BALLOON-BORNE OBSERVATION OF AITKEN NUCLEI IN THE ANTARCTIC STRATOSPHERE AND TROPOSPHERE

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Abstract: The aerosol soundings were carried out at Syowa Station (69°00′S, 39°35′E), Antarctica in October 1983. The vertical distribution of concentrations of Aitken nuclei (particles larger than 0.002 μm in radii) up to 15 km in height was obtained at 1600 LT October 17 by use of the sonde which comprises an adiabatic expansion fog chamber with a photo-electric detector.

The main results are summarized as follows: The mixing ratio of Aitken nuclei higher than 1000/mg is observed around 750, 600, 300 and above 200 mb, whereas the surface value is a few hundreds/mg. The maximum mixing ratio is seen in the stratosphere just above the tropopause. The tropospheric high-concentration layer seems to exist commonly over Antarctica, whereas the high concentration in the stratosphere is peculiar to the present sounding.

The high concentration in the troposphere may give an evidence for the possible production of new particles through the photochemical gas-to-particle conversion process in the antarctic troposphere. The high concentration in the stratosphere, which may be partly attributed to the effect of eruption of El Chichón, may give an evidence for the possible occurrence of evaporation and recondensation of aerosol particles in the antarctic lower stratosphere.

1. Introduction

Aitken nuclei ($0.002 \leq r \leq 0.1$ μm) in the atmosphere are produced through gas-to-particle conversion processes and they grow in size by heterogeneous nucleation and other processes to produce larger aerosol particles. In the study of global background aerosol pollution, full knowledge on such aerosol processes in the global background atmosphere is essentially required. In this sense, it is important to examine the behavior of aerosols in a "clean" atmosphere which is not contaminated directly by aerosols and gases emitted from the earth's surface. The antarctic atmosphere is thought to be such a clean atmosphere. From an extensive surface observation of aerosols carried out at Syowa Station (69°00′S, 39°35′E), Antarctica, it has been revealed that various phenomena relating to long-range transports of trace constituents and/or photochemical processes resulting in production, or growth of aerosol particles are clearly observed in Antarctica (ITO and IWAI, 1981; IWAI *et al.*, 1981; ONO *et al.*, 1981; KOIDE *et al.*, 1981; ITO *et al.*, 1982; ITO, 1983, 1985). Furthermore, the importance of polar stratosphere in aerosol study has been recognized through recent works by ROSEN and HOFMANN (1983) and MCCORMICK (1985). However, the observation

of aerosols over Antarctica using an airplane or a balloon was quite rare (HOFMANN *et al.*, 1973, 1976, 1977; HOGAN, 1979).

As part of the Middle Atmosphere Program by the Japanese Antarctic Research Expedition, the year-round observation of gases and aerosols over Antarctica, was started in 1983 at Syowa Station, using lidar, FTIR, instrumented airplane, and aerosol sonde. This paper gives results of observation made by the balloon-borne Aitken nuclei sonde in 1983 at Syowa Station.

2. Instrument

For the balloon-borne observation of stratospheric Aitken nuclei, various types of sonde have been used. JUNGE *et al.* (1961) developed the sonde having an expansion fog chamber with a photographic recorder. The working fluid is water and the expansion ratio is about 1.25, so the supersaturation more than 300% is attained. A similar sonde was used by KASELAU *et al.* (1974). In these sondes, data were obtained after recovering the sonde. LANGER (1972) and ROSEN (1974) developed the sonde with the telemetering system which does not require recovery of the sonde and tedious data processing as the photographic recording type does. Langer's sonde comprises a mixing cloud chamber and an acoustic particle detector. The working fluid is water and the supersaturation is about 1%. Rosen's sonde comprises a thermal gradient diffusional growth chamber and an optical particle detector. The working fluid is glycol. The supersaturation was about 10% in early works, but recently increased up to 100–200% (ROSEN and HOFMANN, 1981).

Another type of Aitken nuclei sonde was reported by ITO *et al.* (1983). The sonde comprises an expansion fog chamber with a photoelectric detector and a telemetering system. The working fluid is water and the expansion ratio is 1.20, which produces the supersaturation of about 230%. The sonde is much small in weight as compared with the ROSEN's, which seems to be of great advantage in operations under severe condition as in Antarctica.

The concentration of nuclei is measured in terms of the maximum intensity of the light scattered laterally from a light pencil traversing fog which is produced by adiabatic expansion in the chamber. In such method, the calibration of nuclei counting is valid only for the measurement made under the constant expansion ratio and the constant temperature of air sample just before the expansion.

