Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

MIS29-01 Room:A01 Time:May 24 09:00-09:15

Comparison of preliminary breakdown pulses of cloud-to-ground and intracloud lightning flashes

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Using Broadband Observation network for Lightning and Thunderstorm (BOLT) which locates radiation sources in 3D associated with lightning electromagnetic waves in a wide frequency range from 500Hz to 500kHz, we have observed and analyzed Preliminary breakdown (PB) which produces bipolar electric field change waveforms at the beginning of intracloud and cloud-to-ground lightning discharges. We classified PB pulses into +PB and -PB, depending on initial polarity of PB pulses in the physics sign convection and identified 334 +PB pulses and 400 -PB pulses. In this study, we set PB parameters (pulse width, pulse interval, pulse number, total pulse duration and PB initial height, propagation velocity) and analyzed differences between +PB which is at the beginning of intracloud discharges and -PB which is at the beginning of cloud-to-ground discharges. We found that some of +PB's parameters (pulse width, pulse interval, total pulse duration and height) were larger than -PB's parameters. On the other hand, pulse number, velocity were similar with each other. In addition, the results show that radiation sources of +PBs propagate upward while those of -PBs propagate downward or horizontally. In the case of downward propagating -PBs, the ending heights of the propagations are similar to the initial heights of horizontally propagating -PBs. We also use Phased Array Radar (PAR) to make a comparison of radar reflectivity factor and consider the association between thunderstorm's maturity degree and PB parameters.

Keywords: Preliminary breakdown, lightning discharges, EM source location

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

MIS29-02 Room:A01 Time:May 24 09:15-09:30

VHF observations of positive cloud-to-ground lightning flashes in summer thunderstorm season

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Positive cloud-to-ground (CG) lightning flashes are defined as those lowering positive charge from cloud to Earth. It is thought that less than 10 percent of global CG flash is positive. Positive CG flashes have attracted considerable attention for the following reasons. 1) The high lightning current and large charge transfers to ground. 2) They can be the dominant type of CG flashes in winter season and during the dissipating stage of thunderstorm. 3) They are related preferentially to transient luminous events (TLEs) in the middle atmosphere like sprites. 4) Reliable identification of positive CG flashes is important implications for various lightning location techniques.

The authors have been conducting cooperative lightning observations in Gifu, Japan, where occupy a lot of hill and mountainous region. Chubu Electric Power Co., Inc. (CEPCO) have has many (over 1.0 cases / 100 km / year) outages in their 500 kV power transmission line caused by lightning. This paper focuses on positive CG flashes observed by a VHF lightning mapper, Broadband Digital Interferometer (DITF) and Lightning Location System (LLS).

DITF is a system to locate a source of VHF impulse based on the digital interferometric technique. A remarkable feature of DITF is its wide detection frequency range, and this system takes no account of a carrier frequency. The system observes the electric field change due to a lightning discharge in the ultra-wide VHF band, and Fast Fourier Transform (FFT) is applied to calculate various frequency components of the received electromagnetic (EM) pulse. Computed phase difference for each Fourier component between two antennas is a function of the incident angle of the EM pulse against the baseline. A couple of antennas as a two-element array of DITF are able to estimate the incident angle. Two pairs of antennas, and independent two baselines, enable two-dimensional (2D) mapping of sources in azimuth and elevation format. Synchronized operations of two or more DITFs with proper separations can bring three-dimensional (3D) source locations by a triangulation.

It is known that VHF impulses are mainly radiated from the tip of breakdown like at the stepped leader tip especially in case of negative breakdown. In case of a negative CG flash, ordinary downward propagating leaders can be shown by DITF. In case of positive CG, radiation source locations do not go downward straightforward to the ground. They sometimes show the tendency of concentration at certain and qusi-constant altitude of the possible positively charged region. According to the bi-directional leader concept, a lightning discharge is initiated with both positive and negative leaders progression simultaneously in opposite directions from its original inception point. The origin of a lightning discharge is normally not to be grounded to the earth, and the bi-directional leader progression should be trivial form the aspects of the charge conservation law. Since the average intensity of VHF radiation by a positive breakdown was about 20 dB weaker than that by a negative breakdown, positive breakdowns masked by the radiation emitted by negative breakdowns are considered to be undetectable by DITF. Active VHF radiation after a return stroke may be mainly due to the continuing currents, because the continuing current is caused by the negative breakdown progression inside the thundercloud.

