Introduction to Terrestrial Laser Scanning for Earth Science Research and Education

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UNAVCO

2014 GSA Short Course

Short Course Summary

Introduction to TLS = lectures, hands-on demonstrations of TLS equipment, and data exploration.

Overview of the basic principles of TLS with emphasis on application examples, theory, practical considerations.

Will ***not*** provide you with detailed training in specific software or hardware.

Goal = solid intro to TLS and a foundation for future learning. We also hope that it will inspire you to explore the technology and to apply it to new applications.

Agenda & Logistics

Agenda…

Course page:

http://tinyurl.com/GSATLS2014

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Introductions

- ***Name & affiliation?***
- ***Your interest in TLS & application area?***
- ***Previous TLS or lidar experience?***

TLS Haiku

Yesterday it worked
Today it is not working
Windows is like that

Out of memory.
We wish to hold the whole sky,
But we never will.

Windows has crashed.
I am the Blue Screen of Death.
No one hears your screams.

A crash reduces
your expensive computer
to a simple stone.

A file that big?
It might be very useful.
But now it is gone.

Serious error.
All data have disappeared
Screen. Mind. Both are blank.

ABORTED effort:
Close all that you have.
You ask way too much.

To have no errors
Would be life without meaning
No struggle, no joy

Chaos reigns within.
REFLECT, REPENT, REBOOT.
Order shall return.

Video…

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

GEODETIC IMAGING AT UNAVCO

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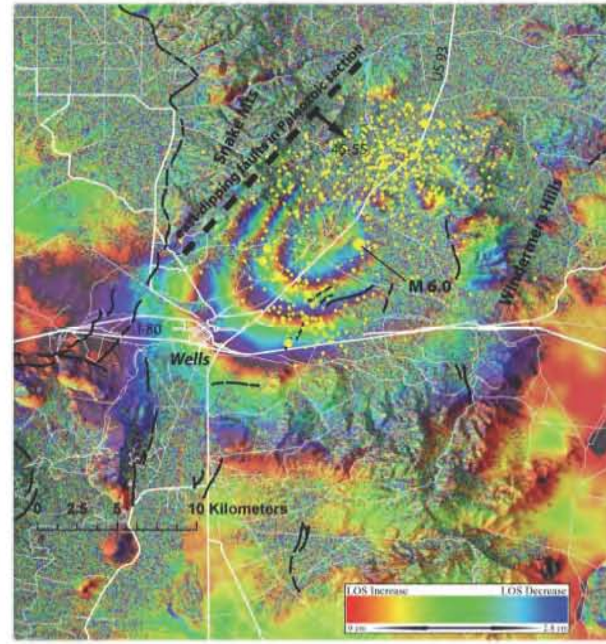
Terrestrial LiDAR

Airborne/ Spaceborne InSAR



Airborne/ Spaceborne LiDAR

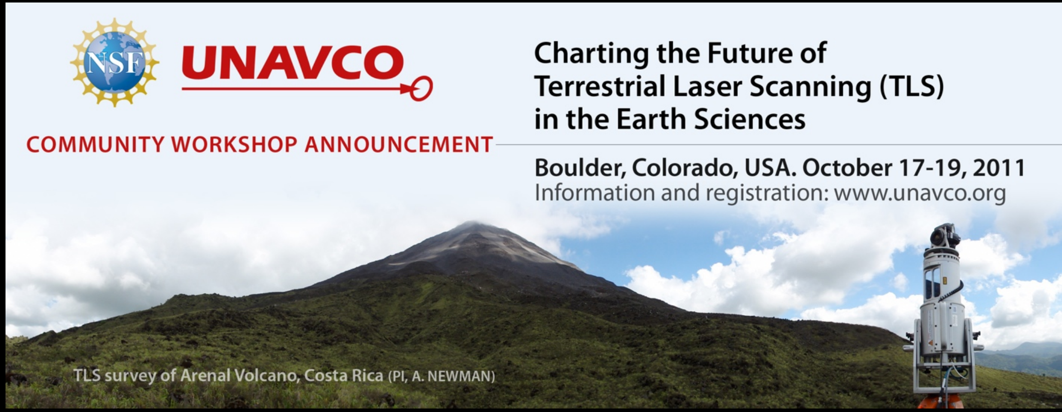
Terrestrial Radar

TLS Community Support

Support Resources
- Instrumentation (6 scanners)
- Field engineering
- Data processing
- Training
- Data archiving & dissemination

Community Building
- Workshops
- Inter-Agency collaborations & partnerships

Education and Outreach
- Training courses
- Field camps (~90 students in 2013)



GSA 2012 UNAVCO TLS short course, Charlotte, NC

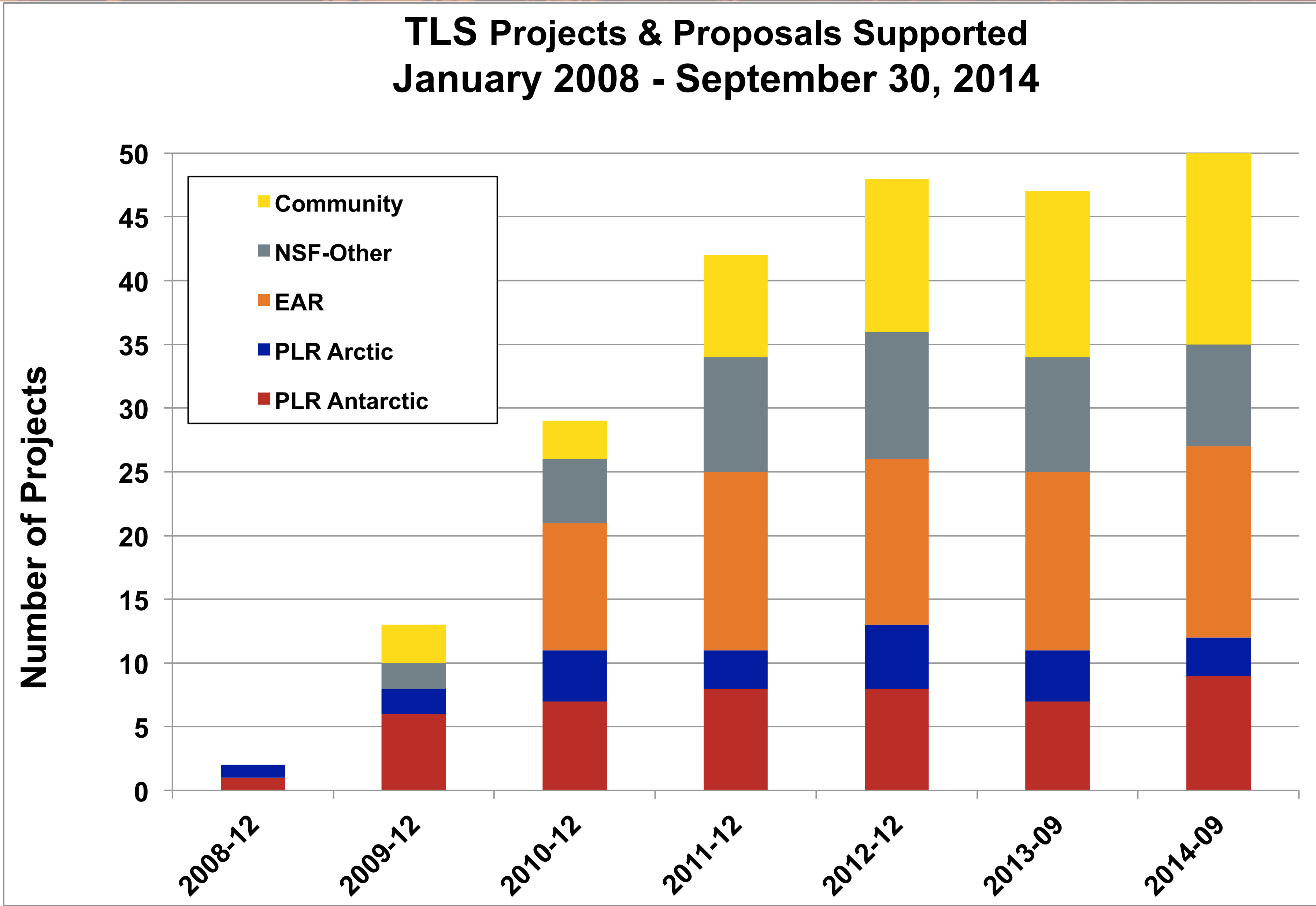
UNAVCO TLS Instrument Pool

Scanners funded by the National Science Foundation

- TLS instrument pool = 6 scanners
  - 3x Riegl VZ400
  - 1x Riegl VZ1000 (full waveform)
  - 1x Riegl Z620
  - 1x Leica C10
  - *NEW scanner TBD*
- Campaign and RTK GPS, tripods, various power supply options
- Instrument validation range
- License server w/ access to RiScan Pro, Cyclone, Polyworks, ArcGIS, Quick Terrain Modeler, MatLab, etc

	 Riegl VZ-1000	 Riegl VZ-400	 Riegl Z620	 Leica C10
Laser Wavelength	1550 nm (near IR)	1550 nm (near IR)	1550 nm (near IR)	532 nm (green)
Effective Range (max)	1400 m	500 m	2000 m	150 m
High-speed meas. rate	122,000 points/sec	125,000 points/sec	11,000 points/sec	50,000 points/sec
Precision	5 mm	5 mm	10 mm	4 mm
Accuracy	8 mm	5 mm	10 mm	6 mm
Field of View	100° x 360°	100° x 360°	80° x 360°	270° x 360°
Dimensions	308mm x 180mm	308mm x 180mm	463mm x 210mm	238mm x 395mm
Weight	9.8kg	9.8kg	16kg	13 kg

TLS Project Support



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

How is range measured?

Time of flight

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

(*Riegl, Optech, Maptek, etc.*)

Phase Shift

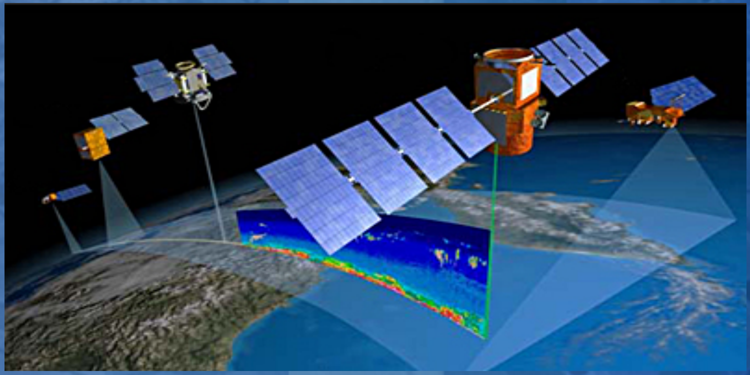
By measuring the phase shift of a pulse, distance is calculated along a sinusoidally modulated laser pulse.

(*Faro, Velodyne, etc.*)

Advantages and Disadvantages

Time of flight	Phase Shift
• Range ~ 100-6000m	• Range ~ 0-100m
• Accuracy ~ 1 mm	• Accuracy ~ 1 micron
• < 300,000 pts/s	• > 1,000,000 pts/s
• Slower, larger	• Noise in data

A Suite of Lidar Platforms



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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).

Lidar Differences

- Platform type
- Profile or scanning
- Single, multiple, or waveform returns
- Footprint Size
- Posting density
- Atmospheric / terrestrial / bathymetric

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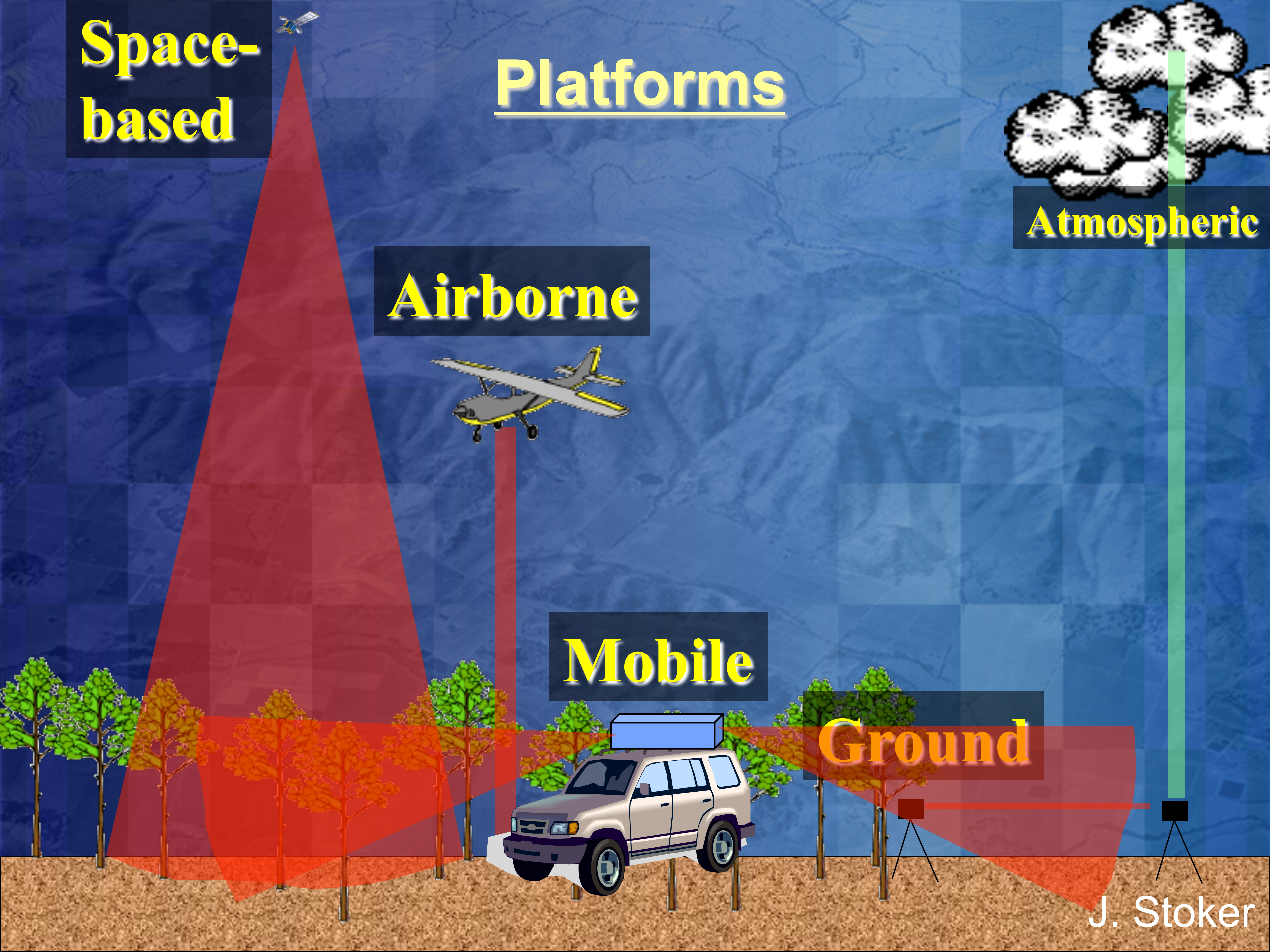

Platforms
Space-based
Airborne
Atmospheric
Mobile
Ground
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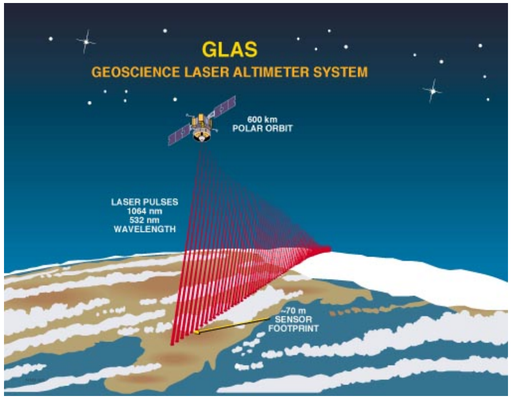
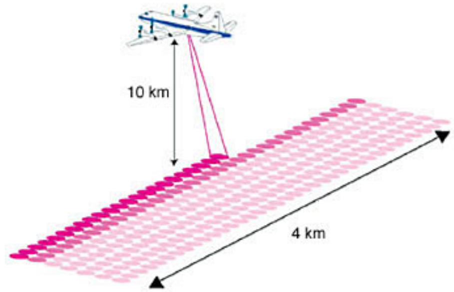
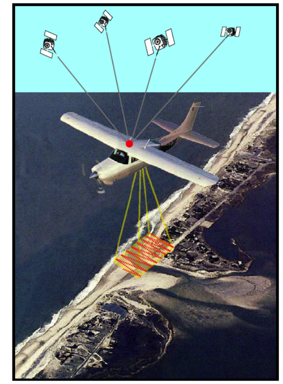
Light Detection And Ranging (LiDAR)

