Referee #1:

General comments.

The manuscript reports good progress in quantifying multiple megacity emissions of CO_2 in China using a plume transport model and CO_2 observations by OCO-2 satellite. The mean estimate of the emissions from selected megacity areas is comparable with inventory data. The manuscript is well written and can be recommended for publication after minor revisions, taking into the account the following comments:

Response:

We thank the referee for the positive comments on our manuscript.

Detailed comments.

Line 42 As for instrument noise (not retrieval noise) it may be better to use a number in the order of 0.3 - 0.6 ppm as in (Worden et al., 2017)

Response:

This sentence has been rewritten as "an instrument noise typically around 0.3–0.6 ppm (Worden et al., 2017)".

Line 49 Authors write "To our knowledge, no attempt has been made yet to infer anthropogenic emissions from actual satellite data over a large area or a long period to evaluate a large-scale CO_2 budget." Suggest being more specific here and write as "actual OCO-2 data", otherwise, when speaking about satellites, there is a study by Janardanan et al., (2016) using several years of CO_2 data for assessing emissions from large regions. Also adding somewhere reference to Kort et al., 2012 is useful from historical context.

Response:

We now use the expression "actual OCO-2 data" and have added the reference to Kort et al. (2012).

Line 176 "The ceiling height of 500 m is comparable to the maximum height that smoke plumes from power plants and industrial plants typically reach." The assumption seems to be weak, as turbulent mixing is supposed to mix CO_2 up to PBL top, exceeding 500 m in many occasions. The practical choice of using a mean wind vector below 500 m may be driven by other reasons.

Response:

To quantify cross-sectional CO_2 fluxes, we need to know the horizontal wind direction and wind speed at the CO_2 plume height (Nassar et al., 2017). For a power plant, Nassar et al. (2017) used the wind vector at the stack height. Since this study focuses on cities that have emission sources with various stack heights, we used the average wind below 500 m following Beirle et al. (2011).

Line 222 More informative reference to ODIAC is given by Oda et al., (2018)

Response:

We have added the reference to Oda et al. (2018) in the revised manuscript.

Line 267 For CO2-M there is a recent mission paper by Janssens-Maenhout et al. (2020)

Response:

We have added the reference to Janssens-Maenhout et al. (2020).

Line 210 Summertime uptake by green spaces in a city should not be used as an explanation here as vegetation uptake is also present in the background used as reference for estimating enhancements.

Response:

The XCO_2 enhancement tends to be lower in summer than in winter (Mitchell et al., 2018) due to the photosynthetic uptake by plants. This phenomenon makes $FFCO_2$ signal not easily separated from the surrounding background, which could partly explain the slight underestimates in the $FFCO_2$ fluxes from OCO-2 XCO_2 retrievals in summer. We have clarified it in the manuscript.

Line 235 There is an impression that there is a 200-300% disagreement between MEIC and other inventories in cities, and it is caused by misplacing industrial emissions. There are other factors apart from placing industrial emissions. ODIAC is using a simple disaggregation of emissions by using nightlights, which may lead to underestimation of road emissions, as found by Gateley and Hutyra (2017), so it is supposed to be missing some emissions in cites still it was found by Gateley and Hutyra (2017) to correlate well with the detailed inventory at 5 km resolution. EDGAR inventory is not supposed to suffer from misplacing industrial emissions to the same extent as ODIAC thus there should be another reason for disagreement. A reader would benefit from providing more details on scale and reason for discrepancies between the inventories in the target areas.

Response:

We provide a brief discussion on the discrepancies between MEIC and other inventories as follows.

"The large discrepancies are not surprising since global emission inventories typically involve large uncertainties at city scales (Gately and Hutyra, 2017; Gurney et al., 2019), because they disaggregate national emissions to gridded maps with simple proxies like population or nighttime light in the countries like China where they lack detailed direct local information. Only large power plants have exact geographic locations (from the CARMA global database (Wheeler and Ummel, 2008)), in principle, not all of the industrial plants like MEIC. The ODIAC uses nightlights to disaggregate national emission estimates to grid cells, which may lead to an underestimation of road emissions in cities (Gately and Hutyra, 2017) and a misplacing of industrial emissions. The EDGAR relies on point source locations to allocate emissions in space while it still suffers from missing local information in China, and gridded population maps have to be used instead. Such an emission mapping approach overestimates emissions over densely populated cities in China (Zheng et al., 2017), because the industry plants, the primary CO_2 emission sources in China, are located far away from densely urban areas. The MEIC inventory estimates industrial emissions at the facility scale, transport emissions at the county scale, and residential emissions at the provincial scale, which can achieve better spatial accuracy in emissions estimates than the global emission inventories."

References

Beirle, S., Boersma, K. F., Platt, U., Lawrence, M. G., and Wagner, T.: Megacity Emissions and Lifetimes of Nitrogen Oxides Probed from Space, Science, 333, 1737-1739, doi: 10.1126/science.1207824, 2011.

Mitchell, L. E., Lin, J. C., Bowling, D. R., Pataki, D. E., Strong, C., Schauer, A. J., Bares, R., Bush, S. E., Stephens, B. B., Mendoza, D., Mallia, D., Holland, L., Gurney, K. R., and Ehleringer, J. R.: Long-term urban carbon dioxide observations reveal spatial and temporal dynamics related to urban characteristics and growth, Proc. Natl. Acad. Sci., 115, 2912-2917, doi: 10.1073/pnas.1702393115, 2018.

Nassar, R., Hill, T. G., McLinden, C. A., Wunch, D., Jones, D. B. A., and Crisp, D.: Quantifying CO_2 Emissions From Individual Power Plants From Space, Geophys. Res. Lett., 44, 10,045-010,053, doi: 10.1002/2017gl074702, 2017.

References

Janardanan, R., Maksyutov, S., Oda, T., Saito, M., Kaiser, J. W., Ganshin, A., Stohl, A., Matsunaga, T., Yoshida, Y., and Yokota, T.: Comparing GOSAT observations of localized CO_2 enhancements by large emitters with inventory-based estimates, Geophys. Res. Lett., 43, 3486-3493, doi:10.1002/2016GL067843, 2016.

Janssens-Maenhout, G., B. Pinty, M. Dowell, H. Zunker, E. Andersson, et al: Towards an operational anthropogenic CO2 emissions monitoring and verification support capacity. Bull. Amer. Meteor. Soc., https://doi.org/10.1175/BAMS-D-19-0017.1, 2020.

Kort, E. A., Frankenberg, C., Miller, C. E., and Oda, T.: Space-based observations of megacity carbon dioxide, Geophys. Res. Lett., 39, L17806, doi:10.1029/2012GL052738., 2012.

Oda, T., Maksyutov, S., and Andres, R. J.: The Open-source Data Inventory for Anthropogenic CO_2, version 2016 (ODIAC2016): a global monthly fossil fuel CO_2 gridded emissions data product for tracer transport simulations and surface flux inversions, Earth Syst. Sci. Data, 10, 87–107, https://doi.org/10.5194/essd-10-87-2018, 2018.

Worden, J. R., Doran, G., Kulawik, S., Eldering, A., Crisp, D., Frankenberg, C., O'Dell, C., and Bowman, K.: Evaluation and attribution of OCO-2 XCO_2 uncertainties, Atmos. Meas. Tech., 10, 2759–2771, https://doi.org/10.5194/amt-10-2759-2017, 2017.