Response to Reviewers

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Title of Paper: The impact of tropical cyclones on regional ozone pollution and its future trend in the Yangtze River Delta of China

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Dear Editor,

We would like to submit our revised manuscript entitled "**The impact of tropical cyclones on regional ozone pollution and its future trend in the Yangtze River Delta of China**" to ***Atmospheric Chemistry and Physics***.

On behalf of my co-authors, we thank you for handling the peer review of our manuscript. We appreciate the time and effort put in by you and the referees in reviewing our manuscript. These constructive comments are all valuable for revising and improving our manuscript. We have carefully studied these comments and made correction as requested. In the point-by-point responses, the reviewer's comments are in black, the author's responses are in blue, and the changes made to the text are highlighted in red. The line numbers in the author's responses are obtained from the clean version of revised manuscript, in which all the revisions have been accepted.

Best regards,

Authors

Anonymous referee #2:

General comments: The manuscript investigates the impact of tropical cyclones on ozone and its future changing trends in the Yangtze River Delta region. Their results shows that the regional O_3 pollution are affected by tropical cyclones, and based on future scenario data, they further discuss the changes in tropical cyclones and their impact on the trend of O_3. The results are interesting for understanding the future change of tropical cyclones and O_3. Several points of the manuscript still need to be improved before accepted. Specifically, they show that the regional O_3 pollution usually occurred before and after tropical cyclones in 2018−2022 as shown in their analysis, why do they use the data reconstruction about the TC weather patterns to evaluate the annual change of O_3 concentrations in the future, instead of extreme O_3 pollution? I believe that the evaluation of extreme O_3 pollution may be reasonable. Therefore, the manuscript needs to make major revisions before their paper is considered acceptable. Please see the following comments.

Response: We thank the referee #2 for the constructive comments and suggestions, which are very helpful for improving the clarity and reliability of the manuscript. We have revised some sentences for better readability and enhanced the clarity of some figures. Please see our point-by-point responses to your comments below.

Main comments:

1. As show in manuscript, the regional O_3 pollution usually occurred before and after tropical cyclones in 2018-2022 as shown in their analysis. They use the data reconstruction about the TC weather patterns to evaluate the annual change of O_3 concentrations in the future, instead of extreme O_3 pollution? I believe that the evaluation of extreme O_3 pollution may be reasonable. Please discuss this point.

Response: Thank you for your careful review of our manuscript and your scientific suggestions. Based on your suggestion, we have adjusted the study period. Our previous analysis shows that O_3 pollution in the Yangtze River Delta YRD typically occurs during **June–September**. This period not only coincides with the peak tropical cyclone (TC) activity but also corresponds to the highest O_3 pollution occurrence, making it the most relevant timeframe for our study. To better investigate the impact of TCs on O_3 pollution, we no longer perform weather pattern classification for the entire year, but focus on June–September each year. After classifying the weather patterns, we found that the frequency and intensity of these patterns are strongly correlated with O_3 concentration variations. Following previous studies, we reconstructed the annual warm season O_3 variation sequence based on the frequency and intensity of the weather patterns. **In this study, the reconstructed sequence also represents O_3 variations during June–September each year when extreme O_3 episodes occur.**

We note that tropical cyclone events can lead to extreme O_3 episodes. However, as our reconstruction method is based on weather pattern frequency and intensity, it does not allow for analysis of individual extreme events, although it effectively captures the main interannual variability of O_3. In this study, we use this method to reconstruct future annual O_3 variation sequences in warm season when extreme O_3 episodes usually occur, and to explore the changes in the occurrence days of TC-related weather patterns and their contributions to the reconstructed sequences.

In our future work, we will combine numerical simulations with observational data to further investigate the relationship between tropical cyclones and extreme O_3 pollution, providing a more comprehensive understanding of the impacts of TCs on O_3. Now, the study is going on, and some of the reviewers' suggestions are also adopted.

