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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Identification of the main attribute of river flow temporal variations in the Nile Basin" *by* C. Onyutha and P. Willems

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GENERAL

The authors in the paper tried to answer three main questions. First, the spatial and temporal variability in the basin. Second, the relation between the rainfall and runoff and if the rainfall can be used solely to explain the variability in the flow. Finally, if the response of the catchments have changed in simulating the rainfall-runoff relation. The answers for the first two questions were expected and agree with some of the literature the authors cited in their paper. The third question, is the most interesting and may increase our knowledge of the behavior of the basin.

REPLY

The authors agree with the remark of the reviewer that the investigation of whether the response of the catchments have changed in simulating the rainfall-runoff relation may increase our knowledge of the behavior of the basin. Such knowledge would be vital for integrated water resources management as required by the Nile Basin.

COMMENT No.1

However, the approach the authors adopted is not very thorough. For example, they used three different hydrological models without giving a lot of details about these model and the simulated processes inside them.

The authors agree with the reviewer on the need to be thorough on the flow variation attribution in the study area. To address this comment in a comprehensive way, the recommendation of Merz et al. (2012) on the call for rigor in flow change attribution was considered for the revised manuscript. Both data- and simulation-based ways of flow change attribution to assumed drivers were considered. It is so perceptible that the comment of the reviewer is on the simulation-based approach. This will be addressed in two ways. Firstly, the methodology of the model results for attribution will be presented in a more considered way. Secondly, the details on the general processes of the rainfall-runoff models will be provided.

For the details on the general processes of the rainfall-runoff models, references that the reader can consult were given in lines 4-9 (page 12174) of the Discussion Paper. However, in the revised manuscript, more text as below will be used to replace the sentence in lines 4-9 (page 12174).

VHM has been selected because its model-structure identification and calibration approach nicely fits with the objective of this research to analyze flow and catchment changes in a data-based way paper. The VHM approach starts from a generalized model structure (Figure 1a), which describes the main, lumped catchment-scale rainfall–runoff responses and processes underlying these responses. The model structure is kept parsimonious by only including processes that can be identified from the available meteorological (model input) and river flow (model output) data. This data-based approach also allows to identify changes in catchment-wide responses and related processes. More specifically, Willems (2014) explains that in the VHM approach, the lumped macroscopic catchment responses are analyzed and main processes derived using a step-wise procedures including: 1) separation of observed discharge into overland flow, interflow and base flow, 2) extraction of nearly independent extremes in the form of peak over threshold events. These time-series processing procedures can be done using the tool provided by Willems (2009). These different sub-flow components from (1) are used to identify linear or exponential relationships in the various sub-models describing the rainfall fractions contributing to the surface storage, soil moisture storage and groundwater storage. Quick flow is obtained from a combination of the overland and interflow, which are routed separately each using a single linear reservoir. The baseflow is also routed from the groundwater storage using a linear reservoir. The total runoff is obtained as the sum of the quick flow and base flow.

For comparison reasons, the VHM results were in this study compared with the results from two other, internationally well-established models NAM and HBV whose structures are the compared in Figure 1b and Figure 1c respectively. They all consist of a number of interrelated storages for surface, soil and groundwater, relationships describing the influxes in the reservoirs, mainly depending the time-variable relative soil saturation state (derived from the soil water storage), evapotranspiration losses, and sub-flow routing by means of linear or non-linear reservoir models. Total runoff also comprises the combination of base flow and quick flow.

All three models use catchment-averaged rainfall and potential evapotranspiration (PET) as inputs. The actual evapotranspiration is calculated by the models based on the PET and the soil water storage results.

Whereas the original models include snow modules, these were left out from the descriptions and application, given the location of our study area in a tropical region.

The definition of the model parameters for calibration are presented in Table A1 of the Discussion Paper.

» SEE FIGURE 1 at the end of this document (or see the supplementary file)

COMMENT No.2

I would rather select one model and verify that is able to accurately simulate the complete hydrological cycle of the basin. What are the inputs for these models, how well do they simulate other variables that are important for the hydrological cycle, for example, temperature and radiation. These details need to be verified before reaching a conclusion about the behavior of the basin to simulate the rainfall-runoff relation.

