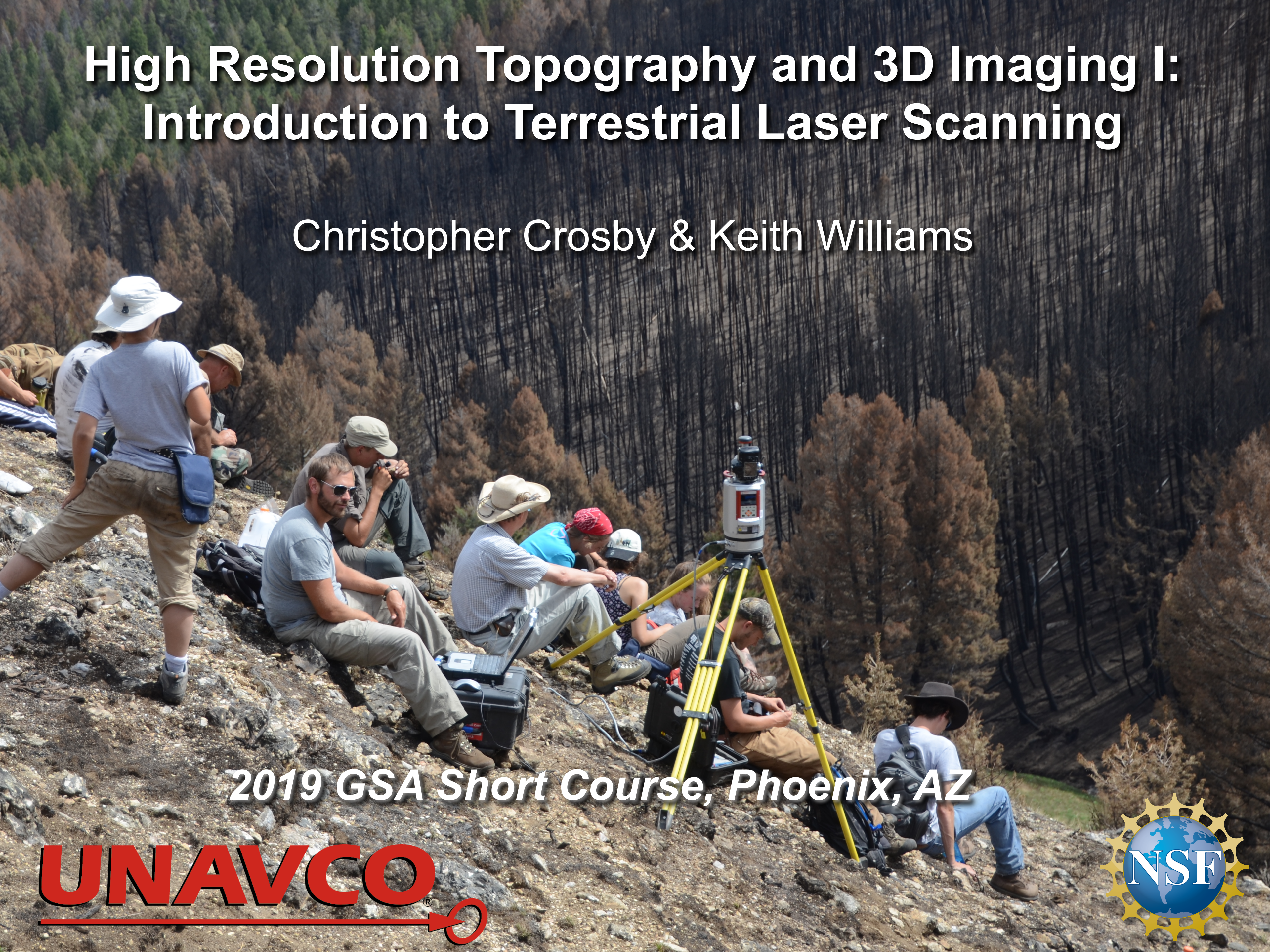
High Resolution Topography and 3D Imaging I: Introduction to Terrestrial Laser Scanning

Christopher Crosby & Keith Williams



2019 GSA Short Course, Phoenix, AZ

UNAVCO

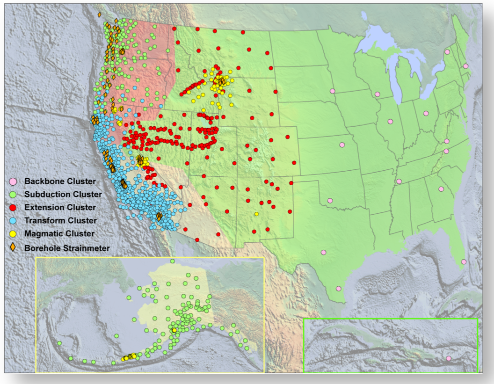
NSF

GAGE National Science Foundation's Geodetic Facility for the Advancement of Geoscience

UNAVCO is a non-profit, membership governed consortium of universities that facilitates geoscience research and education using geodesy.

UNAVCO supports GPS, borehole geophysics, InSAR, and lidar data acquisition, data archiving, equipment, development & testing, training.

UNAVCO Education & Community Engagement works to promote a broader understanding of Earth science.



Video…

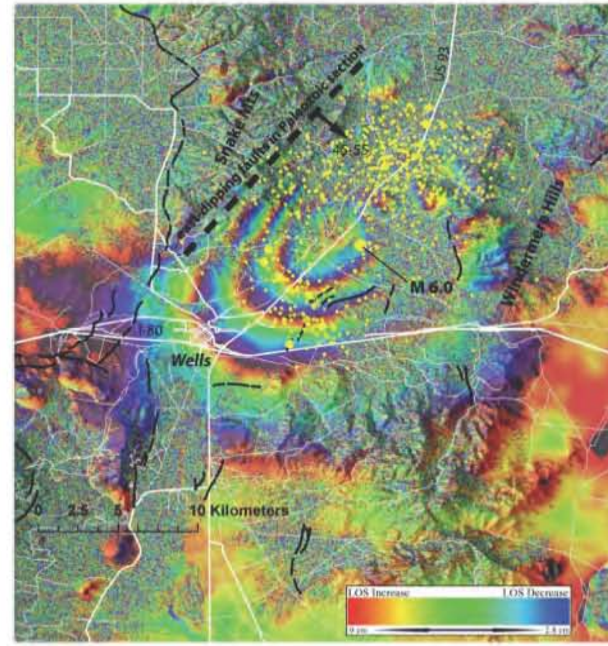
https://www.youtube.com/watch?v=yxLMk120vMU

GEODETIC IMAGING AT UNAVCO

UNAVCO

Terrestrial LiDAR

Airborne/
Spaceborne
InSAR



Airborne/
Spaceborne LiDAR

Terrestrial Radar

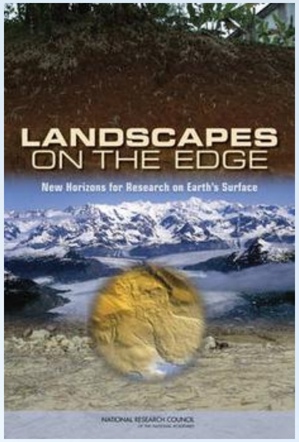
THE SCIENTIFIC VALUE OF HIGH RESOLUTION TOPOGRAPHY

National Research Council sponsored

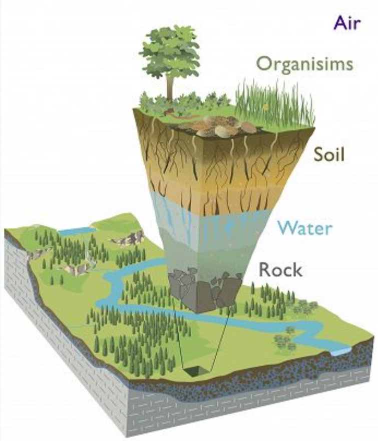
NSF communities

USGS sponsored

EXAMPLE SCIENTIFIC MOTIVATIONS



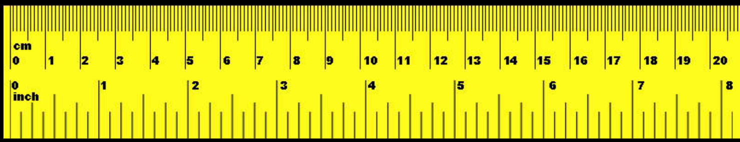
- How do geopatterns on the Earth's surface arise and what do they tell us about processes?
- How do landscapes influence and record climate and tectonics?
- What are the transport laws that govern the evolution of the Earth's surface?



- 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

“Seeing” at the appropriate scale means measuring at the right scale



Surface processes act to change elevation through erosion and deposition while tectonic processes depress or elevate the surface directly— their record is best characterized with the right fine scale.

Applies in particular to statistical self similarity

How long is the coast of Britain?
Statistical self-similarity and fractional dimension
Science: 156, 1967, 636-638

http://en.wikipedia.org/wiki/How_Long_Is_the_Coast_of_Britain%3F_Statistical_Self-Similarity_and_Fractional_Dimension

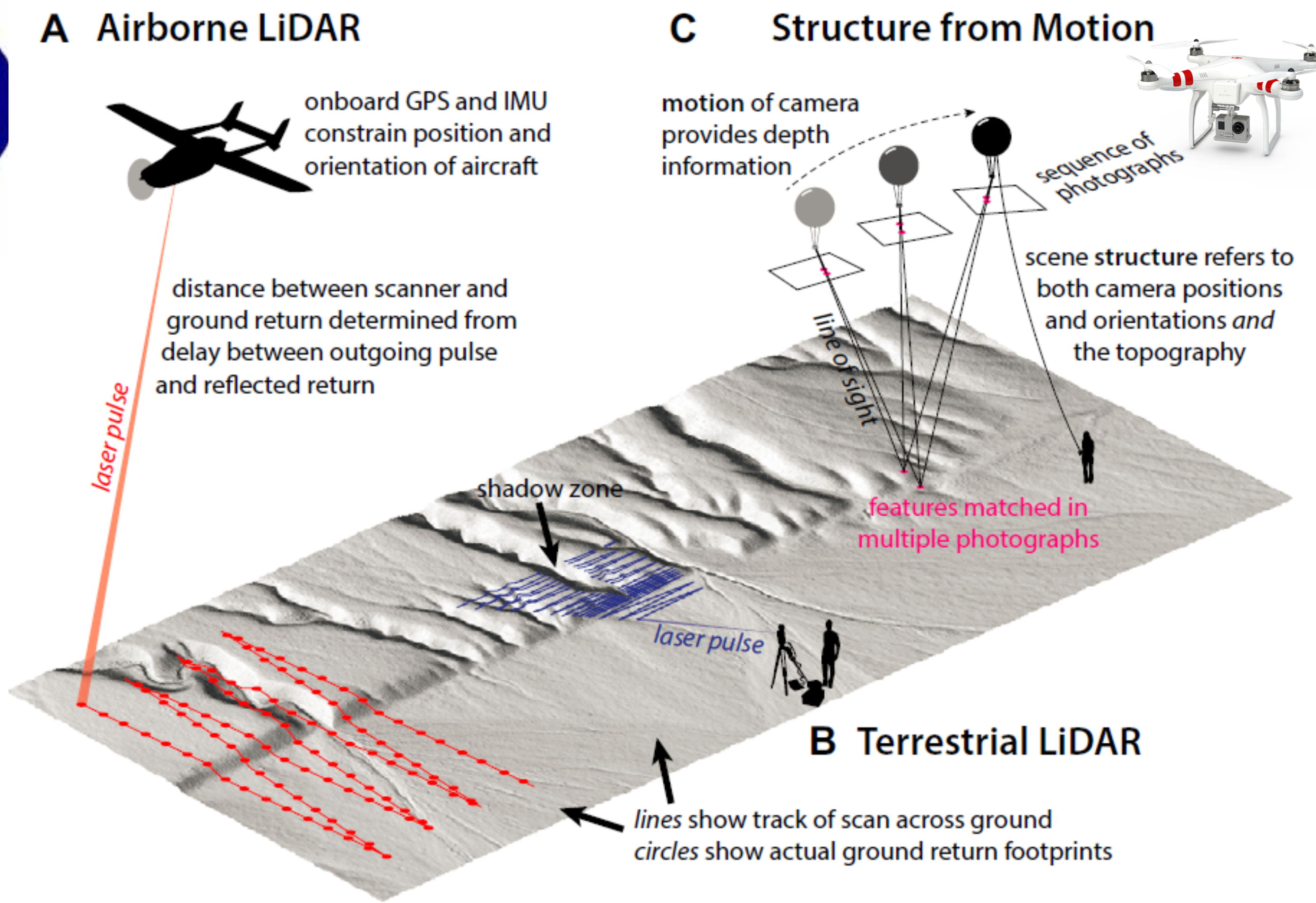
B. B. Mandelbrot

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

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

+ASTER, ALOS, etc

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.

