Synoptic-scale conditions with occurrence of winter lightning in the Hokuriku district of Japan

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Generally, almost all lightning is negatively charged, while the ratio of positive lightning increase in winter thunderstorm. Some studies have indicated that the positive lightning would be caused by strong vertical wind shear and/or weak updraft. This study examined difference of synoptic-scale atmosphere conditions between the negative and positive lightning with occurrence of winter lightning based on lightning data obtained by Lightning Location System in Hokuriku district of Japan and atmospheric data obtained by Japan Meteorological Agency Meso-Scale Model. The relationships among the causes were evaluated by composite analysis for 8 years from Oct 2006 to Mar 2014.
In the positive lightning cases, from December to March, Hokuriku district were located near the southern part of the cyclone passing over the Sea of Japan. Further, vertical wind shear was relatively strong and updraft was relatively weaken in the positive lightning cases, which are consistent with the results mentioned in some previous studies. In the negative lightning cases, negative and positive geopotential height anomalies appeared in the east and west the Sea of Japan, respectively, and there were the cold air anomalies in the mid-troposphere. In contrast, remarkable differences were not identified in the synoptic-scale atmospheric conditions between the positive and negative lightning cases in October and November.

Keywords: positive cloud-to-ground lightning, winter lightning, thunderstorm

Lightning Observation Network with LF Broadband Sensors around Toyama Bay

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It is well known that lightning flashes during winter thunderstorm seasons in the Japan sea coastal area show a number of remarkable features. Winter lightning causes serious damages in electric power transmission and distribution systems. All lightning processes can be studied by measurement of the EM fields associated with the charge transfer.

We have been designing and installing a lightning location system in 3D based on the broadband digital interferometry technique in LF bands. The LF band sensors consists of four or more observation stations which detect electromagnetic (EM) waves in a wide frequency range from 1kH to 150 kHz associated with lightning discharges. Since each station detects EM waves in LF, the lightning discharges several hundred kilometers away from the sensor are detectable.

During the winter thunderstorm season in 2016-17, we conducted lightning observation campaign with the LF sensors around Toyama bay. The locations for EM waves associated with return strokes, preliminary breakdown process, and continuing current are succeeded. Notable long lightning channels will be discussed in this talk.

Keywords: Winter thunderstorm, Lightning discharges, EM observations

Improving accuracy of locations and lightning charge moment changes using multi-point simultaneous observations of ELF transients

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In this study, we simultaneously observed ELF transients at Rikubetsu, Hokkaido and Tarumizu, Kagoshima prefecture. Source locations of lightning discharges were derived by using the triangulation technique. We compared these estimated lightning locations with those from Japan total lightning network.
Moreover, we derived corresponding charge moment changes (CMCs) by current moment waveforms integrated over time.

Keywords: ELF band sferics, Location of lightning discharges, Charge moment changes

A comparative study on intermittent propagation mode of positive and negative leaders

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The mechanism of intermittent propagation mode of both negative leaders and positive leaders remain on one of the largest mystery in lightning physics. In order to shed some light on this mechanism, recently we have made a comparative study on the optical propagation characteristics of an upward positive leader and an upward negative leader recorded using a high speed video camera operated at 300000 fps. The negative leader is a typical stepped leader with a few branches, while the positive leader exhibited both continuous propagation mode and intermittent mode.
It was found that each step of both positive and negative stepped leaders starts with a stem. For the positive leader, this stem usually initiates at a distance more than 100 m ahead from the tip of the leader, while for the negative leader, the stem usually initiates at a distance of around 50 m. The stem in the negative leader usually lasts less than 25 us, while the positive leader stem could last over 300 us. All the stems tend to progress in bi-direction modes. Although the backward propagation (in relative to the leader propagation direction) speed of the stem for both leaders are similar, the forward propagation speed of the negative leader stem is much larger than that for the positive leader stem. In the final paper, we will not only report on the detailed results but also try to present a schematic to explain the reasons of the differences.

