Dear Editor,

We appreciate the prompt reviews and would like to thank the reviewers for insightful comments and suggestions on our manuscript entitled “Impact of northward tropical cyclones on ozone in Southeastern China” (MS No.: egusphere-2025-5765). We have carefully considered all comments and suggestions. Listed below are our point-by-point responses to all comments and suggestions of this reviewer (Reviewer’s points in black, our responses in blue).

## Anonymous Referee #2

We appreciate the encouraging comments and suggestions.

**1. Definition of “TC Day/Non-TC Day” and “TC influence” is unclear and not reproducible.**

The manuscript compares ozone levels on “TC Days” versus “Non-TC Days” (e.g., Fig. 3a; around L154) and uses “periods of TC influence” to derive the 37% reduction applied to solar radiation and photolysis rates in NO_TC (Section 2.3). However, the criteria for classifying a day/time as “TC influence” are not explicitly stated. Please provide a clear, reproducible definition, including: (i) the spatial domain used to detect TC presence (e.g., west of 140°E only？); (ii) the temporal resolution (6-hourly samples vs daily aggregation) and how multiple TCs in one day are handled; (iii) whether post-landfall residual circulation days are counted as TC days; and (iv) objective criteria for the three track types (westward/landfalling/northward). In addition, please explicitly define the spatial boundary of SEC (lat/lon box or a land mask) in the Methods and show it in the figures (at least Fig. 3).

**Response:**

We appreciate this helpful suggestion. It is an oversight that the definitions of “TC Day/Non-TC Day” and “TC influence” were insufficiently explicit in the original manuscript. We have now revised Section 2.2 of the revised manuscript to provide clear and reproducible definitions of the spatial domain used to identify TC presence, the temporal resolution, the handling of days affected by multiple TCs and post-landfall residual circulation, and the objective criteria for the three TC track types used in this study (page 4, lines 102 to 108). We have also defined the spatial boundary of SEC in line 79 and marked it in Fig. 3b and the related figures. The revised text of Section 2.2 is reproduced below for your information.

**Page 4, line 102 to 108:** In this study, TCs active over the western North Pacific during autumn from 2014 to 2024 are identified at a 6 h temporal resolution, and days with at least one TC record are defined as TC Days, while the remaining days are classified as Non-TC Days. Specifically, if more than one TC is present on the same day, that day is still counted only once as a TC Day. Considering the spatial range of TC influence on SEC (Deng et al., 2019; Lin et al., 2024), we further restrict the TC study domain to 105–140°E, 10–40°N. Any day with at least one TC record within this region is regarded as a "TC influence" day, including post-landfall residual circulation days. Based on the above definitions, TC tracks are further classified into three types following by (Ouyang et al., 2026): westward TCs, landfalling TCs, and northward TCs (Fig. 3b–d).

**2. The linkage between the multi-year statistical hypothesis and the two-case "validation" is incomplete due to missing mechanistic diagnostics in the case simulations.**

The study first uses long-term statistics (Figs. 4–5; box/violin plots) to propose a mechanistic framework (radiation/photochemistry, boundary-layer mixing, transport, and wet processes). However, the subsequent case-study simulations (Figs. 10–12 and related discussion) mainly show ozone differences (and limited wind/cross-section information), while key variables invoked by the mechanistic explanations are not shown, such as SSRD/photolysis rates, cloud/precipitation, wet/dry deposition, precursor/NOy transport, and/or process terms. Consequently, the case simulations cannot robustly support the mechanism inferred from the long-term statistical signals

(Figs. 4–5), leaving the key mechanistic claims insufficiently justified.

For example, L234–236 states that under STY–SSTY "enhanced wet scavenging begins to outweigh" despite generally favorable photochemical conditions. Yet Fig. 6(d–f) shows predominantly negative RH anomalies over southern China/SEC; RH anomalies alone cannot demonstrate enhanced wet scavenging, and the phrase "wet scavenging of ozone" itself is contentious without quantitative evidence. Similar issues apply to the explains of Figs. 10–12 and Table 2, where only ozone changes are shown but the interpretation relies on unshown changes in radiation, precipitation/deposition, and precursor transport.

