Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2019-334-AC1, 2019

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "On the representation of water reservoir storage and operations in large-scale hydrological models: implications on model parameterization and climate change impact assessments" *by* Thanh Duc Dang et al.

Thanh Duc Dang et al.

stefano_galelli@sutd.edu.sg

Received and published: 25 September 2019

General Comments

R: This paper presents a computational framework based on the Variable Infiltration Capacity (VIC) model and a Multi-Objective Evolutionary Algorithm that enables to analyze the effects of water reservoir representation on the parameterization of hydrological models. The modelling approach was applied to the upper Mekong river basin, upstream the Chiang Saen gauging station, considering two configuration schemes

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Discussion paper

with and without water reservoirs. The authors exposed the theme in a clear, logical sequence, which resulted in a well-written comprehensive text. In my opinion, this work should be accepted for publication at the Hydrology and Earth System Sciences (HESS) journal after minor revisions. Attached you find some comments/suggestions.

A: We thank the reviewer for the positive comments and practical suggestions for improving the manuscript.

R: Introduction: A comprehensive literature review was done concerning hydrological modelling applied to large river basins, highlighting the limited number of model approaches that enables the direct representation of reservoir water storage with target operating rules to achieve pre-defined objectives. Furthermore, the scientific contribution of this manuscript is clearly defined from line 21 to 34 (Page 03).

A: Thanks for the positive feedback.

R: Study area: The study area description looks poor. Please include more information concerning soil properties and classes, land use, geology and geomorphology, just to enable a better comprehension of main driving forces related to hydrological processes in the Upper Mekong river basin.

A: Yes, we will include more details regarding the soil properties, land use, geology and geo-morphology. Specifically, we will include the following paragraph in Section 2: "The aforementioned orography and climate conditions are not particularly suitable for agricultural activities, which are indeed limited. The basin is mountainous, with mostly rocks and a shallow Quaternary alluvium (Gupta, 2009; Carling, 2009). Due to the impermeability of bedrock underneath isolated valleys, only a very small fraction of water leaks into the ground through karst aquifer units (Lee et al., 2017). As a result, subsurface water is mostly generated in the shallow loam layer in the form of baseflow. Reservoirs are created by roller-compacted concrete gravity dams in narrow river sections with rocky abutments. Thus, foundation, abutments, and dams can be considered impervious."

R: In Section 3.2.1 you present the way the input variables (Land use and land cover data, soil data, and flow direction) are obtained/processed, but a discussion about those data is lacking.

A: We will add the following explanations in Section 3.2.1:

- Second paragraph (on land use and land cover data): "In the basin, broadleaf forest and grassland dominate other types of land cover. The upper part of the catchment has high elevations, so vegetation is mostly grassland. The lower reaches have complex terrain and large altitudinal variations, resulting in mixed coniferous forest ecoregions."
- Second paragraph (on soil data): "In the Chinese part of the basin, soil is characterized by a shallow layer consisting of loam, sandy loam, and clay. At the border between China, Myanmar, and Laos (near Chiang Saen station), soil characteristics are dominated by the presence of sandy clay loam." - Third paragraph (on flow direction data): "Following the main direction of the Mekong river and altitudinal gradient of the region, the flow direction is predominantly southward."

R: Materials and methods: The way used to achieve the objectives of the manuscript is clearly presented and well-organized. Nevertheless, I would suggest including a sensitivity analysis of the model results to the parameters controlling the rainfall-runoff process (Ds, Dmax, Ws, b, d1 and d2) in the Variable Infiltration Capacity model.

A: Thanks for the suggestion. We will include an analysis to explore the sensitivity of the model output with respect to the values of these six parameters (for both model configurations). Specifically, we will proceed by linking VIC (with and without reservoirs) with SAFE toolbox (Pianosi et al., 2015), which provides a number of global sensitivity algorithms. In order to limit the number of figures and tables in the main manuscript, we will likely include the sensitivity analysis results in the Supplement.

R: Results: The questions raised in the introduction section were answered. The results showed that a flawed model parametrization by disregarding anthropogenic interventions (such as hydraulic infrastructure) led to the overestimation of baseflow and runoff during the dry season to compensate water release related to hydropower production. Despite this, I would suggest discussing more deeply the model parameterization and results. According to the authors, the VIC model has been previously used by other researchers. Could your results be compared with them? Or other models with similar purpose.

A: Literature offers a few studies that implemented VIC model to the Mekong River basin (e.g., Zhong et al. (2019), Chang et al. (2019)). Unfortunately, these studies do not report details about the parameterization–they tend to focus on the modelling accuracy. The same comment applies to studies that applied other hydrological models to the Mekong (e.g., Lauri et al. (2012), Rasanen et al. (2012), Hoang et al. (2016)). For this reason, we cannot carry out a direct comparison between our parameterization and the one obtained by previous studies.

