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Wind Convolution and Ozone Distribution over Nigeria

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ABSTRACTS

The effect of zonal and meridional wind on surface ozone variability in Nigeria in the four quarter of the year was explored using data from Atmospheric Infrared sounder (AIRS) of NASA. Namely, December, January, February (DJF); March, April, May (MAM); June, July, August (JJA) and September, October, November (SON). The study revealed that both the day and night time surface ozone distribution in DJF season recorded a significant correlation of 0.7 with the zonal wind flow pattern, and a less significant correlation of 0.36 with the meridional wind flow pattern. Average maximum ozone concentration of 281.4DU southward and 260.3DU northward were observed in DJF. In JJA, the meridional wind pattern recorded strong west to east flow which was non-parallel to the latitudinal lines. It had a significant negative-correlation of – 0.56 with the ozone distribution for that season. Also the JJA zonal wind flow unlike that of DJF, recorded significant west to east flow resulting in partial atmospheric blocking which constrained the maximum ozone concentration westward with an average of 307DU retained within longitudes 2^oE - 6^oE in western Nigeria, for all the seven years studied. This was contrary to the direction of the prevailing meridional flow for the season which was predominantly eastward.

Keywords: Ozone distribution, zonal wind, meridional wind, Rex blocking.

INTRODUCTION

The complexity involved in the atmospheric distribution of ozone concentration is a study that cannot be easily exhausted. According to previous researches, upper level winds that are nearly parallel to the lines of latitude are termed zonal wind and those that cross the latitude lines at sharp angles are termed meridional (Haby, 2012). Naturally, the tropical lower atmosphere is made up of highly complex horizontal scale winds which vary very abruptly and are intra-seasonal. Part of the convolution resulting from tropical atmospheric dynamics in West Africa is the inter-tropical convergence zone (ITCZ), (Sultan and Janicot, 2003). This zone represents the storm tracks formed by the deep convection within the propagating atmospheric motions. The atmospheric dynamics associated with the abrupt ITCZ shift has been known to affect the distribution of traces gases like ozone within the region as reported by Akinyemi and Omotosho (2010). The various complexity involved in atmospheric motion are known to contribute significantly to the distribution of surface ozone concentration (Tarasova *et al*., 2003; Meigen *et al*., 2002).

Another atmospheric dynamic constraint that influences the distribution of ozone is atmospheric blocking. Atmospheric blocking is defined as a persistent latitudinal ridging in the jet stream, it is a large-scale phenomenon that is yet to be well represented in climate or forecast studies over the equatorial region (Scaife *et al*., 2010). Blocking over the mid and high latitudes has been studied by many researchers, although its theoretical description is yet to be brought under a very decisive conclusion but very little work has been done on it in the tropical zones (Berrisford *et al*., 2007).

According to (Tyrlis and Hoskins, 2008) atmospheric blocking which is a well-known feature of the Mid-latitude low-frequency atmospheric dynamics is often related to the breakdown of the “high kinetic energy level” state of the atmosphere into a “low kinetic energy level” state. The onset of blocking usually obstructs the eastward advance of weather systems. Blocking has a barotropic signature.

Blocking is a result of strong interaction between smaller scale atmospheric waves associated with low pressure and large-scale quasi-stationary ridging. Blocking represents the up-scale transfer of energy from the smaller-scale to the large-scale. When blocking occurs, atmospheric patterns tend to be repetitive; this results in the same pattern being repeated for several days to even weeks. Such situation can lead to flooding, drought, above normal temperatures, below normal temperatures and other weather extremes (Berrisford *et al*., 2007; Scaife *et al*., 2010).

Lejena¨s and Økland (1983) proposed a concept that for a longitudinal zone to be blocked, the latitudinal average of the zonal wind flow across the zone must be easterly at that longitude, which can be expressed by the equation,

$$Z_{\phi-\Delta\phi/2} - Z_{\phi+\Delta\phi/2} < 0 \qquad (1)$$

This implies that the average index value few degrees to the west and east should be negative. This concept was found to be most observable at the 500mbar height by Pelly and Hoskins (2003).

