

Major Comments

Comments 1: The Results section should focus on reporting experimental outcomes and data interpretation only. Methodological explanations, such as the description of the Affinity Propagation (AP) algorithm (Line 304), should be moved to the Methods section for better structural consistency.

Response 1: Thank you very much for your constructive suggestion. We greatly appreciate your feedback regarding the organization of our manuscript. We fully understand the importance of presenting the content in a clear and concise manner. In response to your comment, we will revise the manuscript to ensure that the Results section focuses exclusively on reporting experimental outcomes and data interpretation. The methodological explanation of the Affinity Propagation (AP) algorithm (currently at Line 304) will be moved to the Methods section to achieve better structural consistency and logical coherence.

Furthermore, we will refine the overall structure of the Results and Discussion sections to enhance the manuscript's readability and flow. We believe that these planned revisions will make the paper more concise and easier to understand. Once again, we sincerely thank you for your valuable and helpful advice.

Comments 2: Please justify the representativeness of these catchments or consider expanding the validation dataset to reinforce the robustness of your conclusions.

Response 2: Thank you very much for this insightful comment. We appreciate the reviewer's concern regarding the representativeness of the selected small catchments used for validation. We fully agree that clarifying the representativeness of these catchments or expanding the validation dataset can further strengthen the robustness of our conclusions.

In response to this comment, we will revise the Validation Results section (Section 3.3) to explicitly justify the selection of the ten representative catchments. Specifically, we will provide additional details on their spatial distribution, climatic diversity, and geomorphological variability to demonstrate that they adequately represent the major climate regions and catchment types identified through the SOM – FCM classification framework.

We also fully agree that expanding the validation dataset would further enhance the reliability of the results. However, due to the practical challenges in obtaining long-

term, high-quality, and natural (unregulated) runoff data—one of the core motivations behind focusing on ungauged regions in this study—a large-scale expansion of the validation dataset is currently difficult. Therefore, we will include a clear statement in the Discussion or Conclusion section identifying dataset expansion as an important future research direction. Specifically, we will point out that future work could extend the validation to additional climate regions to further examine the generalizability and robustness of the proposed classification framework.

We sincerely thank the reviewer for this valuable suggestion, which will help to strengthen the scientific rigor and credibility of our study.

Comments 3: Please include a paragraph discussing the limitations of the proposed method and outline possible future research directions to improve applicability and generalization.

Response 3: Thank you very much for this constructive suggestion. We fully agree with the reviewer that discussing the limitations of the proposed method and outlining potential future research directions will improve the completeness, transparency, and scientific rigor of our study.

In response, we will add a dedicated paragraph in the Discussion and Conclusion sections to explicitly address these limitations and outline future work. Specifically, we will acknowledge the following points:

(1) Limitations related to static catchment attributes and data availability:

Our classification framework is based on long-term average hydroclimatological and geomorphological attributes, which inherently represent a static perspective of catchment characteristics. It does not explicitly account for dynamic processes such as land use and land cover change, anthropogenic impacts (e.g., increasing water withdrawals), or long-term climate shifts. Moreover, the resolution and accuracy of the classification depend on the quality and spatial resolution of the underlying national datasets. In regions with sparse gauge networks, data limitations may introduce additional uncertainty.

(2) Limitations in validation dataset coverage:

Although the selected validation catchments are representative, their spatial coverage remains limited due to the availability of long-term, high-quality, and natural runoff

records. This restricts the full assessment of classification performance across all climate regions.

Furthermore, we will outline future research directions, including: (1) integrating more dynamic hydrological variables (e.g., evapotranspiration, snowmelt indices) to enhance model interpretability and physical realism; (2) testing the transferability of the classification across additional climate zones and transboundary basins to evaluate generalization; and (3) coupling the classification framework with process-based hydrological models to improve simulation performance and applicability in ungauged catchments. We believe that including this discussion will provide a more balanced and comprehensive assessment of the proposed methodology, while clearly identifying pathways for its future improvement and broader applicability.

Comments 4: I think you need check the English grammar and sentence carefully. Please revise the English description of your manuscript.

Response 4: Thank you very much for your careful reading and valuable comment. We appreciate the reviewer's attention to the language quality of our manuscript. We fully agree that clear and precise English expression is essential for ensuring the readability and professionalism of the paper.

In response to this comment, we will carefully review the entire manuscript to correct grammatical errors, improve sentence structure, and enhance the overall clarity and fluency of the English text. We sincerely thank the reviewer for pointing this out, which will help us further improve the overall presentation and readability of our work.

Comments 5: Please carefully review and standardize all references to conform with the HESS reference style guide.

