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On the characteristics of positive lightning ground flashes in Sweden

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ABSTRACT

In this study the stroke characteristics of positive cloud-to-ground flashes in Sweden were obtained from the electric field records measured from 14 thunderstorms. The electric fields were measured with nanosecond resolution. Together with the fast and the slow electric field records, the narrowband radiation field at 3 and 30 MHz signals were also measured simultaneously. Out of a total of 107 flashes, 30 flashes had two strokes, 7 had three strokes and 3 flashes had four strokes. The arithmetic and geometric means of the interstroke intervals were found to be 116 and 70 ms, respectively. The arithmetic and geometric mean ratio between the peak electric field of the Subsequent Return Stroke (SRS) and the first Return Stroke (RS) were 0.48 and 0.36, respectively. Of the 40 positive multiple-stroke ground flashes, 5% have at least one SRS with field peak higher than the first RS. The percentage of SRS with field peaks greater than the first RS was 6%. In our best of our knowledge, this is the first time a large sample of positive return strokes in Sweden was analysed. It was found to be statistically more significant than the previous studies.

1. Introduction

Positive cloud-to-ground lightning flashes or positive ground flashes transport positive charge from cloud to ground. They play a significant role both in lightning protection and in atmospheric physics. Positive lightning flashes give rise to larger currents and charge transfer than their more numerous counterparts, negative ground flashes. Saba et al. (2006a, 2006b), Rakov and Uman (2003) and Cummins (2000) concluded that the highest currents reported so far in the literature are from positive ground flashes. Thus, the extreme protection procedures recommended in lightning protection standards are based on the features of positive ground flashes. Recently, it had been established that upper atmospheric electrical discharges known as sprites are triggered by strong positive ground flashes. Thus the characteristics of positive ground flashes taking place in different geographical regions are of interest both in atmospheric research and in lightning protection. Moreover, since the occurrence of positive ground flashes is only about 10% of the more normal negative ground flashes, the information available in the literature on positive ground flashes is scarce.

Previously, Cooray and Lundquist (1982) and Cooray (1984) reported the characteristics of radiation fields generated by positive ground flashes in Sweden. The sub-microsecond structure of positive return stroke fields in Scandinavia were documented by Cooray (1986). Cooray and Pérez (1994) studied the flash characteristics of positive return strokes in Sweden. They analysed the number of strokes per flash, interstroke intervals and the relative amplitudes of Subsequent Return Strokes (SRS). However, the number of flashes analysed by them were limited and for this reason they could not extract features of positive lightning flashes with statistical confidence.

The pioneering study of Berger (1967) at Monte san Salvatore had led to the conclusion that the number of strokes in positive ground flashes is much less than the number of strokes in negative ground flashes. Investigations conducted in different geographical regions confirmed that the average number of strokes per flash ranges between 1.04 and 1.33 and this is less than the average number of strokes in negative return strokes by the factor of 3 (Heidler and Hopf, 1998, Heidler et al., 1998; Fleenor et al., 2009; Nag et al., 2012; Saba et al., 2010). There were only 4 observations conducted by Saba et al. (2010) in Brazil, Fleenor et al. (2009) in United States, Heidler et al. (1998) in Germany and Cooray and Pérez (1994) in Sweden, who were reported about the statistical

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information of interstroke intervals of positive ground flashes with small quantities of the data. Note that more significant amount of data is required to perform reliable information of interstroke intervals for positive ground flashes especially from different location.

Due to the scarcity of positive ground flashes, it is difficult to collect a large sample of electric fields generated by positive ground flashes. We have concentrated our field experiments in 2010 and 2011 to gather a significant number of positive return stroke electric fields so that statistically significant information on stroke characteristics could be gathered. In this study, we examine a total of 107 electric fields of positive return strokes recorded in Uppsala, Sweden in 2010 and 2011 from a total of 14 thunderstorms. The electric field records consist of slow electric field, fast electric field and narrowband radiation field at 3 and 30 MHz. From these electric field records we have obtained the number of strokes per flash, interstroke intervals and amplitude distribution of SRS.

2. Experiment

The measurements of electric fields generated by the positive cloud-to-ground flashes were recorded during summer in 2010 and 2011, from June to August, in Uppsala, Sweden (latitude: 59.8 N; longitude: 17.6 E; altitude: 13 m). The site is located 70 km inland of the Baltic Sea. The measurement set up such as the antenna systems for fast and slow electric fields, electronics buffer circuits were identical to that used in the literatures described by Cooray and Lundquist (1982), Galvan and Fernando (2000), Cooray (2003), Baharudin et al. (2012a) and Baharudin et al. (2012b).

