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THE ATMOSPHERIC LAPSE RATES IN A TROPICAL REGIME: NIGERIA (LAT. 05° - 15 °N)

AUGUSTINE O. UDOGWU[1] AND CORNELIUS O. OLUWAFEMI[2]
Nigerian Meteorological Agency, Oshodi, Lagos, Nigeria
Department of Physics, Lagos State University, Ojo, Lagos, Nigeria

Abstract: Environmental and moist adiabatic lapse rates were computed for two Nigerian stations (Oshodi-Lagos; Lat 06° 32'N, Long 03° 23'E and Kano; Lat. 12° 03', Long. 08° 32') for the two seasonal regimes – the dry and the wet season. These preliminary results suggest that the lapse rates are higher in Kano than in Lagos (an average of 10% larger in the dry months and 23% in the wet months) for two atmospheric columns (surface to 500mb and 400-250mb), while the reverse was the case for the atmospheric slice 500-400mb where Lagos exceeds by about 8% in the wet months. The US model atmosphere appears applicable only in certain portions of the atmosphere: 700-600mb and 500-400mb in Lagos; 500-400mb in Kano dry weather.

INTRODUCTION

Model developments and analyses of momentum, energy and mass transfer in the earth's atmosphere (and particularly the planetary boundary layer) require contemporaneous inputs of certain meteorological data. In certain problems, e.g. the attenuation of microwave signals and pollution dispersal modelling, spatial and temporal variations of such meteorological parameters are needed. Such parameters include the height profiles of atmospheric lapse rate and the wind field in the main; others are relative humidity and pressure, all within the lower atmosphere (d•12km).

The global temperature profile of the earth's atmosphere reflects complex energy exchange phenomena between the radiative, convective and dynamical heating/cooling of the surface-atmosphere system (Hurrell and Meehl, 2006). It further indicates why temperature trends at the surface can be expected to be different from the trends in the atmosphere. Manifestations of these include changes in atmospheric circulation or modes of atmospheric behaviour (e.g El Nino-Southern Oscillation [ENSO]) which can produce different temperature trends at the surface and aloft; and these are in conjunction with the effects of the forcing factors – natural (volcanoes and solar) or human-induced (greenhouse gases, aerosols, ozone and land use) which can result in differing temperature trends at different altitudes.

Lapse rate studies tend to unfold the discrepancies between atmospheric warming near the surface vis-à-vis in the upper air; a phenomenon of importance in global climate modelling (Chun-Chen, et al 1996; May et al 1990; May and Mcmillin 1991).

A key feature of the studies highlighted above is that existing model atmospheres have their limitations. In particular, gross parameter values (as in the US Standard Atmosphere - NASA, NOAA, U.S. Air Force (1976) which was developed for the mid-latitudes (30 - 60° N and S) and which specify, among others, a sea-level temperature of 288K (i.e 15° C) and a mean lapse rate of 6.5K/km, are inappropriate for the class of applications first highlighted above for stations near the equator. An associated manifestation is that at low latitudes, lapse rates are essentially moist adiabatic (Stones and Carlson, 1979; Held, 1978) while in the mid-latitudes lapse rate can be approximated by the critical lapse rates for baroclinic adjustment.

Accordingly, height profiles of mean environmental and moist adiabatic lapse rates are computed in this study. This study utilizes the measured meteorological data from radio-sonde ascent of the primary meteorological parameters for the two locations in Nigeria: Lagos (Ikeja station), Lat 06° 35'N, Long 03° 20'E; and Kano, Lat. 12° 03'E. These data were obtained from the Nigerian Meteorological Agency for the period January, 1975 to December 1977, in approximate correspondence with the time domain when the US Standard Atmosphere (1976) became available.

DATA AND METHODOLOGY

From the radiosonde height profiles of temperature, the height profiles of moist adiabatic lapse rate, ã$_{m}$, and the environmental (temperature) lapse rate, ã, were computed using the method of Stone and Carlson (1979); Yang and Smith (1985). The temperature lapse rate, ã, is calculated by dividing the temperature difference between adjacent pressure levels by the corresponding difference of geopotential height. Surface geopotential heights are assumed to be the height of the station above sea level.

