To facilitate the review process, all referee comments are in **black** while the authors response in **blue**.

Final response

Dear Authors,

Glad to see you have successfully addressed most comments by the two referees. However, one of them still has concerns with the statement, which is fully consistent with your results. Please check the comments and the statements/results carefully and revise the manuscript accordingly. I would be happy to make another round of review. Thanks.

Best,
Fuqiang
Tsinghua University

We thank the editor and reviewers for dedicating their time and expertise to review our manuscript. We have carefully addressed each point in detail and updated the manuscript accordingly. We hope that the current version of the manuscript is now ready for publication. The response is organized below addressing each of the points mentioned, with specific details regarding referee comments.

Response to Referee 1

I would like to thank the authors for their careful efforts in revising the manuscript. One of the most significant improvements is the rephrasing to avoid overstated claims, which helps present the results more accurately. Nevertheless, I still find some statements that are not fully supported by the data, and I recommend a further round of moderate revision.

We thank the reviewer for the positive feedback. We have carefully addressed each point and implemented the corresponding changes in the manuscript. Additionally, we would like to highlight that we revised the terms "higher" and "lower" for the correlations to "stronger" and "weaker," following a suggestion from referee 2, to avoid confusion with the signs that r_s may carry.

1. The authors have replaced evaluative terms such as "better" with more neutral language when presenting the results. However, some conclusions remain inadequately supported. For example, in the large-scale analysis paragraph of the Conclusions section, the authors state that "the continental map typically provided higher correlations on average…". While this is true for the mean |rs| (0.42 vs. 0.40), the difference is minimal, and adding or removing a single catchment could change the conclusion. Furthermore, Figure 3 does not clearly indicate in how many catchments the continental map yields higher rs; visually, it appears roughly balanced. I suggest the authors include quantitative metrics to clarify this point, such as the statistical significance of the difference or the proportion of basins in which the continental map provides higher rs.

We thank the reviewer for pointing out this issue in detail. The previous conclusion was indeed misleading relative to our main results. Global and continental maps provide complementary strengths, as we have already discussed earlier in the manuscript. Although the continental map presented consistently high correlations with Q95 and Q mean, for example, the results were more evenly distributed for most of the signatures (including baseflow index). Therefore, we have now carefully reviewed and adjusted the full manuscript to present the conclusions as fairly as possible. As part of these modifications, we also added the proportion of basins where the continental map provides higher correlations than the global (**Figure 4**; **L374–378**) and stressed that neither map consistently outperformed the other (e.g., **L20**, **L378–379**) across all signatures.

Particularly, here we have some of the modifications:

L19-L20: *"At this scale, continental and global geology maps produced different correlation patterns, with neither consistently superior."*

L378–379: *"This indicates that neither map consistently outperformed the other for all signatures at the same time at the large-scale analysis."*

L523-527: "*Our comparison of the two geological maps revealed markedly different correlation patterns with groundwater-oriented streamflow signatures, such as baseflow index and slope of the FDC (Figure 4). The absence of a consistently superior map suggests limited reliability when using broad-scale geological data for hydrological inference. This inconsistency likely reflects both uncertainties in the geological maps themselves and the difficulty of translating lithological information into hydrologically meaningful indicators, such as through reclassification into relative permeability classes."*

L638-640: *"our results showed limited consistency between them, and that neither map consistently outperformed the other in terms of correlation with groundwater-oriented streamflow signatures."*

2. Related to the first comment, I find Figure 3 insufficiently informative. Although the authors have added several Appendix figures as suggested by Reviewer #2, I believe the intent was to display scatterplots comparing rs values computed from different attribute groups. Specifically, the x-axis could represent rs calculated using geology attributes, and the y-axis those calculated using other attribute groups. Such plots would provide deeper insight.

We thank the reviewer for the valuable suggestion. After some discussion, we have decided to modify **Figure 3**, and to insert the suggested new illustration in the **Appendix** (**Figure D3**). Now, **Figure 3** has its correlations

ordered from the attribute group with the highest number of basins to the lowest and have their respective number of basins within. In this way, we believe that readers can now extract useful information from the figure: how basins behaved differently in terms of correlations reached from each group. ranking of groups, the weak correspondence between most of the groups (which is also complemented by the new figure in **Appendix**). Finally, the figure also makes it clearer the inconsistence between the maximum r_s among the geological maps, for instance.

