Short Course:

Imaging and Analyzing Southern California's Active Faults with Lidar

November 4 -6, 2013 @ San Diego Supercomputer Center, UCSD

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Introductions

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

Agenda…

UNAVCO

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.

Agenda & Logistics

1. Evening social & presentations?
   - Who is talking?
   - Slides due at 5 pm to Ramon
   - <= 5 slides each
   - Special requests?

2. Genius bar

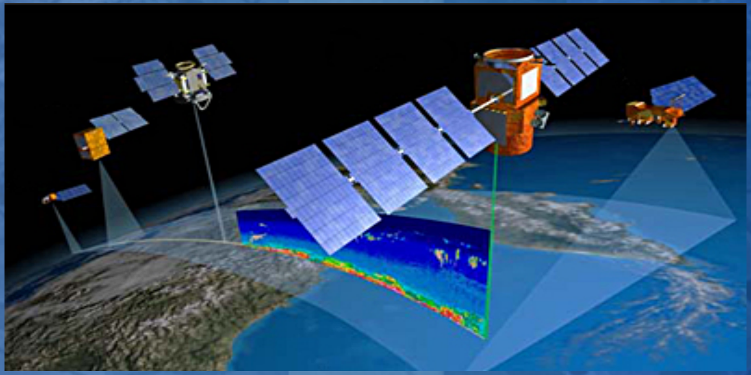
3. Transportation notes:
   - No hotel shuttle in evening (who drove independently?)
   - *Weds*: check out in morning – no plans to return to the hotel at course end. You need to make arrangements for shuttle departing SDSC.

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

A Suite of Lidar Platforms



J. Stoker

USGS

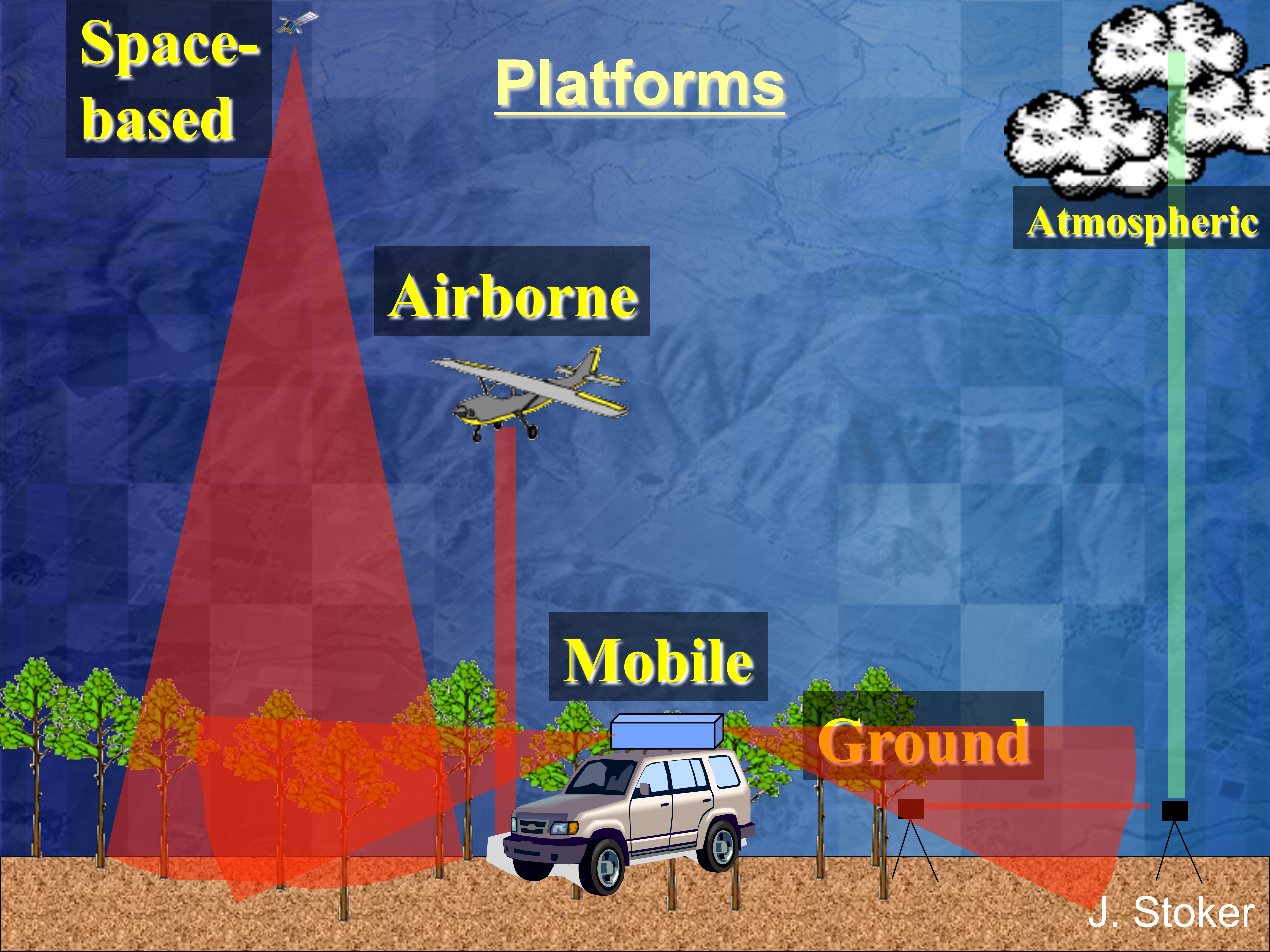
Lidar Differences

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

USGS

J. Stoker

Platforms



Light Detection And Ranging (LiDAR)

Similar technology, different platforms:

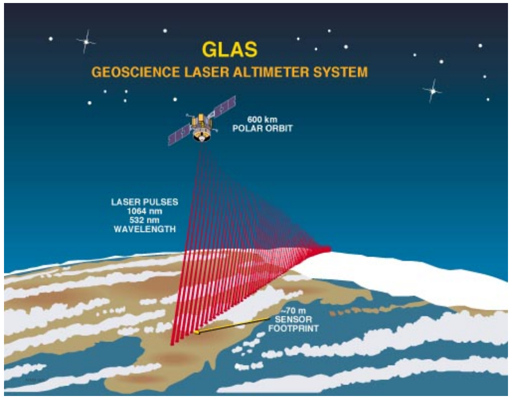
Terrestrial Laser Scanning (TLS)

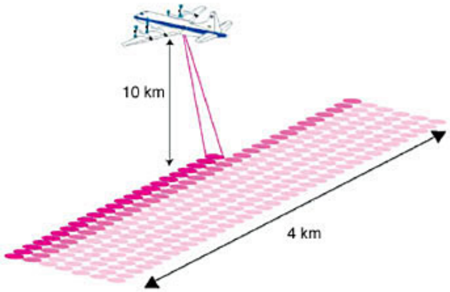
- Also called ground based LiDAR or T-LiDAR.

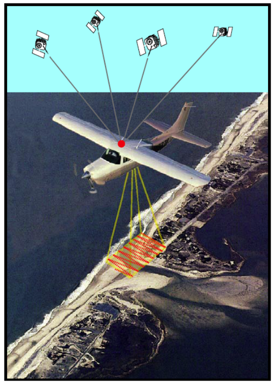
Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

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

Light Detection And Ranging (LiDAR)

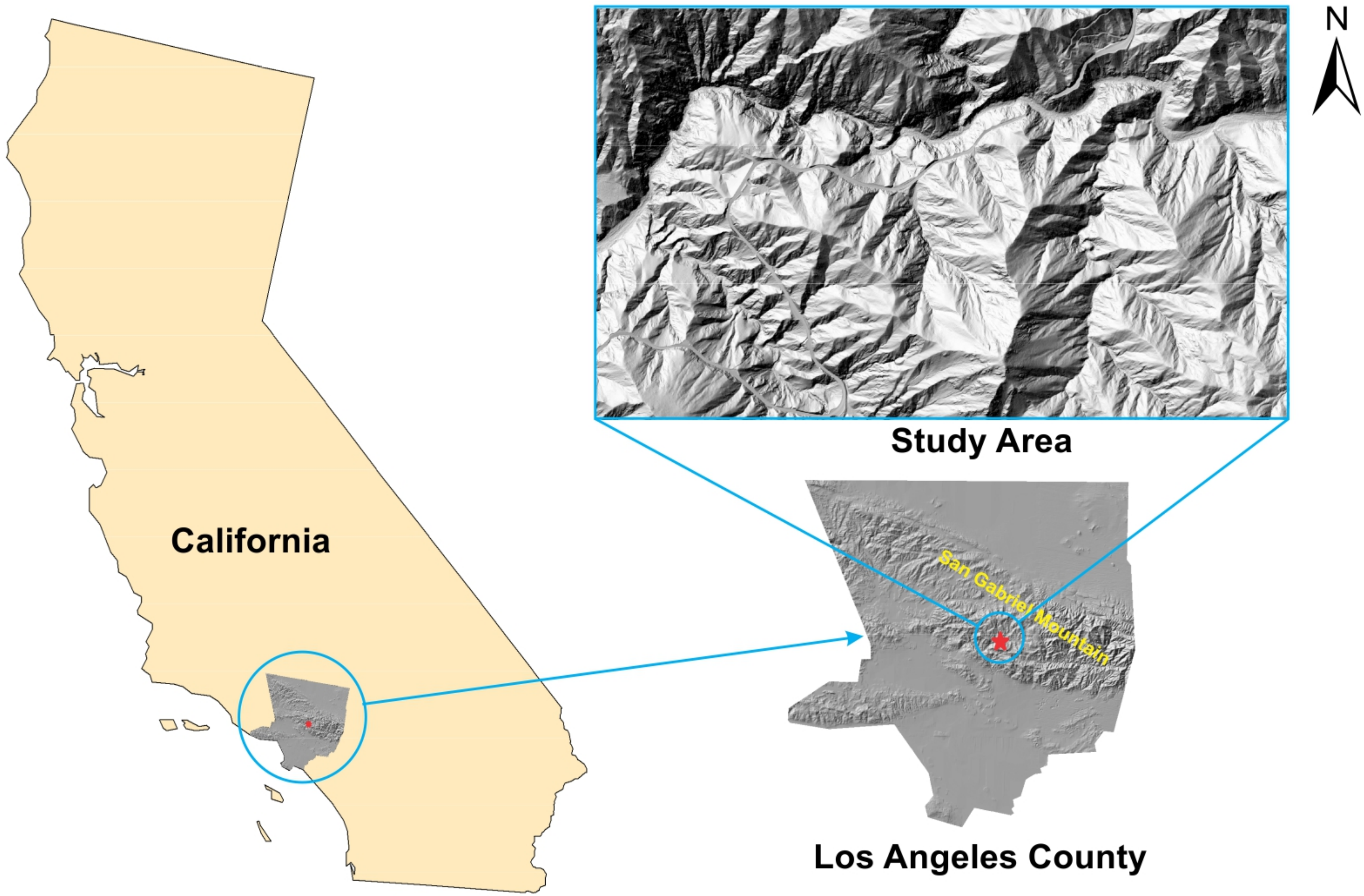






System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1-10 cm
Vertical Accuracy	15cm to 10m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1- 10 cm Depends on range which is few meters to 2 km or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

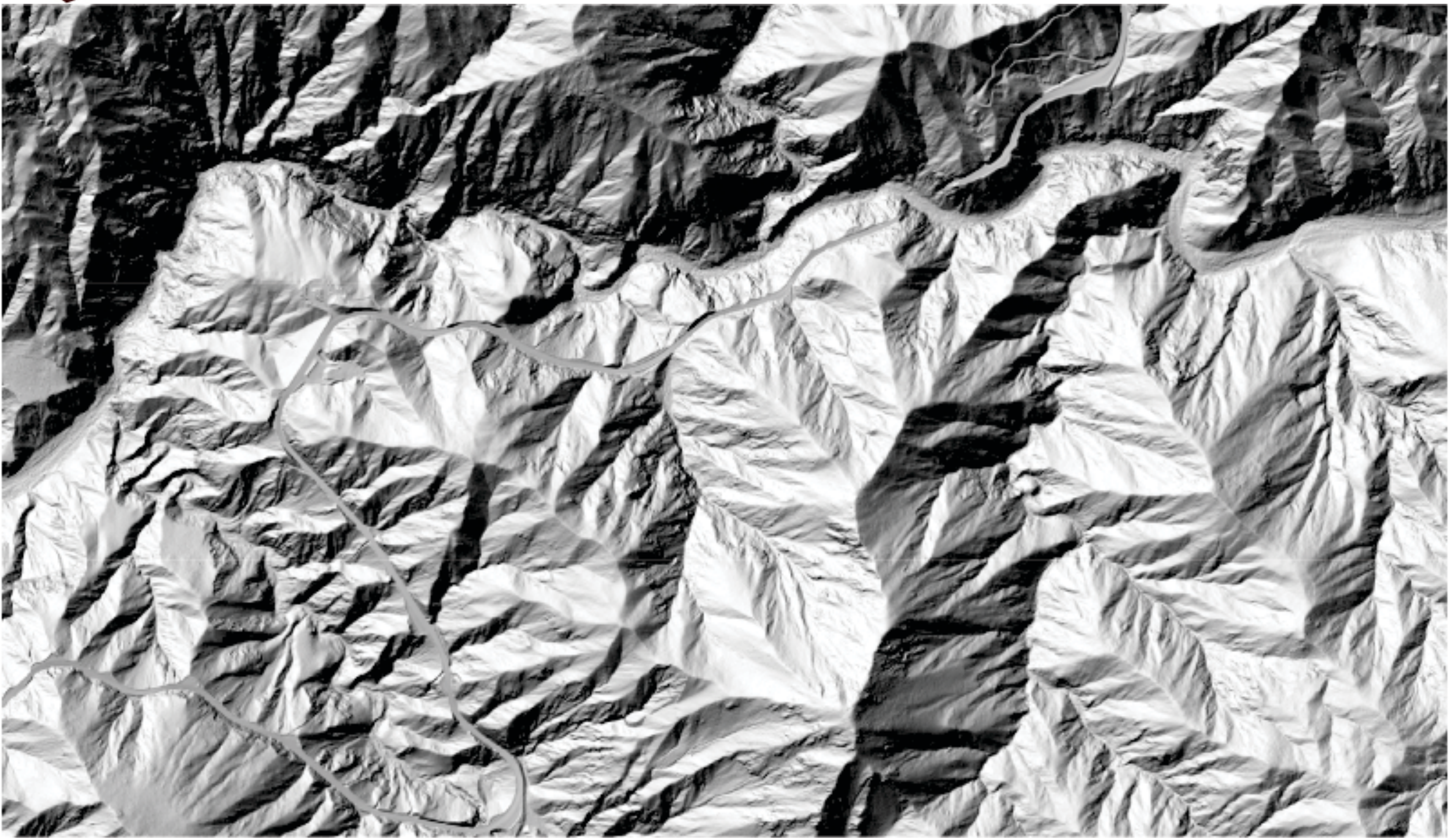
Location of Study Area (San Gabriel, California)



J. Oldow, UTD

Los Angeles County 30m DEM

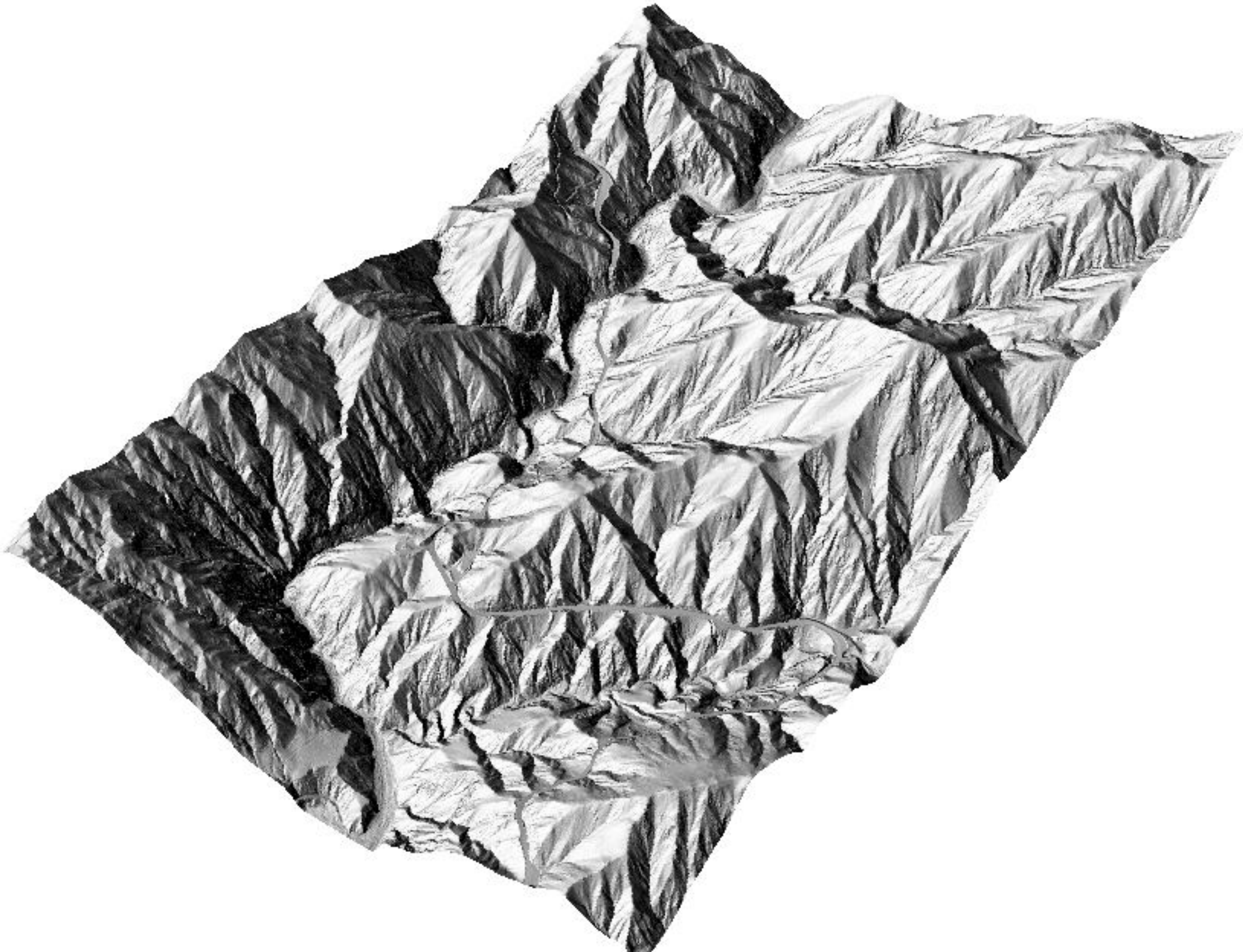
J. Oldow, UTD



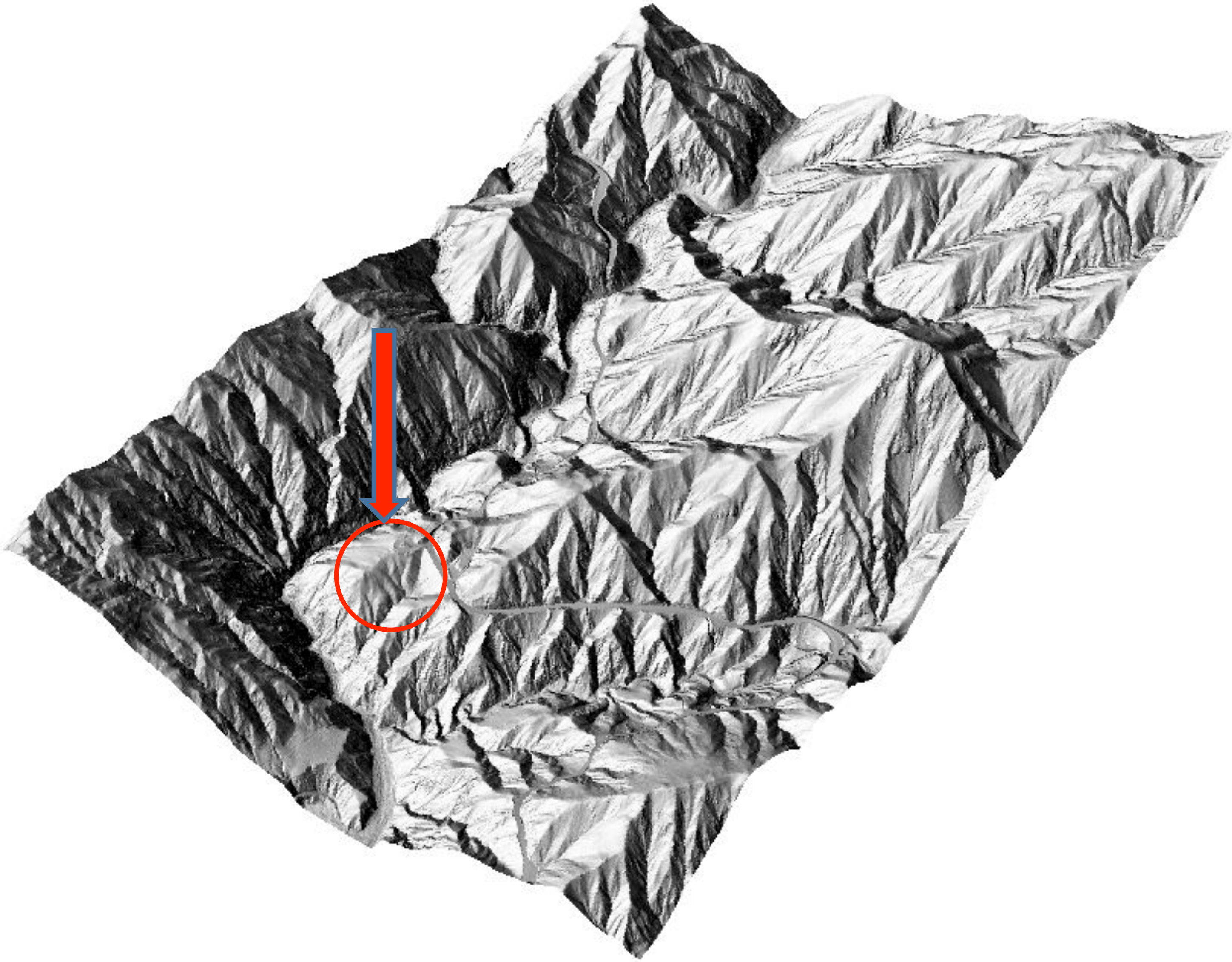
San Gabriel Mountain 1m DEM from airborne lidar

