Response to Reviewer 1

We thank the reviewer for his/her time dedicated to this manuscript. We found the comments highly valuable to improve the quality of our manuscript.

Please see our detailed replies to each comment in blue. Text in bold is text that is copied from the new manuscript. Text in bold and highlighted in yellow is new text added as a result of the review.

This manuscript presents a new scheme for floodplains, adapted to a high spatial resolution river routing in Orchidee. The mechanism is described, and tests are performed, using two atmospheric forcing over the Pantanal wetland, between 1990 and 2013. The scheme is evaluated with river discharge in situ measurements, as well as with GRACE data and satellite-derived surface water extent. The impact of the new scheme is tested, on the soil moisture, on the surface temperature, and on the vegetation density, and on the evapotranspiration. Before being publishable, the paper has to undergo a major revision.

Major comments

1) How sensitive is the scheme to the dataset (here GLWD) used as a maximum mask for the inundation? A test should be performed to assess its effect, as this dataset is certainly valuable, but not perfect. There is a comment about the use of GLWD at lines 334 and following, but it is not said how the relevance of the dataset is tested (and possibly modified).

The scheme is highly sensitive to the dataset used to define the floodplains. The correct description of the flooded area is therefore essential.

To our knowledge, there are no similar global datasets differentiating the different types of wetlands. It is important to distinguish between floodplains and other type of wetlands with different hydrological dynamics.
GLWD (Lehner and Doll, 2004) characterizes all the Pantanal as potential floodplains. Therefore, we consider that the description for the Pantanal is fine and that it seems that there is no potential source of conflict with other wetland types. This is not the case of other large wetlands, which are partially floodplains (cf. answer to comment number 7).

We added the following comment in the text:
There is a large uncertainty in the description of wetlands due to the difficulty to perfectly evaluate the flooded areas from satellite products, and there are also large uncertainties concerning the categorization. Despite this uncertainty, GLWD is combining different types of products to obtain this categorization. The review of other wetland descriptions in Hu et al. (2017) doesn't seem to show a product that would be preferable to GLWD. In this study, the GLWD dataset has not been modified, but the categories in the GLWD dataset

related to floodplains may be changed further in other studies to adjust the floodplains mask.

2) Figure 2 shows an evaluation of the mean annual cycle for the discharge and the models. It would be interesting to test the inter-annual variations (directly plotting the long time series or better by calculating some de-seasonalized anomalies). Is the model able to capture these changes from a year to the next? Same question for the water masses. Is the model able to capture the inter-annual variations observed by Grace?

Thank you for this comment, this is another important aspect that can be assessed. You will find below figures performing this assessment. Figure I shows the time series of the average annual discharge at Porto Murtinho. It principally highlights the difference in terms of mean discharge over the period already plotted in Figure 2 from the paper.

Figure II shows that variations in the FP simulations is less noisy than NOFP simulations which have more important variations compared to the annual cycle, i.e. FP has a more stable annual cycle. Also, FP de-seasonalized monthly discharge time series is closer to the observations than NOFP.

We decided to include these figures in Annex, and we added the following comment in the text:

The interannual variability has also been assessed and is shown in Figure I. The FP simulations with floodplains have higher correlations with observations compared to the NOFP simulations concerning the interannual variability of the mean annual discharge. However, these correlations are only significant for WFDEI_GPCC simulations. Also, this correlation is much higher in WFDEI_GPCC_FP (correlation of 0.71) compared to AmSud_GPCC_FP (correlation of 0.17).

Figures II shows the de-seasonalized time series of the monthly discharge at Porto Murtinho. We can observe that the FP simulations are less noisy and much closer to the observations compared to the NOFP simulations.

