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Effect of terrain smoothing on the correction of terrestrial cosmogenic nuclide production rates for skyline shielding

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In-situ produced cosmogenic nuclides are increasingly used to quantify geomorphological process rates, and the laboratory and computational techniques required for cosmogenic nuclide studies are becoming increasingly available to the earth science community. As analytical and theoretical errors continue to be reduced, the relative importance of the common correction factors, such as topographic and snow shielding, increases. The derivation of an additional correction factor for topographic or skyline shielding for large areas is still problematic. One important issue that has yet to be addressed is the effect of the accuracy and resolution of terrain representation by a digital elevation model (DEM) on topographic shielding correction factors.

Most topographic metrics derived from DEMs such as slope and roughness scale with the resolution of the input elevation data. This effect is primarily due to terrain smoothing, resulting in a reduction in the relief (local and global) across an area. Therefore, DEM-based estimates of topographic shielding of cosmic rays are expected to be dependent on the pixel size of the input topographic data as well.

Here, we undertake a systematic study of the effect of scaling caused by terrain smoothing on estimates of topographic shielding. We selected a wide range of natural terrains in order to capture maximum variability of surface roughness : (1) extremely flat terrain, Flanders, Belgium; (2) mature fluvial valleys, Appalachians, USA; (3) incised canyons, Arizona, USA; (4) steep mountain valleys, Andes, Ecuador; (5) glacial mountain valleys, Wyoming, USA. The effect of terrain smoothing on the resulting basin-wide topographic shielding factors was quantified by calculating the bias of shielding factors for the range of grid resolutions that are commonly used in geomorphological applications.

Our data indicate that basin-average topographic shielding factors increase as the grid size of the input elevation data increases. This effect is accentuated in high-relief mountain basins, the rough landscapes which are exactly those that are most often studied with cosmogenic nuclide derived basin-averaged denudation rates. Our results indicate that errors in excess of common analytical errors are possible in steep mountainous settings when using medium resolution (30-100 m) DEMs input data for estimation of topographic shielding. Based on our calculations for a wide range of topographic settings, we derived an empirical model for estimating topographic shielding factors based on simple landscape metrics, which allows a determination of the errors associated with terrain smoothing for various topographic settings.