Reviewer #1

General comments

It has been recognized that the global significance of the inland freshwater carbon cycle. However, it has been completely overlooked owing to the inadequate data and improper models. The new model branch, ORCHILEAK evolved from ORCHIDEE, not only improves our understanding of carbon transformations but also provides a fundamental for the assessment of the impacts of climate change. The main purpose is clear and it is worth developing to quantify the lateral exports of carbon off the terrestrial ecosystems. The results showed that QRCHILEAK could successfully simulate the fluvial transport of DOC and CO2 evasion in Amazon basin. However, I have several specific comments from the perspectives on the model development and verification.

Specific comments

1. What was the time step to execute this model? Several spatial and temporal resolutions were mentioned, e.g. at a 30 min time step and a 1o (or 0.5o) resolution for the hydrology model and at a 6 min to daily time steps and a 1o (or 0.5o) resolution for the C fluxes. I was wondering how the model was executed in practice. How did different time steps work together in one model? Besides, did the choices of time steps operate in coordination with the spatial resolutions?

In theory, the length of all time-steps can be changed. Here, for reason of simplicity, we want to stick to the standard setting at which the model was run. Practically, the whole model runs at a 30-minute time step. However, the lateral routing of water and dissolved C is executed only every 48th time-step, i.e. when one day is over. At each 30 min time-step, the routing module of ORCHILEAK aggregates the runoff, discharge and C inputs to the river or floodplains simulated in the soil C module. When the end of the day is reached, the lateral flows of water and carbon are simulated for that whole day using those aggregated water and C inputs. Similarly, the flows of C and water back to the soil column (Fflood2soil, Fup2swamp), which are simulated in the routing module at this daily time step, are used as inputs to the soil hydrology and soil carbon modules at each of the 48 30-minute time steps over the following day of simulation, simply by evenly distributing the daily fluxes over the 48 30-minute time steps.

The 6-minute time step is used as an iteration (240 iterations per day) to approximate the continuous interplay of CO_2 inputs to the water column and CO_2 evasion from the water column using a sufficiently short time-step. CO_2 inputs are increasing the water-atmosphere pCO_2 gradient, while the CO_2 evasion flux also controls the water-atmosphere pCO_2 gradient by continuously decreasing it. All the inputs of CO_2 to the water column which have been aggregated to the daily time step of the routing module, be it from decomposition of DOC in the water column, the decomposition of submerged litter or from the respiration in inundated soils, are thus split over the 240 6-minute time-steps of the day. The pCO_2 and the CO_2 evasion are calculated for each of those 6-minute time-steps, and the CO_2 storage in the water column is updated accordingly. The CO_2 evasion is then simply aggregated over the 240 iteration time-steps to obtain the daily values.

We followed the advice of Reviewer 2 and included the information on different temporal resolutions into Figure 3. A colour code, explained with a legend, now indicates the temporal resolution of each flux.

We also added a more detailed description for the choice of the different time steps at the end of subsection 2.2.1:
"Like the cycling of water and C in vegetation and soils, the allochthonous inputs of DOC from S_{can} and S_{soil} into the inland water network (F_{RO}, F_{DR}, $F_{soil2flood}$, $F_{soil2river}$, see Fig 3) are computed at a temporal resolution of 30 minutes and at the spatial resolution of the grid cell. The lateral transfer between the S_{fast}, S_{slow}, S_{river} and S_{flood} and the transformation of C within those storage reservoirs are only simulated at a daily time step and at the spatial resolution of the basin. Therefore, to simulate the lateral transfers, the allochthonous DOC and CO_2 inputs are first aggregated over 48 30-minute time steps until one full day is over. The fluxes from the water column back into the soil column ($F_{flood2soil}$,$F_{up2swamp}$ in Fig. 3) are simulated at the daily time-step of the routing module, but are used as inputs in the soil carbon module, which runs at a 30 minute temporal resolution. This is achieved by downscaling the daily fluxes uniformly over the 48 30 minute time-steps of the following day of simulation. The evasion of CO_2 from river and floodplain water surface ($F_{river2atm}$, $F_{flood2atm}$) is also simulated at the daily time-step of the routing module, but to approximate the continuous interplay of CO_2 inputs and CO_2 evasion controlling the water-air gradient in CO_2 partial pressures (pCO_2) a much shorter time-step of 6 minutes is used, and the CO_2 inputs to the water column are thus uniformly distributed over the 240 6-minutes time-step contained in each day."

2. I would suggest a table showing the input details essential for the model execution and the outputs, perhaps including their spatial and temporal resolutions.
We agree with the reviewer suggestion and have added a new table 1 in the revised manuscript.

3. There is not any information regarding the calibration and validation, e.g. the performance measures in the calibration and validation.

