# Comparison between UV irradiances in Christchurch City and the Port Hills

Richard L. McKenzie, Dan Smale, John Sansom

National Institute of Water and Atmospheric Research (NIWA), Lauder, Central Otago, New Zealand

Kathryn M. Nield, John D. Hamlin, Gerald Smith

Measurements Standards Laboratory, Industrial Research Ltd (IRL), Gracefield Rd., Lower Hutt, Wellington, New Zealand

**Abstract**. Measurements of the Ultraviolet Index (UVI) in Christchurch city were compared with those made at a nearby site above the city on the Port Hills. After removing effects of altitude differences and calibration differences, we found that reductions in UVI due to pollution effects on a clear winter's day were ~40%. The effects increased at larger solar zenith angles.

## Introduction

For several years, sun-burning UV has been monitored by IRL at population centres in New Zealand using broad-band International Light Monitors (ILM) (Smith et al. 1997). Instruments are currently located at Auckland, Wellington, Christchurch and Dunedin (another is located at NIWA Lauder, Central Otago for quality assurance purposes). The sensors are calibrated annually against irradiance standards traceable to NIST that are maintained by IRL. Data from these instruments complement those from NIWA's network of Robertson-Berger (RB) type meters at more remote locations. Data from the latter network are available through NIWA's public Climate Data Base (http://cliflo.niwa.co.nz/), and work is in progress to make the IRL data similarly accessible to the public. In both cases, data are logged at 10 minute intervals, and provided in terms of the UV Index, (UVI)[1]. It is well-known that Christchurch city suffers from pollution effects associated with winter inversions. Here we investigate the effects of altitude and pollution differences in UVI by comparing measured and calculated values of UVI in the city and at a nearby site on the Port Hills above the inversion layer.

## Study Method

Measurements of UVI at the Christchurch city site were complemented by an identical set of instrumentation which was set up on the Port Hills, at an altitude higher than the usual inversion layer. Details of the sites are shown in Table 1.

| Site | Lat (°S) | Long (°E) | Alt (m) |
|---|---|---|---|
| NRL, Victoria St. Christchurch city | 43.53 | 172.63 | 5 |
| Gondola Restaurant, Port Hills, Christchurch | 43.59 | 172.71 | 438 |

**Table 1.** Details of the observing sites.

The TUV radiative transfer model (Madronich & Flocke 1995) was used to calculate the expected differences between the two sites under clear sky conditions, taking into effect the differences in altitude, as well as a range of differences in extinctions due to aerosols and trace gases (ozone, $SO_2$ and $NO_2$) in the boundary layer. Results are shown in Figure 1. The calculated ratio in UVI between the two sites is relatively small for generally-accepted choices of the aerosol parameters. Unlike a previous study comparing UV over a much wider range of altitudes (McKenzie, R.L et al. 2001), we expect only a weak dependence on solar zenith angle (SZA) between these two sites.

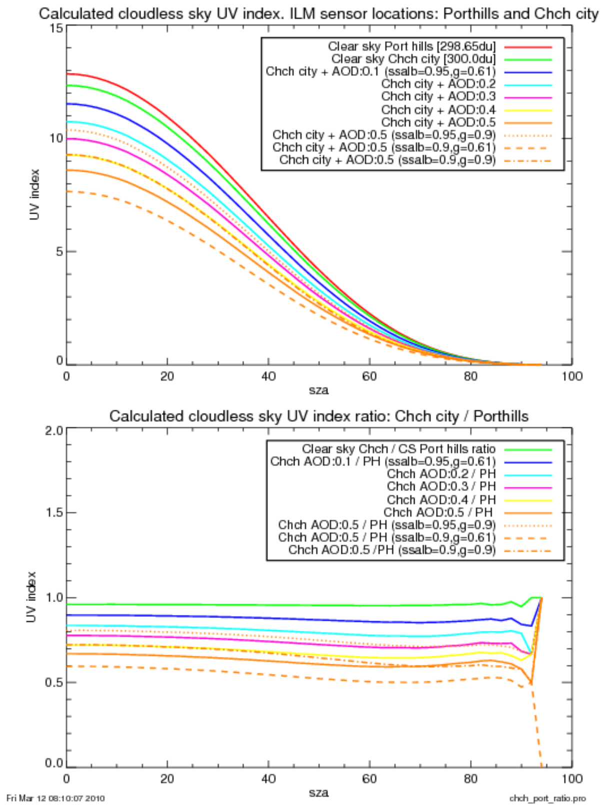


**Figure 1.** Calculated effects of differences in altitude and pollution effects, plotted as a function of solar zenith angle.

## Results

As a quality check, UVI measurements at the two sites were compared with NIWA measurements and with a radiative transfer model for clear skies. Data has been collected from the Port Hills site since December 2003, but unfortunately there are frequent gaps in the earlier years. Data coverage was much better in 2007 and 2008.

[1] UVI = 40 x $UV_{Ery}$, where the erythemally-weighted UV ($UV_{Ery}$) is the spectral irradiance in W $m^{-2}$ $nm^{-1}$, multiplied the erythemal action spectrum (from McKinlay & Diffey, 1987).

