Intro to Lidar, Data Access, and Processing with OpenTopography

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AGIC - Wednesday, August 31, 2022

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Workshop Outline

https://opentopography.org/workshops/AGIC2022

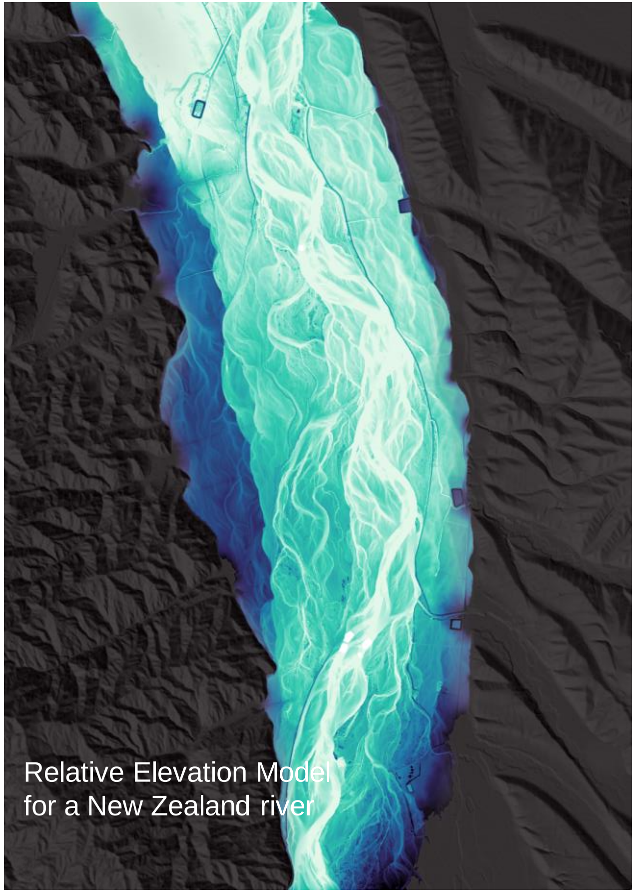
- Introductions (1:30-1:40): Where do you work? Experience with lidar? What do you want to learn today?
- Lecture: Intro to Lidar (1:40-2:10)
- Hands on – Point Clouds and raster processing on OpenTopography (2:10-2:35)
- Break (2:35-2:45)
- Lecture & Hands on: Topographic Differencing (2:45-3:45)
- Break (3:45-3:50)
- Lecture & Hands on: Extracting hydrologic information from DEMS (3:50-4:50)
- Questions/revisit topics of interest/General (4:50-5:00)

- What is OpenTopography?
- Lidar basics
- Data collection
- Deliverables: Point clouds and DEMs
- Making DEMs

What is OpenTopography?

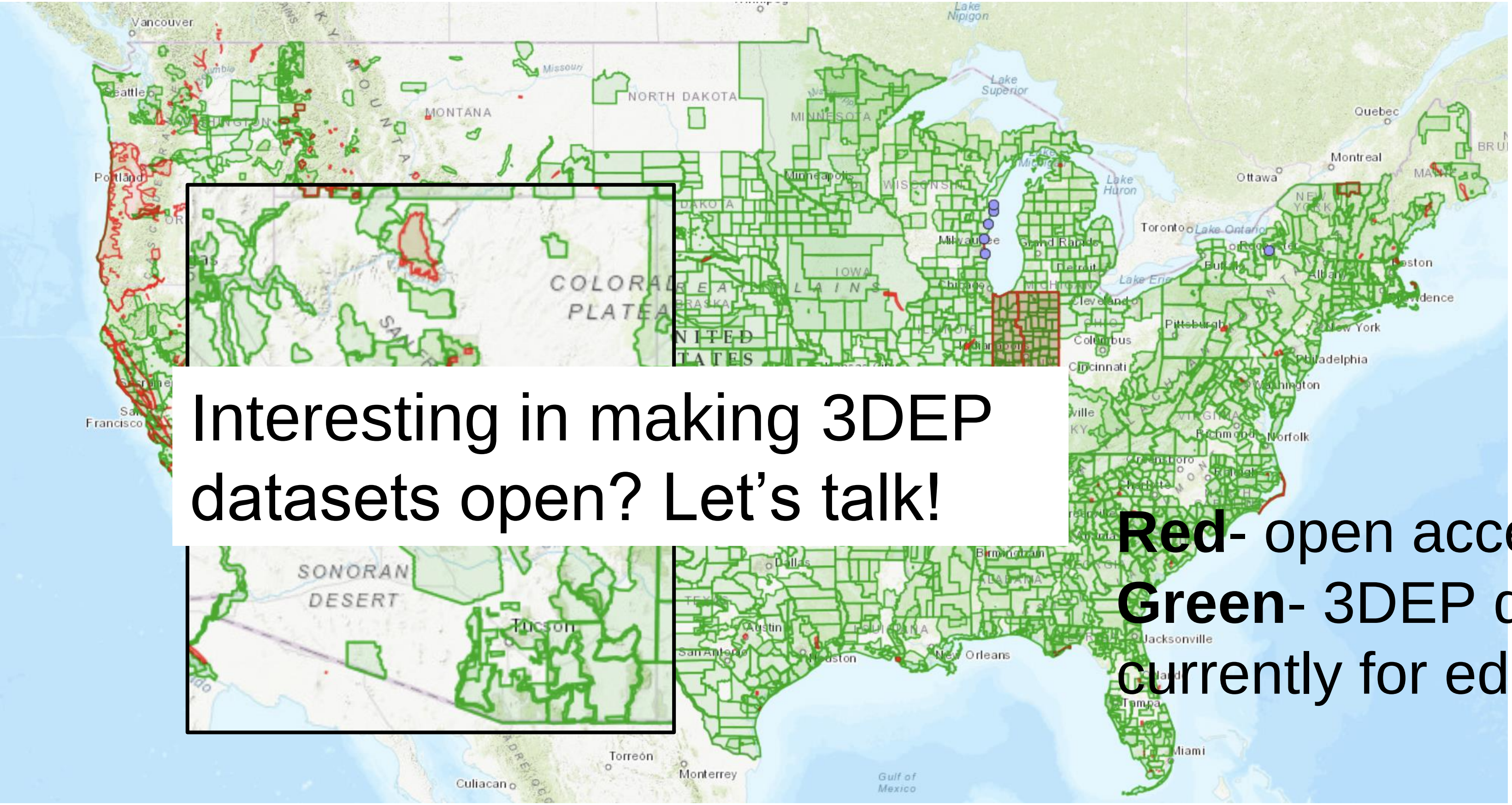
Access to topography data and processing tools via your web browser

- Lidar, photogrammetry & satellite data
- Tiered data access–raw point cloud to easy-to-use derived products
- On-demand processing tools accessed via a user-friendly interface
- Education: Online resources and short courses



Relative Elevation Model for a New Zealand river

Open access to high resolution topography and tools



Interesting in making 3DEP datasets open? Let’s talk!

