Spectral measurements of solar UV at several altitudes under Australian conditions

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Abstract. ARPANSA maintains a network of broadband solar UV dataloggers in major Australian population centres, all of which are currently at or near to sea level. However solar UV levels are known to increase with altitude (Blumthaler *et al.*, 1997, McKenzie *et al.*, 2001). Most previous studies on the altitude effect have been conducted in the Northern hemisphere and to our knowledge no spectral investigation has been completed under Australian conditions. ARPANSA is currently undertaking an investigation of the effects of altitude on the measured solar UV spectrum at various sites in the state of Victoria, Australia. Results from this study will be used to help validate the models used for the Cancer Council's SunSmart UV Alert programme.

Introduction

The broadband solar UV network operated by ARPANSA currently operates in nine locations around Australia (see Figure 1). Data from the network is posted in near real time (updated once a minute) on the ARPANSA website.

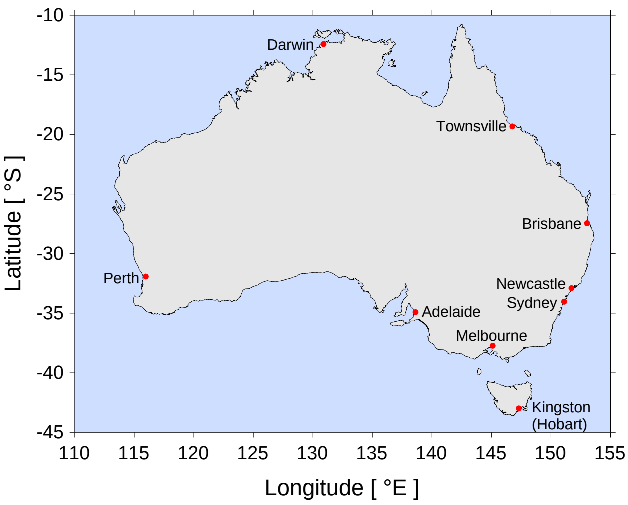

Figure 1. Map of Australia showing the locations of ARPANSA's broadband UVB detectors.

The solar UV spectrum has been measured periodically by various groups at a number of sites in Australia including the Bureau of Meteorology (BoM) at Darwin (altitude 31 m), Alice Springs (547 m) (Kalashnikova *et al.*, 2007) and Cape Grim (94 m), the University of Southern Queensland at Toowoomba (693 m) (Parisi *et al.*, 2003) and James Cook University at Townsville (30 m) (Bernhard *et al.*, 1997).

Since late 2008 ARPANSA has also been routinely recording solar UV spectra each day from its laboratory in Yallambie, a suburb approximately 15 km from the centre of Melbourne.

SunSmart UV Alert

The SunSmart UV Alert programme is a joint initiative of the Cancer Council Australia, the Bureau of Meteorology (BoM) and ARPANSA designed to prompt the public to take sun protection measures whenever the UV Index exceeds 3. It is reported on the weather page of the major Australian newspapers as well as on the BoM website for over 300 locations across the country.

To be useful and relevant the UV Alert must be specific for the region in which it is declared. Sophisticated modelling performed by the BoM is used to forecast the solar UV for all areas of Australia, but there is little measurement data to support these predictions for locations outside the major metropolitan centres.

Of particular interest to the Cancer Council are the Victorian Alpine areas. Although the resident population is small, significant numbers of tourists visit the area all year round. The generally clear atmospheric conditions combined with higher altitudes mean that UV exposures are likely to be higher than visitors from the city might expect and the potential for UV over-exposure is high.

Instruments and Methods

The ARPANSA solar UV network employs broadband UVB detectors (UV Biometer model 501, Solar Light Company, Philadelphia PA, USA). These detectors record erythemally weighted UVB and are calibrated at ARPANSA's laboratory in Yallambie by comparison with a UV spectrometer prior to deployment at the other sites.

ARPANSA currently operates two identical UV spectrometers (model DTMc300, Bentham Instruments Limited, Reading, UK). Each of these detection systems is composed of a double monochromator with fixed slits giving a 1 nm bandwidth, a cosine-corrected Teflon diffuser, fibre optic light guide and a bi-alkali photomultiplier tube. The spectrometers are irradiance calibrated using a 1 kW Tungsten filament lamp traceable to international standards through Australia's National Measurement Institute and wavelength calibrated against the UV spectral lines of a mercury lamp.

One of these systems is installed on the rooftop of the ARPANSA building in Yallambie. The second system is packaged so as to be portable and can be powered by a 12 V battery pack running through a sine-wave inverter.

