

First observations of transient luminous events in Indian sub-continent

Initial observations of optical flashes above thunderstorms were sparsely reported in the late 19th century. But it was in the beginning of 20th century that possibility of discharges above a thundercloud at high altitudes was postulated by Wilson¹ based on electric field computations due to the residual charges of the cloud just after a positive cloud-to-ground (+CG) lightning discharge. But it was after 65 years, Wilson's proposition was confirmed with the observations of spectacular optical flashes above thundercloud accidentally by Winckler group² while testing experimental low-light television camera (LLTV) on one dark night. The observation attracted global attention and initiated experimental and theoretical studies in this area as these discharges electrically connected lower atmosphere to ionosphere and were considered as important contributor to global electric circuit (GEC).

Transient luminous events (TLEs) are short-lived flashes of lightning discharge observed above large thunderstorms in the stratosphere and mesosphere regions of Earth's atmosphere. TLEs depending on their geometrical shape and luminosity are mainly classified as: Sprites, Halos, Blue Starters, Blue Jets, Gigantic Jets, Elves, etc. These optical emissions above thunderstorms are considered very energetic and more powerful than terrestrial lightning discharges. Studies in this field are being carried out since the last two decades but despite much advancement in technology and scientific understanding many questions still remain unanswered. During the last two decades ground and aircraft campaigns were carried out across the globe especially in USA, Australia, Japan, Taiwan and Europe and a large number of events concerning TLEs have been identified and studied. On the global scale the Indian subcontinent is the part of tropical regions in the world, where two of every three lightning flashes occur and make this region an important location for TLEs observations. But studies on TLEs generated by Indian thundercloud system are lacking mainly because of two reasons: (1) Belief that thunder clouds over Indian subcontinent do not form Mesoscale Convective Systems (MCSs) which are proposed to produce TLEs and (2) absence of proper TLEs observation

facilities in India. To fill this gap under the collaboration between the Indian Institute of Geomagnetism (IIG) and DTU Space Denmark, the first TLEs monitoring camera system was setup in 2011 by IIG. The setup is also an integral part of global facility to provide simultaneous ground-based observations support to DTU Space led Atmosphere-Space Interactions Monitor (ASIM) payload for the International Space Station and French microsatellite Tool for the Analysis of RADIation from lightNING and Sprites (TARANIS) scheduled to be launched in 2016.

Here we report the first 'Sprites' observed in the Indian subcontinent on 11 April 2012. The optical measurements were conducted at Allahabad (lat. 25.4°N, long. 81.9°E) over the thunder clouds of Indo-Gangatic plain. The TLEs camera system uses two low-light sensitive charge-coupled device (CCD) camera systems³. Two monochromatic CCD cameras are used: one with 16 mm F/1.4 wide angle, horizontal field of view (FOV) of 26.5° and the vertical field of view: 15° for event detection and recording. The second camera consists of a 25 mm F/0.95 narrow angle: horizontal FOV of 7.25°, vertical field of view: 4.8° for high resolution event recording. The cameras are mounted in weather proof housing on top of a QuickSet 20 motorized Pan-Tilt unit which allows for the pointing of the cameras within 360° of

azimuth (also known as pan) and from -35 to +35 degrees of elevation (tilt). The camera frame rate is 250 frames/sec. Both camera systems can be remotely controlled via the internet and also includes trigger software for automatic optical event detection and an automatic event detection algorithm to reduce the amount of data. The digitized video files are time-stamped using GPS unit providing 1-pulse-per-second (PPS) signal was used to ensure high precision time stamping of the data. More details about the TLE observation setup can be found in ref. 3.

On the night of 11 April 2012 at 22:48:53.823 UT, the first 'Sprite' events were recorded in Indian region above the thunderstorm (~35 km above the ground in the stratosphere) (Figure 1) located around (87°E, 24.5°N) ~220 km south east of Allahabad (25.4°N, 81.9°E) (Figure 2). The lightning activity (red dots) \pm 5 min at 22:48:53.823 UT which produced the sprites is shown in Figure 2. This observation is important as it opens new questions about the generation of sprite and related phenomena as well as characteristics of Indian thunder clouds; previously it was thought that because of low energy associated with lightning discharges and absence of MCSs in Indian thunder clouds TLEs cannot be generated and observed. The lightning dataset used in the present observation to understand the characteristic



Figure 1. First optical image of sprites observed on 11 April 2012 at 22:48:53.823 UT.

