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STRATOSPHERIC AEROSOLS AND PINATUBO ERUPTION CLOUDS

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INTRODUCTION

Lidar records of the stratosphere indicate that the variability of the stratospheric aerosol content spans more than two orders of magnitude from background to volcanically perturbed conditions. The sulfuric acid aerosol layer forming in the stratosphere after large scale explosive eruptions causes significant signals to the atmospheric radiation budget and to atmospheric chemistry. Lidar systems provide world-wide valuable information on peak loading, distribution, transport, and decay of volcanic perturbations, and furthermore help to validate satellite observations.

THE PINATUBO PERTURBATION

The violent eruption of Mount Pinatubo in the Philippines on June 15, 1991, injected enormous gas and particle masses into the atmosphere, causing the largest volcanic cloud ever observed in the stratosphere by modern remote sensing and in situ measurement techniques. Satellite data indicated that 20 Mt of SO_2 were transported into the stratosphere, which is three times the mass injected by the El Chichón eruption in 1982 (Bluth et al., 1992).

SAGE II (satellite-borne Stratospheric Aerosol and Gas Experiment II) observations indicated that the volcanic material was initially confined in the tropics in a band extending from 20°S to 30°N, and from the tropopause up to 30 km (McCormick and Veiga, 1992). Also based on SAGE II data detrainment mechanisms from this tropical reservoir and the poleward transport of the Pinatubo aerosol during the first 10 months after the eruption were discussed by Trepte et al. (1993).

The poleward transport and the fate of the Pinatubo cloud has also been well documented by ground-based lidar stations in the northern hemisphere. As an example three profiles of Figure 1 show the maximum load at 47.5°N in February 1992 and the subsequent decay until end of 1993.

Ground based networks like the NDSC (Network for the Detection of Stratospheric Change), ESMOS (European Stratospheric Monitoring Stations) and EPIC (Effects of the Pinatubo Eruption on Climate) allow detailed studies of the variations of the stratospheric aerosol layer, since measurements and retrieval techniques are comparable within the networks. Examples of these activities are given in Figures 2 and 3. In Figure 2 measurements of the maximum optical mixing ratio (particle/molecular backscatter) at Garmisch-Partenkirchen (47.5°N) are compared to data of the EPIC stations Tsukuba (36°N) and Okinawa (26°N). This graph shows the poleward detrainment from the equatorial reservoir lasting until mid-1992. Thereafter the volcanic aerosol is rather uniformly distributed within the extratropical belt represented by these stations. Figure 3 documents the aerosol distribution over Europe during the second year

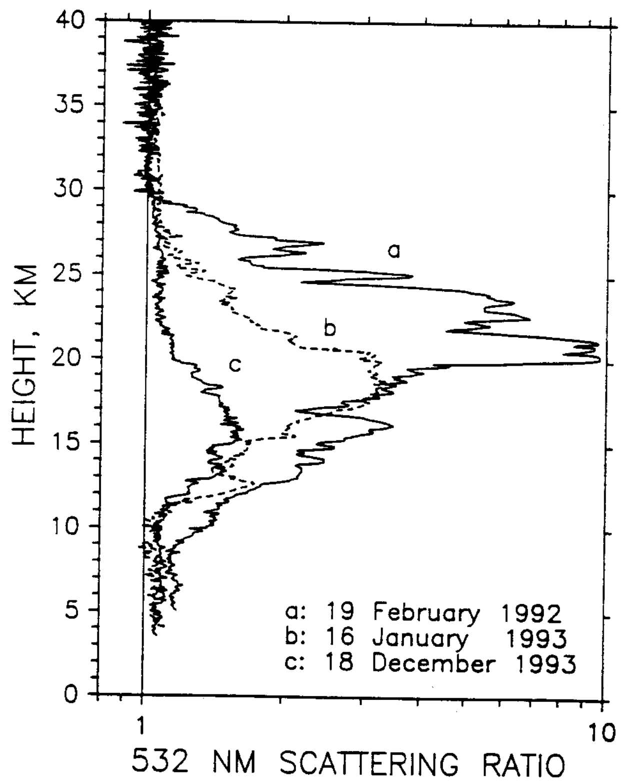

Fig. 1. Lidar observations of the Pinatubo cloud at IFU, Garmisch-Partenkirchen.

