Response to referee comments on "Satellite quantification of oil and natural gas methane emissions in the US and Canada including contributions from individual basins"

We thank the two referees for their careful reading of the manuscript and the valuable comments. This document is organized as follows: the Referee's comments are in *italic*, our responses are in plain text, and all the revisions in the manuscript are shown in blue. **Blue text** here denotes text written in direct response to the Referee's comments. The line numbers in this document refer to the updated **WORD** manuscript **with tracked changes**.

Referee 1

In this paper, the authors use a high-resolution (~ 25 km) inverse modeling to estimate methane emissions from individual oil and natural gas (O/G) basins in the US and Canada based on 22-month satellite observations from TROPOMI. The authors compared their results with wildly-used "bottom-up" emission inventories and other "top-down" emissions. The authors also evaluated the uncertainties from the model and observations. The topic of the paper fits the scope of ACP, and it provides a way to quantify the O/G methane emissions. It is recommended to publish after the authors address the following aspects.

General comments:

1, Do the numbers of samplings in different seasons affect the estimated posterior emissions? The observations in the winter, especially over Canada, are limited because of the snow and high solar zenith angle. Did the authors evaluate the influence of uneven sampling in different seasons?

Response. Thanks. We have a new supplementary figure to show the posterior correction factors from using TROPOMI data in different seasons.

Line 385. We also calculated posterior emissions from the O/G sector using TROPOMI observations in different seasons. Overall, the spatial distributions of posterior correction factors in spring, summer and autumn are consistent with that using the year-round data, especially in the south where TROPOMI observation density is high (Fig. S2). The posterior corrections from using wintertime data are slightly different in Canada and Northeastern US because of the low observation density and low averaging kernel sensitivities (Figure S14).

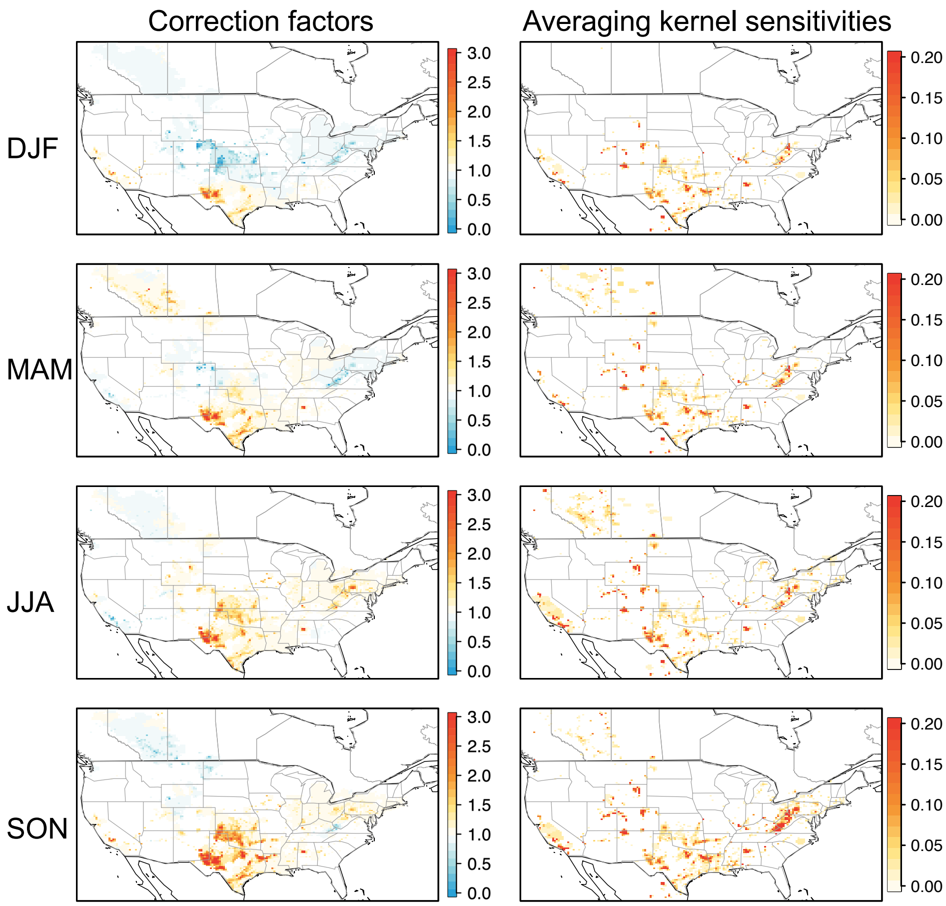

Figure S14. Posterior correction factors relative to the prior inventory and averaging kernel sensitivities using TROPOMI data in different seasons.

