Interactive comment on “Grain sorting in the morphological active layer of a braided river physical model” by P. Leduc, P. Ashmore, and J. T. Gardner.
esurf-2015-16

Response to Referees

1 General comments

The authors would like to thank you all 4 referees and associate editors for their attentive work and high quality comments. The paper has been improved thanks to their work. In several places there are suggestions for further analysis with which we agree and some of which are underway for subsequent papers. Our purpose here was to report the result of an analysis of reach-aggregated vertical sorting which we thought sufficiently novel and important to stand as the primary contribution of the paper. We are planning to make the following changes :

- A conceptual plot (new Fig 6) will be added to explain the main steps of the equivalent texture maps
- Fig 1 (a) will be slightly changed to avoid confusion on negative value and equivalent texture dimension
- Several clarifications and explanations will be made

Our answers are in italic font.

2 Referee #1

Received and published : 6 August 2015

Overview This paper uses a physical scale model of a braided gravel bed to measure the grain sorting in the vertical ‘morphologically active layer’. The topic of the paper is of interest to readers with some interesting findings that are applicable to the wider discipline. I feel the journal should be accepted with minor revisions, as detailed below. However the authors should strongly consider the current balance of the paper as the introduction and methods section is very long as compared to the results and discussion. This currently leaves the reader wanting more detail, particularly in the analysis section. There also needs to be some clarifications to the methodology and results section.

Detailed comments are given below.

Introduction

- Page 579, Line 16 – the term morphological active layer is introduced here. I think it would be good the distinction between the morphological active layer and the grain exchange active layer made earlier – I would suggest moving the 4 lines at the top of page 581 to here just to make the explicit difference clearer.

We have decided to leave the sequence as written – the expanded definition at the top of p. 581 allows us to contrast it directly with previous literature on sediment exchange depths in gravel bed material transport.

- Page 579 – lines 11-15 relating to patchiness seems out of place and I would consider deleting it as it does not add to the understanding of the problem being addressed.

Patchiness, in our minds, refers to relatively homogeneous areas of grain size at channel scale related to sorting patterns associated with bedload and local sorting around these morphological features. Therefore, the primary lateral sorting apparent in our maps is a form of patchiness that translates into the vertical patterns of grain size that we analyze.

- Page 581- Line 23-26 beginning with 'because of the progressive development' doesn't make sense consider re-working

We will rephrased this.

- Page 581- Line 27 beginning 'our solution is to use' – is a very long sentence – consider re-wording

We will split and rephrased it.

Methodology

- Page 582, Line 23 – what was the geometric sorting value of the grain size distribution ?

The geometric sorting defined by $\sigma = \frac{d_{84}+d_{16}}{4} + \frac{d_{95}+d_5}{6.6}$ *is equal to 1.3. The grain size distribution is poorly sorted.*

- Page 583, line 10 – you mention that some bed features were inhered from earlier in the experiment – what re the potential impacts of this inheritance on your results ? Were there specific features which were inherited ?

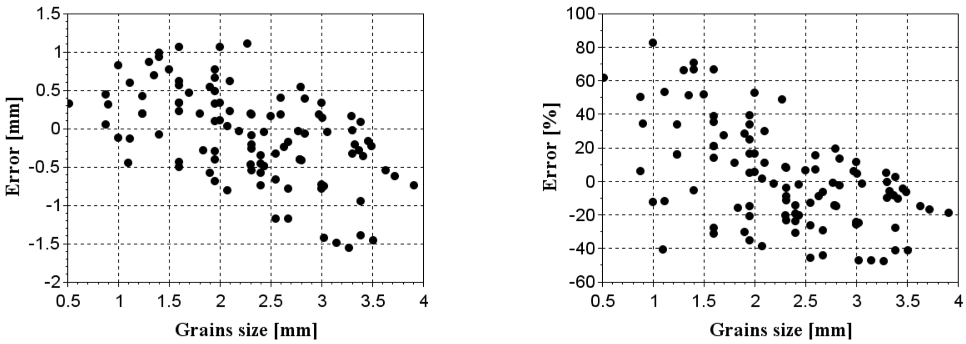
The bed features that we mention refer to the fact that the analysis began from a fully braided river established over a long time period at the same constant discharge and slope to make sure that the data were derived from a bed that had been completely reworked by the river and the braided morphology was well-established, as would be the case in any field study beginning at any given time. Our analysis covers only those parts of the bed that were reworked during the 40 hours of analysis. Pre-existing features that were not re-worked (no measureable elevation change) during the 40 hours were excluded from the analysis so the results do not include these inherited 'no change' areas.

- Page 583- Line 13 – the vertical stereo images were taken of the dry bed surface. It is therefore assumed that the flume was stopped and started 40 times to capture the stereo images ? If so this is likely to have an impact on the sediment transport dynamics, particularly the fine sediment dynamics. Did you take this into account and if so how ? I think this is worth of mentioning in the methodology.

The pictures are taken when the bed has been drained. The time when the discharge is increasing or decreasing (around a few minutes) is small compared to the experimental time, i.e 1 hour. We assume that the effect of flow variability is negligible at the experiment scale. Moreover, flow variations induced by falling stage are found also in natural system. The grain sorting dynamics shouldn't be impacted. A mention is going to be added to the paper.

