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Bedload fluctuations in a steep macro-rough channel

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It is known that bedload fluctuates over time in steep rivers with wide grain size distributions, even when conditions of constant sediment feed and water discharge are met. Bedload fluctuations are periodic and related to fluctuations in the flow velocity and channel bed morphology. In cascade morphologies, the presence of large relatively immobile boulders has a strong impact on flow conditions and sediment transport; their influence on bedload fluctuations is considered in this research.

Sediment transport fluctuations were investigated in a set of 38 laboratory experiments carried out on a steep tilting flume, under several conditions of constant sediment and water discharge, for three different slopes (S=6.7%, 9.9%, and 13%). The impact of the diameter and spatial density of randomly placed boulders was studied for several flow conditions. Along with the sediment transport and bulk mean flow velocity, the boulder protrusion, boulder surface, and number of hydraulic jumps, which are indicators of the channel morphology, were measured regularly during the experiments.

Periodic bedload pulses are clearly visible in the data collected during the experiments, along with well correlated fluctuations in the flow velocity and bed morphology parameters. Well-behaved cyclic oscillations in the auto-correlation and cross-correlation functions confirm the periodicity of the observed fluctuations and show that the durations of these cycles are similar, although not necessarily in phase. A detailed analysis of data time series and image acquired during the tests show a link between bedload pulses and different bed states, boulder protrusion, and surface grain size distributions. A feedback system exists among channel morphology, flow kinematics and sediment transport.

A phase analysis for the observed variables, based on the identification of bedload cycles in the instantaneous signal, is performed. The link between the phases of bedload and each of the morphological parameters show a hysteretic path. The relation between the phase-averaged bedload and the phase-averaged flow velocity show a considerable lesser degree of hysteresis. Comparing the phase averaged bedload of the experiments, it is observed that the shape of bedload cycles is the same for all tested hydraulic conditions. The cycles present a long duration low sediment transport event and a shorter peak transport event. This indicates that long periods of sediment aggradations alternate with short erosion periods, even under constant hydraulic conditions.

The bedload pulses may be characterized by their amplitude and period as a function of various boulder spatial densities and diameters. We show that for higher stream power, the fluctuations decrease, both in cycle duration and in amplitude. The presence of boulders increases the stream power needed to transport a given amount of sediment, thus decreasing fluctuations.

KEY WORDS: Bedload fluctuations; Morphological changes; Sediment transport; Boulders; Steep channel.