Implications of the large geographical and temporal variability in UV radiation

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Abstract. Peak UV intensities in the New Zealand summer and winter are compared with those at corresponding sites in North America. The summer peak UVI values are 40% greater in New Zealand, whereas in winter they are quite similar. The resulting strong seasonal contrast in UV may have important implications for human health. This large range exacerbates both the risk of skin damage and of vitamin D deficiency.

Introduction

The intensity of UV radiation at the surface is controlled by several factors. The solar elevation is most important. If the Sun is below the horizon, the UVI will be zero. Clouds are the next most important. Under heavy overcast conditions, they can attenuate UV intensities by more than 90%. On average, clouds are responsible for reducing clear sky UV by about 30%. Clouds near the Sun can also cause short-term increase in UVI of ~20%, though this fraction decreases at high altitudes. The UVI increases by about 1% for every 1% reduction in ozone. Ozone amounts are measured in Dobson Units (where 1 DU = 2.69 x 10^{16} molecule cm^{-2}), and they vary from a minimum of about 100 DU inside the Antarctic ozone hole, up to a maximum of about 500 DU at mid latitudes. The global average ozone amount is about 300 DU, and away from the Antarctic ozone hole ozone amounts tends to be lowest in the tropics, where they occasionally dip below 200 DU. Aerosol extinctions can lead to reductions in UVI of 20-30%. Even in the most pristine air, UV increases by about 5% per kilometer, and with snow cover you can expect another 20-40%. Again, this increase is less pronounced at high altitudes where there is less air to scatter the radiation. Even the seasonal changes in Sun-Earth separation due to the elliptical orbit of the Earth about the Sun are significant. At closest approach in early January, the UV intensity at the top of the atmosphere is about 7% more than in July. All these factors are lead to large variations in UV throughout the day, from season to season (especially at mid to high latitudes), and from place to place.

Results and Discussion

Figure 1 shows the satellite-derived global distribution of UV in June (summer in Northern Hemisphere (NH)) and December (summer in Southern Hemisphere (SH)). As latitude increase, UV intensity decrease, especially in the winter hemisphere. An exception is Antarctica in December, where the combined effects of low ozone amounts, high surface reflectance, and 24-hours of daylight all contribute to the relatively high UV dose.

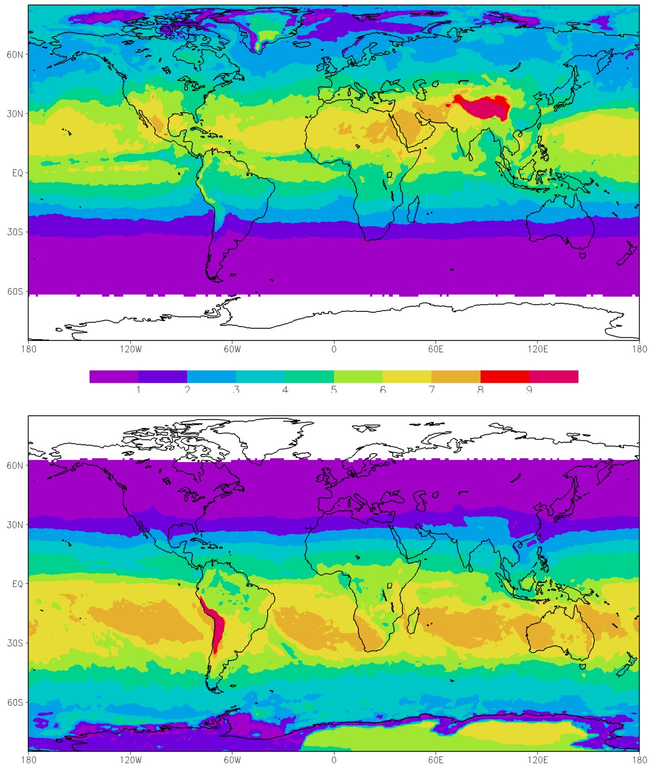

Figure 1. Mean daily erythemal UV dose (kJm-2) for June 2005 (upper panel) and December 2005 (lower panel), as measured by the Ozone Monitoring Instrument (OMI) on board the Aura spacecraft. No UV retrievals were made in the white areas (from Aapo Tanskanen from the Finnish Meteorological Institute).

Data from satellite instruments of this type have been compared with measurements at the surface and have been found to be in good agreement for unpolluted conditions. However they can seriously overestimate UV intensities under polluted conditions [*McKenzie et al.*, 2001]. This pollution effect tends to mask differences in UV between clean locations (such as in the SH) and more polluted locations (such as in the NH). Despite this, the retrieved SH values tend to be larger than corresponding NH values.

Ground based measurements from the USDA network of intercalibrated UV radiometers were used to more carefully investigate differences in peak UV between NZ and corresponding latitudes in the USA. The results are shown in Figure 2. The peak UV intensities in New Zealand are approximately 40% more than those in North America, and are more comparable with those at high altitudes in Colorado, 5-degrees of latitude closer to the equator ,and 1-2 km higher in altitude [*McKenzie et al.*, 2006].