**Response:**

Thank you for the thoughtful comment. We agree that Section 3.1 of the original manuscript proposed a mechanistic framework based on the long-term statistical analysis of meteorological variables, whereas the case-study simulations mainly relied on ozone differences and limited wind/cross-section information to interpret the mechanisms inferred from the statistical signals (Figs. 4–5). Since the key meteorological variables were not directly shown, the mechanistic linkage between the multi-year statistical hypothesis and the two-case "validation" was not sufficiently complete. To address this issue, we have revised and reanalyzed the meteorological statistics shown in Fig. 5 in the revised manuscript (page 11 to 13, line 238 to 279). We have also reexamined the analysis of Figs. 10–12 and Table 2 by incorporating the key meteorological conditions such as solar radiation reaching surface (RGRND), 2 m relative humidity ($RH_2$), and $T_2$, and have added the corresponding differences in RGRND (Figs. S1 and S4), $T_2$ (Figs. S2 and S5), and $RH_2$ (Figs. S3 and S6) to the Supplementary Material. These revisions provide more direct and complete support for the mechanisms inferred from the long-term statistics signals. As a result, the relevant conclusions are no longer solely on ozone differences, but are also supported by the additional meteorological diagnostics.

In addition, we fully acknowledge that RH anomalies alone cannot demonstrate enhanced wet scavenging. Previous studies have shown that, compared with soluble reservoir species, precipitation is generally not effective in directly removing ozone (Cuchiara et al., 2023; Tost et al., 2007). Therefore, expressions such as "wet deposition/scavenging of ozone" used in the original manuscript were not sufficiently rigorous, and we have accordingly removed or revised such wording throughout the revised manuscript and updated the atmospheric circulation anomaly fields shown in Fig. 6 (page 11 to 13, line 238 to 283). The revised interpretation emphasizes that, in STY and SSTY, ozone over SEC remains high but declines slightly rather than increasing further with TC intensification, primarily due to the associated meteorological conditions do not continue to become more favorable for ozone production and accumulation, rather than because of enhanced wet scavenging.

**3. The STY–SSTY "wet scavenging" explanation needs stronger evidence and more precise wording.**

The manuscript attributes the limited ozone increase beyond TY primarily to "enhanced wet scavenging/wet deposition" (e.g., around L215 and later). This statement will likely be questioned, because ozone is not typically removed efficiently by precipitation compared with soluble reservoir species, and the current evidence is indirect. Please clarify whether the inhibition under STY–SSTY is due to (a) reduced photolysis under enhanced cloudiness/precipitation, (b) enhanced ventilation/dilution and boundary-layer structural changes, and/or (c) wet deposition of precursors/reservoir species (NOy, peroxides, etc.) that reduces ozone production potential. Quantitative support (precipitation/cloud/photolysis and deposition diagnostics) is needed.

**Response:**

We appreciate this insightful comment. We acknowledge that it is not appropriate to attribute the fact that ozone does not increase further with TC intensification beyond

TY primarily to “enhanced wet scavenging/wet deposition”. As the reviewer noted, ozone is not typically removed efficiently by precipitation compared with soluble reservoir species (Cuchiara et al., 2023; Tost et al., 2007). In addition, our original use of the term “limiting further increases in ozone” to describe ozone under STY and SSTY conditions was also imprecise. What we intended to convey is that, when northward TCs within the key subregion intensify to STY and SSTY, ozone over SEC remains at a relatively high level but does not continue to increase with further TC intensification, mainly because the associated meteorological conditions (such as SSRD, $RH_2$ and $WS_{10}$) do not continue to evolve in a direction more favorable for ozone production and accumulation than at TY. We have therefore removed such expressions throughout the manuscript and revised the interpretation of the meteorological statistics in Fig. 5 accordingly (page 11 to 13, line 238 to 279). To provide more direct support for this revised explanation, we have also added the corresponding differences in RGRND, $T_2$, and $RH_2$, from the case-study simulations to the Supplementary Material.

**4. The 37% reduction of radiation/photolysis in NO_TC is conceptually problematic for attributing “TC impacts” and needs major clarification and/or additional controls.**

If the goal is to quantify the impact of the TC vortex itself, then in a vortex-removal experiment the radiation and photolysis fields should be allowed to evolve self-consistently after spin-up, reflecting “no TC vortex under the same large-scale background.” Instead, the authors impose a uniform 37% reduction in solar radiation and photolysis rates in NO_TC based on a climatological comparison between “TC-influence periods” and “periods without northward TCs.” This procedure potentially mixes the TC-vortex effect with differences in background synoptic regimes (e.g., WPSH configuration, cloudiness/moisture background) between TC and non-TC composites, thereby confounding attribution. In other words, NO_TC becomes a hybrid experiment (“vortex removal” + “forcing a non-TC radiative regime”), rather than a clean removal of TC effects under the same environment.