Four positive CG flashes are observed both a pair of DITFs and LLS in this study. A multiple positive CG flash, a downward positive leader overlapping with upper negative breakdown, a positive CG flash lowering low-altitude small positive charge like pocket positive, and positive CG flashes without any VHF radiation before the return strokes are noticeable.

Keywords: Positive cloud-to-ground lightning flash, Broadband digital interferometer, Lightning Location System, lightning in summer season

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MIS29-03 Room:A01 Time:May 24 09:30-09:45

Lightning observation using Broadband Observation network for Lightning and Thunderstorm in the Kanto Plain

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We have been designing and developing Broadband Observation network for Lightning and Thunderstorm (BOLT). The BOLT consists of four or more LF sensors which detect LF radiation form lightning discharges and locate LF emission sources in 3D using either time of arrival or digital interferometry. We have lightning observation with BOLT in the Kanto Plain from 2015. In this presentation, we overview the lightning observation, including location error estimation of BOLT for LF emission associated with lighting, and update the BOLT lightning location technique.

Keywords: lightning discharges, thunderstroms, remote sensing

Japan Geoscience Union Meeting 2015
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MIS29-04 Room:A01 Time:May 24 09:45-10:00

The first observational results of Japanese total lightning network associated with severe weather phenomena in 2014

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There has been a lot of attention to the relationship between the lightning activity and severe weather. In particular, total lightning is one of the promising physical parameters for nowcasting the severe weather phenomena such as heavy rain, tornadoes, and wind gusts. In this paper, we first time report the preliminary results of Japanese Total Lightning Network (JTLN) deployed by UEC group. We analyze the temporal dependence of the lightning data focusing on major wind gust events occurred over Japan in 2014. As a result, we found the superiority in the total lightning rather than cloud-to-ground and intra-cloud lightning to identify forthcoming severe weather events.

Keywords: lightning, nowcasting, wind gust, severe weather, total lightning

Japan Geoscience Union Meeting 2015
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MIS29-05 Room:A01 Time:May 24 10:00-10:15

Observation of tornado using a high dense ground observation network in Midori city, Gunma, Japan on 16 September 2013

KIMURA, Hyosun[1*] ; KOBAYASHI, Fumiaki[1] ; NOROSE, Keiko[1] ; KURE, Hirotaka[2] ; YADA, Takuya[2] ; SATO, Kae[2]

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On the midnight of 16 September 2013, a severe thunderstorm passed over Midori and Kiryu City in Gunma Prefecture, causing a gust of wind damage. Japan Meteorological Agency (JMA) estimated that the wind damage was tornado at F1 intensity by damage survey teams. The change of surface pressure was observed by high dense ground observation network POTEKA. The tornado and misocyclone pressure fields are estimated by using the modified Rankine vortex. The result of this analysis shows that we need to discuss the upper air misocyclone and surface tornado.

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MIS29-06 Room:A01 Time:May 24 10:15-10:30

Surface Temperature an Pressure Distributions of Wind Gust captured by High Dense Ground Observation Network 'POTEKA'

YADA, Takuya[1*] ; SATO, Kae[1] ; KURE, Hirotaka[1] ; KOBAYASHI, Fumiaki[2]

[1]Meisei Electric Co. Ltd., [2]National Defense Academy.

Meisei developed low-cost compact weather sensor (POTEKA Sta., hereinafter referred to as the POTEKA), which can measure temperature, relative humidity, pressure, sunlight, and rain detection per one minute and we installed high ground observation network (total 55 stations, 1.5˜4km-mesh) in Gunma in FY2013. The following year, we further improved POTEKA to observe wind direction, wind speed and rainfall. Additionally, we added 93 locations, about 2km intervals, around the elementary school in order to achieve higher density than the existing observation network. Therefore, we can obtain real-time meteorological information per one minute in total 145 stations. This paper presents observation of wind gust on July and August 2014.

The wind gust occurred by cold front in Isesaki city around 12:30JST. The wind gust was estimated to gust front by Japan Meteorological Agency. Surface temperature dropped from 11:50JST, -0.25 ℃ per one minute on average and it drop captured in POTEKA network. The Maximum instantaneous wind speed has a peak after about 20 minutes from the temperature drop, was observed gust of about 19meter per second.

