Available online at www.worldscientificnews.com

World Scientific News

WSN 49(2) (2016) 295-306 EISSN 2392-2192

The Changes in Temperature and Relative Humidity in Lagos State, Nigeria

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ABSTRACT

The variability in the temperature and Relative Humidity (RH) observed within Lagos State, a coastal region in Nigeria, is investigated using data from Nigeria Meteorological Agency (NIMET) for 1980 to 2010. The results reveal an annual mean value of 27.20°C and 83.01% for the temperature and RH respectively and an increasing trend in RH over the study period while such rising trend in the mean temperature is reversed from 2005 to 2010. The findings show an inverse relationship between the temperature and RH while it further indicates that low temperature is associated with increased rainfall under the accompanying cloudy condition and vice versa. These observations are supported by the strong correlation coefficients between the RH and the rainfall (0.72) and that between the RH and the temperature (-0.95) while -0.59 is obtained between the rainfall and the corresponding temperature. The correlations show that the impacts of the precipitation on RH are stronger than the effects it has on the temperature while both temperature and RH strongly depends on each other. Hence, under a future global warming, extremely warm atmospheric condition characterized by high RH in the coastal region could cause heat stroke, discomfort and health problems among the inhabitants. However, the area becomes conducive and attractive to tourists under moderate RH and good temperature.

***Keywords*:** Temperature; Relative Humidity; Rainfall; Global Warming; Heat Stroke; Lagos

1. INTRODUCTION

Instrumental records indicate that the surface temperatures have risen globally with about 0.85 °C over 1880-2012 [1], but the trends are different among regions and seasons due to the varied types of land surfaces [2]. Also, increasing rate of the warming has been reported over the last 25 years during which 11 of the 12 warmest years on record occurred in the past 12 years [2]. The signs of the warming include rising ocean temperatures, increasing sea levels, decreasing sea ice in the arctic, glaciers melting and reduction in snow cover in the Northern Hemisphere [2]. Similarly, the relative humidity (RH) which refers to the amount of water vapour in the air, expressed as a percentage of the maximum amount that the air could hold at the given temperature, is also changing. The RH range of about 30-70% is healthy for humans while very high or low RH may cause health problems [3] and also affect plants' transpiration. Similarly, heat wave from high surface temperature might cause discomfort or heat stroke with the severe cases occurring above 40 °C [4]. According to Meehl et al. 2004 [5], heat wave is a long time of strong hot weather and high RH while T. Burrows put it as period of three or more days of temperature above 32.2 °C [6].

Under global warming, a hot atmosphere with high RH will lead to slow cooling of human body because the rate of evaporation of heat from the skin will be reduced, making human body to feel hotter than the actual surface temperature. This raises the internal heat which could disrupt the functioning of enzymes that control the biochemical activities of our body, causing heat stroke and rise in mortality during heat waves [7] while the effects of low RH include dry skin, sore eyes and dry nasal passages [8]. For example, about 5000 people died from 1980 heat waves in United States of America [9] with properties worth $15-19 billion destroyed [10]. Also, over 70,000 people lost their lives during the extreme 2003 European heat wave [11] while drought and fires ruined farmlands causing damages worth €1 billion [12]. In Africa, increase in temperature could enhance the vectorial capacity of anopheles mosquitoes to spread malaria and other diseases [13]. Ailments like measles, meningitis, heat rashes, dehydration and respiratory problems have been linked to severe heat and high RH while eleven heat related death with loss worth $269 million have also been seen in South Africa [14]. Also, droughts, forest fires and low agricultural yields will be persistent while coastal regions like Lagos State, Nigeria might be affected by flood as sea level rises. Hence, this study will examine the changes in the temperature and RH in Lagos State so as to understand their impacts on the society.

