Review of: Transferring the concept of minimum energy expenditure from river networks to subsurface flow patterns

In this manuscript, the authors use the concept of minimum energy expenditure as an organizing principle to predict the optimal configuration of subsurface channel networks. The authors start with explaining this principle for river networks and subsequently extend this analysis for subsurface flow. The final equations that should be optimized are derived analytically and a short comparison with observations has been made.

I consider this article as highly novel and interesting for HESS and advice publication after some (probably minor) revisions. These revisions should mainly consider a better explanation of all assumption made in the theory development and some extra steps in the mathematical derivation. Maybe the most important assumption made – and to my opinion not well enough justified – is the use of the Hagen-Poiseuille law (P5838, L22) which is restricted to laminar flow. I can imagine that flow through conduits in karstic systems is turbulent. This may be described by the Darcy-weisbach equation, but K is than not proportional to r^4 anymore and the whole derivation will be different. So the authors should justify that flow in the systems they look at are indeed laminar. Otherwise the complete theory collapses!

Below I will discuss other assumptions and missing steps in the derivation:

P5834, Eq.1: Explain that this equation describes the loss of potential energy, under the assumption that the change in kinetic energy is negligible. Maybe refer to Evans et al. (1998) who use this formula to describe the heat gained by frictional losses (which they derived in W/m^2): In fact minimum energy expenditure means minimum frictional losses.

You can also make the link to the principle of maximum free energy dissipation (Zehe et al. 2013). This principle is a more overarching one stating that a system tries to move to thermodynamic equilibrium as fast as possible. For the system described in this manuscript, this means that the depletion of potential energy is as fast as possible: thus with minimal frictional losses.

P5835, L17: Add that this minimization is performed under the constraint that q equals the mean input by rainfall (minus evaporation).

P5837, L6-8: I am not familiar with the Euler-Lagrange equation, but what I understand from Eq. 10 is that q should be maximized (since $q=K\nabla h$). But I don't understand the statement that follows on line 7 and 8.

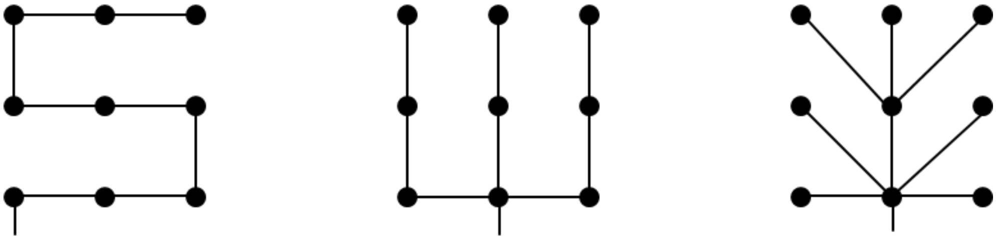
P5839, L5: I could not follow how this formula was derived.

P5843, L18: I came to a different formula: If q(r) equals recharge in the circle between R and r, $q(r)=S \pi (R^2-r^2)$, with S being the recharge.

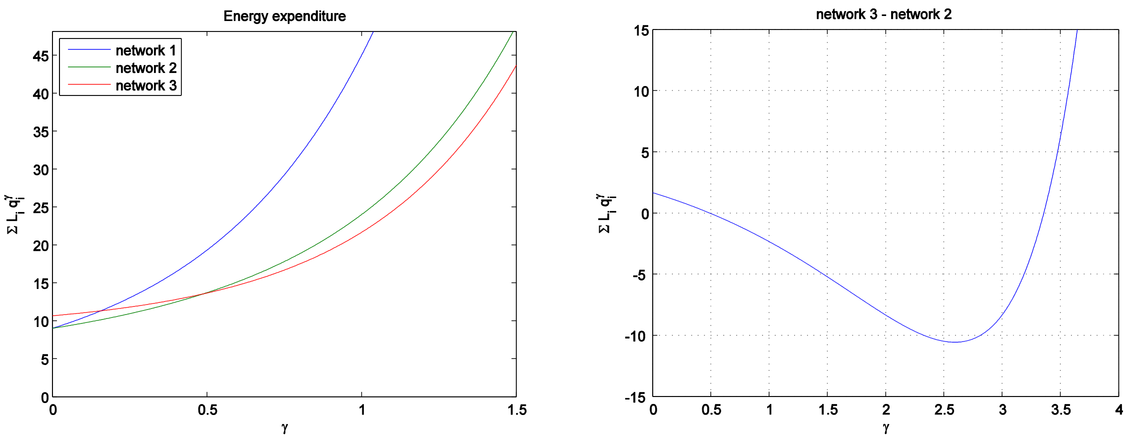
P5844, L4: I could not follow how this formula was derived.

P5845, L21: I don't agree with the statement that 'It is easily recognized that focusing flow reduces the total energy expenditure as long as $\Upsilon< 1$'. It could be that I just don't understand it, and more explanation is needed, but a simple example shows that this statement does not seem to be correct:

Consider the following 3 networks:



assuming that the additive discharge for each grid cell is 1 and the length between two grid cells is either 1 or the square root of 2. Using Eq. 4 along a whole range of Υ results in the following graphs:



Network 3 – which is the most dendritic network – uses less energy than network 1 for Υ>0.16 and it uses less energy than network 2 for 0.5 < Υ < 3.36. So either there is something wrong with this example or the statement is not correct.

Minor comments

P5834, Eq. 1: Use a capital L for length. At first sight I confused it with the divide sign (/).
P5835, L4: change to: surface erosion is in equilibrium with a given, …
P5837, L18: leave the reference to Eq. 10 out: This equation does not describe the mass balance.
P5843, L9: The word 'therefore' seems inappropriate here: the effective transmissivity should only increase if the gradient does not increase enough.
P5848, L6: refer to Eq 47 instead of 46?

References

Evans, E. C.; McGregor, G. R. & Petts, G. E. River energy budgets with special reference to river bed processes *Hydrol. Processes,* **1998**, *12*, 575-595

Zehe, E.; Ehret, U.; Blume, T.; Kleidon, A.; Scherer, U. & Westhoff, M. A thermodynamic approach to link self-organization, preferential flow and rainfall--runoff behaviour *Hydrol. Earth Syst. Sci.,* **2013**, *17*, 4297-4322