The various types of blocking as recognized in past researches include Omega block, Rex block and cut-off block (Haby 2012, Barriopedro *et al*., 2010; Austin, 1980). According to Haby (2012), the region under an omega block tends to experience dry weather and light wind for an extended period of time, while rain and clouds are observed in the troughs on either side of the Omega block. Omega blocks help forecaster determine which areas will be dominated by dry or rainy weather for several days. Previous research showed that Rex blocking sets up strong high-pressure ridge adjacent to a strong low-pressure trough, this causes the air to swing in loops near the same longitude and tends to force the air to lower latitude. They equally observed that the wind flow eastward is significantly restricted and thus wind flow makes little progress to the east (Haby 2012, Austin, 1980; Tyrlis and Hoskins, 2008; Barriopedro *et al*., 2010). According to Barriopedro *et al.*, (2010) Blocking played significant role in the low level total ozone concentrations observed over some temperate regions, especially over the Scandinavian and the Alaska Peninsulas. They related the presence of atmospheric blocking to the creation of ozone miniholes. Ozone miniholes is a situation where the total ozone concentration over a particular region drops below the threshold value and may lead to increase in the solar ultraviolet radiation reaching the earth surface.

MATERIALS AND METHODS

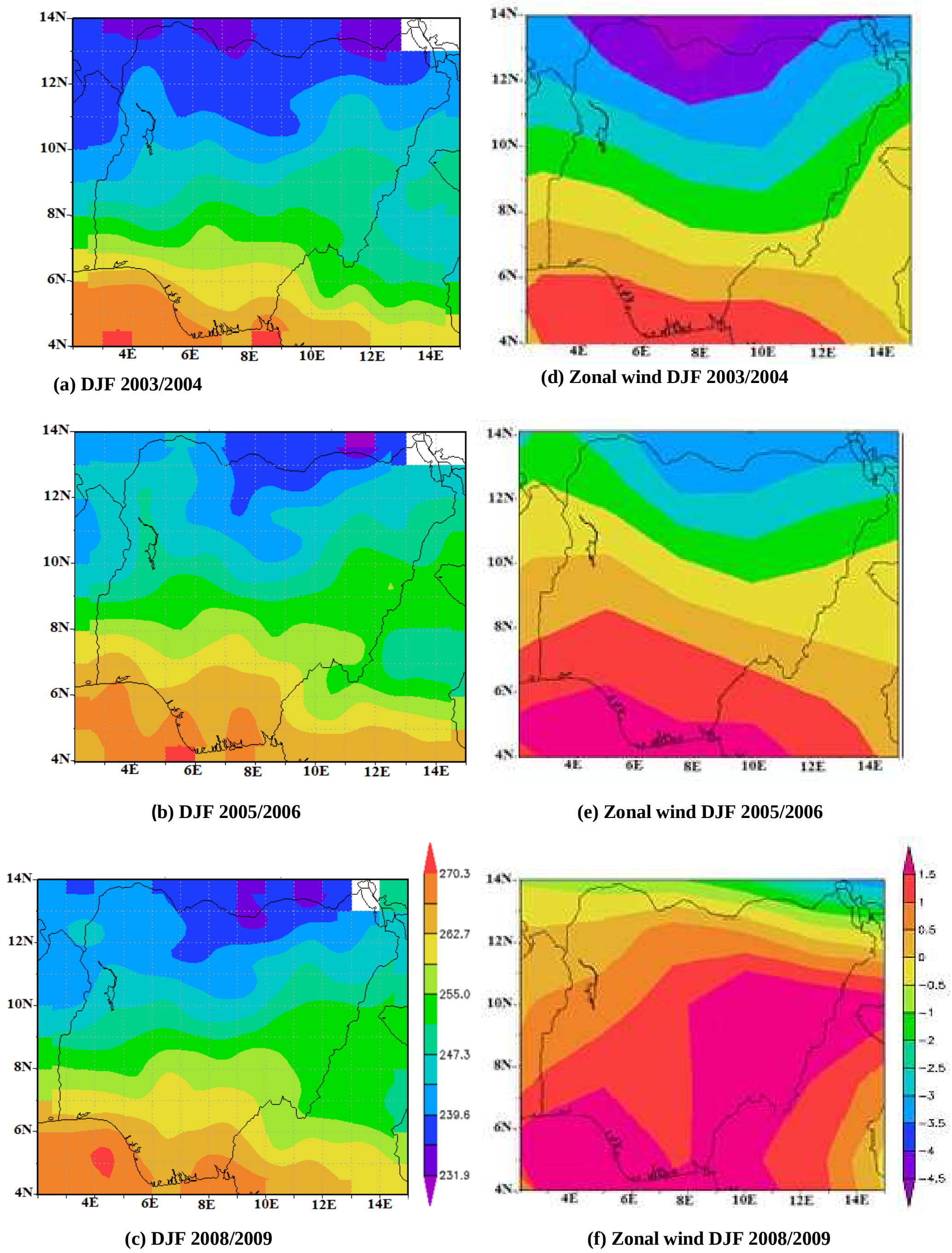
Methodology and Data analysis

