Response to Anonymous Referee #2

"General comments

This work investigated drainage divide asymmetry of the Hengduan Mountains (HDM) using four geomorphic metrics (CRR, HSG, ksnP, and χP) to understand the spatial and temporal patterns of geometric transience of river network in this region. They find clear evidence of widespread transience through a high incidence of strongly asymmetrical divides throughout the HDM with the four geomorphic metrics. The study of landscape transient effect in this complex area is challenging, and the work provides such test using four metrics, and compare the difference between these metrics. From these new aspects, the manuscript is suitable for publishing in ESurf. However, the manuscript may have some problems on the geomorphic metrics that need to be addressed and which may require substantial revision.

(1) ksn and **χ** *are both precipitation-corrected to account the strong precipitation gradient in this region in equations (4) and (6), but the authors seem use the 'local' mean annual precipitation P, in fact it should be the 'upstream' mean annual precipitation of a reference point, i.e., rainfall rate averaged over A, according to Adams et al. (2020). Local and upstream average are quite different."*

We are glad that the reviewer mentioned this point because, while we do use the upstream mean annual precipitation when calculating precipitation-corrected k_{sn} and χ, this was not stated in the text. To address this, we have added the blue text to line 181: "…we multiply A by the upstream mean annual precipitation (P)…."

"For calculating the **χ** *and* **χ***P, the authors chose a base-level of 500 m for the study area to approximate the elevation at the western edge of the Sichuan Basin. This is fine for a base-level of most streams of the Yangtze River in the HDM. However, the work mainly studies the transience of the HDM in the Three Rivers region (not only the Yangtze River), which have three different outlets. Whether the results and conclusions are sensitive if the base-level elevations are set to 1000 m or 1500m, which are approximately at the plateau margin."*

The reviewer is correct that the base-level for the χ and χ_P integration matters and has to be carefully chosen. χ is computed relative to a local base level, where perturbations caused by rock uplift occur only above this base level. Therefore, the stability of the base level's elevation is crucial. We chose the elevation of the Sichuan basin as the base level due to its tectonic inactivity, assuming that its elevation remains constant. Similarly, for the Salween and Mekong rivers, situated at an elevation of 500 meters, they already traverse regions characterized by tectonic inactivity, possibly flood plains.

Of the three main rivers in the study region (Salween, Mekong, Yangtze), the Yangtze River where it enters the Sichuan basin, has the highest base-level. Utilizing the a lower base-level from one of the other rivers would lead to the inclusion of alluvial reaches for rivers draining to the Sichuan basin. This would influence the χ and χ_P integration through distinctly higher erodibility and non-detachment-limited conditions in the unconsolidated sediments of the Sichuan Basin. Moreover, as mentioned in the text (line 193) and shown in Figure 1, the Yangtze River drainage covers a majority of the HDM surface area. With the exception of the Salween and Mekong catchments, all streams in the analysis region eventually drain into the Yangtze and through the Sichuan Basin.

Choosing a higher base-level, as suggested by the reviewer, would change the resulting χ and χ_P maps and some across-divide differences, but would also substantially reduce the area of analysis. Choosing a higher base-level would only be necessary if there were an elevation-dependent variation in the U/K-ratio that should be removed from the analysis. We acknowledge this limitation of χ in the text (lines 62-69 and 292-293) and capitalize on it to test for such U and K variations by comparing cross-divide differences in χ to the other geomorphic metrics, which are only sensitive to local erosion rate (explained on lines 88-90, 289-296, 327-330, and 436-440, and visualized in Figure 5). As stated on lines 330-333, we found that "divide migration direction inferred by χ_P still agrees with local metrics a majority of the time, especially in strongly asymmetrical divides. This suggests that, despite several areas of localized uplift and heterogeneous lithology across the HDM, changes in uplift and erodibility are small enough, or slow enough, that χ_P values at the divides remain dominated by the length of the rivers and their area distributions in most places."

