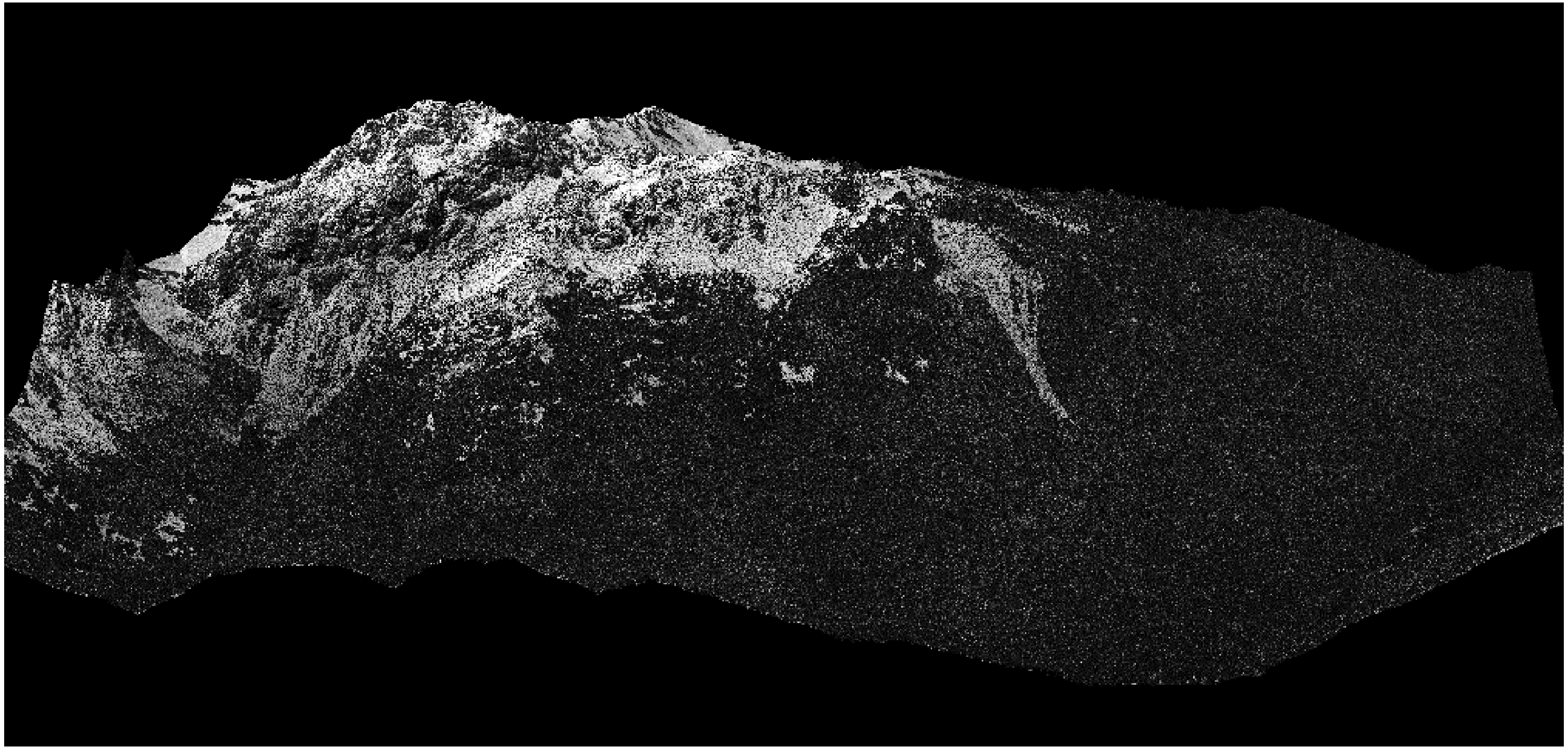


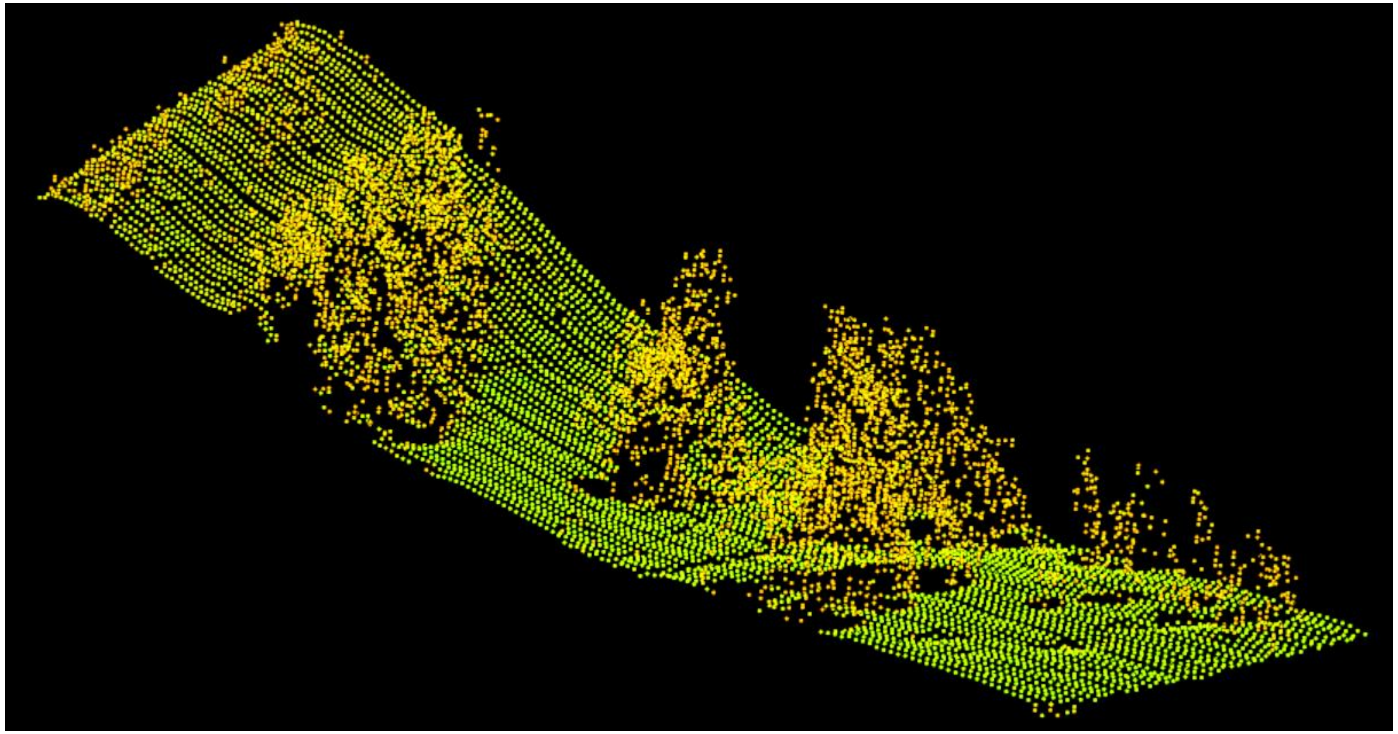
ASO Lidar Processing

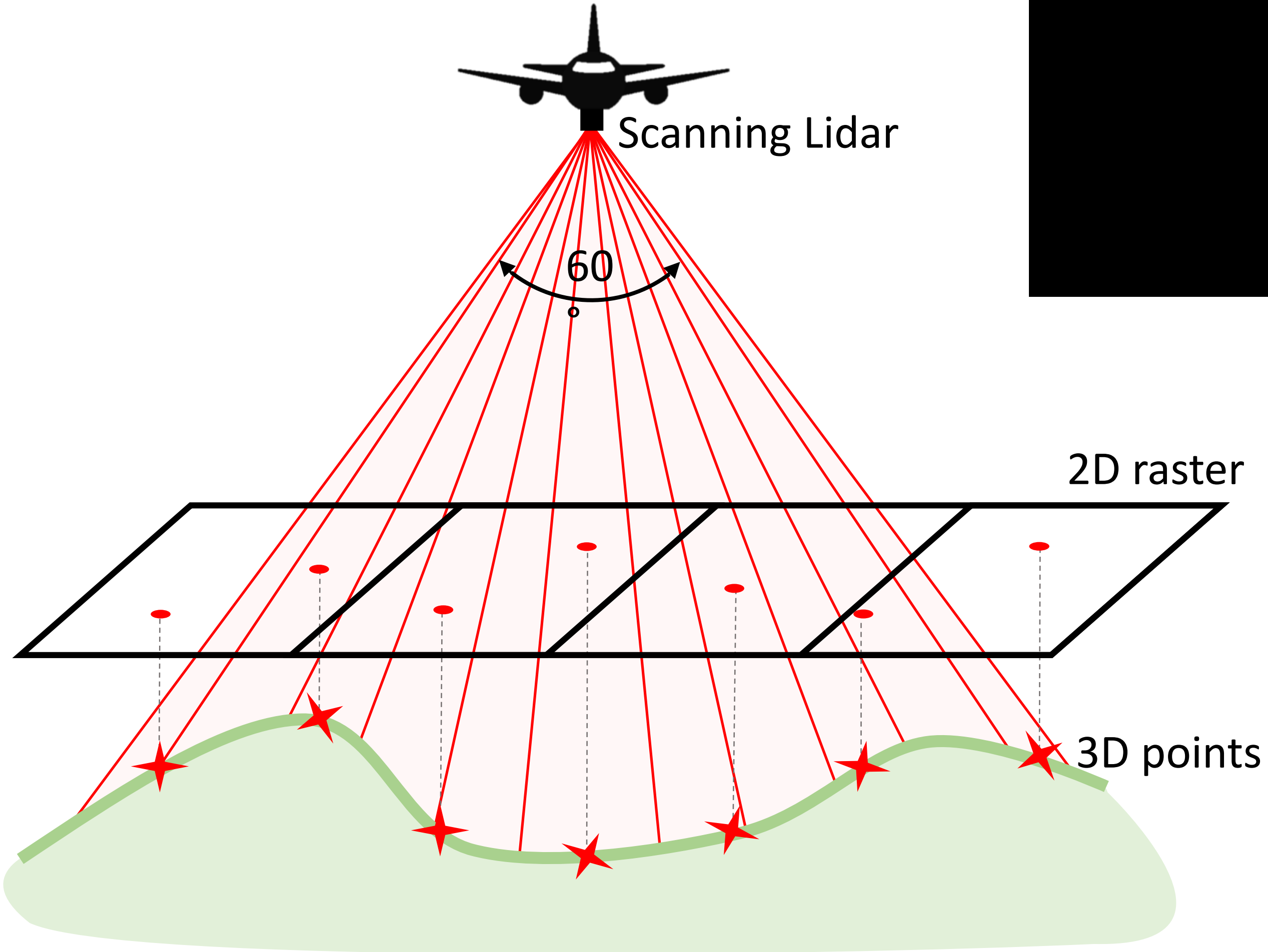
(Point Density, Forest Metrics)

