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RAINFALL VARIABILITY AND THE RECENT CLIMATE EXTREMES IN NIGERIA

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Abstract: Recently, large and extended weather and climate extremes were recorded in different parts of the country, causing significant socio-economic impacts. Weather patterns affecting the country are driven by the northward and southward movement of the Inter-Tropical Discontinuity (ITD) as well as developments within the pressure systems created by the two distinct wind regimes north and south of the ITD. The climate of Nigeria, in particular, the Sahel zone, is characterized by multiyear persistence of anomalously wet and dry conditions.

Climatic and statistical analyses were employed to investigate two extreme events, flood and droughts, in the last four decades. The results showed variations in rainfall across the various climatic zones in the country. In particular, flood and drought episodes were identified. Observation showed that the savannah and semi-arid areas of Nigeria have suffered from inter-annual to seasonal climatic variabilities and there have been droughts and effective desertification processes, particularly since the 1960s. It was further noted that these variations in rainfall usually showed completely different patterns within the same climatic zones and that stations located relatively close to one another exhibited different patterns of rainfall.

Analysis of rainfall anomalies and maximum temperature departures in the last five years brought out some clues to the spate of recent and wide spread of flooding across the country. Therefore, the recent incursion of floods, in parts of the country seriously threatened lives and property, important business centres and agricultural farm lands and was a classical example of the danger that could be posed by weather and climate extremes.

INTRODUCTION

There have been a number of studies on the space –time characteristics of various meteorological parameters. Research into rainfall variations in West Africa and Nigeria in particular has not been carried out on macro-scales alone, but on the meso and micro-scales. Examples of such studies include those of Olaniran (1986) and Omotosho, (1987). For example, Olaniran (1986) examined the distributional pattern of rainfall occurrence in storms of different sizes in Nigeria and related the patterns obtained to three factors, viz: Inter-Tropical Discontinuity (ITD), disturbance lines and altitude. (Ojo et al, 2000), also noted that the distribution of annual rainfall in West Africa and Nigeria in particular depicts a strong latitudinal variation and an altitudinal control. Some scientists noted that the southern extent of the Sahara desert is now extending to the fringes of the extreme northern part of the country (Udoeka, E. D et al, 1998). The authors further confirmed that, there is a steady rise in evaporation and a steady decrease in rainfall over the Sahel zone of the country.

A number of studies have also been conducted into the relevance of the ITD model in explaining rainfall fluctuations in sub-Saharan West Africa. For example, Adejuwon (1991) utilized a combination of statistical techniques including cross-correlation, auto-correlation and spectral analyses on rainfall series within the same climatic belt south of latitude 8^{o}N to examine the relevance of the ITD as a factor in explaining rainfall range. The study showed that significant correlation coefficients occur at lag 0 and 1 between pairs of stations located in the same climatic belt. He noted that while the results of the analyses tend to agree with the hypothesis that rainfall is a function of the location of the ITD, the cyclical fluctuations which are of shorter periodicities obtained from the analyses tend to suggest the influence of other rainfall mechanisms, including the El Nino-Southern Oscilations (ENSO). The main objective of this paper is to identify the spatial and temporal variations which include areas with long-term rainfall trends and inter-annual persistence. The paper will in addition examine the rainfall anomalies and maximum temperature departures from their long-term values in the last

five years, which indeed have given clues to the spate of recent and wide spread of flooding across the country.

