Surface ozone measurements from Dakshin Gangotri, Antarctica

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Surface ozone was measured for seven months in two spells at the Indian Antarctic station Dakshin Gangotri (70.1° S, 12° E) using the Indian electrochemical surface ozone recorder. Tropospheric ozone data from the Indian ozonesondes was also used in the analysis during the breaks in the continuous recording at surface ozone. The main objective of the measurements was to find out the nature of the variations of surface ozone during the rapid depletion and fast recovery of total ozone in late winter and early spring over the Antarctic.

The surface ozone values show a summer minima of the order of 20 ppbv and a winter maxima of the order of 42 ppbv. The transition from the low summer value to the high winter value occurs during May–June. From October to November, there is a sharp fall in the surface ozone values. This sharp fall takes place at a time when the total ozone values are sharply rising from the lowest annual value. Other notable features of the surface ozone at Dakshin Gangotri during 1989 are the near absence of a diurnal variation, even during the summer months and the absence of significant changes during blizzards. The results agree fairly well with the measurements reported from Syowa in Antarctica, a station located in nearly the same latitude. Comparisons with a tropical station Pune (18.5° N, 73.8° E) bring out the sharp differences in surface ozone distribution between the two stations. Pune has the highest values when Dakshin Gangotri has the lowest and *vice versa*. The major difference, however, is that the systematic diurnal variation noticed at Pune almost round the year is not noticed at Dakshin Gangotri. The sharp changes noticed at Pune associated with different synoptic situations, break-up of inversions and wind changes are not noticed at Dakshin Gangotri.

MEASUREMENTS of ozone concentration near the ground and in the upper atmosphere over Antarctica have attracted world-wide attention after the anticipated ozone destruction due to its chemical reaction with CFCs was actually reported by Farman *et al.* (1985). The ozone observational programme at Dakshin Gangotri (70.1° C, 12° E), an Indian Antarctic station, includes the vertical measurement of ozone with electrochemical ozonesonde. In 1989, a continuous surface ozone recorder was installed at Dakshin Gangotri. Surface ozone data obtained during April and May 1989 and again from August to December 1989 at Dakshin Gangotri has been analysed and is presented in this paper. The measurement of surface ozone concentration at Pune, India (18.5° N, 73.8° E) has been made for more than two decades by means of a continuous ozone recorder and ozone variations at Pune during 1989 are also presented with the Dakshin Gangotri data. The annual surface ozone variations at Syowa (Antarctica) are also shown and discussed.

Instrumentation and method of observation

The electrochemical Brewer bubbler ozone sensor used in the ozonesonde, for the measurement of ozone[1], was modified and used for continuous recording of ozone near the surface[2]. The system has been in continuous operation at Pune for more than two decades and the accuracy of the measurements has been estimated to be ±10%. At Antarctica, the sensor was kept inside the laboratory, warm enough to prevent freezing of the electrolyte, with the short PTFE intake tube outside the building for taking in free air. Surface ozone concentrations from the ozone soundings were used for analysis during data gaps in surface ozone recording.

Results and discussion

From the record of daily surface ozone concentration, half-hourly values were computed for a study of the hourly and day-to-day changes, and the annual cycle. Figure 1 shows the day-to-day variation of ozone in the months of April and May and from August to December 1989. Daily wind speed and surface temperature values are also plotted to assess the correlation between these weather phenomena and surface ozone. The day-to-day ozone variations show good correlation with those in surface temperature, as at Pune[3], while the daily wind speed does not show any correlation with surface ozone at Dakshin Gangotri; even during blizzards no significant change was noticed. This is in contrast to the Pune observations, which indicate a sharp rise and fall in surface ozone with downdrafts and updrafts associated with thunderstorms.

The diurnal variation of surface ozone at Dakshin Gangotri is shown in Figure 2. For comparison, the diurnal variations at Syowa station[4] during 1982–83 and Pune, a tropical station, during 1989 are also shown. There is practically no diurnal variation in

