

Comparison of UV measurements between Brisbane, Australia and Lauder, NZ

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Abstract. This paper compares the effects of UV radiation on humans between two dissimilar Southern Hemisphere locations over a one-year period (1996/1997). These locations were chosen based on their unique UV climatology. It is postulated that lower aerosol levels ($\Delta \approx 0.2$), higher altitude ($\Delta \approx 340$ m) and less cloud cover at the higher latitude site ($\Delta \approx 17.6^\circ$), account for the similar maximum and average DUV levels found during summer. In winter, the DUV levels were 4.6 times higher at the lower latitude site. The lower latitude and less air mass contribute to the differences in the average winter DUV levels. This corresponds to an additional daily 9 MED (minimum erythema dose) of available solar erythemal UV at the lower latitude site.

Introduction

Two recent studies have compared UV levels between Northern and Southern Hemisphere mid-latitude sites (McKenzie *et al.* 2001a) and Northern and Southern Hemisphere sub-tropical latitude sites (Sabburg *et al.* 2001). These studies, including earlier studies such as Seckmeyer and McKenzie (1992) and Roy *et al.* (1995), identified unique characteristics of the Southern Hemisphere sites in terms of UV climatology.

The sub-tropical latitude site of Brisbane (27.4°S, 153°E, 30 m altitude) is a coastal, urban city in the Northern State of Australia (Queensland, renowned for high levels of UV) with a relatively humid climate. The average aerosol optical depth (AOD) is estimated to be approximately 0.25, mean annual ozone levels, as measured by a Dobson spectrophotometer, have remained around 276 DU from 1979 to 1997 and the mean cloud cover, as inferred from Total Ozone Mapping Spectrometer (TOMS) reflectivity data, has increased from 3 to 4 okta during this time (Sabburg *et al.* 2001).

The mid-latitude site of Lauder (45°S, 170°E, 370 m altitude), approximately 200 km from the city of Dunedin, is a pristine, unpolluted, dry site located in the centre of the south island of New Zealand (NZ), also renowned for high levels of UV. The average AOD has been measured to be 0.02, mean annual ozone levels, as measured by a spectrometer have been 305 DU in recent years and the mean cloud cover, based on all-sky camera records, is approximately 60% with a relatively high fraction of cloudless days and fully overcast days.

In the case of Brisbane, it is believed that higher levels of cloud cover and lower altitude, compared to a similar latitude National Park site in the USA (Big Bend, 29.3°N,

103.2°W, 1052 m altitude), accounts for similar daily average, erythemally (CIE 1987) weighted (DUV) levels between the two sites (Sabburg *et al.* 2001). Model results included the effects of ozone and the sun/earth separation and recent findings by McKenzie *et al.* (2001b) suggest an altitude effect on UV levels of approximately 7% between the two sites. Roy *et al.* (1995) also found similar DUV levels during summer when comparing Brisbane to another Australian coastal city of higher latitude (Perth). However, this time both cities had a similar altitude and they found that in winter, Brisbane's lower latitude and lesser cloud cover reversed the summer situation.

Although McKenzie *et al.* (2001a) concentrates on intercomparing satellite and ground-based UV measurements at Lauder and other Northern Hemisphere sites, Seckmeyer and McKenzie (1992) specifically investigated possible reasons why UV levels in summer were higher at Lauder when compared to a similar latitude, but polluted site, in Germany (Neuherberg, 48°N, 11.5°E, 500 m altitude). It was found that the differences were mainly due to decreased stratospheric ozone over NZ and increased levels of tropospheric ozone over Germany.

It is the purpose of this present study, with both sites located in the Southern Hemisphere, to determine whether ozone differences, cloud cover variability and/or aerosol levels cause any major differences to the expected UV levels based on latitude and altitude alone and to quantify this in terms of expected effects on human UV exposures.

UV Instrumentation

Details of the UV instrumentation can be found in Sabburg *et al.* (2001) and McKenzie *et al.* (2001b) for the Brisbane and Lauder sites respectively. In summary, the UV measuring instrument at the Brisbane site was a Biometer (model 501, UV radiometer, Solar Light Co. Inc. Philadelphia) (Figure 1a). The spectral range is 290 to 400 nm, and approximates the erythema action spectrum. It has an angular response within 5% from ideal cosine for incident angles. The temperature stability of the instrument is $\pm 0.2^\circ\text{C}$. The UV irradiance was calibrated by comparison to a spectroradiometer whose calibration is traceable to the Australian UV standard lamp housed at the National Measurement Laboratory. The resulting overall error in measuring absolute DUV by the Biometer is estimated to be at best $\pm 10\%$.

