Horizontal difference between sprite-producing positive cloud-to-ground lightning and sprites during winter thunderstorm in Japan

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A number of papers have reported that a horizontal location difference between the sprite optically observed and the sprite-producing positive cloud-to-ground (+CG) lightning electromagnetically estimated often extended approximately 50 km. In order to elucidate the cause of the difference, we precisely measure the horizontal difference between sprites optically observed at three or four ground-based stations and the sprite-producing +CG lightning electromagnetically identified by several data sources, which might be expected to provide more accurate horizontal location. During two winter periods of 2012-2013 and 2015-2016 in Japan, seven events of sprites simultaneously observed at more than three optical stations in Japan were obtained. All events of sprites occurred within 5 - 10 km (7 ±3 km in average) horizontal distance from the largest luminescence of +CG lightning where the upper edge of +CG lightning return stroke was assumed. In the six of seven events and one, the horizontal distances between the center of sprites and the sprite-producing +CG lightning showed 14 - 22 and 7 km, respectively. In addition, column and carrot shapes of sprites could not be categorized by such horizontal difference.

Keywords: Sprite, Winter Lightning, Thunderstorm

Multi-point radiation measurements for gamma-rays from accelerated electrons in winter thunderstorm

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Recent on-ground observations have revealed that winter thunderstorm along the Japan sea radiates gamma-rays with energy extending up to 10 MeV (Torii et al., 2002, Tsuchiya & Enoto et al., 2007). Inside the thunderstorm, electrons are thought to be accelerated to relativistic energy by strong electric field, and to radiate bremsstrahlung gamma-rays. Currently, since the number of observation sites is limited, it has been difficult to trace time- and space-dependent changes of gamma-ray spectra. In order to resolve the electron acceleration mechanism inside thunderstorms (e.g., generation, growth, and disappearance of the relativistic electron acceleration region), we started to construct a new multi-point mapping system of the gamma-ray radiation, which can trace a path of the radiation and can detect a change of gamma-ray intensity and spectral change. In 2016-FY, we have developed a small, inexpensive FPGA/ADC board and a front-end electronics board to be coupled with BGO scintillators and PMT photo-diodes (see also Wada et al., JpGU session at the M-IS 18). We installed these new small radiation detectors on roofs of several high school and universities in Kanazawa prefecture, which area is famous for energetic winder thunderstorms. Our acquisition system has been collecting energy and arrival time (with GPS time tag) of individual photons, with environmental information (e.g., temperature, pressure). On 2016 December 8 and 9, we detected the gamma-ray radiation from winter thunderstorms at Kanazawa and Komatsu cities. We will report current status of our project and future prospects on understanding of the micro physics in the thunderstorms.

