Response to Reviewer 1 (RC1):

Comment: This paper presents numerical simulations for a series of typhoon events using the WRF model and PGW methods to extract the SSP585 far future scenario global warming signal from 16 CMIP6 models, which is added to the ERA5-based historical climate as the IC BC of the model. The authors have invested significant effort in model simulation and demonstrated methodological rigor; the article is well-written and easy to read. It highlights changes in intensity and precipitation in seven typhoon cases under future scenarios, compared to historical control runs, as well as the impact of varying surface and low-level atmospheric temperatures on typhoon intensity.

Reply: We thank Reviewer 1 for the positive feedbacks.

The topic is not related to hydrology or urban hydrology, I'm not sure if it coincides with the scope of HESS journal.

Reply: We believe that our topic is closely related to hydrology, particularly urban hydrology. As mentioned by Reviewer 1 in a previous comment,

- Our study addresses an important hydrological research question: "How will extreme weather and climate events change in a warming climate, especially concerning intensifying landfalling typhoons?";
- We focus on evaluating and understanding the changes in typhoon intensity induced by warming, specifically those making landfall in the Pearl River Delta, where are established metropolises and rapidly growing megacities with a population of approximately 86 million;
- Our findings have important implications for enhancing follow-up studies from an impact analysis perspective, such as assessing compound flood hazards from rainfall and storm surge.

We have carefully checked the Aims & scope of HESS journal by following the link https://www.hydrology-and-earth-system-sciences.net/about/aims_and_scope.html. We believe that our study is within the scope of HESS journal, since "*HESS encourages and supports fundamental and applied research that advances the understanding of hydrological systems, their role in providing water for ecosystems and society, and the role of the water cycle in the functioning of the Earth system.*"

Our study coincides with the second scope of HESS "*2. the study of the spatial and temporal characteristics of the global water resources (solid, liquid, and vapour) and related budgets, in all compartments of the Earth system (atmosphere, oceans, estuaries, rivers, lakes, and land masses), including water stocks, residence times, interfacial fluxes, and the pathways between various compartments;*"

Comment: There are some merits in the study, but there are substantial flaws that prevent the manuscript from publication. The discussion lacks depth concerning the physical mechanisms of climate change impacts on typhoons, especially for the typhoon dynamic and thermodynamic changes. The paper primarily presents changes in typhoon intensity and precipitation as projected by the WRF model and PGW method under a warmer climate, but it fails to systematically explore the underlying dynamic and thermodynamic reasons for these changes. This omission limits the depth of understanding of the complex physical processes involved. Moreover, the conclusions presented are not particularly novel and innovative, focusing mainly on the increase in typhoon intensity and precipitation due to global warming. Addressing these issues could significantly improve the paper's quality.

Reply: We thank the Reviewer for the feedback.

In this revision we have addressed your concerns as follows:
The underlying physical mechanisms driving warming-induced changes in typhoon intensity and precipitation are explored in more detail. Specifically, we have closely followed the Reviewer's suggestions to shed light on the dynamic and thermodynamic factors behind these changes. For example, we compare convective available potential energy (CAPE), vertical winds, and relative

vorticity from PGW simulations with those from ERA5 simulations to improve our understanding of the complex physical processes involved.

The Conclusions section is thoughtfully revised to highlight our key scientific findings, specifically, physical mechanisms driving changes in typhoon intensity and precipitation under varying warming conditions.

Comment: The introductory section is cluttered and lacks a logical structure, and it is more of a thesis introduction than that of a research article. Furthermore, while the authors spend considerable time discussing existing research gaps in current PGW studies, they barely touch upon the specific effects of climate change on typhoon intensity and the physical mechanisms behind it. The authors mention previous studies but do not systematically explain the results and progress made in this field. For instance, whether climate change will lead to stronger typhoons in the western Pacific, how much will the typhoon intensify with one degree SST warming, and how climate change can affect typhoons' intensity and precipitation. There should already be plenty of research covering these topics. Strengthening the introduction would make it easier for readers to grasp what has been accomplished and the scientific basis of it.
Reply: Our introductory section is designed to present the pseudo global warming approach and the storyline approach in the context of warming-induced changes in typhoon intensity.

In this revision a comprehensive literature review has been conducted to systematically present the background and current state-of-the-art research on warming-induced changes in typhoon intensity. Our revised introductory section specifically highlights key findings and achievements in understanding the plausible physical mechanisms of typhoons under warming conditions, including atmospheric effects, oceanic influences, and water cycle dynamics. This strengthens the introduction section and improve the readability.

