Proc. NIPR Symp. Polar Meteorol. Glaciol., **8**, 19–26, 1994

AEROSOL OPTICAL DEPTH OBSERVATIONS BY JARE-33 AND JARE-34 IN 1991 AND 1992

Susumu KANETO, Takayuki KISHI and
Meteorological Staff of 33rd* and 34th** Japanese Antarctic Research Expeditions

Japan Meteorological Agency, 3–4, Otemachi 1-chome, Chiyoda-ku, Tokyo 100

Abstract: To reveal the latitudinal distribution of atmospheric turbidity enhanced by the eruption of Mt. Pinatubo in June 1991 and Mt. Hudson in August 1991, aerosol optical depth at 5 wavelengths was observed with a portable sunphotometer (EKO MS-120) in November to December of 1991 and 1992. The observations were made from Tokyo to Syowa Station, east Antarctica on the icebreaker SHIRASE and on the route from Syowa Station to Dome-F, about 1000 km inland. Another sunphotometer observation has been continued at Syowa Station since 1985. The main results of these observations are as follows.

From onboard observations, aerosol optical depth at 500 nm in November and December of 1991 reached about 4 times the 1979 or 1987 level in the region of the equator. That of 1992 is still about 2 times the 1979 or 1987 level. The 1991 observations show two peaks corresponding to two volcanic eruptions.

From Syowa Station observations, a remarkable increase of aerosol optical depth was seen in late 1991 and a gradual decrease followed it.

The aerosol optical depth on the route from Syowa Station to Dome-F in October to December of 1992 is almost the same as that at Syowa although the largest distance was 1000 km. In early December of 1992, a temporary increase of aerosol optical depth was seen.

1. Introduction

In June 1991, Mt. Pinatubo in the Philippines erupted and injected enormous amounts of volcanic ashes and gases into the atmosphere. After the eruption, many atmospheric phenomena related to it have occurred. In August 1991, Mt. Hudson in southern Chile erupted. The direct solar radiation decreased remarkably, for example, at Syowa Station (69°S, 40°E, 18 m), the decrease reached 20% in December 1991 (JAPAN METEOROLOGICAL AGENCY (JMA), 1993).

To clarify atmospheric turbidity, sunphotometer observations are recommended by the WMO (1978). The sunphotometer uses interference filters and a photo-diode detector. From these observations the aerosol optical depths on some wavelengths can be determined. At Syowa Station, the observations were done in 1980 (MATSUBARA and KAWAGUCHI, 1983) and 1984 (SHIOBARA *et al.*,

*Kazumasa MATSUHARA, Yoshitomo KOJOH, Takayuki KISHI, Hiroshi IGARASHI and Keishiroh HIGASHIJIMA.

**Toshinori TAKAO, Jinji KOIKE, Yoshihiro KAMATA, Okimasa SUGITA and Keizoh SAKURAI.

1987), and the observations have been continued as part of routine meteorological observations since 1985. Furthermore, observations on board the icebreakers Fuji and Shirase from Japan to Antarctica were done in 1979 (Matsubara *et al.*, 1983) and 1987 (JMA, 1990).

After the eruption of Mt. Pinatubo, the onboard observations were prepared and carried out. In addition to this, the 33rd Japanese Antarctic Research Expedition (JARE-33) has started a new Ice Sheet Deep Drilling Project in Antarctica. Meteorological staff cooperated with this program, and the sunphotometer observations were done on the route from Syowa Station to "Dome-F" (78°S, 40°E, 3810 m), the drilling point.

