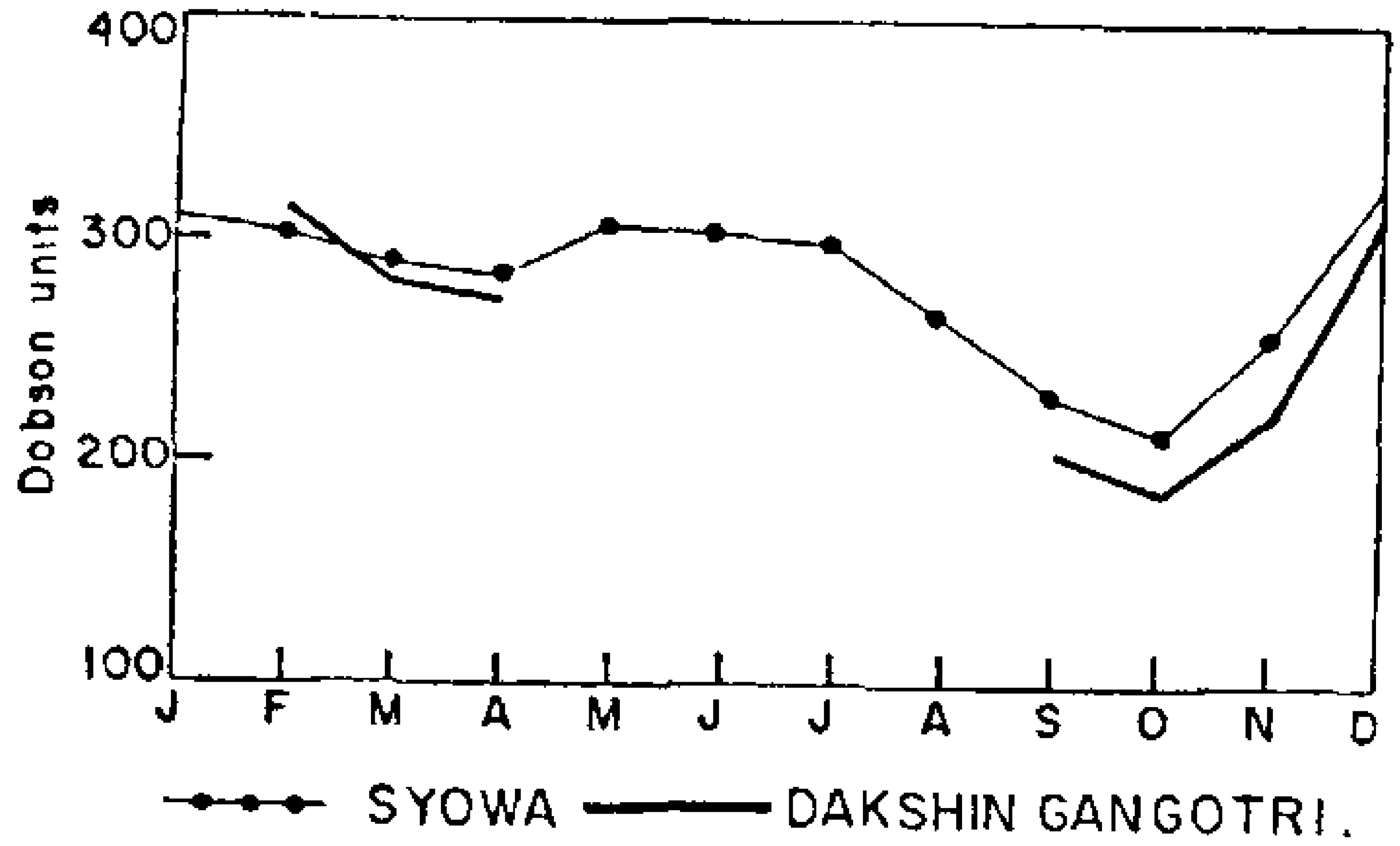

Figure 4. Total ozone.

at Dakshin Gangotri are slightly lower than those at Syowa but the trends are similar.

