Reviewer #1 Lena Höglund-Isaksson

Comment [1-1]: GENERAL: I find this paper very interesting because it manages to shed considerable additional light on many of the big questions about the discrepancy between bottom-up and top-down estimates of methane emissions from North American sources. Without being an expert on inverse modelling myself (but rather bottom-up modelling), I still note that the authors make important improvements in the methodology that are additional to previous studies, i.e., using both satellite and in-situ observations, using a log-normal error function which better represents the high tail emission distributions that are typical for the oil and gas sources, and using an improved prior for wetlands, which does not overstate wetland emissions as has previously been a problem. These improvements seem to lead to results that better explain the total contribution from anthropogenic sources and their attribution to individual source sectors. The paper is also well written and easy to follow and I support publication but would like to see one major concern addressed and a few minor revisions, as listed below.

Response [1-1]: We thank Dr. Lena Höglund-Isaksson for the positive and valuable comments. All of them have been implemented in the revised manuscript. Please see our itemized responses below.

Comment [1-2]: MAJOR CONCERN: Authors are able to show that anthropogenic CH4 emissions are substantially underreported in all three countries USA, Canada, Mexico, and in particular for the US. They conclude that in particular emissions from oil production are underreported by a factor of 2. Looking at the trend 2010-2017 for the US, they conclude that CH4 emissions appear to have peaked in 2014 and thereafter slightly declined with the overall trend for the period still slightly increasing. This is in contrast to US official reporting to the UNFCCC, where emissions decline steadily over the period. The authors attribute the increases they find to oil production and landfill, while emissions from gas production are said to decline (and livestock and coal mining stay flat). Given that according to EIA, US shale gas production increased by 227% (from 165 to 540 bcm) over this period while oil production increased by a more modest 71% (and other natural gas production declined by 39% from 493 to 300 bcm), I am not convinced about the authors' split in attribution between oil and gas sector emissions. I wonder if the inversions can really make this distinction between oil and gas sources as fields in the US are often producing both oil and gas? If authors are not able to do this split in a robust manner, then I would recommend the authors not to report oil and gas sector emissions separately, because from a policy point of view this matters a lot. If there is a risk that authors are wrong about their conclusions here and that in reality it is a strong increase in methane emissions from shale gas production that is picked up (and not oil), then you risk sending the completely wrong signal to policy-makers (i.e., "fix oil but don't' worry too much about gas production", when it could be that the real problem is the shale gas). So if there is uncertainty regarding this, then report oil and gas emissions together and leave it to further research to figure out this split in more detail.

Response [1-2]: Thank you for pointing it out. We have consulted with our EPA collaborators, on this important issue. They recommend separating oil and gas methane emissions in our inversion. This is because the national inventory is required to separate oil and gas emissions when reporting to the UNFCCC, but each country can make its own distinction between oil and gas so definitions will not always align. As our inversion uses the gridded inventory

developed from the official GHGIs as the prior emissions, separating the oil and gas emissions in the posterior emissions can help focus areas of improvement on oil versus gas, which can be useful for compilers of the national reports. We prefer to follow their recommendation and keep the separation of oil and gas methane emissions.

We acknowledge that our methods for separating sectoral methane emissions may not be able to fully split the oil and gas emissions. We quantify this ability at the country-level by calculating the error correlation coefficients (r) in the inversion results for sector pairs, as show in Fig.6. We add the following statement in Section 3.2:"Optimization of the oil/gas sector is well separated from the other sectors in all three countries, and separation between oil and gas is also successful because the two sectors have very different spatial distributions in the gridded inventories (Figure 2). However, there is some ambiguity for the production subsectors, because wells often produce both oil and gas (Maasakkers et al., 2016), and for this reason some studies prefer to refer to oil/gas emissions as a combined sector (Alvarez et al., 2018). Separating oil and gas emissions is useful for our purpose because such separation is required under UNFCCC reporting, but the reader should be aware that this separation is done on the basis of the spatial distributions of emissions in Figure 2."

As for the EPA reports on sectoral emission trends, we find that EPA GHGI also estimates decreasing emissions from natural gas systems from 2010 to 2017 (EPA, 2021). This decrease is mainly driven by exploration (80% decrease from 2010 level) and distribution (12% decrease from 2010 level), while the emissions from gas production are quite flat, even though gas production has increased. The contributing factors to the decreasing gas emissions in the inversion results would require further analyses at basin and process level that we are now addressing in follow-up work.

We add the following statement in Section 3.3: "The EPA inventory reports no significant trend for oil emissions, and attributes the decrease in gas emissions to gas exploration (80% decrease from 2010 level) and distribution (12% decrease from 2010 level), with flat emission from gas production. However, both oil and natural gas productions have increased significantly over the period (https://www.eia.gov/). More work is required to understand the discrepancies in oil and gas trend estimates between the inversion and EPA reports. We cannot exclude the possibility that oil and gas emissions are not adequately separated in the EPA inventory and/or the inversion at this stage."

Comment [1-3]: MINOR CONCERN/EDIT: p.11 row 387: write out the acronym DOFS.
Response [1-3]: We have stated in Line 252 where "DOFS" were first used: "We refer to the diagonal elements of A as the averaging kernel sensitivities, and to the trace of A as the degrees of freedom for signal (DOFS), representing …". We also rephrase here "The number of independent pieces of information afforded by the observations (DOFS = 114) can be placed in the context of the 600 Gaussian state vector elements used to optimize the spatial distribution of emissions."

Comment [1-4]: p.14 row 530: It is suggested that the downward correction for offshore operations can be referred to that methane from offshore oil platforms is piped onshore and inefficiently flared. Another possible explanation could be that when methane leaks happen at the seabed, methane oxidises to CO2 in the water column before reaching the surface and therefore emissions are

considerably lower during offshore production. Could this be an explanation here?

Response [1-4]: Thanks for bringing up this assumption. We have modified the text as "This is consistent with aircraft and TROPOMI satellite observations, which attributed the low offshore emissions to piping of the gas onshore followed by inefficient flaring (Zavala-Araiza et al., 2021; Shen et al., 2021). In addition, methane released to the ocean could be oxidized to CO2 in the oxic water and hence not reach the atmosphere."

Reference

Shen, L., Zavala-Araiza, D., Gautam, R., Omara, M., Scarpelli, T., Sheng, J., Sulprizio, M. P., Zhuang, J., Zhang, Y., Qu, Z., Lu, X., Hamburg, S. P., and Jacob, D. J.: Unravelling a large methane emission discrepancy in Mexico using satellite observations, Remote Sens. Environ., 260, 112461, http://doi.org/10.1016/j.rse.2021.112461, 2021.

Zavala-Araiza, D., Omara, M., Gautam, R., Smith, M. L., Pandey, S., Aben, I., Almanza-Veloz, V., Conley, S., Houweling, S., Kort, E. A., Maasakkers, J. D., Molina, L. T., Pusuluri, A., Scarpelli, T., Schwietzke, S., Shen, L., Zavala, M., and Hamburg, S. P.: A tale of two regions: methane emissions from oil and gas production in offshore/onshore Mexico, Environmental Research Letters, 16, 024019, http://doi.org/10.1088/1748-9326/abceeb, 2021.