2. Data

Figure 1 shows the observation points in 1991 and 1992. The onboard observations from Tokyo to Syowa were done from November 14 to December

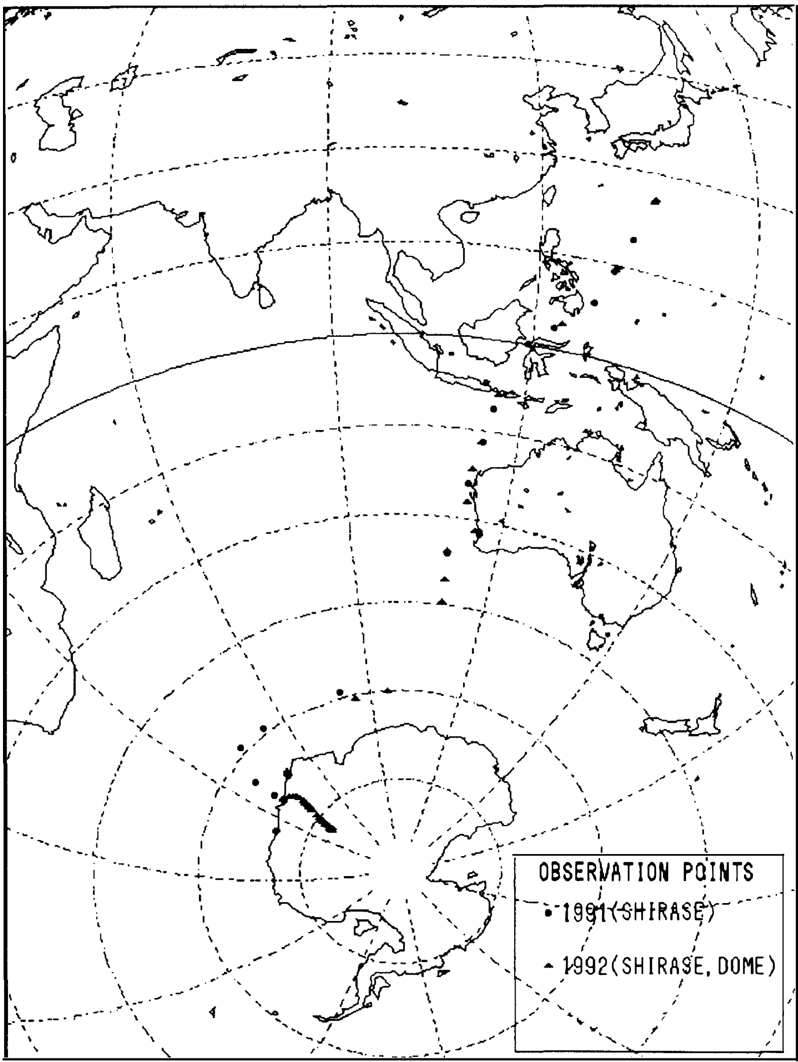

Fig. 1. Observation points from Japan to Antarctica in 1991 and 1992.

20 in both 1991 and 1992. Inland observations from Syowa were started on September 17, 1992, reached Dome-F on October 28 and returned to Syowa on December 24.

The sunphotometer used onboard and inland is an EKO MS-120S type. Its nominal pass wavelengths are 368, 500, 675, 778 and 862 nm. The instrument is portable; pointing to the sun is done by hand. But it has a peak hold function to make observation of peak values easy. The observations were generally done at 30 to 20°C onboard and at 20 to 10°C during inland observations; the correction was done using the temperature correction factor for each wavelength.

At Syowa, an EKO MS-110 type sunphotometer was used on the sun tracker. Its nominal pass wavelengths are 368, 500, 675, 778, 862 and 938 nm. The last wavelength, not provided on the MS-120S, is on the H_2O absorption band and is used to estimate precipitable water. The instrument has a temperature control system; observations are done at constant temperature.

The sunphotometer observations provide relative measurements of sun irradiance. The instrument's constant J_0, the extraterrestrial irradiance output at the mean sun-earth distance, is determined by simultaneous observation with a reference instrument or by self evaluation (Langley plot (WMO, 1978)). The J_0s of both instruments used here were determined by Langley plots; the relative optical air mass (M) change through the morning or afternoon observations was greater than 3 and the smallest M was less than 3.

