Photodetachment of electrons at sprite altitudes by visible radiation of tropospheric lightning discharges as a mechanism of initiation of sprite streamers

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Experimental evidence suggests that a strong lightning discharge is a necessary but not sufficient condition for initiation of sprite streamers [Lang et al., JGR, 116, A10306, 2011]. The strength of the lightning in terms of sprite production potential is usually characterized by a charge moment change (i.e., charge removed by lightning times the altitude from which it was removed), and the existing modeling quantitatively establishes that for experimentally documented levels of charge moment changes the presence of relatively dense plasma irregularities in the mesosphere above thunderstorms is mandatory for the initiation of sprite streamers [Qin et al., JGR, 116, A06305, 2011; GRL, 40, 4777, 2013; Nat. Comm., 5, 3740, 2014]. Although some of the inhomogeneities are documented to appear in the same regions of space as previously formed sprites, and therefore likely represent perturbations left by previous sprite discharges, the exact origin of these inhomogeneities remains unknown. One possibility is that small traces of metallic species existing at sprite altitudes due to meteoric ablation can be ionized by relatively diffuse sprite halos (through electron impact collisions or through photoionization by halo emissions) that often precede formation of sprite streamers [Janalizadeh and Pasko, Abstracts AE21A-08; AE21B-3132; presented at 2018 Fall Meeting, AGU, Washington DC, 10-14 Dec., 2018]. Quick and Krider [JGR, 118, 1868, 2013] provide a comprehensive overview of the available lightning optical pulse data based on the ground [e.g., Guo and Krider, JGR, 87, 8913, 1982], the satellite [e.g., Kirkland et al., JGR, 106, 33499, 2001], and the high-altitude aircraft [e.g., Mach et al., Atmos. Res., 76, 386, 2005] observations. In spite of the significant differences in the sensing technology, the viewing geometry, the effects of clouds and the wavelength dependent absorption of light propagating horizontally and vertically in the atmosphere, the authors have been able to demonstrate consistency (within an oder of magnitude) of different data sets in terms of the median peak powers and the pulse durations [Quick and Krider, 2013]. Quick and Krider [2013] report the median total optical energy (from 400 to 1000 nm, not corrected for atmospheric transmission) for negative first strokes to be 3.6e6 Joules, the median for positive CG strokes 9.3e6 Joules, and the peak for positive CG strokes 2.6e7 Joules. The FORTE satellite median energy is 4.5e5 Joules and the peak is 1e9 Joules [Kirkland et al., 2001]. Following Quick and Krider [2013] we assume that a point lightning source radiates as a perfect black body with 30,000 K temperature [Orville, J. Atmos. Sci., 25, 827, 1968] from altitudes 0 km and 10 km and account for effects of atmospheric absorption along the vertical path toward 70 km altitude. We quantitatively demonstrate that photodetachment of electrons from O-, O2-, and OH- ions at mesospheric altitudes due to optical emissions (400-1000 nm) directly generated by lightning discharges at low altitudes can contribute to formation of initial plasma irregularities required for the initiation of sprite streamers. Additional information on choice of negative ions chosen for this study (i.e., their electron affinities and photodetachment cross sections) is given in a companion abstract on photodetachment by sprite halo emissions presented at this meeting by Janalizadeh and Pasko. We note that we do not consider NO3- ions as these only can be photoionized by UV emissions with wavelength <315.9 nm that are expected to be significantly absorbed for the chosen modeling geometry and therefore are excluded from current analysis.

