Effects of Some Atmospheric Parameters on the Dynamics of Lower Stratospheric Ozone in the Low Latitude.

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ABSTRACT

This work investigates the effects of some atmospheric parameters such as the extra-tropical suction pump (ETSP) and the Quasi Biennial Oscillation (QBO) on the variability of Ozone (O_3) in the tropics with much emphasis on Nigeria, using the Earth Probe Total Ozone Mass Spectroscopy (EPTOMS) data obtained for Lagos station for the period spanning from 1997 to 2005. The results show that the mean O_3 concentration, O_3 temporal oscillation period, its average temporal amplitude of oscillation, and its average maximum daily variation are 273.6± 0.04DU, 5days, 7.81Du and 48.8Du, respectively. The average monthly maximum and minimum O_3 concentrations were found to be 287.8Du occurring between July and August and 192.73Du occurring between December and March respectively.

These variations also follow the trend of the zonal wind speeds obtained for Nigeria between the periods under investigation. This variation in the ozone within the tropics, could be attributed to the effects of the extra-tropical suction pump (ETSP) action which causes the O_3 transport from the tropical stratosphere to the mid latitude region. QBO effect on the O_3 variability is also observed in February 2001; Jan 2003 and Jan 2004. More research work on this topic is still being carried out so as to ascertain other factors affecting the O_3 transport and effects in the tropics

(Keywords: O_3, ozone, extra-tropical suction pump, ETSP, quasi biennial oscillation, QBO, atmospheric gases, atmospheric dynamics, lower stratosphere, atmospheric variability)

INTRODUCTION

Ozone (O_3) pays a key role in the atmosphere; it can protect life on Earth or harm it, depending on its type and location in the atmosphere. In some parts of the world, the O_3 layer has been partially depleted allowing more harmful ultra violet (UV) rays to get through. In spite of a large amount of observational evidence that the O_3 layer depletion is caused by man–made activities, the causes of inter annual and decadal variations of O_3 layer and their relationship with low frequency change of stratospheric circulation and wave activity are not well understood (Jadin, 1999).

One of the key factors that influence the strength of atmospheric dynamics, (especially in O_3 transport) over the tropics is the Extra-Tropical Suction Pump (ETSP). The ETSP through wave driven circulation causes large scale upward transfer of air mass from the tropics into the mid and high latitude regions. Previous studies (Holton et al., 1995; WMO, 1998 and Akinyemi, 2007) have established that the tropical upwelling is primarily controlled by the ETSP action on the tropical stratosphere. The ETSP is a phenomenon, whereby the extra tropical stratosphere and mesosphere through relevant eddy effects act non-locally on the tropical stratosphere as a global scale fluid dynamical suction pump.

Another important factor influencing the variation of atmospheric O_3 over the low latitude is the quasi-biennal oscillation (QBO). QBO is a phenomenon whereby the wind in the lower stratosphere switches from easterly to westerly direction and vice-versa within a period between 22 to 28 months (roughly 2 years). The QBO is driven by a wave transport propagating vertically from the troposphere.

These waves consist of the westerly Kelvin wave during the descending westerly phase of QBO and easterly gravity - Rossby wave during the descending easterly phase (Holten and Lindzen, 1972).

PURPOSE OF THE STUDY

Although some works have been carried out on the variation of O_3 concentration in the tropics (Akinyemi, (2007); Oyekola et al, (2006) and Rabiu and Omotosho, (2003), using a 5 year data (from 1997-2002), yet there is need for further and more detailed study of the dynamics of O_3 in the law latitude. Hence this work investigates the effect of ETSP and QBO on the ozone transport from the upper troposphere to the lower stratosphere of the tropics (using Nigeria as a case study) and the data spanning from 1997 to 2005.

SOURCE OF DATA

The monthly column ozone data are obtainable from Earth Probe Total Ozone Mass Spectroscopy (EPTOMS) version 8 over pass-generated 3rd January 2006.

ANALYSES AND DISCUSSIONS OF RESULTS

It is important to note here that the only available ozone data for Nigeria for now is that obtained at Lagos station at 6.6^{o}N and 3.3^{o}E between the periods of 1996 – 2005. Hence, the analyses of the O_3 in this work are based on this available data. However, the results obtained in this work give a general idea of what could happen at the other stations in Nigeria where ozone data are not yet available. Secondly, the analyses using these data within the available period will also enable us to predict the general effects of O_3 variation on the climate of Nigeria.