To further address the reviewer comment, we have also prepared two additional χ maps, one with a 1000 m base-level and one with a 1500 m base-level, to show the resulting reduction in analysis area. DAI was calculated for three divide segments in the HDM at each base-level and compared (Table R1; black circles in Fig. R1). These are shown below next to the χ map with the original 500 m base-level, but not included in the revised manuscript:

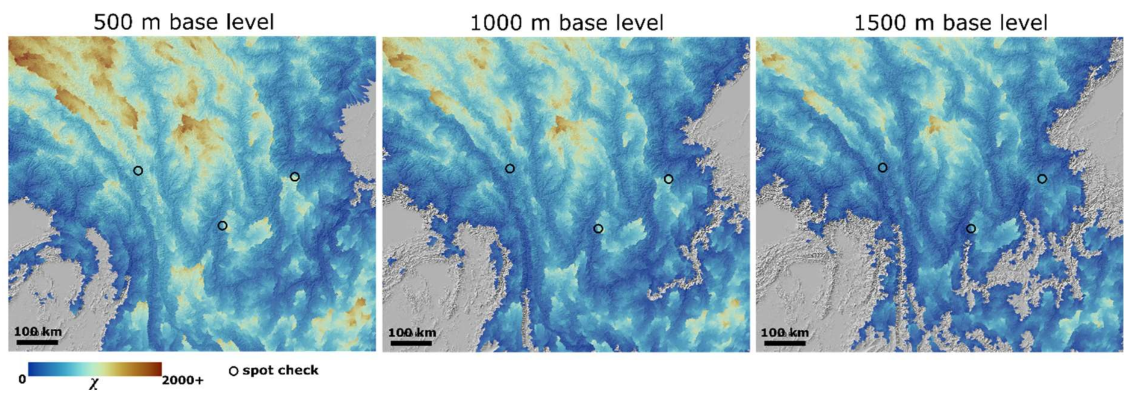

Figure R1. Series of χ maps for the HDM calculated from different base-levels. Left map shows χ from a 500 m base-level (as used in this study), center map shows χ from a 1000 m base-level, and right map shows χ from a 1500 m base-level. Color ramps are set to the same minimum and maximum values for all maps. Black circles indicate locations where divide asymmetry was measured to show how DAI changes with base-level. From west to east, these circles are located at the Salween River-Mekong River divide, Yangtze River-Yalong River divide, and Dadu River-Anning River divide. Their DAI values are compared in the Table R1 (below).

DAI for the divide between the Salween and Mekong rivers is near constant at all three base-levels. DAI for the divide between the Yangtze and Yalong Rivers gradually increases with base-level, likely because of the removal of more of the steep, narrow portion of the Yalong River. DAI for the divide between the Dadu and Anning rivers is roughly the same at 500 m and 1000 m, but decreases by half at 1500 m because this base-level is higher than the knickpoint in the Anning River associated with the capture of its headwaters by the Dadu River. These examples demonstrate that while, yes, changing the base-level can alter cross-divide differences in χ, ultimately there is no one base-level that can eliminate transients and U/K variations in the HDM. Overall, the value of χ as an interpretation tool remains.

Table R1. Comparison of DAI values calculated from χ with three different base-levels for three divide segments in the HDM. The locations of the divide segments are shown in Fig. R1.

		DAI Value		
Map Location	**Divide Location**	**500 m Base-level**	**1000 m Base-level**	**1500 m Base-level**
Western-most (left)	Salween River – Mekong River Divide (in Three Rivers Area)	0.15	0.19	0.15
Central	Yangtze River – Yalong River Divide	0.37	0.46	0.63

	(at Yanyuan Basin)			
Eastern-most (right)	Dadu River – Anning River Divide (at "main" windgap)	0.42	0.44	0.21

For all the above-mentioned reasons, we decided to keep the base-level at 500 m. However, for additional clarity, we will modify the following passages (blue text is new):

L192-194: "A base-level of 500 m was used for the study area to approximate the elevation at the western edge of the Sichuan Basin. The Sichuan Basin is a part of the stable South China Tectonic Block and serves as a natural base-level for most streams in the HDM via the Yangtze River, which possesses the highest base-level of any major river in the region (Fig. 1a)."

"Lines 11-12: The authors claim that they evaluate the relative time scales of this transience by comparing drainage divide asymmetry, but I did not see any time scales of transience in this work."

