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TROPOSPHERIC OZONE MEASUREMENTS AT THE EQUATORIAL REGION (1980-88)

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ABSTRACT

Results from surface ozone measurements at Penang (5.5°N,100°E) over 1980-88 period are presented. The study indicates the ozone concentrations undergoing significant diurnal and seasonal variations. The peak concentration are observed at around mid-day (up to 35 nb) but the O_3 concentration generally drops to zero level in the early evening and remains unchanged until mid-morning. Monthly-averaged daily 1-h average concentrations are generally small (4-13 nb) and decrease continually from the early part of the year to the end. Frequently, varying local weather conditions seem to influence the O_3 concentrations.

1. INTRODUCTION

The natural ozone content of the troposphere is mainly determined by the rate of supply from the stratosphere and the rate of destruction on the earth's surface (Junge, 1962; Van Dop et al., 1977). Natural O_3 is also produced and destroyed within the troposphere by chemical reactions involving free radicals (Crutzen, 1974; Levy, 1988; Logan, 1985; Galbally and Roy, 1991). Besides the natural origin, surface O_3 can be produced photochemically due to the presence of NO_x and reactive HCs in association with high levels of solar near-ultraviolet (u.v.) radiation (Kirchhoff, 1988). Many of the industrial situations (including high emissions from motor vehicles) may result in photochemically produced surface O_3 and the O_3 levels can be of serious health and environmental consideration as elevated concentrations of ozone in the near surface air are damaging to vegetation and human health due to its toxicity. Also, ozone is a strong absorber of infrared radiation and large tropospheric concentrations may have adverse greenhouse warming effect on the earth's climate.

In non-industrial locations, free of relevant chemical pollutants, the information on surface O_3 distribution is helpful in studying the natural production and transport mechanisms as well as in providing benchmark data for future comparisions. In view of these considerations, tropospheric and surface O_3 measurements under different local conditions have been made (e.g. Ogawa and Miyata, 1984; Attmannspacher and Hartmannsgruber, 1981; Oltmans and Komhyr, 1986; Chatterjee et al., 1982). Despite considerable effort on obtaining atmospheric O_3 measurements, there is a serious paucity in surface O_3 and vertical O_3 data for the equatorial region. In view of this, a comprehensive observational programme, involving surface O_3, O_3 soundings, solar u.v. radiation and other related parameters, was initiated at the University of Science at Penang (Malaysia). Some initial results from this programme have appeared elsewhere (e.g. Ilyas, 1987a, b; Ilyas and Barton, 1983). The purpose of this paper is to report the results from the surface O_3 study for the 1980-1988 period incorporating the previously published results covering 1980 - 83 period (Ilyas, 1987a).

2. EXPERIMENTAL AND DATA ANALYSIS

The Island of Penang (5.5°N,100°E) where the University of Science Malaysia is located is ideal for equatorial measurements. The air is reasonably clean from industrial polluting chemicals and the climate is moderate due to land and sea breezes and the centrally running (N-S) hill which passes by the West side of the campus. The instrument used for surface O_3 measurements, is a wet-chemical (KI solution) Brewer type, used in several studies for such measurements. The

instrument was activated in late 1980 and was operational through 1988 but malfunctioned in end 1981, 1982 and some other periods, which gave rise to some discontinuities in the data. In 1985 the ozone calibration source was sent for re-calibration at CSIRO (Australia).

The instrument produces an analog signal suitable for recording on an x-t plotter. Using the equal area averaging method, one-hour (1980-83) and half-hour (1984-88) averages were obtained for the daytime (0930-2100hrs). Also, due to generally small signals, single entries for the remaining night-end (2100-2400) and morning end (2400-0930) were recorded. These hourly/half-hourly averages were then machine processed to form (horizontal) hourly averages for daytime (AVD), night-end (AVN), morning-end (AMN) and day-night time (AVA) for each operational day. Strictly speaking, AVA should represent the hourly average for the day by averaging the hourly/half-hourly totals for the entire day over total day-hours (i.e. 24 hours). However, as before (Ilyas, 1987a) we have averaged it over 12 hours because most of the contribution comes from day-time 12-hours and only occasionally a small contribution may come from the morning and night components. The averaging over 12 hours provides the day-time average concentrations which is what we would experience and is the quantity directly relevant for air-toxicity considerations. But, if the daily concentrations, averaged over 24 hours, is desirable, this can be easily done by reading the scale/numbers to half the indicated values. If on any day, a partial data loss occurred (e.g. power loss), no period-averages were formed.

