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Interactive comment on "Water budget modelling of the Upper Blue Nile basin using the JGrass-NewAge model system and satellite data" *by* Wuletawu Abera et al.

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We would like to thank reviewer 1 for the constructive comments. We welcome all the issues raised. Below, you will find a point by point description of how each comment was addressed. The reviewer comments in bold font, and our response in normal font.

This manuscript proposes a method to improve water budget modelling by using the available, but sparse, hydrometerological data and satellite products. The current manuscript provides a good try to predict hydrological process in data-scarce regions or ungauged basins. Although there are publications related to such topic in ungauged basins, the intent of the manuscript is worthy and significant, and is of interest to readers of HESS. Seeing the potential of this study, I

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[Discussion paper]

am in general supportive of publication if the following comments are addressed in the resubmission.

Dear reviewer 1, we thank you for the general appreciation of our work, the comments and suggestions you give that helps to further improve our manuscript. In the followings, your comments are answered one by one:

Major concerns:

1. I would encourage the authors to rewrite the methodology section. Give a clear message to the reader what you did and how you did. For example, the manuscript entitled as 'JGrass-NewAge model system'. However, I could not find detail or key information about the method. What's the theory of the method based on? What's the advantage of the method? The headings in method section are the same as those in section 5.

Regards to the JGrass-NewAge system, it is a model system built on the object modeling system v3 (OMS3) informatics, which aims to deploy modern modeling solutions, with the philosophy of promoting reproducible research system. The best way to have general information about it is the paper Formetta et al., 2014. JGrass-NewAGE is a collection of various modeling solutions for all hydrological compartments or fluxes. The detail of each component are presented and validated in various papers: rainfall-runoff modeling (Formetta et al. 2011), shortwave solar radiation modeling (Formetta et al. 2013), longwave solar radiation modeling (Formetta et al. 2016), and digital watershed modeling (Formetta et al. 2014b; Abera et al. 2014). We believe the level of details about JGrass-NewAge in page 4 and 5 are enough, but we will revise the section for clarity.

Regarding to the titles of the subsections in methodology and in results section, the components of the water budget (precipitation, evaporation, discharge, and storage, sequentially) is given in both sections. It seems clear for us that the methodology details how we estimate each flux/storage and the results section presents results of

the work.

1.a. Some parts in the results analysis and discussion section are more suitable to be in the methodology section. For instance, it would be better to introduce the indices (i.e., KGE, PBIAS, r) in section 4. In addition, what's the spatial resolution of the HRU? When performing simulation, what are the time step and the spatial resolution of output?

It is true that goodness-of-fitness (GOF) indices can be in section 4. However, since those indices are common in literature, maintaining their detailed in the main text is distractive. That is the reason we decided to move description of the indices in the appendix section. However, we add a phrase that refers to the appendix also in the methodology section.

The mean (standard deviation) spatial resolution of the HRU is about 430 ($\pm$ 339) km2 and we use daily time steps. The simulation results are therefore one for each HRU and at each time step. The HRU estimates should be considered as an average. Discharges however, are simulated at the nodes of the river networks. We will describe better both the spatial and temporal resolution of the simulation in their respective sections.

1.b. There are different hydrometerological data and satellite products, but it is difficult to readers to obtain their information (e.g., what kind of satellite products). I would suggest the authors providing a table to show all the data and their spatiotemporal resolutions. How did you deal with the different resolutions (especially spatial resolution) of input parameters?

The approach we followed on the description of the satellite products is to use a single 'best' satellite product, based on our review, already discussed with detail in another paper for rainfall, e.g. Abera et al, 2016. Then, the product is described in the methodological section along with the description of the methods used to estimate the component. For instance, SM2R-CCI for precipitation, GLEAM for ET (but we will provide

appropriate comparison with MODIS in complimentary material), in-situ hydrometer data for discharge (no other choice possible), and GRACE for storage change (no other choice possible). The methods for processing and estimating the data at each HRU level are described in section 3 and 4. However, we will revise the section for adding clarity. In addition, a separate table describing all the satellite products used in the paper and its spatial and temporal resolutions will be added at the end of the methodology section in the revised paper.

The reference spatial resolution for model inputs and validation is the area of each HRU. So, for each HRU, we estimate the weighted average of the quantity weighted by how much of the pixel area overlaps with the HRU polygon.

