Modelling the global electric circuit, lightning, sprites, jets and elves

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Within the new discipline of Earth System Science, the field of atmospheric electricity occupies a distinct and central role. It is a field which is interconnected - upwards, downwards and laterally (both in latitude and longitude) - with many other important fields of geophysics. Further, it serves as a role model for planetary atmospheric electricity within the discipline of, say, Mars System Science or Titan System Science.

Following a brief overview of the crucial physical processes at work, we provide an equivalent circuit electrical engineering model of the Earth's global circuit developed using the PSpice software package. In this model, the height profile of the atmospheric electrical conductivity is the most significant parameter. We assume that the Earth's land/sea surface and the ionosphere (at a height of 80 km) are equipotential surfaces, the latter being at ˜+250 kV with respect to the former. The current (˜1 kA) around the circuit is driven upwards by modelled generators in tropical thunderclouds and generators below rain/shower clouds at middle latitudes, and flows downwards in the fair weather regions of the atmosphere. Both negative and positive cloud-to-ground lightning discharges are modelled, and their effects on the potential of the ionosphere (charging it and discharging it, respectively) are estimated quantitatively. Elves are considered to be due to the electromagnetic pulse from lightning discharges. Sprites (discharges in the mesosphere) occur above +CG discharges having large charge moments when the breakdown threshold field is exceeded; these are also modelled quantitatively. A sprite halo can be formed 0.2 ms after the +CG lightning return stroke, from the ionosphere down to ˜74 km, and, some ms later, a "carrot" sprite may be formed from ˜67 km down to ˜55 km (about 60 ms after the lightning) by the propagation of negative and positive streamers. The current in the sprite is found to reduce the ionospheric potential by ˜1 V. Finally, the effects of blue jets and gigantic jets are considered briefly.

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