J. Oldow, UTD

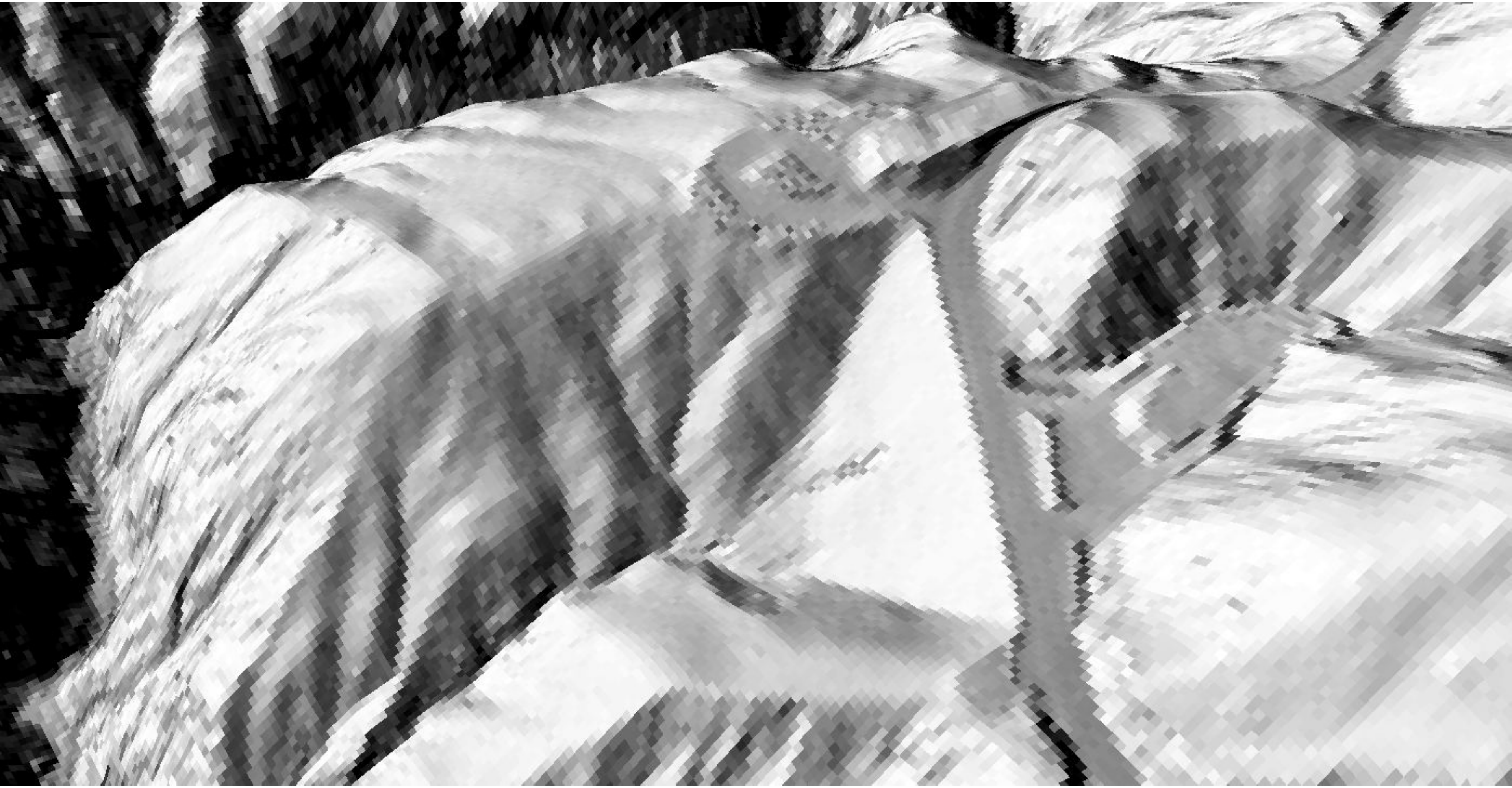
UNAVCO



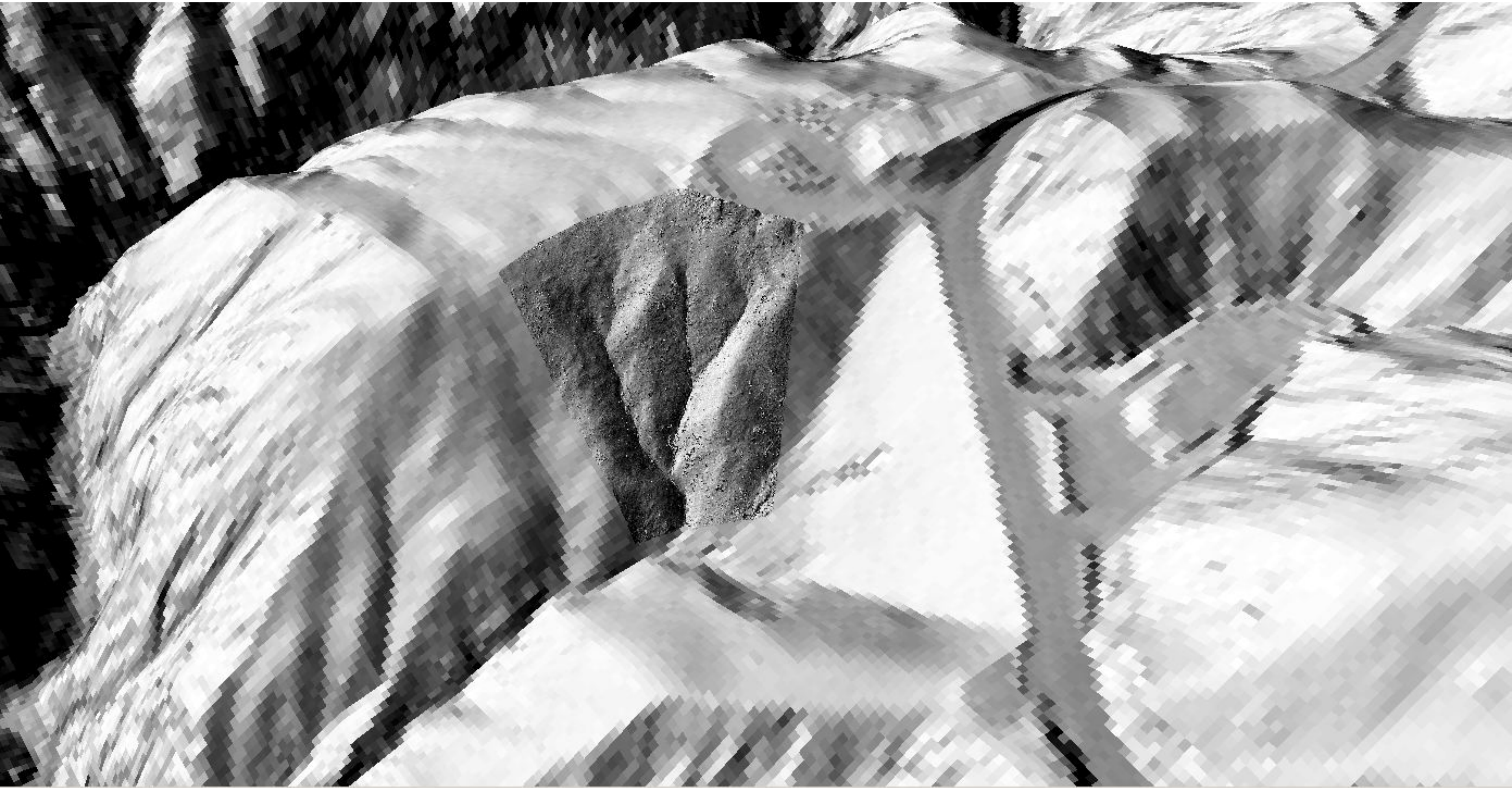
J. Oldow, UTD



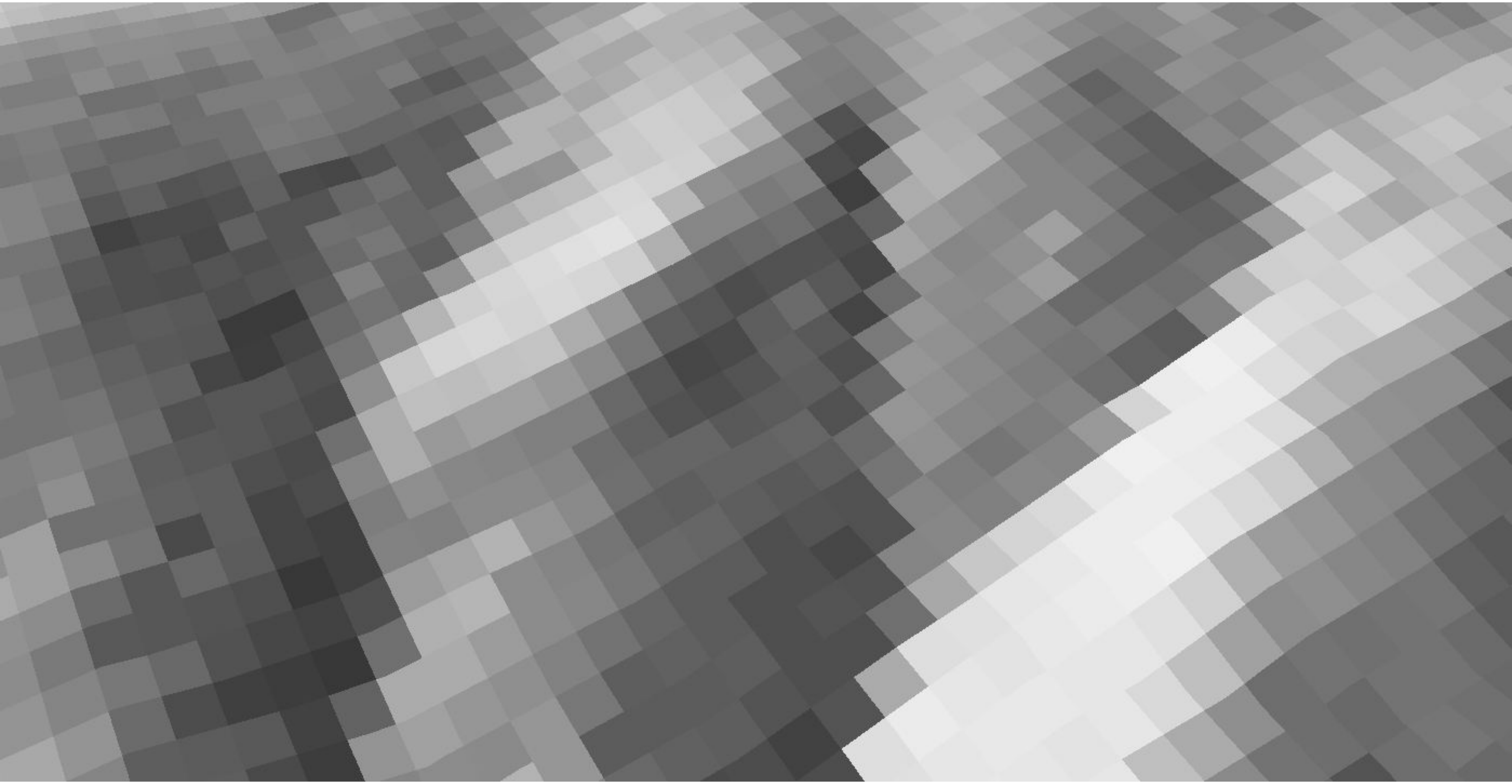
J. Oldow, UTD



J. Oldow, UTD



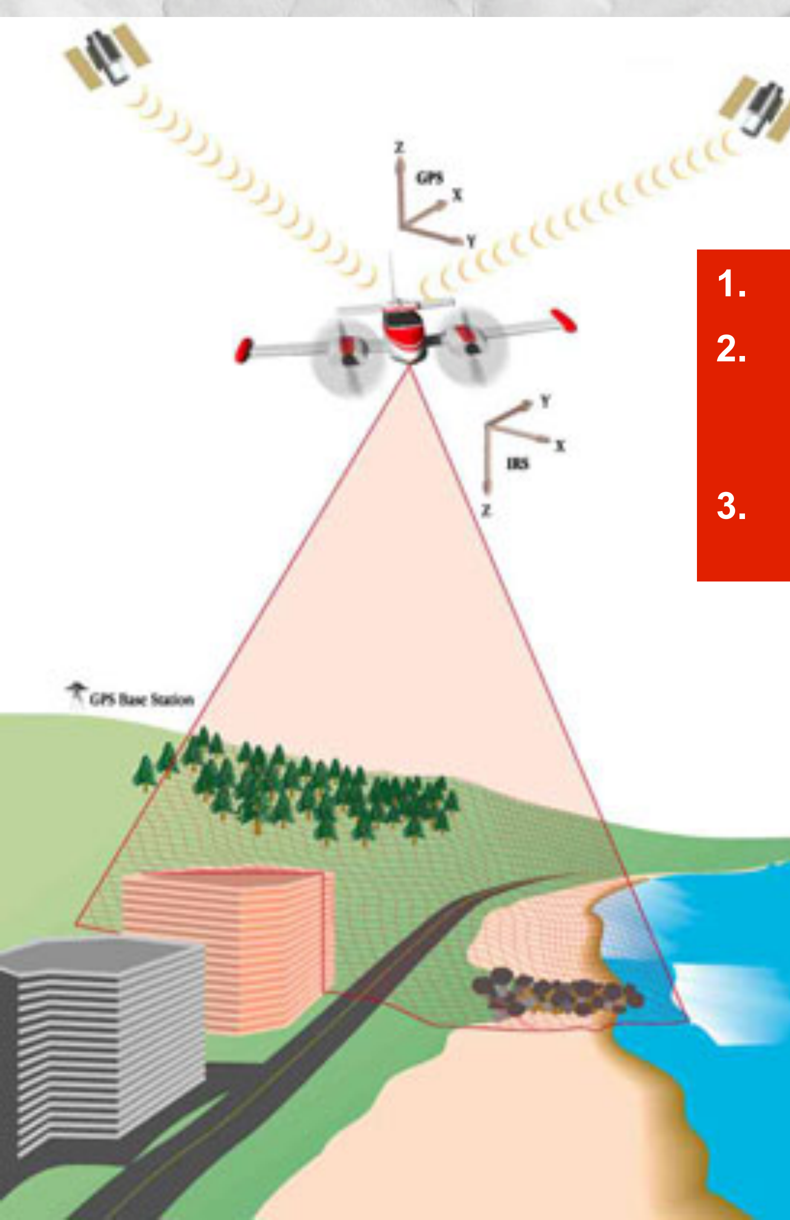
J. Oldow, UTD



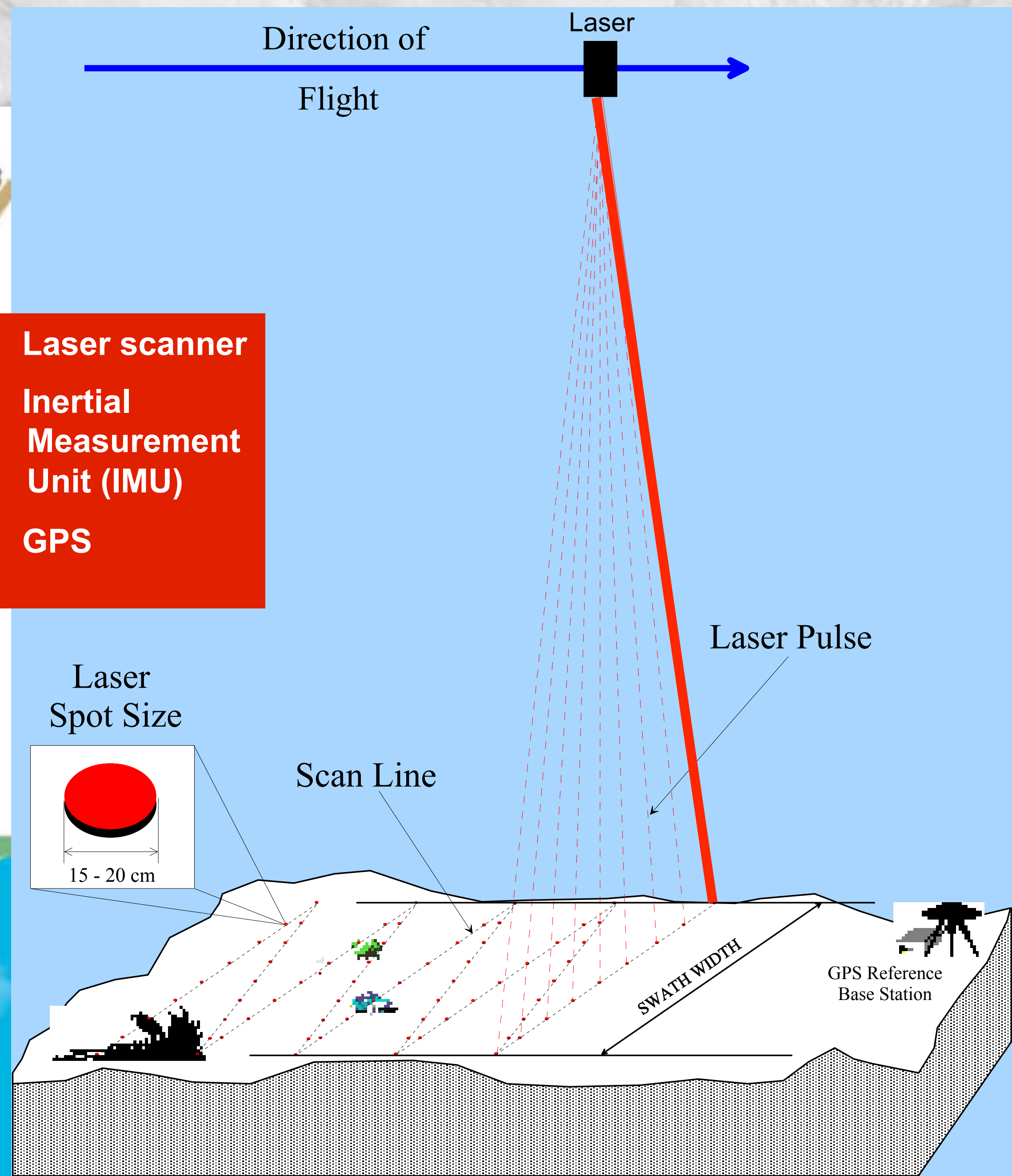
J. Oldow, UTD

J. Oldow, UTD

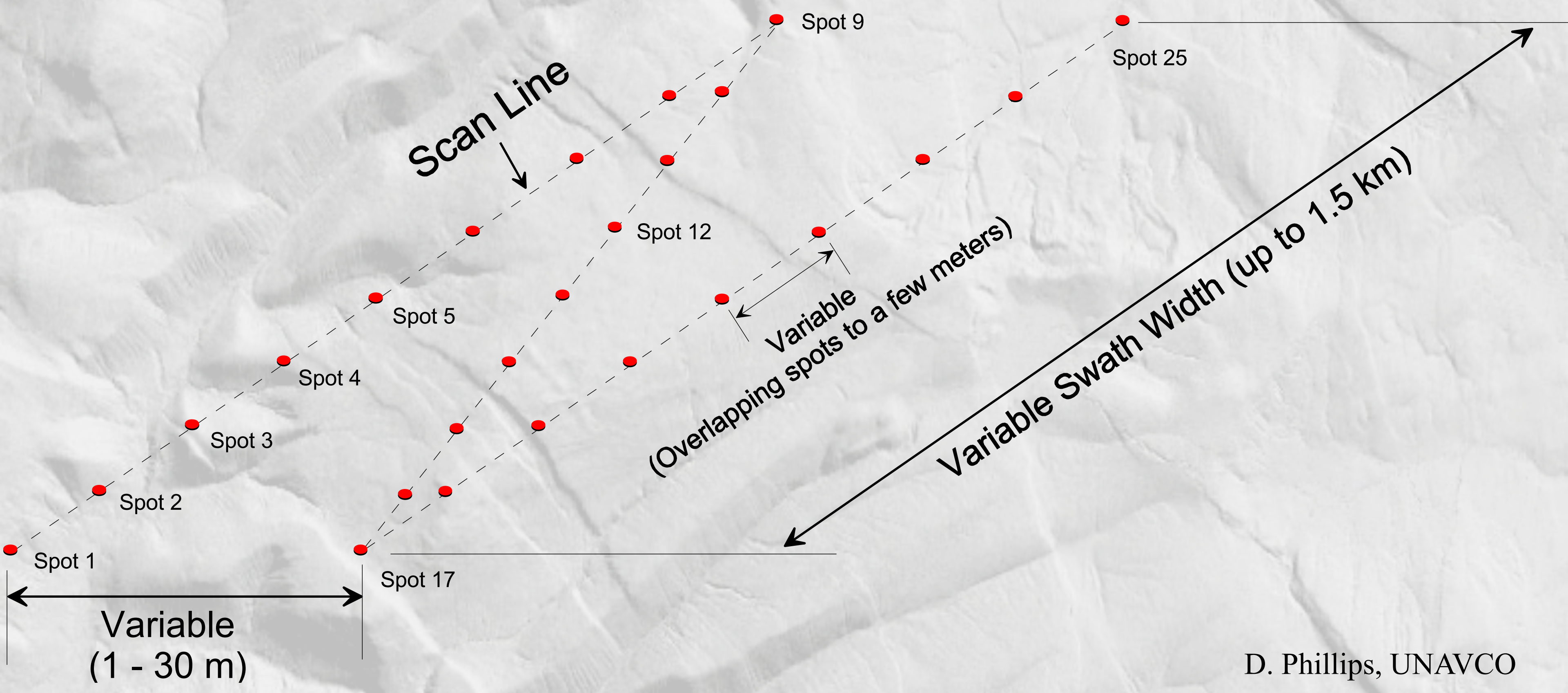
Lidar data collection



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

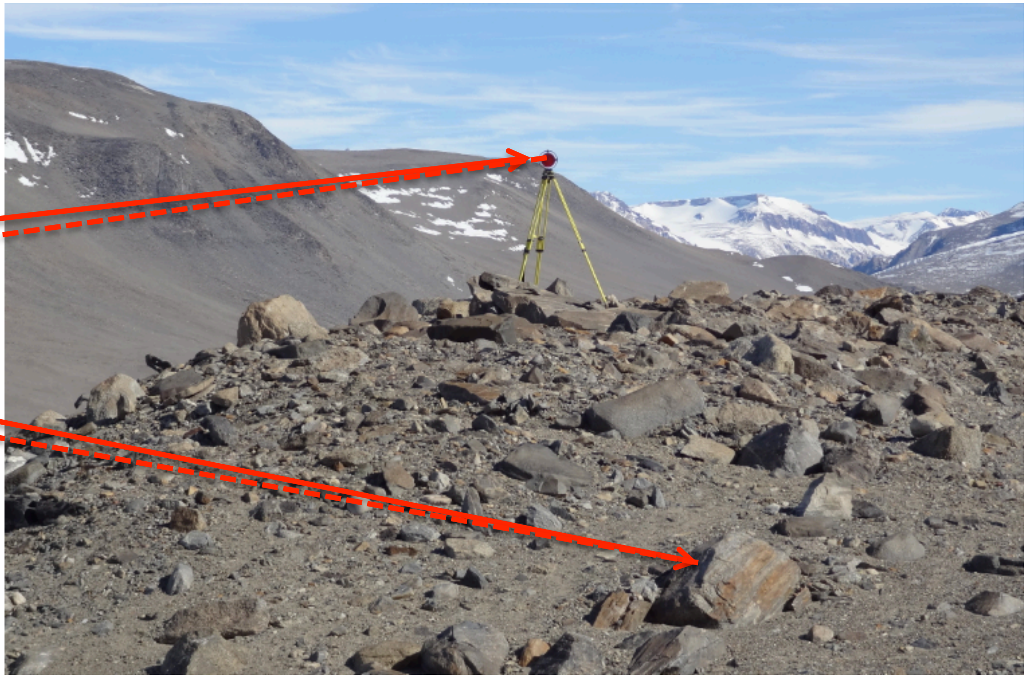
Typical Lidar Data Collection Parameters

- Aircraft: Cessna 337 Skymaster
- Personnel
  - One pilot, one operator in plane
