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Comparative Analysis of Total Ozone Data from Satellite EPTOMS and Ground-Based Dobson Instrument at Lagos-Nigeria *(pp. 162-172.)*

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Abstract: This work represents a comparison study of total ozone data from the ground-based Dobson spectrophotometer and the overpass data from satellite instrument EPTOMS in Lagos-Nigeria (Lat.6.6^{o}N, Long 3.3^{o}E) for the year 1997-2002. The result indicated that EPTOMS ozone series overestimated those of the Dobson's maximally between July-September with an average difference of 11%, while the Dobson ozone profile exceeded the EPTOMS by 6% in the month December-January. A strong anti-correlation of -0.88 was observed between the Dobson's ozone profile and the EPTOMS in the month July-September. The Dobson data showed considerable high frequency fluctuations with no clear seasonal trend. Maximum inter-annual differences for both instruments fell within the period of low precipitation in the West Africa region. Despite the monthly differences in the two set of data, their seasonal and annual component showed significant positive correlation of 0.53 with each other.

Keywords: equatorial ozone, satellite data, dobson ozone

1 INTRODUCTION

The nature of day-to-day total ozone variability has been of considerable interest for some time now. Early studies were limited to few ground based stations located mainly in the mid-latitudes, but the advent of meteorological satellite in monitoring ozone along with other meteorological parameters had provided a more detailed analysis of ozone fluctuation over very wide region including Africa. It is thus expedient to validate the satellite data by comparing it with some ground based generated data. Kerr *et.al* (1997) in his study, made a comparison of the satellite data with the ground based Dobson and Brewer spectrophotometer. They observed a high correlation between the satellite and the ground based data with a percentage difference of 1% per decade.

From previous studies, researchers discovered that the quality control of the ground-based spectrophotometers is an important factor when researching on the inter-comparison of total ozone column from satellite and ground-based spectrophotometers (Fioletov *et al.* 2002, Harris *et al.* 2003). For accurate comparison it was suggested that the data of the Dobson ozone measurements be as close as possible to the satellite overpass time. Measurements taken in ±1hour interval relative to the over-pass time were recommended to be used for the inter-comparison study (Bonawentura *et al.* 2006).

This paper presents the ozone variation from the ground based Dobson spectrophotometer at Lagos-Nigeria and the EPTOMS satellite. The paper elucidate both the seasonal and temporal variation of total ozone concentration at Lagos from 1997-2002, as revealed by both instruments. Total ozone column is a combination of the stratospheric and tropospheric ozone concentration. Tropospheric ozone, is a by-product of urban air pollution emitted from the combustion of fossil fuel in vehicles, industries etc. In the presence of high solar radiation, these emissions react with other atmospheric gases like nitric oxide at different chemical stages to produce ozone. It is generally agreed that tropospheric ozone has increased considerably as a result of these photochemical reactions (Roelofs and Lelieveld, 1997; Jacobson, 2000). Thus ozone in the troposphere is a pollutant and a major constituent of smog frequently observed in urban centres.

2 METHODOLOGY

This study made a comparison of the ozone distribution profiles obtained from the EPTOMS satellite and the ground based Dobson spectrophotometer at Lagos-Nigeria for the period 1997-2002. Average monthly ozone concentration from 1997-2002 measured by the Dobson spectrophotometer at the Meteorological Station Oshodi-Lagos and the monthly satellite EPTOMS data for same period were analyzed for various statistical components. The average EPTOMS monthly ozone series were deduced from the daily data. The Dobson spectrophotometers measure total column ozone in the atmosphere by observations of Direct Sun spectral irradiances(DSIR) of solar radiation at selected wavelengths in the UV part of the spectrum with strong and weak absorption by ozone (Vanicek, 2006). Dobson spectrophotometer derives total ozone values by differential absorption spectroscopy techniques (Komhyr, 1980; Basher, 1982; Kerr 2002; and Evans et al. 2005). Whereas, the ozone vertical profile derived from the EPTOMS is determined by measured radiance which is directly linked to the solar zenith angle of the sun at the time of measurement.

