Some DEM Science applications

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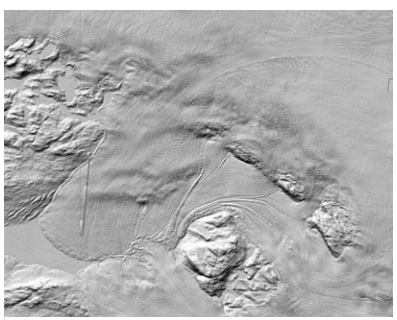
Getting the right coverage in time, space, and resolution for the question

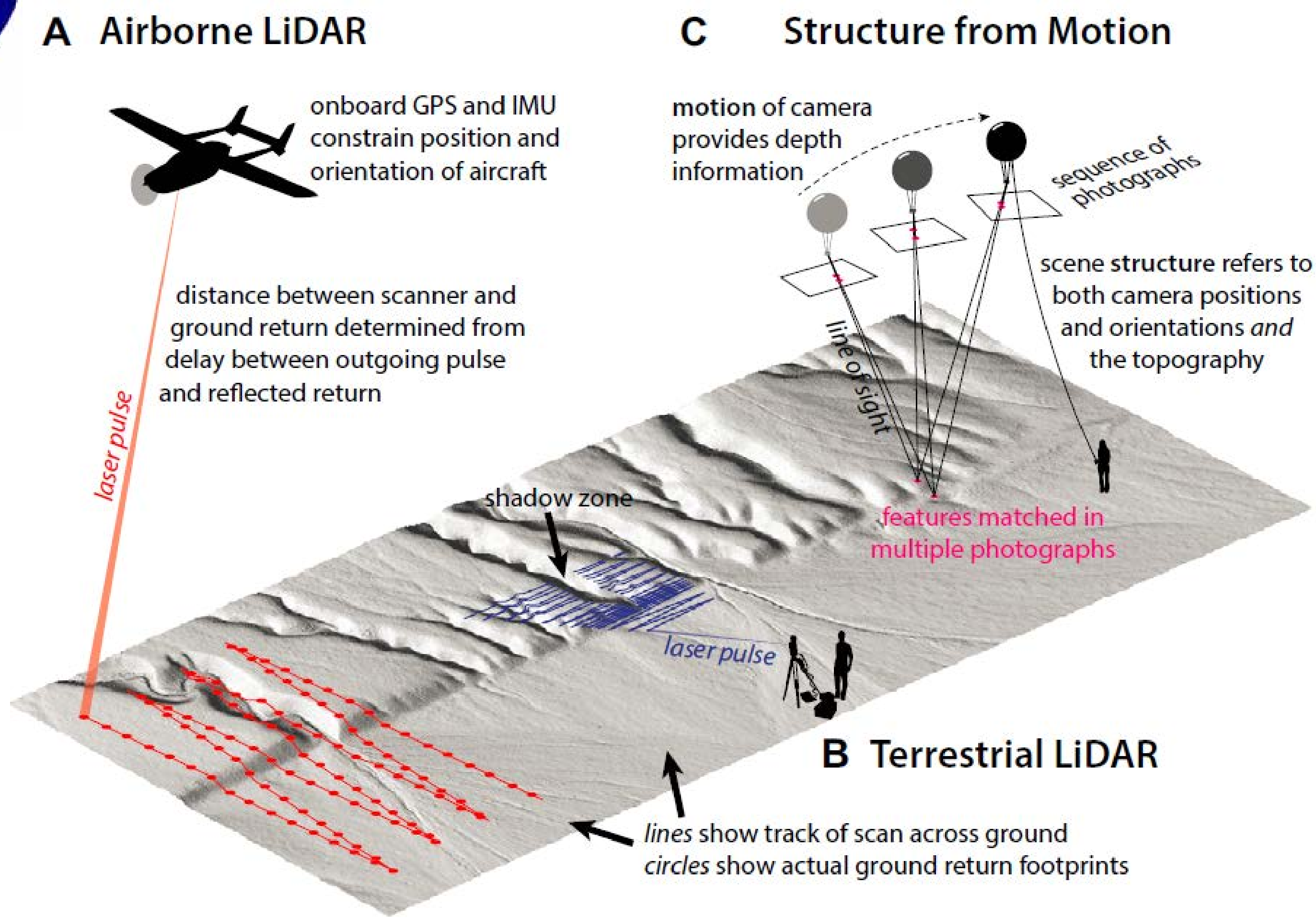
Global and regional topography/bathy (10s-100s m/pix)

+ASTER



Stereo-Photogrammetric Elevation Model (Polar Geospatial Center)

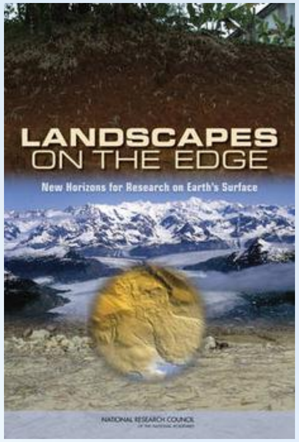
Local to site scale topography (dm to m / pix)



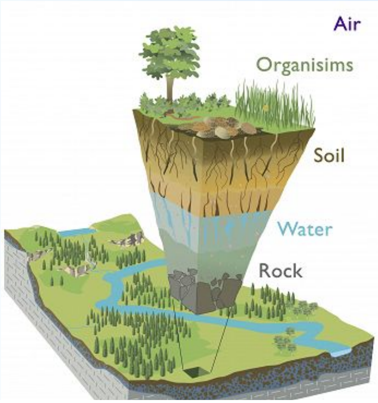
Johnson, K., Nissen, E., Saripalli, S., Arrowsmith, J R., McGarey, P., Scharer, K., Williams, P., Blisniuk, K., Rapid mapping of ultra-fine fault zone topography with Structure from Motion, Geosphere, v. 10; no. 5; p. 1–18; doi:10.1130/GES01017.1, 2014.

