

Introduction to GLIMS mission

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The Global Lightning and sprItE MeasurementS (GLIMS) on the International Space Station (ISS) is a mission to detect and locate optical transient luminous events (TLEs) and its associated lightning simultaneously from the non-sun synchronous orbit, and was launched successfully in July, 2013 as part of the multi-mission consolidated equipment on Japanese Exposure Module (JEM). Our mission goals are to identify temporal and spatial evolutions of lightning and TLEs and to clarify the occurrence conditions of TLEs and global occurrence locations and rates of TLEs from the nadir observation. To achieve these goals, two CMOS cameras, six Photometers, VLF receiver, and VHF interferometer with two antennas, are installed at the bottom of the module to observe the TLEs as well as causative lightning discharges at nadir direction during day and night time. Though the luminous events so-called sprite, elves and jets have been investigated by numerous researchers all over the world based mainly on the ground observations, some important problems have not been fully understood yet such as generation mechanisms of columniform fine structure and horizontal offset of some sprites from the parent lightning discharges. In the JEM-GLIMS mission, observations from our synchronized sensors are going to shed light on above-mentioned unsolved problems regarding TLEs as well as causative lightning discharges.

The optical instruments are two CMOS cameras (LSI-1, LSI-2) and six-channel spectrophotometers (PH1 - PH6). The FOV of LSI is 28.3 deg. x 28.3 deg., and LSI-1 (LSI-2) equips a 766-832 nm wide band filter (a 762+/-7 nm narrow band filter). Each PH channel equips the optical band-pass filter, and these photometers measure the N2 1P, N2 2P, N2 LBH, and N2+ 1N emissions of lightning and TLEs. The radio receivers consist of one VLF receiver (VLFR) and two sets of VHF receivers (VITF). In order to detect TLE-associated whistler waves, VLFR employs a nadir-directing monopole antenna and an electronics unit recording waveform data with a sampling frequency of 100 kHz with 14-bit resolution. VITF consists of two patch-type antennas separated by 1.5 m and an electronics unit, and VITF mainly observes VHF pulses in the frequency range of 70-100 MHz excited by lightning discharges with a sampling frequency of 200 MHz with 8-bit resolution.

JEM-GIMS was successfully launched and transported to the ISS by the H-II Transfer Vehicle (HTV) No.3 cargo transporter at the end of July 2012, and started its operation from December 2013. So far, more than one thousand events were recorded. In this presentation, mission history and overview will be given as an introduction.

Keywords: Lightning, Sprite, ISS

Estimating lightning characteristics by spaceborne spectrophotometric observation

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The present study analyzes satellite optical data to evaluate the effectiveness of spaceborne spectrophotometric measurement in characterizing properties of lightning flash. The main data analyzed here are those obtained by FORMOSAT-2/ISUAL limb observation and ISS/GLIMS nadir observation. While ISUAL spectrophotometer observes optical emissions of 150-280, 316, 337, 392, 762, 600-900 nm at a sampling rate of 10 kHz, GLIMS observes emissions of 150-280, 337, 762, 600-900, 316, 392 nm at a rate of 20 kHz. These data for the first time derive fine spectral and temporal properties of lightning emission observed from space. By analyzing the ISUAL optical data and ground-based radio data, we found that spectral intensity ratio is a new parameter to discriminate intra-cloud (IC) and cloud-to-ground (CG) lightning discharges: the blue/red intensity ratio of CG strokes tends to be lower than that of IC pulses. We also found similar tendency in GLIMS lightning events. A case study showed that the color of lightning turned to red when a very bright impulsive emission, which is consistent with a ground return stroke, occurred. These results consistently suggest that the color of CG component is redder than that of IC component, and we explain this as a result of the Rayleigh scattering which effectively attenuates blue light emissions in the case of light sources located at lower-altitudes such as CGs. Using this technique, we will further examine the lightning characteristics on a global level, focusing on latitudinal dependences and land/ocean contrast for example.

Keywords: lightning, CG, IC, satellite, remote sensing

VLF subionospheric disturbances and electrical properties of lightning discharges observed by JEM-GLIMS mission

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In this paper we report the preliminary results of ionospheric perturbation and causative lightning discharges observed by JEM-GLIMS mission to study the electromagnetic coupling mechanism between the tropospheric lightning and overlaying ionosphere. Continuous nadir optical observations of lightning discharges are performed by ISS JEM-GLIMS mission and many lightning images have been observed globally. Ionospheric perturbations and electrical properties of causative lightning discharges such as polarity and vertical charge moment changes are derived by the data from UEC's ground-based observation networks of VLF/LF transmitter signal reception and of ELF waveforms respectively. We discuss the electrical coupling efficiencies from the tropospheric lightning to the ionosphere by comparing the area of the lightning flash and corresponding subionospheric VLF disturbances and lightning properties.

