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Ozone variation over tropics : Trends revealed from Dobson measurement over Indian stations

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सार — 1966-1988 के दौरान श्रीनगर, नई दिल्ली, पुणे तथा कोडाइकनाल में डोबसन स्पैक्ट्रमी प्रकाशमापी से प्राप्त आंकड़ों का प्रयोग करते हुए ओजोन मात्रा में विचरणों का अध्ययन किया गया है। कुल ओजोन का वार्षिक औसत मूल्य और परत 1 से 9 तक में उमखेरे पद्धति द्वारा उसके उर्ध्वाधर वितरण को अभिकलित किया गया है। 1966-1988 की अवधि के कुल ओजोन तथा उसके उर्ध्वाधर वितरण के लिए मिश्र औसत मूल्य से विचलन का अभिकलन कर दिया गया है। नई दिल्ली तथा पुणे के विचरणों की तुलना डच (1989) द्वारा रिपोर्ट किए गए अरोसा के विचरणों से की गई। नई दिल्ली तथा पुणे में प्रेक्षित ओजोन वितरण में विचरण सामान्यतः वार्षिक परिवर्तनों के अंतर्गत होने के कारण समझाये जा सकते हैं। नई दिल्ली के ऊपर परत 1 में क्षोभ मंडलीय ओजोन, मानवजनिक प्रकृति के कुछ प्रभाव दिखाती है। दूसरी ओर पुणे के ऊपर की क्षोभ मंडल किसी भी परत में चाहें वह क्षोभमंडल हो या समताप मंडल, प्रदूषक के किसी भी प्रकार के प्रभाव को प्रदर्शित नहीं करता।

ABSTRACT. Variations in ozone amounts have been studied using data obtained with Dobson spectrophotometers during 1966-1988 at Srinagar, New Delhi, Pune and Kodaikanal. Yearly average values of total ozone and its vertical distribution by the Umkehr method in layers 1 to 9 have been computed. Departures from composite avarage value for the period (1966-1988) have been computed for both total ozone and its vertical distribution. The variation over New Delhi and Pune have been compared with those at Arosa reported by Dütsch (1989). The observed variations in the ozone distribution at New Delhi and Pune can be explained, as being within normal interannual changes. Tropospheric ozone in layer 1 over New Delhi shows some effects of an anthropogenic nature, on the other hand Pune does not exhibit in any influence of pollutants in any layer, either in the troposphere or stratosphert.

Key words—Ozone depletion, Vertical distribution, Dobson spectrophotometer, Umkehr.

1. Introduction

In recent years the concentration of stratospheric ozone has been observed to decrease markedly over Antarctica every year during September-October. Measurements in higher latitudes also indicate a systematic decrease in the average ozone amounts in the stratosphere and an increase in the troposphere as a green house gas.

In the natural atmosphere ozone is formed in the stratosphere (above 30 km) by photochemical reactions of solar ultraviolet radiation (<242 nm) with oxygen molecules. Ozone also strongly absorbs ultraviolet radiations (220-320 nm) in the Hartley-Huggins bands. Thus ozone forms a thin shield protecting the biosphere from the biologically harmful solar UV radiation. Total columnar amount of ozone in the atmosphere, if reduced to standard temperature and pressure (STP), would occupy only 2 to 4 mm thickness, but this small amount of gas plays an important role in its thermal budget and in protecting life on earth.

The tropical stratosphere is the source region of ozone production; however, the total amount of ozone is a maximum near the poles and a minimum in the tropics, indicating that dynamic processes help in the transportation of this trace gas to higher latitudes. Due to industrialisation and increased human activities, many molecules of anthropogenic origin have been injected into the atmosphere which contribute to the depletion of stratospheric ozone and cause higher concentrations of tropospheric ozone. Both these factors have caused worldwide concern among scientists.

