CHARACTERISTIC PATTERN OF RAINFALL IN CALABAR, NIGERIA - A TROPICAL COASTAL LOCATION

Igwe O. Ewona* and Sunday O. Udo**
*Department of Physics, Cross River University of Technology, Calabar, Nigeria
**Department of Physics, University of Calabar, Calabar, Nigeria

(Submitted:21 February,2008; Accepted:8 May,2008)

Abstract

The characteristic pattern of rainfall in Calabar, a coastal - tropical location has been investigated and analyzed. Monthly total rainfall in millimeters was noted over a 19-year period (1985-2003).Using a rain day as a day with rainfall of not less than 0.5 mm and extreme threshold value of 50.0 mm it was found that total rainfall is significantly correlated with the extreme frequency and extreme intensity indices. This suggests that extreme events are more frequent and intense during years with high rainfall. It was further found that the seasonality of Calabar rainfall coincides with the Indian monsoon winds which blow between April and October and reverses direction from November to March. This accounts for the two major seasons in the area and the whole of West Africa in general. Using SPSS statistical package, it was found that the deseasonalised data show an increase of 1.9 mm over the period. Results further showed that the total annual mean rainfall in the city is the highest in Nigeria being about 2859.84 mm with an average of 174.53 rain days in the year.

Keywords: *Calabar, extreme frequency, extreme event and intensity, SPSS and deseasonalised data*

1. Introduction

The manner at which rain falls and is distributed throughout the year is a prime factor in the regimes of rain caused floods. In the tropics and monsoon areas of the world, the frequency and intensity of rainfall in a particular season results in seasonal floods (Okpiliya *et al.*, 2006). The study of rainfall distribution is important in Rain harvesting, agricultural production, especially plant production, which is highly sensitive to the quantity of rainfall and its distribution throughout its productive season. Agricultural produce storage, architectural designs, building and construction, field work and tourism are all dependent on the manner at which rain falls. The warm humid climate of the tropics characterized by heavy rainfall does not seem to encourage animal production as it is the habitat of many deadly animal pests and diseases.

Rainfall intensities have a clear bearing on flooding, soil fertility and mineral circulation in the soil. Rainfall intensities also reduce infiltration capacities or the drainage network (Ebisemiju, 1989). Although humidity in urban areas is believed to be lower because of low presence of transpiring vegetation and open water surfaces, precipitation can be higher due to increase injection of condensation nuclei and steam from combustion processes. The greater heat generated in urban areas in relation to the country side can cause convectional storms. Particles of dust released into the atmosphere can give rise to increased condensation and therefore greater precipitation (Okpiliya *et al.*, 2006).

Since rainfall is somewhat irregular even within the rainy season and sometimes sporadic, researchers seem to be more comfortable with working on such parameters as total rainfall, extreme intensity, extreme frequency, extreme event and total rain days (where a rainfall day is a day the rain gauge measures at least 0.5 mm of rain or above). There seem to be no standard method as some studies have used values of 1mm and above (Haylock and Nicholls, 2000; Hess *et al.* 1995). In Calabar, and indeed Nigeria in general rainfall of 0.1mm and above are considered significant (NIMET, 2006).

Although an increase in the number of rain days increases with total rainfall and extreme frequency, the proportional contribution from extreme events to the total rainfall depends on the method used to calculate the index (Haylock and Nicholls; 2000, Karl *et al.*, 1995a; Nicholls, 1995; Hennessy *et al.*, 1999). For example, Plummer *et al.*, (1999) found trends in percentiles that depended on the season and region. Suppiah and Hennessey (1998) presented results that are more regionally consistent. They found increasing trends in 90th and 95th percentiles over most of Australia for both summer and winter half years as well as increasing trends in the frequency of events above long-term mean percentiles.

Studies of rainfall trends over West Africa from 1991-2004 showed average rainfall in terms of the 1950 1990 mean events though the years 1999 and 2000 were exceptionally found to be wetter (Christoph and Fink, 2005). In USA, Karl *et al.,* (1995b) employed a threshold value of 50.8 mm rainfall for extreme events. Their studies found a steady increase in the percentage of annual precipitation derived from extreme events exceeding the threshold value contributed mainly by change in spring and summer rainfall.

