Modification of the Lower Ionospheric Conductivity by Thunderstorm Electrostatic Fields

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Recent remote sensing studies have found that thunderstorms can modify the lower ionosphere on a time scale on the order of minutes to hours. Such long-lasting modifications may be related to the effects of thunderstorm electrostatic fields. This paper presents a modeling study of the nighttime conductivity profile of the lower ionosphere above a thunderstorm. A simplified ionospheric ion chemistry model is combined with Ohm's law to self-consistently calculate the conductivity. The electrostatic field produced by a typical thunderstorm is insufficient to activate electron impact ionization, two-body dissociative attachment, and electron detachment processes that are important for high-altitude electrical discharges known as transient luminous events. It, however, can accelerate the electrons in the lower ionosphere to sufficient energies so that both of the rate constant of three-body electron attachment and the electron mobility are significantly reduced. The modeling results indicate that the lower ionospheric electron density can be increased by a factor up to 4-5 due to the thunderstorm electrostatic field, because the three-body attachment slows down. In contrast, the lower ionospheric conductivity is reduced by up to 1-2 orders of magnitude because of the decreased electron mobility. The altitude range of the modification in the conductivity profile depends on the ionospheric electron density profile. For a typical electron density profile, the resulting changes in the nighttime ionospheric reflection heights of extremely low frequency and very low frequency waves are 5 and 2 km, respectively. These findings indicate that the assumption of electric field-independent electron-neutral collision frequency (i.e., electron mobility) used in previous studies can result in significant errors.