Ozone in the tropics

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Introduction

The discovery in 1985 of the 'ozone hole' over the Antarctic and recent reports of ozone depletion over the Arctic have led to serious, world-wide concern of possible damage to the ozone layer that shields the biosphere from the lethal ultraviolet radiation from the sun. Statistical analysis of the long-term measurements of the global average of column ozone has, however, shown no significant fall in total ozone with time[1]. But the Ozone Trends Panel established by the USA National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the USA Federal Aviation Administration (FAA), the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), reported a small but detectable stratospheric ozone reduction in the northern hemisphere and identified chlorofluorocarbons (CFCs) as possible contributors to this reduction and as the most likely primary cause of the drastic springtime ozone depletion over the Antarctic[2]. UKSORG[3] reports that there is strong evidence from satellite data that ozone loss in mid-latitudes is greater than previously thought.

Regular measurements of total ozone and its vertical distribution in the atmosphere, using Dobson ozone spectrophotometers, have been made at a network of six stations in India since the International Geophysical Year, 1957. The data recorded in the Indian network, as well as at 21 additional stations in the tropics from 30° N to 30° S, were examined to see whether the processes, which give rise to the ozone depletions in the Antarctic and Arctic regions, affect the tropical latitudes. An analysis of the available data has shown no significant trend of ozone depletion in the tropics in the last three decades.

General features

World-wide measurements of atmospheric ozone during the last 60 years, from both ground-based and satellite-borne instruments, have enabled us to understand the broad features of the distribution of ozone over the globe. The mean total ozone amount in the atmosphere is about 300 Dobson Units (DU) when averaged over the globe. It varies geographically and seasonally and is a minimum, slightly less than 260 DU at equatorial latitudes and increases poleward in both hemispheres to a maximum of about 400 DU at sub-polar latitudes. Figure 1 shows the average variation of total ozone with latitude in different seasons for the northern hemisphere[4]. At high and middle latitudes, pronounced maxima and minima in total ozone occur in spring and autumn respectively, while in the tropics, the maximum, feeble though it is, occurs in summer and the minimum in winter.

While the total ozone and its vertical distribution over the tropics is more or less constant throughout the year, the pronounced maxima and minima observed in the extra-tropical latitudes arise from large seasonal variations that occur in both total ozone and its vertical distribution at these latitudes. Figure 2 shows the distribution of total ozone in different latitudes, in the two hemispheres[5]. In marked contrast with the situation in the middle and high latitudes, the total ozone in the tropics is subject to much smaller inter-diurnal, seasonal and inter-annual fluctuations. This is primarily because of the very weak coupling between the troposphere and the stratosphere in the tropical regions. A study of the monthly mean total ozone at a

