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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying methane emissions from Queensland's coal seam gas producing Surat Basin using inventory data and an efficient regional Bayesian inversion" *by* Ashok K. Luhar et al.

Anonymous Referee #1

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This paper employs a dataset of quasi-continuous measurements over an 18-month period from two monitoring stations in the middle of a region characterized by a mix of largely anthropogenic methane sources to optimize gridded methane emission inventory estimates. It aims to scale inventory emission estimates for individual grid boxes with a focus on the coal seam gas (CSG) industry. Given the current lack of atmospheric data to inform CSG methane emissions in Australia and elsewhere, this paper is a useful addition to the literature to help researchers improve their methods to quantify emissions from this source. The analysis is very detailed, the paper is well written,

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and the tables and figures are well presented.

However, I have two major comments/questions that may be important for the bottom-line implications of the study:

1. The background methane mole fraction estimation (Supplementary S3) requires some more discussion. As Figure 3 shows, both monitoring stations are surrounded by known methane sources that are being quantified here. The monitoring stations do not measure the background air entering the spatial domain for which the emissions are being quantified here (hence background estimation). Filtering peaks during the early afternoon may exclude the largest point sources, but not necessarily the area sources that are clearly shown to exist in Figure 3. Does this estimation method create a high bias for the background levels, and in extension a low bias for the posterior emissions (especially from distributed sources like CSG wells)? Could this explain why all inverse setups produce smaller posterior total emissions than the prior despite the acknowledgment in the paper that the inventory may miss some sources (so the inventory itself may be underestimated)? Note that the opposite is true when looking only at the CSG sub-domain, which is situated largely between both monitoring stations (thus the sources in the CSG sub-domain affect estimated background values to a lesser extent), which appears to underscore this conundrum. It is also noteworthy that such underestimation may be masked also in the q-q plots comparing observed and modeled concentrations because a potentially underestimated prior and overestimated background would compensate each other.

2. How are the higher-end modelled methane concentrations (but low occurrence, potentially not due to the infrequent emission, but rather due to their being point sources with fewer opportunities to be sampled) weighted against the overall average methane (but high occurrence) in the inversion model framework? Is this objectively weighted in the model (and if so, how), or is it a model design choice?

Below is a list of detailed comments that may help clarify arguments and language,

and correct potential errors.

Main article:

1. Ln 39: For balance, there's an ongoing discussion about the contrasting evidence (contemporary local measurements vs. ice-core 14C data) regarding the magnitude of the fraction of natural geologic seepage: https://www.elementascience.org/articles/10.1525/elementa.383/

2. Ln 58: "independent": I suggest "atmospherically based" instead since inverse estimates are by definition not completely independent of the prior/inventory.

3. Ln 71: Through this or any top-down approach? Would be valuable to mention if other top-down approaches have been used in Australia in the past.

4. Ln 158: Would re-phrase that the two operators account for 1.5% of CSG production activity in the region, not emissions (which would be difficult to establish with any accuracy).

5. Ln 189ff: Spatial resolution of $2.5^\circ \times 2.5^\circ$ means (roughly) 250 x 250 km2. How, then, is it possible to apply it at 5 x 5 km2? Regarding the meaning of the 6 hour availability of met re-analyses, does it means that the temporal resolution is 6 hours?

6. Ln 291: I assume you're referring to the bottom-up emission inventory?

7. Ln 666: Arguably Figure 14b cannot be used to support the trend in the CSG activity data. According to Ln 609, only 4% of the sub-domain emissions are due to CSG wells (and unclear whether the same processing facilities would emit more given more throughput), so any increase in well count may hardly be detectable by the monitoring stations. Thus, the insight here seems to be not that measurements aren't supporting the CSG increase, but that the existing monitoring setup is likely unable to detect.

Supplementary:

1. Ln 99: Emissions of methane due to incomplete combustion of CSG

2. Ln 100ff: Why are methane GWPs used for methane emissions from incomplete combustion, fugitives, and coal extraction? It sounds like the underlying EFs are given in CO2e, which seems illogical.

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