Response to Reviewer 2

Comment: Olschewski et al., investigate tropical cyclones (TCs) over the Pearl River Delta and their physical changes under climate change using the storylines approach. They select historical TCs and change their initial and boundary conditions using the Pseudo-Global Warming method. The method used in this study is interesting, as it takes advantage of the flexibility that storylines offer to carry out a thorough analysis, going beyond mean/median changes in projections. I particularly liked the extra 2 storylines exploring favorable and unfavorable thermodynamic conditions, as this type of thinking helps overcome potential limitations on climate models. The different results obtained for the thermodynamic storylines support the added value of exploring them. I also like the inclusion of integrated kinetic energy (IKE) as an additional metric aimed at offering some proxy for impact. I believe the manuscript contributes to the field and is compatible with this journal. Having said that, I have some comments and questions that could provide more context to the work.

Reply: We are pleased that the reviewer acknowledges the significance of our work. We appreciate the constructive comments for enhancing the quality of our manuscript.

Spectral nudging:

Comment: In the methods section (line 252), spectral nudging is used to minimize spatial variability. I found the idea of combining both approaches interesting. Did you run/check simulations without applying spectral nudging? I wonder how influential this step is in your setup. I think this merits more discussion on the implications of using and not using the spectral nudging.

Reply: We did conduct a substantial number of preliminary simulations to evaluate the performance of our model setup, both with and without spectral nudging. Our findings indicate that the correct application of spectral nudging is crucial for accurately reproducing observed typhoon tracks. This finding aligns with our recent publication (Sun et al., 2024) and is supported by previous studies (e.g., Moon et al., 2018).

The discussions on the implications of using versus not using spectral nudging, in particular in conjunction with the pseudo global warming approach are added into the revised version.

Reference:

Sun, Q., Olschewski, P., Wei, J., Tian, Z., Sun, L., Kunstmann, H., and Laux, P., 2024: Key ingredients in regional climate modelling for improving the representation of typhoon tracks and intensities, Hydrol. Earth Syst. Sci., 28, 761–780, https://doi.org/10.5194/hess-28-761-2024

Moon, J., Cha, D.H., Lee, M. and Kim, J., 2018: Impact of spectral nudging on real- time tropical cyclone forecast. Journal of Geophysical Research: Atmospheres, 123(22), pp.12-647.

Comment: While it makes sense to remove spatial variability to make comparisons more straightforward, a spatial change in TC track as consequence of climate change would be an interesting finding and relevant for impacts. If there are results available for the runs without the spectral nudging, you could consider analyzing them as well.

Reply: We generally agree with the importance of quantifying spatial changes in typhoon tracks due to global warming. However, we found that global warming does not lead to noticeable changes in the simulated typhoon tracks, primarily due to the application of spectral nudging.

In the revision the spatial changes in the simulated typhoon tracks as a consequence of climate change, particularly in runs without spectral nudging are quantitively analyzed. Additionally, the uncertainties associated with the results derived from applying spectral nudging are discussed as well.

Comment: Since you included spectral nudging in addition to PGW, you could discuss the role (e.g., advantages, drawbacks, and when to use each one) of each method - PGW, spectral nudging, and their combined use - in simulating TCs and their use with storylines.

Reply: We thank the Reviewer for guiding the discussions.

The discussion regarding the role of the three methods we employed in simulating tropical cyclones and their associated storylines are enhanced. We have closely followed the Reviewer's suggestions to examine the advantages, limitations, and applicability of PGW, spectral nudging, and their combined use, particularly in the context of evaluating weather and climate extremes induced by global warming.

Temperature levels:
Comment: In figure 2 you demonstrate the resulting delta change in temperature for each model from April to October. I am intrigued to understand the direct relation between the temperature change per model for each storm and the change in relevant metrics, such as precipitation. For instance, in Figure 2b CanESM5 (yellow) shows the largest delta change for 3 months, which made me expect to see the same model causing the largest changes for precipitation across all storms. Instead, only for one case, Hagupit, we see that. Could it be that the other storms occur in months where CanESM5 is not as intense as other models? I believe adding an extra (SI) Figure comparing some results (maybe mean precipitation) to the increase in temperature per model could offer extra insights into the mechanisms behind the increase in impact and the spread across models (do warmer models lead to more changes?).
Reply: We thank the Reviewer for the valuable suggestions.

In this revision the relationships between changes in the hydrometeorological variables (e.g., precipitation or the vertically integrated atmospheric total water) are derived for each storm and each GCM in relation to temperature changes. This analysis enhances our understanding of the Clausius-Clapeyron relationship, particularly for typhoon cases under global warming. As suggested, 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?".

Contextualization:
Comment: I see that the focus of the discussion section was in comparing the results for TC estimations in the DPR with other studies. However, I miss some discussion on your approach and results from a storylines perspective. There are other storyline works that explored TCs in DPR (Qiu et al., 2022), TCs using spectral nudging (Goulart et al., 2024) or even using a similar Pseudo-Global Warming method (Dullaart et al., 2024). I believe also framing the study within the storylines field of work can provide a better contextualization and visibility to your work.
Reply: We thank the Reviewer for guiding the discussions.