Red- open access to all
Green- 3DEP data currently for educators

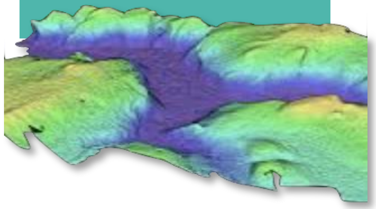
DATA SERVICES

TOPOGRAPHY DATA

PC Data Filtering & Subsetting

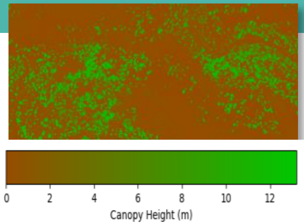
Raster Data Subsetting

3D Visualization

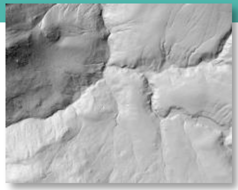


Digital Elevation Models
TIN / Local Gridding

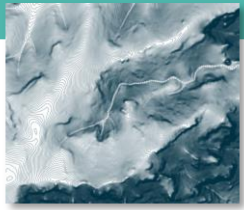
Canopy Height Model



Topographic Hillshades

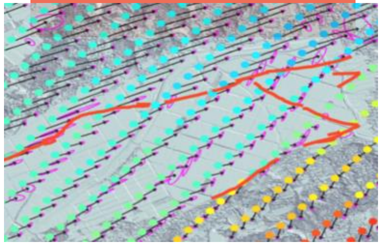


Contour Lines

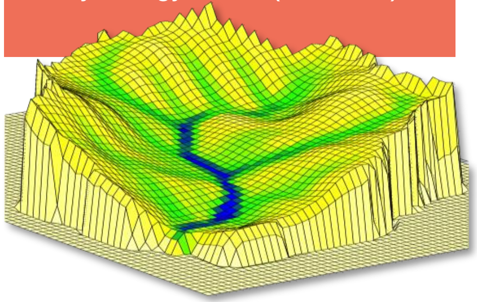


Vertical Differencing

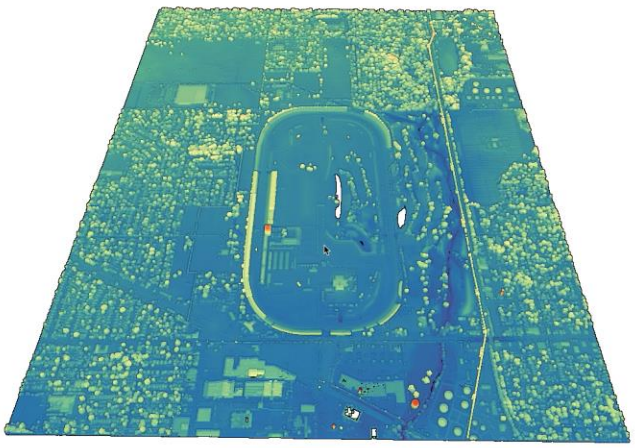
3D Differencing



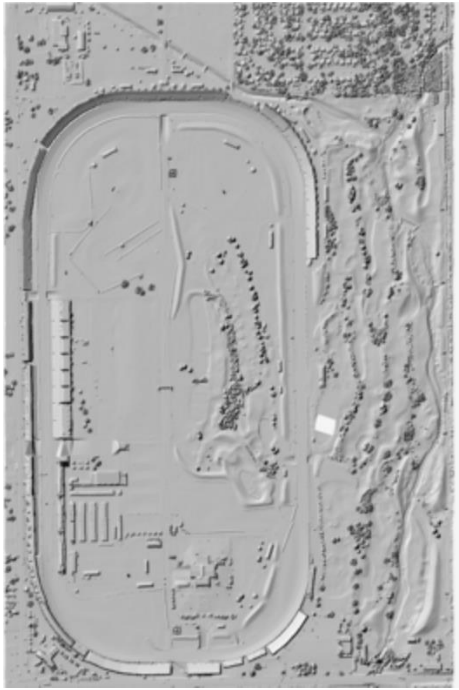
Hydrology Tools (TauDEM)



Indianapolis Motor Speedway



Point cloud *(LAS, LAZ, EPT, COPC)*



Raster: DEMs, hillshade, slope *(GTIFF, IMG, etc.)*

Vector: contours

Where does the processing happen?

SDSC SAN DIEGO SUPERCOMPUTER CENTER

Supercomputer resources are available to all users via a user-friendly in a web browser interface

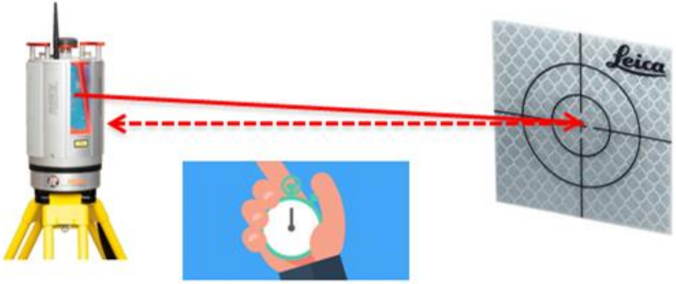
Light **D**etection **A**nd **R**anging

- Distance is calculated by measuring the two-way travel time of a laser pulse
- Need very accurate clocks

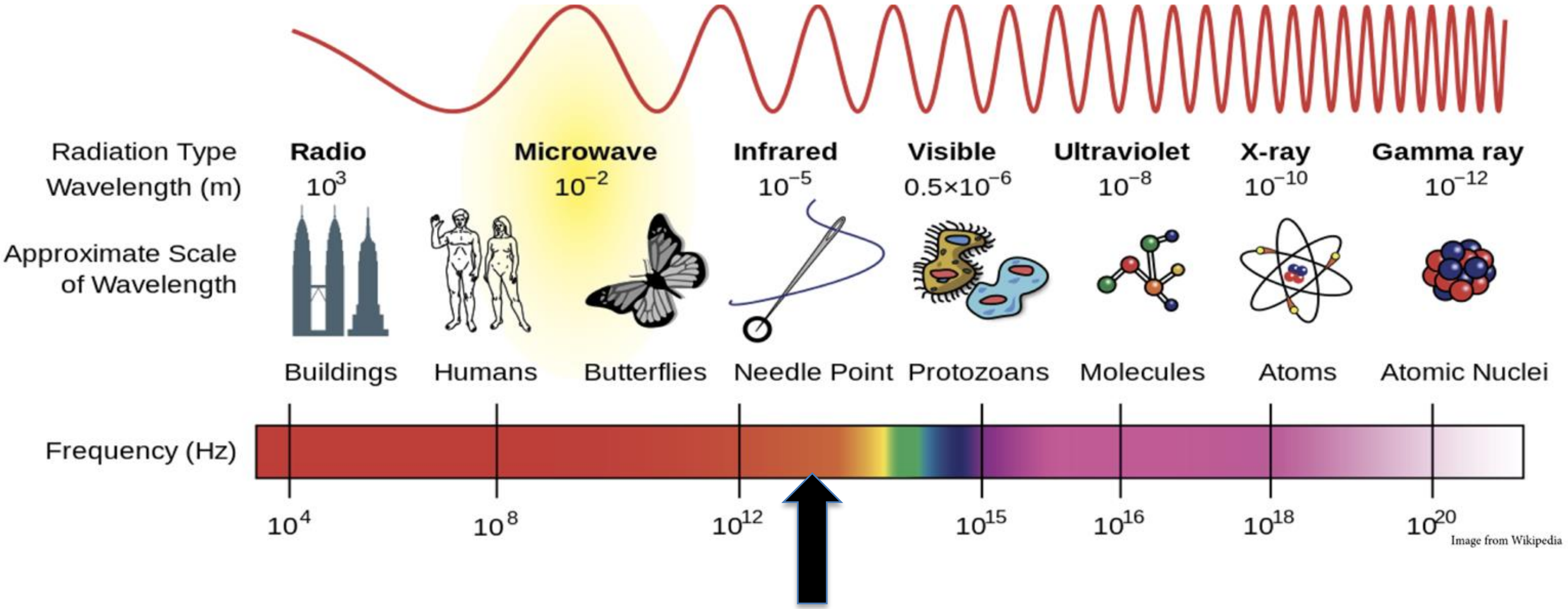
Time of flight

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

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



Lidar basics



Wavelength : ~905-1550 nm

Lidar – mostly near infrared

OpenTopography

Data collection

Various platforms:

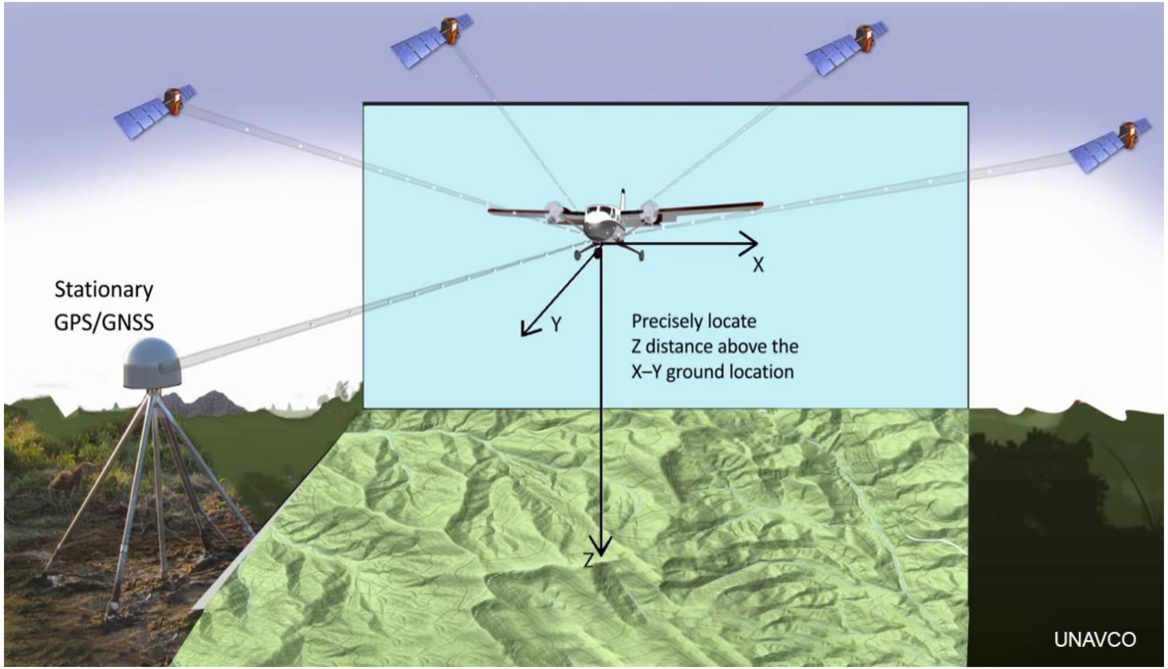
- Terrestrial
- Airborne: planes, helicopters, drones
- Mobile: cars
- Satellite
- Handheld devices, phones

Georeferenced elevation measurements:

Laser & Sensor

Inertial Measurement Unit (IMU): Accelerations and orientations

GPS/GNSS



Data collection

Idealized Scenario:

- Nadir pulse (observations directly below sensor)
- Photons intersect vegetation
- Photons return to detector