  - GPS ground crew (2 to 10+ people)
- Scanner: Optech near-IR (Gemini)
- PRF: 33-125 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

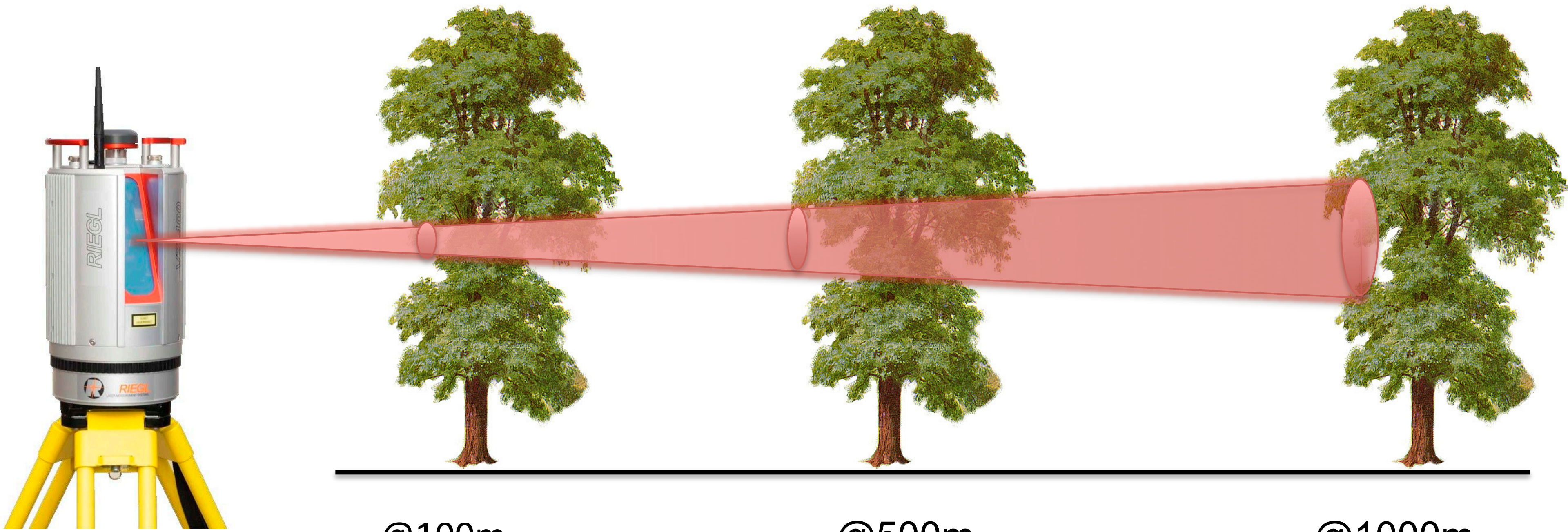
How a Lidar instrument works (Recap)

- 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

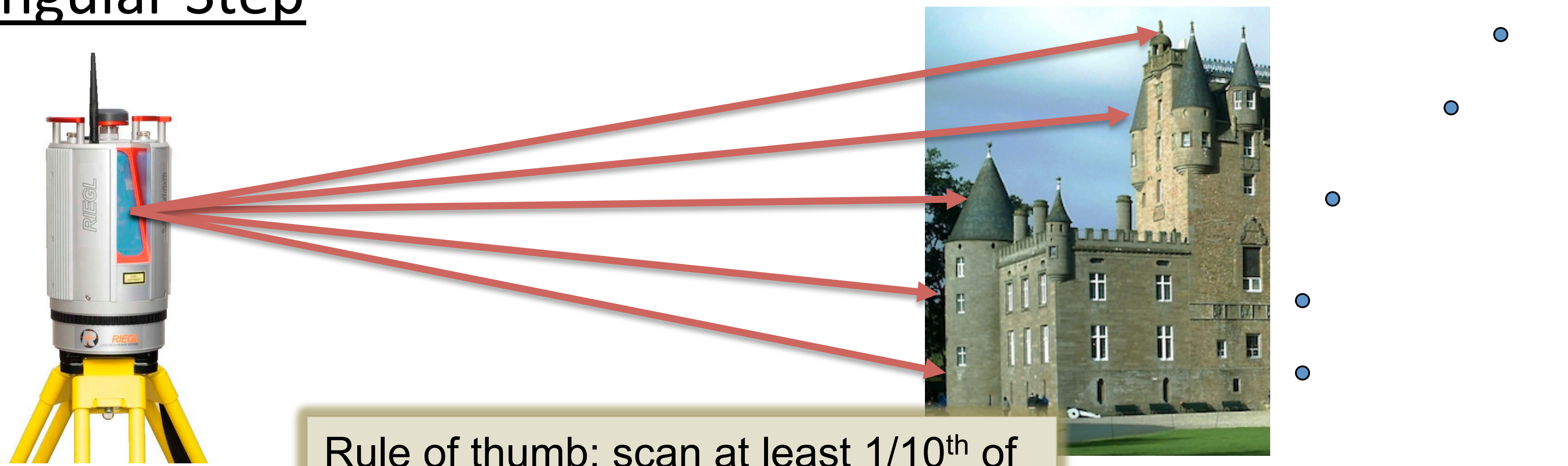


@100m,
Df = 36mm

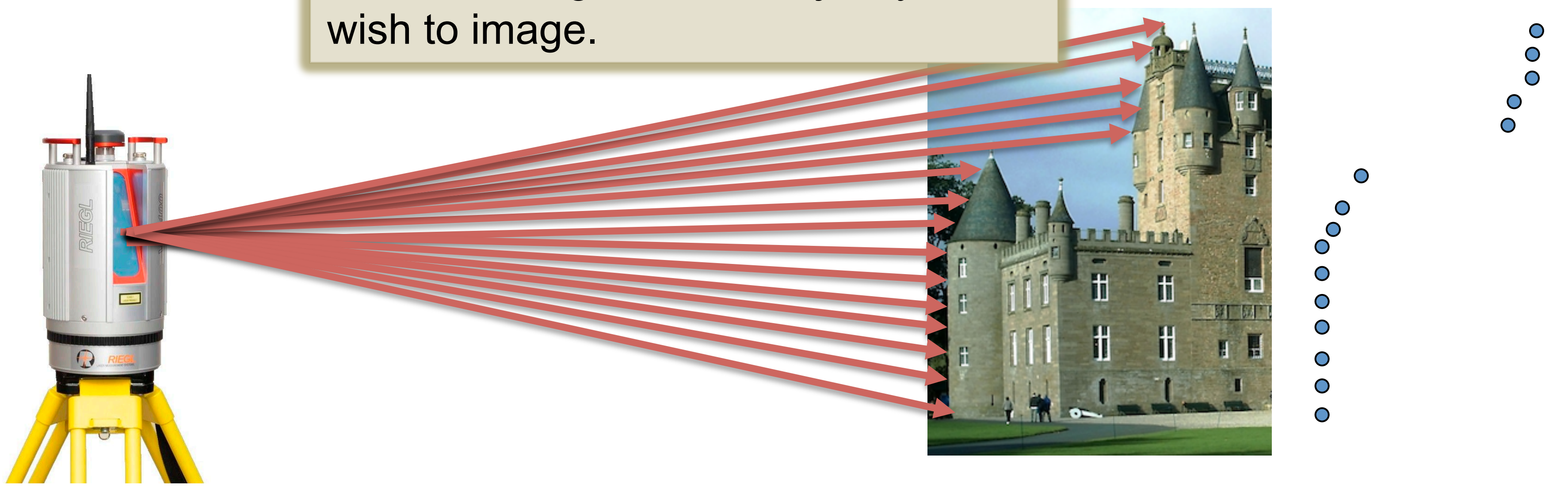
@500m,
Df = 180mm

@1000m,
Df = 360mm!

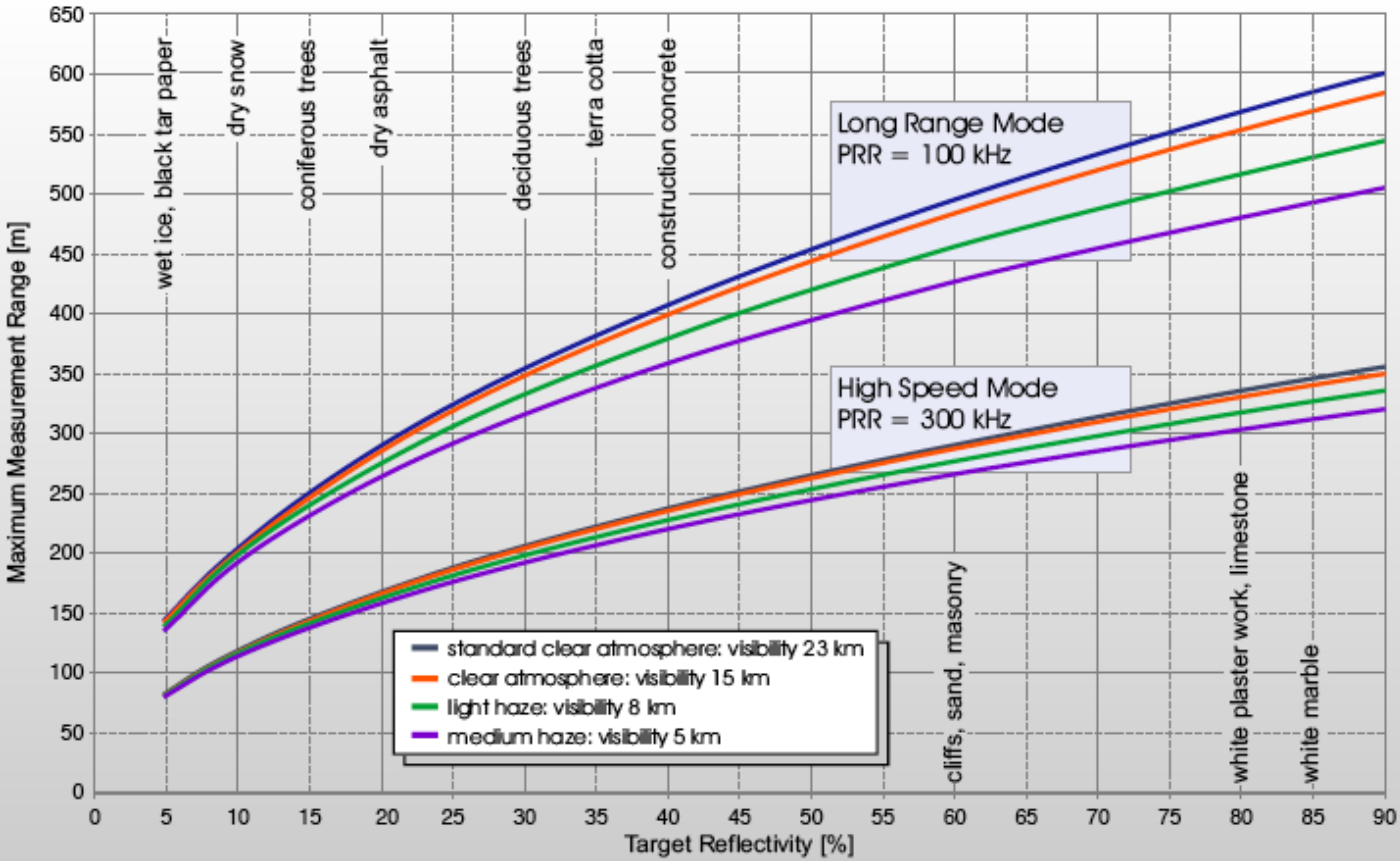
Angular Step

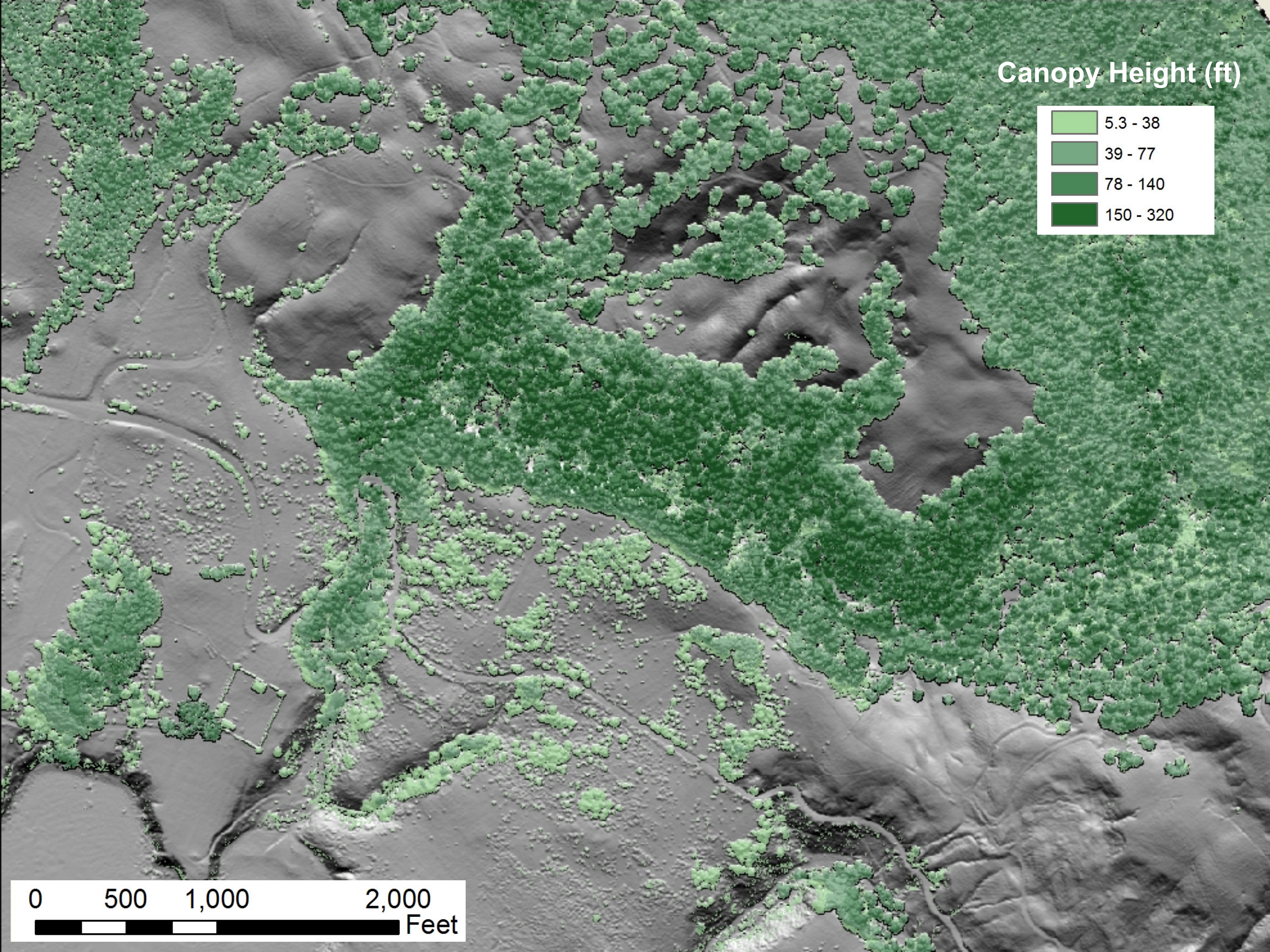


Rule of thumb: scan at least 1/10th of the “wavelength” of the object you wish to image.



