**Atmospheric
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Discussions**

Interactive
Comment

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

**B. Schallhart et al.**

**Answers to Comments of Referee 2**

**Comments of referee 2**
The authors tackel a very important and difficult problem. The UV radiation amount, here expressed for convenience by the UV-Index, is measured regularly, at 15 locations in Austria and in its vicinity. It can therefore be provided to the public in near real time, for these locations. Interpolating between the stations to built complete maps is however very risky, because many parameters modulate the UVIndex, i.e. ozone amount, aerosols, clouds, elevation, surface reflectance. Cloudiness is a very important modulator of UV, and it is the most rapidly variable, both locally and with

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time. The authors propose to use satellite observations of clouds, associated with modeling and ground based observations, to build the UV-Index maps. It is a good idea, although the results are not absolutely convincing.

**Specific comment 1:** The weak point in the paper is section 3.1, and unfortunately it concerns the CMF derived from satellite images, which plays a very important role in the results. After preliminary considerations, it is just said (p.2149, line 17) that the CMF is derived from the cloud optical thickness, but how ? and how is the cloud optical thickness derived from the SEVIRI images ? This section needs to be completely rewritten and to present an informative summary of the method.

**Answer to specific comment 1:** We will include a description of the satellite algorithm. (see below)

**Specific comment 2:** The correlation between ground based and satellite derived CMF (section 3.3) is very bad, as noted by the authors. This makes very dubious the correction proposed in section 3.4; one could even think that the effort placed in the details of this correction is misleading, in giving too much confidence in the final map.

**Answer to specific comment 2:** The proposed correction of the satellite derived CMF is definitely improving the data near the measurement stations, and therefore we think it is worthwhile to do it.

**Specific comment 3:** In the introduction, the authors mention a simple interpolation method (p.2145, lines 13-15). Did they try some comparisons between the results obtained by this method, and their own results ?

**Answer to specific comment 3:** We did not perform a quantitative comparison

between results obtained with the Kriging methode and the methode presented here. The basis of the Kriging methode is to spatially interpolate between single point measurements by using information of long term correlations between the measurements. Since there is no information of the actual cloud situation used with the Kriging methode, a comparison between both methods for cloudy conditions (and this is the interesting case) would not lead to new findings (except that the UVI maps generated with the methode presented here are much closer to the actual situation).

**Specific comment 4:** A good check would be to eliminate two or three sites from the treatment, and to use them for comparison with the retrieval. Of course a few mobile instruments could also be used.

**Answer to specific comment 4:** Data of mobile instruments are not at hand. We agree, a possibility to estimate the accuracy of the presented methode would be to eliminate a site from the treatment with subsequent comparison of the measurement and obtained result. We argue that the accuracy of the calculated UVI map can also 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, 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.

**Detail 1:** Abstract, line 15: replace "provided by Jean Verdebout", by "provided by one of us", or simply give a reference.

**Answer to detail 1:** This will be changed in the revised manuscript.

**Detail 2:** Section 2.2: 10 instruments measure erythemally weighted UV; what is the spectral band of the 5 others, called broadband detectors ? It would be good to add the type of each instrument in table 1.

**Answer to detail 2:** All detectors measure erythemally weighted UV. Some are from Solar Light others from Scintec. This information will be included in table 1.

**Satellite algorithm description**

The processor for retrieving the cloud modification factor from MSG is based on an algorithm previously developed for mapping the erythemal surface irradiance using METEOSAT/MVIRI images, satellite ozone and ancillary geophysical data (Verdebout, 2000). The surface erythemal dose rate is obtained by interpolation in a look up table (LUT) of modelled erythemal irradiance (CIE87 action spectrum), the entries of which are solar zenith angle, total column ozone amount, cloud optical thickness, near surface horizontal visibility, surface elevation and UV albedo. The LUT is generated from fully coupled radiative transfer calculations performed with the UVspec code of the libRadtran package (Mayer and Kylling, 2005). In order to allow using the cloud optical thickness retrieved by inversion from a single band image of MSG/SEVIRI the

cloud model is constrained to be very simple. In practice, it is a single layer water cloud (1 km thick), 1 km above the surface and with a 7 $\mu$m droplet radius. The optical thickness is modulated with the cloud density. All other atmospheric parameters are given standard values (i.e. U.S. standard atmosphere, "troposheric" aerosol model, background stratospheric aerosols). The surface reflectance is assumed to be Lambertian.