2, New infrastructures could also contribute to an increase in CH4 emissions (e.g., in Permian Basin). These new sources, however, are not reported in a priori emission inventories. Besides, scaling a priori emissions to a certain year could not solve this problem, either. How did the authors deal with these "missing" emissions? Whether the model can correctly locate these emissions that are not in the emissions inventory?

Response. Thanks for pointing this out. We have already considered new sources using the Enverus DrillingInfo database.

Line 101. We extrapolated the US emissions for the O/G production sector to 2018 based on upstream well data in the Enverus DrillingInfo database (Enverus DrillingInfo, 2020) together with EPA national totals for O/G production, gas processing, transmission, and distribution (EPA, 2020)

3, Line 221 to 258: About the discussion over Canada, the authors argue that the lower emission than other "top-down" inventories is possibly due to a decreasing trend of O/G emissions after

2014 in Canada. It is quite tricky to argue in this way. The estimation in this paper is still 40% higher than that of ECCC-reported emissions (ECCC, 2020) and EDGAR v6. If the authors want to draw this conclusion, the authors should first prove both "top-down" inventories and "bottom-up" inventories catch the same trend but only show differences in absolute values.

Response. This is a good point. We have removed this argument to make our narrative more accurate.

Line 297. ~~This could be due to a decreasing trend of O/G emissions after 2014 in Canada, as reported by both the bottom-up national inventory (ECCC, 2020) and inversion studies (Lu et al., 2021b), and reflecting the ongoing regulations efforts following Canada's commitment to reduce O/G methane emissions by 40-45% by 2025 relative to the 2012 level (ECCC, 2017).~~

4, The section 3 has a lot of repetitive content with the method section. Please combine them and reorganize the structure of the paper.

Response. We have removed the 2nd and 3rd paragraphs in the old manuscript and combine these contents with the Methods

5, Line 310: I doubt the argument here. First, the number of observations of TROPOMI is limited by the retrieval over water. Many offshore oil/gas sources (e.g., the Middle East) are difficult to be resolved. Second, as shown in Fig S17, many places in the world have no data even with a 22-month recording.

Response. We now soften the arguments here. We deleted the argument that it can be used to effectively assess global O/G emissions. Now we say

Line 450. As seen from Fig. S19, our inversion framework can constrain the posterior O/G emissions with an uncertainty <30% in areas with O/G emission rates > 0.2-0.5 Tg a^{-1} and the number of observations is higher than $5x10^3$ a^{-1}. Our result suggests that TROPOMI can be useful in assessing large area sources with emissions exceeding 0.2-0.5 Tg a^{-1} and observation counts exceeding 5000 a^{-1}.

Specific comments:

1, Line 49 and 56: Please check the format of the two references of Lu et al.

Response. We have updated the reference. Thanks.

2, Line 64: Please give the definition of the blended albedo or refer to the relevant reference.

Response. Now we say

Line 88. The blended albedo is a weighted difference of near-infrared (NIR) and SWIR albedos to filter scenes covered by snow(Wunch et al., 2011).

3, Line 121: The projects of Fig. S5 and S6 seem to be distorted. Please use right projections.

Response. We have updated Figure S6. Please check.

4, Line 122: "gridcells" should be "grid cells". Please correct all of them in the paper.

Response. Corrected throughout the text.

5, Line 126-127: How about the new sources? Although the emissions from bottom-up inventory can be scaled to the later years, the locations won't change, which means the new sources are not included.

Response. We have already considered the new sources using the Enverus DrillingInfo database when we scale the inventory to the year 2018.

Line 100. We extrapolated the US emissions for the O/G production sector to 2018 based on upstream well data in the Enverus DrillingInfo database (Enverus DrillingInfo, 2020) together with EPA national totals for O/G production, gas processing, transmission, and distribution (EPA, 2020)

6, Line 182: Please specify if the authors used XCH4 with the surface correction. According to Figure 1, the authors also should clarify here that XCH4 has been corrected by the elevation.

Response. Now we say:

Line 261. The data shown in Fig. 1a are corrected for topography following Kort et al. (2014), but this correction is not used in the inverse analysis because the GEOS-Chem forward model accounts for topography

7, Line 196: "x" should be "×". Please check the paper and correct all of them.

Response. Corrected.

8, Line 215: Any explanations about the decreases?

Response. Sorry, we don't know the reason. We guess it is related to more stringent emission control in these traditional O/G basins, but we don't find evidence to support this.

9, Line 295: A typo of "areal"?

Response. Corrected.