<u>Reply on RC1</u>

We sincerely thank the reviewer for the careful reading of our manuscript and for the constructive comments. We have carefully considered all the suggestions and revised the relevant text accordingly. Since a revised manuscript cannot be uploaded at the open-discussion stage, the corresponding revisions are provided explicitly below for clarity.

1) The authors refer several times to their previous studies for model configuration, meteorological evaluation, and local circulation characteristics. It would be helpful to clarify more explicitly what analyses and findings are newly presented in the current manuscript compared with Shao et al. (2024a, b), so that the novelty of this study can be more clearly identified.

Response:

Thank you for this helpful comment. Our previous studies mainly focused on the effects of precursor emission reductions on $PM_{2.5}$ and O_3 (Shao et al., 2024a) and the role of local thermal circulations in $PM_{2.5}$ formation in the lower Yangtze River valley (Shao et al., 2024b). In contrast, the present study focuses specifically on the three-dimensional behavior of O_3 by integrating vertical-profile analysis, source apportionment, process analysis, and chemical sensitivity diagnosis.

To clarify this distinction, we have added the following sentence at the end of the penultimate paragraph of the Introduction, immediately before the paragraph beginning with “To better understand…”:

“**Building on our previous studies of emission-control effects (Shao et al., 2024a) and local thermal circulations in $PM_{2.5}$ formation (Shao et al., 2024b), the present study extends the existing modeling framework to investigate the three-dimensional O_3 structure, source contributions, process budgets, and chemical sensitivity.**”

2) In Section 3.4, the high contribution attributed to Region 8 is interpreted as reflecting favorable ozone retention and enhanced daytime ozone formation. Since source apportionment mainly identifies the contribution associated with tagged source regions,

the distinction among source attribution, transport, retention, and local chemical production should be described more carefully. Please clarify the interpretation of the Region 8 contribution and moderate the wording where necessary.

Response:

We appreciate this important clarification. We agree that the source-apportionment contribution attributed to Region 8 should not be interpreted directly as local O_3 retention or local chemical production. In the CAMx source-apportionment analysis, the Region 8 contribution represents the fraction of O_3 attributed to precursor emissions originating from the river-corridor source region. Its magnitude may be affected by chemical production, transport, and meteorological redistribution, and source apportionment alone cannot quantitatively separate these processes.

We have therefore revised the relevant discussion in Section 3.4 to distinguish source attribution from the mechanistic interpretation provided by the subsequent process analysis. The revised text reads:

"**Within this local fraction, the highest contribution from Region 8 occurs in April, exceeding 60%. It should be noted that the source apportionment result represents O_3 attributed to precursor emissions originating from Region 8 and therefore should not be interpreted solely as local O_3 production or retention. Instead, the relatively high contribution reflects the combined effects of precursor emissions, atmospheric transport, chemical transformation, and local meteorological conditions within the river corridor. At 14:00 LST, the contribution attributed to Region 8 increases further, reaching 65.2% in April and 59.7% in July, indicating an enhanced relative importance of precursors originating from the river-corridor region during the daytime photochemically active period.**"

To maintain consistent terminology later in this section, we have also revised the related interpretation as follows:

"**During the daytime, the contribution attributed to Region 8 itself is the largest, reaching 31.5% in January and 60.1% in July, indicating a greater relative contribution from sources within the river-corridor region, with cross-bank contributions from surrounding regions accounting for a correspondingly smaller share**" and "**These patterns suggest that thermally driven local circulations**

modulate the diurnal partitioning between contributions from the river-corridor source region and transport from the regions along both banks, thereby shaping the source composition of O_3 within the Yangtze River corridor".

3) The definition of the high-O_3 conditions in Figure 6 could be clarified. Section 3.1 indicates that observations from nine monitoring stations were used for model evaluation, while Figure 6 refers to hours when the observed O_3 concentration exceeded 120, 160, or 200 μg m^{-3}. Please briefly specify how the observational concentration used for this screening was derived from the nine stations (e.g., citywide mean), and confirm that these thresholds refer to hourly O_3 concentrations.

Response:

Thank you for pointing out this ambiguity. In this study, hourly O_3 concentrations from the nine monitoring stations in Nanjing were first averaged to obtain the citywide mean hourly O_3 concentration. Hours with mean observed O_3 concentrations ≥120, ≥160, and ≥200 μg/m^3 were then identified, and the corresponding modeled source contributions of the identified hours were averaged for each category.

