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Hydrology and Earth System Sciences Discussions

Interactive comment on "Characterization of the hydrological functioning of the Niger basin using the ISBA-TRIP model" *by* V. Pedinotti et al.

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Review : I have one major concern in the proposed research. I personally believe that the deep aquifer plays an important role in the hydrological cycle of the Niger basin, but the aquifer recharge scheme in the manuscript is only validated against just one in-situ measurement data of aquifer recharge rate. Since the aquifer recharge is a highly localized process, it cannot fully ensure the accuracy of the aquifer scheme in ISBATRIP model. I'm afraid that there still exist a possibility that the aquifer routine is just used as the tuning parameter for improving river discharge prediction. For ensuring the robustness of the model, I recommend to include the validation of aquifer scheme using other variables, such as flooded areas or water levels. If the predictability of other

variables is improved by activating the aquifer scheme, the robustness of the aquifer scheme can be improved.

Authors : The authors decided to emphasize the differences between the simulations by focusing on 8 cases : no aquifers, no flooding scheme, TRMM and RFE2 forcing (NOAQ-NF) no aquifers, flooding scheme, TRMM and RFE2 forcing (NOAQ-F) aquifers, no flooding shceme, TRMM and RFE2 forcing (AQ-NF) aquifers and flooding scheme, TRMM and RFE2 forcing (AQ-F)

Moreover, new daily in-situ discharge were provided by the Niger Basin Authority (ABN) and 3 new locations situated before the delta were added. Figure 1 and 2 show the daily discharge simulated by ISBA-TRIP in the four different configurations when the model is forced by TRMM and RFEH respectively. There is a clear change of behaviour of the observed discharge after the delta (Niamey, Ansongo, Kandadji, Malanville, Lokoja) compared to the observed discharge before the delta (Banankoro, Koulikoro, Ke Macina). Indeed, the discharge before the delta is almost twice higher than after. This suggest an impact of the inner delta on the discharge amplitude due to the floodplains. A complete analysis of the figures and of the statistic scores is done in the new version of the article.

Review : P.9174 L.6: Measurements on surface water and discharge are certainly lacking. However, I think observations of other terrestrial water processes such as groundwater recharge or evapotranspiration are also required for making a further discussion on the effect of aquifer discharge, which is one of the main topics of this manuscript.

Authors : We have changed the title and a bit of the focus: the aquifer is just one component of the system. Note that since this model is for GCM applications (indeed, based on the reviewer comments we realized that we did not likely emphasize this enough), parameteriations must be simple (in part because global datasets permitting more detailed models are not cuuurently available). The linear reservoir aquifer scheme formulation is consistent with the other reservoirs in terms of simplicity.

Review : P.9174 L.6: The flooding scheme does have an impact on evaporation loss, but it must also have an impact on the timing and amount of flood peak discharge by dumping flood waters in floodplain storages. Is it possible to make discussion on the contribution of the flooding scheme for separating those two effects?

Authors : The 4 cases simulations allow to focus on the separate effects of the flooding scheme and on the aquifers respectively. It is shown that the discharge impacts the discharge by reducing the peak amplitude and lenghtening the high flow period.

Review : P.9176 L.11: In addition to Dirmeyer et al. (2006) and Sheffield et al. (2008), Kim et al. (2009) recently performed validation of LSMs runoff using a RRM and atmospheric forcing with multi precipitation products. "Kim, H., P. J.-F. Yeh, T. Oki, and S. Kanae (2009), Role of rivers in the seasonal variations of terrestrial water storage over global basins, Geophys. Res. Lett., 36, L17402, doi:10.1029/2009GL039006."

Authors : We added the reference to the paper. In addition, we added a more thorough analysis of the impact of both the REFH and TRMM products: now all results are shown to highlight the differences in model simulations owing to the use of different input rainfall products. (In the original manuscript, for the sake of brevity, we only highlighted results using one. But in response to comments made by the reviewers, we have added this). Note that however, we do not add analysis using other rainfall products (such as CMORPH, PERSIAN etc...) because it has been shown by several papers cited that TRMM and RFE are the best products at representing rainfall over this region, in particular over the Niger basin. And, indeed, owing to large biases, we also found the same results: these products seem to perform poorly over this region. Thus, since this has already been noted in other papers, we simply refer to these papers and state we found the same thing (rather than further lengthening the paper).

