Supplementary Material: Quantifying geomorphically effective floods using satellite observations of river mobility

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Table 1. The r^2 values for the relationships in Figure 2 (main manuscript), for each individual country.'Av. mag.' is the mean peak height in cm (measured above the gauge's mean daily stage) across all flood events in that country.'Av. total' is the mean (across all floods in a country) of the total water level (in cm) exceeding mean stage.'Av. dur.' is the mean flood duration (in days) in that country. 'Av. widening' is the mean reach-averaged widening (in m) across all floods and sites in that country.

Country	r^2, Peak height above mean stage (cm)	r^2, Stage above mean, summed (cm)	r^2, Duration (days)	N. floods	N. gauge sites	Av. mag.	Av. total	Av. dur.	Av. widening
Brazil	-0.018	0.219	0.293	47	10	230	4100	53	1.90
Colombia	0.110	0.321	0.442	87	22	160	5300	57	7.30
New Zealand	0.796	0.278	0.171	11	1	190	1100	29	0.92
Russia	0.348	0.082	0.081	15	8	150	3700	71	3.20

Table 2. The variables used in the random forest model. Column 1 shows how each variable contributed to reducing MSE. The final column shows the rank assigned to each variable by the random forest regression.

% Decr. in MSE	Variables	Rank
22.18	Estimated sediment transport	1
16.77	Channel width	2
15.65	Duration	3
8.54	Total stage exceeding mean	4
7.61	Peak height above mean daily stage	5

