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Spatial Distribution of Surface Water Vapour Density over Nigeria

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Abstract: The spatial distributions of Surface Water Vapour Density (SWVD) over Nigeria during the decadal period 1987-1996 were investigated using daily mean temperature and relative humidity data for seven stations grouped into three areas arranged in a South-North transect; the Southern, the Midland and the Sahelian (Northern) Zones. Results show that the variations in each zone are influenced by the prevailing atmospheric conditions which are largely dependent on the seasonal North-South movement of the Inter-Tropical Discontinuity (ITD) and to some extent, by the topographical features. Values of daily mean of surface water vapour density were found to be higher at midnight than at midday at both the Southern and the Northern Zones whereas at the Midland zone, the reverse is the study.

Key words: Spatial distributions, topographical features, midland zone

INTRODUCTION

Water vapour is the link between the surface and the atmosphere in the hydrological cycle. Almost all water vapour in the atmosphere originated at the surface of the Earth where water evaporates from the ocean and the continents owing to the sun's radiation and is transpired by plants and respired by animals into the atmosphere (AGU, 1995). Once in the atmosphere, water vapour can be transported horizontally and vertically by the three-dimensional circulation of the atmosphere and may condense to form liquid water or ice crystals in clouds. The cycle is completed when water returns to the Earth's surface in various forms of precipitation such as rain or snow. This cycle is closely tied to atmospheric circulation and temperature patterns.

Water vapour causes about two third of the natural green house effect of the Earth's atmosphere and is for this reason, the most important greenhouse gas (Gerding *et al*., 2002). Several climate models show that an increase in atmospheric humidity by 12-25% will have the same global mean radiative effect than doubling the CO_2 concentration (Harries, 1997). But in contrast to the homogeneous distribution of long-lived CO_2, water vapour distribution is highly variable in space and time. Apart from its direct radiative effect, water vapour acts indirectly by interacting with aerosols, clouds and precipitation (Hegg *et al*., 1996; Ramanathan *et al*., 2001). This indirect effect of surface cooling provides one of the largest uncertainties in the understanding of the radiative balance of the Earth's atmosphere (IPCC 2001).

This study describes the analysis of Surface Water Vapour Density (SWVD) over seven meteorological stations in Nigeria. These are Ikeja and Ibadan in the Southern zone, Ilorin and Minna, in the Midland zone, Kaduna, Zaria and Kano in the Northern zone of Nigeria. The aim is to find out for each zone, the diurnal and the spatial distribution of surface water vapour density.

Table 1: Table showing the data collection stations and their zones

City/station	Latitude (degrees)	Longitude (degrees)	Zonal Distribution
Ikeja	06° 33′N	03° 21′E	Southern zone
Ibadan	07° 26′N	03° 54′E	
Ilorin	08° 29′N	04° 35′E	Midland zone
Minna	09° 37′N	06° 32′E	
Kaduna	10° 36′N	07° 27′E	Northern zone
Zaria	11° 08′N	07° 41′E	
Kano	12° 03′N	08° 32′E	

Data and data processing: Daily temperature and relative humidity data for the period 1987-1996 were obtained for the seven stations shown in (Table 1). The data were obtained from the Department of Meteorological Services, Oshodi in Nigeria. These stations possess a long record of daily data and are evenly arranged in a south-north transect.

RESULTS AND DISCUSSION

The diurnal variations of SWVD over all the stations were observed (Fig. 1). The contrast in the distribution of SWVD over the stations is more evident during the dry season. This diurnal distribution shows a decrease from the coast inland which is particularly marked during this period. During the dry season period of November-March (represented here by December, January and March graphs: (Fig 1a-c) the Southern and the Northern zones

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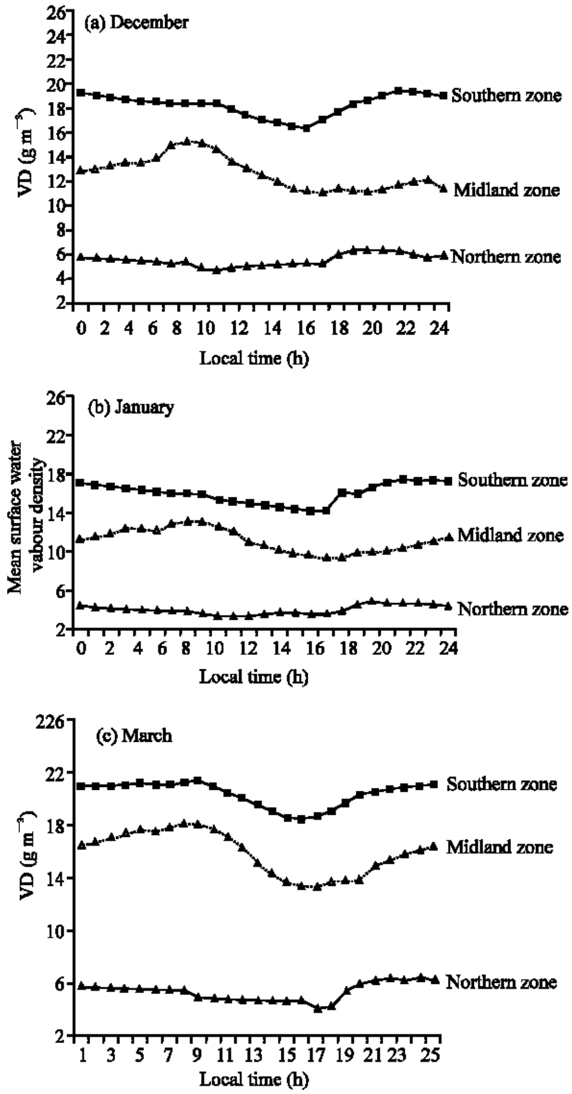

