Original Research Article

Relationship between Rainfall Pattern in North Central and Southern Nigeria and some tropical Climate Systems

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Monthly rainfall data from meteorological stations in Nigeria are analyzed from 1951 to 1992, in relation to some Tropical climate systems: Tropical South Atlantic (TSA) sea surface temperature index, North Atlantic Ocean (NAO) atmospheric index, Tropical North Atlantic (TNA) sea surface temperature index, Central Indian Precipitation (CIP) index and Outgoing Longwave Radiation Anomaly (OLRA). The analysis also includes August break (Monsoon break intensity (MBI)) and annual rainfall anomaly index (RAI). The analyses show that the rainfall anomalies although sometimes intense do not have predictable patterns. The teleconnection between CIP and total rainfall in Nigeria suggests that the rainfall patterns in Nigeria is likely to be modulated by the Tropical Easterly Jet (TEJ) connecting rainfall pattern in Central India to that in Nigeria. The August break is observed to be highly variable and does not show a clear discernable pattern of variability. Its variablility may be connected with multiple forcings from ocean and mesoscale circulations.

Comment [SM1]: Authors should use recent data

Comment [SM2]: Complete the sentence. Do you mean that all these indices are used in this study?

Comment [SM3]: It should be "Analysis"

Keywords: Monsoon Rainfall, Rainfall anomaly, teleconectivity, climate

1. INTRODUCTION

Nigeria has witnessed series of episodes of climate extremes which have continued to pose serious threats to lives and properties. Floods and drought conditions across the country have had far reaching and devastating effect on her economy and food security. Nigeria depends largely on the vagaries of weather, especially rainfall for its rain fed agriculture. The monsoon over West Africa is a seasonal prevailing wind blowing from the South Atlantic Ocean. Monsoon systems affect more than one-third of world's population in numerous and varied ways, from agricultural irrigation to catastrophic disasters on an enormous spatial scale, such as flood or drought (Maher and Hu, 2006). The activity of this wind system has also been closely linked to Hydro power plants, infrastructural development, flood control dams, desert encroachment and visibility. Studies have linked the climate of Nigeria to various global systems such as; Intertropical Convergence Zone (ITCZ) (Chineke *et al.*,2010, Akinsanola and Ogunjobi, 2014), El Nino Southern Oscillation (Okeke *et al.*,2006, Olaniran, 2002) and West African Monsoon (Chineke *et al.*,2010,). Other vagaries include Sea Surface Temperature (SST) which affects rainfall patterns in the Sahel (Thorncroft and Hodges, 2001). How these global and regional climate drivers interact and affect climate change is still not completely known. The ITCZ is the zone of contact between the Tropical Continental (CT) air mass and the Tropical Maritime air mass (MT) and sweeps across West Africa once every year. This region of contact between the two air masses at the surface is therefore a zone of moisture discontinuity and is also known as the Zone of Intertropical Discontinuity (ITD). The ITCZ is both a zonal and global phenomenon (Clement *et al.,* 2009). It is responsible for the rainy season in the tropics. Understanding, interpreting and exploring the dynamics of weather and climate extremes is still an active area of research today (Nnamchi *et al.,* 2015). Nigeria (Latitude 4^o-13^oN and Longitude 2^o-14^oE) is located in the tropics and borders the Gulf of Guinea between Benin on the West and Cameroon on the East. It has an area of 923,765 square km. The country's land mass extends from the Gulf of Guinea in the South to its boundary with Niger and Chad republics in the North. (Thorncroft *et al.,* 2001).

Studies on climate variability in Africa and in Nigeria suggest that the major global systems that drive the climates of the African continent are; the intertropical convergence zone (ITCZ), El Nino Southern Oscillation and West African Monsoon. Sea Surface Temperatures (SSTs) also affect rainfall in the Sahel. (Okeke *et al.,* 2006, Camberlin *et al.,*2001).
Okeke *et al.,* 2006 used monthly precipitation data from meteorological stations in Nigeria from 1950-1992, to study the possible connection to sea surface temperature (SSTs) in the tropical Pacific and Atlantic Oceans. Their analyses showed some indication that rainfall in Nigeria is associated with El Nino-related circulation and rainfall anomalies. Though the correlation values between rainfall anomaly indices (RAI) and different meteorological indices were not all significant. Camberlin *et al.,* 2001 showed that a number of changes in East-West circulation patterns can be associated with ENSO variations. Over West Africa, El Nino events tend to result in enhanced north easterlies and reduced monsoon flow, coupled to weakened upper easterlies, and hence dry conditions over West Africa close to the surface position of the ITCZ, in July-September, as well as January-March. Most of the works on SSTs have focused on the South Atlantic Indices. In this work we focus on investigating the teleconnection between rainfall anomaly (including monsoon breaks) and other climate systems ~~purpoted~~purported to drive the rainfall pattern in North central and Southern parts of Nigeria. Akinsanola *et al.,* 2014, showed that there has been a sequence of alternately decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria during the period 1971-2000.

Comment [SM4]: This sentence is repeated twice.

Comment [SM5]: Analysis

Bain *et al.,* (2010) used satellite fields of infrared (IR), visible (VS) and total precipitable water (TPW) with the Markov Random Field (MRF) model to determine the temporal and spatial evolution of the ITCZ in the East Pacific. Their results showed seasonal migration of the ITCZ and significant interannual variability. They also observed that the location and area of the ITCZ is closely associated with the anomalies from the Tropical Atlantic Sea Surface Temperatures . Many authors (Waliser and Gautier, 1993, Wang *et al.,* 2010 and Ferreira *et al.,*2010) also showed that the band of clouds that form the ITCZ which sometimes extend for many hundreds of miles, sometimes break into smaller line segments which results in irregular precipitation patterns in the tropics. Their work also suggests that the variability of the ITCZ is attributed strongly to the anomalies associated with sea surface temperatures. Which further strengthens the argument for a better understanding of the association between TNA and rainfall anomaly. The teleconnection of these atmospheric vagaries is currently an active area of research (Sang-Wook *et al*. 2018, Datwyler *et al*. 2019)

Chineke *et al.,* 2010 analysed daily series of rainfall data from 1983-2003 between the months of July-August for some sites in the Eastern humid zone of Southern Nigeria. Their work shows that the August break may indeed be breaking. The August break was observed to have reduced to a period of 2-4 days instead of 2-3 weeks. Some authors (Hulme 2001, Chineke *et al.,* 2010) have linked these variations in the West African climate to differential changes in SSTs (Sea Surface Temperatures) of the Atlantic (both north and south) and the Indian Ocean as the primary drivers of climate change in the region. In his work on rainfall anomalies in Nigeria, Olaniran, (2002) observed that during the period 1921-2000, there was a countrywide occurrence of droughts during two periods: firstly from the 1930s to 1950 and recently from 1970 to the mid-1990s. He reiterated that during the last three decades each drought event persisted more in northern Nigeria than in southern Nigeria. His work shows that the possible drivers that could be associated with these anomalies are the ITCZ, Tropical Easterly Jet (TEJ), Tropical Atlantic Sea Surface Temperature Anomaly, El Nino Southern Oscillation (ENSO) and other teleconnections. However, not much work has been done to understand the teleconnection between the rainfall patterns/anomalies in Nigeria to other climate systems. In particular, the present study aims to improve our present understandig of the August and how its strenght may be affected by other climate systems.

