Response to editors: Rimal Abeed et al. (2025)
https://doi.org/10.5194/egusphere-2025-3329

Article title: NO_x emissions changes from 2019 to 2021 in Eastern China as estimated through variational inversions and TROPOMI satellite data

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- In black are the comments of the reviewer
- In blue are our answers

Reviewer #2:

This article presents analysis on NOx emission changes from Eastern China during 2019 to 2021, highlighting the drop of emissions due to the COVID lockdown and the Chinese New Year. **The article is well organized but unfortunately I couldn't see much new features** or points in this work compared to existing works. Substantial revisions should be undertaken before the reconsidering of this paper for publication on ACP. Here are my specific comments:

Comment 1: the spatial resolution of the model is **coarse**, and when you discuss the NO_x emissions from cities like Beijing or Shanghai, it would induce large uncertainties since there may be only 2 a 3 grid cells covered by the city. **I recommend either you improve the spatial resolution of your estimation or you avoid to discuss emissions on such small domains.**

The number of grid cells for the two cities that were displayed in Figure 5 and discussed in section 3.1 was 8 for Beijing and 2 for Shanghai (Figure R2.1).

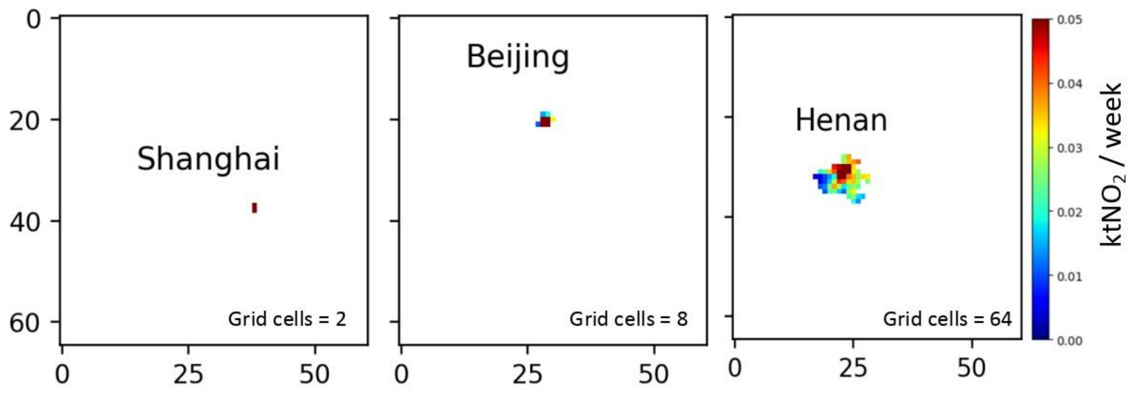

Figure R2.1. We show Shanghai, Beijing, and Henan, as represented on the domain of study; with the number of grid cells shown on each plot. The emissions are for the first week following the LNY.

Following this comment, we acknowledge that Shanghai may not have been sufficiently resolved in space (raising uncertainties in the diagnostics for such a city), therefore, **we replaced it (in Figure 5) by the province of Henan, covered by 64 grid cells**. However, in order to cover such a large area (101.75-132.25°E; 17.75-50.25°N) with a resolution equal to that of the chemistry transport model (CHIMERE, 0.25°), and using a variational inversion system, it is currently difficult to achieve resolutions lower than 0.5°. Moreover, one does not find in the literature equivalent examples lower this scale and resolution. As illustrated by the surface area of Beijing, this resolution is nonetheless sufficient to analyze the budget over major cities and provinces. It is accepted in the literature to show emissions per province at a resolution of 0.5°, for instance Hui Li et al. (2024) show emissions per province in China, using a Mass-Balance method, at a resolution of 0.5°×0.625°.

Comment 2: You discuss the total NOx emissions from anthropogenic and biogenic sources in Eastern China, and compare them between different years, but I recommend you to discuss the **anthropogenic and biogenic sources separately**. And I also recommend you to expand your study to **more years** to discuss the change in biogenic emissions due to the **meteorological factors**. We can only institute emission control on anthropogenic sources and the features in biogenic emissions may have some implications on the policies.