- Page 584, lines 2-15 – you mention that the you calibrated and validated your image texture method over the full grain size range however the axis on figure 1a and b only go up to 4mm when you have a maximum grain size of 8mm – can you explain why this is the case ? You also mention that there is a relative error on the absolute values of up to 100% (although half the set had less than 20%) – were these errors correlated with grain size i.e. were any grain sizes better/ more poorly captured using this technique ? Potentially you could plot a histogram of these errors against grain size to clarify this point. What impact might this have on your results ?

Indeed, the maximum 'grain size' that we obtain is 4 mm with the entropy technique, and the real maximum grain size in 8 mm. The difference is due to the way the entropy is measured. The entropy value is an averaged value of a 1cm² of bed, which implies that on that 1cm², there are a range of grain sizes. That is why, even if we sample on coarse patches, the maximum value of the grain size on the calibration dataset is 4 mm. The error on the grain size depends on the size. The plots below (Fig. 1), display the absolute error (estimated value - real value, Fig. 1a) and the relative error ((estimated value - real value)/real value, Fig. 1b).



(a) Absolute error (b) Relative error

FIGURE 1 – Error on equivalent texture

On the relative error plot (Fig. 1b), we can see that the highest relative error is on the very fine grains. On the absolute error plot (Fig. 1a), we can see clearly the fine grains are overestimated and coarse grains are underestimated.
Despite the large range of values, we are assuming that the error doesn't change our result. We focused on the tails of the distribution for the grain patches and the median value for the entire layer. It implies that the relative proportion of fine and coarse patches is not affected by the error measurement. Moreover, the error on grain sizing is the constant over the layer, the median grain size of all the layer is then affected the same way and shouldn't change the layer sorting.

Analysis and Results

- Page 586, line 20 - The whole section on bed layer construction reads like it should be in the methodology section of the paper. I would move it to after Equation 1.

We thought about this issue at the time of writing and decided that we preferred to think of this as part of the analysis in the sense that it is extracting answers to a particular question from the initial data (DEM and grain maps).

- Page 587, line 5 - The section on equivalent texture distribution covers the main results of your paper yet you dedicate only 12 lines to its description analysis. I think that given the changes to the results section suggested above (namely moving section 3.2 to the methodology section) it would be advantageous to combine the results and discussion section together given the brevity of the analysis section, especially the equivalent texture distribution analysis. This would help the latter part of the paper to flow better.

We will rearranged things slightly and moved the section heading.

Discussion

- Page 587, line 25- you mention that every equivalent texture occurs in each layer with approximately equal frequency- could the resolution you are measuring with have any impact on your results and ability/ inability to pick up some of the grain sizes, especially the fine grains ?

We assume that the error on grain size (regardless the grain size) is quite the same within each layer and also the error on grain size in not spatially based. The sorting of the layer shouldn't be impacted by the error measurement.

- Page 588, lines 19- 24- very long sentence, consider revising

The sentence will be split

Conclusions

- Page 589, line 2 – the experiments are analysed over a 40h period (plus the previous 140 hours formation time) – do you have a feel for how this scales to the temporal dynamics on the Sunwapta River ?

The temporal scaling and more generally the scaling is a complex issue. Our goal here is the first step in understanding how the vertical grain sorting is organized, without any temporal effect. It may be better to think of this as the time required to rework a substantial portion of the braided channel which is likely to be many days (or weeks) of high flow in the field case (and much longer in total given that flows are sufficiently high for only a small portion of the total time). We are continuing to work on this time scale issue using time lapse images from field site.

- Page 589, line 11-12 – you mention that further analysis is needed to understand how the mixing develops. This suggests the obvious link to the temporal dynamics of the system. In the paper, although you analyse over the 40 h time period you do not look at the temporal evolution of the development. I think this would be worth exploring as it would offer real insight into the timescales of development in the field and how we can use those timescales in numerical models and future experiments. I don't think you need analyse this over every hour of the time step but potentially breaking it down into 4-5 hour sections may yield some interesting results.

The temporal evolution of the grain size distribution is a very interesting and promising topic. However, the study that we present here is the first stage of a fuller analysis. Indeed, we aim to look more precisely at a larger range of results : grains size and bed features, grain size 'dynamics' with a new experiment using different time steps and better topographic precision and resolution.

3 Referee # 2

Received and published : 12 August 2015

This paper examines spatial grain size variability in the morphologically active layer of a braided river physical model. The morphologically active layer is defined as that volume of sediment bounded by the surfaces of deepest scour and highest fill at each plan position across the model domain. The model was run for 40 hours. A surrogate measure of bed surface grain size was derived once every hour from the grey-scale properties of bed texture in overhead imagery. Surface DEMs were created photogrammetrically from the same images. At each plan position, the thickness of the morphologically active layer was used to normalise the absolute elevations of each surface and the resulting relative thickness was divided into ten layers of dimensionless bed depth. For a given layer at each time point, a subset of plan positions had associated grain size estimates, so that forty spatially partial maps of grain size were constructed for each layer. Final maps of estimated grain size in each layer were derived by computing the median value of the grain size estimates at each plan position. Averaging by layer across the whole model domain provided an indication of the grain size distribution at specific relative depths in the morphologically active layer. With the exception that the two deepest layers show a tendency to be coarser grained, the distribution of grain sizes was almost identical within each layer. The principal result is then that the morphologically active layer was essentially homogeneous, which leads to the conclusion that in braided rivers, despite locally complex sorting, there should be very little vertical sorting of bed materials at reach scale.

