Response to Reviews

Manuscript: An improved high-resolution passenger vehicle emission inventory for China using ride-hailing big data (egusphere-2025-5554)

We sincerely appreciate the constructive comments and valuable suggestions provided by the reviewer, which have greatly contributed to improving the quality of our study. The response to each comment is listed below. In the point-by-point response, reviewers' comments are marked in black, our responses are in blue, and the revised content in the manuscript is highlighted in red.

Response to Reviewer #2:

General comments:

The article "An improved high-resolution passenger vehicle emission inventory for China using ride-hailing big data" by Li et al., provides information about emission inventory for pollutants emitted by passenger cars in China. The study highlights the importance of average vehicle speed on emission factors. These findings were established in comparison with traditional methods, both showing discrepancies between urban and rural vehicle emissions, weekend relative to workdays emissions and seasonal distribution of pollutants released from vehicular emissions.

Response: We sincerely appreciate the reviewer's positive evaluation of the value of our research findings. Each comment and suggestion have been carefully addressed, as detailed below.

Major comments:

1.The authors should provide more detailed information regarding the vehicular fleet, type of motorization, percentual distribution over the entire country, type of fuel, etc. Also, there is a need to discuss about the type of industrial vehicles and those used for agriculture, passenger car legislation related to the restrictions on pollution and how this apply to other nations.

Response: We thank the reviewer for the constructive suggestions. We have revised this study accordingly in response to these advices. In the supplementary materials, Figure S1b presents the national passenger vehicle ownership in 2019, and Figure S2 is newly added to show the regional distribution of small and mini vehicles under different emission standards. Relevant descriptions of vehicle types and fuel types were also added in the methodology section. This study focuses on passenger vehicles and will expand to industrial and agricultural vehicles in future work. With the growing share of China V and China VI vehicles, the rising penetration of new energy vehicles (China's new energy vehicle ownership reached 31.4 million by 2024, increased by 53.84% year on year; Liang et al., 2019; Wang et al., 2026), and the implementation of vehicle scrappage policies, the overall emission intensity of passenger vehicles in China will continue to decline (Liu et al., 2024; Zhu et al., 2022). These measures synergistically promote emission standard upgrading and energy structure transition, and provide important references for other countries to balance environmental governance, energy security, and transportation development.

In the Methods section: "This study focused on gasoline-fueled passenger vehicles. The vehicle kilometers traveled (VKT) of light-duty gasoline passenger vehicles (LDPVs) in 2019 were obtained from Ma et al. (2022). Based on the China Statistical Yearbook 2004–2019, we calculated the proportion of passenger vehicles by emission standard, the total number of passenger vehicles in each province in 2019 (Fig. S1), and the regional distribution of small and

mini passenger vehicles by emission standard (Fig. S2).″

In the Conclusions section: 〝At present, this study focuses on passenger vehicles; to improve its accuracy and applicability, future research will be further extended to freight trucks, industrial vehicles, agricultural vehicles, and the entire transportation sector.″

"In the future, with the continuous increase in the proportion of China V and China VI vehicles, as well as the rising penetration rate of electric vehicles (EVs) (China's stock of electric vehicles reached 31.4 million by 2024, a year-on-year increase of 53.84%) (MEE, 2025; Liang et al., 2019; Wang et al., 2026), coupled with the implementation of policies for the elimination and renewal of old vehicles, the overall "speed-emission" relationship in the passenger vehicle sector will be gradually weakened (Liu et al., 2024; Zhu et al., 2022)."

