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Comment

Interactive comment on “Impact of transport model errors on the global and regional methane emissions estimated by inverse modelling” by R. Locatelli et al.

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We are very grateful to anonymous referee 1 to have reviewed the manuscript and submitted other helpful comments and suggestions to improve the text. Here we respond to the reviewer point by point. The reviewer comments are copied hereafter in italics with our detailed answers inserted in standard font.

General comments

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(...) it is rather lengthy for a straightforward modelling experiment like this. The paper could profit from shortening, in particular because it contains many repetitions.

An effort has been done to reduce some parts of the manuscript by removing some unuseful repetitions. In particular, we moved some details about figures in the legend parts. We have also removed some explications about the impacts of inter-hemispheric exchanges on the inverse estimates when it had been already given in previous sections.

Moreover, the grammar and wording should be improved.

With the help of one of the native English-speaking co-author, many changes have been done in order to improve the wording and grammar.

Specific comments

P 10963, L 8-10: This sentence is a central part of the abstract as it summarizes the set-up of the study. However, is a bit difficult to understand.

We have rephrased the sentence to explain in more details what the set-up is: "The same methane sinks, emissions and initial conditions have been applied to produce the 10 synthetic observation datasets. The same inversion set-up (statistical errors, prior emissions, inverse procedure) is then applied to derive flux estimates by inverse modelling. Consequently, only differences in the modelling of atmospheric transport may cause differences in the estimated fluxes."

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P 10968, L 28-29: This comparison will only provide a realistic quantification of the transport model error, if the models cover the typical range of different transport models, otherwise the error could be underestimated.

Yes, we agree. However, we can legitimately assume that the range of 10 models used in this study can cover the typical range of transport models. Indeed, the 10 CTMs used in this study are characterized by very different horizontal (from 6x4 to 0.7x0.7) and vertical (from 19 to 67 layers with different coordinate systems) resolutions, meteorological forcings and sub-grid parameterization schemes. However, the sentence you pointed out here is written just before the Section 2.2, which details the characteristics of the different chemistry transport models, that is why we slightly modify the original sentence:

”The comparison between these estimates provides a quantification of the influence of transport model errors on the CH₄ fluxes.” → ”Assuming that the range of the CTMs used here cover the typical range of transport model errors (see Section 2.2), the comparison between these estimates provides a quantification of the influence of transport model errors on the CH₄ fluxes.”

P 10985, L 14-18: This seems to be pure speculation because the high emission estimates could be compensated elsewhere.

Our aim here is to suggest that a compensation occurs between the impact of synoptic variability and the impact of inter-hemispheric exchange time on the estimated methane fluxes: higher synoptic variability and lower inter-hemispheric exchange time in the high resolution version of the models tend to respectively derive higher and lower methane estimates compared to low resolution version of the models. However, the design of the TransCom-CH₄ experiment does not allow to assess the particular impact of each process (synoptic variability, inter-hemispheric exchange time,...) on

the total estimates.

P 10987, L 5-9: Also the vertical resolution of the models might play a role, in particular for the benefit from the use of aircraft profiles. Please comment also on this aspect.

Yes, we agree that vertical resolution plays a role, especially when we use tall towers or aircraft profiles measurements. However, we can not evaluate this benefit accurately, since we do not have two versions of the models differentiated by vertical resolution only.

Moreover, we have plotted (not shown in the manuscript) the differences between NET2 and NET3 estimates for each model in function of their vertical resolutions. We did not find any general correlations between improvements in the vertical resolution of the models and differences between NET2 and NET3 estimates, that is why we did not comment this aspect in the manuscript. Only results for PCTM model have been related to vertical resolution in the manuscript. Indeed, PCTM modellers have suggested that our results for PCTM could be explained by the high number of vertical layers of PCTM compared to other models in the planetary boundary layer.

P 10987, L 14-17: Does this small difference really imply that the actual number and location of measurement stations in Europe is sufficient to constrain the European fluxes? Please comment on this.

This is what we find in this specific study using synthetic observations. For Europe, additional measurements in NET3 configuration (3 tall towers and 1 airplane) represent only 20% of all synthetic measurements of NET2. For comparison, in North America and Boreal Eurasia, the number of synthetic observations added to NET2 to build

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NET3 is higher than measurements in NET2 alone.

The sentence mentioned by the reviewer was too general. Consequently, we have specified: "In our synthetic experiment, NET3 has only 20% additional synthetic observations in Europe compared to NET2. It suggests that NET3 estimates cannot be improved much in Europe compared to NET2 estimates."

