Discharge processes during downward TGFs at the Telescope Array in Utah

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Abstract

High-speed observations of lightning-produced downward terrestrial gamma-ray flashes (TGFs) by the Telescope Array Surface Detector network in Utah have been obtained in conjunction with measurements of the parent lightning flashes obtained with a broadband VHF lightning interferometer, fast electric field change sensor, and a 3-D VHF lightning mapping array (LMA). The measurements confirm in detail that TGFs are produced during energetic initial breakdown pulses (IBPs) that occur during downward breakdown at the beginning of negative cloud-to-ground flashes. The IBPs produce episodes of fast (~1-3 x 10^6 m/s) negative breakdown (FNB) that is embedded in slower activity leading up to and between successive IBPs. FNB is the negative-polarity analog of streamer-based fast positive breakdown (FPB) that occurs as the initiating event of intracloud and negative cloud-to-ground flashes. It is also expected to be streamer-based, and progresses 100-150 m or so before dying out. The gamma bursts typically last less than 10 microseconds, and occur at different times during the IBPs, often in conjunction with leading-edge sub-pulses of 'classic' IBPs. Evidence of the occurrence of relativistic feedback was observed during one of the TGF events.

The observations provide an explanation for how the requisite runaway electron avalanches develop, and why FNB is favored over FPB for TGF production. Energy-based modelling of such streamer systems (Attanasio et al., 2019) shows that the electric field is enhanced over a relatively large cross-sectional area ahead of the advancing system, independent of the breakdown's polarity. Whereas avalanching that develops ahead of FPB will propagate into the advancing positive charge and be quenched, for FNB the avalanching develops rapidly away from the advancing front and will continue through the full extent of the localized strong ambient E-field region. The results are expected to apply to the IBPs of upward negative breakdown during IC flashes, and to be involved in producing satellite-detected TGFs.

Reference:
Attanasio, A., Krehbiel, P. R., & da Silva, C. L. (2019). Griffiths and Phelps lightning initiation model, revisited. Journal of Geophysical Research: Atmospheres, 124, 8076–8094. https://doi.org/10.1029/ 2019JD030399

Topic Areas

Lightning Physics, Characteristics and Measurements

Submission Format

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