# Reviewer #3

The paper is well-written and addresses a critical need of the community by developing a new, relatively finer resolution global scale floodplain map. It uses HAND as the driving topographic attribute. While the paper presents a comprehensive dataset, I do see some major conceptual limitations that make the dataset and the underlying logics questionable. Given these limitations and my strong reservations about ESSD's high standards with regards to study methods, I think this paper would be suitable for a regular hydrology or flood related journal.

Reply: Thank you for recognizing our work and bringing reasonable criticisms to our study, particularly concerning our conceptualization. Your concerns suggest that some potential confusion may need further clarification, which we believe can be addressed through improved framing and writing. We have significantly revised and restructured our Discussion section to clarify any potential confusion about concepts, and to provide a more objective presentation of our results and the contributions of our research. Below, you'll find our point-to-point replies and we hope they clears up your concerns.

(1) The purpose of topography-based hydrogeomorphic floodplain mapping is to (a) avoid complex and computationally intensive modeling approaches, and (b) map flood hazards without any specific return period of extreme event (eg 50, 100, 500 year flood). But this study overrides that concept and uses existing 500-year flood maps from two hydrodynamic models to calculate scaling parameters for HAND. Clearly, this opposes what we know about the science of hydrogeomorphic floodplain mapping. In short, the method proposed in this study takes years of development and conceptual knowledge in a confusing direction. If I have to use hydrodynamic models for creating a hydrogeomorphic model, then the whole idea of hydrogeomorphic modeling is meaningless.

Reply: Thank you for your comment on the possible confusion of our conceptualization. We would like to clarify that we are not using hydrodynamic models to create a hydrogeomorphic model but to better determine the floodplain boundary. Although the conceptual definition of a geomorphic floodplain does not involve such a boundary, in practice, it is essential that we obtain some sort of information, be it from hydrodynamic maps or in-situ measurements as the reviewer mentioned in the other comment, to help us define this boundary. By incorporating outputs from hydrodynamic maps (not models), we are obtaining Floodplain Hydraulic Geometry (FHG) parameters for the already established hydrogeomorphic modelling framework, and the maps from hydrodynamic models have proven to be of use. The contribution in our study to the framework is to add information on spatial variability in parameters.

Conceptually, we believe that different definitions of floodplain boundaries are complementary rather than contradictory, each highlighting different facets of floodplain dynamics. In our case, the concept of a geomorphic floodplain emphasizes the formation process of floodplains, but it is also predominantly shaped by low-probability, high-impact flood occurrences (Lindersson et al., 2021). Considering that FHG describes the extent of inundation depth (hydrological factor) with drainage area (geomorphic factor), our goal of delineating a geomorphic floodplain is subsequently connected with identifying a boundary that encompasses all potentially inundated areas under extreme conditions. **Therefore, we've used two 500-year return period flood inundation maps as references for estimating our parameters, only to ensure a sufficiently large boundary for the carrying out of this algorithm**. **This way, we believe that the geomorphic definition of a floodplain is still obeyed.** While the FHG parameters can be approximated for various return periods (Nardi et al., 2006) and can subsequently be viewed from an inundation perspective, our approach does not focus on a specific return period for inundation. In other words, our goal is not to provide a mere substitute for inundation maps; rather, we aim to consider both the stream's geographical characteristics and hydrological extreme conditions, to identify scaling relationships that align with geomorphic principles, and to offer a more comprehensive understanding of floodplain dynamics.

Thank you again for pointing out this potential confusion on our conceptualization. To better address your concerns, we have largely revised the above discussion on floodplain boundary definition and delineation in the revised Section 4.3 in Discussion. Additionally, to facilitate future studies and reduce computational efforts, we will provide our spatially varying parameters for easier application. These parameters are now available at the same Zenodo repository at https://zenodo.org/records/10440609.

