Atmos. Chem. Phys. Discuss., 8, S2166–S2175, 2008
www.atmos-chem-phys-discuss.net/8/S2166/2008/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "A method to generate near real time UV-Index maps of Austria" *by* B. Schallhart et al.

B. Schallhart et al.

Received and published: 29 April 2008

Answers to Comments of Referee 1

Comments of referee 1

This paper describes a method to be applied operationally for generating area maps of reconstructed UV indices (UVI) for Austria. The reconstructed UVI are computed by estimating clear-sky UVI using a simulation tool to which are given as input a certain number of environmental parameter observations or estimations (ozone, albedo, aerosol turbidity) as well as time and location. The clear-sky UVI are then scaled using a cloud modification factor (CMF) accounting for the influence of the clouds on UV radiation transfer. The main development brought by this method is using CMF derived from cloud information retrieved by the MSG satellite SEVIRI radiometer, and correcting the satellite-derived CMF with CMF information derived from ground-base UVI measurements.

Such line of research is valuable. UVI reconstruction technique based on inferring UV radiation at the ground using a mixture of theoretical knowledge of radiation transfer, empirical information, and observations of proxy parameters is popular because of the difficulty and burdens of precisely and reliably measuring UV radiation. These burdens result in UVI measurements being sparse and the data time series being limited. Because radiation is strongly affected by local phenomena (mainly meteorological), and presents large spatial variability, it is challenging to generate accurate maps of UV radiation. Using satellite information about meteorological conditions is a venue that is worth pursuing.

Comment 1: Unfortunately, the present manuscript only describes a method, but fails at demonstrating its validity, or estimating its accuracy. In my opinion, a major flaw of this manuscript is that there is no section devoted to verifying how accurate is the UVI estimation resulting from the method presented. Such a verification step is needed when presenting a new development in a UV reconstruction method (or any other estimation method). One would expect a result significantly better than the cited results of Verdebout (2004) and Arola et al. (2002).

Such verification step should allow verifying the validity of the method in a statistical way for different conditions. This means it should not be restricted to a limited number of comparisons between algorithm estimation and observations for specific cases. A valuable method would be 1) systematically removing the information from the observing stations one at a time from the algorithm; 2) infer the estimated UVI at the station whose observation was not included in the algorithm, and 3) compare the obtained result with the observation at the station. Repeating this procedure for all stations and a representative number of conditions would allow estimating the accuracy of the method. I would advocate performing such verification for daily doses, rather than monthly doses, because I am not convinced of the usefulness of checking the latter (see specific comments).

Answer to comment 1: We agree that the accuracy of the model should be given. We argue that the accuracy of the calculated UVI map can be estimated by analyzing the correlation between ground based (CMF_ground) and satellite derived (CMF_msg) cloud modification factors at the site pixel.
The final UVI map is obtained by multiplying clear sky model calculations with CMF_msg that are corrected according to ground based measurements. The model calculations are scaled to fit the clear sky measurements at all sites as good as possible. So the main uncertainty in the final UVI stems from erroneous CMF_msg. If a station is omitted in the computation of the map (as proposed by referee 1), no station specific correction is applied to the satellite derived CMF_msg. There may be corrections stemming from neighboring stations, but in the worst case the uncorrected CMF_msg is used to calculate the final UVI at the station pixel. Therefore the maximum error in UVI can be estimated by analyzing the correlation of satellite derived CMF_msg and station based CMF_ground for all weather conditions.
The correlation coefficient of CMF_msg to CMF_ground together with mean and standard deviation of the ratio CMF_msg to CMF_ground of a two years data set (all weather conditions) will be given in the revised manuscript to show the accuracy of the method presented.

Specific comment 1: In the introduction, it is mentioned that a disadvantage of satellite data is the problem of pixel size, and smoothing of atmospheric characteristics over relatively large areas (p 2145, ll. 21-23). While this is a disadvantage, it is not the only one I would mention. Another problem worth mentioning is that there are substantial uncertainties in the cloud characteristics determined by satellites, especially for low clouds or in case of multi-layered clouds, and even more uncertainty in inferring the CMF from these characteristics. The reason I would mention the latter problem rather than the problem of pixel size, is that the method presented (which corrects the satellite-derived CMF with CMF derived from ground-based information) has the potential of correcting part of such uncertainties, but little potential in improving the problem of pixel-size smoothing, except maybe in the very vicinity of the observation.

