Reconciliation of observation- and inventory- based methane emissions for eight large global emitters

Referee #2

This study analyzes methane emissions and their annual variability using multiple bottom-up (BU) inventories and top-down (TD) studies for the European Union (EU) and seven additional countries with substantial emissions. The authors specifically aim to reconcile the BU and TD results by harmonizing the source sectors, and also offer insights to enhance the intercomparison between BU and TD studies. Acknowledging the significance and substantial workload involved in synthesizing a large volume of data, I believe there is considerable room to enhance the discussion, clarity, and readability of the study. Here are some suggestions

We thank Reviewer #2 for valuable suggestions and we acknowledge that the paper lacks some detailed explanations. We will improve the discussion and provide better clarity to the findings.

1.The purpose for such an "update" needs to be clearer. The authors state that "this study updates earlier syntheses (Petrescu et al., 2020, 2021, 2023) and provides a consolidated synthesis of CH4 emissions". What's the need for the update? Compared to the previous syntheses, what new focus, data, and methods have been incorporated in this update?

Previous syntheses were focused on EU28, we have updated that and expanded to major global emitters, as a first step towards building a more global CO2MVS capacity and to independently assess the progress of countries towards their climate targets. However, we agree that this can be made clearer in the introduction of the paper as well as stating the objective.

2. The article does not describe the scope of the inversion results included in the discussion. Why were only the inversion results in Table 1 included in the discussion? What were the reasons for selecting these inversion results?

We focused on systems already developed and/or included in previous projects (e.g., VERIFY) and further developed under the CoCO2 project. During the writing of this paper, we also presented published results in lieu of more recent inversions (Worden et al., 2019 and Nesser et al., 2023). We can explain this more clearly in the revision.

Existing literature contains far more TD inversion studies than those discussed in the paper, with detailed discussions of the regions of interest and providing inversion results for interannual variations.

Our goal was not to include everything what's available out there, and this choice was based on previous collaborations. We believe that the TD inversions selected for this study are also the most representative for the selected domain. We also wanted to avoid duplication of work done by other colleagues (Saunois et al., will soon submit the new updated CH4 global budget).

These existing studies highlight inconsistency between BU and TD studies for many hotspot regions, such as oil and gas methane emissions in North America, coal emissions in East Asia, and wetland emissions in Europe, North America, and Africa, yet these are not reflected in the paper's discussion. This is a significant weakness. A large portion of these existing inversion studies can be found in Jacob (2022)'s review paper.

Thank you for your suggestion. We also highlight inconsistencies and reference some of these studies. We will adapt the discussion and include the references accordingly.

3. Figure 5 and Figure 6: why the uncertainty of CTE-GCP is so large? The uncertainty of total emissions cannot be estimated as the sum of uncertainty from each sector.

The CTE uncertainty does not represent the sum of the uncertainties for each sector. The reason why they are so large can be found in the inversion and its setup, and in the way CTE calculates the uncertainties. They use an Ensemble Kalman Filter with 500 ensemble members in the optimisation, which means that they create 500 different "versions" of the prior emissions using the uncertainties assigned to them (perturbing the prior emissions by taking a random sample). The prior uncertainty is then the standard deviation of these 500 members in a given domain. The optimised result is defined as the average of the 500 members (after optimisation) and the uncertainty is its standard deviation.

The uncertainties can be quite large, depending on how one choses the prior uncertainties and how many observations there were to constrain the optimised emissions. China is a rather large region with few observation sites, similar to Brazil, Indonesia and DR Congo (those countries where CTE shows really high uncertainties in Figure 5 and 6) but if one compares the prior uncertainties with the posterior uncertainties, the optimized uncertainties have decreased.

We would indeed get more information by comparing the posterior uncertainty to the prior uncertainty. However, it still reflects the knowledge and assumptions made for the domain under study, which is an advantage of using the Ensemble Kalman Filter. Here, we show a map of observation sites constraining the inversions (we can also add this explanation to the SI, including the figure).