"These above-mentioned measures coordinate the upgrading of emission standards with the transformation of the energy structure, providing an important reference for other countries to balance environmental governance, energy security and transportation development.″
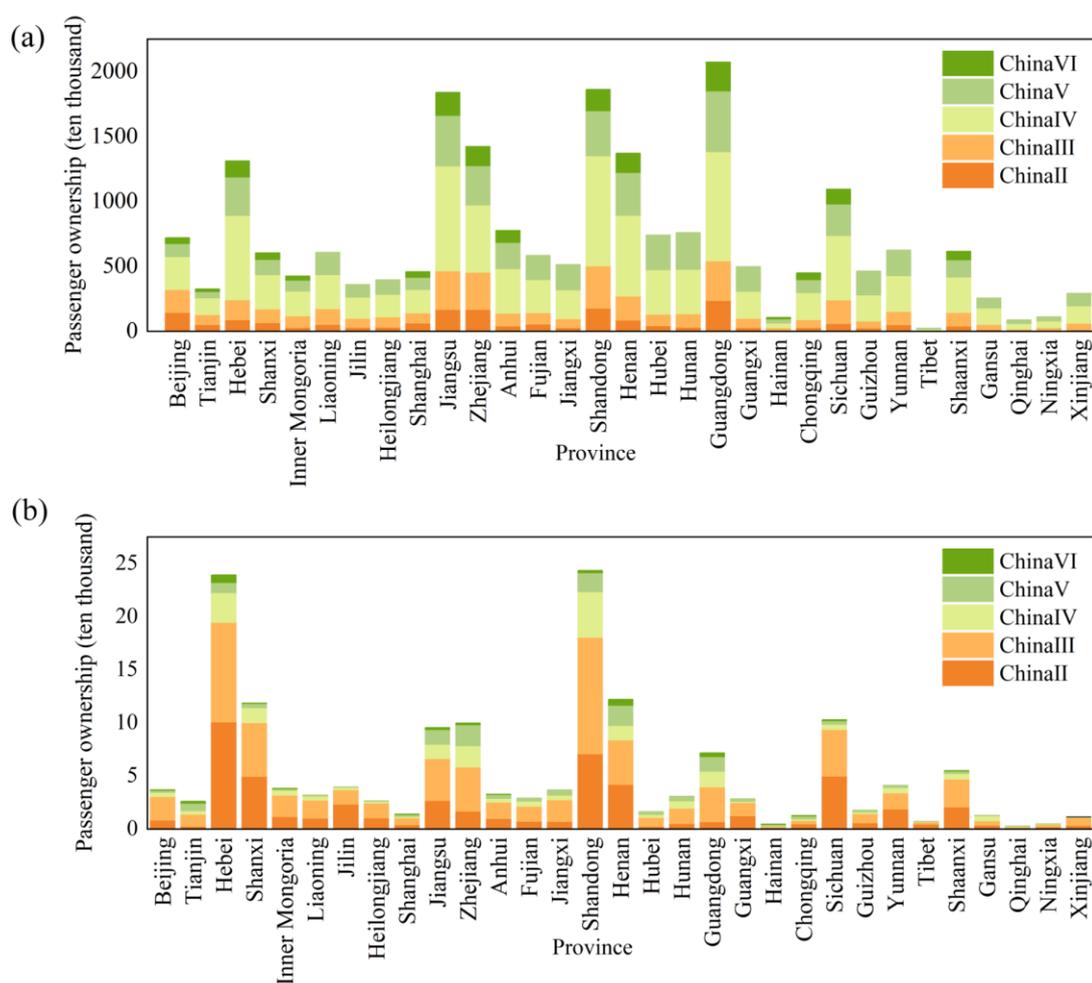

Figure S2. Distribution of passenger vehicles by emission standard in different regions: (a) small-sized vehicles and (b) mini-sized vehicles.

2.The authors should expand their consideration to the traffic worldwide and not over the few cities in China and India, even if those cities are very polluted. The emission inventories steady state data should be presented not over the cities in China and India. Even if the present study construct emission inventory of atmospheric pollutants in China the introduction should include a

wider view.

Response: We appreciate the reviewer for raising this point. We have supplemented the Introduction section with studies on air pollutant emission inventory development in countries other than China and India.

"For example, Dey et al. (2019) estimated the emission levels of 8 types of pollutants from passenger cars in the Greater Dublin Area of Ireland based on the COPERT5 model."

