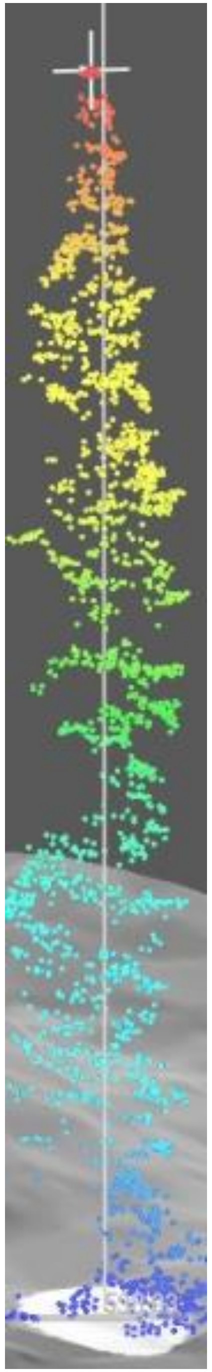


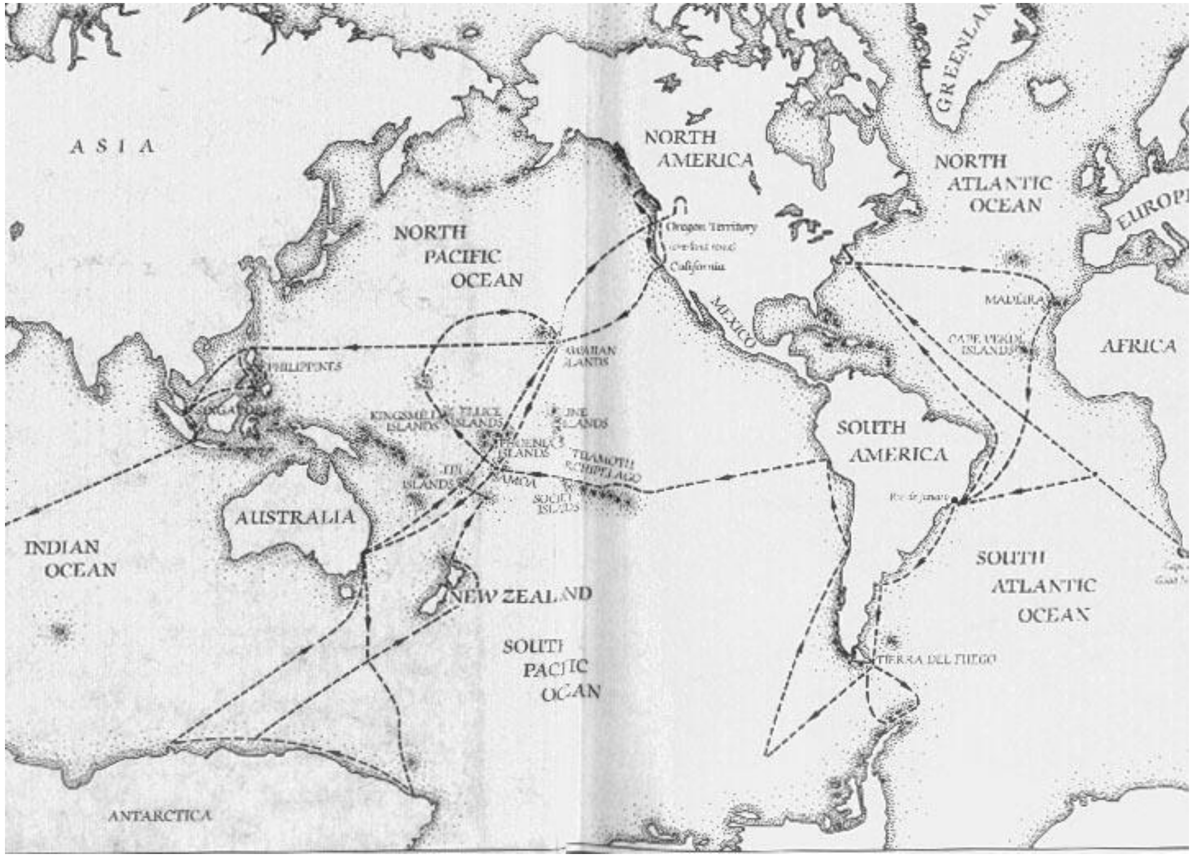
M. Olsen

Point Clouds, Critical Zones, and Conflagrations in the Cascadia Canopy

Josh Roering
Brooke Hunter
Danica Roth
Will Struble

1720

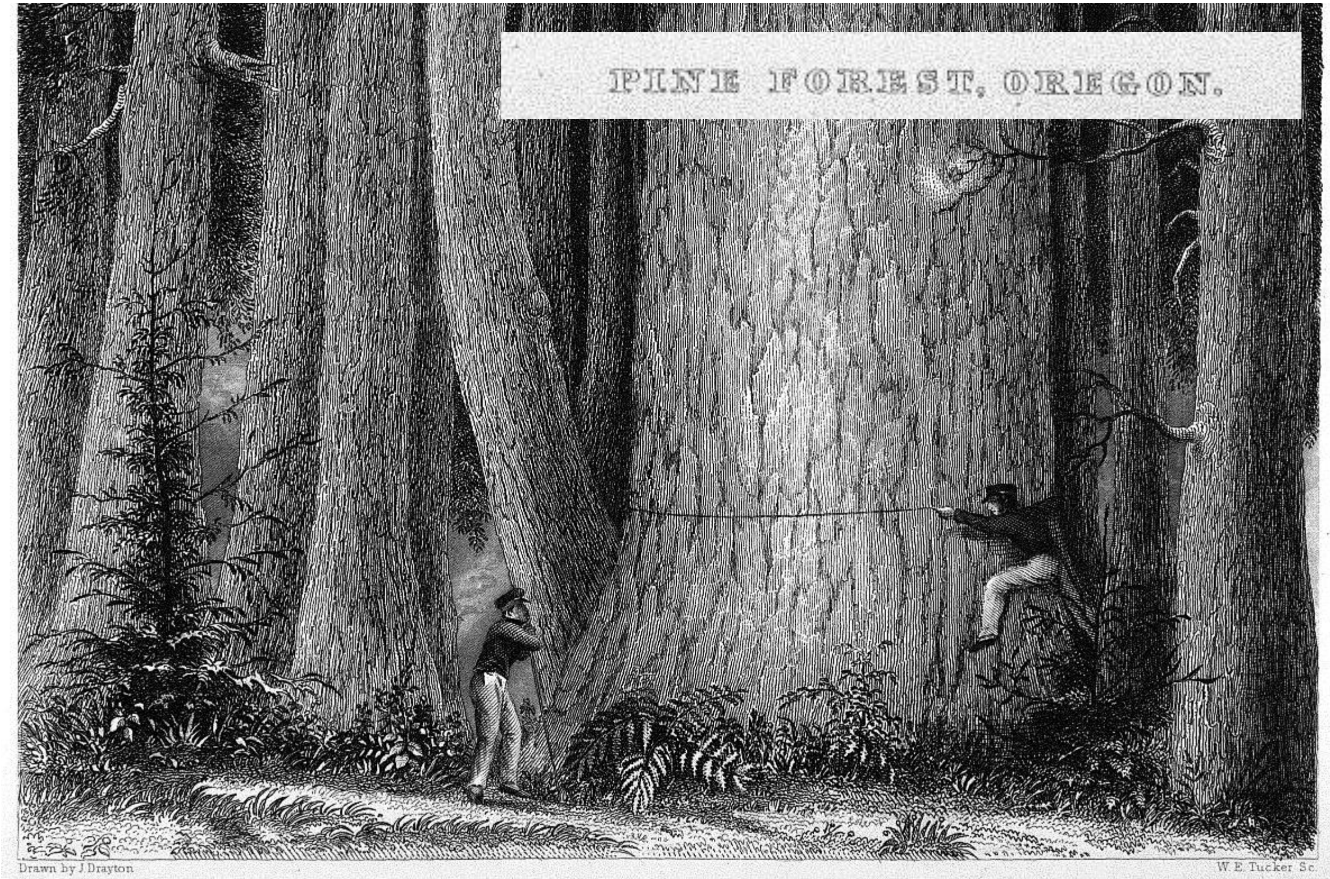
Map by Guillaume Del'Isle



U.S. Exploring Expedition
(Wilke's Expedition), 1838-1842

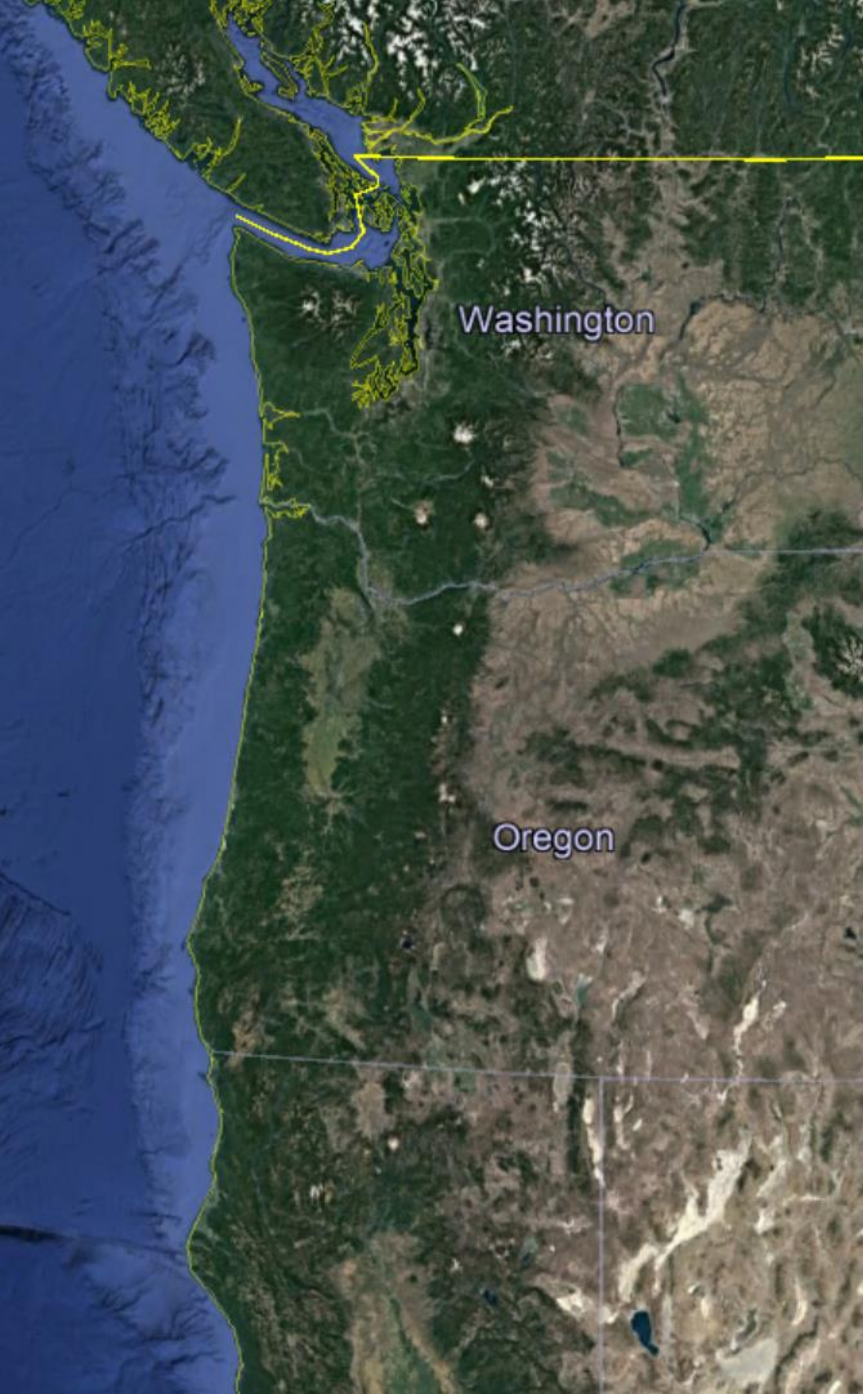
"The whole region elsewhere is broken with hills of little seeming interest, and bristled with evergreens. …presenting in general little that is striking in outline"

-J.D. Dana, 1845


PINE FOREST, OREGON.

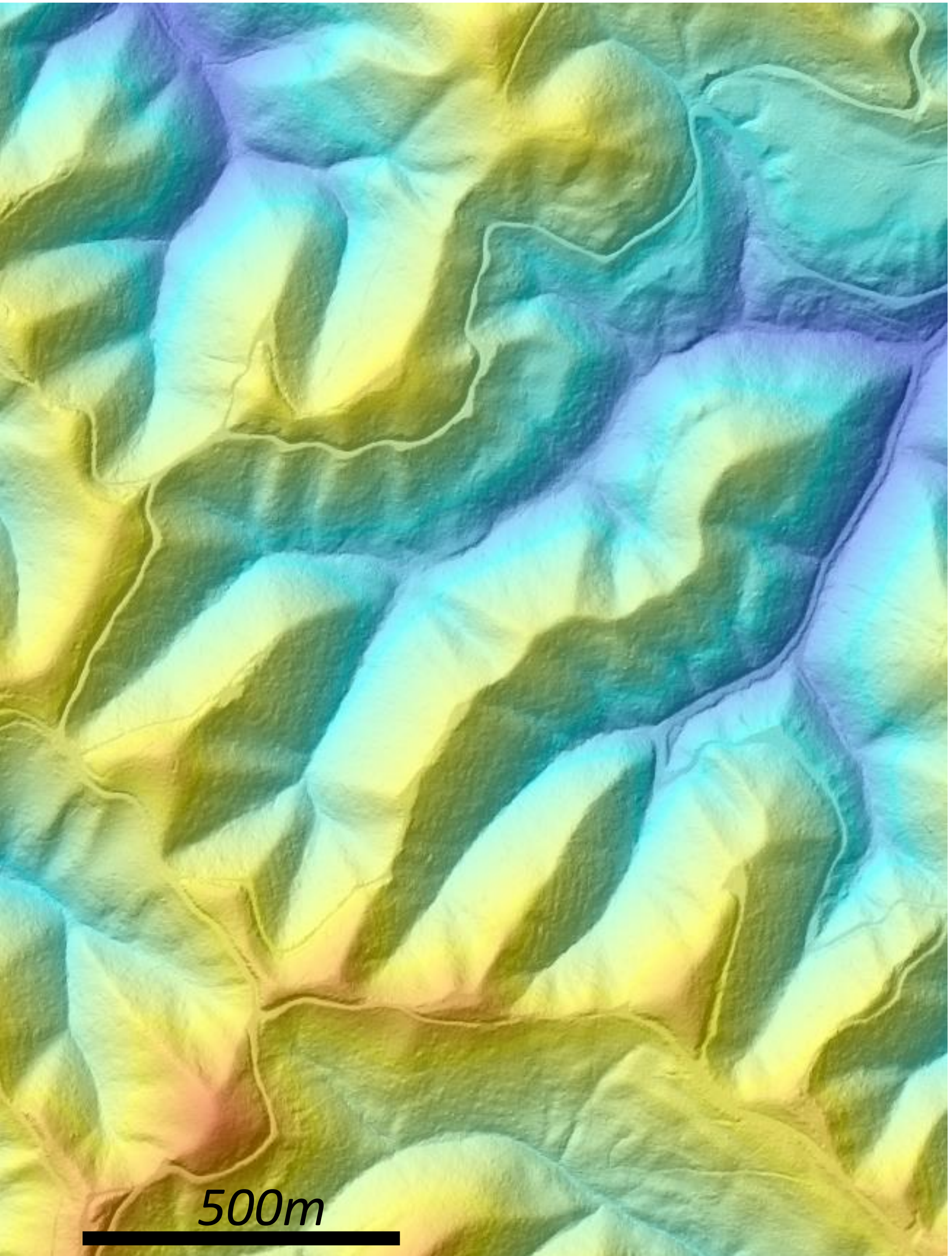
Drawn by J Drayton

W.E. Tucker Sc.

