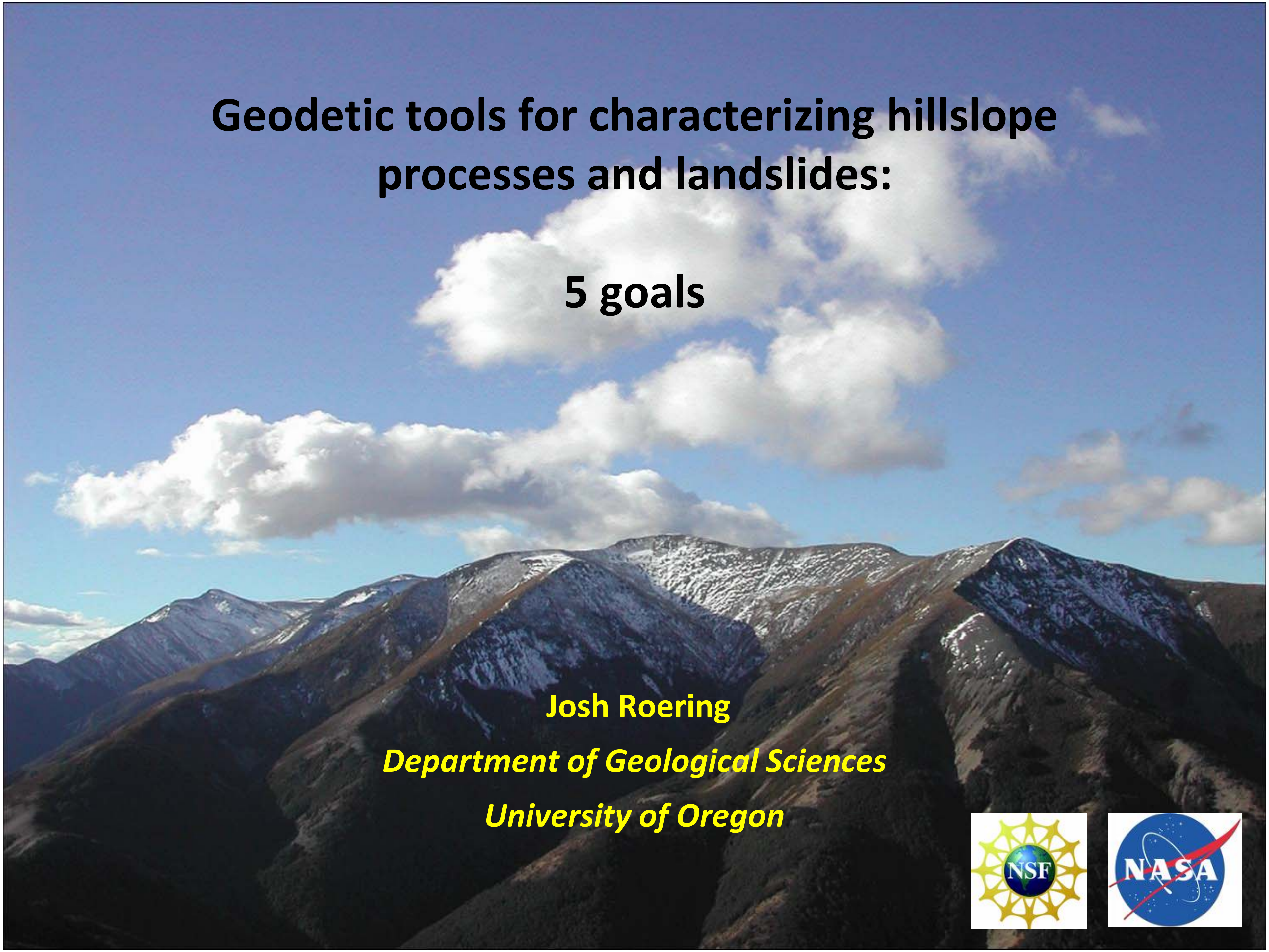

Geodetic tools for characterizing hillslope processes and landslides:

5 goals

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Goal 1. Interpretation and prediction of hillslope evolution

Landscape evolution reflects:
- tectonic forcing
- rock type
- climate & biology

Erosion Tectonics

$$\frac{\partial z}{\partial t} = -\nabla \cdot q_s + U$$

Dietrich et al., 2003

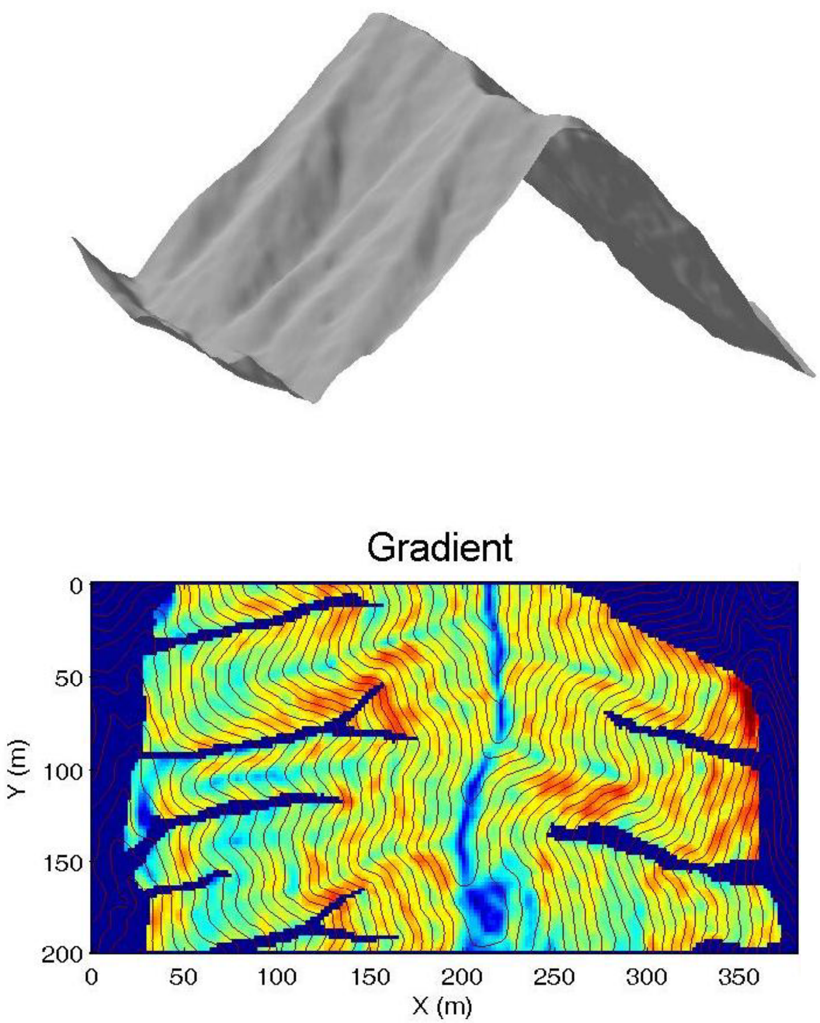
- Most landscapes erode at rates less than 0.5 mm yr^{-1}
- Most erosion rate estimates are derived from river sediments (i.e., catchment-averaged)
- To test/calibrate erosion models, we often rely on landscape morphology (e.g., lidar)

Morphologic change after 500,000 yrs…

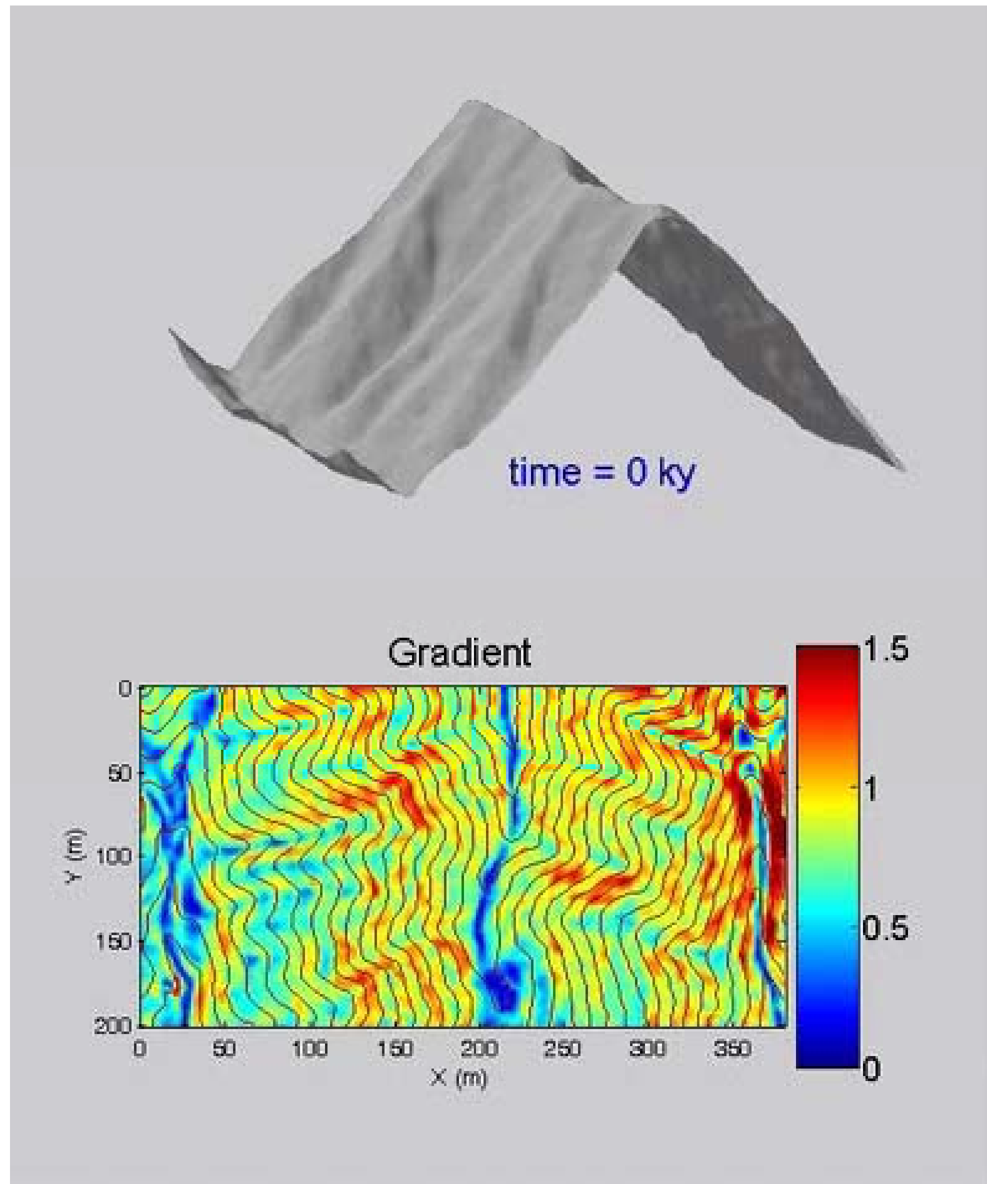
$$q_s = KS$$

S = local gradient

Initial conditions (current via lidar)



