What geomorphologists want from satellite-based observations about the earth surface and processes:

1) high resolution topography (~1 m cell, <0.1 m vertical)…. Everywhere
2) changes with time (yearly and beyond)
3) event based measurements (flood, landslides,…hazards)
4) auto-detection of features (channels, landslides, trees, shorelines…)
5) high resolution (space and time) rainfall data (km scale in places)
6) detection of properties *beneath* the surface (soil thickness, *fractured bedrock*, soil and rock moisture, ice….)

Satellite-based observations will allow us to detect, quantify and model processes and connect process with form at spatial and temporal scales impossible by other means.

Why high resolution?

Three emerging areas of promise for satellite observations

- Landslide processes
- Surface water topography of rivers and inundated floodplains
- High spatial resolution rainfall intensity

Autodetection

- Channel banks
- Landslide scars
- Road networks

THE BIG WISH

- Mapping the invisible landscape- properties of the critical zone at spatial resolutions of 10s of centimeters to depths of 10s of meters.

Conservation of mass equation

$$\frac{\partial z}{\partial t} = U - E - \nabla \cdot \vec{q}_s$$

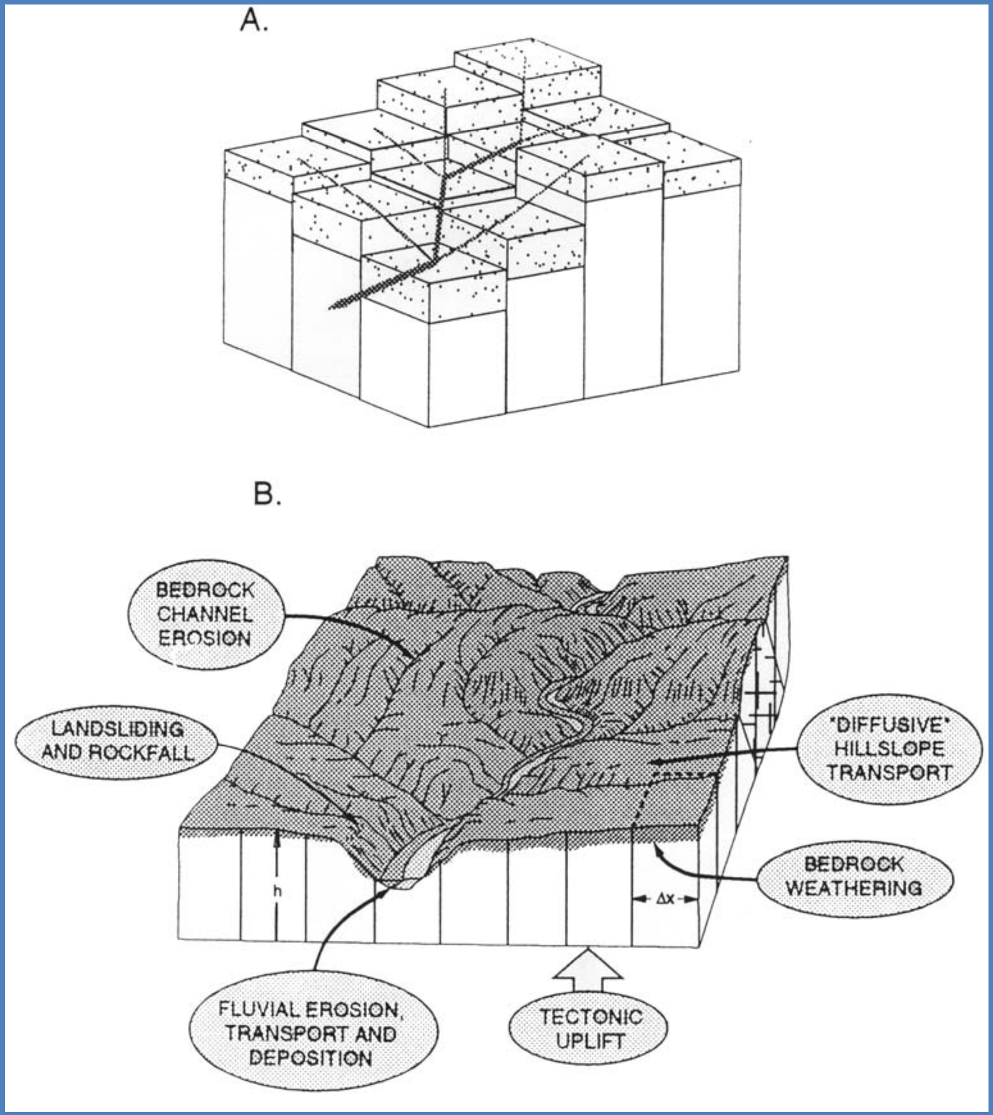
surface elevation change = uplift – bedrock erosion- spatial gradient in sediment transport rate

U = f (?) uplift field (not just vertical component)

$\tilde{q}_s$,E = f (?) Geomorphic Transport Laws

Boundary and initial conditions (history)

All of geomorphology in one equation!



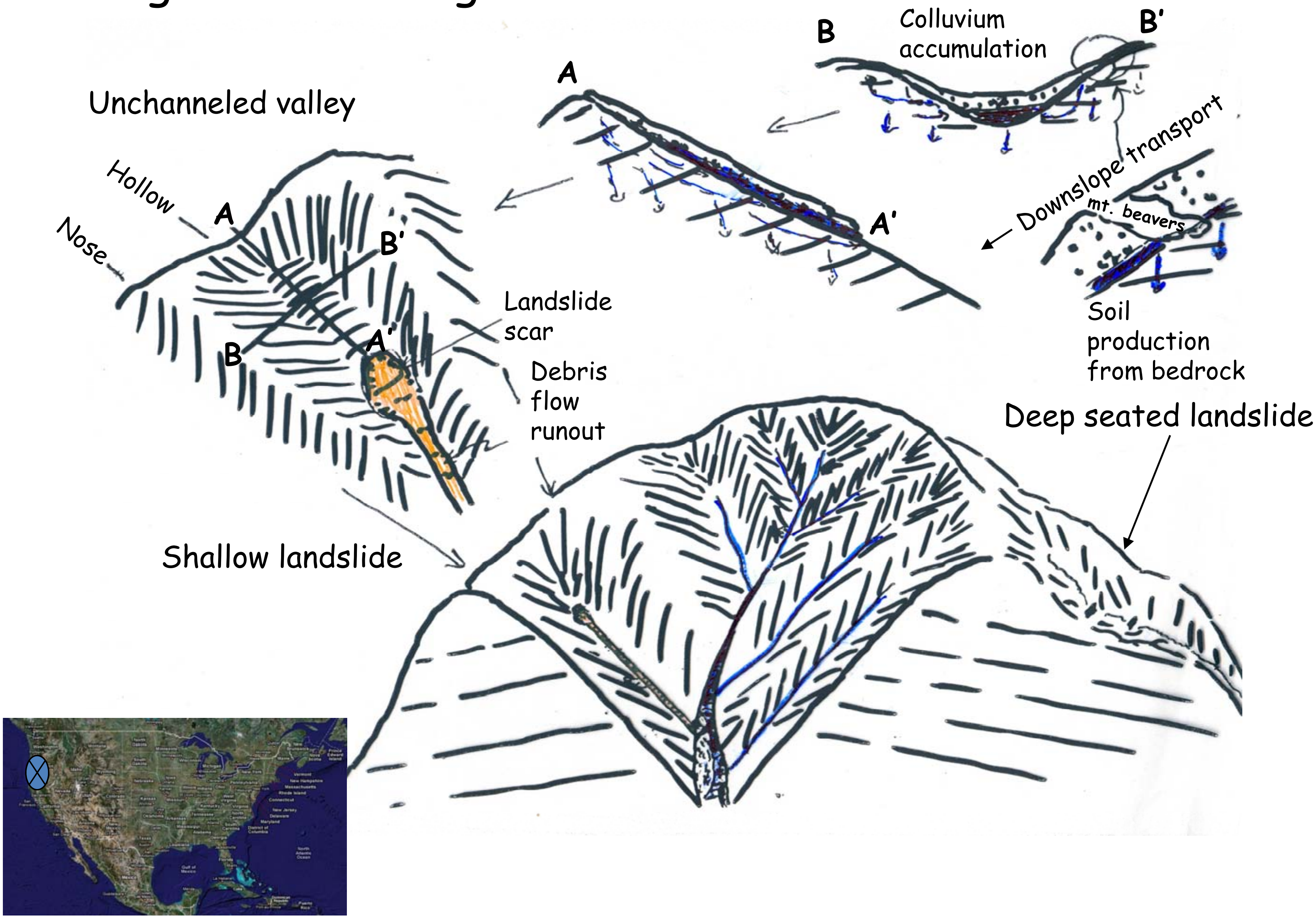
From Tucker and Slingerland, 1994

To solve the mass conservation equation:

$$\frac{\partial z}{\partial t} = U - E - \nabla \cdot \vec{q}_s$$

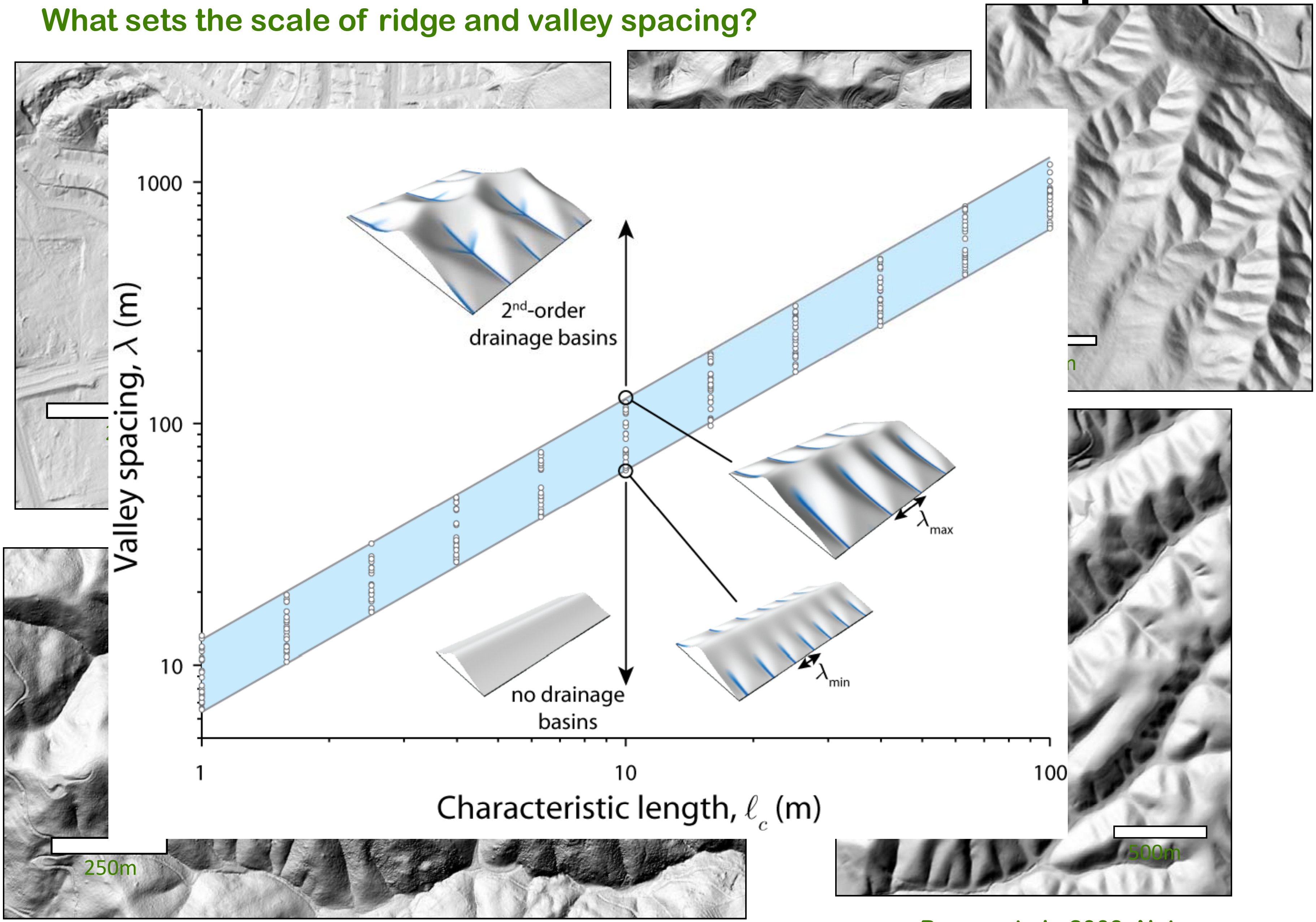
List the distinct processes that control mass flux and seek theory, field observations and experiments to identify geomorphic transport laws

