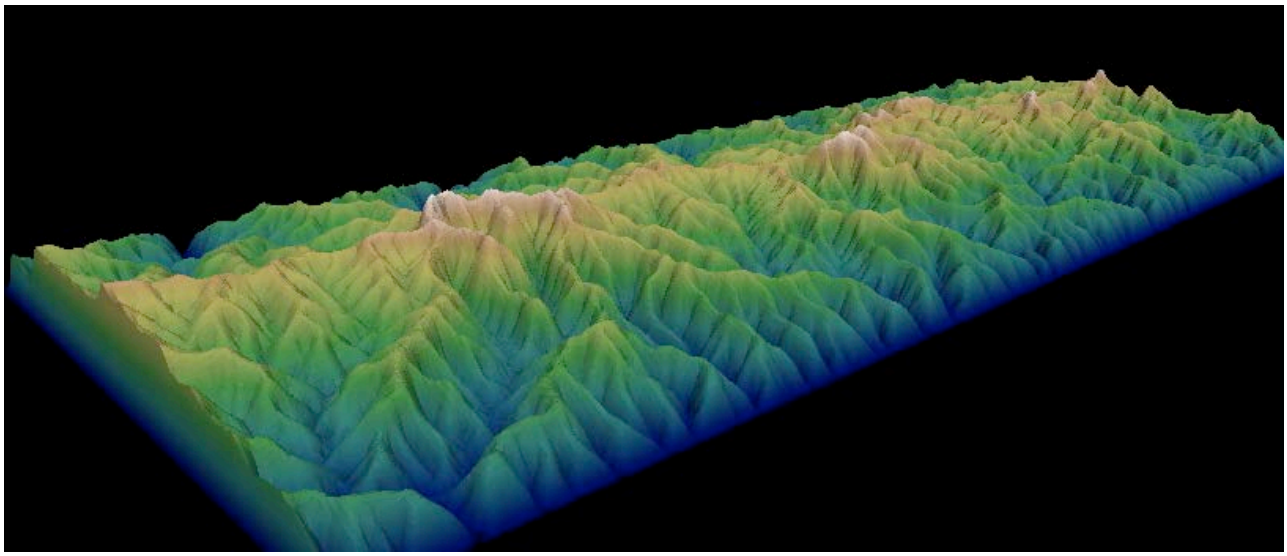
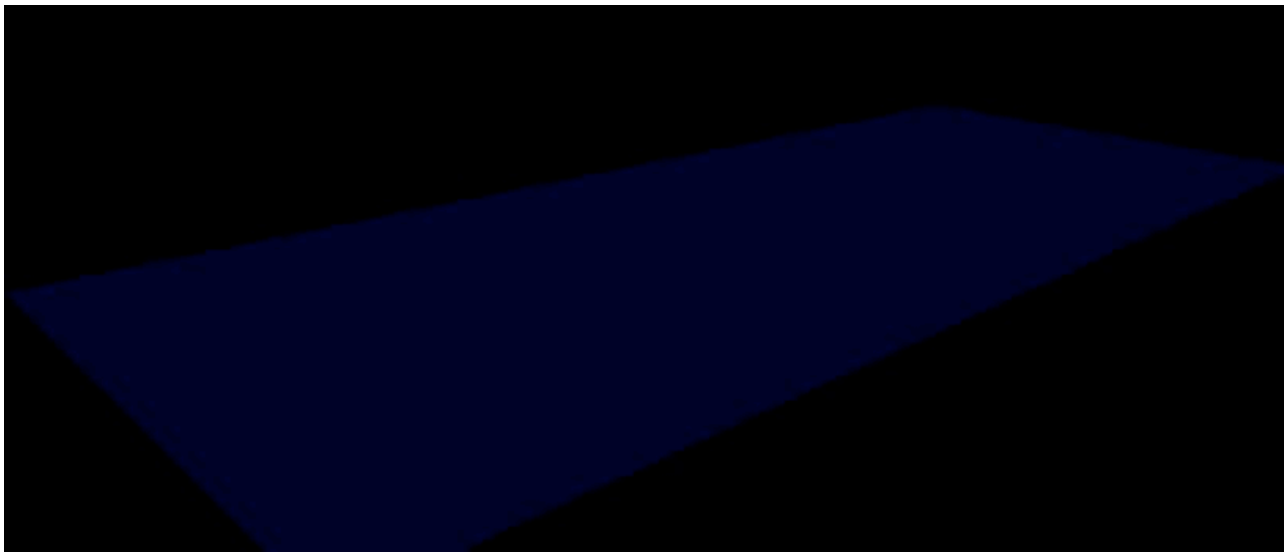