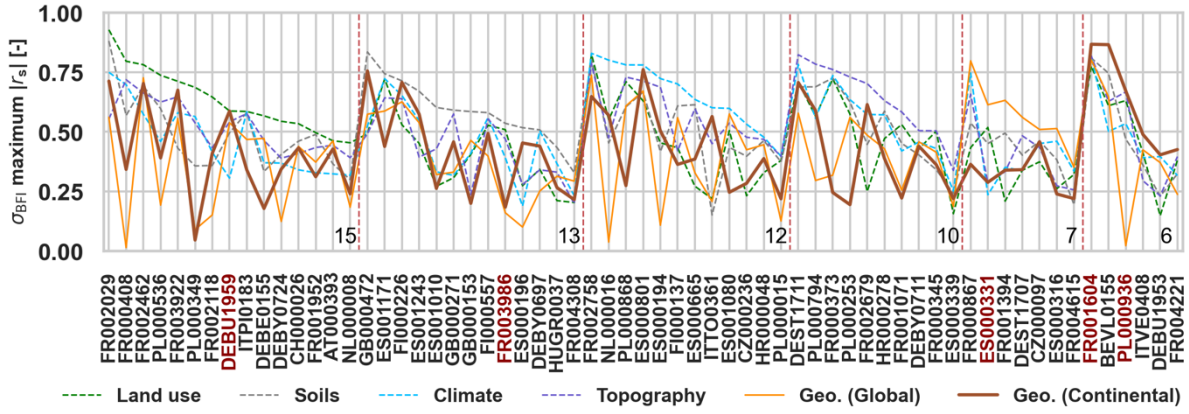

Figure 3. Maximum |rs| values for each catchment attribute group for each river basin. Each color represents the respective maximum |rs| value for a specific catchment attribute group (e.g., climate is shown in blue). The IDs of the Cinca (ES000331), Garonne (FR001604), Vienne (FR003986), Moselle (DEBU1959), and Narew (PL000936) basins are indicated in red. The groups are ordered in descending order starting with the group that ranked the most basins (land use) and ending with the least (continental geology). The number of basins is also indicated in the plot area.

