A-3.5 Analytical Study of Ground-base and Satellite-base Measurements of Polar Stratospheric Aerosols

Contact person Kohei Mizutani
Chief
Optical Remote Sensing Section, Global Environment Division
Communications Research Laboratory
Nukui-Kitamachi 4-2-1, Koganei, Tokyo 184-8795, Japan
Tel: +81-42-327-6955 Fax: +81-42-327-6667
E-mail: mizutani@crl.go.jp

Total Budget for FY1999 - FY2000 16,355,000 Yen (**FY2000**; 8,245,000 Yen)

Abstract It is shown from lidar observation at Hokkaido that the recent stratospheric aerosol load is nearly background level after 1998. Appearances of liquid PSC layers at Eureka in January 1996 were well simulated by Carslaw's chemical thermodynamic model of ternary solution aerosols. The newest retrieval (version 5.20) of the Improved Limb Atmospheric Spectrometer (ILAS) on board the Advanced Earth Observing Satellite (ADEOS) captured more than 60 polar stratospheric cloud (PSC) profiles (with about 200 events) during the winter and early spring of 1997 in the Northern Hemisphere. Comparisons with the theoretically predicted values revealed that the ILAS observed typical type 1b PSCs on January 19th and 20th. Most of the PSCs observed late in the PSC season had features of type 1a PSCs. Polar stratospheric aerosols observed over Dome F in 1997 were investigated and classified from size distribution and back-scattering properties of aerosols. Altitude in which each pattern of PSCs appeared are limited, and they seem to have deep relation of amount of pre-existing particles.

Key Words stratospheric aerosols, PSCs, ILAS, optical properties, lidar

1. Introduction

Stratospheric aerosols affect the atmospheric radiation processes and the chemical processes in the stratosphere. It is recognized that polar stratospheric clouds (PSCs) play an important role in ozone destruction over the polar regions in the early spring as a result of heterogeneous reactions occurring on their surface, which convert inactive reservoir chlorine into active chlorine. We will, here, investigate the movement, conditions of PSCs events, and optical properties of high latitude and polar stratospheric aerosols with the ground based data obtained by lidar and balloon-borne Optical Particle Counter (OPC) and global data by satellite sensors as ILAS.

2. Research Method

(1) Lidar Observation in Hokkaido

Lidar observations in Hokkaido started at Wakkanai and Rikubetsu (Kushiro) after the eruption of Mt.Pinatubo. These systems observe the height profiles and depolarization profiles of aerosols at 532nm and 1064nm in the northernmost region of Japan, where the degree of reduction of the ozone layer is the greatest in Japan and airmasses origination in the Polar Regions pass several times in the winter season.

(2) Observations of PSCs at Canadian Arctic

Lidar measurements of the stratospheric aerosols in the Canadian Arctic is made at Eureka Station (80° 00′ N, 85° 50′ W). We used a Mie Lidar and OPC for the measurements of the stratospheric aerosols. The lidar is designed to measure height distribution of the aerosol backscatter and depolarization at two wavelengths, 1064nm and 532nm. In this study, we analyzed the data obtained in the observation focusing on characteristics of PSCs. Further, we compared the results of the analysis with a chemical thermodynamic model of ternary solution aerosols, which was proposed by Carslaw[1].

(3)Analysis of satellite sensors data about polar stratospheric aerosols

Winter 1996/1997 is well known for its long-lasting polar vortex and significant ozone loss over the Arctic, and the ILAS measurements of aerosols and other gas species were the only spaceborne measurements made on a regular basis (14 times daily) during that period. We used 780-nm extinction data with nitric acid data observed with ILAS to investigate PSC occurrence in the winter and to characterize the observed PSC particles. The 780-nm extinction and nitric acid data were compared with theoretically predicted values assuming the existence of STS, NAD, and NAT. Mie theory was applied to convert the ILAS 780 nm extinction into volume, based on two different size distribution functions. The theoretical particle volume for the formation of STS and the amount of remaining gaseous nitric acid were calculated by applying Carslaw's analytic expression[1]. The vapor pressures of nitric acid in equilibrium over NAD and NAT and their particle volumes were calculated based on Hanson and Mauersberger[2] and Worsnop et al.[3], respectively.

(4)Comparison of the polar stratospheric aerosol data in East Antarctica with ILAS data

Characteristic size, phase, composition, and so on were estimated by comparison between size distributions, ranging from 0.15 to 1.8 μm in radius, obtained with in-situ balloon-borne observation and backscattering property observed with a Lidar, at Dome Fuji (77°S, 40°E, 3810m a.s.l.). Classification of PSCs was also examined with those parameters. Size distributions of pre-existing particles are also investigated by comparison between extinction estimated from in-situ OPC observation and that observed by ILAS, in Antarctic summer.