Devastating climate and weather related events recorded in recent years have captured the interest of the general public, governments, and media, among others. Although difficult to attribute to climate variability and change, the devastating impacts of recent natural disasters, affected a significant part of the country. In 2008, there were diverse extreme weather events such as hail around Jos in June, flooding in some parts of the coastal states such as Lagos, Bayelsa and including Osun states etc. During the 2009 rainy season, Taraba, Gombe, Kaduna, Sokoto, Niger, Adamawa, FCT, Lagos, Bayelsa states were among few states affected by floods. Sokoto, Kebbi, Katsina and Jigawa floods of September 2010, Ogun flood of October 2010, Lagos flood of July 10, 2011, Ibadan flood of August 26, 2011 etc, have demonstrated that many urban areas in the country are highly vulnerable to climate variability and change. It was reported that floods in these cities swept away homes, vehicles, persons, roads, buildings and farmlands (Sunday Punch, July 17th, 2011, Punch Newspapers, September 15th and 18th, 2010). The September 2012 overflow of the River Niger and Benue in Nigeria, was a monumental disaster as virtually all states were affected in the aftermath of the flooding that resulted. There were unestimated loss of lives and properties, as communities, town and villages were submerged in floods. The recent disaster in Nigeria, in particular exposed the urgent need to reverse the planlessness of Nigerian cities and the lack of efficient official pre-emptive and ameliorative mechanisms against natural disasters. The consequences of these extreme events have no doubt demonstrated the fragility of our socio-economic systems and the extent to which these systems depend on weather and climate. Experts warned that climate change is likely to cause shifts in the intensity of flood events while in some regions increasing the exposure of populations to severe flooding. More frequent and more severe extreme weather events, such as storms, flooding and heat waves, put additional pressure on state governments expected to prevent and respond to disasters (Fussel, H. 2009). For example, the design of existing urban drainage infrastructures may have to be revised in light of increasing intensity and frequency of extreme rainfall events (Mailhot, A. et al, 2010). In order to better understand local exposure to climate change hazards, states would require locally relevant data and information, including downscaled, regional climate change projections.

In its proactive mission of providing weather and climate information for sustainable development, every year, the Nigerian Meteorological Agency (NIMET), presents to the public the Seasonal Rainfall Prediction (SRP). The SRP is the Agency's response to vital information required for adaptation against climate abnormalities in those sectors of the economy that are dependent on or affected by rainfall. But experience worldwide informs the need for governments at all levels to prepare for any eventuality arising from the effects of global climate change that has triggered disasters across the world (WMO, 2011).

To meet future challenges, the federal government must explore a new methodology for flood risk management, especially in infrastructural design and urban planning. The Nigerian Institute of Town planning in 2009 lamented that no single Nigerian city follows a laid town plan while the master plan for the Federal Capital Territory (FCT) had been completely derailed. Besides planning its towns and cities, the government at all levels, should prioritize comprehensive, town and city-wide drainage and waste disposal systems. Many countries are putting early flash flood warning systems in place. Such early warnings would provide crucial time for emergency management agencies to implement contingency plans, potentially saving lives and property. National Emergency Management Agency (NEMA) and their state counterparts should rise up to the challenge while the executive and legislative arms of government should respectively provide adequate funding and effective supportive legislation for these agencies.

DATA AND METHODOLOGY

Data

The monthly rainfall and maximum temperature data used in the present study were collected from the Nigerian Meteorological Agency, Oshodi, Lagos. For detailed studies of the inter-annual to seasonal variations in rainfall in Nigeria, fifty meteorological synoptic stations were used. In each climatic zone, at least ten stations have been used to examine the variation and variability of rainfall.

Methodology

For the present analysis, emphasis was placed on climate extremes as related to rainfall variation which can be taken to mean their variations in space and time (see for example, Oguntoyinbo and Odingo, 1979). Also, the data analysis was based on only four climatic zones, which were taken as fairly and climatologically representative of the country. It provides variations, trends and changes in maximum temperatures, rainfall amounts and distributions. The magnitudes of these weather indicators in the past five years were compared with their long term values and those of the previous years. Climate variability indices were also computed to determine the extent of flooding across the country. The index used for defining the two major climate extremes, viz - floods and droughts, thus emphasized rainfall variability, and is the time series of the normalized annual departure of rainfall in the region. For individual stations, the index can be quantitatively expressed in the form,

$$Y_{ij} = \frac{P_{ij} - \overline{P_i}}{\delta} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where P_{ij} is the rainfall for station i in year j and

$\overline{P_i}$ is the mean rainfall for station i and

δ is standard deviation

$$P_{ij} = \frac{1}{N}\sum_{j=1}^{Ni} Y_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Regionally averaged, the standardized rainfall departure can be expressed in the form

Where N is the number of years

Y_{ij} is the normalized departure for stations in the country

For the purpose of defining categories of floods and droughts, the groupings in table 1 were used.