Similarly, Karl and Knight(1998) had earlier found increase in both the intensity and the frequency of extreme events over the USA using thresholds based on long term mean percentiles. Correlations with total rainfall for the number of rain days and the three extreme indices namely extreme intensity, extreme percentage and extreme frequency show highly significant correlations for rain days with extreme frequency and extreme intensity. These suggest that years with high rainfall receive rain on more days, with a higher average intensity in the highest events and a larger number of events above an extreme threshold. Analysis of global circulation models suggest an increase in heavy rainfall and a decrease in light rainfall (Gordon *et al.*, 1992 and Haylock and Nicholls, 2000).

Daily rainfall records for 1961 1990 were analyzed for three stations in Northern Nigeria and one in Southern Nigeria. The authors found consistent decrease in annual rainfall of 8mm per year in all four stations. The majority of the reduction occurred in August or September. The authors attributed the reduction to the decrease of 6-25 days in the number of rain days during the rainy season. There was no significant change in the average rainfall per rain day except in Southern Nigeria which shows a slight decrease(*Hess et al., 1995*).

In the present work, a rain day is defined as a day with total rainfall not less than 0.5mm and 50.0mm as the threshold value for extreme rainfall in a single rain day.

The major object of these studies is to investigate the possible effects of climate change on the amount and distribution of rainfall in Calabar between 1985 and 2003

2. Geography of Calabar

The weather station is located at the Margaret Ekpo International Airport in Calabar which lies at an altitude of 62.3m above sea level, latitude 4°71 and longitude 8°55. It is almost surrounded by sea water at distances between three to five kilometers to the south, east and west of the station. Two major winds which significantly affect the climate of the West African coast blow across this region bringing about two major seasons in the area, namely: wet and dry seasons, probably named after the pattern at which rain falls. While the wet season last between April and October, the dry season is normally from November to March of the following year. The dry season is also marked by a short period of dusty and foggy weather popularly called the hammattan which generally occurs between the months of December and January. The hammattan is characterized by poor visibility, sometimes with light drizzling in the morning hours. The intense heat from the sun at this time of the year encourages high evaporation which quickly condenses on the high concentration of aerosol particles at the lower atmosphere at night when the sun's radiation is withdrawn and the earths heat radiates away uninterrupted by a cloudless atmosphere. It is not surprising therefore to see foggy weather in the early hours of the morning before the sun rises again.

3. Data Source and Analyses

The basic daily data on rainfall, used for the study where extracted from the meteorological records of the Margaret Ekpo International airport in Calabar, from 1985-1994 - a period of ten years and from the National Meteorological services data bank in Lagos, from 1993-2003 - a period of 11 years. This shows an overlap of two years. The daily data extracted directly from Calabar station were hand-written while the data from Oshodi for Calabar station were computer printed. Present study is based on continuous set of data collected between 1985 and 2003 from where monthly total values were computed.

The two-years overlap was to compare the two daily data sets for evidence of accuracy in the records. Wherever there was a discrepancy in entry, the data from Oshodi was preferred to replace the data point and where the data was missing out rightly, the Oshodi data was used to fill the gap. The preference for Oshodi data was due to the fact that, these data points have been studied and where necessary, corrected to reflect the overall character of empirical relationships. Daily measured data that were missing were not estimated by interpolation or other means and were not used in the analyses. This followed the method applied by Dugas and Heuer (1985).

The final set consists of a continuous unbroken monthly total from 1985-2003. The months were spread continuously with January, 1985 being month 1 and December, 2003 as month 228. Such continuity is necessary where trend studies are involved.

4. Methods and Results

Figure 1 is the time series plot of monthly total rainfall in Calabar between 1985 and 2003. It tells of the monthly variation of rainfall over the period under study. The years 1995-1997 can be seen from the plot to be exceptionally wet.

4.1 Seasonal and long term variations

To obtain seasonal functions, we used the moving average to ratio technique to decompose the series in order to obtain the seasonal index in Table 1. The seasonal index is the total average monthly contribution in a year of 12 months. By seasonal variation we mean rainfall pattern within a year of 12 months whereas long term variations will cover a period above two years. Inspecting the seasonal index, we note that rainfall has a pronounced season which starts from April and peaked in July. The rainy season spans through April and October which coincides with the duration of south west trade winds that blow across Africa and the Indian sub continent (Microsoft Encarta, 2006). Months of December and January are almost without rain while February and March have limited rain. This is shown clearly in Table1.

