Reviewer(s)' Comments to Author:

Reviewer: 2

The manuscript by Xu et al. presents a new global NMVOC emission inventory, the MEIC-global-NMVOC database, which offers a valuable data source for atmospheric chemistry modeling and policymaking. This work is important as it provides a very detailed representation of NMVOC-emission-related technologies and their impacts on emission changes, addressing a gap in most previous global-scale studies. The authors also conducted comprehensive comparisons across multiple emission inventories, elucidating key differences. The manuscript is well-written, with high-quality figures and thorough analysis. I recommend it for publication in *Atmospheric Chemistry and Physics*, pending minor revisions.

Response: We thank the Referee for the positive and accurate summary of our work and for the fair and thoughtful comments below. We've made a number of revisions in response, and believe the manuscript has been improved. A point to point response is presented below.

Introduction

1. I suggest that the authors cite several relevant previous studies on NMVOC emission inventories to provide better context for their work. For example:

Bo, Y., Cai, H., & Xie, S. D. (2008). Spatial and temporal variation of historical anthropogenic NMVOCs emission inventories in China. *Atmospheric Chemistry and Physics*, *8*(23), 7297-7316.

Sharma, S., Goel, A., Gupta, D., Kumar, A., Mishra, A., Kundu, S., ... & Klimont, Z. (2015). Emission inventory of non-methane volatile organic compounds from anthropogenic sources in India. *Atmospheric Environment*, *102*, 209-219.

Zhao, Y., Mao, P., Zhou, Y., Yang, Y., Zhang, J., Wang, S., ... & Li, W. (2017). Improved provincial emission inventory and speciation profiles of anthropogenic non-methane volatile organic compounds: a case study for Jiangsu, China. *Atmospheric Chemistry and Physics*, *17*(12), 7733-7756.

Li, M., Kurokawa, J., Zhang, Q., Woo, J. H., Morikawa, T., Chatani, S., ... & McDonald, B. C. (2024). MIXv2: a long-term mosaic emission inventory for Asia (2010–2017). *Atmospheric Chemistry and Physics*, *24*(7), 3925-3952.

Response: We thank the Referee for the constructive suggestion. The studies suggested by the Referee have been added in the manuscript as shown below.

"…and larger gaps can be found for major emitters and specific sectors (Bo et al., 2008; Li et al., 2019; Sharma et al., 2015; Zhao et al., 2017; Kurokawa and Ohara, 2020; Li et al., 2024), highlighting the large uncertainties in current NMVOC emission estimates."

2. Line 38: When discussing the impacts of NMVOC emissions on air quality and health, it would be better to cite and discuss some recent studies. For example:

Xiong, Y., Du, K., & Huang, Y. (2024). One-third of global population at cancer risk due to elevated volatile organic compounds levels. *npj Climate and Atmospheric Science*, *7*(1), 54.

Qin, M., She, Y., Wang, M., Wang, H., Chang, Y., Tan, Z., ... & Hu, J. (2025). Increased urban ozone in heatwaves due to temperature-induced emissions of anthropogenic volatile organic compounds. *Nature Geoscience*, 1-7.

Partha, D. B., Xiong, Y., Prime, N., Smith, S. J., & Huang, Y. (2025). Long-term impacts of global solid biofuel emissions on ambient air quality and human health for 2000–2019. *GeoHealth*, *9*(3), e2024GH001130.

Response: We thank the Referee for the constructive suggestion. The recent studies suggested by the Referee have been cited and discussed in the manuscript as shown below.

"Thus, NMVOC have substantial global impacts on air quality, climate, and human health (Fry et al., 2014; Laurent and Hauschild, 2014; Li et al., 2019; Xiong et al., 2024; Partha et al., 2025). Previous studies have demonstrated that mitigating anthropogenic NMVOC emissions is the key to controlling O_3 and fine particulate matter ($PM_{2.5}$) pollution, as well as addressing other negative effects in various regions (West et al., 2007; Fry et al., 2014; Sharma et al., 2016; Hendriks et al., 2016; Li et al., 2019; Qin et al., 2025)."

3. Line 57: "also contribute to divergent emission estimates" would be better.

Response: We thank the Referee for the constructive suggestion. The sentence has been revised as suggested.

4. Line 66: The authors mentioned "their validation with observations", but this issue is not addressed in their work. I recommend the authors to revise this statement to avoid potential confusion.

Response: We thank the Referee for the thoughtful comment. We have revised the sentence as below to avoid potential confusion.

"Third, comparisons among global NMVOC emission inventories are limited, which hinders understanding of their discrepancies and underlying causes."