The direct effect of these anthropogenic substance was first observed when Farman *et al.*, (1985) reported, on the basis of long-term measurements of total ozone at Halley Bay (76° S, 27° W), a systematic decrease in ozone amount since 1975 followed by a much more pronounced decrease after 1979.

This marked ozone depletion over the Antarctic region, which occurs in the austral spring (September-October) every year, has been confirmed by ozone observations at the Indian station *Dakshin Gangotri* (Sreedharan *et al.* 1989). A detailed study on ozone measurements in tropics and the role of anthropogenic substances has been presented by Mani (1988, 1990). Recent studies on trends in ozone changes in higher latitudes have indicated a systematic decrease in the stratospheric concentration and an increasing trend in tropospheric amount (Dütsch 1989, Logan 1985). In the present paper, changes in ozone concentration over the tropics have been examined on the basis of measurements of total ozone and its vertical distribution by the Umkehr method from Dobson spectrophotometers at four Indian stations.

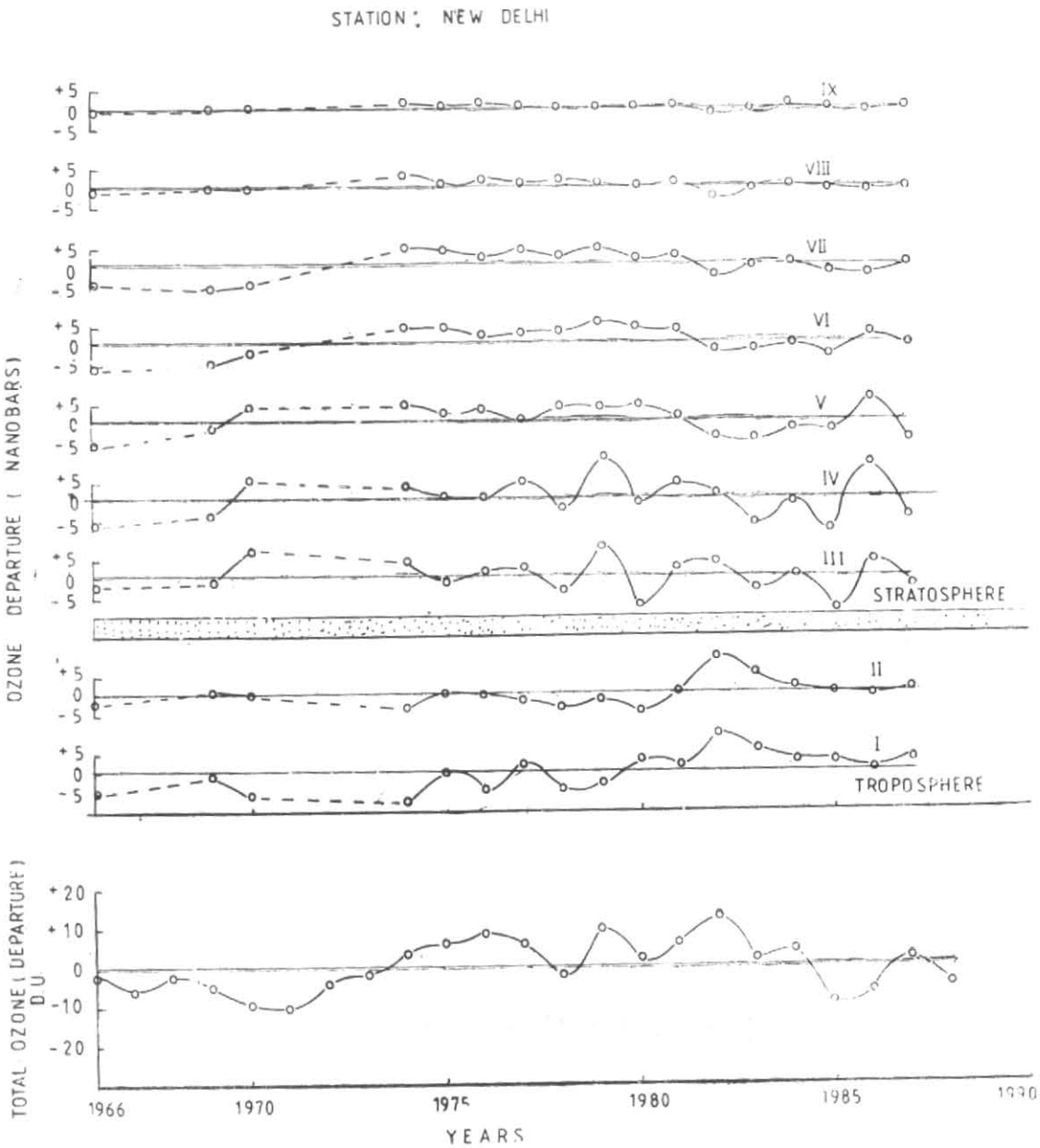


Fig. 1. Trends in ozone variation over New Delhi

2. Data used

