Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2019-75-AC2, 2020

ESurfD

Interactive comment

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.

Fritz Schlunegger et al.

fritz.schlunegger@geo.unibe.ch

Received and published: 25 March 2020

Anonymous Referee #2

We thank reviewer 2 for the very supportive and constructive comments, which we have considered as very useful and helpful. We have considered all suggestions and have adjusted our text accordingly.

Received and published: 18 February 2020 Summary: This paper conducts Monte Carlo simulations to determine the likelihood of bed material mobility of D84 at mean annual flow (maf) in 35 gravel bedded rivers in Switzerland and Peru. The authors find that the probability of gravel mobility varies with the ratio of D96 to D50, such that D84 is less likely to be mobile at maf in channels with more uniform grain size distributions when compared to wide grain size distributions. This is an interesting finding, which should be shared. However, this paper needs substantial work before it is ready for publication.

Reviewer: Intro/general 1. I found the framing in the Abstract and Introduction confusing. Some of this is due to imprecise wording: - The authors talk about the "mobility of gravel bars", but their work is actually focused on the mobility of individual grains of sediment. While bedform migration does require bedload transport, the work presented here never deals with morphologic change. I suggest the authors re-word.

Our response: We use the term mobility of grains instead.

Reviewer: The authors use the phrase "sediment flux" (ln 24) and "sediment discharge" (ln 12) where "sediment supply" would be a more appropriate choice.

Our response: We changed the term and use 'sediment supply' instead, as proposed by the reviewer.

Reviewer: In the title (and throughout the text), the authors suggest that grain "sorting" influences the probability of sediment transport. Isn't it just as possible that the causation runs the other direction? (Sorting reflects sediment transport conditions, as controlled by sediment supply?)

Our response: We find that the mobility probability decreases for better-sorted material. This does imply that the sorting of the material has an effect on the mobility of deposited grains. Therefore, we consider our statement that the sorting influences the mobility as valid. This does not exclude that the ultimate control is sediment supply. We don't have the data to further test this possibility, but we bring this up at the end of the discussion. However, we changed the title to Field data imply that the sorting (D96/D50 ratios) of grains on fluvial gravel bars influences the probability of sediment entrainment. We consider that this title better reflects the contents of the paper.

Reviewer: 2. Many of the ideas presented in the hypothesis go unaddressed in the paper. As I read it, the hypothesis (which begins at Ln 27) is that high sediment supply channels tend to be braided, with high bed material mobility, while low sediment supply leads to single threaded channels with armored, well-sorted beds with lower bed material mobility. However, this manuscript presents no data on sediment supply or armoring. Furthermore, the Swiss channels are not (necessarily) naturally single-threaded channels. I suggest that the authors re-frame their hypothesis so that it is testable with the data presented in the manuscript.

Our response: This has been done. We changed the introduction to better frame the hypothesis to be tested. In particular, the aim of our paper is to explore whether there is a link between the sorting of fluvial gravel bars, in our case quantified by the D96/D50 ratio, and the probability of material transport of individual clasts on these bars.

Reviewer: 3. The motivation for this study seems a little fuzzy (gravel mobility is important because of bar mobility?). Given that the main findings relate to the mobility of D84, the authors could consider using Mackenzie and Eaton (2017 and 2018) as motivation.

Our response: Thank you for this reference. We have rewritten the introduction to better motivate our study and to better focus the hypothesis that we wanted to test. Please see also our response above.

Reviewer: Methods: 4. Channel width was measured from aerial photographs, but I am not sure what width this refers to. Is this the full bank-to-bank channel width? Or the active width at mean flow? Given that mean flow tends to be much lower than the channel-filling flood, this difference has the potential to matter quite a bit for the results. Because flow depth is estimated using Qmaf, the width used in calculations should be Wmaf.

Our response: All Swiss streams are single-threat channels and confined by artificial banks. Channel widths are therefore constant over several kilometres. For these streams, we measured the cross-sectional widths between the artificial banks, which would thus correspond to bank-to-bank channel widths. For the Swiss streams, flows which correspond to Qmean usually occupy the entire channel. The situation is different for the Peruvian rivers, since they are braided and have a large seasonal runoff variability. We acknowledge that this parameter cannot be as precisely quantified as in Switzerland. We accounted for this and conducted a sensitivity analysis where we allow active channels to be twice as large as reported in Table 1, and we additionally add a 50% uncertainty to these values. The consideration of a larger channel width reduces the probability of transport (because the same amount of water has to be shared by a larger cross-section area). However, the results show that the positive relationship between the grain size sorting and the probability of sediment entrainment will remain. We have clarified this issue and present this additional material in the Supplement S5. Since the overall conclusions do not depend on this point, we decided to present the results of this particular sensitivity analysis in the Supplement.

Reviewer: 5. Some of the reported grain sizes are surprisingly small, especially when compared to the images in Litty and Schlunegger (2017). The authors state that "in cases where more than half of the grain is buried, the neighboring grain was measured instead". This reviewer suspects that this method leads to a bias toward measuring small grains. Large grains are more likely to be buried. (And how do you know if it is "more than half buried"?). Do the authors have any field measurements of grain size to support their "photo sieving"?

Our response: These images were mainly presented to illustrate the variability of grain sizes and the shape of the clasts. Admittedly, the accuracy to measure the fine-grained material greatly depends on the resolution of the digital photos. In addition, Watkins et al. (2020) could document that the uncertainties on the smaller grains tend to be larger than on the larger ones. We discussed this point more carefully in the revised manuscript. However, a positive relationship is not only visible between the material mobility and the D96/D50 ratios, but also between the transport probability and the D96/D84 ratios. Therefore, despite a possible bias that is associated with the grain size measuring techniques, the relationships between the parameters characterizing the sorting and the sediment transport mobility will remain. We have additionally analysed the grain size data collected from various photos taken over the same gravel bar, but at different locations. For the D84, the variability and thus the uncertainty along a bar is in the order of 20%. We present these data in the Supplementary file S1.