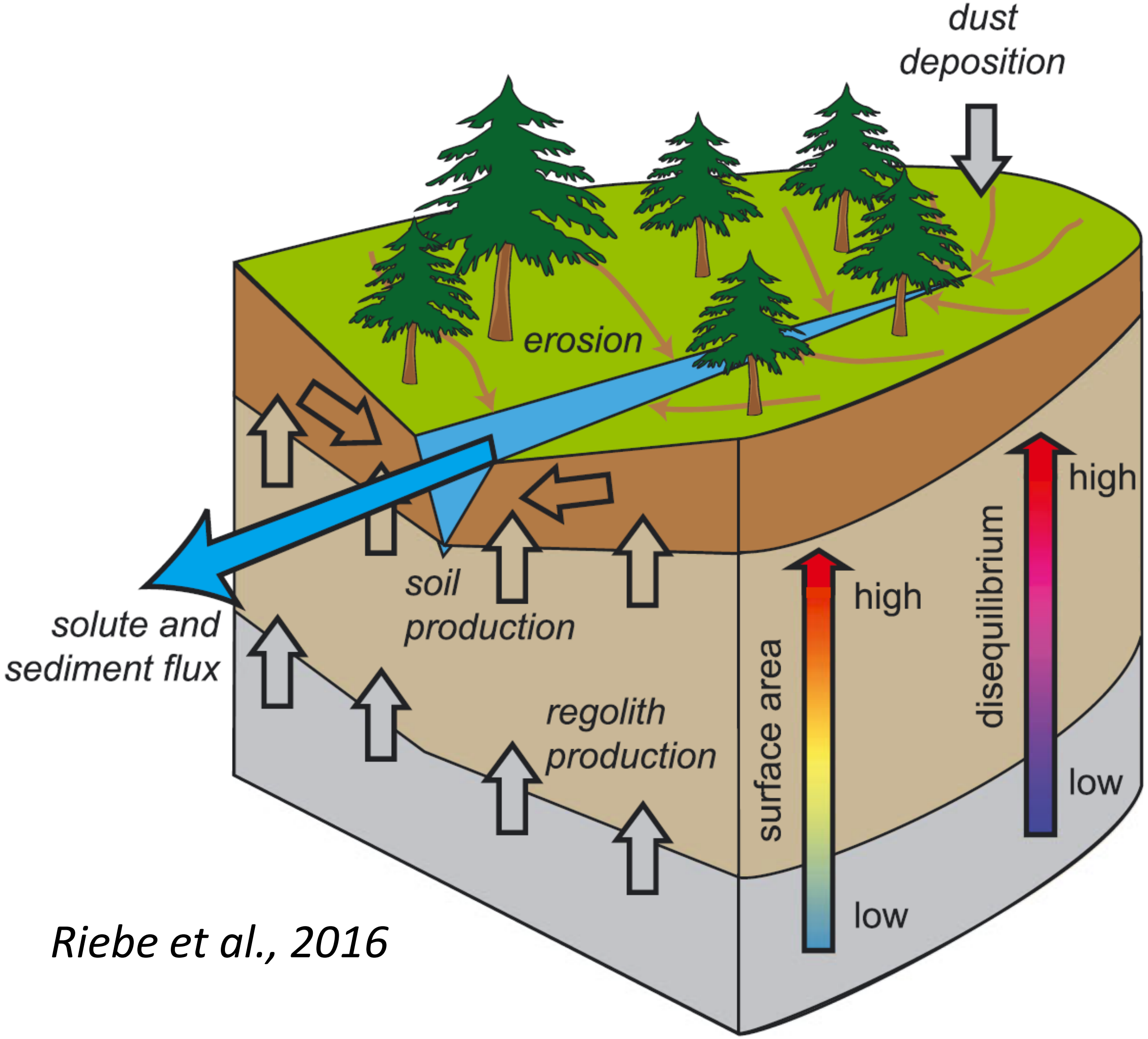


Outline: High-resolution topography for interdisciplinary research

1. Critical zone architecture
2. Hillslope transport models
3. Post-fire change detection and sediment budgets
4. Paleoseismology and landslide chronology



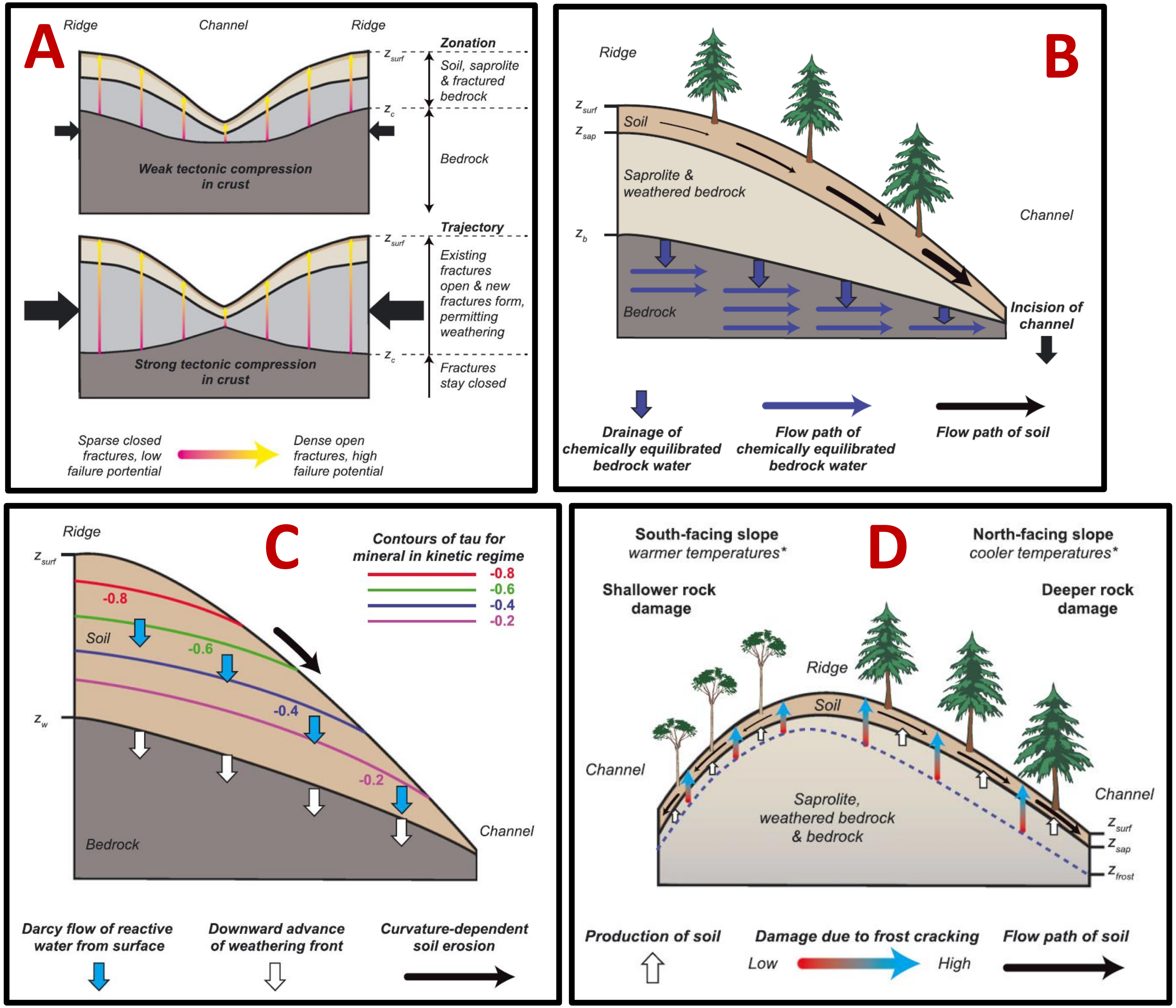
1) Can the critical zone be predicted from topography?



Riebe et al., 2016

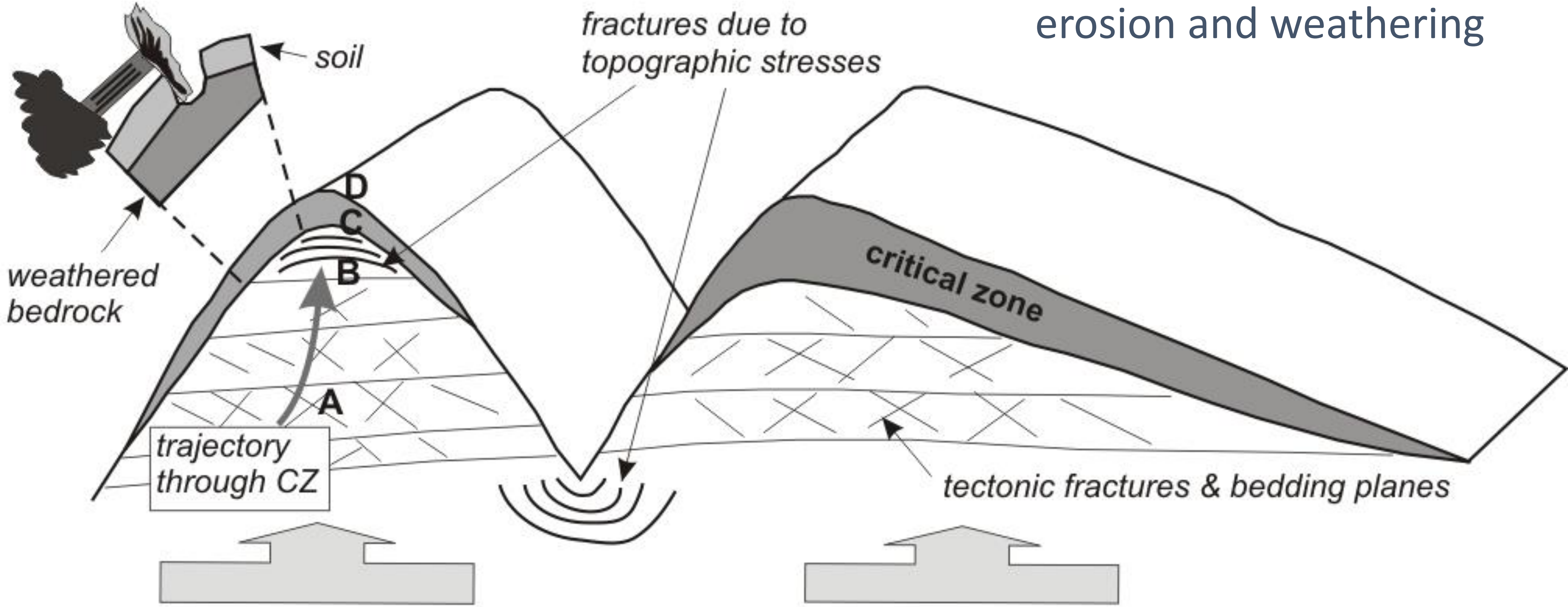
Critical zone models

A. **Topographic stress and fracturing** *(St. Clair et al, 2015)*
B. **Water table and bedrock exhumation** *(Rempe & Dietrich, 2014)*
C. **Reaction front propagation** *(Lebedeva and Brantley, 2014)*
D. **Climate-dependent frost weathering** *(Anderson, 2015)*



