AEROSOL DISTRIBUTION UP TO 33 KM
OVER THE SUBURBS OF BEIJING, CHINA (40°N) IN SUMMER 1984

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Abstract. Number density of aerosol particles larger than $0.3\ \mu\text{m}$ diameter was measured with a balloon-borne dust counter over the suburbs of Beijing, China in summer 1984. It was confirmed that the aerosol density level in the stratosphere was several times higher than the background state in the northern hemisphere mid-latitudes assumed from the data obtained in the volcanically quiescent period. Compared with the values observed between 1975 and 1979 which were probably affected by some volcanic activities, it was still 2 times high. It suggests that the stratospheric aerosol content at the time of this observation was yet in the slowly decaying phase after the El Chichon event. The tropospheric aerosol density was of the same order as the average over Japan islands observed so far. Brief comparison with the lidar data at Toyokawa is also given.

1. Introduction

The first Japan-China cooperative balloon experiment was carried out in August 1984 to measure the vertical distributions of aerosol, nitric monoxide and ozone. This report is concerned with the aerosol observation up to 33 km altitude in this experiment. The aerosol state in the mid-latitude stratosphere during the years 1983 and 1984 is recognized to have been on the steady decay of aftereffect of the Mexican volcano, El Chichon which erupted in March to April, 1982. The major interest in this experiment is to confirm the mid-latitude stratospheric aerosol state in this period, and to examine some difference between the aerosol distribution above China continent and Japan islands.

2. Outline of the experiment

The experiment was performed in the cooperation between Nagoya University and Institute of Atmospheric Physics, Academia Sinica as the first trial of Japan-China cooperative balloon campaign.

The apparatus for the aerosol measurement is a light-scattering type dust counter which was designed and manufactured in Nagoya University for balloon use. The details of it were reported elsewhere (Morita and Takagi, 1983; Takagi et al., 1985). It measures the number concentration of aerosol particles in two size ranges, respectively for the diameter larger than 0.3 and $0.5\ \mu\text{m}$.

The balloon, telemeter and command system, meteorological sonde, and all ground facilities for balloon launching, tracking, telemetering, payload recovery, etc. were supported by Academia Sinica. The flight was made from Xianghe Observatory (39.8°N , 117.0°E), 50 km ESE of Beijing, in the afternoon of 23 August, 1984 by using a plastic balloon of $30,000\ \text{m}^3$

capacity.

The balloon reached the altitude of 33 km after 2 hours ascent, and then level-floated in the ceiling altitude for about 1 hour. The measurement of aerosol density was made satisfactorily for these periods. Just before the balloon entering over the city of Beijing the payload was cut off, descended with a parachute, and recovered without any serious damage. The apparatus recovered was again checked carefully in the laboratory for assuring the accuracy of obtained data.

3. Results

Figure 1 shows the vertical profile of number density of aerosols larger than $0.3\ \mu\text{m}$ in diameter. A stratospheric aerosol layer is found in the altitudes from 17 to 23 km, and the maximum density in it is about $2\ \text{cm}^{-3}$ at 20 km. The profile observed at Sanriku, Japan (37°N) in October 1982, half a year after the El Chichon eruption, is also shown in a broken line for comparison (Morita and Takagi, 1985). The peak value in summer 1984 is about half that in the profile in fall 1982. The altitudes of aerosol layer are almost same in the two observations, though this does not mean the unvariability of aerosol layer altitude. According to lidar observations the stratosphere over Japan in fall 1982 was still under heavy perturbation due to irregular distribution of eruption cloud (Uchino, 1985; Hayashida and Iwasaka, 1985). The monotonous decaying phase in the northern

Fig.1. Vertical profile of number density of aerosol particles of the diameter larger than $0.3\ \mu\text{m}$. Arrows indicate the tropopause height in the respective observations.

mid-latitudes began at around December 1982 (Iwata and Takagi, 1984). In the beginning four months of the decay phase from December 1982 the centroid altitude of aerosol distribution descended from 20–23 km to 17–20 km. Since then any remarkable trend in the aerosol layer height has not been found other than probable seasonal variations.

We have made 5 times the balloon observations of aerosol particle density at Sanriku since 1973 (Morita and Takagi, 1983). Among them the observation in 1973 is considered to indicate nearly the background state, where the values of stratospheric aerosol density were 0.3 to 0.5 cm^{-3} . Three observations between 1975 and 1979 were more or less under the influence of some volcanic activities, and the stratospheric aerosol density was in the range from 0.5 to 1.5 cm^{-3} . The result this time is several times higher than the background level and about 2 times higher than the values in 1975 to 1979. These results support the consideration that the El Chichon event still had some aftereffect in particle density in summer 1984.

