NOTES AND CORRESPONDENCE

**Lidar Measurement of the Stratospheric Aerosol Layer
at Syowa Station (69.00°S, 39.35°E), Antarctica¹⁾****By Yasunobu Iwasaka***Water Research Institute, Nagoya University, Chikusa-ku, Nagoya 464**(Manuscript received 10 December 1984 in revised form 22 February 1985)***Abstract**

The measurements on polar stratospheric aerosol particles using lidar and meteorological sonde at Syowa Station (69.00°S, 39.35°E), Antarctica revealed that the content of stratospheric aerosols noticeably increased in winter when atmospheric temperature frequently fell down to about -80°C in the lower atmosphere.

Introduction

The observations of stratospheric aerosols on high latitudes have not been sufficient because of technical difficulties. Most of previous measurements such as balloon-borne particle counter and sampling of particles using aircraft have been made from late spring to early fall, and not in winter. Recently the satellite measurements by McCormick and his co-workers (McCormick *et al.*, 1982) showed that extremely highly concentrated particle layer was formed in the winter polar stratosphere (They called it "Polar Stratospheric Clouds"). Behavior of polar stratospheric aerosols in winter, even though its nature is not fully known, seems to be very important phenomenon which possibly influences on global budget of water vapor and/or sulfur.

Lidar measurements on stratospheric aerosol has been made at Syowa Station (69.00°S, 39.35°E), Antarctica, since March 1983 as a part of the international project Antarctic

Middle Atmosphere (MAP/AMA). Noticeable enhancement of the stratospheric aerosol layer which correlated with very cold atmospheric temperature was frequently observed in winter. Informations presented here should be useful for studies on particle formation processes of "Polar Stratospheric Cloud", the effect of the winter enhancement of polar stratospheric aerosol layer on global budget of aerosol particles, water vapor, and sulfur compounds in the stratosphere.

In this paper we should like to present the results on the polar stratospheric aerosol layer which were gained at Syowa Station (69.00°S, 39.39°E), Antarctica in 1983. As far as we know, they are first lidar measurements on polar stratospheric aerosols and thus should be very interest even if they are preliminary.

Measurement

The main characteristics of lidar used here are listed in Table 1. During the observational period, we performed lidar observation under the system condition that the height resolution was 0.5 km, laser pulse power in the range from 0.1 J/pulse to 0.5 J/pulse, and pulse repetition rate 0.5 Hz.

The scattering ratio is defined by follow-

1) This paper was presented at the Japan-U.S. Seminar on "Review of work related to sensing of stratospheric aerosol and gas components", Fukuoka, 12-14 June 1984.

Table 1 Main characteristics of lidar system used at Syowa Station
(69.00°S, 39.35°E), Antarctica.

Laser	
Wavelength	: 694 nm
Polarization	: Vertical
Max. Rep. Rate	: 60 ppm
Pulse Energy	: 1.5 J Max.
Pulse Length	: Approx. 36 nS & 1.5 J, 60 ppm
Wavelength	: 374 nm
Polarization	: Horizontal
Pulse Energy	: Approx. 325-375 mJ & 1.5 J of 694 nm
Beam Divergence	: Approx. 78% of energy in 3 mr & 60 ppm, 1.5 J
Beam Diameter	: Approx. 8.5 mm after output coupler
Stability of Fundamental	: Approx. $\pm 7.5\%$ & 60 ppm, 1.5 J
Transmitter Telescope	: 10 cm ϕ
Receiver Telescope	: 50 cm ϕ
Data Processing	: Melcom 70/10 minicomputer system

ing relation,

$$\text{Scattering ratio} = [B_1 + B_2] / B_1 \quad (1)$$

where B_1 and B_2 are backscattering coefficient of atmospheric molecules (Rayleigh scattering) and of aerosol particles (Mie scattering) respectively. In order to estimate the value of scattering ratio, we used so-called "matching method" (e.g., Russell *et al.*, 1976). Air density was estimated on the basis of stratosonde data.