At minimum, the authors should (i) explicitly document how the 37% scaling is implemented (which variable, which hours, and which spatial mask) and whether it is consistent with the region/time window used to derive 37%; (ii) provide spatial maps of SSRD/photolysis differences before/after scaling; and (iii) add at least one additional control to separate dynamical vs radiative effects (e.g., a "vortex-only removal" without radiation adjustment. Without this, the reported ozone reduction (e.g., >10 ppb) cannot be interpreted as a pure "TC impact."

**Response:**

Thank you for the insightful comments and helpful suggestions. We fully agree with that this is a critical issue: If the goal is to quantify the impact of the TC vortex itself, then in a vortex-removal experiment the radiation and photolysis fields should be allowed to evolve self-consistently after spin-up, reflecting "no TC vortex under the same large-scale background". In the current manuscript, however, after removing the TC vortex from the initial fields, we further imposed a uniform 37% reduction in solar radiation and photolysis rates in NO_TC based on the comparison in SSRD between "the two northward TC case periods" and "periods without northward TCs during 2014–2024". We acknowledge, as the reviewer correctly noted, the current NO_TC experiment is therefore a hybrid experiment ("vortex removal" + "forcing a non-TC radiative regime"), rather than a clean isolation of TC effects under the same environment.

The original purpose of the NO_TC experiment was to approximate ozone changes over SEC under conditions without northward TC influence as closely as possible. However, we found that vortex removal alone produced cloud changes that were largely confined to the TC core region, whereas the cloud response over the TC peripheral region remained weak (Fig. R1b, illustrated here using the 2019 case). Such a response may be insufficient to represent the cloud–radiation adjustment expected under actual non-northward TC conditions, thereby introducing bias into the simulated radiation fields (Fig. R2a) and further leading to an unrealistic ozone response over parts of SEC (Fig. R3). Previous studies have shown that the peripheral downdraft region of a TC is typically characterized by clear-sky and low-cloud conditions, which are favorable for ozone production and accumulation (Hu et al., 2022; Li et al., 2021). Under no-TC conditions, cloud and solar radiation would not necessarily remain similar to those under TC influence. Based on ERA5 SSRD (surface solar radiation downwards), we found that the mean daytime radiation over SEC during 12:00–18:00 LT was 15.01 MJ $m^{-2}$ during the two northward TC case periods, but only 9.41 MJ $m^{-2}$ during autumn days without northward TCs in 2014–2024. This indicates that, without the influence of northward TCs, solar radiation over SEC is generally weaker.

From the perspective of the vortex filtering methodology, when a vortex is added to a no-TC background circulation or when an existing TC vortex is intensified, the model can gradually adjust the large-scale environmental fields, including clouds, through its own dynamical integration. As shown in Fig. R1a, after TC intensification, cloud cover increases mainly near the TC core, while the peripheral region remains relatively cloud free. By contrast, when the vortex is removed from a circulation background that originally contains a TC, the original low-cloud conditions in the peripheral region cannot adequately adjust toward a cloud distribution more consistent with no–TC conditions (Fig. R1b). We therefore consider that the cloud–radiation response simulated by vortex removal alone may be insufficient to realistically represent the atmospheric environment without northward TCs. Given the important role of clouds in modulating shortwave radiation and photolysis, we applied an additional uniform 37% reduction to solar radiation and photolysis rates after vortex removal, calculated as $(15.01 - 9.41) / 15.01 \times 100\%$, to partly compensate for the under-response of cloud- and radiation-related fields and to make NO_TC closer to the actual meteorological conditions without northward TCs.

