Changes in ground-based solar ultraviolet radiation during fire episodes: a case study

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Abstract

Solar ultraviolet radiation (UVR) levels are affected by airborne aerosols, such as particles and gases released during biomass burning events. Two large-scale fires in South Africa were identified and selected based on their proximity to solar UVR measurement sites and the prevailing wind direction at the time of the fires. Solar UVR levels were then scrutinized to qualitatively assess whether it could be seen if the fires impacted upon solar UVR levels. It was difficult to make definitive conclusions about the relationship between fires and solar UVR without local high-quality column or ground-based ambient air pollution (particulate matter in particular) data; however, the threat to public health from fires was acknowledged.

Keywords: solar ultraviolet radiation; biomass burning; fire; human health

Introduction

South Africa has relatively high levels of ambient (ground-based) solar ultraviolet radiation (UVR) due to its location close to the equator and with a large part of the country being at relatively high altitude on a plateau. Excess solar UVR exposure poses a threat to human health in the form of sunburn, skin cancer, cataracts and immune suppression. Several other factors influence surface solar UVR including solar zenith angle, surface cover (albedo), ozone, clouds and aerosols.

The effects of aerosols on surface UVR levels may be significant and complex (Otero et al., 2011). Usually airborne particles tend to reduce surface UVR through absorption, scattering and reflection (Bagheri et al., 2008). Burning of biomass is one source of airborne particles and gasses. Smoke aerosols seem to produce a stronger reduction in surface solar UVR than dust aerosols due to loading (Kalashnikova et al., 2007). Biomass burning is a common occurrence in South Africa, occurring naturally as well as part of anthropogenic practices. It poses a respiratory health risk to humans since dust particles of respirable size may be inhaled and have both acute and chronic health effects, e.g. sneezing and itchy eyes to aggravating asthma and pneumonia (WHO, 1999). During a large-scale fire event, this threat to human health may be substantial.

In this case study, we consider two large-scale fire episodes, identified from media reports, and simultaneous ground-based solar UVR levels to try and ascertain whether there was a reduction in solar UVR levels during the burn events, thereby reducing the health threats from solar UVR exposure but increasing the respiratory health risks poses by intense periods of air pollution.

Data and Methods

Solar UVR data collected by the South African Weather Service (SAWS) at Cape Point and Pretoria (Fig. 1) were used. A UV Biometer (model 501) comprising a Robertson-Berger pattern UV radiation detector, digital recorder and control unit is used to measure ambient solar UVR levels at the Cape Point Global Atmosphere Watch station and the Pretoria weather office. The UV Biometer spectral response closely mimics the McKinley/Diffey Erythemal Action Spectrum (CIE, 1987). Calibration of the UV Biometer enables the logged values to be converted into Ultraviolet Index (UVI) units.

The UVI is an index that describes the biologically-effective solar UVR reaching the Earth's surface at a particular location. It is determined by weighting the incident solar radiation at the surface with the erythemal response of human skin at 280-400 nm and then summing over this wavelength range to derive a total effect. One UVI unit is equivalent to biologically-effective solar UV radiation of 0.025 W m^{-2} effective. The UVI is commonly reported in some countries around the world, excluding South Africa, as the maximum or midday value for each day where UVI of 3-5 is 'moderate', 8-10 is 'very high' and greater than 10 is 'extreme'.

Four fire episodes (see Table 1) were extracted from a database on severe fire events occurring in South Africa near the UVR sampling sites as captured in the media.

Table 1. Details of Fires

Fire	Date	Location	Vegetation type
1	9 Dec 2008	Cape Point	Fynbos
2	20 Jan 2009	Scarborough	Fynbos
3	9 Jan 2008	Ngodwana	Plantations
4	9 Feb 2008	Kaapsehoop	Plantations

These fires were then linked to remotely-sensed data products on fire size and fire intensity that have been developed by the CSIR, so as to determine the exact spatial location, area, and intensity of the fires.

Fires were selected based on their close proximity to the solar UVR measurement stations and checking that the prevailing wind direction (data not shown, pers comm P Frost) at the time of the fires led to air movement over the solar UVR measurement station.

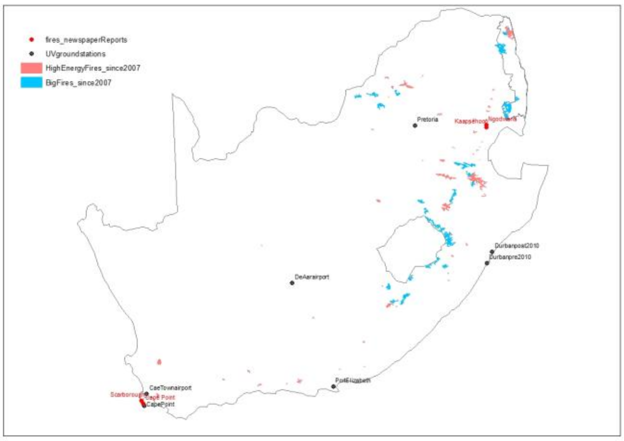
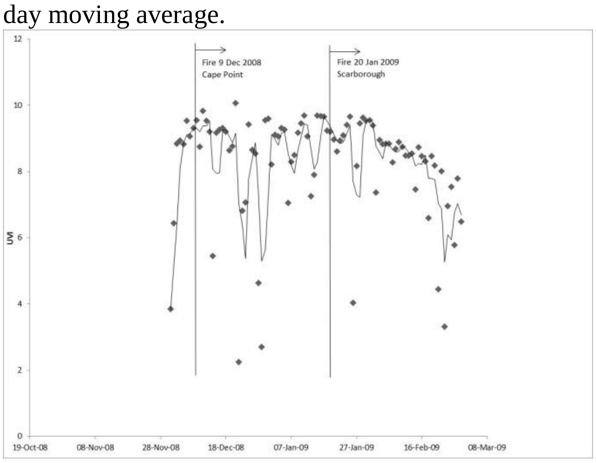


Figure 1. Locations of the ground-based solar UVR stations and the four studied fires as reported in the media defined as Fire 1 and 2 (Cape Point / Scarborough) and Fire 3 and 4 (Kaapsehoop / Ngodwana). Also shown are all the large and high energy fires that have been identified by satellite since 2007.

