

Comment on acp-2022-510

Anonymous Referee #1

Referee comment on "Why do inverse models disagree? A case study with two European CO₂ inversions" by Saqr Munassar et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2022-510-RC1>, 2022

The authors have put together a study examining the impacts of different inverse modeling setups on estimated CO₂ fluxes across Europe. I think the authors have put together a nice study that will contribute to the literature on inverse modeling and atmospheric transport uncertainties. I have a few ideas and suggestions for the authors to consider as they revise the manuscript:

Holistic suggestions:

- (1) The manuscript text has a few English grammatical issues scattered throughout. I would do a close read for grammar before uploading the revised manuscript.
- (2) The authors test out two different choices for atmospheric models (STILT and FLEXPART), two different choices for the boundary condition, and two choices for the prior uncertainty. In several cases, the choices made in each category have some similarities. For example, both STILT and FLEXPART are driven with ECMWF meteorology (albeit different ECMWF products), and the boundary condition is generated using different versions of the TM model. I suspect that the results and uncertainties in the fluxes could look quite different if the authors had made different choices. For example, the differences due to meteorology (e.g., Fig. 7) might look very different if the authors included simulations using non-ECMWF meteorology (e.g., using a product like GEOS, MERRA-2, WRF, etc.). Similarly, differences due to the background might look very different if the authors had used a different approach, like model simulations based on GEOS-Chem or an empirical boundary condition estimate like that developed by Arlyn Andrews for CarbonTracker-Lagrange. I would be careful about generalizing the results throughout the paper and/or be vigilant about bringing in results from existing studies that may have used a wider variety of products or methodological choices.
- (3) I would strongly recommend re-organizing the results and discussions sections (sections 3 and 4). I felt that these sections often duplicated information. E.g., information presented in Sect. 3 is often repeated in Sect. 4. In addition, the text sometimes hops around from topic to topic without a strong sense of direction or flow (e.g., I felt this way about Sect. 3.1 and the beginning of Sect. 3.2.).
 - (a) I would specifically re-think the purpose of sub-sections 3.1 and the beginning of

Sect. 3.2. These two sub-sections present information on a smattering of different topics, information that is often revisited or repeated later in Sects. 3 and 4. I think the authors intended to give a broad overview of the results in Sects. 3.1 and 3.2, but the resulting text felt scattered to me and lacked a direction. For example, the authors mention forward model simulations briefly at the beginning of Sect. 3.2 and then repeat similar information about the forward simulations later in Sects. 3 and 4. I would also avoid generic phrases like "large differences" or "smaller differences" when there are quantitative metrics that could be used instead.

- (b) In addition, I would make sure to use strong topic sentences at the beginning of each paragraph in Sects. 3.2.1, 3.2.2, and 3.2.3. Doing so would help give each section a stronger sense of flow and direction.
- (c) Furthermore, I thought it odd that Sect. 4 repeated each of the topics presented in Sects. 3.2.1, 3.2.2, and 3.2.3, often with duplicate information. I would merge the paragraphs of Sects. 3 and 4 that discuss similar topics (i.e., merge the separate discussions of transport in Sects. 3 and 4).

Specific suggestions:

- Line 18: "wide flux ranging between -0.72 and 0.20 PgC yr⁻¹". Can you provide any context on how large or small this range is? I.e., what do these numbers mean to someone who isn't intimately familiar with CO₂ budgets? Also, what domain are you referring to here?
- Line 25 "models themselves": Can you be more precise about what you mean here?
- Introduction: the introduction feels a bit like a laundry list of different papers, and some themes are mentioned multiple times at different points in the introduction (e.g., vertical mixing and PBL heights). There are definitely a lot of papers in the literature on atmospheric transport errors. It could be more effective to organize the different paragraphs of the introduction around specific themes. E.g., have one paragraph focused on vertical mixing, another on advection, etc.
- Introduction: What knowledge gaps are there in the existing literature that this study attempts to fill? The introduction doesn't really address this question at present; instead the authors frame this study as yet another study on top of the existing studies they mention.
- Introduction: I recommend taking a look at Karion et al. (2019, <https://acp.copernicus.org/articles/19/2561/2019/>). That study is focused on methane, not CO₂, but I think it might be relevant for the themes in the present manuscript.
- Lines 179-180: How were these model-data mismatch errors chosen?
- Line 211 "However" -- I don't think this is quite the word you want here. Maybe "With that said"
- Lines 240-245: Do you have any numbers or quantitative metrics that show the relative impacts of these different model parameters on the fluxes? At present, it's not entirely clear what kind of differences the text is referring to.
- Line 250 "quite large differences": Can you be more specific?
- Section 3.2.2: Differences in background estimates yield smaller uncertainties in the posterior fluxes relative to differences in atmospheric transport models. I wonder if that result could be due, in part, to the fact that both background estimates are generated using relatively similar models (e.g., TM3 vs TM5).
- Lines 326-332: Most of this information repeats information provided at the beginning of Sect. 3.
- Lines 332-342: This material feels like it belongs in 3.2.1. I.e., this information on atmospheric transport seems like it belongs in the sub-section on atmospheric

transport.

- Lines 349-350: This is the third or fourth location where the manuscript mentions forward runs. I would either (1) Consolidate all results/discussion of the forward runs within a single section, or (2) Divide this discussion into the sub-sections of Sect. 3 corresponding to different model parameters.
- Lines 3540-364: This text feels like it belongs in Sect. 3.2.1 with the results on atmospheric transport.
- Lines 368-370: I wasn't able to follow this sentence.
- Lines 402-425: The text feels like it belongs in Sect. 3.2.2.
- Lines 407-409: I'm not sure that I follow here. Who would apply this correction and in what circumstances?
- Lines 413-425: This text appears to repeat information in Sect. 3.2.3. I think the text in this paragraph belongs in Sect. 3.2.3.
- Figure 7: I suspect the differences due to meteorology could be much larger if using a non-ECMWF product. E.g., if using GEOS, MERRA-2, WRF, etc.