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RECENT MONSOON RAINFALL CHARACTERISTICS OVER THE NIGER DELTA REGION OF NIGERIA: A CASUAL LINK

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Abstract: This study presents the inter-annual variability of rainfall over 6 locations spread across the Niger Delta region of Nigeria (4.15°N - 7.17°N, 5.05°E - 8.68°E) from 1981 to 2004. The monthly rainfall variability from rain gauge only datasets of the Nigerian Meteorological Agency (NIMET), rain gauge interpolated datasets of the Climatic Research Unit (CRU) Time Series (TS) version 3.20 and the interpolated datasets from rain gauge, model and satellite estimates of the Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) were analyzed. Also the relationship between the Ocean Nino Index (ONI) and the South Atlantic Ocean Dipole Index (SAODI) which are rainfall driving mechanisms and the rainfall variability over the region has been investigated. The objectives are to present the rainfall variability patterns across the locations within the region as well their annual- and wet season- interannual rainfall variability indexes, and to investigate the links between the ONI and the SAODI and the monthly rainfall variability over the region. The results show increases in the trends of rainfall variability patterns over the region both at the various locations and on the areal average of rainfall whereas it has been noted that the rainfall variability on small areas can be over- or under- estimated when considering large areal averages. However the interannual variability of the monthly rainfall anomaly over the region is not strongly linked to both the ONI and the SAODI, which is an indication that the mechanism(s) driving rainfall variability over the region is yet to be understood.

Keywords: Niger Delta, monsoon, rainfall anomaly, variability, index, trend.

1. Introduction

The West African monsoon, which is associated with tropical seasonal reversals in both atmospheric circulation and its associated rainfall, has experienced significant variability over the recent years. These seasonal reversals are influenced by the position of the Inter-Tropical Convergence Zone (ITCZ) or the Inter-Tropical Discontinuity (ITD) as it shifts from a quasi-stationary location south of the West African region at 5°N, moving northwards, to another quasi-stationary location at 10°N from May-June to July-August (Peter and Tetzlaff, 1998; Sultan and Janicot, 2000). The ICTZ shifts northward with the wet tropical maritime

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air mass (causing the rainy season) from the Gulf of Guinea at the low levels of the atmosphere through the region and recedes southward with the dry tropical continental air mass (causing the dry seasons). Hence the West African monsoon accommodates the primary rainfall producing systems during the summer months as well as provides more than 75% of the annual rainfall within the region (Omotosho and Bayo, 1985; Webster *et al.*, 1998; Afiesimama *et al.*, 2006; Abiodun *et al.*, 2008). But the variation of the rainfall is the most unique characteristic of the West African monsoon as it occurs in both its seasonal duration and intensity from one year to another as well as on small scales from place to place.

A number of studies have been carried out on the variability of the West African monsoon whereas the patterns and the interannual variability of the attendant rainfall over the region have been investigated on different spatial and temporal scales (Lamb, 1978; Motha *et al.*, 1980; Nicholson, 1981 and 1993; Rowell *et al.*, 1995; Mohr, 2004). Moreover, some studies have attempted to identify the reasons for the rainfall variability over the region. In one of such studies, Eltahir and Gong (1996) proposed that a large gradient of boundary layer entropy over the continent would force a strong monsoon circulation resulting in a relatively wet rainy season. In some other studies, it was shown that the Madden Julian Oscillation (MJO) significantly modulates convection in the West African monsoon intraseasonal rainfall variation, accounting for 30% of the 30-90-day rainfall variance over the region in summer (Maloney and Shaman, 2008). Evident from the linear combination of four oceanic modes, it was observed that some specific near global Sea Surface Temperature Anomalies (SSTA) patterns were sufficient to induce coherent changes in the atmospheric dynamics and significant rainfall impacts in West Africa (Fontaine *et al.*, 1998) and this is further highlighted by Janicot *et al.* (1998) who established that the West African monsoon dynamics was controlled by highly positive SSTA in the Gulf of Guinea that is linked to SSTA in the eastern equatorial Pacific, leading to rainfall deficit in the Sahel and positive rainfall anomalies in the Guinea Coast region. In addition, Nicholson and Webster (2007) opined that the inertial instability in the eastern tropical Atlantic contributes to producing wetter conditions in the Sahel. Further to this is the observation that El Nino Southern Oscillation (ENSO) events tend to result in enhanced north easterlies or reduced monsoon flow, which is coupled to the weakened upper easterlies over West Africa, hence influencing dry conditions over the region close to the surface position of the ITCZ (Camberlin *et al.*, 2001). Thus over the second half of the twentieth century, the main influence of ENSO on the interannual variability of the Sahelian rainfall occurs during the developing phase of ENSO or marginally during the decay of some long lasting La Nina (Joly and Voldoire, 2009). Nnamchi and Li (2011) in evaluating the influence of South Atlantic Ocean Dipole (SAOD) on the interannual variability of West African rainfall deduced that the positive phase of the SAOD was associated with positive rainfall anomalies in excess of 40mm per month over most locations at the Guinea Coast.

On the variation of rainfall over West Africa at small study areas, a number of studies in the past two decades have been carried out on the patterns and variation of rainfall over Nigeria at different temporal scales (Adefolalu, 1986; Olaniran and Sumner, 1990; Anyadike, 1992; Odekunle *et al*., 2005; Chineke *et al*., 2010). In more recent times, Oguntunde *et al*. (2011) and Machiwal and Jha (2012) linked the rainfall variation over Nigeria to the distinctive feature of the Quasi-Biennial Oscillation (QBO), ENSO and sunspot cycles, which are associated to the solar cycles that has 22 years periodicity (Moussas et al., 2005). However, the aforementioned studies did not include an investigation of rainfall variations and their relationship with the monsoon rainfall driving mechanisms on small areas.

