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Interactive comment on "Experiments on patterns of alluvial cover and bedrock erosion in a meandering channel" *by* Roberto Fernández et al.

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Fernandez et al. conducted experiments to investigate the spatial and temporal distribution of bed cover in a bedrock meander bend. The study is timely and highly needed, given that there are very few published data on this particular topic. That said, the paper left me wanting for a number of reasons. While results are described in meticulous detail, interpretations, implications, and a placement into the body of current knowledge are largely lacking. While the authors cite a large number of appropriate references in the introduction, I do not have the impression that these were read in connection with the presented analysis. The entire discussion – six pages long – features a lonely five references and actually reads more like a continuation of the results. This is the more surprising as some of the references cited in the introduction actually describe models

and frameworks that are highly relevant for the study. While this is the major issue I have with the paper, there are a few other important points. For example, there is a mixture of methods, results and interpretation in the results and discussion sections, and the method description is thin and unclear in places. As a summary, I think the paper needs some clarifications and re-structuring, and, in particular, a framing of the results in the context of existing literature.

The data that the authors have produced lend themselves for applying and testing recent theoretical work. In this paragraph, I want to highlight some very relevant work. I apologize in advance that this will carry quite a number of references to my own papers; I have spent time thinking about the cover effect for my entire career and have written 8 first-author papers on it (and yes, I tried to stop a few years ago, but it did not work. . .). Please don't feel obliged to cite everything mentioned below in your paper. Have a look and work with what you think is relevant.

1) There is some work upscaling cover from the grain scale using models. This is highly relevant to your work (and the lack of it is even used in the motivation of the study). I know of three studies: Turowski (WRR, 2009), Turowski and Bloem (Geodin. Acta, 2016) and Hodge and Hoey (JGR 2012).

2) Recent work from the group of Hodge and Ferguson at Durham that focusses on field data may also be of interest (Hodge and Hoey, 2016; Hodge et al., 2011, 2016; Ferguson et al., 2017).

3) Rebecca Hodge and I (Turowski and Hodge, ESurf 2017) have recently developed a theoretical framework that seems to be ideal to assess the authors' data set. This framework completely separates the issue of cover from sediment transport dynamics. We also defined benchmark cases and describe physical reasons of why a particular cover curve may deviate from these. Your results and the interpretations you propose seem to align with this. And yes, I am obviously biased, but let me know what you think about it.

4) There is a great little experimental paper on the interaction of erosion, channel morphology and cover in a meandering channel by Shepherd (Science, 1972; see also the follow up by Shepherd and Schumm, GSAB 1974). This is often overlooked but highly relevant.

Before I make a few more detailed comments specific to the manuscript, I would like to address some common misconceptions about the cover effect that persist in the literature and also shine through here.

1) There is a need to distinguish the relationship between cover and sediment mass on the bed from the relationship of cover with the ratio of sediment supply to transport capacity. Although we claimed in a previous paper (Turowski et al., JGR 2007) that these are equivalent, this is not true. Turowski and Hodge (ESurf 2017) derived a formally correct transformation between these two functions. This point affects the discussion, for example the comparison with the linear cover model (that is typically formulated as a function of the ratio of sediment supply to transport capacity).

2) The exponential cover relation arises when assuming that sediment is randomly distributed on the bed, i.e., each part of the bed has the same probability of deposition. This is true for the relationship between cover and sediment mass, NOT for the relationship of cover with the ratio of sediment supply to transport capacity. The exponential function arises whether one considers the static or the dynamic cover effect, or both combined. There is no relation between the exponential cover relation and the assumption of a dynamic cover effect.

3) The exponential function was derived under the assumptions that flow, sediment supply, bed topography (slope, roughness…) can be considered constant within the area of interest. It is clear that spatial variability should change the functional relationship.

4) We put forward the dynamic cover effect using the common framework of a sub-capacity flow (detachment-limited assumption). In this case, capacity is larger than

supply. The river has spare energy for transport and uses this to entrain any stationary sediment. This is the case when assuming that in the control area that is considered, all relevant parameters (hydraulics, supply…) can be considered to be constant (see point 3). In the strict use of these assumptions, a static cover is not possible. This can be resolved by working, for example, in an entrainment-deposition framework (see Turowski, WRR 2009; Shobe et al., GMD 2017; Turowski and Hodge, ESurf 2017).

Specific comments (page.line)

2.21 This is a misunderstanding. The exponential cover term arises under the assumption that deposition is equally likely on each part of the bed. This is independent of whether there is static or dynamic cover or both.

2.22 Dieter Rickenmann and I presented some field evidence for the dynamic cover effect in a paper in 2009 (Turowski & Rickenmann, ESPL, 2009).

2.22 The model of Lague is equivalent to the linear / exponential area-based models when working with the mean sediment thickness.

2.25 ff. This paragraph reads like a random selection of statements. The relevance and the main flow of argument are unclear.

2.30 …presented…

3.9 Shepherd, Science 1972, did some great experiments looking at cover and erosion in a meandering channel. Sadly, his work is often overlooked. There is follow-up paper by Shepherd and Schumm (GSAB 1974).