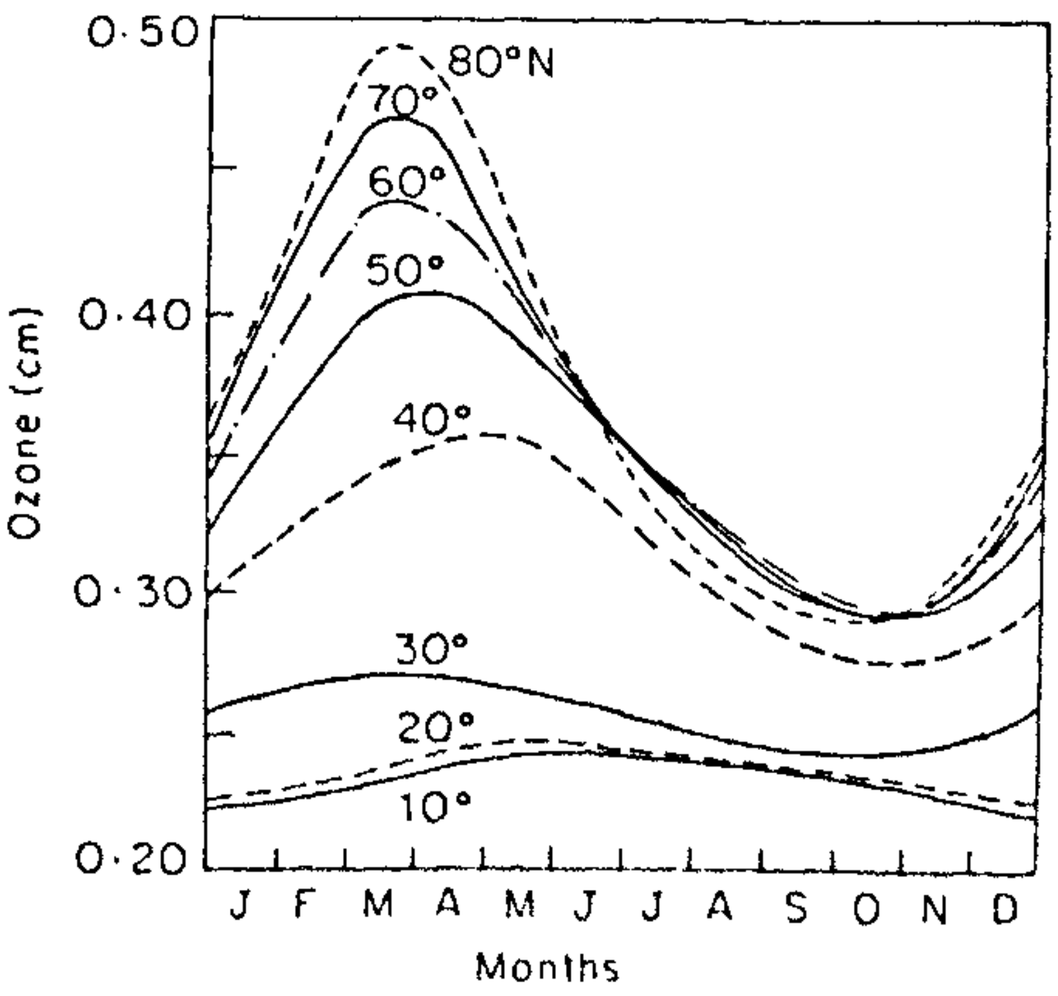

Figure 1. Average variation of total ozone with latitude in different seasons for the northern hemisphere (ref. 4)