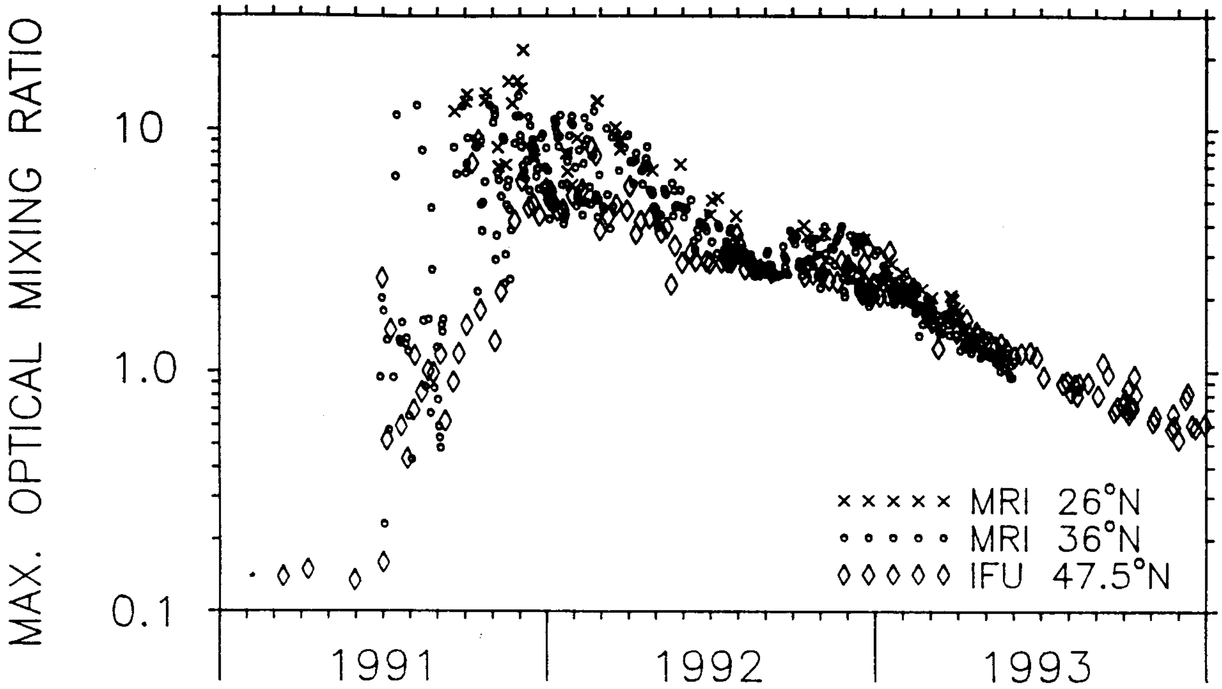

Fig. 2. Comparison of lidar observations at 532 nm at IFU, Garmisch-Partenkirchen, with observations at two EPIC stations of the Meteorological Research Institute, MRI, Japan, at Tsukuba and Okinawa (courtesy of O. Uchino, MRI).

