ABSTRACT

The method for mapping surface UV radiation using MSG follows the general scheme previously used with METEOSAT. It basically consists in using a standard radiative transfer code (UVspec) and in exploiting various sources of information to assign values to the parameters influencing the surface UV radiation. GOME, TOMS or TOVS data are used for the total column ozone. The tropospheric aerosols are taken into account by using observations at ground meteorological stations and the surface altitude by means of a digital elevation model. MSG is used to derive cloud optical thickness and to detect the presence of snow. The MSG NIR band is used as an additional discriminator for this latter purpose. A series of MSG-derived European UV daily dose maps in March 2004 are compared with the METEOSAT-derived ones. The results are also compared with high quality measurements performed at the UV monitoring station in Ispra.

1. INTRODUCTION

Exposure to high levels of UV radiation is harmful to human health (skin cancer, cataract, immuno-suppression), and influences many natural biological processes (marine life, plant physiology). The awareness of these effects has been raised by ozone depletion, which leads to an increase in the intensity of the UV radiation reaching the Earth surface in some regions of the world. It is now felt important to monitor the changes that occur in this environmental parameter. Although the ground radiometers will remain the reference in terms of accuracy, they are too few to offer a comprehensive geographical coverage. Hence the development of methods those aim at mapping the surface UV radiation intensity by combining modelling and satellite data.

The method presented here is using the full resolution images from EUMETSAT’s geostationary meteorological satellites. Over Europe, the spatial resolution is typically 5km (degrading at high latitudes because of the increasing viewing angle).

Fig 1. Overall structure of the UV mapping algorithm
METEOSAT 2 to 7 have been used to build a climatological data set covering the period from January 1984 to October 2003. The algorithm now needs to be transposed to use MSG data.

2. ALGORITHM USING METEOSAT 2 TO 7

The mapping methodology (Fig. 1) is described in detail elsewhere [1]. To summarize, UV radiation maps over Europe (34N-74N, 12W-32E) are generated with a spatial resolution of 0.05 deg., and potentially on a half-hour basis. The surface UV dose rate is obtained by interpolation in a look up table (LUT) of modelled irradiance, the entries of which are solar zenith angle, total column ozone amount, cloud optical thickness (COT), near surface horizontal visibility, surface elevation and UV albedo. The LUT was computed with the UVspec code [2] of the libRadtran package. Both satellite and non-satellite (synoptic observations, digital elevation model) data are exploited to assign values to the influencing factors. The total column ozone is extracted from the gridded TOMS data or other ozone sensors data (e.g. TOVS, GOME). The aerosol optical thickness is tentatively taken into account by gridding daily measurements of near surface horizontal visibility performed by about 1,000 ground stations. The digital elevation model is the GTOPO30 data set from United States Geological Survey (USGS).

With the help of another LUT simulating the "at sensor radiance" (proportional to the image digital count in the visible band), METEOSAT data are processed to retrieve the cloud optical thickness. The entries of this second LUT are solar zenith angle, METEOSAT viewing zenith angle, relative azimuth between illumination and viewing vectors, effective surface albedo and cloud optical thickness. A preliminary step consists in generating an effective surface METEOSAT albedo map by finding cloud free pixels in a series of ten consecutive days. In most cases, the cloudless pixel is chosen as the one corresponding to the lowest signal in the visible band. However, if the surface reflectance is high, the surface may be snow covered and the darkest visible signal does not necessarily indicate the absence of clouds. Therefore, if the effective surface reflectance is found to be above a certain threshold, the discrimination is refined by also using the thermal infrared band. The rationale for this second algorithm is that the pixel brightness

![Deviation of the Monthly Averaged Erythemal Daily Dose with Respect to the 1984-2003 Mean (April)](image)

Fig. 2. Year to year variability of the monthly averaged erythemal daily dose in April.
temperature should be higher when cloud free than when cloud covered, even if snow is present. However, a threshold for discrimination can only be defined locally as the surface temperature varies considerably with geographical location. The land surface was therefore divided in zones according to latitude and geophysical characteristics. In particular, the main mountainous areas (the Alps, the Pyrenees, the Caledonian range in Scandinavia) constitute such zones. In mountain areas, the zone is further subdivided in altitude classes. For each class, the histogram of the infrared METEOSAT brightness temperature over ten days is fitted as a sum of Gaussian functions. The cloud free pixels are associated with the “warmest” Gaussian and a threshold is determined on this basis. 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. The effective albedo map is then used to estimate the cloud optical thickness for the day and time of interest, by inversion using the full LUT. 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 METEOSAT 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. The outputs of the METEOSAT processing are fed into the UV map processor to generate surface UV irradiance maps or dose rate maps when a spectral weight is applied.

The daily dose is constructed by numerical integration of the dose rate estimated at half-hourly intervals from and including the local solar noon (for each pixel). The COT time dependence is described with a stepwise function with as many time intervals as the number of METEOSAT images used per day.

With the method outlined above, it has been undertaken to build a European climatology of UV radiation. As of today it consists in daily dose maps from January 1st 1984 to August 31st 2003. For practical reasons (processing time and amount of data) one METEOSAT image per day only has initially been used. The data set is progressively upgraded to using 3 images per day; this is already the case for March and July from 1990. Although only erythral doses are shown here, the model output is spectral and the dose corresponding to any desired action spectrum can be generated on request. These data are available from JRC for scientific purpose (e.g. impact studies). Fig. 2 shows an example of how the data set documents the year-to-year variability of the surface UV radiation over Europe.

