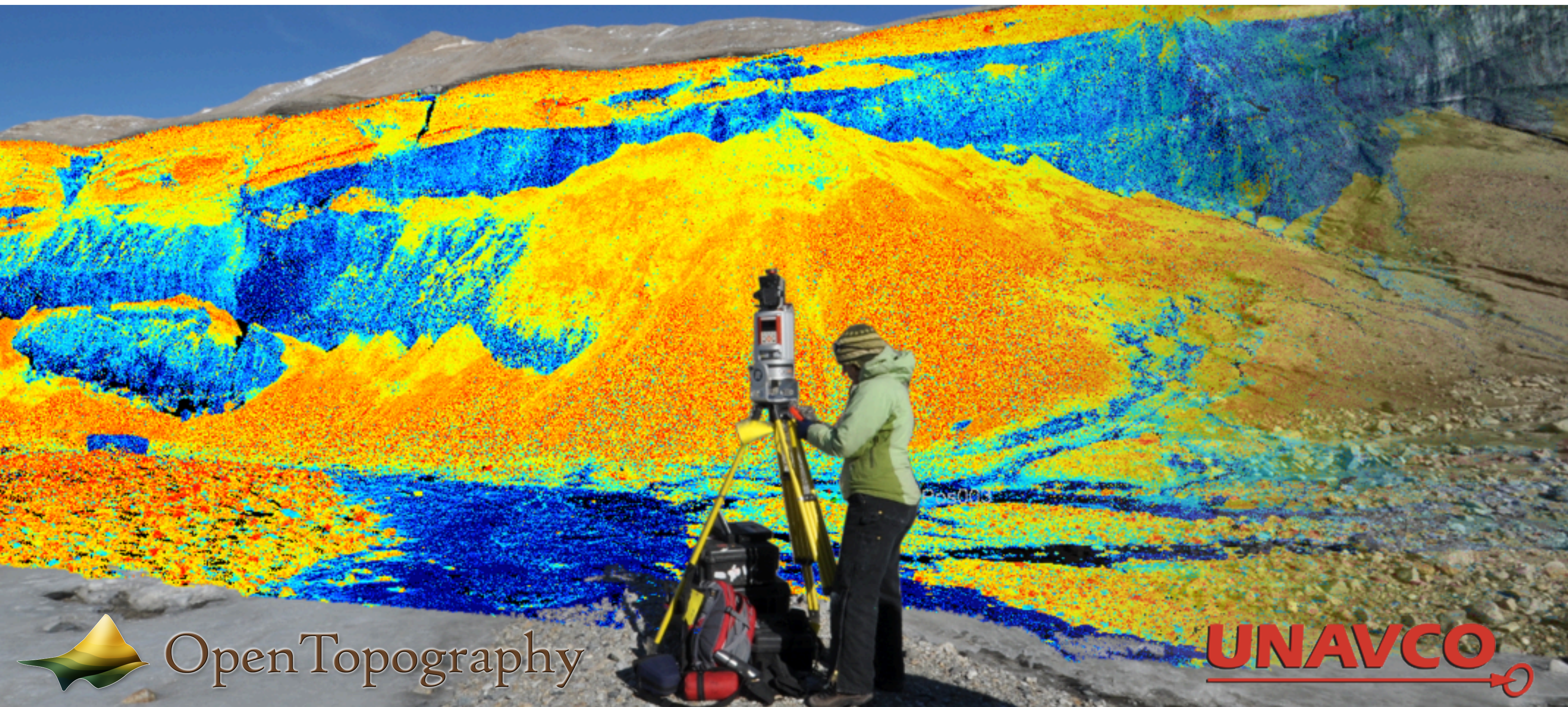
Introduction to Lidar, Terrestrial Laser Scanning Applications

Christopher Crosby
UNAVCO / OpenTopography, Boulder, CO



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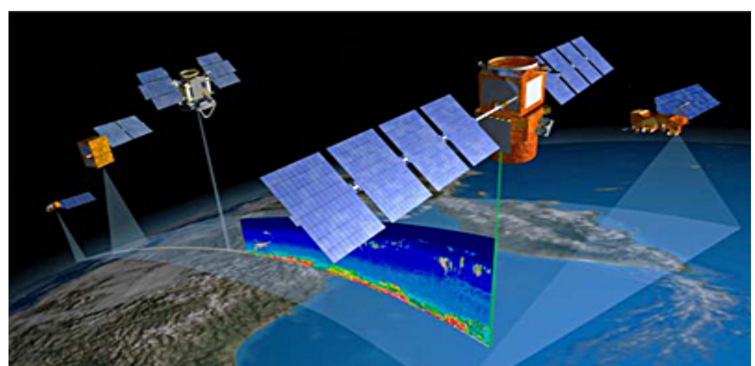
Light Detection and Ranging (lidar)

- 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)

Modified from Ian Madin, DOGAMI

Lidar platforms

BUSINESS WIRE COMMERCIAL PHOTO



J. Stoker, USGS

Light Detection and Ranging (lidar)

Similar technology, different platforms:

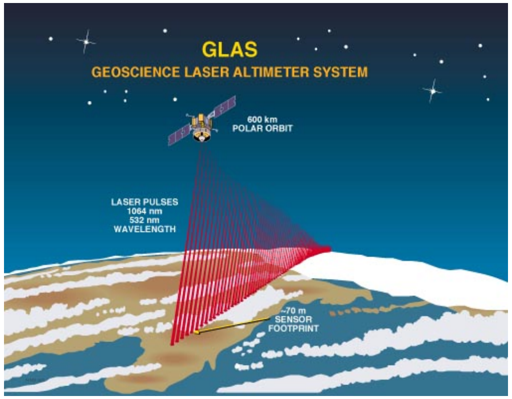
Terrestrial Laser Scanning (TLS)

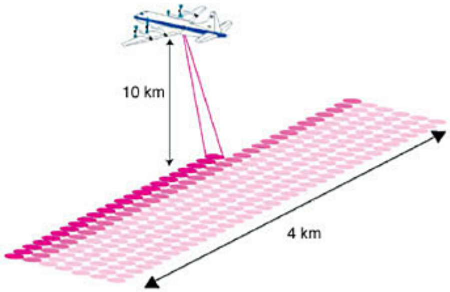
- Also called ground based lidar or T-lidar.

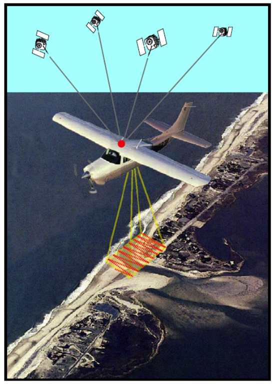
Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

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

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Lidar & Autonomous Vehicles

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

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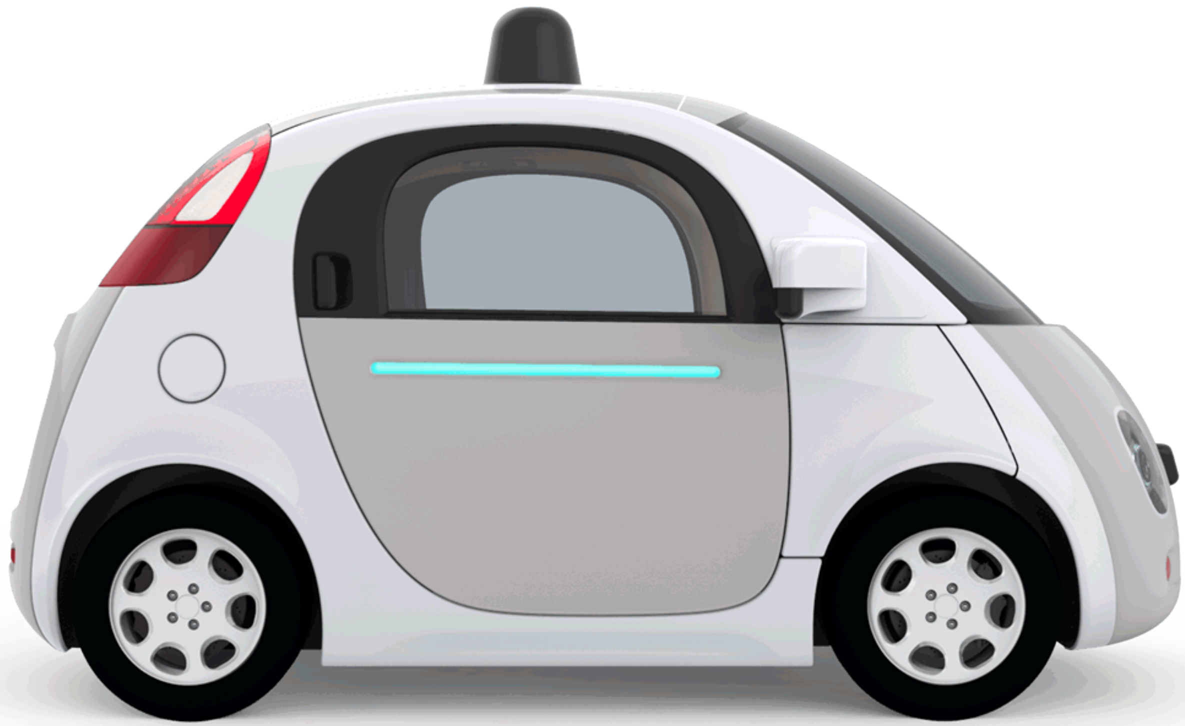
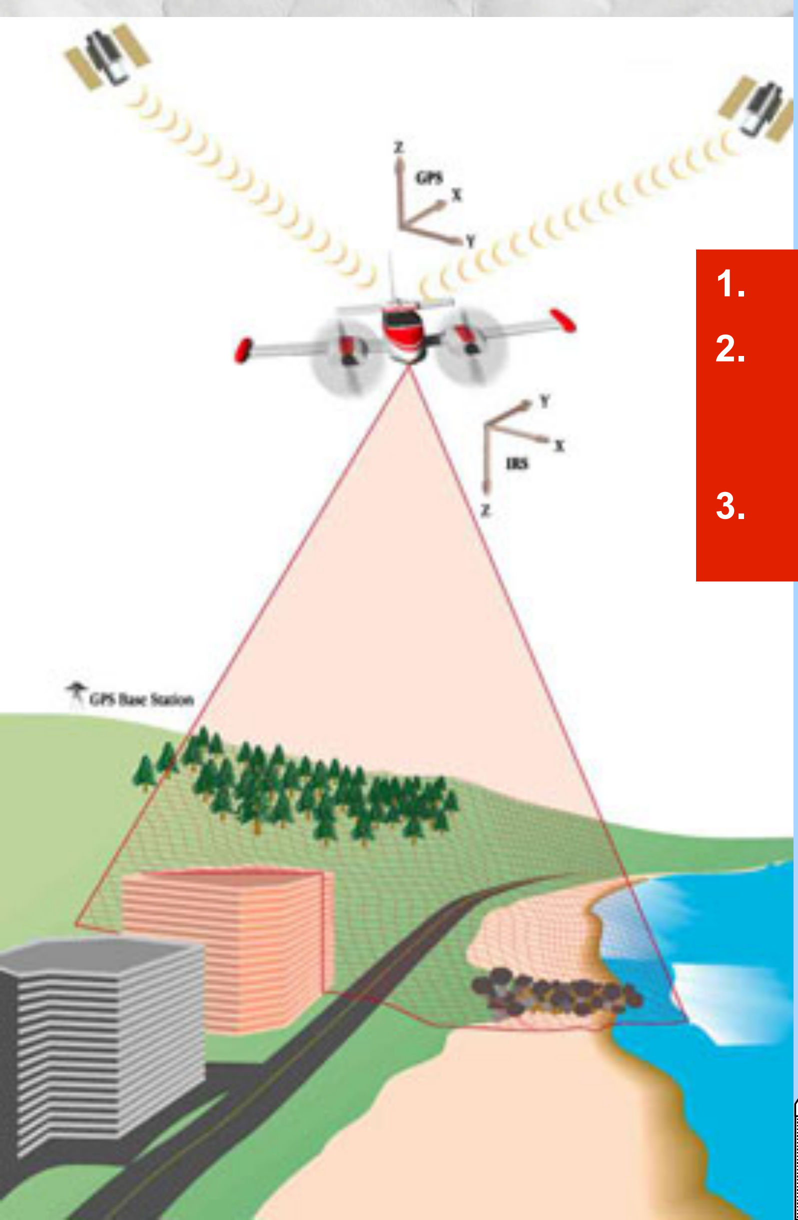
Lidar & Autonomous Vehicles



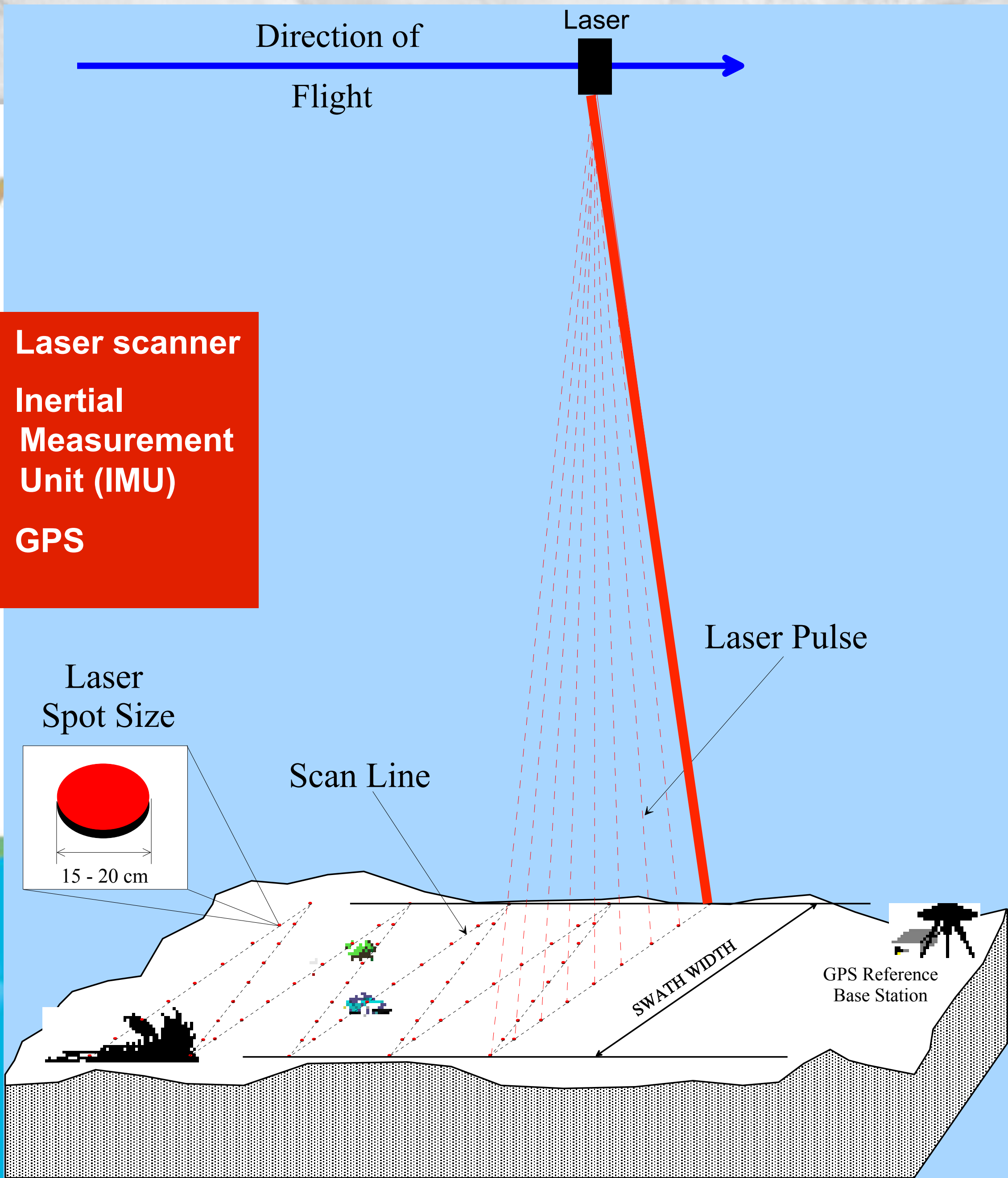
Light Detection and Ranging (lidar)

