

Point-by-point responses to the comments & suggestions from the editor and reviewers

Manuscript ID: EGUSPHERE-2026-1101

Title: “Direct thermal enhancement dominates over emission-mediated pathways in heatwave-induced O₃ and SOA increases across China”

We appreciate the comments from the editor and reviewers on this manuscript. We addressed the comments and suggestions carefully and made necessary changes as shown in the marked revision of the manuscript. The detailed point-by-point responses are listed below in blue and modifications in the manuscript are in red.

Reviewer 2

This manuscript presents a well-designed modeling study on the drivers of O₃ and SOA increases during heatwaves in China. The experimental design is appropriate, and the findings regarding the dominant role of direct temperature effects and the heightened VOC sensitivity in the North China Plain are valuable for understanding climate air quality interactions. The paper is generally well written and organized. However, several minor issues remain that should be addressed before publication. Overall, the manuscript is suitable for acceptance by ACP after minor revision.

Response: We sincerely thank the reviewer for the positive evaluation of our work. We have carefully addressed all of your comments and incorporated the suggested changes into the revised manuscript. Detailed point by point responses are provided below.

1. In the BVOC22 sensitivity simulation, the authors state that isoprene, terpenes, and sesquiterpenes are selected as the dominant BVOC species. Please provide the relative emission proportions of these three groups under the baseline (2021) and heatwave (2022) conditions. This information would help readers assess which biogenic precursors are most responsible for the observed O₃ and SOA changes.

Response: We thank the reviewer for this insightful suggestion. Based on the model outputs, the relative emission proportions of BVOCs remained highly consistent

between the 2021 baseline and the 2022 heatwave conditions (see Fig. 2 below). Under the 2021 conditions, isoprene, terpenes, and sesquiterpenes accounted for approximately 81.8%, 15.5%, and 2.6% of the total emissions, respectively. Under the 2022 conditions, these proportions shifted only slightly to 82.8%, 14.7%, and 2.5%. This indicates that while the absolute emission amounts increased during the heatwave, the primary precursor composition driving the O₃ and SOA changes remained stable. We have revised section 2.3 to help readers better assess the biogenic precursors.

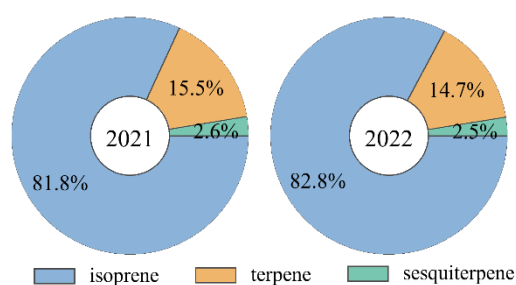


Figure 2. Components of biogenic terpenoid emissions. Contribution of isoprene, terpene and sesquiterpene to total biogenic terpenoids emissions from 2021 to 2022 in China.

Changes in manuscript (lines 81-83): “Based on the MEGAN estimates, the relative proportions of isoprene, terpenes, and sesquiterpenes are highly consistent between the 2021 baseline and 2022 heatwave conditions (**Fig. S1**). They account for 81.8%, 15.5%, and 2.6% of the total BVOC emissions in 2021, and 82.8%, 14.7%, and 2.5% in 2022, respectively.”

2. Section 3.6 reports that the PRD region has the highest O₃ temperature sensitivity, yet Figure 1 shows that summer temperatures in the PRD slightly decreased from 2021 to 2022. Please clarify how a sensitivity slope can be derived under a net cooling condition. Is the sensitivity estimate driven by spatial variability rather than interannual temperature change? A brief explanation would help readers interpret this result correctly.

Response: According to our methodology, the sensitivity in our study is defined as the linear regression slope calculated across all grid cells within a region, which represents

spatial variability rather than an interannual trend. Therefore, although the regional average temperature in the PRD slightly decreased in 2022, the spatial linear regression across the individual PRD grids still yields a highly positive sensitivity slope.

Changes in manuscript (lines 259-261): “As defined in section 2.4, this positive slope represents the spatial linear regression across PRD grids rather than interannual temperature changes. This spatial variability heightens local risks and necessitates targeted mitigation.”

3. Section 3.4 reports that the direct meteorological contribution (MET22) to O₃ in the North China Plain is more pronounced at night than during the day, attributed to temperature inversion trapping surface O₃. However, nocturnal O₃ is typically depleted by NO titration. Please explain why the trapped O₃ is not rapidly titrated by NO under the stagnant, high-pressure conditions described.

Response: We thank the reviewer for this question. The trapped O₃ is not rapidly titrated by NO because the lowered PBL height restricts the vertical diffusion of O₃ and precursors. Within the PBL, these precursors accelerate NO₃ radical chemistry. This pathway consumes NO, which competes with direct O₃ titration (O₃ + NO) and facilitate O₃ to accumulate. We have revised section 3.4 to clarify this mechanism.

Changes in manuscript (lines 228-234): “Moreover, the impact of the BVOC22 on NCP O₃ exhibits a diurnal reversal, from negative in the daytime to positive at night (Fig. 4). During the day, an increase in BVOCs enhanced the oxidation of NO to NO₂, and further facilitated the formation of O₃. However, the concurrently increased NO from NO₂ photolysis also intensifies the O₃ loss via titration (O₃ + NO). When the titration process became slightly dominant, this could lead to a net negative daytime contribution to O₃. Conversely, at night, the suppressed PBL height limits vertical mixing and traps pollutants (Fig. S6). Within this stable layer, increased BVOCs promoted NO₃ radical chemistry, which is verified by the net decrease of nighttime NO₃ concentrations (Fig. 4b). This process consumed NO and thus reduced the nocturnal O₃ titration, facilitating residual O₃ accumulation.”

4. In Figure 2 caption, the difference term is written as “BASE22-BASE2”. It should be “BASE22-BASE21”. Please add the missing digit “1”.

Response: We thank the reviewer for pointing out this typographical error. We have corrected the text in the Figure 2 caption.

Changes in manuscript (lines 172-173): “Figure 2. (a) The differences in simulated BVOC emission rates between BASE22 and BASE21 (BASE22–BASE21, units: mole s⁻¹.”

5. Section 3.4 defines daytime as 8:00 to 20:00 and nighttime as 20:00 to 8:00. Please clarify whether these times refer to local standard time or Beijing Time (UTC+8). Additionally, please confirm whether the model simulations accounted for time zone differences across the study domain (e.g., western China versus eastern China) when aggregating diurnal patterns.

Response: We thank the reviewer for this question. The daytime and nighttime definitions refer to Beijing Time (UTC +8). The model uses the longitude of each grid cell to calculate local solar radiation and photochemistry. For regional aggregation, we used Beijing Time as the unified standard. Since the four selected urban clusters are located in eastern and central China, they geographically align with the Beijing Time zone, minimizing solar time discrepancies. We have explicitly specified this in the Figure 4 caption.

Changes in manuscript (lines 215): “Daytime is defined as 8:00 to 20:00 and nighttime as 20:00 to 8:00 Beijing Time.”