

***Interactive comment on “HESS Opinions
“Hydrologists, bring out shovels and garden
hoses and hit the dirt”” by M. G. Kleinhans et al.***

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We thank the reviewers for their constructive and positive comments. Below we summarise and address each reviewer comment and explain how we modify the paper in response.

Comment 1: There is not enough attention for real-world experiments in hydrology, of which there are many examples (tracer studies, covered catchments, irrigation experiments, etc). Even though these experiments can be considered not true experiments (in the purist's mind), they do have great benefits and help us to advance our understanding of how water moves through the landscape.

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Reply 1: We fully agree that such field experiments are of great value for furthering understanding (see section 2.3.1 in the paper). It goes without saying that nature itself remains our reference situation. We will stress this more in section 2.1. There is an aspect of manipulation in such field work, but we disagree that these studies are experiments, that is, something like experiments. Experimentation by definition allows good *control* over initial and/or boundary conditions and involves the same or similar materials as in nature. The control allows firmer conclusions on relevant causes and exclusion of irrelevant causes of the phenomena under study. If the control aspects in the definition are weakened then the word experiment has hardly any meaning different from that of measurement. This is not merely a matter of definition.

To clarify, we can evaluate laboratory and field experiments along a scale from full to no control. Simple laboratory experiments allow full control over initial and/or boundary conditions. On the other end of the spectrum there is field observation, which allow no control at all. In between these two extremes there are hybrids. One such hybrid is a laboratory experiment on a large block of hillslope material from a field site. This allows full control over the boundary conditions but hardly any control over, e.g., initial moisture content or soil characteristics and presence of macro-pores. This case is somewhere between observation and experiment. Another hybrid is the field experiment, which usually allows but one or two controls such as logging. This case is very close to observation and far from experiment on the scale of control. Note that this continuum is analogous to the continuum between models and experiments by Morgan (2003).

Comment 2: What are the grand challenges of hydrology and how can controlled experiments help us address these?

Reply 2: We hesitated to force our own specific interests into the paper through such grand challenges, but we are thinking along the same lines as the reviewer. Feedbacks between different domains such as hydrology, meteorology, soil, morphology, vegetation and so on are the grand challenges for many earth science disciplines including the discipline hydrology.

C3253

Particularly, understanding and long-term predictions in ungauged basins (i.e. as in the PUB initiative) is a grand challenge. The initial and boundary conditions cannot be measured in sufficient detail for accurate long-term prediction of effects of changing climate, vegetation and so on. Part of the reason is that boundary conditions and properties described by parameters are in fact co-evolving phenomena such as soil and vegetation. So, to understand the dynamics of large basins, it is necessary to understand how the landscape and its structure and heterogeneity came about.

However, landscape evolution takes place over much longer time scales than most hydrological events of interest. Experiments could show how hydrology, soil development, vegetation evolution and morphology change when a different is forced on it. Realistic experimental fluvial or erosional landscapes have been created using a highly simplified hydrological regime consisting of one endless flood or a single-size flood interrupted by a single-size low-flow period. In fact, the formative discharge is a geomorphologically meaningful concept. It would be very interesting to force a more realistic upstream discharge or precipitation pattern on such an experiment to study how response, particularly the hydrological response, differs from that in the constant forcing experiments. The next logical step is to apply changing boundary conditions. Such experimentation could show how important heterogeneity is for the long-term hydrodynamics and how that affects long-term landscape dynamics.

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C3254