Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

AEM002-01 Room:201A Time:May 27 08:30-08:45

Observation, Modelling of Lightning Activity in Hurricanes

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Modern global lightning detection networks enable us to monitor and investigate the lightning activity in areas where there is little or no coverage by local lightning location systems, such as the remote regions or the oceans. Hence, we are now better able to track and understand the complex connection between hurricane development and electrical activity in these dangerous storms. In a recent study (Price et al., 2009) it was shown that in category 4-5 hurricanes (typhoons), there is a clear increase of lightning activity approximately one day before the maximum intensity (lowest pressure, strongest winds) of the storm. Additional analysis confirms this initial finding, possibly allowing us to use real-time lightning observations to forecast the time of hurricane intensification. We have also started modeling lightning activity in hurricanes using the WRF mesoscale meteorological model. Numerical simulations of the electrical activity in hurricanes, employing microphysical parameterization of the charging potential (using the Lightning Potential Index, LPI; Yair et al., 2010) show a reasonable agreement with the observations of lightning for the few case studies we have analyzed thus far. Both observations and modeling results will be presented.

Price, C., M. Asfur and Y. Yair, 2009: Maximum hurricane intensity preceded by increase in lightning frequency, Nature Geoscience, doi:10.1038/NGEO477, 2, 329-332.

Y. Yair, B. Lynn, C. Price, V. Kotroni, K. Lagouvardos, E. Morin, A. Mugnai, and M. d. C. Llasat (2010). Predicting the potential for lightning activity in Mediterranean storms based on the Weather Research and Forecasting (WRF) model dynamic and microphysical fields, J. Geophys. Res., 115, D04205, doi:10.1029/2008JD010868.

Keywords: Lightning, Hurricanes, Storm Intensity, Detection Networks, Modelling, WRF

Japan Geoscience Union Meeting 2011
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AEM002-02 Room:201A Time:May 27 08:45-09:00

Estimation of the global and Asian lightning activity based on the observation of ELF/VLF sferics

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In the recent decade, many researchers have been attracted to the investigation of global lightning activity. One of the reasons is the progresses in the observation of global lightning discharges. Measurements of electromagnetic waves radiated from CGs with ground-based systems have been developed drastically.

Electromagnetic wave radiated from could-to-ground (CG) lightning discharge is observed as transient waveform called as atmospherics or sferics. Sferics in the Very Low Frequency (VLF: 3-30 kHz) and Extremely Low Frequency (ELF: 3-3000 Hz) bands can be detected at a receiver which is several mega-meters from CGs due to the propagation with quite low attenuation. This long propagation enables us to monitor the global CGs activity only with single or few receivers. Using observed waveform in ELF or VLF range, information not only about the location but also about the electrical properties such as polarity, peak current and charge moment (Qdl) of individual lightning stroke can be derived.

In this study, we developed new algorithm to estimate location and charge moments for relatively small Qdl events ($|Qdl|>950$ C-km). This method is applied to the magnetic fields data observed in 1-100 Hz range obtained by global ELF observation network (GEON), Syowa station in Antarctica, Onagawa station in Japan, Esrange in Sweden, and Santa Cruz in U.S.A. Making use of the time-of-arrival method, the accuracy of geolocation and detection sensitivity is greatly modified. Thanks to this new algorithm, about a millions of CGs can be analyzed with one month (during January 2004). Global CGs distribution is derived with annual data (from October 2003 to July 2004) and about a million CGs whose Qdl are larger than 950 C-km are obtained. The results show the monthly and seasonal variation of global CGs distribution.