RESULTS AND DISCUSSIONS

Rainfall Variations

Figure 1 shows the pattern of mean annual distribution of rainfall in Nigeria. The mean values decrease as one moves from the coast to inland. For the purpose of determining the categories of floods and droughts, the groupings in Table 1 above are used. Figure 2 shows the standardized mean annual rainfall anomaly for the Sahel zone of Nigeria. Considering the mean rainfall for the entire record, and taking ±0.5d as moderate, the drought years are 1917, 1926, 1940-1942, 1951, 1968, 1971-1974, 1981-1987, 1989-1990, 1992-1993, 1997, 2009 and 2011. The years with floods include 1918, 1920-1921, 1924, 1927, 1936, 1938-1939, 1945-1946, 1950, 1952-1955, 1957-1958, 1960, 1965, 1967, 1976, 1998-1999, 2005, 2008, and 2010. Fig. 2 shows that on the mean, rainfall has consistently been on the decrease over the Sahel especially since the 1960s. Figure 3 is the standardized mean annual rainfall anomaly for the Rainforest zone of the country. When the mean rainfall for the entire record is considered, and taking ±0.5d as moderate, the flood years are 1962, 1965, 1968-1969, 1978, 1980, 1995-1997, 2002, 2005, 2007-2008, 2010 and 2011. Drought years include 1966, 1970, 1972-1973, 1977, 1981-1986, 1993, 1998 and 2009. Fig. 3 shows that there has been consistent increase in rainfall since late 1980's over the Rainforest zone. Figure 4 shows the standardized mean annual rainfall anomaly for the Sudan savanna zone of the country. Considering the mean rainfall for the entire record, and taking ±0.5d as moderate, the drought years are 1962, 1982-1983, 2005 and 2008. Flood years include 1963, 1966-1969, 1971, 1975, 1980 and 1999. From Fig. 4, the rainfall pattern is showing a consistent and slight decrease in rainfall since the 1980's in the zone.

Table 1: Categorization of Intensities of Climate Extremes

FLOODS		DROUGHTS	
Departure range	**Flood Intensity**	**Departure range**	**Drought Intensity**
0 to $+\frac{1}{2}\delta$	Moderate	0 to $-\frac{1}{2}\delta$	Moderate
$+\frac{1}{2}\delta$ to $+\delta$	Large	$-\frac{1}{2}\delta$ to $-\delta$	Large
$+\delta$ to 2δ	Severe	$-\delta$ to -2δ	Severe
More than $+2\delta$	Disastrous	Less than -2δ	Disastrous

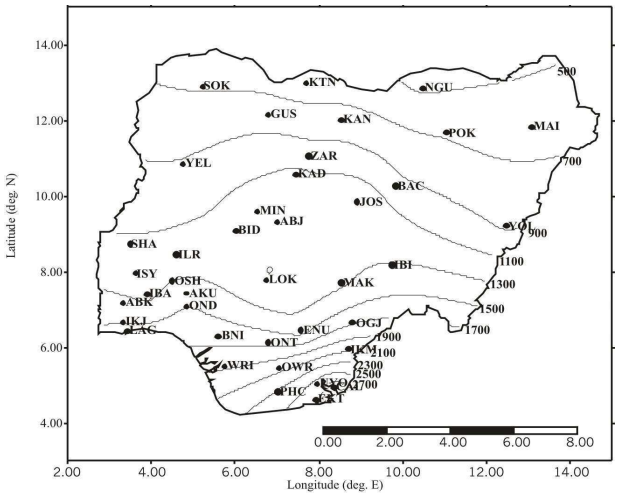

Fig 1: Mean Annual Distribution of Rainfall(mm) in Nigeria

reported in the media. In spite of the heavy rainfalls which occurred in the short period, some of the northern states reported crop failures which were as a result of the dry spells and shortened length of the rainy season. However, above normal rainfall was observed over the extreme north and parts of the southern states leading to floods in some areas. Properties worth billions of Naira and loss of lives were recorded. The length of the wet season was shorter than normal, interspersed with dry spells in parts of the north. Temperatures were generally normal over the country except over parts of the northeast and northwest where they were warmer than normal.