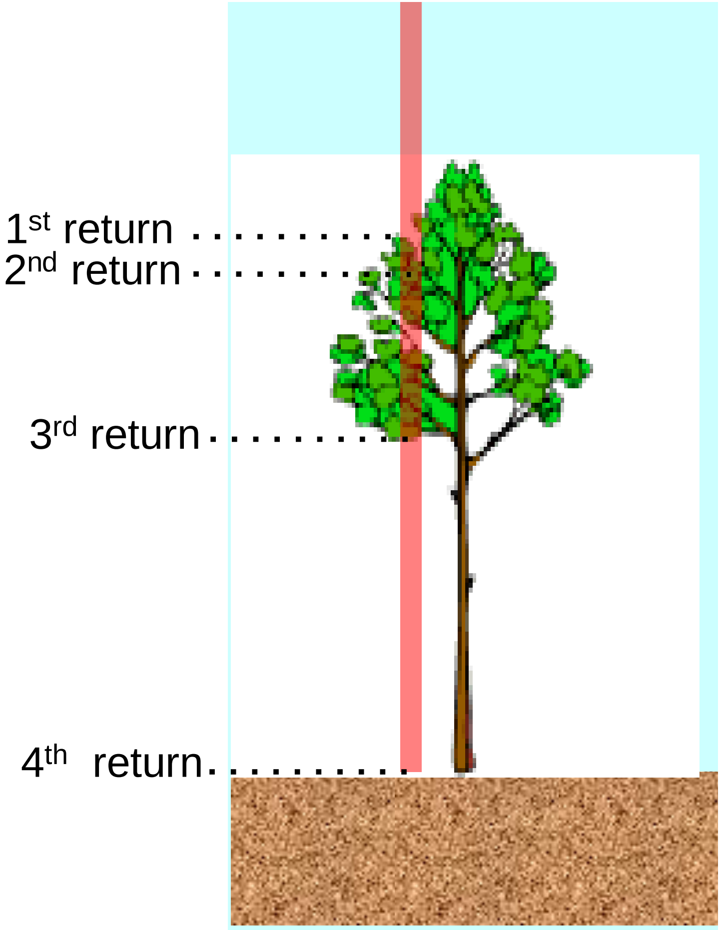
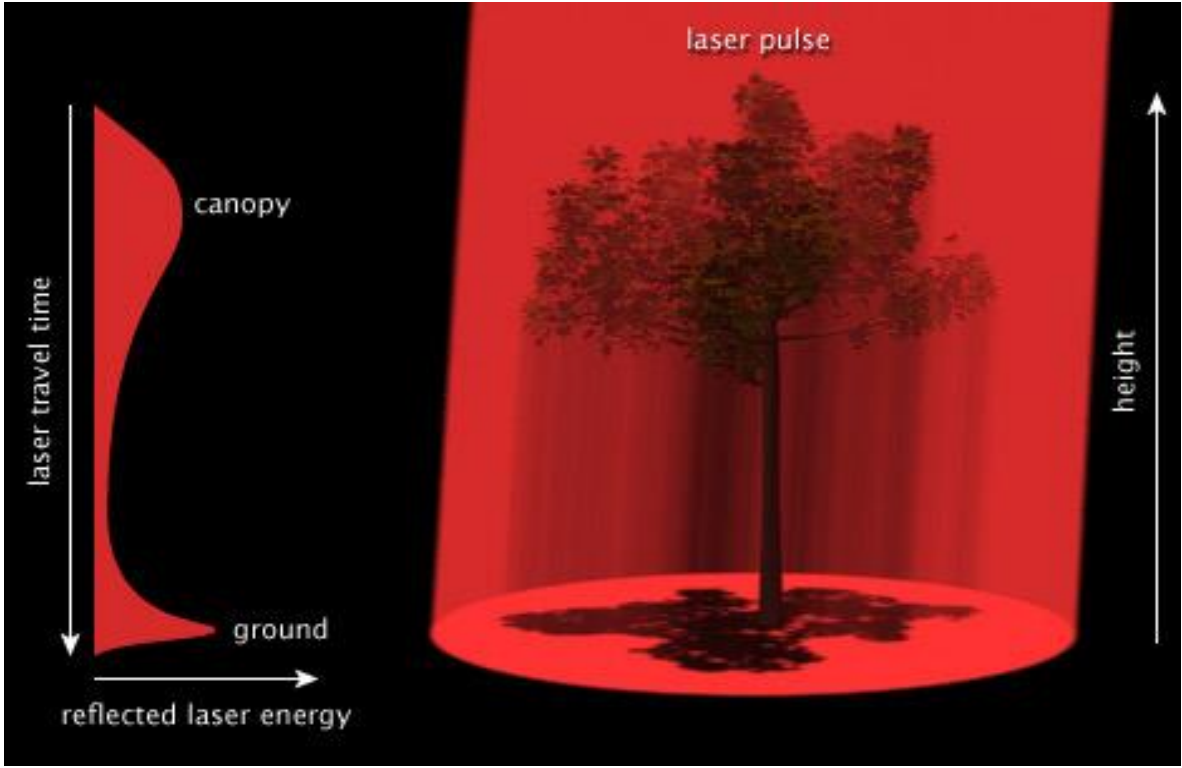


Image credit: Stoker/USGS

Realistic Scenario:

- “Flashlight” analogy with eye as sensor
- Laser is intense and coherent, but still diverges (increase in beam diameter)



Data collection

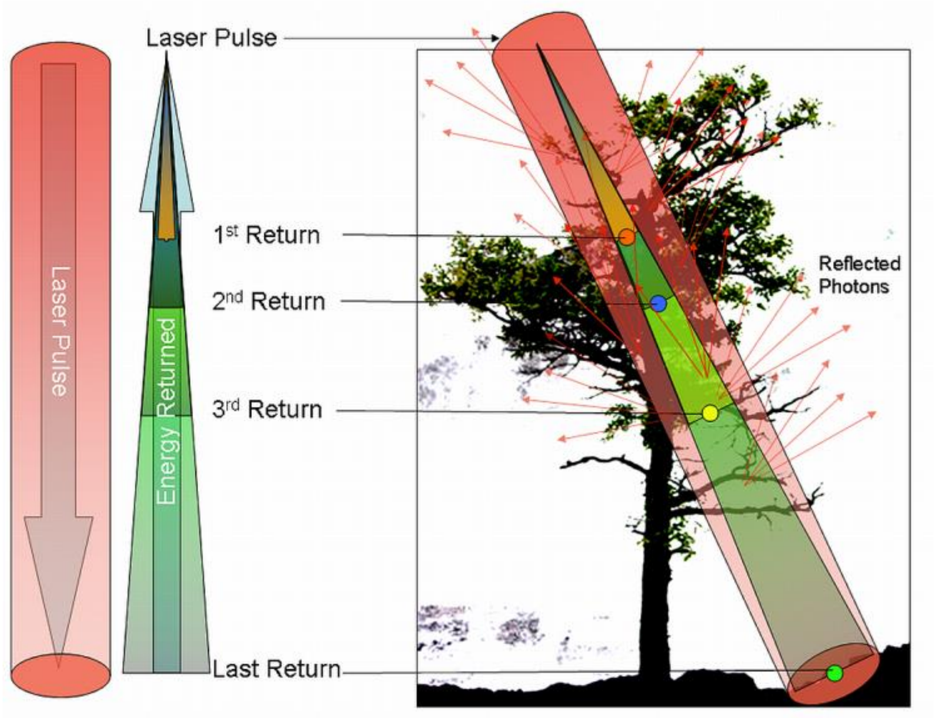
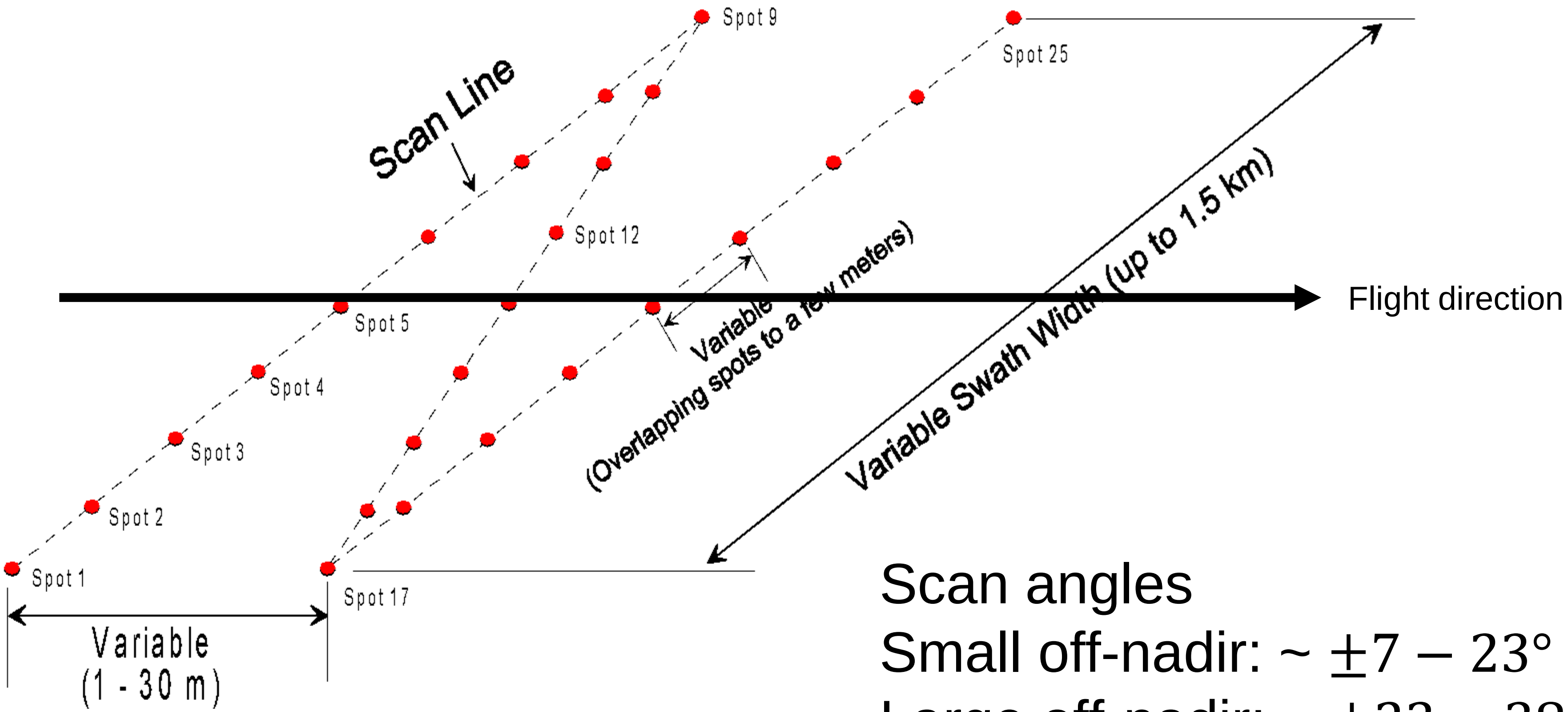