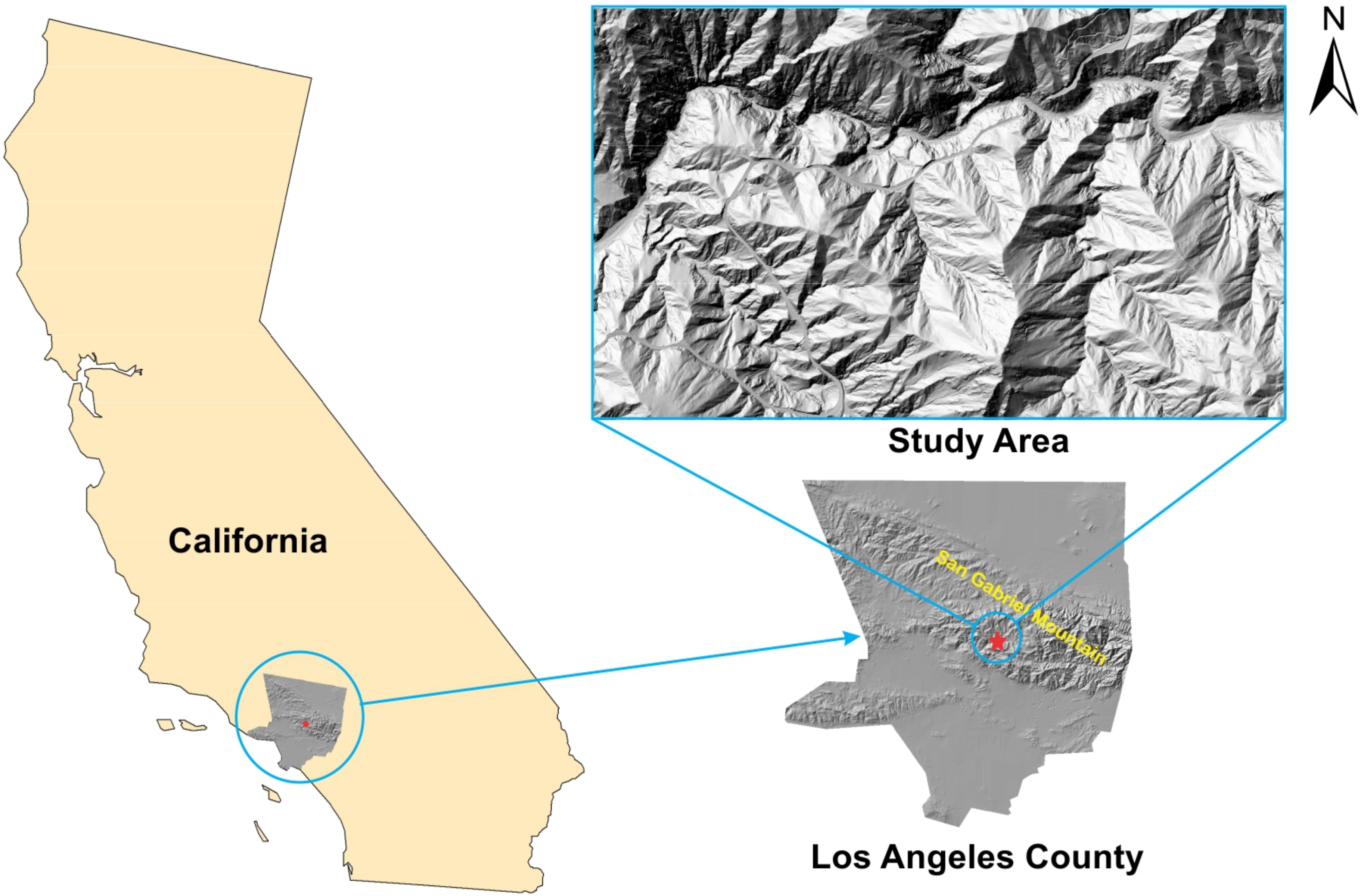






System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1-10 cm
Vertical Accuracy	15cm to 10m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1- 10 cm Depends on range which is few meters to 2 km or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

Location of Study Area (San Gabriel, California)



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Los Angeles County 30m DEM

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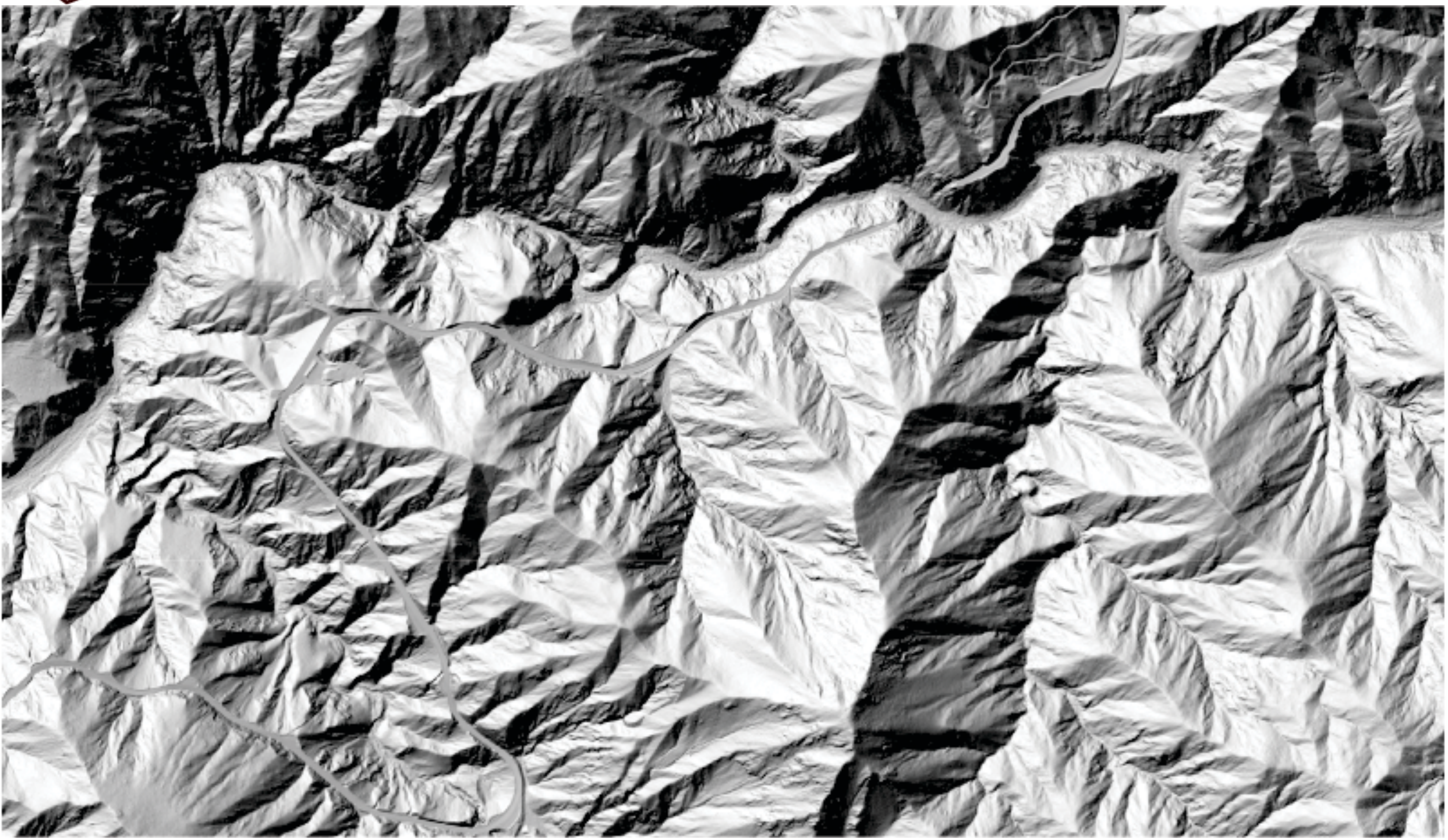

San Gabriel Mountain 1m DEM from airborne lidar

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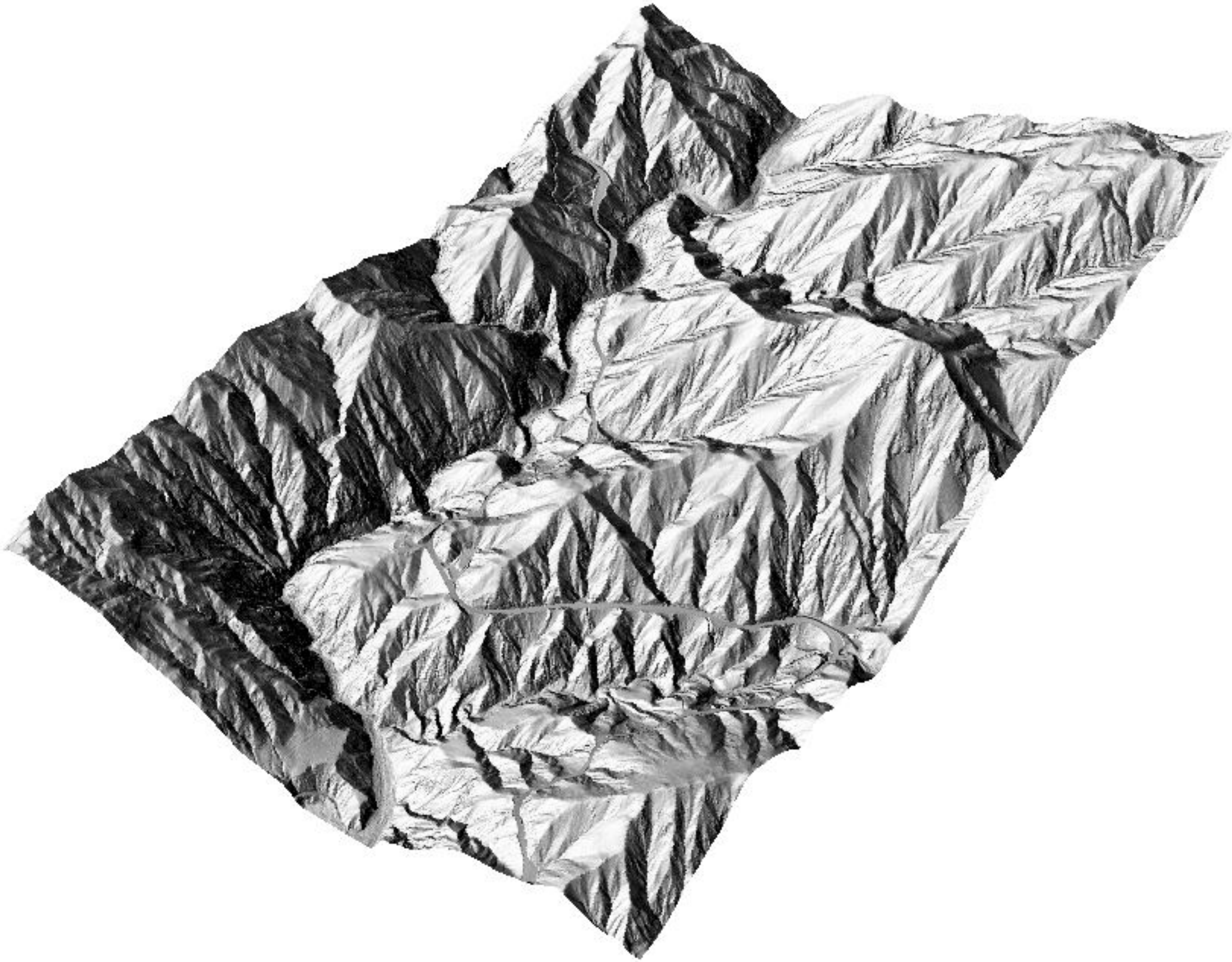

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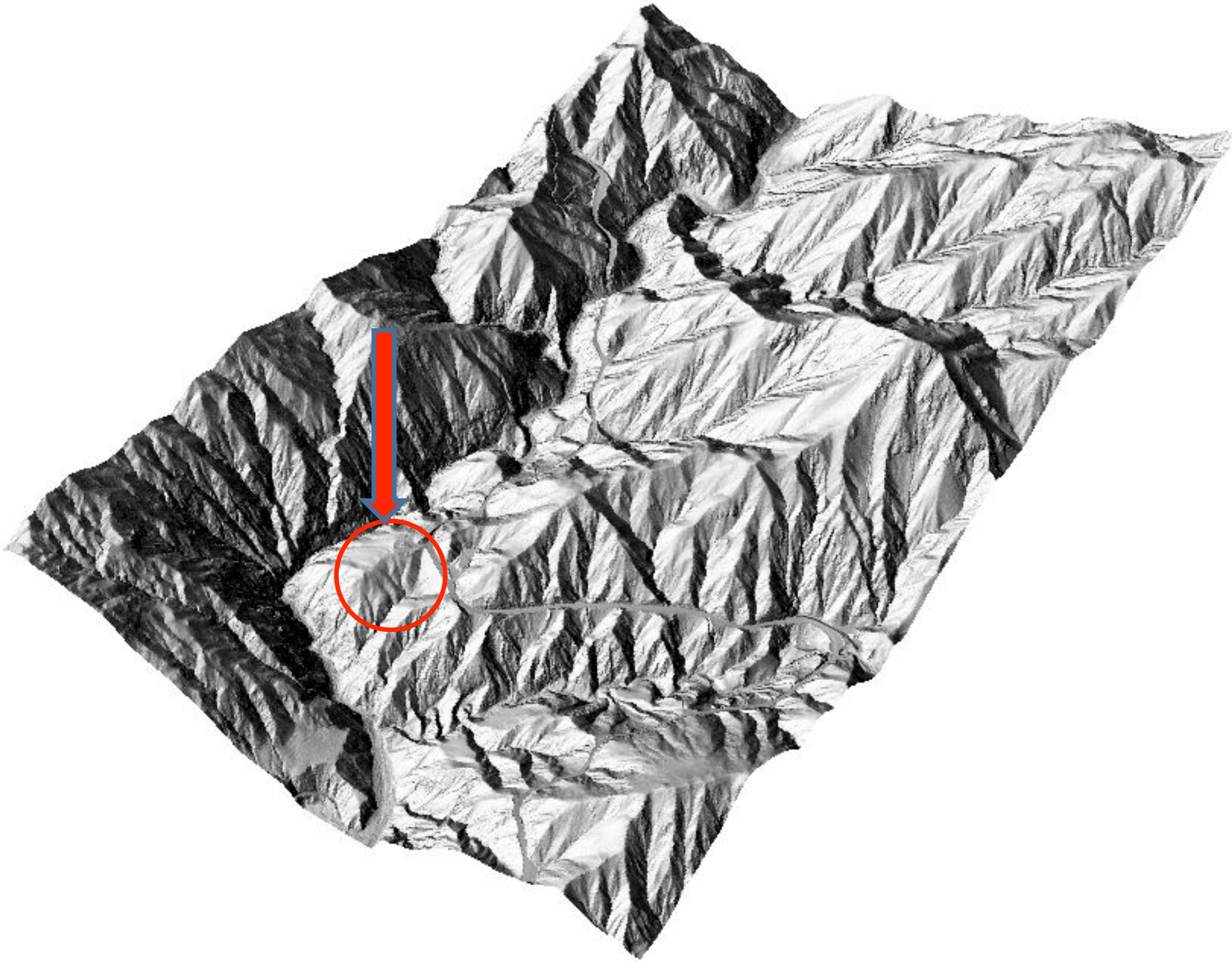

