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Features of positive ground flashes observed in Kathmandu Nepal

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ABSTRACT

Lightning vertical electric fields pertinent to the subtropical thunderstorms occurring over the rugged terrain have been measured and recorded at a hilly station Kathmandu, Nepal. In the present work, waveforms of the positive ground flashes have been selected from all the records and were analyzed. To the best of our knowledge, this is the first time that fine structure of electric field signature pertinent to the positive return stroke; have been analyzed and presented from Nepal. One hundred and thirty three (133) of the total of four hundred twenty-five (425) flashes were selected from seven thunderstorm days and analyzed. Of the data recorded for seven days, 133 flashes (31.3%) were positive flashes and 276 flashes (64.9%) were cloud flashes. Majority of the positive ground flashes were found to be single stroke ones, whereas, the average number of strokes per flash is found to be 1.1 with a maximum value of 4. Majority of the positive ground flashes were found either lacking the initial breakdown process and the leader stage or these processes could not be detected. The return strokes are found to be succeeded by large in cloud activity in the continuing current portion of the flash. The average zero-crossing time of the positive return strokes was found to be 60.45 μs with a range of 447.81 μs and the average rise time was found to be 9.44 μs with a range of 42.56 μs.

1. Introduction

Lightning positive ground flashes, in general, transport the positive charge from the cloud to the ground, occur very rarely. Of all the cloud to ground flashes, the positive ground flashes account for about 10% (Rakov and Uman, 2003). Considering the tripole structure of a thundercloud, the paucity of the positive ground flashes can easily be justified. However, the charge structure of the cloud still remains a mystery. Because of the paucity of their occurrence, positive ground flashes are considerably less studied and hence less understood as compared to their negative counterparts (Nag and Rakov, 2012).

According to Williams (1989), the lightning activity itself follows a specific pattern with the intracloud (IC) lightning normally appearing in the developing stage followed by the cloud-to-ground (CG) lightning during the mature stage, whereas, both types of lightning can occur in the decaying stage of thunderstorms. Lightning in thunderstorms is strongly linked to the microphysics and dynamics of thunderstorms and hence changes in the lightning activity can tell us about changes in the internal processes within the thunderstorms (Price, 2008). Positive ground flashes are of much interest to the lightning community because of their possible association with the upper atmospheric discharges, such as sprites, and due to the magnitude of current possessed by them. The positive ground flashes may also be related to the severe weather phenomena such as tornadoes, hails, derecho etc. Although, the negative ground flashes are predominant during the normal thunderstorms over their positive counterparts Price et al. (2009) has shown that the polarity of the CG lightning shifts to being primarily positive ground flash during the hail portion of the storm. Tornadoes are also associated with certain lightning signatures. Carey et al. (2003) showed that, during an episode of 5 tornadoes within 1 hour, the positive cloud to ground, fraction increased to about 60% of all CG lightning. This shift in lightning polarity is a common feature of tornado storms. Price and Murphy (2002) studied a derecho (severe wind storm with straight-line winds is called a derecho) that exhibited predominantly positive CG lightning activity during the most intense part of the storm.

Signatures of the lightning electromagnetic field pertinent to the subtropical mountainous country Nepal are of much interest to the scientific community as the rugged terrain and high hills may influence the occurrence and the nature of the lightning strikes. The hydrometeorological processes over the rugged terrain, development of the thundercloud, its charge structure and the signatures of lightning flashes are equally interesting for them. Moreover, atmospheric structure and hydrometeorological processes along the south slopes of the Himalayas are not well known or well documented mainly because of the rugged and remote terrain (Barros and Lang, 2003). Monitoring the lightning activity

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(with the help of flash counters) over Kathmandu and its vicinity for 21 months, Baral and Mackerras (1993), found the average proportion of positive ground flashes to the total ground flashes to be 0.28, the proportion was maximum in the postmonsoon with an average value of 0.38 and it is minimum during the pre-monsoon with an average value of 0.26.

This study aims to investigate the nature of occurrence of positive ground flashes, their features and fine structure. The features of positive ground flashes are compared with those from the other geographical regions. This is the first time that the fine structures of electric fields pertinent to the subtropical and mountainous country Nepal, were measured, analyzed and compared with those from other geographical regions.