Quantifying controls of river erosion on geodynamic timescales

Brian Yanites
University of Idaho

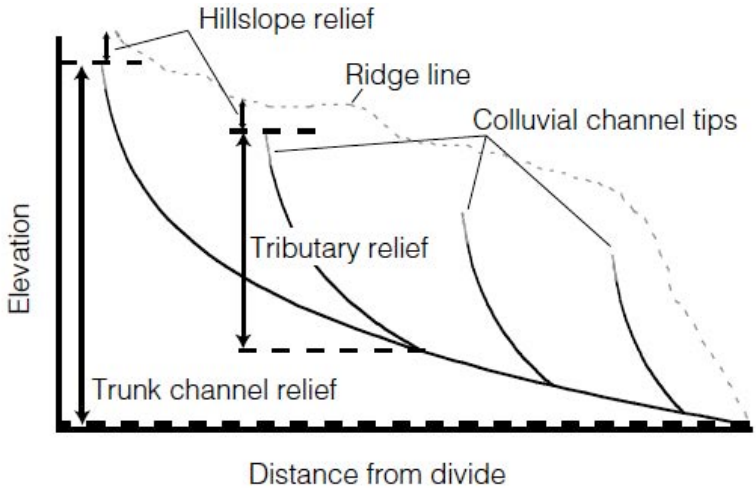


Landscape evolution

dz/dt = Tectonic uplift rate - Erosion rate

Erosion = Fluvial + Hillslope

Why rivers?