"The first category involves constructing high spatiotemporal resolution traffic emission inventories by using complex emission models, such as COPERT, MOVES, and IVE (Yang et al., 2018; Yu et al., 2021; Latini et al., 2005; Huo et al., 2009)."

3.The data collected from Amap Ride-hailing Platform are representative for the entire fleet? All the vehicles on the road send data to the platform? It is possible that, systematically, old vehicles emit constantly more pollutants but are not equipped with the tracking system?

Response: We appreciate the valuable comment from the reviewer. The data obtained from the Amap ride-hailing platform in this study is only used to reflect real-time road driving speeds. It should be emphasized that the platform data is derived from mobile terminal users with GPS positioning enabled; its uploading behavior is mainly related to the activation of the positioning function and has no direct connection with vehicle age. Given the sufficient sample size and wide spatiotemporal coverage of the data used in this study, it can reliably reflect the overall operating speed of the road network without significant bias caused by the exclusion of old vehicles, thus meeting the research requirements.

"The platform data originates from mobile terminal users who have activated GPS positioning. The data uploading behavior is primarily associated with the activation status of the positioning function and has no direct connection with vehicle age."

4.The sections 2.1 and 2.2 include many equations which are not well described and their parameters are not always clearly explained in terms of units and meaning (e.g. congestion delay index, Kj, Ct, etc.).

Response：Thank you for the comments. We have clearly indicated the units and meaning of each parameter in Sections 2.1 and 2.2.

5.Please include in the papers the problems which usually national monitoring stations have in the terms of trustable data provided. Which parameters are usually provided with huge errors and how these uncertainties are affecting the model?

Response: Thank you for raising this important point. In practice, national environmental monitoring data may have certain limitations in spatial coverage, and can be affected by nearby local emissions, instrument conditions, and complex environmental factors (Ding et al., 2024; Zhao et al., 2025). Among these, the monitored concentrations of pollutants such as $PM_{2.5}$, PM_{10}, and CO may affect the accuracy of model validation to some extent and may introduce slight disturbances to model evaluation and concentration comparison (Wu et al., 2018). We have added the discussion of the issues related to national environmental monitoring station data and their impacts in the Discussion section of the manuscript.

"In addition, this may also be related to the insufficient spatial representativeness of national environmental monitoring data during actual acquisition and the influence of local pollution

sources around monitoring sites, which slightly affect the validation results (Ding et al., 2024; Zhao et al., 2025; Wu et al., 2018)."

6.Please describe in the paper the possible effect on the overall model of the average speed of (42.42 ± 5) km h^{-1} for example. This average speed should be considered with a range of uncertainties and to extend this uncertainty to the model output data.

Response: We thank the reviewers for the constructive suggestions. As requested, we employed Monte Carlo simulation to quantify the uncertainty of emission factors. Across all speed intervals, the emission factors and their corresponding uncertainties for CO, VOC, and NO$_x$ were 1.4866 ± 21.42% g·km^{-1}, 0.4042 ± 22.56% g·km^{-1}, and 0.1507 ± 28.30% g·km^{-1}, respectively. Furthermore, uncertainty analysis was conducted for each speed interval. The results indicate that although the 40–80 km·h^{-1} interval exhibited the lowest emission factors, it contributed the largest share of pollutant emissions. In contrast, the uncertainty of emission factors reached its maximum when vehicle speeds exceeded 80 km·h^{-1} (Fig. S3).