Separating the anthropogenic and the biogenic emissions will not change much in our current interpretations. In the supplementary material (Figure S7, shown below), we show the biogenic and anthropogenic emissions separated. As we can see from these figures, anthropogenic emissions are highly dominant, with the biogenic emissions varying between 0.2 and 4% only in this domain, and therefore total emissions are largely representative of the anthropogenic emissions rather than the biogenic. **However, the inverse modeling framework that we are using separates the anthropogenic and the biogenic emissions**. It also assumes that biogenic emissions are negligible throughout the year compared to the anthropogenic ones (Figure S7).

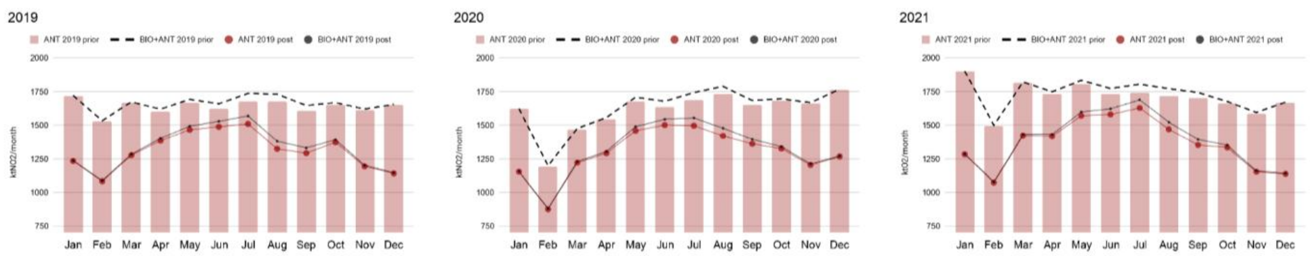

Figure S7. Anthropogenic (red) and total (black) NOx emissions for Eastern China, for 2019 to 2021 (left to right). The red bars represent the monthly prior anthropogenic emissions, the dotted black lines refer to the prior total emissions, the solid red lines refer to the anthropogenic posterior emissions, and the black solid lines refer to the total posterior emissions.

Our set-up of the prior estimate of the biogenic emissions, and of the prior relative uncertainty in this estimate, both limit our ability to increase it by a very large amount, while, based on the results we obtain, we assume that the actual biogenic emissions are significant in spring summer and that a large part of these emissions is erroneously aggregated to the anthropogenic emissions by the inverse modeling system during these seasons. This is mainly the point of our discussion in section 3.3 and in Figure 9. We thus have two options: 1) to analyze in section 3 (Results) the retrieved anthropogenic emissions before discussing our assumption, in section 3.3, that it actually includes erroneously a significant part of biogenic emission in spring-summer, or 2) to state from the beginning that the separation between the anthropogenic and biogenic emissions is not robust enough, and that we should restrain ourselves to analyze anthropogenic + biogenic emissions before discussing what can be said about the inter-annual variations of the anthropogenic emissions, based on the temporal and spatial patterns of the resulting fluxes. Hence, we prefer to stick to the second option, which is the one that is presented in the current version of the article. With this said, we did consider your comment about separating the anthropogenic and the biogenic emissions in the analysis, and **we added to Figure 9 a second panel showing the anthropogenic emissions (Figure 9a).** We also edited the discussion of this Figure to better explain the peak in summer from the anthropogenic emissions. We show Figure 9 (a-b) below and the discussion that follows.

Moreover, extending the analysis and discussion to more years, and studying the effect of the meteorological factors on the biogenic emissions is out of the scope for this study; that aims to look at the changes of NO_x emissions duing COVID-19 and the Lunar New Year in Eastern China, as derived from variational inversions using the CIF inversion model (coupled to CHIMERE chemistry Transport model).

