

Overview:

The manuscript “Multi-species inversion and IAGOS airborne data for a better constraint of continental scale fluxes” by Boschetti et al. describes the effect of including the correlations between multiple species in a bayesian inversion framework in order to improve error reduction compared to solving for individual species independently. The experiment described in the manuscript uses synthetic observations based on measurements made during the IAGOS campaign in Europe in order to assess the potential for future measurements of CO₂, CO and CH₄ during this campaign to better constrain regional emissions of all three species. Finally, there is some discussion of the effect of different assumptions about the prior error of the emissions upon the level of error reduction achieved by the inversion.

Overall the manuscript is fairly well written, with few technical corrections necessary. The figures are generally quite clear and well chosen, although some further detail needs to be provided for some of them. The methods and models used within the manuscript are appropriate for such a study, and are able to provide some assessment of the potential for improvement supplied by future multi-species measurements as part of the measurement campaign. The paper is successful as far as it goes, and whilst it would have been nice to further examine the effect of different experiment set-ups within this paper, the authors acknowledge that this is the case, and may be the focus of a future manuscript.

My main reservation with the study is that the results and discussion section is a little light on detail in places and feels like it was rushed, making the thread of the paper more difficult to follow than it should be. More details and deeper analysis of the results is needed in order to contextualise the findings of the experiment. The authors must make sure that all terms used have been explained or defined, and that they provide enough analysis of their results. See general comments for details. I suggest that this paper is suitable for publication in this journal after the following revisions are carried out and the results section is improved.

Comments:

Page 3 line 6: “Because most biogenic fluxes in Europe are influenced by human activities...” - reference?

Page 4, lines 1-2: “proven to be important in the fields of...” - reference?

Page 8, line 18: the first term in equation (3) should be to the power of (-1).

Page 8, line 31: the term “50% footprint” should be explained.

Page 8, line 15: is it fair to assume no correlation between months? You should comment here (or later in the discussion) on whether this would be the best set-up of the correlation matrix in an inversion using real observational data.

Page 12, line 4: What is *enh*?

Page 12, line 7-8: You need to explain how you derive ϵ_{tran_v} in more detail here.

Page 12, line 18: What method do you use to invert \mathbf{S}_{prior} and \mathbf{S}_e ?

Page 13, line 5: Describe which version of the model output you are plotting in Figure 5. Does it use the prior emissions?

Page 13, line 9: Here, and in the caption of Figure 5, you say that the modelled CO is multiplied by a factor of 2.8. However, the legend of Figure 5 appears to say that the observations have been scaled. Which is correct?

Page 13, line 12: Explain here what it is that is indicated by the performance of the model compared to the observations. Are you saying that the meteorology that you use and the correction to z_i that you apply produce a good indication of the temporal variation of the ML enhancement? Does your choice of z_i display an improvement over the original?

Page 13, lines 25 and 26: You could probably add a little more detail to this one-sentence paragraph. Explain that Figure 6 is showing the prior and posterior emission error covariance matrices for the base multi-species inversion. Do the single-species matrices show a similar overall error reduction? Do you expect to see negative correlations in the posterior matrix? As it stands this sentence is disjointed and appears to come out of nowhere and doesn't relate to other text, making the manuscript unnecessarily difficult to follow.

Page 14, lines 24 - 28: Explain what you mean by “a perturbed version of the prior” here. Also, does the multi-species inversion capture the “truth” any better or worse than the single-species inversion?

Page 15, line 19: How robust do you think the relative uncertainty reductions that you derive are against different manifestations of the “true” fluxes?

Page 15, line 26: Why do you think a smaller prior error for the CO₂ FF fluxes compared to the other species leads to a greater uncertainty reduction for the posterior fluxes?

Page 16, line 3: What makes CO sensitive to different correlation structures during different seasons?

Technical corrections:

Page 1, line 13: no comma needed in “for, GEE”

Page 1, lines 17 and 18: the percentages reported in the abstract here are in some cases slightly different to those reported in the main text of the manuscript (on page 15).

Page 2, line 2: difference -> differences

Page 5, line 10: Matherial -> Material

Page 10, line 3: Section 2.1.6 -> Section 2.1.5

Page 16, line 18: Delete “meaning” - or explain what it means.