Roering, 2008, *GSA Bulletin*



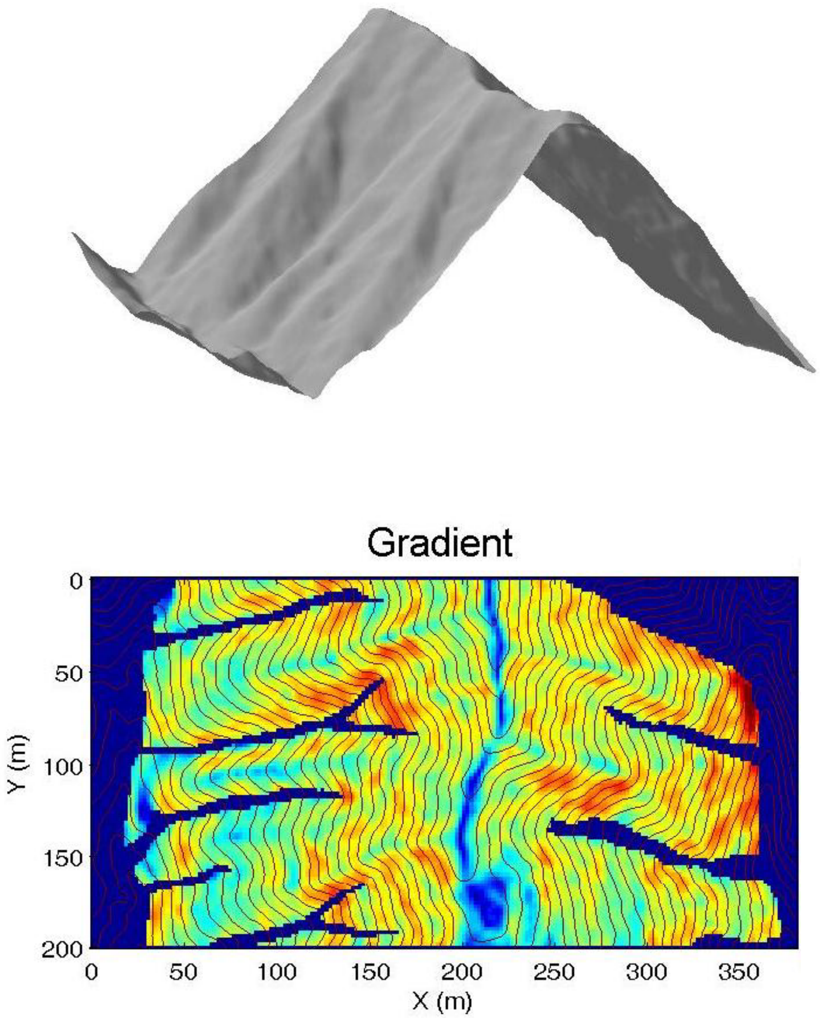
Morphologic change after 500,000 yrs…

1) Steady-state hillslopes?
2) Continuum approximation of transport?

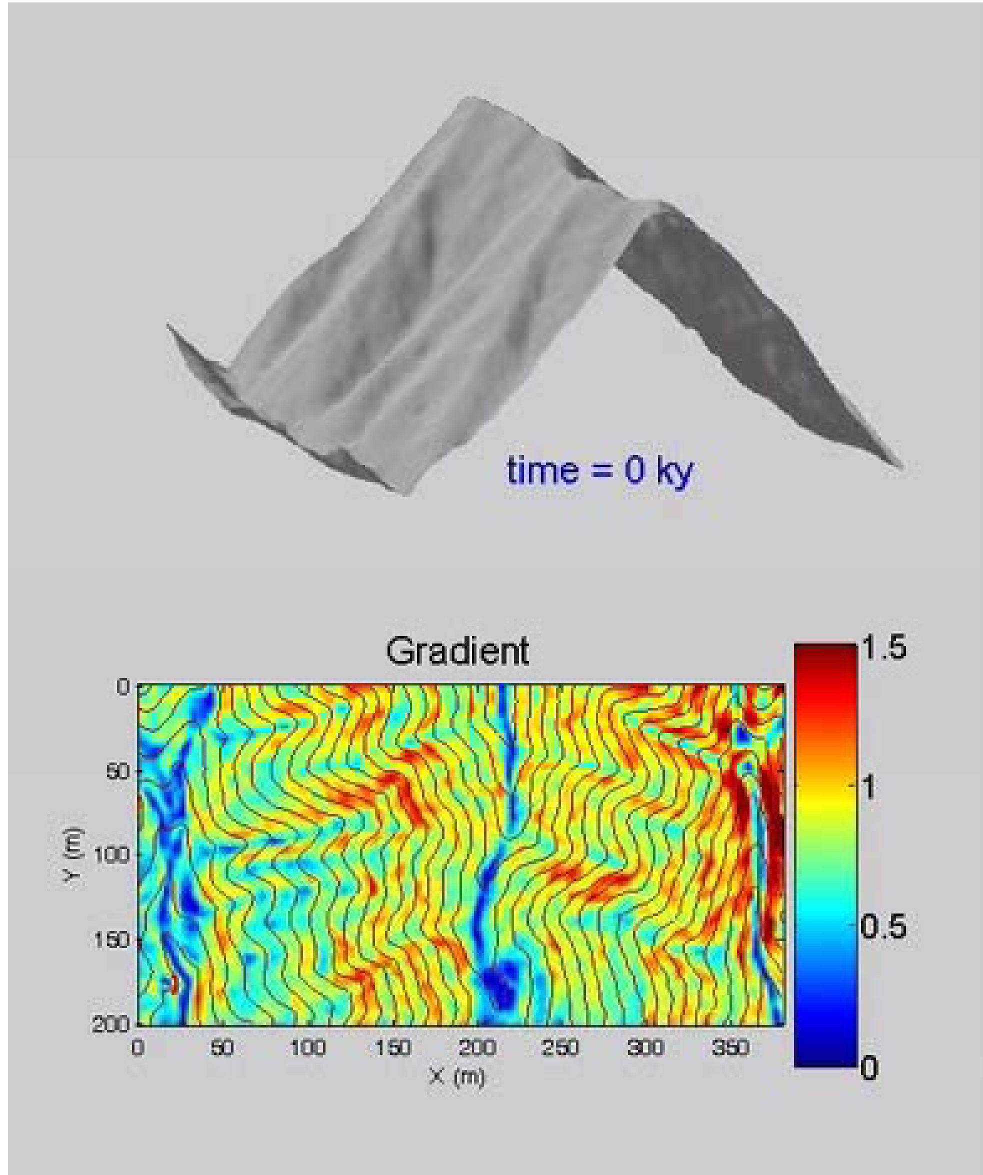
$$q_s = \frac{K(h)S}{1-\left(S/S_c\right)^2}$$

h = soil depth (m)
S = local gradient

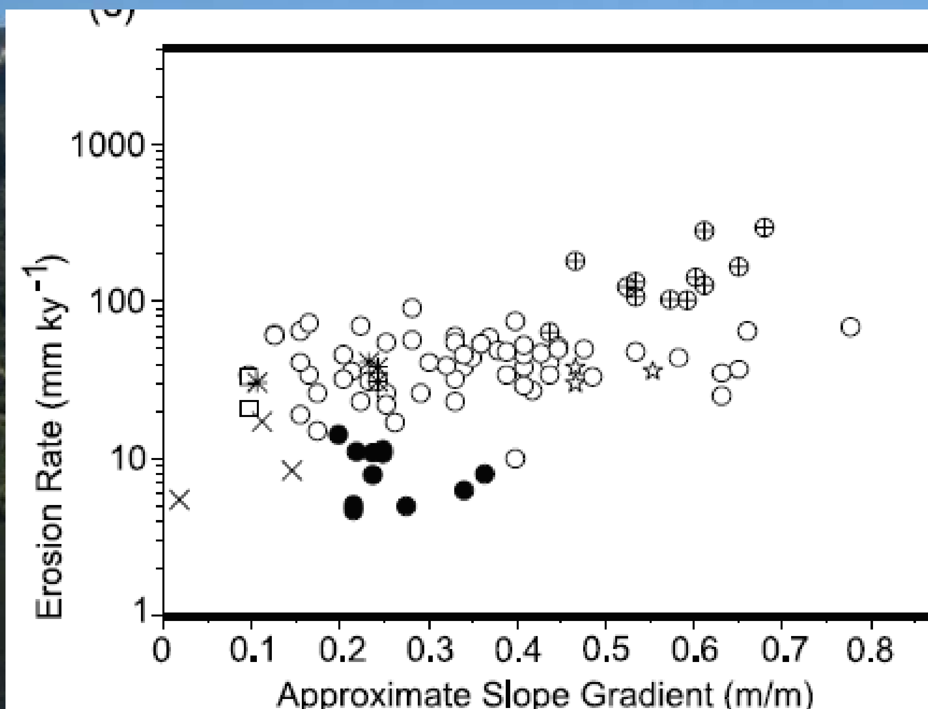
Initial conditions (current via lidar)