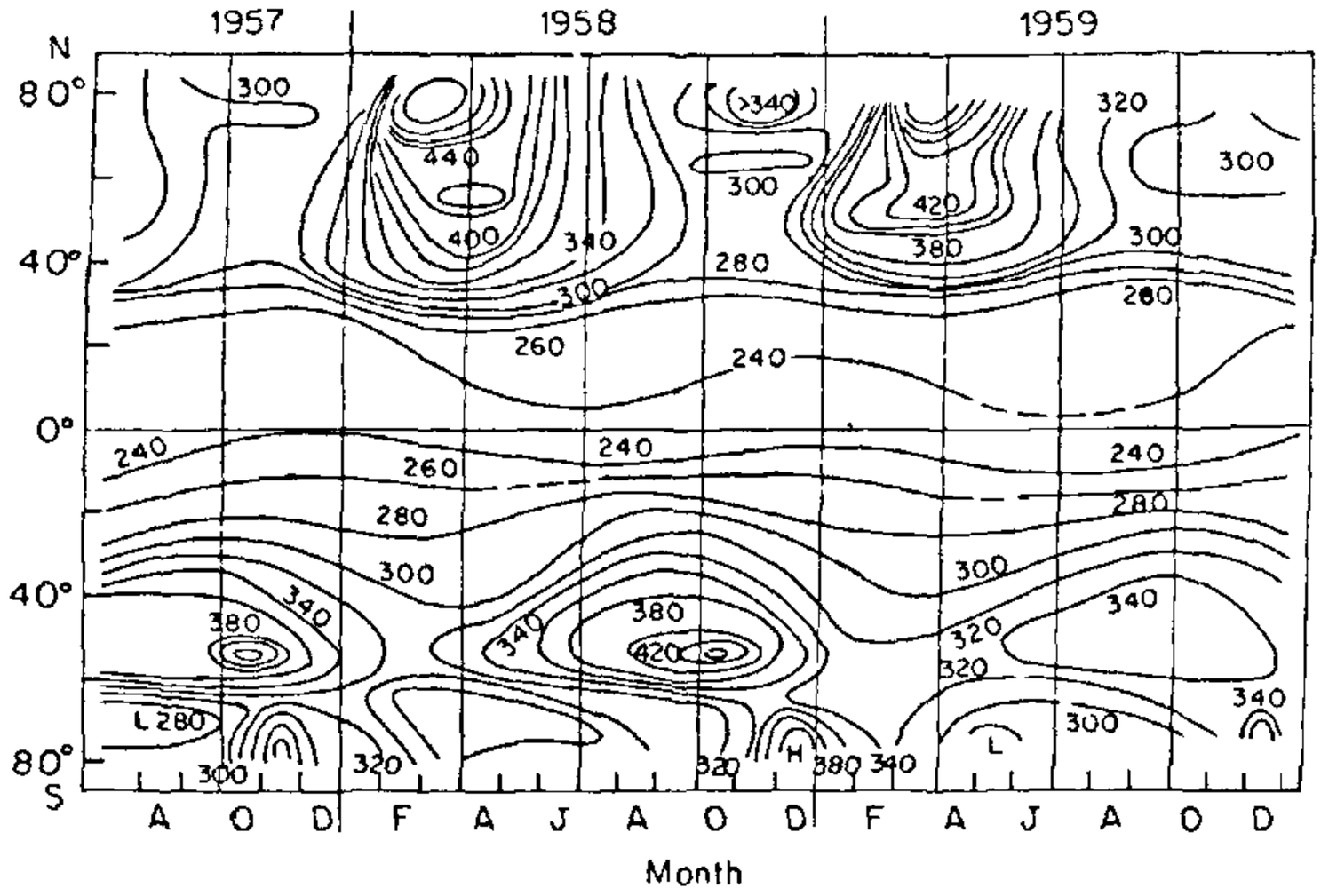

Figure 2. Distribution of total ozone in different latitudes, July 1957 to December 1959 (ref. 11).

few tropical stations by Rangarajan and Mani[6] had shown that certain long-period variations occur simultaneously over large areas and they pointed out that while a part of the variations could be attributed to the quasi-biennial oscillation, the others could only be attributed to volcanic or solar activity or to the destruction of ozone in the stratosphere.

In their study of the global ozone budget, Brewer and Wilson[7] had arrived at a net production of ozone in the tropics, with a maximum at about 30 km and net destruction at high latitudes, particularly in winter hemisphere and below 25 km. To balance the budget, ozone is transported from the region of primary production in the equatorial middle and upper stratosphere, polewards and downwards into the lower stratosphere, mainly by large-scale atmospheric motions, then transferred to the upper troposphere in the middle and high latitudes and eventually destroyed in the lower troposphere or at the surface of the earth. This broad picture of the ozone cycle emerges from most studies but quantitative evaluation of the photochemical processes differs among the various workers[8]. Details of the transport processes are also not yet settled.

Analysis of long-time series of total ozone data in the tropics

Of the 28 Dobson ozone spectrophotometer stations in the tropics (30° N to 30° S), in the global network, only seven stations have continuous data for 25 years or more, for the period 1960 to 1988. These are Ahmedabad/Mount Abu, Brisbane, Kodaikanal, New Delhi, Huancayo, Mauna Loa and Varanasi. Ahmedabad and Mount Abu are considered as one station as they are very close and the same instrument was used at both stations. Nine other stations have data for 10 years or more. The total ozone data for all 16 stations were analysed, although their reliability cannot be guaranteed at the present moment.

Figure 3 shows the year-to-year variations of the annual mean values of total ozone at the first set of seven stations from 1960 to 1988 and Pune (1973–88) and Figure 4 for other eight stations. No steady decrease in the annual means is noticed at any of the 16 stations, although at many stations a fall is observed after 1982, followed by a later rise.

The monthly mean deviations of total ozone are next plotted for the seven stations with long-term data. Figure 5 shows the plots of total ozone monthly mean deviation, normalized by dividing the mean deviation Δ by the standard deviation σ, and smoothed by dividing by four the sum of twice the normalized mean deviation for the month and the deviations for the preceding and succeeding months. The mean deviations are small and evenly distributed on either side of the long-term mean. They also show no steady secular trend, except a decrease after 1982 at Mauna Loa, Varanasi, Huancayo and New Delhi.

In Figures 6*a* and *b* the monthly mean ozone amounts for each of the seven stations for the period 1960–1988 are plotted with the 12-monthly running means superposed on them. Despite the large variability, the biennial oscillation is marked at almost all the stations and is particularly prominent at New

