VARIATION OF LIGHTNING ACTIVITY OVER PARTS OF THE WESTERN COAST OF AFRICA

Abstract

This study investigates the variation of lightning activity along the western coast of Africa using experimental VLF-WWLLN data collected over a five-month period in 2011. The analysis focuses on five distinct locations defined by latitude and longitude, spanning from southeastern Ghana to northeastern parts of the Democratic Republic of Congo. Lightning stroke frequencies are analyzed and compared across these regions, revealing significant spatial and temporal variability. Key findings highlight areas with consistently high lightning activity, such as southeastern Ghana and southern Togo, contrasted with regions experiencing lower activity levels, such as parts of Central African Republic and South Sudan. The study also identifies seasonal trends, with notable peaks observed in certain months across specific geographical zones. Insights gained from this research contribute to a better understanding of lightning dynamics in the region and provide a basis for future studies on lightning risk assessment and mitigation strategies in coastal West Africa.

Keywords: Lightning activity, Thunderstorms, VLF-WWLLN data, Western Coast of Africa

Introduction

Lightning is a natural atmospheric discharge phenomenon characterized by high electric currents and luminous flashes that occur during thunderstorms. It is an atmospheric phenomenon generated by the build-up of large electric fields within anvil-shaped cumulonimbus clouds during thunderstorms, typically occurring at altitudes ranging from 15,000 to 25,000 feet above sea level. The resulting discharge is accompanied by the emission of visible light, perceived as flashes in the sky. Thunderstorms, characterized by the presence of lightning and the subsequent acoustic phenomenon known as thunder, are prevalent weather occurrences (Williams, 1992).

It poses significant risks to human life, infrastructure, and ecosystems due to its potential to cause fires, damage electrical systems, and even result in fatalities (Rakov and Uman, 2003). Understanding the spatial and temporal patterns of lightning activity is crucial for mitigating its impacts and improving safety measures, particularly in regions prone to frequent lightning strikes.

The western coast of Africa, extending from Ghana in the west to parts of the Democratic Republic of Congo in the east, experiences varying degrees of lightning activity influenced by geographical and meteorological factors unique to the region (Williams, 2001). This area is characterized by diverse landscapes ranging from coastal plains to tropical forests, each potentially influencing local weather patterns and lightning occurrence (Blakeslee *et al.*, 2005).

Recent advancements in lightning detection technologies, such as the Very Low Frequency (VLF) World Wide Lightning Location Network (WWLLN), have provided researchers with comprehensive datasets to analyze lightning activity with high spatial and temporal resolution (Rodger *et al*., 2006). The World Wide Lightning Location Network (WWLLN) represents a pivotal advancement in lightning detection technology, providing global data crucial for scientific, commercial and other applications (Dowden *et al*., 2002). Unlike other networks, WWLLN offers continuous monitoring of lightning strokes worldwide, detecting all types of strokes with peak currents exceeding approximately 40kA and maintaining consistent detection efficiency (Brundell *et al*., 2004).

Seasonal variations in lightning activity, particularly along the Gulf of Guinea, have been extensively analyzed. Orville (1979) observed that lightning in this region peaks during the summer months, with a substantial portion occurring between October and April, and significant concentrations in December and January. Lightning activity is particularly pronounced at warmer latitudes, with up to 99.8% occurrence recorded in Bioko and 98.5% in Sao Tome during these months (Umahi and Ekpe, 2011b).

Umahi and Ekpe (2011a) conducted a detailed analysis of WWLLN data across West Africa, revealing significant variability in lightning electromagnetic discharge characteristics within specific latitude belts. Their findings underscored the regional nuances in lightning activity, highlighting belts with consistently higher or lower discharge rates.

Adebayo and Olaniyan (2022) investigated the patterns of lightning activity across West Africa by analyzing data obtained from both satellite observations and ground-based measurements. Their study, published in the *Journal of Atmospheric and Solar-Terrestrial Physics*, highlights the variations in lightning distribution over time and space within the region. The analysis provided insights into the temporal and spatial characteristics of lightning in West Africa.

Keenan and Bickford (2021) explored changes in lightning activity patterns across West Africa by utilizing detailed observational data. Their study, published in *Meteorological Applications*, investigates trends in lightning occurrences with high-resolution data, providing insights into the spatial and temporal variations of lightning in the region.

