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# Year to year variation of rainfall rate and rainfall regime in Ota, southwest Nigeria for the year 2012 to 2015

T V Omotosho[1], O O Ometan[1,2], S A Akinwumi[1], O M Adewusi[1,2], A O Boyo[2] and M S J Singh[3]

[1]Department of Physics, Covenant University, PMB 1023, Ota, Ogun State, Nigeria
[2]Department of Physics, Lagos State University, Ojo, Lagos State, Nigeria
[3]Institute of Space Science, Universiti Kebangsaan Malaysia 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia

Email : omotosho@covenantuniversity.edu.ng[1], luwafunmilayo.ometan@lasu.edu.ng[1,2], oluwasayo.akinwumi@covenantuniversity.edu.ng[1], madewusi@gmail.com[1,2], adenikeboyo@gmail.com[2]

**Abstract.** The tropics is characterized to have convective type of rainfall which has high occurrence of rainfall compared to the temperate regions of the world. In this paper, the accumulation of rainfall in Ota, Southwest, Nigeria (6$^o$ 42 N, 3$^o$ 14 E) has been analysed to present the one-minute rainfall rate and the predominant type of rainfall. Four years' data used for this study was taken using the Davis Wireless vantage Pro2 weather station at Covenant University, Ota, Ogun State. The data collected were used to analyse the one-minute rainfall rate and different types of rainfall predominant in this region. For the prediction and modelling of rain attenuation at microwave frequencies for a region like the Nigeria at various percentage of time, one-minute rainfall rate is required. Nigeria falls into the P zone of 114 mm/hr. as per International Telecommunication Union – Recommendation (ITU-R). The analysis carried out indicated that the measured yearly averaged maximum one-minute rainfall rate for 2012, 2013, 2014 and 2015 are 157.7 mm/h, 148.0 mm/h, 241.2 mm/h and 157.3 mm/h respectively. It also indicated that the drizzle type of rainfall is predominant in contrast to established fact that thunderstorm occurs more in the tropics.

## 1. Introduction

One of the features that is most readily identified with the tropical atmosphere is the Intertropical Convergence Zone (ITCZ) [1]. The ITCZ lies in the equatorial trough, a permanent low-pressure feature that marks the meteorological Equator where surface trade winds, composed of heat and moisture from surface evaporation and sensible heating, converge to form a zone of increased mean convection, cloudiness, and precipitation [1]. Due to this, the tropical region of the world is known for their high rainfall rate. Amongst other atmospheric phenomenon, rainfall has major attenuation effect on propagation of communication signals at frequencies above 10 GHz [2]. Rain is formed when large cloud droplets from water vapour coalesce until the cloud can no longer hold together. Rain can occur as stratiform rain or convective rain. In high latitudes, stratiform rain is more dominant while in the tropics, the convective rain is dominant [3]. Rain, amongst the most common form of precipitation is the easiest to measure.

The cumulative rainfall is recorded using the recording rain gauge type which also gives the duration of rainfall events. The tipping bucket type is used for measuring the amount of accumulated rainfall and the rainfall rate [4]. Obiyemi et al. [5] estimated the point rain rate for Akure for 0.01% to be 120 mm/h. The 0.01% rain rate is about 120mm/h over locations in Malaysia as estimated by

Abdulrahman et al. [6]. The point rainfall rates estimated by Ong and Zhu in Singapore were 104, 118, 115, 111mm/h observed over 2 years using a network of rain gauges' installations at Nanyang Technological University (NTU), Shunfu, Paya Lebar and Tampines respectively [7]. These results are also very similar with the result obtained by Pontes et al. for 0.01% percentage exceedance of rainfall rate in Brazil for different locations which were 118, 123 and 126 mm/h respectively for Rio de Janeiro, Belem and Manaus [8].

Also, precipitating clouds in the tropics have been reported to be entirely convection-generated by cumulonimbus clouds which forms either convective or stratiform rainfall type [9]. Stratiform type of rainfall is presumed to be of major occurrence in the tropics due to inadequate data, but in temperate regions ice particles are formed by nimbostratus cloud layer which are stable. The upward movement of air causes water vapour to be deposited on the ice particles. The ice particles fall to the earth as rainfall as they melt and fall from upper level [9]. Sometimes, the particles may never melt but reach the surface as snow rather than rain under certain cold conditions [9].

