

Response Letter

Dear Editors:

We sincerely thank you for facilitating the review process and for providing us with valuable feedback. The comments we received have been instrumental in enhancing the quality and clarity of our manuscript.

We have carefully considered all the comments and have made comprehensive revisions to address each point raised. Our detailed responses to the reviewers' comments are provided below.

Yours sincerely,
Zining Yang and co-authors

Reviewer #1

General comments:

- *1. This paper presents the results of PM_{2.5} concentrations obtained by two types of simulations. The first one considers the real conditions, i.e., the region around the megacity of Hefei in China close to a lake and the lake is replaced by herbaceous wetland in the second simulation. The period investigated extended for 5 to 20 March 2019 where 5 days were for testing and the rest for the analysis. Spatial distribution of PM composition is presented together with the contrast between these two calculations. Moreover, atmospheric dispersion is considered by the wind fields and the determination of the planetary boundary layer. Although the presented work is noticeable, some minor changes should be introduced prior to the manuscript final acceptance.*

Response: Thank you for your thoughtful comment. We sincerely thank the reviewer for the positive evaluation of our work and for recognizing the significance of our study on PM_{2.5} concentrations under different land use scenarios in the Hefei region. We appreciate the reviewer's acknowledgment that our work is "noticeable" and are grateful for the constructive feedback. We have carefully considered all the minor revisions suggested by the reviewer and have made corresponding modifications to improve the manuscript. Below, we provide detailed point-by-point responses to each specific comment raised by the reviewer. We believe these revisions have significantly strengthened the manuscript, and we hope the revised version now meets the standards for publication in Atmospheric Chemistry and Physics.

Specific comments:

- *1. The authors should indicate if changes in the lake were observed, i.e., they should precise if the lake dries up or not. If changes are not observed, this analysis is a theoretical exercise. Moreover, the lake cannot be suppressed and calculations under these conditions could not be compared with observations.*

Response: Thank you for your insightful comment. We sincerely appreciate the reviewer's comment, which provides us with an important opportunity to clarify the scientific rationale and methodological framework underlying our study. We recognize that there may be some confusion regarding the nature and purpose of sensitivity experiments in atmospheric modeling studies, and we hope the following detailed explanation will comprehensively address the reviewer's concerns.

Our study is fundamentally a scientific mechanistic investigation, rather than an engineering feasibility study or a policy recommendation for lake removal. We neither suggest nor advocate the physical elimination or draining of Chaohu Lake as an air quality management strategy, as such an approach would be neither consistent with environmental protection principles nor practically feasible. The core scientific question we aim to address is whether and how the Chaohu lake system contributes to the spatiotemporal variations of PM_{2.5} pollution in the Hefei megacity region. To rigorously answer this question, the

influence of the lake must be isolated from other confounding factors such as anthropogenic emissions, meteorological conditions, and topography. The sensitivity experiment approach, comparing a reference scenario with the lake present against a hypothetical scenario in which the lake is replaced by herbaceous wetland, represents the most effective and scientifically rigorous method for achieving this factor isolation and advancing mechanistic understanding.

The spatiotemporal distribution of PM_{2.5} pollution is influenced by a variety of factors, including anthropogenic emissions, meteorological conditions, atmospheric chemistry, dry and wet deposition, and land surface characteristics. To fully understand pollution dynamics and develop effective air quality management strategies, it is essential to quantitatively assess the relative contributions of these different factors. As a large water body of approximately 780 km² located at the center of the Hefei metropolitan area, Chaohu Lake represents an important land surface factor that may affect local meteorology through differential heating, lake-breeze circulation, and modifications to boundary layer structure, thereby influencing PM_{2.5} distribution. This study therefore focuses on several key scientific questions, namely whether Chaohu Lake significantly affects PM_{2.5} concentrations in the Hefei region, through what physical and chemical mechanisms the lake influences PM_{2.5} distribution, and how the magnitude and spatial extent of this influence vary under different meteorological conditions. The knowledge gained from this mechanistic study carries important practical implications for improving the accuracy of air quality models and forecasts in the Hefei region, informing urban planning and emission control strategies, and advancing the broader scientific understanding of lake-atmosphere interactions in polluted environments.

It is important to note that this type of controlled sensitivity experiment design has been widely adopted in atmospheric and climate science and is by no means unique to this study. The sensitivity experiment framework allows researchers to decompose complex environmental systems into individual contributing factors, enabling quantitative assessment of specific mechanisms, and represents one of the most rigorous and effective scientific tools for studying the influence of a given factor on atmospheric processes. The fundamental objective of such experiments is not to reproduce a realistic scenario of lake disappearance, but rather to assess the independent influence of this specific factor on atmospheric dynamics and pollutant concentrations. In other words, by comparing the results of simulations with and without the lake (replaced by another land cover type), we can clearly attribute the differences observed in PM_{2.5} concentrations, boundary layer evolution, and wind fields to the influence of the lake. This is a mechanistic research paradigm whose core value lies in providing clear and quantifiable causal attribution signals through controlled comparisons.

A directly relevant example is the study by Zhang et al. (2017), who investigated the impact of Taihu Lake on ozone concentrations in the Yangtze River Delta using exactly the same methodological approach. They conducted a reference experiment with the lake present and a sensitivity experiment where the lake was replaced by cropland, demonstrating that Taihu Lake significantly influenced local meteorological fields and O₃ distributions through lake-breeze circulation, with concentration differences reaching 12 ppbv over the lake region. This study, published in *Advances in Atmospheric Sciences*, clearly establishes that our methodological approach is well-accepted in the atmospheric chemistry community and has been

successfully applied to investigate lake effects on air pollutants in China's megacity regions. Similarly, Zhang et al. (2009) employed sensitivity experiments with the WRF model to quantify impacts of urban expansion and future greening scenarios on summer precipitation in Beijing, not to suggest removing urban areas but to understand how urbanization affects precipitation patterns, which is knowledge essential for urban planning. Zhao et al. (2014) used sensitivity experiments to decompose urban heat island intensity into contributions from background climate (wind speed, humidity, cloud cover) and urban surface properties (impervious surface fraction, anthropogenic heat). Their approach of systematically perturbing individual factors is methodologically identical to ours and has proven invaluable for understanding physical mechanisms driving urban climate anomalies. Chase et al. (1996) conducted systematic perturbation experiments with a general circulation model (GCM) to analyze how changes in global leaf area index (LAI) influence regional energy balance and atmospheric circulation through modifications of surface roughness, evapotranspiration efficiency, and surface albedo. Similarly, Davin and de Noblet-Ducoudré (2010) designed sensitivity experiments comparing complete global deforestation against original vegetation cover, decomposing climate response signals into radiative processes (surface albedo changes) and non-radiative processes (evapotranspiration and roughness changes). It is worth noting that none of these studies were questioned as "theoretical exercises" on the grounds that their experimental scenarios did not correspond to actual observed changes. On the contrary, it is precisely because of the rigor of their controlled experimental designs that these studies are regarded as important contributions to scientific knowledge. Collectively, they demonstrate that sensitivity experiments are not "theoretical exercises" in a pejorative sense, but rather a rigorous scientific approach to advancing our mechanistic understanding of complex environmental systems.