TLS Community Support

Support Resources

- Instrumentation
- Field engineering
- Data processing
- Training
- Data archiving & dissemination

Community Building

- Workshops
- Inter-Agency collaborations & partnerships

Education and Outreach

- Training courses
- Field courses

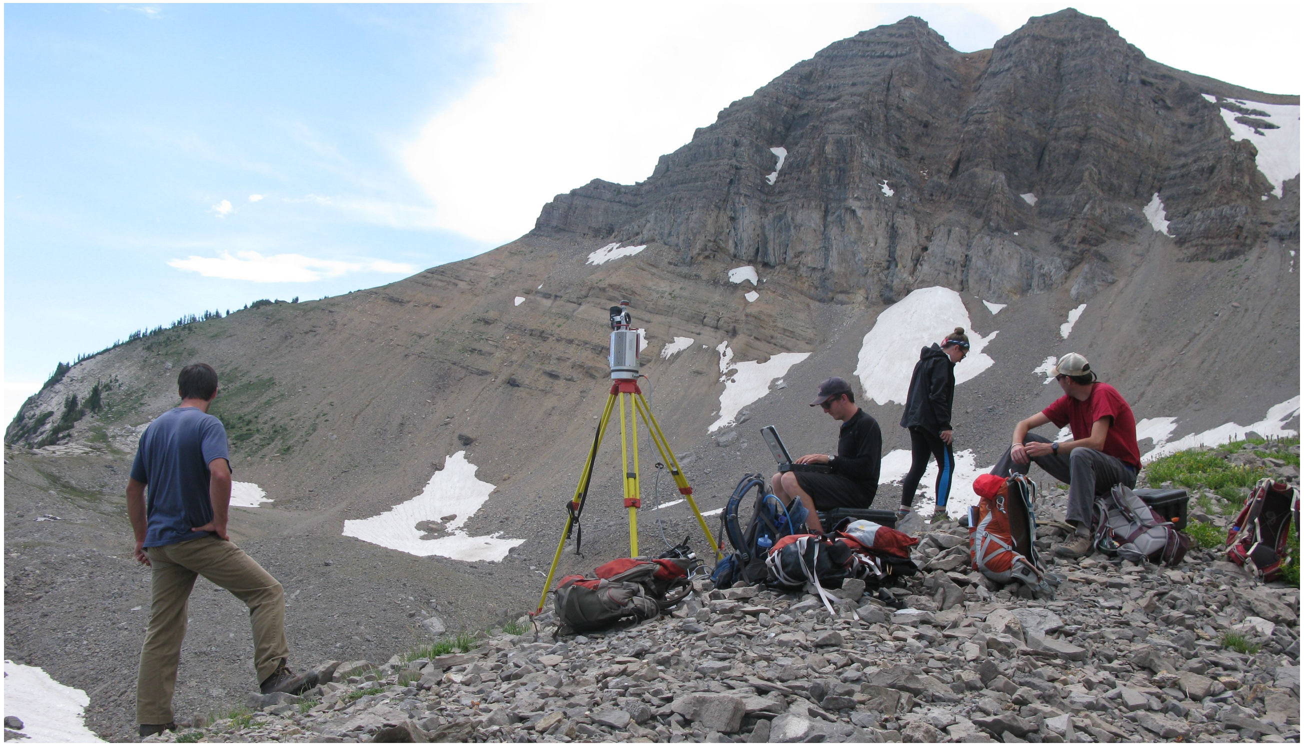
GSA 2012 UNAVCO TLS short course, Charlotte, NC

UNAVCO TLS Instrument Pool

Scanners funded by the National Science Foundation

	 **Riegl VZ-2000**	 **Riegl VZ-1000**	 **Riegl VZ-400**	 **Riegl Z620**	 **Leica C10**
Laser wavelength	Near infrared				532 nm (green)
Effective range	2050 m	1400 m	500 m	2000 m	150 m
High-speed meas. rate	396,000 pts/sec	122,000 pts/sec	125000 pts/sec	11,000 pts/sec	50,000 pts//sec
Precision	5 mm	5 mm	5 mm	10 mm	4 mm
Accuracy	8 mm	8 mm	5 mm	10 mm	6 mm
Field of view	100°x 360°	100°x 360°	100°x 360°	80°x 360°	270°x 360°
Dimensions	308 mm x 196 mm	308 mm x 180 mm	308 mm x 180 mm	463 mm x 210 mm	238 mm x 395 mm
Weight	9.9 kg	9.8 kg	9.8 kg	16 kg	13 kg

Related resources



- Campaign and RTK GPS, tripods, various power supply options
- Instrument validation range
- License server with access to RiScan Pro, Cyclone, ArcGIS, Blue Marble Geographic Calculator & Global Mapper.

Photo Nathan Niemi

Light Detection and Ranging (lidar)

- Accurate distance measurements with a laser rangefinder
- Distance is calculated by measuring the two-way travel time of a laser pulse.
- Near IR (1550nm) or green (532nm)

Photo Bruce Douglas

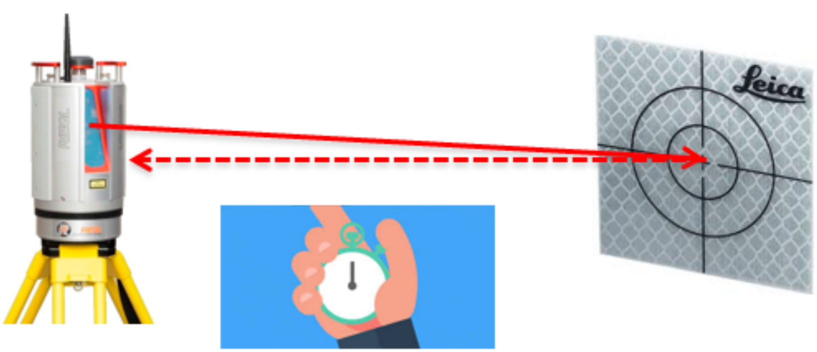
UNAVCO

How is Range measured?

Time of flight

Time it takes for emitted pulse to reflect off object and return to scanner.

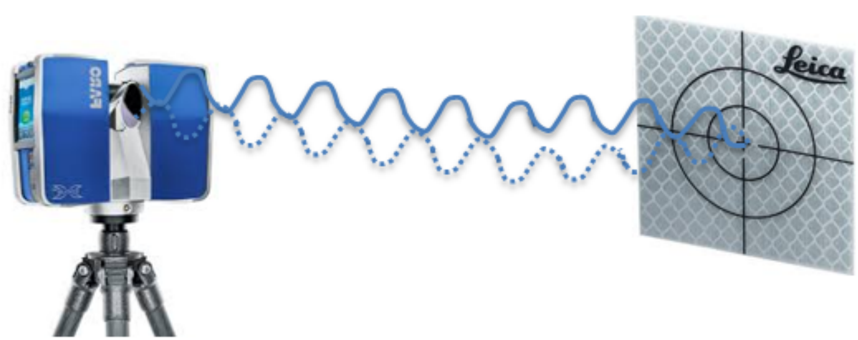
$$\mathit{Distance} = \frac{\mathit{Speed\ of\ Light\ x\ Time\ of\ Flight}}{2}$$



Phase Shift

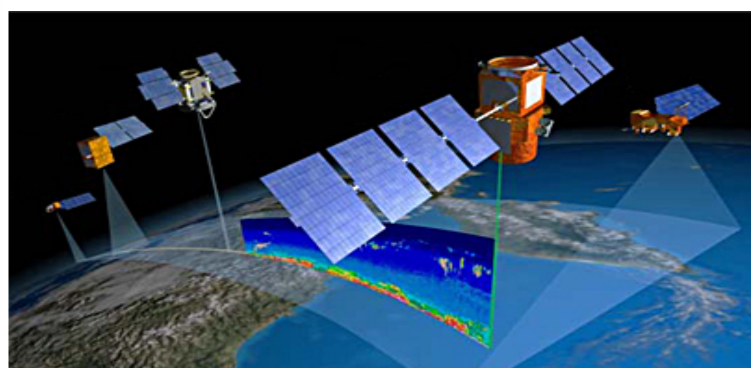
Distance is calculated along a sinusoidally modulated laser pulse.

$$\mathit{Time\ of\ Flight} = \frac{\mathit{Phase\ Shift}}{2\pi\ \mathit{x\ Modulation\ Frequency}}$$



LIDAR PLATFORMS

BUSINESS WIRE COMMERCIAL PHOTO



J. Stoker, USGS

Similar technology, different platforms:

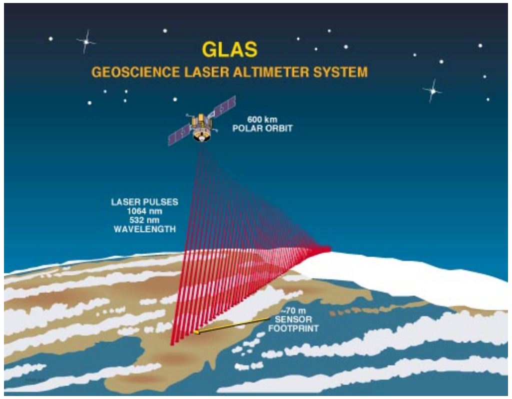
Terrestrial Laser Scanning (TLS)

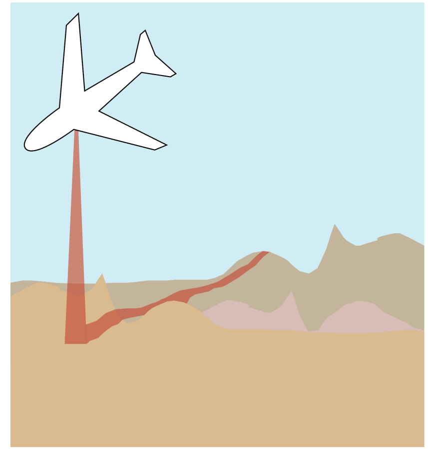
- Also called ground based lidar or T-lidar.

Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

Laser scanning from airborne platform = Airborne Laser Scanning (ALS).

Light Detection and Ranging (lidar)

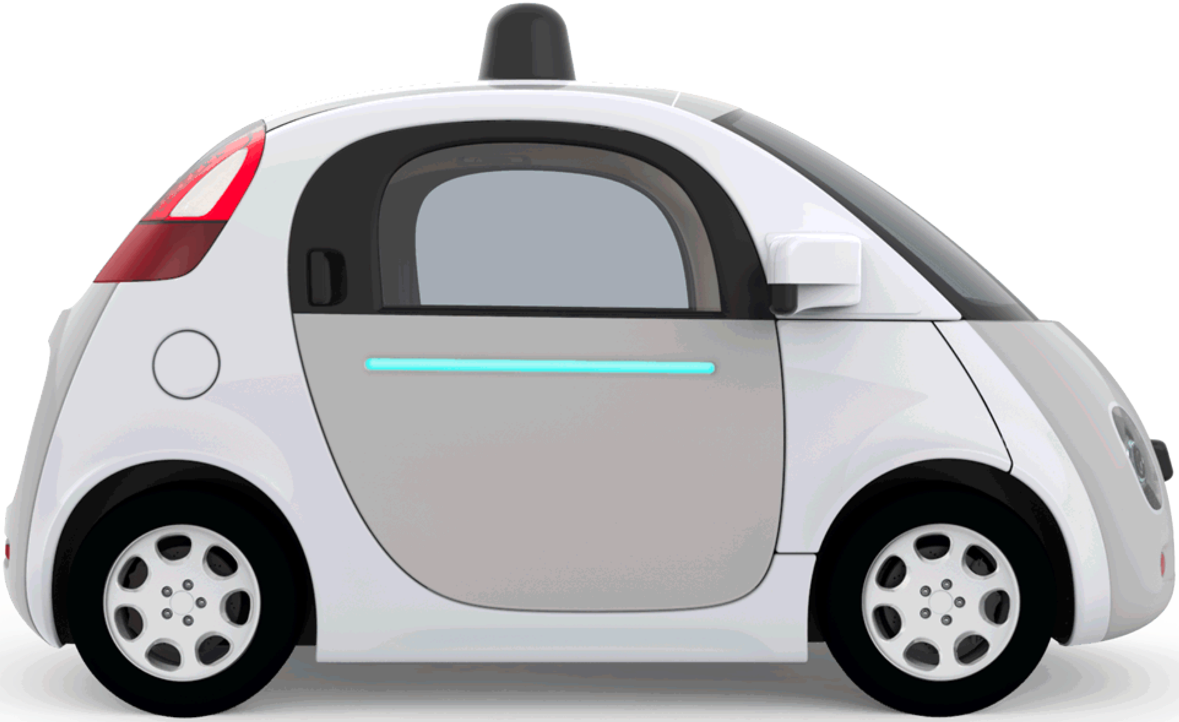




System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1–10 cm
Vertical Accuracy	15cm to 10m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1–10 cm Depends on range, which is few meters to 2 km or more

GLAS/ICESAT

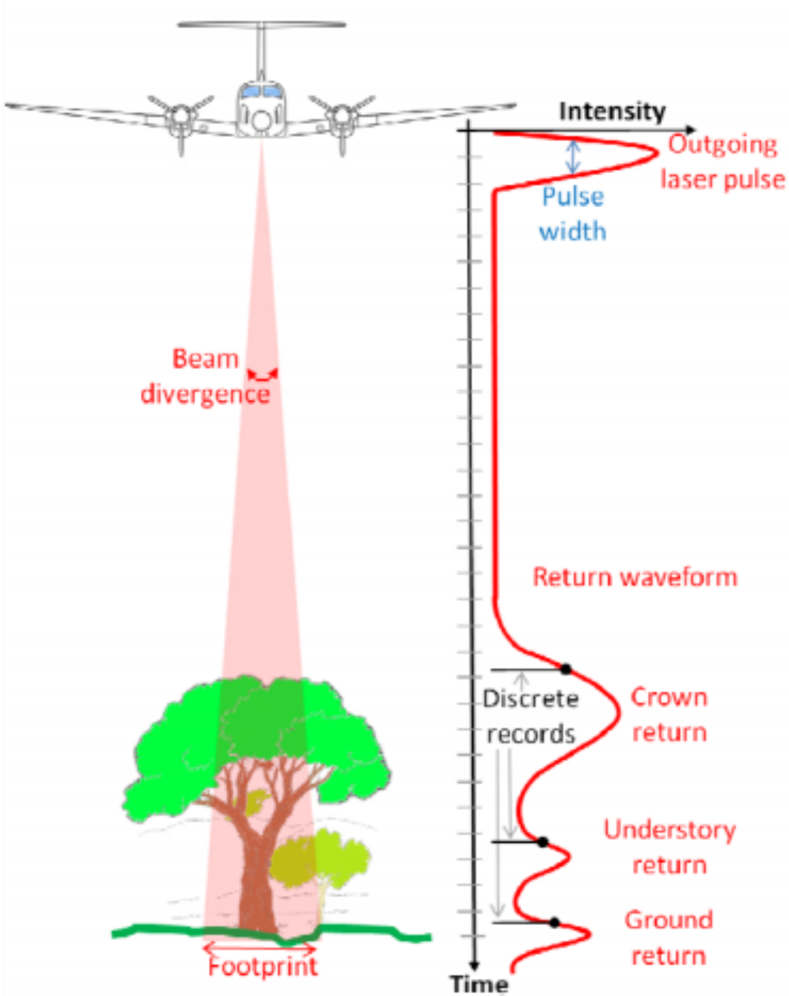
Lidar & Autonomous Vehicles



Lidar & Autonomous Vehicles

Sight Lines, ScanLAB: https://vimeo.com/145248208

DISCRETE PULSE AND FULL WAVEFORM LIDAR



Discrete pulse = binary yes or no return. Only location of return is saved.

