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Recent changes observed in column ozone concentrations over India

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सार - पिछले 23 से 39 वर्षों के दौरान डॉबसन स्पेक्ट्रमीप्रकाशमापी द्वारा नई दिल्ली, वाराणसी, पुणे एवं कोडइकनाल से लिए गए ओज़ोन प्रेक्षणों का विश्लेषण भारतीय केन्द्रों में इनकी दीर्घ अवधि प्रवृति की जाँच करने हेतु किया गया है। इन वर्षों के दौरान घटती हुई प्रवृति वाले वाराणसी केन्द्र को छोड़कर सभी स्थानों से लिए गए प्रेक्षणों में ओज़ोन की बढ़ी हुई प्रवृतियाँ देखी गई है। इन प्रवृतियों में इस प्रकार के परिवर्तन का कुछ हद तक कारण क्षोभमंडल में ओज़ोन की प्रवृतियाँ हो सकती हैं। इन परिणामों से, भारतीय केन्द्रों में ओज़ोन के स्तरों में हाल ही में आए कुछ विशिष्ट परिवर्तनों का भी पता चला है। ये परिवर्तन समग्र ओज़ोन आँकड़ों की दीर्घ अवधि प्रवृति विश्लेषण में कम दृष्टिगत होते है क्योंकि क्षोभमंडलीय ओज़ोन में होने वाली वृद्धि का समतापमंडलीय स्तरों पर ओज़ोन में आई कमी पर प्रतिपूरक प्रभाव पड़ता है।

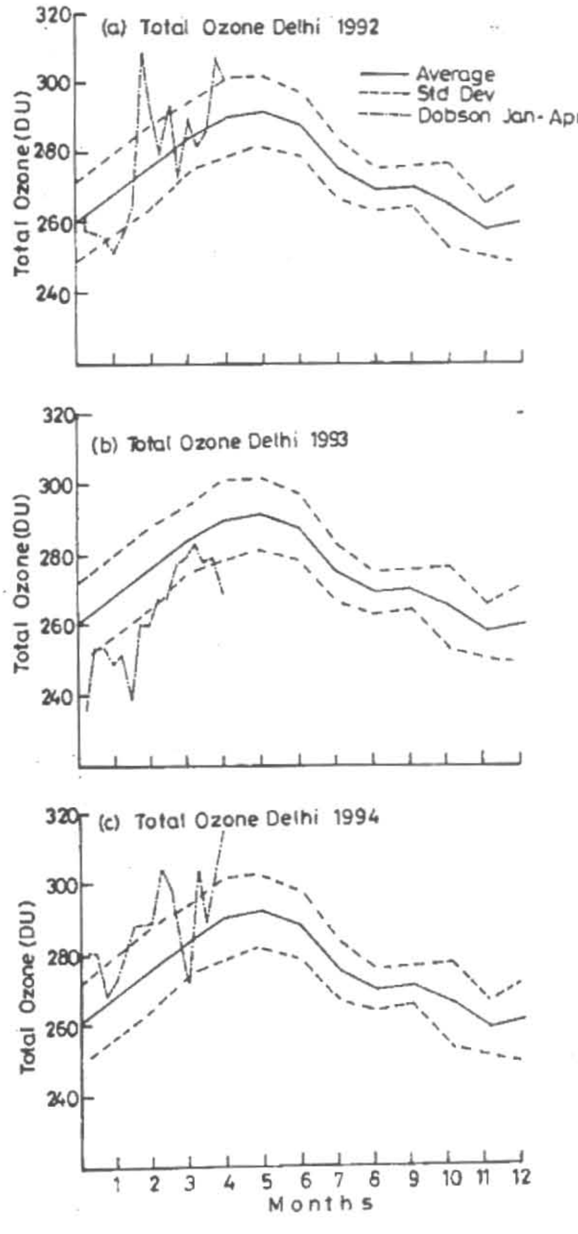
ABSTRACT. Ozone observations taken during the past 23-39 years by Dobson Spectrophotometers at Delhi, Varanasi, Pune and Kodaikanal have been analysed to examine its long-term trend over Indian stations. An increasing trend of this species over the years has been noticed at all the places, except at Varanasi, where a decreasing trend has been found. The cause of these trends could be attributed, partly, to the trends of ozone in the troposphere. The results also indicate that there are certain recent changes in ozone levels at the Indian stations. These changes are less apparent in long-term trend analysis of total ozone data as the increase in tropospheric ozone has a compensating effect to the decrease in ozone at stratospheric levels.

