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SHORT CONTRIBUTION

Changes in solar radiation fluxes after the Pinatubo eruption

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ABSTRACT

Measurements at a high mountain station on cloudless days showed significant changes in solar radiation from summer 1991 to summer 1992 as a consequence of the Pinatubo eruption. An increase in diffuse sky total radiation and a concomitant decrease in global total radiation (sun and sky) of 4% were observed. The optical aerosol depth at 427 nm, obtained from sun photometric measurements, showed a significant increase.

Several months after the eruption of Pinatubo, particularly colourful sunsets and a change in the colour of the sky around the sun were observed world wide. This clearly points to changes in the solar radiation fluxes due to the aerosol cloud caused by the volcanic eruption. The eruption, in June 1991, of Pinatubo in the Philippines released about 20 million tons of sulfur dioxide gas into the lower stratosphere up to 30 km altitude (Bluth et al., 1992). A persistent haze of sulfuric acid droplets developed and was spread globally by atmospheric circulation. This aerosol concentration, which has been observed worldwide, is the strongest occured in the atmosphere since the eruption of Krakatoa in 1883 (Kerr, 1993). Altitude profiles of the aerosol as well as the frequency distribution of the particle size and their effects on atmospheric turbidity have been reported (Jäger, 1992; Winker and Osborn, 1992). Speculations based on model calculations concern cooling of the earth by 0.5°C due to blocking of solar radiation (Kerr, 1993; Luhr, 1991). Furthermore, a deepening of the Antarctic ozone hole (Kerr, 1992b) and enhanced global ozone reduction (Kerr, 1992a) have been predicted. In Northern midlatitudes in particular, the sulfuric acid droplets are assumed to affect ozone levels by a catalytic process favouring the conversion of the chlorines contained in the CFCs into ozone-depleting ClOs. Model calculations have been used to analyze the increase in biological effective UV radiation as a result of ozone reduction (Vogelmann et al., 1992).

Starting in 1981, the Robertson-Berger Sunburn meter and the Eppley UVA radiometer were used to measure solar UVB- and UVA radiation, respectively, at the high-Alpine research station Jungfraujoch (3576 m a.s.l., Switzerland, 46.55° N, 7.98° E) during several measurement periods. The spectral sensitivity of the Robertson-Berger Sunburn meter is well adapted to the erythemal action spectrum. The UVA radiometer is a broadband detector which has its maximum of spectral sensitivity at 345 nm and its half maximum full width at 70 nm. Total radiation (300–3000 nm) was also measured. The global fluxes (sun and sky) were measured for all 3 spectral ranges (UVB, UVA, total), and an identical set of measuring instruments was shaded to measure the diffuse fluxes (sky only). The direct radiation fluxes on the horizontal plane were calculated as the difference between the measured global and diffuse radiation fluxes. Direct solar radiation and turbidity were

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measured with an actinometer (Linke-Feußner). The sensitivity to temperature of all detectors was taken into account when the measurements were evaluated. The accuracy of all instruments was checked at intervals of 2–3 years by comparing them with reference instruments. All data were recorded at 1-min intervals and are available as 10-min means. Cloudiness was registered at 30-min intervals. One series of measurements of about 8 weeks was made in May/June 1991, immediately before the aerosol cloud developed through the eruption of Pinatubo; a second series was made in the same season about a year later. This enables us to analyze the effects of the aerosol cloud on solar radiation. The data obtained are specially suitable for this purpose as the measurements were made in a high mountain area where pollution by anthropogenic aerosols is of minor significance. Only data recorded in cloudless conditions were used for analysis.

The sun photometric measurements made with an OG1 filter (transparent >570 nm) served to determine the optical depth of the aerosol concentration at 427 nm and at different solar elevations (Fig. 1). There is a marked rise in aerosol depth for 1992 (Wilcoxon, Mann, and Whitney one tailed U-test, $p < 0.001$, see *Note added*), which results in significant reduction ($p < 0.005$) of about 10% in direct total radiation (Fig. 2a) and a significant increase in diffuse total radiation ($p < 0.001$, Fig. 2b). Global total radiation shows a slight

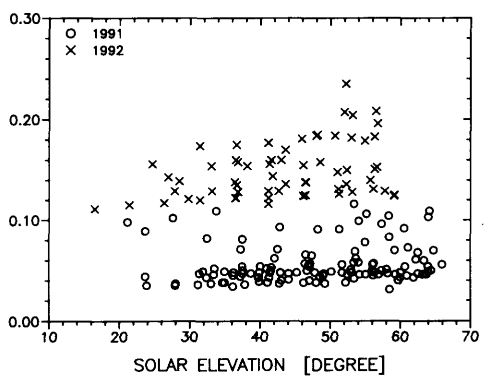

Fig. 1. Aerosol optical depth (427 nm) versus solar elevation at Jungfraujoch station (3576 m a.s.l., Switzerland) in summer 1991/92.

