Supplementary Information for

Climate’s influence on topography encoded in stream network topology and geometry

Minhui Li[1, 2, 3, †], Hansjörg Seybold[4, 5, †], Xudong Fu[1, *], Baosheng Wu[1], Peter A. Raymond[3] and James W. Kirchner[2, 6, 7, *]

[1] State Key Laboratory of Hydroscience and Engineering, Key Laboratory of Hydrosphere Sciences of the Ministry of Water Resources, Department of Hydraulic Engineering, Tsinghua University, Beijing, China

[2] Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland

[3] Yale School of the Environment, Yale University, New Haven, USA

[4] Department of Civil, Environmental and Geomatic Engineering, ETH Zurich, Zurich, Switzerland

[5] Institute for Interdisciplinary Mountain Research, Austrian Academy of Science, Innsbruck, Austria

[6] Swiss Federal Research Institute WSL, Birmensdorf, Switzerland

[7] Department of Earth and Planetary Science, University of California, Berkeley, CA, USA

[*]Corresponding authors: James Kirchner (kirchner@ethz.ch) and Xudong Fu (xdfu@tsinghua.edu.cn)

[†]These authors contributed equally: Minhui Li, Hansjörg Seybold.

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Text S1. Scale effects

Choosing the optimal size of the networks to analyze involves tradeoffs. On the one hand, lower-order, and thus smaller networks, better characterize the local network topology and regional climatic conditions. On the other hand, higher-order, and hence larger networks may give more precise estimates of topological parameters. However, these larger networks also average out local variations in network topology, climate, and geological structure. Our primary findings, presented in the main text, are derived from the analysis of all 17,021 5th-order river networks of the NHDPlus-HR dataset[1]. To explore the impact of varying stream network scales on our results, we additionally performed our analysis on all 3,475 6th-order river networks.

Approximately 76% of the 6th-order networks passed the ANOVA test, supporting the self-similarity hypothesis (compared to 86% of 5th-order networks, as mentioned in the main text; Supplementary Fig. S1). The networks that passed the ANOVA test were further evaluated for Tokunaga self-similarity scaling, using the coefficient of determination (R^2) with a threshold of 0.8, as suggested by Zanardo et al.[2]. With this criterion, 2,432 (or approximately 70%) of all 6th-order networks also met both of the Tokunaga self-similarity criteria (compared to 73% of 5th-order networks, as mentioned in the main text).

Across the 2,432 6th-order Tokunaga self-similar river networks, climatic aridity has no direct influence on Tokunaga parameter c ($\rho_{partial}$=-0.002), but stronger relationships with average channel slope ($\rho_{partial}$=0.33, $p<0.0001$), slope ratio ($\rho_{partial}$=-0.31, $p<0.0001$), and mean side-branching angle ($\rho_{partial}$=0.25, $p<0.0001$), confirming the robustness of our main findings. These variables in turn have strong partial correlations with Tokunaga parameter c, suggesting that climate only indirectly influences network topology, through its influence on topography and network geometry (Table S1).

Tokunaga parameter c is significantly correlated with network-averaged slope ratios ($\rho_{partial}$=-0.20, $p<0.0001$) and mean channel slope ($\rho_{partial}$=0.26, $p<0.0001$). As parameter *c* increases, networks' mean side-branching angles widen ($\rho_{partial}$=0.10, $p<0.0001$). Humid climates (higher AI) are associated with steeper channel slopes ($\rho_{partial}$=0.33, $p<0.0001$) and larger slope differences (smaller slope ratios; $\rho_{partial}$=-0.31, $p<0.0001$). While slope ratios strongly influence side-branching angles ($\rho_{partial}$=-0.48, $p<0.0001$), the effect of steeper slopes is weaker ($\rho_{partial}$=-0.06). Notably, there is a substantial direct correlation between climatic aridity and side-branching angles ($\rho_{partial}$=0.25, $p<0.0001$), when topographic effects are factored out.

