AIRCRAFT MEASUREMENTS OF AEROSOLS IN THE UPPER TROPOSPHERE
AT MID-LATITUDES

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Abstract. Aircraft measurements of aerosols were made during the years 1983 to 1984 in the upper troposphere. In some cases, the influence of the local atmospheric pollution originated from land surface was observed. The background concentration of Mie particle was about 0.1 cm^{-3} at altitude of 6-8 km. Air mass of stratospheric origin was observed over the Japan Sea in winter of 1983 and 1984. Mie particle concentration increased and CN concentration decreased in the stratospheric air mass. Though aerosol count ratio of two size ranges was found to be a large value in 1983, the value decreased to that of background level in the stratosphere in 1984. The volcanic eruption of Mt. El Chichon seems to be responsible for the large aerosol count ratio of the measurements of 1983.

1. Introduction

The recent growth of the industrial potential of the world has resulted in a sort of global pollution. Today there is hardly any place in the world which can boast of a perfectly clean atmosphere. The possibility that pollution may even extend to the upper troposphere and lower stratosphere is now real. For example, the background stratospheric aerosol concentration may have been increasing during the past 20 years (Hofmann and Rosen, 1981). Big volcanic eruptions, such as Mt. St. Helens in 1980 and Mt. El Chichon in 1982, enhanced strongly the number density of stratospheric aerosol layer (e.g. Hofmann and Rosen, 1982 and 1984) and the enhanced aerosols extended over the global stratosphere. The influence of volcanic eruptions is also visible in the upper troposphere. Aerosols in the upper troposphere also play an important role of the formation of stratospheric aerosol layer. Investigation on the temporal and spatial variations of the aerosols in the upper troposphere and lower stratosphere is one of the important subjects to monitor the present and future atmospheric environment. For this purpose aircraft measurements of aerosols were made during the years 1983 to 1984 in the upper troposphere.

2. Measurements

Number concentration and size distribution of Mie particle (aerosol particles with diameter greater than $0.3 \mu\text{m}$) were measured by using a light scattering aerosol particle counter. The particle counter is made to be suitable for the aircraft measurement in the upper troposphere. The photomultiplier detects the light scattered by individual aerosol particles in sampled air when they pass through the focal point of the optical system. The height of detected pulse is a function of size and refractive index of the particles, and the rate of pulse counting indicates the particle number concentration. The counter has two pulse height discriminators to differentiate the size of the particles having the diameter greater than $0.3 \mu\text{m}$ and $0.5 \mu\text{m}$, respectively, for the refractive index of 1.40. A rough indication of the size distribution is obtained from the count ratio of two size ranges.

Fig.1. Aircraft flight paths carried out in 1983 and 1984.

The construction and calibration of the counter are described in detail (Morita and Takagi, 1983). The thermal growth chamber was used for the measurements of aerosol particles with diameter less than $0.1 \mu\text{m}$ (condensation nuclei). The thermal chamber is based on the design of Jugal and Sem (1980). The small particles grow in the chamber to an optically active size and following the growth, the particle is counted individually by the light scattering aerosol particle counter.

Figure 1 shows the aircraft flight paths carried out in 1983 and 1984. The measurements covered the latitude range of about 30°N to 43°N , and sixteen vertical profiles and seven horizontal distributions of aerosols were obtained upto about 8 km over the northern and southern coastal areas of Japan islands. Merlin IV-A aircraft was used in the present measurements.

3. Results and Discussion

Though the measurements have been made over the northern and southern coastal areas of Japan islands, the present discussion concerns the results obtained from the measurements over Japan Sea. Altitude profiles of aircraft measurements versus latitude on Feb. 20, 1983 and on Feb. 14, 1984 are shown

Fig.2 (a). Altitude profiles of aircraft measurements versus latitude on Feb. 20, 1983. Thick lines show the tropopause height.

in Figures 2 (a) and (b). The thick lines indicate the position of the tropopause as determined by radiosonde temperature measurements made at the aerological stations at 0900 JST. On those days, stratospheric air intruded down into the troposphere. The aircraft entered the stratosphere and passed through the intruded air mass as is shown in Figures 2 (a) and (b). The atmospheric ozone was measured simultaneously with aerosols on those days. The ozone mixing ratio increased rapidly when the aircraft passed through

Fig.2 (b). Same as Fig.2 (a). Feb. 14, 1984.

Fig.3. Vertical profiles of Mie particle concentration on Feb. 20, 1983.

Fig.4. Vertical profiles of aerosol count ratio on Feb.20, 1983.

the intruded air mass (Muramatsu, 1984). This fact can be used as an indicator of air masses of stratospheric origin.

Figure 3 shows the vertical profiles of Mie particle concentration on Feb. 20, 1983. The concentration decreases exponentially with altitude up to about 6 km. It is important to note the difference above 6 km between two profiles of 1 and 2. Above about 6 km the concentration attains nearly constant value of about 0.1 cm^{-3} (profile 1). This concentration is thought to be a background level in this region. High aerosol concentration was observed in the stratospheric air mass (profile 2). Vertical profiles of aerosol count ratio on Feb. 20, 1983 are shown in Figure 4. Though the fluctuations of the profiles are observed throughout the altitude range, the average value is nearly constant with altitude except profile 2 which was obtained in the stratospheric air mass. The large count ratio of profile 2 indicates the presence of particles which are abundant in smaller size range than those usually appearing in the lower stratosphere. The volcanic eruption of Mt. El Chichon seems to be responsible for the large aerosol count ratio.

Figure 5 shows the vertical profiles of Mie particle and CN concentration on Feb. 14, 1984. The small increase in Mie particle concentration around 7 km was obtained in the stratospheric air masses. In the stratospheric air mass CN concentration decreases and attains nearly constant value of about 50 cm^{-3} . Figure 6 shows the vertical profiles of aerosol count ratio obtained on Feb. 14, 1984. In contrast with the measurements of 1983, the aerosol count ratio was found to be large in the troposphere and small in the stratospheric air mass. The small size ratio is similar to that of the background level at mid-latitudes (Hofmann and Rosen, 1981). This suggests that the influence of Mt. El Chichon eruption on the aerosol size distribu-

Fig.5. Vertical profiles of Mie particle and CN concentration on Feb. 14, 1984.

Fig.6. Vertical profiles of aerosol count ratio on Feb. 14, 1984.

tion near the tropopause has been disappearing at the time of the measurements of 1984.

In some cases, wide variations in aerosol concentration were observed in the vertical and horizontal measurements at altitudes of 5 - 6 km. The concentration varied from about 0.1 to 5 cm⁻³ at these altitudes. The variations were attributed to the influence of the local atmospheric pollution originated from land surface. The variations also reflect the different influences of transport, source intensity and various removal mechanisms. To understand the complex variations, systematic analyses of the origin and nature of the relevant air masses are warranted.

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