Both satellite and non-satellite (synoptic observations, digital elevation model) data are exploited to assign values to the influencing factors. The CMF is simply obtained by dividing the surface erythemal irradiance by what would be its value in the absence of clouds (obtained from the LUT with a cloud density set to 0). As the radiative transfer calculations are one-dimensional, the satellite-derived CMF never exceeds 1. In other terms, CMFs larger than one, as sometimes produced by 3D scattering effects within the cloud field structure, cannot be modelled. The CMF maps are generated on a latitude/longitude grid with a spatial resolution of 0.05 $\times$ 0.05 deg. This resolution roughly corresponds to that of MSG over central Europe.

In the original method, total column ozone is extracted from the gridded TOMS daily data or other ozone sensors data (e.g. TOVS, GOME, OMI) and the aerosols are taken into account by gridding daily measurements of near surface horizontal visibility performed at ground stations. For the application described here, the CMF is generated in near real time, within about 10 minutes of the MSG images acquisition. The above mentioned data on ozone and visibility are not available within this delay. Because the output is the CMF and not the UV index itself, it was judged that climatological values could be used instead. The daily climatological values for total column ozone and visibility were obtained by averaging the TOMS and gridded visibility data over the 1984 to 2003 period, with a 10 days running window. The averaging period corresponds to that of a 20 years data set of erythemal radiation maps over Europe, generated with METEOSAT/MVIRI, for which the data were readily available (Verdebout, 2004). The digital elevation model is derived from the GTOPO30 data set from United States Geological Survey (USGS) by arithmetically averaging the altitude

in each 0.05 × 0.05 deg CMF output cell. The values for the last two influencing factors, i.e. cloud density and UV albedo are retrieved from MSG/SEVIRI images. This is done using another LUT simulating the "at sensor radiance" (proportional to the image digital count), in the SEVIRI visible band centred at 0.6 $\mu$m. The entries of this second LUT are solar zenith angle, SEVIRI viewing zenith angle, relative azimuth between illumination and viewing vectors, effective surface albedo and cloud density (with the same cloud model as for the UV LUT). A preliminary step consists in generating an effective surface albedo map by finding cloud free pixels in a series of ten SEVIRI images corresponding to the same time slot of ten consecutive days (the nine previous days are used). In most cases, the cloudless pixel is chosen as the one corresponding to the lowest signal in the 0.6 $\mu$m SEVIRI band. However, if the surface reflectance is high, the darkest signal does not necessarily indicate the absence of clouds (the snow reflectance can be higher than that of clouds). Therefore, if the minimal effective surface reflectance is found to be above a certain threshold, the discrimination is refined by also using the 1.6 $\mu$m near infrared and the 12 $\mu$m thermal infrared bands (Verdebout and Gröbner, 2004). These two bands add other discriminating criteria. At 1.6 $\mu$m, a water cloud appears darker than snow while the pixel brightness temperature (computed from 12 $\mu$m band) will in general be higher when cloud free than when cloud covered, even if snow is present. These criteria together with the spatial context (i.e. the albedo values found at neighbouring pixels, the altitude) are used to make a decision on the day in the series that is chosen as cloud free (for each pixel). This decision process also uses histograms of the 1.6 $\mu$m signal and of the brightness temperature, generated for a surrounding area, to dynamically set discriminating thresholds. Although the two additional bands help, the decision can still be wrong because ice clouds appear bright at 1.6 $\mu$m, because the surface can be warmer than the cloud top or simply because some areas are cloud covered during the 10 days. The snow covered areas are also a difficult case because the dynamic of the SEVIRI signal in the visible (with respect to cloud optical thickness) is much reduced. Once the composite cloudless digital count image has

been constructed, it is transformed in an effective albedo map by inversion, using the LUT reduced to the cloudless case. For each pixel, as values for all the other entries are known, the effective albedo map is then used to reduce the LUT to a single function yielding the 0.6 $\mu$m SEVIRI signal dependence on the cloud density. The latter can then be retrieved by inversion from the 0.6 $\mu$m SEVIRI signal for the day and time of interest.

The UV surface albedo is assigned uniform values for land (0.03) and sea/ocean (0.06), except in the presence of snow. In this case it is given a value proportional to the 0.6 $\mu$m SEVIRI band effective albedo. The rationale for proportionality between the albedos in the two spectral ranges is that partial snow cover should affect them in a similar way.

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