We thank the reviewer for this important point. We have now added performance measures (Correlation coefficients, Nash-Sutcliffe efficiency and/or root mean squared errors) to all figures reporting observed vs. simulated values. In addition, to highlight the improvements in the new flooding scheme, we also compare these performance measures for the TRUNK version of ORCHIDEE and the recalibrated version implemented in ORCHILEAK. Similarly, we compare performance measures for the simulated discharges obtained with 1) the TRUNK version using the parameterization of Guimberteau et al. (2012); 2) the ORCHILEAK version using the modified floodplain forcing and the setup of Guimberteau et al. (2012), 3) the ORCHILEAK version with recalibrated discharge. For that purpose, we added a new table to section 3.1 of the revised manuscript summarizing the results of the recalibration.
The calibration of DOC exports from the soil to the river and the subsequent DOC decomposition was difficult because of data limitation, in particular for the exports through the soil-water interface. Thus, we took values from the literature whenever available but sometimes had to make assumptions for some parameters (e.g. $F_{fast+slow,H2O}$). However, we always tried to secure that our simulated DOC exports from the soils to the water (orig. Table 3, now Table 6) were within reasonable ranges. Similarly, we verified that our simulated DOC concentrations in the river were close to observed DOC concentrations. With our final parameterisation, the simulated average DOC concentrations are close to observed average DOC concentrations (see original Figure 14), for the entire set of observed concentrations over all stations (mean deviation of -2% relative to mean observed value) and at Obidos (mean deviation of -1% relative to mean observed value) in particular, the is the sampling location the most far downstream. In the revised version of our manuscript, we now report results from a sensitivity analysis (new Tables 7 and 9) for the most important parameters controlling DOC exports to the water column and decomposition within the water column ($F_{fast+slow,H2O}$, $red_{DOC,base}$, $k_{doc,lab}$, $k_{doc,ref}$).

To better accommodate these modifications into the manuscript, we restructured parts of the results and discussion sections. The parts of sections 3.2.3 (mobilization from soils to the river) and 3.3 (fluxes in and from the river to the atmosphere) dealing with DOC are now merged into a new section 3.3, while the parts dealing with CO_2 are merged into a new section 3.4 (the old section 3.4 becoming now section 3.5). In the new section 3.3, following the logic of reporting first the parameters calibration, we start with the comparison between observed and simulated DOC concentration in overland flow, drainage, and headwaters (now Table 6), and then report the results from the sensitivity analysis on DOC exports through the soil-water interface (Table 7). Next, we compare the observed and simulated DOC concentrations in the river (original Fig. 14), including the sensitivity analysis, and finish with the fluxes of DOC in the river (original Figs. 12 and 13, now Figs. 14 and 15).

For the new section 3.4, dealing with CO_2 evasion, we report at the end the results from the sensitivity analysis, highlighting the weak sensitivity of simulated CO_2 evasion to the gas exchange velocity: changing the gas exchange velocities by +/-50% only lead to a change in total FCO_2 from the Central Amazon basin of only +1% and -4%, respectively. Thus, the choice of a "right" gas exchange velocity does not seem important.

4. P21, L8. What is the performance in terms of the spatial pattern of flood area?

We compared our simulated maximum inundation during the period 1995/1996 to the high-resolution airborne remote sensing data by Hess et al. (2015), which we aggregated to the 1-degree resolution of our simulation. The correlation in spatial patterns is satisfying (R2=0.56, y=0.04+0.90*x (with y = observed data, x = our simulation)). We have added a figure to the revised manuscript (Figure 9), which compares our simulation to the aggregated observations by Hess et al., 2015.

5. Fig. 9. As mentioned above, were there any performance measures showing how good the simulations were? What were the results for monthly time series?

We have calculated the Nash-Sutcliff efficiencies, correlation coefficients and RMSEs for each time series and added them to all the relevant graphs (Figs. 8, 10, 13, 14, 15).

6. Table 1b. I was wondering how the SOC was simulated. What was the initial condition in the model? Did the simulated SOC change with time? How much did it change?

The soil carbon storage was produced by running the entire model for a simulation period of 1000 years, using the atmospheric CO_2 concentration and land cover of the year 1980 and looping over the climate forcing files for the years 1980 to 2000 (the whole of 21 forcing data produced by Guimberteau et al., (2012). These 5000 years simulation was started with an initially empty soil C storage, which then grew and reached a steady state, i.e. apart from minor fluctuation over the 21 year periods of the climate forcing, no significant trend in soil carbon storage occurred anymore. During this initialisation period, the soil carbon stock grew from 0 Pg C to 48 Pg C. Over the subsequent 21-year simulation period reported in this paper, the soil C storage in the Amazon basin fluctuated between 48.6 to 48.2 Pg C, with no trend.

