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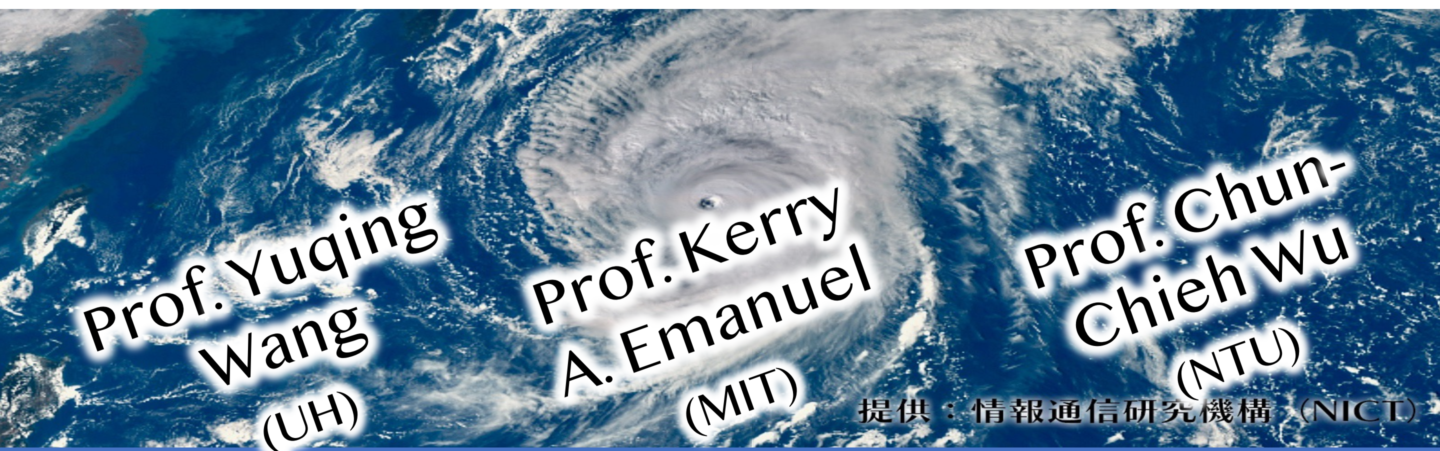
ABSTRACTS (SESSION 3)



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Impact of urbanization on precipitation associated with typhoon landfall

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Previous studies have shown that urbanization can affect the convection, and hence precipitation over or near cities through the modification of land cover characteristics, and the generation of anthropogenic heat and aerosols. Since the last few decades, more and more cities have developed along the East Asia coast, with some of them merging to become the so-called megacities. The question is whether and how urbanization associated with these megacities would modify the precipitation intensity of typhoons that make landfall near these large city clusters.

An observational analysis of the precipitation associated with typhoons making landfall along the South China coast indicates that in recent years, heavier precipitation appears to be more common. In a modeling study, changing the land-surface characteristics of the megacity area to an urban setting also leads to heavier rainfall over the megacity from just before landfall to after landfall through the processes of higher sensible heat flux and stronger surface convergence. If the aerosol concentration is also changed, not only does higher precipitation occur over the megacity, the outer rainbands also develop more vigorously due to the increase of cloud condensation nuclei in these rainbands, and hence ice-phase processes. Modeling studies using different typhoons yield similar results.

These results suggest that in predicting precipitation associated with typhoon landfall near megacities using numerical weather prediction models, the representation of the land use along the coast is very important. In addition, incorporation of aerosol concentration into the models will likely contribute to better predictions.

Energy cascading during typhoon and calm weather scenarios over urban atmosphere

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In urban environments, the intricate interplay of diverse motion scales, ranging from small-scale turbulent activities near the surface to mesoscale atmospheric circulation patterns, exerts substantial influence over energy transfer and dissipation within the atmosphere. Accurate weather prediction and the development of sustainable urban areas hinge on unraveling these interactions. The urban landscape, marked by high concentrations of buildings, roads, and infrastructure, departs significantly from natural surfaces like forests, resulting in disparities in heat absorption and emission. This divergence disrupts the urban-rural energy equilibrium, leading to distinctive energy cascades over urban regions. Although past research has predominantly explored the impact of urban-scale environmental changes on local weather patterns, there remains a critical knowledge gap regarding energy cascading from the broader mesoscale to the smallest turbulent scale due to alterations in the grid-to-urban scale environment. Our study aims to bridge this gap by utilizing CUBE LES to model complex urban geometries and employing Immersed Boundary Methods (IBM). We will investigate LES simulations under diverse wind conditions, including Calm and Typhoon scenarios, as they interact with the urban canopy. Our approach dissects energy scales within urban contexts into distinct spatial and temporal modes, thus deepening our understanding of energy transfer and dissipation mechanisms. Specifically, we seek to identify the fundamental scales of energy transfer, offering insights into scale interactions and enhancing our capacity for severe weather prediction in urban environments.