(2) Alongside the conceptual limitation, the work is self-contradictory. The authors on and on tag their approach as parsimonious and existing hydrodynamic models as uncertain (see Lines 84-86). Parameterizing HAND with two hydrodynamic model-based flood maps, as the authors did, is in no way a parsimonious method. This is also not a practical method. Because if I don't have hydrodynamic models existing in my area of interest (let's forget about uncertainty for the sake of discussion), I won't be able to reproduce the authors' method.

Reply: We respectfully disagree with this point and would like to emphasize that our approach remains parsimonious. Strictly speaking, we did not use hydrodynamic models but rather publicly available flood maps as references, despite their uncertainties and inconsistencies. Thus, no complex models or simulations are involved in our method, as the core process is described by a power-law. The most intricate part of our study is the data filtering scheme, but it still demands significantly less computational effort compared to hydrodynamic models. Besides, we believe that the issue of parsimony and practicality can be better addressed by providing our optimized scaling law parameters. For anyone who wish to reproduce the method/results using terrain data, it is easy to grab our results and derive new maps of their own, thus replicating our method should be feasible.

In addition to the above, in this revision, we have carefully conducted additional investigations into the concern on the uncertainty related to using hydrodynamic maps. Despite their acknowledged inconsistencies, the reference maps we used are informed by climatic forcing and are subsequently expected to offer a more spatially heterogeneous basis than universal geomorphic parameters. In other words, while we do acknowledge these maps can be uncertain, they contain useful information that can be applied to constrain geomorphic floodplain boundaries. We have thus introduced a rigorous data filtering process to optimize the parameters best conforming to the power law contained within the data. Our results show that the filtered data conform well to the power law (see revised Figure 9), supporting the validity of our approach.

We hope this resolves the “self-contradictory” concern for our work. Revisions have also been made more clearly to address your conceptual concerns: for detailed explanations of using these maps as references, please see the newly added Section 4.1, and for the remaining uncertainty please refer to Section 4.2. Our supplied parameter maps can be found in the zenodo repository for more expert users.

Many examples of HAND’s parsimonious applications already exist in literature. HAND is parsimonious in operationalized flood prediction systems where a streamflow or stage height (the H in authors’ scaling equation) comes from an operational watershed hydrology simulation model followed by a process of automatic synthetic rating curve generation. See examples like https://doi.org/10.31223/osf.io/hqpzg

Reply: We thank the reviewer for this comment, and we are actually aware of the alternative thresholding methods for HAND that are available and widely utilized. The paper you provided outlines two approaches: 1) directly estimating stage height, which is useful when in-situ measurements are available, and 2) using a synthetic rating curve, as also calculated from terrain-based methods. The latter method is indeed effective for large-scale applications and is used by the US National Water Model, but it introduces additional sources of uncertainty as it requires estimated Manning's coefficients for water-stage estimation and it is also computationally very demanding as it has not been accomplished worldwide. Therefore, outside of the United States where high-quality data is available, replicating this globally poses significant challenges.

To compare with, the FHG method requires only terrain input, which is recognized as the least uncertain component in global floodplain mapping when using hydrodynamic models. The necessary information is encapsulated in the parameters, making it easier to identify the influence of each parameter. Therefore, we consider the FHG thresholding approach to be more globally consistent and easily applicable, and still a useful contribution to the community. We have added an additional section on FHG in Section 4.1 and included a paragraph on other thresholding schemes for HAND to address your concerns. We have also supplied parameters for use by future researchers to make it parsimonious.

(3) The aridity came out of nowhere. I think bringing aridity into the mix was arbitrary and unnecessary.

Reply: Thank you for pointing out this potential confusion, which was also brought up by other reviewers and which we have carefully addressed in this revision. We'd like to clarify that including aridity in our analysis was purposeful and based on our hypothesis. Our estimated parameters aim to capture spatial heterogeneity of geomorphic floodplain forming factors and, if possible, we should be able to identify significant relationship between examined factors and our derived parameters. Due to uncertainties with the data as well as the scaling law itself, we do not expect the relationship to be perfect. We hypothesized that in humid areas, the stronger discrepancy between small and large rivers would lead to a stronger dominance by larger rivers. While the correlation with the Aridity Index (AI) is not strong, its significance supports our parameter estimation efforts. The largest basins, being hydrologically connected and thus internally consistent in hydrological characteristics, result in stronger correlations with these factors as expected. Despite the seemingly loose correlations, our analyses may still be helpful in identifying geomorphic floodplain-forming mechanisms.

