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Comparing global-scale topographic and climatic metrics to long-term erosion rates using ArcSwath, an efficient new ArcGIS tool for swath profile analysis

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The topography of the Earth's surface is the result of the interaction of tectonics, erosion and climate. Thus, topography should contain a record of these processes that can be extracted by topographic analysis. The question considered in this study is whether the spatial variations in erosion that have sculpted the modern topography are representative of the long-term erosion rates in mountainous regions. We compare long-term erosion rates derived from low-temperature thermochronometry to erosional proxies calculated from topographic and climatic data analysis. The study has been performed on a global scale including six orogens: The Himalaya, Andes, Taiwan, Olympic Mountains, Southern Alps in New Zealand and European Alps. The data was analyzed using a new swath profile analysis tool for ArcGIS called ArcSwath (https://github.com/HUGG/ArcSwath) to determine the correlations between the long-term erosion rates and modern elevations, slope angles, relief in 2.5-km- and 5-km-diameter circles, erosion potential, normalized channel steepness index k_{sn}, and annual rainfall. ArcSwath uses a Python script that has been incorporated into an ArcMap 10.2 add-in tool, extracting swath profiles in about ten seconds compared to earlier workflows that could take more than an hour. In ArcMap, UTM-projected point or raster files can be used for creating swath profiles. Point data are projected onto the swath and the statistical parameters (minimum, mean and maximum of the values across the swath) are calculated for the raster data. Both can be immediately plotted using the Python matplotlib library, or plotted externally using the csv-file that is produced by ArcSwath. When raster and point data are plotted together, it is easier to make comparisons and see correlations between the selected data.

An unambiguous correlation between the topographic or climatic metrics and long-term erosion rates was not found. Fitting of linear regression lines to the topographic/ climatic metric data and the long-term erosion rates shows that 86 of 288 plots (30%) have "good" R^2 values (> 0.35) and 135 of 288 (47%) have an "acceptable" R^2 value (> 0.2). The "good" and "acceptable" values have been selected on the basis of visual fit to the regression line. The majority of the plots with a "good" correlation value have positive correlations, while 11/86 plots have negative slopes for the regression lines. Interestingly, two topographic profile shapes were clear in swath profiles: Concave-up (e.g., the central-western Himalaya and the northern Bolivian Andes) and concave-down or straight (e.g., the eastern Himalayas and the southern Bolivian Andes). On the orogen scale, the concave-up shape is often related to relatively high precipitation and erosion rates on the slopes of steep topography. The concave-down/straight profiles seem to occur in association of low rainfall and/or erosion rates. Though we cannot say with confidence, the lack of a clear correlation between long-term erosion rates and climate or topography may be due to the difference in their respective timescales as climate can vary over shorter timescales than 10^5-10^7 years. In that case, variations between fluvial and glacial erosion may have overprinted the erosional effects of one another.