Materials-Damaging UV Radiation in New Zealand: Comparison with other locations

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Abstract. We extract monthly and annual doses of UV-B (280-315 nm) and UV-A (315-400 nm) from spectral irradiance measurements at several sites covering a wide range of latitudes, and show that although the peak doses in summer are relatively large in New Zealand, the doses during winter months are small. Consequently, the annual dose, which is the important quantity for materials damage, is significantly less than at sites that are closer to the equator in either hemisphere. The annual dose of UV radiation in New Zealand is thus less than the global mean value.

Introduction

Previous studies have shown the peak summertime UVI values at Lauder NZ can be 40% greater than at corresponding latitudes in the Northern Hemisphere (McKenzie et al. 2006). This arises because of differences in ozone, air-clarity, and seasonal changes in Earth-Sun separation. Arising from this is a public perception that building materials, such as paint and plastics that are used outdoors in New Zealand, are subject to unusually rapid degradation by UV radiation.

Satellite data are unsuitable for answering whether this perception is true, because there can be systematic errors in retrievals of UV due to extinctions in the lower atmosphere from clouds and aerosols. Consequently, satellite-derived UV products tend to overestimate the true UV at polluted locations.

Here we make use of ground-based spectral UV measurements to quantify differences between the UV doses in New Zealand compared with other locations. In addition to the site at Lauder, the network of NIWA UV spectrometers includes sites in Australia, USA, and Japan. To improve the geographical coverage, we also make use of data from instruments developed by Biospherical Instruments. These are located primarily at high latitude sites to investigate effects of polar ozone depletion and complemented by measurements at San Diego, California. All these data are traceable to the same NIST irradiance standards and represent the state-of-the-art in global monitoring of UV irradiances. Several of the sites contribute to the international Network for the Detection of Atmospheric Composition Change (NDACC).

Sample spectra taken at similar solar zenith angle (SZA = 90 – Solar Elevation Angle) are shown in Figure 1. Differences arise primarily because of differences in sun-earth separation, altitude, and atmospheric column ozone amount (see Table 1 for site details). It has been shown previously that long term changes in UV have been small at all sites over the measurement period considered (Bernhard et al. 2013, McKenzie et al. 2009).

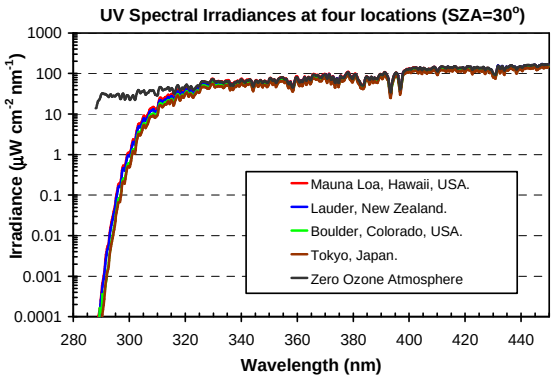

Figure 1. Sample spectra from several NIWA sites compared with the solar spectrum at zero airmass.

Lat (°N)	Alt (m)	Site name	Years	Agency
72.6	3202	Summit	2004-2012	NSF
71.3	8	Barrow	1991-2012	NSF
40.0	1650	Boulder	2002-2012	NIWA/NOAA
35.4	57	Tokyo*	2004-2005	NIWA/U Tokyo
32.8	22	San Diego**	1993-2012	NSF
19.6	3400	Mauna Loa	1998-2012	NIWA/NOAA
-12.4	32	Darwin	2004-2005	NIWA/BoM
-23.8	550	Alice Springs	2007-2012	NIWA/BoM
-38.	110	Melbourne	2006-2012	NIWA/BoM
-45.0	370	Lauder	1994-2012	NIWA
-54.8	30	Ushuaia	1998-2008	NSF
-64.8	21	Palmer	1990-2011	NSF/NOAA
-77.8	190	McMurdo	1990-2012	NSF/NOAA
-90.0	2835	South Pole	1991-2011	NSF/NOAA

Table 1. Site details. Notes:
*. The Tokyo instrument measured actinic flux, which was converted to irradiance as described previously (McKenzie et al. 2002)
**. A correction of 3% has been applied to measurement at San Diego to adjust for errors in cosine response.

Spectra from these instruments can be weighted with any biological weighting function of interest. However, for plastics and paints that are used in the construction industry, the wavelength dependence of UV damage differs between different materials, and in many cases the detailed action spectrum is not well known. Nevertheless, we expect that the most damaging wavelengths will be in the UV-A (315-400 nm) or UV-B (280-315 nm) regions, since shorter wavelength (UV-C) radiation does not penetrate to the Earth's surface, and because photon energies in the longer-wavelength visible and infrared regions are generally insufficient to affect molecular structure.

Thus, we focus on the geographic variability of UV-A and UV-B doses. We argue that if neither of these is large in New Zealand compared with other locations, it then follows then no other realistic UV weighting can be either.