To obtain long term variations, we use the seasonal indexes to deseasonalise the raw data. This will enable trend values to stand out clearly during the analysis. To identify a suitable model for the data, we produce the plot for both auto-covariance and partial auto-covariance functions against lags as shown in Figure 1. From the graphs, we can identify a probable model as autoregressive model of order four i.e. AR(4) based on their Akaike information Criteria (AIC) (Akaike,1974). Hence, the trend of the deseasonalise data follows the AR(4) model after a first difference transformation. The parameters of the trend equations are shown in Table 2. We observed that rainfall has been quite sporadic in the second half of the 1990's as can be seen from the time series of Figure 2. Concerning the trend, deseasonalised monthly total rainfall shows an increased of about 1.9mm whereas the raw data gave an increased of about 300mm as can be seen from Figure3 and 4. The difference between the two trend analyses shows that seasonal variations are much stronger than trend variations in this part of the world.

(a) Autocorrelations: Deseasonalise Rainfall Data
Transformations: difference (1)

```
     Auto- Stand.
Lag  Corr.  Err. -1  -.75  -.5 -.25   0  .25  .5  .75  1
               +----+----+----+----+----+----+----+----+
 1  -.523  .066          *******.**I .
 2   .080  .066                 . I**.
 3  -.075  .066                 .*I .
 4   .007  .065                 . * .
 5   .016  .065                 . * .
 6  -.001  .065                 . * .
 7   .033  .065                 . I*.
 8  -.022  .065                 . * .
 9  -.031  .065                 .*I .
10  -.038  .065                 .*I .
11   .126  .064                 . I***
12  -.040  .064                 .*I .
13  -.051  .064                 .*I .
14  -.048  .064                 .*I .
15   .094  .064                 . I**.
16  -.039  .064                 .*I .
```

b) Partial Autocorrelations: Deseasonalise Rainfall Data

```
     Pr-Aut- Stand.
Lag  Corr.  Err. -1  -.75  -.5 -.25   0  .25  .5  .75  1
               +----+----+----+----+----+----+----+----+
 1  -.523  .066          *******.**I .
 2  -.266  .066               **.**I .
 3  -.239  .066               **.**I .
 4  -.218  .066                *.**I .
 5  -.164  .066                 ***I .
 6  -.132  .066                 ***I .
 7  -.057  .066                  .*I .
 8  -.037  .066                  .*I .
 9  -.080  .066                 .**I .
10  -.167  .066                 ***I .
```

```
11 -.006  .066          . * .
12  .044  .066          . I*.
13 -.047  .066          .*I .
14 -.171  .066         ***I .
15 -.073  .066          .*I .
16 -.071  .066          .*I .
```

Transformations: difference (1)

Fig.1: Plots of (a) autocorrelation (b) partial autocorrelation

5. Relationship with Extreme Events

The relationship between total rainfall and extreme event is examined in this section. Figures 5 and 6 show clearly that total rainfall is well correlated with total extreme rainfall. This means that years with more rainfall are generally characterized by intense (extreme) rainfall. We also notice that extreme events are more frequent and intense during years with high rainfall. The frequency of rain in those years increases also with extreme frequency.

6. Relationship with Other Parameters

The correlation between rain and other meteorological parameters yielded low values as shown in Tables 3 and 4. Except with wind, all other parameters showed consistency in their correlation values in the two tables even though they were computed from different chronological periods. Rainfall recorded appreciable correlations of about -0.69 with maximum temperature and 0.46 with relative humidity perhaps due to their heavy dependence on each other. However, relative humidity value is lower than expected perhaps due to the fact that relative humidity was considered for 9.00 hours GMT only whereas rainfall values were computed over the entire day i.e. from 6.00 18.00 hours GMT. The poor correlation between rainfall and cloud cover provide significant explanation for the nature of rainfall in this coastal city which is that much of the rain may be induced by convectional winds rather than by monsoon trade winds. The phenomenon of lifting, associated with the convergence of the trade winds, results in a band of copious rains near the equator. However, despite the presence of moisture and lifting, clouds sometimes fail to precipitate rain. This phenomenon can result in poor correlation values with wind speed and cloud cover as shown in this work (Blackadar, 2006)

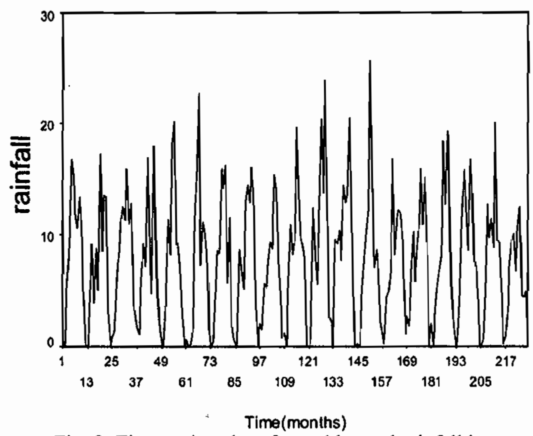

Fig. 2: Time series plot of monthly total rainfall in mm against time (months)

Table 1: Seasonal index of monthly daily total rainfall

Jan	Feb	Mar	Apr	May	Jun
0.088025	0.117689	0.751728	1.074664	1.109222	1.656606
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.87694	1.650555	1.638995	1.318859	0.618184	0.098534

Table 2 Variables in the model.