The Inter Tropical Convergence Zone (ITCZ) at the equator is the major phenomenon that causes changes in rainfall in the tropics [9]. According to Houze (1997), the Global Atmospheric Research Programme Atlantic Tropical Experiment (GATE), radar studies have confirmed, many times over, that a large component of tropical precipitation exhibits stratiform radar-echo structure [9]. The ratio between stratiform and convective precipitation may have significant impacts on other aspects of the simulated climate because of their different heating profiles and other characteristics. [9].

There are mainly four types of rainfall: drizzle, widespread, shower and thunderstorm. Drizzles are made up of small droplets of water that usually last longer. Its diameter ranges from 0.1 and 0.5 mm/hr. Showers are heavy, large drops of rain and usually only last for a short period [9]. Omotosho *et al*., observed from the measurement obtained from the first year that there were elevated values of rain accumulation and rain rates compared to predictions of precipitation for the tropics by ITU-R. [10]. Rainfall measurement continued in the location of interest as this research was done to show the rainfall rate and the predominant rainfall type in Ota, Southwest Nigeria which is a predominant factor to determine the level of attenuation of communication signals for the tropics.

## 2. Methods and Data

The four years' rainfall data used for this research work were obtained from the Davis Wireless vantage Pro2 weather station installed at Covenant University, Ota, Nigeria with geographical coordinates 6.7$^o$N, 3.23$^o$E. It measures meteorological data such as temperature, pressure, wind speed, humidity, water vapour, rainfall rate etc. The receiver antenna is pointed towards the ASTRA satellite located at 36$^o$E in the geostationary orbit. The satellite transmitted power is 50.8 dBW and the stability of the power over time is 98%. The beacon signal frequency is 12.245 GHz and it is vertically polarized. The tipping bucket type rain gauge is used which is connected to the Weather station to obtain rainfall data, all in one package called Integrated Sensor Suite. A sensor interface module (SIM) collects outside data from the ISS and transmits the data to a vantage Pro console via a low power radio at a frequency of 868.0 – 868.6 MHz with a maximum line-of-sight range of 300 m. The beacon measurement was taken through a signal transmitted from the operational transponder. The output signal of the Low Noise Block Converter (LNB), at the satellite dish, was connected to a data logger via personnel computer (PC). The rain collector type is tipping bucket with 0.01 inches per tips (0.2 mm with metric rain adapter). The temperature sensor is PN junction silicon with a range of -40$^o$ to +65$^o$ and an accuracy of ±0.5$^o$C above -7$^o$C, ±1$^o$C under -7$^o$C. The pressure sensor has a range of 540 to 1100 hPa / mb and a sensor accuracy of ±1.0hPa, the humidity sensor has a range of 1 to 100% and an accuracy of ±3% (0 to 90% RH), ±4% (90 to 100% Rh). The data logger was programmed to stored data every second continuously which was recorded as averaged data every 1-minute. 1440 data is recorded per day with 44640 for 31 days per month. The one minute rain rate experimental data obtained were used to analyze rain rate variation from April 2012 to December 2015.

## 3. Results and Discussion

Table 1 presents yearly rainfall accumulation from 2012 to 2015 showing that year 2014 has the highest total rainfall accumulation of 1348.7 mm with the lowest in 2012, 965.4 mm. The peak of the maximum rainfall rate is 241.2 mm/hr in 2014 while the minimum is 148.0 mm/hr. Tables 2 and 3 presents the yearly different rainfall regimes from 2012 to 2015.

**Table 1.** Yearly Rainfall accumulation for Ota from 2012 to 2015

| Year | 2012 | 2013 | 2014 | 2015 | Average |
|---|---|---|---|---|---|
| Total Yearly Rainfall (mm) | 956.4 | 1057.9 | 1348.7 | 954.2 | 1079.3 |
| Total no of rainy days | 116.0 | 127.0 | 159.0 | 114.0 | 129.0 |
| Max. Rain rate (mm/hr.) | 157.7 | 148.0 | 24.0 | 157.3 | 176.1 |