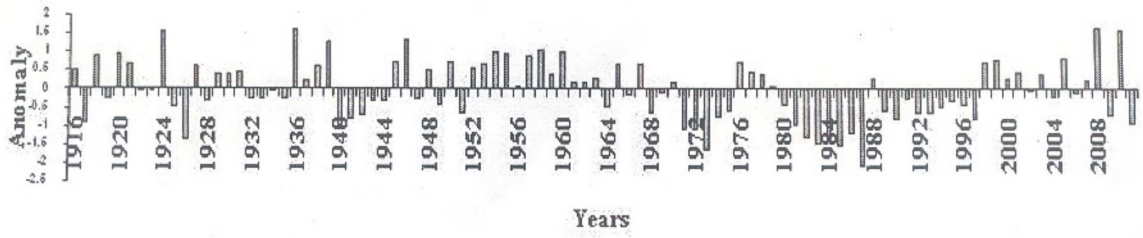

Fig 2: Standardized Mean Annual Rainfall Anomaly at Sahel Zone of the Country

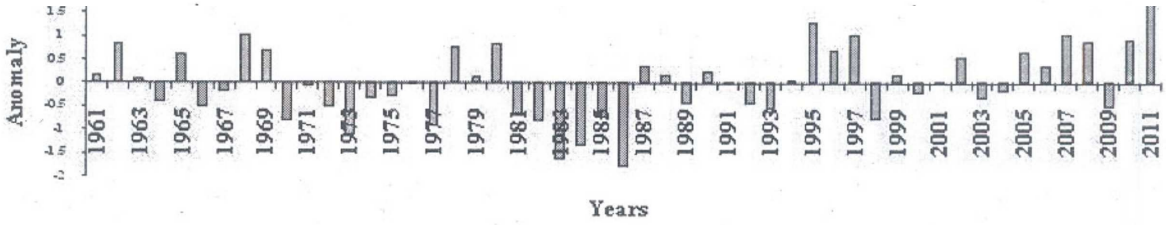

Fig 2: Standardized Mean Annual Rainfall Anomaly at Rainforest/Coastal Zone of the Country

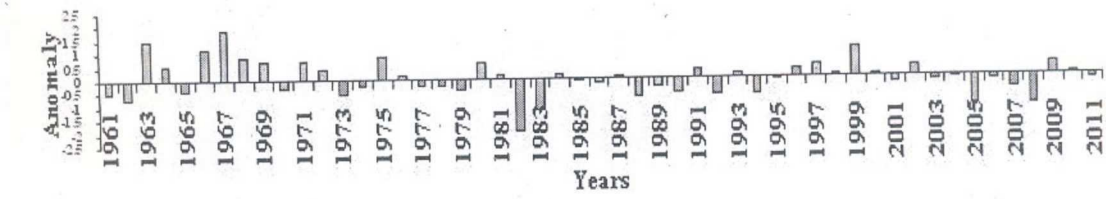

Fig 2: Standardized Mean Annual Rainfall Anomaly at Sudan Savanna Zone of the Country

Extreme Climate Events in 2007

The year 2007 recorded diverse extreme weather events such as flooding in some parts of the north central states, colder than normal harmattan, particularly in the northwestern and southwestern parts of the country and prolonged dry spell in northern parts of the country. The onset of rainy season in the northern states was late and its cessation came early (NIMET, 2007). The pattern of rainfall resulted in flooding episodes that were widely

Rainfall Anomaly

Rainfall in the country generally ranged from normal to wetter than normal when compared with the long term normal. Wetter than normal conditions were observed over Maiduguri, Potiskum, Kano, Katsina, Nguru, Bauchi and Jos (Fig. 5). Also parts of the central states experienced wetter than normal rainfall. However, drier than normal rainfall was observed over cities such as Gusau, Kaduna and Yola.

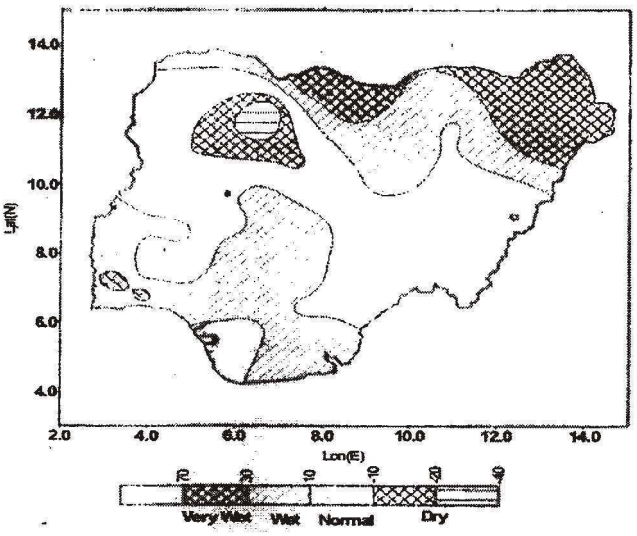

Fig. 5: 2007 Rainfall Anomaly
Source: NIMET

Maximum Temperature Departure
Maximum temperatures were generally normal across the country. However, warmer than normal conditions prevailed over the northeast, northwest, parts of southwest and Niger Delta.

