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Atmospheric Chemistry and Physics Discussions

ACPD

8, S304–S316, 2008

Interactive Comment

Interactive comment on "Hourly resolved cloud modification factors in the ultraviolet" *by* H. Staiger et al.

H. Staiger et al.

Received and published: 22 February 2008

This is the cumulative response to comments and suggestions of referees 1 and 2.

We thank the referees for their comprehensive and valuable suggestions and constructive remarks.

With respect to the comments we will give the following responses and /or will perform changes due to the suggestions. Suggestions not below-mentioned will be implemented as proposed.

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General comments

Full Screen / Esc

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Interactive Discussion

Discussion Paper

Referee 1: While the paper demonstrates that this approach is adequate for estimating the UVI under cloudy conditions, I believe better results would have been achieved if the parameterization had been based on instantaneous measurements instead of daily sums. My assumption is supported by the authors, who admit on page 192, L12 that "an hourly application should result in slightly too high UV-CMFS for small [cloud modification factors for total global radiation] (SOL-CMF)." To correct for the error resulting from applying a parameterization developed for daily doses to hourly samples, another parameterization is introduced (P196, L1-17, Eq. (5), and Figure 4). I believe this correction could have been avoided if the original parameterization had been based on hourly data. In my opinion, data from Bilthoven could have been easily used to develop a parameterization based on instantaneous data. I suspect that this alternative parameterization would have the same form as Eq. (3), but employ a different exponent as well as different coefficients for the parameterization of p(SZA) (Eq. (4)). The authors should explain why they chose their parameterization rather than this alternative (and in my opinion obvious) approach. I encourage the authors to develop the suggested alternative parameterization and apply it to a subset of data from one of the six locations. If results obtained with the alternative method lead to better results, a recalculation of the paper's data should be considered. I realize that this is a lot of work but the reward is a higher accuracy when the methodology is operationally applied to UV forecasting schemes.

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In the 2006 COST-726 modelling exercise the original RIVM algorithm (den Outer et al., 2005) has been applied for UV cloud modification of daily erythemally effective clear-sky UV doses, model B of the Taylor diagram, Fig. 6. Due to the assumed potential for a temporal resolution of one hour, the algorithm has been tested unchanged for cloud modification of hourly clear-sky UV doses too, replacing the minimum SZA of the day by the SZA of the corresponding hour. These hourly UV doses has been accumulated to a daily dose, model C of the Taylor diagram. Overall, model C performs slightly

ACPD

8, S304–S316, 2008

better in comparison to measured daily doses than model B. The main reason of this paper was to report on this finding, to quantify the error, to adjust the clear-sky UV model for very high SZA to better agreement with measurements, and in particular to validate the hourly application against hourly resolved measurements. It is regarded as advantage that the RIVM algorithm is applicable unchanged in hourly and daily resolution dependent on available ancillary input.

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Referee 1: The abstract should be shortened substantially. Particularly lines 6-13 can be omitted or moved to the introduction.

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Referee 2 has given a proposal to rewrite P182, L3 through L8. This is adopted. L9 through L13 will be shortened.

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Referee 1: Sections 2.2 - 2.6 provided ample information on UV data but little information on total global radiation measurements. At least the instrument types should be mentioned. If possible, also the uncertainty of total radiation measurements should be specified. Some of the information on UV has been published elsewhere. The sections could be shortened by citing this material.

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Referee 2 suggests: The information to the measurements should be reduced. Please see response to P184, L25, and P188, L25 under specific comments.

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Referee 1: Section 4.3.2. (Taylor diagram) is hard to understand, in particular the smoothing schemes described on page 199. I believe the main purpose of Section 4.3.2. is to compare the results of the paper with those described by Koepke et al.,

ACPD

8, S304–S316, 2008

[2006], which are based on daily doses. It would have been better to calculate daily doses from the hourly data, and compare the performance of this data set with the results presented by Koepke et al. [2006]. With this approach, the parameters of the Taylor diagram would be consistently based on the day-to-day changes for all data sets. This approach would also eliminate the somewhat obscure smoothing scheme. If smoothing is used, all data sets have to be treated equally to ensure a fair comparison.

