the last WMO Scientific assessment of ozone depletion, 2006. The only well-established ben-

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eficial effect of solar UV is the production of vitamin D3 required for skeleton health [B.Diffey, Phys. Med. Biol. 49 (2004) R1-R11], should also be mentioned in the text.

*) The suggested sentence has been added. Also the new findings of the last WMO 2006 Scientific Assessment of ozone depletion have been included, updating the information, rewriting the text, and including new references as follows:

"Increases of surface UV-B radiation due to stratospheric ozone depletion has been reported also in Antarctica, particularly during the period of the ozone hole in spring (Bernhard et al., 2004, 2006) and at northern high latitudes during summertime caused by chemical destruction and transport processes (Orsolini et al., 2003). In general, increases in surface UV irradiance during the last decade are evident from several datasets. However, this changes are not completely explained by ozone depletion, but attributable to the increasing of atmospheric transmission due to the combined effect of ozone depletion, global reduction of cloud optical thickness, and reduction of the amount or changes in the nature of aerosols (WMO, 2006)."

Bernhard, G., Booth, C. R., and Ehramjian, J. C.: Version 2 data of the National Science Foundation's Ultraviolet Radiation Monitoring Network: South Pole. J. Geophys. Res., 109, D21207, doi:10.1029/2004JD004937, 2004.

Bernhard, G., Booth, C. R., Ehramjian, J. C., and Nichol, S. E.: UV climatology at McMurdo Station, Antarctica, based on version 2 data of the National Science Foundation's Ultraviolet Radiation Monitoring Network. J. Geophys. Res., 111, D11201, doi:10.1029/2005JD005857, 2006.

Orsolini, Y. J., Eskes, H., Hansen, G., Hoppe, U. P., Kylling, A., Kyrö, E., Notholt, J., van der A, R., and von der Gathen, P.: Summertime low-ozone episodes at northern high latitudes. Quart. J. Roy. Meteorol. Soc., 129 (595), 3265-3275, 2003.

World Meteorological Organization: Scientific assessment of ozone depletion: 2006. Global ozone research and monitoring project. Technical Report 50, WMO, Geneva,

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Switzerland, 2006.

-) Page 1091, 9: the last UNEP(2006) report should be mentioned.

*) The last UNEP report is mentioned as follows (page 1091, line 9):

"The projection is a doubling in the incidence of all three types of skin cancers in the next ten years, and a large increase in the number of cataracts attributable to ozone depletion (UNEP, 2006)."

-) Page 1091,21: The degree of effectiveness of UV radiation in producing biological effect depends not only on the incident weighted irradiances on a given surface but also on the time period of exposure ("Reciprocity Principle. A given photobiological effect can be due to low intensity radiation for prolonged time exposure or high intensity radiation for short time exposure"). What are the "notable effects"?

*) We totally agree with the referee. The sentence has been changed to:

"From the point of view of the biological effects, this is the most active band, being able to produce notably harmful effects even for short time exposure."

-) Page 1091 -25: See above the general definition of RAF. Page 1092 -10 total ozone should replace "stratospheric ozone" Page 1092, 18: The station and the period of analysis should be also indicated in the introduction.

*) The suggested wider definition of RAF has been included. Stratospheric ozone has been replaced by total ozone (here and in some other parts of the article). The station and the period of analysis have been included in the introduction.

-) Data Page 1092, 21: Country of the station should be indicated. Broad-band UV-S-E-T erythemal radiometer (Kipp&Zonen, The Netherlands) should replace "broadband UV-S-E-T erythematic radiometer" in the whole text.

Country (Spain) of the station has been indicated (page 1092, line 21). "Broadband UV-S-E-T erythematic radiometer" has been replaced by "broad-band UV-S-E-T erythemal

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radiometer (Kipp&Zonen, The Netherlands)" in the whole text.

-) Page 1093, 10- 14: Which version of the TOMS processing algorithm was used in the study? TOMS data are total ozone amounts.

*) The mention to the TOMS Version 8 processing algorithm has been included in the article. Also "TOMS data" has been replaced by "TOMS total ozone amounts" (page 1093, line 8).

