A-1.3.1 Observational Study on the Variability of Aerosols and Ozone Layer

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Introduction

Total ozone has been considerably decreasing since late 1980's in middle and high latitude regions in the northern hemisphere. Anthropogenic halogen compounds, CFCs, halons, and so on, are primarily responsible for the negative trends of ozone. However, stratospheric aerosols such as Polar Stratospheric Clouds (PSCs), volcanic aerosols and background sulfate aerosols should have been contributing the observed ozone decrease. Contributions of these aerosols are different with time, region and altitude. Therefore, we have been observing vertical profiles of ozone and aerosols in Spitzbergen, Yakutsk in Eastern Siberia, Alaska, Hokkaido and Tsukuba in winter. Parts of these observations were carried out in the framework of SESAME (Second European Stratospheric Arctic and Mid-latitude Experiment) including the cooperation between the National Institute for Environmental Studies (NIES) and the Central Aerological Observatory (CAO). In this report, we describe the activities of the national institutes and universities in Table 1.

Table 1. Aerosol and ozone observations carried out in this research

Principal Investigators	Institutions	Stations
Y. Iwasaka	Solar Terrestrial Laboratory (STEL), Nagoya University	Fairbanks (Alaska) Ny-Alesund (Spitzbergen)
T. Itabe	Communications Research Laboratory (CRL)	Wakkanai and Kushiro (Hokkaido)
T. Ito, O. Uchino	Japan Meteorological Agency (JMA)	Tsukuba
H. Nakane, V. Yushkov	National Institute for Environmental Studies (NIES) Central Aerological Observatory	Yakutsk (East Siberia)

2. Lidar measurements of the vertical profiles of aerosols at Fairbanks, Alaska and Ny-Alesund, Spitzbergen Island

Lidar measurements at Fairbanks, Alaska (64° 49'N, 147° 52'E) and Ny-Alesund, Norway (78° 54'N, 11° 53'E) in December 1991 and January, 1994, respectively, was made to monitor distribution of stratospheric aerosols. The lidar system is composed of a Nd-YAG laser and a 35 cm ϕ cassegrainian receiving telescope.

Observations were made only on clear days to avoid noise from haze and clouds. About 6000 lidar return shots were integrated in order to obtain a profile of aerosol content. The error range is 10 % or less at 25 km. About 20 profiles were observed as routine measurements in a day, and averaged values of those profiles were chosen as the representative profile of that day.

The location of Fairbanks lidar site is advantageous to see the effect of polar vortex wall to stratospheric aerosol density distribution since the lidar site is near the polar vortex wall, and sometimes inside and sometimes outside of the polar vortex owing meandering motion of polar vortex. Lidar site of Ny-Alesund is usually inside of the polar vortex in winter. Comparison of measurements at Fairbanks and Ny-Alesund showed that polar vortex meandering disturbed profiles of stratospheric aerosol content.

Above about 20 km there was little aerosol content when the lidar station was inside of polar vortex. Aerosol load on the local tropopause showed large changes which may associate with aerosol descending from the stratosphere to the troposphere near the wall of polar vortex. On the end of February, 1994, aerosol content of layer peak of Fairbanks was apparently smaller than that of Ny/Alesund even though both lidar stations were inside of the polar vortex. Active erosion of stratospheric aerosols may occur through wave motions near
the edge of the polar vortex (Bauer et al., 1994).

3. Lidar measurements of the vertical profiles of aerosols at Wakkanai and Kushiro in Hokkaido

We made lidar observations at Wakkanai from August 1991 and at Kushiro from December 1994 to investigate the movement of the stratospheric aerosols and the effect of the heterogeneous reaction on the surface of aerosols to ozone destruction. The aerosol layers originating from the eruption of Mt.Pinatubo increased conspicuously from October 1991 and decreased from 1993. The movement of the stratospheric aerosols seems to relate to trends of NO_2 and ozone. This suggests that the stratospheric aerosols play an important role in ozone chemistry. We will continue lidar observations in Hokkaido (Wakkanai and Kushiro) and make a comparative study of lidar data and satellite data.