2. THE STUDY AREA AND DESCRIPTION OF DATA

The study region is Lagos State, Nigeria, a coastal area with capital at Ikeja. The state is located in the south-western part of Nigeria within approximate co-ordinate of 3.40°E and 6.45°N [15]. The state has common boundary with Ogun State, Republic of Benin and terminates in Atlantic Ocean in the south; making it a coastal city where several long and attractive sandy beaches (like Bar Beach) are located (Fig. 1). The state has twenty local government areas in which sixteen are within the metropolitan Lagos while the land coverage is about 3,475 km^2 [16]; however, this size is reduced by Lagoons, rivers, creeks and swamps. The Lagos city is the commercial centre of Nigeria where several businesses are found. For example, the busy Murtala International Airport in Ikeja and head offices of many airlines are within and around the airport while the city and the state also accommodates headquarters of many companies. The region is the home of several expatriates and a tourist destination due to the recent re-modernization of the place and its famous music scenes [17], movie industries, colourful carnivals and lots more. As a coastal city, rising temperature and increase in sea level could lead to disappearance of the beaches under erosion and flooding while the area might also be damaged by storm. These may cause homelessness, death and destruction of the recreational activities along the coastline, leading to job loss, low income for the community and hence poor standard of living.

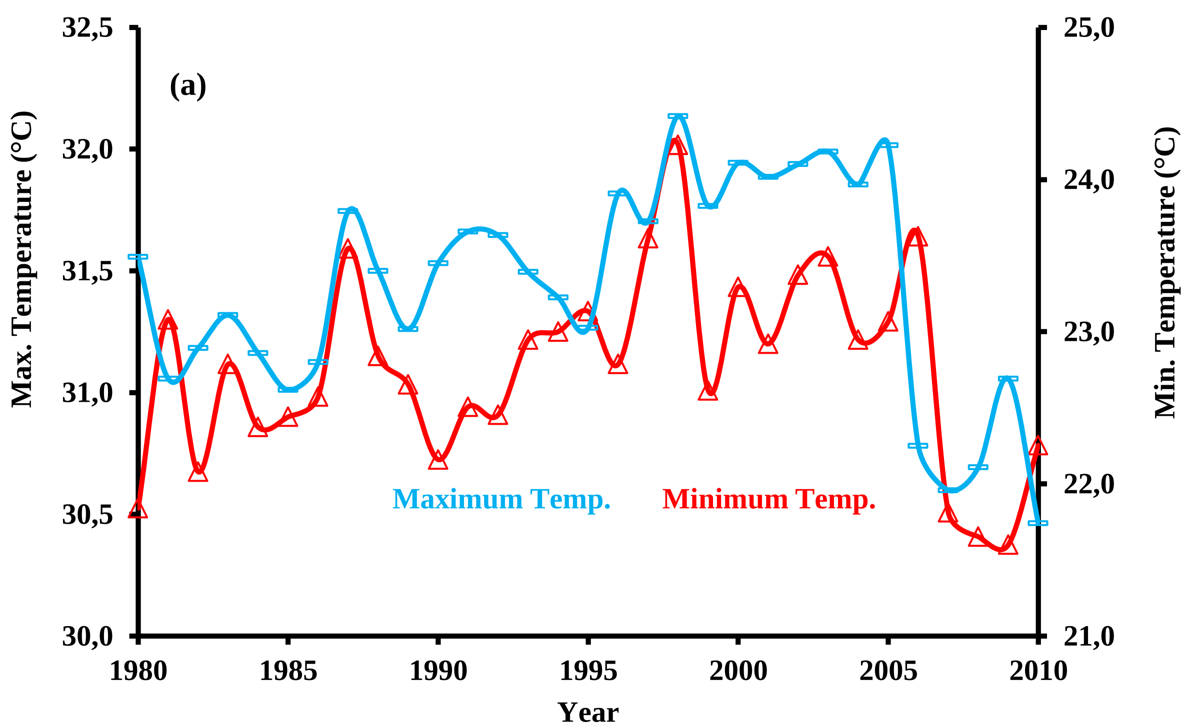
Figure 1. Map of Lagos State with Ikeja (red star) as the capital (Adapted from: NG, 2015 [16]). Inserted is the map of Nigeria that shows the position of Lagos State with red arrow.

