Response

Anonymous Referee #2

This manuscript investigates the responses of GloFAS-ERA5 streamflow reanalysis errors to ERA5 precipitation reanalysis errors and further explores the moderating effects of catchment climatic and physiographic heterogeneity. By combining catchment-specific linear regression, panel regression and case studies of representative catchments, the study analyzes 671 CAMELS catchments and provides insights into both overall relationships and catchment heterogeneity. The research topic is novel to some extent and the results have practical implications for understanding and applying global streamflow reanalysis products.

We are grateful to you for the positive comments.

Several issues related to the physical interpretation of the results, regression modeling, and study limitations should be addressed.

Thank you very much for the insightful comments. Accordingly, we have thoroughly revised this paper. Below please find the point-to-point responses.

Major comments

1. The attenuation of precipitation errors by catchments may involve multiple hydrological processes, including soil infiltration, soil water storage, groundwater recharge, evapotranspiration consumption, snow storage, and river channel routing. Since the 671 catchments exhibit substantial differences in baseflow index, soil water storage capacity, and hydrological memory, the average response coefficient of 0.51 should not be interpreted as a direct quantification of a single physical process. The authors are encouraged to provide further discussion on the specific hydrological mechanisms underlying this coefficient.

Thank you for the valuable comment. The value 0.51 is a cross-catchment average statistical response estimated from the panel regression for 671 catchments rather than a direct quantitative estimate of any single hydrological process. In the revision, we have deleted "the buffering capacity of catchment storage" from the Abstract and added the explicit explanation in the Results:

"For GloFAS-ERA5 v4.0, the panel regression indicates that for every 1 mm increase in precipitation RMSE, the corresponding streamflow RMSE increases by an average of 0.51 mm." (Page 1, Lines 17 to 19)

"It is noted that the value 0.51 is a cross-catchment average statistical response estimated from the panel regression for 671 catchments, rather than a direct quantitative estimate of any single hydrological process." (Page 11, Lines 220 to 222)

Also, the hydrological interpretation of error responses has been analyzed in the Discussion:

"Soil moisture deficits, evapotranspiration and subsurface water storage can limit runoff generation from precipitation in arid catchments (Mingjuan et al., 2025; Farmani et al., 2025; Assouline et al., 2024). As shown in Fig. S1 in the Supplement, the correlation between streamflow reanalysis error and soil wetness index (SWI) is significant in 473 catchments, with the median correlation coefficient of 0.52. This result is consistent with the relatively weaker responses of streamflow reanalysis errors to precipitation errors observed in arid catchments and stronger responses in some humid catchments. Dry antecedent soil conditions generally allow a great proportion of precipitation to infiltrate and replenish soil water storage before reaching the thresholds to generate runoff (Liu et al., 2025; Cui and Tian, 2026). As antecedent soil moisture increases, the remaining storage deficit decreases, thereby enhancing the sensitivity of runoff generation to precipitation inputs (Ye et al., 2023; Ran et al., 2022). Evapotranspiration and groundwater recharge may further modulate the contemporaneous relationship between precipitation and streamflow errors (Berghuijs et al., 2025). Since evapotranspiration and groundwater data are not provided in GloFAS-ERA5 and Daymet datasets (Grimaldi et al., 2023; Thornton et al., 2016), their contributions and the specific distribution of precipitation errors among them cannot be determined.

In high-latitude or mountainous catchments, the seasonal snow storage and subsequent melt can alter the timing and magnitude of the streamflow responses to precipitation (Zhu et al., 2023; Wang et al., 2021; McMillan, 2020). Precipitation errors in snow season may be retained in snow storage and appear months later as streamflow errors (Wang et al., 2021; Hale et al., 2023). As shown in Fig. S2 in the Supplement, the correlation between precipitation RMSE and temperature RMSE over cold days (Daymet temperature ≤ 0 °C) for each hydrological year is significant in 56 catchments but not significant in 275 catchments. Temperature influences precipitation phase, snow accumulation and melt timing, but these physical linkages do not necessarily imply a strong statistical coupling between precipitation errors and temperature errors. The errors calculated over hydrological year partly integrate intra-annual effects of storage and lag (Berghuijs et al., 2025; de Lavenne et al., 2022), but they obscure seasonal contrasts, snow accumulation–melt transitions and intra-seasonal phase errors (Hale et al., 2023; de Lavenne et al., 2022). The annual errors therefore cannot resolve seasonal or event-scale errors, particularly for extreme precipitation and flood events. In addition, as the Daymet dataset is generated by interpolating observations (Thornton et al., 2016), uncertainties associated with station density and interpolation methods may affect the precipitation errors." (Page 19 and 20, Lines 322 to 345)

2. The sources of unexplained errors should be discussed more explicitly. Although interaction terms involving precipitation seasonality and snow fraction are incorporated, the coefficient of determination of the panel regression remains 0.36, indicating that a considerable proportion of streamflow reanalysis errors is still not explained by the current predictors. The authors should discuss other potential factors contributing to the remaining uncertainty, such as soil properties, groundwater processes, model structure, or other catchment characteristics.