Results and discussion

Figure 2 presents the solar UVR ground-based measurements for Cape Point, the station nearest to fires 1 and 2, overlaid with the start dates (straight lines through the start date data point) of the two fires in the area. While little change in solar UVR is evident after the start of the 9 December 2008 fire, there is a slight decrease in solar UVR following the Scarborough fire starting on the 20 January 2009.

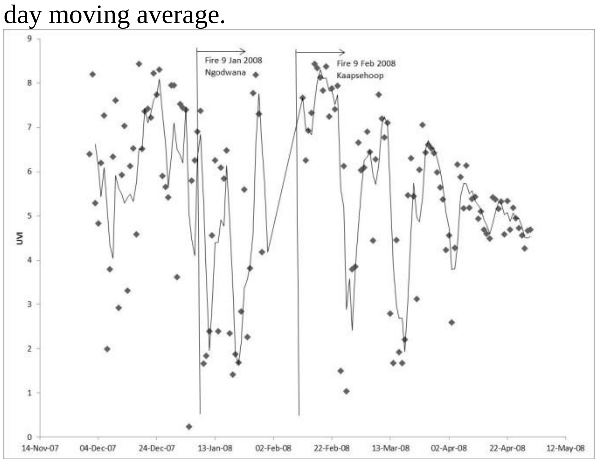
Figure 2. Ground-based midday solar UVR measurements at Cape Point compared to the start dates of the two fire episodes (Fire 1 and 2). Trend line is a 3-day moving average.



It is impossible to definitively state that this is due to the effect of the fire for various reasons. Wind may have blown the smoke plume in different directions on the same day, other air pollution sources may have been present and cloud cover may also have an influence on solar UVR levels.

Similarly, Figure 3 again illustrates the difficulty in identifying an impact of the fires on solar UVR with high variability in the solar UVR data following the onset of both fires 3 and 4. This highlights the need to collect additional data, probably at a finer resolution and scale, to be able to pinpoint associations between these two parameters and incrementally exclude the influence of other factors such as cloud cover and solar zenith angle. The decline in ambient solar UVR levels between 13 March 2008 and 12 May 2008 is due to the change in season from summer to autumn when solar UVR levels typically decline in the Southern Hemisphere.

Figure 3. Ground-based midday solar UVR measurements at Pretoria compared to the start dates of the two fires episodes (Fire 3 and 4). Trend line is a 3-day moving average.

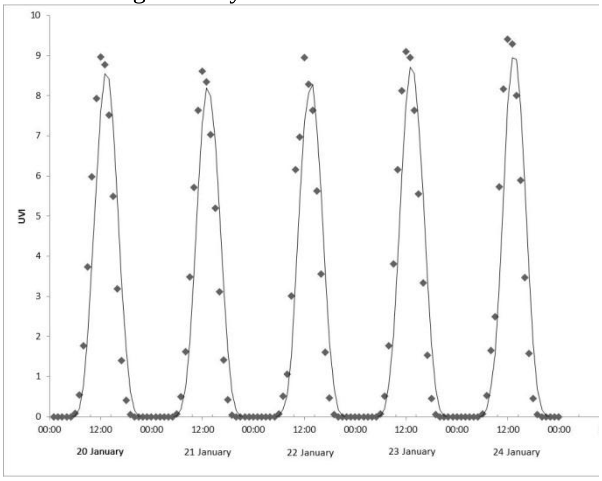


Taking a closer look at the hourly solar UVR measurements for Fire 2 in Scarborough, Figure 4 shows the day of the fire and the four proceeding days after the outbreak of the fire. While there was a slight reduction in the midday UVR readings on the 22 and 23 January, the typical diurnal pattern in solar UVR is evident as a bell-shaped curve, indicative of changing solar zenith angle between sunrise and sunset.

Conclusions

Even though fires were present, suggesting that airborne particles and gasses may have led to reduced solar UVR levels because of reflection and scattering, for various reasons this was not always the case. Solar UVR levels were still relatively high, i.e. up to 9 UVI in some cases (notwithstanding the different locations of the fires and the UVR monitoring stations), hence the health risks from sun exposure were still apparent, and this in combination with the respiratory health risks posed from inhalation of particles and gasses airborne during fire events. From an occupational health perspective, those tasked with putting out the fire would require protection from smoke and temperature as well as sun exposure.

Figure 4. Hourly solar UVR measurements (UVI) for the day of Fire 2 (Scarborough) on the 20 January and the following four days thereafter.



Preliminary research to consider changes in solar UVR levels following the onset of large fires has not led to evidence that fire impacts solar UVR levels based on the data available for this study. Instead, it has highlighted the need for more data and different data sources to be used, together with refined methodologies in such analyses before relationships between different parameters may be observed and defined.

Acknowledgements
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