Effects of conductivity perturbations in time dependent global electric circuit model

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This paper contributes to the understanding of influence of the conductivity perturbations on the ionospheric potential in Earth's global electric circuit (GEC). The GEC is established by the naturally occurring presence of a thin layer of insulating air (our atmosphere) sandwiched between the highly conducting Earth and the conducting mesosphere/ionosphere. Ionospheric potential, defined as the difference between the potential of the Earth and potential of conducting mesosphere/ionosphere is found to be an important quantity, which can serve as global indicator relating the state of GEC to the planetary climate [Williams, E., et al., Atmos. Res., 135, 208–227, 2014]. The results obtained from model based on continuity equation and Poisson's equation [Jansky, J., et al., J. Geophys. Res., 119, 10,184–10,203, 2014]. are compared with classical model of atmospheric electricity in which the atmosphere is divided into two or more columns and is replaced by a simple equivalent electric circuit model [e.g., Rycroft, M. J., et al., J. Atmos. Sol. Terr. Phys., 69, 2485–2509, 2007]. The conductivity perturbations appearing in middle atmosphere produced by γ-ray bursts from magnetars and due to the ionization by electrical discharges like sprites are studied first. The transient response of the ionospheric potential is modeled in this case and timescales of interest are identified ($0.01-10$ s). In these cases modification of ionospheric potential is small. Additionally, the principal effects of topography and reduction of the conductivity inside the thundercloud are studied. Both of these factors effectively increase the ionospheric potential for a classic source in the GEC represented by a current dipole leading to formation of two main charge centers of the thunderstorm. On the other hand for GEC including topography and conductivity reduction in thunderclouds the contribution of sequence of negative cloud-to-ground lightning discharges to the ionospheric potential is decreased. Simulation results show very good agreement with a equivalent circuit models for conductivity perturbations with horizontal dimensions exceeding 20 km.