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

Intensity and frequency of electrified dust storms in the Middle East

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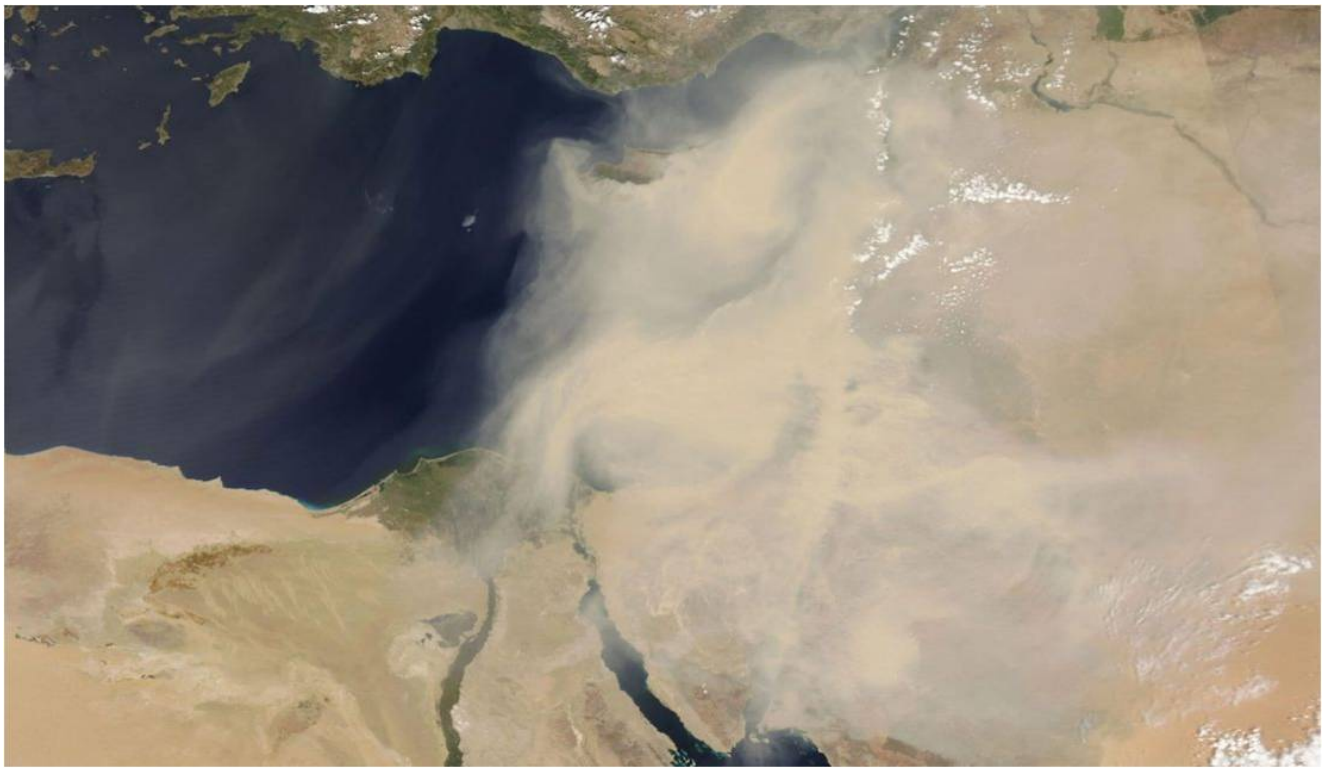
Dust storms in the Middle East are a common natural phenomenon and have become more frequent in recent years, due to the observed warming and drying trends attributed to regional climate change. Such dust storms are often accompanied by large electrical charging, most likely due to saltation and triboelectric processes. We present atmospheric electrical measurements conducted at the Wise Observatory (WO) in Mizpe-Ramon (30^{0}35’ N, 34^{0}45’ E, 850 MSL) and on Mt. Hermon (33°18’ N 35° 47’ E, 2200 MSL) in Israel. Atmospheric electrical measurements during several strong dust storms that occurred in the Middle East in 2015-2016 showed that when dust was being transported above the instruments, very large fluctuations in the electric field (Ez) and the current density (Jz) occurred. Values > 6 kV/m and peak current density of 12pA/m^{2} were observed, persisting for hours during peak aerosol concentrations. The electric field and current density variability and amplitude measured in all events deviate significantly from the mean fair-weather values at both sites. There are also notable differences in the polarity and magnitude of the observed electrical parameters between the dust storms, which are attributed to wind speed, dust episode duration and compositional differences of the soil in the source regions. These differences will be discussed and compared to dust storms in other regions.

Keywords: Electric Field, Dust Electrification, Regional Climate Change



Response of atmospheric electric fields to cloud parameters using a field mill and 95-GHz cloud radar FALCON-I

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It is known that lightning and precipitations of rain droplets generated from thunderclouds are the generator of global atmospheric electric circuit. In the fair weather, the atmospheric electric fields (AEF) are downward (positive), while they are upward (negative) during lightning and precipitations. However, the correlations between the AEF, and the cloud parameters such as cloud cover, weather phenomenon, have been not yet revealed quantitatively. In this study, we investigate the correlations between the AEF and the cloud parameters, weather phenomenon such like lightning and snow using a field mill, the 95 GHz-FALCON (FMCW Radar for Cloud Observations)-I and all-sky camera observations.
In this study, we installed a Boltek field mill on the roof of Engineering Research Building-2 in Chiba University, Japan, (Geographic coordinate: 35.63 degree N, 140.10 degree E, the sea level: 55 m) on the first June, 2016 to observe the AEF. The sampling time of the AEF is 0.5 s and the voltage range is ±20 kV/m. On the other hand, the FALCON-I has been originally developed by our group, and has observed the cloud parameters throughout 24 hours every day. The vertical cloud profiles and the Doppler velocity of cloud particles can be derived by the FALCON-I with high spatial resolutions (48.8 m). In addition, the images of the clouds and precipitations are recorded with 30-s sampling by an all-sky camera using a CCD camera on the same roof during 05:00-22:00 LT every day. The distance between the field mill and the all-sky camera is 3.75 m, while the distance between the field mill and the FALCON-I is 76 m.
We developed the automatic procedure to estimate the cloud cover from cloud optical images using the RGB color values. We estimated the correlation between the AEF and the cloud cover during 05:00 LT – 22:00 LT, June - November, 2016. The AEF decreased with increasing the cloud cover. The standard deviation of AEF was small when the cloud cover increased.
During 08:30 UT –10:30 UT, on 4 July, 2016, we found two kinds of variations in the AEF. One was slow variation due to the movement of thunderclouds, and the other was rapid variation associated with lightning discharges. As for the movement of thunderclouds, the AEF increased when the upper cloud was located over the field mill, which was opposite direction of the previous studies (Boltek Corporation, 2015). This change might be due to the positive charges in the upper cloud more than 14 km altitudes. As for the rapid variations of the AEF, 12 peaks of the AEF coincided with the occurrence of the lightning located within 37 km from the field mill.
On 23-24 November, 2016, we found the variation of the AEF due to snowfall. The AEF oscillated largely during snowfall. The period of the oscillation was about 72 minutes 49 seconds by FFT.
In this session, we will discuss the cause of the variations in the AEF during lightning and snowing.

