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PEM07-01 会場:213 時間:4 月 30 日 14:15-14:30

# Introdution to GLIMS mission
# Introdution 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 lighting 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 lighting 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 introdution.

キーワード: 雷放電, スプライト, 宇宙ステーション
Keywords: Lightning, Sprite, ISS

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# 宇宙からの多波長光学観測による雷放電特性の推定
# 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

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PEM07-03 会場:213 時間:4 月 30 日 14:45-15:00

# JEM-GLIMS 搭載の LSI カメラにより撮像されたスプライトの空間分布
# Horizontal Distributions of Sprites Mesured by Lightning and Sprite Imager Onboard JEM-GLIMS

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Sprite is a transient discharge phenomenon occurring in the mesosphere and lower thermosphere and is mainly excited by positive cloud-to-ground (CG) discharge. Various studies of the sprite occurrences have been performed by numerical simulations and optical observations from ground and airplanes. However, the physical mechanism determining the horizontal distribution of sprite is not clear so far. Recent studies suggested that an activity of the in-cloud discharges preceding a return stroke of a CG discharge would have a severe impact on the determination of the horizontal distribution of sprites. In order to clarify this, it is essential to carry out nadir observations of lightning discharges and sprites from the space.

JEM-GLIMS is a space mission to carry out nadir observation of lightning discharges and sprites from International Space Station (ISS) and started continuous observations from November 20, 2012. In this mission, lightning and sprite emissions can be measured by Lightning and Sprite Imager (LSI), which consists of two CMOS cameras and captures images at a difference wavelength. A wide-band camera named LSI-1 is equipped with an optical filter whose pass-band ranges from 740-830 nm and observes mainly lightning emission, while a narrow-band camera named LSI-2 is equipped with an optical filter whose central wavelength of 762 nm with 10 nm FWHM and observes mainly sprite emission since the lightning emission at 762 nm would be severely absorbed by oxygen molecules in the atmosphere. A spatial resolution of LSI is about 300 m/pix at the 70 km altitude. Then, it is possible to detect the emissions of a columniform sprite whose horizontal scale is a few km typically. In JEM-GLIMS mission, there are also six-channel spectral photometers (PH). One of these PH channels measures UV emission at 150-280 nm, which becomes a good proxy of the sprite occurrence since the UV emission of lightning discharges would be severely absorbed. We have chosen 76 events of transient optical emission captured by LSI and PH. For the purpose to distinguish weak sprite emission from strong lightning emission, we have developed an image subtraction method using LSI-1 and LSI-2 image data. Using this method, we have analyzed 76 events and succeed in detecting sprite emission and clarifying the horizontal distribution of sprites. At the presentation, we will show the characteristics of the horizontal distribution of sprites and their parent lightning discharges more in detail.

キーワード: スプライト
Keywords: sprite, JEM-GLIMS

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# JEM-GLIMS 光学機器で観測されたスプライト・エルブスの特徴
# Characteristics of Sprites and Elves Measured by JEM-GLIMS Optical Instruments

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JEM-GLIMS is a space mission to observe lightning and lightning-associated Transient Luminous Events (TLEs) from the International Space Station (ISS). The main goal of this mission is to identify the spatiotemporal relationship between TLEs and their parent lightning discharges based on the nadir optical and electromagnetic observations of JEM-GLIMS. For this purpose JEM-GLIMS equips two sets of optical instruments (LSI: CMOS camera, and PH: spectrophotometers) and two sets of radio wave receivers (VLFR: VLF receiver, and VITF: VHF interferometer). As all these instruments are installed at the bottom plane of the bus module facing to the Earth, JEM-GLIMS can carry out the nadir observations continuously. JEM-GLIMS was launched by HTV3 and was successfully installed at the exposed facility of the Japanese Experiment Module (JEM) on August 9, 2012. After the initial checkout operations, JEM-GLIMS finally started continuous observations on November 20, 2012. In the period from November 20, 2012 to January 31, 2014, totally 3,130 transient optical events related to lightning flashes and/or TLE emissions were detected by the optical instruments. In 1,062 of these events, both LSI and PH detected clear transient optical signals well above the noise level. In order to derive sprite events from the detected transient optical events, we analyzed PH light-curve data and estimated the intensity ratio between PH channels. We also analyzed LSI image data to clarify the morphological properties of the optical emission. In a transient optical event detected at 19:50:40.306 UT on September 28, 2013, the intensity ratio between PH2 (337 nm) and PH4 (600-900 nm) and between PH6 (392 nm) and PH4 were estimated to be 26 and 25, respectively. This fact implies that the light sources exist not only in the troposphere but also in the mesosphere. At the image data obtained by the narrow-band filter camera (LSI-2), transient optical emission whose shape differs from the lightning emission was confirmed. Thus, we attributed the transient optical emission in LSI-2 image to sprite streamers. At the presentation, we will show the results derived from LSI and PH data analysis and the charge moment change (CMC) of the parent lightning discharges derived from ELF magnetic filed waveform data and will discuss the spatial and temporal characteristics of sprites more in detail.

