Response to Editor

Manuscript ID: egusphere-2025-5605

Title: Technical Note: Rapid assessment of drivers and air quality effects of regional daily changes in air pollutant emissions based on near-real-time techniques.

Authors: Chen Gu, Yutong Wang, Yuan Ji, Lei Zhang, Shuanzhu Sun, Yuandong Bian, Zimeng Zhang, Jiewen Zhu, Wenxin Zhao, Sheng Zhong, and Yu Zhao*

Dear editor,

We sincerely appreciate the editor's recognition of our manuscript and the suggestions provided. These suggestions have helped us enhance the clarity, depth and format of the paper. We have carefully addressed each comment point-by-point as below, and all corresponding modifications have been highlighted in the revised manuscript. Please note that the line numbers mentioned following refer to the clean version of the revised manuscript, unless specifically noted.

Specific Comments:

1. Please change the title to "Rapid assessment of drivers and air quality effects of regional daily changes in air pollutant emissions based on near-real-time techniques". In addition, this manuscript is more like a technical note, instead of an ordinary research article. Maybe the authors can change the title to "Technical Note: Rapid assessment of drivers and air quality effects of regional daily changes in air pollutant emissions based on near-real-time techniques".

Response: Thank you for your suggestion regarding the title of our manuscript. We have revised the title as suggested to "Technical Note: Rapid assessment of drivers and air quality effects of regional daily changes in air pollutant emissions based on near-real-time techniques".

2. The abstract and Conclusion are well written in general (By the way, please change

"Conclusion remarks" (line 905) to "Conclusions" or "Concluding remarks"). The authors are encouraged to further improve these two sections, according to ACP guidelines for the title, abstract, and concluding section:

https://www.atmospheric-chemistry-and-physics.net/policies/guidelines_for_authors.html

Response: Thank you for the editor's suggestions. Firstly, we have revised the section title in Part 4 of the revised manuscript to "Concluding remarks." Secondly, regarding the editor's suggestions on the abstract and conclusion sections, we have revised each section in accordance with the requirements of the ACP journal.

Modifications in Lines 28-50 and lines 906-980 of the revised manuscript:

ABSTRACT

"Fast and timely estimation of air pollutant emissions is critical for understanding the complex sources of air pollution and supporting air quality improvement, while current emission inventory was commonly reported with time lag or coarse temporal resolution. Here we developed a near-real-time approach that calculates the daily emissions of anthropogenic air pollutants, and applied this approach for Jiangsu province, a typical developed region in eastern China. We estimated that the annual total anthropogenic emissions of SO_2, NO_X, primary fine particles ($PM_{2.5}$), non-methane volatile organic compounds (NMVOCs), and NH_3 were 246, 727, 298, 1186, and 377 Gg, respectively, for Jiangsu in 2022. Compared to available national emission inventory (MEIC), application of the provincial-level daily emission estimates provided better model performance of $PM_{2.5}$ and ozone (O_3) simulation for all seasons (represented by January, April, July and October). The NO_X, SO_2, $PM_{2.5}$, and NMVOCs emissions in Jiangsu during April-May 2022 (the period of COVID-19 lockdown in Shanghai) were respectively 8%, 6%, 6%, and 10% smaller than those in the same period of 2023. Transportation and Industry respectively contributed 89% of NO_X emission reduction and 93% of NMVOCs reduction. Combining with machine learning, moreover, we revealed that the changing agricultural NH_3 emissions dominated the variability of daily $PM_{2.5}$ concentration, and that off-road transportation contributed substantially to variabilities of both $PM_{2.5}$ and O_3 levels. The study proved advantages of incorporation of near-real-time data and

machine learning techniques on tracking the fast-changing emissions and detecting the sources of varying air quality."

4. Concluding remarks

In this study, we incorporated near-real-time activity data from multiple sources and developed a framework for continuously estimating the daily air pollutant emissions of anthropogenic origin. We then estimated the spatiotemporal evolution of emissions in Jiangsu Province, a typical developed area in eastern China, with a particular focus on the period during the COVID-19 lockdown in 2022 and the corresponding period after the lifting of restrictions in 2023. Finally, we constructed a rapid assessment approach that utilized machine learning algorithms to quantify the impact of fast changing emissions on variability of daily ambient concentrations of $PM_{2.5}$ and O_3.

