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Relationships between lightning and rainfall intensities during rainy events in Benin

A. Joseph Adechinan, B. Etienne Houngninou, and Hilaire Kougbeagbede

Département de Physique,
Faculté des Sciences et Techniques, Université d'Abomey-Calavi, Benin

ABSTRACT: This study aims at examining the impact of spatial resolution and the time lag on the relationship between the rainfall intensities and the cloud-to-ground lightning rate during rainy events that occurred in North of Benin in 2006. The lightning data used of this experiment have been collected by LINET network and the rain data are provided by a network of 23 rain gauges. The results obtained show that the temporal scales between the beginning of the electrical activity and precipitations are optimal when these letters are synchronized. The average optimal radius is identified at 8 km around the rain gauges location. In most cases (59 %), the maximum of electrical activity precedes the maximum of precipitations. The heavy rainfalls to ground are offset in time with regard to a peak of electrical activity with an average of 5 minutes.

KEYWORDS: rain event, cloud-to-ground lightning, rainfall intensity, time lag, Benin.

1 INTRODUCTION

Several studies have been conducted in order to correlate the electrical activity and the precipitation parameters [1], [2], [3]. These experiments have shown that the rainy and electrical phenomena have a common origin. However, there exists a time lag of a few minutes between the beginning of the electrical activity and the precipitations [4] or between the maxima of electrical activity and the precipitations [5], [6], [7]. This shows clearly that the life phase (development, maturity and dispersion) of the rains cores and the electrical activity are shifted out of line in time and space [8].

In the related literature, different time lags have been fund. For instance, in the United States (USA), [9] has fund that the CG lightning maximum occurs from eight to ten minutes after the cloud has reached its maximal vertical growth. In Mexico, [10] has demonstrated that the maximum of precipitations appear five minutes after the maximum CG lightning. [7] have obtained in Florida, some temporal scales that could sometimes reach 20 minutes. This variability of the results shows that the time lag between the occurrence of heavy rains and the peak of electrical activity originates from the mechanism of stormy cells occurrence [11].

As per the temporal scales between the beginning of the electrical activity and precipitations, the results achieved through the different experiments vary. For instance, [12] have discovered that the optimal temporal scale between the beginnings of electrical activity and precipitations is 5 minutes. [13] have demonstrated in Island that the optimal time lag between the beginnings of electrical activity and precipitations are respectively 15 min and 25 min for the rainfall events associated with floods and not.

In fact, the correlation between two series of data, varying in time and space can be influenced by the time lag existing between them. Since the lightning and the precipitations are parameters characterized by a heavy spatio-temporal variability [14], the analysis of the relationship between these two phenomena can be dodged when these latter's are taken in a synchronized way. The time lag appears as an important factor while looking for the relationship rain-lightning since one of the phenomena can have a delayed answer on the other.

Beyond temporal considerations, current studies have shown that the relation between the lightning rate and the intensity of precipitations can not only be influenced by the time lag but also by the choice of the spatial resolution. Most of these experiments are based on individual storms (or specific rainfall events). For instance, [12] have studied the relationship between the CG lightning intensity and the one of precipitations over nineteen rainfall events in Cyprus. They've discovered that the correlations are really significant for an average spatial resolution of 10 km radius around the location of rain gauges.

To their mind, this value corresponds to the typical size (horizontal scale) of the stormy cells which grow in the studied area. [13] have undertaken a similar study over sixteen rainfall events in Island and discovered average optimal radius of 15 km.

This study stands in the same vain of these former experiments. It aims on the one hand, at estimating the time lag existing between the beginning (and the peak) of precipitations and the one of electrical activity and, on the other hand, evaluating the effect of spatial resolution on the relationship between the precipitations intensity and the lightning rate on the scale the rainfall event.

2 DATA AND METHODOLOGIE

2.1 DATA

This study is based on the Hydrometeorological Observatory of Ouémé Upper Valley (OHHVO). This study area situated on the East on the Greenwich Meridian in the center of Benin (fig 1), covers roughly a surface area of 15 000 km^2 [15]. The climate of this region Sudanese with an interannual rainfall average close to 1200 mm from 1954 to 2005 [16]. The relief of the OHHVO is less sharp with a slope of almost 200 m between Djougou region and Bétérou out let [17]. This area is essentially characterized by a dry season that goes from November to October with a maximum of rain in August [15]. The set of data used in the frame of this study is essentially constituted of precipitations and lightning data.

The lightning data used in this study are obtained from LINET network (Lightning Detection Network). This network was almost held on for five months (from half-June to half-November 2006) and has permitted to record certain lightning parameters such as: the geographical position (longitude and latitude), the date and hour of the lightning occurrence, the range of field discharge, the type of lightning (intra-cloud or cloud-to-ground lightning) and the height of intra-cloud. [18] informs again on the functioning of this network. In the frame of this study, only CG lightning data (without polarity distinction) have been analyzed.

The rainfall data derive from the base rain gauge network of the OHHVO. This network is composed of 55 rain gauges with tipping bucket in 2006. Proceeding from their irregular distribution over the whole study area and depending on the minimal inter-distance (110 m) between those rain gauges, we have identified a sub-network composed of 23 rain gauges (fig 1). The station for which the inter-distance is inferior to 15 km has not been taken into account. This choice is valid with regard to the constraint of the methodology adopted to analyze the rainfall event selected.

