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*Research Article*

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# Monthly, Seasonal and Annual Temporal Variation in Cloud Cover Over Makurdi Town, North Central Nigeria

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**Abstract**
The study analysed the temporal variability of cloud cover in Makurdi Town, North Central Nigeria. Data was collected from the Nigerian Meteorological Agency Makurdi covering 1990 to 2022. Focusing Seasonal, Monthly and annual Temporal variation in cloud cover. Descriptive statistics such as simple line graph, mean, standard deviation, and coefficient of variation were employed, to examine seasonal and annual temporal variability in cloud cover Time series analysis techniques was used to analysed trends in cloud cover, in Makurdi town. The alpha model was used to test the significance at 0.05 significance level. The result on the seasonal variation in cloud cover indicate higher cloud cover during the rainy season, peaking around 2013-2016, while dry seasons show fluctuating cloud cover, peaking in 2013. The result on annual variation in cloud cover shows significant year-to-year fluctuations, with peaks around 1993, 1996, 2006, and 2013-2014, and dips from 1998, 2001, 2008, and 2016-2017. A 3-year moving average highlights a general increase from 2002 to around 2014, followed by a decline. A slight decline trend is indicated, but it explains little variability (R-squared = 0.0046), suggesting other factors such as the position of the sun, atmospheric circulation patterns and the migration of weather systems. The study concludes that cloud cover, noted significant fluctuations over time. The studyrecommendedthat deeper exploration of causes and integration of climate models with observational data for effective climate adaptation strategies.

**Keywords:** Cloud Cover, Temporal Variability, North Central Nigeria, Seasonal

## Introduction

Clouds cover approximately 70% of the Earth's surface at any given time, with substantial variability across different latitudes and longitudes. Equatorial regions tend to experience more extensive cloud cover due to convective processes associated with intense solar heating, while subtropical regions often exhibit clearer skies and less cloudiness [1]. Cloud act as the primary energy gatekeepers for the climate system by reflecting incoming solar radiation and blocking outgoing terrestrial radiation. Overall, clouds cool the surface at a rate of approximately $20Wm^{-2}$ [2].

Several studies have investigated the variability of cloud cover in different geographical contexts, highlighting the complex interactions between atmospheric dynamics, land surface characteristics, and climate forcings. For example, research by Li, Li, and Zhou, (2020) explored the temporal trends in cloud cover over East Asia, emphasizing the influence of atmospheric circulation patterns and aerosol emissions on cloud formation and dissipation [3]. Similarly, studies by Jones, Gage, Linderson, and Schween, (2019) and Wang et al. (2015) examined the variability of sunshine duration in Europe and China, respectively, elucidating the connections between solar radiation, cloud cover, and climate variability [4,5].

In Nigeria, limited research has focused specifically on the temporal variability of cloud cover at the local scale, particularly in regions like Makurdi. However, studies such as those by Adejuwon, Osipitan, Onigbinde, (2017) and Adefolalu, and Adefolalu (2015), have explored broader aspects of climate variability and its impacts on agriculture and water resources in Nigeria's semi-arid and humid zones [6,7]. The temporal

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fluctuations of cloud cover and sunshine duration and their influence on rainfall pattern in Makurdi Town, Benue State, Nigeria, pose a substantial research challenge, given their profound implications for local weather patterns, agricultural output, and climate resilience [8]. These atmospheric parameters play a crucial role in shaping the regional climate and environmental conditions, directly impacting various socio-economic sectors such as agriculture, water resource management, and energy production.

Despite their significance, there exists a noticeable dearth of comprehensive studies dedicated to investigating the temporal dynamics of cloud cover at the local scale in Makurdi Town, Benue State. Existing research in this area is limited and often focuses on broader regional or national scales, overlooking the unique microclimatic conditions and variability experienced within Makurdi Town. This gap in knowledge hinders the accurate assessment and understanding of how cloud cover evolve over time in the specific context of Makurdi Town, impeding effective climate adaptation and mitigation strategies.

