Lidar Measurements of Stratospheric Aerosol over Hefei, China during 1991-1996

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Abstract -- The violent eruption of Philippine volcano Pinatubo in mid June of 1991 caused a serious perturbation on the stratospheric aerosols for a long period. In the paper, we report L625 lidar observational results in the period of 1991-1996, including evolution of volcano Pinatubo cloud. The time variation and vertical distribution of the volcanic cloud height, thickness, peak scattering ratio, and integrated backscattering coefficients will be analyzed. L625 lidar measurement data of stratospheric aerosol reveal the characteristics of background period before the volcanic eruption, the evolution of the Pinatubo volcanic cloud, and present new background level.

INTRODUCTION

Variation of stratospheric aerosol affects atmospheric minor constituents and climate through changes in the radiation field as well as by dynamic and chemical processes. In order to estimate the impact quantitatively, it is very important to observe stratospheric aerosol vertical distributions and their time variations. Lidar is a very powerful remote sensing technique for monitoring the stratospheric aerosols with a high vertical and temporal resolution. This paper will analyze the variations of the stratospheric aerosol profiles measured by a L625 lidar over Hefei (31.9°N, 117.17°E), China, during 1991-1996.

L625 LIDAR AND MEASUREMENTS

L625 lidar system consists of a double frequency YAG laser (wavelength 532nm), emitting 100mJ per pulse at a repetition rate of 5Hz, a receiving telescope of diameter 625mm, and a photon counting unit. A mechanical chopper can cut the strong-intensity signal before it is amplified by the PMT (EMI9817B). The height resolution is 600m, normally. The whole system, which is controlled by a PC computer, is set on the top floor of a building with a dome ceiling at the suburb of Hefei city.

In order for one PMT to cover the whole signal range of about three orders of magnitude from 6km to 35km or higher, the measurement is divided into two steps. In the first step, an averaged profile, for about 1000 laser shots, of return signal is obtained at relatively low altitude (about 6-25km), when the chopper opens at 6km and a neutral attenuator with transmittance of 5% is inserted in front of the PMT. Thus, the photon arrival rate is small enough to eliminate the pulse-pair error. At the second step, the chopper is adjusted to cut off the return signals from the altitudes below 10km, and the attenuator is taken away, so that the return signal can be recorded from higher altitudes (10-35km). the whole measurement takes about 30 minutes. A 'grand composite' profile spanning the altitude region of interest between 6km and 35km can be formed by matching the above two profiles.

The lidar back-scattering ratio, R(z), is defined as

$$R(z) = [B_a(z) + B_m(z)] / B_m(z) = 1 + B_a(z) / B_m(z) \quad (1)$$

where $B_a(z)$, $B_m(z)$ are aerosol and molecular back scattering functions, respectively. The $B_m(z)$ can be calculated from radiosounde data or Elterman model. The backscattering ratio R(z) is calculated by evaluating

$$R(z) = k\, N_s(z)\, Z^2 / B_m(z) / Q^2(z) \quad (2)$$

where $N_s(z)$ is photon number of return signal, $Q^2(z)$ is the two-way atmospheric transmittance, and k is a system constant determined by normalizing the right-hand side of Eq. (2) to an expected minimum value (R_{min}=1.01) of R over a specified altitude range (28-32km). In calculation of the transmittance $Q^2(z)$, molecular extinction is from radiosonde or model, and aerosol extinction is calculated directly from the aerosol backscattering function by using extinction-backscattering ratio values[1] of 22, 40, 43 during the period of Pinatubo volcanic cloud (June of 1991 - June of 1994), and 34, 52, 58 during the period with normal situation, over the height ranges of 15-20, 20-25, and 25-30 km, respectively. The Eq.(2) is solved by using updated value of aerosol extinction for iterations. More than 400 profiles (nights) were obtained during 1991-1996.

VARIATION OF STRATOSPHERIC AEROSOLS DURING 1991-1996

The violent eruption of Philippine volcano Pinatubo in mid June of 1991 caused a serious perturbation on the stratospheric aerosols for a long period. L625 lidar was used at Hefei for measurement of stratospheric aerosol profiles in the period of 1991-1996, including evolution of volcano Pinatubo cloud.

Fig. 1 shows some typical profiles of stratospheric aerosols. The six years from 1991 to 1996 may be divided into three periods: (i) the background period from January to mid-June , 1991 before the eruption, (ii) the volcanic cloud evolution period from June of 1991 to mid-1994, and (iii) the present new background period since mid-1994. A profile taken on May 15, 1991 represents the background prior to the Pinatubo eruption, whose peak scattering ratio, R_{max}, is 1.21 only at 18.3 km altitude. The first increase of the aerosols from Pinatubo eruption was observed at 15.9 km with R_{max} of 4.54 at Hefei on June 27, 1991, just 12 days later after the eruption. On July 19, about a month after the eruption, a strong scattering layer was observed around 21 km. These results are similar with the data observed by MRI lidar system[2] at Tsukuba, Japan. On August 8, the value of R_{max} increased up to 37.62 at 22.5 km. From August 1991, the upper layer grew day by day over Hefei and merged into a broad layer together with the lower layer. Until the end of August of 1991 a double-layered structure could be observed, and since early September same year it was replaced by a single layer with a peak near 22 km. A profile taken on October 3, 1996 represents the nature in new background period, whose value of R_{max} is 1.27 at 17.6 km.

