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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aircraft-based inversions quantify the importance of wetlands and livestock for Upper Midwest methane emissions" *by* Xueying Yu et al.

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We thank the reviewer for the positive review. Reviewer comments and our responses are provided below.

1) The paper "Aircraft-based inversions quantify the importance of wetlands and livestock for Upper Midwest methane emissions" by Yu et al., presents an interesting piece of research regarding the estimates of methane emissions in the upper Midwest US based on aircraft measurements. The authors apply multiple inversion approaches to quantify the methane emissions for three seasons and conclude that wetland emissions are the largest methane source in Midwest US, next by livestock emissions. Generally,

the paper is well-written, and the methodology is sound. However, I feel the section 4 and 5 need to be presented in a clearer way. I also have a few questions regarding the methods and conclusions, mostly about the wetland methane:

Thank you for the positive review. We have revised the draft based on the specific suggestions below.

2) Given such large uncertainty in wetland emissions and wetland extent, how sensitive are the model results and conclusions to the choice of a wetland prior? How reliable is the conclusion based on one wetland methane product? There are a few recent bottom-up ensemble wetland estimates (Saunois et al., 2020) with different wetland extents using different wetland models. Will applying a different wetland prior lead to different conclusions? This would also be helpful to further inform the wetland methane community. The setup of prior emissions for wetlands. I found the treatment of scaling up the WetCHARTs ensemble mean by 10% is not justified and it's unclear how this treatment affects the conclusions that wetland methane is the largest source in the study region. Livestock emissions could also be systematically underestimated, which is suggested by the authors and by Wolf et a., (2017). In addition, WetCHARTs is a global methane wetland product - Why would it need to be scaled up to match the other global estimate (Kirscheke et al., 2013)? Also, Kirscheke et al., (2013) estimates for wetland emissions are not up-to-date. There are a few more recent estimates such as Saunois et al., (2020), which suggests the ensemble mean of bottom-up estimates for wetland CH4 is likely at the low end of the range of the WetCHARTs estimates.

Thank you for these comments. To address this concern, we have now added an additional sensitivity inversion in which we employ an alternate wetland emission estimate as prior. The selected estimate is an individual case among the WetCHARTs ensemble that employs CH4:C q10 = 1 and GLOBCOVER wetland extent. The resulting prior emissions are 137 Tg CH4/yr globally (25% lower than the ensemble-mean estimate used as base case). This alternate prior thus features global emissions within the range of the Saunois et al. 2020 ensemble (102-182 Tg CH4/yr for 2008-2017) and in

fact lower than their central estimate (149 Tg/y). Within our study region the total prior wetland emissions for this sensitivity test are 29% (spring) and 46% (summer) lower than in the ensemble mean case, with prior differences in specific locations ranging from -70 to +40% (interquartile range) in spring and from -78 to +10% in summer. Results for this additional test are now described in Supplemental Information. We find the optimized fluxes in this sensitivity analysis fall within the uncertainty range previously defined by the multi-inversion ensemble. The Figure attached (now included in the SI as Fig. S12) further shows that the derived spatial distribution is broadly similar to that obtained for the base-case adjoint inversion. Accordingly, our major conclusions still hold for this sensitivity analysis, including those pertaining specifically to wetlands (e.g., an underestimate in the Prairie Pothole region / overestimate for Great Lakes region, and biased spring emission onset) – thus supporting the results of our base-case inversions.

The same sensitivity analysis also shows that our results are not overly sensitive to the 10% global scaling mentioned by the reviewers, since emission differences for this test significantly exceed 10%. Finally, we would like to point out that the regulation parameter tests described in the manuscript (now in SI) are specifically designed to test the sensitivity of our results to the prior emission assumptions. As described in SI Section S1, our overall results remain robust even when varying the prior weighting in the cost function by a factor of 10.

3) I would suggest the authors include their findings of the livestock in the abstract regarding whether the inventories underestimate the livestock as found by Wolf et al., (2017). I found it's discussed in the main text but it is not mentioned in the abstract.

Thank you for the suggestion. The abstract states our finding that inventories underestimate livestock emissions in summer/winter. ACP guidelines indicate that reference citations should not be included in the abstract so we have not cited the Wolf paper here. However, we have added a mention of this paper to the summary.

4) Equation 2: how does the wetland extent vary with time while using two static wetland extent products (i.e. GLOBCOVER and GLWD)?

Thank you for catching this omission. Bloom et al. (2016) prescribed the temporal variability in wetland extent using satellite-based or reanalysis-based hydrology parameters. We have now clarified this point in the manuscript as follows:

"Here, A(t,d) is wetland extent (m2 wetland area/m2 surface area) based on either GLOBCOVER (Bontemps et al., 2011) or the Global Lakes and Wetlands Database (GLWD) (Lehner and Döll, 2004), with temporal variability prescribed using satellite-based surface water or reanalysis-based precipitation datasets (Bloom et al. 2017)"

5) Line 122: If I remember it correctly, EDGAR v4.3.2 only has yearly estimates. it's not clear how you obtain the seasonal emissions from EDGAR.2020.

Indeed, EDGAR v4.3.2 only has yearly estimates. However, anthropogenic emissions for our US domain are based on the GEPA inventory, which features seasonal livestock and rice emissions. We have now clarified this point in the text.

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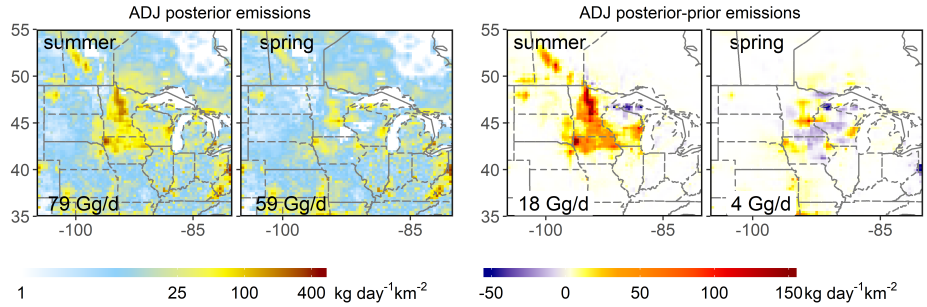

Fig. 1. Optimized emissions using an alternate wetland prior emission estimate. Panels on the right reflect the difference between the optimized emissions and the alternate prior emissions.