χ and χ_P are metrics calculated by integrating drainage area (or a relative discharge proxy) for the entire drainage basin. Therefore, these metrics tend to record transience on long time-scales. In contrast, metrics calculated locally at the divide, such as hillslope gradient, are proxies for the short time scale, even instantaneous, divide motion. This is expressed in the introduction of the original manuscript (lines 66-70), the results (lines 290-291), the conclusion (lines 436-437) and the discussion (lines 315-318) from which we cite: "Metrics are computed on different spatial and, consequently, temporal scales; for example, χ_P is integrated across entire catchments and represents long-term trends in landscape evolution (Beeson et al., 2017; Scheingross et al., 2020), <u>while HSG is averaged across individual divide segments and adjusts to local, short-term changes to catchment structure."</u> To improve the clarity of the text, we have modified the underlined text so it now reads "…while HSG is averaged across individual divide segments and reflects local, short-term rates of erosion."

"Lines 88-90: There are many one-sentence paragraphs in the manuscript, it is quite strange to have one-sentence paragraphs, try to minimize them."

The sentence pointed out in the comment has been added to the previous paragraph. We have also gone through the manuscript and either incorporated the other one-sentence paragraphs into their preceding paragraphs (lines 183-184) or expanded the paragraph into multiple sentences (lines 162-163).

"Lines 178-179: The authors refer to Fig. S2 "A best-fit θref of 0.45 was determined for the HDM through Bayesian optimization with the mnoptim function in Topotoolbox", but Fig. S2 is not on the river concavity, missing a figure?"

We thank the reviewer for catching this oversight. We have added the figure (shown below) to the revised version and have updated the figure numbers accordingly.

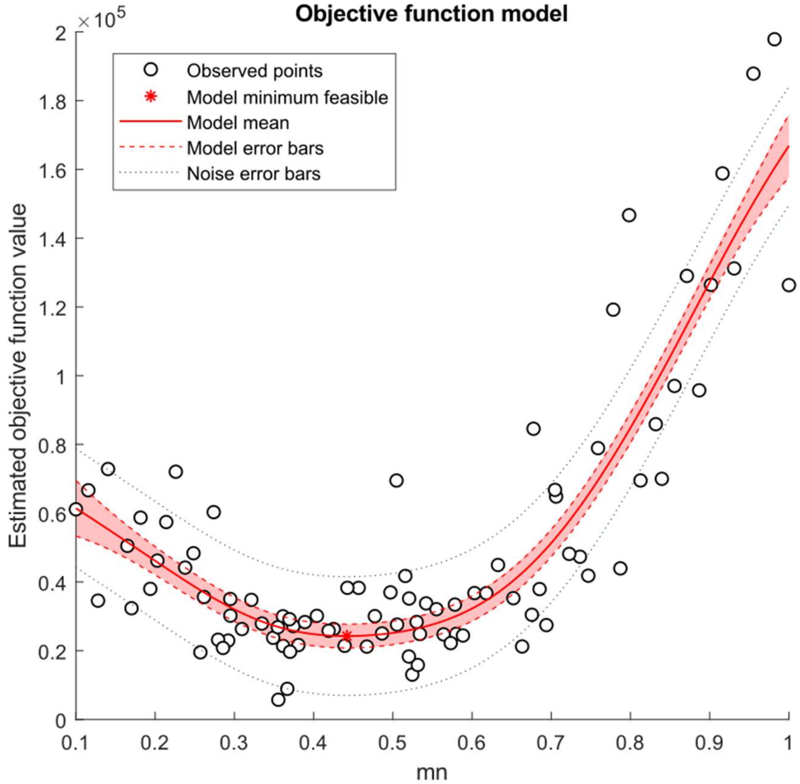

Figure S2. Results of Bayesian optimization of reference concavity (θ_{ref}) for the HDM calculated using the *mnoptim* function in Topotoolbox. Best-fit θ_{ref} of ~0.45 ("model minimum feasible") is marked with a red star. White circles mark calculated θ (*m/n*) values and their corresponding estimated objective function values for each of the 100 model iterations. The model mean is shown with a solid red line and its corresponding error is shown with a dashed red line. The dotted grey line is the noise error bars.