Ian Madin, DOGAMI

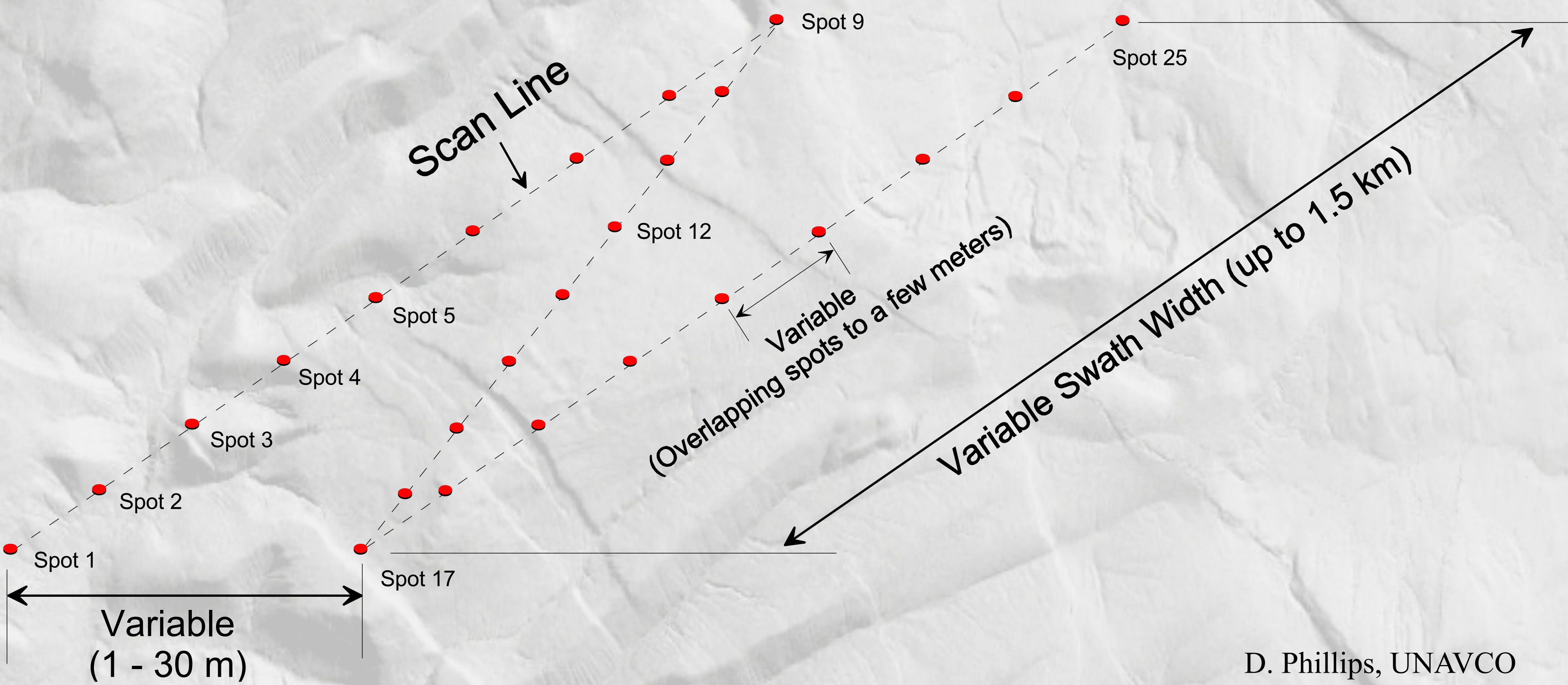
Lidar data collection



1. Laser scanner
2. Inertial Measurement Unit (IMU)
3. GPS



Surface Point Spacing



D. Phillips, UNAVCO

Scan line spacing, swath width, spot size and overlap can all be defined as necessary to achieve target data to specification

Typical Lidar Data Collection Parameters

Aircraft: Cessna 337 Skymaster

Personnel

- **One pilot, one operator in plane**
- **GPS ground crew (2 to 10+ people)**

Scanner:	**Optech near-IR**
PRF:	**33-900 KHz**
Flying height:	**600 – 1,000m AGL**
Flying speed:	**120 mph**
Swath overlap:	**50% nominal**
Ground truthing:	**GPS (campaign & CORS)**
Navigation solution:	**KARS**

Point spacing: sub-meter

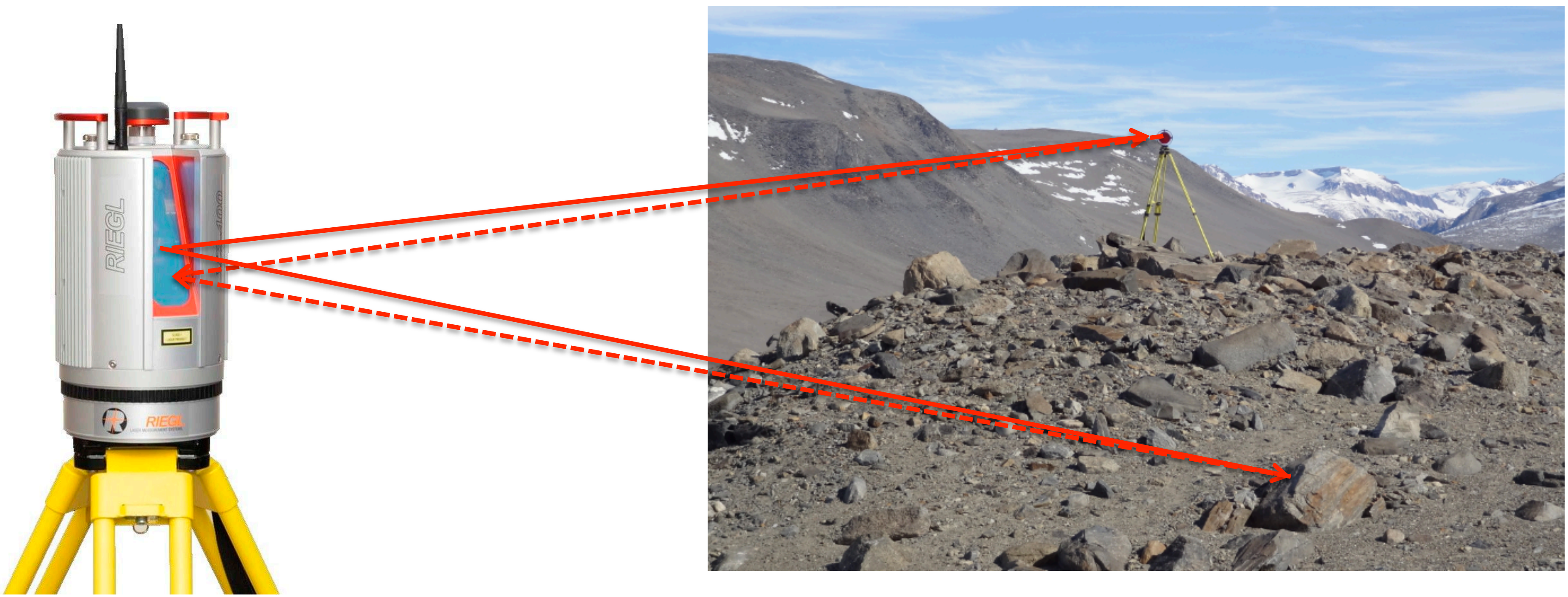
Nominal Accuracy (on open hard and flat surface)

- **Vertical: 3 – 6 cm.**
- **Horizontal: 20 – 30 cm.**

NCALM
The National Center for Airborne Laser Mapping

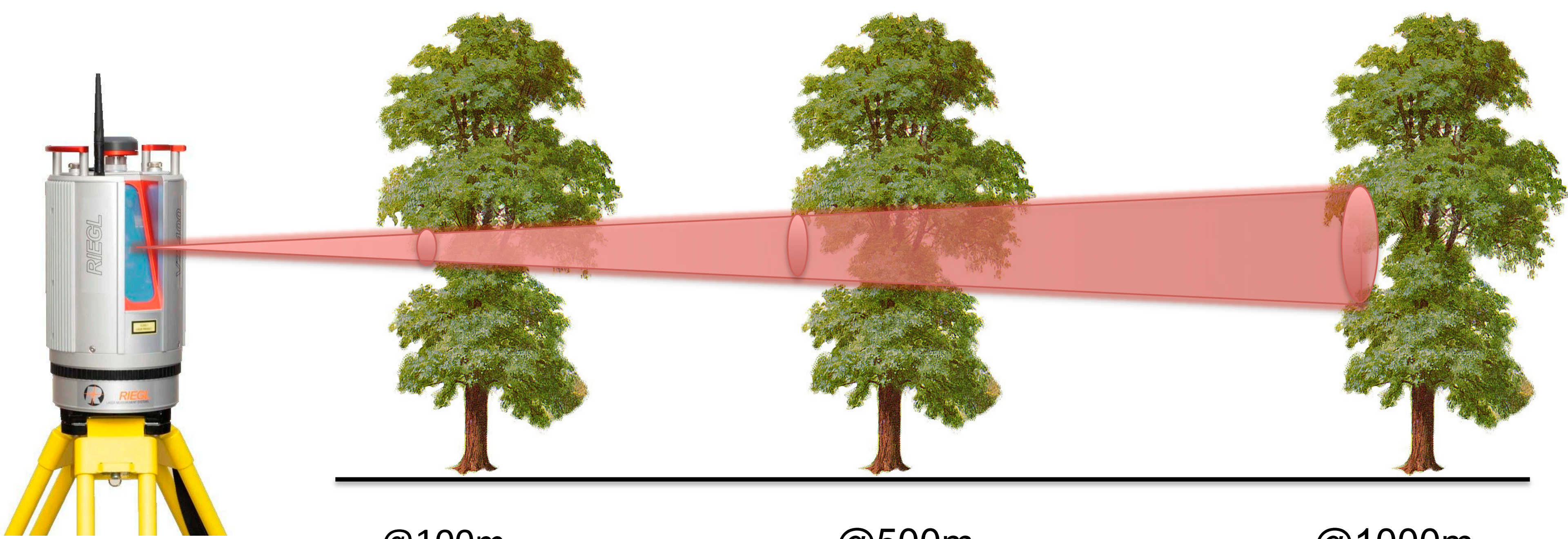
How a Lidar instrument works

- Transmits laser signals and measures the reflected light to create 3D point clouds.
- Wavelength is usually in the infrared (~1550nm) or green (532nm) spectrum



Beam Divergence

Df = (Divergence * d) + Di

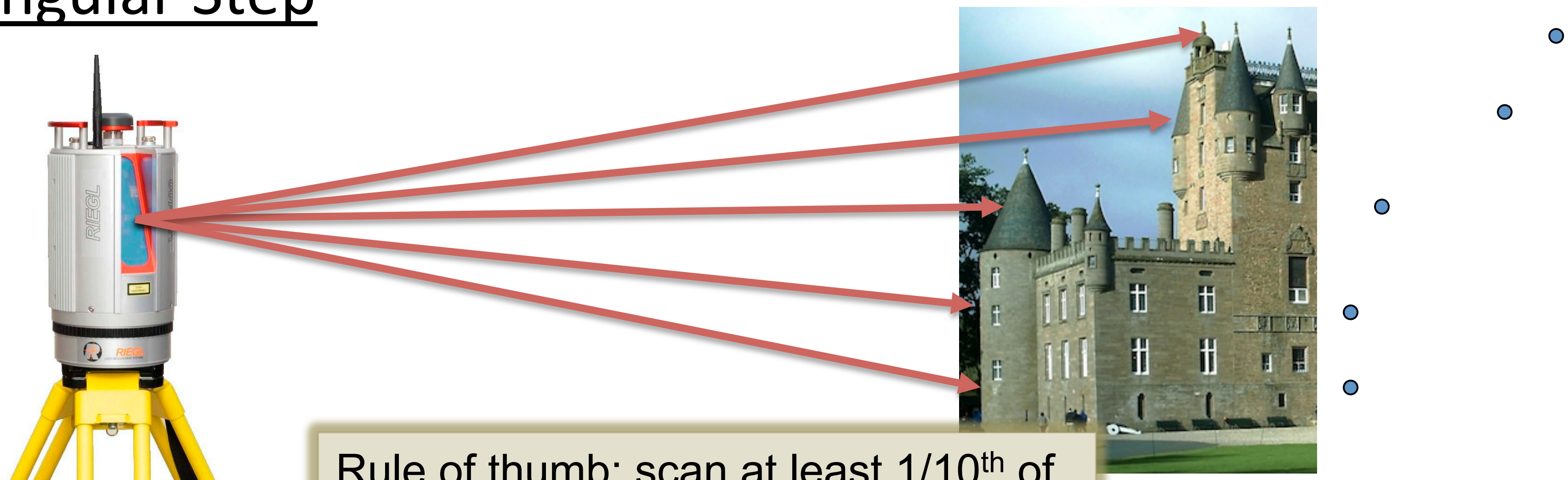


@100m,
Df = 36mm

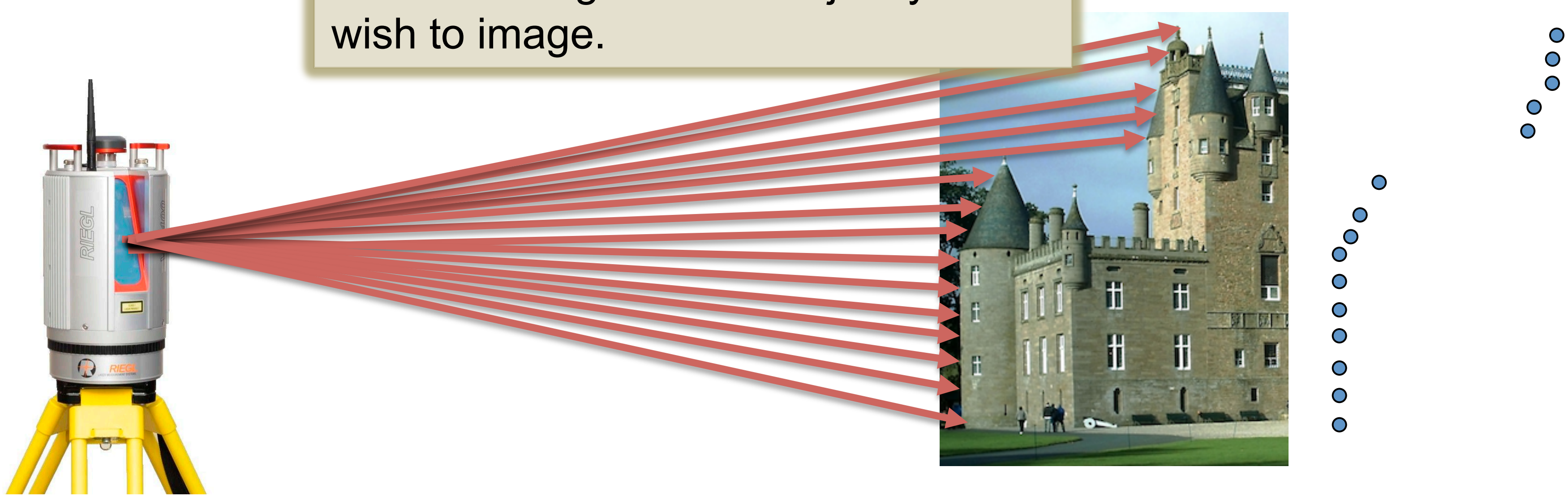
@500m,
Df = 180mm

@1000m,
Df = 360mm!

