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RESULTS OF OZONESONDE OBSERVATIONS AT SYOWA STATION IN 1990

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Abstract: Ozonesonde observations were carried out at Syowa Station in 1990 by meteorological members of the 31st Japanese Antarctic Research Expedition (JARE). The ozone continued to decrease rapidly from August to October. The ozone was destroyed almost completely between 80 and 100 mb during the first ten days of October. The monthly mean of total ozone amount was the lowest ever observed at Syowa Station in August and September. The severe ozone depletion with ozone hole in 1990 was close to those in 1987 and 1989.

We note that polar stratospheric clouds (PSCs) were observed at Syowa Station in winter. We estimated the height of PSCs from the angle between bright PSC edges and the sun. The heights were between 15 and 20 km. When PSCs appeared, the extreme cold region under −83°C, enough for occurrence of type 2 PSCs, was observed with stratospheric soundings.

1. Introduction

CHUBACHI (1984) reported low total ozone amount from September to October at Syowa Station in 1982. FARMAN *et al.* (1985) also reported the same ozone decrease at Halley Bay Station. STOLARSKI *et al.* (1986) showed that Antarctic ozone depletion covered a very extended area in winter and spring using observations from the Total Ozone Mapping Spectrometer (TOMS) on the Nimbus-7 satellite and the ozone depletion area (ozone hole) had begun by the end of the 1970's.

SOLOMON *et al.* (1986) noted that extreme cold temperature in the Antarctic winter and spring leads to PSCs occurrence. The ozone depletion was caused by heterogeneous reactions on the surface of PSC, when sunlight returned in the Antarctic spring.

At Syowa Station the total ozone amount has been observed with a Dobson spectrophotometer since 1961 and the vertical ozone profile has been observed by ozonesonde since 1965 except for several years. We observed the total ozone amount and launched 49 ozonesonde from February 1990 to January 1991 at Syowa Station.

In this paper, we present the annual variation of vertical ozone profile in 1990. In addition, collected ozonesonde data will be published by the JAPAN METEOROLOGICAL AGENCY (1992). We report on the appearance of PSCs which were observed at Syowa Station during June–August 1990.

2. Observation

2.1. Ozonesonde observation

The vertical ozone profile was observed with a ozonesonde of electrochemical type, Meisei KC-79. This is the wet-chemical type, using KI (potassium iodide) solution.

We launched 49 ozonesonde from February 1990 to January 1991. We launched ozonesonde every several days from August to November when the ozone hole appeared, and in the other months from 1 to 4 times a month.

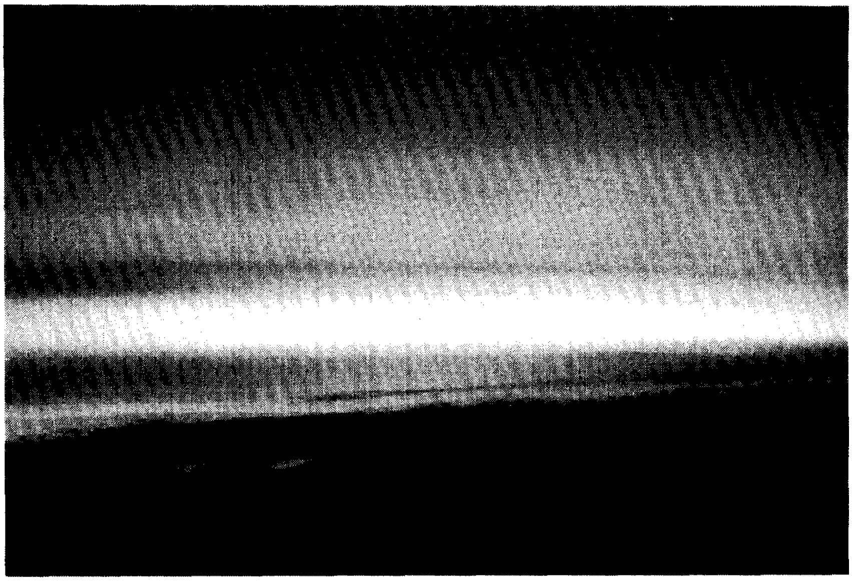

Fig. 1. Bright PSCs after sunset on July 13, 1990 at Syowa Station and the dark clouds (Ci and Ac) in troposphere over the horizon.

