Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v34i2.2025.401
Volume 34(2), June 2025

Long-Term Variations of Visibility and Implications for Flight Operations at Some Nigeria's Airports

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ABSTRACT

Long-term variations in visibility at Nigerian airports, particularly during the rainy season, significantly impact flight operations, leading to delays, cancellations, and diversions with extremely low visibility affecting aviation services that need accurate rainfall and low-visibility predictions for its operations. This study examined the factors, which contribute to the effects and consequences of visibility on 4 selected airports in Nigeria. The data used was provided by Nigerian Meteorological Agency (NiMet). Specifically, they provided data on weather parameters of visibility, rainfall and air temperature for 30 years starting 1992 to 2023. The data were decomposed into dry (November, December, January, February, March) and rainy season (April, May, June, July, August, September, October). We employed month-wise mean to detrend data. This method is beneficial to first remove seasonal trend from all data. Also, we employed statistics to further characterize data. Results showed that Ilorin recorded a large increase in rainfall, a low air temperature and significantly low visibility mostly in August. We found that factors like fog, harmattan haze, thunderstorms, and rainfall contribute to these disruptions with a direct impact on flight safety and efficiency which should necessitate proactive weather risk assessments and management strategies.

Keywords:
Visibility,
Nigeria,
Month wise distribution,
Flight operation.

INTRODUCTION

The most straightforward method of determining the degree of air pollution in any part of the world is visibility, which has become one of the hottest topics in climatology and air quality research. Visibility in meteorology is defined as the greatest distance at which a dark object can be distinguished against a light sky, depending on the application and area of interest. Fadugba et al., (2015) in their work, conducted a search on the air traffic incidence in Nigeria. Air transportation accident data from various databases were examined to create a comprehensive database of aircraft accidents within the Nigeria Airspace. They concluded that air traffic incidence in Nigeria will be on the increase if no precaution is taken. Season plays a minimal role in the number of accidents that has occurred in Nigeria airports (Balarabe et al., 2015). They failed to analyse the weather parameters which has been found to be recurring issues in several accidents and incidents resulting in unnecessary flight delays, diversion and cancellation. For example, Sosoliso airline flight 1145 crash landed on the runway at Port-Harcourt international airport on 10th December, 2005 (Michaels, 2007). The cause of the crash is believed to be weather related. Among the objectives of this work is to identify the seasons with poor visibility in Nigeria airports.

Jin et al., (2022) carried out research on forecast of hourly airport visibility based on artificial intelligence method using the trend test and artificial intelligence algorithm method. They concluded that the visibility of airports in eastern and central China is at a poor level all year round and XLA has good visibility from May to October and poor visibility from November to April. This work, intends to analyze the visibility in twelve (12) Nigeria airports. Two from each of the geo political zones in Nigeria. Ahmed et al., in their work Effects of visibility on Kaduna international airport Kaduna from 2003 to 2012 concluded that flight visibility is greatly affected by dust haze during dry season in Kaduna. He failed to look at other airports in other regions of the country. The work covered only ten years (10) duration (2003 to 2012). He did not compare visibility in dry season in northern Nigeria to that of southern Nigeria. For the rainy season, Dan-Okoro et al., (2018) examined the seasonal effects of weather elements on flight operations at Nnamdi Azikiwe international airport Abuja. They found out that weather elements have a great influence on air transportation especially when they are combined. The work did not consider other regions of the country which this work intends to cover. Numerous weather dangers have hampered Nigeria's aviation industry's expansion and the country's growing reliance on air travel as one of the greatest modes of transportation. Quality forecasts are more important than ever for aviation weather forecasters (Weli & Ifediba, 2014). The number of recorded flight delays, diversion, and cancellations has significantly increased, despite Nigeria's generally favorable weather when compared to other nations (such as Mauritania, Somalia, Japan, etc.). These events are typically ascribed to unfavorable weather conditions like wind shear, thunderstorms, poor visibility, fog, dust haze, and line squalls (National Oceanic and Atmospheric Administration (NOAA), 2004; Sasse & Hauf, 2003; Jones, 2004; Knetch, 2008; Weli & Ifediba, 2014; Musa, 2014; Enete et al., 2015; Onwuadiochi et al., 2020).