Thank you for the insightful comment. In the revision, the potential factors contributing to the remaining uncertainty have been added in the Discussion:

"The performance of streamflow reanalysis is primarily constrained by climate forcings, initial conditions, representation of physical processes and model parameterization (Liu et al., 2023; Nourani et al., 2026; Nanding et al., 2021b)." (Page 20, Lines 344 and 345)

"While the precipitation uncertainty is generally identified as the primary driver of the errors in the simulated streamflow (Tang et al., 2023; Wang et al., 2023), the precipitation errors can explain only a limited proportion of the variance in GloFAS-ERA5 streamflow errors, with the R^2 of the panel regression not exceeding 0.36. The remaining variance may relate to catchment heterogeneity, hydrological models and uncertainties in the reference datasets." (Page 20, Lines 352 to 355)

3. The manuscript attributes the weaker influence of precipitation errors on streamflow errors in arid catchments to soil moisture deficits absorbing part of the precipitation errors. However, further explanation is needed regarding where the "absorbed" errors are ultimately reflected in the water balance. For example, do these errors mainly contribute to changes in evapotranspiration, soil water storage or other hydrological components? A more cautious discussion of this mechanism is recommended.

Thank you for the instructive comment. Since the available variables in the GloFAS-ERA5 and Daymet datasets only support analysis of soil water and snow storage, we have added additional diagnostic evidence to the Supplement and have stated this limitation explicitly in the Discussion:

"Soil moisture deficits, evapotranspiration and subsurface water storage can limit runoff generation from precipitation in arid catchments (Mingjuan et al., 2025; Farmani et al., 2025; Assouline et al., 2024). As shown in Fig. S1 in the Supplement, the correlation between streamflow reanalysis error and soil wetness index (SWI) is significant in 473 catchments, with the median correlation coefficient of 0.52. This result is consistent with the relatively weaker responses of streamflow reanalysis errors to precipitation errors observed in arid catchments and stronger responses in some humid catchments. Dry antecedent soil conditions generally allow a great proportion of precipitation to infiltrate and replenish soil water storage before reaching the thresholds to generate runoff (Liu et al., 2025; Cui and Tian, 2026). As antecedent soil moisture increases, the remaining storage deficit decreases, thereby enhancing the sensitivity of runoff generation to precipitation inputs (Ye et al., 2023; Ran et al., 2022). Evapotranspiration and groundwater recharge may further modulate the contemporaneous relationship between precipitation and streamflow errors (Berghuijs et al., 2025). Since evapotranspiration and groundwater data are not provided in GloFAS-ERA5 and Daymet datasets (Grimaldi et al., 2023; Thornton et al., 2016), their contributions and the specific distribution of precipitation errors among them cannot be determined.” (Pages 19 and 20, Lines 318 to 329)

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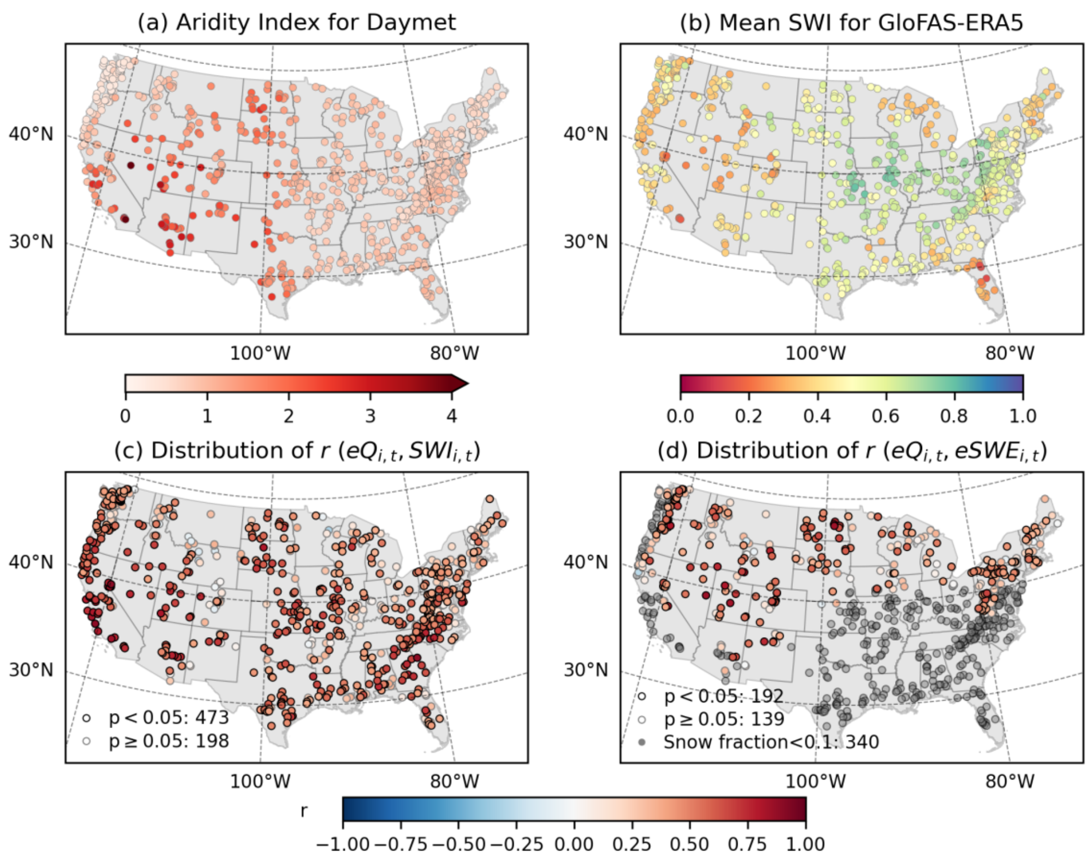