The state is essentially a Yoruba-speaking environment where the people are mainly farmers; however, it is a meeting point of both Nigerians and many foreigners. The seasons in the area is broadly divided into dry and wet under the influence of Intertropical Convergence Zone, ITCZ (where easterly trade winds originating from northern and southern hemispheres converge) that migrates along with the position of strongest rainfall [18]. The report further shows that the dry season is around November-March while the rainfall is high in the presence of the ITCZ between April-October. The region is usually hot with high RH throughout the year due to its proximity to the Atlantic Ocean. The Lagos State is choosing for this study since it is one of the most economically important towns in Africa and it has the largest urban area where the leading port in Nigeria and one of the largest and busiest in Africa is located [18,19]. For instance, its population of about 21 million people makes it the biggest city in Africa [20] and one of those with the largest inhabitants and fastest growing population in the World [21-26]. Since temperature and RH outside the accustomed range pose human health threats [27], the aim of this study is to investigate the changes in the temperature and RH in Lagos State so as to understand their physical and health impacts. The study is in accordance with the similar work reported by Vikas et al. 2015 [28] over the coastal city of Surat, India. The 1980-2010 data used in the investigation are the temperature (°C), RH (%) and rainfall (mm) measured by the Nigeria Meteorological Agency (NIMET) over Ikeja, the capital of Lagos State. The observations are used as the approximate values for the entire Lagos State since data representing the whole area are not available for this report.

3. THE RESULTS

A. Temperature Variability

The variations in the temperature are shown in Figure 2 (a, b) where the maximum values are in red colours and the light-blue stands for the minimum temperature while the brown shows the mean values averaged over the 1980-2010 period. The maximum temperature revealed several spikes which have the highest value of 32.02 °C in 1998 and an overall increasing trend over the years (Fig. 2a). The general results show an increasing trend over the time interval with the exception of 2007 during which the maximum temperature dropped sharply to the least value of 30.38 °C in 2009 before rising. An investigation with the minimum temperature reveals spikes which are in close agreements with the patterns observed in the maximum temperature but with reduced magnitudes. Also, there is a general increasing trend of the minimum temperature until 2005 where strong decrease to the lowest value of 21.74 °C in 2010 is seen with the exception of a small peak of 22.69 °C in 2009 while the overall peak value of 24.42 °C is seen in 1998.