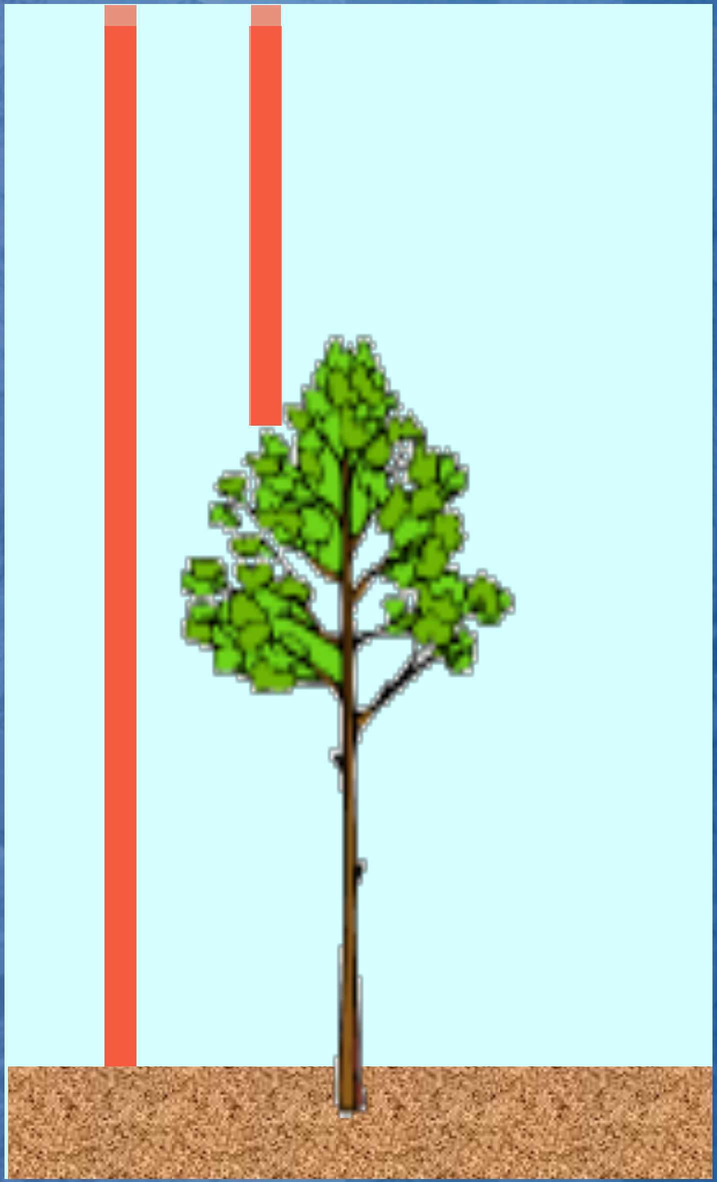
Riegl VZ400 Maximum measurement range as function of target material




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

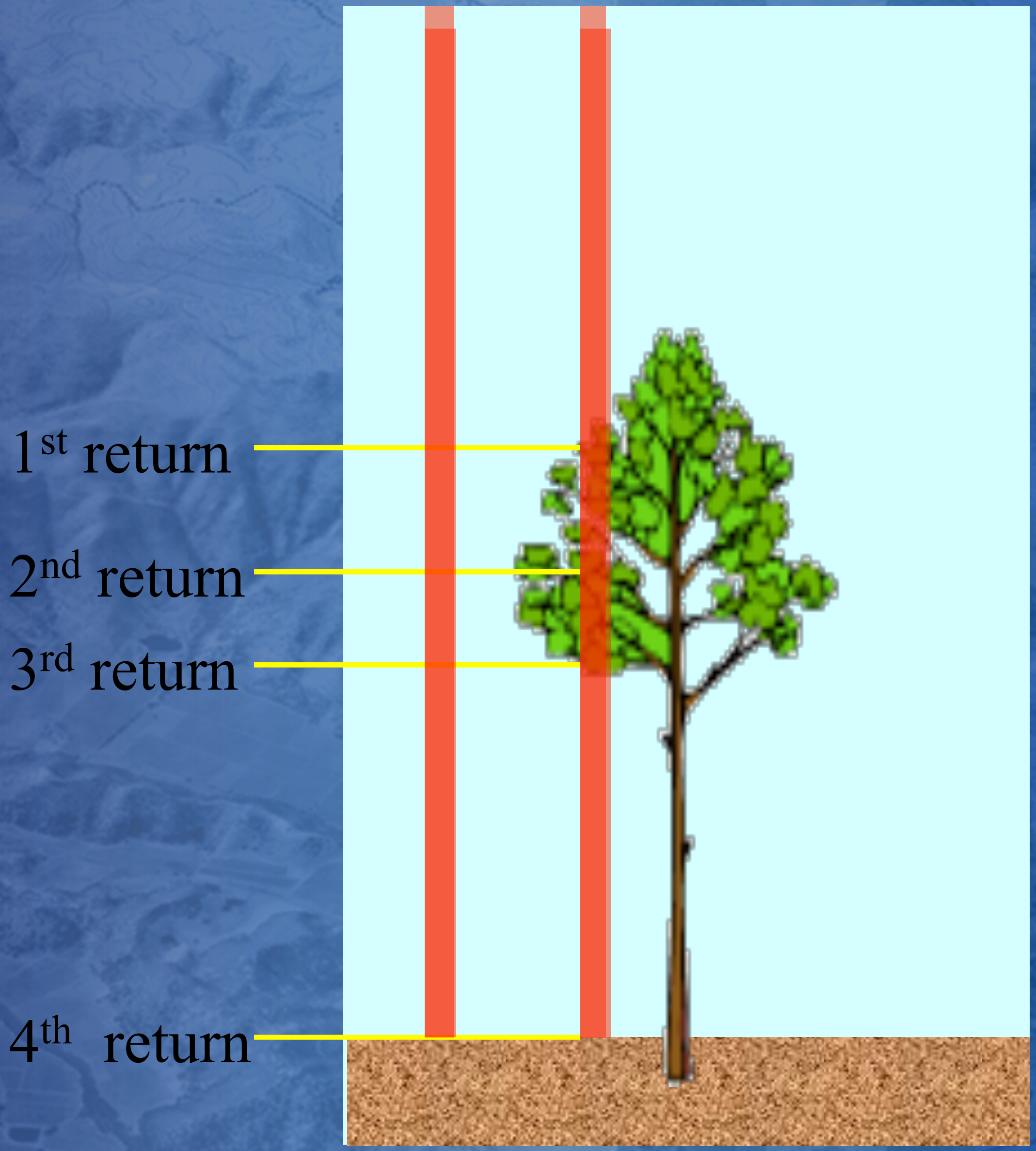


USGS

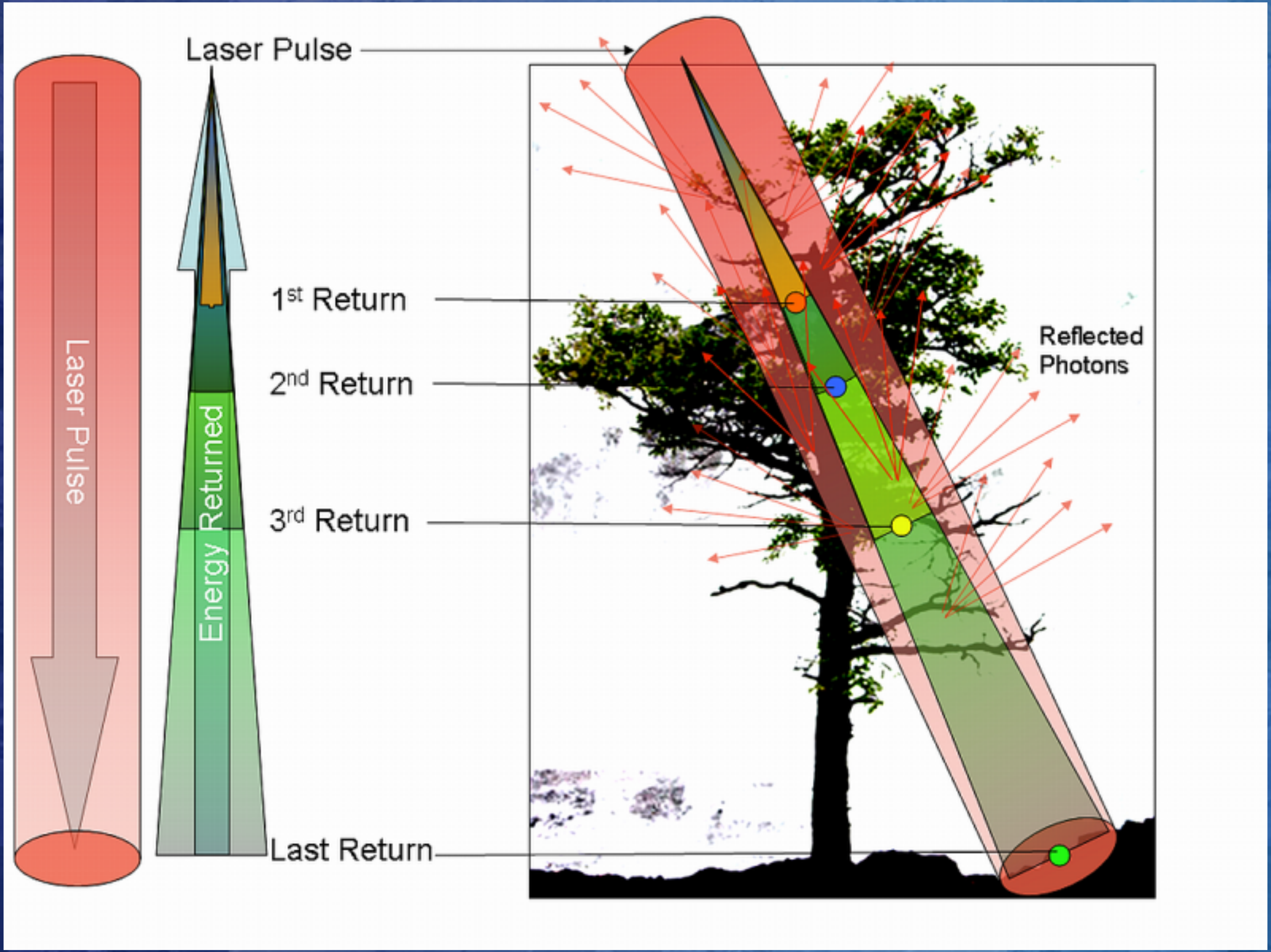
J. Stoker

Returns

- Single Return
- Multiple returns
- Waveform Returns

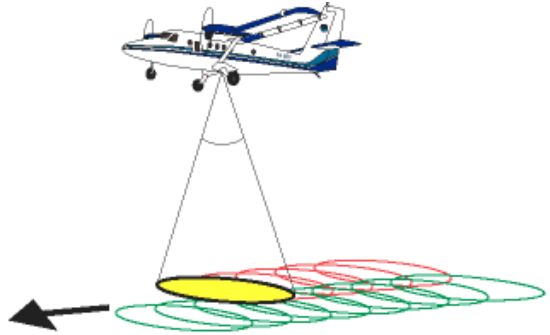


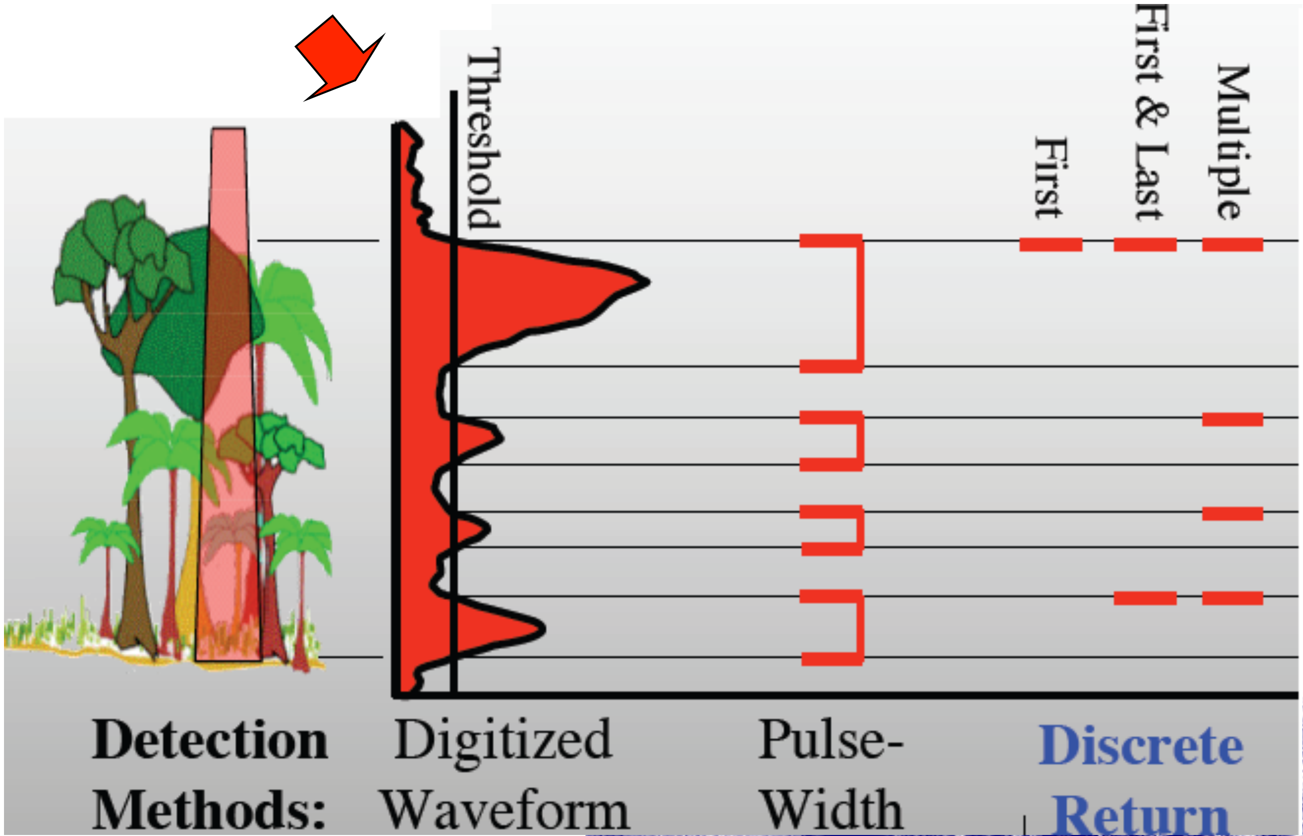
J. Stoker


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

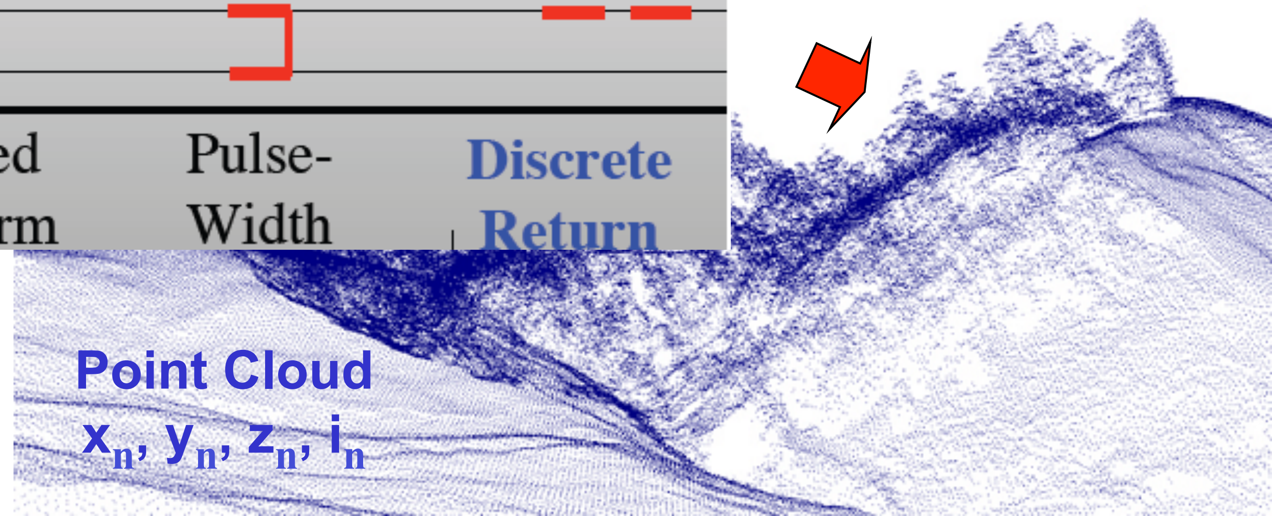
USGS

Lidar = Geodesy and signal processing

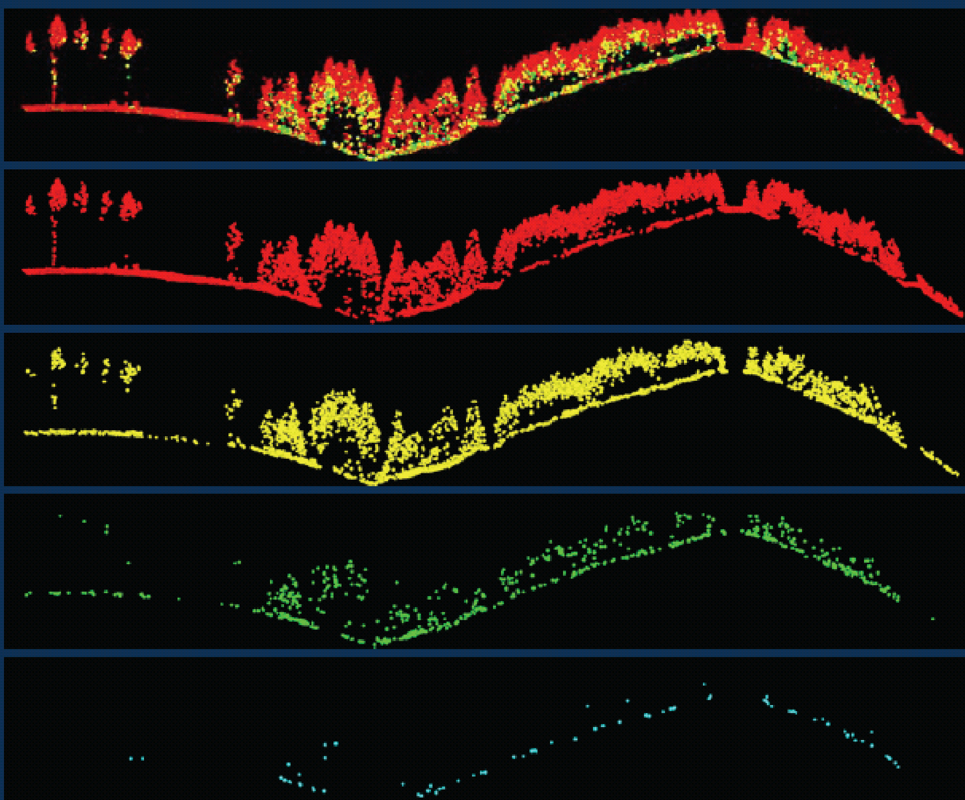




D. Harding, NASA



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%)