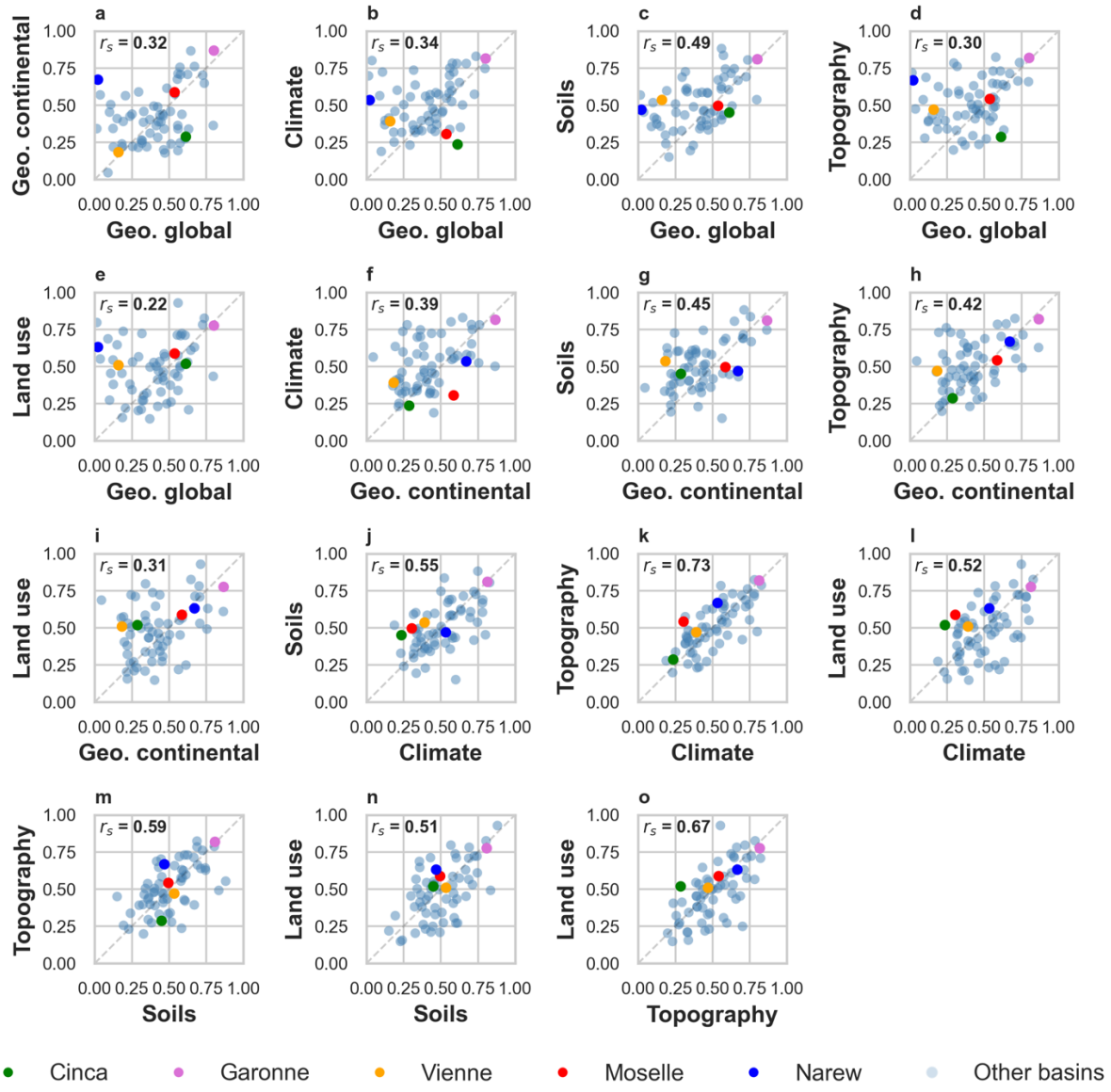

Figure D3: Scatter plots between the different attribute groups for their maximum |rs| values for the baseflow index. Each light blue circle represents one of the river basins evaluated, with the five selected river basins highlighted using distinct colors: green (Cinca), pink (Garonne), orange (Vienne), red (Moselle) and blue (Narew). Moreover, the subplots show the correlation between the correlations from both maps.

3. Regarding the small-scale analysis, I question whether a consistent correlation sign is truly an appropriate indicator. Runoff generation mechanisms differ among catchments, so the sign of the correlation may legitimately vary. For instance, t_flat_area_fra exhibits high |rs| values in all catchments except one, where the sign differs. This exception may not be problematic; rather, it could indicate a distinct runoff mechanism in the Sure subcatchment. I recommend that the authors interpret the correlation results more appropriately, acknowledging potential process differences.

We thank the reviewer for bringing up this discussion. We have carefully reviewed the text while taking this into consideration, making sure to clearly indicate when we argue that the sign consistency is related to our hypothesis (**L21-22; L657-659**), and to incorporate the proposed observation in the results section (**L502-507**). In particular, we have added the following sentences:

L21-22: *"The small-scale experiment reinforced these findings, as the regional map highlighted controls more consistent with process understanding."*

L502-507: *"It is important to highlight that high and sign consistent correlations do not necessarily imply causality even if they align with process understanding and expectations (i.e., hypothesis 1 and 2 in section 3.3). It is well known that dominant processes vary widely as well their controls. For instance, the fraction of flat area correlated strongly with σBFI in all sub-catchments, yet the Sure exhibited a positive sign, suggesting a different process dominance there. These results emphasize the importance of complementing statistical approaches with detailed hydrological insights to improve the understanding of hydrological controls."*

L657-659: *"However, the regional map was the only one that provided sign consistent and relatively high correlations across all sub-catchments, aligning with our initial, physically motivated hypotheses about the role of geology in baseflow variability in the Moselle basin."*

4. L658: This appears incorrect, as the global geology map does not yield the lowest rs for BFI (0.54, which is higher than the rs produced by climate and soil attributes).

We thank the reviewer for pointing out this mistake. We have corrected the phrase by removing the incorrect statement, which now reads as:

L463-464: *"Using the global attributes, geology ranked below at least one other landscape or climate attribute across all signatures."*

Response to referee 2

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I thank the authors for these revisions that successfully address all reviewer comments. One small note: To clarify the text further, I'd recommend using "stronger/weaker correlation" instead of "higher/lower correlation". This avoid ambiguity in cases of positve and negative correlations

We thank the reviewer for their positive feedback and suggestion. We have taken it into consideration throughout the text.