Antarctic Research, Vol. 6, No. 2, 66～71, December 1995

The observations on Polar Stratospheric Clouds at Zhongshan Station, Antarctica*

Sun Jinhui (孙金辉), Xia Qilin (夏其林), Qiu Jinhuan (邱金桓) and Lü Daren (吕达仁)
Institute of Atmospheric Physics, Academia Sinica, Beijing 100029, China

Received May 24, 1995

Abstract A lidar system (694 nm) was used to measure the stratospheric aerosol layer at Zhongshan Station (69°22′S, 76°22′E) in 1993. A total of 53 sets of lidar data presented in this paper were obtained over a period of 224 days between March 27 and November 5, 1993. The average vertical profiles of stratospheric aerosol backscattering ratio and the integrated backscatter coefficient over the 12 km～30 km altitude range were reversed from the return signal of lidar. The results of observations show that the stratospheric aerosol content more noticeably enhanced in 1993 than that in 1990 due to Mt. Pinatubo eruption in Philippines in June of 1991. Polar Stratospheric Clouds (PSCs) were observed from late May until early August. The vertical profiles of stratospheric aerosol backscattering ratio at Antarctica in 1993 show a clear double-layer structure. One layer is at an altitude of about 12 km, the other is at an altitude of about 25 km. The upper layer is varied with season.

Key words lidar, aerosol, Polar Stratosperic Clouds (PSCs), ozone hole, backscattering ratio, integrated backscatter coefficient.

1 Introduction

The extremely dense particle layer which is formed in the wintertime of Arctic and Antarctic regions in stratosphere is called Polar Stratospheric Clouds (PSCs) (McCormick and Trepte, 1986). In 1973 Stanford noted that an optically thin layer of clouds over Antarctica had been reported by ground observations in 1949～1951 (Collins *et al.*, 1993). However, the continental scale and seasonal persistence of PSCs was not appreciated until they were observed by satellite in 1979 (McCormick *et al.*, 1982). One of current chemical models relies on the presence of Polar Stratospheric Clouds to explain the rapid destruction of ozone observed each spring at Antarctica. Some scientists noted that the clouds condition the stratosphere during the winter for the subsequent springtime ozone loss by removing free nitrogen compounds from the lower stratosphere and providing sites for heterogeneous chemical reactions. Some people including scientists and politician are interested in the reason of formation and variation of ozone hole at Antarctica, and paying attention to them. Observations and researches of PSCs have been on-going at sev-

---

* This project was supported by National Natural Science Foundation of China and Academia Sinica.

eral Antarctic sites by lidar, since PSCs was observed by Iwasaka using a lidar system at Syowa Station (69°S, 40°E) in 1983 (Iwasaka, 1985). Scientists from Italy and United States observed it using lidar at several Antarctic station (90°S; 67°S, 140°E; 78°S, 167° E) (Collins *et al.*, 1993). A lidar system (694 nm) was installed at Zhongshan Station and operated on March 27, 1993. The lidar data were obtained between March 27 and November 5, 1993. The observations and some discussions are presented in this paper.

2 Lidar system and method of data processing

The lidar system used here consists mainly of a ruby laser, a transmitting telescope and a receiving telescope, optical detector and data processing system (Sun *et al.*, 1986). A convenient form for expressing the vertical profile of stratospheric aerosol particulate concentration is the "Backscattering ratio" $R(z)$, which is defined as:

$$R(z) = [B_m(z) + B_p(z)]/B_m(z) = 1 + B_p(z)/B_m(z) \tag{1}$$

where B_p is backscattering coefficient due to Mie scattering of aerosol and B_m stands for backscattering coefficient due to Rayleigh scattering of atmospheric molecules.

Generally we use a integrated aerosol backscatter coefficient, $IBC(z_1, z_2)$, to show the feature of scattering of aerosol between altitudes z_1 and z_2.

$$IBC(z_1, z_2) = \int_{z_1}^{z_2} B_p(z)\mathrm{d}z = \int_{z_1}^{z_2} [R(z) - 1]B_m \mathrm{d}z \tag{2}$$

where z_2 is the upper boundary for the altitude integration, and z_1 is the lower boundary for the altitude integration.