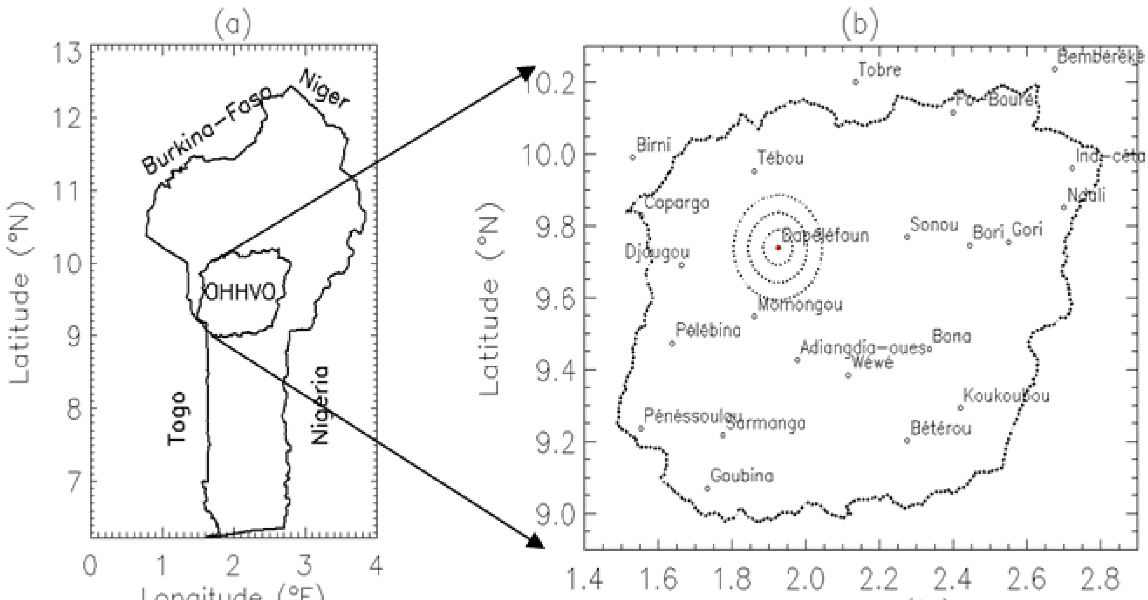

***Fig. 1.** (a) Geographical situation of Benin with the boundaries of the OHHVO, (b) sub-network composed of twenty three rain gauges used for the study.*

The events studied in this paper have been defined on a hydrologic point of view and on three criteria [15]. They are as follows: i) a temporal criterion of no rain interruption on the whole network (rain mustn't stop for more than 30 min on the whole network); ii) a criterion of spatial continuity of the event which is a minimal proportion of the network reached (almost

30% of the rain gauges stations of the network record rain); iii) a quantitative criterion which is a minimal quantity of rain recorded at least on one station of the network (almost 1 mm of water recorded on almost one of the station reached).

Starting from this definition, ninety five rainfall events have crossed the study area in 2006. Among them, sixteen have been chosen in reference to the dates suggested by [19]. Those dates correspond to days of heavy electrical activity. Some characteristics of these events are summed up in table 1. The values written in that table are valid for the sub-network of twenty three rain gauges.

Since the storms are rarely stationary [7], an event can stop at a given station of the network while rain still pours down on other stations. So, we learn from this study that the beginning of any rainfall event on a specific rain gauge corresponds to the timing of the first knocking over of the bucket. In addition, the end of the event on the rain gauge will correspond to the timing of the last knocking over of the bucket, even though the precipitations have continued without causing an extra knocking over of the bucket on the rain gauge.

Table 1. Some characteristics of rainfall events used in the frame of this study.

n°	Start event	End event	Maximal Cumul (mm)	Rain gauge with maximal cumul	Maximal rain intensity (mm/5min)	Rain gauge with the maximal intensity
1	23/06/2006 01h :15min	23/06/2006 08h : 25min	34.58	Birni	6.70	Tobré
2	03/07/2006 13h : 55min	03/07/2006 18h : 40min	42.76	Birni	9.88	Birni
3	04/07/2006 16h : 15min	04/07/2006 20h : 45min	34.09	Koukoubou	8.36	Koukoubou
4	15/07/2006 01h : 15min	15/07/2006 10h : 25min	51.51	Pélébina	11.22	Bembéréké
5	19/07/2006 16h: 20min	20/07/2006 17h: 20min	109.08	Ndali	12.74	Ndali
6	28/07/2006 04h : 35min	28/07/2006 10h : 00min	17.39	Tébou	4.76	Tébou
7	30/07/2006 17h : 20min	31/07/2006 00h : 05min	104.13	Momongou	10.40	Pénéssoulou
8	10/08/2006 15h : 55min	10/08/2006 21h : 25min	83.22	Djougou	12.05	Djougou
9	22/08/2006 14h : 55min	22/08/2006 23h : 10min	77.97	Dapéréfoungou	14.49	Adiangdia-ouest
10	26/08/2006 12h : 30min	26/08/2006 18h : 55min	70.67	Pélébina	17.41	Ndali
11	30/08/2006 11h : 05min	30/08/2006 17h : 50min	210. 06	Ndali	41.80	Ndali
12	11/09/2006 22h : 25min	12/09/2006 12h : 00min	68.82	Gori-bouyerou	10.86	Tébou
13	19/09/2006 14h : 00min	20/09/2006 06h : 05min	44.49	Bembéréké	9.89	Momongou
14	22/09/2006 14h : 55min	23/09/2006 08h : 20min	93.70	Koukoubou	13.18	Tébou
15	18/10/2006 15h : 50min	18/10/2006 18h : 15min	20.73	Tébou	10.64	Ndali
16	23/10/2006 13h : 40min	23/10/2006 20h : 30min	22.42	Tébou	8.32	Ndali

To well receive these events on each rain gauge, some lightning parameters (maximal number of lightning in 5 min per event, total number of lightning per event) have been correlated with some precipitation parameters (maximal rain intensity in 5 min per event, total rain per event).

