International Workshop on Typhoon Science and Technology Research 2025

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HAMAGIN-HALL YOKOHAMA

Abstract

Keynote Lecture I: Oct. 21, 10:10-11:10

A Global Perspective on the Use of Airborne Observations to Advance the Understanding and Prediction of Tropical Cyclones

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Airborne observations are a key component of a balanced approach, involving observations, modeling, and theory, toward advancing the understanding of tropical cyclones (TCs). They provide real-time information on TCs, assess the performance of models, and provide a test for theories. These capabilities can combine to improve the prediction of TC behavior. In particular, the prediction of intensity change, especially rapid intensification (RI), is a key challenge, and one which is well-suited to be improved by using airborne observations.

The first airborne mission into a tropical cyclone occurred in 1943 in the Gulf of Mexico in the Atlantic basin. These missions became routine in the 1950s, during which time the National Hurricane Research Project (NHRP), the first experiment dedicated to TC research, began, with airborne observations forming a critical component. Project Stormfury, a hurricane modification experiment, began shortly thereafter. Project Stormfury attempted to weaken hurricanes using cloud seeding techniques from aircraft, ultimately ending in 1983 with inconclusive results. In the western North Pacific basin, reconnaissance missions from U.S. military aircraft began in 1945. Routine U.S. airborne TC missions ended there in 1987, however, resulting in a significant increase in errors of 24-h track and intensity forecasts the following year. Partly in response to this, affected countries in the region developed their own capabilities in the 2000/2010s. Development continues to this day, representing a truly global airborne capability to observe and study TCs (Fig. 1). These missions provide valuable information on tropical cyclone location, intensity, and structure for forecasters.

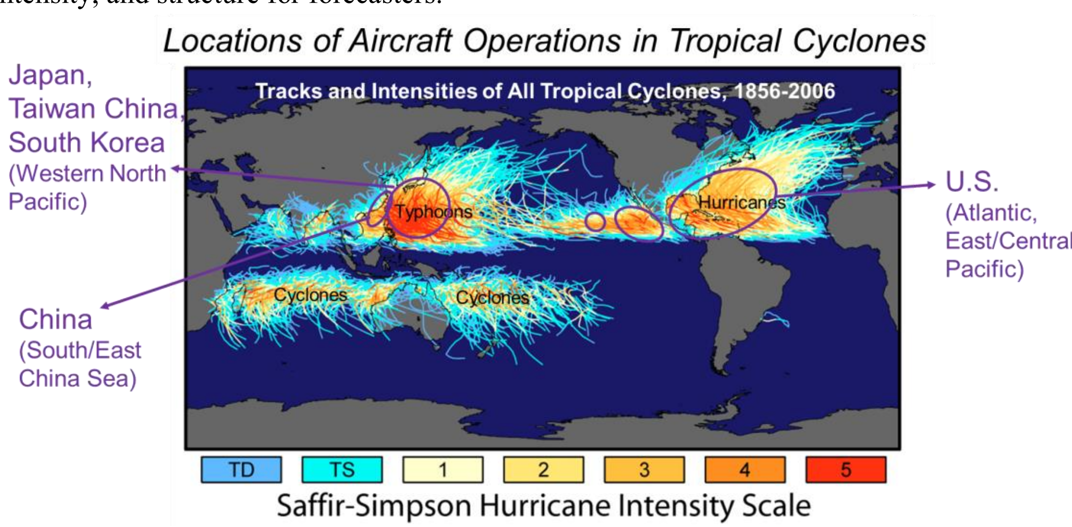

Fig. 1. Track and intensities of all TCs from 1856-2006. Locations of airborne operations, and the countries carrying out these operations, indicated.

Current airborne TC-focused field campaigns across the globe include the Advancing the Prediction of Hurricanes Experiment (APHEX) in the Atlantic, led by NOAA in the U.S.; the Experiment on Typhoon Intensity Change in the Coastal Area (EXOTICCA-II) in the western North Pacific, led by the Shanghai Typhoon Institute, Hong Kong Observatory, and the Asia-Pacific Typhoon Collaborative Research Center in China; and the Tropical cyclone-Pacific Asian Research Campaign for Improvement of Intensity estimates/forecasts (T-PARCII), also in the western North Pacific and led by Nagoya and Yokohama Universities in Japan. These experiments have a variety of objectives, such as improving the prediction of TC hazards, studying the processes governing TC structure and intensity change before and after landfall, and improving the estimation and forecasting of TC intensity. Combined, these experiments also have a range of airborne capabilities, including aircraft that penetrate the TC inner core at low and high altitudes, dropsondes, airborne Doppler radar, in situ cloud physics probes, ground-based mobile and fixed platforms, and uncrewed systems.

Observations collected from these aircraft have contributed to substantial improvements in TC track and intensity forecasts (including RI forecasts) as well as TC rainfall forecasts. They have provided key measurements used to improve numerical model formulations of TC boundary layer structure. Airborne data have also been used to advance the understanding of the relationship between inner-core vortex and convective structure and TC intensification, vortex and boundary layer structure, warm core structure, and boundary layer rolls. Such advances have occurred from observations collected in both the Atlantic and western North Pacific basins.

Looking toward the future, innovative observing technologies are being developed and tested, including aircraft- and ground-launched uncrewed aerial systems, "swarms" of small dropsondes, and rocketsondes. These technologies provide the ability to sample areas that crewed aircraft cannot safely sample but are crucial for improved prediction of TCs, such as near the air-sea interface. In the western North Pacific, uncrewed aerial vehicles (UAVs) have been successfully operated in TCs, and the first multi-plane mission in the South China Sea occurred last year in Typhoon Trami. New research is being pursued that uses hypotheses developed from data collected in the Atlantic basin to guide observations collected near the coast of China to better understand vortex alignment, a key step in RI onset.

An important development being implemented this year is international collaboration between EXOTICCA-II and T-PARCII. T-PARCII has a G-IV aircraft capable of sampling the inner core of TCs from high altitude over the open ocean, while EXOTICCA-II has a King Air and a UAV, along with an extensive network of ground-based assets such as dual-Pol Doppler radar, lidars, and profilers. The observing strategy consists of T-PARCII sampling a typhoon while in the Fukuoka (Japanese) Flight Information Region (FIR) and "handing off" sampling responsibility to EXOTICCA-II as the typhoon crosses into the Shanghai (Chinese) FIR (Fig. 2). Such a strategy has the potential to provide the first-ever observations of the full lifecycle of a typhoon, from birth over the ocean to death inland in China. It also has the potential for a two-plane mission when the typhoon is at the boundary of the two FIRs (or even a three-plane mission with the South Korean King Air if the typhoon is also at the boundary of the Incheon FIR).

The developments presented here describe an exciting set of airborne TC measurement capabilities that have rapidly grown around the world, including in the western North Pacific. These observations will provide valuable information for forecasters, models, and researchers to improve prediction and mitigate the impacts of TCs. International cooperation, data sharing, observational and research partnerships, and technological innovation are all key activities vital in building resilient communities and protecting life and property from the evolving threats of TC hazards

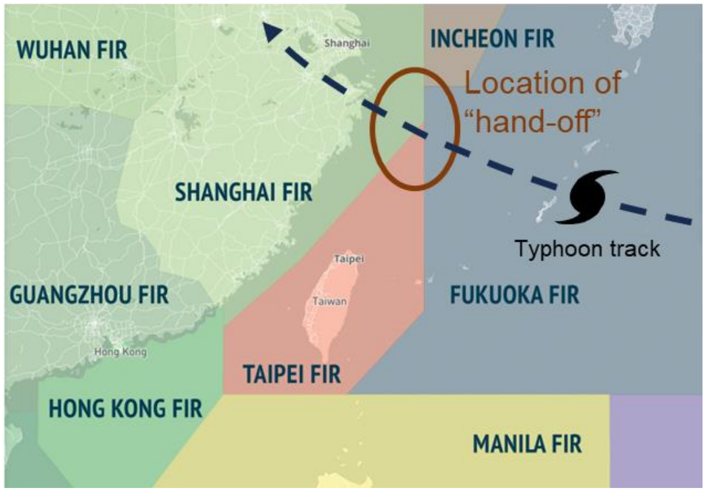

Fig. 2. Schematic of hypothetical typhoon track, flight information regions, and location where sampling responsibility could be "handed off" from T-PARCII to EXOTICCA-II.

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Keynote Lecture II: Oct. 22, 9:00-10:00

Recent Results on Tropical Cyclones and Climate Change

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In this talk I'll summarize recent results of future projections of tropical cyclone activity. First I'll discuss the environmental fields associated with tropical cyclone (TC) activity in phase 6 of the Coupled Model Intercomparison Project (CMIP6) models, as well as the TC-like storms in those models as described in Camargo et al. (2025). I'll show how these environmental fields change in the CMIP6 models, using three future scenarios separately as well as combining scenarios and times according to specific greenhouse warming levels. Multiple proxies for TC activity are considered, and we show that the signs of the future changes are dependent on the choice of genesis index. The relationship between climate sensitivity and potential intensity change across the multimodel ensemble will be examined. The statistics of the TC-like structures in the historical simulations are also examined, using the number of TCs (NTC) and accumulated cyclone energy (ACE) as diagnostics, including calculations of the percentage changes in NTC and ACE at the end of 21C as compared with 20C. Large decreases in both of these quantities are found in the highest emission scenario.

On the second part of the talk, I'll introduce a new theoretically derived genesis index discussed in Chavas et al. (2025) that is proportional to the product of the ventilated potential intensity and the absolute vorticity raised to a power. This new index performs comparably well to existing indices in reproducing the climatological distribution of tropical cyclone genesis and its covariability with El Niño–Southern Oscillation, while only requiring a single fitting exponent. When applied to CMIP6 projections, GPI predicts that environments globally will become gradually more favorable for TC genesis with warming, consistent with prior work based on the normalized entropy deficit, though significant changes emerge only at higher latitudes under relatively strong warming. This new genesis index helps resolve the debate over the treatment of the moisture term and its implication for changes in TC genesis favorability with warming, and its clearer physical interpretation may offer a step forward toward a theory for genesis across climate states.

In the last part of the talk I'll discuss future projections of the modulation of El Niño-Southern Oscillation and tropical cyclones based on the results of Lee et al. (2025) based on CMIP6 models downscaled by the Columbia Hazard (CHAZ) model. The multimodel mean of CHAZ–CMIP6 simulations accurately captures the observed ENSO–TC relationship, defined as the differences between anomalous TC activity during El Niño and La Niña events. TC activity is represented by density maps of genesis, track, and accumulated cyclone energy. We found that anthropogenic warming indeed affects the historical ENSO–TC relationship. There is an overall reduction (increase) in TC activity during El Niño (La Niña) events in both the North Atlantic and eastern North Pacific, where the historical ENSO–TC relationships have opposite signs. A warming climate reduces this contrast between the two regions. Other ENSO–TC relationship changes include increased (reduced) TC activity in the South Pacific during El Niño (La Niña) events, which enhances the historically positive anomaly in tropical South Pacific TC activity but weakens the negative anomaly south of 15°S. There is also a westward shift of the positive anomaly of the southeast–northwest dipole pattern in the western North Pacific. These changes, however, are relatively small, and thus, the currently known ENSO–TC relationship persists as the climate warms. The analysis of individual CMIP6 models suggests that warming-induced changes in the ENSO–TC relationship vary by model and basin, with differences likely due to the changes in ENSO characteristics within the models.

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Eyewall Replacement Cycles as a Structural Driver of the Bimodal Distribution of Tropical Cyclone Lifetime Maximum Intensity

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Elliott Fosler-Lussier

Key words: Tropical cyclones, eyewall replacement cycle, lifetime maximum intensity, probability distribution function

Tropical cyclone (TC) lifetime maximum intensity (LMI) shows a pronounced bimodal distribution, with one peak near tropical storm strength and a secondary peak near major hurricane strength. Here, we develop a best-track based algorithm to detect eyewall replacement cycles (ERCs) and classify storms by their post-ERC evolution. We find that ERC storms contribute almost exclusively to the secondary, high intensity peak. Among ERC storms, those that reintensify after an ERC move over higher sea surface temperatures with greater ocean heat content and experience lower vertical wind shear, driving extreme upper end intensities. The relative scarcity of storms at intermediate intensities (85–105 kt) reflects rapid intensification propelling them through that range. These findings clarify the mechanisms behind the bimodal LMI distribution and underscore the value of identifying ERCs to improve tropical cyclone intensity forecasts.

Day1 (Oct. 21), Session 1

Limited Influence of Pre-Existing Tropical Cyclones on Subsequent Cyclogenesis in the Western North Pacific

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Kenji Yamauchi (Japan Meteorological Agency)

Key words: genesis; Rossby waves; tropical waves

Previous studies suggest that a tropical cyclone (TC) may contribute to the genesis of another TC to its east or southeast in the western North Pacific (WNP) through Rossby wave dispersion. However, the influence of a pre-existing TC (PTC) has not been fully clarified in realistic simulations. This study conducted 42 numerical experiments (NPTC) for 1981–2022, in which a PTC was removed by horizontal smoothing from the initial conditions 120 hours before the genesis of a subsequent TC (STC). Compared to control simulations with the PTC (WPTC), the number of STC formations was identical (WPTC: 35, NPTC: 35). STCs exhibited a minor intensification in WPTC. STCs were typically located to the south or southwest of a subtropical high. The experiments showed wave-like anomaly patterns in the vorticity field southeast of PTCs and in the geopotential height field northeast of the PTCs. Vertical wind shear (VWS), enhanced by PTC outflows, created an unfavorable environment for STC formation and intensification. Reanalysis data supported strong VWS and a similar wave-like pattern. A positive sea surface temperature (SST) anomaly over the central equatorial Pacific induced westerly wind anomalies in the southeastern WNP. The spatial collocation of PTCs and STCs was frequently observed when the active eastern convection is expected by the indices of Madden–Julian Oscillation, Boreal Summer Intraseasonal Oscillation, and El Niño–Southern Oscillation. These conditions promote TC genesis farther east, suggesting that such collocation does not imply PTC-induced formation. Thus, impact of PTCs appears minor than previously assumed.

Day1 (Oct. 21), Session 1

Convective "butterflies" lead to tropical cyclone rapid intensification

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Derek J. Posselt (Jet Propulsion Laboratory, California Institute of Technology)

Key words: rapid intensification, convection, muti-scale intereaction

Predicting changes in tropical cyclone intensity, particularly the onset of rapid intensification (RI), remains far more challenging than forecasting cyclone tracks because of the chaotic interactions among multi-scale physical processes, strongly modulated by convective-scale phenomena. Previous studies have shown that vortex alignment driven by inner-core convection is crucial for initiating tropical cyclone intensification. However, the intrinsically chaotic nature of moist convection introduces large variability into the mechanisms that trigger intensification, complicating efforts to isolate the impact of individual convective events.

In this study, we present a new experimental framework employing convection-permitting numerical weather prediction models to investigate the role of individual convective events. Using the onset of TC RI as a case study, a series of sensitivity experiments was conducted to examine the contribution of convective-scale thermodynamic processes and their upscale interactions to the variability of vortex-scale RI onset. The results indicate that inner-core convective processes, occurring on spatial scales much smaller than the overall TCs, play a critical role in triggering rapid intensification. Given the strong nonlinearity of this process, improving understanding of the sources of uncertainty provides valuable guidance for the design of observation networks that can better constrain tropical cyclone forecasts.

A Horizontal Turbulent Diffusion-Controlled Lower Bound of Tropical Cyclone Radius of Maximum Wind

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Danyang Wang, Yanluan Lin

Key words: tropical cyclone, RMW, boundary layer, horizontal diffusion

The radius of maximum wind (RMW) of a tropical cyclone (TC) plays a critical role in shaping the TC wind field and associated hazards. Observations have found RMW as small as 5 km, but the existence and magnitude of a lower bound of RMW remain unknown. We investigate the presence of a lower bound in an axisymmetric boundary-layer diagnostic model by asking how small the RMW can become before the TC inner-core structure becomes unstable and undergoes a rapid expansion. A non-dimensional parameter measuring the relative magnitude of the horizontal mixing length to the RMW, $\bar{l}=l_h/r_m$, is found to play a key role in the model. It reveals a critical threshold of $\bar{l}=0.2$ for the strength of horizontal turbulent diffusion. Beyond $\bar{l}=0.2$, horizontal turbulent diffusion induces a sharp transition in the boundary-layer ascent structure, serving as a robust indicator of structural instability and placing a strong constraint on the minimum achievable RMW. For a typical mixing length of $l_h=1000$m, this implies a horizontal diffusion-controlled lower bound of RMW at 5 km. The ascent transition resembles eyewall replacement cycles (ERCs) and is interpreted as a manifestation of the dipolar ascent structure associated with the horizontal turbulent diffusion-controlled flow (HDCF). These findings highlight a novel pathway for inner-core reorganization in compact TCs, suggesting that horizontal turbulent diffusion constitutes a stabilizing factor that contributes to the self-regulation of the inner-core structure.

Shallow Convection Suppresses Tropical Cyclone Formation in a Global Storm-Resolving Model

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Key words: Tropical cyclone, Annual cycle, North Indian Ocean, Tropical cyclone seed, Survival rate

Kilometer-scale resolution global storm-resolving models (GSRM) are a promising tool for the future projection of tropical cyclone (TC) activity due to their ability to explicitly resolve deep convective systems, which are central to TC genesis and intensification. This study investigates TC frequency in X-SHiELD, a global storm-resolving model developed at the Geophysical Fluid Dynamics Laboratory. We use a 1-year coupled simulation performed with X-SHiELD, in which sea surface temperatures were nudged toward the observed SSTs in 2020. While X-SHiELD successfully produces warm-cored rotating tropical storms resembling observed TCs, it underestimates TC frequency during peak TC season across Northern Hemisphere TC basins. Analysis of pre-TC disturbances (seeds) shows that the seed frequency in X-SHiELD is similar to observations; however, the seed-to-TC transition rate is much lower than observed. Examination of the thermodynamic structure of seeds reveals a dry bias in the boundary layer and a moist bias in the mid-troposphere, which can be attributed to overly efficient moisture transport from the boundary layer to the mid-troposphere by X-SHiELD's shallow convection scheme. The dry bias in the boundary layer appears to weaken convection in the inner-core region of seeds, a process crucial for seed development of seeds into TCs. These findings emphasize the critical role that sub-grid scale processes, particularly the representation of shallow convection, play in influencing TC genesis and frequency within global storm-resolving models.

Day1 (Oct. 21), Session 1

Reconciling the Discrepancies of Equivalent Potential Temperatures in Atmosphere: A General Pathway Rooted in Entropy Conservation

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Zhe-Min Tan (Nanjing University)

Key words: Equivalent potential temperature, Moist entropy Conservation, Entropy potential temperature

Equivalent potential temperature is a very important thermodynamic variable in meteorological research, related to the temperature, pressure, and moisture content of an air parcel. It is widely used in in atmospheric science, for both scientific understanding and the development of numerical models. For instance, equivalent potential temperature can be employed in isentropic analysis of convection in tropical cyclones, facilitating a deeper understanding of the multi-scale structure of tropical cyclones, the energy cycle, and its interaction with large-scale circulation. However, various formulations of equivalent potential temperature have been proposed in the literature. These formulations involve sophisticated mathematical derivations and exhibit significant differences, posing substantial difficulties in understanding their physical connections. Moreover, some formulations suffer from thermodynamically inconsistent assumptions or approximations, which prevent them from guaranteeing the closure of energy and entropy budgets when used to develop numerical models. Based on the principle of moist entropy conservation, this study proposes a general pathway to define the equivalent potential temperature. Three examples are given to illustrate the mathematical derivations that differ from those in previous studies. It is demonstrated that all existing formulations of equivalent potential temperature are special cases of three examples under specific conditions, explaining the connections and distinctions between different equivalent potential temperatures. Building upon this general pathway, we propose a method for discovering new equivalent potential temperatures that has not been documented in any previous studies. The new pathway has the advantage of mathematical and physical consistency, avoiding complicated mathematical derivations while maintaining a concise physical interpretation. In practical applications, researchers can select or redefine equivalent potential temperatures appropriate for the physical processes under investigation.

