Study and Characterization of Rainfall Intensities in Akure, Southwestern Nigeria

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Abstract

Measurement and characterization of rainfall in a tropical location such as Akure, Southwestern Nigeria, (7.3^{o}N; 5.3^{o}E) is important to various fields of applications. Amongst these are water resource management, agriculture, climate studies, environmental sciences and telecommunications. In this paper, we present the statistical analysis of rainfall rates, measured with high temporal resolution of one-minute integration time, during the occurrence of some rain events in Akure. Rainfall intensities of one-minute integration time were measured using a Davis Vantage Vue Integrated Sensors Suite (ISS) weather station for the months of June2013 to February2014. The study investigates the pattern of rainfall distribution, temporal and cumulative distribution of rain rates, and their contribution to the total rainfall. The rainfall pattern in Akure may be categorized as mainly stratiform with less than 10% convective rains. High intensity convective rains were more prominent in the rain-deficient months, making it difficult to clearly demarcate between the conventional dry and rainy seasons in Nigeria. Comparison of measured rain rate with ITU-R indicates that the ITU-R model underestimates rainfall intensities at higher rain rates above 25mm/h, and above 99.5% of times, while it closely estimates intensities at lower rates below 20mm/h and for 99% of times.

Keywords: Tropical region, one-minute rainfall intensity, Temporal and cumulative characterization of rainfall.

1. Introduction

Rain is the liquid precipitation of condensed water vapor which when it becomes too heavy drops from the atmosphere under gravity. Rainfall has very complex temporal and three dimensional spatial variations [1] which have to do with seasons and geographical locations (longitudes, latitudes and altitudes above sea level). Spatial and temporal distribution of rainfall is a major research concern in agriculture for soil erosion management and study of evapo-transpiration; in climate and environmental studies, for disaster management and in telecommunication, for the accurate determination of link budget because of its impairing effects on the propagation of microwave frequencies from 7 GHz and above. The subject of characterization of rain effects on the propagation of radio waves has been a virile area of research over the last thirty years in Nigeria [2- 6] among others. Since daily and hourly measurements of rainfall data tend to under-estimate rainfall rates [7, 8] it is needful to study the distribution of rainfall data over shorter periods. In this paper, we present the study of real-time point rainfall data accumulated on a one-minute integration time basis, over a period of 9 months (June2013-Feb2014). The analysis focuses on the rainfall pattern over the observed period, temporal and cumulative distribution of the rainfall amount, categorization of the rainfall types, contribution of each rain type to total rainfall and the time series analysis of rainfall intensities on some specific days.

2. Experimental Site, Data Collection and Methodology

The experimental site is at the Department of Physics, the Federal University of Technology Akure (FUTA), Nigeria. Table 1 presents the characteristics of the experimental site as well as the parameters for the rain equipment. Fig. 1 presents the picture of the experimental set-up used to measure and record rain-rates.

Table 1: Characteristics of the experimental site and specification of Equipment

Measurement site/ Climate	Akure (7^{o}17 N, 5^{o}18 E; 358 m)/ Rain forest
Max/Ave/Min Temperatures	Akure: 45 ^{o}C /28 ^{o}C /15 ^{o}C
Rain Equipment /Integration time	Davis Vantage Vue ISS weather station / One min
Gauge resolution of drop-count	1.2/60 mm/drop
Sensitivity / Gauge tip resolution	4 mm/h for 10 secs / 0.8 mm/tip

Figure 1: DAVIS ISS

3.0 Results and Discussion

3.1 Monthly Rainfall Distribution

The average monthly rainfall accumulation for the period of measurement for this study is shown in Table 2. The monthly rainfall is dependent on the effects of the movement of the Inter Tropical Convergence Zone (ITCZ). During the rainy season, the ITCZ discontinuity follows the sun northward; hence, many parts of the country come under the influence of the moisture laden tropical maritime air. As rainfall declines, there is a southward shift of the zone, thus bringing the rainy season to an end. Consequently, Nigeria experiences two distinct seasons per year; the dry season spanning November till around February/early March and wet season covering March to October of the year. During the wet season, because of the prevalence of rain, the ITCZ moves across the country. The month of March/April is usually observed as the beginning of the rainy season, but rainfall does not become intense until June to October; and so, the months of April and May experience scattered rainfall patterns. Also, the Inter Tropical Discontinuity (ITD), while migrating up north, oscillates between north and south within a few latitudinal points to cause the August-break.