Steven Pestana
12/8/2017

ASO Lidar

- Calculates distance with time-of-flight
- Instrument position known (GPS/INS)
- Wavelength / angle of incidence and surface determine reflection intensity





- λ = 1064 nm (NIR)
- 60° FOV (58° effective)
- 2 lasers (fore and aft pointing)
- 800 kHz pulse rate
- 5000 m AGL range

ASO Lidar

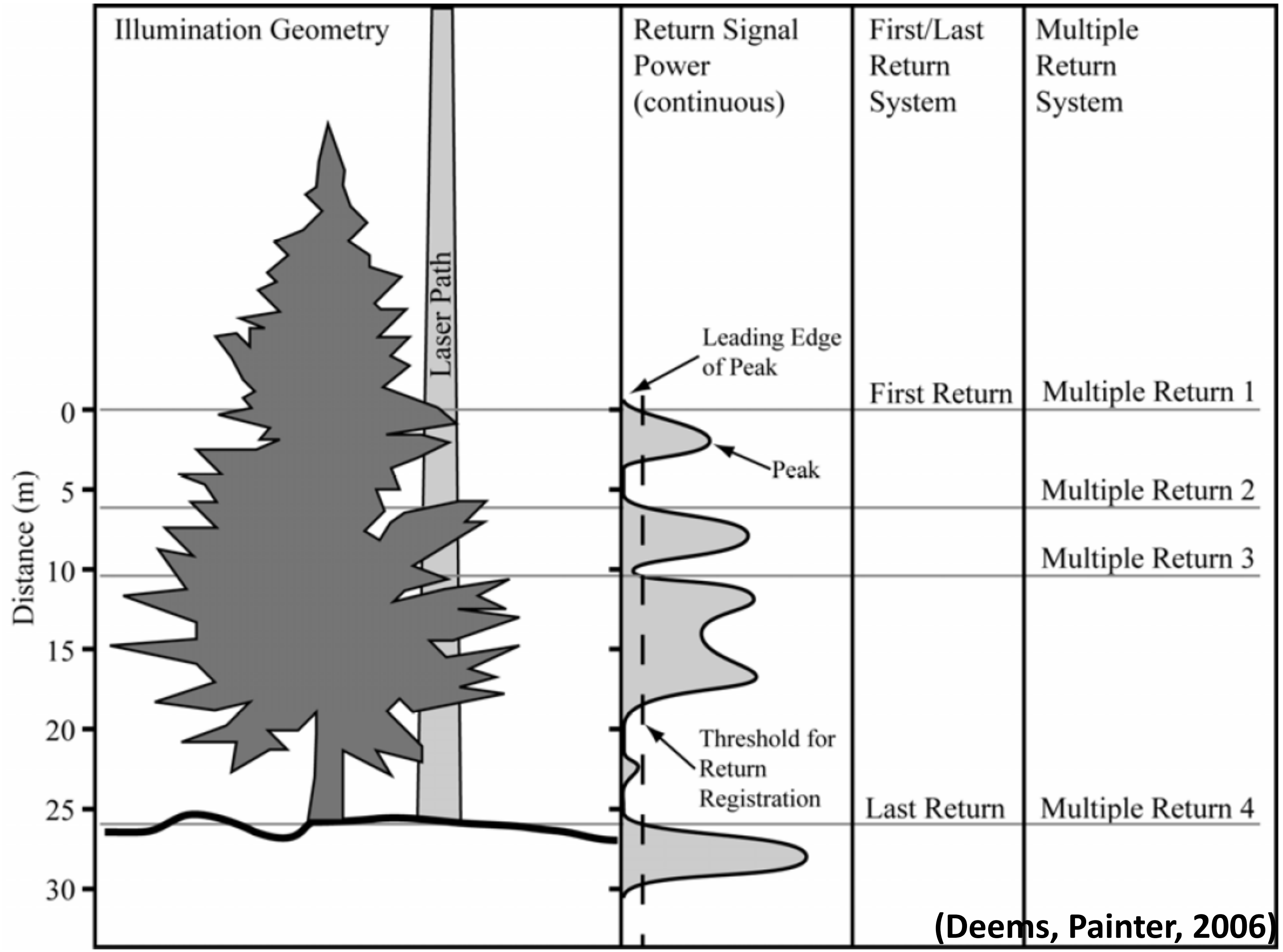
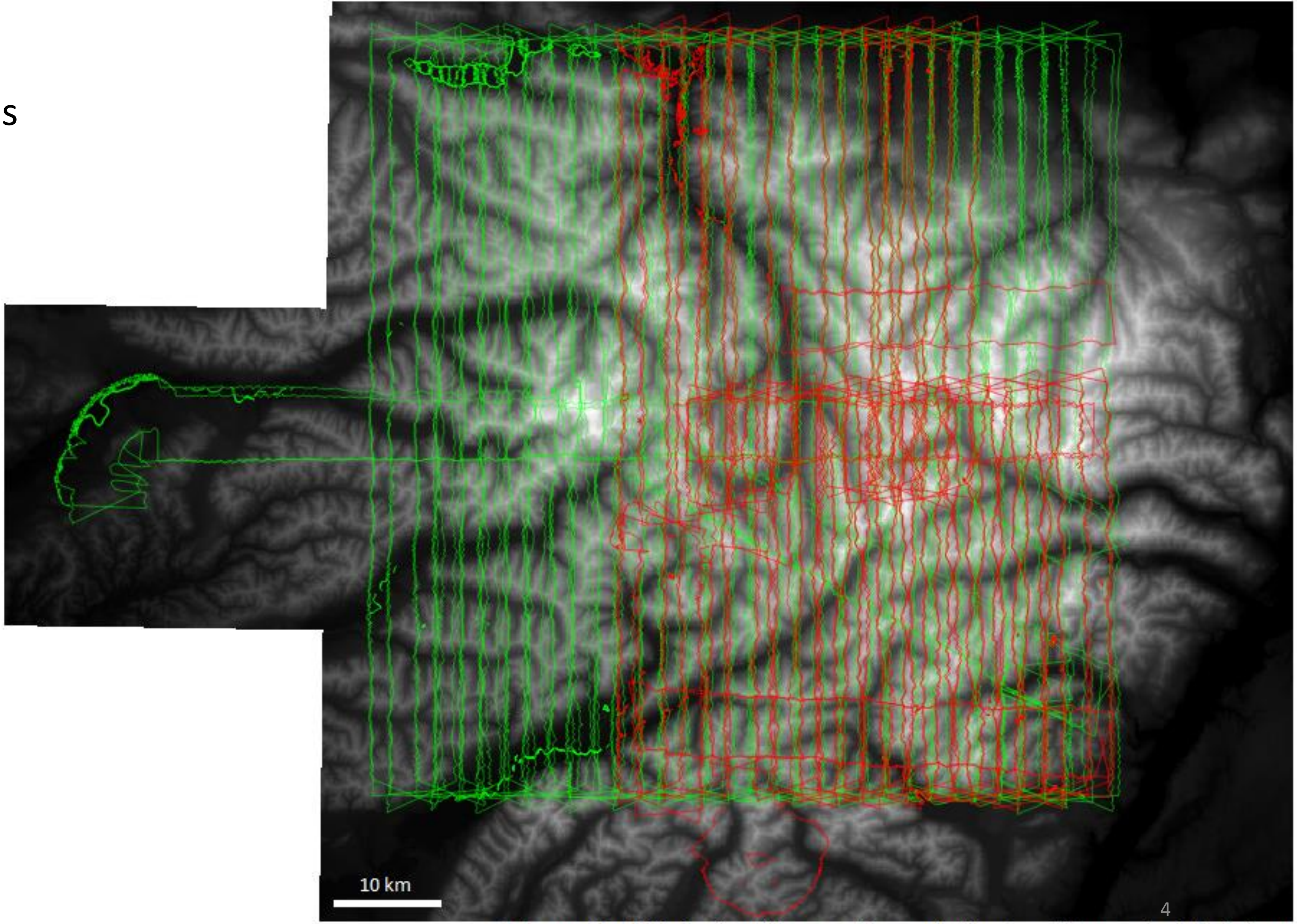


Figure 2. Laser illumination and return signal recording. Portions of the emitted laser pulse are reflected by different targets, resulting in multiple return signals for each pulse. Different LiDAR systems have different return signal recording capabilities. (*after Lefsky et al., 2002*)

- Beam divergence
  ≈ 0.1 – 0.3 m / 1000 m AGL
- Waveform packet returned
- Discretized into return points