In the troposphere a remarkable difference is found between the two profiles. The density just above the ground surface at Xianghe is so high that it far exceeds the measurement limit. The high number density of 5 to 10 cm^{-3} extends from 2 km up to 9 km, while the data at Sanriku show a rapid decrease with the altitude and a quite a low value below the tropopause. However, the density in the troposphere is quite changeable

Fig.2. Ratio of aerosol number densities in two size ranges, respectively larger than 0.3 and 0.5 μm in diameter, in the same observations as in Fig. 1. Arrows indicate the respective tropopause heights.

according as various conditions such as seasons, meteorological or local effects. The observations made 5 times at Sanriku since 1973 show the tropospheric aerosol density very widely ranging from 0.1 to 50 cm^{-3} (Morita and Takagi, 1983). The number density in fall 1982 was occasionally the lowest one of our observations. The value this time in China is actually of the same order as the average values in Japan. In the present stage we cannot say anything on the difference generally recognized between the two sites.

The profiles in Figure 2 are the concentration ratios of two size ranges of aerosol particles larger than 0.3 and 0.5 μm in diameter, respectively. Similarly to Figure 1 the ratios obtained in 1984 and in 1982 are shown in full line and broken line, respectively. As the first impression from the figure the value of ratio this time is less variable with the altitude than that over Japan two years ago. The size ratio in 1982 profile corresponding to the stratospheric aerosol layer was extremely low especially above 20 km, which means the larger size aerosols being relatively abundant. The value less than 3 is due to heavy stratospheric disturbance after the volcanic activities. This time the size ratio in the center of the layer is 3 to 5, which is the value similar to that observed at Sanriku in 1973 and typical one before the eruption (Hofmann and Rosen, 1983). The size ratio in the lowermost stratosphere over Japan measured by aircraft in spring 1984 also shows the similar value (Morita et al., 1986). It suggests that the size distribution, which may be a reflection of chemical composition, of stratospheric aerosols almost comes back to the background state, though the density still exhibits the aftereffect.

4. Comparison with lidar observation

It is not easy to carry out the frequent in situ balloon experiments. It is important, therefore, to compare the balloon results with the lidar remote sounding to follow up the long term variation of stratospheric aerosols. In order to compare the absolute value of aerosol concentration measured by dust sonde with the lidar remote sounding of aerosols, it is necessary to assume the aerosol size spectrum and the optical properties. The conversion was made in a few papers (e.g. Swissler et al., 1982; Hofmann et al., 1983; Russel et al., 1984). We adopted a similar method to that reported by Swissler et al. (1982), who pointed out the effectiveness of taking the size ratio corresponding to 0.3/0.5 μm diameter as a parameter representing the size distribution.

The 532-nm lidar system at Toyokawa (35°N) has been in continuous operation since December 1982 (Iwata et al., 1983), though it was unfortunately not in time for the previous balloon experiment at Sanriku. The lidar observations nearest the balloon campaign in China were those made on 2 September 1984, about 10 days behind the balloon flight. The radio sonde data of the same day at Hamamatsu, ESE 30 km from Toyokawa, was used to evaluate Rayleigh backscattering necessary for the lidar data reduction.

Figure 3 shows the comparison of aerosol backscattering coefficients at the wavelength of 532 nm estimated from the balloon and the lidar data. The disagreement of the two profiles in the troposphere may be explained with the difference of geographical location, 5° in latitude and 10° in longitude, and time of 10 days. In the stratosphere we find a good coincidence in the altitude range of the aerosol layer in the two profiles. But for the values of the respective peaks the lidar data are about twice larger than the balloon data. The difference seems too big to be attributed to that in location and time because the transient perturbation of volcanic origin is thought to have been completely diffused in the strato-

Fig.3. Comparison of aerosol backscattering coefficients at the wavelength of 532 nm, respectively estimated from the Xianghe balloon and the Toyokawa lidar observations. The peak at 14 km at Toyokawa was caused by cirrus.

spheric circulation. However, the order of disagreement may be unavoidable if we consider the following error sources. Horizontal bars in the figure indicate the range of conversion ambiguity from the number density to the backscattering coefficient. It arises from the variety of assumed aerosol size spectrum and refractive index. Uncertainty also comes from that the detector threshold level fixing the size range in the dust sonde is calibrated for the particle refractive index of 1.40. Furthermore the measurement error of lidar backscattering in the stratospheric height is probably not less than 20 or 30 % for this magnitude of aerosol content.

5. Conclusion

The results of balloon-borne aerosol measurement in China are summarized as follows. In the northern hemisphere mid-latitudes in summer 1984, the stratospheric aerosol layer is in the altitude range of 17 to 23 km. The number density of aerosols having the diameter larger than $0.3 \mu\text{m}$ is about 2 cm^{-3} , and the size ratio of $0.3/0.5 \mu\text{m}$ diameter is 3 to 5. These values suggest that the aftereffect of El Chichon eruption is still found in aerosol density, but the size distribution comes back to the background state. The comparison with the lidar observation at Toyokawa shows a rough agreement in a considerable error estimation.

The aerosol content in the troposphere over China continent is at the same order as the mean level over Japan islands observed during 10 years.

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