"Lines 183-184 and Fig. S1: Maybe put ksn and ksnP, χ and χP together for easy of comparing? One-sentence of paragraph is not necessary here."

The reviewer makes an interesting suggestion that we considered. However, we determined that the spatial variations between these metrics are too minor for visual comparison. As Fig. 4 shows, the correlation coefficient between k_{sn} and k_{snP} is 0.99 and between χ and χ_P is 0.97. However, we have chosen to add an additional figure suggested by the reviewer in a later comment, which compares where high and low asymmetry divides differ between k_{sn} and k_{snP} and between χ and χ_P to the supplement, which we believe suits a similar purpose (see response to later comment for more details).

As mentioned in response to a previous comment, we added the sentence to the previous paragraph to avoid having a one-sentence paragraph.

"Lines 238-240: It seems that the threshold for "high" (95th percentile) and "low" (5th percentile) divide asymmetry in each metric is chosen arbitrary?"

The reviewer is correct that the 5th and 95th percentile thresholds are somewhat arbitrary. However, these are commonly used thresholds for outliers in statistical analysis and are relatively conservative.

We chose to use percentiles over alternative methods, such as 1.5x the interquartile range (IQR), because this approach allows for consistency across the different metrics, providing a uniform method of classification that is less dependent on their individual DAI distributions. This is important because, as shown in figures 3 and S4, in Table S1, and mentioned on lines 266-270, DAI distributions are right-skewed and vary by metric. If we were to instead use 1.5x IQR to define high and low divide asymmetry, no metric would have low asymmetry divides and all except local relief (LR) would have more high asymmetry divides (see table below).

Table comparing outlier thresholds using the percentile and 1.5x IQR methods for drainage divide asymmetry by magnitude (DAI) by metric.

Metric	Min	Max	Percentile		IQR	
			5th	95th	Lower	Upper
CRR	1.80E-05	0.9674	0.0040	0.1623	0	0.1121
LR	1.10E-05	0.9674	0.0033	0.1004	0	0.1397
HSG	1.00E-06	0.6057	0.0054	0.1984	0	0.1612
ksn	4.40E-05	1.0000	0.0155	0.5609	0	0.5066
ksnP	1.00E-05	1.0000	0.0152	0.5641	0	0.5077
χ	8.00E-06	0.6878	0.0052	0.2180	0	0.1880
χP	7.00E-06	0.6448	0.0048	0.2077	0	0.1626

"Lines 243-249 and Fig. S2: The authors explain the difference of highly asymmetric drainage divides between χ and χP, but I did not understand by looking at the Fig. S2. It is better to show an overlap figure marking the difference between metrics χ and χP, and a figure marking the difference between metrics ksn and ksnP."

We thank the reviewer for this suggestion. Though, as mentioned in a previous response, the differences between these metrics are very small, such an overlap figure is an excellent way to highlight the minor spatial differences between them. We include the new figure below and have added it to the supplement in the revised manuscript.

