Long term changes in UV in New Zealand due to ozone depletion and other causes

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Abstract. We investigate long term changes in peak erythemally weighted UV (UVI), and in monthly doses of UV-B (280-315 nm) and UV-A (315-400 nm) from spectral irradiance measurements at Lauder, Central Otago. Complementary data sets are used to identify causes of changes. These causes include changes in (a) sun elevation angle, (b) ozone, (c) cloud and aerosol transmission, and (d) possible changes in calibration.

Introduction

High-quality measurements of UV spectral irradiance have been undertaken at Lauder, Central Otago (45°S, 170°E, altitude 370 m) since the late 1980s. Spectra are taken at 15 minutes over the highest sun periods each day, and at 5-degree steps in sun angle at other times of the day. Samples of summer and winter noon spectra are shown in Figure 1.

These UV measurements are complemented by a wide range of trace gas measurements, including ozone, and measurements of aerosol extinctions. Previous studies have shown the peak UVI values at Lauder 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.

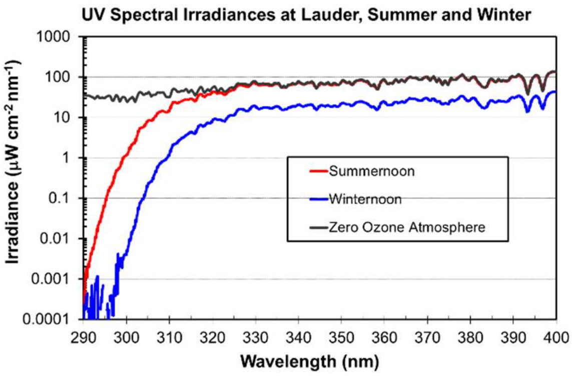

Figure 1. Spectra of UV irradiances measured at Lauder under clear skies near the summer and winter solstices (SZA 23° and 67° respectively). The spectral resolution is approximately 1 nm (fwhm). Reductions in irradiance the UV-B region are dominated by ozone absorptions, shown by differences compared with the black curve (note the log scale). Smaller features are Fraunhofer lines due to absorptions in the Sun's atmosphere.

Results

Sub-sets of these measurements have been used to demonstrate long term changes in peak summertime UVI values (McKenzie et al. 1999). These showed that during the 1990s there was a measureable increase of around10% due to ozone depletion. However, since that period, the trend has flattened and reversed, and peak UV values are now comparable to what they were prior to the onset of ozone depletion, as shown in Figure 2. There are unexplained low values in the early 2000s. We investigate whether these low UVI values are a calibration issue.

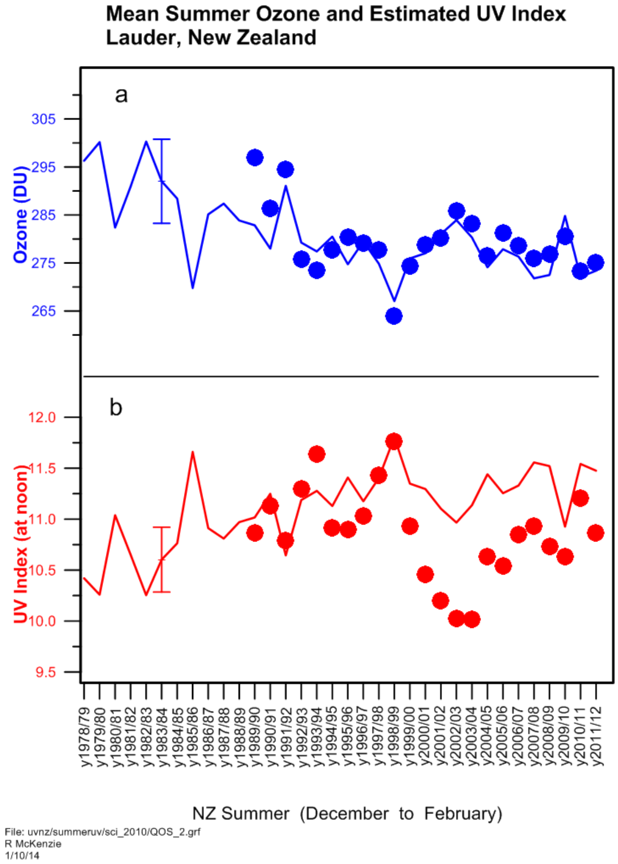

Figure 2. Long term changes in ozone and peak summertime UVI (defined as the mean of the 5 highest UV values in the 5 highest UV days in the months of December, January and February), as measured by UV spectrometers at Lauder (symbols). The lines are the mean ozone values from Dobson instrument for the same period, and corresponding calculated clear sky UVI values.

In addition to ozone effects, which have been relatively small at this site due to the success of the Montreal Protocol, changes in UV due to factors related to climate change, such as changes in cloud cover, are becoming more relevant.

Here we extract monthly and annual doses of UV-B (280-315 nm), which is strongly affected by ozone extinctions, and UV-A (315-400 nm), which is not affected by ozone extinction, from spectral irradiance measurements at Lauder over the last 20 years. Data prior to 1994 are not suitable for this analysis because they were taken only when weather permitted, and they therefore have a clear-weather bias.

