Atmos. Chem. Phys. Discuss., 15, C716–C723, 2015
www.atmos-chem-phys-discuss.net/15/C716/2015/

Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Quantifying methane and nitrous oxide emissions from the UK using a dense monitoring network" *by* A. L. Ganesan et al.

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Received and published: 12 March 2015

We appreciate the helpful comments and feedback from the reviewer and address them below. Reviewer comments are italicized followed by our responses. Page and line numbers correspond to the revised manuscript.

Comments

Abstract, P858 L1-8: These three sentences do not really belong in an abstract, but rather in the introduction.

The abstract has been changed to: The UK is one of several countries around the world that has enacted legislation to reduce its greenhouse gas emissions. In this study, we present top-down emissions of methane (CH4) and nitrous oxide (N2O) for the UK and Ireland over the period August 2012 to August 2014. These emissions were inferred using measurements from a network of four sites around the two countries.

P858 L21: It would improve the readability to start a new paragraph here, between the discussion of emissions and the discussion of uncertainty.

Thanks for the suggestion but we prefer the format of one paragraph for the abstract.

P859 L21: I find the wording of this sentence odd; perhaps 'N2O has the highest emission uncertainty of all the gases in the inventory' or similar.

The sentence has been reworded and now states 'Of all the gases in the inventory, N2O has the highest emission uncertainty.'

P859 L24: Table 1 does show where the emission estimates for CH4 come from in terms of citations but it does not show that anthropogenic sources dominate, as indicated here in the text. It would be useful to add to Tables 1 and 2, or as a new table, the total emission estimates for all these categories (natural and anthropogenic) for CH4 and N2O.

The following has been added on page 9 line 290, 'Natural emissions were compiled from a variety of sources outlined in Tables 1 and 2. To account for anthropogenic land that was classed as natural in these inventories (for example, the natural soil N2O source did not mask out agricultural land), natural emissions were scaled by the fraction of natural land in each UK and European country based on land cover maps [Morton et al., 2011, EEA 2007]. The contributions of the major source sectors to the UK and Ireland totals are presented in Tables 3 and 4. Anthropogenic sources were approximately 90% of the total for both gases.'

P861 L21-P862 L15: The information here is quite hard to follow and would be easier to comprehend as a table, with columns (for example): CH4 instrument, CH4 measurement period, N2O instrument and measurement period, sampling heights available and used, and altitude of each site.

Thank you for this comment. We have added Table 1 to make this information more clear and concise.

P862 L16-26: Why was two-hour averaging chosen? Did data analysis or a previous publication suggest no significant changes within this time, or is it rather a compromise for the amount of data that can feasibly be handled?

The two-hour period was chosen for two reasons: (1) To minimize not only data volume but the amount of model footprints that would have to be generated and used in the inversion; (2) this is consistent with the measurement period of other measurements made on site (Medusa-GCMS system for halocarbons);

In the text on page 4 line 115, we state, 'This period was chosen to minimize data volume and to be consistent with the sampling period of the halocarbon measurement system in the network.'

P862 L24: The abbreviation SD is used several times in the paper and not defined. Although it is relatively common it should still be defined here at the first instance.

We have defined SD on Page 4 Line 124. This notation was implemented by the journal during the typesetting process.

P863 L5: Why were particles tracked for 30 days? Surely most particles would exit the UK domain and even the extended Europe domain long before 30 days.

Due to the size of the extended domain, which will now be clear in Figure 2 (Figure 1 from original supplement), 30 days was used to ensure that particles would have left the domain. We have done tests to find out what percentage error would occur by particles remaining in the domain at the end of the simulation and found 30 days to be adequate in this domain.

P869 Section 5: Should be titled 'Results and Discussion' as no separate discussion section is included. In addition it would improve readability if Section 5 were broken up into a few subsections, according to the different topics ie. total emissions, sectoral comparison, uncertainty...

Section 5 has been retitled Results and Discussion and subsection titles have been inserted.

P869 L24: How much larger were the uncertainties? It would be interesting to know quantitatively how much difference the extra site makes to the total emission estimates.

Uncertainties were on average approximately 36% larger on UK CH4 emissions during January-May 2013 and 50% larger on UK N2O emissions during December 2013-January 2014, than the average of months sampled by the full network.