An Example: processes shaping the Oregon Coast Range



Characteristic Scales of Landscapes

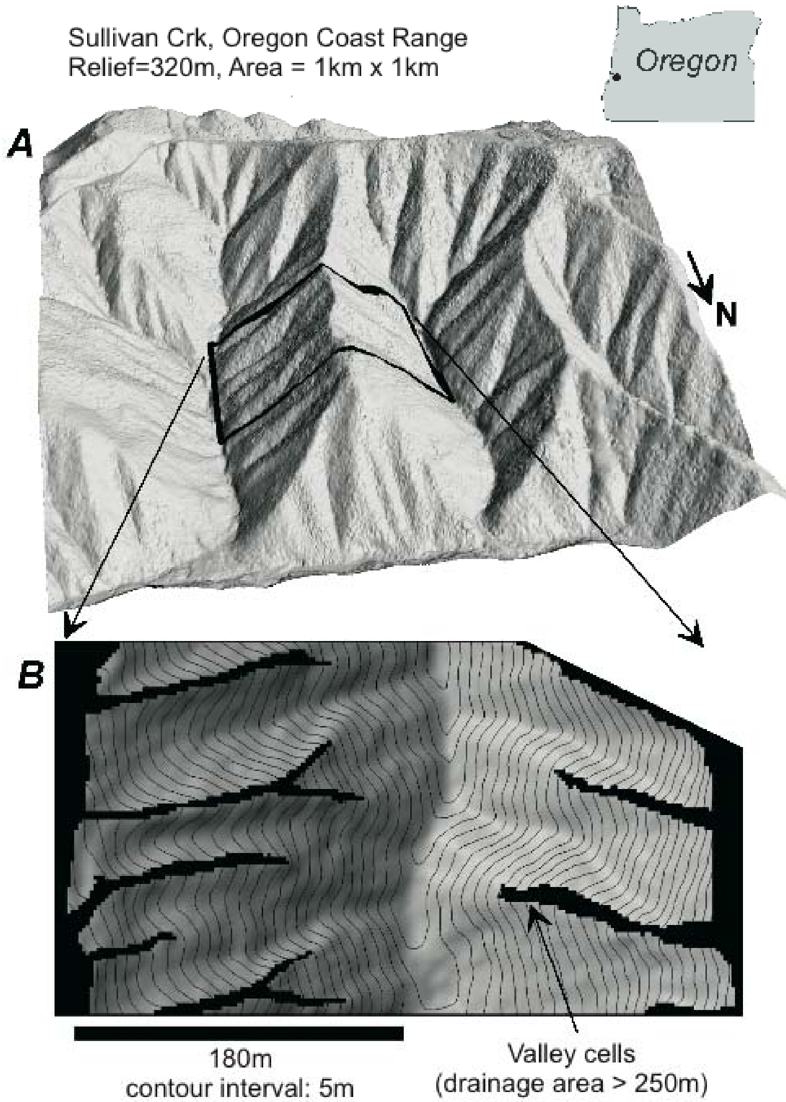
What sets the scale of ridge and valley spacing?

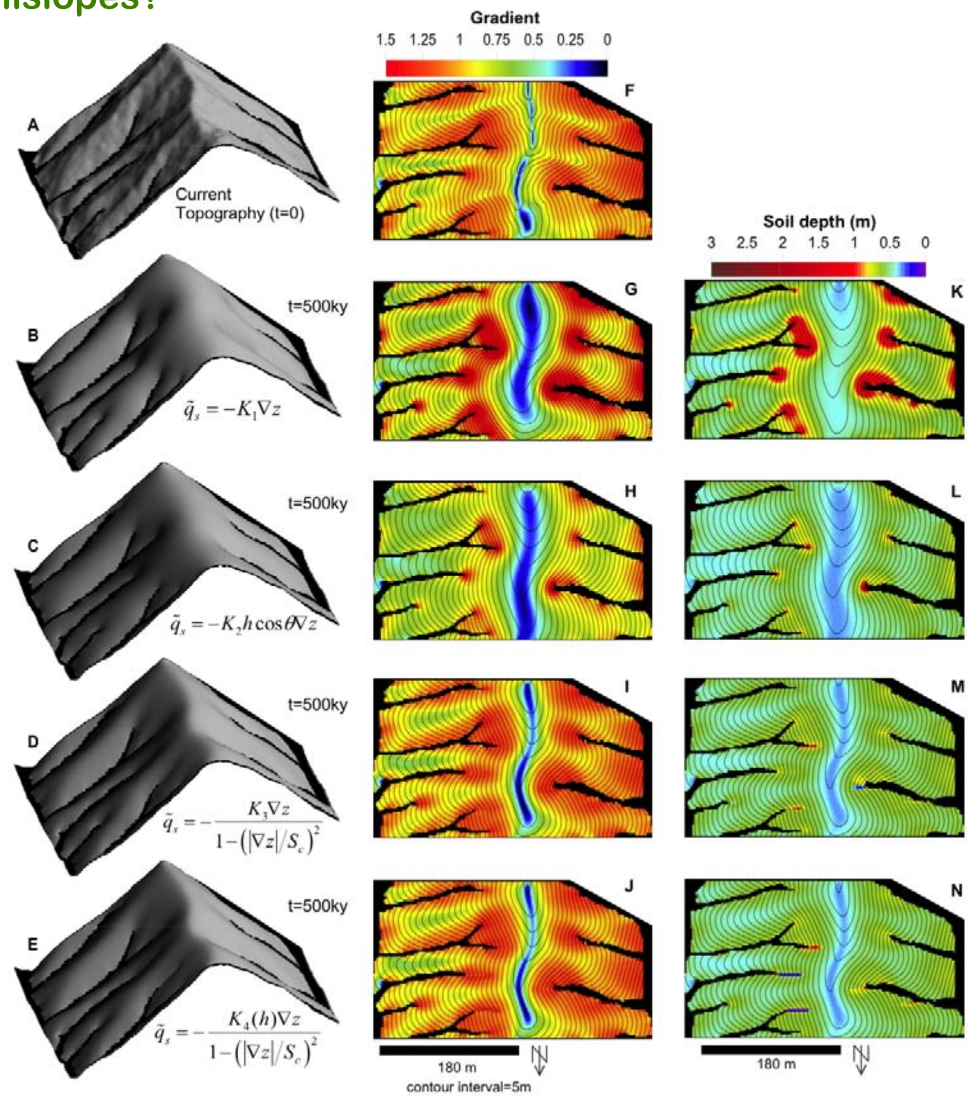


Perron et al., 2009, Nature

Understanding landscape change over 10s-100s of kyr using ALSM data

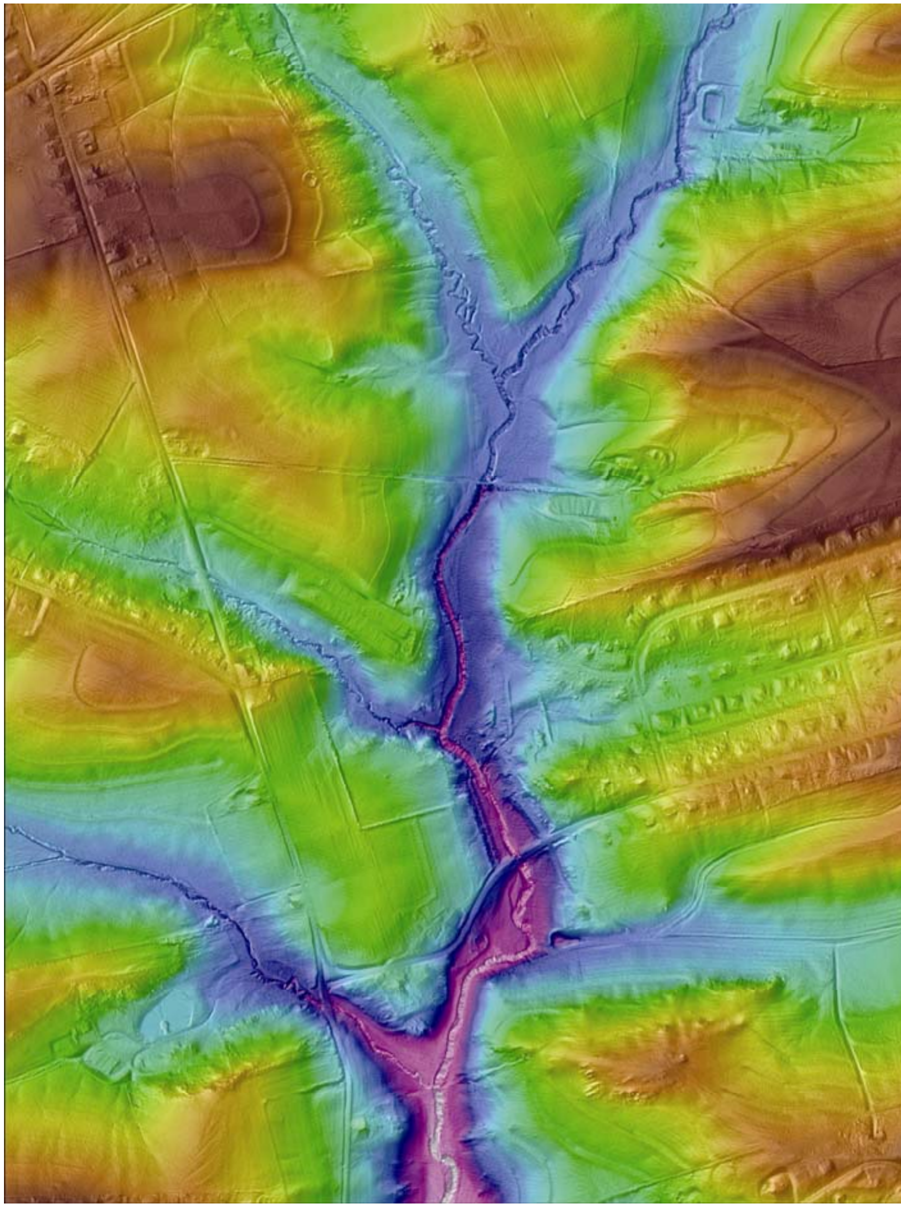
What controls rates of mass transport across hillslopes?

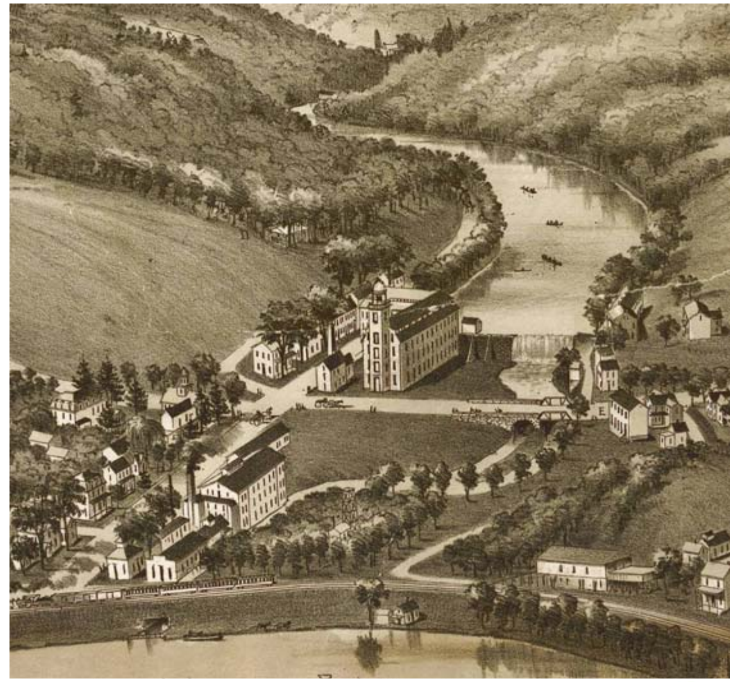




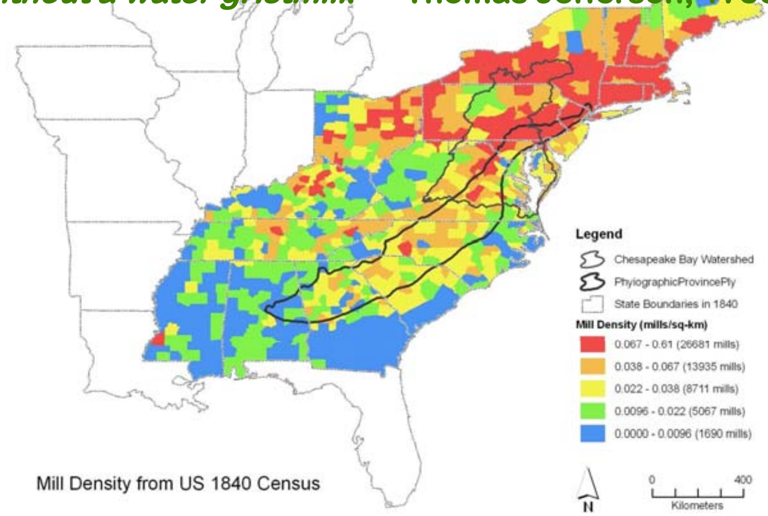
Roering , 2008, GSA Bulletin

Natural Streams and the Legacy of Water-Powered Mills





"There is no neighborhood in any part of the United States without a water gristmill." **- Thomas Jefferson, 1786**

