Response to the Editor

"Minor comments:

Reviewer 2 rightly pointed out that the chosen base level for calculation of χ and χP has an influence on the calculated divide asymmetry index. In your response to reviewer 2, you presented some analyses which show the difference in DAI with base-levels of 1000 and 1500 m. However, none of this analysis or discussion has appeared in the revised manuscript. I think this is an important point, and urge you to highlight this more clearly in your revised manuscript or at least in your supplemental information."

We acknowledge the critical role base-level plays in the calculation of χ and χ_P. It is this base-level sensitivity that necessitates that the primary criterion for selecting base-level is a tectonically stable reference point, with all upstream area responding to uplift with respect to this stationary elevation. Stationarity of the base-level elevation requires that downstream reaches of all rivers have the same steepness, so the same uplift and incision rates. The Sichuan Basin is a rigid tectonic block that has served as a temporally stable base-level for more than two-thirds of the rivers in the HDM throughout the Cenozoic. The lower reaches of the remaining streams (belonging to the Salween and Mekong catchments) are also characterized by tectonic inactive areas and thus have low channel steepnesses with little variation in gradient. By selecting an elevation of 500 meters for our baselevel, we are effectively using the Sichuan Basin and the upper boundary of the low-steepness Mekong and Salween River regions, removing any large differences in χ arising from these long, flat reaches (Yang et al., 2020; Fox et al., 2020; Jiao et al., 2022; Pan et al., 2023).

Furthermore, most cross-divide comparisons in the study are internal to a single river catchment (i.e., Yangtze, Mekong, or Salween), so base-level plays no role (Yang et al., 2015). Only at the borders between the Yangtze, Mekong, and Salween rivers is the chosen base-level important. As shown in our response to reviewer 2 (Fig. R1, Table R1), despite minor differences in asymmetry magnitudes at higher base-levels, there are no striking differences in spatial patterns of χ within or between the major river catchments at higher base-levels. This indicates that the applied base-level of 500 m successfully removes tectonically inactive portions of the drainage network, while maximizing the area of analysis.

We therefore chose not to add these maps to the revised manuscript or supplement. We believe that including multiple χ maps with varying base-levels adds unnecessary ambiguity that may confuse readers and suggest that base-level is arbitrarily chosen, rather than carefully set based on established criteria.

"In Line 394 you state that the general agreement between χP and the other metrics suggests that changes in uplift or erodibility are localised or slow enough that χP acts as a good indication of divide migration direction. However, there are many divides where there are significant differences between χP and the other metrics, and indeed you show that χP is the most different to the other metrics in Figure 3. One way to tackle the erodibility part of the problem would be to include geological data from the region, and test whether the divides with disagreement between χP and the other metrics are those with more variability in catchment lithology/erodibility."

The editor is correct that χ_P shows the lowest agreement on migration direction with the other metrics. However, we would like to note that the difference to the other metrics is minor despite comparing a catchment-wide integration variable (χ_P) to the metrics calculated locally at the divide. For example, χ_P agrees on migration direction with k_{snP} a similar amount as HSG does at 59.3% and 59.9%, respectively (Fig. 3). χ_P and HSG also have similar levels of agreement on migration direction with CRR at 64.5% and 68.1%, respectively. The worst agreement between χ_P and another metric is still 57% (with HSG). Given the complex geologic and tectonic setting of the HDM, we find this behaviour quite remarkable.

To address the problem of divide metrics being influenced by lithology, we have added a lithologic map to the supplement of the revised manuscript (Fig. S1, below).

In this figure, one can see that the strong heterogeneity in lithology persists throughout the entire HDM, without any clear spatial patterns that correlate with strongly asymmetric divides or where χ_P and local-scale metrics disagree on migration direction. Given that χ metrics depend on the integral of erodibility, the effect tends to be small unless there are large-scale, regional differences in erodibility.