Key words — Ozone, Ozone sonde, UV-radiation, Stratosphere, Pinatubo eruption, El-Nino, Quasi biennial oscillations (QBO), Total Ozone Mapping Spectrophotometer (TOMS), Microwave Limb Sounder, Dobson Ozone Spectrophotometer.

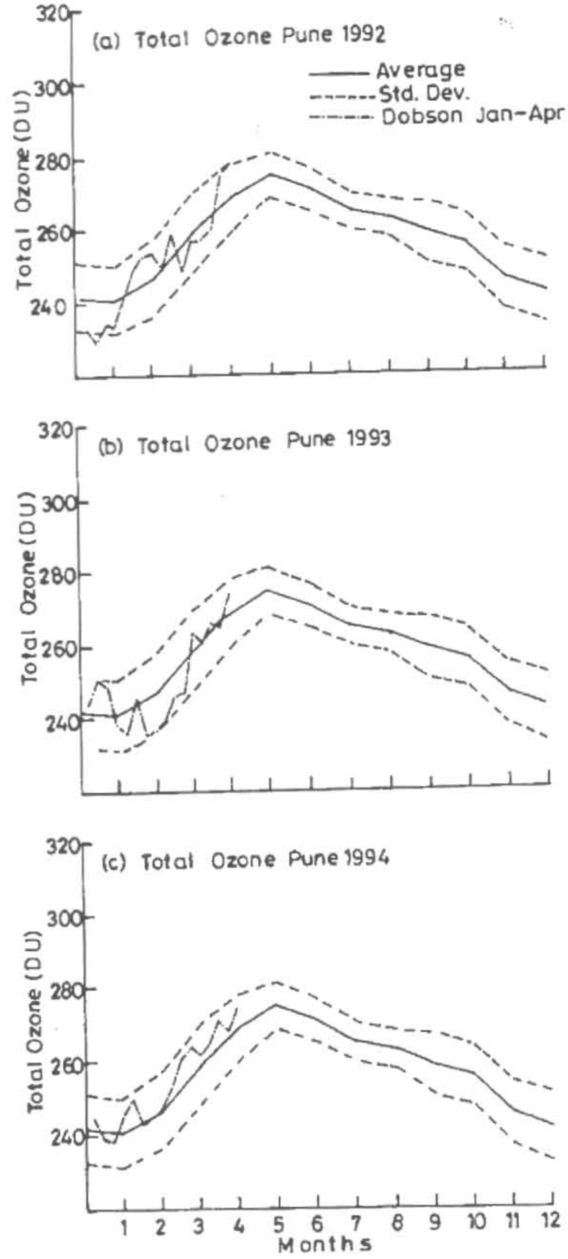
1. Introduction

Satellite based Total Ozone Mapping Spectrophotometer (TOMS) measurements have shown record low ozone amounts between 65°N and 65°S for most parts of the year 1992 and early 1993 (Gleason *et al*., 1993). Low ozone values have also been observed in the Northern Hemisphere (NH) by the Microwave Limb Sounder measurements on the Upper Atmospheric Research Satellite (UARS) in early 1993 (Waters *et al*., 1993). Further, the TOMS data analysis has clearly brought out that daily global averages (region 65°N and 65°S) for the year 1992 are significantly lower than any of the earlier 13 years. Values during 1992 were 2 to 3 % below the observed daily average ozone values of the preceding years, particular interest is the largest decrease in ozone amounts observed over the region from 10° N - 60° N (Kerr *et al*., 1993).