Results

Surface UV irradiances depend strongly on the SZA, mainly because it determines the path length through the atmospheric ozone. Consequently, the contrast between summer and winter UV is a strong function of latitude (Figure 2). For example, at Lauder (45° S), the UV-B dose in winter is less than 10% of that in summer; whereas in the tropics, the doses remain elevated throughout the year.

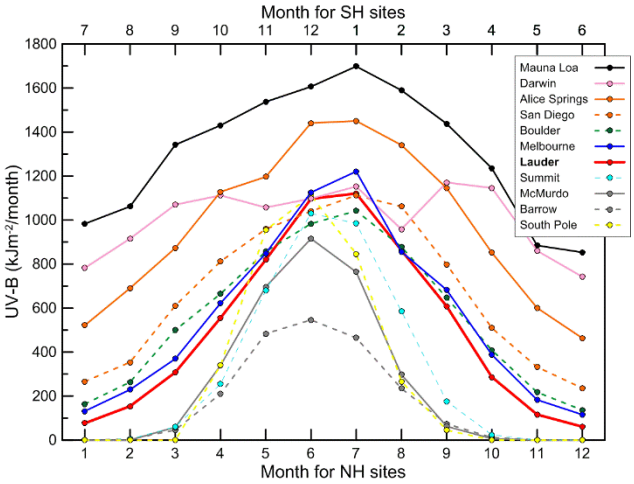

Figure 2. Seasonal variation in UVB at several sites covering a wide range of latitudes.

At Darwin, which is the closest site to the equator, the double-peak corresponding to the two months where the sun reaches the zenith is clearly evident. In the Antarctic region, highly elevated UV doses occur during the period of the ozone hole in late spring early summer. At the high altitude South Pole site, the UV-B in December are comparable with those at mid-latitudes. Effects of altitude and surface albedo are evident when comparing Barrow (Alaska) and the high altitude Summit station (Greenland), which are located within 1.5° of latitude. Peak values at Summit are nearly twice as large. At most sites, clouds reduce the annual doses by approximately 30%, though these cloud reductions are less important at Alice Springs, the high-altitude Mauna Loa site, and sites located on high-albedo ice caps (Summit, South Pole). Peak summer values tend to be larger for SH sites than for NH sites.

Annual doses of UV-A and UV-B are shown in Figure 3. Although these are larger in the SH than at corresponding latitudes in the NH, the difference is much less marked than for the peak irradiances discussed previously. Generally, the annual dose decreases with latitude, with stronger latitudinal gradients in the UV-B region than in the UV-A region. Even allowing for differences in altitude between these sites, which can account for differences of approximately 5% per km (McKenzie et al. 2001) (i.e., 15% more UV at Mauna Loa and 10% more at Boulder), these results imply that UV doses in the latitude range of New Zealand (about 34° to 46° S) are less than for sites within the latitude range from 30° S to 30° N: a range which corresponds to half the area of the globe.

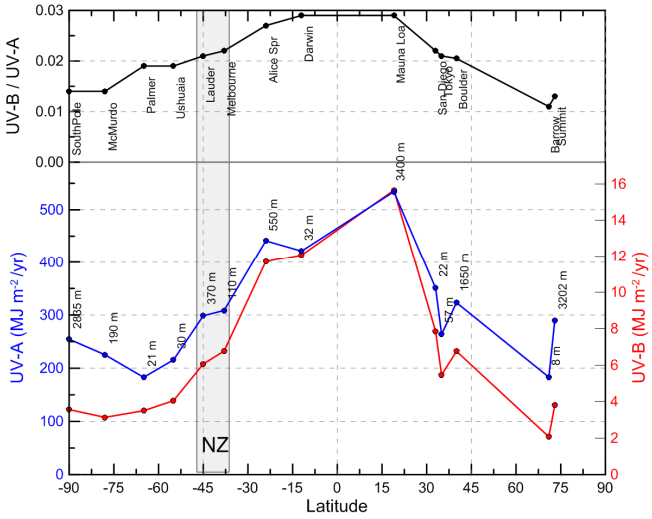

Figure 3. Latitudinal variability in UV-A and UV-B.

Conclusions

UV dose is a strong function of latitude, so the annual dose in New Zealand should be well represented by the range of values between Lauder (Central Otago) and Melbourne, which has a latitude similar to Auckland's. Peak summer UV doses are relatively high at these sites compared with corresponding latitudes in the Northern hemisphere. However, the data show that the annual doses of UV in New Zealand are significantly less than at sites within 30° to 35° of the equator, a region which represents more than half of the global surface area. It has been suggested (UNEP 2011) that material damage by UV is accelerated under high temperatures. However, compared with tropical sites, temperatures in New Zealand are relatively low. In contrast, it may be worth investigating whether there are synergies or anti-synergies between UV induced damage and the large diurnal temperature ranges (including frosts) that are common through much of New Zealand.

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