Comment: On page 5, line 155, the manuscript states that 28 typhoons were initially selected for performance assessment, but only seven were ultimately chosen for detailed study. This selection process raises questions about the model's ability to accurately simulate typhoon tracks and intensities. As the author mentioned in the introduction: "How well are historical typhoons affecting the PRD represented by our selected model set up regarding track accuracy and intensity?". If only seven out of 28 typhoons demonstrate reasonable model performance, this suggests potential limitations in the model's reliability for simulating such events.
Reply: We acknowledge the limitations in our current model setup for simulating typhoons. We are fully aware of the uncertainties arising from model physical schemes, configurations, synoptic conditions, and warming scenarios. However, before reaching the final model setup (shown in Figure 4), we conducted numerous preliminary simulations with different domain sizes, domain numbers, grid spacing, and physical schemes to identify a suitable model setup. These preliminary simulation results indicated that it is challenging to find a single model setup that performs well for all 28 typhoons. As a result, our PGW analyses are limited to the 7 selected typhoons, where the WRF model setup led to good performance.

In this revision additional PGW simulations for one of the typhoons with poorer performance are conducted to assess whether the performance of the WRF model impacts the credibility of the remaining PGW simulations. The limitations of WRF in simulating typhoons in the region are critically elaborated in the "4.3 Limitations of the study design" section.

Comment: On page 8, line 250, the use of spectral nudging is mentioned, but it's unclear whether it was applied across all domains. Typically, spectral nudging is used at the outermost model domain to minimize its impact on simulation results. Clarification of how spectral nudging was implemented in this study is needed for a better understanding of its influence on the results.
Reply: The clarification of using spectral nudging has been added into the Methods section.

"In our study, spectral nudging is applied in both the outermost and innermost model domains to prevent the model from deviating from its boundary conditions. We used spectral nudging only for horizontal wind components (i.e., *u* and *v*) above the 500 hPa level."

Comment: The analysis of Figure 4 focuses only on the mean bias of maximum wind speed and minimum sea level pressure, which may not fully capture the model's reliability and accuracy (results are also very sensitive to the time period chosen for time averaging). A more robust approach would be to compare the time series of the model's maximum wind speeds and minimum sea level pressures against best track data, to assess both intensity and temporal accuracy more comprehensively.
Reply: In Figure 4, the mean bias is used to quantitively assess the model's performance in simulating typhoon intensity. However, we acknowledge that mean bias does not capture the model's performance in terms of temporal evolution.

In this revised version we have introduced additional metrics, such as the Kling-Gupta efficiency (KGE), to more comprehensively evaluate temporal accuracy.

References:

Gupta, H. V., Kling, H., Yilmaz, K. K., & Martinez, G. F. (2009). Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling. Journal of Hydrology, 377, 80–91. https://doi.org/10.1016/j.jhydrol.2009.08.003

Kling, H., Fuchs, M., & Paulin, M. (2012). Runoff conditions in the upper Danube basin under an ensemble of climate change scenarios. Journal of Hydrology, 424–425, 264–277. https://doi.org/10.1016/j.jhydrol. 2012.01.011

Comment: Section 3.2.2 discusses experiments comparing loS-hiA (low surface - high atmospheric temperatures) and hiS-loA (high surface - low atmospheric temperatures) scenarios. While the comparison is interesting, the deviation from realistic conditions and the lack of in-depth analysis on the physical mechanisms influencing typhoon dynamics is a major drawback. The authors only describe time series plots of typhoon intensity and precipitation, which is seriously lacking in the analysis and explanation of the mechanism from the point of view of typhoon dynamics, thermodynamics, and physics. A reasonable research article should not only pose scientific questions to identify problems but also provide well-founded explanations and reasons, rather than merely describing the observed model outputs.
Reply: We thank the Reviewer for guiding us toward a more in-depth analysis of the physical mechanisms.

We would like to emphasize the scientific contributions of the loS-hiA and hiS-loA scenarios. Developing these two additional storylines from available GCMs allows us (1) to quantitively assess changes in uncertainties associated with simulated hydrometeorological variables (e.g., Figures 7 and 8); (2) to enhance risk awareness by investigating deep uncertainties beyond the recognized limitations of GCM ensembles, particularly in relation to "Gray Rhino" or "Black Swan" events in the context of weather and climate extremes. In the revised version, we will include the above statements to highlight the novelty of our study.

In the revised version, the physical mechanisms behind the warming-induced changes in typhoon intensity and precipitation are systematically explored. Specifically, we closely follow the Reviewer's suggestions to shed light on the dynamic and thermodynamic factors driving these changes. For instance, we compare convective available potential energy (CAPE), vertical winds, and relative vorticity derived from PGW simulations with those from ERA5 simulations to enhance our understanding of the complex physical processes involved.

We thoughtfully revise the Conclusions section to emphasize our key scientific findings, particularly the physical mechanisms behind changes in typhoon intensity and precipitation under different warming scenarios.