Keywords: Transient Luminous Events, lightning discharges, GLIMS, ionospheric perturbation, charge moment

The building of multipoint measurement network for observing electrostatic field changes caused by lightning discharge

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It's not easy to understand the developing process of thunderstorm only with existing meteorological measurements because of its small spatial scale (less than an order of 1 km) and rapid change of the complicated structure. Electrostatic field under the thundercloud or its predecessor reflects the distribution of electrical charges, which is the result of frictions between ice crystal and hail due to strong vertical wind inside the thundercloud. If we measure the vertical electric field at multipoints on the ground, we could estimate the 3 dimensional distribution or the changes of the distribution of electrical charges, from which we may know the detailed development of thunderstorm. The traditional equipment for atmospheric electrostatic field measurement is field-mill sensor, which costs an order of 1 M JPY. In order to increase the number of observing stations, we should reduce the price of the instrument. Here we introduce a thunderstorm observation campaign, carried out in mountain area of Yamanashi prefecture, August 2013. We developed new plate-type electric field sensor, which costs about 0.2 M JPY or less including recording device and battery for one site. This sensor was placed at seven locations in every 4 km with recording system and GPS clock. As a result, we succeeded to record the electrostatic field changes at the same time in multi points, which occurred due to lightning strikes for three days.

Keywords: lightning discharge, electrostatic field, multipoint measurement

Preliminary results of global lightning study by the DEMETER satellite

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We investigate statistical property of global lightning activity by means of the DEMETER satellite. The DEMETER satellite which was launch by CNES, France, was operated from 2004 to 2010. In the study, we use electric field data to measure Whistler waves generated by lightning. In this presentation, we show preliminary results of this study.

Keywords: Ionosphere, Lightning, Whistler waves

VHF lightning observations by digital interferometry on JEM-GLIMS

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Global Lightning and sprfTe Measurements (GLIMS) mission is now ongoing on Exposed Facility of Japanese Experiment Module (JEM-EF) of the International Space Station (ISS). This paper focuses on an electromagnetic (EM) payload of JEM-GLIMS mission, very high frequency (VHF) broadband digital InTerFerometer (VITF). JEM-GLIMS mission is designed to conduct comprehensive observations with both the EM and the optical payloads for lightning activities and related transient luminous events (TLEs) expecting to give us many scientific impacts to the field.

VITF consists of two sets of antennas, band-pass filters, amplifiers, and 2-channel-AD-converter. Impulsive EM radiations received by the antennas are digitized by the AD converter synchronizing with another channel through the filters and the amplifiers. A patch type antenna is developed within the size of 200*200 mm. It is mounted on the antenna base made of aluminum alloy and Teflon block with the total height of 100 mm to gain its bandwidth and to reduce the interference from other structural objects. The same two units of antennas are installed with the separation of 1.6 m. Their bandwidths with the higher return loss than -3 dB are from 70 to 100 MHz. The signals received by the antenna are transmitted along cables with the same lengths to the electronics. The AD converter records 130 waveforms as maximum of one dataset with the duration of 2.5 μ s with 200 MS/s. The developments of VITF are based on the heritage of VHF sensor on Mado-1 satellite.

JEM-GIMS mission payload was successfully launched at the end of July 2012, and transported and installed to the ISS. After the initial checkout and maintenance, its nominal operation is continued from December 2012. Through the operation period, VITF corrects numerous VHF EM data synchronized with optical signals. About 650 VITF datasets were obtained in January and February 2013, for instance. The estimations of the EM direction-of-arrival (DOA) are attempted using the broadband digital interferometry. Some results agree with the optical observations, even though DOA estimation has difficulties caused by its very short baseline of the antennas and multiple pulses in short time, namely burst-type EM waveforms. VITF is designed expecting to estimate the DOA with about 10 km resolution that is equivalent to the scale of a thundercloud. The results on narrow bipolar pulses (NBPs) and/or transionospheric pulse pairs (TIPPs) are also expected as well as TLEs. The recorded VHF EM signals and the results of their DOA estimations, and the comparisons with optical observations will be introduced in the presentation.

Keywords: lightning, VHF radio observations, GLIMS, International Space Station