The data used in this study were retrieved from AIRS satellite for the years 2002 to 2009. For ease of identification and analysis, the map of Nigeria which could be contained in a rectangular box of latitudes 4^o-14^oN and longitudes 2^o-15^oE, was subdivided into eight zones namely; North-North (NN), North-East (NE), North-West (NW), North-Central (NC), South-South (SS), South-East (SE), South-West (SW) and Middle-Belt (MB). Samples of the diagrams showing the locations of the maximum and minimum ozone, direction and strength of zonal and meridional wind flow are shown in Figures 1, 2, and 3.

RESULTS AND DISCUSSION

Correlation of the Zonal Wind Flow with the DJF ozone distribution

This study revealed that surface ozone concentration over Nigeria had strong correlation with the zonal winds flow in DJF. Distinct trends and patterns observed from AIRS satellite data for the period 2002- 2009 in DJF revealed the strong influence of zonal wind pattern on the surface ozone distribution over Nigeria. Ozone distribution pattern was observed to follow the same trend as the zonal wind patterns (Figure1). In DJF, ozone distribution pattern was nearly parallel to the latitudinal lines, which might be responsible for the significant correlation it recorded with the zonal wind flow. The maximum zonal wind strength of average $4.5ms^{-1}$ was observed in the northern part of the country in the DJF season (Table 1), while the direction of the flow was from north to south (Figure1). The study also showed that both the day and night time north-south surface ozone distribution in DJF season recorded a significant correlation of 0.7 with the zonal wind flow pattern, and a lower value of correlation of 0.36 with the meridional wind flow pattern. The zonal wind pattern in DJF followed a north to south trend in all the seven years studied, while the meridional was northeast to southwest pattern for the same DJF season (Figure1).