Assuming that the size distribution and the index of refraction of stratospheric aerosols are constant, $IBC(z_1, z_2)$ gives a measurement of the aerosol loading in the atmosphere over the altitude range z_1 to z_2.

All observations were made at night without cloud. The effective measuring range of lidar system used here is within the limits of 35 km. The height resolution of the measuring data is 7.5 m. During the data processing, the data had been smoothed. The average profiles of backscattering ratio in Fig. 1 were obtained from the average value of the lidar return signal of 10 laser pulse firings and their height resolution is 300 m. Every data in the profiles is obtained from an average value of 400 data sets of lidar return signal. The duration for every observation is about 1～2 hours.

3 Observations and discussion

Table 1 presents the observation periods, the peak backscattering ratio, maximum of $R(z)$ and the integrated backscatter coefficients. The $IBC(z_1, z_2)$ presented in this paper are calculated over the 12～30 km altitude range.

Tabel 1. Log of lidar observations at Zhongshan Station, Antarctica

Date	IBC$\times10^{4}$(sr^{-1})	R(z)max.	Date	IBC$\times10^{4}$(sr^{-1})	R(z)max.
March 27	7.3	2.9	August 1	14	4.8
March 31	9.6	3.4	August 7	25.3	8.1
April 1	10.2	3.3	August 12	1.75	2.4
April 2	12.0	3.3	August 14	3.6	3
April 11	13.6	3.5	August 22	7.7	4.5
May 2	6.1	3.9	August 24	10.5	4.7
May 4	6.9	2.7	August 31	2.3	2.5
May 5	3.7	2.2	September 3	7.9	4.4
May 7	3.5	2.4	September 4	10.9	5.2
May 14	5.7	3.6	September 6	3.6	3
May 23	13.3	4	September 17	16.3	6.2
May 24	14.6	4.5	September 18	14	8.3
May 27	19.8	5.9	September 19	12	5.9
June 6	9.4	4	October 3	5.6	2.6
June 10	18.9	4.9	October 4	2.1	3.3
June 11	17.9	4.4	October 5	5.2	2.4
June 15	18.6	5.9	October 9	9.7	4.7
June 27	9.8	3.9	October 10	15.4	5.2
July 2	17.9	5.3	October 13	9.9	6.7
July 4	13.2	4	October 15	1.9	2.6
July 6	28.2	5	October 24	5	3
July 9	10.4	3.8	October 29	10	4.4
July 12	11.4	4.8	October 31	5.8	3.1
July 19	34	9.1	November 3	13.6	4.6
July 22	10.4	4.5	November 5	6.7	3.3
July 28	7.2	2.6			

Fig. 1 shows some of average backscattering ratio profiles for the observation periods between end of March and early November in 1993 at Zhongshan Station. Fig. 2 shows the seasonal variation of IBC. Our observation results show the following facts.

(1) The maximum values of $R(z)$ and IBC obtained between March 27 and November 5 tend to be larger than that at Amundsen-Scott South Pole Station in 1990 (Collins *et al.*, 1993), but smaller than that at Syowa Station in 1983 (Iwasaka, 1985). These differences are due to the enormous increase of stratospheric aerosol particulate content after Mt. Pinatubo volcanic eruption in Philippines in June of 1991. The average backscattering ratios observed by Collins using a lidar system (589 nm) at South Pole Station before late May and after early August of 1990 are less than 1.3 except October 18 and the integrated backscatter coefficients are less than 1×10^{-4}(sr^{-1}), close to 1×10^{-5}(sr^{-1}). These data show the background levels of Antarctic atmosphere. However, the peak backscattering ratios are about 2.2～3.9 and the integrated backscatter coefficients are about $(3.5\sim10.2)\times10^{-4}$(sr^{-1}) obtained by us during the period from

