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OZONESONDE MEASUREMENTS AT SYOWA STATION (69°00′S, 39°35′E): PRELIMINARY RESULT

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Abstract: Ozonesonde measurements at Syowa Station (69°00'S, 39°35'E) from 1971 to 1984 showed that ozone depletion was most striking in the altitudinal region of 10 to 25 km for the spring of the last five years. This ozone loss region corresponded to the region where a noticeable temperature drop was observed, also only in the spring, from 1981 to 1985.

The comparison of the change in temperature field of the Antarctic stratosphere with that in the other regions suggests the possibility that the changes with a long time scale of about 10 years in the global-scale temperature field (and possibly with the dynamical systems in the stratosphere) are associated with the Antarctic ozone depletion in the last 10 years or so.

1. Introduction

The rapid drop in total ozone during the Antarctic spring reported by FARMAN *et al.* (1985) has led many atmospheric physicists and chemists to postulate a number of theories on the drop. Many investigators pointed out that the decline of total ozone in the last ten years was well correlated with the decline of the stratospheric temperature (*e.g.*, ANGELL, 1986; NEWMAN and SCHOEBERL, 1986). These previous studies were made on the basis of total ozone observations but not of ozonesonde observations.

Also the previous comparisons of the Antarctic ozone with the stratospheric temperature were limited mainly to the Antarctic stratosphere. If we wish to find out whether or not a global-scale air motion affects the ozone depletion in Antarctica, it would be helpful to examine the temperature field changes on the global scale.

The purpose of this short paper is to present the results of the ozonesonde measurements at Syowa Station from 1966 to 1985, and to discuss the long-range temperature decline in the Antarctic stratosphere from the viewpoint of global temperature changes.

2. Ozone Measurement

In Fig. 1, trends in the total ozone measured at Syowa Station from 1966 to 1986 are shown in Dobson unit (10^{-3} atm·cm). The decrease in total ozone in the

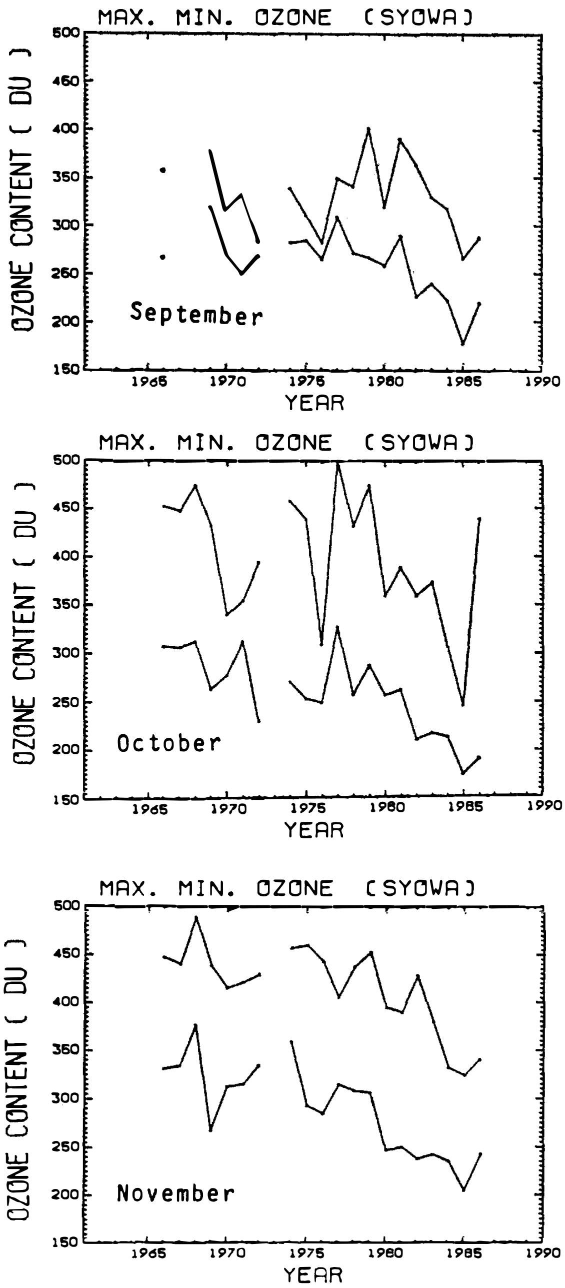

Fig. 1. Trend of monthly maximum and minimum total ozone contents measured by Dobson spectrometer at Syowa Station (69°00′S, 39°35′E) for September, October and November. Unit is in Dobson unit (10^{-3} atm·cm).