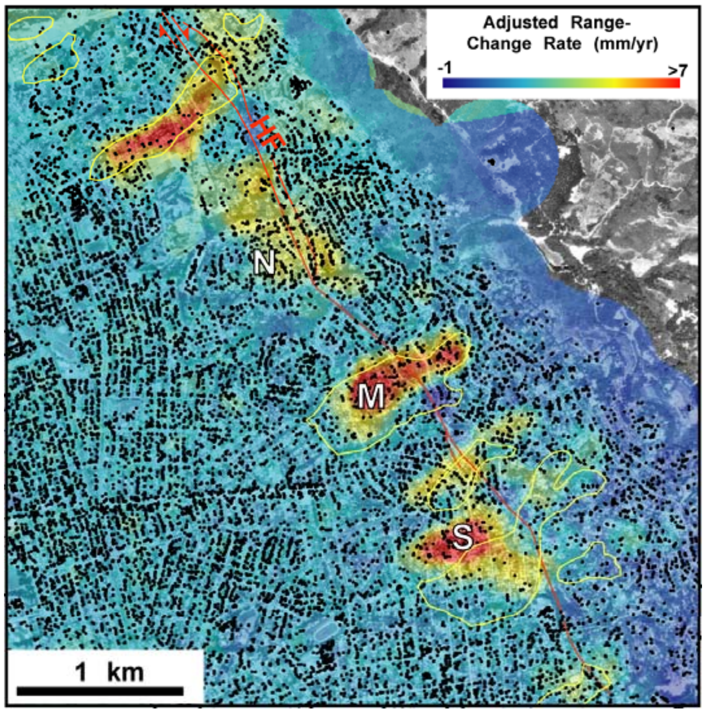


Mill Density from US 1840 Census

Walter and Merritts, 2008, Science

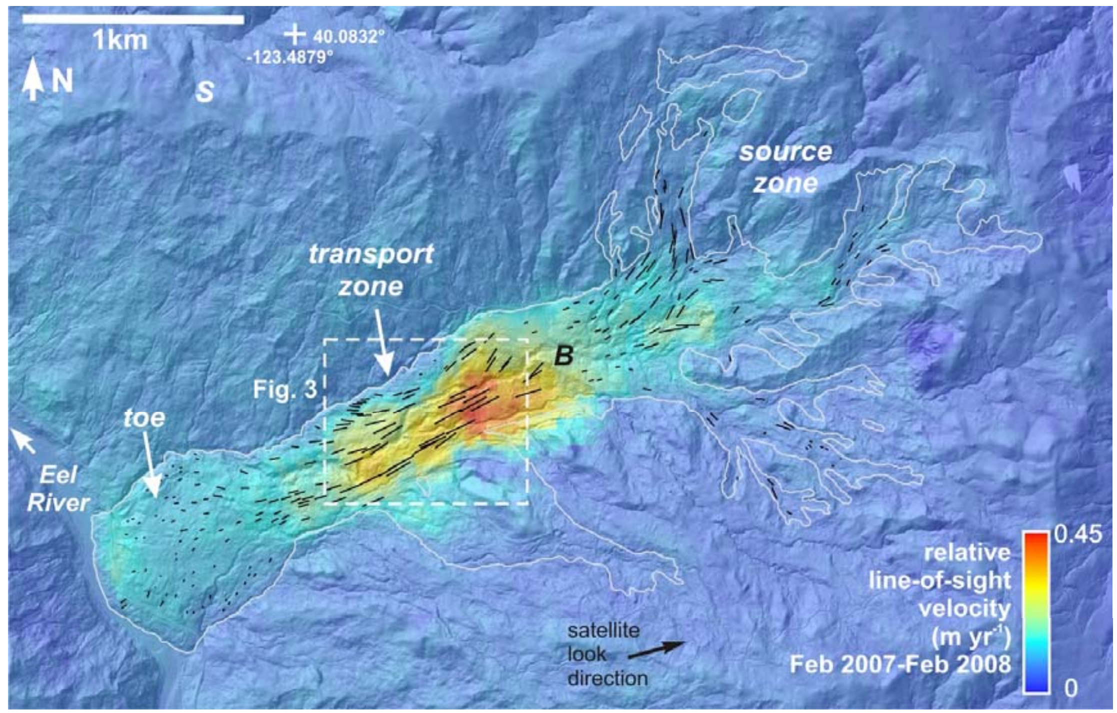
Locating and Quantifying Rates of Motion of Active Landslides Using InSAR and ALSM Data

- **Quantifying Rates of Motion of Active Landslides (InSAR + ALSM)**

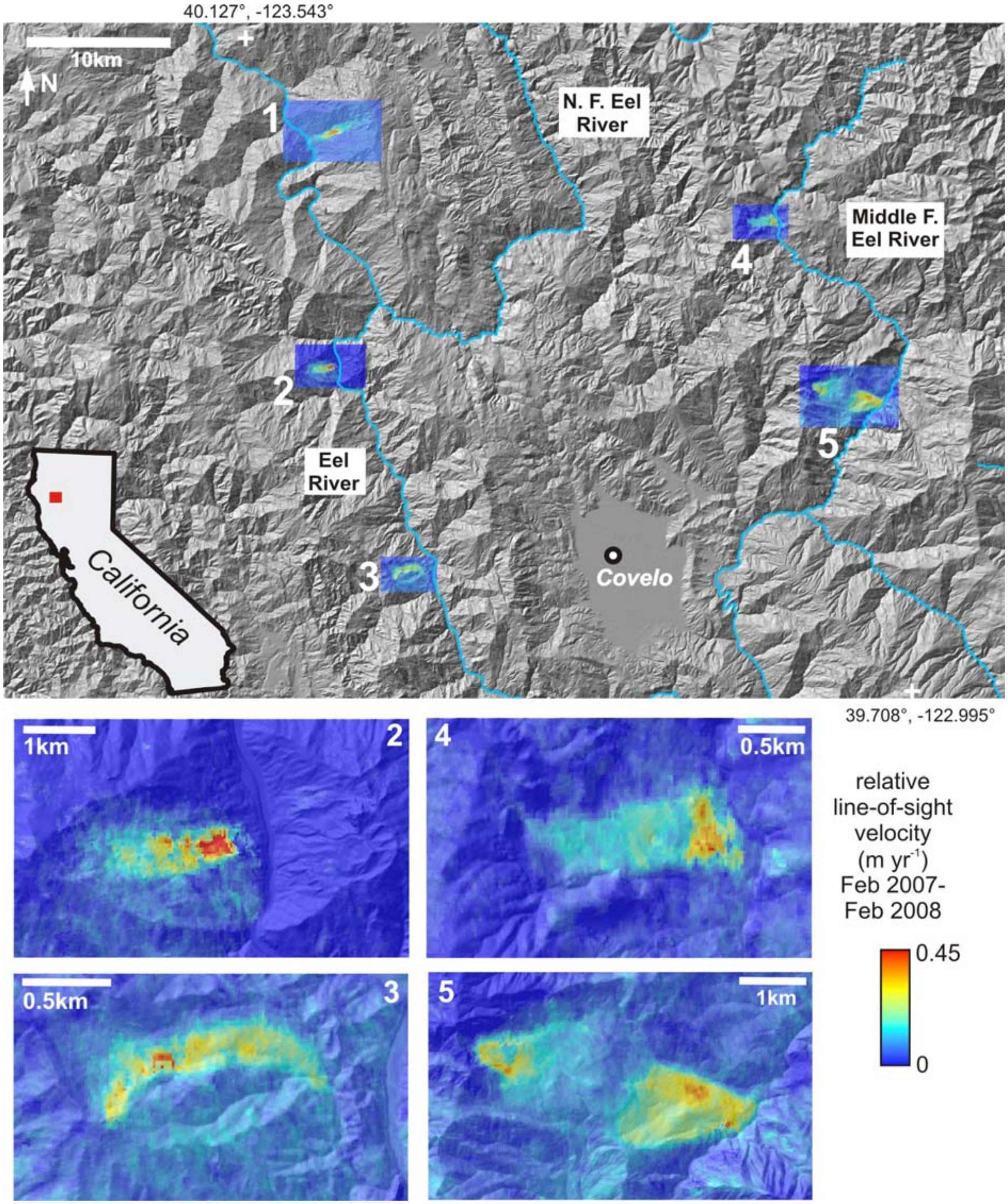


Hilley et al. , 2004, Science

=



Roering et al., 2009, GRL



See Ben MacKey

Figure 1. Shaded relief map of the central portion of the Eel River catchment, northern California. Color overlays show large (>1 km), slow-moving landslides identified using 17 stacked ALOS DInSAR interferograms collected from February 2007 to February 2008.