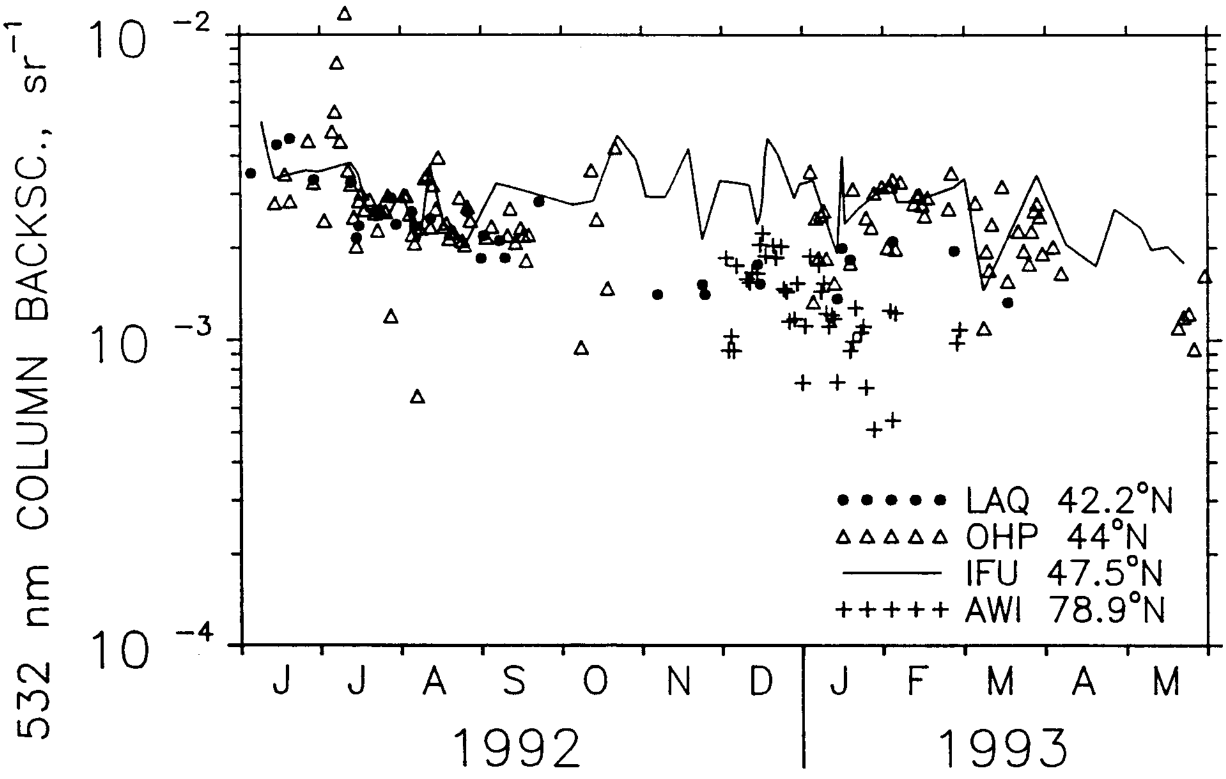

Fig. 3. Lidar observations of ESMOS network stations at University of L'Aquila, SLAQ, (Italy), Observatoire de Haute Provence, OHP, (France), IFU (Germany), and AWI (Germany) at Spitsbergen (courtesy of F. Masci, SLAQ, S. Godin, OHP, and R. Neuber, AWI).

after the Pinatubo eruption. The observations are made by ESMOS stations at northern mid-latitudes (L'Aquila, 42.2°N, Haute Provence, 44°N, and Garmisch-Partenkirchen, 47.5°N), and within the polar winter vortex at Spitsbergen (Ny Alesund, 78.9°N). This graph shows latitudinal variations during the winter season 1992/93.

