Analysis of an extensive time series of UV irradiation and AOD measurements in the UV-B region at Uccle, Belgium

De Bock, V., De Backer, H., Van Malderen, R.

Royal Meteorological Institute of Belgium

1 INTRODUCTION

Since the study by De Backer (2009), the Uccle time series of erythemal UV doses (UV), total solar irradiance, total ozone and AOD (at 320nm) has been extended. Also, the AOD values (retrieved with the method of Cheymol & De Backer. 2003) have been subject to some changes, more specifically by adding a cloud screening procedure to the retrieval process.
We have analysed the extended time series (1991-2011) by investigating possible trends and change points and by using multiple regression analysis and correlation coefficients to determine the contribution of total solar radiation, ozone and AOD to the variation in erythemal UV radiation.

2 THE VARIABLES

- **Erythemal UV doses:** obtained from the UV measurements of the Brewer spectrophotometer
- **Total solar radiation:** measured by pyranometers
- **Total ozone:** measured by the Brewer spectrophotometers
- **AOD at 320 nm:** retrieved from the direct sun measurements of the Brewer spectrophotometer

All measurements are performed at Uccle, Belgium (50°48'N, 4°21'E, 100m asl).

3 TIME SERIES ANALYSIS

3.1 General pattern

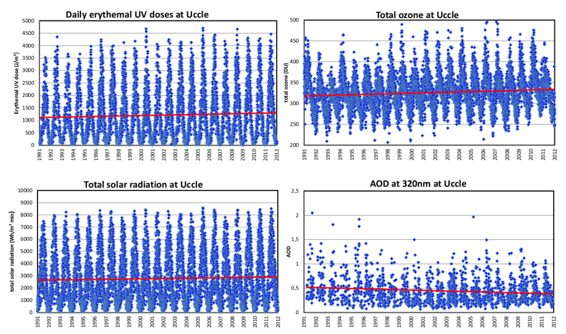

Figure 1. Time series of daily values of daily erythemal UV doses, total ozone, total solar radiation and AOD (at 320 nm) at Uccle

The erythemal UV doses at Uccle show an increasing trend over the time period from 1991 to 2011. This is also the case for the total solar radiation and the total ozone at Uccle. The AOD however decreased over the past 21 years (Fig. 1).

A clear seasonal cycle is present in all the variables:

- For both the erythemal UV dose and the total solar radiation, the maximum and minimum values occur respectively in summer and winter.
- Ozone values start increasing during late winter to reach their maximum values in spring. The lowest ozone values occur in autumn.
- The maximum AOD values are reached in spring and summer and the minimum value can be found in winter.

3.2 Monthly anomalies and change points

In order to reduce the influence of the seasonal cycles on the measurements, the monthly anomalies of the variables are calculated and shown in Fig. 2.

Figure 3 shows the cumulative deviations, which are obtained by calculating for each monthly (anomaly) value the sum of the deviations of the preceding monthly values with the global mean. (By definition, the monthly cumulative deviations of a time series start and end at zero.)

We used the Pettitt-Mann-Whitney (PMW) test, which is a nonparamtric test based on the ranks of the values of the sequence, to find a single change point in the different time series.

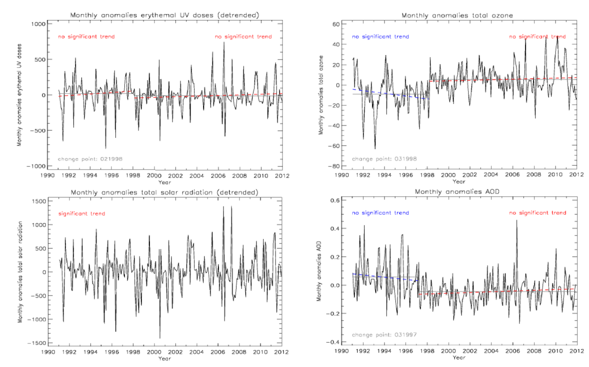

Figure 2. Monthly anomalies of erythemal UV doses, total ozone, total solar radiation and AOD (at 320 nm) at Uccle

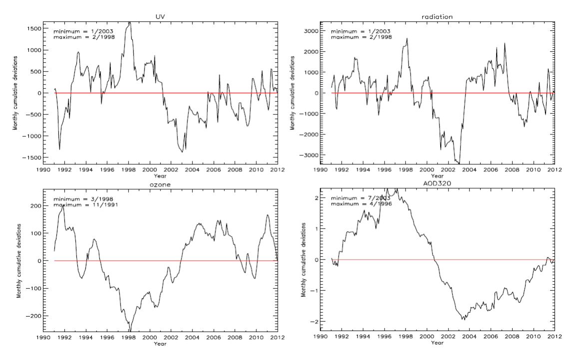

Figure 3. Monthly cumulative deviations of erythemal UV doses, total ozone, total solar radiation and AOD (at 320 nm) at Uccle.

	not detrended	detrended
UV	around 2003	around 1998
Total solar radiation	around 2001	around 1998
Total ozone	around 1998	around 2004
AOD	around 1997	around 2003

Table 1. Overview of the change points in the monthly anomalies. The values in blue are significant at the 90% confidence interval.

