Occurrence of Narrow Bipolar Event as Part of Cloud-to-Ground Flash in Tropical Thunderstorms

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ABSTRACT: This paper reports a recent observation of Narrow Bipolar Event (NBE) occurrence as part of cloud-to-ground flash activity in tropical thunderstorms. Electric field change measurement has been conducted in Southern Malaysia (latitude 1°34′12.00″N, longitude 103°38′42.00″E) during Northeastern monsoon season between November and December 2012. From the total 173 recorded NBEs, more than half, (60.7%), appeared to occur in isolation; that is, no other lightning flashes occurring prior to or following the NBEs within the record length of 500 ms with a 150 ms pre-trigger delay. The remaining 36.4% of NBEs have been observed to occur as part of cloud-to-ground flash activity. We found that more than one third of NBEs with cloud-to-ground flash, about 38.1% have occurred between return strokes. Both polarities of NBEs (+NBE and –NBE) were recorded between the return strokes. The other one third of NBEs, about 36.5% have been observed to follow the last return stroke with both polarities of NBEs were recorded. On the other hand, only about 25.4% of NBEs (both polarities) have been observed to occur prior the first return stroke. The range of time intervals between the NBEs and the first return strokes is from 19 to 158 ms. The range of ratios of –NBEs peak amplitudes to the first return stroke peak amplitudes is found to be much larger than +NBEs, between 0.3 and 3.8 for –NBEs when compared to 0.3 and 2.6 for +NBEs. Furthermore, we observed 5 events (4 +NBEs and 1 –NBE) where NBEs have preceded preliminary breakdown process (PBP) before the first return stroke. Interestingly, +NBEs have occurred at much shorter time intervals before the first pulse of PBP compared to –NBEs. The range of time intervals between the +NBEs and the first pulse of PBP is between 5.8 and 52 ms while for –NBE it is 115 ms.

INTRODUCTION

Recent observations [Nag *et al.*, 2010; Ahmad *et al.*, 2010; Wu *et al.*, 2011] showed that Narrow Bipolar Events (NBEs) also occur as part of ordinary cloud-to-ground flash. Nag *et al.* [2010] reported about 6% of the total examined +NBEs have occurred as part of ordinary cloud-to-ground flash in Florida thunderstorms. Ahmad *et al.* [2010] reported about 2.8% of the total recorded NBEs have occurred as part of ordinary cloud-to-ground flash in Malaysia thunderstorms during southwestern monsoon season. Wu *et al.* [2011] reported about 0.2% of the total examined NBEs have occurred as part of ordinary cloud-to-ground flash in West and South China thunderstorms. Nag *et al.* [2010] have observed the

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occurrence of NBEs event in between return strokes (see Fig. 4, single +NBE occurrence between RS3 and RS4) where the RS4 has created a new termination on ground, which coined the possibility that RS4 was initiated by the +NBE. However, such event was detected only once.

In this paper, we present new experimental results from tropical region that may give new insights about NBE occurrence and perhaps, its association with lightning initiation process. In addition to the existing observations of NBEs occurrence with cloud-to-ground flashes [Nag *et al.*, 2010; Ahmad *et al.*, 2010; Wu *et al.*, 2011], we report new observation of NBEs occurrence with both polarities prior and following the first return stroke. Also, we observed the occurrence of NBEs just before preliminary breakdown process (PBP) pulses that possibly related with initial breakdown process of cloud-to-ground flashes.

INSTRUMENTATION

The measurement was carried out during the Northeastern monsoon season between November and December 2012 at the premise of Observatory Station in Universiti Teknologi Malaysia (UTM), Skudai, Johor, Malaysia. The measurement site was located at the southern tip of peninsular Malaysia (latitude 1°34′12.00″N, longitude 103°38′42.00″E), 132 km above sea level and 30 km from Tebrau strait. The electric field change recording system consisted of a circular-parallel flat plate antenna placed on a metal stand 1.5 meters above ground connected via a 60 cm shielded coaxial cable to a battery-powered buffer circuit. The buffer circuit was connected to a LeCroy Wave Runner 44Xi-A DSO via 10 meters long shielded coaxial cable and placed inside the building. The configurations of parallel flat plate antenna and buffer circuit were similar to the configurations used by Ahmad *et al.* [2014]. The DSO digitized the output of the buffer circuit at 25 Mega Samples/second (20 ns time resolution with 500 ms full window size and 150 ms pre-trigger delay) and 8-bit vertical resolution with a 100 MHz bandwidth (10 ns impulse width resolution). The DSO was triggered by either positive or negative edge of incoming signal with trigger level was varied between 0.5 and 1 V.

RESULTS AND ANALYSIS

Wu *et al.* [2011] found that only 0.2% from the total examined NBEs were occurred as part of cloud-to-ground flash activity. 2 +NBEs and 1 –NBE were observed to occur prior return stroke while 2 +NBEs and 3 –NBEs were observed to occur after the last return stroke. Nag *et al.* [2010] found much higher occurrence percentage of NBEs with cloud-to-ground flash. 3 +NBEs were observed to occur prior return stroke within the range between 72 and 233 ms. Moreover, they also observed the occurrence of +NBEs in between return strokes (see their Fig. 4, single +NBE occurrence between RS3 and RS4) and +NBEs following the last return stroke. One important finding mentioned by them is that RS4 has created a new termination on ground, which coined the possibility of relationship between the +NBE and RS4 occurrences.