General comments : The paper addresses a knowledge gap – we know very little about the 3D variability of bed material grain size in braided river deposits. I agree with the authors that this is a significant gap, for example when seeking to parameterise numerical models of braided or wandering river processes or when applying the morphological method to derive transport rates from measurements of morphological change. The modelling approach is appropriate ; indeed, physical modelling is almost certainly the only practicable means of studying this question. The idea of the morphologically active layer is very useful and normalisation of the cell-by-cell elevations by active layer thickness provides a sensible means of conceptualising and analysing the problem. In detail, the derivation of a median grain size surrogate using Carboneau's method is pragmatic and reasonably well constrained. The results are novel – I am not aware of any equivalent assessment of textural variability with depth for braided river deposits – and the conclusions will be of interest to the braided rivers community and those who work on related systems, including wandering gravel-bed rivers. Overall presentation is good. In sum, this is an interesting, well executed piece of work that can be published subject to consideration of some relatively minor points.

Specific comments :

- 1. The derivation of final grain size maps for each layer (Figure 7) is described in section 3.2. It is too succinct. It took a significant amount of time to understand the procedure (I hope the synopsis above is correct). A better explanation would improve the paper and a schematic diagram that illustrates how final maps were derived from layers, time and cell position would be beneficial. Readers will not be convinced by the results without a clear appreciation of how the layer by layer data were obtained.

We agree that the explanation of our method is perhaps too succinct. The following drawing will to be added to the paper (Fig. 2), as figure 6 on the paper. On the plot, the main steps are highlighted and present the core of the procedure.

- 2. A niggling concern is that the reconstruction of the sediment volume is based on multiple maps of the surface bed material. Where grain sizes from multiple time steps are available for a particular point in a particular layer you use the median to represent the cell's grain size (page 587, line 5), but no other modification of the grain size is made to account for post depositional alterations unless the surface is completely replaced. You therefore assume that the surface textures are preserved at each time step without subsequent modification or alteration. I'm not convinced that this is straightforward or reasonable. Some discussion is needed to clarify your thinking about the relation between the surface measurements that you use and the sediment volume that you derive.

Our method (limited to our conclusions) doesn't quite assume that the surface textures are preserved at each time step. At a particular time, the grain size is what it is. With that grain size, we link simply to its position in the morphological active layer using our dimensionless equation. The extrapolation on a bed core is indeed using the hypothesis that the grain size is preserved through time, and it also assumes that the layer is homogeneous vertically. That assumption is quite strong and we aim in further analysis to effectively dig the bed and try to find layers and boundaries. It is not clear what alternative assumption could be made given that any significant change in grain size from one time to another would likely be related also to a change in elevation. Our method is also likely to be analogous to any comparable

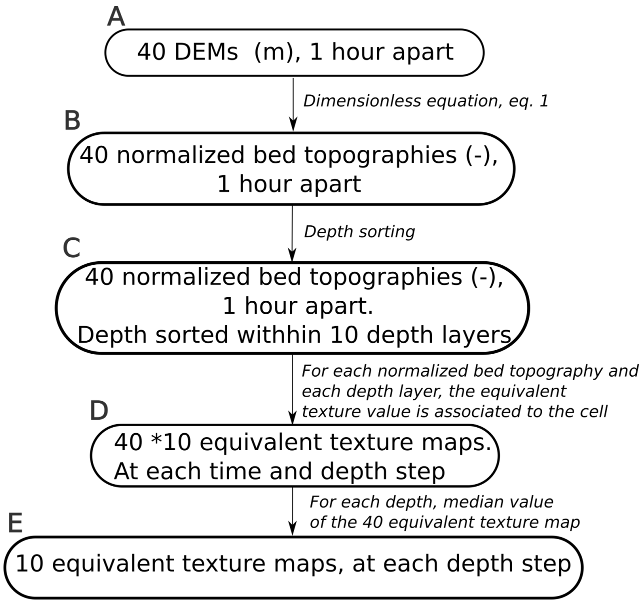


FIGURE 2 – Construction of the texture maps : (a) the bed topography derived from the photogrammetry process, (b) the normalized bed topography using eq. 1 (c) normalized bed topography sorted in 10 layers, the minimum and maximum surface are not included in the layers, (d) 400 equivalent texture maps (e) 10 median equivalent texture maps for each normalized bed depth.

numerical scheme.

- 3. Figure 9 is not terribly convincing. The associated text is quite speculative, so it just about works, but a fuller analysis of the spatial coincidence of the confluence zones and coarsest patches would improve the argument.

The figure 9 presents the coarse patches relative to the confluences over the bed. It comes from classic direct observations that the downstream end of the confluences is generally coarser than the upstream. The map is also time integrated i.e. the confluence mask represents the position and the migration of the confluence over the time period that it existed. A much finer and fuller analysis may make the result more convincing and the intention of this section is only to point to those possibilities and interpretations. The confluence and grain size study is the subject of another paper in preparation.