In the context of Makurdi, Benue State, Nigeria, an examination of the temporal variability of cloud cover is particularly pertinent due to the region's reliance on rainfed agriculture and its susceptibility to climate-related hazards. Makurdi Town, situated in Nigeria's Middle Belt region, experiences a tropical savanna climate characterized by distinct wet and dry seasons. Changes in cloud cover profoundly impact precipitation patterns, temperature regimes, and overall environmental conditions in this region [8].

This study aimsto address this research gap by conducting a comprehensive analysis of the temporal variability of cloud cover in Makurdi Town, Benue State, Nigeria. By utilizing meteorological data collected from the Nigerian Meteorological weather station, this research seeks to identify seasonal, monthly and annual variability and trends in cloud cover. Insights gained from this analysis will contribute to a deeper understanding of local climate dynamics, facilitate improved weather forecasting capabilities, and inform adaptive strategies for climate-resilient development in the region.

**Study Area**

Makurdi Town lies between Latitude 7o40' and 7o35' North of the equator and between longitude 8o25' and 8o40' East of the Greenwich Meridian. It comprises the urban areas within Makurdi Local Government Area, including Mission, Clark/ Market, Wadata/Ankpa, North Bank I and Wailomayo political divisions or council wards, as well as parts of Fiidi, Modern Market, Bar and North Bank II council wards. It is situated within a physiographic zone called the Benue trough with a mean elevation of 92 meters above sea level (Geographical Information System (GIS) Laboratory, Benue State University, Makurdi, 2023) [9]. Makurdi Town has a land area of about 810 square kilometers and situated in the Benue Valley on the banks of River Benue. Makurdi is a transit/nodal point (rail, road, and inland waterways) between the South-East and Northern parts of Nigeria [10].

Makurdi Town is bounded by Gwer West Local Government Area to the west, Gwer East Local Government Area to the south, Guma to the North East and Doma to the North West. Politically, it falls within the Middle Belt region of Nigeria and has a radius of 16 kilometres from its centre. It is the capital of Benue State and headquarters of Makurdi Local Government Area. It serves as a major link between the Northern and Southern parts of Nigeria. The Town has several drainage channels. These channels include river Benue, which bisects the town into South and north banks, and its tributaries including Urudu, Demekpe, Kereke and Mu and the smaller ones include Idye and Dyeghe [11].

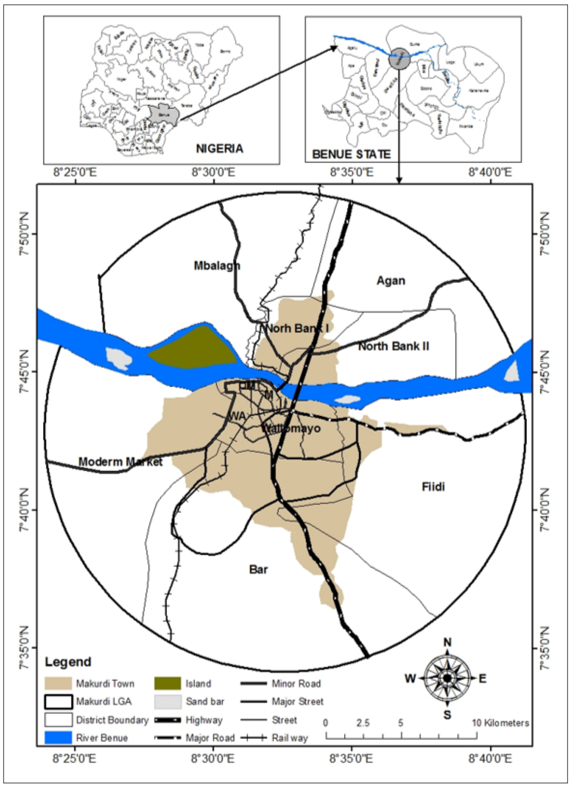


**Figure 1:** Map of Makurdi local Government Area Showing Makurdi town

**Source:** Geographical Information System (GIS) Laboratory, Benue State University, Makurdi (2023) [9].

The climate of Makurdi town is the tropical Aw type with alternating wet and dry seasons which are also hot and cool. The rainfall periods are from April to October, with rainfall amount ranging from 900mm to 1500mm with the heaviest rains in June and September which decline with increasing latitude. The dry seasons begin in November and end in April. Temperatures are generally high, with a mean annual temperature of 32.5oC. The hottest months are February to April and the coldest, December to January.

