Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-326-RC1, 2020

Geoscientific Model Development Discussions
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Interactive comment on "PMIF v1.0: an inversion system to estimate the potential of satellite observations to monitor fossil fuel CO_2 emissions over the globe" *by* Yilong Wang et al.

Anonymous Referee #1

Received and published: 18 February 2020

1 Overview:

Review of "*PMIF v1.0: an inversion system to estimate the potential of satellite observations to monitor fossil fuel CO2 emissions*" by Wang *et al.*

Wang *et al.* present an OSSE framework to estimate error reductions for a proposed satellite. It's based on a Gaussian plume that they run for many emission hotspots. They've done this over a large domain (globally) at fairly high spatial resolution (2 km). The work is interesting but the description of the methods could use quite a bit of work. There are some important steps in the actual implementation that are quite convoluted.

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Discussion paper

Fixing this seems like a critical for publication in a journal focused on geoscientific model development. I suggest major revisions for the manuscript.

2 Comments:

2.1 Solution to their inversion

I'd prefer the authors not use $\mathbf{A}$ as the posterior covariance matrix, I usually think of $\mathbf{A}$ as the averaging kernel. This is particularly confusing because you are solving for emission reductions that are the diagonals of the averaging kernel matrix. In any case, Supplemental Section 1 presents what the authors are *actually* doing, which differs from the equations they present in Eq. 1 and 2. In Supplemental Section 1 the authors present a derivation that is both important and convoluted. It's unclear if this is something the authors devised themselves or if it follows from other work. Typically when people decompose error covariance matrices into spatial and temporal components they use a Kronecker product (e.g., Yadav & Michalak, GMD 2013). The Kronecker product greatly reduces the computational expense. The assumptions that go into a Kronecker product are also easy to follow because it is widely used. It's also amenable to sparse matrices (I'm assuming the authors are using sparse matrices).

I think the authors should remove Equation 2 and bring Supplemental Section 1 into the main text. Supplemental Section 1 is important because this is what they are *actually* doing. This seems like the main contribution to me.

Finally, I would strongly suggest not using "pseudo" in Supplemental Section 1 because that implies computing a pseudoinverse, which has a very specific mathematical definition. Unless, of course, the authors are computing a pseudoinverse in which case that should be made clear.

The authors should change the title. It's not an *inversion framework* as they are not estimating fluxes.

2.2 Justification on the use of a Gaussian plume

Real plumes are only Gaussian in the time-averaged sense. The satellite observations provide a snapshot in time that likely would not be Gaussian. I think the authors need to provide some justification as to why a Gaussian plume is appropriate for data that is not time-averaged. A Gaussian plume may give a reasonable upper bound on the uncertainty reduction, but will likely induce systematic biases if implemented operationally. These potential biases should be discussed.

The authors should give more explanation of σ_j. There are two parameters in a Gaussian plume model and they spend one line talking about σ_j: "The σ_j is a function of downwind distance i and atmospheric stability parameter. We take the form for σ_j from Ars et al. (2017).".

2.3 Clumps

I don't like the terminology "emission clumps". It doesn't fit with the actual definition of a clump:
noun: *"a compacted mass or lump of something"*
verb: *"form into a clump or mass"*

Emissions don't clump. The various sources have just been grouped together. The abstract of their 2019 paper seemed to use "hotspot" and "clusters" which I would prefer to "clump". A cluster would be a much more intuitive name for this.

2.4 References

The authors show a very strong bias towards European studies. They don't seem to mention any of Ray Nasser's work in the intro even though his 2017 GRL paper used a Gaussian plume model with satellite observations to study individual sources. They also seem to have missed Eric Kort's work using GOSAT to study megacities (Kort et al., GRL 2012; among others).

2.5 3 hours vs 6 hours

Why is there a 6-hour window for Paris and a 3-hour window globally? I see, it's defined afterward. This should be moved forward to explain why Broquet chose 6 hours and why they choose 3 hours. How is 3 hours chosen? It seems to just be picked randomly.

3 Specific comments:

Title: Remove fossil fuel from the title. I don't see how they could differentiate fossil from non-fossil sources in their analysis.

Section 2.1: Should reference the sections that define the error covariance parameters.

Line 126: what is $\mathbf{y}^{\text{fixed}}$?

Line 181: rephrase, too colloquial: "but the PMIF can hardly handle hourly emissions when covering a whole year".

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