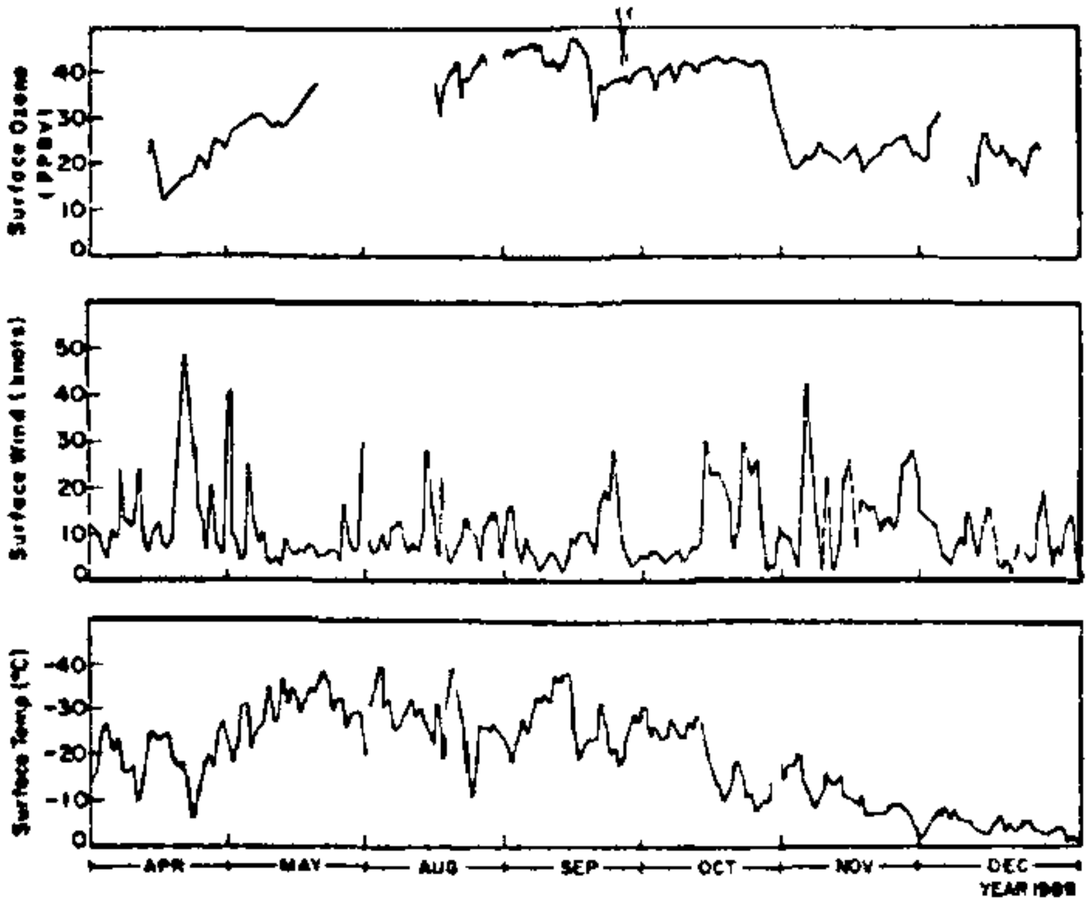

Figure 1. Day-to-day variation in surface ozone, wind speed and temperature at Dakshin Gangotri.

