Geophysical Research Abstracts
Vol. 15, EGU2013-4017, 2013
EGU General Assembly 2013
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Maximum Entropy Production under periodic forcing: results of a simple toy model

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In recent years, different optimality principles have been explored as a new way to estimate model parameters. The principle of maximum entropy production (MEP), for example, implies that natural systems organize themselves in a way to maximise their entropy production, given a set of boundary conditions and sufficient degrees of freedom. If the principle holds, it should allow quantitative estimation of a system's 'degrees of freedom' or model parameters, if they represent the degrees of freedom.

When fluxes are described as potential gradients divided by resistances, the entropy production due to a particular flux becomes the potential gradient squared divided by its resistance. In the presence of competing fluxes, the MEP principle can help determining the resistance of one flux, given the resistances of the other fluxes. Based on the above considerations, Kleidon and Schymanski (2008) showed in a simple example how the relevant resistances for runoff and evapotranspiration could be determined given constant precipitation and the resistance of one or the other.

Here we show that the optimal resistance for one flow always equals the prescribed resistance of the other flow in this example with two competing fluxes and constant input. This is independent of gradients that drive the fluxes or the total input rate. However, we know that in reality, the resistances of different fluxes differ by orders of magnitude. In this study we show that this could be explained by the 'periodic' input of rainfall, as the same model leads to different optimal resistances, depending on the periodicity of rainfall.

Using the model of Kleidon and Schymanski (2008), the resistances start differing from each other when the groundwater reservoir gets empty in-between two rainfall pulses. When the principle is applied to two coupled reservoirs, a different optimal resistance occurs when transpiration is assumed from only one of the two reservoirs.

Both concepts still remain to be applied to real catchments, but since the model structure is similar to many hydrological models, the approach presented here can readily be related to existing models and data. For example, the two-reservoir model can be interpreted as a double domain model for the unsaturated zone where one reservoir represents matrix flow, and the other macropore flow.

Reference:

Kleidon, A., and S. Schymanski (2008), Thermodynamics and optimality of the water budget on land: A review, Geophys. Res. Lett., 35, L20,404, doi:10.1029/2008GL035393