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Unusual lightning electric field waveforms observed in Kathmandu, Nepal, and Uppsala, Sweden

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ABSTRACT

Unusual lightning events have been observed in Uppsala, Sweden, and Kathmandu, Nepal, using essentially the same electric field measuring system developed at Uppsala University. They occurred in the storms that also generated "normal" lightning events. The unusual events recorded in Uppsala occurred on one thunderstorm day. Similar events were observed in Kathmandu on multiple thunderstorm days. The unusual events were analyzed in this study assuming them to be positive ground flashes (+CGs), although we cannot rule out the possibility that some or most of them were actually cloud discharges (ICs). The unusual events were each characterized by a relatively slow, negative (atmospheric electricity sign convention) electric field waveform preceded by a pronounced opposite-polarity pulse whose duration was some tens of microseconds. To the best of our knowledge, such unusual events have not been reported in the literature. The average amplitudes of the opposite-polarity pulses with respect to those of the following main waveform were found to be about 33% in Uppsala (N = 31) and about 38% in Kathmandu (N = 327). The average durations of the main waveform and the preceding opposite-polarity pulse in Uppsala were 8.24 ms and 57.1 μs, respectively, and their counterparts in Kathmandu were 421 μs and 39.7 μs. Electric field waveforms characteristic of negative ground flashes (-CGs) were also observed, and none of them exhibited an opposite-polarity pulse prior to the main waveform. Possible origins of the unusual field waveforms are discussed.

1. Introduction

Lightning is an electrical discharge that takes place between two charged cloud regions or between one of those regions and ground. Properties of many lightning processes have been unveiled with the aid of fast optical and electromagnetic instruments, but some of those processes remain poorly understood. A number of previously unrecognized lightning events have been recently identified. For example, compact intra-cloud discharges (CIDs) producing characteristic narrow bipolar pulses (NBPs) were observed to occur mainly at lower latitudes (e. g., Lu et al., 2013; Nag and Rakov, 2010; Sharma et al. 2008(b); Smith et al., 1999). Further, preliminary breakdown pulse trains characteristic of CGs, but not followed by return - stroke waveforms were observed by Sharma et al., (2008a) and Nag and Rakov (2008). Finally, the so-called transient luminous events including sprites, halos, jets, and elves have been observed in the middle and upper atmosphere [e.g., Rakov and Uman 2003; ch. 14 and references therein]. Although each lightning flash is unique, there are well established common features of cloud flashes and cloud-to-ground flashes. A cloud flash consists of two stages that are referred to as active and final, with the former one exhibiting large microsecond-scale bipolar pulses and the latter being accompanied by smaller pulses (e. g., Bils et al., 1988; Villanueva et al., 1994; Sharma et al., 2005). Cloud-to-ground lightning flashes, depending on the polarity of charge transferred to ground, are divided into two main categories: negative ground flashes and positive ground flashes. Negative ground flashes are more common (about 90% of all ground flashes) and the positive ground flashes are relatively rare (usually less than 10% of the total ground flashes) (Rakov and Uman, 2003). There are also bipolar lightning flashes. The negative ground flash includes a number of processes namely, preliminary breakdown (PB), stepped leader, first return stroke, dart leader, subsequent return stroke, continuing current, M component, and some others. The positive ground flash includes similar process, but usually contains no subsequent strokes. Also, it is characterized by a larger charge transfer to ground compared to its negative counterpart.

In this paper, we present unusual lightning events that are characterized by a pronounced opposite-polarity pulse just prior to the main electric field waveform. For the first time, such events were noticed by

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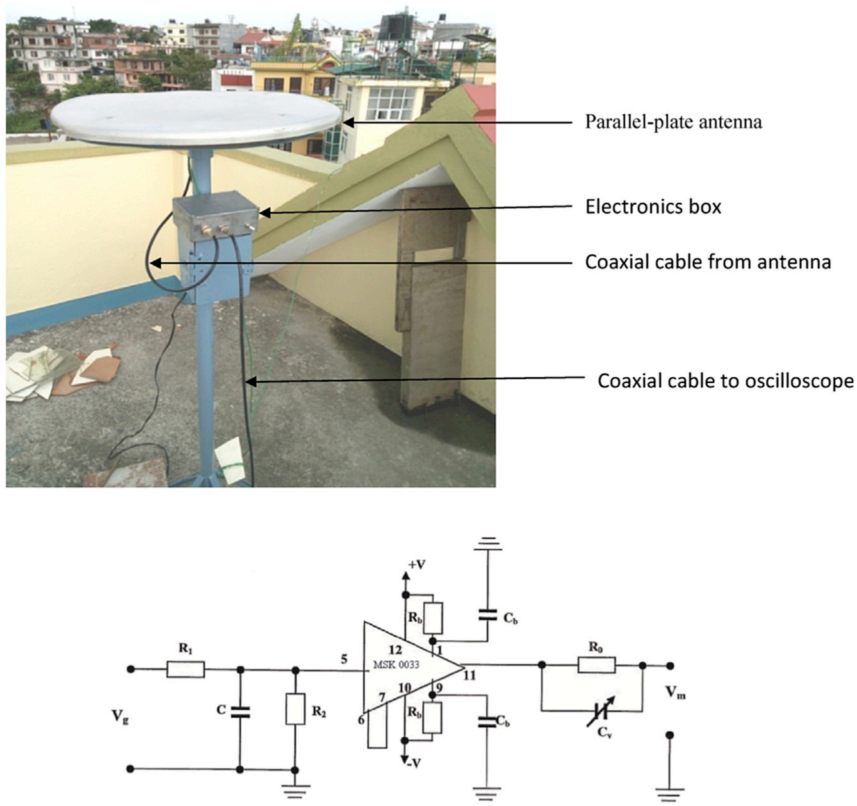

