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Scaling laws for glacial valley networks derived from a global analysis of glacier polygons and terrain data

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Rivers represent the backbone of alpine landscapes. They shape the drainage system and control the evolution of upland topography. The resulting fluvial valley networks are well understood and seem to follow simple scaling laws. However, in the late Cenozoic, erosion in many mountain ranges has been dominated by glacial processes, and the question arises to which extent they have altered fluvial drainage systems.

To answer this question, we investigate the scaling of recent glaciers in mountainous terrain and their valley networks. We made use of the Randolph Glacier Inventory (RGI) and a global digital elevation model (DEM) with a resolution of 90 m. We analyzed more than 150'000 glaciers worldwide with an area > 2 DEM cells and an elevation range > 50 m. We combined information provided by the RGI, such as glacier area and longest flow path, with metrics extracted from the glacier shapes, such as maximum length (distance from terminus to most distant point) and width (measured perpendicular to length vector), and from the DEM, such as the hypsometric integral of the ice surface and the length of the flow path following the largest upstream area. We compared our results to scaling laws reported for river networks.

Among other results, we found that the relation between glacier flow length and glacier area is similar to the scaling between river length and drainage area, also known as Hack's law. Furthermore, the Euclidian distance between origin and terminus of the glacier scales linearly with glacier flow length. A similar sinuosity behavior has been found for rivers and is also predicted for optimal channel networks. The length of the glacier shape scales linearly with the width, which is also in accordance with the length-width relation observed in fluvial catchments. These findings imply that valley glaciers either tend to follow the same scaling laws as rivers or did not significantly alter the pre-glacial geometry of fluvial valley networks so far.