ASO Lidar

- “Snow-On” Flights
  - Feb. 8, 9 2016
  - Mar. 29, 30 2016



Background 30m DEMs from http://gis.ess.washington.edu/data/raster/thirtymeter/wa75/index.html

Non-proprietary 3D point cloud data interchange format

LAS file specifications managed by the ***American Society for Photogrammetry and Remote Sensing***

Point Data Abstraction Library
Open-source, C++ library for manipulating point-cloud data
Command line tools, JSON pipelines, API
Python extensibility

rapidlasso LAStools
Windows-based suite of tools
Command line and GUI
Automating pipelines with batch scripting

Lidar Point Density

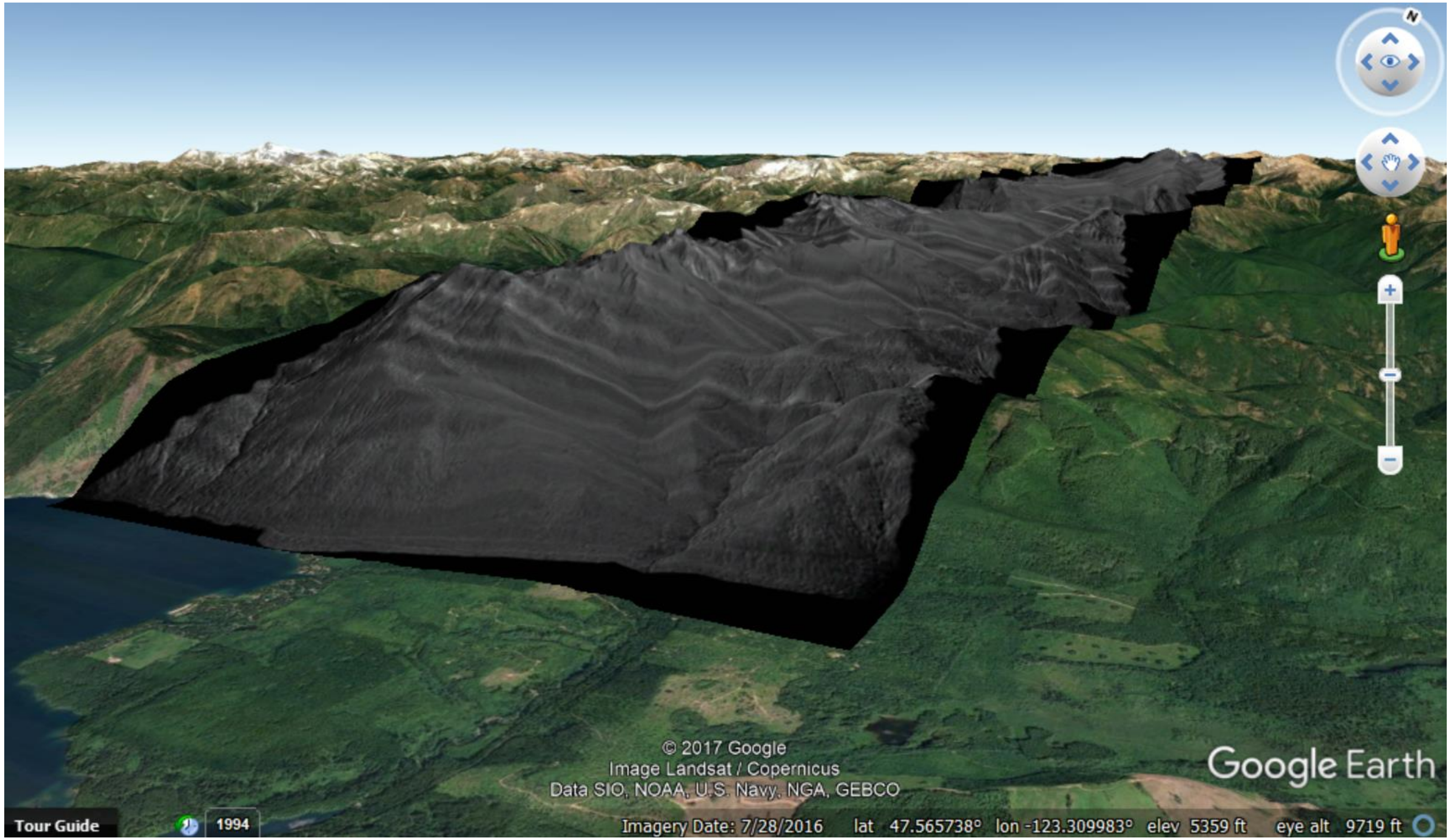
Cross-Track Point Spacing:
- Instrument pulse rate
- Instrument scan rate (oscillating or rotating mirror angular velocity)

Down-Track Point Spacing:
- Aircraft pitch/yaw
- Aircraft ground speed
- Instrument scan rate
- Instrument scan pattern

Swath Width:
- Aircraft's altitude AGL
- Instrument scan angle

Flightlines:
- Overlapping swaths
- Minimizing incident angles

Using first returns to remove the effect of multiple reflections from a single pulse. 1 return ≈ 1 pulse



"pulse density"

$$D = \frac{\#\ returns}{m^2}$$

$$D_1 = \frac{\#\ first\ returns}{m^2}$$

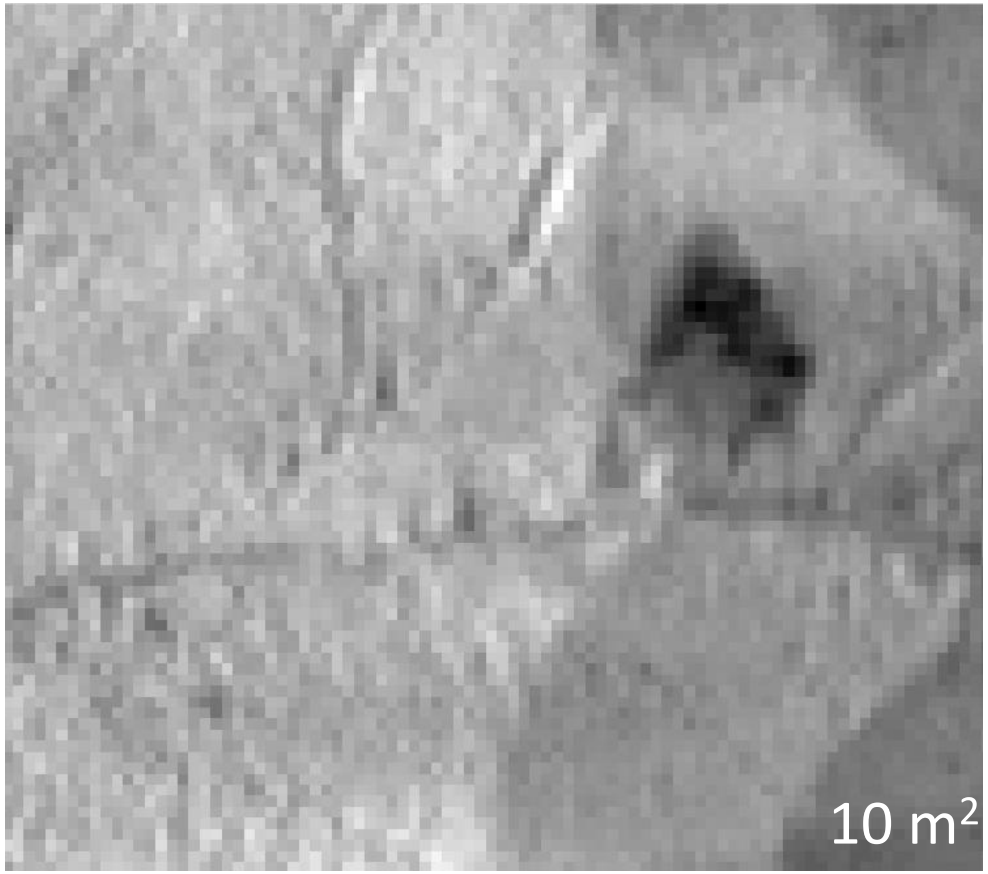
Lidar Point Density

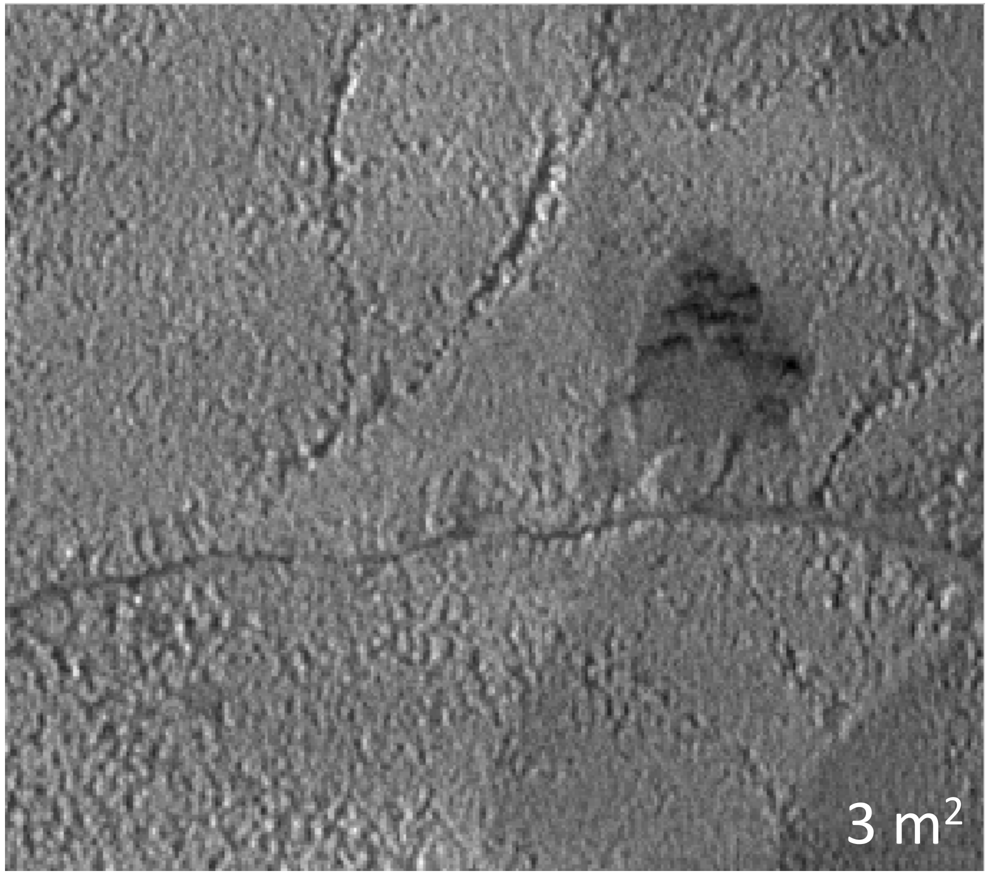
Point density helps give context for later processing:

- Creating DSMs via TINs
- fewer points = more interpolation (IDW or other)
- DSM grid element size ≈ mean point spacing
- Rasters with small pixel size (high resolution) derived from a point cloud have empty pixels

ASO did not target specific/constant point density

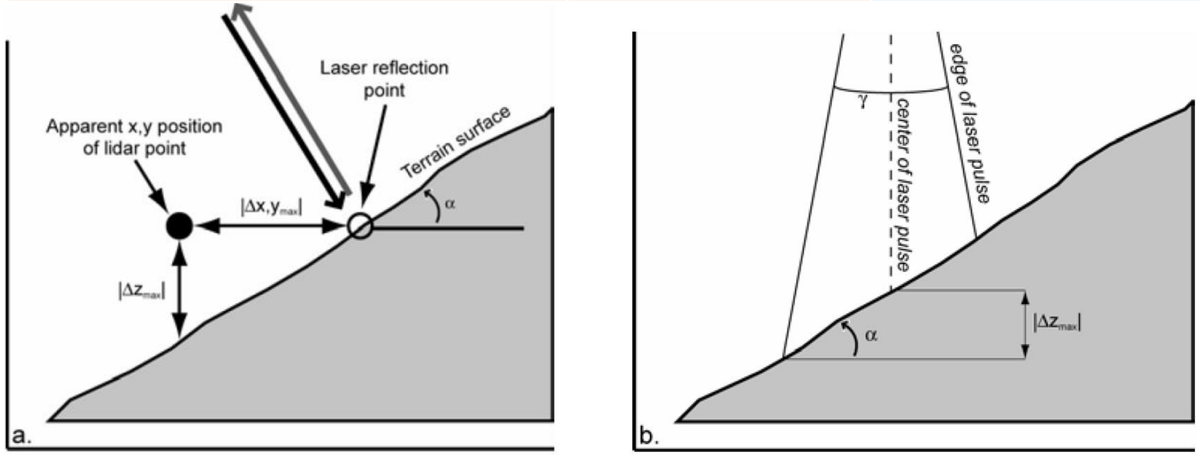
- ≈ 12 / m^2
- Lower densities expected in lower elevations





Lidar Error Sources

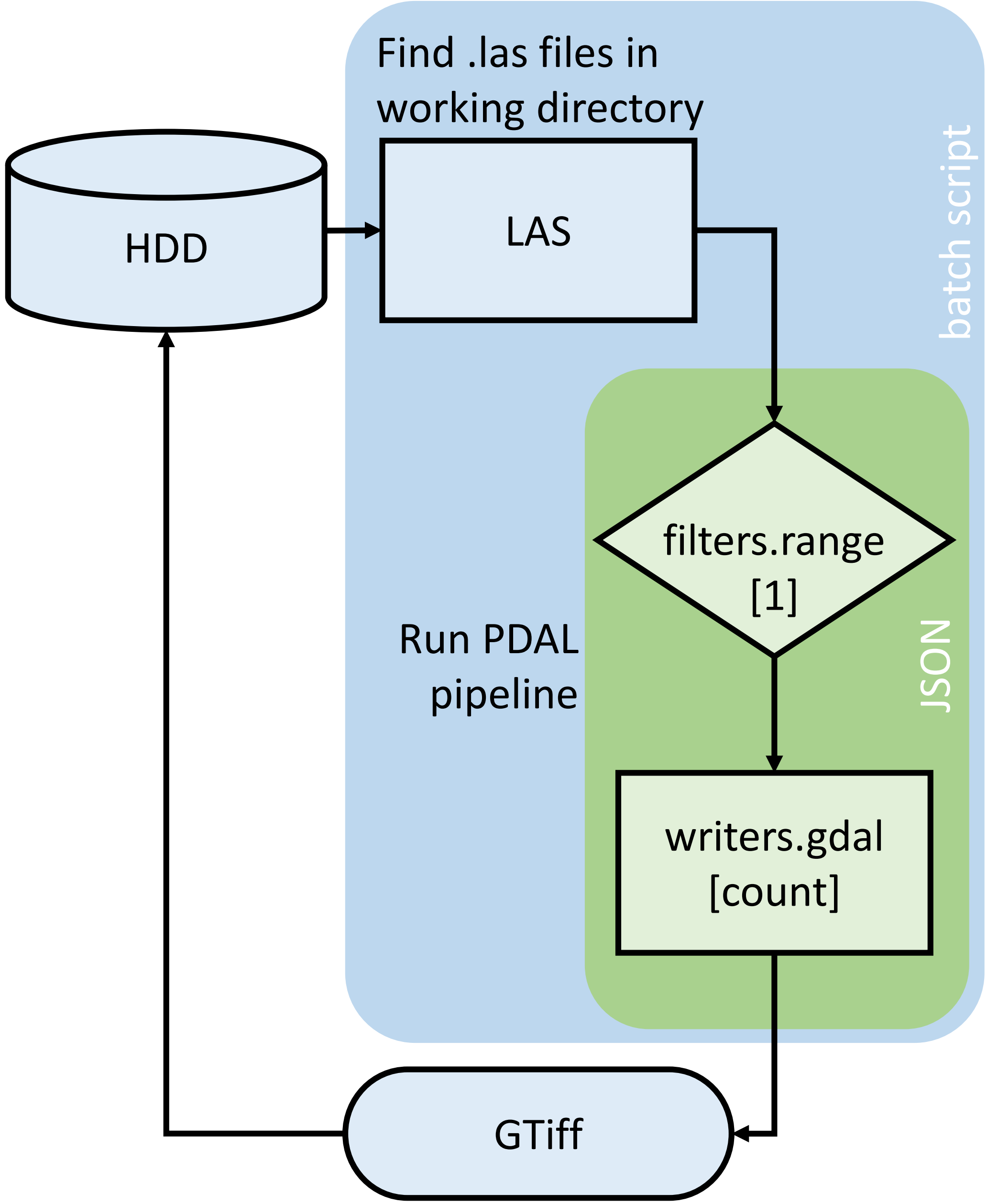
Error Source	Magnitude	Minimizing Error
Instrument GPS/INS position	< 0.1 m	Instrument calibration
Complex/steep sloping terrain (a. Z errors, b. “timewalk”)	~ 0.5 m	Minimize large incident angles with surfaces Multiple, overlapping, flightlines
Thick vegetation	~ 0.1 m	Multiple flightlines with different incident angles to penetrate vegetation
Absorptive/scattering surfaces	~ 0.01m on snow	At 1064 nm, transmission is a function of grain size, where in coarser grains: • optical depth decreases (increases transmission) • absorping path length increases (decreasing transmission) Multiple flightlines for different incident angles