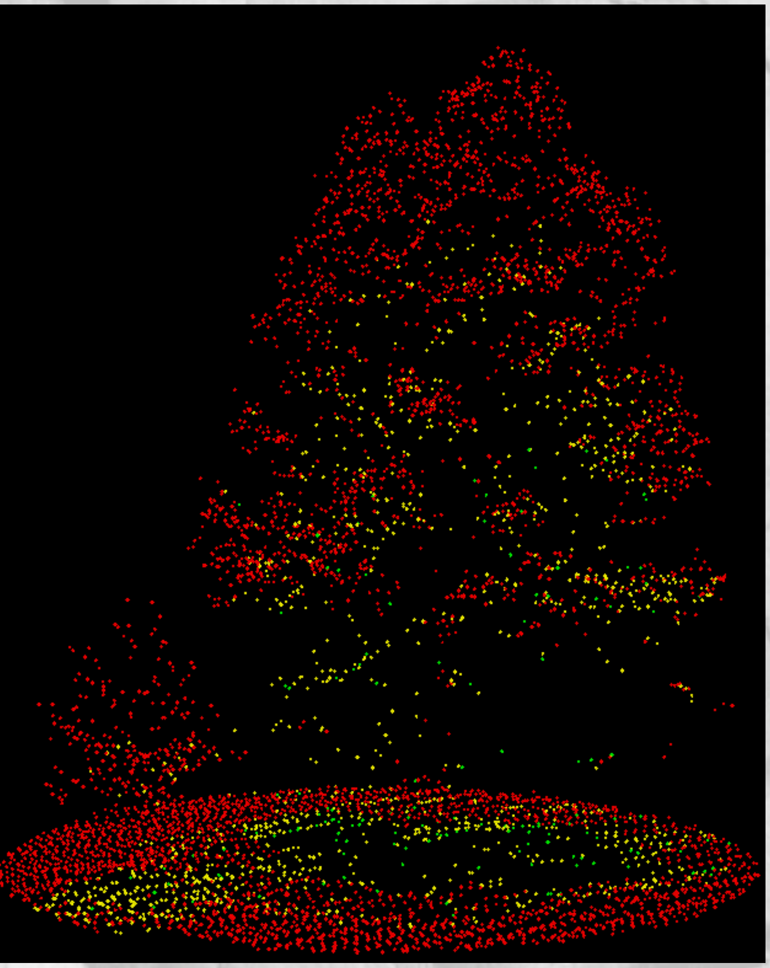
USGS

J. Stoker

Image courtesy Hans-Erik Anderson

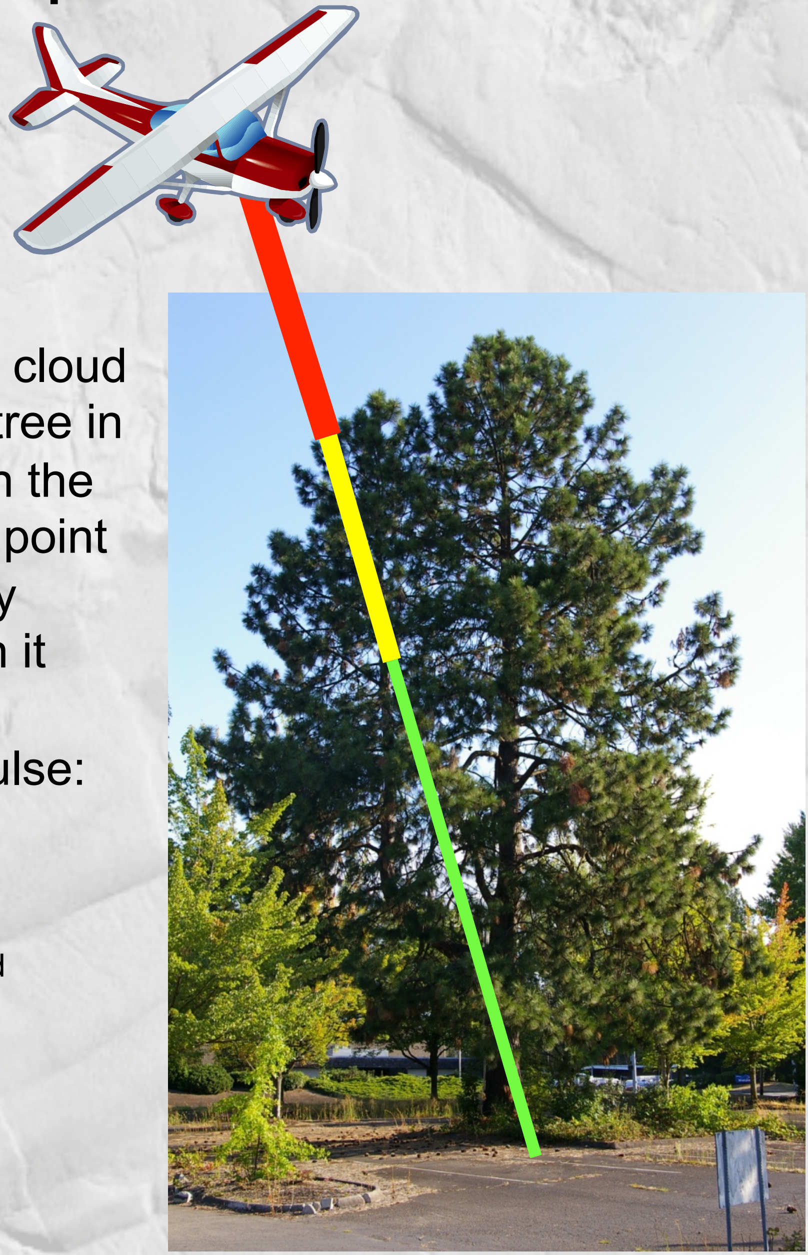
Each laser pulse can produce multiple consecutive measurements from reflections off several surfaces in its path

Ian Madin, DOGAMI



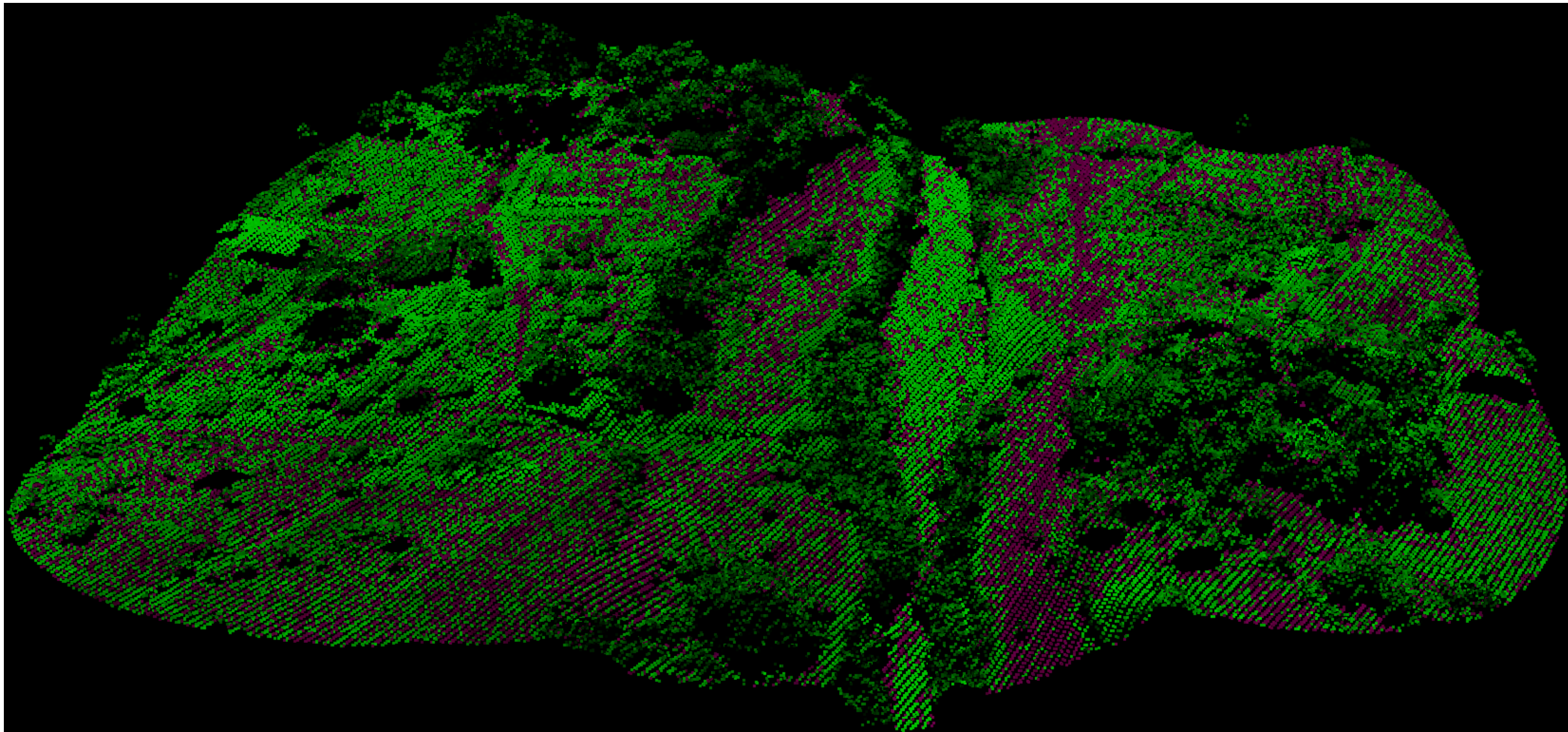
- Left = point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

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



Vegetation is a headache is geoscientists

- *Our noise is someone else's signal*
- How to get good ground model? - Automated vs manual?



Dumay Slip-Rate Site, Enriquillo Fault, Haiti

P. Gold, UCD

What is ground?

Three assumptions:

1. **Ground is smooth**
2. Ground is continuous (single-valued)
3. Ground is lowest surface in vicinity

Modified from: R. Hagerud, USGS

Ground is smooth $\Rightarrow$ despike algorithm

Approach:

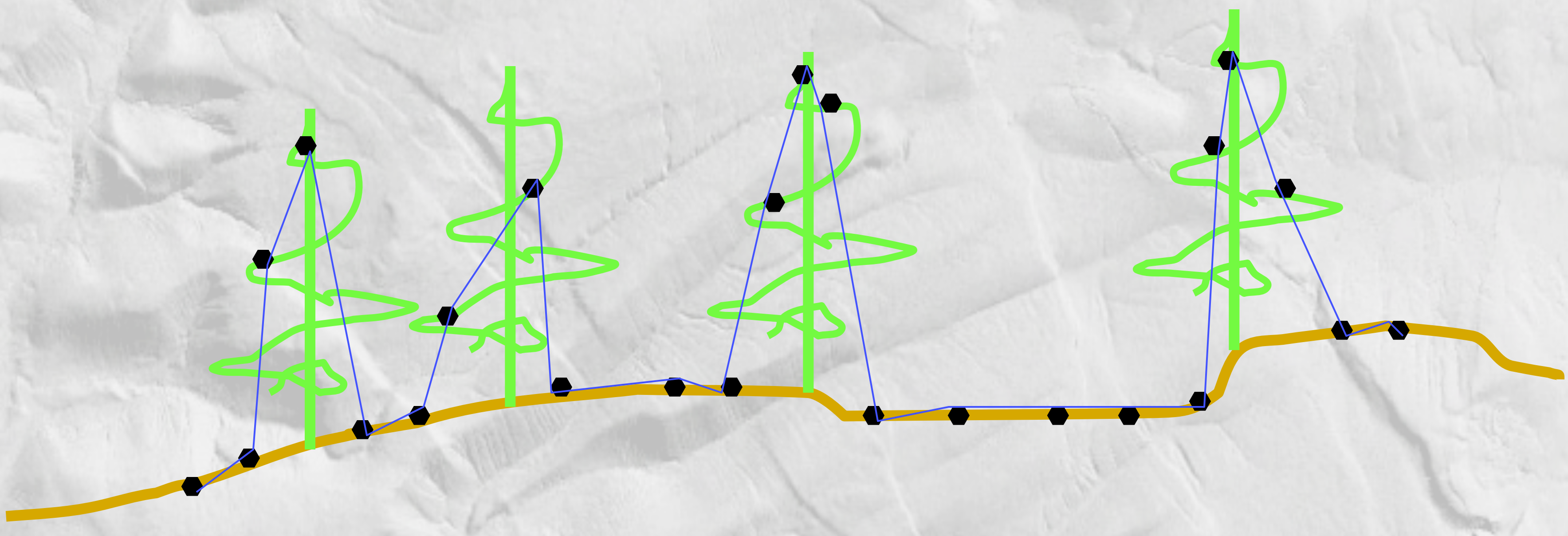
1. flag all points as ground

2. repeat:
   - build TIN (triangulated irregular network) of ground points
   - identify points that define strong positive curvatures
   - flag identified points as not-ground

3. Iterate until no or few points are flagged

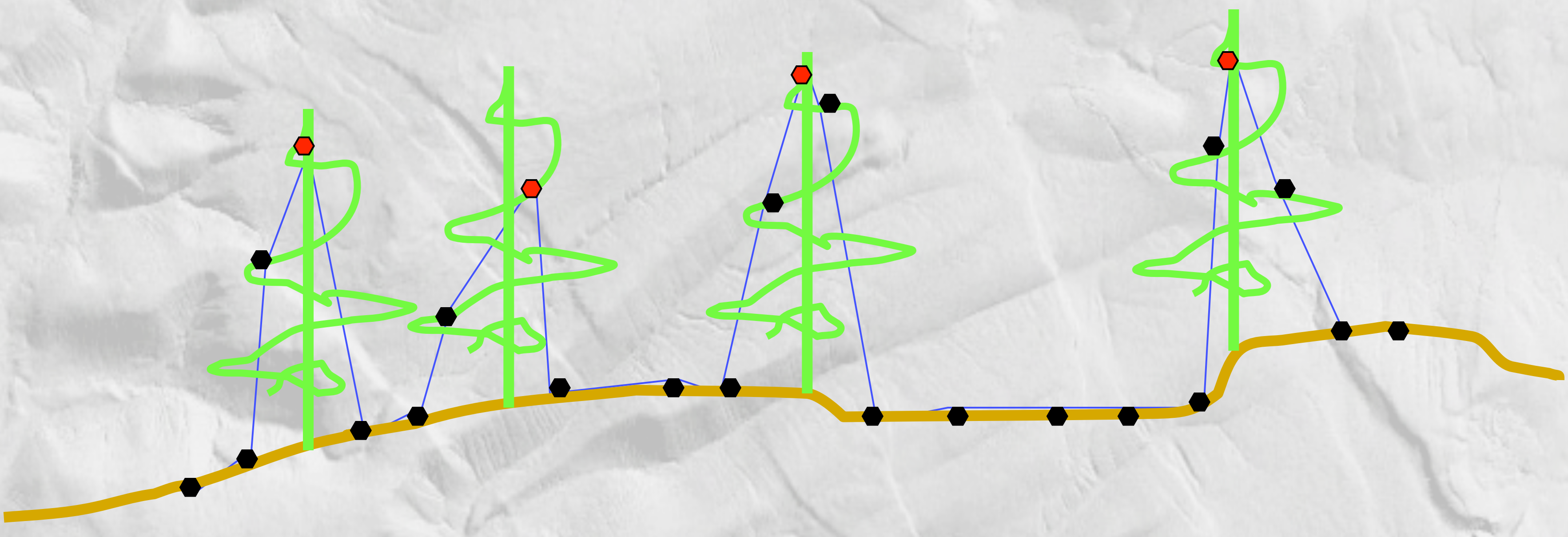
R. Hagerud, USGS

Start with mixed ground and canopy returns (e.g. last-return data), build TIN



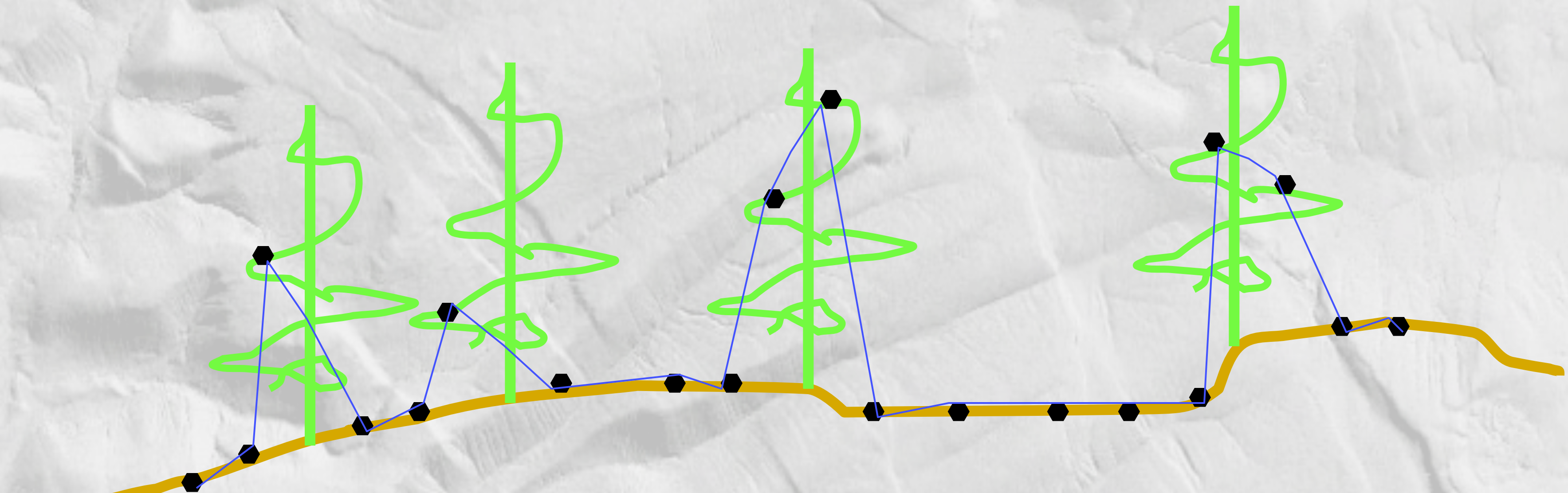
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



