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SIGNATURE OF ATMOSPHERIC DYNAMICS ON SURFACE OZONE VARIABILITY IN NIGERIA

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ABSTRACT

An examination of analysis revealed that surface ozone concentration over Nigeria varied with direction of the local trade winds, namely the Harmatan, and the Gulf of Guinea maritime trade winds. In DJF and MAM the period of the dry dusty Harmatan seasons, surface ozone concentration in the southern Nigeria exceeded that of the north by 21DU and 24DU respectively. Whereas in the JJA and SON, the rainfall season, reversal was the case, the surface ozone concentration in the northern Nigeria exceeded that of the south by 20DU and 15DU respectively. Maximum temporal variation gradient of 20DU was also observed in MAM season while the minimum of 11DU occurred in JJA which is the peak of the raining season.

Keywords: Surface ozone concentration, spatial gradient, temporal gradient.

INTRODUCTION

Air transportation is the major atmospheric constituents recognised as one of the key factors influencing the variability of total surface ozone concentration and distribution Tarasova *et al*. (2003), though photochemical processes is also a major contributor, it has been shown that the contributions of photochemical process and atmospheric dynamic process differs for different seasons except in strong localized convective currents when vertical atmospheric velocities are relevant. But majorly the horizontal wind flow dominates the atmospheric motion which makes its effect more pronounced on total ozone distribution. The most important of the horizontal flow in ozone variation and distribution is the horizontal frictionless flow (HFF) Tyson (1997). HFF is assumed to be the wind flow that is well above the boundary layer and much higher than all the uneven terrain within the lower troposphere.

If we let the components of the horizontal pressure P be expressed in forces in the natural coordinates as b_z *and* b_n

$$b_z = -\alpha \frac{dP}{dS} = -\alpha \frac{dP}{N} \sin\gamma \qquad (1)$$

$$b_n = -\alpha \frac{dP}{dn} = -\alpha \frac{dP}{dN} \cos\gamma \qquad (2)$$

Where n is the coordinate in the direction of the horizontal pressure gradient.

γ = the cross-isobar wind direction assumed positive towards lower pressure and negative toward higher pressure. Assuming rough approximation by taking the wind along the isobars, HFF can results in three kind of a geostrophic wind component depending on horizontal variation of pressure gradients namely;

(a) Diffluent isobar patterns (straight or curved)
(b) Parallel isobars patterns (straight or curved)
(c) Confluent isobar pattern (straight or curved)

These three major HFF trends were observed in this study. A strong correlation had been observed between the seasonal HFF of air masses, a key component of atmospheric dynamics and seasonality of total ozone distribution (Fusco and Salby, 1999; Kawa *et al*., 2005). Sharp increases in total ozone concentration during winter had been observed for a long time. According to them total ozone during a particular season reflects its net change during the preceding season. This makes it important to study seasonal peculiarity of total ozone distribution in a more detailed manner over Nigeria.

MATERIALS AND METHODS

Methodology and Data analysis

In order to make the influence of atmospheric signal on total surface Ozone distribution over Nigeria distinct and easy to identify, the Map of Nigeria which could be contained in a rectangular box of latitudes 4^o-14^oN and longitudes 2^o-15^o S, 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 are shown in figure 1(a-f) for the day and night pattern. The data used in this study were retrieved from AIRS satellite 2002 to 2009.

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RESULTS AND DISCUSSION

Intra-Seasonal Atmospheric Dynamic Signature in Total Ozone Distribution

The study of analysis revealed that surface ozone concentration over Nigeria varied with the local trade winds. Distinct trend and pattern observed from both day and night data (AIRS satellite 2002- 2009) revealed the strong influence of atmospheric dynamic on the surface ozone concentration over Nigeria. Ozone transportation was observed to follow various isobars patterns (Tables 1 and 2), direct singular flow occurred in DJF 2003-2005 (daytime), with flow direction from NN to SE, resulting in minimum concentration in the NN and maximum in the SE, wide spread flow occurred in DJF 2007-2009 (night) with flow direction from NW/NE to SW/SS; diffluent isobar pattern occurred DJF 2006-2009 (daytime) NN to SW/SE and confluent isobar pattern DJF 2006 (Night) only, NW/NE to SS.