2.2 Methodologie

In the present study, the concept of the time scale will be tackled on two folds such as: i) the time lag between the beginning of electrical activity and precipitations; ii) the time lag between the maxima of electrical activity and precipitations.

2.2.1 Time Lag Between The Beginning Of Electrical Activity And Precipitations

The time lag between the beginning of electrical activity and precipitations during a given rainfall event is defined in this paper like the duration between the moment of the first CG lightning cutting out in circle of radius R focused on a specific rain gauge, and the moment of the first knocking over of the bucket of this rain gauge. The methodology used in this study to analyze the sixteen rainfall events held is based on the one used in the literature [12], [13]. However, some stages have been modified in this methodology due to the nature of the dataset and the duration of the events selected. As it was the case of other experiments [4], [13], the main hypothesis of this methodology is that the electrical activity precedes the evolution of precipitations. The fig 2 shows an illustration of that procedure. It is a diagrammatic representation applied to any event, for a fixed radius R and on a specific rain gauge station.

In fact, during any rainfall event i, we've got after resampling the gross data for each active rain gauge (any rain gauge of the network that has recorded almost 1 mm rain during the event i), the series of rain intensity (mm/5min) during the duration of the event. On this basis we determine in the same way the number of CG lightning corresponding to the inner inside of a circle with radius R centered on the position of the rain gauge used. On looking at the inter-distance between the rain gauges of the sub-network considered, the radius R of the circle demarcated around the position of the rain gauge has been limited on 15 km. We thus make this radius vary between 5 and 15 km on each 5 km (see the example illustrated in fig 1 at the meteorological station of Dapelefoun). As long as this radius increase, the couple of rains without lightning decreases at a regular timing of 5 min for each value radius R. The two series of data set are now gathered in a half hour consecutive time interval (fig 2).

Time lag of 5 min								
	Number of CG lightning each 30min	68	84	92	112	103	84	70
	Rain cumulus each 30 min	12.67	12.61	11.78	7.04	5.22	3.06	2.04

Time lag of 0 min									
	Number of CG lightning each 30min	68	84	92	112	103	84	70	51
	Rain cumulus each 30 min	11.86	12.67	12.61	11.78	7.04	5.22	3.06	2.04

CG (fl/5min)	3	5	4	22	20	14	19	13	24	13	1	0	0
rain (mm/5min)	0.24	0.48	1.52	5.14	2.08	2.40	1.05	0.42	0.69	0.40	0.26	0.24	0.03
Date & Hour	23 / 06 / 2006 02:40	23 / 06 / 2006 02:45	23 /06 / 2006 02:50	23 / 06 / 2006 02:55	23 / 06 / 2006 03:00	23 / 06 / 2006 03:05	23 / 06 / 2006 03:10	23 / 06 / 2006 03:15	23 / 06 / 2006 03:20	23 / 06 / 2006 03:25	23 / 06 / 2006 03:30	23 / 06 / 2006 03:35	23 / 06 / 2006 03:40

Fig. 2. Diagrammatic representation of the methodology applied to the event n°1 (table 1) for a fixed radius of 5 km around the rain gauge positioned at Bori.

The active rain gauges that have not recorded any CG lightning whatever be the value of the radius during the whole event have not been taken into account. In addition, because of the different time lags tested, the active rain gauges that have a rain accumulation time less than half an hour during the whole event have been cancelled.

Regarding the variability of the number of lightning detected and the volume of water collected during a rainfall event, [14] has mentioned that it is difficult and also impossible to establish a linear relationship between these two parameters. Therefore, [7] have shown that this relationship is possible since the report between the volume of precipitation and the number of CG lightning is globally constant for most of the storms they studied. Recently, [12] have evaluated the relationship rain-lightning with some simple linear regression on nineteen rainfall events in South Korea. [13] have also tackled the problem with the same approaches on sixteen rainfall events in Island and have found statistically significant coefficient. The unanimity on the use of a linear regression to quantify the link between the lightning parameters and the precipitations is far from being accepted. Despite those differences, the linear correlation coefficient from Pearson has been used in the present study to quantify the relation between the intensity of precipitations and the rate of CG lightning for all the events held in the frame of the present study. This coefficient allows measuring the intensity of the variation between two quantitative variables.

Some correlations have thus been calculated in synchronous and asynchronous way. This allows checking whether in shifting from 5 to 5 min the beginning of the series of precipitations of the electrical activity; one can discover a maximal variance between the precipitation and the electrical activity with a temporal scale situated between 0 and 15 min. This technique is advantageous in the sense that it identifies the time lags for which the evolution of precipitations and the electrical activity are similar. The correlation coefficients discovered are significant for a p-value inferior to 0.05 with a trust level of 95 %.