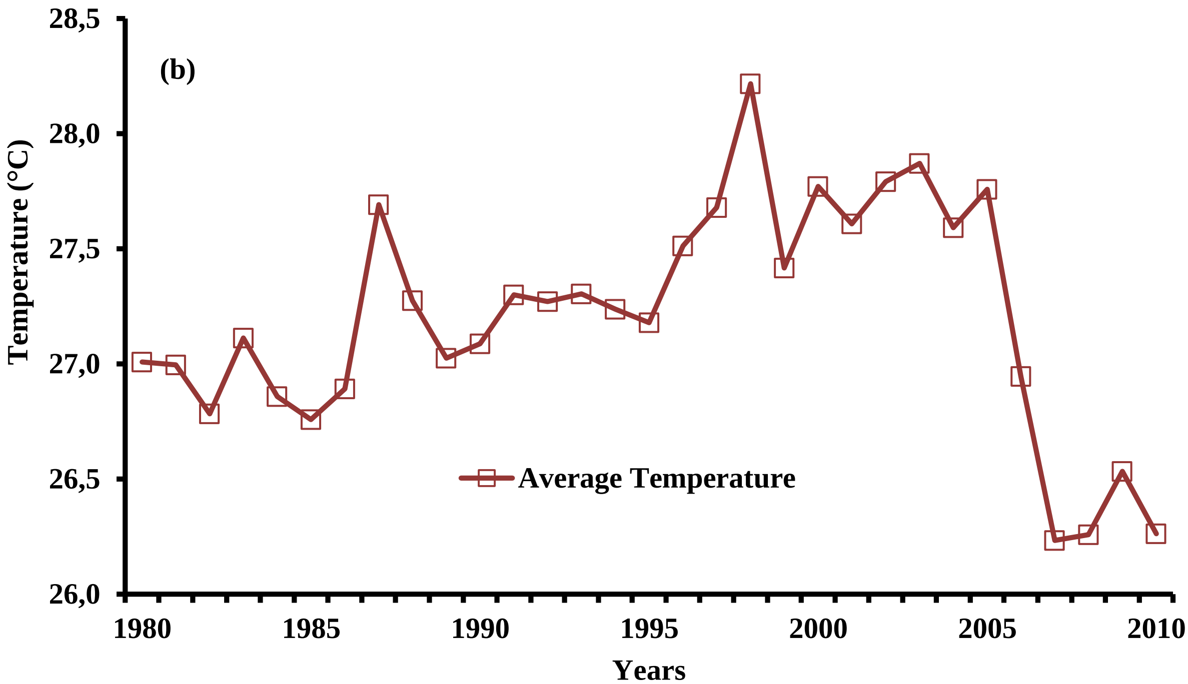


Figure 2. The plots of years against (a) maximum (°C) and minimum (°C) temperatures, and that of (b) years against the average temperature (°C).

Further analysis using the average temperature [$\frac{1}{2}$(maximum temperature + minimum temperature)] reveals an increasing trend till 2005 after which it reduced drastically (Fig. 2b). The small peak (27.11 °C) in 1983 later rises to a high temperature of 27.69 °C in 1987, the rising trend reaches the maximum value of 28.22°C in 1998. However the temperature falls again in 1999 to a low magnitude of 27.42 °C while it rises until 2003 before showing a general reduction with a strong attenuation from 2005 to the least value of 26.26 °C in 2010. Thus, the observed continuous increase in the maximum and minimum temperatures might make the region too hot for normal life; however, a sustained recent decreasing trend in the temperatures to conducive magnitude in both cases, could reverse the situation by making the region more habitable.

B. Variations in the Relative Humidity (RH)

Investigation using the RH suggests that a high value of 85.42% is recorded in 1980, which later decline to the least value (79.08%) in 1983 (Fig. 3). This is followed by rising peaks from 1985 to 1987 through 1991 to reach the first maximum value of 85.58% in 1996; these peaks are interrupted with dips which are strong in 1989 and in 1993 during which the value is very low (79.25%). The RH descends after 1996 to attain a slightly low magnitude of 80.83% in 2000 after which the intensities appreciate and maintain an overall increasing trend till 2010 where the highest peak of 86.50% is recorded in the study area (Fig. 3).