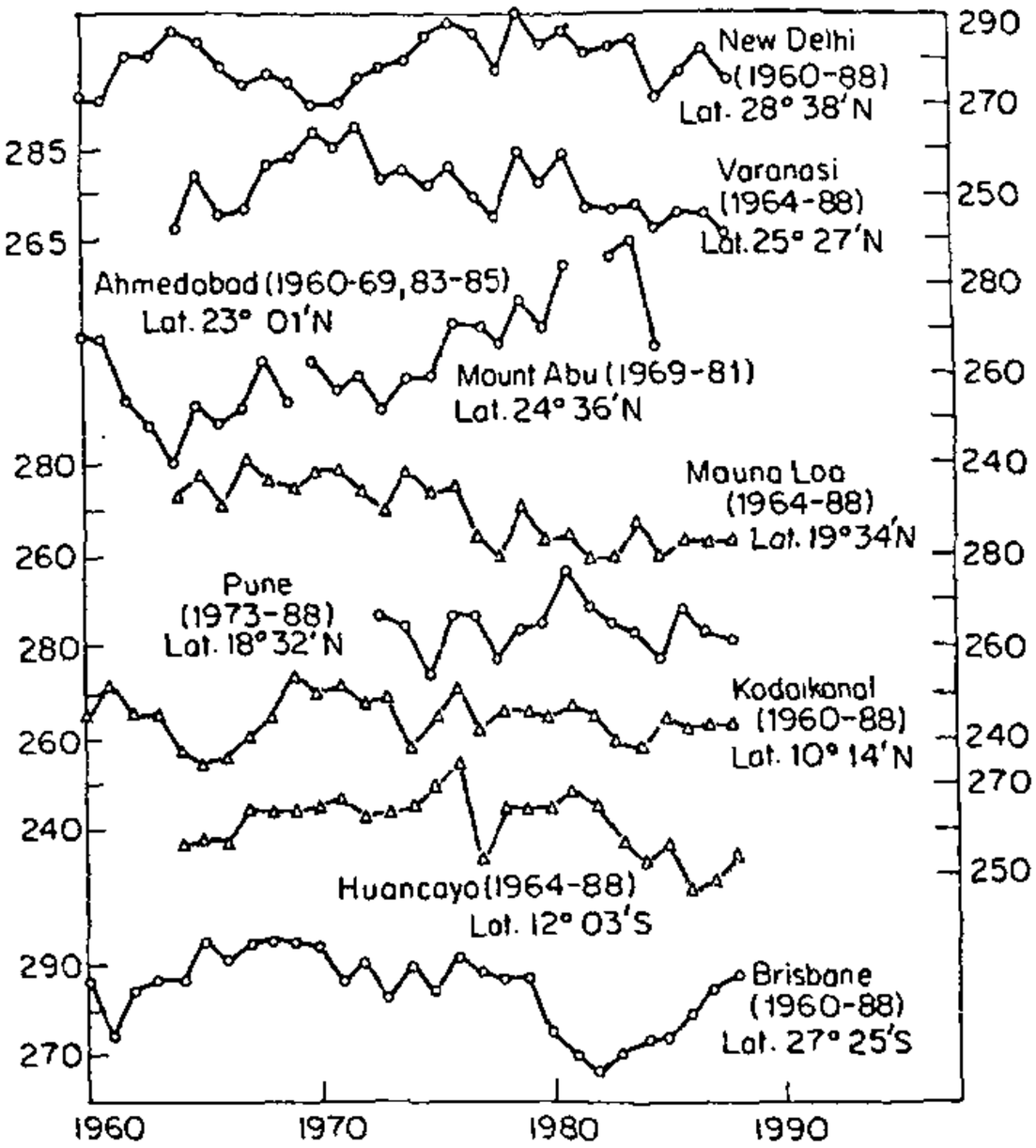

Figure 3. Year-to-year variations of the annual mean values (in Dobson Units) of total ozone at seven stations and Pune.