Changes in the revised manuscript (lines 260–263 and 397–406) are shown as follows:

3.2 Main synoptic weather patterns in the YRD

"Based on the analysis of O_3 variation characteristics in the YRD, O_3 concentrations were generally high from **June to September**, coinciding with the peak season of TC activity. We selected June to September during 2018−2022 as the research period and used the PTT weather classification method to classify the weather situation…"

3.4.1 The role of changes in the intensity and frequency of SWPs in the reconstruction of the annual variation series of O_3

"Different dominant SWPs produced varying near-surface meteorological conditions, which in turn affected atmospheric processes such as O_3 photochemical production, transport, diffusion, and wet and dry deposition. Changes in the frequency and intensity of SWPs were two key factors influencing O_3 concentration variations. We reconstructed the annual time series of O_3 concentrations from **June to September** between 2018 and 2022 by considering only changes in SWP frequency (fre) and changes in both SWP intensity and frequency (fre+int). In our study, we first removed the influence of emission sources on O_3 concentrations based on the results of Yan et al. (2024). Subsequent analyses were conducted using O_3 concentration series that were free from emission source influences. Using the O_3 trend reconstruction method, we quantified the contribution of SWPs to annual variations in O_3 concentrations from June to September."

2. The authors utilize the data reconstruction about the TC weather patterns to evaluate the annual change of O_3 concentrations in the future. This data reconstruction of O_3 concentrations only considers the effects of weather patterns, I want to know the effect from the perturbations in precursor emissions. Maybe the perturbations in precursor emissions can dominate the future change of O_3 concentrations. Therefore, please check the relative contributions of climate change (or weather patterns) and perturbations in precursor emissions to future O_3 concentrations.

Response: Thank you for your helpful suggestion. On the early stage when establishing the reconstruction relationship for weather patterns, we did not remove the influence of emissions. Considering the reviewer's comment, in the revised manuscript, we first applied detrending and **removed the effect of emission sources** from the O_3 data before establishing the reconstruction relationships. This allows us to analyze the future impact of weather patterns on O_3 more accurately.

We acknowledge that perturbations in precursor emissions may dominate future O_3 changes, but evaluating their relative contribution is beyond the scope of the current study. The primary focus of this work is to investigate the role of tropical cyclone-related weather patterns in driving interannual O_3 variability. Numerous studies have already analyzed the contribution of emissions to O_3, while our study emphasizes the influence of weather patterns on future O_3 trends. The reconstruction method used in this study is also based solely on the frequency and intensity variations of weather patterns and does not include any calculation related to precursor emissions.

In future work, we will combine numerical simulations with emission scenario analyses to further quantify the relative contributions of climate/weather pattern changes and perturbations in precursor emissions to future O_3 variations.

Changes in the revised manuscript (lines 397–406) are shown as follows:

3.4.1 The role of changes in the intensity and frequency of SWPs in the reconstruction of the annual variation series of O_3

"Different dominant SWPs produced varying near-surface meteorological conditions, which in turn affected atmospheric processes such as O_3 photochemical production, transport, diffusion, and wet and dry deposition. Changes in the frequency and intensity of SWPs were two key factors influencing O_3 concentration variations. We reconstructed the annual time series of O_3 concentrations from June to September between 2018 and 2022 by considering only changes in SWP frequency (fre) and changes in both SWP intensity and frequency (fre+int). In our study, we first removed the influence of emission sources on O_3 concentrations based on the results of Yan et al. (2024). Subsequent analyses were conducted using O_3 concentration series that were free from emission source influences. Using the O_3 trend reconstruction method, we quantified the contribution of SWPs to annual variations in O_3 concentrations from June to September."

3. In the global climate models, they can directly simulate the surface O_3 concentrations in historical and future scenarios (e.g., Turnock et al., 2020). I suggest that the authors added the results from the Coupled Model Intercomparison Project Phase 6 (CMIP6) to further examine the Figure 9.

Turnock, S. T., Allen, R. J., Andrews, M., Bauer, S. E., Deushi, M., Emmons, L., Good, P., Horowitz, L., John, J. G., Michou, M., Nabat, P., Naik, V., Neubauer, D., O'Connor, F. M., Olivié, D., Oshima, N., Schulz, M., Sellar, A., Shim, S., Takemura, T., Tilmes, S., Tsigaridis, K., Wu, T., and Zhang, J.: Historical and future changes in air pollutants from CMIP6 models, Atmos. Chem. Phys., 20, 14547–14579,

https://doi.org/10.5194/acp-20-14547-2020, 2020.

