Dear Dr. Thomas Geay,

We appreciate your valuable comments on this manuscript. All the comments are important and help to improve this manuscript. We agree with your comments and have been able to incorporate changes to reflect the suggestions. We have highlighted the changes within our manuscript.

Here is a point-by-point response to the comments and concerns, which we hope meets with your approval. In our responses, the line number citations refer to the revised version of the manuscript.

Comments from Reviewer #2

- **Comment 1:** This paper deals with the use Swiss Plate Geophone (SPG) for bedload monitoring and it studies the effect of transport modes (rolling, sliding, saltating particles) on SPG signals. This work gives a new understanding on how bedload particles are transported and how it affects the signals monitored by surrogate methods. In the introduction, the scientific question is well presented, with a nice overview of the existing literature. I also appreciated to read the method section as the description of the setups and notations are very clear. The results and discussion sections are also well written. We can learn how several parameters of SPG signals are affected by transport modes, bedload diameters, angle of impact, ect. These results help to understand the variability of the SPG calibration curves obtained in field experiments. These results can be extended to study the behaviour of other bedload monitoing technics that are in development (seismic, acoustic methods for example).

  Finally, I recommend this paper with minor revisions and thank the authors for their careful job. Some suggestions and remarks are listed in the supplement file, joined to this comment.

  Response: Much appreciated of your valuable comments which are very helpful to improve our manuscript. We agree with your comments, and some revisions have been made and highlighted in the revised manuscript. The responses to the comments are presented as follows.

- **Comment 2:** **Introduction. L39.** Could be valuable to add other papers using direct calibration. For example:

  Bakker, M., Gimbert, F., Geay, T., Misset, C., Zanker, S., & Recking, A. (2020). Field Application and Validation of a Seismic Bedload Transport Model. Journal of Geophysical Research: Earth Surface, e2019JF005416. https://doi.org/10.1029/2019JF005416

  Geay, T., Zanker, S., Misset, C., & Recking, A. (2020). Passive Acoustic Measurement of Bedload Transport: Toward a Global Calibration Curve? Journal of Geophysical Research: Earth Surface, 125(8), 1–19. https://doi.org/10.1029/2019JF005242

  Rennie, C. D., Vericat, D., Williams, R. D., Brasington, J., & Hicks, M. (2017). Calibration of acoustic doppler current profiler apparent bedload velocity to bedload transport rate. Gravel-Bed Rivers: Process and Disasters, 209–233. https://doi.org/10.1002/9781118971437.ch8

  Response: Thanks for the valuable advices. We agree that it is worthwhile to cite more papers using direct calibration in the manuscript (L33-35, L646-648, L702-703, L752-754).

- **Comment 3:** **L56-58.** To my mind, Thorne [1985] has not shown that transport modes are associated to different acoustic response (it is only suggested in this paper). Please check my remark and remove this reference if this review is true.

Response: Agreed. This citation has been removed in the manuscript.

- **Comment 4:** **Methods. Table 1** - When monitoring bedload, we are interested in estimating bedload fluxes (in kg/min, g/m/s or else). In the presentation of the Flume experiments (section 1.1.2), I think important to have an estimation of these bedload fluxes (even if imprecise). I believe that the number of moving particles strongly affects the modes of transport and their associated characteristics (impact velocities/angles, etc.), due to interaction between particles. This was suggested in the following paper: Gimbert, F., Fuller, B. M., Lamb, M. P., Tsai, V. C., & Johnson, J. P. L. (2018). Particle transport mechanics and induced seismic noise in steep flume experiments with accelerometer-embedded tracers. Earth Surface Processes and Landforms. https://doi.org/10.1002/esp.4495. The number of moving particles is dependent on bedload fluxes and bedload sizes. For me, it is therefore very important to give an overview of the bedload fluxes used in these experiments.

Response: Thanks for this valuable advice. We agree that the number of moving particles can strongly affect the modes of transport, and the number of moving particles is dependent on bedload fluxes and bedload sizes. In the present study, we focus on each particle impact on the bed or on the geophone plates.