Keywords: Atmospheric electric fields , Field mill

Recent results from the Japanese total lightning network

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In recent years, the relationship between the lightning activity and extreme weather phenomenon has gotten a lot of attention. In this paper, we will demonstrate the recent results from Japanese total lightning detection network (JTLN) in relation with extreme weather events in Japan. We will show that the flash rate of total lightning tends to increase about 20 minutes before the onset of the extreme weather event.

Keywords: lightning, wind gust, total lightning, extreme weather

Research of derivation of lightning electrical characteristics using by lightning irradiance observed from ISS

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In this paper, we compare lightning irradiance / lightning integral irradiance observed from GLIMS (Global Lightning and sprIte MeasurementS on JEM-EF) mission onboard ISS with current moment / lightning charge moment derived by ground based observation of ELF magnetic field observation, and verified the accuracy of the derived values. As a result, we got the high correlation (correlation coefficient > 0.76) between two values. We think that lightning charge moment, which is the energy of lightning discharge, estimated by only optical observation from space.

Keywords: International Space Station, GLIMS, ELF, Lightning charge moment

SATREPS project for development of extreme weather monitoring and alert system in the Philippines

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Thunderstorm causes torrential rainfall and is the energy source of typhoon. In these decades it has been revealed that lightning discharge is a very good proxy of thunderstorm activity. However, no operational and sustainable observation system that can provide information of charge moment changes for most of lightning strokes has been established. On the other hand, 50-kg micro-satellite is now one of the operational tool for remote-sensing, which could be fabricated by developing countries. SATREPS project titled “Project for development of extreme weather monitoring and alert system in the Philippines” will be carried out in the fiscal years of 2017-2021 under bilateral cooperation between Japan and Philippines supported by JST and JICA. In this project, we make use of two new technologies, that is, the lightning activity estimated by the ground-based lightning networks with ~10 sites for VLF radio wave measurement in nation-wide of Philippines and with ~50 sites for electrostatic field measurement in Metro Manila, and the 3 dimensional capturing of thunderstorms by the on-demand operation of remote-sensing by 50-kg micro-satellites. We will establish a new way to obtain very detail semi-real time information of thunderstorm and typhoon activities that cannot be achieved only with existing observation methods. Based on these new techniques together with advanced radar system and drop/radio sondes, we will try to construct the cutting-edge observation system to monitor the development of thunderstorm and typhoon, which may greatly contribute to the prediction of disasters and the public alerting system.

Keywords: lightning, micro-satellite, thunderstorm

Heavy rainfall observation in Metro Manila, Philippines for understanding the relation of lightning activity and tropical cyclone

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The Philippines is an archipelago country which is located in the western side of tropical western Pacific. Nearly 20 tropical cyclones in a year approach Philippine area. There are distinct summer monsoon in the western side of the country including Metro Manila. The project of Science and Technology Research Partnership for Sustainable Development (SATREPS) starts from April to develop a methodology on short term forecast of extreme weather (torrential rainfall and lightning) and typhoon intensities in Metro Manila cooperating with Researchers of Advances Science and Technology Institute (ASTI) in the Philippines. Summer monsoon rainfall in the western side of the Philippines including Metro Manila is intensified when the tropical cyclone passes over the Philippine Sea. Even when tropical cyclone does not land in the Philippines, moist southwesterly wind prevails in the west of Philippines associated with the circulation of tropical cyclone. We will deploy lightning detecting network in the Philippines to understand the relation of heavy rainfall and lightning activity. Several kinds of field observations of upper-air observations and dropsonde observations are planning to capture the atmospheric structure of thunderstorm clouds and tropical cyclones in the Philippines.

