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Introducing a new generation of solar UVR detectors for the ARPANSA UV monitoring network

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Abstract. ARPANSA has been monitoring solar UVR using Robertson-Berger type broadband radiometers at major Australian cities for more than twenty years. Now a new generation of UV sensitive photodiode detectors is being introduced to the network. This paper presents and discusses data collected by both types of UV sensors whilst operating at the same locations. The measurements reveal very good agreement between the devices despite their quite different approaches to the measurement of solar UVR. The ARPANSA website used to report these UV Index measurements to the public has also been recently redesigned. Presenting the data in near real time has revealed some issues with the interpretation of the UV Index and how its use has evolved over time. Challenges in clearly informing the public about the dangers of UV over-exposure through the use of the UV Index are discussed.

Introduction

Historically, the ARPANSA UV monitoring network has relied on the use of Robertson-Berger (RB) type broadband radiometers (UV Biometer model 501, Solar Light Company, Philadelphia PA, USA). These devices employ visible light filters to deliver cosine-weighted solar UVR to a temperature stabilised phosphor gel. Visible light is emitted by the phosphor and is detected using a GaAs photodiode. The resulting current is amplified and converted to a frequency signal which varies between 1 and 2 Hz, corresponding to an input UVR level of 0 to 10 MED/hr (equivalent to UV Index of 0 to 22). A data logger is then used to count the number of pulses arriving from the sensor over a given time period (typically 1 s). These values are then averaged over a longer time period (typically 1 or 10 minutes) to determine the average UVR level.

UV sensitive photodiodes offer a more direct way to measure solar UVR levels (Cosine UV Index Sensor, sglux GmbH, Berlin, Germany). A Teflon housing provides cosine weighting and some filtering of visible light. Then a hybrid SiC photodiode with extreme visible light blindness responds directly to the incoming UVR. The sensor's spectral response approximates the erythema action curve of human skin by combining the outputs from two photodiode elements that respond optimally to UVA and UVB wavelengths. The resulting voltage signal varies between 0 and 5 V, nominally corresponding to an incident UV Index of 0 to 30. The voltage signal is sampled at predetermined intervals (typically 10 s) and these values are averaged and recorded by a data logger (typically every minute).

Discussion

RB instruments are known to be sensitive to temperature and humidity fluctuations if not carefully controlled. The measured signal is inherently averaged over the full time period. These devices have proven to be quite durable and although they require regular maintenance they have been successfully used in many other UV monitoring networks.

SiC photodiodes are essentially blind to visible light, have very low temperature coefficients and very low dark currents. The reported UV level is an average of periodically sampled values. Our testing has found these sensors to also be quite durable. There are no serviceable parts to these sensors, but fortunately they are much less expensive than the RB type detectors that they replace.

For over a year now the photodiode sensors have been collecting data on the roof of the ARPANSA building in Melbourne alongside the RB type Biometers. Both systems are calibrated against a spectroradiometer (model DTMc300, Bentham Instruments Limited, Reading, UK) also operating on the roof at the ARPANSA laboratory prior to deployment at remote monitoring sites.

Figure 1 shows the output of both types of sensors at one minute resolution. The time series shows good agreement between the two detector types although the photodiode reports slightly higher readings at large solar zenith angles in the early morning and late afternoon. This is likely due to a combination of cosine response effects and differences in the spectral responsivity of the two types of sensors. The very strong correlation between the two data sets over the entire month of February 2018 is shown in Figure 1b.

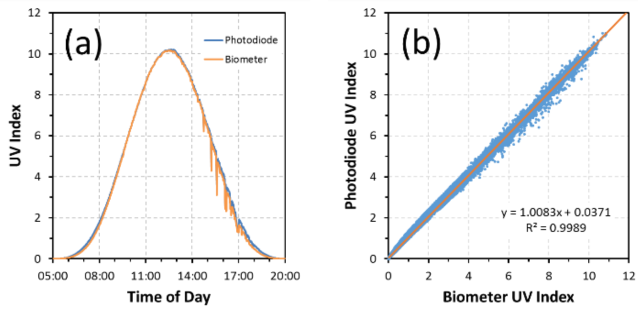

Figure 1. One minute UV Index data for Melbourne. **(a)** Time series for both sensors on 1 February 2018. **(b)** Correlation diagram for the whole of February 2018.

So far nine of eleven monitoring sites in Australia have been upgraded to new sensors: Adelaide, Alice Springs, Brisbane, Canberra, Darwin, Kingston (Hobart), Melbourne, Perth and Townsville. Biometers continue to operate alongside photodiodes at six of these sites. The remaining two sites at Sydney and Newcastle are due to be upgraded to the photodiode sensors in mid-2018.

Comparing the data collected at different sites shows an acceptable agreement between the two detection systems over a wide range of UV Index values. Relative bias of the one minute data points (difference between Photodiode and Biometer values divided by the Biometer value) is less than ±10% for all sites as shown in Table 1.

ARPANSA has recently upgraded its website and the interface to present the UV measurements to the public. Efforts have been made to conform with the joint recommendations put forward by the World Health Organization (WHO), World Meteorological Organization (WMO), United Nations Environment Programme (UNEP) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) for the display and reporting of the UV Index, hereafter referred to as the WHO Guide (WHO 2002). However, attempting to address the public desire for regularly updated readings can lead to outcomes that are not always consistent with the recommendations of the WHO Guide.

