A Study on Lightning Channel Properties using High-Speed Photographic Techniques

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Abstract

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Physical processes taking place in electrical discharges can be studied by analyzing the properties of the discharge channel. Uncovering hidden properties are not only important to understand breakdown phenomena but also important when developing lightning detection and locating systems. In this work, image analysis techniques were used to analyze the features of discharge channels, both in laboratory sparks and natural lightning. High-speed video and still photography were utilized to record the luminosity variations of discharges.

The discharge channels of ground flashes, whose mechanism is known rather well, were initially analyzed using this technique. The results were in good agreement with the current knowledge pertinent to these discharges which support the idea of using luminosity variations to identify mechanism of electrical discharge breakdowns. For ground flashes, a current loss which increased with the channel length was observed. The estimated value for this loss was around 3% from top to bottom of the channel. Cloud flashes showed more variability in luminosity compared to ground flashes. The majority of cloud flashes were initiated as positive leaders without the stepping process. The average time duration of cloud flashes that start with positive leader was about 181 ms. These characteristics were compared and contrasted with existing models to understand the process of cloud flashes. It was shown that, as in the case of ground flashes, the cloud discharge cannot be described by a singular process other than to ascertain that it was mainly a charge transfer between two charge centers. The M components observed in lightning channels were also studied using high-speed video recordings. It was found that the mean time duration between a return stroke and an M component is about 71 ms and mean time duration between two consecutive M components is approximately 5 ms. Mean time duration of a M component is about 0.4 ms.

The phenomenon of bead lightning, where the lightning channel appears to break up into luminous fragments, is still a mystery. The bead nature of lightning was observed in long laboratory sparks in this study. Time resolved photographs exhibited a 'bead pattern' in the decaying stage of the discharge and they occurred mainly in regions where the channel split into two parts forming loops. This observation provided the first evidence that rapid cooling of non-uniform channel sections could lead to the formation of beads. It is suggested that periodically occurring non-uniform channel sections could explain the bead pattern of lightning discharges.

The complex tortuous nature of channels was studied by applying Hill's method and Fractal techniques on long laboratory sparks. It is shown that the two methods are correlated. No particular pattern was observed for the variation of tortuosity along the channel. High tortuosity was seen at the breakdown. A larger value for fractal dimension was obtained for the edges of the channel when compared with its center. An important formula between channel diameter and length was derived in this study. Results show that the value of fractal dimension depends on the angle of view.

The work carried out under this thesis show that image processing techniques can give useful insight to electrical breakdowns and complements lightning electric field measurements.