ISEC 2017

Abstracts

Techniques of dual-Doppler wind analysis

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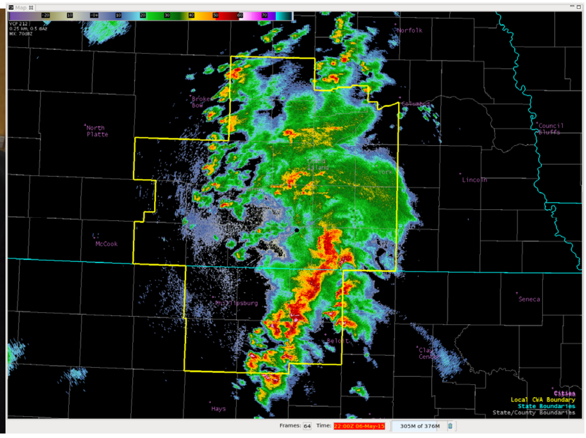
In this short course we consider the problem of dual-Doppler wind analysis, that is, the analysis of the vector velocity field from radial wind data obtained from two scanning Doppler radars. We also examine some of the auxiliary techniques used to pre-process the radar data, including the use of advection correction to account for the non-simultaneous nature of the data collection (different parts of an analysis volume are scanned by the two radars at different times). Time permitting, we will also examine dual-Doppler-based thermodynamic retrieval, a technique whereby the dynamical equations of motion are used to post-process the dual-Doppler retrieved wind fields to obtain the pressure and temperature fields.

The first wind analysis we consider is the "poor person's" dual-Doppler wind analysis, a simple and quick technique to get the horizontal wind field from the radial wind data. We then examine three types of techniques in which a mass conservation equation is combined with the radial wind data to obtain the horizontal and vertical velocity components: (i) the classical "Co-plane" method, (ii) traditional iterative algorithms, and (iii) the three-dimensional variational (3DVAR) technique. The similarities and differences between the various methods are stressed, including the role of boundary conditions, the stability of the algorithm, and options to incorporate/enforce spatial smoothness on the analysis. We then consider an extension of the 3DVAR technique in which the anelastic vertical vorticity equation is used as an auxiliary constraint to improve the vertical velocity field in cases of missing low-level data. Time permitting, we will briefly consider the use of 4DVAR and the EnKF in dual-Doppler wind analysis.

"Severe Weather Forecasting Simulation" Short Course Proposal for ISEC 2017 Conference in Kyoto

Proposed by: *Alex Zwink, Eric Jacobsen, and Jill Hardy, OU CIMMS & NWS WDTD (Warning Decision Training Division)*

Overview

The Warning Decision Training Division hosts multiple in-residence training workshops each year where severe weather simulations are used to give hands-on training to new NWS forecasters. Using operational software and datasets, WDTD provides a realistic experience of the demands of severe weather warning decision making situations which protect lives and property. To be able to perform these training simulations, OU CIMMS at WDTD have developed the WES-2 Bridge (Weather Event Simulator for AWIPS-2), which provides archived data playback for the AWIPS-2 software used by the NWS.

We propose a short course for the 2017 ISEC conference in Kyoto, based on a miniature version of the simulations described above, to provide participants with insight into the demands and tools of an operational forecasting environment. This course will not only highlight the types of data useful for quick decision-making, but provide a unique opportunity to use actual software used by U.S. meteorologists. As such, this course will supplement the research-to-operations theme of the ISEC conference through first-hand experience as an end-user presented with a variety of real-time data and algorithms. This experience in turn stands to inform participants' future research through a broader appreciation of the forecasting environment and forecaster needs in fast-paced decision-making scenarios.

CIMMS/WDTD Qualifications

In addition to providing formal, yearly training to U.S. National Weather Service forecasters, OU CIMMS/WDTD staff have experience with guiding non-NWS users through simulations of this sort. In particular this includes several occasions with visiting Japanese private-sector and government forecasters, but also including the general public during weather-themed fairs and camps.

Format

An overview of the operational software (AWIPS-2) to be used in the course will be given, thus no prior experience with AWIPS-2 will be necessary, and staff will be on-hand throughout the workshop to guide participants through the warning workflow and answer any questions. A brief overview of the meteorological conditions present in the simulation will also be given, although the primary purpose of the course will be to learn and experience the tool-set available to forecasters.

Some of the data/tools which will be particularly emphasized during this experience include:

- 88D (S-band) Dual-Pol Doppler Weather Radar
- Geostationary Satellite Observations
- Real-time damage reports
- Warning product generation software ("WarnGen")

A small laboratory of 6 laptops, each capable of running a simulated severe weather event, will be provided by OU CIMMS. Each workstation supports a small group working together, on which the forecaster is able to review weather data and even issue warning products. The course can be tailored to any length, with the following as a couple of proposed options:

1) Two one-hour courses where a group of 2 students will produce of a series of severe weather warnings. This format will allow for more students to go through the course (12 students per course, 24 students maximum).
2) One 2.5 hour course where a group of 3 students will produce a series of severe weather warnings and dig a bit deeper into data available for warning forecasters. While there will be fewer seats available for students (18 students maximum), more time will be given to the students to incorporate more data into their warning decision making process.

Once dedicated times are set for the short courses, we would be able to adapt the course to fit the schedule.

Participant Requirements and Enrollment

Any ISEC participant with a strong interest in research to operations will benefit from the exposure to operational software, datasets, and a simulated decision-making environment which this course will offer. That said, the degree to which a participant is comfortable with English (although one CIMMS team member can speak a little Japanese) and general forecasting principles will affect their enjoyment of and retention during the experience. CIMMS staff have experience with a range of English language proficiencies and meteorological knowledge, however, so a lack thereof should not limit a would-be participant.

If desired, prioritization can be given to certain enrollees (such as Japanese) in the event of limited space, since this opportunity is more readily available to students in Oklahoma, and whereas it is not regularly provided outside of the United States. If such prioritization is not desired, the short course will be first come, first serve. In addition, if participant names are able to be provided in advance of travel, certificates can be made and given to students upon completion of the short course.

Introduction of Research Institute for Sustainable Humanosphere (RISH) and Its Atmospheric/Ionospheric Studies

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RISH defines the "humanosphere" as the spheres that support human activities, including the human living environment, the forest-sphere, the atmosphere and the space environment. We aim to investigate present and future problems of the humanosphere and explore innovative technology that will contribute to establishing a sustainable society in harmony with the natural environment. Our institute is approved as the Joint Usage/Research Center for the science of the humanosphere. In this institute there is atmosphere research group that is conducting variety of atmospheric and ionospheric studies. Our main facility is the MU radar in Shigaraki which is the mesosphere-stratosphere-troposphere (MST) radar established in 1984. The MU radar was awarded IEEE Milestone as the first atmospheric radar with the active-phased array antenna system. Another important facility is the Equatorial Atmosphere Radar (EAR) in Kototabang, West Sumatra, Indonesia. We have network of wind profilers, several lidars, and join satellite missions. In this lecture we briefly overview research fields of RISH, and after that we will show examples of unique studies by the atmosphere research group in RISH.

Recovery from Natural Disasters

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Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) was adopted at the third United Nations World Conference on Disaster Risk Reduction in 2015. Sendai Framework sets four priorities for action to prevent new and reduce existing disaster risks. And “recovery” was selected as one of priorities for action, “to "Build Back Better" in recovery, rehabilitation and reconstruction.”

Japan is disaster frequent country and has many experiences of recovery from disaster, and now is working for recovery from the 2011 Great East Japan Earthquake Disaster (the 2011 GEJE). It takes at least ten years to complete a long term recovery from a catastrophic disaster. Situation of an impacted community are changing. And recovery plans reflect the economic and societal situation of a community. In the growing society both on economy and population, recovery from disaster can be a chance of economic developments in addition to making safer community from disaster. 1970s recovery plan in Japan was a community development plan with mitigation countermeasures. In the growing community, recovery from impacts would be automatically completed by original economic growth. However, recovery in shrinking community such as recovery from the 2011 GEJE is very hard task. It is difficult to even come back to the status before the disaster, though the huge budget has been used for recovery. It is because the trend of the community growth is down ward.

New concept in disaster risk reduction, pre-disaster recovery planning is emerged from several lessons recovery both in growing community and shrinking community. Recovering from disaster is just reflection of resilience of a society. Good community can recover well, and bad community cannot. Preparing to disaster by making good community can be a pre-disaster recovery activity.

References

Norio MAKI, Long term recovery from the 2011 Great East Japan Earthquake and Tsunami Disaster, Advances in Natural Hazards Research Vol.44, Post-Tsunami Hazard; Reconstruction and Restoration, pp.1-14, Springer, 2015

OU and Weathernews, Inc. Radar & Warning Decision Training Project Overview

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CIMMS= Cooperative Institute for Mesoscale Meteorological Studies

Abstract:
In the fall of 2014 WNI approached OU seeking an educational program to improve their forecasters' abilities to forecast and nowcast for various types of mesoscale severe convective weather including tornadoes, hail, damaging thunderstorm winds, and flash flooding. Three WNI forecasters were chosen to participate in this 2-year training project. During each year, they first learned foundational material through 25–30 hours of distance learning modules. They then traveled to the U.S. for month-long visits to extend and practice their learning through hands-on simulations covering radar interpretation, storm-based warnings, flash flood warnings, and advanced warning concepts. Hands-on applications were supplemented with many guest speakers on topics ranging from an overview of the U.S. weather enterprise to forecasting tornadoes in high-shear, low-CAPE environments. WNI forecasters also presented data from recent tornado events for discussion. After each visit, WNI forecasters prepared local training and considered how to best translate learning to WNI's data sources and forecasting environment. Currently, internal training at WNI is underway, and WNI has built a new Nowcast Center to further utilize this training and a new radar developed in partnership with OU. This talk will present the motivation for the project, how the two-year training project was designed and executed, and the impacts it has had on WNI operations.

Wind-related Disaster Risk Reduction and Full-scale Storm Simulator (FSSS)

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Past devastating wind-related disasters in the Asian region are first discussed, and the results of post-disaster investigations conducted recently by the authors' group in the East Asia region are introduced to provide reliable scientific information (see Fig.1). The combined effects of strong wind and accompanying water hazards due to heavy rain and storm surge caused almost all of these disasters, which are named "wind-related disasters". Some important lessons learnt from the investigations, and points to note for wind resistant design of buildings, are discussed. The importance of the performance of claddings and components in wind resistant design of buildings is demonstrated. The numbers of disasters and people affected have recently been increasing. There has been a particularly significant increase in the number of devastating weather-related disasters. The majority of them have been caused by windstorm and flood. The reason for this cannot be simply attributed to increasing and intensifying of natural hazards due to global warming or climate change. The main reason for repeated wind-induced damage is lack of information on the real performance of claddings, components and structural frames under wind actions. There are many other emerging issues to be tackled by researchers and engineers in the wind engineering field in order to reduce "wind-related disaster" risk and to realize safer and securer communities worldwide. Past wind engineering studies have focused on wind loading estimation, but few have been made on performance estimation. In order to check the real performance of buildings and structural systems, including claddings/components, tests under realistic and controlled conditions of extremely strong actions of wind, rain, snow, fire, solar heating and so on are necessary. The focus should be "From Load estimation to performance estimation" and "From model-scale to full-scale".

Figure 1 Damage to Leyte Convention Center, The Philippines, due to Typhoon Haiyan, 2013

Recent enhancement of meteorological observations of JMA

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New and re-renewal observation systems by Japan Meteorological Agency (JMA) listed below are introduced in my talk.

1. Geostationary meteorological satellite: Himawari-8, Himawari-9
   - Increase of the channel number into 16
   - High time resolution: every 2.5 minutes near Japan region
   - High spatial resolution: 0.5 – 1.0 km in visible, and 2.0 km in infrared

2. Airport weather radar:
   - From Doppler radar to the solid-state polarimetric radar
   - Rapid updating

3. General weather radar:
   - From conventional radar to Doppler radar
   - Utilization for Numerical weather prediction and monitoring tornadoes

4. Research radar: Phased array radar at MRI-JMA

5. Nowcasting on high-resolution precipitation, tornadoes, and lightning using new observation systems above

Multi-function Phased Array Radar Observation Targeting of a Convective Storm

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Observation targeting is based on the notion that a particular subset of observations can be nearly as impactful as all potential observations when assimilated into NWP models (Torn 2014). The method determines which observations should be collected at a future time to ultimately produce the best possible forecast. This is beneficial for planning data collection operations.

In this presentation, observation targeting is applied to an idealized supercell thunderstorm. Synthetic radar observations of radar reflectivity and Doppler radial velocity are harvested from a truth run and assimilated using an ensemble Kalman filter (EnKF). A 50-member ensemble is created by perturbing the truth run's homogeneous environment. The initial experiment assimilates full volume scans which can be computationally expensive. One feature of multi-function phased array radar (MPAR) is the ability to rapidly sample a particular area. In other experiments, the observation targeting technique will be applied to these synthetic MPAR observations in order to determine if adaptively scanning a convective storm will yield accurate analyses and forecasts. Observation targeting will be a crucial component of MPAR data assimilation when creating very short-term forecasts with finite computational resources and narrow time windows.

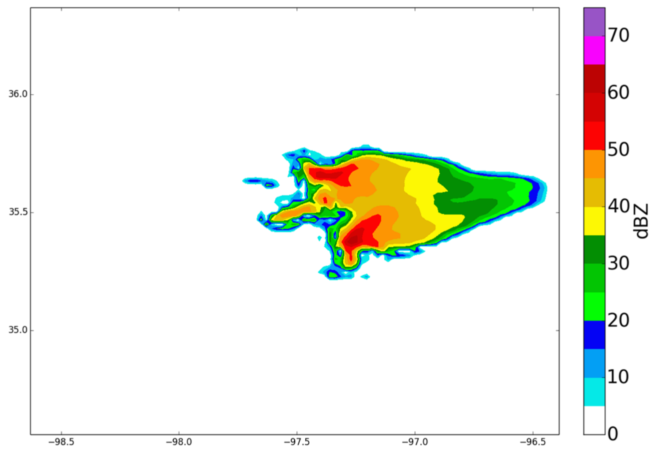

Figure 1. Truth simulation low-level reflectivity of splitting supercell 90 minutes after initialization

Reference

Torn, R. D. (2014) The impact of targeted dropwindsonde observations on tropical cyclone intensity forecasts of four weak systems during PREDICT, *Monthly Weather Rev*iew, 142, pp. 2860–2878.

Mobile Doppler radar and lidar analysis of a strong density current and MCS on 15 July 2015 during PECAN in the United States

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A nocturnal mesoscale convective system (MCS) occurred over the Great Plains of the United States on 15 July 2015 during the Plains Elevated Convection at Night (PECAN) field project. A density current propagated ahead of the MCS, producing severe winds. This density current (and subsequent MCS) were observed by the Truck-Mounted, Wind Observing Lidar Facility (TWOLF) and the Rapid-Scan X-Band Polarimetric (RaXPol) mobile Doppler radar. An analysis of the MCS will be presented as well as analyses of related atmospheric phenomenon (including gravity waves). RaXPol collected 180° range-height indicator (RHI) data every ten degrees azimuth every two seconds, resulting in a high spatiotemporal dataset. Data from the vertically-pointing scans from TWOLF indicate ascent of nearly 13 m s^{-1} at the leading edge of the density current and data from both instruments indicate near-surface wind speeds of nearly 25 m s^{-1}.

Novel Radar Techniques for Polarimetric and Microphysical Analyses of the Stratiform Rain Region of MCSs

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The stratiform region behind the main convective line in mesoscale convective systems (MCSs) is typically difficult for models to accurately resolve, an issue often attributed to poor microphysical parameterizations. Increasing in situ observations of such stratiform precipitation is crucial to improving model parameterizations. Additionally, connecting in situ measurements of the stratiform rain region of MCSs with ground based radar observations has the potential to improve understanding of how various polarimetric fingerprints are to be interpreted, especially if it can be done using operational radar data and without needing special radar scans. In this study, in situ microphysical data collected during both the Midlatitude Continental Convective Clouds Experiment (MC3E) and Plains Elevated Convection at Night (PECAN) are compared with operational WSR-88D radar data, using a novel column vertical profile (CVP) technique. CVPs are made by taking data collected using traditional volume scans—such as are done by WSR-88D radars—and averaging and interpolating the data such that they are displayed in a time-height format. Similar to quasi-vertical profiles (QVPs), CVPs are unique in that they are representative not of the entire distance in range and 360° in azimuth around a radar, but of only a sector of set width in range and azimuth, facilitating more exact comparison of radar data to microphysical data. Data of particular interest collected by in situ probes include particle habits, number concentration, and ice water content, which could lend insight into the causes of various polarimetric fingerprints seen in both QVPs and CVPs.

Development of a C-band High-Resolution, Mobile, Polarimetric, Phased-Array Radar System: Polarimetric Atmospheric Imaging Radar (PAIR)

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ABSTRACT

Mobile radar platforms have the unique capability to provide high spatial resolution by sampling storms at close range with good angular resolution. Adding polarimetric capability to radars can improve data quality, classify different types of hydrometeors, provide quantitative precipitation estimation, etc., making these instruments even more essential. The need to match this fine spatial resolution with better temporal resolution has driven radar development into the realm of phased array technologies. However, current examples of mobile rapid-scan radars all operate at X-band and either do not have dual polarimetric capability or are still based on a "spotlight" mode of operation which uses a narrow beam steered sequentially in time, and ultimately limits their temporal resolution. Therefore, there is great interest in and need for development of a polarimetric phased array radar that maximizes the benefits of the mobile platform. To address the limitation imposed on temporal resolution by spotlight operation, the single polarized X-band Atmospheric Imaging Radar (AIR) was developed in the Advanced Radar Research Center (ARRC), at the University of Oklahoma (OU). AIR operates in a "floodlight" mode, utilizing a 20° vertical fan beam on transmit and 36 receiving arrays capable of a 1° beamwidth using digital beamforming (DBF). In other words, the current AIR can collect 180° by 20° volumes in *approximately 9 s*. Numerous other advantages of imaging radar technology exist, such as clutter filtering and low antenna sidelobes using adaptive beamforming, excellent Doppler frequency resolution, a flexible number of beams, and increased dynamic range. Nevertheless, the AIR is also limited by the lack of dual-polarimetric capabilities, its moderate sensitivity, and inherent attenuation at X-band.

The ARRC received an award from the National Science Foundation in 2015 to develop a C-band, mobile, polarimetric, imaging radar, that provides simultaneous snapshots of a storm with unprecedented temporal resolution and flexibility and can be shared by the scientific community. Compared to the AIR and other existing systems, the PAIR achieves dual-polarization through a novel phased array antenna design, improved sensitivity through integrated solutions provided by solid state power amplifier (SSPA) technology, faster update time through DBF in elevation and electronic scanning in azimuth, less susceptibility to attenuation with C-band operation, and a robust innovative mechanical design that facilitates rapid deployment in severe environments. In this presentation, the benefits of an imaging radar's high temporal resolution will be demonstrated using data collected by the AIR. The design concept, expected capability, and specifications of PAIR will be presented. Moreover, new science and engineering developments enabled by the PAIR, including tornado studies, lightning studies, flash flood warning, calibration of polarimetric phased array system, and others will be presented.

Near-Surface Atmospheric Refractive Index by Receiving Digital Broadcasting Signals

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The theoretical principle and implementation method on extract on refractivity along the radio path of the digital broadcasting transmitter with the bi-static system was explored and evaluated in this study. In the previous studies, the ground clutter of the weather radar has been employed to estimate refractivity between the weather radar and ground clutters. Although this method has been researched very well in the aspect of the principle, evaluation and limitation, he major limitation exists that the observation is limited to only paths between weather radar and fixed clutter source such as the power pole tower. In addition, a useless contamination clutter such as strong precipitation echo, the sway of vegetation, and the phase variation due to the surface wettability should be removed in empirical method.

This study developed a bi-static method to solve the above disadvantage and to enable us to observe the refractivity along arbitrary path by locating receivers at the favorite places. Despite the previous method observe the clutter echo by one radar with careful data quality check, in the new method, the individual receivers detect direct transmitted wave. Recently, the preliminary researches reported the potential of the bi-static system. However, their study cannot solve the most important problem in the bi-static method: the precise synchronization of the oscillator in the transmitter (TX) and the receiver (RX). In the order analysis, the precisition of 10^(-11) (Hz/Hz) or less is required to obtain temporal variation of refractivity from the carrier phase data. Due to this difficulty, the previous researches remains in the trial stage.

Aiming at a breakthrough in the bi-static method, this paper newly invented an analytical operation to synchronize between center frequency of TX and RX. The detailed formulations and quantitative error analysis will be explored and evaluated to derive refractivity. A suitable implementation scheme will be also described. In addition, a tiny discrepancy of digital sampling intervals between TX and RX was diminished to improve the precision of refractivity.

Rainfall over the Asian coastal regions observed by TRMM precipitation radar: Role of orography, diurnal cycle, and intraseasonal oscillation

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Rainfall over the coastal regions of western India (Western Ghats; WG) and Myanmar (Arakan Yoma; AY), two regions experiencing the heaviest rainfall during the Asian summer monsoon, is examined using a Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) dataset spanning 16 years. Satellite observations in previous studies showed that the rainfall maxima occur upstream of the WG and AY. In contrast, the TRMM PR data show that the rainfall maxima occur over the upslope of the WG and on the coast of AY. Previous studies using IR data assumed that heavy rainfall results from deep convection, leading to an overestimate of rain area from the cold brightness temperatures associated with extensive cirrus anvils and an underestimate of the orographic rainfall associated with relatively low cloud tops. The spatial shift of the IR-derived rain maxima away from the PR rainfall maxima is attributed to westward advection of cirrus anvils from the convection associated with relatively low and warm cloud tops over the upslope by upper-level easterlies.