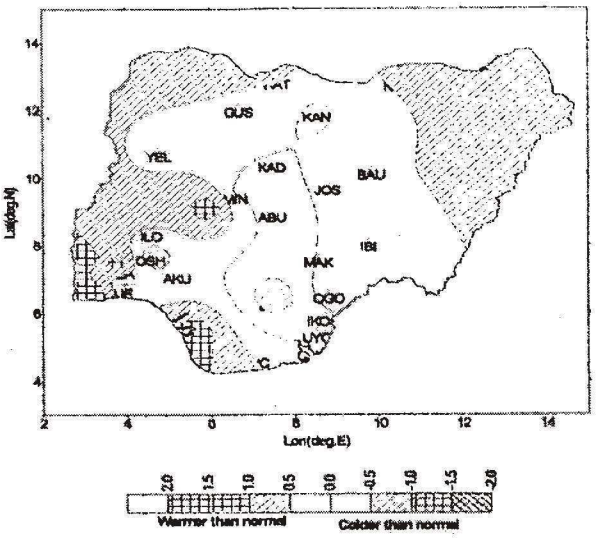

Fig. 6: 2007 Maximum Temperature Departure from (1971 – 2000) normal
Source: NIMET

Extreme Climate Events in 2008
Rainfall in 2008 was generally normal and higher than the 2007 amount. Isolated cases of wetter than normal and drier than normal conditions were experienced in the western half and parts of the north respectively. The length of the rainy season in 2008 was normal and longer than that of 2007 in most places. The year was slightly warmer than normal. However, the rains ended abruptly in the northern part of the country. The heavy downpours and the accompanying strong surface winds in the southern part of the country led to flash floods, destruction of properties worth billions of Naira, gully erosion, created internal refugees, etc. In the north, dry spells during the rainy season and the abrupt end of the rains caused farmers and water resources managers great concern and financial losses.

Rainfall Anomaly
The extreme coast, including Ilorin, Bida, Yelwa, Kano and Ibi experienced wetter than normal rainfall (Fig. 7). The extreme northwest, parts of central states including Yola and Mambila Plateau had drier than normal conditions. The rest of the country received normal rainfall.

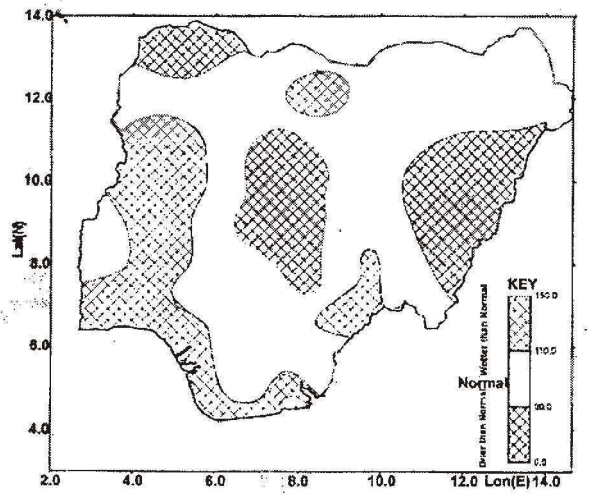

Fig. 7: 2008 Rainfall Anomaly
Source: NIMET

Maximum Temperature Departure
Maximum temperatures were generally warmer than normal conditions across the country (Fig. 8). Isolated colder than normal maximum temperatures were observed over cities such as Gombe, Lokoja and Eket environs.

