Transition from Initial Leader to Stepped Leader in Negative Cloud-to-ground Lightning

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Extended Abstract

Several recent studies have shown that visible luminosity accompanies the initial breakdown (IB) stage of cloud-to-ground (CG) and intracloud (IC) lightning flashes [1, 2, 3, 4, 5]. In the present work, high-speed video and electric field change (E-change) data are used to describe the character of the luminous development during the earliest 5 ms of a natural negative CG flash. These observations reveal a distinct difference in appearance of both the luminosity and the pulses before the leader transitions to propagating as a stepped leader (SL). During the IB stage of this flash, the initial leader advances 78-175 m forward, at intervals of 100-280 μs, in bursts that are bright for several 20-μs video frames. The accompanying IB pulses have similarly long duration, large amplitude, and a characteristic bipolar shape in nearby E-change observations. In the time between IB pulses, the leader usually is not bright enough to be visible. Later, during the SL phase, the leader tips advance 20-59 m forward at more regular intervals of 40-80 μs during relatively dim and brief steps; the accompanying SL pulses have very short duration, small amplitude, and are typically unipolar. These data indicate that when the entire initial leader length behind the lower end begins to remain illuminated between bursts, the propagation mode begins to change from IB bursts to SL steps. Additionally, in this flash and in a few other flashes from the same video dataset, the return stroke luminosity speed is found to decrease sharply upon reaching the topmost initial leader section of the channel, and that section of channel does not always saturate the video intensity while the remainder of the channel is saturated. The results of these analyses support an earlier hypothesis [1, 3] that the early initial leader development occurs in the absence of a continuously hot channel, and is thus unlike the self-propagating advance of the later stepped leader. In the final part of this study, the evolution of the total light intensity during several large-amplitude CG-type IB pulses are compared to the evolution described in earlier work [5] during very large-amplitude IC-type IB pulses of the sort that have been associated with the production of Terrestrial Gamma-ray Flashes.

References

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