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 (Tables 1 and 2). In these seasons, average surface ozone concentration in the south exceeded those of the north by 21DU and 24DU respectively. Relating this to wind flow transport, trace gases such as smoke flow in the direction of the wind pattern downstream. The wind flow pattern during the season DJF is from north to south. DJF is the peak of the dry season over the country, when the dry Harmattan wind blowing across the Sahara desert bring along with it the dust from the desert as it proceeds toward the Gulf of Guinea of the Atlantic Ocean. It can therefore be suggested that the same atmospheric dynamics responsible for the hazy and dusty Harmattan season

Table 1. Day-time Seasonal and Spatial Variability of Ozone Maxima and Minima.

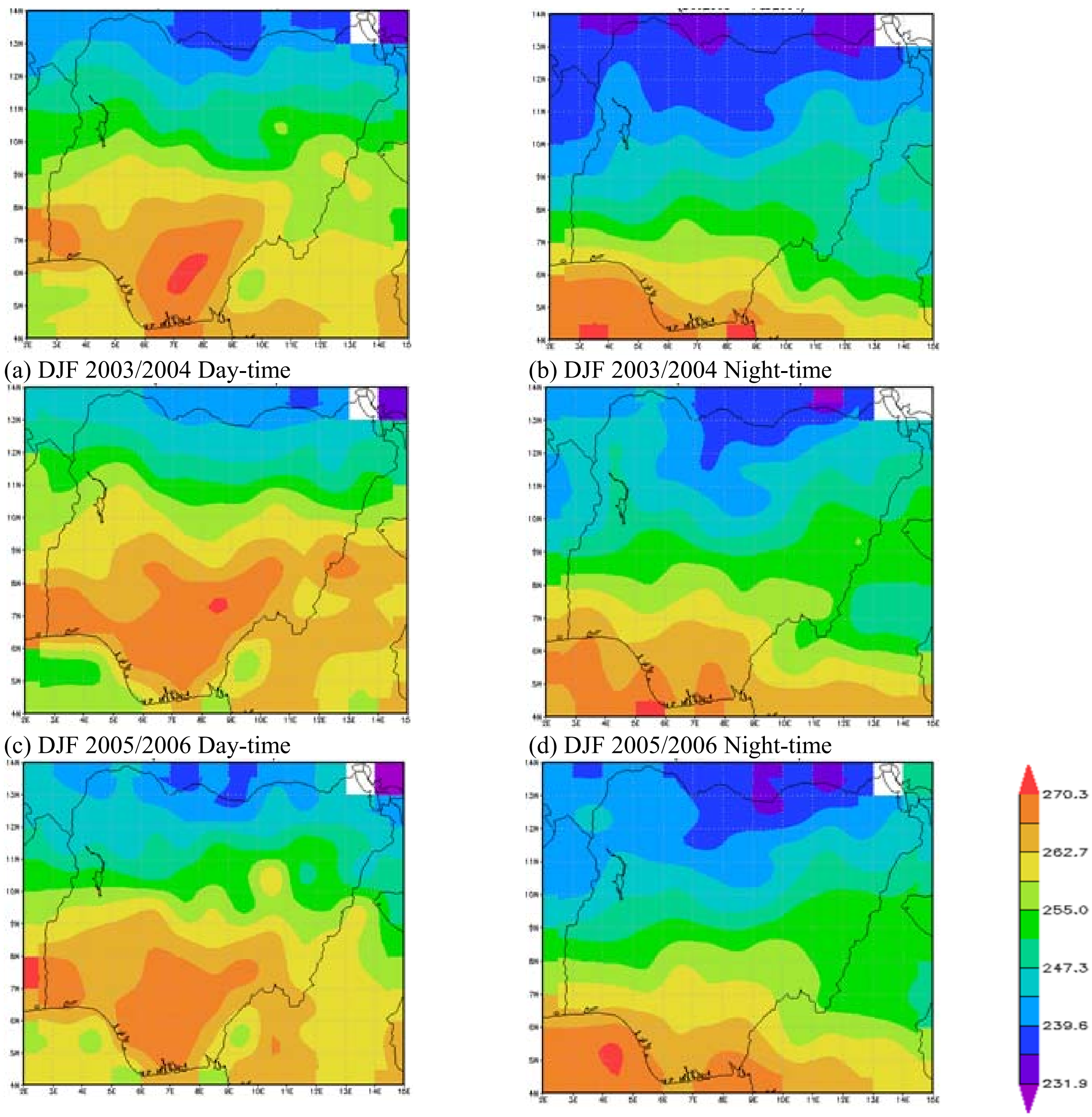
Year	Pattern	Seasonal Location of Maximum and Minimum Ozone Values (DU)			
		DJF	MAM	JJA	SON
y03	Max	SE (279)	NE (301)	NW (310)	NE-MB (288)
	Min	NN (261)	NW (279)	SS (281)	SS (274)
y04	Max	SE (281)	SS (297)	NW (315)	NE (284)
	Min	NN (253)	NN (270)	SS (301)	SS (269)
y05	Max	SE (286)	SE (294)	NW (295)	SW-MB (299)
	Min	NN (272)	NN (269)	SS (273)	SS (284)
y06	Max	SW-SE (278)	SE-SS (303)	NW (318)	NE (287)
	Min	NN (259)	NW (278)	SE (299)	SS (272)
y07	Max	SW-SS (276)	SE-SW (299)	NW (300)	SW (292)
	Min	NN (259)	NW (278)	SS (272)	SS (282)
y08	Max	SE-SS (282)	SS (309)	NC (311)	NW (293)
	Min	NN (253)	NW (282)	SS (299)	SS (270)
y09	Max	SW-SE (288)	SE (298)	NW (302)	SW (298)
	Min	NN (265)	NW (278)	SS (288)	SS (286)