To clarify these important methodological aspects and prevent potential misunderstandings, we have added a detailed explanation in the revised manuscript (Section 1): "It should be emphasized that this sensitivity experiment approach is employed as a scientific tool to isolate and quantify the lake's influence on PM_{2.5} distributions, rather than to evaluate the feasibility of lake removal as an air quality management strategy. The primary objective is to advance our mechanistic understanding of how large water bodies affect atmospheric pollution in megacity environments. "

Regarding the concern that the sensitivity experiment (no-lake scenario) cannot be directly compared with observations, we need to clarify the relationship between sensitivity experiments and observational validation. The scientific objective of sensitivity experiments is not to predict the future or simulate realizable scenarios, but rather to isolate and quantify the influence of specific factors through comparative analysis. Therefore, the sensitivity experiment itself does not require direct validation against observations, which does not imply a lack of scientific rigor in the research. In sensitivity experiment studies, the primary scientific comparison target is the difference field between the two sets of simulations themselves, rather than directly comparing the sensitivity simulation with real observations. Specifically, the reference experiment with the lake present represents actual atmospheric conditions, and we have added comprehensive validation analysis of this reference experiment against meteorological fields and PM_{2.5} concentration observational data during the study period in the revised

manuscript (Section 3.1). This validation confirms that the model can accurately reproduce the observed atmospheric states and pollutant distributions, thereby establishing the credibility and scientific foundation of our entire modeling framework. The sensitivity experiment where the lake is replaced by herbaceous wetland is a controlled numerical experiment specifically designed to isolate the lake's influence. Although this scenario itself does not correspond to observable reality and therefore does not need to and cannot be directly compared with observations on a one-to-one basis, the difference field between the two experiments can quantify the independent contribution of the lake system in a scientifically rigorous manner. This difference represents a scientifically meaningful signal that advances our mechanistic understanding of how the lake system affects PM_{2.5} pollution through meteorological field modulation and boundary layer structure changes, which is precisely the core scientific objective of this study. It should be noted that a more comprehensive and in-depth discussion of the detailed validation analysis and comparison between observations and simulations will be provided in our response to the next comment.

To more clearly demonstrate the model validation results and enhance the credibility of our research, we have added systematic comparative analysis between the reference experiment and observational data in Section 3.1 of the revised manuscript, including validation of meteorological fields (temperature and wind fields) and spatiotemporal distributions of PM_{2.5} concentrations. The relevant text in the revised manuscript is as follows:

“Before presenting the simulation results of PM_{2.5} surface concentrations over lake and urban areas during daytime and nighttime, a systematic evaluation of the Lake experiment is first conducted to verify the capability of the simulation framework in reproducing real atmospheric conditions with the lake present. The evaluation covers the meteorological fields and PM_{2.5} surface concentrations during the study period from March 10 to 20, 2019, which are compared against in-situ observational data averaged over 10 MEP sites in Hefei.

The model's performance in reproducing meteorological conditions is assessed by comparing the simulated 10-meter wind speed and 2-meter temperature with observational data from four AWSs in the Hefei region, as shown in Figure S4. Overall, the model performs well in simulating both variables and successfully reproduces the temporal evolution throughout the study period. The simulated 2-meter temperature agrees well with observations, indicating that the model accurately characterizes the surface energy budget and thermodynamic conditions that form the physical basis for analyzing the lake-land thermal contrast in this study, as shown in Figure S4a. The model overestimates peak wind speed during the strong wind event around March 20, likely attributable to complex mesoscale interactions. Nevertheless, this bias does not compromise the overall assessment of circulation characteristics throughout the study period, as demonstrated in Figure S4b. The model's ability to reproduce PM_{2.5} surface concentrations is then assessed against observational data from 10 MEP sites in the Hefei region. Figure S5 shows the comparison between the simulated and observed diurnal variations of PM_{2.5} averaged over the study period. The model captures the key features of the observed diurnal cycle well, including the nocturnal accumulation of PM_{2.5} under stable boundary layer conditions and the daytime concentration decrease driven by boundary layer development and enhanced turbulent mixing. The simulated diurnal variation are generally consistent with observations, while the

overestimation of nighttime concentrations is primarily attributed to insufficient representation of turbulent mixing intensity under stable nocturnal boundary layer conditions in the model (Yang et al., 2025).

It is worth noting that the Nola experiment, in which Chaohu Lake is replaced by cropland, is a controlled sensitivity experiment designed to isolate lake-induced effects and does not represent an observable atmospheric state, so independent observational validation is neither feasible nor necessary. Given the overall satisfactory performance of the Lake experiment demonstrated above, the simulation framework is considered reliable, and the lake-induced signals identified through the differential analysis between the two experiments are sufficiently credible to support the discussion in the following sections.”

Reference:

Chase, T. N., Pielke, R. A., Kittel, T. G. F., Nemani, R., and Running, S. W.: Sensitivity of a general circulation model to global changes in leaf area index, *Journal of Geophysical Research-Atmospheres*, 101, 7393-7408, <https://doi.org/10.1029/95jd02417>, 1996.

Davin, E. L. and de Noblet-Ducoudré, N.: Climatic Impact of Global-Scale Deforestation: Radiative versus Nonradiative Processes, *Journal of Climate*, 23, 97-112, <https://doi.org/10.1175/2009jcli3102.1>, 2010.

Zhang, C. L., Chen, F., Miao, S. G., Li, Q. C., Xia, X. A., and Xuan, C. Y.: Impacts of urban expansion and future green planting on summer precipitation in the Beijing metropolitan area, *Journal of Geophysical Research-Atmospheres*, 114, <https://doi.org/10.1029/2008jd010328>, 2009.

Zhang, L., Zhu, B., Gao, J. H., and Kang, H. Q.: Impact of Taihu Lake on city ozone in the Yangtze River Delta, *Advances in Atmospheric Sciences*, 34, 226-234, <https://doi.org/10.1007/s00376-016-6099-6>, 2017.

Zhao, L., Lee, X., Smith, R. B., and Oleson, K.: Strong contributions of local background climate to urban heat islands, *Nature*, 511, 216-219, <https://doi.org/10.1038/nature13462>, 2014.

Yang, Z. N., Du, Q. Y., Yang, Q. K., Zhao, C., Li, G. D. Z., Xia, Z. H., Xu, M. Y., Yuan, R. M., Li, Y. B., Xia, K. H., Gu, J., and Feng, J. W.: Modeling urban pollutant transport at multiple resolutions: impacts of turbulent mixing, *Atmospheric Chemistry and Physics*, 25, 8831-8857, <https://doi.org/10.5194/acp-25-8831-2025>, 2025.

- *2. The authors should compare the modelled concentrations with those from surface stations to investigate the contrast between the modelled values and the measured ones. Figure S4 could not fill this gap since it was obtained from multiple sources.*

Response: Thank you for your insightful comment for this important comment regarding model validation. We have substantially revised the manuscript to address this concern by adding comprehensive model-observation comparisons that systematically validate our simulation results.

In response to the reviewer’s concern, we have now added a dedicated model evaluation section (Section 2.4 and Section

3.1) that systematically validates our Lake experiment against in-situ observations. Specifically, we selected 10 national air quality monitoring stations operated by the Ministry of Environmental Protection of China within the Hefei area to validate $PM_{2.5}$ surface concentrations, and four automatic weather stations (AWSs) to validate meteorological fields. The locations of these stations are marked in Figure 1b (red dots for pollutant stations, purple dots for AWSs).

As shown in the newly added Figure S4, the model successfully reproduces the temporal evolution of 2-meter temperature and 10-meter wind speed throughout the study period. The simulated 2-meter temperature agrees well with observations, indicating that the model accurately characterizes the surface energy budget and thermodynamic conditions that form the physical basis for analyzing the lake-land thermal contrast in this study. Figure S5 demonstrates the comparison between simulated and observed $PM_{2.5}$ diurnal variations, showing that the model captures the key features of the observed diurnal cycle well, including nocturnal accumulation under stable boundary layer conditions and daytime concentration decrease driven by boundary layer development and enhanced turbulent mixing. While some overestimation of nighttime concentrations exists (primarily attributed to insufficient representation of turbulent mixing intensity under stable nocturnal boundary layer conditions), the simulated diurnal variations are generally consistent with observations, and the overall performance is satisfactory for investigating lake-urban air quality interactions.