Furthermore, a new VLF observation network (Asian VLF observation network: AVON) is developed to monitor the activity of CGs in Southeast Asia. Observation sites of this system are located at Tainan in Taiwan, Saraburi in Thailand, and Pontianak in Indonesia. In this study, data observed at Tainan station and Pontianak station during three days (from October 13th, 2010 to October 15th, 2010) is used for the initial analysis. Using the waveforms obtained by this network, 1-3 sferics per seconds are geolocated. Median of geolocation error is estimated as 93 km comparing with WWLLN data using about 400 CGs located in the Maritime Continents. Furthermore, charge moment distribution for the CGs of $>$ 200 C-km in the Maritime Continents is derived with a combination of CG locations obtained by AVON and the transient waveform observed by GEON.

In this presentation, we introduce the speculation of new observation network to monitor the lightning activity in Southeast Asia and demonstrate the efficiency of combination of the measurement of ELF sferics and that of VLF ones.

Keywords: lightning, sferics, ELF, VLF

Japan Geoscience Union Meeting 2011
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AEM002-03 Room:201A Time:May 27 09:00-09:15

The characteristics of global lightning activities observed by ISUAL experiment

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Lightnings serve as an important charge transporter between cloud and ground, and emit sferics that propagate in the ground-ionosphere cavity. During the six-year observation of ISUAL/FORMOSAT-2, besides surveying upper atmospheric transient luminous events, more than 110,000 lightnings which exceeded the ISUAL trigger threshold were recorded. In this presentation, the distribution, the occurrence rate, distribution and seasonal variation of these lightnings at local time between 22:30 and 23:00 are reported and compared with those of the LIS experiment (Christian et al., 2003). The ocean-to-land ratio and geographic distributions suggests that the lighting recorded by ISUAL is averagely more energetic than the ones registered by LIS mission and intense lightning is more frequent over oceans. The anomaly of occurrence between warm and cold phases of ENSO will also be discussed in this presentation.

Keywords: Lightning, ENSO, ISUAL

Japan Geoscience Union Meeting 2011
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AEM002-04 Room:201A Time:May 27 09:15-09:30

Energetic radiation associated with thunderstorm activity

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Intense gamma rays likely associated with lightning and/or thunderstorm activities have been detected in recent years, at various altitudes ranging from the ground level to the ionosphere. However, neither the source of this radiation nor its nature has been clarified. We report gamma rays lasting for several minutes attributed to both winter and summer thunderstorms in Japan. Our findings in winter thunderstorm indicate that the gamma rays were emitted continuously from a downward hemispherical surface, the bottom of which was about 300 m above sea level, and this source of gamma rays moved from north to south above the observation site at a speed of about 7 m/s. The radiation source probably moved along with the charged region of the cloud at a height of around 1 km, because the estimated migration of the radiation source was consistent with the observed movement of atmospheric electric field variation between ground-based observation sites and with the wind speed and direction at about 1 km altitude. This movement implies that the intense electric field produced by the charged region in the thundercloud generated a radiation source beneath the charged region. On the other hand, gradual energetic radiations probably caused by a summer thunderstorm have been observed at the top of Mt. Fuji, Japan. The largest of such variation was gradual and lasted for about 20 minutes, and was found to be high-energy gamma rays having a continuous energy spectrum up to 10 MeV or more. Both the observations help explain probably the lightning initiation urged by the radiation.

Japan Geoscience Union Meeting 2011
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AEM002-05 Room:201A Time:May 27 09:30-09:45

ISUAL recorded halos brightness and their parent lightning emission

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Halo, another type of transient luminous event, is a bright disk at altitude 80-85 km above the thunderstorm. Unlikely the fact that almost exclusively +CG triggered sprites, most of halos were induced by -CG that occurred exclusively over the open water [Frey et al., 2007]. In this presentation, we analyzed total 185 ISUAL recorded pure halo events from July 2004 to Dec 2007. Using 1PN2-filter Imager, the average brightness of halos is ˜ 0.25 MR. We also derived the current moment using the 777.4 lighting emission of their parent lightning to [Adachi et al., 2009]. It is found that a relatively strong linear relationship between lightning peak current and lightning-induced halo emission. In total recognized 121 events by ELF radio emission at Nagycenk Observatory (NCK), Hungary, the polarities of their parent lightning for 23 halos are identified as +CG while 98 halos are for ?CG associated with NCK recorded ELF data. From NCK estimating CMC, we found a relatively weak correlation between NCK CMC and halo brightness. Furthermore, the extremely brightest halos over ocean were also found, and their lightning polarities were dominated by ?CG. The finding reflects the nature of intense peak current for oceanic lightning [Fullekrug et al., 2002]. It seems that lighting current may have more important effect on halos generation than charge moment.

