Title: Process-based Evolution Models of Steep River Channels by Migration of Bedrock Steps

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Abstract: Bedrock erosion is an important driver of landscape evolution, as it governs the base level lowering rate in mountainous landscapes. In many settings, the lateral migration of bedrock steps or small knickpoints accomplishes most of the vertical erosion in bedrock channels. However, most models of channel evolution focus on abrasion without accounting for the entrainment of blocks at the downstream edges of bed steps. Therefore, the magnitude of channel erosion and the detailed geometry of bedrock channels are not captured well. The diverse erosional components of bedrock channels prevent treatment as a continuum, and so to address this we present our first attempts to incorporate bedrock step migration in channel evolution models by explicitly tracking the extraction of individual blocks on a channel bed comprised of discrete blocks of prescribed size and aspect ratio. We base their probability of entrainment on the physics of block toppling and sliding. In the required force balance, we include the effects of a pressure difference between the upstream and downstream faces of the block. We inform the pressure fields and the probability of toppling and sliding of blocks with Computational Fluid Dynamics (CFD) experiments. In particular, for a prescribed water discharge, we explore the effects of the block aspect ratio on the forces that promote block motion. Varying the aspect of a block in the lee of a step affects the pressure fluctuations downstream of the block by altering the length of the recirculation zone. Low fluctuations in this pressure enhance block entrainment. Both abrasion and plucking of the bed are prevented in the topographic lows in the channel where sediment preferentially accumulates. Together, these rules allow self-organization of the bed into small-scale knick zones that propagate upstream. The location and longevity of the knick zones are governed by joint spacing (block size) and lithology. The propagation of the knick zone stalls at larger block sizes and more resistant lithologies. This work illustrates the roles of block size and aspect ratio, and hence of the geological setting, in governing the pace and the shape of evolving bedrock channels.