UV Radiation Climatology and Trends

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Abstract. The global distribution of erythemally weighted UV radiation and its seasonal changes are compared with the corresponding trends due to changing atmospheric composition. Because of the success of the Montreal Protocol, the trends in UV radiation have been relatively small outside the regions directly affected by the Antarctic ozone Hole. We do not expect further large increases in UV radiation from future ozone depletion. We therefore need to focus on both the benefits as well as the risks of the large geographical and seasonal differences. The vitamin D weighted UV, which leads to beneficial health effects, has an even stronger seasonal and geographic variability than erythemally weighted UV.

Discussion

Since the realisation that world's protective ozone layer was at risk from a build-up of man-made trace gases in the atmosphere, there has been increased interest in understanding the variability and trends in UV radiation.

Good progress has been made through improvements in instrumentation, calibration procedures and data quality assurance. The widespread adoption of a standardised metric for reporting UV radiation – namely erythemally weighted UV (UV_{Ery}), or the UV Index (UVI) [*WHO*, 2002], which is simply a scaled version: $UVI = 0.4 \times UV_{Ery}$, (when the latter is expressed in units of Wm^{-2}), has also facilitated meaningful comparisons. The status of our understanding of UV radiation and its effects on the environment are updated regularly. The most recent of these assessments predicted that although the ozone layer would gradually recover over the next few decades, though the outlook for future UV was less certain [*UNEP*, 2007; *WMO*, 2007].

Despite the progress in instrumentation, any changes in UV_{Ery} attributable to ozone depletion have been difficult to detect, because of (1) uncertainties in UV measurement, (2) a relatively low sensitivity of UV_{Ery} to changes in ozone, and (3) the effects of other changes in atmospheric composition (e.g., changes in aerosols and clouds).

In New Zealand, summertime ozone, and therefore UV_{Ery} is influenced by the export of ozone poor air from the Antarctic ozone hole. Long term measurements at Lauder provide some of the strongest evidence for increases in UV_{Ery} attributable to ozone depletion (Figure 1). The increases in peak UV_{Ery} due to ozone depletion were ~10-15%. However, no further increases have occurred since the late 1990s, and more recent data in fact show lower values of UV_{Ery}. Other sites, which are generally more polluted, show larger variabilities from sources other than ozone. These findings demonstrate that, outside the region affected by the Antarctic ozone hole, changes in UVI due to changes in ozone are rather small and are within the range of variability from other causes. These relatively small changes in UV are attributable to the successes of the Montreal Protocol, and its subsequent amendments and adjustments

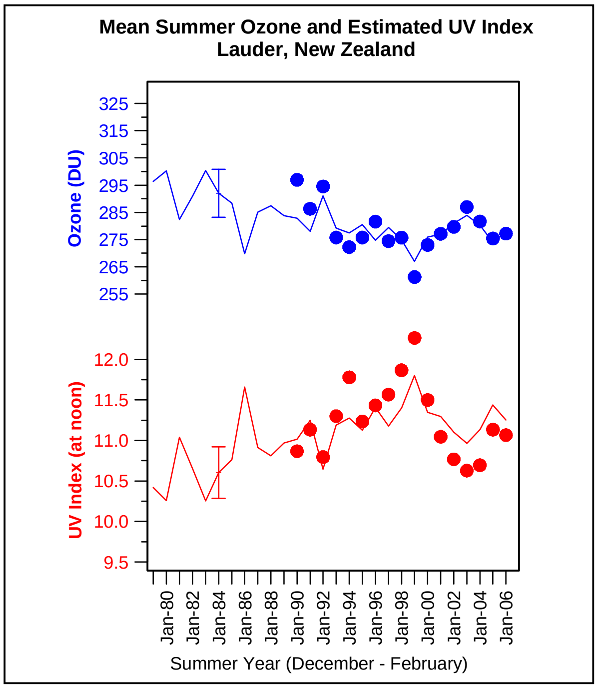

Figure 1. Long term changes in summertime ozone (upper panel) and in peak summertime UVI (lower panel) at Lauder, New Zealand. The symbols show the average ozone and corresponding noontime UV Index derived from UV spectral irradiance measurements. The lines represent the average satellite-derived ozone, and the corresponding UVI calculated from those ozone values (from *UNEP*, [2007]).