Historical trends of tropical cyclones and related compound hazards along the coastline of Vietnam

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The concept of compound hazards refers to the simultaneous occurrence or rapid succession of multiple hazards within a specific area. These can pose greater risks than individual hazards and may result in more significant economic losses. In this study, we considered three types of hazards: TCs, high temperatures, heavy rainfall, and their combinations, i.e. compound hazards. A temperature hazard (rainfall hazard) is identified if the maximum temperature (rainfall amount) of a given day exceeds the 95th percentile of all daily values recorded over the study period. A location is exposed to a TC hazard on a given day if the distance from that location to the TC center is less than 250 km.

We computed the number of hazards over 10 selected stations along the coastline of Vietnam for the period 1980–2018. The TC track data were sourced from the International Best Track Archive for Climate Stewardship (IBTrACS), and daily maximum temperature and daily accumulated rainfall were obtained from the Vietnam Meteorological and Hydrological Administration (VMHA).

The results indicate that the average annual number of TCs affecting most stations has decreased slightly, while the number of rainfall (temperature) hazards exhibits inhomogenous trends across the stations. The annual number of compound hazards shows statistically significant increasing trends over three out of 10 stations, and is insignificant over the remaining seven stations. The increasing trend in the number of compound hazards is largely contributed to by the increase in temperature hazards. At the seasonal scale, compound hazards usually occur from March to November, primarily associated with temperature hazards in the first half of the year and with TCs and rainfall hazards in the later months. The peak of the sum of the individual hazards occurs at a different time than the peak of the compound hazards, suggesting that the compound hazard analysis may provide additional information for resilience and adaptation management planning.

Keywords: Tropical cyclones, compound hazards, historical trends, Vietnam

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Observing system simulation experiments toward objective analysis of tropical-cyclone intensity by assimilation of satellite-based cloud-tracking winds in the typhoon inner core

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Tropical-cyclone intensity estimation at tropical-cyclone warning centers around the world is mainly performed by a statistical method of the Dvorak technique with cloud patterns from satellite imagery. Compared with hurricane intensity estimation with available aircraft observations, the typhoon intensity estimation relatively relies on the Dvorak technique after operational aircraft reconnaissance entering the storm center ceased in 1987. After new-generation geostationary meteorological satellites such as Himawari-8/9 and GOES-R were launched, high-frequency observations (with 1- or 2-minute intervals) over limited areas including typhoons were available. Recently, some studies proposed new techniques to track horizontal motions of cloud top at the mesoscale using continuous images from the high-frequency observation. The cloud tracking quantitatively estimates spatiotemporal distributions of the horizontal wind near the cloud-top height including meso-vortices associated with shallow cumuli within the typhoon eye. By combining the cloud-tracking winds with data assimilation procedures, we considered the possibility of an objective typhoon intensity estimation (i.e., an assimilation-based objective analysis for typhoon).

In this study, we examine the availability of the cloud-tracking winds for the typhoon objective analysis. We use a nonhydrostatic atmosphere model and data-assimilation system (SCALE-LETKF) to perform observing system simulation experiments (OSSEs) for a real typhoon after the mature stage. Assimilated virtual observation data are produced by vertically averaging axisymmetric tangential winds over a specified layer at every 4-km radius from the vortex center in a (true) numerical simulation. We designed one experiment without any assimilations (i.e., free run) and three experiments with assimilating cloud-tracking observations in different areas, (Case1) inside the radius of maximum wind speed (RMW) in the lower troposphere, (Case2) at radii with outflows in the upper troposphere, and (Case3) both Case1 and Case 2. Note that the winds at the RMW are not included in the virtual observations because the geostationary-satellite-based cloud tracking is not available at the RMW in general. We performed identical (non-identical) twin experiments by producing the virtual observation data from the SCALE (a different model from SCALE) simulation.

In the identical twin experiments, the overdevelopment of the typhoon vortex in the free run was suppressed by assimilating the cloud-tracking winds and the vortex structure in the assimilation run resembled the true vortex. The observations in the eye (Case1) suppressed the eyewall contraction associated with overdevelopment in the free run. The results suggest that the cloud-tracking winds can be effective for the objective typhoon intensity estimation. In the non-identical twin experiments, the results were qualitatively similar to the identical experiments. However, the tangential wind at around the RMW, where the cloud tracking is not available, in the non-identical experiments was still stronger than that in the true vortex. This feature might be due to the difference in the configuration such as boundary-layer processes and evolution of sea surface temperature between the numerical models used to produce the virtual observation data.