P871 L4-22: The discussion here is a little hypothetical and somewhat meaning- less. It is clear that the prior disagrees regarding seasonality, as it is annually resolved, so no information can be found from the seasonal differences to the prior. It is also well-known from countless studies that fertilisation leads to N2O emissions, and that factors such as fertiliser and climate affect agricultural N2O emissions. It would be interesting to know if fertiliser is in fact applied earlier (ie. Spring) in eastern England than in central England (summer) in agreement with the posterior modelled seasonality in the emission distribution; or whether climate such as rainfall patterns may be able to explain the different seasonality between these regions in the posterior. This may provide new information on whether the seasonality seems dominated by fertiliser or climate for the modelled years in the UK.

We agree with the reviewer that it is well known that fertilizers are linked to N2O emissions. However, the seasonal patterns of fertilizer application in the UK are not necessarily well known, and unfortunately, fertilizer application information (type and rate used) in the UK is proprietary information that was not available to be used as part of this study. There is limited information released on 'recommended' fertilizer application - type and rates based on crop type, however, extrapolating this to real concentration data is challenging - the meteorological conditions of the two years of this study have been quite different, with 2014 being one of the wettest on record with significant portions of the UK being flooded and this would likely impact when and how fertilizers were applied, that would deviate from the 'recommendation'. We very much agree with the reviewer that disentangling the sources of the variations in the

UK, spatially and temporally, through the use of process-models and/or regression analyses is very interesting and very important, and this is the subject of future work.

We have added on page 12 line 378, 'Further elucidating the drivers of this seasonality requires process or empirical models of N2O production.'

P871 L24: It is difficult to see if this is true from the referenced figures, as the uncertainties in the figures are relative to the median emissions. In fact it looks like emission uncertainty is lowest across Ireland and south-east England, and quite high around Mace Head and Tacolneston, but perhaps this is due to the magnitude of emissions as well. It may be useful to include a fourth panel to each figure showing the absolute uncertainty in the posterior emissions, or the uncertainty reduction relative to the prior uncertainty.

A panel (d) has been added to Figures 4 and 5 that shows uncertainty reduction from the prior. This panel will further indicate the regions that the observations are most sensitive toward.

P872 L24: Insert a line break and start a new paragraph before switching the discussion from CH4 to N2O.

We feel that this paragraph is about the uncertainties derived for both gases, as we compare the two together to gain insight into the sources of discrepancy. For this reason, we feel it is best to remain in the same paragraph.

P872 L24-27: The ratio between uncertainty at RGL and at TAC is 0.78 for CH4, *while for N2O it is 0.80 (as far as I can tell from the figure). It is therefore not really true that the uncertainties are similar for N2O and different for CH4 at the two sites. I would say the uncertainty is higher at TAC for both gases. This may even suggest that it is model error rather than unresolved emission processes - opposite to what the authors propose at L26-27.*

The ratio of RGL to TAC is 0.78 for CH4 and 0.95 for N2O, so there might have been an error interpreting the numbers from the figure.

P874 L16: The inclusion of isotope measurements was not discussed in this paper at all. It would of course be interesting to have a discussion of how much isotope measurements may improve results in the current set-up, although it may be beyond the scope of this paper. Otherwise, a paper showing that isotope measurements can improve modelling results should be cited (eg. Rigby et al. 2014?).

The analysis of the additional constraint provided by isotope measurements is beyond the scope of the paper because these measurements do not currently exist. However, we have included the citation for the Rigby et al., 2012 publication showing the value of isotopologue measurements for source partitioning.

Conclusions: Other changes mentioned throughout the results should be reflected in updated conclusions.

Ireland emissions are included in conclusions.

Regarding natural sources: ‘The small natural sources in the UK are not likely large

enough to account for the full discrepancy between the prior and posterior emissions’

NAEI has been changed to anthropogenic inventories to include Ireland in the conclusions

Figure 1: I would find it useful to see the total emission distributions for CH4 and N2O, as well as the major sectoral emissions.

We have provided maps of the dominant anthropogenic sources along with a map of the total annual average prior. We have also included Tables 3 and 4, with the percentage breakdown of each source to the UK and Ireland totals (natural sources are 5-12%). Together, the reader will understand the contribution of natural emissions in the UK and Ireland.