Mausam, (1990), **41**, 3, 421-426

551.510.534 : 551.553.21

Ozone field and monsoon rainfall

HAMID ALI

Meteorological Office, New Delhi

(*Received 19 April 1988*)

सार — अच्छे मानसून वर्षों और खराब मानसून/सूखे वर्षों के लिए भारतीय स्टेशनों पर ओजोन क्षेत्र का अध्ययन किया गया है। यह पाया गया है कि (*i*) खराब मानसून/सूखे वर्ष में कुल ओजोन मैक्सिमा का मूल्य पूर्ववर्ती/अनुवर्ती अच्छे मानसून से अधिक होता है और (*ii*) अप्रैल के महीने के चौथे ओजोन सतह (19.2-23.7 कि. मी.) में ओजोन का सान्द्रण खराब मानसून/सूखे वर्ष की तुलना में पूर्ववर्ती/अनुवर्ती अच्छे मानसून वर्ष से अधिक होता है।

ABSTRACT. Ozone field over Indian stations for good monsoon years and bad monsoon/drought years has been studied. It is noticed that (*i*) 'total ozone' maxima in the bad monsoon/drought year has a higher value than in the preceding/ensuing good monsoon year and (*ii*) the concentration of ozone in the IVth ozone layer (19.2-23.7 km) for the month of April is higher for the bad monsoon/drought year than for the preceding/ensuing good monsoon year.

1. Introduction

Need for long range forecasting of southwest monsoon over India is vital for Indian economy. Various studies based on tropospheric data for long range forecasting of southwest monsoon have already been made and many are being continued by individuals as well as groups of scientists. Besides, number of workers have linked stratospheric circulation with the southwest monsoon performance. For instance, Raja Rao & Lakhole (1978), using the rocket wind data of Thumba have studied the stratospheric circulation and found that the phase of Quasi-Biennial Oscillation (QBO) feature in upper air over the equator appears to give a prior indication of onset of southwest monsoon over Kerala and also the rainfall in the central parts of the country. Appearance of the easterlies in the lower stratosphere over Gan Island in May is considered an indication of the onset of monsoon over Kerala a month later. QBO phase of lower stratosphere has been related by Thapliyal (1979, 1984) and Singh (1986) with the anomalous characteristic of tropospheric circulation and hence, the annual variability of rainfall over India. According to Thapliyal, the westerly phase of QBO over Trivandrum at 50 hPa in January and February was followed by below normal rainfall in 1965, 1968, 1972 and 1974. Singh has shown that the presence of Berson westerlies (quasi-biennial westerlies) over Trivandrum between September and May of the next year and their withdrawal with the onset of monsoon coincides with below normal rainfall over India. On the other hand, easterly phase of QBO during this period over Trivandrum has normally coincided with a good rainfall over India.

Ramanathan (1963) and Rangarajan (1964) showed that biennial changes of the zonal winds over equatorial latitudes were connected with changes in phase in the biennial oscillation of the ozone content over the equator. During epochs, when the easterly stratospheric winds above 25 km weaken and changes to westerly, the ozone content increases, whereas during epochs when such westerly winds weaken and change to easterly winds the ozone content falls.

The relationship between monsoon rain fall and QBO of the stratospheric winds and the further relationship between QBO of the stratospheric winds and QBO of ozone content form the background for this study of ozone field over Indian stations for years of good monsoon and of bad monsoon/drought. The results are discussed in this paper.

2. Discussion

2.1. *Monsoon rainfall*

2.1.1. *Monsoon rainfall in* 1968, 1972, 1979, 1982 *and* 1987 — In 1968, a bad monsoon year, Punjab, east Rajasthan, Gujarat, Andhra Pradesh had 20-50% deficient of rainfall whereas Uttar Pradesh, West

