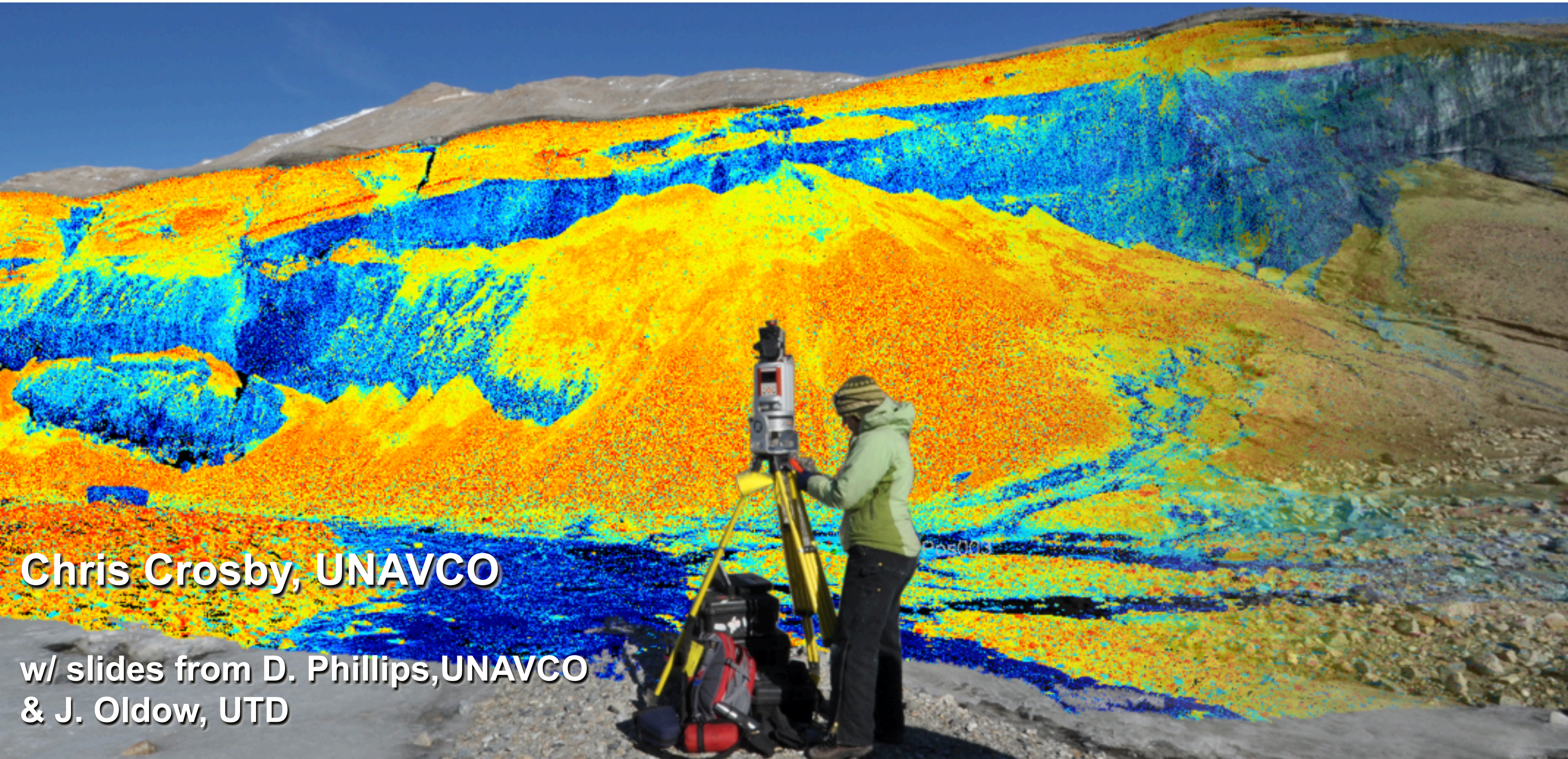
TLS Data Products & Analysis



Chris Crosby, UNAVCO

w/ slides from D. Phillips,UNAVCO
& J. Oldow, UTD

The problem…

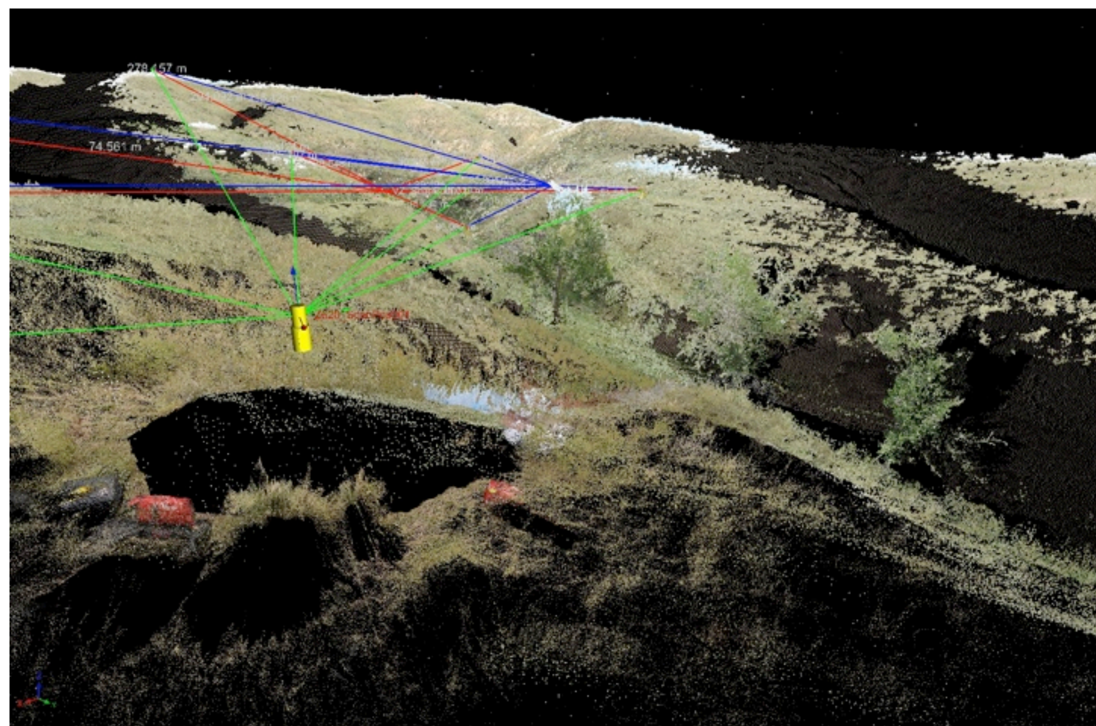
Data volume – multi-GB per day of scanning

Scanner technology far outpaces most software available for data processing, management, and analysis.

Complex, multi-software workflows

Commercial ($$) software

How do you get from 10s or 100s of millions of X,Y,Z points to science?