The bedload particles were released into the flume several meters upstream of the SPG system with known particle numbers and masses for each experimental run (see Section 2.1.2). The transport velocity of bedload particles for all grain size classes was calculated ranging from 1.74 m/s to 2.91 m/s with a mean value of 2.08 m/s, resulting in the bedload fluxes estimated in our study ranging from 0.092 kg/m/s to 20.31 kg/m/s. We have added and expanded Tables (Tabs. 1 and 2) with information on both flow conditions in the flume and on unit bedload transport rates.

Some related statements have been added in the revised manuscript (L120-121, L126).

- **Comment 5:** **L128-130** - What are the average impact velocities of the particles in the flow (i.e. in the flume experiments)? Is it comparable to the particle velocity in the inclined chute experiments? Please add a sentence on this comparison.

Response: The particle impact velocity in the inclined chute experiments was estimated to be much higher than the average impact velocities (fractions of a meter per second) of the particles in the flume experiments. This is because the potential height of the particles released on the chute bed is considerably higher than the particle hop height in the flume experiments. The inclined chute experiments were performed here only to investigate the effect of (two) impact angle(s) on the SPG signal response.

Some related statements have been added in the revised manuscript (L137-141).

- **Comment 6:** **Figure 2b.** Add “view” to read “Cross-sectional view of the FEM model of the SPG system.”

Response: Agreed. This sentence has been revised in the manuscript (L156).

- **Comment 7:** **L154** - Maybe delete “the” from “the bedload particles”.

Response: Agreed. This definite article has been deleted in the sentence.

- **Comment 8:** **L210** –is k_{IPM} comparable to the k_b of almost all other studies [Rickenmann et al., 2013; Wyss et al., Nicollier et al., 2021]? Should it be recalled to trace the continuity of these works?

Response: The number of impulses I is found to be reasonably well correlated with the total transported bedload mass M_{Tot} (see below) based on direct bedload measurements at various field sites.

$$I = k_b M_{Tot}$$

where k_b is the site-dependent calibration coefficient. The coefficient k_b is further developed for different grain size classes j as the coefficient k_{bj}, which has been utilized to infer bedload transport by grain-size fraction from the SPG signal (Wyss et al., 2016c; Nicollier et al., 2020).

The mass-impulse coefficient k_{IPM} given in the present study is similar to the coefficient k_b in other studies (Rickenmann et al., 2013; Wyss et al., Nicollier et al., 2021) but has not exactly the same definition. k_{IPM} is more comparable to the k_{bj} value, although not completely the same. The k_{bj} values also include the mass of non-impacting particles, while k_{IPM} is defined as the number of impulses (triggered by each impact) per particle mass in present study. Note that the particle impact locations (concrete, plate G1, plate G2, or plate boundaries) and impact instants are determined during our video analysis, and the signal impulses used for the calculation of k_{IPM} are extracted from the real packets. Therefore, the propagating signal noises caused by apparent impacts have been excluded in our analysis, resulting in the different definitions between k_{IPM} and k_{bj}.

$$k_{IPM} = \frac{I}{M}$$

where I is the number of signal impulses recorded by the SPG system and M is the corresponding mass of the transported particle.

Some related statements have been added in the revised manuscript (L231-236, L319-320).

- **Comment 9:** **Equation (5)** – I agree with the definition of your **centroid frequency**. However, be careful, the definition of Thorne is called "central frequency" and is not the same. The definition of the central frequency by Thorne is given by this equation:

$$\int_{f_1}^{f_c} P(f)df = \int_{f_c}^{f_2} P(f)df$$

in Thorne [1986], Laboratory and marine measurements on the acoustic detection of sediment transport. I tried both formulations on several bedload data (acoustic and seismic signals) and observed that it gives different results. Maybe add a small note on this remark? "Note that the formulation of the central frequency [Thorne, 1986] is different from the formulation of the centroid frequency (equation 5)."

Response: Thanks for this valuable comment on the calculation of (central) frequency. We agree and the sentence suggested by the reviewer has been added in the text (L246-247).

