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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Analysis of atmospheric CH_4 in Canadian Arctic and estimation of the regional CH_4 fluxes" *by* Misa Ishizawa et al.

Anonymous Referee #1

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The authors have put together a really interesting paper on methane emissions from the Canadian Arctic. I think the datasets used in this study are really exciting data to work with, and I think recent monitoring efforts at Environment and Climate Change Canada could help move forward the field of high-latitude greenhouse gas fluxes. I have a few suggestions related to the paper. Most of these suggestions relate to better motivating the introduction and giving more prominence to the most important scientific results.

Overarching suggestions:

- In the intro, you explain that some of the uncertainty in greenhouse gas budgets could be due to different inverse modeling methodology. However, you use one flavor of Bayesian inverse modeling in the paper (albeit with different atmospheric models

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Discussion paper

and prior estimates). I think you could strengthen the intro by framing this discussion around uncertainties in transport and uncertainties due to the prior – topics that you actually explore in depth in the paper.

- I would be careful with the references throughout the text. In some cases, the references feel incomplete (particularly in the introduction), or you cite a reference that either did not focus primarily on that particular topic or was not the first to develop the concept.

- Most of the text in the results and discussion is dedicated to discussing more technical or methodological issues related to atmospheric transport, the inverse modeling setup, etc. I think the most interesting scientific conclusions of this paper are buried in Sect. 4.6.3 at the end of the results and discussion section. I would consider de-emphasizing some of the more methodological elements of the discussion and move the bigger science questions to a more prominent place. For example, you could pose the most important science questions at the end of the intro; that would give the reader an idea of what to expect. You could also move Sect. 4.6.3 to the beginning of the results and discussion and lengthen that section. You could also move the more methodological components of the discussion to the end and shorten that text.

Abstract:

- What provinces/territories or latitudes/longitudes do you define as the "Canadian Arctic"? That definition would help put the budget estimate in context.

- Abstract and throughout: The authors use the word "the" too often throughout the text. Some sentences would be smoother with fewer articles. For example, in line 9, "the regional CH4 flux" could be changed to "regional CH4 fluxes", and in line 10, "the recent observations" could be shortened to "recent observations." There are similar examples in most paragraphs of the manuscript.

Introduction:

- Pg. 2, lines 1-2: This sentence feels out of place. It does not summarize the content of the previous paragraph. Rather, it feels like the topic sentence of the paragraph starting in line 3.

- Pg. 2, lines 3-24: I would restructure these paragraphs. In the first two paragraphs, you state several times that methane fluxes are uncertain and only provide detail in the third paragraph. I would condense these three paragraphs into one and provide specific numbers sooner in the text.

- Pg. 2, line 25: What do you mean here by "the fluxes"? Are you referring to Arctic methane fluxes or greenhouse gas fluxes more broadly? The studies cited in this paragraph are not all methane studies. - Pg. 2, line 26: 4Dvar, Kalman filter, and geostatistical studies are all Bayesian.

- Pg. 2, lines 30-31: Can you provide references for this statement? Also, can you be more specific about how these differences have affected inverse modeling results in the past? What implications might those differences have for your study (i.e., for estimating Arctic methane)?

- Overall, the introduction includes a lot of broad, brush-stroke statements that sometimes lack specifics, and it is not always clear how these statements concretely relate to the present study. I think you could strengthen the introduction two ways: (1) provide more specific information to illustrate how uncertain or challenging these scientific questions are, and (2) Discuss why these uncertainties are particularly relevant to the present study or to understanding greenhouse gas fluxes from the Arctic.

- Pg. 3, lines 7-12: I think it would be stronger to frame this study around specific scientific questions instead of framing the study around presenting and analyzing observations.

Measurements:

- Sect. 2.2: Some of this analysis might be a better fit for a results and discussion

section than a methods section. Furthermore, it seems like the main conclusions of this paper center around the inverse modeling results. Hence, I think some of this detail could go into a supplement.

Model description

- Sect. 3 title: Can you be more specific about which model you are referring to? The atmospheric transport model, the inverse model, or both?

- Pg. 7, line 13: I think the number of days required really depends upon the size of the domain and the geographic extent of the influence footprint.

- Pg. 7, line 24: Are you referring to a "model setting" or a "model setup"?

- Sect. 3.2: I think it would be helpful to have more descriptive flux model names than "C1", "C2", and "C3".

- Sect. 3.2: Somewhere in the text, it could be useful to include a sentence that explains why you chose these three particular prior models.

- Pg. 10, lines 22-23: How did you decide on these values of sigma?

- Pg. 10, line 24: What do you mean by "not strongly dependent"? Can you be more specific?

- Eq. 2: Lin et al. 2004 did not derive this equation and are not the first ones to use it. Instead, I would cite a textbook by Rodgers, Tarantola, or Enting.

- Pg. 11, line 7: The inverse model does not necessarily need to provide a perfect constraint on every region. Many modern inverse modeling studies estimate fluxes at model grid scale, even though the observations may not constrain each model grid box. If the observations do not provide a robust constraint at a particular location or time, the inverse modeling estimate will be guided by the prior estimate and the structure of the covariance matrix D_prior.

- Pg. 11, line 15: I think it would be useful to include one sentence explaining why you process the observations in this way.

Results and discussion

- Sect. 4.1: Why do you think the footprints are different, and is there one you think is better or more robust than another?

- Sect. 4.2: I don't think this information is essential to the paper – if you're looking to trim the text at all. Presumably, this information should also be reflected in the posterior uncertainties of the inverse model.

- Pg. 13, line 1: The word "significant" is often shorthand for "statistically significant." If you used a statistical test, I would clarify here with a p-value. If not, I would pick a different word than "significant" because that word may have specific meaning to many readers.

- Sect. 4.6.1: This result seems unsurprising to me. The inverse model includes several observing stations and more observations than unknowns. As a result, the prior and the covariance matrices do not need to do much "work" in the inverse model. I suspect that one would get similar estimates using a linear regression to estimate the scaling factors.

Summary:

- The summary feels like an extended abstract. It also repeats the description of some of the methodology. You might consider changing this section to a conclusions section and instead contextualize the results, discuss the possible implications of these results, and potentially make recommendations for future monitoring efforts in the North American or Canadian Arctic.

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