

Supporting Information for

**Stochastic in Space and Time: Part 2, Effects of Simulating Orographic Gradients in Daily Runoff Variability on Bedrock River Incision**

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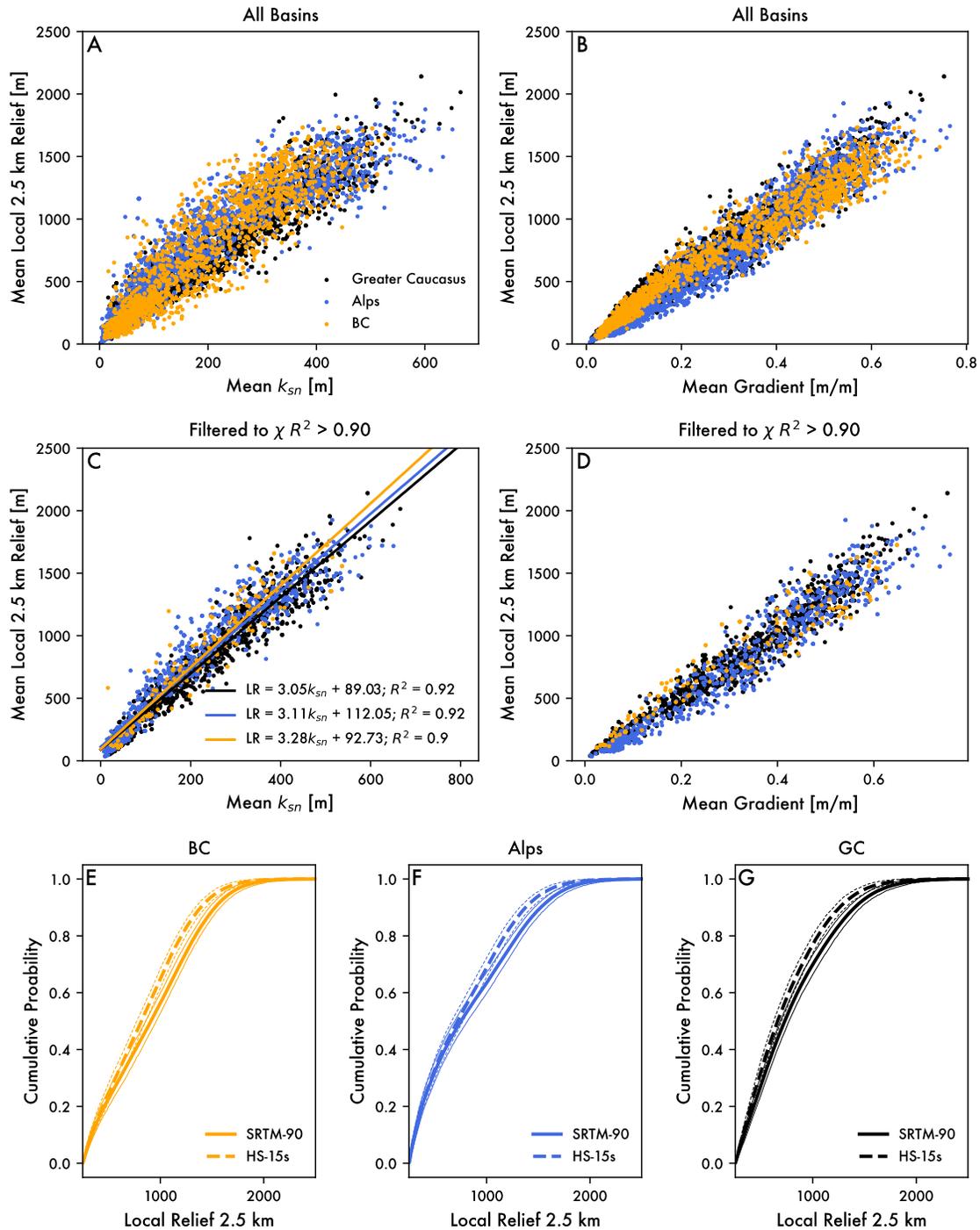
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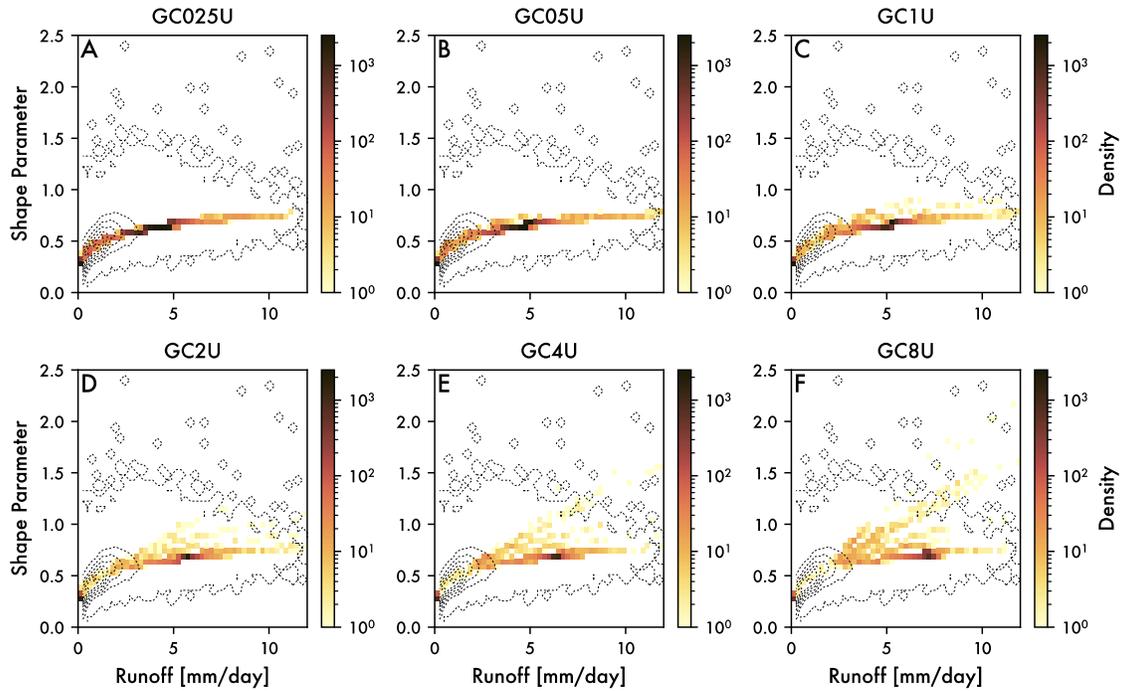
**Introduction**

