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LIDAR MEASUREMENTS OF STRATOSPHERIC AEROSOLS ENHANCED AFTER THE ERUPTION OF MT. PINATUBO: ALASKA, WINTER 1991/1992

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Abstract: Lidar measurements made at Poker Flat, Alaska in winter 1991/1992 suggest that stratospheric aerosols were extremely enhanced after the volcanic eruption of Pinatubo. The vertical profile of aerosol concentration had maxima 16–17 km, and 22–23 km. An additional aerosol layer was identified only in the measurements of December 15, 1991.

1. Introduction

The global dispersion of aerosols injected into the stratosphere through major volcanic eruptions has become a matter of great concern from the viewpoint of volcanic impact on atmospheric chemistry and transfer of solar radiation.

The volcano Pinatubo in the Philippine Islands (15.09°N, 120.19°E) underwent a number of eruptions during June 1991. These climaxed in a massive eruption on June 15, 1991, which injected a large cloud of volcanic debris into the stratosphere. According to MCCORMICK and VEIGA (1992), SAGE II satellite measurements show that the stratospheric volcanic cloud dispersed to about 70°N latitude by late July.

Simulation of the Pinatubo aerosol cloud using a GCM (General Circulation Model) (BOVILLE *et al.*, 1991) suggests that the volcanic cloud initially drifted westward and expanded in longitude and latitude; in the northern hemisphere there was substantial transport into high northern latitudes by August and this transport continued from August to December (the simulation ended at mid-December).

The effects of volcanic aerosols on ozone chemistry in the polar stratosphere attract many investigators' interest since volcanic aerosols can act as nuclei of polar stratospheric clouds (PSCs) and as absorbers of atmospheric N_2O_5.

Lidar measurements at high latitude can provide useful information for discussing long range transport of volcanic materials and their effects on atmospheric chemistry during their travel. Here we describe the lidar measurements of the Pinatubo-enhanced stratospheric aerosols at Poker Flat, Alaska (64°49′N, 147°52′W) in winter 1991/1992.

2. Lidar Measurements

Lidar measurements on stratospheric aerosols were made in mid-December, 1991 at Poker Flat, Alaska. The main characteristics of the lidar are summarized in Table 1. The matching point where an aerosol-free atmosphere was expected was chosen to be above about 30 km. Observations were made only on clear days to avoid noise from haze and clouds. About 6000 lidar return shots were integrated in order to obtain a profile of aerosol content. The error range is 10% or less at about 25 km.

The scattering ratio, SR, is defined by

$$SR=[\beta_1+\beta_2]/\beta_2, \quad (1)$$

$$=1+\beta_1/\beta_2, \quad (2)$$

where β_1 and β_2 are the backscatter coefficients of air molecules and of particulate matter, respectively.

The parameter [SR-1] can be regarded as the mixing ratio of atmospheric aerosols.

Table 1. Main characteristics of lidar.

Laser: Nd-YAG	
Wavelength	0.53 μm
Power	0.5 J/pulse (maximum)
Repetion rate	10 Hz (maximum)
Receiving mirror	Cassegrain type
	35 cm diameter

