Geophysical Research Abstracts
Vol. 15, EGU2013-13065, 2013
EGU General Assembly 2013

Spectra of X-ray and Gamma-ray Bursts Produced by Stepping Lightning Leaders

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Terrestrial gamma-ray flashes (TGFs) are bursts of high-energy photons originating from the Earth's atmosphere in association with thunderstorm activity. TGFs were serendipitously discovered by BATSE detector aboard the Compton Gamma-Ray Observatory originally launched to perform observations of celestial gamma-ray sources [Fishman et al., Science, 264, 1313, 1994]. These events have also been detected by the RHESSI satellite [Smith et al., Science, 307, 1085, 2005], the AGILE satellite [Marisaldi et al., JGR, 115, A00E13, 2010], and the Fermi Gamma-ray Space Telescope [Briggs et al., JGR, 115, A07323, 2010]. Moreover, measurements have correlated TGFs with initial development stages of normal polarity intra-cloud lightning that transports negative charge upward (+IC) [e.g, Lu et al., JGR, 116, A03316, 2011]. Photon spectra corresponding to well-established model of relativistic runaway electron avalanches (RREAs) usually provide a very good agreement with satellite observations [Dwyer and Smith, GRL, 32, L22804, 2005]. However, it has been suggested that high-potential +IC lightning leaders could produce a sufficient number of energetic electrons to explain TGFs [Celestin and Pasko, JGR, 116, A03315, 2011] and Xu et al. [GRL, 39, L08801, 2012] have shown that this mechanism could explain the TGF spectrum for lightning potentials higher than 100 MV. In addition to TGFs, X-ray bursts are produced by negative lightning leaders in association with stepping processes and are observed from the ground [Dwyer et al., GRL, 32, L01803, 2005]. However, the energy spectrum of X-ray bursts from lightning is still poorly known, mainly due to the low fluence detected from the ground.

In this work, we use Monte Carlo models to study the acceleration of runaway electrons in the electric field produced around lightning leader tip and the associated bremsstrahlung photon spectra observed by low-orbit satellites in the case of high potential +IC discharges and from the ground in the case of negative cloud-to-ground discharges. We particularly investigate the variability of the photon spectrum with the lightning electric potential.