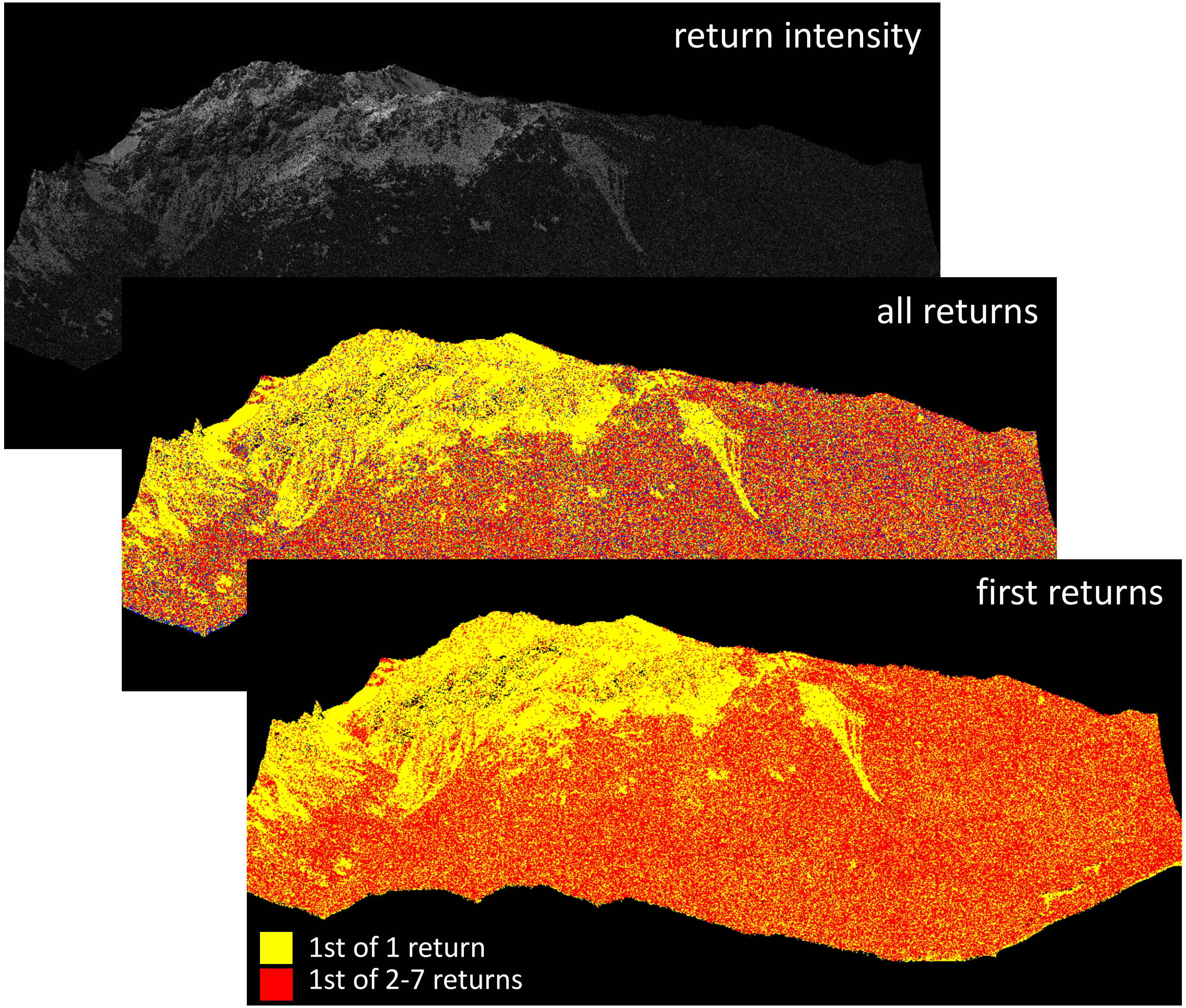


A higher point density can help minimize some of these.

(Deems, Painter, 2006)

Point Density Workflow





First Return Point Density Pipeline (*first_return_point_density.json*)

- Input and output filepaths are substituted in batch run
- Using filters.range to select first returns:
  - `limits` - selecting only the first returns (range from 1 to 1)
- Using writers.gdal to write out raster image
  - `resolution` - pixel side length in units of original las file (use lasinfo or pdal info to get file metadata and statistics)
  - `output_type` - "count" for number of points within each pixel (other options)
  - `gdaldriver` - GeoTiff

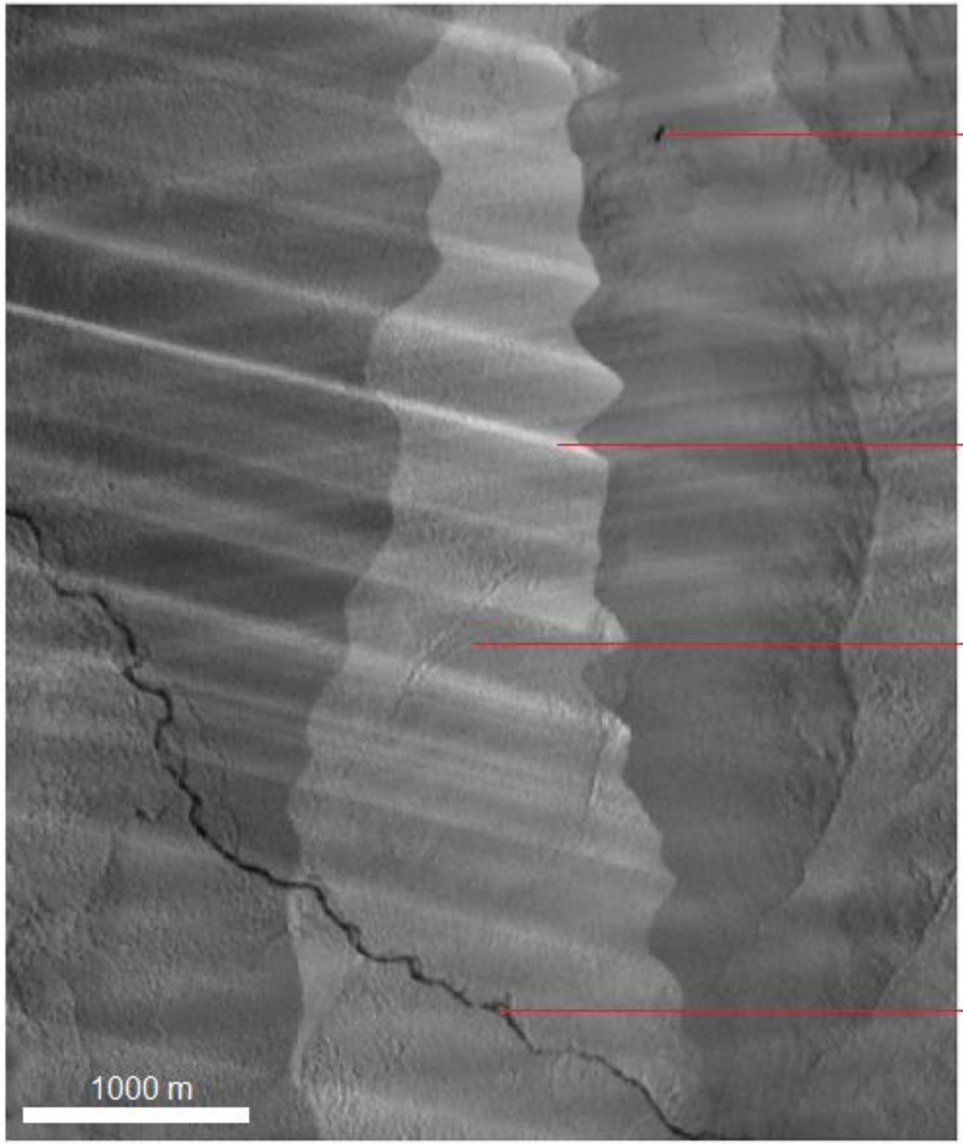
```
{
  "pipeline":[
        "input.las",
    {
          "tag" : "firstReturns",
      "type" : "filters.range",
      "limits" : "ReturnNumber[1:1]"
    },
    {
          "tag" : "densityRaster",
      "type" : "writers.gdal",
          "inputs" : [
                              "firstReturns"
                       ],
          "resolution": 10,
          "output_type" : "count",
          "gdaldriver" : "GTiff",
      "filename" : "output.tif"
    }
  ]
}
```

Point Density Product

NAIP Imagery

10:1 NAIP Imagery m_4712315_sw_10_1_20150817_20151123 3.75 x 3.75 minute JPEG2000 from The National Map: USDA-FSA-APFO Aerial Photography Field Office.

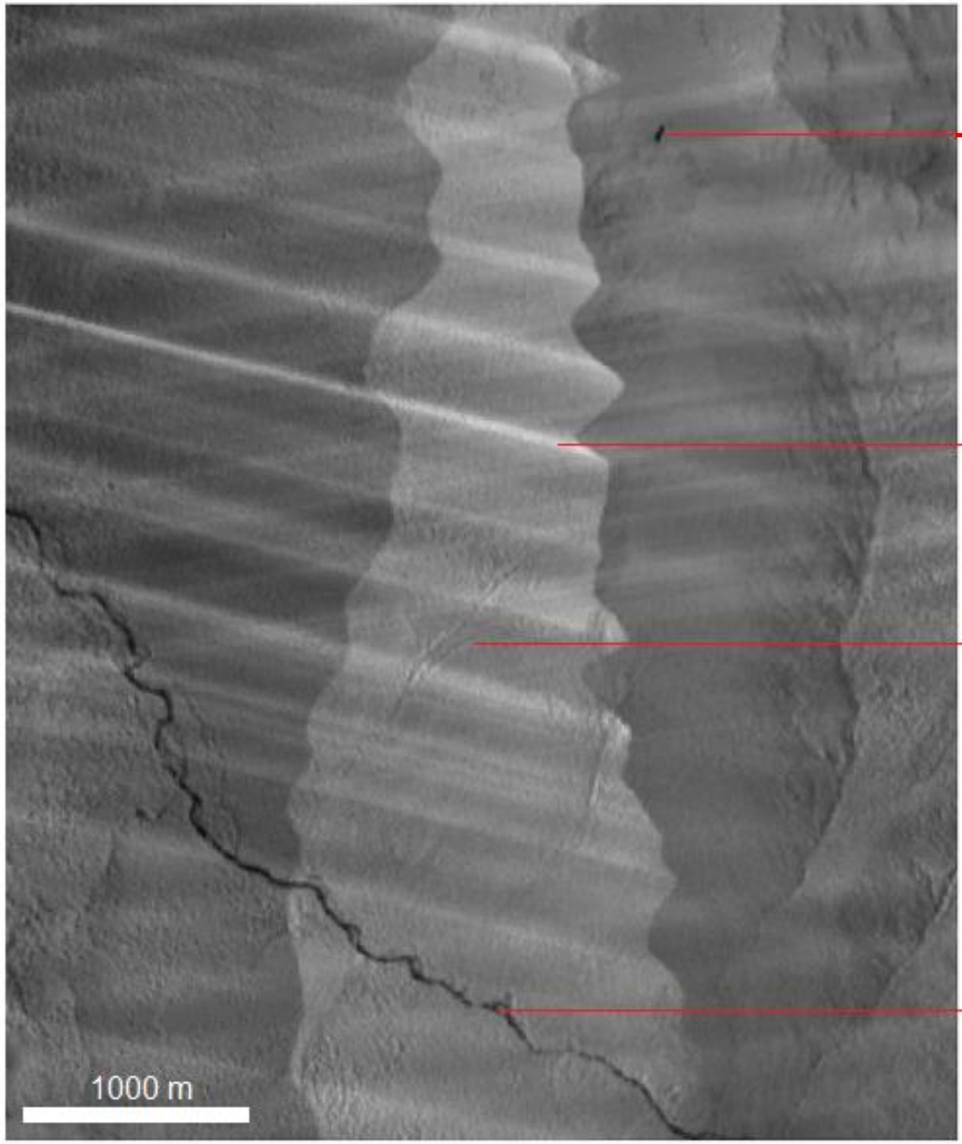
ASO Lidar, 10m point density map



ASO (Feb. 9, 2016; snow-on) lidar-derived point density map at 10m resolution (S. Pestana) Centered on 47.7716 N, 123.2339 W

