Geophysical Research Abstracts
Vol. 18, EGU2016-11652-1, 2016
EGU General Assembly 2016

A numerical solution to define channel heads and hillslope parameters from digital topography of glacially conditioned catchments

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The analysis of the slope-area relationship in bedrock streams is a common way for discriminating the channel from the hillslope domain and associated landscape processes. Spatial variations of these domains are important indicators of landscape change. In fluvial catchments, this relationship is a function of contributing drainage area, channel slope and the threshold drainage area for fluvial erosion. The resulting pattern is related to climate, tectonic and underlying bedrock. These factors may become secondary in catchments affected by glacial erosion, as it is the case in many mid- to high-latitude mountain belts. The perturbation (i.e. the destruction) of an initial steady state fluvial bedrock morphology (where uplift is balanced by surface lowering rates) will tend to become successively larger if the repeated action of glacial processes exceeds the potential of fluvial readjustment during deglaciated periods. Topographic change is associated with a decrease and fragmentation of the channel network and an extension of the hillslope domain. In case of glacially conditioned catchments discrimination of the two domains remains problematic and a discrimination inconsistent. A definition is therefore highly needed considering that (i) a spatial shift in the domains affect the process and rate of erosion and (ii) topographic classifications of alpine catchments often base on channel and hillslope parameters (i.e.or hillslope relief).
Here we propose a novel numerical approach to topographically define channel heads from digital topography in glacially conditioned mountain range catchments in order to discriminate the channel from the hillslope domain. We analyzed the topography of the southern European Central Alps, a region which (i) has been glaciated multiple times during the Quaternary, shows (ii) little lithological variations, is (iii) home of very low erodible rocks and is (iv) known as a region were tectonic processes have largely ceased. The region shows a distinct increase of mean elevation from the major overdeepend valleys near the Foreland to the alpine main divide at around 4000 m.a.s.l. within a distance of only 150 km.
To define channel heads we first analyzed the variations to fine-scale topography of catchments by calculating the plan curvature at low topographic wavelengths. Higher elevated catchments more frequently impacted by glacial erosion show a higher degree in topographic flattening than catchments with a lower mean elevation where rougher fluvial (steady state) channels dominate. We found that this process of glacial destruction of fine-scale topography can well be analyzed by extracting the plan curvature from a DEM (1-30 m resolution). We furthermore found that the plan curvature frequency depends on the mean elevation of a catchment. Accordingly, the correlation between mean elevation of basins and the related density of pixels with a certain curvature is highly controlled by the used curvature threshold (e.g. used range of curvature pixels). A statistically derived optimum of the negative plan curvature was taken to define a threshold for the concavity of channels. The resulting fragmented network of channel segments was then fully integrated by utilizing a steepest descent algorithm. The upstream-most point of this fully integrated network was then defined as channel head. Our approach offers not only a consistent method to derive (i) hillslope and channel parameters in formerly glaciated catchments but also to (ii) measure the degree in glacial conditioning and therefore (iii) separating non-glacial from glacial catchments.