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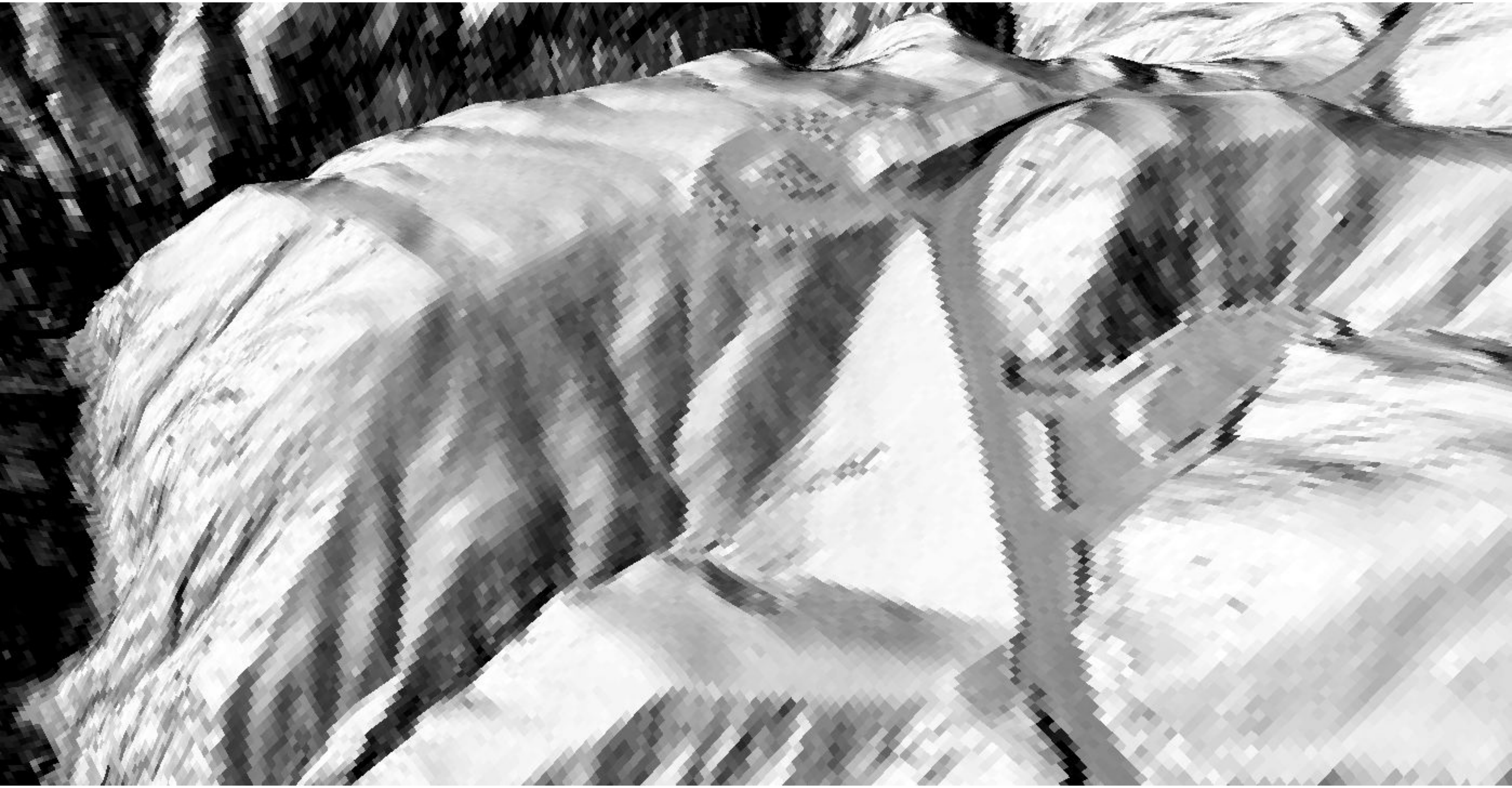

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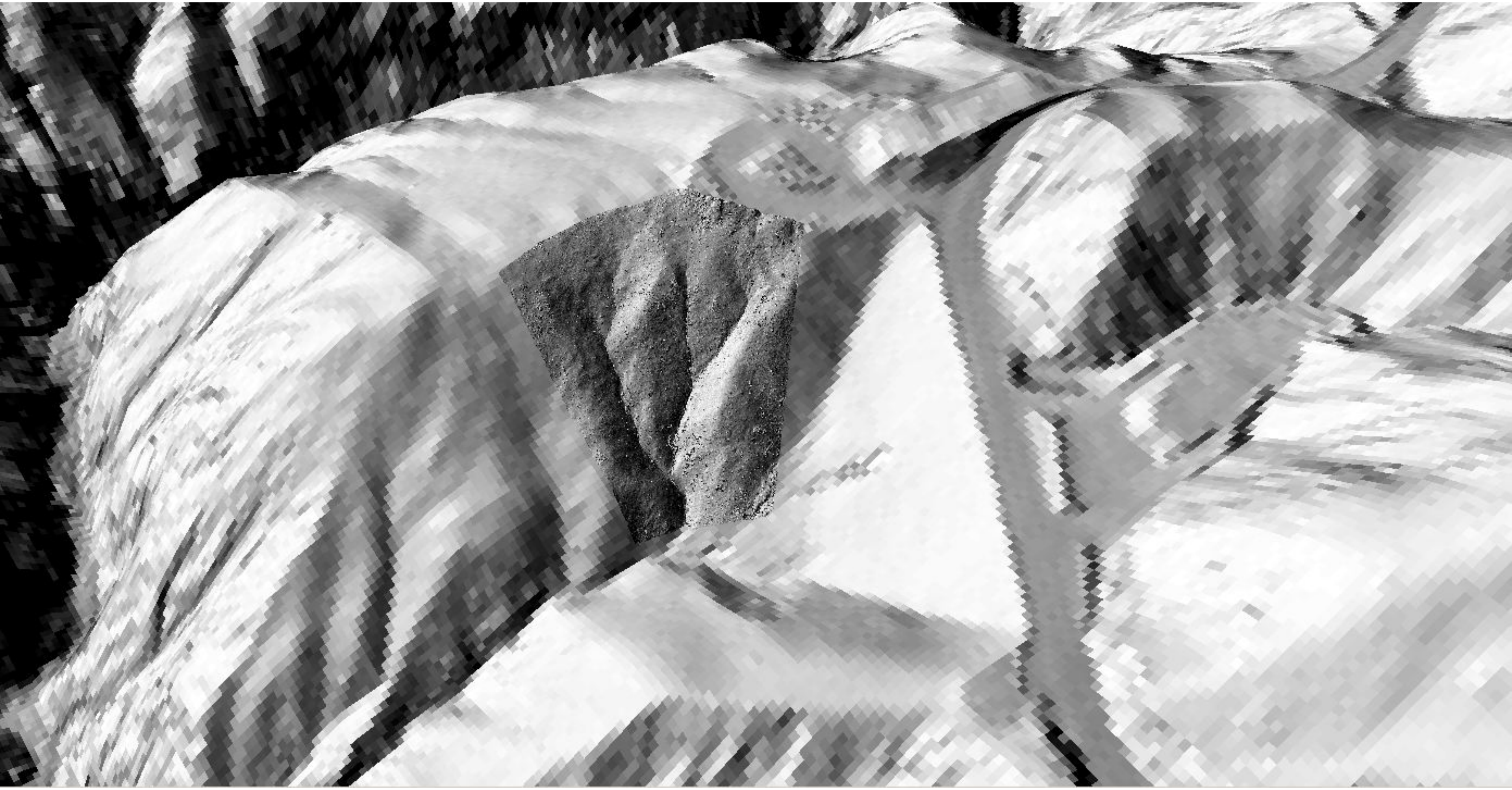

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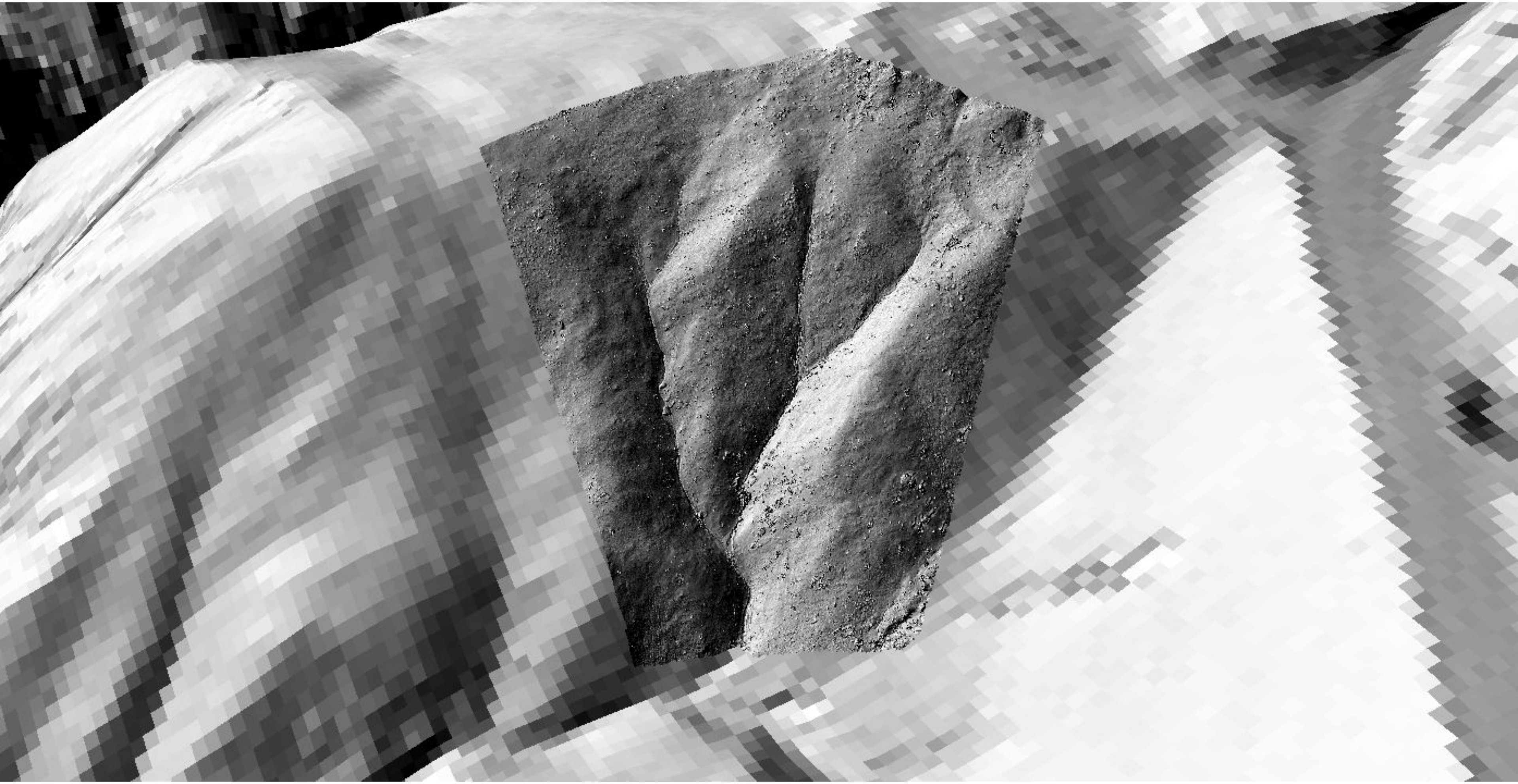

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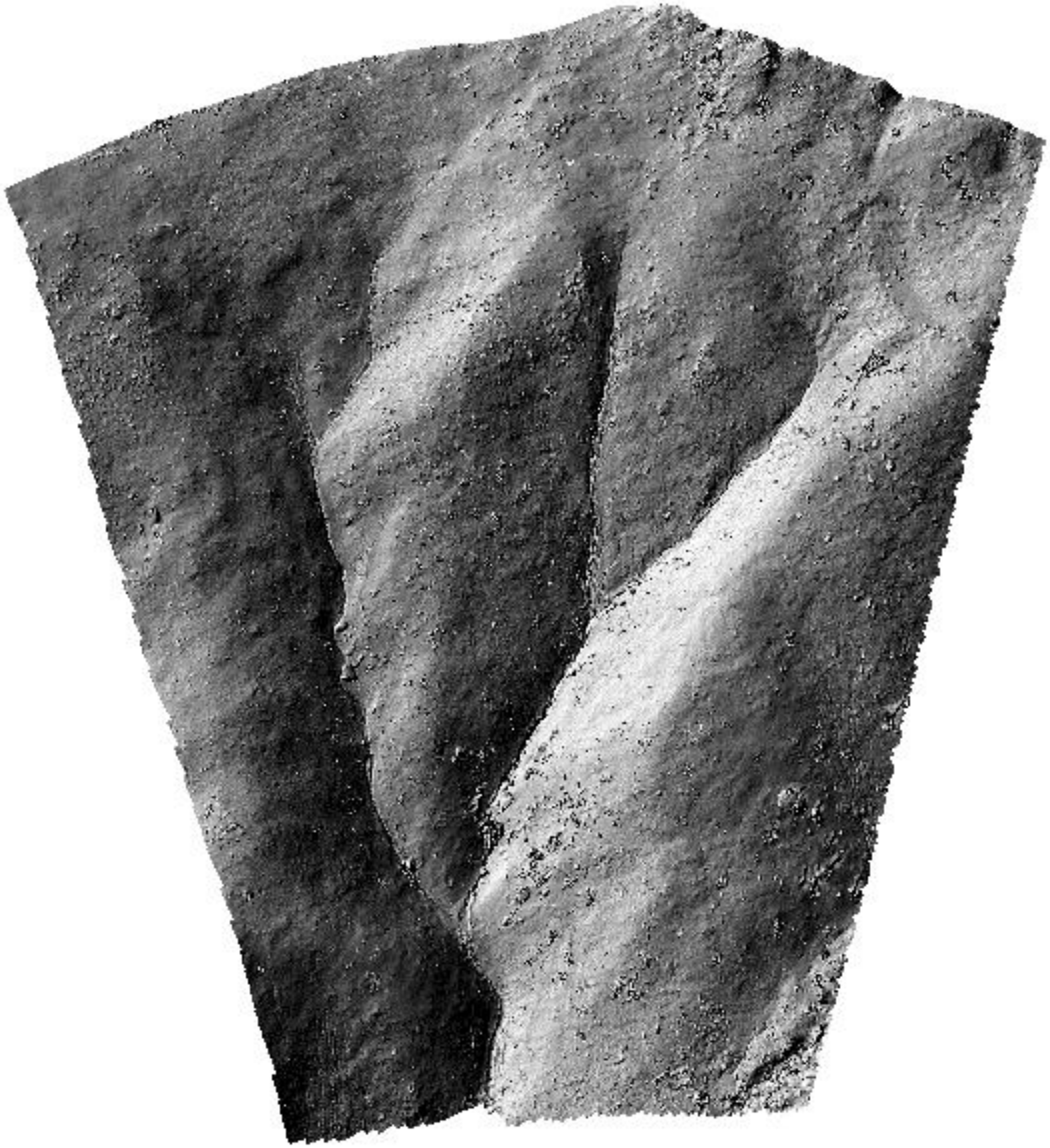

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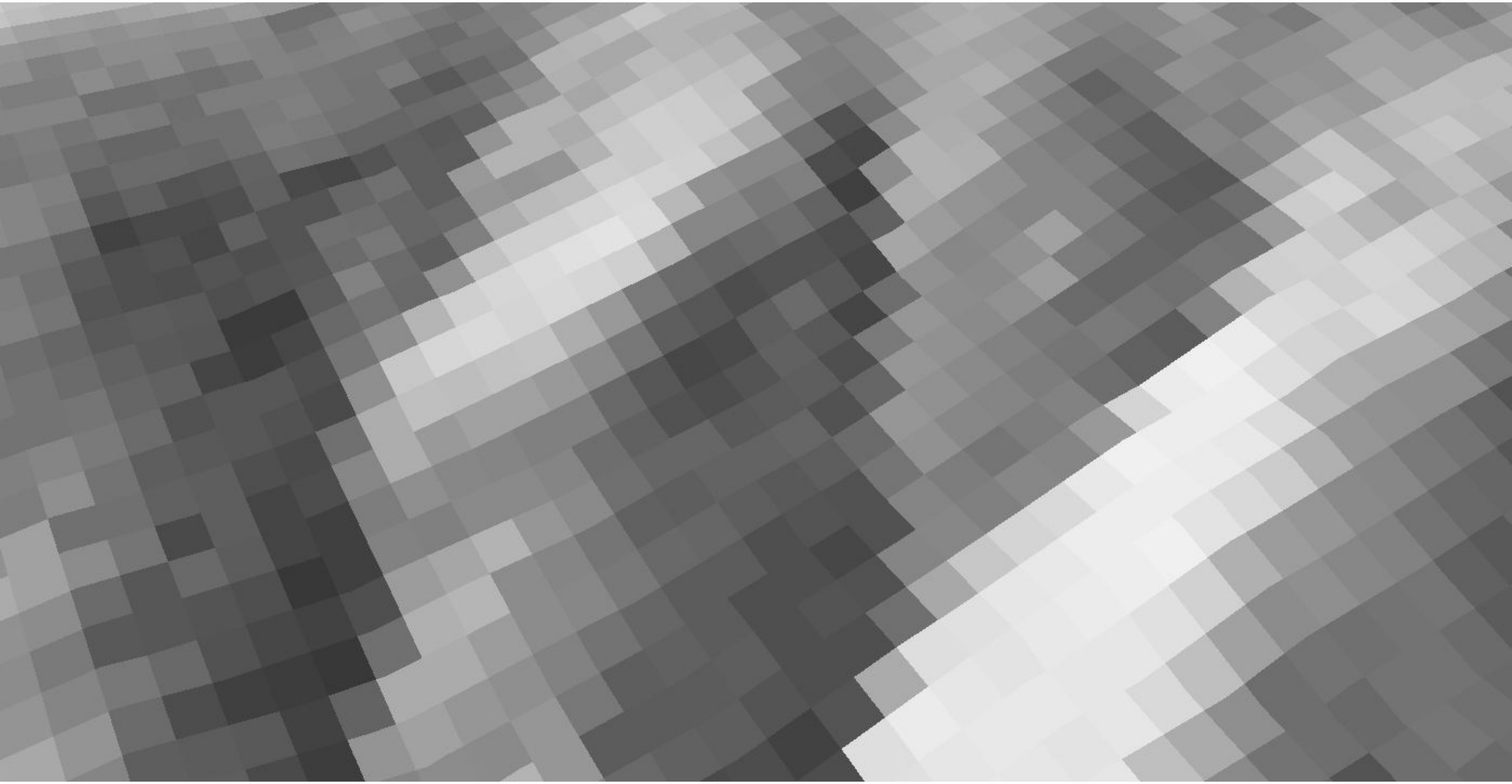