2.2. PSCs

We made meteorological observations every day. We sometimes observed PSCs which was bright gold before sunrise or after sunset in a clear sky in winter. Figure 1 shows the PSCs on July 13, 1990 at Syowa Station. When it was taken, the sun was 4.9° below the horizon. PSCs extended like a mist or Cs (cirrostratus), sometimes with a slight stripe. The stripe almost paralleled the horizon. But we couldn't observe the wave patterns of PSCs which are sometimes observed in the Arctic.

When the sun is below the horizon, the sun lights only objects high above the sea. So we can estimate the height of the bottom of PSCs when we know the elevation angle of the bright PSCs edge and the sun. The height H can be obtained from eq. (1).

$$H = \frac{\tan\phi}{\tan\theta + \tan\phi} \times \frac{1-\cos\theta}{\cos\theta} \times R, \tag{1}$$

Where R is the radius of the earth, and ϕ and θ are the elevation angles of PSCs and the sun. In Fig. 2, we show the relation between the height of PSCs bottom

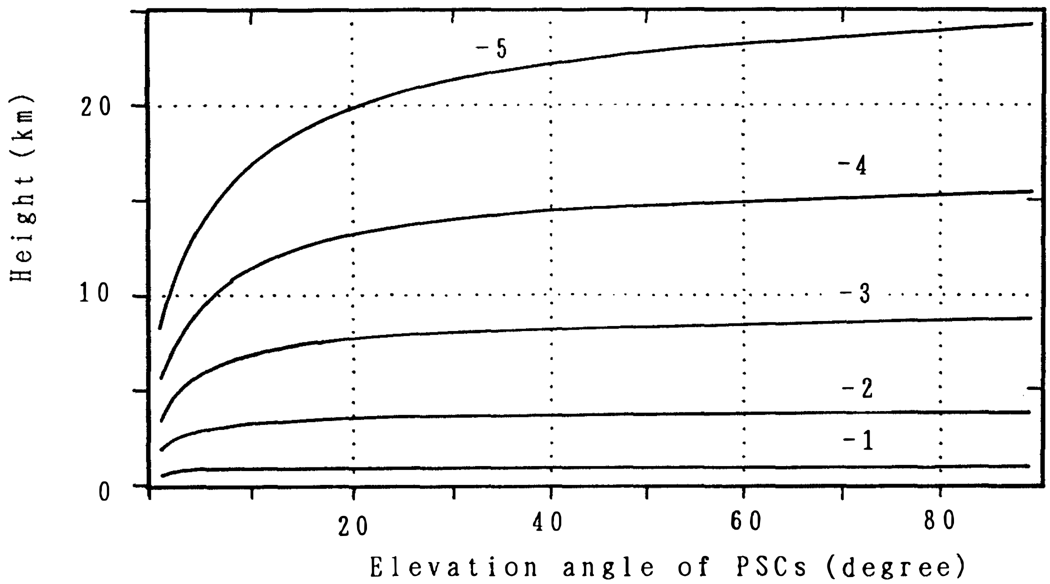

Fig. 2. The height of PSCs bottom and the elevation angle of the bright PSCs edge for sun elevation angles of −1, −2, −3, −4 and −5°.

and the elevation angle of the bright PSC edges for sun elevation angles of −1, −2, −3, −4 and −5°. When Fig. 1 was taken, the elevation angle of PSC was 23° and that of the sun was −4.9°. So the height of the PSC is estimated at 20 km.

Since PSCs are very thin compared with clouds in troposphere, the edge of the PSC bright region is not clearly detected. The PSC angle, thus, contains an error of a few degree.

