

Geosci. Model Dev. Discuss., referee comment RC2
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Comment on gmd-2021-238

Anonymous Referee #2

Referee comment on "How well can inverse analyses of high-resolution satellite data resolve heterogeneous methane fluxes? Observing system simulation experiments with the GEOS-Chem adjoint model (v35)" by Xueying Yu et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-238-RC2>, 2021

The authors conduct Observing System Simulation Experiments (OSSEs) to assess the ability of TROPOMI observations of atmospheric methane columns for constraining monthly methane emissions at the 25 km scale through inverse analyses. I think the paper is within the scope of GMD and is well-written. I recommend publishing the paper after considering my comments below:

General comments:

The analyses of inversion performance are done over the whole North America. As the authors conducted high-resolution (~25km) inversions, I think it would be more interesting to focus on regional performance. For example, southeast US includes large sources from oil/gas, agriculture, and wetlands, while the number of observations is very limited there as shown in Fig. 2. What would inversion performance look like in this region?

Specific comments:

L43-44: "a spatial correlation of just R^2 ". Do you mean coefficient of correlation (R) or coefficient of determination (R^2)? In Section 3 the authors start to use R (e.g. Fig 4). I would suggest the authors use either R or R^2 throughout.

L118-119: How do you generate your synthetic observations? Do you do a forward model simulation and then sample XCH₄ at the locations of TROPOMI observations?

L134-135, L142-143: It looks like instrument error includes only random error. What about systematic instrument error?

L143: Perhaps add a bit more details about TROPOMI observation operator?

L168: "This is a common...". Citations?

L186: Equation (1). Tikhonov regularization for an inverse problem commonly includes the regularization parameter (γ) in regularization term (i.e. prior). Is there a particular reason to put γ in the observation-model term in the cost function? In the supplementary, γ is determined by L-curve. I assume you are referring to Hansen (2005) L-curve criterion which is based on Tikhonov regularization.

In addition, what do you mean "Cost function - Obs" and "Cost function - Prior" in Fig. S3. Please write down the equations you use. Also, please set x/y-axis as log scale for Fig. S3a

L214: Equation (2). Where is the regularization parameter γ ?

L368-369: "meaningful improvements"? Perhaps be more quantitative and specific about "improvements" throughout the whole text.

L471: what do you mean "accumulating transport error"?