-) Page 1093, 23-29: "total irradiance" should be replaced by "global irradiance".

*) "Total irradiance" has been replaced by "global irradiance".

-) Page 1093, 23: the following reference should be included "Brogniez, C., M. Houët, A. M. Siani, P Weihs, M. Allaart, J. Lenoble, T. Cabot, A. de la Casinière, and E Kyrö (2005), "Ozone column retrieval from solar UV measurements at ground level: Effects of clouds and results from six European sites", J. Geophys. Res., 110, D24202, doi:10.1029/2005JD005992, 1- 14, 2005". Page 1094, 1: the manufacturer of CM 6B pyranometer should be included.

*) The suggested reference and information about the manufacturer of CM6B have been included.

-) Page 1095: The authors could explain when the different RAF expressions are used (small or large ozone changes).

*) The text (page 1095, line 18) has been rewritten to explain when the different RAF expressions are used, as follows:

"Eq. (3) is entirely valid for any change in ozone amount. For the particular case of small changes in ozone amount, this expression can be formulated as a function of finite differences as follows:"

-) Page 1096, 1-4: add "Kerr J B 2003 Understanding the factors that affect surface UV radiation Proc. SPIE, Ultraviolet Ground and Space based measurements, mod-

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els and effects III, San Diego August 2003, 5156 1- 14" and the last WMO Scientific Assessment of Ozone Depletion: 2006.

*) The reference of Kerr, 2003 has been included and the corresponding to WMO has been updated.

-) Page 1096, 5- 10: what was the criterion to select cases "with constant values of atmospheric factors (aerosol and troposheric ozone)"?

*) Indeed the selected cases don't correspond to cases with constant tropospheric ozone. Tropospheric ozone is part of the total ozone amount which is the variable analysed in the paper. Aerosols are taken into account inside the clearness index, which is affected by aerosols and clouds. The selection of those cases with clearness index higher than 0.75 guarantees cloud-free and low aerosol load atmosphere and, therefore, variations in UV transmissivity will be mainly caused by variations in total ozone. These ideas have been corrected along the whole text.

-) Page 1096, 7-10: A characterization of site in terms of climatological, atmospheric features and environmental factors (including albedo), if available, should be quoted or it should specified which kind of site is Badajoz (urban , highly polluted etc).

*) The following description of the site of Badajoz has been added to page 1092 line 26 (from out point of view, it seems to fit better in section "Data" than in page 1096):

"Badajoz is located in the west of the Iberian Peninsula. It presents a climate of type Csa according to the Köppen Climate Classification, with long hot summers and mild rainy winters. At 200 km from the Portuguese coast, its weather is mainly controlled by synoptic situations moving eastwards from the Atlantic Ocean. According to the climatological values given by INM (2004), the annual total precipitation is 477.5 l/m2 with maximum monthly values in March (67.9 l/m2) and minimum in July (2.9 l/m2). Monthly mean temperature varies from 8.7žC in January to 25.9žC in July. This area is characterized by a high sunshine duration of 2941 hours per year (Roldán Fernández,

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1987), which emphasizes the interest in monitoring ultraviolet solar radiation in this region. The radiometric station is located at the Campus of the University of Extremadura in Badajoz, in the outskirts of the city. Taking into account the location of the station, the small size of the city (150000 inhabitants), and the absence of industrial activity in the area, the environment of the station can be considered non-polluted and nearly rural. Most part of the vegetation in the University Campus consists of evergreen trees, guaranteeing a fairly constant albedo throughout the whole year."

INM: Guía resumida del clima en España 1971-2000, Instituto Nacional de Meteorología, Ministerio de Medio Ambiente, Madrid, 2004.

Roldán Fernández, A.: Notas para una climatología de Badajoz, Instituto Nacional de Meteorología, Publicación Serie K - no. 23, Madrid, 1987.

-) Page 1096, 21: Total ozone should replace "stratospheric ozone concentration". Page 1097, 4: [O3] should be defined.

*) "Stratospheric ozone concentration" has been replaced by "total ozone amount". Also O3 has been defined as total ozone column amount (page 1094, line 22) and the unnecessary brackets have been deleted.

