Report: "Mobiliteit"

Improvement of the prediction of UV-index

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1 Introduction

The sun emits a broad spectrum of photons which reaches the earth and makes us able to see, makes plants able to do photosynthesis but these photons have a drawback too. Part of the spectrum [1] is harmful to humans, an overload of these photons to human skins increases the chance on skin cancer and eye diseases. Fortunally most of these harmful photons are absorbed or reflected by our atmosphere. Unfortunally, our atmosphere is less capable of stopping these harmful photons the last decennia as a consequence of human influence on the atmospheric composition. The amount of harmful photons which passes through our atmosphere to the earth surface depends on the composition of the local atmosphere and this composition differs from day to day.

This is why efforts are made to make models [2] which predict the amount of harmful photons which reach the earth surface using a prediction for the atmospheric composition. To inform the public the so-called UV index is used. This is a positive number: 0 indicates it's safe, while 10 or even more

[1] WMO/WHO defined 400nm to 280nm waves to be harmful

[2] Madronich, S., UV radiation in the natural an perturbed atmosphere, Environmental effects of Ultraviolet radiation (Edited by M. Tevini), Lewis Publisher, Boca Raton, 17-69, 1993

means it's very dangerous . The UV-index (UVi) is defined by:

$$UVi = 40\frac{m^2}{W}\int_{\lambda_{min}}^{\lambda_{max}} f(\lambda)g(\lambda)d\lambda \tag{1}$$

In this formula, f is a function which describes how harmful a certain wavelength is for human skin, g describes how many photons with a certain wavelength reach the earth's surface. The product is integrated over all dangerous wavelengths (and even further if preferred but in that area $f = 0$ ($\lambda >> 400$nm) or $g = 0$ ($\lambda << 150$nm)). The constant in front of the integral makes sure the UV-index is a dimensionless, easy number. This number can be given to the general population of a country with a legend so they know when it's safe or dangerous to walk in the sunlight.

The object is to improve the UVi forecasting model that is used to calculate the UV-index so more accurate predictions can be done in the future. For this we need to have some idea of how the UVi forecasting model works. It's not possible to understand the entire problem in a short period, but a basic understanding of the adjustable input parameters is important.

There are 3 different kind of inputs to the UVi forecasting model. The first one is an input which is not required: when it's given, it's used, when it's not, a standard value is used. An ozon altitude profile is this kind of input. The spectral aerosol optical properties is another kind of input. A standard profile is inserted in the UVi forecasting model and it's never adjusted unless for research purpeses. The third kind of input is the input which differs from prediction to prediction: total amount of ozon, total amount of aerosols, date.

2 Methods

To improve the UVi forecasting model, random cloudless days in the past 6 years are chosen [3]. Measured ozon and aerosol values of that day are used to predict the UV-index of that day which can be compared to the measured UV-index.

In a second phase, ozon sondes are added to see whether this gives significant improvements.

The results (see further on) showed significant errors on the predicted UV-index on days with high amounts of aerosols. This lead to the idea to try

[3]The ones chosen are (ddmmyy): 010603, 150603, 160603, 100703, 130703, 140703, 150703, 190703, 080604, 290704, 020804, 190605, 230605, 170705, 020706, 100706, 160706, 170706, 180706, 290706

different profiles for aerosol composition. The UV-index was again predicted with and without ozon sondes.

The results of the different profiles showed none was good for all amount of aerosols. A combination of profiles was made and again the UV-index was predicted and compared.

3 Sources

Finding cloudless days is done with data provided by the Brewer spectrophotometer, which is located at Ukkel. [4]

In order to predict an UV-index for a certain day in the past, we need data for aerosols and ozon of that day. This data is also provided by the Brewer spectrophotometer.

To take the altitude profile of ozon into account, ozon sondes are used. Every Monday, Wednesday and Friday at 2 pm (GT), these sondes are launched at Ukkel.

The spectral aerosol optical properties which are normally used in the UVi forecasting model are combined in an urban profile. [5] Alternative profiles have been provided by the university of Ghent, based on samples of aerosols taken at Ukkel.

