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Influence of urban ozone in the measurements of the total ozone column in Mexico City

A. JUAREZ[1], C. GAY

Centro de Ciencias de la Atmósfera, UNAM, Circuito Exterior, CU, 04510, México, D. F., México

J. L. BRAVO

Instituto de Geofísica, UNAM, Circuito Exterior, CU, 04510, México, D. F., México

RESUMEN

En este trabajo se examinan las mediciones del grosor de la columna total de ozono entre 1986 y 1989 en la Ciudad de México. En esta revisión se considera la contribución del ozono superficial a las mediciones efectuadas con el Espectrofotómetro Dobson instalado en el Laboratorio de Radiación Solar de la UNAM al suroeste de la Ciudad de México. Consideramos diferentes capas de mezcla para el ozono dependiendo del periodo estacional y comparamos los resultados obtenidos con los valores de las mediciones reportadas para Mauna Loa en Hawai y Poona en la India, ambos a latitudes similares a la de la Ciudad de México. Nuestra conclusión es que en regiones urbanas con alta contaminación ambiental, el ozono superficial afecta apreciablemente las mediciones del grosor de la columna total de ozono.

ABSTRACT

In this paper we examine measurements of the thickness of the total ozone column between 1986 and 1989 in Mexico City. We consider the contribution of the surface ozone in measurements of the total ozone column made with the Dobson Spectrophotometer located at the Solar Radiation Laboratory (National University), in the southwest of Mexico City. We consider different depths of the mixing layer depending on the season and we compare our results with those reported for Mauna Loa in Hawaii and Poona in India, at the same latitude as Mexico City. In conclusion we confirm that in highly polluted areas the surface ozone has an important effect on measurements of the total ozone column.

KEYWORDS: Tropospheric ozone, Mexico City, Urban surface ozone

1. Introduction

Ozone in the atmosphere is fundamental for the protection of life from solar ultraviolet radiation at the Earth's surface. Recent data indicates that the concentration of ozone in the Earth's atmosphere may be changing in the stratosphere (Stolarski *et al.*, 1992) and at the troposphere (Lefohn *et al.*, 1992, Logan, 1985). The ozone depletion over the Antarctic is a well documented fact (Farman *et al.*, 1985, Gleason *et al.*, 1993).

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[1] Permanent address: Facultad de Ciencias Físicomatematicas, Universidad Autónoma de Puebla, Apdo. 1152, Puebla 72000, Puebla, México

Ozone concentration peaks in the stratosphere, at an altitude of 20 to 25 km, where it is produced photochemically by solar ultraviolet radiation. The ozone distribution in Earth's atmosphere is maintained by a balance between its photochemical production and loss by dynamical transport. These processes determine daily fluctuations, seasonal variations and interannual variability in ozone amounts (Stolarski *et al.*, 1992).

Ozone enters the troposphere from the stratosphere and the air circulation lifts it into the stratosphere. This stratospheric–tropospheric exchange is a substantial source of natural tropospheric ozone (Galbally *et al.*, 1991). However ozone is also produced in the troposphere, specially in urban contaminated areas where photochemical processes increase significatively the ozone concentration. In the troposphere ozone is also destroyed by heterogenous reactions at the Earth's surface.

Stratospheric and tropospheric ozone are not uniformly distributed in the atmosphere. The total ozone column varies with latitude and is determined by several natural and anthropogenic causes. In regions near to the tropics, the ozone concentration is lower than at the other latitudes.

Monitoring the ozone layer in tropical latitudes is important because its thickness is smaller than at middle and high latitudes. A decrease of the stratospheric ozone concentration in this region, represents a more severe threat to the human health in terms of the increment in the intensity of ultraviolet radiation incidence at the surface. A hypothetical 10 % ozone depletion in tropical regions, increases the surface level erythermal ultraviolet radiation dosage in more than 20 %. This increment is almost the same as the level of erythermal ultraviolet radiation dosage that falls normally in mid and high latitudes (Ilyas, 1991). In a recent work, evidence for large upward trends of ultraviolet–B radiation linked to ozone depletion in Toronto has been reported(Kerr *et al.*, 1993).

The behavior of tropospheric ozone has been extensively studied in recent years because of its potential impact on human health and its consequences for climatic changes. The comparison between recent data and data for the 70's, certainly argues in favor of a significant antropogenic impact. Concentrations of ozone in the middle troposphere over Europe and North America appear to have increased at a rate of about 1 % per year over the last two decades (Beck *et al.*, 1994). This behavior is partly a consequence of the sun's radiation on specific air pollutants. The increase in tropospheric ozone contributes to the trend in the total column of ozone and may compensate the decrease in stratospheric ozone over middle and high latitudes (WMO, 1992 and Logan, 1985).

