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The Pinatubo Cloud: Lidar Aerosol-Measurements and Balloonsonde Profiles of O_3 and Temperature at the Meteorological Observatory Hohenpeißenberg

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1 INTRODUCTION

For 1992 and 1993 low ozone values were reported by several instruments at northern midlatitudes, e.g. [1]. Using the scattering ratio $R^*(353)$, as observed by lidar, and the ozone concentration and temperature, as observed by balloon-sondes, this paper describes an apparent correlation between high aerosol loading and low ozone values. A similar correlation has been observed after the El Chichón eruption, e.g. [2]. Heterogeneous reactions occuring on the enhanced aerosol surface have been named as one possible explanation, e.g. [3]. However, changes in transport cannot be ruled out as a cause [1]. Such changes might also be triggered by the enhanced aerosol.

2 INSTRUMENTATION AND METHODOLOGY

The German Weather Service (DWD) has been operating an ozone DIAL system at the Meteorological Observatory Hohenpeißenberg (MOHp) since 1987. The system uses a $XeCl$ excimer laser with an H_2 Raman shifter giving "on" and "off" wavelengths at 308 and 353 nm (see [4] for details). From the 353 nm data the aerosol scattering ratio $R^*(353) = \beta_{aerosol}/\beta_{molecular}$ (here β denotes the atmospheric backscatter coefficient) was derived using seasonal mean profiles of the molecular density from local radiosondes and assuming a fixed extinction to backscatter ratio (45 sr). The resulting error is of the order of 10 %. Standard Brewer-Mast Sondes have been flown 2 to 3 times a week at MOHp since 1967 to provide profiles of ozone concentration, temperature and other meteorological parameters. So far no interference of aerosol on the measured ozone concentration has been observed.

Monthly mean profiles were used for all quantities. For temperature and ozone they are expressed as deviations (in % and K, respectively) from the long term monthly means, as obtained from all data between 1967 and 1992. This reduces the data variance by accounting for annual and semiannual variations.

3 RESULTS

Figure 1 shows the temporal evolution of the aerosol cloud, as described by $R^*(353)$. First traces of Pinatubo aerosol arrived between 12 and 16 km in the summer of 91. The main cloud was not seen until November 91 at 22 km. The highest scattering ratios, exceeding 1.3 (for 353 nm), were observed at about 20 km in January 92. Afterwards the maximum scattering ratio decreased to about 0.5 by the end of 92 and 0.15 by the end of 93. At the same time the layer subsided to lower altitudes, the scattering ratio maximum moved from 21 km at the end of 91 to 17 km by the end of 93. These observations are consistent with observations from other mid-latitude stations.

The deviation of the ozone concentration from the long term mean (1967 to 1992) is shown in Figure 2. Lower than usual ozone was observed in the lower stratosphere for the winters 91/92 and 92/93, as well as in the summer of 92. The winter 89/90 (before the Pinatubo eruption !) showed lower than normal ozone as well. It is interesting that the strongest ozone decreases are observed just above the tropopause, in the region of the coldest temperatures.

While the ozone concentration at MOHp depends on the phase of the quasibiennial oscillation (QBO) [2], the low ozone values in two consecutive winters after the Pinatubo eruption are not consistent with a quasibiennial oscillation [1]. This suggests that they may be related to the increased stratospheric aerosol loading after the eruption.

As an example Figure 3 shows the time series for ozone and temperature change at 17 km along with the scattering ratio at 353 nm. Ozone was below normal throughout 92 and 93, especially in the winter, but low values were observed in the winter 89/90 and in March 91 as well. Ozone values were low in the summer of 92 and 93, whereas they were high in the summers of 90 and 91, before the main Pinatubo cloud. The temperature deviation appears to be highly correlated with the ozone deviation: low ozone almost always coincides with low temperature. Low ozone also coincides with high scattering ratio, e.g. low ozone and high scattering ratio in the spring of 92 and 93, low scattering ratio and relatively high ozone in the summer of 92 and towards the end of 93. However, individual scattering ratio maxima and ozone minima do not always coincide.

The correlation between scattering ratio and ozone at 17 km is shown in Figure 4. Whenever the scattering ratio exceeded 0.3, the observed ozone concentration was below the long term mean. Generally lower ozone

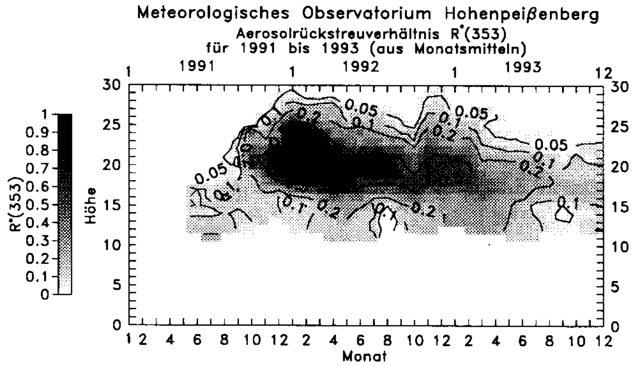

Figure 1: Temporal evolution of monthly means of the scattering ratio $R^*(353)$ at MOHp.

