Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM09-01 Room:101B Time:May 23 09:00-09:15

Global Lightning and Sprite Measurements (GLIMS) from ISS

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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 is scheduled to be launch from Japan in January, 2012 as part of the multi-mission consolidated equipment on Japanese Exposure Module (JEM). Our mission goals are (1) to detect and locate lightning and sprite within storm scale resolution over a large region of the Earths' surface along the orbital track of the ISS without any bias, (2) to clarify the generation mechanism of sprite, and (3) to identify the occurrence conditions of TLEs. 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 GLIMS was launched to the ISS on July 2012 and started its initial observation from November 2012 after the initial testing succesfully. In this presentation, the mission overview and some intial results are briefly and firstly reported before some of the co-authors presents the interesting results more explicitly.

Keywords: Lightning, TLE, ISS

PEM09-02 Room:101B Time:May 23 09:15-09:30

Initial Results Derived From JEM-GLIMS Optical Observations

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JEM-GLIMS is a space mission to carry out the nadir observations of lightning and TLEs from International Space Station (ISS). The final goal of this mission is to identify the spatial and temporal evolutions of lightning and TLEs and to clarify the occurrence conditions of TLEs. JEM-GLIMS consists of four science instruments; (1) Lightning and Sprite Imager (LSI), (2) six-color spectrophotometer (PH), (3) VLF receiver (VLFR), and (4) VHF interferometer (VITF). LSI will acquire lightning and sprite images with a frame rate of 29 fps, and PH will measure absolute intensities of lightning and sprite emissions with a sampling frequency of 20 kHz at the different wavelength of 150-280, 316, 337, 392, 762, and 600-900 nm, respectively. VLFR will measure electromagnetic waves in the frequency range of 1-40 kHz, while VITF will measure VHF pulses in the frequency range of 70-100 MHz. From these science instruments, it is possible to identify the optical occurrence characteristics of lightning and TLEs and the electric characteristics of the TLE-inducing lightning discharges. JEM-GIMS was successfully launched and transported to the ISS, and it was successfully installed at the Exposed Facility of the Japanese Experiment Module (JEM) on August 9. Finally, a continuous observation of lightning and TLEs by JEM-GLIMS was started from December 20, 2012. Up to the end of January 2013, JEM-GLIMS has triggered and recorded 350 transient optical events in total, where strong lightning signatures are confirmed in LSI and PH channels. For some of these events, transient signatures of N2 LBH are confirmed in the PH1 photometer, which strongly implies the occurrence of TLEs. At the presentation we will report more detailed initial results derived from JEM-GLIMS data.

Keywords: Lightning, Sprite, GLIMS mission, International Space Station

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PEM09-03 Room:101B Time:May 23 09:30-09:45

VHF observations on lightning discharges from the International Space Station

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We present the lightning observation missions from space using the electromagnetic waves.

In 2012, Global Lightning and sprIte MeaSurements (GLIMS) mission has been conducted on Exposed Facility of Japanese Experiment Module (JEM-EF) of the international space station (ISS) which is orbiting the earth at an altitude 400 km. The VHF broadband digital interferometer (VITF) attached on JEM-EF is designed to estimate the direction of arrival of electromagnetic waves. The VITF has th bandwidth from 70 MHz to 100 MHz. The VITF on GLIMS is developed on the heritage ofa VHF sensor on Maido-1 satellite. The VITF consists of two antennas, band-pass filters, amplifiers, and 2-channel-AD-converter. The electromagnetic radiations from lighting discharges received by the antennas are digitized by the AD converter synchronizing with another channel through the filters and the amplifiers. The band-pass filter and the amplifier of the VITF are exactly the same as the ones of the VHF sensor on Maido-1 satellite. The basic specification and most of devices in the AD converter of VITF are proven by the one of VHF sensor on Maido-1 satellite.

We will introduce the outline of the mission and the VITF. The initial observational results with the VITF of the JEM- GLIMS mission will be presented. We discuss the resutls and the VHF wave propagation characteristics through the ionosphere.