India has a network of seven Dobson spectrophotometer stations at Srinagar (34° N, 74. 5°E), New Delhi (28.4°N, 77 .1°E), Varanasi (25.3°N, 82.5°E), Ahmedabad (23°. N, 72.4°E), Mount Abu (24.3°N, 72.4°E), Pune (18.3°N, 73 .5°E) and Kodaikanal (10 .1°N, 77 .3°E). Regular measurements of total ozone and Umkehr observations are made from these stations and are published in the "*Ozone Data of the World*". Observed ozone amounts, total and layerwise concentrations, since 1970 (or earlier if available) have been collected and the average amounts for each year have been calculated and a mean value (hereafter referred as normal) calculated from the available data from 1970 to 1988 for each station. The departure (yearly average-normal) for each year has been calculated and the trend in ozone changes have been examined in different layers over New Delhi and Pune where the number of observations are more compared to other stations. Variations in yearly total ozone amount have also been studied at Srinagar, New Delhi, Pune and Kodaikanal.

3. Changes in ozone concentration in tropics

3.1. *Changes in concentration over New Delhi*

The departure of total ozone amounts (from the average) for each year in Dobson units from 1966 to 1988 (as described in section 2) is shown at the bottom of the Fig. 1 while the variation of ozone concentration (nanobar) in layers 1 to 9 is depicted in the top portion of Fig. 1. It will be seen that the total ozone amount was higher than average (normal) from 1974 to

