Optical Emissions Associated with Terrestrial Gamma-ray Flashes

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Terrestrial Gamma-ray Flashes (TGFs) are high-energy photon bursts originating from the Earth's atmosphere. After their discovery in 1994 by the Burst and Transient Source Experiment (BATSE) detector aboard the Compton Gamma-Ray Observatory [*Fishman et al.*, Science, 264, 1313, 1994], this phenomenon has been further observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) [*Smith et al.*, Science, 307, 1085, 2005], the Fermi Gamma-ray Space Telescope [*Briggs et al.*, JGR, 115, A07323, 2010] and the Astrorivelatore Gamma a Immagini Leggero (AGILE) satellite [*Marisaldi et al.*, JGR, 115, A00E13, 2010]. Measurements have correlated TGFs with initial development stages of normal polarity intracloud lightning that transports negative charge upward (+IC) [e.g., *Lu et al.*, GRL, 37, L11806, 2010; JGR, 116, A03316, 2011]. Moreover, *Østgaard et al.* [GRL, 40, 2423, 2013] have recently reported, for the first time, space-based observations of optical emissions from TGF-associated IC lightning flashes. The purpose of the present work is to quantify the intensities of optical emissions resulting from the excitation of air molecules produced by conventional streamer discharges in negative corona flashes of stepping negative leaders and by the large amount of electrons involved in TGF events based on two production mechanisms: relativistic runaway electron avalanches (RREAs) [*Dwyer and Smith,* GRL, 32, L22804, 2005] and production of runaway electrons by high-potential +IC lightning leaders [e.g., *Celestin and Pasko*, JGR, 116, A03315, 2011; *Xu et al.,* GRL, 39, L08801, 2012]. We employ a Monte Carlo model to simulate the acceleration of electrons in the energy range from sub-eV to GeV in either large-scale homogeneous electric field sustaining RREAs or highly inhomogeneous electric field produced around the lightning leader tip region. With the knowledge of the electron energy distribution function, a model similar to that described in [*Liu and Pasko*, JGR, 109, A04301, 2004] is used for the calculation of optical emissions from the first and second positive band systems of N_2 and the first negative band system of N_2^+. Results are compared to those recently published by *Dwyer et al.* [GRL, 40, 4067-4073, 2013].