

Response to reviewer 3

The paper presents an expertly crafted and well written study that directly investigates bedload transport, a core process in Earth surface dynamics, focusing on the critical but understudied context of unsteady flow. It tackles a recognized methodological challenge: monitoring sediment transport during unpredictable, high-energy flash flood events where traditional methods fail, which is fundamental to geomorphology and fits perfectly within the scope of ESurf.

The authors present here a novel application of two key tools used for assessing bedload dynamics: seismic sensors and smartrocks. The choice of using these during flash flood bores in ephemeral streams, is quite challenging and the authors deserve compliments for demonstrating this application in such difficult conditions.

Thank you.

The authors find that rapid stage rises enhance bedload transport in shallow and deep water, but not at intermediate depths, and that these transitions are governed by relative depth (h/d_{84}).

However I am wondering if this substantial conclusion that has been validated for these conditions (characterised by these highly unsteady flows in these few ephemeral streams) can confidently be extended to broader flow conditions with implications for scaling these processes across broader and more different river types.

Our conclusions are intentionally limited to the ephemeral streams investigated in this study, and we do not claim that the observed relationships are universally applicable to all river types. Rather, we suggest that the observed influence of rapid stage rise on bedload transport should be considered in future sediment transport models, as there is currently no evidence to exclude the possibility that similar mechanisms operate in other environments experiencing rapid stage-rise events. This consideration may be particularly relevant for other ephemeral streams subject to hydrological regimes similar to those examined here.

The methods for data collection (seismology, smartrocks, stage logging) are state-of-the-art and clearly described. However, the key assumption that the frequency band best correlated with total gyro velocity is the best proxy for bedload transport might need more clarification (because the total gyro velocity for a rock in a natural setting accounts for both vibrations and downstream transport not only the latter). For example one cannot reliably distinguish between different types of movement that have similar rotational speeds with the gyro velocity alone. Indeed there are studies in controlled (uniform, steady flow and fixed particle pocket) environments that may use this measure as a surrogate that may suitably work, but in highly unsteady flows in the field where the particle can be found in any random pocket geometry, there may be less confidence that the total gyro velocity is either a rock rolling smoothly downstream (linear transport by rolling), or a rock violently spinning in its resting pocket (high-energy vibration - without transport). For instance, using equation 1

discards all the directional and temporal pattern information that is essential for distinguishing movement types - maybe a caveat can be given to discuss this limitation and that perhaps as a next step such cases, if any exist, can be filtered out, by direct consideration of the gyro information from each individual axis. As a result the "Displacement" category might be contaminated by such high-energy vibrations and localized rearrangements that do not contribute significantly to downstream bedload flux. This may imply that the gyro-based evidence for enhanced "transport" during rapid stage rises (especially in Stage 1) might be partly evidence for enhanced "agitation".

We agree that gyro velocity may capture both vibrational motion and downstream displacement. However, as we mention in Section 4.1.2, the use of gyro amplitude as an indicator of displacement is supported by previous studies. Specifically, Pretzlav et al. (2021) demonstrated that gyro amplitude can be used to identify displacement events, while the data presented by Al-Obaidi and Valyrakis (2021) show clear differences in gyro amplitudes between wobbling and displacement-dominated motions. These observations provide support for the interpretation that elevated gyro velocities are associated with enhanced particle mobility, although some contribution from vibrational motion cannot be entirely excluded.

Further since the "total gyro velocity" used to calibrate the seismic signal includes these undistinguished movements, the seismic method is calibrated to detect general bed activity and energy dissipation, not pure bedload transport (but also any high energy vibrations not resulting into transport).

We agree that the frequency range identified using total gyro velocity may include contributions from both vibrational motion and downstream displacement. This limitation is explicitly discussed in Section 4.2, where we note that the selected frequency range may contain a vibrational seismic source in addition to bedload transport signals. For this reason, we interpret the resulting PSD ratios as an upper bound of the actual bedload flux ratio rather than a direct measure of bedload transport alone.

The 30-second median filtering of gyro data is a valid smoothing technique, but the assumption that it adequately captures transport dynamics overlooks the loss of short-duration high energy transport events. Of course for larger rocks, the longer the duration for gyro-data is meaningful but it would be nice to demonstrate the utility of the current choice (and optionally how it may vary for different rocks).

The 30-second window was selected primarily to match the temporal resolution of the stage measurements and thereby facilitate the comparison between gyro velocity and water depth. In addition, results from a follow-up study examining smartrock motion dynamics indicate that individual smartrock displacement lasted on average 90 seconds and up to 606 seconds during flow event. Periods of vibrational motion (wobbling) often persisted for longer durations, although their exact lengths were not evaluated. These timescales suggest that the dominant particle motions observed during flow events are expected to be adequately represented within a 30-second window. We acknowledge that very short-duration transport events may be smoothed

by this approach; however, we consider the selected window appropriate for the objectives of the present study.

The data processing steps for both seismic (PSD calculation, response removal) and gyro (magnitude calculation, thresholding, binning) are described with sufficient detail for reproduction.

The authors use relatively easy to access field data eg the stage, based on the methodology described in the manuscript (primarily in Sections 2.1 and 3.1, and Supplement S2) and acknowledge that stage alone is inadequate for predicting a bed surface grain-scale process due to the turbulent flow field. The assessment of steady flow versus rapid increase of stage is performed through a quantitative analysis of the stage hydrograph data, using a fixed, absolute rate-of-rise threshold: this can introduce an asymmetric relative error, disproportionately affecting low-flow stages.

We understand the reviewer's concern that a fixed absolute rate-of-rise threshold may correspond to different relative hydraulic perturbations at different flow depths, potentially resulting in a stronger relative effect at shallow flows than at deeper flows. We agree that this is an interesting aspect that merits further investigation. However, the available dataset does not provide sufficient observations to robustly evaluate this effect across the full range of flow conditions. The objective of this study was not to quantify the effect of the rate of rise itself, but rather to compare bedload activity during periods of rapid stage rise and steady flow across a range of water depths. Therefore, water depth is treated as a primary explanatory variable, and differences in the response observed across flow depths are interpreted as part of the investigated phenomenon rather than as a source of bias introduced by the threshold definition.

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Pretzlav, K. L. G., Johnson, J. P. L., and Bradley, D. N.: Smartrock transport from seconds to seasons: shear stress controls on gravel diffusion inferred from hop and rest scaling, *Geophys. Res. Lett.*, 48, e2020GL091991, <https://doi.org/10.1029/2020GL091991>, 2021.