Antarctic spring is noticeable for the past 10 years. Most of previous discussions on the depletion were based mainly on the total ozone measurements. However, these measurements were inadequent to study the processes controlling the ozone depletion in the Antarctic spring and information on the vertical profiles of ozone content and its variations has been required. A series of ozone sonde measurements was intensively carried out at Syowa Station (69°00′S, 39°35′E) in 1982 (CHUBACHI, 1984). The results showed distinct seasonal changes in the ozone content profiles but these could not cover the changes on the time scale longer than one year.

The monthly-averaged ozone profiles of 1966–1970, 1971–1975, 1976–1980, 1981–1984 are shown in Fig. 2 on the basis of ozonesonde measurements which had

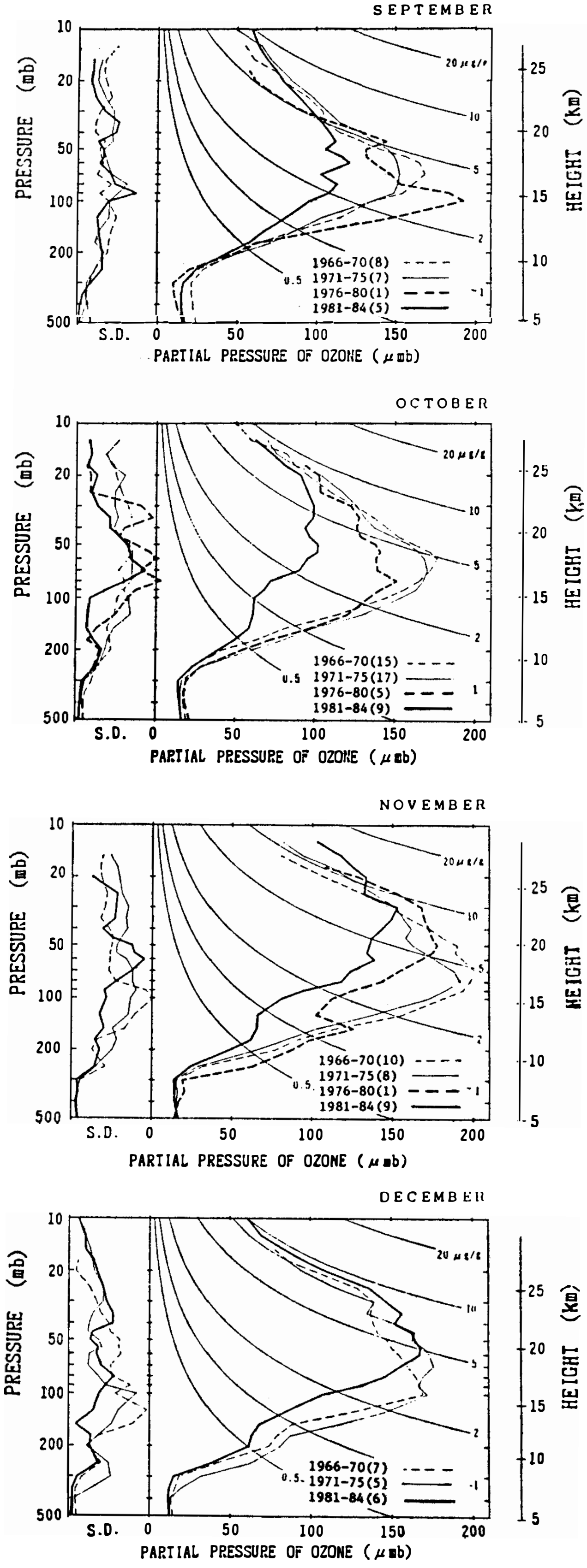

Fig. 2. Vertical profiles of ozone content measured at Syowa Station in spring (from September to December). Curves show monthly-averaged values for the periods of 1966 to 1970, 1971 to 1975, 1976 to 1980 and 1981 to 1984. Standard deviations of the ozone values are also shown in the left part of the figures.

