Answers to the interactive comments from the anonymous referee #2

Firstly, the authors would like to thank you the careful review from the anonymous referee #2. Please allow us to answer below the comments which you gave in the interactive comments. Please note that the **RC** stands for the referee comments, **AR** is the abbreviation of author's response and **AC** indicates the author's changes in manuscript.

For the general comments:

1. More concise descriptions

   RC: Regarding the paper readability, the paper can be improved by making the descriptions more concise throughout the paper, but especially section 3 and discussion. Section 3.3. section seems to be important, but it is a little lengthy, therefore, it is hard to follow. I would like to suggest describing each step in Figure 2a) one by one at the beginning. Also note the specific comments.

   AR: *The authors will refine the text for more concise descriptions with the focus on the section 3 and discussion.*

   AC: *The modification can be found in p.7 l.20, p.8 l.11.*

2. The anthropogenic processes

   RC: The paper emphasizes an importance of incorporating anthropogenic processes on river flow (irrigation, reservoir etc.) at multiple locations throughout the paper (P3-L7, P6-L5-8, P17-L20, P18-L13-15). I agree that this is one of future direction for river modeling. However, this issue is not main topic of this paper, and the paper never mentioned how high resolution gridded network-based model helps to incorporate this nontrivial processes as indicated in P3-L7. I would like to suggest at least how high resolution river network routing helps incorporate these processes.

   AR: *The authors will provide a perspective of how high resolution river network can assist the incorporation of irrigation. In fact, in the earlier version of the routing scheme, the representations of irrigation and floodplain already existed (De Rosnay et al., 2003; Guimberteau et al., 2012b; d'Orgeval et al., 2008; Guimberteau et al., 2012a). Since these representations of human processes or flood plains is based on a hypothesis that HTU were rather large (i.e. at scale of 1/2^o), this is not valid any more and thus these parameterizations need to be revised in order to work with high resolution descriptions of the river basins. In order to represent the irrigation processes in the ORCHIDEE model, the irrigated area map is required to integrate into the routing scheme. The most update global map of the irrigated area is provided at resolution of approximate 10 km by Siebert et al. (2013). The new routing scheme constructs the river networks by connecting the HTUs which can be vary in size from about 1 km^2 to the area of the ORCHIDEE grid cell (e.g. 1/2 ^{o}). Hence, the irrigated location can be located in each HTUs. The difficult part is how to control the store and release processes of the water along the river network that is irrigated. For example, a irrigated region can receive water from different tributaries of a river network as well as depend on the available upstream water.*

   AC: *In the Discussion, the authors suggest how the high resolution network can assist the integration of irrigation in the routing scheme based on the applied idea in the earlier version. Considering all the comments of the reviewer, the arguments of the manuscript is re-organized to make it clear that the old parameterizations cannot work at high resolution and need to be revised. Please also consider the author's reply to the first reviewer which is raised from the same issue.*

3. The title of the article

   RC: The paper states that the authors revised the river routing scheme. This gave me an impression that the author revised actual river routing algorithms, but the paper's contribution is to develop the method to derive river network and basin delineation and routing parameters based on high resolution DEM. Also, I understood that the routing scheme (unit-to-unit routing scheme) has not changed from the previous model. I would suggest describing title more specifically and also reword the routing scheme in the text to specify precisely what is really done in the paper (e.g., P1-L2, P1-L9. P6-L10.).

   AR: *The authors totally agree with the reviewer. The authors will correct the title and reword the mentioned parts.*

AC: *The title is changed as: "ORCHIDEE-ROUTING: Revising the river routing scheme using a high resolution hydrological database". The Abstract and Introduction are reworded to precisely describe the study in this paper.*

4. Total runoff depth

   RC: *Improvement of streamflow estimates, in particular, volume bias, are due to the better representation of sub-basin areas than the previous model. I believe this, but to illustrate this clearly, I would suggest including total runoff depth over the sub-basin based on the new (and old) river network and compare it with observed runoff depth. This can be added in Figure 3.*

   AR: *Runoff depth means that river discharge get divided by the upstream area. In our case, the up-stream area does not change more than 1% from one HTU resolution to the other, so the runoff depth does not change.*

   AC: *No modification in the text.*

5. The computational time

   RC: The paper discusses some issue on computational cost on high resolution river network data (Section 4.3). For GMD paper, I think this is very appropriate. routing model is much less computationally expensive. The paper state recommended HTU resolution improve the computational cost by a factor of 10 compared to the highest (native DEM) resolution in P11-L21. Is this factor scaled for the river basin area? I would also like to suggest stating quantified computation cost (e.g., wall-clock, or core- hours = number of processor cores x wall-clock in hours). a factor of 10 might not be significant compared to the LSM computational cost.