The vertically integrated value of B_2 in the stratosphere given by,

$$\int_{z_2}^{z_1} B_2(z) dz,$$

where z_1 : upper boundary of integration,
 z_2 : lower boundary of integration,

is recognized as the parameter showing the column density of particulate matter in the stratosphere.

Fig. 1 indicates the temporal change of the value of the vertically integrated backscattering coefficient of aerosols (Here we call the integrated value IBC). Various time scale changes of IBC are found in figure. Here we should like to give attention to the variation with the time scale of about several months. Noticeable maximum of IBC is easily found in winter season from curve in Fig. 1. Maximum value of IBC measured at Syowa Station is larger than the peak value of IBC which was measured immediately after the

Fig. 1 The temporal change of the vertically integrated backscattering coefficient in the stratosphere, measured at Syowa Station (69.00°S, 39.35°E), Antarctica, 1983.

volcanic eruption of Mt. El Chichon (Spring, 1982: Mexico) at Japan. This result certainly confirmed the sudden increasing of extinction in winter polar stratosphere which was measured by satellite, SAM II (McCormick *et al.*, 1982).

Usually it has been considered that sudden increase of backscattered light and/or IBC certainly is due to severe eruption of volcanos (for example St. Helens and El Chichon). However the winter maximum of IBC measured at Syowa Station is not due to the direct effect of volcanism since there was no information on the volcanic eruptions which strongly affected on the winter Antarctic stratosphere. Additionally increase of extinction in the polar stratosphere has been measured in every winter since 1979 by

Fig. 2 The variation of temperature measured at Syowa Station (69.00°S, 39.35°E), Antarctica. The rapid decrease of stratospheric temperature was measured on the end of May 1983. Since then the cold region with temperature lower than -80°C was frequently measured. The arrow $\uparrow$ shows the day when lidar measurement was done.

Fig. 3a Temperature profile at 1430 LT 25th May and the scattering ratio measured on the night of 25th May (1900 LT-2300 LT). The bar is the range of error.

Fig. 3b Temperature profile at 1430 LT 29th May and scattering ratio measured on the night of 29th May (1900 LT-2300 LT).

Fig. 3c Temperature profile at 1430 LT 2nd June and the scattering ratio on the night of 2nd June (1900 LT-2300 LT). Very cold atmosphere with $T < -80^{\circ}\text{C}$ appeared above 20 km altitude and the noticeable enhancement of aerosol layer was first measured. The peak centered at 8 km was certainly thin cirrus cloud.

Fig. 3d Temperature profile at 1430 LT 12th June (solid line) and at 0230 LT 13rd June (dotted line), and the scattering ratio measured on the night of 13rd June (1900 LT-2300 LT).

Fig. 3e Temperature profiles at 0230 LT 16th June, and the scattering ratio measured on the night of 16th June (1900 LT 15th June-0300 LT 16th June). The temperature profile measured at 0230 LT 16th June suggested that the temperature possibly fell down to the value lower than -80°C above about 20 km altitude on the night of 15th June.

satellite (McCormick *et al.*, 1982).

Winter enhancement of the stratospheric aerosol layer became to be noticeable on early June, 1983. The results on the early phase of the enhancement are shown in Fig. 2 and 3. The general tendency of temperature change of the stratosphere in early winter is shown in Fig. 2 on the basis of radio sonde measurements which were made routinely (0230 LT and 1430 LT, the difference between local time of Syowa Station and Greenwich mean time was 3 hours). The arrow † in figure means the date when lidar measurement was made.

The scattering ratios measured from the end of May to the middle of June are shown in Fig. 3. The profiles of scattering ratios in Fig. 3 were made by integration of about 700 laser pulse firings. The statistical error due to photon-counting method was at most 7%. The measurement on 2nd June, 1983 was the first one which showed noticeably enhanced feature. As shown in Fig. 2, the very cold air with temperature (T) lower than -80°C was found at about 20 km altitude on 30th May. Since then the region with $T < -70^{\circ}\text{C}$ rapidly spreaded to near the bottom of the stratosphere.

All of scattering ratio profile measured after the appearance of cold air showed enhanced shape (increase of scattering ratio, expansion of aerosol layer), and apparently there was large difference between results gained in May and those in June concerning the shape of scattering ratio profile.