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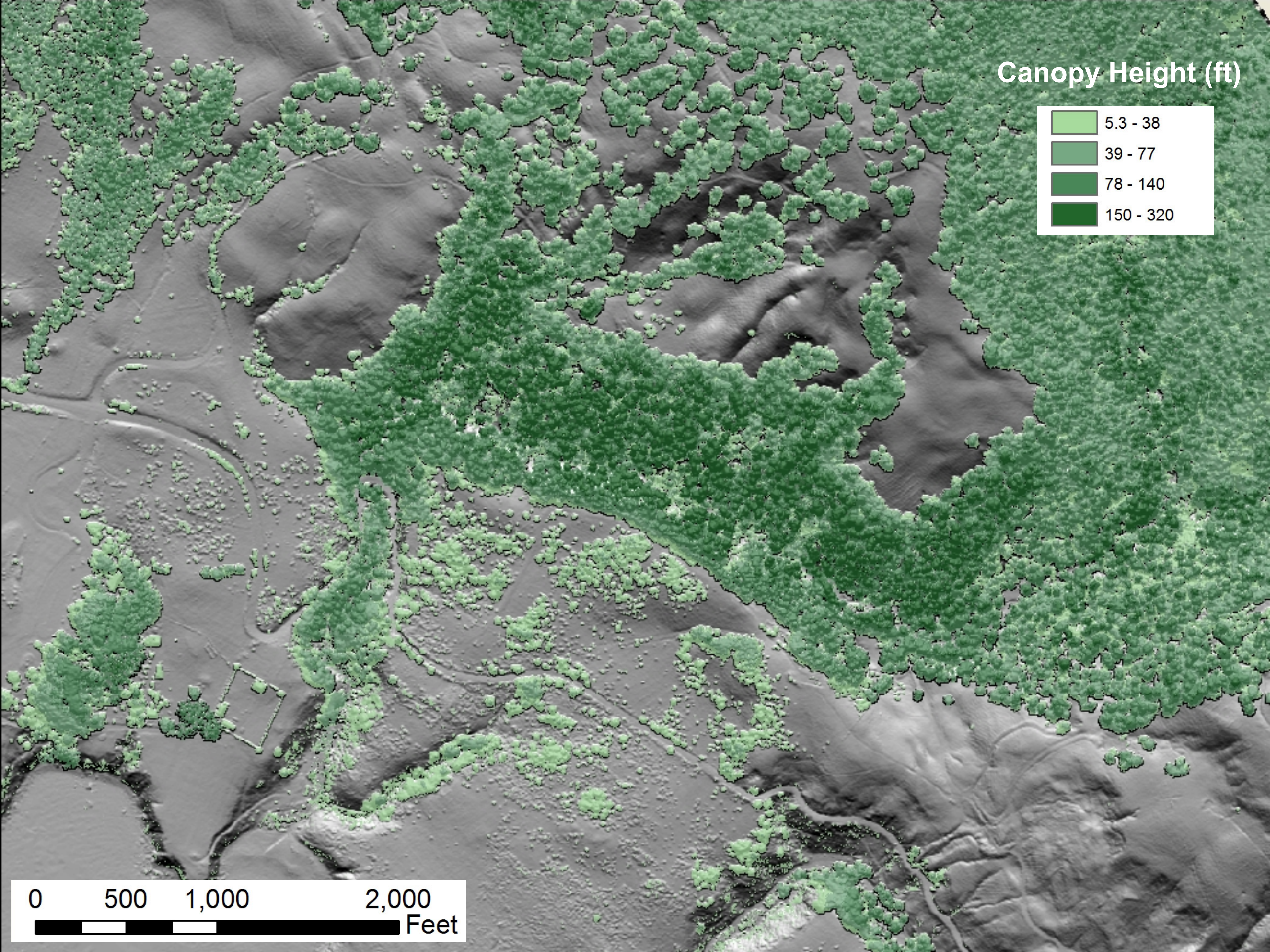
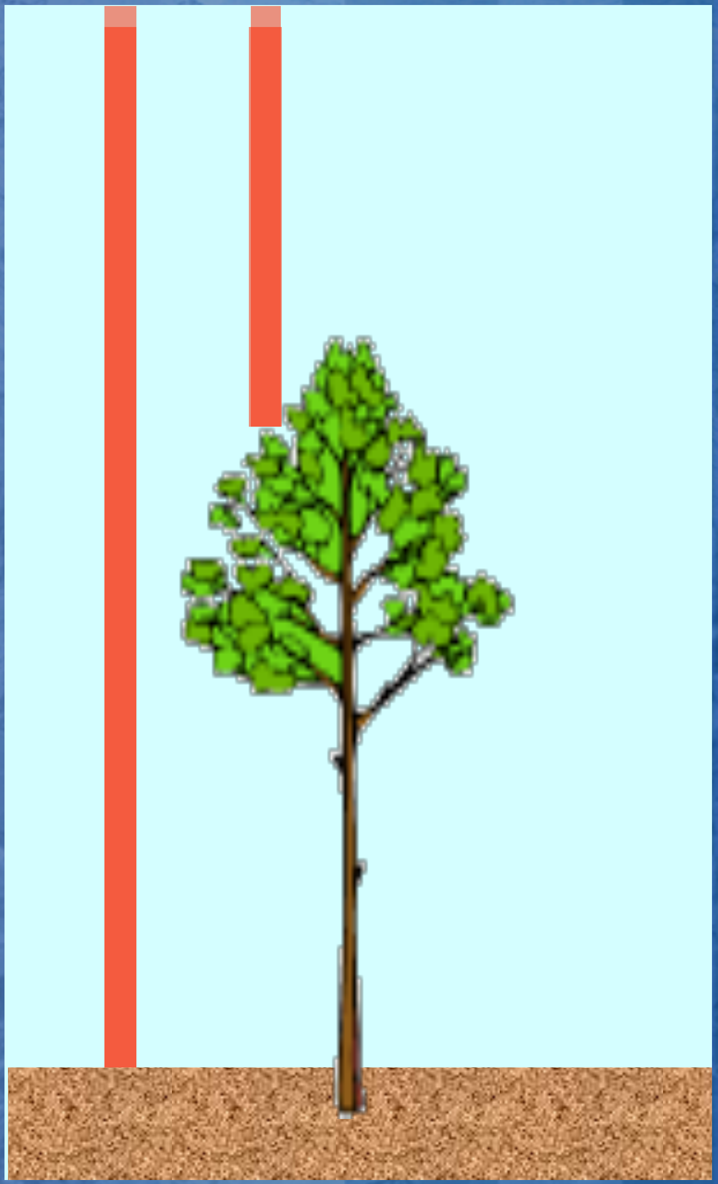

Canopy Height (ft)
5.3 - 38
39 - 77
78 - 140
150 - 320
0
500
1,000
2,000
Feet

Returns

- Single Return
- Multiple returns
- Waveform Returns



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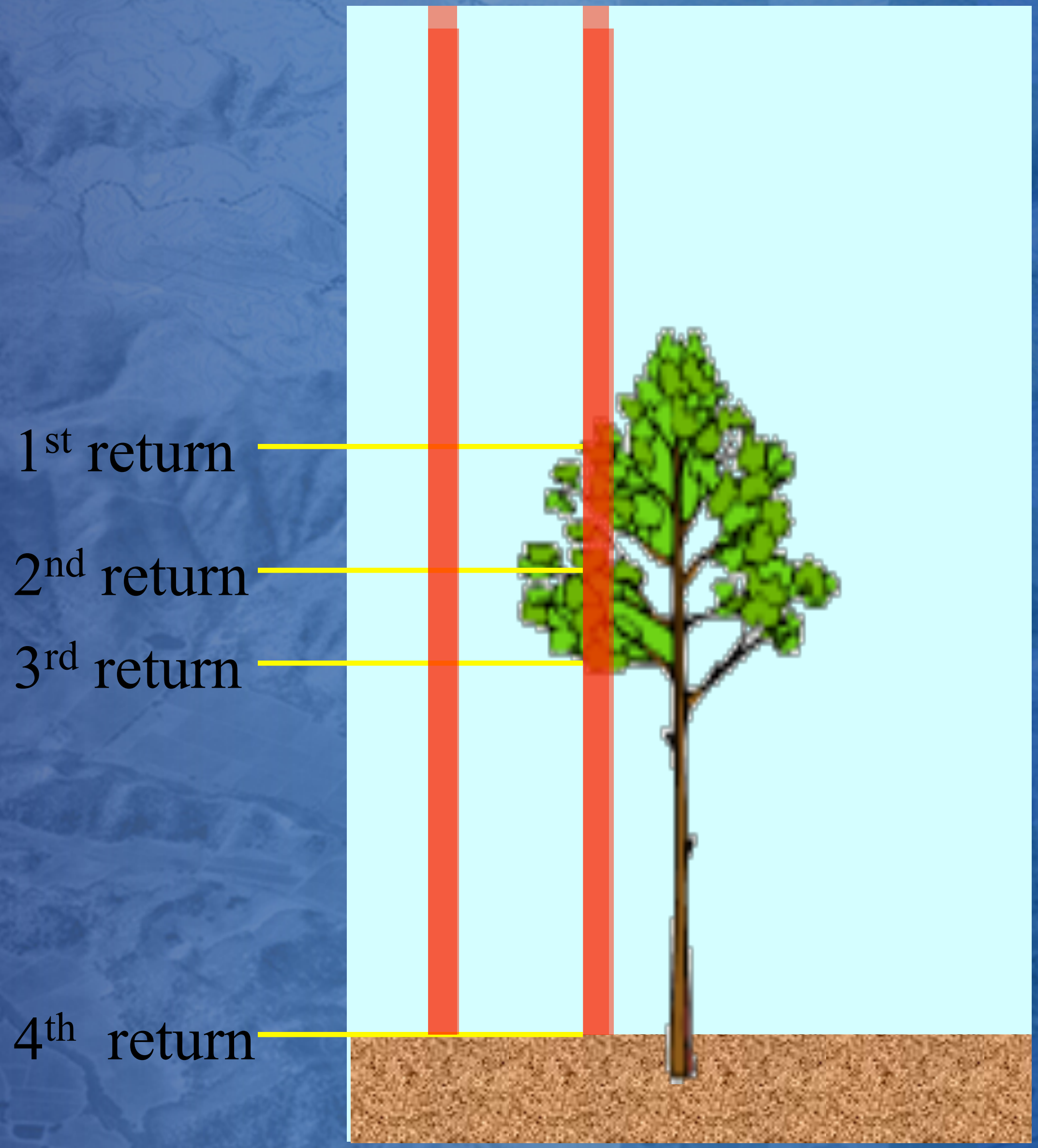
Returns

- Single Return
- Multiple returns
- Waveform Returns



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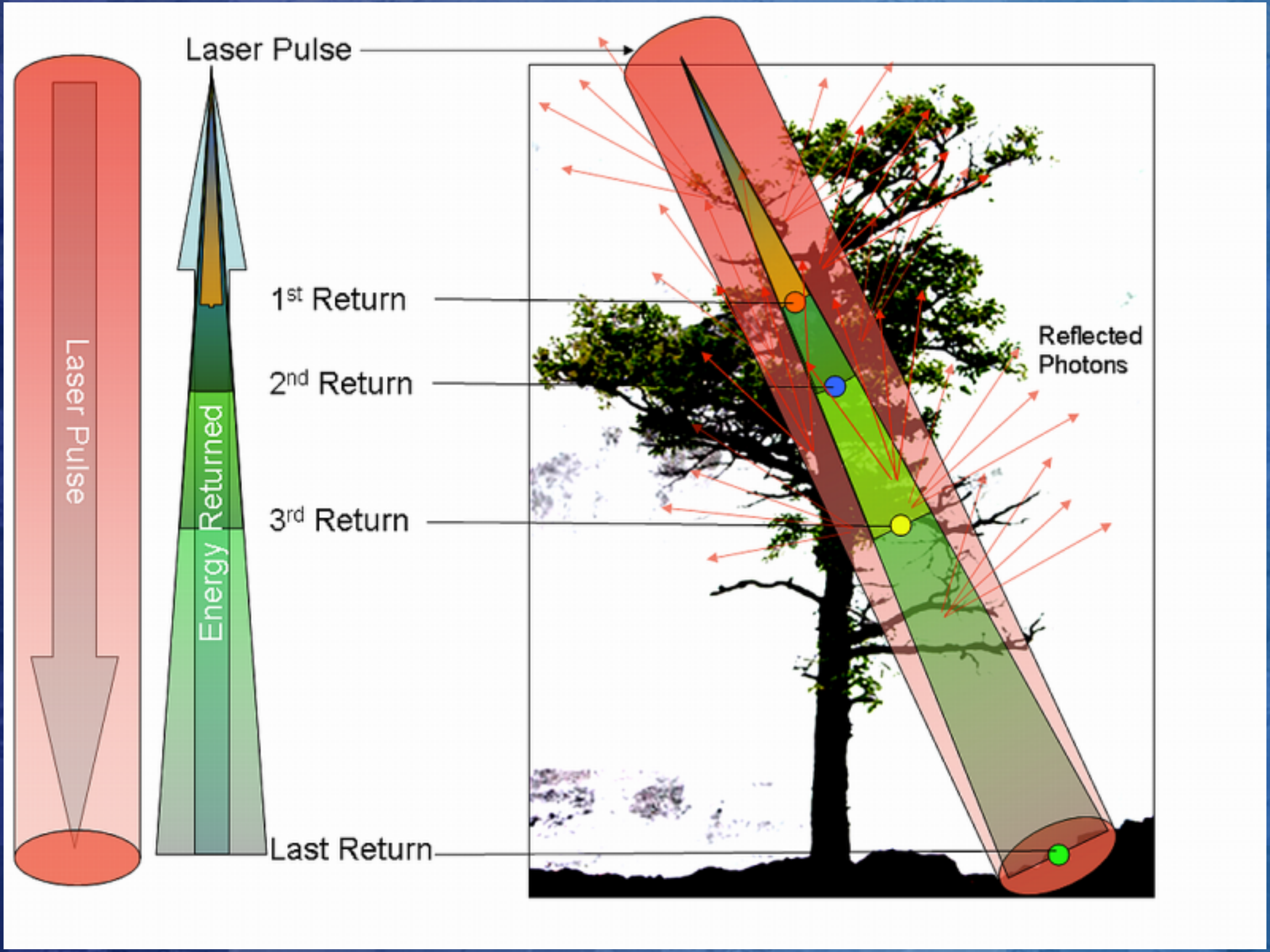