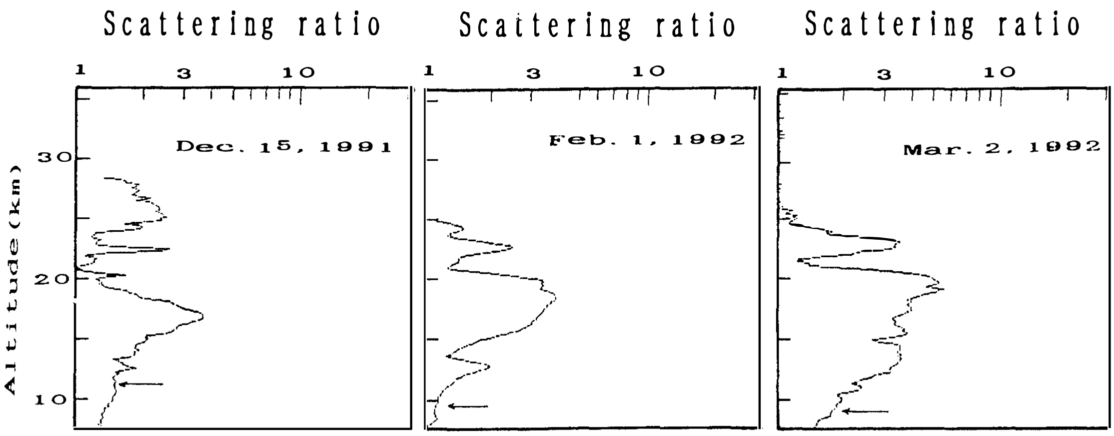


Fig. 1. Scattering ratio measured at Poker Flat, Alaska on December 15, 1991 (left), February 1, 1992 (center), and March 2, 1992 (right). Local tropopause height is shown by arrows '←'.

Figure 1 shows the vertical profiles of scattering ratio obtained on December 15, 1991, February 1, 1992, and March 2, 1992. The local tropopause height was estimated from the weather map produced by the Japan Meteorological Agency, since meteorological sonde data were not obtained in the lower stratosphere at Poker Flat.

3. Discussion

The mixing ratios of particulate matter estimated from the measurements shown in Fig. 1 are much larger in the lower stratosphere than the value observed in the undisturbed stratosphere (typically 0.05 or less). Following the eruption of Mt. Pinatubo many lidar stations observed enhanced stratospheric aerosols (Winker and Osborn, 1992a, b; DeFoor *et al.*, 1992; Jager, 1992; Post *et al.*, 1992; Rosen *et al.*, 1992), and satellite (McCormick and Veiga, 1992; Stowe *et al.*, 1992) measurements showed that the volcanic cloud dispersed to high latitude by late July 1991. The enhanced aerosols observed in Alaska could be related to volcanic disturbance of Mt. Pinatubo. Measurements at high latitude are very limited. According to balloon and lidar measurements at Alert (82.5°N, 62.5°W), Kiruna (68°N, 20°E), Heiss Island (80.5°N, 57.6°E) and other stations (Rosen *et al*, 1992), some volcanic debris arrived at far northerly latitudes below 20 km by October and was apparently incorporated into the

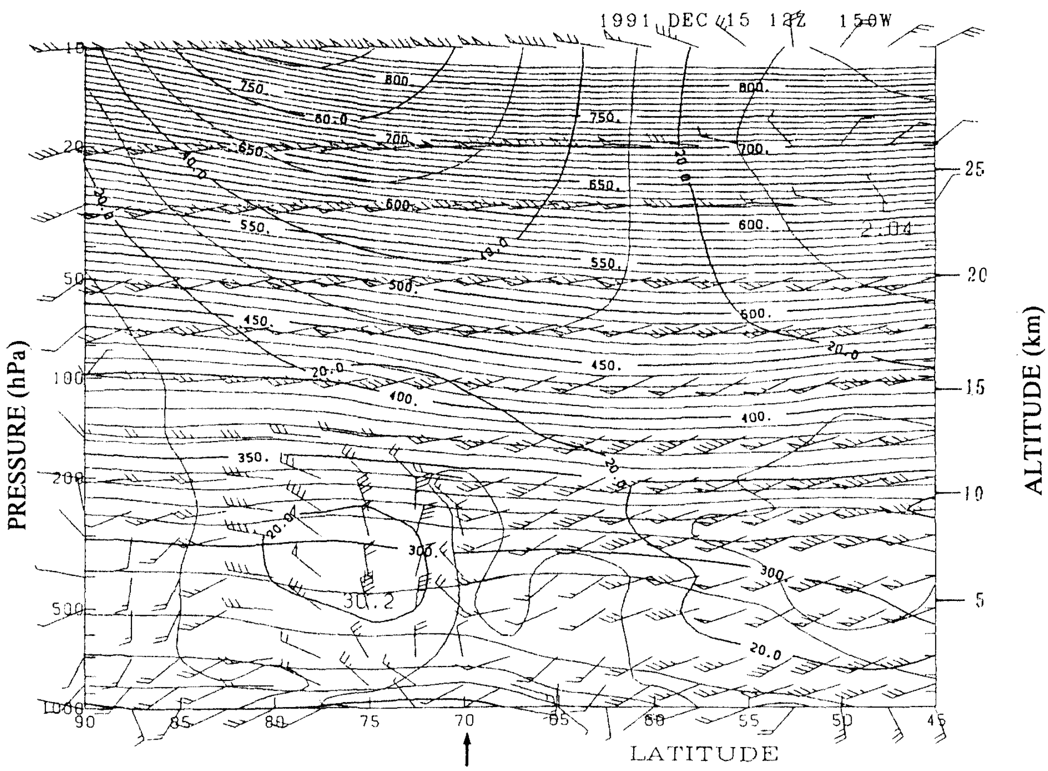
(a)