This work presents the recent interannual variability of rainfall over the Niger Delta region of Nigeria using a maximum period of 24 years (1981 to 2004) monthly rainfall of rain gauge datasets from Nigerian Meteorological Agency (NIMET), the gridded datasets from Climatic Research Unit (CRU) Time Series (TS) version 3.20 and Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP). The paper investigates how this rainfall variation relates to the Ocean Nino Index (ONI) and the SAOD Index (SAODI). Rainfall is an important element for agriculture, economy, food security and water management within this region (Cassel-Gintz et al., 1997). The objectives of this study is to present the rainfall variability patterns across locations within the Niger Delta region as well the annual- and wet season- interannual rainfall variability indexes, and to investigate the relationship of the ONI and the SAODI on the monthly rainfall variability over the region. Section 2 of this paper presents a description of the study area while section 3 describes the data sources for the study. In section 4 the methods utilized in the treatment and analysis of the acquired data is discussed while section 5 presents the results of the study and discussions. Section 6 is the conclusion.

2. Study Area

Figure 1 shows the Niger Delta region, located within the tropical rainforest climate zone (4.15°N - 7.17°N, 5.05°E - 8.68°E) along the Lower Guinea Coast. It extends over about 70,000km^2 and constitutes about 7.5% of Nigeria's land mass. The region has the heaviest rainfall within West Africa with an annual rainfall totals varying from 2400mm to 4000mm (Anyadike, 1992; Nicholson, 2003). The region has the largest mining activity (petroleum) within the country with about 70% of its population living in rural areas and having rain fed agriculture as their major means of livelihood. The area is influenced by the localized convection of the West African monsoon with less contribution from the mesoscale and synoptic system of the Sahel (Ba *et al*., 1995). The monsoon rainy (wet) season over the area starts in May, following the seasonal northward movement of the ITCZ, with cessation in October (Fontaine *et al*., 1998; Druyan *et al*., 2010; Xue *et al*., 2010). The rain-gauge locations are at Akure, Benin City, Calabar, Eket, Owerri and Port Harcourt as shown in Table 1. The locations apart from being of geographically spread across the region, has the longest history of data as well as minimal gaps due to missing data.

3. Data

Observed monthly rain gauge data (mm) were obtained from NIMET for 6 stations under its operation for the periods shown in Table 1. Although with its own uncertainty (not shown), the data is the most reliable ground observation data source that exists within the region. The study covers the period 1981 to 2004 when satellite data could be used in combination with the 14579 rain gauges in the CRU dataset to 14579 gauges in 1981. Furthermore, due to gaps in the available NIMET data prior to 1981 and sparse data at Benin City, Calabar and Owerri after 2004 it has been necessary to select the period 1981 to 2004 for the study.

The CRU TS 3.20 datasets contains data from rain gauges interpolated on a high-resolution of 0.5°x0.5° global grids (approximately 50km) that extends from 1901 to 2011 from meteorological observing stations. The procedure in the data preparation is further discussed in Mitchell and Jones (2005). It may be noted that not only was the data constructed for missing stations in the baseline period but there were also data constructed for stations that never existed. The data is provided by National Centre for Atmospheric Science (NCAS) British Atmospheric Data Centre and this is available online at http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_1256223773328276.

CMAP datasets are monthly and pentad (5 days) global gridded averaged precipitation rate values (mm/day) on a resolution of 2.5°x2.5° global grid (approximately 180km) with temporal coverage from 1979 to 2011. The data includes gauge and model data in the interpolation of gridded fields as well as values obtained from 5 kinds of satellite estimates (GPI, MSU, OPI, SSM/I emission and SSM/I scattering). The procedure is further discussed in Xie and Arkin (1997).The data is provided by National Oceanic and Atmospheric

Administration (NOAA), Boulder, Colorado, USA and it is available online at http://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html.

The Oceanic Nino Index (ONI), which measures the departure from normal sea surface temperature (SST) in the east-central Pacific Ocean, is a three month running mean of NOAA Extended Reconstructed Sea Surface Temperature (ERSST) version 3b SST anomalies in the Nino 3.4 region (5°N-5°S, 120°W-170°W). The departure is computed when the base threshold of +/- 0.5°C is met for a minimum of 5 consecutive over-lapping seasons, based on a centered 30-year base periods and updated every 5 years. The index is further discussed in (Barnston and Ropelewski, 1992; Kumar and Hoerling, 1998; Barnston *et al*., 1999; Xue *et al*., 2000) and is available online at

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_change.shtml.

SAOD is characterized by SST variability of opposing polarity off the coasts of West/Central Equatorial Africa (Gulf of Guinea) called the northeast pole (NEP) in the Atlantic Nino region (10°E–20°W, 0°–15°S) coupled with concurrent cooling of similar magnitude off the Argentina-Uruguay-Brazil coasts called the southwest pole (SWP, 10°W–40°W, 25°S–40°S) parts of the south Atlantic ocean. These SST patterns are coupled to the atmospheric circulation field and regional climates. SAODI is computed by differencing the domain-averaged normalized sea surface temperature anomaly (SSTA) of the two centers of intense warming and cooling associated with the SAOD and is represented by the equation;

$$SAODI = [SSTA]_{NEP} - [SSTA]_{SWP} \quad (1)$$

where the square brackets indicate domain averages. A positive phase signifies warm SST in the coast of West/Central Equatorial Africa and cool SST in the Argentina–Uruguay–Brazil coast whereas the opposite SSTA pattern describes a negative phase. The SAOD is strongly correlated but different from the equatorial zonal mode called the Atlantic Nino (Zebiak, 1993; Latif and Grötzner, 2000; Ding et al., 2010) and it is independent of direct influence of El Nino or global SST variability. The index is further discussed in (Nnamchi and Li, 2011; Nnamchi *et al*., 2011) and is accessible online at http://ljp.lasg.ac.cn/dct/page/65592.

