Earth Syst. Dynam. Discuss., author comment AC2
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Reply on RC2

Hongmei Li et al.

Author comment on "Reconstructions and predictions of the global carbon budget with an emission-driven Earth system model" by Hongmei Li et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2022-37-AC2, 2022

We thank the Reviewer for the time and comments towards improving our manuscript. Please find our point-by-point response (normal font) to all review comments (*italics*) below.

The authors present a forecast system for the global carbon cycle based on the seasonal to decadal forecasting system of the MPI-ESM that requires initializing the physical variables in the model based on observations. The manuscript reads well and the science is sound. However, since the manuscript covers two different aspects of Earth system modelling (the global carbon cycle and seasonal to decadal forecasting) the authors need to make their terminology and descriptions easier to understand for both communities. As a land carbon cycle person myself, there were several aspects of seasonal to decadal forecasting that I was unable to completely understand.

R: In the attempt to make the terminology and descriptions of initialized predictions easier to understand, we plan to add a schematic as shown in Fig. R1 to explain our simulations in a stepwise manner. The box for posting comment only allows a small size figure, the original figure is uploaded as a Supplement.

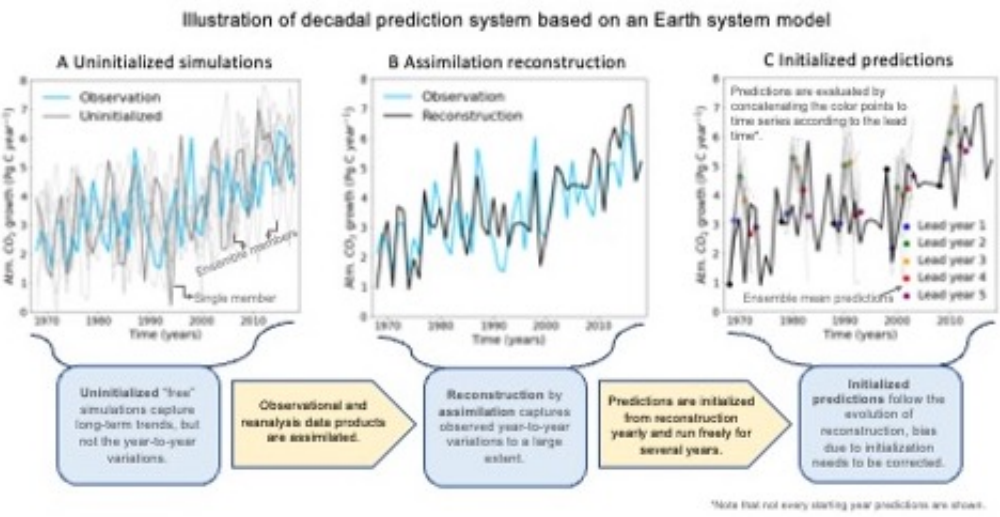

Figure R1: Illustration of a decadal prediction system based on an Earth system model

MPI-ESM simulation of the atmospheric CO_2 growth rate. The time series are annual means from model simulations plotted together with observations from the Global Carbon Project. We conduct 3 sets of simulations, from left to right in sequential order: i) uninitialized "free" simulations which are the same as the Coupled Model Intercomparison Project (CMIP) historical type simulations; ii) an assimilation simulation to reconstruct the evolution of climate and carbon cycle towards the real world by nudging observation and reanalysis data during the integration; iii) initialized predictions are started from reconstruction states produced by the assimilation simulation and integrated freely (i.e., no nudging of data) for 5 years. The left panel plot A time series show that the uninitialized simulations capture the long-term trend well, but the year-to-year variations are out of phase to the observations. The middle panel plot B time series shows that the assimilation simulation forces the variations in the uninitialized freely run simulation towards the real world, and results in a reconstruction closer to the observations. The right panel plot C presents the reconstruction together with 5-year long initialized predictions (i.e., hindcasts). To make the illustration more clear, only predictions with starting years at 10 year intervals are shown.

In particular, as a reader, I am unable to completely understand how the simulations are done.

R: We have made a new illustration figure (Fig. R1). We hope this will help readers to understand how the simulations are done. We have done 3 sets of simulations from left to right sequentially, i.e., the uninitialized "free" simulations, an assimilation simulation, and initialized predictions. The uninitialized simulations are run freely in the same way as the Coupled Model Intercomparison Project (CMIP) historical type simulation spanning the period from pre-industrial to the end of this century, i.e., 1850-2099. The assimilation simulation starts from year 1959 of uninitialized simulation and integrates forward by nudging available observations and data products to capture the actual evolution of the climate and carbon cycle. The initialized predictions start from each year of the reconstruction state from the assimilation simulation and run freely for 5 years to see how long the system keeps the memory from initial conditions.

Are multiple 5-year simulations done starting from each year from 1960-2018, and then the values at the end of the first year of each simulation are used to construct a time series corresponding to a 1-year lead time?

R: No, it is not the values at the end of the first year of each simulation, but rather the annual mean values are concatenated to time series according to the lead time, as shown with the colored dots in Fig. R1C. For example, the blue dots are concatenated for the lead time of year 1 series. Please note that not every starting year prediction is shown, only starting years at 10-year intervals, and ensemble mean dots are shown to make the illustration clearer. The skill of prediction is evaluated by comparing the concatenated time series of predictions (i.e, hindcasts) with the observations/data products.

In addition, several sentences are unclear and I have suggested rewording them in the annotated PDF attached to this response.I suspect that English may not be the first language of the first author, and I think the manuscript would benefit from the attention of other co-authors. A detailed list of comments can be found in the attached annotated PDF of the manuscript which also summarizes my comments so that they can be easily located.I look forward to reading a revised version of this manuscript.

R: Thank you for pointing out the sentences that are unclear, we have reworded them following your suggestions in the annotated PDF. We have also replied to all the review comments in the annotated PDF (see page 54 onwards), this file is uploaded in the Supplement. In the meantime, we asked a native speaker colleague to read and help edit the revised manuscript.

Please also note the supplement to this comment:
https://esd.copernicus.org/preprints/esd-2022-37/esd-2022-37-AC2-supplement.zip