The monthly mean in the O_3 concentration was computed. Similarly, the mean annual O_3 concentration was computed. Hence Figures 1 (a-i) illustrate the seasonal distributions of O_3 concentration in Lagos between 1997 – 2005, respectively.

Figure 2 shows that the variations in the O_3 concentration is periodic, having a temporal oscillation period of 5days, and an average temporal amplitude of oscillation of 7.81DU. Its average maximum daily variation is determined to be 48.8DU, and the annual seasonal oscillation period is 325 days.

The observation of high frequency daily O_3 variability could be linked to the possible interconnectivity between convective activities and stratospheric O_3 redistribution. And the presence of high convective activities could also be linked with change in stratospheric wind speed both in the horizontal and vertical directions.

Changes in the stratospheric O_3 and wind affect the flow of energy at altitudes just below, which then affect the next lower altitudes and so on, all the way to the ground (Allen 2004).

Statistical analysis of the O_3 distributions (Table 1) shows that the mean monthly maximum O_3 concentrations were found to be 283.6Du occurring between July and August. This maximum O_3 concentration coincided with the tropical summer rainfall over the West African region, which peaks between June and September as can also be observed in Figure 3 that shows the mean monthly distribution of precipitation in Nigeria, (between 1997 – 2006), which is also the period under investigation. Thus, there is a relationship between the rainfall patterns and the total O_3 variability in Nigeria.

The occurrence of maximum O_3 concentration in the tropics with the peak tropical summer rainfall could possibly be attributed to the reduction in the strength of ETSP action which causes the transportation of O_3 from the tropical stratosphere into the mid and high latitudinal region. This reduction might be due to the decrease in the energy from the atmospheric heat engine expected to drive the ETSP (Akinyemi, 2007). The tropical rainy season is characterized with minimum tropical surface temperature and evaporation which might be linked with decreases in the atmospheric heat engine responsible for driving the ETSP. Thus, it may be inferred that there is a relationship between reduction in the strength of the ETSP and O_3 distribution during the tropical rainfall season.

On the other hand, an average monthly minimum O_3 concentration is found to be 242.99Du occurring between December and March. This coincides with the period of dry season over West Africa which is characterized by high surface temperature and evaporation.

