Dear Editor,

We thank you for handling our manuscript, and we sincerely appreciate the time and effort that the Referee has dedicated to their thoughtful assessment.

Please find enclosed the revised version of the manuscript titled "**Reducing Hydrological Uncertainty in Large Mountainous Basins: The Role of Isotope, Snow Cover, and Glacier Dynamics in Capturing Streamflow Seasonality**", reference number **EGUSPHERE-2025-664**.

After carefully reviewing the Referee's comments, we believe we have fully addressed each point, as detailed in the attached rebuttal document. We also include a PDF version of the revised manuscript with all modifications clearly marked using track changes.

We believe that the manuscript has significantly improved and now meets the quality standards of Hydrology and Earth System Sciences. We have also ensured that the revised version **complies with HESS guidelines on data sharing and reproducibility**. In particular, we have updated the public data archive and clarified in the manuscript. We also believe that all shared elements are sufficient to support independent assessment and interpretation of the results, even within the constraints imposed by data confidentiality.

Sincerely,
Diego Avesani
on behalf of the authors

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**Reply to Editor and Reviewers**

We thank the Editor and the Referee for the valuable comments. Below we reply point to point and describe the modifications introduced in the revised version of the manuscript. Our replies are evidenced in blue.

**Reply to Editor**

The reviewer is in principle satisfied with the proposed changes in the revised manuscript. There, however, remain a few open questions which I encourage you to address in the necessary detail. Please also make sure to give clear and detailed explanations of the data availability issue and a full description of the reasons what cannot be published and why. To do so follow the open data regulations provided on the HESS website.

**Reply**

As outlined in Section 2.1, streamflow data for the Yarlung Tsangpo River, which is part of a transboundary river system with China located upstream, are classified as confidential under Chinese national regulations. As a result, these data cannot be publicly disclosed, shared online, or included in any form of publication. This restriction reflects broader geopolitical considerations, as highlighted by Lin et al. (2023), who emphasize the heightened sensitivity surrounding hydrological data in transboundary basins, particularly in regions affected by resource-related or political tensions. This limitation has been explicitly acknowledged and discussed in the main text of the paper.

Such restrictions are not uncommon and have been acknowledged in several articles published in Hydrology and Earth System Sciences (HESS), where authors have transparently reported data confidentiality and addressed it through alternative data representations and detailed methodological documentation (e.g., Singh et al., 2023; Zhang et al., 2024). In line with HESS open data regulations, this study maintains scientific integrity by ensuring that all shared elements are sufficient to fully reproduce the results.

Nevertheless, to ensure transparency and reproducibility within these constraints, we provide access to the 5th–95th percentile confidence bands derived from the prior and posterior streamflow distributions. These are clearly referenced in the Data Availability section and enable readers to evaluate the uncertainty structure and relative discharge variability represented in the analysis. In addition, the Supplementary Material includes dimensionless time series and flow duration curves that were normalized using consistent scales across the three stations. This approach facilitates a fair comparison of streamflow magnitudes while preserving the relative differences between sites. In line with the rationale adopted by Hydrology and Earth System Sciences regarding restricted datasets, these choices are clearly justified in the section on data availability and confidentiality.

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**Reply to Review 2:**

I acknowledge the efforts that the authors made in revising the manuscript and the point-to-point response to each comment. Many comments have been addressed, while a few comments are partially addressed. I still have some concerns about the results of the revised manuscript.

Discharge:

One of my key concerns is still that it is not possible to assess the simulated discharge performance. For example in Figure 5, the authors plot the discharge without y-axis. Only the best simulated discharge data of the posterior distributions are provided on the Zenodo (https://zenodo.org/records/15605202), however, they are not plotted on the Figure 5. The authors provided the simulation results of two more discharge stations in the supplementary material, but neither observed nor simulated data are provided for these stations. I would suggest the authors to keep consistency: the best simulation's data provided on the link should be plotted on the figures to allow readers to assess the differences between the observation, prior, and posterior distributions. The uncertainty bands are too wide to obtain this information and obscure the difference between the simulation and observation. The title of the manuscript is reducing hydrological streamflow uncertainty by using snow, glacier, and isotope data. However, the differences of the simulated discharge with these data are hardly seen in Figures 5, S6, S7 (a,c,e,b,d).

**Reply**

We thank the reviewer for their polite and constructive comment, and we are grateful for highlighting the importance of better representing the data used in our figures. This suggestion prompted us to further reflect on the role of ensemble means in the context of our modeling framework and to address additional important questions. In response, we have updated the Zenodo archive (https://zenodo.org/records/15605202) to include not only the 5-95% uncertainty bands but also the mean streamflow trajectories for both the prior and posterior ensembles at all three gauging stations (Nuxia, Yangcun, and Nugesha). These simulation means are the same as those now shown in Figure 5 of the main text and in Figures S6-S7 of the Supplementary Material.