The sunphotometer output, intensity of solar radiation (J) is shown in a functional formula, $J=J_0/S\cdot\exp\,(-(\tau_R+\tau_O+\tau_A)\cdot \mathrm{M})$. Here, τ_R is the optical depth for molecules, τ_O is the optical depth for ozone and τ_A is the aerosol optical depth; and S is the correction factor for the mean sun-earth distance. The values of τ_R and τ_O for each wavelength are taken from WMO (1978). The observations were done when the relative optical air mass was less than 6.

All the data obtained by onboard, inland and Syowa observation after 1985 have been reported in Antarctic Meteorological Data Volume 26–33 by JMA (1987–1994).

3. Results and Discussion

Figure 2 shows the result of onboard and inland observations of aerosol optical depth at 500 nm. The turbidity in 1979 and 1987 is the result of observations of clean atmosphere not affected by volcano (MATSUBARA *et al.*, 1983; JMA, 1990). In these years, the turbidity in the Northern Hemisphere was about 0.1 and that in the Southern Hemisphere varied from 0.05 to 0.02 near the Antarctic coast. The peak value of aerosol optical depth observed near the northwest coast of Australia (15°S to 20°S) in 1979 is considered to have originated from the continent (shown by hatching in Fig. 2). In 1987 at the same position, the high value was observed. The aerosol optical depth of 500 nm in November 1991 reached about 2 to 4 times the 1979 or 1987 level in the Northern Hemisphere and equatorial region. In the Southern Hemisphere, the aerosol optical depth shows a minimum near 30°S and maximum at 60°S in

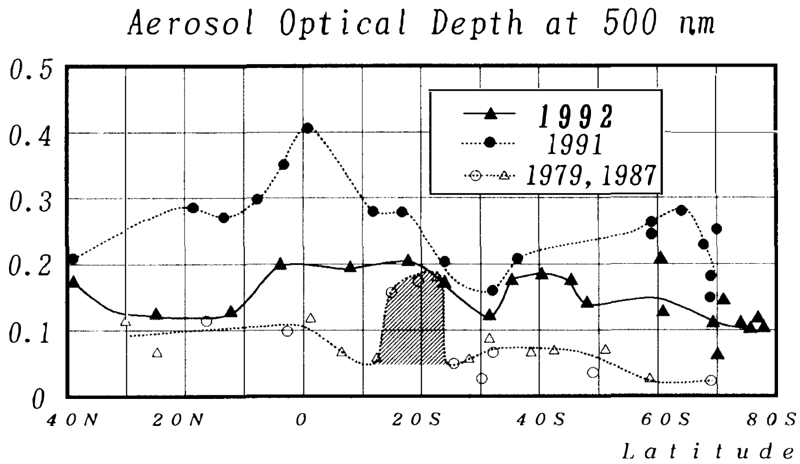

Fig. 2. Latitudinal distribution of aerosol optical depth at 500 nm, mainly using daily representative values. The data near 40°N are the results at Ryori, northern Japan in both November 1991 and 1992 (JMA, 1993, 1994). The data from 30°N to 70°S are the results from JARE research vessels in November and December of 1979 (MATSUBARA et al., 1983), 1987 (JMA, 1990), 1991 (JMA, 1994) and 1992 (to be published). The data south of 70°S are from inland observations from October to December, 1992 (JMA, 1994). Hatched data originated on the Australian continent (MATSUBARA et al., 1983).

