Response to Editor's Comments on "Reconstructions and predictions of the global carbon budget with an emission-driven Earth System Model"

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We thank the Editor for his time and efforts towards improving especially the English writing of our manuscript. We have incorporated most of the rewording suggestions. Only few are not taken because of the reasons as explained below, our point-by-point response (normal font) to all comments (*italics*) are also listed as below. Please note that the comment numbers (#*) and line numbers (L*) should refer to the annotated document from Editor.

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Comment #1. L143-145: This seems out of place. You were talking about Figure A2 and then you switched to this.

R: This was unclear because of the order of the sentences. We have moved this sentence to right after the explanation of anomalies and climatological mean state, now this paragraph reads: "The predictive skill is quantified by the anomaly corre-
10 lation coefficient, and the anomalies are calculated by removing the respective climatological mean state. In that sense, the climatological mean bias is removed and the coherence reflects the multi-year variations for which we evaluate the predictions. Here the climatological mean state is based on the ensemble mean of the focus time period, 1970-2018 for Figs. 1-6, and the last 10 years for Figs. 7-8. We exclude the first 12 years, i.e., 1958-1969, from the analyses and focus on the period from 1970-2018, because the assimilation in the first decade is affected by model adjustment. As an example, the spatial pattern of
15 climatological mean ocean net primary production and phosphate nutrient concentration are shown in Fig. A2 in comparison with the respective observations."

Comment #2. Figure 2: Replace y-axis label with "Carbon fluxes (Pg C/yr)" here and in other similar figures.

20 R: The y-axis labels in Figure 2 have been replaced with "Carbon fluxes (Pg C/yr)". We have also applied the revision to other similar figures, i.e., Figures 4-6.

Comment #3. Figure 3: You call it reconstruction here but in the figure it's referred to as assimilation. Comment #4. I see that you have used "assimilation", "reconstruction" and "assimilation reconstruction" to refer to the same thing. Please use

25 *consistent terminology.*

R: In the previous studies on decadal predictions, both "reconstruction" and "assimilation" are used. We added some words to make the connection between both words in section 2.1 "Model and simulations". The "reconstruction" in the figure caption is substituted with "assimilation" to keep the terminology consistent with that in the figure.

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Comment #5. *Figure 3: Note that in panel A and B values over Amazon are like 60 and 40 gC/m2.yr, respectively. But in panel F the RMSD over Amazon is like 100 gC/m2.yr. If the means are only 20 gC/m2.yr apart can the RMSD be so high and around 100 gC/m2.yr. It is not obvious this would be case at least by looking at global fluxes in Figure 2 E. Can you please double check?*

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R: We have double checked the results with different programs for calculating the RMSD and ended up with the same values. Actually the values over Amazon in panel A from MPI-ESM single model simulation is larger than 100 gC/m2/yr, i.e., much larger than the values in panel B from the GCB2019 of multi-model mean simulations. We have tuned the color bar in Panel A and B with explicit intervals to better visualize the different magnitude of values (see Figure 3 with updated color bar). The
40 time series in Figure 2E shows coherence in interannual variations of land carbon sink, however, the values from MPI-ESM assimilation are in general higher than those from the GCB2019. The difference in magnitude of fluxes is more prominent in local areas than in the global mean. In addition, the correlation of CO_2 fluxes over land is relatively lower than over ocean. We have rephrased the sentences to make this clear. Therefore, the large RMSD over Amazon is partly from the difference in mean states and partly from the difference in interannual variations between the assimilation and the GCB2019.

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Comment #6. *L205: "differences in the climatology state" Unclear what this means.*

R: Based on the discussion along the previous comment #5, we have reworded this sentence as: "The correlation of CO_2 fluxes between the assimilation simulation and GCB2019 is high over the ocean, the correlation is relatively lower over the
50 land (Fig. 3E). The root mean square deviation (RMSD) scales with the magnitude of carbon fluxes, i.e., with larger values on land than over ocean (Fig. 3F). The large RMSD, especially over land, is because the relatively low coherence of CO_2 fluxes, also because of the larger values of CO_2 fluxes in the MPI-ESM single model simulation than in a smoothed magnitude of fluxes in GCB2019 from the multi-model mean simulations. The difference in magnitude of fluxes is more prominent in local areas (Fig. 3A-D) than in the global average (Fig. 2E). "

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L227 Rewording suggestion: *"The variations of the globally integrated ocean carbon sink are driven primarily by external forcing (in this case increasing atmospheric CO2) rather than internal variability, as found in McKinley et al. (2020)."*

R: The words in the brackets, i.e., "in this case increasing atmospheric CO2", are not included because other forcings like solar and volcanic variability are also considered.

Comment #7. *L242-243: "This indicates the contribution of a linear trend to the skill of uninitialized historical runs." Unclear.*

R: We have reworded this sentence as: "This indicates the contribution of a linear trend to the skill of atmospheric carbon growth in uninitialized historical runs as shown in Fig. 4D."