4. Methodology

In order to investigate the interannual variation of rainfall at the various study locations as well as the areal average over the Niger Delta region and investigate the relationship of this variations with the monsoon rainfall driving mechanisms, the following procedure has been followed:

a. The Anomaly. The rainfall data from each of the datasets were converted into anomalies in order to compare the capability of each dataset to represent the spatial scales in the interannual variability of rainfall from the climatological means. The anomalies are used as the raw data in most of the subsequent analysis. The anomaly is computed using the equation

$$x' = x - \bar{x} \tag{2}$$

Where x is the monthly raw data and $\bar{x}$ is the climatological mean for that month

b. Normalization. This is used to eliminate the influence of location and spread from the various datasets as well as place the anomalies on the same scale for comparison. The equation for computing the normalization is

$$z = \frac{x' - \overline{x'}}{s_{x'}} \tag{3}$$

where x' is the anomaly, $\overline{x'}$ is the mean of the anomaly and s is the corresponding standard deviation.

c. Linear regression. This is used to investigate the relationship between the rainfall variability over the region and the monsoon rainfall driving mechanisms. It is computed using the equation,

$$y = aM + b \tag{4}$$

where a and b are constants given by

$$a = \frac{\sum_{i=1}^{n}[(M_i - \bar{M})(v_i - \bar{v})]}{\sum_{i=1}^{n}(M_i - \bar{M})^2} \tag{5}$$

and

$$b = \bar{v} - a\bar{M} \tag{6}$$

where M_i and v_i are values for the corresponding time series respectively, $\bar{M}$ and $\bar{v}$ are their means while n is the length of the time series.

d. Coefficient of correlation. This measures the strength of the linear relationship between the rainfall variability over the region and the monsoon rainfall driving mechanisms. The coefficient of correlation has been computed using the equation

$$r = \frac{\sum_{i=1}^{n}[(M_i - \bar{M})(v_i - \bar{v})]}{(n-1)(s_M s_v)} \tag{7}$$

where s_M and s_v are the corresponding standard deviations of the time series.

e. Rainfall variability index. This is used to show the ability of the datasets to represent the standardized precipitation departure of the rainfall time series at different climate regimes as defined by Oguntunde et al. (2011). The index is computed using the equation

$$\delta_k = \frac{(R_k - \mu)}{\sigma} \quad (8)$$

Where k is the year, R is the annual rainfall, μ and σ are the mean annual rainfall and standard deviation respectively over the period of study.

f. T-Test. This is used to ascertain the dependency and underlying uncertainty between the associated variables and it is computed using the equation

$$t = \frac{(\bar{\Delta} - \beta_\Delta)}{\left(\frac{s_\Delta^2}{n}\right)^{\frac{1}{2}}} \quad (9)$$

where $\bar{\Delta} = \bar{M} - \bar{v}$, whereas the population mean $\beta_\Delta = \beta_M - \beta_v = 0$ under H_0 hypothesis (Wilks, 2006).

The gridded datasets represent the values in a grid box centered on the geographical coordinates given in the dataset while the rain-gauge data represents a single site within the grid box with its location varying from the center to the edge of the box and are not evenly distributed. This study was carried out with the rain gauge data which lies within the grid box of the gridded dataset (Mooney *et al.*, 2011; Tozer *et al.*, 2012).

5. Results and Discussion

Figure 2 shows the monthly climatological mean of rainfall as recorded by NIMET rain gauges within the Niger Delta region. Various locations show a bimodal rainfall pattern (Lamptey, 2008) with a maximum monthly rainfall record of 374mm at Owerri in July and September, 254mm at Akure, 327mm at Benin City and 368mm in Port Harcourt in September and 437mm at Calabar in July. At Eket there is a unimodal distribution of monthly rainfall with a maximum of 369mm in August. This behavior could be attributed to the depreciation or disappearance of the little dry season (Nicholson *et al.*, 2000; Chineke *et al.*, 2010). In order to compare the monthly rainfall of the three datasets at the various locations, the resolution of the gridded datasets shows that CRU has grid boxes representing each of the rain gauge location whereas CMAP has grid box (6.25N, 6.25E) representing Akure, Benin City and Owerri, grid box (6.25N, 3.75E) representing Port Harcourt and grid box (8.75N, 3.75E) representing Calabar and Eket. In view of the above, the time series and the linear regressions of the interannual variation of monthly rainfall anomaly from the CRU and NIMET climatology of each of the locations is shown in figure 3. Both datasets (NIMET and CRU) show very strong correlation at each location with values of 0.58 at Akure, 0.74 at Benin City, 0.48 at Calabar, 0.28 at Eket, 0.31 at Owerri and 0.56 at Port Harcourt with a t-test significance at 99.9% confidence level. Also evident from both datasets is increment in the interannual variation of the monthly rainfall anomalies at each of the locations from the trends using linear regression.

Figure 4 shows the interannual variability index of the annual rainfall at each of the locations. Both datasets confirms an increase in the annual rainfall over time at each of the locations except at Owerri where NIMET showed a decline in the annual rainfall variability index whereas CRU showed an increment in the linear regression of the trends. Although both datasets have inherent uncertainties (Covey et al., 2002), they agreed on the variability patterns (+ or - values) at 66.67% over Akure, Calabar and Port Harcourt, 83.33% over Benin City, 54.17% over Eket and 58.33% over Owerri. Similarly the wet season (May - October) rainfall interannual variability index from both datasets shows that CRU and NIMET confirms increase in the wet season rainfall over Akure, Benin City, Calabar, Eket and Port Harcourt as shown in figure 5. At Owerri, both datasets varied in their trends as CRU showed increment in the wet season rainfall whereas NIMET showed a decrease. However, both datasets agreed on the wet season rainfall variability patterns (+ or - values) at 50% over Calabar and Eket, and at 62.50%, 79.17%, 58.33% and 75% at Akure, Benin City, Owerri and Port Harcourt respectively.

