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An acoustic model for monitoring bedload transport with microphones array

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Accurate measurements of bedload flux in mountain rivers remain an important issue in hydraulic engineering. Diverse acoustic-based monitoring devices have been utilized to record continuous vibration signals triggered by bedload particle impacts, aiming to translate bedload information such as transport rates and grain size distributions from the generated signals. However, the spatial variability of bedload impacts on the river bed (or on an impact plate) contributes to uncertainty in the calibration relationship between the recorded signal and bedload flux.

The present study develops an acoustic model based on microphone data to determine the characteristics of the air shock waves induced by the bedload particle impacts on the bed. A phased microphone array (PMA) system is established on the plane underside of an impact plate flush with the river bed, which includes a number of mini microphone elements set apart from each other at a specific spacing distance. The model allows for a calculation of the cross-power matrix of the air vibrations recorded by each microphone of the array. The acoustic vibrations recorded on the PMA plane are subsequently reconstructed and transformed to an acoustic image of the sound source on a scanning plane of the plate surface, considering different air propagation models corresponding to monopole, multipole and moving sources. As a result, the locations of the bedload particle impacts can be detected, connecting to the central coordinates of the reconstructed sound source. The signal amplitude extracted from the sound intensity in the reconstructed acoustic image potentially provides a better way for classifying bedload particle size than just utilizing the raw data recorded by one of the microphone elements.

The findings of this study contribute to the measurement and monitoring of the bedload transport with an acoustic system, illustrating a promising way to identify bedload impact locations, which could be helpful in grain size classification during the transport process.