Example scientific motivations

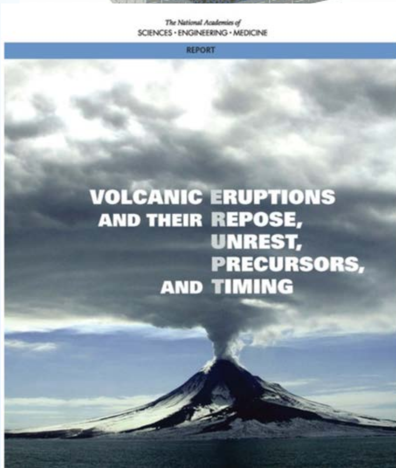
- How do geopatterns on the Earth’s surface arise and what do they tell us about processes?
- How do landscapes influence and record climate and tectonics?
- What are the transport laws that govern the evolution of the Earth’s surface?

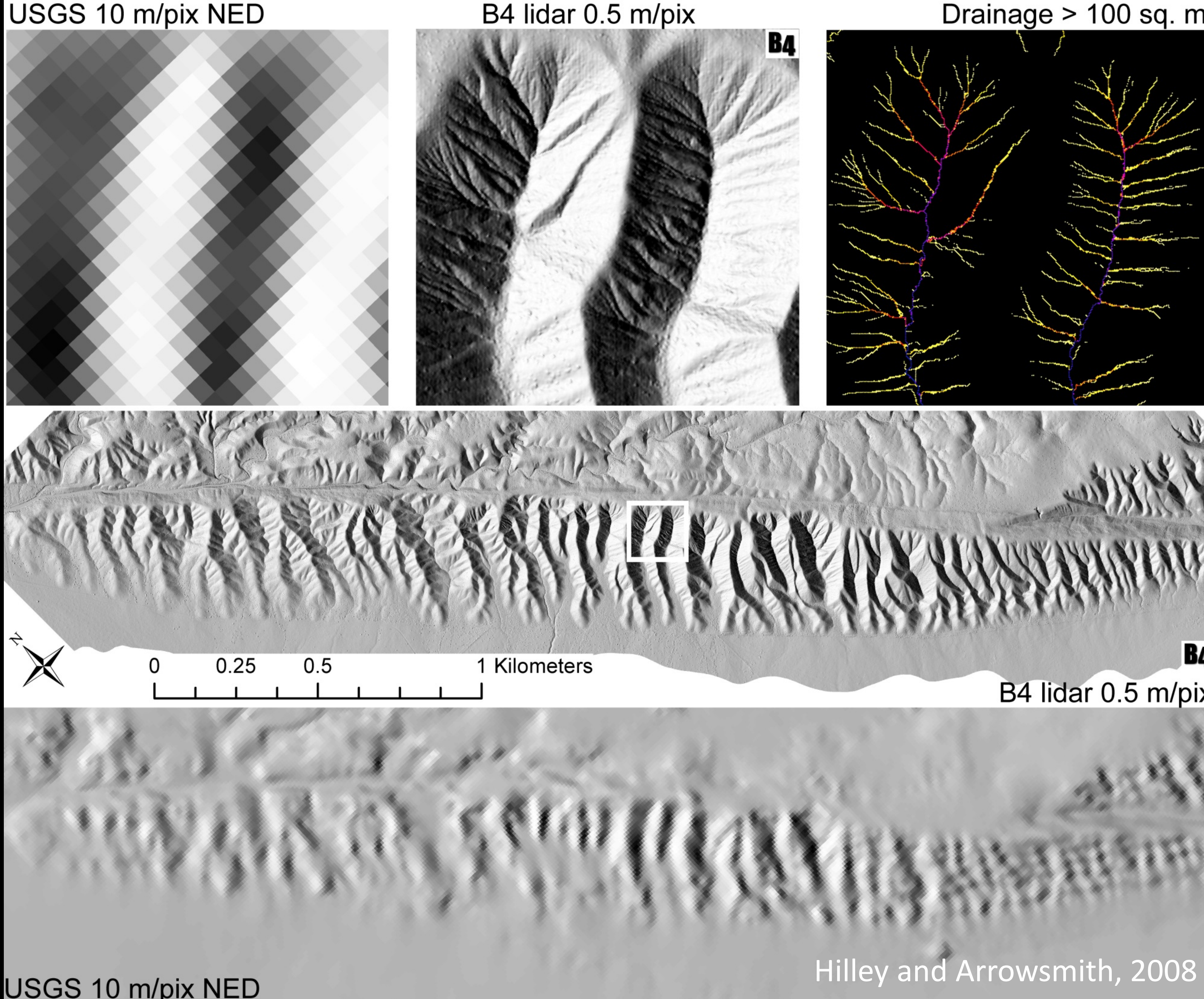


- Coupled hydrogeomorphic-ecosystem response to natural and anthropogenic change
- Landscape and ecosystem dynamics



- Volcano form and process
- Changes in volume of domes, edifice, flows over time
- Stability and hazard




USGS 10 m/pix NED
B4 lidar 0.5 m/pix
B4
Drainage > 100 sq. m
N
0
0.25
0.5
1 Kilometers
B4
B4 lidar 0.5 m/pix
Hilley and Arrowsmith, 2008
USGS 10 m/pix NED

What science can be done with ≤2 m DEMs?

In particular, can we identify scale breaks in phenomena which are crossed at this high resolution (and accuracy)?

Go beyond steady, time independent process rules

Surface processes and change: observe the phenomena at the appropriate fine scale at which the processes are operating

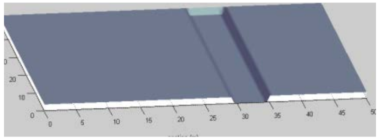
One way to describe applications:

- 3D mapping for structure (folds, faults, fractures, contacts, unconformities, sedimentary packages, igneous structures, etc.)
- Landscape reconstruction
- Surface process interactions with tectonic, volcanic, cryospheric, ecological processes
- Differencing of repeat surveys—measure change in 2.5-3D

Also (geo)science education!