It is worth noting that the Nolake experiment, in which Chaohu Lake is replaced by cropland, is a controlled sensitivity experiment designed to isolate lake-induced effects and does not represent an observable atmospheric state, so independent observational validation is neither feasible nor necessary. Given the overall satisfactory performance of the Lake experiment demonstrated above, the simulation framework is considered reliable, and the lake-induced signals identified through the differential analysis between the two experiments are sufficiently credible to support the discussion in the following sections.

We have added Section 2.4 to introduce new observational meteorological and Environmental data:

“2.4 Observational data

2.4.1 Meteorological data

The meteorological data were obtained from automatic weather stations (AWSs), which were established based on the operational standards issued by the China Meteorological Administration (CMA, 2018). The hourly data underwent quality control (QC) by local meteorological bureaus of Anhui, following World Meteorological Organization guidelines (Estevez et al., 2011). The QC included checks of consistency, such as internal, temporal-spatial, and climatic range validations. These QC data were used to determine daily mean, minimum, and maximum meteorological variables. The AWSs recorded various parameters, including air temperature (T , °C), wind speed (U , m/s), air pressure (P , Pa), and wind direction. In this study, we focus on the 3-hourly 2 m temperature and 10 m wind speed obtained from four AWS stations located in the study region. The four AWS sites are marked by purple solid dots in Figure 1b.

2.4.2 Environmental data

Ground observations of hourly $PM_{2.5}$ surface concentrations during March 2019 were obtained from the website of the

Ministry of Environmental Protection of China (MEP of China). As our study concentrates on the Hefei region, we selected 10 monitoring stations within this area for detailed analysis. These stations are marked by red solid dots in Figure 1b.

While hourly observations for both meteorology and pollutants are available, model outputs are provided at 3-hour intervals to balance computational efficiency and storage requirements. Hourly output data would provide higher time resolution but significantly increase storage demands. Given that we ran simulations at 1km resolution, hourly outputs would have generated prohibitively large data volumes. On the other hand, this 3-hour output interval remains sufficient for our primary research objective of investigating the diurnal reversal effect of lake impacts on $PM_{2.5}$ concentrations and elucidating the coupling mechanisms between physical processes (turbulent mixing, dry deposition, local circulation) and chemical processes. This approach effectively captures the distinct daytime pollution enhancement and nighttime purification patterns without losing essential detail for understanding lake-urban air quality interactions. To ensure consistent temporal resolution between model and observations, hourly observations were sampled to match our 3-hour model output intervals.”

In the revised manuscript (Section 3.1), we have added a detailed comparison between simulated and observed meteorological variables and pollutant concentrations across all observational stations:

“Before presenting the simulation results of $PM_{2.5}$ surface concentrations over lake and urban areas during daytime and nighttime, a systematic evaluation of the Lake experiment is first conducted to verify the capability of the simulation framework in reproducing real atmospheric conditions with the lake present. The evaluation covers the meteorological fields and $PM_{2.5}$ surface concentrations during the study period from March 10 to 20, 2019, which are compared against in-situ observational data averaged over 10 MEP sites in Hefei.

The model’s performance in reproducing meteorological conditions is assessed by comparing the simulated 10-meter wind speed and 2-meter temperature with observational data from four AWSs in the Hefei region, as shown in Figure S4. Overall, the model performs well in simulating both variables and successfully reproduces the temporal evolution throughout the study period. The simulated 2-meter temperature agrees well with observations, indicating that the model accurately characterizes the surface energy budget and thermodynamic conditions that form the physical basis for analyzing the lake-land thermal contrast in this study, as shown in Figure S4a. The model overestimates peak wind speed during the strong wind event around March 20, likely attributable to complex mesoscale interactions. Nevertheless, this bias does not compromise the overall assessment of circulation characteristics throughout the study period, as demonstrated in Figure S4b. The model’s ability to reproduce $PM_{2.5}$ surface concentrations is then assessed against observational data from 10 MEP sites in the Hefei region. Figure S5 shows the comparison between the simulated and observed diurnal variations of $PM_{2.5}$ averaged over the study period. The model captures the key features of the observed diurnal cycle well, including the nocturnal accumulation of $PM_{2.5}$ under stable boundary layer conditions and the daytime concentration decrease driven by boundary layer development and enhanced turbulent mixing. The simulated diurnal variation are generally consistent with observations, while the overestimation of nighttime concentrations is primarily attributed to insufficient representation of turbulent mixing intensity

under stable nocturnal boundary layer conditions in the model (Yang et al., 2025).

It is worth noting that the Nolake experiment, in which Chaohu Lake is replaced by cropland, is a controlled sensitivity experiment designed to isolate lake-induced effects and does not represent an observable atmospheric state, so independent observational validation is neither feasible nor necessary. Given the overall satisfactory performance of the Lake experiment demonstrated above, the simulation framework is considered reliable, and the lake-induced signals identified through the differential analysis between the two experiments are sufficiently credible to support the discussion in the following sections.”

Additionally, we acknowledge that direct quantitative validation of lake-surface PM_{2.5} using in-situ observations would be highly desirable. However, in-situ air quality observations over lake surfaces and shoreline areas remain limited in China, with publicly available data being quite scarce. While our urban validation demonstrates the model's capability to reproduce atmospheric conditions where observations exist, the most significant lake effects we identify occur precisely over the lake surface and nearshore areas, where observational data at these critical locations are currently still limited. While satellite-retrieved PM_{2.5} products provide qualitative support for lake surface accumulation phenomena, their spatiotemporal resolution and retrieval uncertainties over water surfaces are insufficient for detailed mechanistic validation, underscoring the necessity of systematic field observations.

This observational challenge is particularly acute in China. Many major cities have developed along inland lakes, yet systematic lake-atmosphere monitoring remains extremely limited compared to North America and Europe. We extensively discuss this in Sect. 4, including specific recommendations for future observational network design. Future research should prioritize the establishment of comprehensive observation networks specifically designed for lake-urban pollution gradients, including monitoring stations deployed at multiple locations along lakeshores, cross-sectional observations along lake-urban corridors, lake-based platform observations (buoys or low-altitude drones), and vertical profiling measurements (tethered balloons, drones, or ground-based remote sensing). These observations will not only directly validate the lake-induced PM_{2.5} gradients and vertical mixing signals identified in this study but also reveal small-scale turbulent mixing and chemical transformation mechanisms. Filling the observational gap in lake environments represents a critical frontier for advancing air quality research in rapidly urbanizing inland lake regions globally.

In the revised manuscript (Section 4), we have added a detailed explanation:

“Additionally, the key limitation of current lake-urban air quality research is the scarcity of direct observations over lake surfaces and lakeside regions. Although this study has validated the simulations against urban observation networks, the most significant lake effects we identified occur precisely over lake surfaces and nearshore areas where observational infrastructure is absent. While satellite-retrieved PM_{2.5} products provide qualitative support for lake surface accumulation phenomena, their spatiotemporal resolution and retrieval uncertainties over water surfaces are insufficient to meet the needs for detailed mechanistic validation, underscoring the necessity of systematic field observations. This observational challenge is particularly acute in China. Many major cities have developed along inland lakes, yet systematic lake-atmosphere monitoring remains

extremely limited compared to North America and Europe. Future research should prioritize the establishment of comprehensive observation networks specifically designed for lake-urban pollution gradients. Such networks should include monitoring stations deployed at multiple locations along lakeshores and cross-sectional observations along lake-urban corridors (such as the A-B-C transect examined in this study) to measure $PM_{2.5}$ concentrations, chemical composition, and meteorological parameters. Lake-based platform observations (buoys or low-altitude drones) can capture spatial heterogeneity and transient features such as lake-breeze fronts, while vertical profiling measurements (tethered balloons, drones, or ground-based remote sensing) can observe boundary layer structure and lake-land breeze circulation. Additionally, measurements of dry deposition velocities and surface fluxes over both lake and land surfaces, combined with dense low-cost sensor networks monitoring fine-scale spatial patterns, will provide multidimensional data support for understanding lake effects. These observations will not only directly validate the lake-induced $PM_{2.5}$ gradients and vertical mixing signals identified in this study but also reveal small-scale turbulent mixing and chemical transformation mechanisms. Filling the observational gap in lake environments represents a critical frontier for advancing air quality research in rapidly urbanizing inland lake regions globally.”