2. Discussion should be enhanced. What's the disadvantage of the method when applying in data-scarce regions with large area? For example, results of figure 5 indicated that the simulated runoffs were underestimated. What's the reason? Was it caused by uncertainties/errors in precipitation products? I could not find any quantitative information about errors of SM2R-CCI. Meteorological stations should observe precipitation, radiation, and etc. Why didn't you use them for validation and discussion?

It is true that the model underestimation is most likely due to the underestimation of SM2R-CCI, as described on the page 11 line 29. Abera et al., 2016 (cited in the manuscript), by comparing with in-situ observations, shows that SM2R-CCI slightly underestimates the total cumulative rainfall in the study area. However, this resulted the best among the products we analysed. Obviously the error estimation can also be caused by models' inconsistencies, and the necessity to work by averaging out inputs over large areas. The fact to be remarked is, however, that our simulations improve previous results.

3. The authors claimed that the JGrass-NewAGE system are described in a series of papers and not re-discussed in this manuscript. What's the difference

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between this study and the previous papers? What's the main contribution of this work?

The previous papers contain description of the single components that were validating separately on other catchments of different size. They cover the informatics, DEM treatment and river network schematisation, radiation, runoff, snow modeling. In this paper those components are united in a modelling solution and work all together cooperatively to solve the water budget closure. In addition, the application in a large basin using various data (satellite and in-situ), which NewAge was originally developed for, is an important contribution of this paper.

Specific comments:

1. 1-21. 'up to 2000 mm per year'. It would be much clearer by adding precipitation.

In the revised manuscript, we will add the exact precipitation value.

2. 3-1. It should have space between 'given' and '('. The authors should proof read the manuscript to avoid such mistakes.

Space will be added; we will remove such errors in the revised manuscript.

3. 3-6. 'the river enters a deep a canyon' contains grammatical errors.

Thank you for this, we will correct it

4. 3-18. The elevation values show certain difference compared to those in page 2 line 3.

Thanks you for spotting this. The one in page 2 line 3 was takes from literature value, and the page 3 line 18 was taken from SRTM digital elevation data. In any ways, we will revise and make it consistent.

5. 3-30. It may mislead to conclude 'the seasonal variability of the basin is very

high' because the authors claimed that the temperature has small seasonal variability.

We will improve this by explicitly mentioning the precipitation and evapotranspiration in the sentence.

6. 4-1. Figure 1. I suggest adding units for axes (also other figures) as well as enlarging the schematic map (at least the text). What does the colour represent in figure 1b?

We will enlarge the figure (text). The color in figure 1b is the mean elevation of HRU in the basin.

7. 4-15. It seems that the citation appeared in the first time, and 2014b should change to 2014a. The authors should proof read the manuscript to avoid such mistakes.

We will correct the citation.

8. 5-4. What does GIS mean? Please consider defining the abbreviation.

Thank you for this. GIS refers to geographic information system. We will add the list of abbreviations in the revised paper.

9. 5-9. How did you divide the basin into 402 subbasins? According to what kind of rules? I'm not sure whether figure 1b is your results or not.

The partition of the basin into 402 subbasins is based on the standard watershed partition approach, and the specific procedure for JGrass-NewAge is described in detail in Formetta et al., 2014 and Abera et al 2014. Yes, figure 1b is the subbasin partition results as mentioned in the caption.

10. 5-13. Figure 2 is difficult to read. The texts were small and difficult to guess their meaning. I suggest the authors redraw it.

We will improve the readability of the figure.

11. 6-23. Works cited in a manuscript should be accepted for publication or published already. There are many publications describing psychometric constant.

Appropriate citation will replace the submitted manuscript.

12. 6-27. What's the relation between S(t) and TB in equation 3? Can you explain more?

There is no relation between S(t) and TB, at least for what related to equation (3). S(t) is the water (storage) present in a HRU. Instead, TB, the Budyko time, affects the alpha in equation (3), because the value of alpha is obtained for balancing the water budget (i.e equation (1)) in such a way that after TB years the storage equals the initial one, i.e. S(TB) = S(0). This implies the use of an optimisation procedure, and such alpha is obtained together with the other parameters of the overall modelling solution (including runoff production, evapotranspiration, etc.) within the calibration procedure. We will try to explain it better in the revised text.

13. 7-26. Semicolon should be replaced with 'and'.

We will replace the semicolon with 'and'.

14. 8-4. What does KGE mean? Please consider defining the abbreviation.

Thank you for spotting this. We will add the definition in the first instance. In addition we will add the list of abbreviations in the revised paper.

15. 8-8. What does 'described in A' mean? Does 'A' represent 'Appendix'?