Keywords: lightning, electromagnetic waves, radio observation

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PEM09-04 Room:101B Time:May 23 09:45-10:00

Nadir observation of lightning and TLEs by JEM-GLIMS: Comparison with ISUAL limb observation

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The present study analyzes the optical data of lightning and TLEs obtained by JEM-GLIMS on the International Space Station. In contrast to former studies based on the ISUAL limb observation, JEM-GLIMS is pointed toward nadir and, thereby, provides an innovative way to clarify the horizontal structures of lightning and TLEs, which are one of the most crucial issues to improve our understanding of atmospheric discharge physics and electrodynamic coupling between the troposphere and the ionosphere. A difficult point, however, is that careful analyses are required to separate the optical emissions of lightning and TLEs which spatially overlap in the field-of-view in the case of nadir-looking geometry.

The main data analyzed here are those obtained by GLIMS dual-color imager (LSI) and six-color spectrophotometer (PH). One LSI channel is equipped with a 762-nm filter to selectively detect high-altitude TLE emissions by minimizing contamination from low-altitude lightning emissions by deep O_2 atmospheric absorption while the other LSI channel has a broadband red filter to equally measure both phenomena. PH detects time-resolved emission intensity at a sampling rate of 20 kHz with six channels measuring at 150-280, 337, 762, 600-900, 316 and 392 nm, respectively. These spatiotemporally- and spectrally-resolved optical data are analyzed in comparison with well-calibrated results obtained by the ISUAL limb observation of lightning and TLEs.

The goal of this study is to separately identify the signatures of lightning and TLEs from GLIMS data and precisely clarify their spectral and spatiotemporal characteristics.

Keywords: lightning, sprites, atmospheric electricity, GLIMS, ISS, Spacecraft

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PEM09-05 Room:101B Time:May 23 10:00-10:15

Remote sensing of thunderstorms and TLEs by RISING-2 microsatellite

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Tohoku University and Hokkaido University developed a new 50 kg-class microsatellite RISING-2, which will be launched in sun-synchronous (12 LT) polar orbit at 628 km altitude as a piggyback of the ALOS-2 satellite with H-IIA rocket in 2013. This satellite inherits the development technique of RISING (SPRITE-SAT), which was designed for the observations of TLEs and launched on January 2009. In addition to the Lightning and Sprite CMOS Imagers (LSI) installed on RISING and JEM-GLIMS, RISING-2 carries a new optical instrument, High Precision Telescope (HPT), developed by Hokkaido University. HPT uses a Cassegrain telescope with 10-cm diameter and 1-m focal length and can observe the earth surface with 5-m GSD. HPT has four sensitive CCDs, and three of them are allocated to Red/Green/Blue bands to make color images. The other CCD is for multispectral observations in the near-infrared region (650-1050 nm) using a Liquid Crystal Tunable Filter (LCTF). LCTF can change the center wavelength to transmit the near-infrared light with the mean band width of 20 nm. By the three-axis attitude stabilization of RISING-2, HPT is able to observe the designated area or direction from the orbit. This allows flexible observations of thunderstorms and TLEs from space with high spatial resolution.

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PEM09-06 Room:101B Time:May 23 10:15-10:30

Spatial and Temporal Evolution of Sprite Streamers Derived from High-Speed Camera Data in Aircraft Observation Campaign

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The occurrence conditions of sprites streamers still remain to be an unsolved problem after 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.

PEM09-07 Room:101B Time:May 23 10:30-10:45

A dynamical model approach to structuring of sprites

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Our recent theoretical studies for structuring of sprites on the basis of quasi-electrostatics and multi-body dynamical model are presented in this talk. The phase transition theory between halo and streamer states has been proposed, and a similar transition could be found in a variety of macroscopic structures of sprites as column and carrot shapes. We construct a multi-body dynamical model that treats the interaction, acceleration, and splitting of streamers in a lightning-induced quasi-electrostatic field. We investigate sensitivity of streamer development to the lightning (measurable) parameters and provide implications for the condition of the phase transition of sprites.

