N95- 11052

UV SPECTRAL IRRADIANCE MEASUREMENTS IN NEW ZEALAND: EFFECTS OF PINATUBO VOLCANIC AEROSOL

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ABSTRACT.

Since late 1989, regular UV spectral irradiance measurements have been made at Lauder, New Zealand (45°S, 170°E), whenever weather permits. Here, the instrumentation and measurement strategy are outlined, and early results are discussed. Following the eruption of Mt Pinatubo in June 1991, large amounts of volcanic aerosol were injected into the stratosphere and were subsequently transported to New Zealand's latitudes in the latter half of 1991. This provides an opportunity to investigate the effects of volcanic aerosols on UV irradiances measured at this clean-air site. Although changes in global (sum of diffuse plus direct) irradiances were below the detection threshold, there were significant changes in the partitioning of radiation between the direct beam and diffuse skylight. Decreases by nearly a factor of two in the direct/diffuse ratio were observed at longer wavelengths, and at smaller solar zenith angles (sza's). The aerosol optical depth due to volcanic aerosol over Lauder in December 1991, was 0.15±0.03 at 450 nm, with lower values at shorter wavelengths. Although effects were relatively small in the UVB region, an implication of the changes is that the contrast between shade and direct sun is reduced, so that shaded areas received relatively more radiation in the summer of 1991/92 in New Zealand.

1. INTRODUCTION

Since December 1989, measurements of UV spectral irradiances incident on a horizontal surface (cosine weighted) have been made at Lauder, New Zealand (45°S, 170°E). The measurements are made at fixed solar zenith angles and at local solar noon whenever weather permits. The spectral range covered is 290-450 nm, at 1 nm spectral resolution, with a wavelength accuracy better than 0.1 nm, and radiometric stability of ±6%. Less frequent measurements are made of UV irradiances from skylight and direct sunlight, when skies are clear at midday.

The instrumentation, measurement strategy, calibration procedures, error analysis, and results from the first year of operation are discussed in *McKenzie et al.* [1992]. These data have also been analyzed to assess the relative importance of the various factors that affect UV levels. Changes in sun angle and cloud amount are more important than changes in ozone. The UV irradiances have been used in conjunction with simultaneously measured ozone columns to deduce the sensitivity of erythemal radiation to changes in ozone. The experimentally deduced radiative amplification factor (RAF) is 1.25±0.20, which is in agreement with calculated values [*McKenzie et al.*, 1991]. A recent development is the implementation of an algorithm [*Stamnes et al.*, 1991] to derive total column ozone amounts directly from the Lauder UV spectral irradiance data

2. AEROSOL EFFECTS

The arrival in New Zealand of volcanic aerosol from the Pinatubo eruption was clearly evident from visual observations at twilight in the latter half of 1991. NO_2 column measurements from Lauder also showed significant reductions, and there was initial concern that these NO_2 reductions were due to heterogeneous processes that would lead to reductions in ozone [*Johnston et al.*, 1992 a, b], and would cause increases in UVB at the surface . However, ozone measured at Lauder during the summer of 1991-1992 was subsequently found to be higher than the previous summer, and within the normal range of variability (unpublished Dobson data).

In the visible spectral region, increases in volcanic aerosol cause reductions in solar irradiance at the surface which are more pronounced in the direct beam than in the global irradiance [*deLuisi et al.*, 1983]. In the UV region the situation is more complicated. Although the aerosol reduces the direct beam component, the increase in the diffuse component can be larger, and recent model calculations suggest that the aerosol can lead to increases in global UV irradiances for large sza's, but decreases for small sza's [*Tsay and Stamnes*, 1992]. Other models predict that volcanic aerosol from El Chichon should have led to large increases in UV at wavelengths less than 300 nm (but decreases at longer wavelengths) even for smaller sza's [*Michelangeli et al.*, 1989, 1992]. In this case however, dramatic increases in UV are expected only for larger surface albedos.

The global UV spectral irradiance measurements from Lauder have an uncertainty of approximately ±6%, and within these error bars, no signal due to the presence of the aerosol has been detected. The measured irradiances in the latter part of 1991 are apparently 2-3% larger than those measured at similar solar zenith angles and ozone amounts before the eruption, although the discrepancy is within the limits of experimental uncertainty.

Direct beam irradiances, and diffuse skylight irradiances are available from a small subset of the UV data, using shadow band measurements made near local solar noon on cloud-free days. The days and solar zenith angles when these measurements were available in 1990 and 1991 are shown in Fig. 1.