Downburst, accompanied with well-developed cumulonimbus, occurred and passed from Takasaki city to Maebashi city around 18:10 on 22 August 2014. A significant drop in temperature is noticed around 17:45, (-0.47 ℃ per one minute on average). The distributions and occurrence time of cold air captured by POTEKA network well coincide with field survey results of the Japan Meteorological Agency. In addition, the first temperature drop was confirmed about 25 minutes before damage occurrence time of the downburst.

In these cases, tendency of temperature and wind is in good agreement with the observed value of Maebashi local weather station, in order to capture wind gusts.

Keywords: compact weather sensor, high ground observation network, gust front, downburst, wind direction and wind speed, summer 2014

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MIS29-07 Room:A01 Time:May 24 10:30-10:45

Relation between charge amounts of lightning discharges derived from ELF waveform data and severe weather

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[1]Hokkaido University, [2]Tohoku University, [3]Tohoku Electric Power, [4]Kyushu University

Previous studies suggested that there are close relations between lightning activities and meteorological phenomena. But in these studies, only the occurrence frequencies of lightning discharges are considered. As lightning is a discharge phenomenon, it is more important to investigate the relation between electrical properties of lightning discharges such as polarities, peak currents, and charge amounts and the meteorological parameters of the severe weather. As the magnitude of the electrification in thunderclouds is considered to be proportional to the intensity of the vertical convection, charge amounts of lightning discharges can be a good proxy to represent the developing process of thunderclouds. In order to measure the lightning currents and to estimate charge amounts, induction magnetic coils named as Rogowski coils installed at tall towers are generally used. However, in this method, only the lightning discharges directly hitting the towers can be measured. Recently, it is shown that the shape of the lightning-generated induction magnetic field waveforms in the ELF frequency range is well comparable to that of the lightning current waveforms [*Sato et al*., 2013]. Therefore, the charge amounts of any lightning discharges occurring within the area where the induction magnetic fields are measured can be easily estimated from ELF waveforms by quantitatively evaluating the relation between ELF waveforms and the current waveforms. In this study, the lightning current waveforms measured by a Rogowski coil installed at Mt. Ogami and ELF waveforms measured at Onagawa observatory are analyzed. From these quantitative analyses, empirical equations that enable us to directly convert from the magnetic field intensities into the peak current intensities and charge amounts were obtained. Furthermore, using ELF waveform data obtained at Kuju station in Kyushu and lightning data of the Japan Lightning Detection Network (JLDN), peak current values and charge amounts for the lightning discharges occurring when severe down bursts were confirmed in the Kanto Plain are estimated by applying the empirical equations. Then, we newly found a clear feature showing that the time variation of charge amounts was drastically changed just before the downburst onset. At the presentation, we will show the results more in detail.

Japan Geoscience Union Meeting 2015
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MIS29-08 Room:A01 Time:May 24 11:00-11:15

MMSE beamforming method for polarimetric phased array weather radar

KIKUCHI, Hiroshi[1*] ; TASHIMA, Takuro[1] ; WU, Ting[1] ; GWAN, Kim[1] ; USHIO, Tomoo[1] ; GOTO, Hideto[2] ; MIZUTANI, Fumihiko[2]

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A polarimetric 2-D phased array radar, which consists of dual-polarized antenna with two-dimensional circular planar phase-array elements, capable of measuring the 3-D rainfall distribution in less than 20 seconds, is under development. We proposed minimum mean square error (MMSE) method for the under developing radar as digital beam forming (DBF) method, which is one of the important components to develop the phased array radar. In this presentation, precipitation radar signal simulations based on the developing radar concept are carried out. We discuss the estimation accuracy of polarimetric precipitation profiles (differential reflectivity, specific differential phase, and copolar correlation coefficient). From comparison of the performance of the conventional DBF methods, MMSE is superior because of the effect of adaptively suppressed side lobes.

