

Atmos. Chem. Phys. Discuss., referee comment RC2  
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## Comment on acp-2020-1195

Anonymous Referee #2

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Referee comment on "Estimating 2010–2015 anthropogenic and natural methane emissions in Canada using ECCC surface and GOSAT satellite observations" by Sabour Baray et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2020-1195-RC2>, 2021

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### Overall suggestions:

I felt that the article introduction could flow better with better connection/continuity among topics. Some of the information in the introduction felt out of place (see specific suggestions below). I would think about what argument you want to make in each paragraph of the introduction and use informative topic sentences to guide the reader through each of these arguments.

It seems like background estimation was a difficult and challenging process in this study. I would consider adding a second approach to estimating the background -- either by optimizing global fluxes as part of the inverse model or by using a background constructed using atmospheric observations (instead of a model-based background). Section 3.1 of the manuscript includes a lengthy discussion of the merits of the model-based background and whether it is sufficiently accurate for the task at hand. Instead of this lengthy discussion, a second background estimate might be a better way to succinctly quantify the impacts of background uncertainties on the estimated methane fluxes.

Several sections of the manuscript are relatively long and wordy, especially section 3. In many cases, I think you could cut or condense some of the written material to yield a leaner, punchier, more concise manuscript.

I also have some concerns about the inverse modeling setup. I understand that redesigning the inverse modeling framework would require large numbers of new GEOS-Chem runs; hence, I would strongly urge the authors to revise their inverse modeling setup for future studies (even if not the current study). The inverse modeling simulations used in this study either (1) optimize the temporal distribution of fluxes assuming the spatial distribution of the prior is correct, or (2) optimize the spatial distribution of fluxes

assuming that the temporal distribution of the prior is correct. In reality, I think both the spatial and temporal distribution of the prior flux estimate could be improved through inverse modeling, and it would be ideal to design an inverse model that does both. Otherwise, I worry that errors in one could interfere your inferences about the other. Also, I think you would see higher model-data correlations in Fig. 10 if your inverse models had more flexibility to adjust both the spatial and temporal distribution of emissions. In future studies, I would also consider using nested North America GEOS-Chem runs instead of using much coarser 2 x 2.5 resolution global simulations.

### **Specific suggestions:**

The abstract is very long at about 400 words. I would consider making the abstract punchier and more concise.

Line 37 "however recent trends in": I think this phrase should be a separate sentence from the previous sentence.

Line 47 - 56: This paragraph feels out of place. It doesn't flow with the previous or subsequent paragraphs, and it is not clear how global atmospheric trends are relevant to the current study on Canada. I would consider cutting this paragraph.

Line 58: I wasn't clear how the first and second sentences of this paragraph relate to one another. I would try to find a topic sentence for this paragraph that summarizes the overall objective of this paragraph. You might want to have one paragraph about Canada's emissions inventory and another paragraph about existing studies instead of putting both topics in the same paragraph.

Line 75 "however studies have": I think this should be the beginning of a new sentence.

Line 75 "have been showing": replace with "show"

Lines 75 - 95: The information in this paragraph overlaps with the information in the previous paragraph. I would either come up with a unique topic sentence for this paragraph to differentiate this paragraph from the previous one, or I would combine the discussion of top-down studies in this paragraph with the discussion of top-down studies in the previous paragraph.

Line 105 "intercomparison": Why not use "comparison" instead?

Line 116 "mean along other GEOS-Chem prior emissions": It feels like there is a word missing here.

Line 147: Was the Chibougamau site decommissioned in 2011, or did it come back online into operation after 2015? This distinction isn't clear in the wording of line 147.

Figure 1: I believe that ECCC has several observation sites in Northwest Territories and Nunavut. Why not include those sites in the inverse model? See the list of ECCC sites shown in Fig. 2.6: [https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR\\_FULLREPORT-EN-FINAL.pdf](https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf).

Equations 1, 2, and 3: I think that vectors should be displayed in bold-italic font and matrices in bold font.

Line 235: Should the dimensions of  $K$  be  $m$  by  $n$ , given the definitions for  $m$  and  $n$  in the article?

Line 248: What are you optimizing for in the monthly inversion? Are you estimating methane fluxes from each individual model grid box in each month? If that were the case, I think the value of  $n$  here would be larger. Or are you optimizing something else?

Line 252: I wouldn't refer to a monthly inversion as "high temporal resolution". I have seen existing studies estimate daily methane fluxes in an inverse model, and numerous inverse modeling studies of CO<sub>2</sub> estimate 3-hourly fluxes.

Line 474 - 475: I disagree that there's a tradeoff between spatial resolution and temporal resolution in the inverse model. Alternative approaches would be to (1) use the GEOS-Chem adjoint in the inverse model, or (2) use a Lagrangian model like Flexpart or STILT in the inverse model. Those approaches would not necessitate a trade-off between the spatial and temporal resolution of the inverse model.

Line 582 "magnitude emissions in Canada": Is there a word missing here?