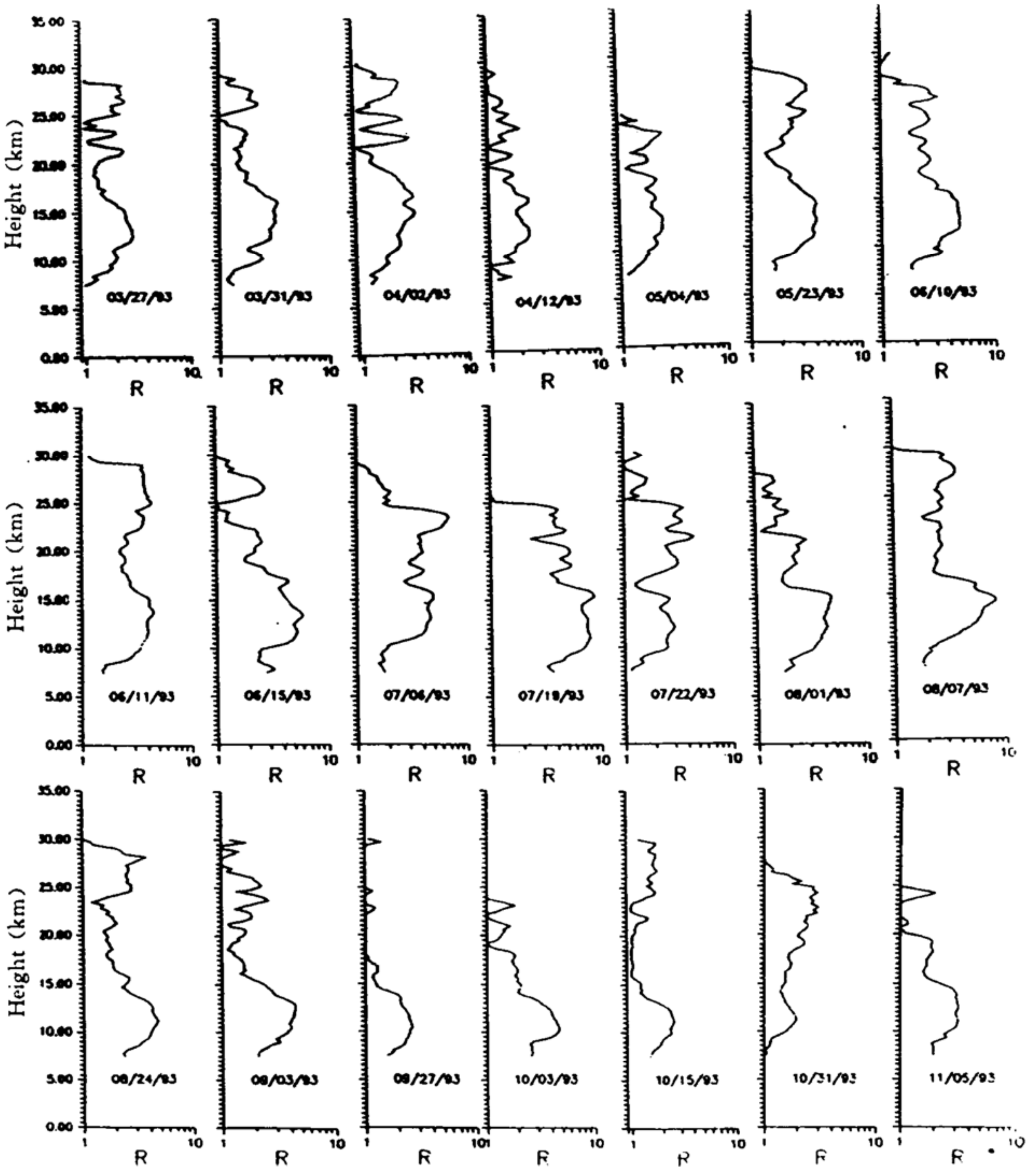

Fig. 1. Profile of $R(z)$ in Zhongshan Station.