Landscape development in areas of active deformation

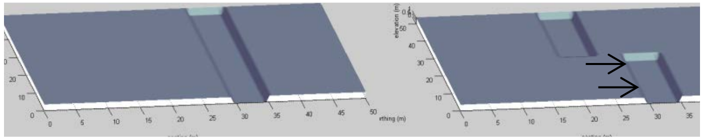
Original
elevation



$$H_0(x, y)$$

Landscape development in areas of active deformation

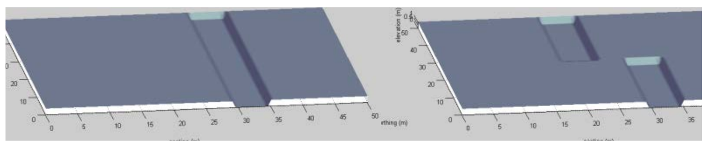
Original elevation + Tectonic displacement



$$H_0(x,y) + U(x,y,t,H)$$

Landscape development in areas of active deformation

Original elevation + Tectonic displacement

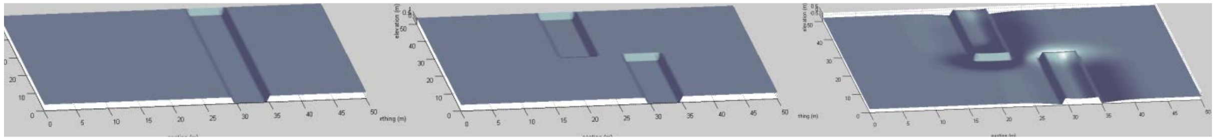


$$H_0(x, y) + U(x, y, t, H)$$

Denali 2002 earthquake rupture
(EarthScope)

Landscape development in areas of active deformation

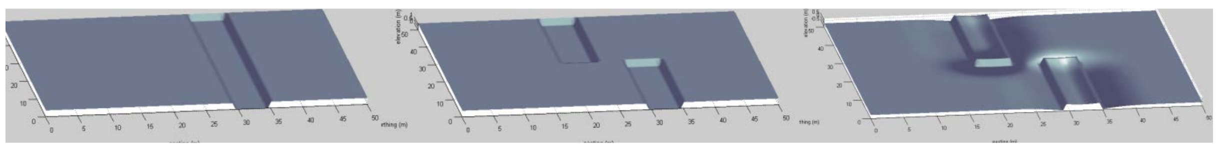
Original elevation + Tectonic displacement + Geomorphic displacement



$$H_0(x, y) + U(x, y, t, H) + V(x, y, t, H)$$

Landscape development in areas of active deformation

Original elevation + Tectonic displacement + Geomorphic displacement

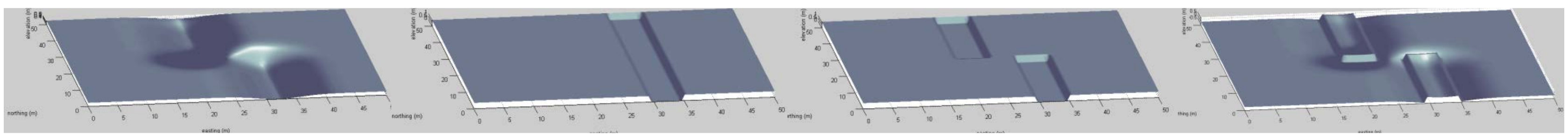


$$H_0(x, y) + U(x, y, t, H) + V(x, y, t, H)$$

Landscape development in areas of active deformation

Surface processes act to change elevation through erosion and deposition while tectonic processes depress or elevate the surface directly.

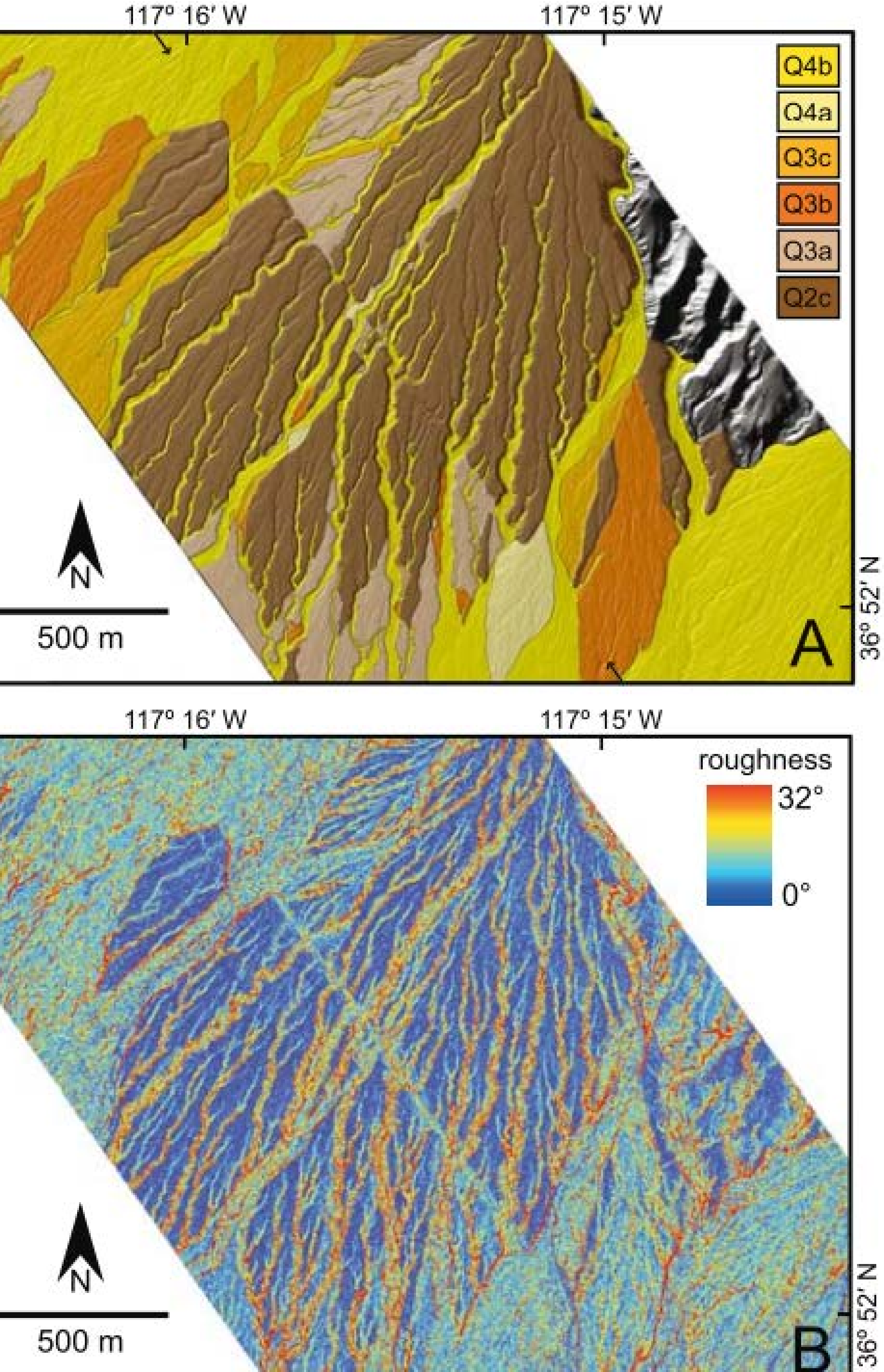
Current elevation = Original elevation + Tectonic displacement + Geomorphic displacement