The three temperature periods experienced in the study are as investigated by Tyubee (2004, 2005) are [12,13]:

1. The cool-dry season at the period of low sun (November to January)
2. The hot-dry season just preceding the rains (February to April)
3. The cool-wet season during the rains (May to October).

Due to the enclosure of Makurdi town in the Benue Valley, the microclimate is greatly influenced hence, the high temperature epically in the months of March and April, culminating into a very uncomfortable and debilitating condition in Wurukum and Makurdi town in general.

The geology of Makurdi Town is composed mainly of sedimentary formations "Makurdi formation" with sandstones as the dominant rock type. The study area is underlain by sedimentary rock formation which covers the whole of Benue trough. Specifically, it is underline by cretaceous sandstone, some of which are exposed to the surface and are seen along the banks of River Benue, some parts of Government Residential Area (GRA), Wadata and Nigerian Army School of Military Engineering (NASME) Barracks. Low lying areas like Wadata are underlain by shale. The sandstone is divided into micaceous and feldspathic sandstones; some of these are exposed in parts of the old GRA. The Makurdi formation is made up of well consolidated sandstones which are texturally immature and compositionally sub-mature [14]. Those sandstones are cretaceous sediments believed to have been derived from Jos and Cameroun areas deposited by a system of meandering river flow in the coastal plain during the regressive phase of the sea in the Turanian era. The limestone that occurs in the Wadata Area of Makurdi formation consists of bipartite and highly neomorphosed bichromatic interbedded with calcareous shalty, sub-arkosic sandstones and fossiliferous shale [14,15]. Nwajide (1984) gave the dimension of the Makurdi formation as 100km and 400-500m thick.

Soils, according to Areola in Oguntoyinbo et al (1983) uses the Food and Agricultural Organisation (FAO) genetic classification system to describe the soils of Makurdi as deeply weathered, red ferrasols with abundant iron oxide without a lateritic iron-pan layer. These form as meta-sediments over sedimentary formations, but on flood plains, there are recent alluvial deposits deposited by the flood waters of the Benue River [16,20]. Soil profiles for Makurdi depict tropical ferruginous soils and characteristically of coarse loamy sand materials [17].

Makurdi Town lies within the guinea savannah belt with different species of trees, shrubs and grasses. Some of these include Danielliaoliveri, Biglibos and Afzeliaafricana. The grass species are Antroposofiegayanus, Pennisetumpurpureum (Elephant grass) and Panicum maximum. These natural plant species have almost disappeared as a result of urbanization, except in few places such as at the outskirts of the town where the natural vegetation has almost been replaced by domestic fruit trees such as mango, citrus and coconut trees; as well as ornamental plants. The destruction of vegetation in the Makurdi town has rendered the land surface bare, thus resulting in accelerated rates of flooding in the area.

The Makurdi Town urban area does not have a good drainage due mainly to the fact that, the town is low-lying with poor geology. The underlying geology is such that creates water-logging in several places in the town especially in Wadata and Wurukum. The Benue State Government has been making serious efforts at the construction of artificial drainage channels, for example, the Idye channel and this has greatly alleviated the poor drainage situation.

The major water channel in the area is River Benue and it divides the Town into two segments. Other drainage channels found in Makurdi urban area include the Urudu, Idye and Demekpe, which are first order tributaries of River Benue. Nyagba in Denga (1995) has identified the extensive flood plains of River Benue as ideal for dry season irrigation agriculture [17]. The Makurdi town is located within the lowest relief zones of the Benue valley, with relief height averaging only 250 meters [18]. Locally, Udoh (1970) divides its relief into two:

i. The high plains- a term applied to those parts of the town generally lying above flood level. They include areas such as the High-level and North-Bank areas. The high plains are characteristically prone to erosion and cut in sedimentary formations.
ii. The flood plains- These include Wurukum, Wadata, Logo, Akpehe, Idye, Gyado Villa and Modern market areas. These are seasonally transgressed by floods when the River Benue is in its highest volume and overflows its banks. They make up the southern part of the town.