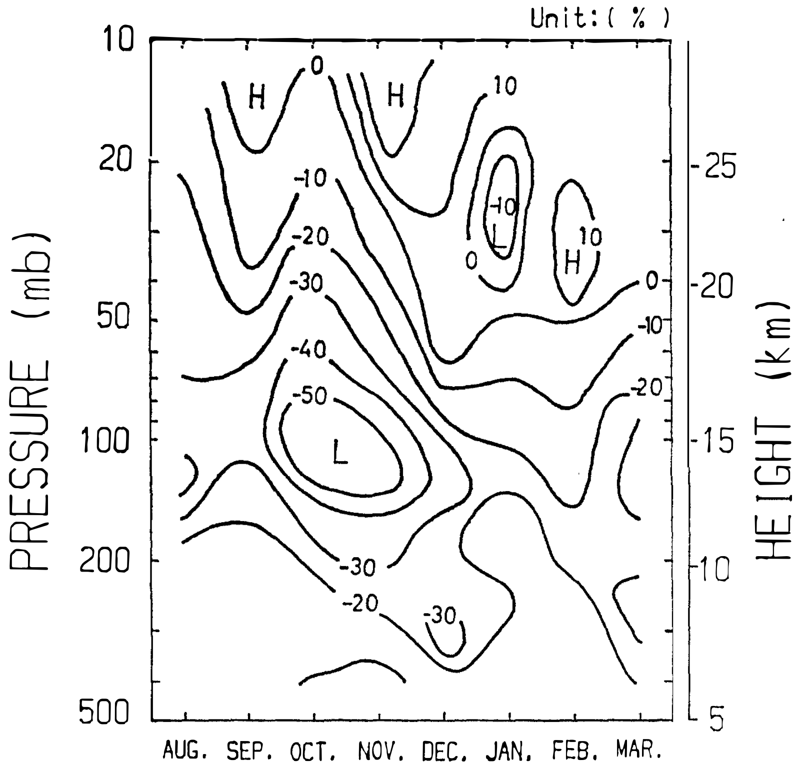

Fig. 3. Month-height section of the ozone depletion rate, defined in the text, at Syowa Station.