Diurnal variations in the rainfall are very weak in the WG and AY regions where low-level monsoon flow is strong. Continuous rain with a slight nocturnal and afternoon–evening maxima occurs over the upslope of the WG, while an afternoon peak over the upslope and a morning peak just off the coast are found in AY, resulting in different locations of the rainfall maxima for the WG (upslope) and AY (coastline). The rainfall amount and diurnal cycle amplitude are functions of the environmental flow perpendicular to coastal mountains. Large rainfall amounts but small diurnal amplitudes are observed under strong environmental flow, and vice versa, implying that rainfall is not associated with thermally driven convection, but rather with mechanically driven convection. Ventilation of the surface by stronger winds may prevent the buildup of a strong temperature difference that would drive thermally forced circulations.

Consistent with past studies, the TRMM PR composites show the northwest/southeast tilted structure and northward propagation of the major rain band associated with the boreal summer monsoon intraseasonal oscillation (BSISO). The rain anomaly over the WG lags behind the major rain band, which was not reported by the previous studies. Orographic rainfall over the WG slope is enhanced with southwesterly wind anomalies of the cyclonic system associated with the BSISO. This lag is not observed in the AY region where more closed cyclonic circulations and more stratiform rainfall regions prevail compared to the WG region. The amplitude of the diurnal cycle over the upslope of the WG is smallest during the largest BSISO rainfall anomaly phase over the WG and it is largest during the large-scale active BSISO phase with the largest rainfall anomaly over the surrounding Arabian Sea, preceding the largest BSISO rainfall anomaly over the WG.

Refer to the paper by Shige et al. (2017) for more detail.

References

Shige, S., Y. Nakano, and M. K. Yamamoto (2017) Role of orography, diurnal cycle, and intraseasonal oscillation in summer monsoon rainfall over Western Ghats and Myanmar coast. *J. Climate*, in press.

Orographic Effects on the Transport and Deposition of Volcanic Ash – A Mount Sakurajima Case Study

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Introduction

Volcanic ash is a major atmospheric hazard that, directly or indirectly, affects life, livelihoods, and infrastructure. Accurate prediction of the transport and deposition of volcanic ash is therefore important for hazard management and mitigation. Dispersal of ash is heavily influenced by local and regional wind fields. Mountainous topography affects atmospheric flow, creating a number of complex phenomena (ie. orographic effects), such as flow spitting, gravity waves and downslope winds, known to affect the deposition of volcanic ash.

Methodology

In the study presented we examined the impact of orographic effects on the transport and deposition of volcanic ash from the Sakurajima volcano in Kyushu, Japan (Poulidis *et al*, 2017). Sakurajima is one of Japan's most active and closely monitored volcanoes. The frequent activity, surrounding mountainous topography, and large amount of observational data make Sakurajima an ideal natural laboratory for the study of these effects. On 18th August 2013 Sakurajima erupted at 1631 JST with a plume height of 5 km - the highest plume height recorded since 2006. Ash was advected to the W-NW and ashfall was recorded as far as 90 km to the west. This eruption has been studied in depth using a dynamic meteorology-ash-dispersion model (WRF-chem) configured with sufficient resolution to represent local topographically-forced flows (down to 500 m horizontal grid resolution). Simulations were also carried out with zero topography to isolate the influence of orographic effects.

Preliminary Results

We show that orographic effects can act in two ways: strong gravity wave activity close to the volcano act to keep ash afloat, while downslope winds closer to the surface can advect ash downwards and force deposition. Orographic effects are seen to increase both horizontal and vertical diffusion of volcanic ash. Due to its low residence time, heavy ash is seen to be relatively unaffected by orographic effects: in terms of deposition, the most readily affected size ranges for particles were of grain size between 3-5φ (0.125 and 0.03 mm). Resolving orographic effects can lead to uncertainties: the initial plume height can be changed due to gravity wave activity over the volcano, leading to a different simulated plume height, something that could affect similar simulations, especially for eruptions with low plume heights.

References

Poulidis, A. P., Takemi, T., Iguchi, M. and Renfrew, I. A. (2017) Orographic effects on the transport and deposition of volcanic ash: A case study of Mount Sakurajima, Japan, *Journal of Geophysical Research - Atmospheres,* doi. 10.1002/2017JD026595.

How much sea ice loss can be attributed to Arctic cyclones?

The rapid decline of warm season sea ice in the Arctic is one of the most visible indicators of the Earth's changing climate. However, while the general trend in Arctic sea ice is fairly well-understood, the large interannual variations remain unpredictable beyond a couple weeks. These reductions in sea ice have profound impacts on nature, from changes in plant and animal life to changes in the jet stream and hemispheric weather patterns. In addition, sea ice reductions have societal impacts to national security, transportation, and the economy. While there has been much advancement in global climate and sea ice modeling, resolution still prohibits the accountability of sea ice loss from shorter time-scale processes such as synoptic-scale surface cyclones. Recently observed high-impact Arctic surface cyclones have revealed strong correlations between Arctic cyclones and sea ice loss. This study evaluates the impact and predictability of Arctic sea ice loss from Arctic cyclones with the hypothesis that a substantial portion of sea ice interannual variability can generally be attributed to Arctic cyclones, and that tropopause polar vortices (TPVs) are a key precursor to the formation of high impact Arctic cyclones.

Key polar processes that impact global weather patterns remain unidentified or not well-understood. TPVs are one of the longest-lived features in the Earth's atmosphere, yet their characteristics and role in Arctic predictability are highly uncertain. While surface cyclones may be associated with rapid sea ice loss events, lifetimes are generally limited from a few days to a week, and hence themselves can be viewed as a consequence of various environmental factors. On the other hand, TPVs are present sometimes weeks to months before the formation of a corresponding surface cyclone. This study will first establish that Arctic surface cyclones are a significant source of sea ice loss by evaluating daily sea ice extent from the National Snow and Ice Data Center (NSIDC) and correlating short-time scale sea ice loss events to Arctic surface cyclones. It will then be shown that every short-time scale sea ice event is associated with a TPV. Through analysis of high atmospheric resolution global models, it will be argued that improved knowledge of TPVs may offer valuable insight into the predictability of Arctic sea ice.

Observational and Numerical Studies on Turbulent Airflows over an Urban Area

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Geometrical features of surface roughness due to natural terrains and man-made buildings cause turbulent airflows in the planetary boundary layer. In this study, we investigated the effects of geometrical features of surface roughness on turbulent flows over an actual urban area by conducting observations and large-eddy simulations (LESs). The City of Kyoto was chosen for our analysis, and 2-m resolution digital surface dataset was used to reproduce Kyoto City in the LES model. The morphological characteristics of Kyoto were compared with European, North American, and other Japanese cities, which indicated that the building morphology of Kyoto City is similar to that of European cities.

We conducted turbulence measurement by a sonic anemometer installed on a 55-m high meteorological tower at the Ujigawa Open Laboratory, DPRI and a Doppler lidar employed near the tower during the period from January to February 2016. The meteorological tower at the Ujigawa Open Laboratory, located in the southern part of Kyoto City, is a unique facility to observe atmospheric turbulence over an urban region. The Doppler lidar, temporally deployed during this specific period, can measure airflows and fluctuations in the vertical from the surface to the 200-m level. We compared the LES results with the observation data and found that the LES model indicates a reasonable agreement with the observed winds. We conducted two numerical experiments: One was the control experiment (CTL) with the actual buildings of Kyoto, and the other was the sensitivity experiment (UNI) in which all the building heights are set equally to the average building height in the computational region. The difference of horizontally-averaged mean streamwise velocity and Reynolds stress between CTL and UNI at a higher altitude was clearly seen in regions behind higher-rise buildings. Reynolds stress increased with building density in Kyoto, which indicates the variability of the building height affects the turbulent features. The quadrant analysis was employed to evaluate the physical processes related to turbulent generation. The ratio of ejection to sweep was consistent with previous studies of block array experiments qualitatively. The contributions of extreme instantaneous momentum flux to the total Reynolds stress increased with the amount of buildings. This result also emphasized the importance of building height variability in turbulent generation over complex geometry.

We will demonstrate some of our recent studies on the coupling of the LES model with a meteorological model and on the LESs of turbulence and dispersion over Oklahoma City.

Convection Genesis by Urban Meteorological Model Based on Large Eddy Simulation

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Localized torrential rainfall disasters in rainy season is called as "Guerrilla-heavy-rainfall disasters" in Japanese media. This kind of rainfall disaster is caused by single or multi isolated cumulonimbus clouds that grow rapidly within one hour after its generation. It is important to detect the clouds at its "baby-cell" stage earlier using X-band weather radar, and to predict the risk of disaster by vertical vorticity in a cumulonimbus cloud at its developing stage. However, the radar cannot detect the "convection genesis", i.e. air motion of thermal without precipitation particles. This trigger of generating baby-cell is concerned to be much affected by urban area. Therefore, we are developing the urban meteorological model based on large-eddy simulation (LES) intended to clarify the convection genesis. This model can calculate through urban canopy layer to above boundary layer on a scale possible to resolve buildings explicitly, and clarify process of formation rain drop by cloud microphysical model. The aim of this study is to understand which factor is the most strong on the generating process and how strong urban areas have influence on convective genesis. Cumulus clouds above urban areas on summer season were simulated by our model. The pair of vortex tubes that produce cloud droplet were analyzed. Backward facing step flow and vertical wind shear came up behind buildings. They made horizontal vortex tubes. In addition, anthropogenic heat and sensible heat from surface and forced ascent by convergence of horizontal wind made upward flow and then vertical vortex tubes rises up with moisture.

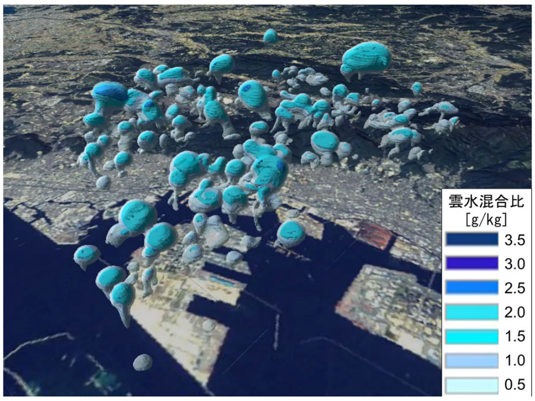

Figure 1 Cumulous simulation by the urban meteorological LES model

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Presentation Title: Investigation of representation of ice and snow categories in a supercell simulation using spectral bin and bulk microphysics schemes

Presentation Abstract: Traditionally, spectral bin microphysics schemes (SBMs) have incorporated greater ice complexity than their bulk microphysics scheme (BMPs) counterparts due to their particle distribution resolution, albeit at a steeper computational cost. Idealized supercell storms are simulated in the Weather Research and Forecasting (WRF) model using the spectral bin Hebrew University Cloud Model (HUCM), and bulk National Severe Storms Laboratory (NSSL) and Thompson (THOM) microphysics schemes. Non-rimed ice and snow moments are compared to understand the hydrometeors' treatment and behavior in the schemes. The spectral HUCM, which contains three ice crystal habits, is found to predominantly consist of plate mass, and plate and column number in the simulation. HUCM PSDs exhibit variability not present in the rigid bulk PSDs, particularly the absence of small snow particles. HUCM also produces larger snow reaching the surface, while BMP snow is typically depleted through melting. Unlike the HUCM and NSSL schemes, the Thompson scheme simulates snow more consistent with both ice crystals and snow in terms of moment maxima, location, and particle size distribution (PSD) structure.

Volcanic Ash Plume Observed by Polarimetric Weather Radar

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Introduction

Although it is widely recognized that weather radar can capture volcanic ash eruption, we can't precisely measure the amount of ash fall or ash inside the plume by conventional weather radars. In such a circumstance, polarimetric weather radar is now expected to get more information inside volcanic ash plume.

Meteorological research institute (MRI) installed an X-band MP radar (MRI-XMP) near Sakurajima volcano, which is located in the southern part of Kyushu, and started observation from March, 2016.

Results

Two RHI scans and five sector PPI scans are conducted in about 74 seconds. We successfully captured dozens of eruptions, and the tendencies of polarimetric parameters have been gradually revealed.

In this presentation, we will show some volcanic eruption cases observed by MRI-XMP and discuss the problems with volcanic ash observation by weather radars.

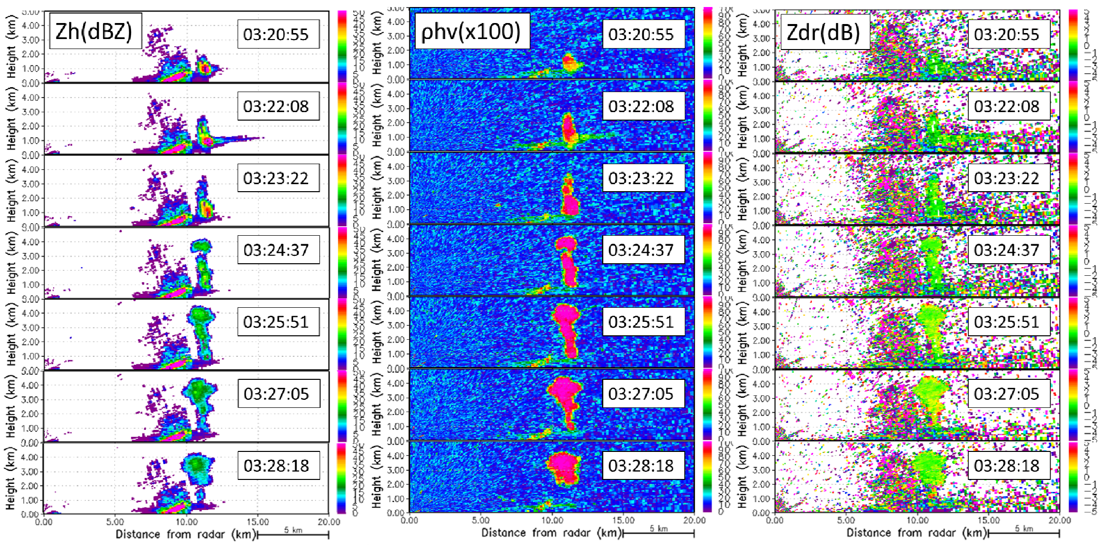

Figure 1 RHI cross sections of an explosive eruption observed by MRI-XMP on May 2, 2017.

Photogrammetric detection of funnel clouds

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Introduction

Tornadoes occur on the shoreline of Kochi Plane almost every year. The frequency of tornado occurrence is more than 30 per year per 10000 km^2. We installed 3 multi-parameter Doppler radars and 12 monitoring cameras to observe tornadoes and their parent clouds. Because most of tornadoes land to Kochi Plane from Tosa Bay, it is possible to issue early tornado warning by detecting funnel clouds offshore. The present study aims to develop automatic detection system of funnel clouds from their monitoring cameras.

Detection Scheme

In order to detect funnel clouds from images of monitoring cameras, we used regions with convolutional neural network (CNN). R-CNN (Regions with CNN features) or Fast R-CNN are well known for object detection and classification from images, however we adopted Yolo (You only look once, Redmon et al., 2016) as the detection algorithm because this algorithm works faster by conducting object detection and classification simultaneously using a single network. We used about 80 examples from pictures of Tsukuba tornado and some waterspouts as materials for deep learning. We can extract object from a picture for 2 seconds by using a conventional PC with one GPU card.

Results and Discussion

The results of cross validation showed that 82 percent of actual funnel cloud patterns were extracted with 96 percent accuracy. Some errors occurred in the pictures including the other objects; e.g., signal, windmill, raindrops and high contrast clouds.

We also adapted the present scheme to the actual tornado case on 10 July, 2014. Two tornadoes occurred in the outer rainband of Typhoon 'Neoguri' and caused F1 damage in Kochi Plane (Yuasa and Sassa 2015). The tornadoes passed west and east sides of our Monobe MP Doppler radar and 4 cameras. Unfortunately some data of couple of minutes lacked due to blackout, but the camera observing west side of the radar caught the west tornado vortex and the northside camera also extracted the east tornado vortex. Though tornado vortices approaching from Tosa Bay were screened by forward flank heavy rainfall of the parent cloud in the present case, we expect that the present detection scheme is highly useful for early tornado warning.

Figure 1 Example of extracted tornado vortex on 10 July 2014.

Acknowledgment

The present work was supported by JSPS Kakenhi 15H02994.

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Videosonde and Radar Observations in Ice-Phase Regions of Stratiform Clouds

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Introduction

Ice particles in clouds are related with precipitation formation processes. In addition, cloud radiation processes related with clouds alter structures of cloud systems. However, representation of cold clouds in numerical model requires to be improved because ice nucleation processes are still unclear at present. Therefore, particles in ice-phase regions require to be characterized from observation. We have conducted observations of particles in ice-phase regions using videosondes as well as radars.

A videosonde is a balloon-borne instrument, which has video camera(s) to take images of particles. There are two types of videosondes. One of them takes images of suspended particles in the air, larger than about 500 μm. Another videosonde measures particles falling on a transparent film larger than about 10 μm. A particle counter sonde, referred to as cloud particle sensor (CPS) sonde, is also used. In addition to precipitation radars, we have started to use Ka-band (35 GHz) radar, which can detect liquid-phase cloud to drizzle particles and small ice crystals. Full polarimetric Ka-band radar is one of the few Ka-band radar and availability of polarimetric capability is focused for Ka-band radar.

Results

Stratiform clouds were mainly selected to be observed by videosonde because, for convective clouds, spatiotemporal variability is large and representativeness is small. Clouds in baiu frontal zone, outflow-layer clouds of typhoons, winter ice clouds in inland Hokkaido, and tropical cloud systems in Palau have been observed during the past decade. For example, number concentration of ice particles in outflow-layer clouds of typhoons was considerably less than ice-phase stratiform precipitation region in baiu frontal zone. Polarimetric parameters of Ka-band radar in the outflow-layer clouds showed presence of isotropic shaped ice particles except for slightly oblate particles at the cloud tops. Because recent studies showed that radiation of outflow-layer clouds alter structures and tracks of typhoons, characteristics of the videosonde and Ka-band radar could contribute to validation and improvement of numerical simulation of typhoons.

Concluding Remarks

Cloud and precipitation particles in ice-phase regions in some environments from tropics to winter inland have been observed using videosonde and radars. Stratiform clouds have been mainly selected in terms of representativeness. In the middle of summer in Japan, cumulonimbus clouds suddenly developed to cause disasters in urban areas occasionally. By applying our observation technique, we have started an observation of initial development stage of cumulonimbus clouds for early detection and studying development potential using multi sensors including Ka-band radar and sonde.

The 3D Mesonet Concept: Extending Networked Surface Meteorological Tower Observations Through Unmanned Aircraft Systems

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Background

Fixed monitoring sites, such as those in the US National Weather Service Automated Surface Observing System (ASOS) and the Oklahoma Mesonet provide valuable, high temporal resolution information about the atmosphere to forecasters and the general public. The Oklahoma Mesonet is comprised of a network of 120 surface sites providing a wide array of atmospheric measurements up to a height of 10 m with an update time of five minutes for most observations. The deployment of small unmanned aircraft to collect in-situ vertical measurements of the atmospheric state in conjunction with surface conditions has potential to significantly expand weather observation capabilities. This concept, which we are calling the 3D Mesonet, can enhance the safety of individuals and support commerce through improved observations and short-term forecasts of the weather and other environmental variables in the lower atmosphere.

3D Mesonet Concept

We report on research being conducted at the University of Oklahoma and Oklahoma State University aimed at evolving the 3D Mesonet concept in general along with developing and constructing a prototype on one such station in particular. The concept would allow networked surface meteorological tower observations to be extended vertically by collecting profiles of atmospheric measurements through the use of unmanned aerial systems (UAS). While there are a number of other technologies currently available that can provide measurements of one or a few variables, the proposed UAS model will be expandable and modular to accommodate several different sensor packages and provide accurate in-situ measurements in virtually all weather conditions. Such a system would facilitate off-site maintenance and calibration and would provide the ability to add new sensors as they are developed or as new requirements are identified. The small UAS must be capable of accommodating the weight of all sensor packages and have lighting, communication, and aircraft avoidance systems necessary to meet existing or future FAA regulations. The system must be able to operate unattended, which necessitates the inclusion of risk mitigation measures such as a detect and avoid radar and the ability to transmit and receive transponder signals. Moreover, the system should be able to assess local weather conditions (visibility, surface winds, and cloud height) and the integrity of the vehicle (system diagnostics, fuel level) before takeoff. After providing a notional concept of operations for a 3D Mesonet, we present progress towards constructing a prototype of a 3D Mesonet station. This is an on-going effort so plans for future development are also discussed.

