Long Term Trends in Erythemal UV at New Zealand Centres of Population

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Abstract. Solar UV radiometers with spectral responsivities that closely match the erythemal action spectrum of skin are installed in central Auckland, Wellington and Christchurch, and have been collecting daily data from 6am to 6pm NZST at 10 minute intervals since 1989. The radiometers are calibrated annually and the data corrected for changes in the absolute spectral responsivity of the instruments. This paper presents erythemally effective UV irradiances at a solar zenith angle of 30º which have been extracted from the data set spanning 1989 to 2005. Both all-weather and "clear-sky" data are presented.

Introduction

The spectral sensitivities of skin to erythema and nonmelanoma skin cancers are similar, with both action spectra showing a rapid decrease in response of several orders of magnitude from 295 to 350 nm. Broadband radiometers with a spectral response similar to the erythemal action spectrum are valuable tools for monitoring solar radiation in this spectral region. Such solar radiation is highly variable due to a number of atmospheric features including relative airmass (solar zenith angle, SZA), absorption by ozone, and backscatter by clouds and aerosols.

Erythemally effective irradiance is the integral with wavelength of the product of the solar spectral irradiance and the erythemal action spectrum (Figure 1). Because of the rapid and opposite change in the latter two quantities with wavelength, measurement of solar erythemal radiation is a technically demanding task and regular radiometer calibration is mandatory.

Instrumentation and Methods

Actinic UV radiometers from International Light Inc were used in this study. Ten minute averages were recorded daily from 6am to 6 pm NZST. The radiometers are calibrated annually by the Measurement Standards Laboratory of New Zealand. The absolute spectral responses are determined, with the calibrations traceable to NIST. Further details of the instruments and calibrations are found in Ryan *et al.* (1996). Annual field comparisons with a calibrated spectroradiometer were also made.

The measured solar UV irradiances were converted to erythemally effective UV irradiances, I, using

$$I_{\text{erythemal}} = K(\theta)\, I_{\text{measured}}$$

where $K(\theta) = \int_{290}^{400} \mathrm{E}(\lambda,\theta)\cdot \mathrm{s}_{\text{er}}(\lambda)\,\mathrm{d}\lambda \Big/ \int_{290}^{400} \mathrm{E}(\lambda,\theta)\cdot \mathrm{r}(\lambda)\,\mathrm{d}\lambda$

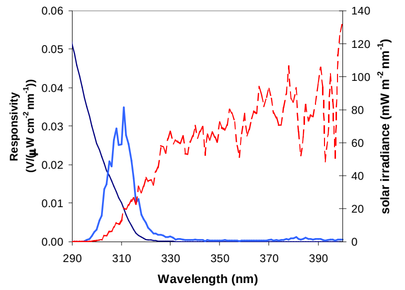

Figure 1 Graph of a) the spectral response of the Auckland radiometer in 2004 (solid line) (similar to the erythemal action spectrum); b) a typical solar spectrum with ozone column = 300 DU (dashed line); c) the product of a) and b) (thick solid line).

λ = wavelength, θ = SZA, $E(\lambda,\theta)$ = solar spectrum, $s_{er}(\lambda)$ = erythemal action spectrum, $r(\lambda)$ = radiometer spectral responsivity. The solar spectra used were provided by R.L. McKenzie, NIWA, Lauder (pers. comm.) and were measured in cloudless-sky conditions at Lauder, New Zealand in 1996 at specific SZAs between 22.4º and 60º and ozone column = 300 DU. This conversion takes account of any differences between the radiometer spectral responsivity and the erythemal action spectrum.

The varying atmospheric pathlength of solar radiation, which depends on latitude and time of day, has a major effect on irradiances at the earth's surface. In order to remove sun-angle-related variables and allow comparisons of UV insolations at different geographical and temporal locations, irradiances at specific SZAs have been extracted. The data presented in this paper correspond to an SZA of 30º.