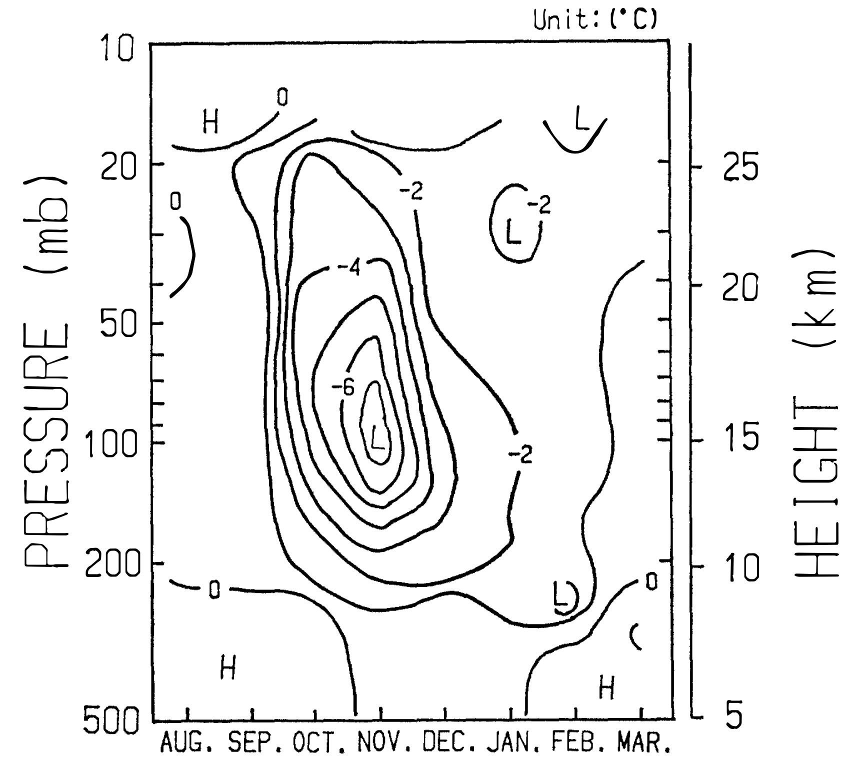

Fig. 4. Month-height section of the temperature difference at Syowa Station (temperatures averaged over the period from 1981 to 1985 minus those from 1971 to 1980).

been made at Syowa Station as part of routine meteorological measurements (for complete data set, refer to the magnetic tape available from Ozone Data for the World). As discussed by many investigators (*e.g.*, FARMAN *et al.*, 1985; SOLOMON *et al.*, 1986; MCELROY *et al.*, 1986), the height of active ozone loss region and loss rate varies according to each model assumed by them. Thus it should be desirable for the study on the ozone depletion problem to present changes in ozone content profiles and height changes in ozone loss rate. Figure 3 shows the month-height section of ozone depletion rate, which is defined by

$$\frac{[O_3(\text{'81–'84})]-[O_3(\text{'71–'80})]}{[O_3(\text{'71–'80})]}\times 100 \quad (\%)\,,$$

where $[O_3(\text{'81–'84})]$ is the ozone content averaged during the period from 1981 to 1984 and $[O_3(\text{'71–'80})]$ from 1971 to 1980. The decrease of monthly-averaged temperatures for the period of 1971–1980 to 1981–1985 is shown in Fig. 4. It is easily found in these figures that at Syowa Station the ozone depletion in spring is well correlated with the temperature decline in the lower stratosphere in spring.

3. Discussion and Conclusion

Many investigations (*e.g.*, ANGELL, 1986) suggested that there was an impressive in-phase relation between the long-term ozone depletion and the lower stratospheric temperature in Antarctica. The present ozonesonde data showed that the height and the time of active depletion of ozone corresponded well to those of decrease in temperature (Figs. 3 and 4). IWASAKA and KONDOH (1987) suggested that the temperature decrease in spring caused the ozone depletion through an activation of production of particulate matter whose surface could act as the heterogeneous reaction site, as first suggested by SOLOMON *et al.* (1986). Many investigators (TUNG, 1986; CHANDRA and MCPETER, 1986; ROSENFIELD and SCHOEBERL, 1986) suggested that atmospheric heating due to the absorption of solar radiation by aerosols drove an upward motion of the air and this motion caused the ozone depletion. A more detailed calculation on radiative energy transfer by SHI *et al.* (1986) showed that the net heating rate is too small to make the sufficient upwelling diabatic motion to bring about the large ozone depletion.

Considering that atmospheric temperature variations are associated with many factors; such as radiative transfer, optical properties of gasses and aerosols, dynamic air motions on various scales, earth and cloud surface conditions and so on, it may be impossible to give a simple scenario to the good correspondence of ozone depletion to cold stratospheric appearance as shown in Figs. 3 and 4. When we use a geopotential height or a layer thickness instead of atmospheric temperature it is easy to image an air motion pattern and an atmospheric temperature field. Here we compare the geopotential height with the total ozone content.

