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Geoscientific Model Development Discussions

Interactive comment on "Atmospheric Inverse Modeling via Sparse Reconstruction" *by* Nils Hase et al.

Anonymous Referee #1

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Review for "Atmospheric Inverse Modeling via Sparse Reconstruction"

This manuscript presents an interesting technique for estimating surface fluxes of methane. It draws on ideas from the inverse problems literature nicely. However, there are some issues, detailed below, that need to be addressed before I can recommend the manuscript for publication.

General Comments

The style of writing is colloquial, which proved distracting for me as a reader. At several places I missed the point of the authors because of the phrasing. I suggest the authors have a senior colleague read through this draft and help them to make the writing more in line with typical scientific writing.

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Discussion paper

The idea of sparsity is fairly straightforward to grasp in terms of a basis (or dictionary), but the way it's introduced here (with the 1-norm providing the definition) is not easily connected to what is seen later. From my vantage point, it would make more sense to first point out that methane is a "point source problem", i.e. a sparsely distributed signal, and then to work forward towards inverse methods that preserve the sparsity. Additionally, it would be useful to see a simple representation of a function using a dictionary that is chosen using the two norms, to see how they perform differently. Figure 1 is too simplistic for this purpose.

In general, I'm confused by the lack of comparison to truth in your OSSEs. It's true that in real life we don't have the truth, but the metrics you've chosen leave out the true error (except for the last section comparing inverse methods). For example, you look at the sensitivity matrix, but don't actually compute the true error for the case study that is due to smoothing, which would directly show the extra smoothing for the 2-norm reconstruction.

Why is there no attempt to use the dictionary approach with the 2-norm? I would think that it would perform pretty well, particularly if the atoms were somewhat orthogonal. It's likely that I'm missing something, but this wasn't addressed in the text.

The text mixes "methods" and "results". For example, most of section 4 really belongs in the discussion of Section 3, and perhaps in a more logical style that explores the methods hierarchically. For example, introducing the 2-norm and 1-norm regularization as is done. Following this, pointing out that using a dictionary helps to focus the solution on "hot spots". Then pointing out that none of these methods enforce positive fluxes, and introducing those techniques. Then moving the material involving results all to a section 4, displaying all of the results from the different techniques side by side.

With these overarching issues, there are only a few specific comments that are pertinent to the scientific underpinnings of the paper:

Page 5, Line 22: What is the reasoning that the 1-norm targets "only a few of the nonzero components"? Surely we could cook up a counterexample to this statement.

Page 8, Line 21: How are you selecting a basis from the dictionary? I expect that this procedure will have an impact on the final solution. I don't think subsampling a dictionary will make the solution less sparse, but it's hard to know for sure.

Page 9, Line 12: "If no uncertainty analysis is carried out" This is a pretty big blow to the technique, as emissions estimates have no value without error bounds. A quick survey of the flux inversion literature will show how variable the uncertainty estimates from different methods are.

Page 13, Figure 5: Leaving out the largest 5% seems to avoid some of the most compelling science, as "superemitters" are thought to have the biggest impact on the methane budget by a wide margin.

Figures 4, 7, 9: Errors would be more appropriate in these plots, as they would directly show "underestimate" vs. "overestimate" and put all of the sizes on the same scale. It would also show systematic behavior for methods more clearly.

Page 18: You call 5.2.1 "Smoothing Error", but no error is actually computed. Only sensitivity. However, I agree with the spirit of your intent, and think you definitely need to add the full smoothing error arising from the difference between the truth and prior/posterior.

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