Image credit: Stoker/USGS

- Off-Nadir pulse
- Pulse spreading and energy loss as beam travels to the ground
- Scattering of light – most photons are reflected or absorbed and don't make it back to the detector.
- Some photons intersect vegetation and/or ground
- Some photons will return to detector
- Issues with water with both nadir and off nadir angles. Some roughness will help.

Flight lines and swaths



Scan angles

Small off-nadir: ~ $\pm 7 - 23°$

Large off-nadir: ~ $\pm 23 - 38°$

Not all lidar is created equal –range in quality, resolution, accuracy

Major source of uncertainty:
- Geolocation (GPS, IMU) uncertainty

Vegetation and terrain conditions also affect uncertainty

Evaluate lidar data quality by:
- Testing against ground control
- Quantifying swath to swath reproducibility

Read the metadata & survey report & expect errors

Data collection

QUALITY LEVEL	DATA SOURCE	VERTICAL ACCURACY RMSEz (cm)	NOMINAL PULSE SPACING (NPS) meters	NOMINAL PULSE SPACING (NPD) points per square meter	DIGITAL ELEVATION MODEL (DEM) cell size (meters)
QL0	**Lidar**	**5 cm**	**<= 0.35 m**	**>= 8 pts/square meter**	**0.5 m**
QL1	**Lidar**	**10 cm**	**<= 0.35 m**	**>= 8 pts/square meter**	**0.5 m**
QL2	**Lidar**	**10 cm**	**<= 0.71 m**	**>= 2 pts/square meter**	**1 m**
QL3	Lidar	20 cm	<= 0.35 m	>= 0.5 pts/square meter	2m
QL4	Imagery	139 cm	N/A	N/A	5 m
QL5	IfSAR	185 cm	N/A	N/A	5 m

NPS: Spacing between first-return points a in single swath
NPD: Nominal pulse density: Typically, the number of first-return pulses per swath
Aggregate NPD: Total pulse density from multiple passes

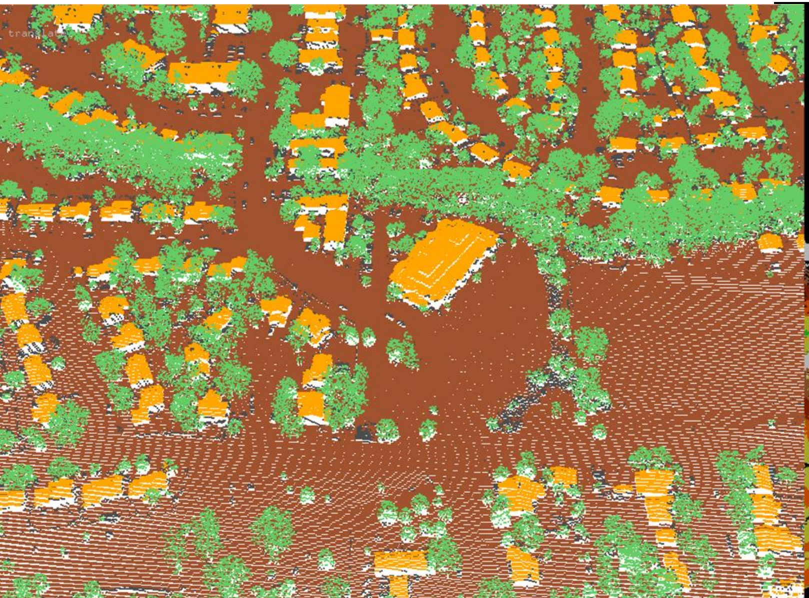
OpenTopography

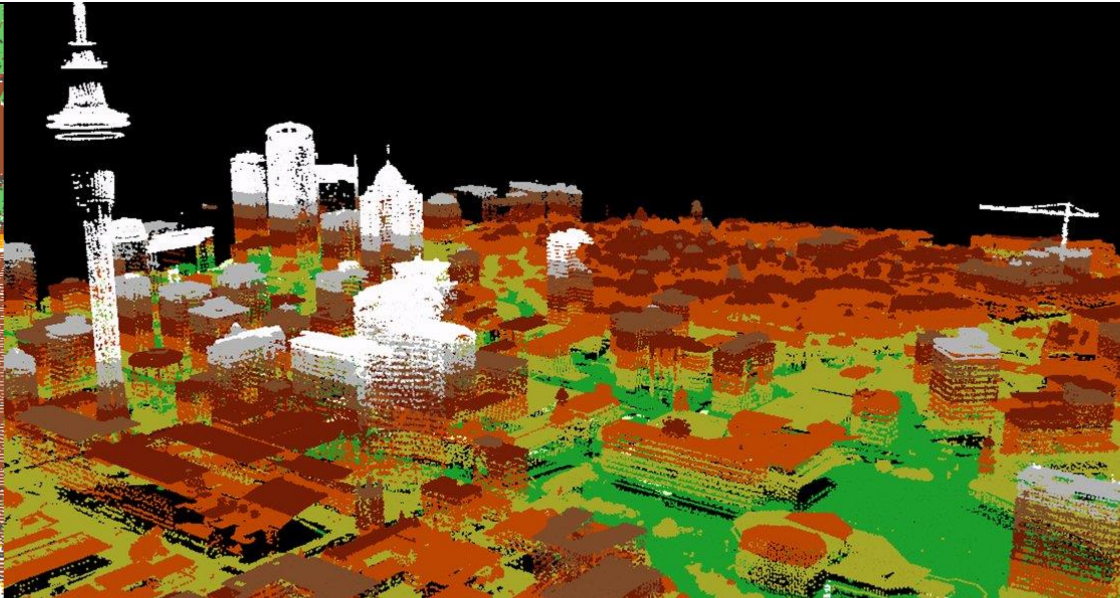
Deliverables

Point cloud- discrete x,y,z points with attributes

Attributes

- Classification: Ground, vegetation, buildings, water, blunders etc.
- Intensity, return number & number of returns, GPS time, RGB…
- LAS, or compressed as a LAZ





Point Clouds Classifications

Code	Description
1	Processed, but unclassified
2	Bare earth
7	Low noise
9	Water
17	Bridge deck
18	High noise
20	Ignored ground (*typically breakline proximity*)
21	Snow (*if present and identifiable*)
22	Temporal exclusion (*typically nonfavored data in intertidal zones*)

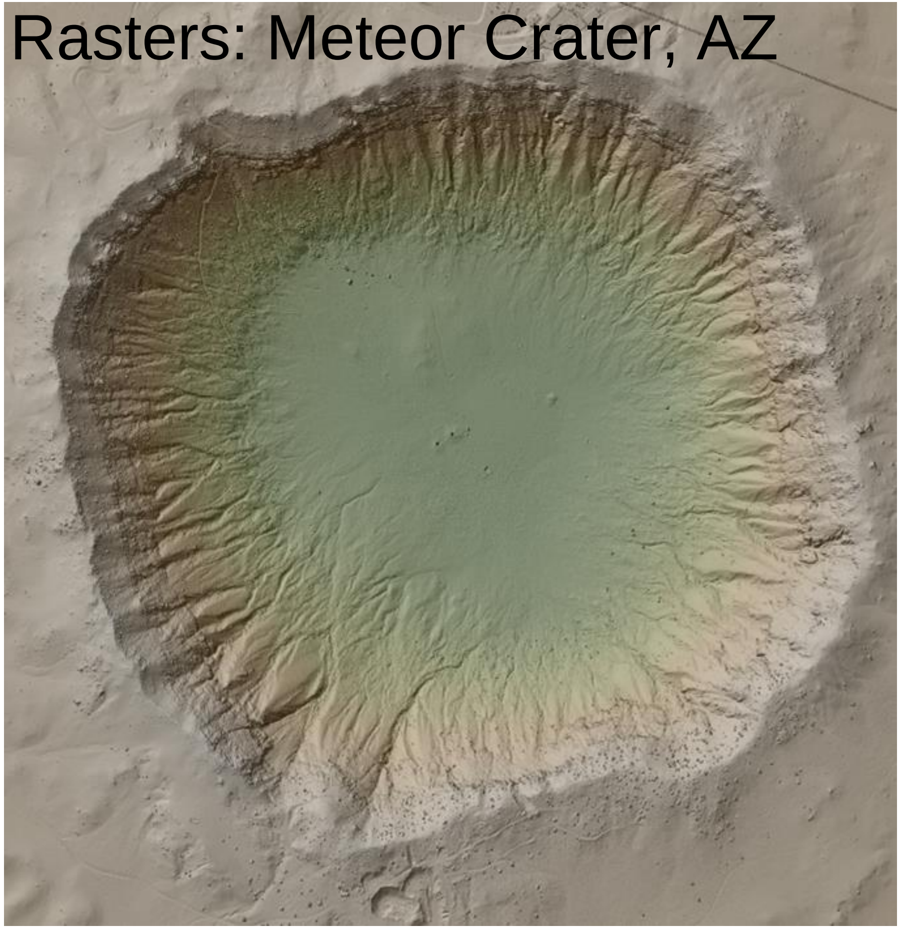
USGS classifications are based on the ASPRS standards

