are larger than predicted by models. Further, the data of Figure 5 show a definite day to night decrease in the altitude region below 40 km. The decrease is of the order of 5% to 10% and current model predictions are only for altitudes above 40 km and the observed decreases remain to be explained.

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ACKNOWLEDGEMENTS. I thank Drs Shyam Lal and A. Jayaraman who have been associated with the rocket ozone programme at Thumba and to Mr Y. B. Acharya who provided engineering assistance for most of the rocket flights.

A statistical analysis of total ozone data at four Indian stations

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Total ozone data are being recorded at a number of Indian stations for over three decades. However, doubts have been recently raised on the consistency and dependability of Indian data. A recent US report omitted Indian data from the global analysis and the UMO even suggested that Indian data may need to be adjusted to correspond to global data. It was therefore felt that a statistical analysis of monthly means of total ozone data available for Indian stations may help in an appreciation of the consistent nature of the data.

Data availability

The periods of data available at the four stations, Kodaikanal, New Delhi, Varanasi and Mount Abu/Ahmedabad are listed below:

Kodaikanal from 1960 to 1988. Six months' data for March 1972, April 1976 and 1978, November 1981 and December 1978 and 1980 were missing.

New Delhi. 1960–1970 and 1975–1988.

Varanasi from 1964 to 1988. Of these, data for 13 months were missing, viz. January 1986, February 1986, March 1982 and 1986, April 1974, 1982 and 1986, May 1982, July 1987, November 1981, 1985 and December 1981 and 1985.

Ahmedabad/Mount Abu. The two stations being close and since the same instrument was used at both stations, the data have been combined for analysis.

Ahmedabad: 1960–69 and 1983–85
Mount Abu: October 1969 to 1981.

Of these, data for 18 months are missing, viz. January 1982 and 1983, February 1982 and 1983, March 1980 and 1982, April, May, August, September, October, November and December 1982, June 1982 and 1985. July 1982 and 1984 and May to December 1985.

As the number of months for which the data are missing is not large, an attempt was made to interpolate the data for these months. In the case of Kodaikanal, values of the long-period means have been substituted for the missing months. For Varanasi, the values interpolated are based on the trend observed in the adjoining months and years. At New Delhi, as data were missing for all the years 1971–1973 and for four of the months January–April 1974, no attempt has been made to interpolate for such long periods. Though data of Ahmedabad and Mount Abu have been combined, the data have not been interpolated but the means for the two stations have been compared and tested for the significance of the differences.

Method of analysis

The data available are for short periods of less than 30 years and detailed statistical tests based on a study of the frequency distributions of monthly means has not been attempted. It is assumed for the present analysis that the data of monthly and annual means follow the normal law of distribution. For a normal distribution, long-period means ± 2 SD includes 95% of the total frequency. Five per cent of the frequency may lie outside the range of mean ± 2 SD. This could be tried as an approach in testing the consistancy of the data. After this analysis, means for different periods have been compared and tested. Linear trends in the monthly and annual means have also been tried as far as possible. Results of these tests are described below (Tables 1–4).

A study of the 5-year averages of monthly means and linear trend

Kodaikanal. Table 5 gives the deviations of five-yearly averages from the long period mean for the different months. Excepting for five, none of the other deviations from the long-period mean are found to be statistically significant.

The linear trend in the monthly and annual means was

Table 1. Comparison of extremes of monthly means with long-term mean ± 2 SD limits at Kodaikanal

Month	Extremes (actual)	Long-period mean ± 2 SD	Values outside column 3 and number	
1	2	3	4	
	D.U.	D.U.	D.U.	
January	231–284	225–269	277, 284	2
February	238–275	234–266	275	1
March	249–270	247–267	270	1
April	256–284	256–283	284	1
May	266–290	265–289	290	1
June, July	(within ± 2 SD)	—	—	—
August	266–289	264–288	289	1
September	259–288	260–287	259, 288	2
October	(within ± 2 SD)	—	—	—
November	245–273	242–272	273	1
December	224–273	229–262	224, 272	2

The number of monthly means outside the limits in column 3 is only 12, less than 5% of the total frequency. Also, 6 of the 12 differ by only one unit which may be regarded as negligible.

Table 2. Comparison of extremes of monthly means with long-term mean ± 2 S.D. limits at New Delhi

Month	Extremes (actual)	Long-period mean ± 2 SD	Values outside column 3 and number	
1	2	3	4	
	D.U.	D.U.	D.U.	
January	255–325	234–311	325	1
February	257–320	258–320	257	1
March	266–320	269–320	266	1
April	268–317	275–321	268	1
May	270–318	273–321	270	1
June	259–308	268–314	259	1
July	253–312	255–302	253, 312	2
August	255–285	256–291	255	1
September	255–294	256–293	255, 255, 294	3
October	258–309	256–290	309	1
November	244–303	246–291	244, 295, 303	3
December	240–302	240–303	303, 306, 309	3

The number of deviations in column 4 is not large. Some of them are 3–4% of the limit(s) in column 3. The rest differ from the limits by one unit only and are hence negligible.