Figure S1. Spatial distribution of (a) aridity index for Daymet, (b) mean soil wetness index (SWI) from the GloFAS-ERA5 dataset and (c-d) Pearson’s correlation coefficients of streamflow reanalysis error to SWI and to snow depth water equivalent (SWE) error. The eSWE represents the RMSE of SWE from the GloFAS-ERA5 dataset by hydrological year using the SWE from the Daymet dataset as reference data.” (Page 1 in the Supplement)

4. This study mainly investigates error responses through regression relationships between annual RMSE values. Therefore, the results provide evidence of statistical *associations rather than strict causal effects. The authors should avoid using overly strong causal language and consider reducing expressions such as "control", "confirm", and "entirely dependent on". For example, in Line 287, the statement "almost entirely dependent on precipitation accuracy" appears too strong and could be revised to "predominantly associated with precipitation accuracy during the examined period".*

Thank you for the insightful comment. In the revision, we have checked throughout this paper and revised the overly strong statements:

"This modulation is further presented by targeted case studies, indicating that the temperature controls the storage and release of snow water, thereby dampening and delaying the responses of streamflow errors to precipitation errors in snow-dominated catchments." (Page 1, Lines 24 to 26)

"These divergent responses reflect that the saturation-excess mechanism may make the precipitation errors immediately affect the streamflow error while soil moisture deficits can dampen their effects." (Page 1, Lines 21 and 22)

"This case study indicates that in humid rain-dominated catchments, the performance of streamflow reanalysis is predominantly associated with the accuracy of precipitation reanalysis rather than temperature." (Page 17, Lines 292 to 294)

Minor comments

1. The GloFAS streamflow data are generally provided in discharge units, whereas streamflow errors in this study are expressed in millimeters. The authors should clarify in the Methods section whether streamflow values were converted from discharge to runoff depth.

Thank you for the instructive comment. The preprocessing of the GloFAS-ERA5 streamflow reanalysis has been added in the Methods:

"The streamflow data of the GloFAS-ERA5 dataset is converted from discharge (m3/s) into runoff depth (mm/d) based on the catchment area." (Page 4, Lines 100 and 101)

2. Daymet is a high-resolution gridded dataset generated through interpolation based on station observations. The authors are encouraged to briefly acknowledge the uncertainties associated with Daymet in the Discussion section.

Thank you for the insightful comment. In the revision, we have added this limitation to the Discussion:

"In addition, as the Daymet dataset is generated by interpolating observations (Thornton et al., 2016), uncertainties associated with station density and interpolation methods may affect the precipitation errors." (Page 20, Lines 340 and 341)

3. Please check the formulation of the R^2 equation. In Equation (4), the numerator and denominator appear to lack squared terms.

We are sorry for the typo. We have corrected it:

"For linear regression of catchment i, the R^2 is calculated:

$$R^2 = 1 - \frac{\sum(eQ_{i,t} - \widehat{eQ}_{i,t})^2}{\sum(eQ_{i,t} - \overline{eQ}_i)^2}$$

Where $\widehat{eQ}_{i,t}$ and $\overline{eQ}_i$denote the fitted value and mean value of $eQ_{i,t}$, respectively." (Page 5, Lines 120 to 123)

4. Please provide a clearer definition of precipitation seasonality. The calculation method and the physical meaning of positive and negative values should be explicitly described.

Thank you for the insightful comment. The calculation and physical meaning have been added in the Methods:

"The precipitation seasonality is estimated by fitting sinusoidal functions to the mean annual cycles of temperature and precipitation. Positive (negative) values indicate that precipitation peaks in summer (winter), whereas values near zero represent a relatively uniform distribution of precipitation throughout the year (Addor et al., 2017)." (Page 6, Lines 143 to 145)

5. Line 163: The word "diversifies" should be used instead of "diversify" in the phrase *"how catchment heterogeneity diversify the error responses".*

Thank you for spotting the typo. We have corrected it:

"Furthermore, by incorporating interaction terms into the random-effects panel regression, this analysis isolates and quantifies the marginal effects of precipitation and temperature errors, revealing how catchment heterogeneity diversifies the error responses." (Page 7, Lines 165 to 167)

6. Line 246: There is an extra word "the" in the phrase "the the saturation-excess mechanism". Please remove the redundant word.

Thank you for spotting the typo. We have corrected it:

"This result suggests that the saturation-excess mechanism makes the precipitation errors immediately affect the streamflow error in humid catchments while soil moisture deficits dampen their effects in arid catchments." (Page 14, Lines 252 to 254)