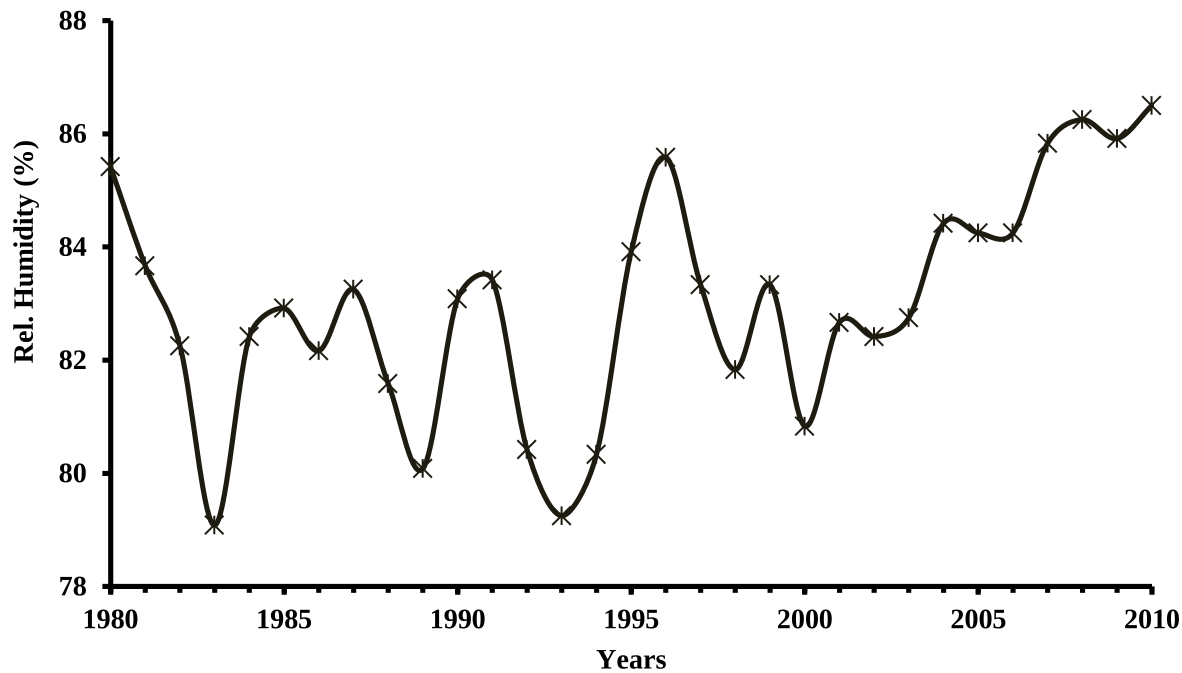


Figure 3. The graph of year against Relative Humidity (%).

C. Annual Variations in the Temperature and RH

Further investigation with the annual mean temperature reveals that the magnitude is highest in February-March while the least value is recorded in August before rising to a lower peak in November-December (Fig. 4a). The overall annual mean temperature is 27.20°C while the maximum magnitude of 28.87°C recorded in February is about 3.54°C higher than the low value observed in August. The temperature of the study area is usually high between February-April of each year during which the intensities are sometimes 34°C-35.3°C; the highest magnitude of 35.3°C is seen in February, 1998 (not shown). In the case of RH, the annual mean intensity is 83.01% while the monthly mean values are low between January and March with magnitude above 70% (Fig. 4b); a limit already considered to be unhealthy for human [3]. For instance, the monthly intensity rises from the least magnitude of 78.06% in February to the peak (87.29%) in July after which it shows an overall reduction that reaches 82.13% in December (Fig. 4b). The analysis suggests that an increase (decrease) in the temperature generally leads to decrease (increase) in the RH (Fig. 4a, b).

The investigation indicates that the variations in RH and temperature patterns might be explained by annual changes in the magnitude of rainfall over the study region. As an example, a quick look at the rainfall signals shows that both rainfall and the RH follow similar pattern (Fig. 4b). The rainfall values are usually low between November and February after which it rises to the maximum of 285.82mm in June and a lower peak of 188.2mm in September; both are interrupted by a reduced value (113.4mm) in August (Fig. 4b). Just like in the case of RH, the overall rainfall pattern reveals an increasing trend over the year from 1980 to 2010 (not shown).

