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Karst Evolution and Minimum Energy Expenditure

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The idea of minimum energy expenditure was introduced in the 1990s in the context of fluvial erosion and the corresponding evolution of drainage networks. It was suggested that river networks evolve in such a way that the total energy spent for the flow of water to the outlet of the basin is as low as possible. In this contribution we transfer this idea to subsurface flow in karstified aquifers, assuming that the evolution of the karst system is reflected in a locally increasing hydraulic conductivity or transmissivity. In case of a two-dimensional, radial-symmetric spring catchment, the spatial distribution of the transmissivity leading to the minimum energy expenditure can be computed analytically. The optimum transmissivity roughly increases inversely proportionally to the distance from the spring. The hydraulic properties of such a spatial distribution of the transmissivity were investigated by Birk and Hergarten 2012 (EGU2012-9777). In principle, even an extremely simplified model for the evolution of the transmissivity through time can be derived from the idea that the rate of increase in transmissivity integrated over the entire domain is given, and that this increase is distributed spatially in such a way that the total energy expenditure decreases as rapidly as possible. Beyond the distribution of the transmissivity, such a model might provide an idea on the growth of the catchment size of a karst spring during its evolution. However, it should be emphasized that the principle of minimum energy expenditure may be reasonable, but cannot be derived from first principles for subsurface flow.