Methods and data

1. Line 110: I think the square brackets in equation (1) should be parentheses?

Response: We thank the Referee for the detailed suggestion. We have revised the equation as below.

$$E_i = \sum_j \sum_k \left[A_{i,j,k} \times \left(\sum_m X_{i,j,k,m} \times EF_{i,j,k,m} \right) \right] \quad (1)$$

2. Line 178: In section 2.2, 228 countries are defined. Why are there only 208 countries here?

Response: We thank the Referee for the thoughtful question. The activity rates for energy consumption are available for 208 countries, consistent with the country coverage of energy-related data sources such as the International Energy Agency (IEA), as illustrated in our previous work on MEIC-global-CO_2 emission inventory (Xu et al., 2024). However, the population data used as the activity rates for certain non-energy-related sources (e.g., domestic solvent use) include an additional 20 small countries/territories. Therefore, the total number of countries/territories included in this study is 228. We have clarified this point in Section 2.2 as below.

"MEIC-global-NMVOC includes 228 countries/territories, an extension from the 208 countries/territories in the MEIC-global-CO_2 inventory (Xu et al., 2024). The additional 20 countries are included because the population data used as the activity rates of a few solvent-consuming sources cover more small countries than the energy statistics used in MEIC-global-CO_2."

References:

Xu, R., Tong, D., Xiao, Q., Qin, X., Chen, C., Yan, L., Cheng, J., Cui, C., Hu, H., Liu, W., Yan, X., Wang, H., Liu, X., Geng, G., Lei, Y., Guan, D., He, K. and Zhang, Q.: MEIC-global-CO_2: A new global CO_2 emission inventory with highly-resolved source category and sub-country information, Sci. China Earth Sci., 67, 450-465, 2024.

3. Line 190: I am curious about what "primary solid biofuel" includes. Are wood, crop residue, or other types of solid fuels distinguished here? If not, please clarify it.

Response: We thank the Referee for the thoughtful question. Primary solid biofuels refer to any plant- or waste-based materials used directly as fuel, including firewood, crop residues, animal waste, sawdust, and other solid biofuels. Due to limitations in data availability, this study does not distinguish between different types of primary solid biofuels; instead, they are used collectively as a single category. We have clarified it in Section 2.4.2 as follows.

"It should be noted that different types of primary solid biofuels—such as wood, crop residues, and animal waste—were not distinguished in this study."

4. Line 234-237: Some references should be supplemented about the impacts of different factors on vehicle emission factors.

Response: We thank the Referee for the constructive suggestion. The references have been supplemented as shown below.

"For start and evaporation modes, the effects of ambient temperature were considered in the calculation, as higher temperatures lead to more NMVOC evaporation (Kourtidis et al., 1999; Rubin et al., 2006), while lower temperatures increase start-mode emission factors due to longer time required for the catalyst to reach operating conditions (Singer et al., 1999; Reiter and Kockelman, 2016). For running emissions, vehicle deterioration was considered, which results in increased emission factors as cumulative mileage rises (Chiang et al., 2008; Borken-Kleefeld and Chen, 2015)."

References:

Kourtidis, K. A., Ziomas, I. C., Rappenglueck, B., Proyou, A., and Balis, D.: Evaporative traffic hydrocarbon emissions, traffic CO and speciated HC traffic emissions from the city of Athens, Atmos. Environ., 33(23), 3831-3842, 1999.

Rubin, J. I., Kean, A. J., Harley, R. A., Millet, D. B., and Goldstein, A. H.: Temperature dependence of volatile organic compound evaporative emissions from motor vehicles, J. Geophys. Res. Atmos., 111(D3), 2006.

Singer, B. C., Kirchstetter, T. W., Harley, R. A., Kendall, G. R., and Hesson, J. M.: A fuel-based approach to estimating motor vehicle cold-start emissions, J. Air Waste Manage. Assoc., 49(2), 125-135, 1999.

Reiter, M. S., and Kockelman, K. M.: The problem of cold starts: A closer look at mobile source emissions levels, Transp. Res. D: Transp. Environ., 43, 123-132, 2016.

Chiang, H. L., Tsai, J. H., Yao, Y. C., and Ho, W. Y.: Deterioration of gasoline vehicle emissions and effectiveness of tune-up for high-polluted vehicles, Transp. Res. D: Transp. Environ., 13(1), 47-53, 2008.

Borken-Kleefeld, J., and Chen, Y.: New emission deterioration rates for gasoline cars–Results from long-term measurements, Atmos. Environ., 101, 58-64, 2015.

5. Line 365: I think a Table can be added in SI to show the waterborne paint proportions within different application purposes. This would be helpful to other research on solvent use emissions.

Response: We thank the Referee for the constructive suggestion. A supplementary Table (i.e., Table S12) has been added in SI to show the waterborne paint proportions within each application purpose in 1970, 1990, 2010, and 2020.

6. There are a few minor grammatical issues. For instance, "besting performing" in Line 194 appears to be a typo. I recommend the authors carefully proofread the manuscript to correct such errors.

Response: We thank the Referee for the constructive comment. We have carefully proofread the manuscript and corrected the grammatical errors.

Results

1. Line 443: Abbreviations such as “PVC” should be spelled out in full when they first appear in the text, as not all readers, particularly those without a background in the chemical industry, may be familiar with such terms.

Response: We thank the Referee for the helpful comment. The full names have been provided in the manuscript as shown below.