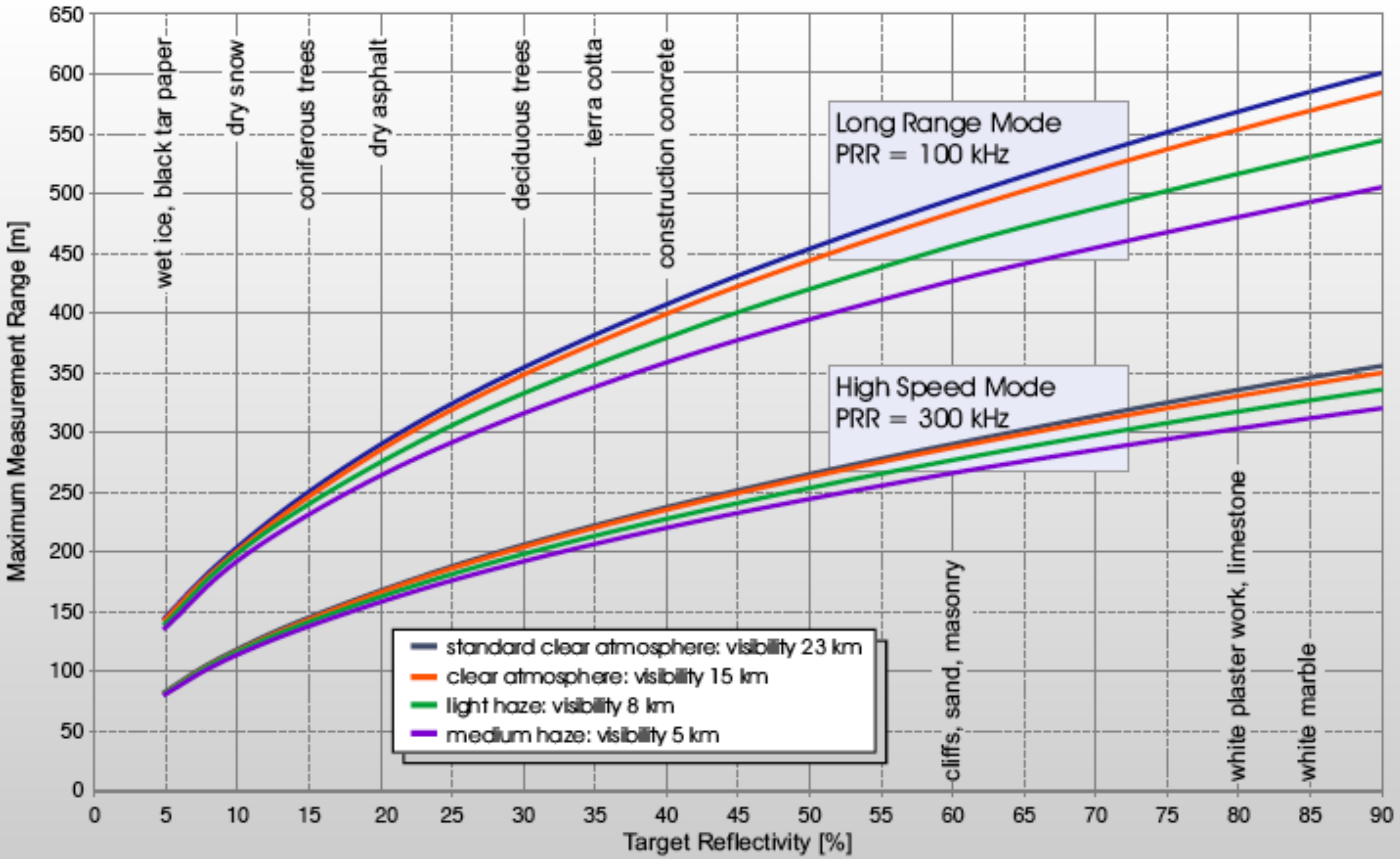
Angular Step



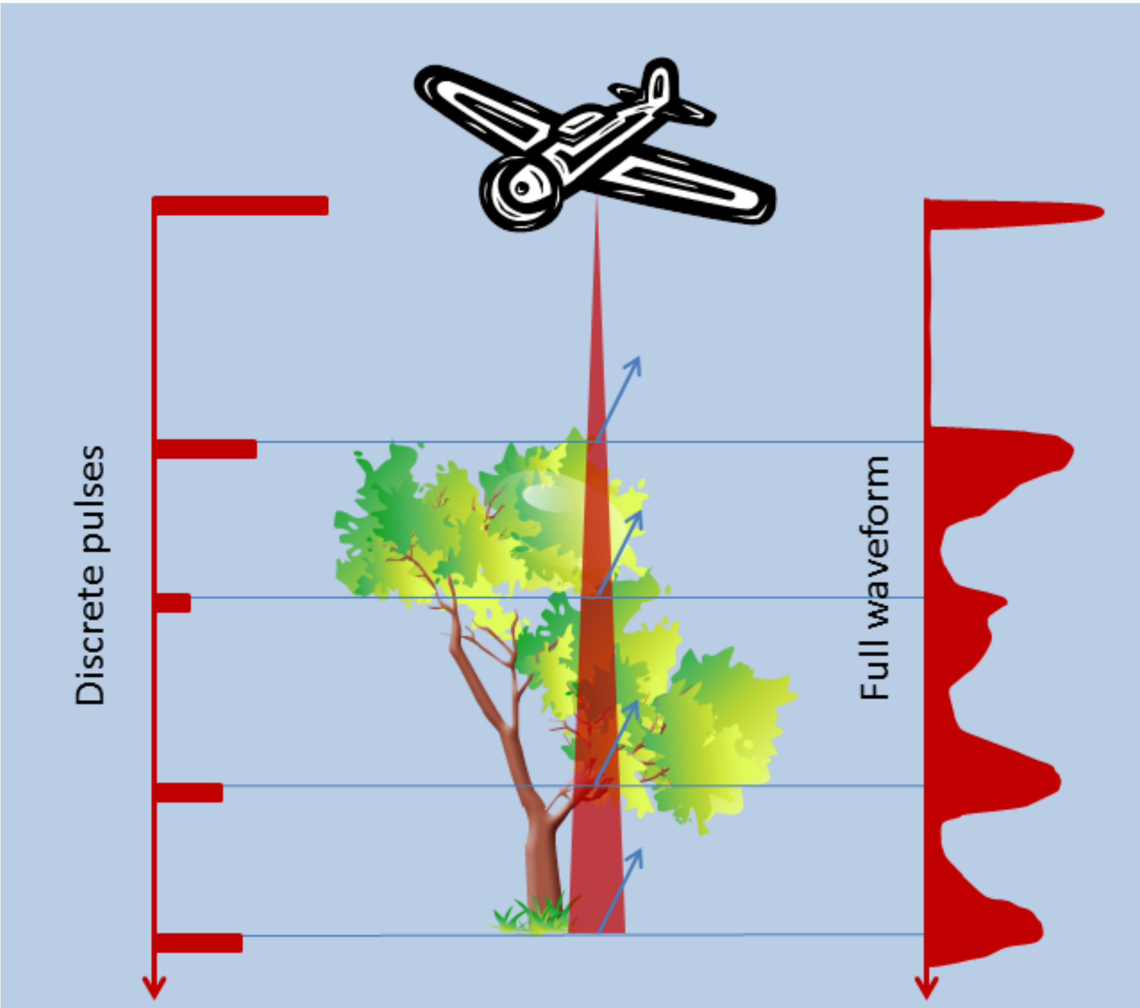
Rule of thumb: scan at least 1/10th of the “wavelength” of the object you wish to image.



Riegl VZ400 Maximum measurement range as function of target material



Discrete pulse and full waveform

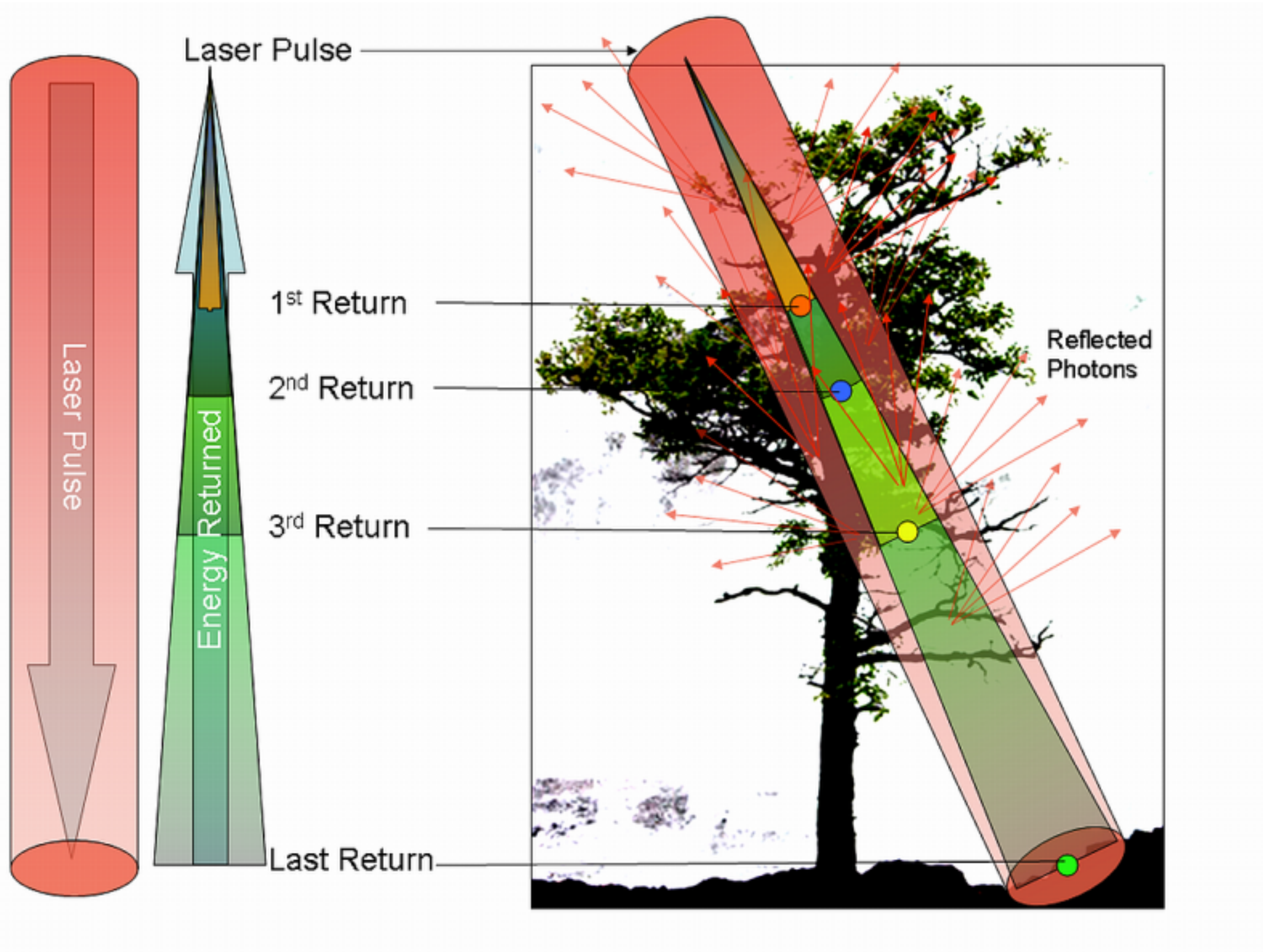


Discrete pulse = binary yes or no return

Full waveform = digitized backscatter waveform

Benefits of full waveform?

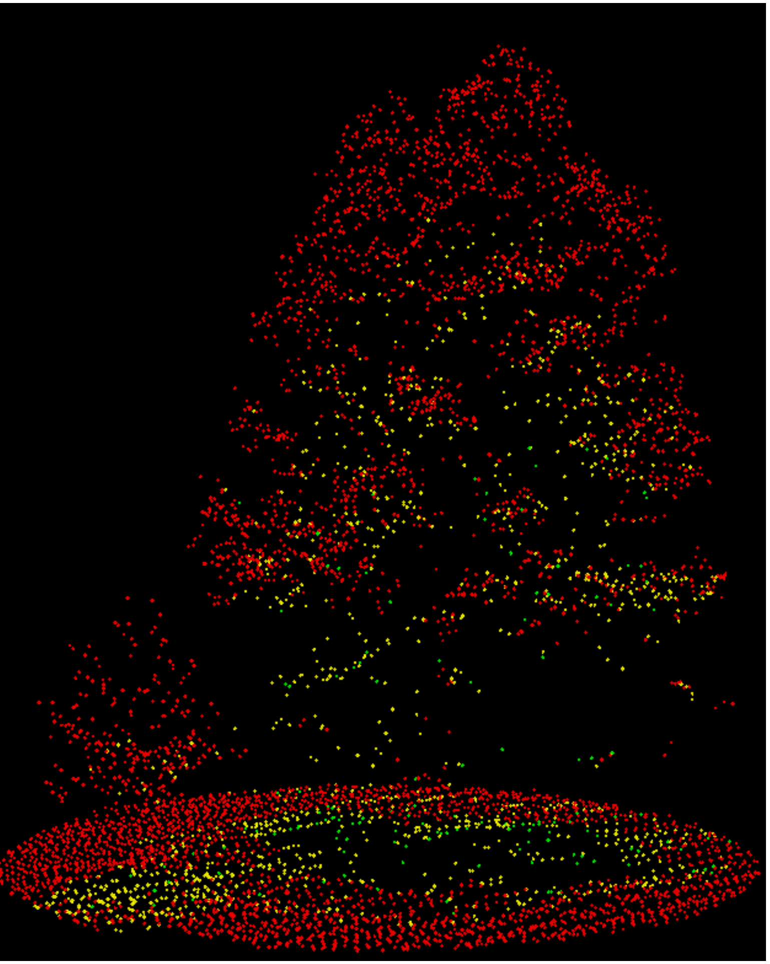
- More resolution between pulse width ambiguity
- Spectral property information
- Improved fitting of geometrically defined targets.



Laser Pulse
Laser Pulse
Energy Returned
1st Return
2nd Return
3rd Return
Last Return
Reflected Photons

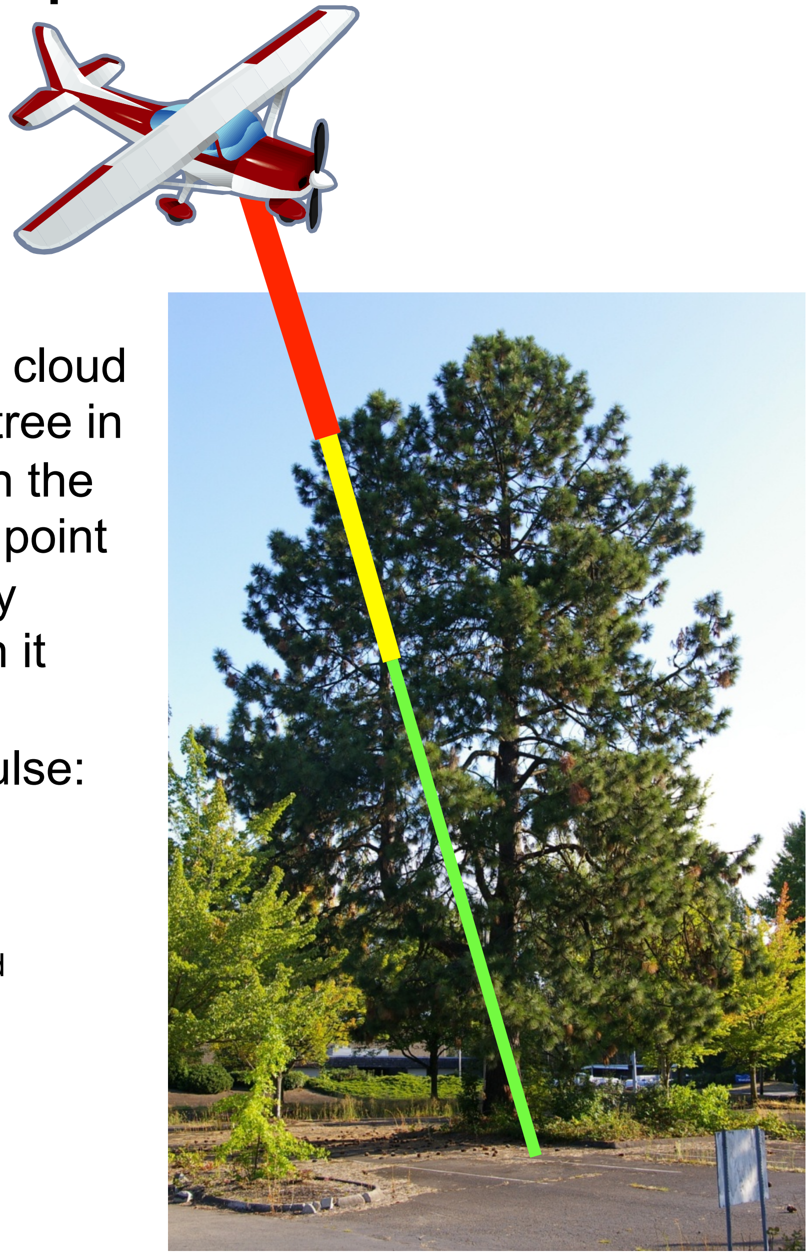
Each laser pulse can produce multiple consecutive measurements from reflections off several surfaces in its path

Ian Madin, DOGAMI

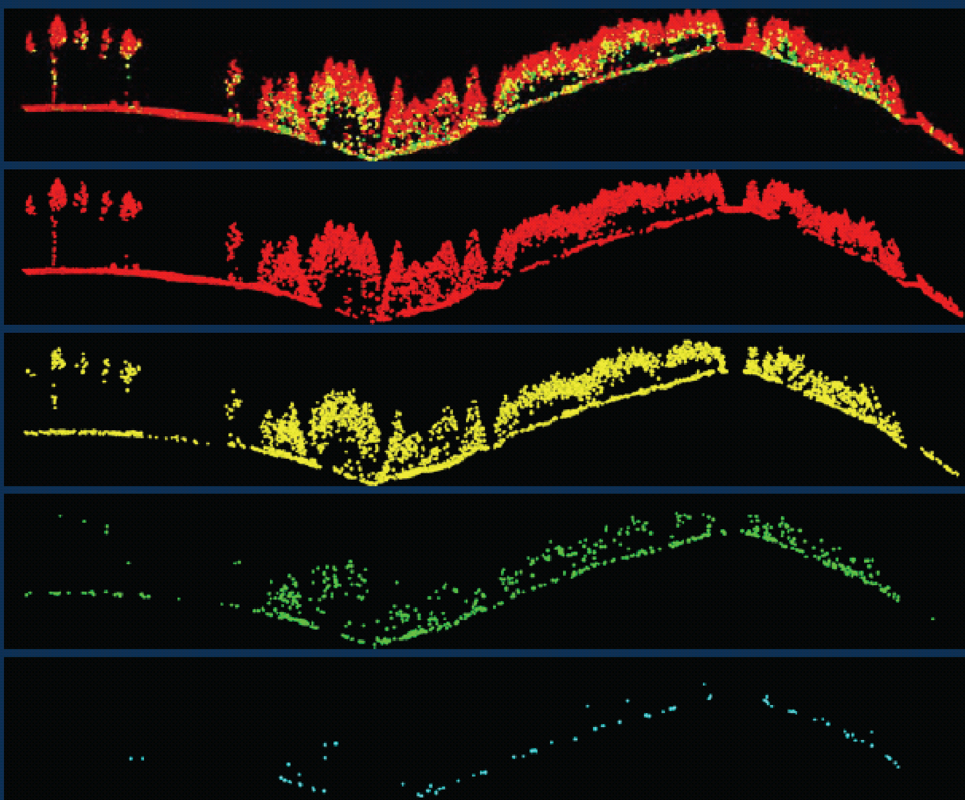


- Left = point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

- Red= 1st
- Yellow = 2nd
- Green = 3rd



Multiple Return lidar systems



All returns (16,664 pulses)