At the end of this procedure, the determination coefficient (r^2) attributable to the event i is the average value of the determination coefficient calculated for the whole active rain gauges during this event. This procedure has been applied to all the sixteen rainfall events and all the rain gauges held in the frame of this study. The table 2 sums up the different combinations of the time lag and the radius R obtained. For each of the combinations, a linear regression line has been adjusted to the lightning data and precipitations.

Table 2. Summary of the different combinations obtained when the procedure puts forth is applied to a specific rain gauge during a given event.

	Time lag			
Radius	0 min	5 min	10 min	15 min
5 km	5-R0	5-R5	5-R10	5-R15
10 km	10-R0	10-R5	10-R10	10-R15
15 km	15-R0	15-R5	15-R10	15-R15

2.2.2 TIME LAG BETWEEN ELECTRICAL ACTIVITY MAXIMA AND THE PRECIPITATIONS

Unlike the temporal scale formerly defined, the time lag between the electrical activity maxima and the precipitations during any rainfall event is written as followed:

$$\Delta t = t_{CG,max} - t_{p,max} \quad (1)$$

where $t_{p,max}$ and $t_{CG,max}$ respectively represent, the cutting out moment of the absolute maxima of precipitations and CG lightning during the event used in the frame of this study. If $\Delta t > 0$, it is supposed that the maximum of precipitation falls before the maximum of CG lightning; if $\Delta t < 0$, so the maximum of precipitation falls after the maximum of CG lightning and when $\Delta t = 0$, then the maximum of precipitations are reached at the same time.

Fig 3 gives an illustration of the time lag between the maximum CG lightning and precipitations observed at the meteorological station of Djougou during the event n°2 (table 1). The application of the relationship (1) to the set of rain intensity and the lightning rate recorded in a radius of 10 km around this station show the existence of positive time lag (Δt = 10 min).

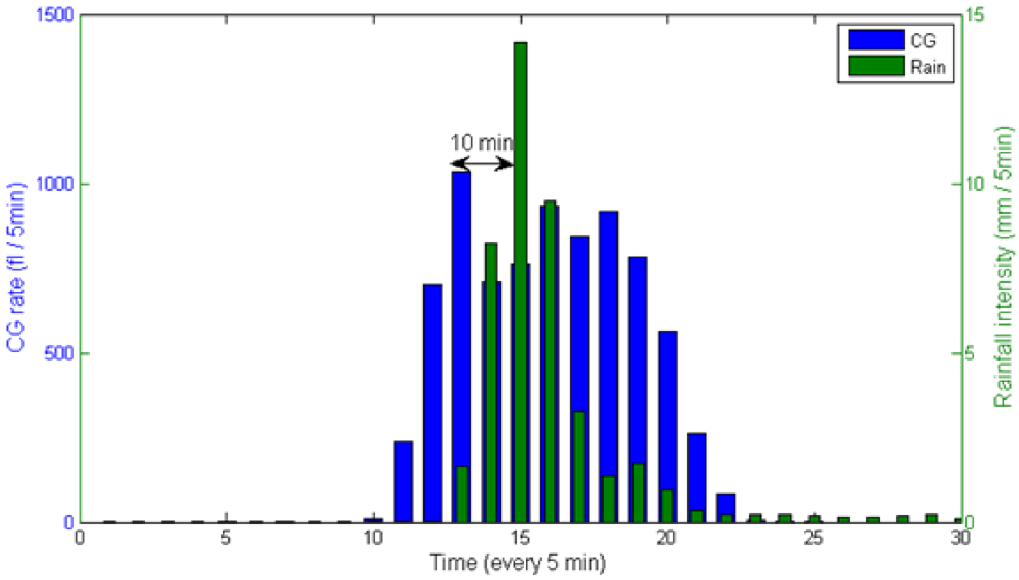

Fig. 3. Temporal evolution of lightning rates and rain intensity show time lag between the maximum CG lightning and precipitation observed at the meteorological station of Djougou during event n°2 (table 1).

The different time lags between the maximum of electrical activity and precipitations have been determined for all the rainfall events on each rain gauge. For these calculations, we have used the average optimal spatial scale and also the average optimal temporal scale reached at the end of the former procedure. Starting from the relationship (1), the active rain gauge during a specific event and for which no lightning has been detected in the field delimitated around them are automatically excluded. The situations in which the series of temporal evolution have been submitted to some irregularities (for example more than one maximum during a same event) have simply been cancelled. In fact, those series could be smoothed down by several methods (for instance the mobile averages method) so as to obtain a remarkable peak, but it would undoubtedly influence our results.

3 Results And Discussions

3.1 Caracteristics Of The Rainfall Events Used In The Frame Of The Study

We have written in table 3 the different values of the determination coefficients found between cloud-to-ground lightning and precipitation parameters detected. The determination coefficients obtained are mostly weak but statistically significant (p-value < 0.05 with a trust level of 95 %). This shows that the different lightning parameters chosen have no explication through the precipitation parameters tested. Whatever be the radius, the heaviest values are found at the level of the couple (maximal rain, total CG lightning), whereas the couple (total rain, maximal CG lightning) yield the weakest values. One can also notice the weakening of determination coefficient as long as the radius R increases from 5 to 15 km on each 5 km.

However, we notice a strong linear correlation between the rain maximal intensity per event and the total quantity of water collected during the same rainfall event, no matter what radius R, considered (fig 4). It is the same thing between the maximal CG lightning (number of CG lightning in 5 min) during a rainfall event and the total number of CG lightning recorded during the same event (fig 4).