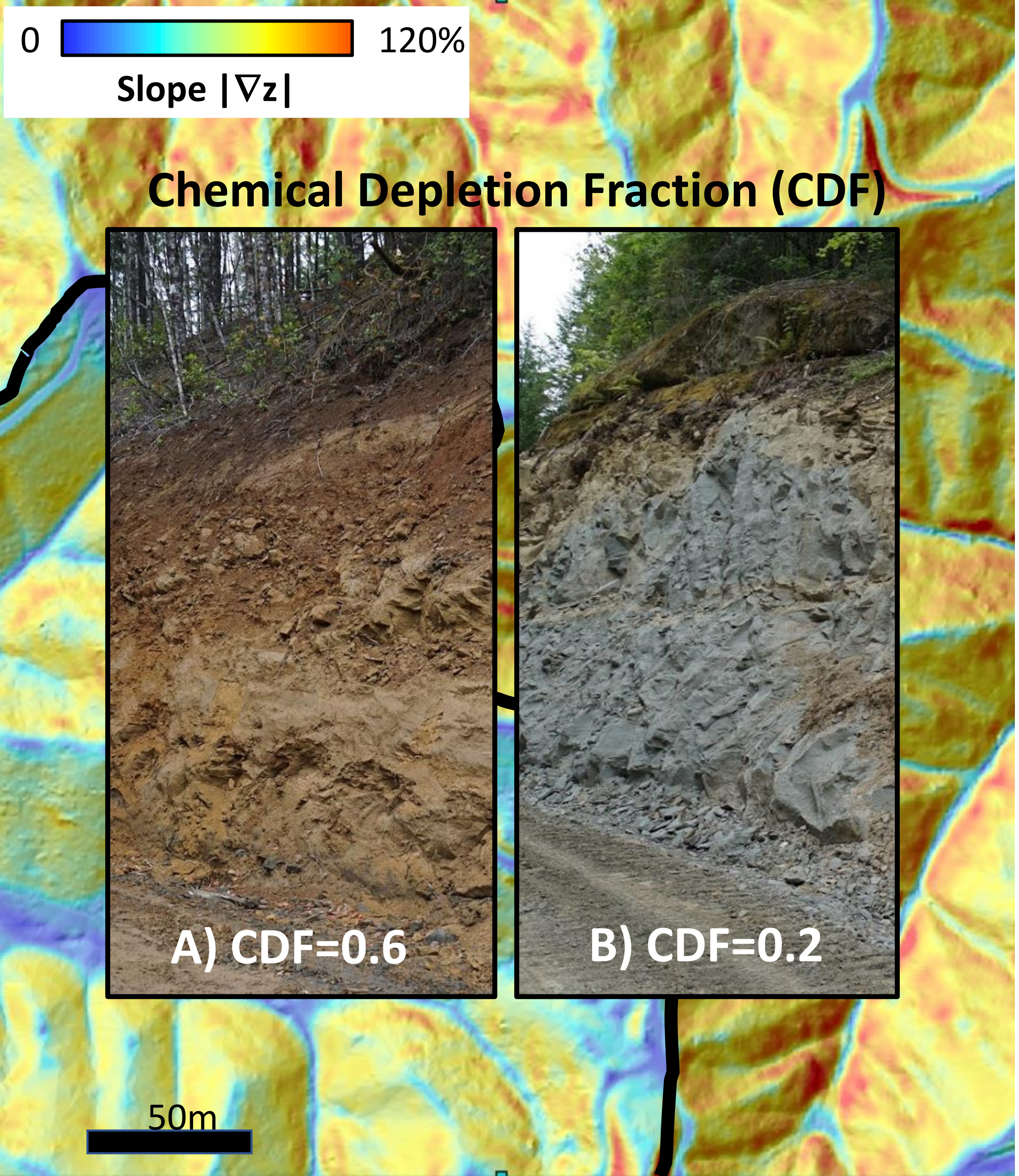
Riebe et al., 2016

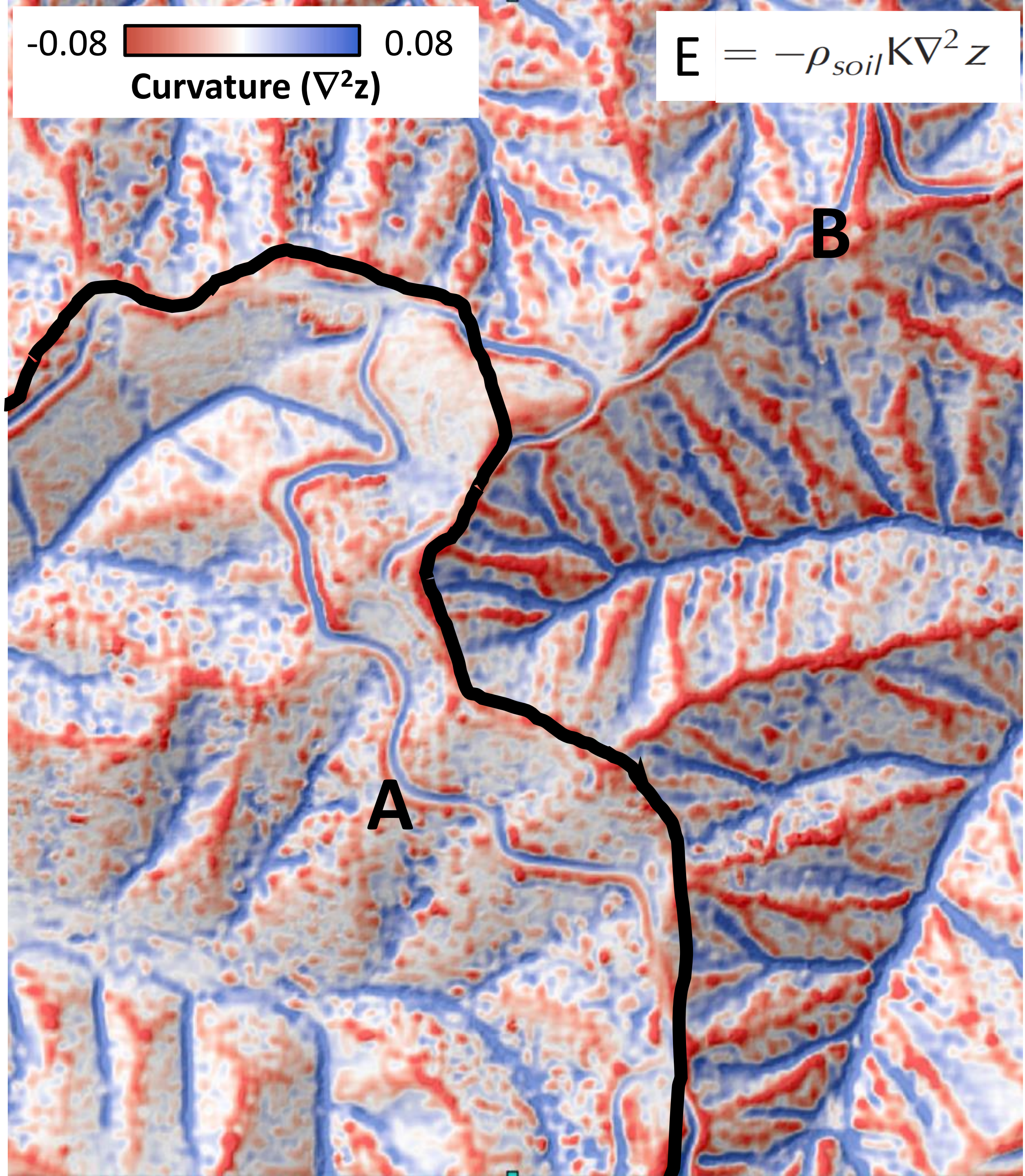
Hypothesis: Balance b/w erosion and weathering



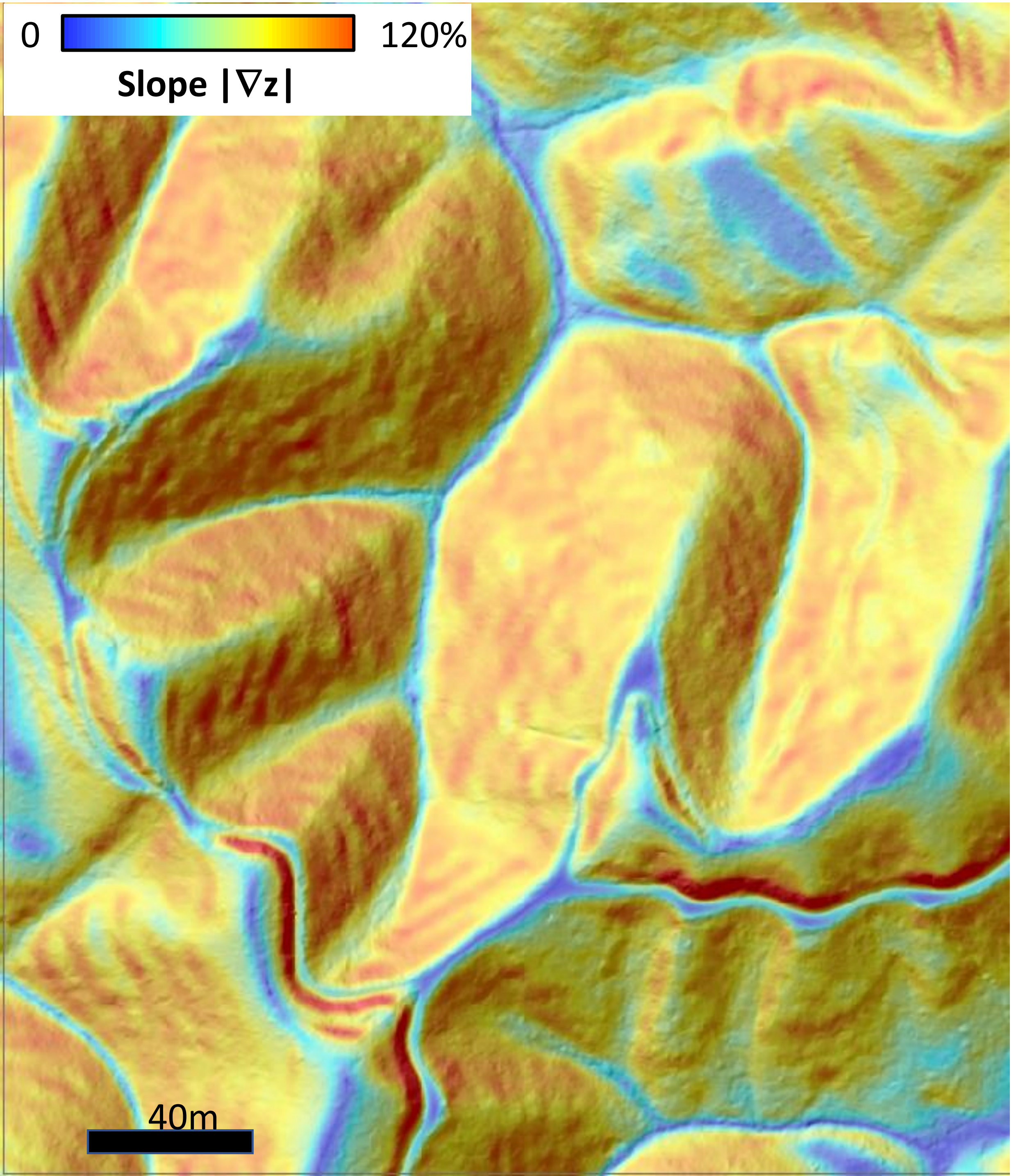
Steady rapid erosion

Slow erosion (transient)