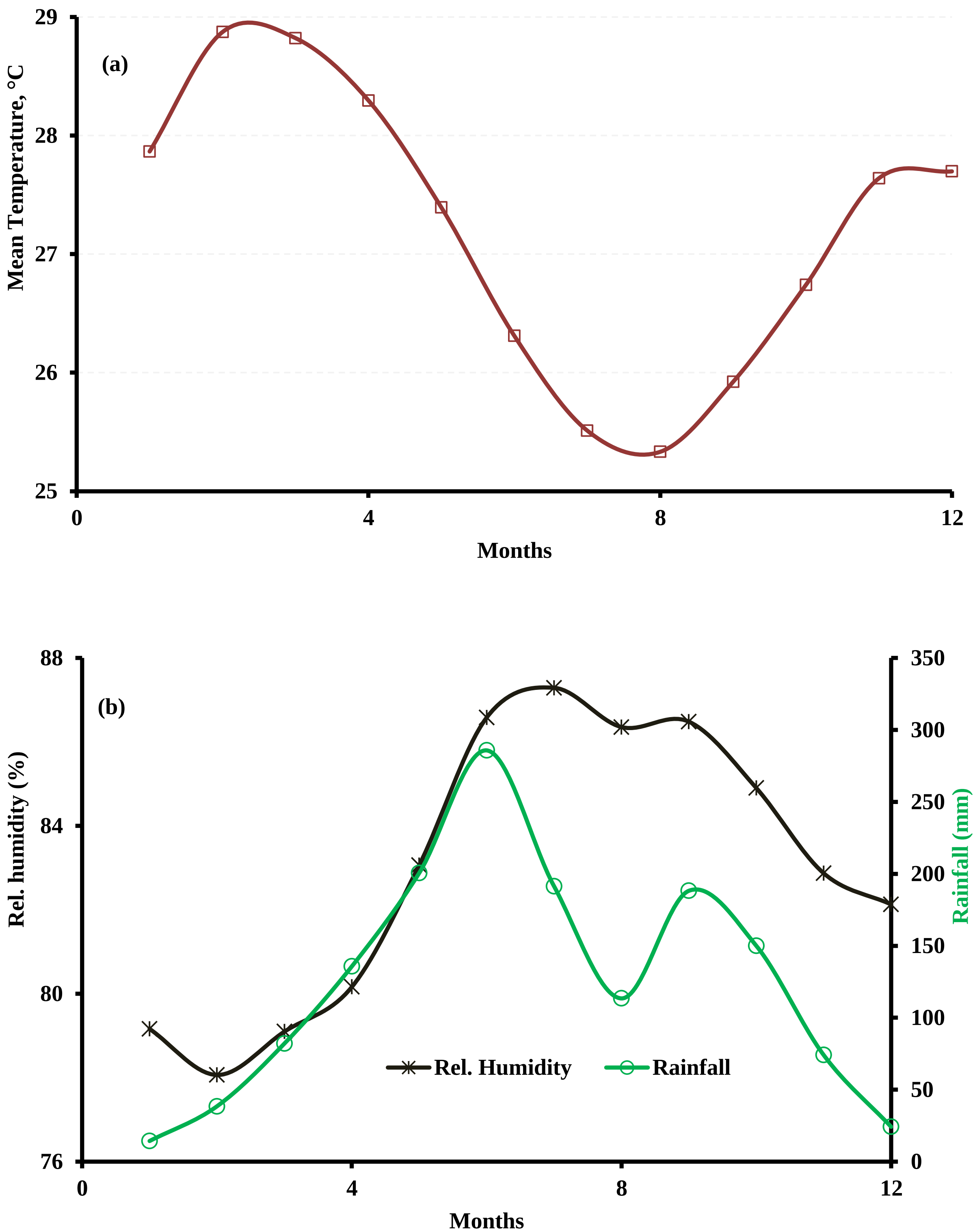


Figure 4. The graphs of monthly variations in (a) temperature and (b) RH and rainfall.

These variations might be explained by the north-south migration of the Sun and the shift in the ITCZ position which is such that the low rainfall around November to February is associated with the movement of the ITCZ to the far south, probably to location outside the boundary of Lagos State. Similarly, the rainfall is strong in March-July as the ITCZ moves northward into the study region while the low intensity in August is due to the movement of the ITCZ to the northern-most position over Nigeria while the secondary peak in September-October coincides with the return of the ITCZ to the study area [18].