The portable spectrometer was taken to four sites within a few hours' drive of ARPANSA at various altitudes as indicated in Table 1. Spectra were collected at each of these sites to compare with the data collected by the rooftop system at Yallambie. All measurements were collected during late Spring and early Summer (October to December) 2009.

A handheld ozone meter (model MicroTOPS II, Solar Light Company, Philadelphia PA, USA) was used to measure the total column ozone at the remote locations.

Table 1. List of measurement locations with distances from ARPANSA, altitudes, range of SZA and the total column ozone amounts from satellite (OMI) and ground based (μTOPS) measurements.

Location	Distance [km]	Altitude [m]	Min SZA [°]	Max SZA [°]	OMI O_3 [DU]	μTOPS O_3 [DU]
Yallambie	----	30	25.0	46.6	313	306
Kinglake	30.5	543	20.7	28.4	315	----
Mt Macedon	60.6	985	14.1	24.9	279	258
Mt Donna-Buang	51.3	1246	19.7	27.8	311	297
Mt Buller	134.3	1720	16.4	33.6	274	258

These measured values were consistently lower (by 2 – 8% over the range of locations) than those reported by NASA from the Ozone Monitoring Instrument (OMI). This level of agreement is quite good considering the spatial resolution of the satellite data is around 100 km².

Results and Discussion

In order to compare the performance of the two systems the portable spectrometer was operated in the grounds of ARPANSA, 15 m below the rooftop system, in a clear grassed area to the north of the ARPANSA building. Simultaneous measurements were conducted at ten minute intervals throughout the middle of the day while the sun was well above the surrounding trees.

Spectra from the two instruments agreed well, within ±3% for total UVR. However the portable spectrometer appears to read consistently lower by 7% in the UVB compared to the rooftop spectrometer.

Measurements at Kinglake were blighted by some passing cloud just after solar noon. Weather conditions at Mt Donna Buang were clear with just a little thin high cloud later in the day while at Mt Macedon skies were fine all day after some early fog and haze. Measurements at Mt Buller were impaired by less than favourable weather conditions.

Spectral irradiances weighted by the erythema action spectrum (CIE, 1987) are shown in Figure 2 for SZA 25°, the smallest SZA common to all sites. The most notable features of these spectra are:

- enhanced UVB due to lower ozone at Mt Macedon
- significantly enhanced UVR for all wavelengths at Mt Donna Buang
- greatly decreased UVR for all wavelengths due to cloud at Mt Buller (despite lower ozone values).

The mean ratio of 25° SZA spectra relative to those measured at Yallambie for UVR (300 – 400 nm), UVA (315 – 400 nm) and UVB (300 – 315 nm) is listed in Table 2. Results from Mt Macedon have been corrected for the lower total column ozone. Excluding the cloud affected results from Mt Buller an altitude gradient may be obtained by linear regression to the data with the result of 22% / km for UVR, 19% / km for UVA and 30% / km for UVB.

Table 2. Mean ratio of spectral irradiances relative to Yallambie portable spectra at solar zenith angle 25°.

	Kinglake	Mt Macedon	Mt Donna-Buang	Mt Buller
UVR	1.06	1.16	1.27	0.65
UVA	1.06	1.11	1.25	0.63
UVB	1.09	1.25	1.40	0.75

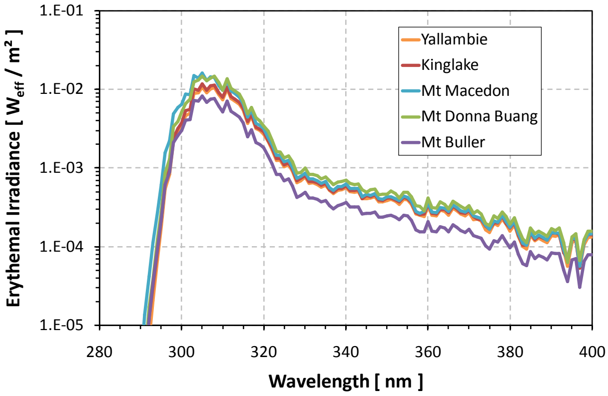

Figure 2. Erythemally weighted spectral irradiances for solar zenith angle 25° measured at five altitudes.

Conclusion

Clear evidence of the altitude effect was observed in this measurement campaign although some of this difference was likely due to the influence of urban pollution. Further measurements are being planned to test this proposition. Linear fits to the data obtained for SZA 25° give an altitude effect of 22% / km for UVR, 19% / km for UVA and 30% / km for UVB. These observations appear to be towards the upper end of the range reported in the literature.

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