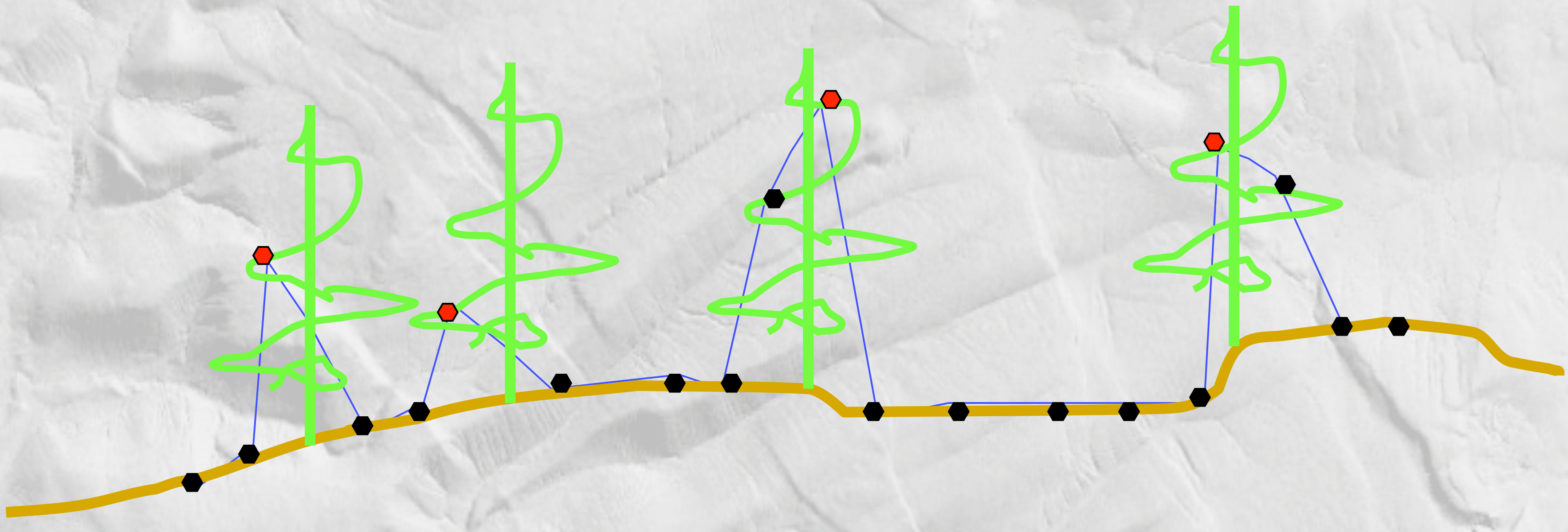
R. Hagerud, USGS

Rebuild TIN



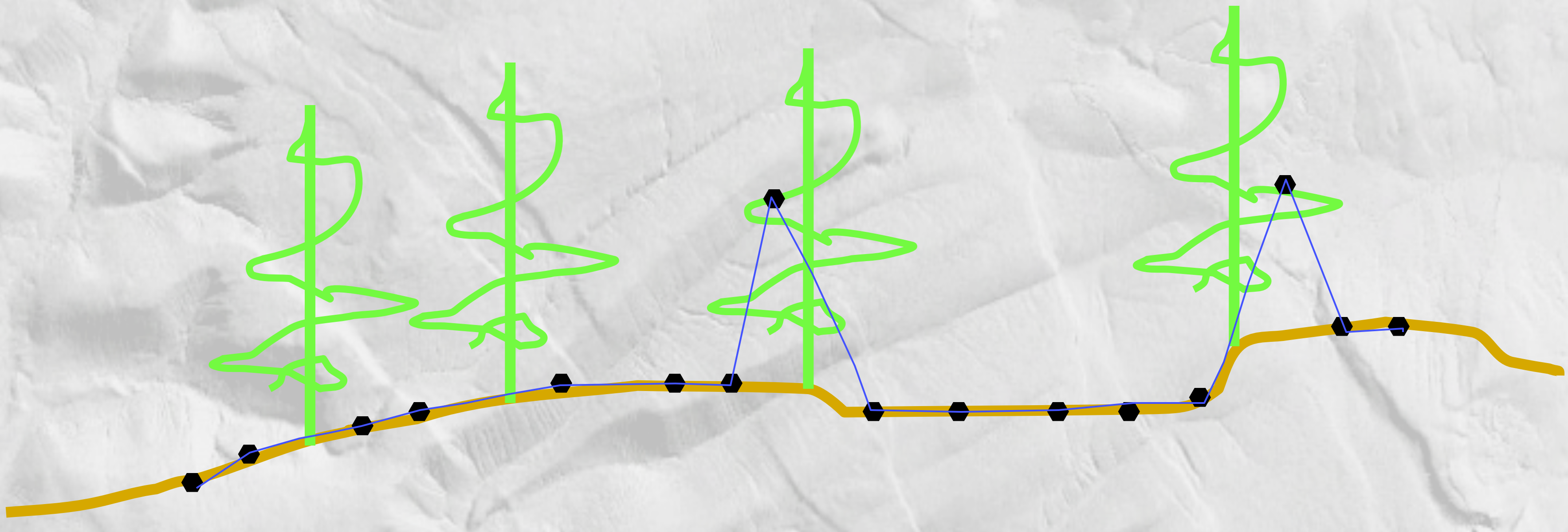
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



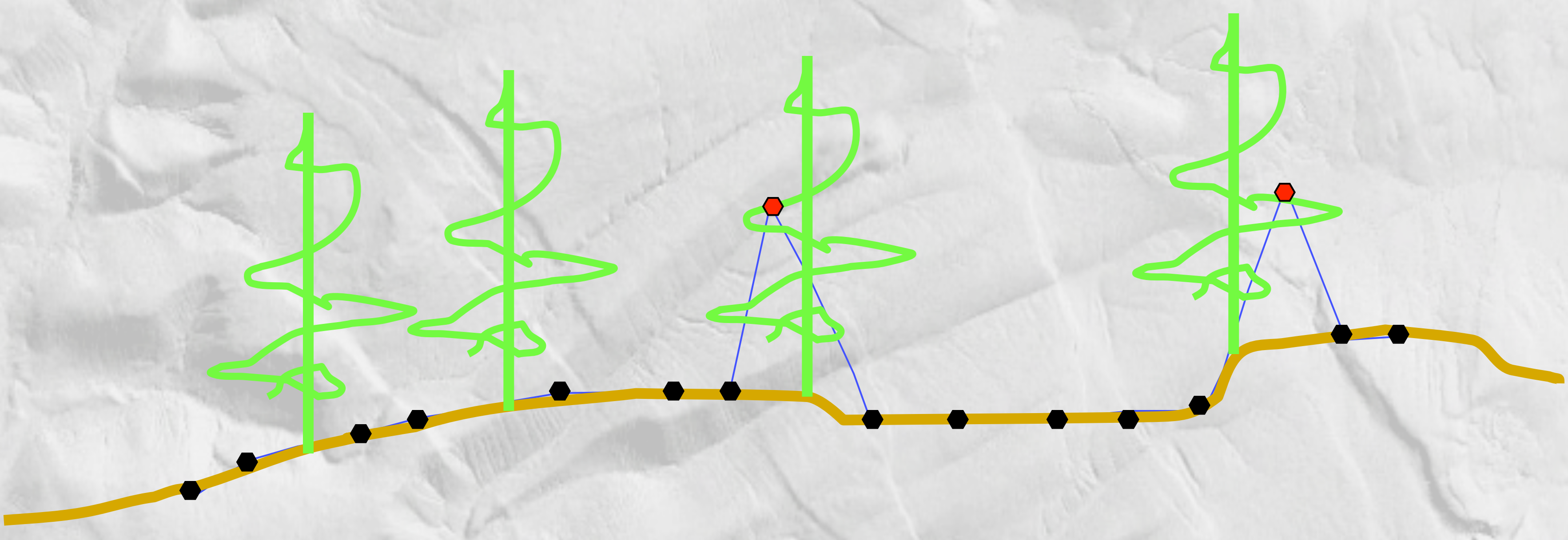
R. Hagerud, USGS

Rebuild TIN



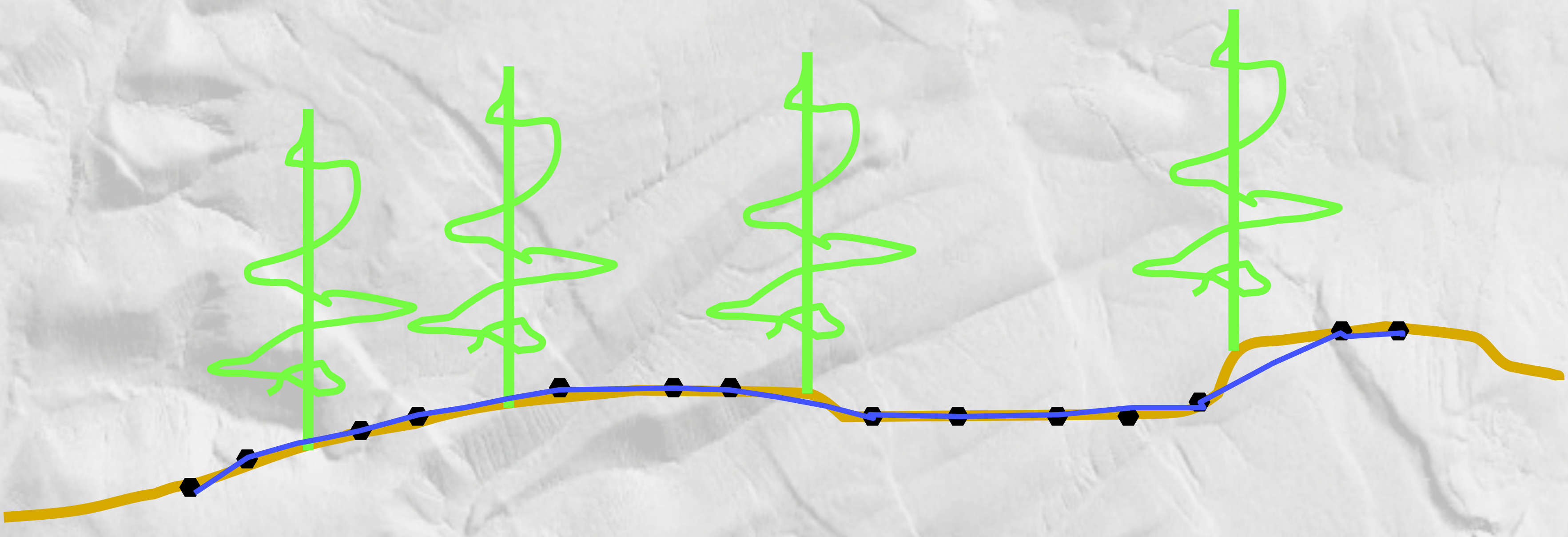
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



R. Hagerud, USGS

Rebuild TIN



R. Hagerud, USGS

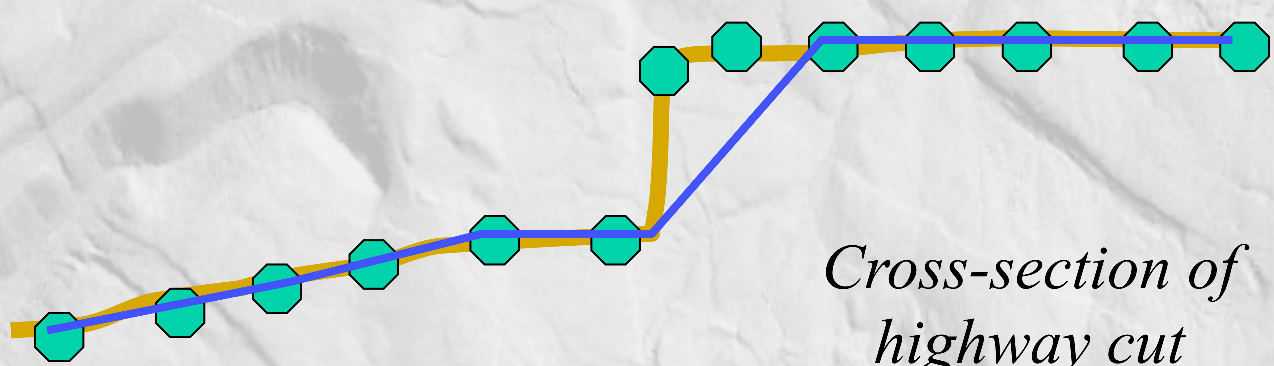
Despike algorithm

<u>Benefits</u>:

- It works
- It's automatic
  - Cheap(!)
  - All assumptions explicit
- It can preserve breaklines
- It appears to retain more ground points than other algorithms

R. Hagerud, USGS

Despike algorithm



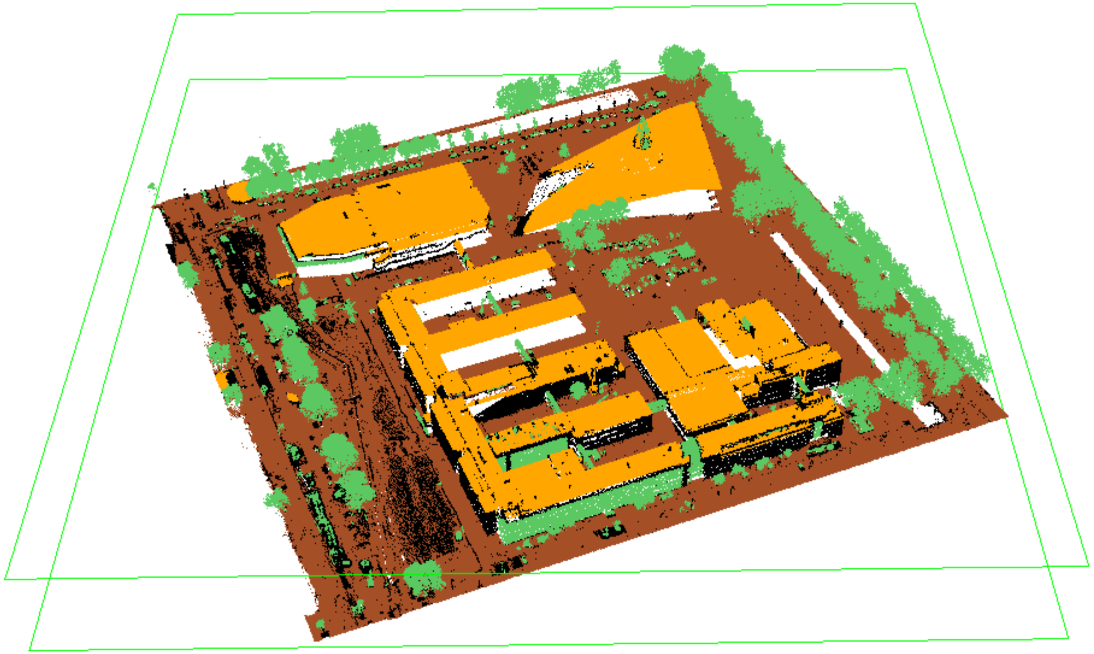
Cross-section of highway cut

Problems:

- Removes some corners
- Sensitive to negative blunders
- Computationally intensive
- Makes rough surfaces
  - Real? Measurement error? Misclassified vegetation?

R. Hagerud, USGS

TLS Processing Workflow – Vegetation Filtering



<u>Commercial – Automated:</u>

- RiScan Pro, TeraSolid, etc.

<u>Open Source - Automated</u>:

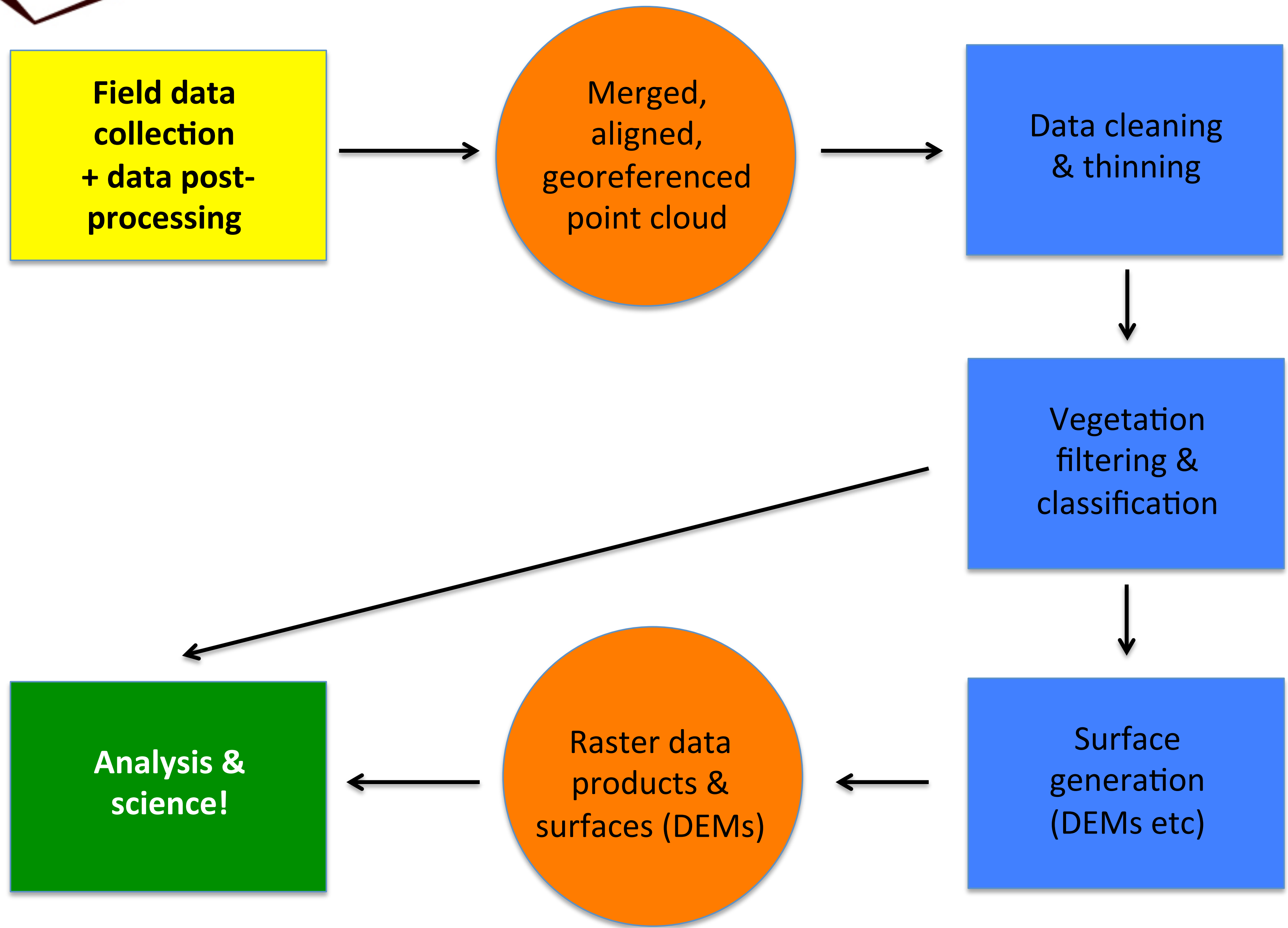
- LASTools –
  lasground.exe &
  lasclassify.exe
- MCC-lidar
  (Evans & Hudak, 2007)
  http://sourceforge.net/apps/trac/mcclidar/
- BCAL lidar tools (requires ENVI): http://bcal.geology.isu.edu/tools-2/envi-tools

More discussion: http://www.opentopography.org/index.php/blog/detail/tools_for_lidar_point_cloud_filtering_classification#comments

<u>Open Source - Manual</u>:

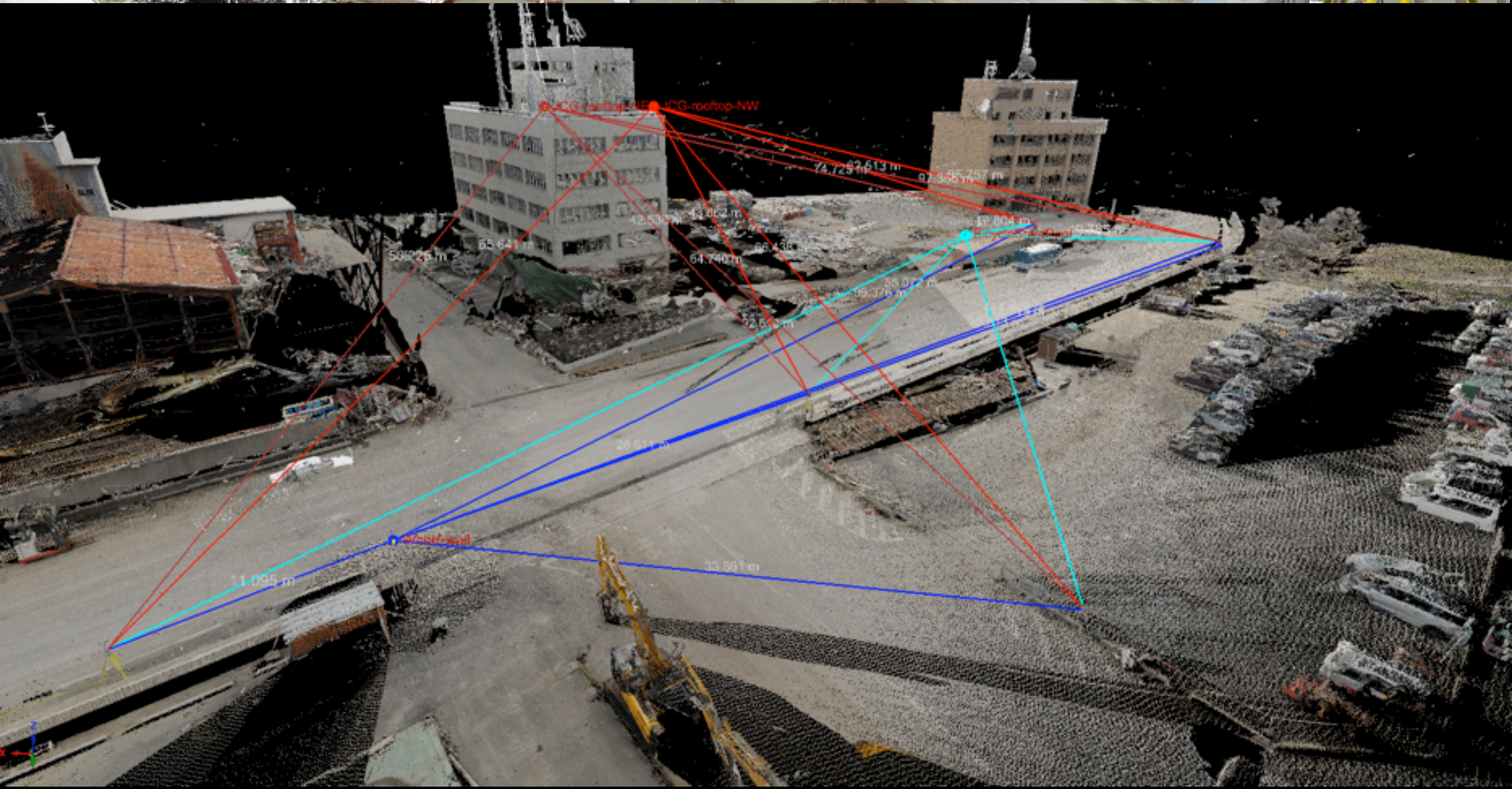
- LidarViewer (KeckCAVES)

TLS Processing Workflow – Overview



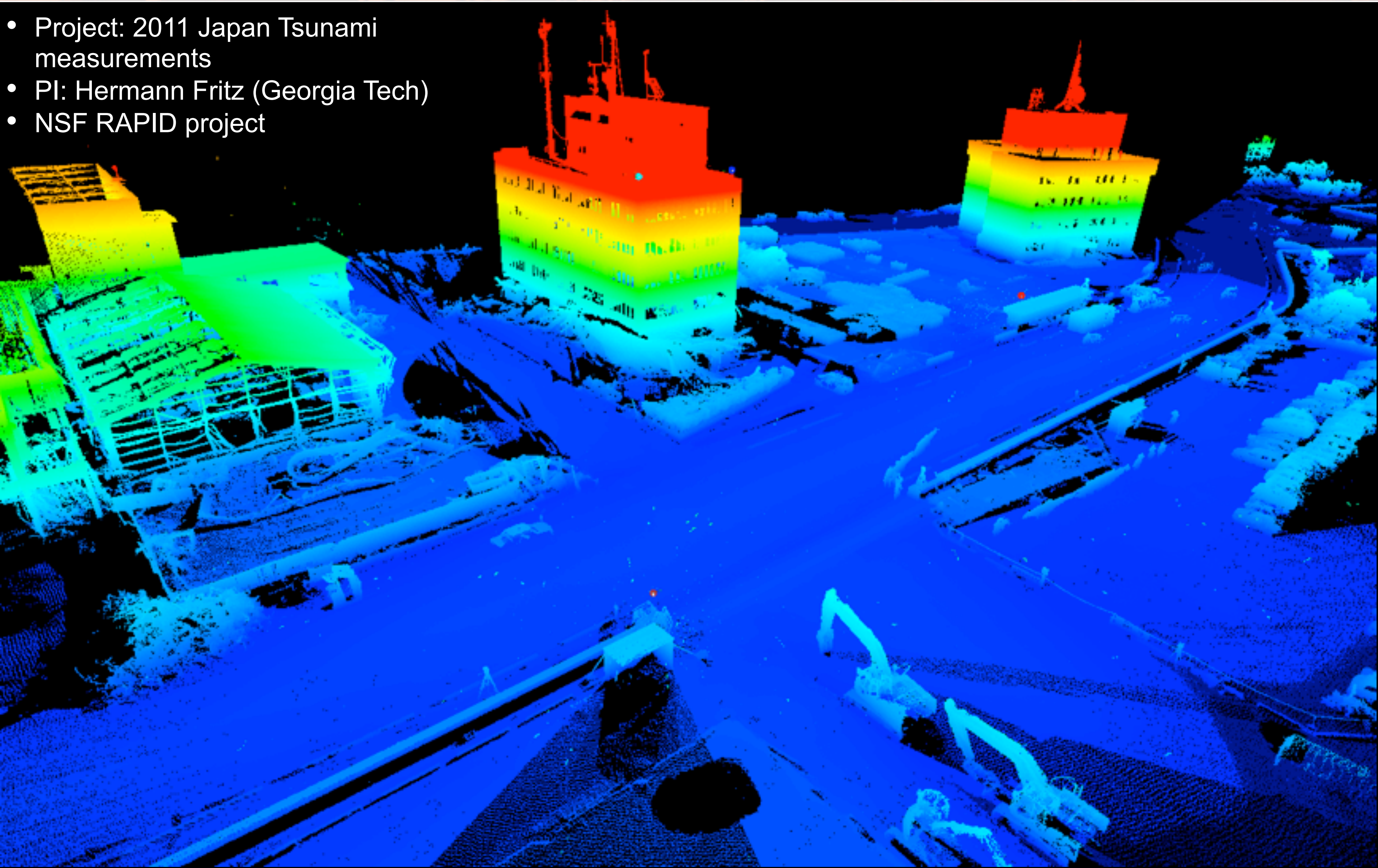
Showcase Tool #1: TLS Terrestrial Laser Scanner

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


JCG-rooftop-NW
Wharf-wall
11.095 m
33.561 m
64.740 m

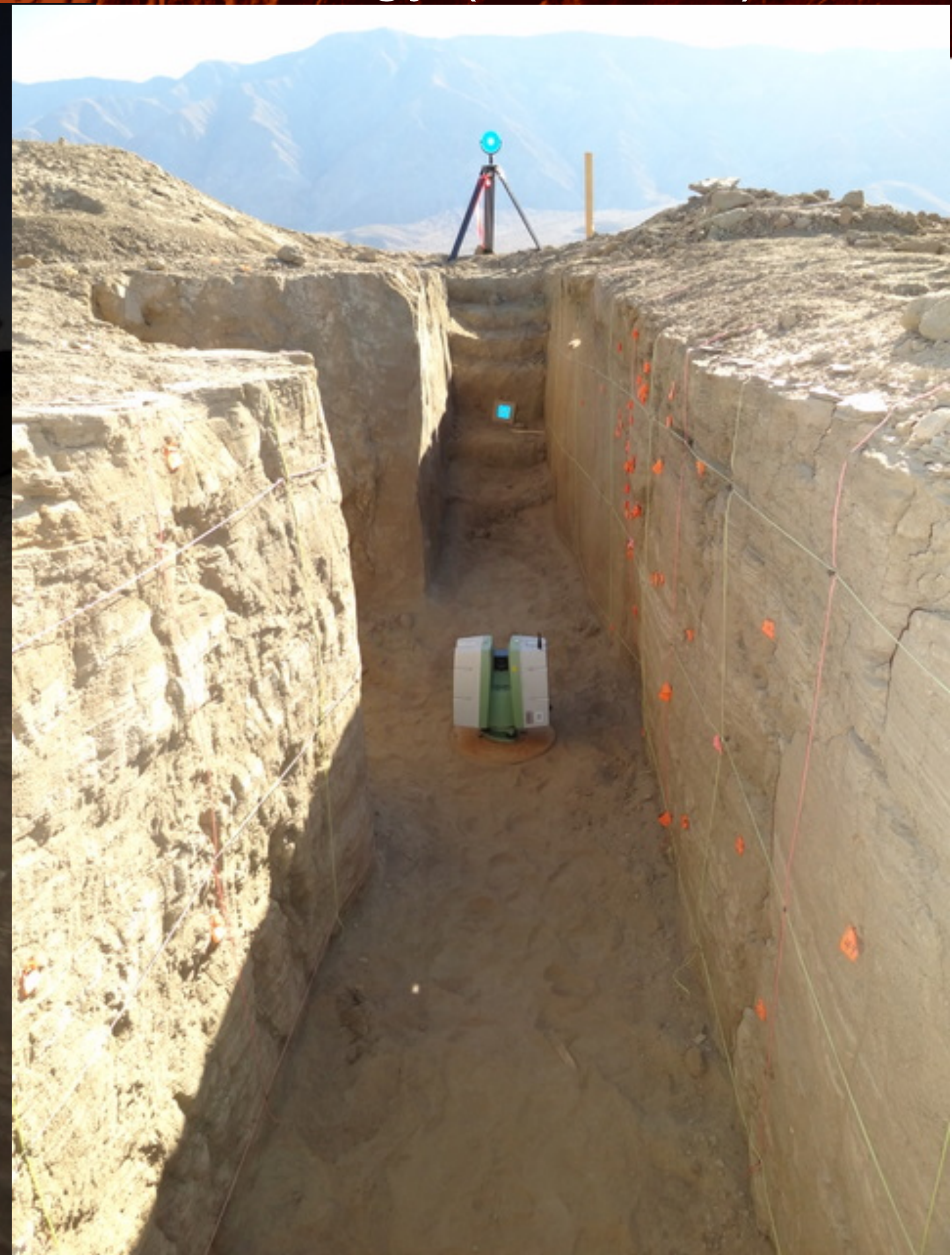
2011 Japan Tsunami

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



UNAVCO

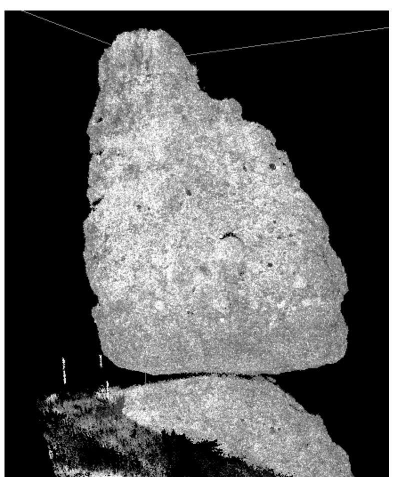
SoCal Paleoseismology (Rockwell)

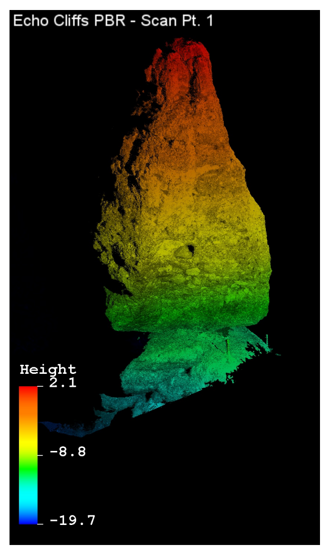


Precariously Balanced Rocks (Hudnut)

- 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.

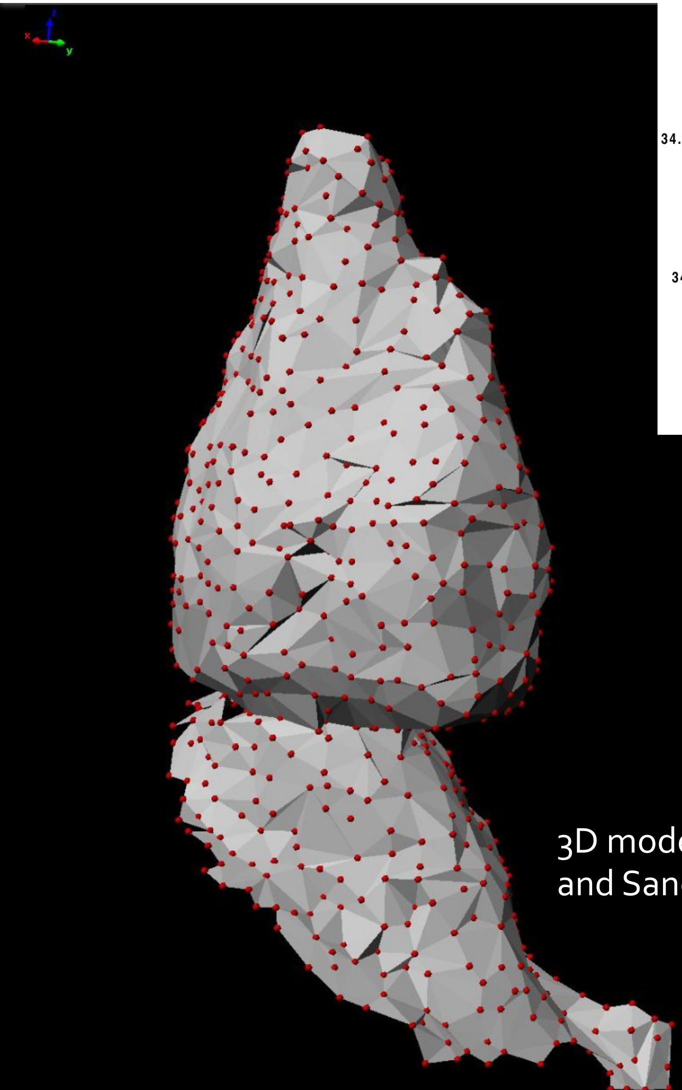


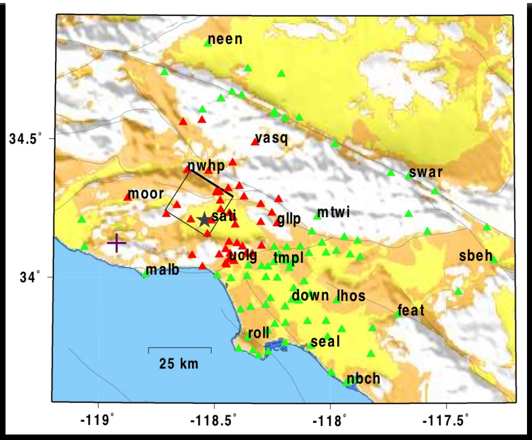


(Hudnut et al., 2009)

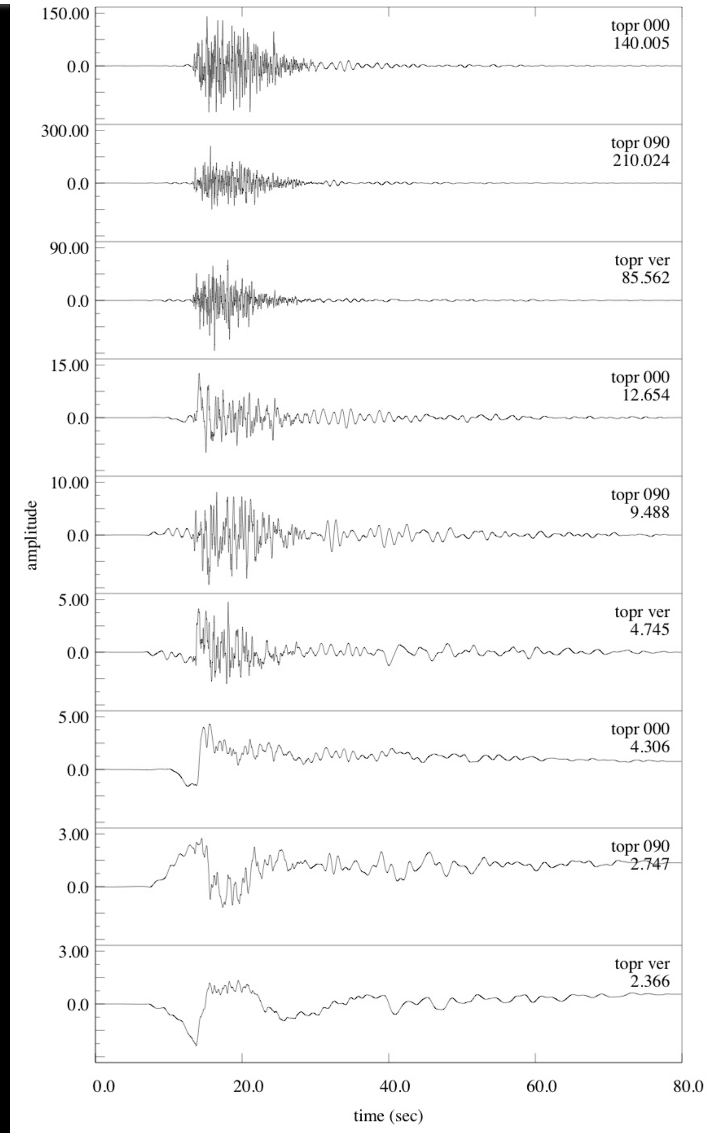
Precariously Balanced Rocks (Hudnut)

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





Northridge 1994 simulation by Rob Graves

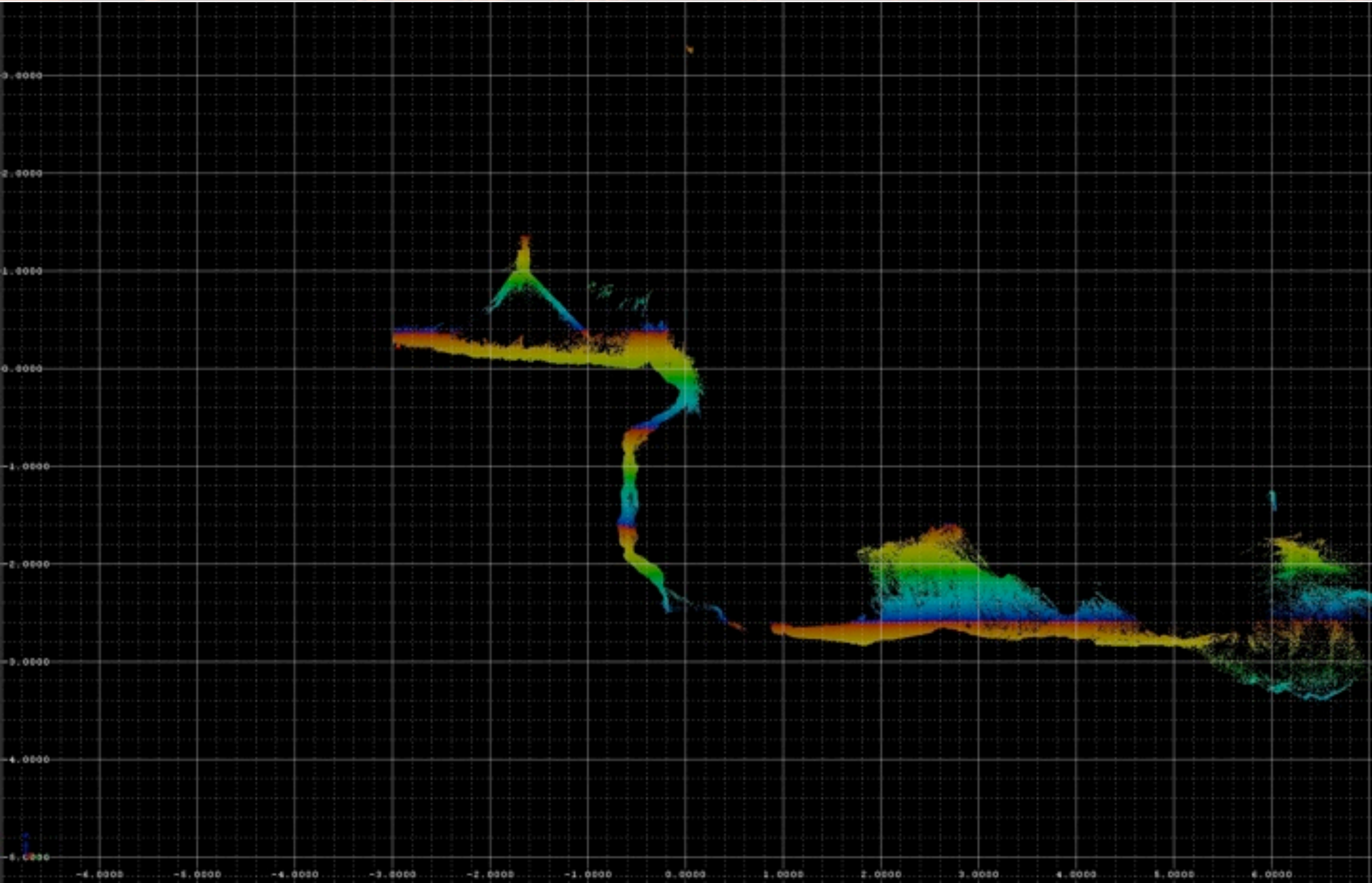


3D model by Gerald Bawden and Sandra Bond

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)