Results and Discussion

Erythemally effective irradiances at 30° SZA for Auckland, Wellington and Christchurch are presented in Figures 2, 3 and 4 respectively. These figures show the full data set at 30º, ie 2 points per day from approximately October to March each year. This includes all cloud-cover conditions. The strong effect of cloud is clearly seen, with the lower points arising from cloudy days. The upper envelope of points arise from measurements taken on clear sky (cloud free) days, or days when clouds near the sun act as a secondary scatterers, increasing the ground-level irradiance. A simple technique was used to fit this clear-sky situation, with a reduced data set of 10 point (usually 5 day) maxima being extracted. A comparison of the two data sets over each summer indicates that the 5 day maxima provide a good, though not perfect, approximation to the "clear sky" data.

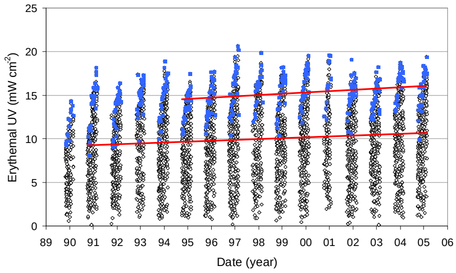

Figure 2. Erythemally effective irradiances at SZA = 30° at Auckland; All-weather data (◊), b) 5-day maxima, “clear sky” (■). Linear regression lines are also shown (details in text).

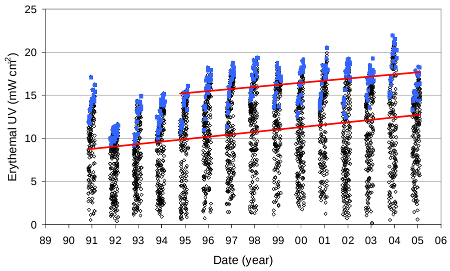

Figure 3. Erythemally effective irradiances at SZA = 30° at Wellington; All-weather data (◊), b) 5-day maxima, “clear sky” (■). Linear regression lines are also shown (details in text).

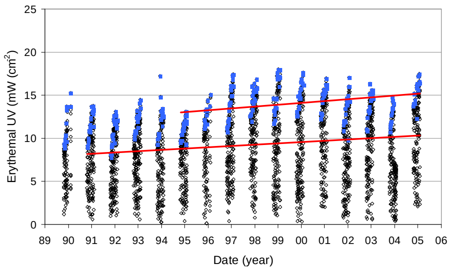

Figure 4. Erythemally effective irradiances at SZA = 30° at Christchurch; All-weather data (◊), b) 5-day maxima, “clear sky” (■). Linear regression lines are also shown (details in text).

Linear regression of the data has also been carried out, and the results included in Figures 2-4. It should be noted that such linear fit analysis has been chosen to give a simple preliminary indication of data trends – inspection of the graphs indicates more complex systematic behaviour than can be accounted for by such a data fitting approach. The lower of the two lines was fitted to the full data set from October 1990 to March 2005. This time period was chosen as the maximum period for which data was available at all sites. The upper line was fitted to the 5-day maxima data set. The time period used was October 1994 – March 2005. In all cases the regression analysis showed a positive increase in erythemal UV levels over the period. These increases amount to approximately 1-2% per year. The statistical significances of these increases are being determined by more detailed analysis of the data currently in progress.

It is difficult to make comparisons with other studies of trends in solar UV levels, as in each case the methodology, data selection criteria and/or time period used are different. However, the trends reported here are in general agreement with those found internationally, which range from 0.5 to 2.0% per annum. (Cappellani *et al.*(1999), den Outer *et al.* (2005), Krzyscin *et al.* (2004), Lakkala *et al* (2003), McKenzie *et al.*(1999), Sasaki *et a.l* (2002)).

It is likely that the preliminary trends reported here that are provisional at this stage provide a maximum limit to the 'true' increases. We are now carrying out a more detailed statistical analysis of the data. One factor which needs to be taken into account is the atmospheric ozone levels at the time of each measurement, as represented by the solar spectra used to convert raw values to erythemally effective irradiances. In the work reported here, a nominal value of 300 DU for the ozone column has been adopted. Use of actual ozone values could affect the data by up to 10%. We also intend to investigate instrumental effects which have recently been observed. In addition, the uncertainties represented by the data will be determined.

Conclusions

Erythemally effective UV irradiances measured in Auckland, Wellington and Christchurch from 1990 to 2005 at a solar zenith angle of 30° have been presented. Both all-weather and “clear-sky” data are shown. A small increase in irradiances over the time period is seen at all three sites.

Acknowledgements

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