- 4. Gravel-bed rivers are generally expected to exhibit armouring, albeit patchy and dependent on sediment supply and it is likely that many readers will be interested in what this data set reveals about relative surface coarsening. It would be good to see some explicit consideration of the degree or not of surface coarsening because armouring plays a key role in our understanding of transport processes and is always a consideration when sampling surface vs sub-surface bed materials.

The analysis that we present is done for the surface grain sizes in each DEM. Armouring is a near-surface phenomenon and our data do not allow us to make the traditional surface / sub-surface layer separation on which analysis of armouring in gravel-bed rivers has been based. Our data do show that grain size varies considerably across any particular DEM and that therefore any surface coarsening is limited in extent and cover layers of various sizes are common (Carson and Griffiths, 1987). See also our response to referee 4 on this subject.

- 5. Sticking with sampling, the results presumably have implications for how braided river deposits should be sampled in order to obtain representative grain size data ? It would be useful to see some consideration of that as a justification for and outcome from the work done.

This is a useful point that we had not contemplated. The sampling of a braided river is a complex topic and it depends on the purpose of the sampling. One interpretation of our result is that a complete map of surface grain size over a sufficient extent may yield data representative of the bulk of the morphological active layer but we have not tested that hypothesis formally. Another implication is that the depth of sampling should not have a large effect on representativeness of bulk samples. This was not our purpose in doing the analysis but we agree that the result may provide some useful guidance for sampling decisions and representativeness.

Technical corrections :

- Page 579, lines 1-15. Many of the sorting patterns and processes at work in braiding rivers may also produce similar sedimentary packages in wandering gravel-bed rivers. Is the literature on wandering river sediments of value here (and might the results be applicable in such rivers ?)

This is an interesting point and one could think of doing comparative analyses of differing river types including laterally stable channels or meandered channels with side bars or point bars. It happens to be the case that for physical modeling (which is the basis of the data collection) the braided case is easiest to develop.

- 2. Page 579, line 20 (and elsewhere, e.g. 578, line 24). It is not clear how you are using the word "aggregated" and whether you are using it consistently. Sometimes it seems to be used to just mean averaging, but in other cases I suspect you mean something else. Clarifying this may help with the need to improve explanation of the process by which the grain size layers were derived.

By aggregated we mean that we take the entire bed area as the sampling volume (full river width and length) from which the grain size (equivalent texture) values are calculated for each layer.

- 3. Page 581, lines 26 on. This sentence is too long and should be split in two.

Change planned in response to same comment from ref 1.

- 4. Page 582, lines 7-9. The final sentence of the first paragraph is not needed and should be deleted.

We will rephrase these lines.

- 5. Page 583, line 1. Is this discharge figure correct ? It seems very small.

The discharge is correct, 2.1 litres/s. the initial channel was 1.5 cm deep and 50 cm wide. Approximately 1 :30 Froude scaling means that this scales up to about 10 m3/s (discharge scale is length scale to 2.5 power) and 15m wide / 0.45m deep initial channel.

- 6. Page 583, line 9. Did you have a set of criteria that helped you decide when the flume bed became fully braided ?

Several aspects have been used to set the braided set : the stabilization of the general pattern, if the entire bed has been removed, stabilization of the number of active channels, and the river occupied the full 3m width of the flume.

- 7. Page 583, lines 24-26 are unclear and incomplete. Please unpack Carbonneau's method a little so that readers who are unfamiliar with it gain some insight into what it does.

For example, what is the “entropy value” here.

The entropy is a method use to highlight a similar pattern over a picture. Calculations are done on a window around the investigation point. Within that window, similar pattern (number of pairs with adjacent cell color) is counted, and from that number the entropy is calculated. The high value of entropy indicates a defined pattern whereas a small value of entropy means a surface is poorly sorted. Some details on the entropy concept and method will be added to the paper.

- 8. Figure 6 floats – there does not appear to be any reference to it in the text.

We will correct that.

- 9. Figure 8 is the key analytical figure and is useful in showing that the equivalent GSDs vary little between layers. However, it is much harder to extract from this a straightforward evaluation of how estimated median size varies with depth, which is one of the points you try to make on page 588. A simple plot, perhaps inset in Figure 8, would make this claim easier to evaluate.

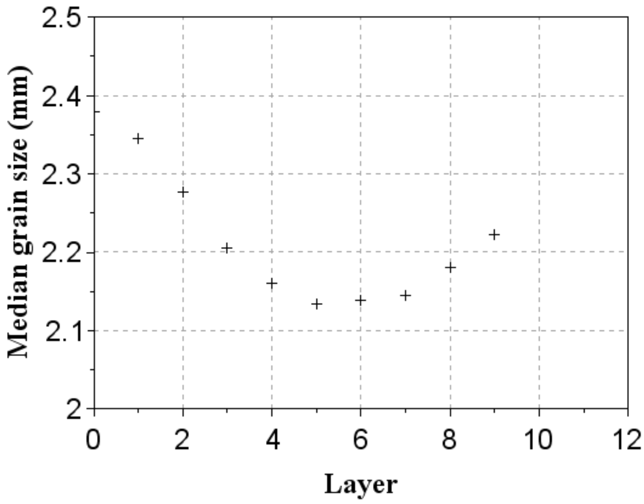


FIGURE 3 – The median grain size of each layer

This simple plot (Fig. 3) is the median size of each layer. The conclusions are essentially the same as the histogram plot in the paper : the coarser layers are closer to the minimum surface. Nevertheless, the main disadvantage of this plot is that we can't see the full range of values within the layer. The first result that we get from our analysis is that every layer is mostly composed by the same pattern. Reducing the histogram to a simple plot removes a part of our results.

