Journal of Atmospheric and Solar-Terrestrial Physics 129 (2015) 1–5

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Long-delayed bright dancing sprite with large Horizontal displacement from its parent flash

Jing Yang [a,b,*], Gaopeng Lu [a,b], Li-Jou Lee [c], Guili Feng [d]

[a] Key Laboratory of Middle Atmosphere and Global Environment Observation (LAGEO), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China
[b] Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science & Technology, Nanjing 210044, China
[c] Department of Physics, National Cheng Kung University, Tainan, Taiwan
[d] Shandong Research Institute of Meteorology, Jinan 250031, China

ARTICLE INFO

Article history:
Received 30 January 2015
Received in revised form
3 April 2015
Accepted 4 April 2015
Available online 6 April 2015

Keywords:
Dancing sprite
Radar reflectivity
Lightning evolution
Magnetic field

ABSTRACT

We reported in this paper the observation of a very bright long-delayed dancing sprite with distinct horizontal displacement from its parent stroke. The dancing sprite lasted only 60 ms, and the morphology consisted of three fields with two slim dim sprite elements in the first two fields and a very bright large element in the third field, different from other observations where the dancing sprites usually contained multiple elements over a longer time interval, and the sprite shape and brightness in the video field are often similar to the previous fields. The bright sprite was displaced at least 38 km from its parent cloud-to-ground (CG) stroke and occurred over comparatively higher cloud top region. The parent flash of this compact dancing sprite was of positive polarity, with only one return stroke (approximately +24 kA) and obvious continuing current process, and the charge moment change of stroke was small (barely above the threshold for sprite production). All the sprite elements occurred during the continuing current stage, and the bright long-delayed sprite element induced a considerable current pulse. The dancing feature of this sprite may be linked to the electrical charge structure, dynamics and microphysics of parent storm, and the inferred development of parent CG flash was consistent with previous very high-frequency (VHF) observations of lightning in the same region.

1. Introduction

Transient luminous events (TLEs) are brief light emissions that could be observed over both summer and winter thunderstorms (Lyons, 1996). So far, the known types of TLEs include sprite, elves (Emissions of Light and VLF perturbation due to EMP Sources), halos, blue jet/blue starter, and gigantic jet. Among the TLE family, sprites are most commonly observed in ground-based observations, and most sprites fall into the shape of column or carrot. In addition to columniform or carrot-shape sprites, dancing sprites (Lyons, 1994, 1996; Winckler et al., 1996; Hardman et al., 2000) were occasionally documented. An obvious feature of dancing sprites is that sequential sprite elements often appear horizontally displaced from the preceding elements and the location of the sprite cluster center changed. Since dancing sprites jump above the storm, they can span a large horizontal distance, and the events in some observations even reach up to 200 km (e.g., Lyons, 1996; Winckler et al., 1996).

Early observations of dancing sprites have been reported by Lyons (1994, 1996), Winckler et al. (1996) and Hardman et al. (2000). Recently, the comprehensive analysis of several dancing sprites in the central United States have been reported by Lu et al. (2013), and the results show that dancing events associated with a single flash could be produced either by distinct cloud-to-ground (CG) strokes of the flash, by a single CG stroke through a series of current surges superposed on an intense continuing current, or by both; the displacement of sprite element from the parent stroke is because of that the charge removed by individual strokes is often from a displaced cloud region. It has also been suggested that the horizontal displacement could be connected to the local plasma inhomogeneity in the lower ionosphere (Qin et al., 2014). Nevertheless, in comparison with tens of thousands of columniform or

* Corresponding author at: Key Laboratory of Middle Atmosphere and Global Environment Observation (LAGEO), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China. Fax: +86 10 82995115.
E-mail address: yangj@mail.iap.ac.cn (J. Yang).

http://dx.doi.org/10.1016/j.jastp.2015.04.001
1364-6826/

carrot-shape sprites that have been documented (e.g., Lyons et al., 2003; Lu et al., 2013), dancing sprites are relatively infrequent although they might act as a unique agent to study the electrodynamic coupling between troposphere and mesosphere. In this paper, an unusual dancing sprite was fortunately captured in north China, and the detailed comprehensive analysis of the parent storm and associated lightning activity is reported by using multidisciplinary data from Doppler radar, lightning location network, and ultra-low frequency (ULF) magnetic field sensor. Relationship between sprite dancing property and storm characteristics, parent CG discharge process is examined.

2. Observations and data

In order to investigate the TLEs and their parent storms and lightning discharges, TLEs observation has been conducted in mainland China since 2007 (Yang et al., 2008). In 2012, another TLE station was installed in Dongying, Shandong province. The camera used in this station is a Watec 902H2 Supreme low-light-level video camera (equipped with a Computar 12-mm/F0.8 lens) with minimum illumination of 0.0003 lx. The observation system can record the static images at a rate of 25 frames/s. Two kinds of lightning location networks are used to provide lightning characteristics. One was provided by Shandong Province Lightning Detection Network, which consists of 10 very low-frequency/low-frequency sensors and one data processing center, and uses the combined time-of-arrival (TOA) and magnetic-direction-finding (MDF) technology (e.g., Cummins et al., 1998). Data from this network were used for characterizing the lightning activity in the storm of particular interest. Additional lightning data are obtained from the World Wide Lightning Location Network (WWLLN), which were used for real time locating the center of electrical activity and for determining the pointing azimuth of camera.

