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Analysis of Seasonal Precipitation Rate in Nigeria Using Dataset from Tropical Rainfall Measuring Mission

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Analysis of Seasonal Precipitation Rate in Nigeria Using Dataset from Tropical Rainfall Measuring Mission

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Abstract. The study aimed to analyze the seasonal precipitation rate using dataset retrieved from TRMM over Nigeria. The Seasons evaluated are December to February (DJF), March to May (MAM), June to August (JJA) and September to October (SON) using ten years (December 2009-November 2019) data acquired from TRMM data base. The result shows that, the precipitation rate differs and these ranges from light precipitation from the northern regions to heavy precipitation in the southern regions. For the DJF season, the northern regions experience little or no precipitation especially during the dry season. Meanwhile, during the MAM, JJA and SON seasons, the northern regions experiences light to moderate ($0 \leq R < 5$ mm/h) precipitation rate according to World Meteorological Organization (WMO) while the southern regions experience moderate to heavy ($0.1 \leq R \geq 0.5$ mm/h) precipitation rate with its peak at MAM and SON seasons which correspond to the wet months/season and early dry season. It follows that the result obtained from this work is in agreement with the WMO. The result from this work will provide an insight on precipitation event which in turn, will help in decision making on various ways of adaptation and also, planning of outdoors events such as agricultural activities (food securities), sport activities and also in the telecommunication and aviation as increase in the rate precipitation increases the attenuation on communication link.

Keywords: Nigeria, Precipitation, Seasonal analysis, TRMM Dataset

1. Introductionr

In climate study, the most important factor is precipitation because of its contribution to the hydrological cycle and its impact on humans [1-5]. From the perspective of climate, the intensity and precipitation distribution are likely to be affected by global climate change. Precipitation events are crucial for the improvement of our understanding on climate change mechanism. The frequency and amount of precipitation is directly connected to agricultural activities and its sustainability. Lack of precipitation and frequent precipitation also affect the security of food. To effectively plan mitigation of climate change, food security and event that threatens humans' life, such as ocean surges, heat-waves, cyclones, frequency, and rate of precipitation must be computed [5, 6]. To completely characterize a variable such as precipitation discontinuously, not only the time percentage of precipitation (frequency) is required but also the accumulation amount, the rate of precipitation averaged over only the precipitation time (Intensity) and the interval of precipitation averaged over the precipitation period (Duration) [3, 4, 7]. Furthermore, because of the importance of precipitation, it is the subject of most studies and its frequency and intensity of precipitation have huge impacts on heat fluxes over land surface, soil moisture, surface runoff and human activities. Moreover, they act metrics for the evaluation of Physics parametrizations in climate models and numerical weather. Also, the amount of daily, monthly, and yearly precipitation rates is important in estimating water budget and the management of water basins. The key difficulty in overcoming this challenge is a result of insufficient rain gauge stations for precipitation measurement [2, 8]. The estimation of precipitation rate from radar gives a better spatial coverage than the rain gauge in a gauging station [2, 9]. The rate at which precipitation is detected and recorded by the radar depends on the terminal speed of the rain drop [10-12]. This is classified in Table 1 according to World Meteorological Organization [13].

Table 1: Rates and types of precipitation [10].

Precipitation Types	Range of R mm/h)	Intensity
Drizzle	$R < 0.1$	Light
	$0.1 \leq R < 0.5$	Moderate
	$R \geq 0.5$	Heavy
Rain	$R < 2.5$	Light
	$2.5 \leq R < 10$	Moderate
	$10 \leq R < 50$	Heavy
	$R \geq 50$	Extreme

The authors in [14] analysed precipitation data on an hourly basis on a 0.25° grid from an observing satellite and disclosed that over 0.02 mm/hr precipitation rate occurs at about 11.0±1.1% of the averaged time over 60° S to 60° N but only approximately 8% of the time is over land. The work of [5, 7, 15] showed that the spatial precipitation variations, its annual cycles, and diurnal are determined largely by how frequently it rains rather the intensity of the rain. Also, the rate of dominance of precipitation is ranges light to moderate rain [16], and its highest precipitation rate is at the intertropical convergence zone [5, 11]. [17] showed that the seasonal cycle frequency and its spatial distribution can be likened to the rate of precipitation although, the rate of rainfall range inversely with the frequency peak. Thus, in the determination of seasonal variations, diurnal cycle and spatial patterns, the rate of precipitation plays an important role in most areas of the earth, however, the intensity of precipitation has an important consequence on extreme precipitation and its future variations [3, 13, 18]. The current study aims to analyse the seasonal rate of precipitation over Nigeria using Tropical Rainfall Measuring Mission (TRMM) dataset.