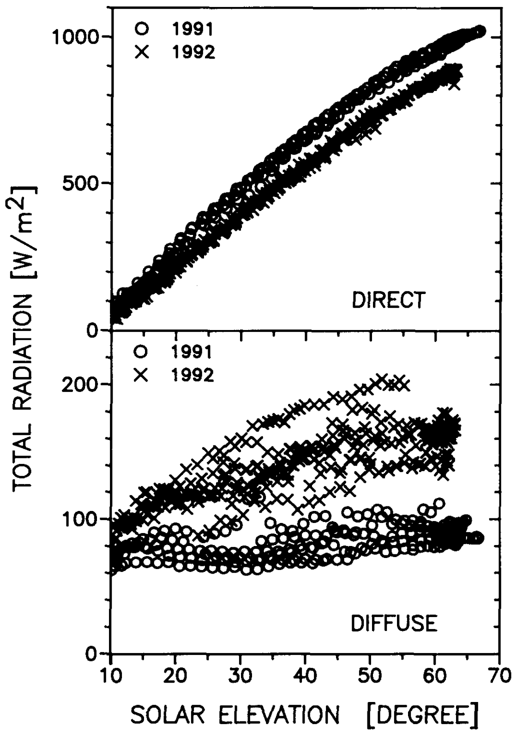

Fig. 2. Total radiation versus solar elevation at Jungfraujoch station (3576 m a.s.l., Switzerland) in summer 1991/92, (a) direct, (b) diffuse radiation flux.

decrease ($p < 0.005$) in the order of 4% between 30° and 60° solar elevation.

Unlike total radiation, diffuse, direct and global radiation fluxes in the UVB range shows no changes between 1991 and 1992. In the UVA range, only the diffuse flux is slightly elevated ($p < 0.05$) (by about 5%) in 1992. The aerosol cloud thus weakened UV radiation to a considerably smaller extent than it did total radiation. This result coincides with spectral transmission measurements of the aerosol cloud emitted by Pinatubo (Valero and Pilewskie, 1992).

In view of these observations, it seems realistic to base models of climate on a changed radiation balance caused by the Pinatubo aerosol cloud to estimate changes in temperature (Kerr, 1993). As far as the biological aspects of solar UV radiation are concerned, no weakening through aerosols has been detected. As no significant ozone reduction was observed in this period, it is unlikely that the weakening through aerosols is masked by an ozone reduction.

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Note added

The Wilcoxon, Mann, and Whitney U-test is applied to samples with any distribution and with different sizes. The one tailed U-test evaluates the null-hypothesis (no difference between the data 1991 and 1992) against the alternative hypothesis (data 1992 are lower than data 1991). The null-hypothesis is rejected with the level of significance less than 0.001.

REFERENCES

Bluth, G. J. S., Doiron, S. D., Schnetzler, C. C., Krueger, A. J. and Walter, L. S. 1992. Global tracking of the SO_2 clouds from the June, 1991 Mount Pinatubo eruptions. *Geophys. Res. Lett.* **19**, 151–154.

Jäger, H. 1992. The Pinatubo eruption cloud observed by lidar at Garmisch-Partenkirchen. *Geophys. Res. Lett.* **19**, 191–194.

Kerr, R. A. 1992a. New assaults seen on earth's ozone shield. *Science* **255**, 797–798.

Kerr, R. A. 1992b. Pinatubo fails to deepen the ozone hole. *Science* **258**, 395.

Kerr, R. A. 1993. Pinatubo global cooling on target. *Science* **259**, 594.

Luhr, J. F. 1991. Volcanic shade causes cooling. *Nature* **354**, 104–105.

Valero, F. P. J. and Pilewskie, P. 1992. Latitudinal survey of spectral optical depths of the Pinatubo volcanic cloud, derived particle sizes, columnar mass loadings, and effects on planetary albedo. *Geophys. Res. Lett.* **19**, 163–166.

Vogelmann, A. M., Ackermann, T. P. and Turco, R. P. 1992. Enhancements in biologically effective ultraviolet radiation following volcanic eruptions. *Nature* **359**, 47–49.

Winker, D. M. and Osborn, M. T. 1992. Airborne lidar observations of the Pinatubo volcanic plume. *Geophys. Res. Lett.* **19**, 167–170.

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