Table 2: Monthly accumulated rainfall at Akure (June2013 Feb 2014)

MONTHS	June 2013	July 2013	Aug 2013	Sept 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014
No. of minutes	682	2079	148	2418	759	331	121	155	266
Highest Rain rate (mm/h)	132	89	58	172	461	49	119	116	126
Rainfall Amount (mm)	93	191	11	207	185	35	36	40	54

It could be observed from the Table 2 that in Akure each of the observed months had accumulated rainfall duration of at least 2 hours. Moreover, except for the month of November, the rain deficient dry season months of December, January and February recorded rainfall intensity above 110mm/h characteristic of the few convective events associated with the months. The months of July and August recorded intensities lower than this value, thereby making it difficult to clearly demarcate between the wet season and dry season. This anomaly may be due to general global warming and climate change. The month of September contributed most to the accumulation of rainfall for the year 2013 and early 2014. This was followed by the month of July, and then October which witnessed several heavy convective rainfall patterns that usually lead to the cessation of the rainy season.

3.2 Temporal distribution and characterization of rainfall types

The rain rate distribution for nine months (June 2013 to February 2014) at Akure, is shown in figure 3. The results show that the lowest rain-rate of 0-5mm/h dominates in all the months, ranging from a minimum of 48-64% in the dry months to the maximum of 80-93% during the rainy months. The highest share for low intensity rainfall occurs in September, accounting for 93% of rain incidences, while October recorded the highest percentage of high intensity rainfall above 50mm/h with a cumulative percentage of 11% (ie more than 75minutes). Higher rain rates above 50mm/h are more prominent in the rain deficient months than in the rainy months in Akure; December accounts for the greatest share with about 14% of rain incidences (17minutes).

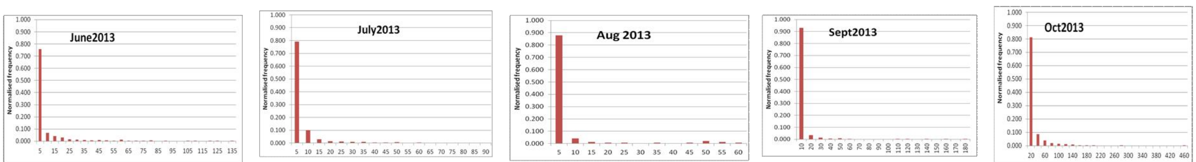

Figure 3: Rain rate distribution at Akure June 2013 – Oct 2013.

Figure 3 also shows the various differences in the distribution of rain rate between the months under study. The lowest range of rain rates between 0-5mm/h drizzle rainfall is more prevalent in all the months. The probability of occurrence of drizzle in Akure ranges from 73% in October to 93% in September. Strikingly, these two months are the months with the highest accumulation of rain precipitation. The worst cases of rainfall which could be classified as Typhoon rainfall occurred in the month of October, and characterize the end of the rainy season.

Results from the time percentages of rainfall in figure 4 further reveal the temporal variation of rainfall in Akure. For all the months observed, 70% of rainfall occurred in less than 30% of the time. In the rain deficient months (November through February) 80% rainfall occurred in 30% of the time or less. This could be due to the characteristic heavy down pour of convective rains from cumuliform clouds.

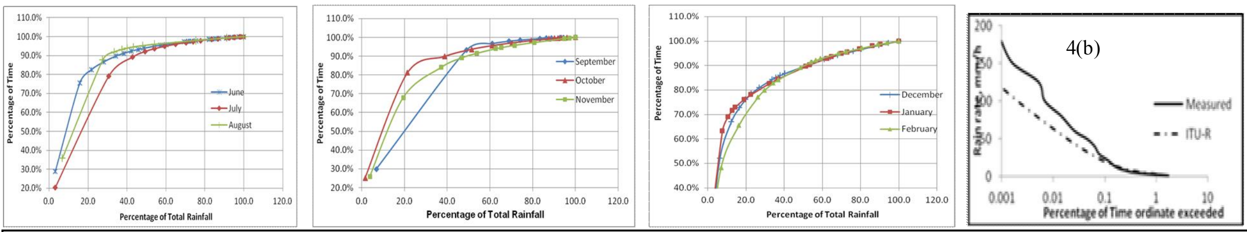

Figure 4: Variation of rain rate with time, June 2013-February 2014. (b) Comparison with ITU-R prediction

3.3 Cumulative Distribution of Rainfall Rate

Figure 4b presents the cumulative distribution of one-minute rain rate over the study location. The results are presented to access the relationship between ITU-R recommendations P. 837-3 [9] and the measured results. We observed a good fit for the location at lower percentages of availability and low rain rates (lower than 20 mm/h). However, considerable differences are obtained between the measured data and the ITU-R model at higher percentages of availability and high rain rates (greater than 50 mm/h). For example, the rain-rate exceedance measured at 0.01 percent of time is about 90 mm/h, which is much higher than the estimated value of about 65 mm/h by the ITU-R model. The underestimation here is about 30%. This indicates that ITU-R underestimates rainfall intensities at higher rain rates, while it closely estimates intensities at lower rain rates. This agrees with previous observations by some researchers like [6, 10, 11,].