Conclusion

The chief features of the diurnal and annual variations in surface ozone at the Indian station Dakshin Gangotri (Antarctica) are —:

(a) The values of surface ozone concentration do not show any significant diurnal variation throughout the year. Day-to-day changes in surface ozone are well correlated with surface temperature changes but not with changes in wind speed.

(b) The annual cycle in surface ozone shows a summer minima with average value of the order of 20 ppbv and a winter maxima of 40 ppbv.

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Ozone soundings over Antarctica

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Two typical balloon ozone soundings with the Indian ozonesonde taken from Dakshin Gangotri, Antarctica, bring out clearly the intense ozone depletion at levels between 14 and 25 km during spring and the later filling up of the ozone hole in summer. At 20 km, the ozone partial pressure during spring fell to 12 μmb from 168 μmb in summer with corresponding temperature changes from −80° C to −36° C.

THE possibility of the destruction of stratospheric ozone in a catalytic chain reaction involving chloroflurocarbons (CFCs) and UV(C) component of sunlight was pointed out by Rowland and Molina[1] in 1975. Ten years later, a dramatic proof of the ozone destruction in the Antarctic stratosphere, apparently caused by CFCs, was presented by Farman *et al.*[2] Since then, concerted efforts have been made by researchers from USA, UK, Japan, GDR and India to make ozone measurements from Antarctica, to obtain a clearer picture of the 'ozone hole' over the Antarctic. The first Indian ozone soundings from the Indian Antarctic station Dakshin Gangotri (Lat. 70° 05′ S, Long. 12° E) were made in 1983 and reported by Sreedharan *et al.*[3] After a break of four years these soundings have been revived, particularly for studying the nature and extent of the ozone depletion during September–October over the Antarctic[4]. In this article we present two ozone profiles which dramatically illustrate the nature of the Antarctic 'ozone hole'.

Observational programme

The ozone soundings from Dakshin Gangotri, Antarctica were carried out with the Indian electrochemical ozonesonde, which had earlier taken part in three successful international intercomparisons. Soundings were made almost every week. In this paper we present the results of two soundings, one on 28 September, 1991 during a period of intense ozone depletion and the other on 14 December, 1991 when ozone distribution in the Antarctic had reverted to the normal pattern. The soundings have not been adjusted to 'total ozone'.

Results

The ozone and temperature profiles on 28.9.1991 and 14.12.1991 are presented in Figure 1. The following

