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Possible Teleconnection Between the Indian Ocean Dipole and the Rainfall Distribution Over Nigeria

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ABSTRACT

The El Nino Southern Oscillation (ENSO) has some level of control over the weather of Nigeria and Africa seasonally, but there has been enough debate as to the extent of the control. ENSO magnitudes do not necessarily translate into impacts in the same direction hence, attempt to investigate possible teleconnections with the Indian Ocean Dipole Mode Index (IODMI) phases over equatorial Indian Ocean that could explain the subsisting gaps in the knowledge of large scale controls on Nigerian Monsoon Seasonal Rainfall (NMSR) pattern is the basis of this paper. Daily rainfall data was obtained from Nigerian Meteorological Agency (NiMet) and Sea Surface Temperatures (SSTs) over the Indian Ocean and the Pacific Ocean were obtained from NOAA site. Pearson, correlation coefficient method, was used to assess the spatial and temporal relationship between the IODMI/NMSR and ENSO/NMSR while the test-of-significance of the correlation results were carried out using two methods- Critical r value and p-value. The results revealed that there is a significant correlation at 10% level between the IODMI and NMSR over the selected stations with contrasting tendencies to increase rainfall at a certain period of the year or decrease it at another period. However, the comparison of the influence of IODMI and ENSO indices negates their effects on NMSR which is dependent on the strength of the correlation, thus with both having a decreasing north to south spatial pattern. Hence, the incorporation of IODMI for the climate prediction of the monsoon rainfall over Nigeria would improve the resilience of different specific sectors of the economy, especially agriculture.

Keywords: ENSO, IODMI, Teleconnection, Rainfall, Climate change

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INTRODUCTION

Rainfall variability and change impacts are already being felt in many parts of the world especially Africa, and are likely to worsen in the future, with clear evidences of changes in climate and weather patterns in many parts of the world based on assessment reports produced by the working groups of the Inter-Governmental Panel on Climate Change (IPCC, 1995; 2001; 2007; 2012; 2013). However, these climate extremes are being felt in Nigeria having resultant effects on increased frequency and intensity of floods/ droughts, delayed onset, early cessation and irregular distribution of rainfall (Ukhurebor and Abiodun, 2018).

The rainfall over the western region of Africa is directly affected by the Atlantic and indirectly by the Indian Ocean. (Preethi, 2015). Among the tropical indo-pacific climate drivers, the canonical El Nino Southern Oscillation (ENSO), (Ramussen and Carpenter, 1983), plays a dominant role in rainfall distribution over various parts of Africa during all the seasons (Janowiak, 1988; Janicot et al., 1998).

The El Niño Southern Oscillation (ENSO) has been recognized as an important manifestation of the tropical ocean-atmosphere-land coupled system. However, the more recently discovered Indian Ocean Dipole (Saji et al., 1999; Behera et al., 1999; Webster et al., 1999) is another important manifestation of the tropical air-sea interaction.

The IOD is defined by the difference in Sea Surface Temperature (SST) between two areas (or poles, hence a dipole) – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia. IOD develops in the equatorial region of Indian Ocean from April to May peaking in October. The climate variability in the Indian Ocean is dominated by the Indian Ocean Dipole (IOD) during September–November, which is related to the inherent ocean and atmosphere coupling processes (Saji et al., 1999; Yamagata et al., 2004; Behera et al., 2006). IOD also known as the Indian Nino, is an irregular oscillation of Sea Surface Temperature (SST) in which the western Indian Ocean becomes alternately warmer and cooler than the eastern part of the ocean. This leads to a coupled ocean-atmospheric phenomena in which convection, winds, SST and thermocline take part actively (Vinayachandran et al., 2007).

It involves an aperiodic oscillation of SST between “positive”, “neutral” and “negative” phases. A positive phase peaks is in September-October (Murtugadde et al., 1999) and has been shown to be associated with greater than average SST and greater precipitation in the western Indian Ocean region with a corresponding cooling of waters in the eastern Indian Ocean, which tends to cause droughts in adjacent land areas of Indonesia and Australia (Saji et al., 1999; Ashok et al., 2001; Behera et al., 2006). On the other hand, the negative phase of the IOD brings about the opposite conditions with warmer water and greater precipitation in the eastern Indian Ocean and cooler and drier conditions in the west. Hence, the negative phase of IOD can be considered as an intensification of the normal state whereas the positive phase of the IOD represents conditions nearly opposite to the normal (Ashok et al., 2001; Vinayachandran et al., 2007).

The positive phase SST anomaly can be accompanied by above average rainfall in eastern Africa and the tropical western Indian Ocean and diminished rainfall over Indonesia and the tropical southeastern Indian Ocean (Saji et al., 1999, Webster et al., 1999, Black et al., 2002). During the positive phase of IOD, unusually strong winds from the east push warm surface water towards Africa, allowing cold water to upwell along Sumatran coast. Strong zonal wind anomalies trapped to the equatorial Indian Ocean are a characteristic of atmospheric feature during such Sea Surface Temperature Anomalous (SSTA) events (Murtugudde et al., 2000).

However, the perception that the Indian Ocean is passive and merely responds to the atmospheric forcing has been shown to be untrue. Hence, in a research work carried out on the relationship between IOD and ENSO using observed sea surface temperature data from 1871-1998 and observed wind data from 1958-1998, by Ashok et al. (2001) discovered Indian Ocean Dipole (IOD) is a physical entity. Thus, the discovery of the IOD and the studies that followed have demonstrated that the Indian Ocean can sustain its own intrinsic coupled ocean-atmosphere processes and is not merely a slave to the events happening over the Pacific Ocean in connection with ENSO (Schott et al., 2001).