4. Measurements of the vertical profiles of ozone by ozone sondes at Tsukuba

JMA started ozone sonde observation at the Aerological Observatory, Tsukuba in 1968. The observation is carried out every Wednesday routinely and providing the important data for the research of ozone trend. We made the additional observations between January and April from 1994 to 1996 at the Aerological Observatory to clarify the state of stratospheric ozone depletion over the Northern hemisphere in this research. They were held as a part of the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME). Although observed ozone profiles show large day-to-day changes, we can see low amount of ozone in altitude range of 19 to 26 km compared with the long-term means.

5. Measurements of the vertical profiles of ozone and aerosols at Yakutsk in Eastern Siberia

Simultaneous balloon measurements of the vertical profiles of ozone and aerosols were carried out at Yakutsk (62 °N, 130 °E) in Eastern Siberia during the Second European Arctic and Mid-latitude Experiment (SESAME) in winter 1994/1995. Ozone sondes and backscatter sondes measurements were carried out by cooperation between National Institute for Environmental Studies (NIES) and Central Aerological Observatory (CAO) and the measurement of the size distribution of aerosols using a balloon-borne optical particle counter, by cooperation among NIES, CAO and Solar Terrestrial Laboratory (STEL) of Nagoya University.

Simultaneous balloon measurements of ozone and aerosol density were carried out on January 14, February 21, March 1 and March 16 using ECC ozone sondes and aerosol backscatter sondes. On March 1, an optical particle counter (OPC) was also launched using another balloon to measure size distribution of aerosols. Yakutsk was inside the polar vortex on February 21 and March 16, outside the polar vortex on March 1, and at the edge of it on January 14. Examples of the vertical profiles of ozone, temperature and aerosols is shown in Fig. 1. Those vertical profiles show following differences between inside and outside the polar vortex:

(1) Ozone density (partial pressure) in the lower stratosphere was high outside the vortex and at the edge of the vortex. Its peak value sometimes exceeded 200 nbar. Ozone density was almost half inside the polar vortex in the lower stratosphere (15 km - 20 km).
(2) Temperature was much lower around 17 km inside the polar vortex.
(3) Aerosol layers had an upper edge at 18.5 km on February 21 and at 14.5 km on March 16 km inside the polar vortex, while aerosol density (scattering ratio) decreased gradually with altitude outside the polar vortex.

Figure 1 also shows fine structures in ozone and aerosol profiles and negative correlation between ozone and aerosols below the edge of the aerosol layer mentioned in (3), and positive correlation above the edge. On March 1, the layer with low ozone and high aerosol density was clearly shown at 14.5 km.

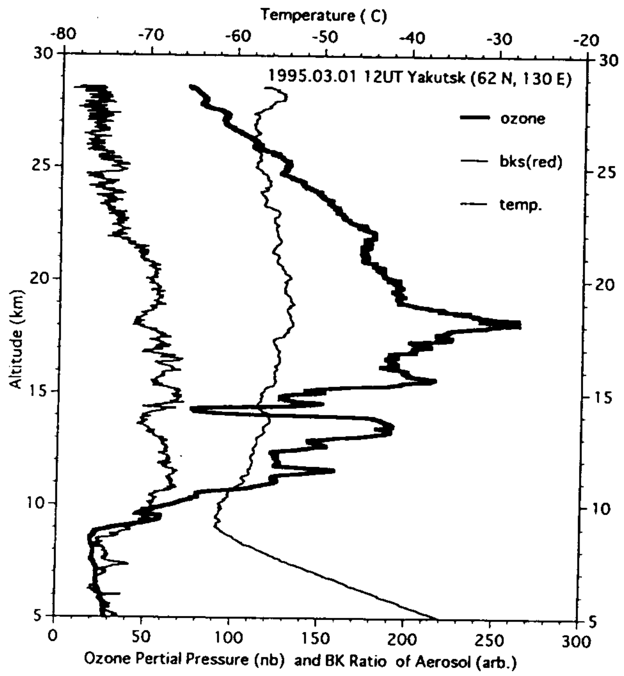
These observed results can be understood consistently when we assume the following structures of aerosols inside and outside of the polar vortex. Ozone density was lower inside the polar vortex in the lower stratosphere in winter and spring 1995. Subsidence is one possible mechanism to make the upper edge of the aerosol layer inside the polar vortex. In this case, the speed of subsidence can be calculated from the height of the upper edge (= Zc) of the aerosol layer observed on February 21 and on March 16, which was 0.2 km/day. In the polar vortex, aerosol density was lower above Zc and higher below Zc compared to those outside the polar vortex. Therefore, there should be negative correlation between aerosol and ozone profiles below Zc if there is exchange of air through the wall of the polar vortex at a certain altitude. Such negative correlation can be seen easily between the vertical profiles of ozone and aerosols obtained on March 1, 1995 in Fig.1.

