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Evaluating the influence of erosion and tectonic processes on California's topography by measuring its fractal dimension and anisotropy across scales

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Roughness is paramount in Earth sciences, and landscapes, laboratory alluvial fans, river bed elevation, bedload transport and the friction laws of fluid mechanics all exhibit a fractal behavior described by a scale-persistent roughness. Yet, for a given landscape, the exact meaning of statistical roughness, or fractal dimension, remains unclear. The fractal dimension of topography is mainly understood as two end-members: at large spatial scales, it describes tectonic processes; at small spatial scales it describes erosion processes. In this study, we nuance this description by identifying the spatial scale at which erosion processes are inadequately described by fractal dimension and provide quantitative bounds on the meaning of the statistical roughness of topography at scales from 0.25 km to 100 km using three lines of evidence. First, we leverage spatial statistics to evaluate the auto-correlation structure of topographic statistical roughness across the physiographically diverse state of California, USA. Second, we identify the down-slope and across-slope directions using two-dimensional Fourier analysis, and measure the anisotropy of topography by evaluating statistical roughness in each direction. Third, we perform a spatial correlation analysis between statistical roughness and the Péclet number which describes the balance between diffusion and incision processes. Our preliminary results indicate that correlation between statistical roughness and Péclet number fades at scales greater than 4.6 km. In addition, auto-correlation saturation occurs for statistical roughness at scales greater than 16.5 km. Hence our analysis provides a more nuanced description of the statistical roughness of topography: it represents erosion processes at scales up to 4.6 km while being dominated by tectonics at scales greater than 16.5 km.