In addition to the quantitative validation above, to further support the plausibility of the simulated lake-surface $PM_{2.5}$ accumulation, we examined the spatial distribution of satellite-retrieved hourly high-resolution near-surface $PM_{2.5}$ data from the ChinaHigh $PM_{2.5}$ dataset (Wei et al., 2021) over eastern China, with results shown in Figure S6. It is important to emphasize that this comparison is not intended for quantitative validation but serves purely qualitative purposes, to demonstrate that the phenomenon of elevated daytime lake-surface $PM_{2.5}$ concentrations relative to surrounding urban areas is physically plausible and supported by independent observational evidence. As noted by the reviewer, the ChinaHigh $PM_{2.5}$ data are from 2018 rather than our simulated period in March 2019, precluding precise temporal matching with our model output. Furthermore, satellite-retrieved $PM_{2.5}$ estimates have inherent uncertainties, particularly over water surfaces, making meaningful quantitative comparisons with model output infeasible. Therefore, Figure S6 is presented purely for qualitative purposes, to demonstrate that elevated lake-surface $PM_{2.5}$ relative to surrounding areas represents a physically plausible phenomenon supported by independent observational evidence, rather than a spurious artifact of model configuration. Figure S6 shows that daytime lake-surface $PM_{2.5}$ concentrations are comparable to or exceed those in adjacent urban areas, with this feature most pronounced during local time 11:00-16:00 (Figure S6d-i), qualitatively consistent with the accumulation mechanism identified in our simulations.

In the revised manuscript (Section 3.1), we have added a detailed explanation:

“To further support the reliability of the simulated $PM_{2.5}$ accumulation over the lake surface, we examine the spatial distribution of satellite-derived hourly high-resolution near-surface $PM_{2.5}$ data over eastern China from the ChinaHigh $PM_{2.5}$ dataset (Wei et al., 2021), which provides hourly near-surface $PM_{2.5}$ concentrations during 08:00–17:00 LT. The corresponding results are shown in Figure S6. It should be emphasized that this comparison is not intended as a quantitative validation of our simulation results. The ChinaHigh $PM_{2.5}$ data used here are from 2018 rather than the simulated period of March 2019,

precluding an exact temporal match with our model output. In addition, satellite-derived $PM_{2.5}$ estimates are subject to inherent retrieval uncertainties, particularly over water surfaces, which renders meaningful quantitative comparison with model output unfeasible. Figure S6 is therefore presented purely for qualitative purposes, to demonstrate that elevated $PM_{2.5}$ concentrations over the lake surface relative to surrounding areas represent a physically plausible phenomenon supported by independent observational evidence, rather than an artifact of the model configuration. Figure S6 shows that daytime lake-surface $PM_{2.5}$ is comparable to or exceeds that over adjacent urban areas, with this feature being most pronounced during 11:00–16:00 LT (Figures S6d–i), which is qualitatively consistent with the accumulation mechanism identified in our simulations. We acknowledge that direct quantitative validation of lake-surface $PM_{2.5}$ using in-situ observations would be highly desirable. Unfortunately, in-situ air quality observations over lake surfaces and shoreline areas remain extremely scarce in China, with very limited publicly available data. Targeted observational deployments are discussed further in Sect. 4.”

We believe these revisions adequately address the reviewer's concerns by systematically validating our simulation results and clearly articulating both the strengths and limitations of available observational data.

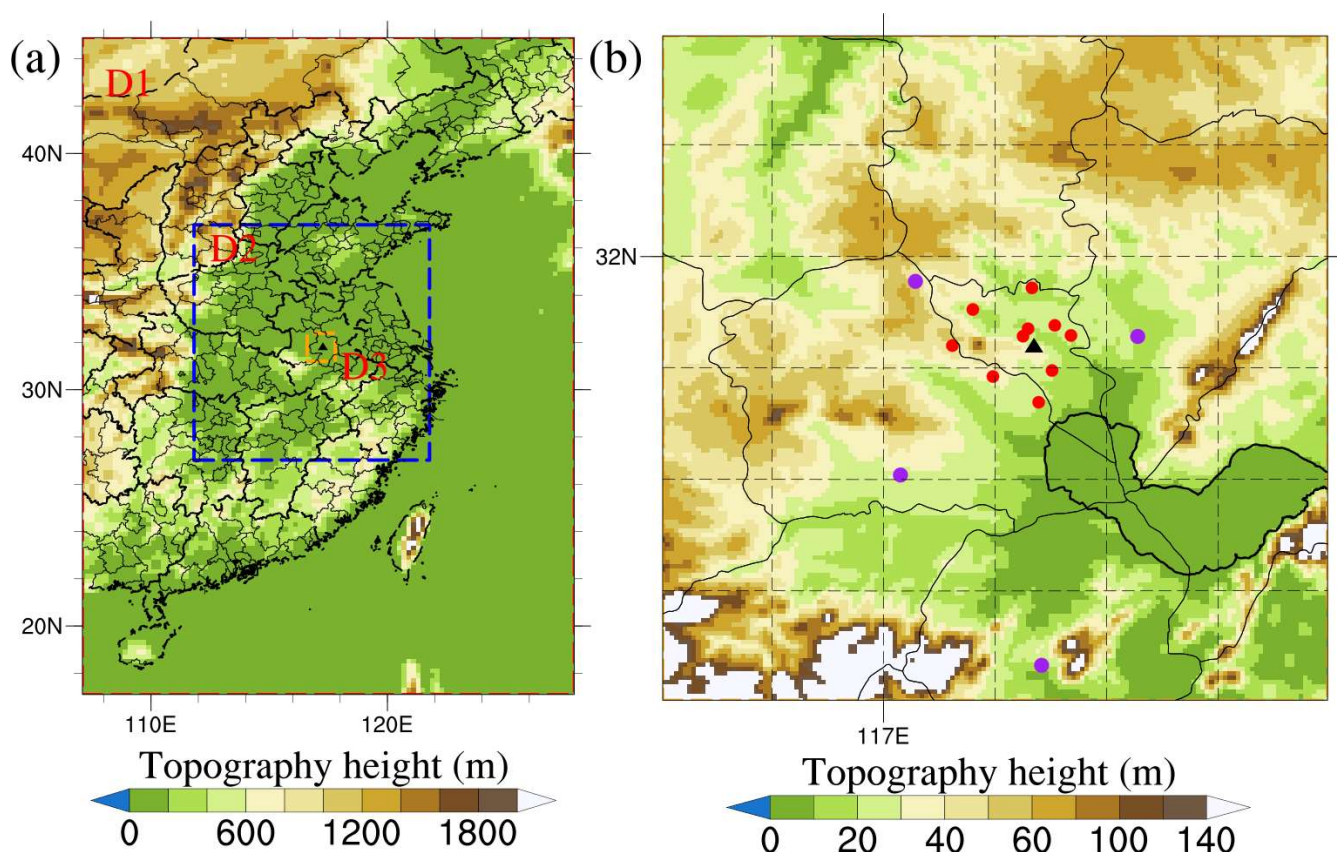


Figure 1. (a) The three domains used in the WRF-Chem simulations and the terrain height (m) of each domain. Domain one (D1) has a horizontal grid spacing of 25 km, domain 2 (D2) 5 km, and domain 3 (D3) 1 km; (b) The spatial distribution of the terrain height (m) in D3. The solid black triangle indicates the location of Hefei, the solid dots triangles indicate MEP monitoring sites, and the purple solid dots indicate AWSs locations.