The 2006 national census puts the population of Makurdi Town at 300,173 people at a growth rate of 3.0. Out of this figure, 156,384 are males while 143,789 are females. The most predominant economic activities in the study area include commerce, service sector and agriculture. Commerce and civil service make up the higher proportion of the population. Agriculture is however practiced on a small scale, basically market gardening around the river banks and other swampy areas of the town. Fishing is also an activity that is been carried out in the river. With these activities in the town especially commerce and civil service, Banks have been established to provide services to residents. Higher institutions of learning such as the Benue State University Makurdi, the University of Agriculture, School of Nursing and midwifery, and other colleges have also contributed to the increased population in the town.

Recreational activities such as parks, the drilling of clay from the river, disposal of refuse, the cultivation of farm lands [19]. The nature of land use in Makurdi varies from administrative, residential, educational, commercial, and recreational to industrial uses, urban agriculture, settlements, transportation, and industries amongst others.

## Materials and Methods

### Data Collection and Sources

The research design adopted for this study was observational design. The rationale for adopting this design is because observational designs allow us to collect data from real-world settings without manipulating variables or introducing experimental conditions. This is essential for studying natural phenomena such as cloud cover in a specific geographical location like Makurdi Town.

The data for this research study was obtained from the meteorological Nigerian Meteorological Agency Makurdi. The data covers a time series of 32 years (1991 – 2022). The data consist of climatologically observation of mean cloud cover measured in (Oktas) which is observed at 09:00 GMT (10: am local time) and 1500 GMT (4: pm local time)

**Methods of data Analysis**

Descriptive statistics such as simple line graph, mean, standard deviation, and coefficient of variation were employed, to examine seasonal and annual temporal variability in cloud cover Time series analysis techniques was used to analysed trends in cloud cover, in Makurdi town. The alpha model was used to test the significance at 0.05 significance level.

**Results and Discussion**

**Seasonal Variation in Cloud Cover**

Figure 4.1 depicts the temporal variation in cloud during the rainy and dry seasons in Makurdi, Benue State, Nigeria, over a span of 32 years (1990-2022). The cloud cover during the rainy season is consistently higher than during the dry season, with both seasons displaying distinct trends and fluctuations. The rainy season shows a slight upward trend in cloud cover from 1990 to 1997, followed by stable fluctuations until 2003. From 2003 to 2016, there is a gradual increase, peaking around 2013-2016. Post-2016, the cloud cover stabilizes around the 39-40 range, indicating a relatively consistent pattern in recent years.

In contrast, the dry season exhibits lower cloud cover with more pronounced fluctuations. There is an increasing trend from 1990 to around 1995, followed by a significant dip around 1998. The cloud in the dry season shows a gradual increase from 2003 to 2013, reaching a peak around 2013. However, post-2013, there is a noticeable decline, with cloud cover stabilizing at a lower range (around 35-36) from 2017 onwards. These seasonal comparisons align with the expected climatic patterns, where the rainy season is characterized by increased cloudiness and higher rainfall, while the dry season experiences lower cloud cover.

The depiction of seasonal and annual variations in cloud in figure 4.1 and 4.3 cover is crucial for understanding the local climatic conditions in Makurdi. This analysis addresses the study's objectives by highlighting the temporal dynamics of cloud cover and suggesting a potential relationship between cloud cover and rainfall patterns. The consistent higher cloud cover during the rainy season supports the hypothesis of its influence on rainfall, providing a basis for further exploration in the study. Understanding these patterns is essential for developing effective climate adaptation and mitigation strategies, particularly in the context of local agricultural output and water resource management.

