*NIWA UV Workshop, Wellington, 4-6 Apr, 2018 (www.niwa.co.nz/atmosphere/uv-ozone/uv-science-workshops/2018-uv-workshop)*

# Solar UVR climatology on the edge of Antarctica

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**Abstract**. ARPANSA has been monitoring solar UVR using broadband radiometers at all the permanently staffed Australian Antarctic stations on the edge of the Antarctic continent for over twenty years. This long term collaboration with the Australian Antarctic Division Polar Medicine Unit aims to characterise the UVR environment in Antarctica and assess the impacts of UVR exposure on expeditioners' health.

The data record shows that the Australian Antarctic stations have annual total solar UVR doses and daily maximum UV Index values significantly higher than would be expected on the basis of their latitudes. This is primarily due to the ozone hole and the presence of ozone depleted air passing above the stations during springtime and the resultant enhanced transmission of UVB wavelengths to the earth's surface during that time.

Measurements of solar UVR at Casey (66.3°S), Davis (68.6°S) and Mawson (67.6°S) stations will be reported and discussed along with efforts to determine temporal trends.

## Introduction

The network consists of broadband detectors at the three permanently staffed AAD stations on the Antarctic continent: Casey (66.3°S), Davis (68.6°S) and Mawson (67.6°S). Data collection began in 1996 at both Casey and Davis, while the detector at Mawson was installed in 2002.

The network employs broadband UVB detectors (UV Biometer model 501, Solar Light Company, Philadelphia PA, USA). The UV Biometers are Robertson-Berger style detectors that measure erythemally weighted UVB. These detectors filter the UV component of sunlight which then excites a temperature stabilised phosphor and the visible light emitted is monitored by a GaAs photodiode.

The detector output is proportional to the incident UVR level and is nominally reported in units of Standard Erythemal Dose per hour (SED/hr). One SED is defined as 100 J/m² when weighted with the CIE erythemal response (CIE 1998). Generally, two SED will produce erythema (sunburn) in people with fair skin. The average value of the signal is recorded at the end of every minute and an instrument specific calibration factor is applied to convert the value to a UV Index. The daily maximum UV Index and daily total UV Dose in SED are calculated for each date where sufficient data is available. An example of a single day's data collected at Davis station is shown in Figure 1a.

UV Index values are classified as low (0 – 2), moderate (3 – 5), high (6 – 7), very high (8 – 10), or extreme (11+) in accordance with the scheme recommended by the World Health Organisation (WHO 2002). As expected, the histograms of UV Index are heavily skewed towards the low category at all stations, although extreme readings have also been recorded at each site. Figure 1b shows the histogram of UV Index data recorded at Davis. The highest recorded UV Index and daily UV Dose values listed in Table 1 are comparable to those found in summer on the southern parts of the Australian mainland at latitudes approximately 30° closer to the equator (Gies et al. 2004).

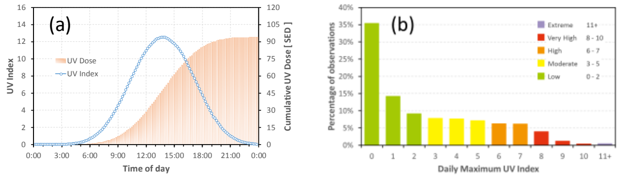


**Figure 1. (a)** UV Index and cumulative UV dose recorded at Davis station on 8 December 2015. **(b)** Histogram of UV Index values recorded at Davis from 1996 to 2018.

**Table 1.** Highest recorded ten minute UV Index and daily UV dose values at each of the stations.

| Location | Highest UV Index | | Highest UV Dose [SED] | |
|---|---|---|---|---|
| Casey | 22 Nov 1999 | 13.7 | 26 Nov 1998 | 92.5 |
| Davis | 2 Dec 2015 | 13.6 | 8 Dec 2015 | 94.3 |
| Mawson | 2 Dec 2015 | 14.9 | 2 Dec 2015 | 107.6 |

The peak readings of solar UVR coincided with extremely low total column ozone values passing over the stations as measured from satellites (Earth Probe TOMS and OMI Aura). The ozone hole is defined as the region with total column ozone levels below 220 Dobson units (DU) where 100 DU is equivalent to 1 mm of ozone at standard temperature and pressure. On the occasions where the maximum UV Index and UV dose values were measured the total column ozone readings were 191 DU over Casey, 184 DU over Davis and 176 DU over Mawson.

Despite operating in a very harsh environment, the UVR detectors have performed remarkably well over time. Detectors have been replaced on a semi-regular basis, generally every two to three years, when logistically possible.

## Discussion

Reducing the raw data to a single parameter (daily maximum UV Index or daily total UV dose) for each date reveals an obvious annual pattern, although it is far from clear whether any long-term trend exists. In Figure 2a we show the daily maximum UV Index recorded at Casey. This is the most complete data set of the three stations. There are occasional significant gaps in the data due to hardware failures that were unable to be repaired until replacement equipment arrived on site with the next resupply voyage.