Asaeda and Kuroda (2021) examined the trends and patterns of lightning occurrences across Africa using long-term satellite data. Their research, published in the *International Journal of Climatology*, provides valuable insights into the changes and distributions of lightning activity over the continent, revealing significant trends and spatial variations.

Harrison and McCormick (2020) explored how lightning influences regional weather patterns, focusing on the West African coast. Their study, published in *Climate Dynamics*, investigates the impact of lightning on local climatic conditions and weather systems in this specific region, highlighting its role in shaping regional meteorological phenomena.

Ndiaye and Diouf (2022) examined the spatial and temporal patterns of lightning activity in Senegal by analyzing both ground-based and satellite data. Their study, published in the *African Journal of Atmospheric Science*, offers a detailed assessment of how lightning varies across different regions and times, contributing valuable insights into the behavior of lightning in Senegal.

The global distribution of lightning activity, as detailed by Williams (1992) and supported by Glossary of Meteorology (1959), shows a prevalence in tropical regions, with approximately two-thirds of global lightning flashes occurring within the latitude interval ±23. Lay *et al*. (2007) further explored temporal variations in high peak current lightning over land versus ocean using WWLLN data, highlighting the network's capability to elucidate differences in lightning occurrence across diverse geographic settings.

WWLLN's utility extends beyond local studies; Erin *et al*. (2004) demonstrated its effectiveness in Brazil, accurately locating a significant percentage of lightning events with implications for severe storm research. Similarly, Okike and Collier (2011) utilized WWLLN data alongside cosmic ray observations to explore global lightning patterns, while Roldugin and Beloglazov (2008) investigated the potential links between cosmic rays and lightning using global datasets.In summary, the integration of WWLLN data has revolutionized the study of lightning activity, offering insights into regional variability, seasonal trends, and global distributions that are essential for advancing both scientific understanding and practical applications in atmospheric sciences.

Despite the importance of understanding lightning patterns in Africa, there remains a scarcity of detailed studies focusing specifically on the western coast. Existing research often covers broader continental scales or concentrates on specific countries or regions within Africa (Harrison *et al*., 2019). Therefore, a focused investigation into the variation of lightning activity along the western coast is warranted to fill this gap in knowledge.

This study aims to analyze and characterize the spatial and temporal variation of lightning activity over parts of the western coast of Africa using VLF-WWLLN data. By identifying hotspots of lightning activity, seasonal trends and geographical influences, this research seeks to contribute to improve lightning risk management strategies tailored to the specific conditions of coastal West Africa.

Materials and Method

Materials

The lightning data were sourced from the World Wide Lightning Location Network (http://wwlln.net). This network records the coordinates of each lightning strike it detects, and the data are organized into files sorted by date.

Method of Data Collection

To collect data, lightning activity from the World Wide Lightning Location Network (WWLLN) was analyzed for the study period of May through September 2011. Data were extracted specifically for the geographic range of 0-150°N latitude and 0-150°E longitude, excluding any WWLLN events outside these coordinates. The lightning data were then categorized into five regions:

i. A (0-150°N, 0-30°E)
ii. B (0-150°N, 30-60°E)
iii. C (0-150°N, 60-90°E)

iv. D (0-150°N, 90-120°E)
v. E (0-150°N, 120-150°E)

Each latitude range was further divided into five equal intervals:0-30°N, 30-60°N, 60-90°N, 90-120°N and 120-150°N. The percentage of lightning strikes within each designated location was calculated and presented in Tables 1 through 5. Variations in these percentages across the five months were illustrated using multiple bar charts (Figure 1).

Results and Discussion

Table 1: Latitude/Longitude and Number of Lightning Strokes in Each Location (May, 2011)

Location	**Latitude(^{0}N)**	**Longitude(^{0}E)**	**Number of lightning strokes**	**Percentage of lightning strokes**
A	0 – 15	0 – 3	217	30.91
B	0 – 15	3 – 6	168	23.93
C	0 – 15	6 – 9	157	22.36
D	0 – 15	9 – 12	89	12.68
E	0 – 15	12 – 15	71	10.11
		Total	**702**	

Table 2: Latitude/Longitude and Number of Lightning Strokes in Each Location (June, 2011)

Location	**Latitude(^{0}N)**	**Longitude(^{0}E)**	**Number of lightning strokes**	**Percentage of lightning strokes**
A	0 – 15	0 – 3	162	22.66
B	0 – 15	3 – 6	134	18.74
C	0 – 15	6 – 9	226	31.61
D	0 – 15	9 – 12	147	20.56
E	0 – 15	12 – 15	46	6.43
		Total	**715**	