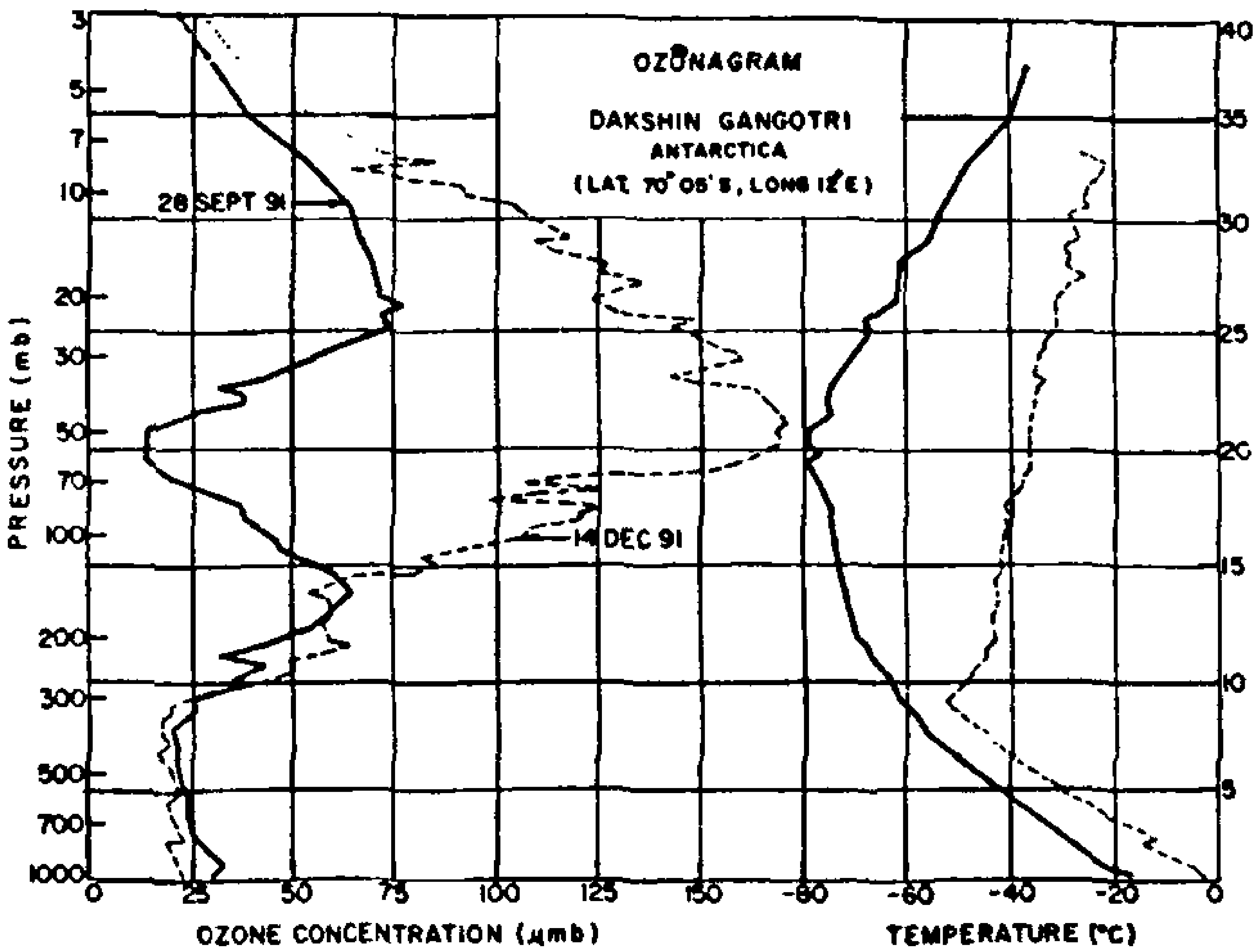

Figure 1. Ozone soundings from Dakshin Gangotri, Antarctica (Lat. 70° 05′ S, Long. 12° E), during spring and summer of 1991.

features of the ozone depletion in spring and subsequent revival of the ozone concentration in summer are seen clearly in the profiles.

(a) The ozone depletion in spring takes place mainly between 150 mb and 20 mb (approximately 14–25 km).

(b) The maximum difference, in ozone concentration between September to December is of the order of 150 μmb, and occurs at about 20 nm (50–60 mb).

(c) There is no significant change in the concentration of ozone in the first 10 km of the troposphere.

(d) While the bulk of the ozone depletion in September takes place between 14 and 25 km, the ozone concentration shows an increase at all levels above 14 km in December.

(e) The lowest temperature of −80° C is observed in spring in the middle of the 'ozone hole' at 20 km and during summer the same level warms up to −36° C.

Discussions

All known mechanisms of ozone production, destruction and distribution have to be looked into to find an explanation for the observed ozone depletion in the Antarctic. The known production and destruction mechanisms are photochemical reactions involving certain wavelengths in UV and gas phase chemical reactions which do not involve any photochemistry. The ozone distribution mechanisms are dynamical in nature involving subsidence, upwelling or horizontal transfer of air.

Photochemical production/destruction mechanisms can only explain the gradual decrease in the 'total ozone' during the Antarctic nights but cannot explain the sudden drop in 'total ozone' during September–October caused by the selective destruction of ozone in the 14 to 25 km region.

