Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2019-75-AC1, 2020

Interactive comment on "Short communication: Field data imply that the sorting (D_{96}/D_{50} ratios) of gravel bars in coarse-grained streams influences the probability of sediment transport" *by* Fritz Schlunegger et al.

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Received and published: 25 March 2020

Review #1 by Georgios Maniatis

We thank the reviewer for the very detailed and careful assessment of our work. Please find below our explanations of how we handle the comments and suggestions.

General comment by the reviewer The authors quantify and cross-compare the probability of sediment mobilisation in a number of streams in the Alps (Switzerland) and the Andes (Peru). They attribute the observed differences in the probability of mo-

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Discussion paper

bilisation between the two environments to the different degrees of sediment sorting characterising the two settings (quantified as the D(96)/D(50) ratio). The authors provide adequate context and they use a well-known modelling framework (based on the exceedance of critical shear stress $\tau > \tau^*$) to calculate the probability of sediment mobilisation. They also use standard techniques to approximate grain sizes and merge different sampling techniques in a convincing way. Uncertainties are then propagated using a Monte Carlo framework and the derived results are analysed using standard regression techniques. These two latter components of the paper need to be discussed more. The Monte Carlo calculations need to be introduced separately from the bed load modelling and the grain size sampling framework to a) enhance readability** and b) extend the justification on the assumed uncertainties used in the error propagation.

Our response: This has been done. We explain the Monte Carlo framework in a separate chapter of the main text along with an explanation of how we have assigned uncertainties to the variables, and how we justify these. We additionally present further information in the Supplement on how we have estimated the uncertainties for the D84. We base this on the analysis of the intra-bar variation of the D84 for selected gravel bars in Switzerland. These data is presented in the Supplement S1. For the Peruvian streams, the uncertainties on channel slope and particularly on channel widths are much larger, mainly because of the lower resolution of the DEM (2m in Switzerland versus 30 m in Peru), and since the Peruvian streams are to large extents not confined in artificial channels. Therefore, we cannot fully quantify the uncertainty on the channel widths for the Peruvian streams, and we acknowledge this in the main text. However, we run sensitivity tests to explore the dependency of sediment transport probability on the assigned uncertainties. The dependency between grain size sorting and transport probability will remain. We illustrate this in the Supplement S4 and S5. In Peru, channel width data were collected from digital images that were taken between March-August, which also corresponds to the season when the digital photos for the grain size analysis were made (Mai 2015). However, we acknowledge that because of the strong seasonality of water discharge in Peru (please see Table 1 in the main text that displays the intra-annual variability, and Supplement S2), widths of active channels vary greatly within one year. We therefore performed a Monte Carlo simulation for the case where active channels are up to twofold wider, and we additionally added a 50% uncertainty to these values. The results show an identical dependency between sediment mobilization probability and grain size sorting. We illustrate the results of these sensitivity tests in the Supplement S4 (Swiss rivers) and S5 (Peruvian streams).

Further general comment by the reviewer The regression analysis needs further validation and does not directly quantify the relationship explored in this work.

Our response: This is done, and the results are displayed in the new Figure 3b. I consider those revisions to be minor since they can be directly addressed using the existing calculations and the should not affect the key outcomes of this work. I find the main message of the paper, the dataset and the methodological approach very interesting, important and within the scope of EarthSurfD. But I also believe that the presentation can be enhanced.

Specific comments Reviewer: 1. Lines 32-34 Need to clarify this hypothesis. For example, for the first part: "well sorted bars are less frequently reworked", I think it is necessary to add "under relatively low sediment flux conditions". The second part (“braided streams host gravel bars...") is clearer.

Our response: This has been done. We have changed the introduction and clarified the hypothesis to be tested.

Reviewer: 2. Lines 41-42: That sentence is vague. How is the mobilisation quantified? If it is an approximation based on a function of critical shear stress then it is a threshold by definition. Is this an a-posteriori evaluation? (implying that the authors observed particular events?)