**Table 2.** The yearly different rainfall regime for 2012 and 2013

| Year | 2012 | | | | 2013 | | | |
|---|---|---|---|---|---|---|---|---|
| Rain Regime | Number of events | Total rain intensity (mm/hr.) | Rain (Minutes) | Percentage (%) Rain Minutes | Number of events | Total rain intensity (mm/hr.) | Rain (Minutes) | Percentage (%) Rain Minutes |
| *Drizzle* $0 < R \leq 5$ | 5895 | 11116.4 | 5895 | 72.1 | 5966 | 11348.2 | 5966 | 71.1 |
| *Widespread* $5 > R \leq 10$ | 929 | 6623 | 929 | 11.4 | 796 | 5696.2 | 796 | 9.5 |
| *Showers* $10 > R \leq 40$ | 840 | 17420.6 | 840 | 10.3 | 1049 | 22056.4 | 1049 | 12.5 |
| *Thunderstorm* $40 > R$ | 514 | 40058.6 | 514 | 6.3 | 575 | 45240.6 | 575 | 6.9 |
| Total | 8178 | 75218.6 | | | 8386 | 84341.4 | | |

**Table 3.** The yearly different rainfall regime for 2014 and 2015

| Year | 2014 | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|
| Rain Regime | Number of events | Total rain intensity (mm/hr.) | Rain (Minutes) | Percentage (%) Rain Minutes | Number of events | Total rain intensity (mm/hr.) | Rain (Minutes) | Percentage (%) Rain Minutes |
| *Drizzle* $0 < R \leq 5$ | 7963 | 15027.8 | 7963 | 72.5 | 5241 | 10112.6 | 5241 | 70.8 |
| *Widespread* $5 > R \leq 10$ | 1086 | 7592 | 1086 | 9.9 | 697 | 4951.6 | 697 | 9.4 |
| *Showers* $10 > R \leq 40$ | 1253 | 25806.9 | 1253 | 11.4 | 983 | 20795 | 983 | 13.3 |
| *Thunderstorm* $40 > R$ | 677 | 53163 | 677 | 6.2 | 477 | 35650 | 477 | 6.4 |
| Total | 10979 | 101589.7 | | | 7398 | 71509.2 | | |

Investigations from Table 1 shows that the drizzle type of rainfall has a greater percentage of occurrence of 72.1 %, 71.1 %, 72.5 % and 70.8 % for 2012, 2013, 2014 and 2015 respectively. Figures 1 to 4 shows the variations in the occurrence of the different rainfall regimes. In 2012, there were two peaks in June and October with December recording the lowest. In 2013, there were three peaks: May, July and September with July recording the highest. Also, December shows the lowest in 2013. There is a variation in 2014 compared to 2012 and 2013. There were two peaks: June and October with February recording the lowest. In 2015, two peaks were also seen in June and October respectively with December being the lowest.