Figure 5 shows the geopotential heights of 100 mb surface zonally averaged in the regions from the equator to 20°S, from 60 to 80°S, from the equator to 20°N, and 60 to 80°N in spring. The following are suggested from the figure;

1) The steep and long-term decline of the geopotential heights is found only at

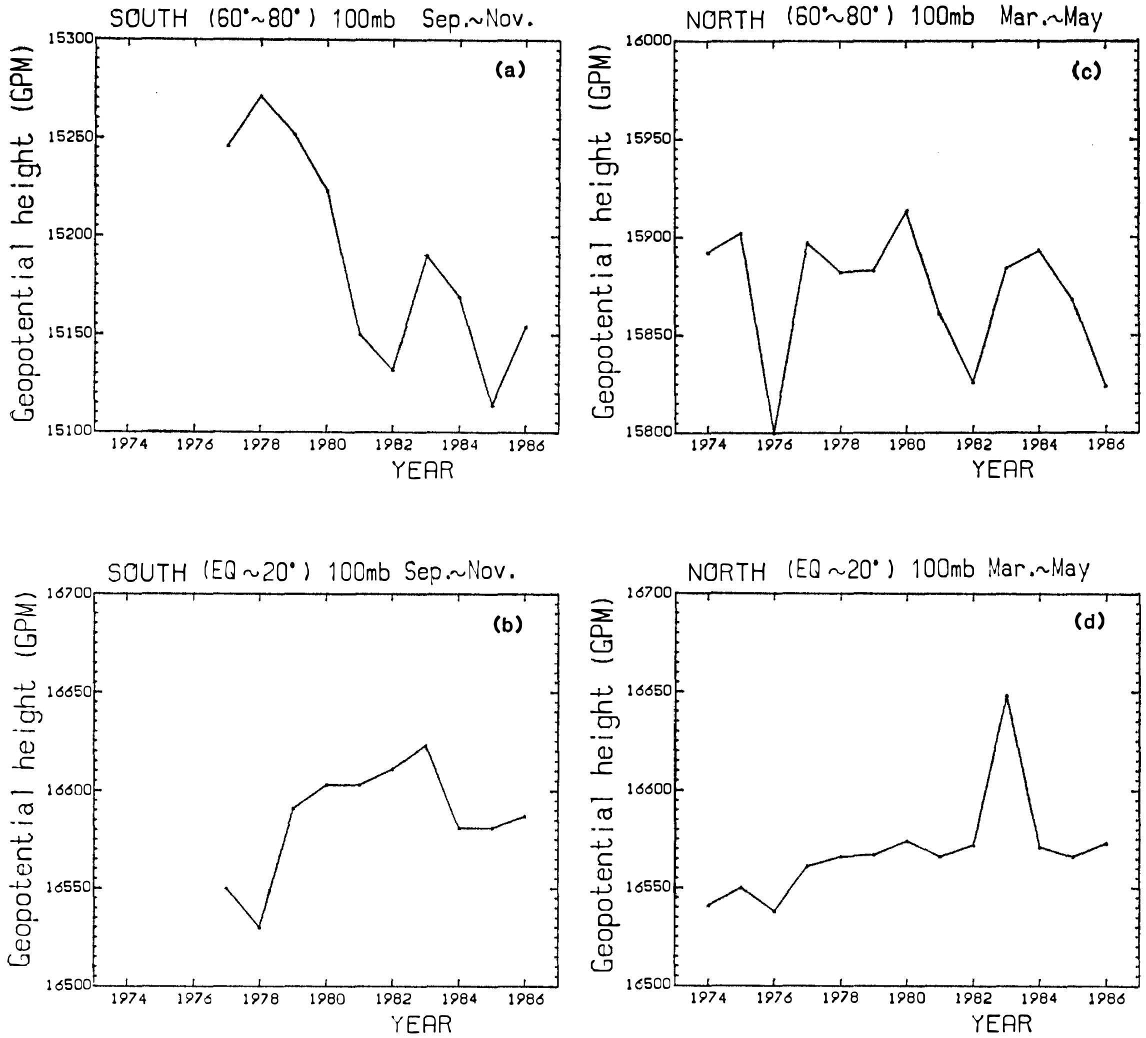

Fig. 5. Zonally-averaged geopotential height of 100 mb surface in spring. (a) September, October and November, 60°, 70° and 80°S, (b) September, October and November, 20°, 10°S and the equator, (c) March, April and May, 60°, 70° and 80°N, (d) March, April and May, 20°, 10°N and the equator.

high latitudes in the southern hemisphere, and fluctuations of 2–3 years are superimposed on the decline.