	B	SEB	T-ratio	Approx prob
AR_1	-0.77818187	0.06485096	-11.999543	0.0000000
AR_2	-0.51748521	0.07876901	-6.569655	0.0000000
AR_3	-0.39325556	0.07874974	-4.993738	0.00000118
AR_4	-0.21626646	0.06494949	-3.329764	0.00101494

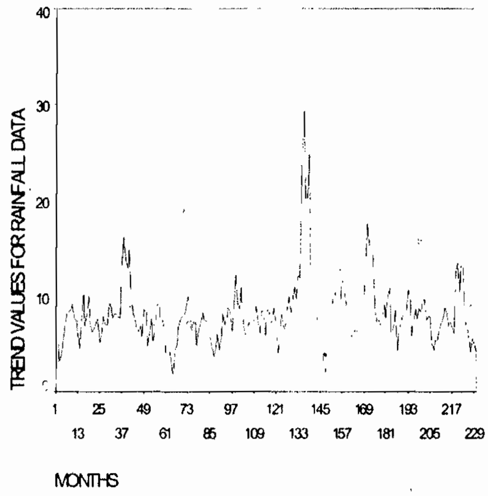

Fig. 3: Trend graph of deseasonalised monthly daily total rainfall against months.

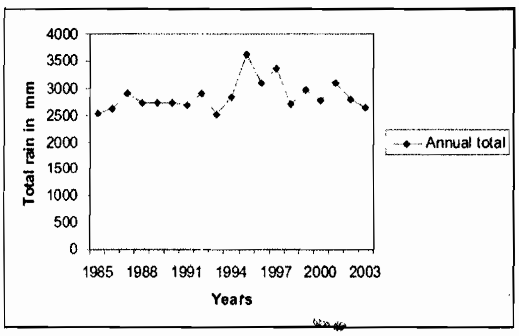

Fig.4 Trend graph of raw monthly daily total rainfall against months.

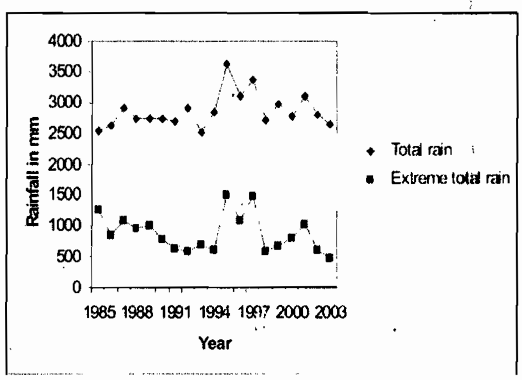

Fig.5: plot of annual total rain and annual extreme total rain

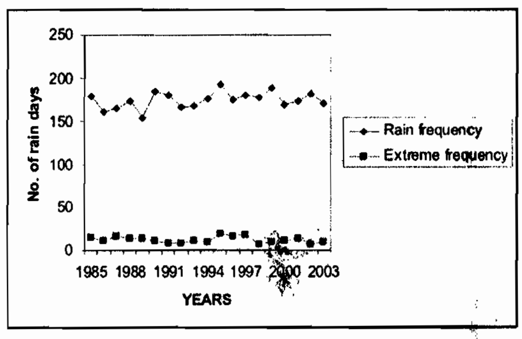

Fig.6: plot of total number of rains and total days of heavy rainfall

Table 3: Correlations between 1993 and 2003

Parameter	Max. temp.	Min. temp.	Temp. diff.	Sunshine	Humidity	Wind speed
Rainfall	-0.69	0.07	-0.40	0.01	0.46	-0.13

Table 4. Correlations between 1989 and 1994

Parameter	Max. temp.	Min. temp.	Temp. diff.	Sunshine	Humidity	Wind speed	Evap.
Rainfall	-0.69	0.07	-0.40	0.10	0.46	-0.07	-0.22

Table 5: Half-yearly distribution of rain in Calabar.