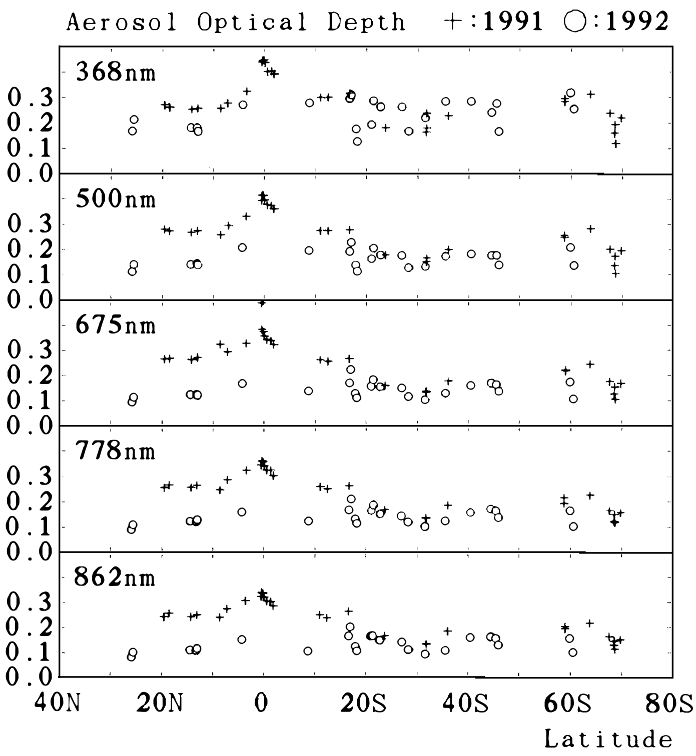

Fig. 3. Aerosol optical depth of 1991 and 1992 from onboard observations at each wavelengths (All data of M<3 are used).

December 1991. NOAA/CAC (1991) reported from satellite observations of aerosol optical depth in November 1991 that the Pinatubo SO_2 cloud extended to about 20°S and another SO_2 cloud belt from Hudson was seen south of 40°S. The onboard observation result of 1991 at Fig. 2 matches this report very well. In November and December of 1992, the aerosol optical depth was still about 2 times or more the 1979 or 1987 level except near 20°N, but was much lower than in 1991. The minimum near 30°S was also seen in 1992 but the cause is not clear.

Figure 3 shows the aerosol optical depths at each wavelength in 1991 and 1992 obtained by onboard observations. In the Northern Hemisphere, at shorter wavelengths the decrease from 1991 to 1992 was small but at longer wavelengths it was large; in the Southern Hemisphere, at all wavelengths it was small.

Figure 4 shows the time series of monthly results at Syowa Station for each wavelength. In the polar region, the background atmospheric turbidity is very small; the aerosol optical depth at 500 nm is 0.01 to 0.03 (*e.g.*, SHAW, 1982; YAMANOUCHI, 1982). At Syowa in 1985, the influence of the Mt. El Chichon eruption in 1982 was still seen; from 1986 to early 1991, the atmospheric turbidity remained at background level (Table 1). In late 1991, a remarkable increase of aerosol optical depth is seen. At 368 nm, the turbidity reached 5 times the background level and the monthly minimum value gradually decreased; at 500 nm, 10 times the background appeared in November; at 675, 778 and 862 nm, the November peak was about two times that of October and the monthly