2. MATERIAL AND METHODS
2.1 SOURCES OF DATA

Monthly rainfall data (mm/month) for the period 1951 - 1992 were collected at six meteorological sites (Warri, Enugu, Makurdi, Minna, Ondo and Calabar) from http://climexp.knmi.nl/_all stations. The stations are part of the Nigerian Meteorological Agency (NMA) network of surface stations measuring meteorological parameters like, maximum and minimum temperatures, rainfall amount, wind speed, solar radiation and sunshine hours.

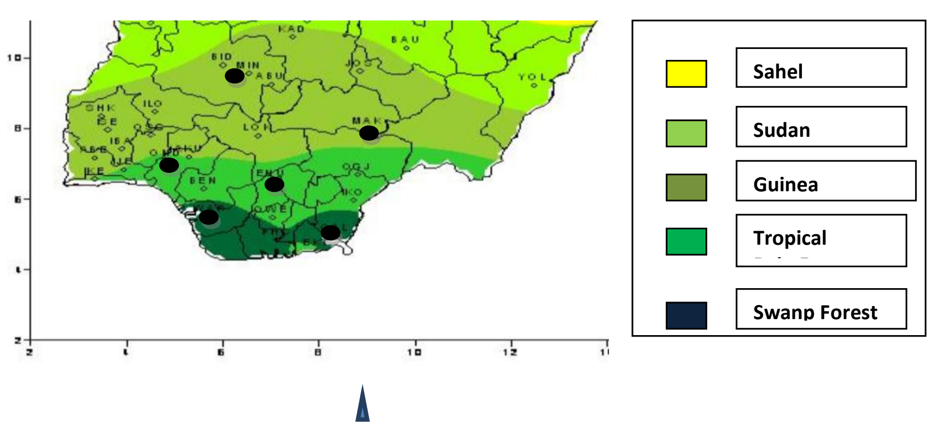

Fig. 1:Part of Map of Nigeria showing the locations of the stations used

Table 1: Stations Used and their Abbreviations.

STATION	ABBREVIATION	LATITUDE(^oN)	LONGITUDE(^oE)
WARRI	WAR	5.52	5.73
ENUGU	ENU	6.50	7.00
MAKURDI	MAK	7.70	8.60
MINNA	MIN	9.56	6.54
ONDO	OND	7.10	4.83
CALABAR	CAL	4.97	8.35

Monthly data of climate indices (Tropical North Atlantic TNA), North Atlantic Oscillation (NAO), Central Indian Precipitation (CIP) and Tropical South Atlantic (TSA). Sahel Standardized Rainfall (SSR).were obtained from the following website: National Oceanic and Atmospheric's Earth System Research Laboratory. http://www.esrl.noaa.gov/psd/data/climateindices/list/; for the period 1951-1992

We also obtained Outgoing Long Wave Radiation (OLR) monthly data from: National Oceanic and Atmospheric's Center for Disease Control: http://www.cdc.noaa.gov/map/clim/olr.shtml/; for the period 1975-1992

2.2 In other to study the association between monsoon break and various climate systems we quantified the monsoon break by a factor ε (after works by Zablone and Zhu 2012), which describes the intensity of the break in total rainfall expected around August. (Also known as August Break).

$$\varepsilon = \left(\frac{H_1 + H_2}{2}\right) - H_3 \qquad \mathbf{1}$$

Where H_1 is the first rainfall Maxima,(which usually occur around June/July) see fig. 1, H_2 is the second rainfall Maxima,(which usually occur around September/October) while H_3 is the minimum between H_1 and H_2. (H_3 usually occurs arround August) see fig. 1 (ε = 0 if the profile is unimodal i.e. no monsoon break).

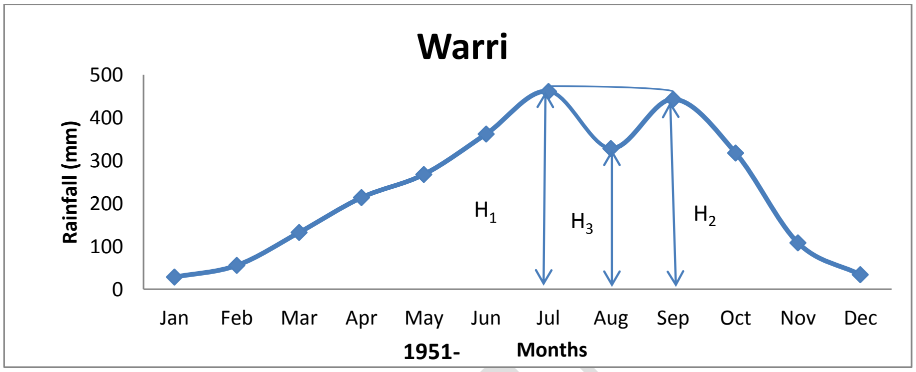

Figure 2: Rainfall data of Warri

To calculate the intensity of the monsoon break (ε), we plotted the rainfall profile for each year as shown in fig. 1.H_1, H_2 and H_3 were identified from the plots. The intensities for each year were calculated. This was done for each station.

2.2 Derivation scheme for other precipitation factors from Monthly Data.

The average monthly rainfall (AMR) was calculated as the average rainfall of each month from 1951 -1992. The plots of AMRs are presented in fig. 2-7, while the summer monsoon rainfall (SR) was calculated as the sum of the monsoon rainfall in the months of June, July, August and September (JJAS). The total annual rainfall (TR) was calculated as the sum of the total annual rainfall from January to December. The long period average (LPA) was calculated as the mean of the TR. The anomalies are calculated by subtracting yearly TRs from the LPA. The plots of the anomalies are presented in fig. 8.

2.3 Correlation Analysis.

We assume that linear association exists between the anomalies from one station to another. Linear correlation between the monsoon break and annual rainfall anomaly of the stations was carried out using equation (2). Similarly we carried out the linear correlation between monsoon break intensity computed from equation (2), with different climate indices. We also correlated the monthly rainfall data with the monthly data of the climate indices. The correlations are presented in tables 2-.3. The Pearson's correlation coefficients r_{xy} is given by

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2} \qquad 2$$

Where: x and y are the dependent and independent variables respectively, and $\bar{x}$ and $\bar{y}$ are the mean of x and y respectively, while n is the number of variables.All the correlations were perfoemed at *p=0.05* significance.

The first-order partial correlation was used which measure the linear relationship between two variables after removing the effect of or controlling for a single (third) variable. The first-order partial correlation is given by

$$r_{xy.z} = \frac{r_{xy} - (r_{xz})(r_{yz})}{\sqrt{1 - r_{xz}^2}} \quad 3$$

We also conducted t-test to validate the significance of the correlations. The t-test is given as

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{Var_x}{n_x} + \frac{Var_y}{n_y}}} \quad 4$$

Where: x and y are the dependent and independent variables respectively, Var_x and Var_y are the variances of x and y while n_x and n_y are the number of variables of x and y, $\bar{x}$ and $\bar{y}$ are the mean of x and y respectively.