TLS Processing Workflow – Software

9. What software do you use to process and/or analyze TLS data? Choose all that apply.

	Response Percent	Response Count
PolyWorks	29.9%	23
Cyclone	19.5%	15
Riscan	35.1%	27
TerraSolid	13.0%	10
Arc/GIS	**61.0%**	**47**
QT Modeler	18.2%	14
Matlab	32.5%	25
Other (specify)	28.6%	22
	Other (please specify)	32

TLS Processing Workflow – Software

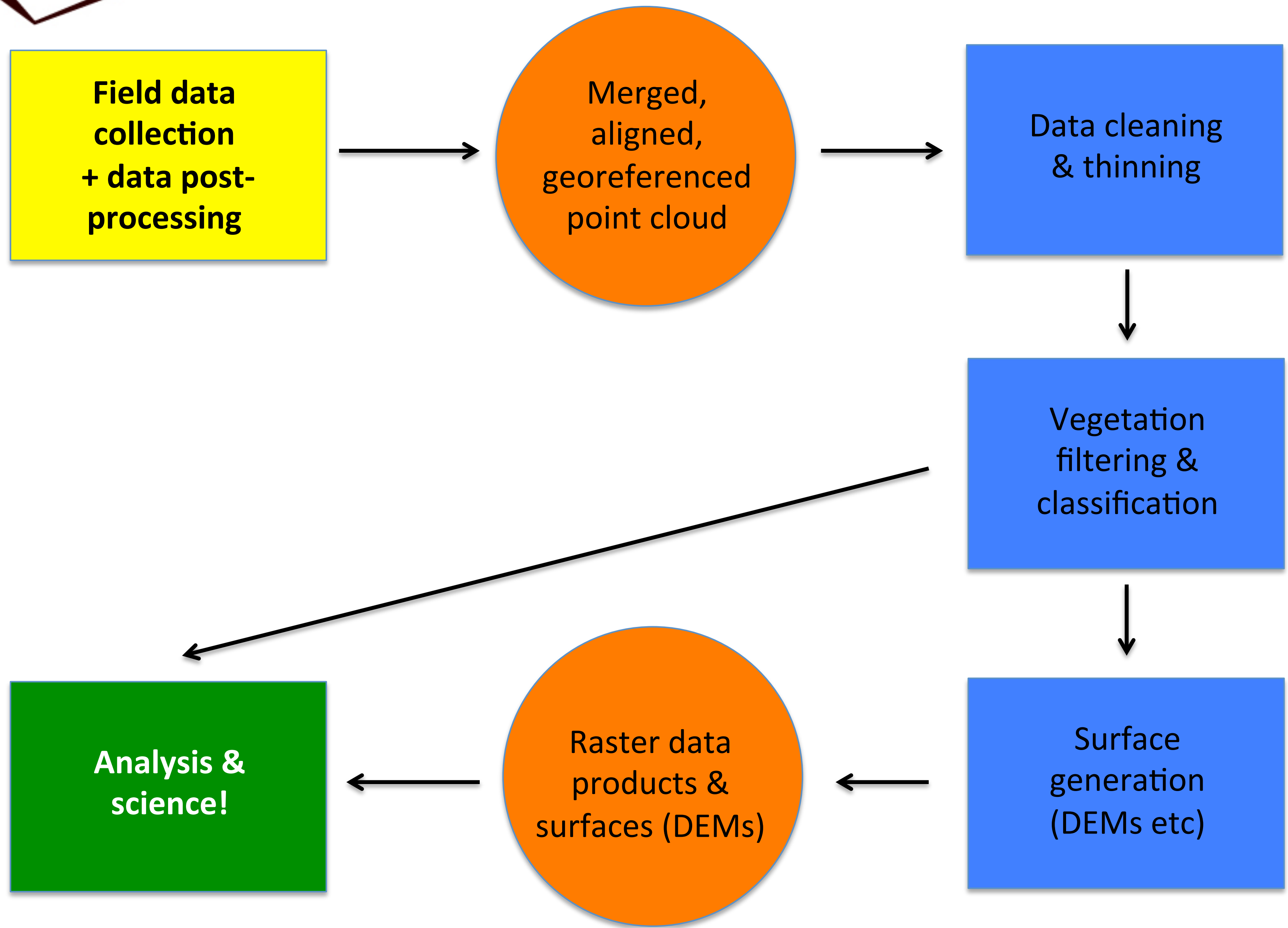
Other:

- 3D Studio
- 3dReshaper
- AutoCad
- BCAL LiDAR Tools
- Blender
- CloudWorx
- Crusta
- ENVI
- FARO Scene
- GDAL
- GeoAnalysis Tools
- Geovisionary
- Global Mapper
- GMT
- GRASS
- IDL
- Kingdom Suite
- LASTools
- libLAS
- MapScenes
- MapTek I-SiTE Studio
- Meshlab
- MicroCad
- MicroStation
- MicroSurveyCAD
- OpenTopography DEM generator
- OpenVC
- Point Cloud Library (PCL)
- Points2Grid
- PointTools
- Python modules and custom tools
- RealityLinx
- Split-FX
- Surfer
- TerraModeler
- Trimble RealWorks
- UC Davis tools
- (LidarViewer, Crusta)
- “home grown software”

Point Cloud

- 3D "point cloud" of discrete locations derived from range and orientation of scanner for each laser pulse.
- XYZ position in cartesian coordinates plus associated point attributes: intensity, RGB, etc.
- 3D point clouds are the basis for subsequent analysis and used to create CAD or GIS models
- Typically ***ASCII XYZ*** + attributes or ***LAS***
  - E57 = New standard under development, minimal adoption
- UNAVCO ***standard deliverable*** = merged, aligned, georeferenced point cloud in ASCII or LAS format.

TLS Processing Workflow – Overview



TLS Processing Workflow – Digital Elevation Models

- Digital representation of topography / terrain
  - "Raster" format – a grid of squares or "pixels"
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - "2.5D"