Moist adiabatic lapse rate ã$_{m}$, is calculated from the standard formula (Stone and Carlson, 1979)

$$\gamma_m = \gamma_d \frac{1 + \varepsilon L e_s/PRT}{1 + (\varepsilon L/C_p P)(de_s/dT)}$$

where P is the Pressure, R the gas constant, C$_{p}$ the specific heat at constant Pressure,

$$\frac{de_s de_s}{dT\ dT} = \frac{\varepsilon L e_s \varepsilon L e_s}{RT^2\ RT^2}$$

$$e_s = e_{s_0} exp\left[\frac{\varepsilon L}{R}\left(\frac{1}{T_0} - \frac{1}{T}\right)\right]$$

where ã$_{d}$ = 9.8K km^{-1}, µ=0.622, R=0.287 J g^{-1} K^{-1}, C$_{p}$=1.005 J g^{-1}K^{-1}, e$_{s0}$=6.11 mb, and T$_{0}$=273 K. L was computed from the expression for a perfect gas, linearized about T=T$_{0}$, i.e.,
L = 2510 -2.38(T – T$_{0}$) [J g^{-1}].

For purposes of gross (climate model) tropospheric values of the parameters, the tropospheric mass weighted rates,
$\bar{\gamma}_m\bar{\gamma}_m$, and $\bar{\gamma}\ \bar{\gamma}$, were computed:

$$\bar{\gamma}_{1,2}\bar{\gamma}_{1,2} = \frac{\Sigma\gamma_{p_j}\rho_{p_j}\Sigma\gamma_{p_j}\rho_{p_j}}{\Sigma\rho_{p_j} \quad \Sigma\rho_{p_j}},$$

where P = Pressure
ã$_{1}$ = ã, ã$_{2}$ = ã$_{m}$
and ã$_{Pj}$ = ã$_{j}$ for P$_{j}$
ñ$_{Pj}$ = density at pressure P$_{j}$

RESULTS AND ANALYSIS

Table 1 shows that the U.S. model mean lapse rate of 6.5 Kkm^{-1} is perhaps appropriate in Lagos within the atmospheric slice 700-600hpa in the dry months, January and February, with lapse rates of 6.14 Kkm^{-1} and 6.44 Kkm^{-1} respectively. Interestingly a similar value (6.25 Kkm^{-}1) to the January/February values for this slice is repeated in August (but not in July) which exhibits similar weather (rainfall) pattern to the dry months in Lagos. For the 500-400hpa slice of the same period, lapse rate values are 6.12 Kkm^{-1} and 6.34 Kkm^{-1} respectively. For Kano, values conforming to the Standard Atmosphere values are not consistent except for the 500-400hpa slice where values of 6.48 Kkm^{-1} and 6.54 Kkm^{-1} were observed in January and February respectively. Besides the atmospheric slices highlighted above, the others differ significantly for both Oshodi and Kano from the U.S. model value of 6.5Kkm^{-1}. So computations for Oshodi, Table 1; and Kano, Table 2, are in agreement with Rennick, (1977) that lapse rate indeed varies significantly, depending on height, latitude and season. For each seasonal regime between the surface and 500hpa; and 400 to 250hpa, the two lapse rates are larger in Kano than Lagos (an average of 10% larger in the dry months and 23% larger in the wet months); however, in the wet months the reverse was the case in the narrow upper air slice (500-400hpa) where it was larger in Lagos than in Kano by about 8%.

These results show a somewhat remarkable manifestation of the peculiarities of the surface (1000-800hpa) and tropospheric (850-300hpa) temperature trends recently reported by Alexeev (2005) for the time regimes 1958-2004. In the later regard, the 10-30^{o}N trend seems attractive with regards to the Kano results.

From the table of mass weighted tropospheric mean of “ and “$_{m}$, (table 3), it can be seen that only Oshodi with a value of mean environmental lapse rate of 6.45 Kkm^{-1} in the month of January can be approximated to the U.S. Standard Atmosphere value. The other values for the two stations show significant departures.