Also considering the rainfall variability on the Niger Delta using a real averages of NIMET, CRU and CMAP over the region, a time series of the normalized monthly rainfall anomaly of the three datasets is shown in figure 6. The normalized NIMET monthly rainfall anomaly shows stronger correlation with the CRU (r=0.65) than with the CMAP (r=0.48) both significant at 99.9% confidence level from t-test. The linear regression equation of the trends shows that all datasets confirm increment in the rainfall variability from the normalized areal averages at 0.0015 $month^{-1}$, 0.0014 $month^{-1}$ and 0.0031 $month^{-1}$ from NIMET, CRU and CMAP respectively. Figure 7 shows the interannual variability indexes of the annual and wet season rainfall over the region from the areal averages. The indexes show positive trends with higher values observed in the variability of the annual rainfall than in the wet season rainfall. The trends varied at 0.04 $year^{-1}$, 0.05 $year^{-1}$ and 0.09 $year^{-1}$ for NIMET, CRU and CMAP for the annual rainfall, whereas it varied at 0.03 $year^{-1}$, 0.04 $year^{-1}$ and 0.07 $year^{-1}$ for NIMET, CRU and CMAP for the wet season rainfall. Nevertheless the three datasets showed agreed on the patterns (+ or - values) of the interannual variability indexes as CRU and NIMET concurred on 79.17% whereas CMAP and NIMET agreed on 75% for the annual rainfall. For the wet season rainfall, CRU and NIMET agreed on 62.50% of the patterns whereas CMAP and NIMET agreed on 75%. The dry years of 1983, 1984 and 1987 as well as the wet year of

1994 reported over the West African region were observed in the indexes (Adefolalu, 1986; Nicholson, 1993; Nicholson *et al*., 1996; L'Hôte *et al*., 2002).

Figure 8 shows the scatter plots of the areal averaged rainfall variability over the region and the ONI. It is seen from the relationship that the normalized NIMET, CRU and CMAP monthly rainfall anomalies show weak negatively correlation with the ONI with values of -0.022, -0.010 and -0.031 respectively. The linear regression analysis of the trends show that the monthly rainfall anomaly over the region is negatively influenced by an increase in the ONI at values of -0.03°C^{-1}, -0.01°C^{-1} and -0.04°C^{-1} for NIMET, CRU and CMAP respectively although the correlation values for the relationship are not significant from t-test. This result confirms that the ONI does not have a direct or significant influence on the monthly rainfall variability within the Niger Delta region (Nicholson and Entekhabi, 1986; Ropelewski and Halpert, 1987; Janicot *et al*., 1998).

Similarly, figure 9 shows the scatter plots of the normalized areal average of the monthly rainfall anomaly and the SAODI. The relationship shows weak correlation over the region however with CRU and CMAP having positive correlations with values of 0.067 and 0.020 respectively whereas NIMET have a negative correlation of -0.027. Though contrarily to (Joly and Voldoire, 2010; Nnamchi and Li, 2011; Nnamchi *et al*., 2011) that the Gulf of Guinea SSTA and SAOD is significantly correlated with rainfall anomalies over West Africa especially the Guinea Coast, a result which may have masked variations in small areas within the region, it is evident that over the Niger Delta region, such correlations are not significant. Also observed is that the linear regression of the trends in rainfall variability over the region shows more influence from the SAODI as compared to the ONI with values of -0.05°C^{-1}, 0.13°C^{-1} and 0.04°C^{-1} for NIMET, CRU and CMAP respectively. Nevertheless the variability of the monthly rainfall anomaly over the Niger Delta region cannot be strongly linked to the SAODI.

6. Conclusion

The variability of monthly rainfall as well as the interannual variability indexes of both the annual- and wet season- rainfall across 6 locations within the Niger Delta region over a maximum period of 24 years has been studied using rainfall data from rain gauges (NIMET), interpolated rain gauge data (CRU) and blended data from interpolated rain gauge, model and satellite estimates (CMAP). Moreover the linear relationship between the rainfall variability over the region and the ONI as well as the SAODI has been investigated. This paper shows that rainfall variability in small areas can be over- or under- estimated when large areal averages are being considered. This is evident as although there is observed increments in the trend of the monthly rainfall variability over the region in recent times, these increments occurred on different scales at the various locations within the study period. These variations are seen in the rate of change in trends of the areal averages over the region (figure 6) and that at each of the gauge locations (figure 3). These variations are also observed in the rates of change in the trends of the areal averaged (figure 7) and the gauge locations (figures 4 and 5) annual- and wet season- rainfall interannual variability indexes, which confirms that rainfall variability observed from large areal averages masks significant variations in small areas within the region.

Also the relationship between the variability of monthly rainfall anomaly over the Niger Delta region of Nigeria and the monsoon rainfall driving mechanisms confirms that both the ONI and the SAODI show weak correlation with the rainfall variability over the region. Nonetheless, the linear regressions of their trends show that the SAODI has more influence than the ONI on the monthly rainfall variability. It can be inferred that the variability of monthly rainfall anomaly over the region is not significantly linked to the ONI or the SAODI. From the above, it is certain that the mechanism(s) driving the rainfall variability over the Niger Delta region is yet to be fully understood. This presents more opportunity for research and collaborative study on rainfall variability over the region. Mindful of the constraint from the number of rain gauges used, these results are imperative as understanding rainfall variability in small areas is directly linked to the socio-economic status of the people, among other factors.