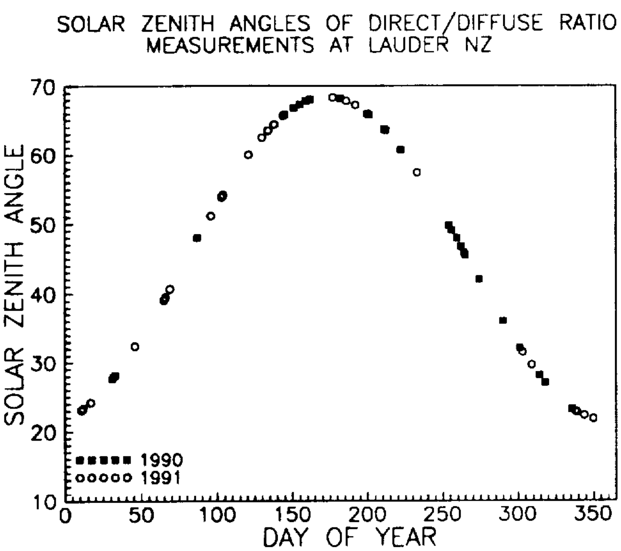

Fig. 1. Solar zenith angles of cloud-free days at Lauder in 1991 and 1992 when shadow band measurements were available

The corresponding direct/diffuse ratios for two wavelength regions are shown in Fig. 2. In the visible end of the spectrum logged (Fig 2a), the irradiance is dominated by the direct component, whereas in the UV region (eg erythemally-weighted UV in Fig 2b) the scattered skylight component dominates for most of the year. In 1990, the ratios showed a decrease from a summer maximum to a winter minimum. In the second half of 1990, the ratios increased back to the summer maximum. There was one outlier, with lower ratios, which occurred on a day described in the log sheets as "hazy". In the first six months 1991 before the arrival of the volcanic aerosol, the ratios were similar to those observed the previous year, However, in the second half of 1991, all of the ratios were markedly reduced, so that a much larger fraction of the irradiance was from diffuse skylight. The largest effects are seen at small sza's, and at longer wavelengths. The reason for this is that for these conditions, the scattering from background aerosols is small, so the Pinatubo aerosol effect is relatively more important. Similar data is available for the first half of 1992 (not shown in Fig. 2), which indicates that the period of greatest perturbation was near the end of 1991.

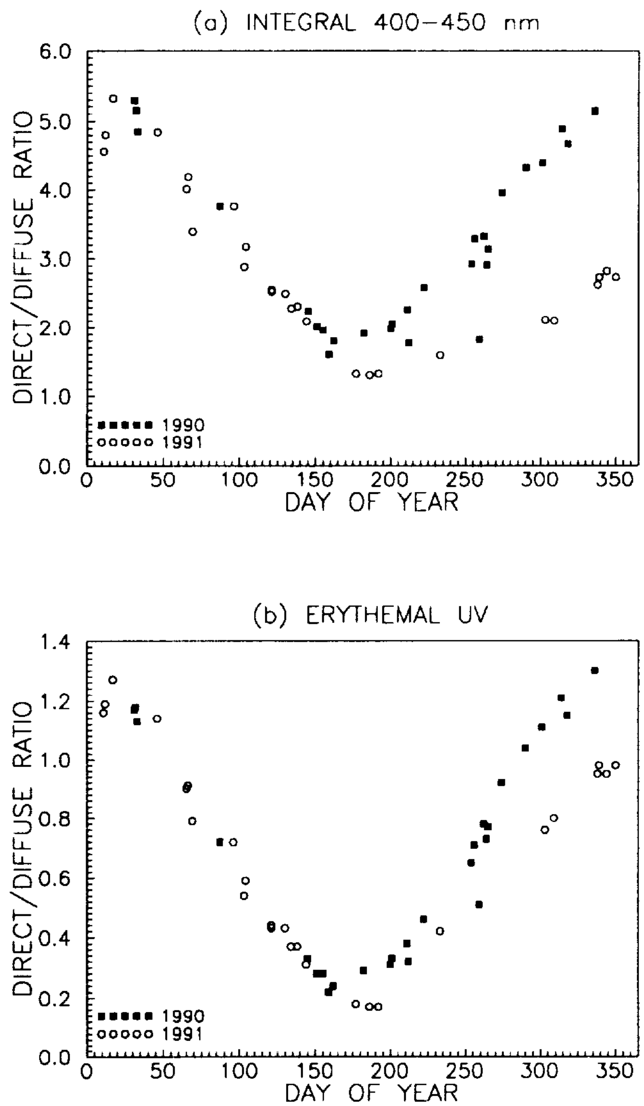

Fig. 2. Direct/diffuse (sun/sky) ratios from shadow band measurements (a) Integrated 400-450 nm, (b) Erythemally weighted UV [*McKinlay and Diffey*, 1987].

The spectral dependence of the direct/diffuse ratio is shown in Fig. 3, in which ratios measured near local solar noon in the summer before the eruption of Mt. Pinatubo are compared with those measured in the following summer. The fine structure in this plot, particularly near 390 nm is related to Fraunhofer absorptions in the solar atmosphere. The shapes of these Fraunhofer lines are modified by scattering from air molecules. This process is known as the "Ring Effect" [*Grainger and Ring,* 1963], and results in residual features in measured ratios. On broader wavelength scales, Fig 3 shows that the ratio is close to unity in the UVB region, but is reduced perhaps 20% in the perturbed conditions after the eruption. At longer wavelengths there is a more marked effect. Before the arrival of the aerosol the ratio at 450 nm was > 6, but this was halved during perturbed conditions. At smaller sza's the ratios decrease at all wavelengths, with larger decreases at longer wavelengths. There is a broad minimum in the ratio near 300 nm. These measured ratios are in agreement with those calculated by *Frederick et al.*, [1989] for summer conditions at 45°N. However, the agreement between model and measurement is poorer at larger sza's (eg in winter). The reason for these differences is still under investigation.