The general pathway does not rely on thermodynamically inconsistent approximations or assumptions, hence can help choose appropriate thermodynamic variables during the development of dynamical cores and physical parameterization schemes within ESMs.

Day1 (Oct. 21), Session 2

On Tropical Cyclone Genesis Types and Their Intensification Rate

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Ming-Han Chung (National Taiwan University)

Key words: Tropical Cyclone Genesis Types; Intensification Rate

Higher tropical cyclone (TC) intensification rates are associated with a smaller radius of maximum wind (RMW). Previous studies have shown that convection distribution is affected by the TC genesis type. However, no studies have identified the impacts of TC genesis types on both the initial RMW and convection distribution. In this study, a new objective method is developed to classify TC genesis types based on the K-means clustering algorithm of critical atmospheric parameters available from reanalysis data. For comparison between intensification rate and RMW, the lifetime maximum intensification rate (LMIR) in each case is also examined. The result shows an inverse relationship between the LMIR and the RMW during the LMIR period. Furthermore, TCs with larger initial RMW usually have lower LMIR, implying the importance of initial RMW. The K-means cluster analysis shows four TC genesis types: (i) easterly wave (EW), (ii) monsoon confluence (MC), (iii) monsoon shear (MS), and (iv) monsoon depression (MD). EW has the most aggregated convection and a moist area only around the center, explaining why the EW type has a small RMW. In contrast, MD has more scattered convection and larger circulation than others. Consequently, MD has a significantly larger initial RMW and lower LMIR than EW. Although both MC and MS have medium RMW sizes that fall between those of EW and MD, their LMIR is as high as that in EW because of aggregated convection similar to EW, resulting in RMW contraction and an LMIR similar to EW.

Day1 (Oct. 21), Session 2

Tornadogenesis Associated with Mesovortices in Tropical Cyclone Yaas (2021) over the Bay of Bengal

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Kazuhisa Tsuboki (Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan)
M. Rafiuddin (Department of Physics, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh)

Key words: Tornado, Mesovortex, Tropical cyclone, Bay of Bengal

Tornadoes associated with tropical cyclones (TCs) have rarely been reported in the North Indian Ocean, including the Bay of Bengal (BoB) and Arabian Sea. A sudden tornado outbreak in West Bengal (WB), India, 15-16 hours prior to the landfall of Cyclone Yaas on 26 May 2021 marked the first such event documented in association with a TC originating over the BoB. While TCs in the BoB already pose significant threats to low-lying coastal regions, such as tidal surges, flash floods, and intense rainfall, additional localized damage from embedded or distant tornadoes within the TC environment has not yet been adequately addressed or monitored, mainly due to limited research and observational data. To investigate this event, the Cloud-Resolving Storm Simulator (CReSS) model was employed at 2.5 km and 500 m horizontal resolution to analyze the rainband of Cyclone Yaas and the associated WB tornado. The simulations revealed the development of numerous mesovortices (on the order of $10^{-3}\ s^{-1}$) within quasi-linear convective systems in the TC rainbands. These were driven by the barotropic instability linked to a strong low-level horizontal shear gradient (~10 ms^{-1}) during landfall of the rainbands. Additionally, the environment exhibited moderate instability (~1060 Jkg-1) and environmental helicity (EH ~110 m^2s^{-2}). Tilting of horizontal vorticity (~$3\times10^{-5}\ s^{-1}$) led to the formation of mesovortex couplets, with maximum positive vorticity reaching ~$11\times10^{-3}\ s^{-1}$. These vortices extended vertically up to the 500 hPa level. One mesovortex core, co-located with an intense updraft (~4.5 ms^{-1}) and high potential vorticity (60 PVU at 900 hPa), intensified due to a localized thermal gradient, near-surface convergence (~$3\times10^{-3}\ s^{-1}$), and vertical stretching >$12\times10^{-5}\ s^{-1}$.

This core also showed elevated helicity, with EH of 191 m2s－2 and storm-related helicity (SREH) of 264 m2s－2, indicating a strong rotational potential that ultimately contributed to the genesis of the observed WB tornado.

Day1 (Oct. 21), Session 2

Scientific Collaborations on Typhoon Studies Enabled by HPC and AI

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Key words: AI, HPC, Academia-Industry-Partnership

Since 2022, we have been advancing science and technology on typhoons through an academia–industry partnership. The goal of this collaboration is to combine Fujitsu's strengths in AI and computing technologies with the meteorological expertise of TRC/YNU; that is the Fujitsu-SRL project of the Fujitsu–YNU Typhoon Research Laboratory. As part of this effort, we developed a prediction system for typhoon rapid intensification using Fujitsu's explainable AI, Wide Learning. Although the learning and prediction inputs are based on a common database of typhoon conditions and environments (i.e., SHIPS predictors), the non-linear learning capability of Wide Learning has enabled us to achieve higher prediction skill. This is a fascinating result for AI applications in meteorology, as it shows that we still have opportunities to improve predictive skill by better utilizing data and accounting for non-linearity. On the HPC side, in 2024 we undertook a simulation that included both tornadoes and a typhoon. Typhoons, in particular their rainbands, are recognized as environments conducive to the formation of supercells that may generate tornadoes. This requires both high resolution and a wide computational domain simultaneously. To meet this demand, we leveraged the supercomputer Fugaku and applied Fujitsu's HPC technologies to enhance performance on the massively parallel system. As a result, we successfully conducted a 4-hour simulation with 80 m grid spacing over an area of approximately 600 km × 600 km in only 74 minutes using 8,192 nodes of Fugaku. The simulations revealed multiple strong vortices beneath convective clouds in the typhoon rainband region, clearly demonstrating the ability to seamlessly simulate phenomena across scales—from typhoons down to tornadoes. This achievement also highlights the potential for more accurate tornado prediction in the future. We are still on the journey forward and will continue to make progress through scientific collaboration.

Day1 (Oct. 21), Session 2

Spectral analysis of LES During Tropical Cyclone Development

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Key words: Large-eddy simulation, Intensification, Spectral analysis

Typhoon intensification is driven by multiscale processes involving complex interactions across a wide range of spatial scales. Using an idealized large-eddy simulation (LES) that captures the full lifecycle of a tropical cyclone (TC), from genesis through rapid intensification, we investigate the scale-to-scale transfer of kinetic energy (KE) during storm development.

We apply a spectral transfer analysis that resolves energy exchanges via nonlinear triadic interactions in wavenumber space. This framework allows us to quantify both the direction and magnitude of energy cascades across scales and to identify how these transfers evolve at different stages of the storm, particularly during the transition to rapid intensification. We partition the domain radially to diagnose localized cascade behaviors, such as in the eyewall and boundary layer.

To assess the impact of model resolution on these dynamics, we conduct a controlled comparison with a convective-permitting model (CPM) simulation using the same physics and environmental conditions but coarser horizontal resolution. The LES reveals more energetic and spatially variable KE transfers, particularly during early intensification, highlighting the importance of small-scale processes that are not captured in coarser models.

While previous studies have examined KE spectra and mean-eddy conversions in tropical cyclones, few have directly quantified triadic scale-to-scale KE transfers across the storm lifecycle, and none have done so in a controlled resolution experiment. Our results offer new insight into the internal energy dynamics of typhoons and demonstrate the value of high-resolution modeling for improving the representation of intensification in forecasting systems.

Day1 (Oct. 21), Session 2

Application of the rotating convection paradigm to the problem of the evolution of a tropical cyclone in a uniform environmental flow

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Key words: Rotating convection paradigm, cyclone evolution in uniform flow, boundary layer control

Over the last decade Roger Smith and I have developed a robust conceptual model of tropical cyclone evolution. The model is based on fundamental physical principles and unrestricted to axially-symmetric dynamics of convective rings. It is unrestricted also to ad-hoc geometric assumptions with tacit sources of cyclonic absolute angular momentum. In this talk I will summarize some of our recent work with John Persing that re-examines the dynamics of tropical cyclone intensification in a uniform flow. This problem is a critical benchmark because it represents a natural first step towards an improved dynamical understanding of the asymmetric and symmetric spin-up dynamics within an environmental flow with deep vertical-shear.

Complementing an earlier study by Thomsen et al., a comparison of the simulated updraft structure with that predicted by Shapiro's asymmetric boundary layer theory for a translating vortex suggests strongly that, while the surface moisture fluxes act to maintain deep convection in the near-core region of the moving vortex, the asymmetric pattern of this convection is primarily frictionally controlled rather than by surface enthalpy fluxes. An analysis of three idealized, three-dimensional, numerical simulations with and without a uniform flow has revealed a number of interesting and important differences in the evolution of the simulated vortex. Several analysis techniques are presented and interpreted including a comparison of ventilation diagnostics for the simulations, the role of eddy processes, and a novel sector partitioning method that serves to extend the classical axisymmetric spin-up ideas to an intrinsically asymmetric flow. The latter analysis highlights asymmetric features of the spin-up process in which the storm-relative tangential velocity is amplified in the main updraught sector by the strong inward flux of absolute vorticity in the lower troposphere there. This vorticity is subsequently transported into the remaining sectors by the tangential circulation, where there is a weak outward vorticity flux that alone would lead to spin down. This geometrical feature broadly explains why there is a weaker spin up rate in the presence of storm translation.

Time permitting, some implications of this work will be discussed.

Day1 (Oct. 21), Session 2

Boundary layer control of tropical cyclones

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Key words: Tropical cyclones, typhoons, boundary layer

The dynamics of the slab boundary layer model for an axisymmetric vortex are re-examined in the light of the continued relevance of this model as a benchmark for understanding aspects of tropical cyclone structure. Of particular relevance is the control the boundary layer has on the location of deep convection. The calculations show that in relatively narrow vortices, the location of maximum ascent out of the boundary layer lies inside the radius of maximum gradient wind, but as the breadth of the gradient wind profile increases, the location of maximum ascent moves outwards beyond that of the maximum gradient wind. These findings provide new insight towards understanding airborne Doppler radar observations of certain structural differences between rapidly developing and mature storms. The calculations show also the propensity of the boundary layer of broad vortices to produce secondary maxima of tangential wind and ascent out of the boundary layer well beyond the radius of maximum gradient wind. This intrinsic boundary layer feature has relevance to understanding secondary eyewall formation.

Asymmetric solutions for translating vortices will be discussed also. These complement the seminal study by Lloyd Shapiro in 1983 and provide a theoretical basis for interpreting the boundary layer influence on asymmetries of deep convective in translating tropical cyclones. Because the roots of deep convection lie within the boundary layer, this theoretical basis would seem relevant to understanding asymmetries of convection in vertically-sheared storms as well.

Suppression of Tropical Cyclone Development by Lower-Tropospheric Diabatic Heating outside the Eyewall

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Key words: idealized TC simulations, artificial intervention, Moonshot

Under Japan's Moonshot Goal 8, we have explored the feasibility of weakening tropical cyclones (TCs) via artificial intervention since 2022. Among various methods, cloud seeding has shown promise in reducing TC intensity in numerical experiments. However, the mechanisms behind this suppression remain unclear. We hypothesize that intermittent diabatic heating outside the eyewall can induce secondary circulations governed by TC-balanced dynamics, which act to weaken the primary circulation.

Using the nonhydrostatic TCM4 model, we conducted idealized TC simulations with four nested domains and 2.5 km grid spacing. We applied Sawyer–Eliassen (SE) diagnostics and tangential wind budget analysis (BA) to examine the effects of diabatic heating. The horizontal/vertical advection terms (MRA/MVA) were further decomposed using SE-derived secondary circulation (SE-MRA/MVA), enabling quantitative attribution of heating-induced changes.

We identified a "hot spot" (HS) of intermittent heating in the lower troposphere outside the eyewall (35–45 km radius). During periods when HS was active, maximum wind speeds decreased by ~3 m/s (~5%), while periods without HS showed intensification. SE diagnostics revealed that HS suppressed inflow near the radius of maximum wind (RMW) and induced vertical motion that diverted moisture away from the eyewall, weakening its persistent diabatic heating (EW). SE-MRA due to EW was $+18.9\times10^{-4}$ m/s^2, while that due to HS was -1.2×10^{-4} m/s^2.

These results suggest that targeted diabatic heating outside the eyewall can suppress TC intensification via (1) reduced radial inflow near the RMW and (2) moisture disruption to the eyewall. This work highlights a plausible pathway for artificial TC weakening, subject to further validation.

Acknowledgement
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Day2 (Oct. 22), Session 3

Tropical cyclone intensity modification by putting small cloud droplets outside the eye wall

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Key words: Tropical Cyclone Intensity, cloud microphysics, upper level clouds, nonhydrostatic model

We explore possible change of tropical cyclone (TC) intensity by cloud microphysical modification within the TC. For this purpose, we conduct numerical simulation using a global nonhydrostatic model, NICAM. A case study of Typhoon Jebi (2018) is presented. In the sensitivity simulations (MOD), we increase the number concentration of cloud droplets by 1000 times that in the control simulation (CTL) within the 100~300 km distance from the center of the incipient TC, with various vertical range and timing of the modification (more than 10 cases were conducted). The results show that the lifetime minimum central pressure of TC was increased by 5~10 hPa in the MOD simulations. The impact is greater for the cloud microphysics modification in the middle to upper troposphere then in the lower troposphere due to greater amount of ice condensates formation outside the inner core. In the MOD simulations, the cloud formation was accompanied with enhanced upward motion, latent heat release, and outward flow in the upper troposphere at around 50 km outside the eye wall during the rapid deepening stage of the central pressure. This led to subsequent change in the quasi steady-state structure of the eye wall circulation and latent heat release at the mature stage. These results are supportive of the possible mitigation of TC intensity by cloud formation (e.g., by spraying cloud nuclei or freezing of supercooled cloud water) surrounding the TC inner core. A novel aspect of our results is that the impact can originate in the upper troposphere and reach near the bottom of the TC.

Day2 (Oct. 22), Session 3

Impacts of Typhoon Intensity Variations on Surge-Induced Flooding and Economic Losses in Tokyo Bay

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Key words: Typhoon intensity, Storm surge, Economic loss, Nonlinear amplification, Tokyo Bay

Storm surge is one of the most severe coastal hazards, and its impacts are highly sensitive to changes in typhoon intensity. This study investigates how variations in central pressure and wind speed of typhoons affect surge height, inundation extent, and economic losses in Tokyo Bay. Atmospheric forcing fields were generated by the WRF model and then applied as input to the JAGURS-surge model to simulate storm surge and flooding. Based on Typhoon Faxai (2019), 24 typhoon intensity scenarios were designed by scaling pressure and wind conditions. Three sets of cases were considered: pressure-only, wind-only, and combined pressure–wind adjustments, ranging from –50% to +30% of the control case. The results show that storm surge response is strongly nonlinear. Pressure changes produced relatively gradual increases in surge and flood volume, resulting in a moderate economic loss gap of +66.3% between the weakest and strongest scenarios. In contrast, wind-induced surges amplified both the inundation area and losses substantially, with a gap of +242.5%. The combined scenarios produced the most dramatic cascading effects, with economic losses increasing by up to +289.4%. A critical threshold was identified between the +10% and +20% typhoon intensification scenarios. While peak surge height increased only by 20.9%, economic losses escalated by 71.7%. This indicates that once surge height exceeds damage-critical levels, inundated areas regarded as total loss (e.g., flood depth >2 m) expand rapidly, leading to disproportionate socioeconomic consequences. These results demonstrate the nonlinear and threshold-sensitive nature of surge-induced flood risk and provide important insights for improved loss estimation and adaptation strategies in low-lying coastal cities.

Day2 (Oct. 22), Session 3

Navigating Moral Uncertainty in Typhoon Control: A Philosophical Perspective

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Key words: ELSI, Ethics, Risk, Democracy

When we try to implement new technologies like typhoon control in society, we face several kinds of uncertainty. Obviously, one is scientific or technical uncertainty—we do not always know if the technology will work as planned. But there is another kind of uncertainty that is less obvious, but equally important: moral uncertainty. People have different views about what is morally right, and we do not know which view is correct. So, when we think about the ethical, legal, and social implications (ELSI) of new technology, we must also deal with this uncertainty about values and ethics.

How should we respond to this kind of moral uncertainty when we discuss typhoon control? In this presentation, I focus on the ideas of William MacAskill and others who have recently developed a framework for decision-making under moral uncertainty. In short, they suggest that we should assign degrees of confidence to competing moral views and then act in a way that maximizes expected moral value.

Building on this idea, I explore how such a framework can be applied to the ELSI of typhoon control. I argue that this approach provides a philosophical basis for taking a wide range of stakeholders' moral perspectives seriously. Finally, I sketch some implications of MacAskill's view for responsible research and innovation.

Day2 (Oct. 22), Session 4

Has track prediction reached its predictability limit for landfalling tropical cyclones?

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Key words: track prediction, predictability, landfalling tropical cyclones

In the last two decades, significant improvements have been made in the track prediction of tropical cyclones (TCs). Some have suggested that because of the uncertainties in the data and the identification of the TC centre, track prediction has reached its predictability limit. While this might be likely on the average, it will be shown in this study that for landfalling TCs, appreciable track errors still exist. This is especially important because a wrong landfall location would lead to a misplacement of disaster preparedness efforts, and hence potential large loss of life and property.

We first present case studies demonstrating the “systematic” biases in the numerical weather prediction (NWP) models in their prediction of landfalling TCs. Specifically, the predicted tracks tend to be slower and to the right of the observed ones. Results of idealized numerical simulations show that different land surfaces can lead to changes in both the direction and speed of landfalling TCs. Modifying the land-surface representation for real TCs in numerical experiments show that the predicted tracks are much closer to the observed. These results suggest the importance of re-examining the land surface distribution as well as boundary-layer parameterization in the NWP models.

Day2 (Oct. 22), Session 4

Paradigm shift from Human Forecaster to AI Forecaster

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Key words: AI forecast, Geostationary satellite data, validation

People have attempted to predict the weather informally for thousands of years. Ancient weather forecasting methods usually relied on observed patterns of event, also termed pattern recognition. In about 350BC, Aristotle described weather patterns in "Meteorologica".

In 1854, Le Verrier, he produced the first weather chart using a network of meteorological observations and the the telegraph, playing a key role in advancing the transition from the era of meteorological instruments to the era modern weather forecasting. In 1922, English scientist Lewis Richardson published "Weather Prediction by Numerical Process" and practical use of numerical weather prediction began in 1955.

Global big tech. and NMHS(National Meteorological and Hydrological Services) agencies are rapidly developing AI based forecasting models. The Korea Meteorological Administration, KMA) is building an operational AI forecasting system by monitoring international advances and strengthening collaboration with universities and Institutes. Three AI models have been installed and are currently used alongside the existing global numerical model (KIM, UM, ECMWF), with emphasis on short-term precipitation.

The Typhoon Research Center, Jeju National University and KMA evaluated five AI models and ECMWF IFS using eight typhoons that affected Korean Peninsula after 2020. Results showed that 's GraphCast provided the most accurate 7 day track forecasts, while ECMWF IFS most accurate of intensity. However, AI models generally underestimated intensity, indicating a need for improvement.

Although 1st and 2nd Geostationary Satellite images, KMA have enhanced intensity predictions, further progress remains necessary.

Further work will focus on expanding verification cases, improving intensity forecasts, and extending AI applications to seasonal prediction.

Day2 (Oct. 22), Session 4

Target observations and ensemble forecasts of tropical cyclones based on the nonlinear optimal methods

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Key words: Target observations, ensemble forecasts, tropical cyclones, nonlinear optimal methods

There is always forecast uncertainty in numerical forecasts/predictions. Thus, it is necessary to conduct predictability research which aims to study the predictability limit, source of the forecast uncertainty, and how to reduce it accordingly, etc. In the past several decades, Professors Mu and Duan's team have devoted themselves to the predictability research especially for severe weather and climate events as tropical cyclones. They proposed a series of nonlinear optimal methods to identify the initial and model errors those will lead to the largest forecast uncertainty. As two successful examples, these methods have been utilized to identify the sensitive areas in target observations, which help to reduce the forecast errors by additional observations with the lowest cost, and to produce finite and representative initial perturbations for ensemble samples, which can provide complete forecasts. Both have displayed improved forecast skills for tropical cyclone.