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Table 1. The coordinates of the rain gauge locations and their elevations.

Location	Lat(^{0}N)	Lon (^{0}E)	Elevation (m)
Akure	7.167	5.083	349.0
Benin City	6.317	5.600	89.0
Calabar	4.950	8.325	28.0
Eket	5.050	7.933	18.0
Owerri	5.483	7.033	73.0
Portharcourt	4.750	7.000	18.0

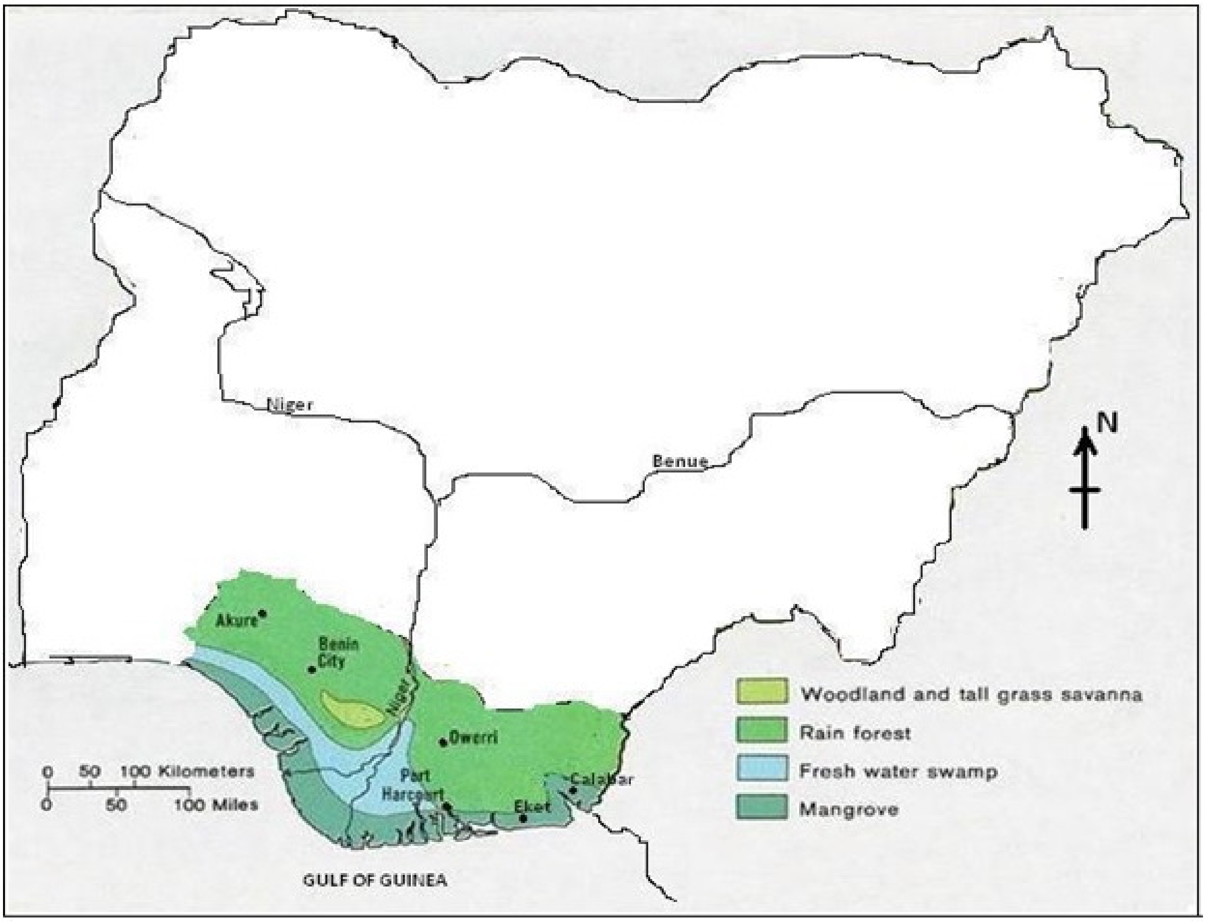

Figure 1: Map of Nigeria showing the Niger Delta region (Shaded portion), rain gauge locations (dots) and their vegetations

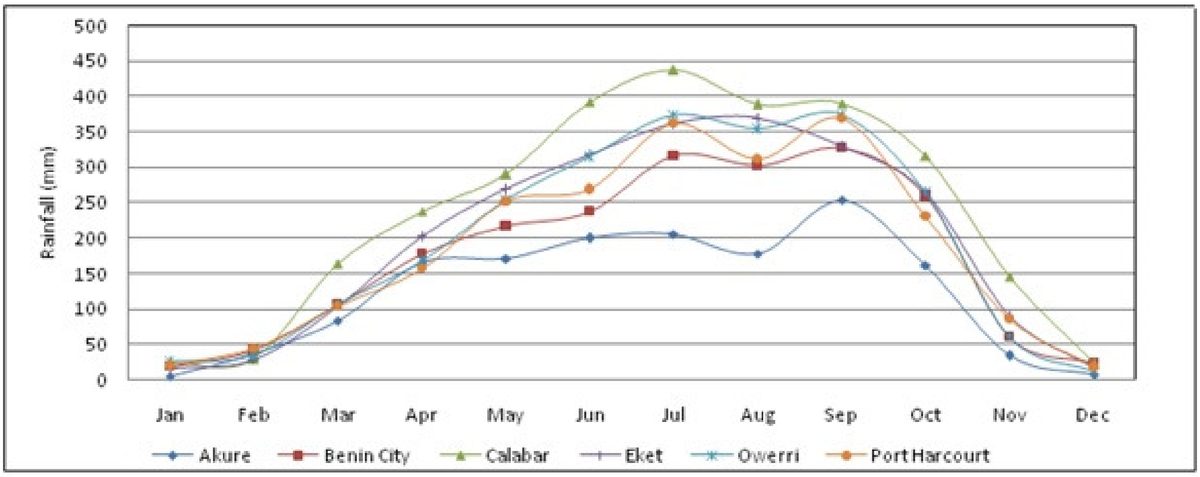

Figure 2: Monthly climatological mean of rainfall at each location in the Niger Delta region as recorded by NIMET

