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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evidence of a possible turning point of UVB increase over Canada, Europe and Japan" *by* C. S. Zerefos et al.

Anonymous Referee #1

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The manuscript by Zerefos et al. discusses changes in spectral solar irradiance at 305 and 325 nm over the last 20 years in relationship to changes in total ozone, aerosol optical depth, and cloudiness. The study focuses on changes observed in Canada, Europe and Japan. The authors show that the data record can be broken into three sub-periods: the period between 1991 and 1994 that is dominated by aerosols from the eruption of Mt. Pinatubo, the period between 1994 and 2006 that can be characterized by an increasing trend in UV, and the period between 2006 and 2010 that shows signs of a slowdown of this trend. The observation that the increase in UV has leveled off is an important observation that warrants publication.

The topic of the paper is appropriate for ACP and should be of interest to all readers involved in UV research. Unfortunately, the manuscript contains several inconsisten-

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cies (see below) and the description of the data and methods often lacks clarity and detail. These deficiencies should be resolved before publication of the paper in ACP. The standard of English is adequate but the language is sometimes not precise. The paper would benefit from thorough copyediting.

General remarks

For the last two years of the data record, Figure 1 shows a large increase in ozone, large decrease in spectral irradiance at 305 nm, noticeable decreases in AOD, and noticeable increase in cloudiness. These obvious changes are not being discussed. What is the explanation for these changes? Is it possible that they are an artifact of the data processing? For example, are these changes apparent in the datasets of all stations or is it possible that an incorrect dataset of one station or an isolated event had a large effect on the average?

Like the second Referee (S. Diaz) , I would like to see some discussion whether or not the observed changes are representative for stations in all geographic regions (Canada, Europe, Japan) discussed in the paper. For example, I would have expected reductions in AOD for Europe and Japan in response to stricter air pollution laws, but such a reduction would be less obvious for the sparsely populated regions of Canada (excluding Toronto).

Specific comments

P 28546, L 10: The statement “The second period is characterized by a UVB increase caused by the synergy of ozone decline. . .” is contradictory with the following statement (P 28550, L 11): “It is interesting to note here that total ozone at the sites studied had a long term increasing trend after the volcanically perturbed period.” Figure 1 indicates that total ozone is increasing after the Pinatubo period. The first statement provided in the abstract is therefore incorrect and needs to be changed.

P 28546, L 13: Regarding “During this second period, the long term variability is

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the brightening of +0.94%yrˆ(−1) and +0.88%yrˆ(−1) at the wavelengths 305nm and 325nm respectively." The numbers (percent per year) suggest a trend, not a variability. Change to: "During the second period, the trend in spectral irradiance is 0.94%/yr at 305 nm and +0.88%/yr at 325nm."

P 28546, L 20: Provide a reference for the "world avoided" scenario here, for example: P. A. Newman, L. D. Oman, A. R. Douglass, E. L. Fleming, S. M. Frith, M. M. Hurwitz, S. R. Kawa, C. H. Jackman, N. A. Krotkov, E. R. Nash, J. E. Nielsen, S. Pawson, R. S. Stolarski, and G. J. M. Velders (2009): What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated?, Atmos. Chem. Phys., 9, 2113–2128, available at: www.atmos-chem-phys.net/9/2113/2009/

P 28547, L2: Regarding "...with about 2/3 being attributed to decreasing of cloudiness and aerosol optical depth and 1/3 to the ozone decline...": While this statement is consistent with the conclusions reached by den Outer et al. (2010), it is inconsistent with the ozone record shown in Figure 1, which shows an increase roughly between 1994 and 2009. This inconsistency needs to be explained.

P 28547, L22 ff.: Two overlapping datasets are mentioned. The enumeration starts with dataset "(1)" but dataset (2) is not mentioned, albeit it could be the GACP dataset. This should be clarified and also the period of the second aerosol dataset should be provided.

P 28548, L1: Better describe what is meant with "cloudiness data" from ISCCP. Is it cloud fraction and cloud optical depth as in the case of the MODIS? If it is a different cloud parameter, how were the two datasets combined? Is there the risk that there is a bias between the two datasets that could be misinterpreted as a real change in optical depth or cloud fraction? (Figure 1 indicates that the two datasets are indeed consistent, but this should also be mentioned in the text.)

P 28548, L9: What is the accuracy of "NASA/GACP AOD data" for land and water pixels?

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Section 2 first discusses AOD data, then briefly mentions cloudiness data, before returning to AOD data and repeating some information on cloud data. The section should be restructured such that all parameters are discussed separately, e.g. first AOD, then cloudiness, then ozone, then QBO, etc. Of course a different sequence could be chosen.

P 28549, L1: I assume the UV datasets had some gaps. How were these gaps treated when calculating monthly means and what is the uncertainty of monthly means caused by missing data?

Equation (1): The equation and its arguments should be discussed in much greater detail. For example: How were UV data deseasonalized? Was Eq. (1) evaluated separately for each station or were monthly averages from individual stations averaged over all stations to calculate Y_t? If so, how was the problem addressed that not all stations have data for the entire period discussed in the paper (see Table 1)? Was the averaging done consistently for Y_t and the other terms of Eq. (1)? What exactly are the "QBO terms", "cld term", and "solar cycle term"? Explicit equations for these terms should be provided. If the authors feel that the flow of the paper would suffer from additional equations, these could be put into an appendix. The statement "the cld term to describe the cloud cover effect" is too vague. I realize that some of that information is provided in the works by Reinsel (2002) and Newchurch et al. (2003), but these papers do not discuss UV radiation, and therefore, their methods are not identical to the method used in this manuscript.