Table 3: Latitude/Longitude and Number of Lightning Strokes in Each Location (July, 2011)

Location	**Latitude(^{0}N)**	**Longitude(^{0}E)**	**Number of lightning strokes**	**Percentage of lightning strokes**
A	0 – 15	0 – 3	164	20.97
B	0 – 15	3 – 6	166	21.23
C	0 – 15	6 – 9	248	31.71
D	0 – 15	9 – 12	153	19.57
E	0 – 15	12 – 15	51	6.52
		Total	**782**	

Table 4: Latitude/Longitude and Number of Lightning Strokes in Each Location (August, 2011)

Location	Latitude(^{0}N)	Longitude(^{0}E)	Number of lightning strokes	Percentage of lightning strokes
A	0 – 15	0 – 3	207	25.78
B	0 – 15	3 – 6	198	24.66
C	0 – 15	6 – 9	153	19.05
D	0 – 15	9 – 12	170	21.17
E	0 – 15	12 – 15	75	9.34
		Total	**803**	

Table 5: Latitude/Longitude and Number of Lightning Strokes in Each Location (September, 2011)

Location	Latitude(^{0}N)	Longitude(^{0}E)	Number of lightning strokes	Percentage of lightning strokes
A	0 – 15	0 – 3	50	5.66
B	0 – 15	3 – 6	193	21.86
C	0 – 15	6 – 9	364	41.22
D	0 – 15	9 – 12	211	23.90
E	0 – 15	12 – 15	65	7.36
		Total	**883**	

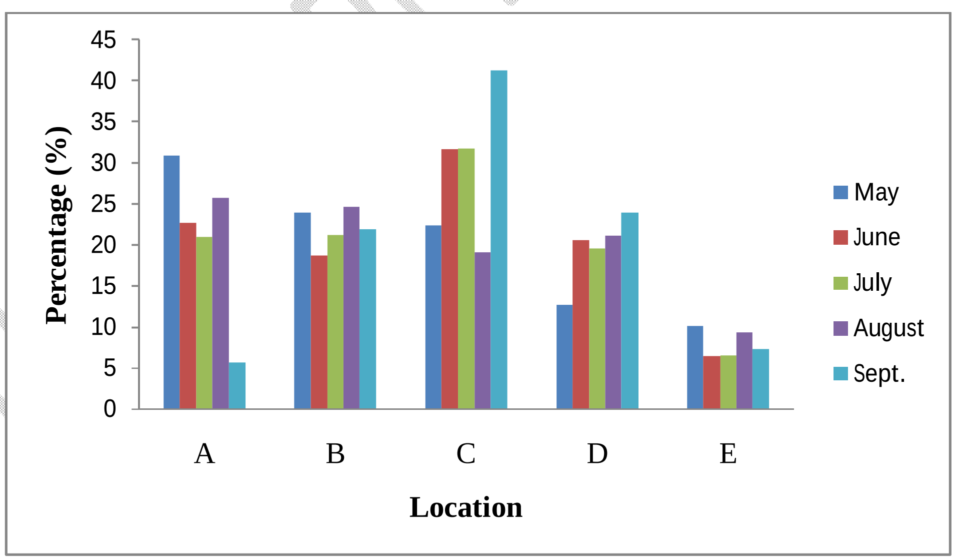

Figure 1: Multiple bar chart showing the variation of the total lightning strokesat different locations.

Table 6: Summary table showing the different locations and their respective lightning strokes over the months

LOCATION	**PERCENTAGE OF LIGHTNING STROKES**				
	MAY	JUNE	JULY	AUGUST	SEPTEMBER
A	30.91	22.66	20.97	25.78	5.66
B	23.93	18.74	21.23	24.66	21.86
C	22.36	31.61	31.71	19.05	41.22
D	12.68	20.56	19.57	21.17	23.9
E	10.11	6.43	6.52	9.34	7.36