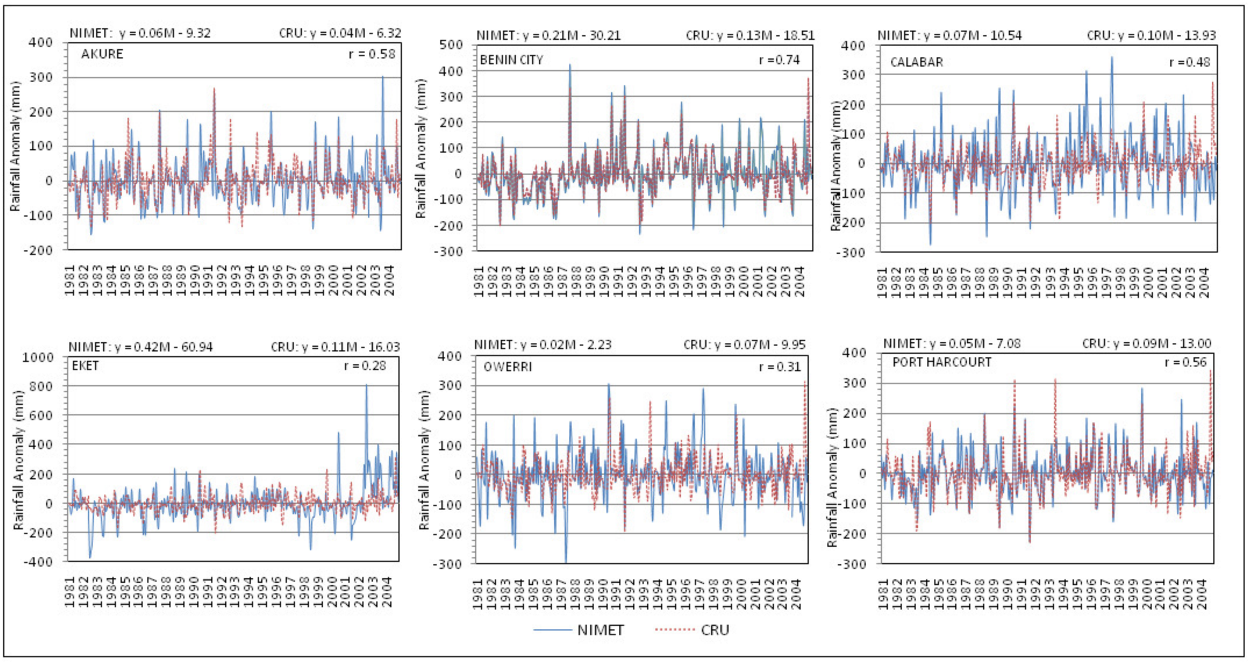

Figure 3. Time series of monthly rainfall anomalies from the climatological means of CRU and NIMET with the correlation coefficient (r) between the two datasets (insert) and the linear regression equations of the trend for each dataset (above each panel) at each location.

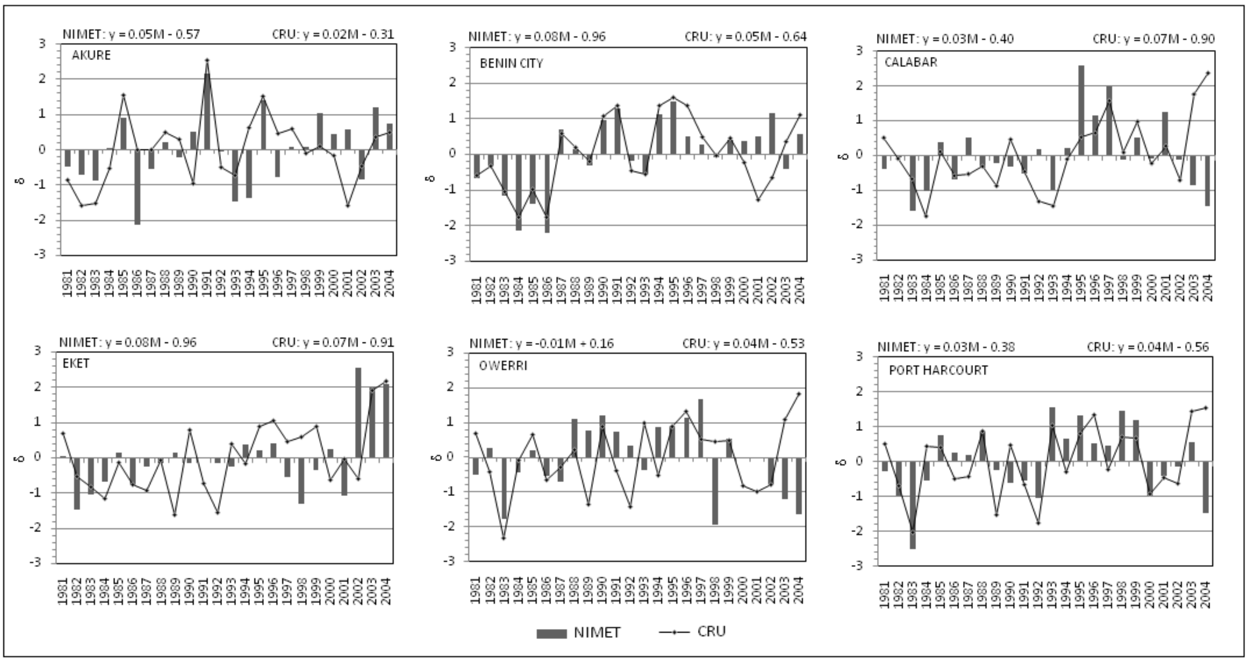

Figure 4. Interannual rainfall variability index of annual rainfall at each location from NIMET and CRU showing the linear regression equations of the trend for each dataset (above each panel).

