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Thermodynamics, maximum power, and the dynamics of preferential river flow structures

A. Kleidon (1), E. Zehe (2), U. Ehret (2), and U. Scherer (2)

(1) Max-Planck-Institut für Biogeochemie, Jena, Germany (akleidon@bgc-jena.mpg.de, +49-(0)3641-577217), (2) Karlsruhe Institute of Technology, Karlsruhe, Germany

The organization of river basins shows some reproducible phenomena, as exemplified by self-similar fractal structures and typical scaling laws, and these have been related to energetic optimization principles, such as minimum energy expenditure or maximum "access". Here we describe the organization and dynamics of river systems using thermodynamics, focussing on the generation, dissipation and transfer of free energy associated with river and sediment flow. We argue that the organization of river networks reflects the fundamental tendency of natural systems to dissipate driving gradients as fast as possible through the maximization of free energy generation, thereby accelerating the dynamics of the system. This effectively results in the maximization of sediment flux to deplete topographic gradients as fast as possible and potentially involves large-scale feedbacks to continental uplift. We illustrate this thermodynamic description with a set of three highly simplified models related to water and sediment flow and describe the mechanisms and feedbacks involved in the evolution and dynamics of the associated structures. We close by discussing how this thermodynamic perspective is consistent with previous approaches and the implications that such a thermodynamic description has for the understanding and prediction of subgrid-scale organization of river systems and preferential flow structures in general.