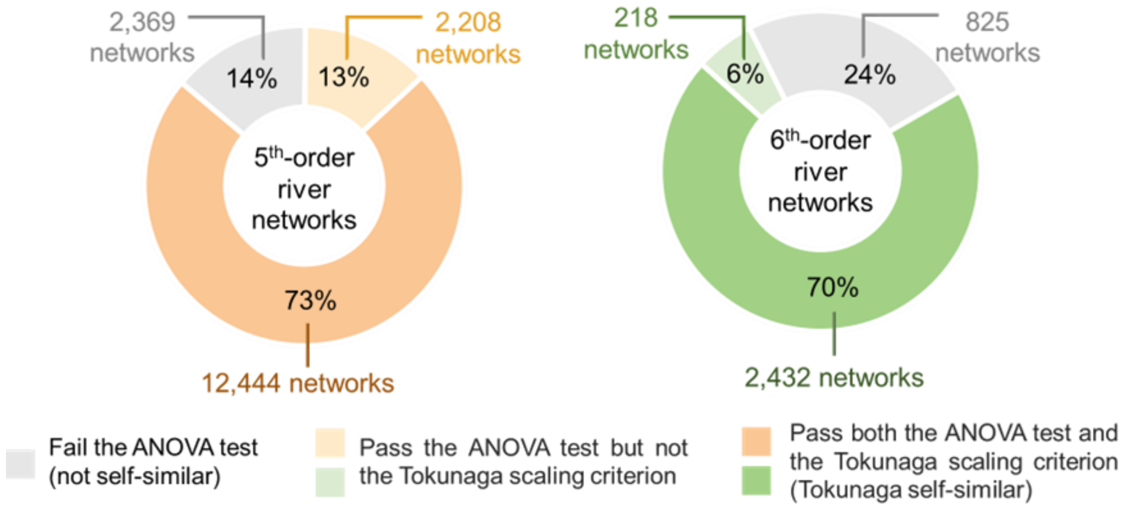

Fig. S1. Percentage of 5th- and 6th-order river networks in different classes based on the self-similarity test. Among all 5th-order networks, 73% are Tokunaga self-similar (denoted by dark yellow; passing both the ANOVA test and the Tokunaga scaling criterion; following the method outlined by Zanardo et al.[2]). 13% of all 5th-order networks pass the ANOVA test but not the Tokunaga scaling criterion (light yellow), and 14% fail the ANOVA test and are thus not self-similar (grey color in the left pie chart). Among all 6th-order river networks, 70% are Tokunaga self-similar (dark green). 6% of all 6th-order networks pass the ANOVA test but not the Tokunaga scaling criterion (light green), and 24% fail the ANOVA test and thus are not self-similar (grey color in the right pie chart).