キーワード: スプライト, 雷放電, 国際宇宙ステーション
Keywords: Sprite, Lightning, International Space Station

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# 冬季スプライトと親対地雷の発生位置の差異について
# Displacement between Winter Sprites and Parent Could-to-Ground Lightning

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A various investigation of sprites, one of frequent observable transient luminous events (TLEs), has been reported. Sprites are induced from mesosphere to lower ionosphere by a strong electric field attributed to the neutralization of a large amount of positive charges at the upper part of thunderstorm when cloud-to-ground (CG) lightning occurs. Many papers have implied that the complex physics of sprite-induced CG lightning, namely parent CG lightning, causes various morphologies and lifetime of sprites and the time delay of sprite occurrence, which have been some of unsolved issues in the TLEs studies. In addition, the major issue might be the large horizontal displacement between the center of sprites and the observed parent CG lightning, which often reaches 50 km. On the other hand, sprites occur just above the luminous center of parent CG lightning from satellite observations. It is expected that the luminous center of parent CG lightning over the thunderstorm is equivalent to the horizontal position of positive charges at the upper part of thunderstorm. Few study, however, discusses the horizontal discrepancies among the center of sprites, the luminous center of parent CG lightning over the thunderstorm, and the observed strike point of the parent CG lightning. Thus, we investigate the discrepancies among them through an optical measurement, assuming that the position of positive charges at the upper part of thunderstorm is the luminous center of parent CG lightning over the thunderstorm.

We conducted sprite observation campaign from December, 2012 to February, 2013. Low light CCD cameras were deployed at Tokyo and Shizuoka prefecture to observe the sprites above the Sea of Japan near the west coast of Japan. During the campaign, more than 50 events were captured. We analyzed the horizontal difference between sprite and lightning flash from CCD cameras records. Parent thunderstorm and CG positions are investigated by radar echo and several lightning location system, respectively. In particular, six sprite events were observed simultaneously in Tokyo and Shizuoka, which gave the location of sprites. From the observations, we found that the most of lightning flash center was located under the center of sprites but the reported CG location differed from them. In the presentation, we propose a plausible model to explain such discrepancy.

Keywords: Sprite, Lightning, TLEs

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# 航空機観測に基づくスプライトストリーマの三次元空間分布及び立体構造
# patial and Temporal Evolution of Sprite Streamers Derived from High-Speed Camera Data in Aircraft Observation Campaign

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the discovery of sprites. Though the detailed three-dimensional spatial structures and the temporal evolution of sprite streamers are the key parameters to clarify the occurrence conditions, these spatiotemporal characteristics are not clearly identified. In order to specify the detailed spatial and temporal evolution of sprite streamers, we have conducted the optical observation campaign using high-speed cameras from two jet aircrafts in summer US. In this campaign, we succeeded to capture sprite images for 28 events by the high-speed cameras with a sampling rate over 8,000 fps at each aircraft simultaneously. Using these image data, we have performed triangulation analysis to estimate the horizontal spatial distribution and vertical extent of sprite streamers. We have analyzed two types of columniform sprites; one is the columniform sprite with a preceding dense inhomogeneous halo, and the other is the columniform sprite with a preceding dim halo or without a halo. In the later case (dim halo plus columns), the following results are identified. (1) The longer the distance between sprite columns and the parent CG becomes, the higher the bottom altitude of columns becomes. (2) The longer the distance between sprite columns and the parent CG becomes, the slower the speed of downward streamer tips becomes. These results are first clear observational evident showing the horizontal spatial gradient of the quasi-electrostatic field produced by the parent CG discharge. At the presentation, we will show the electrical characteristics of the parent CG discharges derived from CMC waveforms and will discuss the possible mechanisms determining such spatial dependences.

