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Interactive comment on "Assessment of spatial and temporal patterns of green and blue water flows in inland river basins in Northwest China"

by C. F. Zang et al.

Anonymous Referee #1

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General comments:

The article deals with assessing blue-green water resources which can be further used to address issues on water shortage in arid and semi arid regions and the essential to improve water policy in highly managed and complex watersheds where human intervention leads to a complex pattern of surface-ground water interaction. This is an active area of research in different research centres around the world. The current article, however, seems to be a hasty effort which unfortunately leads to a shallow analysis of the subject matter. A major fault of the study is the lack of adequate hydrological and management data and a superficial calibration-validation of such complex river system. Calibration based on two discharge stations from upstream which represent small proportion of the entire region, may lead to enormous conclusion with respect to blue-green water flow and propagate it to the entire basin where high human intervention and complex management condition dominates natural hydrological processes. Over all, it is hard to see the value added this study to the other similar studies in literature. The current text is more likely a local interest and the approach used is not novel enough to apply in arid and semi-arid regions. I would recommend a major revision of the text taking above points into

consideration and the following specific corrections:

Authors' response:

We thank the reviewer for his/her review and as we understand from the comments there are two main issues: (1) the small number of hydrological stations limits the model calibration, and (2) the simulation under natural conditions cannot reflect strong human intervention to the river basin.

Both the comments are closely related to the main research objective of our article, which is to quantify the spatial and temporal dynamics of green and blue water in the entire Heihe river basin under natural conditions. We would like to focus on simulations under natural conditions because we found that many studies have paid attention to the influence of human activities, but have often ignored research into ecosystem states under natural conditions. We believe that hydrological model simulations to characterize natural conditions are an overlooked area of research. The results of such simulations can be used as a reference to inform researchers and policy makers about the original state of the Heihe river basin and a baseline to study the extent to which human have modified natural river ecosystems. Hence, as a first step, we mainly emphasize the green and blue water flows under natural conditions without considering human intervention. Certainly, the effects of human activities are also of importance, and this will be the next step of our research.

Only two upstream hydrological stations were chosen for the calibration since we aim to represent and benchmark the natural flows in the Heihe river basins with this study. More than 85% of the annual discharge flows through the two hydrological stations, and both the stations have not been significantly affected by human activities. Hence，we are confident that these two stations can work well for the calibration purpose and serve our research objective. The good agreement between the simulation results and observations for these two stations indicates that the SWAT model set-up is suitable

for the hydrological simulation under natural conditions for the Heihe river basin.

We have explicitly discussed the formulation of the research objectives and clearly stated these objectives in the revised manuscript (See page 4 line 18-24 and page 5 line 14-25). The reasons for only using two hydrological stations are also explained (See page11 line 18-26 in the revised version). We acknowledge that the research objectives were not clearly defined in the previous manuscript and apologize for that.

Specific comments:

What is missing in the Introduction is a clear and explicit formulation of objectives that can be concluded upon in the Conclusion section. Use short and understandable sentences for that and further use objectives to structure the results and discussions.

Authors' response:

We agree with the reviewer that there is a need of clear and explicit formulation of objectives. We have rewritten our objectives in response to the reviewer's suggestion. Based on a literature review, we found that many studies have paid attention to the influence of human activities, but have often ignored research into ecosystem states under natural conditions. Hydrological simulations under natural conditions using modelling tools are an overlooked area of research. The results of such simulations can be used as a reference to inform researchers and policy makers about the original state of a river basin and a baseline to study the extent to which human have modified the natural river ecosystems. Hence, there is a need focus on simulations under natural conditions. The overall aim of the paper is to quantify the spatial and temporal dynamics of green and blue water in the entire Heihe river basin under natural conditions. Specific objectives were (1) To calibrate and validate the SWAT model at two hydrological stations that account for 85% of the total discharge in the Heihe river basin but are unaffected by human intervention; (2) to quantify the spatial and temporal dynamics of green and blue water in the entire Heihe river basin and discuss

implications for further research.

We have explicitly discussed the formulation of the research objectives and clearly stated these objectives in the revised manuscript (See page 6 line 1-5 in the revised version).

Comments:

Page 3315, Line 2: It has been recorded in the literature that the Heihe River Basin has an area of 116000 Km^2. Please check this.

