Review for ESSD 2024 - 103

Overview:

In this study, the authors compare an ensemble of inversion-based estimates of terrestrial greenhouse gas fluxes including CO_2, CH_4, and N_2O with National Greenhouse Gas Inventory (NGHGI) estimates. The gridded inversion-based flux estimates are processed using an updated methodology so that they can be directly compared with country-(or group-of-country)-scale sector-specific flux estimates from the NGHGIs. For CO_2, the authors use an updated land mask to filter out inversion-based fluxes from unmanaged lands (i.e., intact forests) and also account for lateral transport of carbon via rivers, crop trade, and wood trade, allowing for direct comparison of the inversion and NGHGI non-fossil CO_2 fluxes. For CH_4, the inversion-based fluxes were partitioned into three "super-sectors" (agricultural and waste, fossil fuels, and biofuel + biomass burning excluding wildfires) for comparison with the NGHGIs. For N_2O, anthropogenic fluxes were obtained from the inversions by subtracting natural fluxes from lakes and rivers as well as from wildfires. For each greenhouse gas, the authors compare the ensemble of processed inversion-based flux estimates with NGHGIs in a variety of countries, while also comparing to the previous study of Deng et al (2022) to show the impact of the new datasets and updated land mask on the inversion ensembles. Notable discrepancies between the inversion ensembles and the NGHGIs are discussed for each gas. The accompanying dataset is accessible at the given identifier, is easy to use, and contains all necessary information to perform statistical tests and reproduce the key figures in the manuscript. In particular, there is nothing to indicate that the data are erroneous, and the format of the CSV files makes it very easy to perform statistical analyses on them.

I think the submitted manuscript is appropriate to support the publication of this data set. The data and methods presented are a useful and valuable update to the work presented in Deng et al (2022). The differences in methodology and data availability between this work and Deng et al (2022) are clearly explained, and their impacts on the results are illustrated throughout the manuscript by comparing the updated inversion ensembles with those of Deng et al (2022). Limitations and uncertainties associated with the methodology are also discussed in appropriate detail. The overall structure of the manuscript is sensible and easy to follow. Overall, I think this dataset and the accompanying manuscript will be useful and interesting to anyone working on global greenhouse gas emission studies in the future. I have a few general comments and suggestions for the authors to consider below, as well as a list of specific comments and technical corrections at the end of this document.

General comments:

The manuscript may benefit from a slightly longer discussion of the impact of the prior fluxes on the CH_4 inversion results in Section 6.4. The authors demonstrate that CH_4 emissions are sensitive to the prior in several regions in Figure 11 and SI Fig 2, and they mention this earlier in the text as well (Line 175) when they discuss the work of Tibrewal et al (2024), but I think it would helpful to expand this discussion since the impact on the results was quite pronounced in a few regions.

I also think the comparison of the N_2O results between this study and Deng et al (2022) described in Section 6.5 and Figure 12 was too brief, given how much time was spent earlier in

the manuscript describing the N_2O methodology and results. In particular, there is a good discussion of uncertainties in anthropogenic N2O emission estimates in Section 5 where the authors explain possible reasons for the discrepancies between inversions and NGHGIs. For the sake of future users of this dataset and existing users of the Deng et al (2022) dataset, I think it would be helpful if the authors could connect some of these (or other) sources of uncertainty with the discrepancies we see in Figure 12.

The accompanying dataset may benefit from some additional metadata, specifically for flux units and full "super-sector" names. This information is all available in the manuscript, but it would be more convenient for future users of these files if all the necessary information was self-contained in the data files. If this is not practical, perhaps include a README file with additional metadata on the Zenodo archive.

The presentation quality of the manuscript and dataset is generally good. The methods section in particular was very thorough. However, some of the descriptions of results in Sections 3, 4.1, and 4.2 are a bit too long in my opinion. Figures 3, 4, 5, and 6 are well-made and easy to understand, so some of the descriptions of these results could probably be made a bit more concise. Shortening these descriptions would also free up some space to expand on the discussion in Sections 6.4 and 6.5, as mentioned above. Other than a few typos or small grammatical issues, the language was consistent and precise. Tables were informative and easy to read, and Figures were well-made and clear (except colour issue in Figure 3, see "Minor comments").

