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Title: # GENERATION OF ELVES BY SPRITES AND JETS

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Generation of Elves by Sprites and Jets

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1. Introduction

Recent years of observations of the upper atmosphere and the lower ionosphere brought a facinating collection of new phenomena including optical, radio, and gamma-ray emissions originating in the 20 to 90 km altitude range. Up to now, the most diverse phenomenology has emerged from the optical observations which have led to the identification of red sprites, blue jets, blue starters, e.g. [1-4], and elves, e.g. [5], [6]. Most of the studies have concentrated on relating such phenomena in the upper atmosphere to regular lightning discharges in the troposphere. For example, sprites and jets are beleived to be optical manifestations of electrical discharges in the upper atmosphere caused by quasi-electrostatic fields penetrating to high altitudes during a regular lightning discharge. The sprite/jet discharge itself can be caused by the runaway air breakdown, e.g. [7], or regular air breakdown [8]. The standard theory [9] for optical airglow transients [5] in the lower ionosphere above the thunderstorms also known as elves [6] suggests that they are produced during interaction of electromagnetic pulses (EMP) from lightning with the lower ionosphere. Heating of the ambient electrons by the EMP in the D region can result in excitation of optical emissions once the optical excitation thresholds are reached. In this paper we suggest that in addition to this mechanism [9] elves can be caused by an EMP generated by sprites and jets. If sprites and jets are indeed accompanied by electrical discharges then some energy of their EMPs reaches to the ionosphere and heats ambient electrons there that in turn stimulates optical emissions similar to EMPs from regular lightning.

2. Model

In our description of the model we will refer to Figure 1. Let us start from the moment when a regular cloud to ground discharge occurs. At this time an EMP from lightning (L-EMP) is generated followed by quasi-electrostatic (QE) fields that are established in the upper atmosphere. When a L-EMP reaches to the ionosphere it can generate optical emissions in that region known as elves [6]. In the model that we consider sprites and jets are produced by the runaway discharge mechanism, e.g. [7] and other papers at this conference from our group, that is developed from cosmic ray seed MeV electrons in the presence of QE-fields. Such sprite/jet discharges generate their own EMP (SJ-EMP) that reaches the ionosphere and can generate optical emission in the same manner as a L-EMP does.

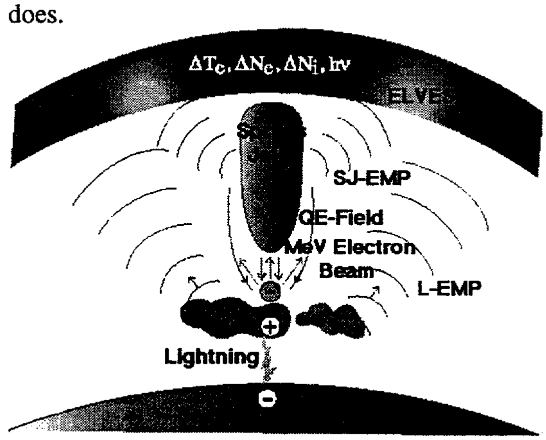

Figure 1. Comparison of lightning and sprite/jet mechanisms of elves generation.

The proximity of sprites/jets to the lower ionosphere means that in their case the power of an EMP could be several times lower than the power of a L-EMP and still cause generation of elves comparable in brightness to the ones generated by a L-EMP.

3. Results

The results of our computations indicate that the typical time duration of a SJ-EMP is 100 to 200 μs, for figure see Yukhimuk et al. at this conference. Such duration is comparable to duration of a L-EMP. Figure 2 shows dependence of the maximum electric field of a SJ-EMP at the altitude of 80 km versus radius. Duration of the stimulating lightning discharge was 5 ms. To draw conclusions concerning the generation of optical emissions by an EMP with such electric field at the bottom of the ionosphere we refer to paper [9] where it is shown that an

EMP with about 100 μs duration and an electric field amplitude larger than 20 V/m is sufficiently potent to produce optical emissions with intensities twice that of the nighttime background. From the radial distribution of electric field in Figure 2 we conclude that the emissions are generated in the region between two radii where the condition E > 20 V/m is satisfied.

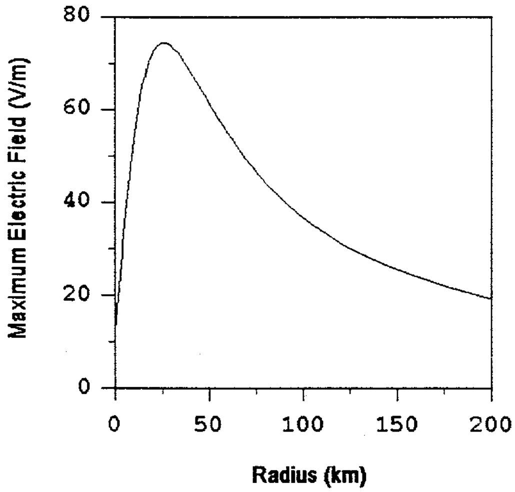

Figure 2. Distribution of maximum electric field of SJ-EMP versus radius. Duration of the driving lightning discharge is 3 ms.

Figure 3 summarizes results on the maximum electric field of a SJ-EMP and the radius of elves generated by such an EMP as a function of lightning duration. At this point we give rough estimates of these parameters. When the driving lightning discharge is slow (> 7 ms) a SJ-EMP becomes weak and we do not expect generation of elves for such cases.

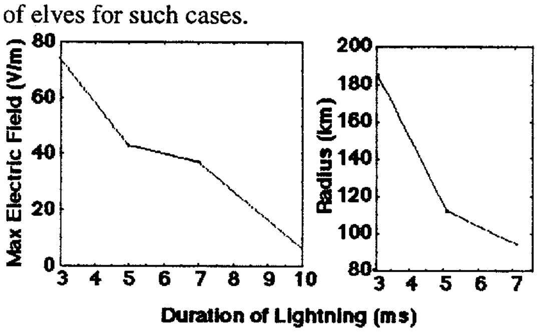

Figure 3. Maximum electric field of sprite/jet EMP at the altitude of 80 km and the expected radius of elves.

4. Conclusions

Our simulations demonstrate that sprites/jets driven by the runaway air breakdown mechanism can generate a powerful EMP that can stimulate transient airglow brightenings in the lower ionosphere also termed elves [6]. The sequence of events involved in this process is the following: *i)* an atmospheric cloud to ground or intracloud discharge occurs that leads to *ii)* establishment of strong QE fields in the upper atmosphere, *iii)* where runaway air breakdown [7] is stimulated by ambient cosmic rays, *iv)* such a discharge can produce a strong EMP with duration of 100 to 200 μs that is predominantly upward directed due to the relativistic nature of the source [10], *v)* the EMP in turn can produce optical emissions, perturbations of electron density and chemical perturbations in the lower ionosphere [9]. We find that parameters of a SJ-EMP are similar to those produced by regular lightning which makes it difficult in observations to distinguish an EMP produced by two different sources: lightning and sprites/jets. This fact makes the picture of electromagnetic interactions in the atmosphere more rich and facinating.

5. References

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