"To further quantify the impact of average vehicle speed on the model results, this study conducted a quantitative assessment of model uncertainty using Monte Carlo simulation. Across all speed intervals, the emission factors and their corresponding uncertainties for CO, VOC, and NO$_x$ were 1.4866 ± 21.42% g·km^{-1}, 0.4042 ± 22.56% g·km^{-1}, and 0.1507 ± 28.30% g·km^{-1}, respectively. Furthermore, uncertainty analysis was performed for each speed interval. Although the 40–80 km·h^{-1} interval exhibited the lowest emission factors, it represented the dominant driving range for passenger vehicles, with the highest probability density. In contrast, the uncertainty of emission factors reached its maximum when vehicle speeds exceeded 80 km·h^{-1} (Fig. S3)."
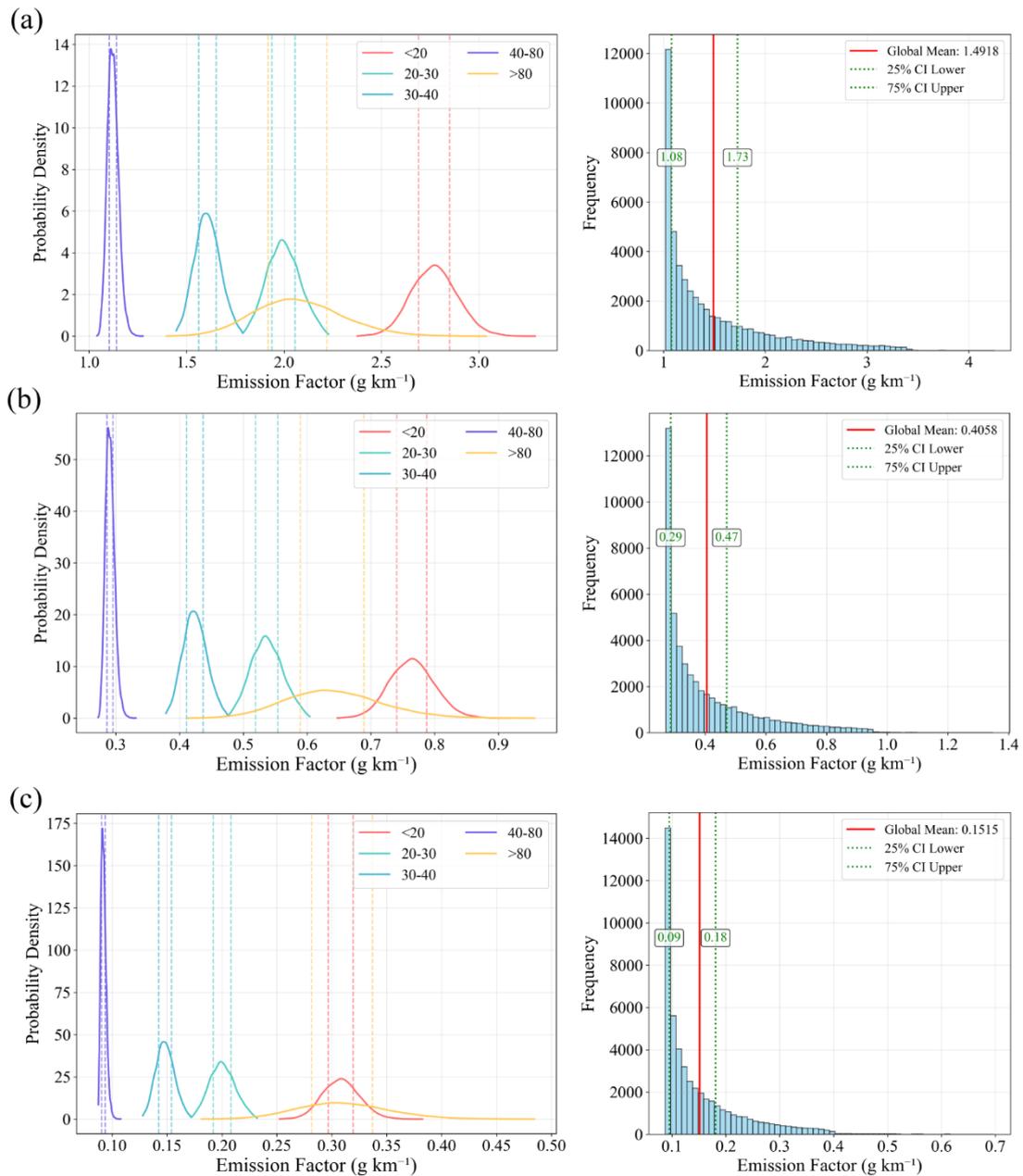
Figure S3. Probability density distributions of passenger vehicle emission factors across speed intervals and overall frequency statistics: (a)CO; (b)VOC; (c)NO_x.