In general, the magnitude of the temperature is high between November to February during which rainfall has considerably reduced in the area; the temperature is however damped later in the year under the cloudy condition which comes with rainy period. Also, the fluctuations in the temperature and the RH are checked using their anomalies which correspond to the departure in their monthly mean values from their long-term mean averaged over 1980-2010.

The anomalies clearly reveal an out-of-phase relationship between the intensities of the temperature and the corresponding RH (Fig. 5). The results show that the intensity of the temperature (RH) is usually high (low) in March-April while it reverses and lead to the lowest magnitude in August and the highest value in July for the temperature and RH respectively. Previous studies by [18] have shown that the temperature of the region is mainly controlled by changes in insolation forcing and further influenced by the variations in rainfall patterns.

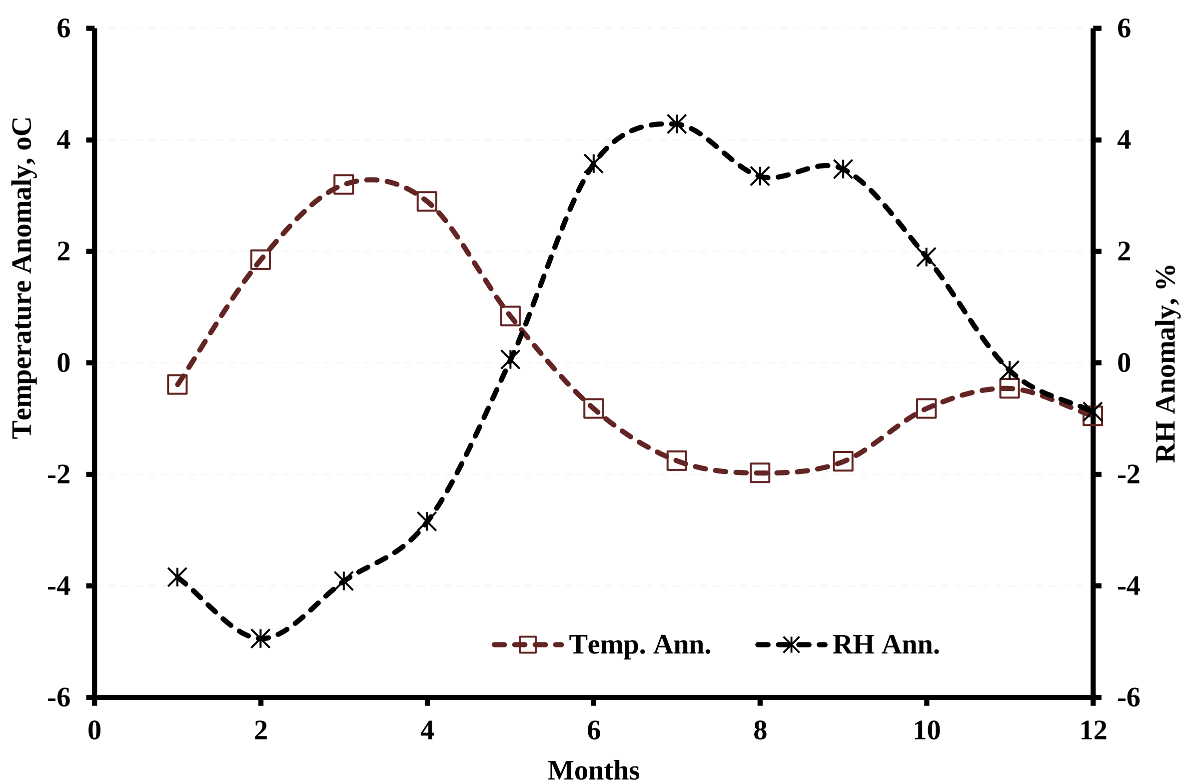


Figure 5. The plots of annual cycle of the temperature anomalies and the mean RH. The colour codes are similar to those presented in Figure 4 with the exception that broken lines are used.