Our response: The approximation is based on a function of critical shear stress, so it is a threshold. We have specified and clarified this point.

Reviewer: 3. Lines 45-46 One can read this as selecting from a braided river the only segment that is not effectively braided. How can the authors justify that the confined segment will have similar (or relevant) mobility with the rest of the (braided) river?

Our response: We acknowledge that this selection could bias the analysis towards a greater mobility, mainly because the streams have greater shear stresses where water flow is confined in one single channel. We add a related cautionary note in the modified version of the paper.

Reviewer: 4. Lines 54-55 This is very clear, but it is necessary to clarify the corresponding part of the introduction as well (Comment 2).

Our response: This has been done.

Reviewer: 5. Lines 63-66 It is not very clear how you employ the full range of φ, I assume that you imply a uniform distribution between 0.03 and 0.06 in a randomisation type framework, but it needs clarification.

Our response: This is indeed the case. We have clarified our methodological approach accordingly and expanded the section where we justify the employment of φ. We are also mentioning this in the new section related to the Monte Carlo simulations

Reviewer: 6. Lines 73-74 I am not sure the reference to the D(50) threshold adds anything to the methodology here. On the contrary, it slightly complicates it.

Our response: We agree. The D50 is frequently used as threshold by previous authors, and therefore we decided to mention this. However, we specify and clarify why we prefer the D50 as threshold grain size.

Reviewer: 7. Line 92. This similarity needs to be explained (or the comment needs to be re- moved).

Our response: We decided to remove the comment.

Reviewer: 8. Lines 93 to 96 The Monte Carlo framework needs to be introduced earlier. That will put in context some of the methodological comments that are difficult to understand (e.g. Comment 5). It is also possible to separate completely the layout of the bed load equations from the error propagation and devote one short section on the Monte Carlo calculations only.

Our response: We prepared a new chapter referred to as ‘Monte Carlo simulations’ where we explain of how we proceeded. We additionally add a new section where we justify the assignment of uncertainties to the variables.

Reviewer: 9. Lines 105-106 This is a small detail, but it would be great (for completeness) if the authors could state how they calibrated their photographs (what is the measured dimension that converts from pixels to length?)

Our response: This has been done.

Reviewer: 10. Line 110 "few millimetres" is vague. A number is needed here (preferably in conjunction with the pixel-length conversion).

Our response: The resolution of the digital images indeed sets the lower boundary for measuring the fine-grained fraction, which adds a bias in the analysis. In our case, grains smaller than 4-5 mm cannot be identified with confidence. Watkins et al. (2020) showed through a comparison of sieving and the application of the Wolman (1954) method that the differences in the results are largest for the smallest grains including the D50, but that the results are quite identical for the D84 and larger grains including the D96. If we would consider the relationships between the probability of sediment transport and the D96/D84 ratio (instead of the D96/D50 ratio), the conclusions will be the same. We address this point more carefully in the revised manuscript.

Reviewer: 11. Lines 119 and 121 The assignment of those uncertainties is not justified in a quantitative manner. It would be useful to see (here or in appendices) some quantification on the variance of channel widths and gradients (a simple boxplot would be more than enough) and statistics of the validation of DEMs (which must be already calculated). Similarly, the uncertainty assigned to the grain size data set should also be a function of natural variability and measurement error.