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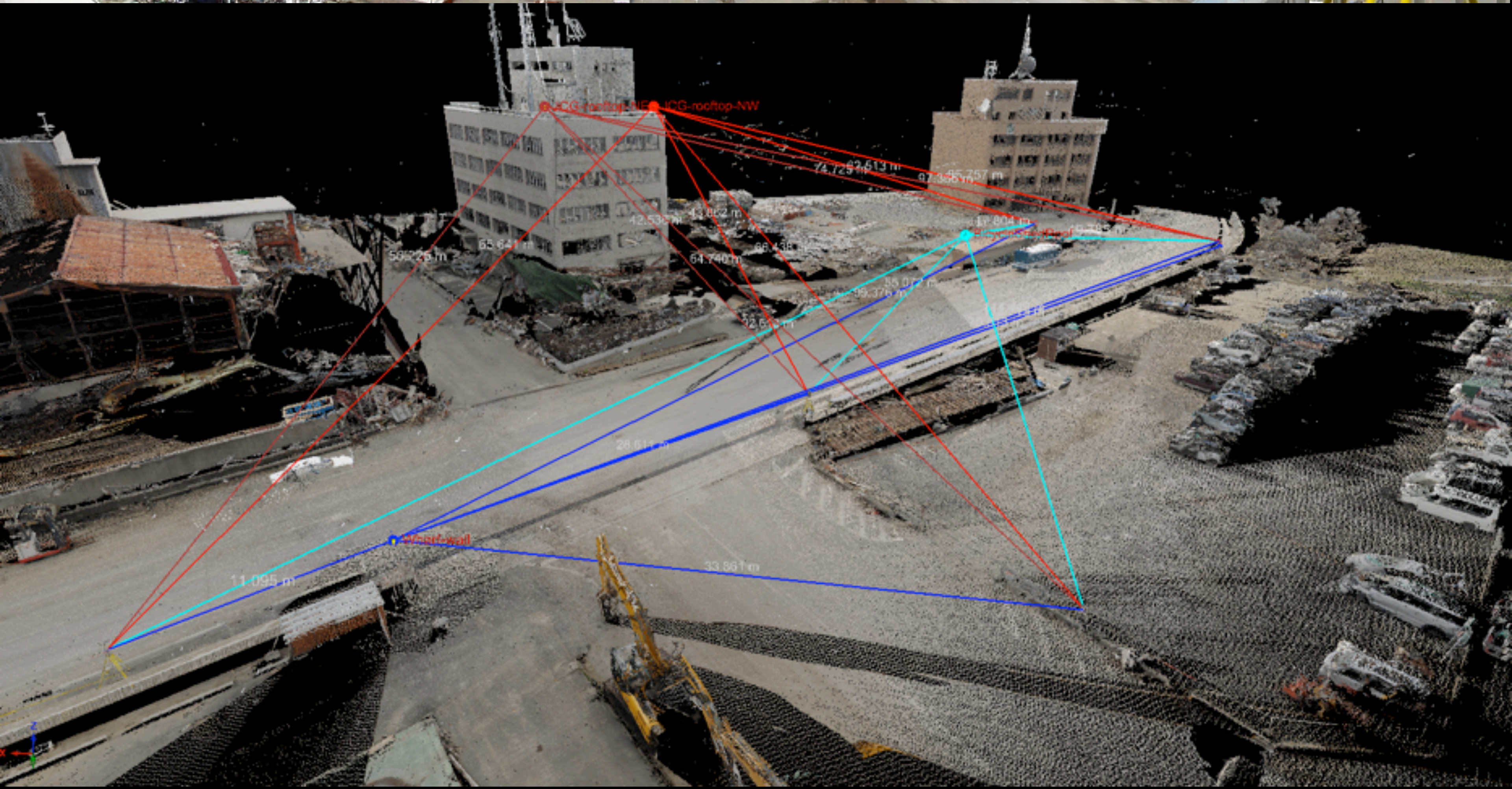
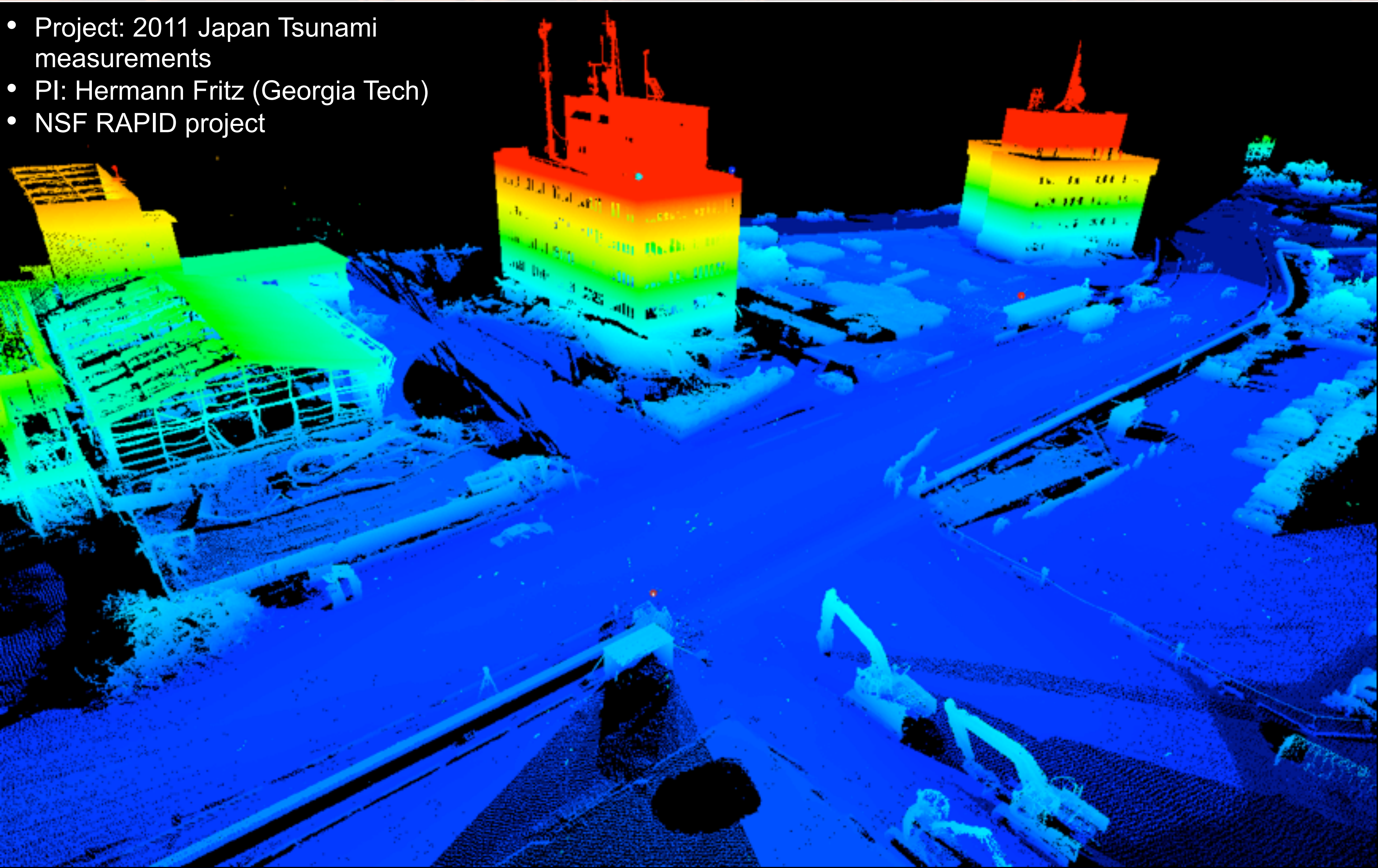
Showcase Tool #1: TLS Terrestrial Laser Scanner

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

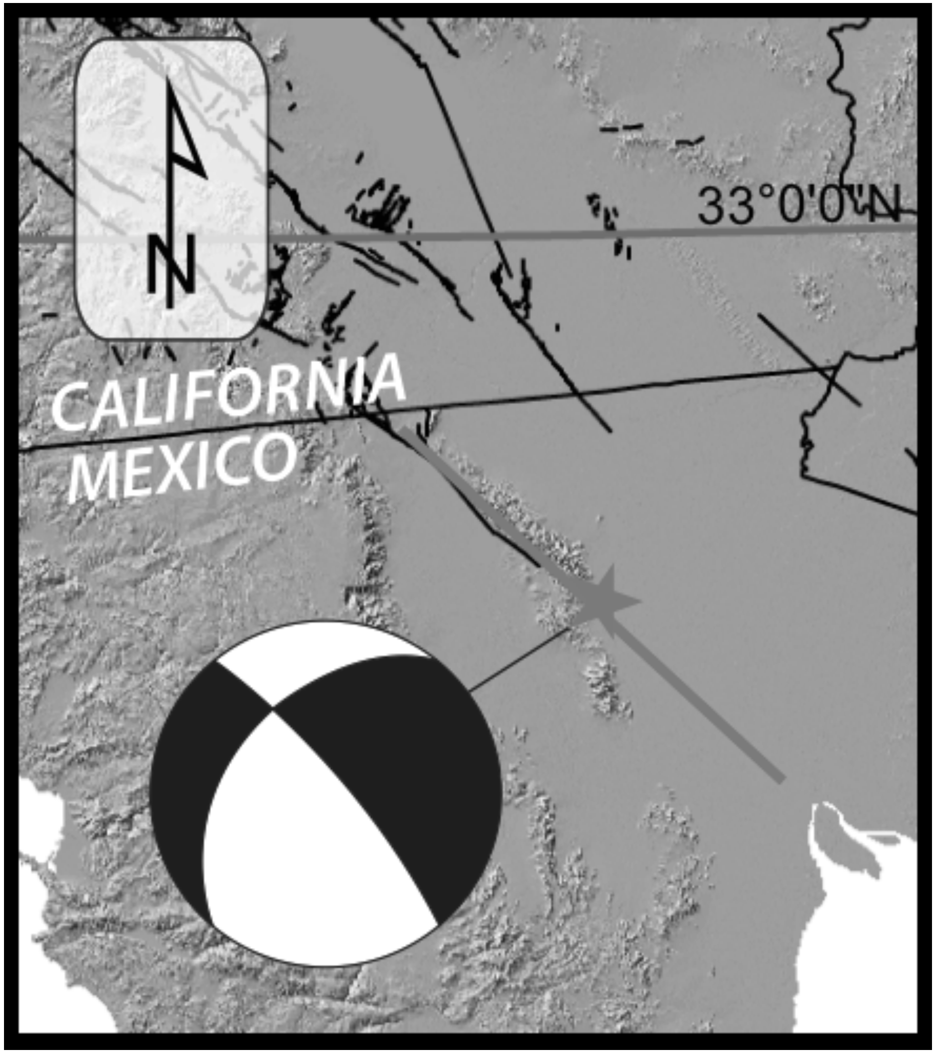

ICG-rooftop-NW
64.740 m
28.611 m
33.561 m
11.095 m

2011 Japan Tsunami

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



El Mayor-Cucapah Earthquake



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

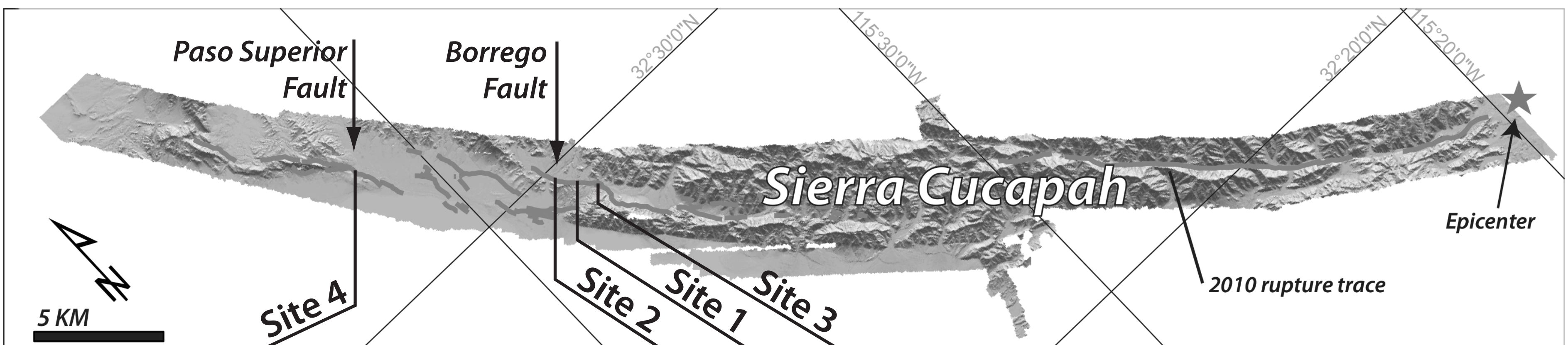
- > 3m right-normal slip north of epicenter
- < 1m right-normal blind faulting south of epicenter

P. Gold, UCD

Motivations: Data Collection

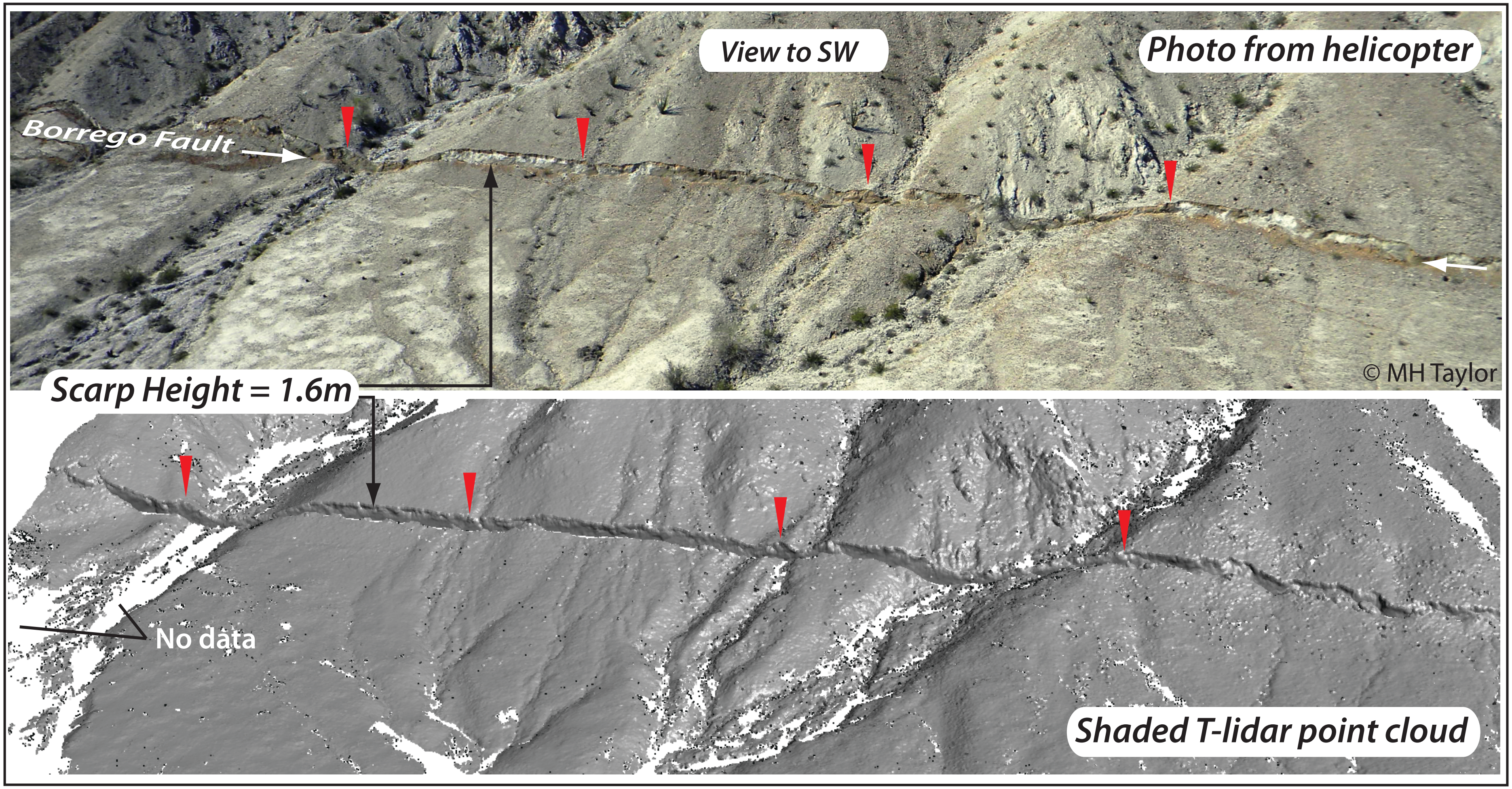
- Preserve primary rupture features for:
    - Remote measurement/analysis
    - Comparison to future scans