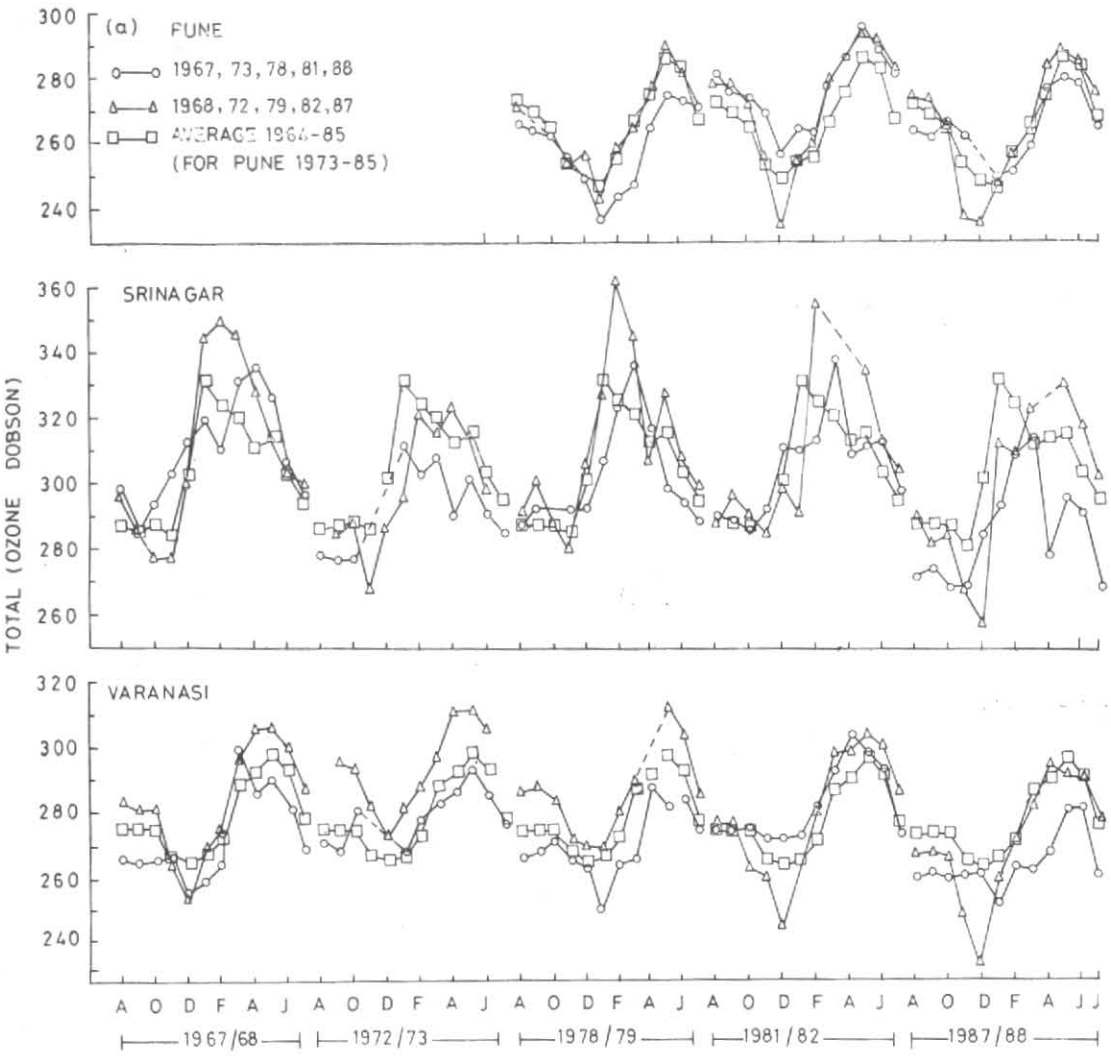

Fig. 1(a). Seasonal variation of total ozone at Pune, Srinagar and Varanasi

Madhya Pradesh, Orissa, Maharashtra, north Karnataka and Tamil Nadu had 11-25% deficient of rainfall. Delayed onset of monsoon in June, and prolonged break in it in second half of July, led to drought in many parts of north India and north Peninsula in 1972. Jammu & Kashmir, Rajasthan, east Uttar Pradesh, north Bihar, Punjab, Maharashtra and north Andhra Pradesh had 25-50% deficient of rainfall. In 1979 also the monsoon was below normal and led to drought conditions in many parts of north and central India. The rainfall was deficient in Uttar Pradesh by 50% and in Punjab, Haryana & Himachal Pradesh by 30% to 40%. In 1982 there were only few spells of good rainfall activity interspersed with periods of poor rainfall during the monsoon period over the Peninsula and in September in northwest and central parts of the country. The seasonal rainfall was normal in 24 and deficient in 11 meteorological sub-divisions. Bihar, Saurashtra, Kutch & Diu, Vidarbha and Tamil Nadu had 27% to 46% deficient of rainfall.

The summer monsoon rainfall during 1987 was excess in only 10 sub-divisions of which 6 sub-divisions were from northeast India, three from the Peninsula and 10th was Lakshadweep. Deficiency of rainfall varied from 37% to 80% in Himachal Pradesh, Haryana, Punjab, Uttar Pradesh, Saurashtra and Gujarat.

2.1.2. *Monsoon rainfall in* 1967, 1973, 1978, 1981 *and* 1988 — In 1967, the activity of monsoon was generally normal over the country. Only Jammu & Kashmir, northeast India, west Madhya Pradesh, south Karnataka and north Bihar were having 11% to 25% deficient rainfall. In 1973, 1978, 1981 and 1988, monsoon rainfall was normal or excess over most part of the country. Except

