GROUND FLASH DENSITY OF THE BRASS COAST OF NIGERIA

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Abstract:

With the present industries and the expected industrial growth in the Brass Coast, it was necessary to study the ground flash density in the area. It is a lightning prone area because of the location and the environmental conditions.

Data for thunderstorm days in the year was collected from 2008 to 2012 from the meteorological department of the oil company and meteorological department of the College of Education Okpoma. Several observations were compared and the data were analysed. The ground falsh density was found for each year in the two locations. The ground flash density (GFD) was about 10 flashes/km^2/year to 15 flashes/km^2/year.

This data is necessary because it will help Electrical and Telecommunication Engineers and operators to involve safer and better methods to protect and minimize danger to life and equipment.

Key Words: Ground flash density, thunder storm day, lightning activities, keraumic level, probability density

Introduction

Brass is becoming the most industrialized place in Bayelsa State due to the presence of the oil terminal of Agip Oil Company and the liquefied Natural Gas Company. It is expected that the oil refinery company will soon take off.

Brass is situated at the coast of the Sombrero River that emptied into the Atlantic Ocean. The Brass town is not more than 500m to the Atlantic Ocean and it is surrounded by rivers and tall mangrove swamps [1]. This is an area of high keraunic level with intermittent and unexpected stormy weather with the ocean breeze. During the month of November the stormy weather is persistent that it affects the economic life of the people.

A Survey on Lightning Distribution

Research on lightning distribution in Africa is limited. Several global detection satellites provide coverage of the continent [2], though the spatial resolution and temporal coverage is limited. The most comprehensive flash density results for the continent was produced by Christian et al (2003) using the Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS). The Congo Basin was identified as the lightning hotspot of the world. In this regard, South Africa has played leading role in the field of lightning research in Africa [2, 3]. Since then several modern techniques have been used for effective lightning detection.

Nigeria has been living with the global records with little effort to have local records except with the multi-national companies and aviation industries operating in some localities. These records can only be restricted to some areas and can not give a global record of the country. For the development of a country or industrialization, these records are vital for the power and telecommunication industries.

It has been established that the highest flash densities occur in coastal area, mountainous regions, regions frequented by migrating synoptic scale cycloves and convergence zones [2, 4]. That is why air movements and different meteorological data affect lightning activities in localities.

A ten year average ground flash density map on U.S.A. [4] indicated areas of different (GFD), elevation or convectional air movement.Among the areas of high GFD are

- The state of florida as well as all the Southern States along the Gulf of Mexico. Other areas are the state of Georgia and Southern Caroline. To the West state, Arizona is the only state with GFD levels as high as 8 flashes/km^2/year.
- Rakov *et al* [5] said that lightning discharges produced by winter storms in the coastal are of the sea of Japan exhibit a number of features that have not been observed during the summer months or in any season in other geographic locations.
- The Iberian Peninsula is also distinguished by its high incidence of lightning due to elevation.
- Sariano and De la Rose [6] indicated that the most frequent lightning activities tend to occur near the Mediterranean coast where warm, humid air increases convection.

The Brass Coast like any other coastal area in the globe is prone to high ground flash density, therefore the study was necessary to have a lightning record for this area.

Stochastic Characteristics of Lightning Strokes

The most important lightning return stroke parameters are:

(i) Peak current, I_p
(ii) Current front time t_f
(iii) Return stroke velocity V
(iv) Ground flash density

These parameters are stochastic in nature. Analysis of field data shows that the statistical variation of the peak current, I_p and current front time t_f of the return stroke current fit lognormal distribution [7]. The probability density function of I_p can be expressed as:

$$\rho(I_p)\frac{e^{-0.5 f_1}}{\sqrt{2\pi}\,.\,I_p\,.\,\sigma_{1n\;I_p}} \tag{1}$$

Where $f_1 = \left(\frac{I_n I_p - I_n I_m}{\sigma_{In\,I_p}}\right)^2$

Similarly, the probability density function of t_f can be expressed as:

$$\rho(t_f) = \frac{e - 0.5\,f_2}{t_f \cdot \sigma_{In} \cdot \sqrt{2\pi}} \tag{2}$$

Where $f_2 = \left(\frac{In\,t_f - In\,t_m}{\sigma_{In\,t_f}}\right)^2$

The joint probability density function, $p(I_p t_f)$ is given by

$$\rho(I_p t_f) = \frac{e-\frac{0.5}{1-\sigma}\left(f1 - 2\rho\sqrt{f_1\,.\,f_2 + f_2}\right.}{2\pi\,(I_p\;.\;t_f)\left(\sigma_{In\,fp}\;.\;\sigma_{In\,t_f}\right)\sqrt{1-\rho}} \tag{3}$$

Where ρ is coefficient of correlation
I_m is mean current
t_m is mean time
σ is standard deviation

The statistical parameters of return stroke current are as follows [8, 9]

Median time to crest, t_{fm} = 3.83 μS, Log (to base e) of standard deviation $\sigma(Int_f)$= 0.553
Median Peak Current $I_{pm1} = 61.1$KA, Log (to base e) of standard deviation σ = 1.33
Median Peak Current $I_{pm2}$is 33.3KA, Log (to base e) of standard deviation σ = 0.605
The coefficient of correlation ρ = 0.47.

