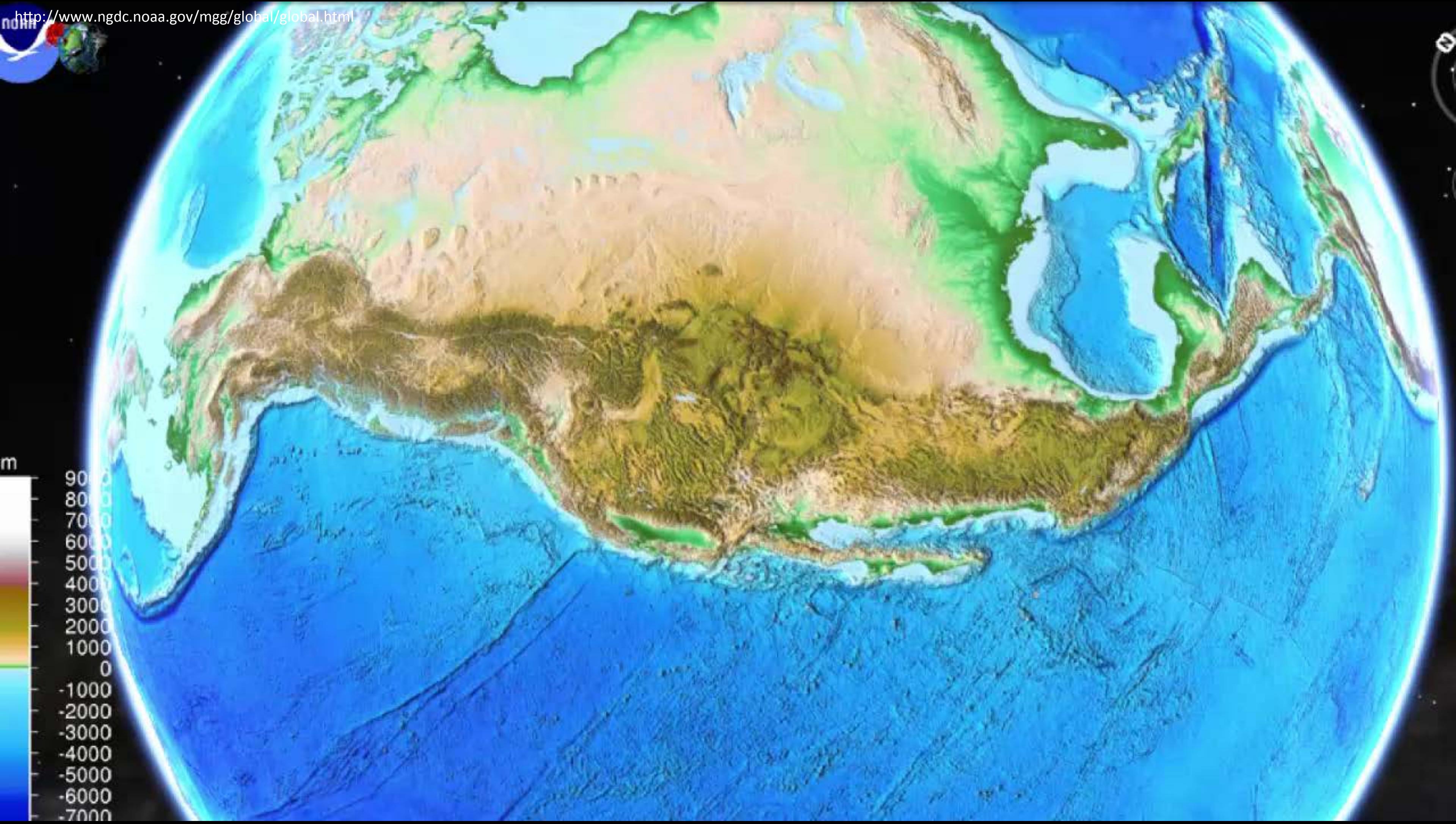


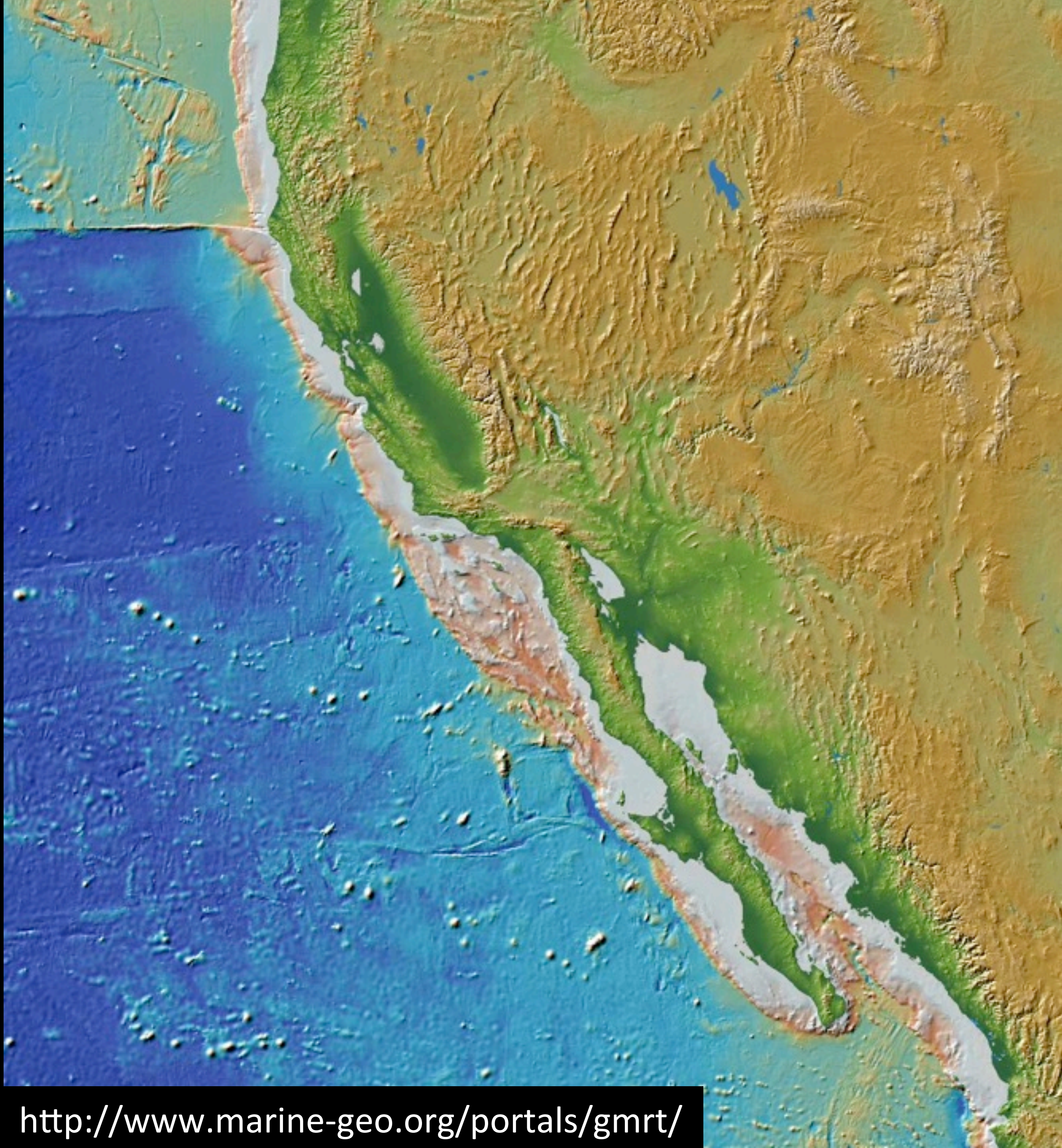
Tectonic geomorphology
& ideas for communicating science data and results to the public, based on experience with Earthscope and OpenTopography

Ramon Arrowsmith (ASU) + Hilley, Kirby, Nissen, Oskin, Whipple, others
& Bohon, Crosby, Nandigam, Robinson, Semken

Tectonic geomorphology
- Big questions
- Topography as the fundamental observable
- Larger spatial scale examples (orogenic ; dynamic topography)
- Finer spatial scales (Fault zones mostly)
- Facility needs

Communicating (briefly)
- Place based education
- Social media

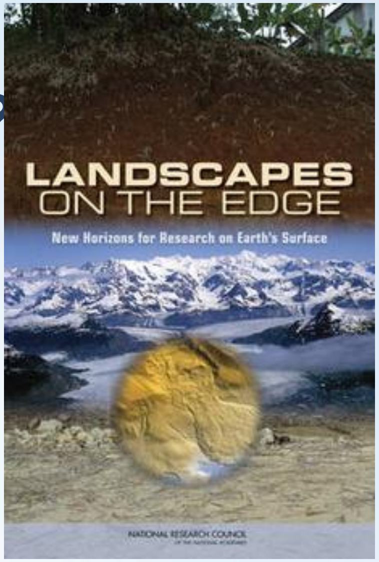
Connection to longer time scales, geomorphology and geology



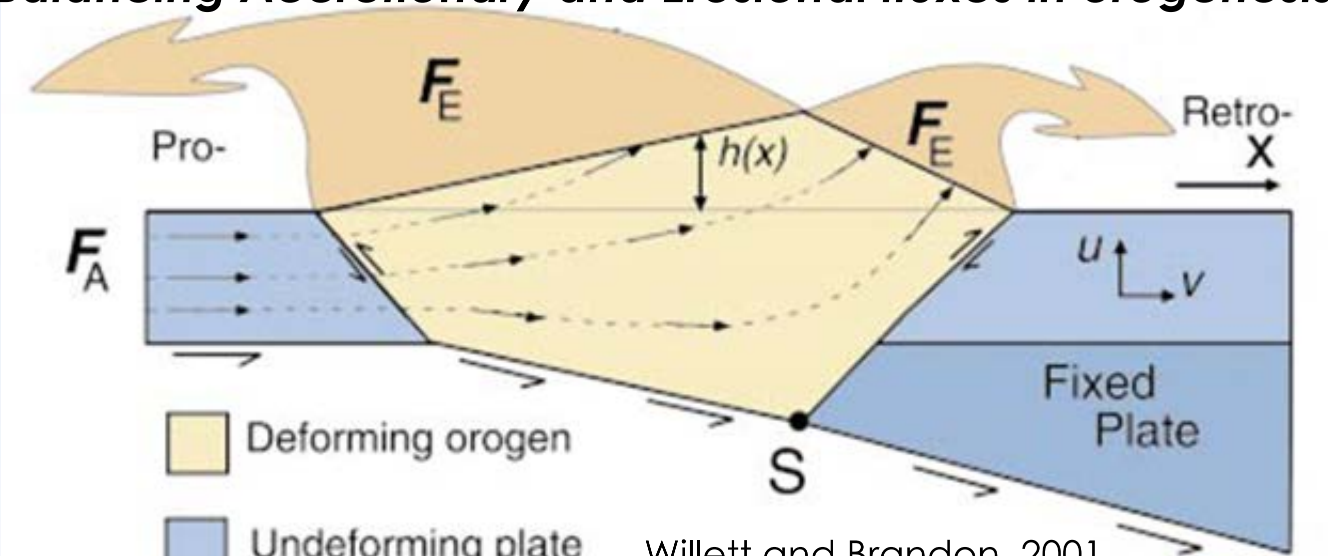
http://www.marine-geo.org/portals/gmrt/

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?
- How best can we retrieve the record of paleoearthquakes from the landscape?



Balancing Accretionary and Erosional fluxes in orogenesis

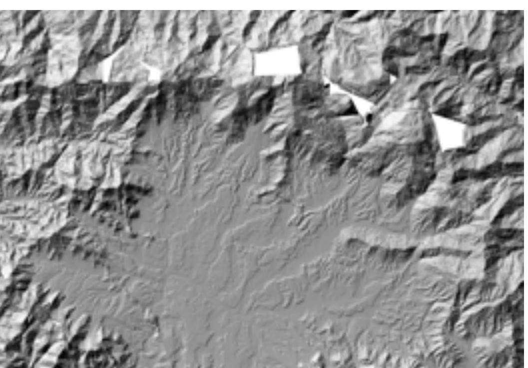


Willett and Brandon, 2001

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

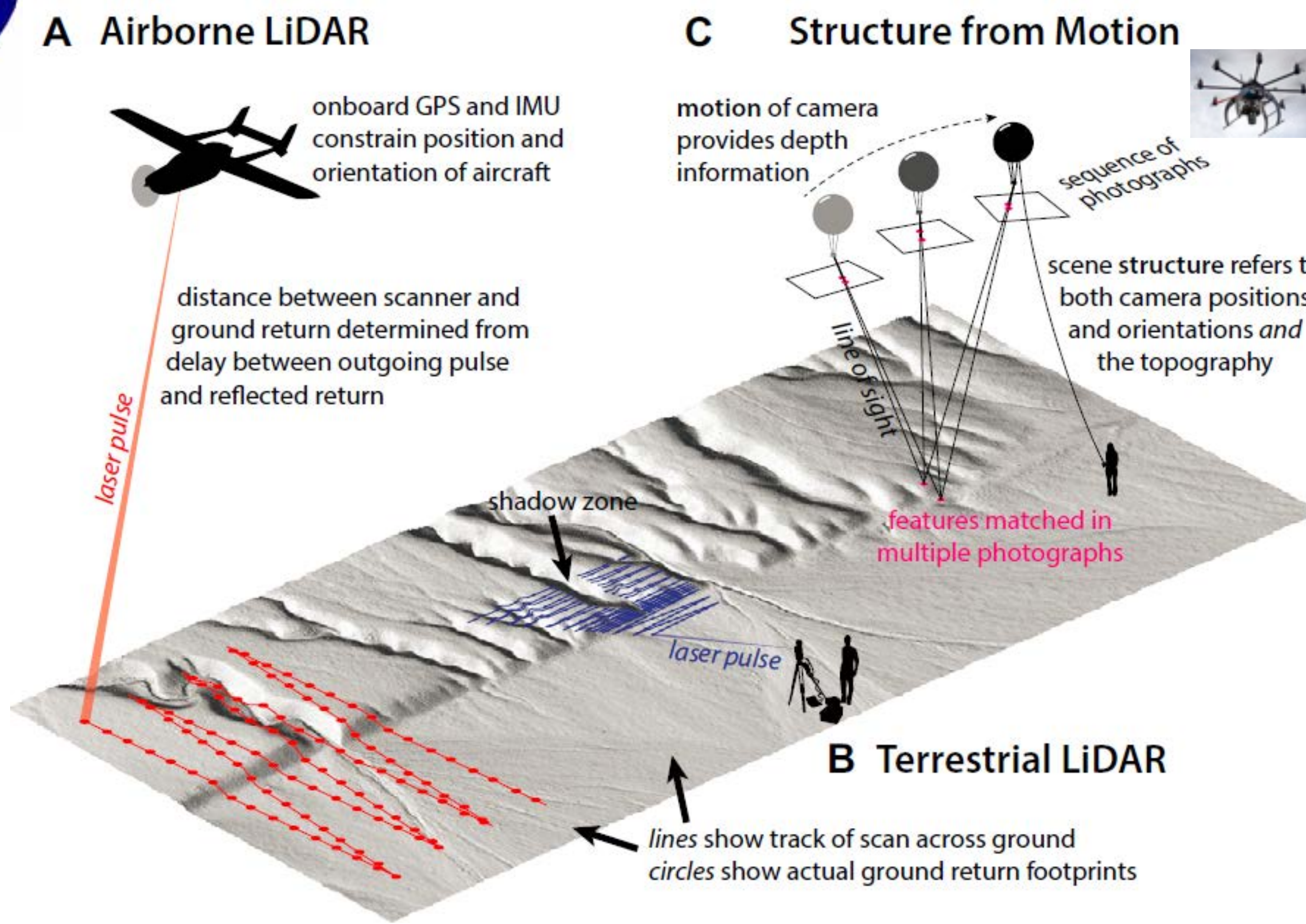
Global and regional topography/bathy (10s-100s m/pix)

+ASTER



Kathmandu area Stereo-Photogrammetric Elevation Model (Polar Geospatial Center)