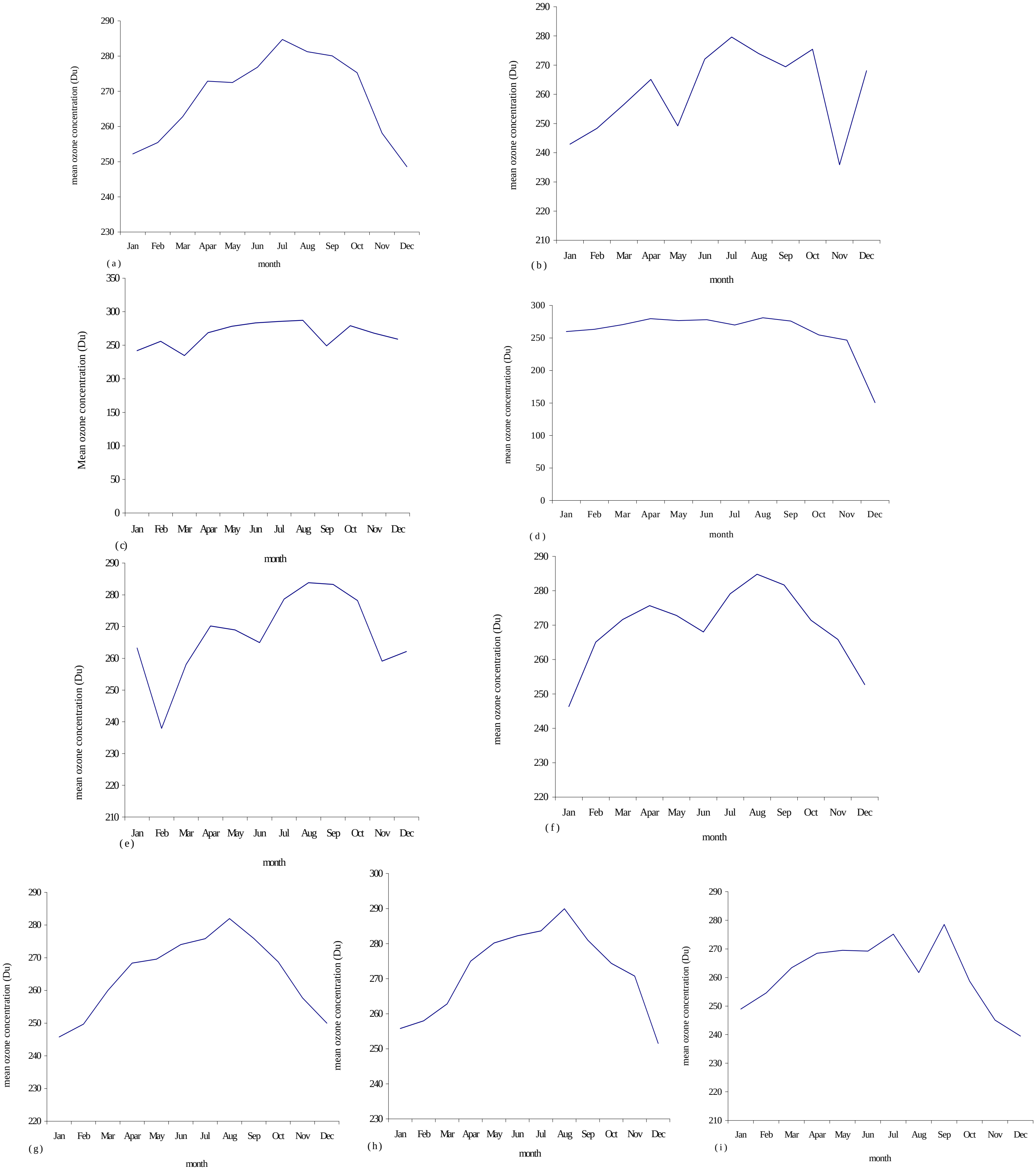

Figure 1: Monthly Distribution of O_3 in Nigeria (1997 – 2005).

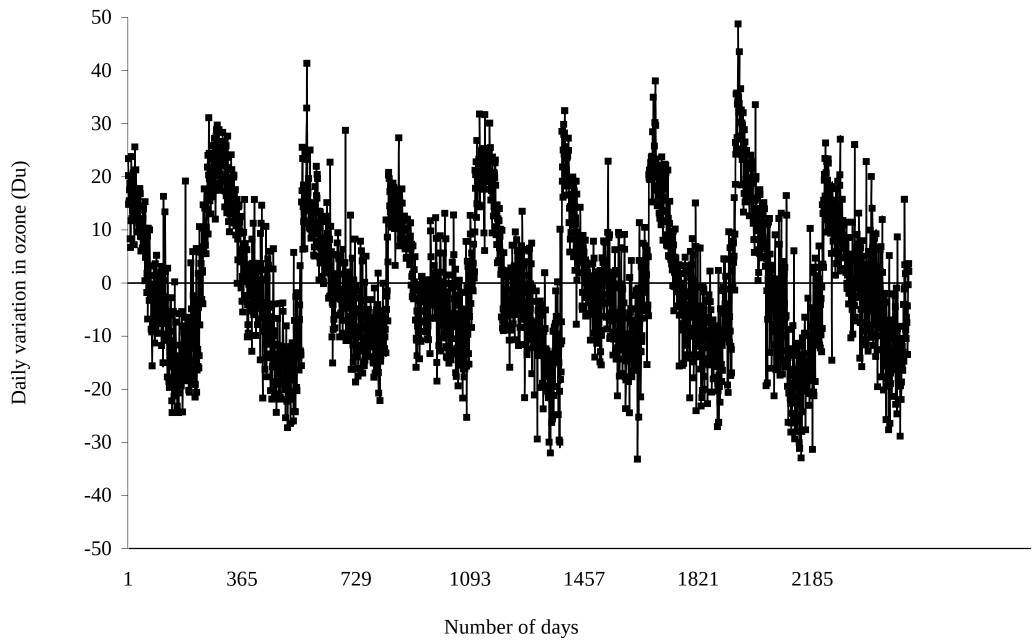

Figure 2: The Daily Variation of Ozone at Lagos (1997 – 2005).