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
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	350	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	400	350	300	250	200	150	100	50	0
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0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
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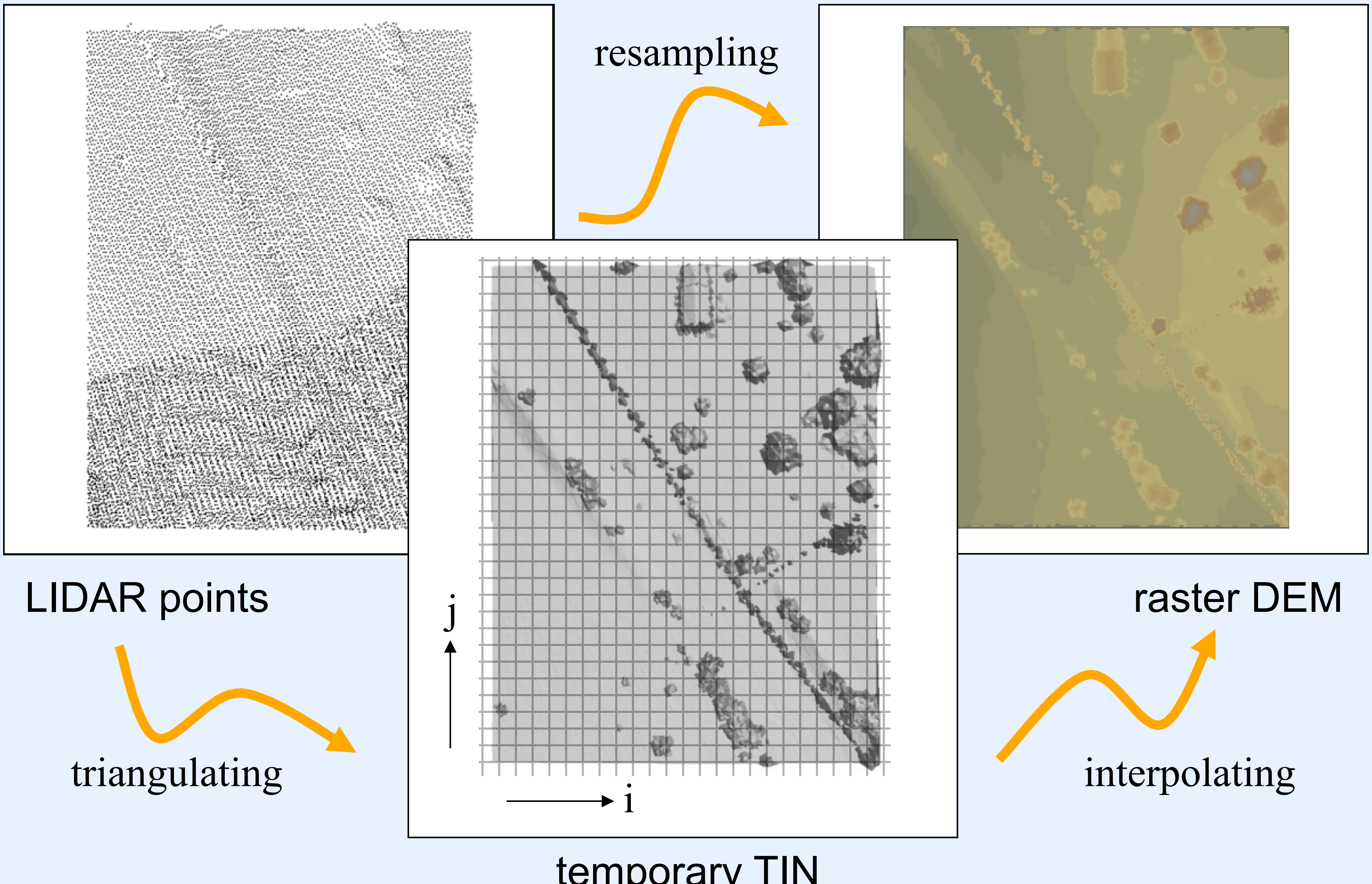
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

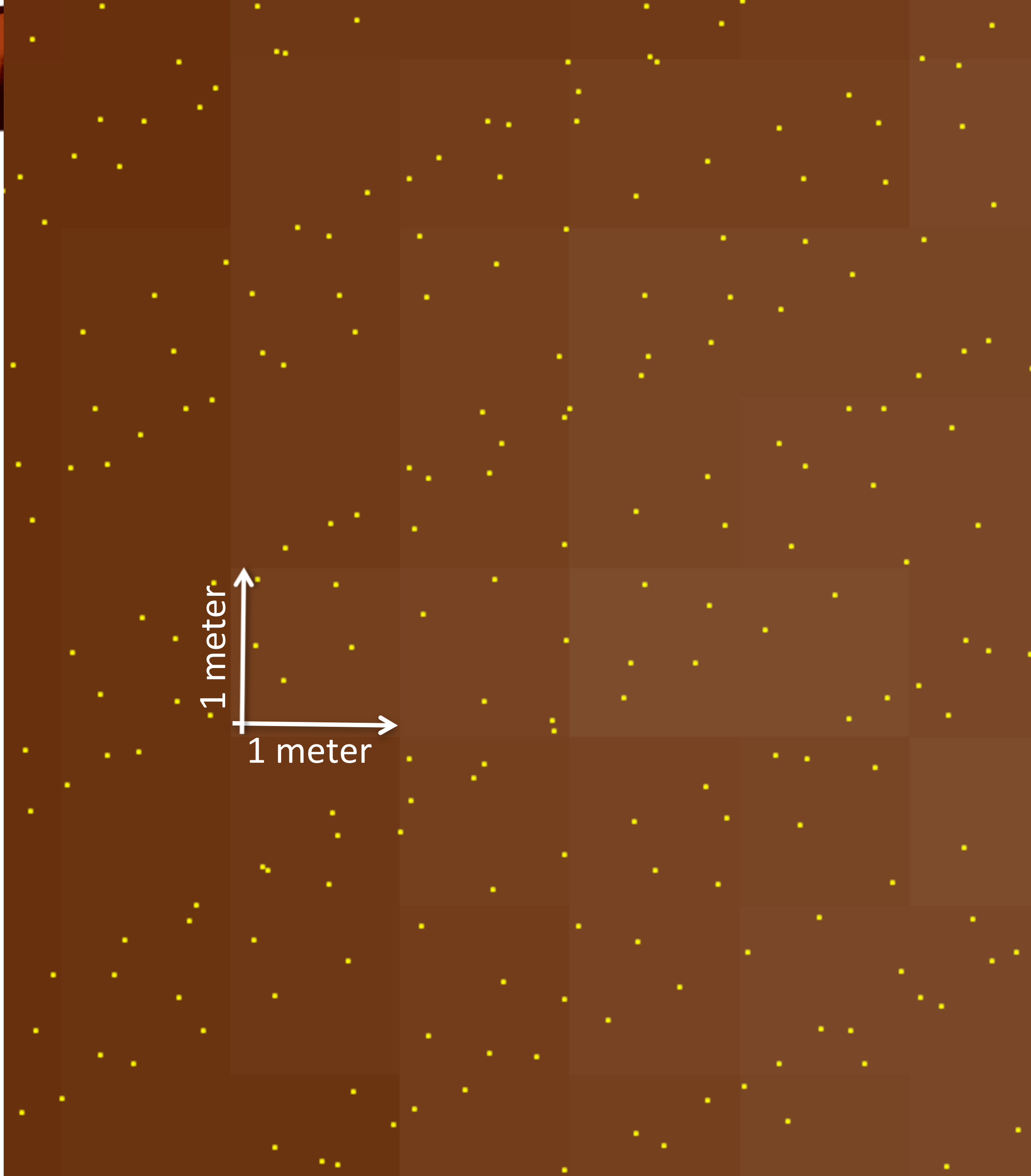
- Grid resolution is defined by the size in the horizontal dimension of the pixel
  - 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