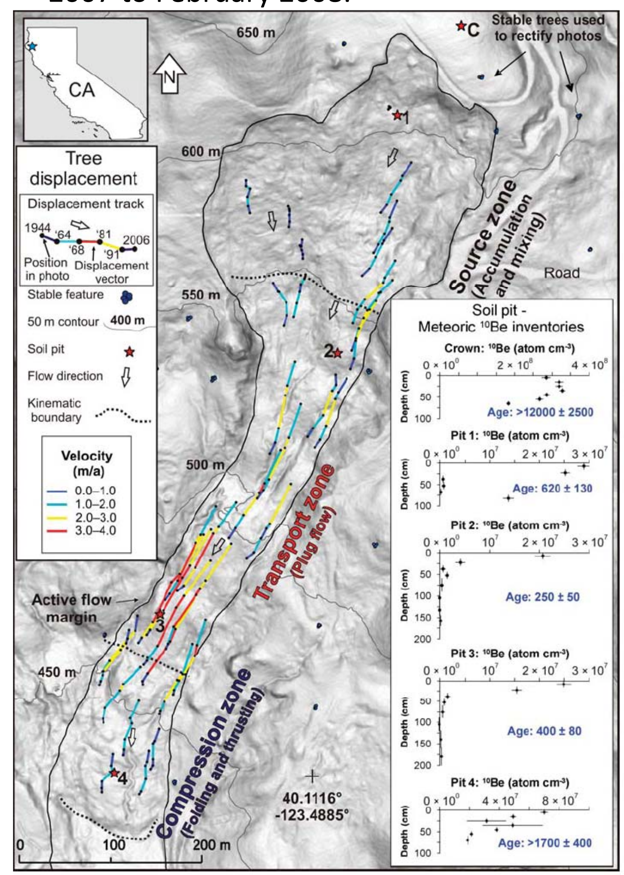
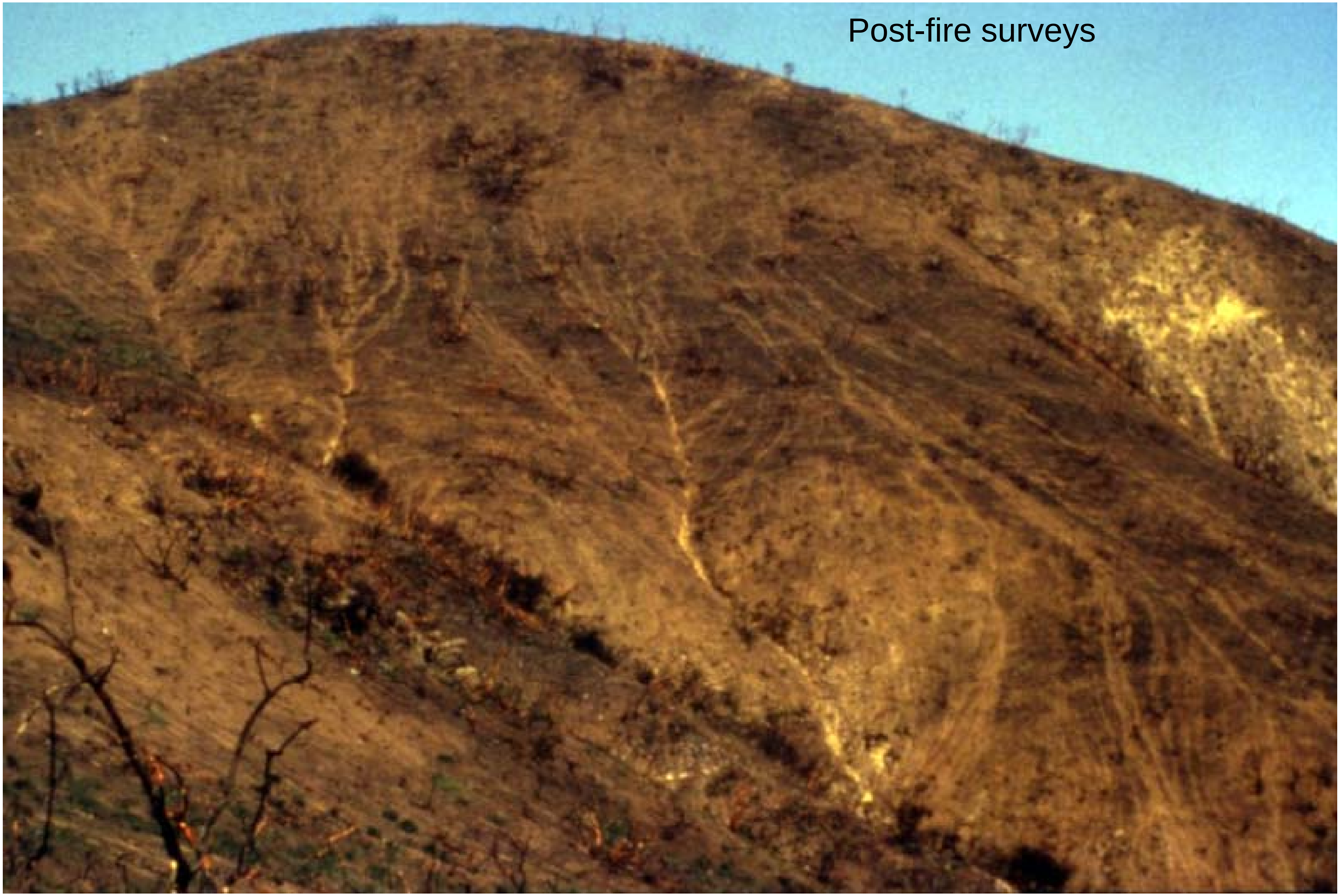
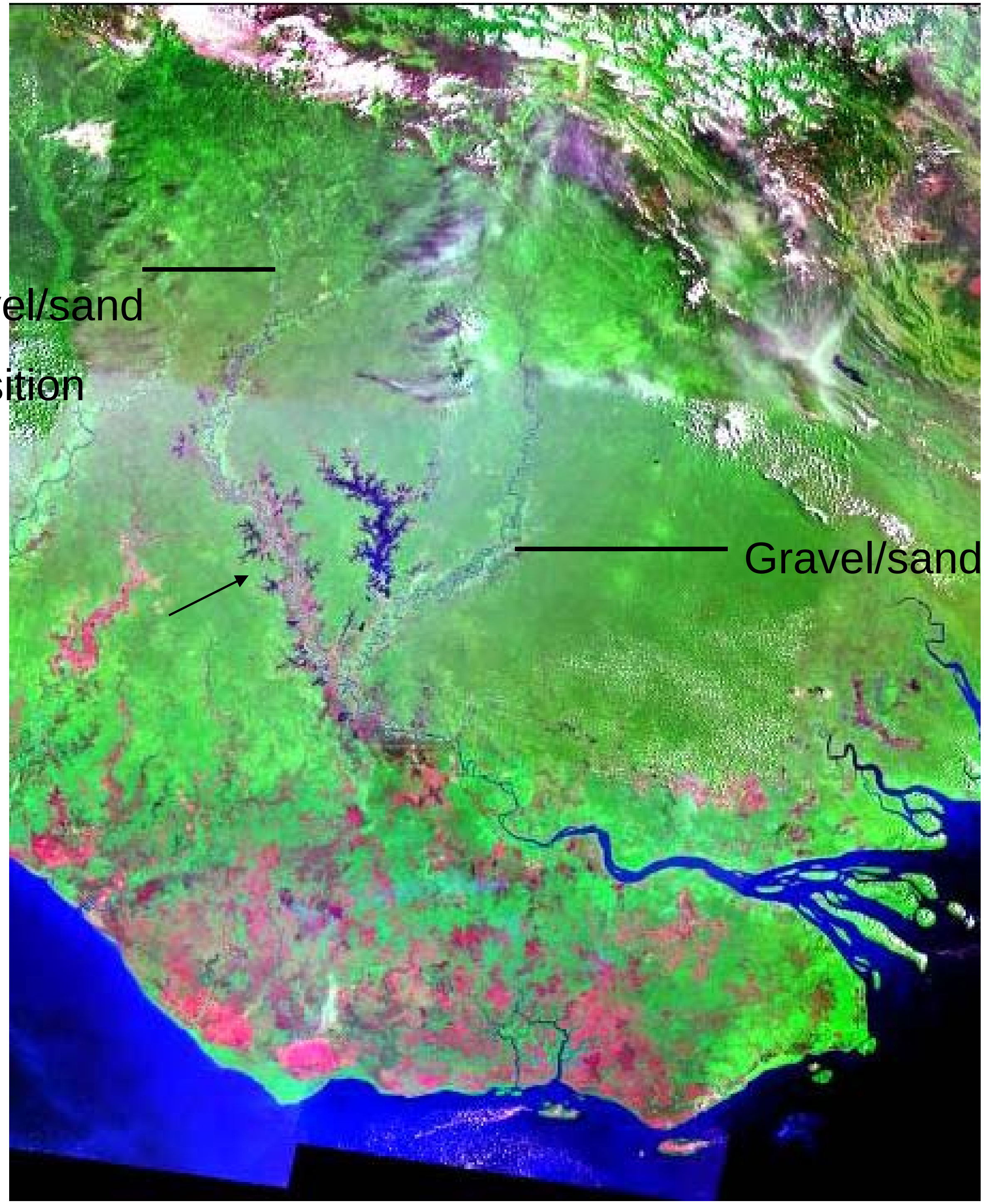


Figure 1. Colored lines show trajectories of trees growing on earthflow from 1944 to 2006,

Post storm surveys


Post-fire surveys

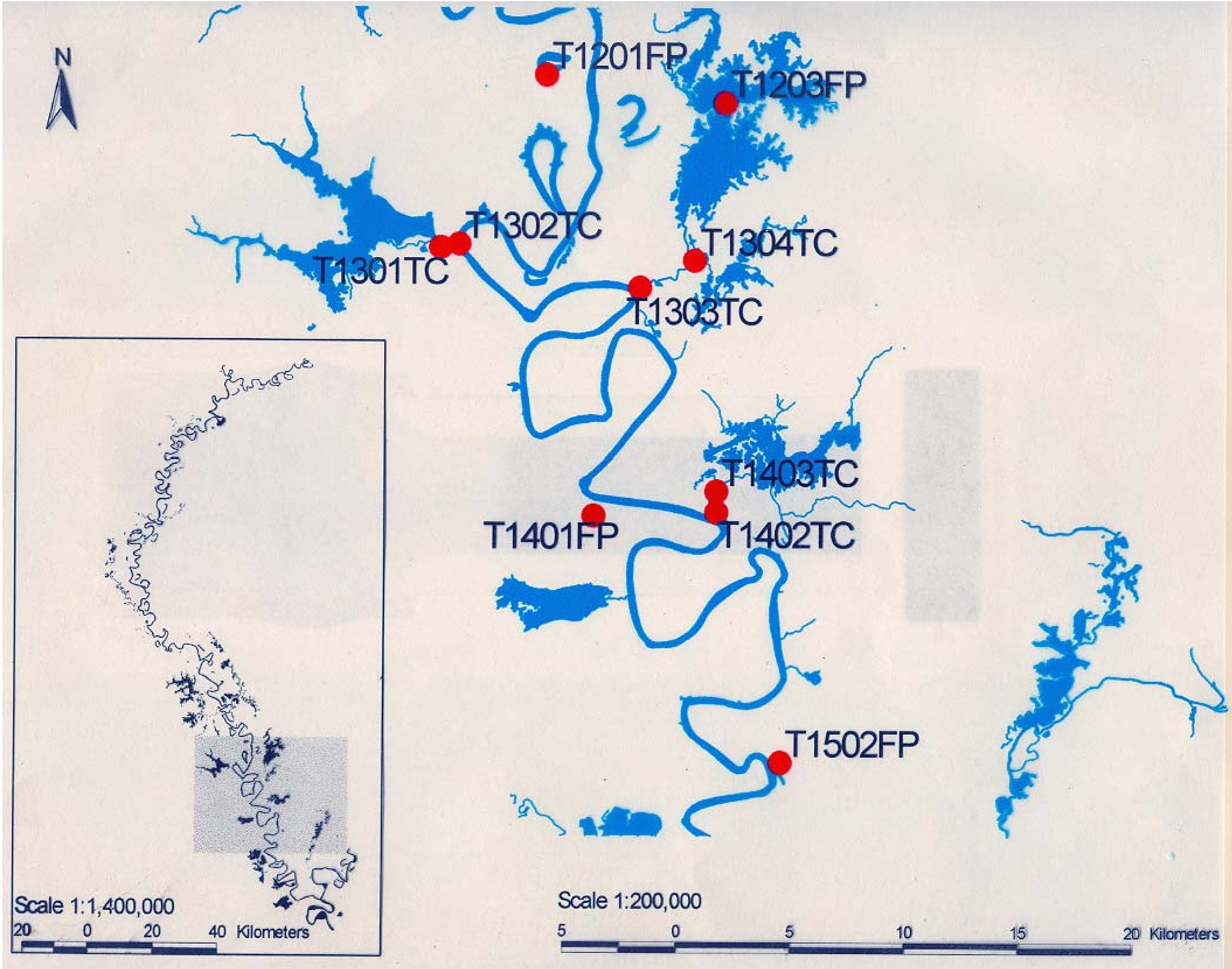
Mapping water surface elevation, water depth, and estimating discharge of rivers



Rising stage on Fly without rain on the floodplain

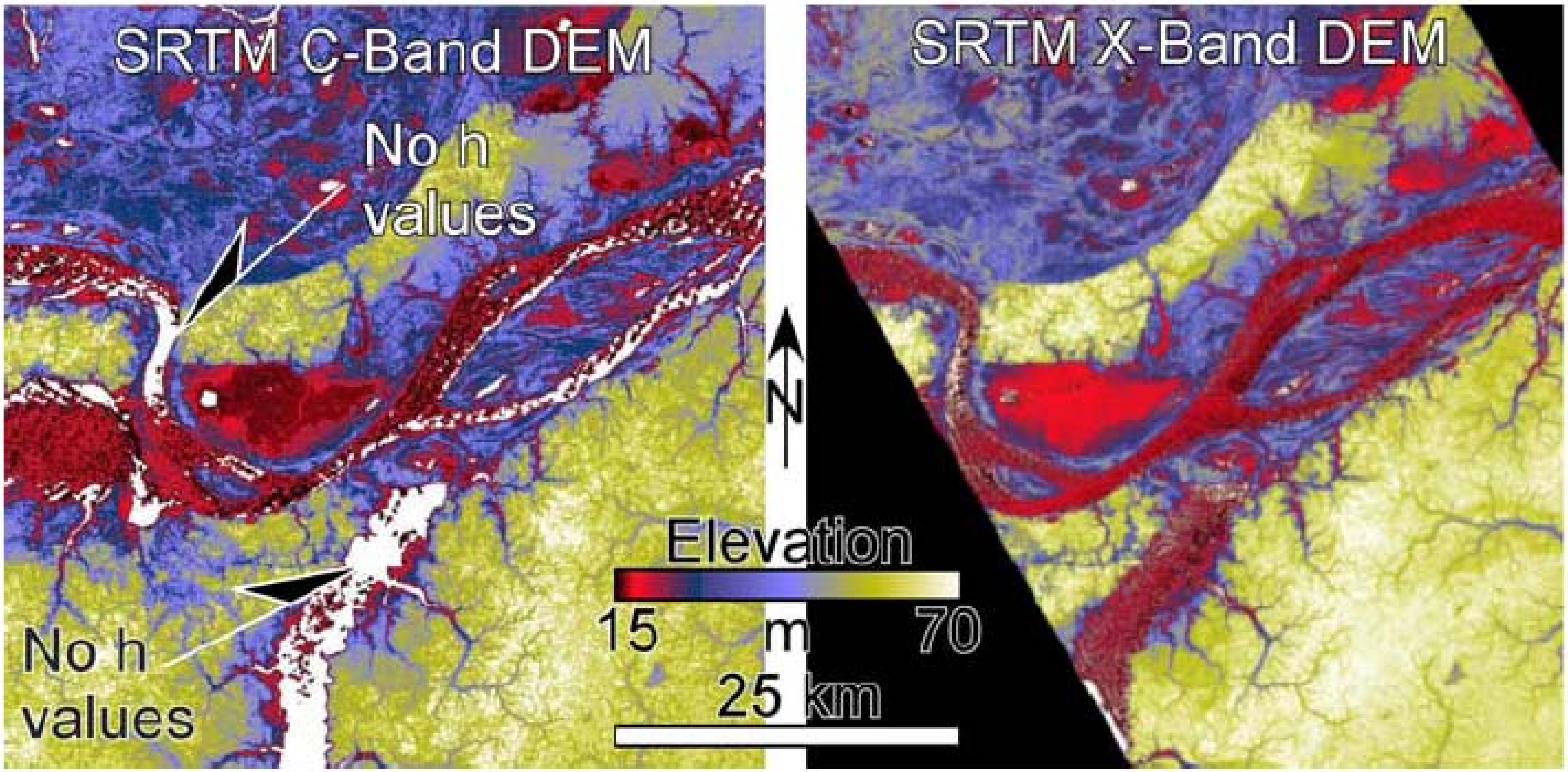
Fly River high flow prevented from crossing the floodplain because it is already flooded due to rain on the floodplain