This supplemental file contains seven supplemental figures that contain additional details on model results. It also contains two tables. Table S1 are the invariant STIM parameters common to all models, whereas Table S2 highlights the values or properties that change between model runs. Table S2 is provided an Excel sheet.

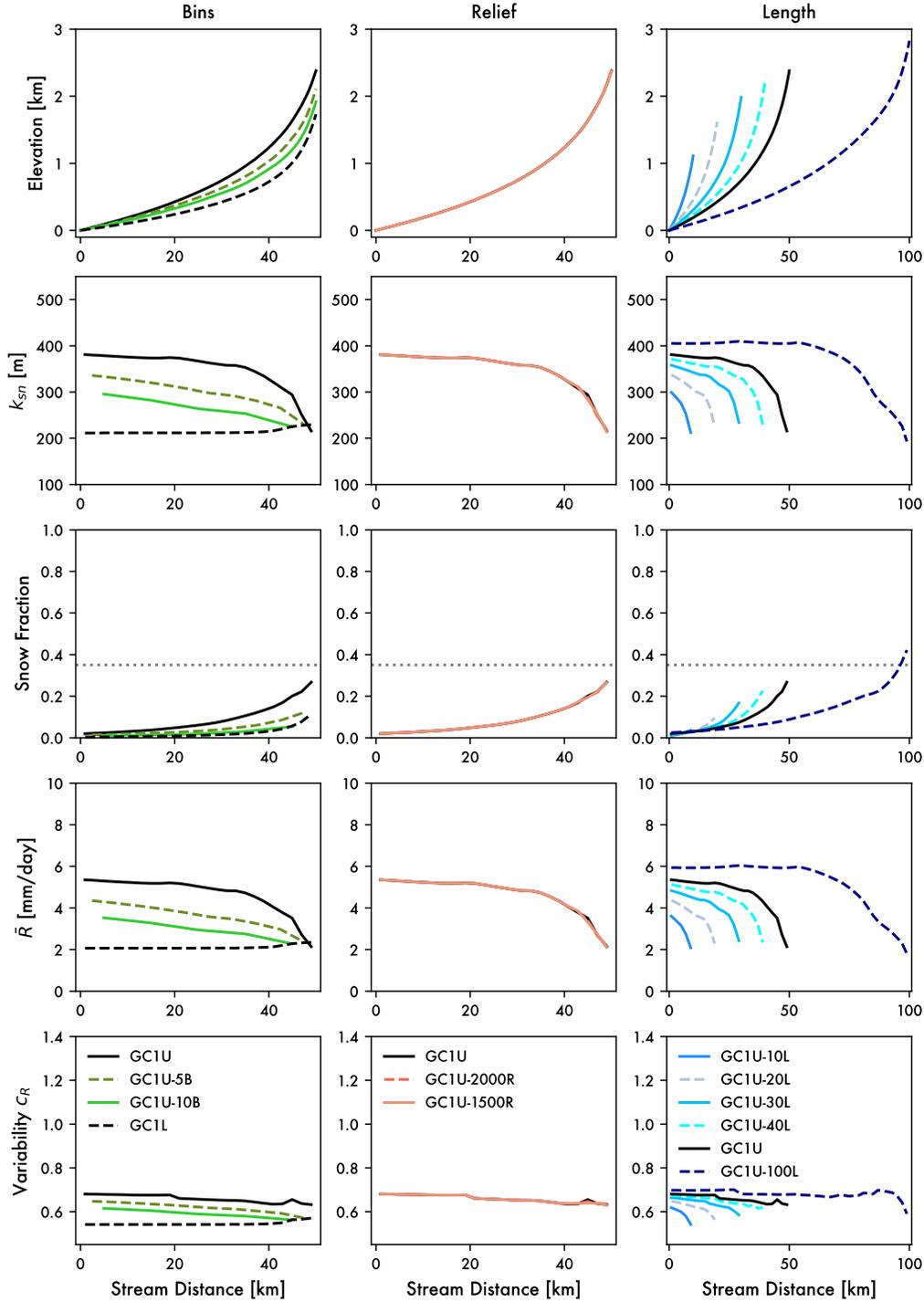


**Figure S1.** A) Mean basin  $k_{sn}$  compared to mean local 2500 m relief for randomly selected basins for the three example locations. B) Mean hillslope gradient compared to mean local 2500m relief for the same basins. C) Filtered mean basin  $k_{sn}$  compared to mean local 2500 m relief, using a cutoff of 0.9 for the  $R^2$  of the  $\chi$ -elevation relationship as a proxy for basins without major knickpoints. Also shown are linear fits between  $k_{sn}$  and relief which are used in the models. D) Same as B but for the filtered basins shown in C.

E) Comparison of the cumulative probability of 2500 m local relief calculated from the Hydrosheds 15 arcsecond DEM and 2500 m local relief from SRTM 90 for the British Columbia region. F) Same as E but for the Alps region. G) Same as E but for the Greater Caucasus.