A subset of the 10 minute data, where all three instruments were operational was extracted. Ratios of UVI between City and Port Hills sites are plotted in Figure 2. As expected, UVI values in the city are lower than on the Port Hills, especially for larger SZA. There is a wide range in these ratios which arises because at any time one site may be cloudy while the other is clear, and vice versa. For example for small SZA approximately 50% of the radiation is from direct sunlight, so if the sun is obscured at one site but not the other we would expect the ratios to approach 0.5 or 2.0 respectively. Also, the ratios are plotted as a function of SZA at the city site, and for larger SZA, geographic differences between the two sites become important. However, the observed effect is systematically larger than anticipated by the model, with ratios sometimes being as small. This is probably due to calibration differences.

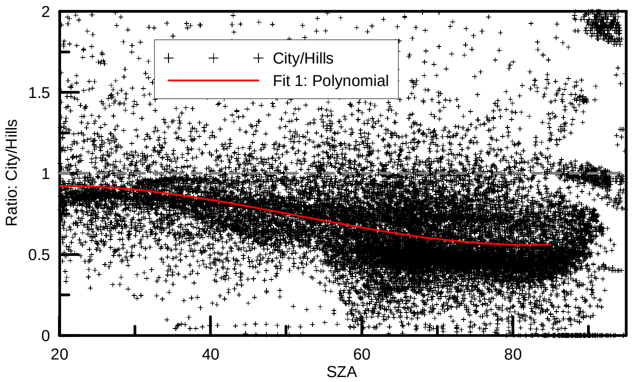


**Figure 2.** UVI ratio for City/Port Hills, plotted for all coincident data as a function of SZA at the city site. The red line is a polynomial fit

Corresponding ratios for typical clear summer and winter days are shown in Figure 3. The pollution effect increases with SZA, and is larger in winter than in summer. Apart from occasional outliers possibly caused by shadows, the patterns are similar in the morning and afternoon observations. The minimum ratios are ~0.8 and ~0.5 in summer and winter respectively.

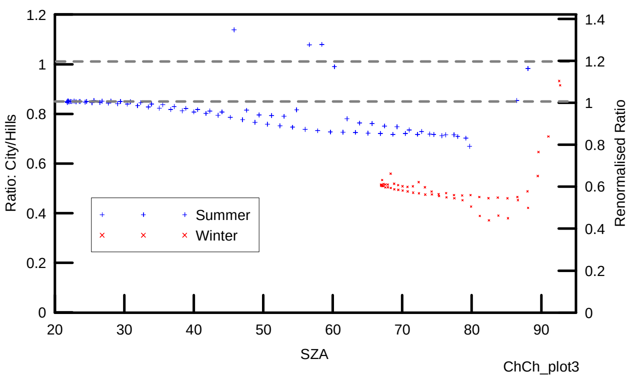


**Figure 3.** UVI ratio for City/Port Hills on a clear summer day (12 January, 2008) and a clear winter day (18 June, 2008).

It is reasonable to assume that pollution effects would be relatively small on the summer's day. Based on that assumption, the lower ratios in the summer day must be due to the combined effects of altitude differences for clean air (< 5%) (McKenzie, et al. 2001), differences in surface albedo, more extensive horizon, or calibration uncertainties. After re-normalising the data to unity at low SZA to remove these effects (see right axis of Figure 3), we find that the winter pollution effect remains substantial, with the boundary layer effects reducing UVI values by ~40% (R=0.6) at midday, and by up to 50% (R=0.5) for SZA ~85°.

## Conclusions

The observed effects of boundary layer pollution in Christchurch due to extinctions by aerosols and absorptions by trace gases is much larger than predicted by a radiative transfer model using the generally accepted aerosol optical parameters. If these differences are real, then this has important implications for modelling of UV radiative transfer in polluted conditions. And the results could help explain why peak UVI values at unpolluted sites in NZ are so much greater than at corresponding latitudes in the more heavily polluted northern hemisphere (McKenzie, et al. 2006). There would be better agreement between model and measurement if the single scattering albedo of the aerosols were much lower – more strongly absorbing aerosols. Further work needs to be done to verify the cross-calibration between the two instruments. Spectrally resolved measurements would help identify the causes of any differences.

## References

Madronich, S., Flocke, S. 1995. Theoretical estimation of biologically effective UV radiation at the earth's surface. *In*: Zerefos, C.S., Bais, A.F. (eds). Solar Ultraviolet Radiation. NATO, Series I: Advanced Study Institute, pp. 23-48. Springer, Berlin.

McKenzie, R.L., Johnston, P.V., Smale, D., Bodhaine, B., Madronich, S. 2001. Altitude effects on UV spectral irradiance deduced from measurements at Lauder, New Zealand and at Mauna Loa Observatory, Hawaii. J. Geophys. Res. 106(D19): 22845-22860.

McKenzie, R.L., Bodeker, G.E., Scott, G., Slusser, J. 2006. Geographical differences in erythemally-weighted UV measured at mid-latitude USDA sites. Photochemical & Photobiological Sciences 5(3): 343-352.

McKinlay, A.F., Diffey, B.L. 1987. A reference action spectrum for ultra-violet induced erythema in human skin. *In*: Passchier, W.F., Bosnajakovic, B.F.M. (eds). Human Exposure to Ultraviolet Radiation: Risks and Regulations, pp. 83-87. Elsevier, Amsterdam.

Smith, G.J., Ryan, K.G., Ireland, W. 1997. The IRL solar ultraviolet radiation measurement programme. in "UV Radiation and Its Effects - An Update", Wellington, New Zealand, 4-5 December 1997, Royal Society of New Zealand, Miscellaneous Publication 49, 18-20.