It has been observed that El Niño and IOD events account for 30% and 12% of the tropical Indian Ocean SST variability respectively (Saji et al., 1999). It means that both aforementioned phenomena explain most of the tropical Indian Ocean variability. The IOD events have a strong influence on the climate of the immediate neighboring regions such as East Africa and Indonesia (Saji et al., 1999), and also on the Indian summer monsoon region (Ashok et al., 2001), East Asia (Saji and Yamagata, 2002b; Guan et al., 2002), the Mediterranean, Australia, and Brazil (Saji and Yamagata, 2002b).

However, there has also been observed changes in the spatio-temporal distribution of rainfall over Nigeria resulting in changes in onset, cessation, frequency, intensity and duration of rainfall that is influenced by a lot of factors which include; large-scale monsoon circulation, the migration/oscillation of ITD, orography and other forcing functions. Hence, several studies have been carried out on the influence of the forcing functions on rainfall over Nigeria, (Nicholson, 2012; Sylla et al., 2013) but little or no study has considered the influence of the IOD on rainfall in Nigeria.

Having established the facts that ENSO plays a huge role in the determination of the rainfall regime in Africa (Preethi et al., 2015), this study focused on investigating the unexplored influence of IOD SST anomalies on rainfall distribution over Nigeria against the backdrop of the propagation of active mesoscale convective systems (line squall) from the tropical western Indian ocean affecting both the Zonal (east-west) circulation and the meridional (north-south) circulation in the troposphere, as shown in the RGB satellite imagery in Figure 1, that could explain the subsisting gaps in the knowledge of large-scale controls on Nigerian Monsoon Seasonal Rainfall (NMSR) pattern which would improve the resilience of different specific sectors of the economy especially agriculture.

METHODOLOGY

Study Area

The study area as shown in Figure 2 comprises of 16 synoptic stations evenly spread out in Nigeria (Latitudes 4˚–14˚N and Longitudes 3˚–15˚E) within the tropics of African continent, bordered with the Republics of Niger,

Figure 1. Showing mesoscale convective clouds in RGB-Dust Meteosat imagery.**Source**:NIMET, 2015.

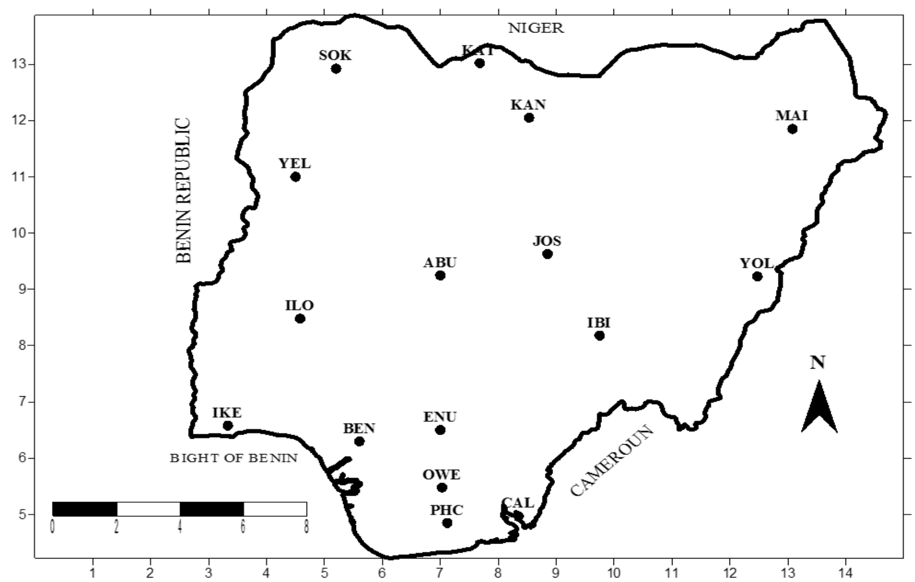

Figure 2. Map showing the selected stations of Nigeria. Source: NIMET, 2018.

Cameroon and Benin and the Gulf of Guinea, to the north, east, west and south respectively.

Due to its location just north of the equator, Nigeria enjoys a tropical climate characterized by the hot and wet conditions associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator (Science Direct, 1977). The climate of Nigeria is characterized by two main seasons; wet (April - October) and dry (November- March), which is as a result from the interplay of the two major wind currents namely: the south-westerly tropical maritime (mT) air mass and the north-easterly tropical continental (cT) air mass (Weli et al., 2016). Rainfall in Nigeria falls within a distinct period (Adeniyi et al., 2009) which vary from the northern part to the southern part of the country because of their relative distances from the Atlantic Ocean. Rainfall starts earlier and ceases late in the southern parts while it starts later and ceases earlier in the north. The onset month in the south varies between March and April while the cessation month is October. In the North, however, rainfall starts in May and ends in September (Adeniyi, 2014). There is rainfall occurrence all over the country from June to September. However, in August, there is a period of little dry season in the southern part of the country (Adejuwon and Odekunle, 2006).

Data Analysis

The rainfall database consisting of sixteen (16) synoptic Nigeria stations as shown in Figure 2, has 33 years of

Table 1: Three months moving average correlation analysis results between MQI and DMI during monsoon season for 1983-1993.