In contrast to these relatively small trends in UV_{Ery}, the geographical and seasonal changes (as well as diurnal changes) are large. Figure 2 shows the global distribution of midday UV_{Ery} measured by the OMI instrument in the two solstice months. The figure UV_{Ery} doses rather than peak irradiances because both the damaging effects of UV radiation as well as the beneficial effects of UV radiation will depend on the doses ,which show much larger seasonal variabilities because the longer hours of daylight in summer and the shorter hours of daylight in winter. Further, to illustrate the global variability of UVI, a colour scale that is different from the WHO recommendation would be needed. The WHO colour scale is clearly inappropriate for most of the globe, where UVI regularly exceeds 13, and especially for sites such as the Alti-Plano area of South America, where the UVI can reach 25 [*Liley and McKenzie*, 2006]. In the WMO colour definitions, the highest defined category is for UVI>10 (purple). [*WHO*, 2002]

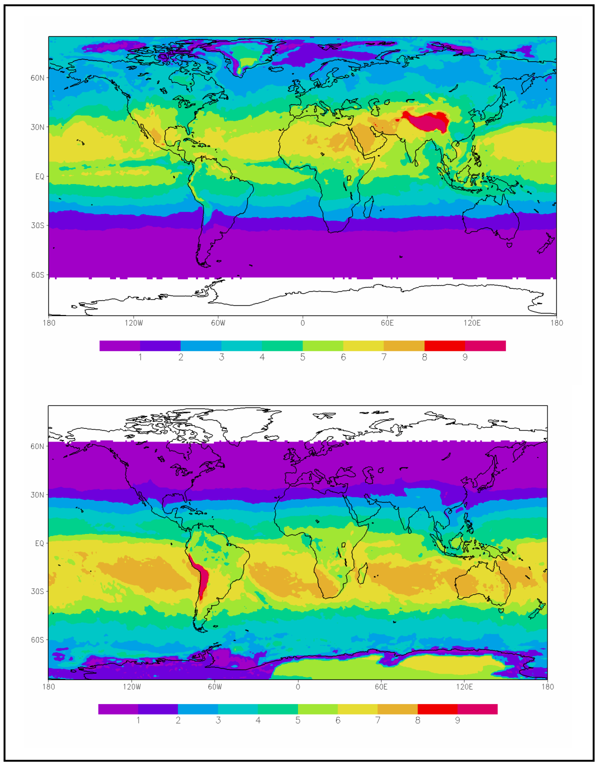

Figure 2. Global distribution of the average cloud corrected erythemal daily dose (in kJ m^{-2}) for June 2005 (upper) and Dec 2005 (lower) from OMI measurements. White areas have no data. Figure provided by Dr Aapo Tanskanen (from *UNEP*, [2007]).

At mid-latitudes, the daily UV_{Ery} dose in summer is comparable with that in the tropics. But in the winter, it is less than 10% of the summer dose. As the latitude increases, the seasonal swing becomes more and more marked until within Arctic and Antarctic circles, the wintertime dose is zero. It should be noted that these satellite derivations tend to overestimate the UV_{Ery} in polluted locations because extinctions within the atmospheric boundary layer are not well probed by these sensors.