-) Results and discussion Page 1097, 23: ozone concentration should be replaced by total ozone

*) "Ozone concentration" has been replaced by "total ozone" and the sentences have been rewritten.

-) Page 1098, 1-7: Did the authors investigate on the ozone variability in previous studies? If yes references should be added.

*) One paper by the autors about the January 2007 ozone mini-hole has been referenced as follows:

"This minimum value corresponds to an ozone mini-hole episode previously reported

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by Antón et al. (2007)"

and the corresponding reference has been included:

"Antón, M., Cancillo, M. L., Serrano, A., Vaquero, J. M., and García, J. A.: Ozone mini-hole over South-Western Spain during January 2004: Influence over ultraviolet radiation, Geophys. Res. Lett., 34, L10808, doi: 10.1029/2007GL029689, 2007."

The authors have investigated more on the ozone variability but the results o this study has not been published yet.

-) Page 1099, 4: The RAF value (1.31)quoted in the legend of Fig.4 should inserted in the text. Is this calculated using eq 5?

) Yes, the RAF was caculated following Eq. (5). However there was a typographic mistake in the legend of Fig. 4. The RAF* value should be 1.35 as stated in page 1099, line 4, and not 1.31 as stated in the legend of Fig. 4. This has been corrected. Additionally, for the sake of clarity, the following sentence has been included in page 1098, line 27:

"The RAF* was estimated as the slope of a least square regression of Ln(T) versus Ln(Z) as described by Eq. (5)."

-) Page 1099, 7: The increase of 27% derives from eq.6, what about the increase of 35%? In this case the RAF is 1.75.

) "Using the estimated value of RAF=1.35 and according to Eq. (5), a 20% decrease in slant ozone (Z) results in a 35% increase in UVER transmissivity (T). However, if the same RAF* value is inserted in an approximated expression consisted in a linear relation between relative changes in slant ozone and relative changes in transmissivity in a similar way as Eq. (4), then a wrong increase of 27% would be obtained."

This sentence has replaced the former explanation which was not clear enough.

-) Page 1099, 27-30 it is not clear at that point of session the comment about Fig.6 that

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should be inserted later.

*) We totally agree with the referee. Lines 27-30 of page 1099 have been inserted after page 1100 line 10, where it fits better.

-) Page 1100, 5: what is N in Table 1? This should be specified in the text and in the legend.

) "Number of cases (N), correlation coefficient (R2) of Ln(T) versus Ln(Z), and values of the new RAF parameter calculated for four kt intervals." has been included in the text and in the legend.

-) Conclusions Page 1101: the seasonal behaviour was not discussed in results and discussion as it should be done.

The data corresponding to the total ozone column have been added to Fig. 3, and the seasonal behaviour of UVER transmissivity related to ozone has been discussed as follows (page 1098, line 17-22):

"For these cases, monthly average of total ozone, slant ozone, and UVER transmissivity are shown in Fig. 3. The error bars are calculated as the standard deviation of the monthly mean of the data. In principle, the seasonal behaviour of the UVER transmissivity results from the combined seasonal evolution of two variables: the total ozone column, and the solar zenith angle. However, Fig. 3 shows that UVER highly correlates with the slant ozone column but not with the total ozone column. Thus, it can be concluded that the UVER transmissivity is mainly controlled by the evolution of the solar zenith angle and, to a lesser extent, by the ozone seasonal cycle."

-) The erythemal weight function is more sensitive to the shorter wavelength and hence to ozone changes.

*) The comment does not contradict what is written in the Conclusions. However, the explanation of the fact that the RAF is affected by changes in total ozone was rewritten, according to Michelleti et al. (2003), as follows:

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"It was found that the new RAF* is notably affected by changes in total ozone. Thus, there is an important decrease in the RAF* when high values of total ozone are considered. This behaviour could be attributed to the predominance of the absorption by ozone for shorter wavelengths and to the higher sensitivity of the erythemal weight function also to the shorter wavelenghts, that contribute proportionately less when the total ozone increases."

-) References. Lopez-Abente is not the right alphabetic order; WMO: the year is 2002 as indicated in the text

*) Both points have been corrected in the text.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 1089, 2008.