- **Comment 10:** **L249** – The term water flow velocity is not clear. Do you mean depth-averaged velocity? Velocity close to the bed? Please precise.

Response: In relation to Eq. 9 in this paper, the water flow velocity V_W means the depth-averaged flow velocity based on Julien and Bounvilay (2013). Comparably, the flow velocity in our flume experiments was measured by using a flow meter (OTT MFpro) positioned 0.1 m above the SPG plate in the middle of the cross-section.

The term “depth-averaged” has been added in the corresponding sentence (L280).

- **Comment 11:** **L252** – Replace V_P^{Cal} by V_P^{Est}

Response: Thanks for this comment. "V_P^{Cal}" in this line should read "V_P^{Est}", which is the estimated particle velocity in the present study.

This sentence has been revised based on the reviewer’s comment (L283).

- **Comment 12:** **L272-275** – “Obviously, the number of effective impacts (=real impacts + apparent impacts) for all transport modes is larger than that of the real impact” Yes, it is obvious…I don’t see the point of this sentence.

Response: This is the first time the term “effective impacts” appears in the article, so we defined it in the text. This sentence has been rephrased in the manuscript (L303-304).

- **Comment 13:** **L280-283** – Can you explain this result? Is it coming from the filtering method or from the video counting?

Response: $r_{i,j}^{Packet,V\_F}$ is actually the ratio of the packet counts using two different methods. It is defined as the ratio of the total number of real packets over all transport modes based on the video observations to the real-packet number determined by the filtering method:

$$r_{i,j}^{Packet,V\_F} = \frac{N_{i,j}^{Packet,V}}{N_{i,j}^{Packet,F}} \text{ (Eq.6 in the manuscript)}$$

where $N_{i,j}^{Packet,V}$ is the total number of real packets for experimental run i and grain-size class j over transport modes based on the video analysis; $N_{i,j}^{Packet,F}$ is the number of real packets for experimental run i and grain-size class j, determined by the filtering method.

The purpose is simply to cross-check the results of packet counts and make the data more reliable.

Some related contents have been added to the manuscript (L265-270, L374-384).

- **Comment 14:** **L301** – “Both the inclined chute experiments and the FEM simulations indicate that the impulse-mass coefficient k_{IPM} varies only moderately with impact angle for a given particle size” I think you should moderate this statement as you have few data concerning the chute experiments (only two different values and comparable angles). I think more adapted to delete “Both the inclined chute experiments” in order to read “The FEM simulations indicate that the impulse-mass coefficient k_{IPM} varies only moderately with impact angle for a given particle size”

Response: Agreed. This sentence has been rephrased based on the reviewer’s comment (L338).

- **Comment 15:** **L313/315** (fig. 9b) – As previously, the experimental data are not very usable (few data and no clear trend). Should be better to read something like “The FEM simulations show that the maximum amplitude of a packet $Amp_{Max,Pac}$ increases with increasing particle impact angle θ up to about θ = 60° (Fig. 9b). The inclined chute experiments do not show a clear trend.”

Response: Thanks for this comment and we agree. This sentence has been rephrased in the text (L348).

- **Comment 16:** **L333-338** – I globally have a problem with this paragraph as I’m not convinced by the given explanations. First, for smaller particles, $r_{i,j}$ <1, it means that N_{video}<$N_{filtering}$ method (equation 6). You write that "This is due to the fact that in the experiment, only the particle impacts that are on the SPG plates are selected. The signal that is produced by the impacts on the concrete is dampened during wave propagation and filtered using the numerical method" Do you mean that N_{video} is only computed considering the impact on the plates and that $N_{filtering}$ method includes some impacts that were generated on the concrete. Finally, do you mean that the filtering method is not totally efficient for the smaller diameters?