Point Density Product

ASO Lidar, 10m point density map

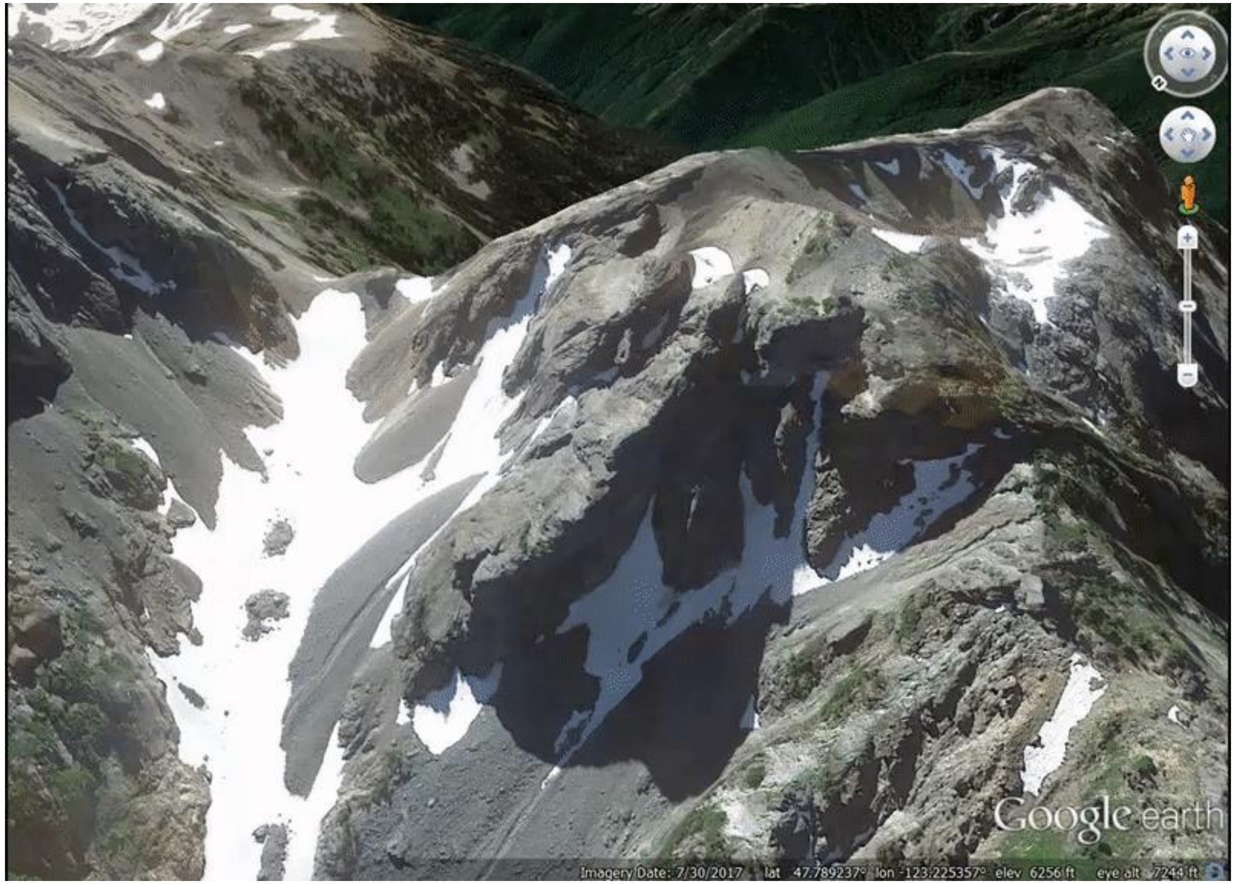


shadows

scan lines

swaths

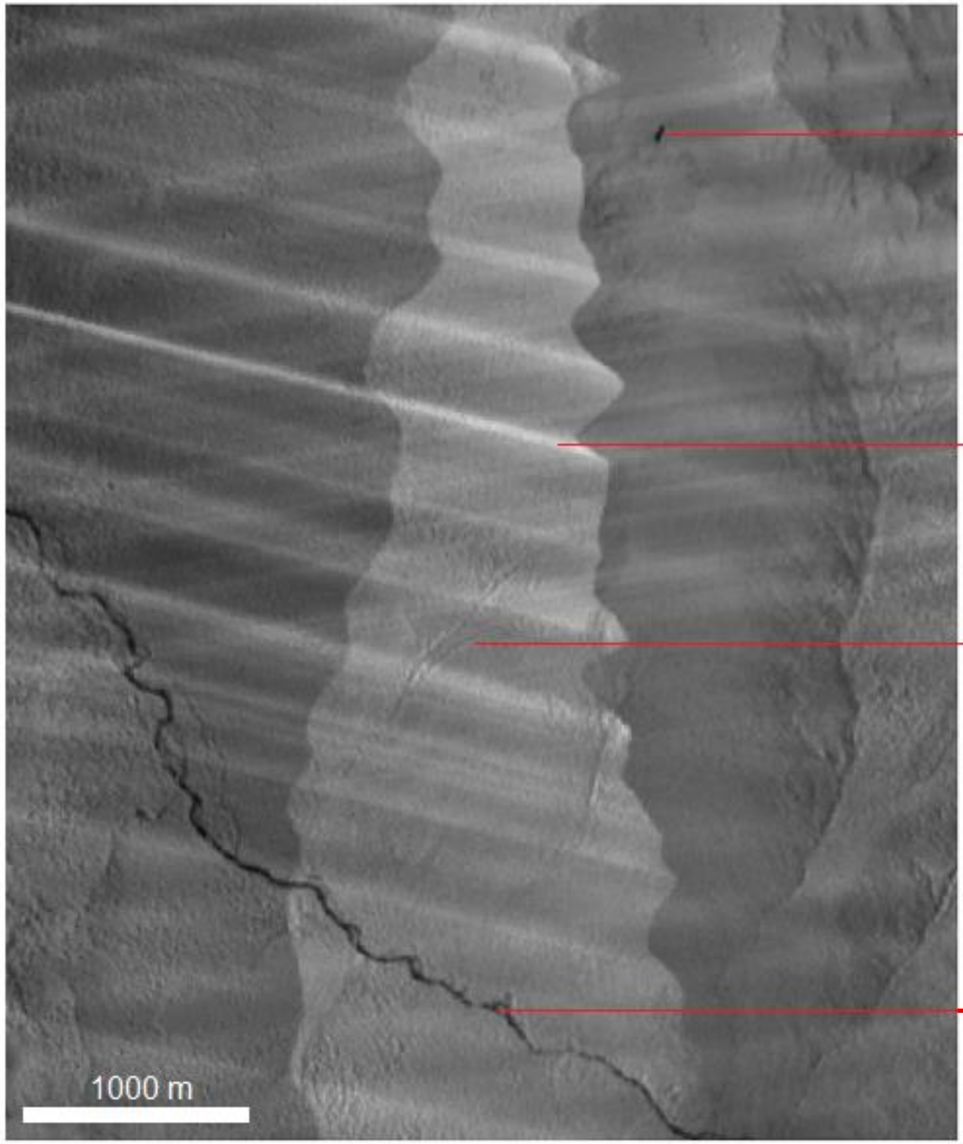
river



ASO (Feb. 9, 2016; snow-on) lidar-derived point density map at 10m resolution (S. Pestana) Centered on 47.7716 N, 123.2339 W

