Referee #2

This manuscript is an update on the previous one (Petrescu et al., 2021), which synthesized and compared the estimates of CH4 and N2O emissions over Europe from NGHGI, and BU and TD approaches. The current manuscript follows the nice structure established in the previous version, while with improvements in uncertainty estimation and spatial patterns for posterior CH4 and N2O fluxes from inversions. The manuscript is well written with highlights on the improvements and changes compared to the previous version.

We thank Referee #2 for his review comments and we answer below to it:

A few comments and remarks as follows:

As the results are mainly for 1990-2019 with few data in 2020, the title should not include 2020.

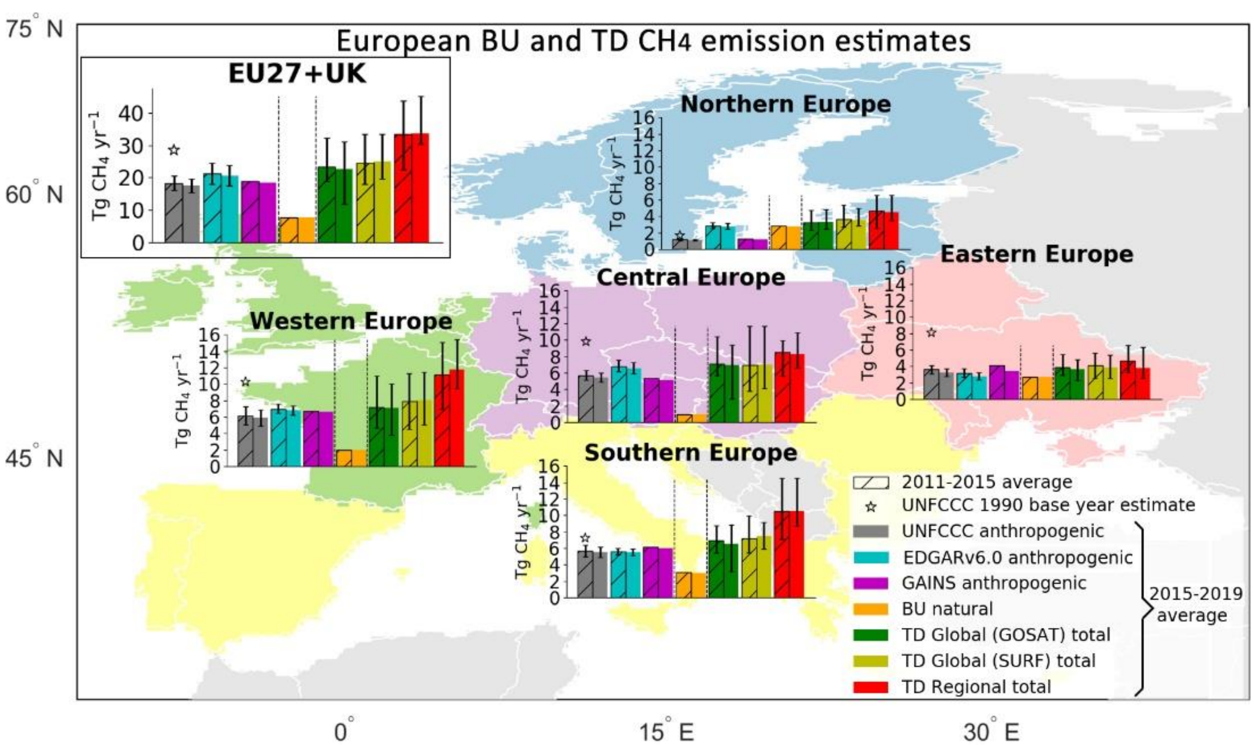
We agree with the reviewer that the majority of datasets used in this study provide data until 2019, therefore we will change the title as suggested.

The resolution of the figures are low at least in the current pdf version.

Thank you. We will make sure, if the manuscript will be accepted for publication, to provide the journal with good quality figures as we already received from the modelers.

Figure 2 and Figure 10: The bars between 2011-2015 and 2015-2019 are difficult to tell. In particular the yellow uncertainty range are almost invisible. It could be better to use two bars instead one bar for each estimates, which will give clearer information on both mean and uncertainty.