We have clarified this procedure in Section 3.4 by adding the following description:

"**High-O_3 periods were identified based on the citywide mean hourly observed O_3 concentration averaged across the nine monitoring stations. Hours with mean O_3 concentrations ⩾120, ⩾160, and ⩾200 μg/m^3 were selected separately, and the corresponding modeled source contributions were averaged for each category.**"

The caption of Figure 6 has also been revised as follows:

"**Figure 6. Monthly mean proportions (%) of local source contributions to O_3 along the Yangtze River (Region 8) under different temporal and pollution conditions. Daytime is defined as 08:00-18:59 LST, while nighttime includes 00:00-07:59 and 19:00-23:59 LST. '14:00' represents the monthly mean source-contribution proportions at 14:00 LST. ⩾120, ⩾160, and ⩾200 represent the mean source-contribution proportions during hours when the citywide mean hourly observed O_3 concentration, averaged across the nine monitoring stations, was ⩾120, ⩾160, and ⩾200 μg /m^3, respectively.**"

4) The earlier transition to NOx-limited conditions in the river corridor is attributed to river-breeze-induced NOx dilution. The temporal pattern is consistent with this interpretation, but the causal wording may be slightly stronger than the evidence directly presented. I suggest briefly clarifying how the onset and weakening of the river breeze were identified, or alternatively moderating the wording to "associated with" or "consistent with" river-breeze-induced NOx dilution.

Response:

We agree with the reviewer that the original wording may imply stronger causality than can be established from the present analysis alone. We have therefore adopted the latter suggestion and moderated the causal language. The temporal correspondence between the sensitivity transition and the development of the river-breeze circulation is now described as being consistent with or associated with river-breeze-induced NO*x* dilution, while acknowledging that other concurrent meteorological and chemical processes may also contribute.

The relevant discussion in Section 3.5 has been revised as follows:

"…approximately two hours later at 11:00 LST. **This earlier and stronger sensitivity shift in Region 8 is consistent with the development of the Yangtze River breeze. The river breeze may dilute NO*x* concentrations along the river corridor, thereby favoring an earlier shift of the VOC/NO*x* balance toward NO*x*-limited conditions compared with the broader urban area. The subsequent convergence of the two curves after ~18:00 LST coincides with the weakening of the river breeze, further suggesting an association between local circulation and the sensitivity transition.** "

For consistency, the corresponding statement in the Abstract has been revised to:

"**O_3 formation remained volatile organic compound (VOC)-limited in spring and autumn, whereas an earlier shift to nitrogen oxide (NO*x*)-limited conditions in the river corridor, approximately two hours ahead of the surrounding urban area, was consistent with river-breeze-induced NO*x* dilution in summer.**"

5) There is a minor inconsistency in the discussion of ozone sensitivity. January is excluded from the CPA diagnosis because photochemical activity is negligible, but the Conclusions state that ozone production is "predominantly VOC-limited throughout the

year." This statement should be revised to distinguish the diagnosed VOC-limited conditions in spring and autumn from the weak wintertime photochemical activity and the summer transition toward NOx-limited conditions.

Response:

Thank you for identifying this inconsistency. We agree that the phrase "throughout the year" is not appropriate because the CPA indicator is not informative in January due to negligible photochemical activity. We have therefore revised the summary of the CPA results and the corresponding statement in the Conclusions to distinguish the VOC-limited conditions diagnosed in April and October, the summer transition toward NO*x* limitation, and the limited applicability of the CPA indicator in January.

The summary paragraph at the end of Section 3.5 now reads:

"**Overall, O_3 formation remained predominantly VOC-limited in April and October, whereas a transition toward NO*x*-limited conditions occurred in July, particularly over the Yangtze River corridor. In January, weak photochemical activity limited the applicability of the CPA indicator for a meaningful sensitivity diagnosis. These findings highlight the importance of VOC control during photochemically active periods and coordinated VOC–NO*x* reductions in summer, while accounting for the spatiotemporal effects of local meteorological processes.**"

The corresponding paragraph in the Conclusions has been revised to:

"**CPA-based sensitivity analysis indicates that O_3 formation is predominantly VOC-limited in spring and autumn**…."

6) A careful language and terminology check is recommended. For example, the first sentence of the Introduction contains a grammatical error, and some expressions in the discussion of Figure 5 are repetitive. The section titles "O_3 transport revealed through source apportionment technology" and "O_3 formation revealed through process analysis technology" could also be simplified to more conventional wording.

Response:

We have performed an additional language and terminology check throughout the manuscript and corrected the grammatical and repetitive expressions noted by the reviewer. We have also simplified the titles of Sections 3.4 and 3.5.

Specifically, the first sentence of the Introduction has been revised to:

"**Air pollution episodes arise from complex interactions between intensive anthropogenic emissions and meteorological conditions and can adversely affect ecosystems and human health.**"

The repetitive expression in the discussion of Figure 5 has been revised to:

"**Comparing Figures 5(c) and 5(d) highlights the contrasting roles of different local forcing mechanisms at the same local noon: the longitudinal transect (5c) reveals pronounced spatial heterogeneity associated with industrial emissions, localized convective uplift over Baguazhou, and terrain-induced upslope transport near Mt. Zijin, whereas the latitudinal transect (5d) features a more horizontally uniform elevated O_3 layer associated with strong convective mixing over the urban core.**"

The section titles have been revised to:

"**3.4 Source apportionment of O_3**" and "**3.5 Process analysis of O_3 formation**"