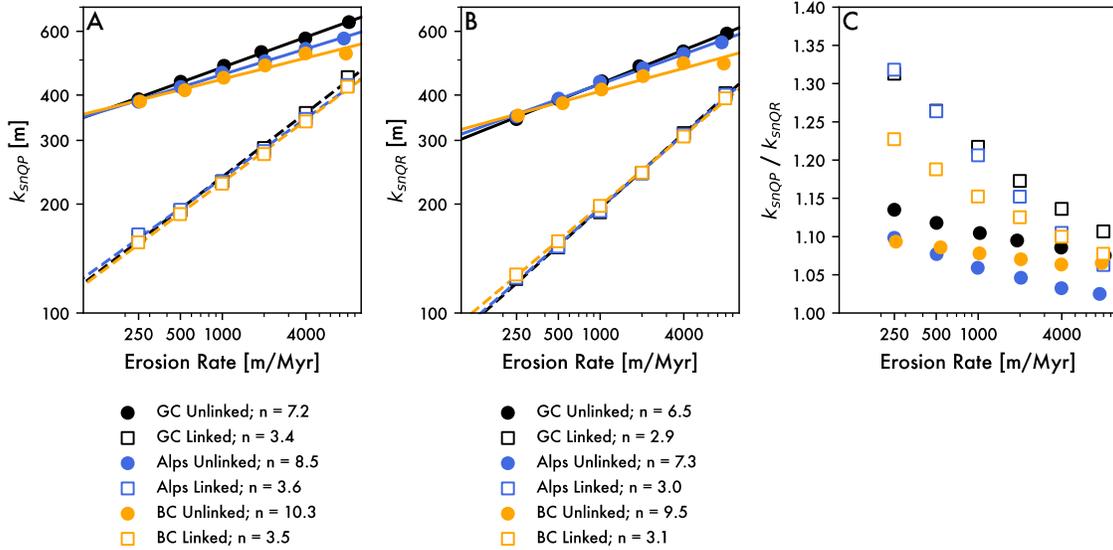


**Figure S2.** 2D density plots of individual pairs of runoff and variability within all bins across all timesteps between model initiation and achievement of steady state for the base Greater Caucasus unlinked runs. Generally, the majority of the time in the models are spent in portions of parameter space well represented in the WaterGAP3 data (e.g., Figure 2A), which are shown with the contours.