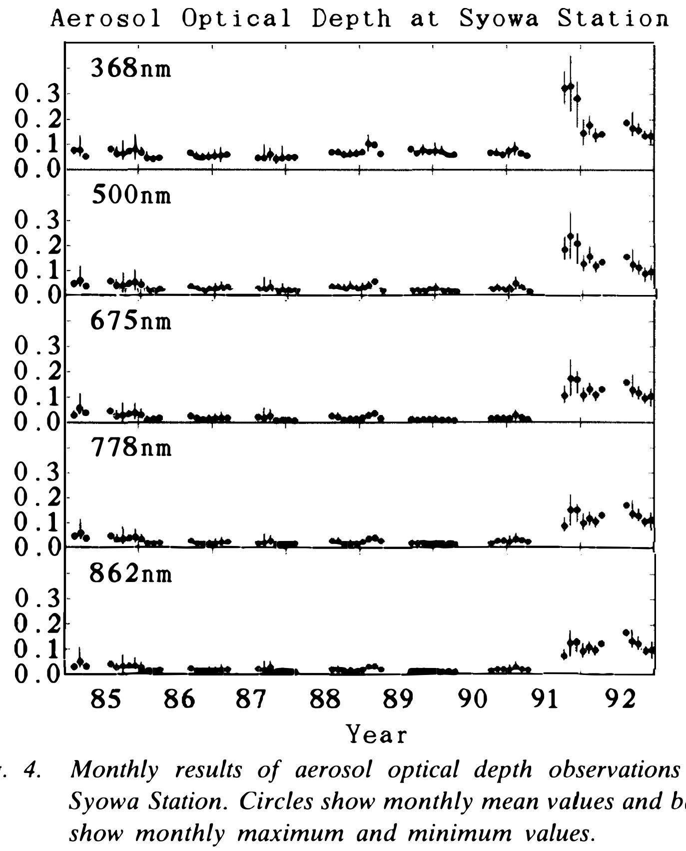

Fig. 4. Monthly results of aerosol optical depth observations at Syowa Station. Circles show monthly mean values and bars show monthly maximum and minimum values.

Table 1. Background values of aerosol optical depth at Syowa Station, averaged from 1986 to 1990.

Wavelength (nm)	368	500	675	780	862
Aerosol optical depth	0.060	0.027	0.016	0.021	0.017

minimum value had increased. The turbidity in December agrees with the results of onboard observations near 70°S. In early 1992, the turbidity at each wavelength remained at almost constant level, about half that in late 1991. During late 1992, the turbidity gradually decrease at all wavelengths, but the start value of this period is larger than that of the end of early period of 1992. This discontinuity shows the complex influence of two volcanic eruptions at Syowa. A possible explanation of the turbidity change at Syowa is that, Hudson influenced levels in late 1991 which quickly decreased especially at shorter wavelengths; then Pinatubo influenced levels from mid 1992 which then gradually

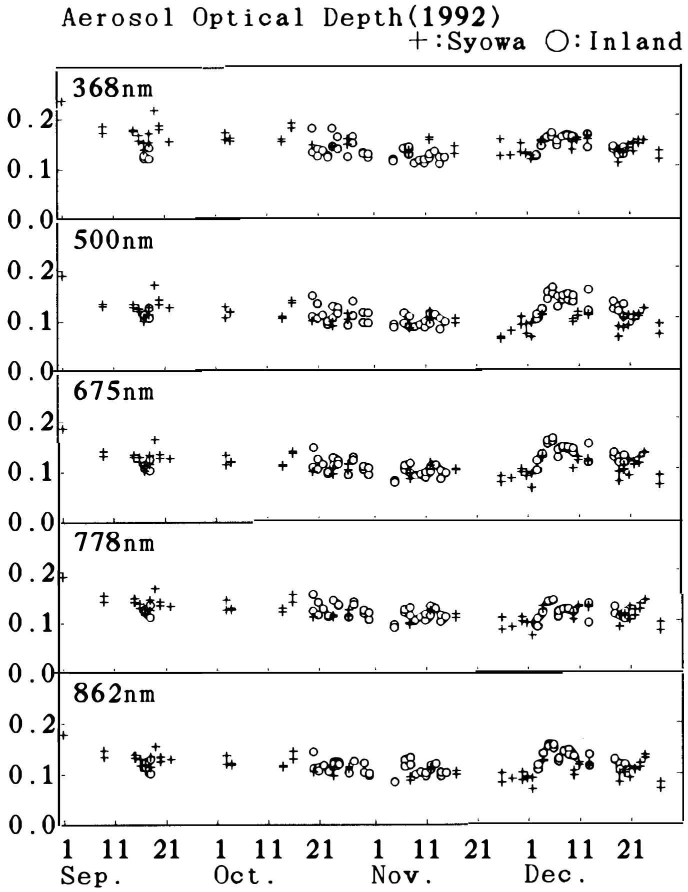

Fig. 5. Aerosol optical depths from September to December 1992 observed by the Syowa fixed instrument and the portable inland one (daily maxima and minima are shown). The September data are results of simultaneous observations at Syowa.

decreased at all wavelengths. Unfortunately, the polar night season interfered the sunphotometer observations; the details are not clear.