4 Referee #3

Received and published : 25 August 2015

General comments : The authors present an analysis of vertical sorting over the surface layer that is subject to reworking in a physical experiment of a braided stream. The experiment was previously described by Gardner and Ashmore (2011). The main message of the paper, i.e., there does not seem to be significant evidence of vertical sorting in the physical braided stream, is clear and a finding that is expected to be significant to many readers. Although this is interesting, the referee does not quite understand why the authors do not discuss sorting issues in other directions, of which lateral sorting seems more relevant than streamwise sorting. A discussion on the similarities and differences regarding vertical sorting between braided streams and dune-dominated rivers is currently missing. The referee would propose to change the term "morphological active layer", because the term "active layer" is generally applied to the Hirano mixing layer that is required in numerical computations of mixed-sediment rivers. This numerical active layer (i.e., the Hirano mixing layer) is not necessarily the same as the "morphological active layer" that the authors consider in their paper, which may confuse the reader. The referee therefore proposes to change the name of the authors' "morphological active layer" to something like "layer of reworking" or "reworking layer", and its thickness to "depth of reworking".

Thank you for the comment related to terminology and especially the link to concepts and definitions used in computational river mechanics. It seems to be common to refer to bed layers of the type we are discussing as 'active', 'mixing' or 'exchange' layers depending on the circumstances. In gravel bed transport theory and measurement the term active layer is often used to denote the surface layer for particle exchange between the bed and the active transport over short time scales of grain entrainment-distrainment. We are referring to something different but related - the layer of sediment that exchanges with transport over longer time scales and greater depth during the morphological development of the river bed (bed scour and fill, braid bar development etc.). With that in mind, we adopted the 'active layer' concept but added the 'morphological' component to convey the connection to, and difference from, the active layer concept. It seems that we are also very close to what Hirano (and others) conceive in numerical fluvial dynamics as the mixing layer – the layer that supplies sediment to sediment transport, including that involved in exchange with the bed during bedform (e.g. dune) migration. In our case however we are adding longer-term development, and therefore a thicker layer, related to local scour-fill, short term aggradation-degradation and the like (similar to ideas and terminology of Viparelli to which we refer). So we think that we are actually not far apart and that "morphological active layer" or "morphological mixing layer" is consistent with Hirano and others by extending the mixing layer to the depth of the minimum surface of morphological re-working and perhaps extending the time scale of reworking that is considered. For those reasons we prefer to stay with our terminology which seems to link to physical and numerical analysis of bedload and bed morphology in gravel-bed rivers. It is also consistent with other numerical schemes such as that used by Sun et al. (2105).

More specific comments :

- the title would be more informative if it sounded like 'Vertical sorting in a braided river physical model' - the introduction is quite extensive compared to the description of methodology and results. - Vertical sorting is not evident from the measured data, yet lateral sorting seems to be quite important. The current manuscript lacks a description of lateral sorting processes.

The lateral sorting is important in river dynamic and sediment transport processes. Vertical sorting is not so obvious in our planform maps but is the result of the co-variation of grain size with local elevation and is in part due to lateral sorting on bed features of varying elevation and topographic amplitude. We chose to focus here on the vertical sorting and present this distinctive result. The analysis that we have done is only the first step of the application of our method. With our data set we aim eventually to get a fully 3 D study, including the lateral sorting.

- p583 the entropy method is not yet clear to the referee.

The entropy of the picture is used to find some common pattern : the more there is a defined pattern the higher is the entropy. The calculation is made over a window surrounding the investigation point. In that window, we keep record of the number of specific couple (e.g. on *a greyscale, cell with 54 next to a cell of 10). We use different sums to extract the entropy value. The entropy gives an idea of the roughness of the image (and therefore the bed surface) i.e. smooth vs noisy areas. A mention of the meaning of the entropy index will be added to the paper.*

- p584 and Fig1. The scatter in these figures is not negligible and this may not be reassuring. Can the authors comment on this ?

We recognize that scatter is quite large. One fundamental aspect of the calculation on the entropy has to be considered :
The entropy value is an averaged value over a 1 cm^2. On that area, the bed is composed of a mixture of grain sizes. As only the median grain size is taken into account, several bed mixtures can be associated with the same real grain size but not the same entropy value. As the entropy measurement is spatially based, we tried to minimize this error by choosing the window size that minimizes the scatter of the plot.

- p584 line14-15. The term "equivalent texture" is not sufficiently clear to the referee. Are we here talking about a mean grain size on phi-scale ?