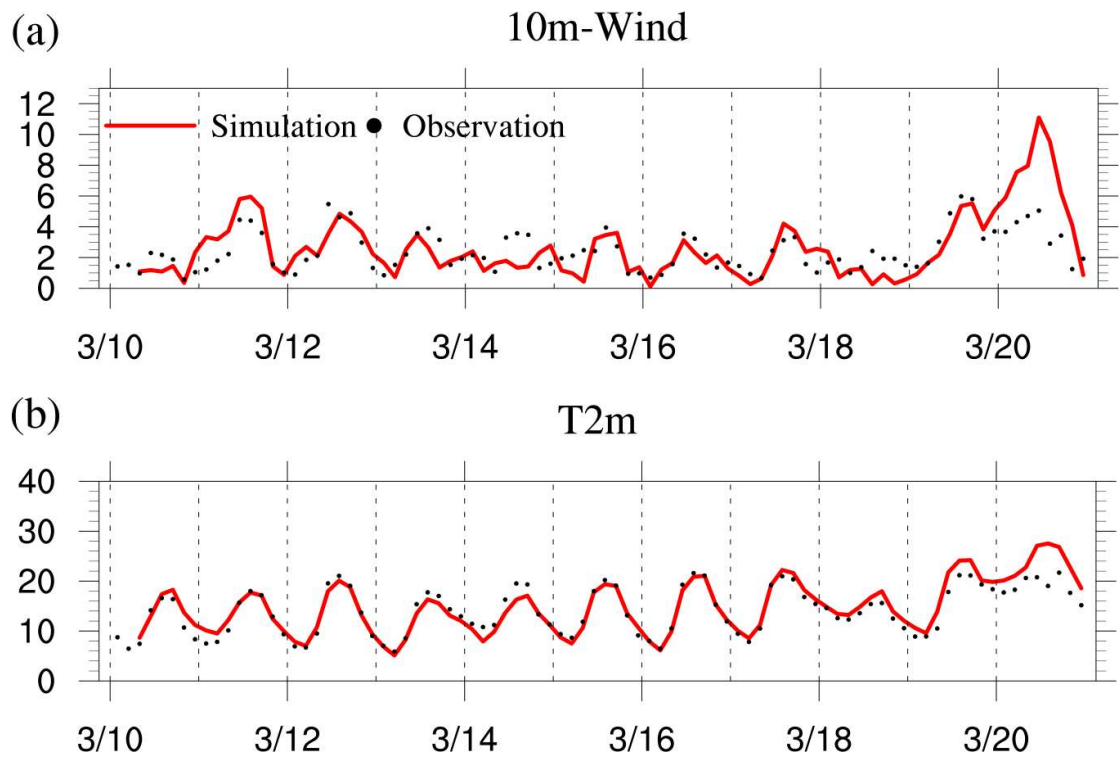


Figure S4. Time series of observed (black dots) and simulated (red line) wind speed at 10 m (top panel, m s^{-1}) and temperature at 2 m (middle panel, $^{\circ}\text{C}$) from the Lake experiment, averaged over 4 AWS sites in Hefei.

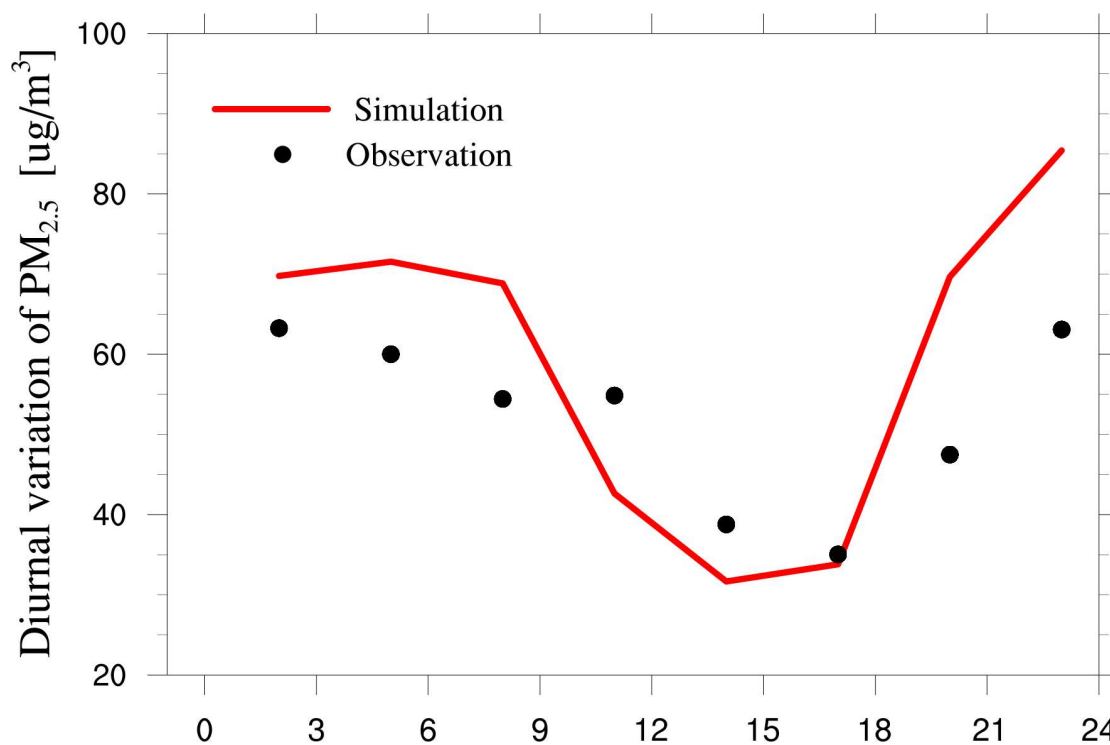


Figure S5. Diurnal variation of PM_{2.5} surface concentrations within 24 h averaged over 10 MEP sites in Hefei during the study period for the Lake experiment (solid red line) and observations (black dot). Both the simulated results and observations are sampled at the model output frequency, i.e., 3-hourly.

Reference:

- CMA, 2018: Technical Specifications for Maintenance of Regional Automatic Weather Stations. QX/T 465–2018. (in Chinese). Available at: <http://cmastd.cmatc.cn/standardView.jsp?id=3076>. Accessed on 5 May 2022., 2018.
- Estevez, J., Gavilan, P., and Giraldez, J. V.: Guidelines on validation procedures for meteorological data from automatic weather stations, *Journal of Hydrology*, 402, 144-154, <https://doi.org/10.1016/j.jhydrol.2011.02.031>, 2011.
- Yang, Z. N., Du, Q. Y., Yang, Q. K., Zhao, C., Li, G. D. Z., Xia, Z. H., Xu, M. Y., Yuan, R. M., Li, Y. B., Xia, K. H., Gu, J., and Feng, J. W.: Modeling urban pollutant transport at multiple resolutions: impacts of turbulent mixing, *Atmospheric Chemistry and Physics*, 25, 8831-8857, <https://doi.org/10.5194/acp-25-8831-2025>, 2025.
- Wei, J., Li, Z., Pinker, R. T., Wang, J., Sun, L., Xue, W., Li, R., and Cribb, M.: Himawari-8-derived diurnal variations in ground-level PM_{2.5} pollution across China using the fast space-time Light Gradient Boosting Machine (LightGBM), *Atmospheric Chemistry and Physics*, 21, 7863-7880, <https://doi.org/10.5194/acp-21-7863-2021>, 2021.

- *3. Since the investigated period is quite short, the authors should discuss the period representativeness. Moreover, the influence of circulation patterns is not considered. The authors could discuss the effects of such patterns and the front passages on the calculated concentrations.*

Response: We sincerely thank the reviewer for this important and constructive comment. We fully agree that the relatively short analysis period and the potential influences of large-scale circulation patterns and frontal passages need to be adequately discussed in the manuscript.