In the other regions, the spread among estimates is reduced in NET3 configuration and the estimates move also closer to the target emissions. We assume, in this case, that the system can not take properly into account large differences between surface measurements and measurements of methane vertical profiles. As a consequence, it derives estimates closer to the prior.

We have explicitly explained these two different assumptions in the manuscript.

*P 10989, L 20-24: This was just mentioned in Sect.3.1 not shown.
Please rephrase.*

We have rephrased this sentence. We also noticed that we have to refer to the Section 3.2.2 and not to Section 3.1.

P 10991, L 21-23: This statement follows from Saito et al. (2013). But it remains unclear if a larger interhemispheric gradient is more realistic. If there is any support from observations please mention it here.

The study of Saito et al. (2013) gives some indications to improve the modelling of inter-hemispheric exchanges: they show that TransCom models exhibiting the strongest interhemispheric gradient (TOMCAT for example) are usually characterized by strong vertical gradients coupled with slow meridional transport. They come to this general statement by using the results of Patra et al. (2011) which compare inter-hemispheric (IH) exchange times simulated by different chemistry transport

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model with IH exchange time measured from SF_6 measurements. In particular, they show that LMDZ-SACS has a very low IH exchange time. Knowing also that LMDZ-SACS is characterized by a weak vertical gradients in the free troposphere and that LMDZ-SACS has the smallest number of layers among the models of the TransCom experiment, we are on the progress to improve the modelling of IH exchange time simulated by LMDZ-SACS. First, it has been decided to increase the vertical resolution and secondly, the parameterization schemes of vertical transport in the boundary layer are going to be updated with new schemes. We have mentioned these explanations in the conclusion part.

Technical corrections

Figure 12: The different colors in the maps are difficult to identify, in particular because the maps are very small and the colors in the color scale are partly difficult to distinguish. Better use a simple blue-white-red color scale.

Done. This figure has been updated.

P 10963, L 18: Should it not be 'involved' rather than 'invoked'?

The second reviewer has proposed 'examined'.

P 10963, L 23: Don't you mean 'errors in the covariance matrix' rather than 'errors of the covariance matrix'?

Yes, 'errors in the covariance matrix'.

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P 10964, L 4: Is CH₄ given in volume ratio (ppbv) or mole ratio (ppb)? Usually, measurements are in dry air mole ratio. Your model results are also mole fractions, as you mention later in the text.

In ppb.

P 10965, L 23: Not the 'discrepancies' are limitations to further improvement but rather the 'deficiencies' in the models. From the discrepancies between the models we might even learn - as you nicely show in this study.

Ok, we use 'deficiencies' now.

P 10966, L 1-3: The sentence is difficult to understand. Maybe replace 'that' by 'because'.

Done.

P 10966, L 3-4: 'solicited' and 'appariton' might not be the correct expressions.

We have changed 'solicited' by 'required' and 'apparition' by 'availability'.

P 10966, L 7-8: ...provides... ...requires...

Done.

P 10966, L 10: Moreover

Done.

P 10966, L 16: Replace 'applying' e.g. by important or active

We have replaced "applying" by "active".

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P 10966, L 22: ...into consideration...

Ok.

P 10966, L 28: ... have shown...

Ok.

P 10967, L 1: ...wind were... or ...wind was...

Ok.

P 10967, L 26: ... participating in...

Ok.

P 10968, L 23: . . . emission pattern.

Ok.

P 10969, L 5-10: Please give references for each model / model variant.

We have added the reference for the two high resolution model variants.

P 10971, L 17: Please specify: the maximum of which quantity?

This is the "maximum of emissions".

P 10972, L 6: Could be misleading: Y contains just one set of synthetic observations for the whole period.

Ok. "Y contains one set of synthetic observations for the whole period."

P 10973, L 2: Rödenbeck

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Done.

P 10973, L 13: reconsider the choice of words, 'applying' seems strange.

We have completely rephrased this sentence: "...to avoid edge effects and only keep estimated fluxes for the year 2005."

P 10973, L 23-24: Better join both paragraphs.

Done.

P 10974, L 17-18: What is meant by 'measurements included in the PBL'? Please rephrase this to be easier to understand.

We have rephrased it by: 'measurements sampled within the PBL'.

P 10974, L 21: The difference between NET2 and NET3 will provide this information.