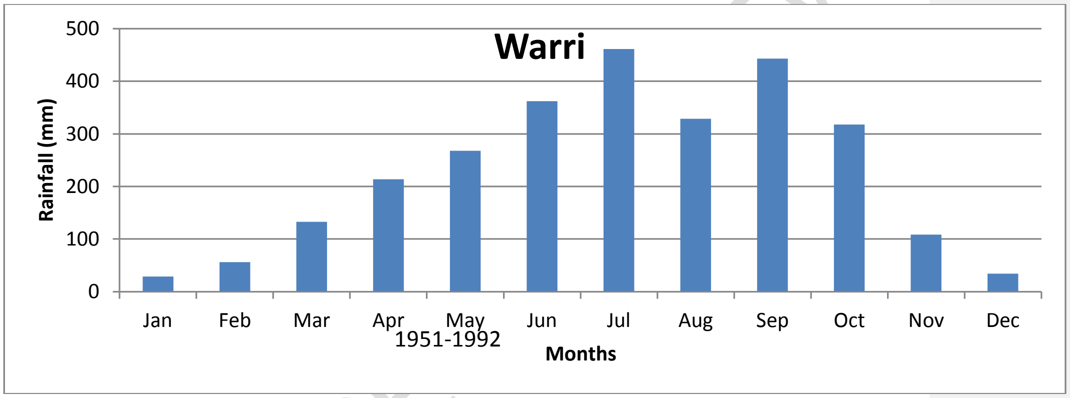

Fig. 3: Average monthly rainfall profile for Warri.

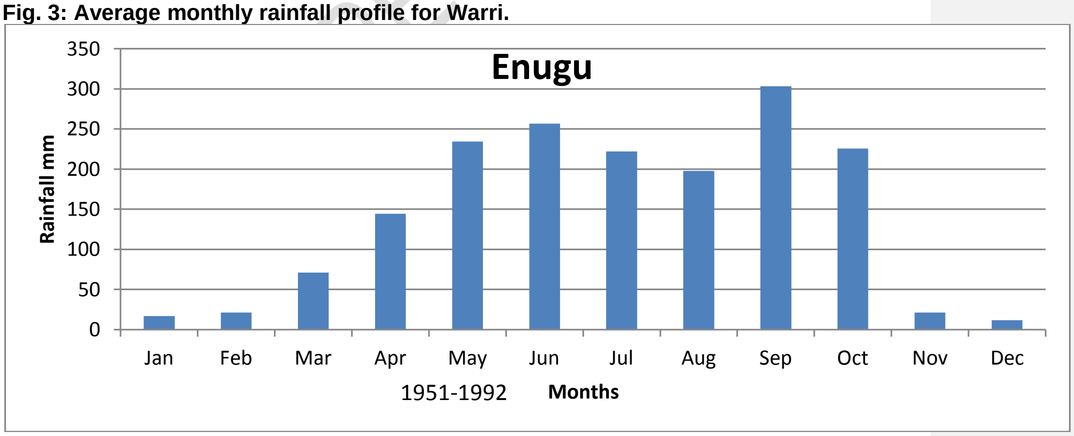

Fig. 4: Average Monthly Rainfall profile for Enugu.

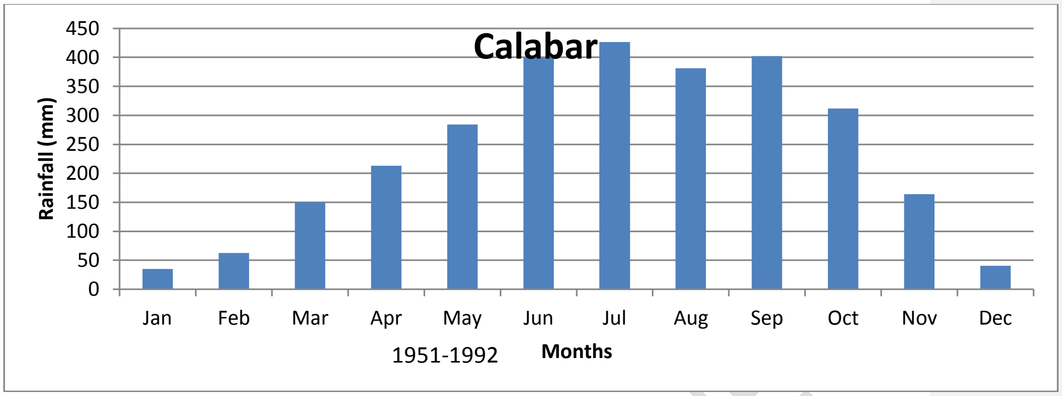

Fig. 5: Average Monthly rainfall profile for Calabar.

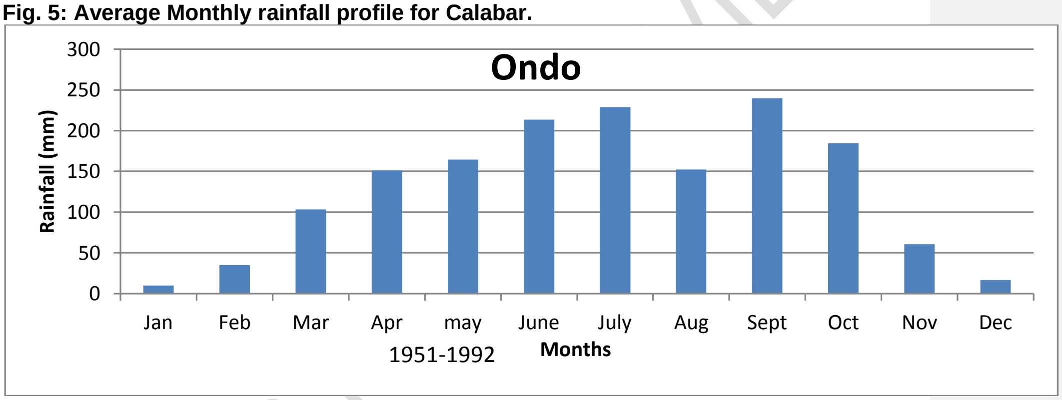

Fig. 6: Average Monthly rainfall profile for Ondo.