Table 2. Night-time Seasonal and Spatial Variability of Ozone Maxima and Minima.

Year	Pattern	Seasonal Location of Maximum and Minimum Ozone Values (DU)			
		DJF	MAM	JJA	SON
y03	Max	SS (265)	MB (275)	NW (297)	NW-NE (275)
	Min	NE (243)	NW (263)	SE (268)	SE (266)
y04	Max	SW-SS (267)	SS (283)	NW (303)	NW-NE (272)
	Min	NW-NE (236)	NW (258)	SE (287)	SE (255)
y05	Max	SW-SS (273)	NE-NW (274)	NW (285)	NE (282)
	Min	NE (253)	SSE (257)	SE (260)	SE (265)
y06	Max	SS (264)	NE (281)	NW (307)	NW-NE (275)
	Min	NW-NE (239)	NC (265)	SE (289)	SE (256)
y07	Max	SW-SS (262)	SS (282)	NW (290)	NE (279)
	Min	NW-NE (238)	NE (265)	SE (262)	SS (264)
y08	Max	SW-SS (272)	SS (290)	SW (300)	NW (281)
	Min	NW-NE (239)	NC (268)	SE (287)	SS (255)
y09	Max	SW-SS (276)	SS-MB (279)	NW (295)	SW (282)
	Min	NW-NE (247)	NC (261)	SE (273)	MB (274)

carries along with it some ozone rich air from the northern part of Nigeria southward. This could be responsible for the consistent observation of minimum ozone concentration in the north and maximum in the southern part of the country in this period. This trend was observed in the seven years studies for the two seasons DJF and MAM. This confirmed distinctly the signatures of the atmospheric flow pattern on the ozone distribution in DJF and MAM in Nigeria (Fig.1a-f).