To address your comment regarding the clarity of our purpose, we have clarified our hypothesis and strengthened the tests we conducted in this revision. In terms of writing, we have explained this in the Methods section and elaborated on it in the revised Section 4.1 on our hypothesis with the FHG parameters.

Experimentally, we conducted two additional analyses. First, we included more variables in our analysis, such as LAI, terrain (mean and deviation), and soil factors (soil components in a river buffer). Our hypothesis was that AI would be the most significant factor, with LAI inherently related to AI, while terrain and soil might also be related but with less clear mechanisms. The results showed that AI was indeed the most significant, with LAI only significant in large basins. Other factors exhibit inconsistent correlations with b, also as expected. We also tested the estimation of the parameters at different scales (i.e., Level-4 and Level-5 basins) to increase the sample size. The results showed that AI and LAI have statistically significant relationships with the exponent b, while terrain factors showed significant but much weaker relationships, followed by soil factors that do not show statistically significant relationships with b (see our Supplementary Figure 1, included below).

While the correlations shown in the above analyses may not be very strong, they meet our expectations: AI is significant as the primary factor for explaining the spatial variability of b, LAI plays a role, and terrain might be related but not showing readily detectable correlations with the exponent b.

**Table 1 (Supplementary Table 1 in the revised manuscript). Correlation of FHG parameter *b* and relevant hydroclimatic factors.** Results from Level-4 and Level-5 basins are filtered by the amount of available reference grids in the basin. Soil data are from the Soilgrids 2.0 dataset [3] and processed within a 10-km buffer calculated by hydrological distance.

| | | **Aridity Index** | **LAI** | **Elevation Mean** | **Elevation STD** | **Clay** | **Silt** | **Sand** |
|---|---|---|---|---|---|---|---|---|
| **Level-3** | All | 0.335*** | 0.083 | -0.007 | 0.121 | 0.152* | 0.170* | -0.041 |
| | Largest | 0.680*** | 0.668*** | -0.165 | 0.208 | 0.314 | -0.134 | -0.042 |
| **Level-4** | | 0.338*** | 0.256*** | 0.131** | 0.246*** | -0.067 | 0.050 | -0.003 |
| **Level-5** | | 0.405*** | 0.349*** | 0.104*** | 0.188*** | -0.033 | -0.019 | 0.033 |

We've revised our manuscript accordingly to include both the more clearly stated hypothesis and our interpretations. Please refer to the newly performed analyses in Supplementary Table 1, and more objective statements of our parameters and hypothesis in Section 4.1.

References:

1. Lindersson, S., Brandimarte, L., Mård, J., and Di Baldassarre, G.: Global riverine flood risk – how do hydrogeomorphic floodplain maps compare to flood hazard maps?, Nat. Hazards Earth Syst. Sci., 21, 2921–2948, https://doi.org/10.5194/nhess-21-2921-2021, 2021.

2. Nardi, F., Vivoni, E. R., and Grimaldi, S.: Investigating a floodplain scaling relation using a hydrogeomorphic delineation method: HYDROGEOMORPHIC FLOODPLAIN DELINEATION METHOD, Water Resour. Res., 42, https://doi.org/10.1029/2005WR004155, 2006.

3. Poggio, L., de Sousa, L. M., Batjes, N. H., Heuvelink, G. B. M., Kempen, B., Ribeiro, E., and Rossiter, D.: SoilGrids 2.0: producing soil information for the globe with quantified spatial uncertainty, SOIL, 7, 217–240, https://doi.org/10.5194/soil-7-217-2021, 2021.