Journal of Atmospheric and Solar-Terrestrial Physics 173 (2018) 57–65

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Horizontal electric fields of lightning return strokes and narrow bipolar pulses observed in Sri Lanka

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ABSTRACT

Simultaneous measurement of both vertical and horizontal electric field signatures of lightning was carried out in an elevated location in Colombo, Sri Lanka. The experimental setup used in this work was similar to an earlier study carried out by a different group in the late 1980s. To our knowledge, this is the first instance that such a study is conducted in this region. Data were acquired during the active months (April–May) of the southwest monsoon period in 2014. Lightning flashes from the most active thunderstorm was analyzed by selecting 65 Return Strokes (RS), 50 Negative Narrow Bipolar Pulses (NNBP) and 40 Positive Narrow Bipolar Pulses (PNBP). The wave shapes were initially validated against results of a previous study and subsequently via a theoretical method as well. Since the direction and the distance information was not available, rather than the amplitudes, ratios of the peak amplitudes of vertical electric field (Ev) and corresponding horizontal electric field (Eh) were compared. The average ratio for the return stroke was 0.024 ± 0.008. The same for the NNBP was 0.041 ± 0.004. The PNBP had a ratio of 0.031 ± 0.006. The average 10%–90% rise times (Tr) for Ev for RS, NNBP and PNBP was 2.124 ± 1.088 μs, 0.734 ± 0.077 μs and 1.141 ± 0.311 μs respectively. The Tr values for Eh for RS, NNBP and PNBP were 1.865 ± 1.200 μs, 0.538 ± 0.061 μs and 1.086 ± 0.423 μs.

1. Introduction

A lighting flash causes significant change in the global atmospheric electrical circuit. These changes are studied by analyzing their recorded electric field signatures. These recordings are further segregated based on its directional components as vertical electric field (Ev) and horizontal electric field (Eh) changes.

Typically the magnitude of Eh surpasses Ev in the immediate vicinity of the lightning strike (Miki et al., 2002). But at longer distances this becomes the opposite, where Ev becomes significantly high compared to Eh (Thomson et al., 1988a). Thus when obtaining Eh recordings of distant flashes, it becomes extremely difficult since a minute tilt in the recording apparatus would cause the recorded Eh to be interfered or overshadowed by the Ev signature, which makes the Eh impossible to identify. This practical issue is the main reason for the physically obtained data sets of Eh to be limited to just five in number up to date (Shoory et al., 2011).

When considering the lightning generated electromagnetic field interactions with power lines, underground cabling and other networks related to power and communication, the study on characteristics of Eh is considered to be the more important than that of Ev (Cooray and De la Rosa, 1986; Nucci et al., 1993; Rachidi et al., 1999). Also the phenomena of surface flashover at point of strike of lightning flashes are considered to be facilitated by this Eh as well (Cooray, 2010).

The first known instance of measured Eh was presented by Thomson et al. (1988a). The authors utilized a unique experimental antenna which was of spherical shape (Thomson et al., 1988b). They were able to record simultaneous Ev and Eh data of 42 lightning return strokes of 27 flashes at distances ranging from 7 to 43 km. They observed that the ratio between amplitudes of Eh and Ev to be 0.03 ± 0.007. The overshadowing effect of Eh from Ev was experienced in their study and mathematical adjustments were utilized to rectify it.

The second observational data set was from Michishita et al. (1996). Eh of Lightning flashes that occurred far (16–150 km) from the observational site were recorded by using a broadband sensor whilst the Ev was recorded using the parallel plate antenna (Galvan and Fernando, 2000). They observed that a 0.5% of contamination from Ev on Eh present in their data.

In contrast to Michishita et al. (1996) study, Miki et al. (2002) studied the Eh of very close proximity lightning flashes. They used triggered lightning with measurement distances of 0.1–1.6 m between the source and the observation point with the sensors being elevated 2 m above ground level. They witnessed that for lightning flashes in the near vicinity; Eh became larger in magnitude with respect to Ev. This observation was quite important in proving the fact that even without a direct lightning strike; the close proximity changes in Eh could be more

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https://doi.org/10.1016/j.jastp.2018.04.010
Received 17 December 2017; Received in revised form 19 April 2018; Accepted 20 April 2018
Available online 22 April 2018
1364-6826/