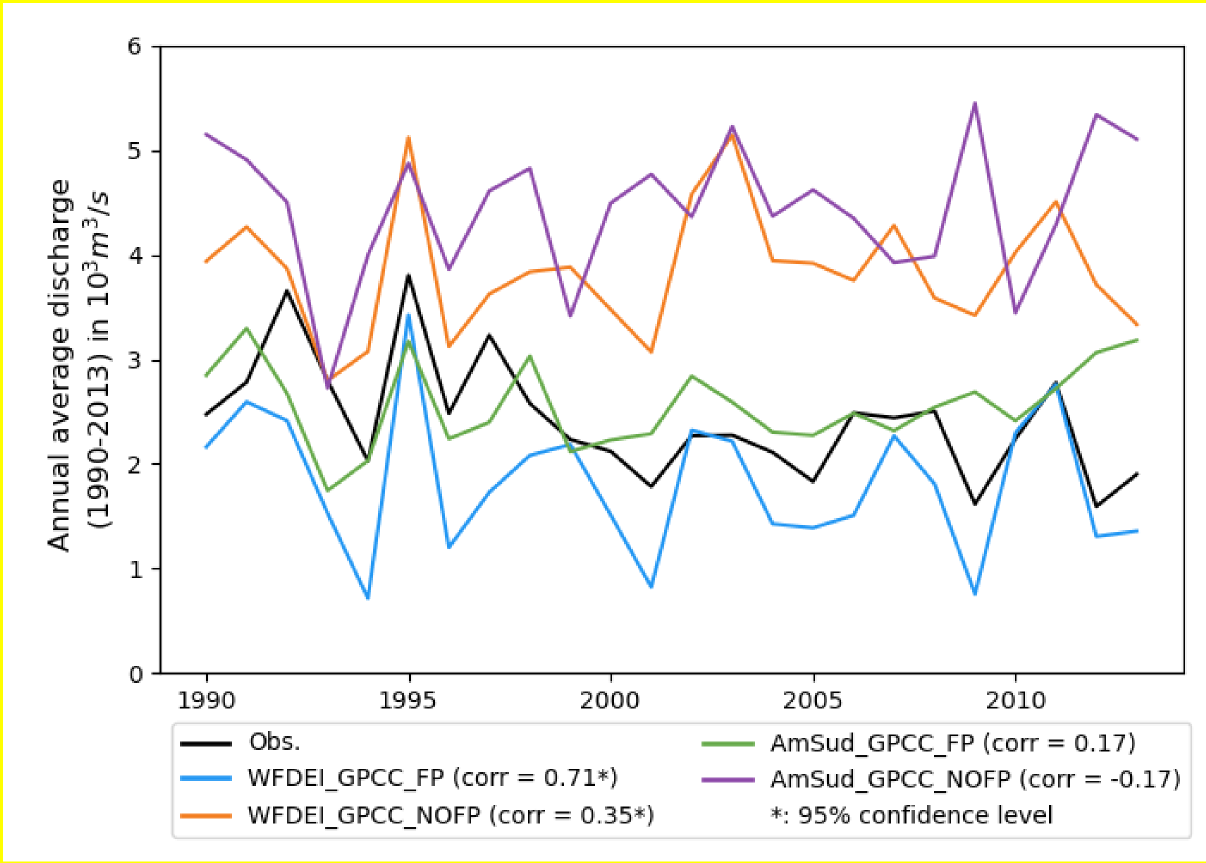

Figure I: Time series of the annual average of the discharge at Porto Murtinho between 1990 and 2013.