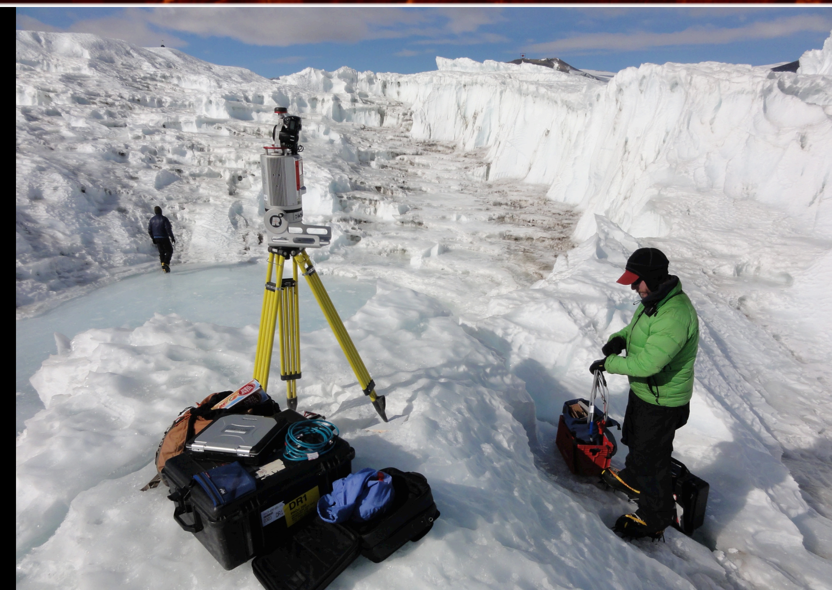


Four Mile Fire Erosion (Moody, Tucker)

UNAVCO

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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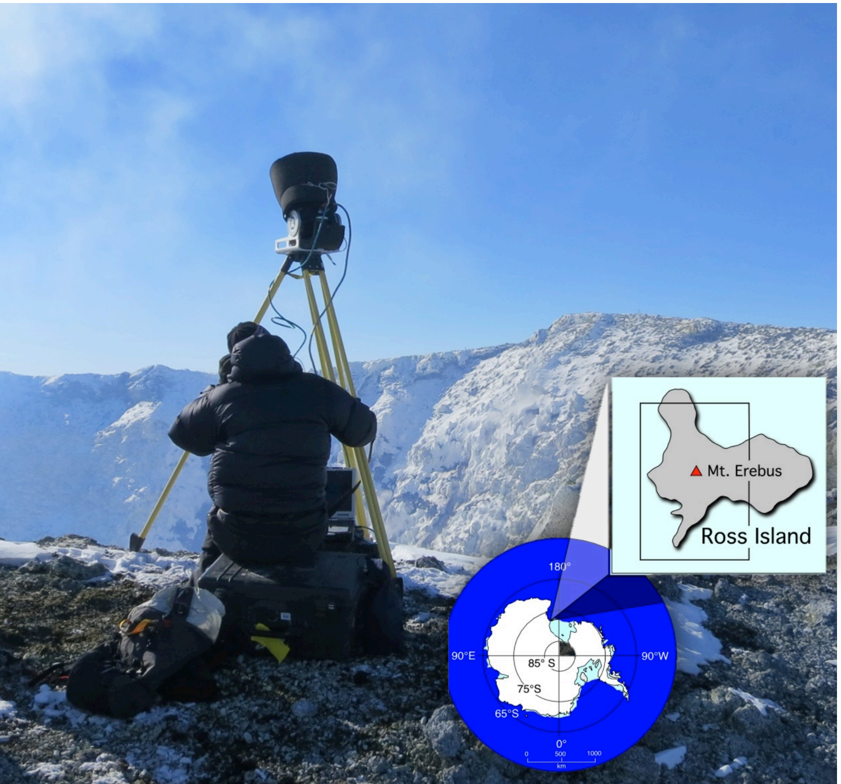
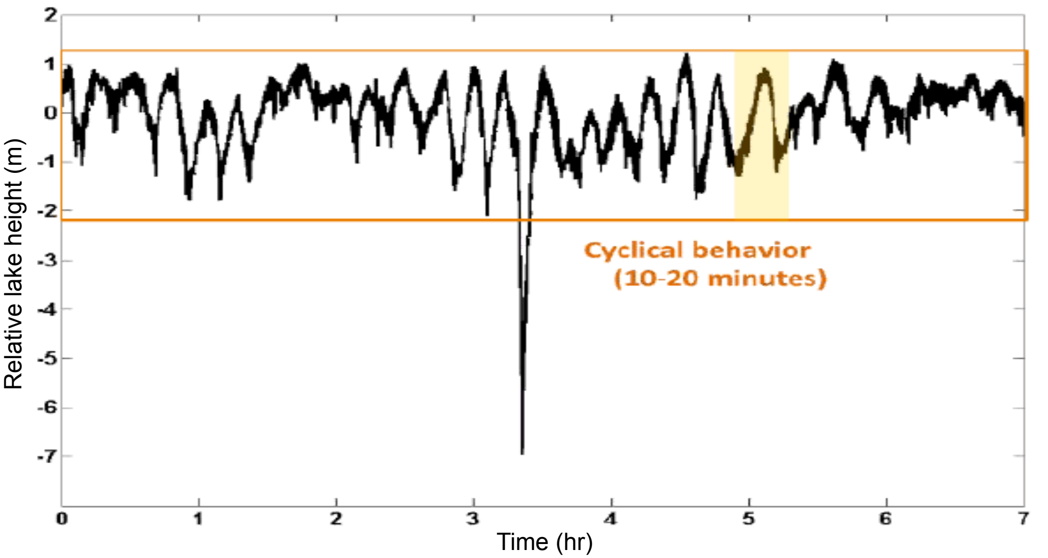
Scanning in Polar Environments: Mount Erebus, Antarctica

- **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**





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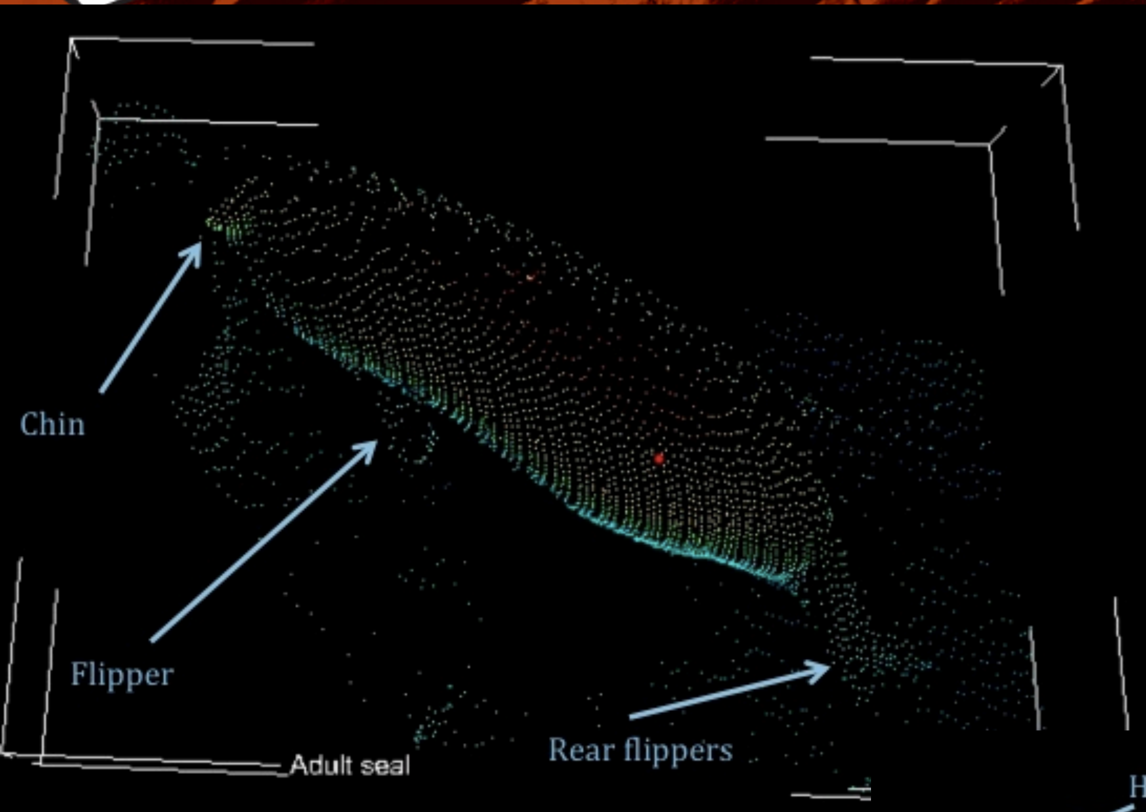
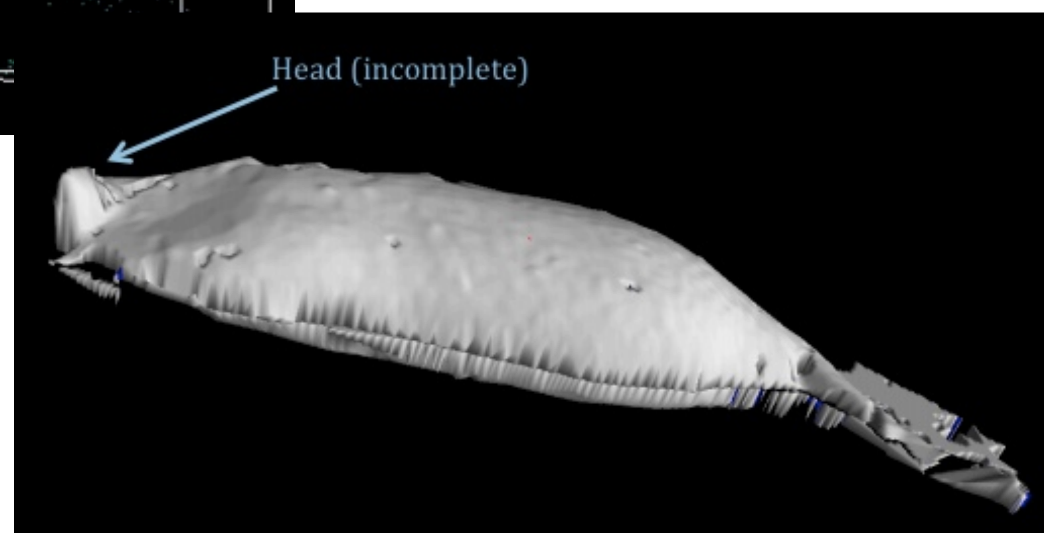
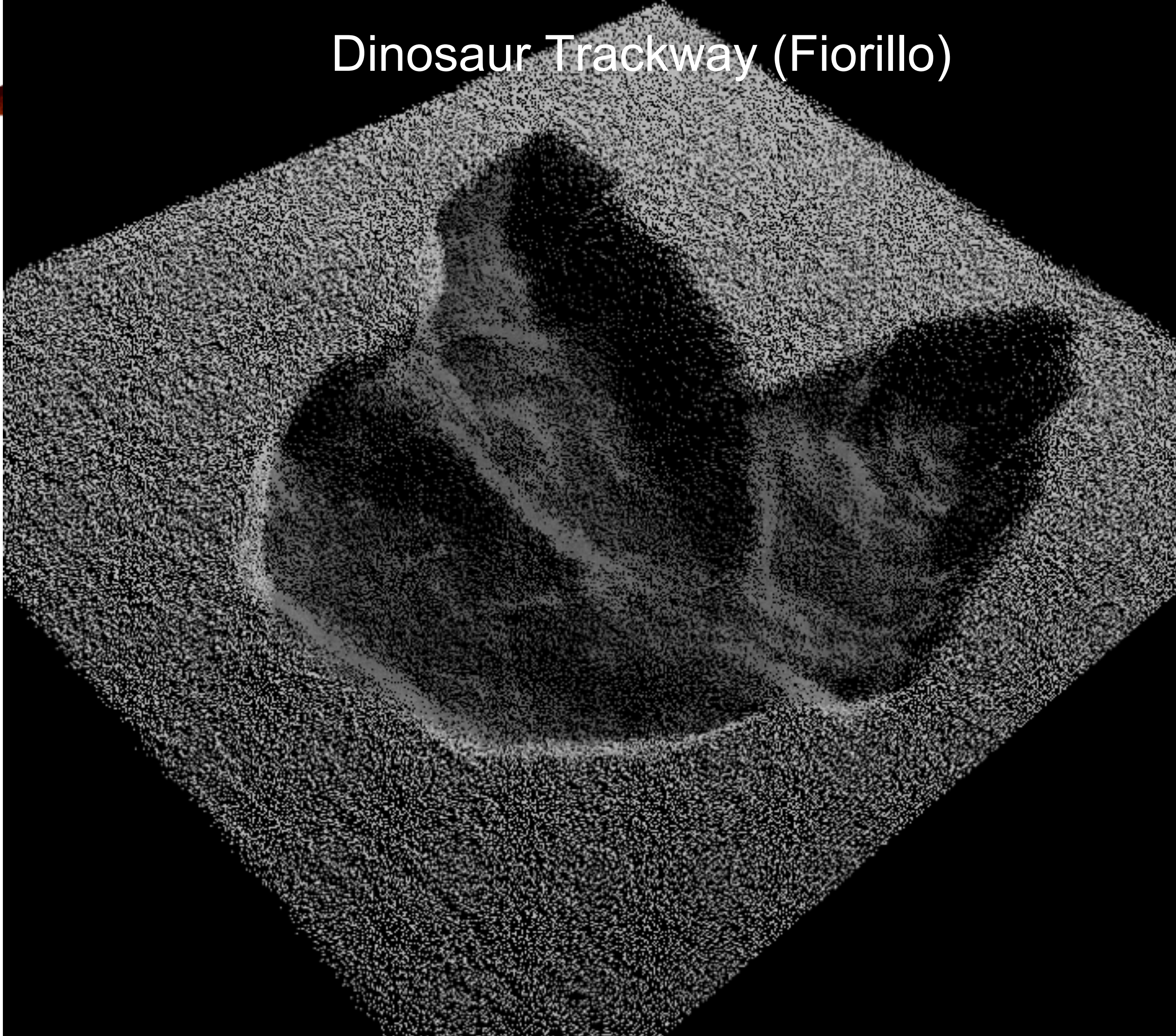
Using TLS to Obtain Volumetric Measurements of Weddell Seals in the McMurdo Sound

Seal body mass = proxy for availability of marine food resources

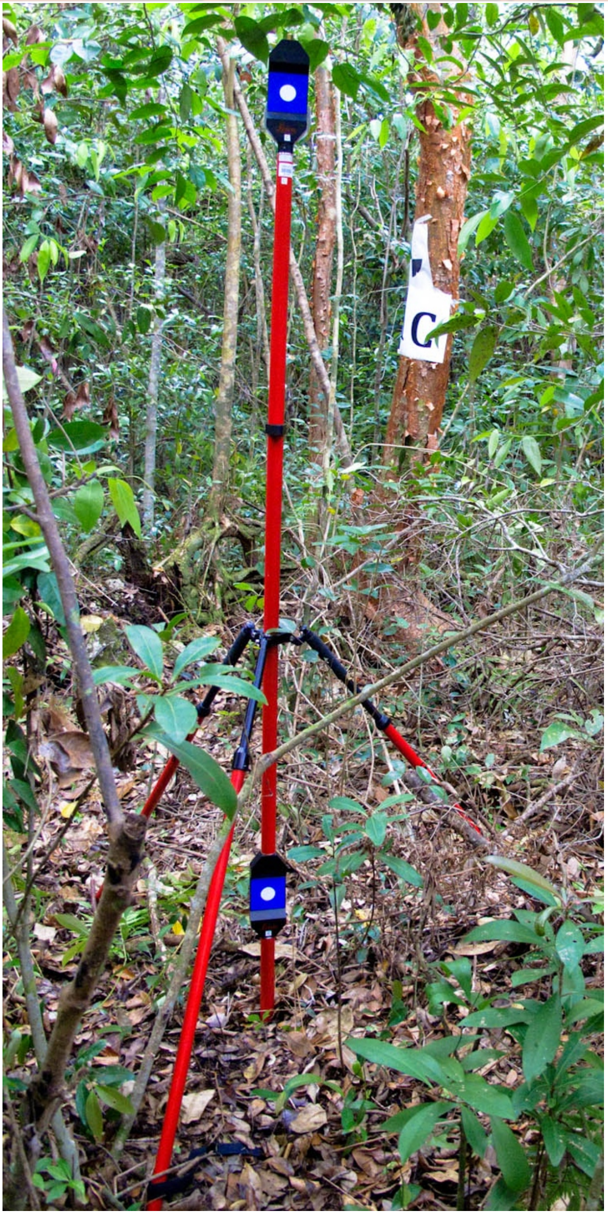




Dinosaur Trackway (Fiorillo)



Everglades Biomass (Wdowinski)



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

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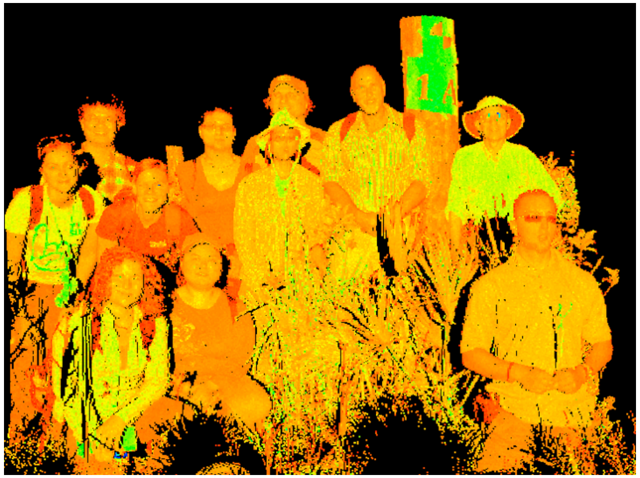
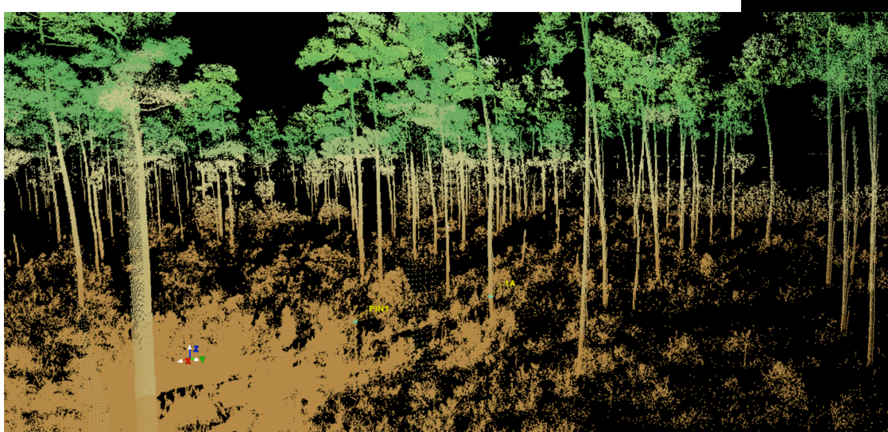
Everglades Biomass (Wdowinski)





Everglades Biomass (Wdowinski)

Thanks!

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http://unavco.org/tls