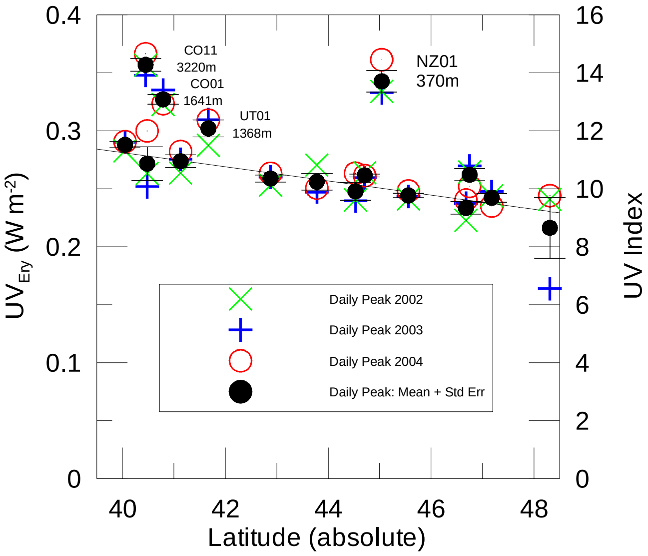

Figure 2. Peak UV values in Lauder New Zealand compared with 15 rural North American sites at similar latitude.

By contrast, when wintertime values were compared, we found the peak values in New Zealand were quite comparable with those in North America. Model calculations showed that these differences can attributed as shown in Table 1.[*McKenzie et al.*, 2003]

Parameter	Summer	Winter
Total ozone	20	-3
Aerosol	0 to 20	0 to 20
Sun-Earth separation	7	-7
Ozone Profile	2	-2
Temperature Profile	0	-2
Total	+40±10	-5±10

Table 1. Contributions to differences in peak UV at 45ºS compared with that at 45ºN (all in %)

When these differences due to aerosols are included, the effects of ozone depletion are seen to be a relatively small contribution to the observed differences in UV between New Zealand and corresponding Northern latitudes, as shown in Figure 3.

Conclusions

New Zealand's summertime UV is relatively intense for its latitude (e.g., it is 40% more than USA), due to our lower ozone, the closer Sun-Earth separation in our summer, and our atmospheric clarity. It's like moving 5º equator-ward and 1-2 km higher.

By contrast, New Zealand's wintertime UV is not intense for its latitude (e.g., it is similar to that in USA). Our resulting summer/winter contrast in UV is high, and our wintertime peaks of UV are typically only 10% of those in the summer. This large range exacerbates both the risk of skin damage and of vitamin D deficiency. Over the winter months, the protective effects of sun tanning diminish under the low UV intensities. With the onset of high UV in summer, unexposed skin is susceptible to damage. However, with the onset of the following winter, our sun tanned skins tend to diminish penetration of the already-low levels of vitamin D producing UV radiation. Messages to public must recognise both sides of the UV coin. Public advisories should be provided throughout the year, and should include cloud effects if possible. The risk from high summertime UV is at its greatest now, when ozone is close to its minimum. Although ozone appears to be slowly recovering, it will be decades at best before a complete recovery, and our UV risk will in any case remain high.

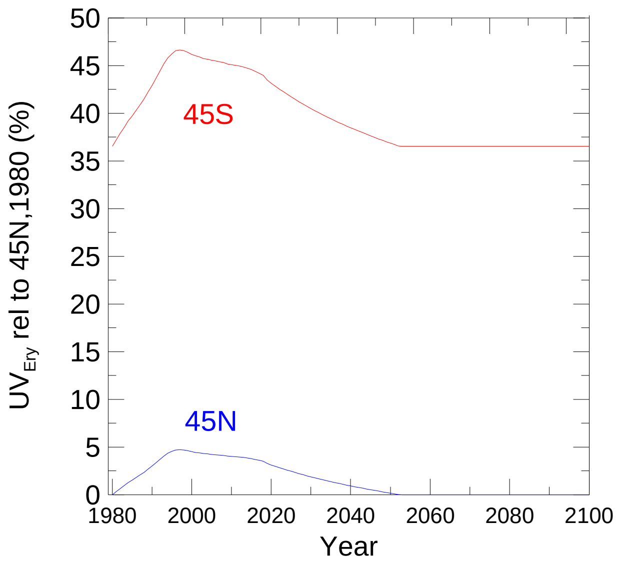

Figure 3. Erythemally weighted UV at 45ºS compared with that at 45ºN, and their predicted evolution in response to the decline and expected recovery in ozone.

Acknowledgements

The surface UV images in Figure 1 were supplied by Aapo Tanskanen of the Finnish Meteorological Institute. OMI is a joint effort of KNMI, NASA, and FMI, and is managed by NIVR/Netherlands. White areas have no UV data coverage

References

McKenzie, R., D. Smale, G. Bodeker, and H. Claude, Ozone profile differences between Europe and New Zealand: Effects on surface UV irradiance and its estimation from satellite sensors, *Journal of Geophysical Research*, *108* (D6), 4179 doi: 10.1029/2002JD002770, 2003.

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

McKenzie, R.L., G. Seckmeyer, A. Bais, and S. Madronich, Satellite retrievals of erythemal UV dose compared with ground-based measurements at northern and southern mid-latitudes, *J. Geophys. Res.*, *106* (D20), 24051 -24062, 2001.