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Reservoir Assessment Tool version 3.0: a scalable and user-friendly software platform to mobilize the global water management community

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1 Context

The Reservoir Assessment Tool (RAT) is a software that utilizes satellite remote sensing and hydrological models to estimate reservoir parameters such as inflow/outflow, surface area, evaporation, and storage changes. Version 1.0 covered 1598 reservoirs but had limitations in robustness and scalability, which were improved in version 2.0. RAT 3.0 optimizes open collaboration and customization, enables advancements in reservoir management, and utilizes a web application for global monitoring and training, promoting sustainable and equitable use of water resources.

Justification

Dams alter water and sediment flow, water temperature, and obstruct the movement of organisms and nutrients, affecting aquatic habitats and ecosystem services, and can exacerbate droughts and floods, negatively impacting fishermen and farmers (Poff and Hart, 2002). Therefore, monitoring dam performance is crucial to ensure safe operations and mitigate negative effects. Traditional monitoring methods are costly and require regular maintenance. Satellite remote sensing, on the other hand, enables efficient global monitoring, providing near real-time data on reservoir extent and elevation, facilitating more effective management and overcoming political and logistical barriers in transboundary river basins (Bonnem).

In 2021, Biswas et al. presented a solution to address gaps in reservoir monitoring through a satellite data-based tool with no assumptions called Reservoir Assessment Tool (RAT) version 1.0. This version was later improved by Das et al. in 2022, resulting in version 2.0 (RAT 2.0).

RAT assists water managers in tracking the dynamic state of a reservoir, including variables such as inflow and outflow, evaporation, storage change, storage level, and extent. Version 1.0 was operational for 1598 reservoirs worldwide with a monthly update frequency, generating monthly estimates of reservoir dynamic states.

In version 2.0, the update frequency was improved to sub-weekly using data from multiple satellites. Additionally, the accuracy of storage change and outflow was improved through a more advanced multisensor surface water classification technique called TMS-OS, developed by Das et al. (2022). However, so far, RAT 2.0 operations have been mainly limited to the Mekong River basin and interested parties from intergovernmental agencies, and its scalability and reproducibility for the water management community at large have not yet been explored.

For a user interested in reservoir monitoring with limited knowledge of satellite remote sensing data, operating RAT 1.0 or 2.0 for reservoir tracking in a chosen river basin would require significant training.

RAT (version 3.0)

RAT 3.0 is an enhanced version designed to attract a broader audience, allowing local execution on any Unix machine and simplifying data input requirements. This makes the tool accessible even to users with no expertise in hydrology or remote sensing. Additionally, RAT

3.0 facilitates open-source development contributions, promoting continuous advancements in water management.

This version also enables modeling of human impacts on the water cycle and climate through experiments with digital twins, which was previously difficult to achieve. These experiments are essential for understanding how human activities affect water resources. RAT 3.0 streamlines global setup under different scenarios and assumptions, enabling the scientific community to easily conduct such experiments. Furthermore, the data generated by RAT can be used to forecast extreme events, such as floods, thus enhancing risk management. With these improvements, RAT 3.0 aims to catalyze scientific efforts to address knowledge gaps in water management.

Table 2. Comparison of enhancements in RAT 3.0 compared to RAT 2.0 in terms of scalability, robustness, user-friendliness, and efficiency.

Aspect		RAT 2.0	RAT 3.0
Scalable	(a)	Limited to Mekong River basin and its dams	Generalized for any reservoir worldwide
	(b)	High number of manual input requirements	Automatic input generation reduces number of inputs required from user
	(c)	Manual work required to use assets in Google Earth Engine and create inputs	Does not use Google Earth Engine assets; automatic creation of inputs at the time of execution
Robust	(a)	Does not handle missing meteorological data	Improved handling of missing data with automatic interpolation
	(b)	Limited error handling; difficult to debug with one log file	Enhanced error and exception handling; easy to debug with two log files
	(c)	Failure in one component disrupts entire execution	Modular architecture allows independent execution
User-friendly	(a)	Disorganized output files	Intuitive directory structure for organized outputs
	(b)	All inputs were not provided through a configuration file	Single configuration file handles all inputs
	(c)	Lack of operationalization feature	Built-in feature for operationalization that works with cron job
Efficiency	(a)	No hot-start feature, less efficient use of resources	Hot-start feature for efficient resumption of execution
	(b)	Limited use of parallel processing within RAT Framework	Parallelization with Dask library for resource efficiency in RAT framework
	(c)	Accumulation of output files, inefficient memory use	User-selectable automatic deletion of intermediate output files