Keywords: lightning, stepped leader, streamer

Multi-point Observations of Thundercloud Gamma-rays: Development of Portable Detectors and Results of Fiscal 2016 Winter Observation

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On-ground detections of bremsstrahlung gamma-rays with energy extending up to 10 MeV from winter thunderstorms indicate electron accelerations inside thunderclouds (e.g. Trii et al., 2002, Tsuchiya et al., 2007). In order to resolve time variation and structure of the electron accelerators, we started to construct a multi-point system to detect thundercloud gamma-rays (Enoto et al., JpGU 2016 M-IS14, Enoto et al. 2017 M-IS05). In fiscal 2016, we have developed a small electronics board consisting of a FPGA/ADC board and a front-end board. The FPGA/ADC board, with 9.5 cm ×9.5 cm area, has a 4ch Analog-to-Digital Convertor which is controlled by Raspberry Pi. The front-end board has preamplifiers and shapers to be coupled with BGO scintillators and PMTs, a GPS receiver, and high voltage suppliers. We set up portable detectors including the electronics board and a BGO scintillator. Five detectors were installed in Kanazawa and Komatsu on October 2016, one in Suzu and two in Kashiwazaki on December 2016. In December 8th to 9th, four detectors in Kanazawa and Komatsu detected thundercloud gamma-rays for several minutes. The gamma-ray enhancements exhibited continuum spectra extending up to 10 MeV. In addition, we succeeded in a multi-point detection of gamma-rays from an identical thunderstorm by two detectors in Komatsu because a difference of the detection time is consistent to a passing time of the thunderstorm. We will report current status of the electronic board development and a result of the fiscal 2016 winter observation.

Keywords: winder thunderstorm, gamma-ray, electric field, electron acceleration

Ground observation of thermal neutrons from Terrestrial Gamma-ray Flash above wind turbine

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During a thunderstorm on December 3rd, 2015, coincident with an upward leader originating from a lightning protection tower next to the wind turbine in Uchinada, the Gamma-ray Observations During Overhead Thunderstorms (GODOT) instrument observed a large, ~100ms duration, flux of radiation with a spectral signature characteristic of thermal neutron production. We will present our observations and show comparisons to monte-carlo simulations, proposing that we have the observed the first neutron glow from a Terrestrial Gamma-ray Flash, produced by photonuclear reactions of gamma-rays with the air and ground molecules around the wind turbine.

Keywords: Lightning, Terrestrial Gamma-Ray Flash, TGF, Radiation, Neutron, Wind Turbine

Charge change estimation at short-burst energetic radiation in winter thunderstorm

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The physical mechanism of lightning-induced energetic radiation has been considered to be caused by the relativistic runaway electron avalanche hypothesis proposed by Gurevich and his group. For further comprehensive understanding of the mechanism, we conducted the observation of lightning-induced energetic radiation and atmospheric electric field using field mills at Uchinada, Kanazawa, Japan during 2015-2016 winter. In general, taking into account the lightning position identified by lightning location system, the observed transient electric field changes (normally detected by slow antenna) at two observation points provide charge changes inside the thundercloud at the time of lightning and the charge height. Although field mill might not be suitable for such observation due to signal smoothing, we evaluated these two parameters using four field mills. Our estimation shows that errors of two parameters was within 20 %. In the presentation, we show these parameters at the time of lightning-induced energetic radiation.

Keywords: Energetic radiation, Winter Lightning, Thunderstorm

Origin of summer-thunderstorm-induced energetic radiation

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We conducted the radiation and atmospheric electric field measurements at the summit of Mt. Fuji during the summer of 2013 and 2016. On July 26 and Aug. 5 of 2013 and Aug. 26 of 2016, the long burst of the energetic radiation was observed with 10 % enhancement. From the analysis of X-band MP radar, the radiation was observed tin the dissipation stage of thunderstorm. In all the cases, negative electric field (upward direction) was observed with approximately -30 kV/m, which is not enough to cause relativistic runaway electron avalanche (RREA). Therefore, plausible radiation source might be around the positively charged area in the thunderstorm.

Keywords: Energetic radiation, Thunderstorm, Mt. Fuji

Study on lightning and precipitation activities by EM observations

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The lightning and precipitation activities are studied in this paper by Ku-band broadband radar (Ku radar), VHF Broadband Digital Interferometer (DITF) and Lightning Location System (LLS) observations. The authors have been conducting cooperative lightning observations in Toyama, Japan, in where winter thunderstorm are developed. This paper focuses on the time development of thunderstorm activities.