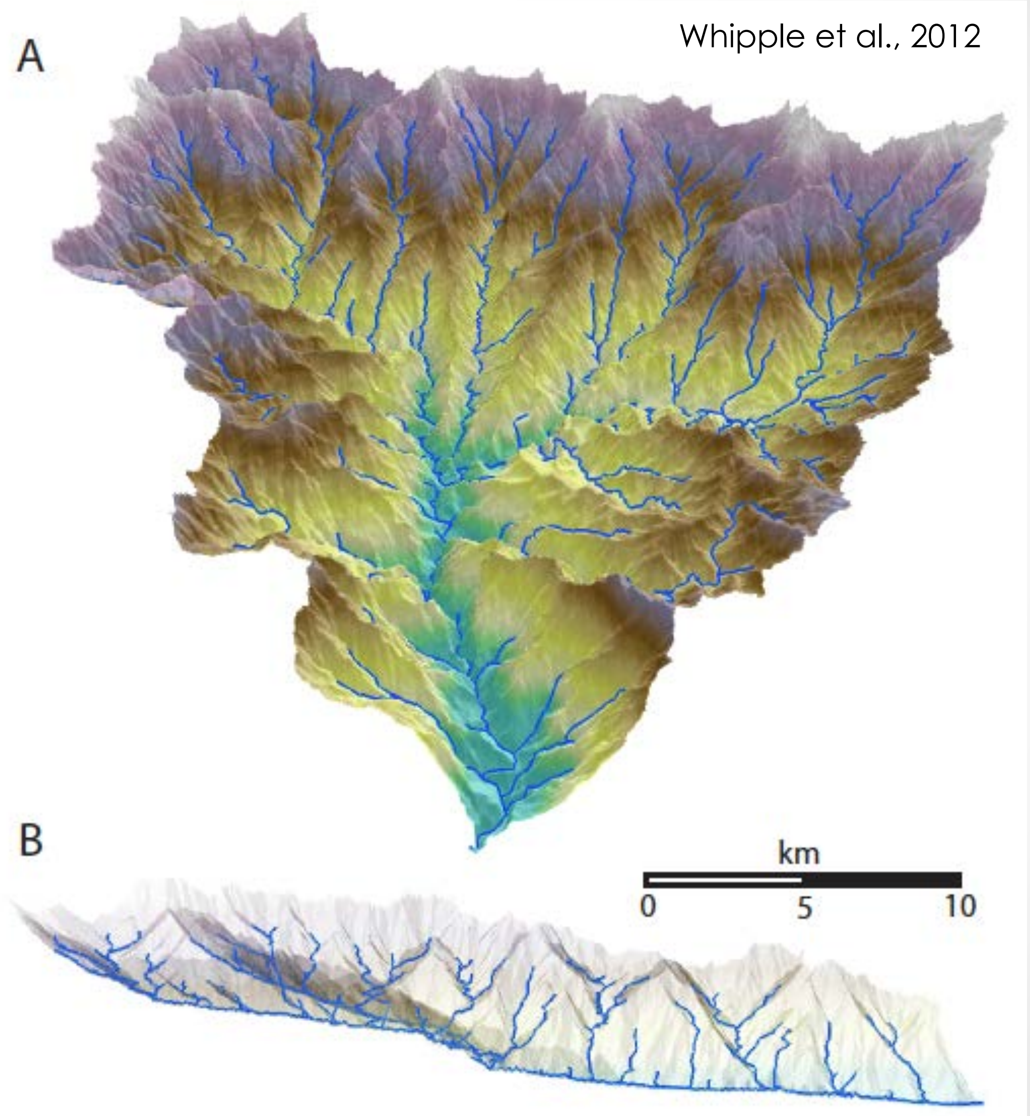
HiRT: Local to site scale topography (dm to m / pix)



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.

One approach – analysis of stream profiles

- Landscape relief adjusts such that erosion rate balances differential uplift of rock
- Most relief in active mountain belts on channel network
- Channels govern landscape response to changes in tectonics, climate



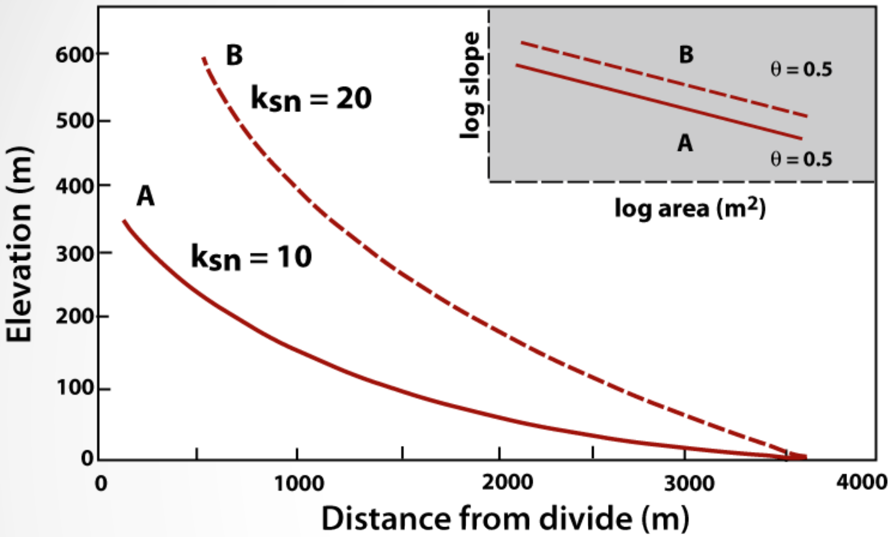
- Encode information on spatial wavelength, rates and history of deformation

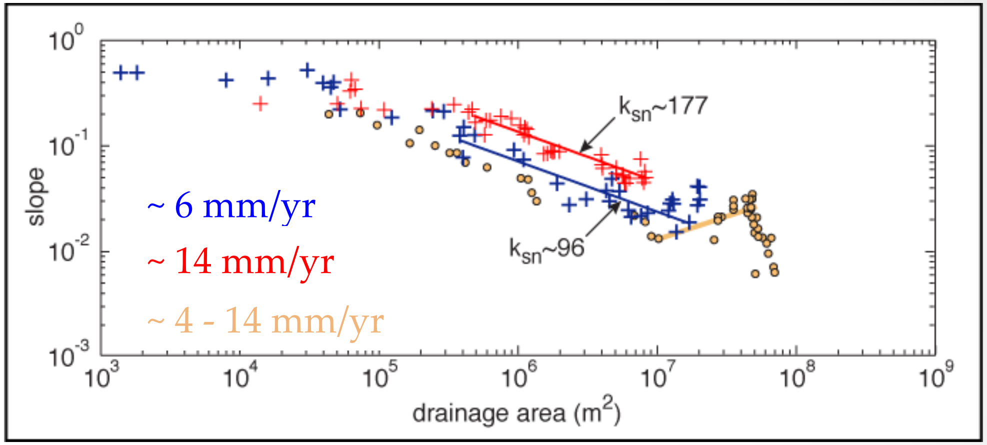
-E. Kirby

Channel adjustment to rock uplift

Channel steepness

$$S = k_{sn} A^{-\theta ref}$$





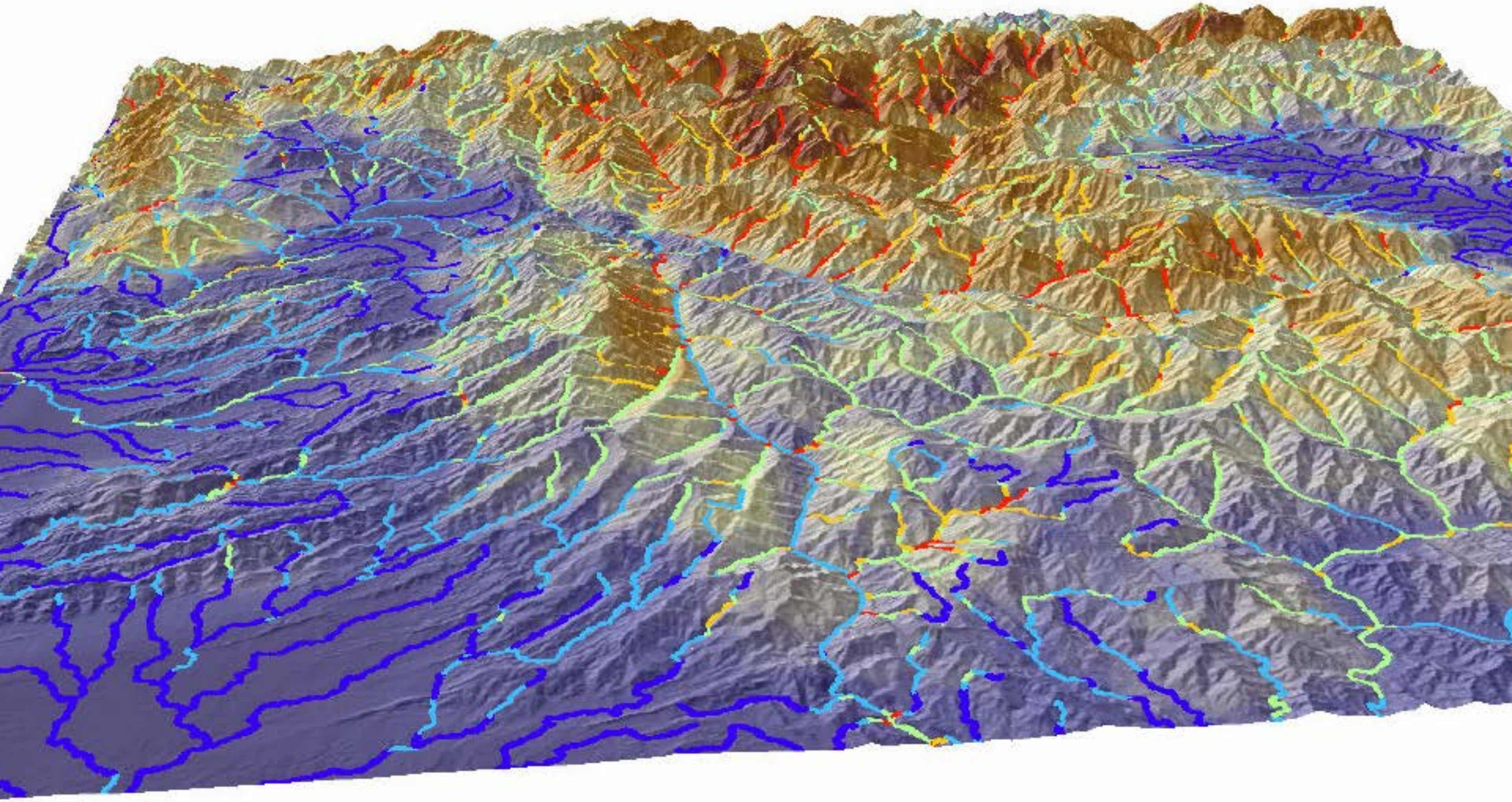
Siwalik Hills, central Nepal – Kirby and Whipple, 2001

- Steepness index (k_{sn})
  - A measure of channel gradient normalized for differences in discharge/area
  - Scales with erosion/rock uplift rate (Kirby and Whipple, 2012)

- Holds in systems subjected to simple boundary conditions:
  - King Range, CA (Snyder et al., 2000; 2003)
  - Santa Ynez Range, CA (Duvall et al., 2004)
  - Siwalik Hills, Nepal (Kirby and Whipple, 2001; Wobus et al., 2006)

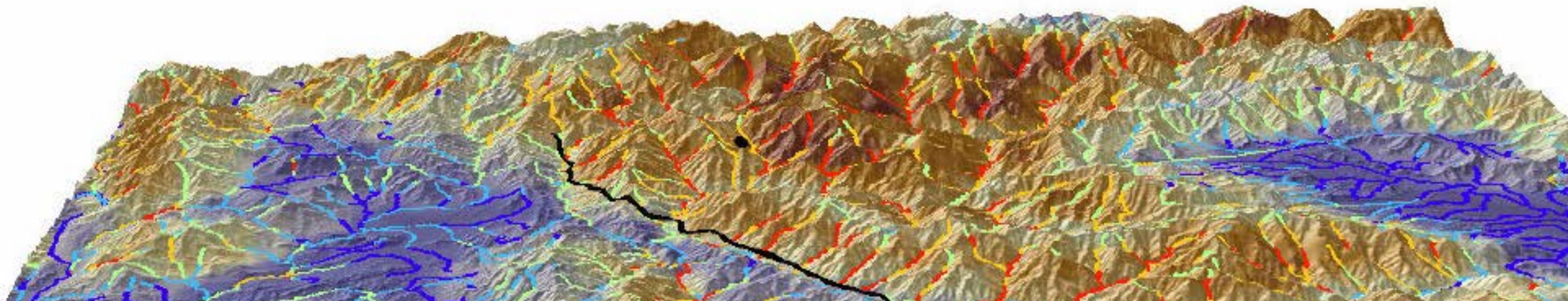
-E. Kirby

Qualitative: Is There an Active Fault? Where?



-K. Whipple

Qualitative: Is There an Active Fault? Where?

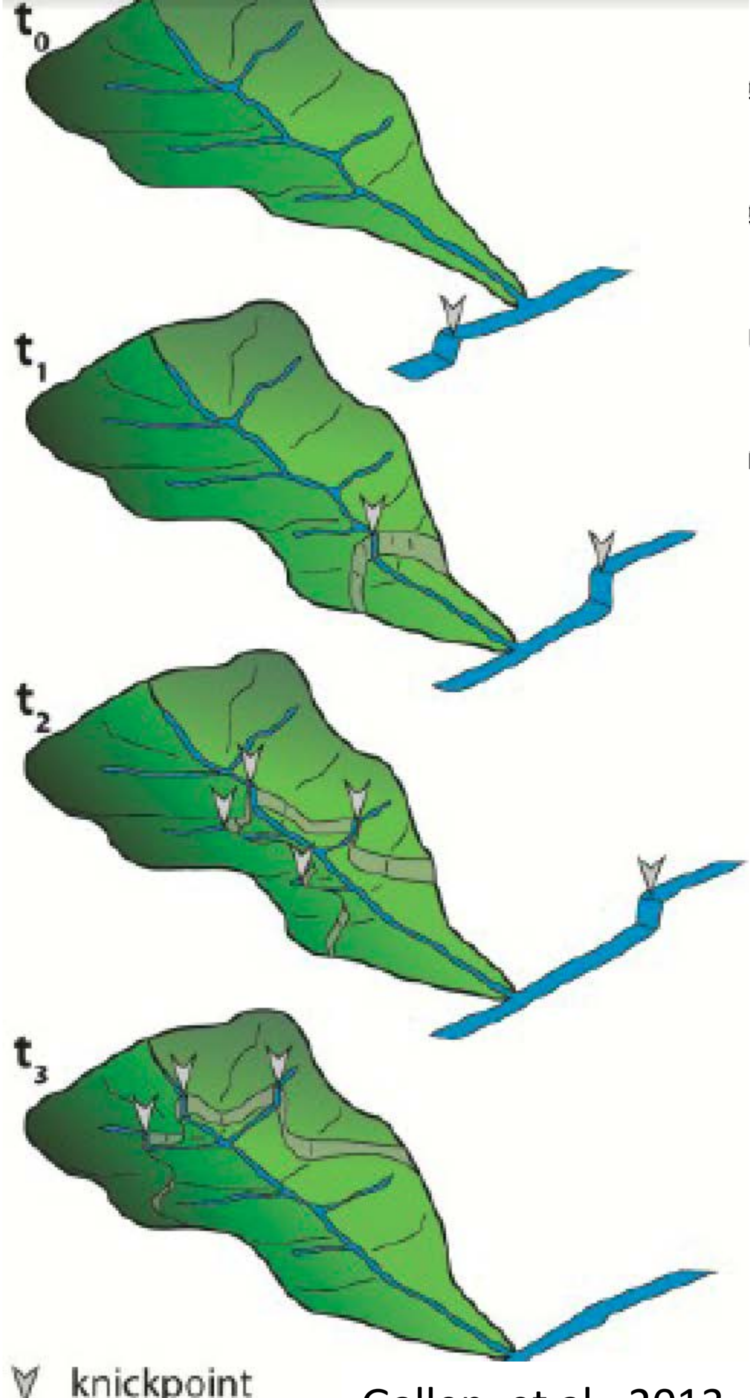


2005 Kashmir Earthquake

Date	October 8, 2005
Magnitude	7.6 M_W
Casualties	100,000 dead (18th deadliest earthquake of all time) 138,000 injured 3.5 million displaced [1]