We indicated that emission controls have played a crucial role in abatement of air pollutant emissions. The provincial emissions of SO_2, NO_X, $PM_{2.5}$, NMVOCs, and NH_3 decreased 17%, 33%, 18%, 7%, and 11%, respectively, from 2019 to 2022. Implementation of ultra-low emission retrofits for industrial sectors has proven effective in reducing primary $PM_{2.5}$ and NO_X emissions. However, there is an urgent need to enhance NMVOCs emission control in key industrial sectors and areas. Regarding the temporal variabilities, the emissions of SO_2 and $PM_{2.5}$ were influenced greatly by fossil fuel consumption pattern, while NO_X emissions were increasingly dominated by that of transportation. The NMVOCs emissions peaked in the summer and declined in winter, followed by a rebound in emissions after the Chinese New Year. Comparative analysis showed that the emissions of NO_X, SO_2, $PM_{2.5}$, and NMVOCs in Jiangsu during the COVID-19 lockdown of Shanghai in April-May 2022 were respectively 8%, 6%, 6%, and 10% smaller than those in the same months of 2023. Transportation was identified as the primary contributors to the reductions in NO_X and $PM_{2.5}$ emissions, while industry accounted for 93% of the reduction in NMVOCs, closely associated with the disrupted cross-regional product supply chains. Indicated by the contributions of changing emissions from pollutant-sector combinations to the variability of $PM_{2.5}$ and O_3 concentrations, reducing agricultural NH_3 emissions should be critical for $PM_{2.5}$ pollution alleviation, and off-road transportation has become a priority target for coordinating control of both $PM_{2.5}$ and O_3 pollution.

The near-real-time techniques and estimation of daily-level emissions offer substantial practical implications for current air quality management in China. Specifically, it can be directly integrated into the "Emergency Response for Reducing Heavy Pollution Weather" program. By providing the near-real-time feedback on emission variations, policy makers can reasonably determine the short-term emission reduction measures and timely evaluate their actual effectiveness (e.g., temporary suspension of specific industrial or traffic restrictions). Furthermore, combined with machine learning techniques, this framework allows policy makers to decouple the environmental benefits of long-term policies of air quality improvement from short-term emergency controls or unexpected socioeconomic shocks (like the COVID-19 lockdown). The obtained knowledge provides a scientific basis for formulating more cost-effective and reasonable strategies for coordinating the $PM_{2.5}$ and O_3 pollution controls.

Furthermore, the framework could be potentially applied for predicting future emission as it establishes a dynamic linkage between sector-specific activity factors and emissions. By adjusting these activity factors (such as the penetration of electric vehicles, the abatement of industrial production during haze events, and targeted reductions in agricultural activities), researchers and policy-makers could fast and reasonably project the emissions of diverse future scenarios. Coupled with the rapid assessment approach with machine learning, the framework presents a promising pathway to quantify how the emission changes might affect the daily variability of air quality, thereby better supporting the policy design and adjustment for regional complex pollution controls.

The limitations of this work exist mainly in the near-real-time information of multiple sources and the rapid assessment of air quality variability. For instance, CEMS were only applied for big point sources, thus we had to assume that the small and fugitive sources followed similar variability of emissions as point sources. As CEMS only covers SO_2, NO_X, and particles, the use of electricity consumption data for NMVOCs may introduce substantial uncertainty. Future improvement in online monitoring of NMVOCs will enhance the estimation of temporal variation of emissions. While our research framework demonstrates robust performance in Jiangsu Province, its heavy reliance on CEMS and provincial traffic monitors poses a limitation for its transferability to less developed regions or other developing countries without sufficient data support. To adapt this methodology for those regions, future applications could be expanded to other datasets with global accessibility. For instance, satellite-derived tropospheric NO_2 columns, daily nighttime light fluctuations, and generalized mobile phone signaling data could serve as alternative proxies to estimate the activity levels and their temporal profiles. Expanding this framework to incorporate such multi-source remote sensing data will be more crucial for establishing near-real-time emission inventories in regions with less data support. Moreover, the machine learning process ignored the contributions from regional transport, which could result in some bias in analyzing the impacts of anthropogenic emissions on air quality. However, in contrast to time-consuming numerical modeling, machine learning offered a rapid and reliable assessment of the impact of daily emission changes on air quality, and was thus recommended in future policy making of air pollution controls.