2. Methodology

2.1. Study Area

Nigeria is a West Africa country that lies on lat. 4° N to 14° N and long. 4° E to 14° E. It is bordered in the North by Sahara Desert and in the South by the Atlantic Ocean as shown in Figure 2. This makes the country experienced a different climatic pattern all through the year. The weather system of Nigeria is driver by the Intertropical Discontinuity (ITD) which is an area over West Africa with low pressure that separate the Atlantic Ocean from the moist Southern monsoon and the Sahara Desert from the dry northern trade winds. The south and north of the ITD are always characterize by dew point temperature above 15° C and below 15° C, respectively. The southern and northern path of the ITD atmosphere is moist and dry (and dusty), aiding cloud formation as well as fog at low altitude and preventing cloud formation except cirrus and altocumulus at high altitude respectively [19-21]. Also, the weather systems in Nigeria are control by the movement of the ITD. Although, the ITD is associated with three unique overlapping movement all throughout the year. A yearly movement which follows the sun's path is responsible for the seasons, while the diurnal movement consist of a slight northward and southward shift in the afternoon and morning respectively, while an intermediate movement is also observed during the winter months of the northern hemisphere [16]. Nigeria is associated with four climatic zones: in the northeast (warm desert climate), in other regions of the north (warm semi-arid), in the Niger-delta (monsoon climate), and in the middle belt and parts of the southwest (tropical savannah climate). The key ecological zones in Nigeria shown in Figure 1, are the semi-arid, savannah and tropical rainforest associated with the north, middle-belt (North central), and south zones respectively [22]. In Nigeria, the two well-known seasons are the wet season and dry season. In this work, the following seasons will be considered; the early-wet season (March, April, May – MAM), late-wet season (June, July, August – JJA), early-dry season (September, October, November – SON) and late-dry season (DJF).

Figure 1: The coordinate of Nigeria in Africa (Wikipedia).

2.2. Dataset source

TRMM is an association between JAXA and NASA. TRMM is aimed to estimate precipitation rate and lightning over the tropics and subtropical regions on lat. 40^{o} N to 40^{o} S on the surface of the earth. TRMM started operation November 1997, and its assignment came to an end in April 2015. The platform carries five different sensors. There are five sensors onboard the platform of which three of the sensors; precipitation radar, visible infrared scanner and microwave imager were used to estimate the rate of precipitation. Moreover, the multi-satellite precipitation analysis (TMPA) is a merged product of precipitation dataset from satellite-gauge measured every single three hours from lat. 50^{o} S to 50^{o} N. The measured dataset is then retrieved from the satellite systems in the TRMM precipitation satellite constellation. The TMPA dataset is a monthly dataset measured at a resolution of 0.25-degree x 0.25 degree [23-26]. Figure 2 shows the TRMM satellite and its scanning geometric of the three sensors instruments. In this research, the TMPA 3B43 monthly precipitation for the period of December 2008 to November 2019 were used.

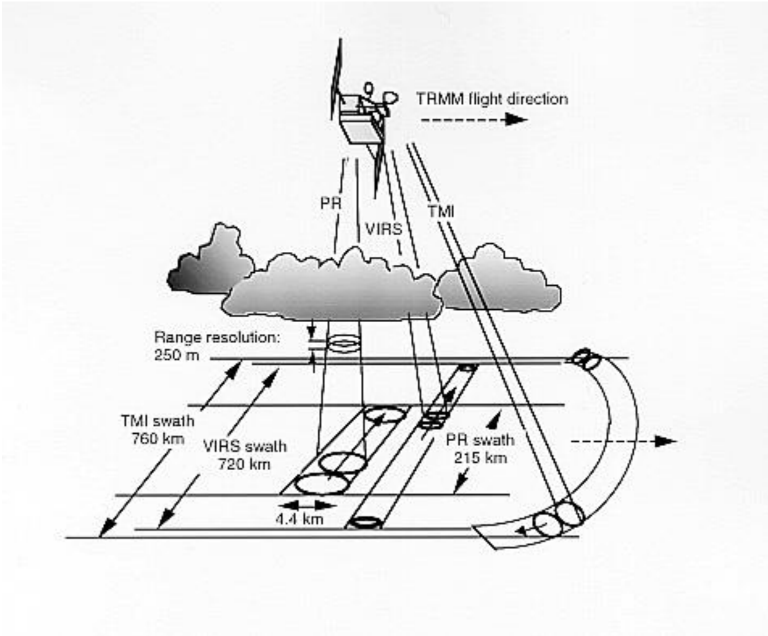

Figure 2: TRMM satellite and the geometric of scanning of the three sensors instruments [23-25]