2.1 Comparison of the satellite data and ground based

Figure 1 shows the variability of total ozone recorded by the satellite EPTOMS and that measured by the Dobson spectrophotometer. The figure revealed that the mean EPTOMS ozone data overestimated those of the Dobson spectrophotometer for the greater part of the period studied. The average ozone concentration profile for the EPTOMS and the Dobson, in the six year studied were 270.8 DU and 256.8 DU respectively, yielding an average percent difference of 5.5%. Similar results were found by Weihs *et al.* (2006) with measurements performed at Villeneuve d'Ascq station (near urban site) in France. Furthermore, Bais *et al.* (2007) confirmed that satellite OMI-derived profiles overestimated ground-based data with values ranging between 20% and 30% at three sites in Greece. This trend could also be related to the fact that satellite instrument EPTOMS may not effectively probe the aerosols contribution which can be important in the boundary layer, especially in an urban centre like Lagos-Nigeria (Ialongo *et al.*, 2008).

The only time when the Dobson ozone data exceeded those of EPTOMS was in the period December-January (Figures 1b, 1d - 1f). This trend was significant between December-January of 2000-2002. In December 2000 the Dobson ozone exceeded that of EPTOMS by 6.4%, followed by 11.5% in January 2001. In December 2001 the Dobson ozone exceeded that of EPTOMS by 2.1%, followed by 2.5% in January 2002. And in December 2002 the Dobson ozone exceeded that of EPTOMS by 7.7%. These observations were associated with increase in surface ozone generated from photochemical reactions of emissions from fossil fuel and biomass combustions with solar radiation, which generally soars during this period. December to February is the period of the dry season over the West African region, during which precipitation is minimal, so there is a lot of air pollutants accumulation in the atmosphere. This pollutants comprising mainly of hydrocarbons and oxides of nitrogen react with each other in the presence of intense sunlight to produce more surface ozone within the boundary layer than usual. It could therefore be suggested that this excess surface ozone contributed to the overestimation of the Dobson ozone level above that of the EPTOMS during December-February period.

Surface ozone is a major component of the photochemical smog which is common over the station especially during the dry season. The term ‘photochemical smog’ is used for air pollution found near most urban areas, which also reduces visibility over the region. Thus Dobson spectrophotometer was observed to be more sensitive to the increase in surface ozone concentration than the EPTOMS satellite. This is in accordance with some previous findings (Ialongo *et al.*, 2008).

EPTOMS recorded average monthly maximum ozone concentration of 288.6DU in July-August, which coincided with the peak period of Tropical Summer rainfall, while the ground-based Dobson spectrometer recorded a lower average value of 263.6DU. This observed trend in EPTOMS profile could be suggested to be due to reduction in the strength of the extra-tropical suction pump (ETSP) action responsible for the transportation of ozone concentration from the tropical stratosphere into the mid and high latitudinal region during this period (Yulaeva *et al.*, 1994; Rosenlof, 1995; Holton *et al.*, 1995). While it could also be assumed that the low ozone value concentration recorded by the ground-based Dobson spectrometer in July-August is due to increase in surface relative humidity during this period. This trend is in accordance with some previous findings that relative humidity has a strong anti-correlation with ozone formation. Thus as surface relative humidity increases the contribution of the surface ozone to the total column ozone reduces. A strong anti-correlation of -0.88 was observed between the Dobson ozone profile and the EPTOMS in July-August.

Previous studies confirmed that weather patterns play a major role in escalating low tropospheric ozone concentration or terminating episodes of high ozone concentrations as the case may be. Meteorological processes like wind speed were directly linked to whether ozone precursor´s species are contained locally or transported downwind with the resulting ozone. It was discovered that ozone formation was most conducive during warm, dry, and cloudless days with low wind speeds, (Naja *et. al*., 1996, Adame *et. al.*, 2007).