A clear understanding of visibility is important for determining its impact on aviation operations. In addition, it is a good indicator of air quality, with a range of values reaching approximately 260 km (Horvath, 1995; Weli and Emenike, 2016). Visibility has remained one of the major climatic factors which affect all forms of traffic, from road to aviation (Hughes, 1982). Most importantly, the aviation problems have been on the increase due to significant reduction in visibility. The general world statistics indicate that weather conditions have contributed to above 30% aviation accidents (Aili et al., 2016). For example, Stocker et al. (2013) reported aviation crash in Russia following heavy fog. Also, Fadugba et al. (2015) studied aviation incidents in Nigeria. The results of their analysis clearly indicated a low correlation of aviation problems with season. Recently, Jin et al. (2022) applied use of machine learning to analyze 10 years' visibility data of 47 airports in China. It was indicated that airports located in the eastern and central region recorded low visibility all year round. However, results of previous studies have indicated that aerosols as principal air pollutant in Nigeria that is responsible for low visibility. Results of low visibility has been reported in Nigeria (Kehinde et al. 2012), that shows explicit adverse on traffic and economic impact. For example, air crash reported in Kano state of Nigeria in 1973 was as result of low visibility, which remain a function of season. Sub-Sahelian Africa is characterized by high atmospheric aerosols because of its climatological location. Under such conditions, low visibility could be observed and can cause disruption of socio-economic activities (Adefolula, 1984). Anuforom et al. (2007) analyzed 30-year visibility data from 1970-2003 over 4 Nigerian stations and observed decreasing trend. In addition to visibility analysis over major cities and the implication for flight operation, we have analyzed 30 years' visibility and meteorological data using 4 airports located in Nigeria. The orientation of the paper presents the introduction, the data and method of analysis and the results.

MATERIALS AND METHODS

To analyze visibility and meteorological data, we employed 30 years data over 4 airports decomposed into rainy and dry season. Data were provided by Nigeria metrological agency (NiMeT) on request, from 1994 to 2023. We employed month-wise mean to detrend data and decomposed months of April to October as rainy season and November to March as dry season. This method is beneficial to first remove seasonal trend from all data. Data over 4 airports, Lagos, Abuja, Owerri and Ilorin analyzed to conclude results. The geographical location of stations is presented in Fig 1. Nigeria is in the tropics of West Africa.

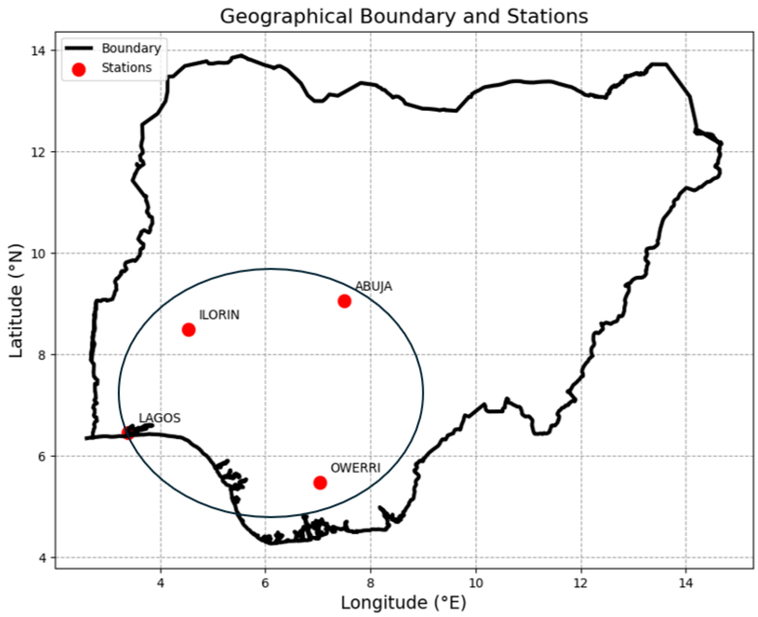

Figure 1: Geographic map of study stations

Lagos is located between Longitude 3˚18'30"E & 3˚23'00"E, and Latitude 6˚39'30"N & 6˚33'00"N with estimated average temperature and rainfall of 27.2°C and 1461 mm, respectively. Abuja airport is located at latitude 09° 0′N and longitude 07° 5′E and at altitude 314.98m. Imo airport, located in Latitude: 5.4228 and Longitude: 7.2035. While Ilorin airport is at latitude: 8° 26' 15.59" N and Longitude: 4° 29' 23.99" E.