Our response: We present data in the Supplement that illustrates how the D84 grain sizes vary within the investigated gravel bars (Supplement S1). The mean of these variations is c. 20%, which corresponds to the assigned uncertainty. We cannot precisely constrain the uncertainty on the channel gradients as we don't have the required information. However, it is very likely that the uncertainties on the slopes and the wetted channel widths are smaller in Switzerland (and possibly smaller than 10%) than in Peru because the water runoff in all Swiss streams is confined in single-thread, artificial channels with a constant width over several kilometers, while the Peruvian streams are braided. In addition, the resolution of the available DEM is much higher for the Swiss sites (2 m lidar DEM) than in Peru. For the Peruvian sites, the largest uncertainty for the assignment of values to channel widths stems from the difficulty to precisely determine the width of the wetted cross-section during the conditions of a mean annual water discharge (Qmean), mainly because of the braided character of these streams and since we lack the required information. We therefore run Monte Carlo simulations where we allow the Peruvian channels to be twice as wide for the same Qmean. As will be outlined in the discussion, the positive relationships between sediment transport probability and grain size sorting will remain.

Reviewer: 12. Lines 154-155 Is Maggia the only river with a confluence <1km upstream? I think the argument about the response to an extreme holds better.

Response: We agree and have adjusted the text accordingly.

Reviewer: B. Lines 158-162 I find this interpretation quite strong. These regressions show (in my opinion), that sorting explains a higher percentage of the variance of the mobilisation probability in the Alps than it does for the Andes.

Response: We read the diagram in the sense that the probability of transport occurrence is higher for poorly sorted sediments than for better-sorted ones for both the

Peruvian and Swiss streams, and we justify this interpretation by because the relationship is significant. We present p-values and the residuals. The data shows that a relationship between transport mobility and sorting does exist for Switzerland and Peru, and it is stronger for Switzerland. However, other parameters/mechanisms such as sediment supply and stochastic processes could influence the sorting, which we discuss in the article.

Reviewer: Additionally, the weak correlation for the Peruvian rivers indicates that sorting can be a secondary control in the Andes.

Response: We acknowledge that the correlation coefficient is rather weak for Peruvian rivers, which we explain by the stochastic nature of sediment transport and the large variability of processes at the reach scale.

Reviewer: Consequently, it is difficult to compare the two regressions (the model for the Alpes and the model for the Andes) in terms of the effect of sorting. That would be the case if they were two very strong regression models and there was a noticeable difference between the regression parameters.

Response: We agree that it is difficult to compare both cases in terms of the effect of sorting. However, we state that the differences in sediment transport mechanisms between non-confined braided streams in Peru versus single-thread (artificial) channels in Switzerland are likely to explain some of the observations, and they also appear to be reflected by the different relationships between the sorting and the probability of sediment transport occurrence. We agree that on Figure 3a itself, we do see that the regression of the Swiss rivers (slope=0.16 ± 0.06; intercept -0.34 ± 0.31) appears different to that of the Peruvian streams (slope=0.18 ± 0.11; intercept -0.02 ± 0.46). Admittedly, if we look at the regression parameters (i.e. slope and intercept), the parameters are not significantly different. We acknowledge this observation in the text.

Reviewer: 14. Lines 178-180 That is true, however no information on the distribution of the residuals is provided so there is a question regarding the assumed linearity of these relationships.

Response: We now provide a new Figure 3B, which illustrates the normalized residuals against the sorting. This plot shows that the normalized residuals do not show any specific and significant patterns, and they are therefore independent on the sorting. This suggests that the inferred linear relationships between the probability of transport occurrence and the D96/D50 are statistically robust.

Reviewer: 15. Lines 182-183 I believe that this is the main message of this work, however the regression analysis presented here does not quantify that difference. It is possible make this observation in the scatter graph of Figure 3 but another type of presentation is necessary.

Response: We additionally present the residuals, which confirm the linearity of the relationships.

Reviewer: 16. Lines 193-194 The regression analysis presented here supports that statement although further validation is needed.

Response: We hope that the presentation of the residuals in the Figure 3B clarifies the situation.

References:

Watkins, S., et al.: Straight from the source's mouth: Controls on field-constrained sediment export across the entire active Corinth rift, central Creece, Basin Res., in press. Doi: 10.111/bre.12444.

Wolman, M. G.: A method of sampling coarse riverbed material, Eos Trans. AGU, 35, 951-956, 1954.

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