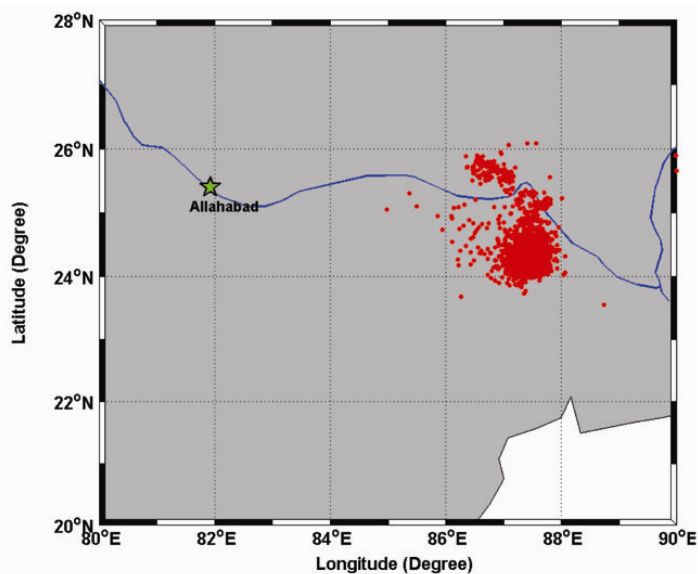


Figure 2. TLE ground observing station at Allahabad (green star) and lightning discharge locations using GLD360 data (red dots) at ± 5 min of 22:48:53.823 UT which produced the sprites of 11 April 2012.

of sprite associated lightning discharge is from Global Lightning Detection 360 (GLD360) network. GLD360 is a network of VLF receivers across the globe, measuring both time of arrival and direction of incoming sferics⁴.

Sprites are widely observed/studied phenomena among the TLEs originating in the stratosphere/mesosphere (~ 40 to 80 km altitude) and extending upwards towards the lower edge of the ionosphere and sometimes downwards into the stratosphere below. They appear like pinkish red luminous columns, more often in carrot-shaped with bundle of filaments, stretching from ~ 40 to 80 km altitude having width less than one km with duration of 5–500 ms (ref. 5). TLEs are usually generated over thunderstorms with MCSs. MCSs are characterized by laterally extensive regions of stratiform precipitation with a total area larger than 10^4 sq. km, which is usually more than an order of magnitude greater than the area of an ordinary thunderstorm⁶ such as over Indian regions. Sprites are predominantly generated by electric field pulse traveling up-ward towards the ionosphere from a +CG lightning strokes possessing large charge moment changes. Sprite resembles closely with the lightning return stroke as both have energies of few electron volts; hence

sprites are also known as high altitude lightnings⁵.

TLEs research has forced scientist to revise the present understanding of electrical process in the atmosphere. Scientists now suggest towards possible connection of TLEs with weather and climate, as the lightning discharges producing TLEs may also cause heating and ionization by depositing significant amount of energy into the overlying neutral atmosphere/ionosphere, therefore leading to conductivity enhancements. TLEs induced perturbation in the ionosphere is widely studied with the use of VLF transmitter generated narrowband VLF signals propagating in the earth-ionosphere wave guide (EIWG)⁷. IIG operates network of three VLF stations in India⁸ which are serving as complementary supporting observations for the studies of TLEs in Indian region. TLEs are also thought of affecting GEC and may be responsible for maintaining it up to certain extent. Possible contribution of TLEs in GEC is the subject of ongoing studies.

TLEs have special significance in Indian scenario, their observation and detailed study will help in characterizing Indian thunderstorms, contribution to GEC and other related meteorological phenomenon. The observed sprite has

open new window for TLEs research in India and quest for observing other TLEs such as Elves, Blue Jets, Gigantic Jets, etc. Since the observation of first TLE on 11 April 2012, continuous observations have been made on more sprites events in India. The results will be reported elsewhere.

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Received 28 March 2014; accepted 9 August 2014

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