The influence of meteorological factors on solar ultraviolet radiation over Pretoria, South Africa for the year 2012

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Pretoria receives a fair amount of solar ultraviolet radiation (UVR). Certain meteorological factors affect the amount of solar UVR that reaches the ground. The most dominant influencing meteorological factors are stratospheric ozone, cloud cover and solar zenith angle. In this paper the following relationships were investigated: solar UVR and cloud cover, solar UVR and solar zenith angle and solar UVR and total column ozone over Pretoria for 2012. The difference between the satellite-based and ground-based solar UVR values was also considered. This study provided insight into the intensity of solar UVR and various influencing factors at various times of the year.

Keywords: Solar Ultraviolet Radiation, Meteorological Factors, Pretoria

Introduction

South Africa receives a fair amount of solar ultraviolet radiation (UVR). Pretoria in particular, has been found to receive high amounts of solar UVR (Wright et.al, 2011; Norval et.al, 2013). In addition to air pollution, certain meteorological factors affect the amount of solar UVR that reaches the ground (IARC, 2012). The most significant influencing meteorological factors are stratospheric ozone, cloud cover and sun position which is determined by time of day, season geographic latitude and solar zenith angle (McKenzie et.al, 1991).

Overexposure to solar UVR is known to have harmful photobiological effects on humans, the most significant of these being the occurrence of sunburn (erythema) and the increased likelihood of skin cancer development (Diffey, 2001). Since overexposure poses a major threat to human health it is important to understand solar UVR.

This paper considers the three dominant meteorological factors and how they influenced the amount of solar UV radiation that reached the ground over Pretoria, South Africa for the year 2012. Satellite-based solar UVR values are also compared to ground-based solar UVR values in order to gauge the magnitude of attenuation (reduction in intensity or amount) of solar UVR due to cloud cover by the time it reaches the ground.

Data and Methods

There were five datasets used for this purpose. All the datasets were for Pretoria (25 48' 34.12" S and 28 15' 22.34" E) for the period 1 January 2012 to 31 December 2012. These datasets were cloud cover data, sun elevation data, total column ozone data, ground-based solar UVR measurements and satellite solar UVR data. The cloud cover data were obtained from the South African Weather Service (SAWS) over the Bolepi House Offices in Pretoria.

The ground-based solar UVR data were also obtained from the SAWS. These data were measured using the research-grade Solar Light 501 UVB Biometer which is located on the roof of the Bolepi House building in Pretoria. Satellite-based solar UVR data and the total column ozone data were obtained via GIOVANNI, a web-based portal site that allows access to data collected by various satellites. The measurements were local noon readings taken by the OMI/Aura satellite instrument. The solar altitude data were obtained from the National Oceanic & Atmospheric Administration (NOAA)'s Earth System Research Laboratory (specifically from the laboratory's Global Monitoring Division). Missing dates in the dataset were omitted.

Non-linear regression analyses were performed in order to show and understand the following relationships: solar UV radiation and cloud cover, solar UVR and solar zenith angle and solar UVR and total column ozone. In order to gauge the difference between the satellite-based solar UVR measurements and the ground-based solar UVR measurements, the root mean square error (RMSE) was calculated. This would allow the average difference between the satellite-based and the ground-based solar UVR values to be determined.

Four days from the year 2012 were selected. These days represented the two days with the highest and the two days with the lowest ground-based solar UVR readings. The days with the highest readings were 2nd January and 26th December. The days with the lowest readings were 5th

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February and 12th October. These days were then used to determine exactly which of the three meteorological factors looked at in this study were likely responsible for the high or low values. This was done to gain further insight into how meteorological factors affect solar UVR. Individual seasons from the year 2012 were also looked at to determine which of the three meteorological factors plays a role in solar UVR attenuation at different times of the year.

Results

The results of the regression analyses are summarised in Table 1. The analysis shows that for the entire year of 2012 solar zenith angle had the highest R^2 value (indicating the strongest relationship) with solar UVR. This was also true for all seasons except summer. In summer the highest R^2 value was seen with cloud cover. This can be corroborated with the four days of very high and very low solar UVI readings. On 5th February 2012 a solar UVR value of 0.261 UVI was measured. Cloud cover of 7 octas was observed on that day.

