

Interactive comment on “Atmospheric CO₂ seasonality and the air-sea flux of CO₂” by P. R. Halloran

Anonymous Referee #1

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In this paper, the author use an offline-forced model to study the impact of stronger atmospheric CO₂ seasonal cycle on the latitudinal air-sea CO₂ flux. For the preindustrial physical forcing, the model shows that instantaneous increase in atmospheric CO₂ seasonal cycle leads to less carbon uptake in the high latitude and more carbon uptake in mid- to high-latitudes. The author concludes that free atmospheric CO₂ concentration (e.g. given seasonal CO₂ emissions) is necessary to capture the additional feedbacks in the earth system model.

The paper is well written and the structure is easy to follow. This is a useful model study and may contribute to better understanding of the future model projection uncertainties related to the CO₂atm seasonal cycle. However, more discussions should be included in the manuscript. Here are some suggestions that I think can improve the paper:

1) Introduction

The author mentions that the amplitude of the atmospheric CO₂ seasonal cycle has increased recently but did not explain which mechanism or process lead to this. I think this is an important question as well as key motivation for this study. As a reader, I am curious what causes this change (if there is any), and whether or not there exist model studies that confirm the process as well as predict the expected outcome (i.e., stronger seasonality) in the future projections.

2) Experiment design

How the author determined the atmospheric seasonal cycle is not clear. Is it based on the seasonal cycle from Mauna Loa? Is it equal for each latitudes? This needs to be clarified, and maybe the author can add a figure of the atmospheric seasonal cycle prescribed for the different latitudes.

The sensitivity experiments selected were 1x and 2x seasonal cycle. Again, why chose these values? Has there any studies that showed a doubling in atmospheric seasonal cycle in the future?

I am not sure why did the author choose to performed the simulation offline. Despite that this method is simpler, it only gives us instantaneous change in the air-sea CO₂ flux. Over a long time scale, I think the change is much smaller than is shown here. If possible, experiments with the preindustrial physical forcings but different atmospheric CO₂ seasonal cycle over at least 100 years would give us much better picture and more convincing sensitivity results.

If it is not possible to redo the experiment, discuss what is the benefit of having such simple experiment. What are the caveats? And finally how do you justify the simplicity of the experiment on the statement on your abstract: interesting implications for glacial-interglacial climate change, which occur on much longer time scale than this experiment. Do we know what is the atmospheric CO₂ seasonal cycle during the

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glacial-interglacial period?

3) Results

While Fig. 2 shows that latitudinal change in air-sea CO₂ flux, what is the net global annual change? Is it significant or within the model error bar?

The author may be correct conceptually in identifying the changes in CO₂ flux is due to the solubility and sea ice effects. But is this also the case in a fully coupled model simulations. For example, changes in air-sea flux in mid latitude will alter the subsurface DIC concentration transported into the high latitude water mass, hence the air-sea flux there as well. Having longer simulations with active carbon cycle processes would really be beneficial in this case.

Others:

P 8308, L 25 Add reference(s) to the statement "The steady-state atmos"

P 8309, L 28 Add reference(s) after the statement "A large seasonal cycle ..."

P 8311, L 8: "Given the findings" This is a very important statement, and it would be better if the author can show whether the accumulated change is significant or not.

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