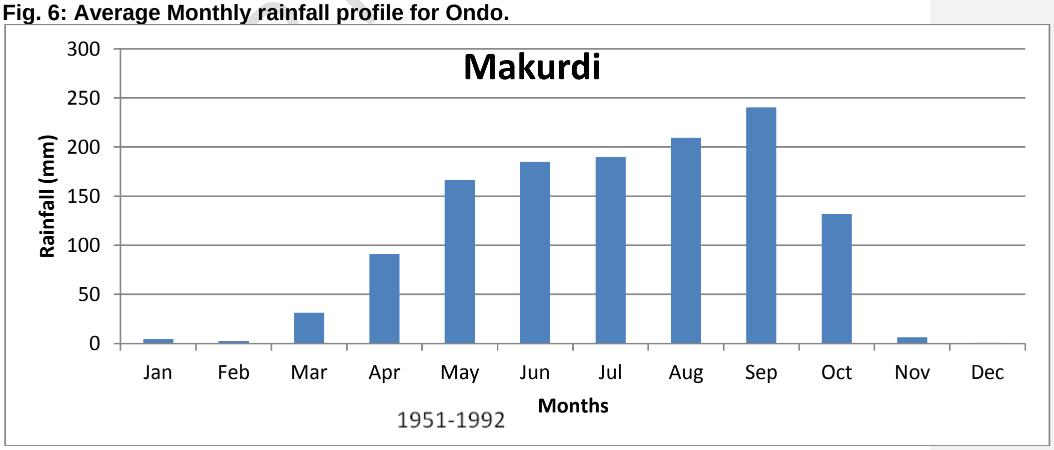

Fig. 7: Average Monthly rainfall profile for Makurdi

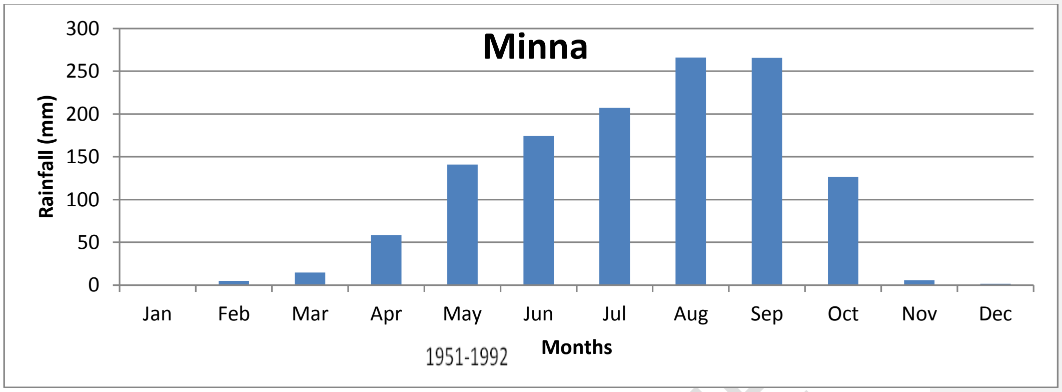

Fig. 8: Average Monthly Rainfall profile for Minna.

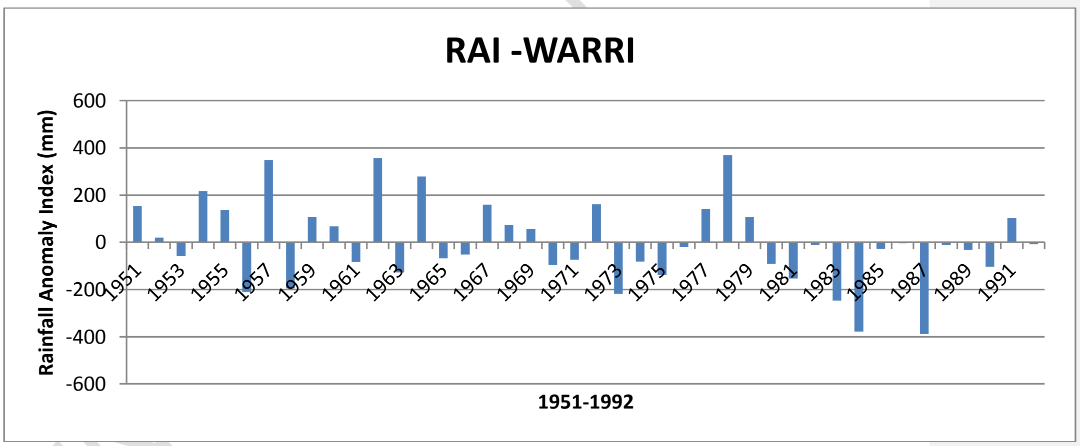

Fig. 9 Time series of yearly of rainfall anomaly for Warri.

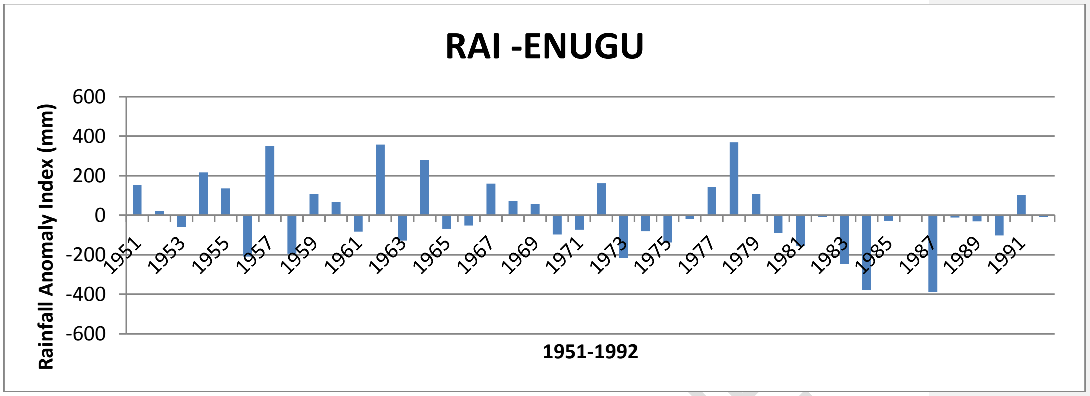

Fig.10 Time series of yearly rainfall anomaly for Enugu.

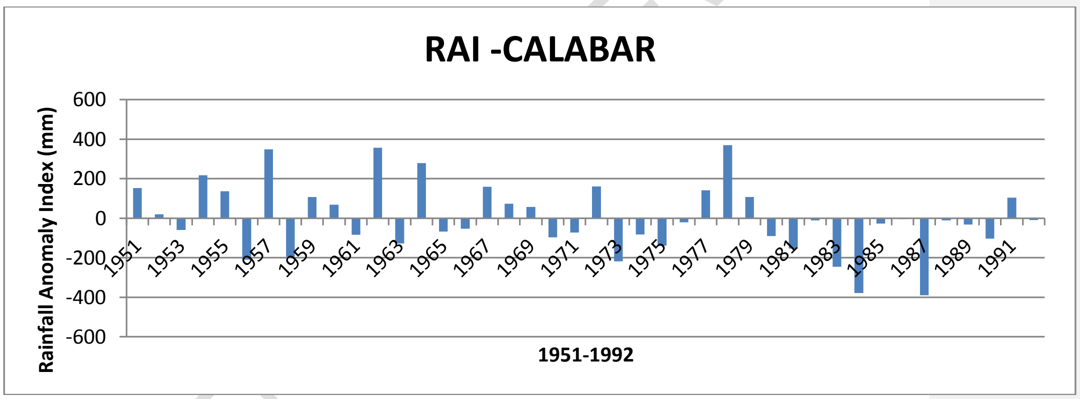

Fig.11 Time series of yearly rainfall anomaly for Calabar.

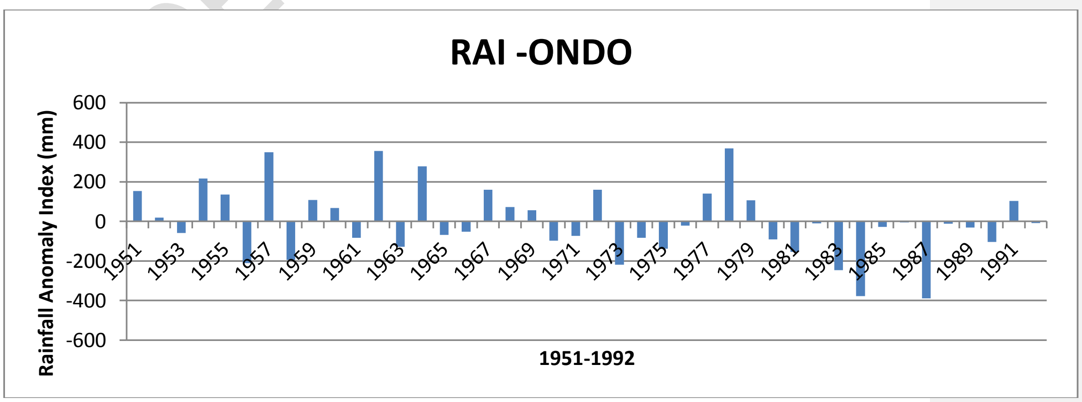

Fig.12 Time series of yearly rainfall anomaly for Ondo.