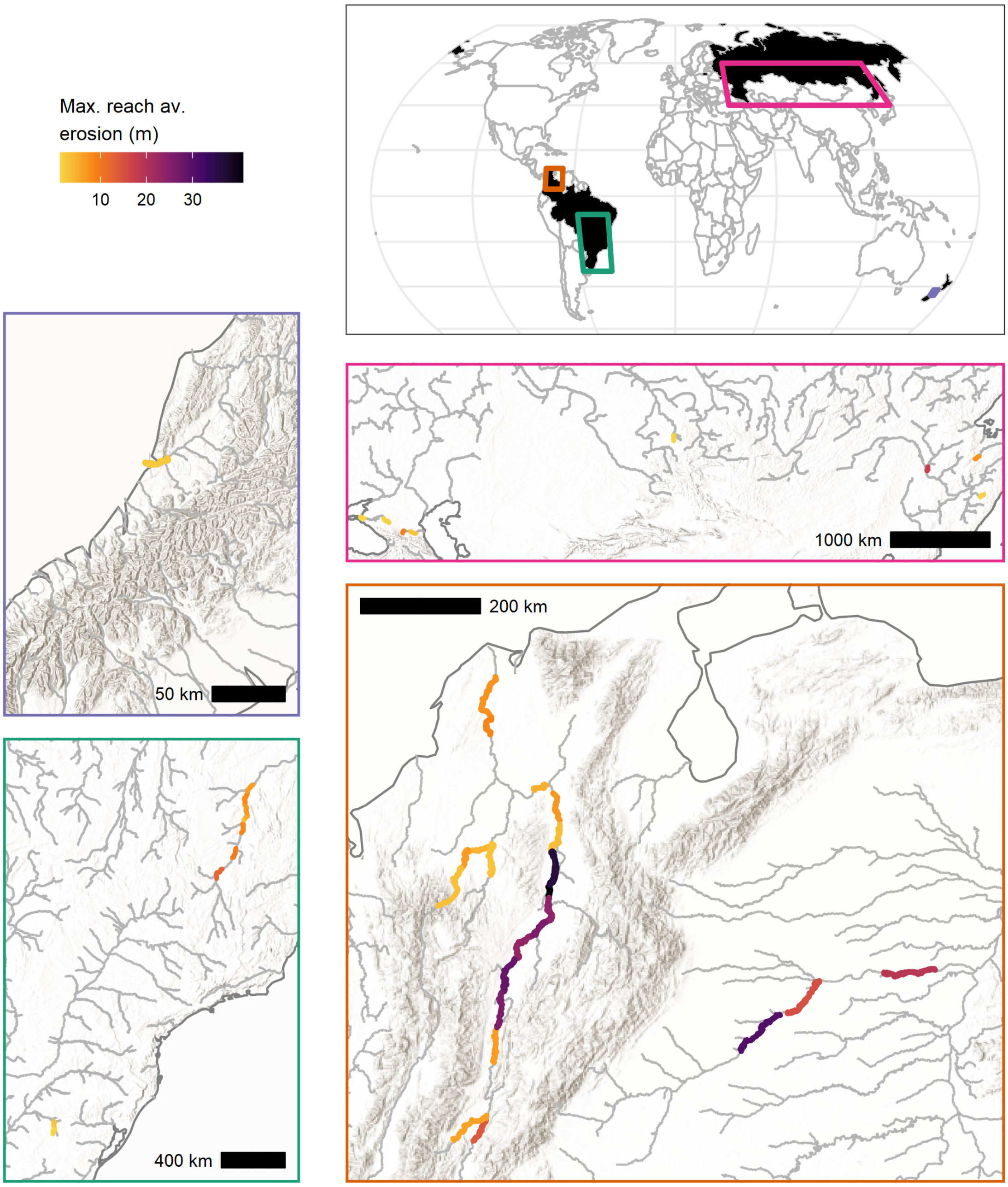

Figure 1. Map showing the areas of interest (AOIs) associated with each gauge. Colors show the magnitude of reach-averaged widening (in metres) during the most effective flood at each site.

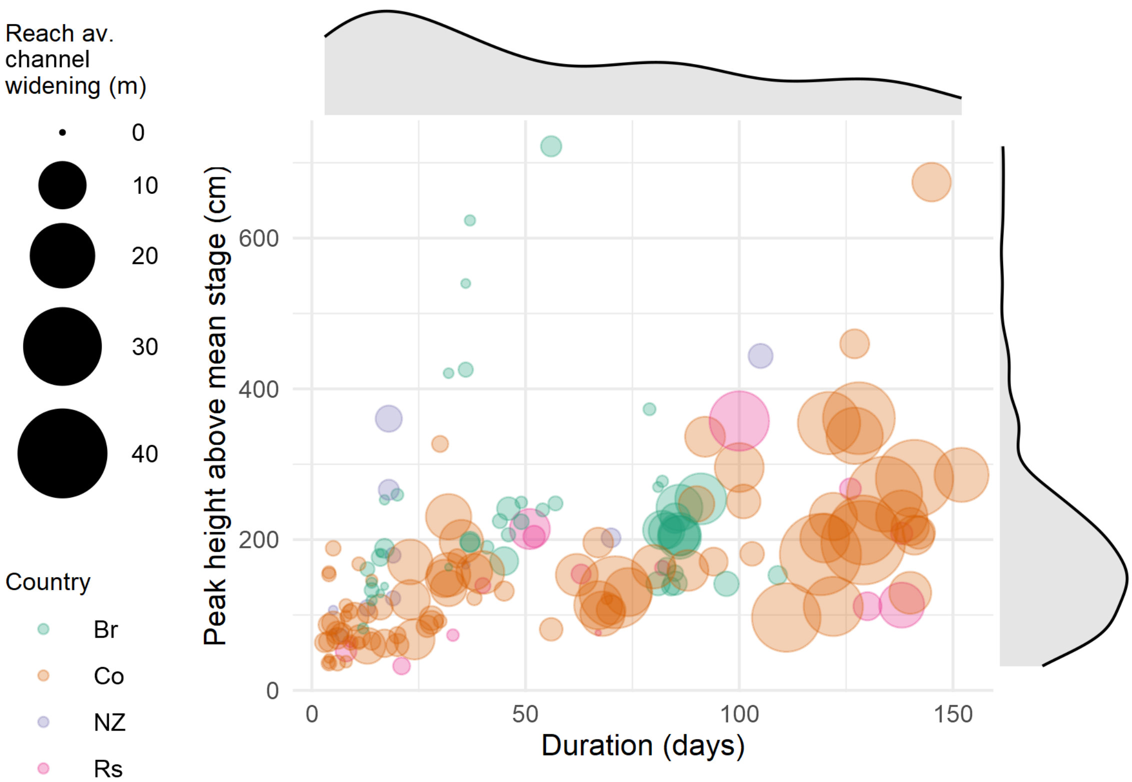

Figure 2. Duration, magnitude (peak height) and geomorphic effectiveness (reach-averaged erosion) for each flood event in our dataset. Each point is one flood event; colours correspond to countries and size corresponds to geomorphic effectiveness of each flood.

1 Sediment transport capacity

We estimated sediment transport capacity based on the stage and slope data available to us. Sediment transport equations often predict transport as the $\frac{3}{2}$ power of some flow property — often that which exceeds a threshold value at which sediment of a given size can be entrained (Church, 2010). Often that flow property is the dimensionless shear stress τ_*, but we have no data on grain size with which to calculate this. Instead, we approximate the dimensional boundary shear stress τ, which scales with the depth-slope product dS. We have no data on flow depth and approximate it with flow stage h instead; our estimates of channel slope S are calculated along the area of interest polygon for each gauging site using elevation data from the MERIT DEM (Yamazaki et al., 2017).