The next two seasons JJA and SON revealed clear reversal in the trend of ozone distribution over the country. In the two seasons, surface Ozone concentration in the north exceeded the south by 20DU and 15DU respectively. This observation is also in accordance with the prevailing atmospheric phenomenon over the country. The period coincided with the Tropical rainfall season. Rainfall over West Africa is controlled by advection of moisture from the Gulf of Guinea. Through atmospheric dynamics, the moisture rich air flow northward inland and brings the Inter-Tropical Convergence Zone (ITCZ) and the associated rainfall maxima to the farthest north which is the Sahel region (Cook,1999; Diedhiou *et al*., 1999; Sultan and Janicot, 2000). During these seasons JJA and SON maximum ozone concentration was consistently observed in the north except on two occasions when it migrated to the SW (Table 2).



(a) DJF 2003/2004 Day-time

(b) DJF 2003/2004 Night-time

(c) DJF 2005/2006 Day-time

(d) DJF 2005/2006 Night-time

(e) DJF 2008/2009 Day-time

(f) DJF 2008/2009 Night-time

Fig. 1. Temporal and spatial variability of ozone concentration in Nigeria in DJF season showing the day and night pattern

Spatial and Temporal Variability of Ozone maxima and minima in Nigeria

The transition in surface ozone pattern as dictated by the day and night atmospheric dynamics was also observed in the study. The major factor influencing variability in day and night is the change in temperature and solar activity. Maximum temporal variation gradient of 20DU was observed in MAM season while the minimum of 11DU occurred in JJA which is the peak of the raining season. DJF and SON both had temporal variation gradient of 13DU

In the day time ozone advection and transportation was observed to follow either the parallel straight isobar patterns or the diffluent isobar pattern. Example of the parallel isobar pattern flow was DJF (day) 2003, 2005, and DJF (night) 2007-2009, while DJF (day) 2006 to 2009 recorded diffluent isobar pattern flow (Table 1). In the diffluent isobar pattern the minimum ozone concentration was observed in the North-North (NN) while there was a spread out of the maximum from SW across to the SE. Night time maximum surface ozone concentration in the DJF season were observed to move farther south above the Gulf of Guinea, while the minimum covered much wider expanse as expected due to nil solar radiation.

In the seven years studied, the confluent isobar pattern flow was observed only in 2006 DJF (night) when minimum ozone concentration spread was observed from NW to NE but maximum was localized to SS, this revealed the convergence of atmospheric dynamics toward SS.

The exact locations of ozone maxima and minima over Nigeria in the day time were observed to differ slightly from those of the nights. DJF day time ozone minima for the seven years were centred in NN, while night minima for the same season DJF, were observed at either NW or NE for the seven years. Similarly for the JJA, the day time minimum was centred in the SS majorly whereas the night time minimum was in SE (Table2). The following average temporal variations between day and night surface ozone values were observed; DJF and SON recorded 13DU, while maximum of 20DU was in MAM, and minimum of 11DU in JJA. The JJA minimum temporal variation in surface ozone concentration coincided with the period of minimum temperature gradient observed in the peak rainfall season.

CONCLUSION

Result from the analysis showed the effect of the Harmattan wind in DJF and MAM blowing from north to south, and that of the Gulf of Guinea Maritime coastal wind blowing inland from south to north in JJA and SON on the distribution of surface ozone concentration in Nigeria. These two trade winds which are the main drivers of the dry and wet seasons in Nigeria have been associated with the spatial and temporal variability of surface ozone concentration in Nigeria from this study.

This study revealed a correlation of 1.0 between the prevalent atmospheric flow pattern across the country and spatial distribution of maximum and minimum ozone concentration per season in DJF (day and night) and in JJA (day and night) when all the minimum concentration was northward and maximum southward for DJF, while the reverse was the case in JJA when all the minimum concentration was located in the south and maximum in the north, with the exception of 2008 JJA (night) only. This confirmed the signature of atmospheric dynamics on spatial and temporal variation of ozone concentration over Nigeria.

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