Keywords: lightning, tropical cyclone, Philippines

Changes in extreme rainfall in the Philippines for the 100-year period (1911-2010)

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Extreme rainfall values were examined to detect long-term changes in the Philippines and to investigate whether such changes are associated with the rising near-surface global mean temperature and the El Niño–Southern Oscillation (ENSO) for the 100-year period (1911-2010). The generalized extreme value distribution was formulated to its stationary and non-stationary forms, and then was fitted by the maximum likelihood method to the series of daily rainfall annual maxima (RX1day) at 23 meteorological stations in the Philippines. Subsequently, statistically significant changes in extreme rainfall in the country were detected. Such changes were further linked to the near-surface global mean temperature and ENSO. Specifically, the study has revealed a country-averaged increase in the median intensity of extreme rainfall associated with the rise in the near-surface global mean temperature. Furthermore, a seasonal influence of ENSO on extreme rainfall in the Philippines has been shown. In particular, the stations located in the northwest section of the country, where 75–100% of the RX1day occurred in the summer monsoon season (July–September) during the entire period of 1911–2010, showed an average increase in the median intensity of extreme rainfall associated with the ENSO index. These findings imply a potential intensification and increase in the occurrence of extreme rainfall into the future as the global mean temperature continues to rise, and such trends should be considered in adaptation strategies to minimize the disasters caused by extreme rainfall events in the Philippines. In order to minimize these disasters appropriate early detection system of heavy rainfall events are urgently needed in this country.

Keywords: climate change, extreme rainfall, global warming, generalized extreme value distribution

Doppler radar observations on the structure and intensity of tropical cyclones in the Ryukyus and the Philippines

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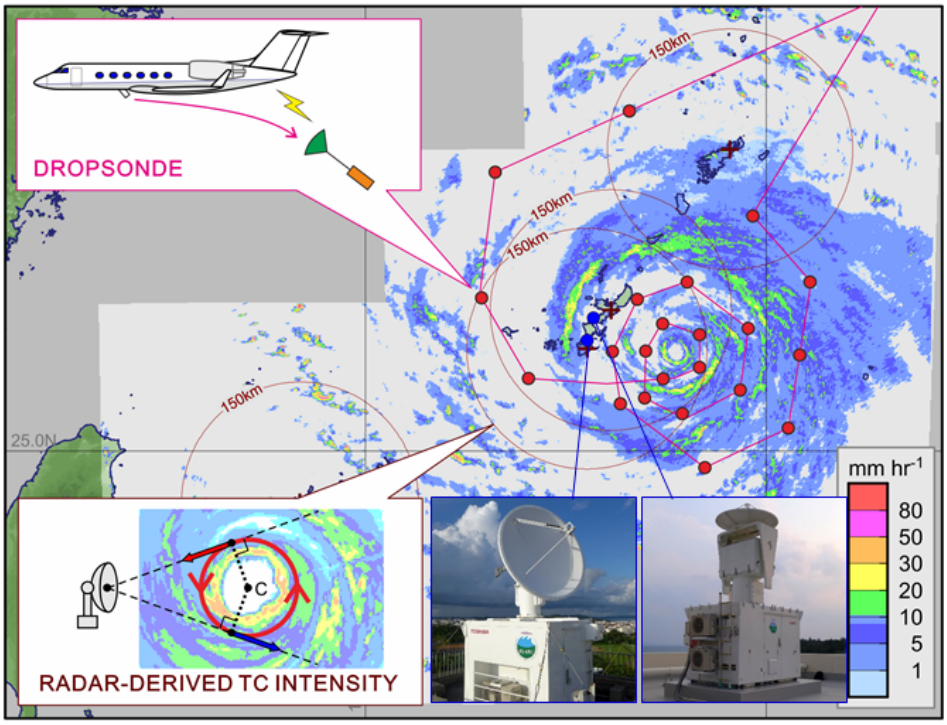
The western North Pacific is the basin with the largest number of tropical cyclones on the planet. Previous studies pointed out the frequent occurrence of rapid intensification and the increasing number of these cases in recent years. The accurate estimation of tropical cyclone intensity is essential for both disaster prevention in the coastal regions and further understanding of physical mechanisms governing intensification. We investigate the relationship between the structure and intensity of tropical cyclones using Doppler weather radars operated in the Ryukyu Islands of Japan and those along the Pacific coast of the Philippines. Analyses were made for several intense typhoons including Haiyan (2013), Goni (2015), and Chaba (2016). In addition, we found the rapid development and subsequent weakening of Kompasu (2010), which is not on the best track records. In these analyses, we focused on the slope angle of the eyewall and its relationship to flow structure and intensity. The relationship between the eyewall skewness and lightning activity from a viewpoint of cloud microphysics is also within the range of our interest. In this presentation, an overview of dropsonde observation of typhoons starting this year using a Gulfstream-II jet airplane will also be introduced.