UAV-Based Multistatic Passive Radar for Mobile Observations of Severe Weather

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Introduction

Field experiments seeking to obtain multiple Doppler weather observations require the carefully coordinated deployment of multiple ground-based mobile radars. These radars are both costly and limited in terms of potential deployment locations by ground clutter and terrain features. These issues limit areas of operation, as well as the number of simultaneous Doppler measurements which it is practical to collect. A UAV-mounted passive radar system, utilizing existing radars in the national network of WSR-88Ds as transmitters of opportunity, is proposed to mitigate these challenges. The passive aspect of the system greatly reduces its cost and minimizes its size and weight such that it may be mounted on a small, airborne platform. This means that a network of several of these systems could plausibly be procured for a fraction of the cost of a single monostatic radar (Wurman 1993). Furthermore, this network could be deployed in cluttered environments and complex terrain where operations would be difficult or impossible for ground-based radars. An additional potential benefit of this system is its potential use for clear air wind measurements, as a multistatic geometry makes Bragg scatter measurements feasible at S-band (Tulu 2006).

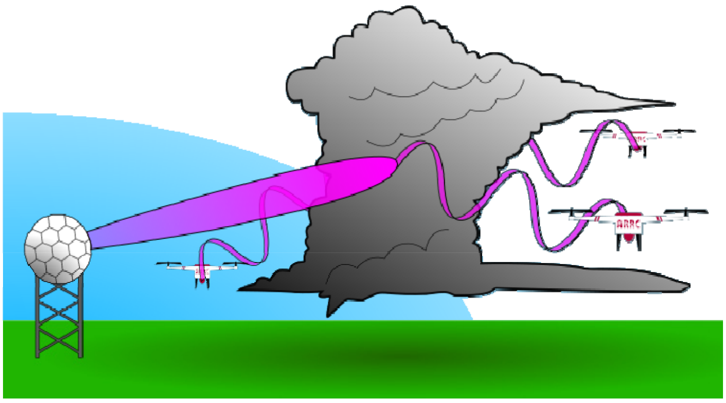

Figure 1. Conceptual illustration of the deployment of a UAV-based multistatic passive radar network.

Preliminary Simulation Results

As an initial step toward the development of this system, a simulator has been developed to emulate observations of user-specified weather fields using arbitrary multistatic geometries and system specifications. This simulator can be used to study the effects of these factors on SNR as well as the accuracy of wind field retrievals. It is also capable of simulating dual-Doppler wind field retrievals using multiple monostatic radars, which is useful as a point of comparison for the multistatic passive results. Finally, the simulator has a Bragg scattering mode which allows for studies into the use of the proposed system for clear air wind measurement. Initial simulation results will be presented and discussed.

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Autonomous UAV Systems for Remote Sensing Applications

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Presentation format request: Poster

Abstract
Advances in unmanned systems and remote sensing technologies have extended the possibilities for many science applications. For example, in boundary layer meteorology, difficulties in performing an adequate sampling using conventional techniques (towers, balloons, etc.) can be overcome using small unmanned aerial vehicles (UAV). At the University of Oklahoma (OU), two UAV systems were designed and developed in-house for atmospheric science and antenna measurements: the CopterSonde is a small octo-rotor copter for atmospheric sensing, and the RF1250 is a medium-sized octo-rotor copter for antenna and radome calibration. To complement the capabilities of the UAV systems and to provide fully-automatic operations, a prototype Ground Base Station (GBS) is being developed. With the objective of moving towards unattended UAV operations, the GBS will provide shelter for the UAV systems, serve as a communications hub by securely encrypting and storing data, monitor the status of the UAV and GBS, integrate risk mitigation technologies, act as a pad for precise landing and takeoff between missions and as an autonomous battery charging station. Current progress on precision landing and automatic battery recharging aspects of the autonomous UAV system will be presented in this work and future potential remote sensing applications shall be discussed.

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Overview of fundamental and practical researches on generation and development of baby-rain- cell aloft in a severe storm

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In July 2008, five people were killed by a tragic flash flood caused by a local torrential heavy rainfall in a short time in Toga River. From this tragic accident, we realized that a system which can detect hazardous rain-cells in the earlier stage is strongly needed and would provide an additional 5 to 10 min for evacuation. By analyzing this event, we verified that a first radar echo aloft, by volume scan observation, is a practical and important sign for early warning of flash flood, and we named a first echo as a "baby-rain-cell" of Guerrilla-heavy rainfall. Also, we found a vertical vorticity criterion for identifying hazardous rain-cells and developed a heavy rainfall prediction system that has the important feature of not missing any hazardous rain-cell.

Being able to detect heavy rainfall by 23.6 min on average before it reaches the ground, this "early detection and risk prediction system" is implemented in the Kinki area in 2015 in XRAIN which is the Japanese operational network composed of 39 X-band polarimetric Doppler radars managed by the Japanese Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT). XRAIN in the Kinki provides three-dimensional radar information with spacio-temporal resolutions of 250m and one minute. Also, the National Institute for Communication Research (NICT) developed the decision support system for the localized torrential rainfall using the early detection and risk prediction system developed by the MLIT. The NICT's system utilizes dual phased array weather radars developed the PANDA system (Phased Array weather radar and Doppler lidar Network fusion Data system). The phased array weather radar can observe three-dimensional rainfall every 30 seconds. For the decision support system, a dynamic hazard map with location-dependent degree-of-risk information is provided by integrating the early detection of the localized torrential rainfall and the local static hazard map. The dynamic hazard map is displayed on the control screen and the warning information is also distributed by e-mail for a limited number of the authorized staff. Real time demonstration test was conducted in Kobe city from August to October, 2016.

Additionally, as a pioneering attempt and a fundamental analysis, we also performed a brand new vorticity analysis of baby-rain-cells in the events of Guerrilla-heavy rainfalls. As a result, we verified the existence of vertical vortex tubes inside rain-cells even which did not develop into supercells. Furthermore, vortex tube tilting motion, similar to that in a supercell, was also proven to exist in the rain-cell which formed a Guerrilla-heavy rainfall. These two results not only make a breakthrough of baby-rain-cell analysis, but also help to clarify the importance of vorticity analysis for efficient identification of hazardous baby-rain-cells. As a further fundamental analysis, it is also proven that a Ka-band polarimetric Doppler radar (cloud radar) has a potential to detect cloud cells aloft earlier than 15-25 minutes earlier than X-band radar (precipitation radar) detects rain the baby-cell aloft. Also, it is found the pair of vertical vortex tubes inside a developing cloud can be verified to exist. Also, numerical experiments using the LES cloud numerical model developed in Kyoto university simulated the existence of the pair of vertical vortex tubes inside a developing cloud

To better understand the developing mechanism of a baby-rain-cell, it is critical and necessary to analyze flow structure in a cumulonimbus cloud aloft in the atmosphere before raindrop generation. So, further analysis of multi-sensors observation by the cloud radar, a boundary layer radar (BLR), a Light Detection and Ranging (Lidar) , and rapid scan type weather satellite will be our future task. With better understanding, it is certain that the precise quantitative risk prediction system of Guerrilla-heavy rainfall could be realized, and perfect protection of human lives from flood disasters can be surely guaranteed in the near future.

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The Advanced Radar Research Center at the University of Oklahoma – An Interdisciplinary Approach to Radar Science

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Based on a foundation of research and development at NOAA and the University of Oklahoma (OU) in the USA, in 2005 the university established the Advanced Radar Research Center (ARRC) with the goal of becoming a leading academic force in the field of radar meteorology. After more than a decade, the ARRC has become the largest academic research program in the USA focused on advancements in radar and applied electromagnetics. With 18 faculty members, a strong engineering staff, and over 100 interdisciplinary graduate students from meteorology and engineering, the ARRC has become a major force in the international field of radar. For example, OU hosted the 2015 American Meteorological Society's Radar Meteorology Conference with its largest-ever attendance. In addition, the ARRC's radar program in defense applications has also been recognized by the community and will host the most important conference in the field with the 2018 IEEE Radar Conference. This presentation will provide an overview of the research currently underway in the ARRC, including the development of several advanced weather radars, phased array radars, signal processing algorithms, and resulting scientific studies. An important goal of the presentation is to foster international research exchange in both the engineering and meteorology aspects of radar.

Maintenance Mechanism of Back-Building Rainband in A Numerical Simulation of A Heavy Rain in July 2010 in Western Japan

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Introduction

The back-building rainband (BBR) frequently occurs in summer season in Japan. The quasi-stationary BBR tends to cause severe heavy rain, hence it sometimes leads to the natural disaster. Maintenance of updraft at the rear edge of BBR are necessary characteristics for the quasi-stationary BBR. Kato and Goda (2001) found that the low-level convergence of synoptic scale cold front is essential environmental condition to maintain the updraft. However, the synoptic scale cold front has large horizontal scale compared to that of the updraft. The mechanism of maintaining the BBR on the synoptic scale cold front is still open question. Therefore, we aimed to clarify the mechanism by a numerical simulation of a heavy rain case in Western Japan in July 2010.

Numerical simulation and the maintenance mechanism of the simulated BBR

The SCALE-RM (Nishizawa et al. 2015) was used for the numerical simulation with triple nested domains by online nesting system of CONeP (Yoshida et al. 2017). The grid-spacing of innermost domain is 500m with vertical 80 levels. Time integration period was from 09 JST July 10, 2010 to 09 JST July 15, 2010 with the JMA GSM-GPV data. As shown in Figure 1, the quasi-stationary BBR was simulated from 23JST 11 to 03JST 12. We found that the new cell was organized on the intersection between a cold front and an envelope of the moist area. The location is corresponding to the rear edge of BBR. The intersection moved eastward slowly, and the BBR also moved eastward following the intersection for this period. This suggests that the cold front induces a forced ascent, and the ascent flow is accelerated by diabatic heating of condensation. These two conditions of trigger and acceleration were satisfied simultaneously on the intersection. As a result, the new convective cells were organized continuously, and BBR was maintained for a long period.

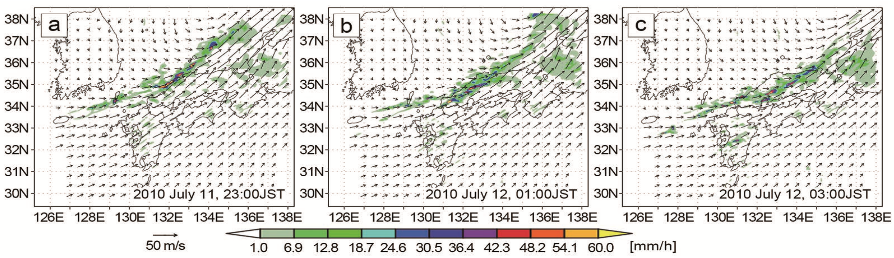

Figure 1 Simulated precipitation in Domain 2 (2.5km horizontal grid-spacing)

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High resolution numerical study of migrating strong downslope wind "Hira-Oroshi" in Japan

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This study aims to develop the precise forecast system of Hira Oroshi" (hereafter, called as HO), the downstream gustwind browning down from the Hira mountain range to the West coast of Biwa Lake in Shiga prefecture, Japan. Our system improved the forecast score of gust occurrence to 54.8% from 78.9%. In this study, the occurrence of downstream gustwind in HO region is defined as the maximum wind speed exceeds to 20 m/s with the wind direction of WEW-NNE. The intensive observation network was constructed to monitor the detailed behavior of downstream gust and selected three observation points, which can represent the wind feld in the whole HO region.

The non-hydrostatic meteorological forecast system with the horizontal resolution of 200 m is constructed by installing WRF (Weather Research and Forecast) to the A-KDK system in Kyoto University. The initial and boundary data is automatically obtained from JMA and other meteorological agencies every six hours. A long-term computational experiment from October 1, 2013 to March 31, 2014 shows very interesting characteristics of wind speed pattern, which appears, only when the gustwind was observed. Narrow strong wind regions extending from the Lake Biwa toward the foot of Hira Mountain range appears and extends to the land in HO region. This structure is used to identify the appearance of gustwind in HO region. The threshold of strong wind in the forecast model is defined as 14 m/s in this study by considering the model wind velocity represents the averaged wind speed in horizontal grid and integral period. The new method by using this threshold shows very good forecast performance of hit ratio of 78.9%.

Dynamics and Predictability of Downward Propagating Stratospheric Planetary Waves Observed in March 2007

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The predictability of a downward propagating event of planetary waves in the lower stratosphere observed in early March 2007 is examined by conducting ensemble forecasts using an AGCM. It is determined that the predictable period of this event is about 7 days. Regression analysis using all members of an ensemble forecast also reveals that the downward propagation is significantly related to an amplifying quasi-stationary planetary-scale anomaly with barotropic structure in polar regions of the upper stratosphere. Moreover, the anomaly is 90° out of phase with the ensemble mean field. Hence, the upper stratospheric anomaly determines the subsequent vertical propagating direction of incoming planetary waves from the troposphere by changing their vertical phase tilt, which depends on its polarity. Furthermore, the regressed anomaly is found to have similar horizontal structure to the pattern of greatest spread among members of the predicted upper-stratospheric height field, and the spread growth rate reaches a maximum prior to the occurrence of the downward propagation. Hence, we propose a working hypothesis that the regressed anomaly emerges due to the barotropic instability inherent to the upper stratospheric circulation.

In fact, the stability analysis for basic states comprised of the ensemble-mean forecasted upper-stratospheric streamfunction field using a non-divergent barotropic vorticity equation on a sphere supports our hypothesis. Thus, the barotropic instability inherent to the distorted polar vortex in the upper stratosphere forced by incoming planetary waves from the troposphere determines whether the planetary waves are eventually absorbed in the stratosphere or emitted downward into the troposphere.

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Large ensemble climate simulations with high-resolution AGCM and RCM

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An unprecedentedly large ensemble of climate simulations with a 60-km atmospheric general circulation model and dynamical downscaling with a 20-km regional climate model has been performed to obtain probabilistic future projections of low-frequency local-scale events. From the large ensemble simulations for more than 5,000 years, named "d4PDF" (Mizuta et al. 2017), probabilistic future changes in extreme events are available directly without using any statistical models. The atmospheric models are highly skillful in representing localized extreme events, such as heavy precipitation and tropical cyclones. Figure 1(a) is the frequency distribution of daily precipitation in the historical simulation for the grid square including Tokyo, compared with the observational station data, without bias correction, showing that the model simulates extreme precipitation events very well. Figure 1(b) shows its future change, indicating that the precipitation increase is larger with higher precipitation rates. Since mean climate changes in the models are consistent with those in phase 5 of the Coupled Model Intercomparison Project (CMIP5) ensembles, the results enable the assessment of probabilistic change in localized severe events that have large uncertainty from internal variability.

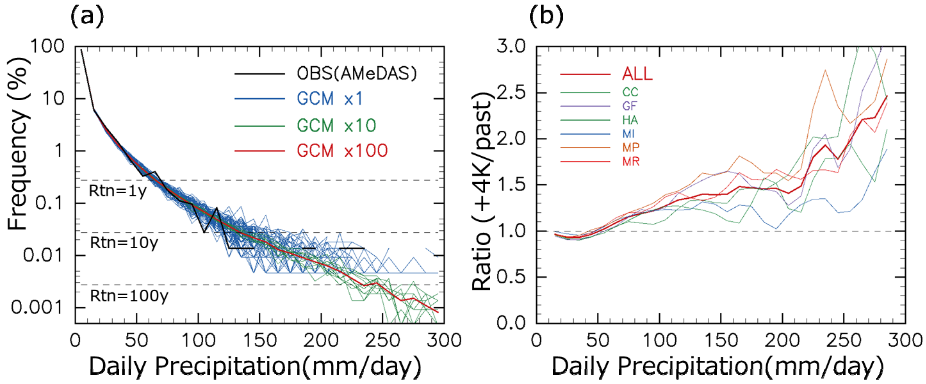

Figure 1: Frequency distributions of daily precipitation on the grid square including Tokyo of the AGCM, (a) for the historical simulation, and (b) for the change from the historical to +4K simulations.

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Observed Characteristics of Tropopause Polar Vortices over Summit Station, Greenland

Presenter: Sarah Borg

Tropopause Polar Vortices (TPVs) are long-lived, coherent vortices that are identified by closed material contours of potential temperature on the tropopause. These potential vorticity anomalies spend most of their lifetime in the Arctic and can impact their surrounding environment by introducing variability in sea ice, generating surface cyclones, and intensifying midlatitude weather systems when carried equatorward by the Polar jet stream. While several studies have modeled the structure and climatology of TPVs, there is much to be discovered in terms of their evolution, intensification, and genesis. Past studies have used results of a water-shed based tracking algorithm of TPVs on the 2 PVU surface in the NCEP-NCAR reanalysis dataset to model TPV composite structure and intensity changes. Case studies from these model runs have shown that changes in TPV intensity can be attributed to local factors such as radiative cooling and latent heating, while cloud top radiative cooling had the most influence on increasing potential vorticity. However, due to the sparse nature of observations in the Arctic, no observation-based studies have focused on TPV characteristics to compare to these model results. This study uses observations to investigate if liquid or mixed-phase clouds contribute more significantly to TPV intensification by radiative cooling than ice-only clouds or clear-sky conditions.

As part of the Integrated Characterization of Energy, Clouds, Atmospheric State, and Precipitation at Summit (ICECAPS) project, observations of tropospheric and cloud properties at Summit, Greenland have been collected since 2010. Using temperature and humidity profiles from soundings, we compare the TPV composite characteristics from previous modeling studies to the observed data. With ground-based instruments such as a vertically pointing polarization sensitive lidar, millimeter cloud radar, and microwave radiometer, we also consider what cloud characteristics are associated with TPVs passing over Summit. Additionally, sounding data in conjunction with the stand-alone version of the Rapid Radiative Transfer Model are used to analyze shortwave and longwave radiative contributions to TPV diabatic intensity changes from both clouds and clear-sky water vapor effects.

Real-time Auto Calibration and DSD retrieval for Polarimetric Radar at Attenuating Frequency

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Introduction
Dual polarimetric radars require an accurate method for absolute power calibration for reflectivity and differential reflectivity measurements to achieve their full potential. The systematic bias in differential reflectivity measurements can be estimated by calibrating with vertical measurements in rain. However, it is quite difficult to estimate the bias in the observed reflectivity. The calibration for the reflectivity is traditionally achieved by comparing radar data with external reference data such as rain gauge, but the reliability of the systematic bias estimated with the method of this kind is quite low. The reason for this could include the fact that the sampling volume of the reference data is quite different from that of radar and makes it difficult to obtain reliable reference data.

Auto-calibration technique
Goddard et al. (1994) proposed an auto-calibration technique for S-band, which estimates the systematic bias using polarization redundancy and requires no external reference data. This method is also available for C-band if the path-integrated attenuation is small (Gourley et al. 2009). Although the systematic bias in Z measurements could be estimated by this method, the bias in the observed Z could vary with the beam direction and time because it contains excess attenuation due to the wet radome of the antenna in addition to the systematic bias. Because of the time dependency, the actual bias should be estimated in real-time even when the attenuation is large, which may result in fails of the auto-calibration method.

Expanded-auto-calibration and DSD retrieval
In the present study, thus, we propose a new method. The algorithm was developed based on the auto-calibration method but was expanded to take into account the attenuation effect by describing the interrelation among the polarimetric measurements. Moreover, this algorithm retrieves the three DSD parameters and rainfall rate from the interrelation and could process the data in real time. The performance of this algorithm was evaluated by comparison with surface observations. The evaluation of the algorithm showed that the bias-and-attenuation corrected reflectivity, differential reflectivity, and three DSD parameters of raindrops from actual C-band polarimetric radar data have fairly good agreement with those obtained by surface measurements.

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Development of EAR Multi-Channel Receiver System Using Software-Defined Radio

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Abstract

Equatorial Atmosphere Radar (EAR) was established in June 2001 by the collaboration between Research Institute for Sustainable Humanosphere (RISH), Kyoto University and Indonesian National Institute of Aeronautics and Space (LAPAN) to improve the understanding of the equatorial atmospheric and its dynamical and electrodynamical coupling processes. EAR is a VHF Doppler radar operated at 47 MHz with an active phased-array antenna system and located at the equator at Kototabang, West Sumatra, Indonesia (0.20oS, 100.32oE, 865 m above sea level). It uses a quasi-circular antenna array with a diameter of approximately 110 m which consists of 560 three-element Yagi antennas. The maximum output power of the EAR is 100 kW.

Currently, the EAR has only a single receiving channel. The rapid development of multi-channel receiver system in most radar system allows for the implementation of more sophisticated observation technique such as spaced-antenna (SA) and spatial imaging observations. Here, we present the initial development of multi-channel receiver system for the EAR using general-purpose software-defined radio receivers.

The multi-channel digital receiver system will be developed using the combination of Universal Software Radio Peripheral 2/N210 (USRP2/N210) series and GNU. The receivers are synchronized using 10 MHz reference clock and 1 pulse per second (PPS) signal. Signals processing such as filtering, range gating, and coherent integration will be performed in real time utilizing a personal computer and GNU Radio software and the data produced will be stored in an external hard disk for post processing.