Point Density Product

ASO Lidar, 10m point density map

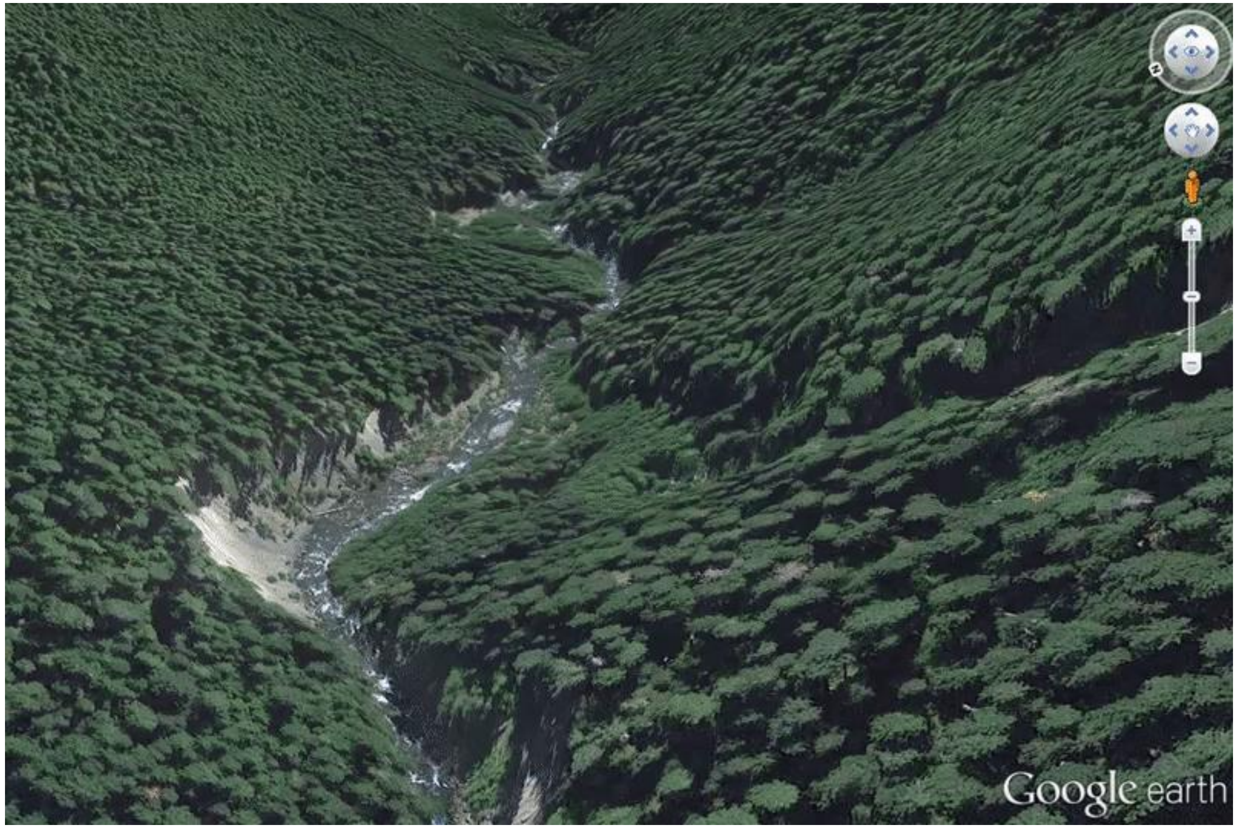


shadows

scan lines

swaths

river



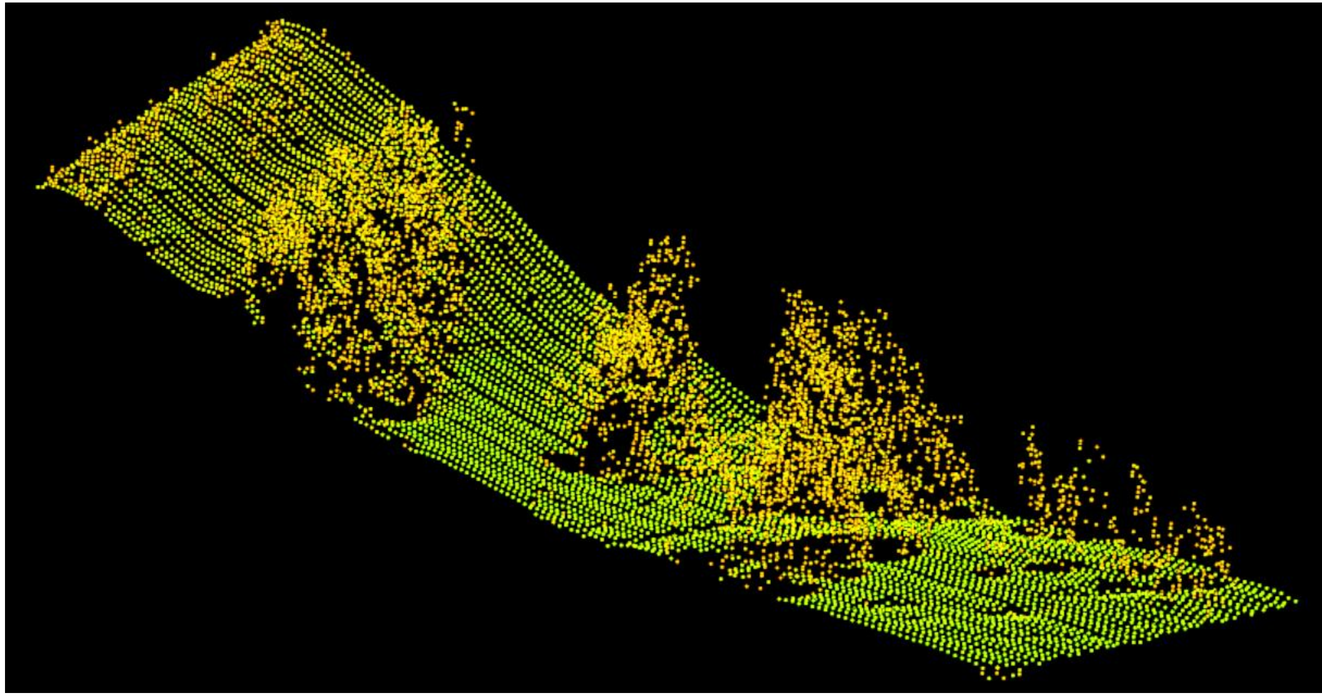
ASO (Feb. 9, 2016; snow-on) lidar-derived point density map at 10m resolution (S. Pestana) Centered on 47.7716 N, 123.2339 W

Forest Metrics

- We want to characterize forest structure

Can we see underneath all trees?
How does forest structure affect snow under trees?

- Need classified ground points for height above ground calculations, threshold (H)



Canopy Height (CH): Height above ground-normalized surface

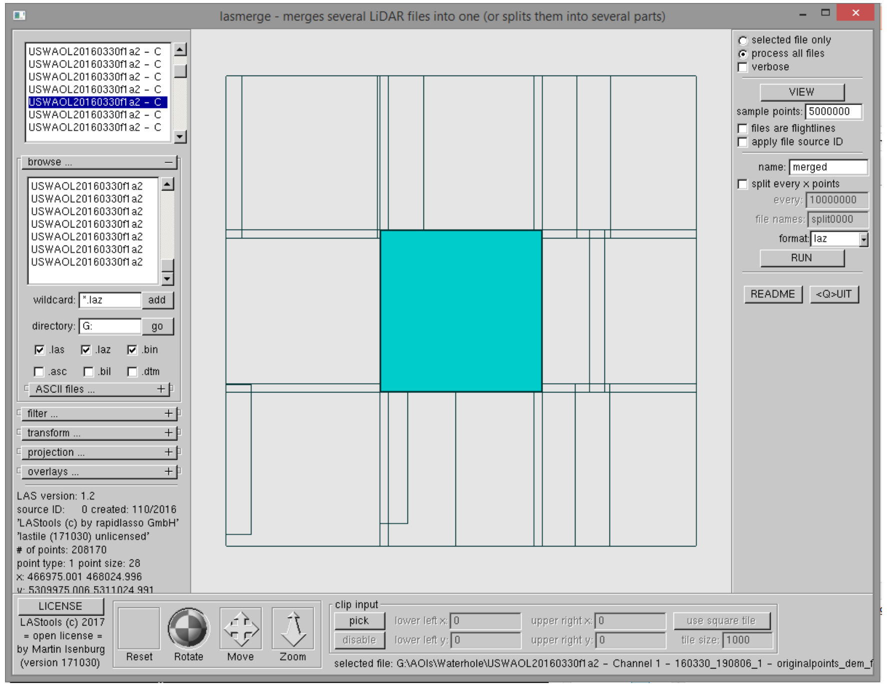
Canopy Cover (CC): Proportion of first return points above a threshold

$$CC = \frac{\#\, first\ returns > H}{\#\, all\ returns}$$

Canopy Density (CD): Proportion of points above a threshold

$$CD = \frac{\#\, returns > H}{\#\, all\ returns}$$

Merging / Stacking LAS File Tiles



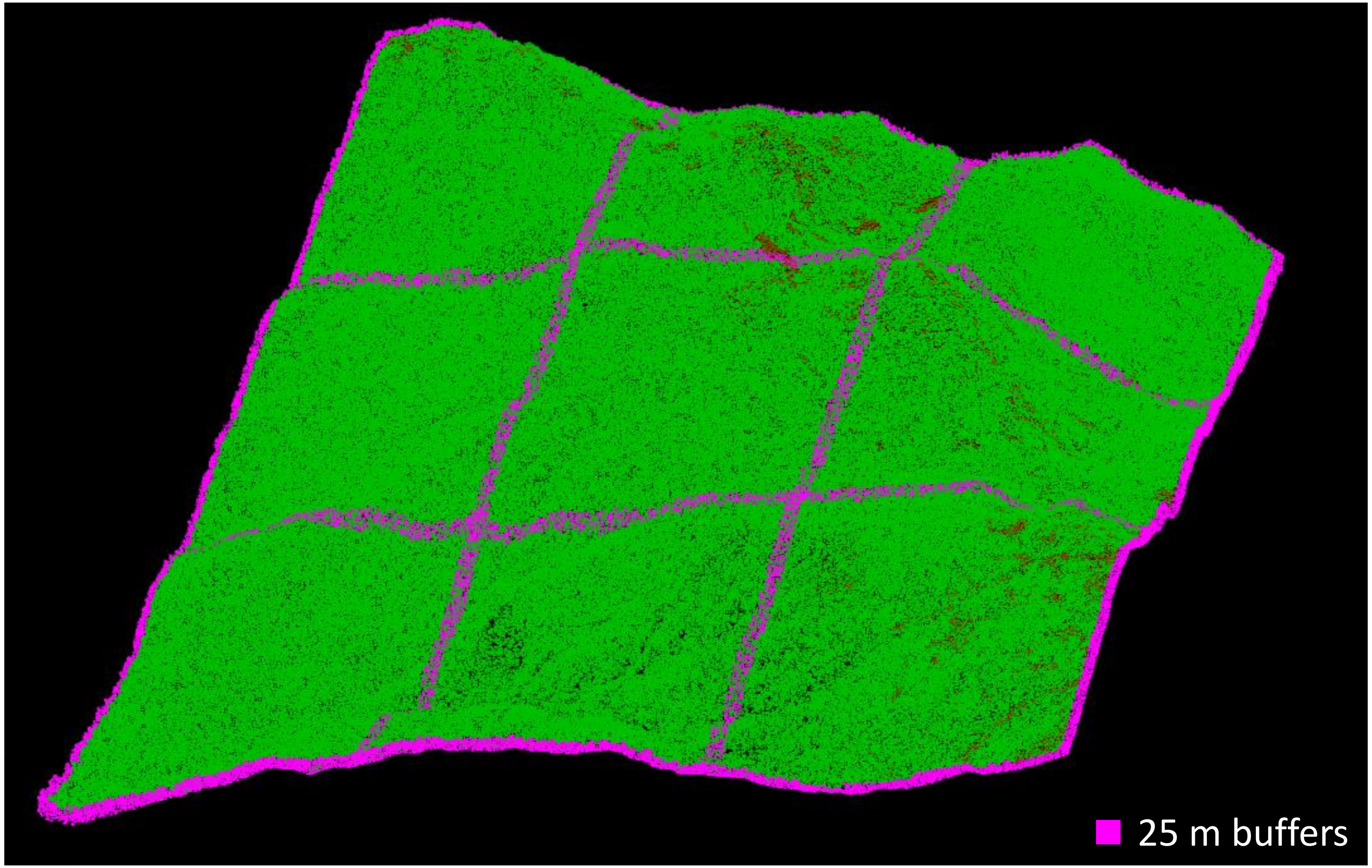
lastile – split original flightline LAS files into 1000 m^2 tiles

