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Atmospheric Measurement Techniques Discussions

Interactive comment on "Quantifying CO_2 emissions of a city with the Copernicus Anthropogenic CO_2 Monitoring satellite mission" *by* Gerrit Kuhlmann et al.

Anonymous Referee #1

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The manuscript by Kuhlmann et al., entitled "Quantifying CO2 emissions of a city with the Copernicus anthropogenic CO2 monitoring satellite mission", attempts to evaluate the potential of a future satellite mission to constrain CO2 emissions from a city. I have major questions about the two methods used to estimate emissions and therefore propose the paper be reconsidered after major revisions.

The two methods included in the paper for emission estimation are an analytical inversion method and a mass-balance approach. The two methods are set up as a dichotomy and characterized as "encompassing the range between optimistic and pessimistic assumptions regarding the capability of atmospheric transport models". How-

ever, the optimistic nature of the inversion method is highly contrived. For instance, the inversion assumes perfect knowledge of atmospheric transport and the background CO2 field (Eq. 1). Why do the authors not introduce transport errors of difference magnitudes to the inversion and examine the impacts on the retrieved emissions? Furthermore, estimation of the background CO2 is a key methodological challenge in top-down urban emission quantification. The "y_BG" field used in Eq. 1 is a simulated quantity that cannot be observed in the real-world. Assuming y_BG is the "true" background CO2 field, how, then, would the atmospheric inversion attempt to derive this background CO2, and how would the resulting background error affect the atmospheric inversion? I would like to see both the transport and background error analyses incorporated into the atmospheric inversion.

The second, mass-balance method is referred to as "pessimistic". But I believe that it can also be viewed as optimistic since the assumed transport appears to be highly simplified, assuming simple averaging of wind vectors. However, my main criticism of the mass-balance method as it is presented the lack of clarity in its description. After re-reading Sect. 3.2 multiple times, I still have problems visualizing and understanding the methodology adopted by the authors. For instance, what does the "vertical control surface" look like? How is Fig. 1 relevant for the methodology? Probably what is lacking is a cartoon (perhaps in 3D) that describes the method visually, to help the reader grasp the relevant variables and geometry of the method. Also, I suggest that the authors consider using an actual case with a field of satellite-"observed" XCO2 such as shown in Fig. 4a within a figure like Fig. 1. Otherwise Fig. 1 is too abstract and removed from its actual application.

Finally, the authors did not consider diurnal variations in CO2 emissions; just the seasonal pattern. Given the 11:30LT satellite overpass and systematic sampling of midday CO2 distributions, what would be the potential sampling bias? This seems like a major omission. I strongly urge the authors include the diurnal sampling bias into the analyses.

With the aforementioned issues with the methodology, I reserve evaluation of the results and conclusions for a revised manuscript, when the issues have been addressed.

OTHER POINTS: Page 9: The “CO2-weighted wind vector” is used in the mass balance method. Shouldn’t the wind vector also be weighted by air density as well and not just CO2 concentrations?

Figure 2b/d: What is meant by the numbers at the top of the panel: e.g., “60/74”, “60/70”, “59/73”? Should be explained in the figure caption.

Page 12: “rare opportunities for observing plumes in winter”. Should explain why the wintertime opportunities are rare. Is this because of the solar zenith angle and ground snow cover?

Fig. 4a: A better color scale is needed. The plumes in Berlin are hardly visible. Another colorscale to be considered is to range from dark blue (negative) to dark red (positive), with gray in the middle, like in Fig. 10c. Also, the pixels appear quite noisy, with sign reversals from pixel to pixel. Why?

Fig. 4b: Is this the emissions represented on the y-axis from the entire city of Berlin? Clarify

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