Nadir Observation of Lightning and TLEs by JEM-GLIMS

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JEM-GLIMS is a space mission to observe lightning and TLEs with a nadir view from the international space station, and it consists of two optical instruments and two radio wave receivers. JEM-GLIMS was successfully launched and installed at the exposed facility of the Japanese experiment module (JEM) and started continuous observation from Nov. 20, 2012. So far, it succeeded in detecting 3,130 transient optical emissions originated in cloud-to-ground (CG) and intra-cloud (IC) discharges. It is identified that some of these events are clearly related with TLEs. Global distribution of the lightning events detected by JEM-GLIMS shows clear seasonal variation, which is comparable to the lightning distribution derived from OTD and LIS observations. JEM-GLIMS also succeeded in detecting fireball emissions by camera and photometers. Examples of the observed lightning, TLEs and fireball events will be introduced.

1. Introduction

One of the issues to be solved in the sprite studies is the mechanism determining the horizontal spatial distribution of sprite bodies, which is the "occurrence condition" of sprites. Up to now, various possibilities to answer this are introduced and discussed [1][2][3][4][5], but it still remains an unsolved problem. Though it is essential to estimate the horizontal distribution of sprites observationally and to identify the relation to the parent lightning discharges, it is not easy to do because of the low feasibility to carry out the multipoint simultaneous observation of sprites due to the limitation of the geographical and weather conditions and to perform triangulation analysis. Thus, it is essential to carry out the nadir observation of sprites from space globally and to identify the spatial distribution and temporal evolution of sprites. For this purpose, we planned a space mission to observe lightning and TLEs from the international space station (ISS), which is named as JEM-GLIMS (Global Lightning and sprIte MeasurementS on Japanese Experiment Module) [6].

2. JEM-GLIMS Instruments

JEM-GLIMS instruments consist of two types of optical instruments (LSI, and PH), two types of radio wave receivers (VLFR and VITF) and an onboard data processing unit (SHU) [7][8][9][10]. LSI (lightning and sprite imager) has 33 ms time resolution and 28.3°×28.3° field-of-view (FOV), which becomes 400m×400m and 320×320m spatial resolution at the ground surface and 80 km altitude, respectively. LSI-1 and LSI-2 equip a wide band (766-832 nm) and narrow band (762 ± 7 nm) optical filter. PH (spectrophotometer) consists of six channel photometers measuring the emission of N_2 1P, 2P, LBH and N_2^+ 1N bands. Five of six PH channels have 42.7° FOV, and the other PH channel has 86.8° FOV. The absolute intensities of the emission are recorded with 20 kHz sampling frequency with a 12-bit resolution. VLFR (VLF receiver) consists of a 15 cm monopole antenna and an electronics unit recoding waveform data with 100 kHz sampling rate with 14-bit resolution. VITF (VHF interferometer) consists of two patch-type antennas and an electronics unit recording VHF waveform with 200 MHz sampling frequency with 8-bit resolution. JEM-GLIMS was successfully launched on June 2012 and installed at the JEM exposed facility. After the initial checkout operation, we started the continuous observation of lightning and TLEs since Nov. 20, 2012.

3. Summary of JEM-GLIMS Lightning Events

In the period from Nov. 20, 2012 to Jan. 31, 2014, totally 3,131 lightning events including TLEs were detected by JEM-GLIMS. From a global map of these events it is clear that most of the events were detected over Central America, Africa, and South-East Asia. We have estimated the seasonal distribution of the detected events and found that the most of the lightning events were detected in the

local summer hemisphere. All these facts are well comparable to the lightning distributions derived from OTD and LIS measurements.

4. Optical Properties of CG, IC Discharges

JEM-GLIMS detected the optical flashes emitted by not only IC discharges but also CG discharges. It is found that the optical properties of these flashes are quite different according to the LSI image data and PH light-curve data. In the CG events, optical emission starts weak glow emission lasting for a few tens of ms, which may be related with the preliminary breakdown (PB) in the cloud [11][12]. Then, intense flash with a following exponential decay occurs, which is related with the return stroke. In some cases, gradual glow emission with a few tens of ms follows the return stroke flash, which may be related with in-cloud discharges. On the other hand, in the IC discharge events multiple flashes occurring within 10 ms are measured typically. The light-curve of these multiple flashes closely resembles the waveforms measured by electric field antenna, such as fast antenna.

In this analysis, ELF waveform data are used to identify the discharge type (*i.e.*, CG or IC) for the GLIMS lightning events. However, the estimation of the intensity ratio between GLIMS PH channels enables us to distinguish the discharge type by itself as suggested by T. Adach [13]. This analysis will lead detailed latitudinal

5. Optical Properties of TLEs

As reported in the previous papers, TLEs can radiate strong FUV emission (N_2 LBH) [14][15]. Though lightning discharge may also radiate FUV emission, such emission will be perfectly absorbed by the atmosphere and will not reach the ISS altitude. Thus, the optical signal at GLIMS PH1 (150-280 nm) is a good proxy of the occurrence of TLEs. In addition to this, intensity ratio between PH channels, differences of the optical shapes between LSI-1 and LSI-2 images, CMC values estimated by using ELF waveform data are the good materials to judge the occurrences of TLEs.

Transient optical event detected at 19:50:40.306 UT on Sep. 28, 2013 over central Africa is an example of a sprite event. In this event, diffuse and somewhat structured emission was confirmed in LSI-2 images, which shows different spatial and time evolution from that in LSI-1 image. The intensity ratio of ($PH2_{(337\ nm)}$ / $PH4_{(600\text{-}900\ nm)}$) and ($PH6_{(392\ nm)}$ / $PH4_{(600\text{-}900\ nm)}$) becomes ×26 and ×28, respectively. CMC value is estimated to be +1843 C·km. All these facts suggest the occurrence of sprite.

On the other hand, in the transient optical event detected at 16:26:32.807 UT on Oct. 15, 2013 over South-East Asia strong PH1 signal was detected but no emission was detected by LSI-2. This result suggests the occurrence of elves. Since elves rapidly expands in the lateral direction and has thin optical depth, it is not possible capture elves image by LSI. But, PH has enough high sensitivity rather than LSI, and it seems to be possible to detect FUV emission of elves.

6. Fireball Event

At 09:20:48.222 UT on Feb. 2, 2014, transient optical signal emitted by a fireball was detected. In the LSI image, clear trail of the fireball was confirmed, and only FUV signal was detected by PH1. Assuming that the fireball moves horizontal direction, the speed was estimated to be about 30 km/s, which is comparable to the typical meteor speed. Not only this event but also other events that seems to be related with the meteors are confirmed in the JEM-GLIMS events.

7. References

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