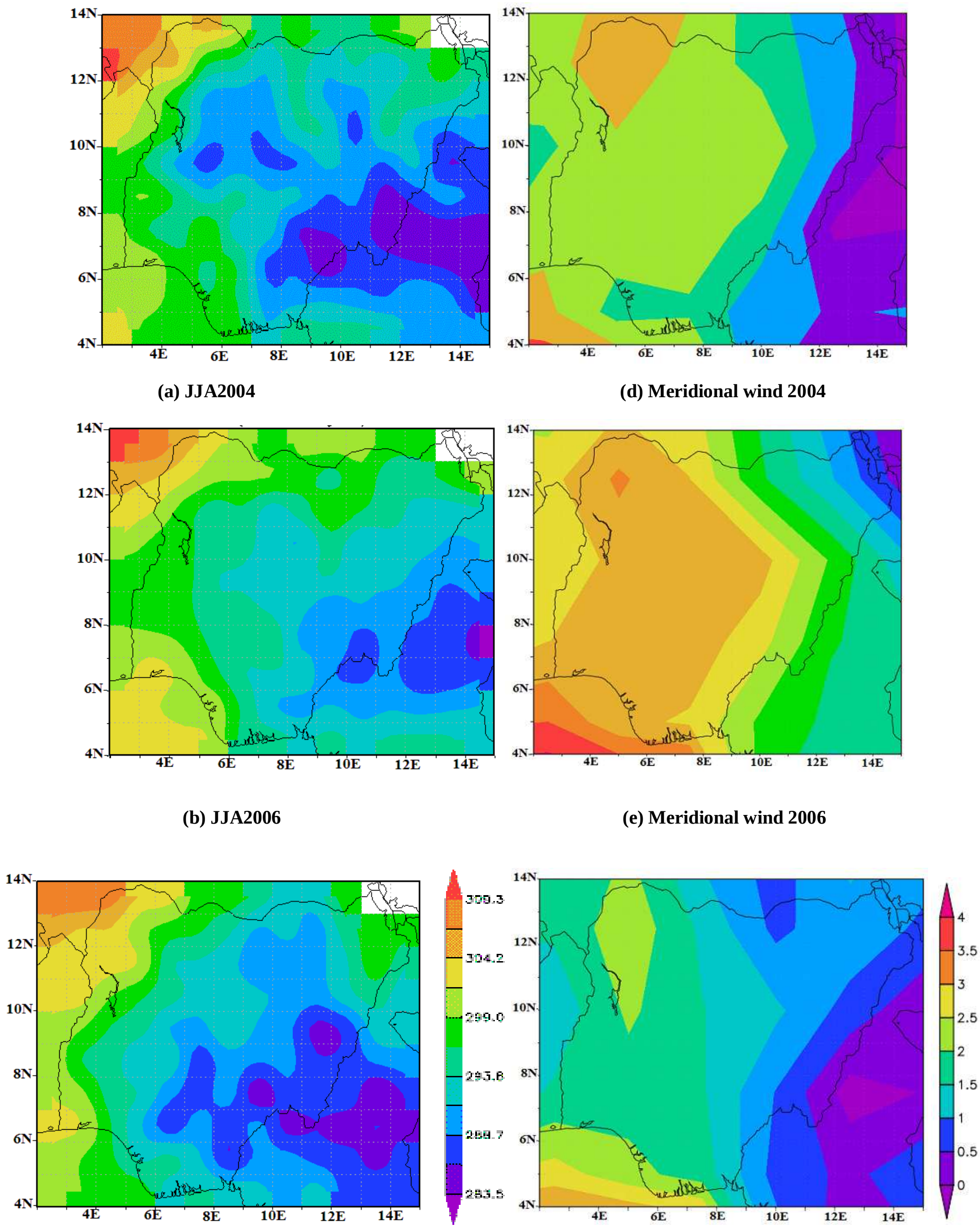
(a) DJF 2003/2004 (d) Zonal wind DJF 2003/2004

(b) DJF 2005/2006 (e) Zonal wind DJF 2005/2006

(c) DJF 2008/2009 (f) Zonal wind DJF 2008/2009

Figure1: Comparison of DJF ozone distribution patterns and zonal wind flow in Nigeria

This implies that atmospheric trace gases such as ozone under consideration is expected to flow along with the prevailing direction of the wind pattern and should have higher concentration southward. This trend was observed in the seven years studied, as maximum ozone concentration average values of 281.7DU occurred in the southern part of Nigeria and an average minimum of 260.3DU was recorded in the north in the DJF season.



(c) JJA2009

(f) Meridional wind 2009

Figure2: Comparison of JJA ozone distribution patterns and meridional wind flow in Nigeria

Table 1: Ozone Concentration and Maximum Wind Strength location

Year	Pattern	DJF Ozone	DJF Z-Wind	JJA Ozone	JJA M-Wind
Y02/03	**Max**	SE (279)	North (5.5)	NW (310)	West (3.5)
	Min	NN (261)	-	SS (281)	-
Y03/04	**Max**	SE (281)	North (4.5)	NW (315)	West (3.0)
	Min	NN (253)	-	SS (301)	-
y05	**Max**	SE (286)	North (5.5)	NW (295)	West (3.5)
	Min	NN (272)	-	SS (273)	-
y06	**Max**	SW-SE (278)	North (6.0)	NW (318)	West (3.0)
	Min	NN (259)	-	SE (299)	-
y07	**Max**	SW-SS (276)	North (3.5)	NW (300)	West (3.0)
	Min	NN (259)	-	SS (272)	-
y08	**Max**	SE-SS (282)	North (2.5)	NC (311)	West (3.5)
	Min	NN (253)	-	SS (299)	-
y09	**Max**	SW-SE (288)	North (3.5)	NW (302)	West (3.0)
	Min	NN (265)	-	SS (288)	-