Generating DEMs from LIDAR



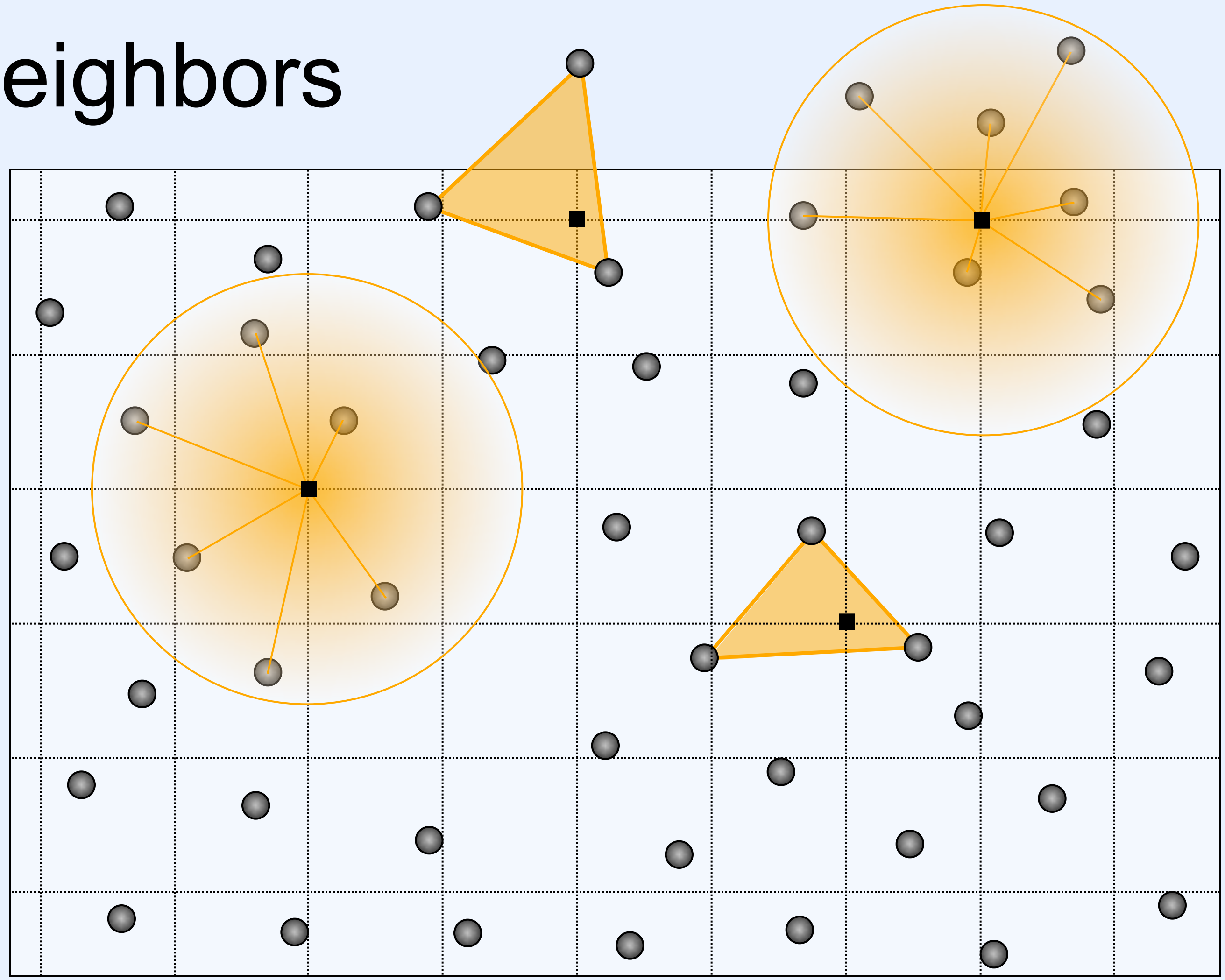
Isenburg, et al., 2006

- EarthScope lidar data
- Example from flat area with little or no vegetation. Ground sampled 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.

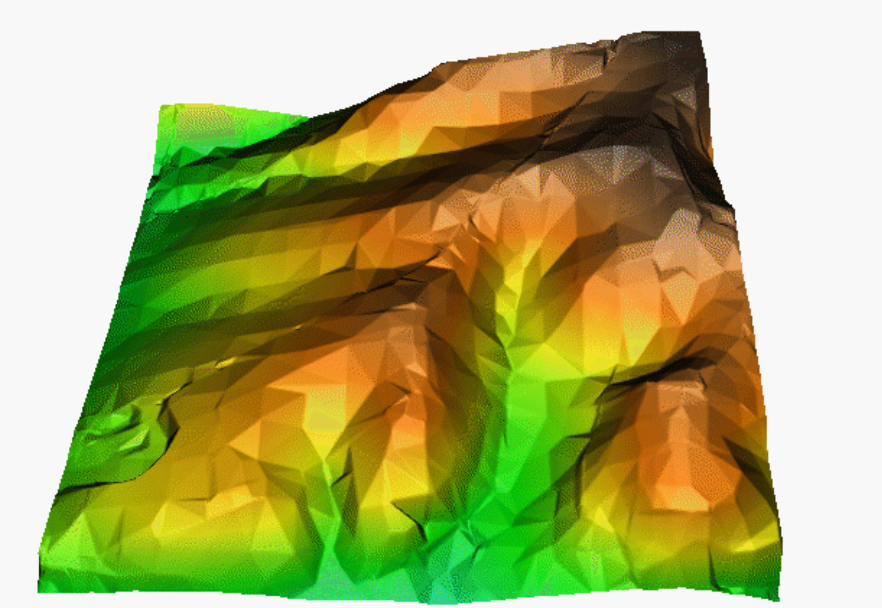


Interpolation Methods

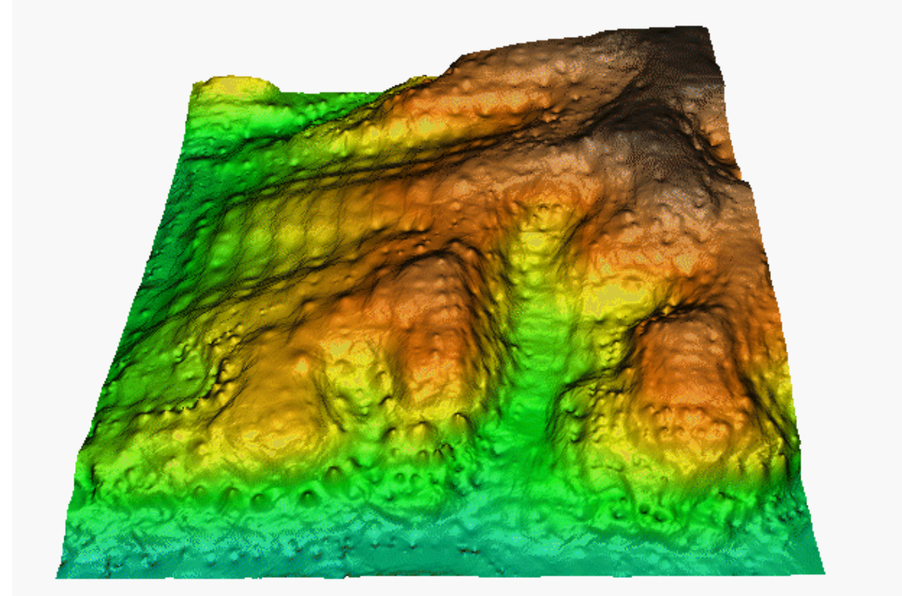
- Inverse Distance Weighting (IDW)
- Natural Neighbors
- Kriging
- Splines
- TIN
  - linear
  - quintic
- …



