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Climate-sensitive feedbacks between hillslope processes and fluvial erosion in sediment-driven incision models

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Surface erosion and sediment production accelerated dramatically in most parts of the world as the climate cooled in the Late Cenozoic, (e.g. Molnar, Annu. Rev. Earth Planet. Sci. 32, 2004). In many high mountain ranges, glaciers emerged for the first time during the Quaternary, and they represent a likely explanation for the accelerated erosion in such places. Still, observations and measurements point to increases in erosion rate also in landscapes where erosion is driven mainly by fluvial processes (e.g. Lease and Ehlers, Science 341, 2013). Why fluvial incision responds to climate change remains enigmatic, in particular because the obvious links to variations in precipitation, and hence water flux, are not generally supported by erosion rate measures (Stock et al., GSA Bulletin 117,
2005).

This study explores potential links between accelerating rates of river incision and sediment production on hillslopes that surround the channel network. Hillslope soil production and soil transport are processes that are likely to respond to decreasing temperatures, because the density of vegetation and for example the occurrence of frost influence rates of weathering and sediment flow.

We perform computational landscape evolution experiments where a sediment-flux-dependent model for fluvial incision (e.g. Sklar and Dietrich, Geology 29, 2001) is coupled to models for sediment production and transport on hillslopes.
The resulting coupled landscape dynamics is of a highly nonlinear nature, where even small changes in hillslope sediment production far up in a drainage network propagate all the way through the downstream fluvial system. Dependent on the total sediment load, the fluvial system may respond with increased incision that steepens the hillslopes and starts a positive feedback loop that accelerates overall erosion.