2.3. Analysis of Seasonal Average Precipitation Rate using TRMM Dataset

This process comprises of importation of the 3B43 precipitation dataset in Network Common Data Form (NetCDF) into Panoply for rasterization. The dataset retrieved from TRMM, was then converted into a point for interpolation to final mapping of the precipitation pattern over the study area (Nigeria).

3 Results and Discussion

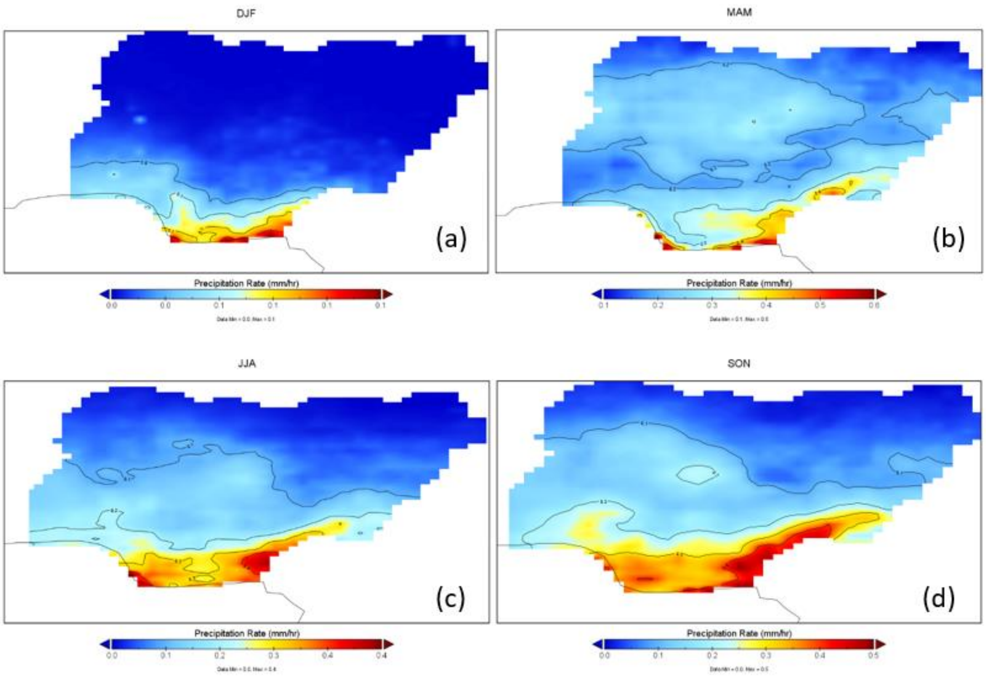

Figure 3: Analysis of mean seasonal precipitation rate over Nigeria during the period 2009-2019.

In this section, the monthly average for the seasons, December-February (DJF), March-May (MAM), June-August (JJA), and September-November (SON) are considered during the period (2009-2019) under investigation. The investigation is based on monthly outputs of precipitation rate for DJF, MAM, JJA, and SON observed From the TRMM dataset. From Figure 3(a), the seasonal mean precipitation rate for DJF, is 0 mm/hr, for NE, NW, and NC regions while its value is 0.1 mm/hr for SS, SE, and SW regions. In Figure 3(b), the seasonal average precipitation rate for MAM is 0.05, 0.05 and 0.20 mm/hr for NE, NW, and NC regions respectively while its value for SS, SE and SW are 0.30, 0.30 and 0.40 mm/hr respectively. The seasonal mean precipitation rate for JJA in Figure 3(c) ranges from 0.20 to 0.30 mm/h for NE, NW, and NC regions respectively while its values for SS, SE and SW regions are 0.50 to 0.60, 0.40 and 0.20 to 0.30 mm/hr respectively. The average seasonal precipitation rate for SON is 0.10, 0.10 and 0.20 mm/hr NE, NW, and NC regions, respectively. The seasonal mean precipitation rate ranges from 0.40 to 0.50 for SS, 0.30 for SE and 0.20 to 0.30 mm/hr for SW regions, respectively.