Thank you for your comment. Figures 1 and 10, indeed, are complex and try to summarize the results. We separated the previous 2011-2015 average period and plotted it next to the 2015-2019 one.



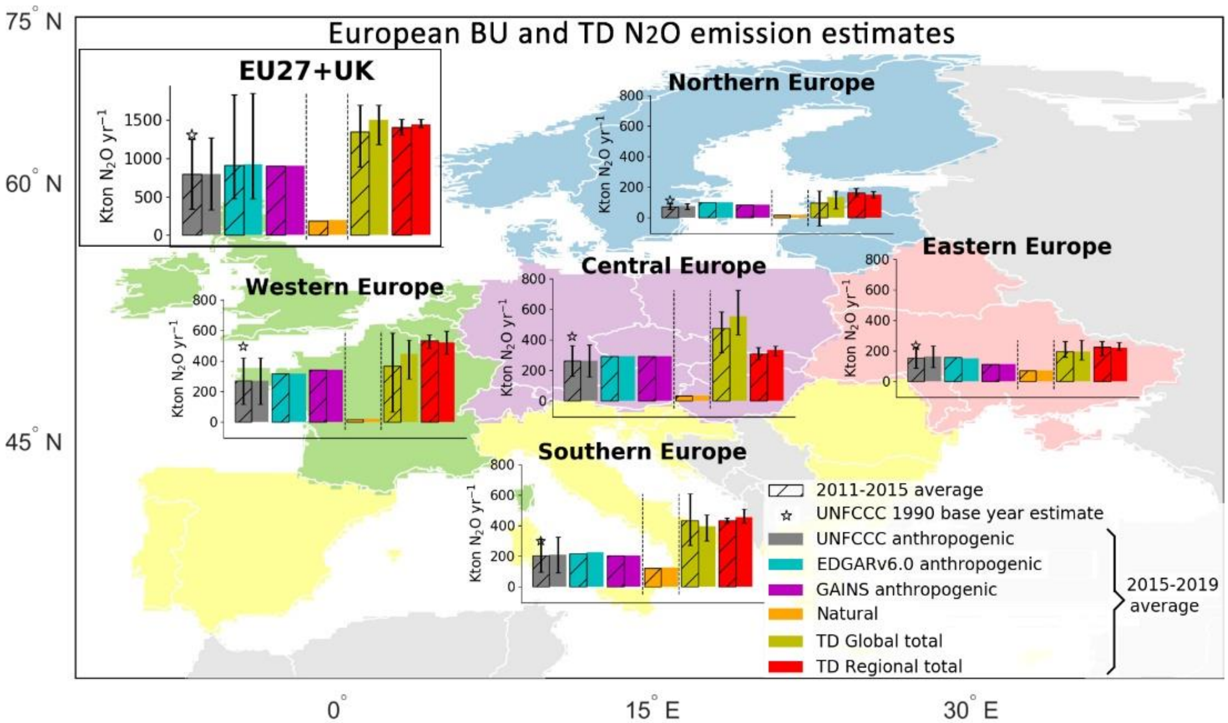


Figure 4b The colors for inland waters, peatlands and mineral soils, geological emissions and biomass burning are difficult to tell.

We agree with the reviewer that natural CH_4 fluxes are similar in both magnitude and color, and hard to separate. Therefore we will add to Appendix B a separate figure (Figure B1c) for natural CH_4 emissions and the following text on L580:

"....from BU natural sources, represented separate in Figure B1c, Appendix B.."

