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Reply on RC4

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-AC4, 2022

The manuscript titled “Satellite observations reveal thirteen years of reservoir filling strategies, operating rules, and hydrological alterations in the Upper Mekong River Basin” by Vu et al., simulated the cascade reservoir operation in Upper Mekong River using satellite observations. This study applied the SRTM-DEM, Landsat and Jason Altimetry observations over the study area and inferred the storages variations of two largest reservoirs to assess the reservoir operations against meteorological changes. The manuscript is generally well structured, however, there are concerns regarding the validation of the models/results, which would hinder the reliability of the conclusions made. My main comments are as follows:

Response: Thank you for these detailed comments, which we will help us strengthen our study. In our response below, we clarify various aspects related to the methodological approach, elucidate on the reliability of methods and results, and explain how the results validation can be further extended.

1. SRTM-DEM was used in calculating the reservoir water storage. As stated in the manuscript, the reservoir constructions happened after the year of 2000 whereas SRTM bathymetry measurements was conducted in 2000. Such SRTM-DEM measurements may miss out the potential bathymetry changes caused by local reservoir constructions.

Response: Thank you for raising this point. Yes, it is true that reservoir construction may change the bathymetry, but is also true that these changes are negligible (at least for our study site). That’s because of two reasons. First, Lancang’s reservoirs have horizontally narrow and long shapes. Their length varies from about 25 km (Dahuaqiao) to about 198 km (see Figure 2). Because of these characteristics, dam construction sites (often carried out near the dam location) only affect a very small portion of the reservoir bathymetry. Second, Lancang’s reservoirs have a large portion of dead storage, from about 32% (Xiaowan) to 87% (Wunonglong) (see Table S1 for the specific volumes of the reservoirs). Therefore, we can say that the reservoir bathymetry in the variation range of the reservoirs are barely affected from dam constructions. These are point we can further stress in a revised version of the manuscript.

To make our results more reliable, we compared the E-A curves estimated from DEM data *with the ones obtained by paring altimetry water level and Landsat-derived water surface area—which are not affected by bathymetry changes caused by reservoir constructions. This comparison showed good agreements in the cases of Xiaowan and Nuozhadu (see Figure 7). With more altimetry water level data published on G-REALM recently, we will provide the comparisons for a few other reservoirs.*

The spatial resolution of SRTM-DEM is 30m, however, the authors calculate "the surface area corresponding to each 1-m elevation of the DEM" (Page 7), Please explain in more details for the processing procedure.

Response: SRTM-DEM has a spatial resolution of 30 m that is the actual size of each pixel on the ground, with the value of each pixel being the elevation of the area represented by that pixel. The processing procedure works as follows:

- *First, we isolate the DEM data with the contour corresponding to maximum water level and dam crest line. The purpose of this step is to calculate the curve within the extent of the reservoir only and thus avoid errors due to the surrounding areas.*
- *Then, we calculate the surface area corresponding to each 1-m elevation of the DEM. Specifically, with each elevation value (each meter) from the lowest elevation within the reservoir extent to the maximum water level, we count the number of pixels having a value equal to or smaller than that elevation value. This is because, when water reaches that elevation, the area corresponding to those pixels is inundated. Then, we multiply the number of pixels by the pixel size (30 m x 30 m) to get the water surface area (on the ground).*
- *Finally, we fit a five-degree polynomial (degree determined by trial-and-error) to the data points so obtained.*

We can include these additional details in the revised manuscript.

2. Landsat dataset is another key to solve water surface area in the article. The biggest challenge for the image interpretation is to distinguish water-covered cells from the non-water areas impacted by cloud and other contributors. Water regions suffered from, or chlorophyll concentration or aquatic plants are not inclined to adopt NDWI as the water index is sensitive to vegetation. Matching to the maximum water extent from Pekel et al., (2016) may be caused by the aqua-vegetated problem. Meanwhile, for the water regions with narrow width, some other researchers are inclined to use MNDWI (Li et al. 2019). This deserves the authors a careful investigation for the local reservoir conditions.

Response: Thank you for making this point. We are aware that the spectral indices for water surface extraction perform differently in different regions. This is why we carried out our initial assessment on the performance of three commonly used spectral indices (NDVI, NDWI, MNDWI), an assessment that will be further extended (please refer to our response to comment no. 5). In addition to our comparison with the maximum water extent from Pekel et al., (2016), we manually checked the obtained water layers with the true colour Landsat images before making our decision of using NDWI. We will further stress this point. Finally, we note that the reviewer did not provide a reference for "Li et al. 2019", so we were not able to rely on this paper for this specific response.

3. For the water area extraction with cloudlessness, although the pixels are free from cloud, they may still be affected by ground conditions, such as vegetation, deep or shallow bottom, or water turbidity. Setting the water index threshold as a constant 'zero' value may not be reasonable enough to deal with the aforementioned problem. Additionally, the operations of [1.4] and [1.5] tend to artificially increase the water coverage and would cause the total water storage larger than it potential might be. Such operations are lack of a solid theory to support. It might be a little bold to be directly applied over an ungauged basin without observations taken as validation. I would expect the authors could provide

more reasons for doing so.