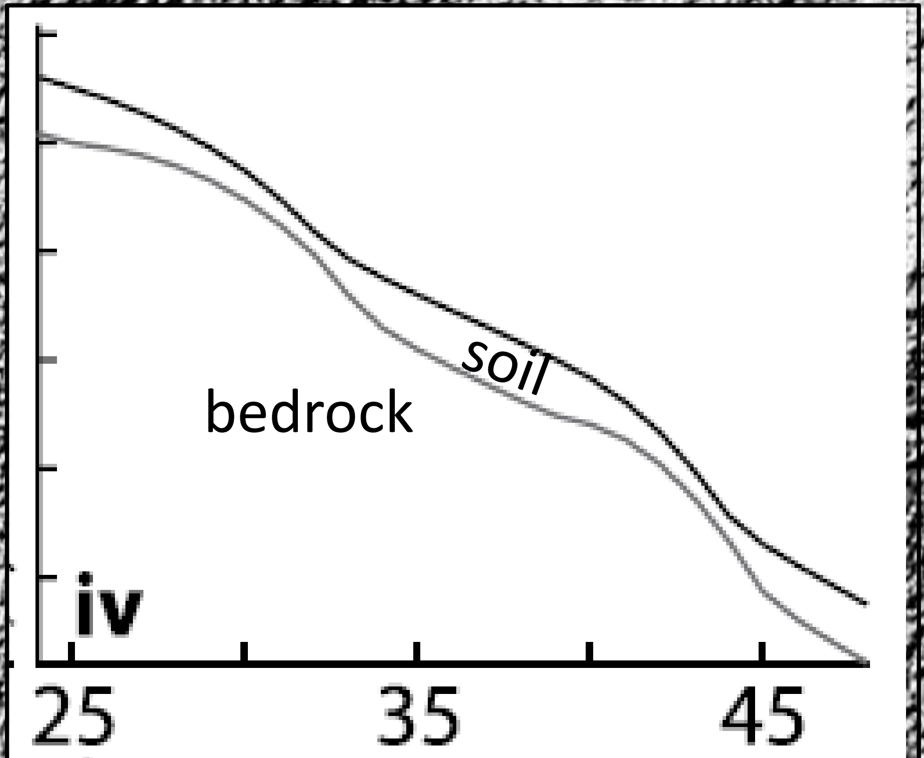




$$E = -\rho_{soil} K \nabla^2 z$$

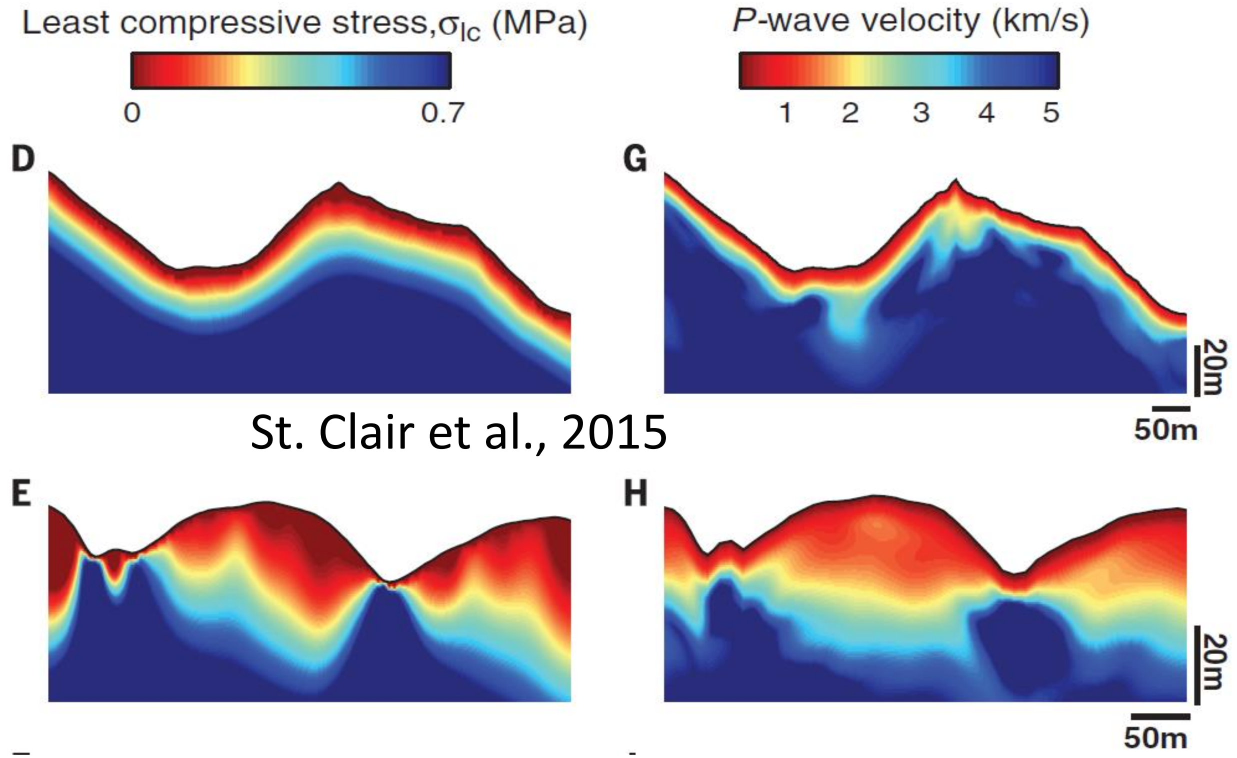



Johnstone & Hilley, 2015



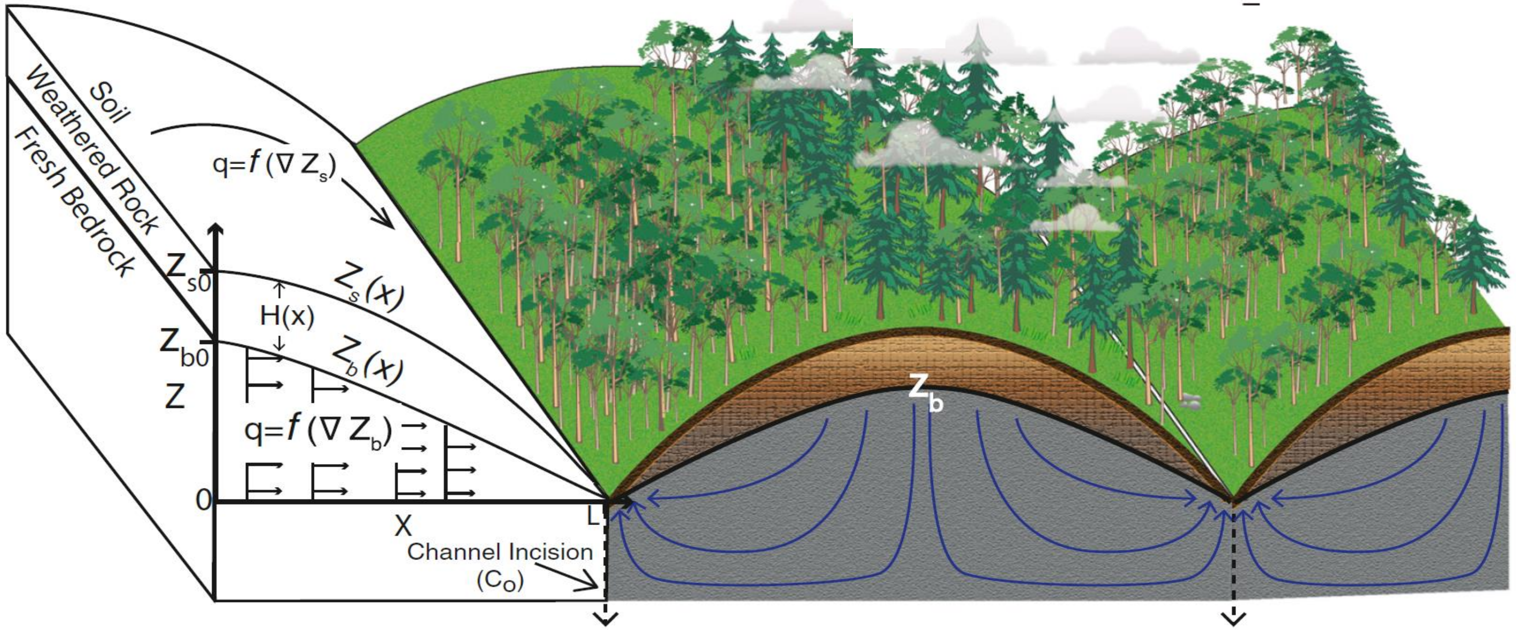
1) Challenges and needs:

- Topographic context and process models to inform instrumentation and sampling
- Smooth/enhance features: how? how much?
- Can emerging tools (e.g., machine learning) help reveal signals/patterns?

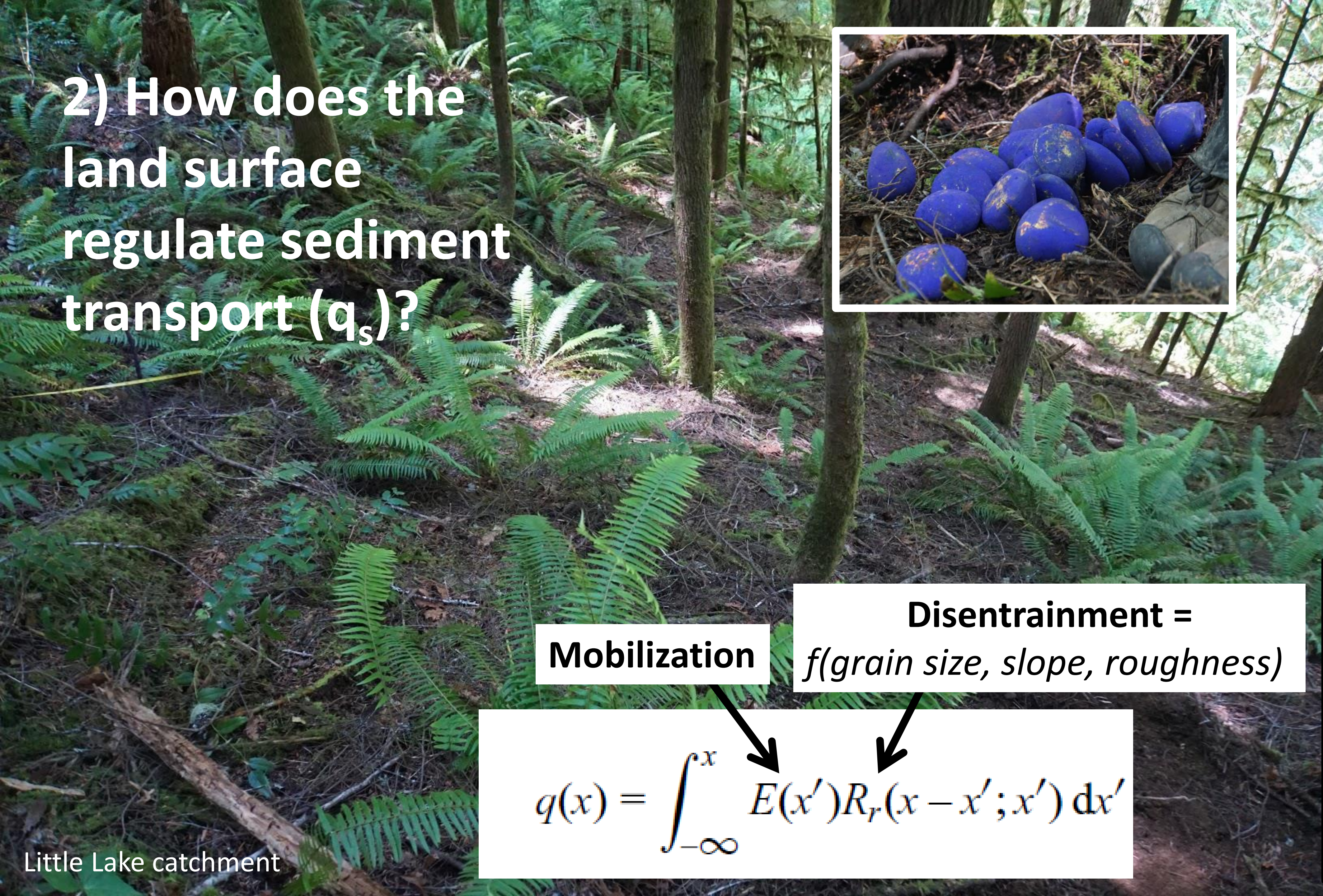


St. Clair et al., 2015

Rempe & Dietrich, 2014



2) How does the land surface regulate sediment transport (q_s)?



Little Lake catchment

Mobilization

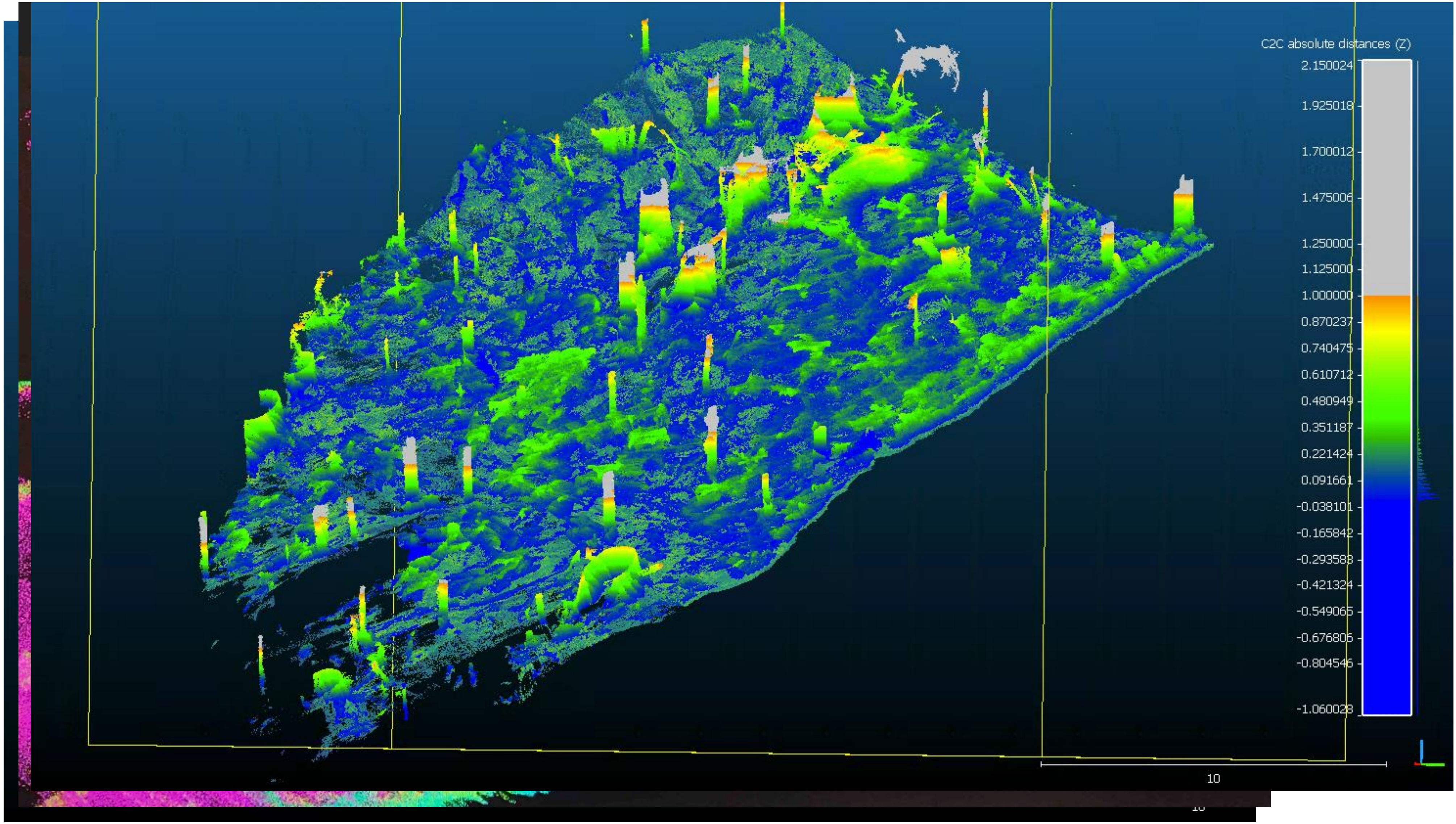
Disentrainment =
f(grain size, slope, roughness)

$$q(x) = \int_{-\infty}^{x} E(x')R_r(x - x';x')\,\mathrm{d}x'$$

Danica Roth

David Furbish

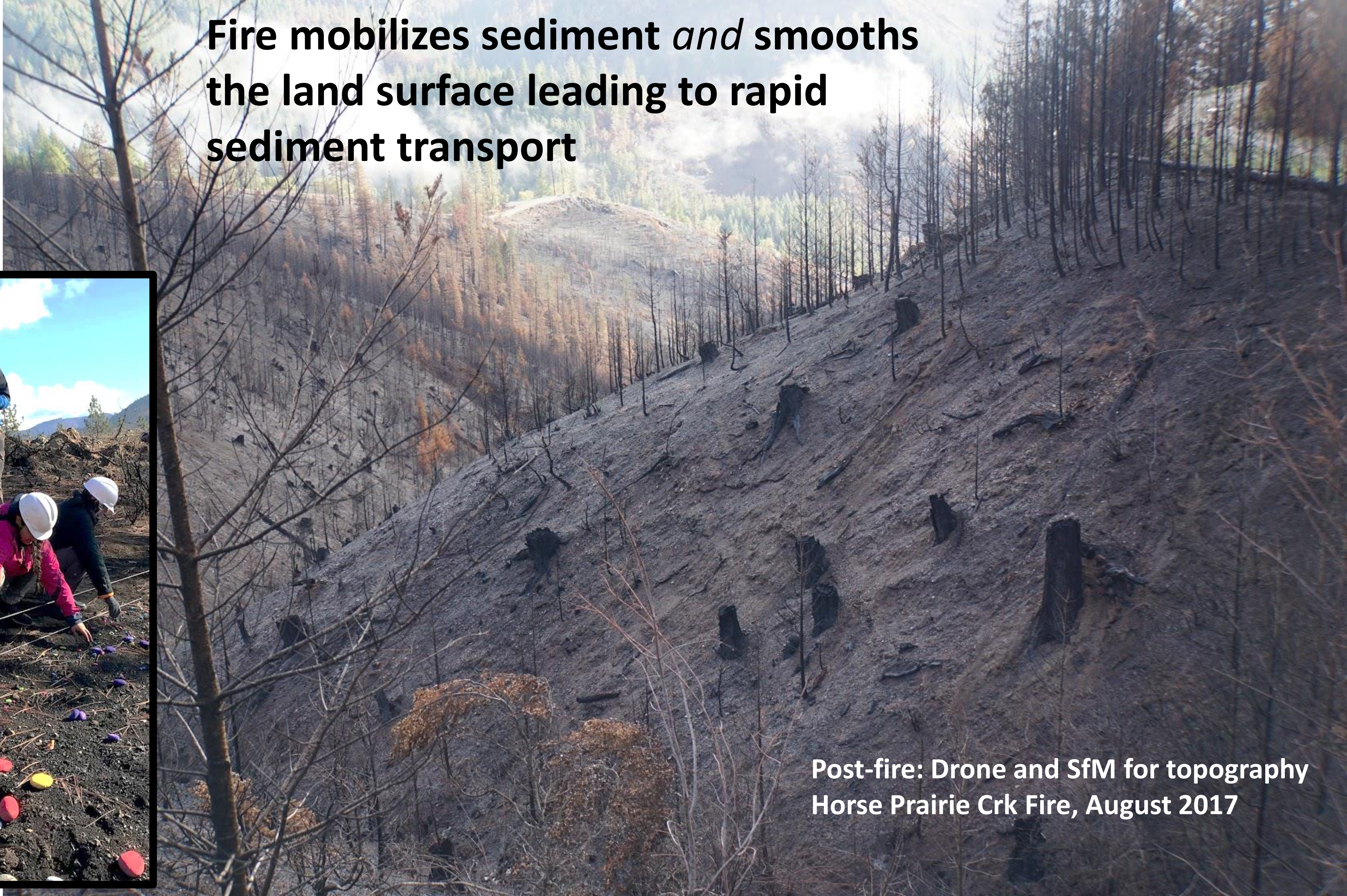
Quantifying surface slope and roughness (TLS)