4 Results

First the urban profile, which is used as a standard for the UVi forecasting model nowadays, is tested. The result can be found in figure 1 and 2 as it generates the black line. A perfect UVi forecasting model and measurements would normally generate a $y = 0$ function, since the y axe gives the difference between the measured UV-index and the calculated one.

A systematic error was noticed and different profiles were tested, hoping to find better results. The blue curve is a continental profile, the yellow one is an urban profile with continental influence, the red and green ones are continental profiles with maritime influence with different humidity. None of the profiles seems good for all values of aerosols.

[4] Brewer, A.W., A replacement for the Dobson spectropotometer, Pure and Appl. Geophys., 106-108, 919-927, 1973.

[5] URBAN/INDUSTRIAL model, World Climate Programme, A preliminary cloudless standard atmosphere for radiation computation, march 1986, WMO/TD-NO. 24, World Meteorological Organization.

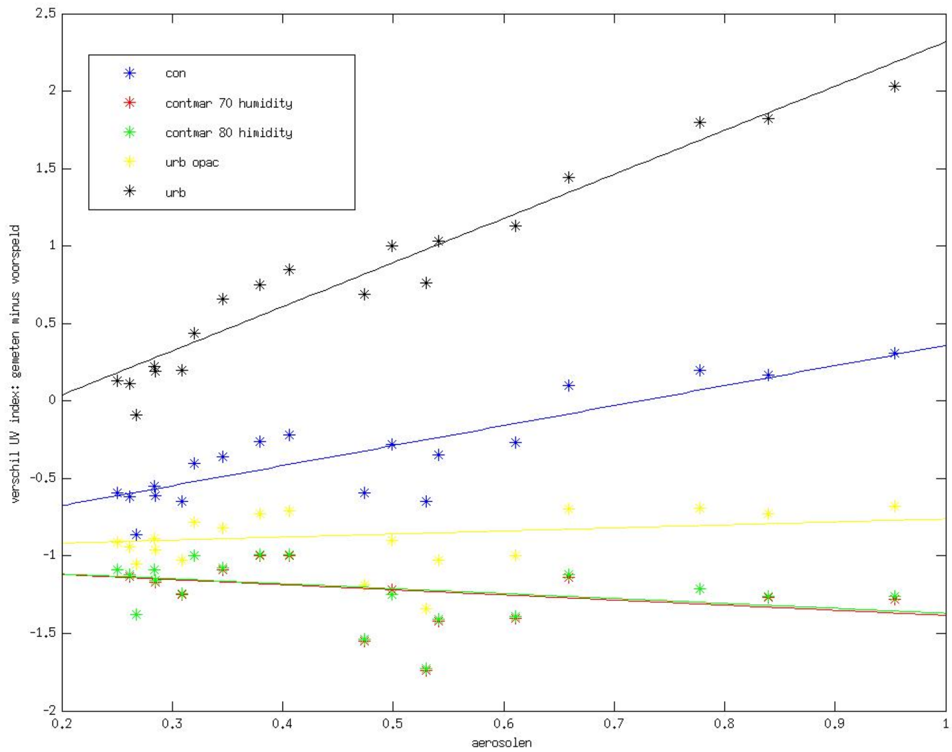

Figure 1: The error on the predicted UV-index (measured - predicted) in function of the amount of aerosols. It's clear a systematic error occurs with increasing aerosols. The standard profile generates the black line which has the largest error for large amounts of aerosols. The continental profile is accurate for large amounts of aerosols but isn't for small amounts. Direct sun measurements are used for ozon values.