Keywords: ISUAL, Halo

Japan Geoscience Union Meeting 2011
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AEM002-06 Room:201A Time:May 27 09:45-10:00

High-speed imagery of elves from airplane

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NHK's project"Beach of the Cosmos"

Elves are a kind of Transient Luminous Events (TLEs), which are optical events occurring in middle atmosphere and at lower ionospheric altitudes, and they are directly related to the electrical activity in underlying thunderstorm. Elves are occurring at an altitude of ˜90 km, can spread ˜300-600 km laterally and shape like a doughnut. In addition, the luminous duration at a certain point is ˜0.1 ms and the emission spread throughout within ˜2 ms with phase velocity which is faster than the velocity of light. The luminous duration of elves is extremely short.

The temporal and spatial emission variation of Elves have observed using multi -anode photometer arrayed in a vertical direction [Fukunishi et al., 1996], and using photometer arrayed in a broadband horizontal direction [Barrington-Leigh et al., 2001]. However, there was no two-dimensional image of Elves structural variation.

In full cooperation with NHK, we succeeded in capturing the first image using high-speed camera from jet airplane flown at an altitude of ˜13 km. The camera was installed on a window of airplane and trained on horizontally to the travelling direction. We used panchromatic camera, and frame rate is ˜8000 fps.

In November 28th, 2010, there were lightning swarm activities ˜400 km out at sea of Chiba prefecture from ˜18:00 and the data are images of elves which are that lightning induced. On the day, the airplane took off heading out to sea of Kanto at ˜20:30 and captured images from 21:48 to 22:45. We captured 21 TLEs for an hour and confirmed that at least 3 events of them are elves in initial analysis.

We investigate the relation between temporal and spatial variation of Elves structure and characteristics of parent lightning.

Japan Geoscience Union Meeting 2011
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AEM002-P01 Room:Convention Hall Time:May 27 10:30-13:00

The use of cloud classification and rainfall radar data to improve geostationary satellite based rainfall estimation

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The use of geostationary satellite dataset for rainfall estimation has several advantages that it has a hemisphere coverage and high temporal resolution. However, we can only use Visible/Infra Red (VIS/IR) sensor that carried by geostationary satellite. Because of the cloud is opaque in VIS/IR spectral band, an indirect approach is used for rainfall estimation, i.e. according to several top surface cloud characteristics such as shape, brightness, temperature etc. Another rainfall estimation approach is by using Passive Micro Wave (PMW) sensor. The microwave spectral band has characteristic that can penetrate the cloud and interact with the hydrometeor. Those of characteristics make the PMW method more direct in term of rainfall estimation. PMW sensor usually mounted on polar orbit satellite, so it has limitation on temporal resolution and coverage. This study combines the advantage of geostationary satellite and PMW satellite images for rainfall estimation. We use MTSAT datasets that is blended with TRMM 2A12 to estimate the rainfall over Japan. We make a statistical relationship between cloud top temperature from MTSAT and rainfall rate from TRMM 2A12, according to assumption that on the convective cloud situation lower cloud top temperature is associated with higher rain rate. In the actual situation such assumption sometimes cannot be fulfilled. The cloud top temperature of the cirrus cloud i.e.: cold but not produces rain and the nimbostratus cloud i.e.: produces rain but warm have disturbed such relationship. The cloud classification according to the cloud type and cloud height will be performed. We use several cloud classification methods such as segmentation method, split-window method and maximum likelihood method to classify the cloud type. We investigate the statistical relationship among cloud classes and height to the rain rate. A calibration with the C-band rainfall radar data will also be conducted. The estimation result will be validated with the measured rainfall (Automated Meteorological Data Acquisition System/AMeDAS System). We expected that cloud classification based on cloud type and height as well as C-band rainfall radar calibration will improve the rainfall estimation accuracy.