Keywords: precipitation measurement, polarimetric radar, phased array radar, beamforming method

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MIS29-09 Room:A01 Time:May 24 11:15-11:30

The examination of antenna performance for the calibration of Phased Array Radar

SHIBAIKE, Naoya[1*] ; MEGA, Tomoaki[1] ; SHIMAMURA, Shigeharu[1] ; KIKUCHI, Hiroshi[1] ; KIM, Gwan[1] ; USHIO, Tomoo[1] ; HANADO, Hiroshi[3] ; MIZUTANI, Fumihiko[2]

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In recent years, meteorological disasters caused by severe weather phenomena such as tornadoes and heavy rains occur frequently in Japan. In general, these disasters are caused by cumulonimbus clouds. It is very difficult to make observation of severe phenomena because they are developed within a few minutes. Weather radar is very helpful to observe those phenomena, however, the conventional radar, which has about 10 minutes temporal resolution and 500m spatial resolution, is not able to catch the detailed cloud growths and movements spatially or temporally. Thus, we have been developing the Phased Array Weather Radar (PAR) which is installed on the 13th floor rooftop of a building in Suita Campus, Osaka University, Osaka, Japan. PAR, which uses array antenna system, is provided with 128 slot antenna elements and generates multi-beam by means of digital beam forming. This feature enables us to track a great multiplicity of Doppler components due to rainfall. Therefore PAR has about 10˜30 seconds temporal resolution and is more suitable to observe severe weather phenomena than conventional radars.

In general, weather radar measures backscatter cross section of targets to make meteorological observations. We can know a weather condition by assigning it to radar equation. Radar equation includes radar constant which is determined by transmission power, transmission gain, receiver gain, and beamwidth; therefore we need to calibrate them to make the observation accurate.

In addition, each antenna elements of PAR has a bias error individually. the digital beam forming method cannot work well to form the received beam pattern. Therefore we take the bias error of each array into account when we calibrate PAR.

Here, we measured PAR's antenna pattern of transmitted and received beam to know actual gain and beamwidth. Furthermore, we measured the phase of the received signal, and compared it to the phase expected. From the result of the comparison, we calculated the bias error of each array and proposed the method of phase error correction.

Keywords: phased array radar, weather radar, array antenna, calibration

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MIS29-10 Room:A01 Time:May 24 11:30-11:45

Digital Beam Forming methods on Observation Result of Phased Array Radar

TASHIMA, Takuro[1*] ; KIKUCHI, Hiroshi[1] ; WU, Ting[1] ; SHIMAMURA, Shigeharu[1] ; KIM, Gwan[1] ; USHIO, Tomoo[1] ; GOTO, Hideto[2] ; MIZUTANI, Fumihiko[2]

[1]Osaka University, [2]Toshiba

We have been developing the Phased Array Radar (PAR) which detects small scale weather phenomena. We adopt Beam Former method (BF) in the way of adaptive digital beam forming (DBF) to sharpen fan beam of elevation angle to about 1 degree. In BF, an antenna pattern is uniform in the radar system, and sidelobe level is high. As a result, a fake echo appears in the observation result in consequence of high building or heavy rain in near region.

On the other hand, in Minimum Mean Square Error method (MMSE), we can turn the null-point to inference signal direction and the mainlobe to desired signal direction. As a result, we can decrease a fake echo. However, a calculation cost of MMSE is about 200 times more expensive than this of BF.

Therefore, we propose faster MMSE method. In this presentation, we show and compare the PAR observation results of radar reflectivity and calculation time with BF, MMSE, and our proposed method.

Keywords: Phased Array Radar, Digital Beam Forming, Minimum Mean Square Error method, severe phenomena

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MIS29-11 Room:A01 Time:May 24 11:45-12:00

Precipitation attenuation retrieval method with Phased Array Radar network

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Remote sensing technology is effective in precipitation observation, including severe phenomena such as heavy rain and tornadoes. Most of conventional weather radars have parabolic antennas, which radiate electromagnetic wave with beam width of around 1 degree. In elevation and azimuth directions, the scanning mode of the radar is mechanical. It takes about 1˜5 minutes to observe at low altitude and 5˜10 minutes for three-dimensional observation. Besides conventional radars have range resolution of 500 meters. However, severe phenomena regionally occur during several minutes at low altitude, so it is not sufficient for conventional radars to detect these phenomena. Additionally in the most observable area, conventional radar can not detect anything in the lowest altitudes due to earth's curvature. On the other hand, X-band Phased Array Radar(PAR), located at Suita campus of Osaka University and Nishi Ward, Kobe city, can observe severe phenomena because of it's high resolution and scanning mode. PAR has range resolution of 100 meters and temporal resolution of 30 seconds. Additionally PAR scans electronically at elevation direction and mechanically at the azimuth direction. The coverage is not affected by earth's curvature so much. These advantages enable PAR to observe within a range of 60 km in 30 seconds. However, X-band wave can be attenuated more seriously than waves at lower frequency bands. Precipitation attenuation is a critical and inherent problem for most precipitation radars since it often yields a large negative bias error which makes us underestimate reflectivity factor of precipitation. A radar network observation is a strategy to deal with this problem. The reason is that when one radar can not observe precipitation because of large precipitation attenuation, the other can complementarily observe it. There is also another problem. Hitchfeld-Bordan(HB) method, a precipitation attenuation retrieval method, is one of attenuation retrieval method which is occasionally used in low frequency band radars such as S-,C-band because attenuation is very slight. However, if we apply HB method to X-band radar, divergence of correction value happens at times. In this study, a new integration method to correct the reflectivity factor of two PARs is proposed and has been used in the overlapped area at the radar network.

