A Numerical Study on TGFs and Relativistic Feedback Discharges

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Terrestrial gamma-ray flashes are sub-millisecond bursts of >1 MeV photons originating from thunderclouds in the earth's atmosphere [e.g., Fishman et al., Science, 264, 1313, 1994]. They are normally produced in the initial stage of positive intra-cloud lightning discharges [e.g., Shao et al., JGR, 115, A00E30, 2010; Lu et al., GRL, 37, L11806, 2010; Cummer et al., GRL, 38, L14810, 2011]. In addition to the relatively short TGFs, thunderclouds and lightning can also make minute long gamma-ray glows according to ground-based [e.g., Chilingarian et al., PRD, 82, 043009, 2010] and airborne measurements [e.g., Smith et al., JGR, 116, D20124, 2011].

The relativistic electron avalanche theory was first suggested to explain the production of energetic photons in the earth's atmosphere. However, it was found that the relativistic electron avalanches acting on the cosmic rays alone could not generate enough number of energetic photons to make the observed TGFs. Dwyer [GRL, 30, 2055, 2003] introduced the relativistic feedback discharge mechanism for explaining the TGF production at thundercloud altitudes. A resent modeling study based on this theory successfully reproduced many observed TGF aspects [Dwyer, JGR, 117, A02308, 2012].

In this talk, we report a new modeling study on the TGFs and the relativistic feedback discharges following Dwyer's work. A new numerical code was independently developed, which implements the same model as the work of Dwyer [2012]. The code is built on a streamer code that has been used for studying streamer discharges in sprites, lightning and laboratory experiments [e.g., Liu and Pasko, JGR, 109, A04301, 2004]. The components for modeling the relativistic feedback discharge and the production of energetic photons have been added. In contrast to the work of Dwyer [2012], the new code can fully model transport of low energy electrons and ions, ionization, attachment, and recombination. It also uses very different numerical approaches to solve the relativistic discharge model equations. However, simulations show that the major properties of the relativistic feedback discharge and the gamma-ray produced are very similar, e.g., the pulse shape and width of the TGF, the formation of a self-propagating discharge named as the relativistic feedback streamer. In this talk, we discuss the new simulation results in detail and compare them with the TGF observations and Dwyer's work.