Hydrology and Earth System Sciences Discussions

Hydrol. Earth Syst. Sci. Discuss., author comment AC2
https://doi.org/10.5194/hess-2021-360-AC2, 2022

Reply on RC2

Dung Trung Vu et al.

Author comment on "Satellite observations reveal 13 years of reservoir filling strategies, operating rules, and hydrological alterations in the Upper Mekong River basin" by Dung Trung Vu et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-360-AC2, 2022

This paper aims at assessing the reservoir release rules and downstream discharge of ten large reservoirs along the Lancang River reach by using DEM data, Landsat images, and altimetry data. These data are used to identify elevation-storage and area-storage curves, generate monthly time series of water surface area, and validate the results. I found the study really interesting and well written. Overalls the paper is well structured and with a solid method based on established post-processing approaches for remote sensors data. I think that the paper could be accepted after a moderate revision. Below are my main comments:

Response: Thank you for the positive feedback as well as the useful comments for improving the paper.

1. One of the main results reported in the abstract is that "two reservoirs were filled in only two years, and that their operations did not change in response to the drought that occurred in the region in 2019-2020". However, this issue is barely discussed in the paper (last paragraph of section 4). Tiezzi (2016) and Hecht et al. (2019) showed that emergency releases from upstream reservoirs could mitigate severe drought in the downstream countries of the Mekong basin in March 2016. Why this is not the case for the drought event that occurred in the period 2019-2020? What is the reason? What is the influence of changes in human presence within the river basin during that drought period on hydropower consumption?

Response: There could be different reasons behind these divergent management strategies (adopted in 2016 and 2019-2020), such as the inability to reach a political agreement between the riparian countries or the need of following a given hydropower production schedule. Unfortunately, such information is not available in any form, so what we can offer is a plausible explanation based on the timing and magnitude of the two droughts. The 2016 drought had limited magnitude and occurred during the first half of the year, when the reservoir system was releasing water following its normal operations. Right after that, the monsoon season arrived with a relatively high rainfall contribution (please refer to the monthly precipitation anomaly in the Lancang River Basin, Figure 11 (a)). Therefore, the concomitance of monsoon season and emergency releases helped alleviate the drought in the downstream countries. Differently, the 2019 drought had greater magnitude and occurred from the second half of the year, when the reservoir

system was storing water. The release of water during the subsequent dry season only partially alleviated the effect of the ongoing drought, since the low precipitation period persisted until mid-2020. We will extend our discussion on these findings in the revised version of the manuscript.

2. The authors used the VIC-Res model developed in Dang et al. (2020) to assess the inflow to the reservoir (Eq.3) to then assess the parameter θ. The first upstream reservoir considered in your study is Wunongiong, which is downstream of the reservoirs Guodo and Jinghe considered in Dang et al. (2020) (Figure 1). I was wondering how the non-optimal estimation of the streamflow values from the VIC-Res model, based on rule curves conceived to maximize the hydropower production (similarity to Piman et al., 2012), for the Guodo and Jinghe reservoirs may have affected the inflow to the downstream reservoir of Wunongiong. An uncertain estimation of the inflow could lead to an uncertain estimation of the reservoir release (parameter θ). Do you think these may significantly affect the outcome of your study? Is there a way to compare the simulated streamflow with observed values?

Response: In our study, we calculated the fraction θ of the filling period for the two largest reservoirs, Xiaowan (2009-2010) and Nuozhadu (2012-2013). For that estimation, it is true that the non-optimal estimation of the streamflow values for the Guodo and Jinghe reservoirs may have an effect on the estimated inflow to the downstream reservoirs. However, there are reasons to believe that their effect is marginal. First, Guoduo reservoir joined the system in 2015, after the filling period of both Xiaowan and Nouzhado. Second, Jinhe reservoir—which joined the system in 2004—is located on the Sequ Qu River (a tributary of the Lancang River) instead of the mainstream and, most important, has a capacity of 4 MCM only, while the monthly inflow to Xiaowan varies from about 500 to more than 7500 MCM. Also, note that during the filling period of Xiaowan, all mainstream reservoirs in the upstream of Xiaowan did not exist yet. As for the comparison between simulated and observed streamflow, we note that the VIC-Res model was validated with observed discharge at Jiuzhou station, located right upstream of Xiaowan reservoir. We understand that all these details are relevant to the presentation of our results, so we will include them in the revised version of the manuscript. Such changes—as also suggested by reviewer #1—are needed to better describe the VIC-Res model.

3. Have you compared the simulated release from the VIC-Res model (Dang et al., 2020) based on rule curves conceived to maximize the hydropower production (Piman et al., 2012) with the reservoir's releases estimated in your study?

Response: To answer this question, let us first explain how VIC-Res was used in our study—something we only partially accomplished in our first version of the manuscript. In Dang et al. (2020a), we presented a hydrological-water management model that simulates not only hydrological processes (evapotranspiration, infiltration, baseflow, and runoff) but also the streamflow routing and storage dynamics of each reservoir. As for the dams, we (1) considered the ones built before 2005 and (2) used the rule curves proposed by Piman et al. (2012). That poses two challenges for our current study, since we now: (1) consider more reservoirs (all dams built until 2020) and (2) have the actual storage data retrieved from satellite data. To setup VIC-Res in our study, we therefore proceeded as follows. For each reservoir, we take data on inflow (simulated), storage (estimated from the satellite data), and evaporation (simulated) and invert the mass balance equation to calculate the release. That release time series is used in VIC-Res (Dang et al., 2020b) to simulate the storage dynamics of each reservoir. The process is repeated sequentially—starting with the most upstream dam—so as to ensure that the cascading impacts of dams are captured correctly. Because our simulated release is 'driven' by the observed storage, we believe it may not be relevant to compare it against the one obtained in Dang et al. (2020a) when using the rule curves introduced by Piman et al.