Parameter	Jan.-Jun.	Jul.-Dec.	Annual total
Rainfall	1116.87mm	1742.97mm	2859.84mm
Percentage	39.05%	60.95%	
Rain days	67.53	107.00	
Extreme freq.	5 DAYS	7 DAYS	12 DAYS
Extreme total	374.14mm	510.14mm	884.29mm

7. Summary

By way of summary we present in this work the characteristic pattern of rainfall in Calabar as follows:

1. Total average annual rainfall is about 2859.838mm/y which fall in 174.53 days.
2. Monthly mean total rainfall is about 238.32mm.
3. Extreme intensity of rainfall is about 74.337mm/day
4. The heaviest single rain was 181mm and that was in June 18, 1989
5. While the wettest months are July followed by August the driest months are January followed by December.
6. Extreme rainfall increases with total annual rainfall and the frequency of rainfall also correlate with extreme frequency.
7. 31% of the total rain that falls in the year is heavy rainfall and occurs in just about 12 days
8. Annual distribution of rain throughout the year is shown in Table 5 and indicates that more rain falls in the second half of the year and more days. Similarly extreme rainfall is more intense during this period.
9. Extreme rainfall accounts for about 31% of the total rain fall in the year. Details of the half yearly distribution of rain are shown in Table 5.
10. Rainfall pattern in the city is highly seasonal.

An average of 60.9% of the total rain falls within the second half of the year. Extreme intensity of 74.34mm on average accounts for about 31.0 % of the total rain in the year and occurs in just 11.84 days. There was an evidence of intense rainfall which increases surface runoff that results in gully erosion-one of the largest ecological problems of the area.

References

Akaike, H. (1974): A new look at the statistical model identification. I.E.E.E. Trans. Automatic Control, AC 19, 716-72.

Blackadar, A.K. Rain, Microsoft Encarta (2006):[CD], Redmond, WA. Microsoft Corporation, 2005.

Christoph, M.& Fink, A.H. (2005): Recent Rainfall Trends Across Tropical West Africa: Observations and Potential causes. African Center of Meteorology and Development, ACMAD, 16.

Ebisemiju, F (1989): The Response of Head Water Stream Channels to Urbanization in the Humid Tropics: Hydrological Processes, 3,237-253

Gorden, H.B., Whetton, P.H., Pittock, A.B., Fowler, A.M. & Haylock, M.R. (1992): Simulated Changes in Daily Rainfall Intensity Due to the Enhanced Green House Effect: Implication of Extreme Rainfall Events. Climate Dynamics 8, 83-102.

Haylock, M. & Nicholls, N. (2000): High Quality Data Set for Australia, 1910-1998. Royal Meteorological Society, 8, 67

Hennessy, K.J., Suppiah, R. & Range, C.M. (1999). Australian Rainfall Change, 1910-1995. Australian Meteorological Magazine, 48, 1- 13

Hess, T.M., Stephen, W. &Mayan U.M.(1995). Rainfall trends in the north east arid zone of Nigeria 1961-1990. Agriculture and Forest Meteorology, 74(1-2), 87-89

Hoyt, D.V.A. (1978). Model for calculation of global solar insolation. Solar Energy, 22, 27

Karl,T.R. & Knight, R.W. (1998). Secular trends of precipitation amount, frequency, and intensity in the United States. Bulletin of the American Meteorological Society, 79, 231- 141

Karl,T.R., Derr, V.R., Easterling, D.R., Folland, C.K., Hofmann, D.J., Levitus, S., Nicholls, N., Parker, D.E., & Wittee, G.W. (1995b). Critical issues for long term climate monitoring. Climate Change, 31, 185-221

Karl,T.R., Knight, R.W. & Plummer, N. (1995a). Trends in frequency climate variability in the twenthieth century. Nature, 377, 217-220

Nigerian Meteorological agency, NIMET, (2006). Climate: Annual mean rainfall in Nigeria by State.

Nicholls, N. (1995). Long term climate monitoring and extreme events. Climate Change, 31, 231-245

Okpiliya, F., Ekpoh, I.J., Afangideh, A.I. and Achi, A.(2006). Climate and human environment, Calabar, Tabson Resources.

Suppiah, R. & Henessy, K.J.(1998). Trends in total rainfall, heavy rain events and number of dry days in Australia 1910-1990. International Journal of Climatology, 10 1141-1164

Microsoft Encarta (2006) [CD]. Trade winds, Redmond, WA. Microsoft corporation, 2005