

Interactive comment on “Observing carbon dioxide emissions over China’s cities with the Orbiting Carbon Observatory-2” by Bo Zheng et al.

Anonymous Referee #2

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The study by Zheng et al. uses the complete XCO₂ data record available from the OCO-2 satellite instrument to estimate the CO₂ emissions of 60 individual sources (cities, power plants, industrial areas) in China, accounting for almost one fifth of China’s total CO₂ emissions. Several previous studies showed the potential of OCO-2 to detect and quantify strong point sources, but those studies were demonstrations rather than systematic analyses of OCO-2’s ability to quantify regional emissions as presented here. The study by Zheng et al. is thus an important step forward. The applied methods are thorough and convincing. I particularly appreciated the conservative and careful selection of cases, for which emission quantification was safely possible. The results of the study nicely demonstrate the potential but also the great challenges offered by spaceborne CO₂ observations for emission quantification.

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Emissions were estimated in the same way as in previous studies, i.e. by computing the integral amount of CO₂ in cross-sections through the plume multiplied by the wind component perpendicular to these cross-sections. However, there are novel elements that go beyond previous studies, notably the combination of a detailed emission inventory for China with a Gaussian plume approach where sources (e.g. cities) are not treated as individual plumes but as superpositions of multiple plumes emanating from individual area and point sources. Although the information from these super-positioned plumes was not used directly for plume quantification, it was used to attribute the plumes to specific emission sources, which was a critical step in the selection of suitable cases.

Overall, the paper is very well written and an important contribution to the growing literature on the quantitative interpretation of OCO-2 observations. I thus support publication after addressing the following points.

Main points:

- The title of the manuscript suggests that the study is about emissions of cities. However, the 60 plumes are not only from cities but also from "industrial regions". The authors should state explicitly how many of these plumes were representing emissions from cities, power plants and industrial complexes. This is important information for the planning of future satellite missions, since it is still not clear how well plumes from cities can be observed in comparison to those from power plants.
- The choice of a maximum distance of 50 km (page 4, line 100) between sources and OCO-2 track seems rather arbitrary. How does this choice affect the results? 50 km seems a rather short distance. More distant sources could contribute to the plumes and bias the corresponding estimates. The model-based study of Kuhlmann et al. (<https://doi.org/10.5194/amt-12-6695-2019>), for example, demonstrated that the plume of a power plant (Jänschwalde) 100 km away from a city (Berlin) could significantly overlap with the city plume in some cases.

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- According to Bieser et al. (<https://doi.org/10.1016/j.envpol.2011.04.030>), roughly 90% of emissions from power plants occur between 200 m and 500 m above surface. How would emission estimates for power plants change using an average wind speed over this range rather than an average over 0 – 500 m (page 6, line 176)? Note that at the small distances between source and OCO-2 track considered in this study one cannot expect a homogeneous mixing of the plume over the depth of the PBL.

Minor points and grammar:

- Page 1, line 18: Change "from the detailed China's emission inventory" to "from China's detailed emission inventory"
- P2, L34: "with the footprints" → "with footprints"
- P2, L35: "natural CO2 budget" → "natural CO2 budgets"
- P2, L36: "has allowed the initial insight" → "has provided initial insight"
- P2, L46: "spaceborne CO2 observation" → "spaceborne CO2 observations"
- P3, L64: "relies on the information about the wind" → "relies on auxiliary information about winds"
- P3, L66: "provides the location" → "provides the locations"
- P3, L75: "satellite sampling of OCO-2 capability" → "sampling capability of OCO-2"
- P3, L77: "centered at the locations" → "centered on the locations"
- P3, L86: Why should several XCO2 anomalies belong to the same CO2 plume? There is only a single transect per plume. Because of the moving windows?
- P4, L91: "8 footprints if no is missing" → "8 footprints if none is missing"
- P4, L93: "within CO2 plume" → "within the plume"
- P4, L104: Only a detail: Why is the along-wind distance measured in kilometres, but

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the across-wind distance in meters?

- P5, L136: I think it would be clearer to state "We find 49,322 cases with local XCO₂ enhancements". It wasn't clear to me initially whether these were individual pixels or plumes.

- P5, L144: 50 km is not an appropriate scale for synoptic transport. I suggest to simplify to ".. or transport of CO₂ over a longer distance"

- P5, L148: "in space to make it difficult" -> "in space making it difficult"

- P6, L153: It would be better to write "Although the total number of selected cases is small, it is several times larger .."

- P6, L163: "at about local 13:30" -> "at about 13:30 local time"

- P6, L164: "part of OCO-2 ground track" -> "part of the OCO-2 ground track"

- P6, L175: "CO₂ fluxes" -> "CO₂ flux"

- P6, L178: Why shifted by 1°? Maybe it would be clearer to state "shifted by 1° in this case".

- P7, L186: How was the uncertainty of the hourly emission rate of Qinhuangdao determined? Does the MEIC inventory include uncertainties?

- P7, L194: There were 4 cases where the same source was quantified twice. It would be good to know how consistent those double quantifications are with the estimated uncertainty of <24%.

- P7, L203ff: The interpretation of the small differences of 5-6% between satellite based estimates and MEIC in different seasons is pushed too far in this section considering the uncertainties. At least the arguments should be presented as possible explanations rather than as facts (e.g. write "could be due to" rather than "are due to"). The over-interpretation of the results culminates in the statement that human respiration

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accounts for 38% of the (5.5%) difference and that the remaining difference could be due to a bias in MEIC. The numbers deduced from the satellite observations are not sufficiently robust to speculate about a bias in the inventory as small as 3 percent. Uncertainties in the method (notably the assumption that the 0-500 m average wind speed is representative) could easily explain such differences, probably also differences in the results between summer and winter since vertical mixing is different in these seasons.

- P8, L233: "principle, not all" -> "principle, but not all"
- P8, L235: "densely urban areas" -> "densely populated urban areas"
- P8, L44: The last section should be renamed to "Conclusions".
- P9, L271: "with less CO2 inventory infrastructures" -> "with less advanced CO2 inventory infrastructures"
- Figure 1: The blue bar should be called "XCO2 anomalies" rather than "XCO2 outliers"

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