3. Result and Discussion

3.1. Annual variation of ozone

3.1.1. Total ozone amount

Figure 3 shows the annual variations of daily total ozone amount and 30 mb temperature at 00 UTC. Total ozone amount was observed with a Dobson spectrophotometer and the temperature was observed with rawinsonde at Syowa Station. Total ozone amount couldn't be obtained in July because it was cloud every day.

Total ozone amount varied between 250 and 350 m atm-cm during February-June. But ozone decreased tapidly from the last ten days of August towards the middle ten days of October. The monthly mean of total ozone amount recorded lowest ever observed at Syowa Station in August and September. From TOMS, the ozone hole was over Syowa Station during the same time. Total ozone amount suddenly increased in the middle ten days of October. Then the monthly mean of total ozone amount was close to the normal mean.

Figure 4 shows the TOMS map in the southern hemisphere on October 10, 1990 when Syowa Station (dot shows its location) was covered by the ozone hole.

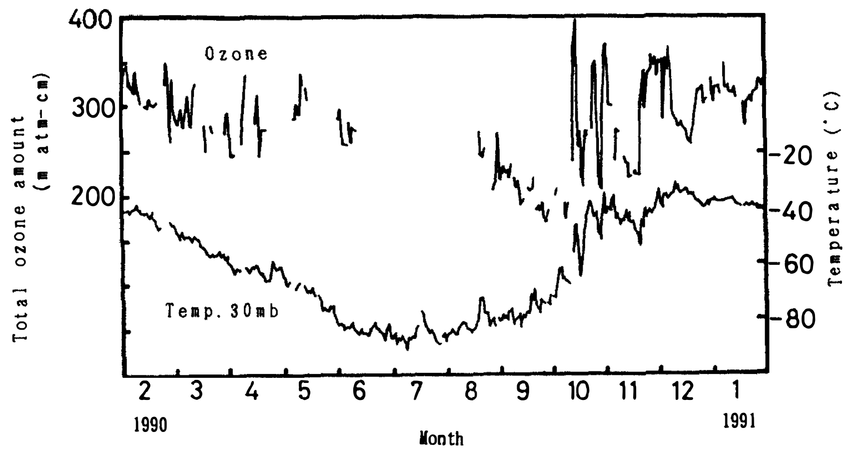

Fig. 3. The annual variation of daily total ozone amount (m atm-cm) and the temperature (°C) of 30 mb at 00 UTC at Syowa Station.

Fig. 4.

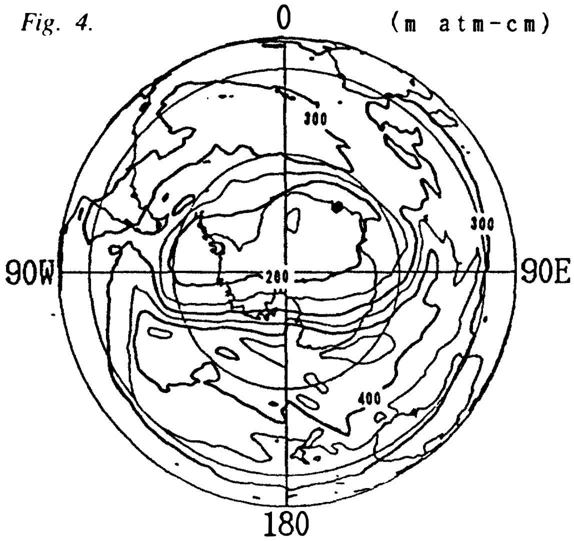

Fig. 5.

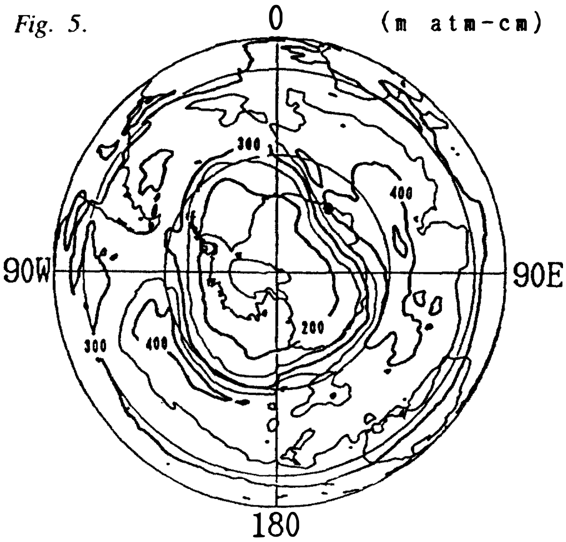

Fig. 4. TOMS total ozone (m atm-cm) for the southern hemisphere on October 10, 1990 (low ozone at Syowa Station). Dot shows the location of Syowa Station.