Figure 5 shows the turbidity, from September to December 1992, of two sunphotometer observations, the Syowa fixed instrument and the inland moving one. September observations were done at Syowa Station. The result is that except for the 368 nm data, the two instruments' data are in good agreement. October to December inland data were obtained on the route from Syowa to Dome-F and return to Syowa. The maximum distance of two observation points was about 1000 km in the latitudinal direction; the maximum height difference reached 3800 m. The aerosol optical depth observed by the two instruments nearly agreed. In this period, the atmospheric turbidity was about 5 times the background level. This high turbidity observed even at the 3810 m height point shows that the aerosol amount under the 3800 m level is negligible at the polar inland region. Generally, at all wavelengths, the aerosol optical depth decreased in this period. In December 1992, there was temporary variation of aerosol optical depth at both point. The data seem to show that the inland turbidity is higher than that at Syowa. This discrepancy may be explained partly by the horizontal distribution of aerosols.

4. Summary

Aerosol optical depth observations at 5 wavelengths were done with a portable Sunphotometer (EKO MS-120S) to reveal the latitudinal distribution from Japan to Antarctica. A continuous series of observations of aerosol optical depth were done at Syowa Station. The summary of this study is as follows.

(1) From onboard observations, aerosol optical depth at 500 nm in November and December of 1991 reached about 4 times the 1979 or 1987 level in the region of the equator. That of 1992 was still about 2 times the 1979 or 1987 level. Two peaks of aerosol optical depth for 1991 near 20°N and 60°S correspond to the Pinatubo and Hudson eruptions. From 1991 to 1992, in the Northern Hemisphere, the decrease of aerosol optical depth at shorter wavelengths was small while at longer wavelengths the decrease was large; in the Southern Hemisphere, at all wavelengths it was small.

(2) From Syowa Station observations, inter-annual variation of aerosol optical depth at 500 nm shows remarkable increase at the end of 1991 and gradual decrease in 1992. At the shorter wavelengths the decrease was large but at the longer wavelengths it was not. This is opposite to the changes in the Northern Hemisphere.

(3) The aerosol optical depth on the route from Syowa Station to Dome-F in October to December 1992 is almost same as that at Syowa despite the large departure distance of 1000 km. In early December of 1992, temporary variation of aerosol optical depth was seen.

Acknowledgments

We thank all the JARE members for their effort to obtain the data at Syowa Station and on the route to Dome-F Camp. The authors are also grateful to Dr. T. YAMANOUCHI, National Institute of Polar Research, and to an anonymous referee for useful comments in revising this paper.

References

JAPAN METEOROLOGICAL AGENCY (1987–1994): Antarctic Meteorological Data, Vol. 26–33.

JAPAN METEOROLOGICAL AGENCY (1993, 1994): Annual Report of Background Air Pollution Observations 1991, 1992.

MATSUBARA, K. and KAWAGUCHI, S. (1983): Spectral extinction measurement by sunphotometer at Syowa Station, Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **29**, 85–93.

MATSUBARA, K., OHATA, T. and KAWAGUCHI, S. (1983): Turbidity over the Indian Ocean. Mem. Natl Inst. Polar Res., Spec. Issue, **29**, 77–84.

NOAA/CAC (1991): Climate Diagnostic Bulletin, December 1991.

SHAW, G. E. (1982): Atmospheric turbidity in the polar regions. J. Appl. Meteorol., **21**, 1080–1088.

SHIOBARA, M., TANAKA, M., NAKAJIMA, T. and OGAWA, H. (1987): Spectral measurements of direct solar radiation and the sky brightness distribution at Syowa Station, Antarctica. Atmospheric Radiation, Progress and Prospects. Beijing, Science Press, 629–637.

WMO (WORLD METEOROLOGICAL ORGANIZATION) (1978): International Operations Handbook for Measurement of Background Atmospheric Pollution. rev. version. Geneva, WMO, 110p.

YAMANOUCHI, T. (1982): Derivation of atmospheric turbidity at Mizuho Station, Antarctica from broadband solar radiation measurements. Mem. Natl Inst. Polar Res., Spec. Issue, **24**, 1–12.

(Received December 27, 1993; Revised manuscript received May 23, 1994)