The equivalent texture is derived from the texture calculation. As we want to keep in mind that the entropy calculation is spatially based and is not a 'grain scale' grain sizing (e.g. edge detection or manual sieving of individual grains and the statistics of that sample as conventionally done in physical analysis of grain size distributions), we prefer to keep the result of the entropy calculation "equivalent texture" distinct from the "grain size" that results from conventional analysis to remind readers of the nature of our particle size data.

- p585 To avoid confusing the reader, the referee proposes to change the term "the active layer involved in particle exchange during bedload transport" to "the surface layer that represents the sediment that interacts with the flow at a specific time and so determines the rate and GSD of the transported sediment".

We prefer to keep it as written and as usually discussed in literature on fluvial gravel transport. The active layer is not only the surface grains but rather a surface layer extending (typically) to 2D90 below the surface. It is the distinction from our (deeper) morphological exchange layer that we wish to emphasize.

- p585 Eq1 and above and below. Here the term 'depth' is not used well. One needs to distinguish between "elevation" and "depth or thickness". Please also use different symbols for elevation and depth parameters. h(x,y) and DeltaH both are a "thickness", whereas H and Hmin are "elevations".

The modification will be made, and symbol of thickness and depth will be different.

- p585 line 19. H(x,y) is not just the "initial" bed elevation, right ?

The H(x,y) is indeed the initial bed elevation of the DEM. The sentence will be rephrased.

- p588 lines 2-5. Could the fact that the lower elevations of the "reworking layer" are slightly coarser than above have to do with the fact that there were bars migrating through the system that deposit the coarser fractions at the base of their fronts (eg Blom et al. 2003) ?

With the analysis that we are presenting here, we are not able yet to answer to that question. Analysis at the bed feature scale could answer that interesting point. Using further analysis we aim to look at grain size in relation to specific features in more detail. There may be some coarsening at the base of abrupt bar fronts but these are not common and migration distances are short. It may point to significant and diagnostic differences between the two types of morphology and bedform dynamics.

- Figure 3. The parameters plotted in Figures 3a, b, and c are different ones. Therefore please use different symbols, and describe the symbols. Please make a distinction between elevation and thickness. Please use the same colorbar for Figures 3a and 3b.

We will change the symbols to match eq1, and also color bar for 3a) and 3b)

- Figure 5. The caption says "Fine sediments are lighter than coarse sediments." Isn't this a trivial statement, unless we would speak of a difference in their mass densities ?

The "lighter" refers to the color shade (grey scale) of the picture. We will clarify this in the caption.

Some details :

- p579 line 7 near-surface → subsurface ?

We prefer it as written.

- p581 line 1 10.D90 → 10 D90

We will change that to match the previous symbol ($2 \times D_{90}$)

- p582 line 7 Can we start a sentence with "but" ?

We are not aware of strict usage rule that forbids it.
Support for this can be found, for example, here : http://www.quickanddirtytips.com/education/grammar/can-i-start-a-sentence-with-a-conjunction.
We will, in any case, reword the two sentences in response to this comment and a related comment from ref 2.

- p583 line 13 The 'one hour intervals' need to be explained better. Is the flume drained before each measurement ?

The flume is indeed drained before each measurement because photogrammetric measurement cannot be done through the water free surface (light reflections on the surface are one of the problems). We are assuming the flow increase and decrease (few minutes each time) don't disturb the sediment dynamic at the experiment scale (40 hours). Stage drops very quickly compared to, for example, falling limb of a natural hydrograph and we see only very local effects such as modification of (the few) abrupt bar faces and these kinds of features are also very common in field settings.

- p586 line 22. The brackets are not well oriented.

The brackets are oriented on purpose : $x \in]a, b] \Leftrightarrow a < x \leq b$. The boundary value of the layer can't be in 2 different intervals. The minimum and maximum surface are defined by themselves.

- p587 line 11. "almost identical" → "similar"

We prefer it as written because it gets us closer to our intended emphasis.

- p587 line 14. Not sure if the term "the minimum surface" is well describing what you want to say.

The term minimum surface refers to the minimum elevation for each cell the DEM array that the bed reaches during the 40 hours. On fig 8 on the paper, layers 1 and 2 are layers that are respectively at 10 % and 20 % of the morphological active layer (from the lowest point), therefore close to the minimum surface.

- Figure 4. Which two parameters are plotted precisely ?

The main purpose of our work is to look at the vertical distribution of grain size. One way could be simply to plot the relationship bed elevation vs. grain size. Plot 4 is that relation : grain size = f(bed elevation) for each cell. On that plot we can see that there is not a clear trend and this relation is disturbed by the slope. Indeed, the same elevation can correspond to a channel bottom or a top of bar, and depends on slopes (transverse and longitudinal). This simply shows that even on a single DEM there is no clear relationship between bed elevation and grain size over the full amplitude of bed topography. It helps to assure us that the result we see for the full array of DEMs is reasonable in this sense. The difference is that we are able to put this bivariate relationship into a spatial/3D context.