RESULTS AND DISCUSSION

The detrend analysis provides a valuable data technique for removing seasonal influences on meteorological data. In the analysis of rainfall, air temperature and visibility following longitudes and regions provided excellent characterization of weather patterns during the rainy and dry seasons. Generally, there is increasing interest in the relationship between weather conditions and passenger ridership (Ngo, 2019). This is because the conditions of the weather play an important role in fluctuations of atmospheric or weather parameters and transit operation. For example, the results of the analysis provided an explicit method to correlate rainfall and visibility, followed by visibility and air temperature during both seasons. The analysis of visibility in standard geographic information entails determining the direction of view and the maximum visible distance. This approach is helpful for determining the possible time of flight and the time needed to cancel flights. For example, Aili et al (2016) reported that visibility analysis has been mapped under geographic locations using GIS, which is widely used. Therefore, incorporating visibility analysis with rainfall and air temperature data for airport locations in Nigeria is very important for characterizing weather comfort for airplane operations. Figure 2a shows the seasonal peak-to-peak patterns of rainfall, air temperature and visibility as functions of year. There is an increasing trend of visibility from 1995 until 2023. There is a strong inverse correlation of air temperature between air temperature and visibility in 2023, which shows that the observed visibility could be from precipitation, for example, as observed in rainfall for the same year and month. It can also be observed that September showed an increase in rainfall and visibility.

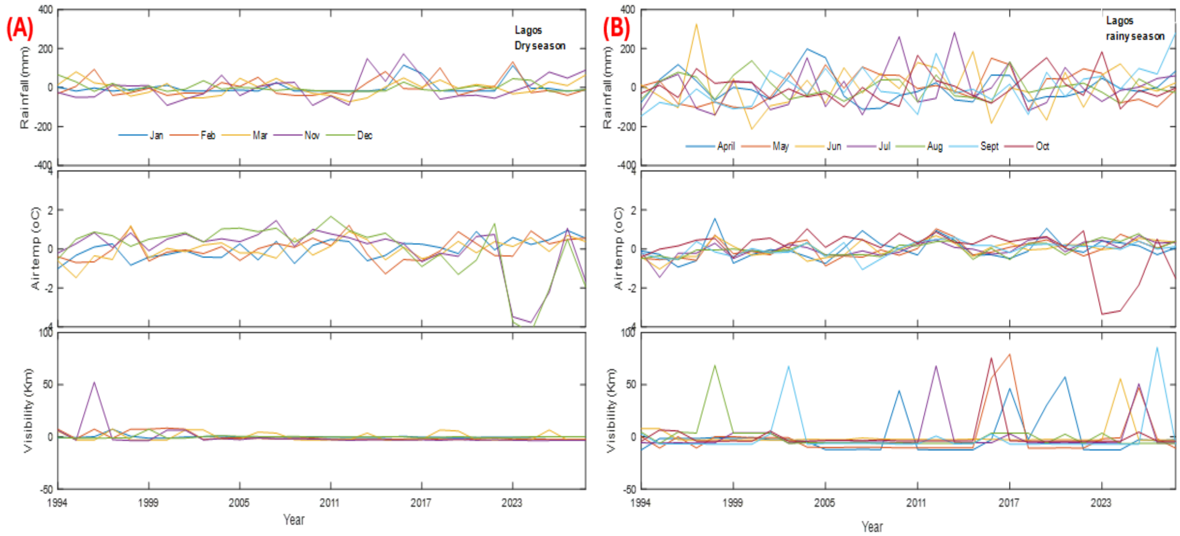

Figure 2: Rainfall, air temperature and visibility time series over Lagos during the (a) dry season, (b) rainy season

There is an abnormality during the dry season, as shown in Figure2b. This shows a significant difference compared with the observed visibility during the rainy season. Visibility above 50 km was observed only in the month of November (1995-1996). In the months of November and December, there was a strong decrease in temperature that had no effect compared with visibility. Additionally, very low rainfall values were confirmed during this period.