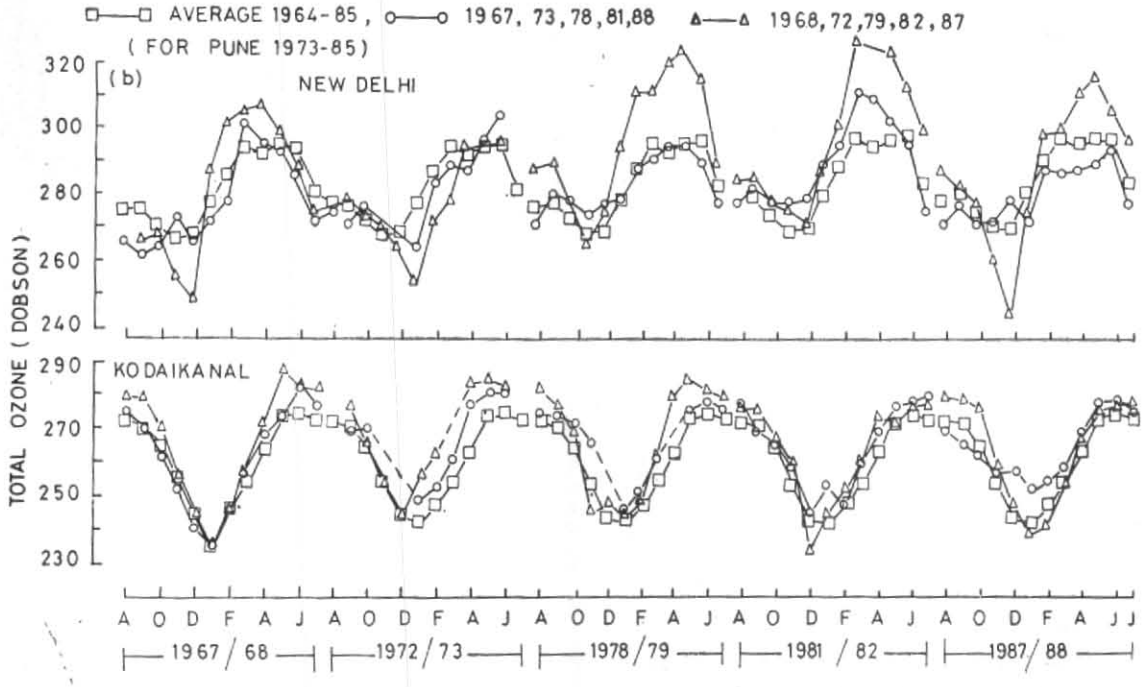

Fig. 1 (b). Seasonal variation of total ozone at New Delhi and Kodaikanal

in West Bengal and coastal Andhra Pradesh rainfall was normal/excess in the country in 1973. Only two sub-divisions Sub-Himalayan West Bengal (—18%) & Sikkim (—12%) were having slight deficiency in rainfall in 1978. In 1981, the only sub-divisions where the rainfall was deficient were Nagaland, Manipur, Mizoram & Tripura, hills of west Uttar Pradesh, Himachal Pradesh and west Rajasthan. The deficiency was about 20% to 30%. In 1988, except hills of west Uttar Pradesh and Rajasthan, the rainfall was normal or excess over the country. Jammu & Kashmir, Marathwada, Saurashtra &'Kutch, Haryana, Chandigarh & Delhi, Rayalaseema and Punjab had 60% to 100% excess of rainfall.

2.2. *Ozone field*

2.2.1. *Total ozone* — 'Total ozone' in the atmosphere over a station is the amount of ozone contained in a vertical column of air of 1 cm^2 area extending from ground to the top of the atmosphere. It is expressed as the height of an equivalent column of ozone at Standard Temperature and Pressure (STP) and its unit is 10^{-3} cm STP or one milli atmos. centimetre commonly called a 'Dobson Unit'.

Figs. 1 (a & b) show seasonal variation of total ozone for Kodaikanal, Pune, Varanasi, New Delhi and Srinagar for bad/good monsoon paired years 1967/68, 1972/73, 1978/79, 1981/82 and 1987/88. Figs. 1 (a & b) also show the long period average (1964-1985) seasonal variation of total ozone at these stations. Kodaikanal, Pune, Varanasi and New Delhi have their maxima in total ozone during the months, April to June and Srinagar during the months, January to March. But it is evident from the figure that this maxima in total ozone has a higher value in the year of bad monsoon/ drought than in the preceding/ensuing year of good monsoon. This difference in the value of maxima in total ozone is appreciable for New Delhi, Varanasi and Srinagar. Over New Delhi, the values of maxima in 'total ozone' in 1968 and 1967 were 305 and 300 DU (Dobson Unit), in 1979 and 1978: 317 and 291 DU, in 1982 and 1981 : 323 and 298 DU and in 1987 and 1988 : 311 and 289 DU respectively. In 1972 and 1973 maxima in total ozone value were 294 and 302 DU respectively. Maxima in these two years were in the month of June which is an abnormality itself as the maxima in total ozone value over New Delhi generally appears in the month of April or May. Over Varanasi, maximum total ozone in 1968 and 1967 were 306 and 300 DU, in 1972 and 1973: 311 and 294 DU, in 1979 and 1978: 312 and 285 DU and in 1987 and 1988 : 296 and 280 DU respectively. In 1981 and 1982 they were equal at 305 DU. Over Srinagar the maximum total ozone were 349 and 331 DU respectively in 1968 and 1967, they were 320 and 311 DU in 1972 and 1973, 361 and 336 DU respectively in 1979 and 1978, they were 354 and 337 DU respectively in 1982 and 1981, they were 330 and 313 DU respectively in 1987 and 1988.