Keywords: phased array radar, precipitation attenuation, precipitation attenuation retrieval, radar network

Japan Geoscience Union Meeting 2015
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MIS29-12 Room:A01 Time:May 24 12:00-12:15

Low-altitude Velocity Field Estimation in Doppler Radar

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Doppler weather radar radiates electromagnetic waves into the atmosphere. The waves are reflected by objects such as precipitation particles and buildings, away from the radar and scattered in many directions. Some of them return to the radar and the radar antennas receive the reflected waves. The object is moving under the influence of wind, so phases of received signals are shifted by the Doppler effect. The difference between phase of transmitted and received signal enables to measure velocity of wind around the object, which is Doppler velocity. Precipitation particles in the atmosphere are moving independently by the influence of turbulence, so Doppler velocity measured by multiple of the transmitted wave shows certain distribution. Such distribution is expressed as a function called Doppler spectrum whose independent variable is Doppler velocity and dependent variable is received power.

The most common method of calculating Doppler spectrum is Fast Fourier Transform (FFT) method, but there is a problem in FFT method. In Low-altitude observation influence of clutters such as mountains and buildings increases. In such circumstance spectral side-lobe level is high, and weather signal is buried and cannot be extracted by conventional filtering process. In this research, we proposed Minimum Mean Square Error(MMSE) method as a new method of calculating Doppler spectrum to solve the problem. We verified accuracy of the new method by simulation and presented results of applying this method to observational data. In the result, it was found that MMSE method solved the problem of FFT method and enabled to extract weather signal by reducing side-lobe. Therefore, MMSE method is effective as a spectral calculation method for Low-altitude observation.

Keywords: Doppler Radar, Minimum Mean Square Error, Doppler Spectrum

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MIS29-13 Room:A01 Time:May 24 12:15-12:30

Variations of sferic waveforms in VLF range observed by AVON

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Previous studies suggested that there exists a good relationship between lightning activity and atmospheric convection [e.g. Deierling and Petersen, 2008]. The lightning data can be used as a proxy for the presence of deep atmospheric convection. Previous researches estimated statistically the total optical lightning flashes for understanding the relationship between lightning activities and atmospheric convection [e.g. Boccippio et al., 2000]. However it is difficult for optical observation to estimate electrical properties of lightning discharge. When we can measure electrical properties of each lightning and the flashes of lightning, it is possible to understand more detailed relationship between the lightning activity and atmospheric convection.

In this study, we use Asia VLF observation Network (AVON) and estimate the location of lightning and electrical characteristics of each lightning stroke in South-East Asia. AVON monitors electromagnetic waves in the frequency range of 0.1 kHz – 40 kHz. We estimate the lightning locations using 3 stations of AVON, that is, at Tainan, Taiwan, Saraburi, Thailand and Potianak, Indonesia, by time-of-arrival method and the charge moment change (CMC) using the waveform of sferics in VLF range. However, there is a difficulty in estimating CMC with VLF wave forms occurred at long range (>200 km) since the ground wave is overlapped by sky waves. We investigated the relationship between the ground wave and sky waves for different ranges. The observed data is from 06:00(UT), December 1st 2010 to 00:00(UT), December 2nd 2010 and the total number of analyzed events is 72. We divided to consider change of the ground wave and sky waves by depending on ranges at intervals of 100km.

It is found that the sky waves are dominant as compared with the ground wave at long range and it is possible that we estimate CMC of CG lightning, considering low frequency of the lightning discharge. We found that there was the time variation of arrival time for sky waves because of the changes of the ionospheric height. It could be possible to identify a lightning pulse as one of them using sky waves, considering the ionospheric height. We discuss about the geolocation of CG lightning using arrival times of sky wave and estimation of CMC using observed data from AVON.

