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Long Term Variability and Cloud Effects in UV Irradiances from NDACC Spectroradiometers

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Abstract. The long-term variability of UVI is shown for sites equipped with NDACC-quality UV spectrometer systems. The effects of ozone and clouds are also compared between sites.

Introduction

NIWA spectroradiometer systems were first deployed in December 1989 at Lauder New Zealand, where measurements have continued until the present. Current measurement systems comply with the demanding standards required by the international Network for the Detection of Atmospheric Composition Change (NDACC).(De Mazière et al. 2017,McKenzie et al. 1997) Similar compliant NIWA spectrometers have also been set up to undertake long-term measurements at several other NDACC sites, in collaboration with NOAA in USA and BoM in Australia. Here we analyse long-term data from the three longest time series: the clean air laboratory at Lauder NZ (45°S, alt 0.4 km), the high–altitude Mauna Loa Observatory Hawaii (20°N, 3.4 km), and Boulder Colorado (40°N, 1.6 km). We also compare with observations undertaken in Antarctica, where ozone changes have been much larger. We demonstrate the geographical and seasonal variability in noon time UVI, and the wavelength-dependence of cloud effects. Because of the success of the Montreal Protocol (M-P), long term changes in UV have been small at these sites since measurements began, and long-term changes are within the year-to-year variability due to other factors, such as clouds.

Discussion

In Figure 1 we display, for each site, time series of ozone (upper panels), a comparison of measured peak daily UVI (near noon) and modelled UVI for solar noon (centre panels), and a comparison between measured and modelled trends for summer months. The model calculates UVI from the solar zenith angle and total ozone, and assumes low aerosol optical depth and low surface albedo. Measurements often exceed model results at MLO because underlying cloud increases the albedo, but summer peaks are usually less than model values at Boulder because of aerosol extinction

There are large seasonal and geographical differences, but at all three sites, there are no significant long-term changes since measurements began. The year-to-year variability attributable to cloud effects is comparable with that due to ozone.

In Figure 2, we show statistics of cloud effects for UVA, UVB and the UVI at Lauder. These are shown for two cases: with cloud modification factors (CMFs) calculated using assimilated ozone (at left), and using ozone retrieved from spectra for which irradiance changes during the scan period are less than 10% (at right). Enhancements due to

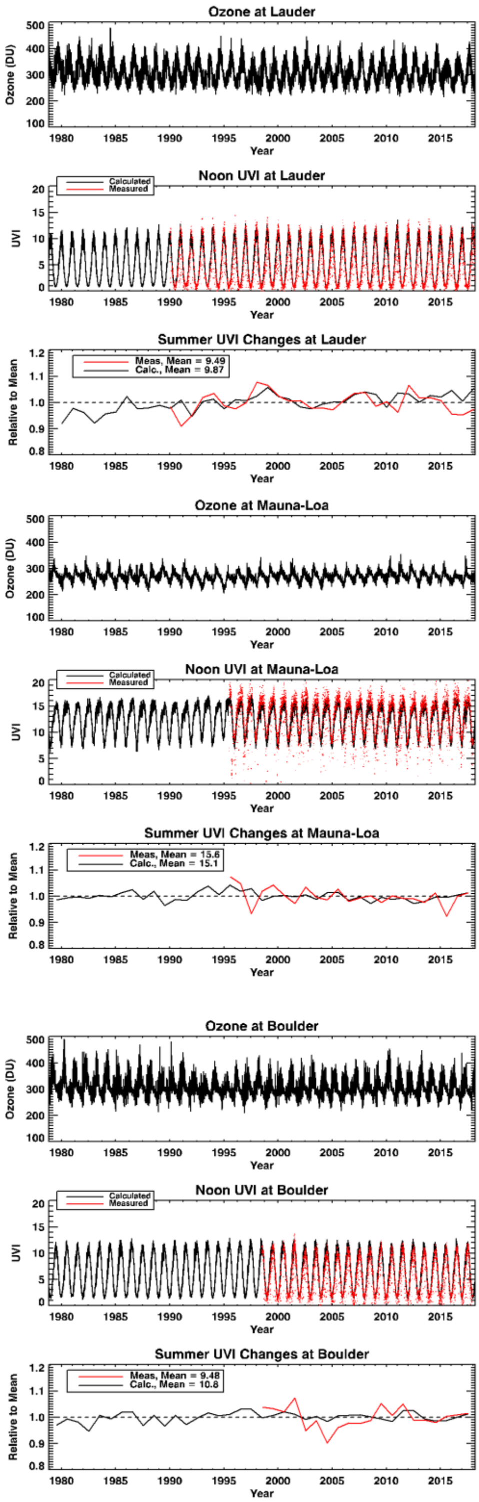

Figure 1. Time series of ozone and UVI (see text) for Lauder New Zealand, Mauna Loa Observatory Hawaii, and Boulder CO.

clouds show little wavelength dependences, with CMFs being less than 1.3 in 99% of cases.
The characteristic bimodal pattern, and the peak CMFs are similar at the other two sites (not shown).

