The present paper is an extension of a previous work of the Authors regarding the analysis of the runoff process at the hillslope scale in a energy perspective. The extension concerns the inclusion of the transient regime, with respect to the previous steady stat analysis. This is crucial since intermittent rain events provide potential energy to the open hillslope system which can be either dissipated or stored. These energy dynamics are linked to characteristic geomorphology aspects of hillslopes in search of a connection between energy balance and the erosion process.

The paper is really interesting and presents an innovative perspective to the problem. I enjoyed reviewing it. At the same time, I think it could be clearer and more accessible after few comments listed below are addressed.

Comment 1

From Eq. (2) it is my understanding that $D_{HS}(t)$ represents the amount of kinetic energy of the surface runoff that is dissipated. This dissipation can be of different natures, e.g., viscous and turbulent dissipations or erosion of the soil.

Then in Eq 7b

$$\widehat{D}_{HS} = 1 - \widehat{J}_{HS} - \widehat{E}_{HS} = \widehat{A}_{HS} - \widehat{E}_{HS}$$

where $\widehat{A}_{HS}$ is the available cumulated amount of energy (i.e., potential energy from the rain event minus the kinetic energy that has left the system at the closer section) and $\widehat{E}_{HS}$ is the stored potential + kinetic energy of the surface runoff (i.e., the sum of the area below the curves in Fig. 5a and 5b for a given scenario).

At this point, my understanding is that a high value of $\widehat{E}_{HS}$ is indicative of a surface runoff with a high energy content, e.g., high velocities with a high kinetic energy component or high water levels which favor the potential energy component. That it is, high $\widehat{E}_{HS}$ means high energy in the surface water, i.e., less energy is available to be dissipated. But at lines 422-425 it is stated that "Interestingly our results show that the latter (SW) results in less energy efficiency of surface runoff, or differently stated a larger fraction of the provided free energy by rainfall is dissipated than for SC hillslope types (cf. Fig. 6b). This means that there is relatively more energy available for work on the surface of SC profiles (be it in the form of detachment or transport of sediment particles)." This is to say that small values of kinetic dissipation $\widehat{D}_{HS}$ favors the erosion of soil, but the above description was pointing towards the idea that higher dissipation of kinetic energy would favor dissipative processes associated with the flow (i.e., kinetic energy) of the surface water either that being turbulent losses or soil erosion. In the proposed framework there is not a distinction on the type of kinetic energy dissipation. It is true that smaller values of $\widehat{D}_{HS}$ means more relative energy in the flowing water $\widehat{E}_{HS}$ (as a sum of potential and kinetic components), but that it is energy possess by the of the surface water while $\widehat{D}_{HS}$ embeds what is lost/dissipated without specifying in which form is lost, e.g., turbulent dissipation? sediment transport?

Shouldn't be a differentiation on the components of dissipated kinetic energy whit a focus on the part available to sediment erosion/transport?

Comment 2

Lines 422-425: "Interestingly our results show that the latter (SW) results in less energy efficiency of surface runoff, or differently stated a larger fraction of the provided free energy by rainfall is dissipated than for SC hillslope types (cf. Fig. 6b). This means that there is relatively more energy available for work on the surface of SC profiles (be it in the form of detachment or transport of sediment particles)."
Lines 609-611: "In the next section we do not only confirm this general erosion pattern but also show that highest erosion rates coincide with highest relative dissipation rates and therefore maximum work which overland flow performed on the sediments"

Aren't these two statements in contradiction? What am I missing?

Comment 3

In the numerical experiment the profile of the hillslope is given and the hydrodynamic part is solved. If the Author are testing (Lines 260-261) " … we test our hypothesis that the evolution of landscape forms is directly linked to energy efficiency of transient overland flow events" should not the hillslope profile co-evolve with the transient overland flow?

Comment 4

How adding the groundwater compartment would affect the framework? Would that impact the assumption that (Lines 221-222) "In this case we regard the potential energy which enters the system much larger than the potential energy which leaves the system and therefore also $J^{pe}{}_{HS,out}\ (t)$ (watt) to be negligible" since much of the water could leave the system as infiltrating groundwater?

Comment 5

After introducing Eq. (5) there is an interesting discussion in Lines 229-243. However, it could help to introduce the definition of free energy and power in terms of the quantities in Eq. (5) to help the reader. For example, it is hard to grasp the meaning of Lines 236-237 "If a system receives a certain amount of energy influx, it is therefore clear that optimization must happen through adjustment of the internal spatial structure which determines temporal derivatives of free energy conversion rates" without a definition of free energy and free energy conversion rates clearly stated.

Minor comments

Lines 276-277: "In its simplest form sediment transport capacity C is at least dependant on accumulated discharge and local gradient $C=Q^m$ x S^n" please specify what is Q and S. Moreover, local gradient of what?

Lines 212-213: "Eq. 1 to 4 are a simplification of surface runoff, as we do not consider other types of energy than potential and kinetic energy of water" maybe better after Eq. (4).

Line 335: "where y is the averaged variable in time" should not be f(y)?

Caption of Figure 3: "in space is integral over time (blue)" should not be (yellow)? The same in the text at line 343.

The text appears to be sometime a bit convoluted. For example, Lines 47-48 "At the hillslope scale, one can depending on the morphological age of the system observe typical hillslope forms." Might be better formulated as "At the hillslope scale, depending on the morphological age of the system, one can observe typical hillslope forms". Another example, Lines 93 "while the vast majority has dissipated at the downstream/downslope outlet." Should not be Is dissipated?. Lines 124-125: "Moreover, maximum power in the combined sediment-water flux does in steady state correspond to maximum entropy production." The sentence would flow better as "Moreover, maximum power in the combined sediment-water flux corresponds to maximum entropy production during steady state condition". Line 155: "but also relates to larger friction coefficients which in turn limit overall energy efficiency" limit THE overall energy efficiency. Lines 303-304: "which has been set to equal 1.0 for a uniform velocity distribution." Should not be 'has been set to 1.0' or 'has been set equal to 1.0'?

Lines 53-55: “However, despite of these obstacles, there has been continuous research to discover the seemingly hidden physical laws governing and constraining the co-development of form and functioning of the Earth’s hydrologic systems” It is my understanding that ‘these obstacles’ are the semi-empirical relationships and the use of tunning parameters that are mentioned earlier in the text. Yet, when the latter are introduced the fact that these are problematic might not be clear to all the readers, try to emphasize why is that so.