The hourly/half-hourly averages for each time-interval were processed to produce monthly averages and daily-hourly averages for the specific hours as well as monthly averages thus completing a monthly summary.

3. RESULTS

The diurnal and seasonal ozone variability is shown in Figs. 1 and 2. In a typical diurnal behaviour, the O_3 flux increases from the zero level at around 9 a.m. (solar time) to a maximum value slightly before noon (true mean noon at 1320 hrs). It maintains the high level in the early afternoon and slowly decreases to zero level again in the later part of the evening. There are, however, significant variations to this pattern depending upon weather conditions which undergo rapid changes over the period of a day. Occasionally an O_3 level of as much as 5-10 nb may be maintained right through the night to the morning. Although night-time concentrations are usually zero level, on nights with significant thunderstorm activity (usually in the early mornings), traces of O_3 concentrations are recorded on the chart indicating O_3 levels increase during these activities.

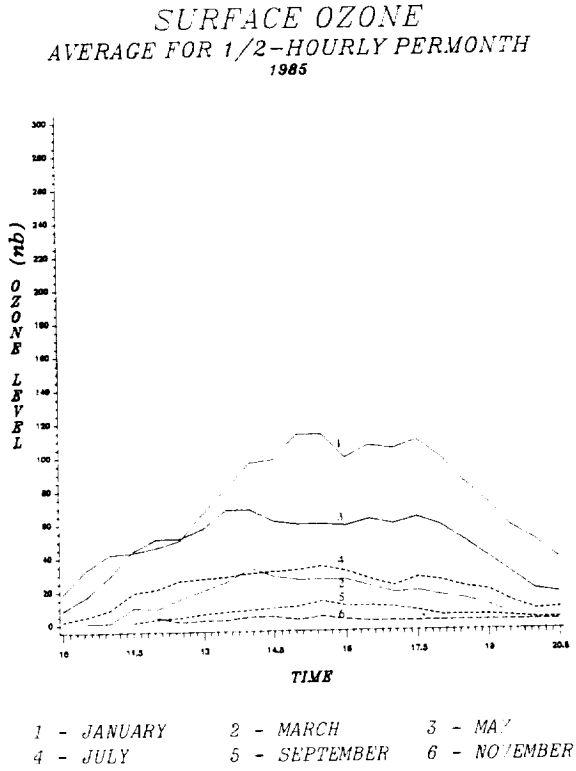

Fig. 1. Average monthly means of hourly-average ozone data as a function of local stands data; mean (local noon at 1320 local time) to show diurnal variability for different months for 1985.

The curves in Fig. 2 show seasonal variations using monthly averages of daytime hourly averages (AVA) for different years. The ozone concentrations usually drop to zero level in the late evening and maintains this level until late in the mid-morning.

Although the daytime 1-h average concentrations (partial pressure in nanobars) are relatively low (4-13 nb), the average-hourly maximum concentrations were found to be significantly higher (10-20nb),

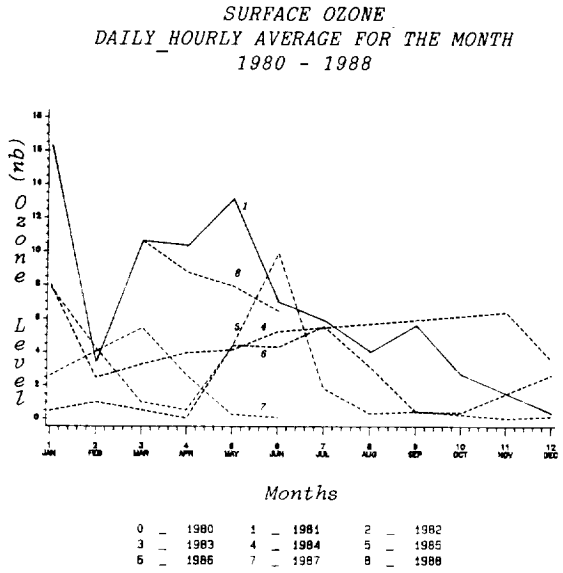

Fig. 2. Seasonal variability of monthly means of hourly-average ozone concentrations for the 1980-88 period.