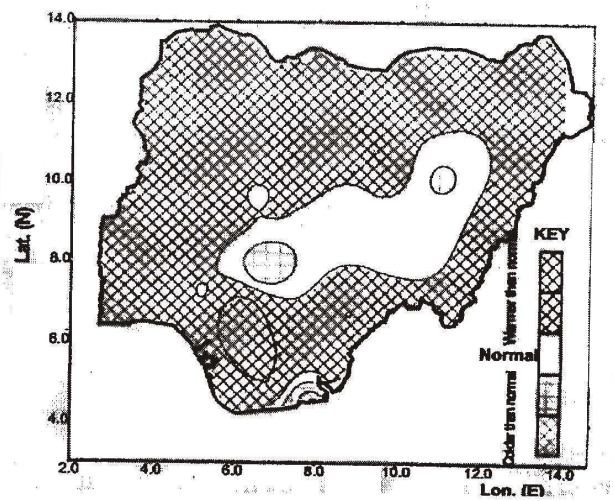

Fig. 8: 2008 Maximum Temperature Departure from (1971 – 2000) Normal. **Source:** (NIMET)

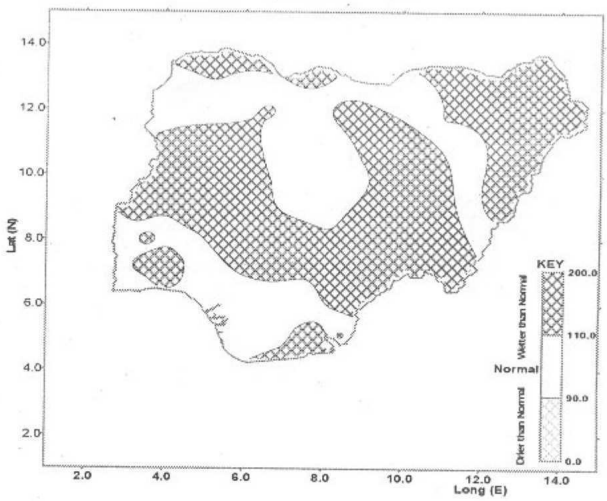

Fig. 9: 2009 Rainfall Anomaly
Source: NIMET

Extreme Climate Events in 2009

A number of cities in the northern part of the country experienced above normal rainfall during the year 2009, which is a significant departure from the low rainfall pattern of the area in recent years. The extreme northeast recorded below normal rainfall since 2007. Cities in the southern part of the country enjoyed normal rainfall although some areas had excess rainfall which led to flooding and soil erosion, especially in the southeast. In the last two years, a greater part of the South enjoyed normal to above normal rainfall.

Rainfall Anomaly

The annual rainfall anomaly is depicted below in Fig. 9. Wetter than normal conditions were experienced over cities such as Bauchi, Jos, Bida, Yelwa, Lokoja and Makurdi in the North, Ibadan and Ijebu Ode in the southwest and Port Harcourt and Eket in the southeast. The entire northeast, Katsina and Sokoto in the northwest, had drier than normal rainfall. The rest of the country recorded normal rainfall.

Maximum Temperature Departure

Warmer than normal conditions prevailed over most places in the country especially around Sokoto, Yelwa, Ilorin and Asaba. Colder than normal conditions prevailed over Gombe, Iseyin, Ibadan, Ijebu-Ode and Eket environs. Maximum temperature departures were colder than normal in the southeast corner (Fig. 10). The magnitude of maximum temperature departures in the southeast corner in 2008 and 2009 were identical.

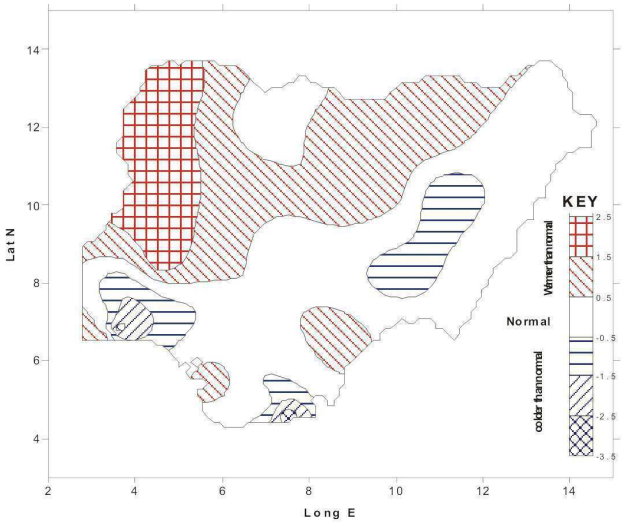

Fig. 10: 2009 Maximum Temperature Departure from (1971-2000) normal

Extreme Climate Events in 2010

The results from 2010 analysis, presented scientific information on the magnitude, departures from long term conditions and trends in maximum temperatures, rainfall amount and distribution. The relative variability indices computed over some selected synoptic stations gave insight into some abnormal and extreme weather occurrences in the country in year 2010.