Authors' response:

There are two often-used river basin boundaries. The old one has an area of 116000 km^2. This boundary was created based on administrative boundaries (mainly the boundaries of different counties), but it lacked a practical hydrological sense. Realizing this, the Heihe Data Research Group has worked on a more accurate and complete new river basin boundary by integrating hydrological simulations with measured river system data (http://www.westgis.ac.cn/datacenter.asp). The output is the new river basin boundary with an area of 234000 km^2. Such a boundary does not only reflect a more accurate division with an explicit hydrological meaning, but also reflects a watershed boundary under natural conditions. The new boundary is more often used by researchers nowadays, and we believe it is more reasonable to use the new boundary than the old one in our manuscript, particularly with its main focus on hydrological simulations under natural conditions.

We have clearly compared the two river basin boundaries, and clarified the reasons for using the new boundary in the revised version (Page 6 Line 10-19 in the revised version).

Comments:

Page 3315, Line 3: In Figure (page 3331) the Latitude and Longitude of the study area is missing and being not familiar with Chinese river systems, it is hard to understand direction of the river. Please add grid divisions in the map and a DEM in the background. In addition, please show the Qilian mountain (the origin of the river) and the lake Juyanhai (where it terminates) explicitly in Figure 1. Please also show the sub-basins which are delineated and studied in this work.

Authors' response:

Agreed. We have added the grid division and a DEM in the background of the graph. The Qilian Mountain and Juyuanhai Lake and the subbasin boundaries are also added to the map. (See page 27 line 1 in revised version)

Comments:

Page 3315, the first paragraph: can you provide more detail on the hydrological matters of the area? For instance 200-500 mm precipitation in upstream does not reflect its seasonal variation and that if it is mainly in the form snow or rain? This is important to understand process with respect to surface-ground water interaction. Please give some information about water supply-demand situation in the three sections of the basin.

Authors' response:

Agreed and we have added this information to the paper. (See page 7 line 1-13 in revised version)

Comments:

Page 3315, the first paragraph: please mention to the temperature variation in the

three different sections of the study area.

Authors' response:

Agreed. We have mentioned temperature variation in the three different sections in the revised version (See page 6 line 24-25in revised version)

Comments:

Page 3315, Line 23: Please mention to the source of water used for irrigation (whether it is from river or ground water). This is very important when discussing on the model results and calibration matter.

Authors' response:

We accept the advice. We have mentioned the source of irrigation water in midstream and downstream in the revised version. (See page 7 line 16-18 in revised version)

Comments:

Page 3316, Line 19: I do not see any water "quality" assessment in "wide range of scales" in the paper by Faramarzi et al., but by Gassman 2009, who gives a review on the application of the SWAT model in a broad range of studies and scales. Please avoid using Monireh et al., but refer to Gassman et al., 2009 or 2007.

Authors' response:

We have changed the reference to Gassman et al., 2007 (See page 9 line 3 and page 24 line 16-18 in revised version)

Comments:

Page 3317, Line 4: why most of the studies have focused to simulate upstream segments and not entire or downstream watershed? Please explain this.

Authors' response:

An important reason is that past research on hydrological cycles is often focused on human water use, particularly blue water use, thus overlooking water use by ecosystems. The up- and middle segments are regions where blue water is generated and used, but the downstream segments and surrounding areas are dominated by natural ecosystems and a low population density. Hence, most of the studies have focused on simulating upstream segments and not the entire basin or downstream watersheds. However, we argue that studying the hydrological processes for the entire basin is essential since water is not only required by human beings but also needed by natural ecosystems. An additional reason for the emphasis on upper river segments may also be the lack of available data for the downstream river segments.

We have added the above analysis in the revised manuscript (See page 9 line 10-22)

Comments:

Page 3317, line 5-7: "The SWAT model is …2009)) is a general statement about SWAT model. Please move it to the beginning of the paragraph on page 3316, Line 16 and rewrite the paragraph to avoid replication of the statements.

Authors' response:

Thanks for the comments. We have modified the manuscript based on the comments. (See page 8 line 19-22 in revised version)

Comments:

Page 3317, Line 7, please replace “Monire et al., 2009”with “Faramarzi et al., 2009”.

Authors’ response:

Agreed and replaced. (See page 8 line 22 in revised version)

Comments:

Page 3328, Line 27: Please rewrite the reference as follow:

Faramarzi, M., Abbaspour, KC., Schulin, R., and Yang, H.: Modelling blue and green water resources availability in Iran, Hyrol. Process., 23, 486-501, 2009.

