"Atmospheric oxygen as a tracer for fossil fuel carbon dioxide: a sensitivity study in the UK" – Response to Anonymous Referee #4

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Below we describe the changes that have been made to the re-submitted manuscript "Atmospheric oxygen as a tracer for fossil fuel carbon dioxide: ac sensitivity study in the UK" as recommended in the comments from the two reviewers.

Additional small changes that primarily relate to typos spotted by the authors have also been made and are listed towards the end of this document. Please note that these small additional changes made by the authors do not substantially affect the scientific findings.

Referee comments are stated in black with author responses in blue. Proposed changes to the manuscript are clearly stated throughout (usually in bold typeface).

RC2 referee comments

General comments:

1. The structure of the results is challenging to follow. Sections 3.1 to 3.5 discuss sensitivity results related to APO simulation, while Section 3.6 presents estimated CO_2. It's unclear whether the main focus of this work is on the robustness of the methodology or the CO_2 emission results. If the goal is to infer CO_2 emissions, why not directly use CO_2 emission results for sensitivity testing?

While we agree that the analysis is (necessarily, we feel) somewhat complex, we do not feel that it would be desirable to express everything in terms of $ffCO_2$ in these sections (note however, that this is the fossil fuel CO_2 mole fraction, not emissions). This is because: a) $ffCO_2$ is derived from APO, so we feel that is important to understand how this quantity underlying the $ffCO_2$ calculation is influenced by each factor; b) $ffCO_2$ requires an estimate of the background APO, which is one of our sensitivity tests.

2. Given the complexity of the study's methodology, it would be helpful to provide an overall workflow figure at the beginning to help readers better understand the process. Similarly, creating a table listing all sensitivity test settings could improve the readability of the sensitivity tests.

It is a good idea to include a table outlining the different sensitivity tests that have been carried out. We have added the following at L219:

"The sensitivity tests (for APO and $ffCO_2$) are summarised in Table 1.

Table 1: Summary of sensitivity tests. The left-hand column indicates the parameter being investigated and whether the sensitivity to APO or $ffCO_2$ is being investigated. The middle column briefly describes the method employed to determine the sensitivity, and the relevant results section is shown to the right."

Sensitivity test	Method	Section
APO: Biosphere exchange ratio (α_B)	Monte Carlo ensemble	3.2
APO: Fossil fuel exchange ratio (α_F)	Monte Carlo ensemble Comparison of GridFED and NAEI-derived ratios	3.2
APO: Ocean flux estimate	Comparison of NEMO, ECCO-Darwin, Jena Carboscope flux estimates	3.3
APO: Fossil fuel flux magnitude and distribution	Monte Carlo ensemble Comparison of NAEI and EDGAR distributions	3.4
APO: Background	Comparison of JC and REBS	3.5
$ffCO_2$: Background and ocean flux estimate	Comparison of JC and REBS baseline Comparison of NEMO, ECCO-Darwin, Jena Carboscope ocean fluxes	3.6

3. In my opinion, the usage of the term 'the regional contribution' may not be suitable for this study. Generally, 'regional contribution' refers to the portion or influence of a specific region on a particular phenomenon or variable. In this study, 'the regional contribution' is used to indicate contributions from ocean and fossil fuel components, which could lead to misunderstanding.

We do not believe that the reviewer is correct here. In this study, "regional contribution" does indeed correspond to the influence of fluxes from a particular geographical domain. It's just that we examine the influence of different sources (fossil, ocean, etc.) from within this region.

4. The selection of August and December as the study period should be explained and justified, especially when the other months, like June (with the lowest R^2) and November (with the highest R^2) as shown in Figure 6, might be more prominent.

Whilst there is good data availability of observations from Weybourne in 2015 (except during February) we found the balance of data availability, statistical goodness-of-fit, and having two months that represent sufficiently distinct parts of the APO seasonal cycle led to using August and December for the study period.

We have included the following at the start of Section 3:

"*Here we show our APO model results for 2015. As example, one summer (August) and one winter month (December) are shown throughout.* ***These months were selected based on data availability, statistical goodness-of-fit and having two months that represent sufficiently distinct parts of the APO seasonal cycle. Simulations for all months of …***"

5. The presentation of data in figures is quite simplistic, and there is a lack of standardization in the formatting of words inside the figures. For example, 'co2' should be written as 'CO_2.' It's necessary to review all figures and consider diversifying the ways data is presented.

We have updated the labelling in figures so that they are more standardized. We will take into consideration the way the data is presented (and opt for more diverse ways) in future work.

Specific comments:

6. Caption in Figure 1. What is fullname of UKGHG?

We have amended the caption in Fig. 1 to include the full name of the UKGHG flux model. Please note we have also corrected the reference from White et al. (2019) to Levy (2020), which is more appropriate.

7. Figure 4. Combine Figure 4, there is no need to split it across two pages.

We understand the reviewer's point of view regarding Fig. 4. However, having tried combining this figure onto one page makes it unclear for the reader to see the temporal variations of the different lines. On reflection, we think it is clearer to keep the figure as presented.

8. Figure 6. When using gray lines as major grid lines, I recommend that the author refrain from using gray lines for plotting the "no ocean" results. Please review all your figures to correct them.

We understand the reviewer's point of view regarding the line colours. However, whilst similar line colours are used for the "no ocean" results we have used a different line style to differentiate from the gridlines used in the plots.

9. Table 1. The table caption should be positioned above the table.

Thank you for spotting this, we have now moved the caption for Table 1 as suggested.

Additional changes made by the authors.

In addition to small changes in the wording of the manuscript text, that are detailed in the tracked changes document, the following changes of note have been made to the manuscript.

1. A typo on the left-hand-side term of Eq. 3 in the manuscript has been corrected from "APO" to "δAPO".

2. We have adjusted Eq. (4-5) to match the derivation presented in Manning and Keeling (2006) and to use the same notation. We introduce Eq. (6), formerly Eq. (5), that includes the correction term for atmospheric O_2. This has been done to make it clear where this term of $1/(1-X_{O2})$ comes from as it is not included in the derivation presented in Manning and Keeling (2006)

3. Errata on line 45: The thesis of Kuijpers modelled atmospheric O_2 for autumn of **2014** and compared simulations with observations from **two** sites.

4. Figure 13. In the text this is described as "The correlations (R^2) between the observation-derived $ffCO_2$ and the $ffCO_2$ model" but the figure caption are in per meg, not ffCO2 in ppm. We have corrected the figure label and caption.