The Lauder site maintains a purpose built spectrometer (UVM) that samples at 0.2 nm intervals in the range 285 to 450 nm (Figure 1b,c). The instrument has a superior cosine

response resulting in corrections that are very small as well as temperature stability maintained to within $\pm 0.5^\circ$. Corrections for temperature changes within those ranges are also applied (typically about -0.7% per degree). The absolute calibrations are traced back to the NZ Standards Lab (Industrial Research Limited) to the National Institute of Standards and Technology (NIST) in the USA. The uncertainty in spectral measurements is $\pm 7\%$.

Results and Discussion

Figures 2 to 4 present graphs showing the comparison of DUV, ozone and reflectivity data between the two sites during a one-year period from November 1996. The gap in the Biometer time series is due to missing data. The measured DUV data shown in Figure 2, ranged from 7.3 kJ/m² (16th January) to 20.8 J/m² (5th July) at Brisbane and 7.3 kJ/m² (28th December) to 13 J/m² (9th May) at Lauder. The corresponding average values were 3.6 kJ/m² and 2.4 kJ/m² respectively. Other than the expected seasonal and cloudy day variation in DUV at both sites and the latitudinal difference between the sites, it can also be seen that the maximum values at Lauder approach the maximum values at Brisbane for the first four months during summer and once again at the very end of the time series. Given the higher altitude of 340 m, accounting for less than 3% increase in DUV for clean conditions, and lower AOD of 0.2 between Lauder and Brisbane, it could be expected that maximum UV levels would be similar all year round compared to the situation if altitudes and AOD were the same. However, this does not explain why this only occurs over a four-month period.

Figure 3 shows the natural variation of ozone due to changes in photochemical reactions and large-scale air circulation at the two locations. The TOMS data was used for the Brisbane ozone dataset whereas the Lauder ozone was measured by the UVM. It has been found that the UVM measures ozone to within 5 DU compared to a standard Dobson spectrophotometer and the TOMS ozone equally as well to the Dobson at Brisbane. TOMS values are about 5 to 10 DU higher at Lauder.

Other than the natural increase in ozone during spring and ozone depletion in autumn, Figure 3 also shows that for most of the year the 7-day ozone average was higher for Lauder compared to Brisbane. The average for the 12-month period was 275 DU for the Brisbane site and 300 DU for Lauder, and for summer 270.9 and 285.5 DU respectively. Thus, this does not explain the higher than expected DUV values (based on latitude) at Lauder during the four months, in fact the higher levels of ozone would decrease the DUV values as a 1% difference in ozone gives a -1.2% difference in DUV.

Natural variability of the TOMS reflectivity data (proxy for cloud cover at both locations), presented in the graph of Figure 4, was not as evident as for the DUV and ozone levels. There appears to be an anti-correlation between the 7-day average reflectivity data of the sites with values for Lauder generally higher than for Brisbane, however, this will not be considered at this time. The averages of the reflectivity data over the 12-month period were 20% and

30% corresponding to Brisbane and Lauder respectively. These values for the snow-free, dry site of Lauder seem to be too high compared to the humid subtropical climate of Brisbane. Indeed, McKenzie *et al.* (2001a) report that the TOMS reflectance over the Lauder site, where the ground based UV and ozone measurements are made, is not typical of the satellite footprint, thus causing overestimation. Subsequently, no valid comparison of cloud cover can be made based on TOMS reflectivity data at this stage, however, Roy *et al.* (1995) did report that Brisbane's skies are usually cloudier in summer than winter, and this is confirmed by the reflectivity data in this present study (27% in summer, December to February and 16% in winter, June to August). This may contribute to lower levels of average DUV levels in summer compared to winter for Brisbane. If average summer DUV values are calculated, then a DUV value of 4.9 kJ/m² for Brisbane and 5.0 kJ/m² for Lauder and correspondingly for winter, 2.3 kJ/m² and 0.5 kJ/m² are found. Thus the average DUV values indicate that UV levels at Lauder are similar to those at Brisbane during the summer months and average values at Brisbane are approximately 4.6 times as high as Lauder in the winter.

Considering the scenario of outdoor workers who are outdoors all day, this group of the population are subjected to an additional 1.8 kJ/m² per day of available solar erythemal UV during winter at Brisbane compared to Lauder. This corresponds to an additional 9 MED/day (minimum erythema dose) (Diffey 1992) of available solar erythemal UV. Summed over the three winter months, this accumulates to an additional 165.6 kJ/m² or 828 MED.

Additionally, as the temperature decreases in winter, the usage of UV protective strategies also decreases (Kimlin *et al.* 1998). This research shows the importance of the contribution of winter solar UV at the Brisbane site to the annual human UV exposure.