We therefore estimate unit sediment transport q_s as a function of stage and slope. We do not have data on the threshold for motion in our study sites, so we assume that the threshold is 25% of the difference between minimum and maximum stage in each gauge record, during the ˜7 year period for which we have satellite data. While arbitrary, this value of 25% is based on a literature search for reported values of the onset of transport as a percentage of peak discharge, and it also performed better than other thresholds we tried.

We thus estimate a flood's cumulative transport as a function of changes in stage:

$$q_s = \sum_{1}^{n}((h - h_{r25})S)^{\frac{3}{2}} \tag{1}$$

where n is the total number of days in the flood, h is the stage value for each day, $r25$ is the stage that is 25% of the difference between the minimum and maximum stage during the satellite record, and S refers to the channel slope. We performed this calculation for each day in a flood and summed across the entire event.

Finally, we multiply q_s by channel width to estimate the channel-integrated (total) sediment transport Q_s. While q_s did not scale with erosion as well as the flood duration or summed hydrograph did, the estimated Q_s scaled rather closely ($r^2 = 0.63$) with each flood's geomorphic effectiveness (Figure S3). It is Q_s that we used in our random forest model.

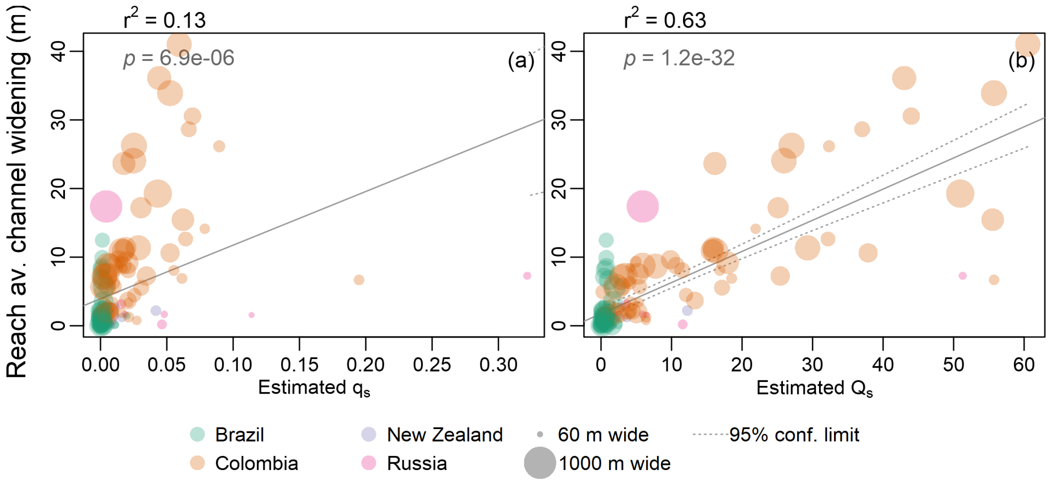

Figure 3. Linear regression of flood-driven erosion (reach-averaged) against our estimates of the cumulative sediment transport capacity of each hydrograph: (a) unit transport q_s (b) integrated (total) transport Q_s.

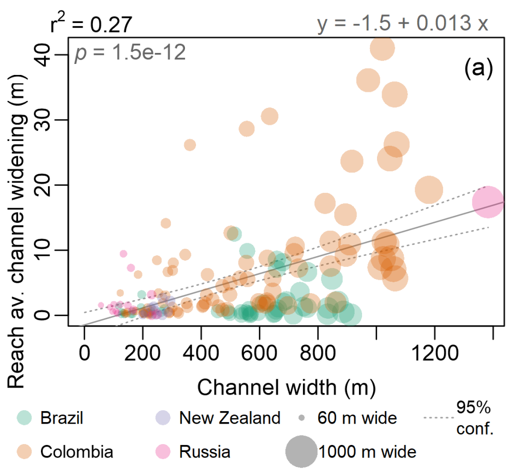

Figure 4. Linear regression of flood-driven erosion (reach-averaged) against mean channel width prior to each flood.