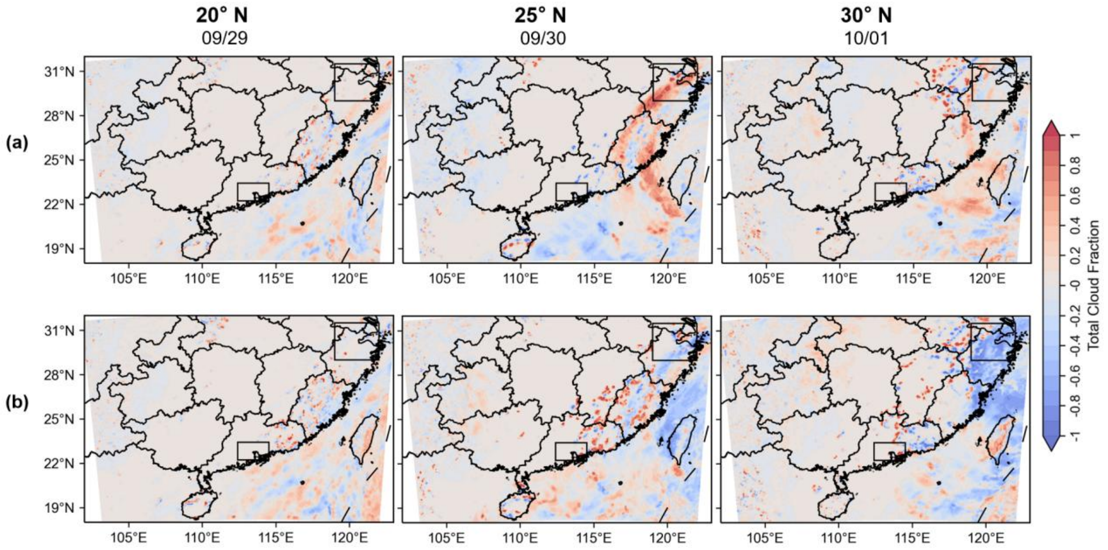

Figure R1. Differences in Total Cloud Fraction between T_TC and CTL (a) and between NO_TC and CTL (b).

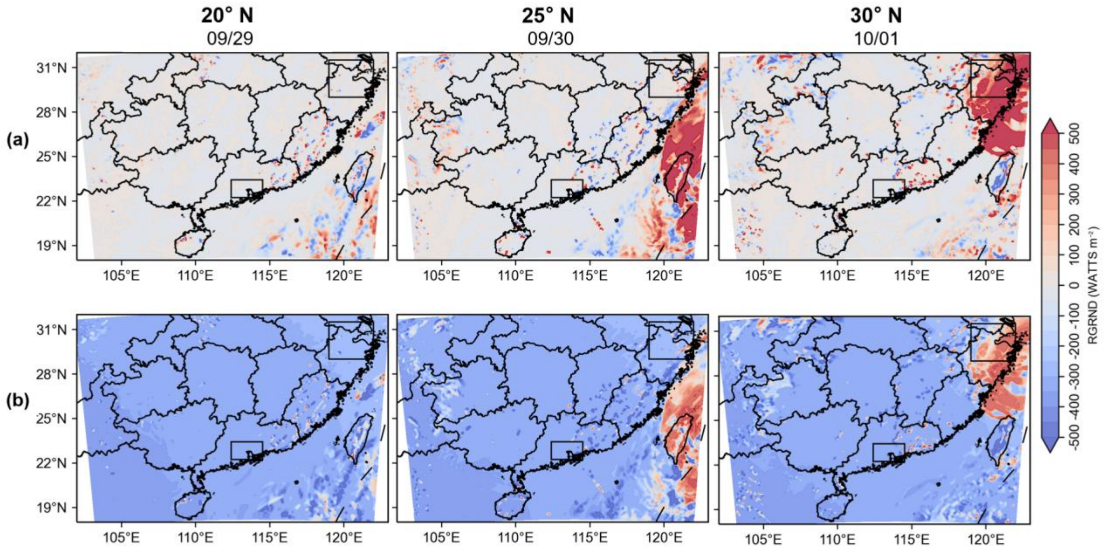

Figure R2. Differences in solar radiation reaching surface (RGRND) between pre-scaling and CTL (a) and between post-scaling and CTL (b).

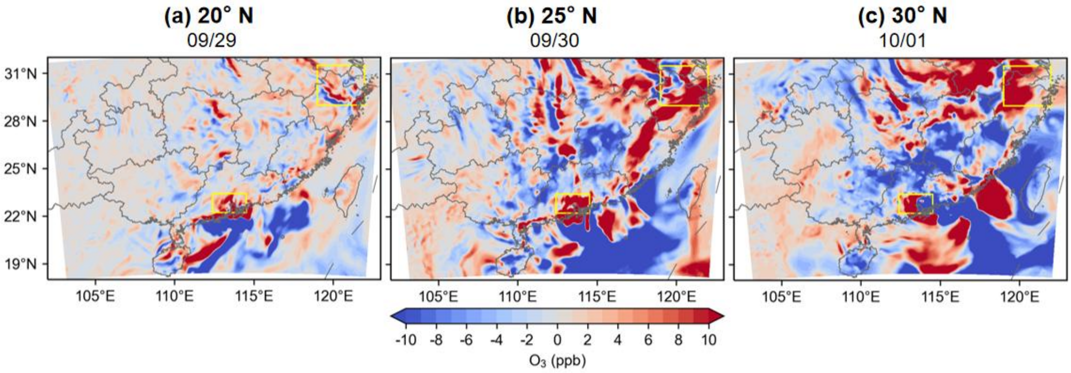

Figure R3. Difference in surface ozone concentration between the vortex-removal-only experiment (without radiation adjustment) and CTL.