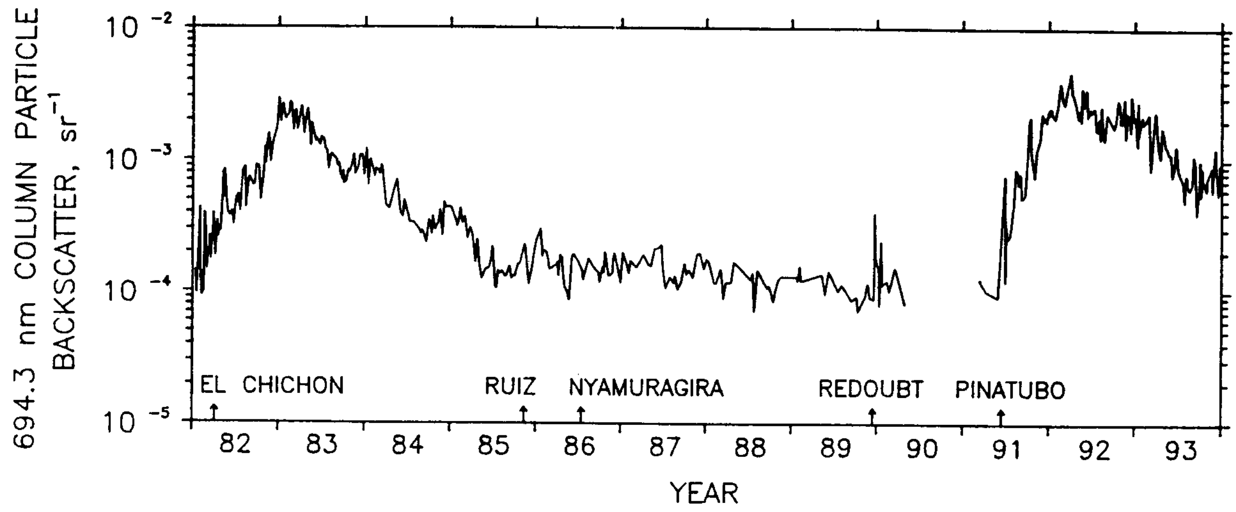

Fig. 4. Time variation of the integrated particle backscatter at Garmisch-Partenkirchen. Data are integrated from 1 km above the tropopause to the top of the layer.

Time series of ground-based lidar observations also allow to compare former volcanic impacts on the stratosphere with the present perturbation (Figure 4). The trend of the decay of the Pinatubo cloud so far seems to follow that of the El Chichón cloud.

LIDAR DERIVED QUANTITIES

Lidar data can provide basic data for the computation of climatically relevant parameters like aerosol optical depth and particle surface area. Conversion data may be derived from in situ aerosol measurements (e.g. Jäger and Hofmann, 1991) or from multispectral lidar measurements (e.g. Ansmann et al. 1993).

Height and time resolved size distributions were used at the IFU to define conversion factors which allow to infer particle extinction, particle mass, particle surface area, and wavelength dependences from lidar measured backscattering. Distribution data were provided by balloonborne particle counter measurements at Laramie, WY. The applicability of these size distributions obtained at 41°N to northern midlatitude lidar measurements had been demonstrated by Jäger and Hofmann (1991), who had defined conversion functions for the 1980-1987 period, which include fresh volcanic (El Chichón, 1982/83), aged volcanic and background aerosol conditions in the stratosphere.

For the period May 1991 until January 1993 Laramie particle size distributions (T. Deshler, private communication; Deshler et al., 1993) were used to calculate conversion factors to describe the pre-Pinatubo aerosol, the maximum of the Pinatubo perturbation, and the early decay period. A comparison of these conversions with those characterizing the El Chichón aerosol load shows generally good agreement. This indicates similarities of these two perturbations, which were both caused by equatorial eruptions at comparable latitudes and seasons. El Chichón functions, therefore, were used to describe the decay of the Pinatubo cloud during 1993 (aged volcan-

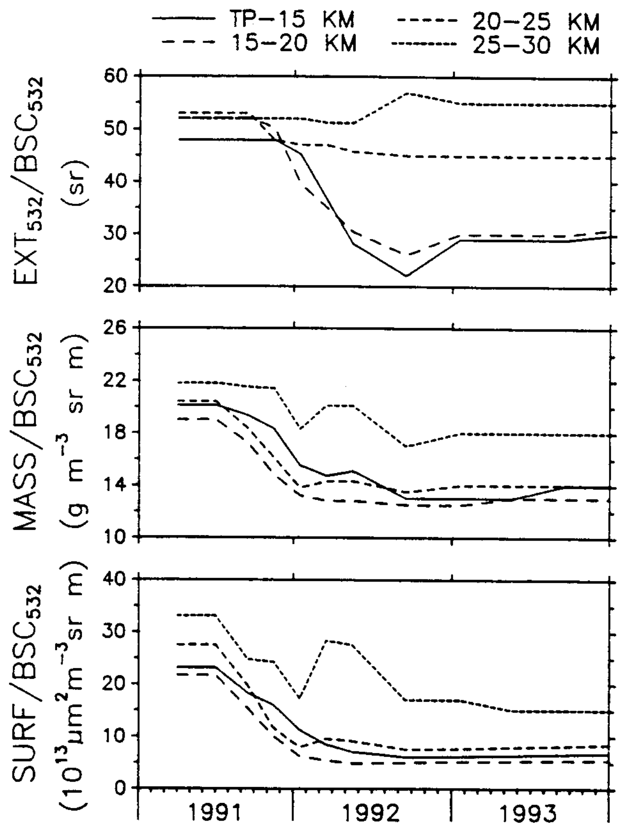

Fig. 5. Conversion functions of particle extinction, mass and surface area to 532 nm particle backscatter.

ic condition). Figure 5 shows these conversion factors of particle extinction, mass, and surface area to particle backscatter at 532 nm and Figure 6 resulting column extinction, mass, and surface area variations.

