Summary

The manuscript 'Atmospheric observations consistent with reported decline in the UK's methane emissions, 2013–2020' presented by Mark Lunt and Co-workers describes the results of atmospheric inversions of methane in the UK and Ireland. The manuscript builds on established inverse modelling frameworks but widens the scope of previous studies by applying these methods to a longer period, analysing the impact of variations in the observational network, the prior emissions and the employed transport model. As such the manuscript offers new insights and well-timed discussion on the requirements of observational networks for the estimation of nation emissions and their trends. The work is well organised and described and should be published after some minor corrections and additions (as detailed below) are implemented.

Minor comments

Section 2.1: The distinction between DECC and GAUGE is not always very clear. In the introduction they are described separately but in this section the title is just DECC. It would help to add a column to table 1 to indicate which network each station/platform is/was part of. A short statement of measurement uncertainty for the different sites/instruments would be good (maybe as part of Table1). How was this observation uncertainty considered in the inversions?

Table 1: It would also be good to include the full names of the sites in the table.

Inversion domain: It is not clear from the figures focusing on the British Isles how large the complete inversion domain was. It is hinted that European regions were part of the inversion, but were those only the ones shown for example in Figure 1? If the domain was as small as shown I would think that the boundary condition (baseline) problem may be much larger than currently discussed considering the large emissions located to the Southeast in the Benelux area. If the inversion domain was much larger the question arises, why no additional observations from other sites in Europe were considered?

Section 3.2: The description how source sensitivities were obtained with GEOS-Chem is rather brief. It would be good to provide a little more detail in order to better understand the limitations/advantages of the approach over the NAME approach.

Section 4: Outside the UK EDGAR v4.3.2 was used as prior distribution and again in the sensitivity tests. What was the reference year for EDGAR? There are also much newer versions of EDGAR available. Why not use them?

L234: Here it says that the 'model error correlation time scale' is part of the hierarchical approach, but on line 238f it says that it was fixed to 6 hours. What is correct?

Model uncertainty: rj-mcmc and InTem use quite different approaches for the model uncertainty used in the inverse step. Would it be possible to compare/comment on the finally used uncertainties? Could these be the main source

of the very different a posteriori uncertainties dervied by the systems?

Section 5.3: Is it correct to conclude that InTem used the less strict filter criterion for the observations? How much data was retained in the InTem case? Was there a seasonality in the amount of data used by the two systems and could that explain the differences in the seasonality of a posteriori emissions?

Figure 3: From the x-axis of the 2-monthly inversions it is not clear for which 2-month intervals the inversions were carried out. Jan/Feb, Mar/Apr, etc? Maybe this could be reflected by the axis labels instead of using just numbers.

L300: Please comment on which of the two uncertainty estimates (rj-mcmc vs. InTem) is more realistic. This is important when discussing the significance of any trend in the emissions.

L302: How were the trends and uncertainties calculated? Were the uncertainties of the posterior in the individual months taken into account? From Figure 3 I would have judged that the trend for InTEM is not significant given the large uncertainties.

L339f: The emission 'anomaly' in summer 2018 is much stronger in the rj-mcmc results than in InTem. Again the question if this could be due to different observations being assimilated. Furthermore, it would be interesting to see where these differences occur spatially.

Figure 5 and related discussion: Are there no InTem results available on the sub-national scale? It would be important to show that the inversions agree also on smaller than the national scale. In this regard, it would also be beneficial to include some figures of a posteriori distributions or increments in the manuscript or supplement. This concerns both the differences between the inversion systems but also the question how stable the distributions are over time.

Section 6.3 and Table 2): From the description it is not clear what is really used in the last 3 cases. Ferry and FAAM is clear, different mobile platforms, but were these used in addition to the DECC towers or exclusively? Table 2 contains another case GAUGE what does this include? Later when the results are discussed these points become more clear, but the information should already be given when the cases are introduced. It would also be good to indicate in the table for which periods the inversions were run.

Discussion of results in Section 6.3: The impact of the network on national and sub-national totals is discussed, but what is the impact on the estimates by sector? If you conclude that UK total CH4 emissions can be estimated from just two sites this may be correct, but isn't there additional benefit if one could learn more on the emissions by sector? See additional comment below.

Figure 6: It is interesting to note that the posterior uncertainty on the continent seems to decrease most when just MHD or MHD/TAC are used in the inversion, whereas large parts of the Benelux area remain white when the whole network was used. How is that possible?

L423f: The comparison in Figure 3 is not against the MHD only inversions. So the second sentence only refers to Table 2. The 'Ferry' and 'FAAM' results in Figure 3 are never really commented on.

L442f: Were the flight observations neglected for the combined observations? Why?

L449: Figure 7 also includes results for Ireland not just UK and DA.

L454: Larger variability is not very obvious. Maybe for England, but certainly not for the other areas.

L456: Is this RMSE for all observations from all sites? Separating this for the different sites could indicate where GEOS-Chem has more trouble. Most likely for the more polluted sites due to a lack of resolution in the local transport. Furthermore, does a bias play a role in the RMSE calculation? If so it may be better to compared a bias-corrected (centered) RMSE.

Section 6.5: Also here it would be interesting to show and comment on the posterior distributions from these inversions. Where does the correction of the EDGAR prior happen? How much detail can be picked up from the flat prior?

L514f: I would be more careful with this conclusion. Halocarbons often have a much more pointy emission distribution than CH4. Furthermore, this distribution is much less well known both spatially but also in magnitude. For CH4 your conclusion may be correct but in the end differences between prior and posterior remained relatively small, even in the flat prior case. Hence, the small impact of additional sites may simply come from the high quality of the prior. You simply don't need more information to bring the emissions in agreement with the model.

L541f: Again, this conclusion is a bit general. The UK is an island! For similarly large countries/regions on the continent surrounded by other emitting ares, the conclusion may not be correct, because a separation of contributions from different countries may not be as straightforward for any inversion system.

L544: 'beyond the total country annual emissions'. Exactly this may however be the important information inversions should be able to deliver for example when evaluating if reduction measures in individual emission sectors or even processes where as successful as envisaged by mitigation measures. Really just a comment.

Technical comments

Reference to supplementary material: It would be nice to refer to a concrete figure/section/table of the supplement instead of just stating that something is available ....

L42: 'through' instead of 'though'.

L90: 'Tohoku University' instead of 'Tohoku university'.

L203: Add ',' after J.

L357: Delete 'the' before 'Ireland's'.