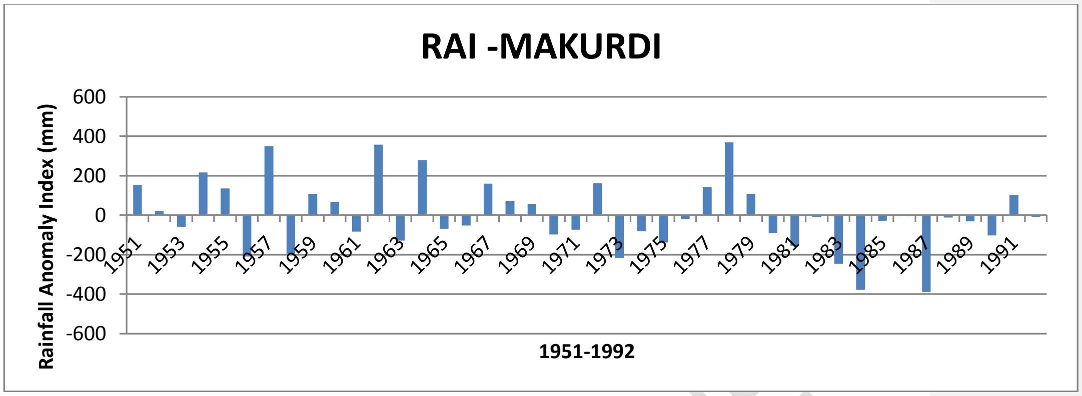

Fig.13 Time series of yearly rainfall anomaly for Makurdi.

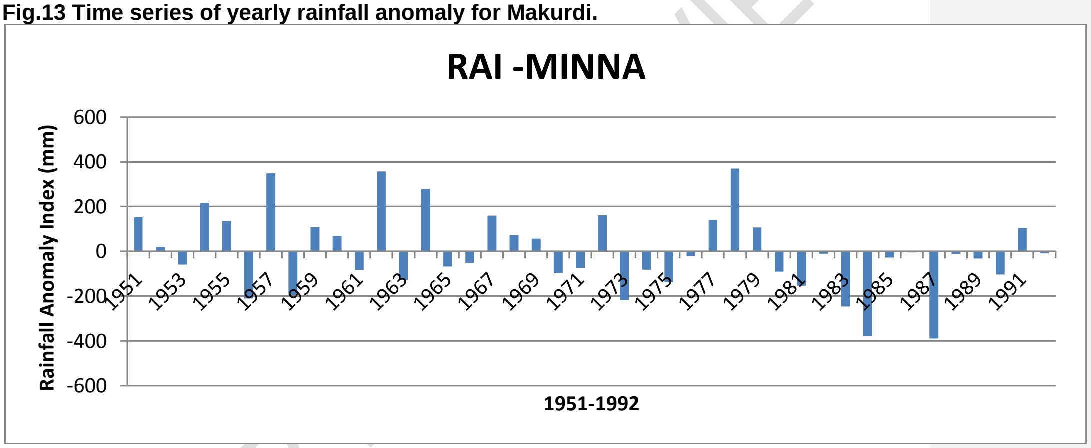

Fig.14 Time series of yearly rainfall anomaly for Minna.

Table 2:Correlation of various climate indices with monthly rainfall intensities.(1951-1992)

STATION/ INDEX	WAR	ENU	CAL	OND	MAK	MIN
TNA	**-0.07**	**-0.06**	**-0.05**	**-0.03**	**-0.07**	**-0.08**
NAO	**0.22**	**0.24**	**0.21**	**0.2**	**0.24**	**0.21**
CIP	**0.66**	**0.54**	**0.64**	**0.51**	**0.65**	**0.75**
TSA	**0.02**	**0.04**	**0.02**	**0.02**	**0.03**	**0.03**
CIP*	**0.65**	**-0.37**	**0.63**	**0.48**	**0.68**	**0.75**
OLRA*	**0.11**	**0.01**	**0.16**	**0.15**	**0.13**	**0.11**

CIP*(OLRA effect removed)	0.64	-0.37	0.61	0.47	0.67	0.74
CIP (NAO effect removed)	0.64	0.51	0.62	0.49	0.62	0.73
CIP*(NAO effect removed	0.50	-0.38	0.62	0.48	0.67	0.74

Table 3:Correlation of various climate indices with monsoon break intensities. (1951-1992)

STATION/ INDEX	WAR	ENU	CAL	OND	MAK	MIN
RAI	-0.31	-0.24	-0.15	-0.48	-0.21	0.03
TNA	0.05	0.07	-0.06	0.01	-0.01	0.04
NAO	0	-0.02	-0.05	0.19	-0.11	0.06
CIP	0.47	0.34	0.17	0.5	-0.14	-0.03
CIP (NAO effect Removed)	0.47	0.34	0.17	0.48	-0.13	-0.03
TSA	-0.29	-0.16	-0.12	-0.51	-0.1	-0.16
CIP*	0.45	0.17	0.2	0.38	-0.14	0.36
OLRA*	-0.1	0.11	0.21	-0.31	0.04	-0.17
CIP*(OLRA effect removed)	0.5	0.15	0.16	0.48	-0.16	0.43
CIP*(NAO effect removed)	0.45	0.17	0.2	0.37	-0.14	0.36

Table 4: Percentage of summer to annual total rainfall with corresponding ranges.

STATION	AASR	AATR	%AASR/AATR	RANGE
WARRI	1643	2757	59	46-73

ENUGU	**988**	**1708**	**58**	**42-76**
CALABAR	**1586**	**2783**	**57**	**46-65**
ONDO	**860**	**1563**	**54**	**42-76**
MAKURDI	**819**	**1250**	**66**	**46-77**
MINNA	**882**	**1214**	**73**	**56-86**

***Data available for 1975-1992**

Table 5: correlation of interstation monsoon break intensities.

STATION	WARRI	ENUGU	CALABAR	ONDO	MAKURDI	MINNA
WARRI	1	0.66	0.37	0.62	0.02	0.37
ENUGU		1	0.02	0.66	0.24	0.43
CALABAR			1	0.33	-0.23	0.08
ONDO				1	-0.06	0.44
MAKURDI					1	0.04
MINNA						1

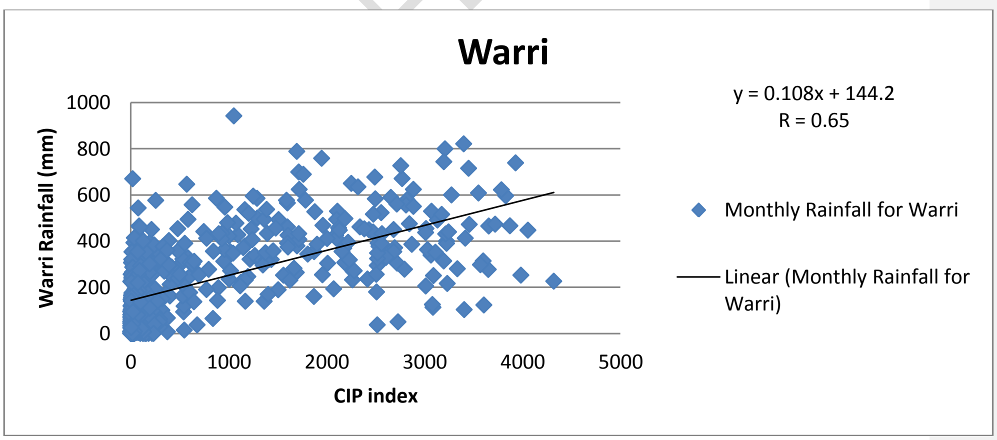

Fig. 15: Scatter Plot of monthly Rainfall for Warri vs CIP index.