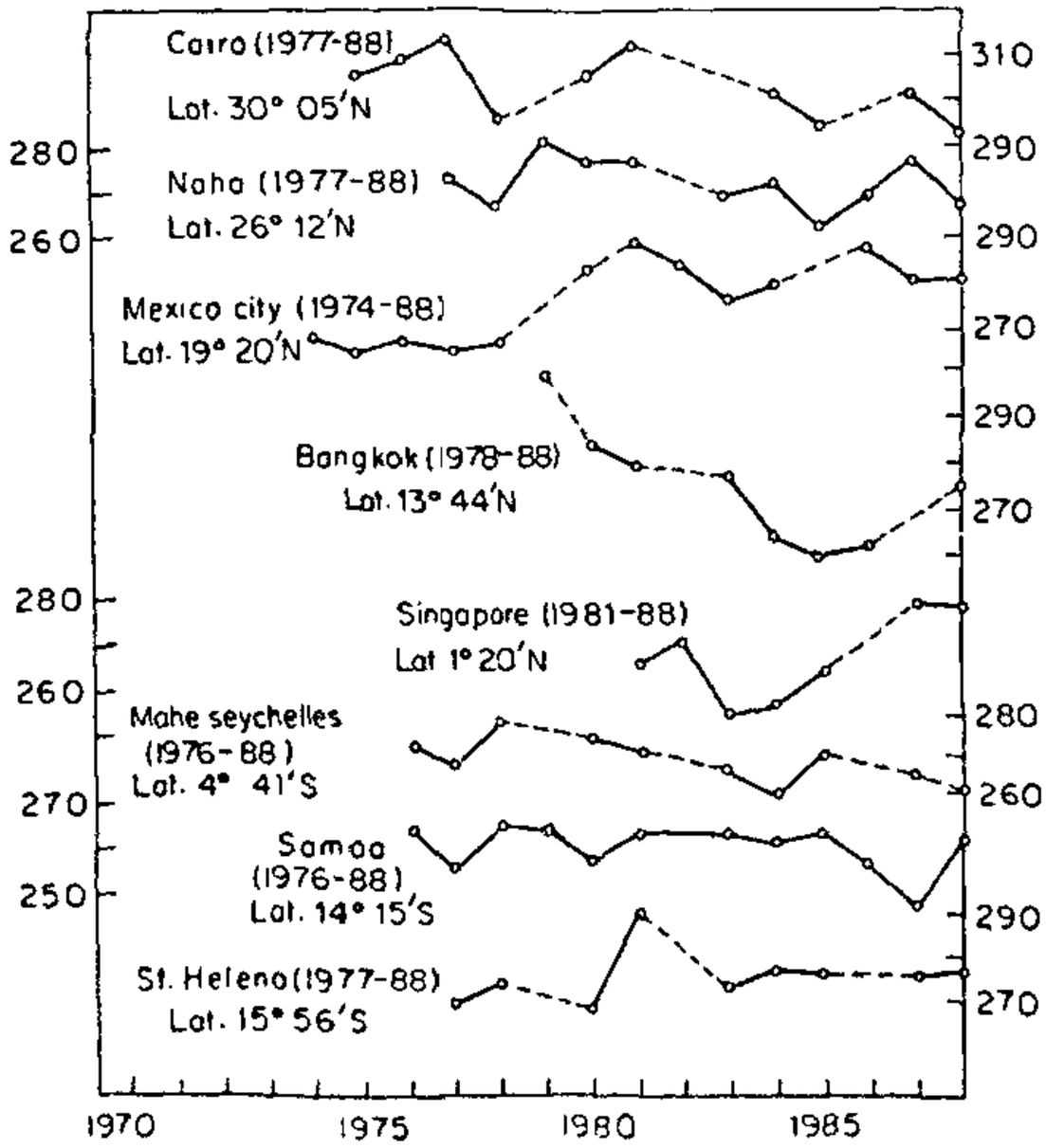

Figure 4. Year-to-year variations of the annual mean values (in DU) of total ozone at eight stations.

Delhi, Ahmedabad/Mount Abu, Varanasi and Mauna Loa. Ramanathan[5] had reported quasi-biennial oscillations in ozone amounts at New Delhi, Abu/