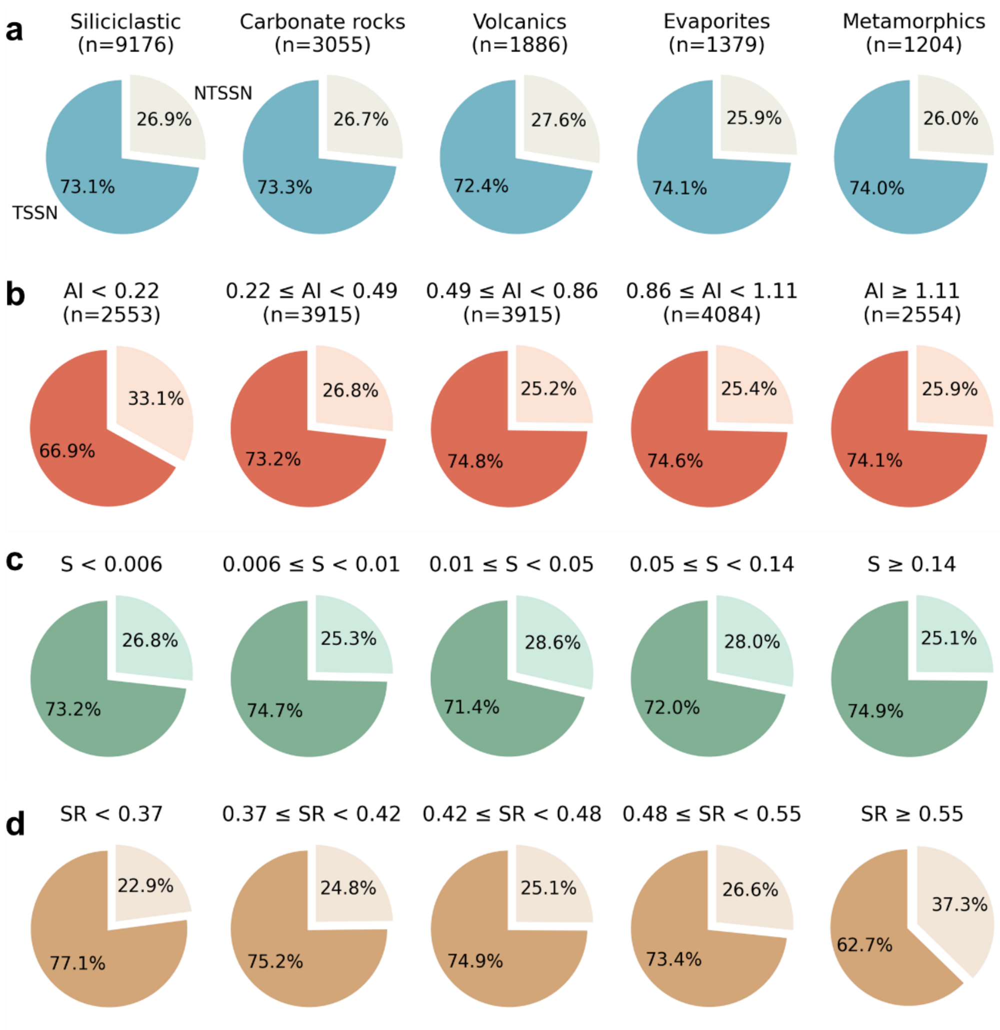

Fig. S2. Distributions of 5th-order stream network self-similarity types across different classes of (a) lithology, (b) aridity index (AI), (c) channel slope (*S*), and (d) slope ratio (SR). Stream networks are categorized into two types: Tokunaga self-similar networks (TSSN; dark colors) and non-Tokunaga self-similar networks (NTSSN; light colors). In panel a, 321 networks with mixed or missing lithology data (see Methods) had to be excluded; these networks are included in panels b-d. The number of networks in each lithology class is shown in brackets. In panels (b–d), networks are grouped into five classes: the lowest and highest classes represent values below the 15th percentile and above the 85th percentile, respectively, while the remaining three classes contain approximately equal numbers of networks. The number of networks in each class is shown in brackets in panel b. The fraction of TSSNs does not show systematic variation with (a) lithology or (c) channel slope. However, TSSNs are less frequent under arid conditions (AI < 0.22) but remain relatively stable when AI > 0.22 (b). A slight decline in TSSN occurrence is observed with increasing slope ratio (d).

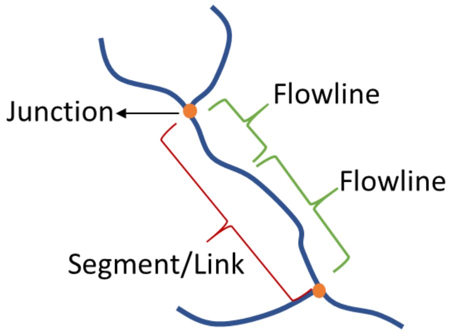

Fig. S3. Definitions of flowlines, river segments, and links in the high-resolution National Hydrographic Dataset. A river segment or link is a river section connecting two adjacent junctions or a channel head with its first downstream junction. Flowlines refer to individual components of river segments as defined by the National Hydrographic Dataset.

Table S1. Spearman rank correlations (plain font, upper yellow triangle) and partial rank correlations (bold font, lower green triangle) for 6th-order Tokunaga self-similar networks, with (*) meaning p<0.05, (**) meaning p<0.01 and (***) meaning p<0.001. Partial rank correlations quantify the association between each pair of variables after any linear confounding effects of the other variables are removed.

	Tokunaga parameter c	Side-branching angle	AI	Slope ratio	Channel slope
Tokunaga parameter c		0.24***	0.21***	-0.24***	0.13***
Side-branching angle	**0.10*****		0.47***	-0.68***	-0.28***
AI	**-0.002**	**0.25*****		-0.45***	0.06**
Slope ratio	**-0.20*****	**-0.48*****	**-0.31*****		0.47***
Channel slope	**0.26*****	**-0.06****	**0.33*****	**0.48*****	

Supplementary references

1. Moore, R. B. *et al. User’s Guide for the National Hydrography Dataset plus (NHDPlus) High Resolution*. *Open-File Report* https://pubs.usgs.gov/publication/ofr20191096 (2019) doi:10.3133/ofr20191096.
2. Zanardo, S., Zaliapin, I. & Foufoula-Georgiou, E. Are American rivers Tokunaga self-similar? New results on fluvial network topology and its climatic dependence. *J. Geophys. Res. Earth Surf.* **118**, 166–183 (2013).