Geophysical Research Abstracts, Vol. 7, 01359, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01359

Measuring and modeling periodic ridge-and-valley structures in landscapes

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Landscapes often contain periodic topographic structures, including regularly spaced ridges and valleys. We apply spectral analysis techniques to high-resolution topographic maps of several landscapes to demonstrate the strong periodicity of ridges and valleys at the scale of first-order drainage basins (typically hundreds of meters).

Simple physical and geometrical arguments imply that valley spacing might be determined by a competition between advective erosion processes (e.g., stream incision), diffusive erosion processes (e.g., soil creep), and erosion thresholds. We solve a nonlinear advection-diffusion equation numerically to investigate the factors controlling valley spacing. Using dimensional analysis, we infer the form of a relationship between valley spacing, the rates of the advective and diffusive processes, the magnitude of the erosion threshold, and spatial and temporal boundary conditions. Numerical solutions of the advection-diffusion equation confirm the general form of this relationship. The transient behavior of the numerical model illustrates the ways in which erosion processes interact over time to produce periodic ridges and valleys. Our results also help to explain transitions from rill-like drainage networks to branching networks, and the upper and lower bounds on length-to-width ratios of first-order drainage basins.