Day2 (Oct. 22), Session 4

Improving Subseasonal Typhoon Forecasts Using Global Ensemble Models and a Probabilistic Formation Index from Deep Learning

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Key words: Tropical Cyclone, Subseasonal Forecast, Deep Learning, LSTM

Subseasonal forecasts of tropical cyclones (TCs) up to four weeks ahead are operationally monitored at the Central Weather Administration (CWA) using multiple global ensemble models. In addition to the real-time forecasts of the NCEP Global Ensemble Forecast System (GEFS), TCs are objectively detected in the 46-day ECMWF ensemble and the CWA Global Ensemble Prediction System (GEPS) to support the TC Threat Potential Forecast product.

To complement these forecasts, a region-specific probabilistic TC formation index is developed and applied as a forecast confidence level (FCL). The FCL is derived from a deep learning model based on an Encoder–Decoder Long Short-Term Memory (LSTM) architecture. It incorporates the influences of large-scale environmental factors such as the Western North Pacific Monsoon Index (WNPMI), sea surface temperature (SST), Madden–Julian Oscillation (MJO), and Boreal Summer Intraseasonal Oscillation (BSISO). A special loss function is further utilized to mitigate data imbalance during training.

Evaluations of week-1 to week-4 TC forecasts over the western North Pacific show promising skill, particularly in the week-1 and week-2 ranges. The relationships between model forecast skill and the probabilistic FCL are further examined to demonstrate the applicability of the approach in real-time forecasts. Additional results will be presented at the meeting.

Day2 (Oct. 22), Session 4

Trends and variability of late season (October-November) successive landfalling tropical cyclones in the Philippine

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Key words: the Philippines, landfall, multiple, successive, tropical cyclones

The months of October and November have the most number of notable landfalling tropical cyclones (TCs; i.e., Haiyan (2013), Mangkhut (2018), Goni (2020), Ulysses (2020), etc.) in the Philippines. We investigated the landfall frequency of TCs and their drivers, and found that there is an increasing number of landfalling TCs by 0.5 TC/decade since 2000. Moreover, there is also an increase in multiple successive TC landfalls. The variability of landfalling TCs is highly correlated (r=0.78) with the product of total TC formation number and the frequency of the leading mode of the empirical orthogonal function of the 500 hPa geopotential height. This result suggests that landfall is determined not only by the total number of TCs that formed in the season, but also by how frequently the subtropical high, which is an important steering mechanism of TC, is extended westward. This also explains why there is an increasing trend in landfalling TCs since 2000. As the multi-decadal mean westward extension of the subtropical high reached the Philippine landmass in 2000, its strength became a strong determinant of landfall. The principal component depicting the variability of the subtropical high strength is correlated to global SST variabilities related to the Atlantic Multi-decadal Oscillation (r=0.56), Pacific Decadal Oscillation (r=0.41), and El Nino Modoki Index (r=0.36), all at a 99% significance level.

Day2 (Oct. 22), Session 4

Diverse response of tropical cyclogenesis to different pattern of future change in sea surface temperature

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Key words: Tropical cyclone genesis frequency, global warming, sea surface temperature pattern

Since tropical cyclone (TC) uses heat flux from ocean as its energy source, future change in sea surface temperature (SST) influences TC activity. Future projection of tropical cyclone genesis frequency is still controversial. One of the reasons is discrepancy of spatial pattern of SST projection among models. In Japan Meteorological Agency, Meteorological Research Institute (MRI), ensemble atmosphere-ocean coupled simulations are conducted from 1961 to 2100 by using MRI Earth System Model version 2.0 (MRI-ESM2) with the horizontal resolution of T319 (approximately 60 km), which is TC-permitting model. In this study, we analyzed results of SSP5-8.5 scenario run from 2021 to 2100, which has 10 ensemble members. Projected change patterns in ocean temperature and salinity from CMIP6 models (9 models and their ensemble mean) were prescribed into the ocean component of MRI-ESM2. Using 10 patterns of the projections, we evaluated response of TC genesis frequency (TCGF) to increase in tropical SST (30S–30N). Although all the ensemble members projected decrease in TCGF, the decreasing rate varied from -4%/K to -12%/K. Over the western North Pacific, eastern North Pacific and South Pacific, there were significant differences in TCGF change between ensemble members, with the signs of change being opposite. The member with the lowest reduction projected an increase in TCGF over the western North Pacific, which showed the trend of SST with La Nina-like and Pacific Meridional Mode.

Changes in tropical cyclone translation speed: Multidecadal variability and long-term trends

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Kew words: tropical cyclone; translation speed; tracks; AMO; trends

Tropical cyclone (TC) translation speed (TCS) over the western North Pacific (WNP) has experienced a long-term decreasing trend. To date, however, little is known about the multidecadal variability of TCS and its possible influence on this trend. This study investigated the multidecadal variability of the WNP TCS and the underlying physical mechanisms. Results show that the WNP TCS presents robust multidecadal variability during the past seven decades, which is dominated by the TCS over the extratropics. Further analysis shows that the Atlantic multidecadal oscillation (AMO) is responsible for the TCS multidecadal variability. AMO positive (negative) phases lead to favorable (unfavorable) large-scale environmental conditions for maintaining TCs over the extratropics, which results in longer (shorter) residence time for TCs having been accelerated by the midlatitude westerlies, thus, leading to higher (lower) TCS. The TCS phase shift strongly offsets its slowdown trend, leading to the inconsistent trends during past decades. This inconsistency may also relate to the influence of extratropical transitioned cyclones without being totally excluded. These cyclones may be inhomogeneously recorded due to the absence of satellite observation before the 1980s. Our results indicate that internal variation such as AMO may dominate TCS low-frequency variations over the past several decades. Previous studies
have attributed the inconsistent trends of TCS during different subperiods to data inhomogeneity. This study shows that AMO can modulate the TCS trends in different subperiods with phase shift, thus providing new evidence for the recent controversial TCS slowdown.

Day2 (Oct. 22), Session 5

The Aeroclipper, an instrument to look into typhoons' eye

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Key words: Tropical Cyclone in situ observation, Aeroclipper system development

The Aeroclipper is a balloon that is stabilized at ~40 m height above the ocean surface by a guide rope and that freely drifts with the surface wind in quasi-Lagrangian trajectories. An Aeroclipper can fly for up to 20 days and reach remote areas of the tropical oceans where it measures low-level dynamic and thermodynamic variables every minute. In particular, it can be used to target Tropical Cyclones (TC). If successful, the aeroclipper would converge to the TC eye and remains in it. It would then follow the TC during its life-cycle, continuously monitoring surface parameters and providing invaluable real-time information to research and operational centers. In 2007, two Aeroclippers were indeed captured by TC Dora in the Southern Indian Ocean. Unfortunately, only their positions could be retrieved. We will show that these trajectories nevertheless contain precious information to accurately spot the TC center and study the eye structure and its dynamics including hints of mesovortex presence.

The two 2007 Aeroclippers were heavy weight and expensive 110 m3 streamlined balloons. A lighter and cheaper version, easy to deploy from the coast or from a Research Vessel, have been developed at LMD and tested from Guam in 2022 and 2023 in collaboration with Guam Weather Forecast Office (WFO, Meteorologist in charge: G. C. Miller). There has been no capture by a TC so far, but the 6 test flights from Guam demonstrated that the system performed well. Two Aeroclipper systems are still available in Guam and will be deployed in optimal meteorological conditions for a TC capture. In the future, for operational TC monitoring based on these balloons, it will certainly be necessary to define a network of several optimal launching sites for each TC basin.

Observational fine-scale evolutionary characteristics of concentric eyewall Typhoon Doksuri (2023)

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Key words: Track oscillation, Rapid intensification, Rapid weakening, Concentric eyewall, Typhoon Doksuri (2023)

The variations in the track and intensity of a tropical cyclone (TC) are closely correlated with the fine-scale evolution of its structure. The fine-scale track, intensity, and structural evolution of Typhoon Doksuri (2023) can be comprehensively analyzed by combining multi-source observations. The results herein show that Doksuri (2023) experienced secondary eyewall formation (SEF), concentric eyewall maintenance (CEM), and eyewall replacement cycle (ERC) processes when entering the South China Sea and prior to landfall. These processes can be further delineated into three subsequent stages. In the first stage, the SEF phase, the secondary (outer) eyewall formed, exhibiting features that were non-concentric with the inner eyewall. Concurrently, the track of Doksuri (2023) displayed notable oscillations in both its forward translational direction and speed, accompanied by the emergence of two radial maxima centers of wind speed. Subsequently, during the second stage, the CEM phase, the geometric centers of the inner and outer eyewalls of Doksuri (2023) coincided, initiating a rapid intensification process characterized by an accelerated forward translational speed. Both the inner and outer eyewalls further contracted during this phase. In the third stage, the ERC phase, the asymmetry of the inner eyewall increased, and the outer eyewall gradually contracted while the inner eyewall dissipated until the replacement was completed prior to landfall. Accordingly, Doksuri (2023) experienced rapid weakening. These findings have the potential to enhance our understanding of the physical mechanisms governing the intricate structures of

TCs at fine scales, bolstering the forecast accuracy of TC tracks and intensities.

Day2 (Oct. 22), Session 5

The Role of Pristine Ice Crystal Shape in Cloud–Radiation Feedbacks : A Case Study of TC Idai (2019, Indian Ocean)

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Key words: Numerical modelling, Ice crystals, Cloud-radiative forcing, Microphysics

Cloud–radiation interactions in tropical cyclones (TCs) occur across a wide range of scales, making it challenging to assess their impact on trajectory, intensity, organisation, and life cycle. In particular, the role of hydrometeors—especially pristine ice crystals—remains poorly understood.

Within the non-hydrostatic French research community model Méso-NH, the two-moment microphysics scheme LIMA is coupled with the ecRad radiative transfer code to provide a more accurate representation of cloud–radiation interactions. In this framework, three kilometre-scale simulations were conducted to evaluate the sensitivity of Tropical Cyclone Idai (2019, Indian Ocean) to pristine ice crystal shapes: one with hexagonal plates, one with columns, and one with bullet rosettes. To ensure a realistic representation of air–sea exchanges, the atmospheric model is coupled to the ocean model CROCO and to the wave model WaveWatch III through the OASIS coupler.

The simulations suggest that the shape of ice crystals primarily modulates cloud structure, both in terms of hydrometeor concentration and spatial extent. For instance, the concentration and location of hydrometeors strongly differ between simulations and are linked with well-defined convective structures. This in turn induces variability in the associated radiative fluxes and modifies the radiative heating profile. This thermodynamic modification also slightly impacts the intensity, with a pressure difference of up to 5 hPa at landfall. However, the trajectory and total precipitation appear to be relatively insensitive to the ice crystal shape.

Climatological Characteristics of Depressions over the Bay of Bengal during Monsoon and Post-Monsoon Seasons

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Key words: Depression, Monsoon trough, Moisture flux, Bay of Bengal

Depressions (wind speeds up to 33 knots) over the Bay of Bengal (BoB) exhibit a primary frequency peak in August during the monsoon season and a secondary peak in October during the post-monsoon season, based on a 35-year (1990-2024) climatology. Monsoon depressions (MDs) generally do not intensify into tropical cyclones (TCs), whereas post-monsoon depressions (PDs) may develop into TCs under favorable environmental conditions. Both MDs and PDs typically form within the monsoon trough, where sea surface temperatures average around 29° C. This trough lies over the northern BoB during the monsoon and shifts southward below 20° N in the post-monsoon period. The study investigates the structural and environmental characteristics of MDs and PDs using ECMWF-ERA5 reanalysis with horizontal resolution $0.25^\circ \times 0.25^\circ$ and GSMaP (version 8, $0.1^\circ \times 0.1^\circ$) data from the past 15 years. MDs typically originate in the northern BoB and move northwestward over land with a lifespan of 3–4 days. At formation, they exhibit a relatively strong structure, with a central pressure around 993 hPa and peak vorticity of approximately 27×10^{-5} s^{-1}. They are associated with greater low-level moisture flux convergence (~1.4×10^{-7} kg m^{-2} s^{-1}) and around 90% relative humidity at 700 hPa, supporting potential instability of -1.6 K between 850–500 hPa, even after landfall. In contrast, PDs form under weaker environmental shear, with central pressures near 1003 hPa and about 50% lower vorticity than MDs. They tend to dissipate quickly after landfall due to reduced moisture supply (~ 85 g kg-1m s-1) and mid-level dry air intrusion from the northwest, which enhances a stable atmosphere. Precipitation around PD centers is, on average, 16% lower than that of MDs. Rainfall is notably concentrated in the left (right) quadrant in MDs (PDs) relative to the direction of movement.

Day2 (Oct. 22), Session 5

Defining Multi-Hazard Worst-Case Scenarios: Insights from Large Ensemble Tropical Cyclone Forecasts

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Key words: Tropical cyclone, Ensemble forecast, Multi-hazard, Worst-case scenarios, Multi-objective optimization

Ensemble forecasting is a powerful tool for supporting informed decision-making in managing multi-hazard risks associated with tropical cyclones (TCs). Although TC ensemble forecasts are widely used in operational numerical weather prediction systems, their potential for disaster prediction and management has not been fully exploited. Here we propose a novel, efficient, and practical method to extract meaningful Multi-Hazard Worst Case Scenarios (MHWCS) from a 1000-member ensemble TC forecast. We performed the ensemble atmospheric forecasting of TC Hagibis (2019) using the Japan Meteorological Agency's (JMA) 5-KM nonhydrostatic model. The simulated atmospheric predictions were serving as inputs for the JMA's operational flood forecast model, as well as statistical storm surge model. These models estimate river flooding, storm surge, and wind hazard intensities in Tokyo. By accounting for uncertainties in ensemble multi-hazard forecasts, we objectively demonstrate that Pareto-optimal solutions can effectively identify the meaningful MHWCS. These solutions illustrate complex trade-offs among competing hazard components across various forecast locations. While some identified MHWCS pose severe risks for a single hazard type or location, others present moderately high risks across multiple hazards and locations. This diversity in potential scenarios requires risk managers to prepare multiple response strategies for both imminent risks and post-disaster management. Our findings further underscore the importance of evaluating Pareto-optimal solutions to assist forecasters and risk managers in understanding how combinations of TC meteorological variables—such as translation speed, TC size, intensity, and rainfall—shape worst-case scenarios.

Day2 (Oct. 22), Session 5

Bridging System between “21·7” Predecessor Rain Event in Henan and Typhoon In-Fa (2106)

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Key words: 21·7 predecessor rain event; tropical cyclone; dynamic forcing; wave energy flux

An exceptionally heavy rainstorm during July 17–22, 2021 flooded many cities in Henan, China, when Typhoon In-Fa (2106) was located over the western North Pacific. This study investigated the remote dynamical effects of In-Fa on the “21·7” predecessor rain event (21·7PRE). By applying recently developed the multiscale window transform (MWT) to decompose and reconstruct the total field, we identified that the mid-to-low-level anticyclone ahead of In-Fa served as the bridging system connecting In-Fa with the 21·7PRE. This anticyclone played a pivotal role in transporting abundant moisture into the 21·7PRE region and contributed prominent south-northward convergence. The initial formation of the anticyclone was likely due to β effect associated with an East Asian cyclone present on 18 July 2021. While, the mid-to-low-level anticyclone was sustained by wave energy flux feeding originating from In-Fa. In addition, upper-level cold-air subsidence induced by outflow of In-Fa contributed to the maintenance of this anticyclonic ahead of In-Fa. The intraseasonal-scale easterlies prevailing between In-Fa and the western Pacific subtropical high (WPSH) to its north served as an effective waveguide for wave energy propagation which not only transport wave energy from In-Fa to the anticyclonic ahead of In-Fa at low level, but also transport wave energy from Japan to Henan along 30–40° N at upper level. The latter energy transport contributed to the intensification of the upper-level divergence over the 21·7PRE region.

In summary, In-Fa provided essentially dynamic forcing for the 21·7PRE. Coupled with local low-level mesoscale cyclone, In-Fa contributed remotely to the occurrence of the 21·7PRE.

Day2 (Oct. 22), Session 5

Re-intensification of seafalling tropical cyclones

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Key words: tropical cyclones, landfall, seafall, atmosphere-ocean interaction, numerical modelling

After making landfall, a tropical cyclone (TC) generally weakens due to loss of heat and moisture supply from the ocean and increased surface friction. However, if such a perturbed system re-enters the ocean (hereafter seafall), it can re-intensity. TCs in the western North Pacific and North Atlantic basins often pass over land and re-intensify over the ocean before making another landfall, as demonstrated by Typhoon Noru (2022) and Hurricane Ian (2022).

Studies on seafalling TCs have been limited. Brand & Blelloch (1973, 1974) summarised statistics of TCs crossing the Philippines and Taiwan, respectively, but provided little insight regarding the physical processes driving their structural evolution and re-intensification. Others have proposed land-induced eyewall replacement as a mechanism, based on full historic simulations of individual TCs crossing either the Philippines or Taiwan. However, according to Chou et al. (2011), only 57% of the TCs that cross the Philippines experience land-induced eyewall replacement, and the figure is even lower for Taiwan.

It is therefore important to establish the general processes of TC seafall re-intensification. A clear understanding of the physics behind and the associated structural evolution should allow for better predictions of their behaviour leading up to the second landfall, and could aid operational forecast and risk mitigation efforts.

Here, idealised simulations reveal that the re-intensification of seafalling TCs comprises a two-stage fast-slow process driven predominately by a change in surface friction initially and then by heating. The previous land decay causes seafalling TCs to be larger and intensify more slowly with milder inner-core contraction than in ocean-only cases. Nonetheless, they reach the same intensity but with almost twice the integrated kinetic energy. Seafalling TCs can therefore be more damaging and costly at the second landfall due to their larger footprint of destructive wind, even before they are fully re-developed.

Day2 (Oct. 22), Session 5

Effect of northward ageostrophic wind on PRE enhancement: Secondary circulation

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Key words: PRE, Typhoon precipitation, ageostrophic wind, secondary circulation

When a typhoon is located over the southern seas of Japan, heavy rainfall can occur on the mainland. This phenomenon is often described as a "typhoon stimulating the front." Similar cases of typhoon-induced remote precipitation enhancement have been observed overseas and are referred to as Predecessor Rain Events (PRE).
During the approach of a Typhoon in 2009, significant northward ageostrophic winds were observed in western Japan. Saito (2019) conducted numerical experiments with a horizontal grid spacing of 10 km and demonstrated that this northward ageostrophic wind could be reproduced in the simulation. They showed that the phenomenon are explained dynamically using the horizontal wind acceleration vector. Saito and Matsunobu (2020) focused on the water vapor flux associated with the northward wind from the typhoon. They found that while the ageostrophic wind was more pronounced in the upper levels, numerical experiments indicated that when the water vapor amount corresponding to the contribution of the ageostrophic wind was removed, precipitation in western Japan decreased significantly. Saito et al. (2023) conducted a follow-up study using a cloud-resolving model with a horizontal grid spacing of 2 km. They demonstrated that the presence or absence of upper-level moisture associated with the ageostrophic wind affects the amount of condensation, the thickness of MAUL, and the strength of convection in Japan.
It is known that when northward ageostrophic flow occur at the entrance of a jet stream, large-scale ascending motion develops as the secondary circulation, enhancing precipitation. To investigate the effect of secondary circulation of ageostrophic winds on precipitation near Japan, an experiment is conducted. A 10 km grid model is nested within a 10 km model, and the ascending motion and horizontal divergence from a dry model are subtracted in the boundary condition for running the

nested model to analyze the resulting changes in precipitation.

