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Bedform dynamics in glacier-fed rivers

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Discharge and sediment supply in glacier-fed rivers exhibit daily and seasonal cyclic fluctuations. The morphology and bedload regime of these systems depend on channel geometry and sediment properties, which set the time scale of bed evolution, and the time scale of hydrological forcing. In this work, we used a physical model of a gravel-bed, glacier-fed river to answer the following questions: 1. What is the typical sediment flux signature of a glacier-fed river? 2. How do water and sediment supply unsteadiness affect channel morphology? 3. How does channel morphology modulate sediment waves?

The physical model consists of a 24 m long straight channel with fixed banks. Three values of channel width were selected in order to obtain a range of channel configurations (plane bed, alternate bars, wandering) and two sediment mixtures were used, namely a well-sorted sand and a poorly-sorted mixture. Discharge and sediment supply are software-controlled and bedload was monitored using a continuous weighing mechanism. Topographic information was acquired using a laser profiler or Structure-from-Motion.

For each channel configuration, the flume was run under steady flow conditions to estimate transport capacity and reconstruct equilibrium bed morphology for a range of discharges. Afterwards, daily discharge fluctuations were simulated as sequences of 30 identical, symmetrical triangular hydrographs. Sediment supply at each hydrograph step was set to transport capacity. In addition, staggered sediment supply was simulated by assigning a phase lag to input bedload. Bed topography was acquired at four stages (minimum and maximum discharge and halfway through the rising and falling limb).

Output bedload signal changes substantially between individual hydrographs, but the inherent variability of sediment transport can be filtered out by computing the ensemble mean over a set of cycles. Mean bedload output is higher during the rising phase, resulting in a clockwise hysteresis cycle with respect to water discharge. Hysteresis is independent from sediment supply lag, suggesting that the effect of sediment input timing is limited to the uppermost sections of a glacier-fed river. Analogously, during runs with staggered sediment supply the channel undergoes cyclic degradation and aggradation but only immediately downstream of the inlet.

In the case of alternate bars and wandering channels, sequences of hydrographs produce cyclic variations of bed morphology in terms of bedform shape and celerity of downstream migration. However, at any given hydrograph step bars are different from those observed for the same discharge under steady flow conditions. This suggest that in a typical glacier-fed river morphological processes are fast enough to modify bar morphology in response to daily flow variations. At the same time, they are not fast enough to build bedforms that are in equilibrium with discharge at each flow stage.