Figure 1 Equatorial Atmosphere Radar (EAR)

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Shigaraki UAV-Radar Experiments (ShUREX): Measuring turbulence in the lower troposphere

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The Shigaraki UAV-Radar Experiment (ShUREX) is an international (US-Japan-France) observational field campaign, aimed at measuring and obtaining a better understanding of turbulent mixing and atmospheric structures in the lower troposphere. During the three campaigns in 2015-2017, the unmanned aerial vehicle (UAV) DataHawk (developed at the University of Colorado and equipped with high frequency response cold wire and pitot tube, as well as an IMET sonde) was flown near and over the VHF-band MU radar. The MU radar was operated in range imaging mode to provide high vertical resolution of 20 m. In ShUREX 2015 campaign, we were able to sample interesting atmospheric structures such as sheets and layers (SL), midlevel cloud-base turbulence (MCT) and convective boundary layer (CBL). Salient results have been obtained, but the less than optimal frequency response (100 Hz), combined with the high noise level of the coldwire and pitot turbulence sensors, prevented the use of the spectra above a certain frequency, leading to rather narrow inertial subranges in the turbulence spectra. In addition, the vibrations induced by the motor contaminated the turbulence spectra and the discrete frequency spikes in the data had to be removed before deducing turbulence parameters. ShUREX 2016 campaign carried out in May-June 2016 used higher frequency response sensors (800 Hz) with much lower noise floor, which yielded broader inertial subranges without contamination by motor vibrations. This enabled more accurate and reliable derivation of the TKE dissipation rate and turbulence structure parameters. ShUREX 2015 and 2016 campaigns have demonstrated the presence of fine scale structures in the moist troposphere. They also enabled simultaneous sampling of turbulent atmospheric structures such as MCT by in-situ turbulence sensors flown on a UAV and the radar. As productive as these campaigns have been, they do suffer from the deficiency that we were unable to map the complete evolution of structures such as MCT, SL and CBL. We were unable to catch a KHI event.

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Water vapor profiles observed from Raman lidar calibrated with GNSS precipitable water vapor

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Water vapor is one of the key parameters for understanding of the localized extreme weather related with severe weather disasters such as torrential rain and floods. Raman lidar techniques are useful for observing water vapor profiles. However, the calibration factor based on the system constants must be determined before observations. Because the calibration factor is generally evaluated by comparing the results of independent measurements (e.g., radiosonde) of water vapor mixing ratio, it is difficult to apply lidar observations at sites where radiosonde observations cannot be carried out.

In this study, we propose a new calibration technique for water vapor Raman lidar using global navigation satellite system (GNSS)-derived precipitable water vapor (PWV) and the Japan Meteorological Agency Meso-Scale Model (MSM). The analysis was accomplished by directly fitting the GNSS-PWV to integrated water vapor profiles combined with the MSM and the results of the Raman lidar observation. This method can be applied to lidar signals under a limited height range due to weather conditions and lidar specifications. Moreover, it will allow the utilization of various types of Raman lidar systems and provide many opportunities for calibration. We demonstrated the potential of this method by using the Raman lidar, which can observe the water vapor profiles within 2.0 km height in maximum, at the Shigaraki MU radar observatory in June 2016. The derived calibration factor by the proposed method was in good agreement with that by the combinational method using radiosonde data under optimal conditions such as clear skies.

Diurnal LST Characteristics over the Urban Area in Japan

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Introduction

Urban heat island is the phenomenon caused by human activities and deteriorate a hot environment of the urban areas. This phenomenon leads to environment issues, such as increasing energy consumption, retention of air pollutant and increasing the number of patient suffered by heat stroke and so on. The urban heat island intensity (UHII) is generally defined as the air-temperature difference between the urban and surrounding rural areas. When the hot environment is evaluated in the summer season, however, the air-temperature difference is lower than other seasons. In addition to the anthropogenic heat source, the difference of surface coverage between urban and rural areas causes the heat contrast. Therefore, it is important to consider the land surface temperature (LST) based UHII. In this study, we develop a new retrieval method of the LST using Himawari-8 data, and then we attempt to apply it to the urban area in a summer season. Himawari-8 is the Japanese new-generation geostationary satellite which has high spatial (about 2 km) and temporal resolution (10 minutes). The aim of this study is to clarify the temporal change characteristics of LST in urban area by using the Himawari-8 LST product.

LST Retrieval from AHI/Himawari-8

The AHI has three thermal infrared (TIR) bands (centered at 10.4, 11.2 and 12.4 μm) in the spectral range of 10–12.5 μm. We developed a nonlinear three-band algorithm that makes the best use of these bands to retrieve the LST. The input data of the algorithm are the brightness temperatures and land surface emissivities (LSEs) for the three TIR bands. We constructed the LST retrieval method which includes the LSE estimation and cloud masking. The LST product was evaluated by comparison with MODIS LST product over the Japan area, and then the validity was confirmed.

Observation results

Figure 1 shows the time changes of LST at four different areas in Osaka on August 12, 2016 observed by our retrieval method. Figure 2 shows the land use state of each observation area. The diurnal range of LST is different in each area. The residential area A is crowded with low-buildings and has highest LST during the daytime, while the commercial area is crowded with high-buildings and has highest LST during the nighttime. The agricultural area has lowest temperature and smallest diurnal range. We will show more detail results and discussions in the poster presentation.

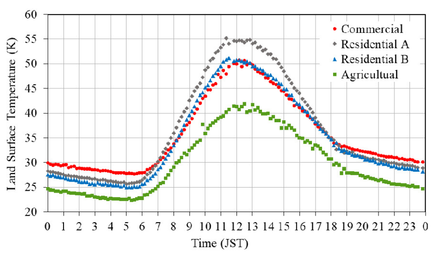

Figure 1 Time changes of LST at four areas in Osaka.

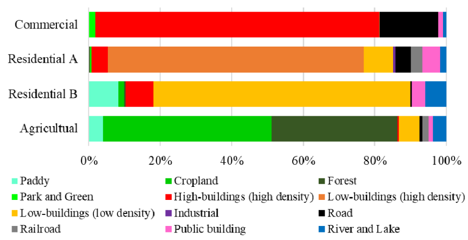

Figure 2 The land use state of each observation area.

Prospective of future spaceborne precipitation measuring mission

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Introduction

Dual frequency precipitation radar (DPR) onboard the core satellite of the Global Precipitation Measurement (GPM) has been demonstrated its feasibilities for three years. In the scientific viewpoint, GPM/DPR is contributing to provide precipitation structures globally including snowfall over 90 % of global coverage, almost 20 years of accumulation of accurate global rainfall (mainly tropics to sub-tropics) since the observation by the precipitation radar (PR) onboard the Tropical Rainfall Measuring Mission (TRMM) satellite, and hourly global precipitation map (such as GSMaP) by combining not only the sensors onboard the GPM/core satellite but also the satellites that equip microwave radiometer. The societal importance of the space based precipitation observation has changed since the launch of the TRMM. The TRMM mission is rather a process-study mission to reveal the three dimensional heating profiles of the precipitation systems especially for the tropical rainfall systems. Success of the TRMM in terms of the accurate precipitation measurement and long-term observation period, provision of the accurate precipitation map was added for the TRMM's role. Global precipitation maps such as GSMaP which is one of major purposes of GPM provide hourly 0.1 degree in latitude/longitude data and utilized for the flood forecasting/warning system, agricultural applications and so on. On the technological aspect, the success of the GPM/DPR has shown maturities of its technology such active phased array system using slotted waveguide antenna, solid state power amplifier and so on. In addition, recent studies on the pulse compression technology and the TRMM end of mission experiment (Takahashi et al., 2016) indicate the further advances of the spaceborne precipitation radar are possible with current technology.
Based on achievements of TRMM and GPM, science targets of the future precipitation mission have been discussed among the GPM science community.

Proposed future precipitation measuring mission from space

Three types of mission are proposed and studied: 1) DPR-2, 2) Small precipitation radar constellation, and 3) GPR (Radar observation from geostationary orbit).
The DPR-2 is an upgraded DPR in terms of the sensitivity, swath width and horizontal resolution by using the current state-of-art technologies, such as GaN amplifier and pulse compression of transmit signal. The small and low-cost precipitation radar constellation aims the achieve the very high rain sampling by radar for the better accuracy of GSMaP. The GPR is one of the ultimate missions using precipitation radar. It enables to monitor the precipitation very large area (such as 50 degrees in latitude and longitude) continuously (e.g. one hour intervals).
Preliminary feasibility study indicates that the DPR-2 is almost ready for full development. The small and low-cost precipitation radar needs more trade-off studies on the satellite size and antenna size. Then the target of mission is 5 to 10 years from now. The GPR needs more studies on the large size antenna and its deployment, footprint size, and sensitivity. Therefore, the target of this mission is mid 2030's.

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An Analysis of cumulonimbus cloud development using Ka-band Doppler Radar

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Introduction

Localized heavy rainfall events resulting from suddenly-developed cumulonimbus clouds often occur in metropolitan area in the summer season in Japan, and cause flash floods and underground inundation to bring a lot of human and economic damages. Nakakita et al.(2013) developed a prediction system for torrential rainfall using vertical vorticity in a first echo aloft using 3-D volume scanning data of X-band polarimetric Doppler radar (X-MP for short) and Katayama et al. (2015) implemented this system. Besides, some literatures (Sakurai et al. 2012; Hikita et al. 2016) report that Ka-band polarimetric Doppler radar (Ka-MP) can detect cloud cells 15-25 minutes earlier than X-MP detects rain drops. Also, they show growing rate of reflectivity could estimate the risk of cloud development. In this study, in order to clarify the mechanism of cloud development, we analyzed vertical vorticity using Doppler velocity for early risk judgement as well as the leading time and reflectivity in the earlier stage of cloud development.

Method

Simultaneous observations of cumulonimbus clouds by a Ka-MP and X-band Doppler polarimetric radar (X-MP) were performed from July 2015 to August 2015 in Nagoya region, central of Japan. Three X-MP are set in around Nagoya. Ka-MP and X-MP conducted plan position indicator scans at 11 elevation angles in 10 minutes and 14 elevation angles in 5 minutes, respectively. From the observations we selected 7 cases of an isolated and strongly-developed cumulonimbus cloud. By comparing the echoes of Ka-MP and X-MP, we analyzed the time series of cloud echo backward to its first echo. The visible band data provided by Himawari-8 Satellite was subsidiarily used in the analysis.

Results

In the 7 events, Ka-MP detected the first cloud echo (-20dBZ) in the height between 1 and 3 km above the sea level 20 minutes or more before X-MP detected the cloud. It was revailed first echo height is about 1000m above LCL and it was inferred the relationship cloud particle generation and Ka-band radar detection ability made this result. In terms of risk judgement systems, Ka-MP detected vorticity 10minutes before X-MP detection and in some cases vortex tube are detected. These result show the usefulness of Ka-MP for applying early detection system and risk judge system.

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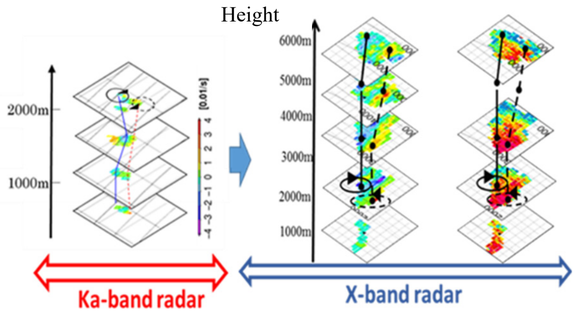

Figure1: Vorticity tube development observed by Ka-MP and X-MP

Development of MU radar real-time processing system with adaptive clutter rejection

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Strong clutter from a hard target such as a mountain, a building, or an airplane often cause problems of observations with atmospheric radars. In order to suppress the clutter, it is effective to use norm-constrained and directionally-constrained minimization of power (NC-DCMP), which makes null toward the direction of the clutter, which is received. It has been Middle and Upper atmospheric(MU) radar, but it is processed in off-line. We successfully implement the clutter rejection by NC-DCMP into the on-line processing system of the MU radar. Accordingly, the recording amount of observation data can be reduced. However, NC-DCMP mainly suppresses the clutter from a stationary target such as mountain or building, but it is insufficient to suppress the clutter from a moving target such as an airplane. This presentation introduces the new clutter rejection system of MU radar, which can be suppressed both the ground clutter and the airplane clutter.

We have applied the NC-DCMP real-time processing since November 2015. However, as we have mentioned earlier, NC-DCMP is insufficient to suppress the clutter from a moving target such as an airplane. In the previous study, a two-step NC-DCMP has been proposed as a method to suppress the airplane clutter. This method consists of two procedures: First, airplane clutter reproduced using the NC-DCMP based on the estimated the arrival direction of the airplane echo is subtracted from the original received signal. Next, ground clutter is suppressed using NC-DCMP. In the previous study, real-time processing is impossible, because all directions are searched to estimate the arrival direction. Therefore, we consider limiting the search area of the arrival directions by using Automatic Dependent Surveiliance-Broadcast(ADS-B), which is the system in which the airplanes broadcast various information such as positions, altitude, and speed with high accuracy. The timing in which airplane information is acquired by ADS-B depends on the airplane broadcasting timing. Therefore, if airplane information is recquired in the processing timing, in which airplane information is absent, we should make up the airplane information using a filter. It is well known that α-β filter is suitable for predicting airplane position and speed. In this study, airplane position and speed are predicted from the airplane information obtained by ADS-B.

We can apply the achievement of this study to the Equatorial MU radar(EMU), which is proposed to be constructed at West Sumatera, Indonesia. The EMU system is the similar as the MU radar, but its antenna consists of 1045 Yagi antennas with 55 groups.

PRELIMINARY INVESTIGATION OF GENERATION OF GUERILLA-HEAVY RAINFALL USING HIMAWARI-8 AND XRAIN INFORMATION IN KINKI REGION

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Introduction

An isolated cumulonimbus cloud could develop less than 30 minutes before heavy rainfall occurs. Localized torrential rainfall generated by a rapidly-growing isolated cumulonimbus in summer season is called "Guerilla-heavy-rainfall" in Japan. Heavy rainfall ever triggered flash floods to cause serious life and property damages in the urban area in Japan. It is very important to investigate the developing mechanism of guerilla heavy rainfall to prevent from its serious damage. For early-warning, Nakakita et al. (2010) have proposed a technique to detect the rain cell of Guerilla heavy rainfall in the early stage by using radar information. The objective of this study is to use Himawari-8 satellite data to identify the characteristic cloud process before the first radar echo of Guerilla-heavy rainfall.

Data and Methodology

The rapid scan observation of Himawari-8 and XRAIN are used in this study. We overlaid 16 cases of brightness temperature (BT; band13) of Himawari-8 and radar observational data to find the distance between them. Based on the distance we retrieve the linear equation to solve parallax effect. The displacement vector of cloud movement in band13 is used to relocate cloud location and Rapid Development Cumulus Area (RDCA) data as well. Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA) developed RDCA concept. It developed by using a logistic model considering the occurrence of a cumulus cloud in the basic spatial scale of 10 km^2 within 1 hour. The output of original RDCA is simply 0 or 1, which denotes the occurrence or non-occurrence of a thunderstorm at a targeted location within one hour. In this research, using the concept of RDCA index, we propose a modified RDCA index ranging from 0.1 to 0.9 for more detailed and quantitatively analyzing the occurrence probability of radar first echo aloft.

Result and Conclusion

By using the modified RDCA index we analyzed 43 cases of RDCA occurrences. We found that the RDCA detected earlier than radar first echo aloft. Fig. 1 shows the sample of the difference time detection. The RDCA detected at 13.15 (Fig. 1a) or five minutes earlier than radar first echo aloft (Fig. 1b). Whilst the detection of RDCA is 15 minutes earlier than the detection of rainfall on the ground (Fig. 1c).

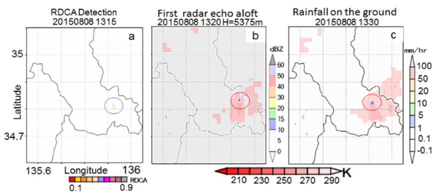

Fig 1. Time detection of a) RDCA, b) first radar echo aloft and c) rainfall on the ground

Based on 43 case studies, we conclude that combining data of Himawari-8 and radar observations can predict the initial stage of a GHR before the first radar echo aloft.

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Large-Eddy Simulation of Turbulent Organized Structures over Block Arrays with Various Building Heights.

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It is known that turbulent organized structures exist in the atmospheric boundary layer and play an important role in momentum and scalar transport. The structures over urban surface are still not clear because of inhomogeneity of urban buildings. In order to understand the physical transport processes in urban areas and develop modelling of urban environments in numerical weather prediction models, it is important to reveal the effects of urban buildings on the organized flow structures.

One of the most important features on urban buildings is building height variability. Previous studies revealed that buildings with height variability significantly influence turbulent flow fields and statistics. Therefore, we conducted large-eddy simulations over block arrays with various building heights to investigate turbulent organized structures over urban buildings. We carried out three cases with different building height variability V_h (the ratio of standard deviation in building height to the average building height). The values of V_h are 0.0, 0.5 and 1.0. Fig 1a shows the vertical profiles of Reynolds stress over the block arrays. The peak of Reynolds stress increases with the increase of V_h. It is also found that the peak height becomes higher than the increase of V_h. The quadrant analysis is used to investigate organized motions of turbulent flows. Ejection and sweep obtained from the analysis are associated with organized turbulent motions so the difference between ejection and sweep ΔS_0 is a good indicator for determining characteristics of turbulent flows. Fig 1b shows the vertical profiles of ΔS_0 over the three arrays. The profiles with building height variability indicate large peaks and the peaks are positive. This means that turbulent flows with sweep are dominant at the height. At the height of the peaks on Reynolds stress, it seems that ΔS_0 is nearly zero. This indicates that both ejection and sweep contribute to the peak of Reynolds stress.

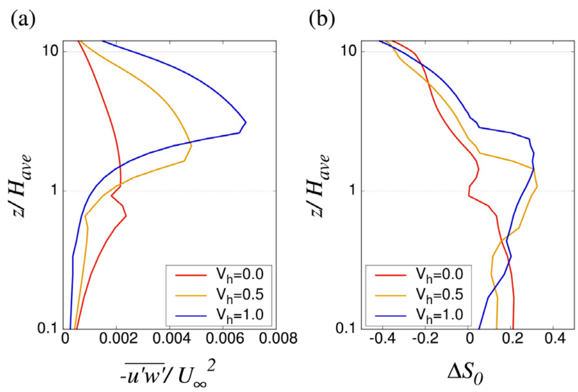

Figure 1: Vertical profiles of (a) Reynolds stress normalized by free stream velocity U_∞ and (b) ΔS_0 averaged spatially over the analysis regions.

Study on the Forecast of Localized Heavy Rainstorms by Combining Coherent Doppler LIDAR and Numerical Forecast Model

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This article studied the impact for non-hydrostatic numerical forecast model by assimilating the radial velocity data obtained with coherent Doppler LIDAR (CDL) on Jul. 24, 2015, when many localized heavy rainstorms were appeared in the Kanto district.
WRF-ARW (Weather Research and Forecasting Model- Advanced Research) was employed to improve the horizontal resolution of MSM (Meso Scale Model) with the nesting method until the horizontal resolution of the model was equivalent to that of CDL data. The CDL data were assimilated with three- and four- dimensional variational assimilation methods (hereafter, referred as 3D-VAR and 4D-VAR, respectively.)

Previous literatures about the convective initiation (CI) pointed out that, under low convective stable condition, the updraft generated by small-scale convergence could be the source of large convective system. This article focused on the evaluation of this prediction by comparing the location of strong convergence with that of rainstorms in the assimilation result.

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Optimal Interpolation of River Water Levels for Real-Time Inundation Mapping Based on the RRI Model

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Introduction

The Rainfall-Runoff-Inundation (RRI) model is a two-dimensional model which simultaneously analyzes rainfall-runoff process and flood inundation process. It is important to improve model accuracy at ungauged grid cells with observed river water levels, for the use of such distributed hydrological models including the RRI model on the real-time basis. This study proposes an optimal interpolation method applied to the RRI model and verifies the effect to river water levels and inundation depths.

Methodology

Optimal interpolation method is one of data assimilation methods and interpolates the difference between model and observation so that the error variance of interpolation result is minimum. This method requires two covariance matrices empirically or statistically determined beforehand; background error covariance matrix and observation error covariance matrix. This study computed the background error covariance matrix, which influences the assimilation accuracy, based on ensembles of the RRI simulation of different rainfall events.

This study uses the RRI model applied to the Chikusa River basin in the Hyogo Prefecture, Japan, where eleven water level gauging stations are available, as shown in Fig. 1. The target event is the 2009 Sayo flood due to the typhoon 0909. The assimilation was implemented every one hour between 1 a.m. on Aug. 9th and 12 p.m. of 10th. The assimilated water levels were the initial condition of water level distribution for following one hour simulation.

Results

The hydrographs at three gauging stations lying along the downstream part of the main river approached to observed values especially in their rising limbs. Cross validation at four observation time shows that the optimal interpolation decreases RSME between model and observation, assumed as true values, suggesting the effectiveness of the optimal interpolation applied to the RRI model.

Assimilated river water levels further influence inundation depths. Improvement of overestimated maximum inundation depth were observed in the downstream area of the basin. At the area where serious inundation occurred, the assimilation result shows one hour delayed peak of inundation depth compared to the original simulation.

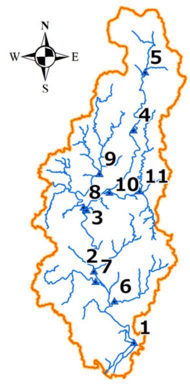

Figure 1 The Chikusa River basin

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Forecasting developing and mature stage of mesoscale convective systems by ensemble assimilation of XRAIN

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Mesoscale convective systems (MCSs) often lead to events such as floods, inundation, and debris flow. The short-lead time rainfall prediction by Numerical Weather Prediction (NWP) has some difficulties in the spin-up problem. It is important to provide a high-quality initial condition in NWP, because initial condition has a huge effect on short-lead time prediction. Therefore, data assimilation (DA) using radar data is expected to improve the initial condition in the model. In Japan, an X-band Doppler polarimetric radar network, known as XRAIN, has been in operation since 2010. The purpose of this study is to demonstrate the predictability of both the developing and mature stages of MCS by assimilation of XRAIN data.