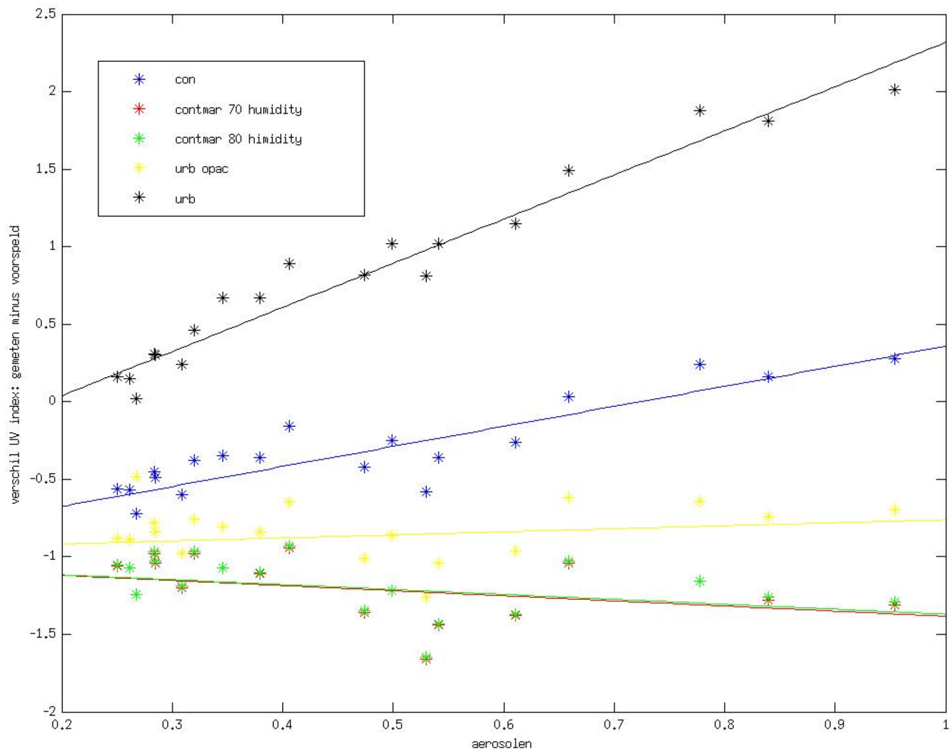

Figure 2: idem figure 1 but zenith measurements are used for ozon values.

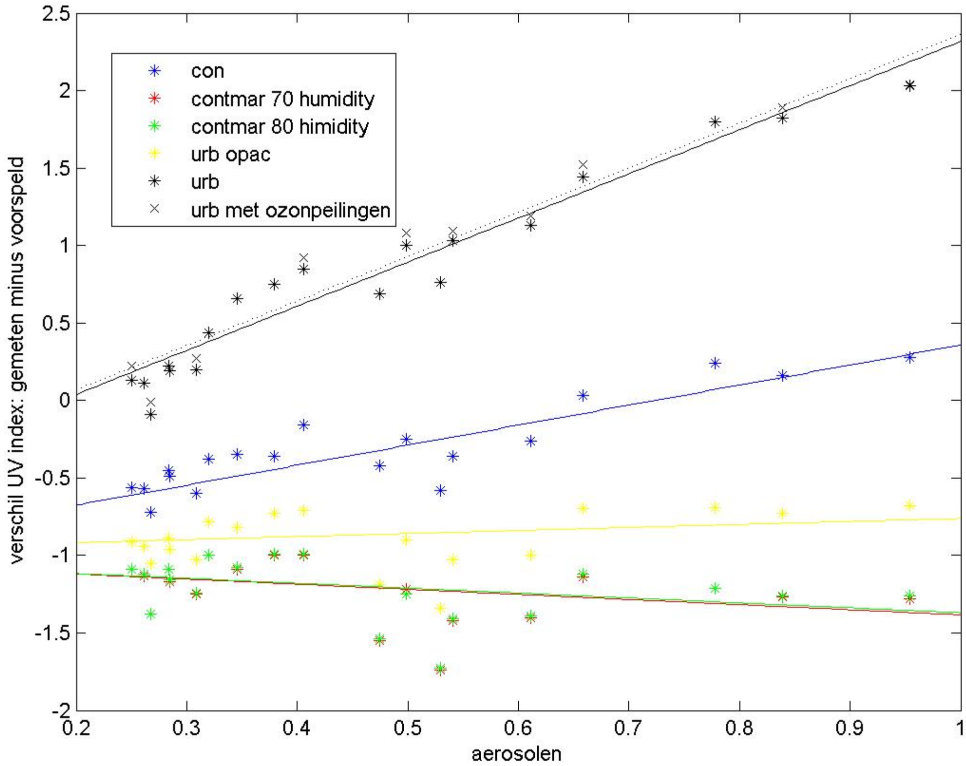

Figure 3: The dotted line gives the correction on the urban profile by taking ozon altitude profiles into account.