Poster Session

Poster 1

Infrared-Based Structural Analysis of Tropical Cyclones: A Comparative Study Across Global Basins

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Key words: IR Images, Machine learning, tropical cyclone core structure, structural analysis

Tropical cyclones (TCs) exhibit substantial morphological diversity that reflects the environmental characteristics of the ocean basins in which they develop. Despite advancements in satellite observation and artificial intelligence-based detection methods, structural variations of TCs across basins remain underexplored. This study systematically characterizes basin-dependent morphological differences using physically interpretable structural indices derived from infrared (IR) satellite imagery.

A dataset of over 6,000 IR images was compiled from the NCEP GPM MERGIR archive, spanning six global basins: the North Atlantic (NA), Northeast Pacific (NEP), North Indian Ocean (NI), Northwest Pacific (NWP), South Indian Ocean (SI), and South Pacific (SP). For each TC, best-track positions from IBTrACS were used to extract 1800 km^2 georeferenced IR imagery centered on the storm. Five structural indices axisymmetry, symmetric ratio, compactness, skewness, and eccentricity were computed from pixel-level brightness temperature patterns to quantify storm morphology.

Statistical analysis using one-way ANOVA and Tukey's HSD test revealed significant inter-basin differences ($p < 0.0001$) in all indices. TCs in the NA basin exhibited the highest symmetry, while those in the SP basin showed pronounced asymmetry and eccentricity. NI storms were highly compact and asymmetric, whereas NWP and NEP

storms displayed more balanced structures. SI storms demonstrated a combination of moderate symmetry with elevated eccentricity. Among the indices, symmetric ratio and skewness contributed most prominently to inter-basin contrasts.

These findings highlight that storm morphology is not uniform globally and is shaped by basin-specific atmospheric and oceanic conditions. By capturing these structural signatures quantitatively, the study provides a foundation for improving basin-adapted cyclone detection and classification models. The results emphasize the utility of structural metrics in enhancing the physical understanding and operational forecasting of TCs.

Poster 2

The Relationship between Typhoons Intensity Changes and Lightning Activity based on eXplainable AI analysis

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Key words: lightning wind shear machine learning XAI

We approached the question that the number of lightning shows both increases and decreases
trends when a typhoon undergoes rapid intensification (RI) stage. To identify environmental condition related to the temporal evolution trend of lightning, we applied an explainable AI "Wide Learning" developed by Fujitsu Ltd. to data on both lightning and typhoon environmental indices. We designed the AI model to determine the temporal evolution trend of lightning in RI stage. The
AI model we developed in this study was able to classify 71.4% of the increase or decrease in the
number of lightning when a typhoon undergoes RI stage. The trained AI model reveals that the
vertical shear of horizontal winds increases when the number of lightning increases, and that the
vertical shear of horizontal winds decreases when the number of lightning decreases. We
hypothesize that the response mechanism is related to the distribution of cumulonimbus clouds;
a wider spatial distribution could lead to an increase in lightning frequency.

Acknowledgement

The explainable AI "Wide Learning" used in this study was provided by Fujitsu Ltd. as a part of the Fujitsu – Yokohama National University Typhoon Research Laboratory, Collaborative Research. We thank for their collaboration.

Poster 3

The role of the moisture conveyor belt on high precipitation events over the western coast of the Philippines during the southwest monsoon season

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Key words: Enhanced southwest monsoon, high precipitation events, rainfall variability, southwest monsoon, tropical cyclones

This study uses rainfall data from 11 weather stations located along the western coast of the Philippines and identifies all the high precipitation days (HPDs) from July to September between 1961 and 2022. The HPDs were classified into direct tropical cyclone (TC), indirect TC, and southwest monsoon (SWM) HPDs depending on the location of the TC with respect to the stations. A relationship between TC distance and TC intensity with HPD rainfall amount was not found, implying that the TC's characteristics are not the only modulators of HPD rainfall over the Philippines. High precipitation events (HPEs) were then identified by grouping together the HPDs that were less than 5 days apart from each other. Lag composites of TC-related HPEs and non-HPEs revealed the presence of a moisture conveyor belt (MCB) during HPEs, but not during non-HPEs. This means that not all TCs to the northeast of the Philippines are able to produce HPEs. The presence of an MCB, which brings moisture from the Indian Ocean towards the Philippines, is integral to the occurrence of HPEs. Additionally, the formation of the MCB seems to be dependent on the moisture flux anomalies over the Arabian Sea, the Bay of Bengal, and the southern half of the South China Sea. Positive anomalies in these regions are found before both

the occurrence of HPEs and the formation of the TC, and seem to increase the likelihood of the MCB forming, thus increasing the likelihood of an HPE.

Poster 4

Characteristics and Preliminary Causes of Tropical Cyclone Remote Precipitation over China

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Key words: tropical cyclone; remote precipitation; objective identification method; characteristics; causes

At present, the identification of tropical cyclone remote precipitation (TRP) requires subjective participation, leading to inconsistent results among different researchers despite adopting the same identification standard. In this study, an objective synoptic analysis technique for TRP (OSAT_TRP) is proposed to identify TRP using daily precipitation datasets, historical tropical cyclone (TC) track data, and the ERA5 reanalysis data. This method includes three steps: first, independent rain belts are separated, and those that might relate to TCs' remote effects are distinguished according to their distance from the TCs. Second, the strong water vapor transport belt from the TC is identified using integrated horizontal water vapor transport (IVT). Third, TRP is distinguished by connecting the first two steps. Case diagnosis analysis, compared with subjective TRP results and backward trajectory analyses using HYSPLIT, indicates that OSAT_TRP can distinguish TRP even when multiple TCs in the Northwest Pacific are involved. Then, the characteristics and preliminary causes of TRP over China during the period from 1979 to 2020 are investigated. Results indicated that approximately 72.42% of TCs in the Western Pacific produce TRP over China. The peak months for TRP are July and August. The four key regions of TRP are the adjacent areas between the Sichuan and Shanxi Provinces, the northern coast of the Bohai Sea, the coast of the Yellow Sea, and the southern coast area. The typical distance between the station with TRP and the TC center ranges from 1500 to 2500 km. The south–west water vapor transportation on the west side of the TC is crucial to TRP. TRP has a decreasing trend because of the decrease in the number of TCs that generate TRP, the decrease in IVT in Mainland China, the weakening of upward motion at approximately 25° –35° N, and an increase in low-level vertical wind.

Poster 5

Cyclone Pattern Analysis Near Sri Lanka Using ERA5 and IBTrACS Data: A 40-Year Retrospective Study

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Key words: Tropical Cyclones, ERA5 Reanalysis, IBTrACS, Climate Pattern Analysis, Sri Lanka

Tropical cyclones are among the most devastating natural hazards in the North Indian Ocean, frequently affecting Sri Lanka due to its geographic proximity to major cyclone genesis regions. Despite this vulnerability, long-term cyclone analyses focused specifically on Sri Lanka remain scarce. This research presents a 40-year retrospective study of cyclone patterns near Sri Lanka using ERA5 reanalysis data and IBTrACS cyclone track archives spanning 1980–2020. The study aims to provide a comprehensive understanding of cyclone frequency, intensity, and trajectories, while highlighting temporal and seasonal variations that influence Sri Lanka's exposure to these hazards.

ERA5, offering high-resolution atmospheric and oceanic variables, is employed to extract environmental conditions such as wind, temperature, and surface pressure, while IBTrACS provides consolidated cyclone track information across multiple agencies. The integration of these datasets enables a robust statistical and spatial analysis of cyclone behavior. Key objectives include identifying trends in cyclone intensity, shifts in genesis locations, and landfall probabilities affecting Sri Lanka. Preliminary analysis indicates increasing cyclone intensity during the northeast monsoon and subtle eastward shifts in storm genesis within the Bay of Bengal, suggesting evolving risk patterns linked to climate variability.

This research is novel in presenting one of the first integrated, multi-decadal analyses dedicated to Sri Lanka, bridging meteorological reanalysis and cyclone track data. The findings provide critical insights for disaster preparedness, climate adaptation, and policy formulation in the region. By enhancing scientific understanding of cyclone risks, the study contributes to strengthening early warning systems and resilience planning for vulnerable coastal communities. Ultimately, this work underscores the importance of localized, data-driven approaches in addressing climate-induced hazards in the Global South.

Poster 6

Economic Loss Ranking of Tropical Cyclones affecting Japan in the past 50 years

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Key words: Optimization; Risk assessment; Loss estimation; Tropical Cyclones

Tropical Cyclone Hazard is a topic regarding social resilience which comes with great uncertainty. Having better understanding of the pattern of disaster impact and economic disruption will help establish feasible adaptation alternatives and comply with SDG goals.
To better assess the overall impact of tropical cyclones, we need to analyze and historical tropical cyclones' risk levels and link them with meteorological and hydrological models to have implications for the future scenarios. Islam and Sawada have established a novel approach to objectively evaluate and rank the meteorological, hazard, and impact aspects of historical TCs by implementing Pareto optimality, and identifies more impactful TCs despite the lower number of casualties and asset loss counts. Based on this result, we also highlight Kanto, Chubu, and Kansai regions as economic vulnerability hotspots, collected all the typhoon (n=105) which passed within 150km radius of these regions and special cases which poses great influence from a distance to join the ranking. We reassessed the tiers based on Hazard Potential from previous research and linked the results and tiers to pre-established loss simulations conducted by our research team. Based on the linkage, we extended from the ranking of risk level to detailed classification of multiple categories of both direct and indirect losses, and seek Pareto frontier from both the characteristics of the TCs and from the risk distribution between the 3 major economical hotspots. Based on this results, we extended further to look into the future projections from simulations of events with the corresponding reoccurrence rate and the future population distribution and structure change projections.

This research provides an extension to Multidimensional Risk Ranking of Historical Tropical Cyclones, providing both economic details and future projections which have implications for infrastructure planning and optimization.

Poster 7

Tropical Cyclones and Sea Surface Temperature Patterns over the Western North Pacific: Present and Future

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Key words: tropical cyclones, large-scale circulation, sea surface patterns, warming scenario

Tropical cyclone (TC) activity is modulated by the surrounding environmental conditions. TCs are more likely to form in regions characterized by greater large-scale ascent, high moisture content, finite-amplitude cyclonic vorticity, and other environmental factors that also favor TC intensification—such as warm sea surface temperatures (SSTs) and low vertical wind shear. Their motion is primarily governed by the large-scale steering flow, which steers TCs into environments that further influence their evolution—that is, changes in intensity and structure. These key environmental factors are closely coupled with patterns of SSTs.

This study investigates the relationship between TC activities and SST patterns using historical observations, historical model simulations, and future projections under a warming scenario. We focus on analyzing the geographic density distributions of important TC metrics—such as TC occurrence, genesis locations, and lifetime maximum intensity (LMI) positions—as well as large-scale environmental conditions associated with several dominant SST patterns over the western North Pacific. Of particular interest is the examination of their long-term trends and variations on interannual to decadal timescales. Ultimately, the study aims to (1) assess the reliability of models in representing SST-pattern-related TC activities, (2) identify the most likely changes in TC activity under future climate warming, and (3) evaluate the associated uncertainties.

Poster 8

Modulation of ENSO-Tropical Cyclone Genesis Frequency Relationship by Sea Surface Warming of Different Spatial Patterns

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Key words: tropical cyclone genesis frequency, global warming, warming patterns, ENSO

The El Niño–Southern Oscillation (ENSO) strongly modulates tropical cyclone genesis frequency (TCGF) at interannual timescales, yet how future spatial patterns of sea surface temperature (SST) warming may modify this relationship remains unclear. Here, we use high-resolution climate model simulations to quantify how three distinct SST warming patterns—uniform warming, El Niño-like warming (characterized by enhanced central/eastern Pacific warming), and La Niña-like warming (characterized by suppressed central/eastern Pacific warming)—alter the ENSO–TCGF linkage. All three warming patterns generally project a weakening of the ENSO–TCGF relationship across most tropical ocean basins. Especially, ENSO's influence on TCGF over the North Atlantic is uniformly suppressed across all warming patterns, but the degree of suppression intensifies from Uniform to El Niño-like to La Niña-like warming. However, an exception is found in the southeastern western North Pacific, where both Uniform and El Niño-like warming patterns strengthen the ENSO–TCGF relationship. In contrast, La Niña-like warming continues to weaken it. These divergent responses result from pattern-dependent changes in the Walker circulation and atmospheric heating sources, which in turn affect local large-scale environmental conditions including vertical wind shear, low-level vorticity, and mid-tropospheric humidity, thereby modulating the ENSO–TCGF relationship. Our results highlight that the spatial patterns of SST warming, not its magnitude, plays a pivotal role in modulating future ENSO–TCGF relationships, with important implications for regional cyclone risk and future seasonal forecasts.

Poster 9

Classification of historical typhoon tracks by Self-Organizing Maps and the corresponding typhoon induced rainfall patterns in Japan

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Key words: typhoons, self-organizing maps, typhoon induced rainfalls, clustering of typhoon tracks

To improve the prediction of heavy rainfall events, it is beneficial to establish a link between the characteristics of typhoon tracks and typhoon-induced rainfall. In this study, self-organizing maps are used to classify the typhoon tracks that influence Japan from 1988 to 2022 into ten relatively robust classes based on selecting geometric features of typhoon tracks, and the spatial patterns of typhoon-induced rainfall are calculated for each class. The typhoon classes are distinguished physically by their degree of curvature/linearity, travelling distances, duration/intensity, as well as starting and ending locations.

The results suggest the rainfall patterns in the south and north of 40N in the domain of Japan and the surrounding oceans are very different in terms of the magnitude and trend of extreme rainfall as well as diversity of patterns. In the region south of 40N, the rainfall patterns are less diverse with similar locations of hotspots of extreme rainfall across multiple typhoon track classes than in the region north of 40N where rainfall patterns are generally more diverse. Although extreme rainfalls is generally more severe in the region south of 40N, the trend of increasing typhoon induced rainfall is comparable for both the south and north of 40N, and for some classes, the trend for rainfall in the north of 40N can exceed that in the south.

We found the degree of curvature and location of sharp turning of typhoon tracks may influence the typhoon induced rainfall patterns in terms of magnitude and locations of intense rainfall. Moreover, the typhoon tracks are likely to be influenced by different large-scale climate factors south and north of 40° N, such as the western north subtropical high pressure system in the lower to mid latitiudes and East Asian jet strem in the higher latitudes.

Poster 10

The nature, dynamics and interactions of organized spiral banded patterns in a typhoon: an investigation based on an LES simulation and SAR imagery

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Key words: Typhoon Dynamics, Large Eddy Simulation, Spiral Rainbands, Internal Waves, Synthetic Aperture Radar

Spiral rainbands are a characteristic feature of typhoons, shaping the distribution of precipitation, vertical velocity, and vorticity around the eyewall. Over the years, various types of spiral structures have been identified, linked to processes such as internal waves, boundary-layer instabilities, and convective patterns advected by the primary vortex. While individual mechanisms have been studied in both observations and simulations, their interactions and their relationship to storm intensity and dynamics remain poorly understood. Of particular interest is the role of spiral patterns as indicators of the force balance inside and above the boundary layer, where inflow and outflow regulate intensity changes. This study investigates a Large Eddy Simulation of a mature typhoon to characterize the spiral structures emerging within the boundary layer. Distinct banded features are identified, and their nature, propagation, and evolution are disentangled, revealing how different processes interact and influence one another. Comparisons with synthetic aperture radar observations further validate the simulation, allowing spirals extracted from surface wind fields to be linked with corresponding patterns in simulated vertical velocity and precipitation. By establishing connections between observed spiral patterns and underlying circulation processes, this analysis provides a pathway toward diagnosing boundary-layer and vortex dynamics from spiral structures. Such an approach may ultimately support real-time monitoring and forecasting of typhoon intensity changes.

Poster 11

Observed and d4PDF-simulated impacts of different El Niño transition types on summer precipitation and tropical cyclone-related precipitation around Japan

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Key words: El Niño, summer precipitation, East Asia

We examine how different types of El Niño transitions from winter to the subsequent summer affect summer precipitation anomalies around Japan, with particular emphasis on their modulation of tropical cyclone (TC)-associated precipitation. The JRA-3Q reanalysis and 60-km mesh global ensemble simulations from d4PDF are analyzed. The JRA-3Q reanalysis shows that summer mean precipitation (Pav) generally increases in all transition types around Japan. However, when the Pav anomalies are separated into TC and non-TC components (Pav_TC and Pav_nTC), distinct characteristics emerge. Pav_TC increases in the El Niño developing summers, whereas it decreases in the post-El Niño summers, consistent with anomalies in TC frequency around Japan. The summer maximum daily precipitation total (Rx1d) is more strongly influenced by TC activity than Pav. The d4PDF past simulations successfully reproduce these observed characteristics. In the future simulations, the deviations from the future climatology are comparable in magnitude to those in the past climate for both Pav and Rx1d. However, when measured as deviations from the past climatology, all transition types exhibit substantially larger positive anomalies. This amplification is mainly attributable to climatological increase in the non-TC components.

Poster 12

Relationship between Typhoon Characteristics and ENSO Indices Based on the Fixed-SST Ensemble Climate Experiments by MRI-AGCM

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Key words: Typhoon, SST, ENSO, MRI-AGCM,

ENSO and global SST variations are primary drivers of TC activity worldwide. For the Western North Pacific, the physical mechanisms behind long-time variations in typhoon activity remain poorly understood. While increasing model resolution has been a key strategy to improve the representation of ENSO-related SST anomalies, such approaches often lack generality as they are based on single models. To address those issues from a different perspective, this study employed GCM simulations with fixed SST boundary conditions by intentionally removing temporal SST variability, which allows for a more direct isolation of the impact of specific SST spatial patterns on typhoon intensity. Previously, we developed the slab ocean coupled atmospheric global climate model (MRI-AGCM) by incorporating the ocean cooling induced by strong wind and then improved the model performance of typhoon intensity. Based on the coupled model, we conducted large ensemble simulations of active typhoon season under several representative SST conditions because the variability of typhoon characteristics is considered related with SST spatial patterns. The representative SST conditions were selected to cover the historical SST variability by cluster analysis of 70 years of historical SST data. Based on the ensemble experiment, we evaluated the correlation of the ENSO indices of SST spatial patterns and the simulated typhoon intensity. As a result, The ENSO indices generally correspond to the variation in the maximum wind speed, regardless of the model resolution. The correlation coefficient is 0.88 and 0.92 for Niño West and 0.50 and 0.52 for Niño 3 in the 60 km and 20 km models, respectively. The results of the fixed-SST 20 km model simulation showed a slightly higher correlation than the 60 km model. The intensity of typhoons tended to increase as the Niño West SST anomalies became negative.

Poster 13

Characteristics and Near-Landfall Behavior of Tropical Cyclones Affecting the Philippines (1979–2024)

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Key words: landfall, Philippines, IBTrACS, Rapid Intensification, Rapid Acceleration

The Philippines faces frequent and high-impact tropical cyclones (TCs), yet important questions remain about how storm behavior evolves as they traverse national warning domains. We analyzed 372 landfalling TCs from 1979–2024 across the Tropical Cyclone Information Domain (TCID), Advisory Domain (TCAD), the Philippine Area of Responsibility (PAR), and the Philippine Coastal Waters (PCW), which we used here as a landfall proxy. Through domain-level statistics, latitude-dependent characteristics, and temporal evolution centered on landfall, we offer a multidimensional view of how storm intensity and motion evolve as TCs approach and cross the archipelago.

We find that while storms often linger within TCAD (median: 117 hours) and PAR (median: 84 hours) for several days, their interaction with the coastal zone is brief (median: 21 hours). A subset of storms undergoes rapid intensification (RI) within 24 hours before landfall, reaching peak intensity just prior to or at landfall, highlighting critical operational challenges. These RI cases often begin within PAR, emphasizing the need for improved nearshore monitoring and forecast responsiveness. We also find a strong latitude dependence: southern landfalls are faster and tend to accelerate more rapidly, while northern landfalls are typically stronger and slower, increasing the risk of prolonged impacts.