Comment: Following up on the previous comment, after reviewing sections 3 and 4, I am concerned that the results presented in this article do not sufficiently support the research paper. While it is evident that the authors conducted a large number of experiments using the WRF model, the results section primarily showcases time series plots of typhoon intensities and precipitation (including the Integrated Kinetic Energy) from these experiments. These findings are not particularly novel and innovative, as several studies have already employed the WRF and PGW methods to investigate the impact of climate change on typhoon intensity and precipitation, often arriving at similar conclusions. My suggestion is for the authors to conduct a comprehensive analysis of the model results, comparing the simulation outcomes of PGW signals derived from individual CMIP6 models. It is helpful to determine whether the variations between different experiments stem from discrepancies in CMIP6 model global warming signals and to assess how these differences specifically affect typhoon intensity. The authors should also delve into the reasons behind changes in typhoon intensity and precipitation, detailing the specific dynamics and thermodynamics of typhoons and how these alterations influence typhoon behavior, which is a crucial aspect of this research. For example, in comparisons such as loS-hiA and hiS-loA, the study should explore how varying temperatures introduced through PGW modify the typhoon structure and dynamics, rather than merely describing the time series of typhoon intensity.
Reply: Thank you for your thoughtful and detailed feedback.

In this revision, we have closely followed the reviewer's suggestions. We dive into the analysis to explore the physical mechanisms behind our results. For example, we compare the WRF-PGW simulations derived from individual CMIP6 models. This comparison helps us determine whether the variations between different experiments arise from discrepancies in the global warming signals of the CMIP6 models and assess how these differences specifically influence typhoon intensity.

In this revision the physical mechanisms driving the warming-induced changes in typhoon intensity and precipitation are systematically investigated. We closely follow the Reviewer's suggestions to shed light on dynamic and thermodynamic factors. For example, we compare convective available potential energy (CAPE), vertical winds, and relative vorticity from the PGW simulations (including the loS-hiA and hiS-loA scenarios) with those from ERA5 simulations. This enables us to quantitatively examine how temperature variations introduced through PGW affect typhoon structure and dynamics.

Comment: As noted in Section 4.3, line 636, the author acknowledges that "The selected sample size of 7 typhoons is too small to draw a generalized conclusion on typhoon intensity over the PRD under climate change." If the model accuracy can't be improved, I will recommend that the authors extend their analysis to include all 28 typhoon cases, regardless of whether the WRF accurately reproduces the typhoon's path and intensity very accurately. This broader analysis could enable the authors to draw more general and comprehensive conclusions. For instance, they could determine how much warming per degree of SST might lead to an enhancement of typhoon intensity; and whether the increase in typhoon rainfall due to SST, atmospheric temperature, and typhoon intensity, following the Clausius-Clapeyron (CC) relationship. The authors should also compare these findings with those from existing references to provide a more robust evaluation of the impacts of climate change on typhoons.
Reply: We appreciate the Reviewer's suggestion to include all 28 typhoon cases, regardless of the WRF model performance. However, we have chosen to focus on the 7 selected typhoons for our PGW investigation. This choice is based on our evaluation of the model's performance using objective metrics. Since our study specifically aims to investigate warming-induced changes in typhoon intensity, these 7 selected cases represent a range of intensities from Category 1 to Category 4. For each typhoon, we conducted 18 warming scenario simulations. We believe that this sample size is sufficient to support our conclusions. Of course, we are fully aware of the uncertainties arising from

model physical schemes, configurations, synoptic conditions, and warming scenarios. However, our preliminary simulations indicated that it is challenging to find a single model setup that performs well across all 28 typhoons. Conducting WRF simulations for all 28 typhoon cases across 18 storylines would require significantly high computational resources and storage capacity. Therefore, our selection is a balance between computational efficiency and model accuracy, and our PGW analyses are restricted to the 7 selected typhoons.

In this revision we have closely followed the Reviewer's suggestions to investigate the Clausius-Clapeyron relationship. Specifically, the relationships between changes in hydrometeorological variables (e.g., precipitation or the vertically integrated atmospheric total water) are analyzed for each storm and each GCM, as well as changes in the temperature. This analysis enhances our understanding of the Clausius-Clapeyron relationship, particularly for typhoon cases under warming conditions. We focus on the uncertainties in the Clausius-Clapeyron relationship derived from the PGW simulations, for example, comparing the simulated responses of Hagupit and Neoguri forced by the CanESM5 model. Accordingly, the relevant physical mechanisms behind the increase in the impact and the spread across models are revealed. Eventually, these insights enable us to address the research question: "Do warmer models lead to more changes?".

In this revision the comparison of our findings with those from existing references is added into the "Discussion" section to provide a more robust evaluation of the impacts of climate change on typhoons.