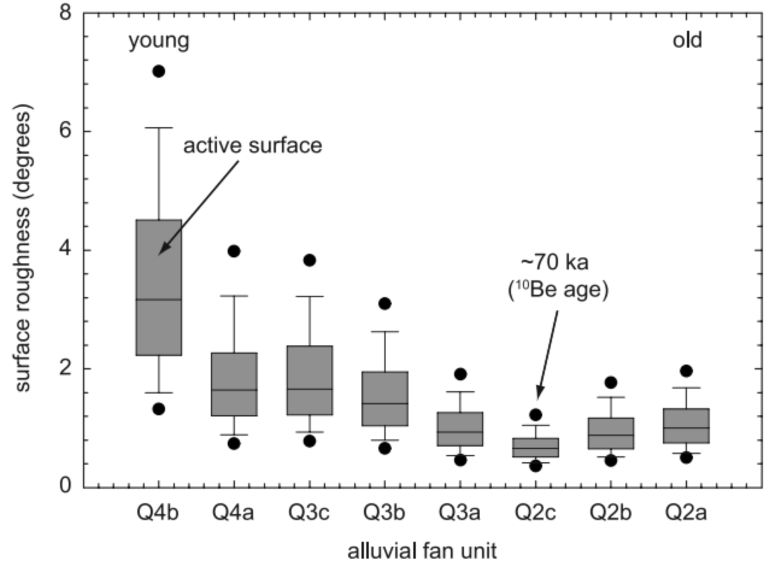


$$H(x, y, t) = H_0(x, y) + U(x, y, t, H) + V(x, y, t, H)$$

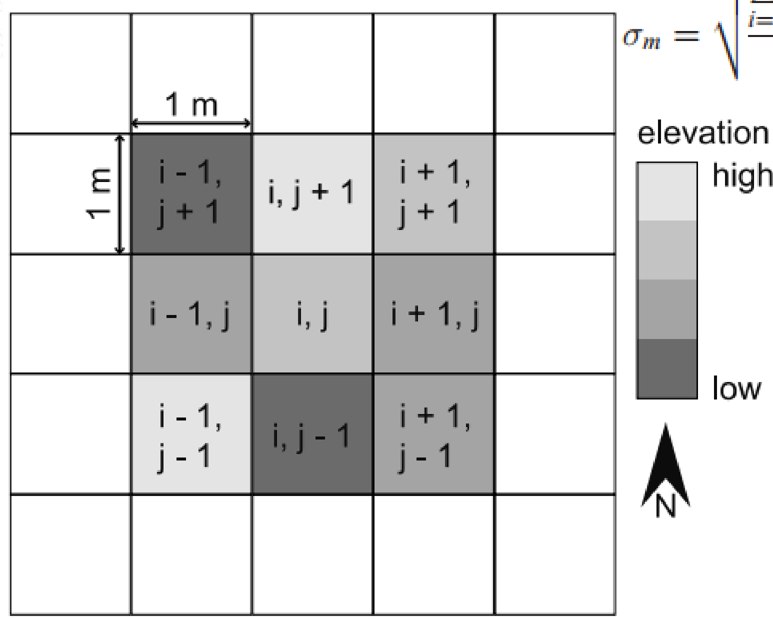
Teton Fault System: US Basin and Range
DSM and DTM hillshades from OpenTopography