This is such that the temperature intensifies in Ikeja, Lagos as the Sun moves northward across the equator around March while there is simultaneous reduction in the RH as the air warms. However, the temperature (RH) lowers (increases) as the Sun moves further northward, reaching the minimum (maximum) value around August when the Sun is at the northernmost position over Nigeria [18]. The warming rises again as the Sun returns southward in September while the corresponding RH reduces: however, the average value of the RH is usually high throughout the year due to the presence of the Atlantic Ocean.

4. SUMMARY AND CONCLUSION

The variability in the temperature and RH observed over Lagos State, a coastal region in Nigeria, is investigated using NIMET (1980-2010) data. According to the results, the RH reveals an increasing trend over time while the similar rising trend in the mean temperature reverses in 2005. Also, the results indicate that the variations in the temperature and RH are influenced by changes in the rainfall patterns. The monthly mean temperature (rainfall) is usually high (low) between November to March (Fig. 4a) while the rainfall and the corresponding RH are high between June to September of each year with the exception of a slight (strong) reduction in RH (rainfall) during August (Fig. 4b).

The annual mean temperature of 27.20 °C and RH of 83.01% are recorded in the coastal region; however, some exceptionally hot days (34-35.3 °C) with high RH are observed between February-April (not shown). These observations are supported by the strong correlation of 0.72 between the monthly mean rainfall and the RH and the high value between the temperature and the corresponding RH which stood at -0.95 while the correlation is -0.59 between the rainfall and temperature. Thus suggesting that a high (low) temperature comes with low (high) RH while it further indicates that high temperature is accompanying by reduction in the rainfall and vice versa; however, the impact of the precipitation on RH is stronger than the effects it has on the temperature.

This study suggests that unsafe times of high temperature, period of increased RH and enhanced rainfall are likely to happen more in the coastal region under a future global warming condition. Such periods of high RH coinciding with warm atmospheric condition could result in heat stress in the coastal area where RH is usually high throughout the year. In agreement with these results, a media report published in early March, 2016 confirms the existence of heat wave across Nigeria with strong magnitude in Lagos where the temperature is currently higher than the 32.2 °C threshold, causing discomforts and raising the energy consumptions of the people [14]. According to the report, experts linked the warming to February-April that are usually hot and also serve as the transitional period between dry and rainy seasons in Nigeria and within the study area while putting in mind the era of global warming. The precautionary steps suggested include taking cold baths, drink enough water to replace the lost body fluids, stay in a well ventilated room and avoid long stay in the sun while kids and pets must not be left unattended to in a closed car. However, the heat waves and the discomfort it brings will reduce and life will become better in the area under moderate RH and conducive temperature during the raining period, bringing benefits to the people through enhanced fishing, tourism with increased availability of jobs and lots more.

Similarly, improved weather forecasts, warnings and good infrastructures will support the aviation industry in the region and also assist the community to cope under such future climate related problems. This is important since aircraft's performances are lowered owing to weak acceleration and hence longer runways and reduced climb gradient during takeoff due to low air density when temperature and RH are very high; however, increase in the weight of aircraft's wing when ice formed on it in a cold humid air is also dangerous [29]. Hence, the coping strategies in the study area might include improved drainage systems and careful erection of solid barriers at appropriate places along the coast to help in preventing destruction of the coast by floods and washed away sands should be replenished. While proper education of the inhabitants of the area on coping strategies are important, new buildings could also be designed with their internal climates modified so as to make them conducive for heat waves [30,31] or climate related hazards. Air-conditioned rooms, good medical equipments and reliable transport systems should be provided at affordable rates while government must create awareness about the related diseases and be financially ready to combat future climate related problems.

Acknowledgments

The authors wish to express their profound appreciation to the National Metrological Agency [NIMET] of Nigeria for making the quality data available.

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(Received 15 May 2016; accepted 05 June 2016)