The same graph was produced with an ozon altitude profile but no significant improvements occured. For this reason only one figure is shown with a line produced with an altitude ozon profile. (fig 3)

An attempt was made to explain the systematic error of the difference in UV-index as a function of the amount of aerosols. Apparently, the urban profile was good for low amounts of aerosols but failed at high amounts. This can be explained as if the composition of the aerosols changes with the amount of aerosols. In other words, the average aerosol optical properties (such as single scattering albedo) changes when there are more aerosols.

At an industrial environment, there is always a certain amount of aerosols due to the industry. However when the amount of aerosols increases fast, it's not because suddenly more aerosols are produced in the city, but because wind brings a lot of aerosols from another environment. These aerosols have of course other properties which should be taken into account so the profile

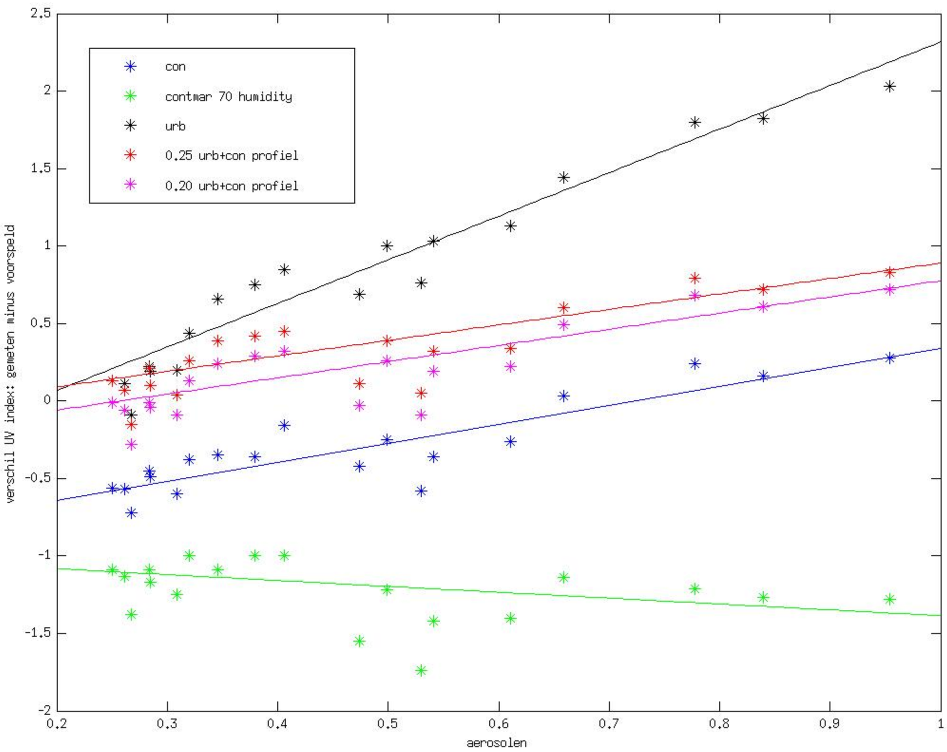

Figure 4: A combination of 0.20 (purple line) or 0.25 (red line) of the urban profile and all other aerosols due to continental. Serious improvements can be seen but there is still an error with large amounts of aerosols. Taking maritime aerosols into account might solve this.

which describes should depend on the amount of aerosols.

Depending on the direction of the wind, we need to combine an invariant amount of urban aerosols with continental or maritime aerosols. The calculation for the cloudless days was done again, using a combined profile with either 0.20 or 0.25 urban aerosols and all other continental aerosols. The results can be found in figure 4.

5 Conclusion

Most improvement of the UV-index predicting UVi forecasting model can be made adjusting the aerosol profile. A first attempt combined urban with continental aerosols which already proved useful. Further improvements can be made by taking the wind direction into account and combining urban with either continental or maritime depending on the wind direction. The effect of the aerosol composition of the previous day or days might get important when even more improvements want to be made.