P 28549, L16-19: Also this section is not detailed enough. How is the "unified index" defined? How was it constructed? I do not understand the sentence "The cloud cover term was used as pertaining to the geographic area of the UV time series." Was a different cloud term used for every station or is there only one term that is representative for the (large!) geographic area covered by the stations?

P 28549, L 23: Please describe better how data were deseasonalized and averaged.

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This is related to my question above whether or not Eq. (1) is applied individually to every station or to the average of deseasonalized data of all stations.

Figure 1: QBO is not mentioned in the figure caption. Indicate what the QBO dataset represents and its unit. What cloud parameter is displayed? Is it cloud optical depth, cloud fraction, a combination of both or something else? The terms "cloud cover" used in the legend and "total cloudiness" used in the caption are ambiguous. The solar cycle is considered in Eq. (1). I suggest to include this parameter in Figure 1 also.

P 28550, L 11: I am glad to see that it is stated here that "total ozone at the sites studied had a long term increasing trend after the volcanically perturbed period." As discussed above, this (correct!) statement is in conflict to assertions used earlier and later in the paper.

P 28550, L 15: I suggested changing the sentence to: "The data indicate that spectral irradiance at 305 nm is affected by two competing factors: the increase of total ozone, which reduces spectral irradiance at 305 nm, and the decrease of aerosol optical depth, which increases both UVB and UVA. There is no significant change in cloud optical depth and cloud fraction [use the most appropriate term!]. The effect of clouds on long-term trends in UV irradiance is therefore negligible."

P 28550, L 15: I don't understand how the authors can conclude from the "above arguments" that "a turning point of the long term increasing trends in this part of the spectrum would be found with our data sets." A turning point in UVB can only be expected if there was a change in either the trend of ozone or aerosol optical depth. While Figure 1 supports this conclusion, The "above arguments" do no mention a change in the trend of either of the two parameters.

P 28550, L 26: I accept that there is no trend in cloud fraction and QBO. It should be explained why the two terms were not used here. Even if there are no trends in these terms, both terms reduce the variability in the regression model such that the residuals would be better represented by random numbers. Use of the two terms

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would consequently lower the uncertainty of the trend estimate for spectral irradiance at 305 nm and 340 nm. What would be the value of the trends and their uncertainty if the QBO and cloud terms had been included in the calculation? There is also an inconsistency between the trend estimate for spectral irradiance at 305 nm provided in the text (0.55%+/-0.03%)/yr and Table 2 (0.55%+/-0.02%)/yr, which should be resolved.

P 28551, L 22: With respect to "The total UVB decreasing tendency during the 2006–2010 period, shown also in Fig. 1..." I don't see this decreasing tendency in Figure 1. In fact , spectral irradiance at 305 nm increases between 2006 and 2009, and only decreases during the last year. While the end point is indeed smaller than the value for 2006, describing the pattern of that period as "decreasing tendency" is not justified. What could be said (and what is supported by the CUSUM approach discussed later) is: "Figure 1 hints that the positive trend in spectral irradiance at 305 nm observed for the 1994 - 2006 period has leveled off in the last five years of the data record".

P 28551, L 27: The trend in cloud optical depth during the last year shown in Figure 1 is positive, not negative as stated in the text.

Comparison of Figure 1 and Figure 3. The residuals shown in Figure 3 do not match the pattern of the 305 nm dataset of Figure 1. For example, spectral irradiance is decreasing between 2005 and 2006 in Figure 1 while the residuals don't show a trend for this year. This discrepancy is likely caused by the QBO. It would be helpful to include additional sub-panels in Figure 3 showing spectral irradiance at 305 nm and 325 nm corrected for QBO, solar cycle, and clouds according to Eq. (1). The change (or slowdown) in the UV trend since 2006 suggested by the authors and supported by Figure 3 should become visually obvious in such a figure.

P 28552, L 26: Radiation amplification factors (RAF) depend on solar zenith angles and ozone. The UV data used in the paper were monthly means of daily doses and there is an annual cycle of SZA. So calculations at SZA = 63° may not be representative.

P 28552, L 29: "Using the same columnar AOD and a ..." The sentence is somewhat

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confusing. It should be expressed that, for constant aerosol optical depth, aerosols have a larger effect on UV when they are redistributed from the troposphere to the stratosphere. (I recall that the effect has a large SZA-angle dependence and calculations at 63° may not be appropriate. The RAF for the volcanic aerosol scenario should also be calculated for additional solar zenith angles).

P 28553, L 12: "The second period is characterized by a UVB increase caused by the synergy of ozone decline and tropospheric aerosol decline. . ." No, ozone is increasing during this period!

P 28553, L 14: Change "During this second period, the long term variability is the brightening of 0.94%/yr and +0.88%/yr at the wavelengths 305nm and 325nm respectively." to "During the second period, the trend in spectral irradiance is 0.94%/yr at 305 nm and +0.88%/yr at 325nm."

P 28553, L 16: Figure 1 indicates that "maximum UVB exposure" during the last 10 years was in 2009. So the final sentence needs some rewording.

Technical corrections

P 28549, L 15: change ". . .residuals (CUSUM)." to ". . .residuals (CUSUM) in Section 3."

P 28550, L 11: Change "More interesting thought. . ." to "More interesting though. . ."

P 28550, L 15: Change "as well as to the fact that" to "because"

P 28550, L 25: Change ". . .time series for both the cloud fraction and for the QBO. . ." to ". . .time series for cloud fraction and QBO. . ."

P 28551, L 13: Move the reference (Mayer and Kylling, 2005) after "LibRadtran package".

P 28552, L 23: "a significant 8% ozone. . ..": Sentence misses a verb.

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