1、Regarding the research positioning and period selection

First, we would like to clarify the scientific positioning of this study. This research aims to conduct a high-resolution, process-oriented sensitivity experiment rather than a long-term climatological statistical analysis. Our core objective is to quantitatively isolate the net impact of the lake surface on PM_{2.5} through comparison between Lake and Nolake numerical experiments at 1-km resolution, and to identify the underlying physical and chemical mechanisms (boundary layer modulation, turbulent mixing modification, dry deposition alteration, thermodynamic effects on secondary aerosol formation, etc.). Ultra-high resolution (1 km) WRF-Chem simulations are computationally extremely demanding, requiring approximately 20 hours of wall-clock time on 112 CPU cores to simulate a single day over the 150×150 grid domain used in this study. This computational cost renders long-term or multi-seasonal integrations infeasible with current resources.

The selected study period was not arbitrarily chosen but carefully determined based on the following scientific considerations: (1) PM_{2.5} pollution in the Yangtze River Delta region exhibits strong seasonal variation, with high concentrations occurring primarily from October to April during the pollution season, while summer concentrations are typically much lower. Since this study focuses on lake effects on PM_{2.5} pollution, it is scientifically appropriate to focus on the pollution season; (2) March represents a transitional season between winter and summer circulation patterns, when PM_{2.5} concentrations remain relatively high while lake-land thermal contrasts are sufficiently strong to drive significant lake-breeze circulations and affect boundary layer evolution; (3) the selected period is characterized by predominantly clear-sky and dry conditions with moderate background winds, which minimizes confounding factors such as wet removal.

2、Regarding the influence of circulation patterns and representativeness of results

Following the reviewer's suggestion, we further examined the 850 hPa wind fields for January, March, and October using ERA5 reanalysis data, with these three months representing winter, early spring, and autumn pollution periods, respectively. ERA5 analysis results indicate significant differences in large-scale circulation backgrounds over eastern China across these months. January is more strongly controlled by winter monsoon circulation, March exhibits transitional circulation characteristics, while October shows autumn circulation features distinct from the previous two, as shown in Figure S1. These differences suggest that the intensity and spatial extent of lake-induced meteorological perturbations and their impacts on PM_{2.5} may vary with seasons and weather backgrounds. Therefore, we agree that the March case analyzed in this paper cannot be considered statistically representative of all pollution seasons. Rather, our results should be interpreted as revealing the lake

effects on $PM_{2.5}$ under meteorological backgrounds similar to this spring transitional period. The physical and chemical processes we identified (boundary layer suppression, turbulent mixing modification, dry deposition alteration, temperature-dependent chemical reactions, etc.) represent lake-atmosphere-pollutant coupling under the specific meteorological conditions studied. Under different circulation backgrounds, the relative contributions of these processes may differ. We have added this discussion in the revised manuscript (Section 2.2 and Section 4) and included ERA5 circulation analysis figures in the Supporting Information. Meanwhile, we also note that the Lake and Nolake experiments employ identical initial and boundary conditions. Therefore, large-scale synoptic circulation constitutes a common background forcing in both experiments, and the differences between simulation results primarily reflect perturbations induced by lake presence. In this sense, although the absolute response magnitude may depend on the specific circulation pattern, our experimental design can robustly isolate the net lake effect in the selected study, and the identified mechanisms are physically unambiguous.

3、 Regarding the influence of frontal passages

Concerning the influence of frontal passages, we fully agree with the reviewer that frontal systems may significantly affect $PM_{2.5}$ concentrations through multiple pathways, including wind field reorganization, enhanced ventilation, boundary layer structure adjustment, thermal condition changes, and precipitation-related wet removal. To address this important question, we further examined meteorological field characteristics during the study period, particularly total column cloud water and ice content and precipitation fields. Analysis results indicate that the selected period is characterized by predominantly clear-sky and stable conditions, as evidenced by total column cloud water and ice content ($< 0.1 \text{ kg m}^{-2}$ in most areas) and negligible precipitation within the model domain (cumulative precipitation $< 1 \text{ mm}$ at most area) (detailed spatial distributions are not shown here, please see our response to the other reviewer's comments). These conditions indicate minimal influence of frontal systems during the study period, and the Chaohu-Hefei region was not dominated by persistent, widespread, strong frontal precipitation processes during the analysis period. Therefore, wet removal and frontal passage-related removal processes were not the main controlling factors for $PM_{2.5}$ evolution in this study. However, we fully agree with the reviewer that frontal passages represent an important class of meteorological events that could significantly alter lake-atmosphere-pollutant interactions. The interplay between frontal dynamics and lake processes on air quality constitutes a complex and interesting topic that warrants dedicated investigation in future studies. We have added these contents in the discussion section of the revised manuscript.

Finally, we fully acknowledge that under other seasons, different circulation patterns, or more significant frontal activity conditions, the response of $PM_{2.5}$ to lake presence may differ in impact intensity, spatial distribution, and even dominant mechanisms. Therefore, future systematic studies based on longer time scales covering multiple seasons and different weather patterns would be of significant importance, but this is beyond the scope of the current study. We have now clearly stated this limitation in the revised manuscript and listed it as an important direction for future research.

Corresponding revisions have been made in the manuscript, and the ERA5 circulation analysis has been added to the

Supplementary Material as Figure S1. In the revised Methods section (Section 2.2), we have added a detailed explanation of this question:

“This period corresponds to the pollution season when $PM_{2.5}$ concentrations are typically much higher than in summer, and lake-land thermal contrasts remain sufficiently strong to drive significant lake-breeze circulations. Importantly, the episode was characterized by predominantly clear-sky conditions, with total column cloud water and cloud ice content remaining at low levels (less than 0.1 kg/m^2 in most areas) and negligible precipitation (hourly accumulation greater than 0.5 mm). These conditions are favorable for isolating the intrinsic lake effects while minimizing confounding influences from cloud microphysics and wet scavenging on $PM_{2.5}$ distributions (detailed spatial distributions are not shown here). Additionally, March represents a transitional season between winter and summer circulation patterns, which facilitates the investigation of interactions among lake-induced meteorological perturbations, boundary layer evolution, and $PM_{2.5}$ pollution. Given the extremely high computational cost of 1-km resolution WRF-Chem simulations, the 10-day period can capture diurnal variations of lake effects while remaining computationally feasible. It should be noted that ERA5 reanalysis dataset (<https://rda.ucar.edu/datasets/ds630.0/>, last access: 15 April 2019) indicates significant differences in large-scale circulation across different months during the pollution season (October, January, March) (see Figure S1 in Supporting Information), and the selected period represents springtime transitional conditions with moderate background winds. Therefore, our results should be interpreted as lake effects under specific springtime meteorological conditions, and the lake impact mechanisms may differ in other seasons, rather than being statistically representative of all pollution seasons. The sensitivity experiments employ identical initial and boundary conditions, ensuring that simulation differences primarily reflect perturbations induced by lake presence.”

