Comments from the reviewer and editor are in red text and the response is in blue text.

Editor's comments:

I would strongly recommend that the authors consider some of the recommendations provided by the reviewer. From the revised submission, it becomes clear that the FDT method has been applied before. However, this does not lessen the scientific value and significance of this work, which makes it highly relevant the carbon cycle science community. The manuscript would be made much stronger and valuable if the authors at a minimum provide a more detailed quantitative comparison with a figure or table to demonstrate that the FDT approach is improved by adding the ensemble part. This goes beyond the fact that a clear advantage of the EFD approach is the ability to calculate uncertainties as shown in Section 5.1. And/or expand more on the advantages of their method over the ZCD method. All of this can be handled via a short discussion section - again pieces of which are scattered in the text and Conclusions. Overall, the authors have done a commendable job in handing the reviewer comments and suggestions from the original version and I look forward to seeing the impact the proposed methods have on improving our understanding of the carbon uptake period.

Response:

Thank you for suggesting the resubmission of the manuscript with revisions. The suggestion was to strengthen the comparison between the EFD and the approach in Barlow et al., (2015) (hereafter referred to as Barlow) or between the EFD and the ZCD method. We address this in a new section (Section 5.3) where we test the sensitivity of the three methods (ZCD, EFD and the approach in Barlow) to actual changes in the CUP. We compare the three methods based on their ability to identify changes made in the CUP of idealized NEE fluxes. The ZCD method is found to be the least sensitive, adding to the advantage of methods based on the first derivative of the CO_2 time series over the ZCD method, in addition to those discussed previously. We do not find substantial differences between the sensitivity of EFD and the approach in Barlow. However, the approach in Barlow does not give an uncertainty estimate. Hence the uncertainty in its sensitivity could not be evaluate, clearly showing a disadvantage of the method. Thus, the sensitivity analysis strengthens our claim that the EFD method adds to the benefits of the method in Barlow and gives robust estimates than the ZCD method.

Reviewer's comment:

In my initial review of the paper, I found the first derivative threshold (FDT) method for estimating the carbon uptake period (CUP) to be the interesting aspect of this study. It is unfortunate that the authors were not aware that this method had been previously published by Barlow et al. (2015). While the authors have acknowledged this multiple times in the revised manuscript and provided some discussion, the lack of the novelty of the FDT method weakens the paper's suitability for publication in AMT. To make the paper stronger, the authors need to provide some additional analysis.

The paper needs to provide a clearer explanation of the advantages of using an ensemble threshold approach with FDT. There is very limited discussion and no figures or tables comparing their ensemble first derivative (EFD) and FDT methods. Instead, the paper extensively compares the performance of the EFD method and the zero-crossing dates (ZCD) method. The authors hint that the ensemble approach is better than the FDT method, but these claims need to be backed by quantitative analysis, including a figure. Additionally, the paper needs to explain in detail how the data-derived year-to-year uncertainty from their ensemble approach provides a more robust threshold estimate, and how this could improve trend analyses of seasonal cycle changes in the context of understanding the climate cycle.

Given that Barlow (2015) has already shown that the FDT method provides a more robust estimate of the key dates that define the CUP than the ZCD method, the authors need to clearly state what additional advantages of the EFD method over the ZCD they have identified in their analysis.

The most interesting analysis in the study is in response to reviewer 2's comment. The authors show, using a transport model run, that the mixing ratio CUP derived from the ZCD method is much less sensitive to flux CUP than the mixing ratio CUP from the EFD method. This analysis is very insightful, although it would have been better if the analysis had been conducted at multiple measurement sites instead of just MLO and if the inter-annual variability in the transport model had not been removed.

In conclusion, I recommend major revisions of the paper with a focus on one or more of the following points:

Thank you for the detailed review. We agree that the manuscript would be improved through the addition of a more quantitative comparison between the different methods. We carried out a synthetic data experiment which addresses these points, as described below.

1. Provide a more detailed quantitative comparison with a figure or table to demonstrate that the FDT approach is improved by adding the ensemble part.

In response, we added a new figure (Fig 12) and section (5.3) comparing the sensitivity of the different methods to changes in the actual CUP. We performed a synthetic data experiment where known changes in the CUP were imposed on idealized NEE fluxes and we simulated CO_2 time series using an atmospheric transport model. The different CUP estimation methods were evaluated for their ability to capture the imposed CUP changes from the simulated time series, as in the previous response to Reviewer 2. We find that the EFD method and the approach in Barlow have similar sensitivities to imposed CUP changes. However, the uncertainty in sensitivity for the approach in Barlow, could not be evaluated as the method does not give an uncertainty range for its estimates, showing the advantage of the ensemble approach to constrain uncertainties in metrics.

2. Use transport model analysis to demonstrate how the application of the FDT/EFD method on mixing ratios is better than the ZCD method to determine CUP of fluxes.

From the experiment described above, we find that the CUP estimation methods based on the first derivative of the CO_2 time series (i.e., the EFD and approach in Barlow) are more sensitive to CUP changes than the ZCD method. This can be seen from the mean slope of the fitted regression lines in Fig. 12.

3. Clearly state the new advantages of the FDT/EFD method over the ZCD method found in this study, in addition to those stated by Barlow (2015).

The sensitivity experiment demonstrates the advantage of the EFD method over the ZCD method more conclusively than what was presented by Barlow. Not only is the ZCD method less sensitive to changes in the CUP, it also has higher uncertainties.

4. Show how a tighter constraint on the mixing ratio CUP using the EFD method leads to a reduction in errors in flux CUP.

As seen by the slopes of the lines in Fig. 12, none of the methods are able to estimate the true length of the CUP or the changes therein. The 15% threshold was chosen in order to minimize the uncertainty with the onset time (as seen in Fig. 5) while with minimal truncation of the CUP. Figure 12 compares only the changes in the CUP inferred from the mixing ratio (i.e., ΔCUP_MR): when comparing the absolute length, we find that CUP_MR is, on average, 5 days longer when using the 15% threshold compared to the 25% threshold.

Other comments:

Please complete your list of affiliations by including country names.

Thank you, the country names are included in the list of affiliations.

Please note that, there is a change in the order of the list of authors.

Previous: Theertha Kariyathan[1,2], Wouter Peters[2], Julia Marshall[3], Ana Bastos[1], Pieter Tans[4], and Markus Reichstein[1]

Current: Theertha Kariyathan[1,2], Ana Bastos[1], Julia Marshall[3], Wouter Peters[2], Pieter Tans[4], and Markus Reichstein[1]

Reference:

Barlow, J. M., Palmer, P. I., Bruhwiler, L. M., and Tans, P.: Analysis of CO_2 mole fraction data: first evidence of large-scale changes in CO_2 uptake at high northern latitudes, Atmospheric Chemistry and Physics, 15, 13 739–13 758, https://doi.org/10.5194/acp-15-13739-2015, 2015.