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Landscape characterization with DAC (DIVIDE AND CAPTURE), a new surface evolution model

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A long lasting challenge in geomorphology is to characterize the geometry and topology of natural stream channel networks and to identify characteristics that distinguish them from other tree networks. Moreover, such characterization should also be indicative of the landscape geology and of the various endogenic and exogenic processes that shape it. Landscape evolution models allow a straightforward technique for addressing this challenge since the models' input is the geology, tectonics, and climate and their output is the spatio-temporal evolution of a channel network, where the topology and various geometrical relations of the channel network may be measured. We apply a new landscape evolution model, DAC (DIVIDE AND CAPTURE), that combines analytic solution for first order channels together with numerical solution for higher order channels. DAC solves explicitly for the location of the channels' divide and allows divide migration and channel capturing. The analytic solution for the first order channels combines Hack's law with a stream power law to solve for channel slope, and therefore it requires the specification of Hack's exponent, h. The slope of the higher order channels is found numerically based on a stream power law and the measured contributing area. For higher order channel h is not an input but an emergent property. It is found that in order to fully tile the space, h must be 1 for the first order channels. It is further observed that this value of h does not percolate to higher order channels that exhibit $0.5<h<1$. The difference in Hack's exponent between channels of different orders leads to differences in the average slope, where first order channels exhibit significantly steeper slopes for the same contributing area. In the simulations we vary the shape and aspect ratio of the studied domains, the initial distribution of erodibility, and the time and space dependent tectonic and climatic forcing functions. We measure the resultant Horton's ratios to characterize the network topology, and various geometrical properties of the sub-basins such as length, area, and slope. Deviations of the measured quantities from the mean value that characterize general tree networks are interpreted as a signature of the initial and boundary conditions and of the input forcing. We thus seek functional relations between the input and output of the model, and the physical mechanism behind these relations.