Atmos. Chem. Phys. Discuss., 8, S1178–S1185, 2008
www.atmos-chem-phys-discuss.net/8/S1178/2008/

Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Long-term solar UV radiation reconstructed by Artificial Neural Networks (ANN)" *by* U. Feister et al.

U. Feister et al.

Received and published: 1 April 2008

Reviewer:

The introduction states, that the study focuses inter alia on small-scale spatial characteristics that have been derived from data at two sites with small spatial distance (Potsdam and Lindenberg). From my point of view interesting is the finding of increased differences in daily sunshine duration on short distances compared e.g. to global irradiation. It will restrict significance in spatial differences applying ANN#1. The findings on small scale differences are of value to be mentioned in abstract and conclusions.

Response to review 2:

The issue of small-scale characteristics will be covered by a changed title of the paper to Long-term reconstruction of solar UV radiation by the Artificial Neural Networks

(ANN) model with emphasis on spatial characteristics of input data. The issue of data variability in space and time will be addressed in the revised text, in particular in the abstract, in the conclusions and in section 2.3. The scale of spatial variability of a parameter is connected to its time domain. The target value for reconstruction in this study has been daily UV irradiation. If monthly and annual values are derived, the correspondence of variations between parameters and their spatial representativeness is different to that of daily values. As an example, we have added a scatter plot of monthly sunshine duration at Potsdam and Lindenberg, where the close correspondence between both parameters can be seen. The correlation coefficient between daily sunshine duration at Potsdam and Lindenberg over the period 1951 to 2005 is 0.929. For the same period, the correlation coefficient between monthly sunshine duration at the two sites is 0.989. All model calculations of daily UV irradiation refer to the respective site only. If monthly and annual values are derived from them, the reconstruction will also be representative for a larger area.

In addition to that aspect, the ANN model modifies the effect of an input parameter such that the typical spatial characteristics of the target variable will be modelled. Even a small-scale variability of sunshine duration will be modified by the ANN such that the variability of reconstructed daily UV radiation differs from that of the input parameter.

Reviewer:

I miss some basic information on ANN concerning bias and root mean square error (RMS) given by Tab. 2. The bias shows the more pronounced differences (ANN#6 – ANN#1 = -16 % for UV-B) compared to RMS (-6.8 %), however, it is not discussed. P465, L15-L21 annotates only, that the bias has been removed after reconstruction. ANN#6, bias -4.5 % for ERY, differs from ANN#5, bias -1.2 %, by the inclusion of surface albedo. What is the advantage to use ANN#6 for 1984-2003 and not ANN#5? Is there a meaning of RMS to select an ANN version for application?

Response:

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We will comment on this issue below.

Specific responses:

S 227, L 20ff: UV reconstruction by the ANN model shows long-term changes due to anthropogenically forced long-term ozone changes between about 1970 and 2003 for Potsdam with all sky conditions, as is illustrated in Fig. 11. For ozone values in the time period before 1964, the following issues need to be mentioned:

i) ozone data before 1964 are not available for the Potsdam site,

ii) we are not aware of an anthropogenically forced long-term ozone trend for the period before the 1970ies,

iii) it has been mentioned in the paper in section 3.2 that use of climatological seasonal ozone values would not reduce the uncertainties of reconstructed erythemal UV irradiation,

iv) uncertainties for reconstruction with ozone and without ozone are shown in Table 2,

v) it may be speculated that large volcanic eruptions such as the ones in the beginning of the 20th century as discussed in section 4.1 may have affected atmospheric ozone for a few years after the eruption. However, a long-term effect of the eruptions on column ozone is not likely.

S 228, L 4ff: The paper focuses on input data and reconstruction of daily solar UV irradiation at two close sites Potsdam and Lindenberg. As an illustration of the applicability of the ANN method to other European sites, UV reconstruction results are also mentioned in the last section. A detailed discussion of input data of other sites would go beyond the scope of the present paper. Therefore, another publication has been cited in section 4.2 that discusses the comparison of reconstruction results between different models in detail. A few results of the ANN model reconstruction for other European sites are mentioned in the last section 4.2 of the paper. Therefore, the list auf co-authors will be extended in the revised paper by more authors representing

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measurements of input data at those sites.

S 228, P 454, L3: sunshine duration will be included in the text as an input parameter

S 228, L16 to L18: We added the following information at the end of section 2.1.1: from 290 nm to 450 nm at time steps of 6 minutes were used. The Bentham instrument was also calibrated by lamps traceable to PTB.

S 228, P 460, L3 to L6: The main objective of the study has been the reconstruction of daily UV irradiation with the best data sets available. Due to the long time steps of Brewer UV scans, daily UV irradiation was derived from measured spectra with the help of additional information on the variability of UV radiation in between two spectral UV scans. One-minute values of measured global irradiance were chosen for that purpose, which contain information on the variability of radiation in time. We note that other modifications and corrections to UV data have been also applied such as the spectral extension from 325 to 400 nm and correction of cosine errors. In the case of UV filter radiometer data, additional measured values such as column ozone values may have been used for UV raw data correction. Their use could have affected the data base of daily UV irradiation at the sites. On the other hand, use of additional data is helpful and needed to provide a more reliable database for comparison with model-derived UV radiation.