Fig. 5. TOMS total ozone (m atm-cm) for the southern hemisphere on October 16, 1990 (high ozone at Syowa Station).

Figure 5 shows the TOMS map on October 16, 1990 when Syowa Station was out of the ozone hole and the ozone rapidly increased. Total ozone amount varied very much after the middle ten days of October. Due to extensive planetary wave activity, Syowa Station had been influenced for a few days by mid-latitude air with high ozone and high temperature. A close positive correlation exists between ozone and 30 mb temperature. The ozone hole remained until December 1990.

3.1.2. Vertical ozone profile

Figure 6 shows the annual variation of vertical ozone profile observed with ozonesonde at Syowa Station. In this figure, contours are ozone partial pressure in units of nb and the dots at the bottom line show the days of ozonesonde

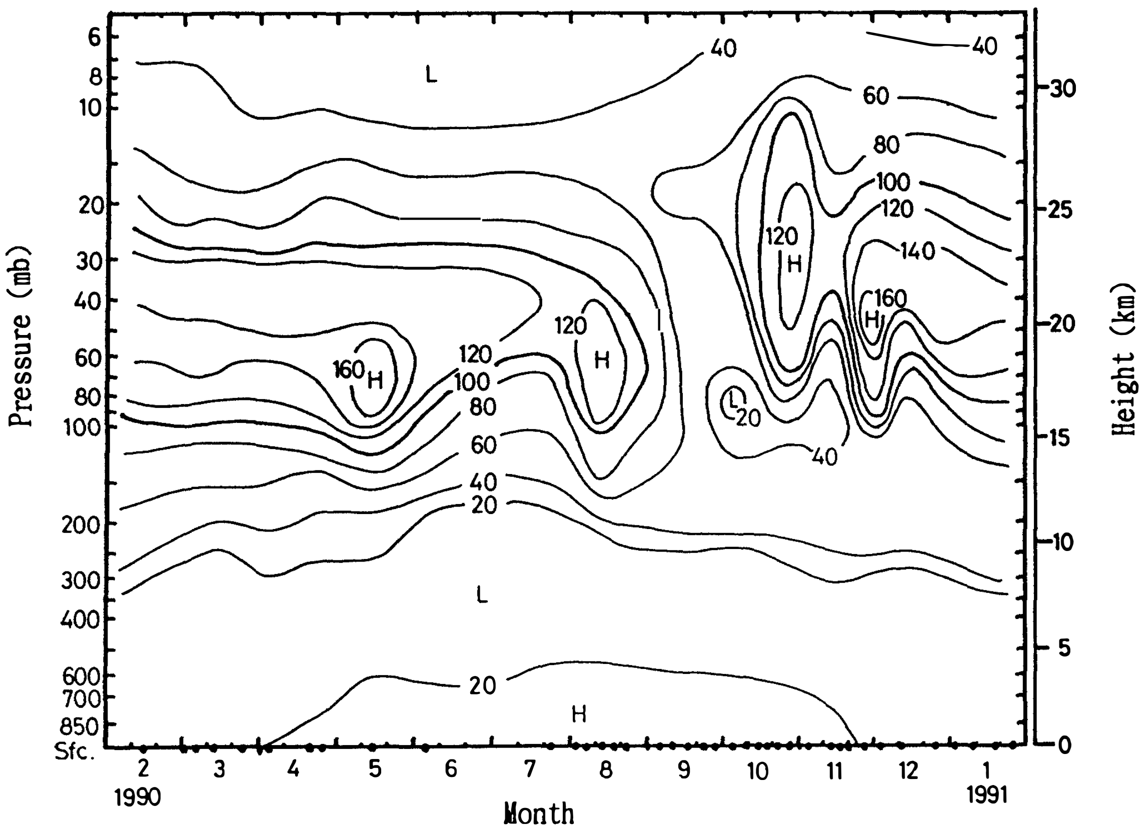

Fig. 6. *The annual variation of partial ozone pressure (nb) profile observed with ozonesonde at Syowa Station. Dots show ozonesonde observation days.*