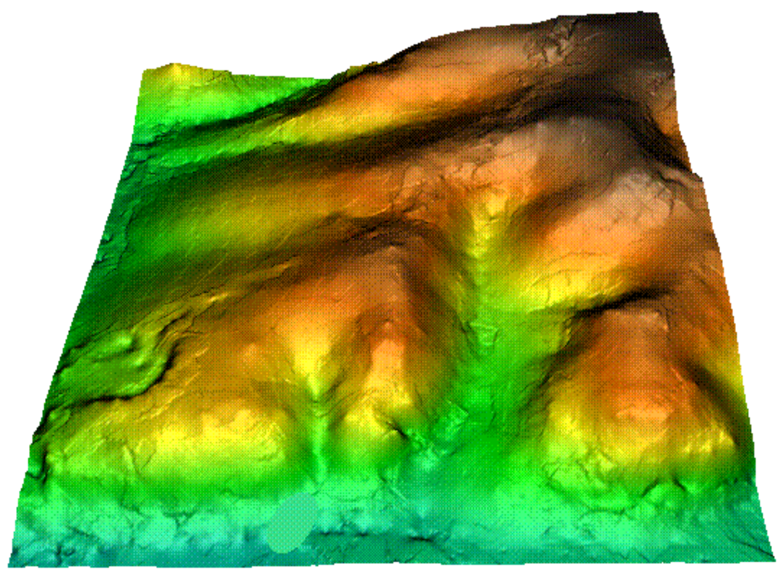
Isenburg, et al., 2006



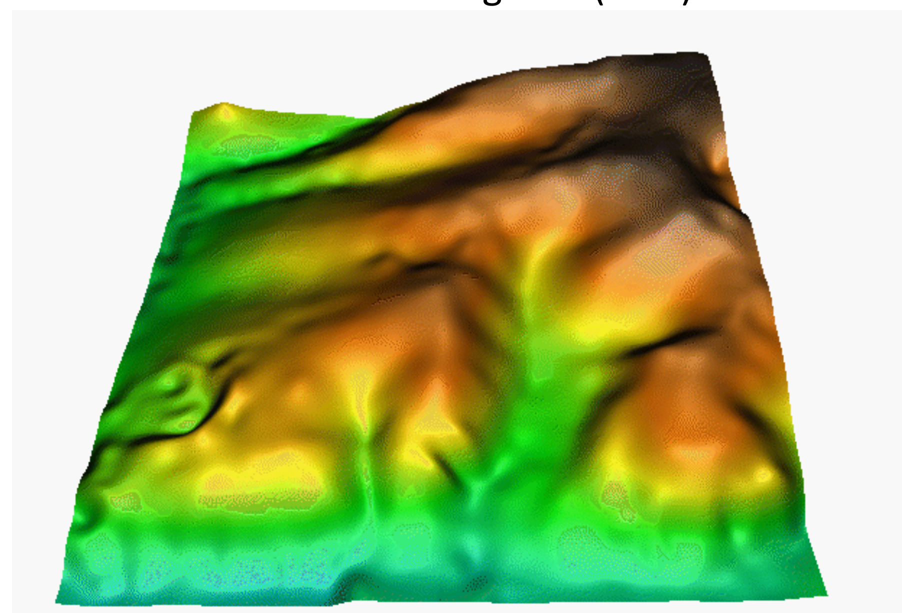
Triangulated Irregular Network (TIN)



Inverse Distance Weighted (IDW)



Kriging

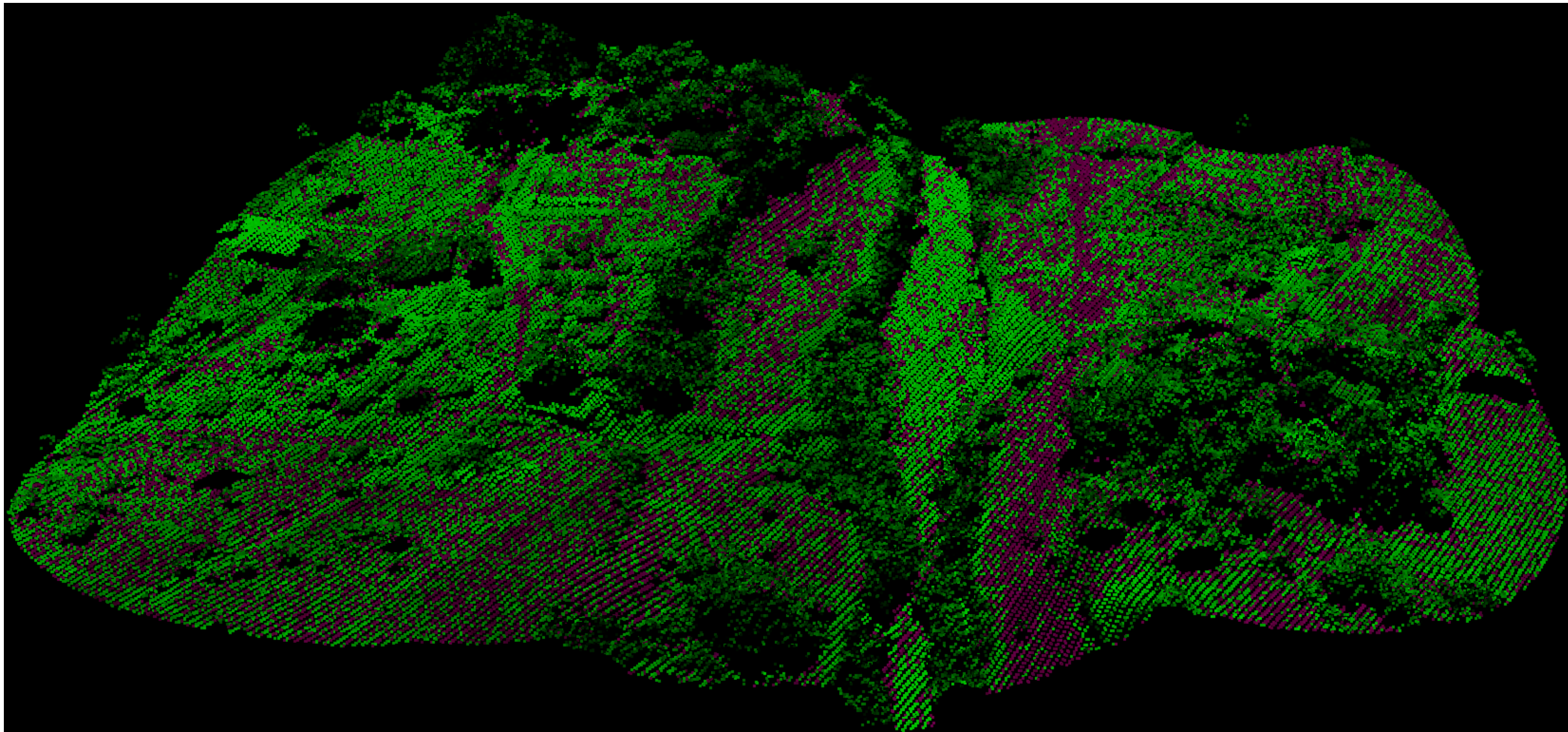


Regularized Spline with Tension and smoothing (RST)

Figure from Helena Mitasova (NCSU): http://skagit.meas.ncsu.edu/~helena/gmslab/index.html

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**
   – **despiking, iterative linear interpretation algorithms**