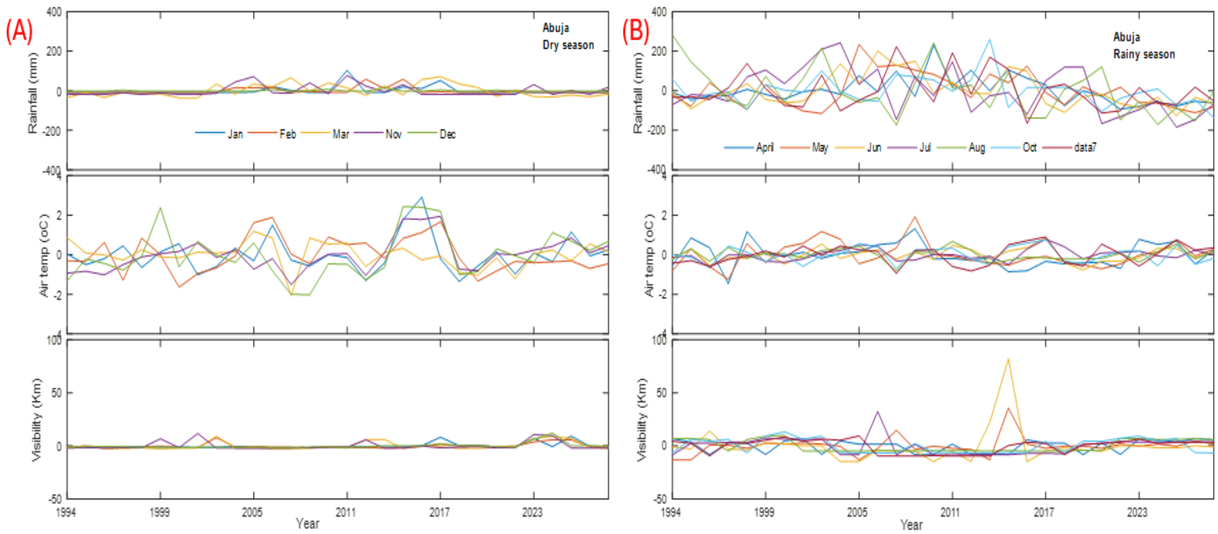

Figure 3: Rainfall, air temperature and visibility time series over Abuja during the (a) dry season, (b) rainy season

Figure 3a shows the months of the dry season for Abuja. Variations in air temperature with peaks in the months of January and December are clearly observed. There is minimal or no amount of rainfall during the period. The variations in temperature showed a peak during 1998, a sudden decrease in 2007 and an increase in 2018. During this period, visibility was low, with peaks occurring in the months of November and January. Figure 3b shows variations during rainy seasons. It is observed the variations in rainfall and the significant increase in visibility during October and 2014. The month of August showed high values during the early year but did not reappear until 2021.

Figure 4a shows a significant amount of rainfall during the season in Owerri, with moderate temperatures and peak-to-peak visibility in April, July, September, August and October. Figure 4b shows the parameters of rainfall, air temperature and visibility during the rainy season. The rainfall was minimal but slightly increased in November 2023. The variations observed in air temperature showed a slight increase. Additionally, there was high visibility mostly in March and November.

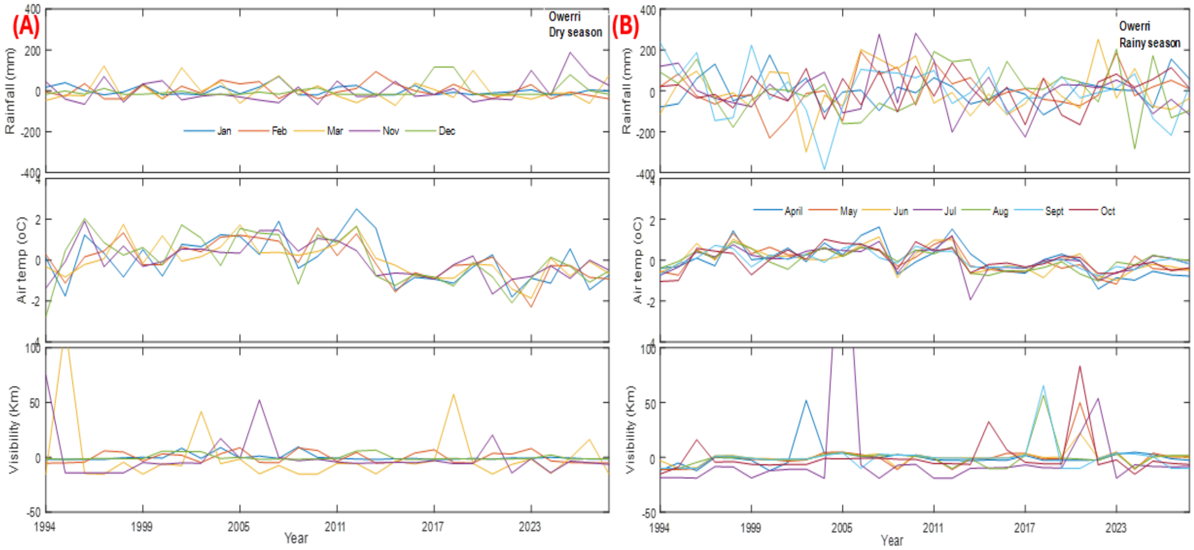

Figure 4: Rainfall, air temperature and visibility time series over Owerri during the (a) dry season, (b) rainy season

Figure 5a shows a clear difference compared with that in the rainy season. The amount of rainfall recorded was minimal. This difference compared with the air temperature values. The air temperature clearly peaked in January. Visibility showed a strong peak in March, November and February, with a strong negative correlation with air temperature. Figure 5b shows a large increase in rainfall at this station, a low air temperature and a significant increase in visibility. There was a peak-to-peak increase in visibility, mostly in August.

