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# Antarctic ozone depletion measured by balloonsondes at Maitri — 1992

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**सार** — अंटार्कटिका अवक्षय के होने से संबंधित चार्ट तैयार करने के लिए 1992 की दक्षिणी बसंत ऋतु के दौरान मैत्री केन्द्र पर गुब्बारा वाहित ओजोन सौन्डे के कई आरोहणी के प्रोफाइलों का प्रयोग किया गया है। अवक्षय बने होने के सभी चरणों में स्तरण की स्थिति सहित ओजोन परत की ऊर्ध्वाधर सरंचना के बारे में इसमें चर्चा की गई है। सितम्बर और अक्टूबर के महीने में 15 से 23 कि.मी. के क्षेत्र में 97% 'अवक्षय 1992 के ओजोन आरोहणों की मुख्य घटना है। यह एक विलक्षण घटना है।

**ABSTRACT**. Profiles from a series of balloon borne ozonesonde ascents are used to chart the development of the Antarctic depletion over Maitri in the austral spring of 1992. The vertical structure of the ozone layer is discussed, including the presence of stratification, which occurs at all stages of development. The main feature of 1992 ozonesonde flights is depletion of 97% in the months of September and October between 15-23 km, which is unique.

Key words — Ozone, Stratosphere, Polar vortex, Denitrification.

## 1. Introduction

The stratosphere is the atmospheric region extending from just above the tropopause, to an altitude of about 50 km. The tropopause varies from a value of about 10 km over high latitudes to about 17 km over the equator. Within this region the air temperature generally increases with altitude rising from –50°C or lower at the tropopause to greater than –20°C at 50 km. The relative warmth of the stratosphere results from the absorption of solar ultraviolet radiation by ozone, which has its highest mixing ratio in the stratosphere. This heating by solar absorption is balanced by cooling through emission of thermal infrared radiation, primarily from the 15 μm band of $CO_2$. After the autumnal equinox, the polar regions fall into darkness and the solar ultraviolet ceases. Emission of thermal radiation quickly cools the polar stratosphere to temperatures much lower than those of the mid-latitude stratosphere. A latitudinal pressure gradient then develops between the pole and mid-latitudes, which combined with earth's rotation, produces a circumpolar belt of westerly winds referred to as the polar night jet or polar vortex. This isolates the south polar region from the surrounding atmosphere and prevents ozonerich air from the middle latitudes from penetrating the Antarctic stratosphere.

## 2. Chemistry in the polar vortex

Under normal winter conditions in the lower stratosphere, the temperature within the polar vortex falls low enough so that clouds of nitric acid tryhydrate and ice can form despite the dryness of the stratosphere (2 to 4 ppm mixing ratio of water). These clouds are referred to, generally, as polar stratospheric clouds (PSC's). Pure ice clouds near –88°C at 50 hPa pressure