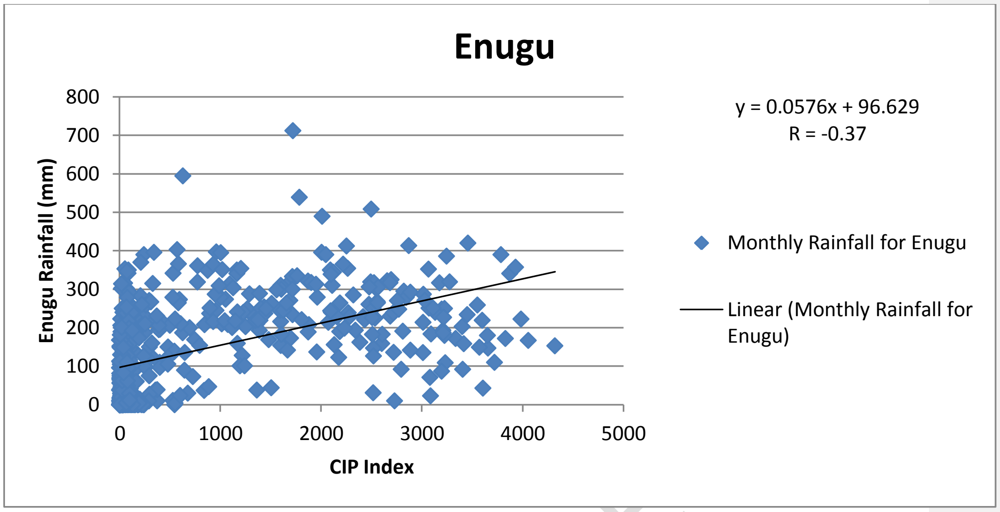

Fig., 16: Monthly Rainfall for Enugu and CIP index.

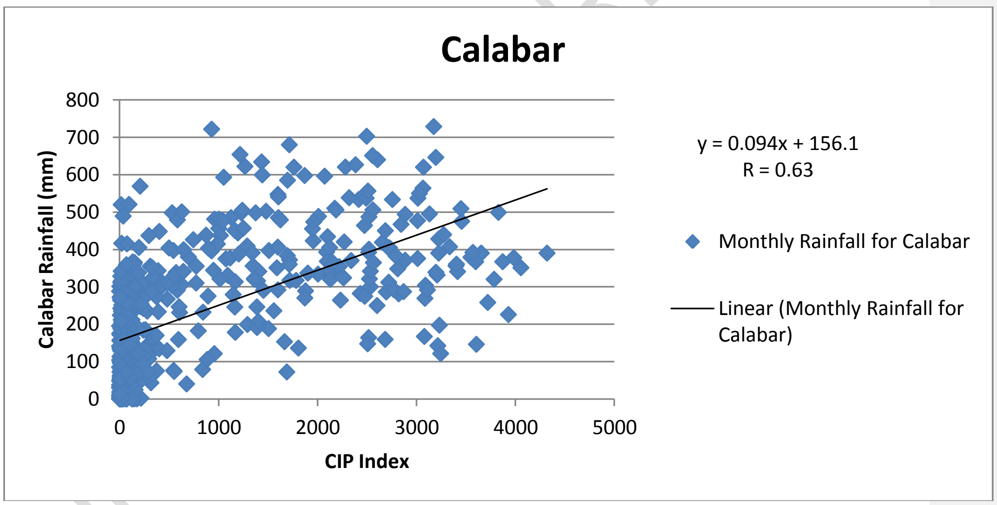

Fig., 17: Monthly rainfall for Calabar and CIP index.

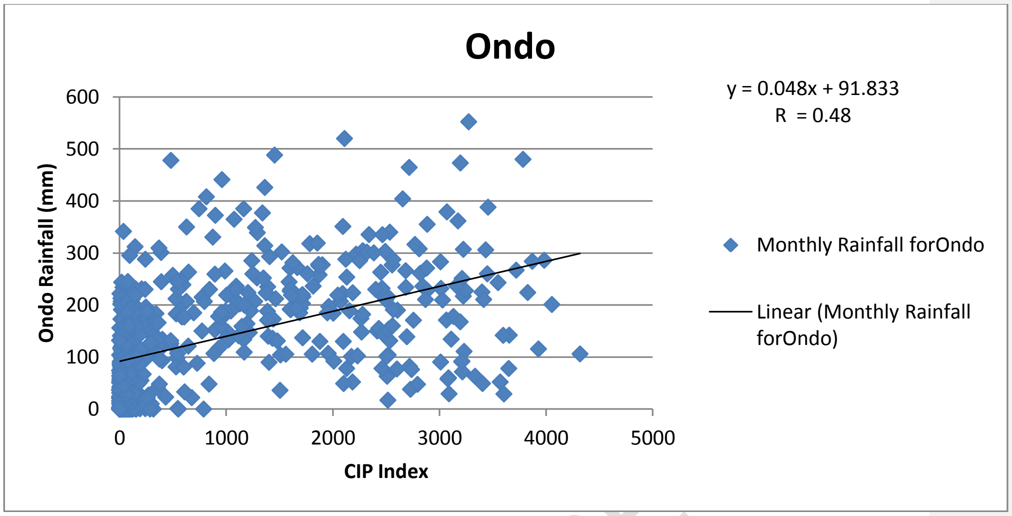

Fig., 18: Monthly Rainfall for Ondo and CIP index.

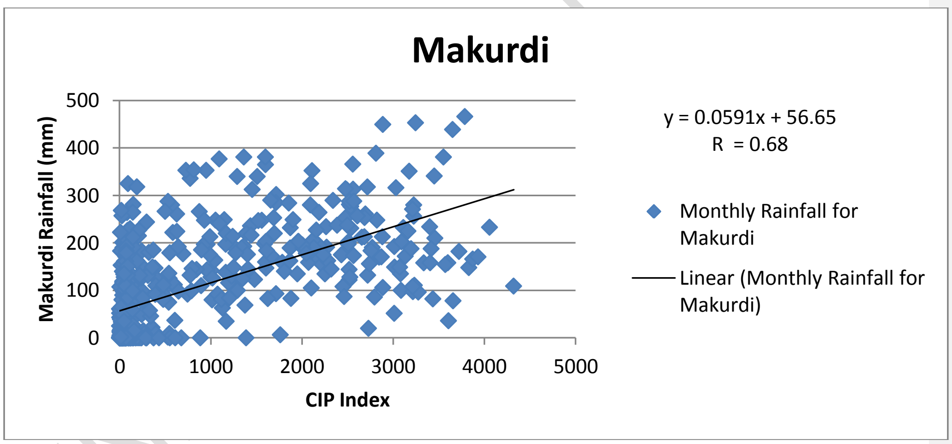

Fig., 19: Scatter Plot of monthly Rainfall for Makurdi vs CIP index.

