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Grain size indicators of sedimentary coupling between hillslopes and channels in a dryland basin

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In dryland landscapes, heterogeneous and short-lived rainstorms generate runoff on slopes and streamflow in channels, which drive sediment movement from hillslope surfaces to channels and the transport of bed material sediment within channels. Long-term topographic evolution of drainage basins is partly determined by the relative balance of hillslope sediment supply to channels and the evacuation of channel sediment. However, it is not clear whether supply or evacuation is dominant over longer timescales (»100 y) within dryland basins. One important indicator of local cumulative sediment transport is grain size (GS). On dryland hillslopes, grain size is governed over long timescales by weathering, but on short time scales (events to decades), is controlled by event-driven transport of the debris mantle. In the channel, GS reflects the input of hillslope sediment and the selective transport of particles along the bed. It is currently unknown how these two processes are expressed systematically within GS distributions on slopes and in channels within drylands, but this information could be useful to explain the history of the relative balance between hillslope sediment supply to channels and net sediment transport in the channel. We investigate this problem by combining field measurements of surface sediment grain size distributions in channels and on hillslopes with 1m LiDAR topography, >60 years of rainfall and channel discharge data from the Walnut Gulch Experimental Watershed (WGEW) in Arizona, and simple calculations of grain-sized based local stress distributions for various rainfall and discharge events.
Hydrological scenarios of overland flow on hillslopes and channel flow conditions were derived from distributions of historic data at WGEW and were selected to reflect the wide range of storm intensities and durations, and channel discharges. 1) We used three quartiles of the entire distribution of measured discharge values for ∼80 locations throughout the channel network to represent low, medium and high flows. 2) For rainfall we used three quartiles of the entire distribution of measured rainfall intensity and duration from 85 rain gauges spanning the basin, to derive low, medium and high rainfall durations. We then calculated the corresponding rainfall intensities based on four intensity-duration curves that were characteristic of different parts of the phase space of the measured datapoints. 3) The derived rainfall intensities and durations were converted into hillslope overland flow using Coup2D (a hillslope rainfall-runoff model) for 44 hillslopes within WGEW for which we have GS and topographic data. We employ the median grain size (D50) to compare stress metrics on hillslopes and in channel for each location. Typically, low-order streams experience greater influxes of hillslope derived sediment than is evacuated by the channel. However, the main channel stem is characterised by sediment removal in most scenarios including low discharge, long duration rainfall, suggesting most hillslope supplied sediment is balanced by channel evacuation. Near tributary junctions, and close to the mouth of the basin there are fluctuations in net balance of sediment transport from evacuation- to supply-dominance for different scenarios. These fluctuations could influence channel bed GS distribution and longitudinal profile development.