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PEM07-07 会場:213 時間:4 月 30 日 15:45-16:00

# 2013 年富士山山頂で観測された雷雲に関連する高エネルギー放射線
# High-energy radiation and atmospheric electric field that are observed at Mt. Fuji

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雷活動を起因とする放射線は「Relativistic Runaway Electron Avalanche (RREA) 仮説」が発生機構であると考えられている。RREA 仮説では、高エネルギー宇宙線が大気に衝突することにより、２次生成物を生じる。その２次生成物が高電場中で制動放射や対消滅をすることで、雪崩的にガンマ線が発生するという一連の過程である。本研究では、富士山で計測したガンマ線と大気電場の結果を用いながら RREA 仮説の検証を行う。

キーワード: 雷雲, ガンマ線, 富士山
Keywords: Thunderstorm, Gamma ray, Mt. Fuji

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# 落雷規模と雷雨活動の関係
# Relationship between lightning magnitudes and thunderstorm activity

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Previous studies have suggested that there is correlation between occurrence frequency of lightning and meteorological parameters, such as precipitation, radar reflectivity, and updraft of thunderstorms. However, previous studies used only the information of lightning occurrence frequency, nevertheless each lightning has a different electrical properties, such as charge moment change (CMC). CMC is a physical quantity which neutralized charge amount of lightning discharge times vertical discharge length. The negative cloud-to-ground lightning discharge (-CG) account for 90 % or more of CGs expect in winter in Japan. The CMC of most of the -CG is smaller than 100 C·km. In order to estimate the smaller CMC than 100 C·km, observation of the radiowaves in Very Low Frequency (VLF) range radiated by return stroke is required. In addition, in order to link short-term meteorological forecast and the lightning data in the future, the method of estimation of CMC in a short time with high detection efficiency is important. However, by the current lightning detection systems, which use radiowaves at a higher frequency over 100 kHz, only the peak current of stroke is estimated and the CMC cannot be derived. The purpose of this study is to establish the methods of analysis to estimate small CMC of -CG and to investigate the relationship between developing process of thunderstorm and lightning activity with information of magnitudes (CMC) of each lightning stroke. A continuous monitoring of VLF waveform in frequency range of 2 kHz — 35 kHz at three stations in Kanto region located in the range of 150 km from Tokyo, Japan, has been carried out since May 15, 2013.

The methodology to estimate peak current using waveform in VLF band, which is detectable at far distance than that in LF band was established. A new method of estimation of impulsive CMC (iCMC) with a duration of 1 ms or less without use of frequency analysis nor VLF propagation model was established. The iCMC is estimated using the duration time of electric field of groundwave identified from the VLF waveform and peak current. The detection efficiency (DE) of iCMC estimation of -CG in this study is about 72 %. The DE of VLF lightning observation system for estimation of iCMC is the highest level in the world. The relationship between iCMC and the peak current estimated from VLF data was examined. It is shown that correlation between iCMC over 20 C·km and the peak current is small ($R^2$ = 0.21), and correlation between iCMC less than 20 C·km and the peak current is high ($R^2$ = 0.69). These results suggest that iCMC cannot be estimated from the peak current for the event over 20 C·km.

Using the estimated iCMC, the relationship among a time variation of rain volume, the area size of radar echo height (nearly cloud top) more than 12 km and lightning parameters for the 3 cases was examined. The rain volume and the area size of echo height more than 12 km were calculated using the Japan Meteorological Agency (JMA) C-band radar data every 10 minutes. It is found that the absolute value of iCMC of -CG increases as occurrence frequency of -CG, the area size of the radar echo height more than 12 km and rain volume increase (i.e., with the development of thunderstorm) for the first time. It is shown that occurrence frequency of -CG shows temporal decrease in advance of the occurrence of downburst on the ground by ∼15 minutes, while the area size of radar echo height more than 12 km is continuously increasing for the first time in Japan. In addition, it is shown that -CG with iCMC smaller than 5 C·km in absolute value is dominant in the occurrence time period of the downburst. Comparing the distribution of the estimated lightning magnitudes with meteorological radar data, examples of the electrical properties of CG change according to the developing process of thunderstorm in some cases were suggested for the first time.
Keywords: lightning, charge moment change

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# AVON および日本の VLF/LF データを用いた雷 EMP に関連した D 領域電離圏変動
# Variations in the D-region ionosphere associated with lightning EMP using AVON and VLF/LF data in Japan

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It is known that the electromagnetic pulse (EMP) originated from cloud-to-ground and inter-cloud lightning discharges can couple directly into the D-region ionosphere. The conductivity in the D-region changes due to the EMP. When VLF/LF waves propagate under the disturbed D-region, the amplitude and phase or the reflection height of the VLF/LF waves varies largely. For example, 'early VLF events' show large variations in amplitude and phase and are caused by the coupling between the D-region and lightning. Early/fast events, early/slow events, and long recovery events are included in the term of 'early VLF events'. The descent (rise) of VLF/LF reflection height corresponds to increase (decrease) in electron density in the D-region. We have conducted Asia VLF observation network (AVON) in South-East Asia: Taiwan, Thailand, Indonesia, Philippines, and Vietnam since 2007. The observations consist of 5 stations in Taiwan, Thailand, Indonesia, Philippines, and Vietnam. The aim of the AVON is to monitor the lower ionosphere and lightning in South-East Asia. We observe North-South and East-West wideband magnetic components with loop antennas, a vertical broadband electric component with a dipole antenna, and amplitude and phase of narrowband LF transmitter signals with a monopole antenna. We investigate the VLF/LF perturbations associated with the lightning discharges using both the AVON data and the VLF/LF data observed in Japan. In the presentation, we show the results of coupling between the D-region and lightning using AVON data.