3.12 The issue of scale is ok and I agree that this has been insufficiently addressed. Nevertheless, Hodge and Hoey (JGR 2012) and I (Turowski, WRR 2009; Turowski and Bloem, Geodin. Acta 2016) used models to look at cover dynamics from a grain perspective. The assumption in this work is that the appropriate area or length scale to average cover over is much larger than the grain size. It would be easy to assess how much larger it needs with the models developed in the mentioned papers.

3.14 It is my impression that here two separate issues are confounded. The term 'transient' is ambiguous, because it could mean that a particular patch of cover is created and destroyed over time, or that the sediment in the patch is continuously replaced by new sediment. The relevant point here is not that cover is transient – most model deploy a temporal average or a stochastic notion of a steady state – but that cover patches in a bend may persist in location and thus time-averaged incision varies along and across the channel. This means that, over the long term, the bed is not lowering at the same rate everywhere.

3.16 I do not have the impression that this is not acknowledged by the modelers.

3.18 This is a good question, and again, there is some work setting up the basics for this. The above-mentioned stochastic models of resolve these aspects explicitly and in a previous paper (Turowski, WRR 2009), I derived probability distributions of cover and erosion rates. Temporal fluctuations in cover are also modelled by Lague (JGR 2010). The model of Turowski and Hodge (ESurf, 2017) also predicts the temporal evolution of cover. In the latter paper, a mass balance framework is also presented that can easily be extended to look at cover dynamics along and across a channel.

4.3 This notion (transport can happen only on covered portions of the bed) is only true if a dynamic cover effect is assumed. Even then, I find the formulation highly misleading. Clearly, sediment can transported over a clean bedrock bed (think about a single particle driven by water in an otherwise empty flume!), and the notion would imply that there always needs to be a long-stream connected cover. There are many observations suggesting that this is not the case.

4.21 I suggest a more careful formulation here. Yes, in channel bends, there can be stationary deposits. For a given geometry, the location and size of these is dependent on discharge (or the ratio of discharge or capacity to supply). If the term 'mixed bedrock-alluvial channels' indicates a bedrock channel with a partially covered bed, we would need to integrate over the variable discharge to calculate long-term incision

rates. During the highest floods, the entire channel may still be stripped of cover.

5.10 Information on methods and set up is incomplete. What was the size of the sediment (median, distribution)? Was the foam erodible? Why foam? Which type of foam? How were the foam sections linked (the description suggests that there where sharp steps every 0.5m)? What was the initial pattern of gravel in the flume (spatial distribution, thickness)? Why was this pattern chosen (does the initial distribution affect the results)? Did the concrete completely cover the gravel or did bits stick out, contributing to roughness? Can you give some more information on the concrete that was used (e.g., the sand fraction may affect the bed roughness)?

5.12 How were bedforms averaged out? How were bedforms defined?

5.16 What is the 'maximum of the foam'?

5.23 Please give information on the model and a reference.

5.23 Can you be precise in giving the precision?

5.23 Why and how were these locations chosen? Are these line (cross-sections?) or areal scans?

5.24 I do not understand the exact protocol here. Why a 4th order polynomial?

5.25 Why do the authors think that this particular protocol gives and adequate measure of the macro-roughness?

6.18 If you know the weight, why don't you tell the reader? There is no need to be secretive.

6.18 I have trouble understanding the rationale of this experiment. Please explain more clearly what you intended to do. From the writing, it seems that you wanted to measure the minimum mass of sediment necessary to fully cover the bed, correct? I guess I was confused by the term 'sediment supply ratio'; my first impression was that you wanted to measure sediment supply divided by transport capacity (which would be the typical definition of the term ‘sediment supply ratio’). It be would be good to explain the intention of the experiment clearly, including the physical or theoretical reasoning behind it (see Turowski and Hodge, ESurf 2017, for a discussion of why the minimum mass necessary to cover the bed is a useful normalization factor).

6.22 How was macro-roughness measured?

6.25 Why did you think that a single repetition was sufficient to mitigate for human errors?

8.10 and following. I suggest to use ‘persistent’ instead of ‘permanent’ throughout the paper. The cover was not permanent, because it was established throughout the run and removed after it. The dictionary gives a definition of permanent as “lasting or intended to last or remain unchanged indefinitely”.

8.18 Are these percentages applied to spatial or temporal variance?

8.18 This information should go into the method section.

8.22 The legend of the figure should go into the caption. Here, better describe the main features that you want to highlight for the reader.

9.12 Section 3.5 does not give results. The way of calculating erosion potential should be moved to the method section.

9.13 Again, the legend of the figure should be placed in the caption. In the main text, describe the results that you want the reader to see on the figure (e.g., ‘A correlates with B’, or ‘A shows a maximum at a value of B = XX’).

9.24 dot missing after ‘al’

10.6 The logistic curve is defined over the space from minus to plus infinity, while the cover is defined between 0 and infinity. Further, we know that (in Fig. 5b), the curve should go through the point 0,0. In a recent paper, Rebecca Hodge and I developed a mathematical framework to deal with such cases (see Turowski and Hodge, ESurf,

2017).

11.24 and following. Yes, and this is not really surprising. What are the implications, for example for meander development and channel width?

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