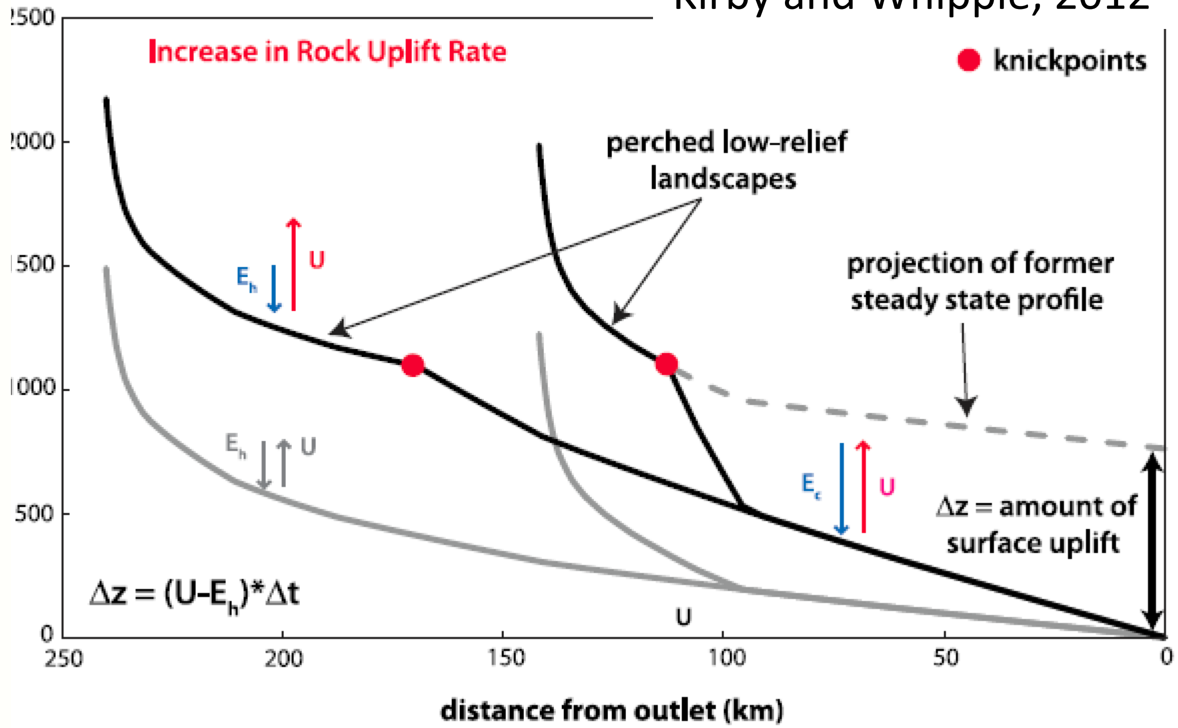
Date October 8, 2005

-K. Whipple



Gallen, et al., 2013

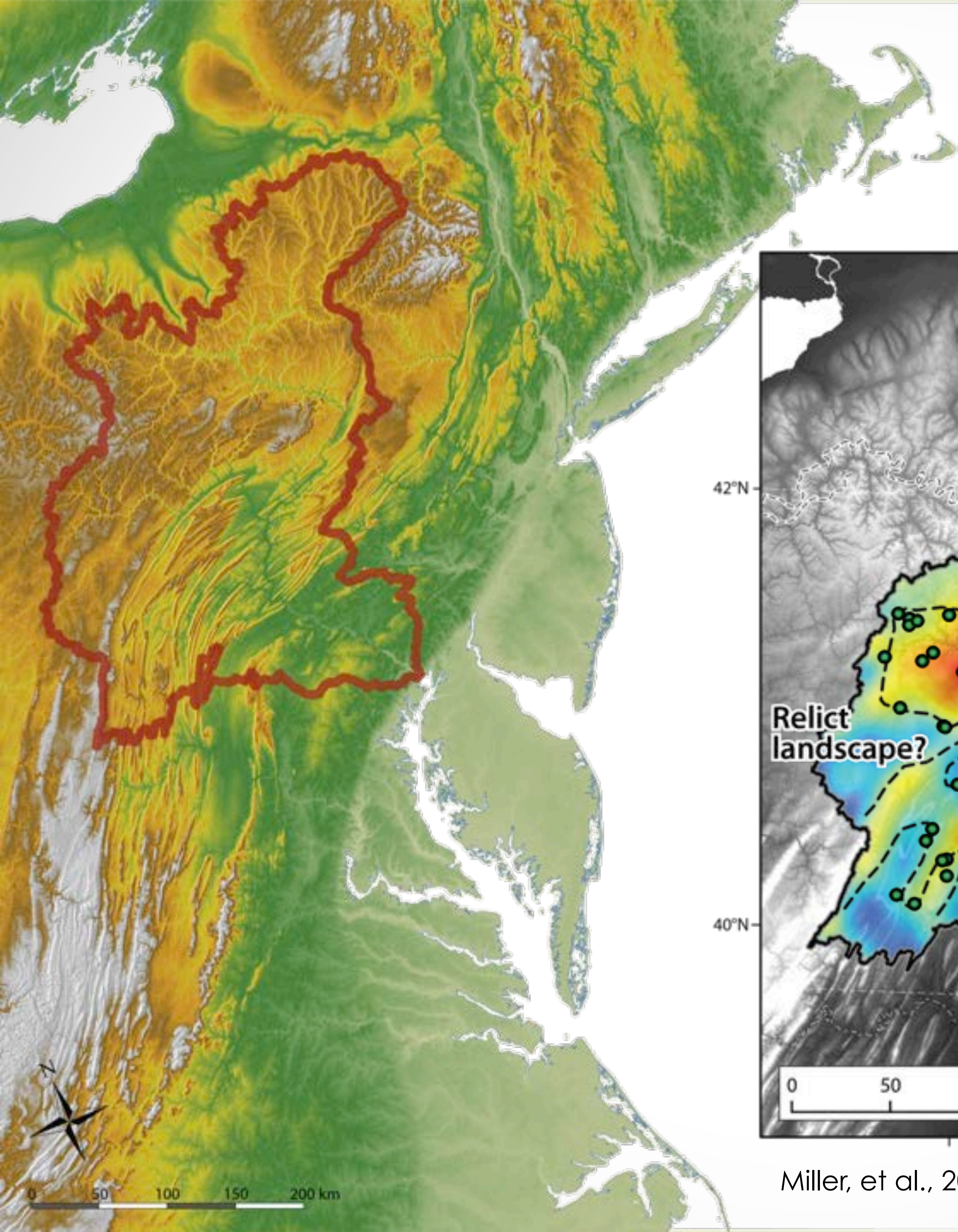
Kirby and Whipple, 2012

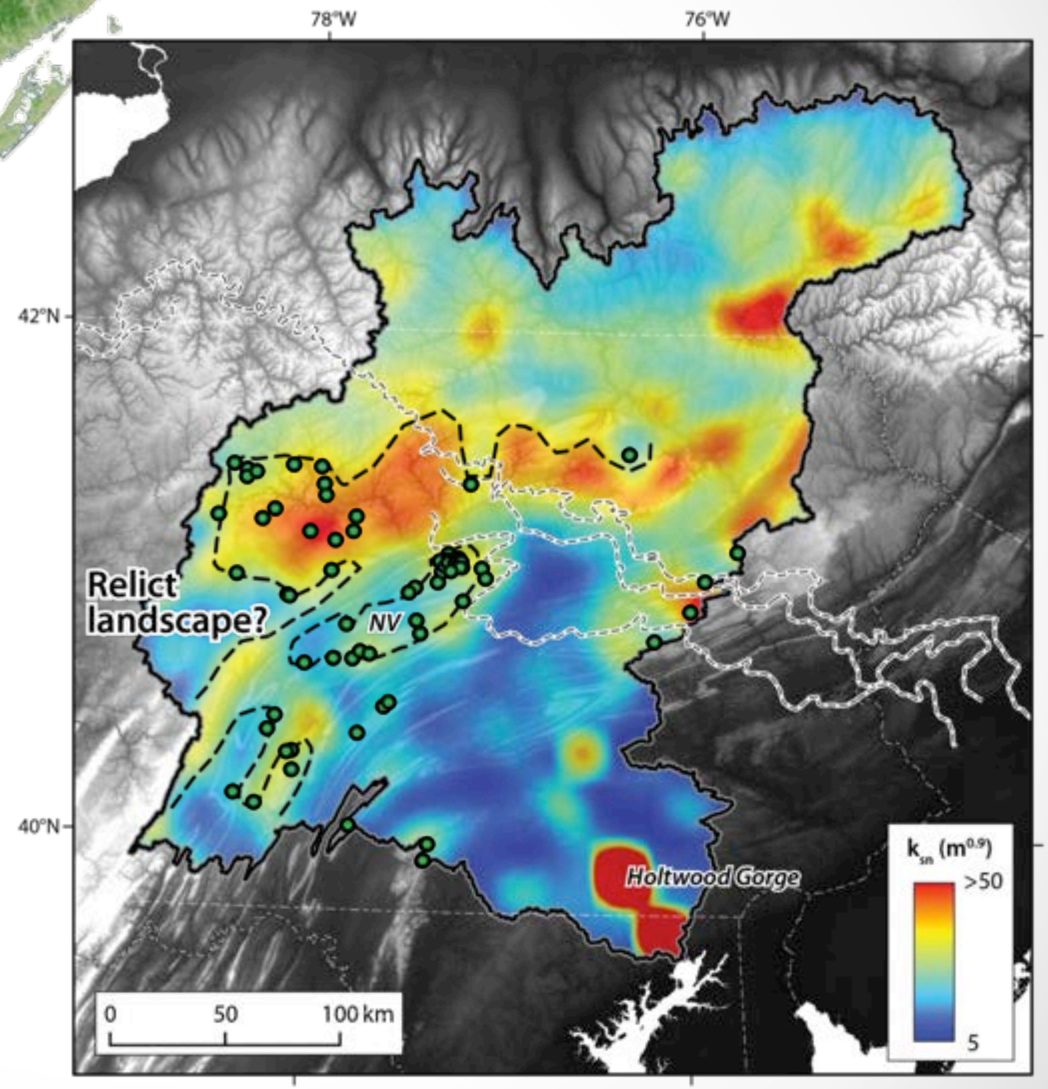


Transient channel response to change in baselevel

Channel adjusts; signal sweeps upstream

Susquehanna River and Neogene dynamic topography of ENAM

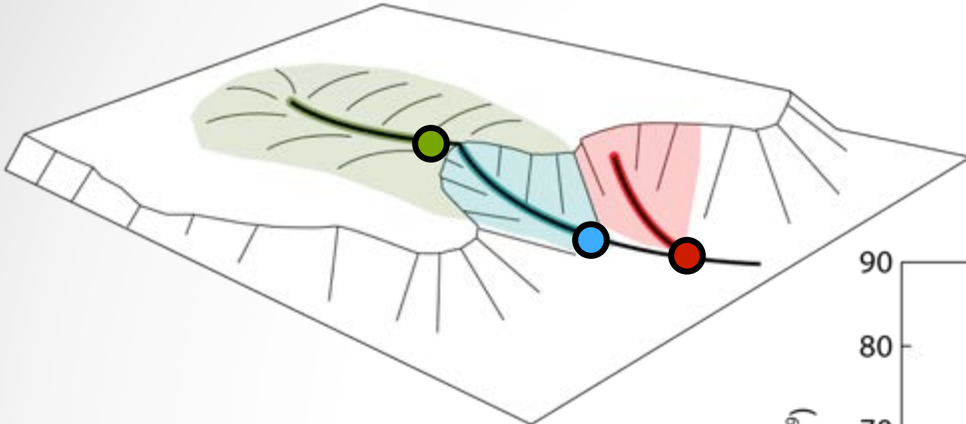


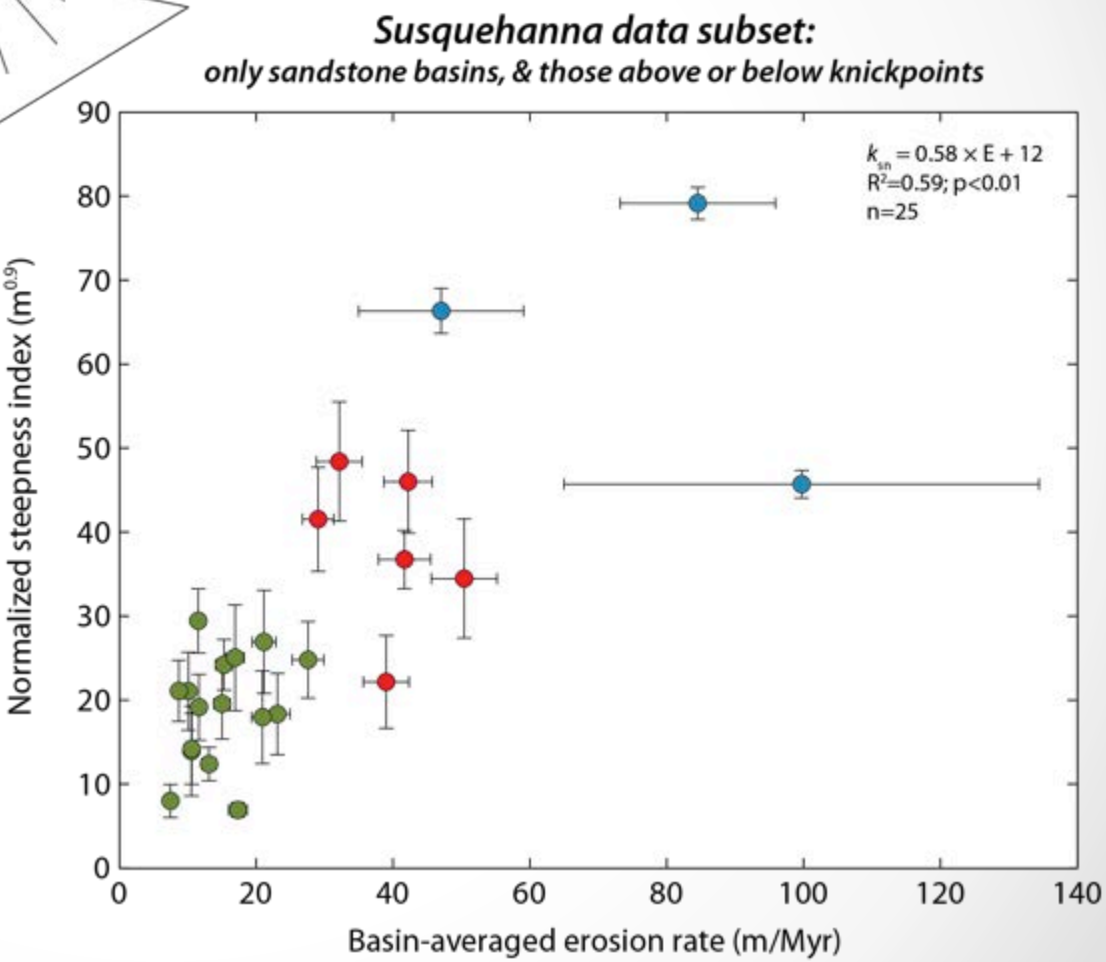


Miller, et al., 2013 - EPSL

-E. Kirby

Erosion rates are tied to channel morphology and position relative to knickpoints