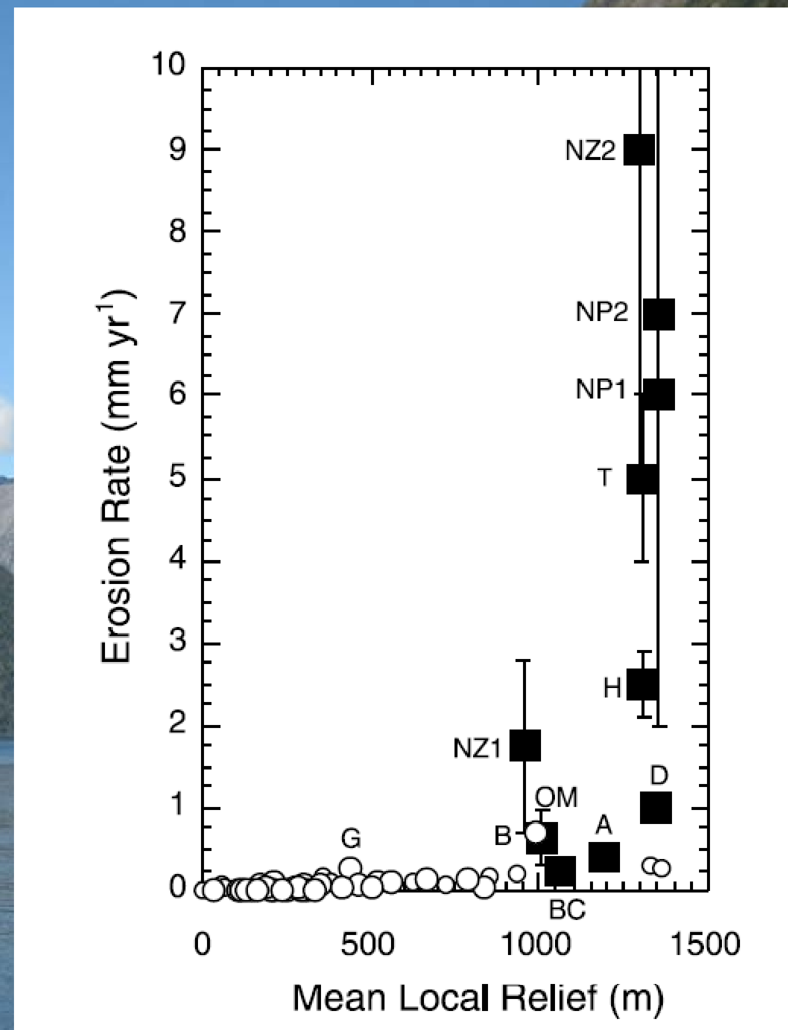
Roering, 2008, *GSA Bulletin*



Goal 2: Infer rock uplift and erosion from morphology



Von Blanckenburg et al., 2004

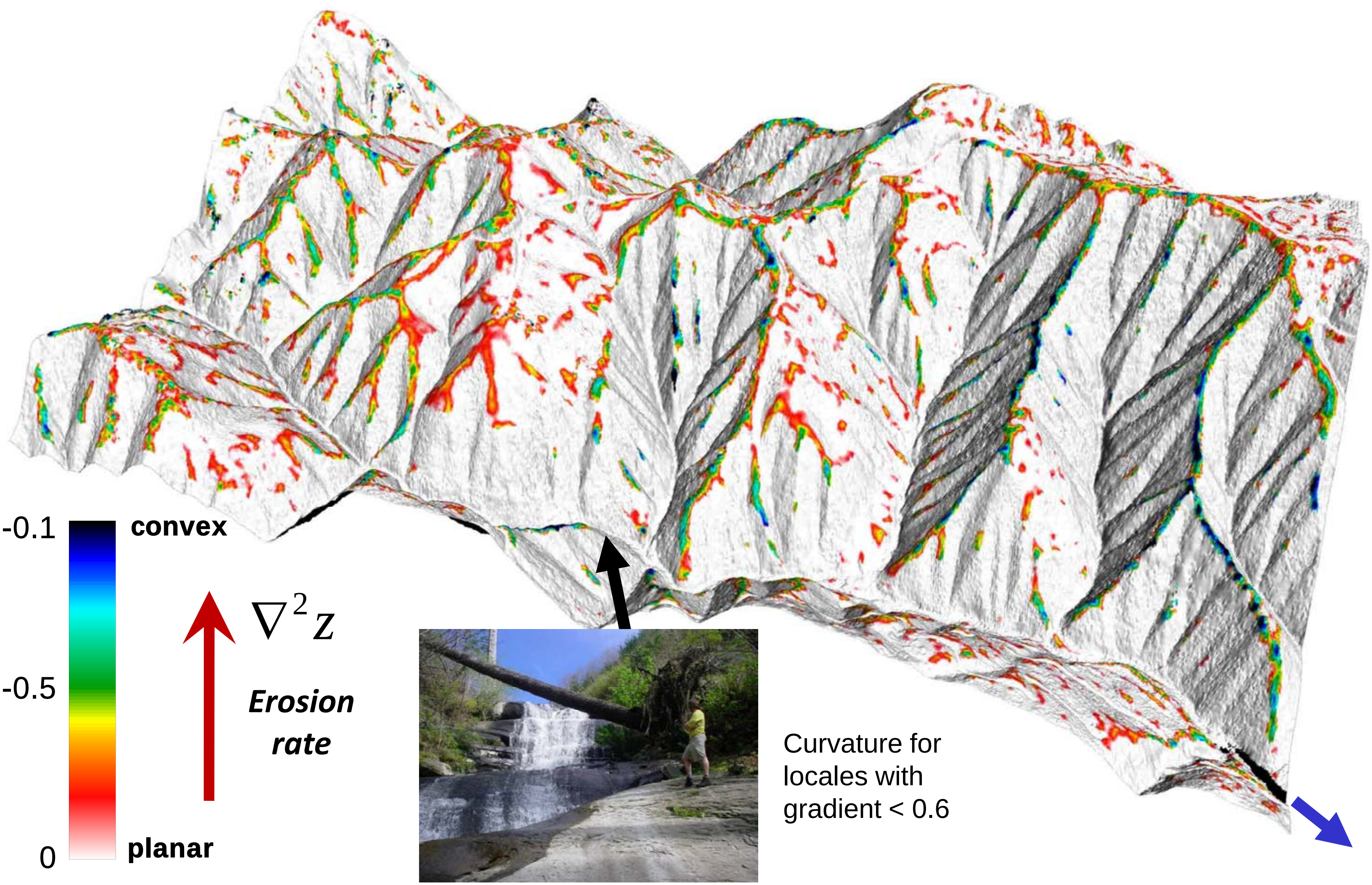


Montgomery & Brandon, 2002

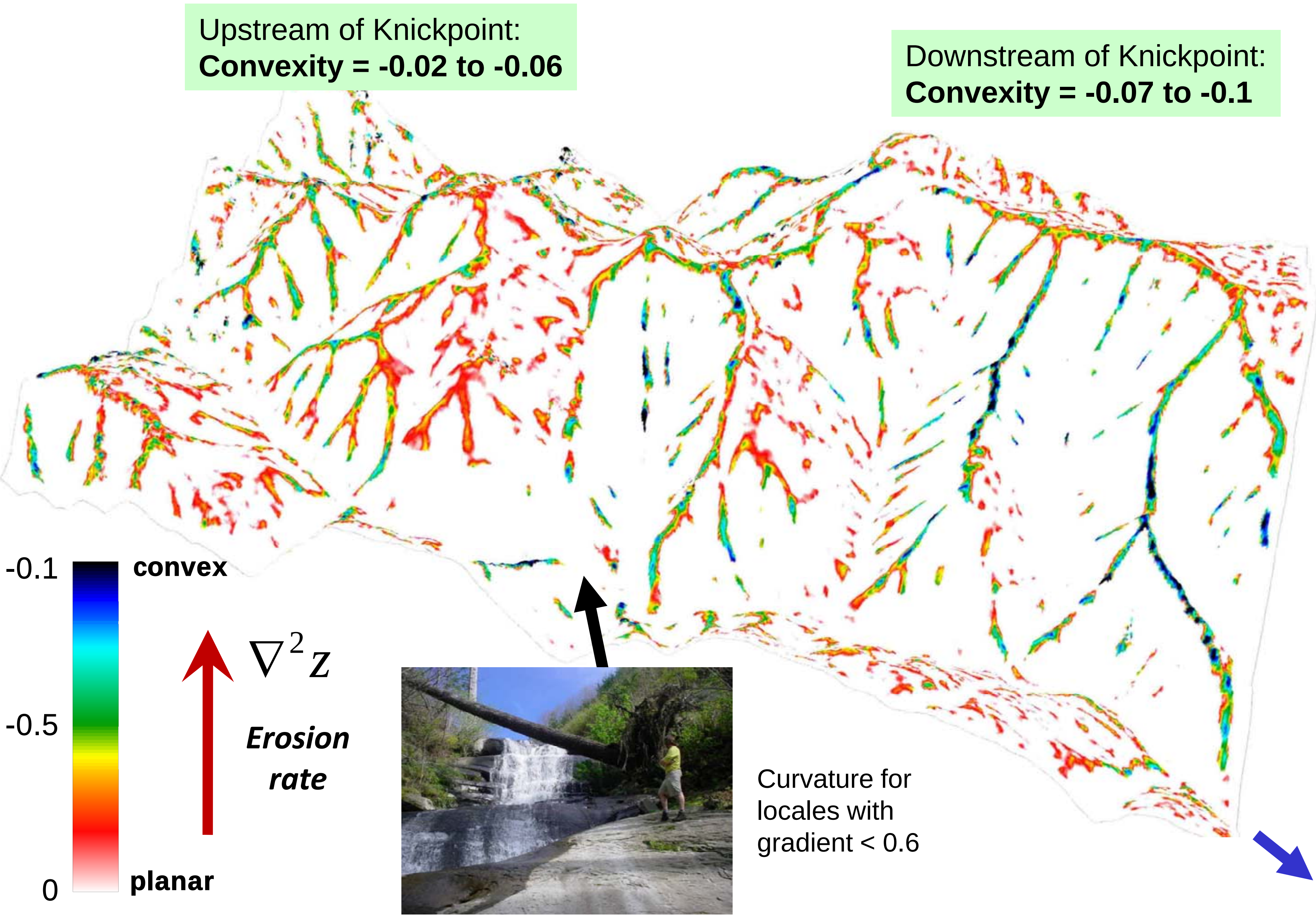
Process-scale investigations:

Knickpoint evolution in rivers and landscape response

Spatial variation of hilltop convexity and landscape adjustment

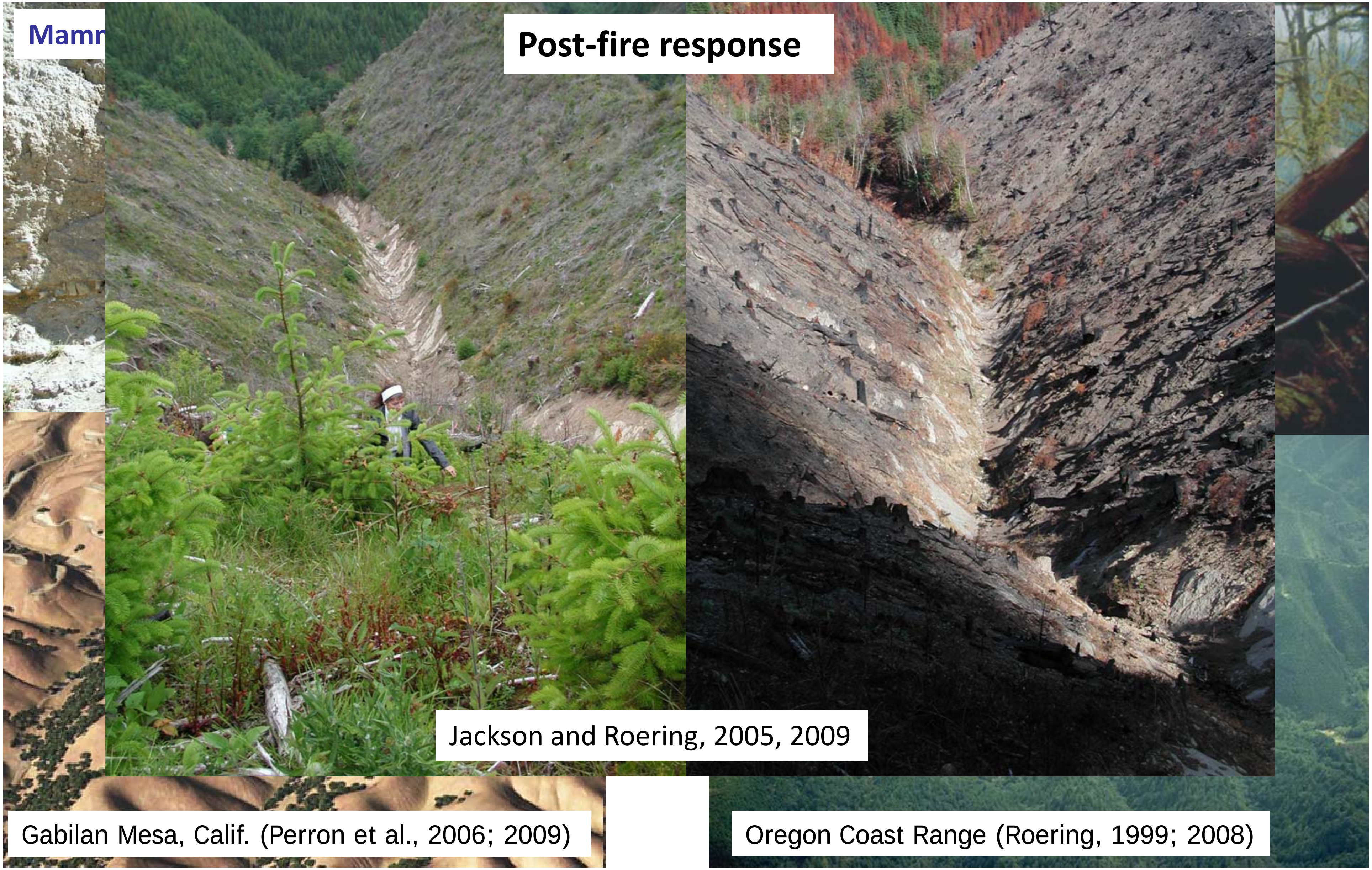


Spatial variation of hilltop convexity and landscape adjustment



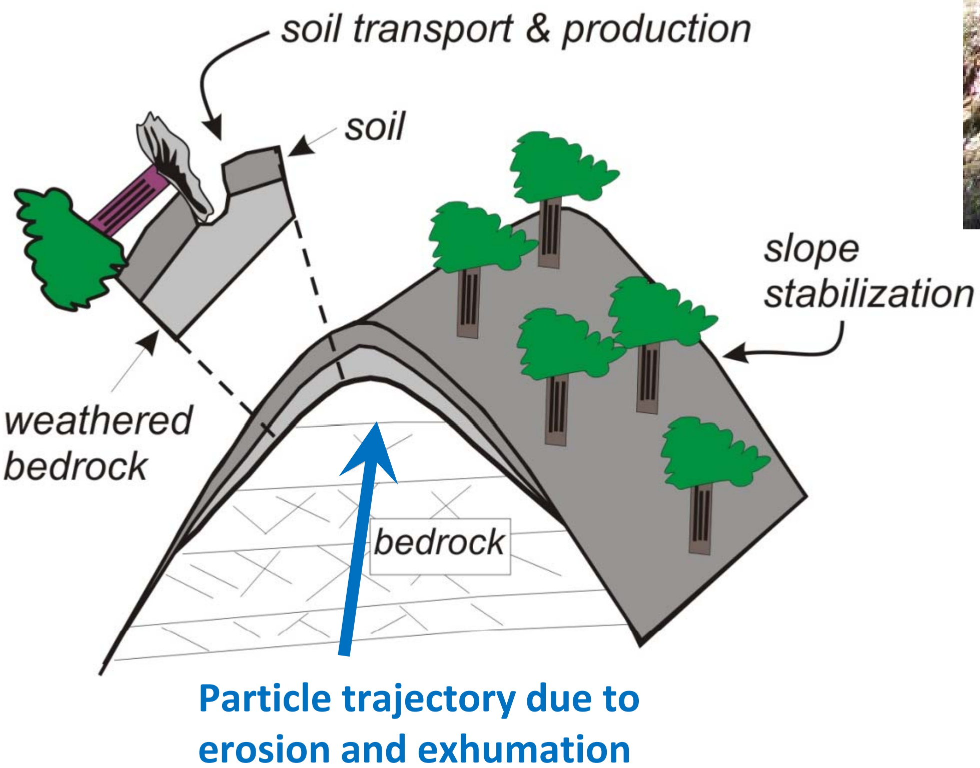
Goal 3: Measurement of stochastic hillslope processes

What is the magnitude-frequency relationship of disturbances that drive soil production and transport?