2. Instrumentation and measurement

The lightning electric fields were recorded at a measuring station in Kathmandu, Nepal, which is situated at 27°44′N; and 85°19′E; and about 1300 m above the average sea level height. Based on the WSI Global Lightning Network (GLN), 133 positive return strokes, that have been recorded and analyzed, are ranged from 30 km to 500 km from the measuring station, however, precise location of each individual strike was not possible owing to the fact that our system was synchronised with that of WSI. The vertical electric fields pertinent to the lightning flashes were sensed by the flat plate antenna fixed on a 1.5 m high post and was placed on the rooftop of a house at a physical height of about 12 m from ground. The capacitance of parallel plate antenna is 60 pF. The parallel plate was connected to a buffer circuit through a 60 cm long RG 58 coaxial cable. The signal passing through buffer amplifier was fed to digital storage oscilloscope (Pico-scope 6404D) through a 20 m long RG 58 coaxial cable. The signals so received were recorded by the Pico-scope. The window size of the scope was varied from 200 ms to 500 ms at different sampling rates. Accordingly, the sampling rate was varied from 312 MS/s to 40 MS/s. Longer window size was chosen to capture the whole flash activity and its multiplicity and the shorter window was chosen to capture the details of the activity.Indeed, we might have missed some subsequent activities (strokes) by making the window size shorter, however, when the window size kept to 500 ms it was observed that the flash activity ceases after 200–250 ms. It is therefore we thought it fair to compare the multiplicity with that of others.

Electric field intensity at the measuring station is recorded as a function of digitizer voltage as

$E(t)=V(t)/h_{eff}$ where h_{eff} is the effective height of the antenna, $V(t)$ is the voltage between the upper plate of the antenna and the ground and $E(t)$ is the electric field to be measured. Also, $h_{eff}=0.149h_{phy}+0.039$ where h_{phy} is the Physical height of the antenna. However, owing to the fact that lightning flashes could not be exactly located, the field intensity was not calculated. A schematic diagram of the antenna and recording system that has been used in this study, is depicted in Fig. 1, and is adopted from Sharma et al. (2005, 2008) and Sharma (2007).

3. Observation

Electric field generated by the lightning flashes were recorded during the pre-monsoon 2015. A total of one hundred and thirty three positive ground flashes were selected and analyzed. Most of the positive ground flashes were found to have single strokes, however, some of the positive ground flashes consisted of two or more return strokes. The data acquired on the different days of March, April and May 2015, and analyzed in this study are depicted in Table 1. Also shown in Fig. 2 is the google map of the positive ground flashes that occurred on the different dates, mentioned in Table 1. As is depicted in Table 1, a total of 425 lightning flashes were recorded on different seven days of pre-monsoon, out of which 133 strikes were observed to be positive ground flashes, whereas the number of cloud flashes were 276 and the number of negative ground flashes were just 16. Evidently, the majority of ground flashes that have been observed during those days were of positive type.

By using the atmospheric electricity sign convention in which the air above the surface of Earth (in cloud) contains positive charge, while the Earth's surface charge is negative. So the current flows from the cloud containing positive charge to the ground containing negative charge. That means the negative charges flows from ground to cloud. The electric field signatures are classified based on the well established field structures and the polarity of the field. For example, the cloud flashes produce electric field that has in general two stages i.e. initial or active stage and late stage, and do not possess return stroke. Similarly, the negative ground flashes consisted of initial break down stage with positive field change followed by the stepped leaders and return strokes, whereas the positive ground flashes produce the negative field change. The actual number of flashes occurring during the activity was significantly higher than the number recorded and analyzed in this study. Although, the trigger level was set for both positive as well as negative field changes, the oscilloscope often did not trigger for the positive field change (that corresponds to the negative ground flash) and as a result the trigger level was set for

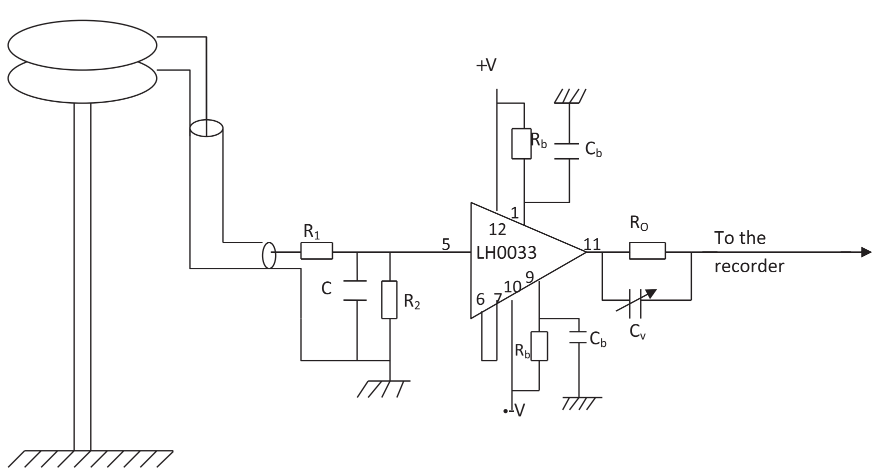

Fig. 1. The parallel plate antenna and the buffer circuit used in this study for the electric field measurement.