On further analysis, the mean annual difference (in percent of the Dobson ozone) between the annual means of the EPTOMS and that of ground-based Dobson of the total ozone data for the period 1997-2002, were computed. The period 1997 to 2000 had an average value of 7.6%, while a sharp drop to an average of 1.5% was observed in 2001-2002 resulting in an average step-decrease of 5.1%.

The sharp drop in the mean annual difference between the two instruments in 2001-2002 was attributed to possible recalibration of the ground based Dobson to probe the higher altitude ozone column better, as its data had higher correlation with those of the satellite in the period 2001-2002 than the earlier part of the period studied. This is in accordance with other researchers who observed that the calibration of the instrument wedges during the inter-comparison period seems to bring about possible source of step- changes (Bonawentura *et. al.*, 2006*).* The average EPTOMS ozone profile for the two-year period (2001-2002) was 270DU while that of Dobson was 266DU. Whereas the average EPTOMS ozone profile for the period (1997-2000) was 271DU, while that of the Dobson for same period was 252DU.

In order to determine the seasonality of the data series, the coefficient of relative variation (CRV) of the two sets of ozone data was computed. The EPTOMS satellite data was observed to have clear seasonal and annual trend, while the Dobson data showed considerable high frequency fluctuations with no clear seasonal trend Figures (2a and 2b). The EPTOMS ozone series revealed two clear seasons, the first season peaked between December and January coinciding with the dry season (the West African Harmattan period), while the second peaked between July and August coinciding with the West African Tropical raining season.

The relative standard differences (RSD) of the Dobson ozone data series from those of the EPTOMS were derived. Observations showed that the EPTOMS ozone series exceeded those of the Dobson's maximally between July and September with an average difference of 11%. The RSD values between the two instruments had an average constant value of 5.7% between March and June, from which it rose to the peak value of 11% in August. The period of minimum RSD coincided with the months in which the ground based Dobson ozone profiles exceeded that of the EPTOMS (Figure 3).

The inter-annual differences of the monthly ozone series by both instruments were also studied. The EPTOMS inter-annual difference varied between 2.7% and 7.4%, while that of the Dobson was between 5.8% and 16%. The Dobson's recorded two peak values of 16% in March and 15.2% in October, while the two peaks for the EPTOMS occurred in February and November with average value of 7.4%. Thus, the maximum inter-annual variation for both instruments was observed to coincide with the period of minimum precipitation in the West Africa region. In summary, it was observed that the contribution of the anthropogenic activities and other lower tropospheric meteorological factors to the total ozone variation at Lagos-Nigeria, are maximal in the months of December/January and August.

In order to further investigate the effect of surface ozone precursor and other boundary layer activities on the total ozone variation, some further statistical analysis were performed (Figure 4). X_1 is the average coefficient of relative variation (CRV) of the Dobson ozone data, X_2 is the average CRV of the EPTOM ozone data, Y_1 is their sum and Y_2 is their difference. Y_1 had a high correlation value of 0.92 with X_2 and a lower value of 0.57 with X_1. Thus both the Dobson and the EPTOMS instruments had significant correlation with their average CRV. Also it was observed that the seasonal components of the ozone data measured by the two instruments along with their RSD revealed similarity in trend. Both the Dobson and the EPTOMS seasonal components correlated well with their relative differences with values of 0.97 and 0.73 respectively, while the direct seasonal correlation of the two instruments was 0.53, which can also be considered significant. Thus, despite the monthly differences in the two sets of data, there was appreciable seasonal and annual positive correlation between them.

3 CONCLUSIONS

The total ozone measurements by Dobson spectrophotometer utilizing results of the period 2001 and 2002 corresponded fairly to the total ozone measured by the satellite EPTOMS. The overestimation of the Dobson ozone profile above the EPTOMS in December-January was attributed to increase in surface ozone due to increase in air pollution accumulation from fossil fuel combustions and heavy biomass burning during the dry season. A strong anti-correlation of -0.88 was observed between the Dobson ozone profile and the EPTOMS in July-August which coincided with the peak tropical raining season. Further investigations on both the satellite EPTOMS and the ground based Dobson ozone data are required to give hints about the possible contribution of uncertainty in effective probing of the aerosols generation in the boundary layer and the inaccuracy generated due to atmospheric transmittance and other meteorological variables.

