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Thunderstorm Charge Structures as Revealed by Hybrid Lightning Flashes

Maribeth Stolzenburg (1), Thomas Marshall (1), and Sumedhe Karunarathne (2)

(1) Department of Physics & Astronomy, University of Mississippi, MS USA, (2) Baptist College of Health Sciences, Memphis, TN USA

Generally, a hybrid IC/negative CG lightning flash begins first as a normal intracloud (IC) flash and then becomes a cloud-to-ground (CG) flash with one or more normal negative return strokes. The IC flash initiation is normal in that the initial breakdown pulses are IC-type (i.e. positive-going electric field change in their initial half cycle), and the negative leader moves initially upward into a region of positive charge. Thus the IC initiation location is a region of large negative ambient electric field. After tens or hundreds of milliseconds of IC activity, the negative stepped leaders of these hybrid flashes begin moving downward, into other regions of positive charge in the cloud; they eventually exit cloud base and reach ground as a normal negative return stroke. Some hybrid IC/CG flashes also have a set of CG-type initial breakdown pulses (i.e. negative-going E-change in their initial half cycle); these pulses unambiguously indicate the time of the change in flash type and also yield the time and location of large positive ambient electric field in the cloud. In this study we use electric field-change array data, 3-D lightning source locations, meteorological radar data, and high-speed video imagery for hybrid IC/negative CG flashes to derive the electrical structure of their parent thunderstorms. These flashes are extensive and long-lasting (active over tens of kilometers and for about one second) and have incredibly complicated sequences of optically visible and E-change events. Our analyses show that the electrical structure in the clouds at the time when these flashes occur is complex in the vertical, horizontal, and temporal dimensions.