Table 3. Comparison of extremes of monthly means with long-term mean ± 2SD limits at Varanasi

Month	Extremes (actual)	Long-period mean ± 2SD	Values outside column 3 and number	
1	2	3	4	
	D.U.	D.U.	D.U.	
January	251–295	244–292	295	1
February	253–299	258–297	299	1
March	257–300	261–307	257	1
April	268–311	280–313	268	1
May	282–312	281–314	None	—
June	282–305	278–307	"	—
July	262–292	260–296	"	—
August	258–286	259–289	259	1
September	255–295	255–292	295	1
October	254–293	255–292	254, 293	2
November	249–282	246–283	None	—
December	242–282	240–285	"	—

The number of monthly means outside ± 2 SD is only 8, though one may expect ± 14 to lie outside the limits. Most of the deviations from ± 2 SD are small and of negligible order.

next examined using the equation

$$y = a + bt, \tag{1}$$

which may be written in the form

$$y - \bar{y} = r \cdot \frac{\sigma_y}{\sigma_t}(t - \bar{t}) \tag{2}$$

$\bar{y}$ and $\bar{t}$ are the representative means of y and t for the entire series considered; σ_y and σ_t are the respective standard deviations. r is the correlation coefficient between the series of monthly means (y) and time t in years; y is the total ozone content. The monthly and annual correlation coefficients (CC) and regression coefficients $r\ \sigma_y/\sigma_t$ are given in Table 6.

All the CC are found to be statistically insignificant most of them being low, less than even 0.25. The annual CC is only −0.1113, i.e. of the order of 0.1 numerically. r^2 explains the percentage of total variance and is about one per cent only, a totally negligible quantity. The linear trend analysis shows no significance and hence the series of monthly and annual means has no trend.

A point, however, needing mention is that during 1980–88 the deviations are mostly negative, leading to negative CCs and regression coefficients, though these are not found to be statistically significant. However, the negative sign of the CCs and regression coefficients may be noted for most of the months and for the year as a whole. On this, it may be tempting to suggest a decreasing feature with time, even though it is statistically insignificant.

New Delhi. Table 7 gives the monthly and annual deviations of the 5-yearly averages from the long period means (1960–88). The different deviations have been tested for significance and those which are significant at 5% level and 1% level are indicated in the last column of the table. Of the six which are significant at 5% level only four are significant at 1% level. Another point noted is that most of the significant differences relate to the five year period (1960–64). The annual deviations for the different periods are not statistically significant.

Because of the break in data from 1971 to 1974, the difference between 1960–70 and 1975–88 was also

Table 4. Comparison of extremes of monthly means with long-term mean ± 2 S.D. limits at Ahmedabad/Mount Abu

Month	Extremes (actual)	Long-period mean ± 2 SD	Values outside Col. 3 and number	
1	2	3	4	
	D.U.	D.U.	D.U.	
January	232–287	223–279	287	1
February	232–282	232–286	—	—
March	240–300	241–295	240, 300	2
April	260–300	247–303	—	—
May	263–311	256–306	311	1
June	258–310	253–308	310	1
July	245–397	245–294	297	1
August	238–301	237–295	301	1
September	240–299	236–292	299	1
October	236–235	236–288	—	—
November	227–279	224–276	—	—
December	232–273	223–273	—	—

The number of deviations outside ±2 SD is small, only eight in a total frequency of about 300 values.

Table 5. Deviations of five-year averages from long-period means for different months. (Kodaikanal).

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1960–64	−1.5	1.8	2.9	1.3	1.5	1.8	1.4	1.4	1.4	1.1	−0.7	0.9	—
1965–69	−6.9	−2.0	−0.5	−0.7	−0.1	−1.8	0.0	0.6	1.6	−2.1	−4.1	−8.5	—
1970–74	11.5	4.2	3.5	7.9	5.7	3.4	0.2	1.2	−0.6	−1.1	0.7	1.9	—
1975–79	1.9	1.4	−1.3	−1.3	−1.1	2.0	1.6	0.8	0.6	3.9	3.3	6.5	—
1980–84	−3.1	−5.4	−3.7	−4.7	−4.1	−4.4	−2.4	−1.8	−1.2	−1.1	0.9	−4.4	—
1985–88	−3.0	0.2	−0.6	−1.0	−2.4	−1.2	−0.9	−2.4	−1.6	−0.8	−0.2	3.4	—
Long-period means in DU	246.5	249.8	258.2	269.7	276.9	278.2	276.4	276.0	273.6	268.5	256.9	247.9	264.9