Going beyond pretty pictures: the hillshades are very nice, but…





$$\sigma_m = \sqrt{\frac{\sum_{i=1}^{n} (m_i - \overline{m})^2}{n}},$$

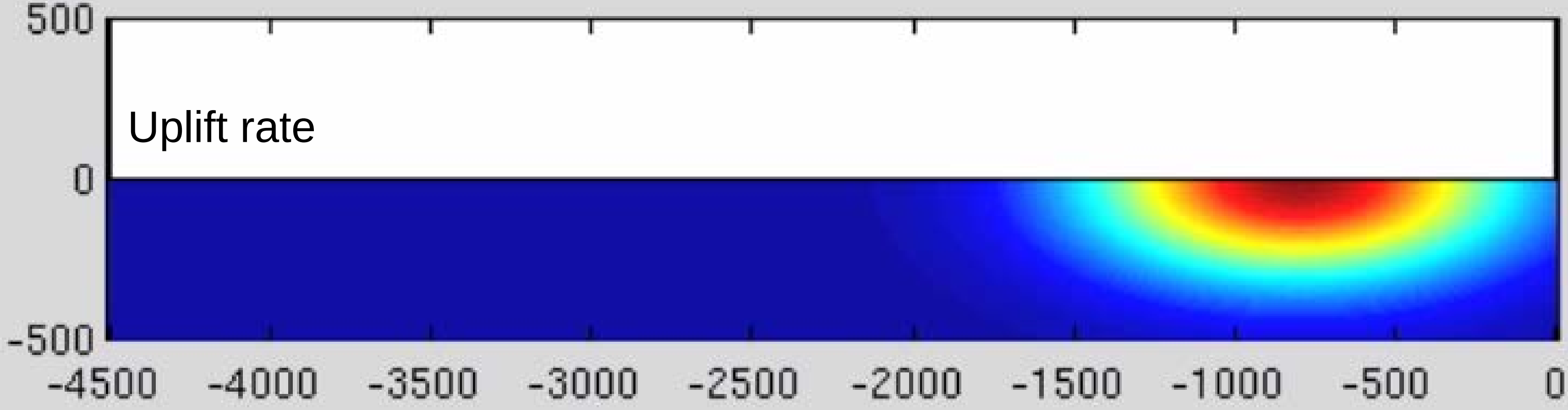


Characterizing arid region alluvial fan surface roughness with airborne laser swath mapping digital topographic data

Kurt L. Frankel[1] and James F. Dolan[1]

JGR, 2007

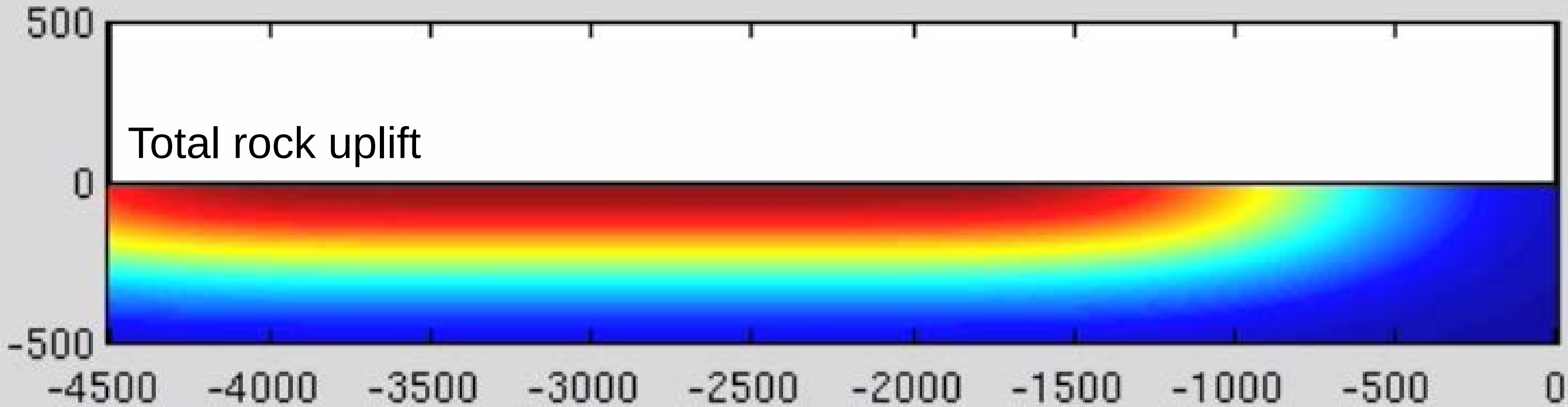
Understanding geomorphic response to uplift



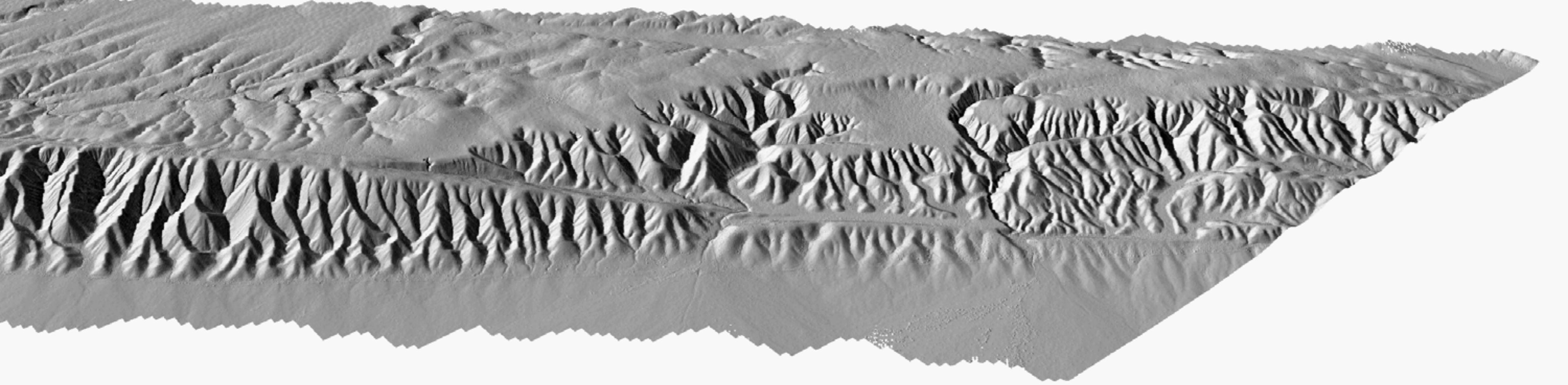
Material moves along fault though relatively stationary uplift zone:

How does landscape respond?