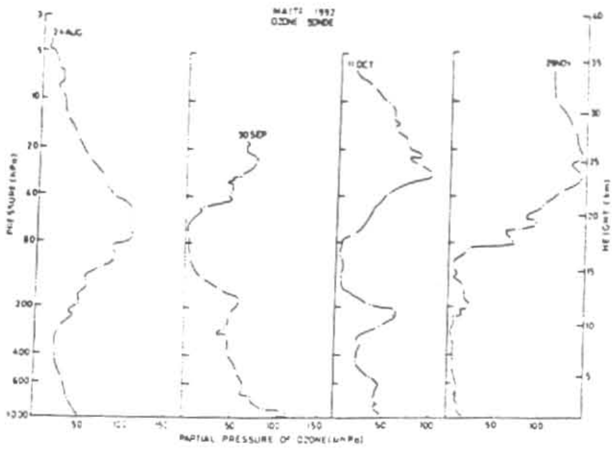

**Fig. 1.** Profile of partial pressure of ozone (nb) over Maitri

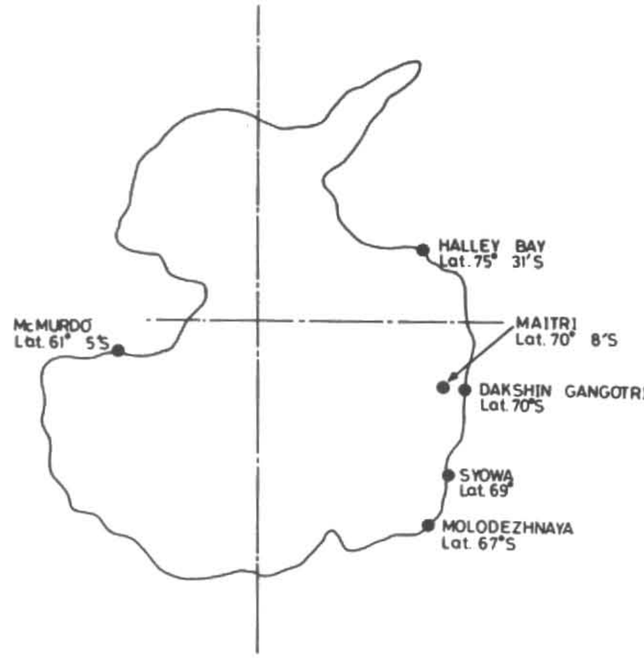


**Fig. 2.** Locator map of Antarctic stations

(roughly 20 km), an extreme temperature that is rarely maintained for long periods except in the Antarctic winter stratosphere. The clouds of nitric acid trihydrate form at temperature roughly 10°C warmer and thus, probably, account for most of the PSC's. The PSC's are now recognized as the key ingredient in the spring time destruction of ozone and the formation of the ozone hole. They are the sites for a group of heterogeneous reactions that perturb the normal gas phase chemistry in the polar region. The most important heterogeneous reaction is that which converts the relatively unreactive chlorine species, chlorine nitrate and hydrochloric acid (the dominant chlorine reservoirs), to molecular chlorine and nitric acid,

$$ClONO_2 + HCl \xrightarrow{M} HNO_3 + Cl_2 \qquad (1)$$

where M is a third body molecule or particle. The molecular Chlorine is photolyzed in the spring sunlight, the atomic chlorine quickly reacts with ozone to form the chlorine monoxide radical (ClO). Substantial catalytic ozone destructions at rates of 0.5 to 1% per day begins with the formation of the dimer (ClO) and the reaction of ClO with bromine monoxide (BrO) (Anderson *et al.* 1989). Widespread ozone destruction during the Antarctic spring requires cold stratospheric temperature (below −78°C) for a sufficiently long time supporting the formation of polar stratospheric clouds. The main role of PSC's being denitrification of air in the polar vortex through heterogeneous chemistry. To prevent the conversion of ClO back to unreactive chlorine nitrate through the reaction of ClO with $NO_2$, active nitrogen compounds must be suppressed. The formation of PSC's sequesters $HNO_3^-$ in trihydrate particles after the heterogeneous reaction by condensation and also denitrifies the vortex air. The observed ozone destruction in both hemispheres is, therefore, contingent on the stratosphere remaining denitrified during the period of ozone loss, and this means that mid-latitude air containing reactive nitrogen compounds cannot be mixed into the polar vortex. The dynamical characteristics of the polar vortex provide this chemical isolation and the ozone hole develops poleward of the latitude of strongest westerly winds.

In order to study the temporal development of the Antarctic spring ozone depletion, a programme of ozonesonde flights was undertaken at Maitri (70°S, 120o E; Fig. 2) in 1992 using the Indian electrochemical ozonesonde (Sreedharan 1968). More than 50 ascents were taken during the period January-December, of which twenty were in the crucial months of August, September and October. The