Role of atmospheric blocking and Meridional flow in JJA ozone distribution

The study observed that the JJA zonal wind flow was dual in direction, partly north to south and partly west to east, while the meridional wind flow for the same JJA was majorly west to east in direction. But unlike the DJF ozone distribution where maximum ozone concentration was recorded southward in alignment with the predominant zonal flow, maximum ozone concentration was observed westward contrary to the direction of the prevailing meridional flow which was eastward for the JJA season. Atmospheric blocking was suggested to be responsible for the prevention of maximum ozone concentration flowing eastward along with the direction of the prevalent meridional wind observed in JJA. An average maximum ozone concentration of 307DU was observed in the northwest in all the seven years studied. (Table 1). The meridional wind component strength for JJA averaged about 3.5ms^{-1} moving from west to east. As expected the maximum ozone concentration should have been observed towards the east, which is the direction of the prevalent flow, but this was not the case for the JJA season (Figure 2). Longitudinally, Nigeria spread over longitudes 2^{o}E - 15^{o}E, the maximum ozone concentration was observed majorly between longitudes 2^{o}E - 6^{o}E.

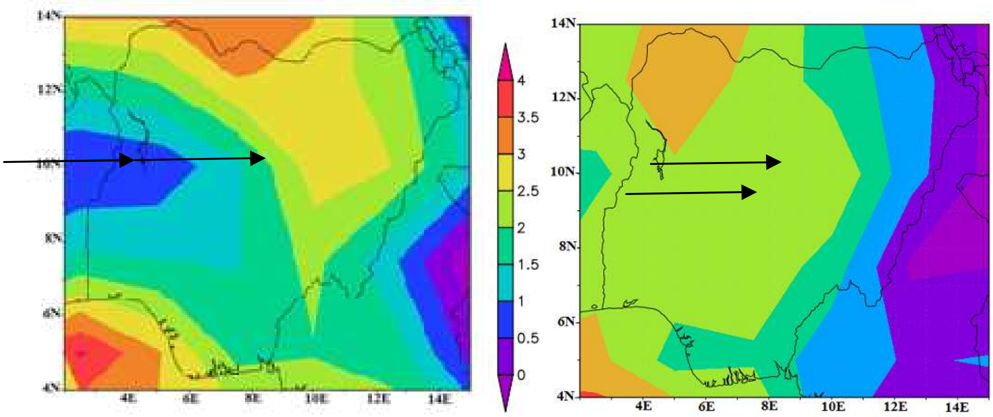
The exclusion of maximum ozone concentration to the west side of Nigeria while the prevalent meridional flow direction was eastward revealed that instead of the ozone concentration being carried along with the wind direction eastward, it seemed to be restricted in the trough of the meridional flow within longitudinal coverage of 2^{o}E - 6^{o}E. The blocking due to the meridional flow can be associated with temporal scale interactions which are seasonal and also of high-frequency components. According to Lejena¨s and Økland (1983), for a longitude to be blocked, the latitudinal average of the zonal wind flow must be easterly at that longitude. This was observed to be so in JJA for most of the seven years period studied (Figure 2).

The latitudinal average of the zonal wind flow of 2.0ms^{-1} in east direction was observed at the longitude 2^{o}E - 6^{o}E (Figure3). According to Pelly and Hoskin (2003), local blocking frequency on the annual mean for longitudes 10^{o}W to 40^{o}E was about 28%. This corroborates the idea of atmospheric blocking as playing significant role in ozone redistribution over Nigeria. From the observation made in this study, it can be concluded that the atmospheric blocking experienced over Nigeria is the Rex blocking (Figure 3).

In addition, according to Lupo and Smith (1994), part of the evidences of the presence of blocking includes a sharp change from predominant zonal flow to meridional flow and the continuity of this trend for a minimum of two weeks average. This was distinctly observed in this study as the zonal flow in JJA tended strongly after the meridional west-east pattern (Figure 3a). As noted earlier, wind flow that moves parallel to the lines of latitude are termed zonal wind and those that cross the latitude lines at sharp angles are termed meridional.

