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Analyses of the ISUAL Secondary TLEs

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Abstract

From July 2004 to December 2012, ISUAL (Imager of Sprites and Upper Atmospheric Lightning) has captured over 24,000 TLEs (transient luminous events) in the Earth's atmosphere, including 35 particularly interesting events. These events exhibit complex generating sequences, which typically start with a sprite and then other TLEs soon follows. In this report, the follow-up events are termed as secondary TLEs. According to their features, they are classified as the secondary sprites (3 events), the secondary jets (27 events) and the secondary gigantic jets (5 events; [2]). In this work, the characteristics of these secondary TLEs are analyzed in detail, and the possible generating scenarios are proposed.

1. Introduction

Previous ground observations have reported that secondary discharges sometimes form under the preceding sprites and then propagate from the cloud top toward the lower edge of the sprites. *Marshall and Inan* [3] postulated that the sprite currents transport positive charge from the ionosphere, down to the bottom of sprites, following a +CG. The +CG leaves an excess of negative charge in the thundercloud. In the process, the positive charge relocating to the bottom of the sprite may enhance the electric field at the lower altitudes; thus an electric breakdown may be initiated to produce the observed secondary TLEs. In fact, some TLEs with complex generating sequences, which are termed as secondary TLEs in this work, had also been captured by ISUAL. Some of them share similar features with the previously ground observed events, while the others exhibit different characteristics that have not been reported before. Here, the generating sequences of the three kinds of secondary TLEs are presented, and the probable generating scenarios are also discussed.

2. Secondary sprites

2.1 Generating Sequences

From July 2004 to May 2012, about 1,700 sprites were recorded by ISUAL. Most of them were singly-occurring sprites and were not followed by other TLEs; while about 7% of them have complex generating sequences, which typically start with a sprite and then followed closely by another sprite with notable spatial displacements from the preceding sprite. Almost all of these multi-sprite events show horizontal shifts between the preceding and the follow-up sprites, thus they are termed as the dancing sprites. ISUAL also documented three events with the follow-up sprites show only altitudinal displacement from the preceding sprites, which are termed as secondary sprites here. These three events share similar generating sequences. They all start with an elve and a clustering sprite, which span the altitudes of ~60-85 km, and then ~30-60 ms later, another sprite occurs at the lower altitudes of ~40-65 km and seems to develop along the dimming luminous channels of the preceding sprite.

3.2 Possible Generating Scenario

It is possible that a +CG-induced preceding sprites initiated at the altitudes of ~ 70-85 km right above the region where the cloud charges are removed and where the electric field exceeds the breakdown electric field. By chance, the subsequent leaders in the cloud continue to develop mainly in the vertical direction and to move cloud charge to the ground. A succession of these discharges may have enhanced the electric field above this area to a point that the electric field at altitudes of ~60-70 km (a region

where the electric field strength did not immediately exceed the breakdown value after the +CG stroke) rises above the breakdown limit. Therefore, a secondary sprite has a chance to initiate from this lower altitude and to develop downward.

3. Secondary Jets/ Secondary GJs

From July 2004 to May 2012, only 32 secondary jet-like events were identified. Morphologically, these secondary jet-like events can be categorized into two groups, according to their terminal altitudes. The first group of 27 events is called the secondary jets and the second group of five events is the secondary GJs.

3.1 Secondary Jets

As shown in Figure 1 (a) and (b), after the occurrence of a single column sprite or a cluster of sprites, one or several secondary jets were seen to propagate from the cloud top region toward the base of the preceding sprite(s). Three characteristics can be inferred from these secondary jets: firstly, all of the secondary jets seem to occur near the cloud top region that is directly under the preceding sprites; secondly, the secondary jets all have straight luminous columns; thirdly, the number of the secondary jets seems to correlate well with the number of the preceding sprite column(s).

3.2 Secondary GJs

Depending on their location in relative to the preceding sprites, they can be classified into two types: shifted secondary gigantic jets (two events) and pop-through secondary gigantic jets (three events). After the occurrences of sprites, the curvy shifted secondary GJs tend to extend outside the region occupied by the preceding sprites, as in Figure 1 (c); while the straight pop-through secondary GJs developing through the center of the preceding circular sprites, as shown in Figure 1 (d).

3.3 Possible Generating Scenario

In this work, the secondary jets and secondary GJs were observed to closely follow the preceding sprites. Therefore, the sprite-producing lightning may have upset the charge balance in the cloud much like the IC(s) for the GJs[1], and then entice the jet to develop from the mid-level negative charge layer. The lowered ionosphere plate near the bottom of the preceding sprites mainly plays a role in constraining the terminating height of the subsequent jets/GJs but is relatively less important in triggering the subsequent jets/GJs.

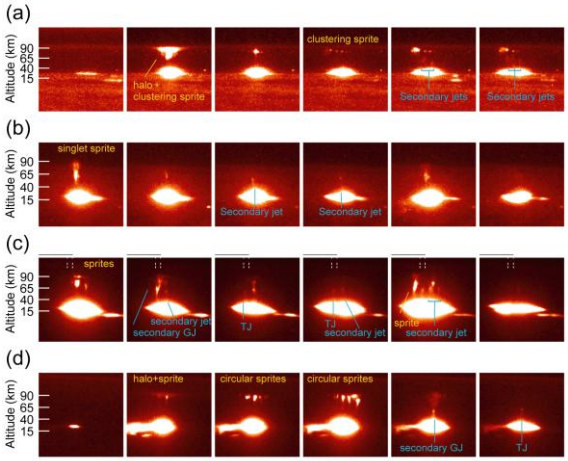

Figure 1: Representative image sequences of ISUAL [2]. (a) Secondary jets (b) secondary jet (c) shifted secondary GJ and (d) pop-through secondary GJ.

Acknowledgements

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