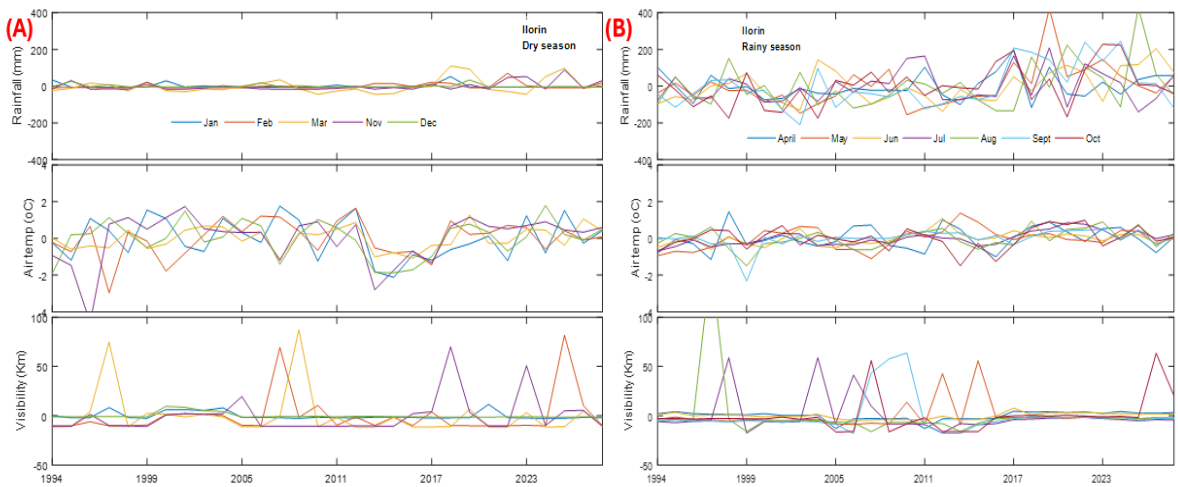

Figure 5: Rainfall, air temperature and visibility time series over Ilorin during the (a) dry season, (b) rainy season

We see in Figure 5 the rainfall, air temperature and visibility time series over Ilorin during the seasons of the year for the duration studied. From the analysis, heavy rain can drastically reduce visibility, making it difficult for pilots to see runways and other aircraft, potentially leading to accidents during takeoff and landing. It is obvious that changes in wind speed and direction, particularly during thunderstorms, can create wind shear, making it difficult for pilots to maintain control of the aircraft during takeoff and landing. In addition, thunderstorms can also pose a risk of lightning strikes to aircraft, though modern aircraft are designed to mitigate this risk.

Table 1 shows the correlation analysis of visibility with air temperature and rainfall during rainy and dry seasons. The correlation index (R), as shown in the table, recorded location-to-location differences as a function of longitude. For example, at Lagos station, visibility has a poor correlation with rainfall and air temperature during the rainy season but a strong correlation with visibility and rainfall during the dry season.

Table 1: Statistics of correlation of visibility with meteorological parameters

S/N	Station	Correlation coefficient (R)			
		Rainy season		Dry season	
		Visibility-rainfall	Visibility-air temperature	Visibility-rainfall	Visibility-air temperature
1	Lagos	-0.16	-0.15	0.92	0.30
2	Abuja	-0.17	-0.25	0.72	-0.61
3	Owerri	0.18	0.1	0.85	-0.79
4	Ilorin	0.81	0.09	0.42	-0.32

Figure 6 and Figure 7 shows further statistics of standard deviation, variance and skewness for all parameters in all stations during the dry and rainy season.