(2012). We will provide all this information in the revised version of the manuscript (please also refer to our response to reviewer #1).

4. It is mentioned in section 2 that MODIS data were not considered as "may not be best suited for this study". Indeed, MODIS imagery has high frequency (twice a day) but lower spatial resolution (250 m), which makes it unsuitable for estimating the water surface area of narrow reservoirs, as the case for the Nuozhadu and Xiaowan reservoirs with width between 1000m to 1500m. However, is this the case also for the remaining 8 reservoirs?

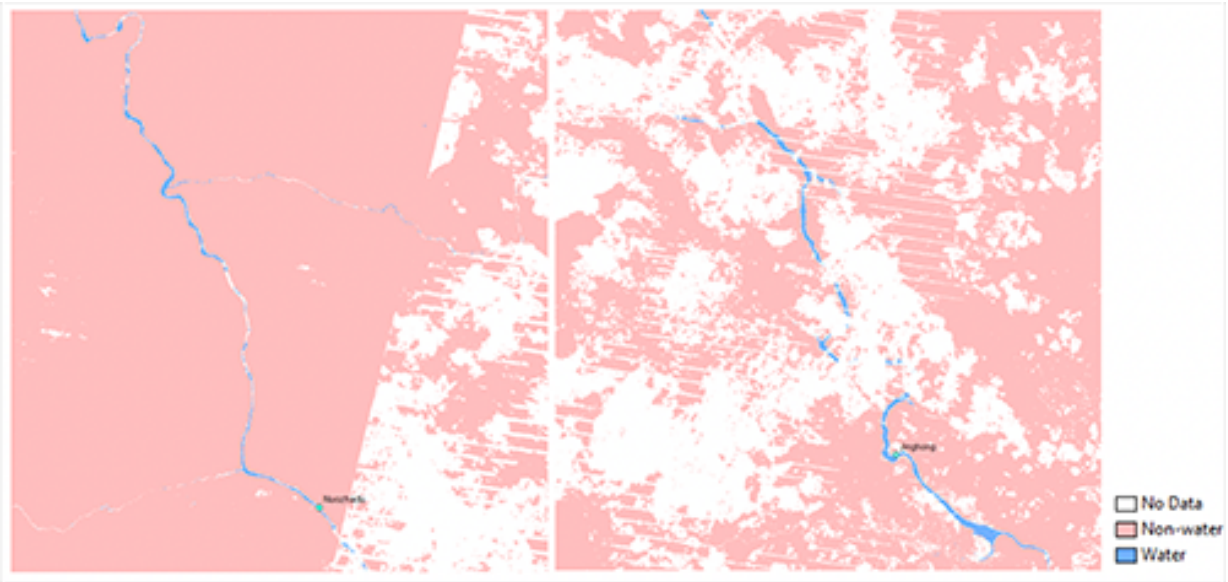
Response: Yes, the remaining eight reservoirs have even smaller surface areas and narrower widths than Nuozhadu and Xiaowan reservoirs. We will further clarify this point.

Would it be more beneficial to use MODIS (high frequency but slightly coarser spatial resolution) rather than Landsat images (higher spatial resolution but low temporal frequency) to catch finer fluctuations of reservoirs releases over time?

Response: This is an option we considered. However, the lower spatial resolution of MODIS makes it unsuitable to capture changes in the water surface area of these reservoirs. In turn, that is likely to lead to higher uncertainties in the water surface estimation process. Because of this reason, we preferred Landasat images (lower temporal resolution, but higher spatial resolution) over MODIS images.

5. Have you compared the WAS results with the water surface area from Pekel et al. (2016)? They also used Landsat images for assessing global surface water. This comparison would further strengthen your method and the results of your study. You could include this validation in the supplementary material.

Response: Thanks for your suggestion. We actually considered using the monthly water surface dataset developed by the European Commission's Joint Research Centre (Pekel et al., 2016) to directly infer reservoir operations. However, that dataset is still partially affected by clouds and other disturbances—please refer to the figure below for an example. Naturally, those features do not act as limitations in Pekel et al. (2016), since that study is carried out at the global scale, but are a non-negligible challenge for the goals of our work. In fact, this is why we resorted to a specific algorithm for estimating the water surface area. Because of this reason, we believe that adding such comparison may not add much to the validation of our results. For further details, please refer to our response to reviewer #3, comment #1.



Water extent of Nuozhado (left) and Jinghong (right) reservoirs extracted from Landsat observations in September 2009 by the European Commission's Joint Research Centre (Pekel et al., 2016). Water detection results are affected by clouds and other disturbances such as the no-data stripes in Landsat 7.

6. Could you summarize the limitations of this study and include them in the discussion?

Response: Thanks for your suggestion. Given the comments raised by all reviewers, we understand that it is necessary to further discuss the limitations of our study. These limitations (and associated sources of uncertainty) must be mainly sought in the accuracy of the WSA estimation algorithm, the temporal resolution of our data points (monthly), and the use of a hydrological model to estimate the inflow to the two main reservoirs. We will provide a through discussion in Section 5.

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