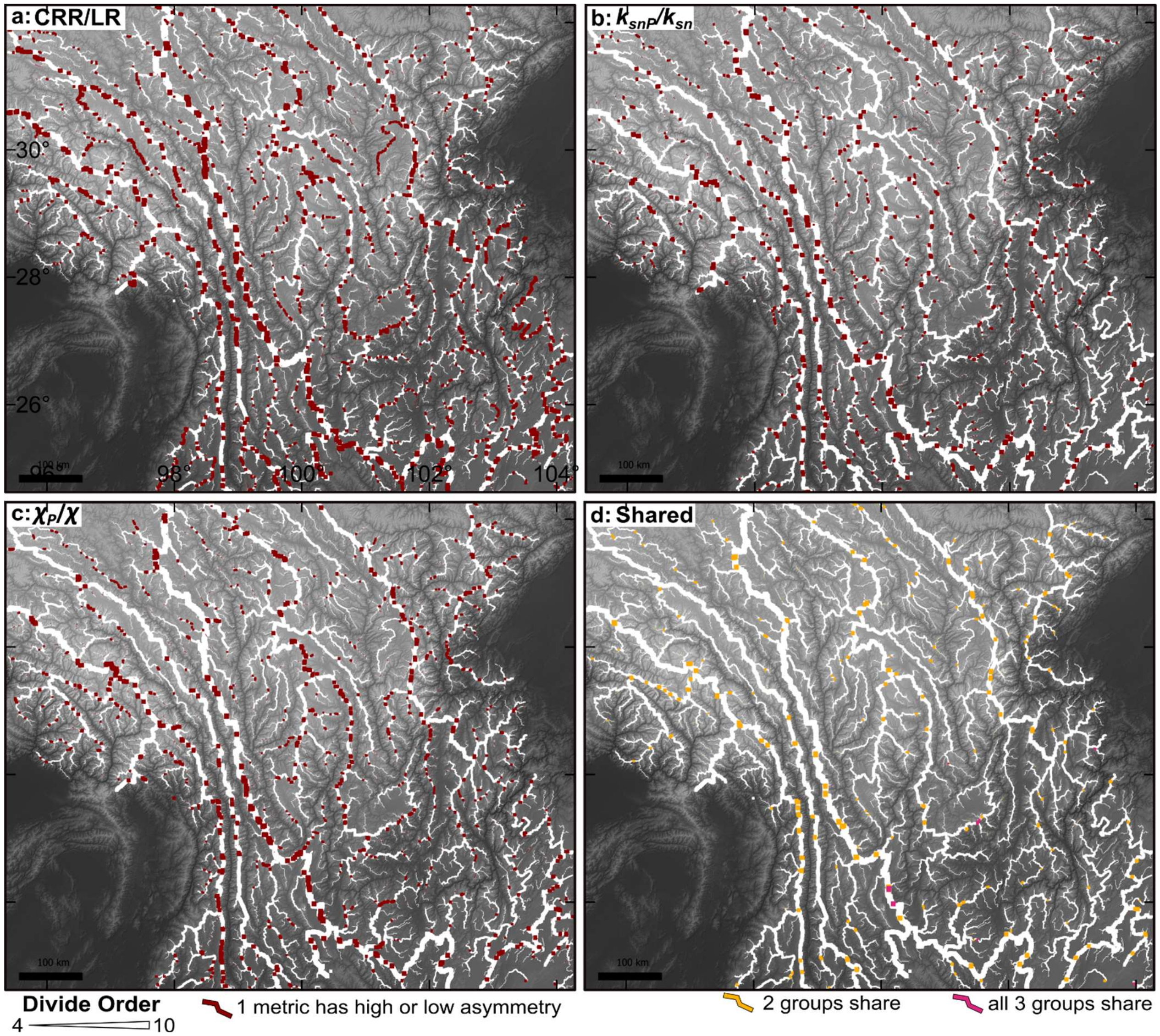

Figure S4: Locations of drainage divides that have do not have consistently high or low asymmetry between two similar geomorphic metrics (i.e., one metric has high asymmetry when the other does not) are marked in red. Divide line thickness increases with divide Strahler order (4-10). Panels include (a) CRR vs. LR, in which 2,533 divide segments (11%) have conflicting asymmetry classifications, (b) k_{snP} vs. k_{sn}, in which 1,313 divide segments (6%) have conflicting asymmetry classifications, and (c) χ_P vs. χ, in which 1,599 divide segments (7%) have conflicting asymmetry classifications. In no instance in a-c does any metric have low asymmetry when its counterpart has high asymmetry. Panel (d) shows the locations of divide segments for which all of the metric pairs in a-c have conflicting asymmetry classifications (pink, 11 divides) and of divide segments for which two of the metric pairs have conflicting asymmetry classifications (orange, 342 divides). Metric-specific thresholds for high and low DAI can be found in Table S1.

"Fig. 3. It is very difficult to understand this figure. It took much of my time to understand it. I suggest simplifying this figure. For example, changing the y-axis in right-hand side to the grey color. Move '%' in y-axis of the left-hand side to the end of Migration direction agreement."

