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# ***Interactive comment on “Climate change increases riverine carbon outgassing while export to the ocean remains uncertain” by F. Langerwisch et al.***

**F. Langerwisch et al.**

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We thank the reviewer for the time she/he took and for the very helpful comments provided which will help us to improve the manuscript!

Anonymous Referee #2: This manuscript takes on the rather daunting task of coupling a large scale dynamic vegetation model with a highly aggregated river carbon model to address the potential changes in river carbon fluxes under different climate change scenarios. The plus/minus to doing this are: Plus. It is very useful to think about developing overall system models, coupling the multiple key sectors. It forces critical thinking, and the mobilization of information from multiple sources. Not an easy task!

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Minus. That said, at what point is the aggregation so great and assumptions so broad that there is a little confidence in the output?

Reply: Thank you very much for your comments. With our manuscript we try to assess the importance of including the inundation and associated carbon export by the river to a vegetation model. We will write more clearly that we don't intent to fully understand the temporarily and spatially complex carbon fluxes in this coupled land-river-system. Rather we aim to establish a concept to estimate the effect of coupling land with river in a mostly from a terrestrial or riverine perspective investigated system.

BROAD ISSUES 1. The model development discussion is very generic, and shows little understanding of the Amazon itself, at multiple levels. - It starts with the space and time scales of the model, set to 0.5o and monthly. In a month, a parcel of water travels from high in the Andes to the Atlantic. A 50 x 50 km cell covers rather a lot of territory, relative to the scale of stream and river channels. - It seems that all rate terms including in-river are computed within LPJmL, which is purely terrestrial. It would be useful –essential- to evaluate these relative to in-river measurements (literature). – I started to go through the model setup topic-by-topic, and tracking each to output, but don't have enough time to complete that.

Reply: Yes, our approach on assessing the terrestrial-riverine coupling on monthly time-steps and on a spatial resolution of 0.5x0.5° is rather coarse. We are aware that there are certain limitations to the model approach. But we aim to assess general large scale carbon patterns and changes and accept that on a smaller scale the model is not able to reproduce the local patterns very well. With our work we try to understand how much the basin-wide carbon balance depends on the interaction with the river and how much it could change in the future. To clarify our objective we will add a paragraph on that in the introduction (and further in the discussion) and will try to make this clearer throughout the manuscript.

2. The analysis breaks the Amazon up into several sectors (northern, western, etc).

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Calibration/validation is done very generically for the “export” values cited (which correspond to the station of Óbidos, though not mentioned). That station represents the highly damped integration of so many very different water sources (Madeira vs Negro, for example) and timing that it doesn’t represent a robust point of calibration, if the intent is to represent the response of different regions (see below).

Reply: We thank the reviewer for this very constructive comment. We will conduct further validations on the sub-basin level and will add this to the manuscript in the results section (P1467 before 3.1) and in an additional paragraph in the discussion section (P1471 before 4.1).

3. It is not at all clear how the values of the different primary pools are established – POC, DOC, (D)IC, other than to say “mobilization.” Processes for each are very different. Is IC total DIC or pCO<sub>2</sub>? DIC includes a significant component of weathering, which is never mentioned. Floodplain autochthonous production is not a negligible component of the river system C cycle.

Reply: The mobilization only includes the export from organic material from the land to the river. All carbon pools in the model are based on the terrigenous carbon and atmospheric carbon. Weathering or other sources of inorganic carbon are not included. We also neglected the autochthonous production of organic carbon, as we mentioned in the methods section (P1452 L 26). We will add some more information why we excluded some processes (such as in-river production or weathering) in the methods section. Additionally we will discuss in more detail how the results would change by including the neglected processes.

4. Carbon flux is, of course, a product of discharge and concentration. Any analysis of carbon flux has to start with hydrology. But we have no idea how well LPJmL does for the Amazon, or how it delivers the hydrology commensurate with the change scenarios. It is thus difficult to have a clue about the carbon part of the argument.

Reply: LPJmL can reproduce the discharge of most of the large river systems very

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well. This was shown by Gerten et al. (2004, Journal of Hydrology) and Gordon et al. (2004, Ecol. Appl.). But for the Amazon basin the hydrograph was shifted. In 2013 we published a study showing that by adapting the flow velocity from 1.0 m s<sup>-1</sup> to about 0.25 m s<sup>-1</sup> (in the lowlands) the discharge was much better reproduced than before (Langerwisch et al. 2013, HESS). By applying the modified flow velocity in the current study we are certain that the discharge patterns in the Amazon basin are adequately reproduced, which is indeed a prerequisite to assess riverine carbon fluxes. We will add some more information on that to the methods section (P1452 L8).

5. The abstract states that the model “successfully reproduces observed values...” Actually, it doesn’t even come close. And even if it did, it wouldn’t mean much, at Obidos, given how many different signals are combined there.

Reply: Thanks for this remark. Our aim is to understand changes in the carbon pools and fluxes and therefore we assumed the reproduction of the general trend could be sufficient. We will add a more detailed validation on the sub-basin level and will also discuss more detailed the consequences of such a large scale approach.

6. Examination of river outgassing relative to terrestrial misses the point that the river outgassing is relevant to the carbon nominally sequestered by on land, it is not part of the daily 24 hour production/respiration cycle.

Reply: We assume that by extracting carbon from one site and finally exporting it to the Atlantic Ocean the carbon is no longer available for the short-term 24h production/respiration cycle. In the results section (3.4) on the effect of including the inundation, discussing the results from our experiments (Standard, NoInun, NoRiv), we will discuss this further, as well as in the discussion section 4.2.

7. In an effort to be all-inclusive, enough detail to be convincing is lost.

Reply: We will make more clear what the aim of our manuscript is, namely not to be all-inclusive, but rather show general trends and possible changes in the future. We

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will add clarifying paragraphs in the introduction and the discussion sections.

**CONCLUSION:** Where does this leave us? At an absolute minimum, the thrust of the manuscript has to be changed. Perhaps start by breaking out by major tributary basin (Negro, Madeira etc)

What it is not. A credible examination of Amazon River carbon outgassing and export to the ocean, under current or future climates. The author's justifications of their results aren't valid. While their idea of serving as a linkage between small-scale observations and global estimates is a good one, it does not justify the large errors between their observed and predicted results in outgassed C or exported OC. The model also does a poor job of predicting outgassed CO<sub>2</sub> under current conditions, so it is difficult to rate the significance of the model's predicted increases. (There are grammar issues with this manuscript as well). What it is/could be. A structure for how to go about developing a modeling framework, for working towards such goals. A useful paper would be to outline the issues involved in doing this. This manuscript could fill a niche in connecting current research on carbon processing in the Amazon with predicted climate change models. At the end of the day, it depends on what the objectives are, here. I question whether or not such a strategy, with its abstractions and scales, could possibly produce a result that is meaningful to how the Amazon actually functions, under either current or future conditions. If it is to be, much better presentation and justifications are necessary. If the intent is to provide an Amazon module for a global model, perhaps it could get there.

Reply: Thanks again for these very helpful comments. We will make it clearer that our aim is to make a first attempt to understand the importance of land-river coupling for Amazonia. We finally want to better estimate the effects of climate change on large scale carbon fluxes especially in tightly coupled systems as the Amazon basin, which is often only assessed from either the terrestrial or the riverine perspective.

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