Electrostatic Modeling of Intra-Cloud Stepped Leader Electric Fields and Mechanisms of Terrestrial Gamma Ray Flashes

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Understanding of electric field configurations created by long intra-cloud (IC) stepped leaders is of significant interest for understanding how these events produce bursts of high energy photons in the Earth's atmosphere, commonly referred to as terrestrial gamma ray flashes (TGFs). In the present work modeling results using the electrostatic moment method solutions are used for quantitative interpretation of electric fields observed at close ~200 m and long ~30 km ranges from IC stepped leaders. The modeling results are consistent with the existence and continuous advancement of VHF-dark positive leaders at the positive end of the bi-directional leader system. It is demonstrated that the electric dipole moment of the entire leader system is a quadratic function of the leader length, and the dipole moment changes due to the leader steps increase proportionally to the overall leader length (i.e., even when step length remains constant), in good agreement with observations. The results indicate that the dipole moment changes on the order of 10s of C km and current moment changes on the order of 10s of kA km, that have been associated with TGFs, are essential attributes of long IC stepped leaders, and directly follow from their intrinsic large scale charge dynamics.