Response: The water layers obtained from the NDWI-based classification (with a threshold of 0) in Step 1.2 are not used to infer the water surface/storage directly. Instead, they are used to create the zone mask and the expanded mask for Phase 2, where we improve the water classification with a robust NDWI threshold obtained via k-means clustering. Note that the expanded mask (Step 1.4) is used for the reservoir extent isolation, not for inferring the water surface/storage, so it does not artificially increase the water coverage/ storage. Also, the expanded mask (Step 1.5) is used for clustering the pixels, not for inferring the water surface/storage. Finally, we would like to stress that our approach is based on a solid theory. In particular, we extend and improve the WSA estimation algorithm introduced by Zhang et al. (2014), which is validated for a few reservoirs in South Asia.

Naturally, in our case it is not possible to collect measured water level/storage of Lancang reservoirs. Therefore, we validated our results with reservoir water level from Altimetry (collected from G-REALM (Birkett et al. 2010a and 2010b)). As explained in our response to comment no. 7, such validation will be further extended. Moreover, we plan to further validate our methodology on a few reservoirs in the Lower Mekong and Chao Phraya Basin, for which storage / water level observations are available to the public.

4. For the water area extraction with cloud and other disturbances, this article "resorts to k-means clustering". This is interesting approach but its reliability in ungauged area is unsure. Since there lacks a solid theory to support and needs manually adjustments. I would recommend the authors try OSTU index (a method dynamically obtain a threshold) to compare the difference they may result in threshold calculation as well as in water storage. By doing this, an uncertainty estimation can be given to the reservoir water storage.

Response: Thank you for your recommendation. As explained above, our methodological approach relies on solid theory and our results have been validated. We will look into the OSTU index, but we anticipate that further extending the validation of our results is, in our opinion, a better approach towards strengthening our study.

5. In Section 3.2, the author states that NDWI is better than MNDWI to infer water surface area of reservoir. However, stating that based on the Xiaowan Reservoir only is insufficient. Could the author explain the reason why the maximum water extent was validated on two reservoirs in instead of the ten?

Response: The reason for which we included the comparison between NDVI, NDWI, and MNDWI for only one reservoir (Figure S1) is that our results (based on NDWI) are then validated. This said, we agree with the reviewer that such comparison should be carried out for the other reservoirs. We will provide the validation for other reservoirs in the supplement.

6. Regarding the WSA estimation algorithm in Figure 4, why were cloudy images taken into account in NDWI calculation to obtain the NDWI Layer? Please specify and explain this.

Response: During the monsoon season, Landsat observations are heavily affected by clouds. If we use cloudless images only, the (estimated) water surface area (WSA) data pertaining to the monsoon season may therefore be inaccurate / missing. Therefore, the main purpose of developing and using the WSA algorithm is to improve water classification for all images (especially for cloudy images). We will further stress this point.

7. Validation of the results (Section 4) is too weak. The author only validated water level

from the Radar Altimetry data and only two reservoirs have Radar Altimetry data. Furthermore, there is no validation of reservoir storage. This makes the results inconvincible.

Response: We agree with reviewer that the validation could be strengthened, but that does not mean that the results are "inconvincible". That's because of three reasons. First, the storage of the two validated reservoirs accounts for about 86.45% of the whole system capacity. As illustrated in our analysis, understanding the storage and release dynamics of these two reservoirs is a key step towards explaining the dynamics of the entire system. Second, the reservoir curves for Nuozhadu and Xiaowan are also validated (Figure 7) with altimetry data, so that yields an explicit validation of surface area and an implicit validation of storage. Third, the methodological approach we build on has been adopted for several other sites in Asia and Southeast Asia (e.g., Gao et al., 2012).

With more altimetry water level data published on G-REALM recently, we will provide the validation with altimetry water level for a few additional reservoirs, including the third largest one in the system—Huangdeng (3.37% of the whole system capacity). For additional details, please refer to our response to reviewer #3 comment no. 3.

8. The author tried to estimate monthly reservoir storage of the ten reservoirs. However, from the results part, we only see the results of the Nuozuo and Xiaowan (Figure 9). Results of other reservoirs are shown in 8 reservoirs. Why didn't the author illustrate monthly reservoir storage of other 8 reservoirs? Please specify and explain.

Response: The monthly reservoir storage of each reservoir is illustrated in Figure S4. As for Figure 9, we prefer to keep it as is (with the storage of the eight remaining reservoirs aggregated into one time series), because the individual capacity of the eight remaining reservoirs is too small compared to the two largest ones.

9. In section 4.3.2, the author used VIC-Res, a hydrological model to simulate the inflow of the reservoir. Could the authors explain in more details on the details of the simulation to justify the performance of the model, i.e. input of the model, parameters, calibration and validation of the results.

Response: We also received a few questions about VIC-Res from the other reviewers. So, we will definitely provide more information about its calibration, input data, and validation.

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