Distribution of attempted leader with monsoon seasons and negative cloud-to-ground flashes in Melaka, Malaysia

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ABSTRACT

Ninety (90) waveforms recognized as attempted leader were identified with both positive (84 events) and negative (6 events) initial polarity observed from four consecutive years of data (N=10,206). The positive attempted leader shows no correlation with the number of thunderstorms producing it during monsoon. Meanwhile, the negative attempted leader during monsoon and both polarity of attempted leader (positive and negative) during inter-monsoon shows positive correlation with the number of thunderstorms producing it. In this study, the yearly statistical distribution of negative cloud-to-ground (CG) lightning flashes which were classified as positive preliminary breakdown pulses (214 events) and negative preliminary breakdown pulses (4982 events) in accordance of their preliminary polarity were also presented. In addition, there is no relationship of attempted leader and the initial breakdown of negative ground flash since both mechanisms performed as a negative correlation.

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1. INTRODUCTION

The basic needs for the formation of thunderstorm are sunlight, moist air and unstable atmosphere. The first stage of cloud formation called cumulus cloud formed when the moist air rises in the unstable atmosphere, and as the air rises higher, the condensation process also happen in faster rate. All thunderstorm formation start with air rising into the unstable atmosphere before forming a convective cell [1]-[7]. However, the air can be upraise in various ways by which where (land, oceanic, or mountain) or when (monsoons) they were form [8]-[10]. All these type of condition will influence to different type and distribution of lightning discharge produced.

The first process of lightning discharge happen in cloud are called preliminary breakdown [7], [11]-[13]. This in-cloud process will initiates the earthward moving step leader preceding the first return stroke in cloud-to-ground (CG) lightning flashes [11]. Negative CG flashes take place between the main negative charge center and ground [14]-[18] while positive CG flashes take place between the positive charge center and the ground [19]-[21]. However, there are condition where the first step leader cannot propagate to the ground completely and this event was terminologically referred as 'attempted leader' [22], [23]. Furthermore, the large current running in the return stroke of most lightning strikes causes damage, as does the heat generated by this and the continuing current [24]-[30]. If lightning strikes a person, the central nervous system, heart, lungs, and other vital organs might be injured by the stroke current; therefore, thorough analysis and monitoring are required to assure the safety of people and property [31]-[34].

Attempted leader is the potential cloud-to-ground lightning flash of first descending step leader in which its propagation may be discouraged by the excessive existence of lower positive charge region (LPCR) [23], [35], [36]. Lightning has both direct and indirect effects on power system performance, with transient high voltages causing flashover on electrical equipment on the power [28]. In other words, attempted leader is the potential cloud-to-ground lightning flash, however the downward moving step leaders die out before being attached with the progressing upward leaders as reported by previous researchers such as [22]-[23], [37]-[39]. This study presents the novel information in large scale of data of attempted leader distribution activities with the correlation of number of thunderstorms producing it with the influence of climatology condition, or monsoon seasons at location of tropical region Melaka, Malaysia. The yearly distribution and correlation of attempted leader with negative cloud-to-ground lightning flashes are also presented in this study.

2. METHOD

The attempted leader activities recorded for four consecutive years (2016 to 2019) are examined in this study. The data was examined from August to December 2016 (2259 data), January to July 2017 (1466 data), August to December 2018 (3692 data), and January to July 2019 (2789 data). From all these data gathered (10,206), ninety events were recognized as attempted leader. The measurement station was located in Melaka (2.1896° N, 102.2501° E). Furthermore, 19, 33, 15 and 23 of attempted leader waveform observed in 2016, 2017, 2018 and 2019, respectively.

In this study, the vertical plate antenna, buffer circuit, coaxial cable, and transient recorder (Teledyne Lecroy HDO4024) has been implemented for measuring, recording and analyzing the electric radiation fields of lightning flashes. Figure 1 shows the arrangement as where the measurement set up was similar to [37]-[39]. The antenna is used to detect the vertical electric fields and arranged perpendicularly to the electric field vector, parallel to the ground in order to prevent the horizontal electric field effect. Additionally, the antenna's physical height is set to 1.5 metre with the effective height of 0.25 metre. The antenna is connected to electronic buffer circuit by using 60-centimetre-long coaxial cable (RG-58) and the signal is transmitted from the antenna to 12-bit digital high-speed transient recorder (Teledyne Lecroy HDO4024) using 10-metre-long coaxial cable (RG-58). This high-speed transient recorder is also equipped with 200 MHz High-Definition Oscilloscope and the transmission to digital transient recorder occur after passing through the electronic buffer circuit.