Authors’ response:

Agreed and rewritten. (See page 23 line 7-9 in revised version)

Comments:

Page 3317, Line 9: Please replace “..monthly time step..” with “..daily time step..”.

Authors’ response:

Agreed. (See page 9 line 23 in revised version)

Comments:

Page 3317, Line 9: the phrase “.. only hydrologic component of the model was used” is misleading. What components exist in SWAT model? What do you mean by “only”? As far as I know different components in the model are interacted and one cannot separate the use of specific component in the model. Please rewrite this part.

Authors' response:

Agreed, we have rewritten this part. (See page 9 line 24-25 in revised version)

Comments:

Page 3317, Line 12, Please remove "In SWAT model,".

Authors' response:

Agreed. (See page 9 line 24 in revised version)

Comments:

Page 3317, Line 15: please avoid using "glacier". Glacier is not simulated using SWAT model, yet, but snow cover and melt during study period. Glacier is essentially a reservoir that gains precipitation in both liquid and solid form, stores a large share of this precipitation, and then releases it with little loss at a later date. The hydrologic characteristics of this reservoir, however, are complex, because its physical attributes change during a year. In late spring the glacier is covered by a thick snowpack at the melting temperature. Meltwater and liquid precipitation must travel through the snowpack by slow percolation until reaching well-defined meltwater channels in the solid ice below. Yet in the summer the process changes.... For this reasons SWAT cannot predict snowmelt from glacier, yet.

Authors' response:

Agree and modified. (See page 10 line 6 and page 14 line 20 and so on in revised version)

Comments:

Page 3317, Line 20: Please refer to “Neitsch et al., 2004” instead of “Arnold and Fohrer 2005”.

Authors’ response:

Agreed. (See page 12 line 5 in revised version)

Comments:

Page 3317, Line 24: As mentioned in the above paragraph (Line 12) a dominant landuse-soil-slop was used to characterize every sub-basin. This means that the subbasins are not divided further into different HRUs based on different combinations of landuse-soil-slope maps. This is in contradiction with the statement “..303 HRU and 34 sub-basins..”.

Authors’ response:

Agreed and rewritten. (See page 9 line 26-27 and page 10 line 10-12 in revised version)

Comments:

Page 3318, Line 24, Can you provide a management map of the study area?

Authors’ response:

We agree that the management map is very useful. Unfortunately, because of a lack of management data we cannot provide a management map of the study area.

Comments:

Page 3330, footnote of the Table 1: avoid using "..an absolute increase.." which is quite misleading.

Authors' response:

Agreed and modified. (See page 25 line 3 in revised version)

Comments:

Page 3330, Table 1, column 1 (left side), Line8: replace "R_SOL_AWC(1)" with "r_SOL_AWC(1)".

Authors' response:

Agreed and modified. (See page 25 line 1 in revised version)

Comments:

Page 3319, Line 18: Please replace "...indexes..."with "...indices...".

Authors' response:

Agreed and replaced. (See page 12 line 9 in revised version)

Comments:

Page 3319, Paragraph 1: The two hydrometric stations selected for calibration in this study, represent hydrological processes of their upstream areas. As also shown in Figure 1, this upstream area accounts for a small proportion of the entire watershed. As well, most of the human intervention exists in the mid-stream (as mentioned in the text). How you can use your calibration results (representing optimized parameters of upstream area), to

draw conclusion about the whole basin where human activities are important and hydro-climatological conditions are quite different.

Authors' response:

Although the upstream area indeed accounts for only a small proportion of the entire watershed area, more than 85% of the annual discharge in the Heihe River flows through these two hydrological stations. Therefore, the optimized parameters of the upstream area will be very important in representing the entire watershed. Our research aim is to analysis the green and blue water distribution under natural conditions which is another reason to choose the location of the calibration and validation stations in the upstream segment which is not much affected by human interference. (See page 11 line 20-26 in revised version)

Comments:

Page 3320, Line 6: please move "... respectively.." to the end of the sentence.

Authors' response:

Agreed and moved. (See page 12 line 19 in revised version)

Comments:

Page 3320, Line 16: please replace "..Monireh et al.." with "Faramarzi et al.". Check this in other parts of the text.