1st returns

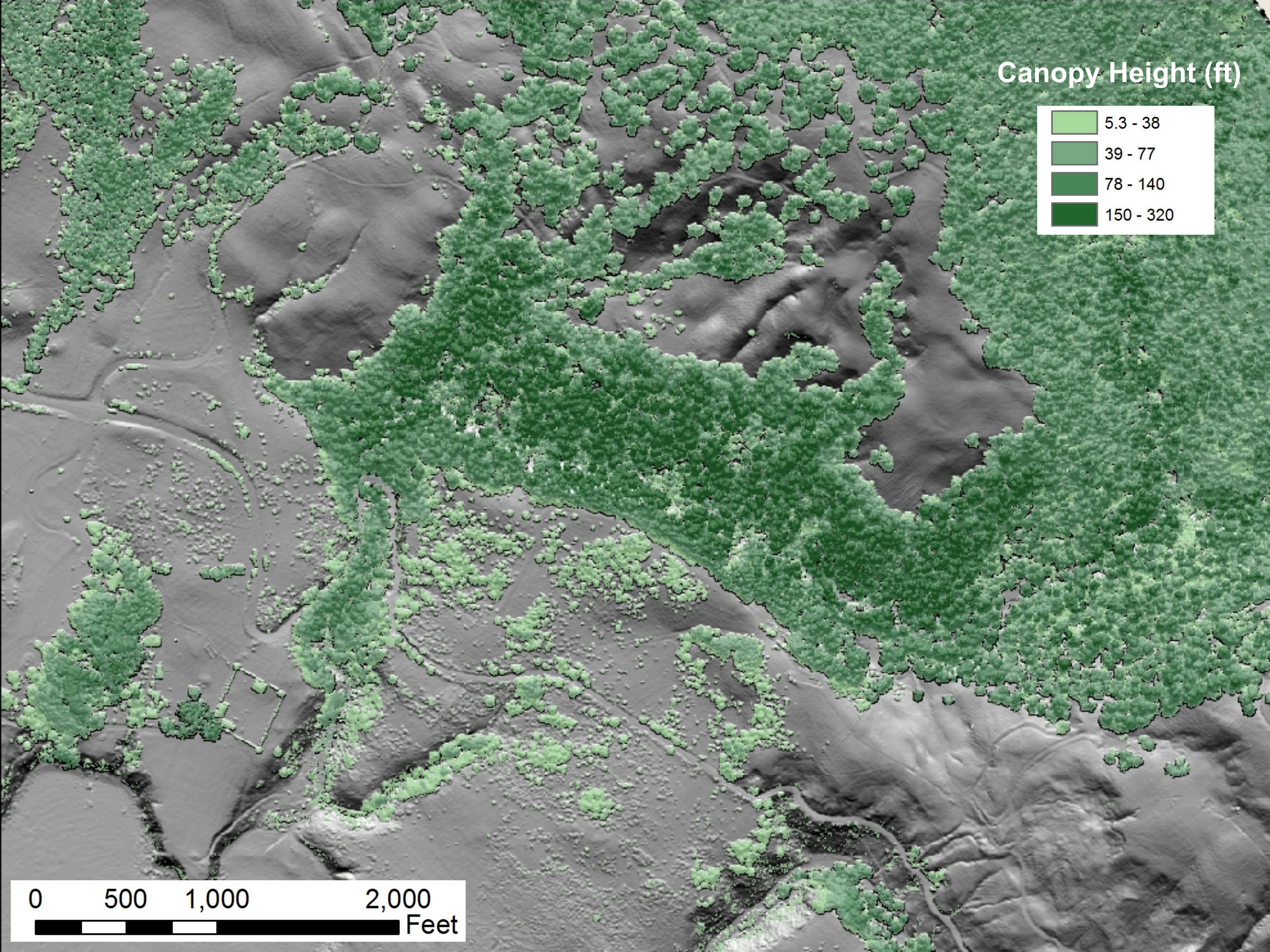
2nd returns (4,385 pulses, 26%)

3rd returns (736 pulses, 4%)

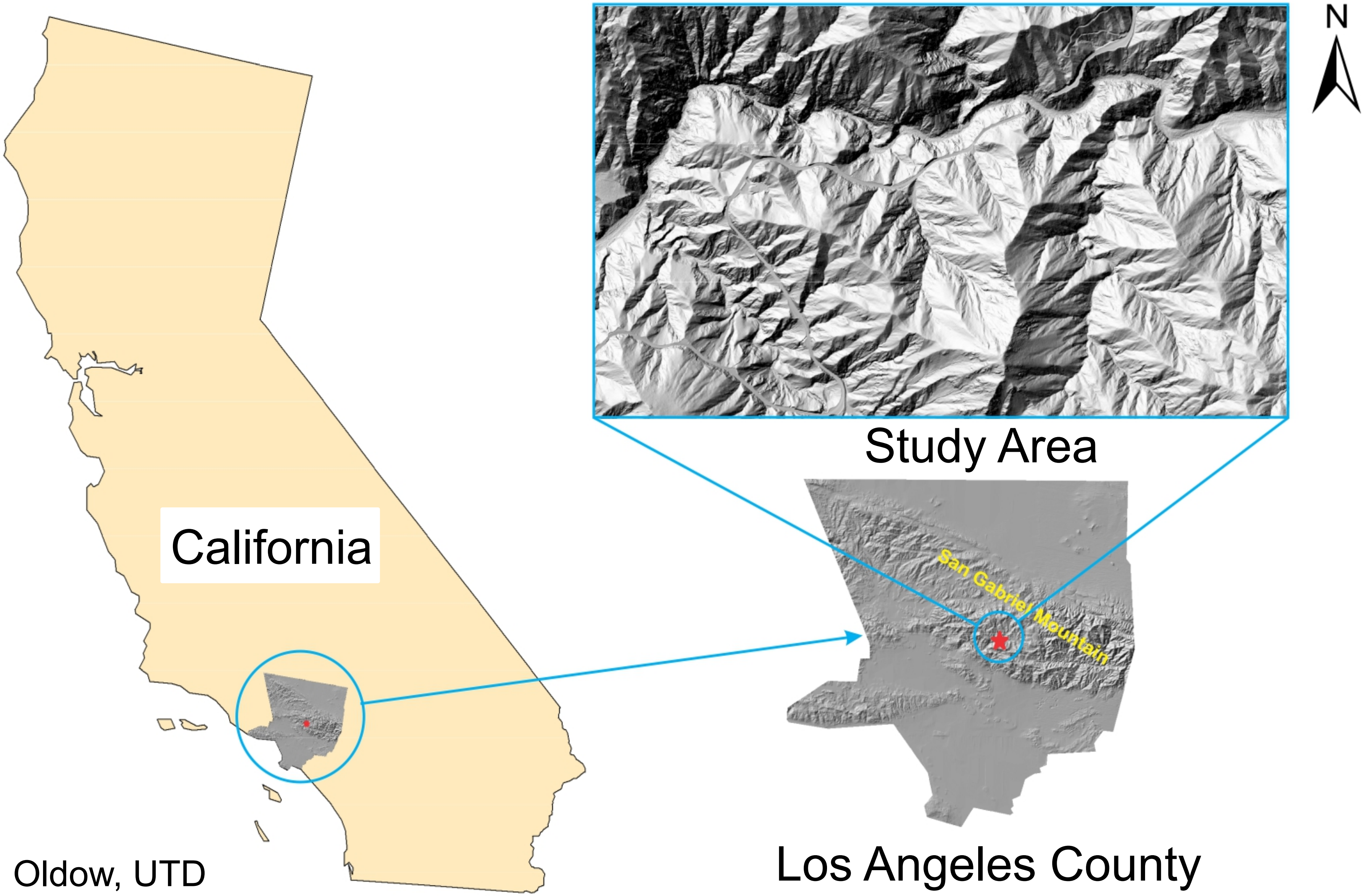
4th returns (83 pulses, <1%)

J. Stoker

Image courtesy Hans-Erik Anderson

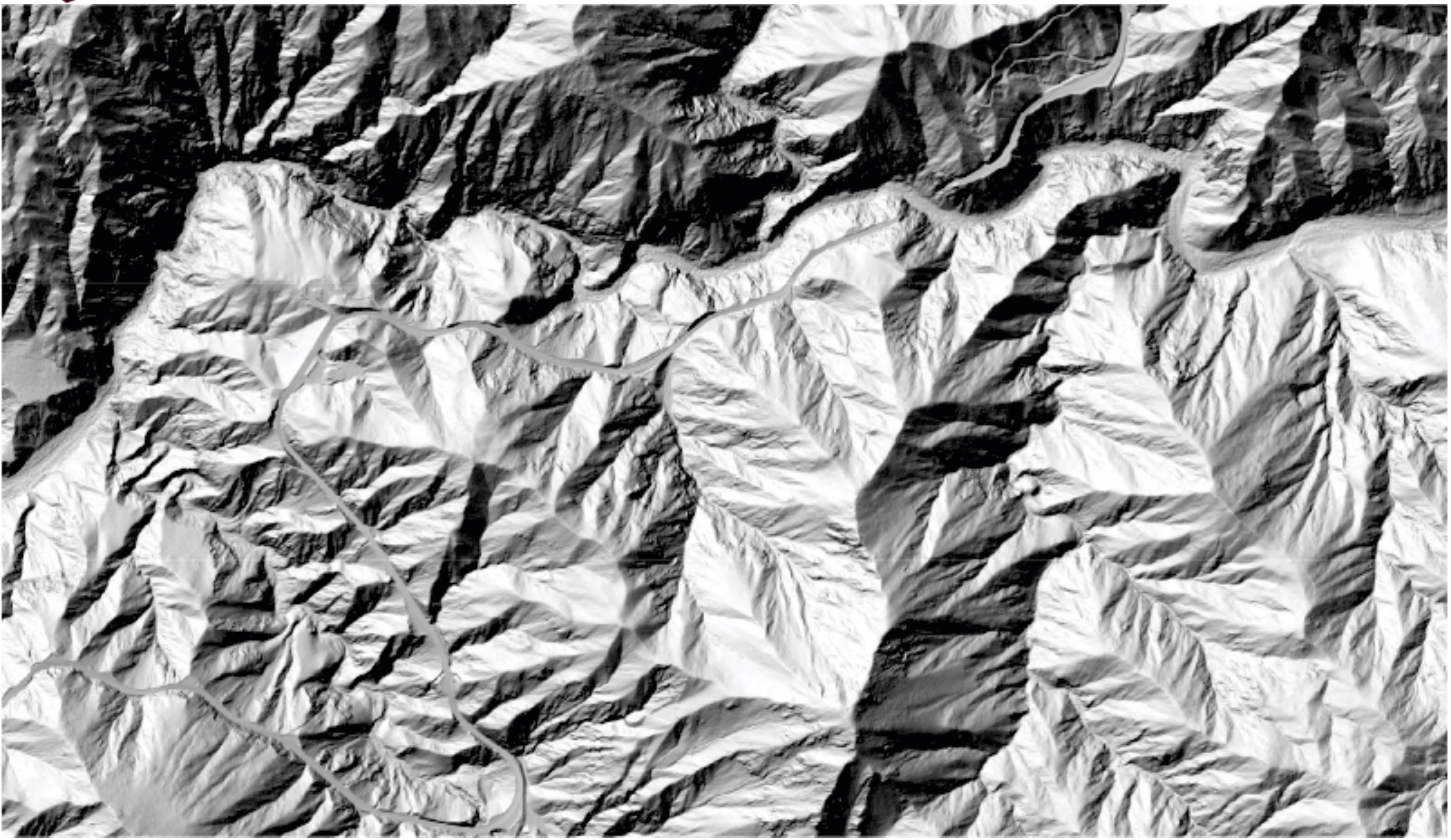

Canopy Height (ft)
5.3 - 38
39 - 77
78 - 140
150 - 320
0
500
1,000
2,000
Feet

Comparison: ALS vs TLS



J. Oldow, UTD

Comparison: ALS vs TLS



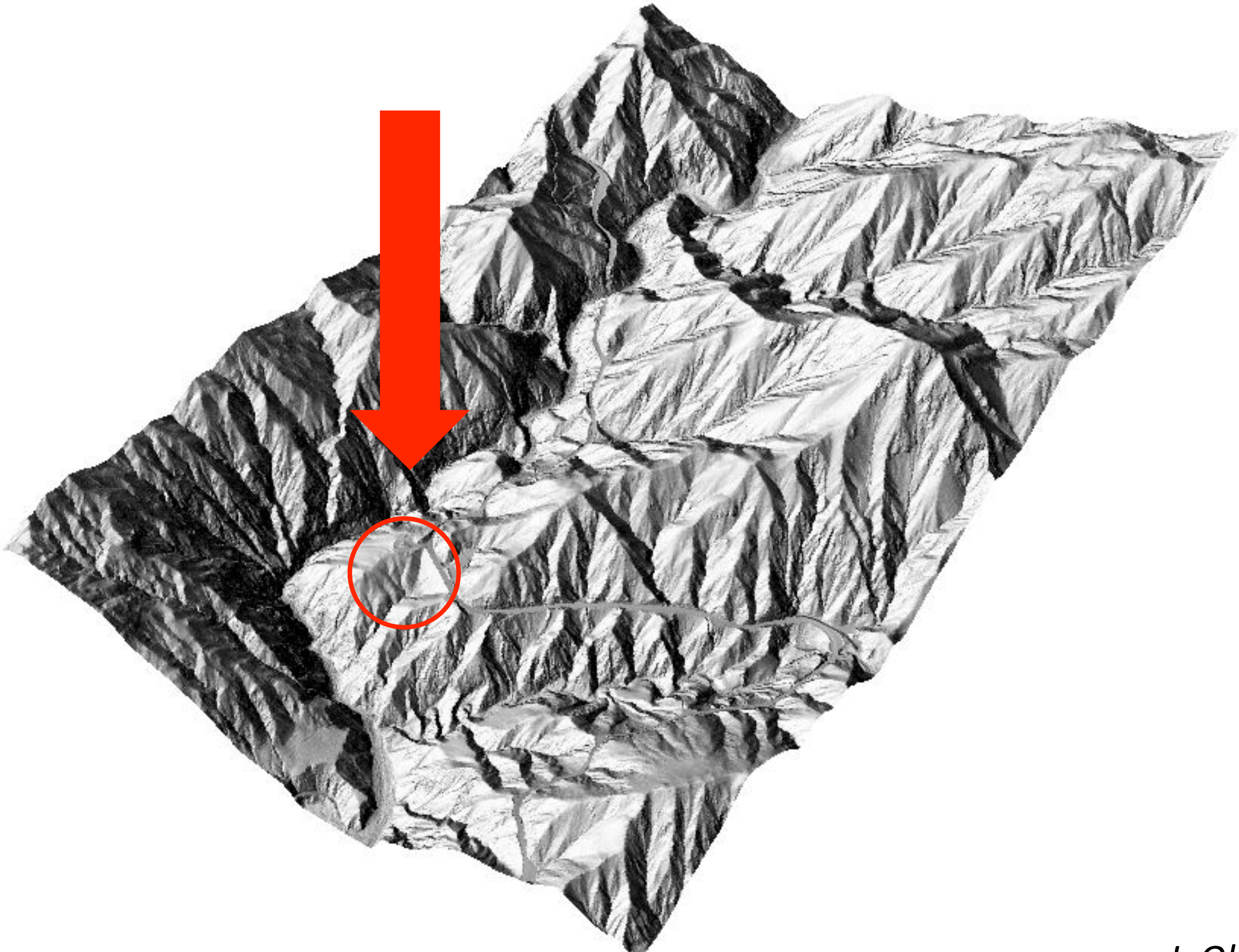
San Gabriel Mountain 1-m DEM from airborne LiDAR