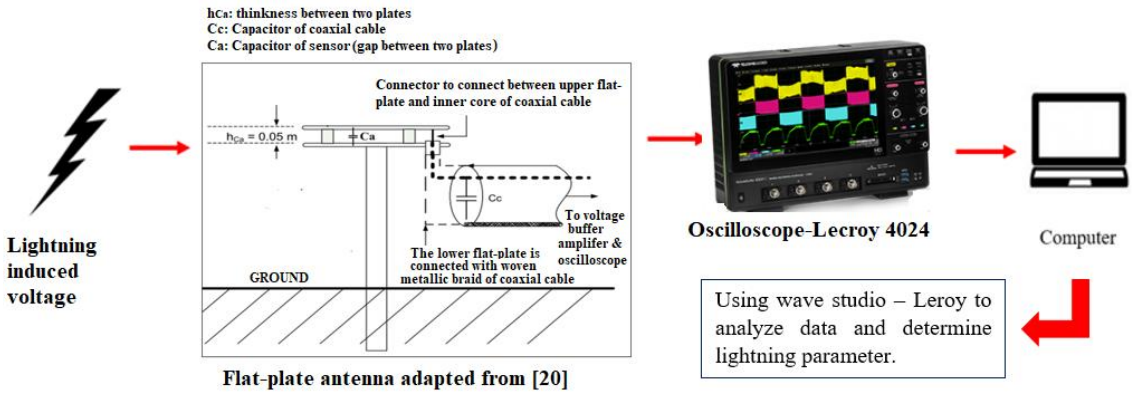
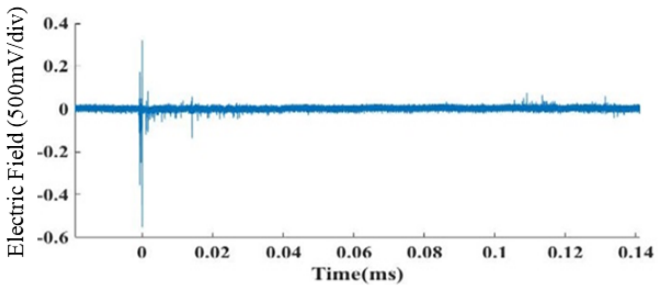


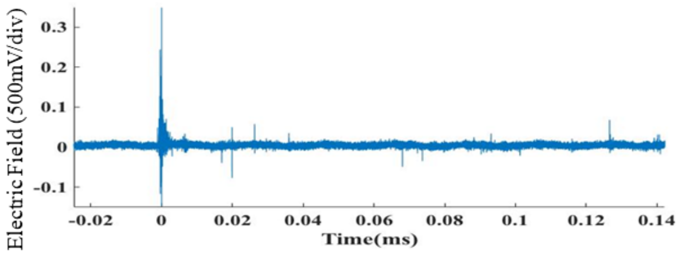
Figure 1. The arrangement of lightning measurement and followed by the recording and analyzing section

3. RESULTS AND DISCUSSION

The study presents the novel information on the statistical distribution of attempted leader activities with number of thunderstorms during monsoon and inter-monsoon for four years (2016-2019) in tropical region Melaka, Malaysia. The author focused only on the microsecond scale of electric radiation field that that fails to propagate to the ground completely and not producing first return stroke. There were 84 positive polarity and 6 negative polarity of electric radiation field of attempted leader observed and the electric radiation field waveform sample are shown in Figure 2 (a) and (b).



(a)



(b)

Figure 2. The attempted leader, (a) positive polarity on 7th December 2018 and (b) negative polarity on 30th September 2018

This study presents the correlation between the attempted leader and thunderstorm under the influence of Northeast Monsoon (October-Mac), Southwest Monsoon (May-September), First Inter-monsoon (March), and Second Inter-monsoon (October), as depicted in Figure 3 (a), (b), (c) and (d), respectively. Result shows that the positive attempted leader activities during monsoon in Figure 2 (a) has negative correlation with thunderstorms. The highest positive attempted leader during monsoon occur in 2017 and 2019 in which twenty-nine (29) and twenty (20) positive attempted leader were observed in only five (5) and four (4) recorded thunderstorm respectively. While in 2016 and 2018, seventy (17) and twelve (12) of positive attempted leader activities were observed in only nine (9) and five (5) thunderstorm respectively. In other word, single thunderstorm during monsoon are capable of producing more than one attempted leader event.