Keywords: lightning, cloud-to-ground lightning, lightning geolocation, sferic waveform, very low frequency

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MIS29-14 Room:A01 Time:May 24 12:30-12:45

The relation between summer sprites and lifecycle of parent storm system: 2013 Mt. Fuji observation campaign

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An isolated-mountain observation was conducted at the summit of Mt. Fuji (3776 m), Japan, to detect transient luminous events (TLEs) off the coast of the Boso Peninsula, Chiba, and the east coast of Japan. Many TLEs caused by energetic positive cloud-to-ground (+CG) lightning occurred in this region during the summer of 2013. Since the summer clouds covering the ground and ocean are usually located below the summit. A 360 degrees view from the isolated mountain along with low atmospheric pressure and unpolluted air over the summit is expected to facilitate the observation of TLEs and their vivid color images, respectively. We detected several distant TLEs with light-sensitive black-and-while CCD cameras and a color single-lens reflex camera. We investigate the relationship among sprites, the parent +CG lightning and the parent storm systems. Six sprite events were associated with +CG lightning and their estimated amplitude was 156 +- 76 kA (89 - 312 kA). Sprites appeared 41 +- 30 ms after +CG lightning. The +CG lightning with sprites were located in the stratiform precipitation region.

Keywords: Sprite, Parent lightning, Thunderstorm

Japan Geoscience Union Meeting 2015
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MIS29-15 Room:A01 Time:May 24 14:15-14:30

Observation of gamma-ray bursts from winter thunderclouds and lightning over the Japan sea coast

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Gamma-ray emission associated with lightning and thunderstorms are reported nowadays. This phenomena was first detected in space by gamma-ray observing sattelite and recently numbers of ground based observation experiments are also carried out. GROWTH (Gamma-Ray Observation of Winter THunderclouds) experiment has been operated since 2006 in Kashiwazaki-Kariwa nuclear power plant located in Niigata prefecture and observing gamma-ray emission from winter thunderclouds over the Japan sea coast region. This experiment reveals that there are two types of bursts. One is called "short-burst" which coincides with lightning discharge and has duration of less than 1 sec. The other type is called "long-burst" which continues more than a minute correlated with thunderclouds and not the discharge(H. Tsuchiya+2007, 2011). Long-bursts normally have a featureless spectra which can be explained by Bremsstrahlung emission from relativistic electrons accelerated by the electric field in the thunderclouds. Typical duration of long-bursts are about 1 min. This time scale is equal to the passage time of a typical thundercloud spreading over ˜1 km size with speed of ˜15 m/s, but may also be an intrinsic lifetime of emission. Essential factors such as, what makes it start, its intrinsic duration and what causes it to terminate, still remain unknown.

At 09:27 (JST) on January 13th in 2012, GROWTH detected curious emission. A short-burst was triggered, correlated with in-cloud discharge within 200 ms, and a long-burst started at the same time with the duration of more than 1 min, with fast rising and exponentially decaying intensity with time constant of 30 sec.

One of the remarkable point of this burst is strong 511 keV electron-positron annihilation line in the spectrum. Equivalent width, the parameter which shows a relative strength of a line compared to a continuum component, of the 511 keV line is usually ˜50 keV. It is 280 keV for the present event, which is 5 times more prominent than usual. As a simplest explanation, this relatively strong line can be explained as follows: Bremsstrahlung gamma-rays are selectively emitted toward the direction of the accelerated seed electrons. The gamma-ray energy as well as its number rapidly decreases with opening angle to the electron direction, forming a gamma-ray beam. If electrons are accelerated in parallel in a 'bulk' electric field, this effect becomes easily observable. High-energy gamma-rays with energy $>$1 MeV can create positrons and eventually isotropic 511 keV emission. If the detector is slightly off the beam, it will observe smaller numbers of those high energy photons, while it wil detect relatively conspicious 511 keV photons. Such 'beam' effect is actually reported as a change in the gradient of the continuum spectrum distribution vs. time as a thundercloud goes by, already(H. Tsuchiya+2009, 2013).