Specific Comments:

R: 1) Page 04, line 07: How large is the Upper Mekong river basin? Please include the catchment area in km2.

A: The Upper Mekong river basin has an area of about 167,400 km2; that's about 24% of the Mekong's basin area. We will add this information to the revised manuscript.

R: 2) Page 04, lines 07-08: The information of elevation ranging from 362 m to 6,494 m should be included.

A: We will add this information.

R: 3) Page 04, line 30: Please include a complementary information explaining why the hydrological alterations became more evident since 1992. The largest reservoir (Xi'er He 1) was built before in 1989.

A: Previous works focusing on the hydrological alterations caused by hydropower dams in the Lancang basin generally consider two periods, namely pre- and post 1991 (e.g., 1960-1991 and 1992-2013) (Cochrane et al. (2014), Lu et al. (2014), Dang et al.

(2016)). The reason for this choice is due to Manwan dam, which received significant public attention because of its location. It is indeed the first dam built on the main stem of the river. We understand that our sentence is potentially misleading, so we will clarify this point in the revised version of the manuscript.

R: 4) Page 05, line 19 and Table 1: How the feasible ranges of the two soil layers thickness (d1 and d2) were defined?

A: The definition of the feasible ranges is based on the ranges that were adopted in other studies applying VIC model to large catchments (e.g., Dan et al. (2012), Park and Markus (2014), Xue et al. (2015)). Note that the same ranges are also recommended by Wi et al. (2017), who developed a general-purpose user-friendly software package for VIC. We will clarify this point in the caption of Table 1.

R: 5) Page 06, line 29: How the target water level is defined for each reservoir?

A: As explained at Page 6 (Line 12-21), the target water level is defined as follows. First, we determine the minimum and maximum water levels that a reservoir should reach within a year. In our case, we use the minimum and maximum elevation levels, which are given in the design specifications of each reservoir. Then, we set the time at which the minimum and maximum water levels should be reached. In our case, we use the months of May and November, which correspond to the beginning and end of the wet season. Finally, we connect these points with a piecewise linear function that gives us the daily target level for each calendar day. With these rule curves, we allow the water level to drawdown during the pre-monsoon months and to recharge during the wet months, thereby maximizing the hydropower production–for further details, please refer to Piman et al. (2012).

R: 6) Page 08 lines 02-17: What processes are considered in the reservoir water balance and operation? Are infiltration loss and groundwater inflow disregarded?

A: We considered three main processes, namely inflow, release, and evaporation. As noted by the reviewer, there are two other processes that could be considered, that is, infiltration and seepage (via dam body, abutment, and foundation). The reason for which we disregarded them is twofold. First, the Upper Mekong basin is a mountainous region, with mostly rocks and a shallow Quaternary alluvium (Gupta, 2009; Carling, 2009), so the infiltration losses are to some extent marginal as compared to inflow, release, and evaporation. Second, the dams considered in our study are built with concrete (and with rocky abutments and foundations), so seepage is indeed limited. We will touch upon this point at the beginning of Section 3.1.2 and refer to the expanded discussion on soil properties, land use, geology and geo-morphology (please refer to our reply to the first comment).

R: 7) Page 09, line 11: "parellelized" should be changed to "parallelized".

A: Thanks for spotting this typo, which we will correct in the revised manuscript.

R: 8) Page 11, lines 05-24: Please discuss the pattern observed in Figure 6, with different ranges of the model parameters for the simulation with and without reservoirs. Some parameters presented a more spread pattern for the scenario with reservoirs and a more uniform one for the scenario without reservoir and vice versa.

A: Thanks for raising this point. As mentioned in our reply to the third comment, we will carry out a global sensitivity analysis for both model setups (i.e., with and without reservoirs). We believe such analysis will help us expand the discussion on Figure 6.

R: 9) Fig. 2: Please use the term “modelling approach” instead “model” (Figure legend).

A: We think that the term “model” is more appropriate, since the picture depicts two specific numerical models (i.e., VIC’s rainfall-runoff and routing modules) and an optimization algorithm (i.e., epsilon-NSGA-II)–and not a family of similar models that could be denoted with the term “approach”.

R: 10) Fig. 3: Please include a legend describing the four levels highlighted in Figure

3c.

A: Thanks for the suggestion. Yes, we will include either a legend or a detailed explanation in the caption.

R: 11) Fig 8: I would suggest to reduce the number of baseflow intervals to enable a better visualization of model results related to the configuration scheme with and without reservoirs.

A: Thanks for the suggestion. We will modify the number of baseflow and runoff intervals.

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