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The form of smoothing has been selected such to ensure a fair comparison to the daily doses by treating the hourly resolved data equally as the daily data has been treated in the COST-726 intercomparison. The paper gives reasons for the applied smoothing method. Obviously, the text is too compact and should highlight some more details. Following the reasons for smoothing and the methods are explained in more detail: Time series often show a high autocorrelation. COST-726 has removed autocorrelation by calculation of the residuals of the measured as well as of the associated modelled values to smoothed averages of the measurements (high pass filter). The residuals are input to regression analysis. In the daily UV doses the autocorrelation is a function of time, represented by the day of the year (DOY). The dominating effect in autocorrelation is the dependence on noon SZA. This is a direct function of DOY. Secondary effects in autocorrelation will be e.g. seasonal variations in total ozone column, and in aerosol optical depth. These can be estimated to be in influence about one order of magnitude less than the SZA dependence. A power spectrum of the hourly UVI's would reveal at least two significant peaks, one at the frequency representing diurnal cycles, one for the frequency of annual cycles. Both will depend on SZA. A scatter-gram of measured hourly UVI's dependent on SZA and following the calculation of a smoothed average dependent on SZA and of the residuals for each measured and modelled data point will remove the autocorrelation due to seasonal and diurnal variations in SZA. Thus, the method is equivalent compared to smoothing of the daily sums and applies the same smoothing method.

The modified text will better highlight the autocorrelation due to SZA in both datasets. The comparison of the modelled hourly values with the modelled daily sums should be retained. It shows the model performance applying the UV-CMF algorithm in hourly resolution and on a global scale. Fig. 6 will be extended to additionally present the result of daily erythemal UV doses of improved model C in full compatibility to COST-726, i.e. will exclude Everglades and Lauder, but include daily modelled UV doses for Potsdam 1999.

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Referee 2: It should be mentioned that UV means erythemal weighted UV, even if it is clear in the special issue of ACP that will be used for the paper. This is of relevance with respect to the spectral variability of CMFs. Regarding to the title, the UV-CMF as function of the SOL-CMF are the final result: Thus this aspect (Eqs.3, 4 and 5, for Eq.5 see below) should be collocated in one chapter 'results', independent from the way how the data have been derived, especially for the readers who only are interested in high quality UV-CMF for their personal use. These results could be presented together with a short description of the uncertainties, especially if the daily UV dose is modelled on hourly values or using only noon SZA. (This information is given in the manuscript, the suggestion is only for a certain rearrangement for better reading).

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Three of the European sites have exclusively provided erythemal UV measured by broadband instruments. Thus, modelling for hourly application and validation has been restricted to CMF's of erythemal UV. This will be mentioned as suggested. It has to be noted here, that den Outer et al. (2005) provide special values of the parameter p for a number of wavelengths, i.e. a spectral application of their algorithm is possible too.

The paper will be restructured as suggested. A new section 'results' will reassemble parts of section 3 and section 4.2. Section 4 will be renamed to 'model performance', and the subsection headlines adjusted.

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Referee 2: The font used for figures, and in particular figure legends, is generally too small. Legends will be unreadable if figures are not changed for the ACP print (PDF) edition.

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The font of the figures legends will be increased and the legend specifications of Fig. 3 and 6 reduced.

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Specific comments

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Referee 1: P183, L3: I doubt that clouds can enhance UV radiation (and in particular erythemal UV) by a factor of two or more. Such enhancements are only possible for visible radiation. If the authors believe that such large increases are possible in the UV, a reference should be provided.

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The statement has been based on modelling results for SZA > 85° that has not been published. Thus it will be rewritten to: Clouds may have a dramatic effect on the ultraviolet (UV) and global solar radiation reaching the earth surface ranging from almost complete extinction under heavy thunderstorms to enhancements of a factor of 2 or more in the case of global solar radiation and up to factors around 1.4 for UV.

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Referee 1: P183, L18: Snow can have a very large effect on UV transmission (or CMFs). In particular over high-latitude ice sheets, albedo moderates the effects of clouds considerably. See for example: Nichol et al., Moderation of cloud reduction of

ACPD

8, S304–S316, 2008

Interactive Comment

UV in the Antarctic due to high surface albedo. J. Appl. Meteorol., 42(8), 1174-1183, 2003.

