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Does the soil's effective hydraulic conductivity adapt in order to obey the Maximum Entropy Production principle? A lab experiment

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The Maximum Entropy Production (MEP) principle is a conjecture assuming that a medium is organized in such a way that maximum power is subtracted from a gradient driving a flux (with power being a flux times its driving gradient). This maximum power is also known as the Carnot limit. It has already been shown that the atmosphere operates close to this Carnot limit when it comes to heat transport from the Equator to the poles, or vertically, from the surface to the atmospheric boundary layer. To reach this state close to the Carnot limit, the effective thermal conductivity of the atmosphere is adapted by the creation of convection cells (e.g. wind).

The aim of this study is to test if the soil's effective hydraulic conductivity also adapts itself in such a way that it operates close to the Carnot limit. The big difference between atmosphere and soil is the way of adaptation of its resistance. The soil's hydraulic conductivity is either changed by weathering processes, which is a very slow process, or by creation of preferential flow paths. In this study the latter process is simulated in a lab experiment, where we focus on the preferential flow paths created by piping. Piping is the process of backwards erosion of sand particles subject to a large pressure gradient. Since this is a relatively fast process, it is suitable for being tested in the lab.

In the lab setup a horizontal sand bed connects two reservoirs that both drain freely at a level high enough to keep the sand bed always saturated. By adding water to only one reservoir, a horizontal pressure gradient is maintained. If the flow resistance is small, a large gradient develops, leading to the effect of piping. When pipes are being formed, the effective flow resistance decreases; the flow through the sand bed increases and the pressure gradient decreases. At a certain point, the flow velocity is small enough to stop the pipes from growing any further. In this steady state, the effective flow resistance of the sand bed will be compared with the theoretical optimal flow resistance obtained with the MEP principle. For this study, different magnitudes of the forcing will be tested, while also the effect of dry spells will be explored.