Thank you, we will add Appendix before 'A'.

16. 9-18. It is curious to use J representing precipitation. In addition, precipitation, evapotranspiration, and discharge are components of water budget. Why did you use different section headings (i.e., 5.1, 5.1.1, 5.1.2, . . .)?

We usually adopted J for precipitation, as for instance, in Rigon et al. 2016, but we can adopt any other symbol. Yes, there is error in the heading sections. We will use the same level of heading for all the components.

17. 9-21. I would suggest the authors adding 'the Oromia region (or other mentioned places)' into Fig.1.

Thank you for this. However, we argue that the important idea here is to show the spatial pattern within the natural basin. We already verified that adding regional boundaries (information) makes figure 1 very crowded. It seems better to delete the region name from the text, as it is the only one mentioned.

18. 10-1. Figure 3a indicates precipitation is highest in southern region. However, figure 3b showed a different pattern (i.e., east shared highest precipitation), especially in JJA.

The two figures are different. Figure 3a shows the long-term mean precipitation as perceived by reviewer 1. Figure 3b, however, shows the level of percentage share of precipitation falls by seasons. In the east part of the basin, the highest percentage share (of its lower annual precipitation) falls in summer (JJA) in comparison to the other parts.

19. 11-4. How and why did you select only some subbasins? Did you consider r and PBIAS (figure 4, e.g., high r and low PBIAS, and low r but high PBIAS)?

We didn't consider r or PBIAS to select the subbasins. We select the three sub basins systematically to cover the basin spatial distribution: one from eastern, center, and western part of the basin.

20. 11-10. 'while the it tends to' contains grammatical errors.

We will remove 'the' from this sentence.

21. 11-23. 'within the basin at the internal channels (2)'. What does '(2)' mean?

It is changed to "(Table 2)" in the new manuscript.

22. 11-27. I do not think r2=0.92 is lower than r=0.93 or r=0.94. I suggest the authors to unify the index.

It is very difficult to find similar index across all the papers. But, having PBIAS and r are relatively common, we decided to use r and PBIAS for comparison, in addition to KGE which is our primary index of model evaluation. We are also prudent to do comparison with other studies. So in this section, we just indicate the comparative performances "……(KGE=0.92, PBIAS = 2.4, r = 0.93). The results show that the performances of the NewAge simulation are similar to the performances reported by Mengistu and Sorteberg (2012), with slightly lower PBIAS value (PB=8.2, r2 =0.92)".

23. 13-1. Are all the parameters unitless? Why are two [−]? Furthermore, I could not find table 1 in the context.

The three parameters (with [-]) are unit less and for others it is length and time, which is given by [L] and [T] respectively in the table. Thanks for indicating the confusion between the two α[-]. In the revised manuscript the first and second α[-] will be changed into α_{hymod}[-] and α_{ET}[-] respectively.

24. 13-2. Can you number the hydrometer stations and then add these IDs into figures 1b and 5?

Yes, we will do that

25. 14-8. Are Wase-Tana and FlexB commonly used models? Please consider defining the abbreviation.

It is true the two models are not common. We will define them. In addition we will add these in the list of abbreviations.

26. 18-5. Can you provide some radiation, cloud, and wind observations? This may be better to draw the conclusion.

We don't have observations of radiation, cloud and wind. We used JGrass-NewAge shortwave component to estimate the radiation data, together with the information of cloud fractional cover (CFC) from EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF) project (Schulz et al., 2009). Wind data is not used at all in this study. It is true that including the radiation estimates and cloud data provides more insight to understand the conclusion given at this particular line. Providing spatial maps of these data in the manuscript, however, reduce its fleetness. But, we will add some of these data in complimentary materials. Here are some samples of the cloud cover map for the basin: http://ecohydrogeomorpho-metry.blogspot.it/2016/04/cloud-cover-on-surface-net-radiation.html

27. 19-9. What does S mean?

We will change this into ds/dt.

28. 19-11. The number of decimal places was set to 3 for precipitation. Is it necessary? I suggest the authors unify the number of decimal places.

Of course it is not important. We will unify the decimal number throughout the paper.

29. 21-12. 'figure' should be 'figures'.

We will change to 'figures'.

30. 26-6. 'et al.'. The authors should list all the authors of a citation and unify the citation style. The authors should proof read the manuscript to avoid such mistakes.

We will correct all citation errors.

31. Texts of most of the figures are unclear. I would suggest the authors redraw the figures.

In the new manuscript, we will improve the figure clarity.

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