Whipple et al., 1999 Nature

They dictate the orogen scale relief

"Stream Power" model of river incision

$$E = K A^m S^n$$

Erosion Rate

Erodibility

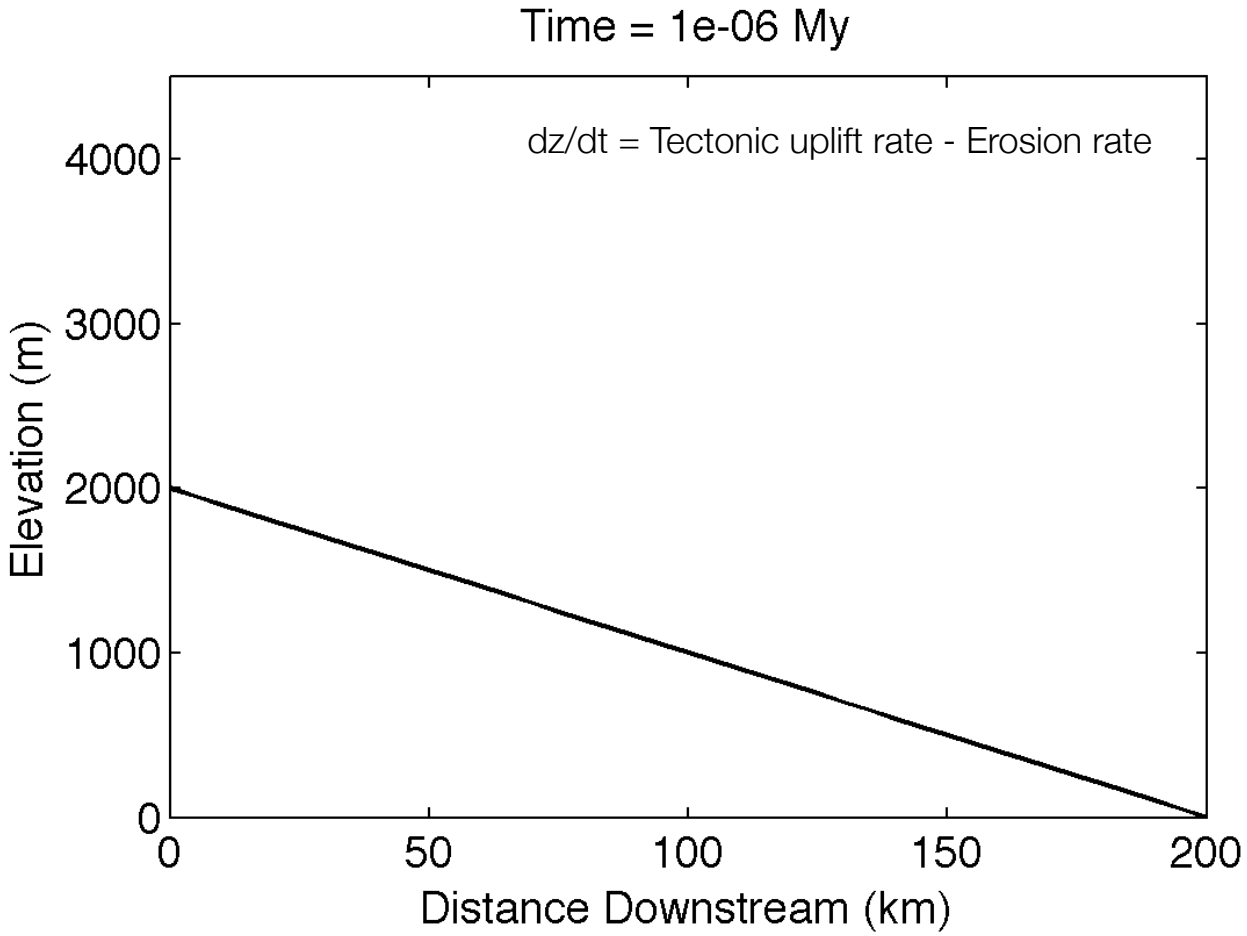
Drainage Area

Slope

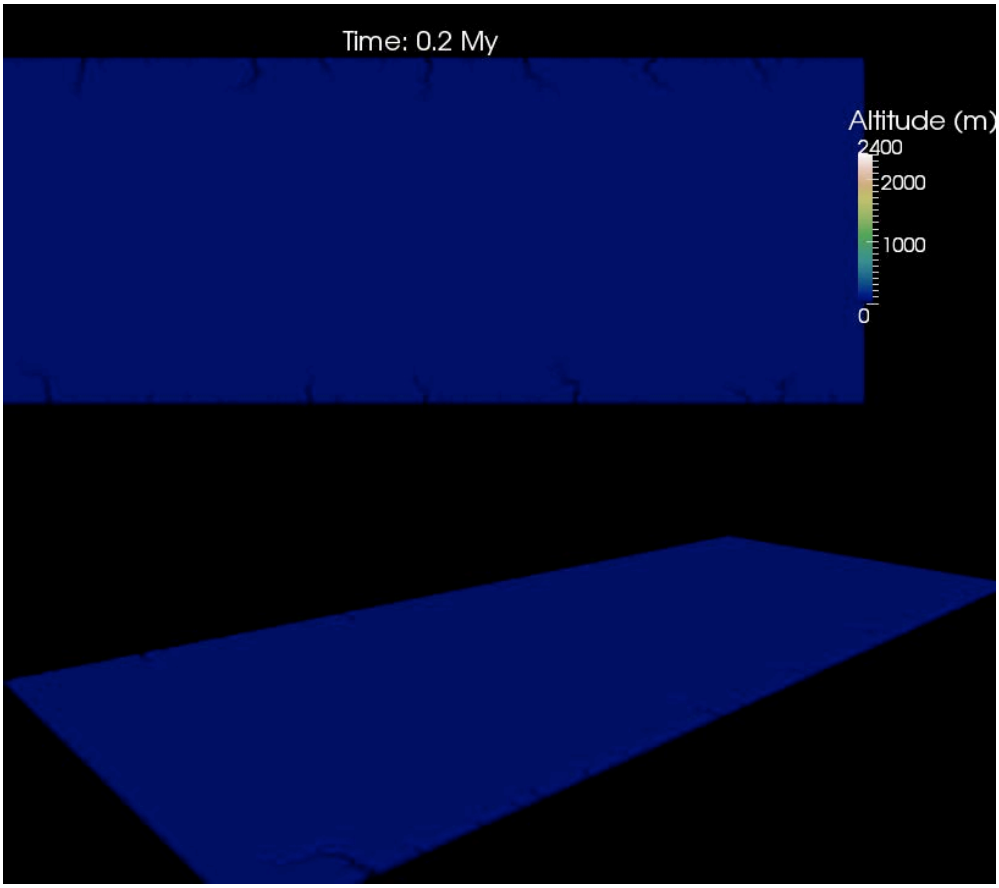
Water flowing over a landscape has potential energy

