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Quantifying the effects of hydrograph shape and flow transience on coarse sediment bed load transport

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The rate of bed load transport under steady flow is known to vary both spatially and temporally due to various hydrologic and granular phenomena. Grain size distributions and riverbed properties (packing, armoring, imbrication, etc.) have been observed to affect flux for a particular value of applied flow stress while hydrology is mainly assumed to control the magnitude of the applied bed stress above the threshold for bed material entrainment. The prediction and measurement of bed load sediment transport in field settings are further complicated by the inherent transience in the flood hydrograph, but relatively little is known about how flood transience differs from a steady flow. Here we investigate the role of flood transience for gravel bed load transport through controlled laboratory experiments in a 28 m long 0.5-meter wide flume. We explore transient flow through the use of short duration hydrographs as the combination of unsteady and intermittent flow, where unsteady flow varies in magnitude over a given duration, and intermittent flow is characterized by turning the flow on and off. Experimental runs consist of sequences of steady and unsteady flood hydrographs of various shapes, but equivalent integrated excess transport capacity. These flood sequences are run for a variety of competent flow durations and peak stress magnitudes. We find that even for a narrow unimodal grain size distribution and constant sediment supply we observe clockwise hysteresis in bed load flux, different thresholds for entrainment and distrainment for the rising and falling limbs of a flood, and a threshold of entrainment that can vary from one flood hydrograph to the next. Despite complex transport phenomena at the particle scale, we find that the total bed load transported for each flood plots along a linear trend with the integrated excess transport capacity, in agreement with prior field results. These experiments indicate that while the effects of transient flow and hydrograph shape are measurable, they are second-order compared to the integrated excess stress.