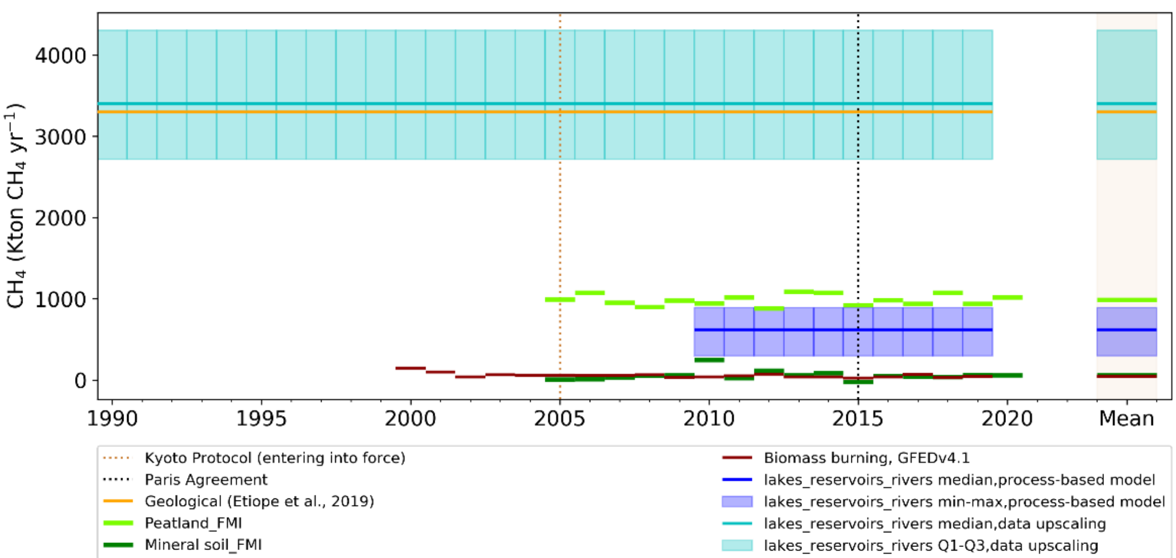
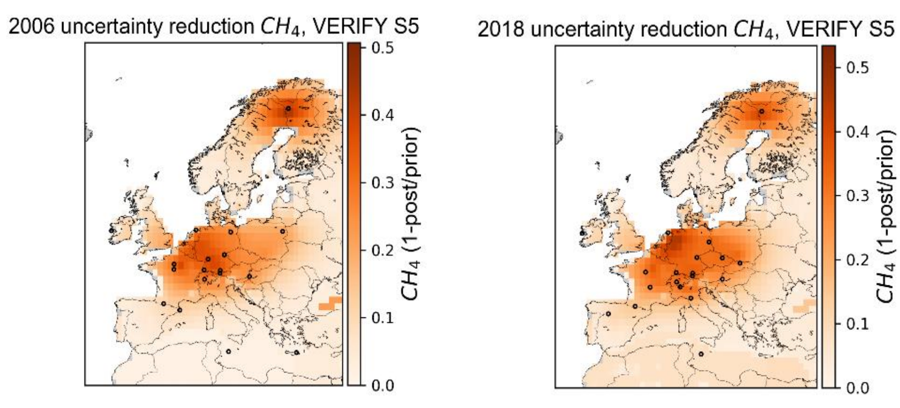


Figure 4 and 13: It is a little surprising that top-down estimates varied a lot between Petrescu et al., 2021a and current study. It would be necessary to explain such differences (model improvements, site observation availability, satellite data availability etc.).

We agree with the reviewer that more explanation is needed regarding differences between previous results shown in Petrescu et al., 2021a and current study. Below we summarize the reasons as following, and this paragraph will be added from L588 onwards:

"The differences between inversion results in current study and Petrescu et al., 2021a can be summarized as following: for the version used in this study, FLExKF-CAMSv19r_EMPA, the background mole fraction was taken from a global CAMS v19r assimilation run with assimilation of surface observations of CH_4 only (no satellite data) where the domain was cut out following the two-step approach of Rödenbeck et al. (2009). Background concentrations from CAMS v19r are on average about 5 ppb lower than those of the TM5-4DVAR system used previously, which results in somewhat higher emission estimates over Europe compared to Petrescu et al. (2021a). The major differences to previous CTE-FMI run are the prior fluxes, except for biomass-burning which remained GFED. The new VERIFY_S5 (core) run uses fluxes as described in Thomson et al., 2021. Lake & geological emissions were not included in Petrescu et al., 2021a synthesis, but are included in the current CTE-FMI simulation, which probably also contributes to higher total emissions. On top of this, the assimilated data (i.e. observation network) contributes to the differences (enlarged observation network, more sites (five core sites for CH_4 located in Spain, France and UK were added). The FLEXINVERT version used in this study updated the atmospheric observation network (more sites were added) as well as the prior emissions. The background mole fraction was also coupled with that from CAMS v19r assimilation run, which, similar to FLExKF model, might imply higher emissions."