Some authors [7, 8] proposed the following empirical relationship between the return – stroke peak current and its velocity as

$$V = \frac{C}{\sqrt{1 + \frac{500}{I_p}}}\ \text{(m/s)} \tag{4}$$

Where c is velocity of light.

Besides the I_ρ and t_f, the ground flash density is the next significant parameter in estimating the lightning performance of power system. The ground flash density n_g varies regionally and seasonally and the geographic region varies by a large margin from year to your usually it is a long-term average value and ideally it should take into account the yearly variation that take place within a solar cycle-believed to the period within which all climate variation that produce different GFD level occur.

The ground flash density can generally be defined as the average number of lightning flashes per square kilometer per year in a geographic region.

De la Rosa [4] discussed how to determine the ground flash density as a function of thunder day (T_{α}) or Keraunic level or thunder thour (T_h). This is important where GFD is not available from the lightning location.

Basically any of these parameters can be used to et a rough a approximation of GFD. Using the expression described in Anderson et al [9] and MacGorman et al [10] respectively.

The ground falsh density n_g is

$$n_g \;=\; 0.04{T_{\alpha}}^{1.25} \text{ flashes } 1\text{km}^2/\text{year} \qquad (5)$$

$$n_g \;=\; 0.05{T_h}^{1.1} \text{ flashes } 1\text{km}^2/\text{year} \qquad (6)$$

Methodology

Meteorological data (pressure, daily temperature and thunder storm) were taken from 2008 to 2012. In order to have records for some other location, records were taken from the College of Education. The records available was from 2010 to 2012 and some of the records not detailed.

These data were compared to the data taken from the different centres. From the given records the five years lightning days were tabulated as shown in table 1.

Result and Analysis

A flash which is made up of one or more strokes may take place between two clouds known as cloud to cloud (CC), flashes within the same cloud is inter cloud (IC) and flashes from clouds to ground is known as cloud to ground (CG).

If the CC to CG is 3:1, then

The number of lightning days (CG) = $\frac{Total\ \ Number\ \ of\ Thunder\ Storm\ day}{n}$

The ground flash density was calculated from the equation 5.

From table 1, all results (the number of lightning days, GFD) are shown.

Table 1: Thunderstorm Days For The Brass Coast and Inland site.

MONTH	BRASS COAST					BRASS INLAND SITE				
	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
JAN	7	4	6	2	8	4	2	3	6	8
FEB	28	16	10	26	17	15	12	12	20	18
MAR	63	50	48	57	48	40	48	38	50	50
APR	70	61	60	62	63	42	42	37	64	48
MAY	65	57	55	60	59	50	47	49	52	55
JUN	54	44	39	50	51	35	40	36	45	45
JUL	40	30	36	42	37	32	29	25	37	30
AUG	28	21	27	30	25	21	30	22	18	16
SEP	42	36	29	40	36	20	20	18	36	19
OCT	62	49	54	52	40	41	50	42	50	35
NOV	20	23	18	24	28	20	18	16	21	20
DEC	6	8	66	4	7	8	6	4	5	6
TOTAL NO. OF FLASHES	485	399	388	449	419	328	344	302	404	350
FLASHES CG	122	100	97	112	105	82	86	76	101	88
GFD		13	12	15	13.5	10	11	9	13	11

In fig. 1, the diagram given the variation of lightning days for the period of five year in the Brass Coast.

From the given record, the average GFD is

(i) The Brass Coast average GFD is 14

(ii) Inland site average GFD is 11.

The average annual temperature and relative humidity (2008 – 2012) were recorded in table 2 and 3 respectively.

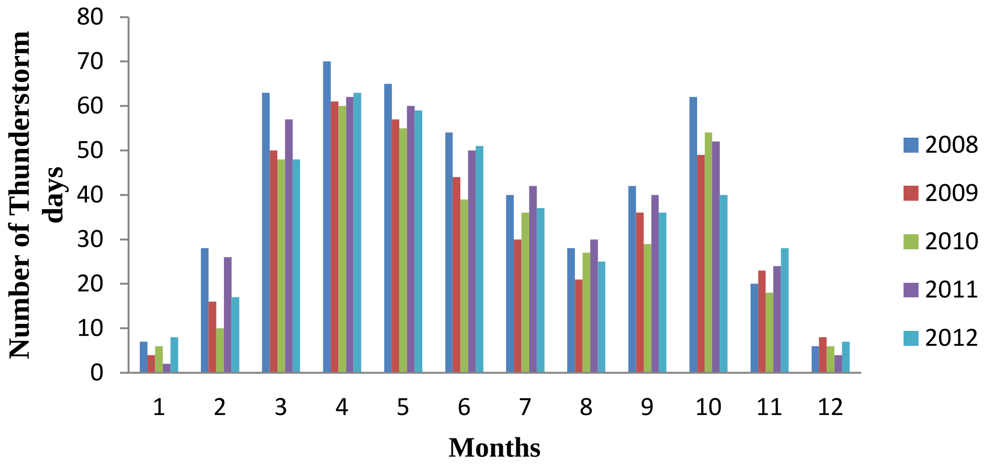
Table 2: Mean Annual Temperature (Average for 2008 – 2012)

