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Comment on acp-2021-734

Anonymous Referee #2

Referee comment on "Quantifying fossil fuel methane emissions using observations of atmospheric ethane and an uncertain emission ratio" by Alice E. Ramsden et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-734-RC2, 2021

I think the authors have put together a nice manuscript on ethane and methane emissions from the United Kingdom. I have a few minor suggestions and questions related to the manuscript, and I recommend the article for publication in ACP.

Overall suggestions:

- This study uses a spatially constant ethane:methane ratio, which likely makes sense for the United Kingdom. In many other countries, like the US, this ratio is spatially variable. In this manuscript, I think it would be useful to think about how the proposed inverse modeling framework could be applied in locations where the ratio is spatially heterogeneous. For example, I wasn't completely sure how one would use Eq. 5 for the case where the ethane:methane ratio is spatially variable.

Specific suggestions:

- Last paragraph on pg. 4: Which MCMC algorithm do you use (and/or build upon for the inverse model)?
- Line 165: How does this case work if the spatial distinction of sources in the prior does not exist?
- Line 168: What is the unit on the "7 x 7" resolution listed here?
- Lines 255 - 261: I'm guessing that the accuracy of the estimated emissions in case 2 depends on how you construct the prior pdf on the ethane:methane ratio. I.e., if the mean of this pdf were 50% higher or 50% lower than the true ethane:methane ratio, I assume that the estimated sector-specific methane emissions would also be relatively inaccurate. Line 296 explains that the inverse model converged on a Gaussian distribution for R only 20% of the time, and that makes me wonder even more about

this point. I think an important advantage of this framework, however, is that the posterior uncertainty bounds should encompass the real value if the prior pdf is carefully constructed.

- Lines 295-296: Do you think a range of 0.009 to 0.2 is a physically realistic range of values? (After reading the entire manuscript, I see that there is more discussion of this point in Sect. 3.4. You may want to refer the reader to this section for discussion of whether a range of 0.009 to 0.2 is realistic.).
- Appendices: You might consider moving the appendices to the supplement. With that said, I think it's a point of personal preference.