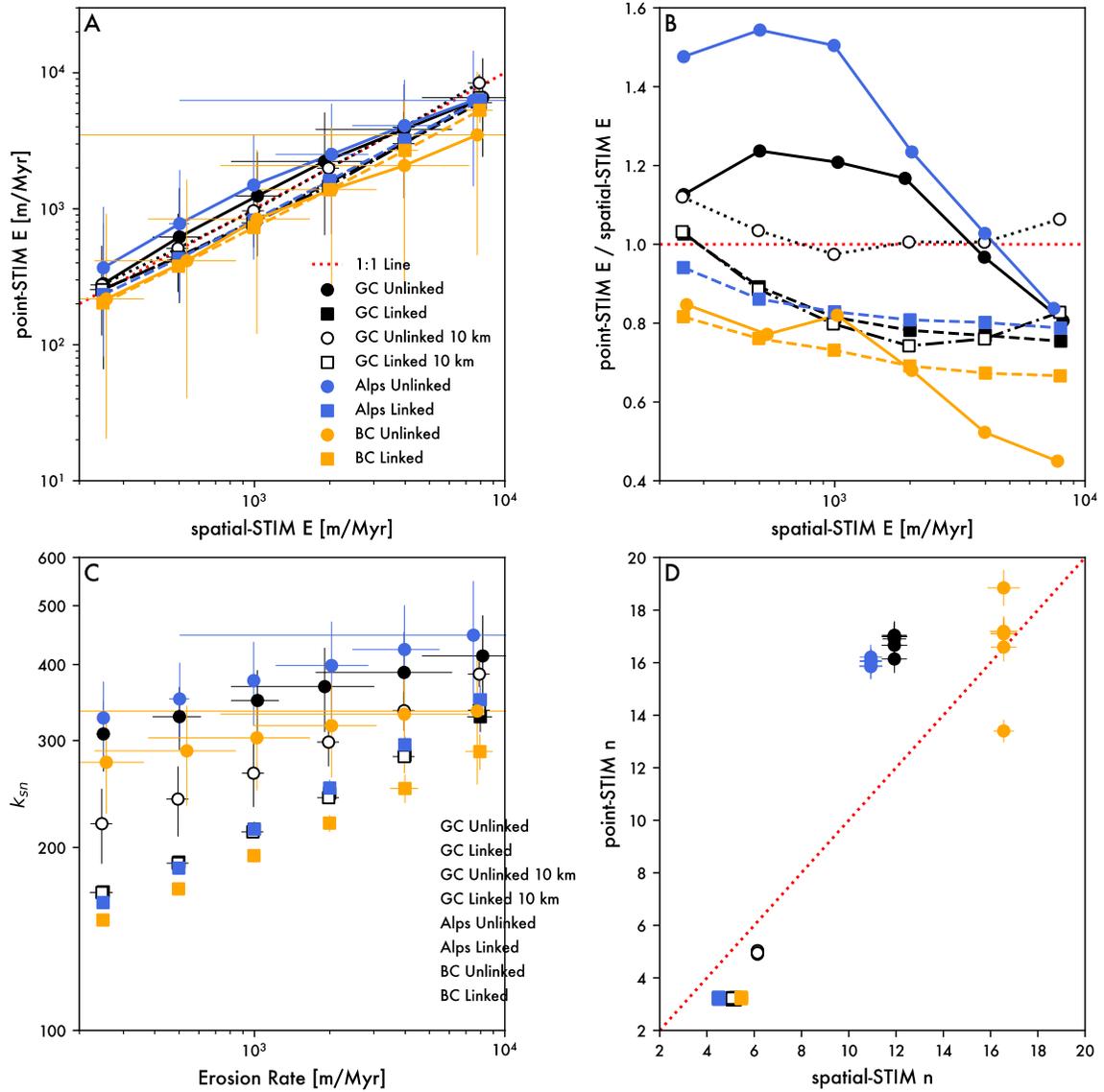


**Figure S3.** Comparison of evolution of model GC1U to the sensitivity test runs discussed in the main text. Setup of figure is identical to that of main text Figure 4. The right column considers similar models with different size runoff bins, specifically 5000 m (GC1U-5B) and 10000 m (GC1U-10B). Model GC1L is also included for reference. The center column considers models with different imposed maximum local relief, specifically 1500 m (GC1U-1500R) and 2000 m (GC1U-2000R). The right column considers models

with different stream lengths, specifically 10 km (GC1U-10L), 20 km (GC1U-20L), 30 km (GC1U-30L), 40 km (GC1U-40L), and 100 km (GC1U-100L).