CONCLUDING REMARKS

Lidar observations of both the equatorial eruptions of El Chichón and Pinatubo at northern midlatitudes show so far similar decay patterns. This allows to predict that the decay of the Pinatubo perturbation will approach pre-Pinatubo values at northern midlatitudes in 1995. An average maximum mass load of 0.065 g/m^2 at 47.5°N during the months February to May 1992 would, if uniformly (admittedly not too realistic) distributed, convert to hemispheric 17 Mt of stratospheric aerosol. High values of sulfuric acid aerosol surface area, exceeding the threshold of 10^{-7} cm^2/cm^3 for catalytic destruction of ozone (as indicated by Prather, 1992) had been observed at northern midlatitudes mainly in the 15 to 20 km height range from late 1991 until early 1993. These values have to be taken into account when analysing the low total ozone observed during the winters following the Pinatubo eruption.

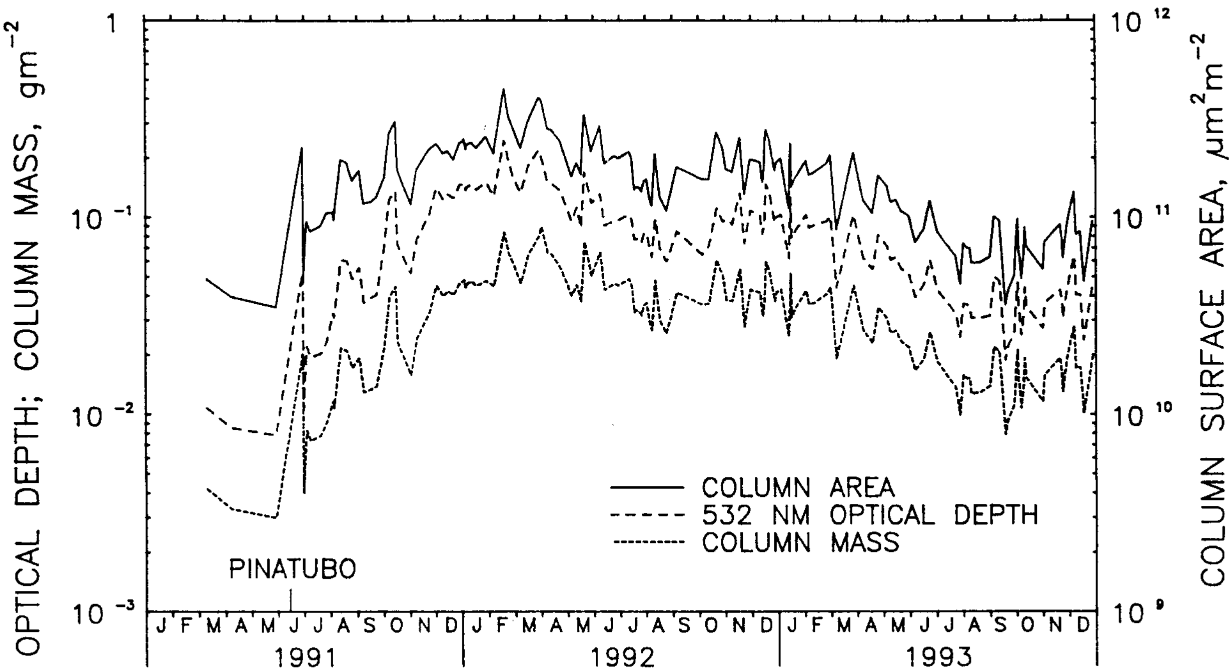

Fig. 6. Particle mass, surface area and optical depth derived from lidar backscatter measurements at Garmisch-Partenkirchen.

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