Comparison with complementary data sets suggests that the spectral data may have been biased low in the mid 1990s early 2000s (Figure 3). However, any bias is less than the expected measurement uncertainty of 5%.

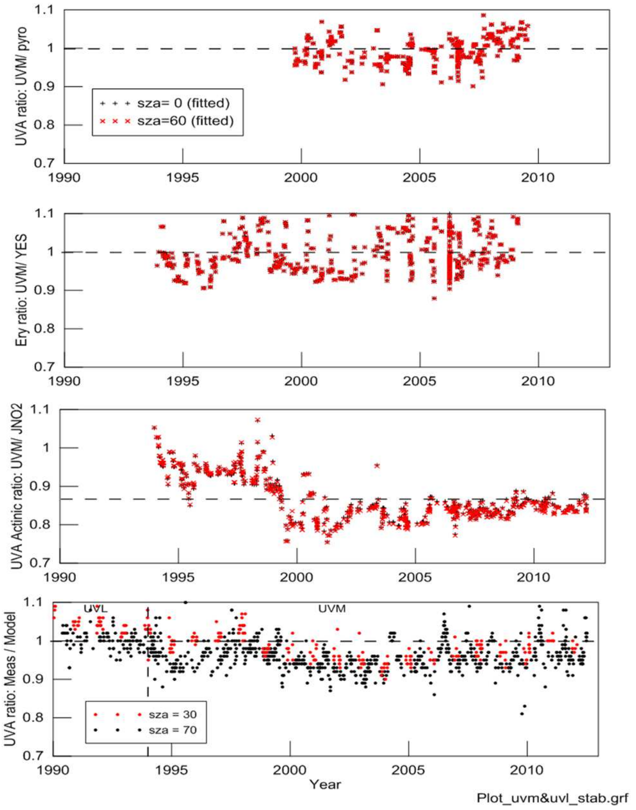

Figure 3. Time series of ratios of clear-sky UV spectrometer values compared with values from ancillary instruments. Steps in data common to all would be due to calibration errors in the spectrometer. Other steps, such as the large reduction in J(NO_2) ratios, which do not occur for other instruments, show that the problem is with the other instrument. The lowest panel shows ratios with respect to a clear-sky model. On the balance of evidence, it appears that the spectrometer data are about 4% low in the period 1995-1996, and 2002-2006. The differences are within experimental uncertainties. However, they illustrate the difficulty of detecting long term trends.

Figure 4 shows that the main variability in these UV doses is due to seasonal changes in solar zenith angle (SZA). Year to year changes in cloud cover are also important. Although changes in aerosol are not important at Lauder, they can have a large contribution at more polluted sites. The relative importance of differences in aerosol, altitude and surface albedo are demonstrated by comparison between the data at Lauder and other NDACC sites (see (Kotkamp et al. 2014)).

Conclusions

- Maintaining accurate calibration over the long term is challenging. Although there are apparent shifts in calibration, the overall absolute accuracy remains stable to within ±5%.
- Any trends due to ozone depletion are small, and are insignificant compared with cloud effects, and the large seasonal changes due to changing sun angles.
- Because of the success of the Montreal Protocol, any changes in UV doses have been small, and are below the detection threshold.
- In contrast to the small trends in UV, there are large seasonal (and latitudinal) gradients due to changing solar elevation angles.
- In the future, changes in aerosols and clouds are likely to have larger effects than those due to expected changes in ozone.

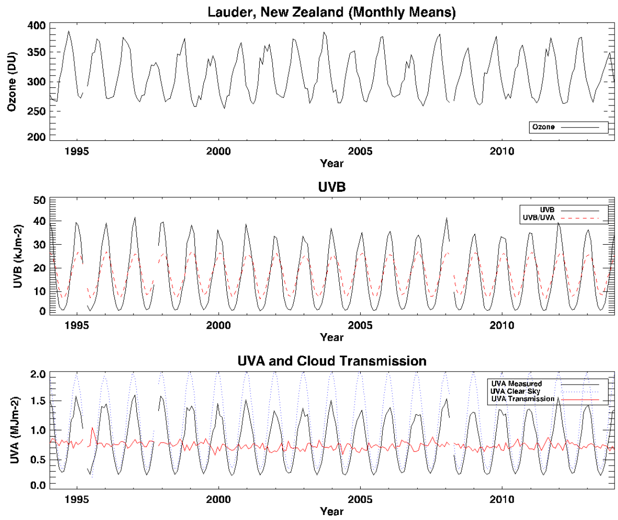

Figure 4. Long-term changes in ozone, UV-B, UV-A doses, and cloud transmission. Although seasonal changes in ozone are large, any long terms trends have been small. Similarly, any trends in UV are small. Changes in UV doses are dominated by seasonal changes in SZA rather than ozone. Mean cloud transmissions are relatively constant throughout the year, and any long terms trends are less than the month to month variability.

References

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