

Response to referees' final minor comments

We sincerely thank both reviewers for the time they devoted to reviewing our manuscript and for their reports. We are grateful that the modifications and corrections made during the third revision round addressed their main concerns. Below, we provide our responses to the remaining comments and describe the corresponding revisions made in the manuscript

Minor Comments of Referee #2

Comment 1

The abstract should be revised to better reflect the research purpose and key findings, e.g. the reason to choose two models and two basins.

Response:

We thank the reviewer for this valuable suggestion. We revised the abstract to more accurately reflect the study's purpose and key findings (and responses to the research questions).

The revised abstract is as follows :

“Large-scale hydrological models like CTRIP and MGB are essential for simulating river dynamics and supporting large-scale climate studies. Their accuracy can be significantly improved through satellite data assimilation. This study leverages the stand-alone value of 20 years of ESA Climate Change Initiative (CCI) high-resolution discharge and water surface elevation (WSE) products (2000–2020) for improving large-scale hydrological simulations through data assimilation. To evaluate the added-value of these products across contrasting modelling and hydrological contexts, we assimilate altimetry-derived discharge, multispectral-imagery-derived discharge, and WSE anomalies into two existing ensemble Kalman Filter frameworks: HyDAS in CTRIP, a global-scale physically based and uncalibrated river-routing model, and HYFAA in MGB, a calibrated semi-distributed regional hydrological model. The experiments are conducted over the Niger and Congo basins, which differ in hydrological variability, river-network structure, wetland influence, and CCI product availability.

Across the experiments, discharge assimilation generally outperformed WSE anomaly assimilation because discharge is directly represented in the routing models, providing a more direct and physically consistent correction, while WSE requires consistency between observed and simulated rating curves to be converted into effective discharge corrections. In the Niger basin, where the seasonal signal and station coverage better constrain the main river dynamics, assimilating altimetry-derived discharge led to the strongest improvement in MGB, increasing the median Nash-Sutcliffe Efficiency (NSE) to 0.83 and the correlation coefficient to 0.94. WSE anomaly assimilation was beneficial in specific cases, particularly

when the baseline simulation was poor and when observed and simulated rating curves were well aligned.

Temporal data density in discharge assimilation emerged as a key driver of performance gains. Assimilating high-frequency discharge data from multispectral imagery significantly reduced bias, from 1.2 to near 1 in MGB, and from 2.3 to 1.78 in CTRIP (median values), supporting hydrological assessments related to long-term variability. Furthermore, the higher temporal resolution allowed for better capture of flow variability, with Kling-Gupta Efficiency γ approaching 1.0 in MGB, which is relevant for both seasonal climate studies and short-term predictions, such as extreme hydrological events.

The comparison with the Congo basin highlights the limits of transferability across hydrological contexts and emphasizes the trade-offs between temporal resolution, spatial sampling, and product quality. Improvements within the Congo basin were more modest and more product-dependent because the available CCI stations provide a weaker spatial constraint on a basin where discharge integrates contributions from large tributaries, and because of lower discharge product quality at some stations. Overall, the results demonstrate that ESA CCI WSE and discharge products can improve large-scale hydrological simulations, but the magnitude and reliability of the improvements are not uniform and depend on the interaction between product type and quality, temporal and spatial sampling, model configuration, and basin-specific hydrological processes.

Future work includes merging altimetry and multispectral discharge data, improving discharge retrieval algorithms using SWOT data, and refining data assimilation techniques to support climate studies and river system modeling in complex, climate-impacted basins.”

Comment 2

The discussion part can be better organized, e.g. divided into two to three subsections, to echo the research questions raised in the Introduction part.

Response:

We agree with the reviewer and we have reorganized the Discussion section in two subsections :

- The first sub-section “Role of ESA CCI assimilated variable and product characteristics” : addressing the first two research questions by discussing the comparison between discharge and WSE anomaly assimilation, as well as the role of CCI product characteristics such as temporal density, spatial sampling, quality, and uncertainty.
- The second sub-section “Robustness across modelling frameworks and basin contexts” : addresses the third research question concerning the comparison between CTRIP-HyDAS and MGB-HYFAA, as well as the comparison between the Niger and Congo basins.