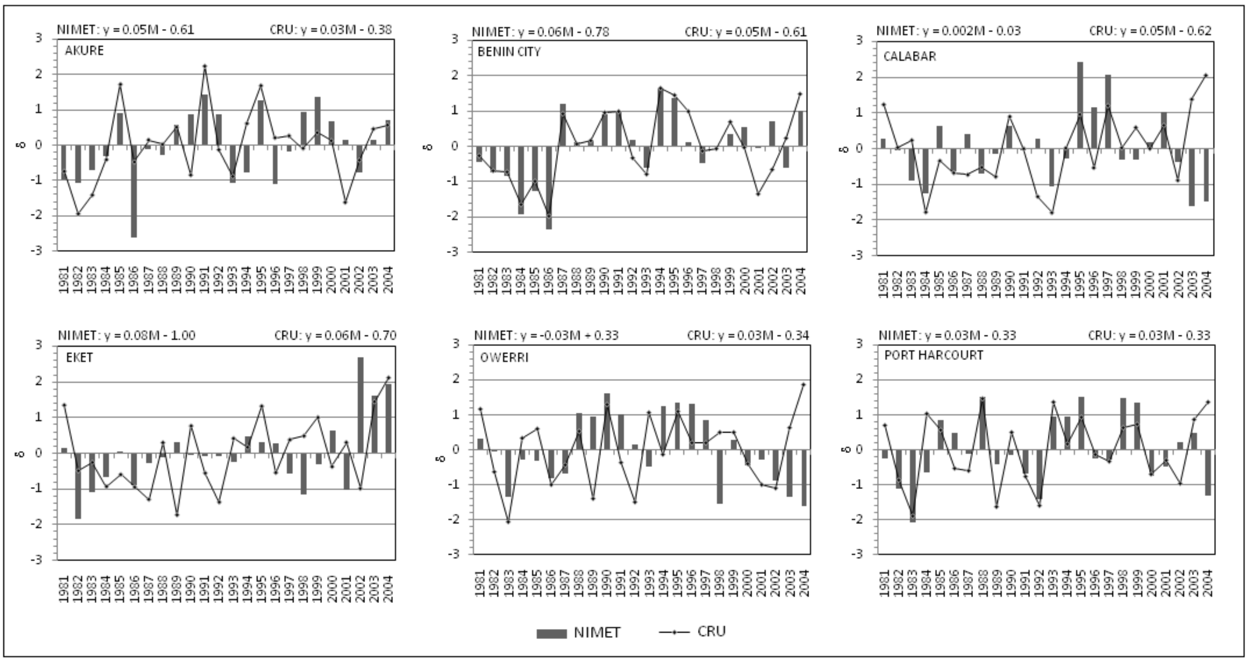

Figure 5. Wet season (May - October) rainfall interannual variability index at each location from NIMET and CRU showing the linear regression equations of the trend (above each panel) for each dataset.

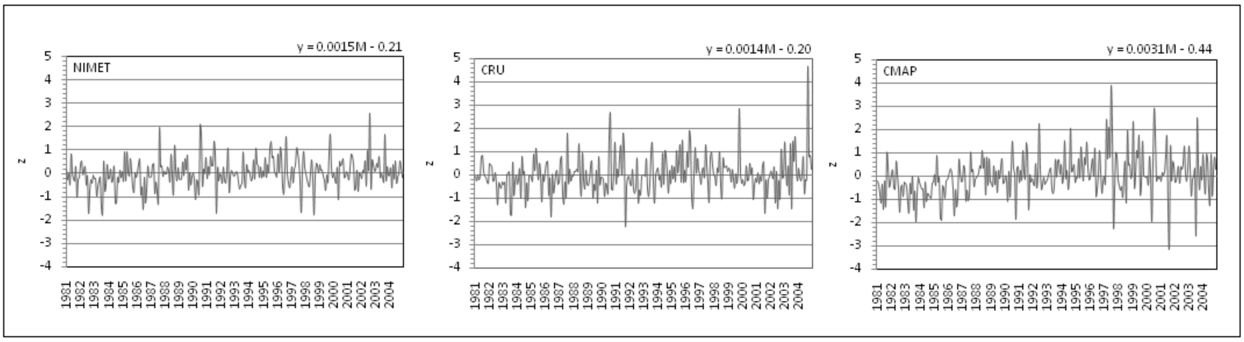

Figure 6. Normalized time series of NIMET, CRU and CMAP for the areal averaged monthly rainfall anomaly over the Niger Delta region and the linear regression equation of the trends above each panel.

