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Quantitative measurement of bedload transport variability with acoustic monitoring systems: Insight from controlled laboratory flume experiments

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Predicting bedload transport is a key element of water-related hazard assessment and hydraulic engineering applications. However, knowledge of bedload transport processes remains limited, particularly in steep mountain streams. Previous studies have revealed that bedload transport rates in mountain streams exhibits a large spatio-temporal variability for given flow conditions. This results from the direct influence of streambed structure on bedload transport, where sediment movement, in turn, interacts with streambed evolution. Furthermore, variations in sediment availability contribute to the spatio-temporal bedload variability. The complex interactions between water flow, bedload transport, and bed structure are not yet fully understood. In this work, systematic flume experiments were conducted to investigate the acoustic signal responses of impact plate geophone systems generated by bedload particles impacting on the flume bed during experimental flows in the transitional regime. The experiments varied in the grain size distribution of the transported particles and the bed material, and the compactness and the water content of the flume bed. Geophones were installed on the underside of steel plates flush with the flume bed both upstream and downstream to effectively capture the changes in vibration signals generated by the moving bedload mass impacting on the bed. Triaxial force sensors were utilized to measure the impact forces of the bedload particles on the bed material layer. Pore-water pressure sensors were embedded at different depths in the bed material to measure the change in pore-water pressure in the bed under the influence of the bedload mass. Flow velocities and depths of the moving bedload mass were recorded using a binocular high-speed camera and were analyzed with an image processing method. The observed vibration signals and fluctuating forces were used to calculate the characteristic parameters of bedload transport using calibrated relationships and seismic theory. In addition, a high-precision Digital Elevation Model (DEM) of the bed was constructed using the photography and 3D modeling techniques. The results of this work show that geotechnical material parameters of the bed such as compactness, compression modulus, and grain size distribution may affect the changes of bed structure caused by bedload transport This in turn influences the spatio-temporal variability of the transport rate. The findings of this work may help to explain the variability of the bedload transport process in mountain streams.