How that potential energy is converted to work is dictated by values of n and m

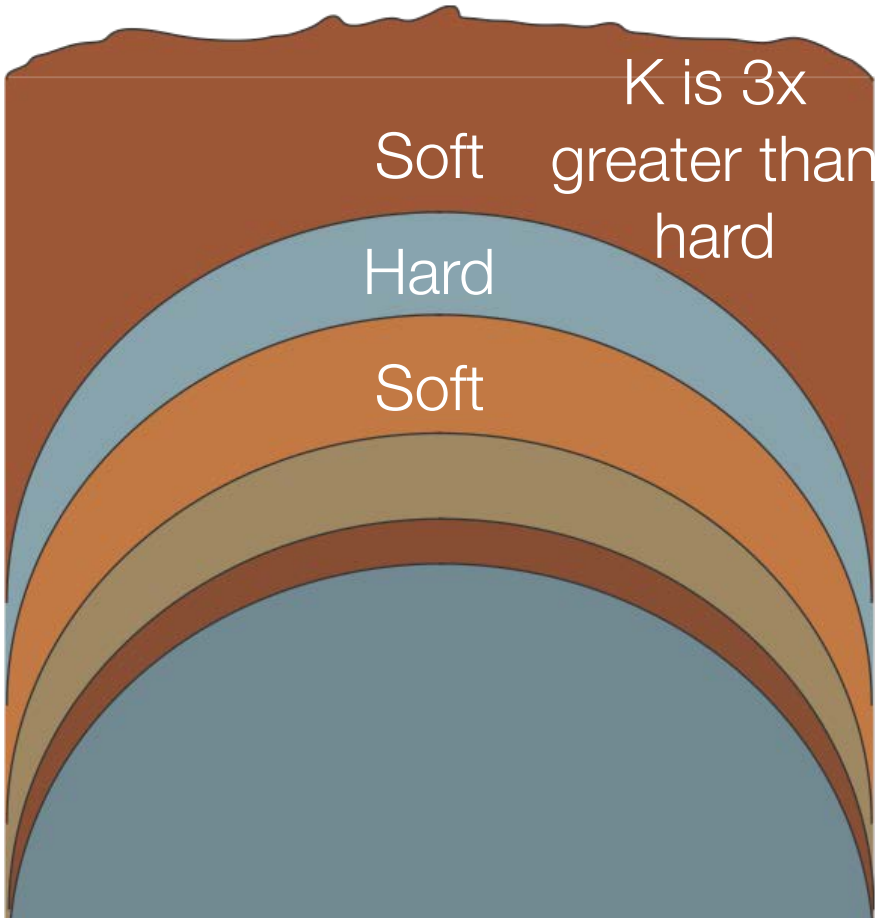
River response to a 5x increase in rock-uplift at 2 My