Average latitudinal variation of Ozone concentration over Nigeria

Further study of ozone variability with latitudes over Nigeria for the seven years (2002-2010) showed that maximum seasonal variation occurred at latitude 14^{o}N and minimum at latitude 4^{o}N (Figure 4). The seasonal amplitude between DJF and SON seasons were 25DU and 0DU at latitude 14^{o}N and 4^{o}N respectively. This showed that the ozone seasonal amplitude variability increased with latitudes.



(a) Zonal wind 2004 **(b) Meridional wind 2004**

Figure 3: Both the average zonal and meridional wind flows were significantly eastward in JJA

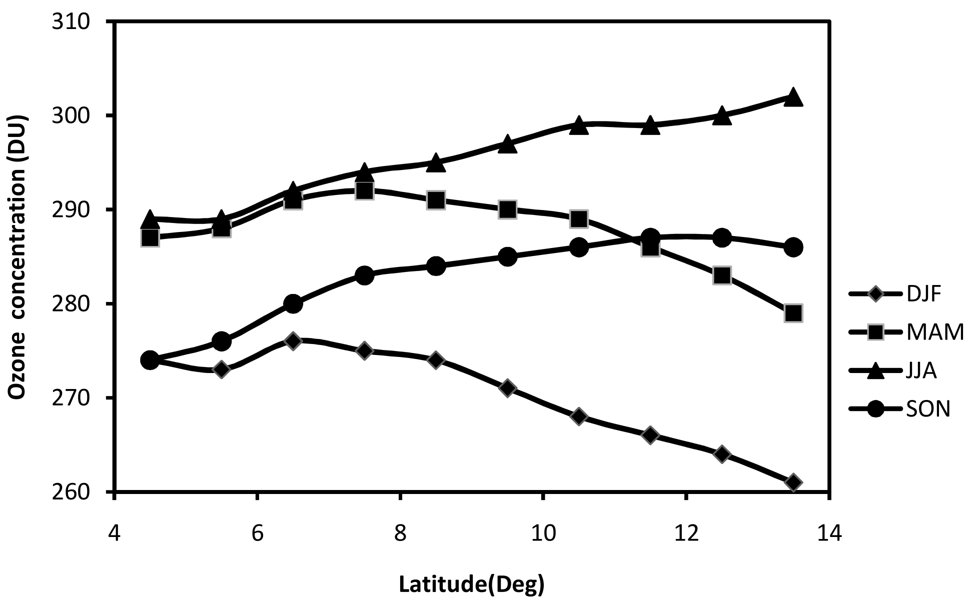


Fig. 4: Average seasonal variation of Ozone over Nigeria from 2002 to 2010

Similar trend was recorded for the amplitude variability between JJA and MAM seasons, with seasonal amplitude value of 2DU at latitude 4^oN to 7^oN and 22DU at 14^oN (Figure 4). Both the SON-DJF and JJA-MAM ozone amplitude variations recorded very strong positive correlation of 0.94 with each other.

Further analysis of the plot of the amplitude variability between JJA and MAM with latitudes, yielded an exponential curve with equation (Figure 5).

… (2)

While the amplitude variability for DJF- SON with latitudes yielded a linear trend with equation (Figure5).

$$= 2.93z - 13.8 \qquad \ldots (3)$$

β represents the ozone seasonal amplitude differences and z the latitude.