Ozone is formed during the oxidation of CO, CH_4 and hydrocarbons in the presence of nitrogen oxides and destroyed by reactions with HOx radicals (Logan, 1985). The influence of cloud photochemical processes on the production of tropospheric ozone at tropical and mid latitudes, has been reported recently (Lelieveld *et al.*, 1990).

In this paper we review data for the total ozone column obtained with a Dobson Spectrophotometer located in the southwest of Mexico City (19° 20' N) for the period of 1986-1989. Mexico City is located at an elevated basin (2260 maSL); its conurbated area is one of the largest and more populated of the world (Fig. 1). The high pollution in Mexico City includes high levels of surface ozone concentrations. Surface ozone concentrations in the urban area show higher values on the southwest sector of the city (Jáuregui and Luyando, 1993) and an increasing trend (Riveros *et al.*, 1993), which take into account to review measurements made with the Dobson Spectrophotometer. The revised data are obtained substracting the urban ozone contribution from the measurements of the total ozone column.

We compare the adjusted data with those reported in the "Ozone Data for the World", for Mauna Loa (19° 34' N) in Hawaii and Poona (18° 32' N) in India. Since these places

are at similar latitudes than Mexico City, their reported data reflect the general tendency of stratospheric ozone at these latitudes.

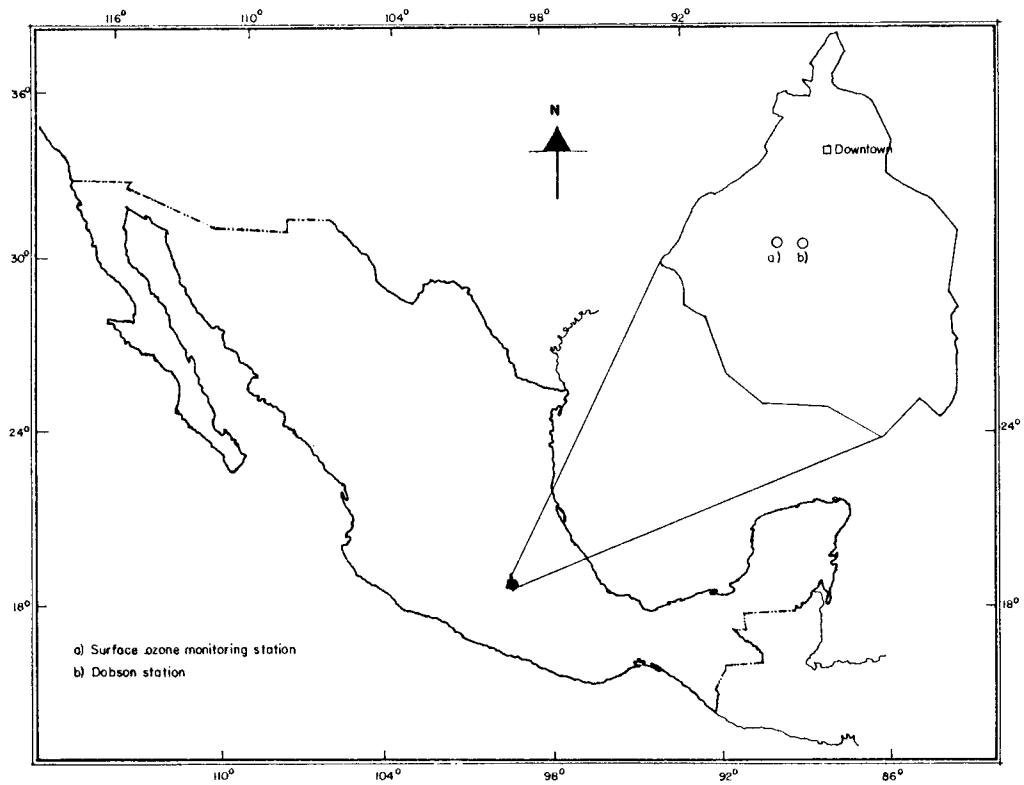


Fig. 1. Location of the Dobson station and of the surface ozone monitoring station "Pedregal de San Angel" in Mexico City.

