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Parameters of Lightning Discharge and Atmospheric Conductivity Required for Generation of Sprite-Producing Quasi-Electrostatic Fields - a Theoretical Study

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Red sprite is the most prominent among the newly discovered transient luminous events in the lower ionosphere above thunderstorms, which is driven by strong quasi-electrostatic fields (QSF), after a positive cloud-to-ground lightning discharge during a nighttime thunderstorm. The parameters of sprite-producing lightning have been widely studied. We theoretically determine the set of parameters of both the causative lightning discharge and the atmospheric conductivity, by which the QSF generated are capable to initiate a breakdown in the lower ionosphere above a thunderstorm. We propose an analytical model for QSF peak intensity, which is based on the Maxwell's equations under quasi-static conditions. The QSF peak intensity is studied as a function of the parameters of the causative lightning discharge (the height and magnitude of the charge removed, its distribution, and the discharge time), as well as of the atmospheric conductivity profile. We assume that the conductivity up to about 85 km is isotropic due to the intense electron heating and evaluate the conductivity modification self-consistently with the electric field applied. We show that the most determinative factor for a sprite onset is the conductivity profile (this can explain why a sprite occurrence is sometimes possible even due to moderate discharges). Two altitudes are revealed by us to be candidates for initiation of a sprite: the altitude where the relaxation time is equal to the discharge time, and the 'knee' of the conductivity profile at about 70-85 km. This fact allows us to determine the set of parameters which lead to a sprite onset.