Stns	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
ABU	-0.6	0.7	0.6	0.7	-0.8	-0.7	-0.4	0.6	-0.5	0.0	-0.8
BEN	-0.9	-0.4	-0.2	-0.3	0.1	0.1	0.4	0.0	-0.7	0.9	-0.4
CAL	-0.8	0.7	-0.2	0.0	-0.1	-0.6	0.3	-0.2	-0.6	0.9	-0.8
ENU	-0.9	-0.1	0.8	0.7	-0.7	-0.7	0.2	0.6	-0.5	0.9	-0.7
IKE	0.1	-0.4	-0.3	-0.1	-0.4	0.1	0.5	0.5	-0.7	-0.2	-0.1
ILO	-0.2	-0.4	0.9	0.7	-0.9	0.1	-0.5	0.7	-0.5	0.5	-0.8
JOS	-0.8	-0.6	-0.1	0.6	-0.9	-0.5	-0.2	0.7	-0.7	-0.1	-0.7
KAN	-0.4	0.7	-0.3	0.4	0.6	-0.8	-0.8	-0.8	-0.7	0.8	0.6
KAT	-0.7	-0.6	-0.3	-0.6	-0.2	-0.9	-0.8	0.7	-0.8	0.6	-0.4
MAI	-0.6	0.3	-0.3	-0.4	0.6	-0.9	-0.6	0.6	-0.7	-0.3	-0.7
OWE	-0.4	-0.4	0.8	0.5	-0.8	0.0	0.3	-0.1	-0.5	0.7	-0.1
PHC	-0.3	-0.1	0.7	0.4	-0.7	0.1	0.5	-0.1	-0.6	0.5	0.5
SOK	-0.4	-0.7	-0.6	-0.6	-0.9	-0.8	0.6	-0.9	-0.8	-0.5	-0.7
YEL	-0.8	0.5	0.4	0.4	-0.9	0.0	0.5	0.7	-0.4	-0.5	0.6
YOL	-0.1	0.4	0.6	0.8	-0.7	0.1	0.6	0.6	-0.6	0.7	-0.6
IBI	-0.8	-0.4	0.5	0.7	-0.8	-0.6	-0.6	0.6	-0.6	0.7	0.6

Source : Author's Analysis, (2018). **Note:** The red color depicts rainfall scenario while the blue color depicts drought scenario.

daily rainfall records covering the period from 1983-2015 were obtained from the Nigerian Meteorological Agency. Moisture Quality Index (MQI), (Usman, 2000) was the rainfall derivative that was used for the analysis.

$$MQI = \frac{r_{mm} \times Nbi}{{R_i}^2} \qquad \text{Equation 1}$$

Where
I= Year identifier
rmm= Highest weekly rainfall total for the month
R= Monthly rainfall total
Nb= Number of 'breaks' in rainfall per month. A break is taken as any pentad period with less than 5mm of rain.
Furthermore, Monthly SSTs over Indian Ocean (IODMI) and over Pacific Ocean (ENSO) were obtained from NOAA website: http://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/DMI and http://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Nino34/ respectively for the same study period.
The three months moving average of monthly MQI, IODMI and ENSO data was done specifically during the Monsoon Period - MAM (March, April, May), AMJ (April, May, June), MJJ (May, June, July), JJA (June, July, August), JAS (July, August, September), ASO (August, September, October) and SON (September, October, November). So for any of the given period j, the moving average was calculated using these formulae respectively;

$$MQI_j = \frac{1}{3}\sum_{i=1}^{3} MQI_i \qquad \text{Equation 2}$$

$$DMI_j = \frac{1}{3}\sum_{i=1}^{3} DMI_i \qquad \text{Equation 3}$$

$$ENSO_j = \frac{1}{3}\sum_{i=1}^{3} ENSO_i \qquad \text{Equation 4}$$

Thereafter, Pearson Coefficient correlation was used to quantify the teleconnection between the Nigerian Monsoon Seasonal Rainfall (NMSR) with the IODMI and ENSO respectively using

$$r_{xy} = \frac{{}^{1}/_{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{{}^{1}/_{n}\sum_{i=1}^{n}\{(x_i - \bar{x})^2 . {}^{1}/_{n}\sum_{i=1}^{n}\{(y_i - \bar{y})^2\}}} \qquad \text{Equation 5}$$

Where x is MQI, DMI and ENSO.
However, P-value and Critical Value r methods were used to test the significance of the Pearson correlation between NMSR/IODMI and NMSR/ENSO at 10% level based on these hypotheses
H_0= "the correlation coefficients is not significant at the 10% significant level."
H_1= "the correlation coefficients is significant at the 10% significant level."
Finally, spatial pattern analysis using Quantum GIS (QGIS) software, Bar Charts and Tables were used to show the nature of the teleconnection between the NMSR/IODMI and NMSR/ENSO.

RESULTS AND DISCUSSION

Analysis was carried out to assess the relationship between IODMI and rainfall during monsoon seasons starting with MAM, AMJ, MJJ, JJA, JAS, ASO and SON over each station. The values of the Pearson correlation coefficient analysis was computed using equation 5 and presented in three periods (1983-1993), (1994-2004), (2005-2015) as shown in Tables 1 to 3. However, the red and blue colored results showed the correlation coefficient ≥ +0.5 or -0.5 respectively that have some significant relationship.

Table 2: Three months moving average correlation analysis results between MQI and DMI during monsoon season for 1994-2004.

