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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, and *Dwyer et al.* [GRL, 40, 4067, 2013] recently quantified optical emissions associated with TGFs based on assumption that these emissions are similar to those produced by extensive air showers. In the present study, we quantify optical emissions resulting from the excitation of air molecules produced by the large population of electrons involved in TGF events based on two possible production mechanisms: relativistic runaway electron avalanches (RREAs) [*Dwyer and Smith,* GRL, 32, L22804, 2005] and acceleration of thermal runaway electrons produced by high-potential intra-cloud lightning leaders [e.g., *Celestin and Pasko*, JGR, 116, A03315, 2011; *Xu et al.,* GRL, 39, L08801, 2012]. Using Monte Carlo simulations, we show that electron energy distributions established from these two production mechanisms are inherently different over the full energy range, and also substantially different from those produced in extensive air showers. Moreover, we show that TGFs are most likely accompanied by detectable levels of optical emissions and that the distinct optical features are of significant interest for constraining and validating current TGF production models.