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
MAX	33.8	33.8	33.9	32.8	32	30.4	29.4	29.2	29.8	30.8	32.4	33.5
MIN	21.5	23.8	24.0	23.5	23.1	22.8	22.1	22.8	22.9	22.9	23.3	23

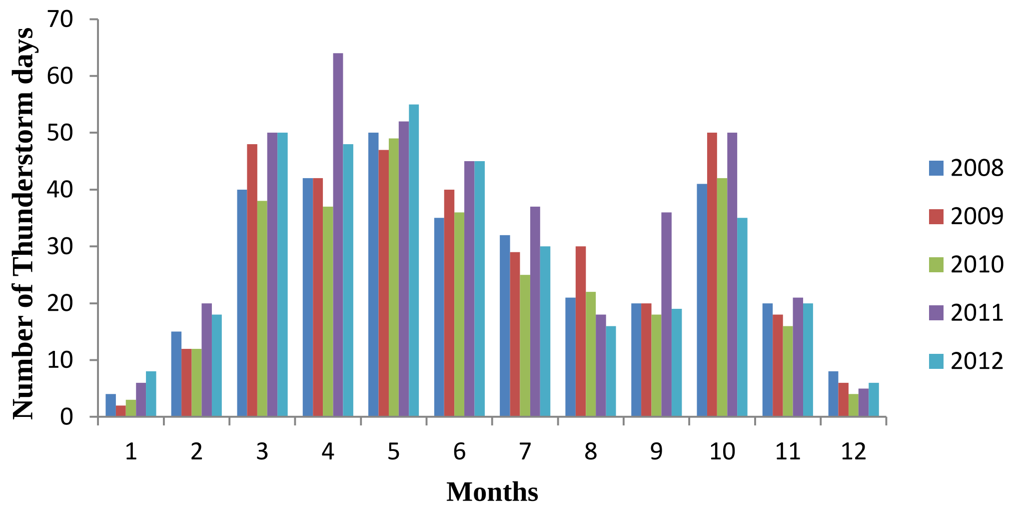
Table 3: Annual Relative Humidity (Average for 2008 – 2012)

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
RELATIVE HUMIDITY	75	79	80	84	87	89	90	91	90	89	85	76

From the results, yearly thunderstorm days was presented in a histogram as shown in figure 1.



(a) Brass Coast



(b) Brass Inland site

Figure 1: Histogram of Thunderstorm days for ecach month of the years 2008 – 2012.

Discussion

Thunderstorm may be as a result of orographic uplift that occur in mountainous area. Mountain slopes are heated more rapidly than valley causing air to rise against the slope initiating vertical development of convective air mass. Thunderstorm is also associated with cold front. Warm air is displaced as cold air masses move underneath at frontal surface resulting in rigorous uplift. This explains the more frequent thunderstorm days in March, April and May and at October. These are periods of transition from dry sunny seasons to the rainy seasons and vice-versa [11]. These periods are marked with sever and prolonged thunderstorms with multiple flashes. The rainy periods (April to

September) are periods of heavy rain with high humidity (90 percent) and the thunderstorm are more devastating. It is obvious that more cloud to ground lightning are experienced.

Diendorfer et al [12] conclude that the percentage of single stroke flashes vary significantly from storm to storm even in the same region and depend probably on seasons and type of thunderstorm. In the Brass coast is more significant that lightning activity occurred mainly overland mass with an average land to ocean ratio of 10:1. This explains the marked difference of the ground flash density of the Brass coast to the inland site.

Conclusion

Lightning parameters are the bases for the design of lightning protection equipment and for the calculation of lightning radiated fields and their interactions with power and telecommunication lines. Lightning peak current is one of the most important lightning parameters and all national and international standards are based on lightning current measurements. Modern multiple station lightning location systems are necessary because their output besides lightning co-ordinates, includes estimates of lightning peak current and number of strokes per flash (multiplicity).

Also, some location systems masses the first stroke and misidentifies the second stroke as the first one. Statistical evaluations based on data for a few storm day may not be a true representation of the total lightning activities in a region therefore frequent measurements and for several years are necessary. Identifying the number of thunderstorm days may only serve some geographical purpose but for scientific data and analysis more modern lightning location systems are necessary in the country. More so, most systems do not record the lightning with low frequency.

Recommendation

It is necessary to recommend that the government, scientific organizations and institutions of learning need to encourage researchers in this area in the country to have reliable records.

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