Review : P.9176 L.18: There is an advanced study of satellite altimetry by Enjolras and Rodrigues (2009), which intended to derive water surface elevation of narrow river channels by using likelihood-estimation problem. " Enjolras, V. M., and E. Rodriguez

(2009), Using altimetry waveform data and ancillary information from SRTM, Landsat, and MODIS to retrieve river characteristics, IEEE Trans. Geosci. Rem. Sens., 47(6), 1869-1881."

Authors : Reference added

Review : P.9178 L.14 or around: Most recently, Yamazaki et al. (2011) and Paiva et al. (2011) developed new river routing models which explicitly describes floodplain topography and thus predict water surface elevations and discharge from diffusive and full-dynamic equations for 1-D river channels. Those works must be sited as recent developments on river routing models. "Yamazaki, D., S. Kanae, H. Kim, and T. Oki (2011), A physically-based description of floodplain inundation dynamics in a global river routing model. Water Resour. Res. 47, W04501, doi:10.1029/2010WR009726." " Paiva, R. C. D., W. Collischonn, and C. E. M. Tucci (2011), Large scale hydrologic and hydrodynamic modeling using limited data and a GIS based approach, J. Hydrol., 406, 170-181."

Authors : Text added (Section 1)

Review : P.9180 L.20 Eq.(1): I think the vertical water flux term "(P-I-E)" should be multiplied by the ratio of flooded area to the grid area because "(P-I-E)" is only affective on floodplains.

Authors : Actually, the ratio of flooded area to the grid area is already included in the terms Pf, If and Ef as the f index refers to the floodplains. This information has been added to the text.

Review : P. 9183 Sections 3.1 and 3.2: The description on meteorological forcing is confusing. I understood that ALMIP forcing is used for the TRIP simulations without flooding scheme and ISBA-TRIP simulations with/without flooding scheme, while ECMWFbased forcing is used for the ISBA-TRIP simulations with/without aquifer scheme. Is this correct? It may be better to separately describe the experiment on flooding scheme in Section 3.1 and the experiment on deep aquifer scheme Sections 3.2 for avoiding miss-understanding.

Authors : This is correct. This is now better explained in the text. To summarize: The TRMM-3B42 rainfall dataset was used for the TRIP simulations with and without flooding scheme as this was the forcing used for the ALMIP experiment. In fact, in the first part of the methodology, TRIP is used in offline mode, ie without coupling with a LSM. Runoff and drainage from each of the 11 LSMs are used as forcing inputs to the offline mode of TRIP. As these diagnostics from the LSMs (runoff and drainage) were calculated using the TRMM-3B42 forcing, the same forcing was used to run the ISBA/TRIP coupled model with/without flooding scheme to evaluate the impact of the flooding scheme on the ISBA LSM discharge. As you noticed further, the comparison of the ISBA-TRIP simulation (with flooding scheme) with the 11 TRIP sumulation (without) flooding scheme show that the change due to flooding scheme is significant because the change due to the floodplain activation is larger than the uncertainty in input runoff given by the LSM ensembles. This comment has been consequently added to the paper. We also propose a more detailed version of the methodology. Previous studies (e.g.s Jobard et al, 2011, Pierre et al., 2011) have evaluated numerous rainfall products over this region and showed that TRMM and RFE were consistently superior to the other off-the-shelf large scale rainfall products. Moreover, several simulations of ISBA-TRIP were done using different rainfall forcing (CMORPH, PERSIANN and RFEH) . The comparisons of these simulations have shown that the RFE-based (RFEH in our paper) and TRMM rainfall gives better estimations of the discharge. The RFEH forcing was then used for further evaluations in order to examine rainfall uncertainties using the 2 best (reasonable) products.