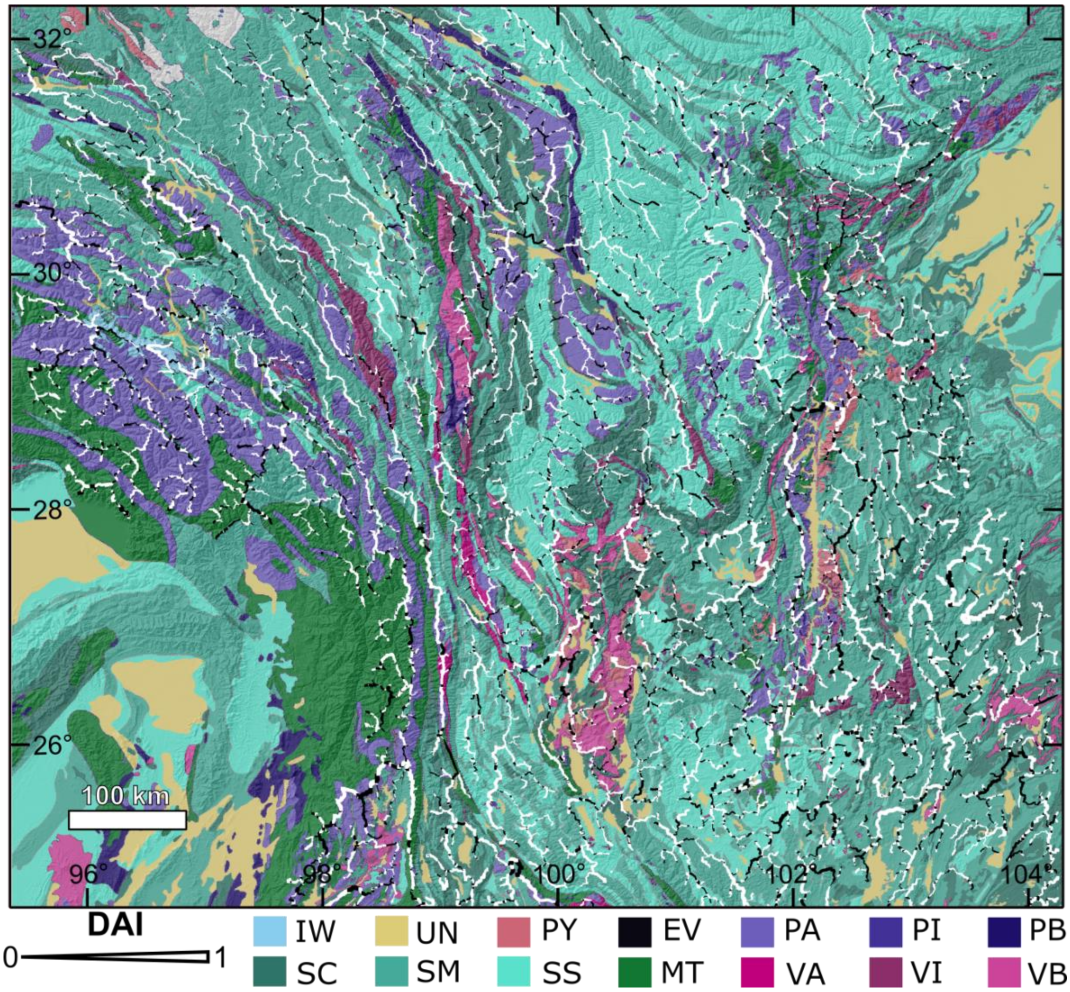

Figure S1. Spatial comparison of HDM lithology and χ_P asymmetry magnitude and agreement with local-scale metrics shows no clear patterns between lithology and strong divide asymmetry or migration direction disagreement. Lines represent drainage divides with line thickness corresponding to χ_P DAI. Divide segments where migration directions in χ_P and a majority of local-scale metrics (2+/3) agree are white; segments where χ_P indicates a divide migration direction contrary to 2 or more local-scale metrics are black. Lithology abbreviations are ice/water (IW), unconsolidated sediments (UN), pyroclastic rocks (PY), evaporites (EV), acidic plutonic rocks (PA), intermediate plutonic rocks (PI), basic plutonic rocks (PB), carbonate sedimentary rocks (SC), mixed sedimentary rocks (SM), siliciclastic sedimentary rocks (SS), metamorphic rocks (MT), acidic volcanic rocks (VA), intermediate volcanic rocks (VI), and basic volcanic rocks (VB). Lithologic data are from the GLiM global lithologic map (Hartmann and Moosdorf 2012a).

"Line 180: although it is good to see that the best fit concavity of 0.45 was tested rather than assumed, it would be beneficial to explain how the mnoptim function actually works

to improve clarity for readers of the manuscript. Does this use a disorder method to test for best fit concavity or does it look for collapse of tributaries onto the main stem?"

To better explain how the 'mnoptim' function works we added the following sentence to the methods:

"The *mnoptim* function loops through subsets of the drainage network, determines in each iteration the concavity that best linearizes the stream profiles of the subset, and then tests this concavity on the remainder of the network to find the best-fit for the entire drainage network."

"Line 186: It's not clear to me what you mean by "critical drainage area threshold" here. Do you mean A0 in the calculation of χ? This should be more clearly explained and justified."

The critical drainage area, refers to the drainage area required for stream initiation. We have clarified this in the revised manuscript. We cite from the revised sentence:

"For all calculations, a critical drainage area threshold for stream initiation of 5 km^2 was used."

"Line 289: this point could be made stronger by including a quantification of "majority" e.g. state the percentage of divide segments that show agreement. There are a couple of other points through the text where additional quantification instead of stating simply "majority" could also help."

We thank the editor for this comment and have added the percentage of divides that show agreement to the referenced sentence and others that did not explicitly state percentages. We cite from the revised manuscript:

L291: "Inferred divide migration directions agree between geomorphic metric pairs for a majority (57% or more) of the 22,837 divide segments analyzed."

L344: "Overall, geomorphic metric agree on divide migration direction in a majority of cases (Figs. 3 and 7), with total agreement between any two metrics ranging from 57% to 97%."

L366: "However, divide migration direction inferred by χ_P still agrees with at least two of the three local metrics 69.2% of the time, especially in divides with strong χ_P asymmetry (83.7%)."

"Best wishes,
Fiona Clubb (Associate Editor)"

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