Fig. 1. The elevated parallel-plate antenna installed in Kathmandu (upper panel) and the buffer circuit (lower panel) used in this study.

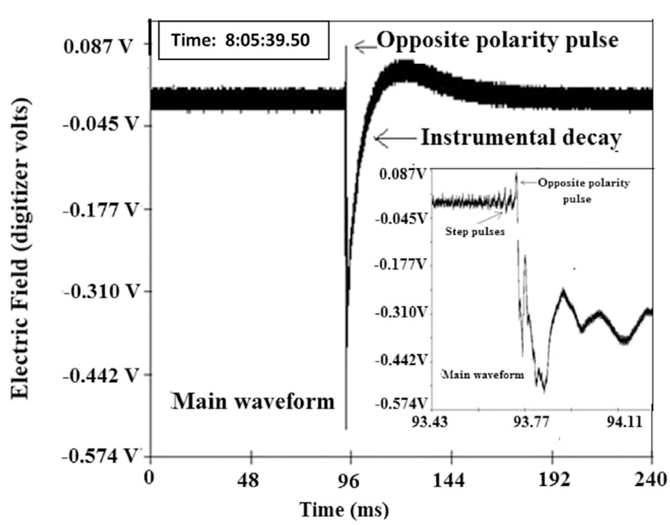

Fig. 2. An example of unusual lightning event recorded on July 1, 2009 in Uppsala, shown on two time scales.

the second author during a lightning observation campaign conducted in Uppsala, Sweden, in June–August of 2009. Over 2000 electric field signatures were recorded, most of which were "normal" (see, for example, Rakov (2013)). On July 1, 2009, however, numerous unusual electric field waveforms were observed between 7:45 a.m. and 9:00 a.m. (Swedish local time). Of the 40 field signatures recorded, 31 had unusual wave-shapes and 9 were "normal" (expected for negative ground flashes, positive ground flashes, and cloud flashes). Although the measurements in Uppsala were carried out for about 3 months, the unusual events were recorded only on the single day. In 2015, similar events were observed during a measurement campaign conducted in Kathmandu, Nepal. In the present work, various features of electric field waveforms produced by the unusual events observed at both locations have been analyzed and compared. All the events discussed here (31 from Uppsala and 327 from Kathmandu) occurred during warm season. The atmospheric electricity sign convention is used in this paper in order to facilitate direct comparison with the results found in the bulk of previous literature. Unfortunately, neither optical data, nor reliable distances are available for the lightning events presented in this paper.

2. Instrumentation

Our data set includes lightning electric fields recorded (a) in Kathmandu, Nepal (27°44′N; 85°19′E), about 1300 m above the mean sea level, during April–June, 2015 and (b) at the Angstrom Laboratory, Uppsala, Sweden (59.8°N,17.6°E), at about sea level, in June–August, 2009. Only data obtained on July 1, 2009 from the latter data set are presented here. In each campaign, the vertical electric field was sensed by a parallel plate antenna mounted on the top of a grounded 1.5 m high metallic post (see Fig. 1, upper panel). The post was installed on the ground surface in Uppsala and on the rooftop of a building, at a height of about 12 m above ground in Kathmandu. The capacitance of parallel plate antenna was 60 pF in both installations, and the output of the buffer amplifier (see Fig. 1, lower panel) was fed to the digital storage oscilloscope (Pico-scope 6404D in Kathmandu and LeCroy WavePro 7100A in Uppsala) via a properly terminated (matched) RG-58 coaxial cable. The RC decay time constant of the field measuring system at both locations was 13 ms, large enough to faithfully record lightning electric field waveforms shorter than 13 ms or so. Later parts of longer electric field waveforms are influenced by the instrumental decay.

The record length in Uppsala was 500 ms, with the sampling rate being 100 MS/s. In Kathmandu, we used sampling rates ranging from 312 to 39.06 MS/s corresponding to 200–500 ms record lengths. Longer record lengths were chosen to capture the entire flash record, whereas the shorter record lengths were used to capture the details of field