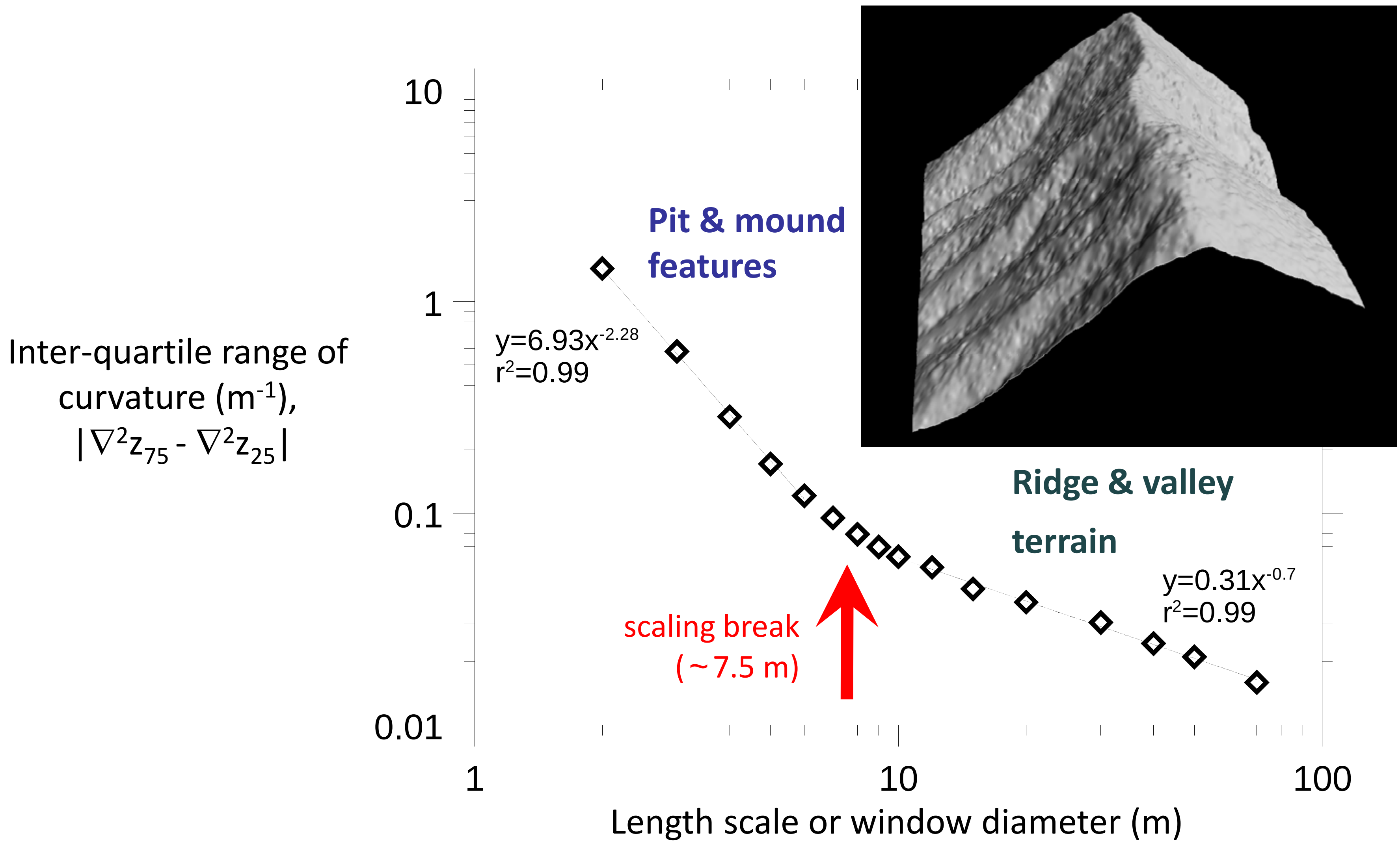
Goal 4: **The evolution of the critical zone**
(top of canopy to base of weathering front…30m?)

- What is the biotic role?
- How do topography and the critical zone co-evolve?



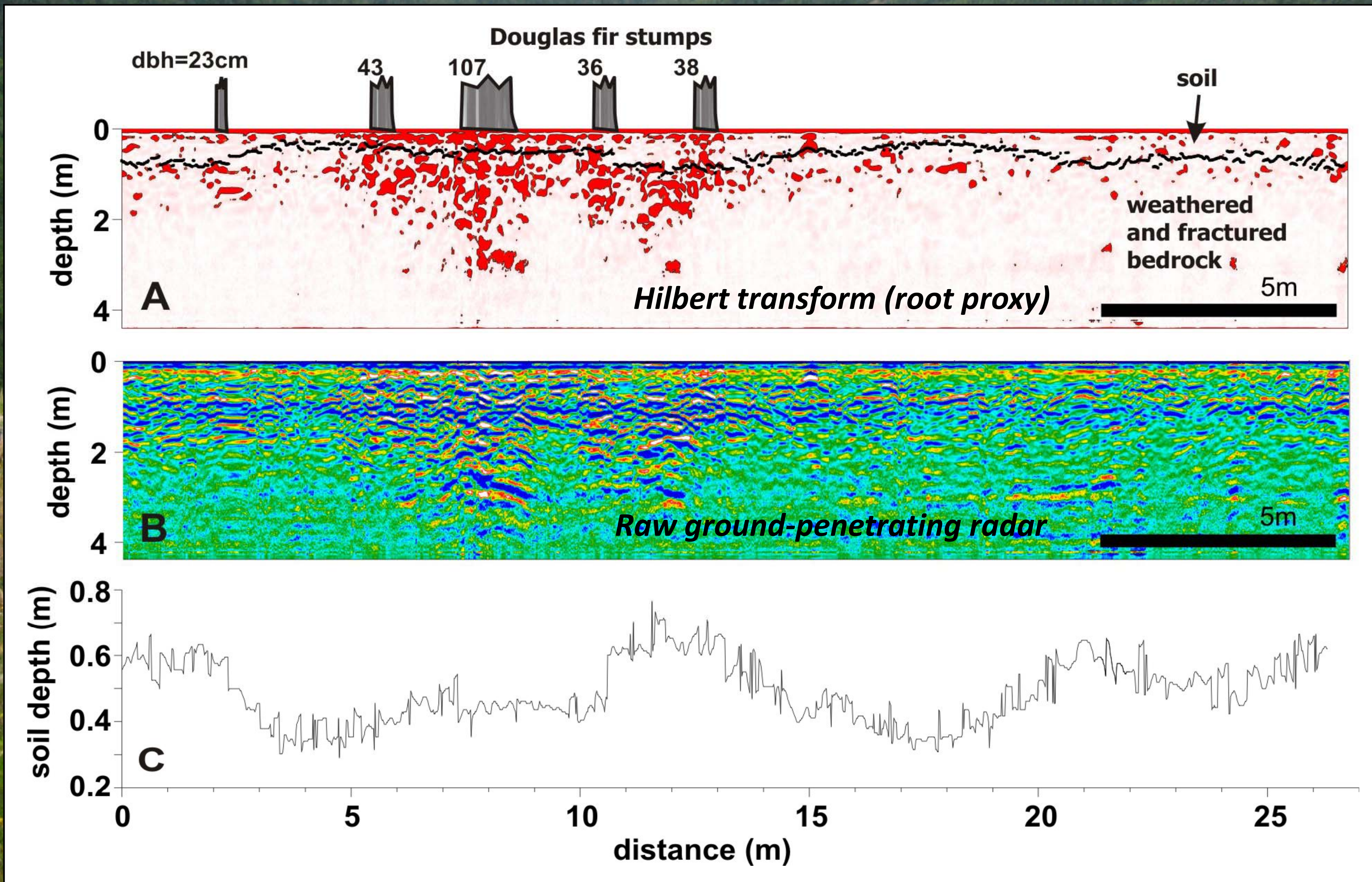
Biotic signature from airborne lidar

- The land surface becomes increasingly rough at short length scales
- Pit and mound features generated by tree turnover dominate small length scales

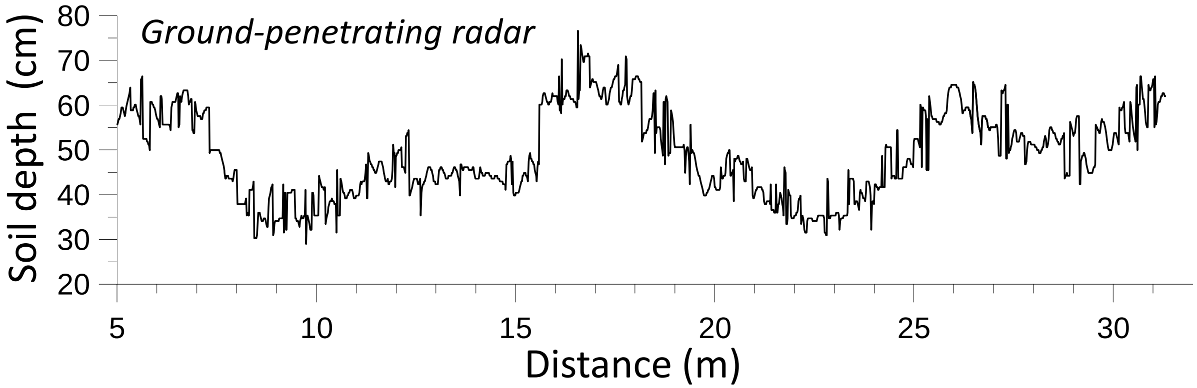


Roering, 2009, AGU

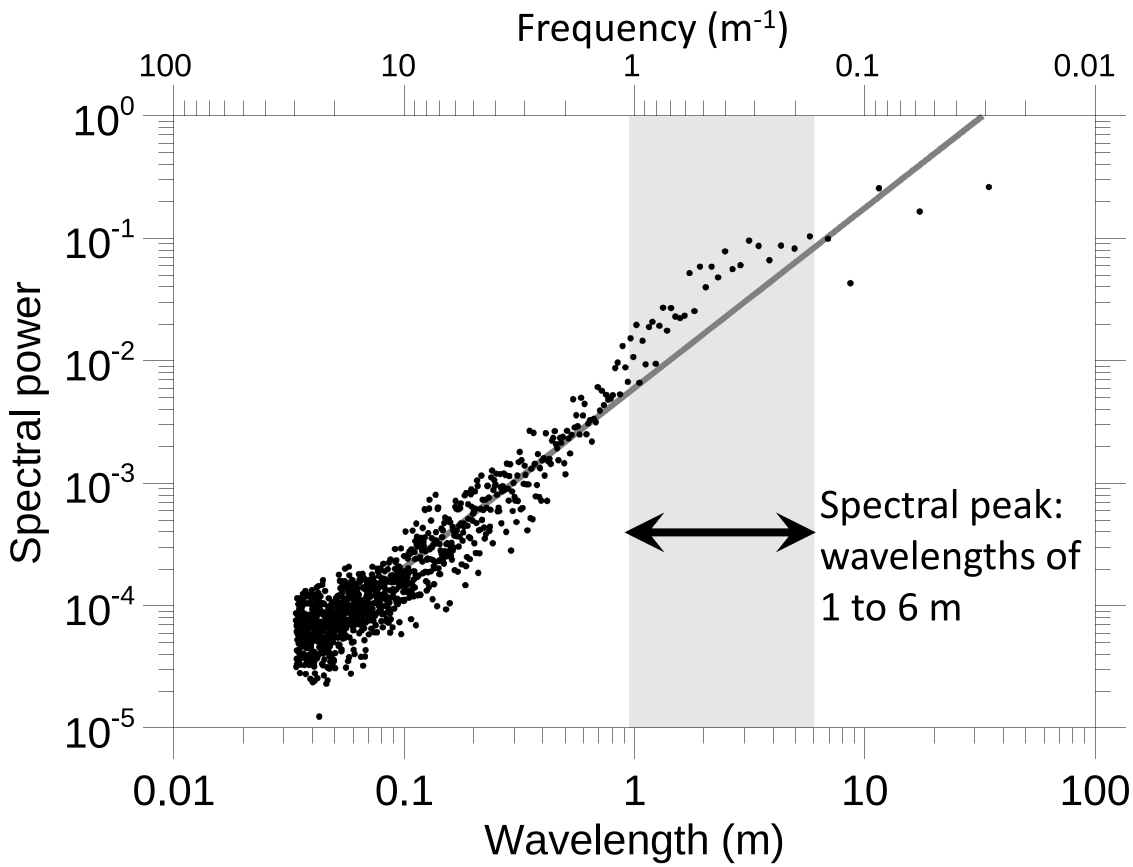
Ground-penetrating radar for mapping soil depth and root penetration into bedrock



Is there a characteristic scale of soil depth variations?