3. COMPARISON WITH MEASUREMENTS

The comparison between satellite estimates and ground measurements is best conducted on daily doses. The satellite estimate is by nature an average over a certain area (the map pixel) while the measurement is punctual. The instantaneous measurement of surface irradiance is sensitive to the detailed cloud structure (it is for instance influenced by a small cloud obscuring the sun). The satellite-modelled value on the other hand corresponds to a uniform cloud reproducing the average cloud optical thickness over the area. The fact that the measurement and the satellite image acquisition are never perfectly simultaneous further complicates the comparison on irradiance. Because the

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Fig. 3. Comparison of modelled and measured daily doses in Ispra; top: all available data from 1992 to 2003 in the form of a scatter plot; bottom: comparison on monthly averaged values (squares: measurement, asterisks: modelled)
clouds move, the time integration performed to estimate the daily dose from the measurements smooths the cloud structure and has an effect similar to the spatial integration in the satellite image. Even so, part of the observed difference between the two data reflects their different nature. This intrinsic difference strongly depends on the cloud structure and variability.

Fig. 3 shows a comparison between the measured and satellite-derived erythemal daily dose in Ispra, in the form of a scatter plot. The data points include every day between 1992 and 2003 for which the satellite data and at least 20 irradiance measurements are available. The high quality spectral measurements were performed with a Brewer spectrophotometer and their expanded uncertainty has been estimated to be 10% \((k=2)\) [3]. The rms value of the relative difference between the satellite estimates and the measured erythemal daily doses is 29% and the bias +3% \((\text{sat-ground})/\text{ground}\). The difference decreases with time averaging (~5% rms on monthly averages). The rms values of the relative difference are high but this is partly due to a restricted number of days for which the relative error is very large. As for the bias, it is within the absolute calibration accuracy of the instrument. Comparisons at four other sites in Europe yield similar results [4].

4. ALGORITHM TRANSPOSITION TO MSG

In a first step, the algorithm was simply transposed to MSG by substituting the visible and infrared bands of METEOSAT with the 0.6 µm and 12 µm bands of MSG. This of course implied re-computing a LUT for the MSG band at 0.6 µm, which was done with the latest version of UVSPEC (1-beta). A number of auxiliary data also needed to be regenerated on the MSG grid, such as the digital elevation model, the land/sea mask, the viewing angles, the areas used in the processing, files for re-sampling the MSG grid to the UV map output grid, etc. For the rest, the logic of the algorithm is identical to that used with METEOSAT.

An additional criterion for distinguishing snow from clouds was later introduced, using the NIR band at 1.6 µm. In this band, snow and ice appear darker than water clouds. In order to reject ice clouds pixels (dark in NIR but cold) as candidates for snow, a discriminator was built, dividing the brightness temperature (in K) by the digital count in the NIR band. It was then assumed that snow corresponds to the highest values of this discriminator. The same algorithm as for the brightness temperature, based on a multi-Gaussian fit of the histogram, was used to determine a threshold. For technical reasons, the discriminator was scaled to approximately the same values as the temperature. Examples of these histograms and thresholds are shown in Fig. 4, corresponding to an area covering the South of Norway (when processing for 11/03/2004). This area is partly snow covered in spring and is therefore a good one to test the snow/cloud discrimination.

The MSG algorithm was tested on a series of 15 days (2nd to 16th March 2004). Figure 5 shows the cloud optical thickness map over Scandinavia, obtained for March 11th, together with the same map obtained with METEOSAT-7. The results are very similar but MSG yields a somewhat more consistent cloud field: small cloudless areas within the cloud field do not appear, as is the case with M7. Fig. 6 shows the erythemal dose rate obtained from MSG slot 11:15 and M7 slot 23. Here too the results are very close to each other. Fig 6 also shows the erythemal daily dose estimated using M7 with 9 slots. Similar results will be obtained with MSG, as this part of the algorithm is independent of the space sensor. Except in exceptional cases, little advantage is expected from the higher temporal
Fig. 5. Cloud optical thickness maps obtained with slot 23 of METEOSAT 7 (left) and MSG at 11:15 (right), on April 11th 2004.

Fig. 6. Erythemal dose rate maps derived with MSG 11:15, METEOSAT 7 slot 23 and daily dose using METEOSAT 7 slots 19 to 27 for 11/03/04.

Fig. 7. Comparison on the daily erythemal dose in Ispra.

Sampling of MSG as the change in the pixel cloud coverage in 15 minutes has a low impact on the daily dose.

In Fig. 7 the MSG and METEOSAT derived daily doses in Ispra are compared with the measurements, for the 16-day period. The MSG and METEOSAT results are almost identical; the difference being well within the uncertainty of the estimates themselves. The difference between the measurements and the satellite-derived values is larger than usually observed. This will be further analysed. The period was perturbed by a snowfall event, which may have affected both the measurements and the satellite estimates. The important point for insuring the continuity of the UV climatology is that METEOSAT and MSG yield the same results, and this is the case.
5. CONCLUSION

A first version of a surface UV mapping algorithm with MSG has been devised and tested. It provides results very similar to those obtained with the previous METEOSAT data. This first algorithm is a simple transposition of that used for building the UV climatological data set with METEOSAT, with an upgraded snow/cloud discrimination using the MSG NIR band.

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7. REFERENCES