5 Referee #4

Received and published : 26 August 2015

This paper reports on a physical model experiment of a braided river that was set up to investigate vertical and horizontal variation in grain size. The model was perturbed with a constant discharge rate and sediment was recirculated through the model. Digital elevation models and grain size maps were constructed for 40 equally spaced timesteps, using photogrammetric and image texture analysis methods respectively. To my knowledge, the paper addresses an important gap in the understanding of grain size distributions in braided rivers. As the authors explain in the introduction, sampling in the field is a Herculean task and therefore the use of a "controlled" laboratory experiment is the most appropriate approach to investigating the research question.
I am confident that this paper will be of interest to readers of ESurf. It is written to a high standard and, in my opinion, requires minor revision before publication. The literature review is thorough and provides a full context for the investigation. The methodological description is also comprehensive although several aspects could be clearer, as I outline below. The analysis and discussion are appropriate but I believe more could be made of the equivalent texture maps.

Detailed comments :

- P582 L20 : What was measured in the field ? A bulk distribution ? What sampling criteria were used ? What proportion of the bulk was ¡ 8 mm ? If a surface, or surface layer, sample was obtained then what are the consequences for the model scaling ?

The grain size was measured in several ways : Wolman, bulk or using an adaptation of the surface paint-and-pick method. Grains have been collected over the years to have a good spatial and temporal overlook of the grain size. Overall almost 7000 grains have been picked. Grains smaller than 8 mm haven't been picked for all the samples. Using the available data, the proportion of grain smaller than 8 mm is ranging from 2 % to 30 % with a mean value of 9 %. The scaling of the model has been done after the first results.

- P583 L15 : Can you provide a fuller report on the mean elevation errors ? How many points and DEMs were considered ? What was the standard deviation of this error ?

*There are 40 DEMS with a 3 mm cell size which represents 3334*868 pixels for each DEM. The error estimation has been done on a flat area that didn't move during the 40 hours of experiment. The DoDs highlight the error measurement. The surface size is 400*50 cells* *which correspond to a surface of 12cm long and 1.5 cm wide. For 39 sets of DoDs we get an error estimate over 781- 950.points (Fig. 4). The mean error is* ν*= -0.02 mm and a standard deviation is* σ*=0.79 mm. We assume a normal distribution and we consider the interval [-3.*σ *; 3.*σ*].*

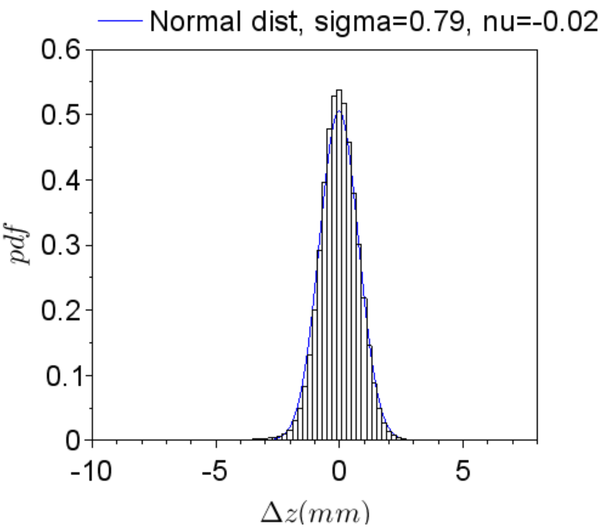


FIGURE 4 – The error distribution

- P584 L21 : Did the calculation of difference account for errors in the minimum and maximum surfaces i.e. was a minimum level of detection or probabilistic DEM of Difference approach used ?

We used the minimum level of detection to build the DEM of difference.

- P584 L26 : The term "deposit thickness" needs to be clearly defined. Is this equivalent to deposition during a one hour DEM sampling interval ? This term may need to be clarified earlier within this section to improve clarity.

The deposit thickness is the actual layer of sediment above the minimum surface at a particular time (the deposit thickness is time dependent). The morphological active layer takes into account the part that has been removed.

$M \in \{$ *deposit thickness at* $t = t_1\} \iff \{M / h_{min} \leq M \leq h(t_1)\}$
$M \in \{$*morphological active layer*$\} \iff \{M / \forall t, h_{min} \leq M \leq h_{max}\}$
A clarification will be added to the paper.

- P585 L18 : The dimensionless analysis is a key part of the analysis but it could be explained more clearly e.g. that this was done for each DEM ? Is the initial bed depth referring to the first DEM, or the initial depth for each time period ? Were there any compensatory patterns of erosion and deposition ? If so, what are the consequences for the results ?

The dimensionless analysis is indeed done for every DEM. We turn the 40 'metric' DEMs into 40 dimensionless DEMs. The initial bed depth refers to the bed elevation of the DEM. The symbol and wording will be changed in the paper to make it clearer. We will add the following conceptual drawing to the paper (new figure 6 in the paper) to make the reasoning clearer (Fig. 5).