The fixed expansion ratio irrespective of the ambient pressure is an essential requirement for the measurement of Aitken nuclei concentration at different heights by balloon or airplane. In the present sonde an air sample is expanded by changing the volume of a fog chamber itself. Volume change is performed by moving a flexible ceiling of the chamber which is made of rubber film. Thus, the expansion ratio is kept at an constant value determined by a ratio of a chamber volume after expansion to that before expansion. The expansion with sufficient speed is also required to attain the supersaturation theoretically expected from the given expansion ratio. The present expansion method has much advantage in attaining sufficient expansion speed as compared with the method used by JUNGE *et al.* (1961) where the expansion is achieved by sliding a cylindrical piston.

The temperature of the fog chamber is conditioned by the waste heat from the water-activated battery which is used as a power source for the electronic circuit of the sonde. After a 30 s flashing of the chamber with fresh air sample, the sample is delayed in expanding for the pre-conditioning in humidity (100%) and temperature (about 20°C). Since the working fluid, that is, water boils at 20°C in the atmospheric pressure lower than about 25 mb, the present sonde is applicable to the altitude lower than about 25 km.

The signal of measured concentration is inserted into rawinsonde signal and transmitted to a ground station, every minute for 10 s. The total weight of a sonde is 8 kg, comprising a 4 kg fog chamber, a 3.5 kg battery and a 0.5 kg rawinsonde.

3. Observation

The sonde was flown with two 3 kg-rubber-balloons at 1600 LT on 17th October in 1983. During the sounding no cloud appeared over Syowa Station. The sounding was made for about 70 min until the battery of the sonde died. Since the resultant ascending velocity of the balloon was about 200 m/min, although 300 m/min was preferred, the concentration was obtained every 200 m or so from the surface to the height of about 15 km.

In Fig. 1, the location of Syowa Station marked on the 500 mb weather map for 1200 GMT on 17th October is shown. The time of this weather map is only one hour earlier than the aerosol sounding. According to the map, meridional exchange of air over East Antarctica is rather large but the air over Syowa Station seems to

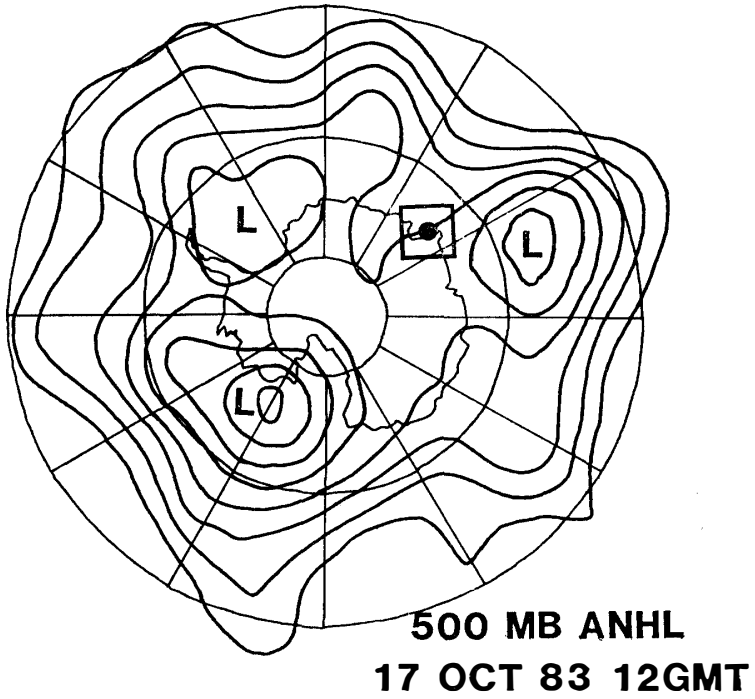

Fig. 1. Location of Syowa Station marked on the 500 mb weather map of 1200 GMT on 17 October 1983.

come from the interior of Antarctica and so the lower latitudinal maritime component in the air mass, if any, seems to have a long time history before reaching over Syowa Station. According to the vertical profile of wind velocity observed rawinsonde at Syowa Station showed that the entire troposphere over Syowa Station was in the southern wind regime since two days before the aerosol sounding, supporting above inferrance.

4. Result and Discussion

Figure 2 shows the vertical profile of mixing ratio of Aitken nuclei obtained by the sounding in 1983. The vertical profile of air temperature measured by the same sonde is also shown in Fig. 2. According to the temperature profile, the tropopause is placed at 200 mb (about 10 km) in height.