These insights reinforce the need to anticipate not only the number of storms, but also how quickly, how strongly, and how abruptly they may evolve near landfall.

Poster 14

Aerosol Sensitivity Experiments on an Isolated Cumulonimbus under a Typhoon Environment Using the Super-Droplet Method

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Key words: aerosol, typhoon, the Super-Droplet Method

Under the Moonshot Research and Development Program Goal 8, we are exploring typhoon modification techniques such as aerosol injection (cloud seeding). Since bulk or bin schemes rely on parameterized microphysics, they struggle to represent supercooled liquid water accurately. The Super-Droplet Method (SDM), which explicitly solves the governing equations for individual particle processes, offers a promising alternative. This study applies SDM to investigate the response of isolated cumulonimbus clouds in a typhoon environment to changes in aerosol concentration. We first reproduced Typhoon Hagibis (2019) with the nonhydrostatic model SCALE-RM (ver. 5.4.5). Thermodynamic profiles were azimuthally averaged within a 3° –5° radius from the typhoon center during its developing stage and used as the environmental sounding. Idealized warm-bubble experiments were then performed with SCALE-SDM, using a horizontal and vertical resolution of 200 m. The control run assumed a soluble aerosol number concentration of 10^5 cm^{-3}, and sensitivity experiments increased this concentration by factors of 2–5.
Results showed that higher aerosol concentrations delayed the peak of precipitation intensity between 10–40 min after convection initiation, although accumulated rainfall after 60 min did not display a systematic trend. Supercooled liquid water content within the freezing layer increased with aerosol concentration, suggesting that droplet growth by collision–coalescence and riming was suppressed due to smaller droplet sizes in the high-CCN cases.
These findings demonstrate that in a typhoon environment, elevated aerosol concentrations increase cloud droplet number in the lower troposphere and enhance supercooled liquid water in the upper troposphere. This highlights the potential role of aerosol loading in modifying storm microphysics. Future work will focus on combining CCN increases with enhanced freezing aloft to improve the scientific basis

and accuracy of cloud seeding strategies for typhoon modification. This study is supported by JST Moonshot R&D Program (Grant Number: JPMJMS2282-03 and JPMJMS2283-13).

Poster 15

The Dependence on Moisture Distribution in Different Convection Aggregation Stages for Tropical Cyclone Seed Genesis

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Key words: convection aggregation, convection cluster, TC seed genesis, idealized cloud-resolving model

This study proposes a novel idealized experimental design to investigate the process by which convection clusters transition into tropical cyclone seeds (TC seeds), with a particular focus on the role of convection-induced secondary circulation. We use cloud-resolving simulations of convection self-aggregation to represent various initial states of convective cloud clusters, ranging from scattered to aggregated. We then introduce a uniform Coriolis force to these initial states to simulate and examine the short-term variations in seed intensity under the same background vorticity. The centroid of positive vorticity is used to identify both the convergence center of non-rotating convection clusters and the cyclonic circulation center of the TC seed to diagnose axisymmetric differences in water vapor distribution, convective core cloud, and secondary circulation among different convection clusters. In convective clusters without an established secondary circulation, the tangential wind of the vortex remains weak and its structure loose. In contrast, when secondary circulation develops, the moist vortex effectivity intensifies within three days. Moisture distribution determines the occurrence of the convection core clouds which contribute the updraft of the secondary circulation. We identify the non-linear relationship between low-level inflow and vortex intensification, which indicates the criticality in TC seed genesis. This can be a useful framework to evaluate moist vortex development in different cloud-resolving models.

Poster 16

Enhanced Cyclone Intensification in the Bay of Bengal: The Role of Marine Heatwaves and Implications for Coastal Bangladesh

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Key words: Marine Heatwaves, Tropical Cyclones, Bay of Bengal, Bangladesh, Cyclone Intensification

The Bay of Bengal (BoB) is a highly vulnerable region to tropical cyclones (TCs), which have shown an increasing trend in frequency and intensity in recent decades, posing significant threats to the densely populated coastal regions, particularly Bangladesh. Concurrently, the BoB has experienced a rise in marine heatwave (MHW) events, characterized by anomalously high sea surface temperatures (SSTs) that persist for days to months. This abstract explores the intricate interactions between MHWs and TC intensity in the Northern Bay of Bengal, with a specific focus on their implications for Bangladesh's coastal region.

Recent studies indicate a strong correlation between the occurrence of MHWs and the rapid intensification (RI) of TCs in the BoB. MHWs contribute to higher oceanic heat content, providing a larger energy reservoir for developing and intensifying TCs. This elevated heat content can lead to reduced vertical wind shear and increased atmospheric instability, both conducive to TC strengthening. For instance, the Super Cyclonic Storm Amphan in May 2020, one of the strongest cyclones in the history of the Bay of Bengal, was preceded by a significant MHW event, highlighting the critical role of ocean warming in its rapid intensification. Similarly, Cyclone Mocha in May 2023, which became the strongest cyclone on record in the North Indian Ocean, also intensified rapidly amidst favorable oceanic conditions, including potential MHW influence.

The coastal region of Bangladesh is particularly susceptible to the compounding impacts of intensified TCs and MHWs. The increased frequency and intensity of TCs,

fueled by MHWs, exacerbate storm surges, coastal erosion, and saltwater intrusion, threatening livelihoods, infrastructure, and ecosystems. The long-term implications include altered precipitation patterns, sea-level rise, and damage to marine ecosystems, further stressing the already vulnerable coastal communities. Understanding these complex interactions is crucial for improving TC forecasting, developing effective early warning systems, and implementing robust adaptation and mitigation strategies in Bangladesh.

This abstract aims to synthesize current knowledge on the interplay between MHWs and TC intensity in the Northern Bay of Bengal, drawing upon recent observational data and modeling studies. We will present a case study focusing on the coastal region of Bangladesh, analyzing specific events where MHWs likely contributed to the intensification of landfalling cyclones. The findings will underscore the urgent need for regional climate resilience planning and integrated coastal zone management to address the escalating risks posed by these extreme weather phenomena in the context of a changing climate.

Poster 17

Understanding The Impact Cold Pools Have On An Approaching Typhoon Using The Non-hydrostatic Icosahedral Atmospheric Model (NICAM)

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Key words: typhoons, cold pools, evaporative cooling

The Moonshot project of the Typhoon Control Research is aiming for a safe and prosperous society. Our research focuses on implementing artificial means to reduce the intensity of an approaching typhoon by generating an artificial atmospheric cold pool. This cold pool is supposed to act as a barrier to convection thereby reducing the amount of heat being fed to the storm. We will use more than one cold pool as a cooling source as opposed to one to see how the approaching cyclone responds to them. Experiments will be conducted on the stretched version of the non-hydrostatic icosahedral atmospheric model (NICAM) with a minimum grid spacing of 1.4km. The cold pools will be generated by evaporative cooling. The cooling sources will be circular, with heights of 1km and radii of 5km. To achieve a constant cooling rate of 10K/hr, we calculate that 4000 tonnes/hr of water would be needed to simulate the rain for the cooling sources. We will test several numbers of the forces that will be situated such that they form a ring-like structure inside the eyewall. The typhoon that we will study is Typhoon Jebi and the model will run from 2nd September to 4th September 2018, 48 hours before landfall in Japan. We will observe the time evolution of the minimum sea level pressure and the maximum 10m wind speed. Snapshots of the slp, 10m wind speed, 2m-temperature, and total precipitation at selected times will be studied to see how the cyclone responds. The differences from the control experiment will be studied to understand the impact the cooling sources will have on the typhoon. After assessing the results, we will decide how effective this method of artificially reducing the typhoon's intensity is.
JST Moonshot R&D Grant Number JPMJMS2282 supported this research.

Poster 18

High-Resolution Modeling of Philippine Damaging Typhoons Under Past and Future Climates: Insights from the Storyline Approach

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Key words: Tropical Cyclones, Global Warming, Storyline Apporach, Damaging typhoons, Philippines

This study investigates potential changes in the characteristics and impacts of three of the most damaging tropical cyclones (TCs) in the Philippines - Haiyan (2013), Bopha (2012), and Mangkhut (2018) - under past and future climate conditions using the Storyline Approach. High-resolution simulations were conducted using the Weather Research and Forecasting (WRF) model at 5 km with cumulus parameterization (5 kmCU) and 3 km convection-permitting model (3 kmNoCU), incorporating PGW deltas derived from selected CMIP6 models. Future climate simulations (SSP5-8.5) consistently produce more intense TCs, with mean maximum wind speed increases of 4%, 3%, and 14% for 5 kmCU runs and 14%, 4%, and 12% for 3 kmNoCU runs of Haiyan, Bopha, and Mangkhut, respectively. Track, translation speed, and size changes are relatively small. The cyclone damage potential index increases by up to 37% in future scenarios. Pre-industrial simulations suggest a weak historical climate influence on TC intensity and negligible impact on track and size. In addition, TC-associated precipitation responses were evaluated across past, present, and future climates. A consistent increase in mean inner-core precipitation is found, with rates rising by ~6% and ~8% from pre-industrial to present in the 5 km and 3 km experiments, respectively. Future simulations project a ~6% per 1K SST increase in rainfall, aligned with Clausius-Clapeyron scaling, though warming of land and sea surfaces alone yields increases exceeding CC expectations, reaching up to 13% per 1K. These increases are linked to enhanced moisture, latent heating, and stronger inner-core updrafts, resulting in broader and more intense precipitation fields. These findings highlight the robust intensification and hydrological impact of future TCs in

the Philippines, underscoring the importance of high-resolution modeling to resolve nonlinear responses in TC intensity and precipitation under warming climate.

Poster 19

Response of convection to forcing that creates a cold pool: possible impact on typhoon intensity by artificial forcing

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Key words: typhoon dynamics, cold pool, eye wall, typhoon intensity

We introduce our research activities at the Typhoonshot project, focusing on implementing intervention methods to reduce the intensity of approaching typhoons. As part of this effort, we have identified several potential approaches that can be realized with current technology. In this talk, we specifically focus on our investigation of the atmospheric response to cold pool forcing, using numerical simulations to evaluate how imposed cooling in the planetary boundary layer influences convection, with particular emphasis on its effects on tropical cyclone intensity and structure.

As a first step, we conduct idealized simulations under radiative-convective equilibrium in a doubly periodic domain. A constant cooling source of 1 K h^{-1} is applied below 1 km altitude. The results show that such forcing effectively suppresses convection over a horizontal scale of approximately 100 km. A simple column model indicates that the horizontal extent of the cold pool is governed by the balance between the mass flux strength and the surface heat supply.

Building on these findings, we extend our analysis to tropical cyclone simulations by applying artificial cold pool forcing within the eye region. These experiments are conducted using a stretched version of the non-hydrostatic icosahedral atmospheric model (NICAM) with a minimum grid spacing of 1.4 km. Multiple cooling sources are arranged in a ring-like structure inside the eyewall to evaluate their combined effect on storm intensity. The differences from a control experiment are analyzed to assess the impact of the cooling sources on typhoon structure and strength. Based on these results, we aim to evaluate the potential effectiveness of this method as a strategy for artificial typhoon intensity reduction.

Poster 20

Study on the Formation of Large-Scale Circulation in Thermally Driven Vortices

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Key words: Vortex, Large-scale circulation, Rayleigh-Bénard convection, Rotation, Dry tropical cyclone

The large-scale circulation (LSC), as one of the critical structures of thermally driven vortices (e.g., tropical cyclones), has not emerged as anticipated in studies employing the standard rotating Rayleigh-Bénard convection (RRBC) model. Axisymmetric vortex simulations were thus conducted to investigate the minimum necessary conditions for LSC to develop. The robust structure of LSC consists of an ascending branch of intense convection along the eyewall, characterized by the negative tangential vorticity, and a descending branch that expands radially outward to its dynamic or geometric limit. Based on the force budget analysis, it is proposed that gradient wind balance is nearly satisfied at the eyewall, while the radial expansion of LSC is dominated by inertia. Compared with the basic RRBC oscillation mode, a solid eyewall resistant to disruption from the inner-core oscillations is necessitated to sustain LSC development. Additionally, the asymmetric thermal boundary conditions are essential for generating net heat injection to dampen the oscillations and prevent the radial outflow inertia from severe vertical interference. A positive feedback exists to reinforce the stability of core structure. The inflow of LSC formed transports more heat into the warm core, and intense ascending branch protected by eyewall gives rise to a warm wall, coinciding with the eyewall, that further dampens the oscillations in warm core. Consequently, both the eyewall and LSC are strengthened under continuous energy influx. In the parameter space, a sufficiently high Rayleigh number facilitates vigorous updrafts and horizontal circulation in the vicinity of eyewall; a moderately high Rossby number mitigates the rotational suppression of convection; and a small Prandtl number is more favorable for inertia preservation.

Poster 21

Impacts of Summer Madden-Julian Oscillation Diversity on Multiple Tropical Cyclone Events over the Western North Pacific

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Key words: Multiple tropical cyclone events, Madden-Julian Oscillation, diversity, western North Pacific

While previous studies have extensively examined the Madden–Julian Oscillation (MJO) influence on tropical cyclone (TC) activity, they often overlook the substantial diversity in MJO propagation behavior. This study addresses this gap by classifying summer MJO events into four distinct patterns—Stationary (Stand), Jumping (Jump), Slow Eastward Propagating (Slow), and Fast Eastward Propagating (Fast)—using a k-means clustering method. We investigate how each MJO pattern modulates the occurrence of multiple tropical cyclone events (MTCEs; multiple TC formations within 3 days) over the western North Pacific (WNP) and explore the associated physical mechanisms. Results show that the Slow and Fast patterns account for ~80% of all MTCEs, with the Slow pattern contributing the most (59%). The Slow pattern is characterized by prolonged eastward propagation and a broad meridional extent, which enhances moisture convergence and ascending motion, thereby promoting widespread TC genesis. The Fast pattern is associated with a more zonally extended monsoon trough and enhanced vorticity stretching, supporting MTCE formation but with less clustering due to its rapid progression. In contrast, the Jump pattern exerts a weaker and more localized influence, while the Stand pattern—with convection confined to the Indian Ocean—has negligible impact. These results highlight the critical role of MJO diversity in shaping intraseasonal TC variability and offer insights for improving TC prediction over the WNP.

Poster 22

Shifted Relationship between the Pacific Decadal Oscillation and Western North Pacific Tropical Cyclogenesis since the 1990s

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Key words: Tropical Cyclogenesis; Pacific Decadal Oscillation; Pacific Meridional Mode

The Pacific Decadal Oscillation (PDO) and Pacific Meridional Mode (PMM) are prominent climate modes in the North Pacific with well-established impacts on tropical cyclone (TC) genesis in the western North Pacific (WNP) basin. While previous research has primarily focused on the roles of the PDO and PMM in regulating TC genesis through the modification of large-scale environmental factors, this study investigates the evolving influence of the PDO on WNP TC genesis since the 1950s. Remarkably, our analysis reveals a shift in the PDO-TC genesis relationship, transitioning from a significant negative correlation to a significant positive correlation since the 1990s. This shift is attributed to variations in the specific large-scale factors through which the PDO affects TC genesis. Furthermore, this study suggests that these changes appear to be linked to the PMM strengthening on the interdecadal timescale in recent decades. The linkage of the PMM strengthening to the PDO-related atmospheric circulation is further confirmed by the results of a 500-year pre-industrial numerical experiment, suggesting that the PMM strengthening may result from natural internal variability. The results underscore the non-stationary relationship between PDO and WNP TC genesis, with the PMM intensity probably influencing their relationship.

Poster 23

Movement of a tropical cyclone due to effective-β-gyre

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Key words: TC track, β-gyre, Numerical simulation

A tropical cyclone (TC) generally moves following the large-scale atmospheric flow in the environmental field, known as the steering flow, as well as β-gyre effect, which moves a TC to the northwest direction according to the meridional gradient of planetary vorticity in the northern hemisphere. If we recall that the conventional β-gyre effect stems from the conservation of the reference absolute vorticity, a horizontal gradient of large-scale relative vorticity can play a role on the TC movement as well as planetary vorticity. However, only a few studies have focused on such effects. In this study, we extended the concept of the β-gyre to the ""effective-β-gyre"", which considers the gradient of large-scale relative vorticity in addition to the planetary vorticity gradient. As a first step, we examined the movement of a 2D barotropic vortex due to the effective-β-gyre.

We used the SPMODEL provided by the GFD-DENNOU Club. The domain is 9600 km by 9600 km, and a time step is 0.02 day. We assumed a basic field with large-scale meridional relative vorticity gradients on both the f-plane and β-plane. We varied the vortex radius and intensity.

On the f-plane, the barotropic vortex moved to the northeast direction. This drift showed a tendency to move more quickly to the northwest direction relative to the basic field as the vortex radius and intensity increased. On the β-plane, a similar trend was seen, but the barotropic vortex moved even more quickly to the northwest direction compared to the f-plane.

This result implies that in real atmospheric conditions, such as the southern edge of the Pacific high or the westerly jet, where a TC is embedded in the gradient of large-scale relative vorticity in the environmental field, the effective-β-gyre may influence in the movement of TC.

Poster 24

Characterizing Rapid Intensification in Tropical Cyclones: A Multi-method Approach

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Key words: Rapid intensification index, machine learning, tropical cyclone

Rapid intensification (RI) of tropical cyclones (TCs) presents complex characteristics, posing significant challenges for accurate forecasting. The current RI definition is based on approximately the 95th percentile of overwater intensity changes in the National Hurricane Center (NHC) best-track database for the Atlantic and eastern North Pacific basins during 1995–2012, evaluated at 12-, 24-, 36-, and 48-hour lead times. This study investigates the deterministic differences in TC structure between RI and non-RI cases, using varying RI definitions, with data from the International Best Track Archive for Climate Stewardship (IBTrACS) in the western North Pacific from 1959 to 2022. Composite analysis was conducted using azimuthal averages of equivalent potential temperature, potential vorticity, and vertical velocity from ECMWF Reanalysis v5 (ERA5) data to identify optimal RI thresholds.
Additionally, linear regression, constrained non-linear ridge regression, and machine learning techniques, such as Random Forest, Support Vector Regression (SVR), and Artificial Neural Networks (ANN), were employed to evaluate the RI index. Results show that, under the 95th percentile RI definition, the RI threshold has significantly increased over the past decade, reaching 42.5 kt/24h, compared to 35 kt/24h reported by Lee et al. (2016). This upward trend indicates an intensification in tropical cyclone strength, particularly during RI events. Linear models revealed that RI cases exhibit the most significant differences in equivalent potential temperature, potential vorticity, and vertical velocity compared to non-RI cases at RI thresholds of 65 kt/24h and 75 kt/30h. Furthermore, constrained non-linear ridge regression and the three machine learning approaches demonstrated robust performance in assessing the RI index across various RI thresholds, underscoring their potential for enhancing RI prediction.

Poster 25

Contribution of mesoscale descending inflows to the outer tangential wind maximum of Typhoon Shanshan (2024) simulated by a numerical model

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Key words: Secondary eyewall formation, numerical model, mesoscale dynamics

Secondary eyewall formation (SEF) often occurs outside the primary eyewall cloud surrounding the eye in developed tropical cyclones (TCs). After the SEF, the TCs experience a series of structural changes: dissipation of the primary eyewall, contraction of the secondary eyewall, and re-intensification on a short time scale ~ 1 day, called the eyewall replacement cycle. Several mechanisms of the SEF have been proposed. In particular, the SEF mechanism related to a mesoscale descending inflow (MDI) is explained as a dominant process, based on observations and idealized numerical experiments. The secondary maximum of tangential wind located at the secondary eyewall radius can be generated by the inward transport of momentum associated with the MDI seen at middle levels in outer rainbands.