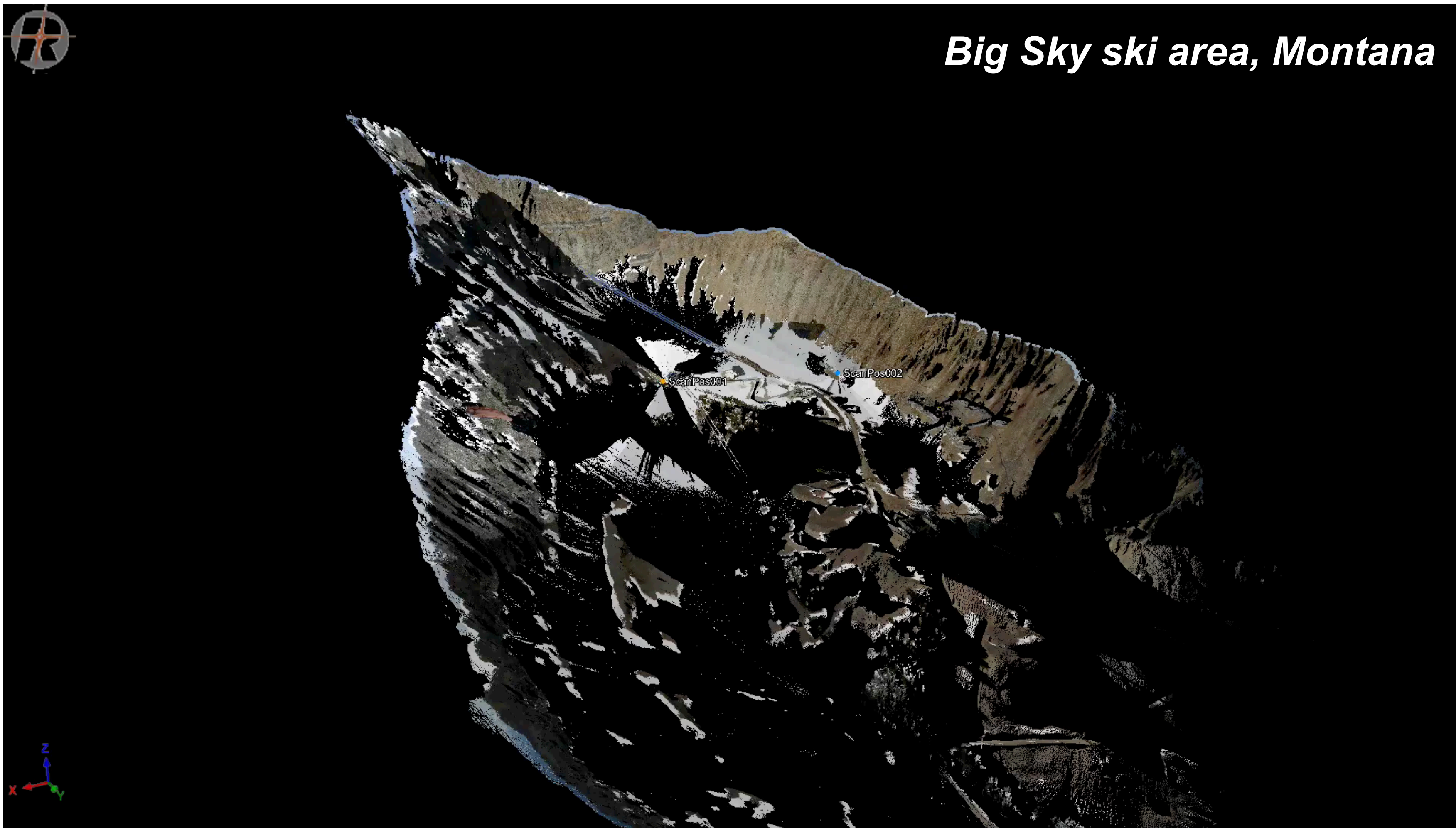
Full waveform = digitized backscatter waveform. Saves the full return energy signature

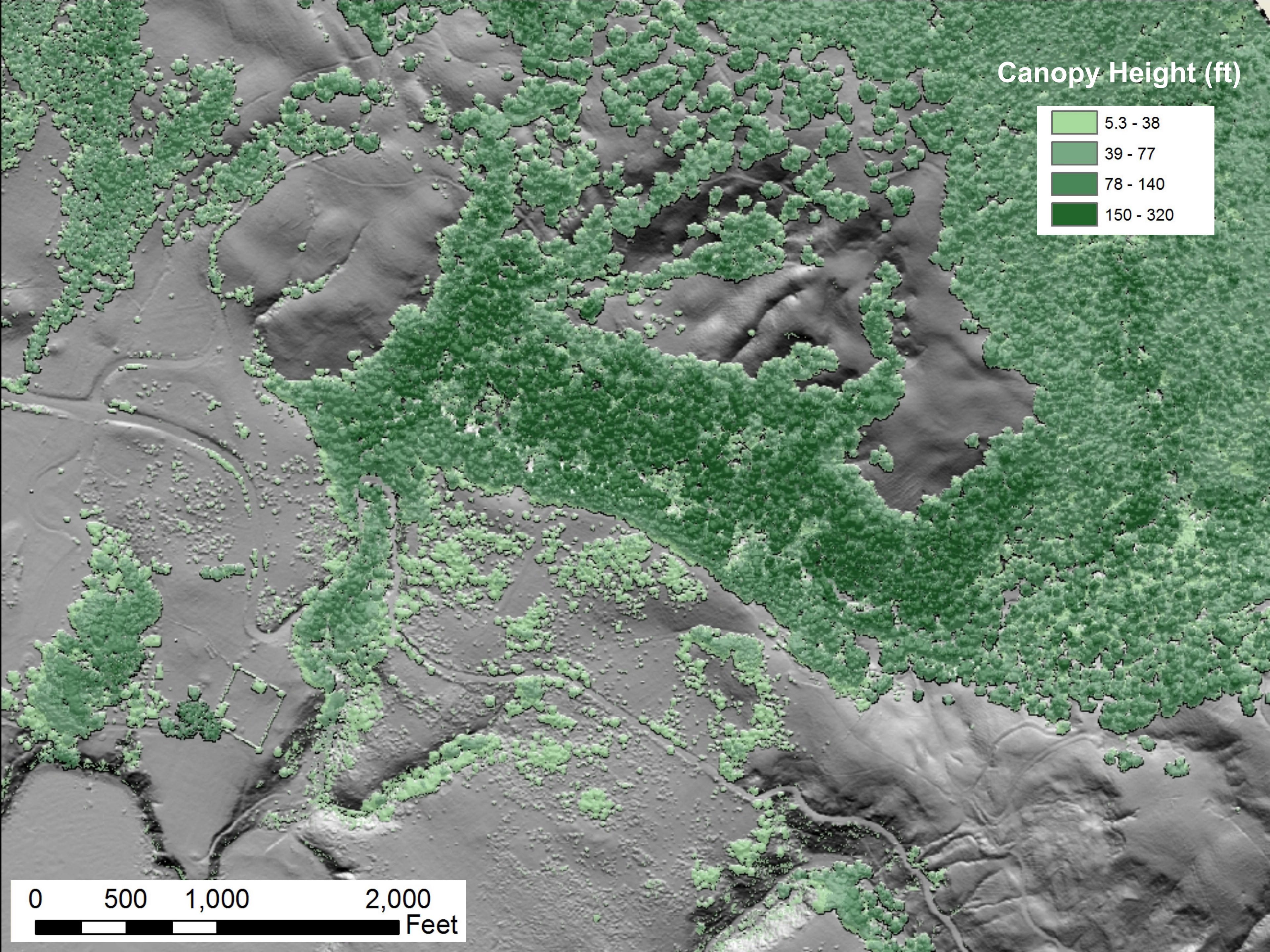
Data size / processing time vs. enhanced information

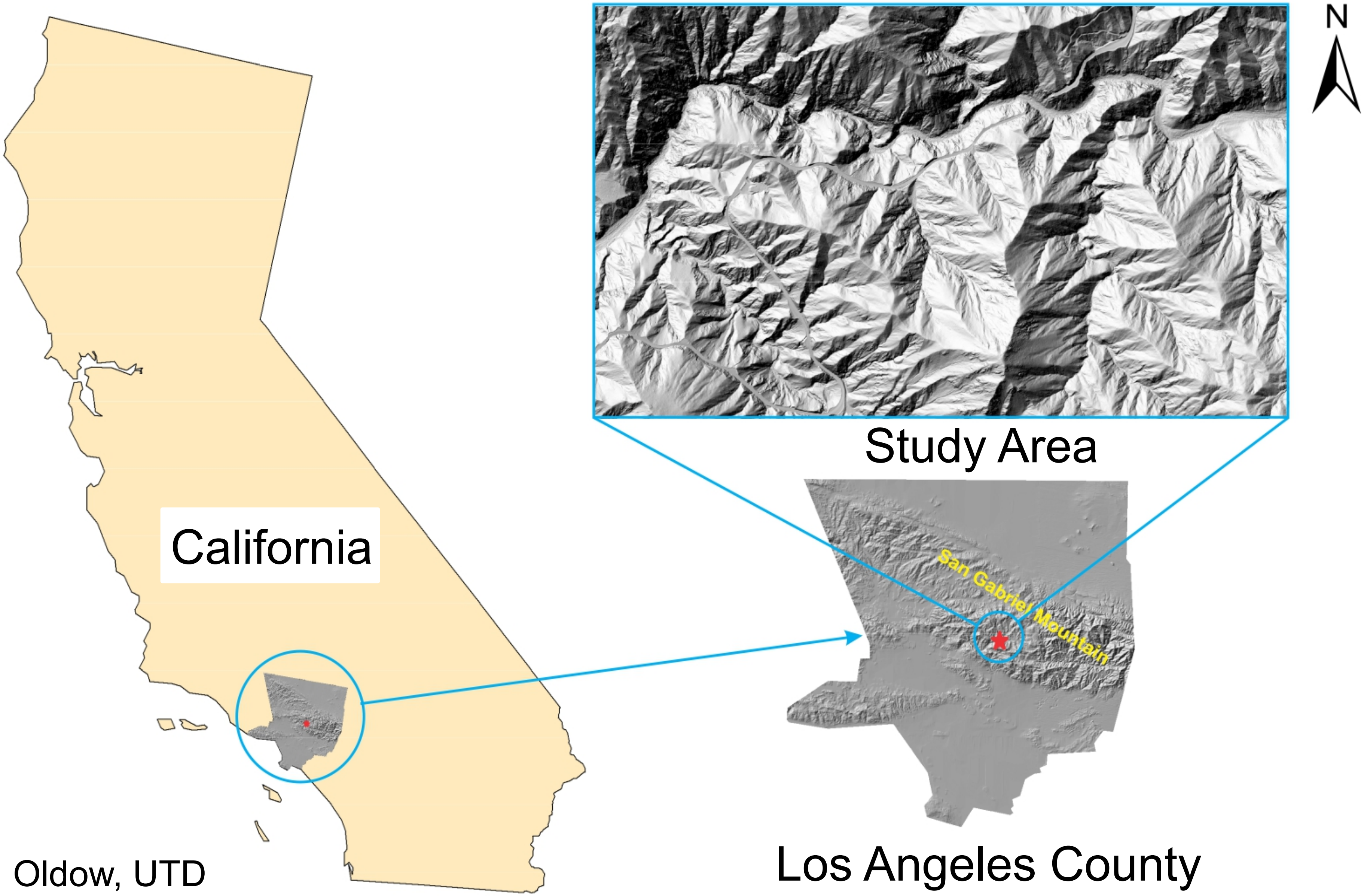
T. Goulden, NEON

LIDAR DATA DELIVERABLES

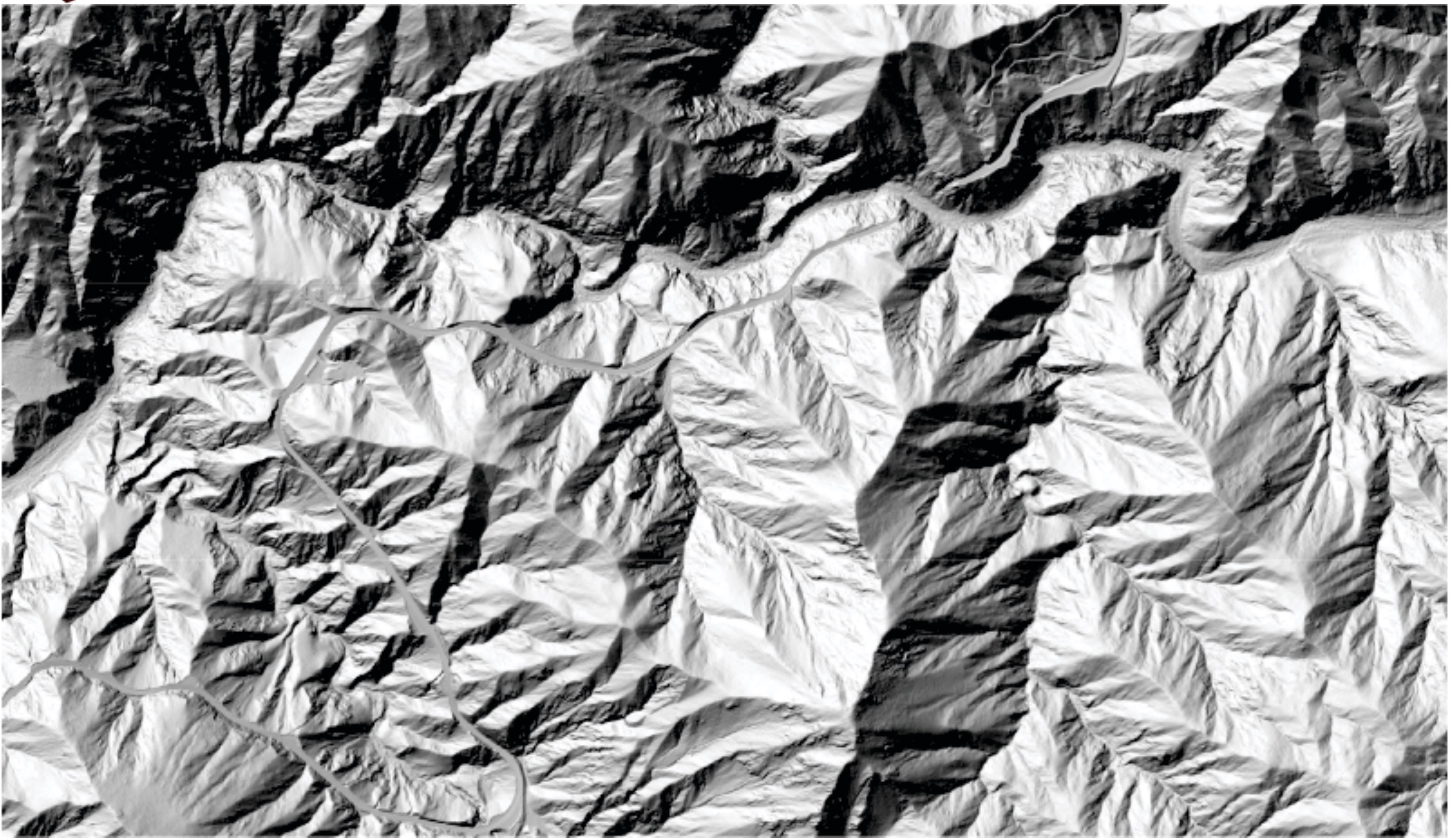
A ***point cloud*** is the fundamental lidar dataset – discrete x,y,z points with attributes (Intensity, return number & number of returns, classification, gps time, RGB…):