Table 1: R^2 values for the relationship between solar UVR and cloud cover, ozone and solar zenith angle for autumn, winter, spring and summer of 2012 and for the entire year of 2012

	Cloud cover	**Ozone**	**Solar zenith angle**
All year	0.2581	0.0517	0.567
Autumn	0.3294	0.0864	0.6347
Winter	0.436	0.1257	0.6458
Spring	0.2871	0.2502	0.4587
Summer	0.3439	0.121	0.1028

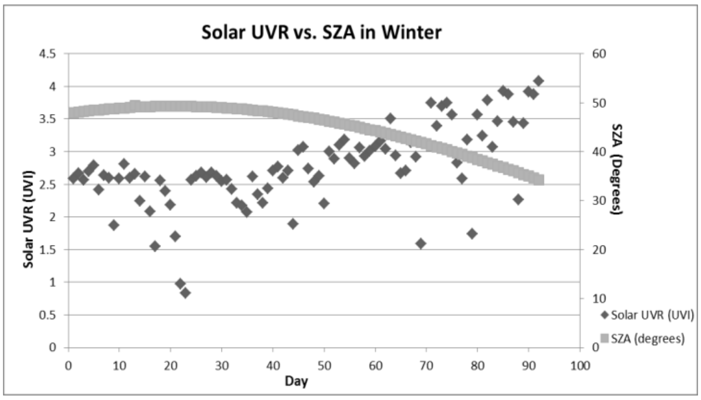

Figure 1: Solar UVR values for June, July and August 2012 compared to solar zenith angle values for the corresponding period

In winter (June, July and August) only 8 out of the 92 days of winter had cloud cover values of greater than 4 octas, but solar UVR values were low. Solar zenith angle values, however, were high. The low solar UVR values were likely due to high solar zenith angle values. Fig. 1 shows that high solar zenith angle values are associated with lower solar UVR values and a decrease in solar zenith angle values coincides with an increase in solar UVR values. A very weak relationship was seen between solar UVR and ozone compared to the other factors. This is largely due to the fact that ozone does not have a great annual variation over one year. A stronger relationship might be seen over a longer time period.

The annual satellite-measured and ground-based solar UVR distributions are shown in Fig. 2. An envelope distribution is seen for both satellite-based and ground-based values, where higher values are generally observed in the summer months and lower values are seen in the winter months. However the satellite-based values are larger than the ground-based measurements. A RMSE of 5.287 UVI was found over the whole year for 12H00 values. This means that on average there was a difference of 5.287 UVI between the satellite-based and ground-based measurements.

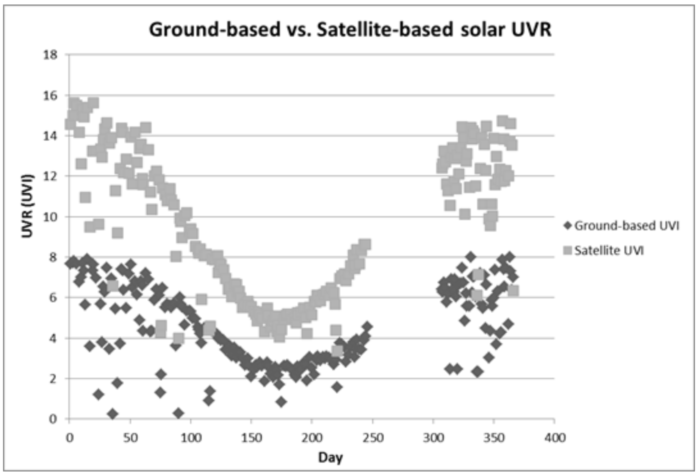

Figure 2: Satellite-based and ground-based measurements of solar UVR over Pretoria for 2012

Discussion and Conclusion

As can be seen from the preliminary results, certain meteorological factors seem to play a stronger attenuating role than other factors during the various seasons of the year. In summer, the highest R^2 value is found for the relationship between solar UVR and cloud cover. It is therefore highly likely that in summer cloud cover is the dominant solar UVR-attenuating factor out of the three factors addressed here. In winter the highest R^2 value is for the relationship between solar UVR and solar zenith angle. This is corroborated by the observation that solar UVR values are low when compared to summer but there are very few days with high cloud cover values in winter. The low solar UVR values can be attributed to the high solar zenith angle values. Therefore it is highly possible in winter the dominant solar UVR-attenuating factor is sun position, in this case, solar zenith angle, rather than any of the other meteorological factors considered. Ozone showed a very weak relationship with solar UVR compared to the other factors since the other factors have a much higher annual variation than ozone and therefore have a greater effect on the variability of solar UVR reaching the ground.

A RMSE of 5.287 indicated that there is a large difference between the satellite-based and the ground-based solar UVR values. This could be an indicator of the strength of attenuation by the meteorological factors looked at in the current study and other factors. However since cloud cover is not taken into account in the algorithm of the satellite values, the attenuating meteorological factor is most likely to be cloud cover.

Looking at relationships that exist between meteorological factors and solar UVR gives further insight into the intensity of solar UVR at the ground. It also leads to knowledge of how solar UVR is influenced by certain meteorological factors. Considering individual seasons allows understanding of solar UVR at various times of the year. Understanding the intensity of solar UVR over Pretoria can help in the development of sun-protective and skin cancer-prevention campaigns. This can ultimately help in better sun-protection measures undertaken by the public.

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