   AR: *The authors totally agree that the computational cost is a worthy discussion point in a GMD paper. For the resolution of 1/2° of the ORCHIDEE model, the simulation time for the entire simulation domain presented in the paper can be reduced from about 30 hours to more than 3 hours. This is based on the wall-clock check in the ClimServ server (http://climserv.ipsl.polytechnique.fr/)*

   AC: *More information about computational cost is added after p.11 l.21.*

For the specific comments:

1. An argument in the Introduction

   RC: P2, L11. I am not sure why scaling causes information loss. I feel I disagree with this statement, but I guess I did not understand the statement.

   AR: *The argument is: "Of course, this transfer ignores feedback interactions between river discharge and soil hydrology of the LSM. It also accepts the loss of information as aggregating different spatial and temporal discretization between two models." The authors will refine this statement to express the idea more clear. Normally, the LSM and the stand-alone routing scheme run on different grids. As the exercise of routing flow is bound by topographic details, a higher resolutions is desirable. This means that the flux of water from the LSM to the routing scheme has to be extrapolated. On the other side, if transported water needs to return to the LSM because it goes back into evaporation or soil moisture, it needs to be aggregated. Interactions between the vertical movement of water (represented by the LSM) and horizontal movements (river routing) becomes more complicated and are filtered by the extrapolation/aggregation.*

   AC: *The sentence is refined as: "If aggregating different spatial and temporal discretization between two models requires interpolation step, it can cause the loss of information."*

2. The statement about hyper-resolution LSM

   RC: P3, L6-7. This is naïve statement to me. Do you mean this by hyper-resolution LSM? Hyper-resolution LSM model does not necessarily provide better simulations (if forcing is not good). Hyper-resolution LSM may provide accurate representation of some of geophysical properties (e.g., topography), but not likely soil, geology.

AR: *The statement is: "In particular, a hyper-resolution model allows providing more precise fresh water fluxes for ocean circulation simulation." The authors will remove this statement.*

AC: *The sentence is removed from the text.*

3. The maximum area of each HTU

RC: P7, L8. "The area of each HTU is limited by an user-defined size". This is not crystal- clear to me. I understood the "maximum" area of each HTU is set by user to constrain the HTU areas. Correct?

AR: *The user can choose the average size of the HTU in relation to the grid size. This allows to use Figure 4 of the graphic to select an average HTU size which does not degrade too much the simulated discharge. The authors will refine this sentence.*

AC: *The phrase is modified as: "The user need to define the average area of HTUs in each ORCHIDEE grid cell."*

4. The Pfafstetter topological coding system

RC: P7, L27. I thought there were eight smaller HTUs and 4 inter-basins. I wonder if I misunderstood something.

AR: *The entire sentence is: "The partitioning process relies on the Pfafstetter topological coding system for streams and basins (Pfafstetter, 1989; Verdin and Verdin, 1999): the flow accumulation is used to identify the main stream of the HTU to partition, and its main four tributaries; this results in dividing the large HTU into nine smaller HTUs comprising the basins of the four tributaries and five inter-basins." This is the original idea of the Pfafstetter code. If you can find 4 tributaries which correspond to 4 crossed points with the main stream, there will be 5 inter-basins which split by these 4 crossed points. But there is sometimes only one crossed point for 2 main tributaries then there are only 3 crossed points and 4 inter-basins.*

AC: *No modification in the text.*

5. The outlet of the combined HTUs

RC: P8, L7-10. Regarding combining the small HTUs, how do you determine the outlet of the combined HTUs.

AR: *Among all small HTUs which we want to combine, the two smallest HTUs will be combined first and the outlet of the new HTU will be the outlet of the combined HTUs. An iteration is made to combine HTUs until reaching the desired number of HTUs.*

AC: *No modification in the text.*

6. A sentence and the equation in Section 3.4

RC: P9, L13-14. I am having difficulty in understanding this sentence (how this derivation of k corresponds to unit hydrograph). P9, L15. I am also having difficulty in this sentence and equation (LHS looks like the velocity over the HTU, and RHS looks induvial 1km pixel velocity?). Also what is D?