Canopy Height (ft)
5.3 - 38
39 - 77
78 - 140
150 - 320
0
500
1,000
2,000
Feet


N
Study Area
California
San Gabriel Mountain
Los Angeles County

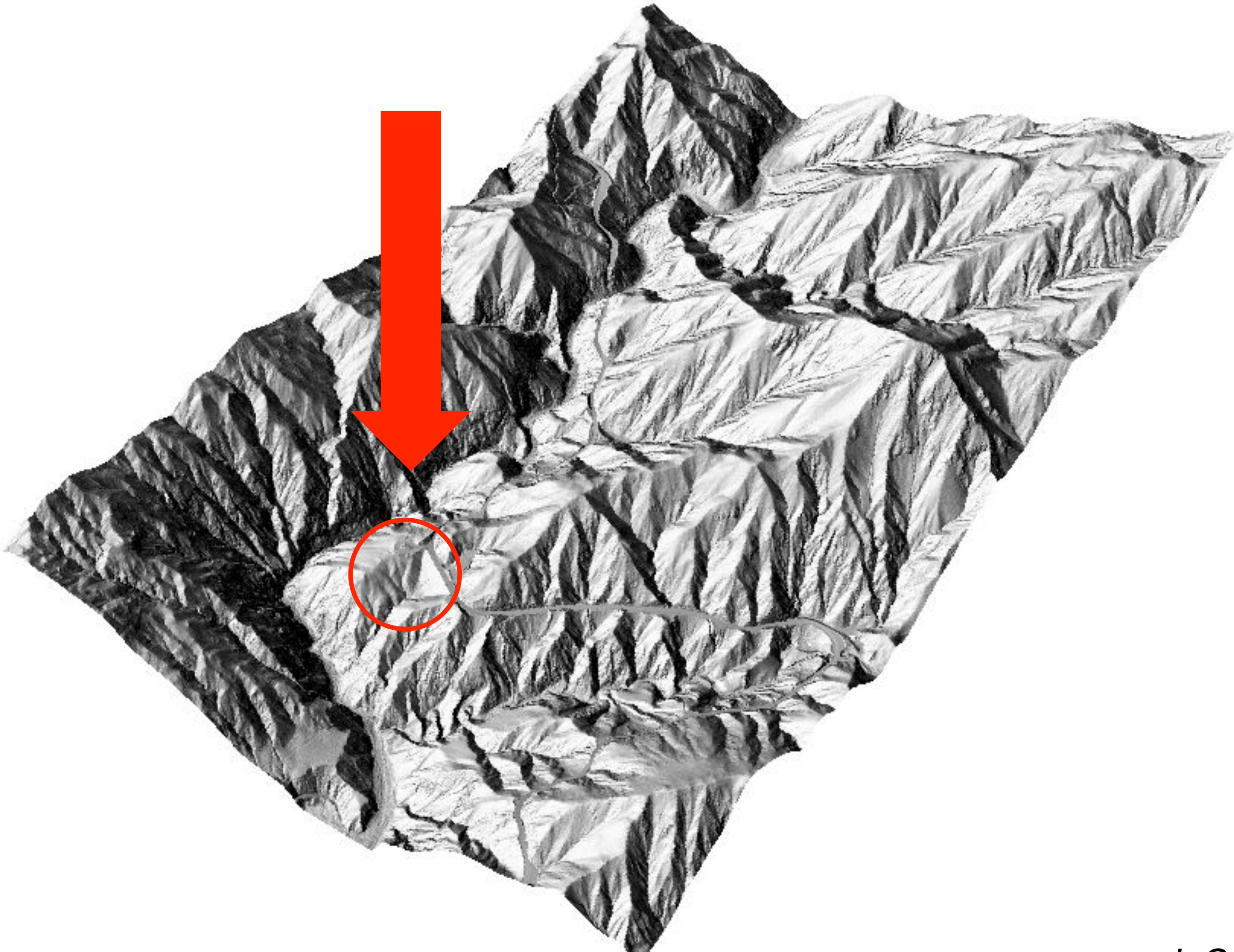
J. Oldow, UTD



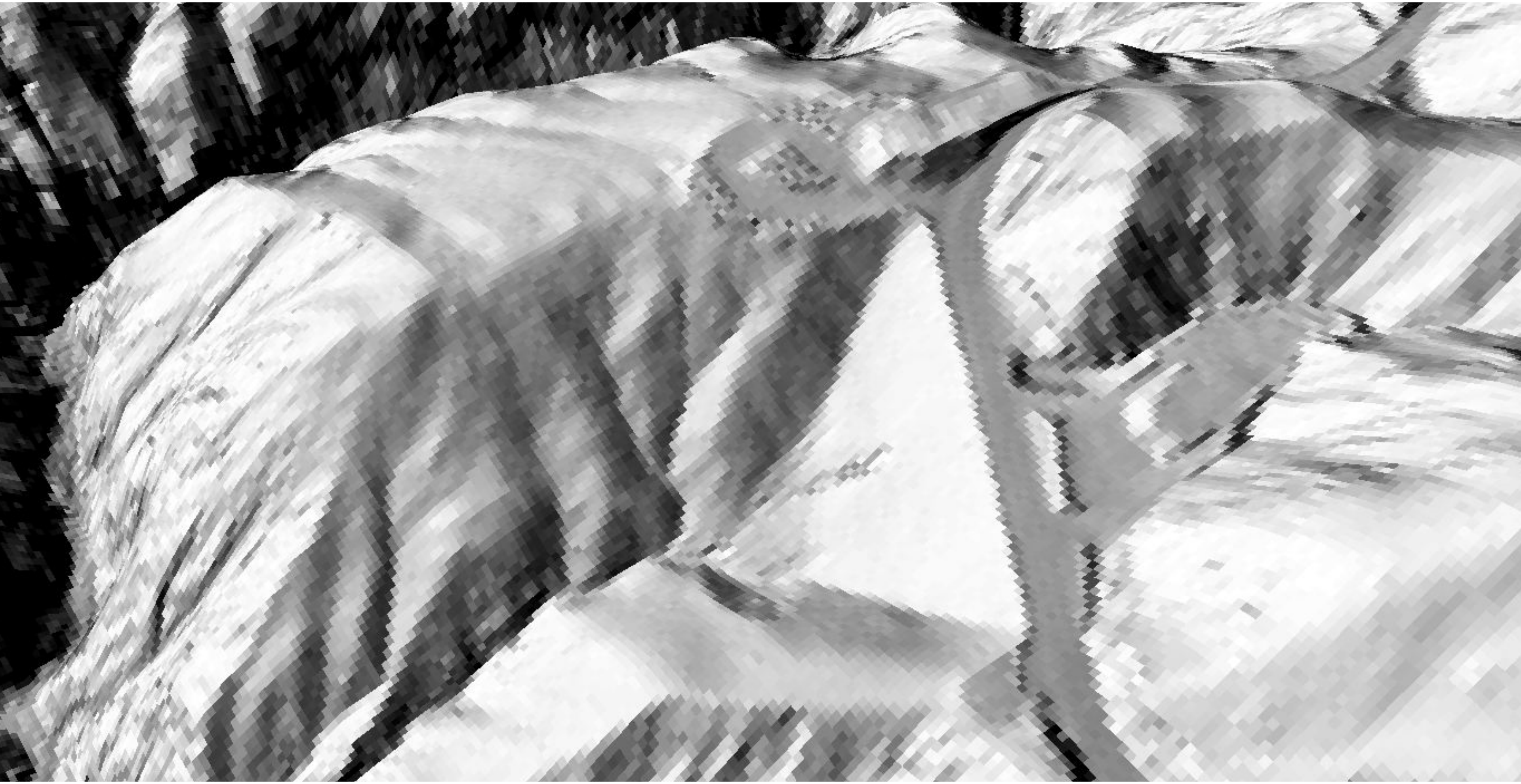
San Gabriel Mountain 1-m DEM from airborne lidar