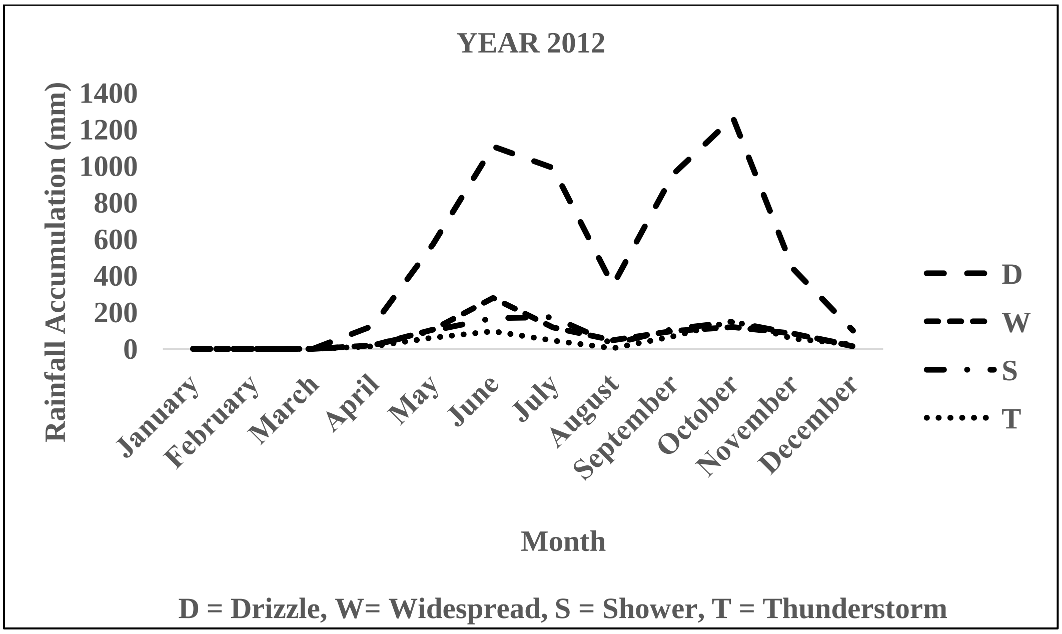


**Figure 1.** The variation in rainfall regime for Ota in 2012

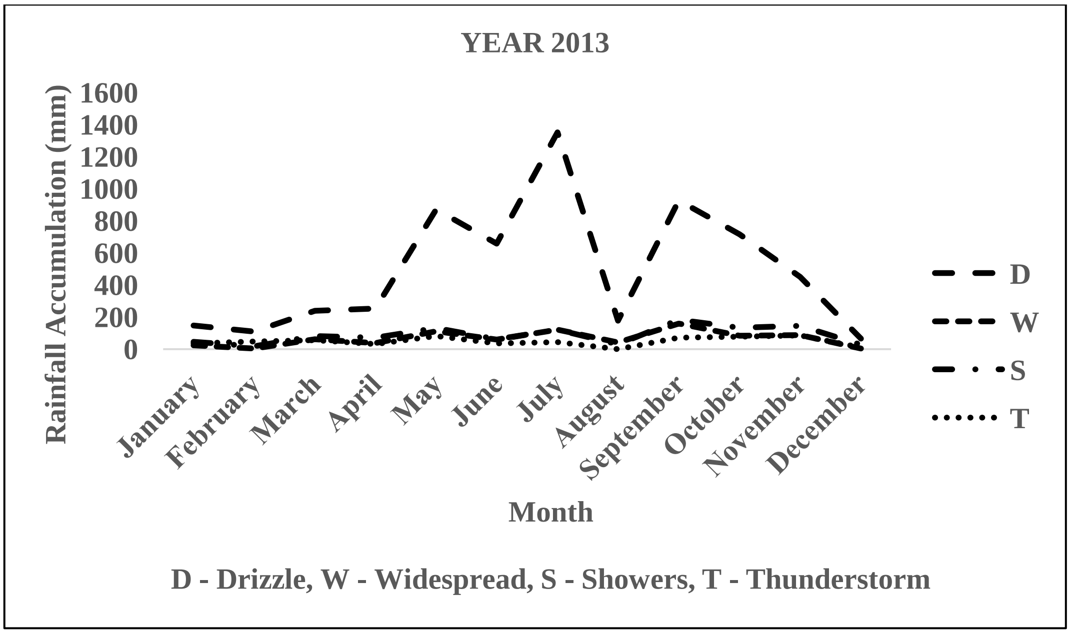


**Figure 2.** The variation in rainfall regime for Ota in 2013.

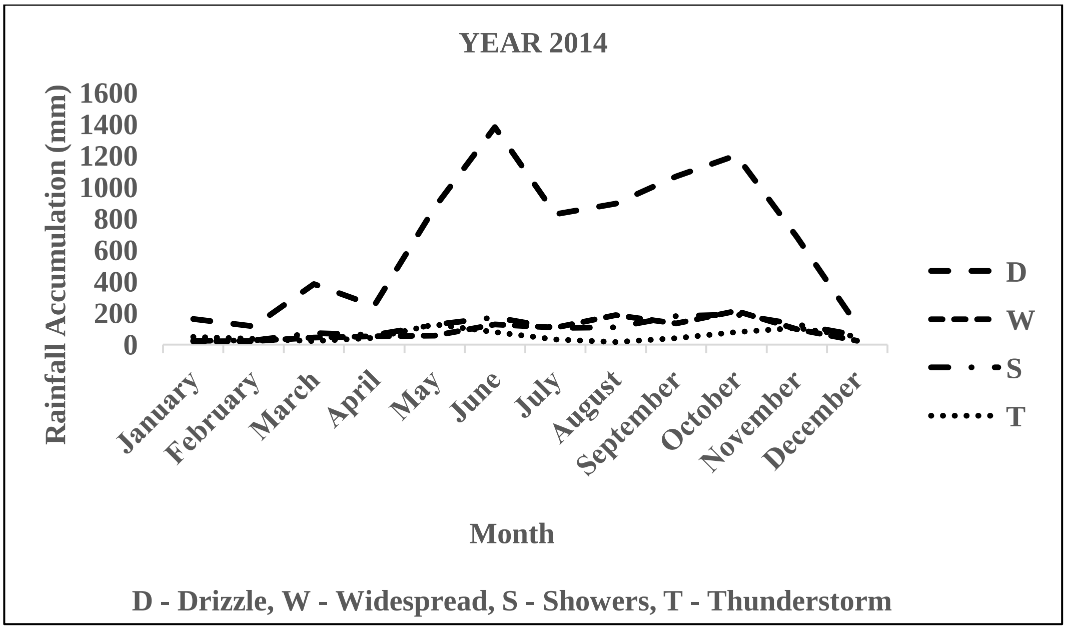


**Figure 3.** The variation in rainfall regime for Ota in 2014.

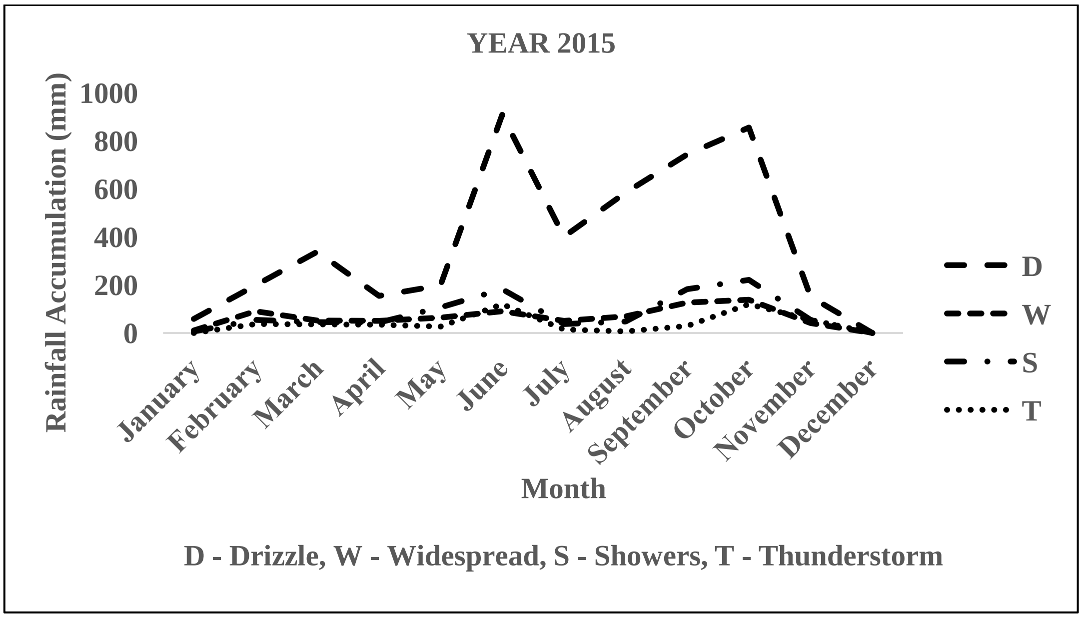


**Figure 4.** The variation in rainfall regime for Ota in 2015.

## 4. Conclusion

The result reported in this study is used for the analysis of the rainfall regimes at Ota in terms of rainfall regime, number of event and total rainfall intensity which shows the weather dynamics of this region. The drizzle type of rainfall is evidently predominant in Ota on the average of 71.6 %. The total numbers of rainy days from 2012 to 2015 are 116, 127, 159 and 114 respectively. The four years of our experiment results indicated that the measured $R_{0.01}$ rainfall rate at Ota is ~ 200 mm/h. The result obtained also indicated that year 2014 had the maximum number of rainy days, maximum total rainfall and maximum rainfall rate which are 159.0 mm, 1348.7 mm and 241.2 mm/h respectively. The results were compared with ITU-R recommendation on the characteristics of precipitation for propagation modelling and it was discovered that the ITU-R [11] model underestimated the rainfall rate. Therefore, the P region recommendation by ITU-R model is under estimated for Ota, the Q-region of ITU-R model would be more suitable. This result will provide adequate information to the communication engineers about the possible attenuation or link reliability that is likely to occur in Ota. Therefore, new model of rainfall rate should be developed using the rainfall rate measurement from the place of interest.

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