Authors' response:

Agreed and replaced throughout the manuscript. (See page 9 line 2 and so on in revised version)

Comments:

Page 3321, paragraph 1, also Figure 2 in page 3332: Why blue single-signal is used for the comparison? Please show how do you measure uncertainty? Representation of the model output using a single signal does not provide enough information while making decision on large scale and complex watersheds. Large scale watershed models subject to uncertainty due to various reasons. As also mentioned in the text, these are conceptual model, input, and parameter uncertainties. Using SUFI_2, propagation of the uncertainty in a parameter, leads to the 95PPU of the output variables. As parameter uncertainty increases, the output uncertainty also increases. So please avoid using a single simulation result for the comparison but the 95PPU resulting from the optimized parameter intervals using Latin Hypercube Sampling approach provided in SUFI2.

Authors' response:

Yes, we agree with the reviewer and we have quantified the uncertainty in our revised manuscript. We have improved Figures 2 where we indicated the P-factor, R-factor and 95PPU. In Figure 4, we have presented the uncertainty of the green/blue water, as per the reviewer's suggestion (see page 28 and page 30 in revised version).

Comments:

Page 3321, Paragraph 1: Please give more detail about calibration procedure and challenges faced while optimizing the parameters. As wells, the p-factor and r-factor are missing from the results and one cannot see the performance of the calibration-uncertainty results. In addition, I'm more curious to see how you modeled the glacier inflow to the river in your study area? As already mentioned, SWAT is still not able to simulate hydrological processes of glaciers. How did you overcome this shortcoming? If any pioneering approach was adapted, it

would be interesting to discuss. Overall, the calibration section is the most

Important part of the study and the rest of the analysis are based on this part. However, it has not been addressed efficiently.

Authors' response:

We now include more details on the calibration procedure and challenges faced while optimizing the parameters. In addition, the reviewer is correct that SWAT is not able to simulate hydrological processes of glaciers and we meant melt water, which has now been clarified (see page 14 line 18-20 in revised version).

Comments:

Page 3321, sections 4.1 and 4.2: Model calibration using river discharge alone does not provide confidence on the partitioning of water between soil storage, actual evapotranspiration and aquifer recharge. A multi variable calibration is required to calculate water resources availability based on water yield and green water components.

Authors' response:

Yes, we do agree with the reviewer that model calibration using river discharge alone does not provide enough confidence on the partitioning of water between soil storage, actual evapotranspiration and aquifer recharge. Unfortunately, we lack data for example soil storage data and actual evapotranspiration data to perform this calibration. Nevertheless, in this paper, we quantify blue water flows as the sum of surface runoff and groundwater discharge. Hence, the portioning of water between surface and groundwater runoff is not a necessity here. We assume total water flow is equal to the sum of blue water flow and green water flow. When blue water flow is calibrated well, we assume green water flow is also simulated with a satisfying

accuracy (See page 16 line 20-25).

Comments:

Page 3321, section 4.2, last paragraph: In SWAT model soil water balance equation is calculated for each subbasin for which the precipitation data are assigned from the closest climate station to each subbasin. In this study density of the climate stations and subbasins are quite coarse especially for the downstream area (Figure 1). As a result, precipitation and consequently the aggregated water resources components may over or under predict the real condition especially for the large subbasins with one climate stations assigned. A simple comparison of the simulated water resources with those of observed-reported data (if available) would be helpful to provide confidence on the model results.

Authors' response:

We agree with the reviewer that a simple comparison of simulated results and reported data are very valuable. We made an attempt to do such comparison for the midstream (Zhangye) by referring to Jin and Liang (2009). Our simulated results are similar to the reported data. Since our paper represents the first attempt for the blue/green water flow simulation for the entire basin, it is not possible to compare our simulation results with any reported data (See page 16 line 20-25 in revised version)

Comments:

Page 3322, Paragraph1: Mention to the "relative change rate" maps of Figure 3 when discussing on the trend change. You have not mentioned to these maps in the text.

Authors' response:

We have modified this part of the manuscript for clarity and now mention relative

change rate. (See page 16 line 5, 7 and so on in revised version)

Comments:

Page 3322, Line 15-17: The human intervention and management change have not been considered in the hydrologic model of the basin, but (more) natural condition. How you can draw this conclusion that "…climate variability is the main reason for the variation of total water flow in Heihe river basin"?