- Scan ruptures in a variety of geologic and geomorphic settings



P. Gold, UCD

Scale of TLS coverage

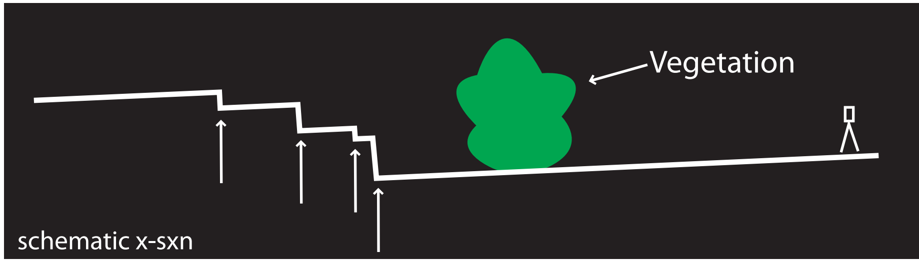


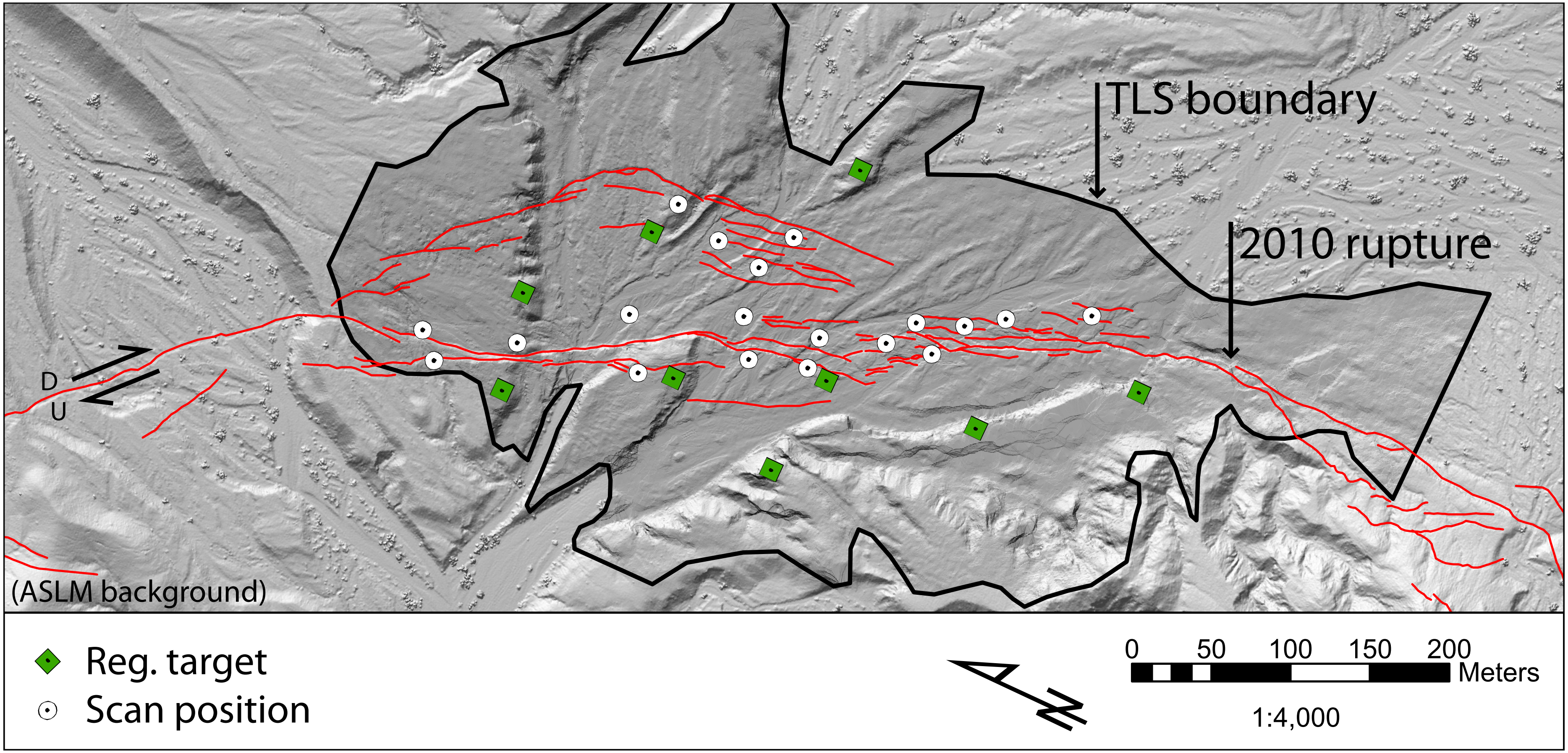
- ~200m along-strike distances

P. Gold, UCD

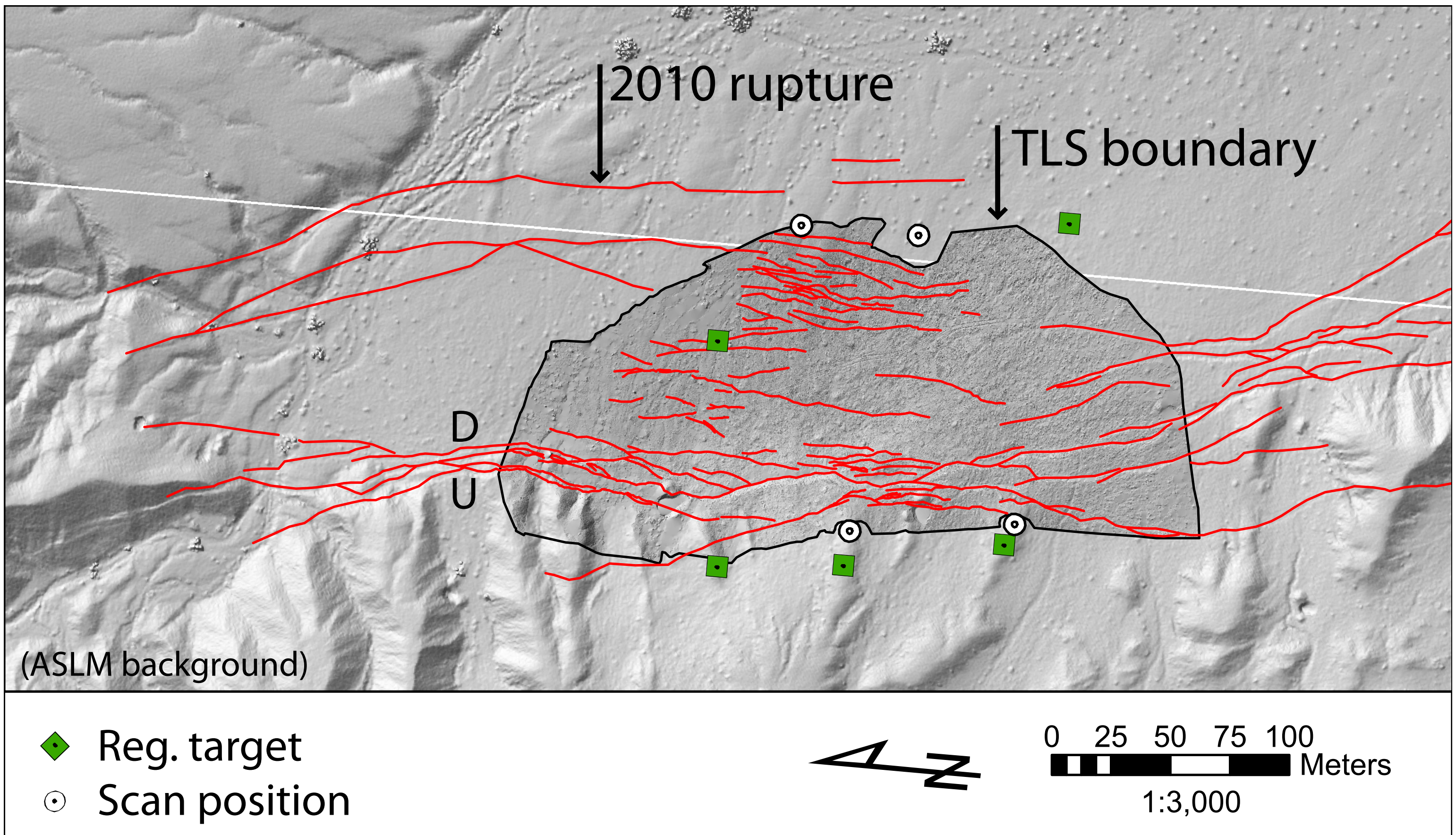
Data Collection

P. Gold, UCD





Data Collection



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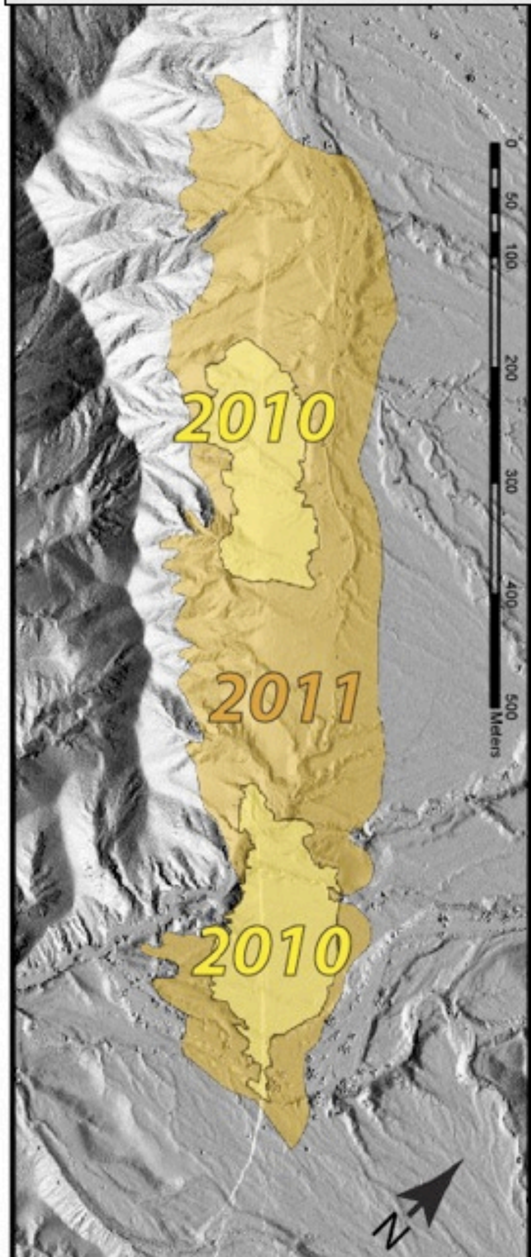
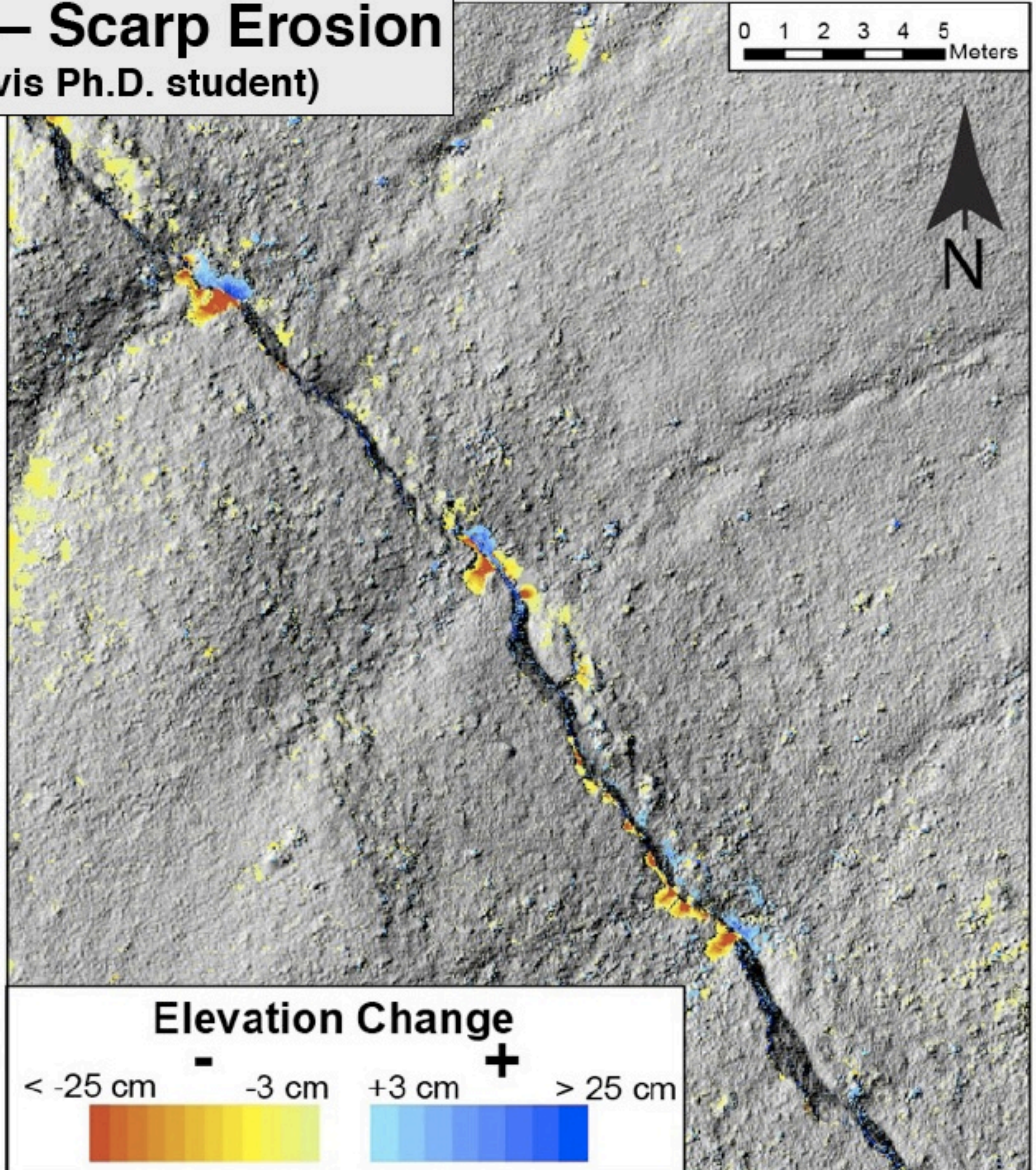
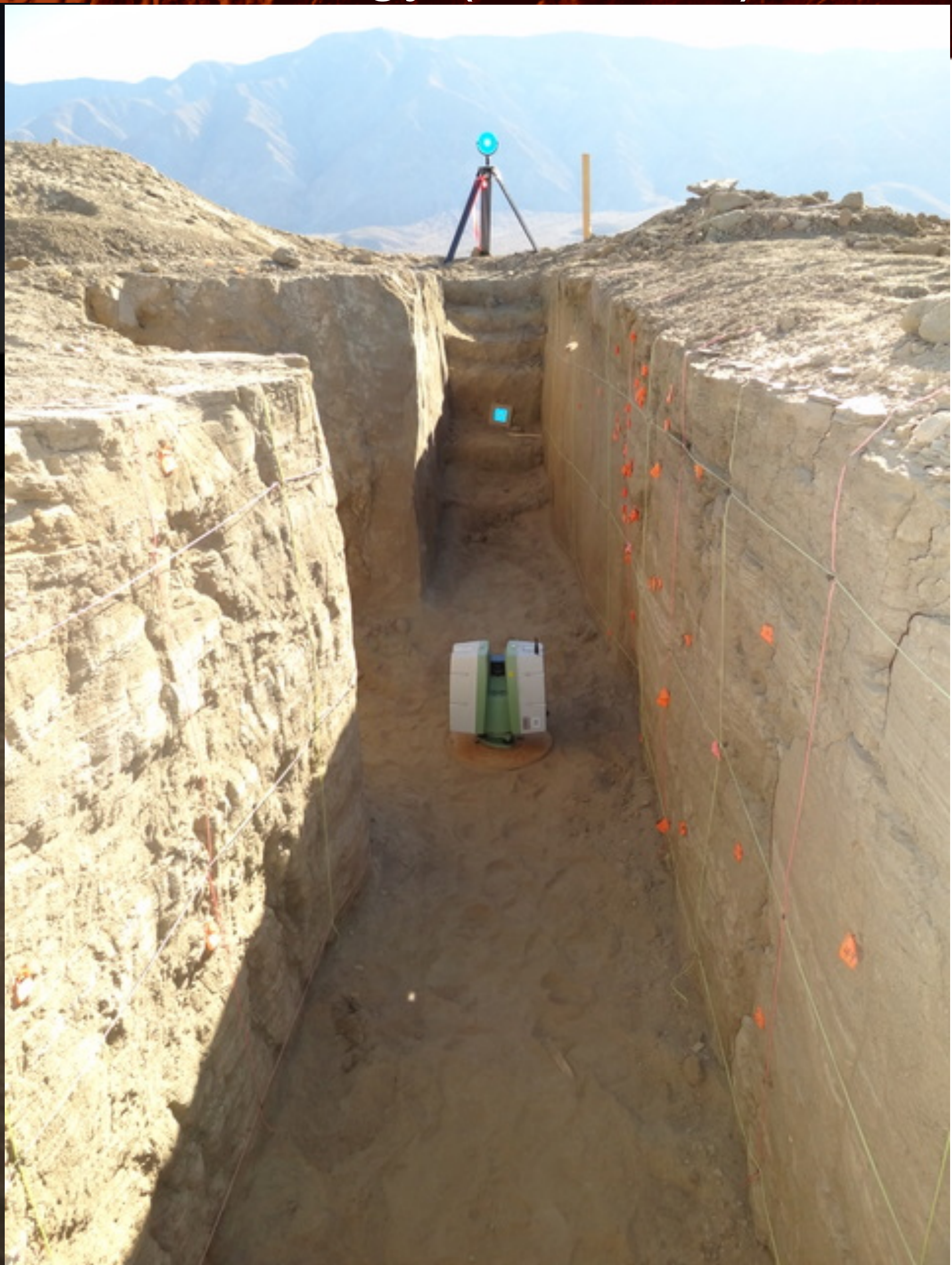
Change Detection – Scarp Erosion

Austin Elliott (UC Davis Ph.D. student)



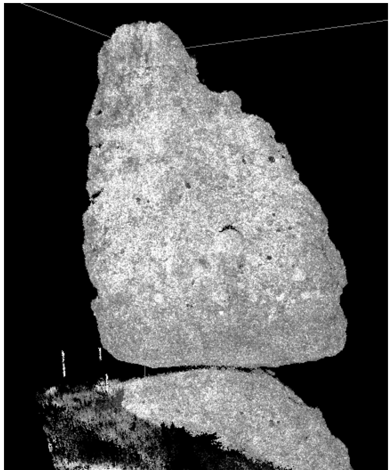


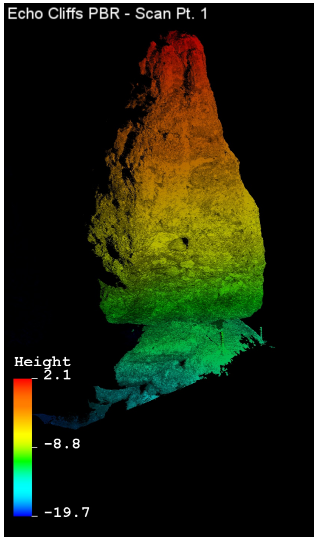
SoCal Paleoseismology (Rockwell)



Precariously Balanced Rocks (Hudnut)

- 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.