In the revised manuscript (Section 4), we have added a detailed explanation about this discussion:

“The lake effects revealed in this study should be interpreted in the context of the meteorological background and the limitations of the simulation period. This study aims to quantitatively isolate the net lake impacts on $PM_{2.5}$ and identify the underlying physical-chemical mechanisms through high-resolution sensitivity experiments, rather than conducting long-term climatological statistical analysis, given the extremely high computational cost of 1-km resolution WRF-Chem simulations. The selected period in March 2019 corresponds to the pollution season when $PM_{2.5}$ concentrations are typically much higher than in summer, and lake-land thermal contrasts remain sufficiently strong to drive significant lake-breeze circulations. However, this study is not statistically representative of all pollution seasons. The 850 hPa wind fields from ERA5 reanalysis for January, March, and October (Figure S1) indicate significant differences in large-scale circulation patterns over eastern China across winter, spring, and autumn. January is more strongly controlled by winter monsoon circulation, March exhibits a transitional circulation pattern, while October shows distinct autumn circulation characteristics different from the former two. This implies that the intensity, spatial extent, and even the dominant pathways of lake impacts on $PM_{2.5}$ may vary with seasonal circulation backgrounds. Additionally, the study period was characterized by predominantly clear skies and moderate

background winds, with weak cloud content and precipitation, which was a deliberate aspect of the study selection strategy to facilitate the isolation of intrinsic lake effects. Although frontal passages can influence $PM_{2.5}$ through wind field reorganization, boundary layer structural adjustments, thermal changes, and wet scavenging processes, this study was not dominated by persistent, large-scale, strong frontal precipitation events, and thus frontal scavenging was not a primary controlling factor in this analysis. Since the Lake and Nolake experiments employ identical initial and boundary conditions, the synoptic-scale circulation constitutes a common background forcing in both simulations, and thus the simulation differences primarily reflect perturbations induced by lake presence. In summary, this study are more applicable to stable weather conditions similar to this springtime transitional period. Future research should systematically evaluate lake impacts on pollutants across multiple seasons and different weather patterns (including frontal events) to establish a more comprehensive understanding of lake-air quality interactions and quantify their seasonal and circulation dependencies.”

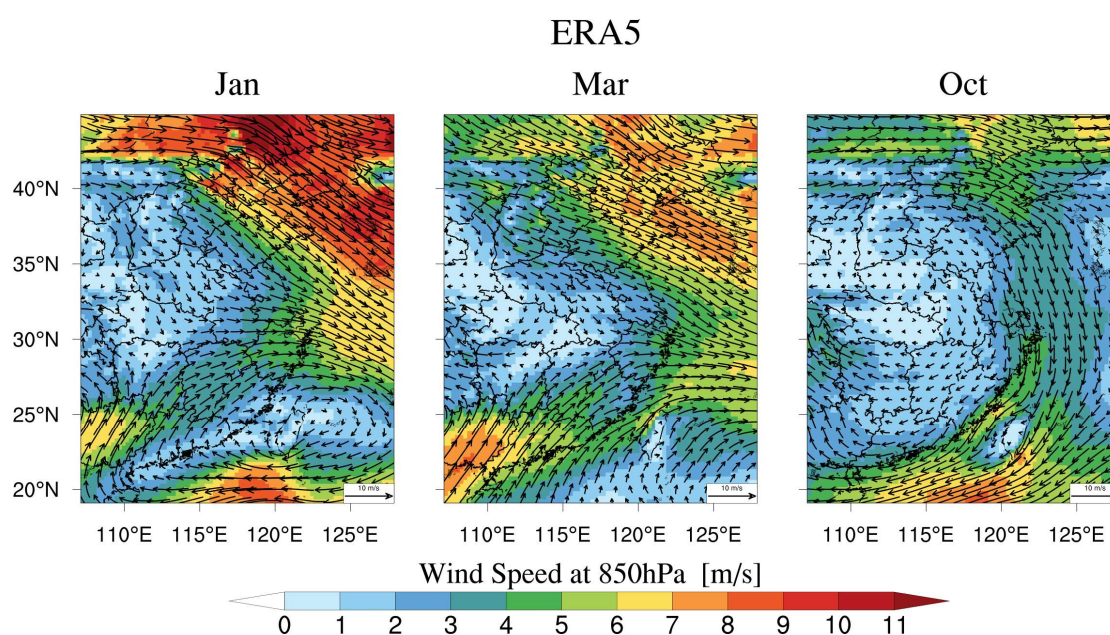


Figure S1. Spatial distribution of wind speeds at 850 hPa from ERA5 reanalysis datasets over East China averaged for January, March, and October of 2019.

- *4. Spatial resolution of emissions presented in Fig. 2(c) is different than that for land use types. This resolution impacts on concentrations presented in other figures, such as Fig. 3. Perhaps the emission resolution could be a procedure weakness.*

Response: Thank the reviewer for this thoughtful comment regarding the difference in spatial resolution between the emission inventory and land use data. We acknowledge this difference and would like to provide clarification on this issue.

The difference in spatial resolution between emissions and land use data in our study is primarily attributed to the limited availability of high-resolution emission inventories at the global or regional scale, which represents a common challenge in current air quality modeling studies. In our simulations, we employed the MEIC (Multi-resolution Emission Inventory for China) emission inventory at a spatial resolution of 0.25° , which was then interpolated to our model simulation resolution of

1 km. This interpolation process indeed cannot capture the fine-scale spatial variability of emissions as effectively as native high-resolution emission data would. However, it is important to note that the 0.25° resolution MEIC inventory represents one of the most reliable and widely validated emission datasets currently available for China. More importantly, the highest spatial resolution of publicly accessible emission inventory for China is currently only 0.1° (Wu et al., 2024), which still requires interpolation to our 1 km model grid. The scarcity of high-resolution emission data is a widespread issue in the atmospheric modeling community and affects virtually all fine-scale air quality simulations globally. In contrast, the land use data we employed is the United States Geological Survey's (USGS) 24-category classification dataset at a native 1 km resolution, which naturally provides detailed spatial patterns at our simulation resolution without requiring interpolation. This difference in native resolution between emissions (0.25°) and land use (1 km) explains the resolution discrepancy noted by the reviewer.

However, we would like to emphasize that this resolution difference does not constitute a fundamental weakness for the validity of our scientific conclusions. The core scientific objective of our study is to investigate the impact of lake presence versus absence on the diurnal variation of PM_{2.5} concentrations in urban areas through sensitivity experiments. In our sensitivity experiment design, all conditions except for the presence or absence of the lake are kept identical between the reference experiment (with lake) and the sensitivity experiment (without lake, replaced by herbaceous wetland), including emission inputs, meteorological initial and boundary conditions, and model configuration parameters. Since both experiments use exactly the same emission inventory at the same resolution, and all other simulation settings remain consistent, any differences in simulated PM_{2.5} concentrations can be confidently attributed to lake-induced changes in meteorology, chemical processes, dry deposition, and boundary layer structure, rather than to emission differences or other confounding factors. This rigorous controlled-variable sensitivity experiment design ensures that our conclusions regarding lake impacts are robust and not affected by emission uncertainties or other interfering factors.

In summary, while we acknowledge the resolution difference between emissions and land use data as a limitation inherited from current data availability, this does not compromise the scientific validity of our conclusions regarding lake impacts on air quality, as our comparative sensitivity analysis ensures consistency of all conditions except lake presence through rigorous variable-controlled design.

Reference:

Wu, N., Geng, G., Xu, R., Liu, S., Liu, X., Shi, Q., Zhou, Y., Zhao, Y., Liu, H., Song, Y., Zheng, J., Zhang, Q., and He, K.: Development of a high-resolution integrated emission inventory of air pollutants for China, *Earth System Science Data*, 16, 2893-2915, <https://doi.org/10.5194/essd-16-2893-2024>, 2024.

- ***5. The calculated values with or without the lake are quite similar and their differences are small. The authors should consider not only if the lake suppression is realistic but if the lake impact is real or not.***

Response: We thank the reviewer for their careful consideration of the magnitude of the lake's influence. We would like to emphasize that our results demonstrate a substantial and policy-relevant impact of the lake on the regional PM_{2.5} distribution, which warrants attention in both scientific understanding and air quality management.