The storm-scale data assimilation system named CReSS-LETKF was developed by Yamaguchi and Nakakita (2008), in which CReSS (Cloud Resolving Storm Simulator), developed by Tsuboki and Sakakibara (2002), was employed as an atmospheric model, and LETKF (Local Ensemble Transform Kalman Filter) was employed as a data assimilation method. In addition, the method of estimation of ice-water mixing ratios, developed by Yamaguchi and Nakakita (2008), were employed. The CReSS-LETKF was performed with 40 ensemble members. The radar reflectivity, Doppler velocity, and the originally developed ice-water mixing ratios were assimilated. The horizontal and averaged vertical resolutions were set to 1km and 250m, respectively.

We investigated the effects of DA on the heavy precipitation event of July 2012 in Kyoto, Japan. In the experiment of assimilating developing period, DA is applied to NWP after the generation of first convective cloud at mountainous regions. It improves predicting accuracy one hour later. However, continuous convective cells that were generated over small mountainous regions could not be reproduced, because the cold air inflow at middle-low levels over the mountainous regions was not predicted well in this event. Therefore, a wider region is used for assimilation in to evaluate low-temperature area in middle atmosphere. As a result, the convective clouds over mountainous regions can be predicted due to reproduction of low-temperature mass by data assimilation. This study shows the assimilation of radar data provides both the direct effects and the indirect effects; the former indicate direct-reproduced rain cloud and velocity, and the latter indicate indirect-reproduced air temperature that is changed by the direct-reproduced rain cloud and velocity.

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Preliminary Research on Identification of Strategies for Long-term Recovery against Flood in 2015 in Myanmar -Case Study from Hinthada Township, Ayeyarwady Region-

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Abstract
Myanmar is the one of high meteorological hazard risk countries in the world due to the geographical factors such as vast delta along with Ayeyarwady River source from range of Himalayan Mountains. Being as Ayeyarwady Region, the delta area, has suffered from seasonal floods in monsoon season historically, long earthen dykes had constructed in 19 century during British colonial period. As a result, one village was divided into two across by the dyke about140 years ago. The Region was severely affected by the floods in 2015, and most of unprotected villages have been inundated for two to three months, while villages inside of the dyke were protected. This preliminary research aims to identify strategies for long-term recovery about housing, livelihood, and community in divided villages by dyke in Hinthada Township through intensive household surveys. The results show that the unprotected villages have adapted their elevated houses against flood and plants water-resistant crops for income source, whereas protected villages have relied on mitigation and maintenance of the dyke with the non-elevated houses and different transformed livelihood. The research provides a hint of the dual strategy for long-term recovery against climate change in Asian context.

Rainfall Impact to El Nino in Batanghari River Basin, Sumatra, Indonesia

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Abstract
The study aims to examine the climate phenomenon affect the rainfall characteristic in Batanghari River Basin, Sumatra Island, Indonesia. The data used in this study is sea surface temperature (SST) monthly data from Optimum Interpolation (OI) SST v2 provided by the NOAA PSD, Boulder, Colorado, USA. The Nino 3.4, calculated from the SST data located in the 5°N–5° and 170–120°W, was used to identify the ENSO. Furthermore, the local SST, which represented by the South China Sea, was calculated from the average of the SST located in 1.5°S–8°N and 102–110°E. Two type of rainfall data are used in this study. The data are Global Precipitation Climatology Center (GPCC) monthly precipitation with the precipitation data set from 1901-present, and daily rainfall recorded data from Sultan Thaha rain gauge data correlation with the rainfall length from 1985-2012. The monthly rainfall of the two data shows that the rainfall pattern in this river basin has two peaks during March-May and Oct-Dec. This result corresponds with Aldrian and Dwi Susanto (2003) which classifid the northern part of Sumatra into region B of climate region of Indonesia which is semi monsoonal climate region with two peak. The long term monthly rainfall from the two data shows no significant increasing or decreasing trend. This result corresponds with Merten et al. (2016) which found out in their study that the climatological trend in the area has not changed over the last 20 years. Furthermore, the correlation between rainfall and SST was investigated by using the Pearson correlation coefficient (PCC). The result indicates that the rainfall in Batanghari River Basin has a strong correlation with the ENSO during JJA (Jun-Aug) and SON (Sep-Nov) season. Meanwhile, the relationship between rainfall and local SST shows high correlation during JJA season only. The correlation coefficient between rainfall and SST is presented in Table 1. This result indicates that the rainfall characteristics in the river basin are affected by ENSO and local SST at the same time during the JJA season and only affected by the ENSO during SON season. However, this result is not in accordance with the study of Aldrian and Dwi Susanto (2003), which they found out that there is no clear relationship between rainfall in this region with the ENSO events. Therefore, further study to examine the other climate phenomena, e.g., IOD, needs to be conducted to give a better understanding of the climate influence on the rainfall pattern in this area.

Table 1 Correlation coefficient between rainfall and Local SST and Nino 3.4. The italic font shows the significance of correlation coefficient higher than 95%.

	Correlation coefficient with the Local SST		Correlation coefficient with Nino 3.4	
Rainfall data	GPCC	Sultan Thaha	GPCC	Sultan Thaha
DJF	0.147	-0.180	0.211	-0.030
MAM	0.014	-0.313	0.191	-0.168
JJA	*0.545*	*0.507*	*-0.633*	*-0.537*
SON	-0.005	0.134	*-0.626*	*-0.525*

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Impacts of environmental conditions on intensification of tropical cyclones

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Introduction

The strong TCs undergo a rapid intensification (RI) process at least once during their life (Kaplan and DeMaria, 2003). However, the relationship between RI and environmental conditions is not well understood. In this study, we will investigate the effects of environmental conditions on RI and maximum intensity of TCs by using an axisymmetric model, i.e., the Cloud Model Version 1 (Bryan, a nd Fritsch, 2002).

Methodology and Results

We focused on effects of tropospheric temperature lapse rate [Γ], tropopause-height temperature [T_o], and tropopause height [H_t] on the intensity changes of the TC. In order to investigate the sensitivity of intensity changes of TCs to those environmental conditions, we have performed numerical simulations under various temperature conditions (Fig1).

It was found that the decrease in the tropopause-height temperature leads to the increase in the TC intensity in a certain lapse rate condition. In addition, the maximum intensity and the rate of intensification of the simulated TC clearly increases with the increase in temperature lapse rate. In contrast, with the increase in tropopause height with keeping the tropopause-height temperature unchanged, the maximum intensity of the TC tends to decrease; this is due to the decrease in temperature lapse rate. The temperature lapse rate seems to have the most significant impacts on the evolution and intensity of the simulated TCs.

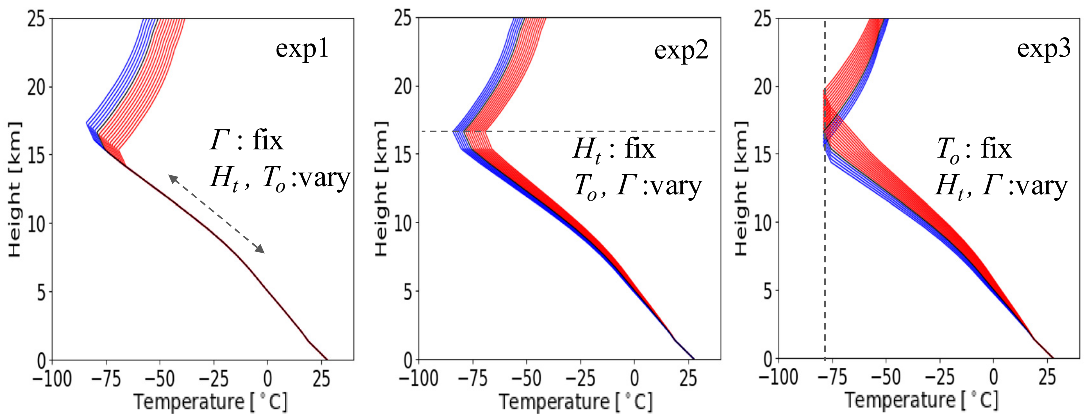

Figure 1 A range of initial temperature condition used in the series of experiments.

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Disparate Mid-latitude Responses to ENSO Categorized by the Winter Climate in the Far East

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Introduction

In the Far East, El Niño (La Niña) typically brings warm (cold) winter. However, significant ENSO events have the opposite tendencies. To understand the cause of the disparate mid-latitude responses, composite analysis has been conducted using long-term reanalysis dataset and the sea surface temperature (SST) dataset.

Our analysis shows that about 70% of all ENSO are classified as typical events and about 30% as atypical events. During the typical events, Western Pacific (WP)-like meridional dipole pattern is evident; surprisingly, Pacific/North American (PNA) pattern is obscure. In fact, PNA pattern dominates during atypical events, with large amplitudes. In addition, SST distributions differ in the west Pacific Ocean. During the typical events, the SST anomaly in the Philippine sea is large amplitude. In contrast to it, the anomaly is not clear in the atypical events. This SST anomaly in the west Pacific Ocean may cause atmospheric responses in the mid-latitude consistent with the winter climate in the Far East during ENSO.

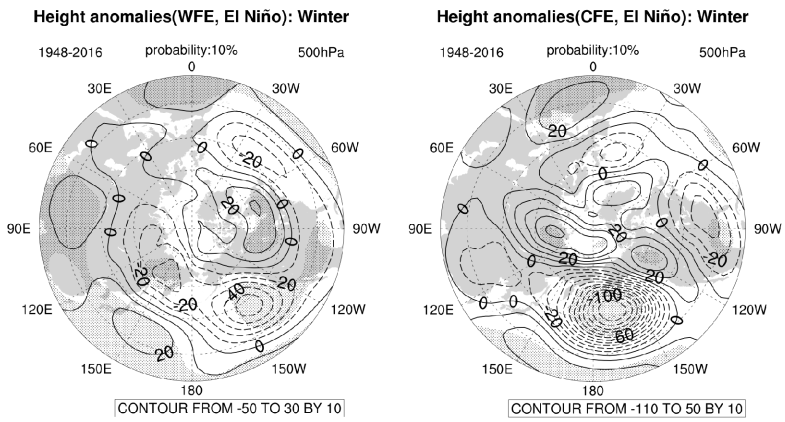

Figure 1 Height anomalies (contours, m) at 500 hPa (≥ 20°N) in DJF during El Niño (typical and atypical events). Statistic significant (90%) regions are indicated by hatches.

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Pseudo-global warming experiments on the intensity of Typhoons Haiyan (2013) and Melor (2009)

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Introduction

In this study, two kinds of ensemble pseudo-global warming experiments are conducted using a high-resolution typhoon model to compare the future changes and their uncertainties of typhoon intensity and between Super Typhoons Haiyan (2013) and Melor (2009) due to the differences of global warming scenarios (SRESs) and general circulation models (GCMs).

Results and discussion

The pseudo-global warming experiments for Haiyan, which was developed over the tropical ocean, show that there is a small future change of typhoon intensities in both SRESs and GCMs. The averaged future changes from present climate (897.1 hPa) are +3.7 hPa for SRESs and +7.9 hPa for GCMs, indicating that a well mature typhoon under the future climate tends to slightly weaken its intensity. On the other hand, the standard deviations of the minimum central pressures among SRESs and GCMs are 5.89 hPa and 9.47 hPa at 5610 min, respectively. The uncertainty of future changes among GCMs is about 1.6 times larger than that among SRESs. The pseudo-global warming experiments for Melor, which moved from the tropical ocean to the mid-latitude ocean. The future changes from the present climate (907.7 hPa) are -5.4 hPa for SRESs and -20.1 hPa for GCMs, implying that future typhoons in both SRESs and GCMs are intensified in the subtropical ocean. There is a tendency that the typhoon intensities among GCMs are especially strengthened much more than SRESs. Moreover, the standard deviations of future changes of Melor is also larger than that of Haiyan, suggesting that the uncertainty of typhoon intensity change is larger in the subtropical ocean than in the tropical ocean. As shown in Fig. 1(a) and (b), the global warming differences of 300 – 850 hPa vertical wind shear of Haiyan and Melor. The upper-level westerly jet dominates in the mid-latitude ocean, and the position and intensity could be changed by the global warming, resulting in the increase of the uncertainties of future changes of typhoon intensity. These results suggest that the expected storm surge disasters associated with future typhoons could be severer in the future climate.

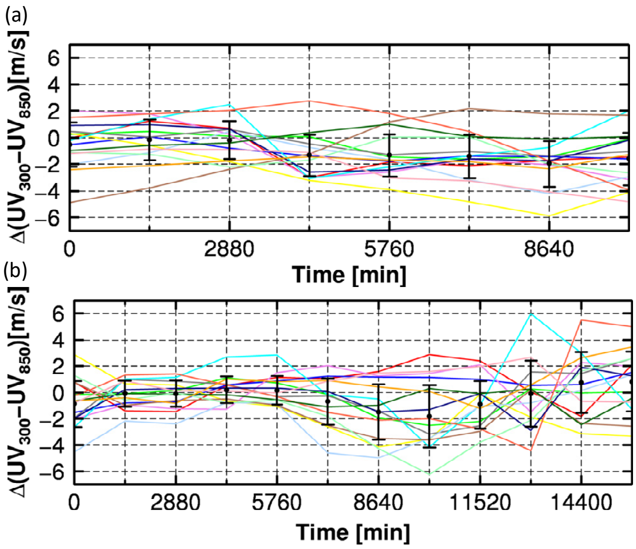

Fig.1 Time series of ten years averaged monthly mean differences of 300-850hPa vertical wind shear of (a) Haiyan and (b) Melor.

Multiscale analysis on the future change of heavy rainfall in Baiu season

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Introduction

Heavy rainfall caused by Baiu front is localized event and its scale is about meso-β (20~200km). On the other hand, Baiu front is formed and affected by meso-α (200~2000km) ~ macro scale (2000km~) field such as inflow of water vapor flux, Pacific High and so on. It is very important to estimate the future change of Baiu heavy rainfall with multiscale analysis relating each scale's event.

We use mainly two climate models' outputs. High-resolution regional climate model, NHRCM05 which has 5km spatial resolution, can represent the heavy rainfall events as an output of precipitation but it has only a few ensemble members. Another is d4PDF20, which stands for 'database for Policy Decision making for Future climate change' and has 20km spatial resolution. It cannot represent the heavy rainfall and the scale that 20km resolution model can represent is more than meso-β such as atmospheric circulation or invasion of water vapor. However, it has a huge ensemble members, present climate has 50 members and future has 90 members both for 60years, therefore we can statistically estimate the future change for more than meso-β scale. In our research, we try to statistically estimate the future change of heavy rainfall events by relating the heavy rainfall (meso-β) with inflow of water vapor into the land (meso-α) and atmosphere (macro) as shown on the Figure 1.

Outline

First, we directly estimate the future change of heavy rainfall events by visual check of precipitation output of RCM05 and picked up some atmospheric characteristics causing heavy rainfall by relating the heavy rainfall events we picked up from RCM05 at the first step to atmosphere. Then, we estimated the future change of these atmospheric patterns by classifying d4PDF20 using a clustering method called as SOM map (Nakakita et al, 2017). As a result, the frequency of heavy rainfall events will increase for the beginning of July and August in future climate. Moreover we succeeded to determine a specific atmospheric pattern which often cause heavy rainfall events and show that its occurrence frequency will significantly increase in future climate.

As future plans, we will try to statistically estimate the future change of heavy rainfall by linking the meso-β with macro scale taking account of inflow of water vapor into the land from the meso-β~α scale.

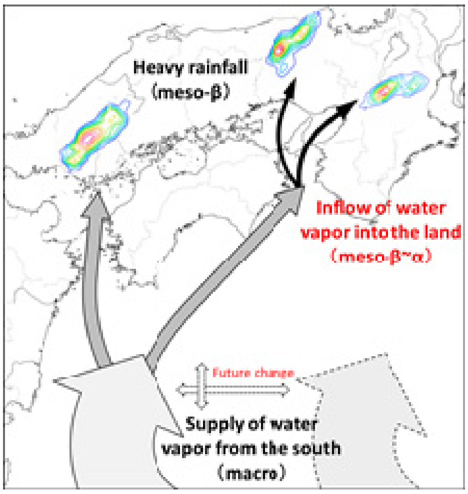

Figure 1 Water vapor path and heavy rainfall

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An Attempt on Analysing the Changes of Small-scale Torrential Rainfall under Global Warming Using Very-fine RCM

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Research Objectives and Data

In recent years, small-scale torrential rainfall, called 'Guerrilla-heavy rainfall (GHR)', triggered some flash flood disasters in small rivers in urban area in Japan. GHR is caused by single cumulonimbus cloud which generates abruptly and develops rapidly in summertime. It is believed to be difficult to reproduce GHR in climate models, since the scale of the phenomenon is very small; its spatial scale is a few km and its lifetime is about one hour. However, it is necessary to investigate the future tendency of GHR risks, in order to prevent possible flash flood disasters in the warming future.

This study aims to estimate the future changes of occurrence frequency of GHR events in Kinki Region, Japan in August, by analysing simulation outputs of the 5-km-grid non-hydrostatic regional climate model (NHRCM05; hereafter RCM5). RCM5 is nested within a 20-km-grid AGCM. The future projection of RCM5 has four ensembles, which adopt different SST as boundary conditions.

Methodology and Results

The days with synoptic-scale disturbances, such as typhoons and fronts, were excluded from the precipitation data of the RCM5 simulations. Then, we used visual judgement to extract possible GHR events from the precipitation images. Here, we referred to the relatively rough 5-km-mesh rainfall distribution of GHR, obtained by smoothing radar observation data of 250-m-mesh in August 2012. We applied this method to RCM5 datasets, including one present and four future climate simulations.

After applying T-test, the result shows that the number of days having GHR events significantly increases in August in the future projections. Also, the increasing tendency is statistically significant at the end of August, but not at the beginning. These results indicate that the durations of GHR risks in summertime may be longer in the future. This increasing tendency may be related to the intensified vapour invasion, although it should be necessary to explore the specific mechanism.

As for the future work, we would like to extract and track rain cells objectively. Here, we will use the output of an even finer 2-km-grid NHRCM02 (RCM2). More precise analyses of GHR can be possible with this RCM2 output, as the model can reproduce high precipitation intensity more realistically.

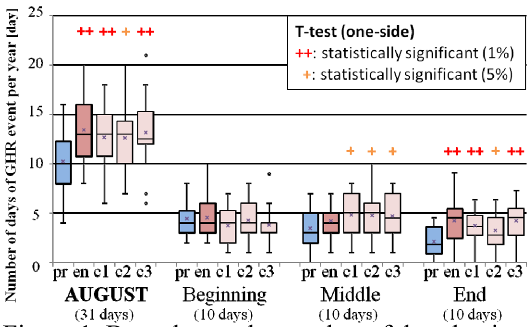

Figure 1 Box-plot on the number of days having Guerrilla-heavy rainfall events in August

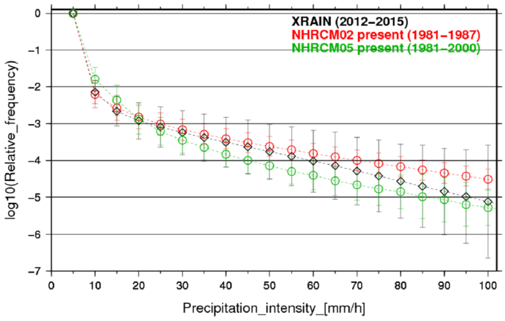

Figure 2 Frequency distribution of precipitation intensity: radar observation, RCM2 and RCM5

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Improvement of the heavy orographic rainfall retrievals in the GSMaP algorithm for microwave radiometers

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An orographic/nonorographic rainfall classification scheme has been introduced for operational algorithm of the Global Satellite Mapping of Precipitation (GSMaP) for passive microwave radiometers. However, problems of overestimations and false alarms of heavy orographic rainfall remain unresolved. This is because the current scheme selected lower constant thresholds of orographic rainfall conditions for global application, and used values of orographically forced upward motion (w) derived from near-surface atmospheric data.

This study improves the conceptual model of warm-rain process for considering strength of upstream flow of the low-level troposphere. Under a weak upstream current, rain reaches the foothills of the windward mountain slope due to sufficient time for condensation and precipitation enhancement by the topography. Conversely, under a strong upstream current, precipitation enhancement occurs nearer the mountain peak. This is because the upstream current flows so quickly that there is insufficient time for enhancement of precipitation over the foothills of the windward mountain slope. Implementing a variable threshold for w that depends on the mean horizontal low-level wind, the area of orographic enhancement of rain was detected reasonably well in cases of both strong and weak winds. To improve the accuracy of estimates of orographic rainfall, an adjustment to the rain estimation was introduced using a lower-frequency channel. The biases of the rainfall estimate for the adjusted scheme from the Tropical Rainfall Measuring Mission Precipitation Radar were improved for the cases and Asian region of heavy orographic rainfall over land.

Study on the extreme weather mechanism of urban area by combining a doppler lidar and high-resolution numerical model

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The small-scale convergence of humidity in the boundary layer is considered as one of the most important factor to determine the generation of such a disastrous rainstorm. The wind condition near the surface of the ground is affected by the ground condition so we cannot get the detailed information by direct observation. And it is very difficult to capture the urban wind condition in complex surface.