As the reviewer pointed out, this treatment increases the complexity of attribution. Accordingly, the reported ozone reduction (e.g., > 10 ppb) should no longer be interpreted as a pure "TC impact". Rather, it should be regarded as the combined result of removing TC-related dynamical effects and introducing a weaker solar radiation/photolysis conditions characteristic of periods without northward TCs. We have revised the manuscript accordingly and avoid interpreting the simulated ozone decrease as arising solely from the TC vortex effect (pages 5, line 132 to146).

In response, we have added the following clarifications and analyses. First, in the Methods section of the revised manuscript, we now explicitly document how the 37% scaling is implemented, including the variables involved, the time period, and the spatial domain, and we clearly state that this percentage is derived from the SSRD climatological difference over SEC between the two northward-TC case periods and autumn days without northward TCs during 2014–2024 (pages 5, line 140 to 142). Second, we provide spatial maps of SSRD differences before (Fig. R2a) and after (Fig. R2b) scaling to directly illustrate the imposed radiative perturbation. Third, we add an additional experiment in which only the vortex is removed and no radiation adjustment is applied, so that the dynamical effect of TC removal can be more clearly separated from the radiative effect (Fig. R3).

**5. Inconsistent TC modification between IT_TC and NO_TC requires**

**justification and validation.**

Table 1 indicates that IT_TC strengthens only the TC-vortex horizontal winds (U, V, U10, V10), whereas NO_TC removes the TC vortex from a broader set of variables (including T, H, RH, ps, etc.). The authors should explicitly explain why the "intensification" and "removal" experiments are configured differently. Does this asymmetric design affect the comparability of the experiments and the interpretation of the results? Please provide reasons so that the subsequent mechanistic attribution is supported.

**Response:**

Thank you for the insightful comments. We acknowledge that the different variable modifications in IT_TC and NO_TC require further clarification. These two experiments were not designed as a strictly symmetric pair of sensitivity experiments, but rather to address different scientific objectives. Specifically, IT_TC was intended to represent a strengthened-TC scenario. Therefore, only the TC-vortex horizontal winds (U, V, $U_{10}$, and $V_{10}$) were enhanced, while the other meteorological variables were allowed to adjust dynamically and thermodynamically during model integration, so as to preserve the physical consistency of the intensified TC evolution. A similar strategy has been adopted in previous studies, such as Zhao et al. (2021), who examined the environmental effects of TC changes by modifying only the TC-vortex horizontal winds. In contrast, NO_TC was designed to approximate an atmospheric state without the TC, rather than a merely weakened-TC scenario. For this reason, TC-related vortex signals were removed from a broader set of variables (including T, H, RH, ps, etc.) in order to eliminate the TC structure as completely as possible.

Accordingly, our intention was not to assess the ozone impact of TCs through a direct comparison between IT_TC and NO_TC. Instead, IT_TC and NO_TC were each compared separately with CTL to diagnose the ozone responses under the strengthened–TC and no–TC scenarios, respectively. In other words, the mechanistic attribution in this study is based on the independent comparisons of IT_TC–CTL and NO_TC–CTL, rather than on the direct comparability between IT_TC and NO_TC. Therefore, this asymmetric design does not affect the interpretation of the results. We have clarified the different purposes of the two experiments in the revised manuscript and have explicitly stated that the discussion of the results is based on the separate comparisons with CTL (page 6, line 150 to 154).

**Figures comments**

1. Define the region of SEC in method part and show in Figure 3.

**Response:**

Thanks for pointing out our negligence. We have defined the region of the SEC (105–123°E, 18–32°N) in the Data and Methods section (line 79) and marked it in Figure 3b of the revised manuscript.

2. Give more details in Figure 5's captions or make the labels larger in each subplot in Figure 5.

**Response:**

Thank you for the helpful suggestion. We have enlarged the labels in each subplot of Fig. 5 and revised the figure caption to provide more detailed information in the revised manuscript.

3. Subplots in Figure 12 are too small for comfortably reading.

**Response:**

Thank you for the helpful comment. We have enlarged the subplots and improved the overall layout of Fig. 12 in the revised manuscript to enhance readability.

## References

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