Ku radar is a low-power high-resolution Doppler radar for meteorological applications. Ku radar employs bistatic system which is composed of a pair of Luneberg Lens Antenna, and solid state amplifier which transmits the wideband signal (80 MHz) in Ku-band. The pulse compression technique, which has the advantage that high range resolution profiles can be acquired by low transmitting power, is applied. However, the range sidelobe of a compressed signal may contaminate the neighboring rain echo. To overcome this disadvantage, the intermediate frequency (IF) signal is acquired by a high-speed analog-to-digital converter (ADC), and then it is processed by sets of digital signal processors (DSPs). In the pulse compression processing, the cross correlation between the signal received from precipitation and reference, namely presampled transmitted signal. Observation time resolution for a full volume scanning and range resolution less than 1 minute and 2.5 m are realized with Ku radar, respectively.

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. 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.

At the time period of most active lighting activities, the bright band radar echo is disappeared. The reflectivity decreases in order of height from highest to lowest with active lightning. It indicates that the relations between deep convective and lightning.

Keywords: Lightning, Radar, thunderstorm

Observation of atmospheric electricity parameters (atmospheric electricity field (AEF), atmospheric ion concentration (AIC), and radon concentration) at Asahi, Boso Peninsula, Japan

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The Ionospheric anomaly is one of the most promising precursory phenomena for large earthquakes. Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model has been proposed to explain these phenomena. To examine the possibility of chemical channel of LAIC through the monitoring of atmospheric electricity parameters, we have installed sensors for the atmospheric electric field (AEF), atmospheric ion concentration (AIC), radon concentration, radon exhalation quantity (REQ), and weather elements. We will report the properties of variation in atmospheric electricity parameters observed at Asahi station (ASA), Japan to identify earthquake-related signals in these parameters.
Radon exhalation quantity variation follows a clear negative correlation with 3 hours delay to the air pressure variation in clear days. Each season differs in daily pattern. AIC and AEF variations show lag correlation with radon exhalation quantity variation. To extract anomalous radon variation related to earthquakes, we should set a network of Radon monitoring and establish a model of radon variation for the future detailed analysis. We also observed cases that AEF has showed a spike-like increase at the same time as the time when AIC has largely increased. It must be going to be checked whether AEF data was taken in fair-weather period, however, it suggested that change in local charge distribution may have influenced AEF.

Keywords: Lithosphere-Atmosphere-Ionosphere Coupling, atmospheric ion concentration, atmospheric electric field, radon exhalation quantity

Comparison study of Lightning Interfeometry via VHF Emission(LIVE)

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Lightning discharges radiate broad band frequency electromagnetic waves from ULF to UHF. Using sensors which detect this radiation is an effective technique to detect lightning flashes, even if they are in a cloud. Using multiple sensors, a lightning flash can be located using various techniques. At low frequencies, the power radiated by lightning is very high, but because the wavelengths are long, the location resolution is somewhat low. At very high frequencies, the wavelengths are much shorter allowing for much better location resolution, but the power radiation is also much lower, making it more difficult to detect. The VHF band is a good compromise between good location resolution, and good detection efficiency. One effective technique to locate VHF signals from lightning is interferometry. With this technique, the signals arriving at least three VHF broadband antennas are coherently combined to produce an 2D image of the lightning flash. The current generation broadband lightning interferometer being developed in Japan by RAIRAN and the University of Osaka called Lightning Interferometer via VIHF Emission (LIVE).
In 2016 summer season, LIVE is installed in Kaizuka, a city to the south of Osaka, near Osaka Bay to observe Japanese summer lightning with four VHF antennas. In the current study, we are tring to calibrate the detailed antenna locations and cable delays which is difficult to measure physically from cross correlate imaging, and comparing the high detail lightning maps produced by LIVE to the lower detail, 3D maps produced by a low frequency time-of-arrival system called the Broadband Observation network for Lightning and Thunderstorms (BOLT) which is spread around Kansai area in Japan.

Keywords: Interferometer

Statistical study of maximum ionospheric electron density deduced from lightning whistlers obtained by DEMETER

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Electromagnetic waves radiated by lightning discharges in the VLF frequency range penetrate through the ionosphere and are observed as plasma waves so-called whistlers. In this paper, we used the fractional hop whistlers recorded by the ICE experiment onboard the DEMETER satellite to estimate the maximum electron density of the ionosphere F2 layer from the dispersion of whistlers. We have developed an automatic long-term whistler detection technique which enables us to carry out the statistical study of many whistlers from the satellite data. As a result, the maximum electron densities estimated by whistlers has a good agreement with those from ground-based measurements by ionosonde. Moreover, statistical properties of latitudinal dependencies of electron-density in different local times and seasons were obtained.

Keywords: Whistler, Ionosphere, Maximum electron density, DEMETER