Comment #8. *L244: "for atmospheric CO2 growth rate". Did I get this correct?*

R: Yes, this has been added.

Comment #9. *L250-252: "Furthermore, the prognostic CO2 from the novel emission-driven decadal prediction system suggests predictability as well, and the atmospheric CO2 growth rate shows a predictive skill of 2 years in the initialized predictions." This is essentially repeating the info in last 2 sentences so can be deleted.*

R: This is an important point on the predictive skill of atmospheric carbon growth rate in addition to the previous sentences on the predictive skill of CO_2 fluxes. We have reworded the sentence as: "The prognostic CO_2 from the novel emission-driven decadal prediction system suggests a predictive skill of 2 years for the atmospheric CO_2 growth rate."

Comment #10 *L254: "simulations" Which simulations unitialized, assimilation, or initialized?*

R: Here we mean all the three types of prediction simulations. We have listed the simulations in the manuscript as: "including uninitialized, assimilation, and initialized simulations".

Comment #11 *L255: "satellite XCO2" I think, you need to tell readers that XCO2 is the CO2 column burden. Correct?*

R: We have added an explanation as: "(i.e., atmospheric column-average dry-air mole fraction CO_2)".

Comment #12 *L255: "model assimilation" What does "model assimilation" means? Do you mean this is from the assimilation simulation.*

R: Yes, we did mean assimilation simulation. This is revised as "assimilation simulation".

Comment #13 *L260:"model assimilation" I am confusing this with "assimilation" simulation."*

R: This part is reworded as: "the sampled values from assimilation simulation".

Rewording suggestion *Figure 7: "The simulated time series from the initialized simulations are bias corrected..."*

R: The bias correction is applied to all simulations to put them in the same level for comparison. We have added this information and this sentence reads: "The simulated time series from the MPI-ESM simulations, including uninitialized, assimilation, and initialized simulations, are bias corrected...".

Comment #14. *Figure 8: Why would we sum these?* *Comment #18.* *Line 280: I am trying to figure out the rationale for adding 2 years of fluxes but can't figure this out. Can you please explain.*

R: The atmospheric CO_2 concentration is a cumulative quantity, which is affected by the strength of CO_2 fluxes in the past. We also need to keep in mind that the concatenated points in time series at a certain lead time are from different initialized simulations, i.e., those are initialized from different years (Fig. 1C). The atmospheric CO_2 concentrations deviate from the initial states with the time of integration. Therefore, the value of atmospheric CO_2 concentration at lead time of 2 years has the influence from the previous time, i.e., at lead time of 1 year. That's the reason we sum up the air-land CO_2 fluxes at a lead time of 1 year and 2 years to understand the inferred changes of atmospheric CO_2 concentration at lead time of 2 years. The red curve in Fig. 8B, which represents the strength of cumulative air-land CO_2 fluxes in the first 2 years, is opposite to the blue curve in Fig. 8A, which represents the atmospheric CO_2 concentration at lead time of 2 years.

Comment #15. *L273-275: But Figure 7D shows that RMSE for uninitialized is 0.47.* *Comment #16.* *Not if RMSE for uninitialized is 0.47. Then 0.46 and 0.47 are more comparable. Please check if RMSE for unitialized is 0.47 (as in figure7D) or 0.72 (as you say in the next)*

R: Thanks for spotting this. The number of 0.72 was from a previous result based on one ensemble member of the uninitialized simulations. We updated the figure with 10-member ensemble mean results but overlooked the number in the text. We have corrected the number to 0.47 in the text and have removed the sentence afterward. That sentence is a minor addition which didn't go into in the abstract and conclusion.

Comment #17. *L280-281: Please rethink this. In my mind, the trend and the cumulative comes from the fact that 50% of the emisisons stay in the atmosphere. The interannual variability rides on top of this. So I cannot imagine how interannual variability of current year in affected by IAV of last several years. That would be lile a positive autocorrelation which you*

haven't explicitly talked about. Please consuider rewording or removing this sentence.

130   R: Here "amplitude of atmospheric CO_2" are more proper words than "interannual variability". We have reworded this sentence as: "As the atmospheric CO_2 concentration is a cumulative quantity, the magnitude of atmospheric CO_2 concentration is affected by the CO_2 fluxes in the current and previous years."

Comment #19. *"reliable" is used twice in this sentence.*

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R: We have reworded this sentence as: "Further future efforts that assimilate more observations to initialize ESMs, and assess their predictive skill will lead to more reliable reconstructions and predictions in global estimates and spatial distribution of CO_2 fluxes and the atmospheric CO_2."

140   **Comment #20.** *Figure A2. Write panel labels here along with the text. Also, why the different time periods for averaging model and observations?*

R: We have added the labels in the figure caption. The different time period of averaging is according to the available observations. We have added this information as well.

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