March 27 until May 14 of 1993. The enormous increase of stratospheric aerosol particulate content was caused by Mt. El Chichon volcanic eruption in April of 1982. Only one year after that eruption, the maximum of IBC which were obtained by Iwasaka at Syowa Station between June and July of 1983, is about $1\times10^{-2}(\mathrm{sr}^{-1})$. Before June and after August IBC by Iwasaka are about $5\times10^{-4}\sim1\times10^{-3}(\mathrm{sr}^{-1})$; but the maximum of IBC obtained by us on July 19 is about $3.4\times10^{-3}(\mathrm{sr}^{-1})$, which is smaller than that obtained at Sywoa Station in 1983. The reason causing the difference is that our observations were made after Mt. Pinatubo erupted 21 months late. The content of stratospheric aerosol

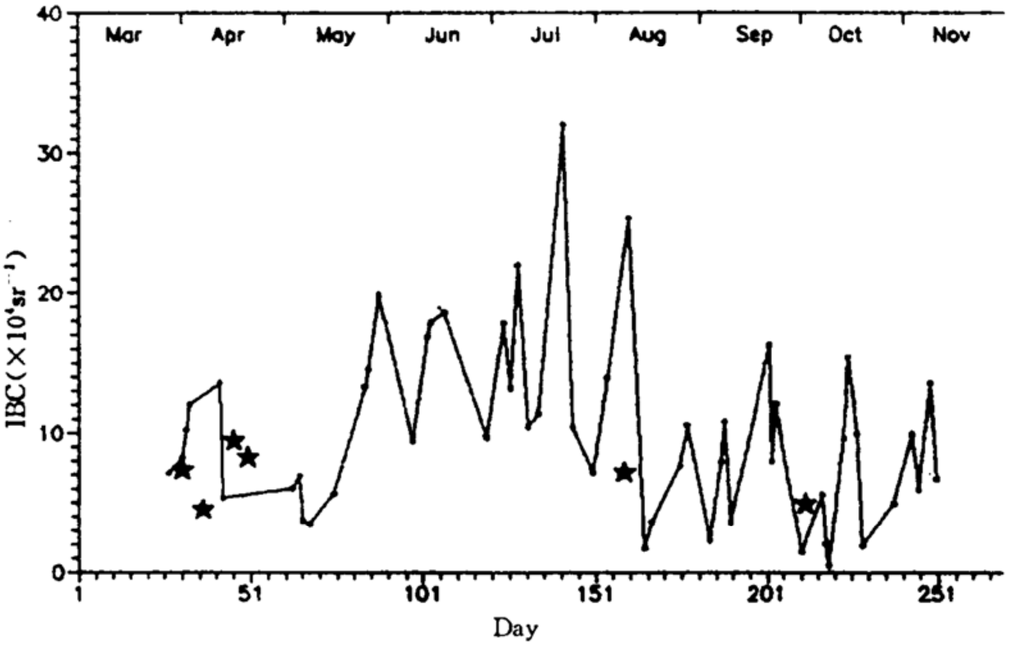

Fig. 2. Seasonal variations of IBC(March, 1993～November, 1993).

particulate due to volcanic eruption decreased with time. According to the results obtained in Germany, Japan and Beijing between 1991 and 1993, the stratospheric aerosol particles must be much more in 1992 than that in 1993 at Antarctica(Sun *et al.*, 1993).

(2) Fig. 2 shows clearly that the stratospheric aerosol particulate concentration increases from late May until early August. 83 per cent of 18 sets of lidar data obtained between May 23 and August 7 has its IBC value larger than 1×10^{-3}, but before and after that period the IBC is almost smaller than 1×10^{-3}(sr^{-1}). Moreover Antarctic stratospheric aerosol layers presented throughout the altitude region between 8 and 28 km in wintertime. The variation of IBC is relatively small in wintertime. Wintertime enhancement of stratospheric aerosol concentration revealed the presence of PSCs throughout Antarctic wintertime of 1993.

(3) These small five-pointed stars in Fig. 2 show the IBC obtained in Beijing. Fig. 3 shows the backscattering ratio profiles measured in Beijing. It is clear that there are large differences in vertical distribution and total content of stratospheric aerosol between Antarctica Zhongshan station and Beijing. The dense aerosol layer distributed at an altitude range of 8～17 km could be observed within a period from March 27 to November 5, but the aerosol particulate concentration varied greatly now and then above 20 km at Zhongshan Station. The stratospheric aerosol layer presented mainly at an altitude range above 13 km in Beijing. The distribution height was lower at Zhongshan Station than that in Beijing. The main reason may be due to that the tropopause is lower at Antarctica than that in Beijing, some radiosonde indicated that the tropopause was located at an altitude between 10 and 11 km, or only 8 km sometimes. Additionally the values of IBC obtained at Zhongshan Station are larger than that in Beijing.