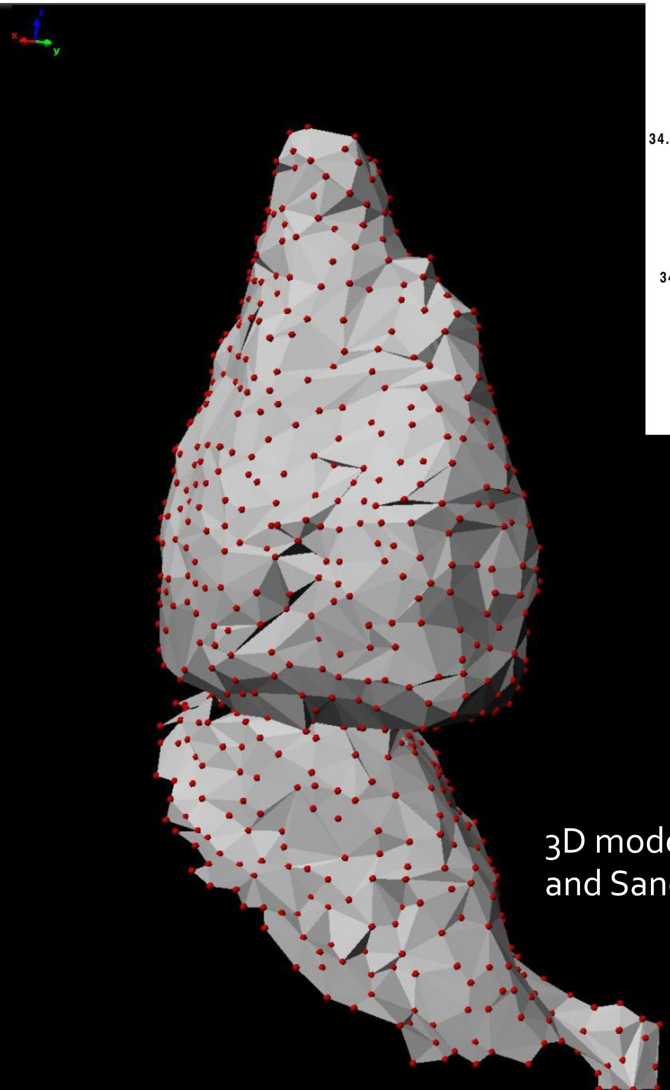




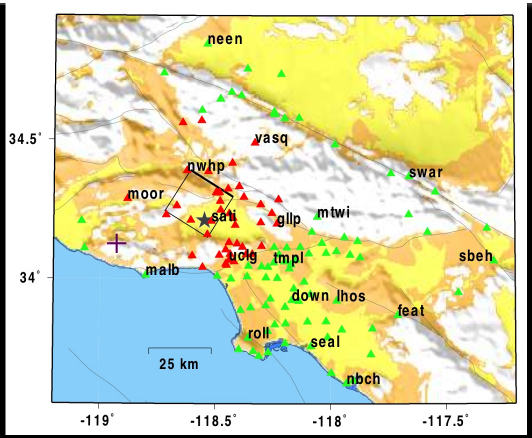
(Hudnut et al., 2009)

Precariously Balanced Rocks (Hudnut)

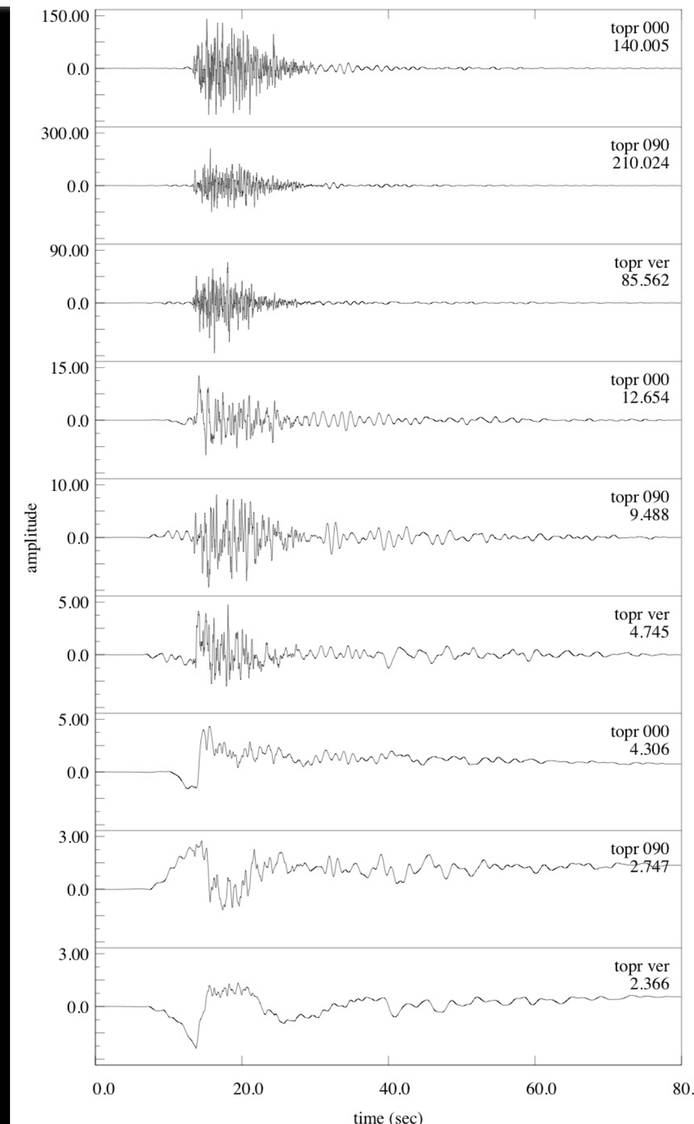
3D surface model (861 nodes) and simulated 1994 Northridge waveforms



3D model by Gerald Bawden and Sandra Bond



Northridge 1994 simulation by Rob Graves



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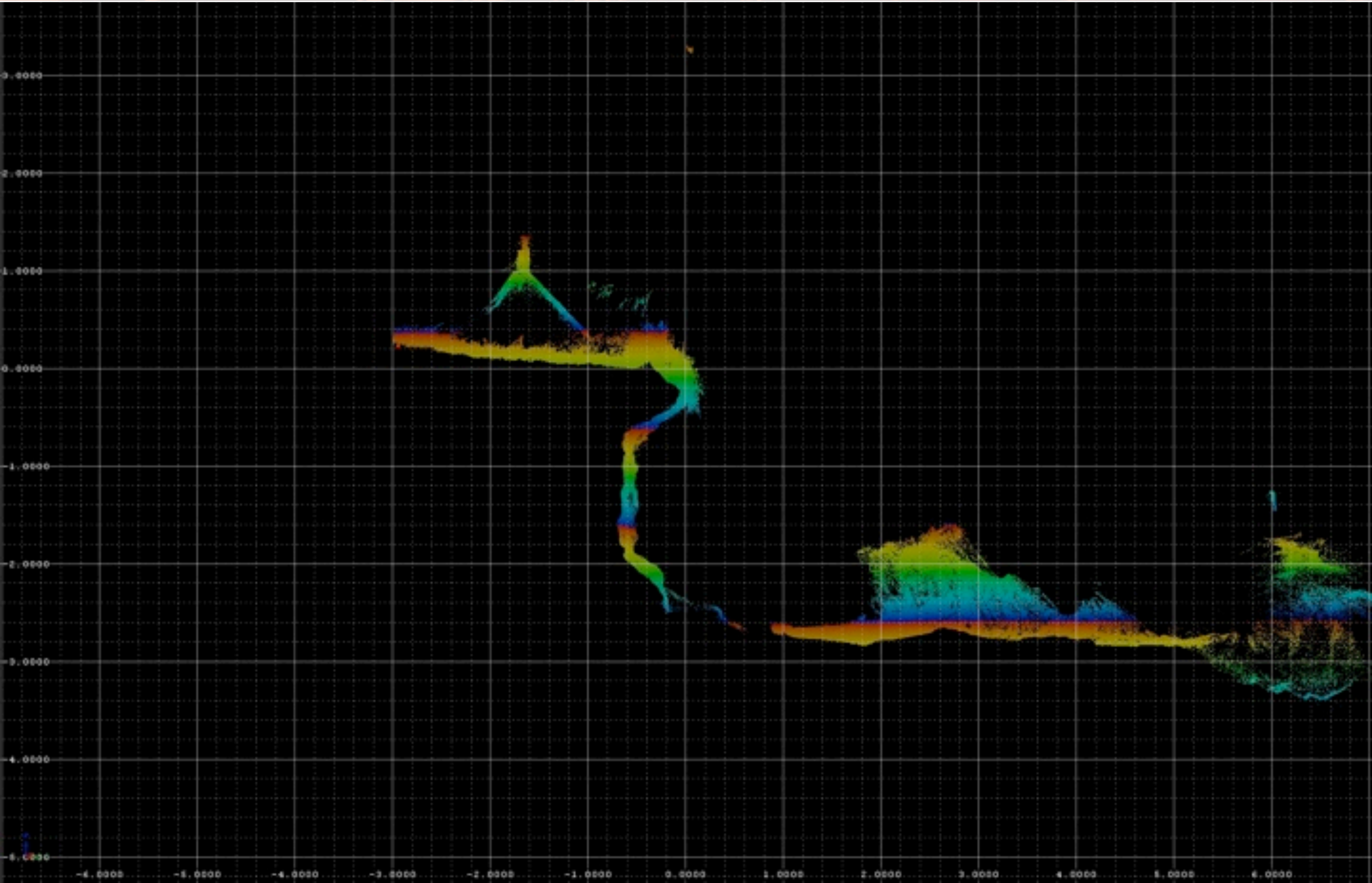
Bijou Creek Surface Processes (Tucker)

- Gully Erosion & Landform Evolution at West Bijou Creek, Colorado
- Greg Tucker (PI) & Francis Rengers (PhD student), Univ. of Colorado
- Image, characterize and quantify morphologic features and changes through time.

Bijou Creek Surface Processes (Tucker)



Four Mile Fire Erosion (Moody, Tucker)

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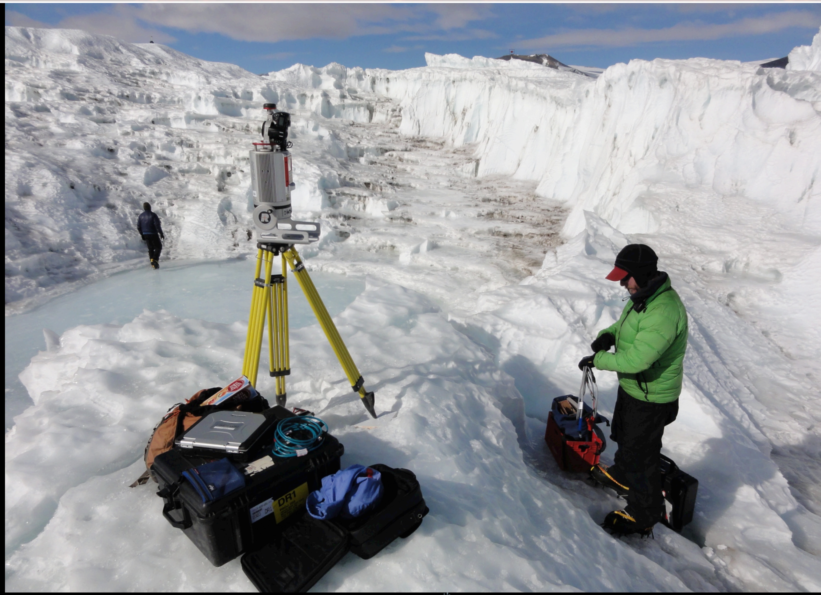
Scanning in Polar Environments

- 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



Science:

- *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

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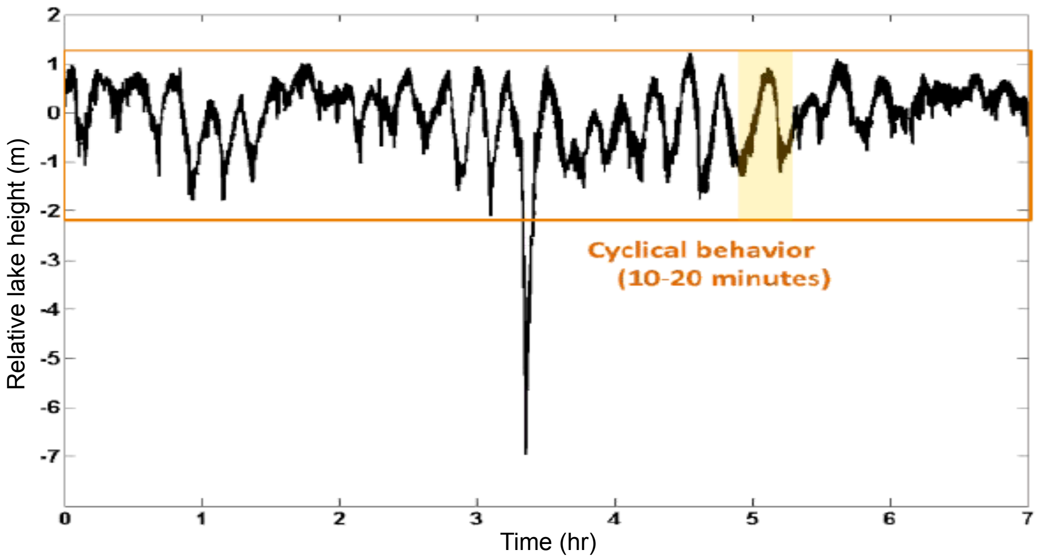
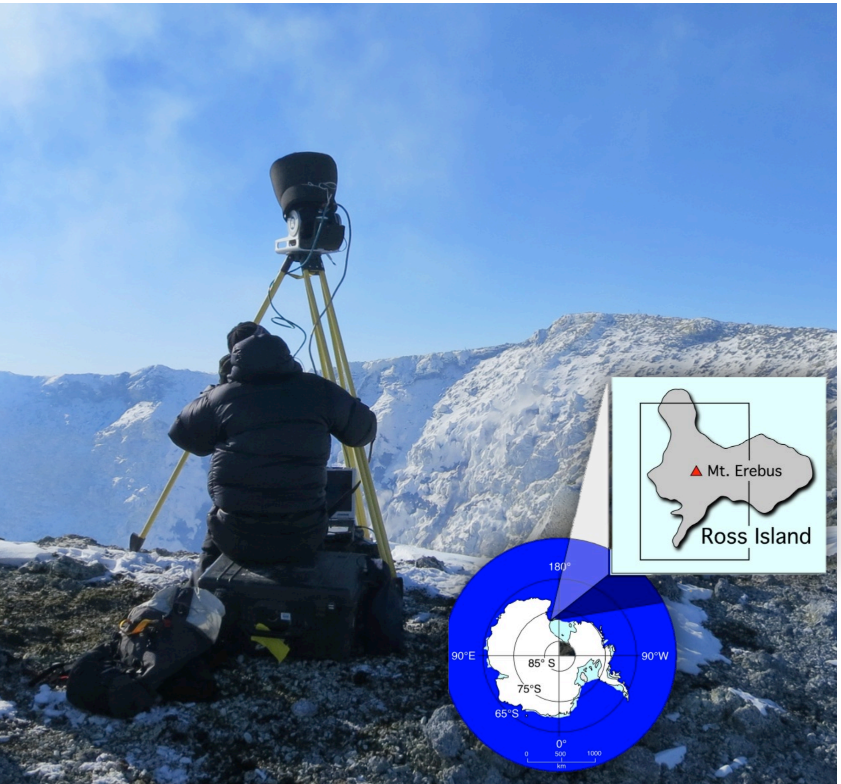
Scanning in Polar Environments: Mount Erebus, Antarctica

