Comment on acp-2022-474
Anonymous Referee #1

Referee comment on "Estimating Enhancement Ratios of Nitrogen Dioxide, Carbon Monoxide, and Carbon Dioxide using Satellite Observations" by Cameron G. MacDonald et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-474-RC1, 2022

The authors present an interesting work merging retrievals from several satellites to investigate enhancement ratios of CO\textsubscript{2}, CO, and NO\textsubscript{2} from a large number of cities around the world. The methodology used to calculate the enhancement ratio appears robust, building off work previously presented in the literature, and applied to newer satellite datasets. Given the growing access to greenhouse gas measurements from space, I find the work an important study as the scientific community strives to find the appropriate analyses and interpretations to deploy with such global measurements.

The manuscript is generally well written and appropriate references are included throughout, however, I find the overall presentation of the work could be improved in the areas described below.

- The methodology section would benefit greatly from the inclusion of more figures to illustrate the various steps of the analysis and aid the reader’s understanding. I find this particularly important since several satellite products are used, each with distinct spatial coverage and overall data handling. For example, the differences in spatial coverage between the various satellite are not shown, nor is the colocaiton of OCO-2 and TROPOMI/OCO-3 SAM data (section 3.1), or the masking that results from taking only using data from the sparser production (section 3.3.3). Similarly, the plume extraction presented in section 3.2 is not shown, nor is the impact of smoothing on the TROPOMI/OCO-3 data (section 3.3.1). At a minimum, a figure showing the different spatial sampling of the three satellites should be included.
- There appear to be two distinct methods used for the enhancement calculation depending on which product is used in the analysis; a cross section taken downwind of the city (OCO) and the enhancement over the entire bounding area for the city (TROPOMI). The manuscript jumps around between these various methods, which is difficult to follow. I suggest clarifying the these two complementary methods within the text or with some sort of figure summarizing the methods.
More specific comments are below:

- Representativeness of enhancement ratios – Due to a limited number of overpasses (e.g. 1 for Toronto), how representative do you think some of these ratios are to the timescale of the inventories? I believe a brief discussion concerning this is warranted since the number of overpasses per city varies, while it appears conclusions about the validity of inventories are drawn from all cities regardless of the number of overpasses used in the ratio calculation.
- Do you expect the biosphere to impact your CO\textsubscript{2} or CO enhancements, and subsequently your ratios?
- Lines 191-194 – How are the secondary sources identified?
- Lines 194-199 – What explains the discrepancy between the MERRA-2 winds and the plume direction, and the resulting variability in overpass retention rates? Is it errors in the wind direction and/or issues with the automatic filtering scheme since manual inspection and correction is required?
- Figure 1 – How are the red points assigned to the city? Without more information or geographical details about the city and location of the overpass, it is hard to interpret.
- Line 273 – What is allowed to change in the bootstrap? Are the anomalies of each species within each overpass resampled?
- Lines 284-285 – “As we are correcting the enhancement ratios, the effect of dispersion cancels out in the ratio.” This sentence is unclear to me. What dispersion?
- Figure 2 – The color scale in the ‘Background’ plot is hard to interpret using the color bar. I understand this the same color bar as the observed data which has a larger spread of values, but I cannot tell if it is all one value for the background or not. This might be an issue with my screen, but it is something to think about.
- Figure 4 & Section 3.4 – It was not until I saw Figure 4 that I realized that a single regression is calculated for all anomalies across multiple days. I would suggest explicitly stating this in the text since, in contrast, Figures 1 & 2 are for single days. In this analysis, are the number of anomaly data points that same for each overpass? If not, is there potential for a subset of overpasses with higher density of data (i.e. more points) to drive the combined regression?
- Figure 5-7 – The number of overpasses that each measurement ratio is based upon should be included in the figure. It seems that this information is at least partially available in the appendix, so another option would be to include a reference to those tables in the caption.
- Figure 5 – I cannot see where the “light blue areas” are on top of the measured ratios. I see black error bars, so perhaps this is a typo.
- Lines 355-358 – Is the comparison for cities both in this work and Lama et al. shown anywhere, in something like a figure or table? If not, I believe this should be added, possibly to the appendix. If this comparison is buried into one of the figures, a reference to it should be added to the text.
- In the introduction, you mention the TIMES scaling of CO\textsubscript{2} by Nassar et al. Do you apply those scale factors to account for the diurnal variability of CO\textsubscript{2}, since your measurements are based on afternoon overpasses? You mention this correction (the magnitude of which is not included) in section 5.2 for LA and Indianapolis, however, it is not clear if these corrections are applied to the ratios shown in Figures 5 &6.
- Lines 425-429 – You present the NO\textsubscript{2} emission estimates based on ratios with and without the NO\textsubscript{2} lifetime correction. The reader should not assume the un-corrected emission rate is accurate, right? If this is the case, I would suggest you state that because as written it is not clear which value for NO\textsubscript{2} is the one the reader should remember.
- Line 455 – underestimations of which species?
- Table 2 – What metric is used to discriminate a “poor” linear relationship? Low
correlation coefficient, low R?
- Tables 2, 3 – You should include how many TROPOMI overpasses are used to generate the NO$_2$:CO enhancement ratios for each city.