Fig. 1: Diurnal variation of surface water vapour densityduring the dry season in Nigeria

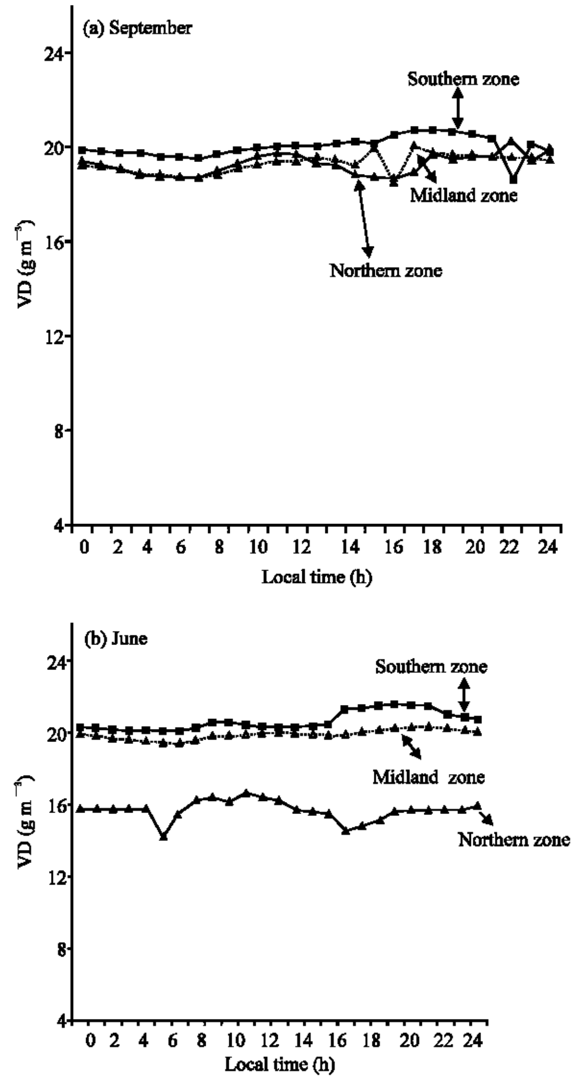

Fig. 2: Diurnal variation of surface water vapour densityduring the rainy season in Nigeria

experience a gentle decrease in SWVD from midnight to about midday. The Midland zone on the other hand, experiences an increase from midnight to around 9 h in the morning before dropping to the lowest values during the day. Minimum values are observed around 15 h in the afternoon in the Southern zone, while in the Midland and the Northern zones, the minimum occurred around 10 h in the morning. These observed differences in the features between the northern and the southern parts of Nigeria are in general agreement with the findings of Hamilton and Archbold (1945), Adedokun (1978) and Garbutt *et al.* (1981), which show that the precipitation climatologies of the northern and southern parts of Nigeria differ appreciably.

During the rainy season period of April-September (represented here by June and September graphs: (Fig. 2a and b), SWVD rises sharply around sunrise to the highest value during the day. This is uniformly maintained till night time when the values drop to their low night values at all the zones. The SWVD pattern during the dry season at the southern zone where the minimum occur around 15 h may be explained using the austauch phenomenon. During this time, the late morning local surface heating of the atmosphere causes the environmental lapse rate near the surface to exceed the dry adiabatic lapse rate causing conditional instability. Air then rises. The adiabatic cooling of the convective rising air allows it to remain warmer and less dense than the surrounding air so that it continues to rise through buoyancy. Water vapour is then transported upwards resulting in its depletion at the bottom level of the atmosphere. At both the Midland and Northern zones, the gentle increase observed during the day may be explained using the atmospheric thermodynamics of these two regions. During this period, the air that is prevalent in the regions is the tropical continental (cT) air. The cT air is dry and stable. Water vapour can only be lifted up where there is instability due to surface heating or mechanical turbulence or when there is ascent of air at a frontal zone or forced ascent of air over an orographic barrier (Roger and Richard, 1982). All these conditions are not likely to occur here because of the prevailing wind. The air is stable; this gives room for accumulation of water vapour at the bottom level of the atmosphere in these regions. The late afternoon peak observed at both the midland and northern zones are also observed in diurnal rainfall variations over the northern part of Nigeria (Griffiths, 1972) and over Niger (Shinoda *et al*., 1999). This reveals the influence of diurnal variation of temperature on humidity. Maximum diurnal temperature occurs in the late afternoon in the tropics leading to maximum conditional instability of the bundary layer due to surface heating.

During the rainy season, values of SWVD at all the stations are closer together, although, the decreasing trend from the coast inland is also discernible. The high values in SWVD observed during this period at all the stations (ranging between 21.72±1.22 at the coast and 16.05±2.23 in the sahel) are due to the fact that during this period, the ITD is farthest North and all parts of Nigeria are under the influence of the moist tropical maritime (mT) air. A gentle increase in SWVD values are observed between sunrise and sunset at all the stations during this period. This behaviour could be associated with the occurrence of adequate vapourization during the day to replace the uplifted water vapour by austauch most especially in the southern zone.

CONCLUSION

The spatial distribution of surface water vapour density over Nigeria has been investigated using daily mean surface data of temperance and relative humidity for ten years. Surface water vapour density over the southern part of Nigeria has been found to be considerably different from those in the midland and northern zones. Strong diurnal variations have been observed over all the regions during the dry season period. Water vapour in the atmosphere drops to the minimum value in the afternoon hours at the southern stations while minimum value in the midland and northern zones are found in the late morning hours. This occurrence in the southern stations has been likened to austauch phenomenon; where water vapour is transported upwards during the day because of local surface heating of the atmosphere by the ground.

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