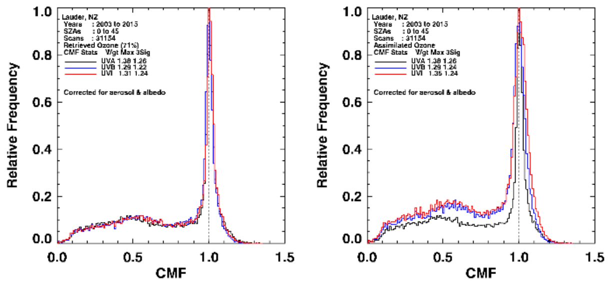

Figure 2. Statistic of cloud effects at Lauder (see text)

We now contrast the variability at the mid- and low-latitude sites shown in Figure 1 with those in the Antarctic spring, where ozone changes have been largest. Results are shown in Figure 3.

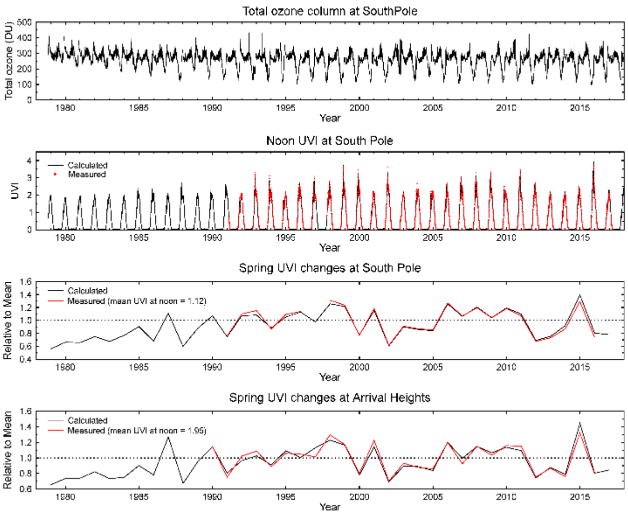

Figure 3. Similar to Fig1, but for noon in the Antarctic spring (September-November), where ozone changes have been largest. Measurements are from NDACC-certified spectrometers of the NSF (up to 2009) and NOAA (from 2009) Antarctic UV Monitoring Networks.

The long-term decline in springtime ozone is clear, but unfortunately, UV measurements began after the period of most rapid decline. Despite the low ozone amounts, these springtime UVI levels are relatively low because of the low solar elevations at that time of year. In spring, the year to year variability due to ozone effects is much larger, and effects of year to year differences in cloud cover are smaller. In summer, the mean noon UVI at Arrival Heights is approximately 3, with smaller year-to-year variability.

At all sites, any long-term trends in UVI due to changes in ozone have been small since measurements began. However, in recent years, summer UVI values at Lauder have been lower. This may be due to changing cloud or aerosol conditions, and will be investigated further.

Conclusions

- Peak summer UVI values in Lauder NZ are comparable with those in Boulder, despite its higher altitude and lower latitude. Peak values at MLO are 50% greater due to the combined effects of its higher altitude, higher albedo, less ozone, and less cloud cover.
- Winter UVI values are lowest at Lauder, where they are typically only 10% of those in summer.
- Clouds cause a bimodal distribution of UV transmission by cloud (or Cloud Modification Factor, CMF). The primary mode, with CMF = 1.0 corresponds to times when the sun is not obscured by clouds. The secondary mode (small at MLO), with CMF ≈ 0.5 corresponds to times when the sun is obscured. UV enhancements due to reflections from clouds give CMF > 1, but CMF < 1.3 almost all of the time.
- In the calculation of CMFs, uncertainties in assimilated ozone make the distributions appear broader in the UVB region. However, this is not the case using ozone derived from the spectra. Both methods show that peak CMFs are only weakly dependent on wavelength, with extrema being similar in the UVA and UVB regions.
- Because of the success of the M-P, any long-term trends in ozone are small over the period of measurements, so changes in summertime UVI are also small outside polar regions, and are within the range of variability due to clouds. Without the M-P, UVI would have increased by approximately 20% at these mid-latitude sites over the measurement period (Bais et al. 2015).
- At Arrival Heights and South Pole, UVI during the springtime ozone hole is still low by global standards. It has probably passed its peak, but year-to-year variability is large.

References

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