Answer to specific comment 1: The satellite estimate is by nature an average over a certain area (the pixel). A ground measurement is influenced by the very local conditions. Whether the "pixel smoothing" is per se a disadvantage is depending on the application. It is sometimes more pertinent to have an information on the average situation over a certain area rather than at a precise location, which may not be representative of the area. To take an extreme case, is it more relevant to communicate to the public the UV index at the summit of a mountain or a value corresponding to a 5$\times$5 km area including this mountain.
Regarding the difference between the satellite estimate and the ground measurement, the satellite pixel can contain a large variability in the influencing factors, especially in mountainous regions. For example the stations of Innsbruck and Hafelekar are practically in the same MSG pixel but their altitudes are 577 and 2275 m respectively. Only because of altitude, the UV radiation will be about 15% higher in Hafelekar than in Innsbruck. By itself, the altitude will affect much less the CMF than the UV index itself (and the same can be said for the aerosols) but the cloudiness over the two stations is also likely to be different in many cases. The satellite estimate cannot at the same time agree with the ground measurements at Innsbruck and Hafelekar. The comparison between the measurements at Innsbruck and Hafekelar actually shows that the CMF is about 20% higher at Hafekelar and the correlation coefficient between the two measurements is only 0.65.
The cloud model (see a description in the answers to referee 2) is admittedly rudimentary but adding complexity would make impossible the retrieval of the cloud optical thickness from SEVIRI. The result will make sense only if most of the variability in the cloud attenuation can be reduced to a single variable (in this case the cloud density,

ACPD
8, S2166–S2175, 2008

Interactive Comment

determining the cloud optical thickness). In this process the cloud density (or cloud optical thickness) retrieved from SEVIRI does not pretend to correctly estimate the real value. It is only an "effective" cloud density and a transitory output, later used to estimate the cloud attenuation in the UV range (with the same cloud model). If, for the same optical thickness, the variability in the cloud detailed structure and micro-physical parameters were producing a large variability in the attenuation, the algorithm would not work at all. This way of doing must also be judged against even more simple ways of taking into account the clouds (e.g. by multiplying the cloudless UV estimation by a cloud fraction).

The same discussion can be made about aerosols. Here again their attenuation of radiation is depending on the optical thickness but also on the single scattering albedo, the Angstrom coefficient, the asymmetry factor, the size distribution, the scattering phase function in general and in addition on their vertical distribution. Unfortunately, this detailed information is only very rarely available and one is constrained to considerably simplify the description.

In addition, the radiative transfer calculations performed to generate the Look Up Tables use standard, fixed values for the atmospheric profiles, for the stratospheric aerosols, neglect the non-Lambertian nature of the surface reflectance, the tropospheric gaseous pollution and all 3D effects.

Specific comment 2: In section 3.1, it is mentioned that rms value of relative difference between satellite estimates and measured erythemal doses was 29% (bias 3%) for daily doses, and that the rms of relative difference decreased to 5% when comparing monthly doses (p 2149, ll. 4-6). Actually, I wonder if there is anything else than the decrease expected from statistics in this decrease of the rms to 5% for monthly doses. The rms gives information on the squared sum of the bias and standard deviation of the average relative difference on days or months. If there is not too much auto-correlation one expects a reduction by square-root of 30 in the standard deviation when going from daily to monthly doses. Using 29% rms and 3% bias on

ACPD

8, S2166–S2175, 2008

Interactive Comment

daily dose, one expects 6% rms on monthly doses just from statistics.

Answer to specific comment 2: The numbers cited in the paper were mere indications. Furthermore, they relate to another product which is substantially different from the MSG derived CMF. We will report statistical information on the MSG derived CMF.
More fundamentally, the analysis of the difference between satellite estimates and ground measurements is a non trivial problem that, we think, cannot be reduced to a couple of statistical numbers. First, this difference is only partly an error as it also contains the intrinsic difference between the irradiance measured at a point on the surface and the average over a certain area around this point (even if the irradiance at a point is influenced by the conditions around this point). To some extend, these comparisons are between apples and oranges.
A systematic difference in the values of an influencing factor at the location of the instrument with respect to those averaged over the pixel will produce a bias. This includes altitude, local aerosol conditions (e.g. urban aerosol or on the contrary particularly clean air on top of a mountain), surface albedo, horizon obstruction and also sometimes the local average cloudiness (for example in mountainous areas). In practice this is aggravated by the fact that the information used in the satellite processor is sometimes available with only a coarse spatial resolution (e.g. the aerosol information). In addition of course, part of the bias results from the biases present in the input model data (ozone, visibility/AOT, etc..). The causes mentioned above are expected to have less impact on the CMF than on the UV irradiance itself as they impact the CMF only through couplings with the cloud effects. In addition, inaccuracies in the satellite retrieval model also contribute (e.g. when transferring the cloud attenuation to the UV range). These can affect the CMF to the same extend as the UV irradiance. Finally, the procedure used to estimate the CMF from the ground instruments can also introduce a bias.
The dispersion mainly results from cloud attenuation. In the satellite retrieval process,