(4) The stratospheric aerosol vertical profiles in Fig. 1 show a clear double-layer

structure at Zhongshan Station in 1993. The lower layer at an altitude of about 12 km was observed throughout a period from late March to early November. The upper layer at an altitude of about 25 km was usually detected in wintertime, but the variation is clear before and after wintertime. The peak backscattering ratio was very small.

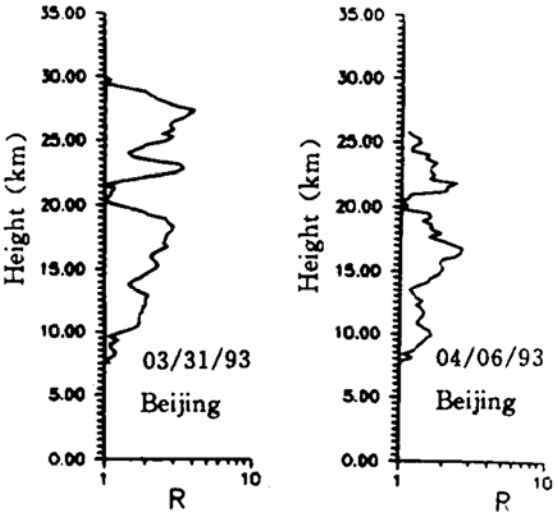

Fig. 3. Profile of $R(z)$ in Beijing.

(5) As shown in Fig. 2, the stratospheric aerosol layers having an IBC larger than $1 \times 10^{-3}(\mathrm{sr}^{-1})$ and peak backscattering ratio larger than 8 were detected on November 5, October 10 and mid-September, but they disappeared rapidly. This kind of dense stratospheric aerosol layer was detected by Collins in 1990(Collins *et al.*, 1993). He called it isolated cloud.

It was reported that the rapid destruction of ozone at Antarctica in springtime of 1992 and 1993 was detected. This phenomenon appeared after Mt. Pinatubo volcanic eruption causing the sudden increasing of stratospheric aerosol particulate content. We are interested in whether one of main reasons of rapid destruction of springtime ozone at Antarctica is caused by the increase of stratospheric aerosol particulate, especially the presence of PSCs in the Wintertime. Its observation and researching work will be done further and supported by Antarctica science research program.

Acknowledgments The authors wish to thank the members of Zhongshan Station of the Ninth Chinese National Antarctic Research Expedition, especially winter-over staffs for their support throughout the year.

References

Collins, R. L., Bowman, K. P. and Gardner, C. S. (1993): Polar stratospheric clouds at the South Pole in 1990. *J. Geophys. Res.*, 98, 1001－1010.

Iwasaka, Y. (1985): Lidar measurement of the stratospheric aerosol layer at Syowa Station(69°S, 39.35°E), Antarctica. *J. Met. Soc. of Japan*, 63(2), 1985.

McCormick, M. P., Steele, H. M., Hamill, P., Chu, W. P. and Swissler, T. J. (1982): Polar stratospheric cloud sightings, SAM Ⅱ. *J. Atmos. Sci.*, 39, 1387－1397.

McCormick, M. P. and Trepte, C. R. (1986): SAM Ⅱ measurement of antarctic PSCs and aerosols. *Geophys. Res. Lett.*, 13, 1407－1410.

Sun Jinhui, Qiu Jinhuan, Xia Qilin and Zhang Jindin(1986): Observations on vertical distribution of stratospheric aerosol backscattering ratio by lidar. *Scientia Atmospherica SINICA*, 10(4), 431 － 436 (in Chinese).

Sun Jinhui, Qiu Jinhuan, Xia Qilin and Zhang Jindin(1993): Lidar Observations of volcanic clouds after Mt. Pinatubo volcanic eruption. *Chinese Science Bulletin*, 38(18), 1557－1560.