2. Observational data

The Dobson Spectrophotometer (DS) in Mexico City was installed in February 1974. Two periods in its measurements can be identified (Bravo, 1984): the first from 1974 until 1978 when the DS was calibrated and intercompared at Boulder, Colorado USA, and the second period runs from August 1978 to the end of 1989 when it suffered a breakdown.

Observations were made mainly during the morning and early afternoon when the sky is free from clouds. Figure 2 shows monthly averages for both periods for Mexico City, Poona and Mauna Loa. Data for Mexico City show a jump in August 1978 that starts the second period of observations (Reinsel *et al.*, 1994). The discontinuity is caused by the change in calibration of the instrument. No new intercomparison has been made after 1978 but rutinary tests have been carried out. The figure shows different linear tendencies, specifically for the second period of data for Mexico City that shows an evident increasing tendency when compared with the linear tendencies of the other data.

Surface ozone has been monitored widely in the urban area of Mexico City during the last years. No great deal of spatial variability in average in the urban ozone data has been found (Riveros *et al.*, 1993). Monthly mean data of daily maximum occurring mainly between 11 and 14 hrs local time for "Pedregal de San Angel" station at the southwest of the city (2 km far from Dobson station), are reproduced in Figure 3 for the period of 1986-1993 (Riveros *et al.*, 1993).

These data show an increasing tendency in surface ozone concentrations, in spite of efforts made to reduce them.

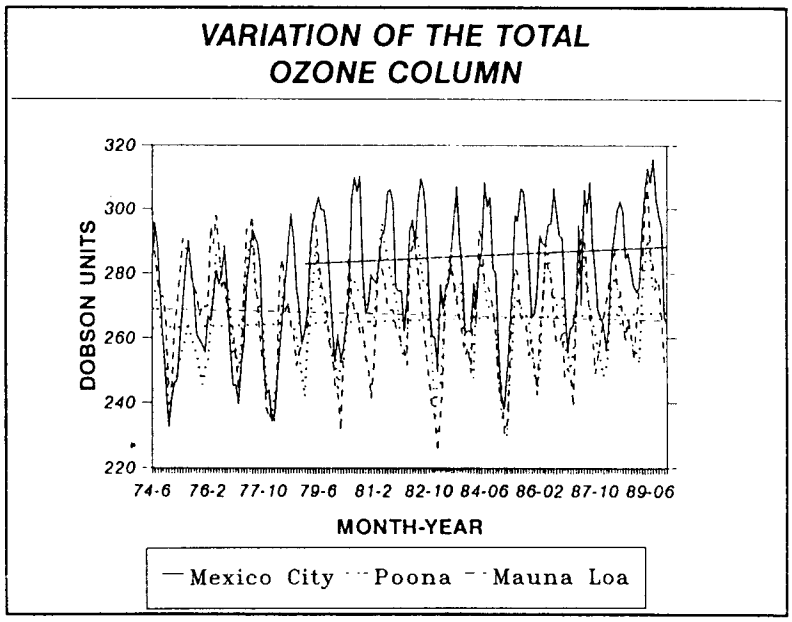


Fig. 2. Comparison between monthly mean values of total ozone in Dobson Units for Mexico City, Poona and Mauna Loa for the period 1974-1989. The straight lines are the best-fit linear trends. The figure shows increasing tendency in the total ozone column for Mexico City.

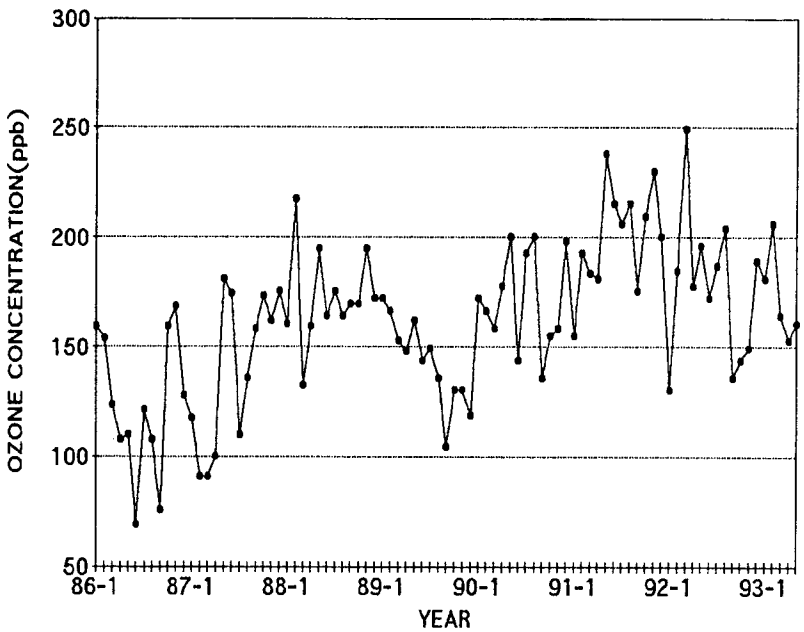


Fig. 3. Monthly mean ozone concentration at the southwest of Mexico City after Riveros *et al.*, 1993. An increasing trend in the surface ozone concentration is shown in the figure in spite of efforts made to reduce ozone concentration.