Keywords: geostationary satellite, rainfall estimation, MTSAT, TRMM 2A12, cloud classification

Japan Geoscience Union Meeting 2011
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AEM002-P02 Room:Convention Hall Time:May 27 10:30-13:00

A warm season climatology of convective precipitation over the Korean Peninsula

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The goal of this study is to investigate the variations in the spatial and temporal patterns of lightning activity over the Koran Peninsula in relation to precipitation during the summer monsoon months during 10 years (2000-2009) and to develop a better understanding of these two meteorological phenomena. In this study, we present the results of an analysis of lightning activity and associated monsoon rainfall over Korea. We obtained precipitation data from 98 synoptic stations and the lightning data were collected from a lightning detection network installed by the Korean Meteorological Administration (KMA).

This study will be of use in understanding the role of convective rain in the extreme precipitation over Korea, and this could eventually enhance skills for understanding the relationship between climate change and extreme precipitation.

Acknowledgement: This research is supported by a project, NIMR-2011-B-2.

Keywords: extreme precipitation, Korean Peninsula, lightning activity, climate change

Japan Geoscience Union Meeting 2011
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AEM002-P03 Room:Convention Hall Time:May 27 10:30-13:00

Global map of thunderstorm activity based on GEON and its relationship to the solar activity

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Hokkaido University developed a global ELF observation network, named GEON, which provides very unique information of each cloud-to-ground lightning discharge (CG), as well as Schumann resonance (SR) power, a proxy of global energy proxy of lightning discharge. From the standpoint of the relationship between the effect of solar activity to the climate of Earth, lightning activity estimated by data obtained by GEON and the outgoing longwave Radiation (OLR), an indicator of cloud amount, are examined for their periodicity and phase in the periodic range of about one month. SR power shows about 27-day periodicity in solar maximum years and it becomes elongated toward solar minimum. On the other hand, OLR shows same kind of 27-day periodicity in solar maximum years, but only in the Western Pacific Warm Pool area. Both the spectra of SR and OLR have a peak around 35-day in solar minimum years. The average spectrum of OLR in solar maximum years also shows an enhancement in the range of 50-60 days corresponding to the main MJO period. In this presentation the relationship between the thunderstorm activity inferred from global lightning distribution observed by GEON and OLR are discussed in detail, comparing the solar activity.

Keywords: lightning, thunderstorm, OLR, solar activity, GEON

Japan Geoscience Union Meeting 2011
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AEM002-P04 Room:Convention Hall Time:May 27 10:30-13:00

Periodic Changes of Global Lightning Activities and Their Regional Dependences

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In order to study the periodic changes of global lightning activity and their regional dependences, we have analyzed ELF magnetic field waveform data obtained at Syowa station in Antarctica, Onagawa observatory in Japan and Esrange in Sweden for the period between February 2000 and December 2009. We have estimated day-to-day amplitude variation of the global lightning activity derived from Schumann resonance (SR) spectral power. As a next step, we have calculated power spectrum of the SR spectral amplitude variation to estimate periodicities using MEM, FFT, and wavelet method. It is found that the periodgram showed steep spectral peak at ˜28-day in 2000-2001 which is the solar maximum period. On the other hand, a peaked period of the SR spectral amplitude variation gradually increased and showed a steep spectral peak over 30-days after 2002. Using the transient SR waveform data and newly developed geolocation method, we have also estimated the occurrence locations of intense lightning discharges for the period between September 2003 and August 2003. We will discuss the relationship between the periodic changes of regional lightning occurrence numbers and periodic changes of the regional lightning activity.

