Study of Sprite Related Electric Fields using FEMM simulations

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We studied sprite generation performing simple simulations of the electric field established in the atmosphere by 2 thunderclouds charge configuration models and Cloud-to-Ground (CG) lightning activity of both polarities. For the simulations we used the Finite Element Method Magnetics – FEMM in an environment that consisted of a 2-D box with 200 km of width and 90 km of height. We modeled two distinct charge configurations: (1) a tripolar model; and (2) the same tripolar model with additional 9 small charge centers of both polarities inside the cloud, such that the total charge was zero. The CG discharges were simulated as a charge removal of -8 C and 20 C. In both cases the horizontal component of the electric field had peaks at 50 km away from the parental CG location. Based on the results we suggest that there is a limited area of possible sprite occurrence of up to 50 km away from the parental CG discharge, which agrees with the observational data.

1. Introduction

TLEs are atmospheric plasma discharges occurring in the region between the clouds and the ionosphere. Discovered in 1989 by [1], they have been the object of scientific studies since the Sprites94 campaign [2].

The study of these events are relevant to better understand the chemistry and energetics on stratospheric, mesospheric and ionospheric heights. However, there are severe experimental limitations to perform in situ measurements of these phenomena due to their altitude height, poor knowledge available about the environment at those altitudes and their transient nature. So it is of great interest to gain environment knowledge to improve the instrumental for observations.

We used the FEMM platform, which is a free software simulator of electrostatic, magnetostatic, heat flow and current flow problems, in order to gain better understanding of the electrical environment of the region between the ground and the ionosphere. With this platform we modelled the effects of thunderclouds on the atmosphere before and after the Cloud-to-Ground (CG) discharge and found that there is a region where the electric field peaks. We speculate that this might be a preferential region for sprite occurrence. We also observed significant changes in the electric field pattern caused by changes in the CG discharge.

2. FEMM Simulations

In the search for a reason why the distribution of Sprites is centred at 50 km from the CG parental discharge [3], we simulated the electrical characteristics of the atmosphere between the ground and 90 km of altitude in the presence of the CG discharge.

The FEMM platform is a free software that simulate electrostatic, magnetostatic, heat and current flux problems. We simulated two thundercloud models, one following the tripolar approximation and the second being the same tripolar model but with additional small charge centers spread through the cloud. The tripolar model consisted of charges of 3 C, - 40 C and 40 C at the central position of the cloud, at the respective heights of 2 km, 7 km, 12 km. The second model had the same charge centers of the tripolar model plus 9 smaller charge centers of both polarities, arbitrarily positioned on the cloud, such that the total charge was zero.

Afterwards we simulated the environment after the CG discharge of both polarities. The CG discharges were simulated as a charge removal from the cloud without going into details about the removal process. The negative discharge was considered as a removal of -8C and the positive was a removal of 20 C.

3. Results

The results of the simulation show that the horizontal component of the electric field had peaks

occurred at 63 km and 136 km. After the positive CG the peaks move to 58 km and 141 km, and after the negative CG they were located at 64 km and 131 km. On the second model peaks were locate at 71 km and 140 km before the lightning discharges. After the positive CG they move to 58 km and 135 km, and after the negative CG the peaks moved to 66 km and 128 km. In both models the peaks invert their polarity after the positive CG.

4. Conclusions

Comparing the results of both models, the results of the thunderstorm electric field of the tripolar model were less realistic because of its simpler symmetry. The peaks of the electric field of the second model were more significant. In both models, the positive discharge resulted in higher peaks of electric field displaced from the lightning discharge, in agreement with the fact that most sprites are generated by positive CGs.

The results of the simulations showing a peak in the horizontal component of the electric field around 50 km from the central position of the clouds agrees with the distribution of lateral displacement between triangulated sprites and CG discharges calculated by [3].

5. References

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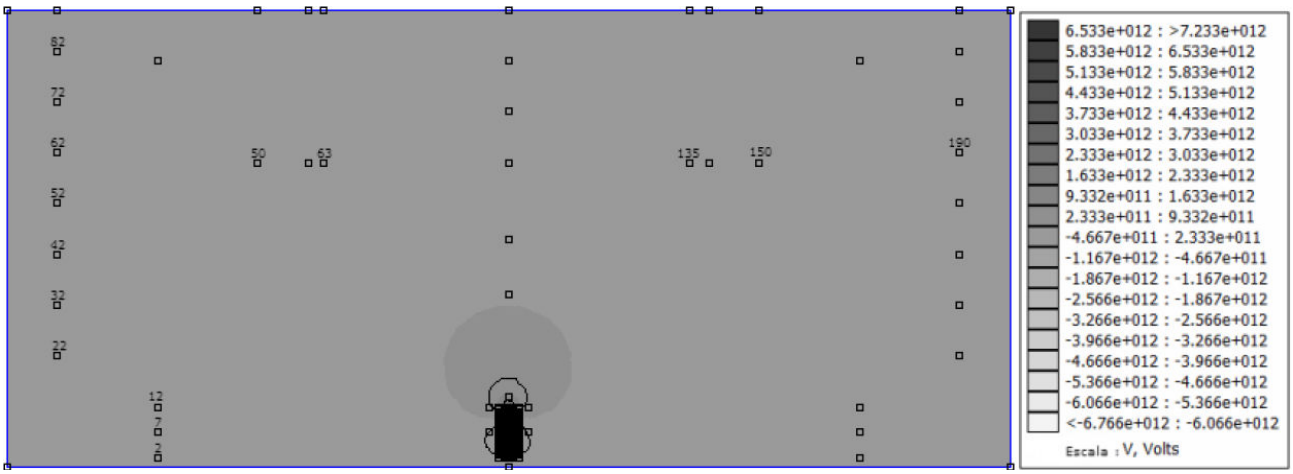

Figure 1: Result of FEMM simulation for the thundercloud on tripolar configuration and electric field before the CG lightning discharge of any polarity