POINT BY POINT RESPONSE TO REVIEWER 2

We appreciate the editor's help in providing us with timely reviews for our manuscript. We also appreciate time and effort the reviewer spent in helping us to improve the quality of our manuscript. We have considered each comment very seriously. Below we summarize the key additional work we have undertaken to address the reviewer's concerns:

- We have edited the manuscript to include the annotated suggestions by the reviewer.
- We have acknowledged the limitation of RAT in accounting for sedimentation of reservoirs in the manuscript and mentioned that SWOT satellite mission will be able to solve the problem.
- We have mentioned extent of retrospective analysis afforded by historical satellite data and how far back one can derive reservoir operations data using RAT.
- We have discussed the role of hydrologic model calibration in RAT in the context of model agnosticism.
- We have clarified the usage of the term 'user-friendly' in the manuscript wherever applicable.
- The system requirements for RAT 3.0 have now been mentioned in the manuscript.

In the section below, our response to each reviewer comment is shown in blue while the reviewer's comments are in black.

SPECIFIC RESPONSES

Sedimentation, especially in medium to small reservoirs can impact storage capacity significantly and often is not considered when designing a dam because of the cost associated to implement mitigative measures. While the authors mention sedimentation as an issue, nothing is said about if/how RAT 3.0 might deal with changing reservoir storage or its limitations. I believe a little more discussion/reference to and impact it has on RAT 3.0 would be helpful.

Response: This is a good point. Sedimentation into a reservoir, regardless of its size, modifies the area-elevation relationship (the hypsometric curve) that defines the bathymetry. Thus, conceptually, RAT 3.0 can handle sedimentation as the area-elevation data is easy to modify or update. User can define their bathymetry data and such bathymetry data can be swapped, updated or modified in a modular fashion. In general, RAT yields the highest accuracy when the bathymetry is based on in-situ topographic surveys pertaining to the period of reservoir simulation. Such modularity in area elevation relationship of reservoirs has been taken advantage of in RAT applications in the Mekong river basin (see Das et al., 2022) and in the Cumberland river basin (see Das et al., 2023).

Despite this modularity in representing bathymetry in RAT 3.0, there is an inherent limitation in global scalability of addressing sedimentation issues. This is because the global digital elevation models (DEM) that exist today are mostly from satellite remote sensing (such as from Shuttle Radar Topography Mission – SRTM) and lack temporal variability. For example SRTM DEM captures the reservoir bathymetry for all reservoirs large or small of the world that were built before 2000 and from the water level that existed during sampling. While such a global DEM provides the complete bathymetry of reservoirs created after sampling time (for SRTM it is February 2000), it does not represent the sedimentation that has taken place since then. For pre-2000 reservoirs, the SRTM DEM is limited due to the submerged part of the DEM requiring parameterizations or additional satellite observations when reservoir was at lower levels (see Bonnema et al. 2017). Thus, the ability of RAT 3.0 to address sedimentation at the global or regional scale is currently limited primarily due to the lack of time-varying global DEM data. Currently overcoming this limitation is an active area of research for RAT 3.0 using sediment trapping concepts and satellite observations of sediment concentration.

In the manuscript, we plan to add the following the Discussion and Conclusion section as follows to address the reviewer's comment:

"The impact of sedimentation on reservoir storage is a critical consideration addressed in RAT 3.0. The framework's modular design allows users to dynamically update the area-elevation relationship, ensuring accurate simulations even in the presence of sedimentation. Localized applications in the Mekong and Cumberland River basins have showcased the framework's adaptability in representing changes in bathymetry due to sedimentation (Das et al., 2022; Das et al., 2023). However, extending this capability globally faces challenges due to the lack of time-varying global digital elevation models (DEM). For pre-2000 reservoirs, such as those covered by the Shuttle Radar Topography Mission (SRTM), representing sedimentation requires additional parameterizations or satellite observations when the reservoir was at lower levels (Bonnema et al., 2017). Future research endeavors with RAT 3.0 will explore potential solutions, involving sediment trapping concepts and the integration of satellite geodetic observations, to enhance its global scalability in addressing sedimentation challenges."

Over what time is the model run? I don't understand if I can run this for a few months, a few years, or back into the 1900's (to what date does satellite data support reservoir surface calculations?). Maybe this is addressed in papers discussing v1 or v2, but I would like to know some recommendations/limitations on specifying data ranges and run time lengths?

