Responses to Comments of Reviewer #2

1. The current layout and structure of the paper need significant improvement.

(1) The introduction of data and model should be divided into two separate sections.

(2) It's strange to include subsection 2.4.2 in the introduction of data and model.

(3) It's strange to include the discussion (i.e. subsection 4.3) in the section of Results.

(4) The layout should be improved, for instance, there are a large number of blank spaces between pages.

Response :

(1) Since we are moving Section 2.4.2 to the supplementary material, the data section will be reduced. Given the size of the remaining subsections, we prefer to keep the introduction of models, DA schemes, and observations together in Section 2.

(2) To improve readability and maintain focus on the core findings, and in line with Reviewer 1's suggestion, we are relocating Section 2.4.2 to the supplementary materials. This ensures that detailed evaluations of satellite-based discharges and the open-loop performance of the models remain accessible without diverting attention from the main narrative.

(3) We agree and will separate the Results and Discussion sections accordingly.

(4) We will also improve the layout to address the issue of excessive blank spaces between pages.

2. The quality of presented figures need significant improvement.

(1) There are too many figures presented in the paper, which I think the authors should try to reduce the number of figures to highlight the main results. For instance, I don't find the necessary to include the Figures 3-6, and Figures 1-2 and 8 can be merged into one figure.

(2) The quality of most figures should be improved, because it's difficult to read the text, numerical values and legend presented in most figures.

Response :

We appreciate the reviewer's suggestions to make the figures clearer and more concise.

(1) Figures 3 and 4 will be combined into a single figure, as we believe it's useful to keep a schematic of both models to highlight their key differences. For Figures 5 and 6, we will keep only Figure 5 to streamline the presentation.

(2) We understand the concern about readability and will improve the quality of all figures to ensure that text, numerical values, and legends are clearer and easier to read.

3. It's not clear why the authors use both CTRIP and MGB models.

Given the fact that the MGB model was already calibrated against in-situ discharge time series, I don't think it's fair to compare its performance to the CTRIP that was not calibrated yet. In addition, the input of precipitation for the two models are also different.

Response :

We thank the reviewer for their comment, which aligns with previous feedback from Reviewer #1 regarding the comparison of CTRIP and MGB. The purpose of this study is not to directly compare the absolute performance of these two models but rather to evaluate how the assimilation of long-term CCI discharge observations impacts their performance.

Both CTRIP and MGB are pre-existing modeling frameworks, each with its own set of parameters (calibrated or not), forcing datasets, and specific objectives. CTRIP is primarily designed for long-term climate studies and large-scale hydrological projections, whereas MGB is developed for operational forecasting at the basin scale. These differences in design naturally result in distinct open-loop performances. However, this diversity is precisely why we chose both models—to assess how discharge assimilation interacts with models that have different parameterization strategies, data inputs, and intended applications.

We acknowledge that MGB has been calibrated against in-situ discharge data, while CTRIP has not undergone formal calibration. However, CTRIP follows a physically based parameterization approach commonly used for global-scale hydrology, which does not necessarily rely on calibration. Similarly, the use of different precipitation datasets reflects the operational requirements of each model: ERA5 for CTRIP, which ensures global consistency for climate applications, and GSMaP/CHIRPS for MGB, which provides finer-resolution rainfall estimates suited for short-term forecasting.

In the revised manuscript, we will clarify these distinctions to ensure that our objective is not a direct model-to-model performance comparison but rather an assessment of how long-term discharge assimilation affects two fundamentally different modeling chains. We will also explicitly state this limitation to enhance transparency.

4. The design of DA experiments can be further enhanced.

(1) The authors can consider implementing only the MGB model for the DA experiment, and I think the authors can consider two cases, the MGB model with and without calibration, to investigate the impact of calibration on assimilating satellite-based products.

(2) The authors can also consider assimilating the in-situ discharge data from the stations where both in-situ and satellite-based data are available, and the remaining stations can be used for the validation. As such, the subsection 2.4.2 can be included in the section of Results, and the impact of uncertainty of the satellite-based data can be further investigated compared to the performance of in-situ observations.