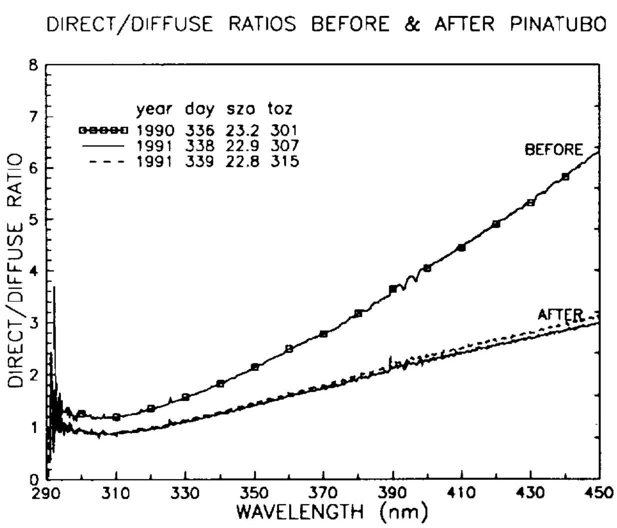

Fig. 3. Comparison of direct/diffuse ratios measured near local solar noon in the summer before and after the eruption of Mt. Pinatubo.

Aerosol extinctions are much larger in direct beam irradiances than in global irradiances. The largest such extinctions occurred in late 1991. Clear-sky UV data obtained on day 338 was compared with similar data obtained a year earlier to deduce the aerosol extinction due to the volcanic aerosol. It was assumed that tropospheric aerosol extinctions, and surface albedo were constant, and a correction was applied to account for the small difference in ozone between the two measurements. For these small sza's the extinctions are relatively small, so that calibration errors lead to significant errors in the derived optical depth. To minimize these, we used the property that volcanic aerosol extinction in the global irradiance is small at 450 nm [*Michelangeli et al.,* 1989] to renormalise the direct beam data. The estimated uncertainty in the aerosol optical depths is ±0.03, which is approximately 3 times greater than the digitisation noise in the figure. Errors are larger at shorter wavelengths, and the apparent structure below 310 nm is due to measurement noise.

Over the spectral region sampled, the optical depth due to Pinatubo aerosols increases from less than 0.10 at 290 nm, to 0.15±0.03 at 450 nm. Generally, one would expect the optical depth to decrease rather than increase with wavelength [eg *Yue,* 1985]. However, optical depths measured after the El Chichon eruption showed a similar wavelength dependence [*deLuisi et al.,* 1983]; and recent theoretical calculations of backscatter cross sections show increases with wavelength in this region [*Srivastava et al.,* 1992].

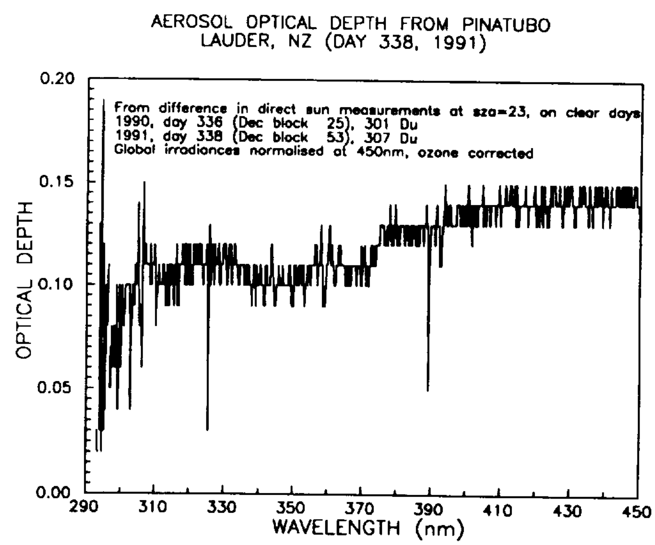

Fig. 4. Aerosol optical depth versus wavelength (290-450 nm) from the Pinatubo volcanic aerosol over Lauder, New Zealand on day 338 1991.

3. CONCLUSION

UV spectra obtained at midday during 1990 and 1991 have been examined to investigate the effects of aerosols from the Pinatubo volcanic eruption. Although there were no detectable changes in global irradiances, there were large changes in the direct/diffuse ratios, so that the proportion of diffuse irradiance was increased by a factor of two at 450 nm, and by 20% in the UVB region. The largest differences were in the summer of 1991/1992, when the aerosol optical depth from volcanic aerosol above Lauder was 0.15±0.03 at 450 nm, reducing to approximately 0.10±0.03 at 300 nm. An implication of these changes in the radiation field is that shaded areas received relatively more radiation in the summer of 1991/1992.

ACKNOWLEDGEMENT

I would like to acknowledge the contributions of Mike Kotkamp who maintained the observational program, and Jasmine Bartlett who assisted with the data analysis and plotting.

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