7.Please include the uncertainty bars in the figure 2 for frequency on speed range. Three different days could have different frequency for the same speed range but there is an absolute number as average speed.

Response: We appreciate the reviewer's valuable suggestions. Regarding the frequency distribution across different speed intervals, vehicle speed frequency better follows a log-normal distribution. Therefore, we used the log-normal distribution to more accurately characterize the dispersion of the data and reflect the frequency fluctuations within the same speed interval on weekday, weekend, and holiday. We have added error bars to Figure 4 and provided the average speed values for each speed interval. The relevant results and discussions have been supplemented in the main text.

"Compared with weekday, there were no morning and evening rush hours on holiday, resulting in a higher proportion in high-speed intervals (Yang et al., 2016)."
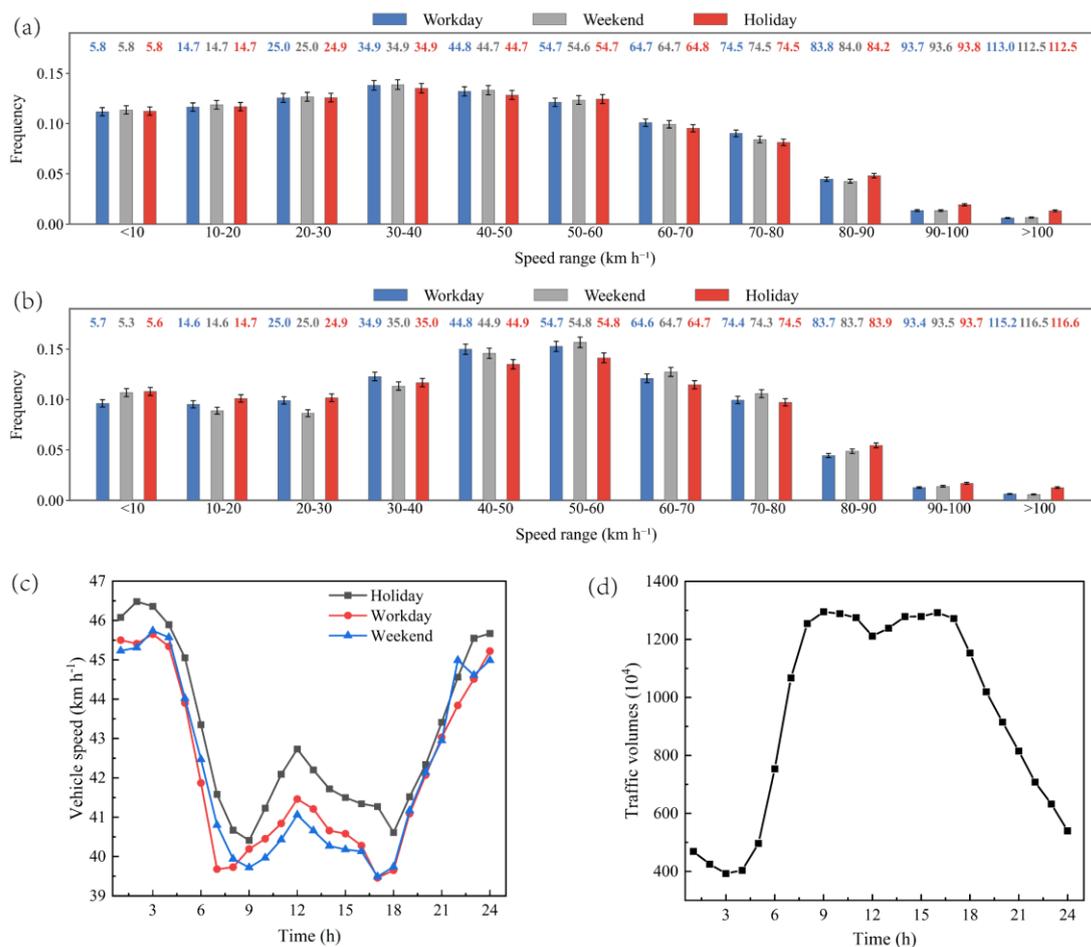

Figure 3. Characteristics of speed and traffic volume changes: speed distribution at (a) 8:00 and (b) 22:00 on workday, weekend and holiday. The values labeled in the figure represent the average speed of each interval; (c) Hourly speed variation on weekend, workday and holiday and (d) hourly traffic volume variation.