I found it difficult to keep track of all the abbreviations used throughout the paper. There are dozens of abbreviations in the text (including subscripts for flux terms, countries or groupings of countries, models used in different inversions, and different kinds of reports for the NGHGIs), and I often found myself flipping back to earlier pages to remind myself what some of them meant. I appreciated that country abbreviations were always re-stated in the figure captions; perhaps periodically re-stating some of the other definitions would be useful as well.

Specific comments:

Lines 57 – 58:

This sentence is unclear to me. The equivalent sentence on Zenodo makes more sense: "Much denser sampling of atmospheric CO2 and CH4 concentrations by different satellites, coordinated into a global constellation, is expected in the coming years."

Lines 107 – 113:

The formatting here is a bit awkward to read, specifically because of the additional semicolons in points 2 and 3. Maybe list these as 6 questions instead of 4, or find a way to rephrase questions 2 and 3.

Table 1:

Could you add a column to this table specifying which transport model is used by each CO2 inversion system? The format of Table 2 and Table 3 is a bit different and the inversion names

seem to include more information about the transport models used (e.g., TM5-CAMS, GEOS-Chem, etc.).

Lines 175 – 176:
Missing a reference for GAINS, and this sentence is incomplete.

Lines 207 – 209:
Is it reasonable to consider everything except intact forests as "managed land"? What about other natural landcover types such as arctic tundra or grasslands (outside of Russia, where you assumed they were all managed)? Would excluding these other types of landcover from the Net Ecosystem Exchange CO2 Flux make a significant difference in your comparison between the inversions and NGHGI estimates?

Line 306:
The definition for E_{nat}^{aq} in Equation 4 is not given until Line 321. Can you move the explanation closer to Equation 4 so that the reader does not have to skip ahead to see what the terms mean?

Lines 352 – 357:
This explanation of how you compared the Net Land CO2 Flux is clear and reasonable, but it would be helpful if you could mention this earlier. In Equation 1 and Line 231 you explain that you are comparing the adjusted inversion NEE flux with the anthropogenic NGHGI fluxes, but it's a bit ambiguous because the adjusted inversion NEE flux does not include fossil CO2 whereas the anthropogenic NGHGI flux does. So it would be helpful to emphasize earlier in the text that the comparison in Equation 1 will actually be done for only the non-fossil component of the NGHGI fluxes.

Figure 3:
It is very hard to see the difference between the light green shading (range of in-situ inversions) and dark green shading (range of satellite inversions). Can you adjust the colour scheme? It was easier to see the different shades in the CH4 and N2O figures so I don't think you need to change those ones.

Lines 410 – 420 (Figure 3 caption):
Can you briefly mention the issue with switching from GOSAT to OCO-2 (described in detail on Lines 464 – 470) in this Figure caption? This is crucial for interpreting the time series plots, so it would be helpful to quickly mention that the satellite inversions use only OCO-2 after 2015 in the caption.

Line 565:
The acronym "IAV" is not defined in the text; is this interannual variability?

Line 641:
Can you give your definition of "ultra-emitter" and explain why they are omitted from NGHGIs?

Lines 820 - 841:

Consider moving SI Fig 2 to the main text to help illustrate impact of prior emissions (see also my general comment about expanding section 6.4).

Technical corrections:

Line 90:
"our framework to process inversion" --> "our framework to process the inversions"

Line 92:
"Atmosphericinversions" --> "Atmospheric inversions"

Line 385:
"Indonesia (IND)" --> "Indonesia (IDN)"

Line 391:
"is a large emitter of oil and gas" --> "is a large producer of oil and gas"

Line 441:
"that the NGHGIs reports" --> "than the NGHGIs reports"

Lines 443 – 445:
The font here is different from the rest of the text.

Line 446:
Replace semicolon with period.

Line 718:
"which may underestimate emissions n when soil" --> ?? I am not sure if there is a missing word here, or if you should just delete the "n"

Line 768:
"difference" --> "differences"

Line 864:
Delete "In this study,"