We have also revised the manuscript accordingly. In the Results section, we added the following paragraph to enhance interpretability and provide a deterministic reference alongside the probabilistic representation:

*"To further enhance interpretability and provide a deterministic reference alongside the probabilistic representation, Figure 5 includes the mean simulated streamflow trajectories for both the prior and posterior distributions, in addition to the uncertainty bands and observed data. As evident from the figure insets and the FDCs, the prior and posterior means exhibit slight differences across all cases, with a more noticeable divergence of the posterior mean from the prior in the case of isotope conditioning."*

Likewise, in the Discussion section, we now explicitly discuss the role and limitations of the ensemble mean:

*"In this context, the posterior mean streamflow, especially in the isotope-conditioned simulations, fails to consistently outperform the prior mean streamflow in reproducing the observed discharge, despite exhibiting narrower uncertainty bands in some streamflow regimes (see Section 3). This deterioration in deterministic skill is not unexpected. Previous studies (e.g., Vrugt and Sadegh, 2013; Botto et al., 2018) have shown that reducing ensemble spread does not automatically lead to improved agreement with observations. Structural model deficiencies and varying accuracy of input data sources (i.e., SCA, GMB, and I) may introduce systematic posterior bias, since the conditioning step attempts to compensate for processes that are poorly captured by the model or affected by different levels of uncertainty (Beven and Freer, 2001; Chowdhury and Sharma, 2007). It is important to emphasize that the ensemble mean does not correspond to the best-performing simulation in terms of NSE, and may smooth out dynamic features that are better reproduced by individual ensemble members. Moreover, the goal of the data-conditioning approach is not to maximize deterministic skill, but rather to reduce predictive uncertainty by constraining the prior ensemble: the shift from prior to posterior aims at narrowing the uncertainty bands of the streamflow simulations, even at the cost of some loss in individual accuracy (Beven, 2006)."*

We believe that these additions directly address the reviewer's concern and strengthen the coherence between the figures, the shared data, and the overall objective of the study.

The simulated discharge for the other two stations (Fig. S6 and S7 only shown for 2005-2010) seem to be worse than Figure 5 (only shown for 2010-2015). The simulation period was set for 2001-2015. Can the authors please explain why the model is better for one station but worse for the other two stations? Why not show the overlapping period of all stations?

**Reply**

We thank the reviewer for this insightful observation. The lower performance at the two upstream stations is mainly due to the absence of site-specific calibration: parameter sets were calibrated at Nuxia and transferred unchanged to Yangcun and Nugesha, so they do not fully capture local hydrological behaviour. This outcome is consistent with earlier findings on parameter transferability (e.g., Khakbaz et al., 2012; Demirel et al., 2024). This clarification is now explicitly noted in Section 3.2 of the revised manuscript. We also acknowledge that, in the previous version, Figures 5, S6, and S7 did not cover the same time period at all stations, this was an oversight on our part. To ensure a fair and consistent comparison, we have redrawn these figures to span the same overlapping period (2001–2010) at all three sites. In addition, each panel now uses a uniform, dimensionless y-axis, which facilitates direct comparison and interpretation of differences across stations. To further support this comparison, we have added a new figure in the Supplementary Material (Figure S9), which directly contrasts the dimensionless observed streamflow time series across the three stations. This provides a clearer view of their relative hydrological regimes and supports the interpretation of ensemble performance discussed in the main text.

In Figure 5(b,d,f), S6(b,d,f), S7 (b,d,f), as there is no y-axis, I am not sure about the high and low discharge distribution, either upside or downside? I also do not understand the unevenly distributed ticks on y-axis.

**Reply**

We thank the reviewer for highlighting this issue. The unevenly spaced ticks in the original panels arose from plotting the flow-duration curves on a logarithmic axis. In the revised figures, the time-series panels now display normalized streamflow, while the FDC panels use a normalized log-discharge scale. This approach maintains the customary logarithmic representation of FDCs yet presents all values in a clear, dimensionless form improving overall readability.

Pareto-front: How do the authors define the Pareto fronts which are not dominated by both objectives in Figure 3 on L231?

**Reply**

We thank the reviewer for this helpful comment and acknowledge that our original phrasing was unclear. We have revised the relevant sentence to clarify how the Pareto front is defined in our analysis. Specifically, we follow standard practice in multi-objective hydrological modelling (Yapo et al., 1998, Efstratiadis and Koutsoyiannis, 2010), and define the Pareto front as the set of nondominated simulations; those for which no other simulation in the ensemble achieves equal or better performance in both objectives and strictly better in at least one. These points represent optimal trade-offs: improving one objective would necessarily deteriorate the other. We have updated the manuscript to reflect this more precise formulation.

**Tech corrections:**
In the data availability, the full names of the abbreviations should be given, e.g. CMFD, HWSD.

**Reply**
Thank you for your observation. We have updated the Data Availability section to include the full names of all abbreviations, including CMFD (China Meteorological Forcing Dataset) and HWSD (Harmonized World Soil Database), to improve clarity and ensure accessibility for all readers.

Figure 2: avoid using red and green color in the same figure to allow readers with color vision deficiency to correctly interpret the figure. This issue has been raised in last round of review but still has not been addressed.

**Reply**
We appreciate the reviewer's attention to accessibility and apologize for not having fully addressed this point in the previous revision. In the revised manuscript, we have updated Figure 2 to avoid the use of red and green in the same figure. The new color scheme has been carefully selected to be distinguishable for readers with color vision deficiency. Additionally, we have validated the updated figure using the Color Blindness Simulator available at https://www.color-blindness.com/coblis-color-blindness-simulator/ to ensure accessibility.

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