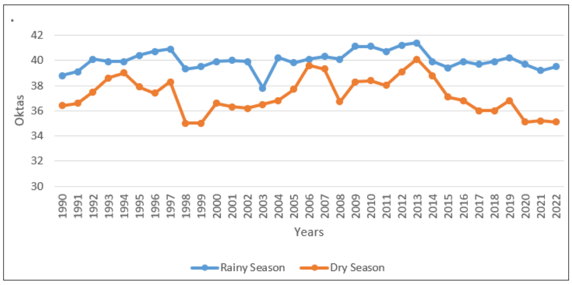


**Figure 4.1:** Seasonal Variation in Cloud Cover

**Source:** Researchers Fieldwork 2023

**Monthly Variation in Cloud Cover**

The results of the Monthly Variation in Cloud Cover in the study area are presented in Figure 4.2. The results show that the Monthly Variation in Cloud Cover was generally low during the dry season between the months of November and March. January had relatively low cloud cover, suggesting clearer skies, with a mean total of 196.8, which increased slightly in February to 201.6. Cloud cover continued to increase in March, with a mean total of 206.2, indicating more cloudy days compared to the previous months. There was a further increase in April, with a mean total of 212.6, suggesting a trend towards cloudier conditions. May experienced a slight decrease in cloud cover, with a mean total of 204.4, compared to April, but it remained relatively high. It spiked significantly in June, with a mean total of 220.4, indicating a substantial increase in cloudy days, possibly due to seasonal changes. Cloud cover remained high in July, with a mean total of 224.2, indicating continued overcast conditions, possibly typical of this time of year. Cloud cover peaked in August, with a mean total of 226.9, suggesting maximum cloudiness for the year. Cloud cover remained high in September, with a mean total of 225.1, but started to decrease slightly compared to August. There was a noticeable decrease in cloud cover in October, with a mean total of 218.8, compared to the previous months, possibly indicating the transition to clearer skies. Cloud cover decreased further in November, with a mean total of 205, suggesting clearer conditions compared to October. There was a continued decrease in December, with a mean total of 199.8, but it remained relatively high compared to earlier months in the year, indicating some cloudiness persists even in late December.

In conclusion, the data illustrates a seasonal fluctuation in cloud cover, with a gradual increase from January to August, peaking in the mid-year months, and then a decline towards the end of the year. These findings likely reflect typical weather patterns and seasonal variations in the study area.

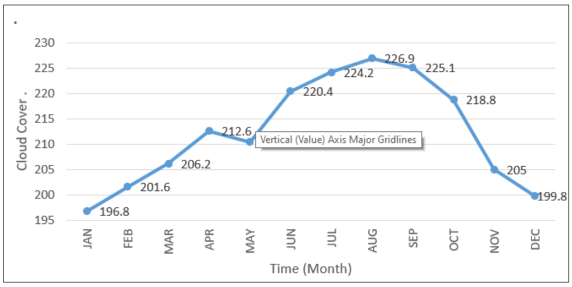


**Figure 4.2:** Monthly Variation in Cloud Cover

**Source:** Researchers Fieldwork 2023

**Annual Variation in Cloud Cover**

Figure 4.3 displays the annual variation of cloud cover in Makurdi Town, Benue State, Nigeria, from 1990 to 2022. The raw data, represented by the blue line, shows significant year-to-year fluctuations, with notable peaks in 1993, 1996, 2006, and 2013-2014, and significant dips around 1998, 2001, 2008, and 2016-2017. The 3-year moving average, depicted by the orange line, smooths these fluctuations, highlighting a general increase in cloud cover frequency from 2002 to around 2014, followed by a decline in recent years. The increase in cloud cover from

2002 to around 2014, followed by a decline in recent years, could be influenced by several climatic factors: Oscillations such as the Pacific Decadal Oscillation (PDO) or the Atlantic Multidecadal Oscillation (AMO) can influence atmospheric patterns, including cloud cover, over multi-year periods, Changes in global temperature can alter atmospheric circulation patterns and moisture content, affecting cloud formation and distribution, fluctuations in atmospheric conditions, such as changes in wind patterns, humidity levels, and air pressure systems, can lead to variations in cloud cover over time, localized climate events, such as the El Niño Southern Oscillation (ENSO) or the North Atlantic Oscillation (NAO), can impact cloud cover patterns regionally and globally, anthropogenic factors such as pollution and land use changes can influence cloud formation and properties, although their direct impact on long-term cloud cover trends may be less significant compared to natural climatic drivers. These climatic reasons contribute to the observed fluctuations in cloud cover as depicted by the 3-year moving average.