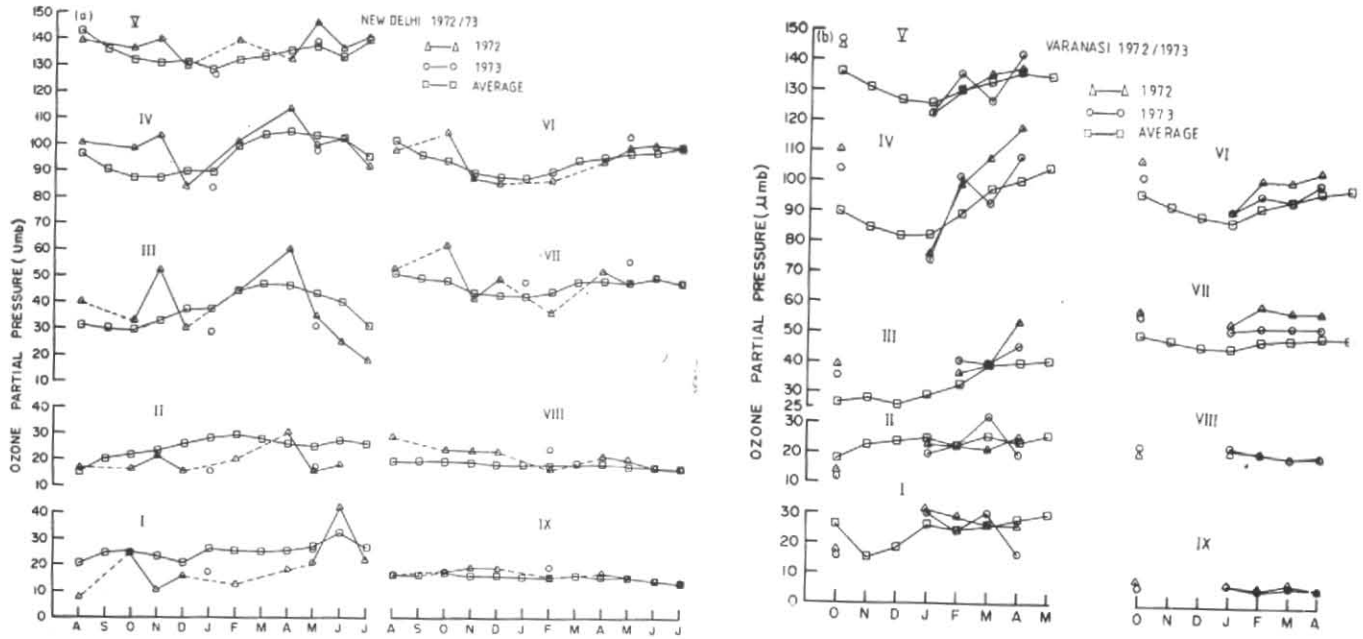

Fig. 2. Seasonal variation of ozone concentration in different ozone layers for the year 1972/73 for New Delhi & Varanasi (Layers — I : up to 10.3 km, II : 10.3-14.8 km, III : 14.8-19.2 km, IV : 19.2-23.7 km, V : 23.7-28.2 km, VI : 28.2-32.7 km, VII : 32.7-37.5 km, VIII : 37.5-42.6 km, IX : 42.6-47.8 km)

