Geophysical Research Abstracts
Vol. 19, EGU2017-6113, 2017
EGU General Assembly 2017

Effects of evolving hydro-geomorphic connectivity on the erosion response during the initial phase of landform development

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The development of land surfaces in non-equilibrium conditions is often characterized by the emergence of drainage networks, a rapid increase of hydro-geomorphic connectivity and a non-linear response of erosion to precipitation events, and conceptual models of landform evolution have related drainage network evolution, hydro-geomorphic connectivity and non-linear erosion behavior. Because of the high dynamics of hydro-geomorphic structures and connectivity during initial phases of landform evolution, detailed studies on surface development on young land surfaces can help to further elucidate mechanisms and parameters relevant for hydro-geomorphic connectivity. In this study, we applied the landscape evolution model CAESAR for assessing different scenarios of surface structure evolution during the initial years of surface development in small catchments. Data from an artificially-created experimental catchment were used for model calibration and validation, and simulations were carried out for the experimental catchment surface and an idealized slope model. Hourly precipitation records for the experimental catchment were rearranged in several scenarios to assess relations between the erosional response of the catchments and states of hydro-geomorphic surface development. The simulations clearly show non-linear erosion responses of the developing surface, related to its developing hydro-geomorphic connectivity: Simulations with high-intensity precipitation events during the very first years of development resulted in clearly higher rill network density and sediment discharge than simulations with high-intensity events during later stages of surface evolution. A detailed analysis of surface flow patterns shows that the reduced erosion response of the further developed surface is a consequence of higher connectivity, combined with a shift from transport- to detachment-limited erosion along major drainage paths. These results indicate that increased surface hydro-geomorphic connectivity does not necessarily imply increased erosion, but can, in contrast, even result in a reduction of erosion in combination with grain-size dependent erosion thresholds. Results also highlight how even surface flow organization on a small scale in interill areas can be relevant for the overall hydro-geomorphic connectivity of small catchments.