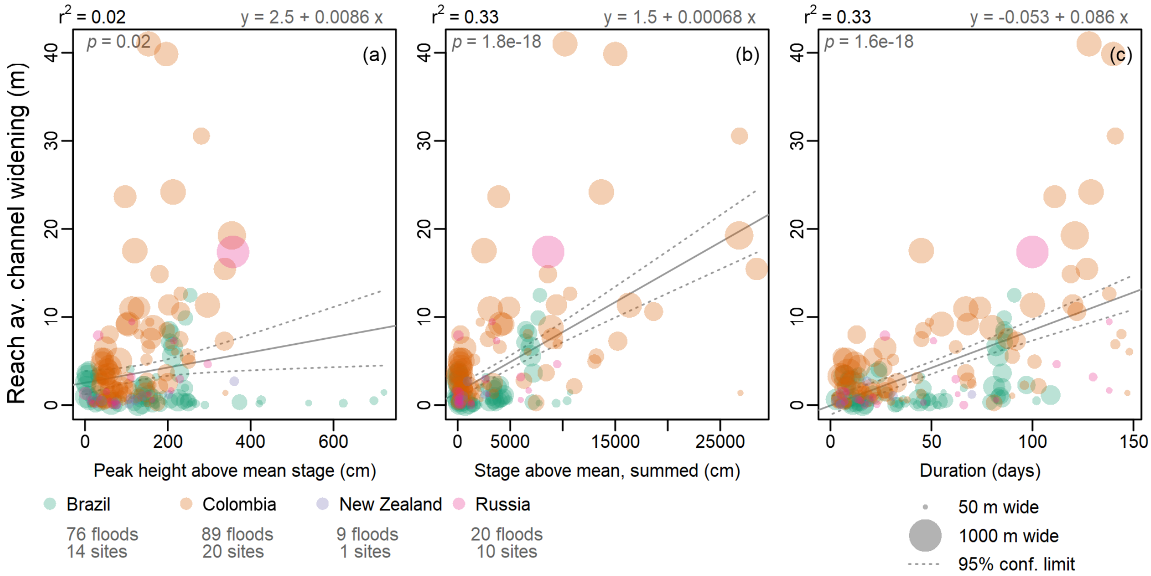

Figure 5. The results in Figure 2 (main manuscript) when the flood-delineation threshold is lowered to the 70th percentile of stage.

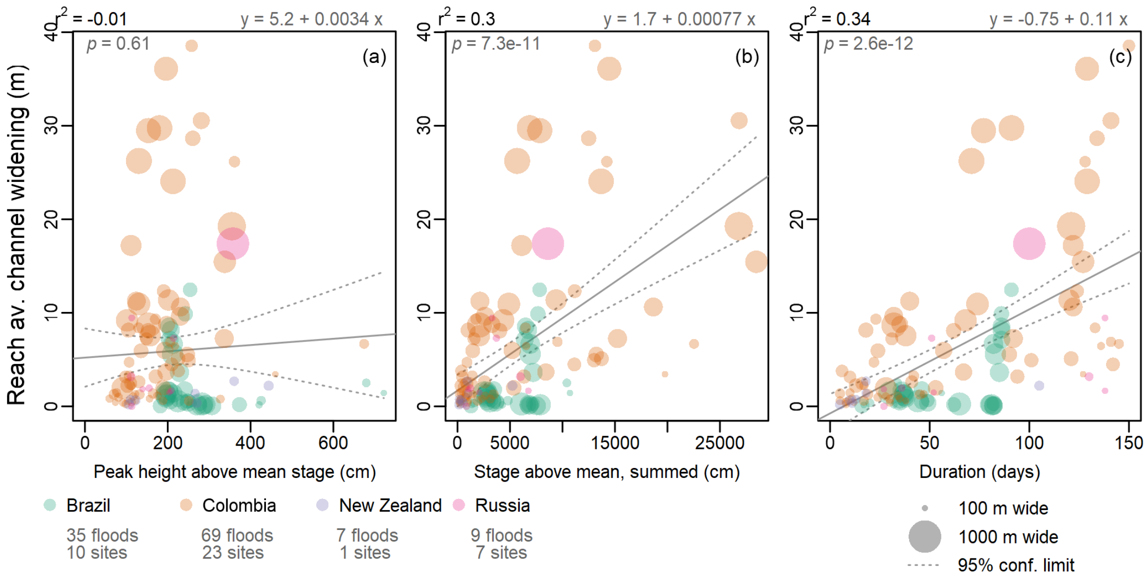

Figure 6. The results in Figure 2 (main manuscript) when the flood-delineation threshold is raised to the 90th percentile of stage.

References

Church, M. (2010). Gravel-Bed Rivers. In T. Burt & R. Allison (Eds.), *Sediment Cascades: An Integrated Approach* (p. 241-269). Chichester: Wiley-Blackwell.

Yamazaki, D., Ikeshima, D., Tawatari, R., Yamaguchi, T., O'Loughlin, F., Neal, J. C., … Bates, P. D. (2017). A high-accuracy map of global terrain elevations. *Geophysical Research Letters*, *44*(11), 5844–5853. Retrieved from `https://developers.google.com/earth-engine/datasets/catalog/MERIT_DEM_v1_0_3#description` (Data accessed via Google Earth Engine)