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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Relationship between erythema effective UV radiant exposure, total ozone and cloud cover in southern England UK: 1991–2015" *by* Nezahat Hunter et al.

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Response to referee comments:

Interactive comment on "Relationship between erythema effective UV radiant exposure, total ozone and cloud cover in southern England UK: 1991–2015" by Nezahat Hunter et al.

Anonymous Referee #3 Received and published: 20 September 2018

The manuscript by Hunter et al is clearly written and well organized. The authors study the short- and long-term changes of the daily erythemal doses over Chilton relative to

the changes of total ozone and cloudiness, using a very long record of ground-based UV measurements. The study is a good contribution for the UV community. However, there are some issues that have to be addressed prior to the publication of the study.

Page 2, lines 58 – 63: Quantification of the effect of each of these factors is not easy, because of the complex interaction between them and the solar UV radiation. For example, the effect of clouds changes depending on the presence of aerosols (and is different for different types of aerosols). At least a discussion pointing out these complex interactions should be added here. Response: Done; see Line 68-69. The authors treat the effects of changes in ozone and cloudiness on erythemal irradiance as linear and independent to each other. However, they are nor linear, neither completely independent to each other. I suggest that a short discussion explaining why the particular methodology was chosen and what are the limitations/uncertainties due to its use should also be added in the introduction.

Response: Statistical linear or non-linear models have been used in a number of applications for the ground UV radiation research (Zerefos et al. 2012; V De Bock et. Al 2014; Smedley et al. 2012). These models statistically relate ground-based measurements of surface UV irradiance as dependent variables and ozone and cloud cover as independent variables. Thus, these models were also used here to make comparison with the published results in the literature. Certainly some of the methods are comparable, e.g. linear versus non-linear models, but as shown here overall estimate and findings were similar using both models. Thus, we do not think discussion regarding statistical modelling issues needed in the introduction section.

Section 2.3 (Estimating trends): The authors have not taken into account the variations of QBO and solar cycle in the analysis. Both phenomena are periodical and affect the variability of total ozone and UV-B radiation. Since these phenomena affect the results of the study, their effect should be either removed or at least quantified.

Response: We have not taken into account the QBO (quasi-biennial oscillation) or the

solar cycle in the analysis. The explanation for this is as follows: Response: We agree with the review that the quasi-biennial oscillation (QBO) and the 11-year solar cycle are also factors that affect UV levels, particularly through their impact on ozone and clouds (Den Outer, 2005). Since the period of the QBO is approximately 2.3 years it affects short term variability rather than long term trends (Harris et al., 2008, Den Outer et al., 2005). This fluctuation is small in comparison to the 25 year timescale being analysed in this paper. Relevant text has been added into section 2.3 see Line 157-163. The 11-year solar cycle has a longer period and therefore has the potential to impact long term trends, however its effect on erythema effective UV levels is small (Den Outer, 2005, Diffey, 2002). We have investigated whether solar activities (the 11-year solar cycle is a cycle of sunspot activity, i.e. the number of sunspots) affect the changes in UV radiation at Chilton. The relationship between UVR values and total sunspot numbers was studied and the relationship between sunspots and UVR also appeared to be reciprocal; UVR being high when sunspot is low, and vice versa. However, using t-test, the correlation between UVR values at Chilton and sunspot numbers was not statistically significant (P=0.27) during the time period from 1991 to 2015. Thus, we have decided not to include the results in this manuscript.

References: Den Outer, P.N., Slaper, H. and Tax, R.B., 2005. UV radiation in the Netherlands: Assessing longâĂŘterm variability and trends in relation to ozone and clouds. Journal of Geophysical Research: Atmospheres, 110(D2). Harris, N.R., Kyrö, E., Staehelin, J., Brunner, D., Andersen, S.B., Godin-Beekmann, S., Dhomse, S., Hadjinicolaou, P., Hansen, G., Isaksen, I. and Jrrar, A., 2008. Ozone trends at northern mid-and high latitudes–a European perspective. In Annales Geophysicae (Vol. 26, No. 5, pp. 1207-1220). Diffey, B.L., 2002. Sources and measurement of ultraviolet radiation. Methods, 28(1), pp.4-13.

Another, useful information which should be added here is the treatment of gaps in the series i.e.: -Is there a minimum number of available days below which a month is not taken into account in the analysis? - What if some measurements are missing during

a day? Is there any particular criterion used in order to include a particular day in the analysis?

Response: There is no minimum number of available days in a month. The criterion for including a day in the analysis is that the data are complete during the relevant period of time for each day – that is, that no data points are missing from 30 minutes before sunrise to 30 minutes after sunset (Fig1).

Response: If any data points are missing during the relevant period of time for each day (30 minutes before sunrise to 30 minutes after sunset) the whole day is rejected. 95.7% of months have 5 missing days or less. 85.3% of months have 1 missing day or less and 68% of months have no missing days at all. Thus, we did not think that it was necessary to include in this manuscript.

Section 3: (Figures 1 and 3): How were the measurements outside the whiskers classified as outliers (i.e. which criteria were used in order to characterize a measurement outlier)? P5, L183: what does the word “corrected” means? How and for what was the monthly deviation corrected?

Response: In statistical term, outliers known as the extreme data points are outside the typical pattern of the other data sets. It is possible to delete outliers from the data set before analysis or use non-parametric statistical methods that are less influenced by outliers. We did not remove them because these points could be real measurements. The UV dose values might have fluctuated more especially in winter at this site due to natural variations which affect UV dose, in particular extremely low total ozone often occurs in winter. We should also bear in mind that the winter data had the lowest UV dose level among the rest of seasons in Chilton. The text has been revised in section 3.1 (Line 208-212). The use of word “corrected” is confusing and it has been removed throughout the paper.

Section 4: The results presented in this manuscript are also in good agreement with the results of Fountoulakis et al (2016) (“Short- and long-term variability of spectral solar

UV irradiance at Thessaloniki, Greece: effects of changes in aerosols, total ozone and clouds") where a turning point in the trends of UV irradiance is reported on 2006. Can the authors comment the similar behavior of UV radiation at the two sites (between which the distance is very long, and the climatological conditions differ importantly)? Response: Done; see Line 527-533.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-828, 2018.

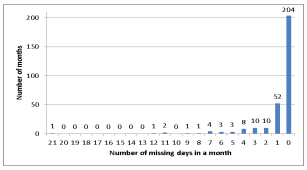

Fig. 1.