Figure 1: Comparison between RAT 2.0 and RAT 3.0 versions

2 Evaluation of RAT Software (version 3.0)

RAT 3.0 software has been designed with a set of features that make it scalable, robust, efficient, and user-friendly. These features have been thoroughly evaluated to ensure their functionality and usefulness in a wide range of hydrological and environmental applications.

Scalability

It has been demonstrated that RAT 3.0 can be configured for any river basin worldwide, allowing large-scale analysis by selecting multiple basins simultaneously. This has been achieved through automation and simplification of the creation of region-specific parameter files.

Robustness

Comprehensive validation measures have been implemented for user input, ensuring chronological correctness of dates and data integrity. The two-level logging system facilitates debugging and error management, including automatic data re-download in case of corruption due to Internet connectivity issues.

Efficiency

Operational efficiency and data management have been significantly improved. RAT 3.0 can remember the basin's equilibrium state at each time step, eliminating the need to restart the model in scheduled cron jobs. Additionally, the reorganization of directory structure facilitates better database management.

Ease of Use

The software architecture has been designed to require minimal user input, with additional flexibility for advanced users. Robustness has been improved, and susceptibility to data gaps or instabilities in satellite remote sensing systems has been reduced.

Case Studies and Practical Applications of RAT 3.0

Flood Monitoring in Mountainous Regions of India

A comprehensive study was conducted using RAT 3.0 to analyze floods in the mountainous regions of India, specifically in Kerala. This study provides a detailed insight into how the software can accurately capture extreme precipitation events and calculate the timing of maximum flooding, onset of flash floods, and recession time. Additionally, the software's capabilities to model complex scenarios where hydroelectric dams compete with flood control are highlighted, underscoring its utility in natural risk management and emergency planning.

Assessment of Dam Impact on the Hydrology of Specific Basins

RAT 3.0 was used to evaluate the impact of dam construction on the hydrology of specific river basins. This study provides a detailed understanding of how the software can capture the historical hydrological response to precipitation events in areas affected by dam construction. The software's capabilities to model changes in flow regimes and the hydrological cycle due to reservoir regulation are emphasized, contributing to a better understanding of the environmental and social impacts of hydroelectric infrastructure.

Development of Algorithms to Estimate Regulated Inflow

RAT 3.0 was utilized to develop an algorithm called ResORR, which allows for the estimation of regulated inflow in a river basin. This study demonstrates how the software can integrate with advanced hydrological models to calculate natural inflow and, from there, estimate the impact of reservoir regulation on flow regimes. The software's capabilities to enhance the accuracy of flow estimates and contribute to the development of more effective water management tools are highlighted.

These case studies provide a detailed insight into how RAT 3.0 can contribute to advancing knowledge in hydrology and water management, demonstrating its ability to address complex challenges and provide practical solutions in various situations.

3 Conclusion

RAT 3.0 has been conceived as a scalable and easy-to-operate tool within an open-source software architecture. Its goal is to empower the global water community by providing access to near-real-time information about reservoir status. This benefits not only governments and hydrology experts but also individual users such as farmers and fishermen, who rely on water resources for their livelihoods.

The ability of RAT 3.0 to provide accurate and up-to-date data enables informed decision-making on irrigation, water conservation, and future use planning. Additionally, it can significantly contribute to optimized hydroelectric generation. The motivation behind the development of RAT 3.0 is to drive water resource management, meeting the local needs of users and fostering a self-sustaining community that contributes to its continuous improvement and maintenance.

4 Link de youtube: Evaluación del software RAT 3.0

Link de youtube