Summary and discussion

We presented the lidar measurements on polar stratospheric aerosols in 1983. McCormick *et al.* (1982) reported that the large increase of extinction was found in the polar winter

stratosphere and concluded that this event was certainly due to the particulate matter increase which was caused by the decrease of stratospheric temperature (They call this thick aerosol layer "Polar Stratospheric Cloud").

The results presented here also suggested that the decrease of atmospheric temperature in winter was an important factor which caused noticeable increase of stratospheric particulate matter.

In Table 2 we summarized the occurrence ratio of the enhanced stratospheric aerosol layer on the basis of the lidar measurements in 1983. It can be easily found that the enhanced aerosol layer with the value of IBC larger than $2 \times 10^{-3} \text{sr}^{-1}$ was measured only in very cold stratosphere with $T < -80^{\circ}\text{C}$. However converses are not always true. Even when the cold air with $T < -80^{\circ}\text{C}$ was found in the lower stratosphere, a few cases did not indicate the enhanced stratospheric aerosol layer. But such cases are minor ones. Here we chose the threshold value of IBC to be $2 \times 10^{-3} \text{sr}^{-1}$ considering that the minimum value of IBC measured during the enhanced period of the aerosol layer was about $2 \times 10^{-3} \text{sr}^{-1}$.

Steele *et al.* (1983) presented the idea that the active growth of ice crystal was main processes which caused the drastic increase of polar stratospheric particulate matter. According to them the ice crystal growth becomes to be very active in the cold atmosphere with $T < -80^{\circ}\text{C}$. It is difficult to conclude that the factor which caused the stratospheric aerosol layer enhancement is only decrease of the stratospheric temperature to -80°C . However the decrease of stratospheric temperature (possibly lower than -80°C) is at least one of the important factors

Table 2 Appearance of the enhanced aerosol layer (Syowa Station, Antarctica, 1983).

	The vertically integrated B_2 was larger than $2 \times 10^{-3} \text{sr}^{-1}$	The vertically integrated B_2 was smaller than $2 \times 10^{-3} \text{sr}^{-1}$
Cold air temperature ($< -80^{\circ}\text{C}$) was measured in the lower stratosphere	36.0%	4.5%
Cold air temperature ($< -80^{\circ}\text{C}$) was not found in the lower stratosphere	0.0%	59.5%

which control the enhanced stratospheric aerosol layer.

Particle concentration is, of course, controlled not only by temperature field but also by other various factors such as density distributions of gases (water vapor, sulfuric acid vapor, and so on) related to aerosol formation, transport of particles due to dynamical air motions and gravity, and others. Therefore it is difficult to show the typical observations which are indicating enhancement due to only the decrease of stratospheric temperature, and reasonable to consider that there is a usually a little difference between the height of cold region and the peak height of aerosol concentration. So it might be meaningless to discuss only complete coincidence of the height of aerosol density peak with that of cold atmosphere region in profiles shown in Fig. 3.

Concerning the effect of wind, we should like to point out that the north-south wind component alternated very often in the lower stratosphere from the end of May to the middle of June, 1983 and that the relation between wind component and enhancement of the stratospheric aerosol layer could not be made clear within the limits of the present experiments.

Summarizing the present observations, the Antarctic stratospheric aerosol layer noticeably enhanced in winter, and the decrease of stratospheric temperature to the level lower than -80°C is possibly an important factor

which causes the enhancement of aerosol layer. The winter enhancement of the Antarctic aerosol layer described here is certainly same phenomenon with "Polar Stratospheric Cloud" shown by McCormick *et al.* (1982). In order to take reasonable understanding about the vertical profile of aerosol content and its temporal change during the enhancement period, it should be necessary, in addition to lidar data, to take information on distribution of H_2O , H_2SO_4 , wind system, aerosol size, chemical composition and so on.

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南極昭和基地 (69.00°S , 39.35°E) における成層圏エアロゾル層のライダー観測

岩 坂 泰 信

名古屋大学水圏科学研究所 千種区, 名古屋 464