Climatologically, the column abundance of ozone is lowest over the tropics (Salby and Callaghan, 1993) due to which these regions experience larger fluxes of solar UV radiation. This fact underlines the need for continuous monitoring and analysis of ozone levels in the tropical and sub-tropical regions, especially the long term trends and fluctuations. Very few studies (Mani and Sreedharan 1973; Tiwari, 1992; Kundu and Jain 1993) are available on systematic analysis of long term variations of total ozone over Indian stations. Kundu and Jain (1993) have used Dobson Spectrophotometer measurements from three total ozone monitoring stations of the India Meteorological Department (IMD) located at Srinagar (34° N), Delhi (28° N) and Kodaikanal (10 °N). Based on data of nearly three decades they conclude that the general pattern of variations agrees well with the results from TOMS data analysis by Stolarski *et al*. (1991). They also report a small long term trend which has a positive value



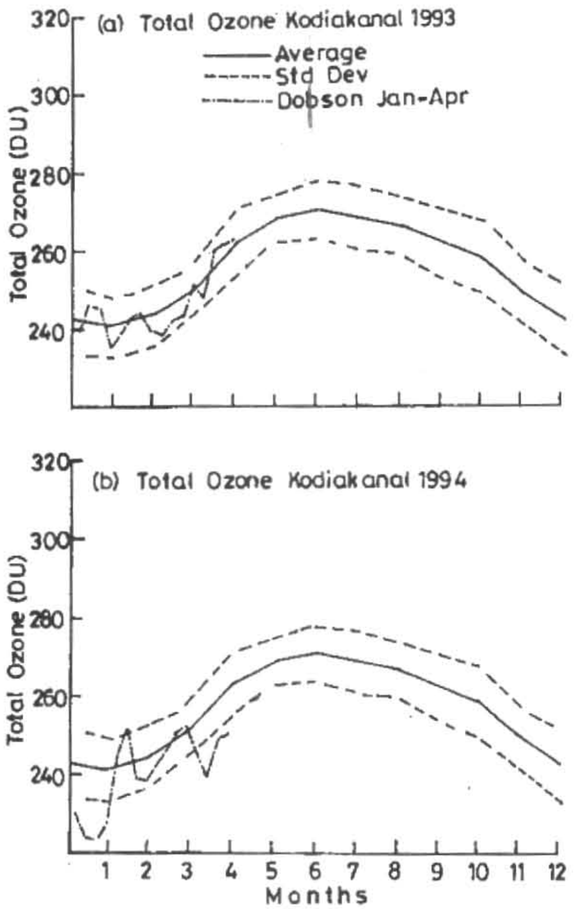
Figs. 1 (a-c). Total ozone Delhi (a) 1992, (b) 1993 and (c) 1994



Figs. 2 (a-c). Total ozone Pune (a) 1992, (b) 1993 and (c) 1994

in the equatorial and subtropical stations and changes to a slightly negative value towards the mid-latitude. Tiwari (1992) has studied the variations in total ozone amounts as well its vertical distribution using Umkehr data. The analysis indicates variations, which are within the interannual changes, with Delhi showing increases in tropospheric ozone.

In this study we present the seasonal characteristics of variations in total ozone amounts at Kodaikanal, Pune, Varanasi and Delhi along with the fluctuations observed at these locations during the recent years. Trends in total ozone values at four stations are also presented. Changes in stratospheric and tropospheric ozone concentrations have also been presented based on a study of ozone sonde data. The phase lag between the high latitude station like Delhi and lower latitude station is consistently present. The occurrence of seasonal maxima and minima over stations is a function of the strength of the photochemical production as well as meridional transport processes from the station Delhi and Pune. The main focus of data analysis was to look for any change/long term trends in ozone amounts over the Indian stations.