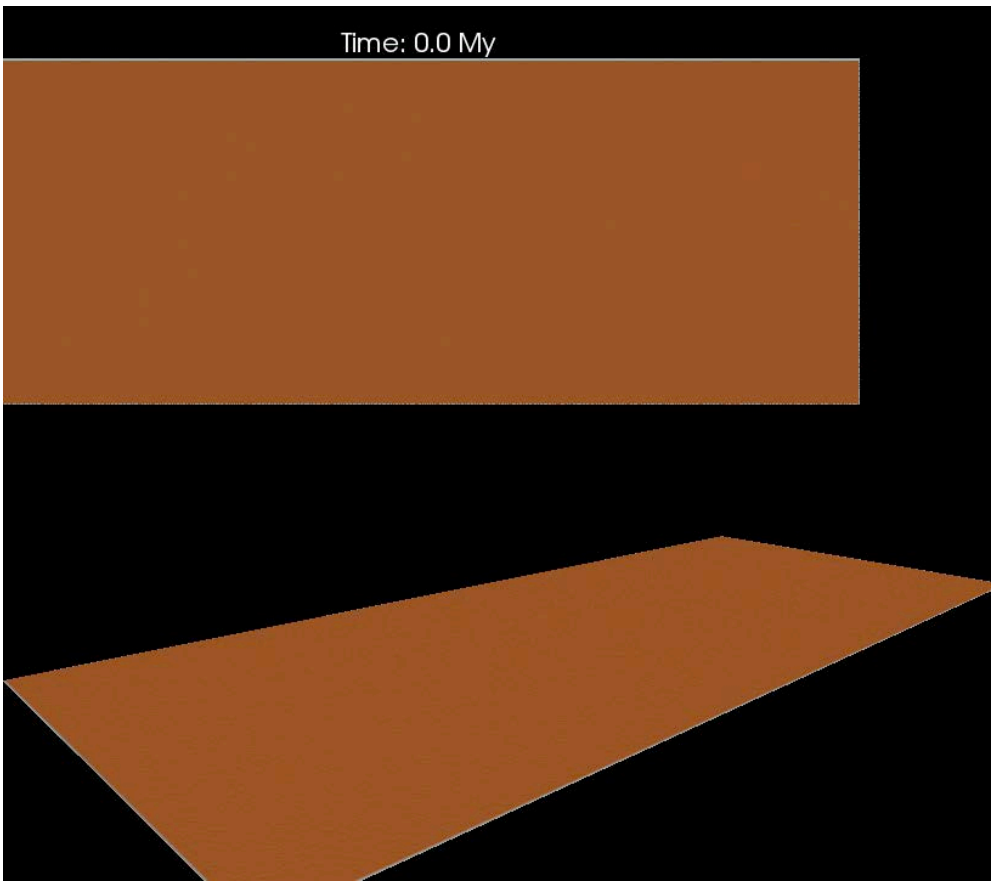


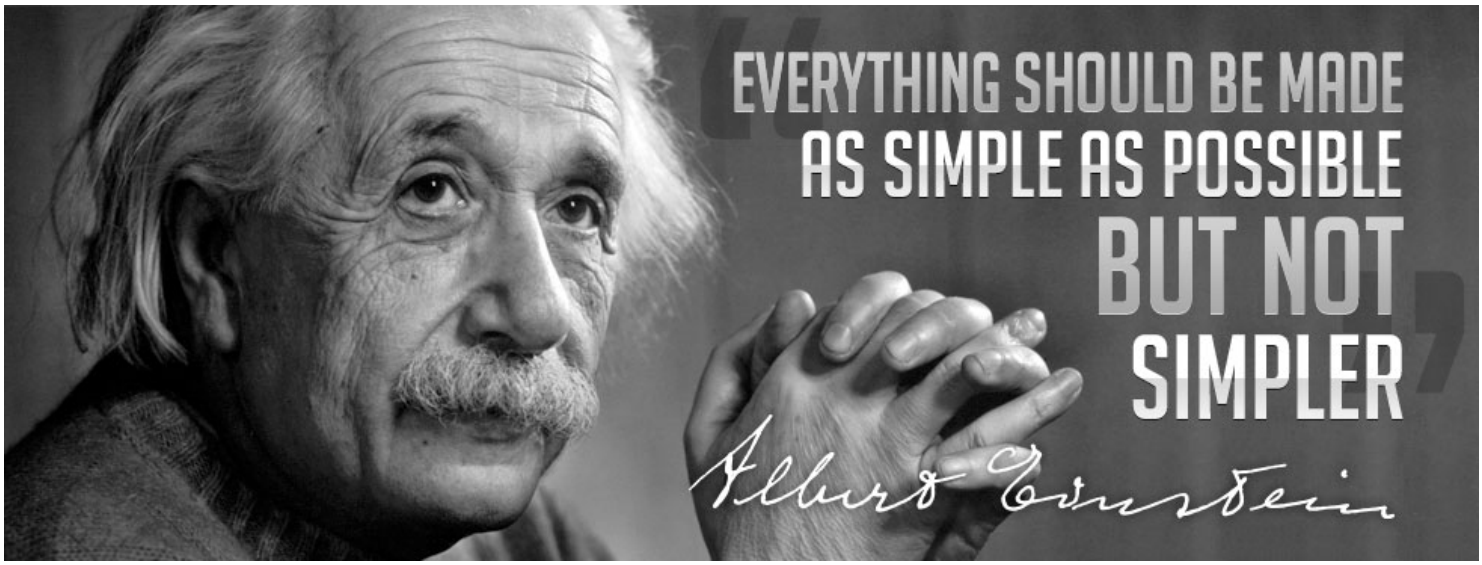
LEM: Predict landscape response to changes in climate, tectonics, lithology, biology, etc.