3.Result and Discussion

(1)Long-term variation of the stratospheric aerosols

The amount of aerosols in the stratosphere, which increased with the eruption of Mt.Pinatubo in June 1991, decreased till 1998 and seems now to have returned to its steady state. Then, the aerosols originated from Mt.Pinatubo eruption still affected the aerosol data in 1996 and 1997 which is investigated here.

(2)PSCs at Canadian Arctic

PSCs layers were appeared in the lidar data of 1996 at Eureka . Comparing the scattering ratios and depolarization ratio, we realize that the large value of the scattering ratio do not coincide with the appearance of the large depolarization ratio. This means that the layers with large scattering ratio were mostly composed of liquid particles, and duration of such layers was not so long as that of solid particles which showed large depolarization ratio for more than one week. We compared the results of the analysis with a chemical thermodynamic model, which was proposed by Carslaw[1]. The results show a good consistency. Then, liquid PSC layers were well simulated by Carslaw's chemical thermodynamic model of ternary solution aerosols.

(3)Analysis of the stratospheric aerosol data obtained over Arctic with ILAS

In mid-January of 1997 ILAS data, both the extinction coefficient and the nitric acid level of the observed PSC events agreed with the theoretical values for STS quite well. They showed that the enhanced volume corresponds to the decrease in the ambient nitric acid, suggesting the uptake of nitric acid into particles as STS particle form. The ILAS observed typical type 1b STS PSCs over a wide vertical range on January 19th and 20th. Although a few PSCs were observed in March, most of the characteristic PSC events in the late PSC season were categorized as NAD or NAT (type 1a PSCs).

The 20-day isentropic backward trajectory was calculated using ECMWF temperature data to examine the thermal conditions in synoptic scale for the observed PSC particles. The temperature histories of the PSC events were consistent with formation theory of liquid or solid particles. From mid-February to early March, some PSC events that were observed with significantly low nitric acid had experienced temperatures around T_{ice} or lower for a fairly long time before the measurements. Most of the solid particle events seemed not to have been influenced by any mountain-induced lee waves, and their formation could be interpreted from their synoptic-scale temperature histories.

(4) Comparison of the polar stratospheric aerosol data in East Antarctica with ILAS data

1) Classification of PSCs based on size distribution

PSCs, observed with OPC and Lidar simultaneously, are classified into following four patterns based on size distribution characteristics (Fig 1).

Pattern A: composed of large amount of sub-micron particles with steep size distribution and super micron particles with low concentration, which shows high depolarization ratio

Pattern B: composed of small amount of sub-micron particles with steep size distribution and super-micron particles with low concentration, which shows high depolarization ratio

Pattern C: composed of a large amount of sub-micron particles with gentle size distribution, which shows low depolarization ratio

Pattern D: composed of a middle amount of sub-micron particles with gentle size distribution and super micron particles with low concentration, which shows high depolarization ratio

Pattern A and B are well-known PSCs, composed of ice or nitric acid hydrate particles. Pattern C is also well-known PSCs, composed of super cooled liquid particles containing nitric acid. Pattern D seem to be composed of ice or nitric acid hydrate particles. Altitude in which each pattern of PSCs appeared are limited, and they seem to have deep relation of amount of pre-existing particles.

2) Size distribution of pre-existing polar stratospheric aerosols

Extinction for 780nm calculated from in-situ observation of size distribution are compared with that observed by ILAS. To calculate extinction, size distributions for full radius range are assumed to have mono-modal or bi-modal log-normal size distributions, with fitting to in-situ observation for size range of 0.15-0.6 um in radius. They show rather good agreement to each together, but estimated extinction values seem to be lower than observed ones systematically. Investigation for size distribution of extinction suggests that the reason is brought by uncertainty of concentrations in smaller size than that of observed by OPC.

References

1) Carslaw, K. S., et al., Geophys. Res. Lett., 22, 1877-1880, 1995.
2) Hanson, D., and K. Mauersberger, Geophys. Res. Lett., 15, 855-858, 1988.
3) Worsnop, D.R., et al., Science, 259, 71-74, 1993.

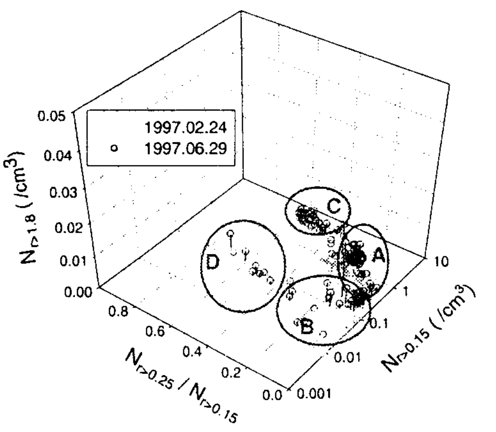

Fig.1 Classification of the stratospheric aerosols into four patterns based on size distribution characteristics observed by OPC in 1997 at Antarctica.