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Figure **Captions**

Figure 1: Comparisons of the monthly ozone profiles from the EPTOMS satellite and the ground-based Dobson Spectrophotometer at Lagos Nigeria (1997-2002)

Figure 2: Dobson's and EPTOMS coefficient of total ozone variability at Lagos-Nigeria (1997-2002), respectively.

Figure 3: The relative standard differences (RSD) between the Dobson's and EPTOMS ozone profile at Lagos.

Figure 4: Monthly trend of the re-evaluated Dobson's and EPTOMS ozone profiles at Lagos-Nigeria. X_1 is the average CRV of the Dobson ozone data, X_2 is the average CRV of the EPTOM ozone data, Y_1 is their sum and Y_2 is their difference.

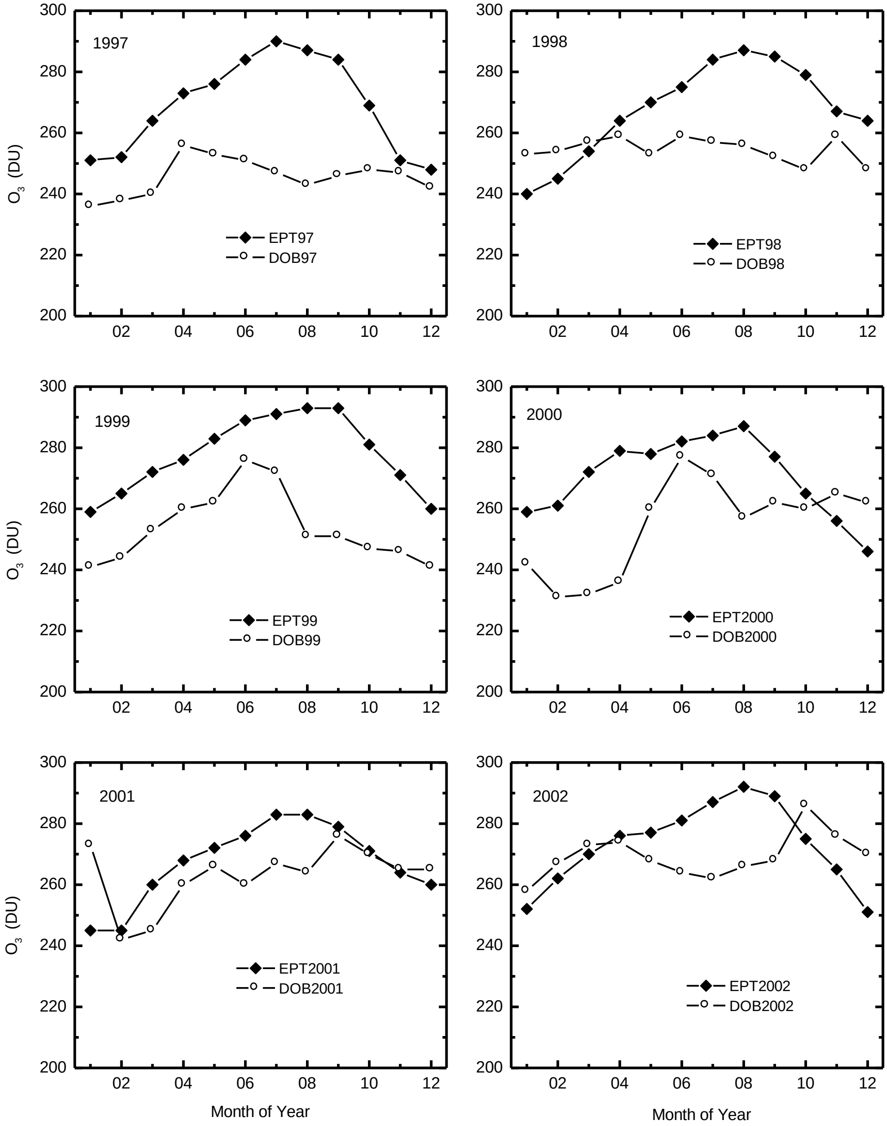

Figure 1: Comparisons of the monthly ozone profiles from the EPTOMS satellite and the ground-based Dobson Spectrophotometer at Lagos Nigeria (1997-2002)