AR: *We will correct this part of the manuscript for better description of the water routing process. The argument using the idea of unit hydrograph is removed. Runoff is routed downstream with a delay time that is controlled by the number of HTUs along the stream, and the properties of each HTU, namely their slope index k and reservoir parameter g, the product of which defines the time lag of each HTU. The slope index is first calculated at the 1-km resolution based on the slope and length of the HydroSHEDS pixels (i.e. mentioned with a formula in Section 3.1). Then it is aggregated at the HTU scale by an algorithm which uses the drainage directions and the resulting distance of each pixel to the HTU outlet. For each pixel, we define K as the sum of all the 1-km values of k along the corresponding downstream line. The upscaled value of k for the HTU is then given by the product of the sum of K across all the pixels composing the HTU and the fractional area of the HTU. As a result, the slope index of HTUs changes with the area and length of stream lines in the HTUs, so that the streamflow velocity does not depend, or weakly, on the HTU scale.*

AC: *After P.9 L.13, the text is modified.*

7. The last paragraph in Section 3.3

   RC: Last paragraph in Section 3.3. Most of sentences in this paragraph seems to be out of place (maybe fit in introduction). I would suggests removing to make this section shorter.

   AR: *The authors will remove this paragraph and separate the arguments to other section.*

   AC: *The last paragraph in Section 3.3 is removed.*

8. The discussion part

   RC: P17, L22-27. Performance of streamflow simulation is based on all the model components (including forcing). These sentences weigh too much on RRS to attribute the simulation performance or uncertainty. I would suggest combining discussions and conclusions potentially sub-section (e.g., limitation of model, future work etc.). The first paragraph in discussion sounds like reading introduction. I would suggest removing (moving to introduction) or making it very short.

   AR: *The authors will refine the first paragraph in discussion.*

   AC: *The first paragraph in discussion is made shorter and is combined with the second paragraph.*

9. The conclusion part

   RC: P18, L9-10. This sentence should appear earlier (section 3.1?)

   AR: *The sentence is: "The routing technique which is still based on a simple the linear reservoirs which requires information on the orography and slopes." The authors will remove this sentence and put the idea earlier.*

   AC: *Removed sentence. Considering also the comments from another reviewer, the conclusion section is re-organized.*

10. The Nile river issues

    RC: *P18, L14-19. Issues on Nile river is already mentioned earlier, and this sentence seems to be out of place. Suggest removing this.*

    AR: *The issues on Nile river is mentioned earlier in Section 2.1 with only one sentence to notice the exclusion of the Nile river from the simulation domain. The Nile issue is recalled in the Conclusion part to support the issue of necessity to address the interaction of human activities and natural river systems in the ORCHIDEE model. The Discussion and Conclusion are also rewritten hence this argument is presented more properly.*

    AC: Re-arrange this issue along with re-organize the Discussion and Conclusion part.

11. The error in the format of Table 3

    RC: Table 3. Why do some rivers have two rows? For example, what is 6.83 and 5.99 for NS of Boara Pisani?

    AR: *It's the mistake in the format of Table 3. The negative number is displayed in two rows. The authors will correct this format mistake.*

    AC: *Table 3 is re-formatted.*

References

De Rosnay, P., Polcher, J., Laval, K., and Sabre, M.: Integrated parameterization of irrigation in the land surface model ORCHIDEE. Validation over Indian Peninsula, Geophysical Research Letters, 30, 2003.

d'Orgeval, T., Polcher, J., and Rosnay, P. d.: Sensitivity of the West African hydrological cycle in ORCHIDEE to infiltration processes, Hydrology and Earth System Sciences, 12, 1387–1401, 2008.

Guimberteau, M., Drapeau, G., Ronchail, J., Sultan, B., Polcher, J., Martinez, J.-M., Prigent, C., Guyot, J.-L., Cochonneau, G., Villar, J. C. E., et al.: Discharge simulation in the sub-basins of the Amazon using ORCHIDEE forced by new datasets, Hydrology and Earth System Sciences, 16, 11 171–11 232, 2012a.

Guimberteau, M., Laval, K., Perrier, A., and Polcher, J.: Global effect of irrigation and its impact on the onset of the Indian summer monsoon, Climate dynamics, 39, 1329–1348, 2012b.

Siebert, S., Henrich, V., Frenken, K., and Burke, J.: Update of the digital global map of irrigation areas to version 5, Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany and Food and Agriculture Organization of the United Nations, Rome, Italy, 2013.