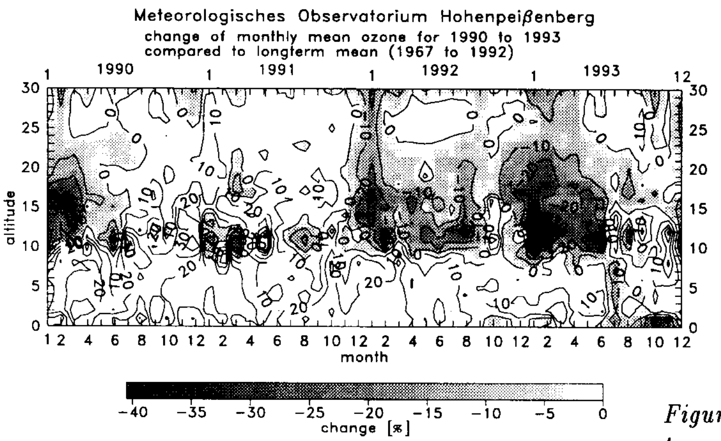

Figure 2: Change of the ozone concentration compared to the long term mean at MOHp. The grey-scale does not show positive values, although they do occur, e.g. in the troposphere.

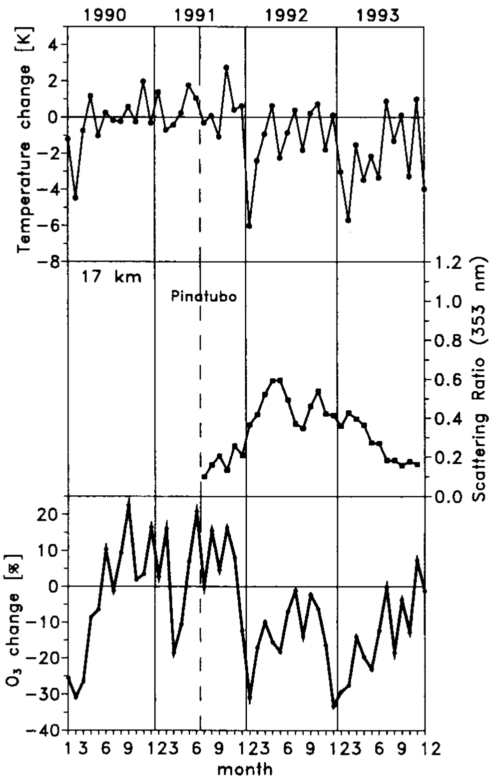

Figure 3: Deviation of monthly means for ozone and temperature at MOHp from the long term mean, as well as scattering ratio at 353 nm for 17 km altitude.

is correlated with higher scattering ratio. The observed decrease in ozone with scattering ratio is stronger in winter (points for 1/92, 12/92, 1/93, 2/93) than in summer (points for 6/92, 7/92, 9/92, 10/92). This may indicate that low temperatures increase the efficiency of heterogeneous processes leading to ozone destruction. On the other hand data from only one station do not allow to reject a change in transport as a cause of the observed ozone depletion.

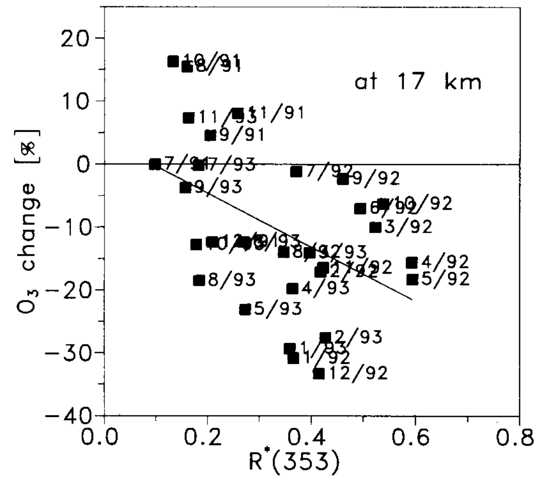

Figure 4: Correlation between ozone change and scattering ratio observed at 17 km after the Pinatubo eruption. The solid line shows the linear regression line obtained.

References

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