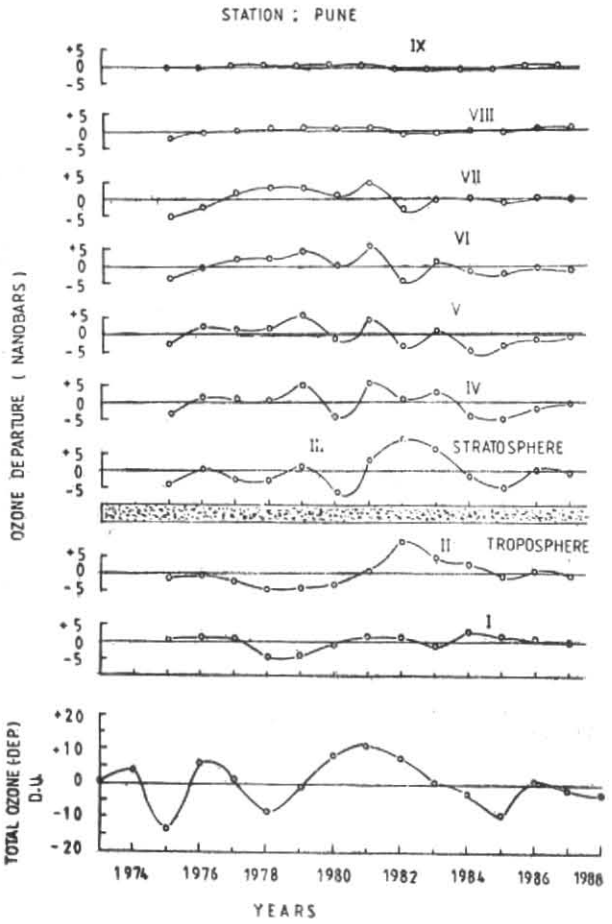


Fig. 2. Trends in ozone variation over Pune

1984. During 1985 and 1986, total ozone amounts show a decreasing trend depicting nearly the same amount as reported in 1970-71. However, these changes are accountable within inter-annual variations.

Changes in ozone concentration in layers 1 (500-250 hPa) and 2 (250-125 hPa) are representative of tropospheric ozone variations. Layer 1 shows a practically constant value up to 1974, a continuous increasing trend from 1975 to 1982, followed by a slowly decreasing trend till 1984 and an almost constant value thereafter. Layer 2 also depicts similar trends as in layer 1 with the inter-annual variations smoothed out. Increasing trends in ozone values since 1974 may be due to increase in air pollutants.

A rapid decrease of ozone concentration in 1985 followed by a rise in 1986 and 1987 is worth mentioning. The decrease in total ozone during 1985 is mainly contributed by decrease in layers 3 and 4 and the increase during 1986-87 is due to increased concentration in layers 3 to 6. This further confirms that meteorological factors affect the ozone changes up to the 6th layer (33 km). Layers 8 and 9 are in photochemical equilibrium and show very little perturbation, layer 7 is a transition layer.

Few Umkehr observations are available prior to 1974 and the years with no reliable data are denoted by dashed lines.

3.2. *Changes in ozone concentration over Pune*

Measurement of ozone at Pune started in 1973 after the Dobson spectrophotometer at Dum Dum was transferred to Pune. Therefore, total ozone observation at Pune are available from 1973 and Umkehr measurements from 1975.

Fig. 2 shows the yearly departure of total ozone amount from the average value of 1973 to 1988. The graph at the bottom of Fig. 2 shows the interannual variation, but there is no sign of any systematic change from 1973 to 1988.

The layerwise concentration in the troposphere shows a practically uniform value in layer 1. In layer 2, the concentration in 1982 was slightly higher but this probably reflects more mixing between the troposphere and the lower stratosphere as seen from an identical increase in layer 3 also. An interesting feature is exhibited during 1980-81 where a fall and rise in ozone concentration is reflected in layers 3 to 7 in the stratosphere.

The yearly ozone departure at all levels and also in total ozone does not show any systematic rise or fall in the ozone values. The slight positive bias in layer 1 observed over New Delhi is also not visible at Pune, probably due to less pollution, whereas the higher ozone concentration in layer 2 during 1982 seems due to mixing between the troposphere and stratosphere.

In order to examine the minute fluctuations in the stratospheric ozone over New Delhi and Pune, the values of ozone concentration in layers 4 to 7 are plotted separately [Figs. 3(a) & (b)]. These graphs reconfirm that the ozone fluctuations are greater up to layer 4, however, layers 5 and 6 also depict a similar increasing or decreasing trend as found in the lower stratosphere but with fewer fluctuations. Figs. 3(a) & (b) further show that a nearly constant ozone concentration has been maintained till 1981 in all the stratospheric layers up to 7, but from 1982 a decreasing trend in layers 4 to 6 is observed; this decreasing trend is most visible in layer 4 up to 1985.

4. Comparison of ozone variation trends in the tropics and higher latitudes

From the long series of ozone measurements at Arosa (46.5°N, 76.6°E), Dütsch (1989) reported a gradual and systematic increase in layers 70-50 hPa and 50-40 hPa from year 1970 to 1988. A similar trend curve is shown in Fig. 4 for New Delhi and Pune in the layers 1, 3 and 4. The variations at Arosa are also drawn for the layers 500-300 hPa (layer 1), 70-50 hPa (layer 3) and 50-40 hPa (layer 4). Though the exact heights in case of layers 3 and 4 are not identical to those layers (70-50 hPa and 50-40 hPa) at Arosa, however, these are comparable.