However, the negative attempted leader activities during monsoon in Figure 3 (b) shows a positive correlation with the thunderstorm. The yearly distribution activities are also far less than that of positive attempted leader during the Monsoon season. Further, in Figure 3 (b), there was no attempted leader event in 2017 during the Monsoon season. Obviously, the thunderstorm produced during Monsoon seasons in tropical climate does not supporting the production of negative polarity of attempted leader since the activity of this profile appeared during this particular period (only three (3) activities recorded for four years). Next, the attempted leader for both positive and negative polarity during the Inter-monsoon in Figure 3 (c) and (d) also shows very positive correlation with thunderstorm. The yearly distribution activities were also not as frequent as can be seen during Monsoon for positive polarity of attempted leader activities. Specifically, single thunderstorm is seen producing not more than one positive and negative polarity during Inter-monsoon. The same scenario also seen during Monsoon for negative attempted leader.

On the other hand, the yearly distribution of attempted leader was also presented to perceive the correlation of attempted leader activities with the negative cloud-to-ground lightning flashes (same and opposite polarity of preliminary breakdown). The percentage of attempted leader on both polarity (positive and negative) in 2016, 2017, 2018 and 2019 were 0.84% 2.25%, 0.41% and 0.82% from the yearly data recorded, respectively. Meanwhile, the percentage of negative cloud-to-ground lightning flashes on both preliminary breakdown polarity (positive and negative) in 2016, 2017, 2018 and 2019 were 77.51%, 59%, 66.66% and 45.39% from the yearly data recorded, respectively. As depicted in Figure 4, the highest activity of attempted leader occurred in year 2017 (N= 33). However, the least activity of negative cloud-to-ground lightning flashes (N=865) were seen in the same year. On the other hand, the lowest activity of attempted leader (N=15) portrayed in year 2018 shows the highest activity of negative cloud to-ground lightning flash (N=2461). Overall, the summary of the correlation between the total attempted leader and negative cloud-to-ground lightning flashes, is presented as shown in Figure 4.

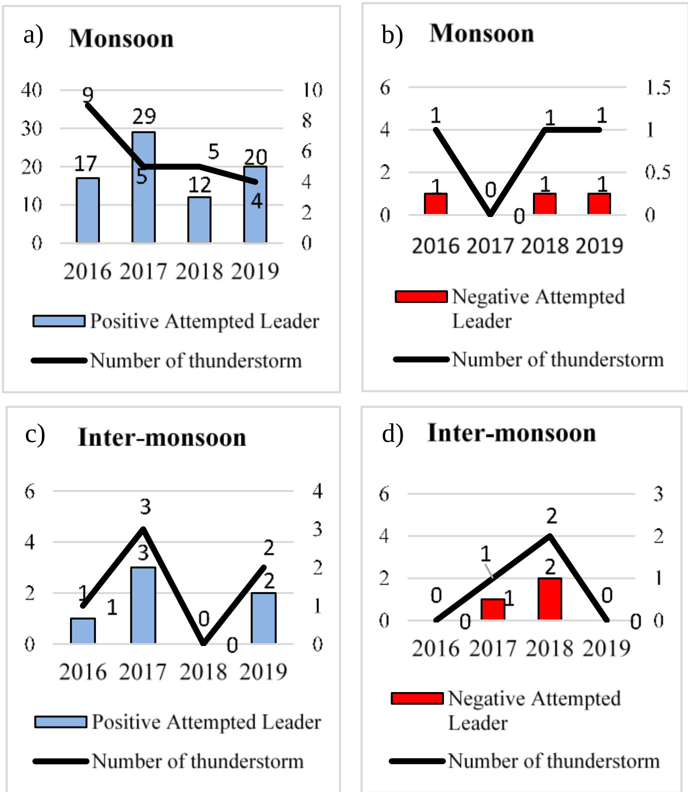


Figure 3. Variation of Monsoon thunderstorms for (a) positive attempted leader and (b) negative attempted leader and variation of Inter-monsoon thunderstorms for (a) positive attempted leader and (b) negative attempted in 2016 to 2019