¿vspace2mm

What can we derive from the change points, Fig.2 and Fig.3?

- Change point (either 1st or 2nd order) in each time series around 1997-1998: The erythemal UV and total solar radiation are higher before 1997/1998 whereas ozone and AOD values clearly decrease after 1997/1998.
  Possible explanation? => effect of Pinatubo eruption will have disappeared + Montreal Protocol regulations will be starting to show results => ozone increase => decrease UV and total radiation
- For AOD: 3 subperiods: (a) increase until 1996, (b) decrease until 2003 and (c) increase after 2003. The increase before 1996 could be a result from the Pinatubo eruption.
- Change in UV around 2003 is related to the change in total solar radiation around that period.

4 MULTIPLE REGRESSION ANALYSIS

The multiple regression technique is used here to analyse the influence of total radiation, ozone and AOD on the erythemal UV dose at Uccle.

4.1 Correlation coefficients

Before applying the multiple regression technique, we calculated the correlation coefficients between the different parameters (to exclude multicolinearity between the predictors). The highest correlation was found between ozone and total radiation (0.25). This value is low enough to allow using the 3 variables (ozone, total radiation and AOD) as predictor variables.

4.2 Multiple regression analysis

The multiple regression technique was applied on the daily values for the entire time period. The results show that 94% of the variation in UV can be explained by the 3 variables. The linear regression equation is:

$$UV = 740.29 + 56.33 * AOD - 5.19 * ozone + 0.61 * radiation$$

If we remove the variable with the highest predictive power (radiation), it seems that ozone and AOD alone only account for 4% of the variation in UV.
The multiple regression is also applied on the seasonal data (Table 2). In situation A, all 3 variables are used, whereas only ozone and AOD are used as predictors in situation B.

% variation in UV explained		highest predictive power
situation A		
spring	90	radiation
summer	85	radiation
autumn	95	radiation
winter	81	radiation
situation B		
spring	11	ozone
summer	5	AOD
autumn	9	AOD
winter	4	ozone

Table 2. Percentage of the variation explained.

It seems that the influence of ozone and AOD on UV depends on the season. In winter and spring, ozone had the highest predictive power, whereas in summer and autumn, AOD was clearly more capable in explaining the variation in UV. This can also be seen when looking at the seasonal correlation coefficients (Table 3).

Correlation coefficients_Spring					Correlation coefficients_Summer				
	UV	radiation	ozone	AOD		UV	radiation	ozone	AOD
UV	1				UV	1			
radiation	0,93	1			radiation	0,9	1		
ozone	-0,33	-0,15	1		ozone	-0,02	0,21	1	
AOD	-0,04	-0,07	0	1	AOD	-0,23	-0,2	-0,07	1
Correlation coefficients_Autumn					**Correlation coefficients_Winter**				
	UV	radiation	ozone	AOD		UV	radiation	ozone	AOD
UV	1				UV	1			
radiation	0,97	1			radiation	0,8	1		
ozone	0,06	0,09	1		ozone	-0,2	0,22	1	
AOD	0,29	0,26	0,09	1	AOD	0	-0,08	0,15	1

Table 3. Seasonal correlation coefficients between the different variables.

5 CONCLUSIONS

Erythemal UV, total solar radiation and ozone show an increasing trend over the 1991-2011 time period, whereas AOD decreases.

Possible change in ozone around 1997/1998 could explain the decrease in UV and total radiation after this change point. The influence of AOD is questionable.

References

- Cheymol, A. and De Backer, H.: Retrieval of the aerosol optical depth in the UV-B at Uccle from Brewer ozone measurements over a long time period 1984-2002, J. Geophys. Res., 108, D24, doi:10.1029/2003KD003758, 2003.
- De Backer, H.: Time series of daily erythemal UV doses at Uccle, Belgium, Int. Journal of Remote Sensing, 30 (15), 4145-4151, doi:10.1080/01431160902825032, 2009.

De Bock V., De Backer, H. and Van Malderen, R., Royal Met. Inst., Ringlaan 3, B-1180 Brussels, Belgium.
Veerle.DeBock@meteo.be

International Radiation Symposium, Berlin, Germany, 6-10 August 2012.

This research was performed under the project AGACC-II contract SD/CS/07A of the Belgian Science Policy.

.be