Response: Thank you for your valuable comment. Our research reconstructs the annual ozone variation series during the warm season (June-September) based on weather patterns. Figure 9 shows the reconstruction results, which are primarily based on the frequency and intensity of weather patterns. Based on your suggestion, we conducted a comparative verification of our results. We find that the overall trends of the reconstructed O_3 sequences under future scenarios are similar to those reported in previous studies (e.g., Turnock et al., 2020, Li et al., 2023), indicating that our reconstruction reasonably reflects the future trends of O_3. Based on this, we revised the introduction and future reconstruction sections.

Changes in the revised manuscript (lines 102–111 and 502–516) are shown as follows:

"Affected by the surrounding atmospheric circulation, the slower the TCs move, the longer their impact duration and the greater their effects, which influence O_3 transport, extend the duration of O_3 pollution, exacerbate O_3 concentration, and expand the spatial extent of pollution. Global climate models (GCMs) are able to directly simulate surface O_3 concentrations under both historical and future scenarios (Turnock et al., 2020). These simulations provide an important reference for understanding the long-term evolution of surface O_3 driven by changes in emissions and climate. In the context of global warming in the future, the increase in unfavorable meteorological conditions will make the O_3 pollution problem more serious (Fu and Tai, 2015; Keeble et al., 2017; Arnold et al., 2018; Akritidis et al., 2019; Saunier et al., 2020). Therefore, studying the trend of O_3 changes under future climate change scenarios is particularly important for formulating countermeasures against O_3 pollution.

The average O_3 concentration in the YRD from June to September during 2018 to 2022 was 123.89 μg/m^3. Under the SSP2-4.5 scenario, O_3 concentrations in the YRD are projected to increase relative to the historical period (Fig. 9a), with an average increase of approximately 1.88 μg/m^3. Based on the reconstructed contribution of SWP changes, future O_3 concentrations in the YRD are estimated to be 2.70 μg/m^3 higher than in the historical period. Under the SSP5-8.5 scenario, O_3 concentrations are projected to increase relative to the historical period (Fig. 9b), reaching 133.80 μg/m^3

in 2100, an increase of approximately 6.86 μg/m^3. Based on the reconstructed contribution of SWP changes, future O_3 concentrations in the YRD are estimated to be 9.85 μg/m^3 higher than in the historical period. In summary, under both the SSP2-4.5 and SSP5-8.5 future climate scenarios, O_3 concentrations in the YRD are projected to increase from June to September, with more severe O_3 pollution under the SSP5-8.5 scenario. Previous studies based on CMIP6 multi-model simulations have shown that surface O_3 concentrations are projected to decrease in response to reductions in anthropogenic emissions, although the magnitude and spatial distribution of changes vary among scenarios (Turnock et al., 2020; Li et al., 2023). The trends revealed in this study are generally consistent with those of previous studies, lending confidence to the robustness of our findings."

References

Li, H., Yang, Y., Jin, J., Wang, H., Li, K., Wang, P., and Liao, H.: Climate-driven deterioration of future ozone pollution in Asia predicted by machine learning with multi-source data, Atmos. Chem. Phys., 23, 1131–1145, https://doi.org/10.5194/acp-23-1131-2023, 2023.

Turnock, S. T., Allen, R. J., Andrews, M., Bauer, S. E., Deushi, M., Emmons, L., Good, P., Horowitz, L., John, J. G., Michou, M., Nabat, P., Naik, V., Neubauer, D., O'Connor, F. M., Olivié, D., Oshima, N., Schulz, M., Sellar, A., Shim, S., Takemura, T., Tilmes, S., Tsigaridis, K., Wu, T., and Zhang, J.: Historical and future changes in air pollutants from CMIP6 models, Atmos. Chem. Phys., 20, 14547-14579, http://doi.org/10.5194/acp-20-14547-2020, 2020.

Finally, we would like to thank the reviewers for their comments and suggestions, which improved the rigor of our work and increased the article's novelty. Once again, thank you for your time. We hope that these revisions, made based on your comments, effectively address all of your concerns regarding our manuscript.