Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2016-190-AC4, 2016

Hydrology and Earth System Sciences Discussions
Open Access

Interactive comment on "In situ investigation of rapid subsurface flow: Identification of relevant spatial structures beyond heterogeneity" *by* C. Jackisch et al.

C. Jackisch et al.

conrad.jackisch@kit.edu

Received and published: 22 August 2016

We thank all five reviewers for their critical and constructive comments on our manuscript. We will carefully address all issues in the revision. In the general reply we provide a revised outline and an overview about the upcoming changes concerning this part of the companion MS. It is followed by detailed replies to and discussions of the comments of each review.

1 Consistency and generality of the presented experiments:

The two companion MS deal with the in situ characterization of rapid subsurface flow. In order to highlight the methodological aspects of the study, we will refer to the general interplay of form and function. In our approach, we address this interplay through the detection of responses (MS1, function) and flow-relevant structures (MS2, form).

In accordance to MS1 a possible revised formulation for the title of this MS is: “Form and function in hillslope hydrology: In situ identification of flow-relevant structures”.

We understand from the comments to both MS that the links between the different experiments, the measurements and the different aspects have not been conveyed as self-explanatory as anticipated. As suggested by the reviewers, we will revise both MS towards more clarity and self-consistency. The form – function reference shall help to clarify this.

Moreover, the lack of clear hypotheses caused substantial confusion. In accordance to the general frame, the MS at hand will primarily address form related issues along the following hypotheses:

H 2.1 Flow-relevant structures can be identified in the field under static conditions. (form described without function)

H 2.2 The characteristics of subsurface stormflow can be understood based on structural investigation. (form reveals function)

H 2.3 The localization of response patterns within the structural domain provides the missing link between form and function. (link form and function)

Printer-friendly version

Discussion paper

2 Revised outline of the MS

Obviously, the structure of the MS requires revision in order to convey the key findings about the capabilities and limitations of multiple methods for subsurface structure identification at the pedon, plot and hillslope scale. Much confusion was caused by overlaps of process and structure related aspects. The revised MS will keep the focus on form-related aspects and leave most of the process interpretation to the companion MS. This clearer focus will also make room for details about the pedon-scale exploration, which has been too brief before.

The upcoming revised MS will be outlined as follows:

1. Introduction

1.1 Form-function relationship in hydrological sciences and subsurface flow

1.2 General introduction about the identification of flow-relevant structures in the subsurface

1.3 Specific introduction including a brief summary about the headwater under study, the hypotheses, and the overall aims of the study

2. Methods

2.1 Local exploration

2.1.1 Sampling Design: Point measurements along catenas in nested sets around observation clusters during one campaign.

2.1.2 Used methods and respective scope, scale and capability

2.1.3 3D GPR survey of the hillslope

2.2 Plot scale experiments

2.2.1 Design: 3 close-by plot irrigations as repetitions with different intensity.

2.2.2 Multi-method: Coherent use of dye and salt tracers, soil moisture monitoring, snap-shots of soil water composition regarding stable isotopes, time-lapse 3D GPR

2.3 Hillslope experiment

2.3.1 Design: Minimal replicate of plot scale setup + focus on lateral reaction on the hillslope. In conjunction with natural event to have an established connectivity and to reduce the effect of initial wetting and thus irrigation intensity and amount.

2.3.2 TDR network as spatially distributed reference. GPR transects as "virtual, non-invasive trenches".

3. Results

3.1.1 Point samples remain trapped in high heterogeneity but we can derive the mean integral plot properties (without its spatial organization).

3.1.2 3D GPR survey suggests a patchy layer of structures which later on prove to be not flow related. The driven case is needed.

3.2 Under dynamic conditions we see preferential flow and a lateral reaction in the deposit layer. But we cannot determine the hillslope response - especially as neither the share reaching the deposit layer nor the characteristics of the flow network can be determined.

3.3 TDR profiles are strongly limited in their spatial reference (resolution in time and space). GPR inferred trenches give a more comprehensive picture into the hillslope flow network as discrete, connected and leaky structures.

4. Discussion

4.1 Methodological discussions of the capabilities and limits of the used setups and methods

4.2 Conceptual discussion of heterogeneity versus structure

5. Conclusions

H 2.1: No, the driven case is needed to identify flow-relevant structures.

H 2.2: Structural investigations (including irrigation experiments) can provide crucial information to understand the processes. However, structure alone does not reveal function.

H 2.3: Form and function are mutually paired in the hydrological system. Overly strong assumptions about structures or processes can be avoided by the presented non-invasive GPR inferred trenching method, which can visualize and localize response patterns. This allows for more specific investigations and monitoring of subsurface processes.