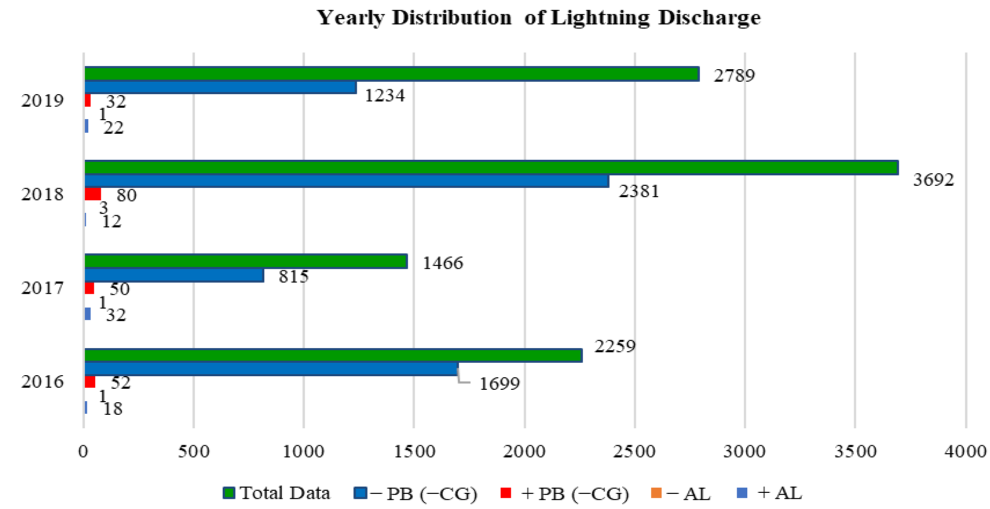


Figure 4. The yearly variation of positive attempted leader, negative attempted leader, positive preliminary breakdown and negative preliminary breakdown of negative CG flashes of 2016 (August to December), 2017 (January to July), 2018 (August to December) and 2019 (January to July) from total of 10,206 electric radiation field of lightning flashes

Figure 5 depicts the attempted leader indicated the negative correlation with the negative cloud-to-ground lightning flashes. It seems like the attempted leader activities are decreases with the increases of cloud-to-ground lightning flashes occurrences. In other words, the more succeeding return stroke of lightning flash activity observed, the less not succeeding return stroke lightning flashes will be observed (attempted leader occurrences). These phenomena agree with the explanation in [7] and [42] where mostly the LPCR in tropical countries are either weak or without any PBP signature possibly due to an insignificant LPCR magnitude. In this situation, initial breakdown processes happened to be in the cloud with a low energy level between the negative charge region and the LPCR, do not need to struggle to break the "blocking" agent in LPCR. Although, the profile of overall attempted leaders in tropical countries were found to have weak compared to negative cloud-to-ground lightning flashes [43]. However, the attempted leaders are commonly existing during the Monsoon season and uniquely the majority exhibit as positive attempted leader.

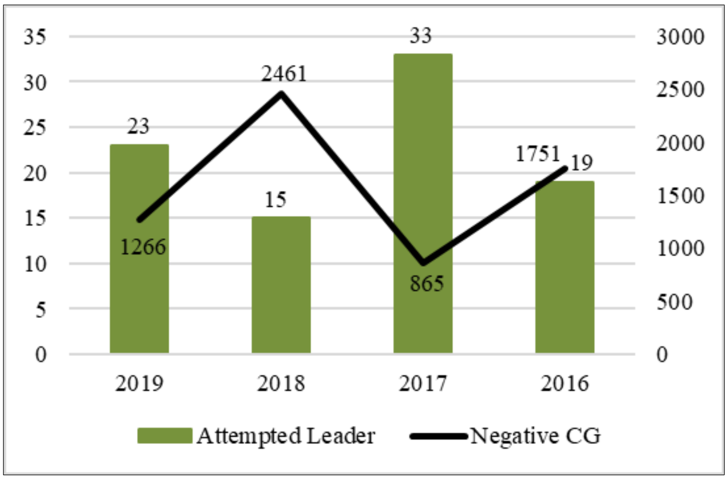


Figure 5. Variation of yearly distribution of both polarity (positive and negative) of attempted leader and both polarity of preliminary breakdown (same and opposite) of negative cloud-to-ground lightning flashes in 2016 to 2019

4. CONCLUSION

From amount of 10,206 data of lightning flashes for four years (August to December 2016, January to July 2017, August to December 2018, and January to July 2019) recorded in Melaka (tropical region), only 90 (0.88%) attempted leader activities which comprises of positive (N=84, 0.82%) and negative (N=6, 0.06%) polarity were observed. The occurrence of positive attempted leader was more common compared to negative polarity especially with thunderstorm during Monsoon seasons. In fact, there were negative correlation between the thunderstorm producing attempted leader and the attempted leader observed. In other word, single thunderstorm during Monsoon were seen sufficient of producing more than one positive attempted leader activities. However, the negative polarity during Monsoon and both polarity of attempted leader activities during Inter-monsoon were seen significantly less than the positive attempted leader recorded during Monsoon. Also, they show very positive correlation with the thunderstorm producing it. In other word, during these period, single thunderstorm was seen only producing single event of attempted leader. Next, the attempted leader activities show negative correlation with the negative cloud-to-ground flashes. The more attempted leader recorded, the less negative cloud-to-ground observed.

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