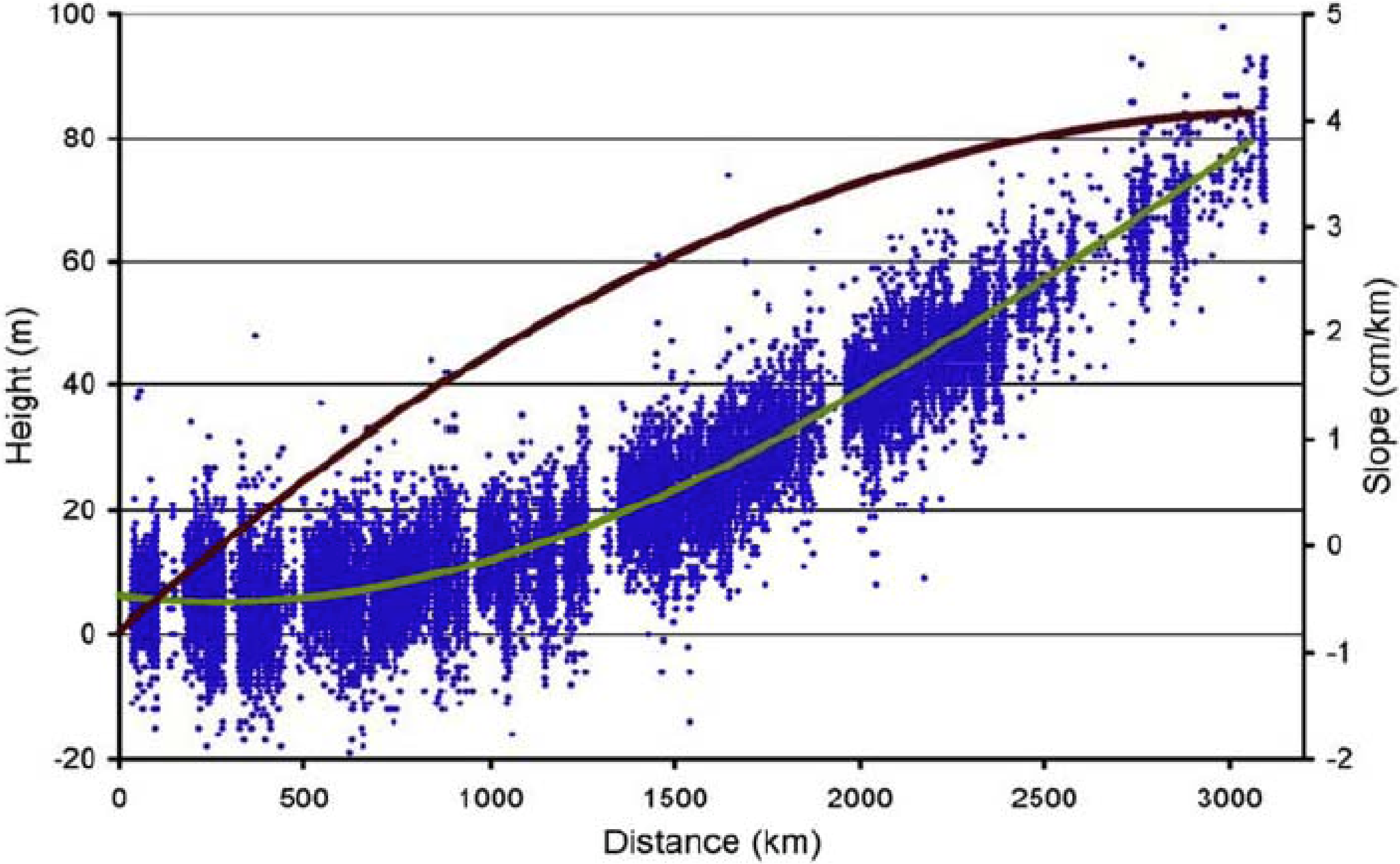
Day et al., 2008, JGR



Geoff Day monitored water level recorders on tie channels and the Fly

Alsdorf et al. 2007, Rev Geophysics





Alsdorf, et al. 2007

Reviews of Geophysics, 2007

Proposed NASA Surface Water Ocean Topography (SWOT)

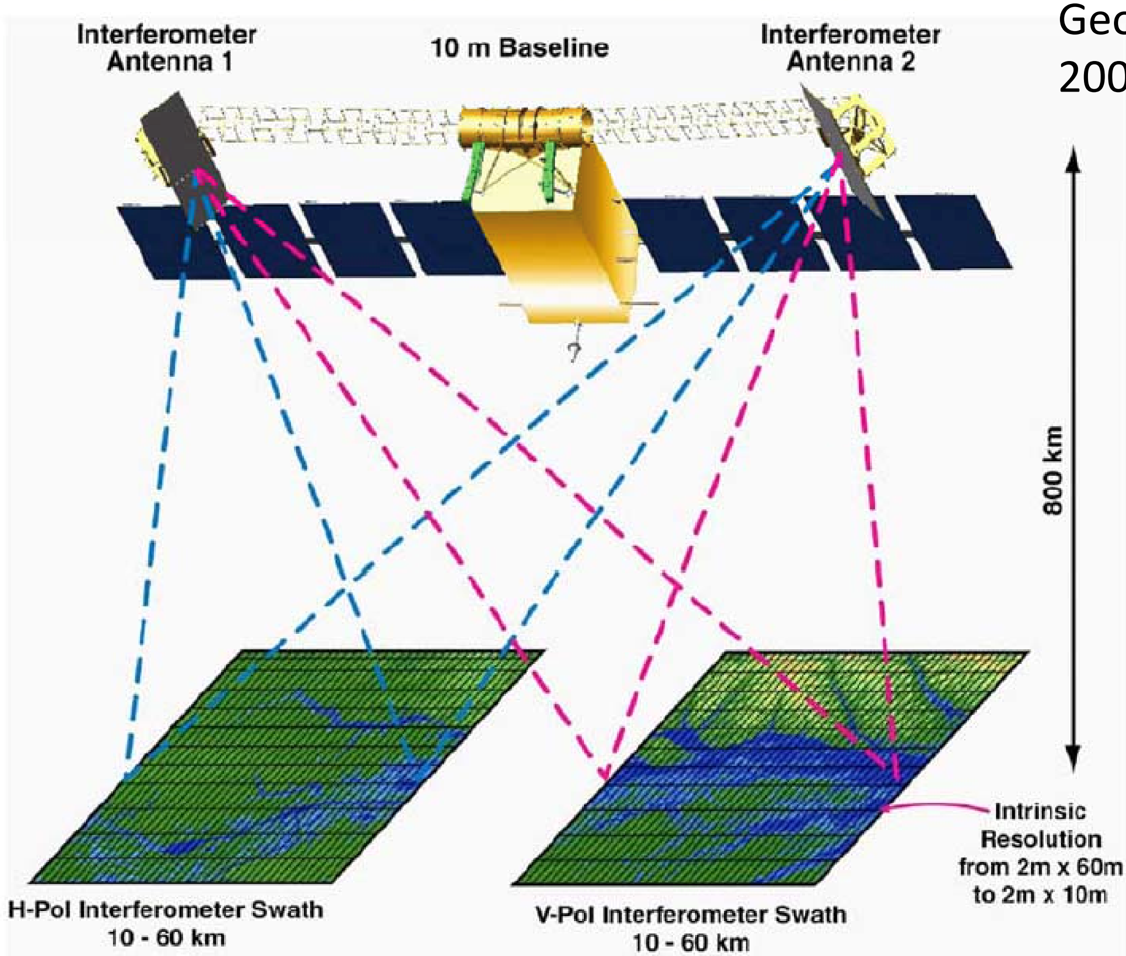
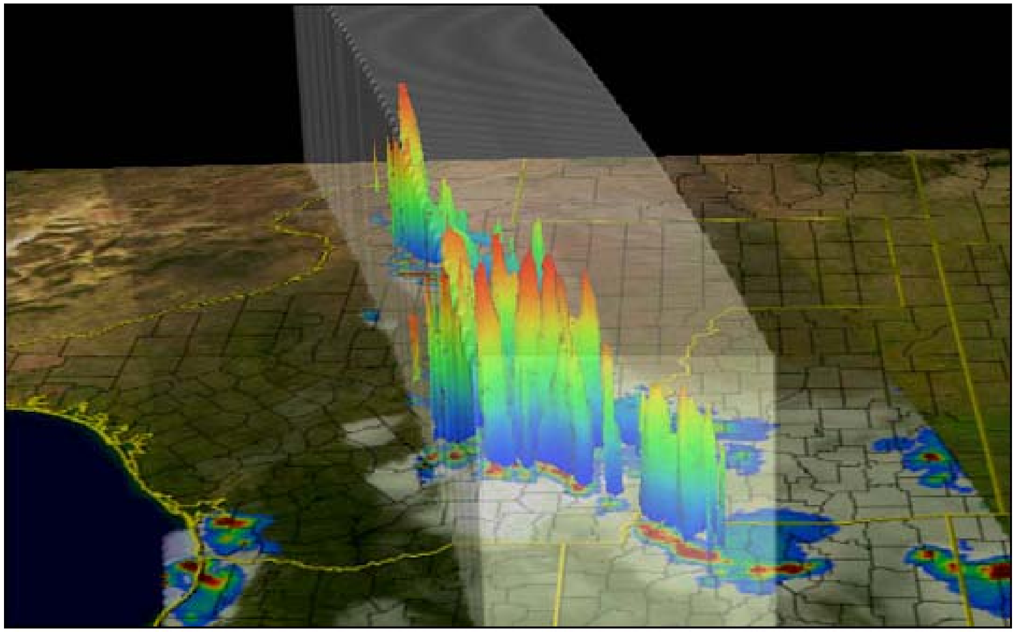


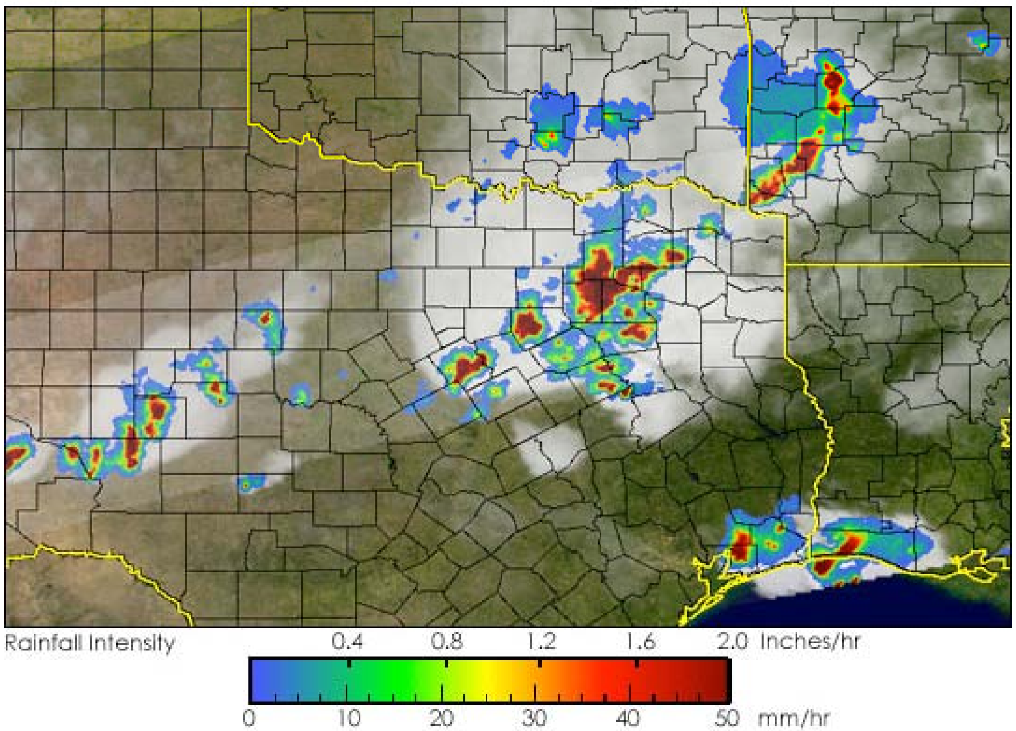
Figure 15. Conceptual view of KaRIN, the Ka Band Radar Interferometer, an interferometric altimeter. Maximum incidence angle is 4.3°; thus the instrument operates very near nadir where water surfaces yield strong radar returns. At Ka band the interferometer will penetrate clouds and relies on subtle canopy openings to penetrate to any underlying water surfaces (openings of only 20% are sufficient). Spatial sampling resolutions are noted in Figure 15. Height accuracies will be ±50 cm for individual "pixels"; thus centimetric accuracies are achieved through polynomial averaging methods.