Fig. 2. Distribution of wind speed (m/s) and potential temperature (K) on December 15, 1991 (a), February 1, 1992 (b), and March 2, 1992 (c) at 150 W. The arrow '↑' shows the location of Poker Flat.

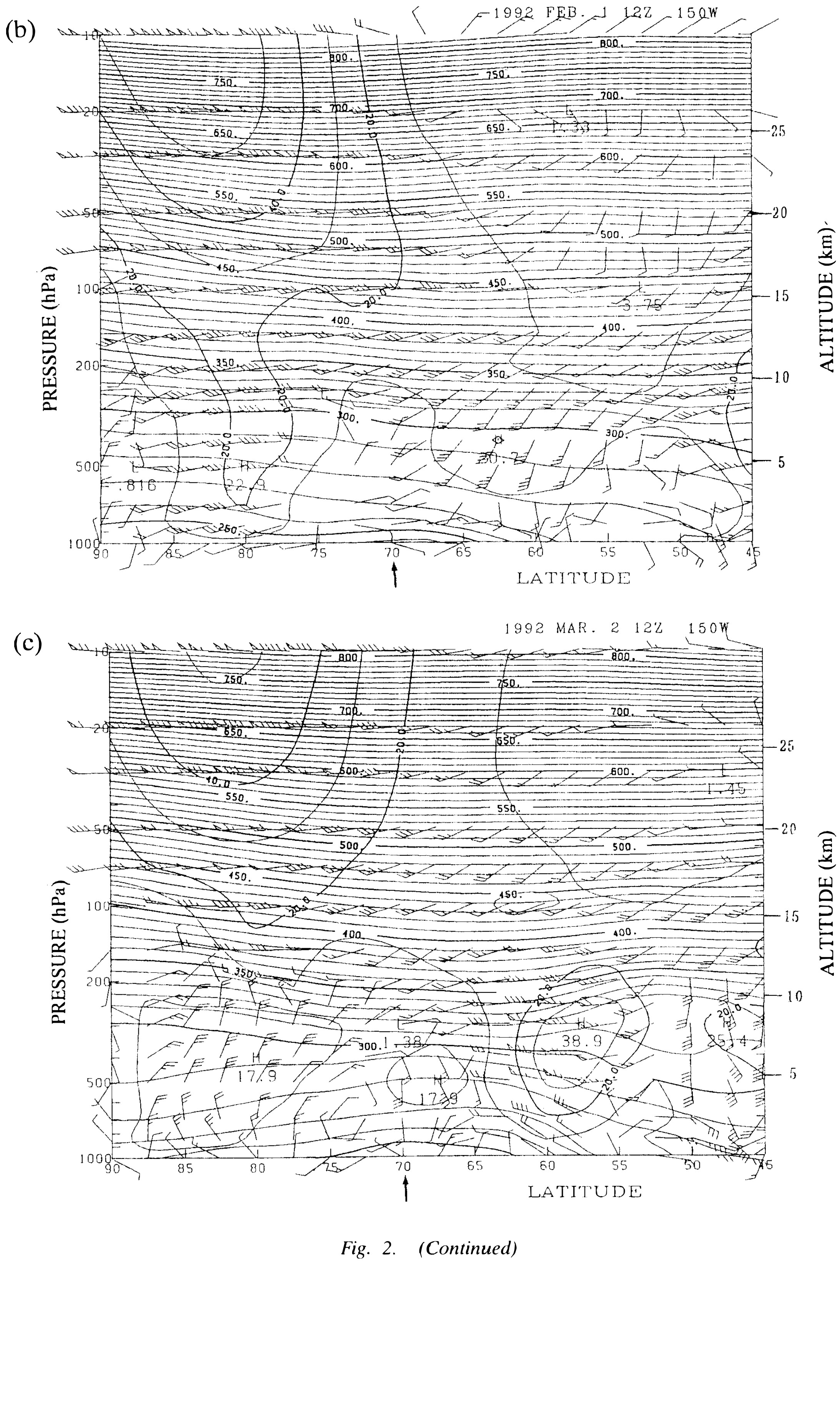


Fig. 2. (Continued)