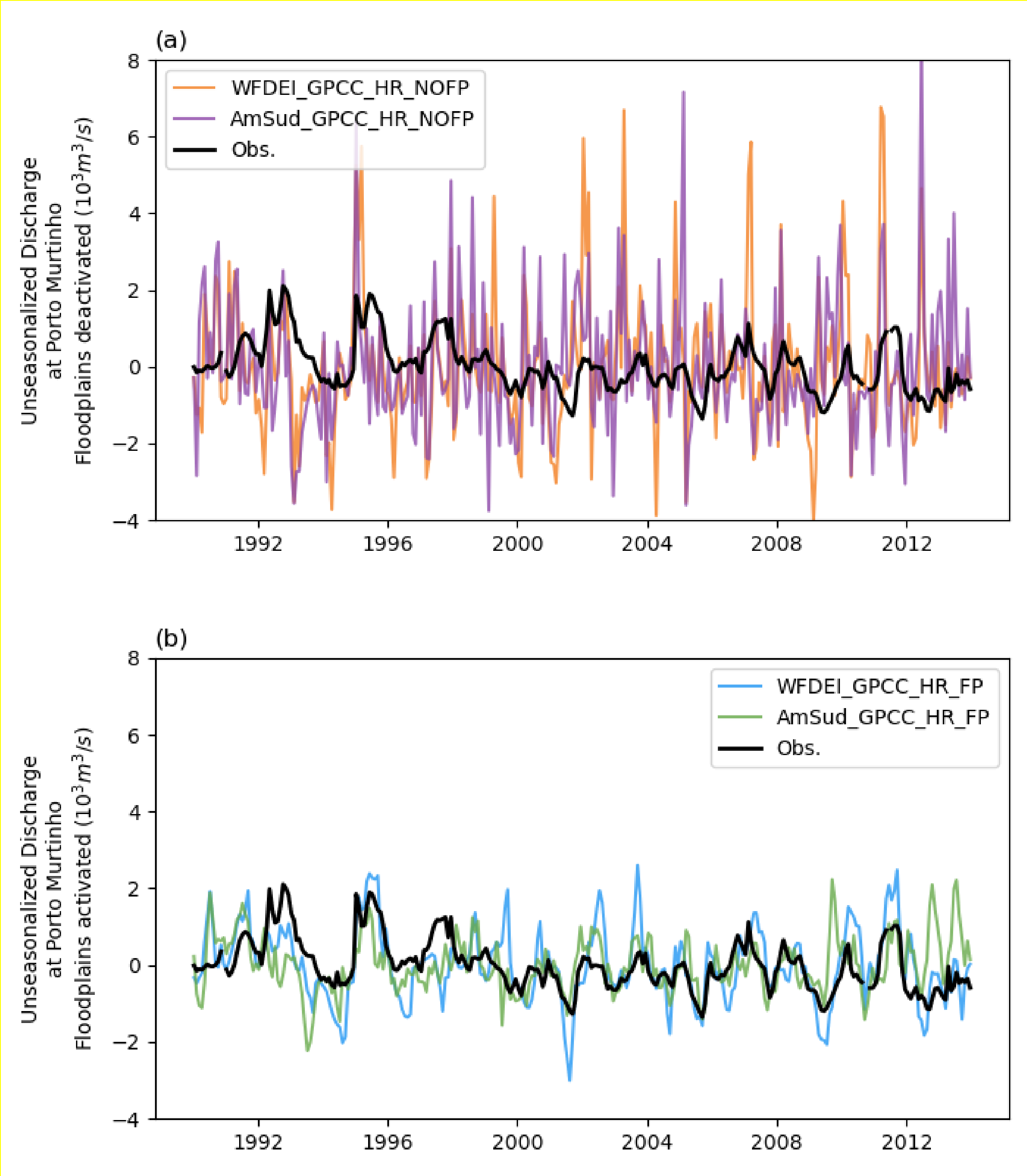

Figure II: Time series of the monthly discharge at Porto Murtinho removing the annual cycle between 1990 and 2013 for (a) the simulations without floodplains and (b) with floodplains.

3) Between the two forcing datasets, the differences in terms of water masses are particularly striking (Figure 3), and as large as the difference between the cases with and without floodplains for the WFDEI case (see for soil moisture or for the slow reservoir for instance). That casts some doubts on the validity of the model / forcing combination. Can you comment?

I agree with your comment that the differences in terms of water mass are quite large, with differences between WFDEI_GPCC_FP and WFDEI_GPCC_NOFP as large as differences between WFDEI_GPCC_FP and AmSud_GPCC_FP.

Two elements that can play an important role in Land Surface Models and can explain these differences.

First, the higher resolution in AmSud_GPCC is playing an important role as, due to the absence of groundwater horizontal transport scheme, the water remains along the largest river where it has the possibility to infiltrate into the soil moisture of the flooded area while in WFDEI_GPCC it can infiltrate over a much larger area.

Secondly, although they have similar precipitation, AmSud_GPCC atmospheric forcing has dryer atmospheric conditions which lead to a more important evapotranspiration in AmSud_GPCC_FP compared to AmSud_GPCC_NOFP. This can explain the fact that the soil moisture content does not increase so much between AmSud_GPCC_FP and AmSud_GPCC_NOFP.

We also want to add that AmSud_GPCC has been used in this paper because we coupled the floodplains scheme with the regional model RegIPSL, that was used to generate the AmSud_GPCC forcing over the same grid, in another study (in writing). Despite the differences with WFDEI_GPCC, this was a way to validate and evaluate the floodplains scheme over this grid.

4) Comparisons of the surface water extent are presented for different satellite-derived surface water. We need a few sentences for each dataset, to know how they have been derived and assess their possible limitations. Otherwise, there is no interest to compare to multiple products. For instance, the sensitivity of the different products to open water / vegetated water should be discussed.

Thank you for your comment. We agree that it is essential to provide some limitations to justify the use of different products. We added the following paragraph:

We use different types of satellite products to have a complete view on the flooded area. Two products have been especially constructed over the Pantanal: Hamilton (2002) and Padovani (2010) so they may be more appropriate due to the specificity of the Pantanal floodplains, however they have some limitations: Hamilton (2002) is based on a relationship between flooded area and river height established during a short and wet period and, therefore, this relationship may differ under different climatic conditions. It is also only available up to 2000. Concerning Padovani (2010) and Schrapffer et al. (2023), the limitation is the infrequent revisit of satellite (data every 6 days) and missing images due to the use of optical satellite imagery. Padovani2010 is interpolated which helps us to have an overview of the full time series of flooded areas while Schrapffer et al. (2023) gives us precise estimates for punctual satellite without any interpolations and is available up to 2013 while Padovani (2010) is only available up to 2010. Therefore, both datasets are complementary. GIEMS-2 is a global dataset and a reference in the scientific literature in

terms of satellite estimate of the flooded area and, it has not been specifically validated over the Pantanal, but we thought it was crucial to include it here.

5) Some mechanisms are mentioned that cannot be considered by this river flooding scheme (l. 550). Add a paragraph in the model description to mention them (section 2)?

Thank you for your comment. We provided an overview of the mechanisms not considered by the river flooding scheme in the description of the model (Section 2):

The floodplains scheme does not include divergent flows, neither groundwater lateral flow. Also, it does not include the reduction of the vegetation due to water logging along floodplains.

6) For the soil moisture estimates, would it be possible to add some SMOS or SMAP retrieval? For the vegetation, any tests with NDVI or other proxy for the vegetation, in terms of seasonality and inter-annuality?

Thank you for this suggestion, satellite estimates of soil moisture face large uncertainties over South America and as the formulas they rely on may not be adapted for open water surfaces / flooded vegetation such as seen by Di Vittorio et al. (2021) in the Sudd wetland. This is why we preferred to use GRACE data to assess water masses.

Concerning vegetation, we thought your suggestion was interesting, so we tried to assess it using LAI which is the main variable driving the vegetation in ORCHIDEE, it is shown in Figure III. We use the NDVI from the GIMMS dataset generated from NOAA's AVHRR and available in Google Earth Engine because it was available from 1990.

Despite the fact that we can observe well the annual cycle in both NDVI, FP and NOFP simulation, this may not help to validate the improvement of the vegetation. Also, the interannual variation of the vegetation cannot be observed in the NDVI, since it saturates for the dense canopy of the Pantanal.