Table 1: Statistical Analysis of Ozone at Lagos (1997 – 2005)

Year	Mean	Max	Month (max)	Min	Month (min)	% Var
1997	269.3	284.7	July	248.6	Dec.	12.3
1998	266.5	279.6	July	235.9	Nov.	15.6
1999	278.1	287.4	Aug.	234.8	Mar.	18.3
2000	274.9	281.2	Aug.	246.6	Nov.	12.2
2001	270.0	283.8	Aug.	237.9	Feb.	16.2
2002	279.3	284.8	Aug.	246.3	Jan.	13.5
2003	273.5	282.0	Aug.	245.8	Jan.	12.8
2004	279.6	290.0	Aug.	251.5	Dec.	13.3
2005	271.0	278.5	Sep	239.5	Dec.	14.0

Mean = Annual mea of ozone concentration
Max = Maximum value
Month (max) = month of maximum ozone concentration
Min = minimum value
Month (min) = month of minimum ozone concentration
*% Var (variability) = 100 * Range / Maximum value*
Ave. % Var = 14.3

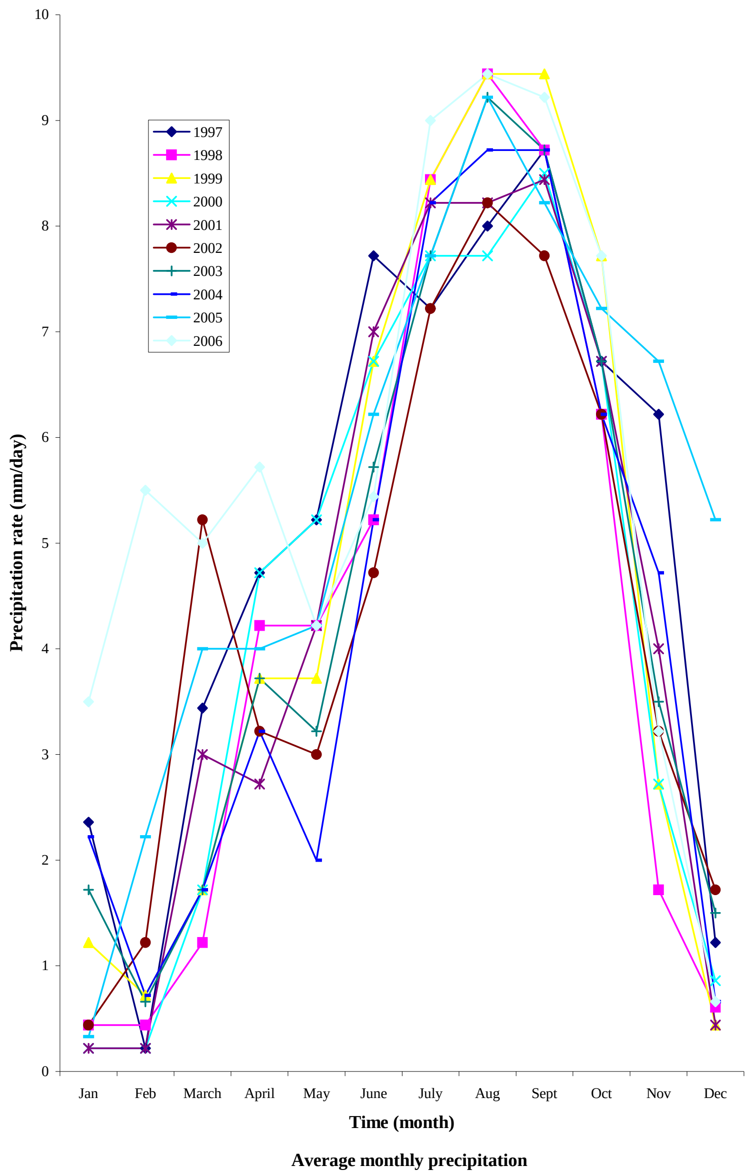

Figure 3: Monthly Distribution of Precipitation Rate in Nigeria (1997 – 2006).