In this study, to get the wind condition of the lower atmosphere, I have started to successfully observe by using coherent doppler lidar (CDL) from May 26, 2015. CDL can observe air convergence of first stage because observing object is not raindrop but aerosol. I got the presence of wind strength in a small scale because the data of CDL is a 100m resolution.

Using model is WRF (Weather Research and Forecasting Model) which is non-hydrostatic weather forecast model. In the model, I analyzed some events which had heavy rainfall more than 5mm/10min in the urban area. I narrowed the calculation domain to 1km and 200m. Using initial data are that terrain data is 10m grid DSM (Digital Surface Model) of the geospatial information authority of Japan, the ground surface data is 100m of ministry of the environment and sea surface temperature of Tokyo bay is 1km of NASA. And I improved the results by using data assimilation which is 3dvar(A Three-Dimensional Vibrational Data Assimilation).

Characteristics of Viscoelastic Dampers against Long-Duration Wind Loadings

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Response of structures to dynamic loadings depends on several factors – mass, stiffness and damping of structures, and frequency and duration of the dynamic loading. Generally for wind loading, which is characterized as low-frequency and long-duration loading, the geometry of structure plays vital role on how the wind acts as a force. This motivates engineers to streamline their design of structures to better withstand against extreme wind. However, wind-induced vibration of structures cannot be completely eliminated but it can be reduced or controlled.

Employing viscoelastic (VE) dampers (e.g. Figure 1(a)) is one effective method in controlling wind-induced vibration. Through shear deformation of the sandwiched VE laminations between steel plates, VE dampers dissipate kinetic energy and convert it into heat – increasing the damper temperature (Figure 1(b)) and softening the VE material. In spite of the increase in temperature, VE dampers are stable and effective in dissipating wind loadings because of their ability to disperse the generated heat to the surrounding air. Incorporating heat generation and transfer, Kasai et al. (2006) proposed analytical models of VE dampers subjected to long-duration sinusoidal loadings. In 2015, Sato et al. proposed a method of representing long-duration random wind loading into its equivalent sinusoidal loading. Results from these analyses agree well with the tests. Currently, technique of simplifying these models is carried out and results are accurate with the test on VE dampers.

With the use of VE dampers, performance of wind-sensitive structures is improved and increases their resiliency to long-duration wind loading.

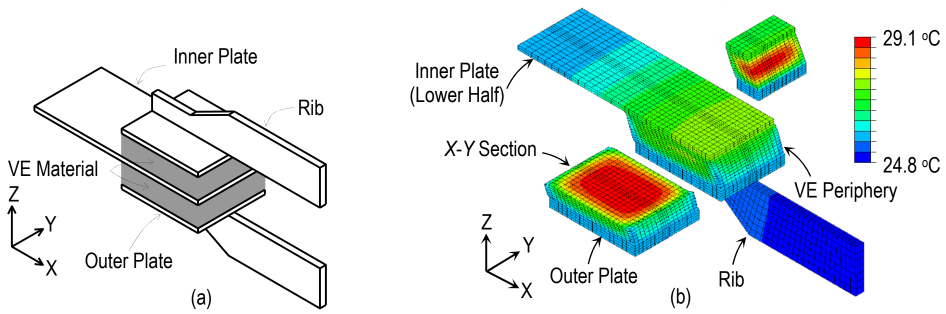

Figure 1 (a) Example of Viscoelastic Damper, and (b) Damper Temperature after 3,000-second Sinusoidal Loading from an Initial Temperature of 24°C (Kasai et al., 2006)

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Trial Manufacture of an Independent Measuring System for Aerodynamic Characteristics of Flying Debris

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Synopsis

Damages to houses in strong wind, e.g. typhoon or tornado, are caused by flying debris in most cases. The configuration of flying debris such as branches of tree, pebbles, pieces of broken structures and so on is categorized as bluff body. Therefore, prediction of flying motion of bluff body is important to evaluate the impact of flying debris for the wind resistant design of claddings and the reduction of damage to houses.

This study aims to develop a system to measure the motion of bluff body and to clarify aerodynamic characteristics of flying debris. Some units of micro-computer, three axis accelerometer, pressure sensors, A/D converter, Wi-Fi adaptor and small battery were assembled as a stand-alone probe to measure the motions and wind forces on a flying body (Figure 1). The measuring probe was built in a prism. The prism was dropped in a test region with no wind. The pressure and the acceleration on the prism were measured, while capturing the motion of the body by taking movies with video cameras and conducting image analysis.

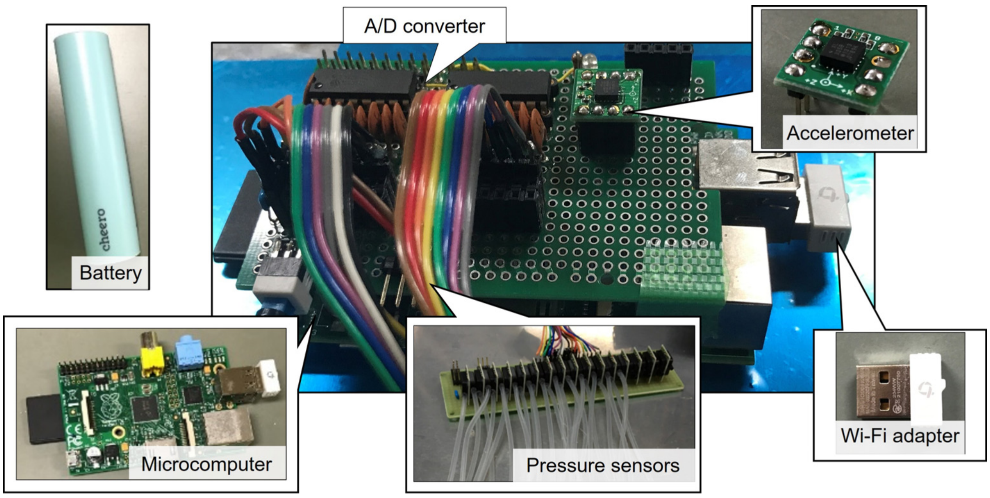

Figure 1 Components of stand-alone probe for measuring the motion and wind force on a flying debris

Ranking CMIP5 GCM Historical Runs for Model Ensemble Experiment over a Regional Scale: A Case Study over Indochina Region

Rattana Chhin[1] and Shigeo Yoden[1]

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The awareness of limitation of multiple model simulations through a model evaluation study is very important before applying them to describe and understand the climate change. To evaluate climate models, performance metrics are used to quantify model performance in reproducing climate characteristic or process (Baker and Taylor, 2016). This study attempts to propose a framework for evaluation of GCMs for multiple perspectives of impact assessment (e.g. agriculture, water supply, hydropower, flood control, and transportation). We also aim at developing a routine to select optimum ensemble members for climate change impact assessment over a specific region by applying for a case study over Indochina Region.

We perform evaluation on monthly precipitation of 43 General Circulation Models (GCMs) of the Couple Model Intercomparison Project Phase 5 (CMIP5) based on 36 performance metrics from the literature review. We use the dataset of the Asian Precipitation-Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) as a reference. The combined sets of diagnosis performance indices are computed by using three different criteria, namely summation of ranking (SR) criterion, Euclidean distance of cluster analysis (CA) criterion, and PCs of EOF analysis (PC) criterion. In addition to the standard case of equal weight on each metric, a specific set of weights are subjectively applied on the performance metrics to evaluate the models for the specific impact assessment perspectives. These indices are then used to select the optimum ensemble subsets for each criteria and weights by applying a culling method.

For a case study area of Indochina Region, the results of model evaluations and multi-model ensemble estimation are shown in two cases: non-weighted case applying equal weight on performance metrics and a weighted case applying weight of one on specific metrics and the remaining of zero to focus the evaluation for agricultural drought-monitoring application. The evaluation of 43 single GCMs based on the 36 performance metrics for equal weight case shows minor difference among the three criteria applied. The GCM rankings obtained from the three criteria show very high correlation, although large differences among the three criteria occurred on some models. The GCM ranking changes considerably for the weighted case. This introduces the effect of weighting on ensemble method in this study. Thus, the model ranking changes depending on criteria and weights applied. In the ensemble estimation of non-weighted case, nine-model ensemble is the optimum subset for SR criterion, and four-model ensemble for CA and PC criteria. In the ensemble estimation of weighted case, on the other hand, 11-model ensemble is the optimum subset for SR criterion, and five-model ensemble for CA and PC criteria. The optimum ensemble subsets from these criteria are shown to improve the reproduction of climate variations over any single model or the total model ensemble. The ensemble subsets from the CA and PC criteria are more improved than that of SR criteria. A simple and user-friendly matrix method of all model members for ensemble estimation is developed, and its good performance is demonstrated.

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Impact of Interactive Chemistry of Stratospheric Ozone on Southern Hemisphere Paleoclimate Simulation

Satoshi Noda[1], Kunihiko Kodera[2], Yukimasa Adachi[3], Makoto Deushi[4], Akio Kitoh[5], Ryo Mizuta[4], Shigenori Murakami[6], Kohei Yoshida[4], and Shigeo Yoden[1]

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2 Institute for Space-Earth Environmental Research, Nagoya University, Japan,
3 Japan Meteorological Agency, Japan, 4 Meteorological Research Institute, Japan,
5 The University of Tsukuba, Japan, 6 Meteorological college

A series of numerical simulations of the mid-Holocene (6 kyr B.P.) climate are performed by using an Earth System Model of the Meteorological Research Institute of the Japan Meteorological Agency to investigate the impact of stratospheric ozone distribution, which is modulated by the change in orbital elements of the Earth, on the surface climate. The results of interactive ozone chemistry calculations for the mid-Holocene and preindustrial periods are compared with those of the corresponding experiments in the fifth Coupled Model Intercomparison Project (CMIP5), in which the ozone distribution was prescribed to the 1850 Common Era level. The contribution of the interactive ozone chemistry in a quasi-equilibrium state reveals a significant anomaly of up to +1.7 K in the Antarctic region for the annual mean zonal mean surface air temperature. This impact on the surface climate is explained by a similar mechanism to the cooling influence of the Antarctic ozone hole but opposite in sign: Weakening of the westerly jet associated with the Southern Annular Mode provides weakening of equatorward ocean surface current, sea ice retreat, and then warm sea surface temperature and surface air temperature. All the mid-Holocene runs by CMIP5 models with the prescribed ozone had cold bias in sea surface temperature when compared with geological proxy data, whereas the bias is reduced in our simulations by using interactive ozone chemistry. We recommend that climate models include interactive sea ice and ozone distribution that are consistent with paleosolar insolation.

References

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Ultrawideband Frequency Modulated Continuous Wave Radar and Ku-Band Synthetic Aperture Radar for Airborne Imaging and Snow Characterization

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Fernando Rodriguez and Carl Leuschen[2]

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Abstract
We present an ultrawideband frequency-modulated continuous-wave (FMCW) radar and synthetic aperture radar (SAR) for airborne measurements of snow over sea ice. The FMCW radar, developed at the Center for Remote Sensing of Ice Sheets (CReSIS), operates over a frequency range of 2-18 GHz, which is capable of 1.5-cm range resolution at an altitude of 500 meters. This system has been installed on a Twin Otter aircraft and flown in past missions near Barrow, AK to demonstrate snow thickness measurements over sea ice as shown in Fig. 1. In addition, due to the multi-look angle, multi-frequency, and multi-polarization capabilities of the system, research is taking place to extract the snow-water-equivalent (SWE) from this measured data. Using SWE, in conjunction with the snow thickness, the density can be determined. Thus, the snow can be fully characterized and used to reduce ice-thickness measurement uncertainty and further enhance future sea-level rise predictive models.

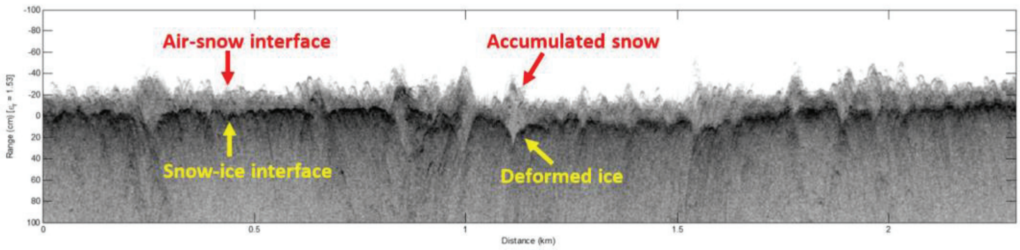

Figure 1 Snow radar echogram at site A with snow cover on sea ice (~20 cm)

A Ku-band synthetic aperture radar (SAR), with a center frequency of 16.5 GHz, is currently under development at the Advanced Radar Research Center (ARRC). While this radar is in its early prototyping stage, it can eventually be used for airborne imaging and provide year to year movement of ice sheets using multi-pass SAR interferometry processing techniques. Both universities are working together as consortium members to develop novel components, systems designs, and packaging techniques, shown in Fig. 2, to advance the state-of-the-art research in radar remote sensing.

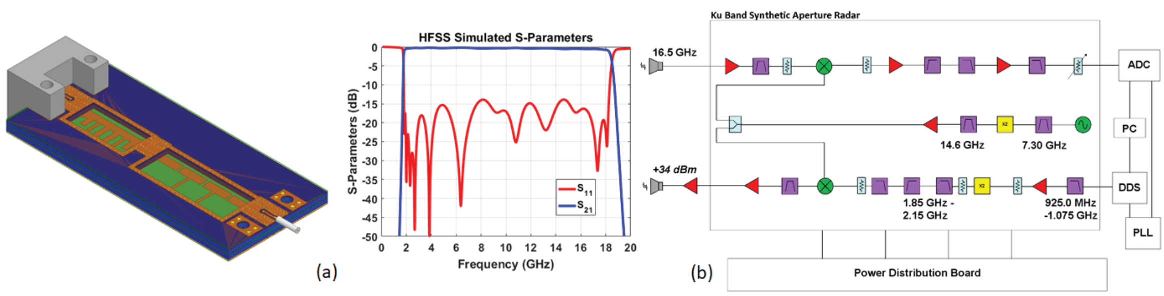

Figure 2 (a) Suspended integrated strip-line (SISL) bandpass filter (b) Ku-band SAR block diagram

Development of a Cloud Particle Sensor (CPS) for radiosonde sounding

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Clouds play key roles in the Earth's radiation budget and thus in the climate system. The microphysical properties such as number density, size, and shape affect the radiative properties of the atmosphere. “In-situ” measurements of clouds are still a technical challenge, and there are few sensors suitable for routine balloon-born observations.

A cloud particle sensor (CPS) has been developed to measure cloud-particle number density, size distribution, and the particle phase (i.e., liquid water or ice). This is a low-cost and light-weighted (~200 g, including batteries) particle counter based on a pollen sensor used in an in-house air purifier. The CPS consists of a light source with a linear-polarization laser diode and two detectors, one detecting the scattered light intensity directly and the other detecting the intensity through a polarization plate to estimate the degree of polarization by particles. The number of counts, intensity of the scattered light, and the degree of polarization correspond to the particle number density, size, and the phase, respectively. The detection limit for small particles was estimated as ～ 2 µm by using reference polystyrene micro-particles. The upper limit of the directly measured particle number concentration is ～ 2 cm^{-3} (2×10^3 L^{-1}), which is determined by the volume of the detection area of the instrument.

We have conducted several test flights at midlatitude sites and tropical sites since November 2012. The results showed that the CPS can detect both ice (cirrus) clouds in the upper troposphere and water clouds in the lower troposphere, and discriminate the phase of the particles by the degree of polarization. The data quality is much better at night, dusk, and dawn than during the daytime because strong sunlight affects the measurements of scattered light

Observation of Gust Front in Tokyo Urban Area by X-band Phased Array Weather Radar

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Introduction
Urban areas in Japan suffer from more and more disasters by severe weather such as heavy rain fall or tornadoes recently. Particularly around Tokyo in summer season, rapidly developing cumulonimbi produce heavy rain; occasionally causing floods.

To observe developing stage of cumulonimbi for analyzing and predicting severe weather, Japan Radio Co., ltd. have developed X-band phased array weather radar. With this radar, it takes only 30 seconds, in comparison with about 5 minutes with conventional parabolic weather radar, to finish volume scan of the cylindrical space with a radius of 80 km and height of 15 km. And more, this radar outputs radar parameters such as reflectivity with high spatial resolution of 50 m. The radar was installed in Chiba city and the experimental operation was started from the summer of 2015.

Observation
On August 4, 2016, several cumulonimbus clouds developed in the vicinity of Chiba Bay Area. The X-band phased array weather radar detected a gust front emerging from well-developed cumulonimbi (Fig. 1). In this presentation, we show the characteristics of the gust front and the three-dimensional structure of the cumulonimbi.

A bow echo that seems to be the gust front was detected at low altitude by the X-band phased array weather radar. The bow echo length was greater than 20 km, its echo top was about 600 m height and its radar reflectivity was very weak within 5 to 15 dBZ. The bow echo propagated eastward or inland at approximately 5.0 m/s for about 1 hour. In addition, the gust front was confirmed by a camera.

The three-dimensional structure of the cumulonimbi was examined by the X-band phased array weather radar. Before the occurrence of the gust front, high intensity precipitation core in the cumulonimbi fell rapidly at about 14 m/s. Therefore this rapid falling seems to generate a strong downdraft, which generated the gust front at low altitude.

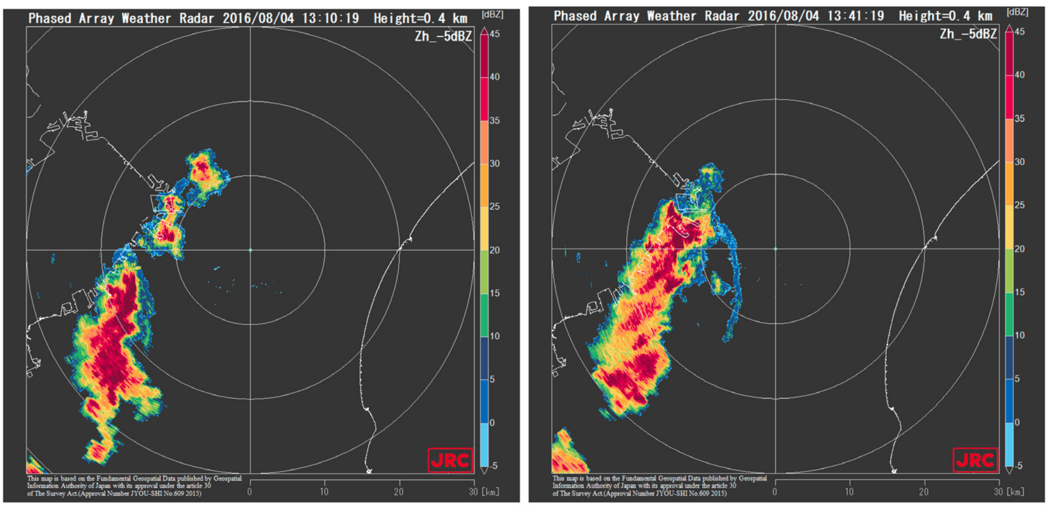

Figure 1 CAPPI at 0.4 km height which shows the bow like gust front emerging from well-developed cumulonimbi.

References
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Title: KU-OU Scientific Collaborations: High-Resolution Tornado Simulations for Tornado Debris and Radar Simulation Studies

Authors: David Bodine, Takashi Maruyama, Robert Palmer

Kyoto University (KU) and the University of Oklahoma (OU) have a long history of scientific collaboration in research and education. Many researchers and students have participated in extended stays at both institutions, helping to foster long-lasting, productive research collaborations. In 2012, Professor Maruyama hosted my six-month stay at Kyoto University to collaborate on tornado debris studies using high-resolution tornado simulations using Large-Eddy Simulation. This talk will focus on the productive collaboration on tornado debris studies, and introduce avenues available to students and scientists to participate in research exchanges.

The first component of our collaborative research focused on the impact of debris loading on tornado dynamics. While past studies had shown that debris loading impacts tornado dynamics, our approach focused on varying surface debris fluxes over a realistic range to explore the extent to which tornado dynamics are impacted over a range of surface types. Next, our studies focused on simulated radar signatures of tornado debris signatures and the impact of debris centrifuging on Doppler velocity at different wavelengths. From these studies, it was discovered that the dominant scatterer type and debris centrifuging bias strongly depended on radar wavelength. Finally, a polarimetric radar simulator was created to study tornado debris signatures using data from the Large-Eddy Simulation model, aerodynamic measurements from the KU wind tunnel, and radar cross sections from laboratory and simulation measurements at OU. The talk will conclude by presenting future collaborative activities, including continued exploration of tornado debris signatures and new scientific studies of tornado dynamics.

Authors: P.E. Kirstetter, Y. Hong, R. Kolar, J.J. Gourley, H. Moreno, J. Basara, H. Vergara, L. Alvarez, R. Clark, L. Labriola

The University of Oklahoma is setting up a graduate program in Hydrology and Water Security that meets the growing need of humanity to address complex challenges, such as flood risk and water scarcity in a changing climate. Hydrology is rapidly changing, and emerging concepts include new techniques for monitoring hydrologic stores and fluxes, platforms that enable global-scale, hyper-resolution modeling, and an increased focus on the complex interactions between biological, ecological, and anthropogenic systems and the water cycle. The need for hydrology-related skills spans multiple diverse economic sectors within the private and public domains. Practitioners already face complex scientific, managerial, and policy problems in the water arena, all of which require high quality training. To meet the rapidly-growing demand for expertise in interdisciplinary water issues, the hydrology program leverages OU's core strengths in the atmospheric, geographic, and engineering sciences, and expertise in hydrologic observations and modeling throughout the environmental column, to deliver transformative research and drive meaningful engagement at the nexus of water, weather, climate, energy, food, policy, and sustainability. In order to reach a global audience, part of the strategic plan is to offer a fully online MS in Hydrology and Water Security in conjunction with traditional ground-based MS and PhD programs.