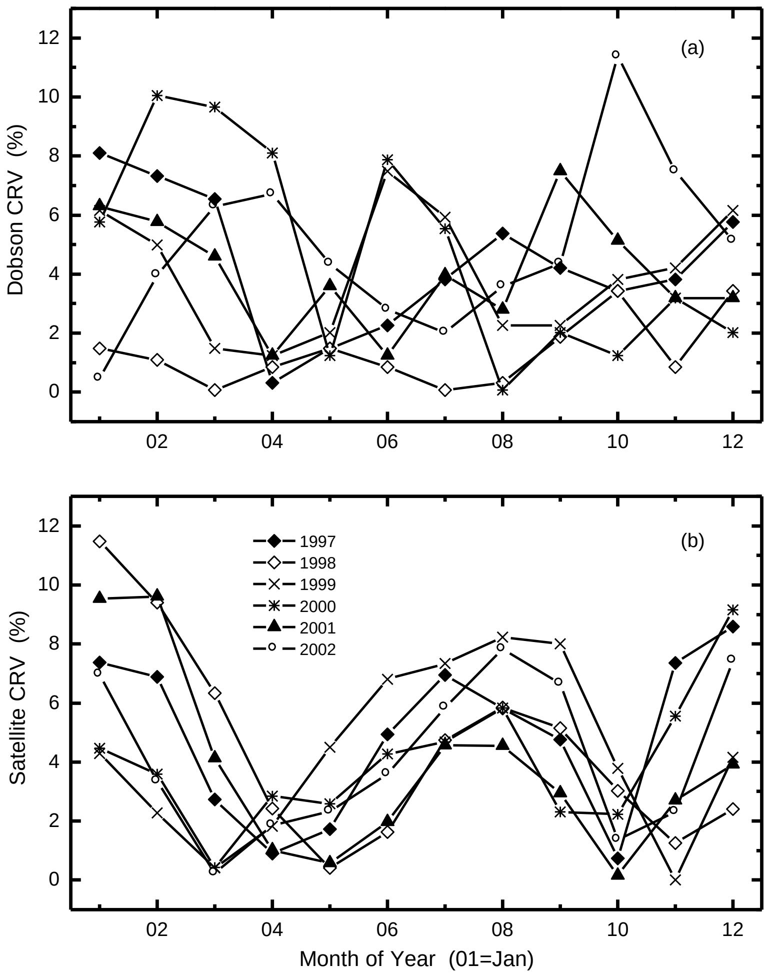

Figure 2: Dobson's and EPTOMS coefficient of total ozone variability at Lagos-Nigeria (1997-2002), respectively