J. Oldow, UTD

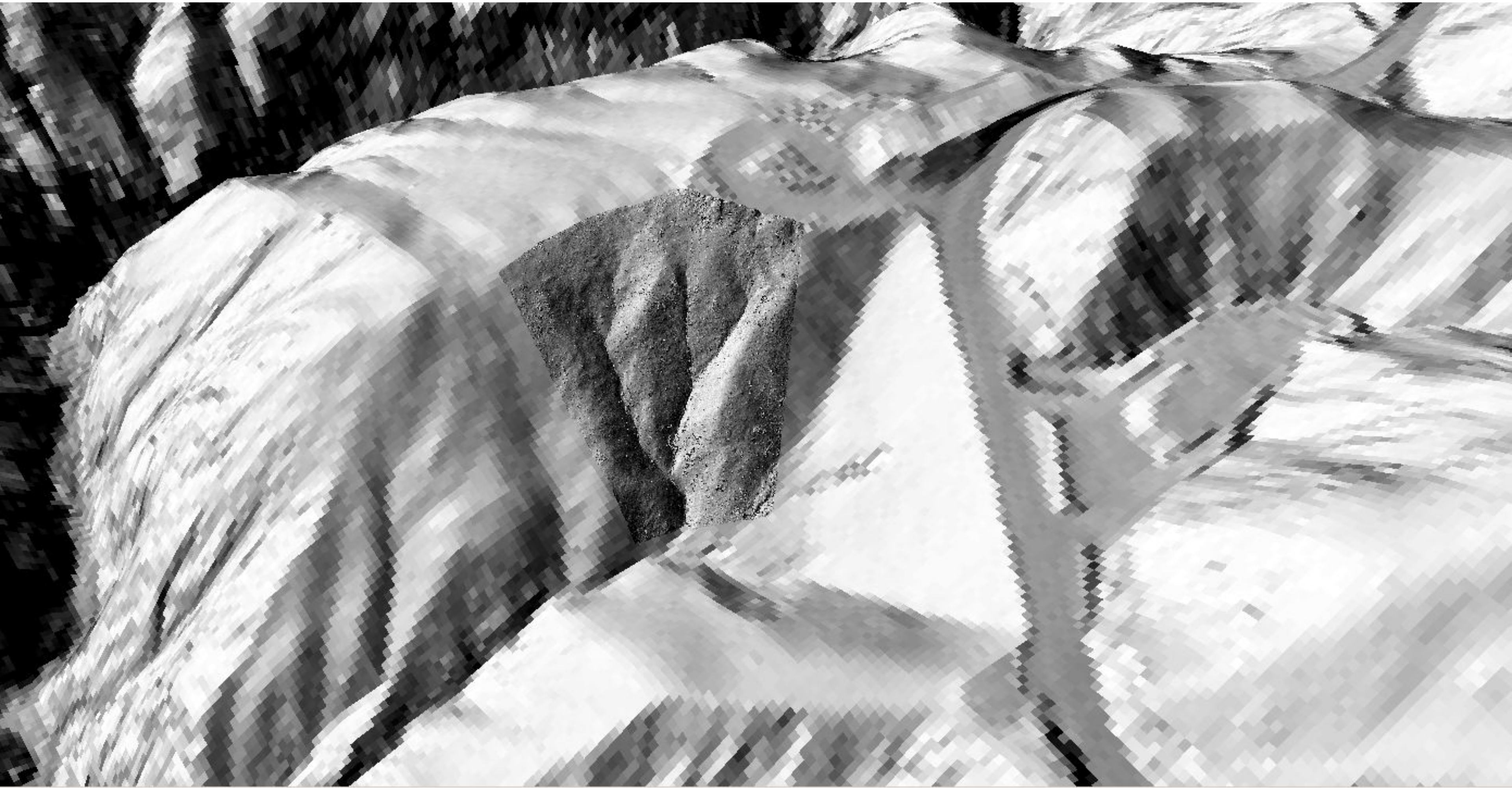
J. Oldow, UTD



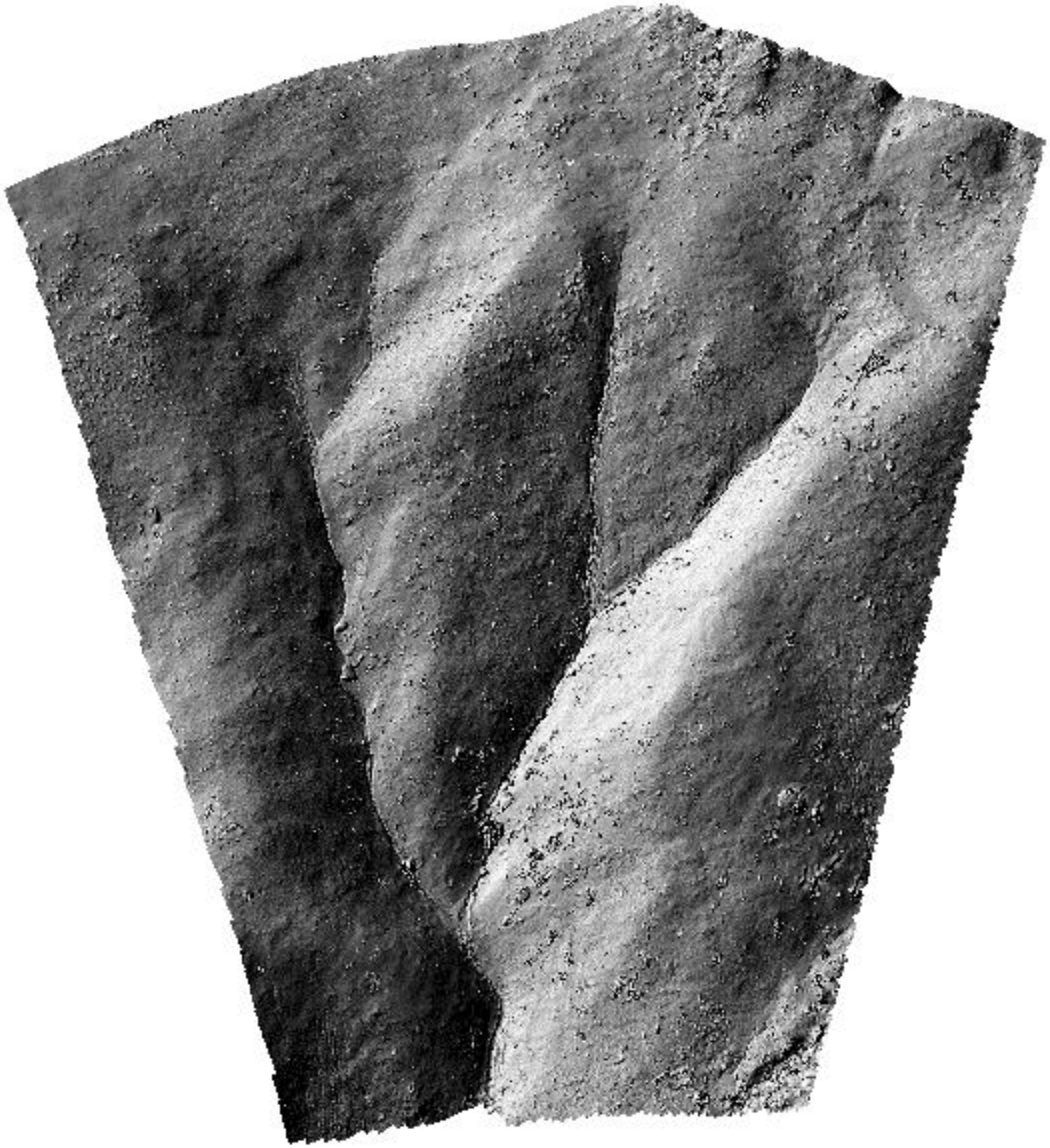
J. Oldow, UTD



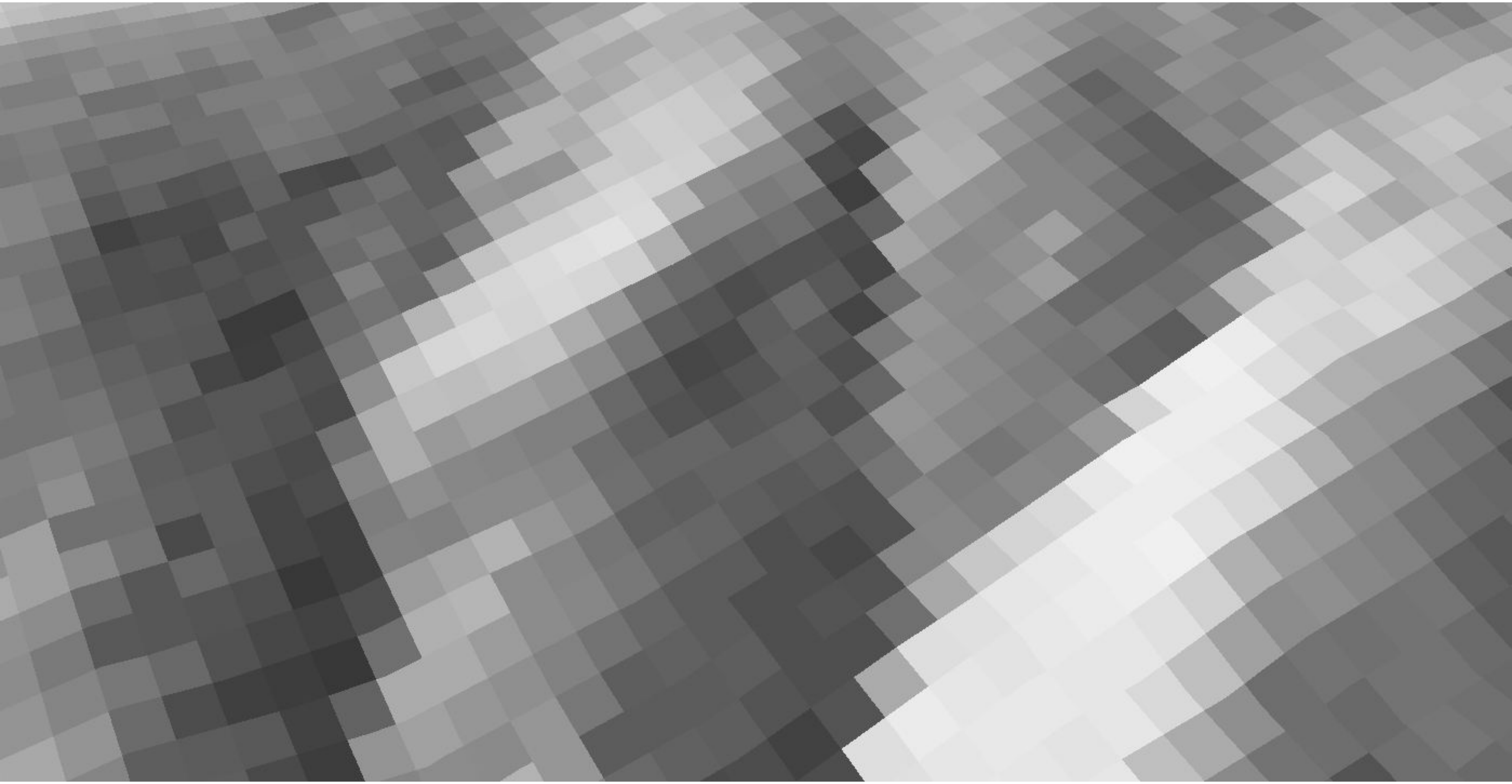
J. Oldow, UTD



J. Oldow, UTD



J. Oldow, UTD



J. Oldow, UTD

J. Oldow, UTD

Showcase Video for TLS

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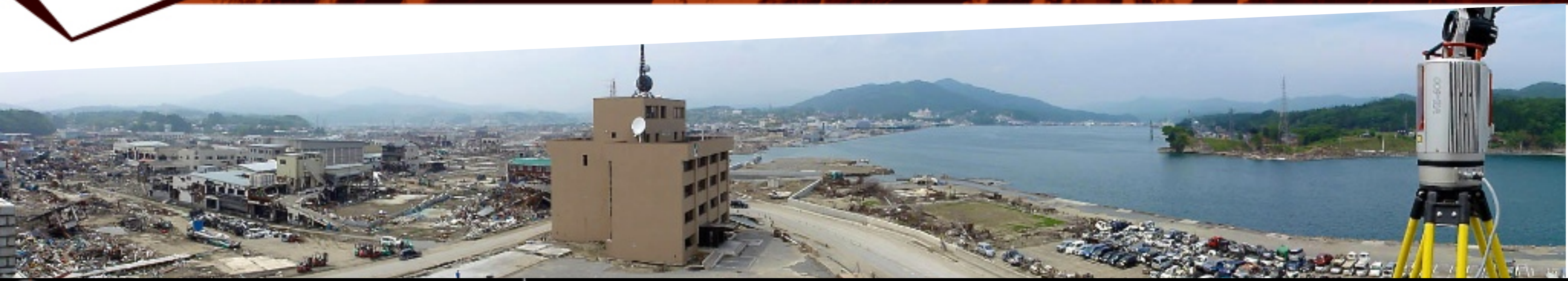
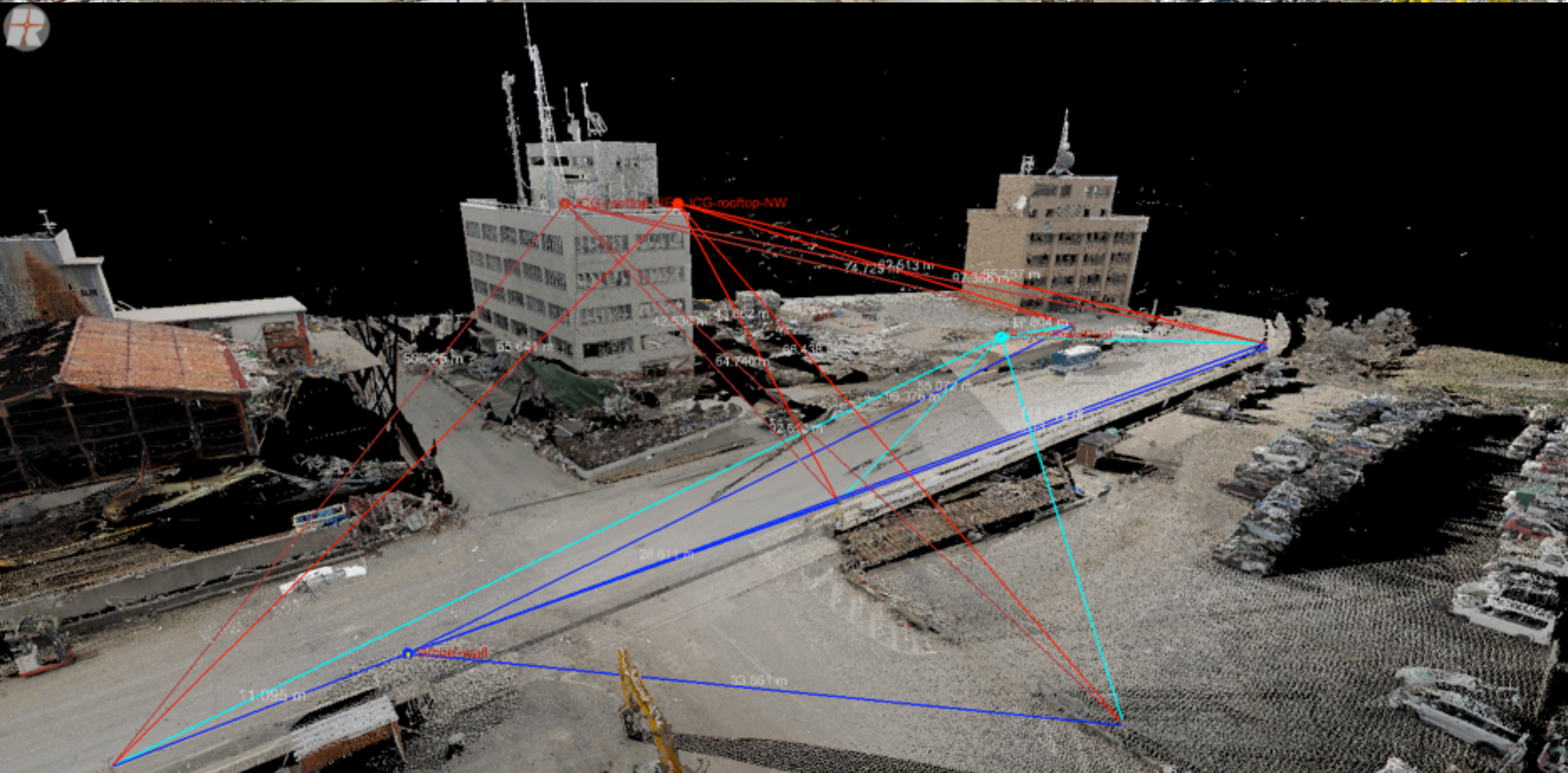
TLS Research Applications

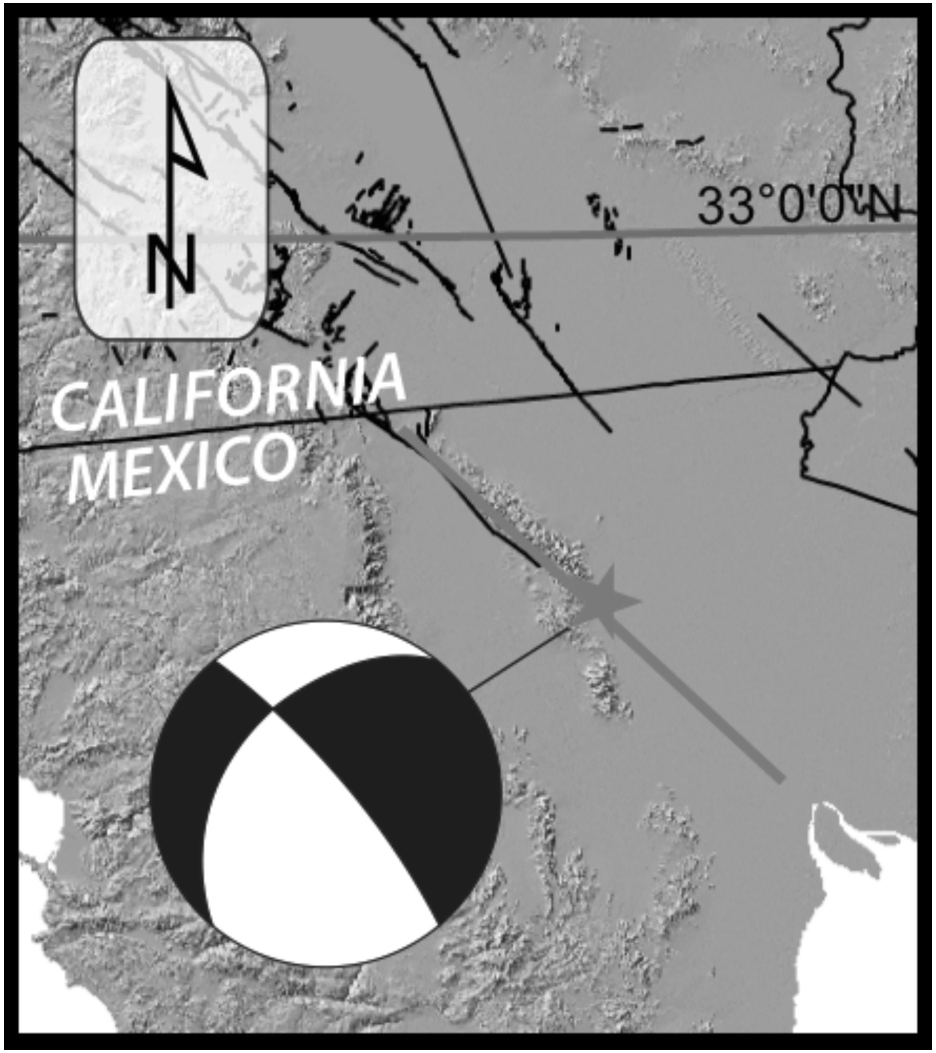
- Project: 2011 Japan Tsunami measurements
- PI: Hermann Fritz (Georgia Tech)
- NSF RAPID project