When we consider only the period 1986-1989 for total 0_3 for the three sites, the tendencies vary as may be seen in Figure 4. Mauna Loa's 0_3 values tend to increase, while those for Poona and Mexico City show a less marked trend. While displaying an increasing trend, data for Mexico City show higher values as compared with those of Mauna Loa and Poona which as has been mentioned are located at about the same latitude.

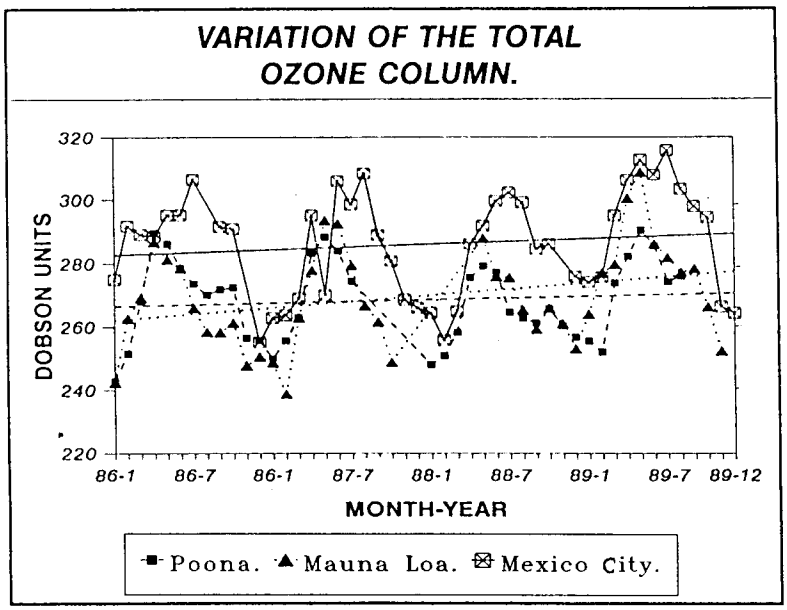


Fig. 4. Linear tendency in the monthly mean values of total ozone for Mexico City, Poona and Mauna Loa for the period 1986-1989. Concentrations for Mexico City seem to be overestimated.

3. Results and discussion

Recent investigations report influences of tropospheric ozone in measurements of the total ozone column, made in terrestrial stations and satellites (Lefohn *et al.*, 1992). It is well established that anthropogenic emissions of contaminant gases like NOx and Hidrocarbons (HC) are precursors in the formation of ozone (Lin *et al.*, 1988). In urban areas, the presence of hydrocarbons increases and the formation of surface ozone also increases (Fig. 3). In particular at the southwest of Mexico City (where the Dobson station is located), in addition to local sources, advection of 0_3 from downtown areas by the prevailing winds, result in higher concentrations of this gas (Jáuregui and Luyando, 1993).

We have estimated the contribution of this surface urban ozone in the measurements for the thickness of the total ozone column. Because the surface ozone concentration is given in parts per million (ppm) in urban areas, to transform surface ozone concentrations specifically for Mexico City into ozone column increments, we have assumed a mixing layer with two different depths depending on the season: Summer 2500 m and Winter 1260 m (Jáuregui, 1979). In this mixing layer we assume a constant mixing ratio for ozone determined by the surface concentrations. We also use a mean tropical atmosphere.

With these assumptions the following transforming formula can be obtained:

$$\text{Dobson Units} = k1 * ppm * [exp(-k2 * h1) - exp(-k2 * h2)], \quad (1)$$

where $k1 = 798.2$, takes into account the Sea Level pressure and the transformation of ozone

from parts per million in volume to Dobson Units (DU) in a differential pressure; $k2 = 0.000117$ is the inverse of the scale height (8570 m), h1 represents the height of Mexico City (2260 m), h2 is the height of the mixing layer and ppm are the surface ozone concentrations.

Results are summarized in Table 1 for the two different depths of the mixing layer, for the periods of 1986 through 1989. Average depth results are also shown.