8.There is not convincingly that new model simulations with a better attribution of average speed parameter are the only responsible for the difference between the results in the model validation. The inventory optimization are actually not an important improvements since 0.36% in NMB and 0.02 for R2 are insignificant changes. Please discuss more in detail about the other advantages of the speed average model improvement.

Response: We appreciate the valuable suggestions from the reviewer. Passenger vehicles accounted for relatively low emission shares of total emissions (approximately 3.2% for CO, 4.7% for VOCs, and 1.2% for NO_x, Li et al., 2023a), which resulted in insignificant improvements in NMB and R values. If this method could be extended to other vehicle categories in future work, it might lead to more substantial enhancements. In this study, the optimization of the average speed model was reflected not only in total emissions but also in the improved accuracy of emission estimates across different date types. Average speeds on weekends were generally higher than those on weekdays. The traditional method underestimated emissions more significantly on weekends (33.4%) than on weekdays (27.7%) because it did not consider differences in speed.

However, the speed-corrected model in this study clearly showed these day-to-day changes. Spatially, the improved method avoided the limitation of using fixed speeds in traditional approaches. It can accurately identify higher emissions on crowded urban roads caused by frequent acceleration and deceleration, and properly show lower emissions on outside roads. This could support the precise implementation of traffic emission reduction measures at the road level. The above content has been elaborated in detail in Section 3.4 of the main text.

"Spatially, the improved method avoided the limitation of using fixed speeds in traditional approaches. It can accurately identify higher emissions on crowded urban roads caused by frequent acceleration and deceleration, and properly show lower emissions on outside roads (Fig. 7a) (Zhang et al., 2023a; Wen et al., 2020; Choudhary et al., 2016)."