***Table 3.** Correlation between the lightning and precipitation parameters during selected events. The values between brackets stand for the p-value for a trust level of 95%.*

	Radius		
r^2	5 km	10 km	15 km
(maximal rain intensity, maximal CG lightning)	0.09 (0.0039)	0.07 (0.0037)	0.04 (0.0194)
(maximal rain intensity, total CG lightning)	0.09 (0.0032)	0.08 (0.0022)	0.08 (0.0038)
(total rain, maximal CG lightning)	0.04 (0.0450)	0.04 (0.0385)	0.02 (0.0895)
(total rain, total CG lightning)	0.05 (0.0261)	0.05 (0.0189)	0.04 (0.0220)

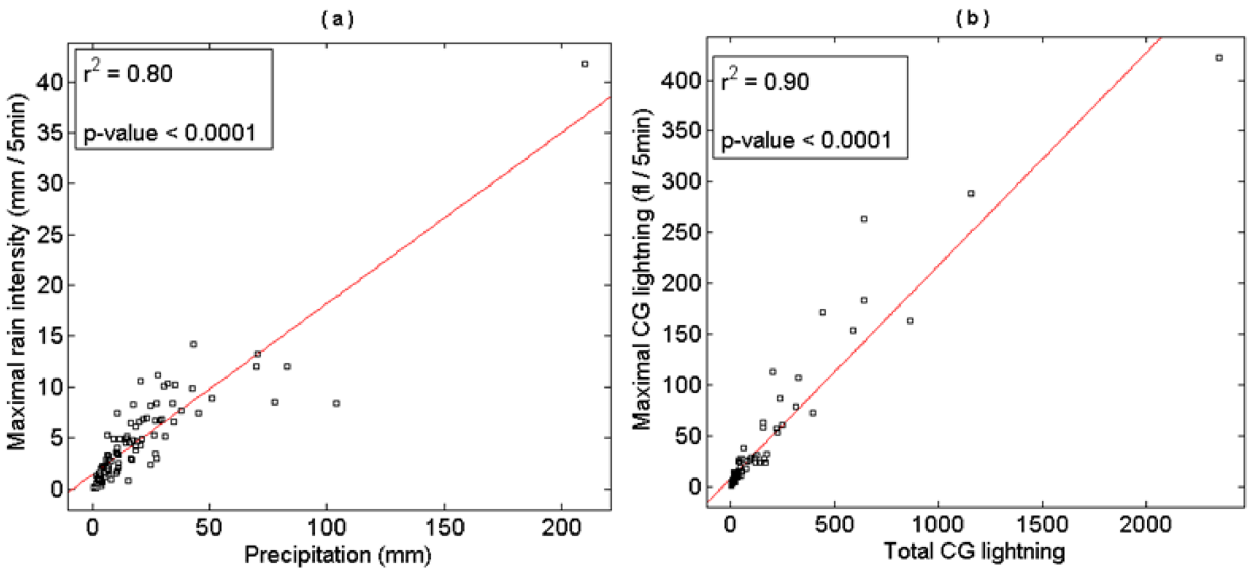

Fig. 4. (a) Correlation between the maximal rain intensity and the total cumulous per rainfall event for the whole selected events; (b) correlation between the maximal rate of CG lightning and the total CG lightning per rainfall event for a 5 km radius around the position of rain gauges.

3.2 Identification Of The Optimal Temporal Scale Of The Electrical Activity And Precipitations

For all the rainfall events studied, precipitations have never stopped on a rain gauge before the stoppage of the electrical activity on this latter, no matter what value of the radius R considered. For all the radius tested and on all the rain gauge stations used in the frame of this study, the average determination coefficient vary between 0.19 and 0.58 with an average of 0.28. Whatever be the value of the radius R, the determination coefficients obtained with a temporal scale superior to 10 min are the weakest. Then, as long as the temporal scale between the beginning of electrical activity and precipitation increases, the probability to have a statistically significant correlation between the precipitation intensity and the CG lightning rate decreases.

We've shown on fig 5 the temporal scale corresponding to the maximal determination coefficient obtained on each rain gauge. It is noticeable that this temporal scale varies from a station to another. The number of stations that have had time lags of 0 min, 5 min and 10 min respectively correspond to 74 %, 9 % and 17 % of all the stations used in the frame of this research. On no stations and for all the time lags tested, is the temporal scale corresponding to the maximal determination coefficient superior to 10 min. The longest temporal scales are observed in the South-West of OHHVO whereas the majority of the stations located in the North-East of OHHVO have a relatively short temporal scale.

This variability of temporal scale between the beginning of electrical activity and precipitations is observed on the spatial scale that allows to obtain the maximal determination coefficient between the precipitation intensity and CG lightning rate. In fact, the radius for which the correlation is maximal varies from a situation to another, between 5 and 15 km with an average of 8 km around the location of the rain gauges. This value is not far from the one found in the literature, precisely by [12].