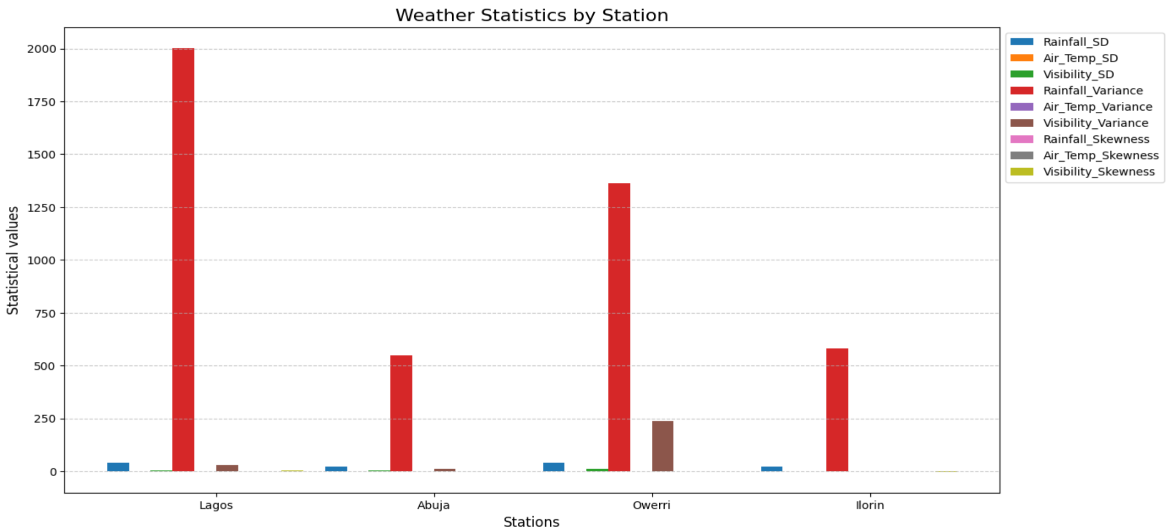

Figure 6: Statistical values of all stations during dry season

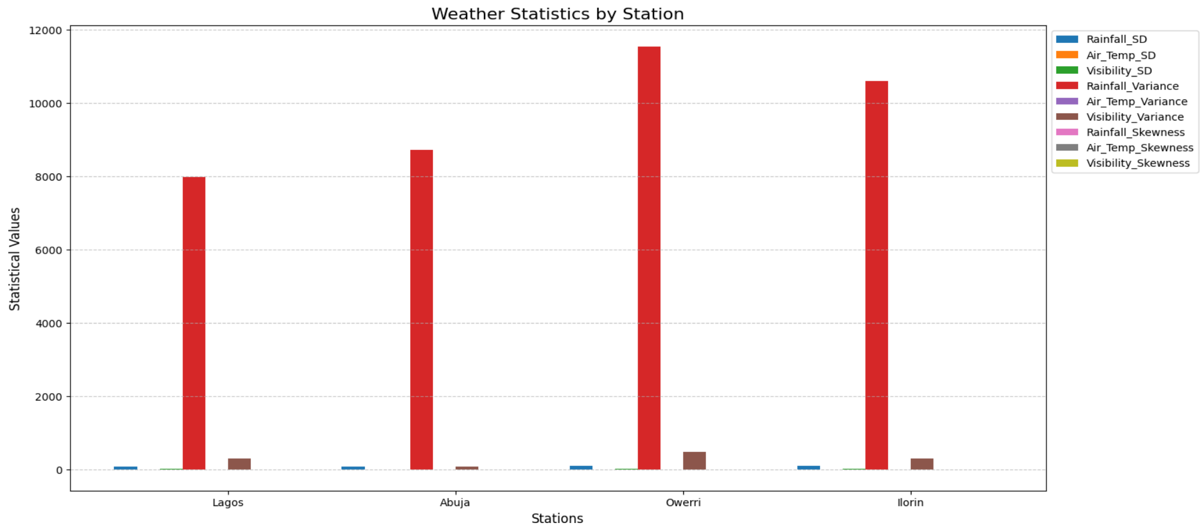

Figure 7: Statistical values of all stations during the rainy season

CONCLUSION

Although several studies have attempted to link visibility with aerosol properties, meteorological data are important for characterizing the type of visibility. The results presented in this analysis, for example, considering rainy and dry seasons using the seasonal index method of analysis with strong support of the correlation coefficient index, were used to characterize the climatology of the stations. For example, stations located within the ocean (Lagos), as shown in Fig. 1, exhibited a significant amount of rainfall and low visibility during the rainy season. This result is clearly different from that in the dry season. Visibility was also observed during the dry season, which provides evidence that aerosols can be major contributors to dry season-observed visibility, while precipitation, for example, cloud cover, provides evidence of rainy season visibility.

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