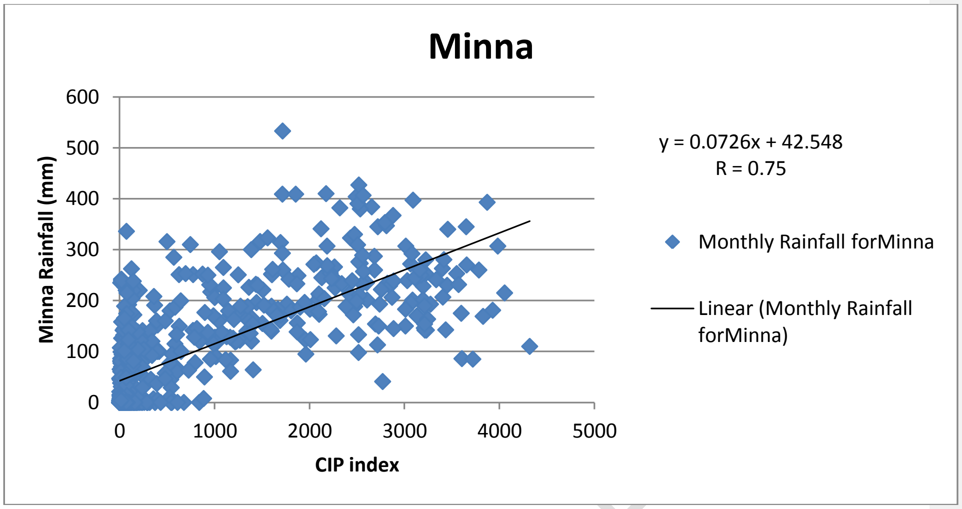

Fig., 20:Monthly Rainfall for Minna and CIP index.

3. RESULTS AND DISCUSSION

3.1 Monthly Rainfall Pattern

Figure 2-7 shows the seasonal (or monthly) rainfall pattern for all the stations. It is evident that Warri, Enugu, Calabar and Ondo had bimodal rainfall patterns while Makurdi and Minna had unimodal rainfall pattern. It is important to note that the figures (i.e. fig. 3-8) were derived from the average of the monthly data for all years considered for each station, so it does not reveal the fine patterns observed on a year to year basis. There are some years (albeit few) with bimodal rainfall patterns in both Minna and Makurdi stations, similarly, there were years (also few) with unimodal rainfall pattern for Warri, Enugu, Calabar and Ondo. Of Southern stations Warri and Ondo showed the most distinct signatures of bimodal pattern. This observation may not be unconnected with their position not too close to the coastal region, and consequently should show greater fluctuations in response to the advancement of the ITCZ. The Calabar station rainfall pattern was particularly interesting. It exhibited a weak bimodal annual rainfall pattern but had the greatest amount of rainfall during the same period when compared with other stations; it is possible that other mesoscale circulation patterns could be affecting its ability to exhibit a stronger bimodal pattern. Moreover the advancement of the ITCZ northward which gives rise to the monsoon break will likely exacerbate the effect of such mesoscale wind structures which appear to predominantly sustain the lesser convections and rainfall during July and August. This observation is further supported by the range of the percentage ratio of average total summer rain to average annual total rain being 46-65 mm for Calabar as against 46-73 mm for Warri. Our findings on the possible role of mesoscale wind structures at coastal regions corroborates the result of (Serr *et al.,* 2002).

The Monthly rainfall for the North central stations (Makurdi and Minna) showed maximum peaks around August/September. This observation is as a result of the migration of the ITCZ to the Northern part of Nigeria during summer. In table 3 we observe that the percentage ratio of the Average Annual Summer Rain (AASR) to the Average Annual Total Rain (AATR) for Minna is the highest (73%). This is due to the fact that most of the rain occurs during summer (June-September) months. This can also be seen with Makurdi station which has a percentage ratio of 66%. The least is that of Ondo which 54% is. These percentages do not differ much from the maximum value observed for the stations. The (AATR) for Calabar 2783 mm is the maximum even though its percentage is 57%. These values show that over 50% of the total annual rainfall occurred during the summer months for all the stations. The northern stations have the highest amount of their total rainfall during the summer months. This can be supported with the dominance of the presence of the ITCZ in that region during the summer bringing about the greatest amount of rainfall around August/September, (Houghton *et al.,* 1995).

From fig. 9 to fig. 14 we observe that the signatures of the rainfall anomalies do not exhibit a definite pattern. The oscillations are eminent and sometimes intense as observed in Calabar, Ondo, Minna and Makurdi. The oscillations tend to observe wide swings between the period 1971 and 1992 as reported in the works of Akinsanola *et al.,*2014 and Okeke *et al.,*2006. The variability in the rainfall pattern were most experienced within this period amongst the stations studied.

3.2 Inter-stations Monsoon break intensity teleconnectivity

The correlation of Minna and Makurdi which is (r > 0.04) is weak and not significant. Warri has a strong and direct correlation with Enugu. This correlation (r > 0.66) suggests a strong teleconnection between the two stations. Also the teleconnection of Warri with Ondo and that of Enugu and Ondo which are (r > 0.62) and (r > 0.66) respectively are also strong and direct. It is evident that a special but strong correlation exists between these stations as compared to the other stations. These stations are all located in the southern region. The correlation of Calabar with these southern stations as seen in Table 5 is much weaker though they are all located in the south. This observation suggests some kind of fluctuations prevalent along that region which does not extend to Warri, Enugu and Ondo. This suggests a variability that could possibly stem from a mesoscale wind structure within that region. The correlation of CIP index with the monsoon break intensity index (MBI) of Ondo station of $r \approx 0.5$ is the strongest, while that of Minna r = -0.03 is the weakest. We also observe that the correlation of Outgoing Long wave Anomaly (OLRA) with the (MBI) of Ondo station of r = -0.31 is the strongest while that of Makurdi; r = 0.04 is the weakest. The correlation of the MBIs with the other climate indices is not all so significant. This dispels the possibility of teleconnectivity between these climate indices with the MBIs in the North Central and Southern Nigeria rainfall pattern. On removing the effect of the OLRA and NAO from CIP, we observe a slight change which is not significant. This still leaves us with the conclusion that the effect of the CIP index on the MBI needs further analysis. The correlation of the MBI of the stations with Rainfall Anomaly Index (RAI) showed some level of association. Ondo station had a correlation of $r \approx -0.48$, while Minna station ha $r \approx -0.03$. This suggests that the MBIs could possibly be driven by the RAIs for Ondo station. For the other climate indices, we did not observe any significant association with the RAI.

3.3 Total monthly rainfall teleconnection with climate indices

The correlation of North Atlantic Oscillation (NAO) index with the monthly rainfall index (MRI) for Makurdi and Enugu is $r \approx 0.24$). This observation dispels the idea of teleconnectivity between the rainfall pattern and NAO index in these stations. The atmospheric forcing over the mid-lattitudes (Icelandic lows and Azores high) may not have reaching effect on the pattern of rainfall observed in this stations.