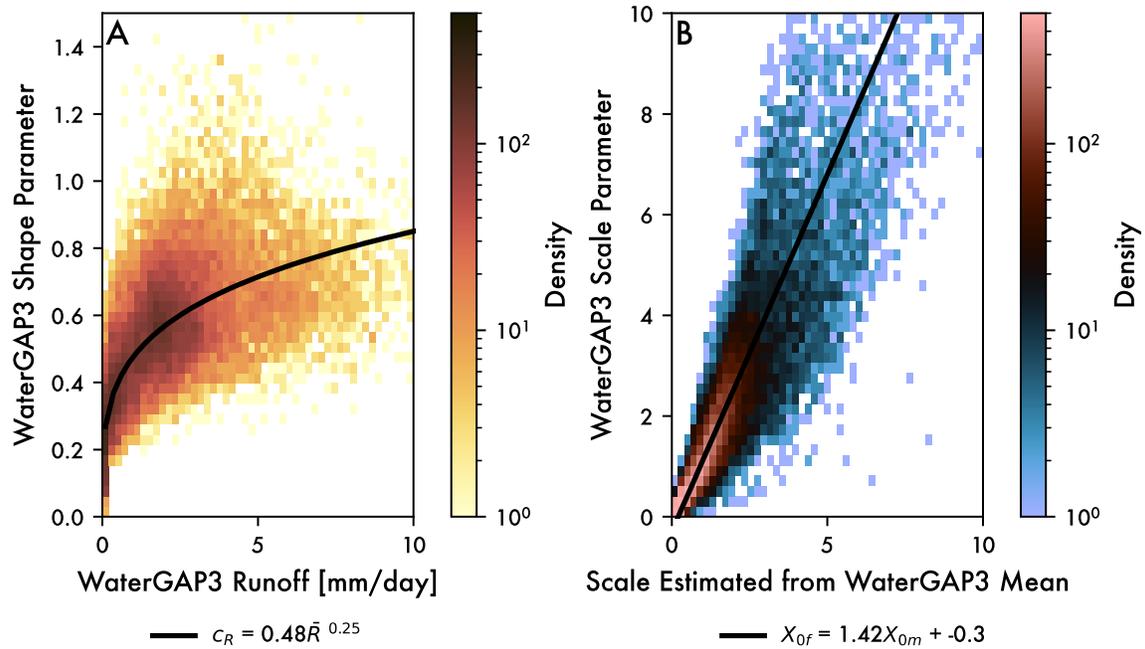


**Figure S4.** Comparison of predictions of different versions of  $k_{sNQR}$ . A) B) Relationship between erosion rate and mean  $k_{sNQR}$  along with power law fits.  $k_{sNQR}$  is calculating  $k_{sNQR}$  sensu Adams et al. (2020) but using runoff as opposed to precipitation. B) Relationship between erosion rate and mean  $k_{sNQP}$  along with power law fits.  $k_{sNQP}$  is calculating  $k_{sNQP}$  identical to Adams et al. (2020). For this, runoff is converted to precipitation using the local linear relation between runoff and precipitation from the WaterGap3 data for each area and then this precipitation value is routed along the profile as if it was runoff. This is what is displayed in Figure 8B. C) Ratio of  $k_{sNQP}$  to  $k_{sNQR}$  as a function of erosion rate.



**Figure S5.** Comparison of predictions of spatialSTIM and a point based version of STIM from Lague et al., (2005) modified to use a Weibull distribution of runoff. A) Mean erosion rate of the main models as determined from spatialSTIM vs the prediction from STIM using the mean  $k_{sn}$ , mean daily runoff, and estimated variability for the steady-state of individual spatialSTIM runs. A 1:1 line is plotted for reference. B) Mean erosion rate of the main models as determined from spatialSTIM vs a ratio of the spatialSTIM erosion rate to the predicted STIM erosion rate from A. This panel appears as Figure 11A in the main text. C)  $k_{sn}$ -erosion rates for the spatialSTIM models (circles and squares) compared to predicted  $k_{sn}$ -erosion rate relationships for comparable STIM models (lines). Note because generally each model for a given hydroclimatic ruleset (e.g., GC vs Alps vs BC), linked vs unlinked, and uplift rate produces a different mean runoff and  $c_R$ , there are a suite of predicted  $k_{sn}$ -erosion rate relationships for a given family of models. E.g., GC unlinked models produce 6 different  $k_{sn}$ -erosion rate relationships, one for each of the 6

uplift rates tested. D) Approximation of the power law exponent (i.e.,  $n$  in the stream power equation) from fitting the spatialSTIM relationships compared to fitting each  $k_{sn}$ -erosion rate relationship in C as predicted by STIM. This panel appears as Figure 11B in the main text.