2011 Japan Tsunami





El Mayor-Cucapah Earthquake

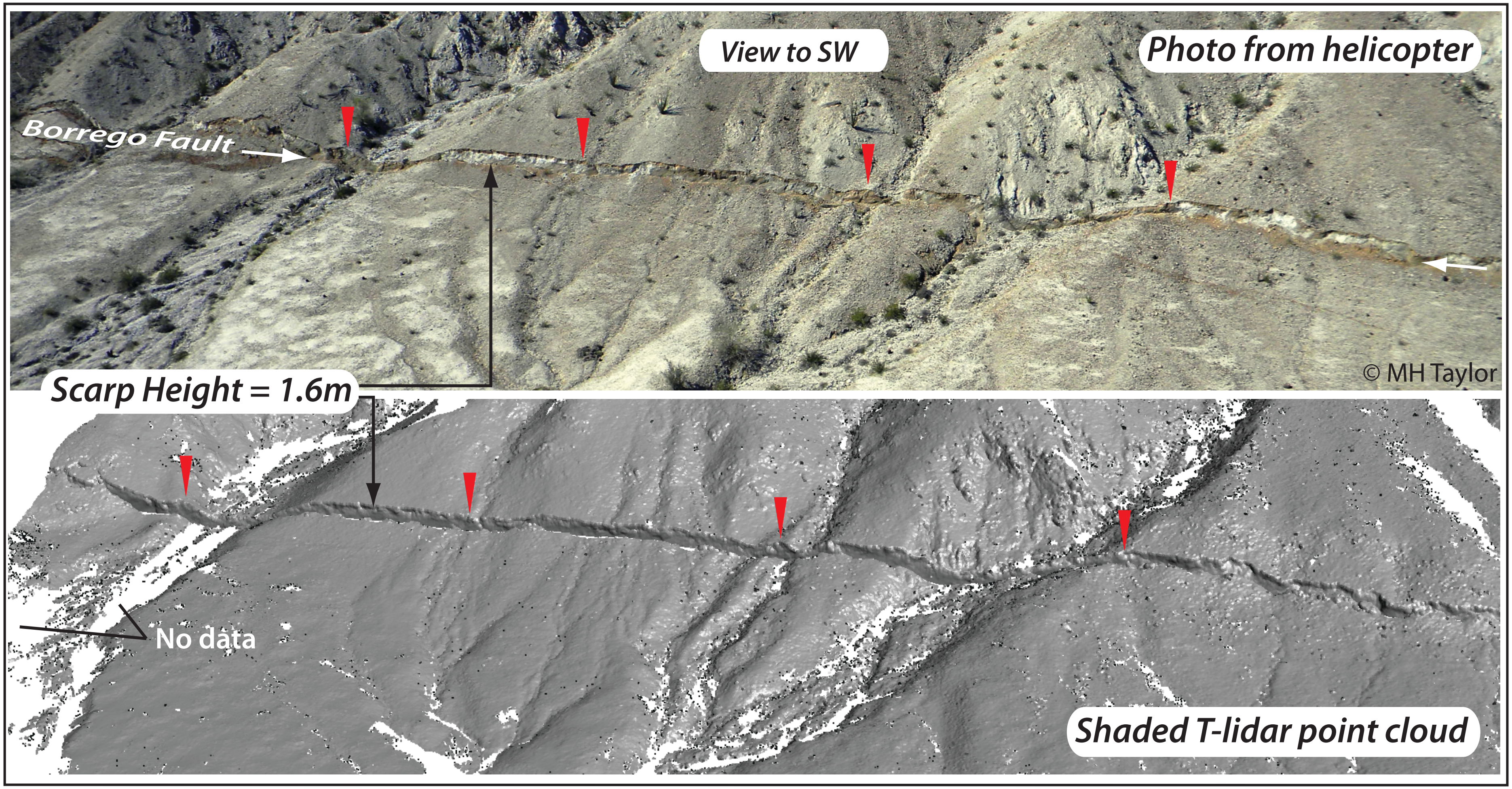


- April 4, 2010
- Mw 7.2
- ~100km rupture
- CA-Mexico border to the gulf

- > 3m right-normal slip north of epicenter
- < 1m right-normal blind faulting south of epicenter

P. Gold, UCD

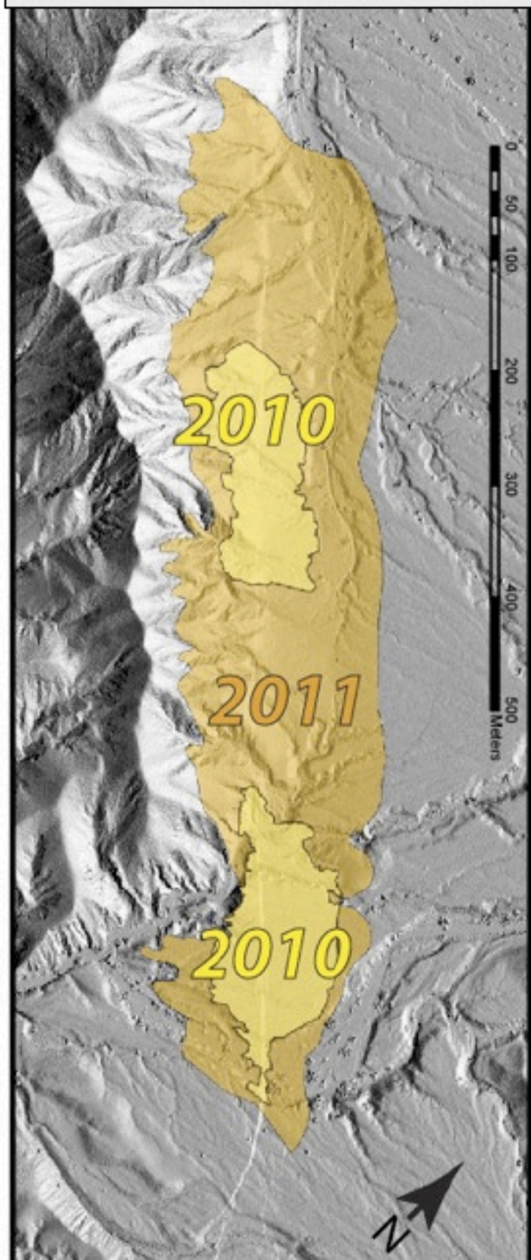
TLS coverage

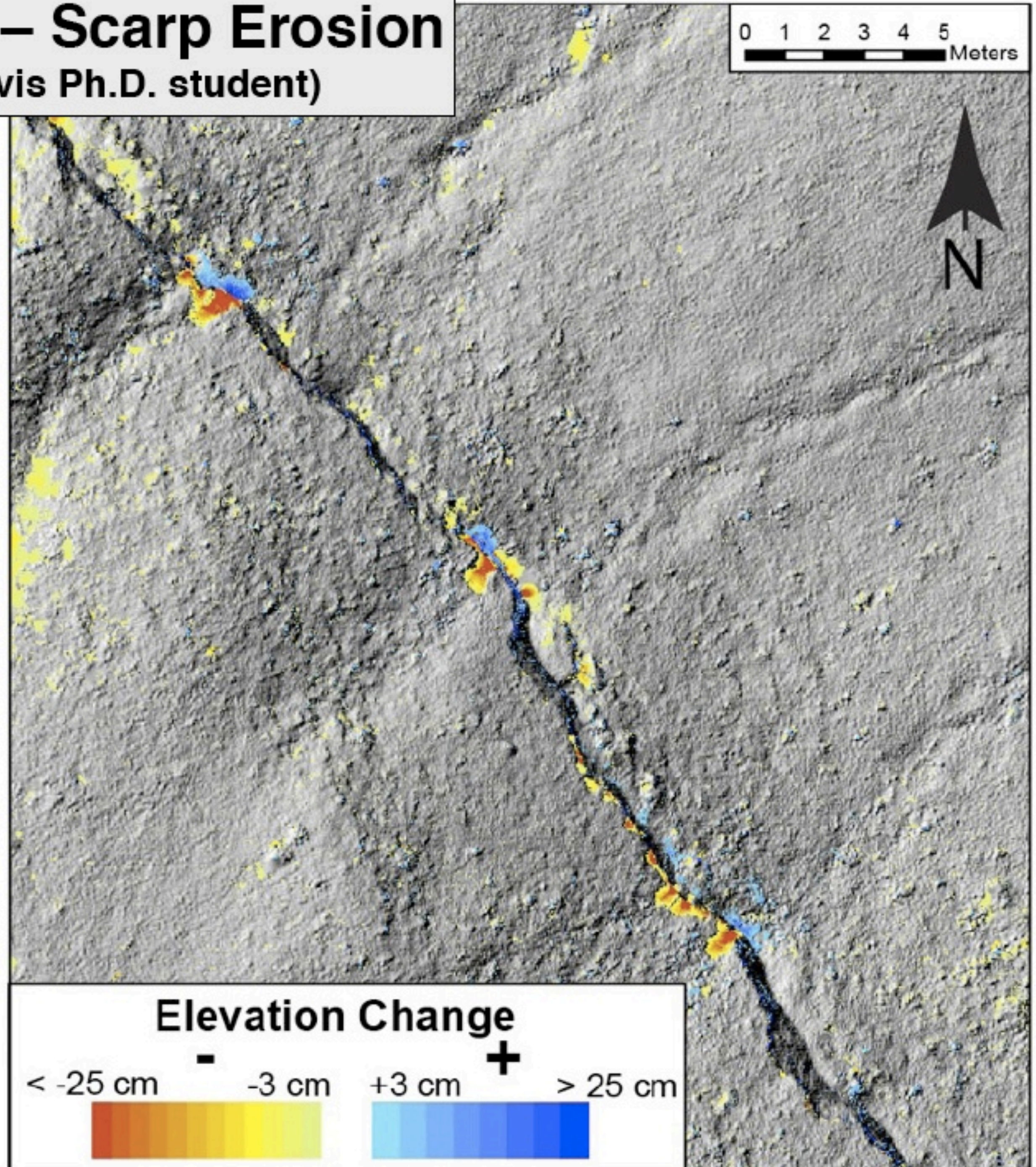


P. Gold, UCD

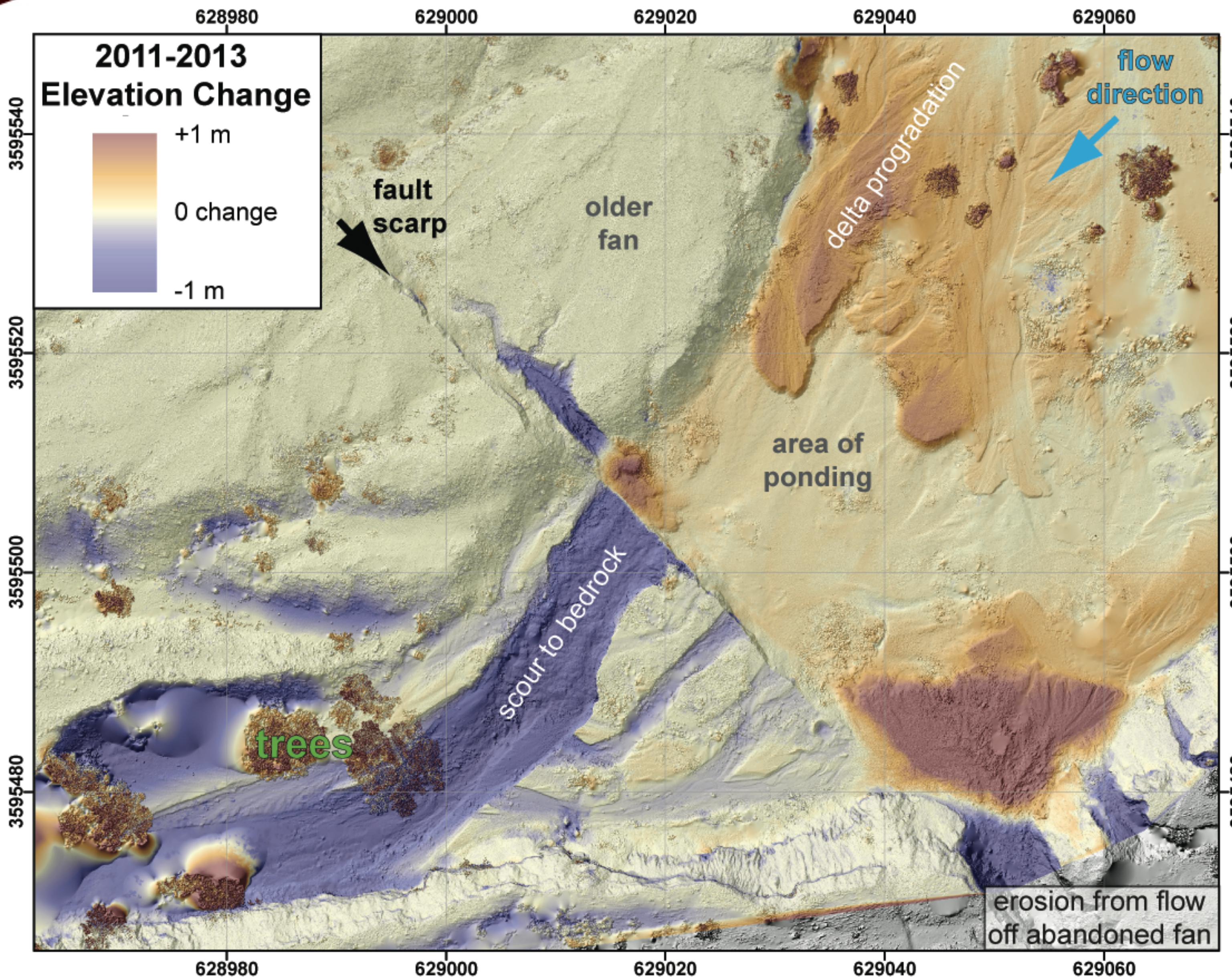
Change Detection – Scarp Erosion

Austin Elliott (UC Davis Ph.D. student)