Fourier transformation and spectra averaging of 6 transects



- Characteristic scale = 1 to 6m
- Subsurface reflection of biotic processes (tree root action)

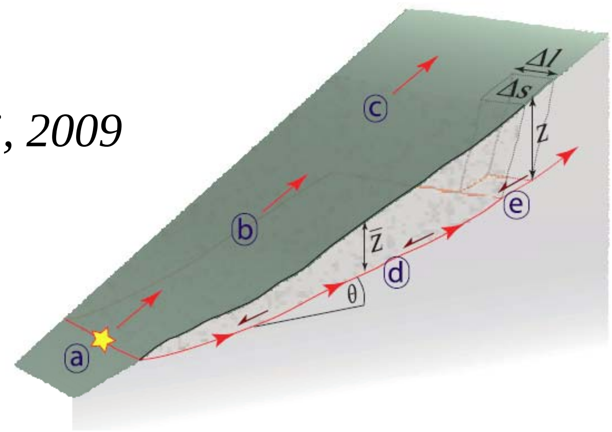
Goal 5: Landslides and landscape evolution

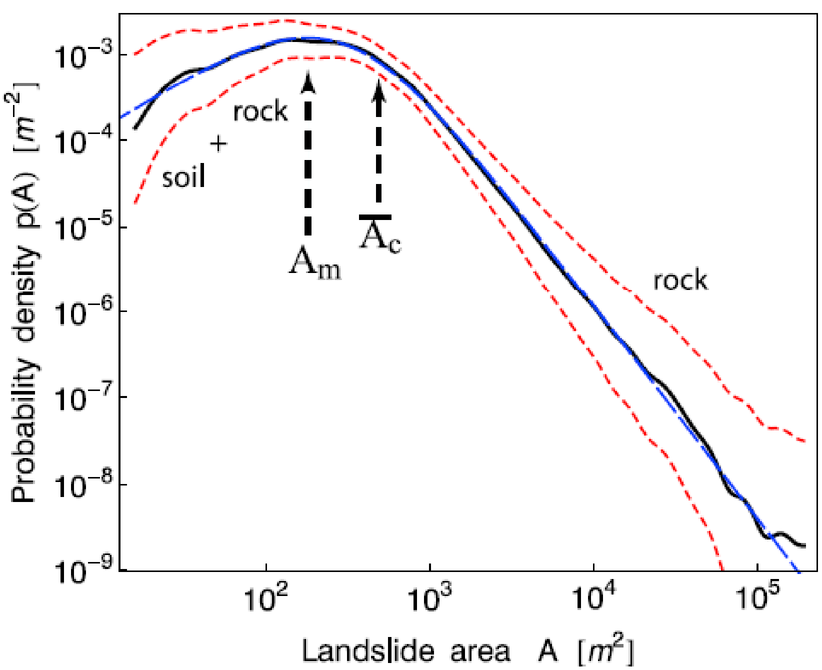
1) What controls the size of landslides and their contribution to landscape evolution?

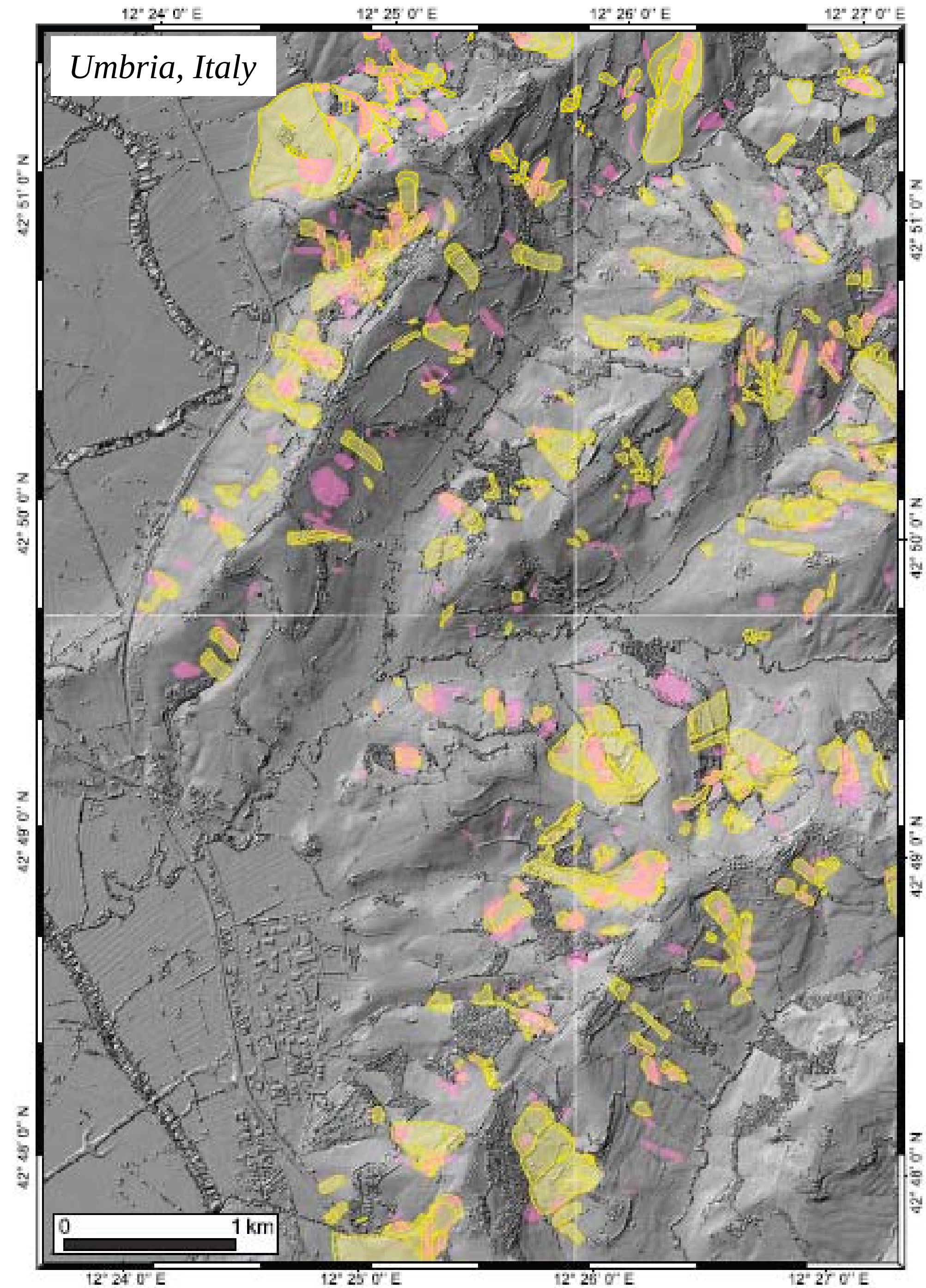
2) Why do some slides fail catastrophically and others deform slowly with seasonality?

Landslide mapping inventories: Do landslide statistics yield mechanistic information?