Fig. 2 shows the evolution of the maximum scattering ratio over Hefei. The values of R_{max} initially showed large fluctuation, reflecting inhomogeneity of the cloud distribution. It was confirmed by SAGE II measurements[3] from June to August of 1991 that the major part of the cloud was confined to an equatorial band 20°S to 30°N. Hefei is just located on the north boundary of the band. The large fluctuation was probably related to the forward and backward movement of the cloud around the equator. After August 1991, the cloud was transported towards the north, the fluctuation became smaller and the peak scattering ratio generally varied between 10 and 20. It was about 10 in the early 1992, then decreased to about 5 in summer of 1992. The altitude of the peak scattering ratio, that is, the cloud height, over Hefei was mostly about 22 km. Positive correlation between peak scattering ratio and the cloud height was observed, i.e., a larger peak scattering ratio was located at higher altitude, generally.

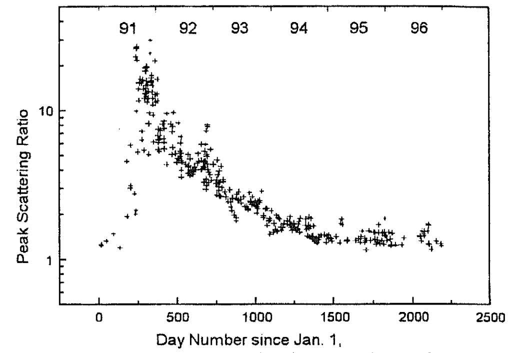

Fig.2 Maximum back scattering ratio

The integrated backscattering coefficient (IBC) represents the total loading of aerosols. IBC is calculated from 16 km to 27 km. The IBC values are approximately 2.0×10^{-4} sr^{-1} and 3.0×10^{-4} sr^{-1} for pre-background period and present background period, respectively. During the effective period of Pinatubo volcano, the maximum value of IBC is 9.24×10^{-3} sr^{-1} on November 25, 1991. The maximum value of monthly average of IBC is 5.10×10^{-3} sr^{-1} for December of 1991. The e-folding decay time of IBC is estimated to be approximately 15 months. The IBC data are averaged for every half a year. Fig. 3 showed the variation of half-annual averaged IBC from 1991 to 1996. The maximum value emerged at the second half of 1991, and it decreased monotonously as time goes on, which reveals the evolution

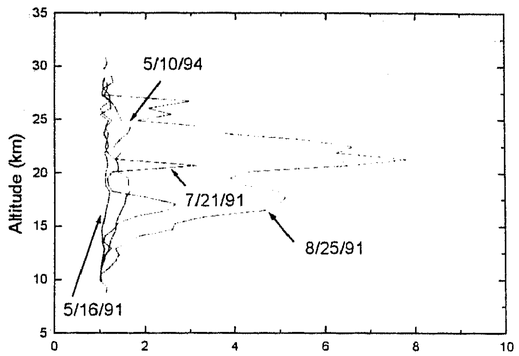

Fig. 1 Back scattering ratio profiles

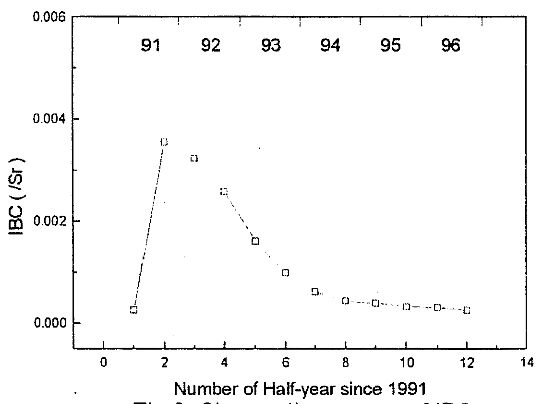

Fig.3 Six-month average of IBC

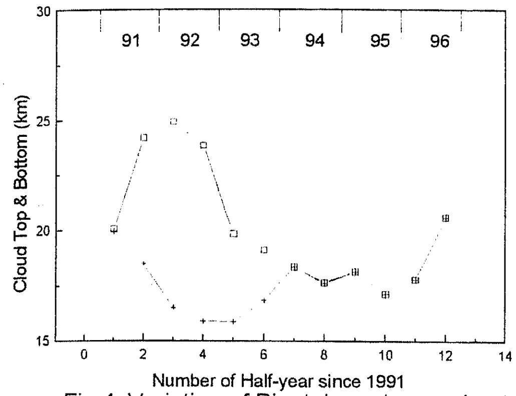

Fig.4 Variation of Pinatubo volcanic cloud

of Pinatubo volcanic cloud. Fig.4 showed the averaged heights of Pinatubo volcanic cloud top and bottom, whose scattering ratio values are defined to be more than 2.0. It can be deduced that the life of Pinatubo volcanic cloud is from June of 1991 to the middle of 1994 over Hefei. The cloud initially was thin layering and sometimes showed a double-peak structure during autumn of 1991. It became thicher and thicker with increasing time until autumn of 1992. The thick kept to be 8-9 km from winter of 1991 to autumn of 1992. The monthly average of cloud thick for April of 1992 was up to 9.8 km. The peak scattering ratio became less than 2.0 after the end of 1993.

REFERENCES

[1] H. Jager and D. Hofmann, "Midlatitude lidar backscatter to mass, area, and extinction conversion model on in situ aerosol measurements from 1980 to 1987", App. Opt., Vol.30, No.1, pp127-138, January 1991.

[2] O. Uchino "Lidar observations of the Pinatubo aerosol layers", Review of Laser Engineering, Vol. 23, No.2, pp161-165, February 1995.

[3] M. P. McCormick and R. E. Veiga, "SAGE II measurements of early Pinatubo aerosols", Geophys. Res. Lett., Vol.19, No.2, pp155-158, January 1992.