Keywords: tropical cyclone, tropical meteorology, Doppler radar

Field Experiment of TC Intensity and Structure in Okinawa

(by Nagoya University, University of the Ryukyus, and MRI-JMA)



Lightning and Radar Observation for Severe Weather Mitigation

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This presentation reviews recent progress in lightning and radar observation for severe thunderstorm, and focus on the relationship between lightning and thunderstorm characteristics. The relationship between lightning flash rate and storm height has been investigated to predict the lightning production from cloud observation. Physical basis to support the relationship comes from the theory that the flash rate is strongly affected by the strength of the charge separation and the geometry of the charge distribution, in which vertical air motion plays a fundamental role. Hence, the flash rate is expected to depend on the intensity of the vertical air motion that is closely related to the storm height. As a practical matter, a case study shows that the flash rate increases as the updraft intensifies and the storm height develops[Goodman et al., 1988]. However, both theoretically and experimentally established correlation between storm height and flash rate is rare. In this study, the relationship between cloud height and lightning flash rate is examined on a global basis using data from the Tropical Rainfall Measuring Mission (TRMM) satellite.

Infrasound multi-site observation of thunders: a preparation for SATREPS

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Infrasound is considered as one of the remote-sensing method of lightning/thunders. Small but impulsive pressure changes caused by rapid expansion of heated plasma/neutral particles along the path of lightning strikes can make shock waves, then it can be detected by infrasound sensors with higher sensitivity range of 10 mPa or less on ground. In 2016, we installed infrasound sensors at three sites with a separation about 15 km in Kochi prefecture and a lightning/thunder event was successfully detected simultaneously at the every three sites on Dec. 13, 2016. Fortunately, the detected event was confirmed as lightning flash by a high sensitivity video camera operated mainly for meteor orbit detection. Forward-scattering radio meteor observation at two sites also detected impulsive lightning signal at the same time. From the comprehensive observation, exact location of the lightning strike was calculated in detail for this example with an error range within 300 m or less. By using the speed of sound as a precise remote-sensing ruler, the infrasound multi-site observation could reveal the lightning activities as close as 100 m scale when the infrasound sensors can be installed with a mesh of 10 km scale or denser. In this talk, we will introduce a possibility of infrasonic remote-sensing for the coming era of internet of thing (IoT) even in the field of geophysical and disaster-prevention studies in the world.

Keywords: Infrasound, Remote-sensing

Study on electrical activity of small convective clouds by using a vertically scanning X-band marine radar