Stratosphere-Troposphere Two-Way Dynamical Coupling in the Tropics

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In the last decade or two, stratosphere-troposphere dynamical coupling has attracted much attention, such as the annular mode variability in both hemispheres and two-way coupling during extreme events as stratospheric sudden warming (SSW). The standard paradigms for interpreting and explaining stratosphere-troposphere coupling have been based on balanced dynamics; the non-local aspects of potential vorticity inversion, planetary wave propagation, and wave-mean flow interaction in both troposphere and stratosphere.

Recently, we started a new international research activity on Stratospheric And Tropospheric Influences on Tropical Convective Systems (SATIO-TCS) under Stratosphere-troposphere Processes And their Role in Climate (SPARC) project of the World Climate Research Programme (http://www.sparc-climate.org/activities/emerging-activities/#c1880). It focuses on stratosphere-troposphere dynamical coupling in the tropics, where no comparable interpretive paradigm exists. Observational data analyses and global and cloud-resolving numerical-model studies all point to an important stratospheric influence on tropical convection and organized convective systems. Multi-scale interactions of these systems are likely to play a vital role in determining the tropical response to such variations and change in the stratosphere.

There are some observational evidences that stratospheric variations associated with SSW events, the equatorial quasi-biennial oscillation (QBO), or anthropogenic cooling trend in the lower stratosphere and around the tropopause, do influence tropospheric variability in the form of moist convection and its large-scale organization into meso-to-planetary-scale systems. The organized moist convective systems include cloud clusters, tropical cyclones, the Madden-Julian Oscillation (MJO), annually varying monsoon systems, and interannual time-scale El Nino-Southern Oscillations (ENSO). Some global general circulation models and regional cloud resolving models show similar features to these observed responses to the stratospheric variations, but such modeling studies are in a rather preliminary state.

In this talk, research progress on stratosphere-troposphere two-way dynamical coupling in the tropics is systematically reviewed for data analyses and theoretical and numerical model studies. Then, recent works of my group on the subject are summarized, including the following papers:

Yoden, S. et al., 2014: A minimal model of QBO-like oscillation in a stratosphere-troposphere coupled system under a radiative-moist convective quasi-equilibrium state. *SOLA*, **10**, 112–116.

Nishimoto, E. et al., 2016: Vertical momentum transports associated with moist convection and gravity waves in a minimal model of QBO-like oscillation. *J. Atmos. Sci.*, **73**, 2935–2957.

Bui, H.-H. et al., 2017: Downward influence of QBO-like oscillation on moist convection in a two-dimensional minimal model framework. *J. Atmos. Sci.*, **74**, in press.

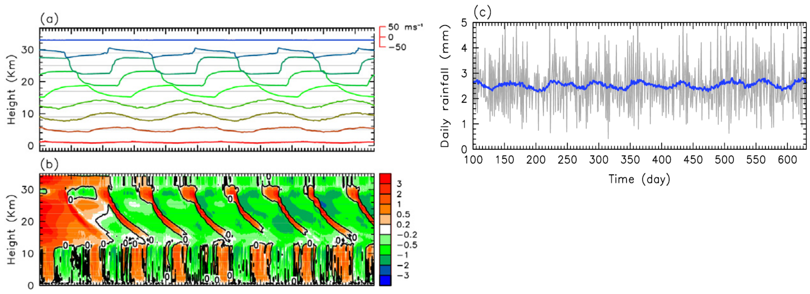

Figure 1 A QBO-like oscillation, (a) *U*, (b) *T'*, and (c) precipitation variation (Yoden et al. 2014)

"Big Data Assimilation" for 30-second-update 100-m-mesh Numerical Weather Prediction

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Abstract

A typical lifetime of a single cumulonimbus is within an hour, and radar observations often show rapid changes in only a 5-minute period. For precise prediction of such rapidly-changing local severe storms, we have developed what we call a "Big Data Assimilation" (BDA) system that performs 30-second-update data assimilation cycles at 100-m grid spacing. The concept shares that of NOAA's Warn-on-Forecast (WoF), in which rapidly-updated high-resolution NWP will play a central role in issuing severe-storm warnings even only minutes in advance. The 100-m resolution and 30-second update frequency are a leap above typical recent research settings, and it was possible by the fortunate combination of Japan's most advanced supercomputing and sensing technologies: the 10-petaflops K computer and the Phased Array Weather Radar (PAWR). The X-band PAWR is capable of a dense three-dimensional volume scan at 100-m range resolution with 100 elevation angles and 300 azimuth angles, up to 60-km range within 30 seconds. The PAWR data show temporally-smooth evolution of convective rainstorms. This gives us a hope that we may assume the Gaussian error distribution in 30-second forecasts before strong nonlinear dynamics distort the error distribution for rapidly-changing convective storms. With this in mind, we apply the Local Ensemble Transform Kalman Filter (LETKF) that considers flow-dependent error covariance explicitly under the Gaussian-error assumption. The flow-dependence would be particularly important in rapidly-changing convective weather. Using a 100-member ensemble at 100-m resolution, we have tested the Big Data Assimilation system in real-world cases of sudden local rainstorms, and obtained promising results. To investigate the Gaussianity of the PDF, we performed a 30-second-update LETKF with 1000 ensemble members at reduced 1-km resolution, and found a strong non-Gaussian PDF corresponding to convective activities. In this presentation, we will present the most up-to-date progress of our Big Data Assimilation research.

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Miyoshi, T., G.-Y. Lien, and co-authors, 2016: "Big Data Assimilation" toward Post-peta-scale Severe Weather Prediction: An Overview and Progress. *Proc. of the IEEE*, 104, 2155-2179. doi:10.1109/JPROC.2016.2602560

Miyoshi, T., M. Kunii, J. Ruiz, G.-Y. Lien, S. Satoh, T. Ushio, K. Bessho, H. Seko, H. Tomita, and Y. Ishikawa, 2016: "Big Data Assimilation" Revolutionizing Severe Weather Prediction. *Bull. Amer. Meteor. Soc.*, 97, 1347-1354. doi:10.1175/BAMS-D-15-00144.1

Title: Primary Atmospheric Drivers of Pluvial Years in the United States Great Plains

Authors: Paul X. Flanagan, Jeffrey B. Basara, Jason C. Furtado, Xiangming Xiao

Precipitation variability has been increasing in recent decades across the Great Plains (GP) of the United States (US). While drought and its associated drivers have been studied in the GP region, periods of excessive precipitation (pluvial) at seasonal to interannual scales have received less attention. This study narrows this knowledge gap with the overall goal of understanding GP precipitation variability during pluvial periods. Through composites of relevant atmospheric variables from the ERA 20th Century (ERA-20C) reanalysis, we highlight key differences between Southern Great Plains (SGP) and Northern Great Plains (NGP) pluvial periods along with the precursor patterns to these pluvial events. The SGP pattern shows an area of negative height anomalies over the southwestern United States along with increased wave activity and a shift in the typical North Pacific waveguide. The NGP pattern is similar, with an area of negative height anomalies over the northwestern US, however no increased wave activity or shift in the North Pacific waveguide is seen. Lastly, analysis of these patterns with sea surface temperature anomalies over the Pacific details a possible connection between the occurrence of these patterns and the Pacific Ocean variability. Together, these results present a possible pathway to predicting the occurrence of pluvial years over the GP. With a better understanding of the causes of precipitation variability over the GP, the threat of water scarcity can be better managed for the public and agricultural sectors.

Forecasting and Communicating Water-related Disasters in Africa

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Abstract

Accurate forecasting and communication of extreme flooding events in developing regions could save untold lives and property. Since 2009, the CREST (Coupled Routing and Excess Storage) hydrologic model has been implemented in dozens of countries as a user-friendly, flexible, and highly extensible platform for monitoring water resources, floods, droughts, and landslides. In collaboration with NASA SERVIR, we will present the updated EF5 (Ensemble Framework for Flash Flood Forecasting) hydrologic ensemble modeling framework with new model physics and better forecasts of streamflow, soil moisture, and other hydrologic states to RCMRD (the Regional Centre for Mapping of Resources and Development) and SERVIR global hub network.

The focus of this project is to implement an ensemble hydrologic prediction system, which uses weather and climate forecasts in a single continuum, to communicate forecasts on scales ranging from sub-daily to seasonal easy to comprehend formats designed for better decision making about water-related disasters. Over the years, the CREST/EF5 model has proven to help researchers and officials in emerging regions be excited about and confident in their ability to independently monitor, forecast, and understand water and water-related disasters. Model users are introduced to EF5 by participating in a series of training workshops and capacity building activities held in throughout the world, including in USA, Africa, Mesoamerica, and South Asia.

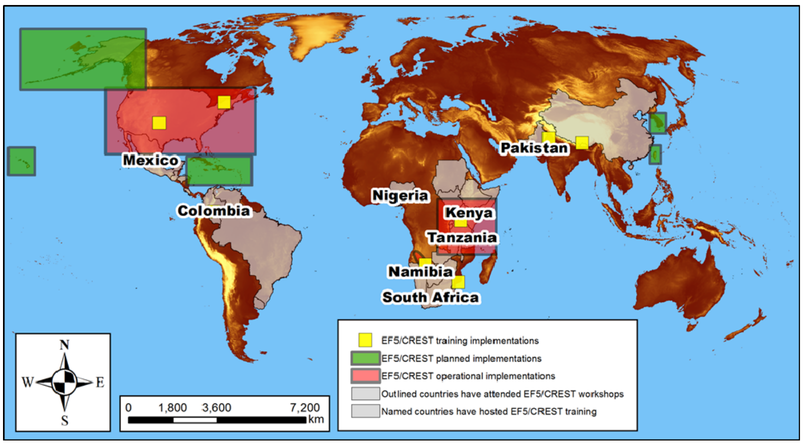

Figure 1 Map of all past, current, and future EF5 implementations and capacity building activities (Clark et al. 2017)

References

Clark, Robert A., Z.L. Flamig, H. Vergara, Y. Hong, J.J. Gourley, D.J. Mandl, S. Frye, M. Handy, and M. Patterson (2017) Hydrological Modeling and Capacity Building in the Republic of Namibia. *Bull. Ameri. Meteor. Soc.*

Integration of Local Information and Flood Modeling for Real-Time Flood Hazard Mapping

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Background

Hazard mapping is an essential step for any counter measures for flood disaster risk reductions. It has various objectives including raising awareness of residents, finding effective evacuation routes and estimating potential damages through flood risk mapping. Depending on the objectives and data availability, there are also many possible approaches for hazard mapping including simulation basis, community basis or remote sensing basis. In addition to traditional paper-based hazard maps, recent advancement in Information and Communication Technology (ICT) promotes more interactive hazard mapping by integrating local information and flood modeling based on data assimilation techniques.

Many studies in data assimilation in hydrology have focused on the integration of satellite remote sensing and in-situ monitoring data into hydrologic or land surface models. For flood predictions also, recent studies have demonstrated to assimilate remotely sensed inundation information with flood inundation models. In actual flood disaster situations, citizen collected information including local reports by residents and rescue teams and more recently social media information may also contain valuable information. The main interest of this study is how to effectively use such local information for real-time flood hazard mapping.

Method

Here we propose a new data assimilation technique based on pre-conducted ensemble inundation simulations and update inundation depth distributions sequentially when local data becomes available. The propose method is composed by the following two-steps. The first step is based on weighting average of preliminary ensemble simulations, whose weights are updated by Bayesian approach. The second step is based on an optimal interpolation, where the covariance matrix is calculated from the ensemble simulations.

Results

The proposed method was applied to case studies including an actual flood event occurred. It considers two situations with more idealized one by assuming continuous flood inundation depth information is available at multiple locations. The other one, which is more realistic case during such a severe flood disaster, assumes uncertain and non-continuous information is available to be assimilated. The results show that, in the first idealized situation, the large scale inundation during the flooding was estimated reasonably with RMSE < 0.4 m in average. For the second more realistic situation, the error becomes larger (RMSE ~ 0.5 m) and the impact of the optimal interpolation becomes comparatively less effective. Nevertheless, the applications of the proposed data assimilation method demonstrated a high potential of this method for assimilating citizen collected information for real-time flood hazard mapping in the future.

Wind Velocity Estimation Based on Timber Structural Damage for Development of Japanese Enhanced Fujita Scale

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Introduction

This study aims to develop the method to select instantaneous wind velocity which is estimated to generate structural damage in timber buildings subjected to the effect of tornadoes. The wind velocities were organized on the basis of the degree of damage (DOD) to timber buildings as shown in Table 1. For the rating of tornado intensity, proposed method in this study has been incorporated into the new guideline for the Japanese Enhanced Fujita Scale (JMA, 2015).

Outline of Wind Velocity Estimation

Damaged portions under the effect of tornadoes are divided into main wind-force resisting system (MWFRS) such as bearing walls and components and cladding (C&C) such as clay tile roofing. For the estimation based on damage to MWFRS, shear strength model of upper structure was developed to evaluate the strength characteristics. Since prospective strength is dependent on structural-related regulation in the building code, the variation of the strength corresponds to the three stages of code revision. Next for damage to C&C, using past data of component testing, the difference of construction method of connection was taken into consideration for the variation of the strength. Estimated instantaneous wind velocity can be explained as the equivalent velocity in which corresponding damage state generated by the effect of tornadoes would be observed.

The above wind velocities were estimated using limited information and condition. Therefore, several suggested ways to select appropriate velocity were also provided for the rational rating of tornado intensity.

Table 1 DOD and corresponding wind speed for timber houses and stores

DOD	Damage		Wind speed (m/s)		
			Rep.	LB	UB
1	Visible damage (breakage of glass)		30	25	35
2	Minor loss/displacement of roofing materials	Clay tile roofing	35	25	50
		Sheet-metal roofing	40	30	55
3	Major loss of roofing materials	Clay tile roofing	45	30	60
		Sheet-metal roofing	50	40	65
4	Destruction/detachment of eaves or sheathing roof boards		50	40	65
5	Damage (deformation, cracking, etc.) to walls from deformation of main frames		55	40	65
6	Loss of metal wall cladding		60	45	70
7	Destruction/detachment of roof frames/components		65	50	75
8	Major destruction/collapse of main structures and frames		75	55	85

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Japan Meteorological Agency (2015) *Guidelines for the Japanese Enhanced Fujita Scale*, (in Japanese)

Investigation of the Effects of Meteorological Factors on Heatstroke Risk for Tokyo in the 2050s based on Mesoscale Meteorological Simulations

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Introduction

Urban areas are subject to increasing temperatures because of urbanization and global warming. The Intergovernmental Panel on Climate Change has concluded that warming of 0.3 to 4.8°C by the end of the 21st century is probable. Global warming is caused by rising concentrations of greenhouse gases, whereas the urban heat island (UHI) effect is caused by changes in land use from natural environments to built environments with intensive energy consumption, which result in anthropogenic heat release. Urbanization enhances the UHI effect, which further exacerbates increases caused by global warming.

In July 2004, the Ministry of Land, Infrastructure and Transport of Japan proposed "Guidelines for Architectural Design to Mitigate the Urban Heat Island Effect" to provide guidance for building design regarding the following topics: ventilation, shading, ground level covering, building cladding materials and exhaust heat from building facilities. The Comprehensive Assessment System for Built Environment Efficiency for Heat Island relaxation (CASBEE-HI) was developed in 2005, and revised in 2006, 2010 and 2017, to quantitatively assess the overall environmental performance of buildings. CASBEE-HI is a tool for evaluating the effects of both UHI mitigation measures and improvement of thermal environments in pedestrian spaces.

During the summer of 2010, Japan experienced a severe heat wave, and the number of heatstroke patients transported by ambulances increased drastically from those of previous years in many major cities in Japan. Since 2010, the number of heatstroke patients each summer has remained elevated. Recently, we proposed a method to estimate outdoor heatstroke risk based on the concept of disaster risk modeling. Heatstroke risk was quantified by assessing hazard, vulnerability, and exposure (Kasai, 2017). The spatial distribution of the daily maximum wet-bulb globe temperature (WBGT) obtained from mesoscale meteorological simulations by the Weather Research and Forecasting (WRF) model was used as the index of hazard. The relationship between daily maximum WBGT and daily incidence rate was approximated by analyzing emergency transport data. This relationship was selected as the vulnerability index. The daytime population density per km^2 was used to determine the exposure index. Finally, the total number of heatstroke patients transported by ambulance was estimated as a risk by multiplying hazard, vulnerability and exposure.

In this study, the impact of climate change on outdoor heatstroke risk in Tokyo was quantitatively evaluated by applying the proposed method for current (2000s) and near-future (2050s) climatic conditions. Then, the contributions of meteorological factors to heatstroke risk were investigated to identify effective countermeasures.

References

Kasai M et al. (2017) Heatstroke Risk Predictions for Current and Near-Future Summers in Sendai, Japan, Based on Mesoscale WRF Simulations, *Sustainability*, 9(8), pp1467.

Equatorial MU radar, plan and progress

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Research Institute for Sustainable Humanosphere (RISH), Kyoto University has been studying the atmosphere and ionosphere by using radars. The first big facility was the MU (Middle and Upper atmosphere) radar installed in Shiga, Japan in 1984. This is one of the most powerful and multi-functional radar, and is successful of revealing importance of atmospheric waves for the dynamical vertical coupling processes. The next big radar was the Equatorial Atmosphere Radar (EAR) installed at Kototabang, West Sumatra, Indonesia in 2001. The EAR was operated under close collaboration with LAPAN (Indonesia National Institute for Aeronautics and Space), and conducted the long-term continuous observations of the equatorial atmosphere/ionosphere. The EAR, however, had a limited sensitivity to the MU radar as the total output power is just 1/10 to the MU radar. As new facility, we now plan to establish "Equatorial MU (EMU) Radar" just next to the EAR site in Indonesia. The EMU will have an active phased array antenna with the 163 m diameter and 1055 crosselement Yagis. Total output power of the EMU will be more than 500 kW. The EMU is the "MU radar class" facility, and can detect turbulent echoes from the mesosphere (60-80 km). In the ionosphere, incoherent-scatter observations of plasma density, drift, and temperature would be possible. Multi-channel receivers will realize radar-imaging observations. The EMU is one of the key element in the project "Study of coupling processes in the solar-terrestrial system" [Tsuda et al., 2016] that is one of the important project in the Master Plan 2014 of the Science Council of Japan (SCJ). Last year we applied the project again to SCJ Masterplan 2017, and was awarded as an important project (total 28 projects were selected this time). In the presentation, we show the EMU system and our efforts toward the new facility.

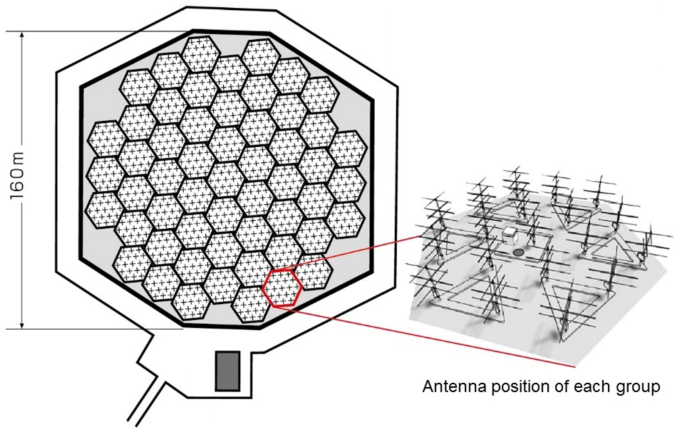

Figure 1 Equatorial MU radar

References

Tsuda, T., M. Yamamoto, H. Hashiguchi, K. Shiokawa, Y. Ogawa, S. Nozawa, H. Miyaoka, and A. Yoshikawa, A proposal on the study of solar-terrestrial coupling processes with atmospheric radars and ground-based observation network, *Radio Sci.*, 51, 1587-1599, doi:10.1002/2016RS006035, 2016.

Early Successes for Atmospheric Sensing Using Rotary-Wing UAS: The Sky is the Limit

Brian Greene[1,2,3], Phillip Chilson[1,2,3], Jorge Salazar-Cerreno[2,3,4], Simon Duthoit[2,3,4], Bill Doyle[2,3,4], Brent Wolf[2,3,5], Antonio Segales[2,3,4], Chris Fiebrich[6], Sean Waugh[7], and Sherman Fredrickson[7], Steve Oncley[8], Laura Tudor[8], and Steve Semmer[8]

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The capabilities of small unmanned aircraft systems (sUAS) to make atmospheric observations is rapidly being realized as a means to collect previously unobtainable observations in the lowest part of Earth's atmosphere. However, in order for these systems to provide meaningful kinematic and thermodynamic data, it is imperative to establish an understanding of the strengths and limitations of the sensors and retrieval algorithms implemented, as well as how they perform under various configurations and flight conditions. This initial objective is comprised of two experimental stages, the first of which is calibration of thermodynamic sensors against reference measurements from the Oklahoma Mesonet and the National Center for Atmospheric Research in order to understand response characteristics in quasi-ideal environments. Furthermore, efforts have been made to calculate horizontal wind fields using Euler angles derived from the rotary-wing's autopilot. The second stage is validation of these sensor performances once mounted onto a rotary-wing sUAS by comparing measurements with instrumented towers, radiosondes, and other sUAS. It appears that these measurements are robust provided that instrument packages are properly mounted in locations that provide adequate air flow and proper solar shielding. Moreover, experiments to locate this optimized location have been performed, and involved systematically displacing the sensors and wind probe underneath the rotor wash in an isolated chamber using a linear actuator.