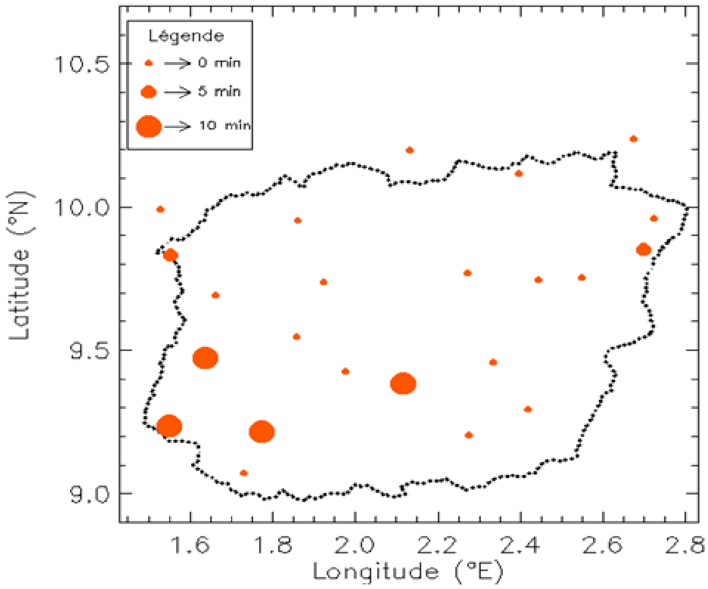

Fig. 5. ***Time lag between the beginning of electrical activity and precipitation corresponding to the maximal determination coefficient obtained on each rain gauge of the network.***

For 52 % of the rain gauges used in the frame of this study, the radius corresponding to the maximal determination coefficient is 5 km. This percentage progressively decreases as long as the radius increases. It is 39% for an optimal radius of 10 km and 9 % for the one of 15 km. This variability of the optimal radius to which weak determination coefficients are added might be explained by the fact of not using threshold value of rain intensity to select the active rain gauges during the events studied. For example on Saturday 26th, August 2006, between 12h:30 and 19 h (UTC), the event n°2 that has yielded important rain cumulous and a particularly intense electrical activity has occurred on OHHVO. During that storm, nine gauges out of the twenty three of our sub-network have recorded heavy rain intensities with cumulous superior to the average cumulous (21.84 mm) of the event. As we can observed on the CG lightning density map (fig 6), the electrical activity has really been intense (96 fl/km^2) in the Western part of the study field. This strong occurrence of CG lightning is obtained at almost four km of the rain gauge that has recorded the maximal rain cumulous during the event whereas the rain gauge station that has recorded the maximal rain intensity stands at ten kilometers.

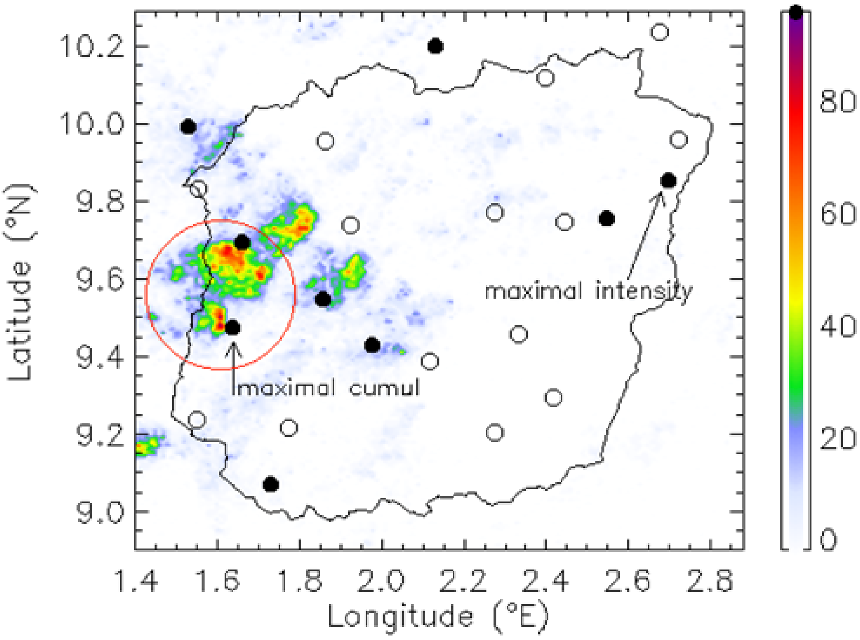

Fig. 6. ***Cloud-to-ground lightning density map corresponding to event n°2. The close circles indicate rain gauges that have had a rain cumulous superior to the average cumulous of the event and the red circle indicates the area that could be considered as stormy area on looking at it lightning density.***

It thus appears that the areas that have had a strong electrical activity are mostly associated with a heavy water volume but the inverse isn't usually verified. This observation matches with the results obtained by [14] at the center and East of Mediterranean. Some active rain gauges during that event and located far from the area of strong lightning occurrence have obtained strong rain intensities associated with very weak CG lightning rates. The correlations obtained on these rain gauges are really weak. This means that the relationship between the rain intensity and the lightning rate is dependent on the position of the rain gauge with regard to the storm but also the storm life span. Thus, it is necessary to establish a lightning density map that will serve as indicator for selecting active rain gauges during the events studied.

The fig 7 shows the evolution of average determination coefficient of each rainfall event for different radius R values when the beginning of electrical activity and precipitations are synchronized. The determination coefficients vary between 0.16 and 0.86 with an average of 0.43. As long as the radius R increases from 5 to 15 km on each 5 km, the average determination coefficient of eight rainfall events decreases, the one of two rainfall events increases and for the remain events, no clear inclination is observed but the correlation is still maximal for a radius of 10 km. The number of rainfall events having statistically significant coefficients is thus increase for a radius inferior or equal to 10 km. These observations are to complete the analysis done on each rain gauge.