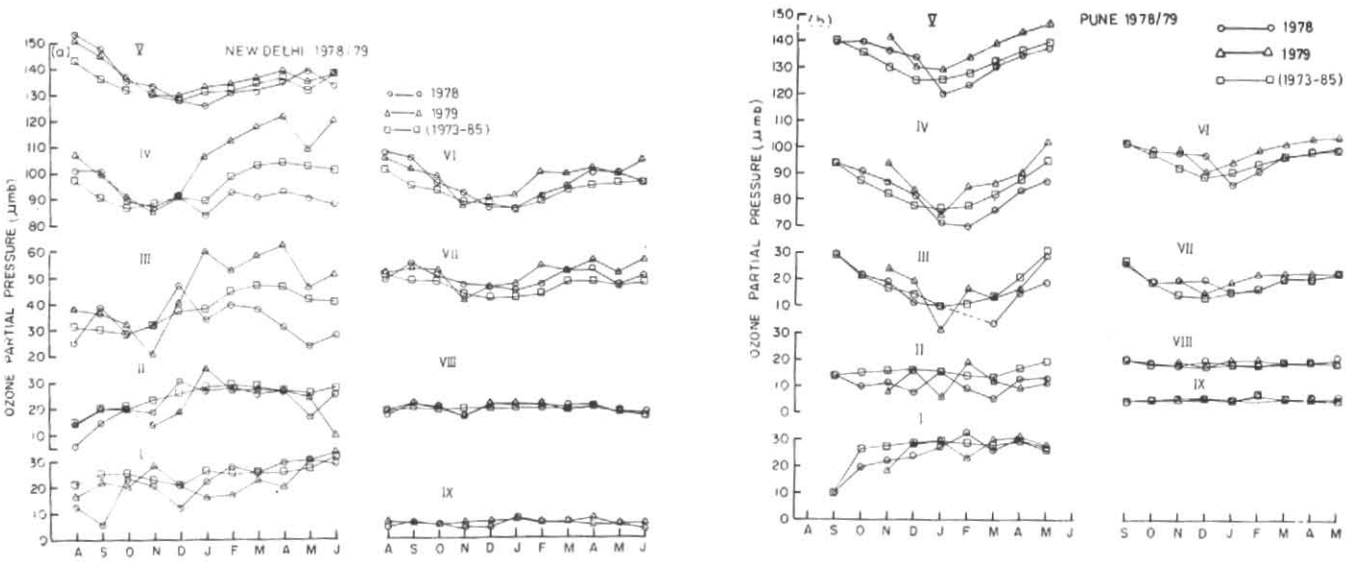

Fig. 3. Seasonal variation of ozone concentration in different ozone layers for the year 1978/79 for New Delhi & Pune (Layers — I : up to 10.3 km, II : 10.3-14.8 km, III : 14.8-19.2 km, IV : 19.2-23.7 km, V : 23.7-28.2 km, VI : 28.2-32.7 km, VII : 32.7-37.5 km, VIII : 37.5-42.6 km, IX : 42.6-47.8 km)