Most places in the country, especially in the north, experienced record flooding due to a combination of above normal rainfall and due to excess water released from the dams. In particular, the above normal rainfall in the northwest area of Sokoto and Jigawa states was quite significant because it occurred at critical stages of crop development. The temperature analysis also revealed that most part of the country was warmer than normal during the year (NIMET, 2011).

Rainfall Anomaly

Wetter than normal conditions were experienced in the extreme northeast, northwest and cities such as Bauchi, Jos and part of Minna in the central states (Fig. 11). Other areas that recorded wetter than normal rainfall conditions included southwest and Ogoja, Calabar and Eket in the southeast. Isolated drier than normal rainfall was recorded at Ilorin. The rest of the country had normal rainfall (Fig.11). In the last three years, the extreme northwest experienced drier than normal rainfall conditions but became wetter than normal in year 2010 (NIMET, 2011)

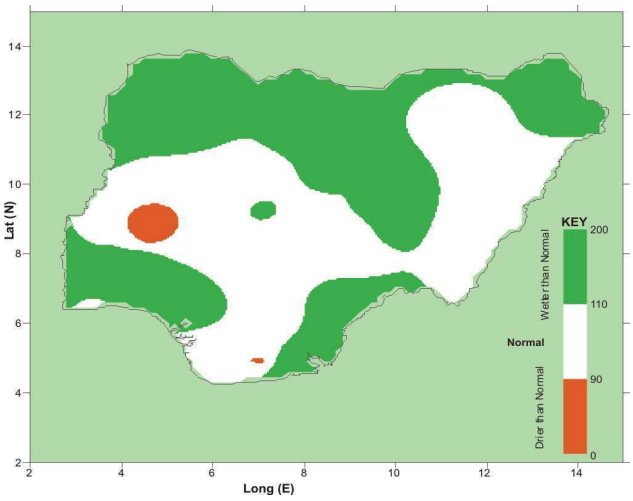

Fig. 11: 2010 Rainfall Anomaly

Maximum Temperature Departure

Warmer than normal maximum temperatures prevailed over most places in the country (Fig. 12). However, colder than normal maximum temperature conditions were experienced in Eket. The rest of the country experienced normal maximum temperatures.

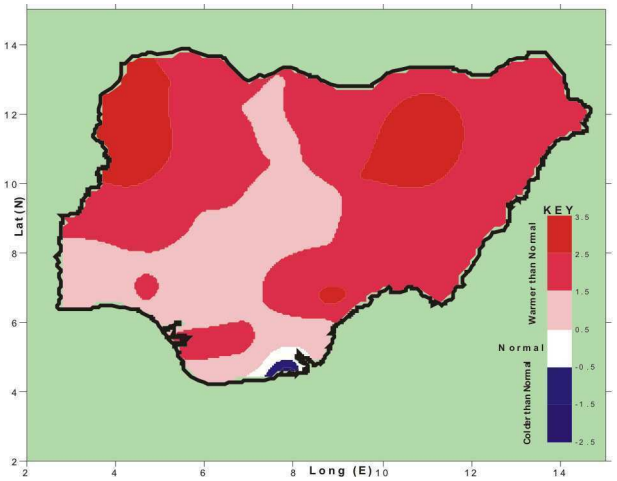

Fig. 12: 2010 Maximum Temperature Departure from (1971 – 2000) Normal

Extreme Climate Events in 2011

2011 witnessed a number of weather hazards. In particular, flooding and windstorms were experienced in different parts of the country especially in most areas that experienced wetter than normal rainfall conditions. Incessant flooding resulting from heavy rains and thunderstorms reported in some parts of the south and north, resulted in enormous losses. In particular, lives were lost and properties and farm land estimated at billions of Naira for example, were destroyed in Lagos, Osun, Kwara, Delta and Cross River states, following the July floods of 2011. Also in August, lives and property, buildings, farm lands livestock were lost in the following states, Plateau, Ebonyi, Edo, Bauchi, Adamawa, Taraba and Oyo states. Again by September, lives and properties were lost, following flooding in Oyo, Lagos and Bauchi states.