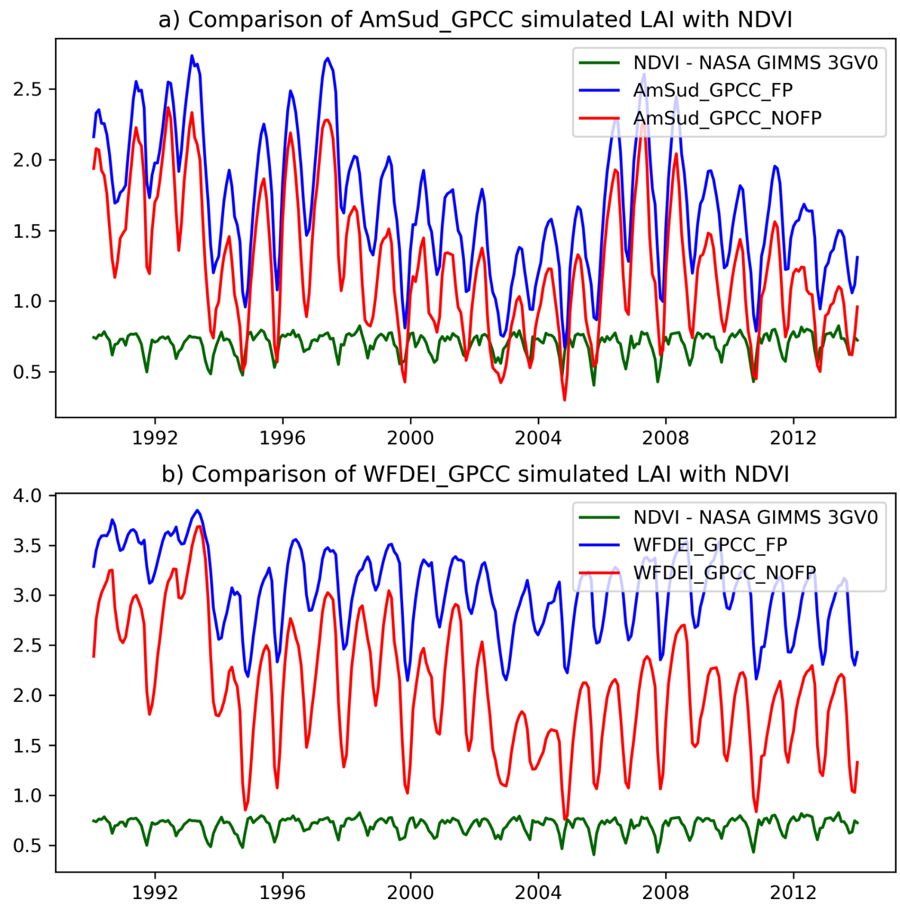

Figure III: Comparison of the NDVI time serie from the GIMMS dataset and generated from NOAA's AVHRR with (a) AmSud_GPCC_FP and AmSud_GPCC_NOFP and also with (b) WFDEI_GPCC_FP and WFDEI_GPCC_NOFP.

7) Applying the scheme to another region and evaluating it would certainly strengthen the paper. It is rather frustrating to have global models and datasets only applied to one specific case. At least another basin that is in the same type of environment (the Orinoco?) and for one common forcing?

Thank you for your comment. Your suggestion is totally relevant. However, the flooding process in other large wetlands in South America are not always mainly driven by overflow from large rivers, as it is the case for the Pantanal. Some other type of wetlands can exist and have major influence over the flooded area, such as the swamps and flooded forest over in the Llanos de Moxos, in the Bananal and in the surrounding of the Amazon River (cf. GLWD). Also, from GLWD, in the Llanos del Orinoco, there is a region in which the flood mechanism is driven by overflow from large rivers (floodplains) but there is also an important area in which flood mechanism is related to swamps and flooded forest processes in the South / North and East. Another difficulty is that there are not always hydrological stations which help to assess the impact of the activation of the floodplains scheme on the basin hydrological cycle.