In the revised manuscript, we clarified this point in the method section:
"To obtain initial soil carbon pools which are in steady-state with the model set-up for the 1980-2000 period, the model was first run for 5000 years, looping over the full set of climate forgings and using the land use and an atmospheric pCO_2 as representative for the year 1980. The terrestrial C pools

simulated during this initialization phase were subsequently used for the simulation over the period 1980-2000 with changing land cover and increasing atmospheric pCO_2."

7. Fig. 14. It is found the simulated DOC basically varied within a small range around 4 mgL-1 except the simulations at M, implying the simulated seasonal variability of DOC fluxes (in Fig. 12) were mainly attributed to the discharge not DOC concentration. I speculate the monthly time series for Q would mimic the DOC fluxes. Are these persuasive results for a DOC model? Besides, I wouldn't say the simulations reproduce well DOC concentration (L1, P33).

In Fig. 14, we made two little mistakes by reporting wrong simulated values for Obidos and Gaviao. With the corrected time-series, there is now little bit more variation in simulated values. However, the reviewer's observation is still correct and the simulated DOC concentrations show a significantly lower variability compared to the observed values, and DOC fluxes therefore mainly follow the variations in simulated discharge.
We clarified this observation in the revised manuscript:
"Comparing observed vs. simulated DOC concentrations, we were able to reproduce the average concentrations at least in the main stem of Rio Solimoes/Amazon River and in the Rio Negro. However, apart for the Rio Negro, we generally underestimate the seasonal variability of DOC concentrations."

8. CH4 evasion was negligible. How about the influence of DIC?

We agree with the reviewer that this is an important point. According to Richey et al., (1990), the fluvial exports of DIC (at Obidos) amount to 35 Tg C yr^{-1}, which is significantly higher than the export of DOC of 22.4 Tg C yr^{-1} after the same source. The same authors report that throughout the Amazon main stem and its major tributaries, 60-90% of the DIC is in the form of HCO_3^- derived from chemical rock weathering, while the remainder is mainly free dissolved CO_2, concentrations of CO_3^{2-} being negligible at the pH values of 6.5 to 7.2 typically reported for the Amazon basin. Thus, the fluvial export of free dissolved CO_2 would lie between 4 and 14 Tg C yr^{-1}. According to our simulation, the average fluvial flux of dissolved CO_2 at Obidos amounts to 8.3 Tg C yr^{-1}, and lies thus within the range reported by Richey et al. 1990. Rock weathering and the related HCO_3^- fluxes are not represented in ORCHILEAK.
Dissolved CO_3^{-2} in the river water could exert a buffering effect on CO_2 produced and transported in the water column by the reaction $H_2O+CO_2+CO_3^{2-} => 2\ HCO_3^-$. However, as the CO_3^{2-} concentrations are negligible in the Amazon, this buffering effect is negligible. For an application of ORCHILEAK to high pH rivers, like for example the Rhine, a full representation of the carbonate system including weathering related fluxes of DIC would be of higher importance to reproduce riverine CO_2 transport and evasion.
In the revised manuscript, we added two sentences to the introduction to include this important point:

"Further, we ignore the fluxes of carbonate alkalinity as at average pH values of 6.5 to 7.2 typical of the Amazon basin (Richey et al., 1990) the concentrations of CO_3^{2-} are negligible and, thus, the carbonate-buffering of CO_2 is limited."

9. Is it possible to give a diagram illustrating the numbers of each C flux for the study watershed, just like Fig. 3 but with numbers on each arrow?

We agree with the reviewer and produced a new figure according to his suggestion along with a short subsection "Synthesis **of simulation results" (now subsection 3.3).**

"3.3 Synthesis of simulation results

Figure 19 summarizes the simulated fluxes of dissolved C, i.e. the sum of DOC and CO_2, through the river network of the Amazon basin. The total simulated export of carbon from the basin amounts to 413.9±50.0 Tg C yr^{-1}, to which lateral exports to the coast contribute only 8.3%, while the remainder is contributed by CO_2 evasion from the inland water surface. 57% of the total dissolved carbon inputs is contributed by flooded soils and litter. Surface runoff and drainage contribute 14% and 28%, respectively. It is interesting that the flux of carbon via throughfall onto the topsoil is as high as the lateral exports of dissolved C from the topsoil, although it is not necessarily its source. According to our simulations, about 8% of the dissolved C mobilized into the water column are reinfiltrating into the soil column in swamps ($F_{up2swamp}$) or on floodplains ($F_{flood2soil}$).