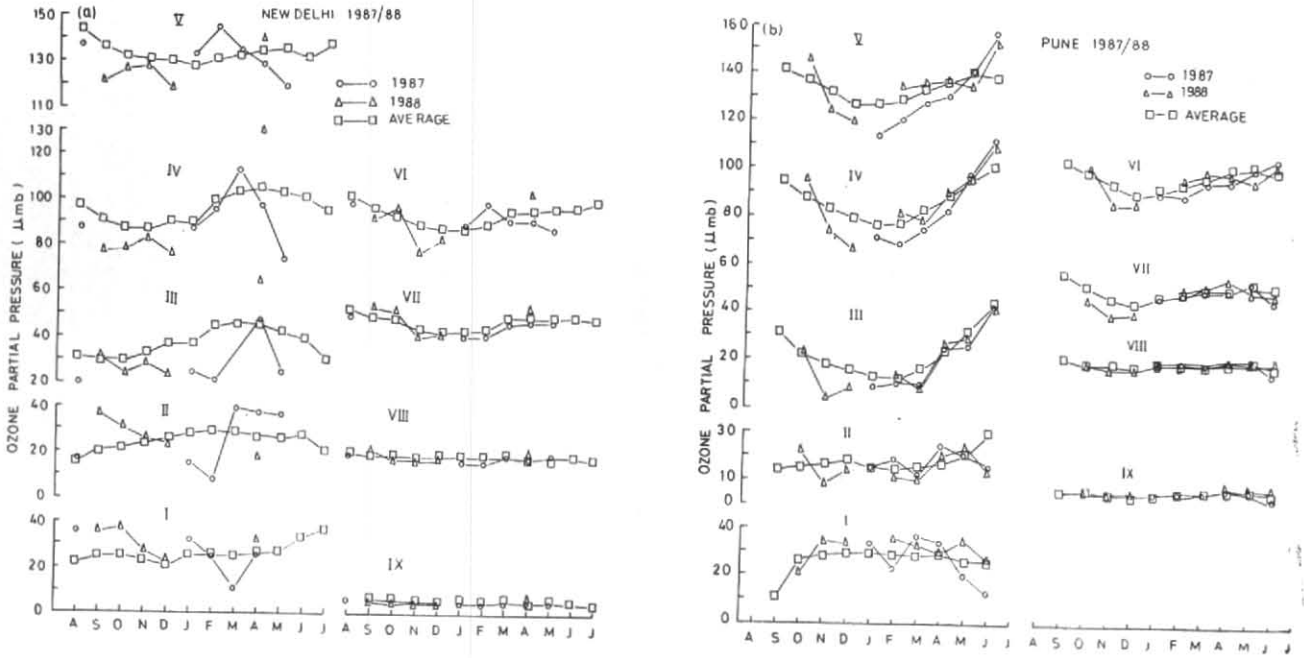

Fig. 4. Seasonal variation of ozone concentration in different ozone layers for the year 1987/88 for New Delhi and Pune (Layers — I : up to 10.3 km, II : 10.3-14.8 km, III : 14.8-19.2 km, IV : 19.2-23.7 km, V : 23.7-28.2 km, VI : 28.2-32.7 km, VII : 32.7-37.5 km, VIII : 37.5-42.6 km, IX : 42.6-47.8 km)

2.2.2. *Vertical distribution of ozone (by Umkehr method)* —Umkehr observations are taken under certain favourable sky conditions only and as such vertical distribution by Umkehr is not generally available through out the year. Available layerwise vertical distribution obtained by Umkehr method for the paired years 1972/1973 for New Delhi and Varanasi is shown in Fig. 2. Vertical distribution for the paired years 1978/1979 and 1987/1988, for New Delhi and Pune, are shown in Figs. 3 and 4 respectively. For Varanasi data for the paired years 1978/1979 and 1987/1988 were scanty and are not shown.

In Figs. 2 to 4 average vertical distribution for New Delhi (1964-1985), Varanasi (1964-1985) and Pune (1973-1985) is also shown. Umkehr observations for Srinagar and Kodaikanal were very scanty for comparison purpose and are not shown here.

The amount of ozone (concentration of ozone) in an atmospheric layer obtained by Umkehr is expressed in milli atmos. centimetre per kilometre (10^{-3} cm STP km^{-1}) and denoted by d_3. The convenient unit in use is the partial pressure of ozone P_3 expressed in micro-millibar (μmb). P_3 is related to d_3 by formula :

$$P_3 = 10.13\ d_3$$

