Climate versus tectonics as controls on river profiles

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Identifying what drives the evolution of drainage basins is a major challenge in geomorphology[1,2] and the question of how strongly climate influences the longitudinal profiles of rivers has been debated for decades[3–5]. In a recent Article[5], Chen et al. used aridity and concavity data from 333,502 river longitudinal profiles to argue that climatic aridity is "a first-order control" on the evolution of drainage basins.

By contrast, here we show that four variables that Chen et al.[5] dismissed as having "no apparent relationship" with river profile concavity—gradient, relief, river length and drainage area—are, in fact, more strongly correlated than aridity with profile concavity. Therefore, we suggest that aridity is, at best, a second-order control on river profile concavity, after several other variables, including those linked to tectonic forcing.

Chen et al.[5] provide an important empirical verification of the relationship between climate and concavity that has long been predicted by the standard stream power model for river profiles[3]. However, characterizing aridity as a first-order control on river profile concavity requires a quantitative comparison with other potential controls. On the basis of a qualitative visual assessment, Chen et al.[5] argued that river profile concavity (as quantified by their Normalized Concavity Index (NCI)) is "not correlated with key river metrics such as river length, gradient, relief or basin area"; however, the relationships between NCI and these four metrics are obscured by the colour scales and binning intervals of the underlying plots (as shown in Extended Data Fig. 4 of ref. [5]). For example, in Extended Data Fig. 4b of ref. [5], a single extreme pixel dominates the entire colour range, masking any relationship between NCI and the slope. Moreover, a comparable plot of NCI and aridity was not provided, making it impossible for readers to assess the relative importance of aridity as a control on NCI.

Using the dataset associated with the previously published paper[6], we calculated that river profile concavity (as quantified by NCI) is correlated two to three times more strongly with four morphological variables (river length, gradient, relief and drainage area) than with climatic aridity (Fig. 1). Specifically, the Spearman rank correlation between NCI and aridity is only $\rho = -0.05$, whereas the rank correlations are markedly stronger between NCI and each of the four variables that Chen et al.[5] considered to have no apparent relationship: $\rho = -0.17$ for relief–NCI (more than 3× that of AI–NCI), $\rho = -0.14$ for mean gradient–NCI (almost 3× that of AI–NCI), $\rho = -0.12$ for drainage area–NCI (more than 2× that of AI–NCI) and $\rho = -0.09$ for river length–NCI (almost 2× that of AI–NCI). The normalization embedded in the definition of NCI guarantees that if the river profile is stretched vertically (thus increasing its gradient and relief) or horizontally (thus increasing its length and decreasing its gradient), the NCI remains unchanged. Therefore, the observed correlations between NCI and gradient, relief and length are not artefacts of how NCI is calculated.

Chen et al. suggest that aridity "overprints other plausible controls on profile concavity on the global scale" on the basis of theoretical simulations (Extended Data Fig. 6 of ref. [5]). However, those theoretical results are not necessarily in agreement with some data suggesting

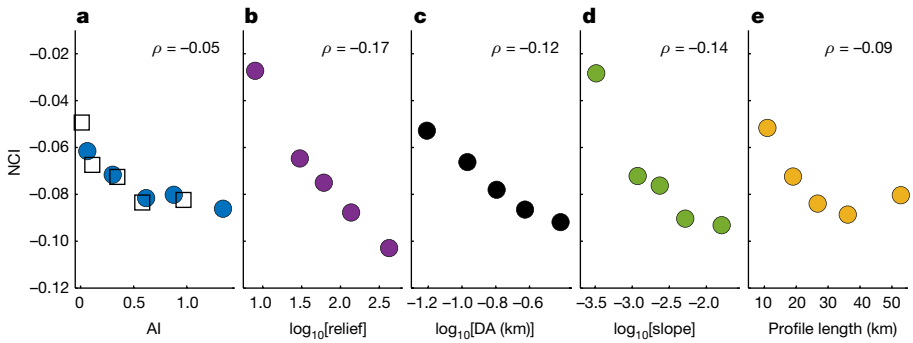

Fig. 1 | Empirical relationship of river profile concavity with climate aridity and four morphological variables. a–**e**, Circles show the relationhips between NCI and the Aridity Index (AI) (**a**), relief (**b**), drainage area (DA) (**c**), slope (**d**) and profile length (**e**), binned in five classes, each containing 20% of the data. Robust median statistics are used to calculate the medians of each class on both axes. **a**, Squares show the robust median relation between NCI and the five AI classes defined by Chen et al. [5]. NCI exhibits much stronger and more consistent trends with relief, drainage area and slope than with aridity. This is substantiated by rank correlation coefficients (ρ), calculated from the original data without binning.

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that river profile concavity might be linked to measures of tectonic forcing[7]. Climate is one of many influences on river profile concavity, but we suggest that it was not demonstrated to be a first-order control.

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