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Microsecond scale optical observations of space leader evolution in natural negative cloud to ground lightning

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Extended Abstract

A space stem is a luminous plasma segment that has been observed to form ahead of the leader tip during the negative leader stepping process [1, 2]. A space stem may eventually thermalize and extend in length to develop into a space leader which may connect to the pre-existing leader channel (PELC). Only a few studies have examined the geometric properties of the space stems and leaders in natural lightning and what remains unclear is the extent to which the electrical characteristics of the PELC influence the formation and extension of space stems.

In this study, we examine in detail three negative stepped leaders observed in July and September 2020 using high-speed video cameras operating at 400, 575, and 780 kilo-frames per second. The frame exposure times were 1.8 µs, 1 µs, and 0.8 µs, respectively. The 0.8 µs exposure time is the shortest (reported to date) used to study space-leader evolution in natural lightning and helps provide new insights into their characteristics. The cameras are a part of the Melbourne Lightning Observatory (MLO), located on the campus of Florida Institute of Technology in Melbourne, Florida. The return strokes following all three stepped leaders were geolocated by the U.S. National Lightning Detection Network (NLDN); their ground strike points were at distances of 2.7 km, 7.9 km, and 4.9 km from the MLO, respectively, and their NLDN-estimated return-stroke peak currents were 17, 104, and 228 kA, respectively. We recorded these stepped leaders as they progressed toward ground between altitudes of 826-922 m, 300-440 m, and 801-978 m, respectively.

We observed the evolution of space leaders from their inception to their attachment to the PELC. For stepped-leaders that led to return strokes having higher peak currents, the space leaders appear to have incepted at farther median distances from their respective PELC-attachment points. These median distances for the strokes with peak currents 17, 104, and 228 kA were 6.1, 16.7, and 21 m respectively. The median space leader 2-D length in the video-camera frame just prior to PELC-attachment was longer in strokes with higher peak currents. These median lengths were 4.3, 11.8, and 14 m, respectively. The space leader attaching to the PELC results in the formation of a new leader-step and the extension of the leader toward ground. The median leader-step 2-D lengths were 7, 28.5, and 30 m for the three strokes and the median leader speeds were 0.4 x 10^6, 1.7 x 10^6, and 1.2 x 10^6 m/s, respectively. Leader-step lengths and speeds are expected to be affected by the different electric field environments at different altitudes above ground [3,4,5].

References

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