Stns	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ABU	-0.4	-0.3	0.6	0.5	-0.4	0.0	-0.9	-0.3	0.7	-0.8	0.5
BEN	0.0	-0.6	-0.3	0.0	-0.3	-0.4	-0.9	-0.5	0.4	-0.5	0.4
CAL	-0.1	-0.1	-0.6	-0.5	0.6	-0.9	-0.2	0.0	0.1	-0.4	0.3
ENU	-0.1	-0.2	0.8	0.5	-0.5	0.0	0.1	-0.6	0.2	-0.7	0.0
IKE	0.8	-0.2	-0.7	-0.4	-0.1	0.1	-0.9	0.0	-0.2	0.8	0.4
ILO	0.1	-0.6	0.6	0.6	-0.7	-0.1	-0.5	0.2	0.6	-0.2	0.5
JOS	0.1	0.0	0.1	0.6	0.6	-0.2	0.0	-0.6	-0.3	-0.2	0.7
KAN	-0.9	-0.6	-0.5	0.2	0.3	0.1	-0.7	0.7	-0.7	-0.8	0.4
KAT	-0.8	-0.7	-0.8	0.3	-0.3	-0.9	0.0	0.7	-0.7	-0.8	0.8
MAI	-0.8	-0.7	0.7	0.5	0.0	-0.4	-0.5	0.9	-0.5	-0.9	0.8
OWE	-0.5	-0.2	-0.6	0.1	-0.5	-0.4	-0.1	-0.5	-0.6	0.2	0.0
PHC	-0.3	-0.4	-0.3	-0.2	-0.3	-0.1	-0.7	-0.4	0.0	-0.3	0.0
SOK	0.5	-0.7	-0.8	-0.5	0.2	-0.2	-0.1	0.9	-0.2	-0.7	0.8
YEL	-0.4	-0.6	0.7	-0.4	-0.5	-0.8	0.0	-0.7	-0.5	-0.5	0.6
YOL	0.1	-0.6	-0.9	0.6	-0.5	-0.3	-0.7	-0.8	-0.6	-0.8	0.6
IBI	0.1	-0.5	0.6	0.3	0.8	-0.7	-0.6	-0.7	0.0	-0.3	0.8

Source : Author's Analysis, (2018). **Note:** The red color depicts rainfall scenario while the blue color depicts drought scenario.

Table 3: Three months moving average correlation analysis results between MQI and DMI during monsoon season for 2005-2015.

Stns	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABU	-0.3	0.5	0.1	-0.9	-0.1	-0.1	0.4	-0.2	0.6	0.8	0.7
BEN	-0.3	0.5	-0.5	-0.5	0.4	0.7	0.2	-0.6	0.6	0.5	0.3
CAL	-0.8	-0.9	-0.5	-0.7	0.3	0.7	-0.3	-0.6	0.4	0.5	-0.9
ENU	-0.2	0.6	0.1	-0.8	0.4	0.0	0.4	-0.6	0.6	0.7	-0.8
IKE	-0.8	-0.2	-0.6	-0.2	-0.8	0.0	-0.3	0.6	-0.1	0.3	0.2
ILO	-0.3	-0.5	0.1	-0.9	0.1	-0.5	0.0	-0.5	0.7	0.8	-0.6
JOS	0.5	-0.5	0.5	-0.7	0.1	0.7	0.1	0.3	0.7	-0.1	-0.8
KAN	0.8	0.8	0.5	-0.4	0.1	0.5	-0.7	0.4	0.7	0.7	0.6
KAT	-0.1	0.7	-0.6	-0.8	-0.2	0.6	0.7	0.4	0.7	0.9	0.7
MAI	0.7	-0.8	-0.8	-0.2	0.4	0.6	0.2	0.3	0.8	-0.3	-0.5
OWE	-0.3	0.6	-0.1	-0.2	0.5	-0.3	0.1	-0.5	0.6	0.8	-0.5
PHC	-0.3	0.6	-0.5	-0.3	0.2	-0.1	0.2	-0.4	0.2	0.7	0.3
SOK	-0.5	0.7	-0.7	-0.8	0.1	0.7	0.8	0.5	0.6	0.8	-0.7
YEL	0.5	-0.7	0.6	-1.0	0.5	-0.3	-0.8	0.0	-0.6	0.8	-0.8
YOL	-0.1	-0.3	0.0	-0.8	0.0	0.8	-0.7	0.1	-0.6	-0.1	-0.9
IBI	0.1	-0.6	0.1	-0.5	0.4	-0.7	-0.8	0.1	0.6	0.7	0.0

Source : Author's Analysis, (2018). **Note:** The red color depicts rainfall scenario while the blue color depicts drought scenario.

Tables 1 to 3 agrees with the fact that the Pearson coefficient correlation analysis shows very strong significant values using the 3-months moving average during the monsoon period (Black et al., 2003; Omay, 2015). In other words, it indicates that there is an existence of a relationship between the Nigerian Monsoon Seasonal Rainfall (NMSR) and Indian Ocean Dipole Mode Index (IODMI).

It also shows that years with dominant positive correlation were 1984, 1985, 1986, 1990, 1992, 1996, 1997, 2004, 2006, 2010, 2013 and 2014 while years with dominant negative correlation were 1983, 1987, 1988, 1991, 1993, 1995, 1998, 1999, 2000,2001,2002, 2003, 2007, 2008, 2011, 2012 and 2015.

However, various studies; Saji et al., 1999, Yamagata et al., 2004 and from Bureau of Meteorology (BOM) website-www.bom.gov.au/climate/iod/, agreed to some positive and negative IOD years to cover the study period as follows; Positive IOD years (1983, 1991, 1994, 1997, 2003, 2006, 2007, 2008, 2012, 2015) while Negative IOD years (1985,1989, 1990, 1992, 1996, 1998, 2005, 2010). Therefore, the comparison of the NMSR and IODMI Pearson correlations during the positive and negative IOD years as shown in Table 4, reveals that there is a negative correlation between NMSR and IODMI during some Positive IOD years (1983, 1991, 2003, 2007, 2008, 2012 and 2015), while there is a positive correlation between NMSR and IODMI during some Negative IOD years (1985, 1986, 1990, 1992, 1996 and 2010), hence, the contrasting tendencies to increase rainfall at a certain period of the year or decrease it at another period.

Table 4 also shows that the tendency of IODMI to reduce rainfall was expected during Positive IOD years while its tendency to increase rainfall were expected during Negative IOD years; however, this was also observed for all season (MAM, JJA and SON) in South Sudan (Omay,

Table 4: Showing the comparison of the (pIOD) years/Negative correlation years and (nIOD) years/Positive correlation years.

