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The effects of lightning and sprites on the ionospheric potential, and threshold effects on sprite initiation, obtained using a PSpice model

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A quantitative model of the global atmospheric electric circuit has been constructed using the PSpice electrical engineering software package. Currents ($\sim$ 1 kA) above thunderstorms and electrified rain/shower clouds raise the potential of the ionosphere, which is presumed to be an equipotential surface at 80 km altitude, to $\sim$ 250 kV with respect to the Earth's surface. The circuit is completed by currents flowing down through the fair weather atmosphere, in the land/sea surface and up to the cloud systems. Using a model for the atmospheric conductivity profile (Rycroft et al., JASTP, 2007), the effects of both negative and positive cloud-to-ground (CG) lightning discharges ion the ionospheric potential have been estimated. A large positive CG discharge creates an electric field which exceeds the breakdown field from the ionosphere down to $\sim$ 74 km, so forming a halo and a column sprite, and, some ms later, from $\sim$ 67 km down to $\sim$ 55 km at $\sim$ 60 ms after the discharge, thereby forming a "carrot" sprite. Estimates are made of the return stroke current and the thundercloud charge moment change (CMC) for a +CG discharge required to exceed the threshold breakdown field, or the threshold field for creating and sustaining negative or positive streamers. The values for breakdown at 80 km altitude are 35 kA and 350 C.km, respectively, and 45 kA and 360 C.km at 70 km altitude. The different temporal and spatial developments of the mesospheric electric field distinguishing between column and carrot sprites agree with the latest deductions from from recent observations. A current flowing in the highly conducting sprite reduces the ionospheric potential by $\sim$ 1 V.