*Yasushi Fujiyoshi

The author is interested in electrical activity of small convective clouds, especially winter snow clouds. Multi-paprameter Doppler radars are quite useful tool to classify hydrometeors type. However, their relatively low temporal and spatical resolutionThe author is interested in electrical activity of small convective clouds, especially winter snow clouds. Multi-parameter Doppler radars are quite useful tool to classify hydrometeor type. However, their relatively low temporal and spatial resolution may limit the research topics to such larger scale of storms as a severe hailstorm and organized convective systems. The lifetimes of small convective clouds (less than several km both in height and width) are generally less than 30 minutes. Their radar echo structures change rapidly associated with formation, growth and distribution of hydrometeors within clouds. Therefore, we studied the relationship between the electrical activity and temporal change in radar echo structure of convective clouds by using a conventional X-band marine radar. Its temporal and spatial resolutions are 2 seconds and 12.5 m, respectively. We conducted simultaneous observation of a vertically scanning X-band marine radar and a field mill deployed on the roof of ILTS of Hokkaido University, Sapporo, from 2013 to 2017. The horizontal and vertical detection ranges of the marine radar are 4 km and 7 km, respectively. Since this radar scans very fast, lightning echoes were sometimes detected as reported by Ligda (1956).
It is well known that the lightning activity of winter snow storms in Hokuriku district, southeastern coastal area of the Japan Sea, is quite high. On the other hand, it is empirically known that the lightning activity of snow clouds in Hokkaido, northern Japan, is much weaker than that in Hokuriku district. The temperature at the radar echo top (20 dBZ) and the altitude of the -10 ℃ level are used as good indicators of lightning activity in winter convective clouds in Hokuriku district (Michimoto 1989). Michimoto (1993) also proposed several criteria to classify the lightning activity.
In this study, we applied the criteria proposed by Michimoto (1989, 1993) to winter snow clouds in Sapporo to study the reason of the low lightning activity in Hokkaido. We used the data observed by an X-band marine radar and a field mill deployed on the roof of ILTS of Hokkaido University during 2013-2017 winter seasons. It is found that almost all winter thunder clouds in Sapporo were found within the criteria (-10 ℃ level < 1.8 km and temperature at the radar echo top < -20 ℃), where snow clouds exhibited no lightning activity or only very weak lightning activity in Hokuriku district. Electric activity of snow clouds in Sapporo became high when radar echo top height exceeded -15 ℃ level. It is also found that multi-cell type of convective snow clouds with much radar echo amount above -15 ℃ level are electrically quite active.

Keywords: electrical activity, snow cloud, X-band marine radar

Short-term prediction of cumulonimbus basing on upstream low-level humidification as a radar data assimilation

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Thunderstorms are induced by well-developed cumulonimbus clouds in general. To predict the activities of lightning, evolution of cumulonimbus clouds should be predicted by some techniques. However, there are some difficulties in prediction of cumulonimbus clouds associated with chaotic properties due to strong non-linearity in cloud forming processes. Short-term prediction of rainfall is performed as the precipitation Nowcast by Japan Meteorological Agency. The nowcast is based on temporal extrapolation of radar observed rainfall distribution assuming the invariance. However, the evolutions of cumulonimbus clouds are accompanied by the significantly large variations. The accuracy of the nowcast remarkably decreases with forecast time. Numerical simulations of cloud-resolving atmospheric models have a capability to predict structures and evolutions of cumulonimbus clouds. However, some problems are included in the data assimilation processes which are calculated to create initial conditions of the simulations. The data assimilation uses computational costs and takes comparably long time until the prediction is produced. In addition, detailed structure within cumulonimbus clouds are not involved in the initial condition of simulations. Thus, the author proposes a new data assimilation scheme for short-term prediction of cumulonimbus clouds, which is named as upstream low-level humidification (ULH) method. In the data assimilation, meteorological radar data are used to detect signals of cumulonimbus clouds. Here, the radar reflectivity information are not used to modify variables of rain water content. Instead, the information is translated to that of initial structure of cumulonimbus cloud which produced observed intense rainfall. In practical, areas where rainfall intensity is larger than 10 mm/h are horizontally advected toward the upstream side with 10-40 minutes. The water vapor in the lower atmosphere below the level of free convection is forced to add to be saturated by the nudging technique. The nudging coefficient is 1 minute. The ULH plays a role in the approximated adjoint calculation for time integration of four-dimensional variational data assimilation. In the installed prediction system, 3-hour forecasts are performed every 10 minutes, because the predictions should be updated with a shorter time interval due to the strong chaotic properties.
This method was applied to a heavy rainfall event observed in the Kanto Plain on September 2, 2013. The heavy rainfall caused by a few cumulonimbus clouds was well predicted by the ULH method up to forecast time of 30 minutes. The upstream advection period of 20 minutes was appropriate for more accurate predictions. The predicted cumulonimbus cloud included a large vertical vorticity that seems to have been associated with the observed tornado. The ULH was also applied to a heavy rainfall event observed at Hiroshima, Japan on August 20, 2014. A line-shaped stationary rainband was observed as a cluster of cumulonimbus clouds. The observed rainband was also roughly predicted by the ULH method. However, there were some problems for ULH method. Unobserved intense rainfall are sometimes predicted. The schemes to remove such unrealistic cumulonimbus clouds are currently developed. The ULH method have a possibility to predict cumulonimbus clouds. The possibility would be extended to predictability of lightning.