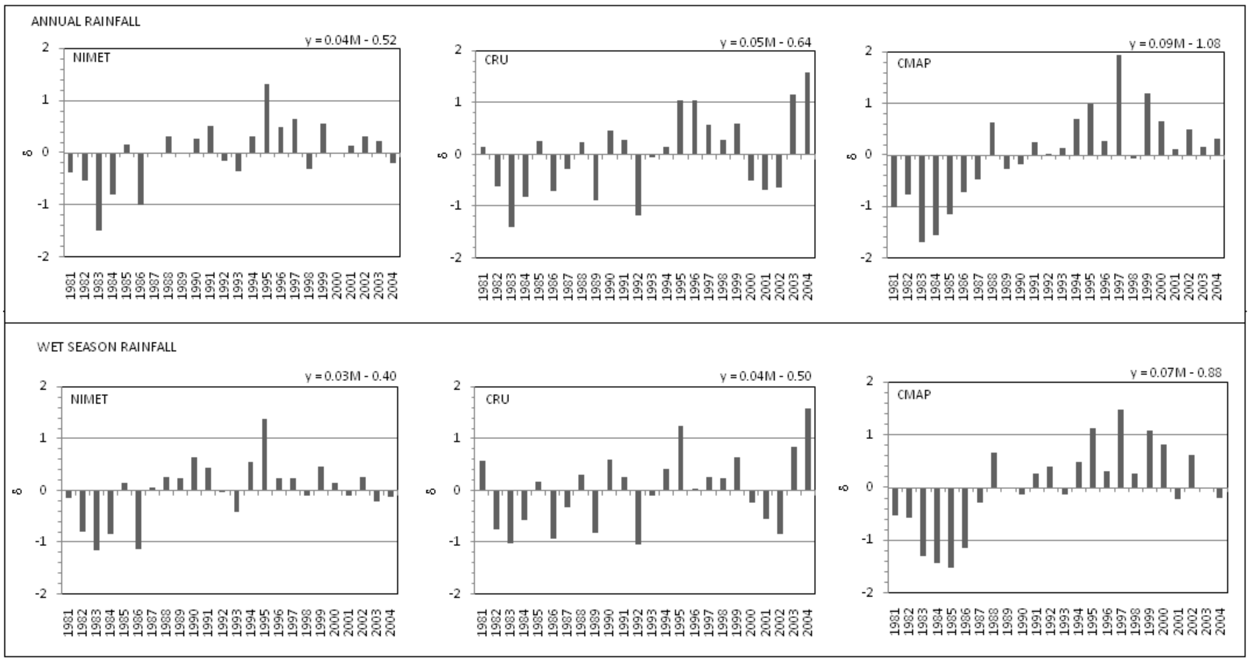

Figure 7. The annual (above) and wet season (below) areal averaged rainfall interannual variability indexes from NIMET, CRU and CMAP over the Niger Delta and the linear regression equation of the trends above each panel.

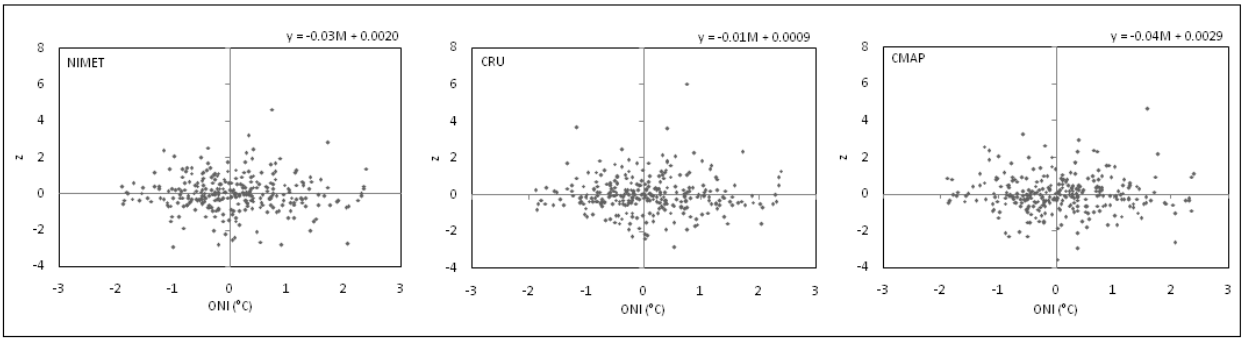

Figure 8. Scatter plots showing the relationship between the normalized areal average of NIMET, CRU and CMAP monthly rainfall anomaly and the ONI. Above each panel is the linear regression equation of the trends.

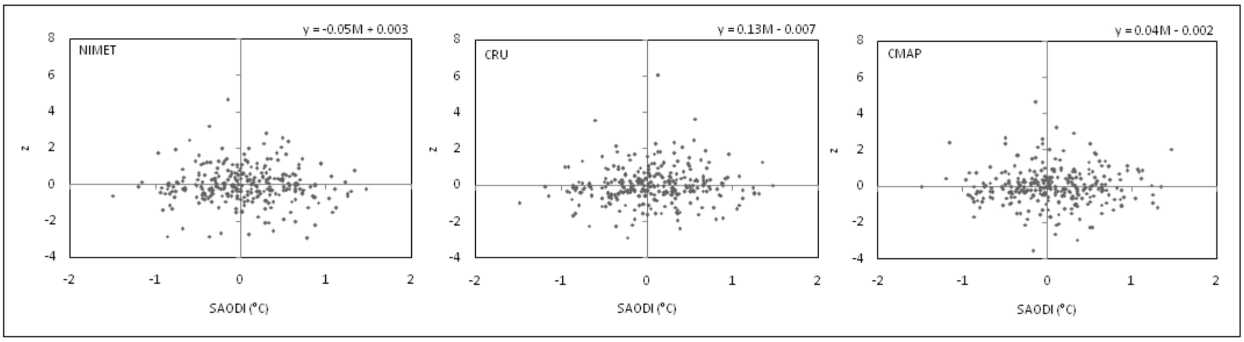

Figure 9. Scatter plots showing the relationship between the normalized areal averages of NIMET, CRU and CMAP monthly rainfall anomaly ant the SAODI. Above each panel is the linear regression equation of the trends.