Table 1. Relative bias of the one-minute data sets measured at Australian cities over the number of days indicated and the range of daily maximum UV Index values.

Location	Relative bias	UV Index range	Number of days
Adelaide	-1.4%	1 – 9	127
Alice Springs	8.1%	5 – 15	61
Brisbane	-3.7%	3 – 16	123
Darwin	6.5%	4 – 17	46
Kingston	-5.0%	1 – 13	261
Melbourne	3.5%	1 – 13	411
Perth	-0.8%	2 – 14	302

Figure 2 shows a screenshot of the main UV Index chart from the ARPANSA website. The dotted line indicates the clear-sky model forecast and the solid line is the one-minute data. The background colour bands are based on the scheme recommended by the WHO Guide, although the colours have been made more transparent. The UV Index exposure categories low (0 – 2), moderate (3 – 5), high (6 – 7), very high (8 – 10), or extreme (11+) are listed on the right. The chart is interactive, allowing the user to select both the location and date for the data to display.

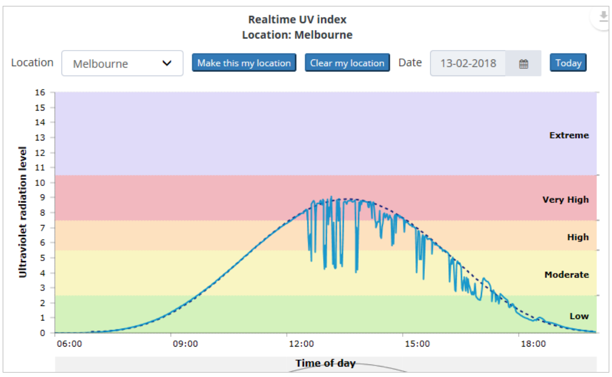

Figure 2. Screenshot of the UV Index chart for Melbourne on 13 February 2018 taken from the ARPANSA website https://www.arpansa.gov.au/services/monitoring/ultraviolet-radiation-monitoring/ultraviolet-radiation-index.

The WHO Guide states that the UV Index should be presented as a single value rounded to the nearest whole number. For this reason, ARPANSA places the transitions between exposure categories at UV Index values 2.5, 5.5, 7.5 and 10.5 on the graph displaying the daily variation of solar UVR levels. However, the graphed data is shown to higher resolution for aesthetic purposes.

The WHO Guide also recommends that a 30 minute time average should be used when reporting the daily maxima. This definition can lead to an apparent contradiction between the daily maximum UV Index and the graph of the diurnal variation. Figure 3 shows the UV Index data recorded by ARPANSA in Melbourne on 15 February 2018, a summer day of variable cloud cover. On days such as this, when the UV levels vary quickly over a large range, the choice of averaging time will have an impact on the reported value of the UV Index. In this case, the one minute data peaks at a UV Index of 9, while the ten minute average data results in a UV Index of 8 and the 30 minute average data gives a UV Index of just 7.

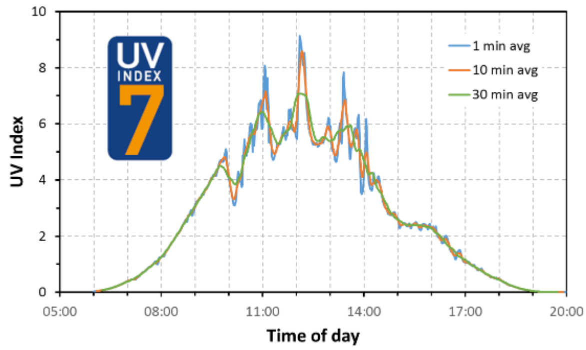

Figure 3. One, ten and thirty minute sliding average UV Index data for Melbourne on 15 February 2018.

The WHO Guide suggests that five to ten minute averages can be useful to display short-term changes. However, with improvements in the measurement and logging technology it is now feasible to present data at a higher resolution that is more in line with public expectations. ARPANSA has chosen to present the UV Index at a resolution of one minute on its website. The WHO Guide is silent on how to perform time averaging. For example, whether the averaging windows should be consecutive, non-overlapping, adjacent periods, or continual sliding averages.

The ability to measure and report UV Index data has advanced greatly in the years since the publication of the WHO Guide in 2002. Technological advances and the public desire for real time data have made it possible to "improve" the reporting of the UV Index in ways not always consistent with the WHO Guide. As noted in the recent review of the WHO Guide (Gies et al. 2018), ultimately, any changes to the definition of the UV Index and how it is presented to the public should be based on biologically relevant effects rather than convenience or measurement ability.

Conclusions

UV Index data has been collected using two different types of detectors co-located at seven sites across Australia. Despite their quite different measurement approaches used by the UV sensors, the two data sets are in good agreement across a wide range of UV Index values and climates.

The ARPANSA website for reporting the data has been refreshed and has highlighted some of the complications involved in reporting UV Index. Many of the recommendations of the WHO Guide are open to a degree of interpretation which can potentially lead to confusing outcomes when reporting results to the public.

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