Authors' response:

We have now modified the sentence to reflect that under natural conditions climate variability is the main reason for the variation of total water flow in the Heihe river basin. (See page 15 line 11 in revised version)

Comments:

Page 3322, Line 16: please replace 2004 with 2000.

Authors' response:

Agreed and replaced. (See page 15 line 12 in revised version)

Comments:

Page 3322, Line 19: replace "decrease" with "decreased".

Authors' response:

Agreed and replaced. (See page 15 line 17 in revised version)

Comments:

Page 3323: Please avoid using separate sections (4.3, 4.4 and 4.5) to discuss on similar subjects. Combine the last two sections with section 4.3.

Authors' response:

Agreed and combined. (See page 15 line 15-16 in revised version)

Comments:

Page 3333, Figure 3: If the maps are based on the long-term average annual values, please mention to this in the figure caption. Again, how you deal with the uncertainty? I suppose you used the best estimation of the variables for every year!

Authors' response:

Yes, the reviewer is correct. We don't deal with uncertainty in Figure 3, but have used the best estimation of the variables and indeed calculate average annual values in the Figure 3. We have clarified this in the manuscript (See page 29 line 1 in revised version)

Comments:

Page 3334, Figure 4: Please mention to the "long term average annual values" in Figure caption if applicable.

Authors' response:

We have updated the Figure caption. (See page 29, 31, 32, 33 in revised version)

Comments:

Page 3323, Paragraph 1: Please mention to the "relative change rate" maps of Figure

6, when discussing on the trend change. Similar comment is applicable for Figure 7 in section 4.5.

Authors' response:

The advice is taken. (See page 16 line 7 in revised version)

Comments:

Page 3323, section 4.5: Again, any conclusion on Evapotranspiration (green water flow, here) which is not calibrated in the model is misleading!

Authors' response:

The reviewer is correct in saying that the evapotranspriation was not calibrated specifically. Since there is a lack of measured evapotranspiration data for calibration and validation purposes we have checked the scientific literature for comparison. Our results are very similar in comparison to previous results. For instance, Jin and Liang (2009) who studied the actual evapotranspiration of Zhangye in the Heihe river basin, located at midstream close to Zhengyi canyon. They found that the annual evapotranspiration in the 1980s and the 2000s were 238 to 355 million m^3, respectively. These values compare very well with our results for the same region (about 200 and 400 million m^3 for the two periods respectively) (Figure 7, see page 33). Similar results were also reported by Cheng et al. (2007). (See page 16 line 20-25 in the revised version).

Comments:

Page 3324, Line 20-23: A large actual evapotranspiration calls for a large amount of water availability in the soil (based on high precipitation which infiltrates into the soil and supplies evaporation from the soil or transpiration from the plant) and a high

Potential ET (based on high temperature). If the precipitation is significantly low in downstream, how a considerably large amount of actual ET is achieved? A large potential ET could be the case, as it is based on Temperature, but perhaps not Actual ET!

Authors' response:

The precipitation is indeed low downstream, and the actual evapotranspiration is also low there. The precipitation in most of the downstream basin is below 50 mm per year (Li, 2009). According to Figure 5 we can see that the green water flow (ET) in most of the sub-basins downstream is lower than 50 mm every year (Figure 5). However, the total green water flows are high because the sub-basin area is large (See page 31 line 1 in revised version).

The following references are added in the revised version.

References:

Abbaspour, K. C.: User Manual for SWAT-CUP, SWAT Calibration and Uncertainty Analysis Programs. Swiss Federal Institute of Aquatic Science and Technology, Eawag, Duebendorf, Switzerland, 93pp, 2007.

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Faramarzi, M., Abbaspour, KC., Schulin, R., and Yang, H.: Modelling blue and green water resources availability in Iran, Hyrol. Process., 23, 486-501, 2009.

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Chloé A. Raderschall, Robert D. Magrath, and Hemmi, J. M.: Habituation under natural conditions: model predators are distinguished by approach direction, Experimental Biology, 214, 4209-4216, 2011.

Jin, Xiaomei., and Liang, Jijun.: The Temporal Change of Regional Evapotraspiration and the Impact Factors in Middle Stream of the Heihe River Basin, Journal of Arid Land Resources and Environment, 23, 88-92, 2009.

Gassman PW., Reyes M., Green CH., Arnold JG.: The soil and water assessment tool: historical development, applications, and future directions. Transactions of the ASABE 50, 1211-1250, 2007

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