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Numerical modelling study of gully recharge and debris flows in Haida Gwaii, British Columbia

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In high mountains, debris flows are a major process responsible for transferring sediment to more downstream fluvial reaches. This sediment transfer begins on mountain hillslopes where various mass wasting processes move sediment from hillslopes to uppermost reaches of the channel system (these reaches are herein referred to as gullies and only experience water flow during high intensity precipitation events). Sediment recharge into gullies, which has received minimal attention in the scientific literature, refers to the transfer of sediment and other debris from surrounding hillslopes into gullies (Jakob and Oden, 2005). Debris flow occurrence and debris flow volumes depend on some precipitation threshold as well as volumes of material contained in the particular gully. For example, if one debris flow has removed all of the accumulated material from the gully, then any subsequent debris flow will be smaller if enough time has not yet passed for notable sediment recharge.

Herein, we utilize the numerical model of landscape development, LandMod (Martin, 1998; Dadson and Church, 2005; Martin, 2007), to explore connections between hillslope processes, gully recharge rates, and transfer of sediment to downstream channel reaches in the Haida Gwaii, British Columbia. Hillslope processes in the model include shallow landsliding, bedrock failures and weathering. The updated debris flow algorithm is based on extensive field data available for debris flows in Haida Gwaii (e.g., Rood, 1984; Oden, 1994; Jakob and Oden, 2005), as well as theoretical considerations based on debris flow studies. The most significant model extension is the calculation of gully recharge rates; for each gully, the total accumulated sediment in gullies at each time step is determined using a power-law relation for area-normalized recharge rate versus elapsed time since the last debris flow. Thus, when the stochastic driver for debris flow occurrence triggers an event, the amount of stored material is known and can be transferred and deposited along the channel system. Results show that the size distribution of debris flows and sediment transfers from gullies to downstream reaches are modified by the inclusion of a module that accounts for sediment recharge when compared to model runs that do not consider gully recharge.