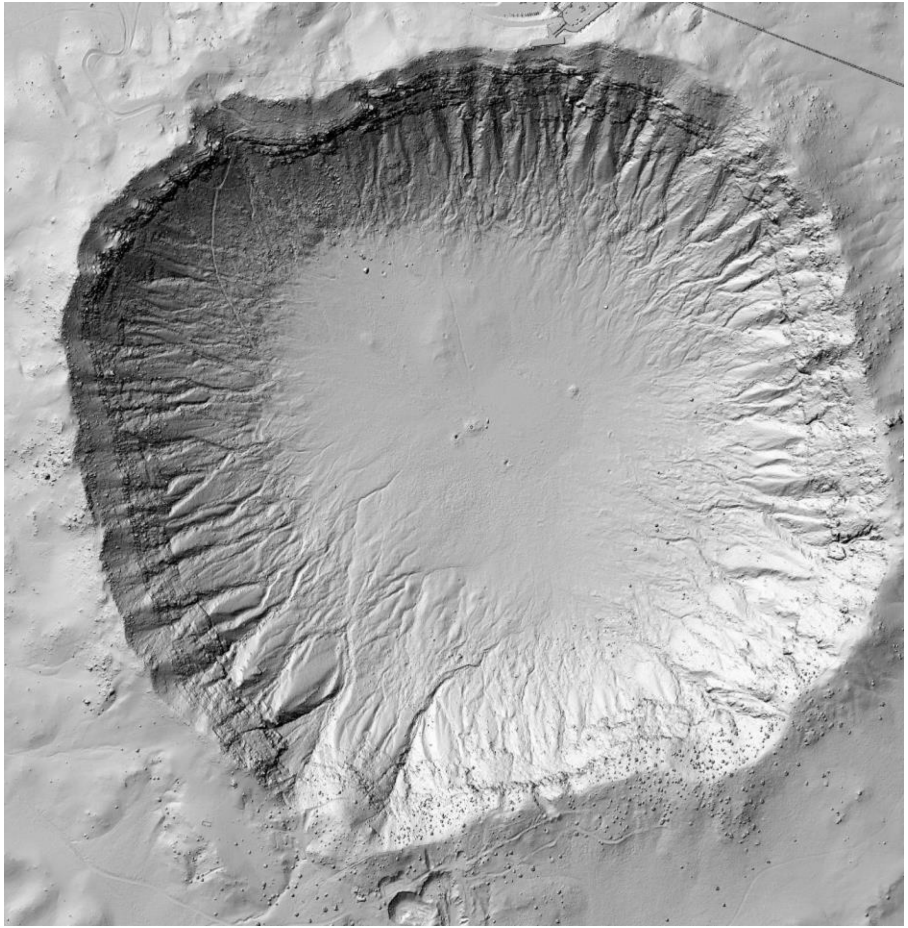
THE IMAGING & GEOSPATIAL INFORMATION SOCIETY

OpenTopography

Deliverables

Rasters: Meteor Crater, AZ





Deliverables

Raster-> Digital Elevation Models

Digital representation of topography

- A grid of squares or “pixels”
- Continuous surface where Z (elevation) is estimated on a regular X,Y grid
- Not True 3D - “2.5D”

Grid resolution is defined by the pixel size in the horizontal dimension

- 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	150	200	200	200	200	200	200	200	200	200	150	100	50	0
0	50	100	150	200	250	250	250	250	250	250	250	200	150	100	50	0
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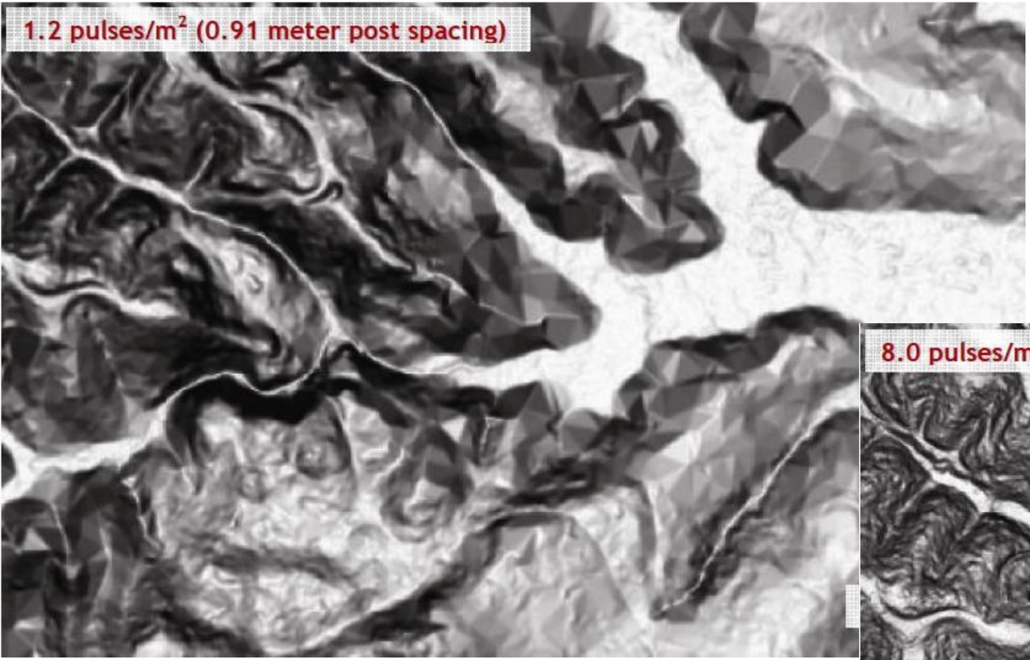
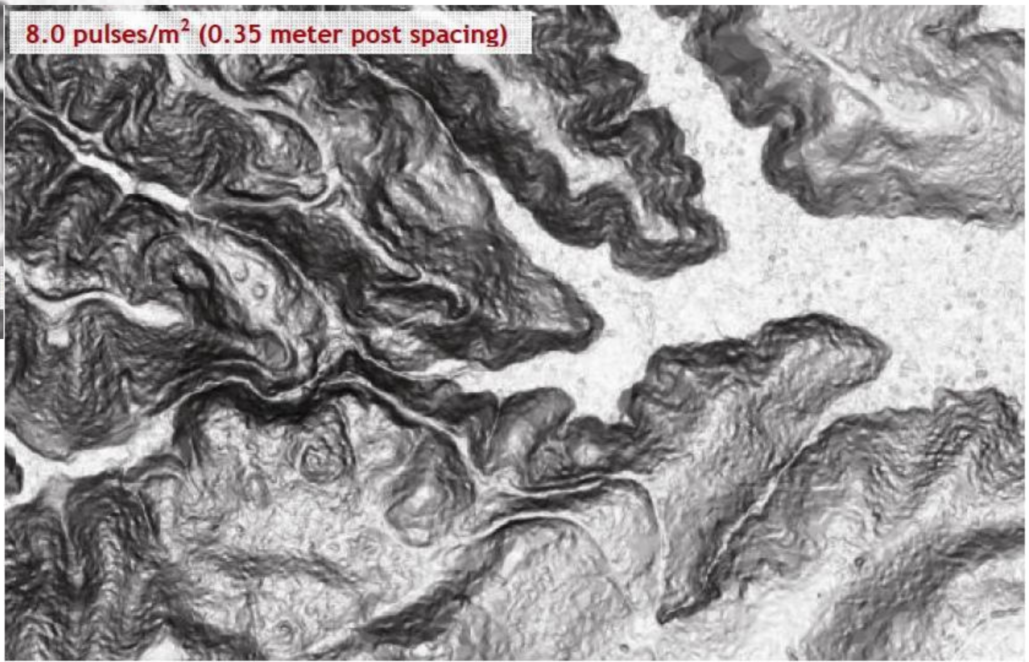
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html