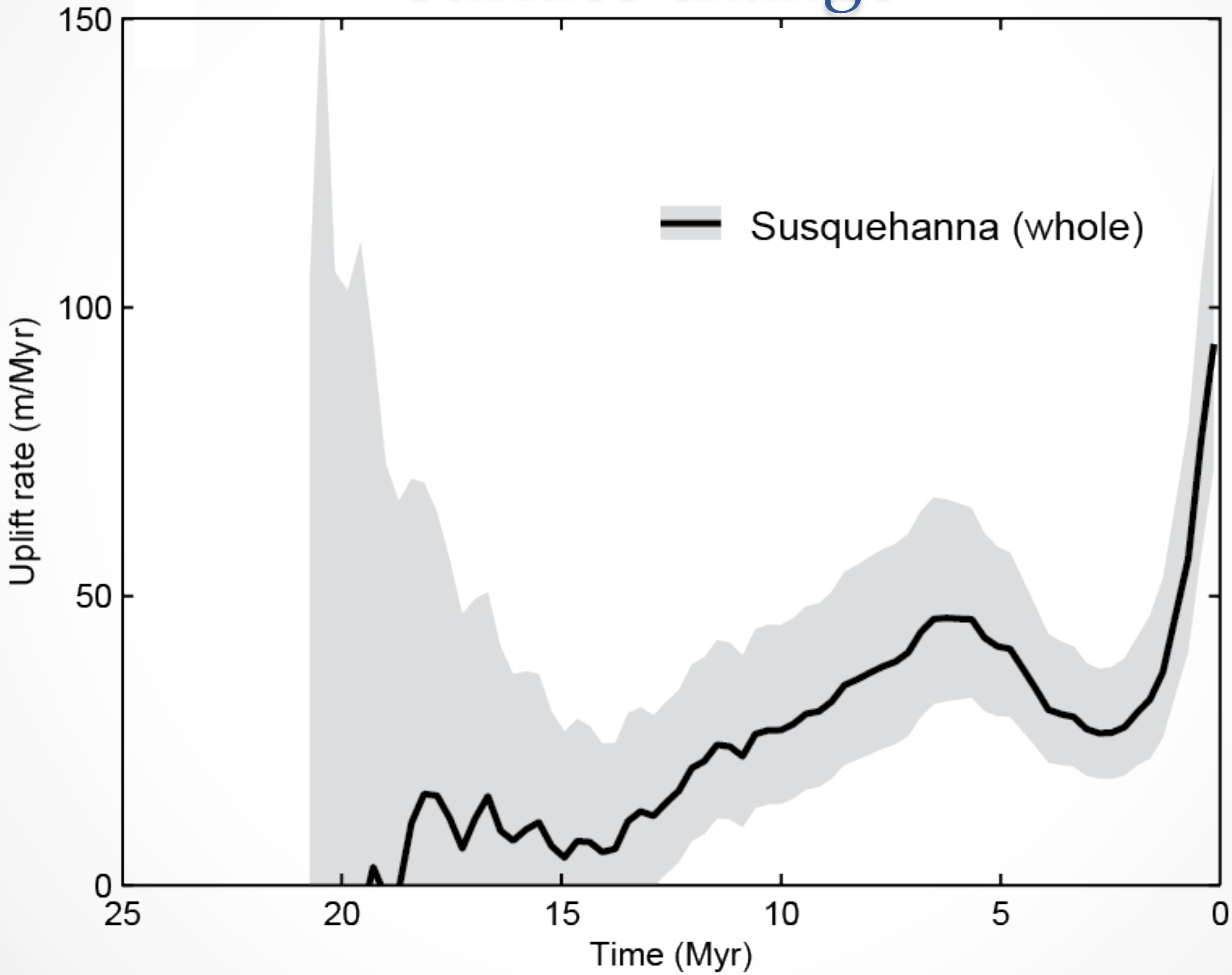


-Need geochronology!

- Miller et al., 2013 - EPSL

-E. Kirby

And, in some cases, be inverted for history of surface change

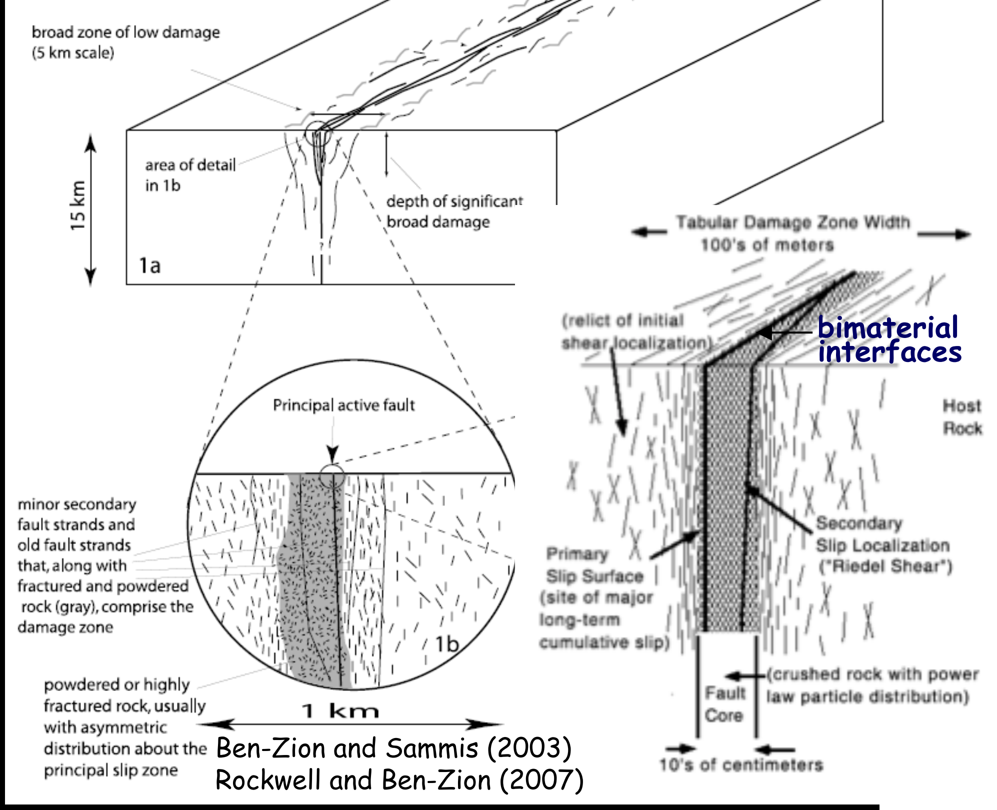


- Miller and Kirby, in prep

-E. Kirby

Zoming into faults

-Fault trace mapping
-Reconstructing slip histories
-Understanding geomorphic response to uplift
-3D topographic differencing

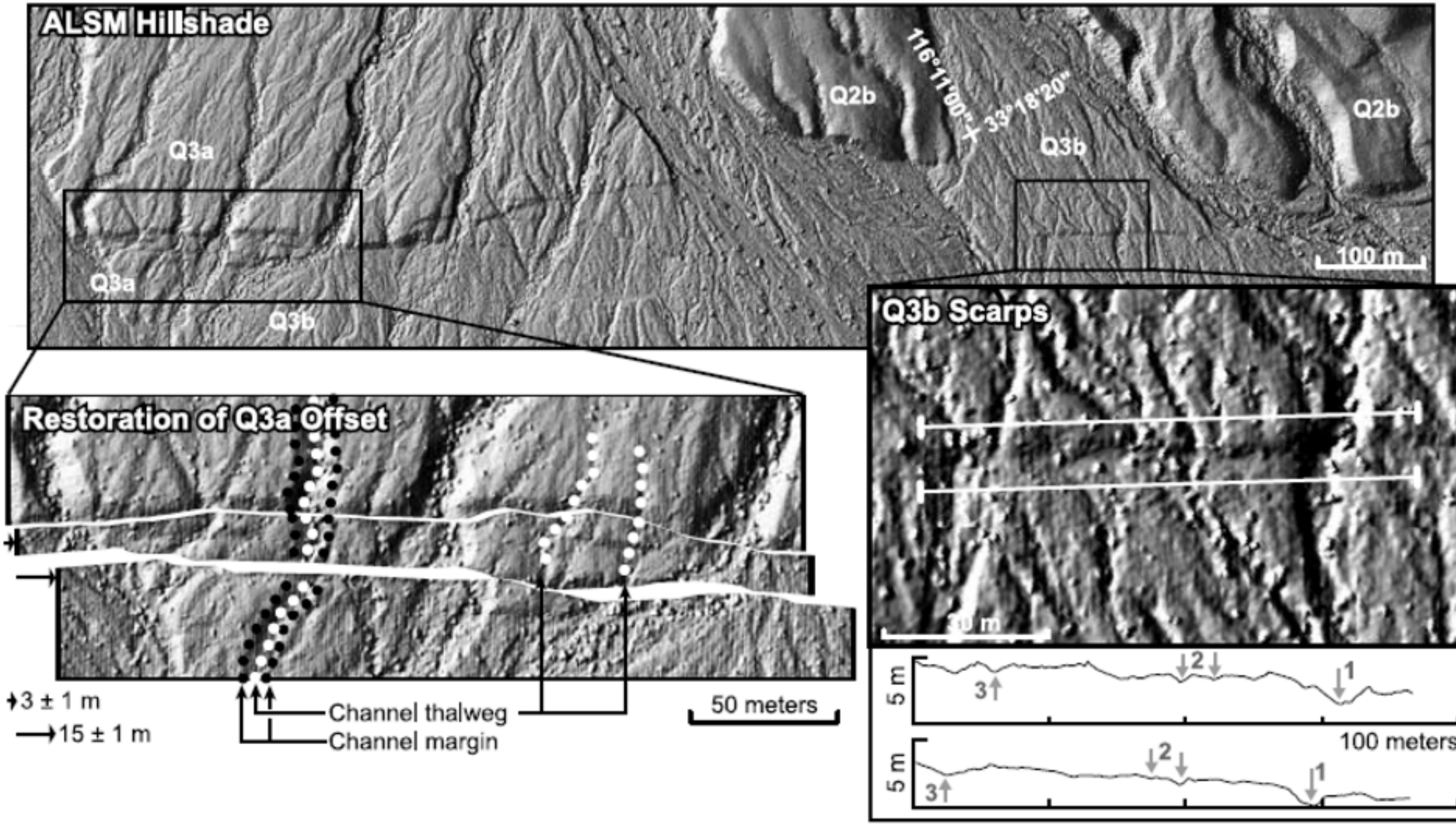


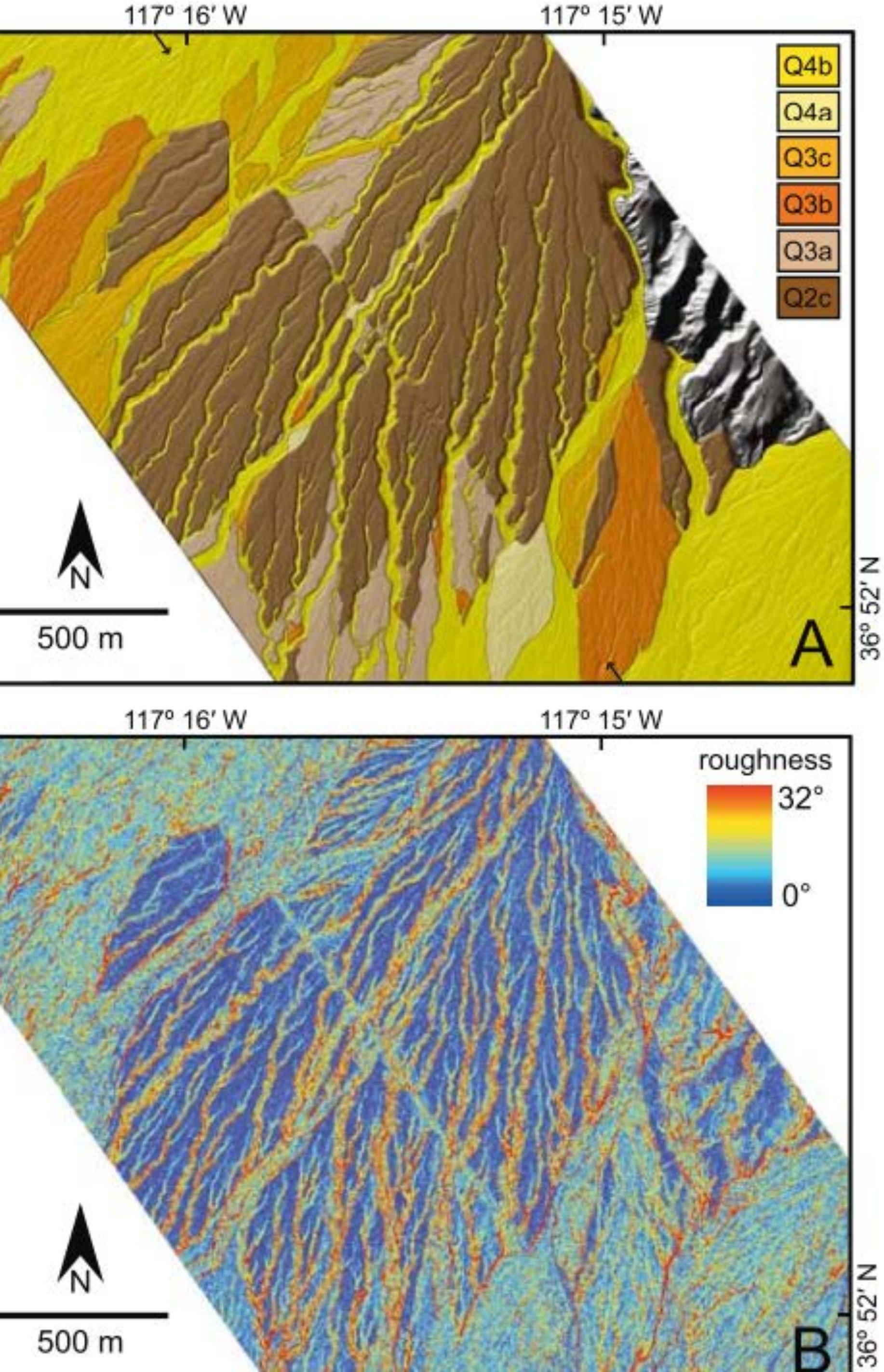
Ben-Zion and Sammis (2003)
Rockwell and Ben-Zion (2007)

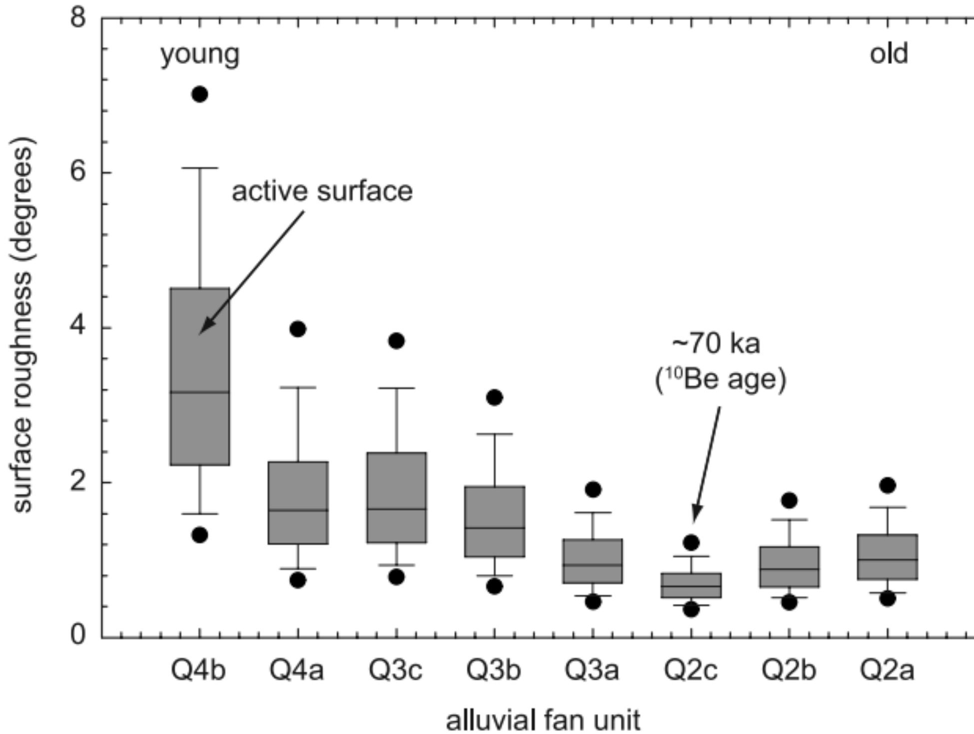
GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L23S05, doi:10.1029/2007GL031295, 2007