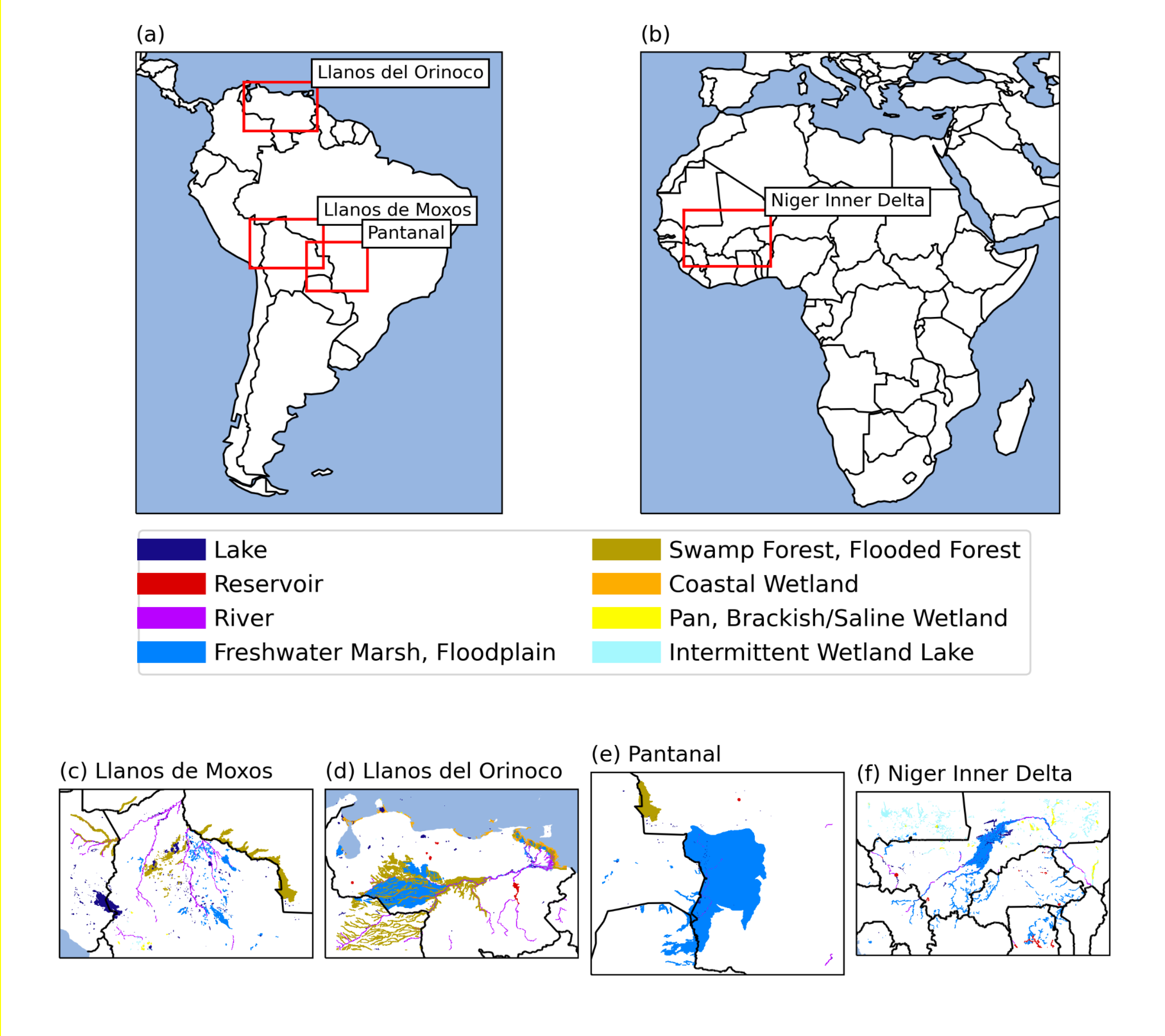

Figure IV: Description of the Lake and Wetlands over (c) the Llanos de Moxos, (d) the Llanos del Orinoco, (e) the Pantanal and (f) the Niger Inner Delta floodplains from the Global Lakes and Wetlands Database (GLWD, Lehner and Döll, 2004). The location c-f are shown in (a) for the South American regions and (b) for the African regions.

However, we follow your advice and performed the analysis over the Orinoco floodplains. There is an hydrological station at the outflow of the Llano del Orinoco but there were no data available during the period of the simulations. Therefore, Figure V shows the impact of the floodplains scheme without showing the observations.

The activation of the floodplains scheme has an impact on the discharge as the annual peak of the discharge is delayed by almost one month and only a small fraction of the flooded area is represented in the output of the model. Although the correlation seems relatively high, the flooded area is importantly underestimated. This may be related to the fact that there are also important mechanisms of swamp forest / flooded forest (see Figure IV.d) and, therefore, the horizontal transfer of soil moisture and resurgence of water will be important to represent well the hydrology of the Llanos del Orinoco. However, these mechanisms are not represented in the ORCHIDEE model. As seen with the Pantanal, their absence is even more important at higher resolution and this is what we can observe through the lower flooded area in the AmSud_GPCC_FP simulation compared to the WFDEI_GPCC_FP simulation.

These Figures have been added in Annex, and we added the following comment in the text:

It is difficult to evaluate the floodplains scheme on other South American floodplains because the flooding process in other large wetlands in South America are not always mainly driven by overflow from large rivers, as it is the case for the Pantanal. Some other type of wetlands can exist and have major influence over the flooded area, such as the swamps and flooded forest over in the Llanos de Moxos, in the Bananal and in the surrounding of the Amazon River (cf. Figure IV). Another difficulty is that there are not always observations available to assess the impact of the activation of the floodplains scheme on the basin hydrological cycle (absence of hydrological stations or stations without data).

Nevertheless, an analysis has also been performed over the Llanos del Orinoco despite the absence of observation at the station at the outflow of the floodplains using both simulations between 1990 and 2013 (cf. Figure V and VI). This flood mechanism is driven by overflow from large rivers (floodplains) but there is also an important area in which flood mechanism is related to swamps and flooded forest processes in the South / North and East (cf. Figure IV). The discharge at the outflow of the Llanos del Orinoco is delayed by one month and the flooded area is underestimated due to the absence of integration of swamps and flooded forest. We can also observe the absence of coastal floodplains which are related to other floods mechanisms.
As shown from Figure IV, the Inner Niger Delta is a region adapted to evaluate the floodplains scheme is the Inner Niger Delta which is also mainly composed by “Freshwater Marsh, Floodplain” category in GLWD.