Table 6. Correlation and regression coefficients

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Correlation coefficient (r)	−0.0086	−0.1670	−0.3025	−0.2224	−0.2674	−0.1800	−0.1614
Regression coefficient	−0.0113	−0.1596	−0.1951	−0.1823	−0.1823	−0.1990	−0.1429
	Aug.	**Sep.**	**Oct.**	**Nov.**	**Dec.**		**Annual**
Correlation coefficient (r)	−0.3416	−0.1943	−0.0456	+0.1073	+0.1442	—	−0.1113
Regression coefficients	−0.1192	−0.1606	−0.0394	+0.0394	+0.1557	—	−0.0696

Time in years t (1960–61, 1961–62, … 1968–69). Trends (linear)

Table 7. Deviations of 5-year averages from long-period means for different months (New Delhi).

Month	1960–64	1965–69	1970–74	1975–79	1980–84	1985–88	Mean 1960–88	S.D.	Significance	
January	+16.4	−7.8	—	+2.4	−1.0	−11.5	282.8	14.2	1960–64,	1%
February	+10.0	−9.6	—	+4.6	+3.0	−10.0	289.0	15.4	—	
March	+2.4	−1.0	—	+2.6	+5.8	−10.8	294.6	12.6	1980–84,	1%
April	−7.0	−1.3	—	+7.9	+1.3	−7.1	298.1	11.4	—	
May	−11.3	−0.8	—	+7.2	+7.2	−0.9	297.2	12.0	1960–64,	1%
June	−9.3	−4.3	—	+10.3	+6.1	+1.3	291.1	11.6	1960–64,	5%
July	−4.2	−1.8	—	+4.6	+4.2	−2.1	278.4	11.9	1975–79	
August	−7.5	−1.5	—	+4.3	+5.7	−0.5	273.5	8.6	1960–64,	5%
September	−6.5	−3.3	—	+4.7	+4.9	+1.0	274.5	9.4	—	
October	+4.6	−4.0	—	+2.6	+0.2	−1.0	273.0	8.5	—	
November	+1.1	−2.3	—	−0.5	+0.3	+4.5	268.3	11.3	—	
December	+20.2	−6.4	—	+0.4	−1.8	−0.3	271.8	15.8	1960–64,	1%
Annual	+1.4	−4.0	—	+4.0	+3.2	−5.2	282.6	7.5	—	

examined for the annual series.

Year	*Mean* D.U.	*SD*
1960–70	280.4	9.0
1975–88	283.7	5.6

The difference between the two as also comparison with 1960–88 shows no significance.

The linear trend was considered for the two periods 1960–70 and 1975–88. The CCs (r_{yt}) between total ozone (y) and time in years (t) are also not significant.

Year	(r_{yt})
1960–70	−0.2524
1978–88	−0.4566

The difference between the two CCs is also not significant.

Varanasi. Table 8 gives the deviations of the five-yearly averages from the respective long period means. The period 1970–74 was one of significant rise with a positive departure of +8.8 and 1985 to 1988 a decreasing period with a departure of −8.2, in the annual values. The negative deviations in some of the months for the period 1985–89 exceeded numerically 10; the highest was −15.7 for March. A number of the monthly deviations for the five-year period 1970–74 and from 1985–1988 are statistically significant. With deviations for all the months and an annual negative value for the period 1985–89, it suggests a decreasing trend in the later years. The annual value decreased from 1983 to 1988, the highest departure from the long-term mean being −11 in 1988. Such a significant feature has not been noted in the case of Kodaikanal and New Delhi though the trend coefficients are negative but not significant in both the cases.

Ahmedabad/Mount Abu. The data of Ahmedabad and Mount Abu are for differing periods — Ahmedabad for 1960–69 and 1983–85 and Mount Abu for 1970–81. Hence the analysis is confined to the annual means for

Table 8. Deviations of 5-year averages from long period means for different months (Varanasi)

Month	1965–69	1970–74	1975–79	1980–84	1985–89	Mean 1965–88	SD
January	−3.3	+9.7	+1.9	+1.7	−13.1	268.1	12.0
February	−9.6	+13.8	+1.8	−0.2	−11.3	275.0	11.1
March	+6.4	+7.4	−0.6	−2.2	−15.7	284.0	11.5
April	+1.9	+8.7	−1.2	−1.7	−10.5	291.5	10.8
May	+0.2	+5.6	+1.0	−0.8	−7.8	297.8	8.3
June	−0.4	+4.6	+1.8	+1.8	−7.2	292.2	7.3
July	−0.4	+9.4	+1.2	+1.8	−12.5	277.8	8.9
August	+2.8	+5.6	−0.6	+1.2	−7.5	273.8	7.6
September	+1.8	+8.4	−0.6	−1.2	−6.0	273.8	9.4
October	+3.6	+9.0	−0.4	−3.4	−6.3	273.6	9.4
November	+6.0	+9.6	0	−3.4	−9.1	264.4	9.3
December	+2.1	+9.1	+1.5	−7.5	−10.1	262.3	11.4
Annual	+0.4	+8.8	+1.0	−0.4	−0.2	277.6	7.5

Period: 1964–1988.