Quantifying fault-zone activity in arid environments with high-resolution topography

Michael E. Oskin,[1] Kimberly Le,[1] and Michael D. Strane[2]



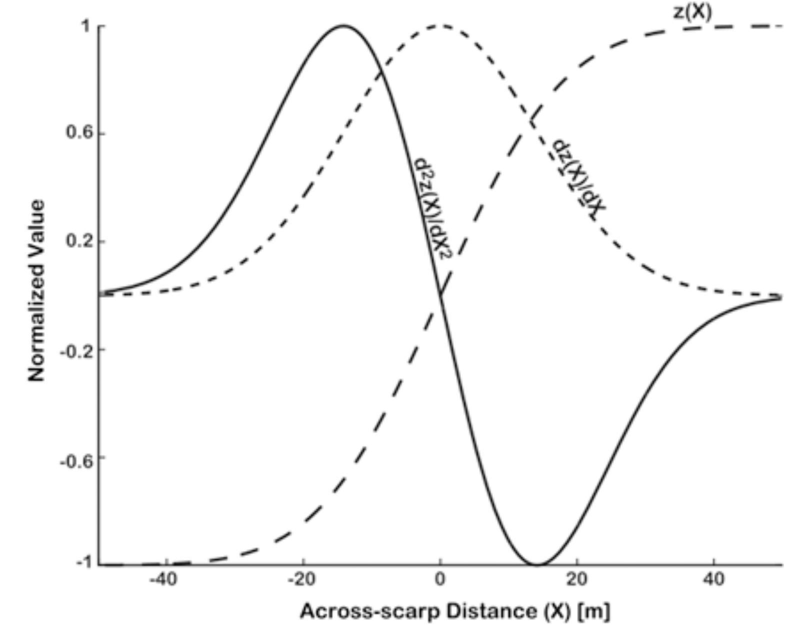


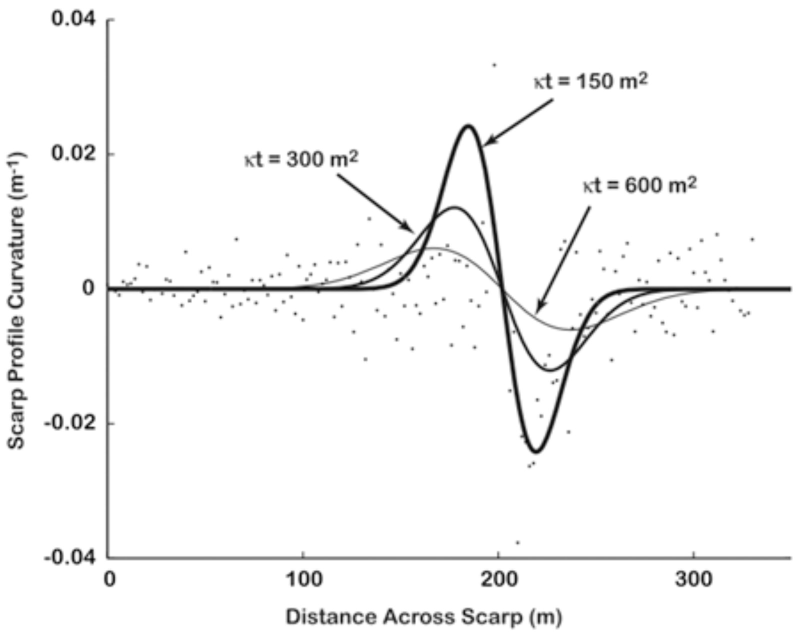


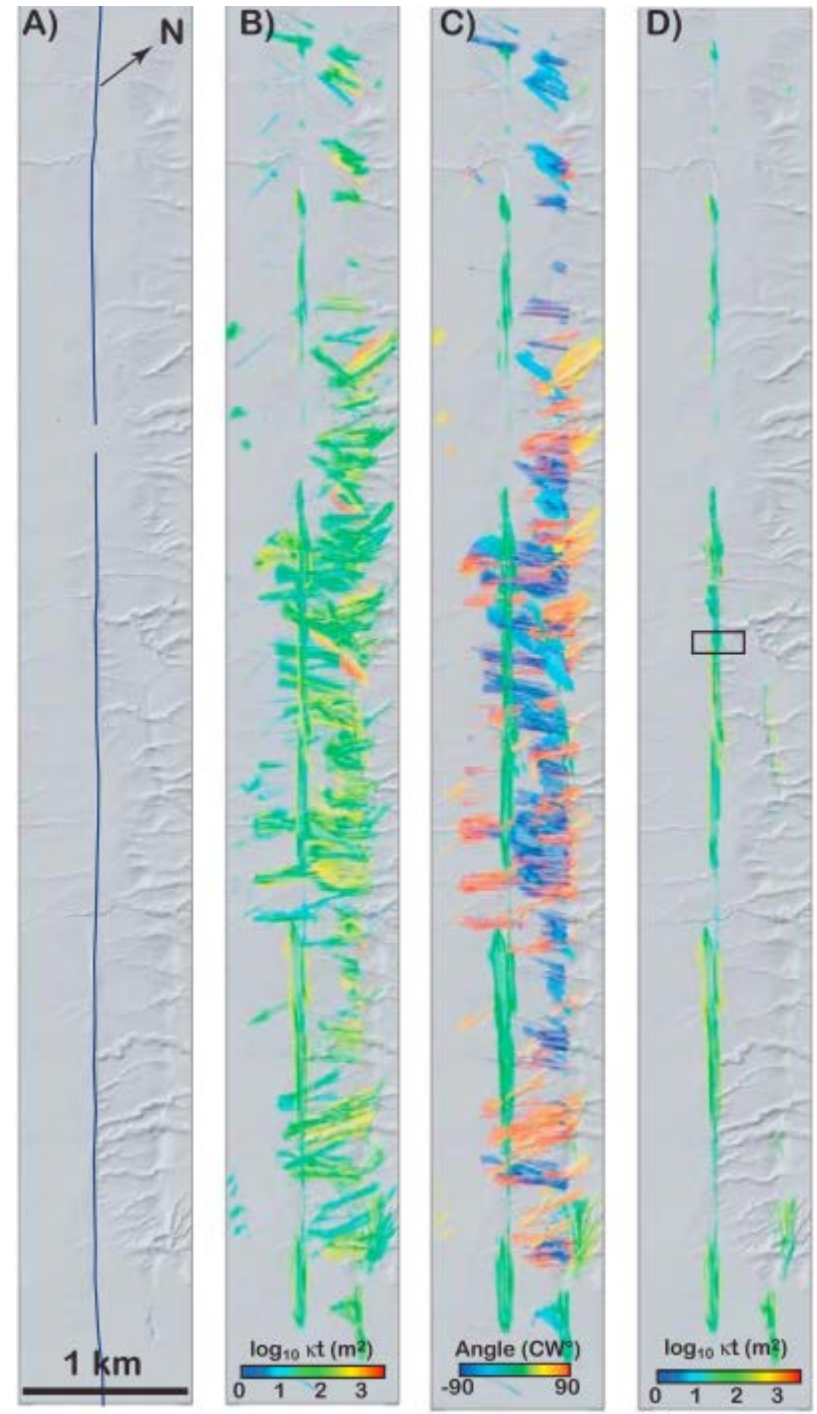
Characterizing arid region alluvial fan surface roughness with airborne laser swath mapping digital topographic data

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

JGR, 2007







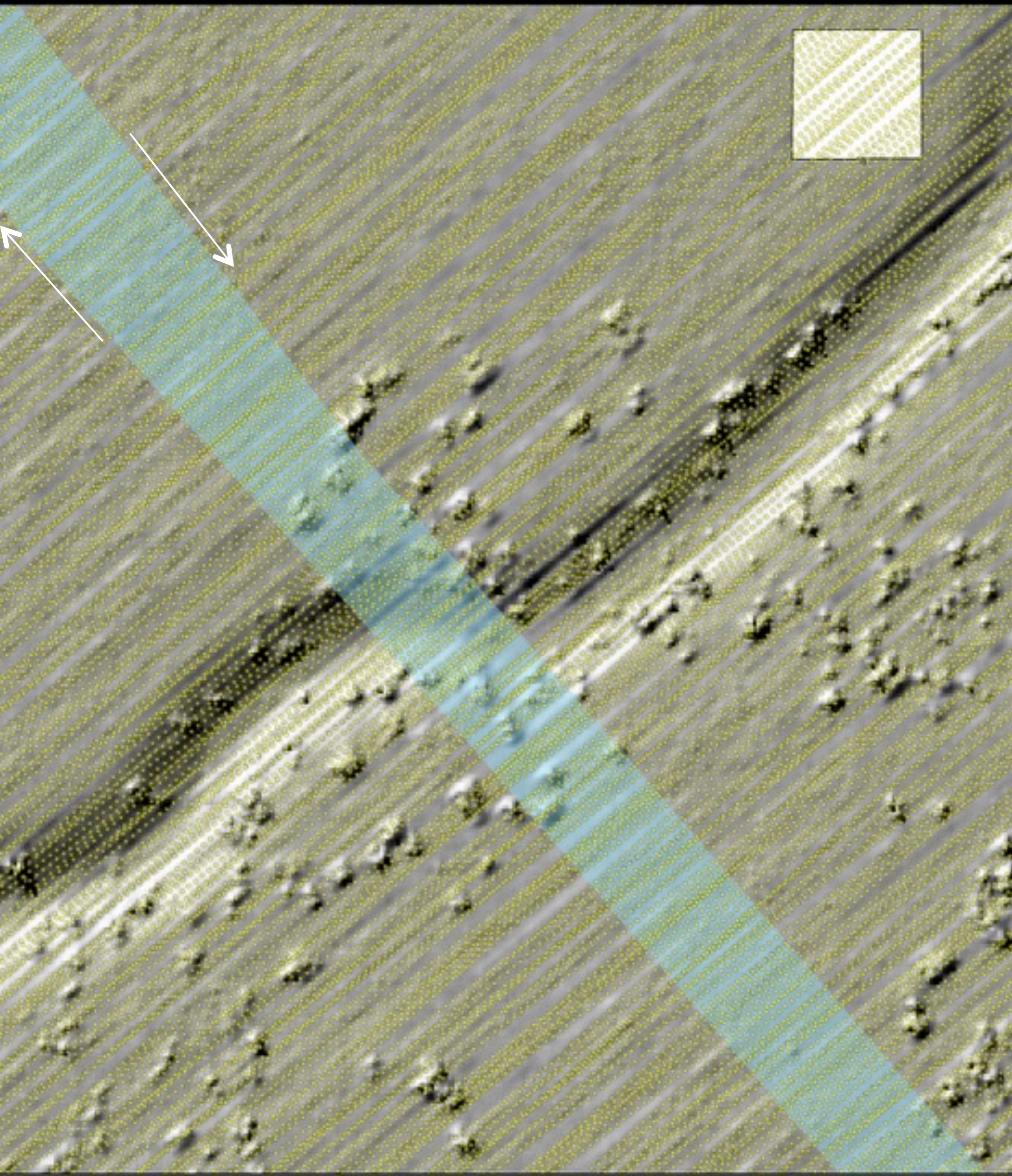
Morphologic dating of fault scarps using airborne laser swath mapping (ALSM) data

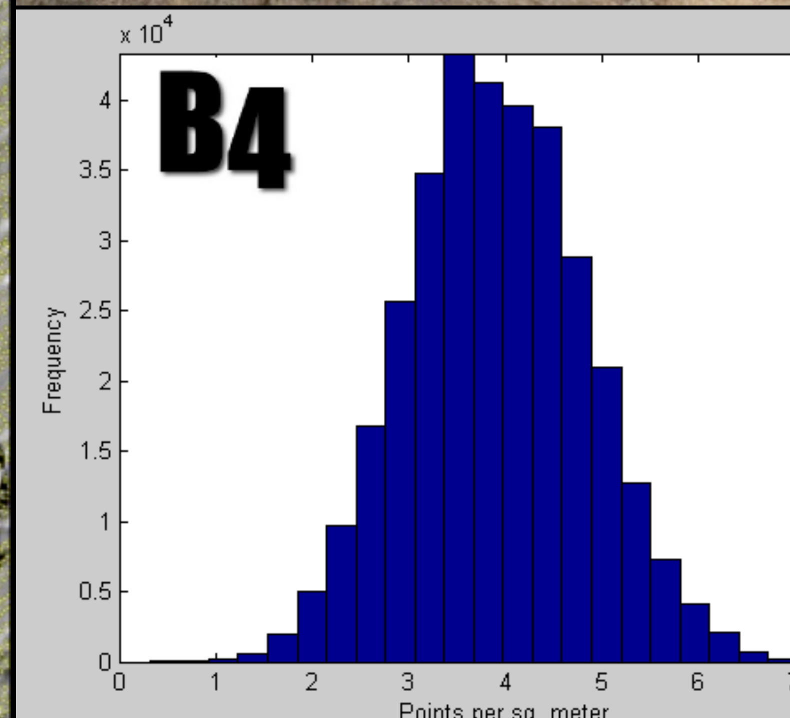
GRL, 2010

G. E. Hilley,[1] S. DeLong,[2] C. Prentice,[2] K. Blisniuk,[3] and JR. Arrowsmith[4]

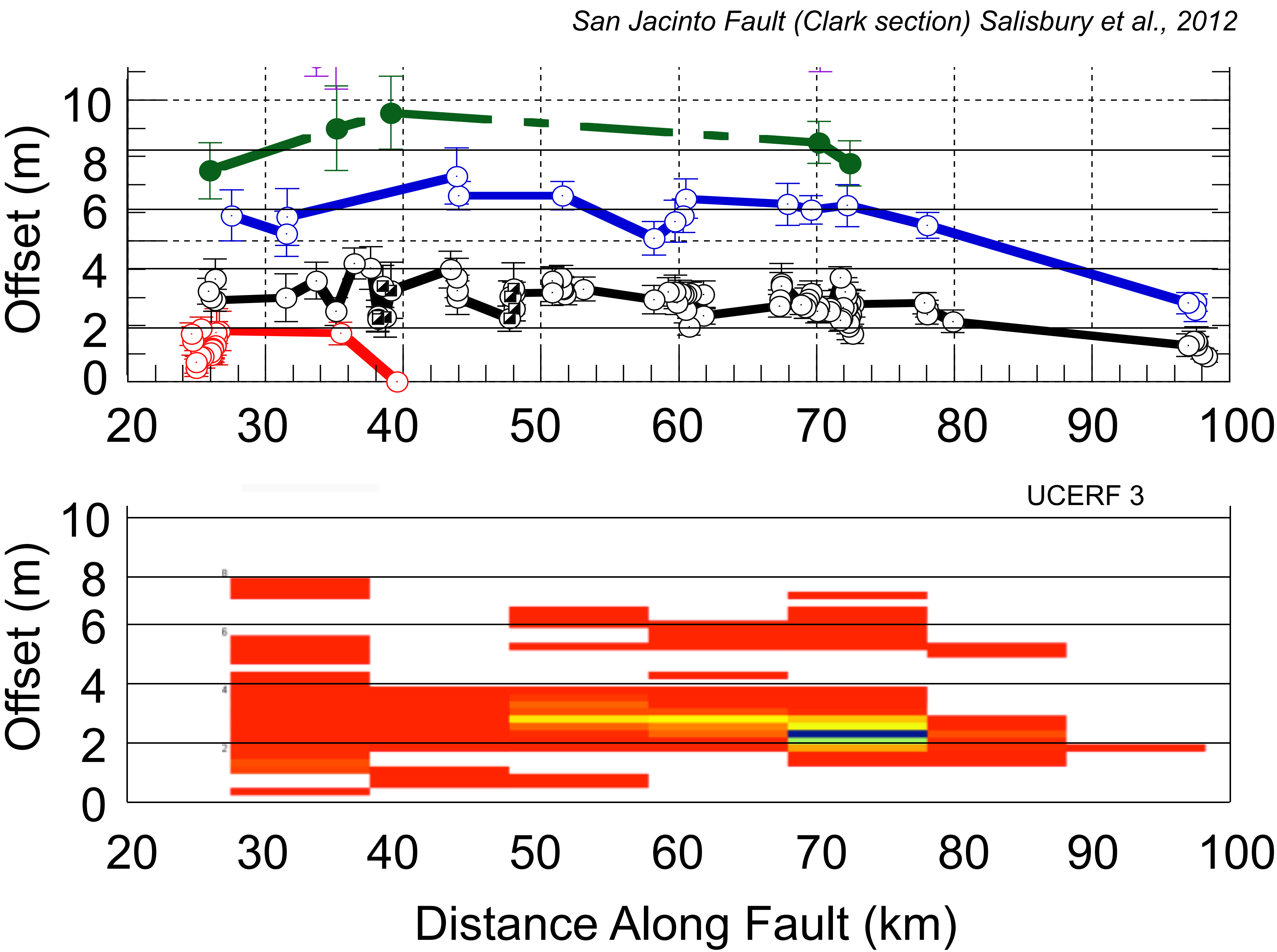
Measure fault slip at the appropriate scale