Another remarkable point of this long-burst is the abrupt initiation correlated with the discharge. Abrupt termination of a long-burst correlated with lightning discharge is already reported(H.Tsuchiya+2013), which can be consistently explained by an electric field dissapearance caused by a discharge. In the present burst, although still controversial, it is possible that the discharge causes the rapid reorganization of electric field within the thundercloud, resulting in start of the electron acceleration.

To testify explanation above and to measure intrinsic intensity vs. time, another new detector with higher sensitivity with a limited angular resolution was developed and set up in the nuclear power plant in Nov. 2014. As a result, this detector succeeded in observing 6 events within a single winter period. This burst occurance rate is about 4 times greater than usual: 12 long-bursts during 2006 and 2013. One of these events with the highest statistics shows a sign of gamma-ray beam. Another event has abrupt termination feature again, which is the second detection of such event by GROWTH.

Keywords: gamma-ray observation from thunderclouds, TGF, positron generation

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MIS29-16 Room:A01 Time:May 24 14:30-14:45

Thunderstorm-induced energetic radiation observed at the summit of Mt. Fuji during July - August of 2013

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We investigate the condition of the energetic radiation caused by the thunderstorm electric filed. From the events of the energetic radiation observed at the summit of Mt. Fuji during the summer, the following features were found: Negatively charged region located in -10 ℃ altitude (approximately 7 km) inside the thunderstorm attributed to the radiation. The observed radiation was enhanced about 10 %. Our Monte Carlo simulation showed that the energetic radiation was observed when the negatively charged region with the -4 nC/m^3 and 1 km radius appeared at approximately 7 km altitude.

Keywords: Energetic radiation, Thunderstorm, Mt. Fuji

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MIS29-17 Room:A01 Time:May 24 14:45-15:00

Measurement of radiation caused by thunderstorm activities by a sounding balloon, an airplane, and the ground

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Energetic radiation caused by thunderstorm activity is observed at various places, such as the ground, high mountain areas, and artificial satellites. In order to investigate the radiation source and its energy distribution, we measured energetic radiation by a sounding balloon, an airplane, and the ground observation. On the measurement inside the thundercloud, we conducted a sounding observation using a radiosonde mounted two GM tubes (for gamma-rays, and for beta/gamma-rays), in addition to meteorological instruments. The balloon passed through a region of strong echoes in a thundercloud shown by radar image, at which time an increase in counting rate of the GM tube about 2 orders of magnitude occurred at the altitude from 5 km to 7.5 km. Furthermore, the counting rate of 2 GM tubes indicated the tendency different depending on movement of a balloon. This result suggests that the ratio for the gamma-rays (energetic photons) of the beta-rays (energetic electrons) varies according to the place in the thundercloud. Then, we measured the variation of the energetic radiation from the top of the thundercloud using an airplane. At this time, we used two NaI detectors different in the size. We performed the radiation measurement by flying around the thunderclouds at 12 ? 14 km in height by the observation in the summer. Moreover, in the winter season, we flew 5 ? 6 km in height and measured the radiation around the thunderclouds. Furthermore, we carried out a ground observation of the energetic gamma rays during winter thunderstorm at a coastal area facing the Sea of Japan. Two types of the energetic radiation have been observed at this time. We report the outline of these measurements and analysis in the session of the JpGU meeting.

Keywords: Transient energetic radiation, Monte Carlo simulation,, Thunderstorm, Balloon, Airplane, Fukushima

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A derivation of basic formalism of the Schumann resonance considering finite electrical conductivity of the solid earth

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The frequency characteristics of the Schumann resonance of the geoelectromagnetic field have been analytically derived with an approximation that the solid earth is a perfect conductor. This approximation is, however, qualitatively inconsistent with observational facts that horizontal electric field variations in the ELF band are recorded in magnetotelluric surveys. Based on the frame of the internal geoelectromagnetism, assuming a simple space that the solid earth is a homogeneous sphere with a finite electrical conductivity, together with a homogeneous insulating spherical shell representing the atmosphere and an infinite homogeneous sphere with a finite electrical conductivity representing the ionosphere, the mathematical expression of the Schumann resonance in the 3-layer earth is derived. In the presentation, the frequency characteristics of 3 components of the TM wave excited by a radial electric current element are shown.