Keywords: cumulonimbus, short-term prediction, cloud-resolving atmospheric model

Dispersive and Non-dispersive Components in the L-band InSAR Image Associated with Heavy Rain Episodes

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Interferometric synthetic aperture radar (InSAR) is known to be a powerful technique to detect surface displacements with unprecedented spatial resolution, and has been applied to numerous earthquakes, volcanic eruptions, glaciers and ice sheets. Meanwhile, the effects of microwave propagation through ionosphere and troposphere can generate non-negligible phase anomaly in InSAR data, which often keeps from detecting small-amplitude displacements. Correcting for the ionsphere and troposphere is therefore a long-standing issue for high-precision geodetic measurements. However, if ground displacements are negligible, InSAR image can tell us the details of the atmosphere.
Kinoshita and Furuya (2017, submitted) detected phase anomaly in ALOS/PALSAR InSAR data associated with heavy rain over Niigata area, Japan, and performed numerical weathr model simulation to reproduce the anomaly; ALOS/PALSAR is a satellite-based L-band SAR sensor launched by JAXA in 2006 and terminated in 2011. The phase anomaly could be largely reproduced, using the output data from the weather model. However, we should note that numerical weather model outputs can only account for the non-dispersive effect in the phase anomaly. In case of severe weather event, we may expect dispersive effect that could be caused by possible presence of free-electrons.
In contrast to GNSS system, SAR imaging is based on a single carrier frequency, and thus no operational ionospheric corrections have been performed in InSAR data analyses. Recently, Gomba et al (2016) detailed the processing strategy of split spectrum method (SSM) for InSAR, which splits the finite bandwidth of the range spectrum and virtually allows for dual-frequency measurements.
We apply the SSM to the heavy rain signals detected by L-band InSAR, and report the presence of phase anomaly in both dispersive and non-dispersive components. While the original phase anomaly turns out to be mostly due to the non-dispersive effect, we can recognize local anomalies in the dispersive component as well. We will discuss its geophysical implications, and may show other case studies.

Keywords: InSAR, Heavy rain, dispersive media, InSAR split spectrum method

Tracking mesoscale convective systems in a future warm climate

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The Amazon basin is the largest water shed in the world and its complex ecosystems play an important role on the regional and global climate system. Due to its warm and moist air, thunderstorms are widely frequent over the basin. A group of these individual thunderstorms can compose one larger, intense, persistent and complex thunderstorm, which is called mesoscale convective system (MCS). MCSs occur with high frequency in the Amazon basin. Besides severe weather, hail, strong winds and lightning, MCSs causes elevated rates of precipitation contributing to the local and global climatology. Even with the increases of the global temperature, other factors, such as deforestation and increased pasture area, are expected to influence the formation of rainfall systems over the Amazon basin. Thus, it is very important to investigate how will be the average occurrence and behavior of MCSs in the Amazon basin in climate change scenarios. We will investigate the behavior of the mesoscale meteorological systems in a future warm climate. Simulations with global domain models give few or none information about mesoscale systems. The present study is part of a larger investigation about the impact of the climate changes on the MCSs occurrence over the Amazon basin. To identify and track MCSs in future climate change projections, we used a modified version of the algorithm Forecast and Track the evolution of Cloud Clusters (ForTraCC) adapted to read precipitation files from the climate model in matrix format. As tracking MCSs requires precipitation data at high temporal and spatial resolution, we used outputs from a regional model with 10 km spatial resolution. The Regional Climate Model system version 4 (RegCM4) was nested in the Hadley Global Environmental Model 2 - Earth System (HadGEM2-ES). The following Representative Concentration Pathways (RCPs) is used: RCP4.5 and RCP8.5. The atmospheric component of the model works with horizontal resolution of 1.25˚ latitude ×1,875˚ longitude, 38 vertical levels and a time interval of 30 minutes; and the oceanic component is performed at a resolution of 1˚ latitude ×1˚ longitude (with increasing resolution near the equator), 40 vertical levels and 1 hour time interval.