Secondly, for larger particles, $r_{i,j}$>1 means N_{video} > $N_{filtering}$ method (eq. 6). You write that this "is possibly (due) because of the high impact energy generated by the large particles". I really don't see the relation between this sentence and the fact that you found less packets with the SPG method than with the video. On the contrary, I would expect that higher energy would generate a larger number of packets in the SPG signals (and so an overestimation of the number of impacts using SPG systems). Could you precise your idea?

Finally, I wonder if the definition of the equation 6 is exact, as I would expect the inverse result (underestimation of impacts with the SPG system for small diameters and overestimation for larger diameters).

Response: For small particles, $r_{i,j}^{Packet,V\_F} < 1$ means that the total number of real packets for experimental run *i* and grain-size class *j* over all transport modes based on the video analysis $N_{i,j}^{Packet,V}$ is smaller than that determined by the filtering method $N_{i,j}^{Packet,F}$. $N_{i,j}^{Packet,V}$ is counted only considering the impacts on the plates. Considering that the signals triggered by small particle impacts are dampened quickly during wave propagation, the filtering method in fact does not have a significant improvement for the identification of real packets caused by small particles. Therefore, one reason for $r_{i,j}^{Packet,V\_F} < 1$ could be the limitation during the video observation and analysis: Limited visibility due to flow turbulence can cause an underestimation of the number of impacts on the SPG plates, because some small particles that impact on the plate boundaries on the other side cannot be easily observed.

For large particles, $r_{i,j}^{Packet,V\_F} > 1$ means that $N_{i,j}^{Packet,V} > N_{i,j}^{Packet,F}$. There may be several reasons:

a) Some particles that impacted close to boundaries (e.g. bolts) of the geophone plates were filtered out.
b) The number of impacts caused by sliding particles increases as the particle size increases. However, some sliding particles could be incorrectly filtered out due to weak impact amplitude/energy.
c) Simply due to the filtering method itself. It was found that some bedload particles can be misclassified in the largest size classes using the filtering method.

Some related contents have been added to the manuscript (L374-377, 379-383).

- **Comment 17:** **L347**: should we read "over the plate" instead of "over the channel bed"?

Response: Agreed. This has been revised in the text (L391).

- **Comment 18:** **L388-390**: "A considerable difference of $Amp_{Max,Pac}$ between the transport modes could potentially be helpful in identifying sliding particles and therefore may improve the signal conversion into fractional bedload transport rates" Yes but there is also a strong dependency of $Amp_{Max,Pac}$ with bedload particle size. This dependency (on diameters and on transport modes) make the use of $Amp_{Max,Pac}$ difficult.

Response: That's a good comment. For a given size experiment or single-size experiment, this finding could be helpful in knowing whether the domain transport mode is saltation or rolling or sliding. However, for natural field conditions, it is very difficult to improve the particle-size identification by removing the effect of transport mode on the signal responses of the SPG system, due to fact that the signal amplitude shows dependency on both particle size and on transport mode. Some statements have been added to the main text (L433-436).

To improve the calibration curves between $Amp_{Max,Pac}$ and particle size D by removing the influence of transport mode, some other information should be combined, which needs to be further studied.

- **Comment 19:** **L400-441**: Finally, can we conclude that the centroid frequency is a good proxy for size identification? [few dependency on transport mode and on particle velocity I guess].

Response: Controlled flume experiments showed that the centroid frequency is less sensitive to varying flow velocities than the maximum packet amplitude (Wyss et al. 2016, WRR). In this study, we found that the dependences of centroid frequency on transport mode and impact angle are less than those of maximum amplitude on transport mode and impact angle. Therefore, we could say that the centroid frequency is somewhat better suited for particle size identification than the maximum amplitude (L476-480).

Furthermore, the information of frequency and amplitude can be combined to further improve the accuracy of particle size identification, which has been developed by Nicollier et al. (2021b, in review), as we have introduced in section 2.4.2 of the present paper.

Additional clarifications

In addition to the above comments, all spelling and grammatical errors pointed out by the reviewer have been corrected in the manuscript.

We look forward to hearing from you in due time regarding our submission and to respond to any further questions and comments you may have.

Sincerely,
The authors of manuscript esurf-2021-72.