Reply 2 :

Based on the model complexity and set of parameters for calibration, the judgment of the confidence in the selection of a particular model to investigate the effect of land-use change on the flow variation is not a simple task. The use of only one hydrological or rainfall-runoff model would lead to the lack of insight about the influence of the model selection on the conclusive flow variation attribution. Moreover, given the data limitation and quality problem for hydrological modeling in the Nile Basin, the use of the three models was to investigate any inconsistence (if any) in the modeled results from each of the models that would affect the conclusion on the attribution.

Since the study area is in a tropical region, the key inputs for all these models were catchment-wide averaged meteorological series including precipitation and PET. This is now included in the model descriptions. It was mentioned in lines 10-12 (page 12174) of the Discussion Paper that PET was computed by FAO Penman-Monteith method (Allen et al., 1998) using minimum and maximum temperature. However in this method, the short wave solar radiation is estimated in terms of sunshine duration using the Angstrom equation. In other words, the two variables including temperature and radiation which the reviewer mentioned as being important for hydrological cycle were used for the computation of the PET, which was a key input into each of the models. Therefore, the accuracy of the models to simulate temperature and radiation lies in how well they capture the rainfall losses due to evapotranspiration. In the same line, the three models including NAM, VHM and HBV were adopted in this study because their robustness to simulate the hydrological cycle of the study area was recently demonstrated by Taye and Willems (2013) (for NAM and VHM), and Gebrehiwot et al. (2013) (for HBV). Eventually these authors applied these models to successfully investigate the overall hydrological regime and climate change effects in the study area.

The above information will be used in the revision of the manuscript.

COMMENT No.3

Finally, the organization of the paper is good, but the authors should elaborate their discussions and include more details.

Reply 3 :

The authors agree with the reviewer on the need to elaborate the discussions and include more details. To address this comment, some of the changes that will be made in the revised manuscript include the following: ==> more considered details in the Methodology Section will be provided on the procedures of detection and attribution of changes in flow in both data- and simulation-based ways. ==> the details on the general processes of the rainfall-runoff models as provided in the reply to comment No. 1 will be presented. ==> the missing gaps in the knowledge on flow variation attribution in the study area will be presented as well as how the current state-of-the-art addresses the gaps. We also refer to our responses to the first reviewer (or see reply "AC C6746" in response to the "RC C6504"). Moreover, to see how the relevant changes will appear in the revised manuscript, the supplementary file provided in reply to the first reviewer can be consulted.

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Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C6809/2016/hessd-12-C6809-2016-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 12167, 2015.

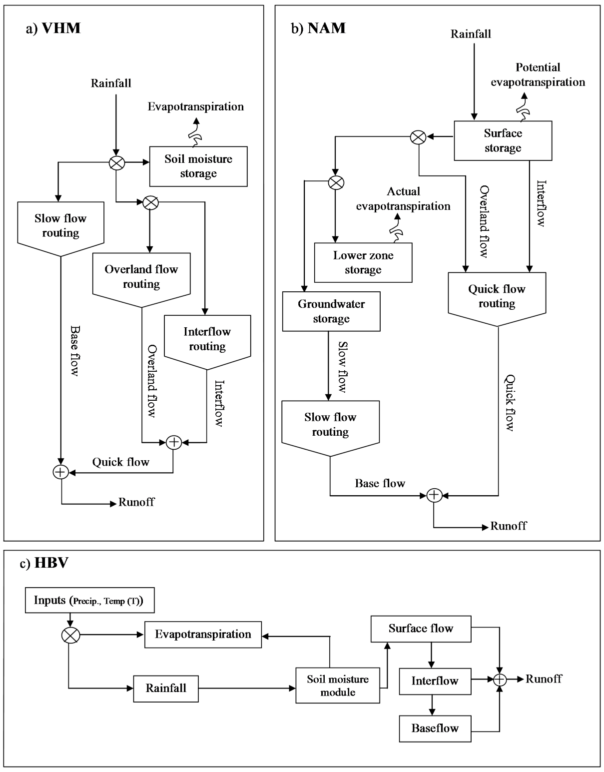

Fig. 1. Figure 1 General processes of a) VHM, b) NAM, and c) HBV.