In addition, a further comparison of the rain datasets was done for every year and has been added to the text. For this, we looked at the averaged monthly ratio for every year (TRMM-RFEH)/(TRMM+RFEH) which represents the relative bias of one dataset regarding to the other. This ratio is calculated only when the monthly sum

(TRMM+RFEH) is bigger than 1mm/day. RFEH generally gives more precipitation in the lower basin during the dry season (from 10 to 80 % more). This has no significant impact on the discharge simulated during the dry season.

The most significant differences are seen in the upper basin during the monsoon season. Figure 3 shows the previous ratio for the monsoon season of every year. From 2002 to 2004, the TRMM rainfall gives 20 to 80 % more rainfall than RFEH. This area is known to its primordial role in the river supply and this difference probably explains the fact that the discharge simulated when the model is forced by TRMM is generally bigger than the discharge when the model is forced by RFEH especially when there is no flooding scheme (twice as large as than RFEH). Moreover, the discharge simulated using TRMM rainfall has a longer recession period probably due to the fact that there is more water going from the floodplains to the river after the flooding season. Figure 3 also shows that in 2005, 2006 and 2007 the relative bias between the two datasets is no longer obvious. Looking at the discharge we can see that during these 2 years, the two rainfall products produce a very similar discharge amplitude, which results in a big reduction of the discharge amplitude simulated by TRMM in comparison with previous years. One possible cause for the reduction in input rainfall is that the gauge analysis source was changed from the GPCC Monitoring analysis to the Climate Prediction Center (CPC) Climate Analysis and Monitoring System (CAMS) in May, 2005. This change was made to take advantage of the timeliness in CAMS, but in retrospect it introduced a discontinuity in the error characteristics of the gauge analysis (G.J. Huffman, personal communication). We have inserted Figure 3 in the paper (along with part of the description above) in order to help explain simulations differences according to the rain forcing used.

Review : P.9185 L.15: Could you please describe the spatial coverage of the MOD09GHK productÂă?

Authors : The spatial coverage of the MOD09GHK product is about 500m. In this study, we use the 8-day product MOD09GHK which provides surface reflectance data globally and is defined as the reflectance that would be measured at the land surface if there were no atmosphere. A reference was added to the paper in which the MODIS reflectances are more described : Vermote, E., El Salleous, N., Justice, C.O., 2002, Atmospheric correction of MODIS data in the visible to near infrared: first results, Remote Sensing of the Environment, 83(1-2), 97- 111.

Review : P.9188 L.3: As I commented above, the floodplain also plays a role for attenuating flood wave by storing inundated waters during flooding. This impact is as important as the evaporation loss from floodplain water surface, thus it's worth being mentioned in this paragraph.

Authors : This effect is mentionned in the paper but might worth being explained more precisely. In the paper, we now explain this: 'Flooded zones can be significant sources of evaporation and have a role of surface water keepers by storing inundated water during flooding. These two effects contribute to the attenuation of flood wave during flooding and their exclusion can result in an overestimation of the discharge for basins with significant annual flooding.'

Review : P.9188 L.23; or Figure 4: The numbers for model statistics are too small to see. Please enlarge the numbers in Figure 4, or add another table for summarize them.

Authors : The model statistics are now presented in tables 2,3,4.

Review : P.9188 L.6: The purpose of using the 11 LSMs ensemble is not clear, because a similar discussion is also made in the following paragraph and Figure 5 using RFEH forcing. I imagine that you wanted to show that "the change due to flooding scheme is significant because the change due to the floodplain activation is larger than the uncertainty in input runoff given by the LSM ensembles". Is it correctÂă?

This is correct and a comment was added to the text to emphasize this argument. Authors : We could have just run ISBA-TRIP with and without floodplains, but the interest of adding the other LSMs from ALMIP is to show that the importance of adding

floodplains exceeds inter-model uncertainties. As this work was done after ALMIP, it was not possible to ask the ALMIP modelers to rerun using RFEH.

Review : P.9189 L.13: Is it possible to include the observation-based validation of evaporation amount? Since aquifer infiltration is only validated by the in-situ observation at one site, comparison between modeled and observed evaporation will improve the robustness of the aquifer scheme.