J. Oldow, UTD

Comparison: ALS vs TLS

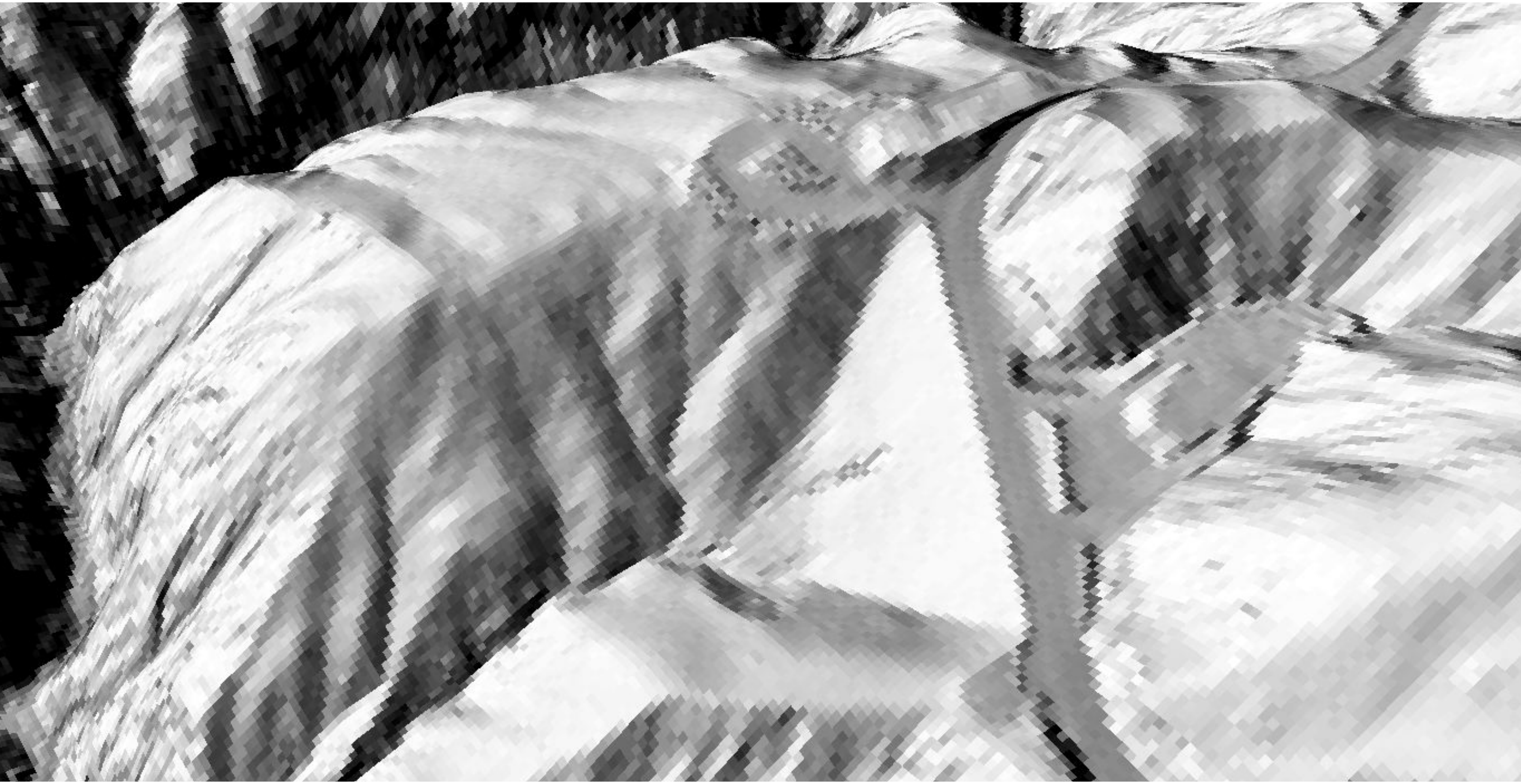
J. Oldow, UTD

Comparison: ALS vs TLS



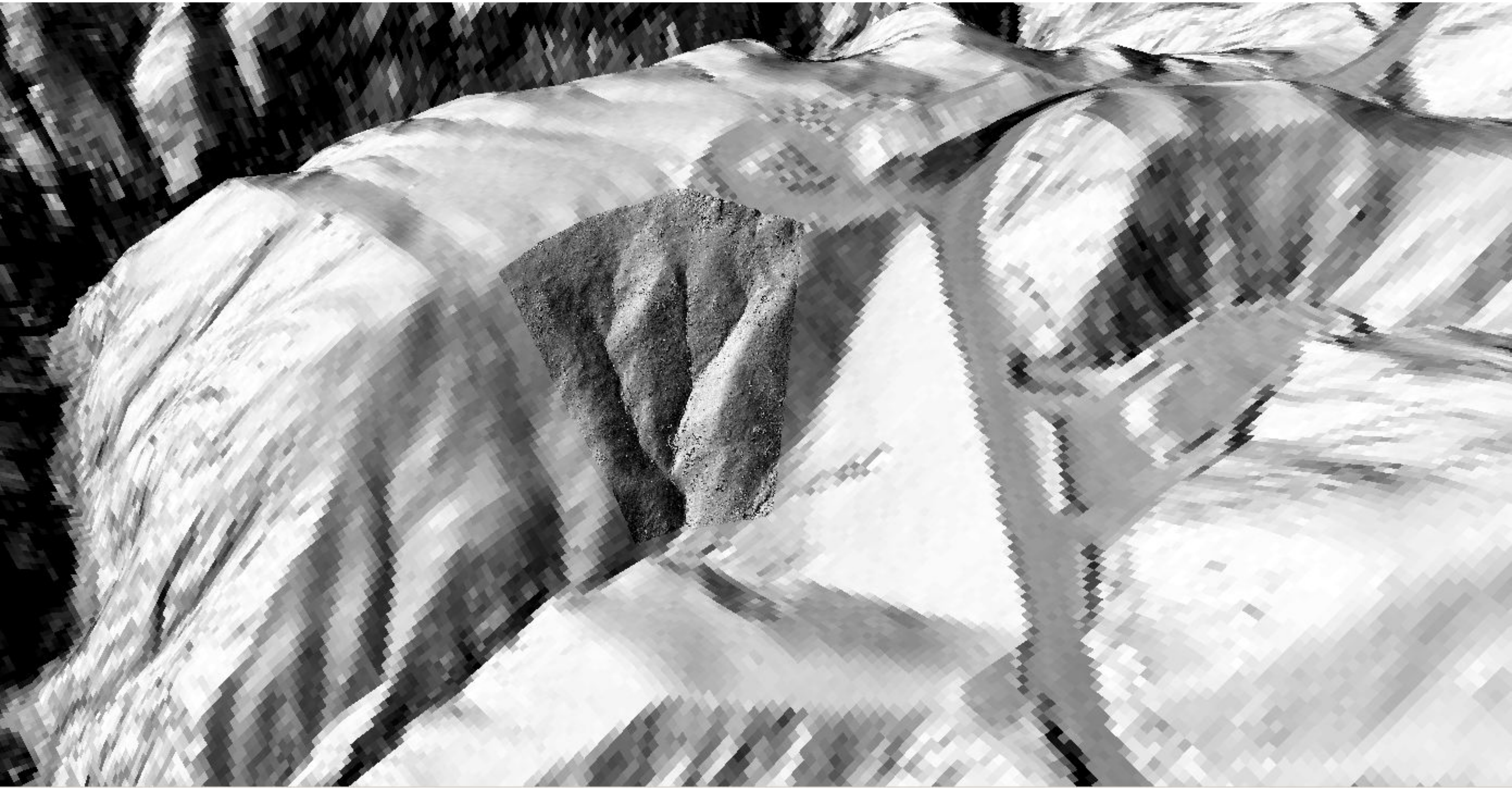
J. Oldow, UTD

Comparison: ALS vs TLS



J. Oldow, UTD

Comparison: ALS vs TLS



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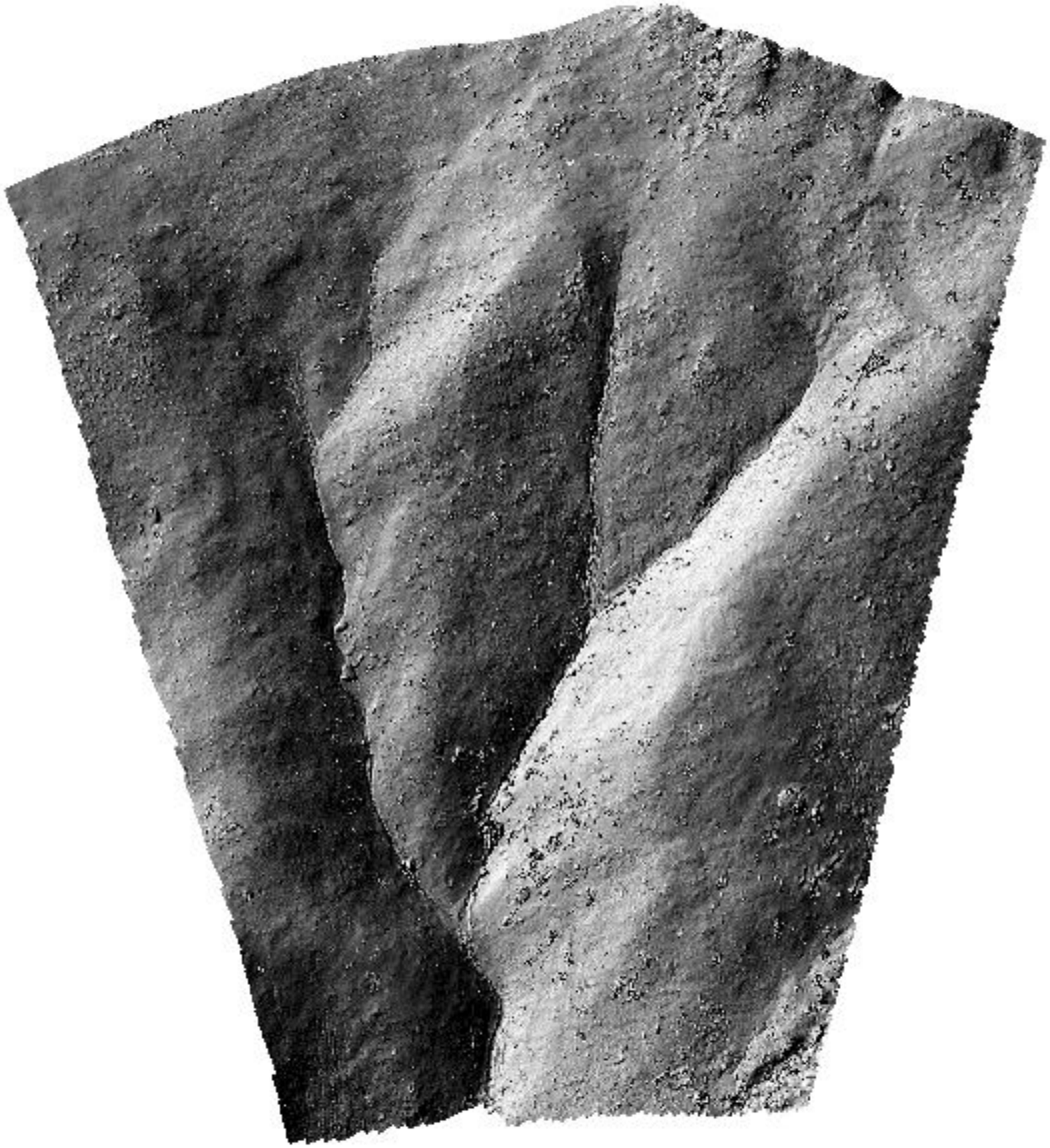
Comparison: ALS vs TLS



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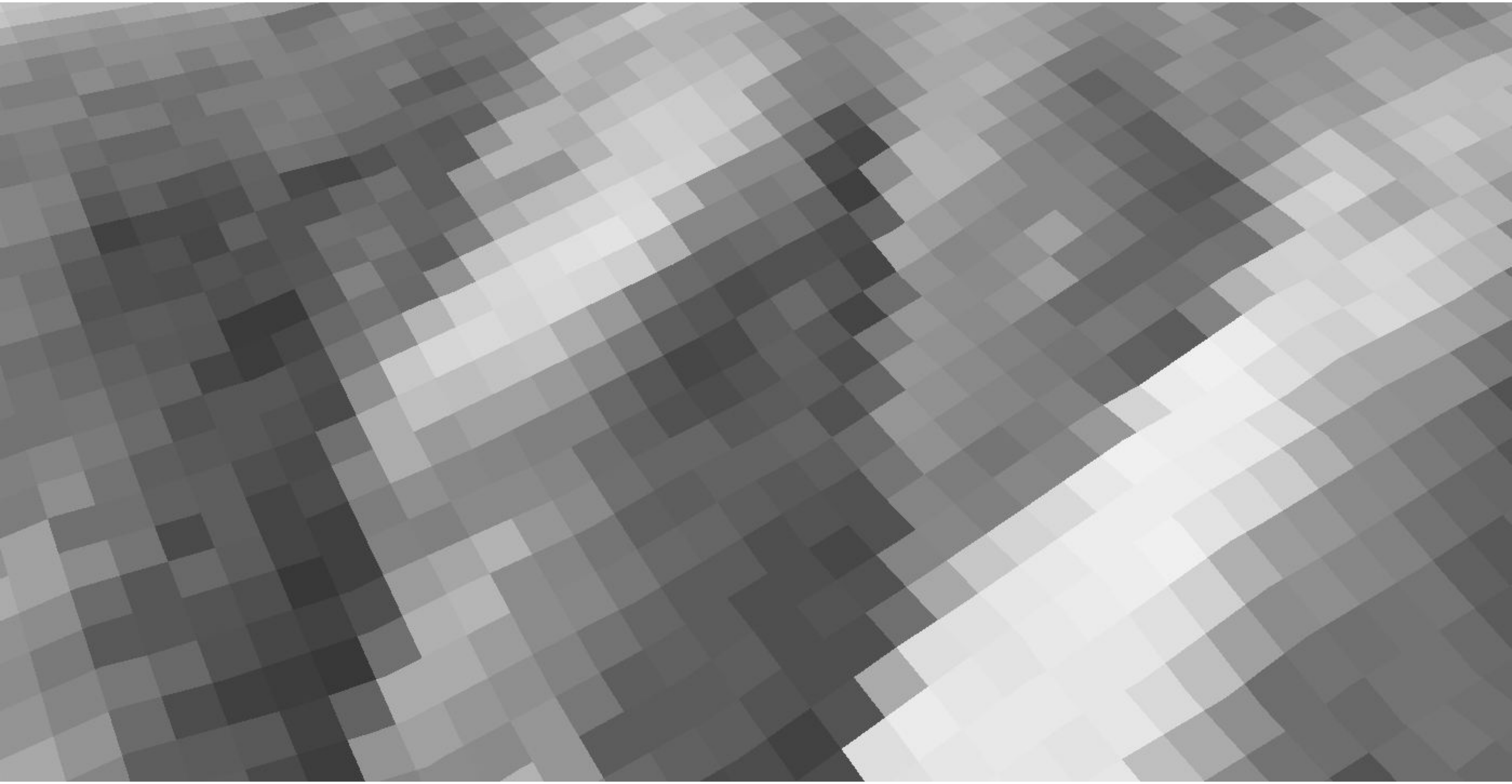
Comparison: ALS vs TLS



