



## Optimality in landscape channelization and analogy with turbulence

Milad Hooshyar<sup>1</sup>, Sara Bonetti<sup>2</sup>, Arvind Singh<sup>3</sup>, Efi Foufoula-Georgiou<sup>4</sup>, and Amilcare Porporato<sup>1</sup>

<sup>1</sup>Princeton University, USA

<sup>2</sup>ETH Zurich, Switzerland

<sup>3</sup>University of Central Florida, USA

<sup>4</sup>University of California, Irvine, USA

The channelization cascade observed in terrestrial landscapes describes the progressive formation of large channels from smaller ones starting from diffusion-dominated hillslopes. This behavior is reminiscent of other non-equilibrium complex systems, particularly fluids turbulence, where larger vortices break down into smaller ones until viscous dissipation dominates. Based on this analogy, we show that topographic surfaces emerging between parallel zero-elevation boundaries present a logarithmic scaling in the mean-elevation profile, which resembles the well-known logarithmic velocity profile in wall-bounded turbulence. Within this region of elevation fluctuation, the power spectrum exhibits a power-law decay resembling the Kolmogorov  $-5/3$  scaling of turbulence. We also demonstrate that similar scaling behaviors emerge in surfaces from a laboratory experiment, natural basins, and constructed following optimality principles. In general, we show that the steady-state solutions of the governing equations of landscape evolution are the stationary surfaces of a functional defined as the average domain elevation. Depending on the exponent of the specific drainage area in the erosion term ( $m$ ), the steady-state surfaces are local minimum ( $m < 1$ ) or maximum ( $m > 1$ ) of the average domain elevation.