Finer resolution than GRACE mission

River bathymetry ?



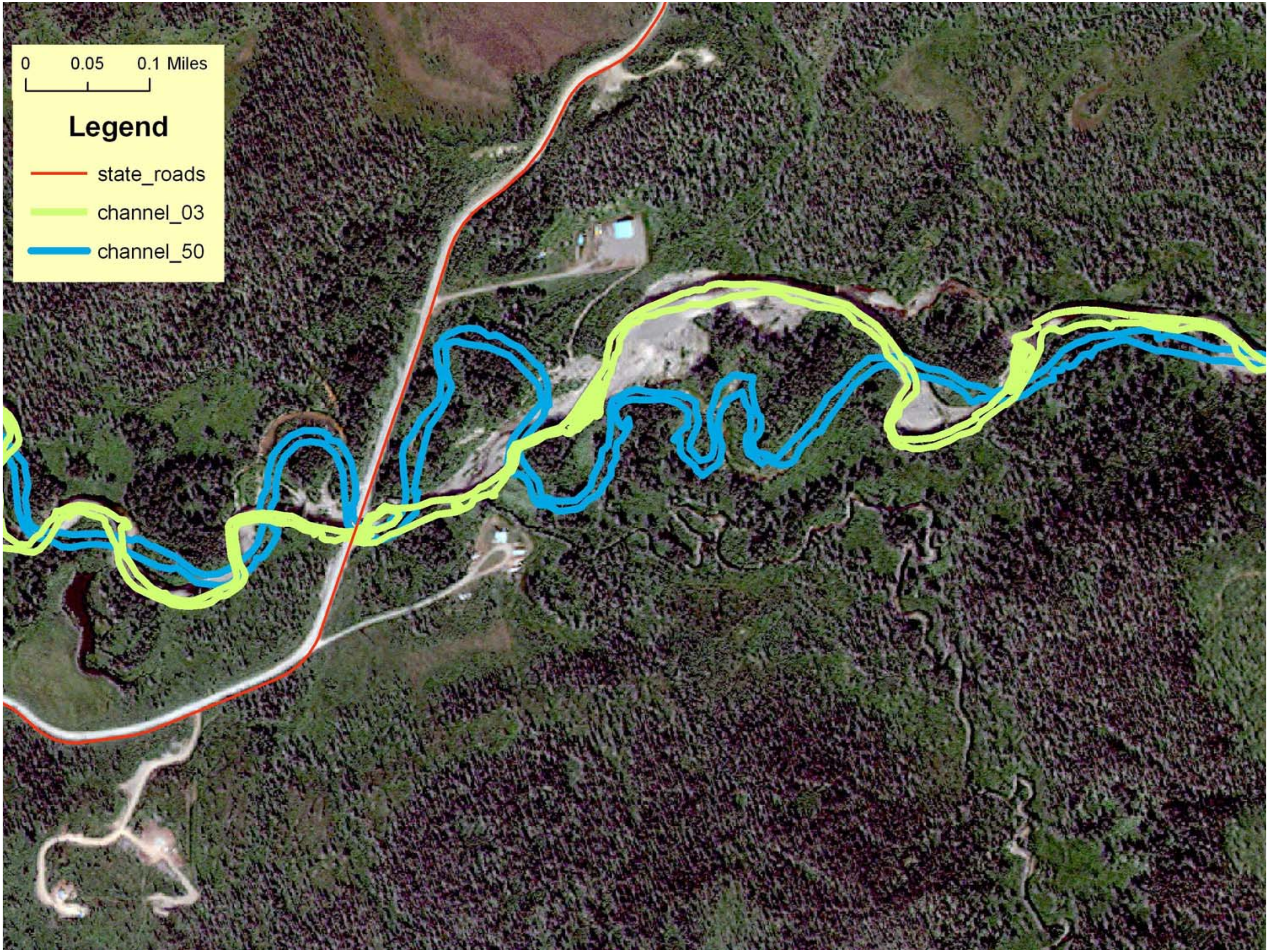
Rain Height

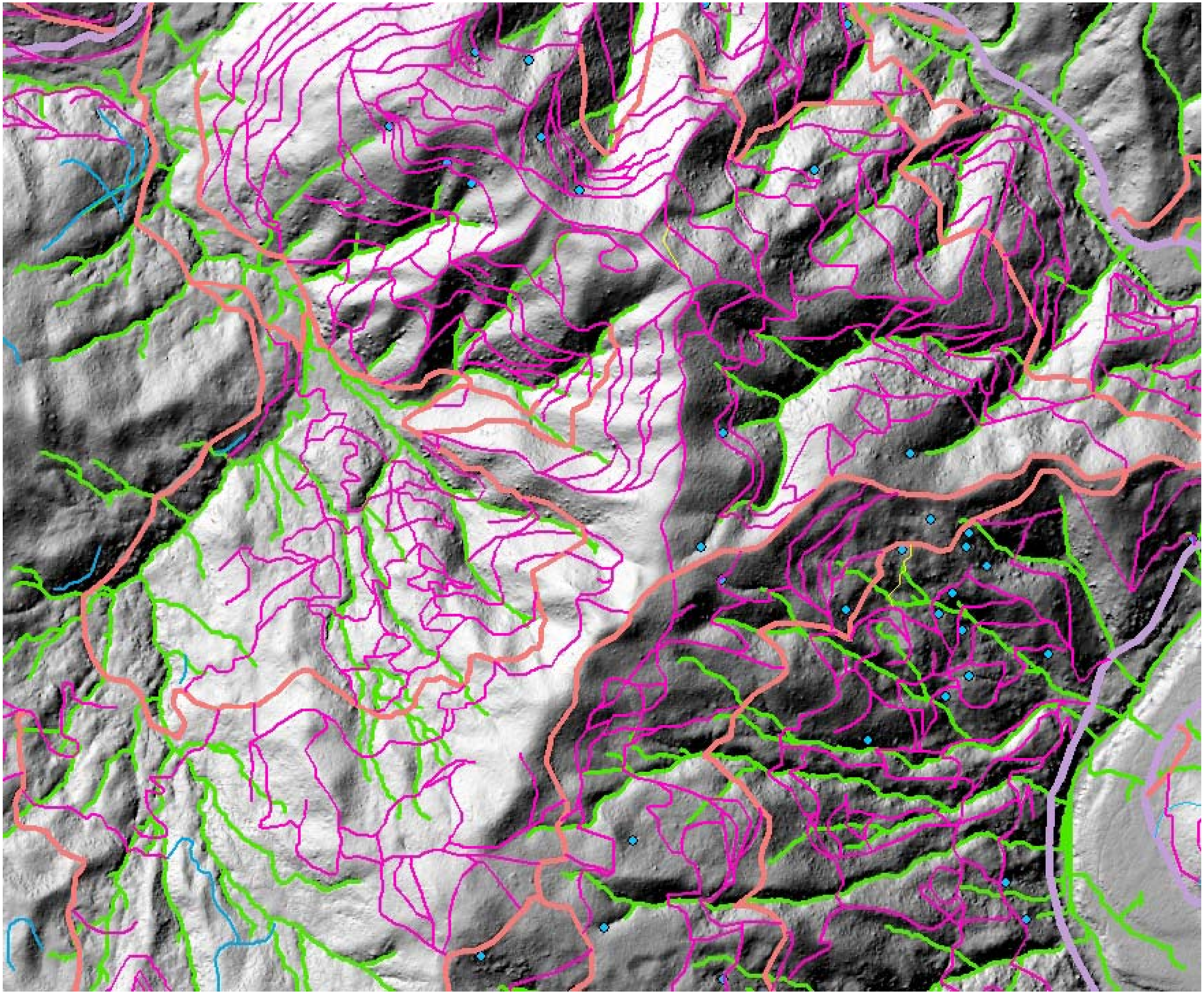


The geomorph community is just learning how to exploit rainfall intensity data.

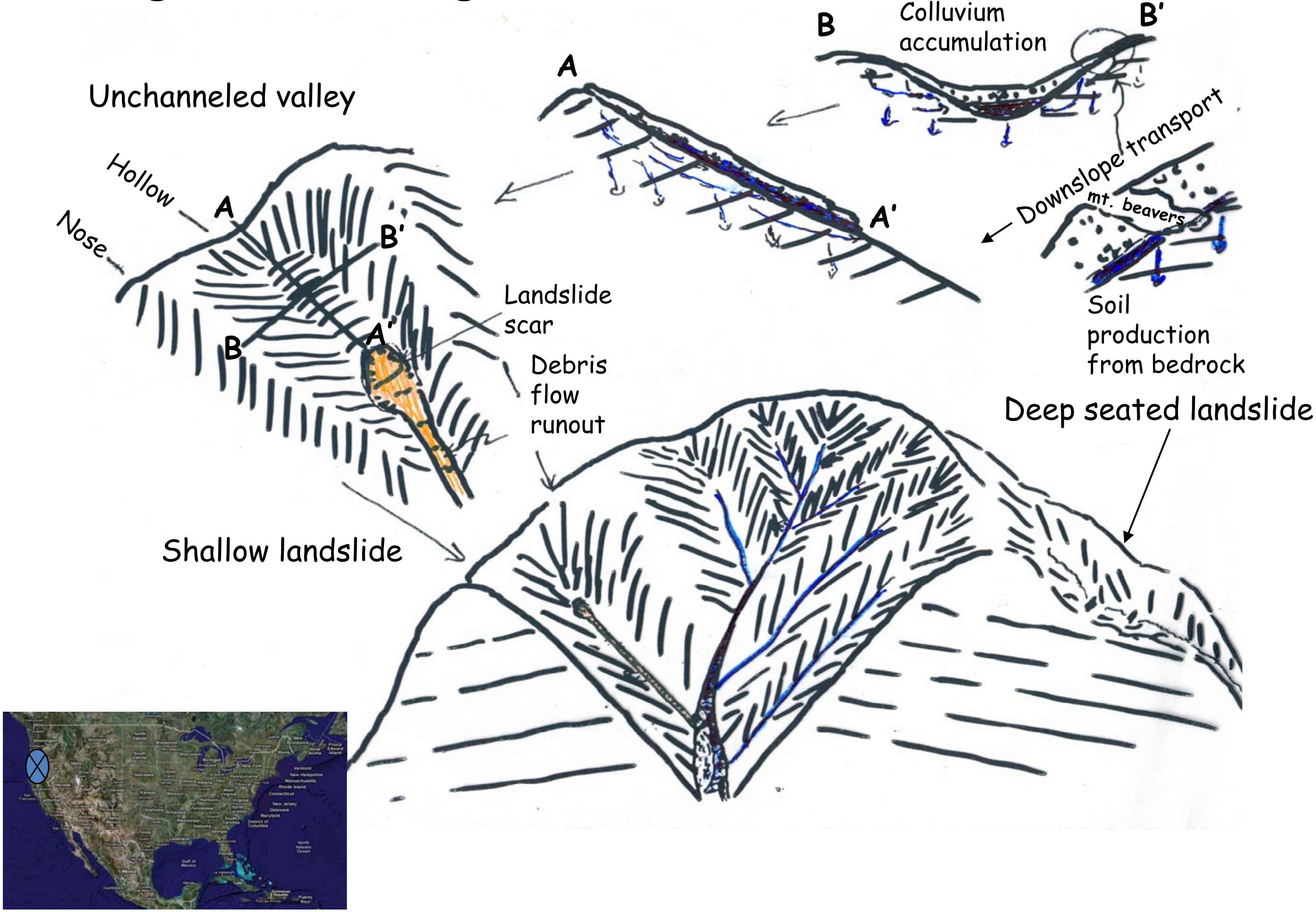
Rainfall intensity from TRMM data over Texas