especially in the early part of the year. Occasionally, the instantaneous (and 1-h average) values on individual days were found to reach as high as 35 nb. The data (Fig. 2) show a narrow dip around February which is the post-monsoon period. The prevailing synoptic situation (circulations) for the region is such that the wind direction changes over Peninsular Malaysia from North Easterly in January to approaching Westerly (April) and South-Westerly (July and October) over the northern part of Peninsular Malaysia including Penang. Although there is a gradual post-monsoon build up of the Westerlies, the general trend in April shows Easterlies able to penetrate the West coast of Peninsula including Penang Island. An examination of the wind data taken at Penang indicated a swift change in wind direction from NE in January to NW in February (and October) which together with a weakening in the winds seems to be associated with the observed variation in O_3 flux (Ilyas, 1987a).

To study the other factors affecting the seasonal behaviour, the daytime average data were compared with seasonal trend of several other parameters based on many years of data at Penang as shown earlier (Ilyas, 1987a). The general trend of decreasing O_3 concentrations seems to be well matched (inversly) with the seasonal variability of several inter-related meteorological factors (sunshine-hours, solar radiation, wind speed, cloud cover and rainfall) (Fig. 3). However, the data for solar u.v.-A radiation and erythmal solar u.v.-B do not seem to show any clear impact of these two components on this seasonal O_3 trend.

4. DISCUSSION

The monthly averages (Fig. 2) clearly show a significant downward trend in 1982 believed to be due to instrument sensitivity changes and may not be used in year to year variability study. Examination of the diurnal monthly averages e.g. data for 1981 and 1988, 1987, 1986, 1985 indicated that the average 1/2- hourly averages and peak values were about the same for these years and thus the monthly-hourly averages in these years are primarily affected by the changes in weather and environmental conditions rather than by

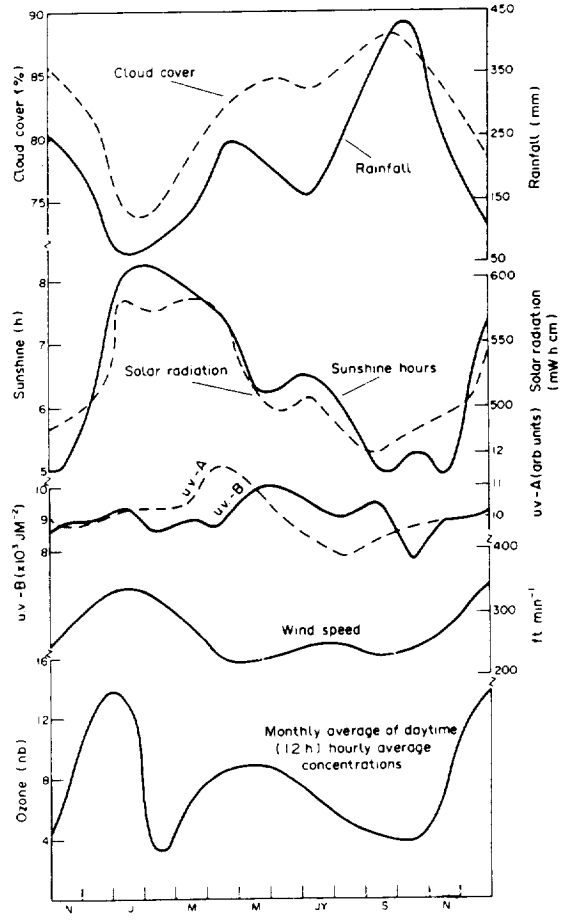

Fig. 3. Seasonal variability of surface ozone with other meteorological factors.

the instrumental sensitivity as in case of 1982.

Based on our experience with this instrument, we find two major maintenance problems. Firstly, the analyser calibration depends on the stability of the ozone source. The calibrator we used employs an opening-control which degrades with time as shown by a re-calibrator at CSIRO, Australia in 1985. The second source of problem comes from the frequent degradation and need for replacement of the air pump. On the whole, this instrument is very demanding in maintenance for the desired high precision data. In view of this, in 1988, we decided to discontinue the use of this instrument at the present location. It is our intention to establish a better type of instrument under a new broad programme at our recently built observatory and take other operational precautions. Despite the above mentioned sources of error, the overall seasonal and diurnal trends are clearly reflected in the Figs.

On the whole, considering the rather low O_3 levels and the absence of significant industrial sources, the surface O_3 in this region at present is considered to be essentially of natural origin and forms a background to possible future build up due to increasing industrial activities.

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