3.4 Cumulative distribution of rainfall

The curves for the five rainy months (June October) are almost parallel to the x-axis after about 20mm/h of rain rate, while those of the dry (rain-deficient) months show a positive slope. This is a further confirmation of the preponderance of low intensity (or stratiform) rainfall below 20mm/h in the rainy months compared to the prevalence of high intensity (or convective) rainfall in the latter, despite the low volume of rainfall.

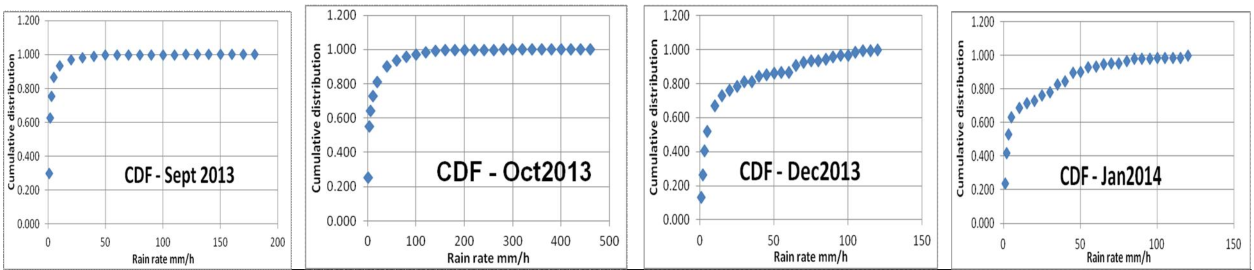

Figure 5: (a) Cumulative frequency distribution of rain rates at Akure for some months.

3.5 Contribution of rainfall Types to Rain Accumulation

The relative duration for which rain rate is below 20mm/h, and the percentage contribution to total rainfall observed for the various months are shown in Table 3 and figure 6. The histogram in figure 6 indicates that rain rates up to 20mm/h account for 53-65% of rainfall in the wet season and 20-45% in the dry season. Further investigation of the cumulative distribution showing the contribution of each rain rate to rainfall accumulation for the year in each of the months, showed that the rain rate range between 20-50mm/h accounts for another 20% in rainy season and 10% in the dry season except for

November where rain rates were hardly above 50mm/h. Above 50mm/h, rainfall accumulation in rainy season was 20% or less, and 50% in the dry season. These inputs are significant to agriculturists and soil scientists in crop planting.

Table 3: Relative contribution of rain rates ≤20mm/h

MONTH	% Normalized Freq	% Contribution to Total Rainfall
JUN 2013	89.7	50.3
JUL 2013	93.7	68.3
AUG 2013	93.9	64.1
SEP 2013	96.7	61.7
OCT 2013	81.1	54.7
NOV 2013	91.8	68.2
DEC 2013	76.0	41.2
JAN 2014	72.9	24.1
FEB 2014	96.2	83.8

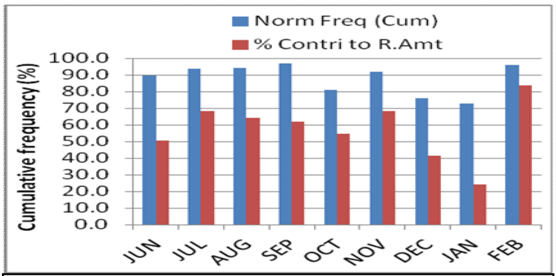

Figure 6: Relative contribution of rain rates 20mm/h to rainfall in each month

4.0 Conclusion

Measurements and analysis of high resolution rain rates have revealed monthly variations in rainfall that would serve as useful planning data for agriculturist, erosion and soil scientists in crop planting. Analysis of the mean monthly accumulation shows that the worst months are September and October. This is very important for determining the quality objectives of telecommunication systems. The rainfall pattern in Akure may be categorized as mainly stratiform with less than 10% convective rains. Comparison of measured rain rate with ITU-R indicates that the ITU-R model underestimates rainfall intensities at higher rain rates above 25mm/h, and above 99.5% of times, while it closely estimates intensities at lower rates below 20mm/h and for 99% of times.

5.0 References

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