TABLE 1. Corrections to the total ozone column from the urban ozone in Mexico City for winter (T1), summer (T2) and the average of both (T3). Data are in Dobson Units.

year month	México City	México T1	México T2	México T3	year month	México City	México T1	México T2	México T3
86-01	275.06	11.89	22.00	17.13	88-01	264.53	11.76	21.76	16.94
86-02	291.86	11.48	21.24	16.53	88-02	255.91	15.96	29.52	22.99
86-03	289.20	9.24	17.09	13.31	88-03	265.00	9.80	18.13	14.12
86-04	288.67	8.26	15.28	11.90	88-04	286.25	11.76	21.76	16.94
86-05	295.25	8.40	15.54	12.10	88-05	291.86	14.28	26.42	20.57
86-06	295.33	5.32	9.84	7.66	88-06	299.71	12.04	22.27	17.34
86-07	306.56	9.01	16.68	12.99	88-07	302.33	12.60	23.31	18.15
86-08		8.26	15.28	11.90	88-08	299.25	11.76	21.76	16.94
86-09	291.67	5.88	10.88	8.47	88-09	284.67	12.31	22.78	17.74
86-10	291.00	11.90	22.01	17.14	88-10	286.27	12.31	22.78	17.74
86-11		12.60	23.31	18.15	88-11		14.28	26.42	20.57
86-12	255.40	9.52	17.61	13.71	88-12	276.00	12.60	23.31	18.15
87-01	262.94	8.82	16.31	12.70	89-01	274.24	12.60	23.31	18.15
87-02	263.85	7.00	12.95	10.08	89-02	275.77	12.04	22.27	17.34
87-03	269.11	7.00	12.95	10.08	89-03	295.17	11.34	20.98	16.33
87-04	295.14	7.70	14.24	11.09	89-04	306.40	10.25	18.96	14.76
87-05		13.44	24.86	19.36	89-05	312.78	11.76	21.76	16.94
87-06	306.14	13.02	24.08	18.75	89-06	308.11	10.78	19.94	15.52
87-07	298.67	8.40	15.54	12.10	89-07	315.75	11.05	20.45	15.92
87-08	308.50	10.08	18.65	14.52	89-08	303.50	10.08	18.65	14.52
87-09	289.00	11.76	21.76	16.94	89-09	298.00	8.11	15.01	11.69
87-10	280.83	12.88	23.83	18.55	89-10	294.54	9.79	18.12	14.11
87-11	268.64	12.04	22.27	17.34	89-11	266.55	9.79	18.12	14.11
87-12	266.13	12.60	23.31	18.15	89-12	264.50	8.68	16.05	12.50

Results for the three cases are also illustrated in Figure 5. Figure 5: a) shows data corrected with the depth of the mixing winter layer, b) shows data corrected with the summer depth and c) shows average data of the two. As one can see the corrected data reproduces the data obtained in Poona and are in better agreement with those reported for Mauna Loa.

We can conclude that the contribution given from the surface ozone to the total ozone column in the urban area of Mexico City is significant since it could represent 10 % of the total column (about 20 DU). In addition we have calculated the correlations based on data shown in Figure 5 for the monthly mean variation in Mexico City (19° 20' N), Poona (18° 32' N) and Mauna Loa (19° 34' N) and found they increase up to 92 % when a time lag of one month is considered in the calculations.

Corrected values on the other hand, show a slight increase for the 1986-1989 period, in general agreement with the data for Poona and Mauna Loa, although the increase for the latter is more pronounced. This contrasts with the behavior of Mauna Loa for the larger period of 1974-1989 for wich the data shows a small decrease of the order of 1 %.

