Monte Carlo Simulation of Neutron Generation by Lightning Leaders

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Terrestrial Gamma-ray Flashes (TGFs) are high-energy photon bursts originating from the Earth's atmosphere [*Fishman et al.*, Science, 264, 1313, 1994]. 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] and it has been suggested that long unbranched +IC lightning leaders could produce a sufficient number of energetic electrons during their stepping processes to explain TGFs [*Celestin and Pasko*, JGR, 116, A03315, 2011]. Moreover, neutron bursts have been observed in association with lightning [e.g., *Shah et al.*, Nature, 313, 773, 1985; *Shyam and Kaushik*, JGR, 104, 6867, 1999; *Bratolyubova-Tsulukidze et al.*, Adv. Space Res., 34, 1815, 2004]. Additionally, the large amount of energetic photons in TGF events has been suggested to be responsible for the production of neutron bursts [*Babich et al.*, JETP Lett, 84, 285, 2006; *Carlson et al.*, JGR, 115, A00E19, 2010].

In the present study, we simulate the acceleration of electrons during the negative corona flash stage of stepping negative lightning leaders. Energetic photons are produced by these runaway electrons either producing gamma-rays or lower energy X-rays depending on the electric potential difference in the leader head region. We have developed a Monte Carlo model that simulates neutron generation through the photonuclear interaction in the atmosphere. In this work, we quantify the properties of the neutron source possibly generated by different lightning discharges and we also investigate the possibility of neutron generation from typical negative cloud-to-ground lightning discharges.