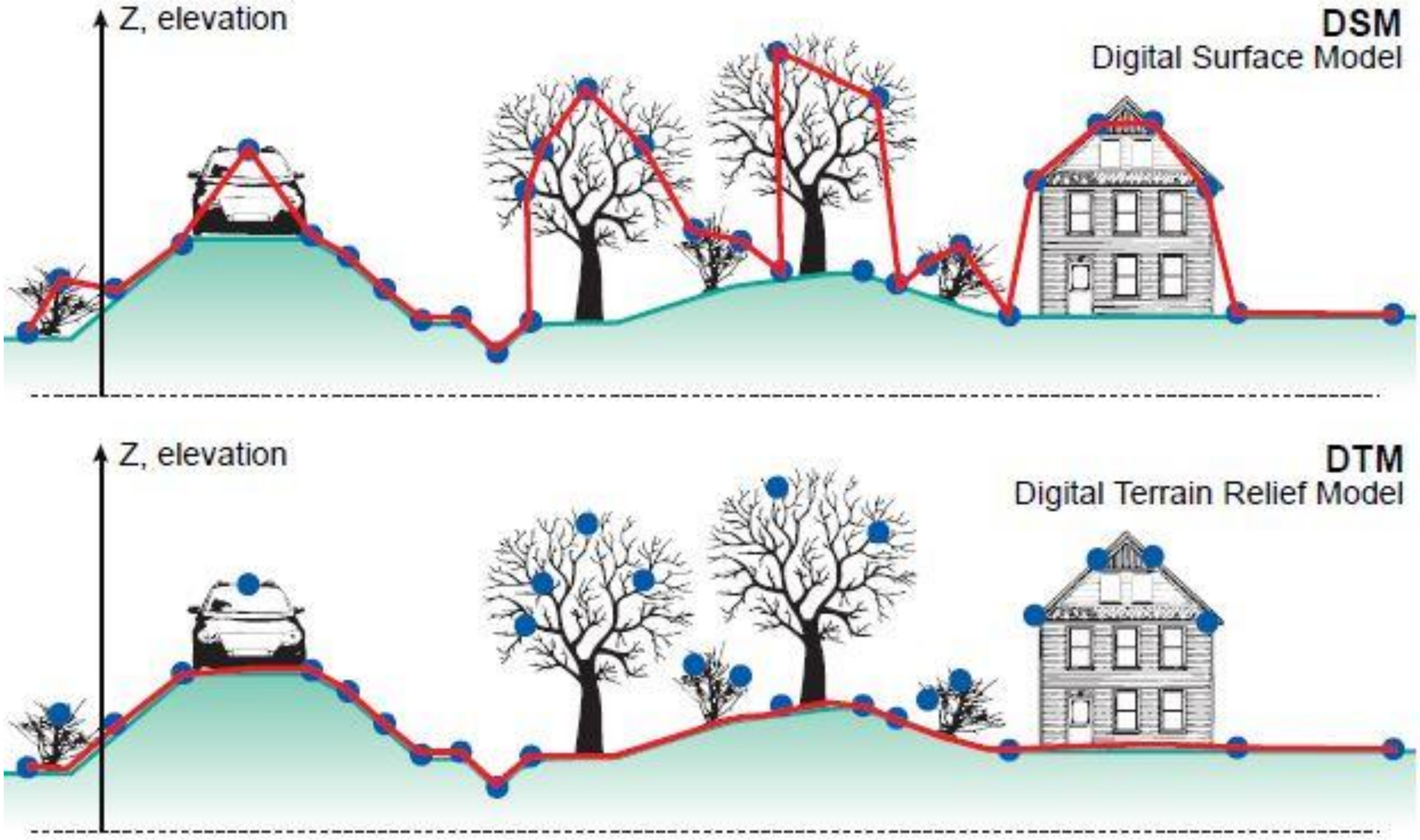
Pulse spacing impacts raster quality





Minimum LiDAR Considerations in the Pacific Northwest
Watershed Sciences, Inc.
http://www.oregongeology.org/sub/projects/olc/minimum-lidar-data-density.pdf

Deliverables



“highest hit”

“bare earth”

Image credit: charim.net

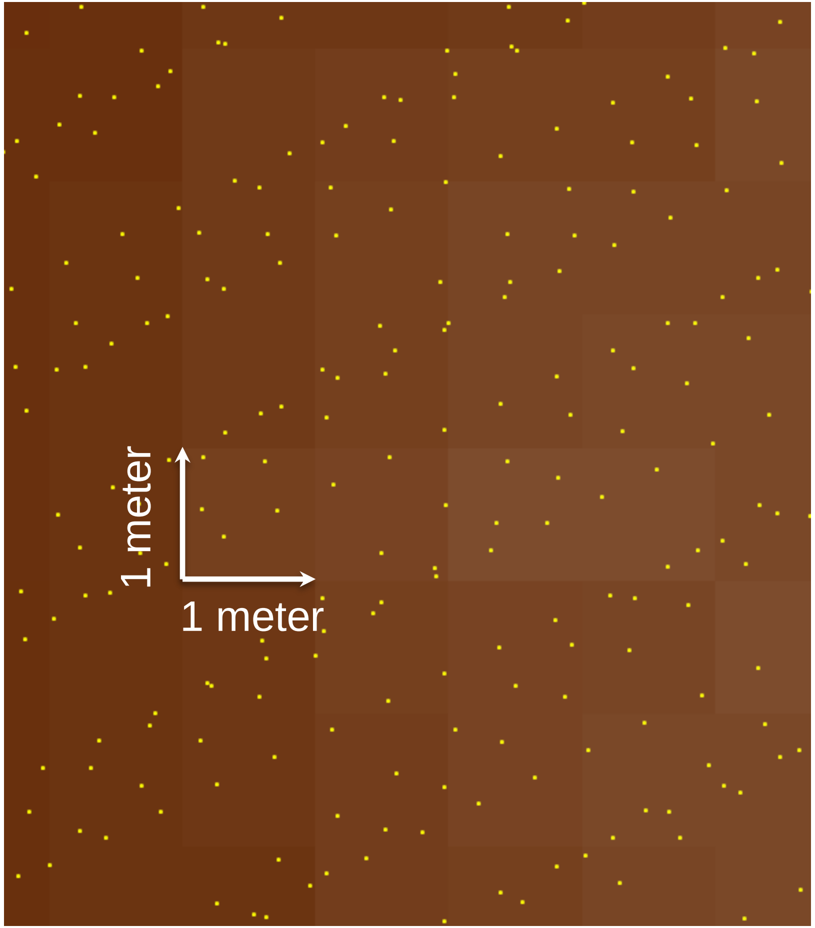
Make a DEM from a point cloud

Typically desire a 1 meter grid

Example from flat area with little or no vegetation so ground is sampled approx. 5+ times per square meter

How do we best fit a continuous surface to these points?

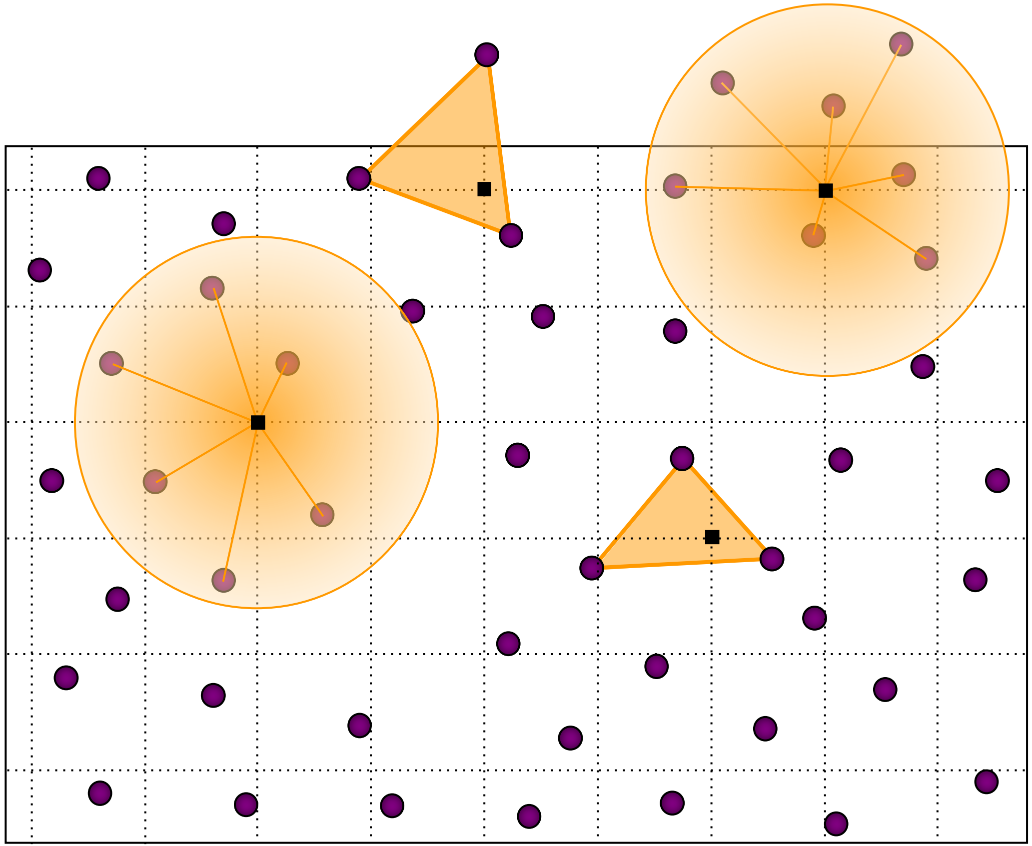
Ultimately wish to represent irregularly sampled data on a regularized grid.



