The Association of Terrestrial Gamma-ray Flashes with Energetic In-Cloud Lightning Pulses

Steven A. Cummer* [(1)], Fanchao Lyu[(1)], Michael S. Briggs[(2)], and David M. Smith[(3)]
(1) Electrical and Computer Engineering Department, Duke University, Durham, NC USA
(2) CSPAR, University of Alabama in Huntsville, Huntsville, AL USA
(3) Physics Department, University of California at Santa Cruz, Santa Cruz, CA USA

Radio emissions continue to provide a unique view into the electrodynamics of terrestrial gamma ray flash (TGF) production. It is generally agreed that most and perhaps all TGFs are produced during the early, upward leader stage of normal polarity IC lightning flashes. Observations have shown that at least some TGFs are effectively simultaneous with a distinct low frequency pulse, indicating likely production of that pulse by the TGF-generating electron acceleration process itself [Cummer et al., GRL, 2011]. Additional observations of an anti-correlation between the TGF-radio association rate and TGF duration [Connaughton et al., JGR, 2013], and detailed comparisons of simulation and measurement [Dwyer and Cummer, JGR, 2013] strongly support this picture.

Here we will describe our recent work on the connection between energetic in-cloud pulses (EIPs) and TGFs. EIPs are a recently identified class of high peak-current lightning events that occur sometimes during the progression of lightning in-cloud negative leaders. They can be easily detected and identified with distant ground-based radio sensors. We will present several lines of evidence that indicate a direct relationship between positive polarity EIPs and a subset of TGFs. Most importantly, we find that of the 5 +EIPs solely identified through lightning data that occurred within 500 km range of the Fermi satellite footprint, all 5 were associated with simultaneously detected TGFs. We also show, using data from 12 +EIP-generating lightning leaders that were well mapped by lightning mapping array instruments, that the altitude progression of all 12 leaders matches that measured previously for GBM-detected TGFs. Lastly, we have used this association to identify two new TGFs that were not found in the direct searches of RHESSI and GBM data. Collectively these findings show that these gamma-ray and radio emissions are intrinsically linked and thus the two views of the same phenomenon, and further enables detection of these TGFs from distant ground radio signals alone. The ground detection of TGFs not only dramatically increases the detection rate of TGFs, but also can identify TGFs in continental and coastal areas that are at latitudes too high for present TGF-detecting satellites and will provide more insights into the mechanism of TGF production.