Danica Roth (UO),
Keith Williams
(UNAVCO)

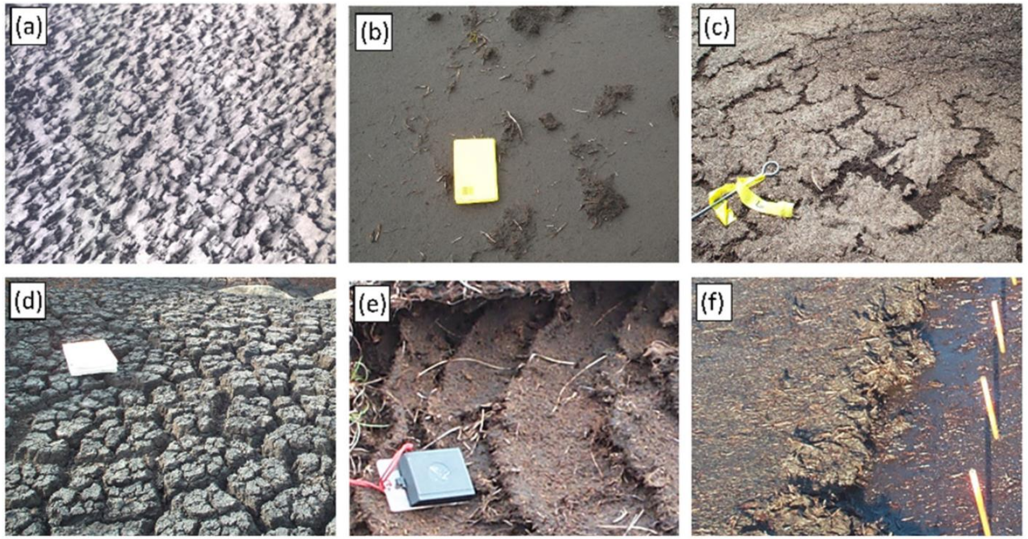
Slope angle = 39°

Fire mobilizes sediment *and* smooths the land surface leading to rapid sediment transport



Post-fire: Drone and SfM for topography
Horse Prairie Crk Fire, August 2017

Quantifying roughness

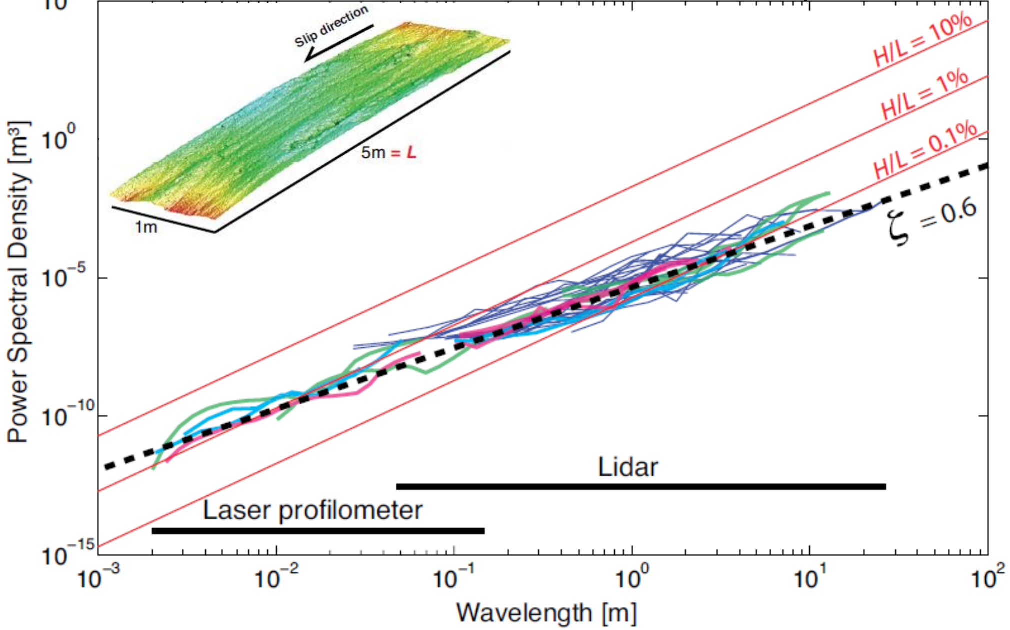


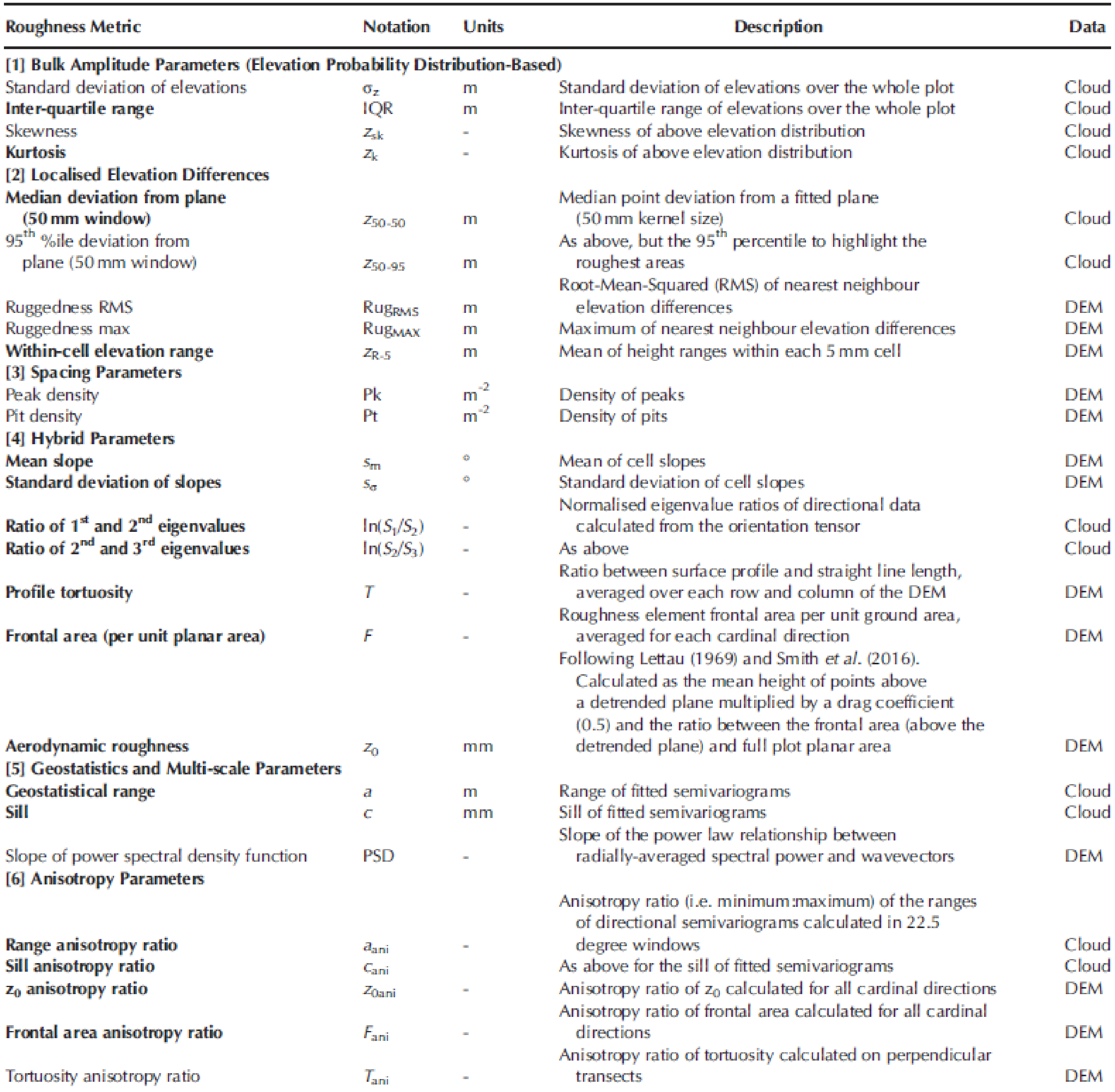
Peat erosion

Smith and Warburton, 2018

Fault surface asperities

Brodsky et al., 2016

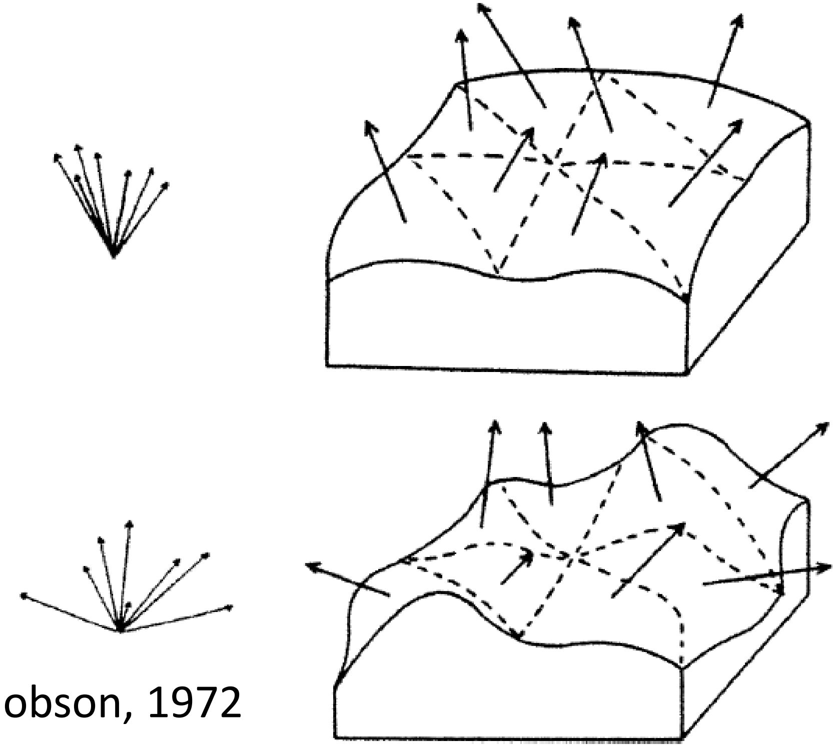




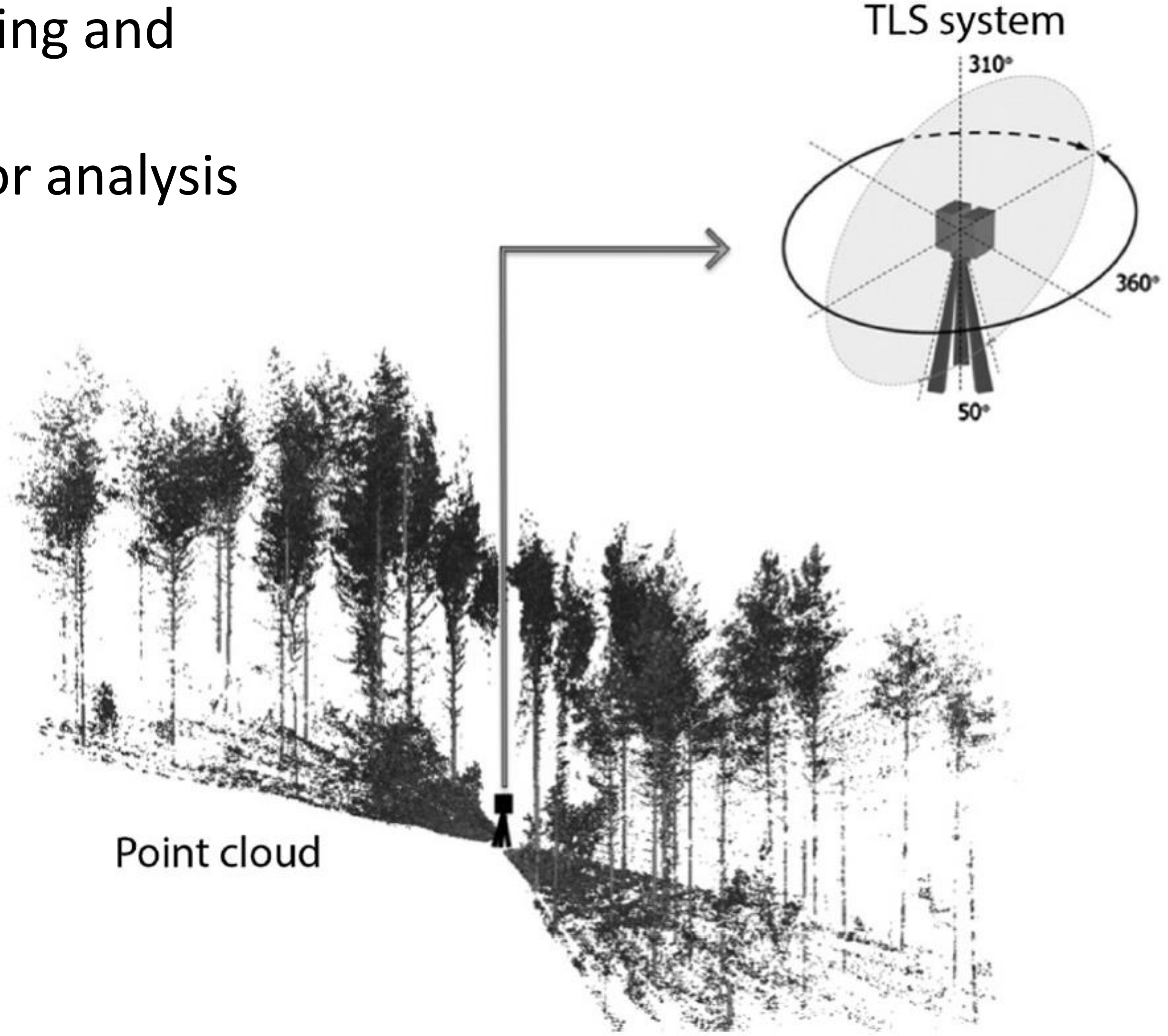
Roughness Metric	Notation	Units	Description	Data
[1] Bulk Amplitude Parameters (Elevation Probability Distribution-Based)				
Standard deviation of elevations	σ_z	m	Standard deviation of elevations over the whole plot	Cloud
Inter-quartile range	IQR	m	Inter-quartile range of elevations over the whole plot	Cloud
Skewness	z_{sk}	-	Skewness of above elevation distribution	Cloud
Kurtosis	z_k	-	Kurtosis of above elevation distribution	Cloud
[2] Localised Elevation Differences				
Median deviation from plane (50 mm window)	$z_{50\text{-}50}$	m	Median point deviation from a fitted plane (50 mm kernel size)	Cloud
95th %ile deviation from plane (50 mm window)	$z_{50\text{-}95}$	m	As above, but the 95th percentile to highlight the roughest areas	Cloud
Ruggedness RMS	Rug_{RMS}	m	Root-Mean-Squared (RMS) of nearest neighbour elevation differences	DEM
Ruggedness max	Rug_{MAX}	m	Maximum of nearest neighbour elevation differences	DEM
Within-cell elevation range	$z_{R\text{-}5}$	m	Mean of height ranges within each 5 mm cell	DEM
[3] Spacing Parameters				
Peak density	Pk	m^{-2}	Density of peaks	DEM
Pit density	Pt	m^{-2}	Density of pits	DEM
[4] Hybrid Parameters				
Mean slope	s_m	°	Mean of cell slopes	DEM
Standard deviation of slopes	s_σ	°	Standard deviation of cell slopes	DEM
Ratio of 1st and 2nd eigenvalues	$\ln(S_1/S_2)$	-	Normalised eigenvalue ratios of directional data calculated from the orientation tensor	Cloud
Ratio of 2nd and 3rd eigenvalues	$\ln(S_2/S_3)$	-	As above	Cloud
Profile tortuosity	T	-	Ratio between surface profile and straight line length, averaged over each row and column of the DEM	DEM
Frontal area (per unit planar area)	F	-	Roughness element frontal area per unit ground area, averaged for each cardinal direction	DEM
Aerodynamic roughness	z_0	mm	Following Lettau (1969) and Smith *et al.* (2016). Calculated as the mean height of points above a detrended plane multiplied by a drag coefficient (0.5) and the ratio between the frontal area (above the detrended plane) and full plot planar area	DEM
[5] Geostatistics and Multi-scale Parameters				
Geostatistical range	a	m	Range of fitted semivariograms	Cloud
Sill	c	mm	Sill of fitted semivariograms	Cloud
Slope of power spectral density function	PSD	-	Slope of the power law relationship between radially-averaged spectral power and wavevectors	DEM
[6] Anisotropy Parameters				
Range anisotropy ratio	a_{ani}	-	Anisotropy ratio (i.e. minimum:maximum) of the ranges of directional semivariograms calculated in 22.5 degree windows	Cloud
Sill anisotropy ratio	c_{ani}		As above for the sill of fitted semivariograms	Cloud
z_0 anisotropy ratio	z_{0ani}	-	Anisotropy ratio of z_0 calculated for all cardinal directions	DEM
Frontal area anisotropy ratio	F_{ani}	-	Anisotropy ratio of frontal area calculated for all cardinal directions	DEM
Tortuosity anisotropy ratio	T_{ani}	-	Anisotropy ratio of tortuosity calculated on perpendicular transects	DEM