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Nichol et al. (2003) describe the absolute UV fluxes under cloudy skies and relate them to modelled clear-sky UV. They refer to modelling results of Shettle and Weinmann (1970) with the finding: For an ideal UV surface albedo of 100 percent, no cloud absorptance in the UV wavelengths, and a uniform crystal size distribution through the cloud the cloud causes no reduction of UV, i.e. all-sky UV equals clear-sky UV. Nichol et al. show by measurements and modelling that especially for the extreme conditions found in Antarctica (South Pole, McMurdo) a high surface albedo can considerably moderate cloud attenuation as a result of multiple scattering between surface and cloud base. In contrast, Spinhirne and Green (1978) investigate the ratio of UV transmission (diffuse and direct) to total solar transmission, relative fluxes, by applying the discrete ordinate method for radiative transfer. Their cited results regarding the influence of UV surface albedo on the relative fluxes are valid for wavelengths greater than 300 nm, a surface albedo of 45 percent in the UV, and of 75 percent in the visible. These assumptions are representative for the maximum in the regional UV albedo applied in the algorithm of Schwander et al. (1999) and a majority of land cover types investigated by Tanskanen and Manninen (2007), see references below. The findings of Nichol et al. that are related to absolute UV fluxes must not be in contradiction of the results of Spinhirne and Green related to the ratio of UV to solar fluxes. Under the extreme conditions of Antarctica the surface albedo in the UV may be higher than in the visible and the relative fluxes may become sensitive to the surface albedo. However, multiple scattering between surface and cloud base will apply for the visible spectral range too and thus will contribute in the absolute flux to an apparent reduction in cloud attenuation, higher SOL-CMF. Clear-sky modelling, Eq. (1), accounts for UV surface albedo. Thus, the error in modelling may increase but should be kept within a limit.

The text will be rewritten to more exactly cite the findings of Spinhirne and Green and will point out a possible sensitivity of surface albedo under extreme conditions as in Antarctica.

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Referee 2: 184/25: The information to the measurements should be reduced.

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Location and altitude of the sites, information on UV instruments and their calibration, albedo, and total ozone column will be summarised in a table. Special settings will be described by the text.

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Referee 1: P188, L25: A silicon diode is only sensitive to about 1200 nm. Instruments for measuring total radiation should be sensitive to at least 3000 nm. Was there a correction applied? What is the uncertainty of the measurements?

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The data are used as published and are in the responsibility of the data provider. The data source is acknowledged. In contrast to Everglades, there is good agreement at Lauder between highest measured daily sums of total global irradiation and modelled clear-sky sums. The data description available via the web does not enable to respond to the detailed questions.

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Referee 1: P190, L20: Is Eq. (2) applied to data of all sites? If so, why is a parameterization that was developed for Bergen appropriate for other sites?

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The paper states: '... the effect could be seen in the relative differences (Koepke et al., 2006) especially for Bergen with a maximum noon SZA of 83°'. Hence, it is seen in the

ACPD

8, S304–S316, 2008

Interactive Comment

other sites too. The small empirical adjustment for high SZA according to Eq. (2) has been applied to all sites in modelling of clear-sky erythemal UV.

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Referee 1: P192, L14-22: The algorithm by den Outer et al. [2000] is not being used in Section 4 (the ESRA method is being used). Why is the description of the den Outer method necessary?

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For a reader interested in application it is of value to have information on high quality alternatives. The clear-sky total global radiation models of den Outer (2000) and of ESRA are evaluated by intercomparison, Fig. 1. Den Outer's model (2000) does not require a Linke turbidity factor, because mean European conditions are implicitly included. The ESRA model explicitly requires a Linke turbidity factor and thus can account for turbidity differing from mean European conditions. Such differences have been seen for Everglades and Lauder. Furthermore, the ESRA algorithm explicitly accounts for the altitude of a site. This has been an advantage in modelling for Davos.

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Referee 2: 194/4: Why only one year for Potsdam?

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Potsdam has exclusively provided measured daily doses of erythemal UV for 1999. In contrast, ancillary data in hourly resolution have been provided, allowing to model in hourly resolution and to accumulate the hourly values to daily erythemal UV doses. These are applied to achieve full compatibility in comparison with the COST-726 results (see the response to the Taylor diagram under general comments). Section 2, observational data, will be adapted.

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Referee 1: P195, L18: I don't see much difference between the 1999 and 2002 data sets for Thessaloniki.

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The differences can also be seen in the UV trend analysis of Feister et al. (2008). They state, that UV radiation strongly decreases after 2000.

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Referee 1: P195, L25ff: I don't understand why applying Eq. (3) with an hourly resolution is a particular problem for the clean-air site Lauder. P196, L11-17: Is this parameterization specific to Lauder or can it be applied to other locations also?

Referee 2: 196/11 Proposal: The reason for Eq.5 should be discussed more clearly. What does it mean for the user? 196/11 It is clear that Eq 5 leads to 1 for CMF = 1, but this should be mentioned, or better the adjustment should be shown as adjustment on UV-CMF in stead on UVI. This, on the one hand, would fit with title of the paper and, on the other hand, would allow a direct use of UV-CMF.