B4 LiDAR topography 0.25 m DEM

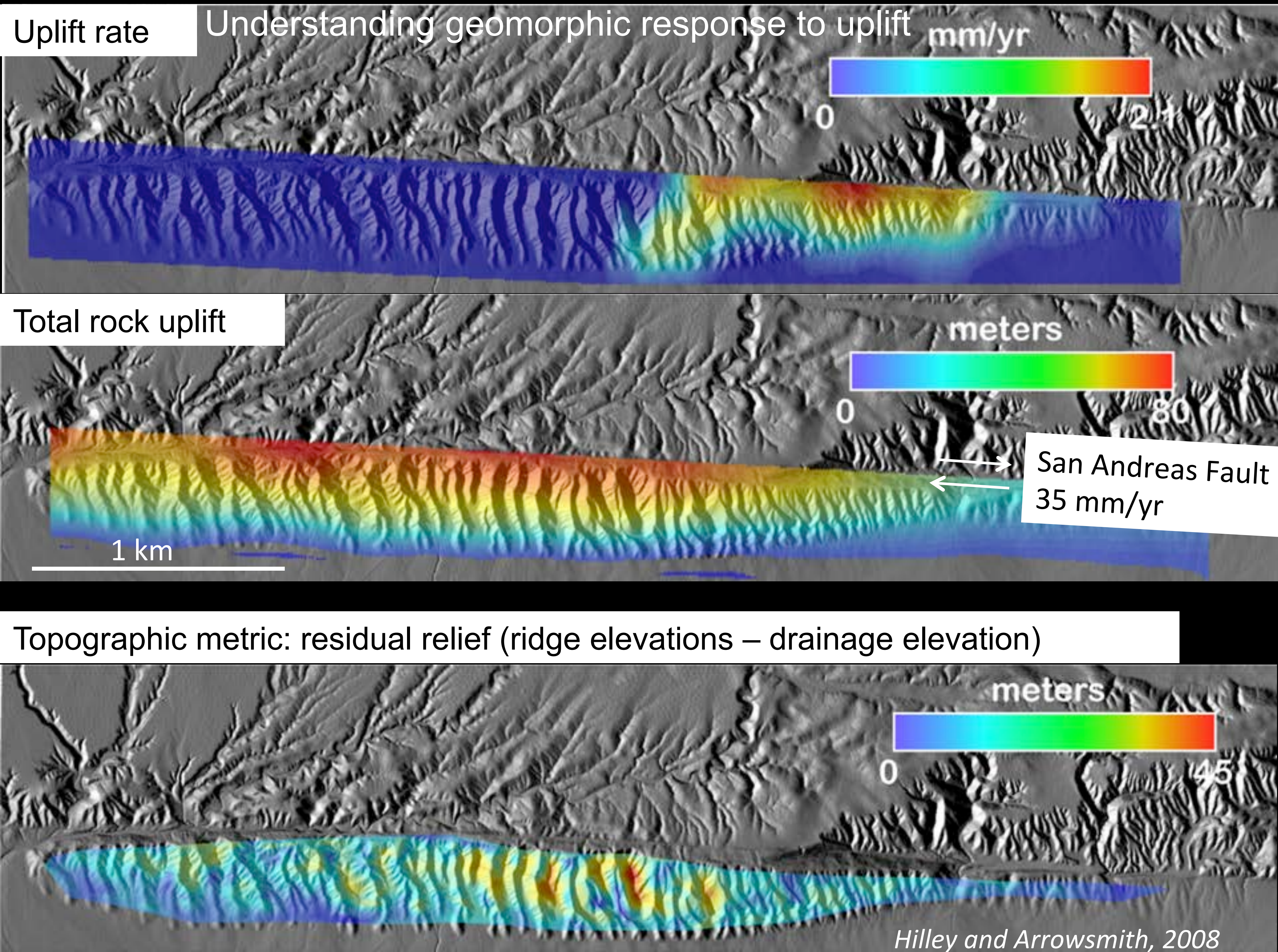




Mean ~4 shots/sq. m

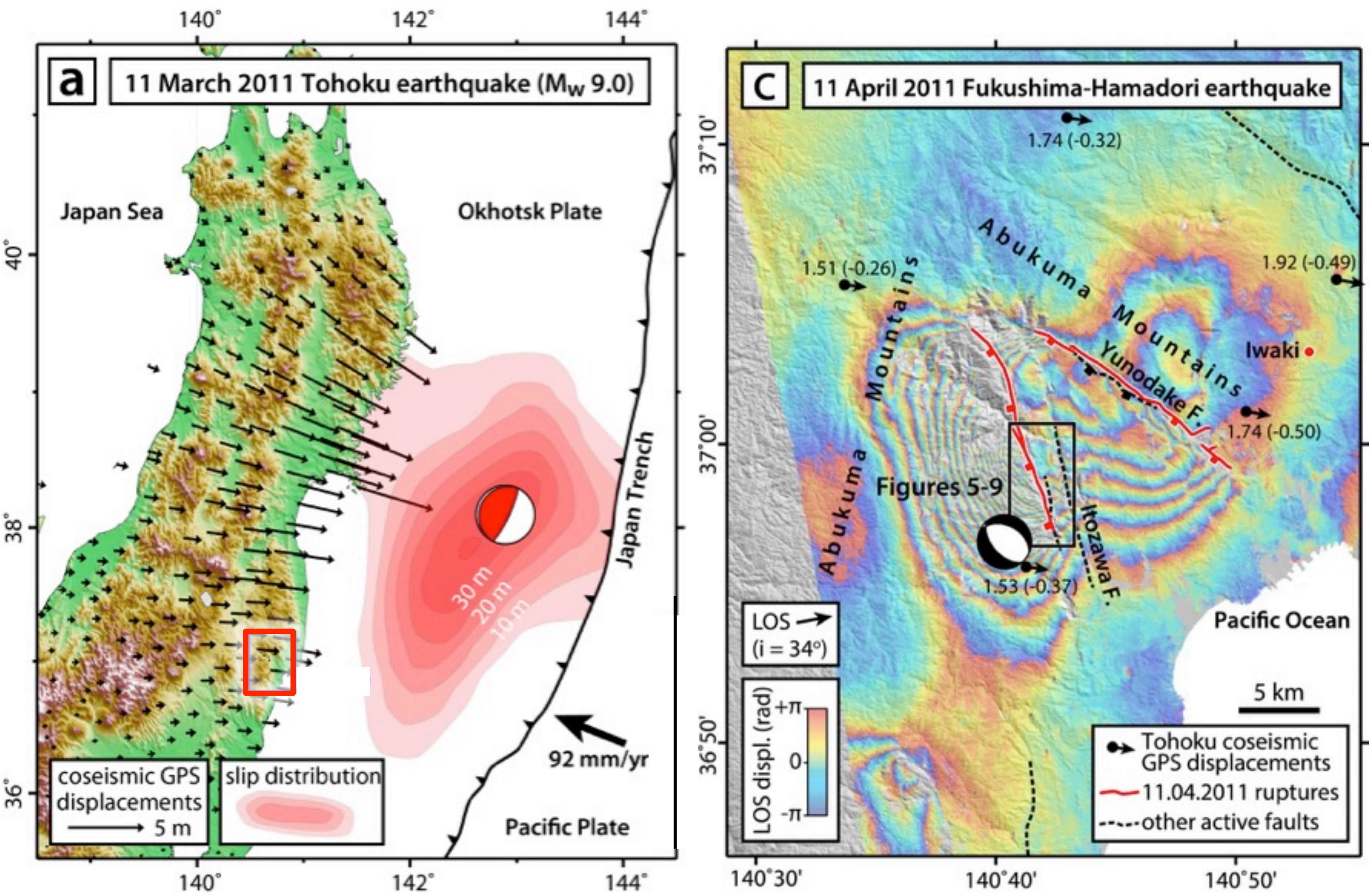

San Jacinto Fault (Clark section) Salisbury et al., 2012
Offset (m)
10
8
6
4
2
0
20
30
40
50
60
70
80
90
100
UCERF 3
Offset (m)
10
8
6
4
2
0
20
30
40
50
60
70
80
90
100
Distance Along Fault (km)

Understanding geomorphic response to uplift



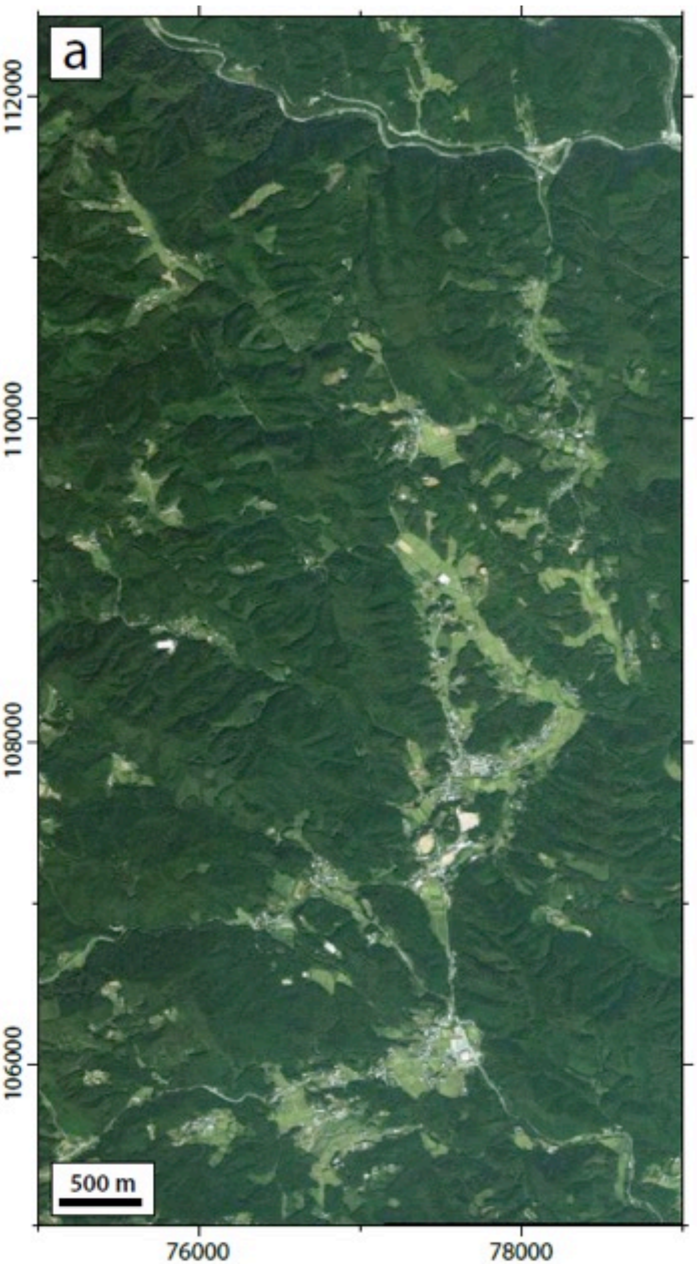
Hilley and Arrowsmith, 2008

11 April 2011 Fukushima-Hamadori earthquake

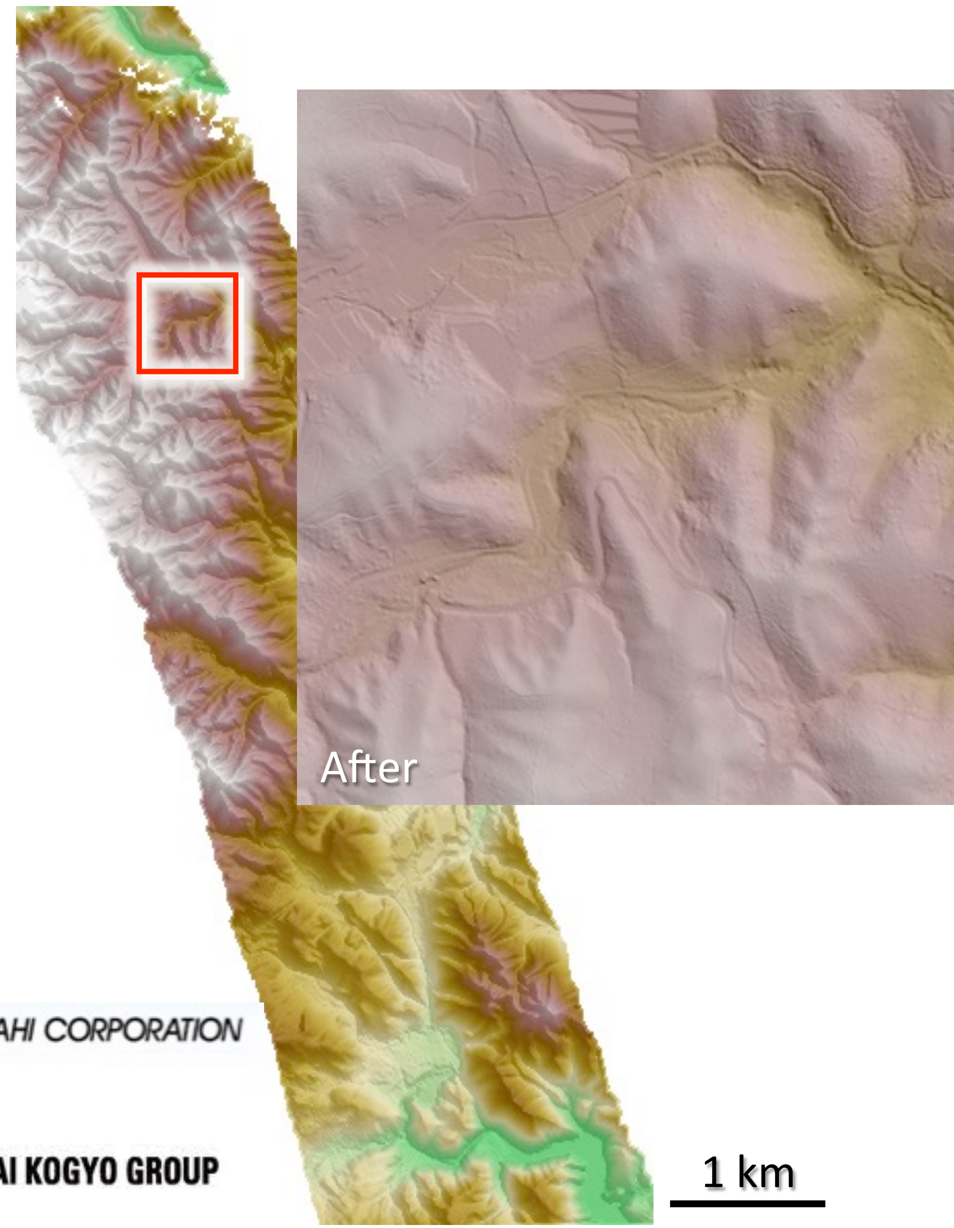


Nissen et al. (2014), *Earth Planet. Sci. Lett.*

11 April 2011 Fukushima-Hamadori earthquake



Tadashi Maruyama (AIST)