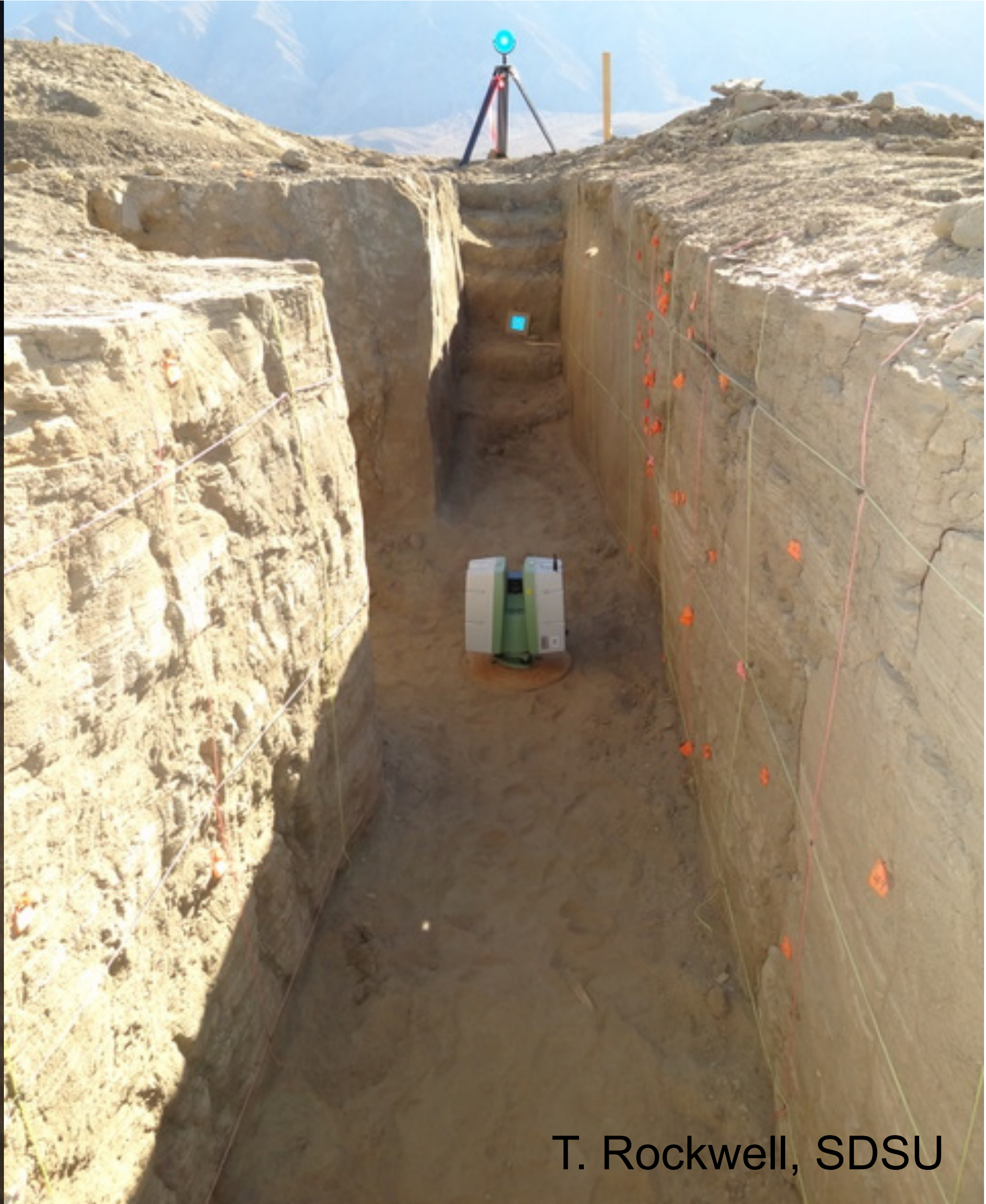




Scarp Erosion, 2010



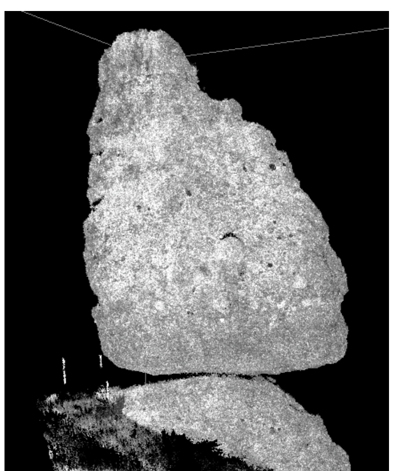
Paleoseismology

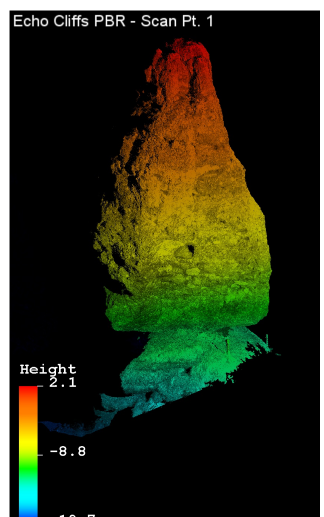


T. Rockwell, SDSU

Precariously Balanced Rocks, PBRs

- Project Highlight: Precariously balanced rock (PBR) near Echo Cliffs, southern California.
- PI: Ken Hudnut, USGS.
- Goal: generate precise 3D image of PBR in order to calculate PBR's center of gravity for ground motion models useful for paleoseismology, urban planning, etc.





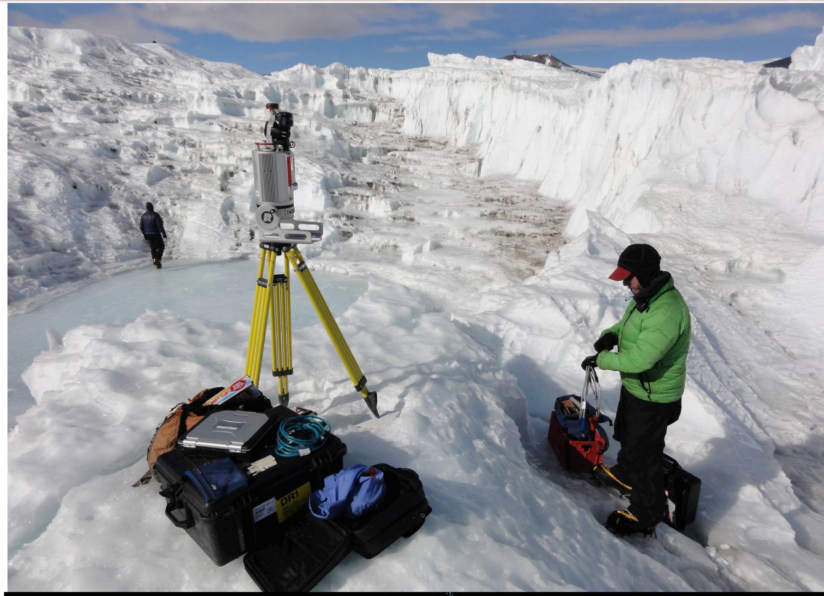
(Hudnut et al., 2009)

Four Mile Fire Erosion, Boulder, CO

Rengers et al., 2016, JGR Earth Surface

Scanning in Polar Environments

- 10–15 Antarctic and Arctic projects/year
- Remote locations, challenging logistics (helicopter, icebreaker, backpack)
- Extreme environmental conditions:
  - -35C to +15C, 20–65 knot winds

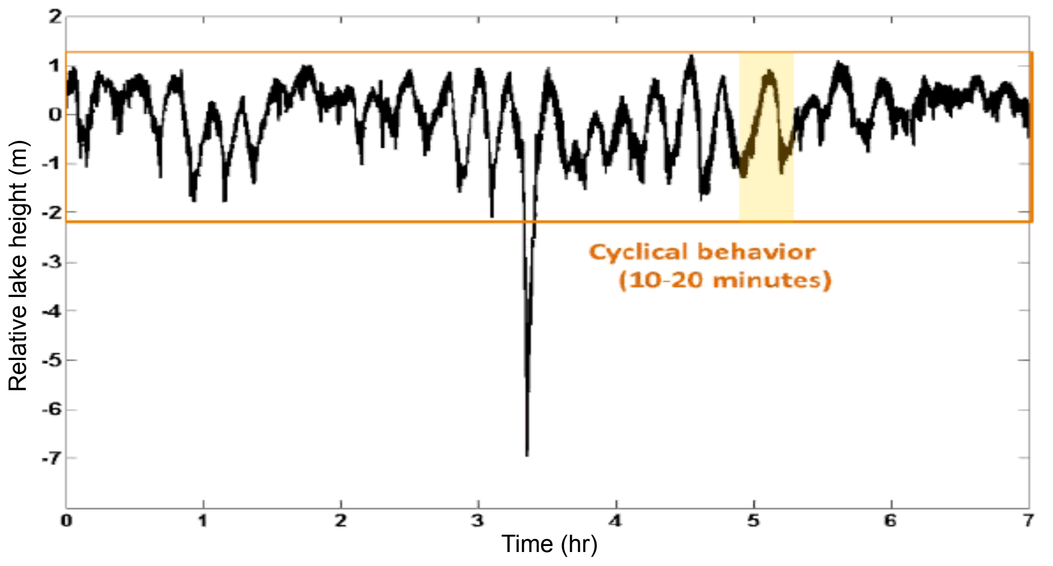


Science:

- *Geomorphology:* Frost polygons and ancient lake beds
- *Glaciology:* Glacier melt and ablation
- *Biology/Ecology:* Weddell Seal volume; Microtopology of tundra in Alaska
- *Archaeology:* Human impact of climate change

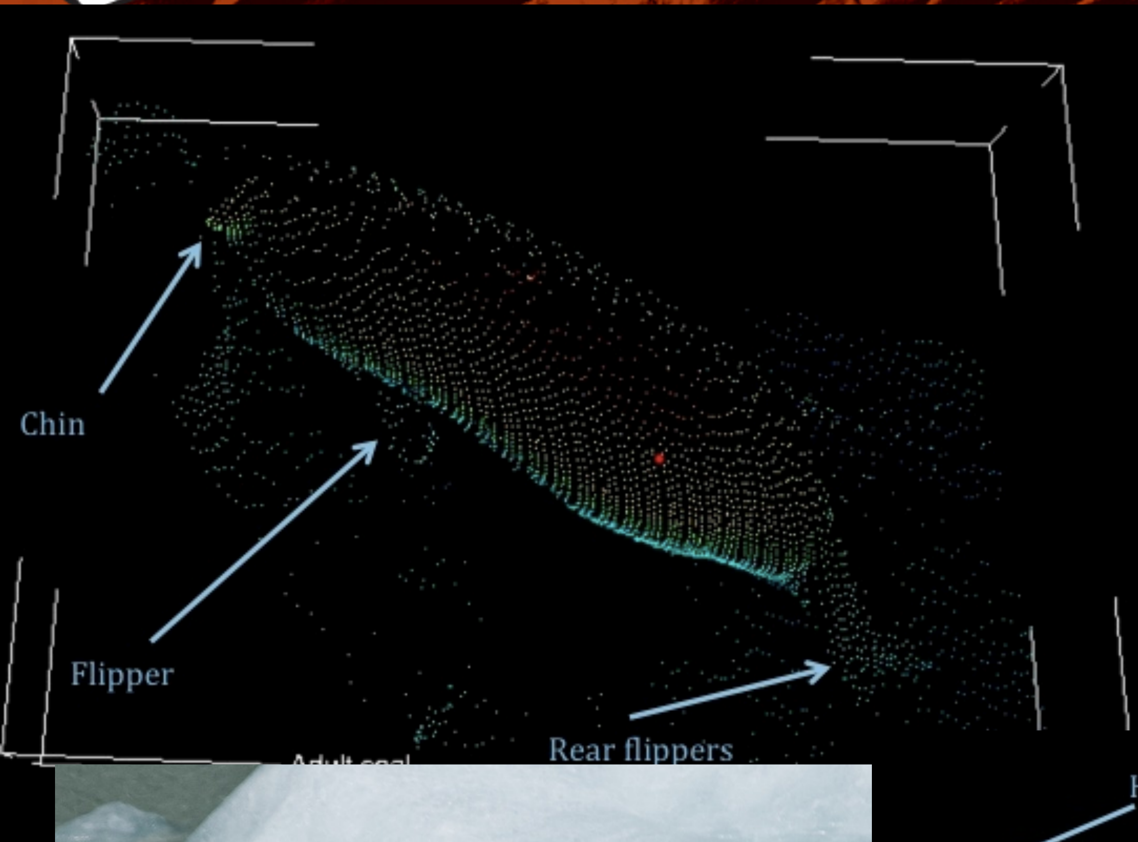
Mount Erebus, Antarctica

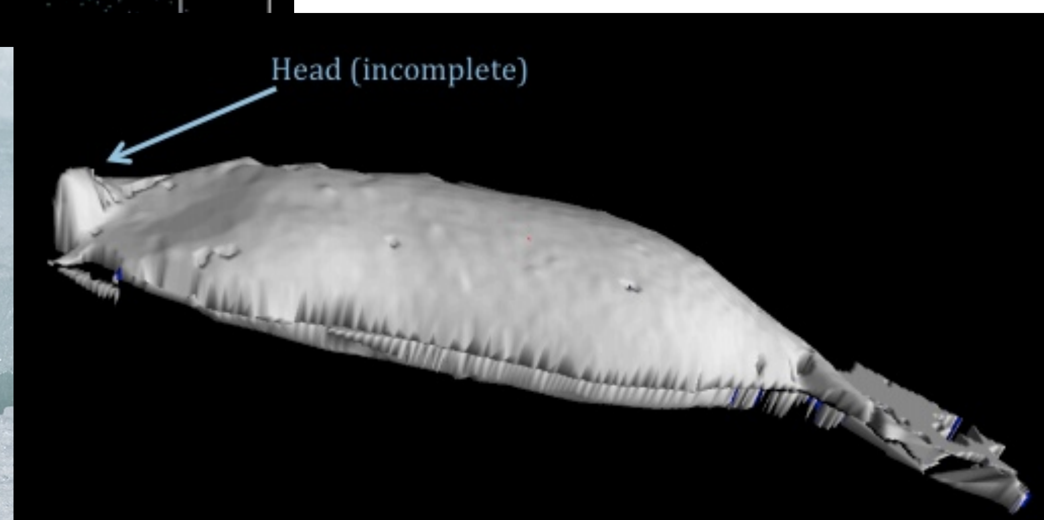
- Lava lake scanned 2008–2013, revealing behaviors invisible to naked eye
- Inner crater scan used to augment and truth 2003 aerial scans
- Scans of ice caves and ice towers help determine thermal / energy budget of volcano