What will the landscape tell us about the geometry of the uplift?

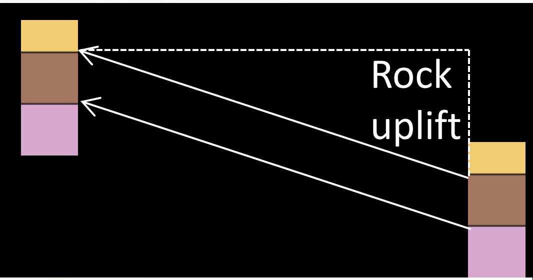


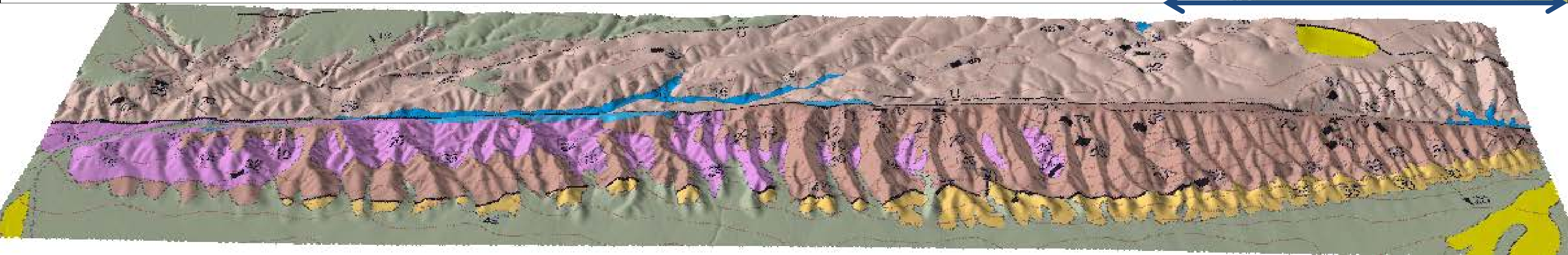
-G. E. Hilley



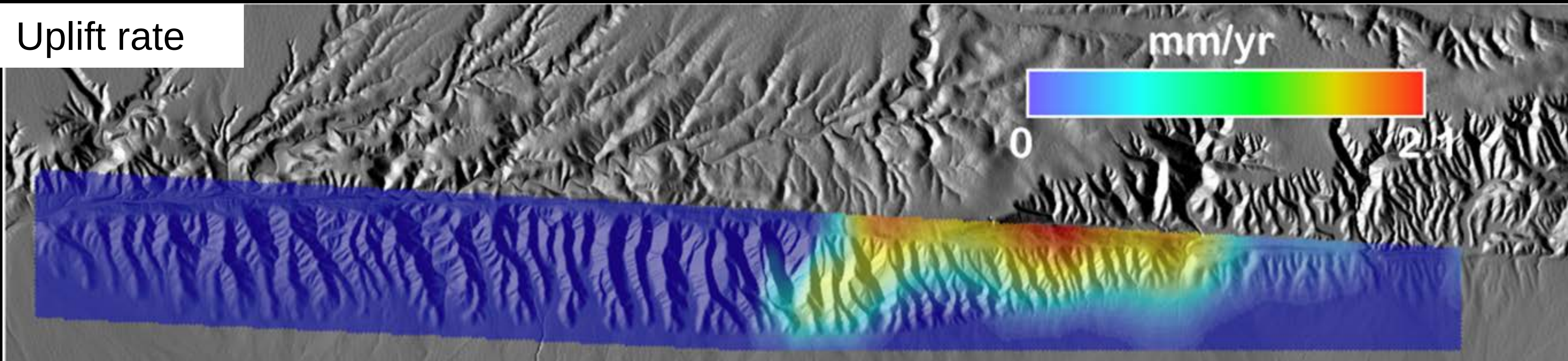
Dragon's Back Pressure Ridge, Carrizo Plain
California