Response :

We appreciate the reviewer's suggestions on enhancing the design of the DA experiments. Indeed, a wide range of additional experiments could be conducted to further explore these aspects, but doing so would significantly extend the scope of the study beyond what is feasible for a single paper.

To ensure clarity, we are revising the introduction to better define the objectives and scope of this work. Our focus is on evaluating the impact of assimilating long-term satellite-derived discharge observations within two pre-existing large-scale hydrological models, each with its own structure and setup. While investigating the effect of model calibration on DA performance or incorporating in-situ discharge assimilation would be interesting, these aspects would require dedicated studies.

We hope this clarification helps situate our study within its intended scope.

5. The Introduction can be further improved to review current progress of assimilating discharge data (including those research using in-situ observations) and relevant DA methods.

Response :

We thank the reviewer for their comment on improving the introduction to provide a broader review of data assimilation (DA) progress, including studies using in-situ discharge observations and relevant DA methods. This suggestion aligns with Reviewer #1's moderate comment #2. In response, we have revised lines 24–33 of the introduction to provide a broader overview of data assimilation (DA) and its context in hydrological modeling. The revised section is as follows:

“Data assimilation has become a crucial tool in hydrological modeling, improving simulation accuracy by integrating observational data to update model states and parameters. This approach is particularly effective in addressing uncertainties in model inputs and structural representations, especially in large-scale applications. Clark et al. (2008) demonstrated how DA could enhance streamflow predictions through the assimilation of in-situ discharge measurements, significantly refining model forecasts. Michailovsky et al. (2013) extended this concept by incorporating remotely sensed water surface elevation (WSE) data into hydrological models, resulting in improved discharge estimates in regions with limited in-situ data.

Following these foundational studies, Paiva et al. (2013) investigated the assimilation of both in-situ and satellite-derived discharge data into the MGB model for the Amazon Basin, showing marked improvements in river flow simulations and flood forecasting. Wongchuig et al. (2019) further investigated the integration of simulated Surface Water and Ocean Topography (SWOT) mission data, demonstrating the potential of high-resolution satellite observations in refining hydrodynamic models. More recently, Feng et al. (2021) and Revel et al. (2023) have advanced DA methodologies by incorporating transformed WSE data, leading to notable improvements in discharge predictions and model performance. Building upon these developments, Wongchuig et al. (2024) introduced the Multi-Observation Local Ensemble Kalman Filter (MoLEnKF), which simultaneously assimilates various satellite-derived hydrological variables, demonstrating significant improvements in large-scale hydrological predictions.

In the context of large-scale hydrological models like ISBA-CTRIP and MGB, the integration of data assimilation (DA) frameworks has proven essential for mitigating uncertainties related to input parameters and model simplifications. Historically, many studies have focused on the added value of water surface elevation (WSE) data assimilation into these models. For instance, Pedinotti et al. (2014) and Oubanas et al. (2018) demonstrated the significant benefits of assimilating WSE data to improve hydrological simulations. More recently, there has been a growing interest in the potential of discharge assimilation. Paiva et al. (2013) successfully combined discharge data with precipitation from TRMM to enhance the MGB model’s simulations of Amazon Basin river dynamics. Similarly, Wongchuig-Correa et al. (2020) showed how SWOT discharge data could improve model accuracy in the Solimões and Negro river basins. Additionally, Emery et al. (2018) used altimetry-derived discharge data to refine simulations of river storage and discharge in large-scale models like ISBA-CTRIP. These efforts reflect a growing interest in leveraging discharge data to further enhance hydrological modeling.

Recognizing the importance of long-term, high-resolution data, the European Space Agency (ESA) initiated the Climate Change Initiative (CCI) Discharge Project to address the lack of long-term, high-resolution river discharge data. …”

We hope this addresses the reviewer’s request.