3 Overview about main upcoming changes

In the specific replies to the reviews much more detail is given to all raised concerns. These changes will be embedded in the following revision schedule:

1. General story line and readability

1.1 Clarity about hypotheses, science questions and story line in abstract, intro, conclusions and rest of the MS.

1.2 Shortening where possible, extension where needed.

1.3 Clarity about the linkage between the methodological and case related aspects of the MS.

1.4 Final editing by a native English speaker.

2. Introduction

2.1 strong revisions to refer to more studies around the globe

2.2 highlight the methodological aspects and refer to such works more specifically

2.3 link more clearly to the conceptual aspects of inferring hillslope-scale process understanding from local or signal measurements

2.4 clarify the used terminology and sketch of the form-function concept

3. Methods

3.1 Add the WHY to each aspect and draw their connection clearly

3.2 Add sampling design (especially of local exploration).

3.3 Add more details on the hillslope experiment (although repetitive to the companion MS).

3.4 Outline again how the methods will answer the overarching question of exploration of a structured subsurface.

4. Results

4.1 more details on local exploration

4.2 split case-related results from method-related ones

5. Discussion

5.1 Shorten discussion on case results and process interpretation to a minimum showing the limits and novelties of the results at the case of the upper Colpach basin.

5.2 Give explicit frame to methodological discussion to streamline the narrative towards the main findings.

6. Conclusions with reference to the hypotheses

Many thanks again to all reviewers and Alex Zimmermann for your time and critique to substantially improve our MS.

4 Reply to Comment by Alex Zimmermann

In this brief comment I wish to highlight two issues that require revision and that have not been mentioned by the previous three reviewers.

1) Incomplete and biased selection of literature. Given the vast amount of literature from small and heavily instrumented catchments, statements such as: a) "very few studies actually examine rapid subsurface flow from the plot to the hillslope and resolve the respective flow paths" (P2 L14-15) and, b) "our current theories are mainly shaped by rather few experiments in experimental basins" (P2 L18-19) rather reflect an insufficient literature search than a lack of field studies. In fact, the authors almost completely ignore data from Asia (particularly Japan) (e.g. Gerke et al., 2015; Sidle et al., 2000). Furthermore, relevant studies from the tropics and subtropics are neglected as well (e.g. Negishi et al., 2007; Schellekens et al., 2004). As a start, a recent meta-analysis (Barthold and Woods, 2015) of studies on stormflow generation in small forested catchments provides insights which data is actually available. Another issue linked to the selection of the references is the number of self-citations. A brief check revealed that more than 25 % of the citations are self-citations. Such an excessive citation of own work should be avoided.

We are very thankful for the highlighted references. We regret and by no means intended that the statements and selected references have caused that image. We will change the formulation and the references accordingly (also avoiding overly close-related citations). We are well aware of other heavily instrumented catchments (e.g. the Kiryu Experimental Basin monitored since the 90's, among many others Shimada et al. 1993 and Ohte et al. 1995) and will review further literature to embed our study. However, the comment again points out that we could not clearly convey the setting of the experiments as a study on how we can and should approach a hydrological system with preferential flow paths. This will be addressed as outlined in the general points earlier.

Printer-friendly version

Discussion paper

2) Insufficient description of experimental design. The study by Jackisch et al. has a strong experimental focus. The authors should therefore provide a detailed description of the experimental approach. Unfortunately this is not the case. In fact, the description of the hydrological measurements (Section 2.1) gives the impression that the study lacks a well-defined experimental design. For instance, there is no information on the selection of the sampling sites. Did the authors choose the sites at random (i.e. according to a simple random sampling design)? On P4 L16, a nested design is mentioned without providing any further detail. This information is not sufficient to assess the applied sampling design (and the reference to Zehe et al. (2014) does not contain the information either). Please note that the way how the sites are selected is of utmost importance for the statistical inference (see de Gruijter et al., 2006 for details). To improve the description of the experimental approach the authors should provide the type of the sampling design, number of samples (this information is e.g. missing for the soil cores, P4 L31), extent of sampling area, support of the measurements, and a map of the sampling sites.

We clearly see the raised issue and will address this by adding precise descriptions of the experimental design in time and space. Actually, the sampling design is not only of "utmost importance for the statistical inference" but also in trouble when the samples necessarily have to integrate over structured entities of the basically unknown subsurface. In the revisions we will put more emphasis to convey and prove this point which is one of the key findings.

To summarize, I believe that the manuscript would greatly benefit from a more thorough analysis of the available literature, a more balanced selection of references, and a better description of the sampling design.

We will streamline the focus of this MS on the identification of flow-relevant structures. This will include an extension of the introductory literature review but also a clearer selection and arrangement of the raised references. We will also extend the description of the sampling design, study site and results in the "local exploration".

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-190, 2016.