This can then be said to follow the earlier suggestion on the link between the strength of the ETSP and O_3 distribution. With high temperature and maximum evaporation during this period, the atmospheric heat engine that drives the ETSP might be suggested to be at its peak performance in lifting of O_3 rich air off the tropical stratosphere into extra tropical region, thus reducing the O_3 amount in the tropics.

Figure 4 shows the graph of the daily coefficient of relative variations, revealing the effect of the QBO on O_3 distribution over the station.

The peaks A1, A2, B1, and B2 depict the periods of QBO. Hence, the first phase of the QBO was observed in January 2001 and January 2003 while the second phase of QBO B1 and B2 was observed in January 2002 and January 2004.

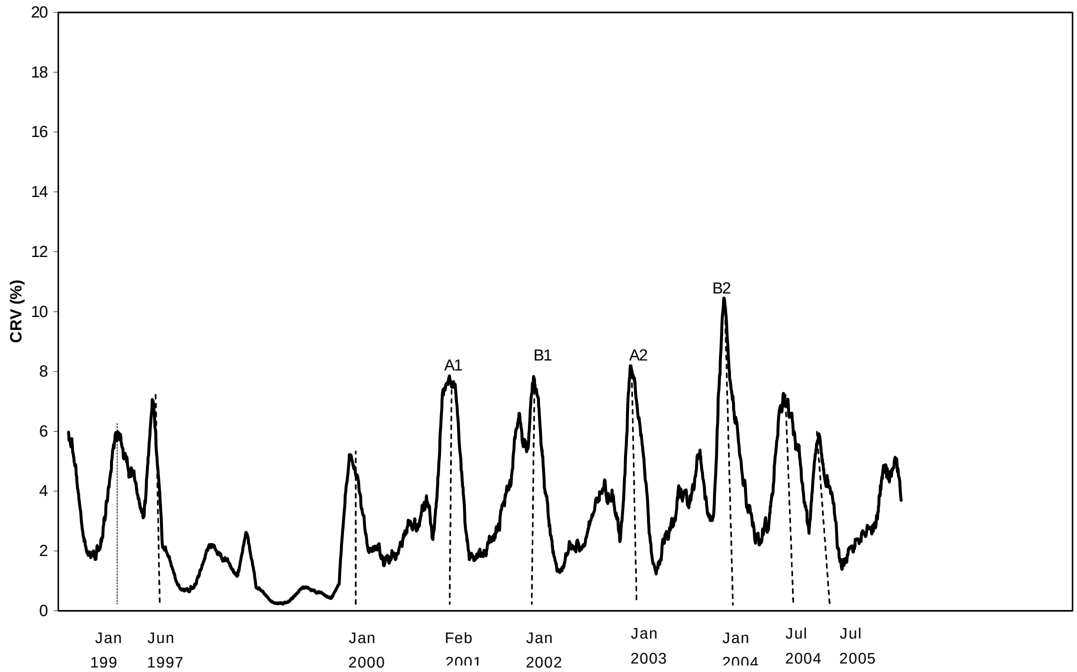

Figure 4: The QBO and Variability of Ozone Concentration at Lagos.

The effects of the QBO was suggested as the maximum lifting of O_3 rich air from over the region to extra tropical zone which coincided with the period of maximum temperature and evaporation at the low latitude (Akinyemi, 2007). This resulted in minimum O_3 concentration during the periods of QBO occurrence as can be observed from Figure 1. Thus, the QBO is confirmed to play a dominant role in the O_3 transport, and hence in the interannual variability of O_3 concentration. This result is in line with the result obtained by Akinyemi (2007), that in the QBO years, the O_3 concentration are small and constant for West Africa.

CONCLUSION

The result of Jadin (1999) which associated the main cause of O_3 hole appearances and O_3 trend in middle and high latitude of the Northern hemisphere with a decadal decrease of planetary wave activity in the middle and high latitudes of the stratosphere was confirmed by the action of ETSP in the tropical stratosphere, as stated by Akinyemi (2007) and is in line with annual variation of O_3 concentration in this work. Hence the transport or dynamics of O_3 in low latitude is influenced by ETSP and QBO.

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