Positive (IOD) Years	Negative Correlation Years	Negative (IOD) Years	Positive Correlation Years
1983	1983	1985	1985
	1987		1986
	1988	1990	1990
1991	1991	1992	1992
	1995	1996	1996
	2000		1997
2003	2003		2004
2007	2007		2006
2008	2008	2010	2010
2012	2012		2013
2015	2015		

Source: Author's Analysis, (2018).

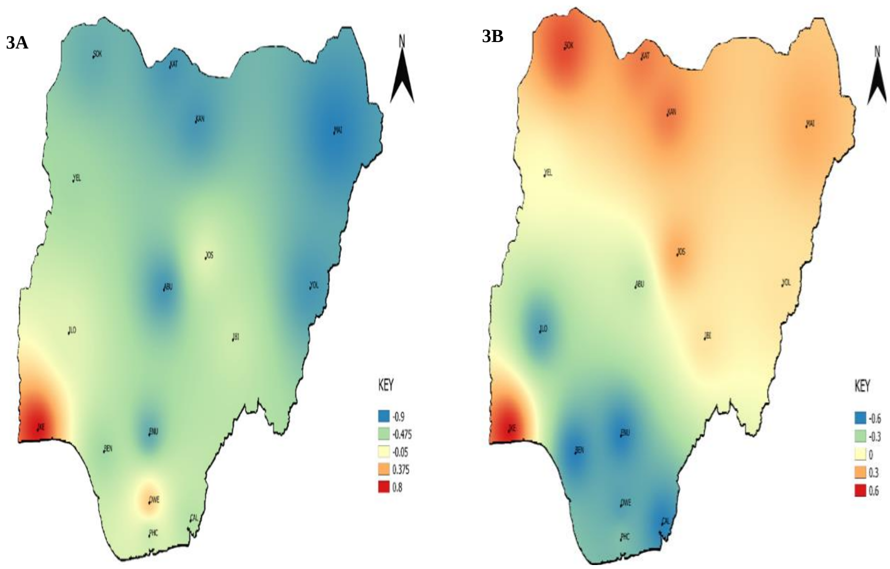

Figure 3: Spatial Pattern of contrasting decreased and increased rainfall during Positive IOD in 2003 and 2012 respectively.

2015).

Thus, the spatial pattern correlation analysis revealed a better nature of the contrasting tendencies of IODMI to either increase or decrease rainfall over the study area at certain periods of the Positive years (2003 and 2012) and Negative years (1990 and 2010) respectively, as shown in Figures 3 and 4.

Moreover, Figure 3A shows the negative correlation between the NMSR and IODMI during the positive IOD in 2003, with observed widespread rainfall decrease which was also in agreement with the first quarter of Standardized Precipitation Index (SPI) hydrological bulletin that showed drought incidences in most synoptic stations in 2003 (Bello, Unpublished data). Hence, the contrasting effects during Positive IOD in 2012 may not be unconnected to the high incidence of rainfall that translated into a widespread flooding in 2012 amidst decreased rainfall in southern Nigeria as shown in Figure 3B. However, it was termed the worst in 40yrs by National Emergency Management Agency, (NEMA) which affected 30 Nigeria's 36 states that killed 363 people and displaced 2.1 million. (Reuter: November 5, 2012).

Thus, the positive correlation between the NMSR and IODMI during the 1990 negative IOD in Figure 4A, showed widespread rainfall increase that was in agreement with the reports of the observed 1990 flooding that took place in April 1990 which destroyed almost all the structures, worth over 2million naira and claimed more than 30 lives, damaged 100 houses, and over 15,000 rendered homeless near the major rivers in the city of Ibadan in the southwest region (Olawumi et al., 2015).

However, the contrasting effect of Negative IOD in 2010

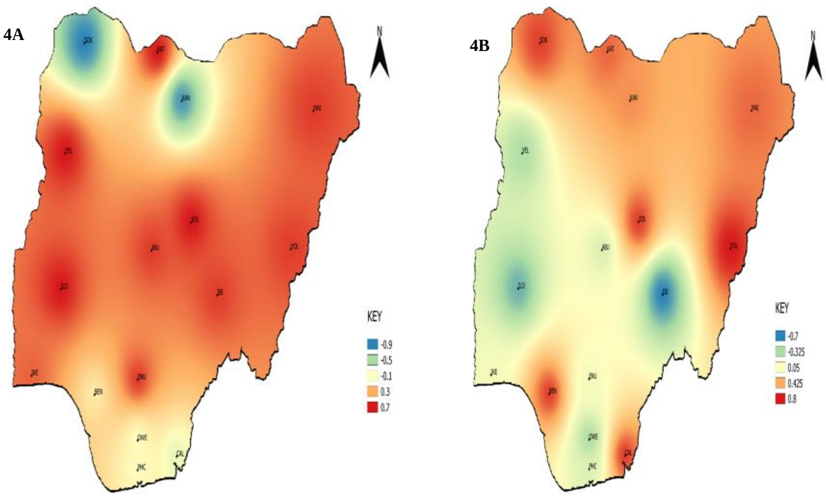

Figure 4:Spatial Pattern of contrasting increased and decreased rainfall during Negative IOD in 1990 and 2010 respectively.

Table 5. Years with significant Pearson correlation between MQI and DMI during monsoon period at 10% level of significance.