The correlation of the Central Indian Precipitation index with the MRI of Minna is $r \approx 0.75$, while that of Ondo is $r \approx 0.51$. Here it shows clearly from the 492 data points correlation that

there is a strong association between the two indices. It is evident that the climate systems that drive the CIP could possibly be responsible for the fluctuations or irregularities associated with the monsoon rainfall pattern of these stations. The tropical easterly jet is one of such drivers as reported in the work of (Okechukwu, 2010 and thorncroft, 2001). These observations validates recent findings by Nnamchi *et al.,* (2015): that atmospheric dynamics (Such as East African Jet Stream) are more likely to drive changes in climate variables than ocean forcing. On further removal of the effect of NAO and OLRA from the CIP index , once again only but slight changes are observed which are not significant.
We further observe that the correlation of OLRA with the MRI for all the stations is weak. Calabar has the strongest but inverse correlation of $r \approx 0.16$. The weakest amongst the stations is Minna with a correlation of $r \approx 0.11$. Also the correlation of the MRI with the OLRI gave us a correlation of $r \approx 0.31$ for Ondo station and $r \approx 0.04$ for Makurdi. This alsosuggests that there is a weak teleconnection between the OLRA with the MRI for Ondo station.

4. CONCLUSION

We have investigated the rainfall anomalies in six location in the Nigeria. The rainfall anomalies although sometimes intense do not have predictable patterns. The teleconnection between Central Indian Precipitation and total rainfall in Nigeria suggests that the rainfall patterns in Nigeria is likely modulated by the Tropical Easterly Jet (TEJ) connecting rainfall pattern in Central India to the pattern in Nigeria. The northern most stations appear to be more associated with Central Indian Precipitation. The August break is highly variable and does not show a clear pattern of variability. Its variability may be connected with multiple forcings from ocean and mesoscale circulations. These results have important implications for modelling of the climate system in Nigeria and West Africa. Considering the strong correlation we observed between the amount of rainfall recorded in these stations with the Central Indian Precipitation data, we suggest that further work be carried out to establish the possible drivers for such high correlation.

REFERENCES

Akinsanola, A.A., and Ogunjobi, K.O. (2014): Analysis of Rainfall and temperature variability over Nigeria. Global Journal of Human-Social Science B: Geography, Geo-Sciences, Environmental Disaster Management, 14(3), 1-19

Bain, C.L., Magnusdottir, G., Smyth, P. and Stern, H. (2010): The Diurnal Cycle of the ITCZ in the East Pacific. J. Geophys. Res., https://doi.org/10.1029/2010JD014835
Clement, A., Burgerman, R., and Norris, J. (2009): Observational and model evidence for positive low-level cloud feedback. Science, 325,:460-464.

Chineke, T. C., Shrikant, S.J. and Okechukwu, N., 2010: West African Monsoon: is the August break “breaking” in the eastern humid zone of Southern Nigeria? Climatic Change 103(3-4): 555-570

Cook, E.R, D’Airigo, R.D. and Briffa, K.R.(1998): A reconstruction of the North Atlantic Oscillation using tree-ring chronologies from North America and Europe, Holocen,8, 9-17

Dätwyler C. Abram N. J. Grosjean M., Wahl E. R. Neukom R. (2019) El Niño–Southern Oscillation variability, teleconnection changes and responses to large volcanic eruptions since AD 1000, International Journal of Climatology, 39(5), 2711-2724.

Farmer, G. and Wigley, T.M. (1985): Climatic Trends for Tropical Africa. A research report for the overseas Development Administration. Climate Research Initiative, Norwich, 136

Ferreira, R.N. and Schubert, W.H., (1997): Barotropic aspects of itcz breakdown. J. Atmos. Sci., 54, 261-285.

Giorgeita, M. (2002): Forcing of the quasi-biennial oscillation from a broad spectrum of atmospheric waves. 'Geophys. Res. Lett.' 29: 861-864.

Houghton, J.T., Filho, L.G., Callander, B.A., Harris N., Kattenberg, A. and Maskel, K.(1995): Climate Change 1995-the science of Climate Change: Contribution of INGI to the second Assessment Report of the IPCC, University Press, Cambridge (UK).

Hulme, M. (2001): Climatic perspectives on Sahelian desiccation: 1973-1998. Glob Environ change 11: 19-29.

Nnamchi, H. C., Jianping, L, Fred, K., In-Sik K., Noel, S. K., Ping, C. and Riccardo F. (2015) Thermodynamic controls of the Atlantic Nino. Nature communications 6, 8895.

Maher, B.A, and Hu, M. (2006): A high-resolution record of Holocene rainfall variations from the western chinese loess plateau: Antiphase behaviour of the African/Indian and East Asian summer monsoons, Holocene, 6(3): 309-319.

Olaniran, O.J. (2002): Rainfall Anomalies in Nigeria: The Contemporary understanding (Innuagural lecture) Uni. Of Ilorin 2002. (Accessed: 15:10:2016).

Okeke, F.N., Marengo, J.A. and Nobre, C. (2006): Investigation of El Nino and La Nina effects and the impact of Atlantic sea surface temperatures (SSTs), on precipitation in Nigeria from 1950 to 1992, Surveys in Geophysics, 27, 545-555.

Palmer, T.N. (1986): Influence of the Atlantic Pacific and Indian oceans on Sahel rainfall. Nature, 322: 251-256.

Sang-Wook Y. Cai W., Min S-K., McPhaden M. J., Dommenget D., Collins M.,Ashok K. , An S. Yim B-Y, Kug I-S (2018) ENSO Atmospheric Teleconnections and Their Response to Greenhouse Gas Forcing , Reviews of Geophysics, 56(1), 185-206

Scaife, A.A. (2000): Realistic quasi-biennial oscillations in a simulation of the global climate. 'Geophys. Res. Lett.' 27: 3481-3484.
Serr, Y. and Houze, R. A. (2002): Observations of variability on synoptic timescales in the east Pacific ITCZ. J. Atmos. Sci., 59:1723-1743.

Sukumaran, S. and Frode, S. (2013): use of daily outgoing longwave radiation (OLR) data in detecting precipitation extremes in the tropics. Pp 570-578 Remote Sensing Letters vol.4, issue 6, 2013.

Takahashi, M. (1996): Simulation of the Stratopheric Quasi-Biennial Oscillation using a general circulation model. 'Geophys. Res. Lett: 23: 661-664

Thorncroft, C. and Hodges, K. (2001): African easterly wave variability and its relationship to Atlantic tropical cyclone activity. Journal of Climate. 14, 1166-1179.

Waliser, D.E. and Gautier, C. (1993): A satellite-derived climatology of the ITCZ. J of Climate, 6: 2162-2174.

Wang, C.C., Chou, C. and Lee,W. L. (2010): Breakdown and reformation of the Intertropical convergence zone in a moist atmosphere, J. Atmos. Sci., 67, 1247-1260

Yanjun, Q., Renhe, Z., Tim L., and Min W. (2008): Interactions between the summers mean monsoon and the intraseasonal oscillation in the Indian monsoon region. Geophysical Research letters, http://doi.org/10.1029/2008GL034517

Zablone, O. and Weijin Z., (2012): East African rainfall seasonality based on modulated annual cycle. International J. Phys. Sci. 7(24).

Zheng, X., Li, A., Wan, S., Jiang, F., Kao, S. J., and Johnson, C. (2014), ITCZ and ENSO pacing on East Asian winter monsoon variation during the Holocene: Sedimentological evidence from the Okinawa Trough, J. Geophys. Res. Oceans, 119,. (7), 4410-4429