"The traditional method exhibited a significant underestimation of passenger vehicle emissions across distinct seasons and day types (Fig. 7c). From a seasonal perspective, this method underestimated the average daily passenger vehicle emissions by 31.6%, 31.0%, 32.7% and 31.8% in spring, summer, autumn and winter, respectively, with a relatively small overall fluctuation range. In contrast, the discrepancy in underestimation across different day types was more pronounced, and the method's underestimation of passenger vehicle emissions on weekends (33.4%) was significantly higher than that on weekdays (27.7%). The formation of this characteristic difference was not only associated with refined vehicle speed correction, but also stemmed from the quantitative analysis of vehicle activity levels across different day types based on congestion indices in this study."
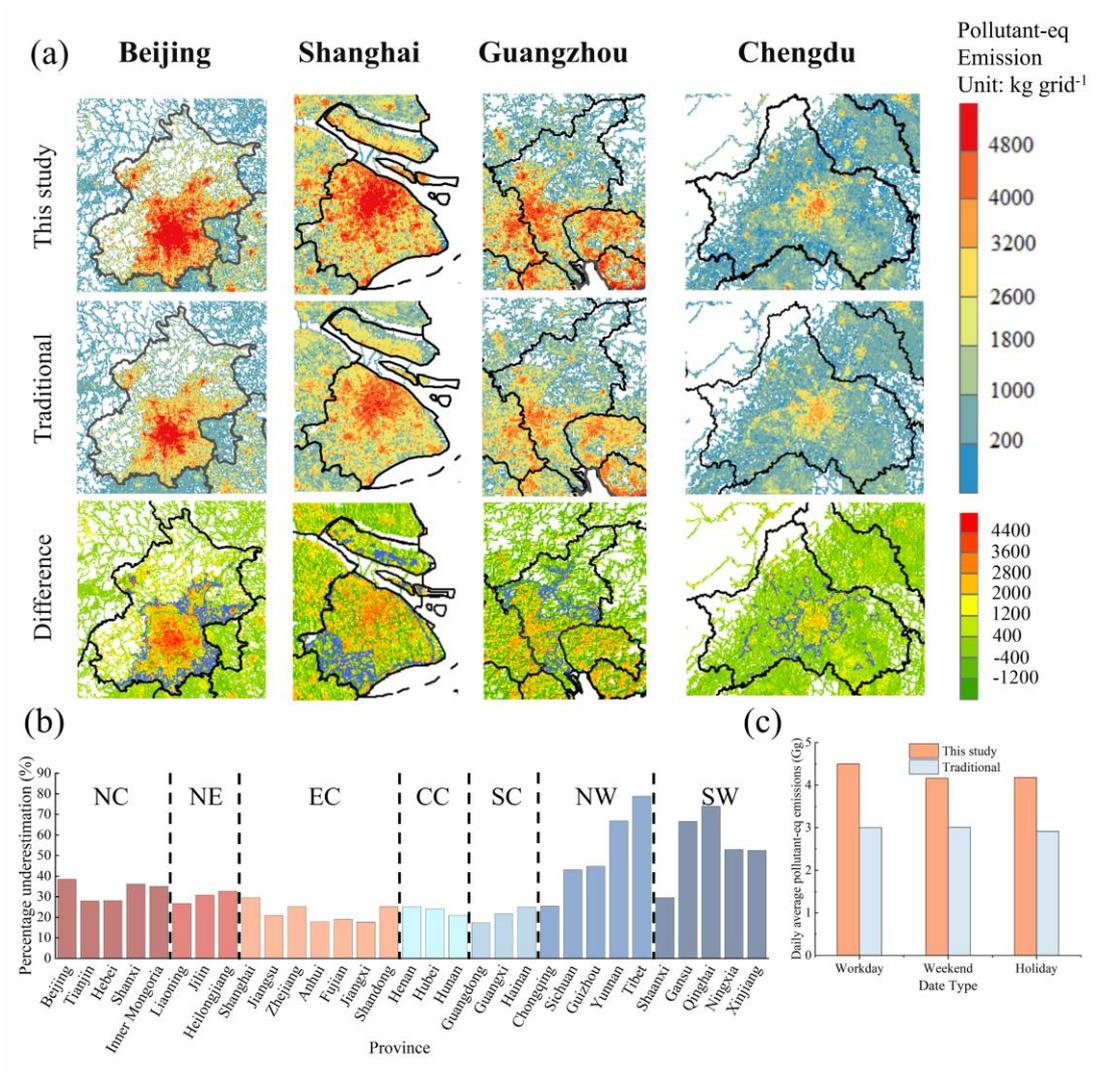
Figure 7. Comparison of this study with traditional algorithms: (a) Beijing, Shanghai, Guangzhou to compare it with the results of the present study (Difference = This Study － Traditional); (b) Comparison of daily average results across (c) four seasons and (d)three date type; The percentage of underestimation for each province calculated with the traditional method. The purple boundary in (a) is the Urban Growth Boundary (UGB).

Minor:

Line 95: please use consistent representation of the units, km per year, and g km^{-1}"

Response: Corrected.

Line 110: please include the year.

Response: Corrected.

Line 135: congestion delay index (λ)

Response: Corrected.

References mentioned in this response:

China Mobile Source Environmental Management Annual Report, Ministry of Ecology and Environment of the People's Republic of China, 2025.

Choudhary, A., Gokhale, S.: Urban real-world driving traffic emissions during interruption and

congestion, Transport. Res. D-Tr., 43: 59-70, doi:10.1016/j.trd.2015.12.006, 2016.

Dey, S., Caulfield, B., & Ghosh, B.: Modelling uncertainty of vehicular emissions inventory: A case study of Ireland. J. Clean. Prod., 213, 1115-1126, doi: 10.1016/j.jclepro.2018.12.125, 2019.