Further consolidation of the data is achieved by calculating the average daily value of the parameter for each month. Figure 2b shows the monthly means of the daily maximum UV Index values for Casey. Seasonal effects are then removed by applying a twelve month centred moving average to the monthly average data before applying a simple linear fit to the deseasonalised data. The resulting trends, listed in Table 2, are close to zero.

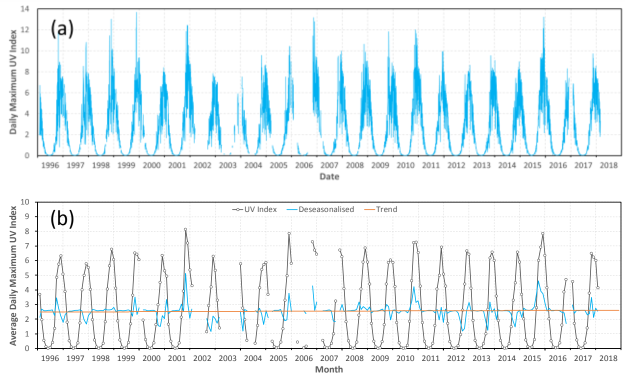


**Figure 2.** UV Index data recorded at Casey station from 1996 to 2018. **(a)** Daily maximum UV Index. **(b)** Trend analysis on deseasonalised monthly means of the daily maximum UV Index values.

**Table 2.** Calculated trends in deseasonalised monthly means of daily maximum UV Index and daily total UV dose for each of the stations.

| Location | Trend per decade | |
|---|---|---|
| | UV Index | UV Dose |
| Casey | 0.19% | 1.50% |
| Davis | 0.06% | 1.43% |
| Mawson | -0.36% | -1.10% |

Detecting trends is extremely difficult especially when dealing with incomplete data sets over limited time periods where the inherent fluctuations in the data are relatively large. Figure 3a shows the range and mean of the daily maximum UV Index measured at Mawson. The standard deviation in the average daily maximum UV Index for any given month ranges from less than 10% (December to March) to more than 20% (September to November). This huge natural variation makes it unlikely that the small trends of less than ±1% per decade showing up in the analysis of these data sets is of any significance.

Unlike mid-latitude sites, where the yearly UV Index maxima occur at the height of Summer (January), the Antarctic sites have their UV Index maxima in late Spring to early Summer (November-December) coincident with the presence of ozone depleted air and transit of the ozone hole over the stations (Klekociuk et al. 2015).

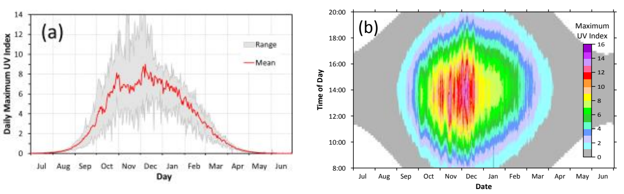


**Figure 3.** UV Index data recorded at Mawson station from 2002 to 2018. **(a)** Range and mean of the daily maximum UV Index by day. **(b)** Maximum UV Index for each ten minute period over all years.

In Figure 3b we show the maximum UV Index values recorded at Mawson during 2002 to 2018. This representation of the data gives an indication of the worst-case UV exposure pattern for the site. The dispersal of the polar vortex as the annual ozone hole breaks down is clearly evident, resulting in the very high to extreme UV levels recorded at the edge of Antarctica during this time.

## Conclusions

The daily maximum UV Index values measured at the Australian Antarctic stations in spring are significantly higher than expected based on the latitude of the sites. The combination of low stratospheric ozone and a relatively clean atmosphere over Antarctica lead to extreme solar UVR levels (UV Index 11+) when these conditions coincide with clear skies. The surprisingly high UV Dose values recorded at the stations are also due in part to the long hours of daylight at these latitudes in summer.

We have attempted to extract trends from the deseasonalised time series of the monthly averages of the daily maximum UV Index and daily total UV dose for each of the stations. The resulting fits gave small trends, less than ±0.5% per decade for UV Index and less than ±1.5% per decade for UV dose. Given the limitations of the data set and its inherently noisy nature, it is not possible to be confident that the detected trends are different from zero.

ARPANSA continues to monitor and report the solar UVR levels at the Australian Antarctic stations in order to characterise the UVR environment in Antarctica.

## Acknowledgements

The authors would like to thank the following ARPANSA staff for their contributions to this project: John Javorniczky, Alan McLennan, Joshua Hofman, Janaka Madamperuma and Zina Sofer.

This work has been undertaken as a part of the Australian Antarctic Science Program project number 4115.

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