Authors : There are two meso-squares which contain flux measurements for several local scale sites (one in Mali, the other in Niger near Niamey) and they were not coloacted aq infilt 5(??). As explained in Boone et al. (2009), owing to the large spatial heteorgeneity in this region it is not really possible to compare evaporation simulated for a 0.5 degree region to local scale observations. But in that paper, it was shown that when LSM evaporation was aggregated using 3 different sites to the scale of a single ISBA-TRIP grid cell, LSM models (and ISBA included) represented the annual cycle of the sensible heat flux for several years reasonably well. Since downwelling radiation was imposed by a calibrated satellite-based product (LAND-SAF radiation) and over a three year period the ground heat flux was relatively small, we deduce that a good simulation of H corresponds to a reasonable simulation of Evap. Of course, this is far from being a perfect evaluation, however, given the relatively small spatial coverage of in-situ data, the spatial heteorgenity characteristic of such sites (thus necessistating multiople sites and a robust upscaling methodology), and the errors in the forcings, we argue that this is the best one can do currently.

Review : P.9190 L.9: I cannot find the sensitivity tests for time decay factor and the function "alpha" in the Section 5.

Authors : The section 5 focuses only on parameters which have significant impacts on the simulation. The sensitivity on other parameters is discussed in section 6. However, as you noticed, the discussion about the sensitivity of the alpha parameter was missing. For better comprehension we put all this text in the section 5.

Review : P.9190 L.17: I think aquifer filling ratio has a large locality. It is difficult to make a comparison between local observation and basin-wide modeled value. At least, could you please show the spatial distribution (and inter annual variation if possible) of aquifer filling ratio simulated by ISBA-TRIP modelÂă?

Authors : The available data concerning the aquifer storage are generally very localized making the comparison with such a global scale model not always relevant. A new figure added to the paper shows the repartition of the aquifer recharge over the basin. As expected, the aquifer recharge is very heterogeneous over the basin and follows rain patterns. There is also more aquifer recharge when the model is forced by TRMM than by RFEH. The aquifer reservoir is simple (only based on one parameter) and linear and cannot represent precisely the fluctuations and repartition of the aquifer recharge. However, the analysis of total water storage have shown that its contribution to this total storage is not negligible and must be taken into account to reproduce the evolution of the water budget. In order to avoid any misunderstanding, the comparison with Vouillamoz aquifer recharge was removed from the paper and the previous comment was added.

Review : P.9191 L.26: The bias of the altimeter can be smaller than 20 cm, but can ISBA-TRIP predict absolute water surface elevations (i.e. height above sea surface)? It seems from Figure 9 that only relative water level change is compared in this study.

Authors : Actually, from a global hydrology point of view, there is no real point to look at this absolute value as the topography of the river is not realistic at all. In fact, in each grid cell, the 'river' is represented by a simple rectangular reservoir which drives the runoff from LSM. To have a good representation of absolute water height, as it is done in small scale hydrological models, a good MNT is needed which is not the case here (at global scale, a good MNT for every basin would be difficult to get). It might be necessary to remind at some point of the study, that the general aim of this kind of study is to export the model from a 1-basin case to a global case (in order to couple the CHS with an atmospheric model). This model is aimed to be used in climatologic

applications in which the interest is to highlight climate anomalies (as temperature anomalies for example). So, from a global scale point of view, what is important here is to get a good representation of the water cycle (ie to represent the relative evolution of its components) and to detect anomalies in these components evolution, such as the water height anomalies which are represented in figure 9. Also, this study mentions that the future satellite mission SWOT will be ideal for improving such schemes, and it will product a height change product.

Review : P.9192 L.9: When kinematic wave equation is used for discharge calculation, the predictability of water surface elevation becomes bad in flat river basins with floodplains (Yamazaki et al., 2011). In addition to the uncertainty in river bed slope, limitation of the kinematic wave approach should be noted. "Yamazaki, D., S. Kanae, H. Kim, and T.Oki (2011), A physically-based description of floodplain inundation dynamics in a global river routing model. Water Resour. Res. 47, W04501, doi:10.1029/2010WR009726".