Regarding the CTE-FMI model we also replaced in Figure 8 the VERIFY S4 runs to S5, as the run S4 included the most assimilated sites, however for comparability reasons we should have used instead the runs having in both years 2006 and 2018 the same number of observation stations, referred here as S5 "core sites".



We therefore rewrote the following paragraph from Lines 719-727:

"The second inversion system, CTE-CH_4 (Tsuruta et al., 2017) calculated the uncertainty reduction maps from surface inversions (SURF) for 2006 and 2018, as those used in Thompson et al., (2021), referred to here as VERIFY_S5

("core" inversion) (Figure 8). The system included two sets of inversions with different observation sets assimilated. However, the degrees of freedom in the state of the system was low, and therefore, the uncertainty estimates may not differ much between the two. The data from CTE-CH_4 includes uncertainties (standard deviations) and fluxes for 2006 and 2018. The differences in the simulations are observation sets and underlying prior covariance structure. "VERIFY_S5" uses data from only those sites that have long-term measurements assimilated i.e. there is little differences in the assimilated sites between the years. From the two panels of the Fig.8, higher uncertainty reductions are seen in 2018 compared to 2006 in E Poland, N Italy and Spain".

L586: The differences in the trends could benefit a bit more explanation or discussion.

Regarding trends, we agree that more explanation is needed, however this will also require additional sensitivity tests and investigations from the modelers, which we hope to have for this year's new synthesis, hosted by the $CoCO_2$ EU funded project. Therefore, we will add the following text (on CH_4) after the new L588 paragraph describing the increase in CH_4 emissions:

"Regarding decreasing trends seen for the current CH_4 results, for FLExKF model the trend in CH_4 emission was slightly negative over 2005-2019, at -0.48% per year, which is lower than the decrease in the prior of -0.8% per year. For the other models, based on Thompson et al., 2021, the differences in trends might be due to regional vs. global inversion differences."

The N_2O discussion will be added after the Figure 13:

"For the N_2O results (FLEXINVERT in Figure 13), after updating the last runs, both the magnitude and trends of the N_2O emissions changed. This new decreasing trend is confirming the UNFCCC trend but shows a larger average source after correcting for the estimate of natural emissions. Future work should focus on establishing the uncertainty and variability in the natural emissions of N_2O so that the results of inversion could be more directly compared to emission inventories."

L608-612: For such interesting findings, it is necessary to explain it more clearly. The current speculation is not easy to understand.

We agree with the reviewer that the short paragraph in lines 608-612 required further explanation and clarification. We thus have added one sentence regarding the main drivers if thee seasonality and corrected the second sentence which contained a typo. Indeed, the words "for rivers" were misplaced in this sentence because the comparison only holds for lakes. We believe that this updated version clarifies the statement:

"Model results however also reveal a strong seasonal variability in CH_4 emissions, with much lower fluxes during winter. ***This seasonality is driven by physical factors (changing ice cover and bottom-water temperature) and biogeochemical factors (autotrophic primary production) that are well established drivers of the temporal variability in lake CH_4 emissions (Del Sontro et al., 2018; Jansen et al., 2022).*** *This finding* ***provides a likely explanation as to*** *why the spatio-temporally resolved model results lead to significantly lower estimates than observation-based methods that do not capture well the temporal variability in lake CH_4 emissions."*

DelSontro, T., Beaulieu, J. J., and Downing, J. A. (2018) Greenhouse gas emissions from lakes and impoundments: Upscaling in the face of global change, *Limnol. Oceanogr. Lett*. 3, 64–75.

Jansen, J., Woolway, R.I., Kraemer, B.M., Albergel, C., Bastviken, D. et al. (2022) Global increase in methane production under future warming of lake bottom waters. *Global Change Biology*, 28-18, 5427-5440, 2022. 10.1111/gcb.16298.

L652: “Further” rather than “father”.

Thank you, we replaced farther, with further.