We have rephrased the sentence by: "The difference between NET2 and NET3 estimates will provide information on the contribution of PBL and tropospheric data on CH₄ flux estimates."

P 10976, L 10: Explain already at this point how STD is split into synoptic and seasonal parts.

Done.

P 10976, L 20: The logical connection is 'area impacting these stations' rather than 'area impacted by these stations'.

Ok.

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P 10977, L 1: ...those simulated...

Done.

P 10977, L 2: This is not a consequence, remove 'Consequently'

Done.

P 10977, L 10: reconsider choice of words: 'deriving' does not fit.

We have rephrased the sentence by: "Stations located in the vicinity of methane sources appear to be associated to strong negative synoptic STD difference values."

P 10977, L 19: . . . transport of signals from remote methane sources.

Done.

P 10977, L 20-22: What is meant by 'amplitude variability'? Please clarify this sentence.

We want to speak here about "the synoptic variation amplitudes simulated by TransCom models". However, this part has been modified in order to shorten the text and this sentence has been removed.

P 10977, L 23: ...is only 2 ppm.

Done.

P 10978, L 4: reconsider choice of words: 'solicited' does not fit.

Ok, we use "required" now.

P 10978, L 11-12: ...distinction can be made...

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Ok.

P 10978, L 15: These are not the 'smallest' differences. In fact differences are very large, however, the differences are negative. Please rephrase the sentence.

We rephrased the sentence by: "the largest negative synoptic STD difference values."

P 10978, L 17: But TOMCAT shows high values around 50N. Please specify in more detail what is meant by 'smallest difference'.

We have rephrased it by "largest positive difference".

P 10980, L 22: ...yields higher average... and lower average...

Ok.

P 10980, L 26: reconsider choice of words: 'exposes' does not fit in this context.

We have chosen the word: 'summarizes'.

P 10981, L 1: '...derives higher estimates... and lower estimates...' or 'derives the highest estimates... and the lowest...'

Done.

P 10981, L 4: Time series... show general...

Ok.

P 10981, L 11: 'twice as large as' or 'two time larger'

We have chosen the expression: 'twice as large as'.

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P 10981, L 11: Not the average of the seasonal cycle amplitude is a factor of 2 higher than that of the target flux but rather the maximum amplitude.

Ok.

P 10981, L 13: What is meant by 'emphasizes'? Please reconsider choice of words.

We use now "accentuates".

P 10981, L 21-22: ...black lines are the values of...

Done.

P 10982, L 25: ...relative to...

Done.

P 10982, L 27: ...amplitude twice as high as...

Done.

P 10983, L 15: reconsider choice of words: 'exposes' does not fit.

The second anonymous reviewer suggested to use "displays".

P 10983, L 24: ...associated with...

Done.

P 10984, L 4: ...both coasts...

Done.

P 10984, L 17: reconsider choice of words: 'reminding'

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The second anonymous reviewer suggested to replace "reminding the dipole of emissions" with "owing to the emission dipole".

P 10986, L 22:....fluxes drop to...

Ok.

P 10987, L 19: ...what was obtained...

Done.

P 10987, L 25: ...statistical errors...

We removed here 'statistical' according to the remarks of the second reviewer.

P 10988, L 25: Hegyátsál

Ok.

P 10988, L 8-10: The issue here is not the increase of the estimated emissions themselves but the increase of the differences to the target emissions.

Yes, you are right. We have rephrased it by saying: "...leading to a larger increase in the global emission differences, compared to the target emissions, for NET1 compared to NET2."

P 10988, L 15-18: The logic behind this sentence becomes not quite clear. Maybe rephrase the statement.

We have rephrased this statement.

P 10988, L 28-28: the errors are not 'given by the inversion' but 'used in the inversion'.

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Ok.

P 10989, L 7: ...took ...into consideration..

Done.

P 10989, L 18: What is meant by 'uneven surface observations'?

We have removed 'uneven' because it is not useful here to specify that surface networks are uneven. We just want to oppose inversions using satellite data where cross-correlations are used with inversions using surface measurements where cross-correlations are usually not used.

P 10989, L 24: ...take into consideration...

Done.

P 10990, L 20-21: ...IH transport differences play an important role .. one of the shortest IH exchange times.

Ok.

P 10991, L 10: ...CH4 flux estimates.

Ok.

P 10991, L 10: Specify what is meant by 'it'.

We replaced "it" by "This spread".

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