Journal of Atmospheric and Solar-Terrestrial Physics 172 (2018) 24–32

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

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

Optical observations of electrical activity in cloud discharges

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ARTICLE INFO

Keywords:
Cloud lightning
High-speed photography
Luminosity variation

ABSTRACT

Temporal variation of the luminosity of seven natural cloud-to-cloud lightning channels were studied, and results were presented. They were recorded by using a high-speed video camera with the speed of 5000 fps (frames per second) and the pixel resolution of 512 × 512 in three locations in Sri Lanka in the tropics. Luminosity variation of the channel with time was obtained by analyzing the image sequences. Recorded video frames together with the luminosity variation were studied to understand the cloud discharge process. Image analysis techniques also used to understand the characteristics of channels. Cloud flashes show more luminosity variability than ground flashes. Most of the time it starts with a leader which do not have stepping process. Channel width and standard deviation of intensity variation across the channel for each cloud flashes was obtained. Brightness variation across the channel shows a Gaussian distribution. The average time duration of the cloud flashes which start with non stepped leader was 180.83 ms. Identified characteristics are matched with the existing models to understand the process of cloud flashes. The fact that cloud discharges are not confined to a single process have been further confirmed from this study. The observations show that cloud flash is a basic lightning discharge which transfers charge between two charge centers without using one specific mechanism.

1. Introduction

The electrical discharges that take place between the cloud and the ground are called ground lightning flashes. The electrical discharges that occur between clouds or within a cloud are called cloud lightning flashes. Even though most of the lightning flashes taking place in the Earth's atmosphere are cloud flashes, detailed features of their mechanism are still unknown.

The processes taking place during ground flashes and the current waveforms associated with these flashes are well documented in many research publications (Cooray, 2015; Uman and Rakov, 2003). Fig. 1 shows the current waveform of a downward lightning flash where various known features are identified. Such a clear picture cannot be constructed for currents in cloud flashes because the detailed mechanism of these flashes are still unknown (Uman and Rakov, 2003).

Most of the studies that have attempted to extract the mechanism of cloud discharges are based on electric field measurements (Cooray, 2015; Vayanganie et al., 2014; Pierce, 1955; Takagi, 1961; Isikawa, 1961; Ogawa and M. Brook, 1964; Mackerras, 1968; Bills et al., 1988; Bodhika and Fernando, 2006). Some of these studies are based on single station measurements and the others on multi-station measurements. Interpretation of the mechanism of cloud flashes using single station electric field measurements is difficult and in some cases impossible. However, multi-station methods that use time of arrival method or interferometric methods can identify the location of the channels inside the cloud and by combining this information with electric field measurements one can obtain a reasonably accurate picture of the cloud flash. However, interferometric methods may not identify the positive leaders completely because these leaders do not radiate efficiently so that their locations can be identified (Shao et al., 1995; Shao and Krehbiel, 1996). Thus, visual observation of cloud lightning channels was found to be the suitable procedure available to identify the mechanism of these flashes. However, visual observations can be used to study only the physical processes taking place in lightning channels located at the bottom of the cloud because most of the channels of cloud flashes are hidden inside the cloud.

Visual observations with recordings of the channel luminosity will be able to infer the characteristics of currents flowing in these channels because there exist a good correlation between the channel luminosity and measured current of electrical discharges (Diendorfer et al., 2003). Direct visual observations are also capable of identifying various features of lightning flashes. For example, Campos et al. (2009) were able to

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https://doi.org/10.1016/j.jastp.2018.03.007
Received 10 February 2017; Received in revised form 11 March 2018; Accepted 12 March 2018
Available online 13 March 2018
1364-6826/