Ding, J., Ren, C., Wang, J., Feng, Z., & Cao, S. J.: Spatial and temporal urban air pollution patterns based on limited data of monitoring stations, J. Clean. Prod., 434, 140359, doi:10.1016/j.jclepro.2023.140359, 2024.

Latini, G., Passerini, G., and Tascini, S.: Roundabouts and traffic emissions at crossroads, WIT Trans. Ecol. Environ., 84, doi:10.2495/SPD050912, 2026.

Li, S., Wang, S., Wu, Q., Zhang, Y., Ouyang, D., Zheng, H., Han, L., Qiu, X., Wen, Y., Liu, M., Jiang, Y., Yin, D., Liu, K., Zhao, B., Zhang, S., Wu, Y., and Hao, J.: Emission trends of air pollutants and CO_2 in China from 2005 to 2021, Earth Syst. Sci. Data., 15, 2279-2294, doi:10.5194/essd-15-2279-2023, 2023a.

Liang, X., Zhang, S., Wu, Y., Xing, J., He, X., Zhang, K. M., Wang, S. and Hao, J.: Air quality and health benefits from fleet electrification in China, Nat. Sustain., 2(10), 962-971, doi:10.1038/s41893-019-0398-8, 2019.

Liu, P., Wu, Y., Li, Z., Lv, Z., Zhang, J., Liu, Y., Song，A., Wang, T., Wu, L., Mao, H., and Peng, J.: Tailpipe volatile organic compounds (VOCs) emissions from Chinese gasoline vehicles under different vehicle standards, fuel types, and driving conditions, Atmos. Environ. 323, 120348, doi:10.1016/j.atmosenv.2024.120348, 2024.

Wang, H., Wen, Y., Wu, J., Cai, R., Shen, Y., Deng, C., Li, Y., Li, Y., Wu, H., Huang, D., Cheng, H., Yan, C., Gao, J., Zheng, M., Liu, Y., Kulmala, M., Mao, F., Smith, J. N., Zhang, S., Hao, J., Li, X.,and Jiang, J.: Accelerated reduction of atmospheric ultrafine particles since China VI vehicle emission standards, Npj Clim. Atmos. Sci, 9(55), doi: 10.1038/s41612-026-01327-6, 2026.

Wen, Y., Zhang, S., Zhang, J., Bao, S., Wu, X., Yang, D., and Wu, Y.: Mapping dynamic road emissions for a megacity by using open-access traffic congestion index data, Appl. Energ., 260, doi:10.1016/j.apenergy.2019.114357, 2020.

Wu, H., Tang, X., Wang, Z., Wu, L., Lu, M., Wei, L., & Zhu, J.: Probabilistic automatic outlier detection for surface air quality measurements from the China national environmental monitoring network, Adv. Atmos. Sci., 35(12), 1522–1532, doi:10.1007/s00376-018-8067-9, 2018.

Yang, L., Shen, Q., and Li, Z.: Comparing travel mode and trip chain choices between holidays and weekdays, Transport. Res. A-Pol., 91, 273-285, doi:10.1016/j.tra.2016.07.001, 2016.

Zhu, X. H., He, H. D., Lu, K. F., Peng, Z. R., & Gao, H. O.: Characterizing carbon emissions from China V and China VI gasoline vehicles based on portable emission measurement systems, J. Clean. Prod., 378, 134458, doi:10.1016/j.jclepro.2022.134458, 2022.

Zhao, J., Tang, Y., Zhu, X., & Zhu, J.: National environmental monitoring and local enforcement strategies, Nat. Cities, 2(1), 58-69, doi:10.1038/s44284-024-00173-y, 2025.

Zhang, J., Peng, J., Song, A., Lv, Z., Tong, H., Du, Z., Guo, J., Wu, L., Wang, T., Hallquist, M., and Mao, H.: Marked impacts of transient conditions on potential secondary organic aerosol production during rapid oxidation of gasoline exhausts, npj Clim. Atmos. Sci. 6, doi:10.1038/s41612-023-00385-4, 2023a.