Stark & Guzzetti, 2009

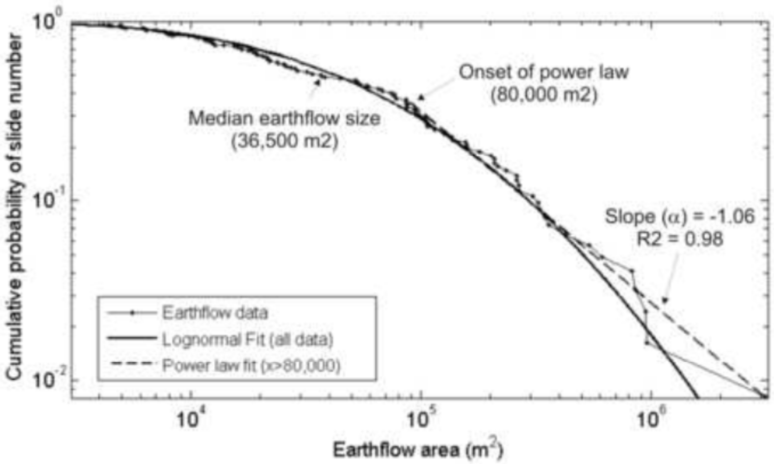


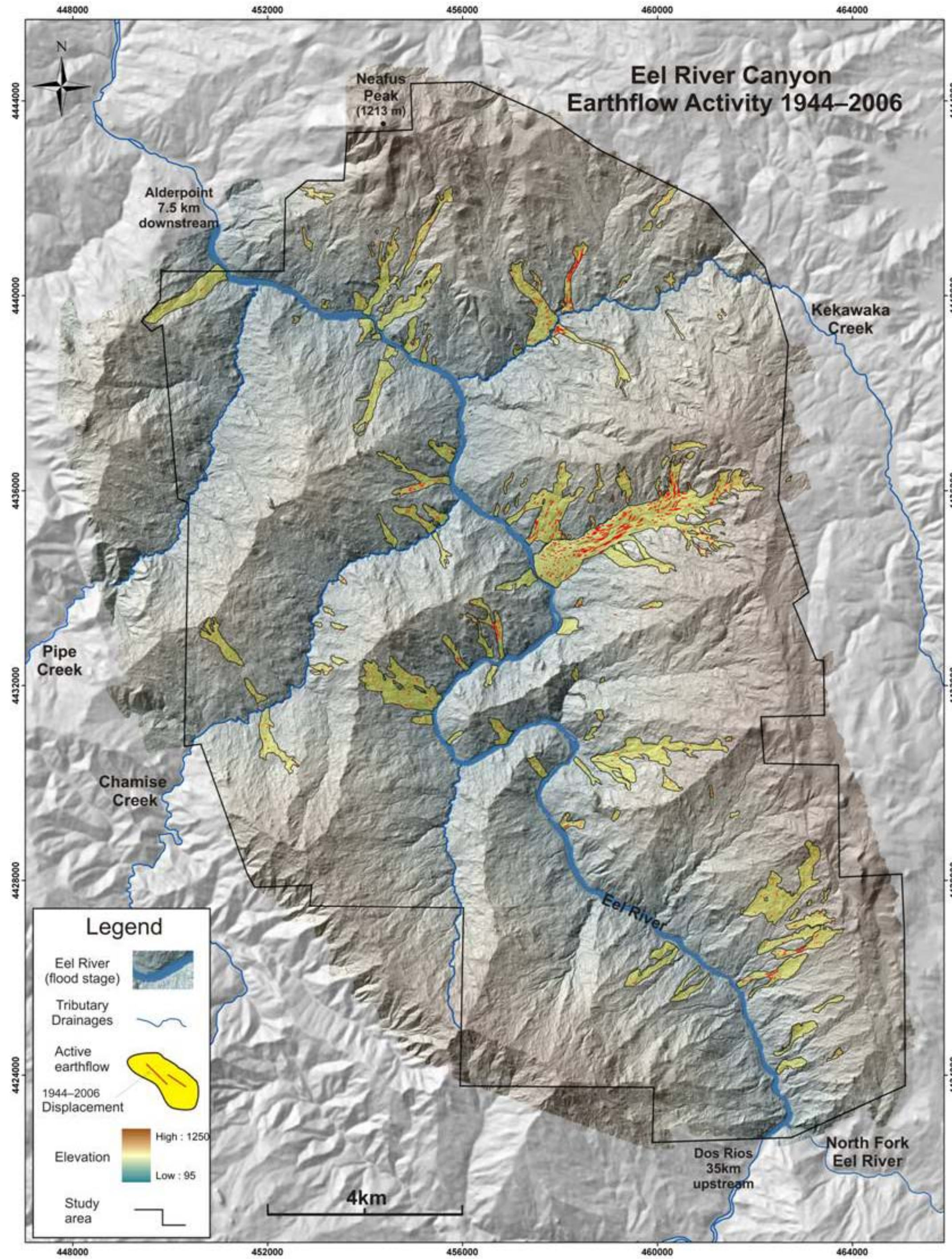


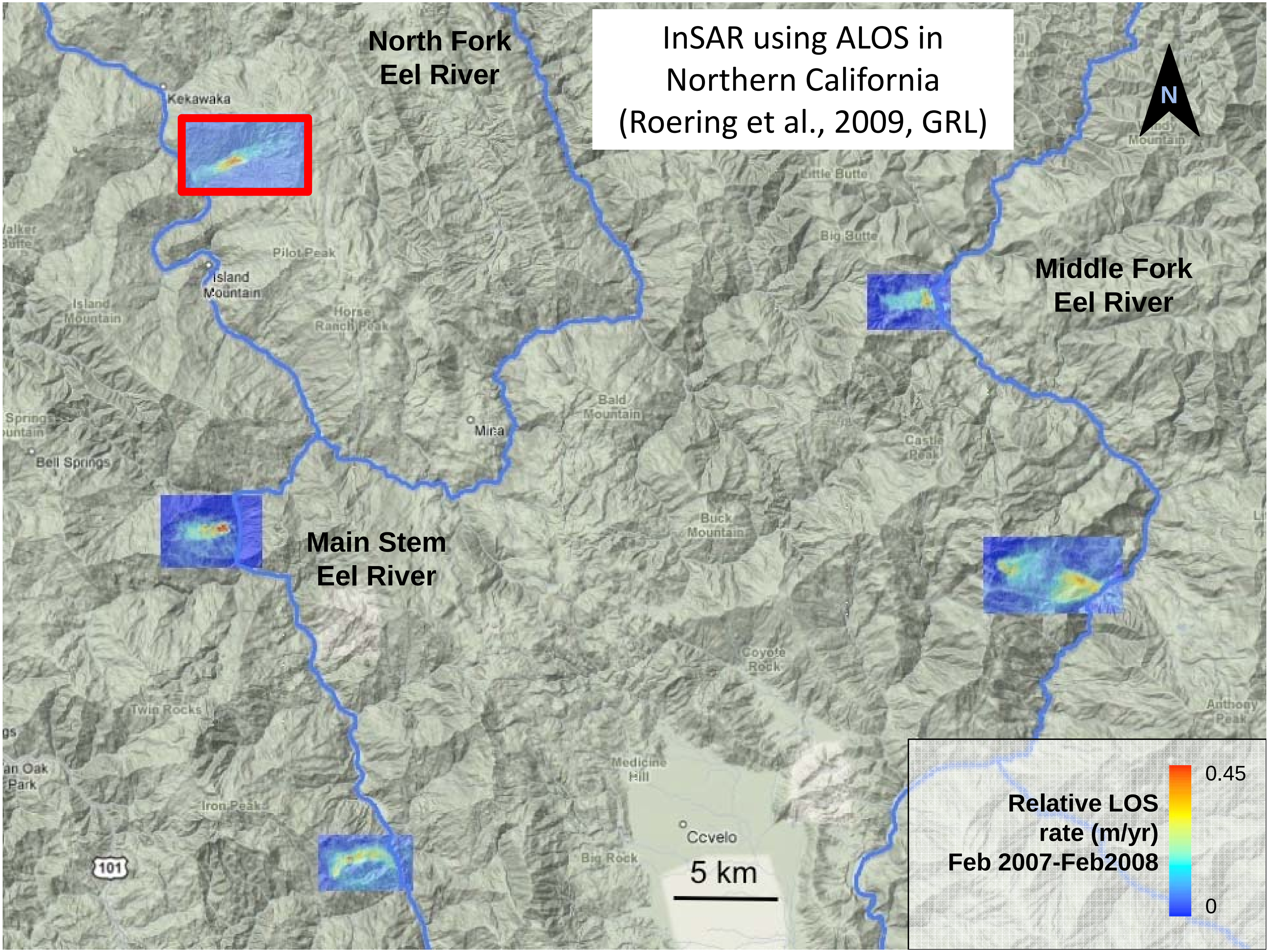


Eel River *(Mackey, PhD. 2009)*

- LiDAR and historical air photos
- 122 active earthflow features (7.3% of study area)
- Earthflow sediment yield to channels: 0.53 mm yr^{-1}
- Denudation from suspended sediment records: ~0.9 mm yr^{-1}



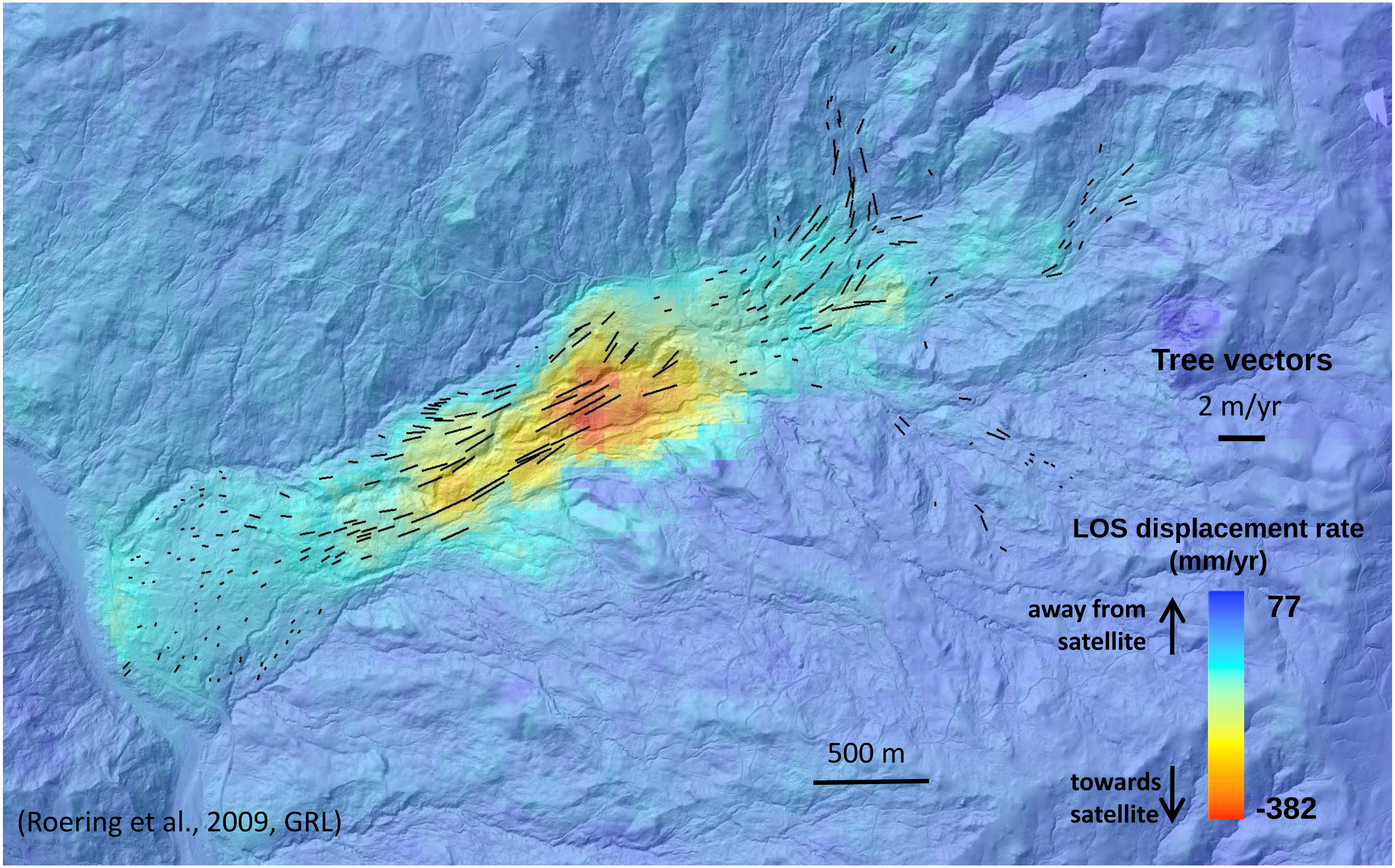




InSAR using ALOS in Northern California (Roering et al., 2009, GRL)
North Fork Eel River
Middle Fork Eel River
Main Stem Eel River
N
Kekawaka
Island Mountain
Pilot Peak
Horse Ranch Peak
Mina
Bald Mountain
Little Butte
Big Butte
Castle Peak
Buck Mountain
Coyote Rock
Bell Springs
Twin Rocks
Iron Peak
Medicine Hill
Covelo
Big Rock
Anthony Peak
101
5 km
Relative LOS rate (m/yr) Feb 2007-Feb2008
0.45
0

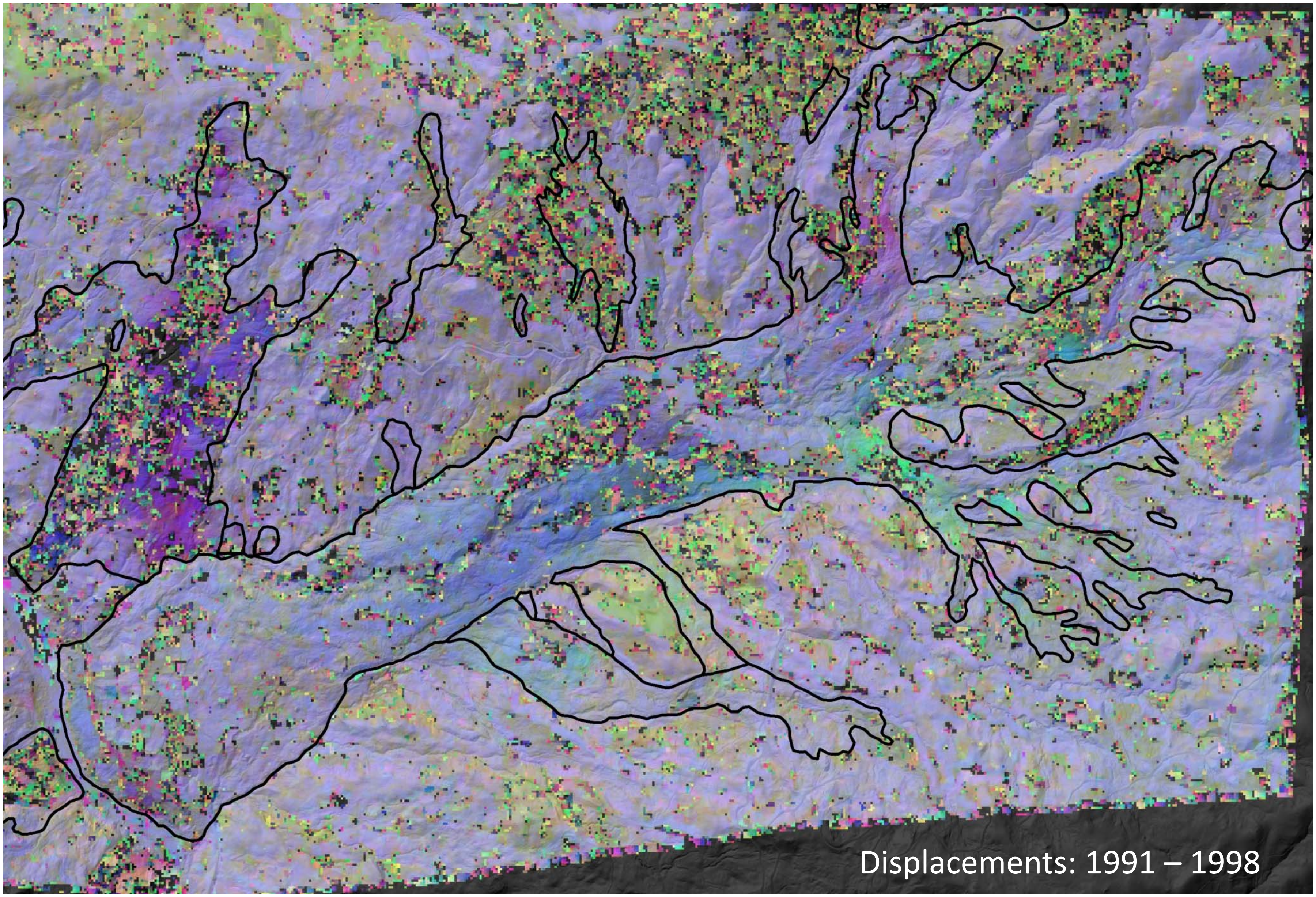
InSAR and photo-derived displacements

- InSAR (stack of 17 infs): Feb 13, 2007 – Feb 16, 2008
- Tree vectors (Mackey, 2009): air photos 1964 – 2006
- InSAR velocities (horizontally projected) are 20% slower
- Satellite orientation relative to terrain and slope deformation