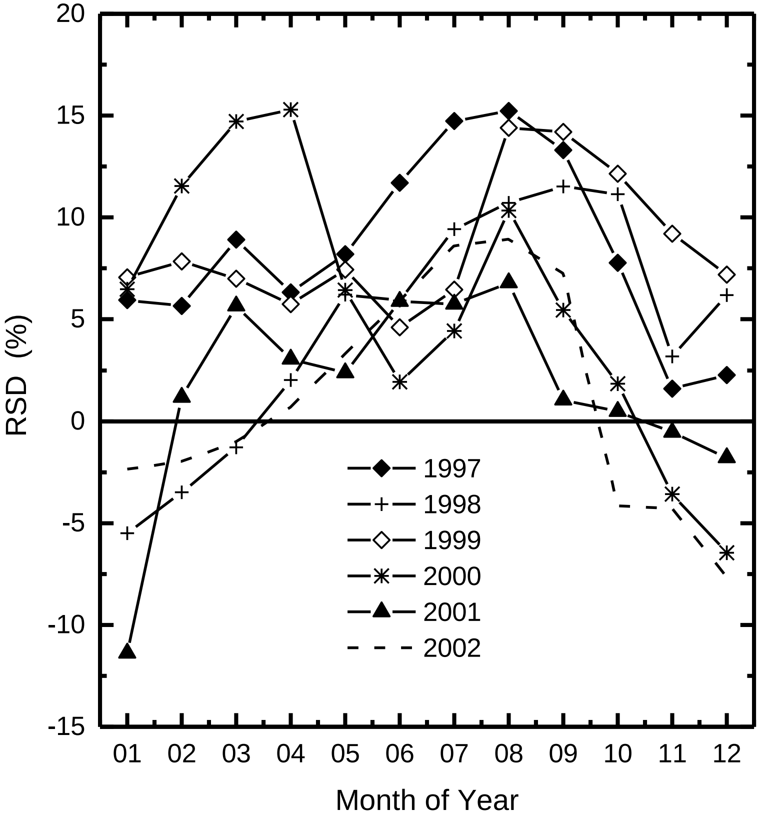

Figure 3: The relative standard differences (RSD) between the Dobson's and EPTOMS ozone profile at Lagos

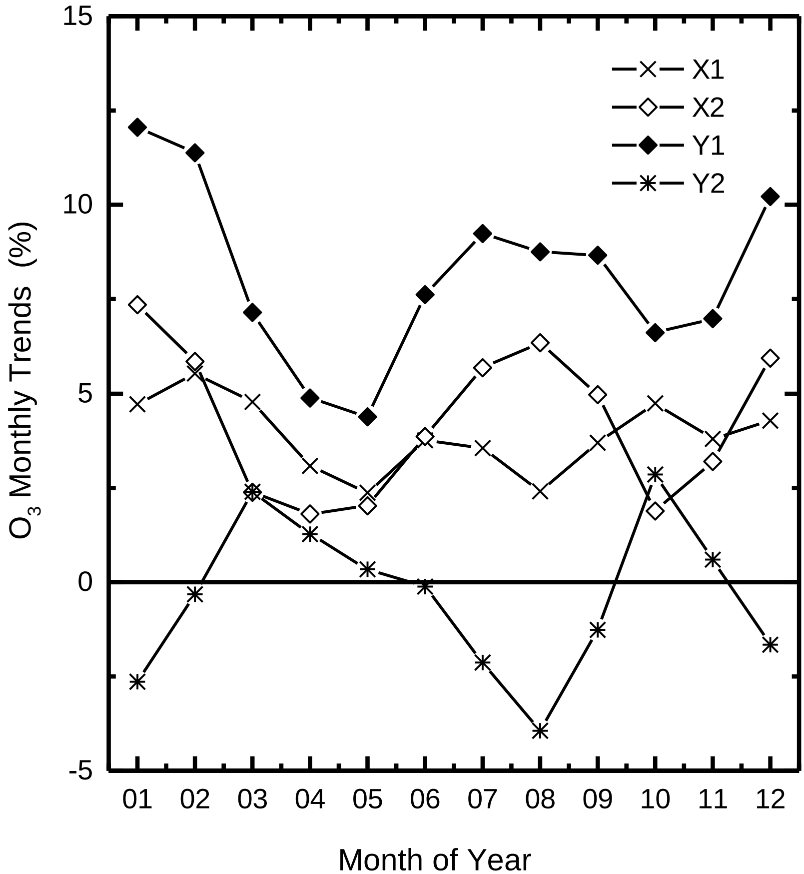

Figure 4: **Monthly trend of the re-evaluated Dobson's and EPTOMS ozone profiles at Lagos-Nigeria.** X_1 **is the average CRV of the Dobson ozone data,** X_2 **is the average CRV of the EPTOM ozone data,** Y_1 **is their sum and** Y_2 **is their difference**