Specifically, using one-minute values of global irradiance in the derivation of daily UV irradiation might have affected the correlation between daily UV and daily global irradiation. To look at that effect, we have added an additional column to Table 3 that shows the correlation coefficients between daily UV and global radiation derived for the different sites. It can be seen in Table 3 that in terms of correlation between UV and G, the highest value of 0.968 occurs for Norrkoeping, and the lowest value of 0.945 for Sodankyaä. Lindenberg and Potsdam rank at positions 3 and 7, respectively. We conclude that the correlation between daily UV and global irradiation derived from Brewer data at Lindenberg and Potsdam is not significantly higher than at other sites.

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S 229, P 460: In this study, the UV data base used for training and testing the ANN model at the sites Lindenberg and Potsdam uses values derived from Brewer data between 1995 and 2003 (Table 1). Other UV data such as Bentham data of one year (2002) at Potsdam that have a higher time resolution, but have not been available over the whole period of time, were used for comparison with the daily UV values from Brewer data to get an estimate on the applicability of the method to derive daily totals from Brewer data with large time gaps, and the resulting uncertainties of daily totals. To avoid confusion, Bentham data have not been considered part of the UV data base in this study. They have neither been used for training of ANN models, nor for deriving ANN model uncertainties. Comparisons between daily UV irradiation from Brewer with those derived from Bentham and from Spectro 320D spectra refer to two different years 2002 and 2005, respectively. Daily UV irradiation values from the three different instruments contain uncertainties of the individual systems that include calibration uncertainties, uncertainties due to spectral extension in the case of Brewer data, data corrections such as for cosine errors of Brewer spectra, atmospheric variabilities due to non-correspondence in time, and in particular uncertainties due to deriving daily doses from individual spectra measured at larger time steps. Average daily ratios between daily doses of two instruments may therefore deviate within certain limits. We have not applied any other corrections to data derived from one instrument to another instrument, but instead used the data base of an individual type of instrument, as it is. It is mentioned in section 2.1.3 that the estimated resulting uncertainties of daily UV irradiation derived from Brewer spectra is within 12 to 14 per cent. Therefore, even annual averages between daily UV irradiation derived from different sources may differ. In the two cases, differences for the two years 2002 and 2005 amount to 6 and 2 per cent. We have not claimed that data of daily UV irradiation derived from Brewer data are the truth, but consider daily UV data from Brewer measurements in this study as (best) estimates to be used for training and testing of UV reconstruction models.

S 229, P 460, L14: A bisection line will be included in all scatter diagrams (Figures 2,4,5,6,9).

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S 229, P 460, L18: Fig. 3 will be removed.

S 229, P 461, L6 to L9: Cloud cover will be included as a predictor in the text of section 2.2, and the parameter surface albedo explained in Table 2.

S 229, P 462, L1 to L12: The overall average derived from monthly ozone values will be added to Fig 2.

S 229, P 463, L3 to L4: The following modifications will be applied to this section. Training set (15 per cent of the data) is changed to training set (70 per cent of the data), and production set (70 per cent of the data) is changed to production set (15 per cent of the data). At P 463 L4, the following text is added: The training set determines the adjusted weights between the neurons. During the training period, the network is tested against the test set to determine its accuracy, and training is stopped when the bias remains unchanged (Junk et al. 2007).

S 229, P 463, L9 to L16: The use of predictors has been based not only on the reduction in RMS, which need not be the same for the three spectral ranges, but mainly on the availability of data. Due to the small number of days with snow cover at Potsdam in the time period used for training and testing, surface albedo has not been a good predictor for that period. It even leads to a small increase in RMS. On the other hand, ANN#6 was applied for the period between 1983 an 1995, where the number of days with snow cover was higher. However, it is not clear, whether the training set was suitable to account for the effect of days with snow cover. If we only would have used the concept of reducing RMS, another network should have been used for that time period.

S 230, P 464, L22 to L26: One-minute values of global irradiance were used in the derivation of daily UV irradiation to account for short-term variations of UV irradiance that could have otherwise led to larger additional uncertainties in daily UV totals. We refer to our response to S 228, P460, L3 to L6.

S 230, P 465, L14 to L15: Fig. 11 shows 12months running averages of erythemal UV

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irradiation, and Figures 12 and 13 show annual totals. Therefore, part of the different patterns is due to different parameters and part of it due to removed biases. To make the Figures compatible, Fig. 11 will be changed such that the bias over different time periods will be eliminated, as in the other Figures. Removing the biases in the ANN training process was not applied, because it would have increased the uncertainties of the model version.

S 230, P 467, L1 to L16: Fig. 14 shows the main results of reconstruction by the ANN model at all sites. Both the large absolute level differences as well as the short-term and long-term patterns can be seen very nicely. Fig. 15 shows the anomalies with some sites that according to our impression show similar patterns and were put together in one of three panels. Therefore, Fig. 14 may also be useful for the reader to check, to what extent those similarities do occur, so we like to leave it to his/her discretion. For example, Norrkoeping shows some similarities to the group of Central European sites as well similarities to the Northern European sites. Therefore, we do believe that both Figures 14 and 15 are thus useful.

S 230, P 467, L14: Zero lines will be included in Fig. 15

S 231, P 455, L6: There can be correlations between input data, e.g. SZA and G, and between input and output data.

S 231, P 472 Table 2: Figure caption of Table 2 has been changed. Added to Table 2: Selected predictors for time periods, and resulting irradiation for the test chart set.

9 = surface albedo from pyranometer data

S 231, P 481 Fig. 8: Figure caption has been changed

S 231, P 484 Fig. 11: dimension checked, ok.

S 231, P 485 Fig. 12: dimension checked, ok,

S 231, P 487 Fig. 14: dimension checked, changed from J/ m^2 to J/cm2

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 453, 2008.

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