2. Ground is continuous (single-valued)
   – No-multiples algorithm

3. Ground is lowest surface in vicinity
   – Block-minimum algorithms

Modified from: R. Hagerud, USGS

Ground is smooth ⇒ despike algorithm

Approach:

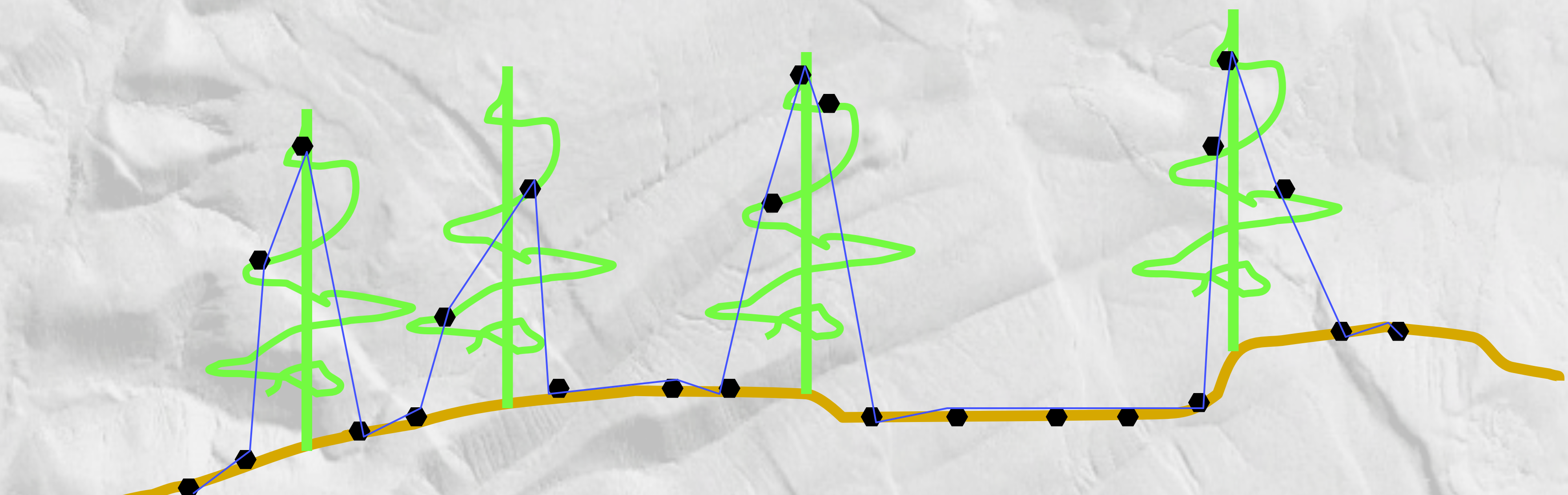
1. flag all points as ground

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

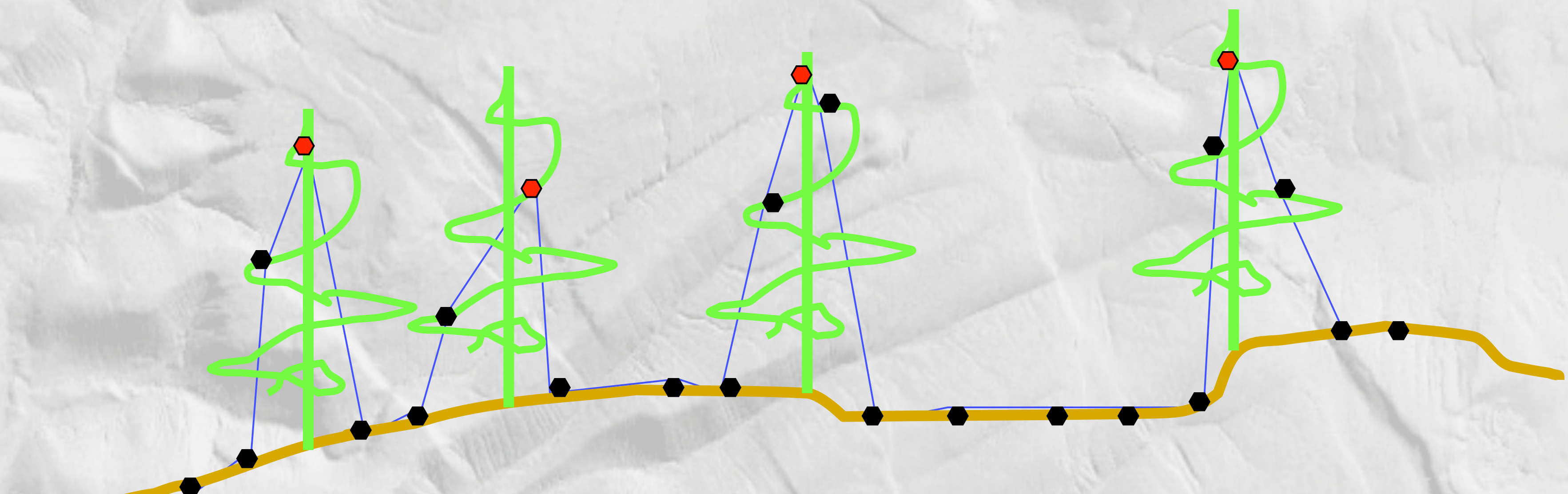
R. Hagerud, USGS

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



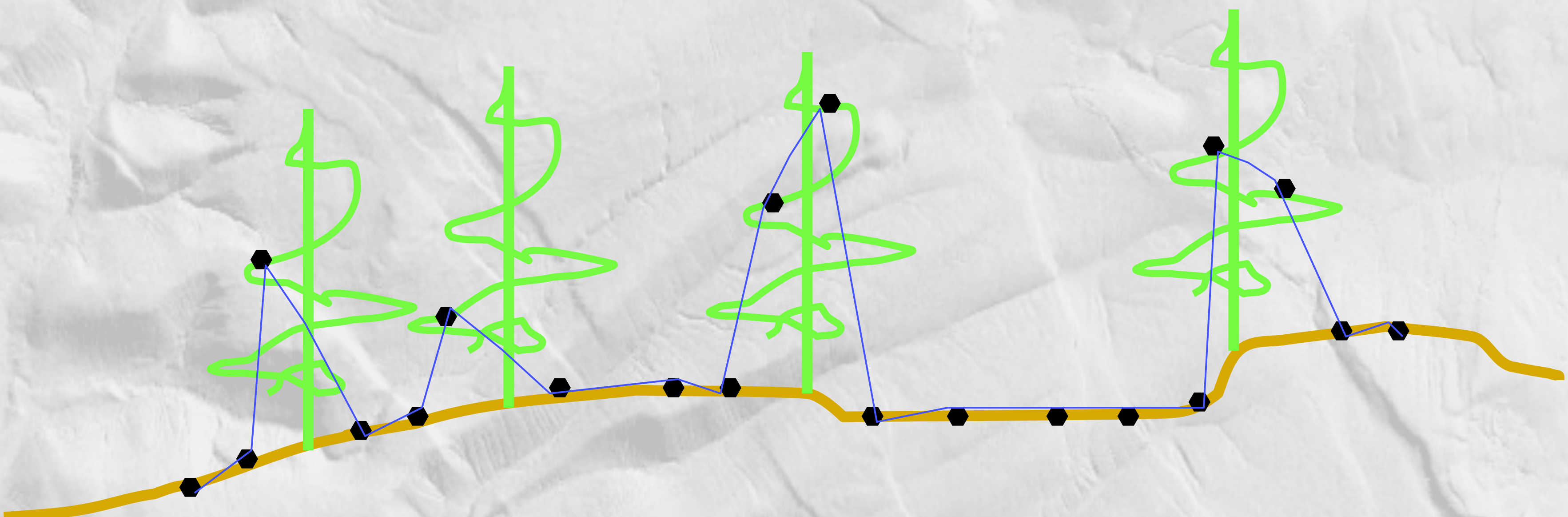
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