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# 1-100Hz 帯磁場観測と 0.1-40kHz 帯電磁界観測に基づいた落雷活動の監視
# Monitoring of lightning activity in the Maritime Continent based on radio observation in 1-100 Hz band and 0.1-40 kHz ba

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Based on measurement of electromagnetic wave radiated from lightning discharge, we can estimate location and electrical properties of each event. In the recent studies, lightning data is focused on as an effective proxy for the monitoring of thunderstorm that causes severe weather. In the previous works, occurrence of lightning discharge has been mainly used. However, recent observation indicates that there is huge lightning whose scale is more than hundreds times bigger than that of averaged one. Lightning data including ″ occurrence ″ and ″ scale ″ makes it possible to monitor thunderstorm activity quantitatively.

In this works, lightning observation network in the MC based on electromagnetic measurement in ELF and VLF band is summarized. This network is developed to estimate not only spatial distribution but also scale one of lightning discharges. We have already installed receivers in 0.1-40 kHz band at Tainan in Taiwan (23.1N, 121.1E), Saraburi in Thailand (14.5N, 101.0E), Pontianak in Indonesia (0.0N, 109.4E), Los Banos in Philippines (14.2N, 121.25E) and Son Tay in Viet Nam (21.1N, 105.5E). For ELF observation, receiver in 1-100 Hz is installed in Onagawa, Japan (38.4N, 141.5E). Data obtained by multipoint observation is synchronized by GPS receiver installed at each station.

At the presentation, we will show the initial result to derive scale distribution of based on the measurement of ELF and VLF sferics.

キーワード: 雷, ELF, VLF, the Maritime Continent, charge moment
Keywords: lightning, ELF, VLF, the Maritime Continent, charge moment

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# ELF 波動観測に基づく雷放電電流の計測
# Lightning Discharge Current Derived from ELF Magnetic Field Waveform Data

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Cloud-to-ground (CG) discharge is one of the types of lightning discharges and has strong peak current and exponential decay current typically. Since it is not easy to predict exact occurrence time and location of CG discharges, the direct measurement of CG discharge current is difficult. It is well known that CG discharges sometimes hit tall towers locating in big cities. Thus, the CG discharge current can be measured by using Rogowski coil, which can sense the induction magnetic field produced by the discharge current flowing at the tower structures. However, such Rogowski coil is generally huge, and the measurement system is expensive. In addition to this, it is not possible to measure the current of CG discharges that occur arbitral time and location though it is possible to measure the current only for the CG discharges that hit the tower equipping the Rogowski coil. Lightning discharges can emit strong electromagnetic waves in the ELF and VLF range. Especially, the wavelength and attenuation rate of ELF waves in the frequency range of 1-100 Hz is extremely long and low, respectively. So, it is possible to monitor global lightning activities even from a single observation site. From this reason, we have installed ELF observation systems recording 1-100 Hz magnetic field waveform data continuously at four observation sites in the world. Using these ELF data, we can detect the transient Schumann Resonance waveforms excited by intense CG discharges, and we can also estimate occurrence time, location, and polarity of these CG discharges in a global scale. In order to examine the ELF waveforms when the CG discharge current was measured, we have compared ELF data obtained at Onagawa observatory with the CG current waveform data measured by a Rogowski coil installed at a tall tower at Mt. Ogami in Japan. We have analyzed the ELF and CG current data obtained in the winter season of 2009. Then, it is newly found that the ELF waveforms are quite comparable to the waveforms of CG discharge current. Since the distance between two observation sites are about 300 km, the ELF waveform measured at Onagawa is supposed to be the induction magnetic field perturbation directly induced by the CG discharge current. Though the absolute values between ELF magnetic field perturbations and the discharge currents are not yet evaluated, this new finding implies that the ELF measurement near thunderstorm must provide a powerful tool to measure discharge current easily and to estimate total charge for arbitrary CG discharges. At the presentation, we will show the results derived from the comparison of the waveforms between ELF magnetic field perturbations and CG discharge currents more in detail, and will discuss the future observation and analysis plans.

キーワード: 雷, 放電電流, ELF 波動
Keywords: lightning, discharge current, ELF wave