We would like to thank the reviewer for the comments and suggestions to our manuscript. In the following, we answer to the reviewer's comments and indicate the changes in the manuscript that were implemented according to the recommendations. The comments are in black. Our answers are in blue.

Referee #1:

General comments

The manuscript presents results of a multiyear inverse modeling study estimating fossil CO_2 emissions using observations in the Paris region. The ability to estimate annual emissions with errors under 10% is a major advance presented in the paper. The paper is well-written and can be accepted after minor revision. One notable deficiency is lack of an inverse model description, suggest adding a section outlining the method.

Response:

We thank the referee for the positive comments on our manuscript. We have added <Section 2.4 Inversion configuration> together with Figure S4 and Table S1 in the revised manuscript to better clarify and summarize the atmospheric inverse modeling system used in this study.

Detailed comments

Page 1 Line 30 Suggest giving an uncertainty range to estimated 5.2% trend (seems to be in order of ±6% based on change of 32.6±2.2 $MtCO_2$ in 2020 to 34.3±2.3 $MtCO_2$ in 2021)

Response:

We have added an uncertainty range in both the abstract and section 3.3, respectively.

"Then, annual emissions increased by 5.2%±14.2% from 32.6±2.2 $MtCO_2$ in 2020 to 34.3±2.3 $MtCO_2$ in 2021."

"The inverse annual emissions in 2021 rose by about 5.2%±14.2% to 34.3±2.3 $MtCO_2$ compared with 2020 (32.6±2.2 $MtCO_2$), but still remains -8.0%±12.6% compared with the pre-COVID-19 level in 2019 (37.3±2.6 $MtCO_2$)."

P2 L18 Need to check if the references are most recent for Boston (Northeast corridor), and also for Los Angeles. Can mention dense NIST network around Washington DC.

Response:

Many top-down studies have used measurements of greenhouse gas mole fractions in an inverse modeling approach to estimate long-term (> 1 year) urban emissions. These studies have not only focused on CO_2 emissions as mentioned in the manuscript, but have also examined CH_4 emissions, such as the case of Los Angeles and Washington DC-Baltimore (Yadav et al., 2023; Karion et al., 2022). These investigations utilized observational data from various sources, including ground-based monitoring stations, aircraft measurements (e.g., Pitt et al., 2022), satellite (e.g., Lei et al., 2021) and more. We thus have refined the sentence to narrow down the scope and cited references that are more closely aligned with the statement. The modified text is as follows:

"To our knowledge, few estimates of city GHG emissions have been published when based on long-term tower-based measurements and atmospheric inversion systems. These include studies covering a period over one to five years for the cities of Paris, Boston, Indianapolis and Los Angeles (Staufer et al., 2016; Sargent et al., 2018; Lauvaux et al. 2020; Yadav et al., 2023)."

Meanwhile, as suggested, we have identified some more recent papers that are now cited as follows:

"The scientific capabilities evolve rapidly with increasing model performances (Deng et al.,

2017) and the deployment of dense networks in cities, e.g., Washington DC-Baltimore Metropolitan Areas (Karion et al., 2020), San Francisco Bay Area (Turner et al., 2020), Los Angeles (Yadav et al., 2021), Indianapolis (Davis et al., 2017), Paris, Munich and Zurich (https://www.icos-cp.eu/projects/icos-cities)."

P5 L17 Suggest giving readers more detail about the method used in Lian et al 2022, when reporting the revisions, that would save readers effort and help them understand the full merit of both this and the previous study. Also, need to give somewhere a summary of key points of the inversion approach, like, using station-to-station concentration gradients as "observations", control state, wind speed filters, horizontal resolution, PBL height filters, etc.

Response:

This suggestion is well taken. We have added section 2.4 in the revised manuscript to describe key points of the inversion approach, including 1) the setup of the control vectors, 2) the selection of the assimilated downwind-upwind CO_2 observation gradients (Figure S4), 3) the reference inversion setup and the sensitivity tests (Table S1), 4) two minor revisions compared to the configurations used in Lian et al. (2022).

P8 L10, L15 Better give 2% and 3% per year trend numbers with uncertainties like 2±X%.

Response:

Linear regression was conducted on the posterior emission data to derive a trend line for each inversion sensitivity test. Subsequently, the average trend and uncertainty were computed by considering all ten trend lines. We have added an uncertainty range for the 2% decrease trend in emissions from 2016 to 2021.

"Our results indicate a decreasing trend in the annual CO_2 emissions over the IdF region with an amplitude of ~2%±0.6% per year at 5% level of significance."

We have added an uncertainty range for the 3% decrease in emissions.

"the posterior emissions exhibit an emission change by about -3%±13.8% over the IdF region when comparing the year 2016 with 2018."

Technical corrections

P2 L10 Better write "inversion" instead of "atmospheric inversion" when citing Tarantola 2005.

Response:

Corrected.

P4 L4 For ODIAC, a more popular reference could be Oda et al ESSD 2018

Response:

Corrected.

P9 L12 Remove extra digits in text: diagnostic phenology41

Response:

Corrected.

Reference:

Lei, R., Feng, S., Danjou, A., Broquet, G., Wu, D., Lin, J. C., O'Dell, C. W., and Lauvaux, T.: Fossil fuel CO_2 emissions over metropolitan areas from space: A multi-model analysis of OCO-2 data over Lahore, Pakistan, Remote Sens. Environ., 264, 112625, https://doi.org/10.1016/j.rse.2021.112625, 2021.

Karion, A., Ghosh, S., Lopez-Coto, I., Mueller, K., Whetstone, J. R., & Pitt, J. R. Seasonal and Inter-annual Variability in Methane Emissions in Washington, DC and Baltimore, MD, USA. In AGU Fall Meeting Abstracts (Vol. 2022, pp. A42L-04), December 2022.

Pitt, J. R., Lopez-Coto, I., Hajny, K. D., Tomlin, J., Kaeser, R., Jayarathne, T., Stirm, B. H., Floerchinger, C. R., Loughner, C. P., Gately, C. K., Hutyra, L. R., Gurney, K. R., Roest, G. S., Liang, J., Gourdji, S., Karion, A., Whetstone, J. R., and Shepson, P. B.: New York City greenhouse gas emissions estimated with inverse modeling of aircraft measurements, Elementa: Science of the Anthropocene, 10, https://doi.org/10.1525/elementa.2021.00082, 00082, 2022.

Yadav, V., Verhulst, K., Duren, R., Thorpe, A., Kim, J., Keeling, R., ... & Whetstone, J.:. A declining trend of methane emissions in the Los Angeles basin from 2015 to 2020. Environmental Research Letters, 18(3), 034004, 2023.