Authors : This comment was added to the text.

Review : P.9193 L.6: Discussion on the role of river water storage can be found in the paper by Kim et al. (2009). "Kim, H., P. J.-F. Yeh, T. Oki, and S. Kanae (2009), Role of rivers in the seasonal variations of terrestrial water storage over global basins, Geophys. Res. Lett., 36, L17402, doi:10.1029/2009GL039006."

Authors : Thank you for this reference which I found really interesting. This allowed to go further in the reflection about the possible origins of biases between GRACE and models in general studies. The reference was added to the text.

Review : P.9193 L.7: Is it possible to make a sensitivity test on the time delay factor in the Section 4.5? I can firstly find the discussion on them in Section 6, even though they are listed in Table 2.

Authors : The text has been moved.

Review : P.9194 L.9: I think sensitivity of water height to the width parameter depends on the condition that whether the site has flooding event or not. When the site has flooding event, the water height change becomes smaller with narrower width because narrower with tend to cause more flooding. While in the site without flooding, narrower width may enhance the water level variation. Could you please check this point?

Authors: This is certainly correct considering the dynamics of floods in the model. This is why the response of the model to modifications of the width parameter is not propor-tionnal to this modification. A further investigation on this point would be interesting.

Review : P.9196 L.5: It is probably better to note that infiltration from river bed to soil is not represented in the model (it only occurs from floodplains to soil, right?), so that simulated river discharge can still be overestimated.

Authors : This is right and might be noticed especially in regions where the discharge is weak. However, the proportion of infiltrated water might be small where the flow speed is high.

Review : P.9196 L.21: The seasonal cycle of simulated aquifer storage is regulated by the time delay factor for aquifer. Actually, the simulated aquifer storage is theoretically possible to be fitted to the GRACE observation by choosing a certain value for the time decay factor. Since there is no observed value for validating the time delay factor of aquifer, we cannot avoid the possibility that simulated aquifer storage is just calibrated against GRACE.

Authors : Sensitivity test to the time decay factors were done and showed that the model is not really sensitive to this coefficient (simulated TWS stays in the range of GRACE products). The figures were not added to the paper to restrict the number of figures but the comment is now done in the text in section 4.6.

Review : P.9198 L.13: It's better to include the sensitivity test for time declay factors in Section 4.6. They are firstly discussed in the "Discussion" section even though they

are listed in the Table 2 in Section 4.6.

Authors : The text has been moved.

Review : P.9200 L.8: "the spatio-temporal variability of the flooded areas". Is it pos-sible to compare the spatial distributions of flooded area between the model and the observationsÂă? It seems only temporal variation is discussed in the manuscript.

Authors : A new figure wad added to the text showing the monthly relative CPP flooded fraction over the period 2002-2007. The monthly values have been divided by the maximum monthly value over 2002-2007. According to these observations, the main inundations occur between July and December in three principal regions : the inner delta in Mali, the Northern Nigeria and the Southern basin. A figure was done showing the monthly spatial correlations between CPP and ISBA-TRIP when the model is forced by TRMM and RFEH with and without aquifers. Over the 3 principal inundated regions, the correlation is bigger than 0.4. This figures are now in the paper.

Review : P.9202 L.14: How is "the downstream river height loss" calculated? The topographic relief within a 0.5 degree grid-box is too large for describing the river height loss, so that simply using grid-averaged elevation will cause large uncertainty. For more realistic representation of the river height loss, we should include realistic sub-grid-scale topography as done by Yamazaki et al. (2009, 2011). "Yamazaki, D., T. Oki., and S. Kanae (2009), Deriving a global river network map and its sub-grid topographic characteristics from a fine-resolution flow direction map, Hydrol. Earth Syst. Sci., 13, 2241–2251." "Yamazaki, D., S. Kanae, H. Kim, and T. Oki (2011), A physically-based description of floodplain inundation dynamics in a global river routing model. Water Resour. Res. 47, W04501, doi:10.1029/2010WR009726."