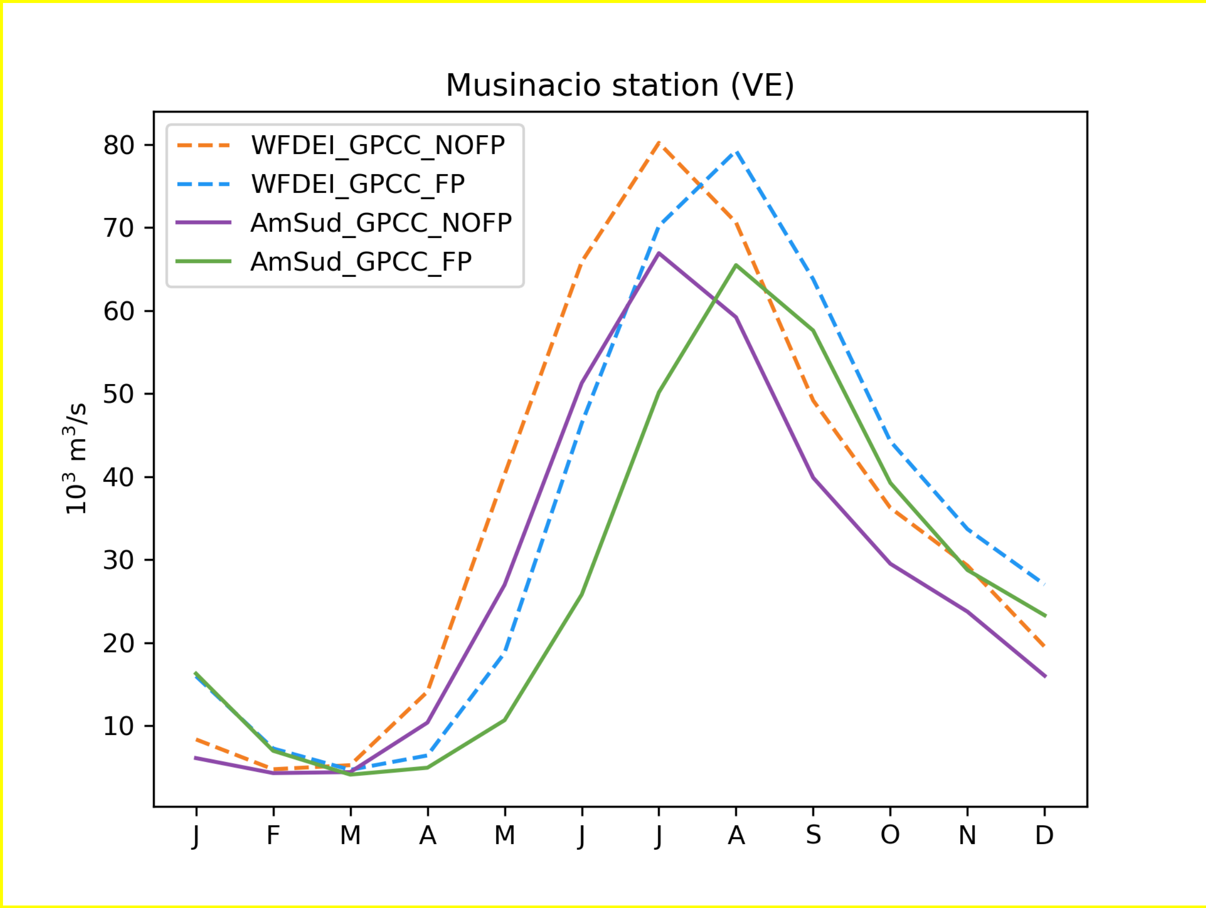

Figure V: Annual cycle of the simulated discharge at the Llanos del Orinoco outflow river discharge station (Musinacio station in Venezuela) by the simulations FP and NOFP for WFDEI_GPCC and AmSud_GPCC between 1990 and 2013.