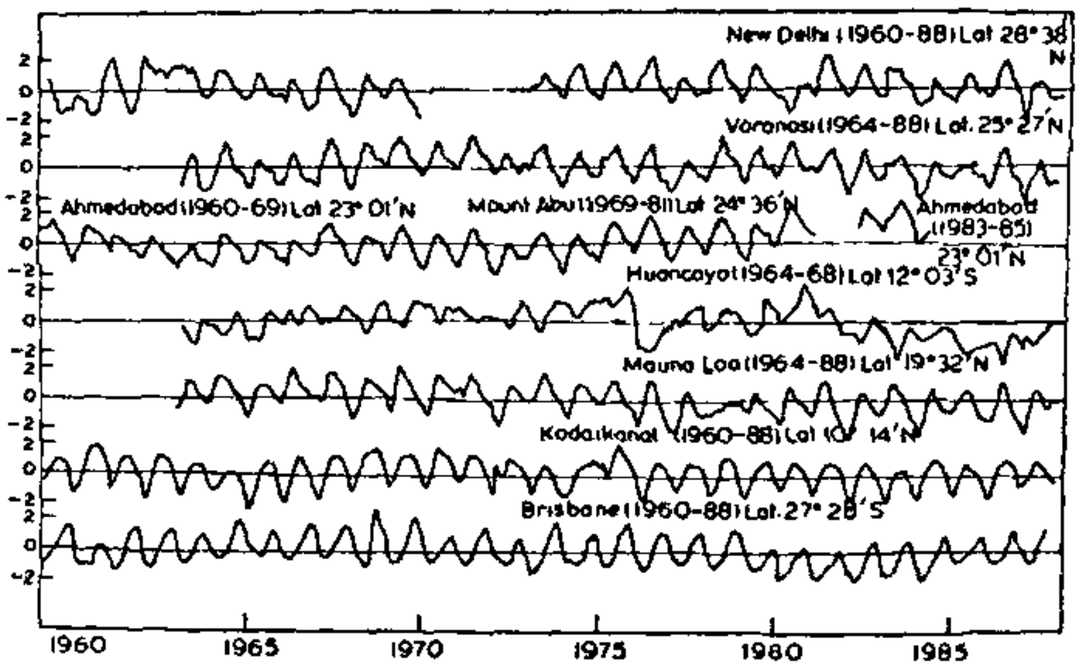

Figure 5. Monthly mean deviation of total ozone.

Ahmedabad, Brisbane and Kodaikanal in the fifties and pointed out that the two-year cycle covers a wide range of latitudes on either side of the equator, both north and south.

Figure 7, which shows 12-monthly minus 24-monthly running means at the seven stations, brings out the biennial variation more clearly. Though the normal cycle has a period of two years, there are breaks in the cycle, which could be associated with the 11-year sunspot cycle[5].

To conclude, no significant trend is detectable in the average column ozone in the tropics. However, there are large variations on many time scales which would make a small trend, of say, less than one per cent per decade, difficult to identify.

Thapliyal and Kulshrestha[9], after a study of data from 1958 to 1986 came to the same conclusion that ozone measurements in India exhibit year-to-year variability but not any systematic increasing or decreasing trend over India and no significant evidence of depletion of ozone over India.

Ozone and climatic trends

Two major changes observed in atmospheric ozone in the last few years are (1) the strong downward trend of springtime Antarctic ozone since 1980 and (2) the widespread decrease in total ozone in subtropical and middle latitudes since 1982, associated with the eruptions of El Chichon in March-April 1982 but which has recurred in succeeding years[8]. The likely causes are either influences of atmospheric chemistry, such as nuclear tests, sunspots, volcanic eruptions, injection of CFCs, etc. or changes in atmospheric large scale dynamics[10].

Attempts have been made to link the 1982/83 minimum of column ozone to the El Chichon eruptions in March-April 1982 and the major El Nino event of 1982/83, beginning shortly after the eruptions. Dütsch[8]