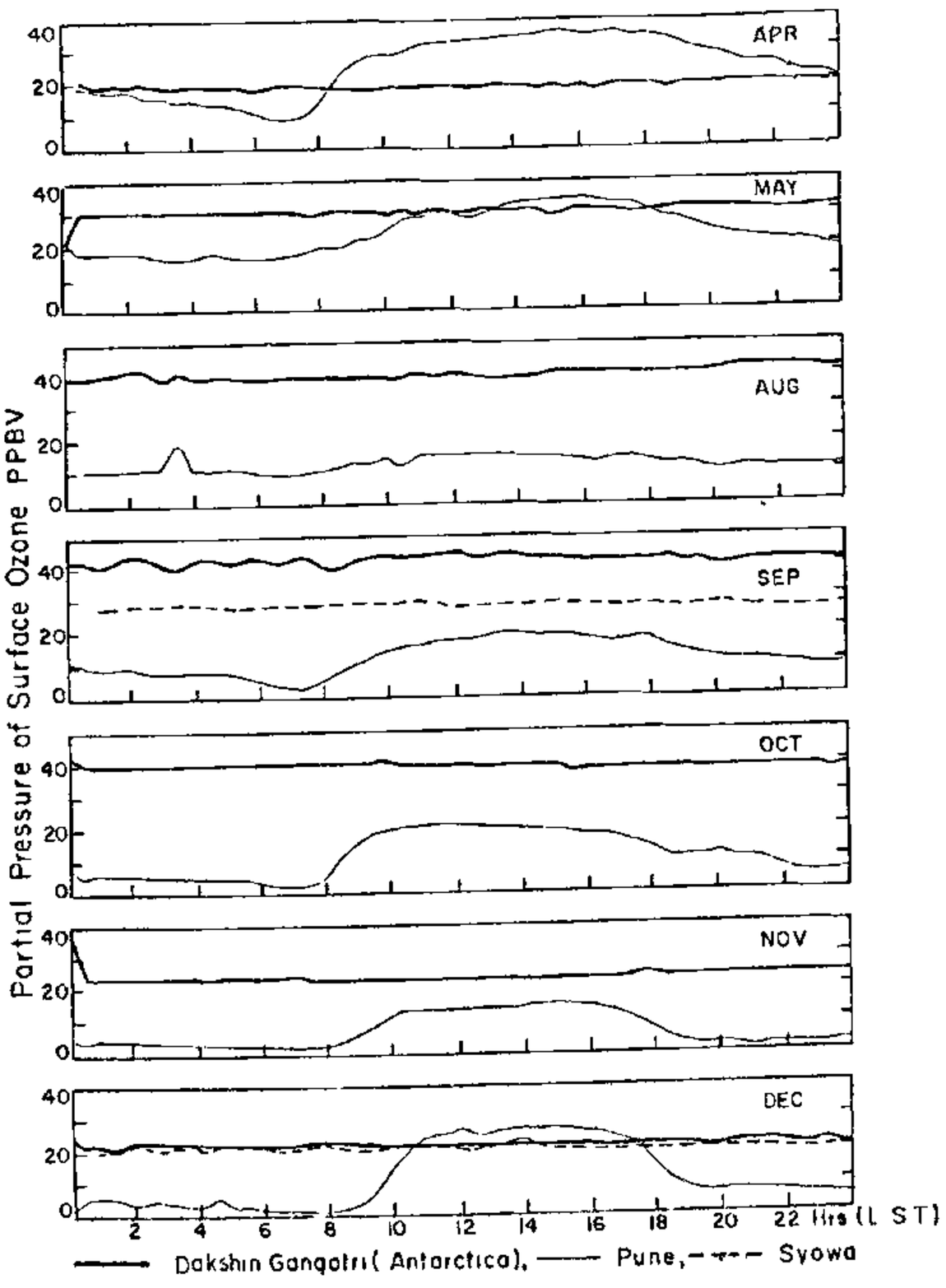

Figure 2. Hourly surface ozone concentration.

surface ozone concentration at Dakshin Gangotri, in agreement with similar observations over Antarctica[4,5]. However, diurnal changes are observed at many tropical and mid-latitude stations[3,6]. Indian stations show a minimum value in surface ozone in the morning hours (around sunrise) and a maximum value in the afternoon hours (around 1400–1600 hours local time).

The diurnal and day-to-day changes in surface ozone can be explained on the basis of changes in the vertical mixing conditions in the boundary layer. During night time, a thin cool and stable layer is formed near the surface, which suppresses the vertical mixing, resulting in depletion of ozone near the surface. While during day time this stable layer is broken and convection currents help in bringing down ozone rich air. Over Antarctica, there appears to be very little change in the mixing conditions between day and night and also there is little depletion since snow cover, devoid of vegetation destroys ozone at a very low rate.

The annual cycle of surface ozone at Dakshin Gangotri is shown in Figure 3, depicting a summer minima and a winter maxima. For two months, during June and July, when surface ozone data were not available, ozonesonde data near the ground have been used (shown as a dotted curve). This data agrees reasonably well with the monthly means. This is also in agreement with measurements at Syowa, Antarctica (also superimposed in Figure 3). The annual maximum occurs in winter (August–September) when total ozone amount starts decreasing. From October to November, there is a sharp fall in the surface ozone value; this occurs at a time when total ozone values are sharply rising from the lowest annual value. The winter maximum over Antarctica could be anticipated because the conventional tropopause is absent during winter, which helps in more vertical mixing across the tropopause.

Total ozone values (monthly means) measured at Dakshin Gangotri during 1988 are shown in Figure 4 with total ozone values observed at Syowa. The values