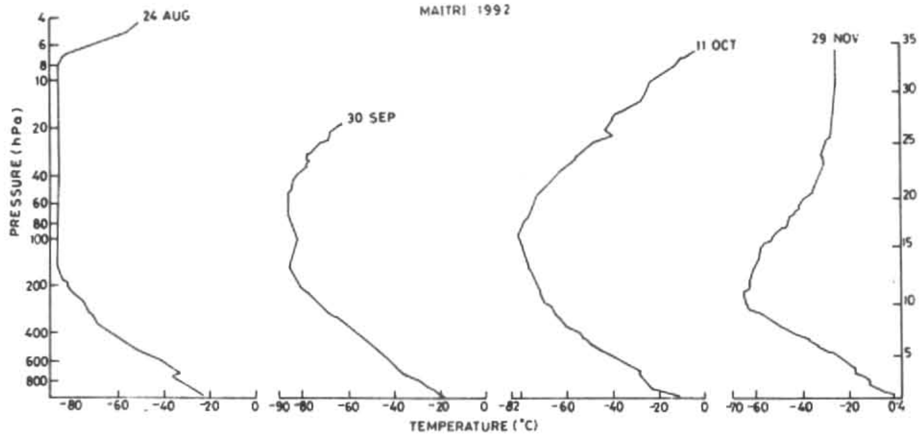


**Fig. 3.** Temperature (°C) profile over Maitri

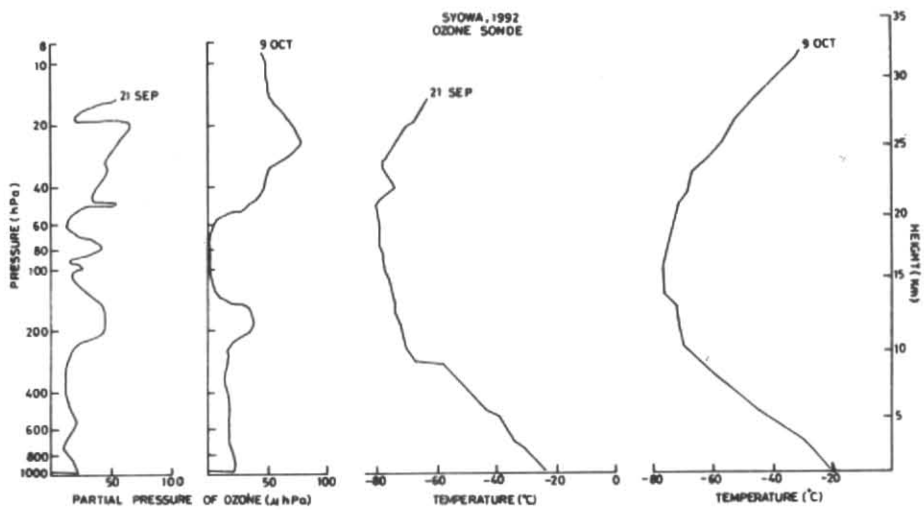


**Fig. 4.** Partial pressure of ozone (nb) and temperature (°C) profile over Syowa

magnitude of the phenomenon is made clear in Fig. 1. The profile of 24 August can be regarded as showing the stratosphere in its normal winter state, with a maximum ozone partial pressure of about 120 nbar at 65 hPa level. By contrast, the lower stratosphere, on 30 September, has lost nearly all the ozone at that level, and is severely depleted throughout a vertical range of many kilometers. From 30 September to 11 October, the depletion is rather more severe than that observed on 13 October 1987 at Halley Bay by Gardiner (1988).

### 3. Results and discussion

The Ozone and temperature profiles on 24 August, 30 September, 11 October and 29 November during 1992 are presented in Figs 1 & 3. The following 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 and 20 hPa (approximately 14-25 km).

(b) The maximum difference, in ozone concentration between September to December is of the order of 150 nb, and occurs at about 23 km.

(c) Bulk of ozone depletion in September and October takes place between 12 and 23 km. Fig. 1 shows 97% depletion at this height for 1992. The ozone concentration shows an increase at all levels above 16 km from the last week of November.

(d) The lowest temperature of above –80°C is observed in spring in the middle of "Ozone hole" at 16 km and during summer the same level warms upto –65°C.

Of all the destruction mechanisms suggested, the most important appears to be the one involving ClO. According to Molina *et al.* (1987), 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.* (1986) have reported ClO mixing ratios in the region around 20 km in the Antarctic spring to be close to 1 ppbv. 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 (PSC's) in the spring time ozone depletion has been highlighted by various workers (McElory *et al.* 1986 and McCormick *et al.* 1986). The PSC's are widely believed to be formed by condensation of nitric acid/water at extremely cold temperatures in the winter polar vortex. In the ozone soundings of 30 September and 11 October 1992, the lowest temperature reached was about –80°C at 16 km as against –45°C at 16 km on 29 October 1992. These lower temperatures prolong the presence of polar stratospheric clouds (PSC's), in particular nitric acid trihydrate (NAT), dominant component of PSC's. This tends to enhance the production and lifetime of reactive chlorine and ozone depletion at the upper boundary of the ozone hole, because chlorine in this region was not totally activated in years with normal temperature. This may be the reason that in 1992 the ozone hole become the deepest. Same has also been observed at Syowa (Fig. 4). Cold sulphate aerosol from Mt. Pinatubo, present at altitude between 10 and 16 km, probably, contributed to the low ozone through heterogeneous conversion of chlorine species.

The part played by atmospheric dynamics in the formation of 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.

## 4. Conclusion

Ozone depletion over Maitri, Antarctica, during the spring of 1992 has been studied by balloon ozonesonde ascents. The major part of the depletion is centered around 16 km. The ozone hole extends for 12-23 km and the ozone partial pressure within the hole drops to as low as 1.2 nb. ClO radicals account for nearly half of the depletion of ozone.

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