Rainfall Anomaly

Normal to wetter than normal conditions prevailed in most parts of the country (Fig. 13). Wetter than normal conditions prevailed over Ijebu Ode in the west, the whole of southeast (except Benin and Warri), extending through parts of east central areas, and up to Kano in the north. Ilorin recorded an

isolated wetter than normal rainfall. The extreme northeast bordering Nguru, Portiskum, Yola and Maiduguri, Sokoto, Gusau and environs in the northwest extending southwards to Minna, Abuja, Bida and lokoja in the north central states experienced drier than normal rainfall conditions. Ibadan and Oshogbo also recorded drier than normal conditions irrespective of the fact that Ibadan recorded cases of flooding during the season

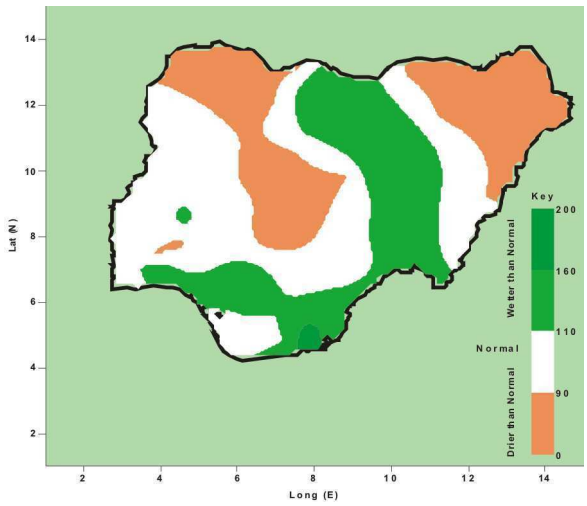

Fig. 13: 2011 Rainfall Anomaly

Maximum Temperature Departure

Maximum temperatures were generally warmer than normal across the country (Fig. 14). However, pockets of colder than normal were experienced over Shaki, Ilorin, Owerri, Uyo and Calabar. Katsina, parts of Maduguri and most parts of the south observed normal maximum temperatures.

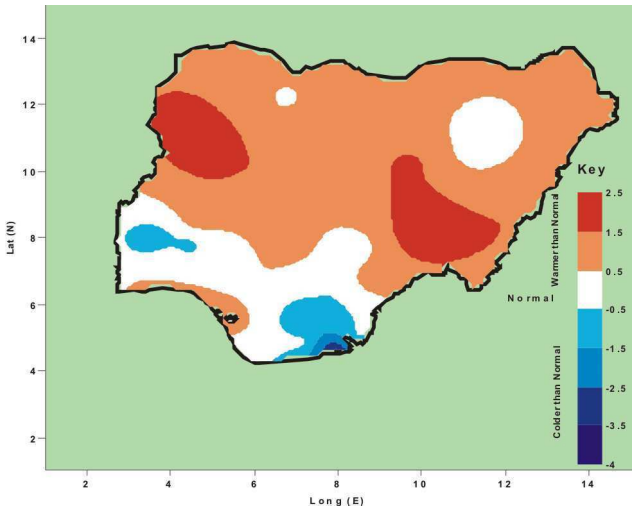

Fig. 14: 2011 Maximum Temperature Departure from (1971 – 2000) Normal

CONCLUSION

Devastating climate and weather related events recorded in recent years have captured the interest of the general public, governments, and media, among others. The type of climate hazards and their spatial variations, the expected frequency and intensity of impacts of climate change on urban areas can no longer be predicted by solely relying on historical data, local experiences and institutional memory. Under the impacts of climate change, state governments need to adjust their planning and decision-making to accommodate imminent changes to their hazard exposure. More frequent and more severe extreme weather events, such as storms, flooding and heat waves, put additional pressure on state governments expected to prevent and respond to disasters. Combining mitigation and adaptation efforts into coherent, integrated strategies is considered key for effective and holistic climate change response. For a multi-level governance approach in climate risk management and adaptation processes, a systematic, truly participatory process of engaging local government staff, civil society groups and private sector stakeholders with climate change is required.

The results from the five-year analysis, presented scientific information on the magnitude, departures from long term conditions and trends in maximum temperatures, rainfall amount and distribution. Most places in the country experienced record flooding due to a combination of above normal rainfall and excess water released from Dams. The temperature analyses also revealed that, in most years of flooding, there were corresponding warmer than normal conditions observed across the country.

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