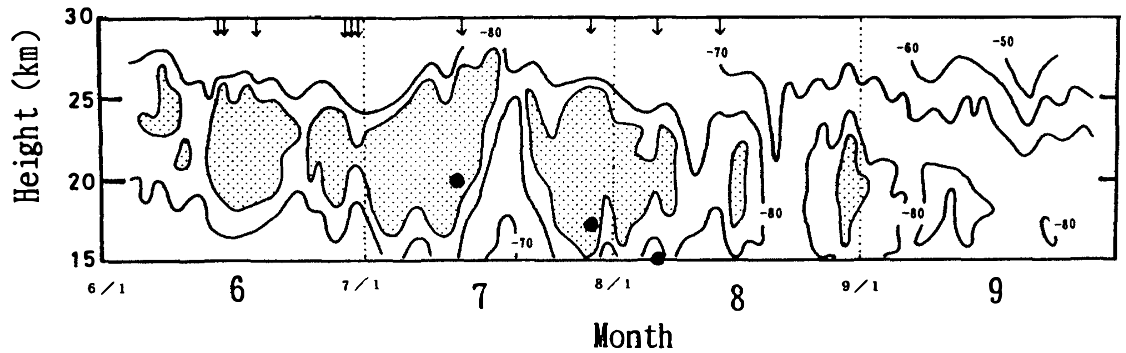

Fig. 7. *The vertical temperature (°C) profile observed with rawinsonde at Syowa Station in 1990. Extreme low temperature below −83°C are shaded. Arrows show days on which PSCs were observed and dots show the heights of PSC bottoms.*

observation. To show the annual variation, contours are smoothed. There was little variance between February and July. The high ozone partial pressure region in the stratosphere between 30 mb and 70 mb disappeared from August to October. The ozone hole was over Syowa Station during the period. The low ozone region descended from 30 mb to 100 mb and the high ozone region began to appear in the upper area from September.

In the last ten days of October, the maximum ozone region appeared again around 30 mb after the subsequent stratospheric warming. The low ozone region about 100 mb remained until November, which is considered to be the influence of the ozone hole. After the last subsequent stratospheric warming in the last ten days of November, the ozone recovered to close to normal. But the poor ozone air in the lower stratosphere between 100 mb and 400 mb remained until January.

3.2. PSCs

Figure 7 shows the vertical temperature profile observed with rawinsonde at Syowa Station from June to September. Arrows show the days when we observed PSCs. We observed PSCs between June 11 and August 14. We could only observe PSCs when there were few clouds in the sky and the sun was about 5° below the horizon. We can't recognize PSCs, when these conditions are not satisfied. So there might have been PSCs when we couldn't observe them. When we observed PSCs, there was a low temperature region under −83°C, enough for occurrence of type 2 PSCs, except on August 14. And this low temperature region descended during winter.

Dots in Fig. 7 show the estimated heights of bottoms of PSC. The heights were about 20 km on July 13, about 17 km on July 28 and about 15 km on August 6. The temperatures at each height were −86°C, −86°C and −79°C. The temperate on August 6, −69°C, was higher than −83°C, but lower than −78°C, enough for occurrence of type 1 PSCs.

Iwasaka *et al.* (1986) reported that high concentrations of aerosol were observed between 15 km and 20 km during June–August at Syowa Station with lidar measurements and aerosolsonde observations. We estimated only 3 cases, in which the heights of PSC bottoms varied between 15 km and 20 km.

Acknowledgments

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