....

Equation (3) is used for all 6 sites. The regression analysis dependent on three bins of UV-CMF (Fig. 3) is a noteworthy result of the paper. It reveals that only Lauder shows the anticipated higher values in UVI for stronger clouded conditions applying a CMF algorithm originally developed for daily sums to a temporal resolution of one hour. In the following the paper discusses, why Lauder does show the effect and the other sites do not. In the pristine air of Lauder there is almost no extinction by aerosol absorption, whereas in Europe there is extinction by aerosol absorption. Inappropriate assumptions of modelling on extinction by aerosol absorption under stronger clouded skies in Europe cover the obviously small error applying Eq. (3) in an hourly resolution. Thus, only the measurements of Lauder enable to quantify the above-mentioned effect, Eq. (5). Equation (5) has been applied to all sites for correction.

As supposed, Eq. (5) and Fig. 4 will be rewritten to adjust for the slight overestimation of UV-CMF applying Eq. (3) to derive hourly resolved UV-CMF.

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Referee 1: P196, L22: I doubt that it is meaningful to calculate the RMSE from all data points considering that measured values vary over a large range. How was the bias (alias 'absolute difference') calculated? Was it 'SUM (modelled - measured),' where the summation goes over all data points? In this case, the results would be dominated by the largest UVIs and the numbers would say little about the agreement at low radiation levels. Rather than presenting Table 2, it would be more interesting to calculate statistics from the results shown in Figure 5. For example, the average bias and standard deviation (both absolute and relative) could be calculated from data contributing to 10-wide SZA-bins, and presented in a table.

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The RMSE from all data, Tab. 1, is justified in comparison with the results of COST-726 and with the empiric hourly UV-CMF's derived from synoptic cloud observations for Potsdam. In particular it enables to assess the increase in scattering due to temporarily higher resolved data. Let x(i) be the measured UVI and y(i) the associated modelled value, than the bias is:

$$y_avg - x_avg = [SUM(y(i))]/n - [SUM(x(i))]/n = [SUM(y(i) - x(i))]/n$$

The right-hand side of the equation is the average of the absolute differences given by Tab. 2. The absolute differences quantify better the agreement for higher radiation levels, the relative differences highlight stronger the effects of lower radiation levels. Following the suggestion, Tab. 2 will be upgraded giving additionally absolute and relative differences for the SZA intervals: 0-30°, 30-60°, and 60-90°.

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Referee 1: P198, L18: 'There is a strong ...' I don't understand this sentence, rephrase.

ACPD

8, S304–S316, 2008

P198, L28: 'The smoothed ...' I don't understand this sentence. What is meant with 'a window of the next 12 percent of the data'?

Referee 2: 199/2: Explain 'window of 12 percent ...'

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To the reasons for smoothing see the response to the Taylor diagram under general comments. Smoothing applies the method LOWESS for the daily sums and the hourly values. It is a locally weighted polynomial regression. The LOWESS window is defined as the fraction of values of the total data set used in calculation of the smoothed average and controls the smoothness of the curve. In the daily sums the window comprises 40 percent of the values, in maximum 146 days closest to the day of the data set. In the hourly values the window comprises 12 percent of the data set, in average about 370 values closest in SZA to the data point. The selected higher absolute number for the window accounts for the secondary influences of seasonal variations of ozone and aerosol optical depth not covered by the SZA dependent smoothing of the hourly data.

Following the general comments, section 4.3.2 will provide some more details. A URL to LOWESS (http://www.itl.nist.gov/div898/handbook/pmd/section1/pmd144.htm) will additionally be provided. The explicit specification of the window will be deleted and instead stated, that the selected degree of smoothness for the hourly data set is comparable to that of the daily sums.

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Additional references

Feister, U., Junk, J., and Woldt, M.: Long-term solar UV radiation reconstructed by Artificial Neural Networks (ANN), Atmos. Chem. Phys. Discussion, 8, 453-488, 2008.

Nichol, S. E., Pfister, G., Bodeker, G. E., McKenzie, R. L., Wood, S. W., and Bernhard,

ACPD

8, S304–S316, 2008

Interactive Comment

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Discussion Paper

G.: Moderation of cloud reduction of UV in the Antarctic due to high surface albedo, J. Appl. Meteorol., 42, 1174-1183, 2003.

Tanskanen, A., Manninen, T.: Effective UV surface albedo of seasonally snow-covered lands, Atmos. Chem. Phys., 7, 2759-2764, 2007.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 181, 2008.