NORTHERN STATIONS	POSITIVE CORRELATION YEARS	NEGATIVE CORRELATION YEARS	No. of Yrs. with non- Sig. r from 1983-2015	No. of Yrs. with Sig. r from 1983-2015	No. of Yrs. with Sig. r coefficient (%) from 1983-2015
SOKOTO	2001,2004,2006,2010,2011, 2014	1984,1987,1988,1990,1991,1993,1995,1996, 2003,2007, 2008,2015	15	18	54
KANO	1984,1992,2001,2005,2006, 2013, 2014	1988,1989,1990,1991, 1994,2000,2002, 2003, 2011	17	16	48
KATSINA	1990,2001,2004,2006,2011, 2013, 2014	1988,1989,1991,1994, 1996,1999,2002, 2003, 2008	17	16	48
MAIDUGURI	1996,2001,2004,2005,2013	1988,1991,1993,1994, 2003,2006,2007	21	12	36
YELWA	1990,1996,2014	1983,1987,1999,2001, 2006,2008,2011, 2015			33
JOS	1990,2004,2010,2013	1983,1987,1991,1993, 2008,2015	23	10	30
YOLA	1986,1992,2010	1996,2001,2003,2008, 2001,2015			27
IBI	1992,1998,2004,2014	1983,1987,1999,2011	25	8	24
SOUTHERN STATIONS	**POSITIVE CORRELATION YEARS**	**NEGATIVE CORRELATION YEARS**	**No. of Yrs. with non- Sig. r from 1983-2015**	**No. of Yrs. with Sig. r from 1983-2015**	**No. of Yrs. with Sig. r coefficient (%) from 1983-2015**
ENUGU	1985,1986,1992,1996, 2014	1983,1986,1987,1988, 2003.2008,2015	22	11	33
CALABAR	1984,1992,2010	1983,1993,1999,2005, 2006,2008,2015	23	10	30
ILORIN	1985,1986,1990,2014	1987,1993,1998,2008	25	8	24
IKEJA	1994,2003	1991,1996,2000,2005, 2009	26	7	21
BENIN	1992,2010	1983,1991,2000	28	5	15
OWERRI	1985,1992,2014	1987	29	4	13
PORTHARCOURT	1985,2014	1987,2000	29	4	12

Source: Author's Analysis, (2018).Correlation is significant at the 10% level (2-tailed).

Table 6. Shows how the Positive IOD and ENSO negates their effects in 1983, 1994, 1997 and 2003. Negative IOD negates ENSO effects in 1990.

Stns	Positive IOD -1983	ENSO - 1983	Negative IOD -1990	ENSO-1990	Positive IOD-1994	ENSO-1994	Positive IOD-1997	ENSO-1997	Positive IOD-2003	ENSO-2003
ABU	-0.6	-0.3	0.6	-0.4	-0.4	0.2	0.5	0.4	-0.8	0.3
BEN	-0.9	0.4	0.0	0.7	0.0	0.6	0.0	-0.2	-0.5	0.6
CAL	-0.8	0.6	-0.2	0.8	-0.1	0.6	-0.5	-0.7	-0.4	0.6
ENU	-0.9	0.7	0.6	-0.4	-0.1	0.6	0.5	0.3	-0.7	0.0
IKE	0.1	-0.9	0.5	-0.6	0.8	0.4	-0.4	-0.3	0.8	0.3
ILO	-0.2	-0.6	0.7	-0.5	0.1	0.7	0.6	0.5	-0.2	0.8
JOS	-0.8	0.8	0.7	-0.3	0.1	0.8	0.6	0.5	-0.2	0.7
KAN	-0.4	0.8	-0.8	-0.1	-0.9	-0.8	0.2	0.0	-0.8	0.2
KAT	-0.7	0.9	0.7	-0.2	-0.8	-0.5	0.3	0.2	-0.8	-0.5
MAI	-0.6	0.9	0.6	-0.3	-0.8	-0.6	0.5	0.3	-0.9	-0.3
OWE	-0.4	-0.6	-0.1	0.8	-0.5	0.2	0.1	-0.2	0.2	0.9
PHC	-0.3	-0.6	-0.1	0.8	-0.3	0.4	-0.2	-0.4	-0.3	0.6
SOK	-0.4	0.9	-0.9	0.3	0.5	0.9	-0.5	-0.7	-0.7	0.3
YEL	-0.8	0.8	0.7	-0.4	-0.4	0.3	-0.4	-0.6	-0.5	0.6
YOL	-0.1	-0.8	0.6	-0.4	0.1	0.7	0.6	0.5	-0.8	-0.5
IBI	-0.8	0.8	0.6	-0.4	0.1	0.7	0.3	0.2	-0.3	0.6

Source : Author's Analysis, (2018). **Note:** The red color depicts rainfall scenario while the blue color depicts drought scenario.

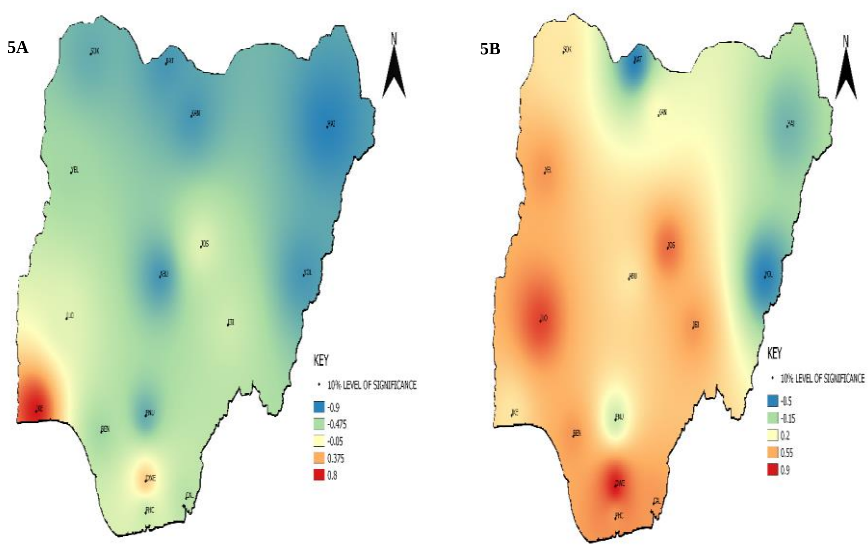

Figure 5: Spatial Pattern of the reverse effects of relationship between Positive IOD and ENSO on NMSR in 2003.

shown in figure 4B, cannot be unrelated to the flood incidence that occurred in 2010 Usmanu Danfodiyo University Sokoto and other parts of the state (Magami et al., 2014) and also in Katsina which claimed 44 people with 20 missing and destroyed more than 500 houses.