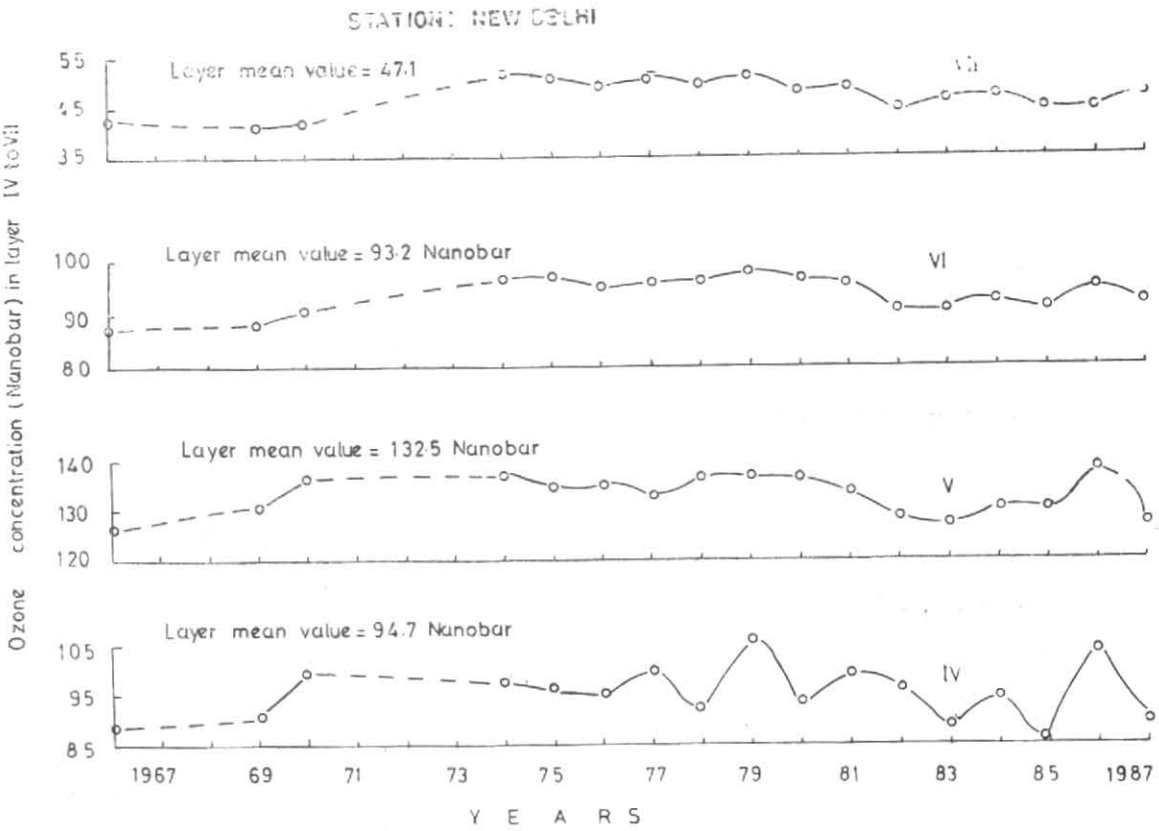


Fig. 3(a). Ozone concentration in layers 4 to 7 at New Delhi

Regression lines in layer 1 for the three stations New Delhi, Pune and Arosa are shown in Fig. 4. Ozone variations at New Delhi show a slight increasing trend in ozone amounts from 1966 to 1984 and a constant level thereafter. This increasing trend in layer over New Delhi is ascribed to increasing amounts of air pollutants in the near the earths surface on account of increasing industrialisation and increase in population.