Keywords: Schumann resonance, Solid earth

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Aviation Tactical Lightning Avoidance System for Weather-Smart Airport Operation

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Aircraft initiated or intercepted lightning is one of the heaviest issues for civilian flights in Japan. Although several accidents have been reported many years ago, it is currently much less possible that lightning strikes cause fatal aircraft accidents due to both of certifications of aircraft design for lightning strikes and many of weather supports for aircraft operation. However, hundreds of lightning strikes to aircrafts were still reported in each recent year in Japan, and airlines have been forced to delay or cancel most of those flights and to cost millions of yen for repair. Especially in the coastal area of the Sea of Japan, winter lightning often gives heavy damages to aircrafts. Though flight safety is secured even with such heavy damages by winter lightning, it is necessary to take much more cost and time to repair after landing compared with normal summer lightning.

As is well known in aviation weather field, it is significant for actual aircraft operation that observed meteorological parameters are converted to decision-making information. Otherwise, pilots, controllers, or operators need to learn meteorology as much as weather experts, and to owe hard work load to interpret observed meteorological data to their risk. Ideally, it is desired to automatically provide them with predicted operation risk, for example, delay time, possibility of flight cancellation, repair cost, etc., caused by lightning as decision-making information. In order to realize products of those operation risks, high quality of weather observation is required. A high resolution radar, such as the phased array weather radar, has potential to detect thunderstorms in their early stage due to the high volume scan rate from 10 to 30 sec. A lightning mapping system, such as Broadband Observation network for Lightning and Thunderstorm (BOLT), indicates electrical structure inside clouds in concert with a co-located radar data. Aircraft sounding and real-time data downlink, especially high-frequency data provided by Secondary Surveillance Radar (SSR) mode S, gives in-situ measurements of three-dimensional profiles of wind and temperature. The in-situ wind data supports a radar to accurately estimate spatial profiles of wind speed and direction. And the in-situ temperature data can indicate altitudes of electrical charge separation.

Our research group started a research and development (R&D) of aviation tactical lightning avoidance system in this fiscal year. The final goal of this R&D is to provide airport officers with products of operation risks caused by lightning which are derived from the novel weather observation devices stated above. In the presentation, overview and progress of our R&D will be described.

Keywords: Aviation weather, Terminal weather system, Lightning

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Development of the GPS tomography of water vapor distribution in troposphere using neural network

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When the rain cloud bringing the damage of a heavy rain and the thunderstorm is developing, there is an apparent flow of the water vapor from the neighborhood. It is possible that the GPS can detect the flow and distribution of water vapor. Therefore, in this study, we develop a water vapor tomography from GPS and AMeDAS data using algorithm of residual minimization learning neural network (RMTNN). We carried out the numerical simulation to investigate the horizontal vertical resolution of the algorithm; the target area is E135- E137, N34-N36, Alt 0 km-10 km. We divided the area into 20 and 50 in horizontal and in 50 vertical, respectively. Therefore, the scale of a voxel is 0.1∗0.1∗0.2 km. We put 400 GPS sites in a total on the surface uniformly; the inter-GPS distance is 0.1. We used GPS satellites coordinates at 09:00 JST on Aug 13, 2012 for the simulation. We added 5% noise to data.

To investigate the horizontal resolution, we perform the numerical simulation to reconstruct the water vapor distribution which has uniformly decrease in exponentially with altitude and a gaussian enhancement in horizontal. The center of the Gaussian enhancement is fixed at E136, N35. We carried out simulation with changing peak values of the Gaussian enhancement; 30%, 20%, and 10% against the background water vapor density, and half?width values of the gaussian enhancement ; 0.5, 0.3, and 0.1. To investigate vertical resolution, we perform the numerical simulation to reconstruct the water vapor distribution which has uniformly decrease in exponentially with altitude and a gaussian signal in both horizontal and vertical. The center of the signal is E136, N35, Alt 2 km, with the peak value of 15(g/mˆ3), half-width value width of 0.3in horizontal and 0.6 km in vertical, respectively.

The results of the numerical simulation demonstrate the following capacities of the developed RMTNN algorithm; (1) for the horizontal resolution, water vapor disturbance with 30% peak value against the background level can be reconstructed by 6 GPS observation sites in a linear profile, disturbance with 20% peak value, 10 GPS observation sites and (2) for the vertical resolution, it is possible to reconstruct an inverted layer of the water vapor distribution with adequate points for restriction points. These facts show that the developed tomography algorithm on the tropospheric water vapor has the ability to reconstruct disturbance without any model dependence.

Keywords: GPS tomography, water vapor