Furthermore, the test of the significance of the Pearson correlation coefficient (r) between the NMSR and IODMI was done using two methods namely; P-value and Critical r value.

However, both methods showed that the correlation is significant at 10% level in some years within the study period with most of the stations in the northern part of the country for instance, Sokoto, Kano, Katsina, Maiduguri, Yelwa, Yola, Jos, Abuja and Ibi while the stations like Enugu, Calabar, Ilorin, Ikeja, Benin, Owerri, Port Harcourt, over the southern part of the country had fewer significant correlations as shown in Table 5.

Furthermore, the comparison of the nature of the teleconnection between NMSR with IODMI and ENSO indices showed that Positive IOD index negated the effects of ENSO which resulted in increased Nigerian Monsoon Seasonal Rains in 1983, 1994, 1997 and 2003 as shown in Table 6.

However, it agrees with the studies of (Behera et al.,1999; Webster et al., 1999) where a Positive IOD index often negated the effect of ENSO that resulted to

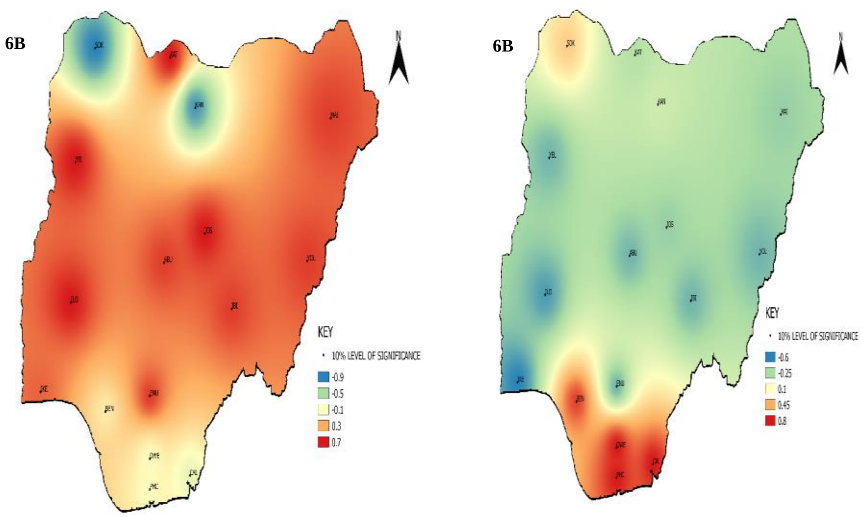

Figure 6: Spatial Pattern of the reverse effects of relationship between Negative IOD and ENSO on NMSR in 1990.

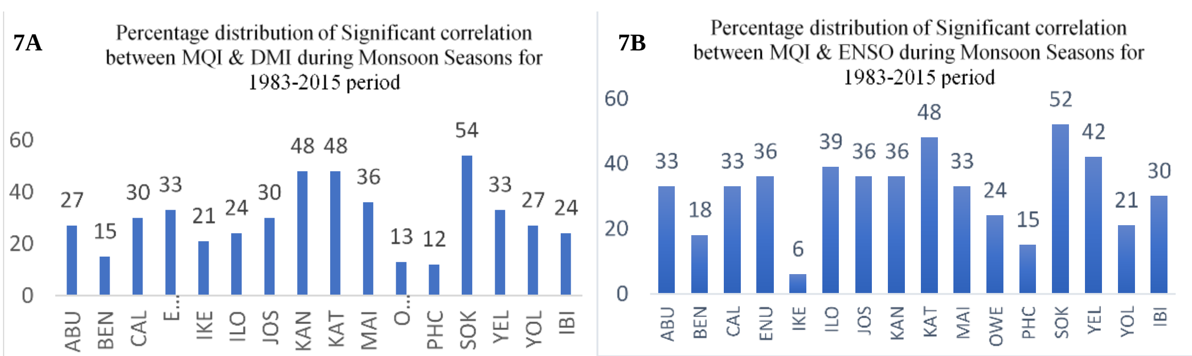

Figure 7: Shows the percentage distribution of significant correlation between MQI&DMI **(A)** and MQI&ENSO **(B)** during the Monsoon Seasons for 1983-2015 period.

increased monsoon rains in some ENSO years like the 1983 and 1994.

Meanwhile, 2003 Positive IOD year coincided with the Negative correlations between the NMSR/IODMI while in the same year the Pearson correlation coefficient between the NMSR/ENSO was positive. Hence, Positive IOD = Negative Correlation while ENSO of the same year = Positive Correlation as shown in table 6. However, this is supported with Figures 5A and 5B which shows the spatial pattern of the contrasting relationship of IODMI and ENSO indices with NMSR in 2003.

In contrast to those mentioned above, during the 1990 Negative IOD year it coincided with the Positive Correlations between the NMSR/IODMI while in the same year, the Pearson correlation coefficient between the NMSR/ENSO were weaker Positive correlations as shown in Table 6. Hence, Negative IOD = Positive Correlation while ENSO of the same year = Negative Correlation, however, this is supported with Figures 6A and 6B that shows the spatial pattern of the contrasting relationship of IODMI and ENSO indices with NMSR in 1990.