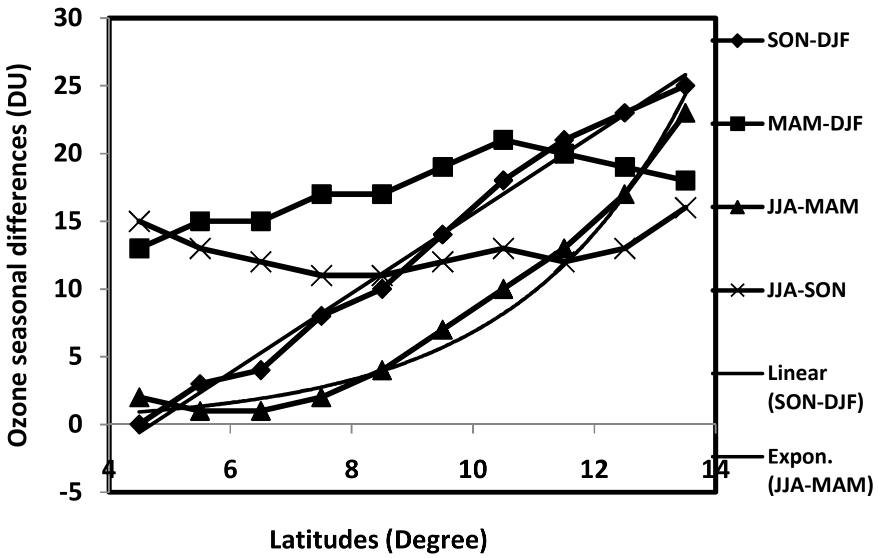


Fig. 5: Average Ozone seasonal differences over Nigeria from 2002 to 2010

The linear trend observed in SON-DJF seasons can be used to corroborate the strong positive correlation between the ozone distribution and the prevalent zonal wind flow direction during that period. This confirmed the influence of the zonal wind flow on ozone distribution pattern in SON-DJF seasons. On the other hand the exponential curve trend observed in JJA-MAM seasons can be an indicator to the presence of the suggested atmospheric blocking effect, which was proposed to be responsible for the maximum ozone concentration being restricted to the western side of the country instead of flowing eastward in the direction of the prevailing meridional wind for the season.

The trend in ozone seasonal amplitude variability with latitude for the MAM-DJF and JJA-SON were not as distinct as the first two discussed earlier. They also recorded maximum ranges of 8DU and 5DU which were much less than 25DU and 22DU recorded by SON-DJF and JJA-MAM respectively. An insignificant anti-correlation of -0.2 for the MAM-DJF and JJA-SON was also observed.

On general observations, minimum ozone concentration was recorded in the northern Nigeria during DJF and MAM seasons, while maximum concentration was recorded in the southern part of the country for the same seasons. In these seasons, average surface ozone concentration in the south exceeded those of the north by 21DU and 24DU respectively (Akinyemi and Omotosho, 2010).

CONCLUSION

A comparative study of ozone map for the DJF and JJA seasons, revealed a strong influence of the north-south zonal wind pattern on surface ozone redistribution in Nigeria especially in DJF season and the resultant influence of the east-west meridional wind on the JJA surface ozone redistribution in Nigeria. In DJF, maximum ozone concentration shifted with the prevailing zonal wind flow southward, while the JJA maximum ozone was observed to be restricted westward instead of flowing east in the direction of the prevailing meridional wind as a result of what can be termed the Rex blocking. Ozone seasonal amplitude variability was observed to increase with latitude for SON-DJF and JJA-MAM.

REFERENCES

[1] ML Akinyemi and TV Omotosho, *Canadian Journal of Pure and Applied Science* **2010**, 4(3), 1289-1292
[2] JF Austin, *Quart. J. Roy. Meteor. Soc.*, **1980**, 106**,** 327–350.
[3] D Barriopedro , M Antón, JA García, *Journal of Climate*, **2010**, 23:14, 3967-3983
[4] P Berrisford, BJ Hoskins, and E Tyrlis, *Journal of Atmospheric Science*, **2007**, 64: 2881-2898.
[5] J Habby, Atmospheric Blocking, **2012** http://www.theweatherprediction.com/habyhints/178/
[6] H Lejena¨s, and H Økland, *Tellus*, **1983**, 35A**,** 350–362.

[7] AR Lupo and PJ Smith, *Tellus,* **1994**, 47A, 439-456
[8] Z Meigen, U Itsushi, S Seiji, W Zifa, B Daewon, and A Hajime, *Geophysical Research Letters*, **2002**, 29, 11, 1545, 10.1029/2001GL014368.
[9] JL Pelly and BJ Hoskins, *Journal of the Atmospheric Science*, **2003**, 60, 743-755
[10] AA Scaife, T Wollings, J Knight, G Martin and T Hinton, *Journal of Climate*, **2010**, 23, 6143-6152.
[11] B Sultan, and S Janicot, *Journal of Climate*, **2003**, 16, 3007-3027.
[12] E Tyrlis and BJ Hoskins, *Journal of Atmospheric Sciences*, **2008**, 65, 1638-1652