In addition to lightning location networks, the magnetic field data obtained at Lulin Observatory have been used to identify the polarity of parent lightning. The magnetic ultra-low frequency (ULF) station (0.3–500 Hz) of National Cheng Kung University (NCKU) is located at the Lulin Observatory, which is on the central mountain ridge of Taiwan. The system consists of a pair of EMI-BF4 magnetic induction coils to record the horizontal magnetic field emitted by the source discharges (Lee et al., 2012). The coil orientations are parallel and perpendicular to the geomagnetic field. The recorded signals can be used to infer the polarity of lightning discharges, the vertical current moment and the time-integrated charge moment change (CMC) of TLEs and lightning (Huang et al., 2011). The thunderstorm evolution and structure are given by Doppler radar data. The radar has two scanning ranges, 230 and 460 km (a resolution of 1 km is obtained with a scanning range of 230 km). The radar image is updated every 6 min.

3. Results

3.1. Features of dancing sprite

During the storm evolution, a total of three sprites have been captured. The first two sprites were recorded at 00:23:24 (it was a negative one and will be reported in another study) and 00:27:33 on 5 August 2012 (Beijing time). The third sprite occurred at about 01:21:33, almost one hour after the first two sprites; this sprite includes three fields and its first two fields were very dim elements (as shown in Fig. 1a and b), but the third field was very bright (shown in Fig. 1c) and displaced horizontally from first two elements. This sprite morphology was defined as dancing events by Lyons (1996) and Hardman et al. (2000).

The dancing sprite in this paper was unusual in several aspects. It lasted three fields and the total duration was only about 60 ms, much shorter than that (about 200 ms) reported by Hardman et al. (2000). This dancing event consisted only three elements, less than results obtained by Lu et al. (2013), and even less than the cases (sprite may contain >30 elements) reported in Hardman et al. (2000). The dancing sprite analyzed in detail by Hardman et al. (2000) consisted of at least >10 elements. On the other hand, the shape and brightness of preceding sprite elements in Fig. 1a and b are substantially different from that shown in Fig. 1c. However, the dancing sprite elements in previous studies usually have similar shape and brightness, as shown by an example in Fig. 9 of Hardman et al. (2000), which is different from the case reported in this study. Sprite elements in Fig. 1a and b did not change their location during evolution. The bright sprite in Fig. 1c was clearly displaced from two previous fields and was much brighter and closer to the observation site.

The parent CG for the dancing event was unambiguously registered by both of the local lightning location networks and ULF magnetic field sensor at Lulin Observatory (23.4686°N, 120.8736°E). The parent CG location, obtained by local lightning location network, was about 38.33°N, 117.50°E, almost north of the magnetic field sensor. The distance between the parent CG and the observation site was only about 145 km, and the image shows that a large portion of the dancing event was not captured by the camera. In addition, the bright sprite occurred at least 38 km away from its parent flash. The horizontal displacement between the bright sprite and the parent CG would be 43 and 90 km, respectively, assuming that the sprite occurred at the two ends (intersections between Lines L1, L2 and sprite azimuth shown in Fig. 2a) along the sprite azimuth. On the other hand, since there is only one station in the observation, and the dancing event could not be triangulated, the horizontal displacement between the bright element and its adjacent dim element would be at least 6 km based on the 2D image. It should be noted that the actual displacement may be larger than 6 km in three dimension.

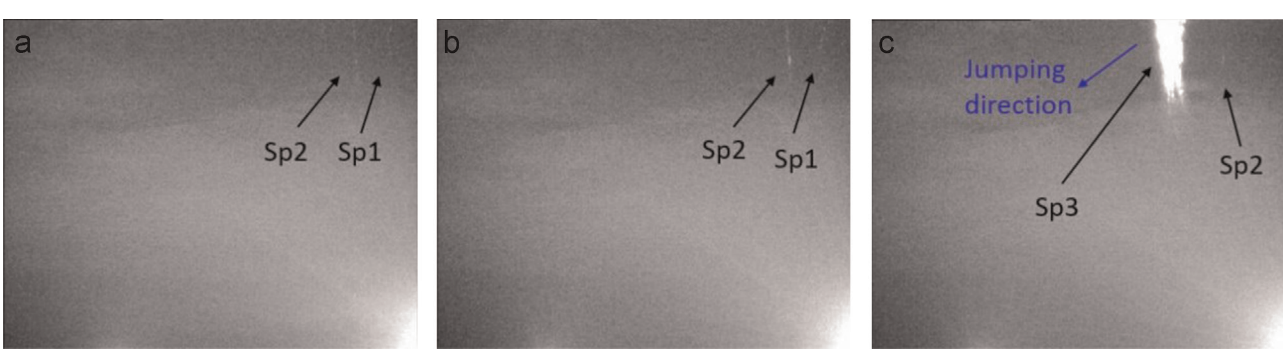

Fig. 1. Sequential images of the dancing sprite recorded on the early morning of 5 August 2012.