In the revision we elaborate on the discussions on the role of the three methods we employed in simulating tropical cyclones. Specifically, the advantages, limitations, and applicability of PGW, spectral nudging, and their combined use, are discussed particularly in the context of evaluating weather and climate extremes induced by global warming. Additionally, our study is framed within the storylines field of work to enhance contextualization and increase visibility.

Minor comments:
Comment: In general, the writing is a bit long and complex, some more direct text could make the flow of the manuscript better.
Reply: We thank the Reviewer's feedback. Our revised manuscript is presented in a clear organizational structure.

Comment: Line 41: biggest natural risk factors -> I think biggest is not the best adjective here.
Reply: "Biggest" has been changed to "destructive".

Comment: Line 120: "This is based on the findings of Shen et al. (2000), Hill and Lackmann (2011), and Tuleya et al. (2016) who found that an increase in thermodynamic atmospheric stability and

increased sea surface temperatures counteract with regards to typhoon intensity" – The text is a bit confusing, and the sentence ends with a comma.
Reply: We have rephrased this sentence for clarity.

"The reassembling strategy is due to the fact that the warming-enhanced atmospheric stability and the increased sea surface temperature have opposite effects on typhoon intensity (Shen et al., 2000; Hill and Lackmann, 2011; Tuleya et al., 2016)."

Comment: Line 164: "initial and boundary conditions from ERA5 are applied on a grid-cell basis" – does it mean for each grid cell you apply a specific delta factor? So, it means that the delta factor is calculated for every grid cell and every timestep of the simulation?
Reply: In this study, the delta factor is calculated for every grid cell on each pressure level of the selected GCMs, but not for every timestep of the simulation.

We derive the delta factor by comparing GCM projections during the far-future period of 2071-2100 and the corresponding GCM simulations during the historical (baseline) period of 1985-2014. Temporally, the delta factor is calculated on a monthly scale, averaged over 30 years. Spatially, it is calculated for each grid cell on each pressure level of the GCMs.

To incorporate climate change signals from GCMs into the ERA5 reanalysis, we first remap the GCM-derived delta factor fields onto the grid cells of ERA5. Then, the remapped delta factor fields for a given month are added to the 6-hourly ERA5 reanalysis for that same month, facilitating pseudo global warming simulations.

In this revision the above-mentioned details about the procedure of deriving and applying delta factors have been added into the "Data and Methods" section.

Comment: Line 366: "simulations the agreement of the historical and simulated tracks is high" -> Is this already including the spectral nudging? If so, it could be a bit clearer.
Reply: Yes, the spectral nudging has been included in the simulations.

We have included this information, and the updated sentence is as follows:
"Across all simulations, the agreement between the historical and simulated tracks is high, primarily due to the application of spectral nudging."

Comment: Line 425: I think it could be rewritten to make it clearer and more direct.
Reply: As suggested, we have rewritten this sentence for clarity.

The updated sentence is as follows:
"Figure 6d illustrates that warming will increase the median of the mean 1-hourly precipitation across the seven investigated typhoons by up to 1 mm h^{-1}."

Comment: Line 624: Missing punctuation in "; Kantha, 2006) Based on"
Reply: A full stop has been added in the revised version.

Comment: Limitations (line 628): Since you already aimed for some impact proxy using the IKE, you could mention that other impact approaches (metrics, models etc.) can also enhance the study from an impact perspective, such as wind and flood modelling.
Reply: We thank the Reviewer for guiding the discussions.

In our revision, in addition to the IKE, the discussion on other impact analysis approaches is expanded. For example, compound events analysis using copulas (e.g., Bevacqua et al., 2017) and storm surge and inundation modeling using hydrodynamic models (e.g., Xu et al., 2024) are discussed in the revised "Limitations of the study design" section.

References:

Bevacqua, E., Maraun, D., Hobæk Haff, I., Widmann, M., and Vrac, M., 2017: Multivariate statistical modelling of compound events via pair-copula constructions: analysis of floods in Ravenna (Italy), Hydrol. Earth Syst. Sci., 21, 2701–2723, https://doi.org/10.5194/hess-21-2701-2017

Xu, H., Ragno, E., Jonkman, S. N., Wang, J., Bricker, J. D., Tian, Z., and Sun, L., 2024: Combining statistical and hydrodynamic models to assess compound flood hazards from rainfall and storm surge: a case study of Shanghai, Hydrol. Earth Syst. Sci., 2024, 28, 3919–3930, https://doi.org/10.5194/hess-28-3919-2024

References:

Qiu, J., Liu, B., Yang, F., Wang, X., and He, X.: Quantitative Stress Test of Compound Coastal-Fluvial Floods in China's Pearl River Delta, Earth's Future, 10, e2021EF002638, https://doi.org/10.1029/2021EF002638, 2022.

Goulart, H. M. D., Benito Lazaro, I., van Garderen, L., van der Wiel, K., Le Bars, D., Koks, E., and van den Hurk, B.: Compound flood impacts from Hurricane Sandy on New York City in climate-driven storylines, Nat. Hazards Earth Syst. Sci., 24, 29–45, https://doi.org/10.5194/nhess-24-29-2024, 2024.

Dullaart, Job CM, et al. "Improving our understanding of future tropical cyclone intensities in the Caribbean using a high-resolution regional climate model." Scientific Reports 14.1 (2024): 6108.

Reply: The recommended literatures are cited in the revised version.