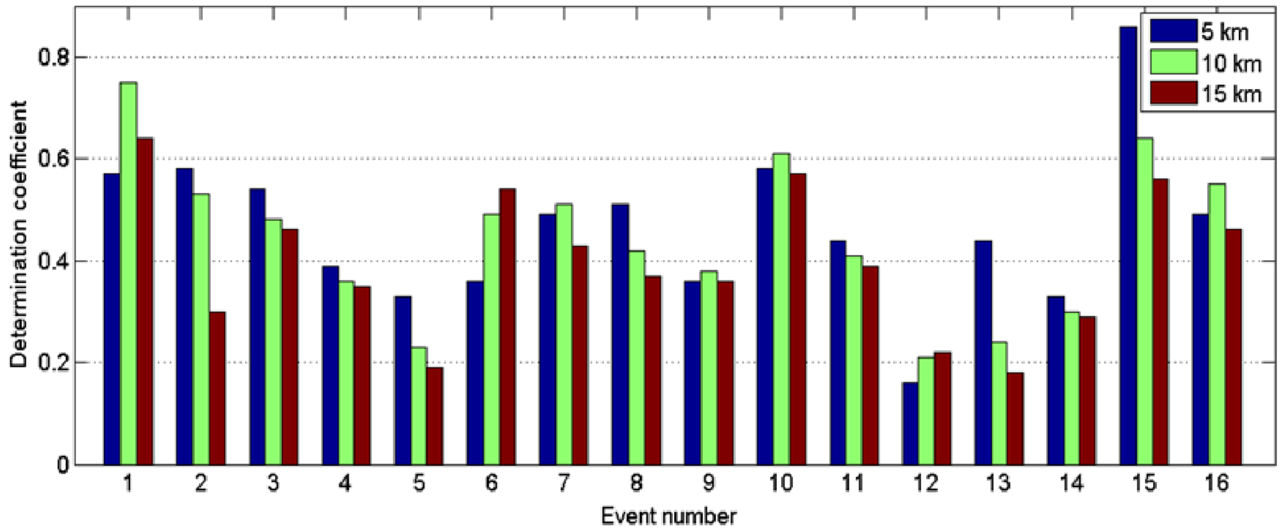

Fig. 7. Average determination coefficients per rainfall event for different values of R when the beginning of electrical activity and precipitations are synchronized.

On looking at the statistics obtained, the analysis of the relation between the precipitation intensity and CG lightning rate on the scale of the rainfall event seems better on the one hand, when the beginning of electrical activity and precipitations are synchronized on other hand, for an average radius of 8 km around the rain gauges.

3.3 Temporal Scale Between Electrical Activity Maxima And Precipitations

Fig 8 shows the frequential distribution of different temporal scales obtained when the relationship (1) is applied to the sixteen rainfall events used in frame of this study and on all the rain gauges of the sub-network. Those time lags between the maximum electrical activity and precipitations on a radius of 8 km around the position of rain gauges. Globally speaking, we notice on this figure that the time lag between the peak of electrical activity and precipitation is negative ($\Delta t < 0$), positive ($\Delta t > 0$) and nul ($\Delta t = 0$), respectively in the proportions of 59 %, 26 % and 15 %. These percentages indicate that for most (59 %) of the events studied, the maximum of electrical activity precedes the one of precipitations in time. This result which is the confirmation of the starting hypothesis matches with the conclusions derived from [7] experiments. These authors have also discovered that on 75 % of the events studied, the maximum lightning usually precedes the maximum of precipitations.

On the OHHVO, the CG lightning peak frequently (17 %) precedes the precipitation peak in time for 5 min. This observation is comparable to the one made in Mexico by [10]. The time lag superior to 20 min are less frequent. However, we record in some situations (4 %), time lags exceeding 1 hour. These time lags are relatively long and can be the result of the life span of certain cloudy systems that are growing in the area. In fact, even after crossing over a rain gauge located on the active part of the cloud, the renewal of new cells due to a heavy located convection can generate in some situations, an increase of the CG lightning rate since the origin of those discharges is associated with ebbing tides [20].

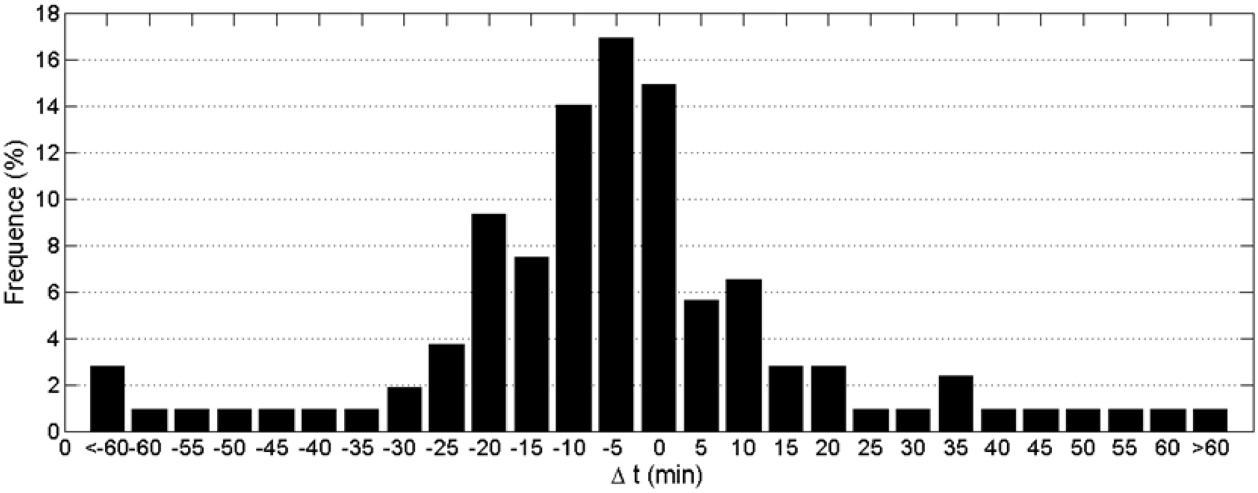

Fig. 8. Frequential spreading of temporal scales between the electrical activity maxima and precipitations for a fixed radius of 5 km around the location of the rain gauges for the overall rainfall events studied.