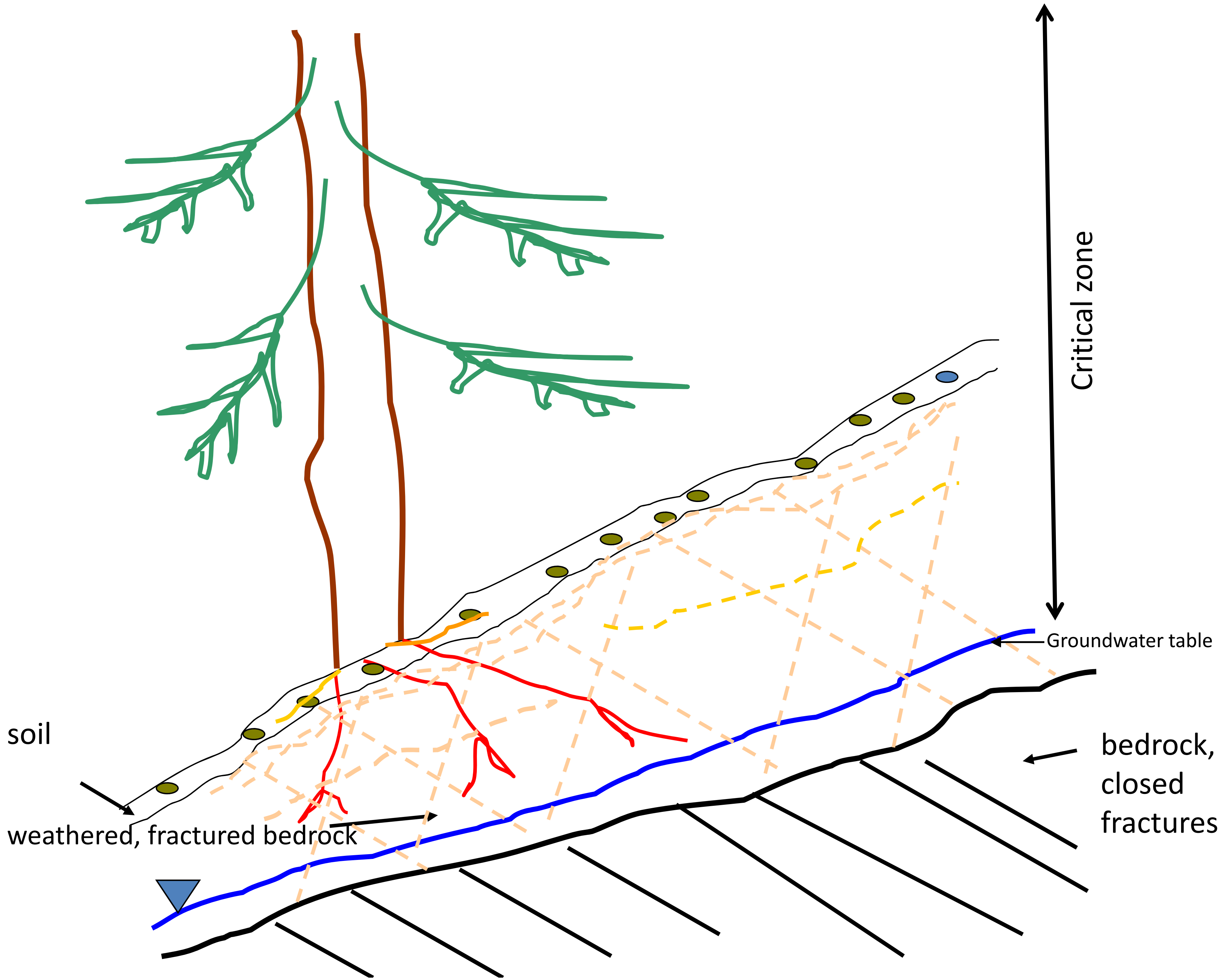
earthobservatory.nasa.gov/IOTD/view.php?id=445

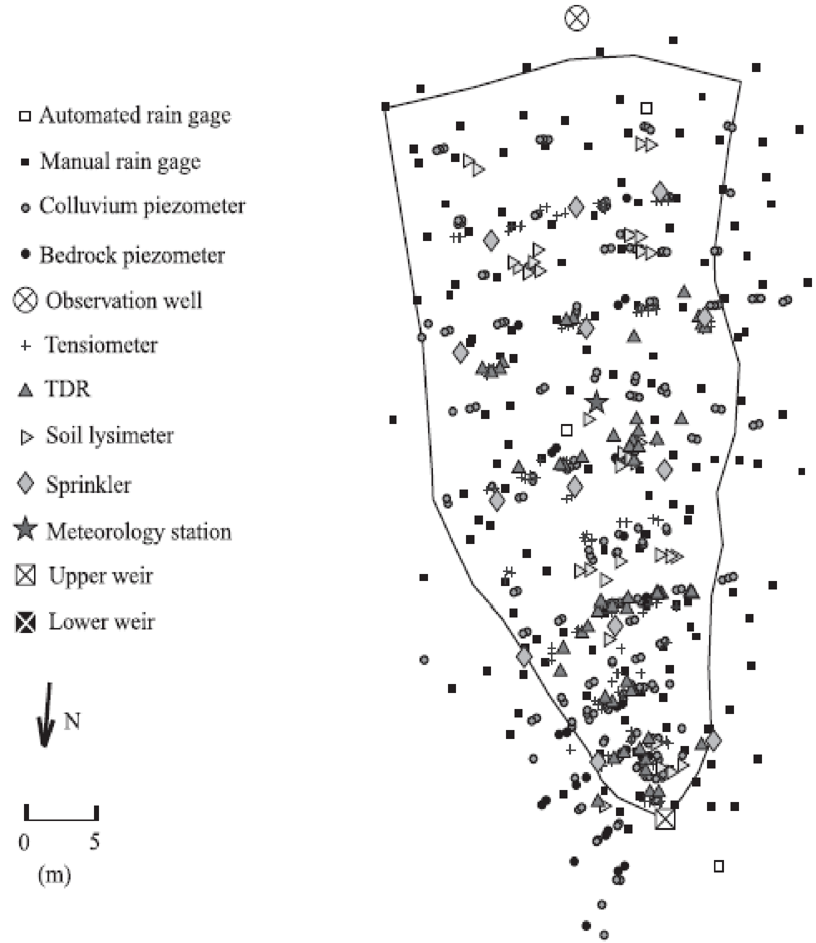

0 0.05 0.1 Miles
Legend
state_roads
channel_03
channel_50



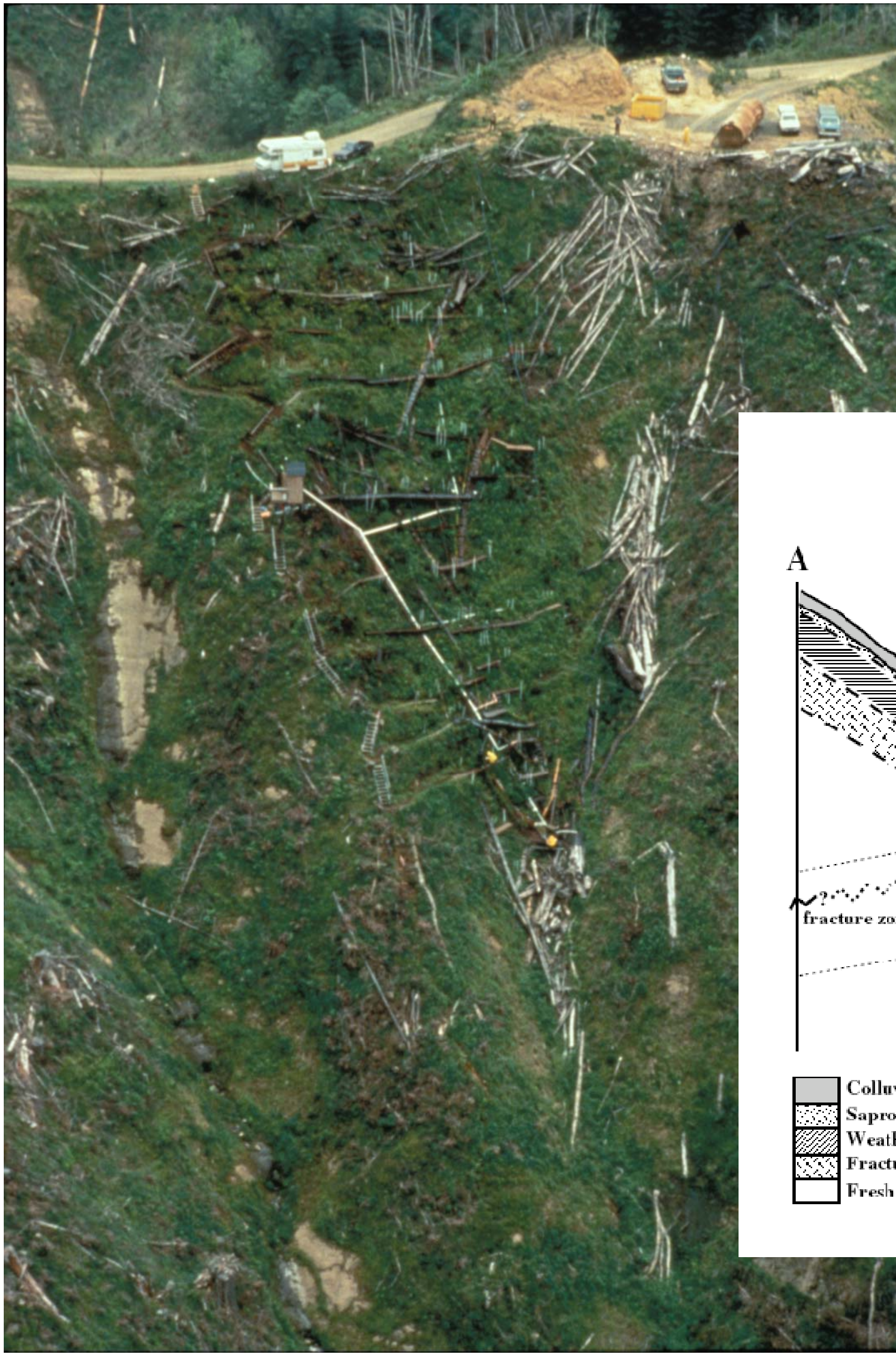
An Example: processes shaping the Oregon Coast Range

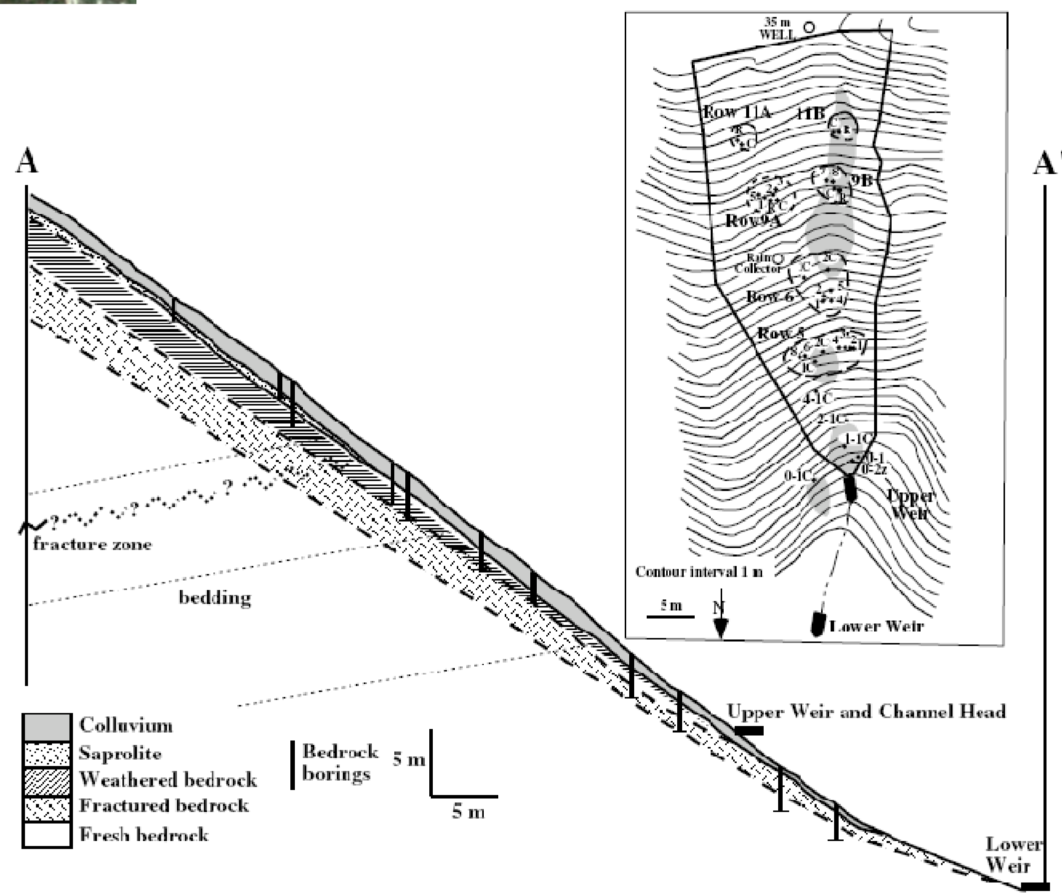



Critical zone
Groundwater table
soil
weathered, fractured bedrock
bedrock,
closed
fractures