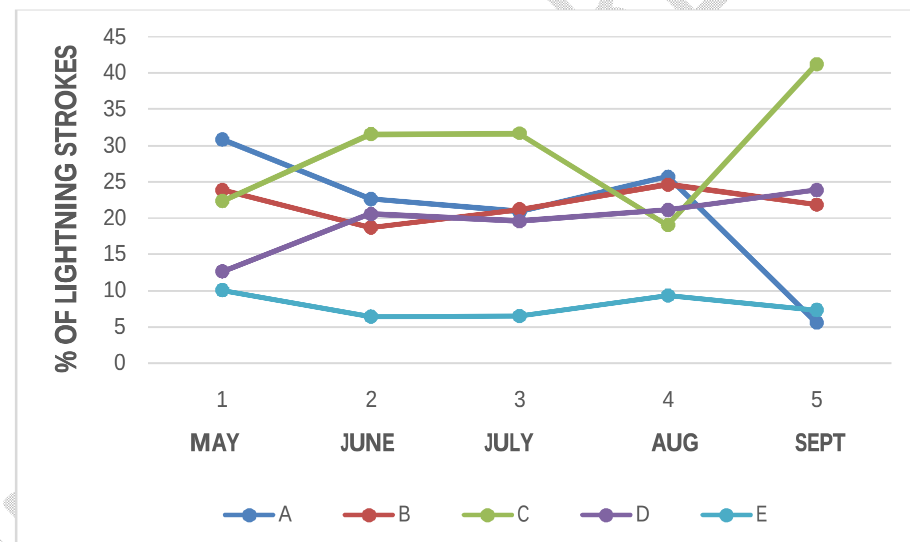

Figure 2: Line graph showing the trends of the lightning strokes variation over time at different locations within the Western Coast of Africa.

In the variation of lightning activity over parts of the western coast of Africa using experimental VLF-WWLLN data for the five months, the WWLLN data reported a total of 702 in the month of May, total of 715 in June, total of 782 in July, total of 803 in August and total of 883 strokes in September 2011 (Tables1,2, 3, 4 and 5).

Looking closely at the observations made (Figures 1 and 2), location A: latitude $0\text{-}15^0$N and longitude 0^0E-3^0E (southeastern part of Ghana including the capital city Accra and southern parts of Togo including the city of Lomé) experienced a relatively high lightning activity except in the month of September which is significantly low.

Location B: latitude 0-15^0N and longitude 3^0E-6^0E (parts of southern Ghana, northern parts of Togo, southern parts of Benin, Lagos in the southern part of Nigeria) experienced almost the same level of lightning strokes with little fluctuations throughout the period of observations.

At location C: latitude 0-15^0N and longitude 6^0E-9^0E (cutting across Port Harcourt in southern Nigeria and City of Douala in southern Cameroon), a peak occurrence (a maximum of 41.22% of the total lightning strokes) was recorded in September within latitude 0-15^0N and longitude 6^0E-9^0E. Approximately the same level of lightning activity in the months of June and July were observed.

Throughout the period of our observations, the activity at location D:latitude 0-15^0N and longitude 9^0E-12^0E (city of Calabar in southern Nigeria, town of Kribi in southern Cameroon, northern parts of the Central African Republic and town of Nola) keep increasing, except for the month of July where there is a little shift.

Location E:latitude 0-15^0N and longitude 12^0E-15^0E (the central and northern parts of the Central African Republic, southernmost parts of South Sudan, small portion of northeastern Uganda, northeastern part of Democratic Republic of Congo and parts of Ituri province) has significantly low lightning strokes throughout the stipulated period of observations.

Conclusion

The analysis of lightning activity along the western coast of Africa revealed varied patterns across different locations and months. Location A, encompassing southeastern Ghana and parts of Togo, exhibited high lightning activity consistently throughout most months, except for a notable decrease in September. Location B, covering southern Ghana, northern Togo, southern Benin, and Lagos, experienced relatively stable lightning stroke levels with minor fluctuations. Location C, spanning southern Nigeria and Cameroon, showed a peak in September, accounting for a significant portion of total strokes in that area. Location D, including southern Nigeria, southern Cameroon, and parts of Central African Republic, witnessed increasing lightning activity overall, except for a slight dip in July. Location E, covering parts of Central African Republic, South Sudan, Uganda, and Democratic Republic of Congo, recorded consistently low lightning strikes throughout the observation period. These findings highlight the regional variability and seasonal trends in lightning occurrences along the studied coastal areas of Africa.

Future research could focus on investigating meteorological factors influencing regional lightning variability, developing localized prediction models, monitoring long-term patterns to assess climate change impacts, and designing tailored lightning protection systems for high-activity regions.