Similar regression lines corresponding to layers 3 and 4 are also shown in Fig. 4 The regression line for New Delhi shows an almost constant amount in layer 4, the variation in layer 3 is practically constant from 1966 to 1982 but after 1982 a gradual decline in the regression curve can be identified. This trend needs to be watched to ascertain whether it is due to a temporary effect from the El Chichon eruption or it is a real decrease due to increasing CFCs. It may be pointed out that this decrease is well within the interannual variation range, however, a close look at the future trend is essential.

An examination of the trend at Pune in corresponding layers does not exhibit any systematic change. From the yearly departure at New Delhi and Pune, it can be inferred that the ozone amount was slightly higher from 1976 to 1981, compared to values before 1976 and after 1981.

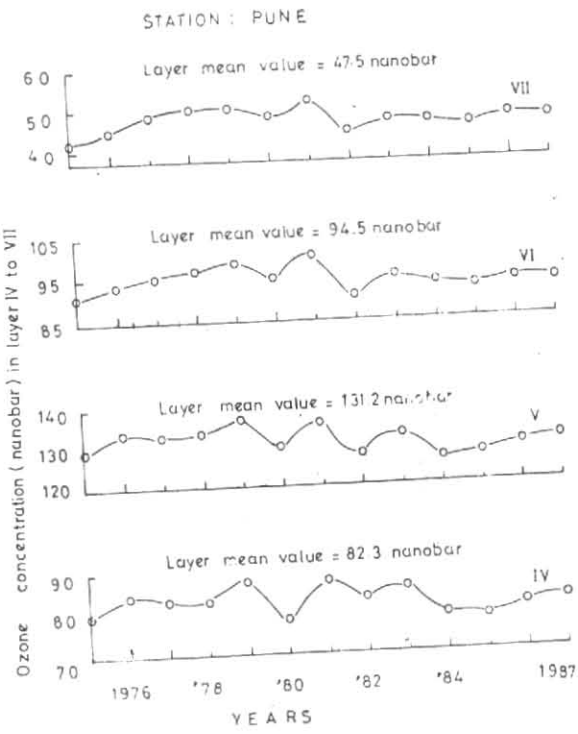


Fig. 3(b). Ozone concentration in layers 4 to 7 at Pune

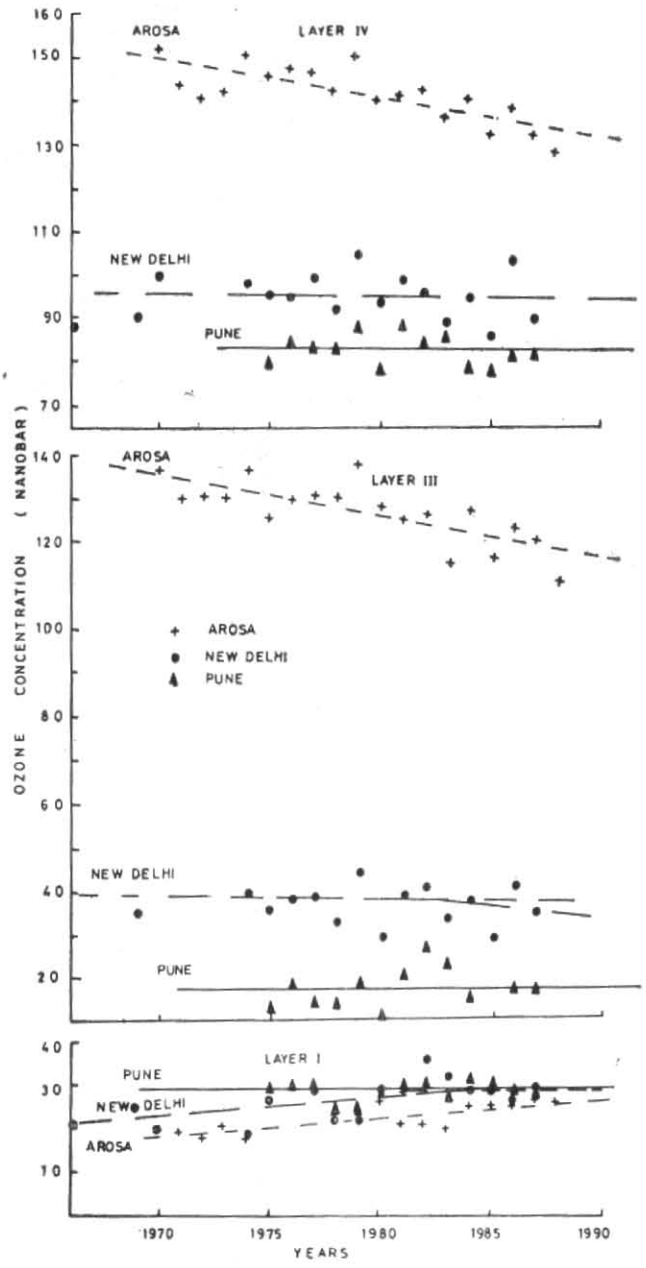


Fig. 4. Changes in ozone amount in layer 1, 3 and 4 at New Delhi, Pune and Arosa

5. Changes in total ozone

The yearly average ozone amounts measured at Srinagar, New Delhi, Pune and Kodaikanal from 1966 to 1988 has also been examined and are presented in Figs. 5(a) & (b). The diagram shows the interannual variation which is a maximum at Srinagar and a minimum at Kodaikanal. At the top of the Fig. 5, the yearly variations are presented after smoothing through a 3-year running mean. This brings out the period of decreasing and increasing trend in total ozone concentration. In the years 1970-72, the yearly ozone amount was low at Srinagar followed by higher values during 1978-80 and a decreasing trend thereafter. New Delhi also depicts nearly the same trend as seen at Srinagar but with a lower magnitude.

The smoothed curves (3 year running means) for Srinagar, New Delhi and Pune show a gradual decrease in ozone concentration after 1983, the lowest value at New Delhi and Pune being attained in 1986 while a reversal of the trend is perceptible from 1987, however, the reversal is yet to be achieved at Srinagar. One can clearly see that the minimum in total ozone amount during 1985-87 is of the same order as that found during 1970.

