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Quantitative Geomorphology: How computers have revolutionized the way we think about landscapes

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The field of geomorphology has seen a real revolution in the past 30 years in great part due to the development of landscape evolution models (LEMs). These models are based on the solution of a wide variety of equations including the stream power law to represent the incision by channelized flow, the under-capacity model that includes the effect of sediment flux on the stream erosional efficiency, various forms of the diffusion equation to represent the transport of material on hillslopes, and various other equations to represent the flow and erosion of ice, the dissolution of carbonate rocks to form karstic landscapes or eolian transport. The strength of the majority of these models is that they integrate in space and time the effects of processes described at the local scale. Most algorithms use classical methods to solve partial differential equations, like the finite difference, finite element or the finite volume technique; some use more exotic methods such as neural networks, statistical or automaton techniques. In this presentation, I will briefly present the variety of processes that have been simulated using LEMs, the basic equations that are solved as well as the techniques used to compute their solution. In a second step, I will review the principal results that have been obtained using LEMs and how they have influenced the way we now think about landscape evolution and its interactions with tectonics and climate. In particular, I will show how steady-state landforms have been be used to extract information about the underlying tectonics (uplift), I will describe how we think horizontal tectonic advection affects landform evolution and explain how the complex interactions between fluvial, glacial and hillslope processes during the recent glacial cycles are responsible for the formation of most mountainous landscapes. I will then briefly enumerate what are regarded as the main shortcomings of our models and describe some of the on-going developments in the field of quantitative geomorphology.