We like the reviewer's suggestions on how to improve Fig. 3 and have updated it, and its counterpart in the supplement, accordingly. Below we show the revised Fig. 3:

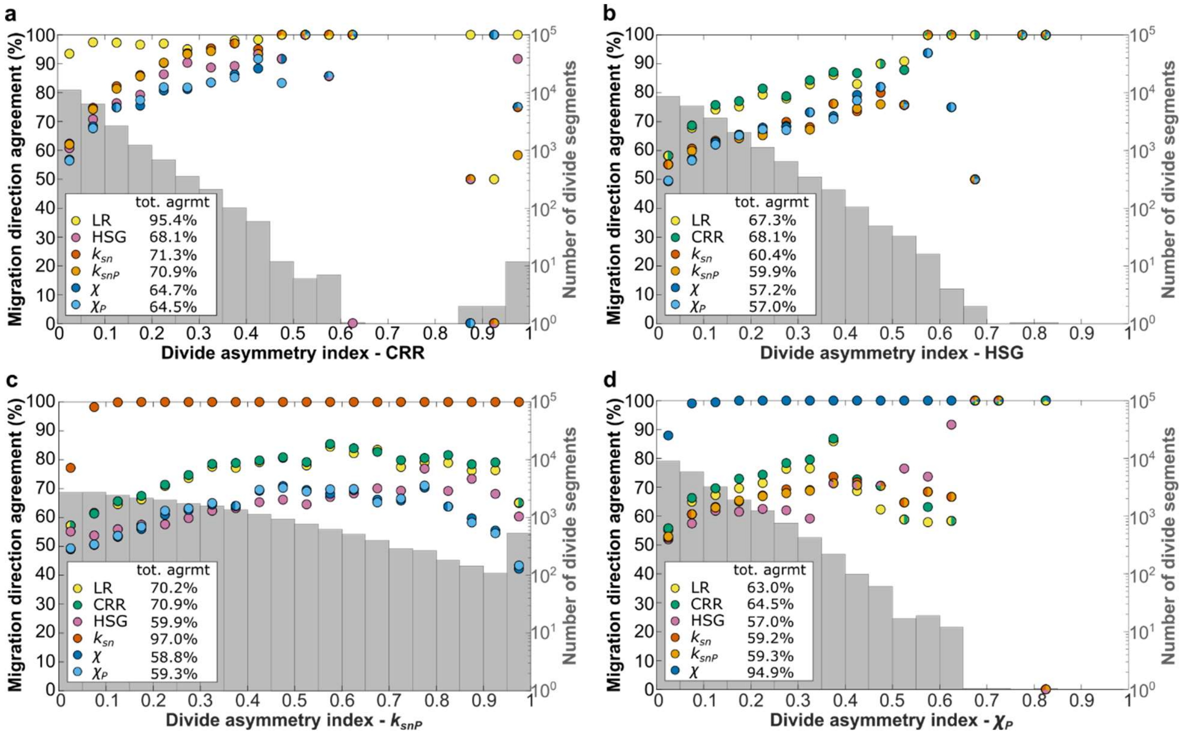

Figure 3: Plots of percent agreement in divide migration direction between chosen metrics and all calculated metrics (colored points), binned by corresponding divide asymmetry index (DAI) for indicated metric in intervals of 0.05. Grey histograms show the distributions of DAI values in log-scale for each metric. Higher DAI corresponds with increased agreement in migration direction between metrics. Histograms show variability in DAI distributions in different metrics.

"Check the unit of KsnP, the unit of Ksn is m^0.9, but KsnP has considered the precipitation with unit of m/yr."

The reviewer is correct that the unit of k_{snP} is not the same as k_{sn} because of the inclusion of precipitation in the equation and we are very glad that they caught this mistake. Following Eq. 4,

$$k_{snP} = (AP)^{\theta_{ref}} S \ ,$$

since slope (S) is unitless, the unit of k_{snP} is

$\left(m^2 \cdot \frac{m}{a}\right)^{0.45} = m^{1.35} a^{-0.45}$. This has been corrected in the manuscript text and figures.

"All equations require a common or a point in the end, they are currently missing throughout the manuscript."

We thank the reviewer for pointing out this oversight. The text has been updated accordingly.

"I hope that these comments are helpful for the revision."

We thank the reviewer again for their constructive critique and helpful suggestions.