In this study, numerical experiments were conducted to quantitatively examine the contribution of the MDI to the SEF observed in Typhoon Shanshan (2024), using a regional nonhydrostatic model at a horizontal resolution of 1 km. The simulated typhoon structures using two different initial conditions were compared with Doppler radar observations operated by the Japan Meteorological Agency. MDI was reproduced in both experiments, but the SEF was reproduced in only one experiment. Budget analysis of axisymmetric tangential wind indicated that inward transport of the momentum by MDI was represented in both experiments. On the other hand, only the experiment reproducing SEF showed a net acceleration of the axisymmetric tangential wind at around the outer eyewall radius. A Sawyer-Eliassen diagnosis indicated that the middle-level cooling in the outer rainband can contribute to the large momentum advection by the MDI. The present study suggests the following: (1) the MDI is a necessary condition for the SEF, and (2) there can be other factors causing the tangential wind maximum in the outer eyewall.

Poster 26

Torrential Remote Precipitation of Typhoon Nesat (2022) over the Greater Taipei Area: Dual-polarization Radar Analysis and Ensemble Simulations

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Key words: Remote Precipitation; Dual-polarization Radar Analysis; Ensemble Simulations

Remote precipitation associated with tropical cyclones (TCs) is one of the challenging weather events. Such events are caused by interactions between TC outer circulation and environmental factors such as cold frontal systems or monsoons. The remote precipitation event related to Typhoon Nesat (2022) is characterized by notable differences (e.g., rainfall hotspots, Siberian High and secondary moisture transport) from other cases previously discussed in the literature. Based on the above unique features, the objective of this study is to investigate the mechanisms that lead to torrential and persistent rainfall in the Greater Taipei Area (GTA). Dual-polarization data from the Wufenshan radar reveal distinct precipitation characteristics between the rainband stage (R-stage) and the convergence stage (C-stage). The R-stage features deeper convection, while the C-stage is dominated by enhanced low-level convergence, leading to significant and prolonged precipitation. The results of ensemble simulations based on the Weather Research and Forecasting model highlight the critical role of frontogenesis in driving heavy rainfall in the GTA. Stronger northeasterly winds and a sharper moisture gradient in the Taiwan Strait are positively correlated with rainfall intensity. Additionally, moisture transport along the edge of the monsoon trough (MT) contributes significantly to the event, acting independently of Nesat's primary circulation. These findings underscore the joint interaction between MT dynamics and local northeasterly flows as a key driver of this torrential remote precipitation event, distinguishing it from mechanisms identified in previous studies. This study provides new insights into the complex interactions

between TCs, environmental flows, and mesoscale processes, enhancing understanding of extreme precipitation events in the late TC season in Taiwan.

Poster 27

On the size-dependence in tropical cyclone intensification theory

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Key words: tropical cyclone, intensification, dynamics

Previous observational studies have shown that the intensification rate (IR) of a tropical cyclone (TC) is often correlated with its real-time size. However, no any size parameter explicitly appears in the recent time-dependent theory of TC intensification, while the theory can still well capture the intensity evolution of simulated TCs. This study provides a detailed analysis to address how TC real-time size affects its intensification and why no size parameter explicitly appears in the theory based on the results from axisymmetric numerical simulations. The results show that the overall correlation between the TC IR and real-time size as reported in previous observational studies, in terms of both the radius of maximum wind (RMW) and the radius of 17 m s21 wind (R17), is largely related to the correlation between the IR and intensity because the size and intensity are highly interrelated. As a result, the correlation between the TC IR and size for a given intensity is rather weak. Diagnostic analysis shows that the TC real-time size (RMW and R17) has two opposing effects on intensification. A larger TC size tends to result in a higher steady-state intensity but reduce the conversion efficiency of thermodynamic energy to inner-core kinetic energy or the degree of moist neutrality of the eyewall ascent for a given intensity. The former is favorable, while the latter is unfavorable for intensification. The two effects are implicitly included in the theory and largely offset, resulting in the weak dependence of the IR on TC size for a given intensity.

Poster 28

Unveiling the dominant factors in controlling long-term variability of Northwest Pacific tropical cyclone intensification rates

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Key words: tropical cyclone; intensification rates; long-term variability; dominant factors

Tropical cyclones (TCs), especially intense TCs, pose serious threats to life and property particularly in the affected coastal regions. Understanding the factors determining the TC intensification rate (IR) remains a great challenge. This study identifies the dominant factors responsible for the observed significant increase in TC IR over the western North Pacific in recent decades using the energetically based dynamical system model of TC intensification. It is found that the environmental dynamical efficiency mainly contributed by vertical wind shear and upper-level divergence is responsible for the long-term changes in TC IR during the strong TC stage, but it played a secondary role in the long-term changes in IR during the weak TC stage. The latter were primarily contributed by the maximum potential intensity, which is a strong function of sea surface temperature. Results also strongly suggest that global warming is the primary driver of the long-term changes in TC IR.

Poster 29

Impact of Cloud Condensation Nuclei Concentration on Convection During the Genesis of Typhoon Faxai in 2019

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Key words: Tropical cyclone, genesis, JST Moonshot Goal 8, cloud seeding

As part of JST Moonshot Goal 8, we explore intervention in tropical cyclones (TCs) by cloud seeding. This study investigates the potential for intervention during the genesis phase of TCs and examines how cloud condensation nuclei (CCN) concentration influences convective cloud characteristics and TC genesis. According to Rosenfeld et al. (2008), low CCN concentration produces fewer but larger droplets in clouds, leads to earlier raindrop formation, reduces cloud water transport aloft, decreases diabatic heating, and suppresses deep convection. In contrast, higher CCN enhances convection. Since TC genesis is a convection process, CCN concentration can affect it. We studied a disturbance in an easterly wave that developed into Typhoon Faxai (2019) at 18 UTC on September 4 over the northwestern Pacific. Numerical simulations were conducted with the WRF-ARW version 4.4 (Skamarock et al., 2019) using 6 km horizontal grid spacing and 45 vertical levels. Simulations were initialized at three different times on August 29, and integrated until 00 UTC on September 6. To examine the impact of CCN concentration, we used the Thompson aerosol-aware two-moment bulk scheme in three experiments: (i) STD (50–300 cm^{-3}), (ii) CLEAN (5–30 cm^{-3}), and (iii) POLLUTED (500–3000 cm^{-3}). Minimum-sea-level-pressure drops began around September 2 in STD case, but drops occurred later in POLLUTED case. CLEAN cases showed more gradual decreases, smaller convective areas, and weaker vortex intensity. According to Kilroy et al. (2017), vertical vorticity transport by convection is important for vortex intensification during genesis under easterly waves. In CLEAN cases, weaker convection near the disturbance center, caused by lower CCN concentration, likely suppressed vertical vorticity transport, leading to weaker vortex development. These results suggest that promoting early raindrop formation may effectively suppress TC genesis.
Acknowledgements: This work was supported by JST Moonshot R&D (JPMJMS2282-04).

Poster 30

Idealized Numerical Simulation to understand the impact of Condensation Nuclei Concentration on Tropical Cyclone Intensity

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Key words: Tropical cyclone, Idealize, Intensity, JST Moonshot Goal 8, Cloud seeding

In the JST Moonshot Goal 8 program, we approach to develop tropical cyclone (TC) weakening techniques through cloud seeding. This study examined how cloud condensation nuclei (CCN) concentrations influence TC intensity. Higher CCN tended to increase central pressure and indicate weakening. We found that these trends were associated with changes in angular momentum distribution and diabatic heating. Previous studies (Zhang et al., 2008; Rosenfeld et al., 2012) suggested similar trends, but the mechanism remains unclear. To investigate a detailed mechanism, we performed idealized TC simulations using SCALE-RM with a two-moment bulk scheme (Sato et al., 2015; Nishizawa et al., 2015). We used 3 km horizontal grid spacing with 45 vertical layers and carried out 10 days integration. A weak vortex initiated the TC, which reached a mature state on the 5th day. We conducted two cases that changed CCN concentration in the whole domain: (i) Clean was no change of CCN; and (ii) Polluted was increased to 1000 cm-3 after 5th day. Results showed that polluted conditions produced a weaker TC. Maximum sustained wind speed decreased by 7 m s-1, and central pressure increased by 12 hPa, averaged over the period of mature stage. The radius of maximum wind remained at 27 km. We defined the inner-core as 3 times of RMW (81 km). The amount of diabatic heating decreased (increased) inside (outside) of the area, while insignificantly changed in the total area of heating. Dynamically, angular momentum increased in free atmosphere in the radius of 100 km but decreased near the center. This implies there are two types of responses, the decrease in heating near the TC center; and the transport of angular momentum to the TC center causes the TC to weaken.
Acknowledgement: This work was supported by JST Moonshot R&D (JPMJMS2282-04).

Poster 31

Oceanic Modulation by the BSISO and Its Impact on TCs in the WNP Simulated by NICOCO

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Key words: BSISO, TCHP, NICOCO

Previous studies have indicated that sea surface temperature (SST) anomalies lead precipitation anomalies on subseasonal time scales (25–90 days). However, how oceanic heat anomalies are modulated by the Boreal Summer Intraseasonal Oscillation (BSISO), and how this modulation affects tropical cyclone (TC) activity, remain poorly understood due to the sparse spatio-temporal coverage of oceanic observations and the limited ability of coupled atmosphere–ocean general circulation models (AOGCMs) to reproduce both the BSISO and TCs.
Here, we conducted 10-year, 20-member seasonal forecast experiments using a high-resolution coupled GCM (NICOCO: 14-km atmosphere and 0.25° ocean) covering the TC season in the western North Pacific (June–October). The results show that tropical cyclone heat potential (TCHP) increases during BSISO phases 3–6 and decreases during phases 7–2. Correspondingly, mean TC intensity is higher in phases 6–7 and lower in phases 2–3. These findings suggest that modulation of subsurface oceanic conditions contributes to the phase-dependent variability of TC intensity in the WNP.

Poster 32

Wavenumber-1 Ocean Surface Wind Speed Asymmetries in the Tropical Cyclone Eyewall Observed by Spaceborne Synthetic Aperture Radar

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Key words: Wind asymmetry, SAR

Tropical cyclone (TC) ocean surface wind asymmetries have been shown to occur in response to storm motion and vertical wind shear. In most cases, earth-relative wind speed maxima occur on the right side of the storm motion, whereas in cases where vertical shear is much greater than storm motion, they can occur on the left side. Furthermore, recent studies have shown that the azimuthal location of wind maxima depends on the relationship between low-level (850-hPa) environmental winds and vertical shear, which produces asymmetries in sea surface fluxes and then leads to differences in TC evolution.

Ocean surface wind retrievals from spaceborne Synthetic Aperture Radar (SAR) have become possible over the past decade, enabling observations of the inner core wind structure of TCs at high resolution without saturation at high wind speeds. In addition, recent atmospheric reanalysis datasets, such as ERA5, generally underestimate TC wind speeds, but, to some extent, provide reliable environmental winds. In this study, we revisited previous studies and examined TC surface wind asymmetries in the eyewall using SAR and ERA5 datasets. Specifically, we investigated wavenumber-1 (WN-1) asymmetries in amplitude and phase in relation to vertical wind shear, storm motion, and low-level environmental winds.

Both datasets show asymmetries in relation to vertical shear and storm motion, consistent with previous studies, but the SAR wind dataset exhibits large variability. The amplitude of WN-1 ERA5 wind asymmetries was generally less than 5 m/s, smaller than that in SAR winds, and showed a weak correlation with the amplitude of SAR asymmetries. The relationship among low-level winds, upper-level winds, and the steering flow, which are related to vertical shear, suggests that the azimuthal location of wind maxima is primarily determined by the low-level wind direction. We

plan to further investigate its relationship with precipitation asymmetries and the potential for estimating wind asymmetries.

Poster 33

The Essential Role of Moist Buoyancy in the TC Dynamics

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Key words: moist buoyancy, CISK, tropical cyclone dynamics

A recent study showed the temperature of a convective updraft is almost the same as the environment temperature (Sugi 2025). The dry buoyancy (temperature buoyancy) is small, and the buoyancy that drives the convective updraft is dominated by the moist buoyancy (water vapor buoyancy). This suggests that conditional instability is not important for convective updrafts, and therefore, 'CISK' is not an appropriate name for the TC intensification theory. However, the concept of CISK as the cooperative intensification theory is valid. The cooperation of convection and TC scale vortex can be represented by the convergence/stretching of absolute vorticity (Sugi et al. 2024). As the kinetic energy of convective updrafts is the source of kinetic energy of a tropical cyclone, we can say that the moist buoyancy which is the driving force of convective updrafts is playing the essential role in the tropical cyclone dynamics.

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Poster 34

Exploring Cloud Seeding Impacts on Typhoon Hagibis Using NHM-Chem

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Key words: Typhoon, Seeding, NHM-Chem, Moonshot

As part of Japan's Moonshot Goal 8 initiative, we investigate the feasibility of artificially weakening typhoons via cloud seeding. This study incorporates a virtual seeding function into NHM-Chem (Kajino et al., 2019), a meteorology chemistry coupled model developed by the Japan Meteorological Agency. The enhanced model represents detailed aerosol properties—hygroscopicity, ice nucleation activity, radiative effects, and size distribution—allowing realistic simulations of CCN, INP and ARI impacts on cloud and radiation processes.

We conducted a case study of Typhoon Hagibis (2019) over the ocean south of Japan. Simulations used a 4 km resolution with 262×302 grids and 40 vertical layers, covering 18:00 UTC on October 10 to 6:00 UTC on October 12. Initial meteorological fields were from JRA55, and chemical fields from an emission inventory.

Seeding was applied from 18:00 UTC on October 10 to 6:00 UTC on October 11 over a 300×300 km^2 region within the atmospheric boundary layer (60,920 m) in the southeastern quadrant of the typhoon. Aerosols had a geometric mean diameter of 100 nm, with a seeding rate of 1×10^9 particles/m^2/s—totaling ~28,500 tons of aerosol mass over 12 hours. Compared to the control run, the seeded simulation showed a ~2 hPa increase in central pressure 15 hours after seeding, suggesting slight weakening. Differences were also noted in precipitation patterns and vertical motion structure. These results indicate that aerosol seeding can modify typhoon internal dynamics.

In future work, numerical simulations will be conducted with varying seeding areas and different aerosol properties, aiming to weaken typhoons more effectively. This research was supported by the JST Moonshot R&D Program (Grant Number: JPMJMS2282-03).

Poster 35

Large-Scale Environmental Drivers of Extreme Tropical Cyclones in the 1959 Western North Pacific

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Key words: Extreme typhoon activity; Rapid intensification; Large-scale circulation; Numerical simulation

In 1959, five Category 5 (C5) TCs were generated over the western North Pacific (WNP) in August–October, and the C5 TC records accounted for 15.1% of all TC records, ranking first in history. Based on TC best track and reanalysis datasets, it is found that the genesis positions of TCs and more frequent occurrences of rapid intensification (RI) led to the enhanced TC lifetime maximum intensity (LMI) and increased the possibility of extreme TCs. In terms of genesis locations, more TCs formed over the open basin of the WNP (7.5° N–17.5° N, 132.5° E–157.5° E), where storms tend to have higher LMI, contributing to a higher basin-mean LMI. On the other hand, 8 TCs underwent RI in 1959, far beyond the climatological mean of 3.73, which also resulted in increased C5 TCs. The changes in genesis locations and RI could be attributed to the enhanced 850 hPa vorticity, 600 hPa humidity, and 500 hPa vertical velocity, which are related to the shift of the monsoon trough and subtropical high. In addition, based on simulation results in the Nonhydrostatic Icosahedral Atmospheric Model (NICAM), the extreme TCs in 1959 could be successfully reproduced, as the enhanced monsoon trough and the eastward shift of the South Asian high are well simulated. However, it still has some difficulties in reproducing similar behavior of the subtropical high.

Poster 36

Impacts of Typhoon Strength and Propagation Conditions on Gravity Wave Variability

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Key words: Gravity waves, ECMWF, Typhoon

Gravity waves are generated by typhoon/hurricane events and are important for coupling process. Typhoon-generated gravity waves can potentially further intensify typhoon activity. This work focuses on gravity waves generated by typhoons to understand whether the source strength (i.e. typhoon magnitude) or gravity wave propagation (i.e. background wind conditions) acts as a stronger control on gravity waves observed in the stratosphere. This work uses 9 years of the high-resolution European Centre for Medium-Range Weather Forecasting Integrated Forecasting System (ECMWF-IFS) operational analysis data and 45 years of ECMWF reanalysis v5 (ERA5).

Both datasets provide gravity waves amplitudes and spectra from ground to ~30-40 km. Specifically, we compare typhoon strength and background wind speed and direction to gravity waves at various altitudes and examine their relative importance to the measured spectrum of convectively-generated gravity waves. Both ECMWF-IFS with 9 km and ERA5 with 31 km horizontal resolution show concentric gravity waves at similar locations, timing, and horizontal wavelengths as AIRS and CIPS observations during Typhoon Yutu occurred in 2018. After this case study, we further analyze 45 years of typhoon events using ECMWF-IFS and ERA5 to characterize concentric gravity waves in the Western Pacific region. We show that stratospheric GW amplitudes are not strongly correlated with the strength of typhoons; however, gravity waves in the stratosphere are more correlated with background wind changes. Our results indicate that amplitudes and shapes of concentric gravity waves observed in the stratosphere are more strongly influenced by the background wind conditions than the source strength in extreme weather environments.

Poster 37

Orography effect of Réunion Island and Madagascar on heavy precipitation during the passage of tropical cyclone Batsirai (2022)

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Key words: TC intensification, orography effect, heavy precipitation

During the passage of tropical cyclone Batsirai (2022), the mountainous regions of Réunion Island and the southeastern part of Madagascar were intensively affected by floods. A control simulation (CTL) using the French non hydrostatic numerical model, Meso-NH (2-km horizontal grid spacing), succeeds in reproducing the lifecycle of Batsirai (2022) during 1–5 Feb. 2022 while another set of simulations (FLT) where the terrain of Réunion Island and Madagascar was flattened, were analyzed to examine the role of terrain in modifying the cyclone lifecycle and producing the localized heavy precipitation. The Batsirai (2022) passed the northern offshore of Réunion Island at the shortest distance of ~144 km in CTL while it landed on the southeastern part of Madagascar. The comparison analysis of CTL vs. FLT revealed that (i) the topography of Réunion Island prevented Batsirai from approaching closer to the island about 35 km, and (ii) the topography of Madagascar modified the arrival point of Batsirai about 32 km toward south and the arrival time about 10 h earlier. In terms of precipitation, the presence of Réunion (Madagascar) topography leads to extreme rainfall by 94 % (82 %) further increased amount exceeding of 2,800 mm (830 mm) in the mountainous region (at the foothill of mountain). The detailed analysis using the numerical simulation results has been done to investigate the roles of the complex terrains of Réunion Island and Madagascar in producing the localized heavy precipitation, and the key results will be presented at the conference.

Poster 38

Laboratory Simulation of Vortex Rossby Waves in the Eyewall of a Typhoon using a Rotating Annulus with radially sloped bottom

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Key words: Vortex Rossby Waves, Rotating Annulus, Eyewall

Vortex Rossby waves (VRWs) are known to contribute to polygonal eyewall structures and breakdown phenomena in a typhoon. Previous laboratory studies (e.g., Hishinuma et al., 2022) used a rotating annulus with a unidirectional sloped bottom and differential heating to simulate VRWs via topographic Rossby waves. However, this configuration limited the experiments to isolated inner- or outer-core regions, without representing the continuous vorticity gradient present in actual typhoons.

In this study, we designed a laboratory experiment using a rotating annulus with a mountain-shaped bottom topography to better approximate the radial vorticity distribution from the typhoon center to outside the eyewall. Warm water was placed at the center and cold water in the outer region, with aluminum powder for surface flow visualization. Experimental parameters included temperature differences (0–20° C), rotation speeds (1–12 rpm), water depths (4–10 cm), and bottom topographies (flat, 1 cm, and 2 cm mountain shapes). The flow field was recorded using a co-rotating 4K camera and quantitatively analyzed via particle image velocimetry (PIV).