The overall mean cloud cover is approximately 77.44, represented by the gray line, serving as a baseline for comparison. The data points frequently oscillate around this mean, indicating periods of higher and lower cloud cover. The linear trend line, shown as a dotted line with the equation y = -0.0137x + 77.44, suggests a slight overall decline in cloud cover over the study period. However, the R-squared value of 0.0046 indicates that this linear trend explains very little of the variability in cloud cover, implying that other factors such as position of the sun, atmospheric circulation patterns and the migration of the weather patterns influenced seasonal changes in cloud cover. This is because the sun's angle and intensity vary throughout the year due to the Earth's axial tilt and orbit. This variation affects heating patterns and atmospheric stability, influencing cloud formation and distribution. Circulation, driven by factors like temperature gradients and pressure systems, determines the movement of air masses. Different circulation patterns, such as high-pressure systems, low-pressure systems, and jet streams, can impact cloud formation and movement. Weather systems, including fronts, storms, and pressure systems, migrate and evolve over time due to changes in temperature, humidity, and pressure. These movements can bring changes in cloud cover as weather patterns interact with different air masses and geographical features. These factors interact with each other and with other climatic drivers to influence seasonal changes in cloud cover. For example, changes in the position of the sun affect heating patterns, which in turn influence atmospheric circulation and weather patterns. Understanding these interactions is crucial for predicting and explaining variations in cloud cover on seasonal and longer time scales.

Overall, figure 4.3 provides critical insights into the temporal variability of cloud cover in Makurdi, supporting the need for localized studies to accurately assess and understand climate dynamics in the region. These insights are essential for developing effective climate adaptation and mitigation strategies, particularly for agriculture and water resource management in Makurdi Town

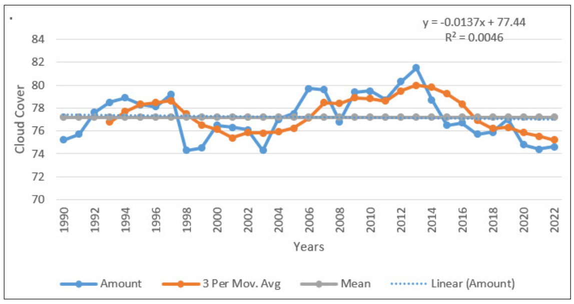


**Figure 4.3:** Annual Variation in Cloud Cover

**Source:** Researchers Fieldwork 2023

## Conclusion

Based on the findings, the study concludes that, the analysis of seasonal and annual variation in cloud cover in Makurdi Town reveals distinct patterns with implications for local climatic conditions and agriculture. The seasonal comparison indicates higher cloud cover during the rainy season, aligning with expected climatic norms. However, the annual variation shows significant fluctuations, suggesting complex influences beyond seasonal trends. These findings underscore the importance of localized studies to understand specific climatic impacts and inform effective climate adaptation strategies. The intricate dynamics influencing precipitation patterns in the region, necessitating comprehensive models that consider various climatic factors.

## Recommendations

i. To enhance understanding, future research could provide deeper into the underlying causes of these variations.
ii. Integrating climate models with observational data can offer more accurate predictions of future cloud cover in Makurdi Town.
iii. The study highlights the potential implications of cloud cover variations on local agriculture and water resource management.
iv. Continuous monitoring of cloud cover, coupled with data sharing initiatives, can enhance resilience to climate variability and change in Makurdi.
v. Educating the public about the importance of cloud cover dynamics in shaping local climate patterns and livelihoods can foster greater awareness and preparedness for climate-related challenges.

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