“Production of a few types of plastics—polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), high-density polyethylene (HDPE), and low-density polyethylene (LDPE)—accounted for a large portion of NMVOC emissions (i.e., 58% and 76% of emissions from organic chemicals in 1970 and 2020).”

2. Line 448: I think “mitigation priorities” would be better.

Response: We thank the Referee for the constructive suggestion. The sentence has been revised as suggested.

3. Line 465-485: Add some references to support the analysis, especially when explaining the reasons of emission changes, as some information is not directly reflected in the work.

Response: We thank the Referee for the constructive suggestion. The relevant references have been added to support the analysis of emission changes.

References:

Geng, G., Liu, Y., Liu, Y., Liu, S., Cheng, J., Yan, L., Wu, N., Hu, H., Tong, D. Zheng, B., Yin, Z., He, K., and Zhang, Q.: Efficacy of China’s clean air actions to tackle $PM_{2.5}$ pollution between 2013 and 2020, Nat. Geosci., 17(10), 987-994, 2024.

Baidya, S., and Borken-Kleefeld, J.: Atmospheric emissions from road transportation in India, Energy Policy, 37(10), 3812-3822, 2009.

Saundry, P. D.: Review of the United States energy system in transition, Energy Sustain. Soc., 9(1), 4, 2019.

Pandey, A., and Venkataraman, C.: Estimating emissions from the Indian transport sector with on-road fleet composition and traffic volume, Atmos. Environ., 98, 123-133, 2014.

McDonald, B. C., Goldstein, A. H., and Harley, R. A.: Long-term trends in California mobile source emissions and ambient concentrations of black carbon and organic aerosol, Environ. Sci. Technol., 49(8), 5178-5188, 2015.

Plant, G., Kort, E. A., Brandt, A. R., Chen, Y., Fordice, G., Gorchov Negron, A. M., Schwietzke, S., Smith, M., and Zavala-Araiza, D.: Inefficient and unlit natural gas flares both emit large quantities of methane, Science, 377(6614), 1566-1571, 2022.

Tran, H., Polka, E., Buonocore, J. J., Roy, A., Trask, B., Hull, H., and Arunachalam, S.: Air quality and health impacts of onshore oil and gas flaring and venting activities estimated using refined satellite-based emissions, GeoHealth, 8(3), e2023GH000938, 2024.

Wu, W., Fu, T. M., Arnold, S. R., Spracklen, D. V., Zhang, A., Tao, W., Wang, X., Hou, Y., Mo, J., Chen, J., Li, Y., Feng, X., Lin, H., Huang, Z., Zheng, J., Shen, H., Zhu, L., Wang, C., Ye, J., and Yang, X. Temperature-dependent evaporative anthropogenic VOC emissions significantly exacerbate regional ozone pollution, Environ. Sci. Technol., 58(12), 5430-5441, 2024.

Klimont, Z., Amann, M., & Cofala, J.: Estimating costs for controlling emissions of volatile organic compounds (VOC) from stationary sources in Europe, https://pure.iiasa.ac.at/id/eprint/6195/, 2000.

4. I think "biofuel" would be better than "biomass" in the context.

Response: We thank the Referee for the constructive suggestion. The word "biomass" has been replaced with "biofuel" in the manuscript.

5. Line 562-563: While the authors discuss the case of India, similar emission characteristics and challenges are also prevalent in other developing regions, such as Africa. It is recommended that the authors add some short discussion to better reflect the urgent need for emission mitigation efforts across these regions.

Response: We thank the Referee for the thoughtful suggestion. A short discussion has been added as below.

"Similar patterns were observed in other developing regions, such as Africa and Latin America, reflecting the urgent need to initiate and enhance NMVOC emission control through targeted policy implementation and technological advancement."

Discussions

1. Line 592: Some research also claimed that agriculture could be an important source of NMVOC emissions (e.g., Hobbs et al., 2004). Some discussions would be appreciated.

Hobbs, P. J., Webb, J., Mottram, T. T., Grant, B., & Misselbrook, T. M. (2004). Emissions of volatile organic compounds originating from UK livestock agriculture. *Journal of the Science of Food and Agriculture*, *84*(11), 1414-1420.

Response: We thank the Referee for the constructive suggestion. The discussion has been revised as below.

"A few minor sources, such as waste treatment and agriculture (Sharma et al., 2019; Hobbs et al., 2004), are also not included."

2. Some activity rates are filled or modeled by statistical approaches, which introduces uncertainties. This should be mentioned in the limitation part.

Response: We thank the Referee for the helpful comment. The discussion on the limitation of activity rates has been added as below.

"Secondly, part of the activity rates are reconstructed by statistical models, which introduces additional uncertainties and should be better constrained as higher-quality data are available in the future."

3. In this work, NMVOC emissions are not speciated. This should be discussed and expected to be an important step in the future.

Response: We thank the Referee for the helpful comment. The discussion on NMVOC emission speciation has been added as below.

"Finally, NMVOC emission speciation is not included in this study, but will be addressed in future work to provide species-resolved emissions and model-ready emissions for different chemical mechanisms."