Reviewer: 6. Peruvian channels have VERY high standard deviation of Qmed. Are these calculated as the standard deviation of the individual years mean annual flow? How many years of Peruvian channel data are there in the dataset? The high stdev of Peruvian channels compared to Swiss channels suggests a very different flow regime. Is it possible that the differences the authors find between Swiss and Peruvian channels is a reflection of flow regime, rather than sediment supply (as they seem to imply)?

Our response: The discharge data for the Peruvian rivers has been taken from Reber et al. (2017) and Litty et al. (2017). The uncertainties reported by these authors correspond to the intra-annual variability (i.e. seasonal) and not to the inter-annual variability like in Switzerland. We acknowledge that we did not specify this point, which has now being done in the revised manuscript. We keep the intra-annual variability for the Peruvian streams to account for the large seasonal character of water runoff. We additionally calculated the inter-annual variability of mean annual runoff (Qmean) for 7 Peruvian streams where the water gauging stations are close to the grain-size sampling sites (distance c. 5 km, please see also Reber et al., 2017, for further characterization). We find that the inter-annual variability is much less (c. ±50% around the Qmean). We conducted the same analysis and propagated a lower discharge uncertainty through our Monte Carlo modelling framework. The results are the same. We present the results of this sensitivity analysis in the Supplement S2 and S5. Unfortunately, we have no sediment supply data to fully address this point. However, find that the consideration of either an up to >100% (intra-annual or seasonal variability) or 50% (inter-annual variability) uncertainty on Qmean has a negligible implication on the probability of sediment transport. Therefore, we do not consider that discharge variability explains the differences between Peru and Switzerland. This then suggests that supply control is more important. However, it is beyond the scope of this paper to address the relationships between supply and transport probability because we have no supply data, as mentioned above. Our focus remains on the sorting and how it influences the entrainment of the deposited material.

Reviewer: Results/Discussion: 7. I am surprised by the finding that D84 is mobile at mean annual flow in near 100% of the simulations in many of the Peruvian channels. That is an extremely mobile bed! Consider that other researchers have predicted D50 mobility of only âĹij12% of the year (Torizzo and Pitlick, 2004), and that in some regions, bed mobility is exceeded only a few days a year (Pfeiffer and Finnegan, 2018). The authors should consider making comparisons to these previous findings in their discussion.

Our response: The relatively high mobility in the Peruvian streams is very likely to be real, but is admittedly biased by the selection of the Qmean, which gives more weight to the larger runoff magnitudes. We are convinced that the Qmean is a good choice because this is the runoff value, which is conventionally being considered in a large number of geomorphological and sedimentological studies, and related data can be found in many tables even for very remote areas. Nevertheless, we ran a test, where we explored how the mobility changes if we take a series of models for various runoff quantiles and then calculate the resulting probability of sediment mobilization accordingly. We then multiplied the probability of occurrence for each quantiles with the corresponding transport probability and summed the values. This integration provides an estimate of the 'real' probability of transport. The analysis shows that this new estimate is positively and linearly correlated with the probability of transport estimated with the Qmean. In addition, these correlations are very similar between the Swiss (slope: 0.74±0.02; intercept: 0.05±0.01) and Peruvian streams (slope: 0.73±0.19; intercept: 0.03±0.14). This then means that the positive relationship between grain size sorting and sediment transport probability remains for both settings and for both scenarios (consideration of quantiles and Qmean). We present the results of this test in the Supplement S3. Nevertheless, since the Qmean is commonly selected in a large number of studies mainly because these data can be readily extracted even for very remote areas (e.g., calculation via TRMM data), we decided to keep the results of the model run based on Qmean in the main text and to illustrate the alternative solutions in the Supplement S3. We note, that Pfeiffer and Finnegan (2018) reported lower transport probabilities that range between 8% and nearly 100% for the West Coast, 1% and 12% for the Rocky Mountains, and <10% for the Appalachian Mountains. In a broader sense, these authors considered the ratio between sediment flux and sediment transport capacity as criteria for the incipient motion of bedload material, which differs from the mobility criteria that we set in our paper. However, the largest dissimilarity stems from the differences in channels slopes. In particular, while the D50 of Pfeiffer and Finnegan (2018) has nearly the same size the D84 reported here, their channel gradients tend to be 3 times lower. Because shear stress linearly depends on gradient (equation 7), then the probability where $\tau > \tau$c will be directly and proportionally affected by this. Nevertheless, even if we would select a different channel gradient, the sediment transport probability will go down (most likely linearly), but the dependency of the transport probability on the grain size sorting will remain. We mention this in the revised text.

Reviewer: I have focused my comments on content, rather than prose. There were several gram- matical errors (e.g. Lines 33, 91) and awkward sentences throughout the manuscript. I suggest that the authors give the next version a more thorough read before re- submitting.

Our response: We apologize for this and corrected the text accordingly.

References:

MacKenzie, L. and Eaton, B.C.: Large grains matter: constraining bed stability and morphodynamics during two nearly identical experiments, Earth Surf. Proc. Landf., 42, 1287-1295, 2017.

MacKenzie, L. and Eaton, B.C.: Breaking from the average: Why large grains matter in gravel-bed streams. Earth Surf. Proc. Landf., 43, 3190-3196, 2018.

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.

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