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Morphodynamic response of glacier-fed rivers

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Glacier-fed rivers exhibit a distinctive flow regime characterized by periodic fluctuations of discharge and sediment flux. Hydrograph shape, magnitude and frequency and sediment are expected to produce a distinctive bedload regime and a complex morphodynamic response which is constrained by valley geometry. In this work, we used a laboratory model to investigate i) the typical sediment flux of a glacier-fed river; ii) the influence of water and sediment supply unsteadiness on bedform shape; and iii) the role of valley geometry.
The physical model consisted of a 24 m long channel with fixed banks. A range of bed morphologies including plane bed, alternate bars, and wandering were created using combinations of discharge ranges, slope and width. In addition, a channel configuration comprising a localized widening was also tested. Two sediment mixtures were used as bed and supply material, namely a well-sorted sand and a poorly-sorted mixture.
For each channel configuration, the flume was first run under steady flow conditions to estimate transport capacity and define equilibrium bed morphology for a range of discharges. Afterwards, sequences of 30 identical, triangular hydrographs were run in order to simulate daily snowmelt cycles. Sediment supply at each hydrograph step was first set to transport capacity; subsequently, staggered sediment supply was simulated by assigning a phase lag to input sedigraphs.
Data collection during model runs comprises continuous measurement of bedload output and time-lapse imagery to monitor sediment transport patterns and bedform evolution. Runs were stopped at regular intervals to acquire high resolution photos of the bed, which were used to reconstruct bed topography (using Structure-from-Motion) and surface texture maps. For unsteady flow runs, images were acquired at four flow stages: minimum and maximum discharge and halfway through the rising and falling limb.
The behaviour of the system at these flow stages was compared to steady flow behaviour for the same discharge to characterize the influence of flow on channel morphology and sediment transport. Output bedload during hydrographs is usually higher during the rising limb and clockwise hysteresis is stronger for more rapid flow variations and weaker for larger peak flows. In the case of alternate bars and wandering channels, hydrographs induce cyclic modifications of bedform shape. However, at any given hydrograph step, bars are different from those observed for the same discharge under steady flow conditions. Analogously, bedload sheets are observed for plane bed configurations, but the minimum discharge required for their formation changes between steady and unsteady flows. Laboratory result therefore showing that the history of flow variations plays a major role in defining bed morphology and sediment flux.