Optical observations and conditions of production of transient luminous events (sprites, elves, gigantic jets)

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Optical observations of TLEs are currently performed from several sites in southern France for several years. The equipment used in these sites consists of a low-light charge-coupled device (CCD) camera (Watec 902H) mounted on a pan-tilt unit remotely controlled by the Internet. Numerous sprites and other TLEs have been observed above storms all along the year over land (France and Spain) or over sea (western Mediterranean Sea and close Atlantic Ocean). Some TLE events and their producing storms have been analyzed by associating various types of data (cloud top temperature from meteosat satellite, cloud structure from radar reflectivity, lightning activity from several detection networks, ELF/VLF electromagnetic radiations from various antennas).

1. Introduction

Several types of transient luminous events (TLEs) have been identified and their physical features have been widely investigated. Sprites are streamers of short duration (0.01-0.1 second) and occur over mesoscale convective systems (MCSs) thanks to a quasi-static electric field resulting from a positive cloud-to-ground (+CG) flash which generates a strong charge moment change (CMC) [1]. Halos are downward-descending diffuse glows from about 80 to 65 km altitude. Elves are luminous patches of airglow near the top of the mesosphere often manifesting as an expanding ring typically ranging from 100-300 km [2]. They occur within about 160 microseconds after and above an intense cloud-to-ground lightning discharge. Gigantic jets (GJ) are electrical discharges shooting up from a thundercloud and reaching terminal altitudes within the lower ionosphere (70-90 km) [3].

From several years and in the frame of Eurosprite program, numerous sprites and other TLEs have been observed with video cameras above thunderclouds which regularly develop in southern and Central France for the summer season, along the Mediterranean coastline and above sea for the fall season [4, 5, 6].

2. Results

2.1. Sprites and elves

Figure 1 displays a panel of different types of TLEs observed at various distances (from 150 km to close to 900 km), locations and periods of the year. These images which correspond to 20-ms frames from the video imagery especially include sprites and groups of sprites of different type (column, carrot, dancing sprite, jellyfish…). The aspect of the sprite event in a frame can depend on its stage of development since it can last several frames after the first streamer triggering at an altitude of about 70 km. The number of elements is very variable in a sprite event and can reach several tens in a group of columns. The elements in a group of sprites can be horizontally displaced from the location of the parent lightning flash, and sometimes they can be oriented toward it [5]. The overwhelming majority of the sprite-producing lightning flashes are positive cloud-to-ground (CG) flashes occurring within the stratiform region of the storm [4, 6]. The carrot sprites can be associated with a halo generally earlier produced by the same flash characterized by a large peak current. The typical frequency of sprite production for a storm during the favourable period is generally around 0.2 min^{-1}. The elves are rather observed above storms over sea and appear as luminous rings with a visible diameter of about 300 km (Figure 1). They can be either produced by positive as negative CG flashes with large peak currents. However, it is possible to observe a unique polarity of elve-producing flash in a given storm.

2.2. Gigantic jets in La Réunion

Five gigantic jets (GJ) have been recorded at close distance of observation (~ 50 km) with video and photograph cameras on 7 March 2010, above an isolated tropical storm east of Réunion Island. The luminosity within the cloud and of the events was analyzed in unprecedented detail. The tops of the

GJs were estimated between 80 and 90 km. All these GJs were accompanied by long continuous cloud illumination and they were preceded and followed by intermittent optical flashes from the cloud, most of time without any cloud-to-ground (CG) flash simultaneously detected, which suggests they originated mainly as intracloud discharges and without any charge transfer to Earth. According to ELF data, the five GJs serve to raise negative charge. All these observation confirmed the theory previously proposed to explain the mechanism of the discharge [9]. New details about the GJ structure and dynamics were provided: (i) the first phase of the GJ (leading jet) had the most variable duration (33 to 167 ms) and propagated faster at higher altitudes. (ii) The second phase (trailing jet) exhibited a continuous decrease of luminosity in different parts of the jet (lower channel, transition zone and for most events carrot sprite-like top) and in the cloud, with possible re-brightening. (iii) The lower channels (~20-40 km altitude) produced blue luminosity which decreased with altitude and became more and more diffuse with time. (iv) The transition region (around 40-65 km) consisted of bright red luminous beads slowly going up (~ 10^4 m s^{-1}) retracing the initial leading jet channels.

3. References

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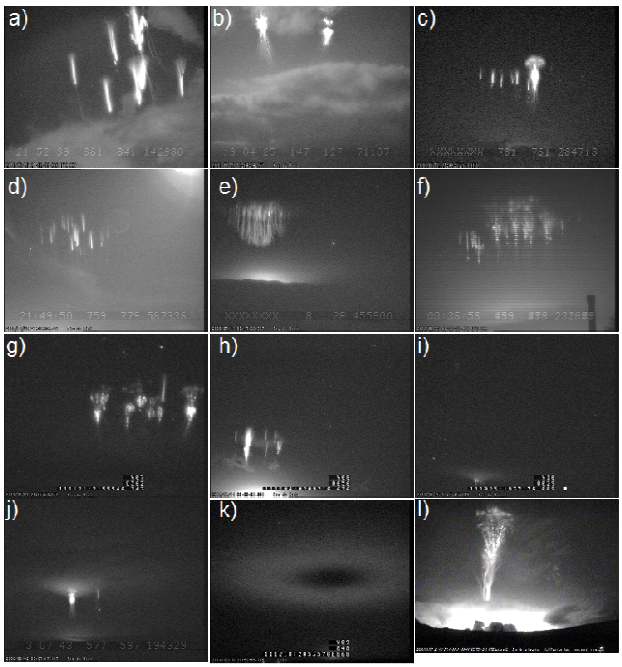

Figure 1. Images of TLEs in 20-ms frames issued from video imagery: a) Column sprite elements above a storm at about 150 km from the camera. b) Carrot sprites at a different development stage, triggered by the same CG flash located at about 200 km from the camera. c) Group of column sprite elements with a jellyfish sprite in the foreground (~ 300 km from the camera). d) Group of column sprites at about 300 km from the camera. e) Group of sprite elements with very developed tendrils (at 320 km from the camera). f) and g) Kind of dancing sprites (at 190 and 260 km from the camera, respectively). h) Group of circular-organized and bended sprite elements (at 380 km from the camera). i) Remote carrot sprite with halo (880 km from the camera). j) Carrot sprite centred below a halo and column element (390 km from the camera). k) Elve above a CG flash located at 340 km from the camera. l) Gigantic jet at the fully developed stage (~ 50 km from the camera in Reunion Island).