The three parallel flat plate antennas were used to sense fast electric field, radiation fields at 3 and 30 MHz signals, while a whip antenna was used to sense the slow electric field signal. The whip antenna consisted of a lower metallic rod, an upper metallic rod (3.3 m) and an insulator (teflon). The lower metallic rod was buried about 0.5 m in the ground while the other end was about 1.5 m above the ground level. The upper metallic rod is fix on the

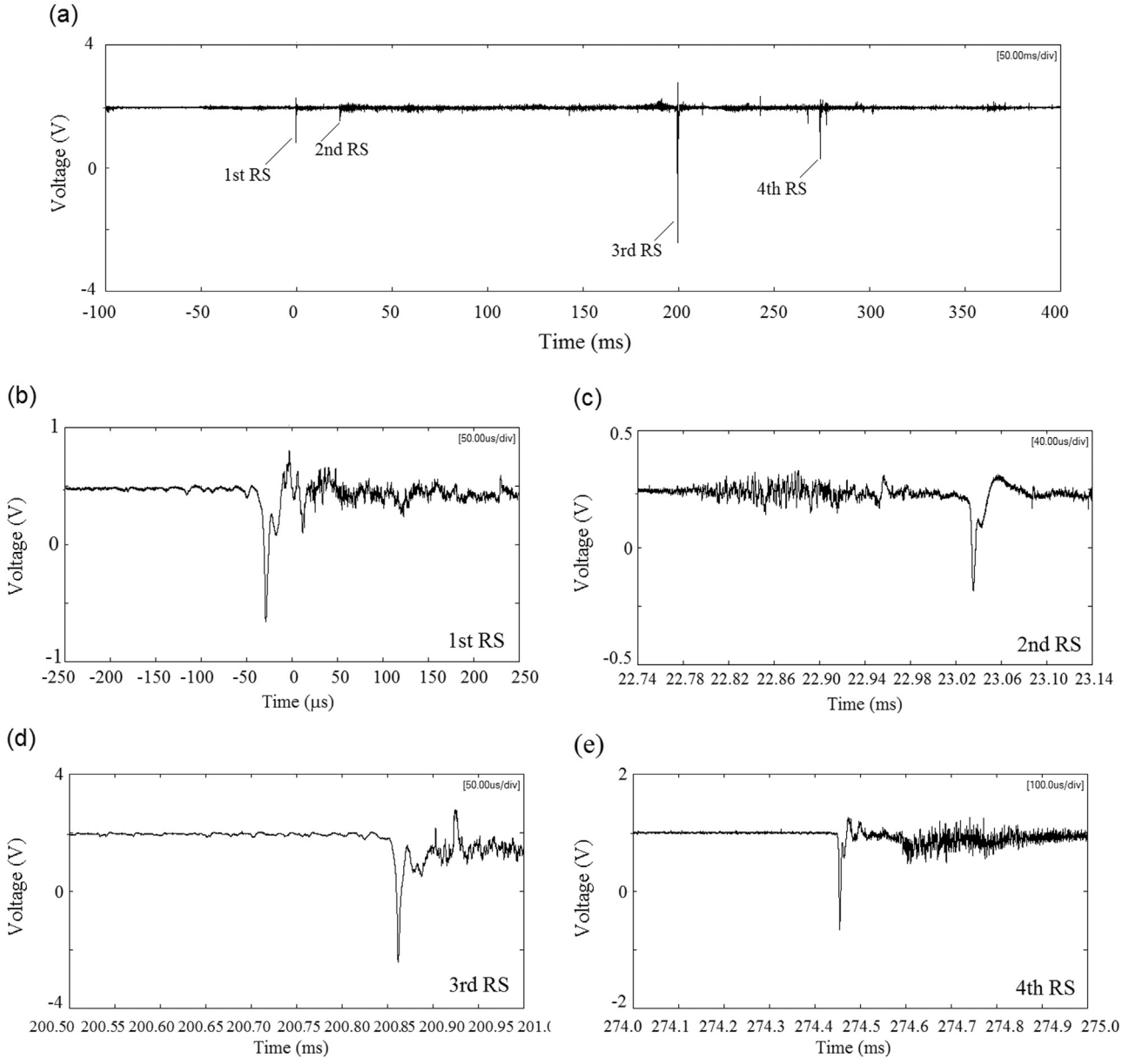

Fig. 1. Electric field records of a positive ground flash with 4 return strokes. In (a) the full record is shown and in (b), (c), (d) and (e) all four return strokes are shown in a narrow time window separately.