Keywords: lightning, Schumann resonance, periodic change

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AEM002-P05 Room:Convention Hall Time:May 27 10:30-13:00

Initial Results of Sprite Observation from Aircraft Using High-speed II-CCD camera and High-Vision Camera

Mitsuteru Sato[1*], Yukihiro Takahashi[2], Yunna Shima[1], Kozo Yamashita[1], NHK Uchu-no-Nagisa Project[2]

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In order to study spatial and time evolution of Transient Luminous Events (TLEs), such as sprites, elves, and blue jets, we have carry out TLE observations from a jet-aircraft using high-speed Image-Intensified (II) CCD camera, Watec CCD camera, EM-CCD camera and high-vision camera. On November 28, we have carried out a first try of the observation and captured about 30 TLE events successfully. At the presentation, we will show the initial results of the spatial and time evolution of sprites measured by high-speed and high-vision cameras.

Keywords: lightning, sprite, high-speed camera, high-vision camera

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AEM002-P06 Room:Convention Hall Time:May 27 10:30-13:00

Global Lightning and Sprite Measurements (GLIMS) from International Space Station

Tomoo Ushio[1*], Mitsuteru Sato[2], Takeshi Morimoto[1], Makoto Suzuki[3], Atsushi Yamazaki[3], Yukihiro Takahashi[2], Yasuhide Hobara[4], Ryohei Ishida[5], Masayuki Kikuchi[6], Zen-Ichiro Kawasaki[1]

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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 Earth's 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. In this presentation, the scientific background, instrumentation, project summaries are given.

Keywords: Lightning, Sprite, ISS

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AEM002-P07 Room:Convention Hall Time:May 27 10:30-13:00

3D mapping of winter lightning discharges observed in the Shonai area

Masahide Nishihashi[1*], Ken-ichi Shimose[1], Kenichi Kusunoki[2], Syugo Hayashi[2], Kenichiro Arai[3], Hanako Inoue[2], Wataru Mashiko[2], Osamu Suzuki[2], Keiji Adachi[3], Kotaro Bessho[4], Shnsuke Hoshino[2], Masahisa Nakazato[2], Hiroshi Yamauchi[2], Yoshihiro Hono[3], Wataru Kato[3], Masako Kusume[1]

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The Shonai area railroad weather project has investigated fine-scale structure of wind gust using two X-band Doppler radars and the network of 26 surface weather stations since 2007, in order to develop an automatic strong gust detection system for railroad. In 2009, the project was expanded and started lightning observation to investigate the mechanism of winter lightning and the application to strong gust prediction. Lightning discharge is known to be related to microphysical and dynamical processes within storms. Many scientists have indicated that lightning activity is associated with severe weather. Therefore, integration of continuous three-dimensional (3D) lightning monitoring (intracloud and cloud-to-ground lightning) and comprehensive high-density meteorological observation can provide useful index for predicting strong gust.

We developed a lightning observation system. The azimuth and elevation of VHF radiation sources originated from lightning flashes are computed using arrival time difference of three VHF pulses. After operation test at Meteorological Research Institute (MRI), we installed this system in the north of Shonai area (Ohama, Sakata) in October 2009. Moreover, we constructed three lightning observation sites in the Shonai area in September 2010, in order to visualize lightning discharges in 3D.

Our sensors detected lightning discharges at 01:13:32 JST on 4 December 2010. Using the VHF waveform data, we conduct 3D lightning mapping. The duration of discharge is about 60 ms and divided into two stages. The locations of discharges are compared with the radar echo data observed with two X-band Doppler radars in the Shonai area. As a result, the distribution of lightning discharges is consistent with the strong echo region. The lightning flash was also recorded with the network cameras at each site. In this presentation, we will show the lightning discharge process in detail.

Keywords: Winter lightning, 3D mapping, VHF observation, X-band radar, Shonai area