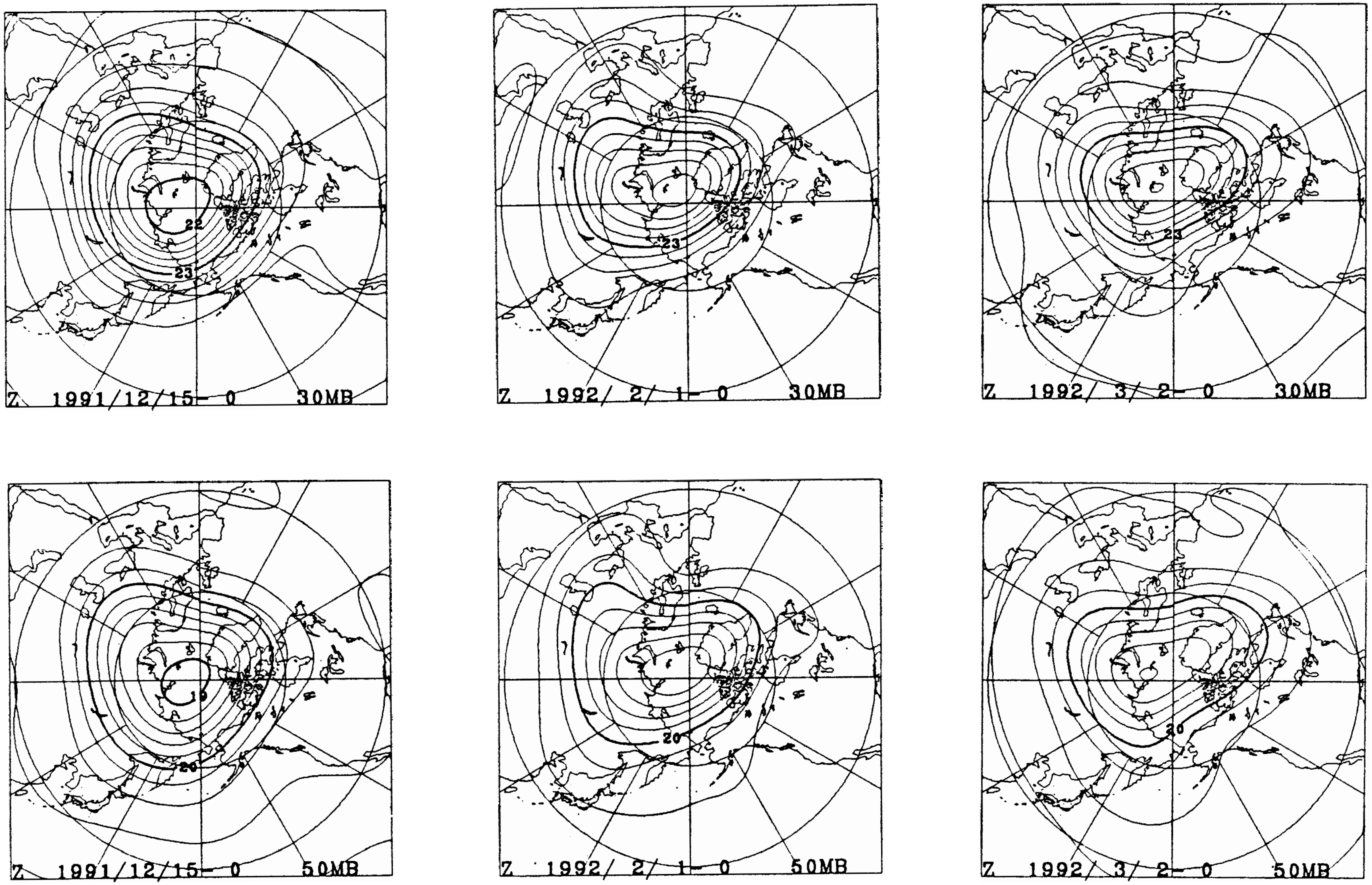


Fig. 3. Height of 30 mb and 50 mb surface (km) on December 15, 1991, February 1, 1992, and March 2, 1992.

initial vortex. Above 20 km and near the center of the vortex, no significant increase in aerosol was found through mid-March.

Figure 1 shows that enhanced aerosol layers were identified at 17–18 km and 22–23 km. Only the profile of December 15, 1991 showed an additional enhanced layer at 25–27 km. In Fig. 2, wind speed contours and potential temperature are shown. The geopotential heights of the 50 and 30 mb surfaces are summarized in Fig. 3. We can see that the Poker Flat lidar site was outside the polar vortex and near the wall of the vortex on December 15, from Figs. 2 and 3.

Kiruna station, where ROSEN *et al.* (1992) made balloon measurements, was inside the polar vortex during this period. Their measurements made on December 11, 1991 showed that the height of the main aerosol layer was at about 18 km and possibly corresponded to the aerosol layer of 17–18 km at Poker Flat on December 15, 1991. The layer observed at Kiruna is due to the transport of volcanic debris which arrived before the winter polar vortex formation. It is interesting that the mixing ratio of the main peak measured at Kiruna was about 13 at laser wavelength 0.94 μm. This mixing ratio corresponds to the value of about 7.3 at wavelength 0.53 μm, and is apparently larger than the measurements at Poker Flat.

The difference in the mixing ratio may suggest that there was considerable inhomogenity in aerosol content. The enhanced layer of 25–27 km was identified at Poker Flat on December 15, 1991 but not on February 1 and March 2, 1992. The measurements made at Kiruna and Alert by ROSEN *et al.* (1992) showed no significant increase in aerosol content at 25–27 km from December 1990 to March 1991. Comparing the lidar measurements of Poker Flat and the balloon measurements at Kiruna and Alert, it can be suggested that the disturbed air mass of 25–27 km reached after the establishment of the polar vortex. It is necessary to know history of the air mass to understand behavior of the enhanced layer of 25–27 km.

4. Conclusion

Lidar measurements at Poker Flat, Alaska in winter 1991/1992 suggests that the stratospheric aerosol content was extremely enhanced. This enhancement is possibly due to the eruption of Mt. Pinatubo, considering other many lidar-measurements, and balloon measurements made by ROSEN *et al.* (1992).

The Alaska lidar showed an enhanced layer of aerosols at 25–27 km on December 15, but the balloon observation made on December 11 at Kiruna by ROSEN *et al.* (1992) showed no significant increase at those heights. Detailed study of trajectory and history of air mass containing the aerosol layer of 25–27 km is needed.

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