Response to Referee #1

1 General Comments

The authors provide a novel re-imaging of the canonical RIP technique in the LETKF through the no-cost smoothing approach in order to provide a better spin-up of the ensemble accuracy. The method is used to estimate surface carbon fluxes through a sophisticated model using real-world observations. Quantifying Earth's is an essential part of our modern understanding of the Earth's climate.

The approach is certainly novel and has the potential to be applicable to a wide range of geophysical—and large-scale in general—data assimilation problems.

Thank you very much for your constructive and insightful comments.

2 Specific Comments

Section 3: It is not immediately clear what error is being measured, and why it is not a time-averaged RMSE.

Thank you very much for the comment. We did use the time-average RMSE. The RMSE value in Table1 and the sub-titles of Figures 3 and 5 are the time-averaged global mean RMSEs. We clarify this in the revised manuscript.

Section 2.2 talks about throwing away 'low-quality' observations. As the authors no doubt know, the Burns Effect places a significant burden on making sure that no unique correct observations are discarded. The reviewer would like to see more justification for this sort of heuristic.

Thank you very much for the comment. The approach to aggregate OCO-2 has been described by Basu et al 2018. We have included a brief description and cited this reference in the revised manuscript.

The observation network from Basu et al 2018 had used to produce pseudo-observations that are somehow statistically representative of real OCO2 data. Since we conducted our study under the OSSE framework, these observations are idealized. The side effects in the real OCO-2 dataset generated by aggregating observation or throwing away 'low-quality' observations will not be carried over to our pseudo-observations. We have clarified this point in the revised manuscript.

In Section 2.2 again, the reviewer would like to see more justification of this type of pseudo-observation.

See response to previous comment.

In section 2.5: As far as the reviewer can tell the paper never explicitly mentions the size of the component space (nor frankly any roughly estimated dynamical properties of either the system or the model) of the model, thus it is impossible to gauge the sufficiency of the ensemble size.

Thank you this comment. We have clarified in the revised manuscript that the experiment (system) include one state variable (co2) and one parameter (surface carbon flux) at each grid point. When we talk about ensemble size, one must consider both sets of variables. Given that the choice of ensemble size is determined heuristically, with due consideration to model-assimilation system complexity and required computational time. We did evaluate the ensemble size through a series of

simulations and determined that a sample size of 20 is reasonable for our assimilation experiments. We have clarified this point in the revised manuscript.

In Section 2.6 Additional clarification about additive inflation being randomly selected from the nature run would be appreciated.
Thank you for this comment. We have added more details on the additive inflation method in the revised manuscript.

In the conclusion the authors talk about advantages over that of 4D-LETKF, but omit to mention vanilla 4D techniques, which are still state-of-the-art, and against which such computationally intensive smoothing would have to compete.
Thank you very much for the useful comment. We do agree that 4D-LETKF is a state-of-the-art technique, though it is not our focus in this paper. We have added some discussion related to 4D technique, as per your suggestion, to the revised manuscript.

3 Technical Corrections
The overall document could use some basic proofreading to address fundamental grammatical and lexical issues. A non exhaustive list:
• p11 l1: LETKF
• p11 l11: LETKF
• p12 l5: the first two months
• Honestly all of section 2.6
Thanks for comments. We have made these changes in the revised manuscript.