Exploring the controllability of chaotic systems through deep reinforcement learning

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Chaotic systems are inherently sensitive to perturbations, which makes them highly unpredictable, and yet the same sensitivity enables highly efficient control. This intriguing nature of chaotic systems have led to the successful modulation of chaotic flows, stabilization of heart arrhythmias, and recently, it has been proposed to utilize the chaos to mitigate extreme weather. One of the core challenges in controlling chaotic systems is to identify an effective control strategy which tells the timing, location, and type of perturbations (e.g., cloud seeding) aimed at achieving control objectives (e.g., weakening extreme weather events).

In this study, we explore the potential of deep reinforcement learning (DRL) to identify the control strategies in chaotic systems. DRL, a subset of machine learning, excels in complex decision-making scenarios and has celebrated successes in areas like playing computer games and controlling nuclear fusion plasma. Here we demonstrate that DRL can identify highly efficient strategy to control the Lorenz chaotic systems. When perturbation shapes are restricted, DRL even offers strategies that transcend human intuition — it demonstrates the possibility of suppressing chaos through temporary chaos enhancement. Additionally, we propose a DRL-based controllability metric: the "value of control." This novel metric provides a perspective distinct from traditional metrics such as the Lyapunov exponent. We will present latest progress on this topic during the workshop.

Development of a method for the typhoon weakening based on the chamber and the numerical simulation experiments

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This study aims to examine the feasibility of the typhoon modification from intervening in the cloud microphysical process as a part of "A core research program for Typhoon controlling aiming for a safe and happy society" in the JST Moonshot Goal 8. Various ideas are proposed by the Moonshot project for the typhoon modification, the intervention method currently envisioned in our group is to weaken the deep convection at the center of the typhoon by invigoration of cumulonimbus clouds instead of cumulus at the outer region of the typhoon. To promote deep convection at the outer region of typhoons, seeding with hygroscopic aerosols will increase the number of cloud droplets, shift the size distribution of cloud droplets toward smaller size, and facilitate adiabatic heating in the upper layers.

Our goal is realization of the typhoon modification method, but we necessary test the idea before starting the development of the technique. To properly understand how cloud droplets formation and ice crystal formation processes can be modified by seeding in a typhoon environment, we investigate the aerosol competition through laboratory experiments using a cloud chamber at Japan Meteorological Agency / Meteorological Research Institute, and to reflect the results in a numerical model. The cloud chamber is undergoing modification of the air inlet section and installation of a large heating and humidification system to enable experiments to be conducted under warm and humid conditions.

As a counter part to the chamber experiment, we conducted ideal numerical simulations by changing the number of cloud droplet ranging from 30 to 3000 cm^{-3} using the SCALE regional model developed by RIKEN to understand the detail processes in the microphysical processes when the cloud droplet number is changed. The intensity of simulated typhoon with the large number of the cloud droplet tends to be weak comparing to the simulated typhoon with the small number of the cloud droplet; this is an encouraging result for our idea.

To understand responses in realistic typhoons and examine the modification hypothesis in the microphysical processes when the cloud droplet number is changed from 50 to 2200 cm^{-3}, we conducted real case numerical simulations. The CReSS regional model developed by Nagoya University was used for the real case simulation. The target case is Typhoon Faxai in 2019. The intensity of simulated typhoon with the large number of the cloud droplet tends to be weak comparing to the simulated typhoon with the small number of the cloud droplet. But the response to the cloud droplet number is not linear and much more complicated than that found in the ideal simulations. Further investigation to examine the best method for TC weakening.

Reducing the Intensity of an Approaching Typhoon Forced by an Artificial Cold Pool Using the Stretched Version of a Non-hydrostatic Icosahedral Atmospheric Model (NICAM)

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Tropical cyclones are highly destructive natural disasters that can be very costly, and therefore, is of grave concern to any society. As a part of the Moonshot project of the Typhoon Control Research Aiming For a Safe and Prosperous Society, a series of experiments are conducted using the stretched version of the non-hydrostatic icosahedral atmospheric model (NICAM) with a minimum grid spacing of 1.4km to see the impact an artificial forcing would have on an approaching typhoon. Each experiment has an artificial forcing with a different intensity to induce a cold pool positioned at 27 degrees North Latitude and 138 degrees East longitude in the pathway of typhoon Hagibi. The experiments run for two days (48 hours) prior to landfall in Japan. The intensities provide a constant cooling source of 1K/hr, 2K/hr, 10K/hr and 20K/hr where each are circular in shape with a radius of 50km.