**Figure S6.** Singular relationships between A) mean runoff and shape parameter and B) scale parameter estimate from the mean runoff and the fit scale parameter for rain dominated WaterGAP3 pixels (i.e., where snowmelt fraction < 0.35). These relationships are used to parametrize the Rain Only models that are presented in main text Figure 11.

<b>Parameter</b>	<b>Value</b>	<b>Units</b>
$k_o$	$1e-11$	$m^{2.5}s^2ka^{-1.5}$
$\tau_r$	45	Pa
$k_w$	15	$m^{-0.5}s^{0.5}$
$k_t$	1000	$m^{-7/3}s^{-4/3}ka$
$\omega_n$	0.5	Dimensionless
$\omega_k$	0.25	Dimensionless
$a$	3/2	Dimensionless
$\alpha$	2/3	Dimensionless

$\beta$	2/3	Dimensionless
$dx$	100	m
$dt$	1	days

**Table S1.** STIM and other model parameters fixed for all runs. STIM parameters are similar to those used by Forte et al., (2022) for the Greater Caucasus.

**See included Excel sheet for Table S2.**

**Table S2.** Model runs and key parameters or properties that are varied between individual model runs. Columns are Model Name (how the model is referred to in the main text), Site (either GC, Alps, or BC), Length (length of the modeled river profile in km), Bin Size (size of individual bins in km, if this is empty, it implies that bin size was a constant area as opposed to a constant length), Bin Size (size of individual bins in km<sup>2</sup>, if this is empty, it implies that bin size was a constant length as opposed to a constant area), Bin Relation (either linked or unlinked), Uplift Rate (imposed uplift rate in mm/yr), Maximum Relief (the imposed maximum relief that the model is allowed to reach in m), Base Level (the base level in meters to which the profile is fixed), Snowmelt (indicating whether snowmelt was included or excluded as it was for the rain only models), and Figures (a list of main text figures and supplemental figures in which results from that model appears).

### References

Adams, B. A., Whipple, K. X., Forte, A. M., Heimsath, A. M., & Hodges, K. V. (2020). Climate controls on erosion in tectonically active landscapes. *Science Advances*, 6(42).

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