Table 2: Precipitation rate across the zones of Nigeria.

Season	**Zone**	**Figure**	**Precipitation rate (mm/h)**
DJF	NE	a	0.00
	NW		0.00
	NC		0.00
	SS		0.10
	SE		0.10
	SW		0.10

Season	**Zone**	**Figure**	**Precipitation rate (mm/h)**
MAM	NE	b	0.05
	NW		0.05
	NC		0.20
	SS		0.30
	SE		0.30
	SW		0.40

Season	**Zone**	**Figure**	**Precipitation rate (mm/h)**
JJA	NE	c	0.20-0.30
	NW		0.20-0.30
	NC		0.20-0.30
	SS		0.50-0.60
	SE		0.40
	SW		0.20-0.30

Season	**Zone**	**Figure**	**Precipitation rate (mm/h)**
SON	NE	d	0.10
	NW		0.10
	NC		0.20
	SS		0.40-0.50
	SE		0.30
	SW		0.20-0.30

The results shows that regions such as NE (Bauchi, Borno, Gombe, Taraba, Yobe), NW (Kaduna, Katsina, Kano, Kebbi, Sokoto, Jigawa, Zamfara) and NC (Benue, FCT, Kogi, Kwara, Nasawara, Niger, Plateau) with precipitation rate of 0.0 mm/h experiences little or no precipitation while regions such as SS (Akwa-Ibom, Bayelsa, Cross river, Delta, Edo and Rivers) with precipitation rate of 0.10 mm/h, SE (Abia, Anambra, Ebonyi, Enugu and Imo) with precipitation rate of 0.10 mm/h and SW (Ekiti, Lagos, Osun, Ondo, Ogun and Oyo) with precipitation rate of 0.10 mm/h experiences a uni-modal precipitation distribution (minimum precipitation) during the DJF season meanwhile, in MAM season, the NE, NW, NC, SS, SE and SW with precipitation rate 0.05, 0.05, 0.20, 0.30, 0.30 and 0.40 mm/h respectively, experiences a uni-modal precipitation distribution across these regions. This correspond to the raining months/season, although the precipitation rate is lower in the norther regions due to the hot temperature experienced in these regions (weather) meanwhile the precipitation rate increases from SS to SE with its peak in the SW region of the country. In JJA season, the SE experience a uni-modal precipitation distribution in that region while NE, NW, NC, SS and SW all experiences a bi-modal precipitation distribution in all these regions. Also, in the SON season, The NE, NC and SE regions experiences a bi-modal precipitation distribution while the SS and SW regions experiences a bi-modal precipitation distribution in this season.

In the DJF season, slight precipitation is observed in the SS, SE and SW regions respectively while there is no precipitation in the NE, NW and NC during this season. This may be due to the fact that during this season (dry season), the norther part of the study area experiences very little or no precipitation. Indeed, this season correspond to the dry season in the region, that result in the flow of air mass of the Tropical Continental (cT) from the Sahara Desert. During the MAM (early wet), JJA (late we) and SON (early dry) seasons, there is an increase in precipitation rate which ranges from light to moderate between $0 \leq R < 5$ mm/h according to World Meteorological Organization from the northern regions to the southern part of the study area with maximum precipitation in the southern part of the regions which ranges from moderate to heavy and lies between precipitation rate of $0.1 \leq R \geq 0.5$ mm/h with its peak at the SS regions during these seasons. This corresponds to the early wet, late wet and early dry months of the study area. This is normal because the northern part of the study area receives less precipitation throughout the year while the southern part of the country which experience bi-modal precipitation all year round (Table 2).

4. Conclusion

This study shows that the precipitation rate over Nigeria plays a significant role in the daily activities of the inhabitant across these regions. As a result of that, the impact of precipitation rate varies from one region to the other; as precipitation rate decreases from the southern to the northern regions of the country. Thus, it is recommended that the results from this work can help decision-makers within the regions under consideration to take proper measures of adaptation and planning of outdoor events such as agricultural, sport and social activities during these seasons.

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