Authors : River bed slope is indeed a critical parameter to compute velocity via the Manning formula. The STN-30p Digital Elevation Model (DEM) provided at 0.5 by 0.5 resolution by the ISLSCP2 database [http://islscp2.sesda.com] has been used. The STN-30p DEM was heavily edited to represent the actual elevation along the river network on a global scale, based on the aggregated HYDRO1 K DEM at 1 km resolution. Further adjustments were made to eliminate some of the unrealistic rapid slope changes in the STN-30p DEM along the global river network. This paragraph was added in the appendix A and the reference by Yamazaki et al. is cited as a possible improvement of these river bed slopes.

Review : P.9203 L.18: I cannot find the description on floodplain width in "Appendix A".

Authors : This is explained in Decharme et al., 2010. But we have added more information in the paper now (see appendix A).

Review : P.9204 L.1: Readers may be interested in how to calculate the depth of floodplains, because it is important variable to calculate river-floodplain water exchange.

Authors : Same answer as for the previous commentÂă(this has been added to the paper).

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 9173, 2011.

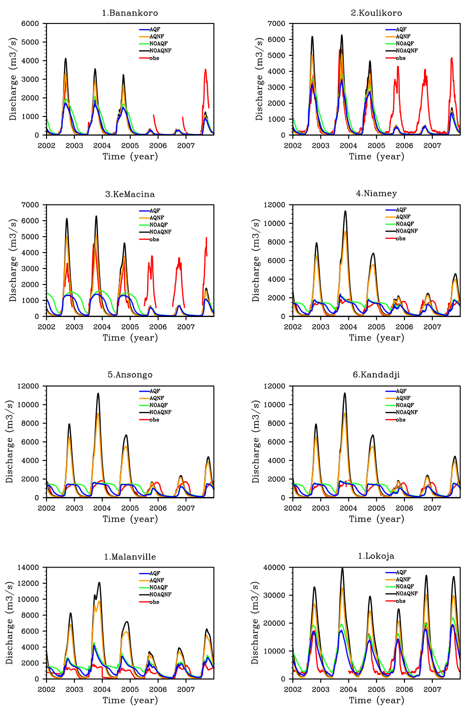

Fig. 1.

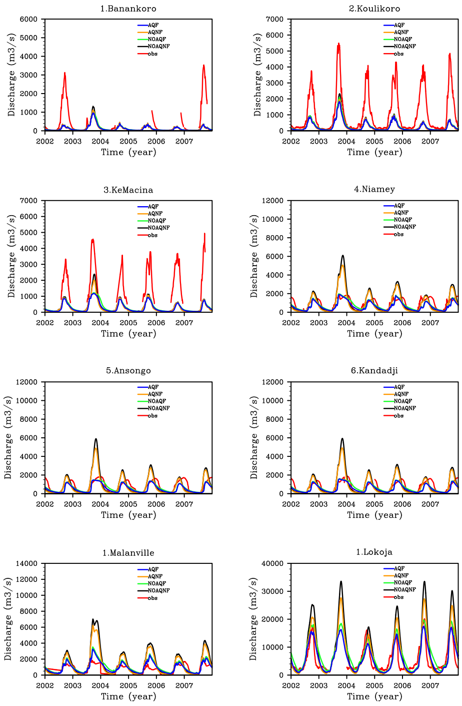
1.Banankoro
2.Koulikoro
3.KeMacina
4.Niamey
5.Ansongo
6.Kandadji
1.Malanville
1.Lokoja
AQF
AQNF
NOAQF
NOAQNF
obs
Discharge (m3/s)
Time (year)
2002
2003
2004
2005
2006
2007

Fig. 2.

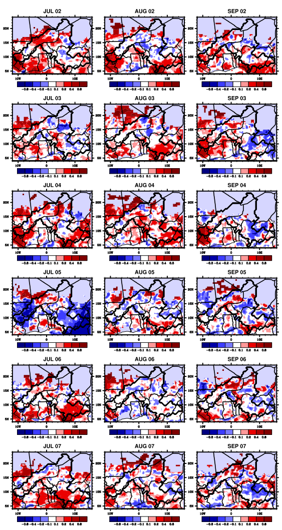

Fig. 3.