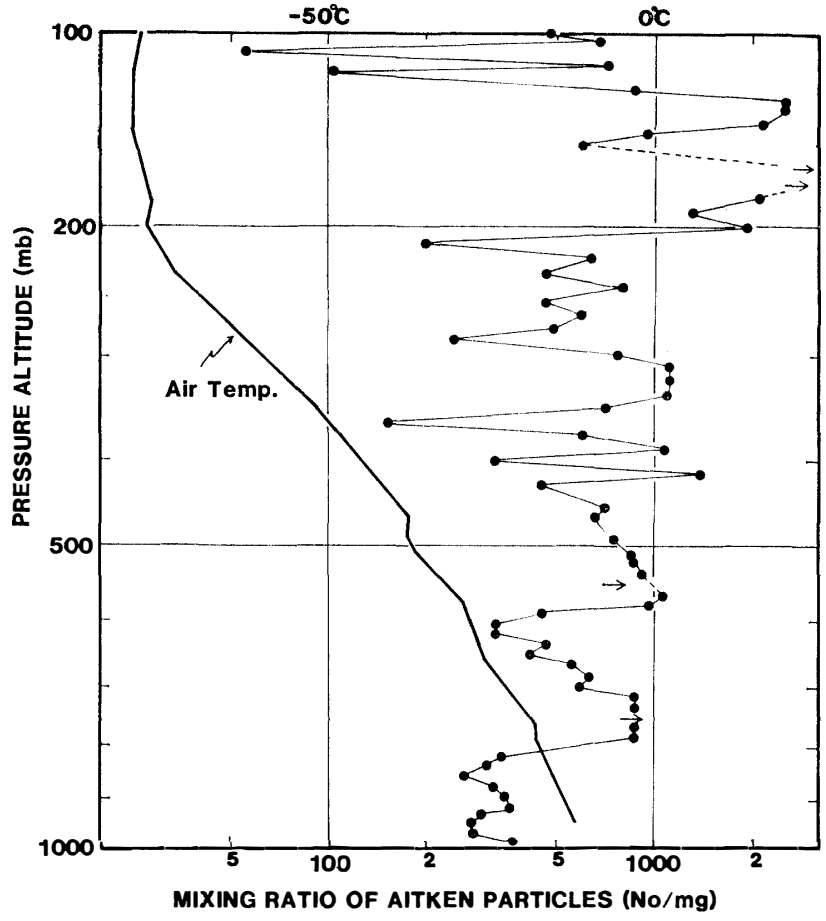

Fig. 2. Vertical distribution of mixing ratio of Aitken nuclei and air temperature over Syowa Station on 17 October 1983.

In the figure it can be seen that the vertical variation of concentration is quite systematic, and random fluctuations of individual measurements are rather infrequent. This fact seems to indicate that the whole system of the sonde including the automatic