Keywords: sprite, dynamical model, phase transition

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PEM09-08 Room:101B Time:May 23 11:00-11:15

Characteristics of Transient Luminous Events in Eastern Mediterranean Thunderstorms: Results from a 7-Year Survey

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Lightning activity in the Eastern Mediterranean and the vicinity of Israel is prevalent in winter, mostly between November and March, in conjunction with the passage of cold Cyprus Lows over the relatively warm water of the Mediterranean Sea. Thunderstorm cells are 6-8 km in height and are often found in cold-fronts and within the ensuing cloud streets, and are sometimes accompanied by Transient Luminous Events. The ILAN campaigns (Imaging of Lightning and Nocturnal Flashes) have been conducted continuously since 2004, monitoring the properties of the TLEs associated with thunderstorms in Israel and its vicinity. The optical observations have been conducted from the Tel-Aviv University campus and from the Wise Astronomical Observatory at Mitzpe Ramon in the Negev desert, at first alternating between sites and later simultaneously. The optical campaigns were accompanied by ELF and VLF data and lightning location systems. We will review the statistical data obtained in 7 winter campaigns (2004/5-2012/13), describe the properties of sprites and of other TLEs, and analyze their dependence on the properties of their parent flashes. A comparison to similar winter storms in Japan and Europe reveals similarities and differences in the properties of winter TLEs.

Keywords: Winter thunderstorms, Lightning, Transient Luminous Events, Sprites, Optical observations

PEM09-09 Room:101B Time:May 23 11:15-11:30

Estimation of lightning current waveform from ELF magnetic induction field

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New project to estimate lightning current waveform from ELF magnetic field observation is introduced. A positive GC lightning event in winter was detected by a Rogowski coil at Mt. Ogami, Niigata Prefecture, Japan on Jan. 2010. The peak current and the electric charge were 26 kA and about 1 kilo-coulomb, respectively. Electromagnetic radiation from the lightning was measure by Lightning Location System (LLS) in Tohoku district and ELF magnetic field observation at Onagawa observatory, Miyagi Prefecture. Although only pulse series' were radiated in LF, a horizontal magnetic field waveform resembling the current waveform was observed in ELF. At the distance of Onagawa (296 km apart from Ogami), the ELF waveform should resemble that of the source current because the ELF signal is mostly composed of the induction components. This means the ELF signal has potential to use direct estimation of current waveform of any lightning discharge as well as the amount of electric charge causing damage to grounded structures. Comparisons of waveforms between the current and ELF have done for several lightning events to find the statistical properties. New observation site is planned in Kyushu distinct with a cooperation of ICSWSE, Kyushu University.

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PEM09-10 Room:101B Time:May 23 11:30-11:45

Construction of lightning observation network in Asia and its applications to meteorology and climate studies

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SE-Asia is one of the most important regions in the world, which is closely related to the important meteorological phenomena, such as Madden Julian Oscillation, El Nino, etc. Also very sever weathers sometimes happen in this area, which leads to loss of human lives and estates. Therefore, monitoring and understandings of atmospheric activities in this region is quite important. However, it is not easy only with existing observation equipments and the limited number of advanced facilities such as expensive meteorological radars. Lightning observation in frequency range of VLF would be a very effective methodology to monitor the activity of thunderstorms which are the drives global atmospheric circulation and may cause significant disasters. We have been developing Asia VLF observation network: AVON, which now consists of 3 stations located at Taiwan, Thailand and Indonesia. The geolocation will be carried out by time-of-arrival method with an error of 10 km. From AVON data, we could estimate the charge moment change of the lightning stroke, which might be a good proxy of meteorological parameters in thunderstorm. In order to improve the accuracy of geolocation and to achieve the redundancy, we plan to add 2 or 3 more stations in SE-Asian countries, such as Philippines, Vietnam. Here we discuss the scope of AVON obsearvation including various possibilities of applications to meteorology and climate studies.

Keywords: lightning, SA-Asia, AVON, meteorology, climate

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PEM09-11 Room:101B Time:May 23 11:45-12:00

Response of the D-region ionosphere to lightning using Asia VLF observation network (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 in Taiwan, Thailand, and Indonesia are performed at present, while we will construct a new observation system in Philippines in February, 2013. We also have a plan of a new observation system in Vietnam after the Philippine construction within 2013. The aim of the AVON is to monitor the lower ionosphere and lightning in South-East Asia. We observe North-South and East-West broadband 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 several early VLF events and discuss the coupling between the D-region and lightning.