Figs. 3 (a&b). Total ozone Kodaikanal (a) 1993 and (b) 1994

2. Seasonal patterns in total ozone and recent changes

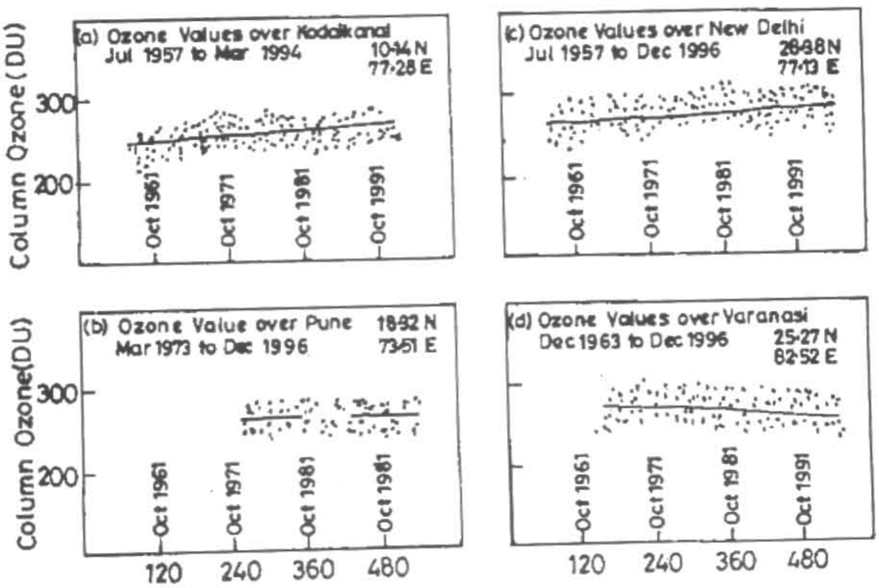
Total ozone data for the period 1970-94 recorded by Dobson Spectrophotometers at three stations *viz.* Kodaikanal (10° N), Pune (18° N) and Delhi (28° N) of IMD ozone network have been used. Means and standard deviations for different months were calculated for each station based on long period average. Recent data for the individual years are superimposed as weekly values, so as to highlight the variations during the recent years.

2.1. *Characteristic seasonal features*

Figs. 1-3 show the seasonal characteristics of total ozone variations at three stations. Monthly mean values together with the standard deviations are illustrated. Month zero in the figure corresponds to the December value for the mean curves and respective weekly values in case of individual years. Kodaikanal and Pune show similar amounts of mean total ozone amounts. In both these stations the minimum values are recorded in January Maximum values are recorded in the month of May in Pune and in June at Kodaikanal. Delhi had the highest mean ozone values with minimum values in the month of November and maximum values in the month of May. Delhi also shows the maximum variability among the three stations. Tiwari (1973) had noted that maximum values of total ozone over Delhi occur during March-April and minimum during October-November. Total ozone maxima and minima over Kodaikanal are reported to occur a little later, during June-August and December-January respectively. Although, in the present study we find the Delhi maxima to be occurring in the month of May, instead of March-April as observed in the earlier studies which are controlled by the global circulation patterns. The mean minimum values of total ozone amounts over Delhi are equal to the average values at the other two stations. Therefore, small variation in the ozone amounts in the southern peninsular region could have more profound biological effects. The seasonal changes from peak to trough are however, within a comparable range for all the three stations. These are generally found to be 13-18 Dobson units. All the three stations show a slight increase in post monsoon total ozone values, which is seen as a kink, particularly marked in case of Delhi. It is also seen that the mean differences in column ozone amounts between Delhi (located at higher latitude) and Kodaikanal (located at a lower latitude) are higher during summer (*i.e.* May) than winter season. This may be due to strong meridional circulation during the summer.

2.2. *Variations during the recent years 1992-94*

Delhi shows significantly low values of total ozone amounts during the first four months of 1993. The values are lower by 2 σ during some of the weeks in January and February months [Fig. 1(b)]. Similar plots for the year 1992 [Fig. 1(a)] and 1994 [Fig. 1(c)] shows weekly values of total ozone during these months to be much higher. Fluctuations during these years mostly remain between $\pm$ 1σ values of total ozone during this period. The pattern of fluctuations observed during the period 1992-94 especially over Delhi is indicative of some perturbations, which have disturbed the equilibrium of normal changes in total ozone amounts. However, it is difficult to link them to the volcanic episode since the lower values of ozone were observed to occur about 2 years later in the case of 1991-Pinatubo eruption (Chakrabarty and Peshin, 1997). The absence of such influences in causing fluctuations is further confirmed by the nature of the recent changes observed over Pune and Kodaikanal. At both these locations, which are nearer to the equator as compared to Delhi, the fluctuations are within normal limits of $\pm$ 1σ.