Among the various destruction mechanisms suggested, the most important appears to be the one involving ClO. According to Molina *et al.*[5], destruction mechanisms involving ClO can explain about half of the observed ozone destruction, if the abundance of ClO is of the order of 0.5–1 ppbv. Solomon *et al.*[6] have reported ClO mixing ratios in the region around 20 km in the Antarctic spring to be close to 1 ppbv. They have also reported that the ClO concentration in the lower stratosphere remains high during most of September but declines substantially by the middle of October, providing further evidence for a coincidence between excess ClO and ozone depletion. Anderson's measurements during the 1987 US Campaign indicate the highest ClO concentration at 18.5 km, rapidly decreasing at lower altitudes. Thus it appears that the ozone depletion observed in the lower stratosphere over Antarctica can only be partly accounted for by the destruction mechanisms involving ClO alone.

The role played by polar stratospheric clouds (PSCs) in the spring time ozone depletion has been highlighted by various workers[6-8]. Remote sensing measurements made by satellite sensor SAM II starting in late 1978 show that more stratospheric clouds exist in both winter polar regions than had been realized earlier by visual sitings[8]. The PSCs are widely believed to be formed by condensation of nitric acid/water at extremely cold temperature in the winter polar vortex. In the ozone sounding of 28.9.1991, the lowest temperature reached was −80° C at 20 km as against −36° C at 20 km on 14.12.1991. It can be seen that this extreme cooling of the lower stratosphere is conducive to the development of the PSCs. It is, therefore, quite likely that the PSCs are partly responsible for the observed ozone depletion. However, the properties of the PSCs and the heterogeneous chemical processes involved in the ozone depletion are yet to be clearly understood.

The part played by atmospheric dynamics in the formation of the ozone hole has also to be looked into. It is clear that the strong circumpolar vortex during winter will prevent the poleward transport of ozone from lower latitudes. The only way atmospheric dynamics could play a part in the observed stratospheric depletion of ozone is by the upwelling of ozone-depleted tropospheric air into the lower stratosphere. On the contrary, available evidence suggests only weak but persistent downward motion in the lower stratosphere in September and October.

Conclusion

At the height of the ozone depletion over Dakshin Gangotri, Antarctica, during the spring of 1991, the major part of the depletion is centred around 20 km. The 'ozone hole' extends from 14 to 25 km and the ozone partial pressure within the hole drops to as low as 12 μmb. While ClO carried to the Antarctic stratosphere from the middle latitudes may account for nearly half of the depletion of ozone, the polar stratospheric clouds (PSCs) and the atmospheric dynamics are presumed to account for the rest of the depletion. There are considerable gaps in our understanding of the factors that lead to the formation and refilling of the 'ozone hole' and intensive research efforts are required before a clear picture of the 'ozone hole' and its implications could emerge.

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ACKNOWLEDGEMENTS. We wish to thank the Director General of Meteorology for the opportunity to participate in the Antarctic expeditions and for permission to publish this paper. We would also like to thank the staff of the laboratories at Meteorological Office, Pune, for the ozonesondes they prepared for the soundings.

The first detection of Antarctic ozone hole

Shigeru Chubachi

Introduction

Since 1984 when ozone depletion in Antarctica was first reported[1], many scientists have been focussing on this interesting phenomenon. In this article, I present the way the ozone hole was discovered. I would also like to emphasize the importance of continuous geophysical observations.

Ozone hole today

I introduce the present state of the Antarctic ozone hole using the data from Syowa Station (69° S, 40° E). In Figure 1, year-to-year variations of the monthly means of total ozone amount at Syowa Station in January (*a*), September (*b*), and October (*c*) are shown. Figures 1*b* and *c* clearly depict the Antarctic ozone hole increase. These figures show that the decrease in total ozone at Syowa Station started around 1982. Antarctic ozone decrease is not limited to spring but is also observed in summer.

Similar characteristics were obtained from the observations at other stations (Halley Bay, South Pole)[2,3] and from TOMS satellite data. The TOMS data derived from Nimbus 7 satellite measurements[4] shows that ozone characteristics found at Syowa Station were common to the Antarctic region.

Ozone layer over Antarctica

Now, I mention the history of ozone observations in the Antarctic. Ozone observations in Antarctica began in