Time evolution of the minimum sea level pressure (slp) reveals that for the first 6 hours the cold pool has no impact on typhoon Hagibi in each of the experiments. From 6 -14 hours there is an impact because the control run (no forcing) has the lowest pressure at all times during this period. Interestingly, the forcings of varying intensities impact the typhoon in the same way during this time period. From 23 hours until the end of the simulation, the forcings that provide a cooling effect of 10K/hr and 20K/hr have a greater and more observable impact than the forcings that provide a cooling effect of 1K/hr and 2K/hr. The cold pool is at its strongest one day (24 hrs) into the simulation. We can see the vertical structure of the cold pool best in the 10K/hr and 20K/hr experiments. There is a strong updraft at the edge of the cold pool which acts as a barrier to the inflowing warm moist air. The experiments for 1K/hr and 2K/hr are not able to show a distinct vertical profile of the cold pool.

To better understand the impact, snapshots of the plane-view of the slp, 10-metre wind speed and the 2-metre temperature values are assessed and the differences evaluated to quantify the impact at specific times. Surprisingly, the range of the differences between the control and the experiment for the slp are similar at the same time interval for all the experiments. This pattern is seen too for the 10-metre wind speed and also the 2-metre temperature. For all experiments, the impact of the cooling is most noticeable one day (24 hours) into the simulation. When the typhoon makes landfall (48 hrs) in Japan, it is not at an appreciable weaken state. The reduction in slp, 10-metre wind speeds and 2-metre temperature is not significant enough and the reduction does not happen throughout the whole typhoon. Wind speeds, convection and precipitation are usually not symmetric in a cyclone because a tropical cyclone tends to be non-axisymmetric. The cooling force for each experiment is only able to weaken the typhoon in certain areas while in other areas there are increases in both the 10-metre wind speed and the 2-metre temperature, and decreases in slp. All indicating that there is no weakening. These results prove that weakening a cyclone will be challenging and using one approach may not be sufficient. Improvements are being made to the forcings.

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Typhoon control and its ELSIs

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The typhoon is a natural phenomenon, which is, at first sight, beyond the control of human beings. However, the climate and weather of our planet are going to have increasingly harsher impacts on human lives and society. As long as we still wish to continue to inhabit the earth, we must find a way to deal with this serious challenge. The typhoon control project under Moonshot Goal 8 proposes one possible—but somewhat dangerous—option for doing this. To make the future control operation happen safely, we should address the possible implications of this activity other than the feasibility of the scientific and technological aspects. These trans-science questions are generally called ethical, legal, and social implications (ELSIs).

This presentation will cover several ELSIs that typhoon control activities would have for society, culture, the environment, and biodiversity if the application of this technology has been agreed on by the year 2050 (the Moonshot target year). We especially focus on (1) the permissibility of controlling nature and (2) the risk of third-party (adverse) influence and discuss them from the humanities and social sciences perspective. The discussion will be based on presumable future and technologically neutral scenarios.

Before examining specific ELSIs, this presentation will explain our team's strategy for struggling with these interdisciplinary and complex questions. We realize that, when discussing the ELSIs of novel technologies, it is important to incorporate a timeline. The maturity of science and technology, as well as the climate and social circumstances, will change the world of the future and people's perceptions. Having said that, novel science and technologies also contain a general feature: **uncertainty**. This applies equally to typhoon control. There is no agreed meaning of "control." The timing, the effect, and the risk of interference with typhoon are still uncertain, and the climate, the intensity of typhoons, and the efficacy of other disaster prevention methods that will exist in 2050 are not sufficiently predictable. This situation can easily lead to the "**technology control dilemma**," meaning that the risks and problems are uncertain at this premature stage, and, when the risks become certain, the technology is already mature and fixed, and it is difficult to reverse it, even when there remain some concerns about it. On the other hand, stalling because of uncertainty could put us in the position of being "too late."

To avoid this situation, our ELSI team and this presentation apply a general approach, providing a comprehensive list of presumable implications of weather control in a broader perspective (a **technologically neutral approach**). This list should help us avoid overlooking important but less obvious issues that should be taken into account. Our team has been continuing to have talks with scientists, specialists in disaster management, communities, and people in other fields. We also have embarked on exchanges in other existing, comparable fields, such as precipitation enhancement and geoengineering (solar radiation modification and carbon dioxide removal). Every new connection gives us new awareness, so the list will be constantly enriched.