As the layer at 14.5 km with thickness of about 1.5 km has lower ozone density, higher aerosol density and lower temperature than those of adjacent layers, this thin layer should have come from the polar vortex. The size distribution measured by the OPC on the same day also support the above assumption. The vertical profile of aerosol mass mixing ratio for aerosols with diameters larger than 3.6 μm has its peak at 14 km and that with diameters smaller than 3.6 μm has its local minimum at the same altitude. This means that the airmass in this thin layer was very much different from that in the adjacent layer.

Potential vorticity maps (PV maps) and backward trajectories at the potential temperature levels of 400 K(14.5 km) and 550 K(21.5 km) were made using the Japan Meteorological Agency (JMA) Global Analysis data and the data analysis system STRAS (Stratospheric Research Assisting System) developed in the National Institute for Environmental Studies (NIES). The PV maps shown do not have fine structures corresponding to the thin layer at 14.5 km. However, the boundary of the polar vortex at 400 K is obscure near Yakutsk which seams to allow small scale transport through the boundary of the polar vortex. On the contrary, the boundary of the polar vortex at 550 K is clear. Backward trajectory from Yakutsk moved only outside the polar vortex. This means that the JMA Global Analysis data, as well as other global analysis data, does not have enough vertical resolution to reproduce the movement by thin layer shown above. In other words, the balloon observation demonstrated its capability to give information about the small scale interactions between the air inside and outside the polar vortex.

The balloon experiment in Yakutsk during SESAME implicates the existence of a transport process from the Arctic polar vortex to the outside of it by thin layers. We should examine the role of these small scale transport processes to the interactions between inside and outside the Arctic polar vortex by further experiments using balloon, ground-based and satellite observations.

(a)



(b)

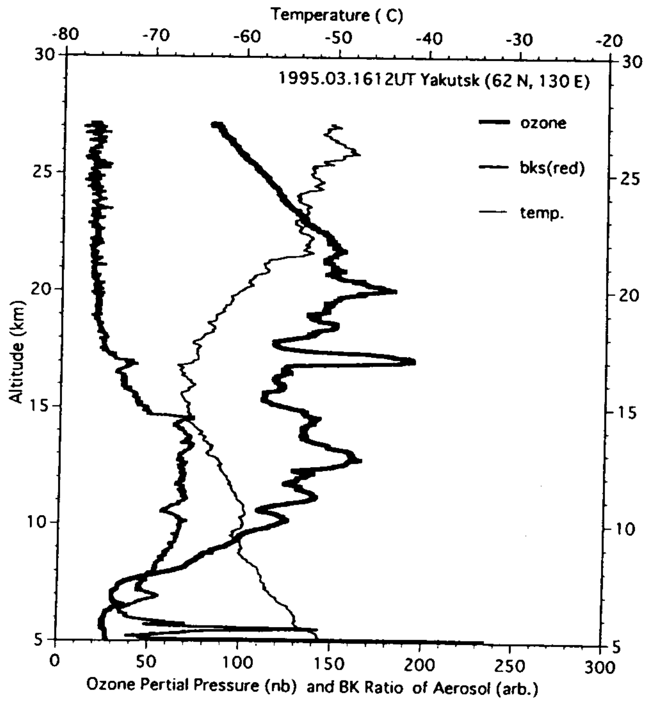


Fig.1 Simultaneous measurements of the vertical profiles of ozone, temperature and aerosol density by balloon experiments in Yakutsk (62 N, 130 E) on March 1 (a; outside the polar vortex) and on March 16 (b; inside the polar vortex).