ACPD
8, S2166–S2175, 2008

Interactive Comment

the cloud is a single layer water cloud covering the entire pixel. The optical thickness of this cloud is determined by inversion from the change in the SEVIRI 0.6 μm signal with respect to the cloudless situation (caused by the backscattering of light by the cloud). Within a SEVIRI pixel, it is impossible to distinguish a broken cloud field (with a structure finer than a few km) from a uniform field. The algorithm will always translate it into the optical thickness of a uniform cloud. This will obviously induce some error on the modelled UV surface irradiance and CMF in the pixel. Under a broken cloud field, the ground instrument will measure an irradiance much lower than the average irradiance over the pixel when it is in the shadow of a cloud and much higher when in a sun spot. This is what, according to us, explains the poor correlation between quasi-instantaneous measurements and the satellite estimates. In addition, when the MSG algorithm mistakes snow for cloud (and this definitely happens), the error is obviously considerable (it can reach several hundreds of %).
As the clouds move, one would expect that the time averaged measurements and satellite estimates would converge ("partial ergodicity"). The impact of time sampling and cloud structure on the theoretically achievable accuracy on daily doses (and that of neglecting 3D effects) was studied using a numerical simulation based on synthetic cloud fields and 3D radiative transfer calculations [Bugliaro et. al., 2006]. The conclusions cannot be summarized in a few words.
The reduction in the dispersion when time averaging may be of the same amplitude (or actually less pronounced) than if the difference was purely random but we think that the phenomenon is not that simple. In this regard, one should note that the distribution of the difference is far from being normal (Gaussian): it is sharper and with extended tails, which probably correspond to cases when the algorithm fails to correctly identify the cloudless situation. As already said, the error can then be very high and it strongly impacts some statistical coefficients. Further clarifying this point is not trivial and we do not want to make it a main topic in this paper.

L. Bugliaro, B. Mayer, R. Meerkötter and J. Verdebout, "Potential and limitations

ACPD
8, S2166–S2175, 2008

of space-based methods for the retrieval of surface UV-B daily doses: A numerical study", JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D23207, doi:10.1029/2005JD006534, 2006

Specific comment 3: In section 3.2, the fact that the ground observations and satellite observations are not perfectly synchronous is emphasized (p 2150, ll. 27-29) just after the mention of a bias between clear-sky observations and model simulations. The way this information is given makes it look like it could also be a cause for the bias. However, I cannot imagine how this could be the case, except if the time difference would systematically lead to a same sign solar zenith difference between the time of simulation and the time when the sky was identified as clear with satellite information. If this is the case it needs to be developed, if it is not this sentence about time synchronization is only confusing.

Answer to specific comment 3: We agree that the sentence about not perfect time synchronization is confusing in combination with the bias between clear-sky observations and model simulations. There is no correlation between the bias and time synchronization. This part will be rewritten in the revised manuscript.

Specific comment 4: In section 3.3, scatter plots of ground-based and satellite-derived CMF are presented, and the correlation between both is discussed. Actually, I could not find any computation of the correlation. Since the discussion is about it, I think it needs to be given as a table for the different stations. At present, the discussion of this point is only qualitative, and does not include quantitative information.

Answer to specific comment 4: We agree. This will be included in the revised manuscript.

Specific comment 5: In section 3.4, it is mentioned that no information on snow line distribution is available in Austria (p 2152, ll. 1-3). While I did not thoroughly check this claim, there is a lot of work on snow mapping (including by satellite) on the Alps (e.g., Foppa et al., 2004, Operational sub-pixel snow mapping over the Alps with NOAA AVHRR data, Annals of Glaciology, 38, pp. 245-252). In case the information from such work is really not suitable, the method for daily estimation of the snow line altitude should be described, at least cursorily.

Answer to specific comment 5: As far as we know there are no online data of the snow line for the region of Austria available. So the altitude of the snow line is estimated daily by observation. This will be included in the revised manuscript.

Specific comment 6: In section 3.4, the correction function for cases when snow covered pixels could be wrongly identified as clouds is indicated as being implemented independently of the site pixel correlation of satellite derived and ground measured CMFs (p2152, ll. 19- 20). I do not understand what the authors mean or what is the difference with the other cases, since the location of the F(ground) vs. F(MSG) point is used as in the other cases.

Answer to specific comment 6: The formulation "Therefore a correction function is implemented independent of the site pixel correlation of satellite derived and ground measured CMFs." (P2152, l. 19-20) is misleading. The correction is made for CMF_ground bigger than 0.8 and pixel above the snow line. There are no additional constraints to the value of CMF_msg. (This is what the author wanted to express.) This will be rewritten in the revised manuscript.

Technical correction 1: P. 2147, l.14 "Finally the results are transferred in units of the UV-Index". Do the authors mean "Finally the results are translated in units of the UV-Index"?

ACPD

8, S2166–S2175, 2008

Interactive Comment

Answer to technical correction 1: Yes we mean "Finally the results are translated in units of the UV-Index". This will be rewritten in the revised manuscript.

Technical correction 2: P. 2150, l. 18 "Albedo and Angstrom coefficient beta are dependent on altitude and on the snow line." Altitude and snow line are important for albedo. While altitude may influence Angstrom beta coefficient, there are many other important factors that influence it (weather situation, etc.).

Answer to Technical correction 2: We agree that the weather situation is influencing the Angstrom beta coefficient but no area wide and online information of the weather is available.
For clear sky conditions the weather situation at the measurement sites is taken into account by scaling the modelled values based on a comparison between measurement and model (P.2151, l. 2-6). By applying this scaling factor the model is also corrected for the effect of the weather on Angstrom beta. For cloudy conditions the model is scaled with the default value of 92% (obtained from a long term comparison of measurement and model). This may not perfectly reproduce the actual weather situation in the modelled values but in that case the main error in the calculated UVI stems from the CMFs anyway.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 2143, 2008.