Response: Thank you for your comment and bringing attention to the temporal scope of the model. The timestep of RAT's tracking of reservoir state is controlled by the time step of the hydrologic model and frequency of satellite observation. Currently, RAT 3.0 is able to run for a period as small as a single day to as long as multiple decades. In its current formulation, RAT 3.0 yields the best performance when multiple area-observing satellites in the microwave and visible wavelengths are synergized in the reservoir storage algorithm called Tiered Multi-sensor-Optical/SAR (TMS-OS; Das et al., 2022). Using Sentinel-1 SAR (microwave) and Sentinel-2 and Landsat satellites in the visible wavelength, RAT can be reliably operated from 2015 onwards. However, RAT 3.0 can also be run from the time of earliest availability of visible satellites from the Landsat 4 mission in 1985. This means that technically RAT3.0 can be run for more than 3 decades starting from the early 80s. In fact, in a recent application of RAT 3.0 for predicting river temperature using satellite data, RAT 3.0 was run from 2000 using Landsat data only. We have added an appropriate summary of this issue in the manuscript in the Discussion and Conclusion as follows:

"RAT 3.0 simulation can span from a single day to multiple decades, and is dictated by the hydrologic model's smallest time step and satellite observation frequency. The Tiered Multi-sensor- Optical/SAR (TMS-OS) algorithm, that calculates reservoir storage change based Sentinel-1 SAR, Sentinel-2, and Landsat satellites, allows RAT 3.0 to operate from 2015 onwards. However, single-sensor functionality can be extended to the early 80s, utilizing Landsat 4 data as has been demonstrated by Biswas and Hossain (2021). "

How much confidence is there in the calculated hydrology of VIC. What if any calibration has been done? I have done enough hydrologic modeling locally and globally with GEOGloWS to know that this is not a simple matter, but the lack of discussion about how good you can expect the inflows computed from the VIC model with global data is a shortcoming of the manuscript. Again, maybe this is given more in other papers, but some further discussion about the quality of the hydrologic model would strengthen the paper. As a side note I'm interested in seeing how GEOGloWS or other models might substitute for the hydrologic inputs to the reservoir as the developers make that possible with the minor upgrades they mentioned. I beleive that will make an important difference to the community of users who often have significant investments in their own hydrologic models (like the National Water Model in the US and EFAS in Europe along with GEOGloWS and other global models like GloFAS).

Response: This is a great point. As RAT is dependent on hydrologic model for inflow, calibration and the choice of the hydrologic model are important topics. The performance of RAT will depend on how well calibrated and representative the gridded hydrologic model is in capturing the upstream most reservoir inflow that is not regulated (i.e. at the head waters). In a recent study by Das et al. (2023) to account for upstream reservoir regulation in predicting the downstream reservoir inflow and RAT-based outflow for lower reservoirs, it was reported that calibration of the hydrologic model is important mostly up to the last upstream boundary point where flow remains naturalized. Beyond that point, calibration ceases to become very sensitive as the assimilation of reservoir storage change (hedging or release) to account for regulated flow downstream using an appropriate regulation algorithm becomes more important (see Das et al. 2023). We plan to demonstrate the impact of hydrologic model calibration and application of flow regulation at multiple river basins around the world in a follow up paper under preparation for the journal Environmental Modeling and Software.

We are also heartened by the reviewer's enthusiasm to alternate model-based streamflow simulations in RAT to account for reservoir regulation. We believe this is quite feasible in the current RAT 3.0 architecture as the current hydrologic model (VIC 5.0) to predict streamflow can be made architecturally modular from the satellite data processing component to estimate reservoir storage change and outflow. Thus, alternate flow data such as GEOGLOWS and forecast flow from GloFAS can replace the current VIC model in the RAT 3.0 architecture, pending appropriate modifications and certain data format, structure and error handling instructions are maintained.

We have addressed the reviewer's comment by discussing this in the Discussion and Conclusion section of the paper as follows:

"The calibration and choice of the hydrologic model play a crucial role in RAT's performance, as it relies on the accuracy of unregulated inflow capture, especially at the headwaters. A recent study (Das et al., 2023) highlights the importance of hydrologic model calibration up to the last upstream boundary point where flow remains naturalized. Beyond this point, sensitivity to calibration decreases, emphasizing the significance of assimilating reservoir storage changes to account for regulated flow downstream using an appropriate regulation algorithm."

Also, additional information regarding the VIC Global Parameters has been added to the manuscript in the section 3.5 that includes how calibration of these parameters is required to get better results.

"Please note that the VIC Global parameters are uncalibrated. Therefore, users are required to calibrate intricate yet challenging-to-measure parameters, including soil depth and the variable infiltration capacity parameter. Achieving an accurate match between simulated and observed inflow requires careful calibration efforts. For a comprehensive understanding of the calibration process and additional details, we recommend referring to the Usage Notes provided by Schaperow et al. (2021)."