Deliverables

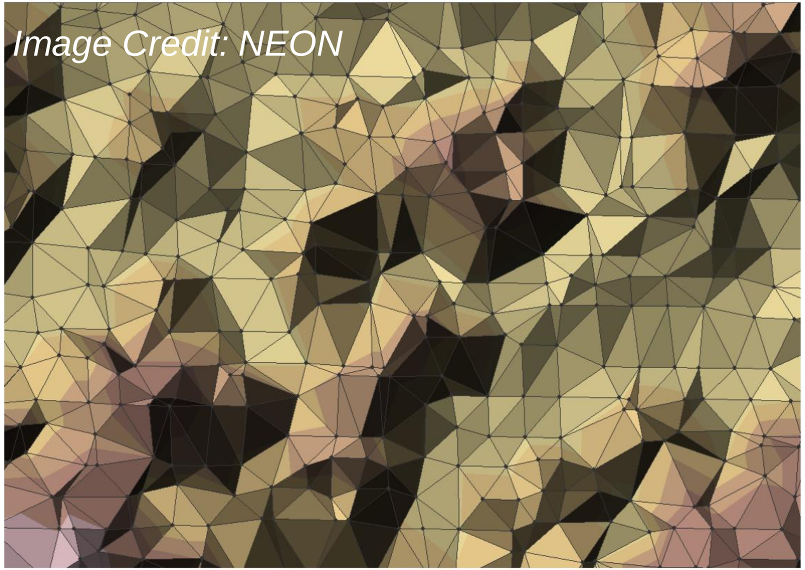
Rasters: Interpolation Methods

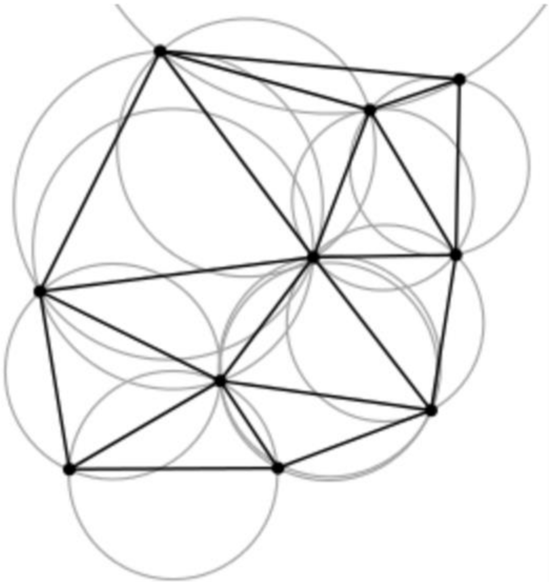
- Inverse Distance Weighting (IDW)
- Natural Neighbors
- Nearest Neighbor
- Kriging
- Splines
- Triangular irregular network



Isenburg, et al., 2006

Triangulated Irregular Network





TINs:

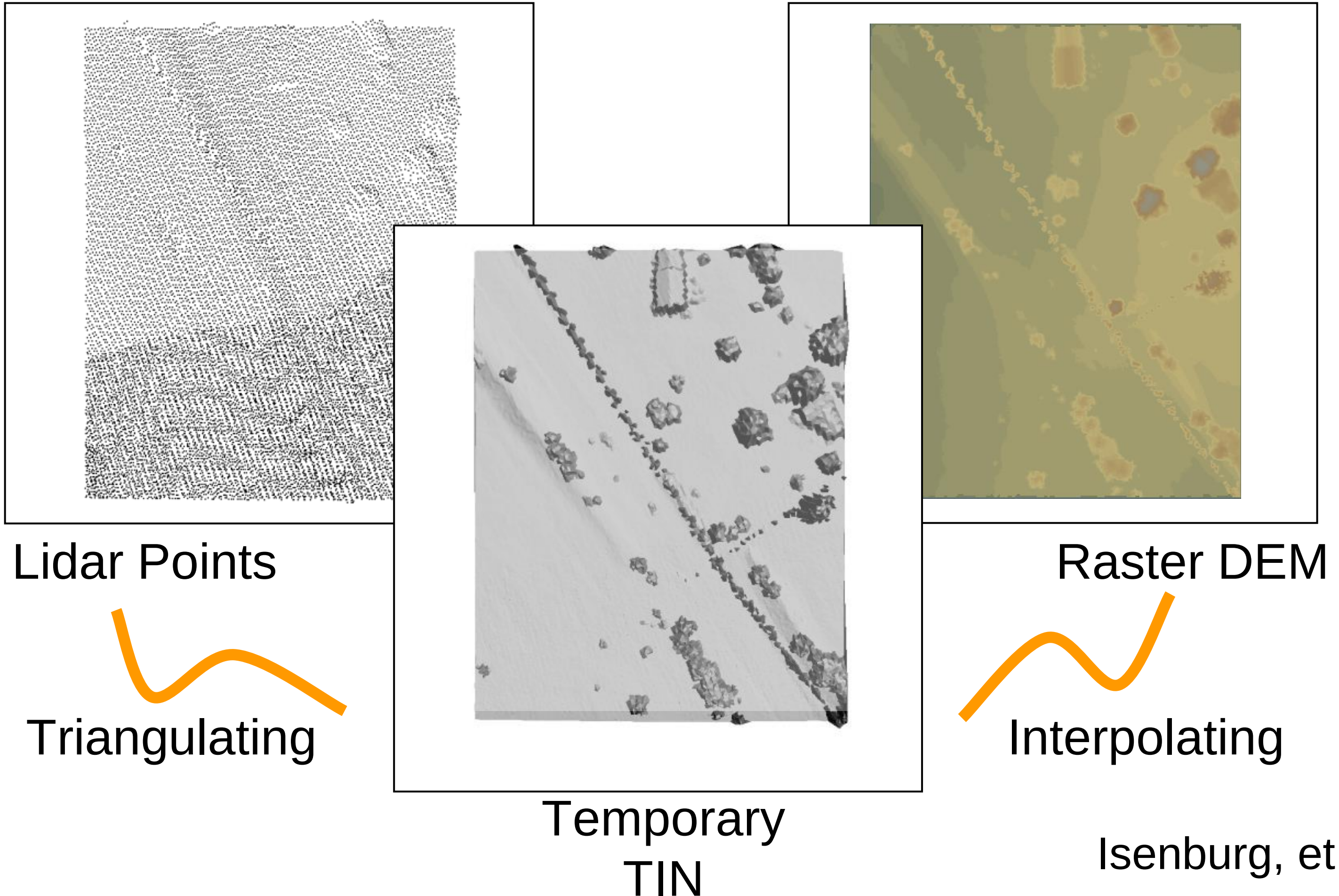
Vector format of a surface

Triangle network from Delauney Triangulation: no long thin triangles

No vertex lies within the interior of any of the triangles in the network

Features such as mountain peaks – TIN nodes

Deliverables



Isenburg, et al., 2006

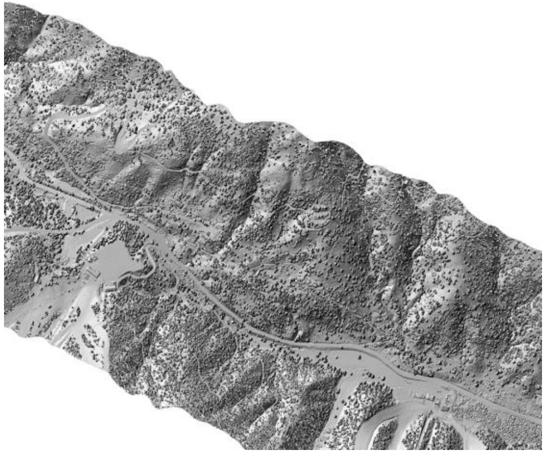
Deliverables

Gridding

Z_{max}

Z_{min}

Z_{mean}



Z_{idw}

Inverse distance

weighting

Deliverables

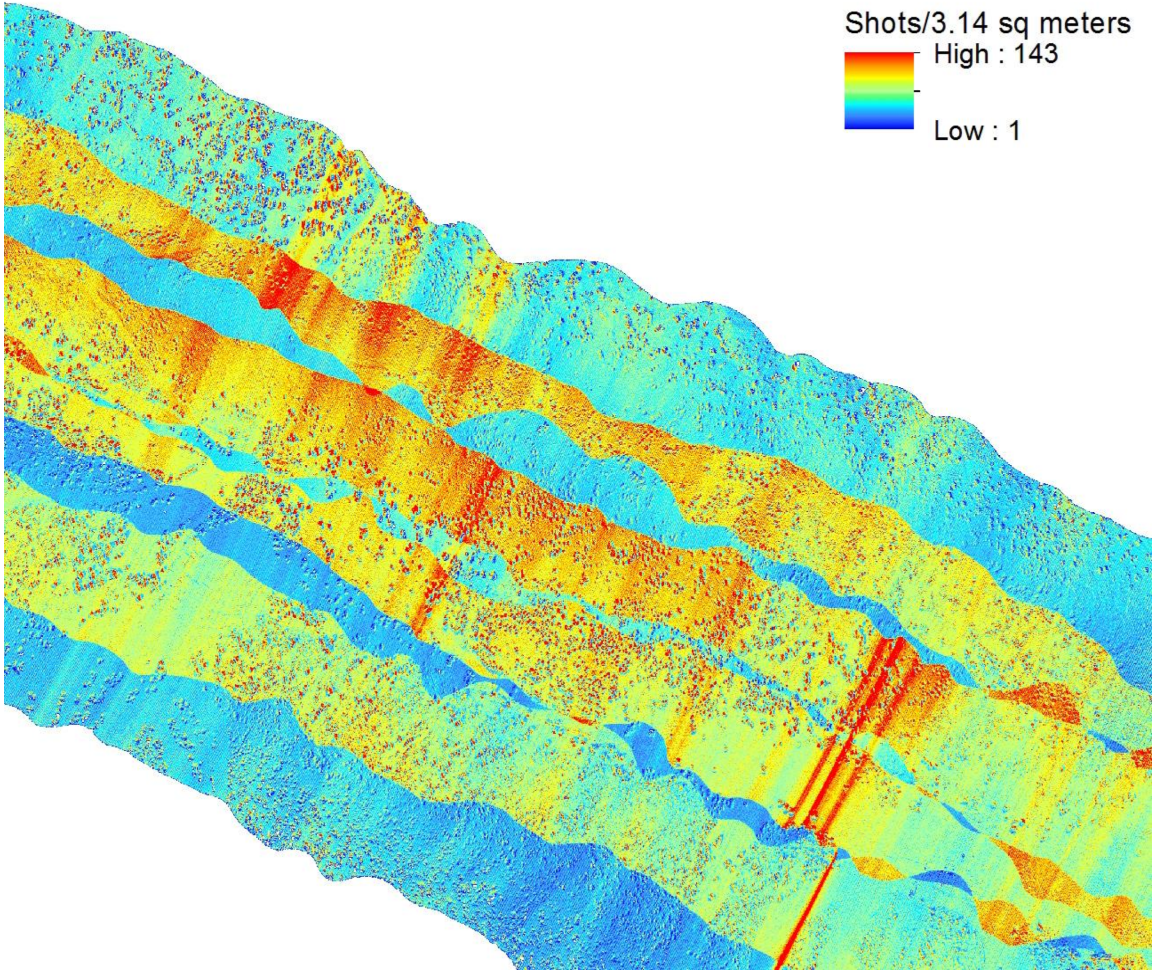
$Z_{density}$

Why?

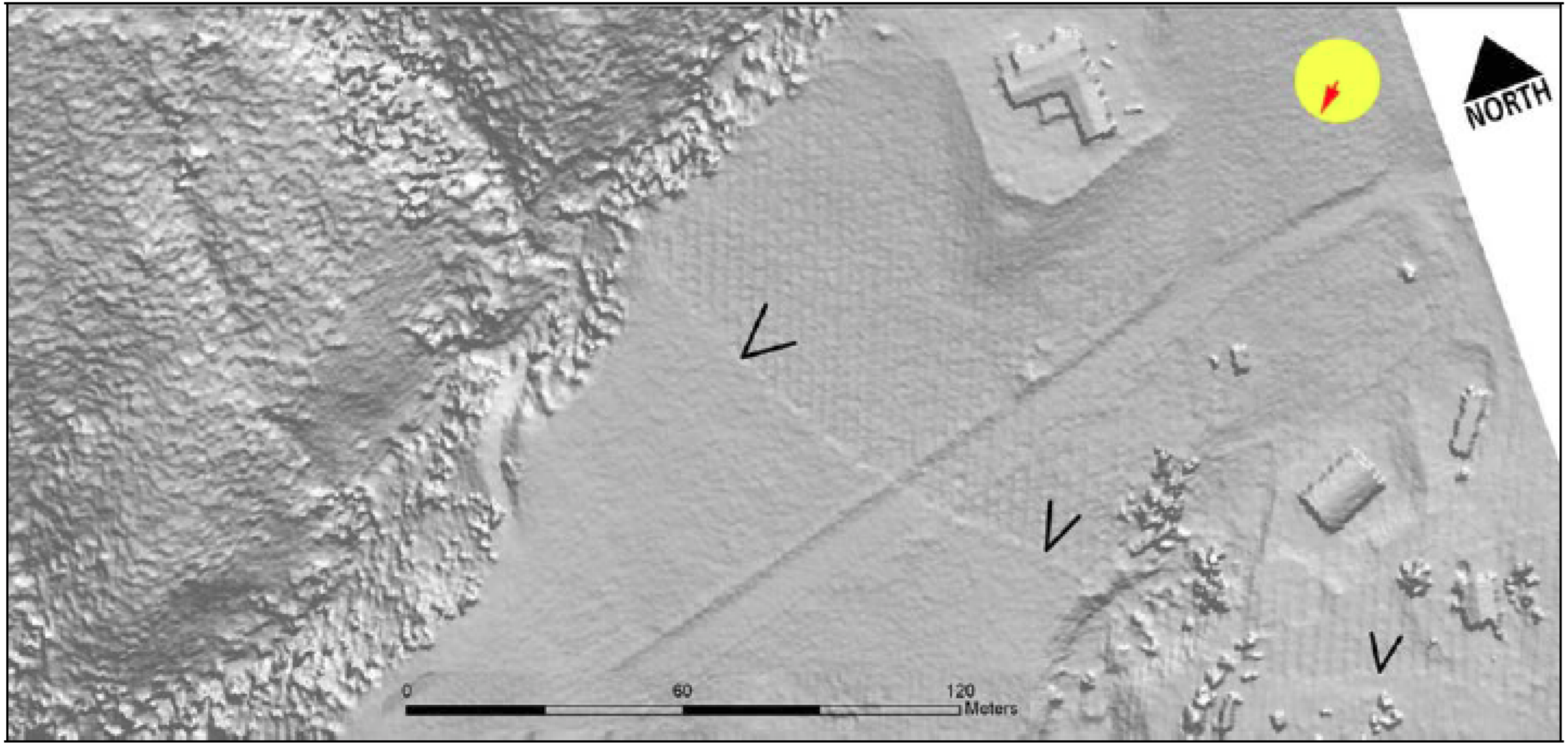
Flight direction

Swath overlap

Errors in the data?



Deliverables



Treiman, Perez, & Bryant, 2010, USGS Award No. 08HQGR0096 Final Tech. Report

Figure 7a. LiDAR artifact (arrows) in the Yucaipa study area. The artifact appears as a linear highlight suggestive of an east-facing scarp. However, the evident “corduroy” texture on one side versus the other alerts one to the likelihood that this is an artifact. Indeed, it corresponds to the overlap margin between LiDAR swaths.

THANKS!

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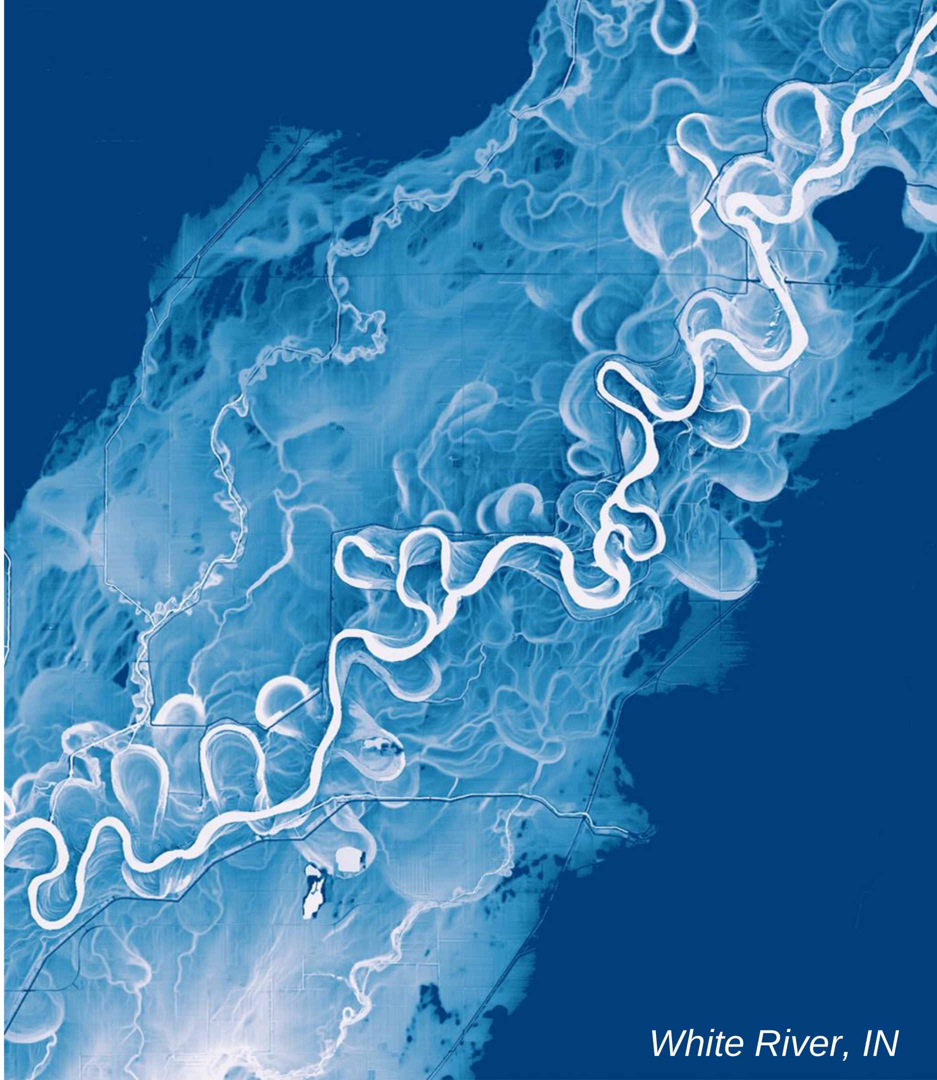
info@opentopography.org



Demo: Process a point cloud & raster dataset

Explore 3D viz already created

PLEASE: Process small datasets during the class today (at most 25 million points). 25+ jobs all started at the same time will take awhile to process. After the class, feel free to process larger datasets.