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Comparison: ALS vs TLS

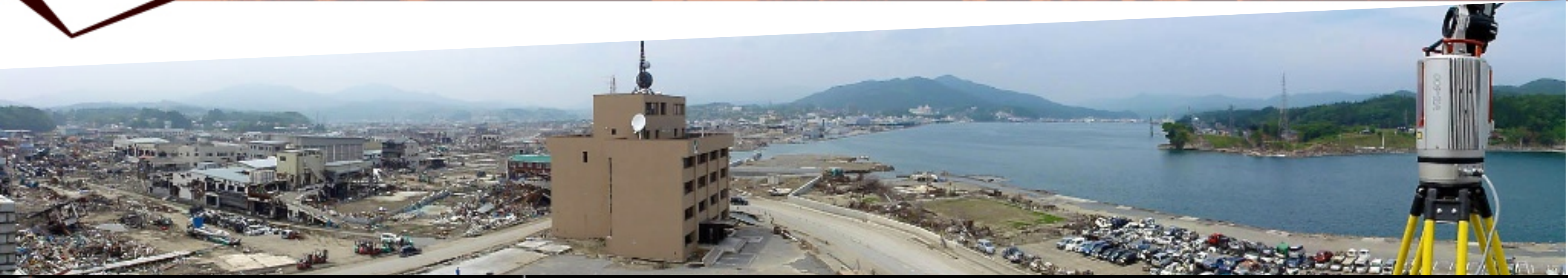
J. Oldow, UTD

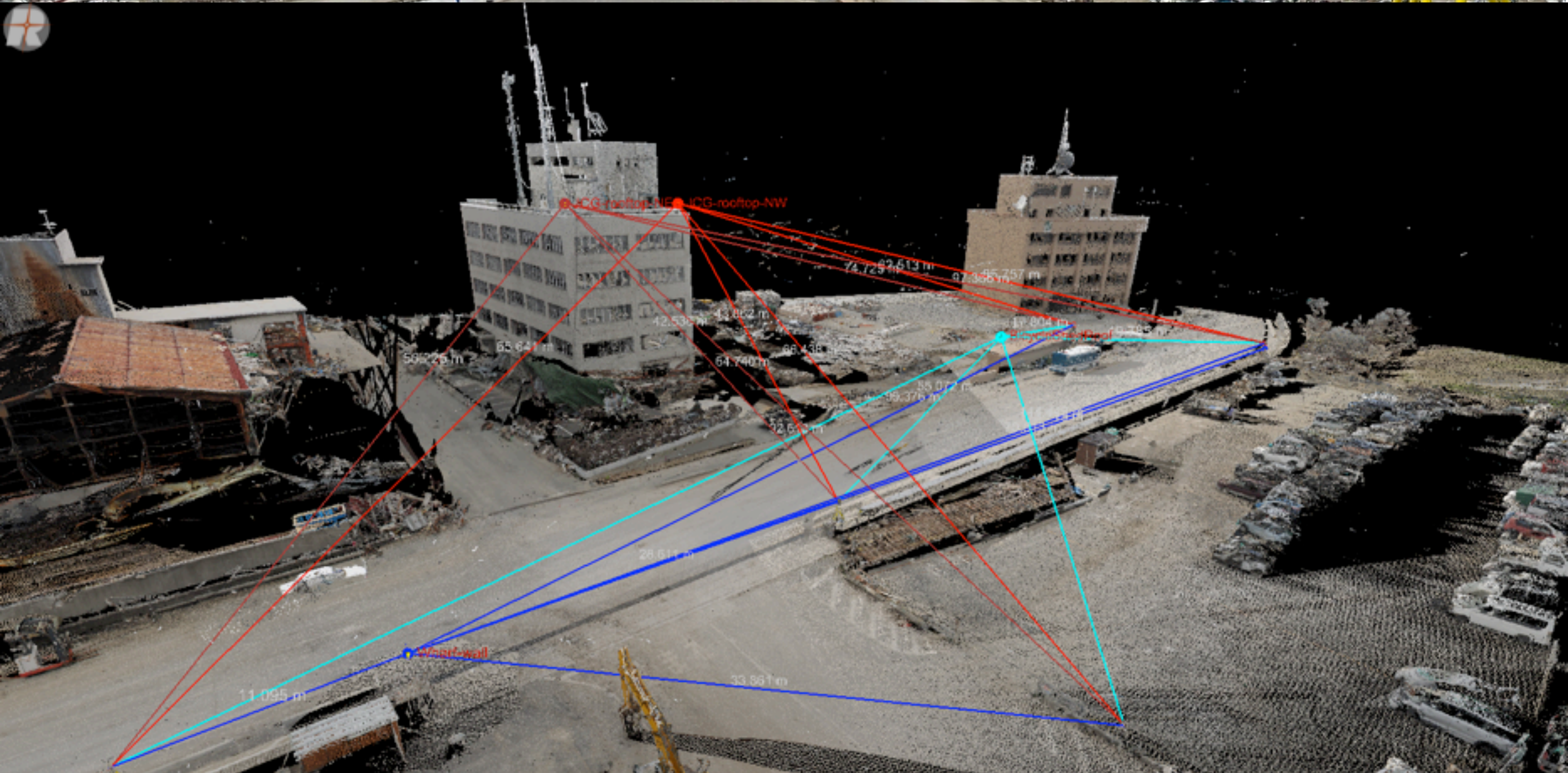
Showcase Video for TLS

TLS Research Applications

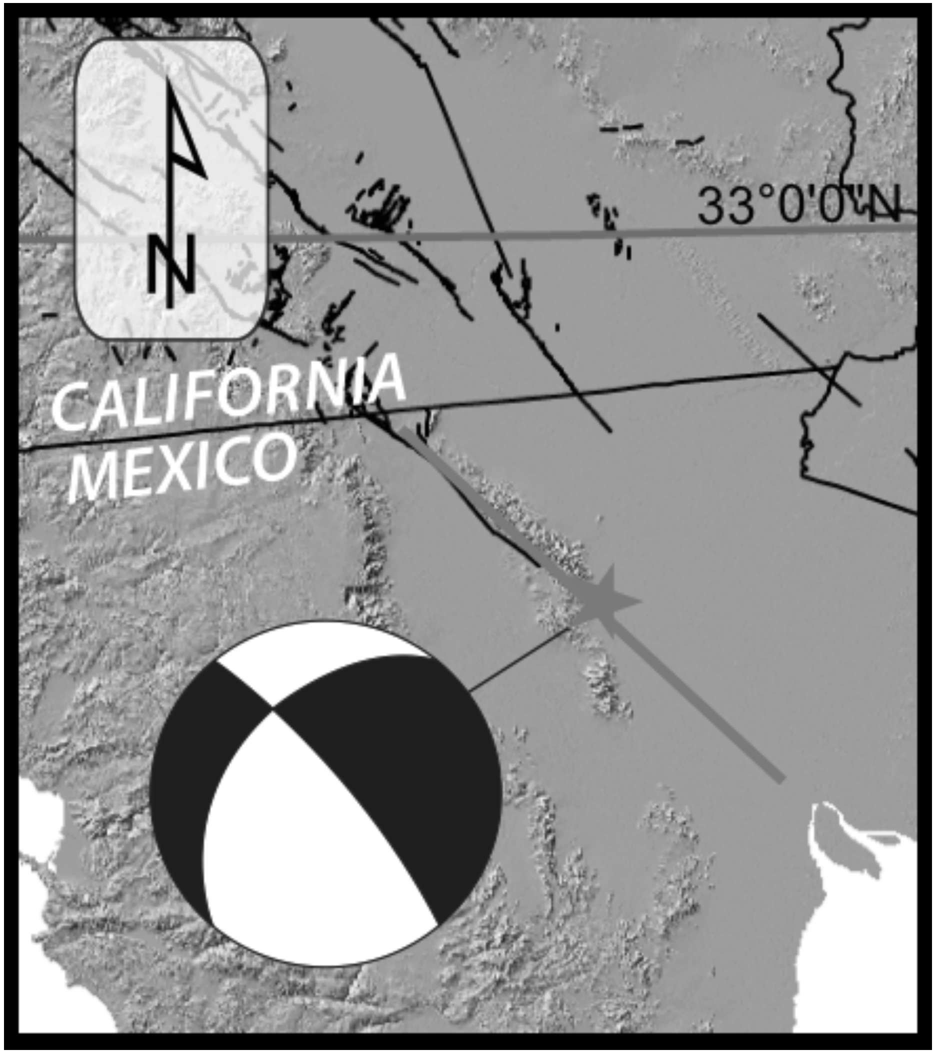
- Project: 2011 Japan Tsunami measurements
- PI: Hermann Fritz (Georgia Tech)
- NSF RAPID project

2011 Japan Tsunami





El Mayor-Cucapah Earthquake, 2010



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

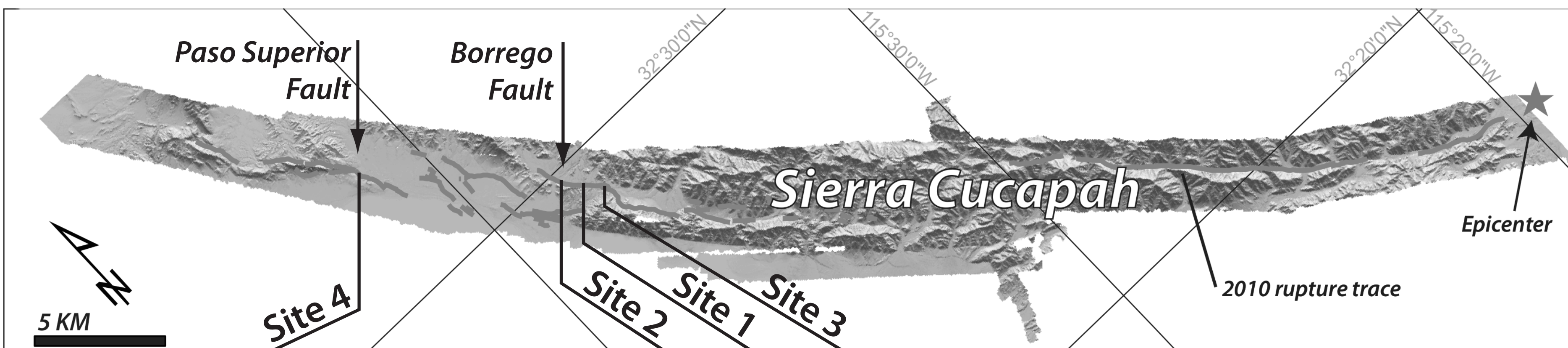
- > 3m right-normal slip north of epicenter
- < 1m right-normal blind faulting south of epicenter

P. Gold, UCD

Motivations: Data Collection

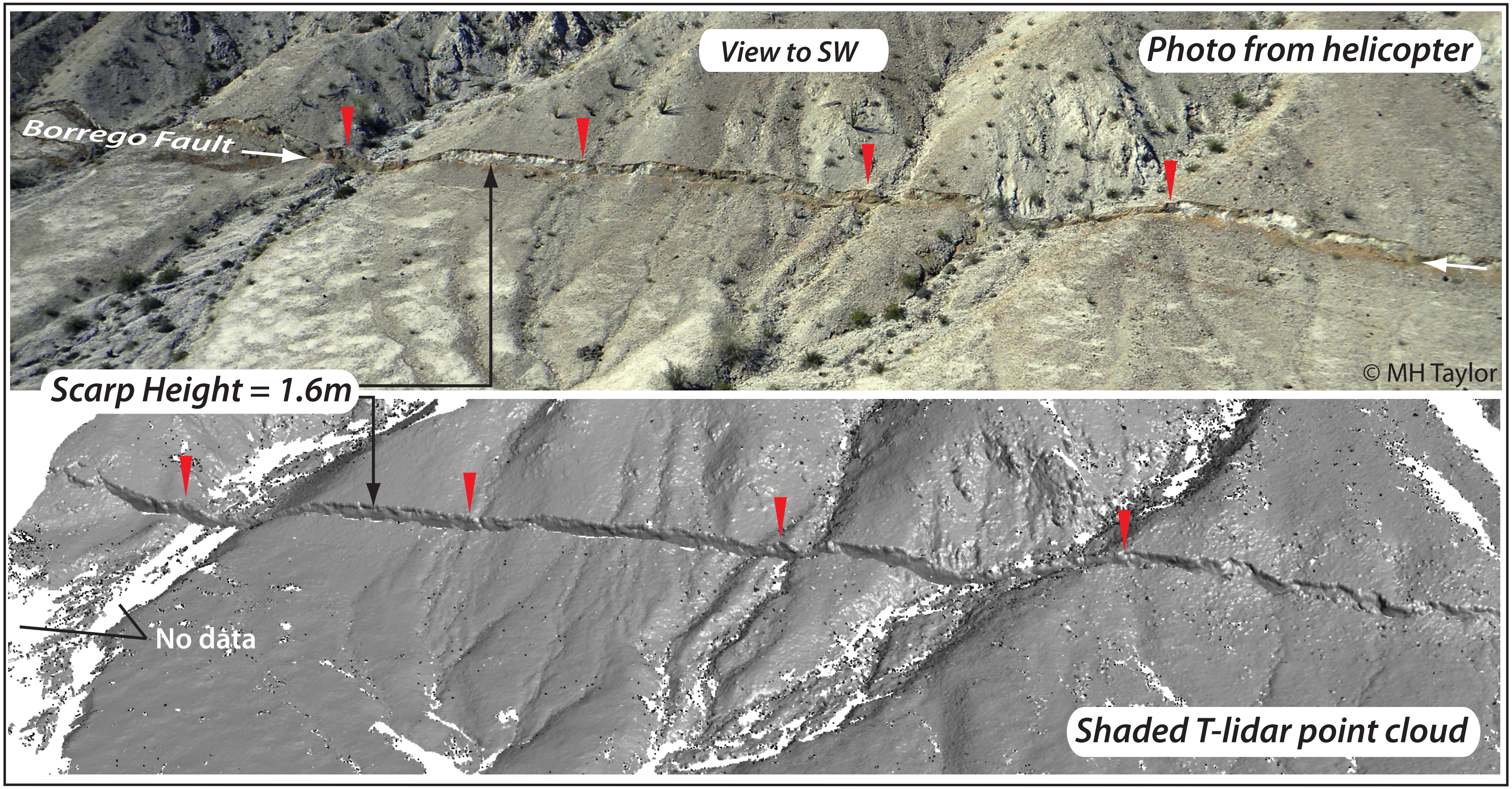
- Preserve primary rupture features for:
  - Remote measurement/analysis
  - Comparison to future scans

- Scan ruptures in a variety of geologic and geomorphic settings



P. Gold, UCD

Scale of TLS coverage

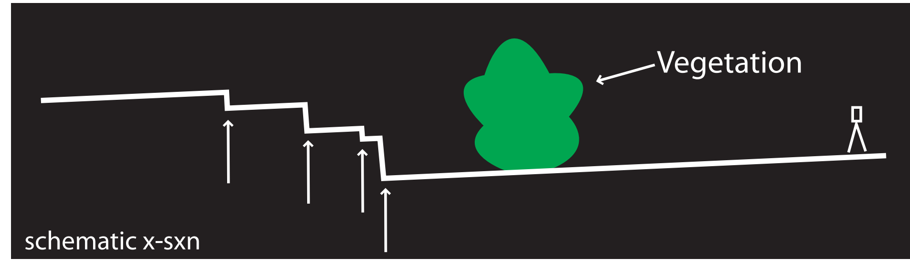


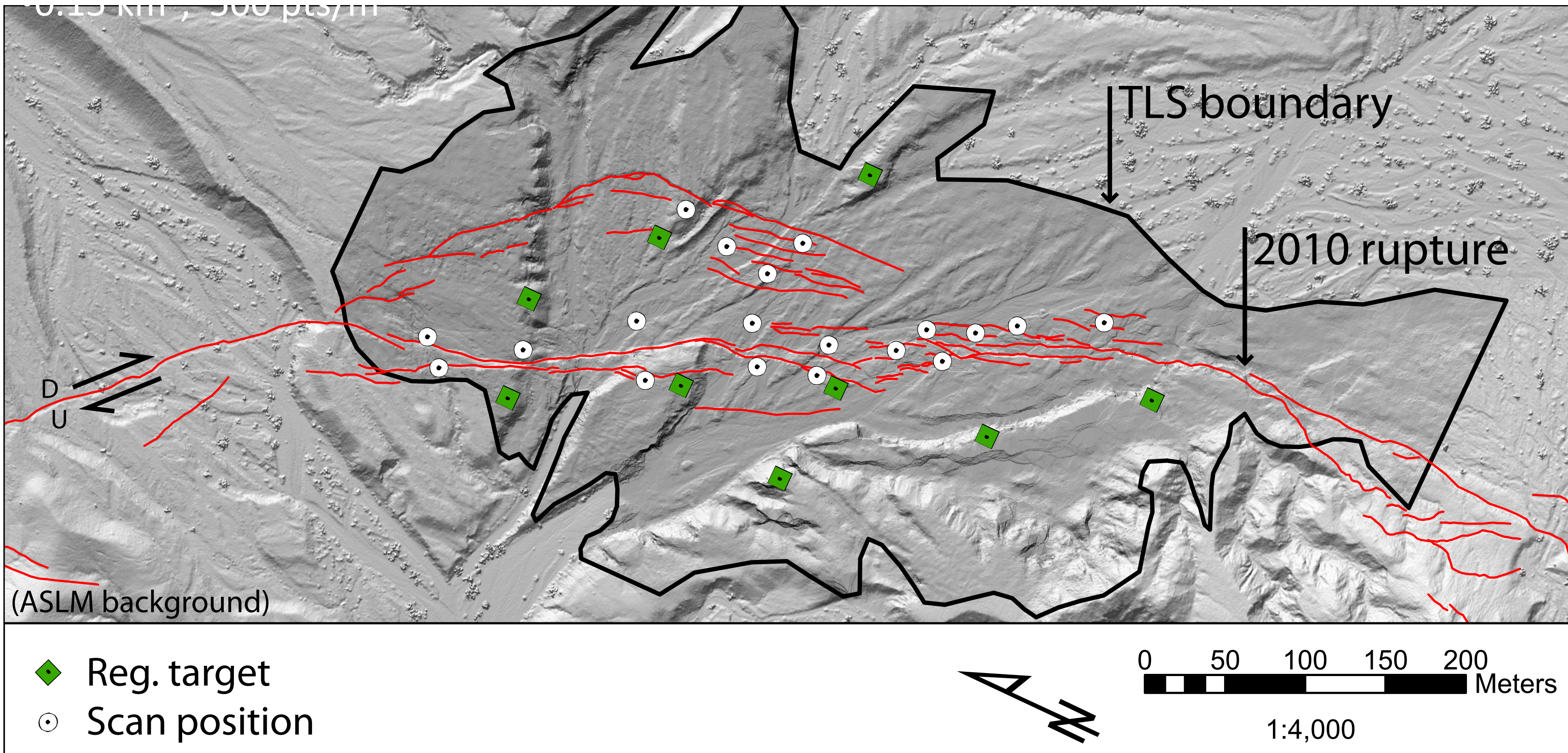
- ~200m along-strike distances

P. Gold, UCD

El Mayor-Cucapah Earthquake, 2010

Data Collection



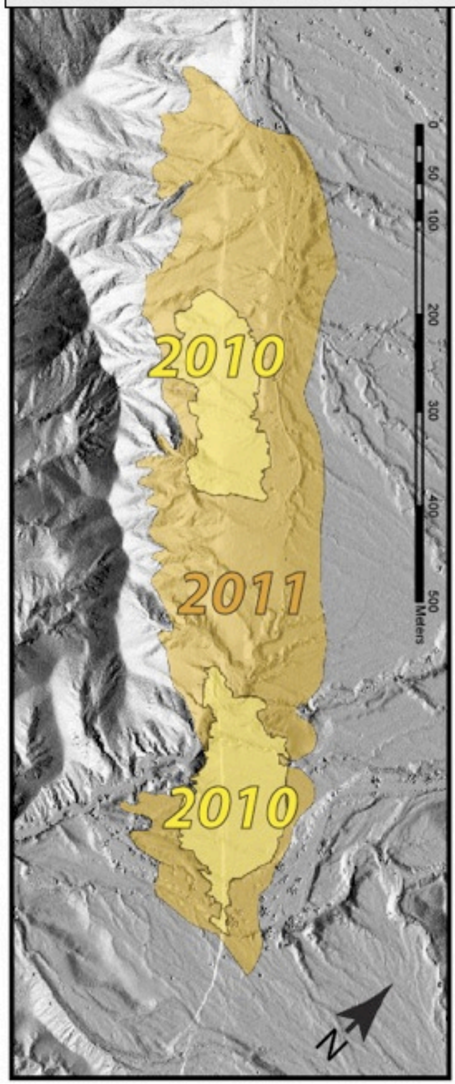


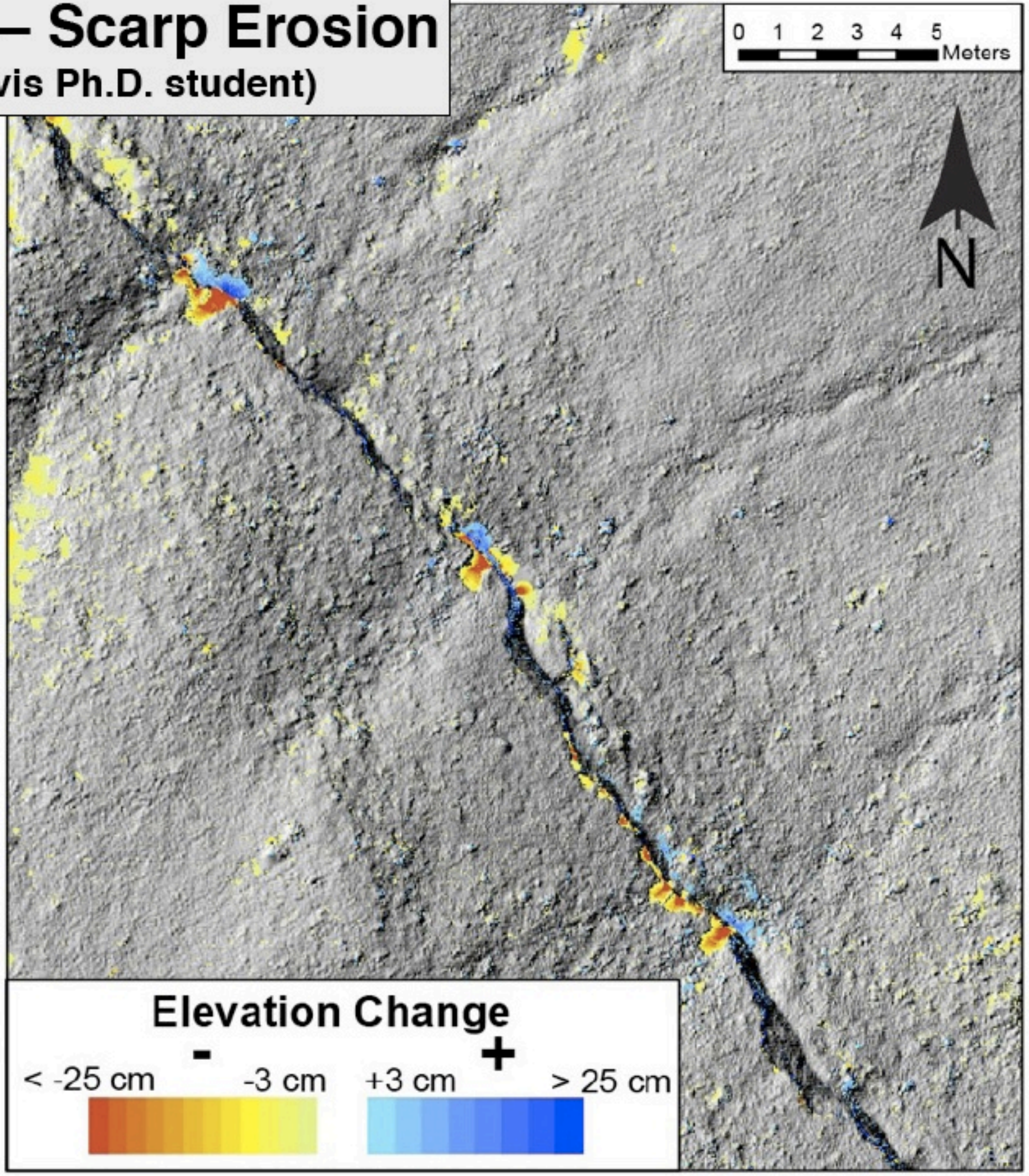
P. Gold, UCD

Scarp Erosion, 2010-2011

Change Detection – Scarp Erosion

Austin Elliott (UC Davis Ph.D. student)