Figs. 4 (a-d). Plot of monthly averaged values of ozone columns *versus* time for four stations of India

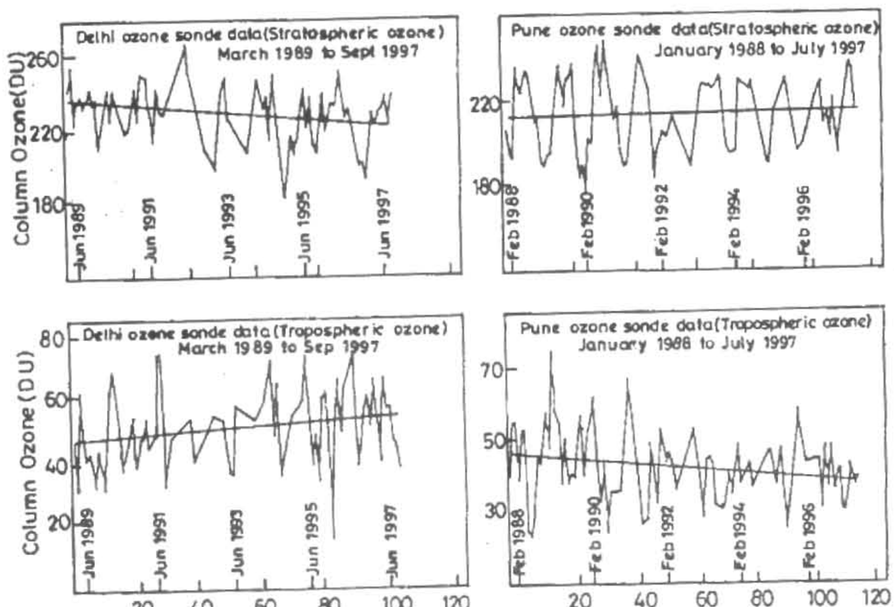


Fig. 5. Time variations of tropospheric and stratospheric ozone columns obtained by ozonesonde at New Delhi and Pune

3. Long term trends in total ozone

Monthly total ozone data series from four stations *viz.* Delhi, Pune, Kodaikanal and Varanasi were also subjected to long term trend analysis to ascertain any increase or decrease in tendencies in the column ozone values over the Indian stations.

Fig. 4 shows the plots of the monthly ozone data for these stations. Since we are only comparing the observations from different stations, we have not filtered the effect of El-Nino or QBO from the data series. The straight lines drawn through the data points are best-fit straight lines drawn by the computer. It is clear both from the linear trend values, as well as the plots that the two stations *viz.* Delhi and Kodaikanal show an increasing trend, at Pune there is almost no trend and at Varanasi there is a decreasing trend of total ozone over the years. Ozone trends at Varanasi and Delhi are different though the latter is only 600 km away from the former in the NW direction. In Fig. 4 we have shown ozone trends using the data of all available periods which are quite long. However, if we consider shorter periods, the trend will be different.

4. Stratospheric ozone concentrations

In order to link the variations and long term trends in total ozone content with changes in stratospheric concentrations where maximum ozone concentrations occur, we have shown in Fig. 5 the trends of tropospheric and stratospheric ozone columns at Delhi and Pune obtained simultaneously by ozone sonde. In the same balloon flight, tropopause height was measured. The value of ozone below tropopause was taken as tropospheric ozone column and the value of ozone above tropopause was taken as stratospheric ozone column. Though the data are for a short period (for Pune from January 1988 to July 1997 and for Delhi from March 1989 to September 1997), still one can see those trends of tropospheric ozone over Delhi and Pune are different. One thing to be noticed in this figure is that variations of tropospheric and stratospheric ozone column are in opposite phase. At Delhi increase of tropospheric ozone and decrease of stratospheric ozone lead to a slight decrease of total ozone column. A marginal decrease of tropospheric ozone and almost no change in stratospheric ozone lead to almost no change in total ozone at Pune. It could be that stratospheric ozone at Pune is increasing as found at Wallops Island at 50 hPa level (0.30 ± 0.29) by London and Liu (1992).

5. Conclusions

The analysis of results indicates that recently some changes have taken place in ozone levels at the Indian stations. These changes are less apparent in the long-term trends of total ozone data, as the increase in tropospheric ozone has a compensating effect to the decrease in ozone at stratospheric levels. Ozone level in the troposphere is linked with human activities. Since human activities, especially in urbanized locations like Delhi are strongly influencing the chemical reactions responsible for ozone production/destruction, the observed increase in tropospheric ozone over Delhi is suggestive of the greater impact of human influences. More detailed analysis with theoretically based chemistry models would be required to bring out the exact nature of linkages. Earlier study of ozone concentrations in the tropical troposphere has indicated the significant spatial and temporal inhomogeneities. This could be one of the reasons for the non-uniformity in the trends between different stations examined in the present study.

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