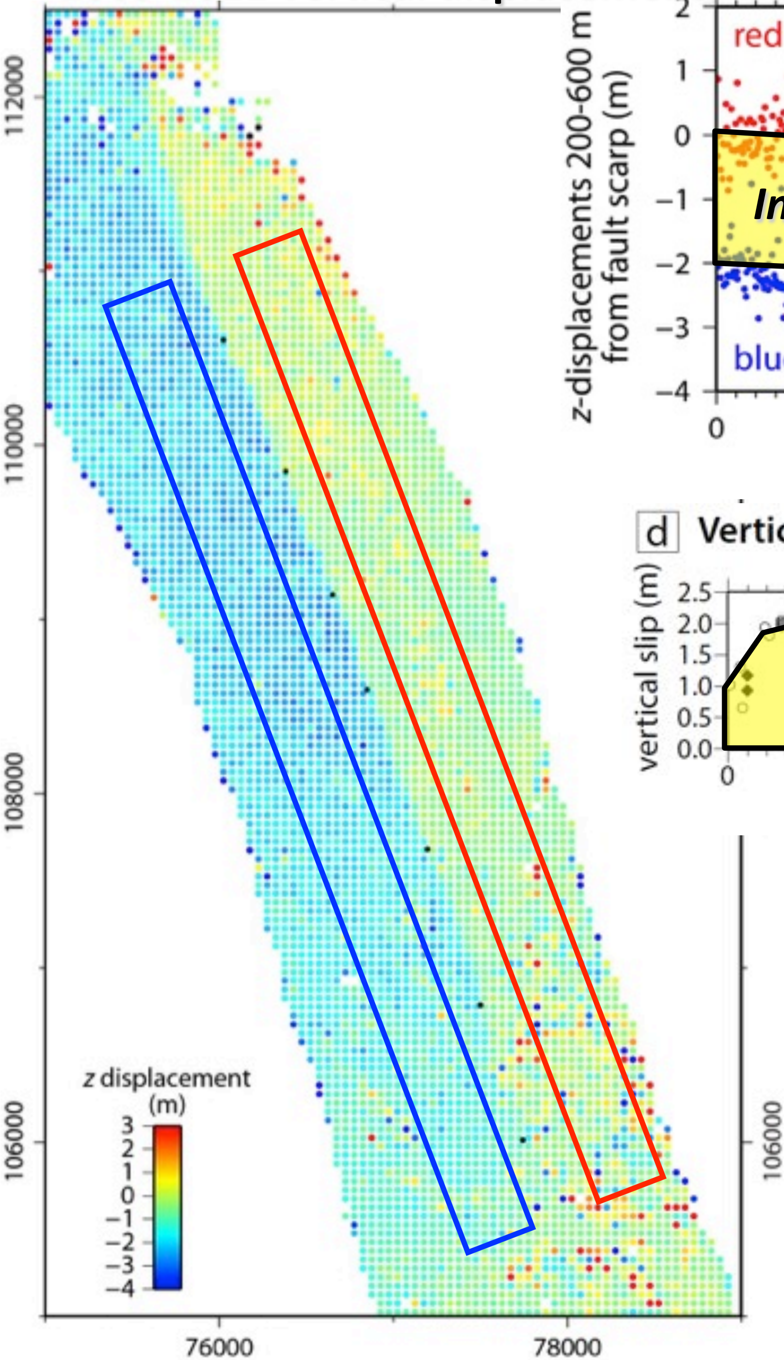
AERO ASAHI CORPORATION

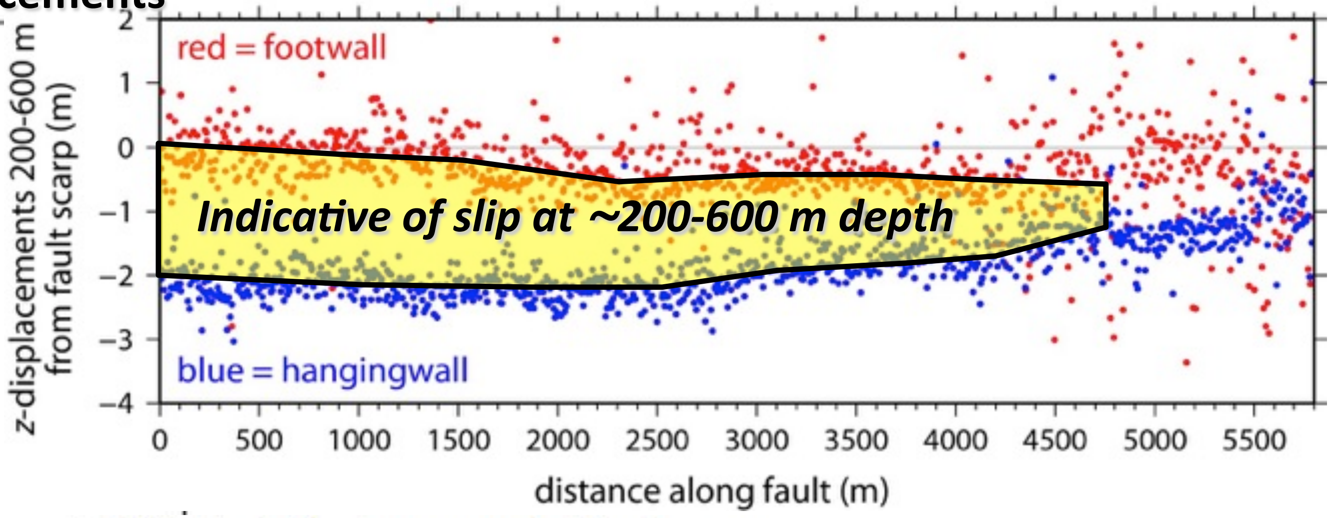
KOKUSAI KOGYO GROUP

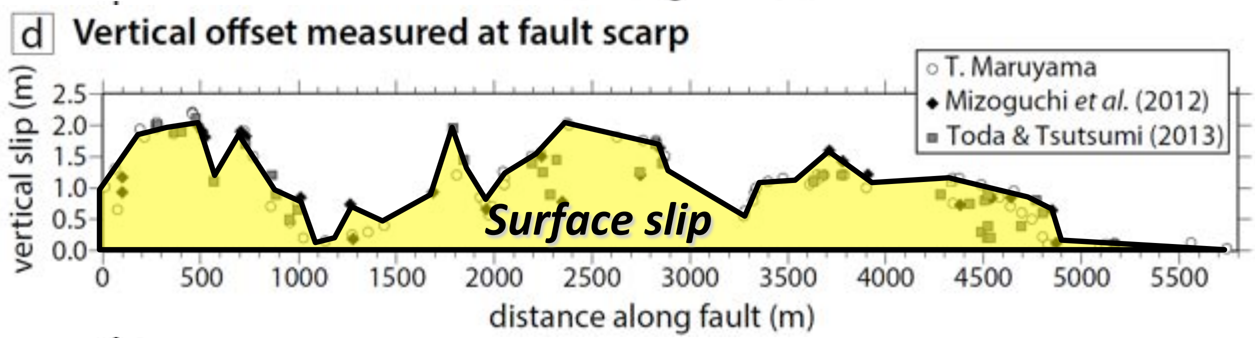
2011 post-event 1 m DEM

AERO ASAHI CORPORATION

2005-2011 vertical displacements

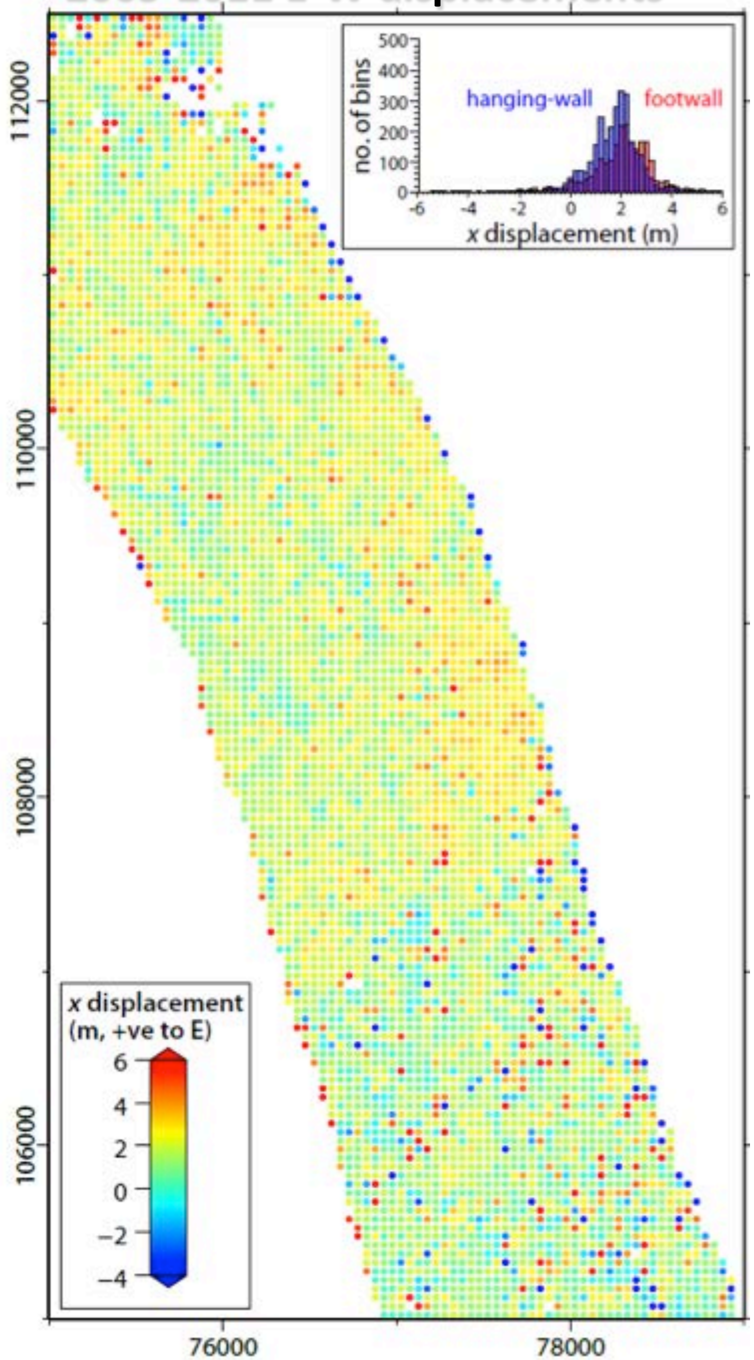


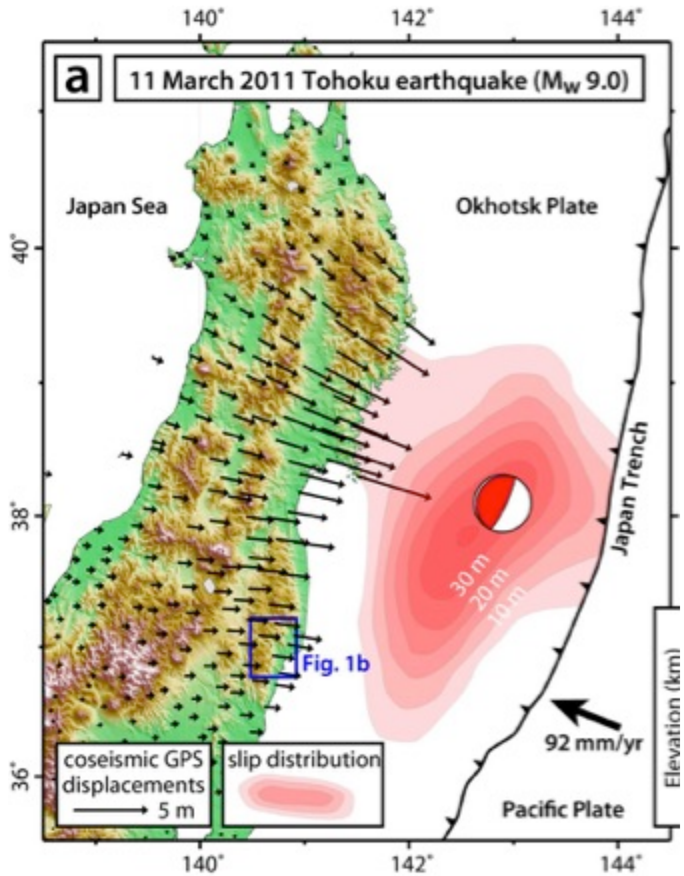


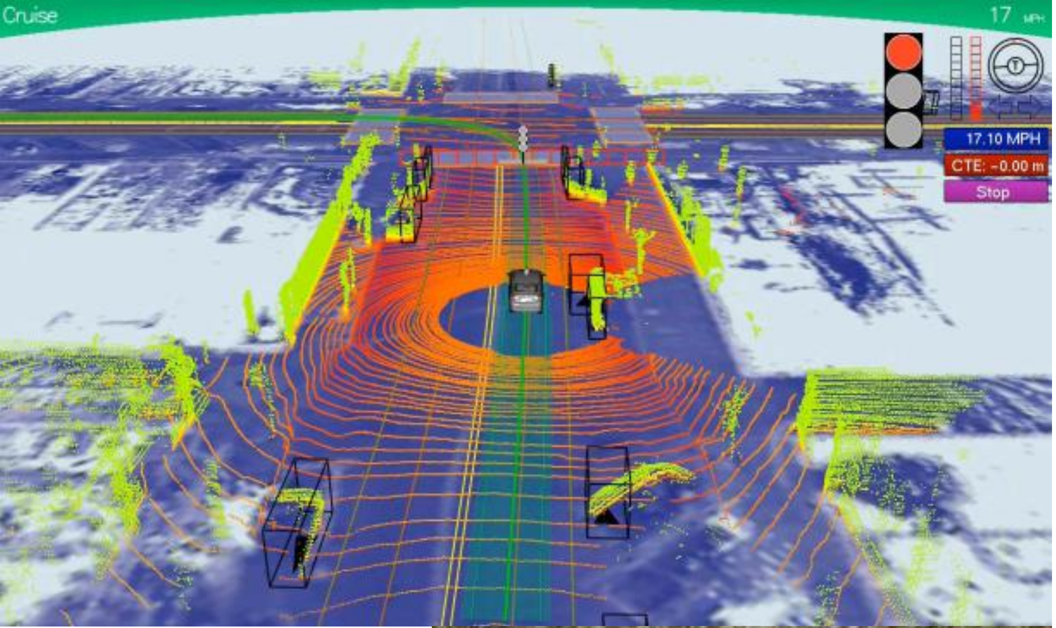


- In many places, only a small proportion of the slip makes it to the surface
- However, slip at depths of a few hundred meters appears to vary smoothly

2005-2011 E-W displacements







Google car: Gb/ sec high accuracy navigation data

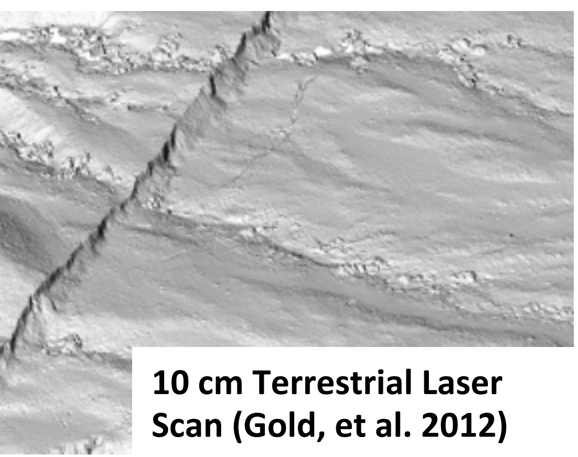
Modeling the World from Internet Photo Collections (Snavely, et al., Int J Comput Vis , 2007)

Ubiquitous point clouds: coordinated (mapping and monitoring) and haphazard (autonomous navigation, individual photo collections, etc.)