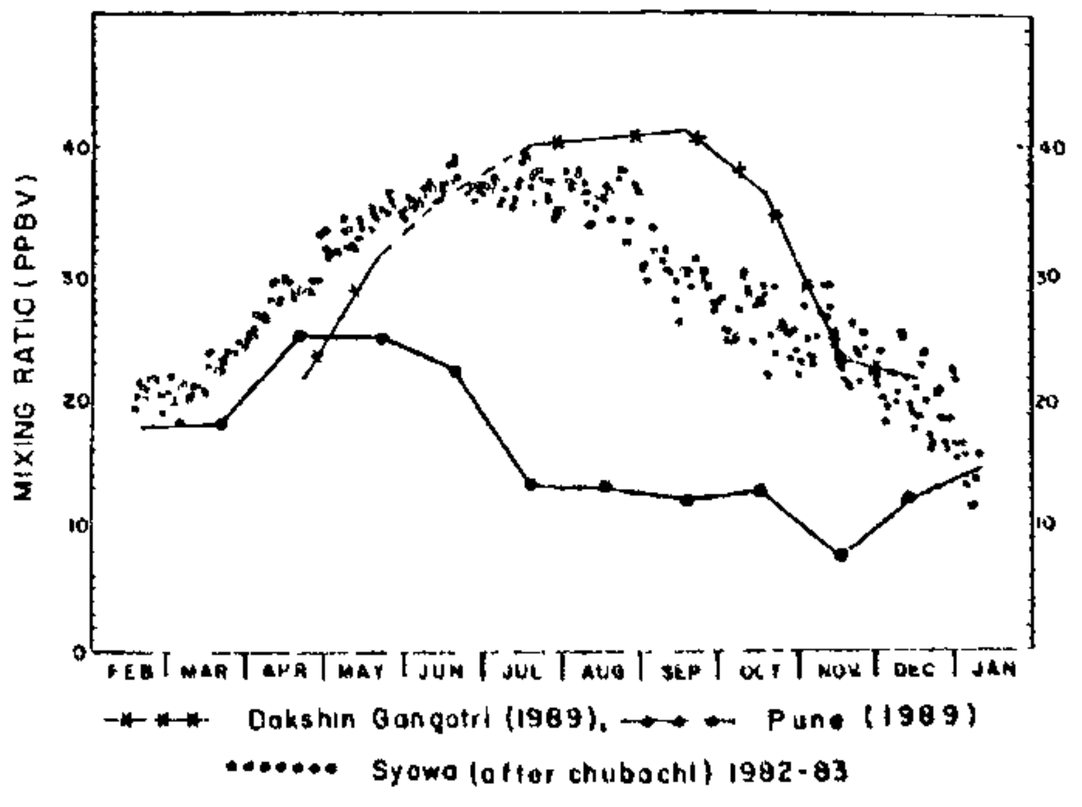

Figure 3. Annual change of surface ozone mixing ratio

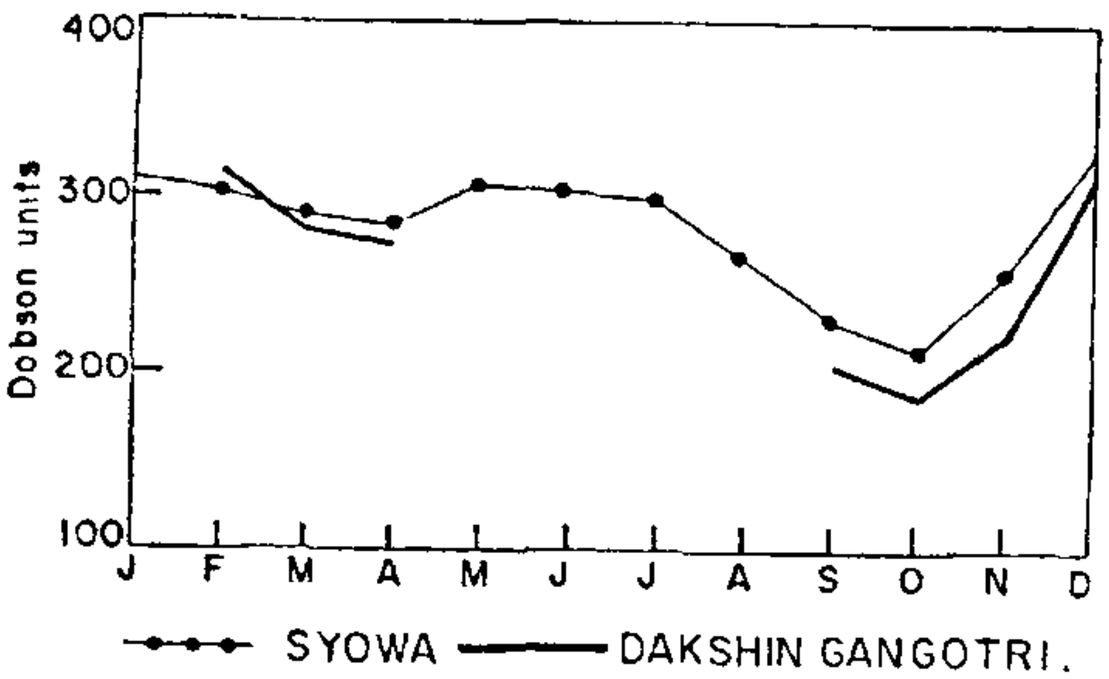

Figure 4. Total ozone.

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. $70^\circ 05'$ 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