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Identification and ordering of drainage divides in digital elevation models

Dirk Scherler (1,2) and Wolfgang Schwanghart (3)

(1) GFZ German Research Center for Geosciences, 14473 Potsdam, Germany (scherler@gfz-potsdam.de), (2) Institute of Geological Sciences, Freie Universität Berlin, 12249 Berlin, Germany, (3) Institute of Earth and Environmental Sciences, University of Potsdam, 14473 Potsdam, Germany

Drainage divides are fundamental elements of the Earth's surface. They define the boundaries of drainage basins and thereby form barriers for the transport of solutes and solids by rivers. It has long been recognized that drainage basins and their divides are not static, but that they are mobile and migrate laterally. Previous studies of mobile divides generally focused on relative differences in landscape morphology across drainage divides, but did not consider the network structure of drainage divides in itself. Here, we propose a novel way to measure and analyse networks of drainage divides from digital elevation models.

We developed an algorithm that extracts drainage divides, based on the drainage basin boundaries defined by a stream network. In contrast to streams, there is no straightforward approach to order and classify divides, although it is intuitive that some divides (e.g. continental divides) are more important than others. We thus propose a divide-network metric that orders divides based on the average distance one would have to travel down on either side of a divide to reach a common location. Because measuring these distances is computationally very expensive, we instead sort divide segments in a tree-like network, starting from endpoints at river junctions. The sorted nature of the network allows assigning distances to points along the divides, which can be shown to scale with the average distance downstream to the common location. Furthermore, because divide segments tend to have characteristic lengths, an ordering scheme in which divide orders increase by one at junctions, mimics these distances.

We applied our new algorithm to natural landscapes and to tectonically deforming landscape evolution models to assess which parameters of divides and divide networks are diagnostic of divide mobility. Results show that hillslope relief, the distance to the nearest stream, and the relative difference in hillslope relief across a divide are useful metrics to assess divide mobility, provided a threshold distance along the divide network, to avoid effects induced by the fact that divides, by definition, start at rivers.