Keywords: thunderstorms, mesoscale convective systems, climate change, Amazon basin

Cloud monitoring by the Philippines' first microsatellite DIWATA-1

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The Philippines' first microsatellite, DIWATA-1, is a 50-kg-class earth observation microsatellite, funded by Philippines' Department of Science and Technology (DOST), built by scientists and engineers from the Advanced Science and Technology Institute (ASTI) of the DOST, the University of the Philippines-Diliman (UPD), Tohoku University (TU) and Hokkaido University (HU). The main objective of DIWATA-1 is to assist in disaster monitoring and natural resource management, specifically in the areas of agriculture, fisheries and forest protection. For that purpose, DIWATA-1 has four different optical sensors for earth observation. By using these sensors, the earth observation data can be acquired with several ground sampling distances (GSDs) from 3m with a field of view (FOV) of 2 km x 1.5 km to 185 m with a FOV of 40 km x 20 km at an altitude of 400km.
To date, it is well known that the Philippines is one of the most vulnerable countries to natural disasters. In a year, on average, there are about 18-19 typhoons that enter the Philippine area of responsibility. Predicting areas that would experience heavy rainfall will give local governments more time to evacuate affected residents. However, there have been few attempts made to perform this early prediction using satellite remote sensing data. In this paper, we focus on cloud monitoring using images obtained by DIWATA-1. Cloud activity is highly correlated with intense rainfall or thunderstorms. New application using DIWATA-1's cloud monitoring could be one of the powerful approach to catch the precursor of such natural disasters.

Keywords: Microsatellite, Disaster monitoring

Methods for Development and Operation of Microsatellite Bus System and Ground Station in PHL-MICROSAT Project

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Since Tohoku University and Hokkaido University started the operation of microsatellite SPRITE-SAT(RISING) in 2009, 50-kg microsatellites dedicated for scientific earth observations are being developed and operated continuously. Inheriting the satellite bus system in RISING-2 which operation started in 2014 and RISESAT which is being developed, first Philippines' microsatellite DIWATA-1 could be completed and its operation started on April in 2016. This satellite is first satellite in the PHL-MICROSAT Project which is joint microsatellite development and operations by Philippines and Japan. In this presentation, development and operation experiences in satellite bus system for DIWATA-1 are described. This achievement can contribute to other new partners in Asian Micro-satellite Consortium (AMC) and technical requirements and performance about satellite and ground station development will be defined.

DIWATA-1 has 52.4-kg mass and the size is 55x35x55 cm. This was released into orbit by International Space Station (ISS) at 403-km height with 51.6-deg inclination. After about 2.5-year orbital lifetime, its mission will finish by re-entering to atmosphere. By using High Precision Telescope (HPT) with 3-m resolution and Spaceborne Multispectral Imager (SMI) with 61-m resolution, the satellite can observe the natural resources on ground, forest, and ocean in Philippines. The wavelength of SMI can be set with 1-nm step in the range of 430-1020 nm. By the attitude control function with target pointing mode, multi spectral images of same target place can be obtained in same observation opportunity.

Satellite bus system for DIWATA-1 was developed by six Filipino students under the supports by faculty members in Tohoku University. Preliminary design started on Nov. 2014, and the satellite could be delivered to launch organization in Jan. 2016, which total duration was only 14 months. To avoid the troubles in design, fabrication and environmental tests, deployment mechanism such as solar paddles was not adopted. Typical consuming power is 49.7 W in image capture mode and 56.9 W in data download mode although body-mount cells generate 38.6 Watts in average. To achieve the stable power management, the attitude control system is active only in Philippines and Japan, and it can safely return to power saving mode in other areas. Of course, the satellite has the ability to capture images also in other world areas. Next satellite DIWATA-2 will include a low-cost and high reliable solar deployable paddles and the observation ability will be upgraded more.

Satellite operation technology accumulated in Tohoku University was inherited to new satellite ground station which was constructed at Advanced Science And Technology Institute (DOST-ASTI) in Philippines. The satellite tracking antenna system is different from Tohoku University and its compatibility is not important. The automatic action of tracking antenna can be individual managed in Philippines and Japan. However, same transmitter, receiver, and satellite operation software were exported from Japan to Philippines to achieve the high-level compatibility in satellite operation methods. After the finish of initial operation from Japan, the methods to upload satellite operation commands and download observation images were transferred to Philippines' local operation team, then the satellite can be fully operated in Philippines now. In this PHL-MICROSAT project, quick construction of satellite operation system could be achieved as well as quick development of microsatellite. These experiences can contribute to next activities with new partnership in AMC.

Keywords: microsatellite, satellite bus system, satellite operation, DIWATA-1, Asian Micro-satellite Consortium