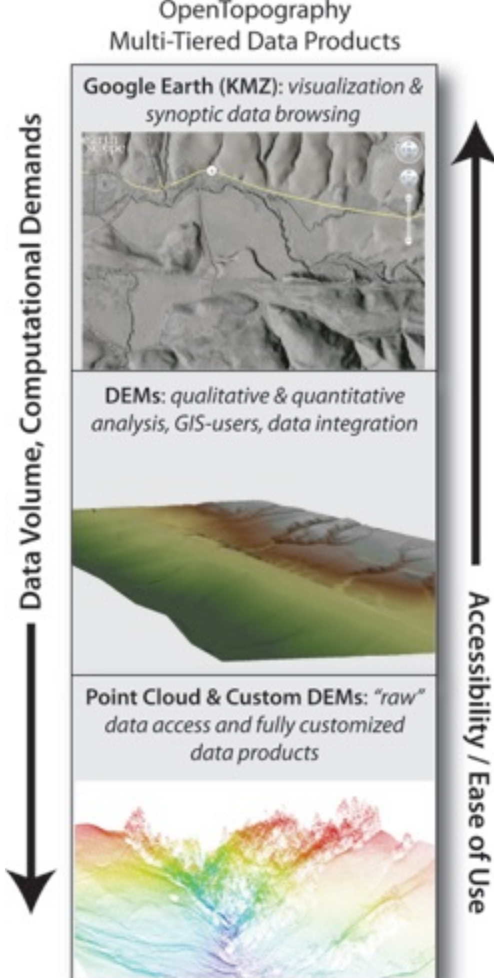
-Need open access and cyberinfrastructure to support archive, and rapid query, data handling, preprocessing, and differencing

Data discovery, sharing, archive, metadata, QA/QC

Interactive analysis and visualization of massive data (e.g., Lidarviewer)

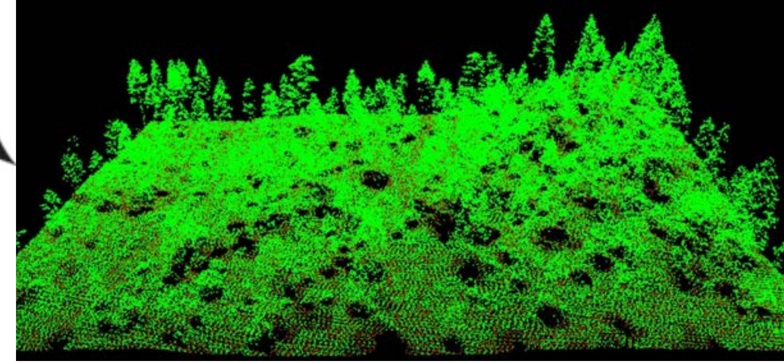


10 cm Terrestrial Laser Scan (Gold, et al. 2012)

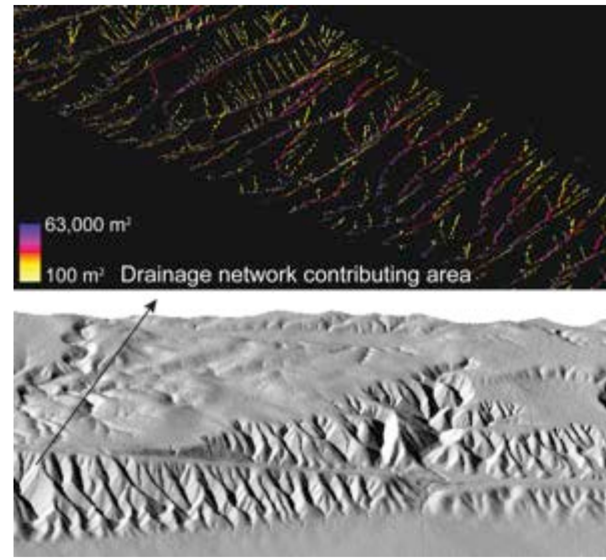


Multiple levels of data products (including topographic metrics, differencing)

Facility thoughts



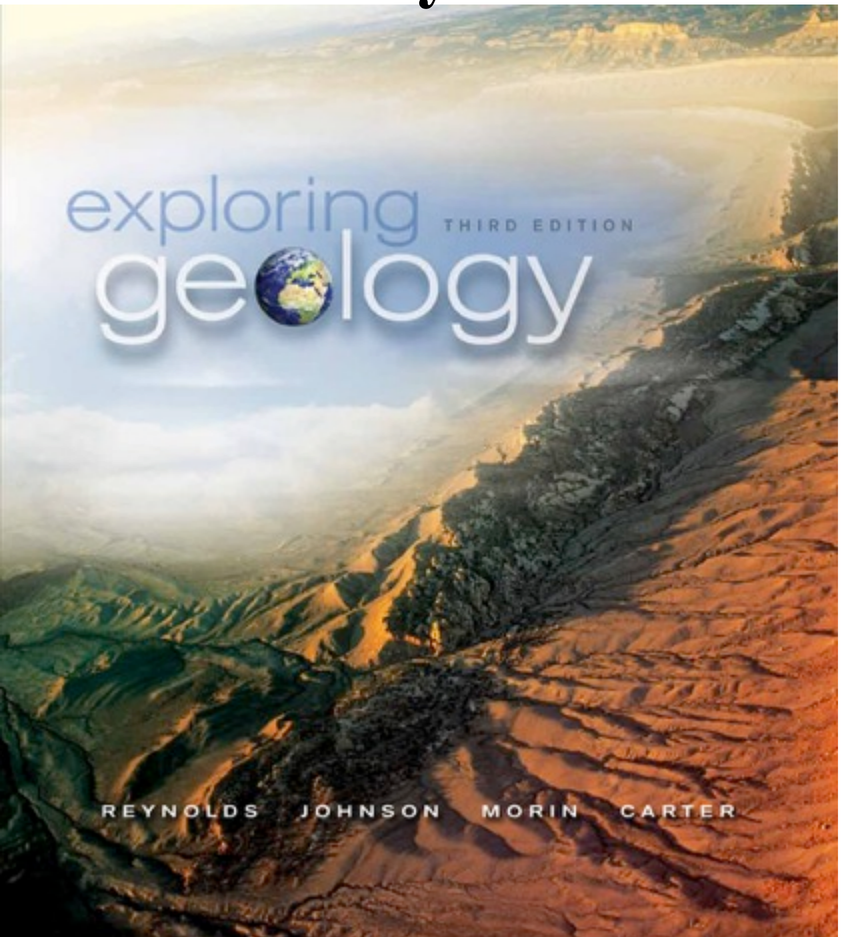
3 and 4D point cloud processing



HPC processing for metrics

People!

Getting HiRT into introductory textbooks!



Chapter 8

Image Number: 08.00.a3: © Duncan Heron; 08.01.mtb1: Spokane Research Lab/NIOSH/CDC; Courtesy of J.M. Logan and F.M. Chester, Center for Tectonophysics, Texas A&M University; 08.02.mtb1: Spokane Research Lab/NIOSH/CDC; 08.03.c6: © Dean Conger/Corbis; 08.10.c2: Ohio State University, USGS, National Center for Airborne Laser Mapping, OpenTopography, and J Ramon Arrowsmith, Arizona State University; 08.11.a9: © Dr. Marli Miller/Visuals Unlimited;

Deformation and Metamorphi

B Where Do Strike-Slip Faults and Shear Zones Form?

During strike-slip movement, one block of rock is sheared sideways past another block of rock. This can various settings, including transform plate boundaries and within the interiors of plates.

Stresses can form a strike-slip zone that functions as a plate boundary or that is totally within a tectonic plate (▶). A strike-slip zone may offset the rocks hundreds of kilometers or less than a meter. A strike-slip fault with relatively small amounts of displacement is typically a single fault or several adjacent faults, but zones with larger displacements are thick zones of shear (shear zones).

Shear stresses can be imposed on rocks horizontally, vertically, or at some intermediate angle. When the shear stresses are horizontal (▲), they act to shear the two sides of a block in opposite horizontal directions. As a result of the stresses, shearing moves rocks horizontally past one another. Shearing in the upper parts of the crust occurs along a fault, as shown here, and is accompanied by fracturing of adjacent rocks. Shearing at depth will occur along a zone of ductile deformation and will be accompanied by metamorphism and the formation of foliation and lineation.

◀ All transform boundaries are faults that accommodate the la placement of one plate past a Most are a boundary betwee oceanic plates, as are the o here by small white arrows, transform fault can also se two continental plates or separate an oceanic pla a continental one.

C What Features Form Along Strike-Slip Faults?

Strike-slip faults result in a number of distinctive features, including offset streams. They also can have fo formed where one block of rock shears past another or where rocks are forced around a bend in the fau

Strike-slip faults displace rocks on either side horizontally relative to one another, so in a simple case would not uplift or downdrop either side. However, many strike-slip faults have bends, where the fault changes its trace across the land surface from one orientation to another. Right-lateral motion on the fault shown here causes compression along the bend, forming ridges and troughs that are the surface expression of folds and thrust faults.

Horizontal displacement surface features, includi agricultural fields, and beds. Over time, offse develop a characteris where they jog para fault, before contin their prefaulting d direction of the j the direction of movement acro

◀ Faults that are currently active can offset streams, ridges, and other topographic features. The San Andreas fault in central California is the linear feature cutting across drainages in the center of this computer-generated view (looking east). The large offset stream takes a jog as it crosses the fault. Is this fault a left-lateral or right-lateral strike-slip fault? Hint: Imagine you are standing in the streambed on the near side of the fault, and then observe which way the streambed on the opposite side has been displaced relative to you.

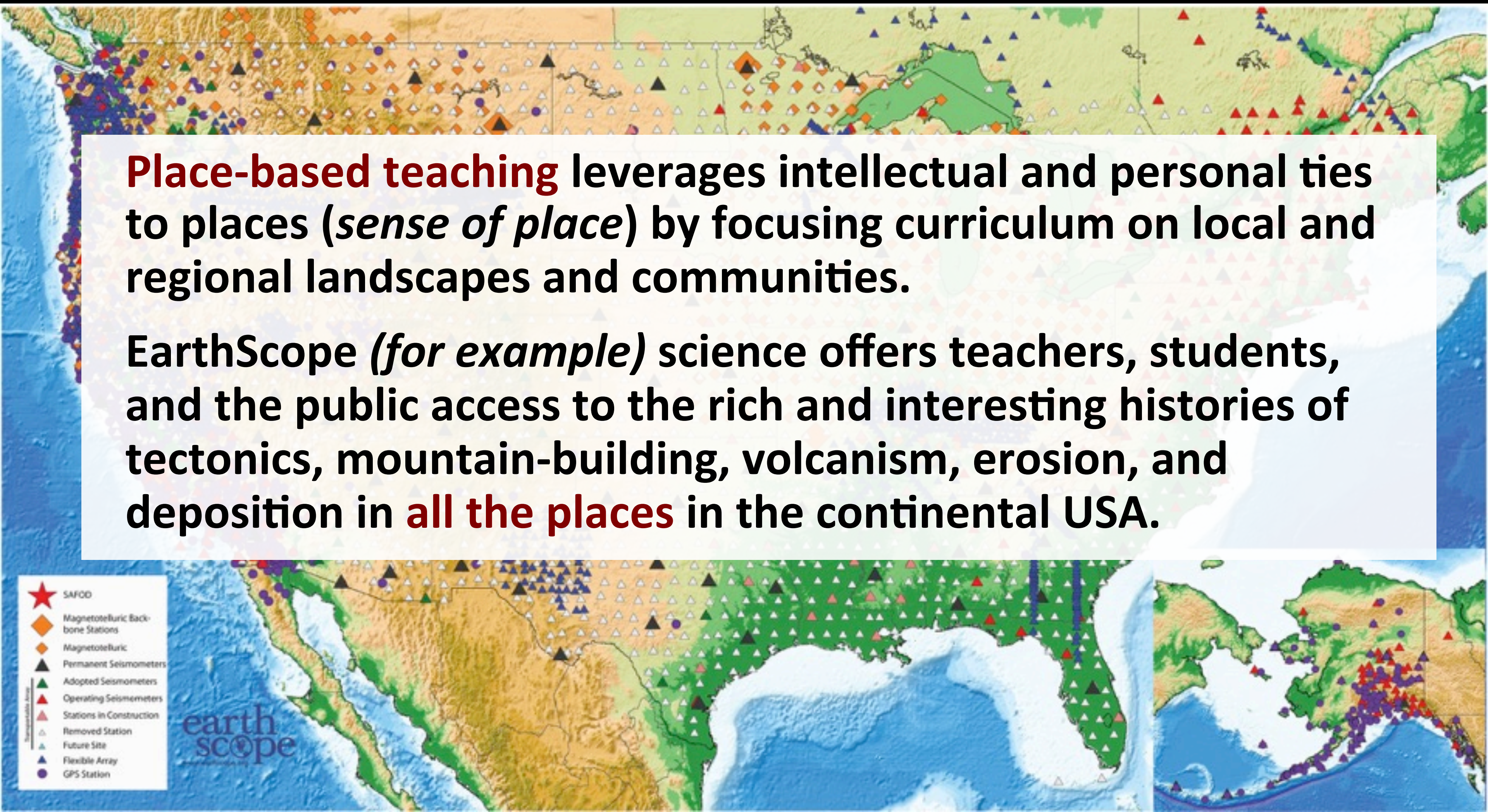
Before You Leave This Be Able To

- Describe or sketch how def and metamorphism occur in continental rifts, rifted cont margins, and mid-ocean rid
- Describe strike-slip faults, s settings where they occur, a features formed on the lan

Fostering and supporting place-based approaches to geoscience education

Place-based teaching leverages intellectual and personal ties to places (*sense of place*) by focusing curriculum on local and regional landscapes and communities.

EarthScope *(for example)* science offers teachers, students, and the public access to the rich and interesting histories of tectonics, mountain-building, volcanism, erosion, and deposition in **all the places** in the continental USA.

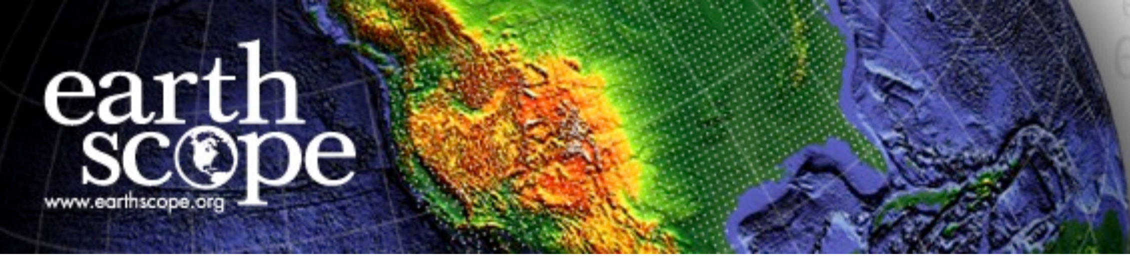


Social Media

- **ES Social media will**
  - Offer high quality science content in a variety of formats that appeal to various age groups
  - Increase public awareness
  - Communicate timely information
  - Engage interactively with the public
  - Provide an informal venue for discussion between scientists and the public
  - Increase brand recognition

Content guidelines

- New ES products/info
- ES in the news
- New products/info from partner organizations
- Science or hazard related events
- Timely or relevant news
- Education related items
- Highlights of ES science, activities, photos



Eos Publication

Building an Effective Social Media Strategy for Science Programs

Social media has emerged as a popular mode of communication, with more than 73% of the teenage and adult population in the United States using it on a regular basis [*Lenhart et al.*, 2010]. Young people in particular (ages 12–29) are deeply involved in the rapidly evolving social media environment and have an expectation of communication through these media. This engagement creates a valuable opportunity for scientific

different ages prefer to interact with different kinds of social media [*Lenhart et al.*, 2010]. To help reach these different age groups, EarthScope's approach has been to ensure a strong presence in a diversity of social media platforms.

In 2011–2012 the EarthScope National Office (ESNO) at Arizona State University created an EarthScope presence on six different social media platforms: Facebook,

Bohon, Wendy; Robinson, Sarah; Arrowsmith, Ramón; Semken, S. (2013). Building an Effective Social Media Strategy for Science Programs. *Eos*, *94*, 237–244.