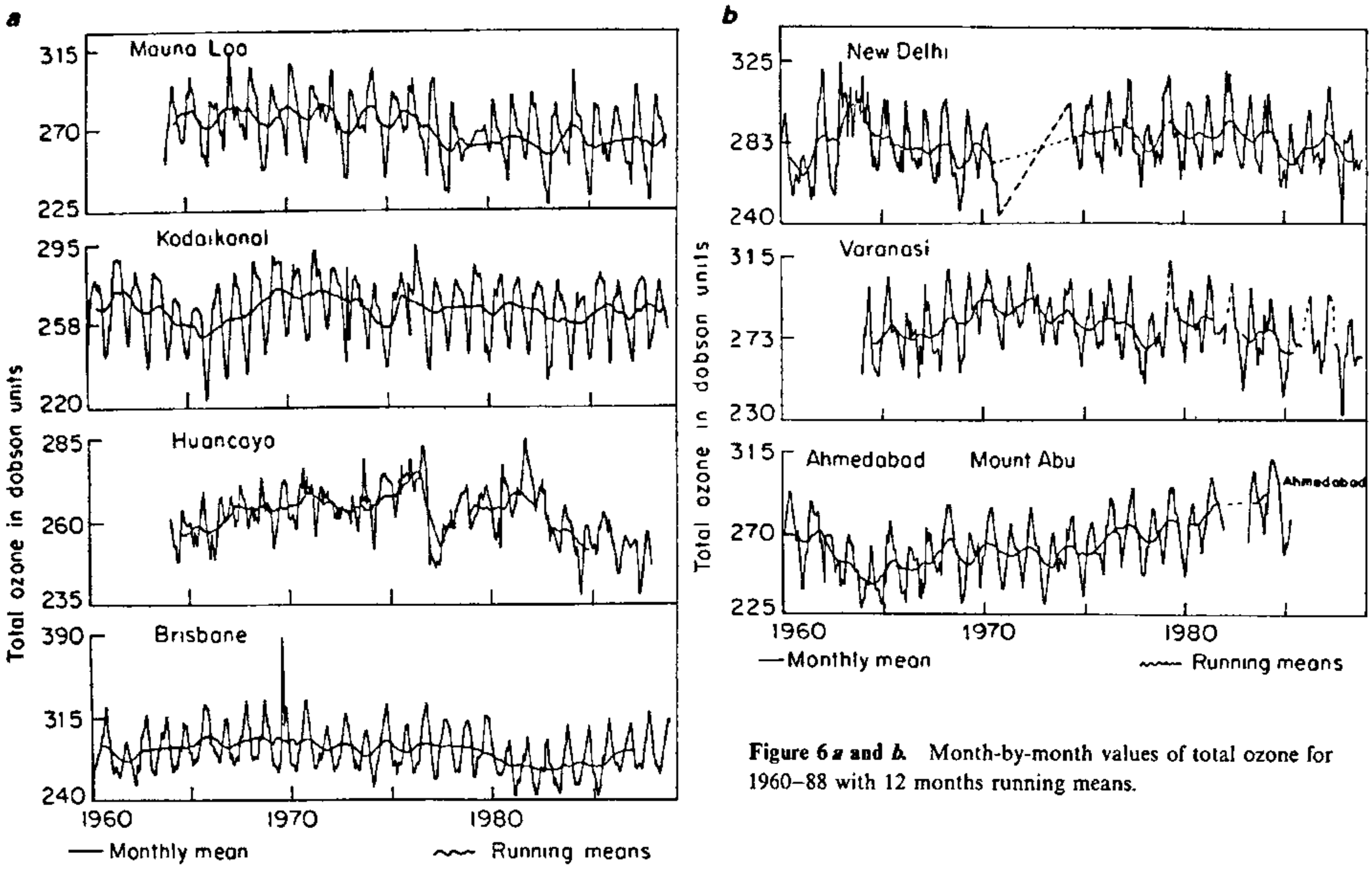

Figure 6 *a* and *b*. Month-by-month values of total ozone for 1960–88 with 12 months running means.