It is evident from Figs. 2-4 that concentration of ozone over New Delhi in layers III and IV, mostly for spring months and in particular for April, is higher for the drought/bad monsoon year than that for good monsoon year of the paired years set. In other layers there is no significant trend in difference in ozone concentration for drought/bad monsoon year and good monsoon year. Ozone concentration over New Delhi, in layer IV for April was 113 μmb for 1972, 122 μmb for 1979 and 130 μmb for 1987 whereas it was 93 μmb for 1978 and 97 μmb for 1988. Data for April 1973 were not available. The average value of ozone concentration over New Delhi for April is 105 μmb. Varanasi and Pune also show the similar difference in ozone concentration for drought/bad monsoon year and good monsoon year.

Available vertical distribution of the paired years 1967/68 and 1981/82 for New Delhi, Varanasi and Pune (not shown here) also shows that the concentration of ozone in layers III and IV for April is higher for the drought/bad monsoon year than that for good monsoon year.

3. Conclusion

It is noticed that (*i*) total ozone maxima in the bad monsoon drought year has higher value than in the preceding/ensuing good monsoon year and (*ii*) in the IVth ozone layer (19.2-23.7 km) for the month of April, the concentration of ozone is higher for the bad monsoon/drought year than for the preceding/ensuing good monsoon year.

Acknowledgement

The author is thankful to Shri Shankar Kumar for typing the manuscript.

References

Raja Rao, K. S. and Lakhole, M. J., 1978, *Indian J. Met. Hydrol. Geophys.*, **29,** 1 & 2, pp. 403-411.

Ramanathan, K. R., 1963, *Quart. J. R. met. Soc.*, **89,** pp. 540-542.

Rangarajan, S., 1964, *Indian J. Met. Geophys.*, **15,** 4, pp. 565-588.

Singh, R., 1986, *Vayu Mandal,* **16,** 3 & 4, pp. 34-40.

Thapliyal, V., 1979, *Hydrological aspects of droughts : International symposium,* 3-7 Dec 1979, New Delhi, **1,** pp. 347-362.

Thapliyal, V., 1984, *Mausam,* **35,** 3, pp. 367-374.