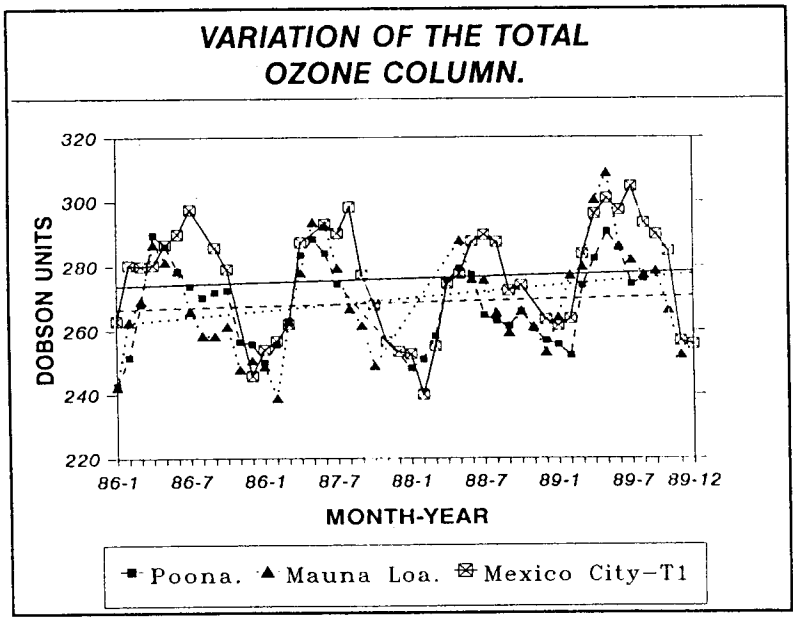
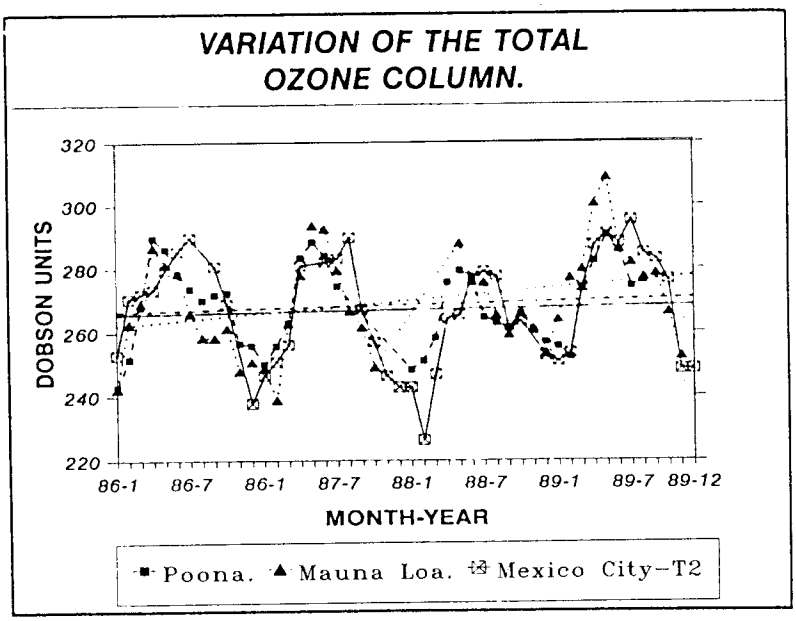
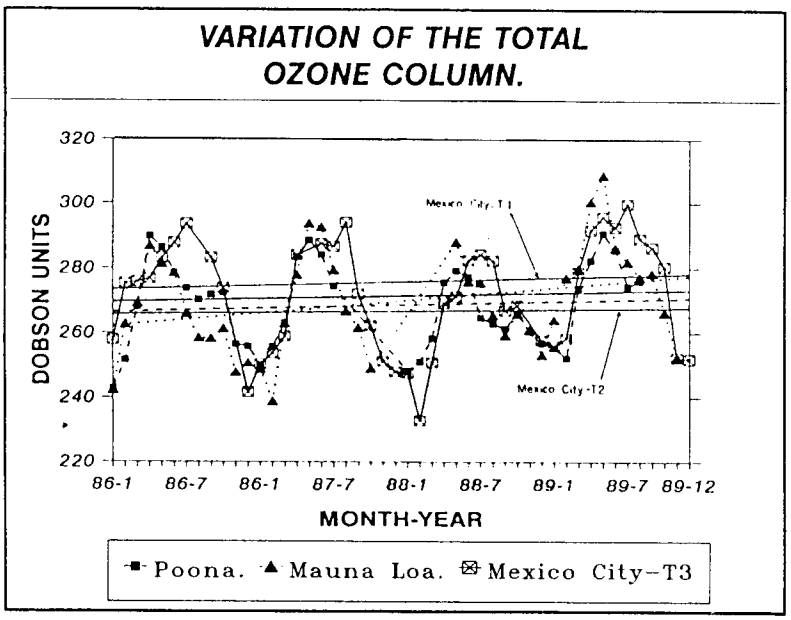


Figure 5: a)



b)



c)

Fig. 5. Revised monthly mean values of total ozone for Mexico City and their comparison with Poona and Mauna Loa in a) corrected for Winter mixing layer depth, b) Summer and c) the average of both. We have drawn the three tendencies in the last figure to see the difference.

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