2) In the Arctic region, a very gentle decrease of geopotential height can be found.

3) The very small increase in the geopotential height at low latitudes is found if we neglect a few years variations.

4) In 1976 in the northern hemisphere a large decrease of the height was observed in the polar region, and a small but noticeable decrease at low latitudes.

5) In 1978 in the southern hemisphere, an increase was observed in the Antarctic region while a decrease at low latitudes. However, no characteristic feature is found in the northern hemisphere in this year.

6) 1982–1983, large variations, decrease in the both polar regions and increase at low latitudes, are worldwidely observed.

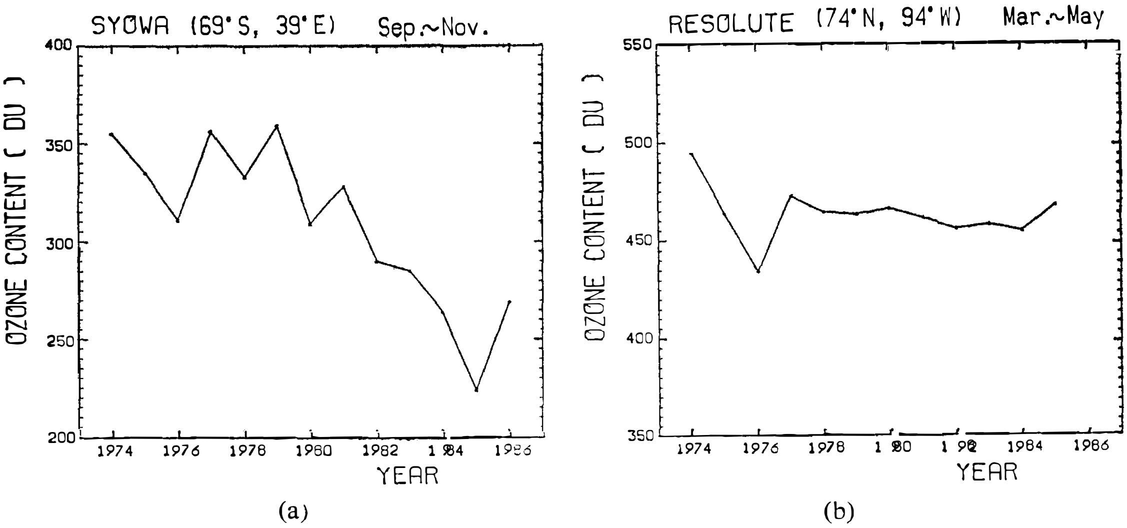

Fig. 6. Geopotential height and ozone content at Syowa Station (69°S, 39°E) and Resolute (74°N, 94°W) in spring.

From these we can conclude that the noticeable temperature decrease in the last ten years occurred only in the Antarctic region. Additionally, the long-term trend of the geopotential height shows a remarkable decrease at high latitudes in the southern hemisphere, but a very small increase at low latitudes. It can be speculated that the temperature decrease observed in the Antarctic stratosphere is a sign of a global temperature change controlled dynamically.

It is worth noting that the southern oscillation index showed noticeable negative values in 1977–1978 and 1982–1983, and the El Niño phenomenon was noticeable in 1982–1983 (LYNN, 1983; SIMPSON, 1984). The sudden increase of the geopotential height in the southern and northern hemispheres from 1982 to 1984 may have a relationship to the ENSO event.

