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Climatic controls on river network topology

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The branching structure of river networks has been actively studied since the 60s, to address a broad range of hydrological, environmental, and socio-economic problems. A commonly accredited property of river networks, based on empirical observations, is a hierarchical self-similar organization often described by the so-called Tokunaga self-similar (TSS) model. This conceptualization allows to characterize – on the average – the river network topology on the basis of two Tokunaga parameters, namely a and c. In this study we test the dependence of the Tokunaga parameters on local climatic regimes. To this end we analyzed 50 river basins, and their respective sub-basins, and extracted a total of 436 river networks that sample different climatological regions of the continental United States. We developed an unbiased statistical estimation framework for the Tokunaga parameters and characterized the two-dimensional space of their variability for the 436 river networks analyzed, observing a narrow range of variability for the parameter a, but a much more extended range for the parameter c. We then tested the dependence of the Tokunaga parameters on three local climatic variables: (1) mean storm frequency, (2) mean storm duration, and (3) mean annual rainfall. We found that the parameter c (which is an indicator of the dis-proportionality between small- and large-order channels) exhibits a significant dependence on climate, as the correlation coefficient between c and the climatic variables considered ranges between 0.44 and 0.8. The statistical significance and robustness of these correlations was also corroborated by further statistical tests. Ongoing laboratory experiments on landscape evolution under variable climatic forcing, while supporting our results, further suggest that this dependence might be attributable to an increased competition among river channels under wet climatic regimes, which results into an increased dis-proportionality between channels of different order.