The results showed that, for rotation speeds of 7 rpm or higher, distinct wave patterns developed inside and outside the core region, exhibiting different phase drift directions. For instance, under $\Delta T = 5°$ C, 12 rpm, 8 cm depth, and 2 cm mountain bottom, the outer and inner waves drifted at -0.04π and 0.05π rad/s respectively, relative to -0.17π rad/s in the flat-bottom case. These findings suggest that the observed phase propagation corresponds to the direction predicted by the topographic β-effect, indicating successful reproduction of VRWs in the eyewall structure.

Poster 39

Potential Intensity Theory of Tropical Cyclones with Ocean Cooling Processes

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Key words: Potential Intensity, Ocean Mixing, Ocean Upwelling

The Potential Intensity (PI) theory explains the maximum strength a tropical cyclone (TC) can achieve under given environmental conditions such as sea surface temperature. It is well recognized that TCs cool the ocean surface through mixing and upwelling induced by cyclonic winds. This study develops a PI theoretical model that incorporates these ocean cooling processes.

Poster 40

Investigating Distributions of Cloud Particle Types in Tropical Cyclones Using EarthCARE observation

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Key words: EarthCARE, Tropical Cyclone, NICAM, and Joint Simulator

The Earth Clouds, Aerosol, and Radiation Explorer (EarthCARE) satellite is able to provide unprecedented observations of vertical cloud motions via its Doppler radar. This enables new insights into the structure of vertical velocity and microphysical properties in convective clouds. This study uses the Japanese Aerospace Exploration Agency (JAXA) level-2 cloud and precipitation microphysics retrievals to investigate the radial distributions of convective updraft and cloud particle types. EarthCARE data from August 2024 to July 2025 are collocated with the International Best Track Archive for Climate Stewardship (IBTrACS). In the Northern Hemisphere, 42 EarthCARE overpasses intercepted TCs, defined by the maximum wind speed exceeding 64 knots, within 300 km distance. Radial composites show that radar reflectivity is significant with vertical updraft in the inner region, less than 100 km radius. In this region, snow is the dominant type of particle between 6 and 12 km height, while 3D-ice particles are the main type above 12 km height. On the other hand, both reflectivity and updraft are weaker outside the 100 km radius. In particular, supercooled water occurs more frequently above the freezing level outside the eyewall, especially beyond 200 km from the center. Below the freezing level, liquid drizzle and warm water are more frequent outside 200 km. The conditional sampling based on vertical air velocity exhibits a strong relationship between cloud particle types and vertical motion. Snow and rain types mainly occur in the updraft areas, while supercooled water, warm water, and liquid drizzle are more common in the downdraft areas. To understand the physical processes responsible for the distributions of vertical velocity and cloud particle types in TCs, we will perform hindcast simulations

using the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) with the Joint-Simulator.

Poster 41

Observing the Air-Sea Interface During a Typhoon's Lifecycle: A Wave Glider Study of Pre-Storm, Peak, and Post-Storm Conditions

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Key words: Khanun, Directional Spectra, Lifecycle, Wave Gliders, Wind-Wave Interaction

The interaction between the atmosphere and the ocean is a fundamental process that governs the evolution of tropical cyclones and their associated hazards. While a theoretical framework exists, a lack of in-situ observations has limited our understanding of air-sea coupling throughout a storm's life cycle. This study addresses this gap by investigating the evolution of the air-sea interface during Typhoon Khanun (2023) using a unique, high-temporal resolution dataset collected by two Wave Gliders (SV2 and SV3).

The gliders were strategically positioned on either side of the typhoon's track as it approached the Okinawa Islands, providing a rare opportunity to observe the spatial and temporal variability of wind-wave dynamics. We aim to analyze the behavior of the wind-wave system across three distinct stages: pre-typhoon conditions, the peak influence of the typhoon, and the post-typhoon recovery. Our analysis will focus on examining the state of equilibrium during the cyclone's passage and the influence of swell on the wind-wave system. These findings will provide valuable empirical insights into the fundamental processes of momentum and energy transfer, which is crucial for improving forecasting models and maritime safety. Ultimately, this research highlights the vital role of autonomous platforms such as Wave Gliders in gathering

essential data from challenging environments. This is crucial for advancing our knowledge of ocean-atmosphere dynamics and for better protecting communities during extreme weather.

Poster 42

Investigation of Water Vapor Sources for Typhoon Ampil (2024) Using Water Stable Isotopes

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Key words: Typhoon, Water Stable Isotopes, Water Vapor Sources

Improving the accuracy of tropical cyclone (TC) intensity forecasts is essential for mitigating wind and flood hazards. Identifying the sources of water vapor contributing to TC development is critical for improving forecast accuracy. Water stable isotopes ($\delta^{18}O$ and δD) are effective tracers for estimating vapor origins. In this study, we investigated the vapor sources of Typhoon Ampil (2024) using isotope-enabled numerical simulations. Following the approach of Li et al. (2023), we examined the characteristics of TC vapor supply.

We used the isotope-incorporated general circulation model IsoGSM (Yoshimura et al., 2008) and the isotope regional spectral model IsoRSM (Yoshimura et al., 2010). IsoGSM was integrated from 1 January to 31 December 2024 at a horizontal resolution of ~180 km. IsoRSM was run at 5 km resolution for 9–20 August 2024, covering Ampil's genesis, intensification, and dissipation. Initial and boundary conditions for IsoRSM were taken from IsoGSM output, following the configuration of Li et al. (2023).

IsoGSM detected Ampil despite underestimating its intensity. The area-averaged precipitation within 200 km of the TC center exceeded 60 mm day^{-1} on 15 and 17 August, showing clearer peaks than in the outer regions. The time series of water vapor d-excess indicated a temporary rise to ~20‰ within 200 km around 15 August, suggesting enhanced evaporation from the ocean surface under strong winds. In contrast, d-excess values generally decreased with distance, dropping below 15‰ at a radius of 1000 km.

These results suggest that this approach can provide valuable insights into TC vapor source processes. This initial case study highlights its potential for diagnosing TC vapor sources. Future work will integrate IsoRSM results and investigate the relationships between isotope distributions, wind fields, and vapor transport to establish a robust methodology for quantitatively determining the vapor origins of TCs.

Poster 43

The Rainfall Variability in Tanzania based on the Tropical Cyclone Routes in South West Indian Ocean

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Key words: Tropical Cyclone, Rainfall, Southeast Africa, South West Indian Ocean

Tropical cyclones (TCs) generated in South West Indian Ocean (SWIO) have occasionally been responsible for causing natural hazards over Southeast Africa. Currently, the region is still facing the threat of that risk. The present study aimed to evaluate rainfall associated with TCs in the Southeast Africa, particularly Tanzania, from 1981 to 2024. In addition, this study attempted to show meteorological conditions under which TCs move toward the coastal areas. A total of 400 TCs which had formed in SWIO and had exceeded a wind speed of 17 m/s at least once during the period of observation were analyzed to investigate the frequency, genesis locations, and tracks. Furthermore, TCs located within 500 km of national borders or coasts were defined as "approaching TCs". These were utilized to calculate precipitation anomalies in the given context. Results showed that 28 TCs were identified as the approaching TCs which brought a positive precipitation anomaly ranging from 10 to 15 mm/day over southeastern Tanzania, central Kenya, and northeastern Mozambique. Additionally, three primary genesis locations of approaching TCs were recognized as potential avenues for advancement towards Tanzania: (1) the open SWIO, (2) the north sea of Madagascar, and (3) the Mozambique Channel. Apart from that, it is mainly known as El Niño-Southern Oscillation (ENSO) affects the basin frequency in SWIO, which is the westward shift during El Niño but the pattern is opposite during La Niña periods. It should be noted that the count of approaching TCs was larger during El Niño (12 cases) than La Niña condition (5 cases). However, when the target area was broadened from Tanzania to Southeast Africa, the number of El Niño events was 25, compared to 34 La Niña events.

Poster 44

Investigating the Environmental Factors Driving Four Landfalling Tropical Cyclones in Nine Days in the Philippines

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Key words: Tropical Cyclones, Easterly Wave, Multiple Tropical Cyclone Event, Genesis

This study analyzed the unique conditions that allowed four Tropical Cyclones (TCs) to make landfall in the Philippines from November 7 to 16, 2024. The Japan Meteorological Agency (JMA, 2024) reported that this was the first time that four TCs were named simultaneously in the month of November. Using the historical best track data from International Best Track Archive for Climate Stewardship (IBTrACS, 2025), the 2024 case is the sole event from 1979 to 2020 that resulted to 4 Philippine-landfalling TCs during November. These TCs, YINXING, TORAJI, USAGI, and MANYI, had an intensity of at least 130 km/hr (36 m/s) upon landfall. This multiple TC event resulted in a combined total 49M USD in damage and 14 reported fatalities (NDRRMC, 2025). Climatological analysis using reanalysis datasets using ERA5 from 1991 to 2020 revealed that, at the time of TC genesis, the 2024 event featured the following anomalies: (i) high Sea Surface Temperature (SST) [~+0.5° C], (ii) stronger easterlies [~+ 1.2 to 1.5m/s]; and (iii) richer low-level moisture [~+4 to 5kg/m2]. More importantly, analysis of the temporal evolution of the environmental conditions from November 7 to 9 revealed that despite the continuous and successive genesis of 3 TCs within 48 hours, the enhanced easterly wave train, together with the high SST and weak vertical windshear, were maintained. Further analysis of this case may enhance our understanding of TC genesis, provide additional insights to multiple TC events, and improve disaster risk reduction and management from these extreme weather phenomena.

Poster 45

Determination of Observing Locations for Typhoons Near Okinawa in 2025 Using Adjoint Sensitivity Analysis

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Key words: adjoint sensitivity analysis, targeted observation, in situ observation, typhoon forecast

To improve our understanding of typhoon development and forecast accuracy, it is essential to obtain in situ observations near typhoon centers, which are often challenging to observe using satellite remote sensing. Since 2021, we have conducted summertime observations each year using two Wave Gliders, autonomous, unmanned surface vehicles (USV). This study focuses on several typhoons that approached the observation area southeast of Okinawa during the 2025 season.

Given the substantial cost of in situ observations, it is crucial to identify regions where such data would yield the greatest improvement in forecast accuracy. We apply adjoint sensitivity analysis with Weather Research and Forecasting Model (WRF-ARW) and its Data Assimilation System (WRFDA) to determine such optimal observation areas. Our modified adjoint computation module enables sensitivity calculations for various parameters in each typhoon case.

To identify effective observation locations at the time of the closest approach for each typhoon, we compute sensitivities of near-surface pressure (i.e., pressure at the lowest model level in WRF) with respect to pressure (P), temperature (T), and zonal and meridional wind components (U, V), six hours after the closest approach. These variables were selected for their strong influence on typhoon intensity and structural evolution.

Sensitivity fields are compared across typhoon cases to identify common high-sensitivity regions relative to the typhoon center, considering both radial distance and position within the storm structure. To enhance comparability, the fields are aligned by azimuthal position and by direction of motion, allowing us to highlight overlapping regions that can inform optimal observation strategies.

For typhoons observed in 2025, observation points are overlaid on the sensitivity fields to determine whether the measurements were located within high-sensitivity regions. These results will serve as a basis for future data assimilation experiments and Observing System Simulation Experiments (OSSEs) to quantitatively evaluate their forecast impact.

Poster 46

Three-Dimensional Structure of Concentric Eyewalls in Western North Pacific Tropical Cyclones observed by Fengyun Satellites

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Key words: Concentric Eyewalls; three-dimensional (3D) thermal and humidity structure; FY-3E/VASS observation

Intense tropical cyclones (TCs) often form concentric eyewalls (CE), with the eyewall replacement cycle (ERC) playing a critical role in modulating storm intensity and structural evolution. While previous studies have primarily relied on passive microwave imagery to detect CE formation, the detailed three-dimensional (3D) thermal and humidity structure of CE (CE-3D) remains poorly understood, particularly from an observational perspective. This study leverages high-resolution atmospheric profiling data from the FY-3E satellite's multi-payload instruments to construct vertical atmospheric sounding system (VASS) retrievals of temperature and humidity. By analyzing time-sequenced VASS profiles, we extract and characterize the CE-3D structure, providing new observational insights into the thermodynamic evolution of ERC.

Taking a typical case, TC Yagi (2024) demonstrated two distinct ERC events. Based on CE-3D and FY-3E observations, we found that both inner and outer eyewalls maintain concurrent high-humidity/high-temperature zones, but with distinct quadrant-dependent widths and vertical stratification (15-20 g/kg specific humidity layer thickness variations). Moreover, the distribution of humidity in the inner and outer eyewall were significantly influenced by TC's intensity and landfall terrain. Additionally, our study compared real-time ERA-5 reanalysis data with FY-3E observation data and found that FY-3E/VASS data demonstrated distinct advantages. It reflected observation superiority, the sharp moisture gradients at eyewall-moat boundaries which scale more detail vertical features, in contrast, some of the CE-3D minute variation was over-smoothed in ERA-5's representations. Our findings

advanced the understanding of TC core dynamics/thermodynamics and offer a novel satellite-based methodology for studying CE and ERC.

Poster 47

Landslide Risk Mitigation in Eastern Uganda-Lessons From Japans Typhoon -Driven Disaster Resilince

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Key words: Landslides,Climate Risk,Early warning Systems,Vulnerable pupolution ,mt elgon,resilince,risk mitigation

Landslides pose a severe and escalating hazard in Eastern Uganda, particularly within the geologically vulnerable Mt. Elgon region. Steep topography combined with intensifying rainfall patterns creates a heightened vulnerability context. Triggered primarily by heavy precipitation saturating soils on unstable slopes, these events cause destructive ground movements. Their frequency and severity have demonstrably increased over the past decade, driven by climatic shifts, deforestation, and unsustainable land management practices.

Analogous to typhoon-affected regions in Japan (e.g., Kyushu, Kii Peninsula), Ugandan mountain communities experience significant landslide risks, resulting in fatalities, destruction of infrastructure including homes and schools, and widespread displacement. While human activities may exacerbate environmental triggers in both contexts, Japan has substantially invested in mitigating technologies (e.g., slope stabilization), sophisticated early warning systems, and community-centric disaster response frameworks, thereby reducing vulnerability and enhancing resilience.

Conversely, Uganda faces critical deficits in systematic risk assessment, effective relocation planning, and public risk awareness. Limited disaster preparedness infrastructure and weak enforcement of land-use regulations perpetuate the exposure of vulnerable populations, who often rebuild in high-risk zones. This paper draws comparative lessons from Japan's advanced risk mitigation strategies. It recommends policy and development interventions for Uganda, emphasizing integrated watershed

management, large-scale reforestation, localized early warning systems, and inclusive, sustainable relocation planning.

As the climate crisis intensifies, the Mt. Elgon region represents an urgent priority. Addressing landslide risk must evolve beyond reactive emergency response towards initiative-taking, long-term resilience building. This necessitates knowledge exchange, institutional collaboration, and targeted investment in community preparedness. Cross-country dialogue offers a vital pathway for Uganda to strengthen adaptive capacity and safeguard lives and livelihoods within this environmentally fragile zone

Poster 48

Kampala Under Water: Equitable Drainage Solutions for Flood-Poor Informal Settlements – Lessons for Typhoon-Resilient Cities

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Key words: Urban flooding, Typhoon resilience, Equitable drainage, Informal settlements, Community-led adaptation

Kampala's informal settlements experience severe annual flooding, with 89% of households in Bwaise and Namuwongo reporting flood-related losses (KCCA, 2023). Drainage coverage remains below 30% in these areas, compared to 85% in planned neighborhoods (UBOS, 2022). This study analyzes the disparities in flood resilience and proposes data-driven solutions for equitable urban drainage.

Using GIS flood mapping, field surveys (n=120 households), and interviews with municipal engineers and community leaders, we identify systemic planning gaps. Results show that informal settlements receive only 12% of Kampala's drainage investments despite housing 60% of the city's population (NEMA, 2023). Flood durations in unplanned areas last 72% longer than in formal zones ($p < 0.01$), directly linking inadequate infrastructure to prolonged displacement.

Community-built drainage systems, though fragmented, reduce flood impacts by 42% compared to areas relying solely on municipal interventions. In Katwe, resident-maintained channels decreased flood frequency from 18 to 10 events annually (primary data, 2024). However, these efforts lack integration with city-wide systems due to outdated zoning laws.

We propose an Equitable Drainage Index (EDI) to prioritize investments in flood-poor settlements, incorporating: Hydraulic need (flood depth/duration), Population density, Existing community mitigation efforts

Policy recommendations include revising Kampala's Drainage Master Plan to adopt EDI and legally recognizing resident-led drainage committees. Pilot tests in Ndeeba show that integrating community systems with engineered drains cuts flood recovery costs by 35%.

This research provides actionable metrics to rectify spatial inequality in flood protection, emphasizing co-designed solutions for Kampala's most vulnerable residents.

Key References:
KCCA (2023). Kampala Drainage Audit Report
UBOS (2022). Kampala Informal Settlement Census
NEMA (2023). Urban Flood Risk Assessment

Poster 49

Enhancing Land Use Planning for Cyclone Resilience: A Case Study of Trincomalee Urban Area on the Eastern Coast of Sri Lanka

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Key words: Communities, Human settlement expansion, Early warning, Preparedness, resilience

Since 1900, more than 25 cyclones have impacted Sri Lanka. The country is highly vulnerable due to its location near the confluence of the Arabian Sea, the Bay of Bengal, and the Indian Ocean. Cyclones originating from the Bay of Bengal can bring strong winds, heavy rainfall, coastal flooding, and storm surges, causing severe damage along the eastern and northern coasts. Coastal communities, particularly along the Northern and Eastern coasts, face the greatest risk and are especially exposed to cyclones forming in the Bay of Bengal during the inter-monsoon and northeast monsoon seasons (October to January).

Although the number of cyclones is relatively small, their impacts are significant. The situation has worsened due to increased land use, economic activities, population growth, and the expansion of human settlements along coastal regions in recent years, amplifying the potential damage from cyclones. In this context, an effective cyclone warning system in Sri Lanka is crucial. Timely information also helps communities improve disaster response and preparedness, enabling proactive measures to mitigate cyclone impacts.

Currently, many communities lack a centralized platform for early warning information and coordinated anticipatory response planning. Establishing such a platform would strengthen disaster preparedness and resilience across coastal communities. This paper examines how land use planning can be better integrated to build climate-resilient communities on the northeastern coast of Sri Lanka. The literature review analyzes exemplary case studies and evaluates urban planning strategies to adapt to the uncertainties of cyclones in the context of climate change. It then examines the existing urban planning practices in the Trincomalee Urban Development Plan, which serves as the case study. The study also provides recommendations for further improvements in cyclone preparedness and mitigation.

Poster 50

Do Global Machine Learning Weather Models Intuitively Learn Tropical Cyclone Physics?

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Key words: Tropical Cyclone Forecasting; Track Error; Machine Learning; Tropical Cyclone Dynamics

Machine Learning Weather Prediction (MLWP) models, such as GraphCast, PanguWeather, Aurora, and FourCastNet, have emerged as competitive alternatives to traditional Numerical Weather Prediction (NWP) models, offering global forecasts at reduced computational costs. However, their skill in predicting extreme weather events, particularly tropical cyclones (TCs), remains underexplored. This study conducts a comprehensive evaluation of four leading MLWP models against observations and three state-of-the-art NWP models (GFS, IFS, UM) across all tropical basins.

Results show that MLWP models exhibit strong TC track forecasting skill, with mean errors below 200 km at 96-hour lead times. However, they consistently underestimate TC intensity (maximum winds and minimum MSLP), likely due to biases in their ERA5 training data and potential double penalization effects. Despite these limitations, MLWP models realistically capture dynamical TC features, including absolute vorticity patterns and their advection, as well as thermodynamical structures like low-level convergence and warm-core anomalies – albeit with weaker magnitudes than observed. The physically consistent relationships among these variables suggest that MLWP models intuitively learn underlying TC dynamics, even without explicit physical constraints. Among the tested models, Aurora outperformed others, likely due to its diverse training datasets.