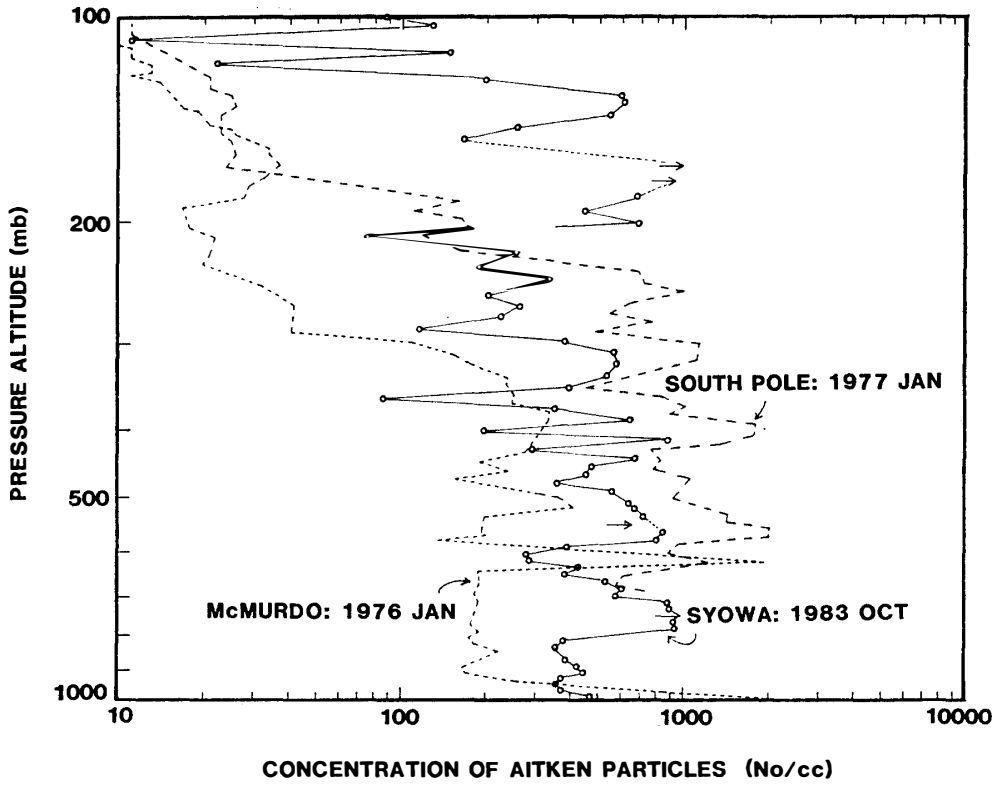

Fig. 3. Comparison of vertical distribution of concentration of antarctic Aitken nuclei.

Aitken counter worked properly. Fluctuations seen in the layer between 500 and 200 mb is probably present as natural phenomena.

The main results can be summarized as follows: The mixing ratio of Aitken nuclei higher than 1000/mg is seen around 750, 600, 300 and above 200 mb, whereas the surface value is a few hundreds/mg. The maximum mixing ratio is seen in the stratosphere just above the tropopause.

In Fig. 3, the previous results obtained at McMurdo in January 1976 and at South Pole in January 1977 by HOFMANN *et al.* (1976, 1977) are reproduced as well as the present result.

4.1. Tropospheric aerosols

It can be seen that the results at McMurdo, South Pole, and Syowa give a quite similar vertical profile of nuclei concentration in the troposphere. The tropospheric average concentration in the present result is comparable with those in the previous results. The high-concentration layers in the troposphere are also seen in the previous results. The high-concentration layer over Antarctica has been also found in the aircraft observation by HOGAN (1979). Thus the tropospheric high-concentration layer seen in the present result seems to be commonly existing in the antarctic troposphere at least in the sunlit months.

The vertical distribution showing rather systematic alternation of high and low concentrations tends to reject the view that the high-concentration aerosols in the antarctic troposphere are transported from the stratosphere by the subsiding current of antarctic direct circulation.

ITO and IWAI (1981) reported the event of sudden increase in Aitken particle concentration, that is, the non-anthropogenic aerosol enhancement which implies surface concentrations of antarctic Aitken particles smoothly increased up to more than 1000 /cc from a few hundreds/cc in hours. The increased component of particles had radii smaller than 0.005 μm and had the volatile nature for which particles evaporate by the heating up to 500°C. In order to explain the cause of the phenomena, they assumed the high-concentration aerosol layer existing in the antarctic troposphere. If the high-concentration layer observed in the present sounding corresponds to that assumed by ITO and IWAI (1981), the particles in the layer would be of ultra fine and volatile ones, being similar to those prevailing in the sudden increase event in the antarctic surface air.

The volatile nature of particles means that the particles are probably produced through the gas-to-particle conversion processes. The ultra fine nature of the particles means the particles are produced quite recently, say, within a few days. According to Fig. 1, the air over Syowa Station were essentially of an antarctic origin. Thus it seems reasonable to consider that the high-concentration aerosol layer commonly seen in the antarctic troposphere is formed through gas-to-particle conversion processes in the antarctic troposphere.

4.2. Stratospheric aerosols

The most important finding in the present sounding is that the high-concentration layer with nearly 1000/cc is seen in the lower stratosphere. This finding gives a quite different figure as compared with the previous results. It has been reported by many researchers that the world stratosphere has been contaminated since 1979 by the large volcanic eruptions. The stratospheric high concentration in the present result may also be attributed to contamination due to volcanic eruption which increased since 1979. It is worthy to note that the present finding of the stratospheric high concentration gives an evidence of formation of Aitken nuclei in the stratosphere. The latest volcanic eruption which is confirmed to have injected large amounts of material to the stratosphere is of El Chichón in April 1982. In the stratosphere, it is hard to consider that SO_2 from El Chichón survived more than fifteen month which is the period between the El Chichón eruption and the present sounding in the stratosphere. Therefore, it seems reasonable to consider that the high-concentration Aitken particles in the stratosphere detecetd by the present sounding is probably attributed to the re-nucleation of sulphuric acid vapor produced by evaporation of large particles. The dramatic increase and decrease in stratospheric temperature usually occurring in the antarctic spring must be playing an important part in such aerosol processes. The quite sophisticated numerical model of stratospheric aerosols has been developed by TURCO *et al.* (1979). The model, however, cannot predict the production of Aitken nuclei in the stratosphere. In order to assess the volcanic effect on stratospheric aerosols, the numerical model including the process of the Aitken nuclei formation in the stratosphere is required.

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