Interestingly, this suggests that in 2003, the positive correlation between NMSR and ENSO resulted to negative correlation with the IODMI. Therefore, this means that the higher correlation between NMSR/ENSO was responsible for the reduced rainfall over the most parts of the selected synoptic stations during the 2003 Positive IOD year as shown in Figure 3A.

However, in 1990 the weaker positive correlation between the NMSR and ENSO resulted to a positive correlation with the IODMI, hence the weaker positive correlations ENSO/NMSR was responsible for the high rainfall on

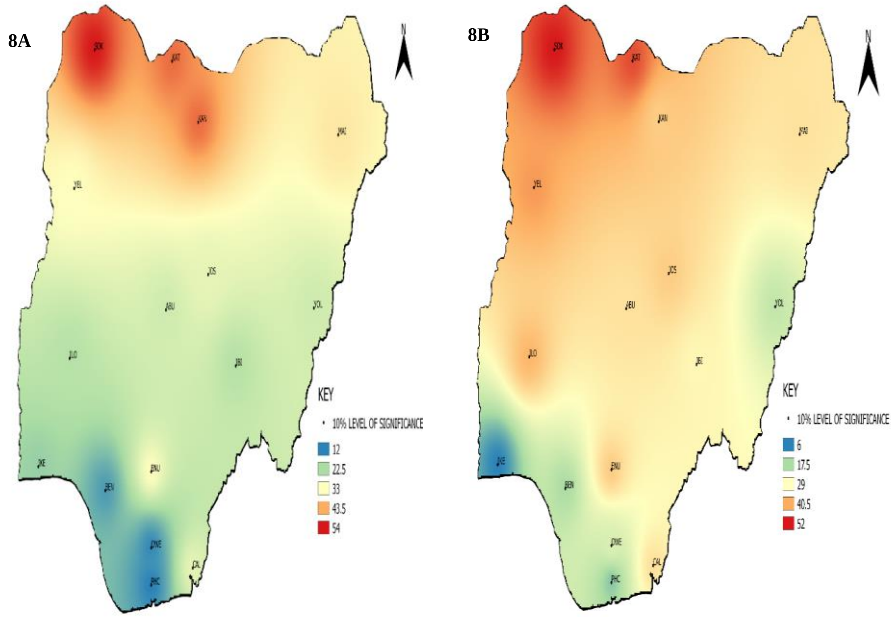

Figure 8: Spatial Correlation Coefficient between the NMSR/IODMI and NMSR/ENSO significant at 10% level from 1983-2015.

most parts of the selected synoptic stations as shown in Figure 4A.
This is in agreement with the study of Ashok et al. (2001), that whenever the ENSO- Indian Summer Monsoon Rainfall (ISMR) correlation is low (high) the IOD-ISMR correlation is high (low.) where for instance, in 1990 a weak correlation between the Indian Monsoon and ENSO resulted to an intense and frequent Dipole Mode events.
Furthermore, the research shows that Pearson correlation coefficient between IODMI and NMSR were significant at 10% level with more percentage of significance over the stations in the northern part compared to stations in the southern part of the country as shown in the bar chart and spatial pattern map in Figures 7A and 8A.
Conversely, the Pearson correlation coefficient between ENSO and NMSR were significant at 10% level with a strong and broad percentage of significance across all the stations except for Lagos that had the lowest significant correlation as shown in Figures 7B and 8B. The low significant correlation over Lagos is in agreement with the study of Nnawuike (2016) that revealed that ENSO has no significant relationship with the rainfall over southwestern Nigeria.

CONCLUSION

This study to a great extent found the existence of a teleconnection between the Nigerian Monsoon Seasonal Rainfall, (NMSR) and the Indian Ocean Dipole based the Pearson correlation coefficient results that were tested by two different tests of significance (Critical r and p-Value) and were found to be significant at 10% over the selected synoptic stations in Nigeria over the 33years period (1983-2015).
This study has also further proven that the El Nino Southern Oscillation (ENSO) which is one of the major indices used by Nigerian Meteorological Agency (NiMet) for weather and climate predictions may not be the only indices that have teleconnection with the weather outcomes over Nigeria.
However, the analysis showed that the impact of IODMI is felt more over the Sahel region of Nigeria, perhaps with ENSO impact in dominance over the selected stations in Nigeria, especially over the Sahel region. Hence, the results showed similar pattern of influence of IODMI and ENSO on NMSR to decrease from north to south over selected stations in Nigeria.

RECOMMENDATION

This study examined only the teleconnection between sea surface temperature (SSTs) over Indian Ocean and equatorial Pacific Ocean with the Nigerian Monsoon Seasonal Rainfall. Hence, further research should include other indices affecting monsoon rainfall over Nigeria for instance Outgoing Long-wave Radiation (OLR), winds and pressure systems etc.
Government and relevant agencies like NiMet, Nigerian

Hydrological Services Agency (NIHSA), National Emergency Management Agency (NEMA) etc. should work harmoniously to enhance the resilience of Nigerian communities through mainstreaming and incorporating Indian Ocean SSTs as part of the weather components in weather monitoring and forecasting especially for the seasonal rainfall prediction (SRP) to various weather-dependent sectors like agricultural production and food security sector and in prevention/ mitigation of weather related hazards like flooding, drought etc. especially in this era of climate change.

The incorporation of SSTs over the Indian Ocean would improve the seasonal forecast of Sahelian rainfall of Nigeria and for the better understanding of multi-decadal modulations of global inter-annual teleconnection between Nigerian Monsoonal Seasonal Rainfall and IODMI.

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