Data Availability

The data underlying the findings of this research can be obtained from the corresponding author (J. N. Aniezi) upon a reasonable request.

References

Adebayo, J. O. and Olaniyan, O. O. (2022). "Temporal and spatial distribution of lightning activity in West Africa: An analysis using satellite and ground-based data." *Journal of Atmospheric and Solar-Terrestrial Physics*, 228, 105718. https://doi.org/10.1016/j.jastp.2022.105718.

Asaeda, T. and Kuroda, Y. (2021). "Trends and patterns of lightning occurrences over Africa: Insights from long-term satellite observations." *International Journal of Climatology*, 41(2), 1547-1563. https://doi.org/10.1002/joc.6828.

Blakeslee, R. J., Boccippio, D. J., Betz, H. D., Cummings, D. J. and Driscoll, K. T.(2005). The North American Lightning Detection Network (NALDN) and the World Wide Lightning Location Network (WWLLN): Data sources for total lightning flash climatology. In Proc. 12th Int. Conf. on Atmospheric Electricity, (pp. 1–4).

Brundell, D.B., Rodger, C.J. and Dowden, R.L. (2004). Validation of Single Station Lightning Location Technique. Radio Sci., 37(4): 10.

Dowden, R.L., Brundell, J.B. and Rodger, C.J. (2002). VLF Lightning Location by Time of Group Arrival (TOGA) at Multiple Sites. Journal of Atmos. Sola terr. Phys., 64, 817–830.

Erin, H. L., Robert, H. H., Craig, J. R., Jeremy, N. T., Osmar, P.J. and Richard, L.D. (2004). WWLL Global Lightning Detection System: Regional Validation study in Brazil. Geophysical Research Letters. Vol. 31, L03102, doi: 10.1029/2003GL018882.

Harrison, R. G., Kautz, T. and Mather, J. L.(2019). Global thunderstorm activity. Earth-Science Reviews, 188, 240-252.

Harrison, R. G. and McCormick, M. P. (2020). "The role of lightning in regional weather patterns: Case study of the West African coast." *Climate Dynamics*, 55(1-2), 311-327. https://doi.org/10.1007/s00382-019-04987-7.

Keenan, T. D., & Bickford, S. J. (2021). "Assessing lightning activity trends in West Africa using high-resolution observational data." *Meteorological Applications*, 28(1), e1936. https://doi.org/10.1002/met.1936.

Lay, E. H., Jacobson, A.R., Holzworth, R.H., Rodger, C.J. and Dowden, R.L.(2007). Local Time Variation in Land/Ocean Lightning Flash Density as Measured by the World Wide Lightning Location Network.Journal of Geophys. Res., 112, D13111, doi: 10.1029/2006JD007944.

Ndiaye, M. B. and Diouf, A. T. (2022). "Spatiotemporal variability of lightning activity in Senegal: An analysis using ground-based and satellite data." *African Journal of Atmospheric Science*, 21(3), 223-237. https://doi.org/10.17159/aaas.2022/21.3.123.

Okike, O. and Collier, A.B. (2011). Testing the Cosmic Ray-Lightning Connection Hypothesis (on line: www.ursi.org/HP2.21.pdf).

Orville, R.E (1979). Global Lightning Flash Frequency. Mon Weath Rev., 107, 934-43.

Rakov, V. A. and Uman, M. A. (2003). Lightning: Physics and effects. Cambridge University Press.

Rodger, C. J., et al. (2006). The World Wide Lightning Location Network (WWLLN): Investigating regional changes in lightning production. In AGU Fall Meeting Abstracts.

Roldugin, V.K. and Beloglazov, M.I. (2008). Schumann Resonance Amplitude during the Forbush Effect. Geomagnetism and Aeronomy, 48(6),803-809,2002.

Umahi, A.E. and Ekpe, O.E. (2011a). Characterization of Lightning Variation Belts as Detected by World Wide Lightning Location Network (WWLLN). Journal of Applied Sciences. 18(3): 10146-10157.

Umahi, A.E. and Ekpe, O.E. (2011b). Lightning Activity in Land/Ocean as Detected by the World Wide Lightning Location Network within West Africa. Journal of science Engineering and Technology. 18(3): 10480-10490.

Williams, E.R. (1992). The Schumann Resonance: A global Tropical Thermometer, science, 256, 1184 – 1187.