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Stream gradient Hotspot and Cluster Analysis (SL-HCA) for improving the longitudinal profiles metrics

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Many researches successfully focused on stream longitudinal profiles analysis through Stream Length-gradient (SL) index for detecting, at different spatial scales, either tectonic structures or hillslope processes. The analysis and interpretation of spatial variability of SL values, both at a regional and local scale, is often complicated due to the concomitance of different factors generating SL anomalies, including the bedrock composition. The creation of lithologically-filtered SL maps is often problematic in areas where homogeneously surveyed geological maps, with a sufficient resolution are unavailable. Moreover, both the SL map classification and the unbiased anomaly detection are rather difficult. For instance, which is the best threshold to define the anomalous SL values? Further, is there a minimum along-channel extent of anomalous SL values for objectively defining over-steeped segments on long-profiles?
This research investigates the relevance and potential of a new approach based on Hotspot and Cluster Analysis of SL values (SL-HCA) for detecting knickzones on long-profiles at a regional scale and for fine-tuning the interpretation of their geological-geomorphological meaning. We developed this procedure within a 2800 km2-wide area located in the mountainous sector of the Northern Apennines of Italy.
The Getis–Ord Gi$*$ statistic is applied for the SL-HCA approach. The value of SL, calculated starting from a 5x5 m Digital Elevation Model, is used as weighting factor and the Gi$*$ index is calculated for each 50 m-long channel segment for the whole fluvial system. The outcomes indicate that high positive Gi$*$ values imply the clustering of SL anomalies, thus the occurrence of knickzones on the stream long-profiles.
Results show that high and very high Gi* values (i.e. values beyond two standard deviations from the mean) correlate well with the principal knickzones detected with existent lithologically-filtered SL maps. Field checks and remote sensing analysis conducted on 52 clusters of high and very high Gi* values indicate that mass movement of slope material represents the dominant process producing over-steeped long-profiles along connected streams, whereas the litho-structure accounts for the main anomalies along disconnected steams. Tectonic structures generally provide to the largest clusters. Our results demonstrate that SL-HCA maps have the same potential of lithologically-filtered SL maps for detecting knickzones due to hillslope processes and/or tectonic structures. The reduced-complexity model derived from SL-HCA approach highly improve the readability of the morphometric outcomes, thus the interpretation at a regional scale of the geological-geomorphological meaning of over-steeped segments on long-profiles. SL-HCA maps are useful to investigate and better interpret knickzones within regions poorly covered by geological data and where field surveys are difficult to be performed.