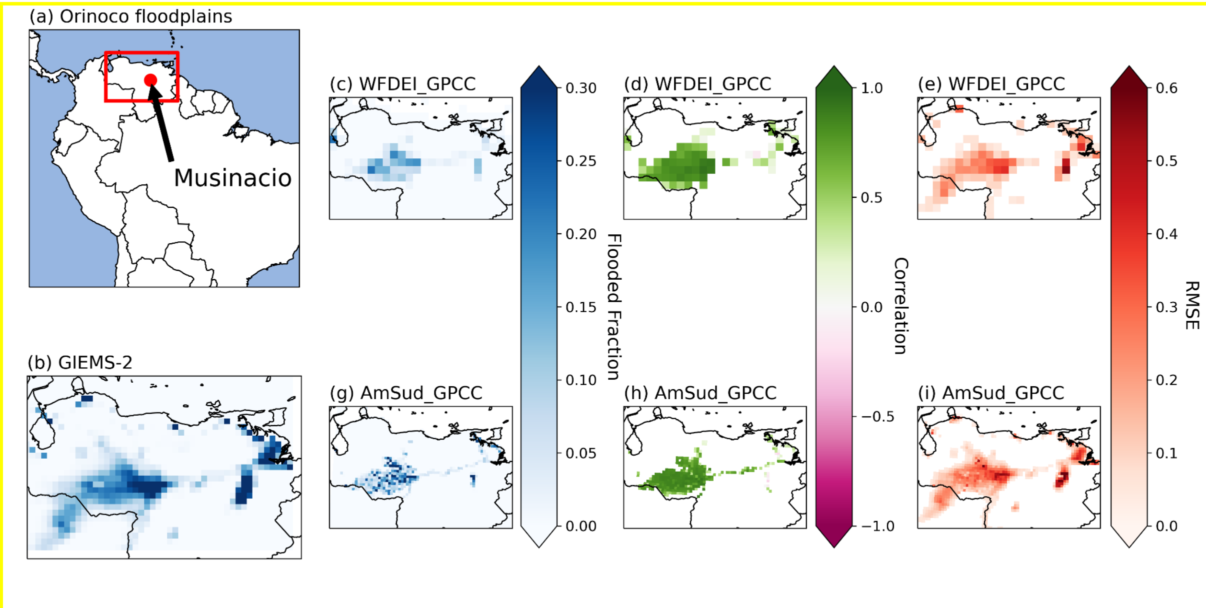

Figure VI: (a) Location of the Llanos del Orinoco region and mean flooded fraction in (b) GIEMS-2, (c) WFDEI_GPCC_FP and (g) AmSud_GPCC, as well as the (d) (respectively h)

correlation between the flooded fraction in WFDEI_GPCC_FP (resp AmSud_GPCC_FP) and GIEMS-2 and also (e) (respectively i) the Root Mean Square Error of between the flooded fraction in WFDEI_GPCC_FP (resp AmSud_GPCC_FP) and GIEMS-2 for the period 1992-2013.

Minor comments

High spatial resolution river routing is mentioned at many occasions, but the reviewer could not find the information about that spatial resolution. That has to be clearly mentioned right away in the paper.

Thank you for your comment, I specified that we are using a 2km resolution DEM to construct the river routing over the different grid. The main point of the concept of high resolution routing is better defined in the companion paper Polcher et al. (2023) to which we make reference. However, I added the following:

In this case, the routing graph have been constructed using the MERIT-Hydro dataset at a 2km resolution.

l.61: 'such as such as'

Thank you for highlighting this mistake. It has been corrected

l.196: the notations are confusing. Clarify.

Thank you for your comment, we reformulated this sentence:

For this reason, the slow and fast reservoirs will not be mentioned further in this paper and as the stream and floodplains reservoir of an HUT i share the same topoindex (αi,stream = αi,f loodplains), we will refer to this common topoindex by αi, with αi = αi,stream = αi,f loodplains.

l.208: 'thRough'

Thank you for highlighting this mistake. It has been corrected.

l.327: 'the routine graphS'

Thank you for highlighting this mistake. It has been corrected.

l.339: it would help to have a map of the area, with the river, its tributaries, and the location of the reference station.

Thank you for your comment, a map has been added in the Annex.