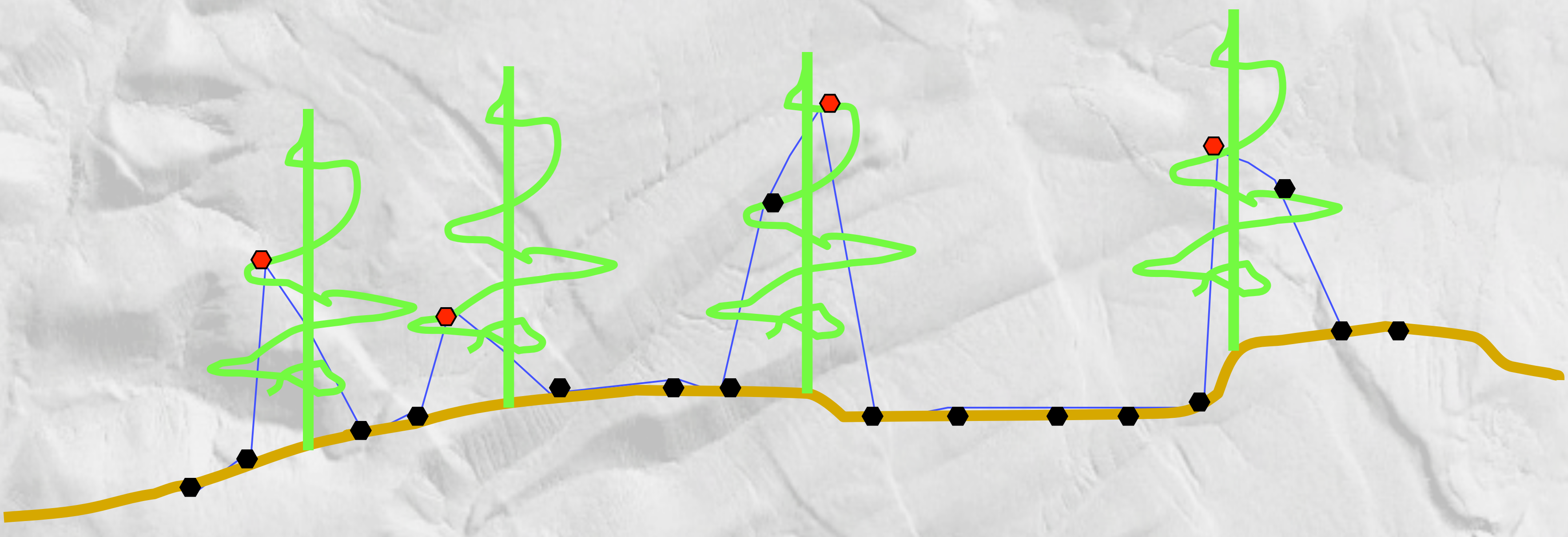
R. Hagerud, USGS

Rebuild TIN



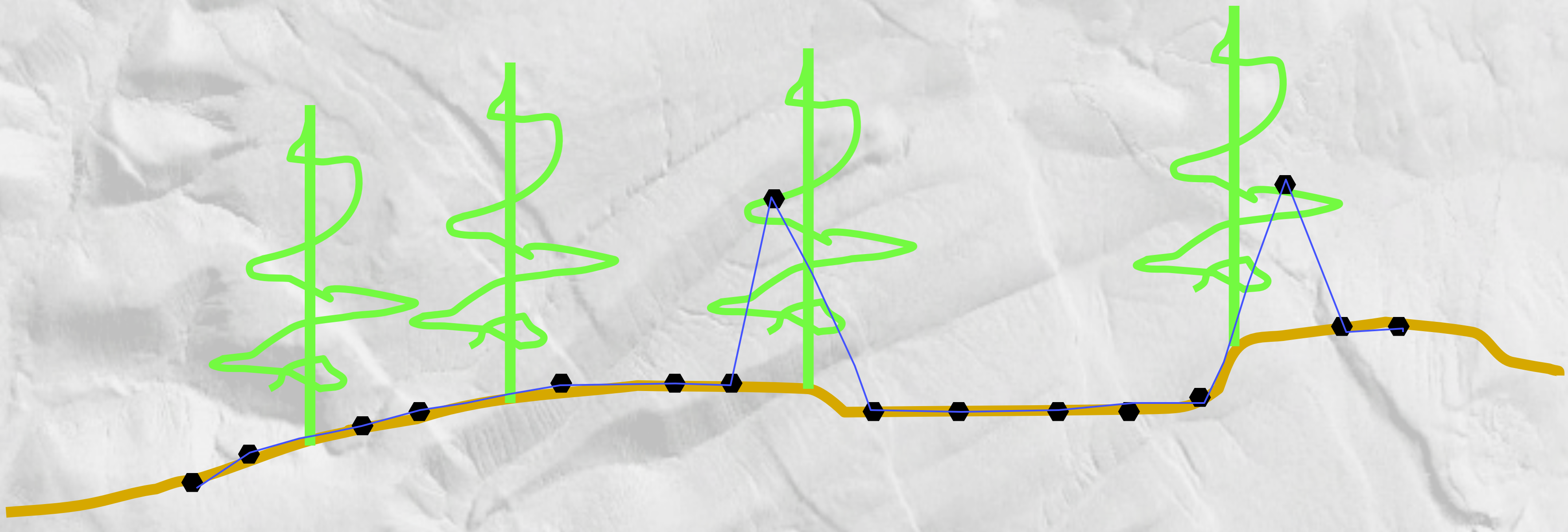
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