SUMMARY

Environmental and moist adiabatic lapse rates are larger in the dry months than in the wet months at two tropical stations (Oshodi-Lagos, Lat

Table 1: Computations of height profile of the lapse rate types for selected months for Lagos (Oshodi)

LAYER (hpa)	MN PRESS (hpa)	MEAN HEIGHT (m)	JAN		FEB		JUL		AUG	
			Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}
SFC-900	950	530	9.30	9.23	9.19	9.12	7.86	7.8	7.96	7.9
900-850	875	1275	4.38	4.35	5.17	5.13	5.2	5.16	4.37	4.34
850-800	825	1780	4.19	4.16	4.6	4.56	4.29	4.26	4.21	4.18
800-700	750	2600	5.93	5.88	5.94	5.89	4.67	4.63	3.94	3.91
700-600	650	3790	6.14	6.08	6.44	6.38	5.76	5.71	6.25	6.19
600-500	550	5145	5.66	5.6	5.09	5.04	5.12	5.07	5.22	5.17
500-400	450	6725	6.34	6.27	6.12	6.14	6.55	6.48	6.18	6.11
400-300	350	8630	7.36	7.27	7.45	7.36	7.25	7.17	7.73	7.64
300-250	275	10385	7.3	7.21	7.22	7.13	7.01	6.92	6.97	6.89

Table 2: Computations of height profile of the lapse rate types for selected months for Kano

LAYER MN (hpa)	PRESS (hpa)	MEAN HEIGHT (m)	JANUARY		FEBRUARY		JULY		AUGUST	
			Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}	Ã Kkm^{-1}	$\tilde{A}_m$ Kkm^{-1}
SFC-900	950	530	10.97	10.9	11.22	11.1	10.28	10.2	10.18	10.1
900-850	875	1275	1.63	1.62	6.71	6.66	5.45	5.41	5.84	5.79
850-800	825	1780	1.57	1.56	3.36	3.33	5.11	5.07	4.61	4.57
800-700	750	2600	6.46	6.4	7.21	7.15	6.74	6.68	6.39	6.34
700-600	650	3790	6.83	6.77	6.82	6.76	6.95	6.89	6.52	6.46
600-500	550	5145	5.4	5.35	5.33	5.28	5.66	5.6	5.74	5.68
500-400	450	6725	6.54	6.47	6.48	6.41	5.9	5.84	5.83	5.77
400-300	350	8630	7.68	7.59	7.61	7.52	7.31	7.22	7.35	7.26
300-250	275	10385	7.91	7.82	8.14	8.04	8.23	8.13	8.17	8.07

Table 3: Mass Weighted Tropospheric Mean (SFC to 250hpa) of Ã and $\tilde{A}_m$ for Oshodi and Kano

MONTH	OSHODI Mass Weighted Ã	OSHODI Mass Weighted $\tilde{A}_m$	KANO Mass Weighted Ã	KANO Mass Weighted $\tilde{A}_m$
JANUARY	6.45	6.38	7.91	7.82
FEBRUARY	7.22	7.13	8.14	8.04
JULY	7.02	6.92	8.23	8.13
AUGUST	6.97	6.89	8.17	8.07

Table 4 (below) summarizes the value of several parameters at each of the defined levels for the US standard atmosphere.

Geopotential Height (km)	Temperature(K)	Lapse RateK/km	Pressure(hpa)	Densitykg/m^3
0	288.15	- 6.5	1013.25	1.225
11	216.65	0.0	226.3206	0.364
20	216.65	+1.0	54.7489	8.803E-02
32	228.65	+2.8	8.6802	1.322E-02
47	270.65	0.0	1.1091	1.428E-03
51	270.65	- 2.8	0.6694	8.616E-04
71	214.65	- 2.0	0.0396	6.421E-05
84.852	186.95	——	0.0037	6.958E-06

06° 32'N, Long 03° 23'E; Kano; Lat. 12° 03', Long. 08° 32') studied. The US model atmosphere appears appropriate within 700-600hpa and 500-400hpa ranges for Lagos; while the surface (1000-700hpa) and upper (400-250hpa) regions significantly differ from the US model. But at Kano, the US model seems justifiable in the dry months within 500-400hpa, while the model does not fit the 1000-500hpa and 400-200hpa regimes.

Overall, the magnitudes of the lapse rates are about 10% larger in Kano than in Oshodi (Lagos) in the dry months and 25% larger in the wet months; except for the narrow upper air 500-400hpa in the wet months where the reverse is the case.

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