In the Southern Hemisphere, the summer winter contrast in UV_{Ery} is more marked because of the phasing of the Earth's orbit about the Sun (closest in January, and furthest in July), and because of differences in the seasonal patterns of ozone. These huge seasonal changes in UV radiation have important implications for Health. High UV intensities in summer contribute to skin cancer, while low intensities in winter result in ailments associated with vitamin D deficiency. In New Zealand for example, the skin cancer rates are among the highest in the world, yet a significant fraction of the population has insufficient vitamin D in the winter. While there is considerable uncertainty regarding the wavelength dependence for vitamin D production, physiological evidence suggests that there is insufficient vitamin D produced in the winter at latitudes poleward of about 40º [*Webb et al.*, 1988]. With the currently accepted action spectrum for vitamin D [*MacLaughlin et al.*, 1982], there is an even larger summer/winter contrast for vitamin D weighted UV than for erythemally-weighted UV (see Figure 3). Surprisingly, it appears that there is no region on the planet where there is no risk of sunburn in summer, yet ample UV for vitamin D production in the winter. Public advice regarding personal behaviour in response to UV variability needs further development, and should recognize both the benefits and the risks of UV exposure.

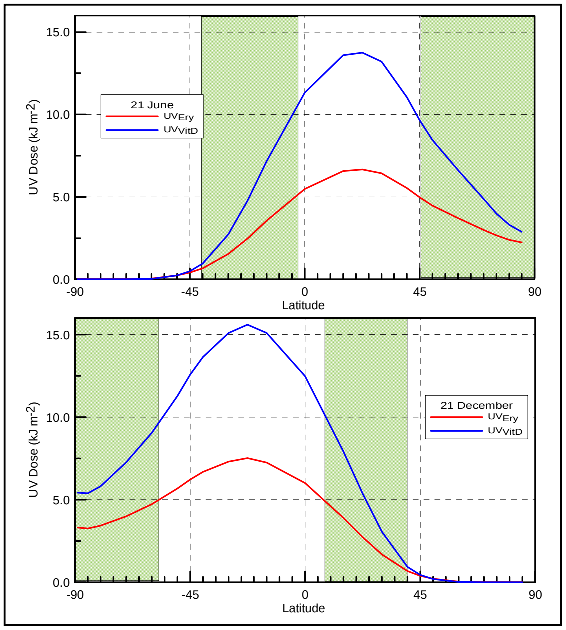

Figure 3. Latitudinal distribution of the daily dose of clear-sky UV, calculated for the two solstices. The "safe" areas in green receive less than 5 kJ m^{-2} of erythemally weighted UV (UVI_{max} < ~10), and more vitamin D weighted UV than at 40^{o}N in winter.

References

Liley, J.B., and R.L. McKenzie, Where on Earth has the highest UV?, in *UV Radiation and its Effects: an update*, pp. 26-37, 2006 (http://www.niwascience.co.nz/rc/atmos/uvconference).

MacLaughlin, J.A., R.R. Anderson, and M.F. Holick, Spectral character of sunlight modulates photosynthesis of previtamin D3 and its photoisomers in human skin, *Science*, *216* (28 May), 1001-1003, 1982.

UNEP, Environmental effects of ozone depletion and its interactions with climate change: 2006 assessment, *Photochem. Photobiol. Sci.*, *6* (3, UNEP Special Issue), 201-332, 2007.

Webb, A.R., L. Kline, and M.F. Holick, Influence of season and latitude on the cutaneous synthesis of vitamin D3: Exposure to winter sunlight in Boston and Edmonton will not promote vitamin D3 synthesis in human skin, *Journal of Clinical Endocrinology and Metabolism*, *67* (2), 373-378, 1988.

WHO, *Global solar UV Index: A practical guide*, 28 pp., World Health Organisation (WHO), World Meteorological Organisation (WMO), United Nations Environment Program (UNEP), and International Commission on Non-Ionising Radiation Protection (ICNRP), Geneva, 2002.

WMO, Scientific Assessment of Ozone Depletion: 2006, edited by A.-L. Ajavon, D.L. Albritton, and R.T. Watson, World Meteorological Organisation, Geneva, 2007.