Analysis of horizontal and vertical electric fields generated by lightning Return Strokes and Compact Intracloud Discharges

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Abstract

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Electric field analysis of lightning plays a vital role in lightning research since induced transients of these E-field changes are notorious for their destructive nature. The E-field is typically subdivided direction-wise as the vertical (E_v) and horizontal (E_h) components. Due to the difficulty in capturing, the E_h component is rarely recorded. In this work, the total E-field data were analysed in the time and time-frequency domains. The data were recorded from two coastal locations of Sri Lanka in the months of April-May in 2013 and 2014 respectively. A parallel plate antenna was used along with a spherical antenna, which was utilised for the first time in the subtropics.

Initially, the E_v of Narrow Bipolar Pulses (NBPs) was studied in the time domain. Unlike previous studies of the same region, NBPs of both polarities were observed, and their polarity dominance was found to differ from each thunderstorm. Temporal properties of pulse duration; 10-90% rise time (T_r), zero crossing time (T_z), Full Width at Half maximum (FWHM), slow front duration and the peak to overshoot amplitude ratio were analysed. The resultant values displayed highly compact NBP events when compared with previous studies of the same. Subsequently, a time domain analysis of both E_v and E_h data of NBPs and Return Strokes (RSs) was performed. This was the first instance (in history) where the E_h data of NBPs was recorded. Initial data were validated by visual and theoretical methods before subjecting to analysis. The peak amplitude ratios of E_v and E_h of NBPs displayed a higher ratio than RSs, and the average rise times of the E_v were larger than E_h for both RSs and NBPs.

Studies on Time-Frequency (TF) domain analysis were initiated by a Wavelet Transform (WT) on E_v data of NBPs of both polarities. A follow-up study was performed on the same data by using the Stockwell Transform (ST) method. The results practically proved the theoretical finding, that the ST method was more suitable than the WT method when analysing transients such as NBPs. Subsequently, two similar TF analyses of E_v and E_h data of the RSs and NBPs of both polarities were performed. This too was the first instance where the total E-field of a lightning event has been subjected to a TF analysis. The ST method was utilised, and the results revealed, that the most energetic frequency spectrum of the E_h was approximately 40 - 50% higher in value when compared to the vertical counterpart, irrespective of NBPs or RSs. Thus, the high frequency radiations caused by the horizontal component are considered to be far more prominent when compared to its vertical counterpart. In addition, these frequency ranges of NBPs and RSs were comparably similar for each direction individually, which suggests the fact that NBPs and RSs have similar characteristics in the frequency domain.