Dynamics using automated photo rectification, coregistration, and subpixel correlation

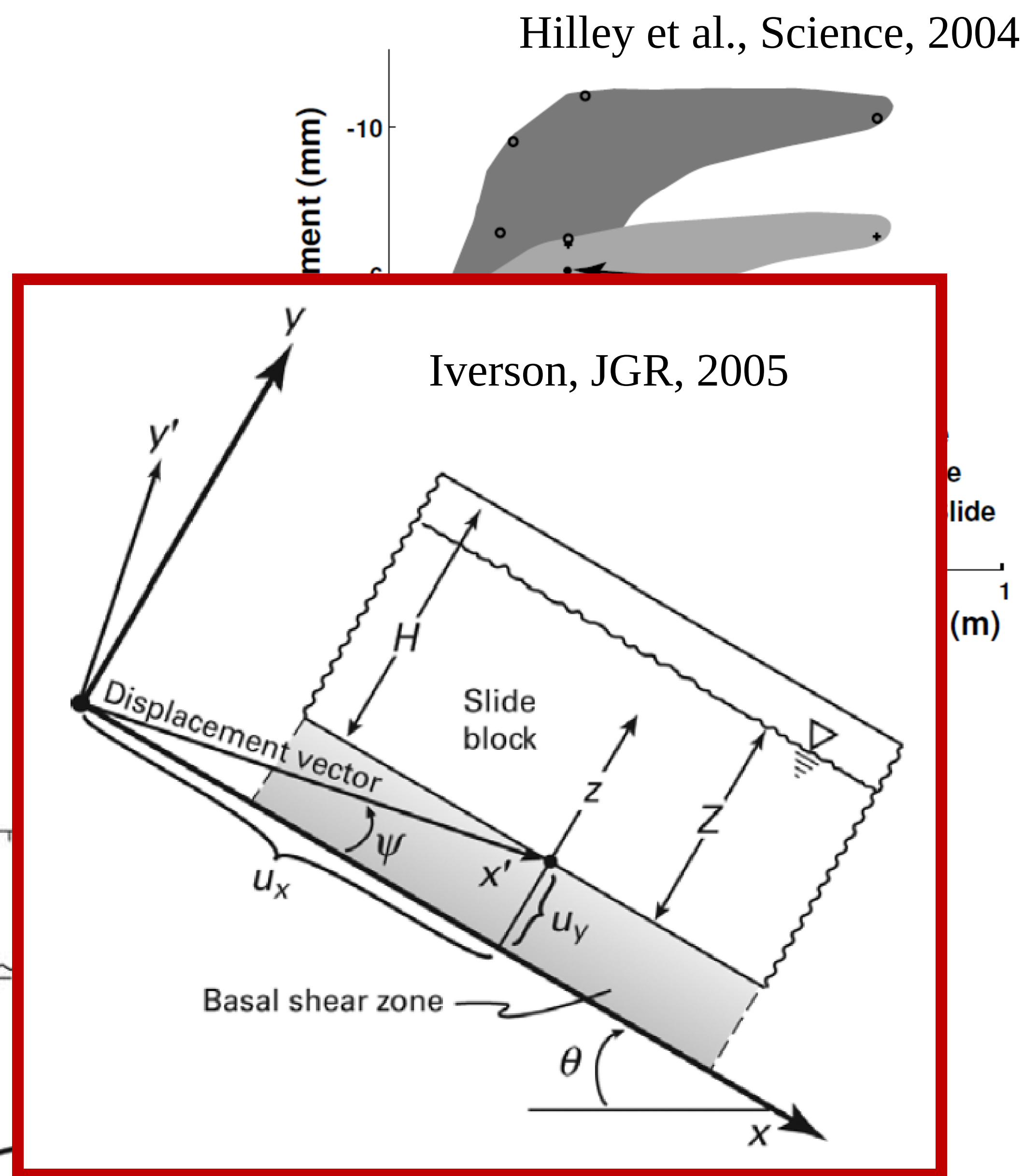
COSI-Corr (Leprince et al., Eos, 2008)

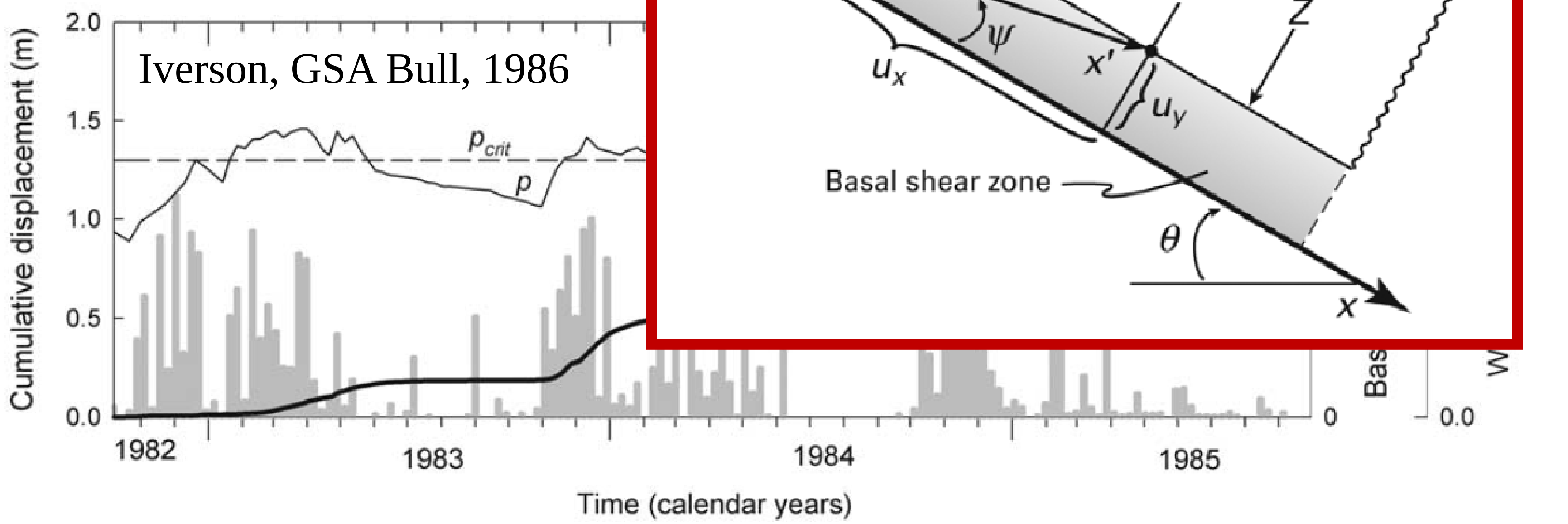


Pervasive slow-moving slides self-regulate and do not fail catastrophically

Shear-zone dilatancy may permit negative pore pressure-shear feedbacks and thus allow for slow, steady motion

- **Can we image this feedback?**
- **Is there a limit to shear zone dilatancy?**



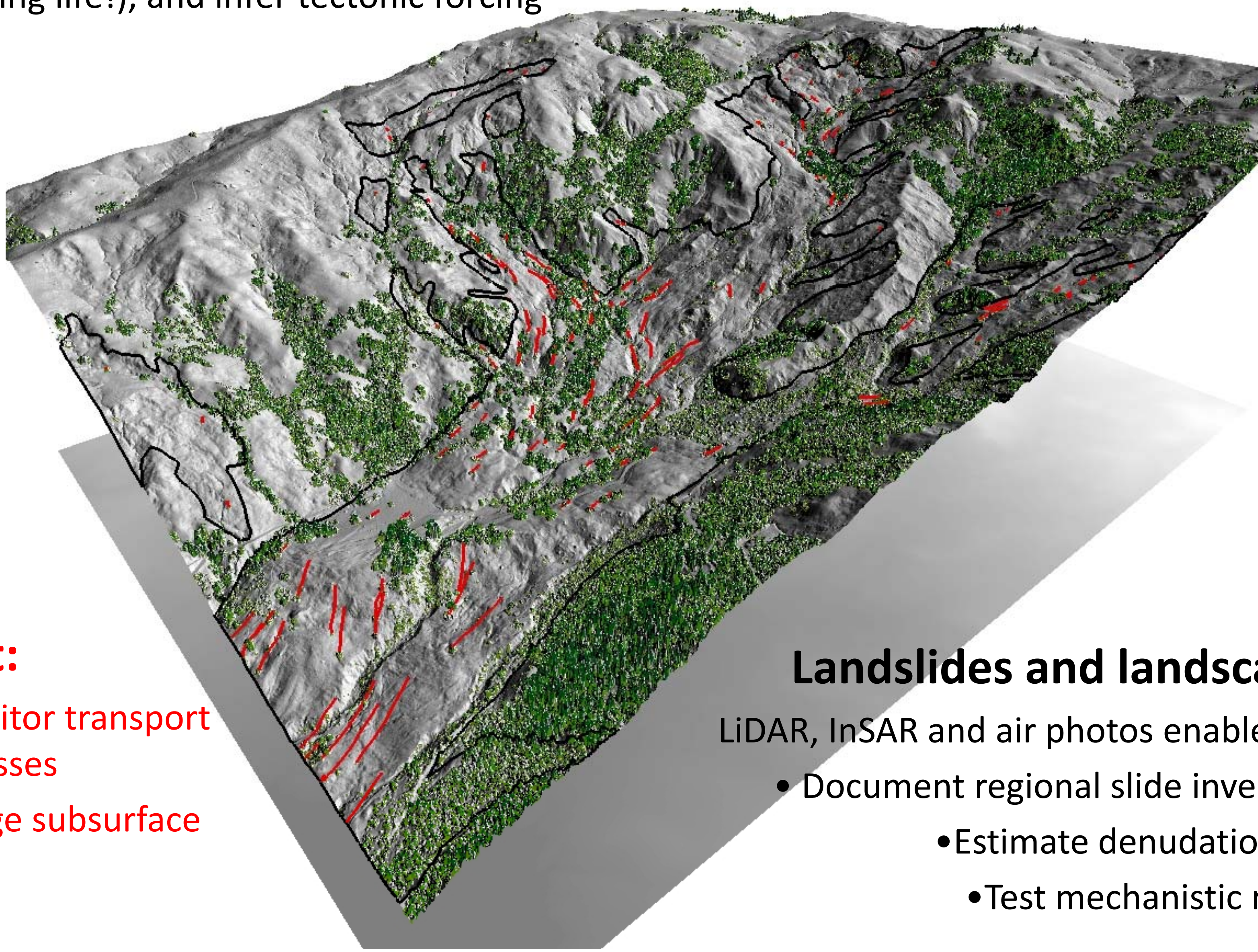


Summary

Hillslopes:

Airborne lidar and radar enables us to:

Test models and make predictions, quantify process signatures (including life!), and infer tectonic forcing



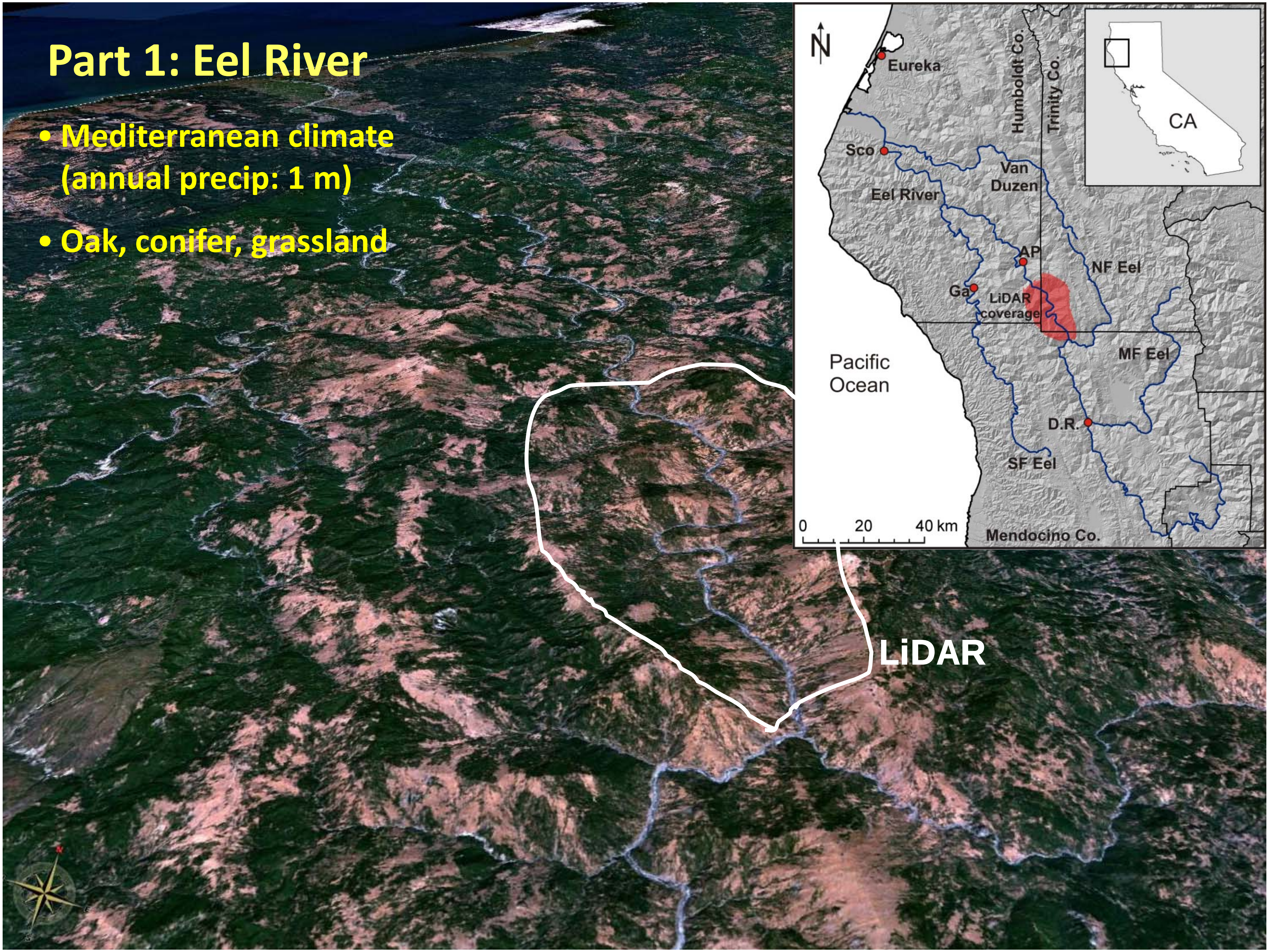
Next:

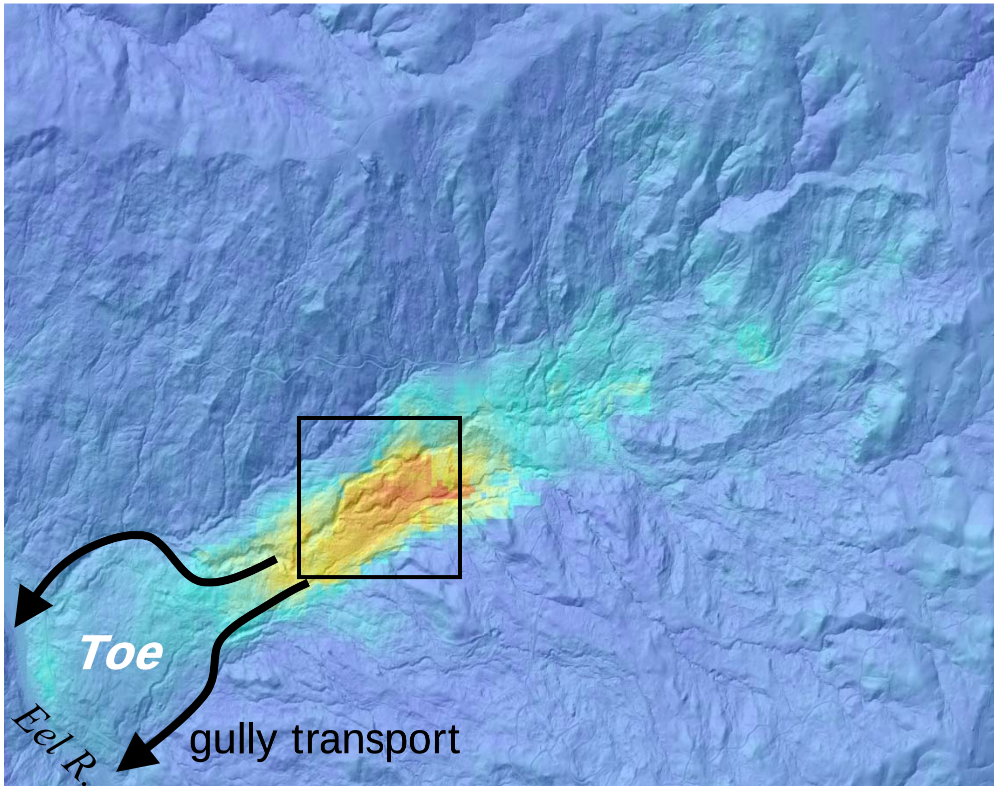
- Monitor transport processes
- Image subsurface

Landslides and landscapes:

LiDAR, InSAR and air photos enable us to:

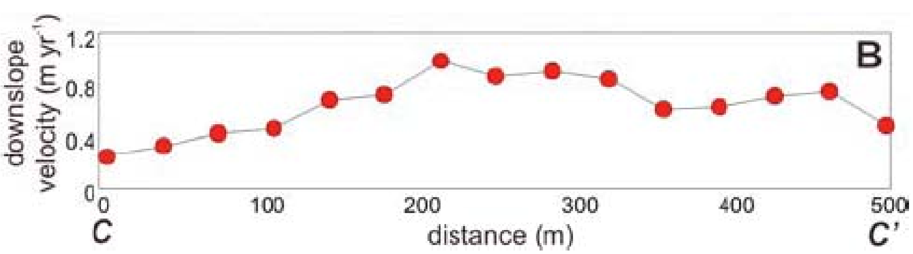
- Document regional slide inventories
- Estimate denudation rates
- Test mechanistic models

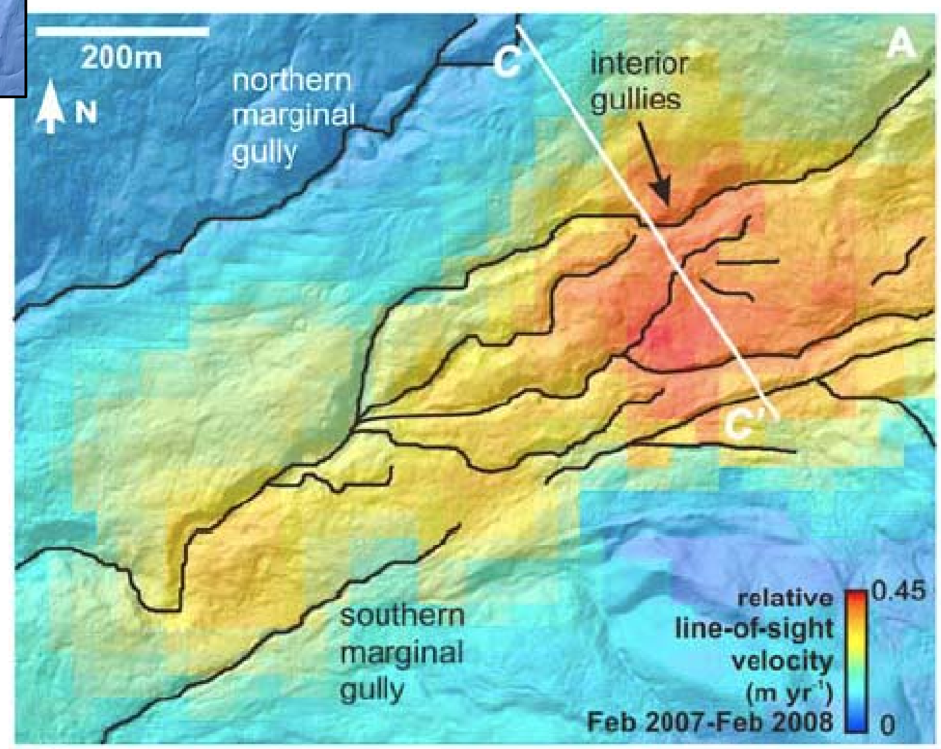

Part 1: Eel River
• Mediterranean climate (annual precip: 1 m)
• Oak, conifer, grassland
LiDAR
N
Eureka
Humboldt Co.
Trinity Co.
CA
Sco
Van Duzen
Eel River
AP
NF Eel
Ga
LiDAR coverage
Pacific Ocean
MF Eel
D.R.
SF Eel
0 20 40 km
Mendocino Co.



Geomorphic implication #1: Sediment production at Boulder Crk

- Sediment flux through transport zone exceeds 4100 m^3 yr^{-1}
- Basin lowering rate ≥ 1.6 mm yr^{-1}
- Gullies appear to facilitate delivery of earthflow-mobilized sediment to the channel network





Roering et al. (GRL, 2009)

Hillslope evolution and nonlinear slope-dependent transport

$$q_s = \frac{-K(h)S}{1-(S/S_c)^2}$$

S = hillslope gradient, ∇z

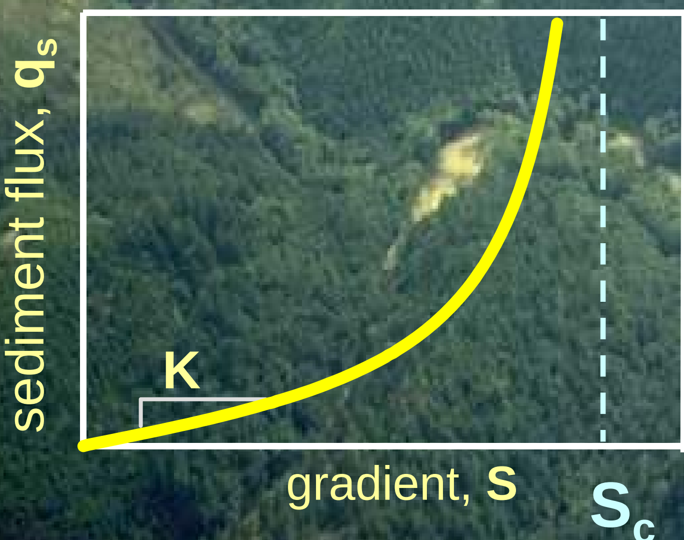
h = soil depth (m)

K = transport coefficient $(L^2/$

S_c= critical gradient

Physically-based formulation:

Roering et al., 1999



- K varies with energy expended by disturbances in the soil mantle…biological connection?