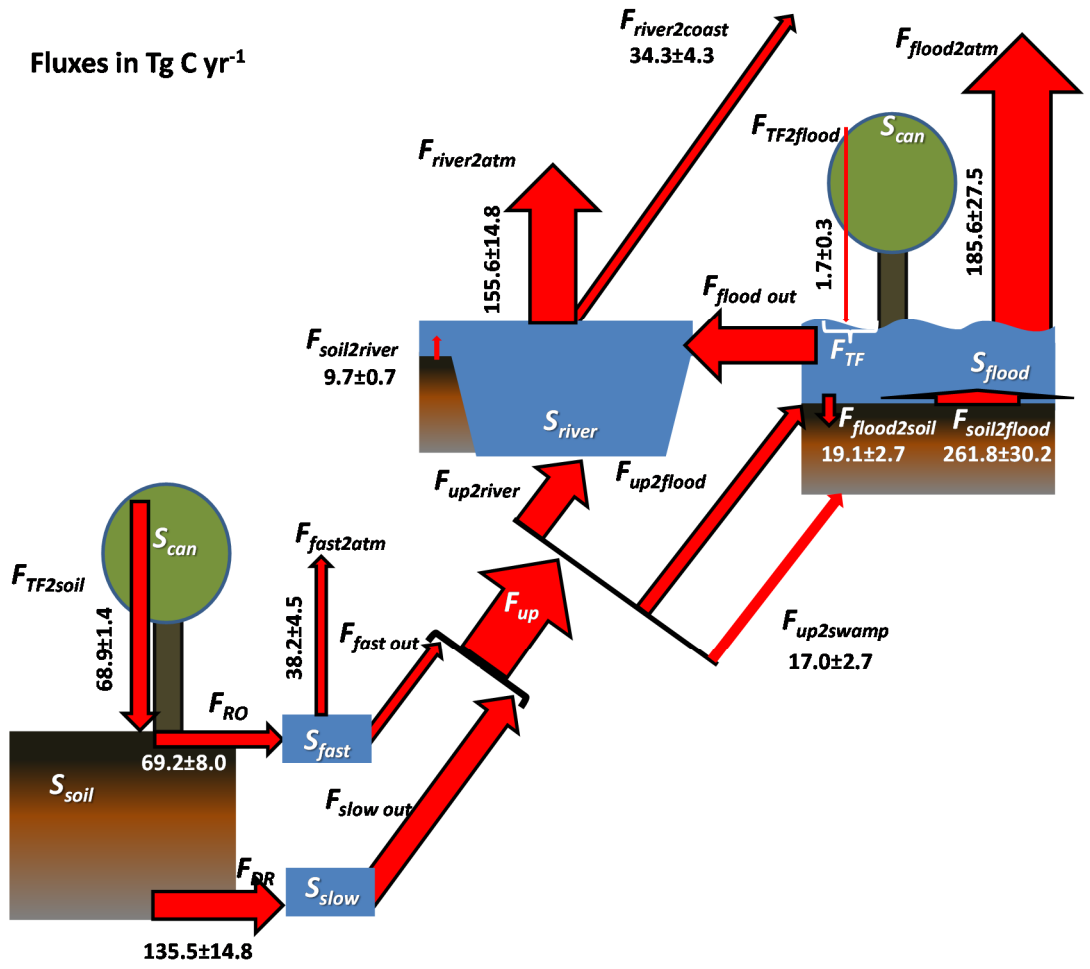

Fig. 19: Simulated fluxes of dissolved carbon (DOC + CO_2) through the inland water network of the Amazon basin. Numbers are average annual fluxes ± standard deviations over the simulation period 1980-2000."

10. Fig. 4. What do the yellow color stand for? Where are the discharge gauges? Do you think landuse map is helpful?

The yellow colour represents the continental area that lies outside of the contributing areas of river sampling locations used in this study. This is now clarified in the figure caption. The river sampling location reported in this map do indeed include discharge gauges. In the revised manuscript, we added a colour code to distinguish locations that are only sampling locations of river water quality, locations that are only used as discharge gauges, and locations that serve for both (river water sampling and discharge gauge).

We added a land use map to the appendix, Fig A.1.

11. Table 4. What do the stars indicate? Why is the surface runoff represented by % for the RO3?

The surface runoff is given in % of the total runoff (surface runoff + drainage). We took those percentages directly from Johnson et al. (2006,2008), which reported surface runoff in that way, without absolute values. For comparison, we thus reported the simulated surface runoff the same way. A footnote, marked by *, should have been included to clarify this point It is now included in the revised manuscript.

Note that in Waterloo et al. (2006) only the absolute value for surface runoff was reported, i.e. values for drainage or total runoff were missing. Therefore, we do not know the percentage of surface runoff at the sampling locations reported in this study. For comparison, we report also the absolute value of our simulated surface runoff, but also that of total runoff allowing the reader to deduce the contribution of simulated surface runoff to the total runoff.