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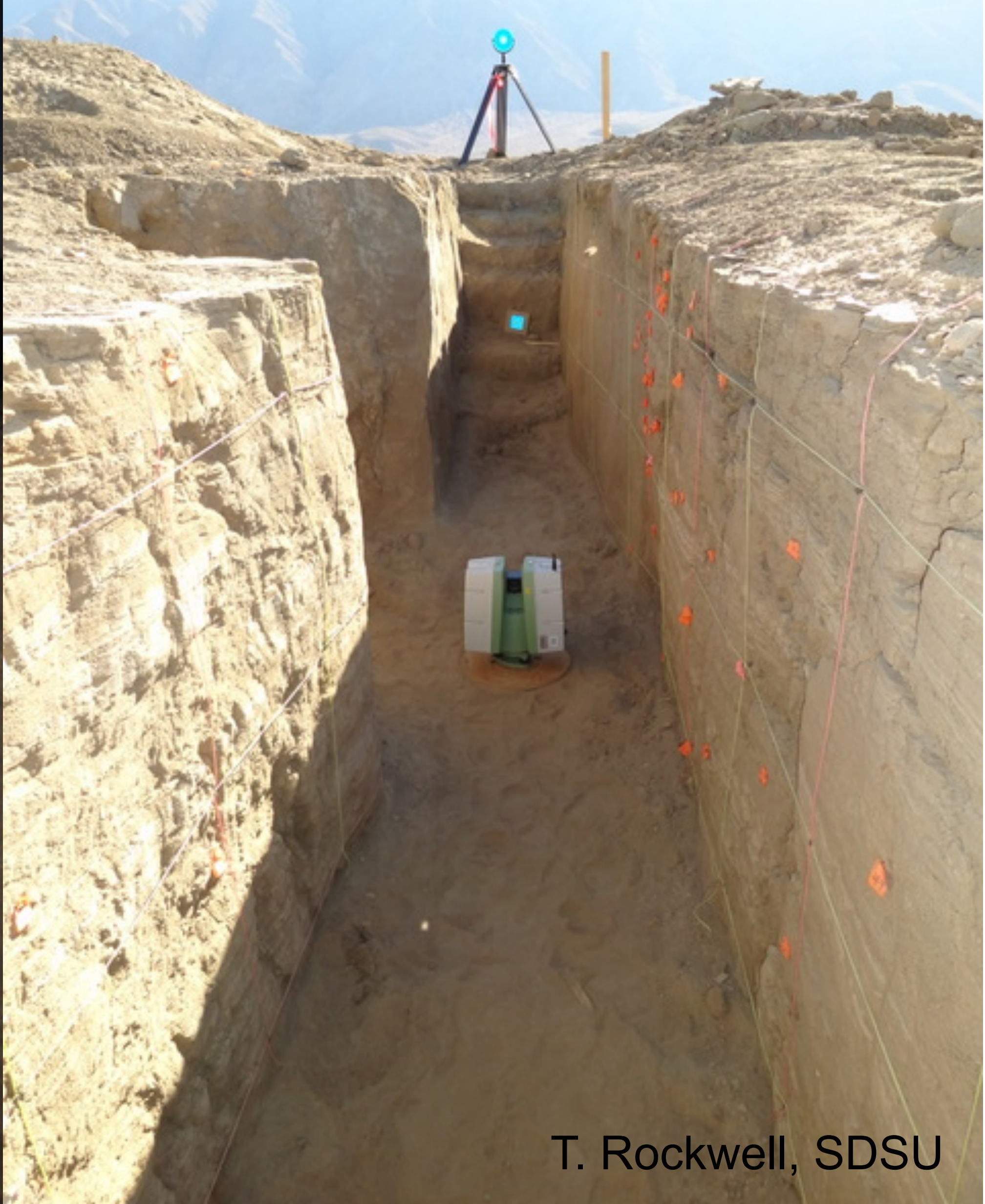
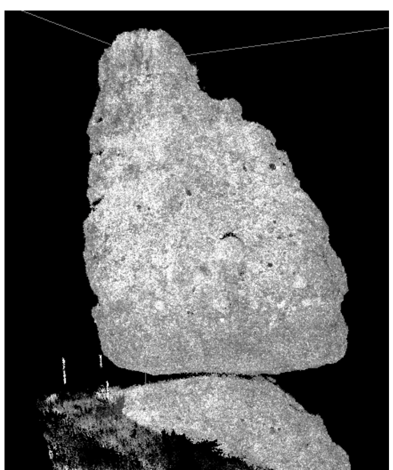
SoCal Paleoseismology

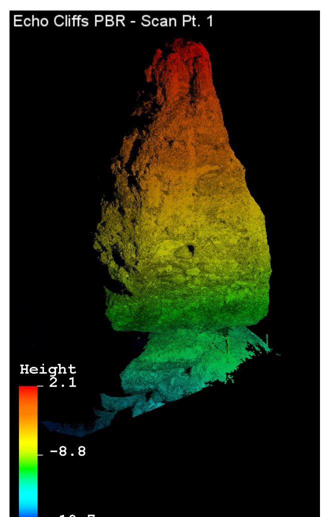


T. Rockwell, SDSU

Precariously Balanced Rocks, PBRs

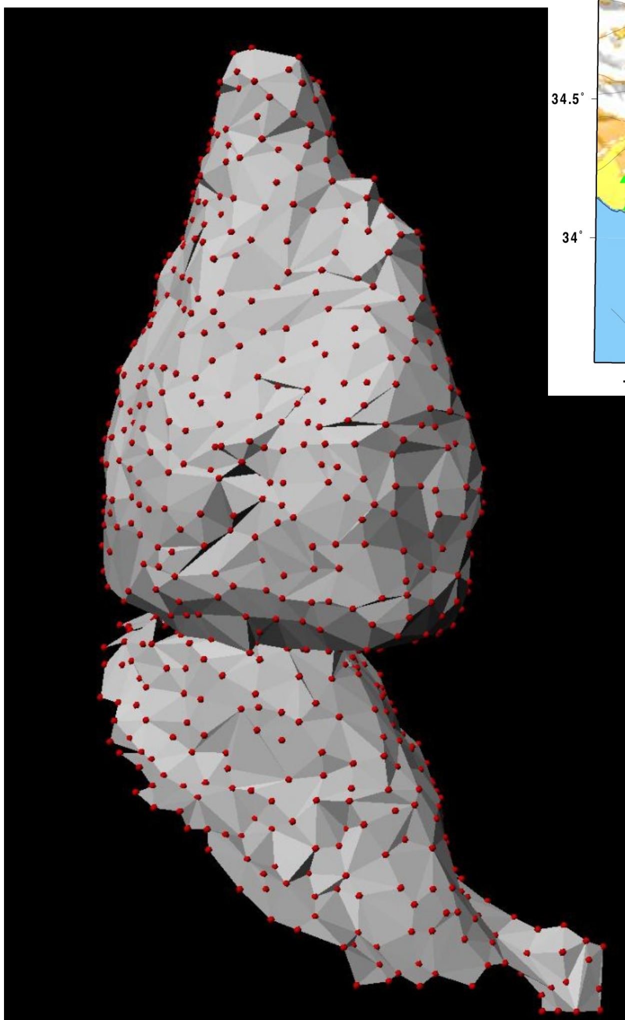
- Project Highlight: Precariously balanced rock (PBR) near Echo Cliffs, southern California.
- PI: Ken Hudnut, USGS.
- Goal: generate precise 3D image of PBR in order to calculate PBR's center of gravity for ground motion models useful for paleoseismology, urban planning, etc.

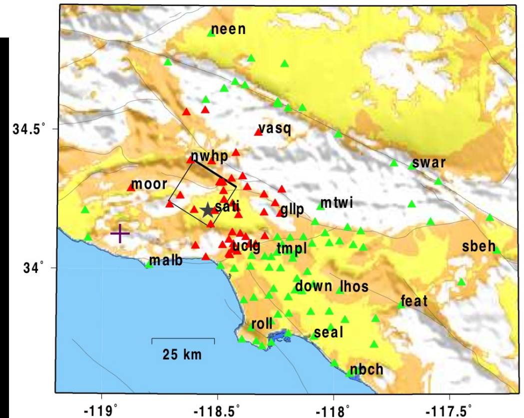




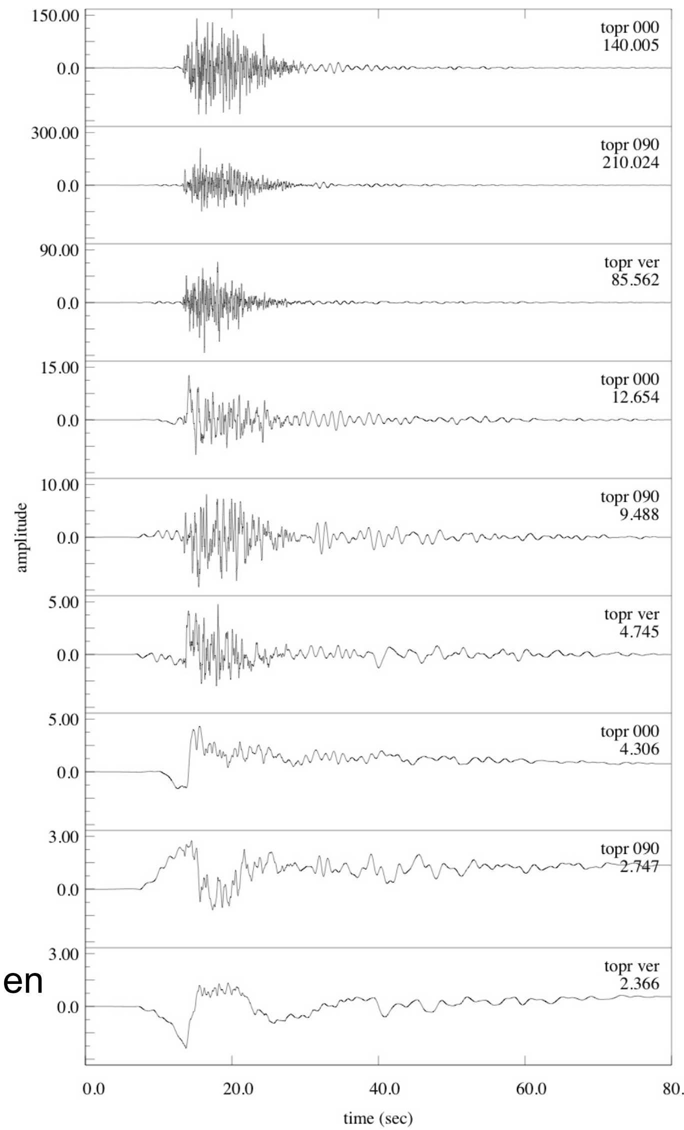
(Hudnut et al., 2009)

3D surface model and simulated 1994 Northridge waveforms





Northridge 1994 simulation by Rob Graves



3D model by Gerald Bawden and Sandra Bond

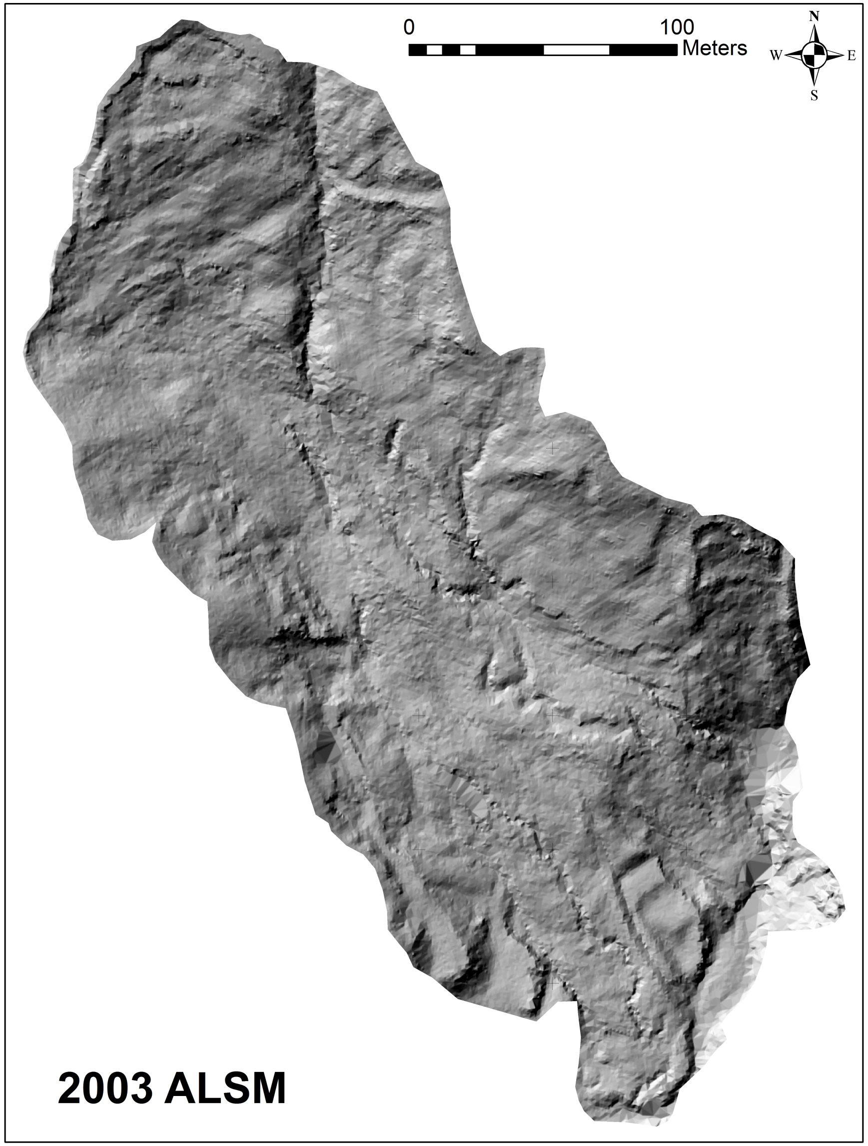
Four Mile Fire, CO, Erosion (PIs: Moody, Tucker)

Mill Gulch earth flow, Sonoma, CA)

Repeat surveys give ability to quantify temporal change.