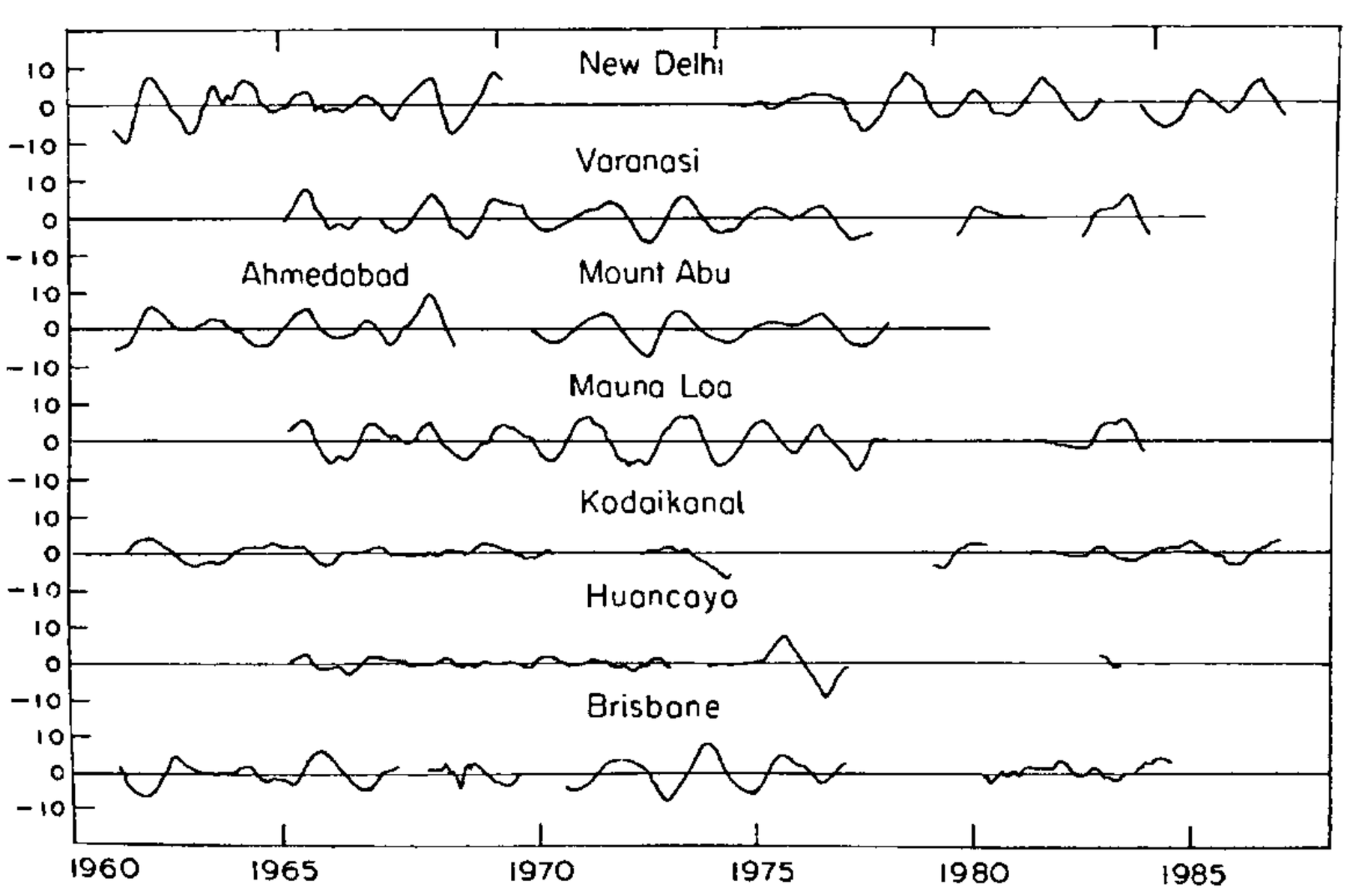

Figure 7. Twelve months minus 24 months running mean.

had reported a downward trend in the total ozone at Arosa, but ascribed the decrease of total ozone after 1970 to reduced poleward transport of ozone during winter.

Newell and Selkirk[10] have examined the seasonal character of recent changes in total ozone at 32 stations selected from the world ozone network. Studying Dobson total ozone data for 29 years, they found

substantial negative deviations in total ozone across a wide span of latitudes from the Antarctic to 20° N, but outside the Antarctic, pronounced deficits generally did not appear until late 1982. They found annually recurring deficits in the region 65° N to 45° N and deficits with a biennial component between 45° N and 20° N. In the southern middle latitudes deficits were observed from late 1985. The two tropical stations, Kodaikanal and Huancayo showed rather small deviations on the year-to-year time scale, consistent with their low variability during their base period 1969–1973.

Newell and Selkirk[10] came to the conclusion that (1) the reductions in the total ozone are highly seasonal in nature both in the Antarctic and elsewhere, where they occur in the cold winter months, (2) as tropospheric ozone has generally been increasing in recent years, the observed decreases in column ozone in a particular region and season are the result of changes in the stratospheric ozone balance, due to either decreased photochemical production, increased photochemical destruction, transport changes or some combination of these three.

Conclusion

The only conclusion, which can be made about long-term trends in averaged column ozone in the tropics, is that there is no identifiable systematic decrease that can be ascribed to anthropogenic causes. There appears to be a steady decrease after 1982 at some stations but whether it is caused by volcanic eruptions or solar activity or large scale atmospheric dynamics cannot be discerned with any degree of confidence.

The latest results demonstrate an undoubted chemical cause in the destruction of ozone by atmospheric chlorine in the Antarctic, but also point to special climatic conditions as the reason why depletion occurs so severely in the Antarctic and so little elsewhere. Although there are still many unresolved questions, and the tropics may be spared the fate of the middle and high latitudes, there is an urgent need to stop further flooding of the atmosphere with CFCs and other pollutants.

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Ozone vertical distribution in the tropics

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In recent years several rocket campaigns have been conducted at Thumba (8.5° N) to study the vertical distribution of ozone over the tropics. Measurements have been made up to an altitude of about 65 km both during daytime as well as night-time. These measurements have not only delineated the basic characteristics of the mean vertical distribution of ozone over a tropical site, but also revealed some new features on the photochemical and dynamical control on ozone at stratospheric and mesospheric altitudes.

THE importance of ozone in the chemistry and radiation balance of the earth's atmosphere has been recognized for a long time. However, in the past two decades there has been an upsurge of interest in atmospheric ozone studies as a result of the recognition of the possibility of a long-term depletion of the global ozone overburden due to catalytic chemical reactions involving several trace gases of the NO_x, ClO_x and HO_x families, some of which are due to anthropogenic activities[1–3]. This danger has been highlighted by the discovery of the Antarctic Ozone Hole[4,5] which is an extreme manifestation of the ozone depletion problem. While the Antarctic Ozone Hole has received adequate attention,