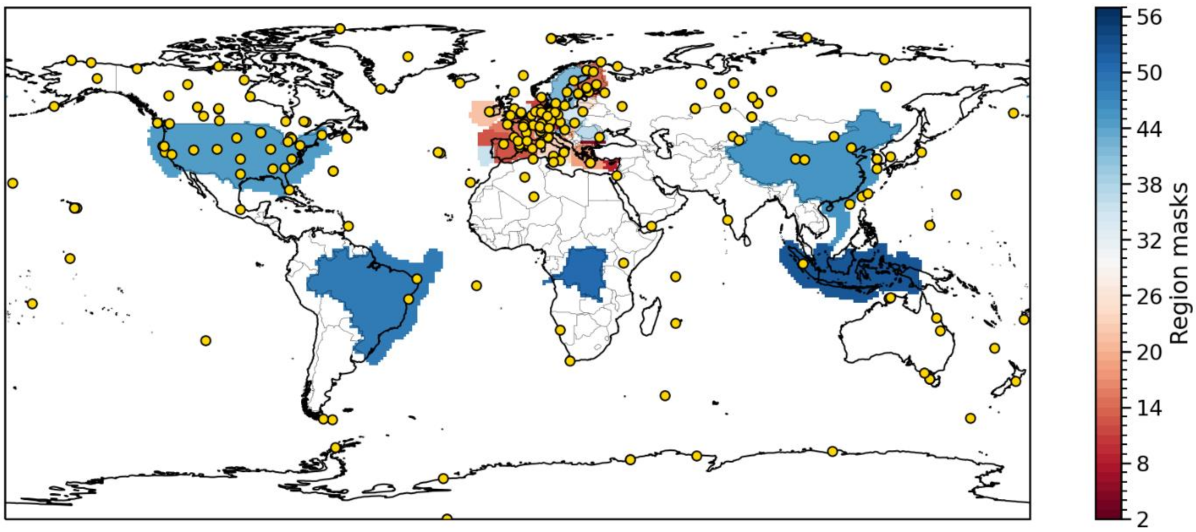

Fig. Region masks used to calculate the emissions and uncertainties and insitu stations used in the inversion (yellow dots)

4. Figure 7: It is very difficult to understand the bar of "BU Natural" and "TD Natural"? Why were the same BU anthropogenic emissions subtracted from the total emissions? Please enhance the clarity of this figure for better readability.

The BU natural and TD natural represent the respective natural emissions from BU and TD products. As explained in Table 4, not all TD products include/report the same partitions for the natural emissions. For harmonization purpose, we added BU estimates to those TD datasets which do not report this information, as hashed bar on top, which represent the missing natural partition.

We do not subtract any BU anthropogenic from the total, we just present the reported sources: anthropogenic, natural and total.

5. It would be great to have a figure that highlights the regions and emission sectors where the differences between current top-down and bottom-up results are most significant.

Thank you for this suggestion. The problem is that we do not have a really complete dataset to be able to make such a figure. There are a lot of gaps in the UNFCCC reporting for the non-Annex I countries. We believe that Figure 7 shows rather good agreement.

We could provide a table with the difference of the median of the BU+Natural and TD, which will give an idea of how big the differences are. This table could contain the countries in the rows, then the columns for median and range of BU, median and range of Natural, BU+Natural (median and range based on sum of squares error), TD median and range, and a final column on the difference. We could then discuss if the TD lies outside of the BU+Natural range, and could also see if they are within uncertainties, and reconciled.

6. There are too many abbreviations in the text. It is recommended to include a table that summarizes the corresponding full forms of these abbreviations, maybe in the Appendix.

Thank you for your observation, we will provide such a table, however we did not include an Appendix to the paper, we will add it to the Supplementary Information file.

7. Line 199 : missing a "."

Reference

Jacob, D.J., D.J. Varon, D.H. Cusworth, P.E. Dennison, C. Frankenberg, R. Gautam, L. Guanter, J. Kelley, J. McKeever, L.E. Ott, B. Poulter, Z. Qu, A.K. Thorpe, J.R. Worden, and R.M. Duren, Quantifying methane emissions from the global scale down to point sources using satellite observations of atmospheric methane, Atmos. Chem. Phys., 22, 9617–9646, https://doi.org/10.5194/acp-22-9617-2022, 2022.

Thank you, we will update the references accordingly.