R. Hagerud, USGS

Rebuild TIN



R. Hagerud, USGS

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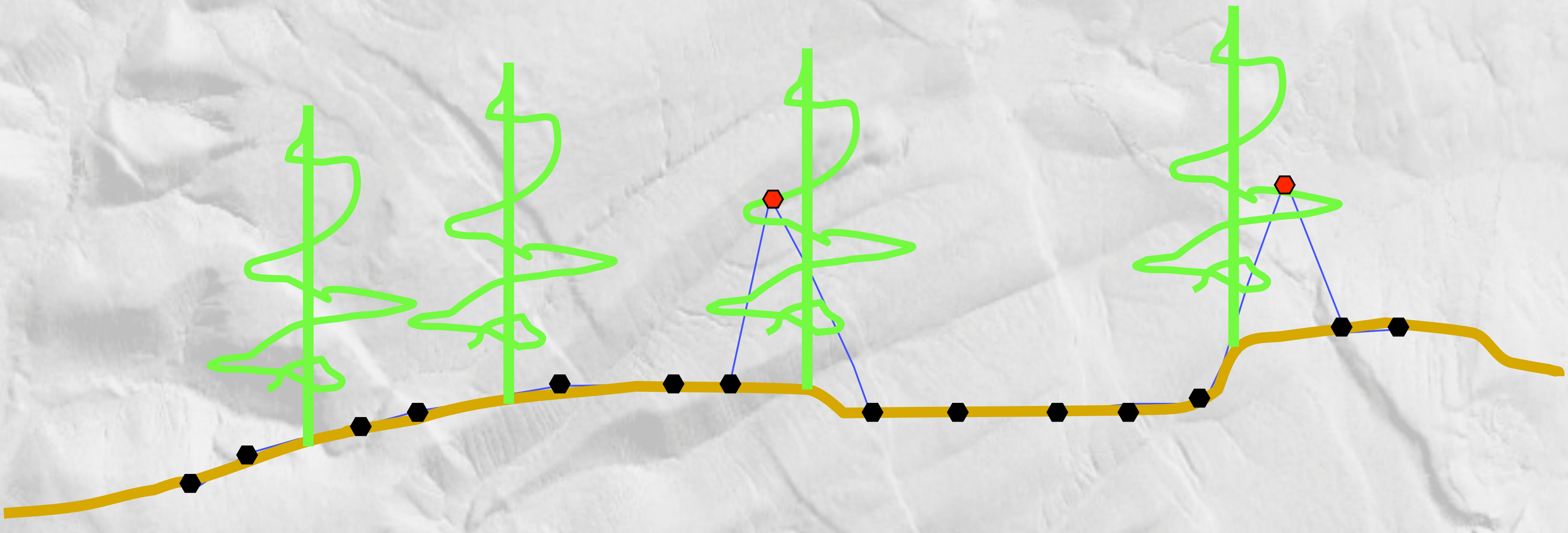


R. Hagerud, USGS

Rebuild TIN

R. Hagerud, USGS

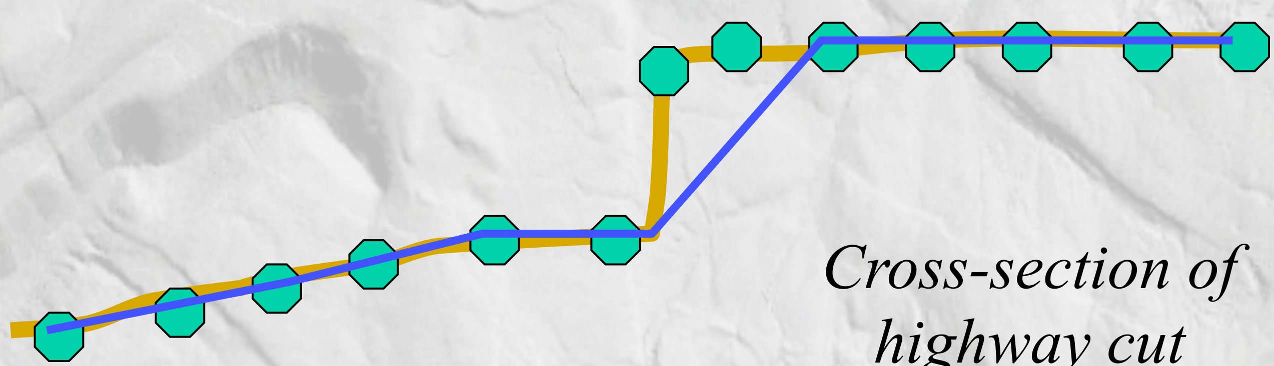
Despike algorithm

Benefits:

- 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



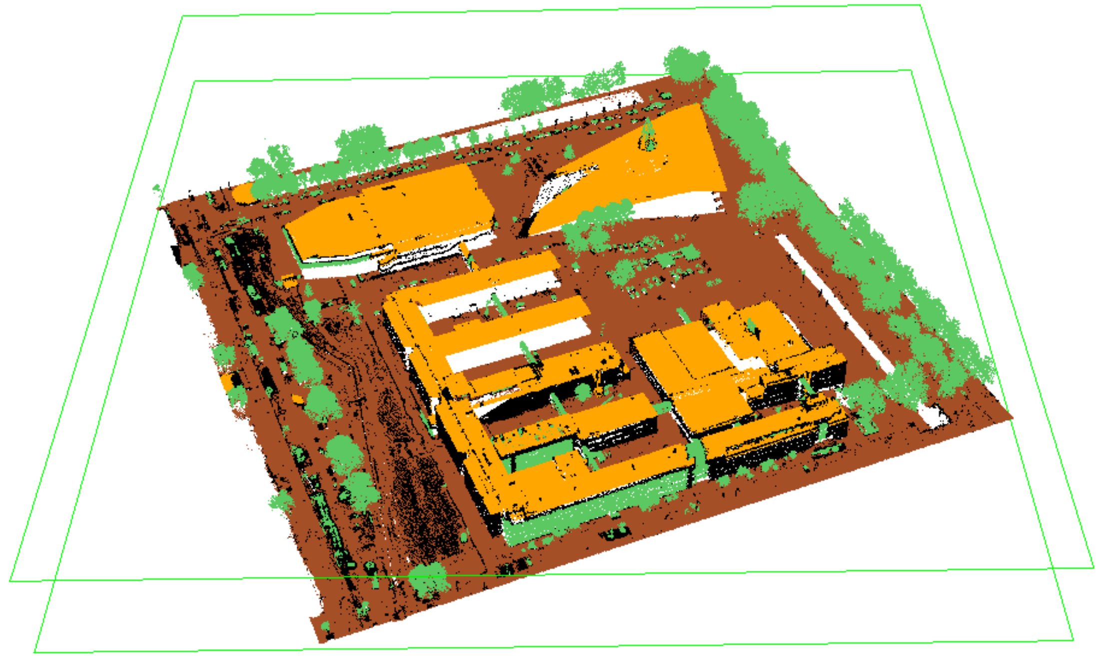
Cross-section of highway cut

<u>Problems</u>:

- 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



Commercial – Automated:

- RiScan Pro, TeraSolid, etc.

Open Source - Automated:

- 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

Open Source - Manual:

- LidarViewer (KeckCAVES)

Change Detection

- Repeat TLS data (or TLS combined w/ ALS data) provide opportunity to explore topographic change and driving processes.
- Vertical change vs 3D displacements?
  - Depends on the geophysical process being studied.
  - Datasets must be well aligned – horizontal and vertical coordinates, datums, etc.
  - Signal must be larger than noise and error in datasets
- Active area of research

TLS Processing Workflow – Metadata & Standards

Community-wide need to standardize and document TLS data processing workflow & products:

- Metadata content and format
- Generic (vendor neutral/open) exchange formats (e.g., LAS, E57)
- Capture of intermediate data products (e.g., point cloud per scan position)
- Attributes associated with final L2 data product (merged, aligned, georeferenced point cloud)
- Provenance – capture all steps of workflow to ensure repeatable and verifiable science.

Currently industry-wide deficiencies in this area.