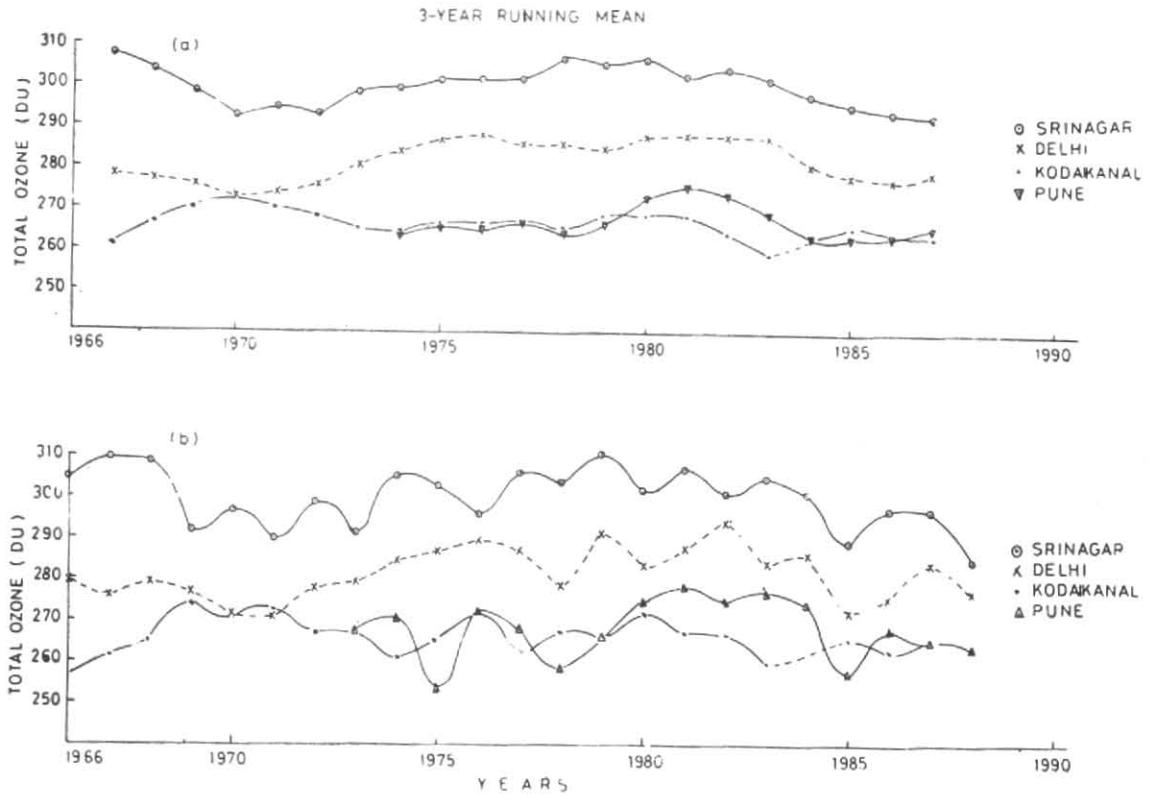
In the preceding section, a decreasing trend in ozone concentration in layer 3 over New Delhi has been observed and the probable cause of its occurrence has been examined. Considering the decreasing trend in total ozone at Srinagar, New Delhi and Pune, it appears more due to some natural periodic variation rather than due to anthropogenic causes. This inference is to be carefully verified from ozone observation of 1990s.

6. Conclusion

Total ozone observations at Srinagar, New Delhi, Pune and Kodaikanal have been regularly made since 1970, but Umkehr measurements are few. In view of scanty Umkehr observations at Srinagar and Kodaikanal, the observations at New Delhi and Pune were mainly used for the present study, which have better coverage of Umkehr data. Based on the variation in total ozone and its vertical distribution in layers 1 to 9 over New Delhi and Pune, following tentative inference can be drawn :

(a) Variations in the total ozone amounts at New Delhi and Pune since 1970 do not indicate any systematic decreasing or increasing trend apart from the normal interannual variations.

(b) Layerwise concentration over New Delhi also depict the normal interannual variations in layers 1 to 6. However, on a detailed examination, ozone concentration in the lower troposphere (layer 1) is seen to show a slight increasing trend from 1974 to 1982 followed by steady values. This probably may be the effect of increasing pollutants in the tropospheric layers over New Delhi. Layer 2 also shows a similar trend. Also in the stratosphere, layer 3 shows a very slowly decreasing trend after 1982. Though this decreasing trend does not exceed the normal value observed during 1970 and earlier, this decreasing trend deserves to be closely watched in future.



Figs. 5(a-b). Yearly total ozone variation at Srinagar, New Delhi, Pune and Kodaikanal

(c) Layerwise changes over Pune do not show any systematic change since 1975. Pune represents a comparatively pollution-free city situated at a height of 500 m a.s.l. Changes in stratospheric ozone also do not depict any anthropogenic effects.

(d) The difference in layerwise concentration over New Delhi and Pune may be due to their latitudinal difference. Pune represents a truly tropical atmosphere while New Delhi is affected by extra-tropical weather disturbances during winter.

(e) Yearly total ozone variation over Srinagar and New Delhi show that the lowest value in ozone amount were observed during 1970-72 followed by higher values during 1978-80, with a decreasing trend till 1986-87. The lower concentration during 1970 and 1986 are almost identical and point to some natural periodicity.

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