Response 5: Thank you very much for this helpful comment. We appreciate the reviewer's careful attention to the consistency and accuracy of our references. We fully agree that ensuring all references strictly adhere to the Hydrology and Earth System Sciences (HESS) reference style is essential for maintaining the quality and professionalism of the manuscript.

In response to this comment, we will carefully review all references in the revised manuscript to ensure that they conform precisely to the HESS reference style guide.

Minor Comments

Comments 1: Line 276: When describing the SOM neuron grid (19×22), briefly justify why this specific grid size was selected (e.g., based on data dimensionality, heuristic optimization, or quantization error minimization).

Response 1: Thank you very much for this insightful comment. We appreciate the reviewer's attention to the justification of the SOM neuron grid configuration.

In response, we will emphasize the rationale for selecting the grid size in the Methods section. Specifically, we will explain that the 19×22 SOM structure was determined through a combination of heuristic optimization and internal network performance evaluation. The grid dimensions were selected by testing multiple configurations and assessing their quantization error (QE) and topographic error (TE) values. The 19×22 grid achieved the optimal balance—minimizing QE and TE while maintaining a sufficient number of neurons to capture the spatial variability and complexity of the input climate data.

This clarification will make the methodological rationale for the SOM configuration more transparent and reproducible.

Comments 2: Figure 2: The description of the SOM component planes is clear but would benefit from a short explanatory note in the figure caption clarifying the color scale meaning (e.g., “red indicates high values, blue indicates low values”).

Response 2: Thank you very much for this helpful comment. We appreciate the reviewer's suggestion to improve the clarity of Figure 2. In response, we will revise the figure caption to include a short explanatory note clarifying the color scale meaning in the SOM component planes. This addition will help readers more intuitively interpret the component planes and better understand the spatial patterns represented by different neurons in the SOM output.

Comments 3: Ensure consistent use of “ ” or “Figure” throughout the manuscript according to the journal's style guide.

Response 3: Thank you very much for your careful observation. In response, we will thoroughly review the entire manuscript to ensure the consistent use of the term “Figure” (or its abbreviated form “Fig.”) in accordance with the HESS journal style guide.

All figure citations in the text will be standardized to follow the required format, ensuring stylistic consistency and improving the overall presentation quality of the manuscript.

Comments 4: The transition between Section 3.1.3 (FCM clustering results) and Section 3.2 (Results of catchment classification) is abrupt. Consider adding a bridging sentence such as: *“Based on the derived climate clusters, we further classified catchments with similar landscape attributes within each climate region.”*

Response 4: Thank you very much for this constructive comment. We fully agree that adding a bridging sentence will improve the logical flow and readability of the manuscript. In response, we will revise the transition between these two sections by adding a short linking sentence to clearly indicate the methodological connection between the climate-based clustering and the subsequent catchment classification. Specifically, we will add the following sentence at the beginning of Section 3.2 *“Based on the derived climate clusters, we further classified catchments with similar landscape attributes within each climate region.”*

This addition will create a smoother transition and help readers better understand how the classification framework progresses from climate clustering to catchment-level differentiation.

Comments 5: Lines 460 – 471: The sentence “The flow regime in climate region II presented multiple peaks following multiple peaks in precipitation in June and July during the same period.” is ambiguous. Please revise or clarify its intended meaning.

Response 5: Thank you for your valuable feedback on our manuscript. We agree that this section could be more clearly written to improve readability and ensure that the findings are easily understood. In response, we will revise the paragraph in Lines 460 – 471 to provide a clearer description of the seasonal flow regime and its relationship to precipitation. Specifically, we will rephrase the sentence to more precisely express that the runoff in climate region II exhibits multiple seasonal peaks corresponding to successive precipitation peaks in June and July. This clarification will make the relationship between rainfall patterns and flow responses more explicit and easier for readers to interpret.

Thank you again for your feedback, and we will make the necessary improvements based on your suggestions.

Comments 6: Line 494: The expression “Additionally, catchments with large spatial distances are capable of exhibiting similar hydrological characteristics (Maduwang and Daiying, year)” needs revision for clarity and proper citation formatting.

Response 6: Thank you for pointing out the issue. We apologize for the oversight. We will revise the sentence as follows: *"Additionally, catchments with large spatial distances are capable of exhibiting similar hydrological characteristics (e.g., Maduwang and Daiying)."*

We will ensure that the correct context is clearly presented in the manuscript. Thank you again for your attention to detail.

Comments 7: Please revised your figure and make it clearly, specially the size and format of figures.

Response 7: We sincerely thank the reviewer for highlighting the need to improve the quality of our figures. We fully agree that clear and well-designed figures are essential for effectively communicating our results. Accordingly, we will carefully check all figures and tables to ensure they meet the journal's formatting and quality standards.