Minimum Charge Moment Change in Positive and Negative Cloud to Ground Lightning Discharges Producing Sprites

Jianqi Qin, Sebastien Celestin, and Victor P. Pasko
CSSL, Penn State University, University Park, Pennsylvania, USA

Sprites with extensive vertical streamer structures are usually produced by the most intense (i.e., large peak current) positive cloud-to-ground lightning discharges (+CGs) in thunderstorms [e.g., *Lyons,* JGR, 101, 29641, 1996]. In the conventional breakdown theory of sprites, a large charge moment change of ∼1000 C km, for which the electric field can exceed the conventional breakdown field E_k (∼30 kV/cm at ground level) at mesospheric/lower ionospheric altitudes, is usually assumed to be necessary for sprite production [e.g., *Pasko et al.,* JGR, 102, 4529, 1997]. However, measurements indicate that surprisingly small charge moment changes of ∼200 C km in positive cloud-to-ground lightning discharges (+CGs) can initiate middle atmospheric gas discharges termed sprites [e.g., *Hu et al.,* GRL, 29, 1279, 2002]. In the present work a plasma fluid model is used to study the necessary conditions for a lightning discharge associated with such a small charge moment change to produce sprites. It is demonstrate that for spherically symmetric initial electron density inhomogeneities, the initiation of sprites by such small charge moment changes is only possible when the ionospheric D-region electron density profile is characterized by a reference altitude h' greater than 90 km. Vertically elongated inhomogeneities are found to be more favorable for sprite initiation consistent with recently published studies of *Kosar et al.* [JGR, 117, A08328, 2012]. It is calculated that for the same ionospheric conditions (i.e., inhomogeneities and h' values) that lead to initiation of sprites by +CGs associated with ∼200 C km charge moment changes, the minimum charge moment change required for initiation of sprites by -CGs is 300 C km. We suggest that the intersection of the rarity of $Qh_Q \simeq 300$ C km and $h' \gtrsim 88$ km leads to the fact that the occurrence of negative sprites are rare, although -CGs associated with $Qh_Q \simeq 300$ C km are not so rare.