This example: lithology

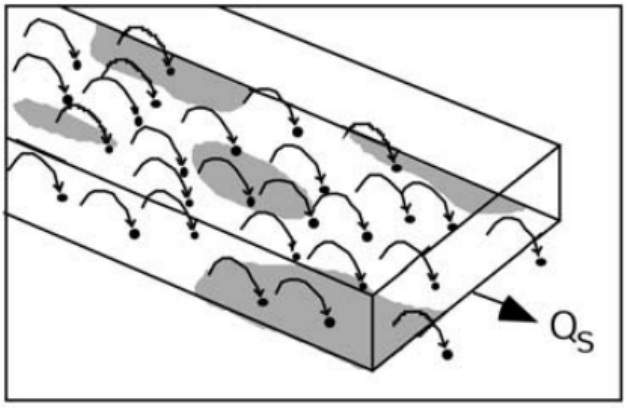



Time: 0.0 My



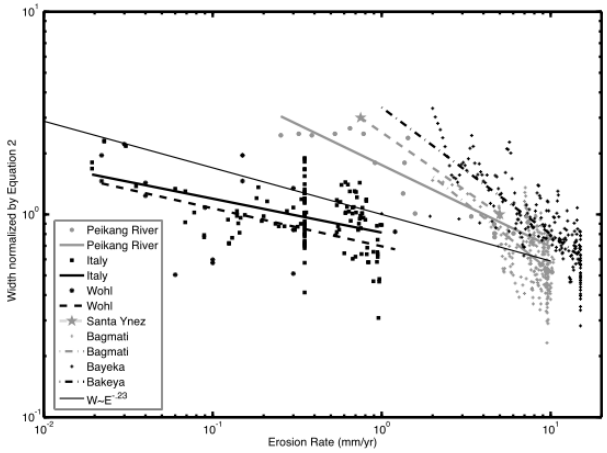
Is the “Stream Power” model too simple?

Mechanics of erosion



Sklar and Dietrich, 2004

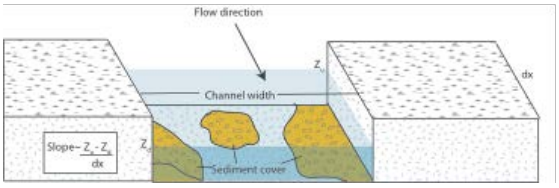
Dynamic cross channel geometry

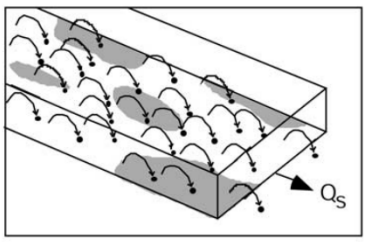


Yanites and Tucker, 2010

Variability and thresholds

See Lague, 2013, Dibiase and Whipple, 2011, Tucker 2004, etc.