These findings highlight MLWP's potential in TC forecasting while underscoring key challenges: (1) training data quality critically impacts intensity prediction, and (2)

further integration of physical constraints could enhance extreme weather modeling. Future work should explore hybrid physics-ML approaches and improved data assimilation to bridge remaining gaps with NWP. This study provides a foundation for refining MLWP models as reliable tools for operational TC forecasting.

Poster 51

Seasonal predictability of mass coral bleaching events between the Pacific Ocean and the East China Sea with a large-ensemble climate model

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Key words: Seasonal forecast, Tropical cyclone frequency, Degree Heating Week

In this study, we investigated the seasonal predictability of Degree Heating Week, a widely used indicator of coral thermal stress and a strong predictor of coral bleaching. We used a 108-member seasonal prediction system to analyze four seasons (March–May, June–August, September–November, and December–February) from nine initialization dates (February 1–9, May 1–9, August 1–9, and November 1–9) between 1982 and 2022. We found that the model skillfully predicts Degree Heating Weeks for most coral reef areas, including southern Japan in summer. Through mixed-layer heat budget and statistical analyses, we found that La Niña and negative Indian Ocean Dipole events contributed to suppressing tropical cyclone activity and thus building up the Degree Heating Week by weakening cooling via vertical diffusion in southern Japan. Successful prediction of the Degree Heating Week, as well as of mass coral bleaching events, at least a few months in advance, could help reduce the risk of coral reef collapse by facilitating the implementation of necessary adaptation measures.

Poster 52

Research on Tropical Cyclone Size Prediction Technology in the Northwest Pacific Based on Machine Learning Algorithms

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Key words: tropical cyclone size, Prediction ,Machine Learning Algorithms

Tropical cyclone (TC) size is one of the key factors contributing to maritime disasters, yet its prediction remains a significant challenge. This study focuses on the mechanisms and forecasting techniques for TC wind structure size variations in the Northwest Pacific. Utilizing datasets from the Joint Typhoon Warning Center (JTWC) best-track data, the Statistical Hurricane Intensity Prediction Scheme (SHIPS), and the China Meteorological Administration's regional numerical prediction system (CMA-TYM), we systematically analyze the spatiotemporal distribution characteristics of TC size changes, key influencing factors, and the impact of initial vortex size errors in numerical models on forecast accuracy. Building on this analysis, we develop a 120-hour wind structure size prediction model by integrating machine learning methods with physically constrained profiles, improving TC size prediction accuracy.

By examining TC size expansion characteristics and their environmental influences, we find that:

1. Both TC intensity and size peak in October, with a higher proportion of large, intense, and long-lived TCs compared to other months. TC size increases (decreases) with strengthening (weakening) intensity. The time when a TC reaches its lifetime maximum size (LMS) lags behind its lifetime maximum intensity (LMI) by an average of 40 hours. Moreover, rapid size expansion and LMS occurrence are typically closer to land than rapid intensification and LMI.

2. The initial TC size influences its LMS—71% of large initial vortices develop into large TCs, with 59% of these intensifying into strong TCs (Category 4–5). The radius of 26-kt winds (R26) affects TC size evolution for up to 66 hours, indicating that initial size cannot be neglected in size prediction.
3. The highest size expansion rates occur under moderate intensity (25–50 m/s), while the highest intensification rates occur when R26 is small (50–100 km). Under conditions of strong upper-level divergence, high relative humidity, substantial oceanic heat content, and moderate-to-weak vertical wind shear, TCs are more prone to outward expansion and even rapid size growth.

Further, by screening key factors influencing TC size changes, we employ a Long Short-Term Memory (LSTM) model to predict the Rankine vortex-derived R17, R26, and R33 wind radii, enabling 6–120-hour forecasts of RMW and wind structure size. The model achieves a mean absolute error (MAE) of 8.3 km (91% of samples <20 km) for RMW and 34.8 km (78% <50 km) for R17 in 24-hour forecasts. At 120 hours, error growth is slower than in traditional methods. Compared to CMA-TYM, the model reduces errors in R26 and R33 forecasts (6–48 hours) by 25.8% and 38.5%, respectively. It also effectively captures asymmetric wind field features, particularly excelling in predicting the major axis direction during intensification.

In summary, the physically constrained machine learning and correction models developed in this study not only enhance the accuracy and stability of wind structure size predictions but also provide a practical and scalable technical pathway for operational systems. This work offers new insights and technical support for advancing TC wind structure forecasting capabilities.

Poster 53

Tropical Cyclone Seed Disturbances in the Deep-learning Climate Emulator ACE2

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Key words: Tropical cyclone seed disturbances, Deep-learning climate emulator, Tropical cyclogenesis, Seasonal cycle, Interannual variability

Deep-learning based global climate emulators are emerging as promising frameworks for reproducing key features of the earth system with lower computing cost than conventional models. Recent studies suggest that such emulators can reasonably capture the observed characteristics of tropical cyclones (TC) frequency. TC seed disturbances are regarded as a key process for both predicting future TC activity and understanding the mechanism of TC genesis. Therefore, it is important to investigate whether deep-learning based global climate emulators can realistically represent both the number of seeds and their development into TCs. We employ the Ai2 Climate Emulator version 2 (ACE2) trained on ERA5 reanalysis, focusing on its ability to reproduce the occurrence of TC seed disturbances and their survival rate, defined as the fraction of seeds that develop into tropical cyclones. We conducted ACE2 simulations for the period 2001–2009, and TC seeds were detected using an algorithm designed to identify moist synoptic-scale cyclonic circulations. ACE2 simulations produce realistic spatial patterns of TC seed genesis and track density, with main genesis regions in the western North Pacific and eastern Pacific, as in ERA5, although TC seed genesis frequency is overall underestimated especially near the land masses. An evaluation of interannual variability reveals that, despite being forced with observed SST and CO_2 concentrations, ACE2 does not exhibit high correlation with ERA5. The result of examining the seasonal cycles and inter-basin differences will be presented at the workshop. Our results suggest the new deep-learning based climate emulator is a powerful tool for TC studies.

Poster 54

Response of Tropical Cyclone-Related Precipitation during Boreal Summer Season over East Asia to Pseudo-Global-Warming Climates

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Key words: tropical cyclone, global warming, extreme precipitation, future projection, East Asia

Climate change has fundamentally altered tropical cyclone (TC) characteristics globally, with TC-related precipitation emerging as a critical hazard under global warming. East Asia (EA) faces increasing risks from extreme precipitation events, yet comprehensive research addressing continental-scale TC precipitation changes under future climate conditions remains limited. This study presents the first systematic investigation of TC-related precipitation evolution across the entire EA continent during boreal summer under a global warming scenario. We employed the pseudo-global-warming technique coupled with high-resolution Weather Research and Forecasting model simulations to examine TC behavior and precipitation patterns. Our analysis encompasses 38 successfully simulated TCs selected from 111 historical cases based on rigorous validation criteria. We distinguished between TC core precipitation occurring within body circulation and TC-related remote precipitation identified through integrated vapor transport channel detection. Results reveal substantial precipitation amplification under the SSP245 scenario, with total TC precipitation increasing by 125.64% over EA relative to present conditions. These changes coincide with significant TC intensification. On the other hand, the western Pacific subtropical high (WPSH) shows a pronounced eastward retreat, fundamentally altering steering flow patterns and promoting deeper TC penetration into mainland China, while increasing Japanese landfall frequency. Enhanced atmospheric moisture content provides favorable thermodynamic conditions for rainfall intensification. These findings indicate that global warming creates favorable development conditions for TC precipitation over the EA.

Poster 55

A First Attempt at Impact-Based Flood Forecasting in Japan: Evaluating the Effect of Typhoon Track Longitudinal Perturbations on Flood Damage for Hagibis (2019)

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Key words: Impact-Based Flood Forecasting; Typhoon Hagibis (2019); Typhoon Track Perturbations

Impact-based flood forecasting combines traditional flood forecast data with vulnerability and exposure data to generate comprehensive flood risk assessment. This type of assessment is crucial for enabling early action before a flood disaster to minimize socio-economic losses. This study employed the Integrated Land Simulator (ILS) to conduct impact-based flood forecasting for Typhoon Hagibis (2019), the most powerful storm to strike Japan.

Our control simulation successfully reproduced the spatial distribution and intensity of rainfall and river discharge. To systematically assess the impact of typhoon tracks on flood damage, we conducted ensemble simulations. The e008 simulation (0.8° eastward shift) resulted in the highest flood damage, totaling 2478.7 billion JPY. A westward shift reduced total flood damage across Japan but increased it in southwestern regions, whereas an eastward shift led to an overall decrease in flood damage nationwide. Flood damage in the worst-case tracks was primarily concentrated in floodplain areas along the Pacific Ocean coast in central, southwestern, and northeastern Japan. In southern Japan, however, flood damage was more concentrated along the Japan Sea coast.

These findings underscore the critical influence of typhoon tracks on flood risk. Flood defense, such as levee and dam, improved the accuracy of flood damage assessments. Impact-based typhoon track ensemble simulation can enhance our understanding of high-risk flood-prone areas and improve disaster preparedness and mitigation strategies.

Poster 56

Future Storm Surge Risk Assessment with the Grid-dependent MPS Model

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Key words: storm surge, climate change, maximum potential intensity, coastal hazard

Under ongoing global warming, it is expected to cause stronger typhoons and stronger storm surges in the future. This study presents the framework of the Grid-dependent MPS (Maximum Potential Storm Surge Height) model, a climatological approach that estimates maximum potential storm surge height based on the maximum potential tropical cyclone framework (MPI theory). Moreover, we show how the trends of storm surge intensity will change in the future using the Grid-dependent MPS model.

The MPS model estimates maximum potential storm surge height by separately evaluating the worst-case pressure surge and wind-induced surge, then summing them. Especially, in the Grid-dependent MPS model, estimated locations of storm surge are determined by the coastline data and the complexity of the bay's shape. This method not only adds objectivity to the determination of estimated locations but also allows for the appropriate assessment of storm surge intensity, which varies depending on the shape of the bay. Furthermore, in the estimation of wind-induced surge, under continuously uniform winds at a constant wind direction and speed, we calculated wind-induced surge with a numerical model to reach a steady state and tuned the coefficient. Therefore, the model allows us to estimate the strongest wind-induced surge that can realistically occur in the bay.

Furthermore, we compared the values of storm surge with some models and observational data as a test case and analyzed long-term changes of MPS in several bays. As a result of the test case, the Grid-dependent MPS model resulted in the highest storm surge among them. This result is beneficial for the model because it aims to estimate MPS. Moreover, our analysis yielded results indicating a rising trend in several bays in Japan.
The details of the results will be presented at the conference.

Poster 57

Identification of Effective Observation Locations for Improving Typhoon Forecasts Using Sensitivity Analysis

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Key words: adjoint sensitivity analysis, targeted observation, Observing System Simulation Experiment

High-resolution observations near the center of a typhoon are vital for improving understanding of its structure and enhancing forecasts of track and intensity (Ito and Wu, 2013). However, direct in situ measurements over the open ocean remain scarce. Continuous deployment of dense observation networks is infeasible due to logistical and economic constraints. Therefore, this study aims to identify effective observation locations that can improve typhoon forecasts through adjoint sensitivity analysis.

Sensitivity experiments were conducted with adjoint sensitivity analysis with Weather Research and Forecasting Model (WRF-ARW) and its Data Assimilation System (WRFDA), which modified to calculate sensitivities for arbitrary variables, locations, and times. Typhoon Khanun (2023, TY2306) was examined, with initial and boundary conditions from NCEP GDAS/FNL. The model domain used 15 km resolution with a 101 × 101 × 41 grid.

Cost functions were defined as model lowest-level pressure near the typhoon center, maximum zonal/meridional winds, and maximum water vapor mixing ratio at 6- and 12-hour forecasts. SLP sensitivities showed alternating positive and negative patterns, expanding at 12 hours while persisting near the center, indicating central pressure is influenced by broad-scale processes. Zonal wind sensitivities were strongest in the outer region, suggesting outer-core winds impact inner-core dynamics within 6 hours.

Water vapor sensitivities formed a radial band aligned with the inflow pathways, converging toward the typhoon center within 6 hours and shifting southeastward by 12 hours, suggesting an influence of the large-scale flow.

These results demonstrate distinct sensitivity structures for pressure, wind, and moisture. Wind sensitivities were highly localized, underscoring the potential of targeted observations, whereas mechanisms governing central pressure sensitivities remain unclear. Future work will explore these mechanisms and test synthetic observations in high-sensitivity regions through Observing System Simulation Experiment (OSSEs) to assess their impact on forecast skill.

Poster 58

The potential risk of landslides damage by virtual typhoon paths

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Key words: risk assessment, landslide, ensemble simulations

Climate change is intensifying typhoons and increasing the risk of landslides in Japan. Conventional observation-based risk assessments are inadequate for predicting such unprecedented events, particularly in areas with no prior experience of such disasters. This study presents a new framework for evaluating potential landslide risks. This framework involves simulating virtual typhoon scenarios to identify potential 'worst-case' impacts.

Our methodology integrates two core components. First, the Typhoon Path Ensemble Simulation (TPES) generates numerous physically consistent virtual typhoon tracks by systematically adjusting the atmospheric conditions of historical events. This enables extreme rainfall to be simulated across the entire Japanese archipelago. Secondly, the Landslide Risk Emulator processes the precipitation output from each TPES member. It calculates the Soil Water Index (SWI) and estimates landslide risk based on region-specific thresholds, effectively replicating the operational risk index of the Japan Meteorological Agency.

A case study of Typhoon MINDULLE (2021) revealed that, although the distributions of precipitation and SWI shift with the typhoon path, the resulting landslide risk varies regionally. Notably, a virtual typhoon path impacting the Kanto region generated a higher risk level than a path producing similar rainfall intensity over the Kansai region. This difference is primarily due to the lower risk thresholds established for the Kanto region, reflecting its greater vulnerability to rainfall-induced landslides.

This research demonstrates that potential landslide risk is governed not only by storm intensity, but also by regional susceptibility. In the future, we intend to convert landslide risk into cost reduction and calculate flood risk and associated costs. Our goal is to create a database that can help assess disaster impacts from a severe typhoon hitting anywhere in Japan.

Poster 59

Assimilation experiments of satellite microwave observations in heavy rainfall events associated with typhoons

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Key words: data assimilation, OSE(observing system experiment), satellite microwave retrievals, TROPICS

To improve the accuracy of heavy rainfall forecasts, it is essential to observe water vapor in the lower atmosphere using satellite microwave sounders. In order to observe the lower atmosphere with high vertical resolution, it is expected that the amount of brightness temperature data from microwave sounders will increase in the future. The currently mainstream method of direct assimilation of brightness temperature is computationally intensive and may not be suitable for handling large data volumes, leading to a reevaluation of retrieved value assimilation. In this study, we assimilated retrieved values from TROPICS satellite observations taken half a day before a heavy rainfall event associated with a typhoon, and evaluated their impact on precipitation forecast accuracy. As a result, assimilating all data led to a decrease in forecast accuracy, whereas limiting the assimilated data based on satellite zenith angle, altitude and temperature difference from the first guess improved the accuracy. Appropriate data selection is important in retrieved value assimilation.

Poster 60

Youth as Storm Tamers: Building Climate Resilience through Ugandan Schools

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Key words: Climate Change Adaptation, Youth Empowerment, Resilience, Community Engagement, Environmental Stewardship, Climate Education, Disaster Preparedness

Background

Uganda faces increasing floods and landslides, similar in impact to typhoons. The 2020 Kasese floods displaced thousands and destroyed key infrastructure. Urgent need: community-led and youth-driven preparedness.

Study Focus

The initiative “Empowering Youth in Climate Change Adaptation and Preparedness in Ugandan Schools” builds a new generation of “storm tamers” by equipping students with hands-on resilience strategies.

Key Interventions

Reforestation (St. Mary’s Kitende SS): reduces soil erosion, lowers flood risk.
Climate-Smart Agriculture (St. Francis PS): drought-resistant crops for food security.
Climate Clubs: youth-farmer partnerships for early warning systems & adaptive practices.

Impact

Students become agents of change, using drama, science fairs, and advocacy campaigns.
Builds a culture of proactive resilience in schools and communities.
Model is transferable to storm-prone regions worldwide.

Takeaway

Resilience starts in the classroom.

Youth, when empowered, can tame storms—whether in Uganda or across the globe.

Poster 61

Typhoon Science for Inland Waters: Linking Remote Cyclone Dynamics to Severe Storm Hazards on Lake Victoria, Uganda

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Key words: Lake Victoria storms Remote tropical cyclones Typhoon–climate teleconnections Early warning and nowcasting Community resilience in inland waters

Lake Victoria, shared by Uganda, Kenya, and Tanzania, is the world's largest tropical lake and sustains more than 40 million people through fisheries, transport, and water resources. Yet it is also one of the deadliest inland waters globally, with storm-related accidents claiming thousands of lives annually among small-scale fisherfolk and transport operators. Despite its socio-economic importance, scientific attention to storm dynamics over Lake Victoria remains limited, particularly regarding the role of large-scale climate drivers.

This study investigates how remote tropical cyclones, including typhoons in the Indian Ocean basin, and associated oscillations (Madden–Julian Oscillation, Indian Ocean Dipole, ENSO) modulate storm activity on Lake Victoria. Using ERA5 reanalysis datasets, IBTrACS tropical cyclone tracks, and local meteorological records from Entebbe and Jinja, the research will examine how cyclone-linked wind surges, upper-level divergence, and moisture fluxes influence the occurrence and intensity of squall lines and convective outbreaks over the lake. Complementary evidence will be drawn from fisherfolk testimonies and safety initiatives in Mukono and Kalangala districts to integrate community knowledge with atmospheric diagnostics.

By tracing cyclone-driven atmospheric precursors to inland storm hazards, this research aims to develop nowcasting thresholds and early warning triggers tailored for Lake Victoria communities. In doing so, it reframes typhoon science beyond coastlines, demonstrating how tropical cyclone research can inform life-saving preparedness on Africa's largest inland water body.

Poster 62

Ground-based Doppler radar observations of wave-like coherent structures along the inner edge of the tropical cyclone eyewall

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Key words: Tropical cyclones, dynamics, radar, turbulence, boundary layer

Observational and numerical studies of intense tropical cyclones (TCs) have occasionally documented small-scale, approximately regularly spaced coherent structures that appear in plan-view reflectivity as filamentary, cellular, or scalloped protrusions along the inner edge of the eyewall and are associated with large perturbation winds and relative vorticity. Characteristics of these features are examined using high-resolution U.S. NEXRAD data in base moment fields (reflectivity, Doppler velocity, and spectrum width) for three Gulf of Mexico hurricanes with different sizes and intensities. In each storm, the wave-like echoes are associated with oscillations in Doppler velocity of similar spatial scale with perturbation amplitudes around ±10 m/s, with higher values observed in Hurricane Michael, our strongest case. Azimuthal Doppler velocity shear values computed using the linear least squares derivative (LLSD) method reveal that individual echoes are collocated with coherent shear maxima with values ranging between 0.005 to 0.02 s-1 depending on the storm intensity. Higher spectrum width and downwind curvature of the Doppler velocity contours are also observed near the reflectivity structures. These signatures are generally most pronounced in the lowest elevation sweeps and diminish with height, consistent with previous reports that such features exist primarily in the TC low levels. Based on these patterns, similar coherent structures were qualitatively identified in ten additional North Atlantic and Pacific storms. Overall, these features are found predominantly to the left (for Northern Hemispheric storms) of the environmental vertical wind shear vector, to the front and left of the storm motion, and in offshore flow. The wide range of storm structure and environments in which the wave-like structures appeared suggests that they are an intrinsic element of TC

inner-core dynamics and constitute a distinct class of TC features, and their preferred azimuthal distribution imply a role of boundary layer dynamics in their development.