Table 4 presents the summary of the total of events per station, number of statistically significant events, optimal temporal scale the determination coefficient and the p-value corresponding to each of the rain gauges used in the frame of this work as well. It is clear from the analysis of this table that the optimal determination coefficient obtained at the level of those rain gauges vary from 0.11 to 0.93 with an average of 0.58. The rain gauges (seven in total) for which the optimal temporal scale is negative represented 30 % and have almost relatively weak significant coefficients. The average optimal temporal scale between the electrical activity maxima and precipitations is also 5 min.

Table 4. Number of events occurring on each meteorological station, optimal determination coefficient, temporal scale corresponding to maximal r^2 with p-value corresponding to each rain gauge.

Name of the rain gauge station	Altitude (m)	Number of event per station	Number of Significant event	Optimal Δt (min)	r^2	p-value
Adiangdia-ouest	456	15	14	0	0.93	$1.26\ 10^{-26}$
Bembéréké	420	11	9	0	0.67	$2.13\ 10^{-13}$
Bétérou	287	10	8	15	0.20	$5.55\ 10^{-04}$
Birni	459	13	13	-5	0.84	$3.70\ 10^{-11}$
Bonazuro	386	10	9	5	0.32	$1.13\ 10^{-02}$
Bori	353	14	10	0	0.85	$1.15\ 10^{-07}$
Copargo	532	13	10	5	0.78	$1.22\ 10^{-26}$
Dapéréfoungou	366	13	11	5	0.68	$8.19\ 10^{-05}$
Djougou	454	15	13	5	0.61	$1.35\ 10^{-07}$
Fo-Bouré	425	13	12	-5	0.11	$6.25\ 10^{-02}$
Gori-bouyerou	353	12	10	0	0.84	$8.54\ 10^{-16}$
Goubono	637	15	10	-10	0.36	$2.95\ 10^{-03}$
Ina-Ceta	404	10	5	0	0.82	$6.71\ 10^{-07}$
Koukoubou	321	8	6	5	0.79	$8.23\ 10^{-06}$
Momongou	406	15	12	0	0.25	$2.32\ 10^{-02}$
Ndali	393	8	6	5	0.86	$2.18\ 10^{-02}$
Pélébina	463	10	8	-5	0.36	$1.44\ 10^{-02}$
Pénéssoulou	419	14	11	-5	0.23	$3.74\ 10^{-03}$
Sarmanga	410	13	10	0	0.35	$1.43\ 10^{-11}$
Sonoumou	406	13	10	-5	0.42	$3.76\ 10^{-06}$
Tébou	383	13	12	0	0.80	$1.99\ 10^{-03}$
Tobré	371	12	10	5	0.60	$6.87\ 10^{-12}$
Wéwé	318	10	8	-5	0.78	$1.01\ 10^{-32}$

4 CONCLUSION

We have examined in this study the impact of choice of spatial resolution and time lag on the relationship lightning-rain and the identification of time lag existing between the peak of electrical activity and precipitation during sixteen rainfall events that occurred during the rainy season of 2006 on OHHVO in Benin as well. The lightning data and precipitations used to reach this goal have been collected during the AMMA campaign (Multidisciplinary Analysis of the African Monsoon) respectively through lightning measuring network (LINET) and twenty three meteorological stations. In total, sixteen rainfall events have been selected and analyzed through a statistic method consisting in shedding a global light on to the temporal evolution of the CG lightning rate and precipitation intensity in concentric circles centered on the position of meteorological stations.

On looking at the results achieved, it appears that the relationship between the CG lightning rates and precipitations intensity, not only depends on the position of the rain gauge with regard to the storm, but also on the life span of the storm. The strong values of the statistically significant determination coefficients are recorded when the beginning of the electrical activity and precipitations are synchronized. For most rain gauges used (57 %), the determination coefficient is maximal for a 5 km radius around their locations. This percentage decreases as soon as the radius R of the circle defined around the rain gauges increases. The average optimal radius for the overall events and all the rain gauges is 8 km. As per the temporal scale between the electrical activity maxima and precipitations, we notice that the heavy rain quantities on the ground are shifted in the course of time with regard to the peak of electrical activity with an average of 5 min. In most cases (59 %), the precipitations maximum is preceded by the CG lightning maximum.

These results lead to an important investigation field on the technique that is to be put forth to anticipate on heavy rain by the electrical activity. With regard to the variability of the temporal scales and radius obtained on each rain gauge, we think that the use of a CG lightning density map for the selection of the active rain gauges during a given rainfall event, and by taking into account certain dynamic and thermodynamic parameters (such as temperature, speed and wind direction) will help to better significantly the correlation between precipitation intensity and the CG lightning rate.

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