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Production of Ionospheric Perturbations by Cloud-to-Ground Lightning and the Recovery of the Lower Ionosphere

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The fact that lightning/thunderstorm activities can directly modify the lower ionosphere has long been established by observations of the perturbations of very low frequency (VLF) signals propagating in the earth-ionosphere waveguide. These perturbations are known as early VLF events [Inan et al., 2010, JGR, 115, A00E36, 2010]. More recently discovered transient luminous events caused by the lightning/thunderstorm activities only last ∼1-100 ms, but studies of the early VLF events show that the lightning ionospheric effects can persist much longer, >10s min [Cotts and Inan, GRL, 34, L14809, 2007; Haldoupis et al., JGR, 39, L16801, 2012; Salut et al., JGR, 117, A08311, 2012]. It has been suggested that the long recovery is caused by long-lasting conductivity perturbations in the lower ionosphere, which can be created by sprites/sprite halos which in turn are triggered by cloud-to-ground (CG) lightning [Moore et al., JGR, 108, 1363, 2003; Haldoupis et al., 2012].

We recently developed a two-dimensional fluid model with simplified ionospheric chemistry for studying the quasi-electrostatic effects of lightning in the lower ionosphere [Liu, JGR, 117, A03308, 2012]. The model chemistry captures major ion species and reactions in the lower ionosphere. Additional important features of the model include self-consistent background ion density profiles and full description of electron and ion transport. In this talk, we present the simulation results on the dynamics of sprite halos caused by negative CG lightning. The modeling results indicate that electron density around 60 km altitude can be enhanced in a region as wide as 80 km. The enhancement reaches its full extent in ∼1 s and recovers in 1-10 s, which are on the same orders as the durations of slow onset and post-onset peaks of some VLF events, respectively. In addition, long-lasting electron and ion density perturbations can occur around 80 km altitude due to negative halos as well as positive halos, which can explain long-recovery VLF events and step-change VLF events.