PEM09-12 Room:101B Time:May 23 12:00-12:15

Estimation of lightning magnitude using VLF sferics in Kanto rigion

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It is pointed out that the relationship between atmospheric parameters and occurrence frequency of lightning is closely correlated. By the current lightning detection systems operated in Japan, which measure higher frequency than VLF range, only the information of peak current of the stroke is estimated and information of its magnitude, such as charge moment change (CMC) cannot be derived. Since the most of the electromagnetic energy of lightning concentrates in the frequency range less than 10 kHz, in order to estimate CMC of lightning stroke, we need to observe the electromagnetic waves in lower frequency range than existing lightning networks which make use of order of several 10s of kHz to M Hz range. Carrying out the continuous observation of VLF sferic, we will investigate the quantitative relationship between atmospheric parameters and lightning activity including information of electrical magnitude for the first time.

We are constructing a VLF observation network with identical observation system, consisting of three observation sites in Kanto region, which enables us to geolocate lightning stroke by time of arrival (TOA) or direction finding methods with an error of 10 km. Each observation system is composed of two horizontal magnetic loop antennas and a vertical electric dipole antenna, receiver, PC and GPS clock. The higher cutoff and sampling frequency are 40 kHz and 80 kHz, respectively.

In order to estimate CMC, the temporal variation of source current with peak intensity is required. We estimated the peak current using a method proposed by Yanagi [2012]. The temporal variation of source current was estimated from the groundwave of electric field, using amplitude and zero-crossing time of the waveform.

In this presentation, we will report the situation of construction of this observation network and the estimation methodology of lightning peak current using sferic data. Also preliminary results based on the data obtained at Yamanashi station are introduced.

This research is supported by grant in aid by Kisho-Bunka-Souzou center and Kakenhi (Kiban-A) No. 2425300202.

Yanagi, Y., Development of VLF electromagnetic wave observation system and estimation method of lightning peak current, Master thesis, Hokkaido University, 2012.

Keywords: lightning, charge moment change

PEM09-13 Room:101B Time:May 23 12:15-12:30

Synchronization between lightning activity in the Maritime Continent and OLR in tropics

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Lightning activity is an excellent proxy of atmospheric circulation in thunderstorm. Therefore, the research of global lightning activity leads to understanding of the global atmospheric circulation. However, there has been no objective global lightning data set. We have developed and been operating the global ELF observation network named GEON. Yamashita el al. (2011) analyzed GEON data recorded in the period of August 2003- July 2004 and estimated location and charge moment change of each lightning stroke with uniform sensitivity over the world for the first time.

We performed correlated analysis between the number of the lightning strokes derived from GEON and Outgoing Longwave Radiation (OLR) in the tropical regions, focusing the variation with about month periodicity.

It was found that the number of lightning strokes in the Maritime Continent (MC) varies with about month periodicity in the period from February to June 2004 and shows positive correlation (R= ˜0.8) with OLR in the Western Pacifc Warm Pool (WPWP). That is, when thunderstorm activity in the MC is enhanced, the OLR in WPWP becomes large, meaning less cloud amount. On the other hand, OLR in the central Africa shows negative correlation with the number of lightning strokes in the MC in that period (R= ˜-0.7). Furthermore, in the central Africa OLR seems to reflect the number of lightning strokes, showing good correlation between them. This implies that the activities of thunderstorms both in the central Africa and in the MC oscillate in the same phase. Also OLR in the central of Pacific Ocean, America and the Atlantic Ocean show negative correlation (R= ˜-0.6). In the central of Pacific Ocean and the Atlantic Ocean, OLR shows low amplitude except the period of negative correlation. Such a synchronization of thunderstorms or cloud amount in global scale without phase difference has not been reported.

Keywords: lightning acgtivity, GEON, OLR, Maritime Continent, teleconnection

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PEM09-P01 Room:Convention Hall Time:May 23 18:15-19:30

Split Condition of Sprite Streamer Tips Derived From High-Speed Camera Observations

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In order to clarify the split condition of sprite streamer tips, the detailed spatial and temporal development of sprite streamers are the key physical properties. According to the pervious ground-based observations using high-speed cameras, it was found that streamer tips usually appear at around ~80 km at the initial stage of the sprite development and propagate downward with an accelerated and expanded motions. After they reach ~70 km altitude, they tend to start splitting. However, detailed splitting mechanism of streamer tips is not fully understand yet since it is difficult to capture the detailed development and fine structures of the splitting streamer tips. In order to specify the detailed spatiotemporal evolution of sprite streamers and to identify the physical parameters determining the splitting condition of streamer tips, we have analyzed image data obtained by high-speed cameras onboard two jet aircrafts.