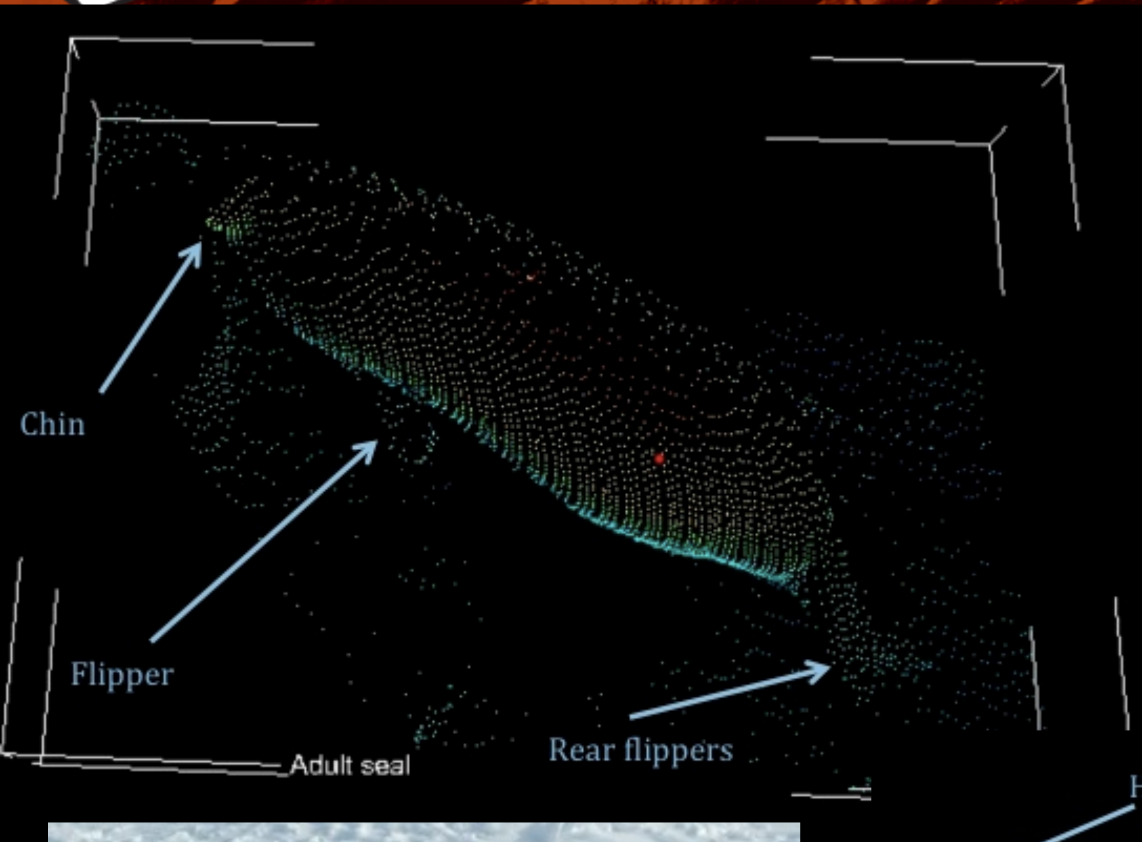
- **Lava lake scanned 2008 - 2013, revealing behaviors invisible to naked eye**
- **Inner crater scan used to augment and truth 2003 aerial scans**
- **Scans of ice caves and ice towers help determine thermal / energy budget of volcano**

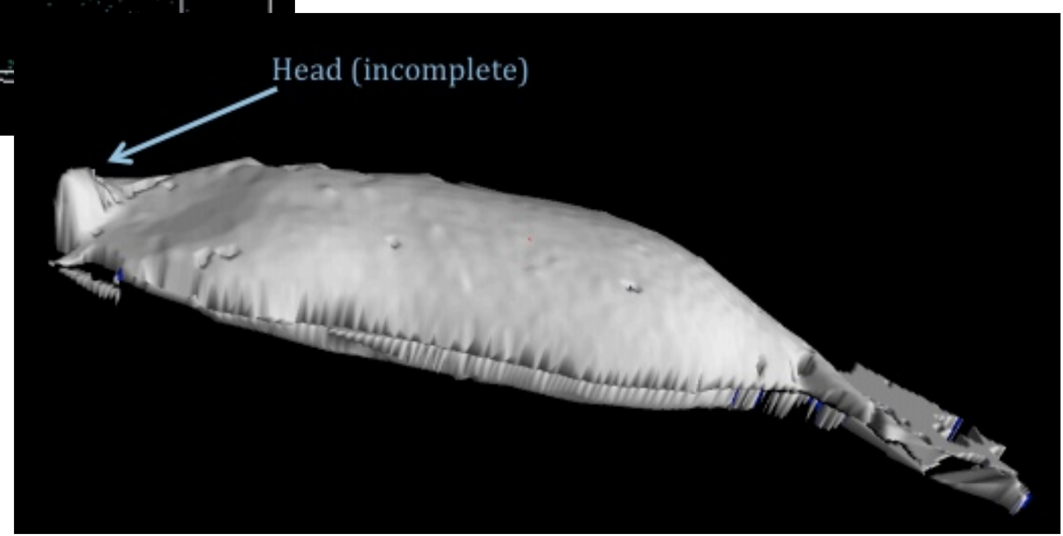




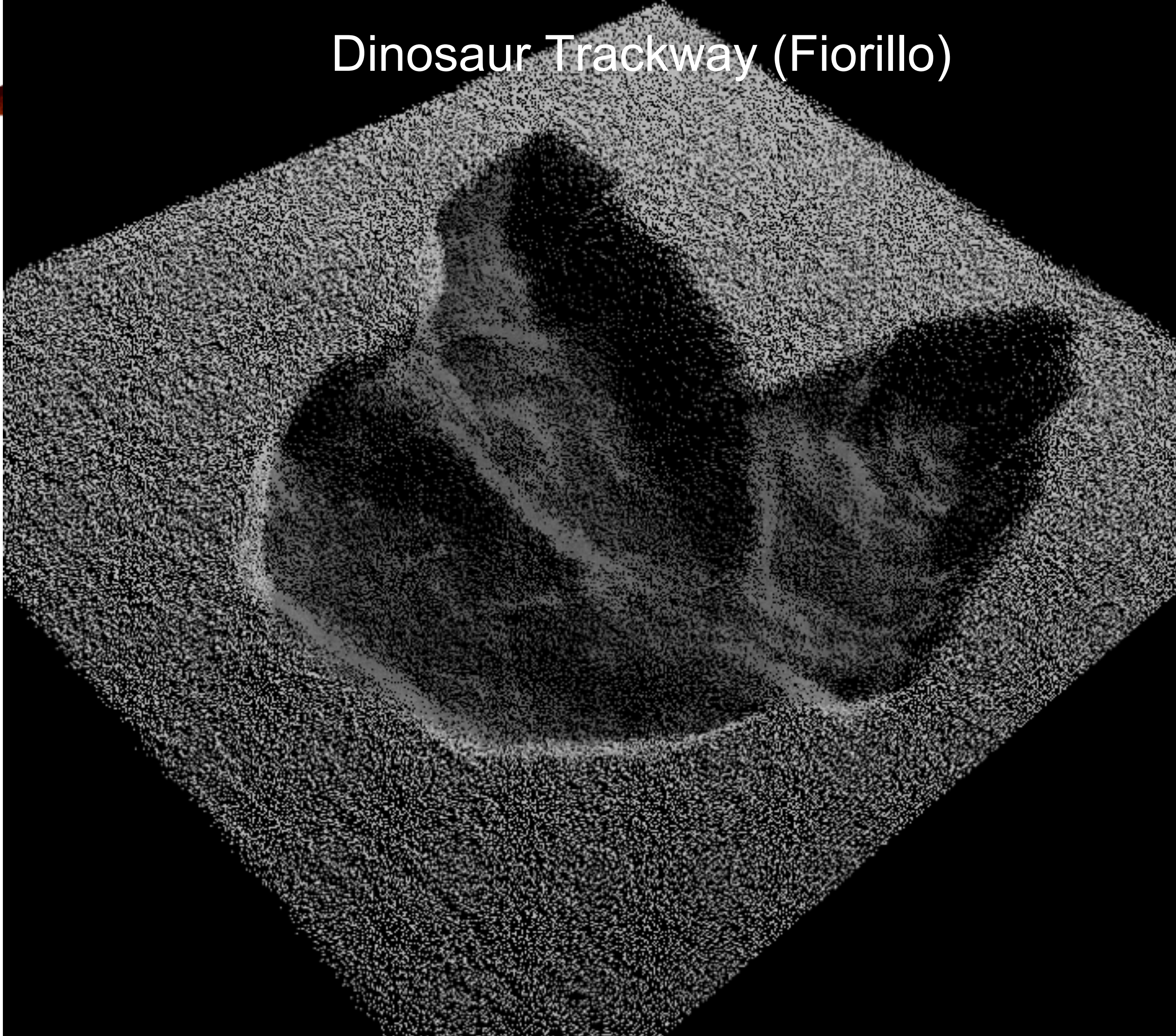
Using TLS to Obtain Volumetric Measurements of Weddell Seals in the McMurdo Sound

Seal body mass = proxy for availability of marine food resources

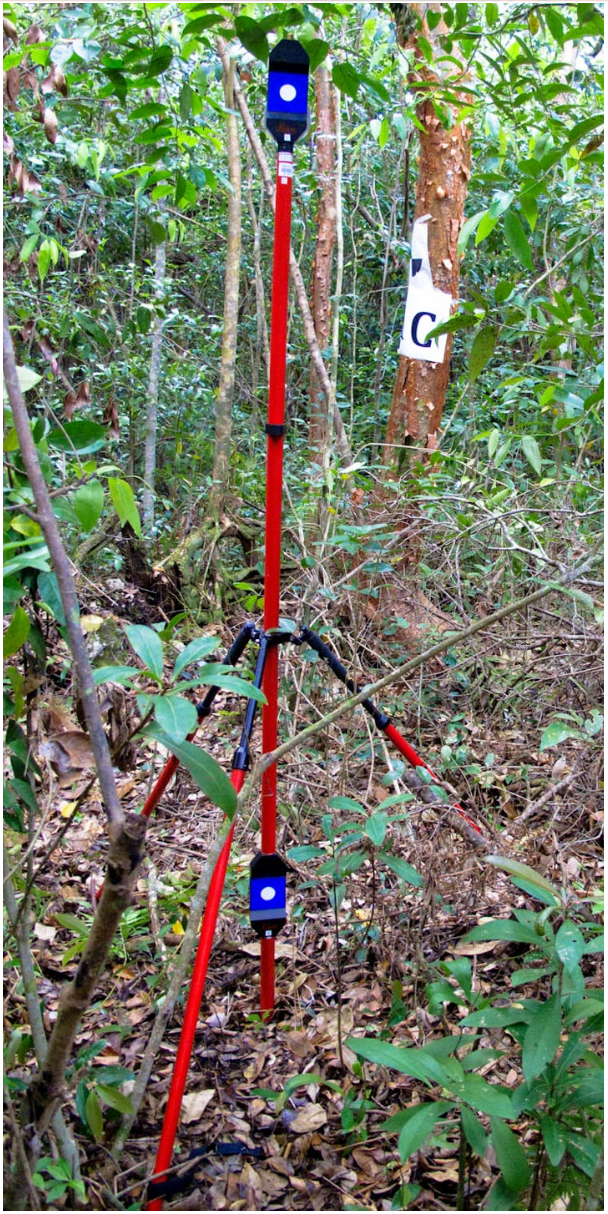




Dinosaur Trackway (Fiorillo)

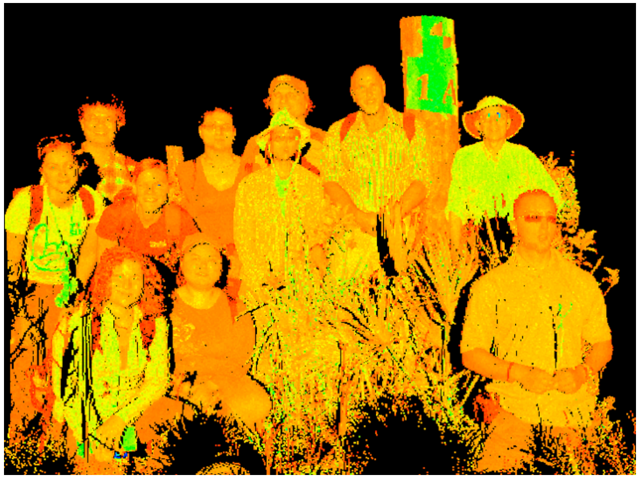


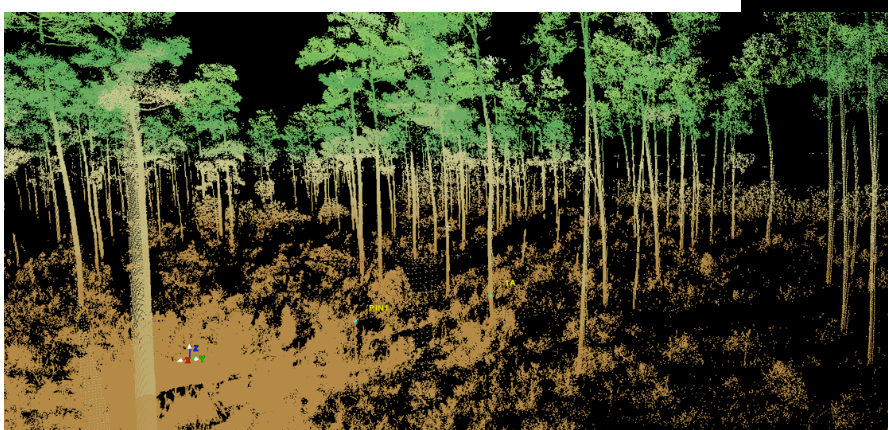
Everglades Biomass (Wdowinski)



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

Everglades Biomass (Wdowinski)





Everglades Biomass (Wdowinski)

TLS in field education

TLS at summer geology field camps

- 2014: Indiana University, University of Houston, University of Michigan, Stanford, University of St. Thomas.
- 100+ geoscience students Introduced to TLS technology and data analysis.

- Demand increasing; Sponsor enthusiastic
- Developing curriculum materials to support program – *TLS Field Camp Manual*

Workshop: Geodesy in field education

<u>Community Workshop</u>:

Field Education and Support by the UNAVCO GAGE Facility

- November 17 - 18, 2014 in Boulder, CO
- Travel support available for participants
- The goal of this workshop is to bring together educators who are interested in, or are already actively using, geodesy in a field education context.

Examples of geodetic methods relevent to field education

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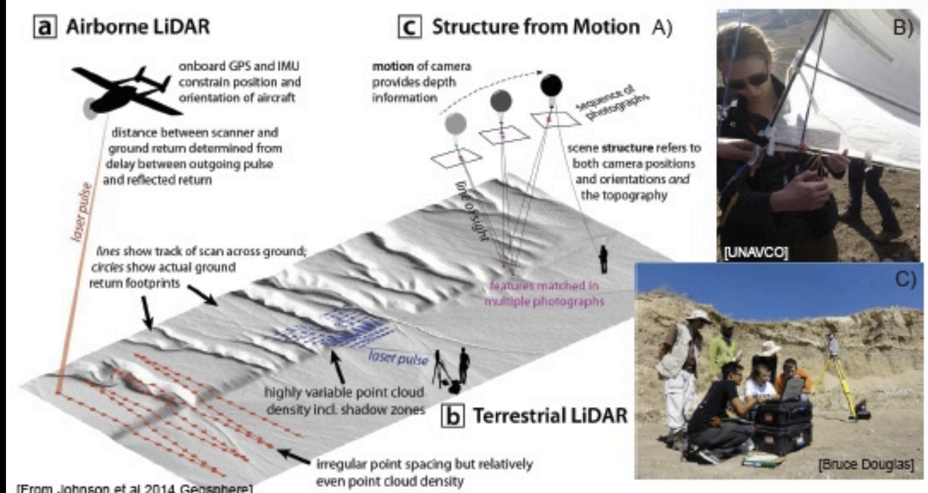

Figure 1. A) Three methods for generating high resolution topography. Airborne lidar is increasingly used to produce detailed base maps for field mapping, and can be used to quantify change over study sites. Terrestrial laser scanning (TLS) has been used in field courses for erosion, fault scarp, and stratigraphic analyses among others. Structure from Motion (SfM) is a fast and affordable method to capture 3D models and rectified imagery of topography, outcrops, and other geologic features in many field environments; B) afixing a camera to a helium ballon for SfM; C) students in Montana run a TLS survey.

Figure 2. Students learning how to conduct GPS/GNSS surveys. Both static and real time kinematic (RTK) have been used in field courses. These methods can be applied to topics ranging from geo-morphic analysis to volcanic monitoring, as well as provide supporting data for gravity, seismic, or TLS projects.

Thanks!

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