2) Challenges and Needs:

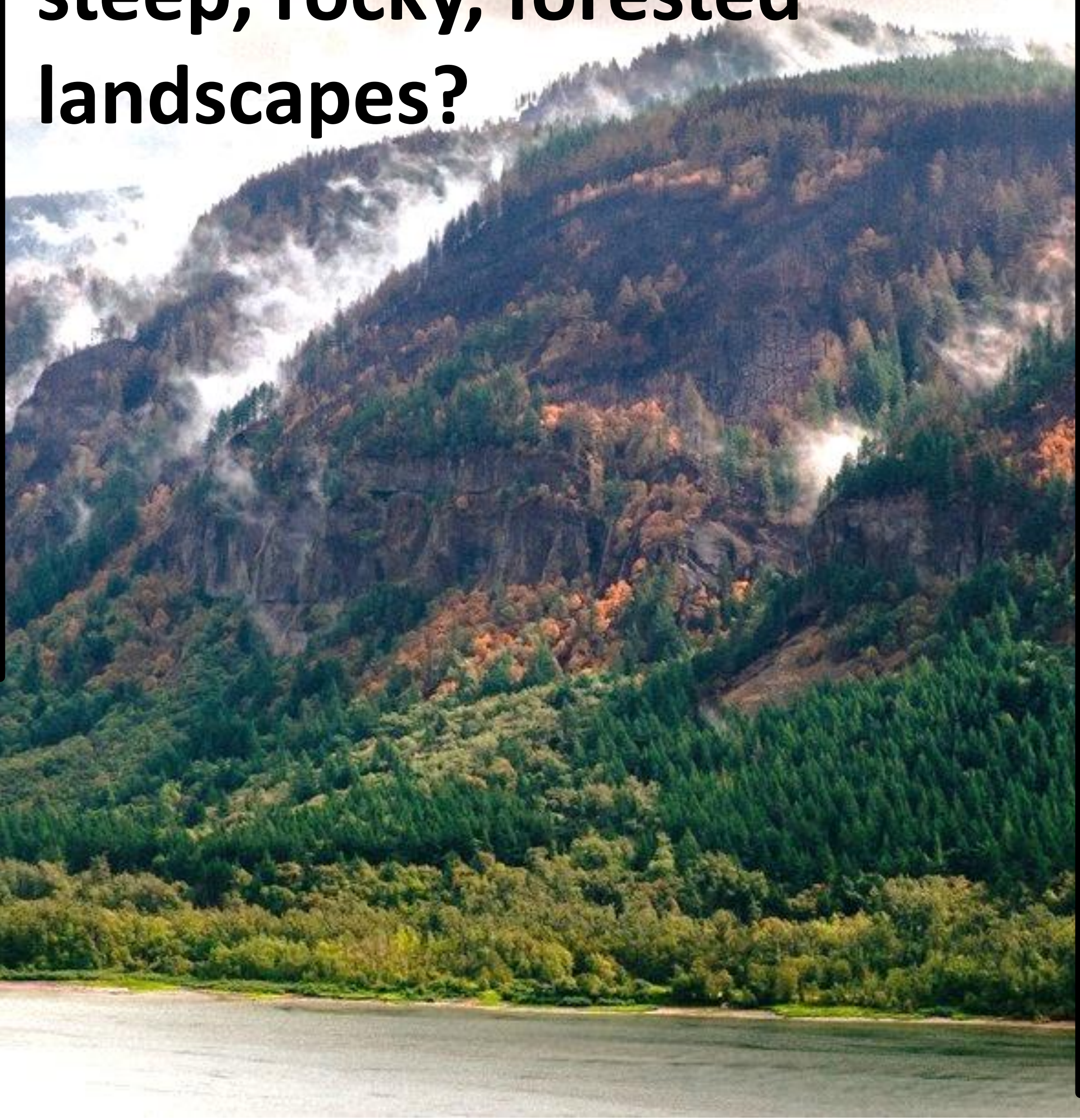
- Accessible classification algorithms
- Computational efficient point cloud processing and topographic derivatives (parallelization)
- Surface roughness: process context and error analysis

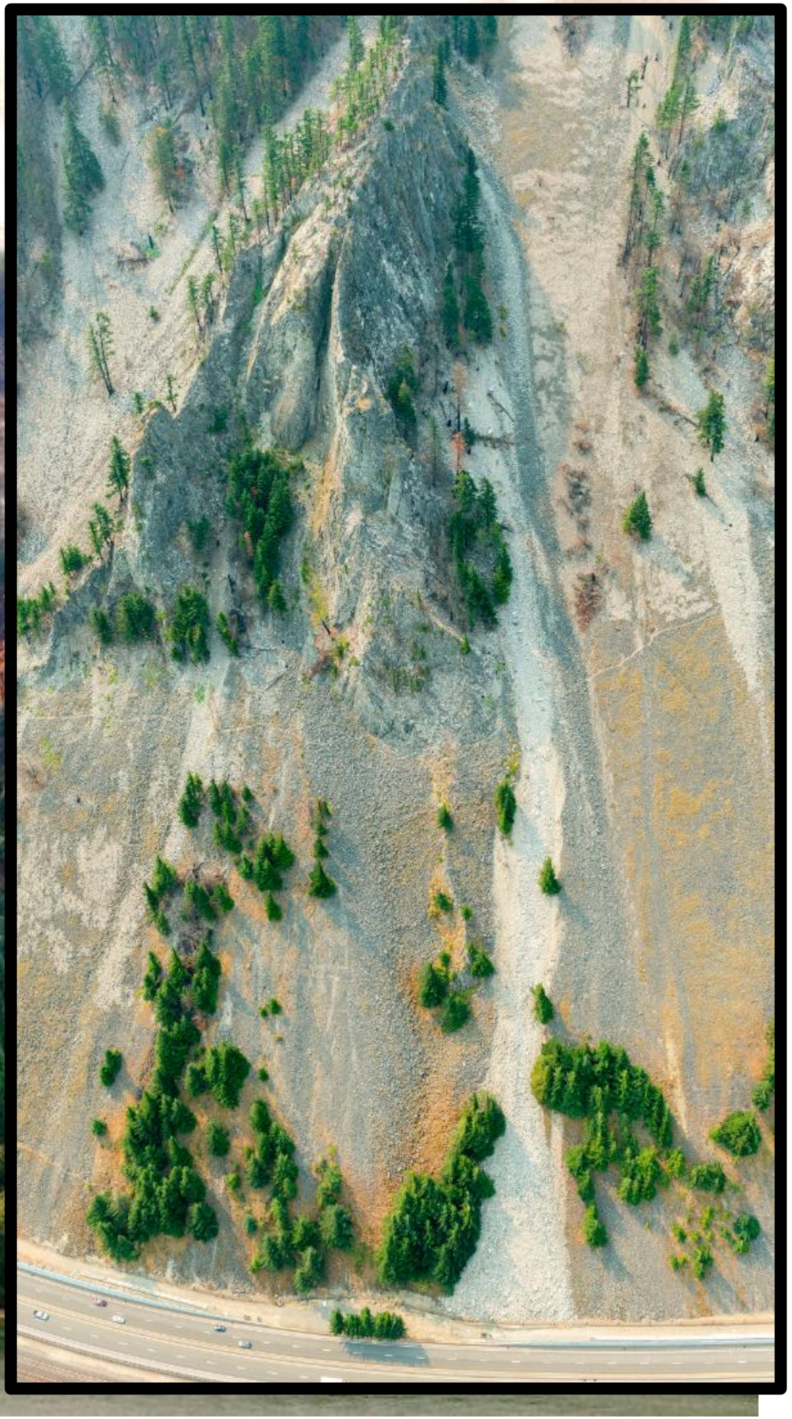


Hobson, 1972



3) How does fire reshape steep, rocky, forested landscapes?