According to TOMS measurements by SCHOEBERL *et al.* (1986), the depletion of total ozone in October, from 1979 to 1985 was 110 Dobson unit (DU) at the South Pole, 70 DU in the southern subpolar region, and 50 DU at the North Pole. They suggested that such a global ozone depletion is well correlated with a systematic decrease in the stratospheric temperatures. BOWMAN (1986) showed that the total ozone decreased also in the northern hemisphere spring from 1979 to 1983. In Fig. 6 we compare the trend of the total ozone content at Syowa Station, averaged from September to November, with the change in geopotential height zonally averaged in the latitudinal region from 60 to 80°S. Although there is no correlation between the ozone content and the geopotential height in the time scale of a few years, the both show a clear decline in about 10 years scale. Figure 6 also compares the total ozone amount at Resolute (74°N, 94°W) with the geopotential height zonally averaged over 60–80°N for the northern hemisphere spring. Similar to the southern high latitudes, we can find a decreases, though very small, in the ozone content and the geopotential height when we neglect the fluctuations in a few years.

In this preliminary result we showed that there is a good correspondence between the height of ozone loss region, which is deduced from ozonesonde measurements at

Syowa Station, and the region where temperature decreased. Analysis of the global-scale geopotential height suggests that the temperature changes in the Antarctic stratosphere may be associated with the global changes of temperature field. If so, it is necessary to take the effect of global-scale air motion into consideration to understand the so-called "ozone hole".

The present analysis seems to indicate the importance of global-scale dynamics to understand the Antarctic ozone depletion. However, the analysis is only preliminary and more detailed ones are desired.

Acknowledgments

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References

ANGELL, J. K. (1986): The close relation between Antarctic total-ozone depletion and cooling of the Antarctic low stratosphere. Geophys. Res. Lett., **13**, 1240–1243.

BOWMAN, K. P. (1986): Interannual variability of total ozone during the breakdown of the Antarctic circumpolar vortex. Geophys. Res. Lett., **13**, 1193–1196.

CHANDRA, S. and MCPETERS, R. D. (1986): Some observations on the role of planetary waves in determining the spring time ozone distribution in Antarctic. Geophys. Res. Lett., **13**, 1224–1227.

CHUBACHI, S. (1984): Preliminary result of ozone observations at Syowa Station from February 1982 to January 1983. Mem. Natl Inst. Polar Res., Spec. Issue, **34**, 13–19.

FARMAN, J. C., GARDINER, B. G. and SHANKLIN, J. D. (1985): Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. Nature, **315**, 207–210.

IWASAKA, Y. and KONDOH, K. (1987): Depletion of Antarctic ozone; Height of ozone loss region and its temporal changes. Geophys. Res. Lett., **14**, 87–90.

LYNN, R. J. (1983): The 1982–1983 warm episode in the California current. Geophys. Res. Lett., **10**, 1093–1095.

MCELROY, M. B., SALAWITCH, R. J., WOFSY, S. C. and LOGAN, J. A. (1986): Reductions of Antarctic ozone due to synergistic interactions of chlorine and bromine. Nature, **321**, 759–762.

NEWMAN, P. A. and SCHOEBERL, M. R. (1986): October Antarctic temperature and total ozone trends from 1979–1985. Geophys. Res. Lett., **13**, 1206–1209.

ROSENFIELD, J. E. and SCHOEBERL, M. R. (1986): A computation of stratospheric heating rates and the diabatic circulation for the Antarctic spring. Geophys. Res. Lett., **13**, 1339–1342.

SCHOEBERL, M. R., KRUEGER, A. J. and NEWMAN, P. A. (1986): The morphology of Antarctic total ozone as seen by TOMS. Geophys. Res. Lett., **13**, 1217–1220.

SHI, G.-Y., WANG, W.-C., KO, M. K. W. and TANAKA, M. (1986): Radiative heating due to stratospheric aerosols over Antarctica. Geophys. Res. Lett., **13**, 1335–1338.

SIMPSON, J. J. (1984): El Nino-induced onshore transport in the California current during 1982–1983. Geophys. Res. Lett., **11**, 233–236.

SOLOMON, S, GARCIA, R. R., ROWLAND, F. S. and WUEBBLES, D. J. (1986): On the depletion of Antarctic ozone. Nature, **321**, 755–758.

TUNG, K. K. (1986): On the relationship between the thermal structure of the stratosphere and the seasonal distribution of ozone. Geophys. Res. Lett., **13**, 1308–1311.

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