Integration of TLS and ALS data

Steve DeLong, USGS



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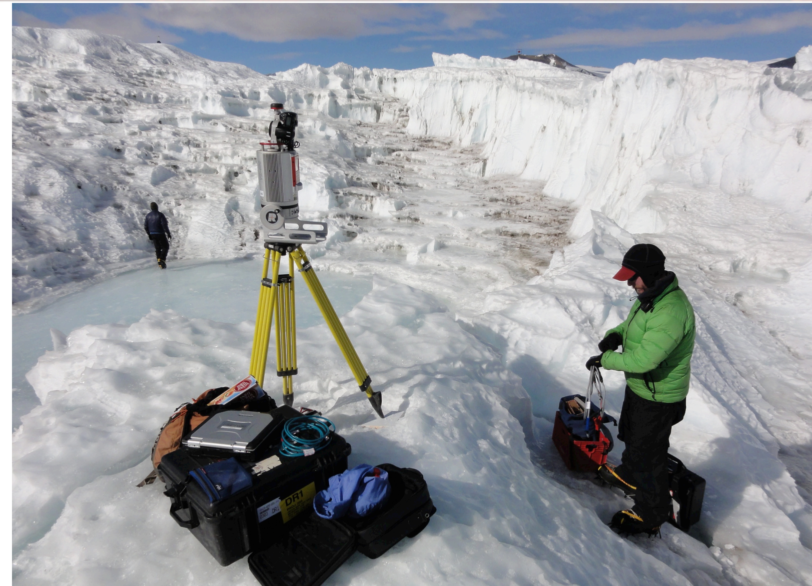
Scanning in Polar Environments

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

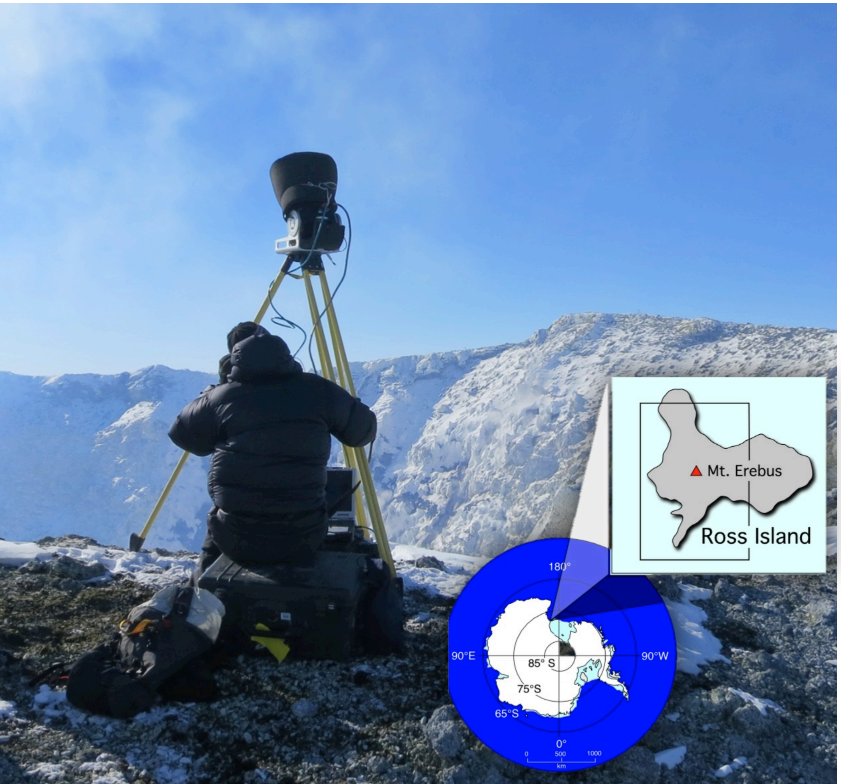
<u>Science:</u>

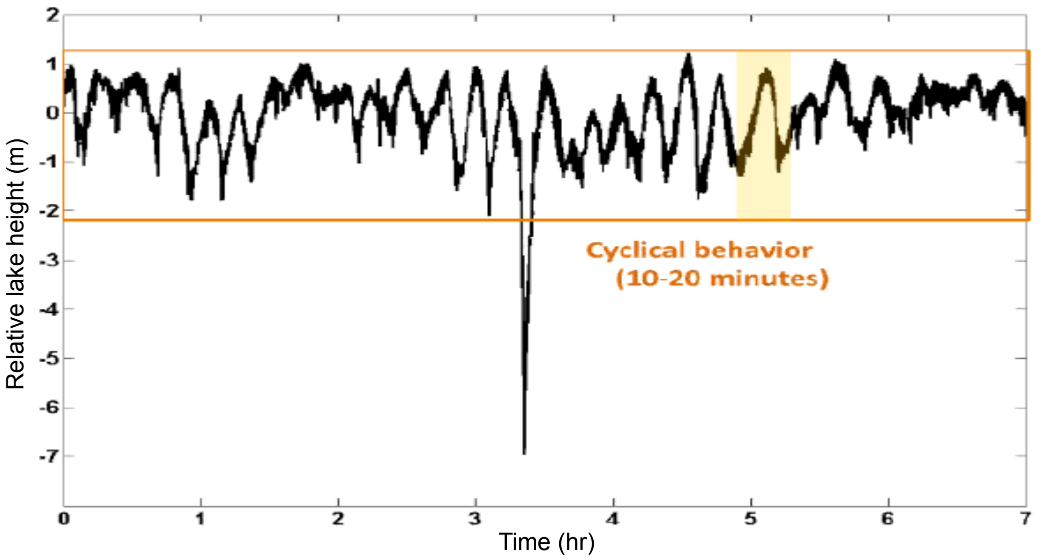
- *Geomorphology:* Frost polygons and ancient lake beds
- *Glaciology:* Glacier melt and ablation
- *Biology/Ecology:* Weddell Seal volume; Microtopology of tundra in Alaska
- *Archeology:* Human impact of climate change



Mount Erebus, Antarctica

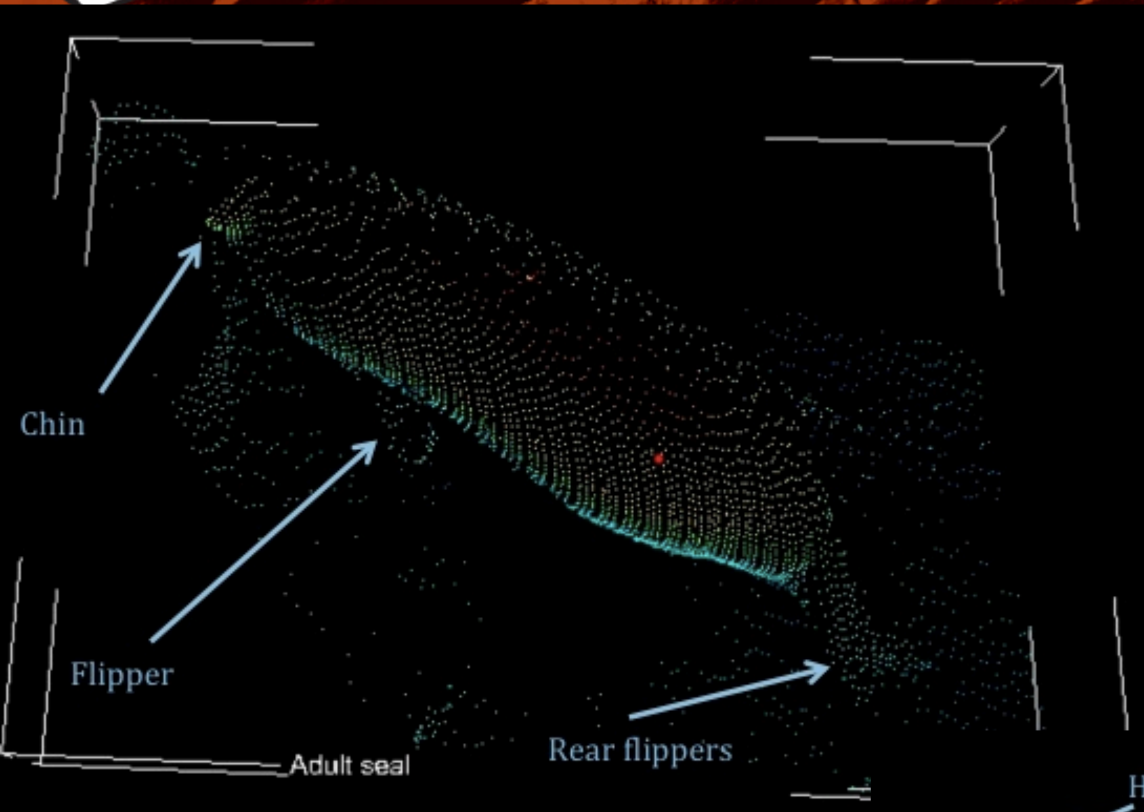
- Lava lake scanned 2008 - 2013, revealing behaviors invisible to naked eye
- Inner crater scan used to augment and truth 2003 aerial scans
- Scans of ice caves and ice towers help determine thermal / energy budget of volcano

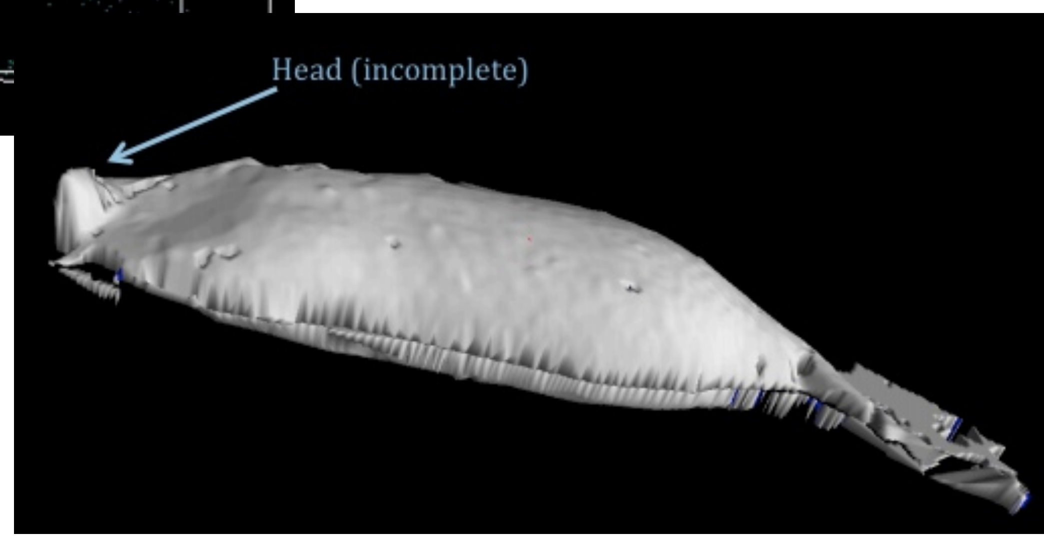




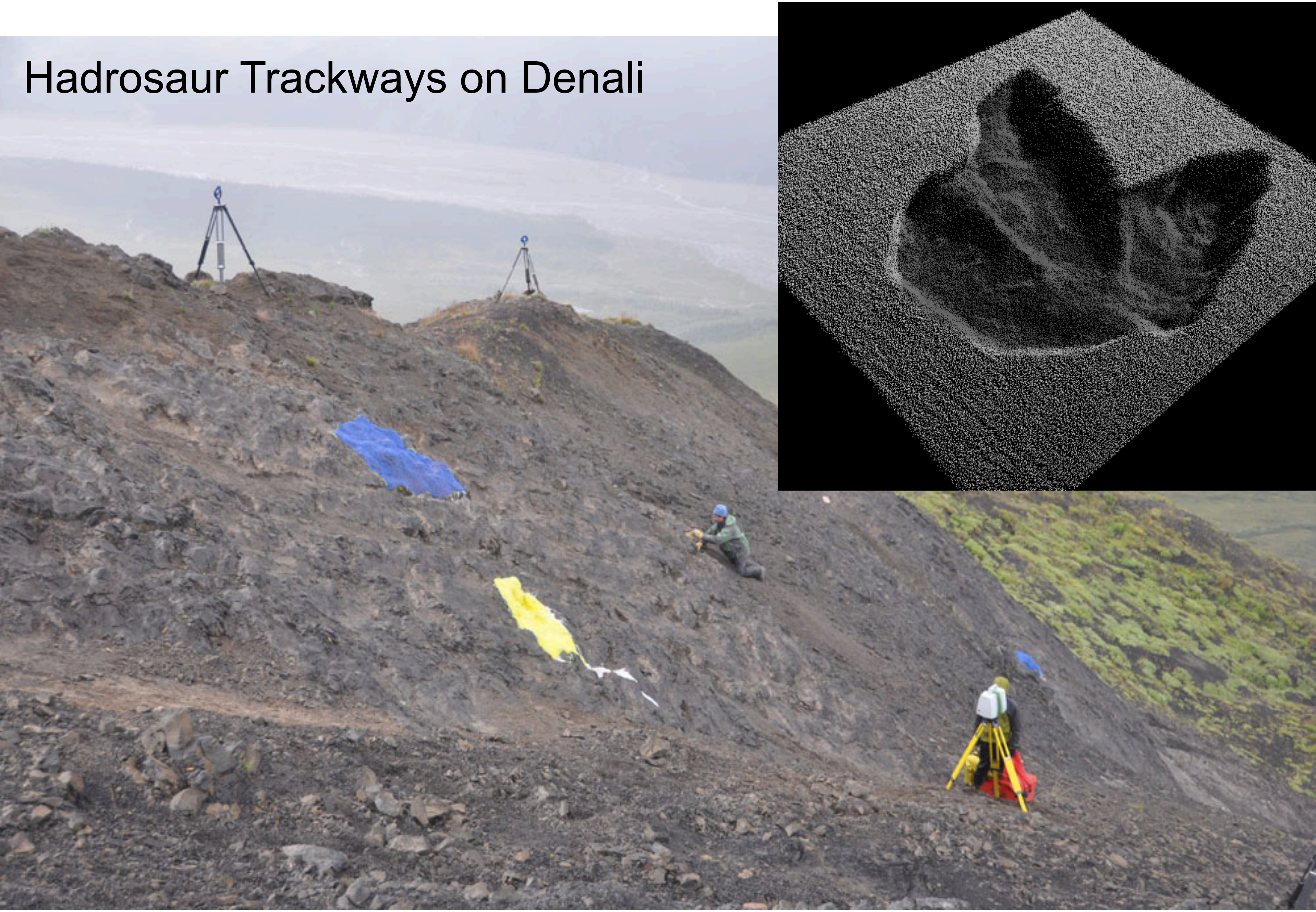
Using TLS to Obtain Volumetric Measurements of Weddell Seals in the McMurdo Sound

Seal body mass = proxy for availability of marine food resources



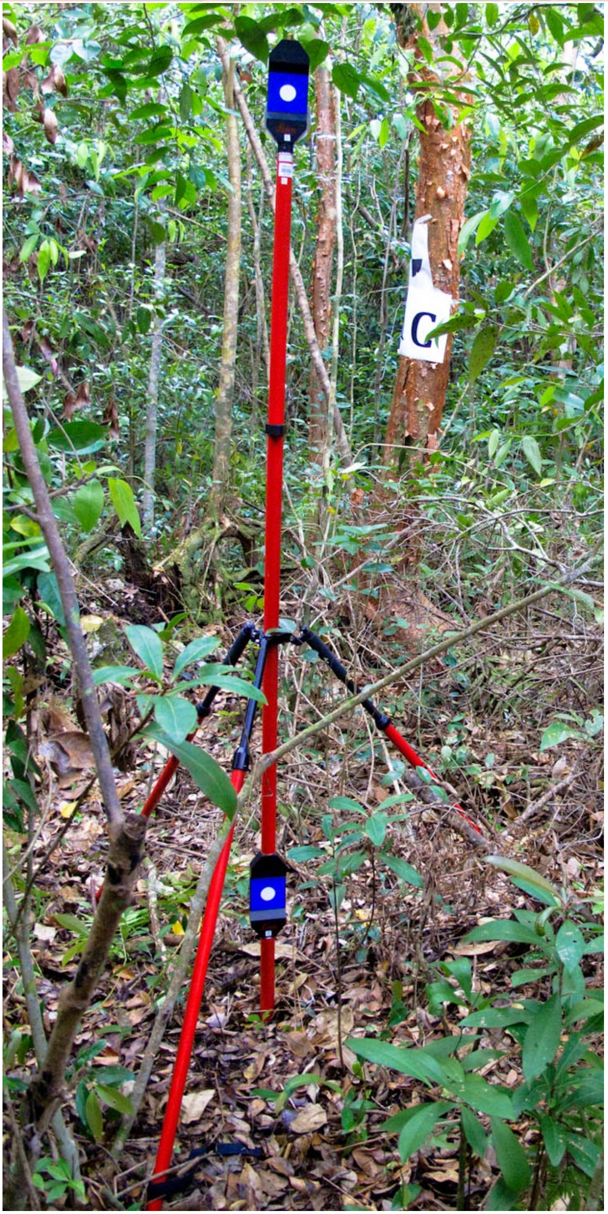


Hadrosaur Trackways on Denali



Fiorillo, et al., 2014, Geology, DOI: 10.1130/G35740.1

Everglades Biomass, Wdowinski



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

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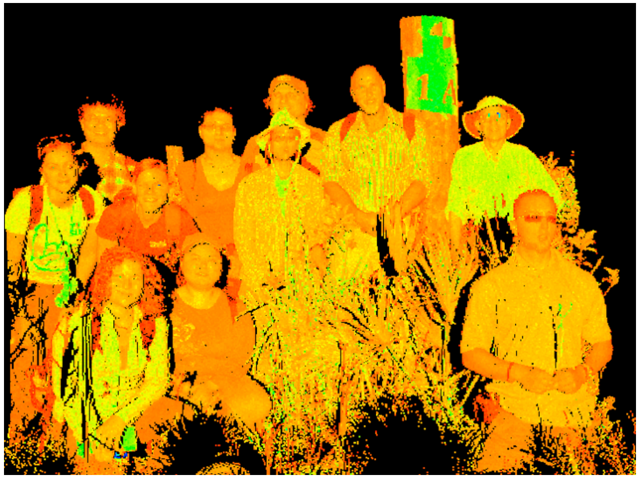
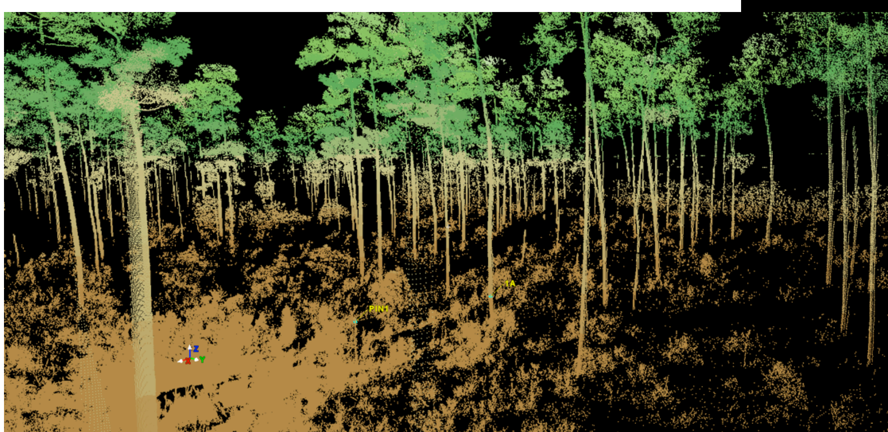
Everglades Biomass, Wdowinski





Thanks!

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