Conclusions

This paper is the first reported comparison of daily erythema weighted UV, ozone and human exposures between these two important Southern Hemisphere sites. It was found that although the average DUV was higher by approximately 33% at Brisbane compared to Lauder, both their average summer DUV and summer maximum DUV levels were comparable. It was found that altitude, ozone and a constant AOD could not account for the values at Lauder being similar to those at Brisbane during the summer months in contrast to values at Brisbane being nearly 5 times as high as Lauder in the winter.

Although not conclusive, it has been suggested that increased cloud cover during the summer months in Brisbane may go part of the way in the explanation, although 1997 was one of the strongest occurrences of the El-Nino effect, resulting in lower than normal cloud cover over North Eastern Australia. It is also possible that Brisbane had increased levels of tropospheric pollutants during summer, thus increasing the AOD and subsequently lowering the DUV. AOD is much less in Lauder. The difference in winter is due to the difference in latitude and

coupled with this airmasses are much greater over Lauder compared to Brisbane during winter and this contributes to lower levels of UV at Lauder during these months as the increased airmass at Lauder dominates.

Acknowledgements

Dr. Richard McPeters, EPTOMS Principal Investigator, NASA. Dr Joe Wong and Lennox Meldrum, Queensland University of Technology. Mike Kotkamp for maintaining the calibrations at Lauder.

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FIGURES



(a) (b) (c)

Figure 1. (a) Similar Biometer as that located at Brisbane, Australia; (b) The optics building at NIWA Lauder showing the sensors on the roof (the top right one is the sensor head for UVM, connected to the room below via a quartz fibre-optic bundle); (c) An example of a more recent version of the UVM but in a self contained weather proof and temperature-stabilised enclosure.

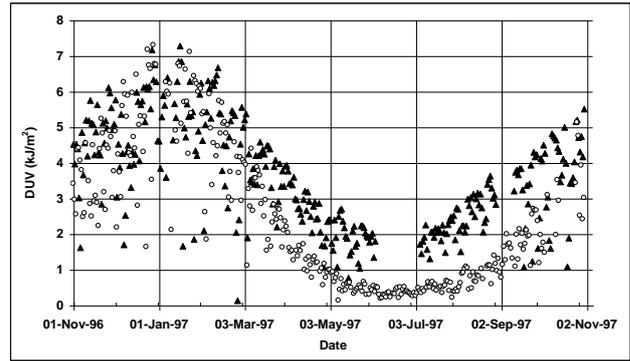


Figure 2. Graph showing the available DUV data for Brisbane (▲) and Lauder (μ) for a 1-year period from November 1996.

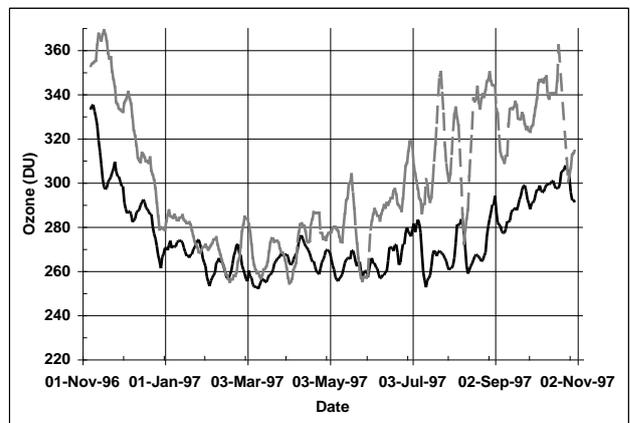


Figure 3. Graph showing the available 7-day running average of ozone data for Brisbane (—) and Lauder (- -) for a 1-year period from November 1996.

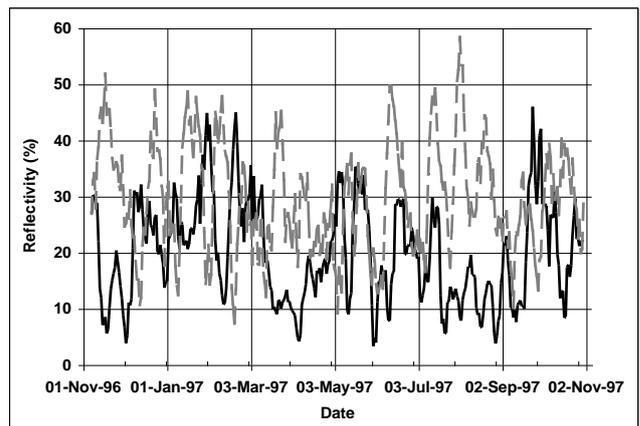


Figure 4. Graph showing the available 7-day running average of TOMS reflectivity data for Brisbane (—) and Lauder (- -) for a 1-year period from November 1996.