We found more than one third or 38.1% of NBEs with cloud-to-ground flash have occurred between return strokes. We have observed the occurrence of NBEs with both polarities (12 +NBEs and 12 –NBEs) between negative return strokes while Nag *et al.* [2010] observed only the occurrence of +NBEs between return strokes. The other one third or 36.5% of NBEs have been observed to follow the last return stroke. We have observed the occurrence of NBEs with both polarities (16 +NBEs and 7 –NBEs) following the

last return stroke, similar to Wu *et al.* [2011] observation.

The remaining 25.4% (12 +NBEs and 4 –NBEs) have been observed to occur prior the first return stroke. Similar to our observation, Wu *et al.* [2011] found both polarities of NBEs to precede the first return stroke. On the other hand, Nag *et al.* [2010] observed only +NBEs to occur prior the first return stroke. The range of time intervals between the NBEs and the first return strokes is between 19 and 158 ms, much shorter than the range observed by Nag *et al.* [2010] between 72 and 233 ms. Further, we found 5 events (4 +NBEs and 1 –NBE) where NBEs have preceded PBP before the first return stroke. Interestingly, +NBEs have occurred at much shorter time intervals before the first pulse of PBP when compared to –NBE. The range of time intervals between the NBE and the first pulse of PBP is between 5.8 and 52 ms for +NBEs while for –NBE is 115 ms. Electric field records of one of the NBEs occurred prior the first return stroke is shown in Fig. 1.

CONCLUSIONS

More than two third of the detected NBEs with cloud-to-ground flashes have been observed to occur after the first return stroke while less than one third of NBEs have occurred prior the first return stroke. Several NBEs prior the first return stroke have been observed to precede PBP pulses within short time intervals between 5.8 and 115 ms which coined the possibility that NBE is associated with the initiation process of negative cloud-to-ground flash.

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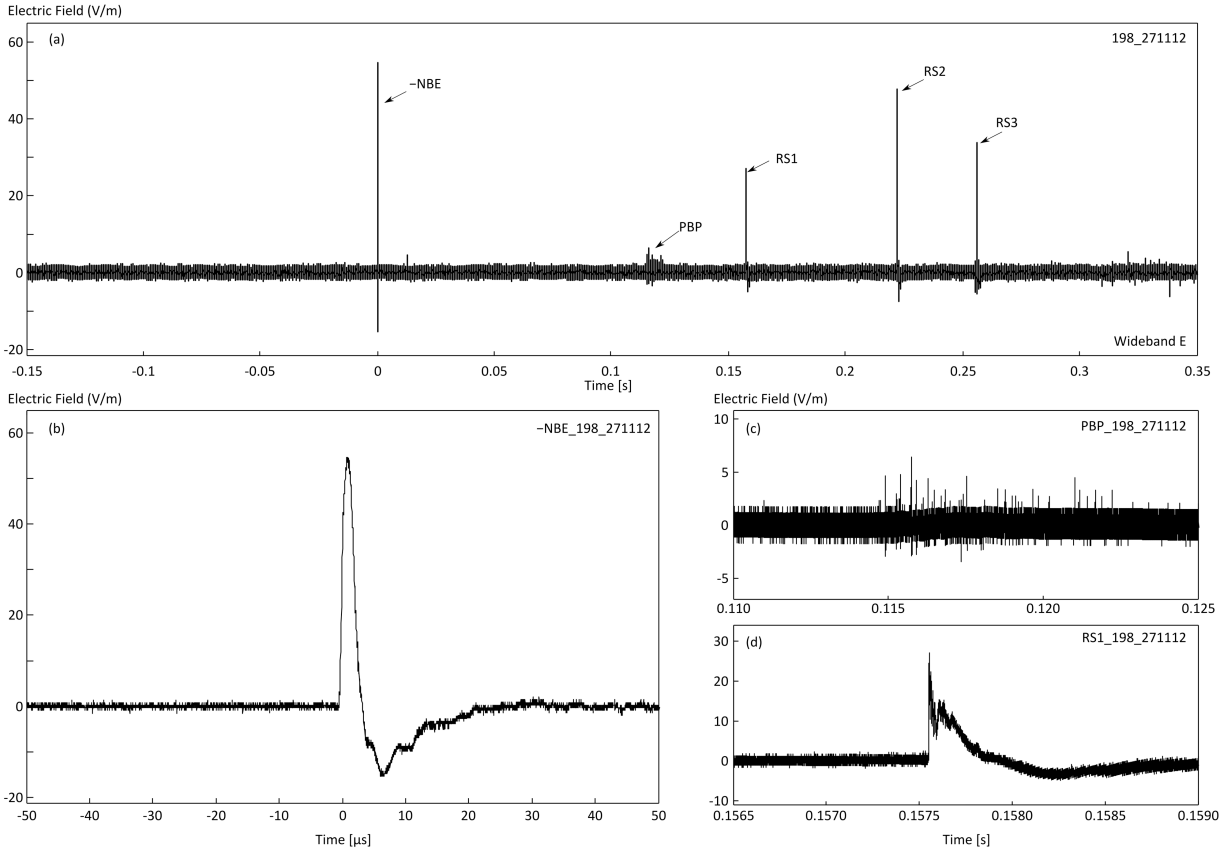

Fig. 1. (a) Wideband electric field waveform of –NBE captured prior the first return stroke (RS1) from a 3-stroke negative cloud-to-ground flash. Note the PBP pulses between the –NBE and RS1. **(b)** The expansion of the –NBE showing pure radiation component. Closed up views of **(c)** PBP preceded the RS1 and **(d)** the RS1.