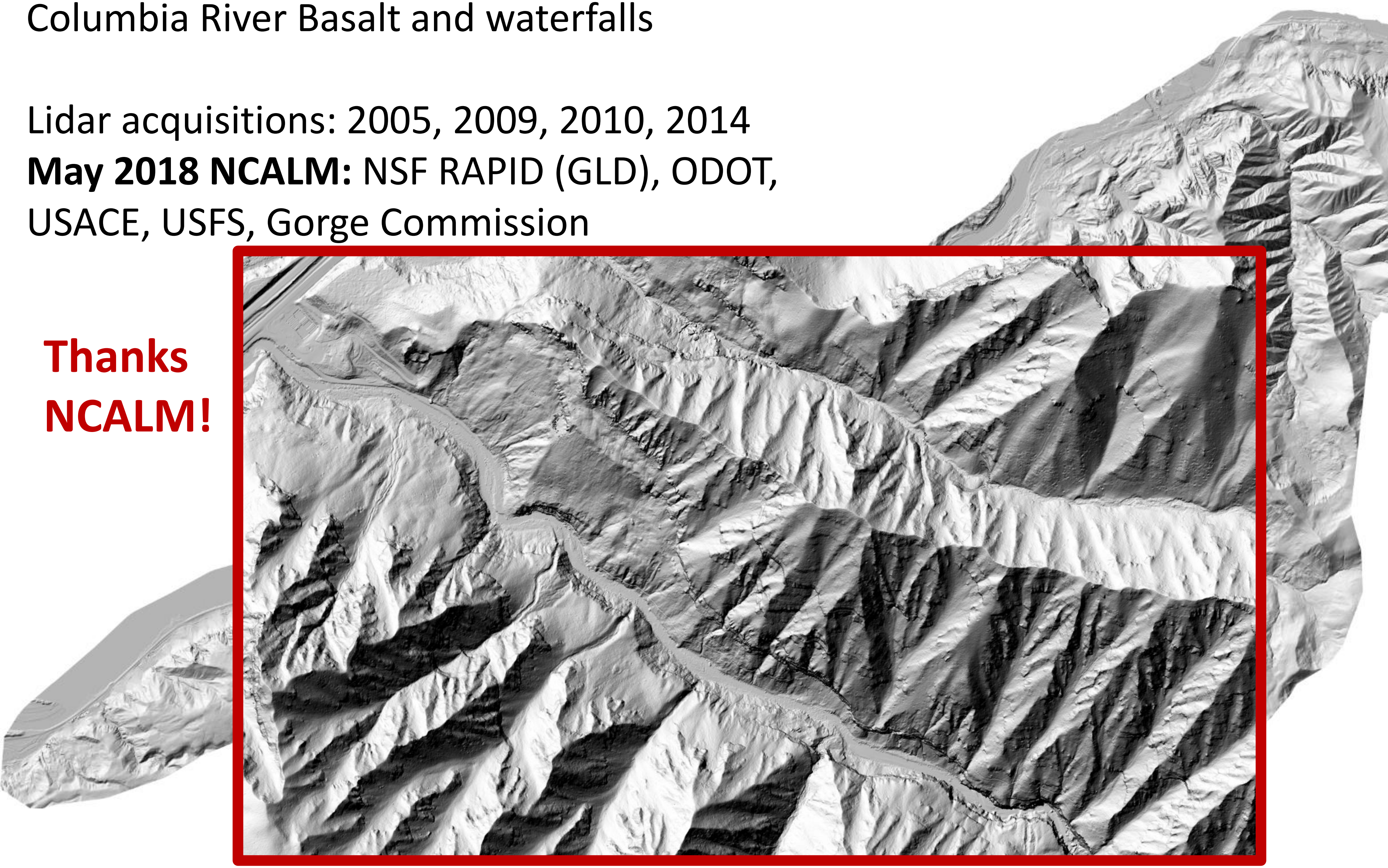




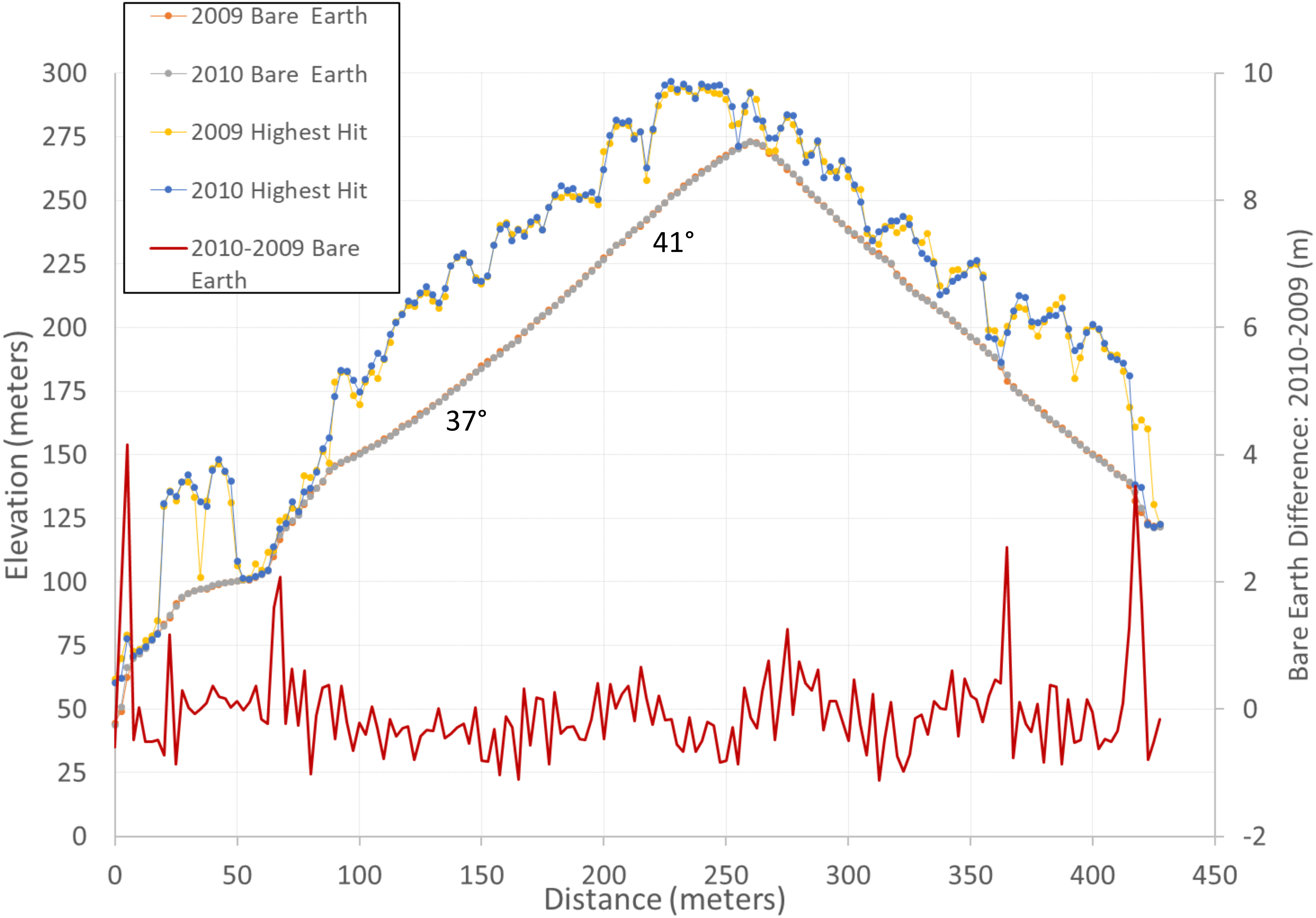
Eagle Crk fire, 50,000 acres, September 2017
Columbia River Basalt and waterfalls

Lidar acquisitions: 2005, 2009, 2010, 2014
May 2018 NCALM: NSF RAPID (GLD), ODOT,
USACE, USFS, Gorge Commission

Thanks NCALM!

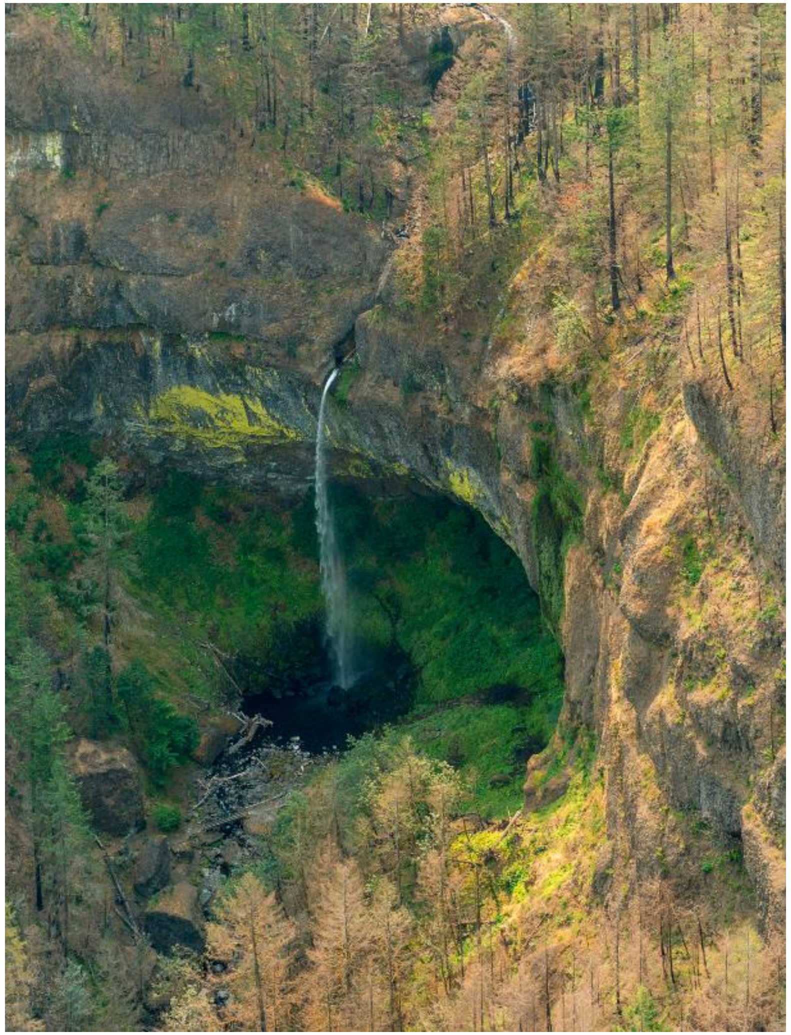


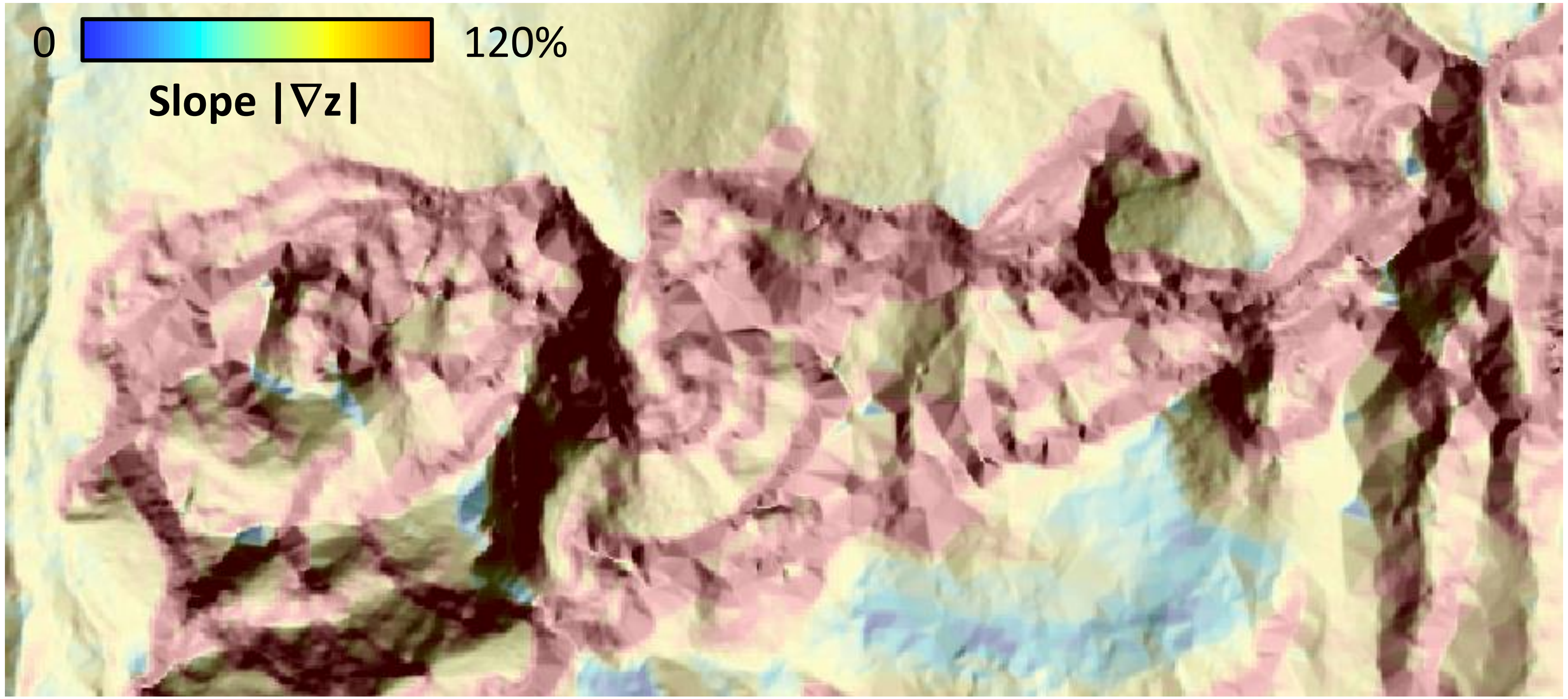
Brooke Hunter

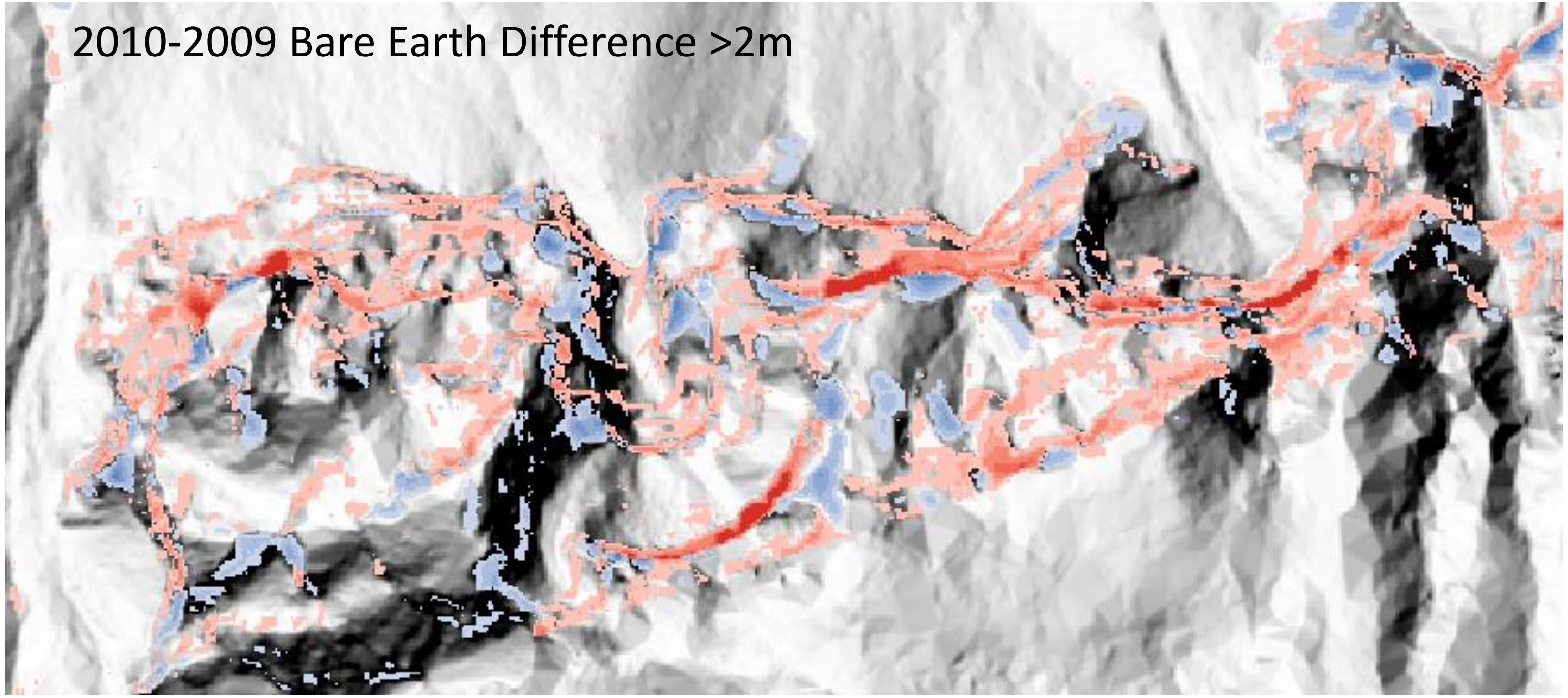

2009 Bare Earth
2010 Bare Earth
2009 Highest Hit
2010 Highest Hit
2010-2009 Bare Earth
Elevation (meters)
300
275
250
225
200
175
150
125
100
75
50
25
0
Bare Earth Difference: 2010-2009 (m)
10
8
6
4
2
0
-2
Distance (meters)
0
50
100
150
200
250
300
350
400
450
41°
37°

3) Challenges and needs:

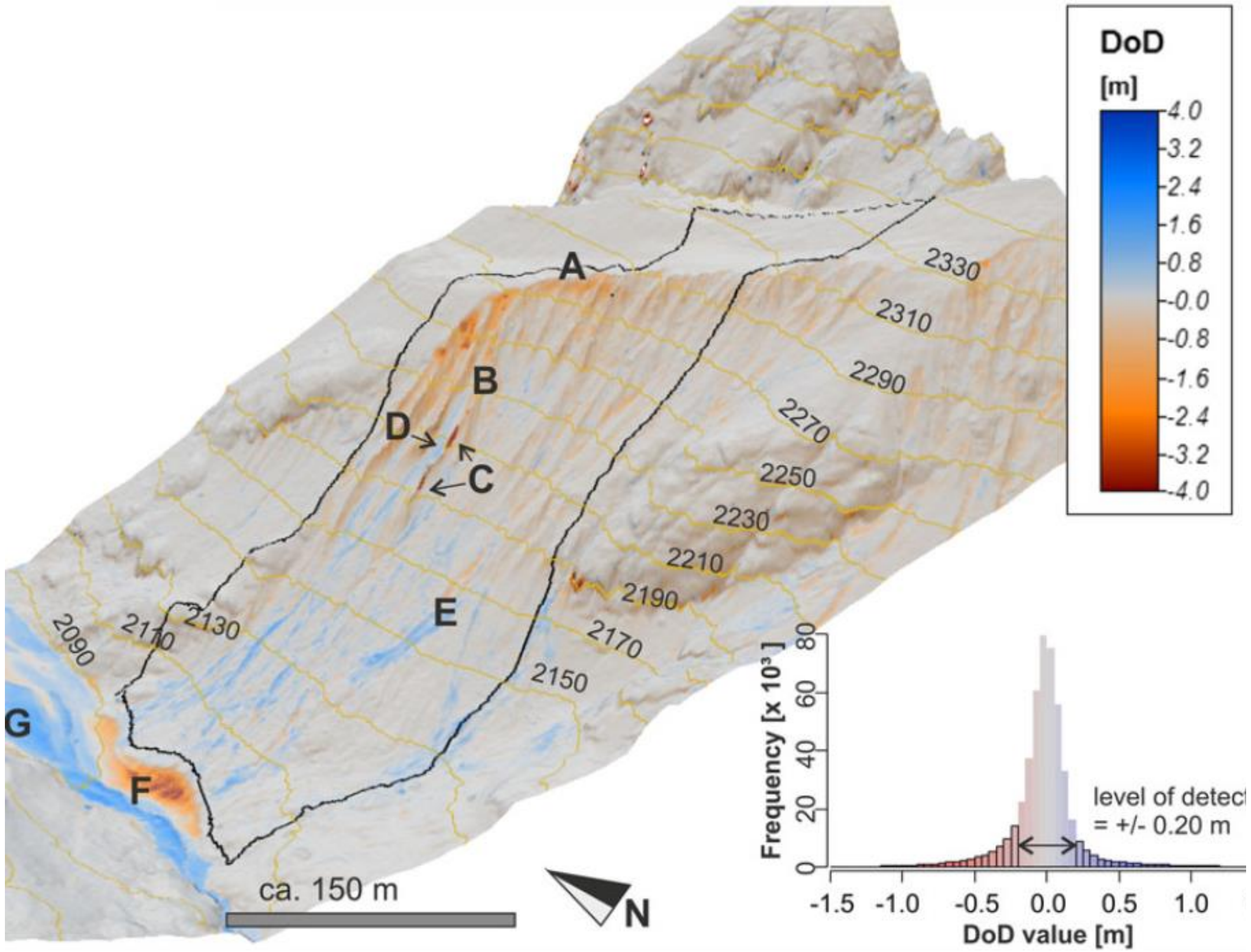
- Change detection in steep (>45°), forested terrain is non-trivial
- Integration of multiple datasets (ALS, TLS, drone SfM)



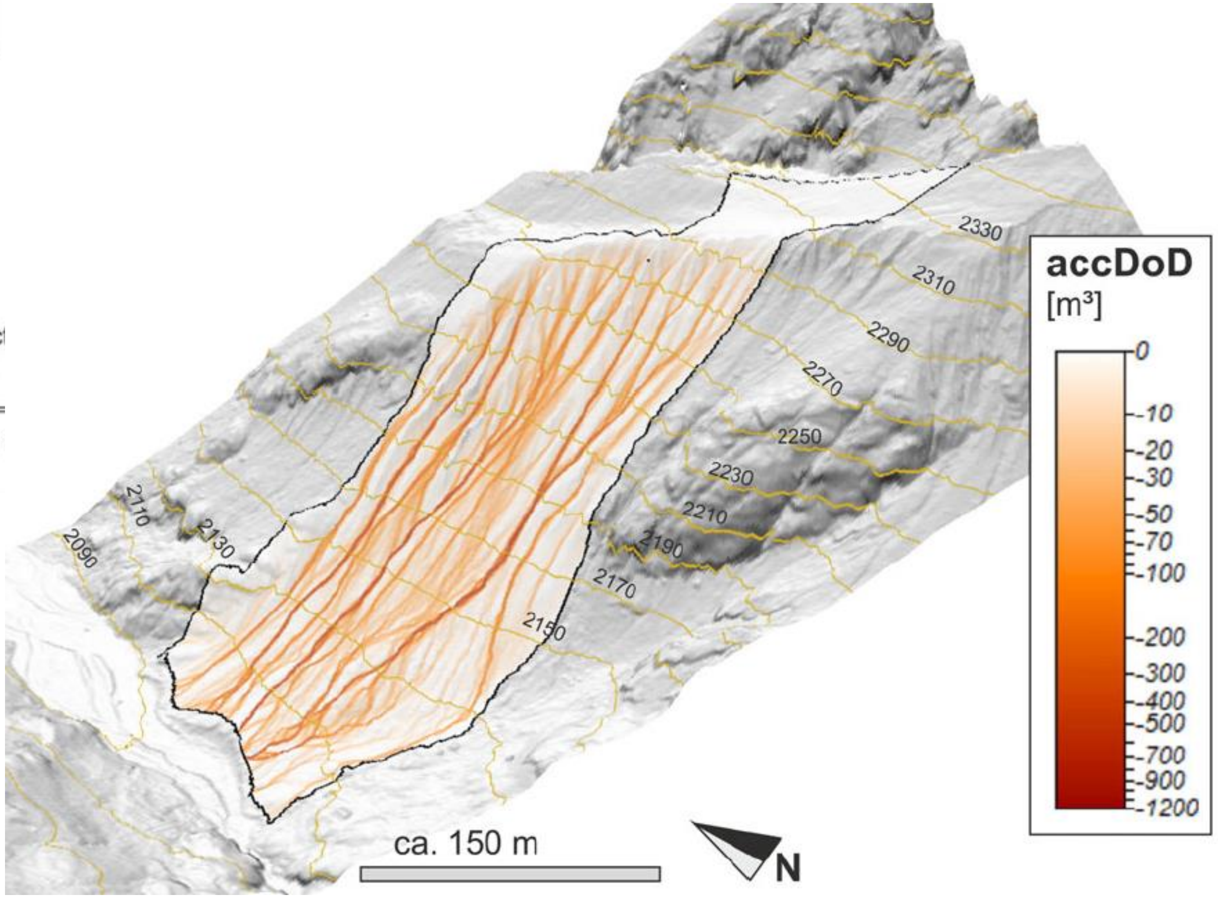




Next step: Sediment continuity and transport paths



Heckmann and Vericat, 2018

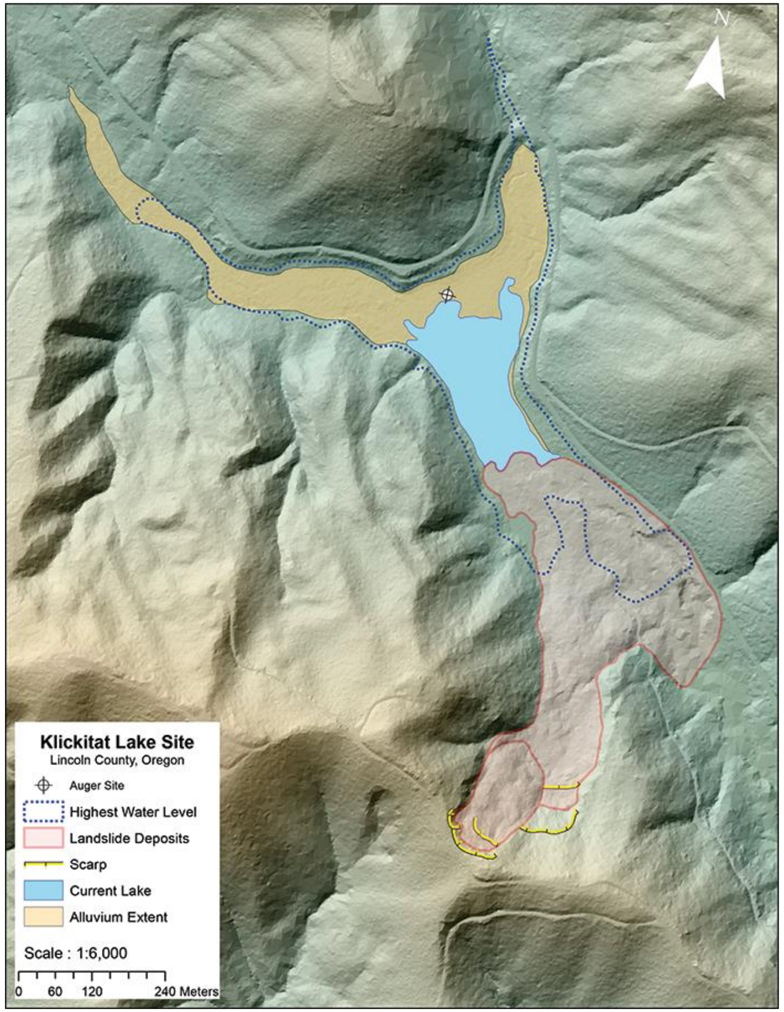


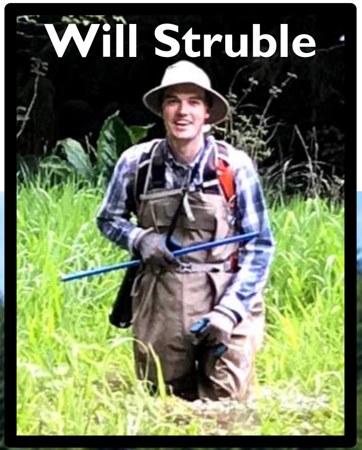
Hunting for Landslides from Cascadia’s Great Earthquakes

4) Paleoseismology

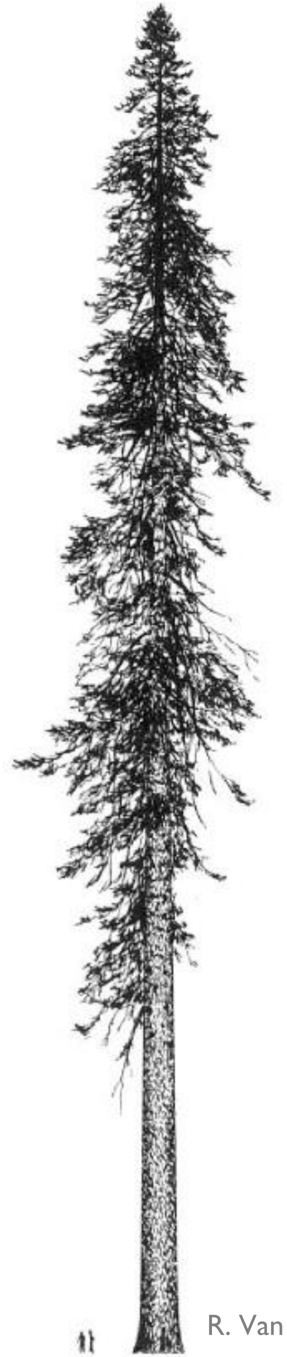
Perkins et al., Eos (Aug 8, 2018)

Researchers examine the rings of drowned trees in landslide-dammed lakes for clues to today’s earthquake hazards in the Pacific Northwest.





“The country offers singular obstacles to the study of geology…the trees are so effective in holding the soil firmly to the hillsides that it is hard to find a rock exposure or even a stone big enough to throw at a bird…This is one of those districts where the geologist must work out his map on his hands and knees.” -Clarence E. Dutton (1841-1912)



R. Van Pelt

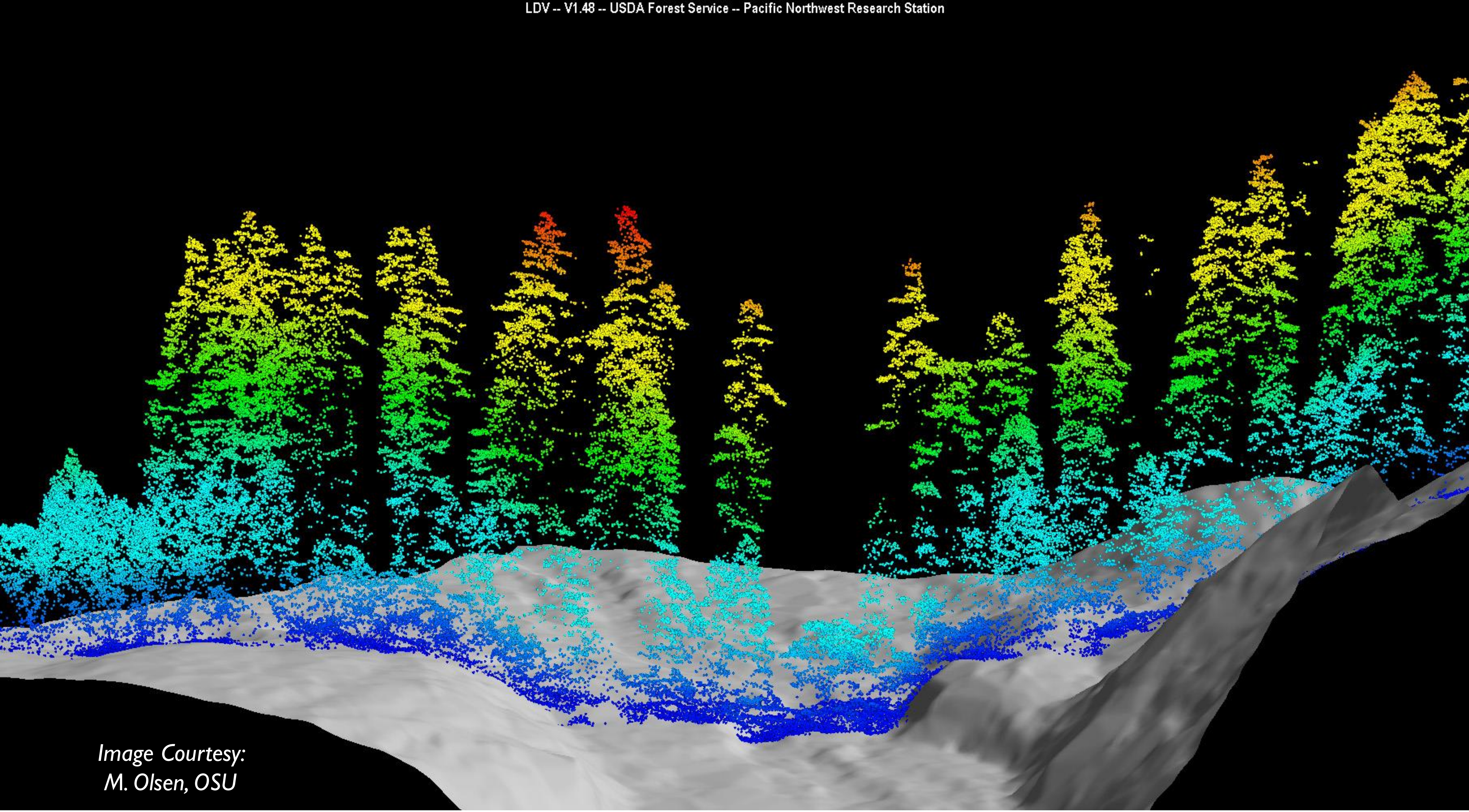


Image Courtesy:
M. Olsen, OSU