Table 9. Mean total ozone values and deviations of 5-year averages from long period means (Ahmedabad/Mount Abu)

Year	Mean	SD	Deviation from 1960–84 mean
	D.U.		
1960–64	258 6	—	−7.2
1965–69	256.2	—	−9.6
1970–74	259.4	—	−6 4
1975–79	270.2	—	+4.4
1980–84	284.4	—	+18 6
1960–84	265.8	13.7	—
1960–74	258.1	12.6	—
1975–84	277.3	16.6	—
Total ozone	mean (1975–84)−mean (1960–74) = 19.2 DU.		

This difference is statistically significant even at 1% level.

the years 1960–84, the mean for 1982 being taken at about the same value for 1983, after seeing the trend for 1981 and 1983.

While generally a decreasing trend has been noted at the other stations discussed before, the Ahmedabad/Mount Abu series has shown marked rise in the year 1976 to 1984.

Concluding remarks

In the above paragraphs the monthly and annual data of Kodaikanal, New Delhi and Varanasi have been analysed using two approaches, i) the listing of monthly means of total ozone which lie outside the long-term mean ± 2 SD, covering a period of 24–28 years, and ii) a study of the five-yearly averages of the monthly means compared with the long-term means using t test of significance and also a study of linear trend in the series where feasible.

The result of the first approach is that there are generally only a few values lying outside the range given by long-term mean ± 2 SD. Interestingly the monthly series formed by combining Ahmedabad and Mount Abu for different periods shows a similar feature.

In the second method of using five-yearly means, Kodaikanal and New Delhi show few significant deviations. Varanasi, however, shows a larger number of significant deviations. For Ahmedabad–Mount Abu, the difference between (1960–74) and (1975–84) means, is found to be significant even at the 1% level. Another feature noted is the very significant rise in the years 1976 to 1984 giving a mean for the total ozone amount for 1980–84 of 284.4 DU higher by 18.6 DU over the long-term mean. The linear trend study of Kodaikanal data shows how small the CCs and regression coefficients are in most of the months. For New Delhi, the linear trend of the annual series shows no significance statistically.

A comparison of Kodaikanal mean data 1960–88 analysed here and the corresponding means given by Newell and Selkirk[1] shows close agreement differing in many months by only one or two units.

The above results broadly support the view that Indian data considered for this analysis are consistent, though there seems to be a need for closer examination of the data of Varanasi and Ahmedabad/Mount Abu.

1. Newell, R. I. and Selkirk, H. B., *Q. J. R. Meteorol. Soc.*, 1988, **114**, 595–617.

BOOK REVIEWS

The Holes in the Ozone Scare. Rogelio A. Maduro and Ralph Schauerhammer, 21st Century Science Associates, Washington, DC, USA, 1992, 356 pp.

Just 20 years ago there was very little public awareness of the existence of ozone in the upper atmosphere and still less of the important role that it plays in filtering out the harmful ultra-radiation from the sun. Now, of course, every educated person has heard about the hole in the ozone layer in the Antarctic, resulting from (it is widely believed) the release into the atmosphere of man-made chlorofluorocarbons (CFCs). Governments have acted with unusual speed in reaching international agreement to protect the ozone shield by banning the manufacture of CFCs. How has all this come about?

According to Maduro and Schauerhammer in their provocative book, the present ozone scare is nothing more than an enormous hoax perpetrated by a few of the world's leading chemical manufacturers who stand to make vastly increased profits by selling expensive patented replacements for CFCs. Once they had realized this possibility, the manufacturers overcame their initial opposition to the scientists who were advocating a CFC ban and used all their influence to stir up public opinion in favour of the ban. But, say Maduro and Schauerhammer, the ban is completely unnecessary and will do far more harm than good; in their view the so-called hole is a natural phenomenon and there are no grounds for trying to scare the public into believing that the continued use of CFCs would lead to disaster.

Before examining these various claims in more detail, it may be useful to recall a few of the salient facts about atmospheric ozone. This triatomic form of oxygen (O_3) is formed mainly in the upper stratosphere (above 30 km) by the action of ultra-violet light on oxygen (O_2). The ozone itself strongly absorbs ultra-violet of wavelengths around 300 nm and in doing so is broken up into a molecule of oxygen and an atom of oxygen. Ozone is also destroyed by a variety of chemical processes in the stratosphere, principally involving chlorine and nitrogen. The amount of ozone in the stratosphere at any one time represents the equilibrium between these various processes. If all the ozone were