Do you have documented use cases of others implementing RAT 3.0? How do you know it is user-friendly otherwise? Other than Figure 11 which showed where RAT 3.0 was implemented, I don't really see evidence of the user-friendliness which even the title uses for local implementations, especially "farmers" which it is implied could use it. I believe farmers could benefit, but not implement and maybe that was the intention here, but even discussing other implementers such as local dam or water districts are not discussed. In some places the manuscript speaks of open software and a developer community and I believe the user-friendliness applies to this group of people (developers) but not as much to stakeholders and sometimes that language in the paper treats both as the same. I think it would be better to distinguish that in the paper.

Response: Thank you for your feedback. We appreciate your attention to the clarity of the term "user-friendly" and its application to different user groups. In response to your feedback, we would like to elaborate on the user-friendliness of RAT 3.0, particularly for diverse user communities.

In the current history of RAT's development, version 1.0 was developed and published in 2021, followed by version 2.0 in 2022 and finally version 3.0 in 2023. It is only in version 3.0 that the RAT can be applied for any river basin across the world in the so-called user-friendly manner as it is available with the most comprehensive user documentation and tutorials. Because the user friendly version of RAT 3.0 is very recent, we need more time to observe if users around the world are indeed able to independently set RAT 3.0 and if the barrier to entry has indeed been lowered. We are heartened by two facts on why we believe RAT 3.0 is more user-friendly than the current state of the art (at least compared to version 1.0 or 2.0). First – at the time of writing this revision, RAT 3.0 software has been downloaded around the world more than 1100 times in 3 months with the lionshare (> 75%) of downloads being from outside of the University of Washington. In addition, there are currently more than 10 followers as software developers that follow RAT 3.0's continuous development on GitHub. Secondly, RAT 3.0 has experienced independent set up in multiple river basins by researchers at the University of Washington who were not RAT developer (Sanchit Minocha) – see for example Darkwah et al. (2023) for Columbia river basin, Das et al. (2023) for Cumberland river basin and Suresh et al. (2023) for Kerala river basins. Given that it was possible to set up RAT 3.0 in a few weeks compared to a few months that typically took for version 2.0 and 1.0, we are confident that RAT 3.0 is the most user-friendly version of RAT that is available.

Specifically, when we refer to RAT 3.0 as "user-friendly" in the manuscript we intend to convey that individuals with varying levels of expertise, particularly those outside the traditional hydrology community, can easily utilize the tool. The emphasis is on minimal input requirements and the need for only basic knowledge of hydrology and remote sensing. In this context, we highlighted the potential benefits for non-hydrology communities, such as farmers and fishing communities, to access and utilize RAT 3.0. By "community," we are referring to the boards or departments responsible for the well-being of these communities, as they can leverage RAT 3.0 in a user-friendly manner. To make this clear we have reframed the statement in section 2.2 as follows:

"Input requirements have been significantly reduced in RAT 3.0, making it easier for non-hydrology communities such as stakeholders representing farmers and fishing communities to operate the tool."

We have also added the following in Discussion and Conclusion section to make it clear for the readers that why the authors believe RAT 3.0 is user friendly.

"The fact that RAT 3.0 is applied in various river basins, coupled with the reduced setup time to a week from 3-4 months (for RAT 2.0), highlights the scalability and user-friendly architecture of RAT 3.0."

To address reviewer's concern about the distinction between developers and stakeholders, we have revised the manuscript, wherever applicable, to clarify that the term "user-friendly" primarily applies to the ease of executing and utilizing RAT 3.0 for obtaining reservoir operations data. We hope these modifications provide a clearer understanding of the intended audience and the user-friendliness of RAT 3.0.

Computational resources? What kind of computational resources are required to install/implement RAT 3.0? This can be a significant barrier both for computer hardware/infrastructure as well as human capacity. Specifying this in the manuscript would be helpful.

Response: Thank you for your valuable feedback regarding the computational resources required for installing and implementing RAT 3.0. To clarify, the primary requirement for setting up and executing RAT 3.0 is a Unix operating system. This restriction is due to the VIC hydrologic model, which is currently available exclusively for Unix operating systems. We have updated the manuscript to include the following information in the Discussion and Conclusion section (other than section 2.2), to addressing the potential barrier related to the choice of operating system. The specific CPU requirements will obviously define the time of computation, but RAT 3.0 is not limited by any specific CPU requirements. Please note that we plan to address these CPU requirements and data logistics for river basins of varying size in a forthcoming paper that is under preparation for submission to Environmental Modeling and Software. We have addressed this issue of CPU resources in the Discussion and Conclusion section of the manuscript as follows:

"In this paper, we have described the redesigned software architecture of RAT 3.0 that can be executed on any Unix operating system and even on supercomputers by making use of parallelization. The operating system constraint arises from the VIC hydrological model's exclusive compatibility with Unix OS. Consequently, a standard laptop with 8 GB RAM, 4 cores, and a 512 GB hard disk is sufficient for running RAT 3.0, with the computational time contingent on the size of the river basin."

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