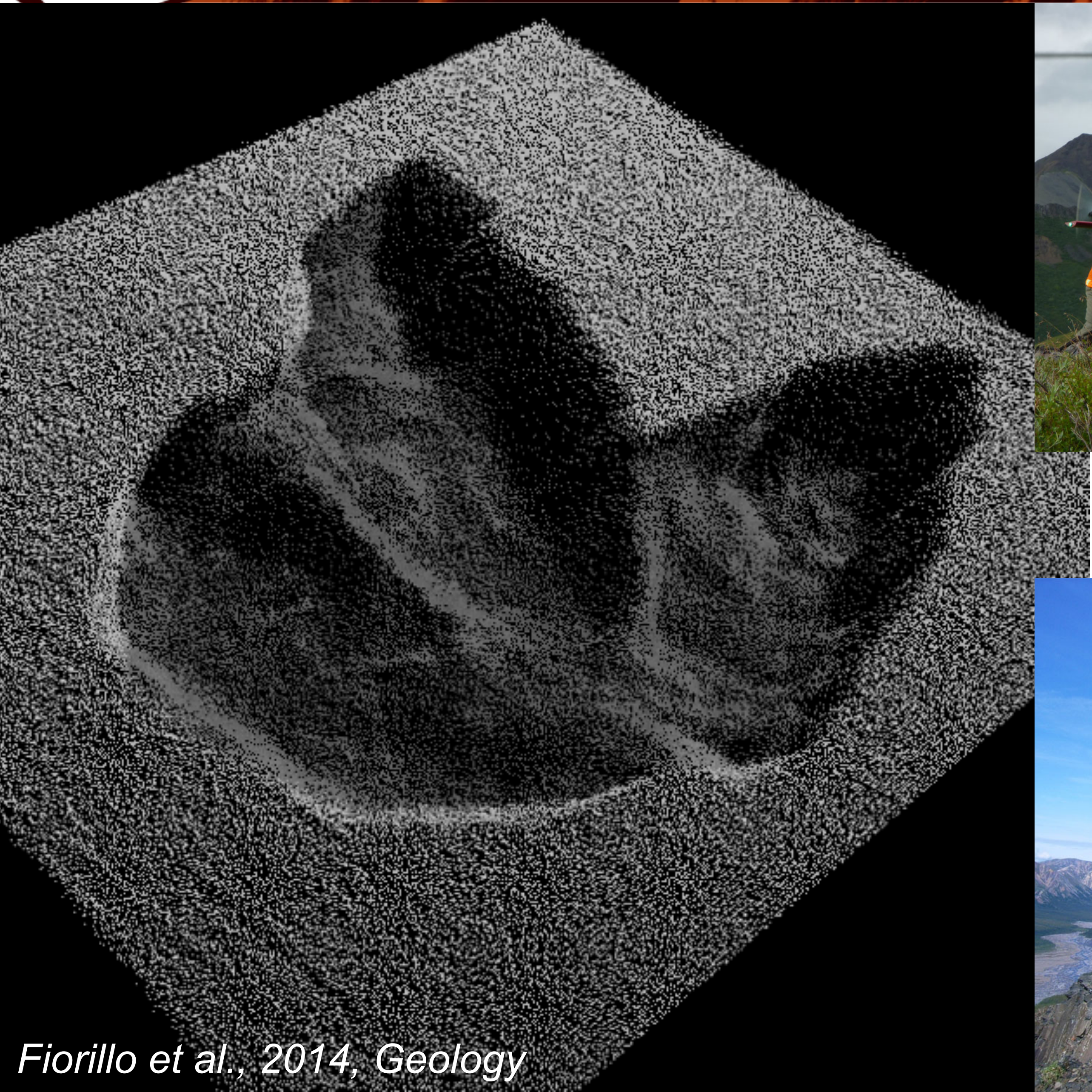
Using TLS to Obtain Volumetric Measurements of Weddell Seals in the McMurdo Sound

Seal body mass = proxy for availability of marine food resources



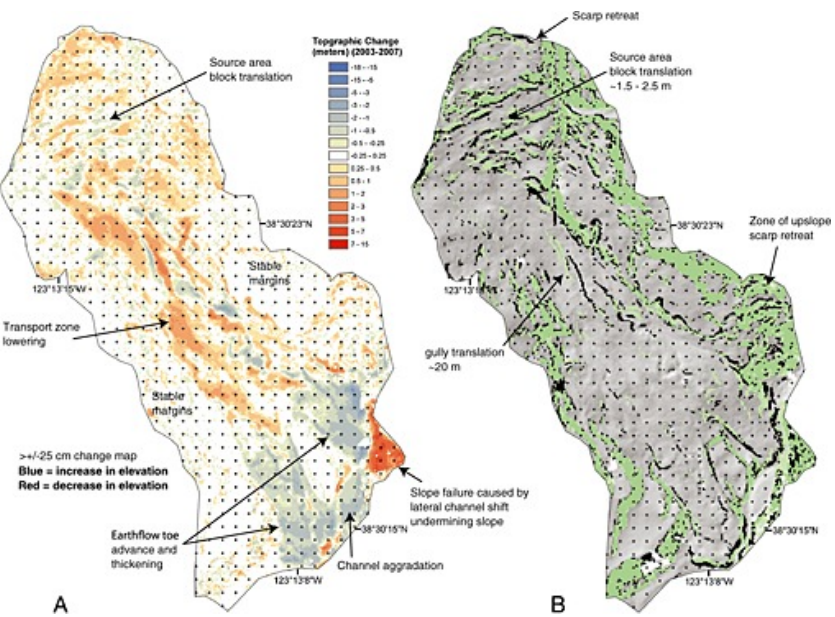


Dinosaur Trackway, Denali National Park, AK

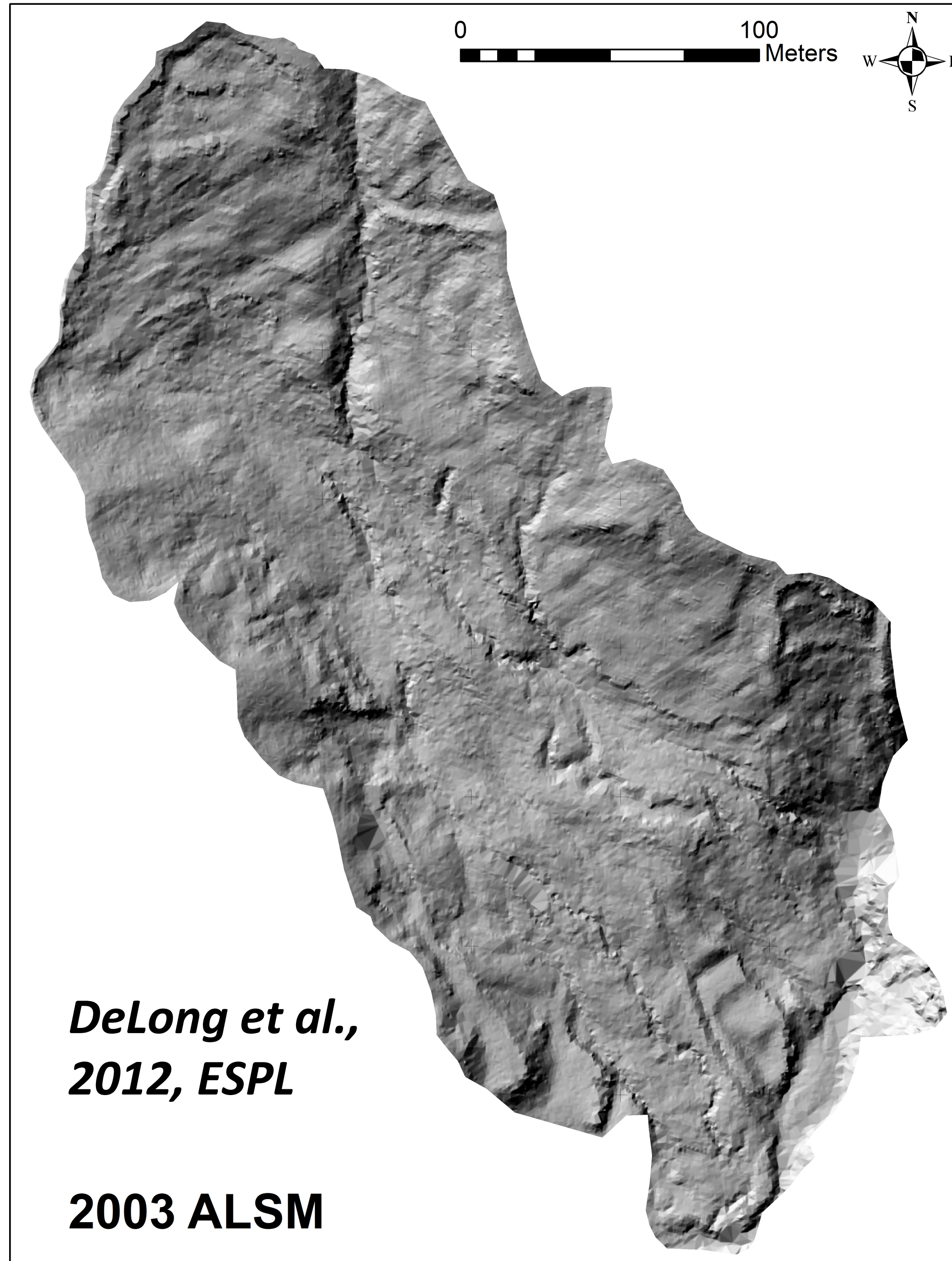


Fiorillo et al., 2014, Geology

Pt. Arena
Mill Gulch earthflow
Santa Rosa
California
38°30'0"N
38°0'0"N
123°30'0"W
123°0'0"W

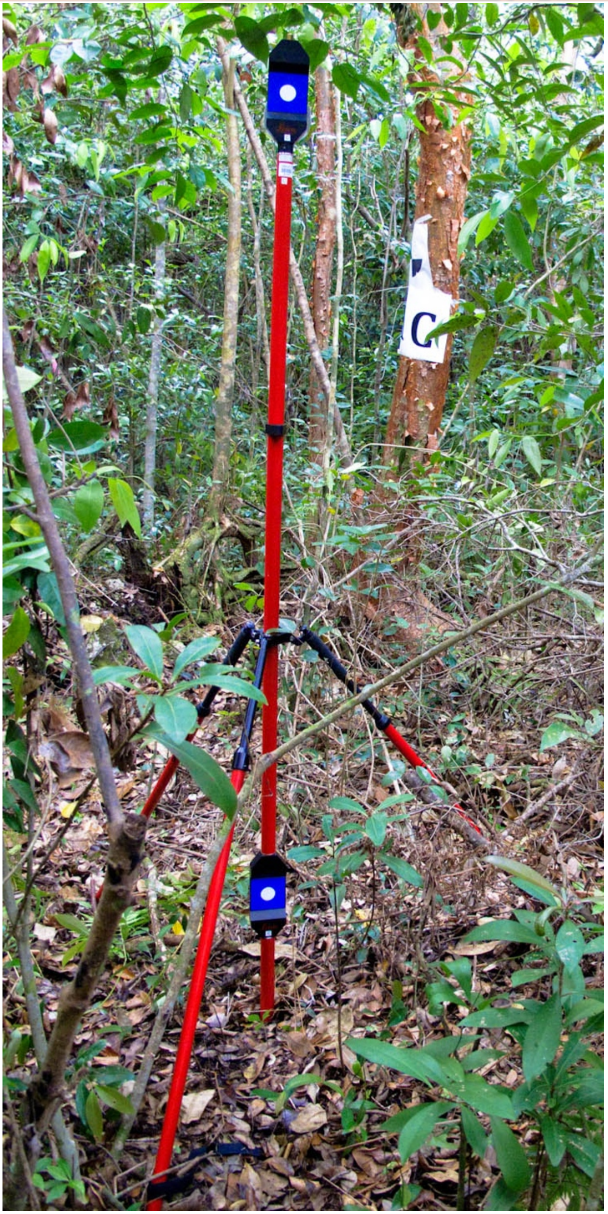


Source area block translation
Topgraphic Change (meters) (2003-2007)
38°30'23"N
Stable margins
123°13'15"W
Transport zone lowering
Stable margins
>+/-25 cm change map
Blue = increase in elevation
Red = decrease in elevation
Slope failure caused by lateral channel shift undermining slope
Earthflow toe advance and thickening
38°30'15"N
Channel aggradation
123°13'8"W
A
Scarp retreat
Source area block translation ~1.5 - 2.5 m
38°30'23"N
Zone of upslope scarp retreat
gully translation ~20 m
38°30'15"N
123°13'8"W
B



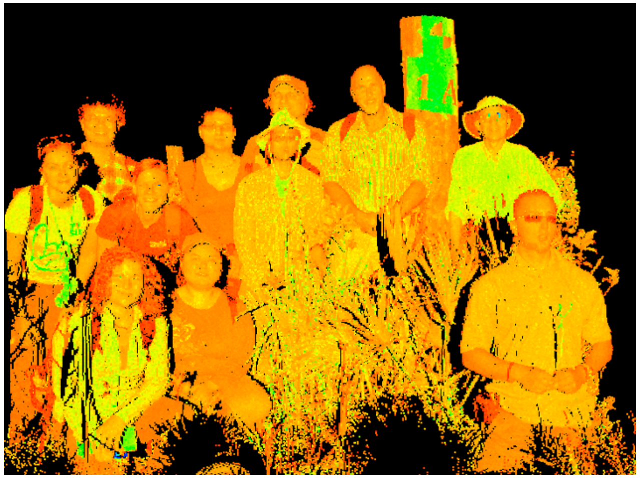
0
100
Meters
N
W
E
S
DeLong et al., 2012, ESPL
2003 ALSM

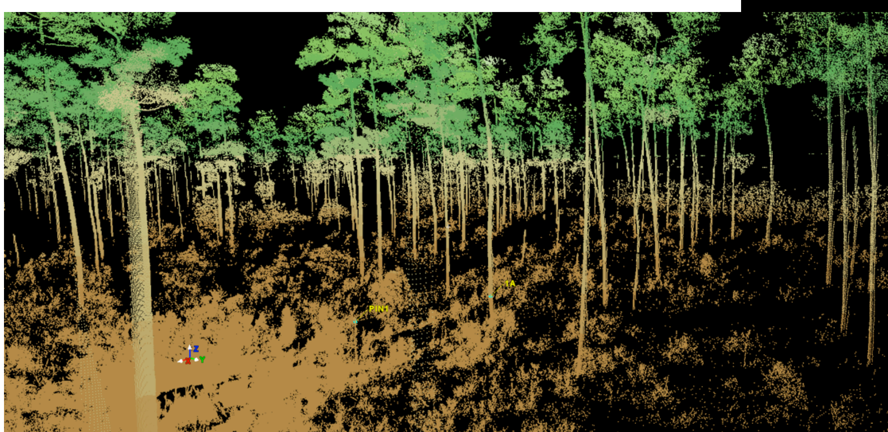
Everglades Biomass, Florida



- Scanning to measure biomass in Everglades National Park (PI: Wdowinski).

Everglades Biomass, Florida





Thanks!

crosby@unavco.org ***http://unavco.org/tls***

Photo: B. Hodge, UNAVCO – Location: RMNP