Once a platform's atmospheric sensing capabilities are optimized, its utility has been proven in applications from the diurnal boundary layer transition and turbulence to providing forecasters with quasi-real time profiles in convective environments deemed by the Storm Prediction Center (SPC) to be of highest risk for severe thunderstorms and tornadoes. After addressing the development of platforms by the Center for Autonomous Sensing and Sampling (CASS) at the University of Oklahoma (OU), results from the recent field campaigns, Collaboration Leading Operational UAS Development for Meteorology and Atmospheric Physics (CLOUD-MAP) and Environmental Profiling and Initiation of Convection (EPIC), will be discussed. These campaigns demonstrated the potential for sUAS to improve forecasting abilities and our understanding of the atmosphere, in addition to gaining national media attention. This is only just the beginning of tapping into the serviceability of rotary-wing sUAS for atmospheric sciences, and this presentation will conclude with an outlook for future possibilities.

CLAMPS Observation Capabilities and WRF Model Analyses

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The Collaborative Lower Atmospheric Boundary Layer Profiling System (CLAMPS) was developed in collaboration between the University of Oklahoma and the National Severe Storm Laboratory. CLAMPS integrates a Doppler lidar, a microwave radiometer, an Atmospheric Emitted Radiance Interferometer (AERI), and a radiosonde system. During the 2015 Plains Elevated Convection At Night (PECAN) field campaign, several Great Plains nocturnal low-level jets (NLLJs) were observed with state-of-the-art integrated profiling systems including CLAMPS. Observations from three PECAN NLLJ missions are interrogated to describe and contrast the evolution of NLLJs.

Numerical simulations with an optimal configuration of the Weather Research and Forecasting (WRF) model are also used in this study to further investigate the role of mesoscale processes in the formation and evolution of the NLLJ cases observed during PECAN. Previous work identified the optimal horizontal grid spacing, vertical grid spacing, and planetary boundary layer scheme for reproducing Great Plains NLLJs with the WRF model. Comparisons between the observed and WRF simulated NLLJs allow for validation of the model configuration. Validated WRF model outputs then provide more detailed information about the observed NLLJ structure and evolution, as the increased spatial and temporal coverage of the numerical simulations permits a more thorough description of the events. Overviews of the three NLLJ cases are presented, and examples are shown of the robust analysis possible when using high resolution observations in tandem with an optimally configured WRF simulation.

In addition to datasets from PECAN, this work shows CLAMPS data from the 2017 Perdigão field campaign. This experiment took place over a double-hill in Portugal as part of the New European Wind Atlas project and aimed to collect a dataset describing flow over complex terrain which can be used to improve the ability of numerical models to represent these flows. Since this field campaign was so recent, analysis of these data is preliminary, but CLAMPS data is shown to showcase the flexibility and capability of such integrated profiling systems both in the field and for various scientific goals.

Authors: Casey Griffin, David Bodine, Robert Palmer

Presentation Title: High-temporal Resolution Observations of the 27 May 2015 Canadian, Texas, Tornado using the Atmospheric Imaging Radar

Presentation Abstract:

Phased-array radars (e.g., the MU Radar run by Kyoto University) have a long and successful history of profiling the middle and upper atmosphere. Only recently has the phased-array concept been utilized to sample weather in the lower troposphere for mobile severe weather research. The Atmospheric Imaging Radar (AIR) is a mobile, X-band radar that uses a variation of the phased-array concept called digital beamforming or imaging to collect simultaneous RHI scans while steering mechanically in azimuth, which allows it to document rapidly changing storm features that would otherwise have been unresolved by traditional, pencil-beam radars.

On 27 May 2015, the AIR collected high-temporal resolution radar observations of an EF-2 tornado near Canadian, Texas. During this deployment, 20º-by-80º sector volumes were collected every 5.5 s at ranges as close as 6 km. The AIR captured the late-mature and decaying stages of the tornado. Early in the deployment, the tornado was 1 km in diameter and exhibited maximum Doppler velocities near 65 m/s. This study documents the rapid vortex structure changes associated with the dissipation stages of the tornado. Axisymmetric analyses are used to interrogate changes in tangential flow and reflectivity associated with a decreasing tornado core diameter and the transition from a two-cell to a one-cell vortex flow. Additionally, a time-height investigation of Delta-V and a high-temporal resolution angular momentum budget will be presented. Finally, the temporal evolution of circulation over a range of areal extents will be studied to understand how the spatial distribution of vorticity changes in time.

An investigation of vortex signatures in strong, damaging tornadoes

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Over the past seven years, a number of high spatial and temporal resolution datasets have been collected by a rapid-scan, X-band, polarimetric Doppler radar (RaXPol) within close-range of strong tornadoes. In most of these cases, observations of the tornado vortex signature suggests a tendency for sampled velocity field to become increasingly divergent as the tornado collects, and subsequently sheds, debris, after which the vortex is often observed to oscillate between convergent and divergent. This work will focus on observations of five separate RaXPol cases: the 24 May 2011 El Reno, OK, tornado, the 19 May 2013 Shawnee, OK, tornado, the 9 May 2016 Sulphur, OK, tornado, and the 24 May 2016 Dodge City, KS, tornadoes.

This study will investigate the behavior of these tornadoes with respect to polarimetric variables such as co-polar correlation coefficient (ρ_{hv}) and differential reflectivity (Z_{DR}), tornado intensity, and to episodes of debris ejection as the tornado produces varying degrees of damage at the surface. In addition, potential links between lofted tornado debris and tornado dynamics will be introduced as we assess potential modulation of the tornado by debris, and examine how characteristics of the debris can lead to varied effects on the vortex. Future work will be discussed including plans to incorporate data assimilation techniques and high-resolution simulations of the tornado vortex into this study to be compared to RaXPol observations.

Improving vertical velocity retrievals from dual-Doppler observations of convection

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Accurate dual-Doppler analysis of the velocity field -- especially the vertical component of velocity -- is of longstanding interest in radar and mesoscale meteorology. In cases of convective weather, strong vertical motion is often associated with strong low-level horizontal convergence. Unfortunately, vital information about this convergence can be lost in cases of significant terrain blockage or ground clutter contamination or if the radars are elevated (e.g., on a ridgetop). In this presentation we explore a variational method of dual-Doppler analysis designed to improve the analysis of vertical motion in cases of missing low-level data. The analysis procedure incorporates radial wind data from two radars, a mass conservation constraint, smoothness constraints, and a prognostic vertical vorticity equation constraint. Key to the use of the latter equation is the estimation of the local tendency of vorticity. Tests were performed using CM1 numerically simulated data of a supercell storm, with a focus on how the vertical vorticity equation adds value to vertical velocity analyses when tendency term estimates are improved using either (i) advection correction procedures or (ii) rapid scan radar data.

Impact of assimilating PECAN IOP observations on the numerical predictions of bores and bore-induced convection

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Despite the steady progress in numerical weather prediction (NWP), forecasts of night-time precipitation exhibit one of the lowest skill scores across different parts of the world. To further advance our understanding and predictions of nocturnal convection, it is critical to explore the specific mechanisms responsible for its development and maintenance. Recent work has concluded that convectively-generated atmospheric bores in the Great Plains could play an important role in increasing the lifetime of nocturnal mesoscale convective systems (MCSs). Therefore, the main objective of this presentation is to evaluate the impact of specialized observations from the Plains Elevated Convection at Night (PECAN) field campaign on the forecast skill of bore-maintained convection. This objective is achieved by utilizing the wide array of observations collected during one of the PECAN missions that took place on 5-6 July 2015.

The first part of the results section summarizes the forecast performance with respect to the bore-induced convection. The findings evince that assimilating the Atmospheric Emitted Radiance Interferometer (AERI) data significantly increases the skill of the convective forecasts. Additional analysis attributes these forecast improvements to the ability of the AERI instrument to observe highly transient surges of moisture within the convective boundary layer. The second part of the results section discusses the representation of the bore and its environment. It is found that the assimilation of PECAN observations improves the theoretical bore predictions by either increasing the confidence about the correct flow regime or by reducing the bias in the ensemble mean bore strength. Nevertheless, preliminary results suggest that the PECAN observations have a small impact on the predicted location of the explicitly resolved bore. Overall, the assimilation of aircraft data results in the largest improvements insofar as the theoretical and explicit bore forecasts are concerned.

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Title: A Tale of Two Mesovortices: Analysis of a Simulated Severe MCS Observed During PECAN on 5-6 July 2015

Understanding and forecasting nocturnal thunderstorms and their hazards remain elusive goals. To this end, an expansive array of fixed and mobile observing systems were deployed in the summer of 2015 for the Plains Elevated Convection at Night (PECAN) field experiment to intercept and observe nighttime atmospheric phenomena. During the night of 5 July 2015, an array of eight mobile radars and numerous ground-based surface and upper-air profiling systems directly sampled a severe mesoscale convective system (MCS) as it moved through southeastern South Dakota. The MCS was responsible for several severe wind reports, including one over 80 mph, and produced an EF-0 tornado near Dolton, SD.

In this study, observations of these phenomena from mobile radiosonde vehicles, Doppler radars, and aircraft are assimilated into an ensemble analysis and forecasting system to analyze this event. All ensemble members simulated low-level mesovortices with one in particular generating two mesovortices within the MCS in conditions very similar to those observed by the PECAN platforms. Forecasts from this member were analyzed to examine the processes leading up to the development of the vortices. In all, a supercell-like mechanism appeared responsible, with vertical vorticity initially developing via tilting in baroclinic downdrafts and then undergoing intense stretching near the surface to form the low-level mesovortices.

The Assimilation of Radar and Surface Data to Improve the Skill of High-Resolution Ensemble Explicit Hail Forecasts

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Abstract

Hail causes over 1 billion dollars in damage annually in the United States, despite this explicit hail prediction using convection resolving models remains relatively understudied. In this study an optimal data assimilation (DA) configuration for explicit hail prediction is developed. An ensemble Kalman filter (EnKF) is used to assimilate surface and radar observations into ensembles run using either Milbrandt and Yau (2005) double- (MY2) and triple- (MY3), or the variable density rimed ice double-moment (Mansell et al. 2010; NSSL) microphysics scheme. The DA configuration developed in this study is used to improve the representation of the microphysical state of a simulated severe hail producing supercell thunderstorm on 19 May 2013. Surface hail forecasts launched from these ensembles are verified against surface based hail reports and radar derived hail products such as the maximum estimated size of hail (MESH) algorithm (Witt et al. 1998).

Preliminary results indicate skillful surface hail size forecasts cannot be produced until hail growth and decay is properly represented. The ensemble run using the NSSL scheme produces surface hail size forecasts with the most skill both in terms of the spatial extent and size of hail. The NSSL scheme has improved representation hail within the melting layer, and explicitly predicts the density of both hail and graupel, allowing the scheme to represent a spectrum of rimed ice particles. Forecasts produced by ensembles using the MY2 and MY3 schemes have less skill in predicting maximum hail size than the NSSL scheme. Both schemes poorly represent hail in the melting layer, causing the schemes to overestimate the size of hail within a hail core.

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Improved prediction of convectively generated bores by assimilating PECAN IOP observations: Data denial experiments and understanding sub-km scale processes with Large Eddy Simulations.

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Atmospheric bores can play a critical role in both the maintenance and the initiation of nocturnal convection. Furthermore, bores are very commonly observed in the nocturnal convective environment of the Great Plains of the United States. Therefore improving the understanding and predictions of bores was one of the main foci of the Plains Elevated Convection At Night (PECAN) field experiment. Observations were collected during PECAN from fixed and mobile observation platforms, including in situ surface and upper air observations, and surface and flight based remote sensing profilers of the kinematic and thermodynamic environment within and near bores. These data provide an unprecedented opportunity to understand the physical processes controlling bore behavior and determine optimal observing network strategies to improve predictions of bores in particular, and nocturnal convection in general.

In this study, the multi-scale GSI-based data assimilation system is used to evaluate the systematic impact of assimilating the PECAN observations on predictions of explicitly resolved bores, using 10 bore-focused Intensive Observation Periods (IOPs). In general, predictions of both bore amplitude and bore speed are improved by assimilating the observations. The impact of each individual type of IOP observations is also evaluated through systematic data denial experiments, with a focus on determining optimal observation network strategies for bore prediction. In addition to statistical analysis of these forecast datasets, case studies will be presented to demonstrate qualitative impacts and provide physical reasoning for the results.

The impacts on bore prediction of model horizontal and vertical resolutions will also be shown, including Large Eddy Simulations down to 50m horizontal grid spacing. The simulations will be used to investigate the upscale impacts of sub-km scale processes in bores and the implications for km-scale modeling of nocturnal convection.

Development of assimilation methods for dual polarimetric radar data

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Introduction

Recently, dual-polarization radars have been deployed for operational purposes, for instance, in the United States, France, Germany and Japan. These radars have advantages over conventional ones for quantitative precipitation estimates because of their superior reliability in estimating the rainfall rate (Bringi and Chandrasekar 2001). Therefore, it is able to expect that data assimilation of polarimetric parameters brings better precipitation forecasts.

Assimilation methods and result

Two types of observation operators have been developed: the first one derives polarimetric parameters assuming an exponential raindrop size distribution obtained by the models and is based on fitting functions against scattering amplitudes by following Jung et al. (2008). And the other estimates the mixing ratio of rainwater from the measured polarimetric parameter K_{DP}. Firstly, we evaluated accuracy of these operators using actual observation and simulated data. And then these operators and their adjoint were implemented into NHM-4DVAR (Kawabata et al. 2014), which performs at convective scales (~ 2 km). Figure 1 shows the first result by this system using the second operator. Detailed description on these operators and the assimilation system will be given in the presentation.

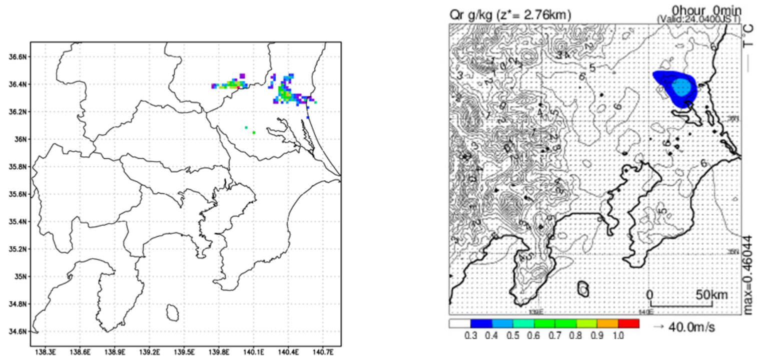

Figure 1. Observed radar reflectivity (left) and the mixing ratio of rain water in the assimilation field (right).

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Assimilation of Rapid-Scan Atmospheric Motion Vector of Himawari-8 to Improve the Rainfall Forecast of the Northern Kyushu Heavy Rainfall

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Introduction

Heavy rainfall that caused the landslides and floods over the northern Kyushu was generated on 5 July 2017. One of generation factors of this heavy rainfall was the continuous supply of humid air by the low-level airflow from the East China Sea. Because the horizontal wind affects the humid air supply, it is expected to be the useful assimilation data to improve the rainfall forecast. We used the atmospheric motion vector that was obtained from cloud images of Himawari-8 by tracing the positions of clouds. The observation interval of Himawari-8 is as short as 2.5 minutes so that the high-frequent and dense horizontal winds can be obtained from the high-frequent images (RS-AMV). In this study, the impact of RS-AMV on heavy rainfall was investigated with Local Ensemble Transform Kalman Filter (LETKF). In this heavy rainfall case, westerly flow was intensified by the assimilation of RS-AMV, and the maximum of the predicted rainfall became to be the observed one.

Assimilation Experiments and Results

The experiment was composed of the following two steps. First, the assimilation with the grid interval of 15 km was performed. The assimilation system we used was the NHM (JMA non-hydrostatic model)-LETKF system. The assimilation cycle was started at 00UTC 30 June. The assimilation window is 6 hours and the conventional and AMV data were assimilated every 1 hour. We used two kinds of AMV data. RS-AMV and conventional AMV data. RSAMV was obtained from the cloud images obtained every 2.5 minutes (Shimoji, 2016). Second, the downscale experiments with the grid intervals of 5 km and 1 km were performed. The initial and boundary conditions of 5 km experiments were obtained from the assimilated fields of AMV data, and the downscale experiments with 1km interval was performed from the outputs of 5 km downscale experiments. In this heavy rainfall case, the westerly component of horizontal wind on the western side of Kyushu was increased when RS-AMV was assimilated. This intensification of horizontal wind increased the rainfall amount. Namely, the rainfall region where 1 hour rainfall amount exceeded more 100 mm appeared, and the rainfall region became closer to be the observed rainfall intensity (Fig. 1).

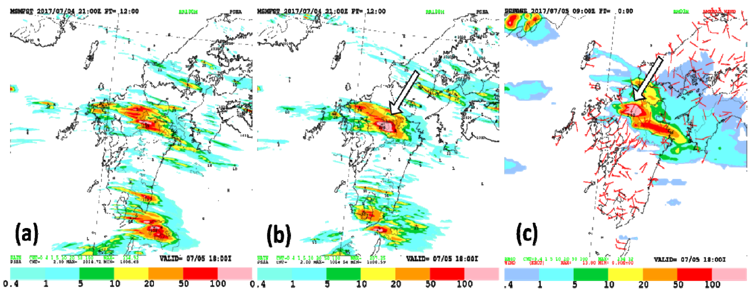

Figure.1 One hour rainfall distributions at FT = 6 hour (15 JST July 5) reproduced by 1 km downscale experiments. Rainfall distributions were obtained by assimilation of (a) conventional AMV and (b) RS-AMV. (c) Rainfall distribution observed by JMA conventional radar.

Assimilation of Radar Reflectivity with EnKF: Additional Ensemble Perturbations to Modify the Atmospheric Field

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Introduction

To improve short-term forecasts of severe weather with numerical prediction model (NWP), making accurate atmospheric field as the initial state of NWP is important. In the direct assimilation of radar reflectivity Z_H with ensemble Kalman filter, we can modify the atmospheric field (zonal wind u, meridional wind v, vertical wind w, temperature T, and water vapor mixing ratio q_v) based on the correlation between (u, v, w, T, q_v) and Z_H calculated by ensemble forecasts. If rainfall is not forecasted at the observation point in all ensemble members, however, the correlation with predicted Z_H becomes zero. Therefore, assimilation of Z_H causes no impact at such points. In the present study, we propose one solution to modify (u, v, w, T, q_v) through assimilation of Z_H even if rainfall is not forecasted at the observation point.

Method and assimilation experiments

To modify (u, v, w, T, q_v) through assimilation of Z_H, we propose the method to add artificial ensemble perturbations δZ_H at points where rainfall is not forecasted in half of ensemble members before assimilation of Z_H. These δZ_H are based on the slope of regression line of (u, v, w, T, q_v) for Z_H in each vertical layer and each analysis time. Thus, (u, v, w, T, q_v) can be modified by this method. To confirm the advantage of this method, we conducted assimilation experiments with 50-member NHM-LETKF (local ensemble transform Kalman filter with JMA non-hydrostatic model). In this experiments, we assimilated Z_H observed by Meteorological Research Institute advanced C-band solid-state polarimetric radar (rain attenuation was corrected by differential phase) in the case of the tornadic supercell in 6 May 2012. The horizontal grid interval was 1 km. The comparison between experiments with and without artificial δZ_H showed that the assimilation with the δZ_H increased midlevel v and q_v at points where rainfall was not forecasted and improved 1-hour rainfall forecast (Fig. 1). Therefore, this method has a possibility to improve short-term rainfall forecast.

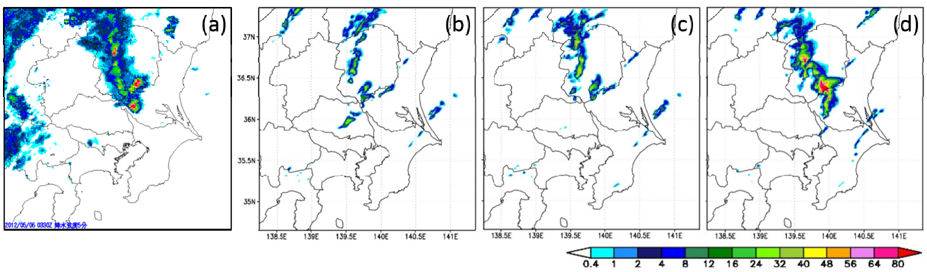

Figure 1 Rainfall rate (mm hr^{-1}) at 1230JST estimated by (a) JMA radars and (b)–(d) 1-hour extended forecasts of rainwater at 1-km AGL after assimilation period from 1100 to 1130JST (b: Z_H was not assimilated, c: Z_H was assimilated without artificial δZ_H, d: Z_H was assimilated with artificial δZ_H).