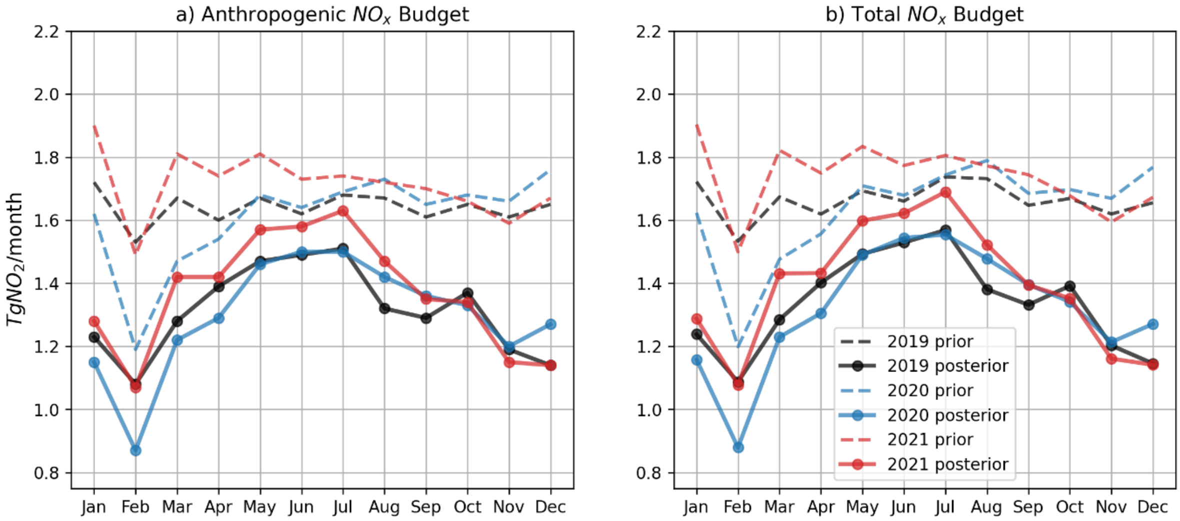

Figure 1. Times series of the monthly prior (in dashed lines) and posterior (in solid lines) for the anthropogenic (a) and total (b, anthropogenic + biogenic) NO_x budgets over Eastern China for the years 2019 (black), 2020 (blue) and 2021 (red), expressed in Tg equivalent NO_2 per month.

*"In contrast with the prior estimate of the emissions (**Section 2.2**), the posterior estimates show an annual maximum systematically occurring in July (Figure 9). The peak in summer agrees with the Daily Emissions Constraint by Satellite Observations (DECSO) emissions estimated from inversions assimilating OMI satellite observations (Ding et al., 2015). It suggests that the biogenic emissions may be underestimated in our prior estimates of the NO_x emissions over Eastern China, hence the absence of the peak in the prior estimates during summer; the peak in August 2020 appearing mostly because of the reduction in emissions in winter. This suggestion would be in line with the study of Visser et al. (2019), showing a strong underestimation of the NO_x biogenic emissions from MEGAN in summer over Europe by a factor of 5. However, it is important to note that our system is emphasizing the correction of the anthropogenic estimates instead of the biogenic ones due to two main reasons: 1) the biogenic emissions estimates being significantly lower than the anthropogenic estimates in the prior, and 2) the current parametrization of the biogenic emissions the prior relative uncertainty being too low. This can result in higher anthropogenic emissions during spring and summer. While keeping this in mind, we can also explain the peak in summer from anthropogenic emissions (Figure 9a) by the increased electricity consumption during hot weather and the resulting power load, as Zhang et al. (2009) shows that electricity consumption and rising temperatures are correlated."*

References:

Li, H., Zheng, B., Lei, Y., Hauglustaine, D., Chen, C., Lin, X., Zhang, Y., Zhang, Q., & He, K. (2024). Trends and drivers of anthropogenic NOx emissions in China since 2020. *Environmental Science and Ecotechnology*, *21*, 100425. https://doi.org/10.1016/J.ESE.2024.100425