Arrowsmith, 1995; Hilley, 2001; Hilley and Arrowsmith, 2008

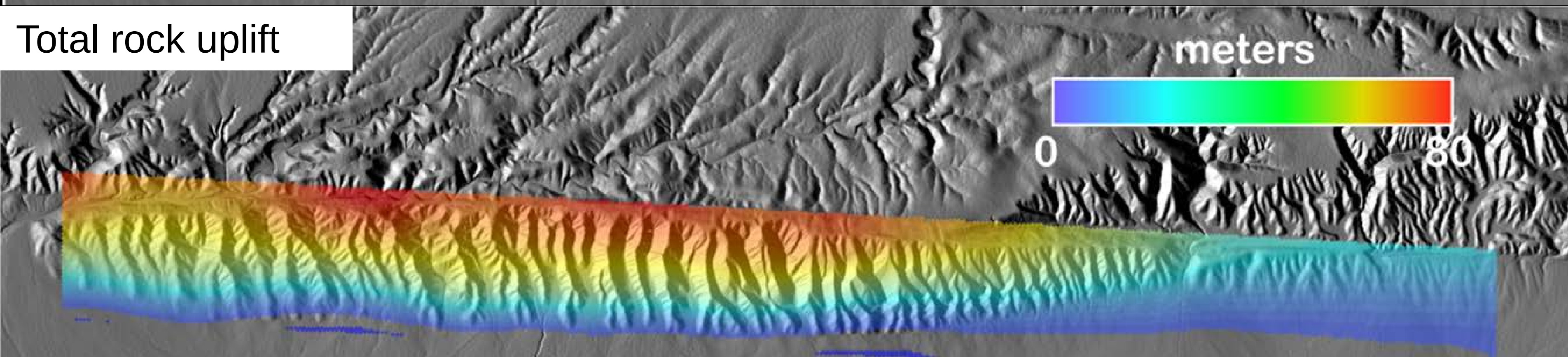




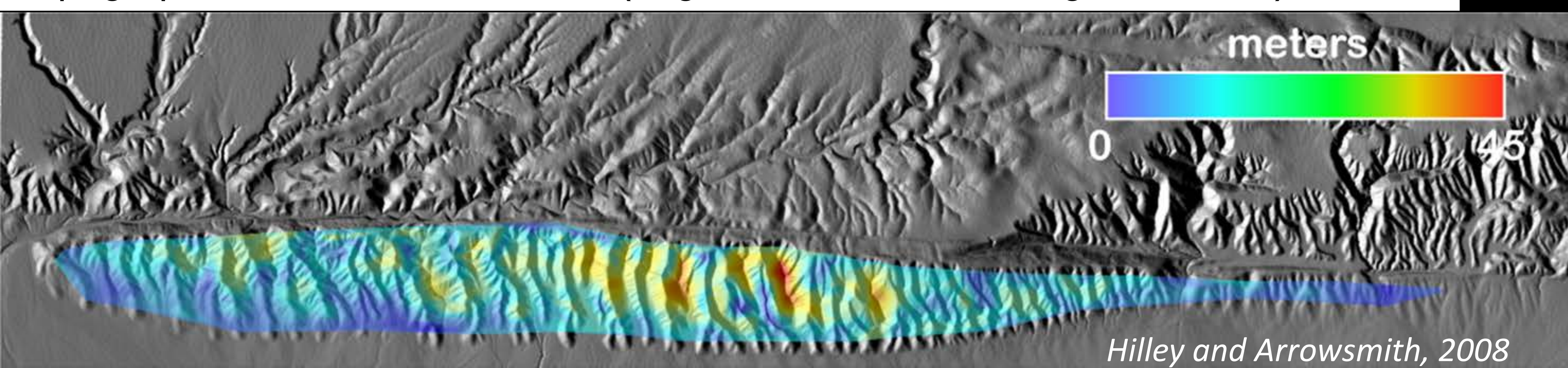
Uplift rate



Total rock uplift



Topographic metric: residual relief (ridge elevations – drainage elevation)