As shown in Figures 3, the lake's impact on PM_{2.5} concentrations is considerable. Over the lake surface, the concentration differences between the Lake and Nolake experiments can exceed 10 µg/m³, while the impacts in the surrounding lake area range from 0-10 µg/m³. Quantitative analysis in Figure 4 further confirms these magnitudes. Figure 4a shows that the peak concentration difference at the lakeshore (point B) exceeds 8 µg/m³ during daytime, while the maximum cleansing effect at the city center (16-17 km from point B) approaches 8 µg/m³ during nighttime. Figure 4c demonstrates that concentration differences can exceed 8 µg/m³ during specific periods, with spatial impacts extending more than 15 km from the lakeshore. These represent substantial perturbations to the regional PM_{2.5} field.

From an air quality management perspective, concentration changes of this magnitude are highly significant. Current air quality standards and policy targets typically involve incremental improvements on the order of a few µg/m³. For example, China's Ambient Air Quality Standards set PM_{2.5} concentration limits where exceedances of even a few µg/m³ can trigger public health warnings and emission control measures. Therefore, lake-induced changes of 0-10 µg/m³ over extensive spatial domains are directly relevant to regulatory compliance and public health protection. More importantly, our findings have significant implications for source apportionment and pollution control strategies. By quantifying that lake-induced meteorological and chemical processes can alter PM_{2.5} concentrations by up to 10 µg/m³ or more in lakeside areas, we provide critical information to policymakers and the public: the elevated PM_{2.5} concentrations observed over the lake surface and adjacent urban areas are not solely attributable to local anthropogenic emissions, but also stem from complex lake-atmosphere interactions. This understanding is essential for developing scientifically sound and cost-effective pollution control strategies.

Zhang et al. (2017) studied the impact of Taihu Lake on ozone concentrations in the Yangtze River Delta, reporting that ozone differences between lake and no-lake scenarios typically ranged from 0-10 ppbv in lakeside areas. These ozone concentration differences were considered significant in that study and have been widely cited. Our PM_{2.5} study shows impacts of similar magnitude.

We respectfully maintain that the lake's impact on PM_{2.5} concentrations is significant, both in terms of absolute magnitude and policy relevance and scientific importance. These impacts are comparable to those reported in previous lake effect studies and are sufficient to affect regulatory compliance and public health outcomes. Our findings provide essential scientific evidence for understanding air quality in major urban areas adjacent to lakes and for developing effective pollution control strategies that account for natural meteorological influences.

Reference:

Zhang, L., Zhu, B., Gao, J., and Kang, H.: Impact of Taihu Lake on city ozone in the Yangtze River Delta, *Advances in Atmospheric Sciences*, 34, 226-234, <https://doi.org/10.1007/s00376-016-6099-6>, 2017.

- *6. Although the number of references is noticeable, most of them are quite old. Perhaps some of them could be replaced by more recent references. Moreover, references are not considered for the discussion. These references could be used to compare the paper results with those from former studies. Without such comparison, the paper appears an isolated analysis.*

Response: We sincerely thank the reviewer for this constructive criticism. We fully agree that the original manuscript relied on some older references and lacked substantive engagement with prior literature in the Discussion section, which limited the contextualization of our findings within the broader research landscape.

In response, we have substantially revised the Discussion section in two respects:

First, we have added a comparative paragraph situating our results within the context of established lake-meteorology and air quality research. Specifically, we now explicitly compare our daytime urban PM_{2.5} enhancement findings with lake-breeze recirculation mechanisms documented over the North American Great Lakes (Brook et al., 2013; Hayden et al., 2011), and draw a qualitative analogy between our observed anomalous daytime PM_{2.5} accumulation over the lake surface and the urban pollution confinement reported by Dye et al. (1995) over Lake Michigan and the elevated near-surface O₃ concentrations reported by Wang et al. (2023) for Lake Taihu. This addition directly addresses the reviewer's concern that the paper appeared as an isolated analysis disconnected from prior work. Second, we have added a paragraph in the emission sensitivity experiment discussion that contextualizes our findings relative to Zhang et al. (2017), who conducted a comparable lake-replacement sensitivity experiment for ozone over Lake Taihu but did not address the treatment of emissions over water surfaces. This comparison highlights both the methodological contribution of our study and the prevalence of this oversight across similar studies.

These revisions have also introduced more recent references, including Wang et al. (2023) and Geng et al. (2024), partially addressing the reviewer's concern regarding the age of the reference list. The revised passages can be found in Section 4 of the revised manuscript:

“The diurnal reversal of lake effects on PM_{2.5} identified here both corroborates and extends prior findings. Earlier studies on the North American Great Lakes demonstrated that lake-breeze circulations promote recirculation of primary and secondary pollutants and enhance aerosol formation rates (Brook et al., 2013; Hayden et al., 2011), consistent with the daytime urban PM_{2.5} enhancement quantified in the present study. The anomalous daytime PM_{2.5} accumulation over the lake surface is qualitatively analogous to the confinement of urban pollution documented by Dye et al. (1995) over Lake Michigan and the elevated near-surface O₃ concentrations reported by Wang et al. (2023) for Lake Taihu. These findings demonstrate that lakes play a complex dual role in regulating regional air quality through distinct physical-chemical mechanisms during day and night.”

“These chemical-physical coupling mechanisms, not previously articulated in lake-urban pollution studies, operate

synergistically to shape the complex spatiotemporal patterns of PM_{2.5} interactions between lakes and urban areas.”

“These findings confirm that accurate emission characterization is crucial for quantifying lakes’ complex role in regional air quality, and further suggest that previous high-resolution air quality modeling studies over lake-containing domains may have erroneously attributed emission-driven pollution hotspots to lake meteorological effects, thereby systematically overestimating the contribution of the lake itself to the spatial distribution of PM_{2.5}. However, most current emission inventories lack sufficient spatial resolution to distinguish water surfaces from land, often erroneously assigning anthropogenic emissions to lake areas and biasing lake effect assessments. Although Zhang et al. (2017) conducted a similar lake-replacement sensitivity experiment for ozone over Lake Taihu, their study did not address the treatment of emissions over water surfaces, an oversight that appears to be prevalent across similar studies. Therefore, the explicit zeroing of anthropogenic emissions over water surfaces during the preprocessing stage of regional air quality simulations should be established as a standardized procedure, a requirement that becomes increasingly urgent as China’s emission inventories are continuously refined under the impetus of clean air action policies (Geng et al., 2024). Developing emission inventories that accurately characterize surface-specific emission patterns is crucial for reliable assessment of lake-urban air quality interactions and effective pollution control strategies.”

Reference:

- Brook, J. R., Makar, P. A., Sills, D. M. L., Hayden, K. L., and McLaren, R.: Exploring the nature of air quality over southwestern Ontario: main findings from the Border Air Quality and Meteorology Study, *Atmospheric Chemistry and Physics*, 13, 10461-10482, <https://doi.org/10.5194/acp-13-10461-2013>, 2013.
- Hayden, K. L., Sills, D. M. L., Brook, J. R., Li, S. M., Makar, P. A., Markovic, M. Z., Liu, P., Anlauf, K. G., O'Brien, J. M., Li, Q., and McLaren, R.: Aircraft study of the impact of lake-breeze circulations on trace gases and particles during BAQS-Met 2007, *Atmospheric Chemistry and Physics*, 11, 10173-10192, <https://doi.org/10.5194/acp-11-10173-2011>, 2011.
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Minor comments:

- *1. Figure 1 (b). The lake is missing. Moreover, additional latitudes and longitudes should be introduced in this figure and similar figures, such as 3, 5...*

Response: We thank the reviewer for this valuable comment. We have revised Figure 1(b) and other relevant figures (such as Figures 3, 5, etc.) following the reviewer's suggestion by adding the lake outline and latitude/longitude labels. These improvements enable readers to more clearly identify geographical locations, understand spatial distribution patterns, and better correlate the simulation results with the actual geographical environment. The revised figures will help readers more accurately interpret the spatial extent and patterns of the lake's influence on PM_{2.5} concentrations in surrounding areas.