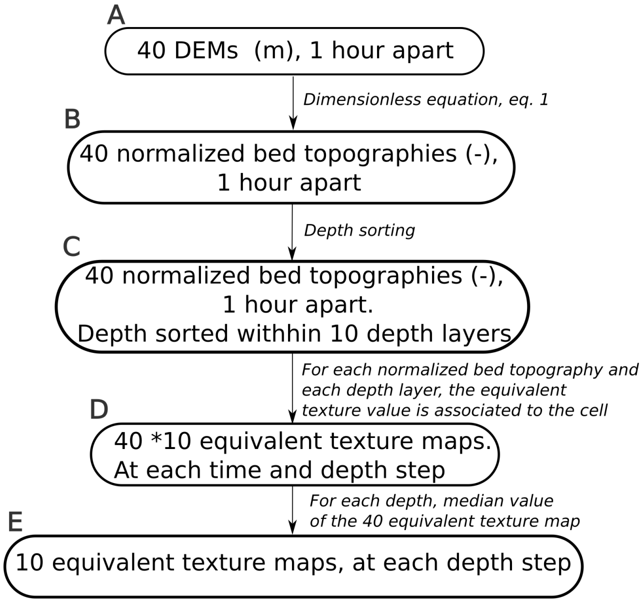


FIGURE 5 – Construction of the texture maps : (a) the bed topography derived from the photogrammetry process, (b) the normalized bed topography using eq. 1 (c) normalized bed topography sorted in 10 layers, the minimum and maximum surface are not included in the layers, (d) 400 equivalent texture maps (e) 10 median equivalent texture maps for each normalized bed depth.

The river was in overall equilibrium, rather than steady, net aggradation, therefore compensatory erosion-deposition occurs frequently as it does in natural rivers in net equilibrium. This is the state that we intended to analyze. This is also conceptually a difference between the morphological active layer and the extant 'lithosome'. The question we address in the paper is whether this 'mixing' of the morphological active layer produces any distinct vertical segregation of grain size.

- P586 L14 : Check brackets around Nelson et al., 2010.

We will make the change.

- P586 L22 : Check brackets – I'm not familiar with this presentation format.

Those brackets (eg]0.1,0.2]) mean that the value 0.1 is not in the interval :$x \in]a, b] \Leftrightarrow a < x \leq b$.

- P586 L26 : This paragraph may be easier to read if it starts with the sentence on this line.

We will make the change.

Discussion :

- The results indicate that an armour layer is not evident within the grain size mix of the upper most layer ? However, winnowing of fines in this layer may be expected in a "real river". Is this a consequence of truncating the grain size distribution at 8 mm ? Also, it would be interesting to investigate whether there are any "signatures" associated with different depositional units : data are available here to consider the question at a finer spatial resolution than the "aggregate reach scale".

We partially answered the armouring question in response to referee 2. Analysis of armouring is usually done in 'real rivers' using a truncation at fine gravel so we expect no difference (see Church et al., 1987 who also find almost no evidence of a distinct coarser 'surface bed' layer) . But in any case our data were not intended to address questions of near-surface armouring. In braided rivers armouring is often poorly developed, Mueller and Pitlick 2013 may have the best recent evidence to support this : `http://onlinelibrary.wiley.com/doi/10.1002/2013JF002843/full` *: Ṕor the 34 sites where we have complimentary data, the ratio of surface median grain size to subsurface median grain size decreases from about 5 to 1.5 as concentration increases. On the other hand, the subsurface sediment size changes very little with sediment concentration. A striking result is the convergence of these sediment populations at high sediment concentrations : at the upper end, armoring is nearly eliminated, and channels are predominantly braided (Figure 12).T́he suggested study on the grain size distribution at the features scale would be highly relevant. However, this paper represents the basic analysis and we aim to go further in that direction in subsequent analyses. Fig. 9 is an initial step in that direction.*

- Fig 1 : Check use of negatives on axes and on axes labels.

The label refers to the variable being dimensionless. The plot will be changed (Fig. 6) to avoid confusion.

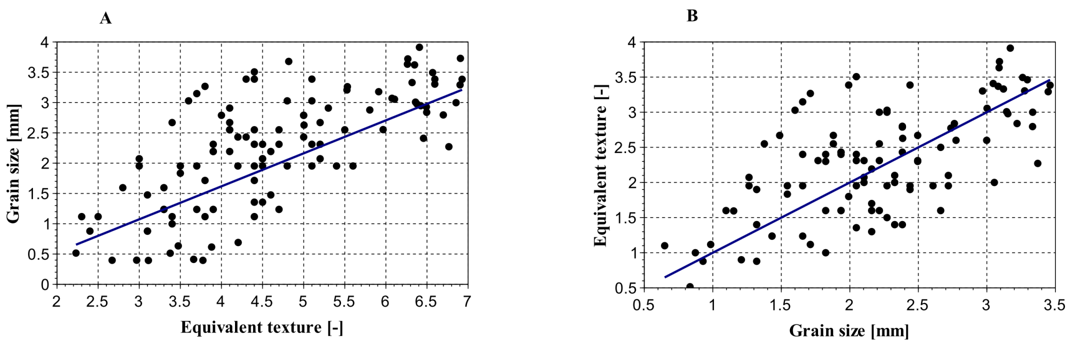


FIGURE 6 – New figure 1 on the paper, the negative values are removed to avoid confusion

- Fig 2 : Comment for (b) that longitudinal gradient is removed ?

Indeed, the longitudinal gradient has been removed to see more clearly the bed form, bars channel. In other words the DEMS are adjusted to a sloping datum equal to the overall river slope.