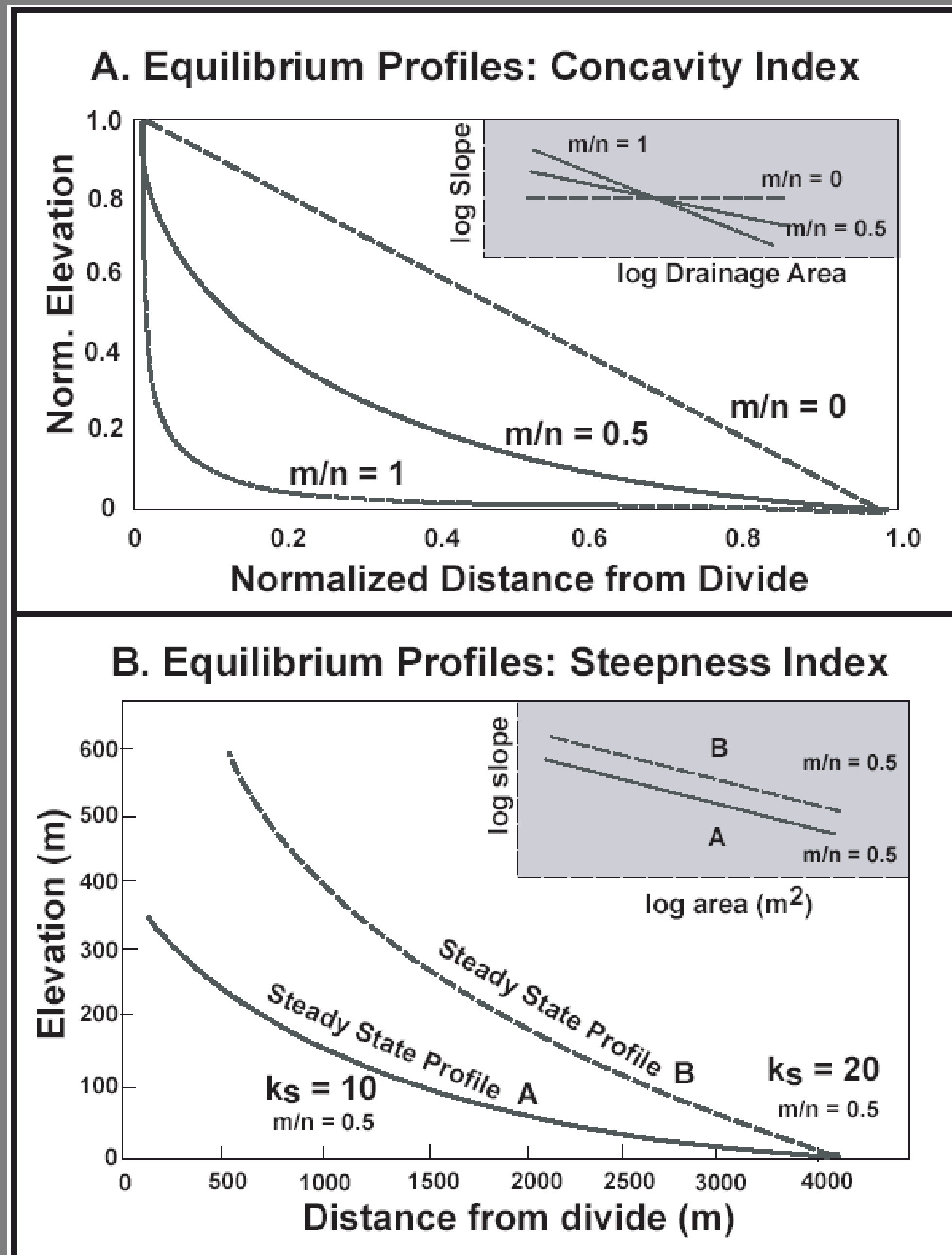
Hilley and Arrowsmith, 2008

Duvall, Kirby, and Burbank, 2004, JGR-ES

U = Rock Uplift Rate

Concavity (θ)
invariant with U

Steepness (Ks)
varies with U

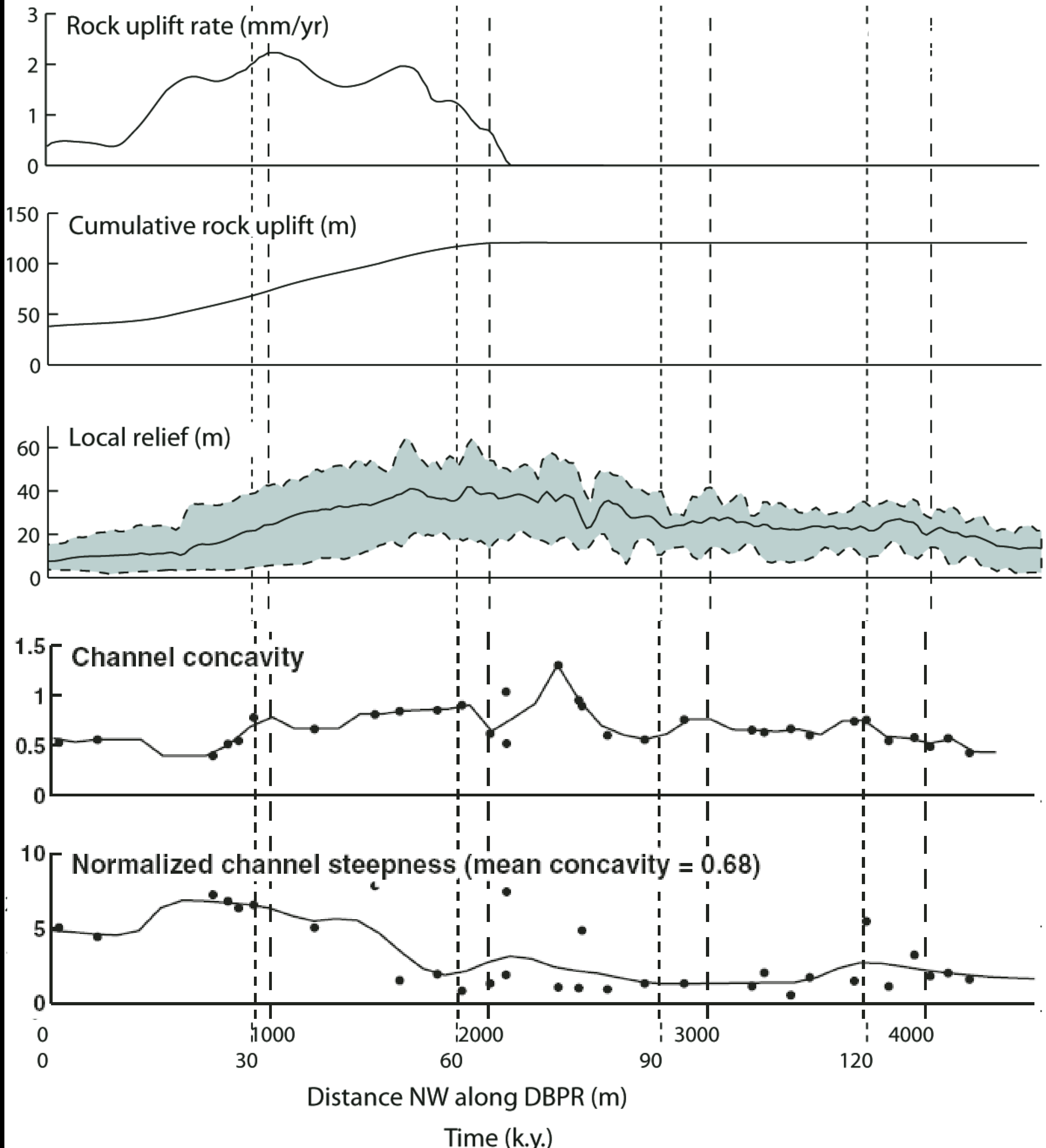


$\theta = m/n$

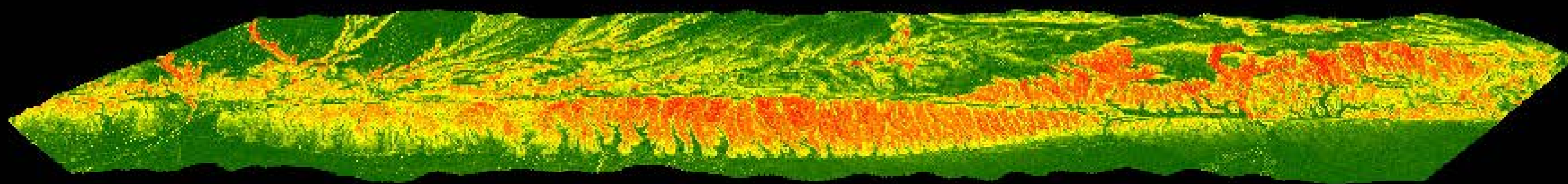
$S = k_s A^{-\theta}$

k_s

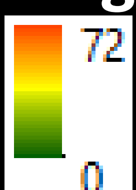
--K. X Whipple



Hilley and Arrowsmith, 2008



Dragon’s Back slope distribution (1 m pix)



degrees

c.f. Hurst, M. D., Mudd, S. M., Attal, M., & Hilley, G. E. (2013). Hillslopes Record the Growth and Decay of Landscapes. *Science (New York, N.Y.)*, *341*, 868–871. https://doi.org/10.1126/science.1241791