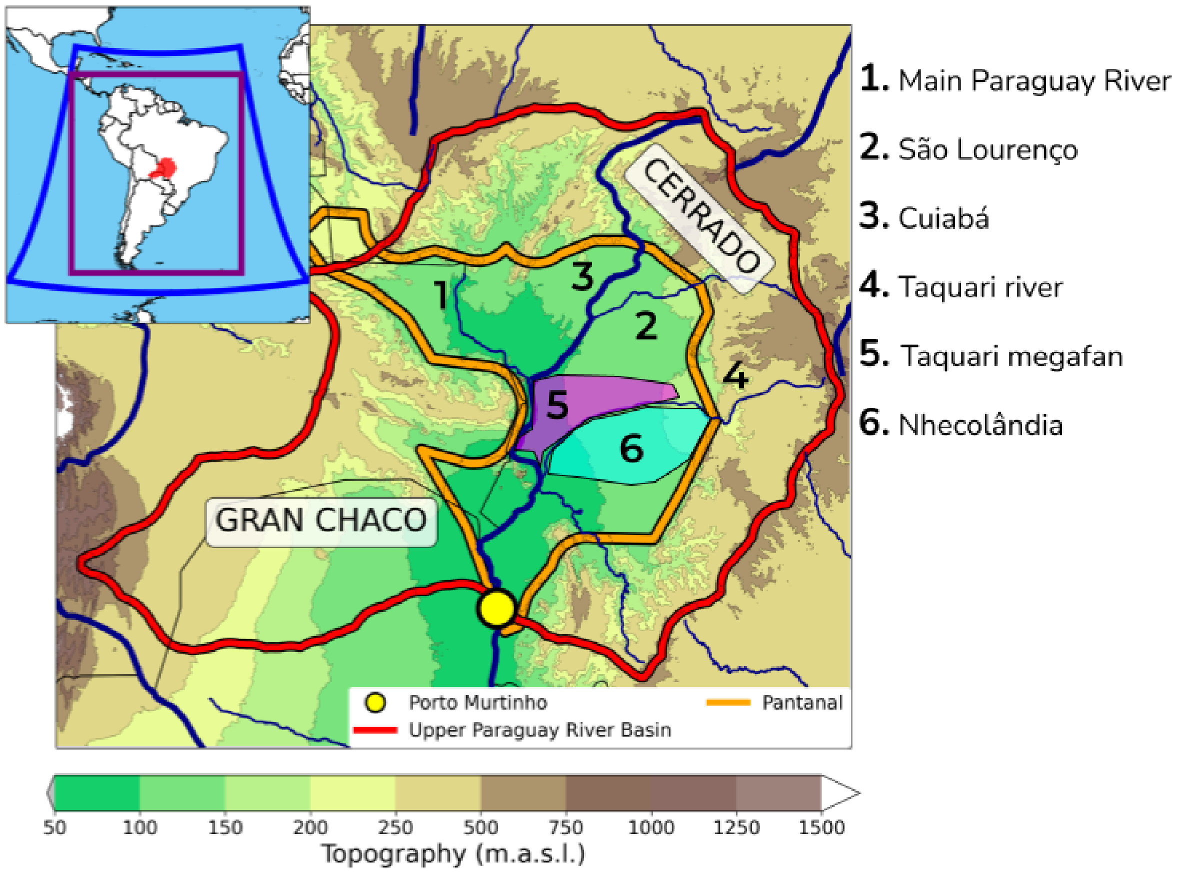

Figure VII: Description of the domain used for both simulations (AmSud_GPCC and WFDEI_GPCC) as well as the description of the Upper Paraguay River Basin region with delimitation of the Pantanal. The different rivers, regions and hydrological stations mentioned in the present articles are also described

l.440: 'Depending on the period simulated, the SIMULATED flooded area simulated was…'

Thank you for highlighting this imprecision. It has been corrected.

Table 2: indicate the meaning of the *. It is done in Table 3, but not here.

Thank you for pointing out this omission.

l.564-565: Surfaces of point 2) are not seen by GIEMS-2. Are they seen by the mNDWI estimates?

These regions are detected by mNDWI however it is may not appear well in GIEMS-2 due to the resolution as the scale of these flooded is much smaller than the other flooded area of the Pantanal.

Figure 5: Add some comparisons with the other satellite-derived estimates. Especially the one the authors are themselves deriving.

We understand your comment. The comparison that we can make would be limited to the satellite derived estimate we derived. However, this represents a technical issue due to the much higher resolution of the satellite estimate flood map (30m resolution) compared to the output of the simulation (20km and 50km). Moreover, the interest of this figure lies in the illustration of the spatial analysis of correlation and Root Mean Square Error. However, the satellite-derived estimate haven't a regular temporal timestep and is more available during specific seasons (less cloudy season), this can potentially introduce bias into the evaluation. For this reason we only focused on GIEMS-2 which have a resolution close to the resolution of the simulations allowing to interpolate it.

l.631: ‘relativeS’

Thank you for highlighting this mistake. It has been corrected.

l.798: ’assess flooded area…principally in areas covered by floods’????

Thank you for highlighting this mistake. It has been corrected. We meant “covered by vegetation”.

l.806: All the satellite-products do not only consider the open-water surfaces. In this work, the model is expected to be evaluated for wetlands. Most wetlands are vegetated surface water. If the satellite-products you use are only sensitive to open-water, it seems that the paper is missing its goal. Clarify.

Just to be more precise, this model is expected to be evaluated on floodplains because the floodplains scheme is not able to represent the processes occurring in other types of wetlands (such as swamps, for example).

Concerning the vegetation, it depends on the type of vegetation, as satellite estimates of flooded areas such as Padovani (2010) have succeeded in identifying the flooded areas over the Pantanal. The issue with these satellite products is not there, the issue is that it can confuse areas with saturated soil but no flood with flooded areas because they detect an important presence of water over the soil. Therefore, these satellite products are not only sensitive to open water, but they are sensitive to saturated soil which are not flooded.

REFERENCES

Di Vittorio, C. A., & Georgakakos, A. P. (2021). Hydrologic modeling of the sudd wetland using satellite-based data. Journal of Hydrology: Regional Studies, 37, 100922.

Hamilton, S. K.: HYDROLOGICAL CONTROLS OF ECOLOGICAL STRUCTURE AND FUNCTION IN THE PANTANAL WETLAND (BRAZIL), IAHS Special Publication. The Ecohydrology of South American Rivers and Wetlands., 2002.

Hu, S., Niu, Z., & Chen, Y. (2017). Global wetland datasets: a review. Wetlands, 37, 807-817.

Lehner, B., & Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of hydrology, 296(1-4), 1-22.

Padovani: Dinâmica Espaço-Temporal das Inundações do Pantanal., Ph.D. thesis, Piracicaba: Escola Superior de Agricultura Luiz de Queiroz, Centro de Energia Nuclear na Agricultura, Universidade de São Paulo, http://www.teses.usp.br/teses/disponiveis/91/91131/tde-14022011-170515/pt-br.php, 2010

Schrapffer, A., María Cappelletti, L., and Sörensson, A.: ESTIMATION OF THE FLOODED AREA OVER THE PANTANAL, A SOUTH AMERICAN FLOODPLAIN, USING MODIS DATA., Meteorologica, 48, 2023