Shear stress

$$E = K\tau^a$$

$$\tau = \rho g R S$$

$$R = \frac{A}{P} = \frac{WH}{W + 2H}$$

Sediment cover

$$E = FK\tau^a$$

$$F = 1 - \frac{Q_s}{Q_t}$$

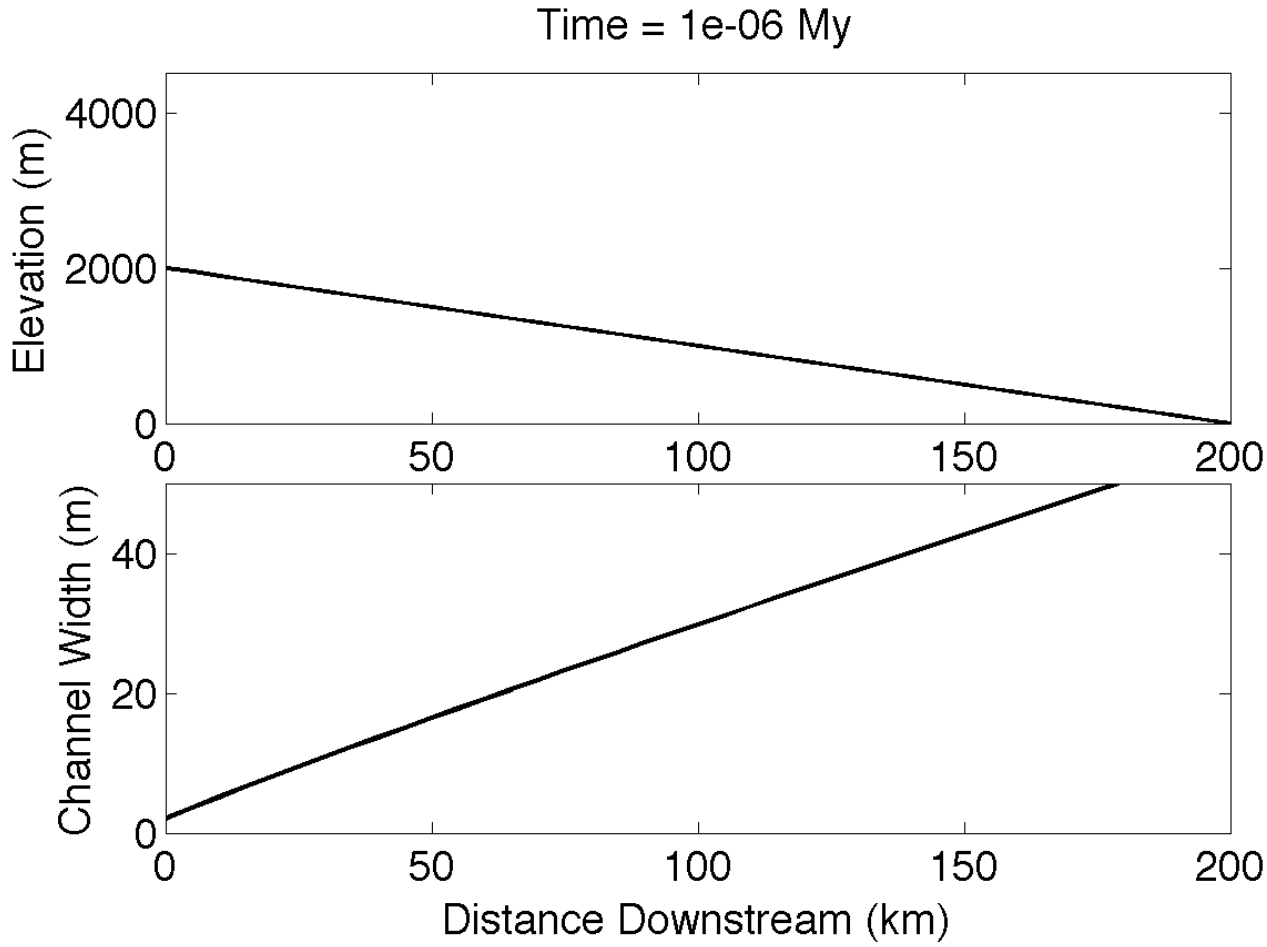
$$Q_t = fxn\{W, \tau^{3/2}\}$$

Saltation Abrasion

$$E = VI_fF$$

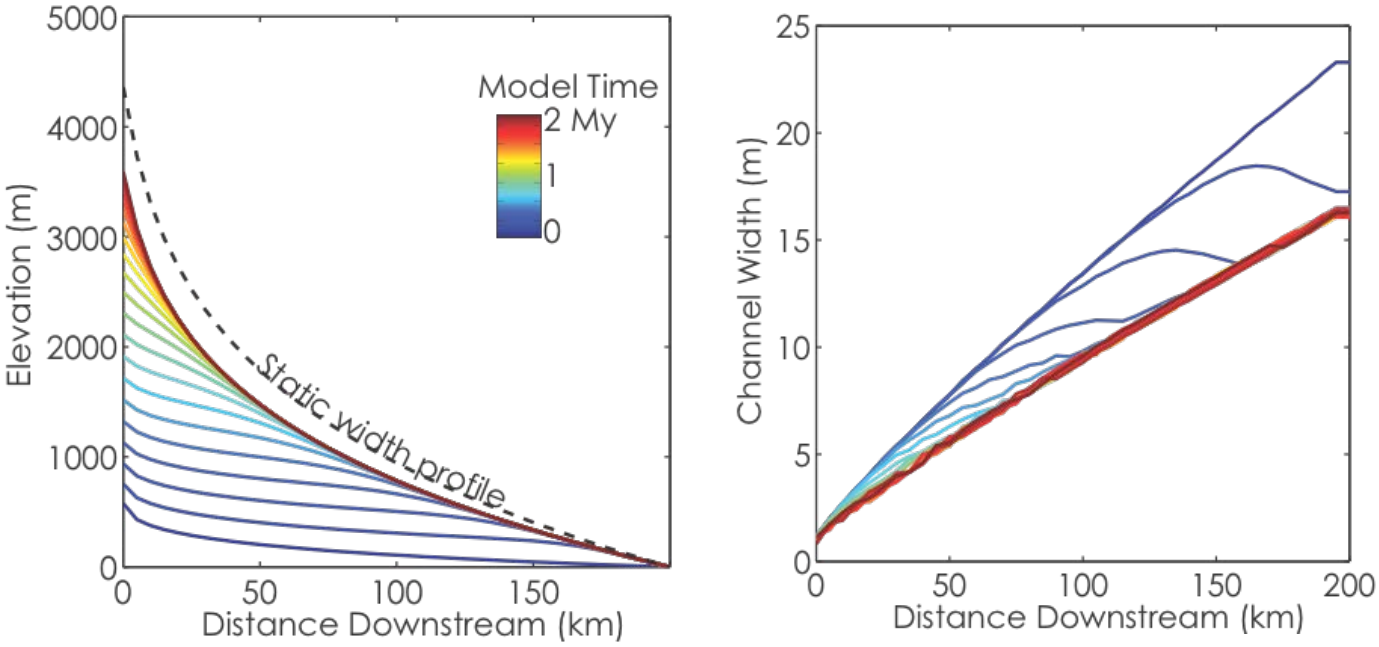
Dynamic channel width $W = W_i \pm k_w\tau$

River response to a 5x increase in rock-uplift



Does it matter?

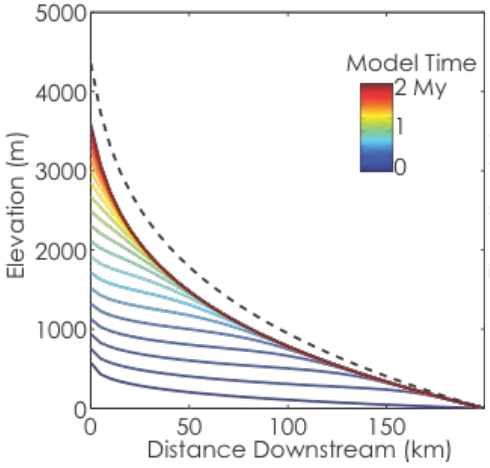
River response to a 5x increase in rock-uplift

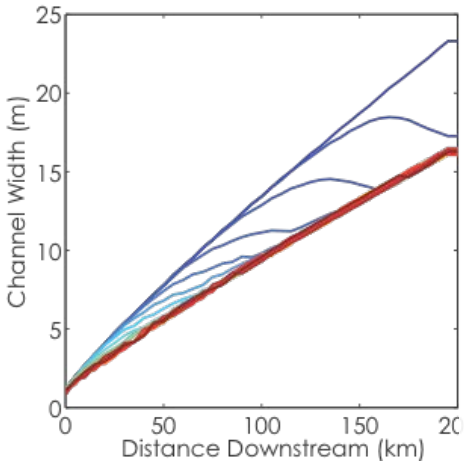


~ 30% higher topography if you ignore channel width

Shear stress

Relief change 420%





Sediment cover

Relief change 237%

Saltation Abrasion

Relief change 154%

Some thoughts in the spirit of this workshop

- Does ignoring factors such as channel width and the role of sediment in river erosion overestimate the coupling between surface processes and geodynamics?
- If so, is it enough to matter?
- ???????????

Summary/review

Rivers control relief evolution of topography

"Stream Power" model is probably too simple in most landscapes, but the simplicity provides an excellent 'first pass' analysis of topographic response to forcings

The traditional "Stream Power" approach probably overpredicts the topographic response to changes in tectonics

Advances in theory and computational tools are generating new models that will more accurately predict topographic response to tectonic and/or climatic forcing

CSDMS framework can help integrate these advances into coupled models in relatively quick and straightforward manner