Magnitude and Frequency of Sediment Transport in Alluvial Channels

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Abstract. What flow or range of flows is most responsible for transporting sediment and maintaining continuity in a river? This question has inspired scores of magnitude and frequency of sediment transport analysis (MFA) studies and has been a focus of the ongoing debate regarding process vs. form-based approaches to stable channel design. We consider this question across the spectrum of stream types from flashy sand bed streams dominated by suspended load to snow-melt gravel and cobble streams dominated by bed load. First we consider the relationship between flow variability, bed material size (entrainment threshold), and the range of the most effective discharges using an updated theoretical approach to MFA. We find a physical mechanism that explains the diverging relationship between the most effective discharge and flow variability in fine vs. coarse bed channels. We also conduct MFA on 152 streams with existing bed material load data collected near a stream gage and characterize relationships between various metrics (e.g., the effective discharge, the percent of sediment transported by discharges less than the effective discharge, and the half yield discharge: the discharge below which a cumulative 50% of bed material yield occurs) versus channel form, flow variability, and bed material properties. We find that suspended load dominated streams are more sensitive to metrics describing flow variability, whereas bed load dominated streams are more sensitive to physical aspects of the channel and bed sediment. We also find that the half yield discharge predicts bankfull discharge very well across stream types, especially in sand bed streams, and that the bankfull discharge is consistently bounded by the discharges associated with the 25th and 75th percentile of cumulative sediment transport. This work expands on previous MFA studies by applying a uniform method of bed material yield analysis across a wide range —and large number—of river types to characterize the relationships between hydrogeomorphic properties and the range, magnitude, and frequency of the most effective flows.