Geophysical Research Abstracts
Vol. 20, EGU2018-3535, 2018
EGU General Assembly 2018

Controls on the disequilibrium condition of mountain gravel-bed streams

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Statistical steady-state for rivers is commonly defined in terms of bedload sediment mass equivalence over channel reaches of many channel widths in length, or longer. Proposals for fluvial equilibrium commonly extend the steady-state condition with the requirement that rivers express a longitudinal bed profile which varies around some well-defined mean condition. Although this definition of equilibrium has merit at relatively large spatial scales, it neglects the key underlying and local physical processes that govern bedload deposition and entrainment, the implications of which can lead to multiple equilibrium profiles. Furthermore, we lack a formal definition of equilibrium based on these processes, which we frame as depositional and entrainment filters acting on the local upstream supply of bedload sediment. We address this knowledge gap and use physical scaling theory with mass conservation statements for the bulk riverbed and the sediment particles which comprise the riverbed to derive two new dimensionless numbers which quantify the rates of bed topography (N_t) and bed sediment texture (N_p) adjustment to upstream water and sediment supplies. Bed sediment texture as used here is defined by the local spatial distribution of grain sizes for bed surface areas that scale as the local width squared. We hypothesize that an equivalence of N_t and N_p is indicative of fluvial equilibrium, and non-equivalence suggests disequilibrium (the more general state). We quantify this perspective as the ratio N_t/N_p, which we term the channel response number N_e. The use of N_t and N_p as disequilibrium metrics can be scaled up to reaches of many channel widths and to larger spatial scales. Calculation of N_t and N_p depends on only four quantities: the rate of topographic adjustment, the rate of particle composition adjustment, the local channel width and a sediment texture term which quantifies the degree of difference between the fractional composition of the local bedload supply and the sediments stored in the bed substrate, in relation to the fractional composition of the long-term average sediment supply. We apply our new view to experiments conducted to examine pool-riffle formation along variable width channel reaches. Among other things we find that equilibrium conditions are achieved for relatively high bed sediment mobility's, but a majority of time disequilibrium conditions prevail. We also show that following upstream supply perturbations, the local response is governed by topographic adjustments which persist for time periods that scale as $\approx$2–20 times the initial perturbation response time scale. The bed sediment texture response plays a more critical role in setting the disequilibrium condition only after the rate of topographic adjustment has tended toward some steady condition. In our talk we will review how we set the problem up, the details of the channel response number N_e, and testing of the idea with experimental data. We will end with ideas of how this new framework relates to previous efforts to identify equilibrium time scales of fluvial systems.