In the period from June 27 to July 10, 2011, we have succeeded in capturing 12 sprite events over the Great Plains in summer US, where the multiple splits of streamer tips are clearly measured by high-speed cameras with a sampling rate of 8300 fps. It was found that streamer tips initiated from approximately 75 km altitude propagate downward with an exponential increase of the brightness before they start splitting first. We estimated brightness changes of streamer tips at each frame of image data recorded by the high-speed cameras, and we also estimated the ratio of the streamer tip brightness just after the tip splits to that just before the tip reaches next split. It is found that the ratio of the brightness at the streamer tip initiation to the brightness just before the first split becomes greater than 1.0. However, it is found that the ratio of the brightness of 1st (2nd) split to 2nd (3rd) split becomes about 1.0. At the presentation, we will show more detailed results.

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PEM09-P02 Room:Convention Hall Time:May 23 18:15-19:30

Statistical Features of Winter Lightning Activity in Tohoku District

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Coastal area of Sea of Japan is one of the well-known hotspots of winter lightning activity. Since winter lightning contains more electrically intensive discharges than summer lightning (Hojo et al., 1989), winter lightning often causes serious damage on electrical equipments in the coastal area (Transmission lines, wind turbines etc.). Previous research also indicates that thunder-day frequency in winter season in Japan has been increasing during the past several decades (e.g. Fujibe et al., 2005).

Numerous studies have been conducted concerning both the electrical and meteorological aspects of winter lightning activity in Japan (e.g. Michimoto, 1993 and Kitagawa and Michimoto, 1994). However, previous studies typically focused on the Hokuriku district of the mid-winter season. On the other hand, there have been few studies that examine statistical features of winter lightning activity in Tohoku district, mostly due to lack of available lightning observational data in this area.

This study investigates seasonal and inter-annual variability of lightning frequency in Tohoku district and the northern part of Hokuriku district based on the observational dataset obtained by Lightning Location System (LLS). The LLS has been operated by Tohoku Electrical Power Co. from 1994 to 2011, measuring real-time lightning location, polarity and peak current within Tohoku, Kanto and Hokuriku districts. The estimated lightning location accuracy and detection efficiency are approximately 2km and 63% respectively during the winter season (Honma et al., 1998 and Honma et al., 2010).

Based on the analysis of lightning location data, the maximum lightning frequency (maximum number of detected lightning discharges within a ten-day period) was found to appear typically from early October to late November in many parts of the study area. The seasonal variation of lightning frequency map shows that lightning hotspot appears around the northern part of Tohoku district during the late autumn season (October - November) and moves southward during the winter season (December - March). In addition, many of the lightning discharges during the late autumn season occur over the ocean area, as opposed to the lightning discharges during the winter season which are concentrated within the coastal area of Sea of Japan. Inter-annual variability of lightning frequency in the study area was also investigated. The results indicate that lightning frequencies in the late autumn season were remarkably high during the EL-Nino years (1997, 2002 and 2006), except for 2009.

Keywords: winter lightning, Lightning Location System

PEM09-P03 Room:Convention Hall Time:May 23 18:15-19:30

Global lightning distribution with information of charge moment change

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Lightning is an electrostatic discharge phenomenon in the atmosphere. Primarily there are three types of discharges, namely, cloud-to-cloud discharge (CC), intra-cloud discharge (IC), and cloud-to-ground discharge (CG). Further, CGs are classified into two types: positive and negative polarities. Charge moment change (Qdl) is one of the parameters representing the significance of lightning discharge. In this study, base on the analysis of lightning waveform observed by global ELF observation network (GEON) we constructed an empirical model of the Qdl distribution, by fitting simple curves to the observational datasets for almost all the Qdl range, that is, from 0 to 3000 C-km. We examined the characteristics of the Qdl distribution in 7 regions where lightning activity is quite high, namely, Maritime Continent in Asia, Australia, Central Africa, South Africa, North America, South America, and South Pacific. The results show a large variation of the distribution depending on the location, season and current polarity. This empirical model of the Qdl distribution can be applied to various purposes, such as an estimation of global circuit current and comparison with meteorological parameters.

Keywords: lightning, charge moment change, global distribution, empirical model