Ebel, et al., Am J. Sci, 2007





A
A'
fracture zone
bedding
Upper Weir and Channel Head
Lower Weir
Colluvium
Saprolite
Weathered bedrock
Fractured bedrock
Fresh bedrock
Bedrock borings
5 m
5 m
35 m WELL
Row 11A
11B
9B
Row9A
Rain Collector
Row 6
Row 4
Upper Weir
Contour interval 1 m
5 m
N
Lower Weir

Regolith mass balance in a gneissic watershed, South India

raun et al., 2009,
ieochem cosmo
cta

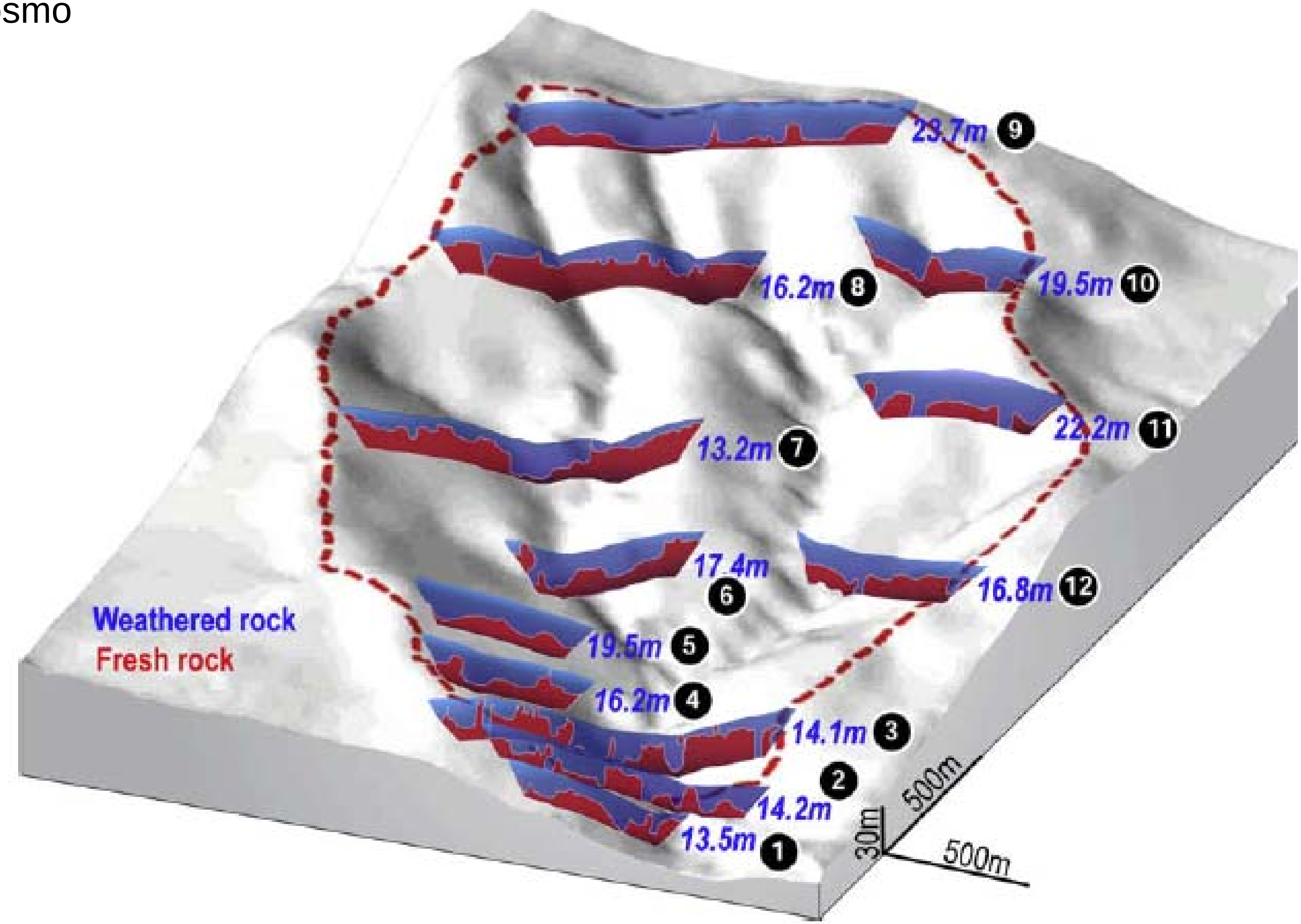
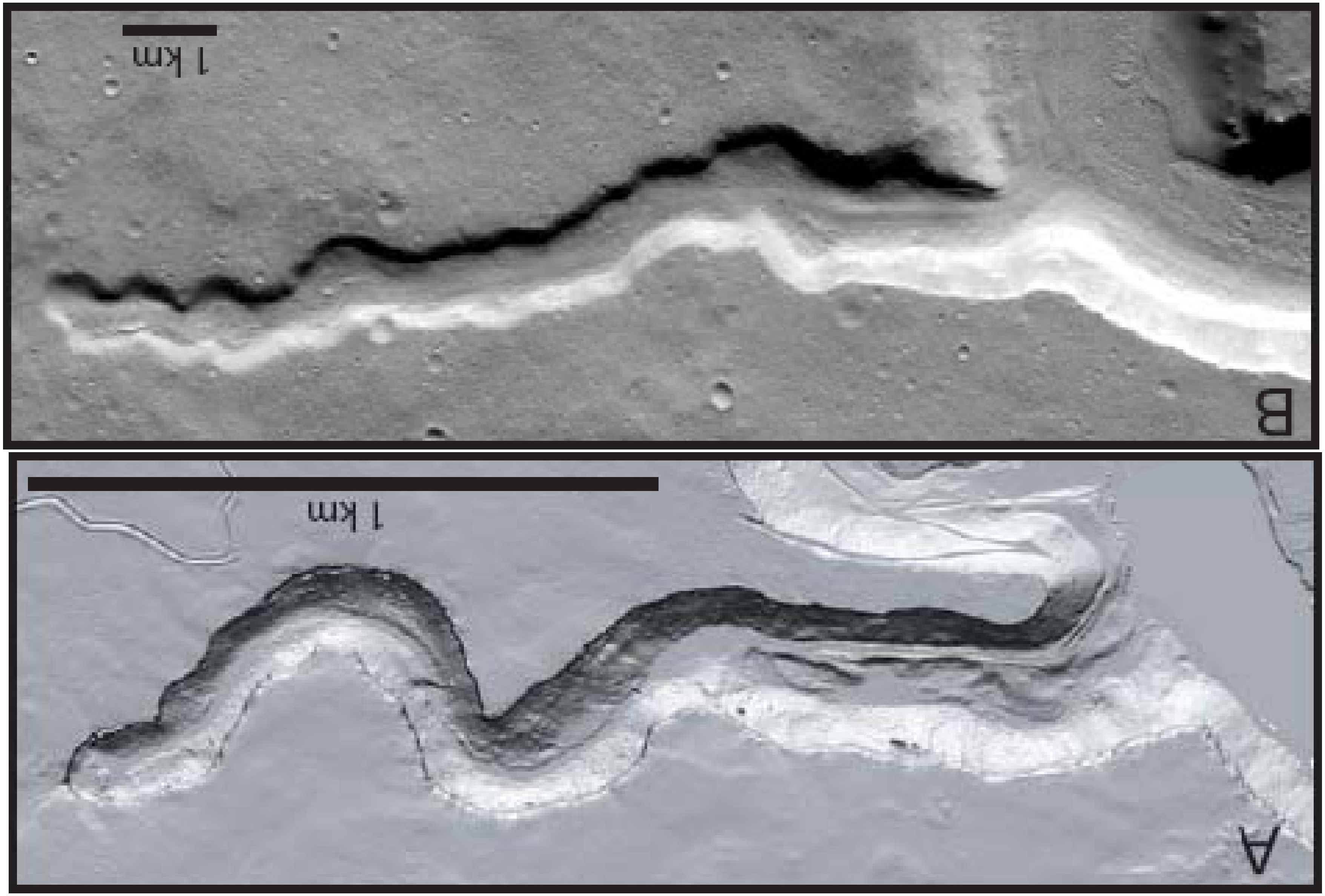


Fig. 9. Interpretation of the 12 ERT profiles and corresponding average thickness of the re

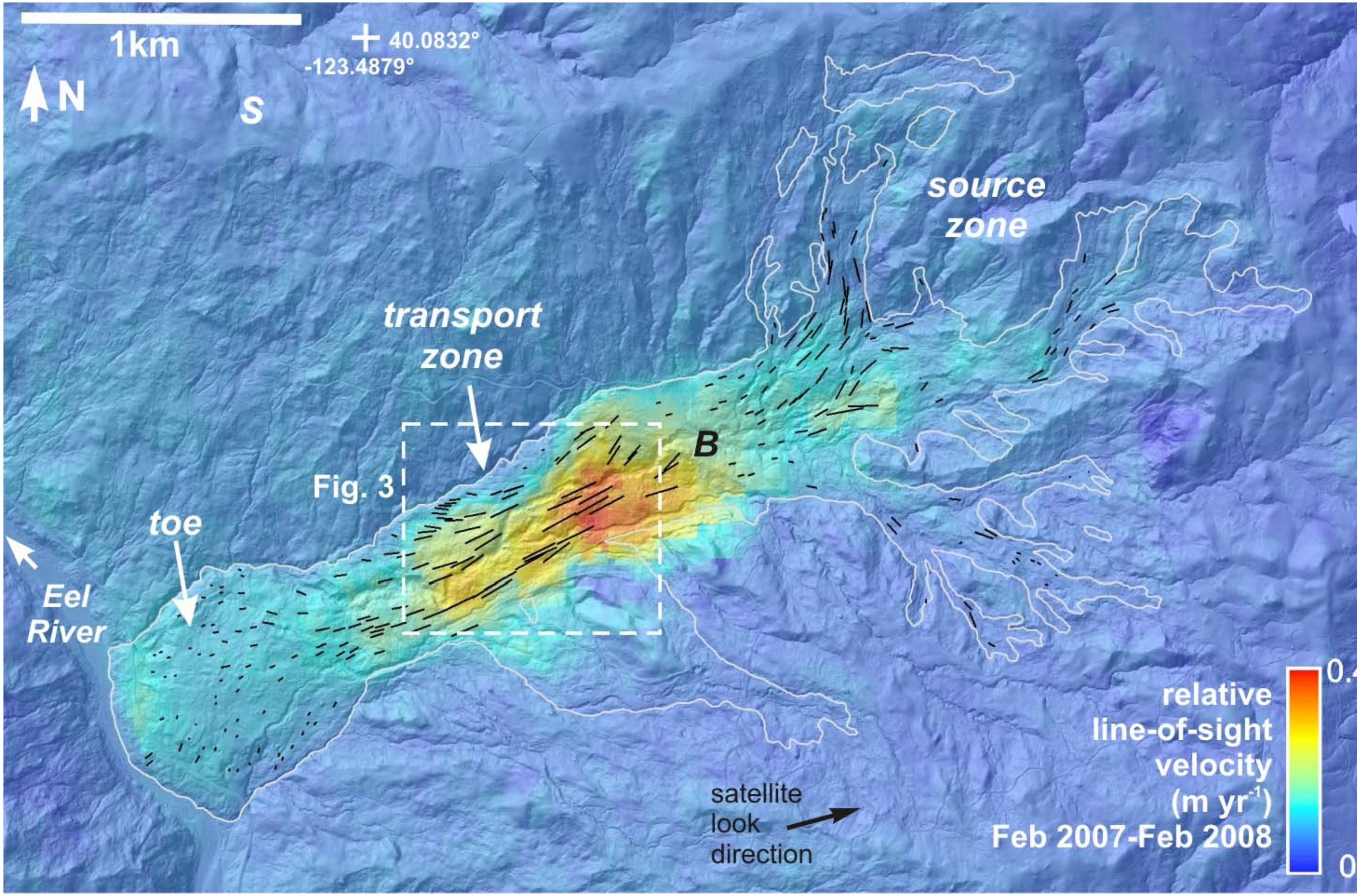
Conclusion

- Satellite-based observations have the potential to transform geomorphology via:
  - Full coverage of the earth with high resolution topographic data, flown at some regular interval
  - Event-driven surveys (fire, flood, landslides…)
  - Mapping of surface water elevation (*and depth*) (enables process studies and discharge calculations)
  - Surveys that could quantify the properties of the subsurface (that could document soil and rock moisture, groundwater table topography, bedrock fractures, and ice presence): the invisible (and inaccessible) landscape



Lamb et al., 2008, Science

Formation of Box Canyon Idaho by Megaflood: Implications for Seepage Erosion on Earth and Mars


1km
40.0832°
-123.4879°
N
S
source
zone
transport
zone
B
Fig. 3
toe
Eel
River
relative
line-of-sight
velocity
(m yr-1)
Feb 2007-Feb 2008
0
satellite
look
direction