lasmerge – merge 3x3 tiles, from multiple flightlines, around AOI

Buffers to avoid “edge artifacts”

- Empty pixels, TIN “slivers”
- Classify as synthetic points for removing buffers later

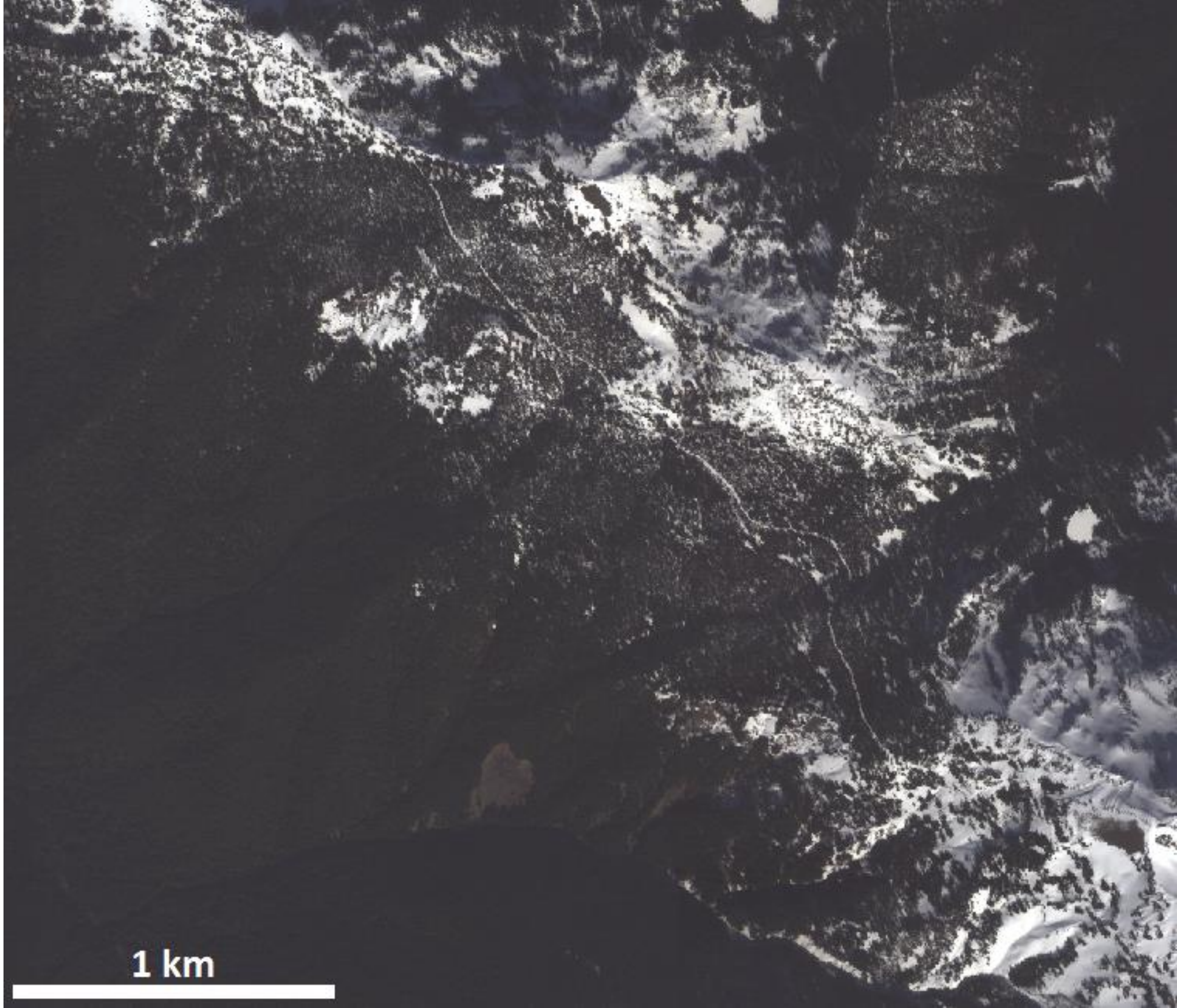
3x3 grid of tiles merged/stacked around area of interest



CASI Imagery

Waterhole

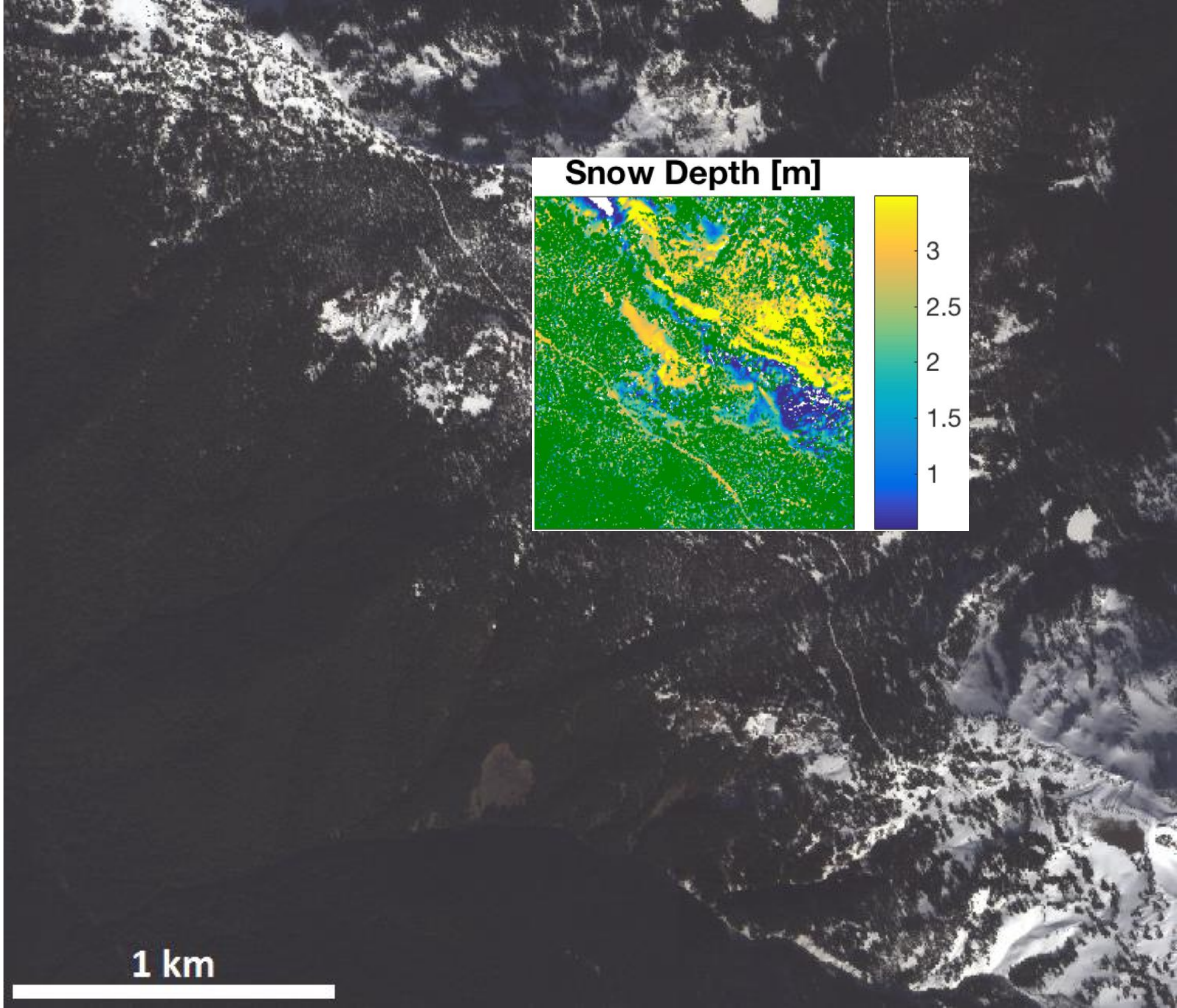
467818.94, 5310943.98 (10T) UTM



CASI Imagery

Waterhole

467818.94, 5310943.98 (10T) UTM

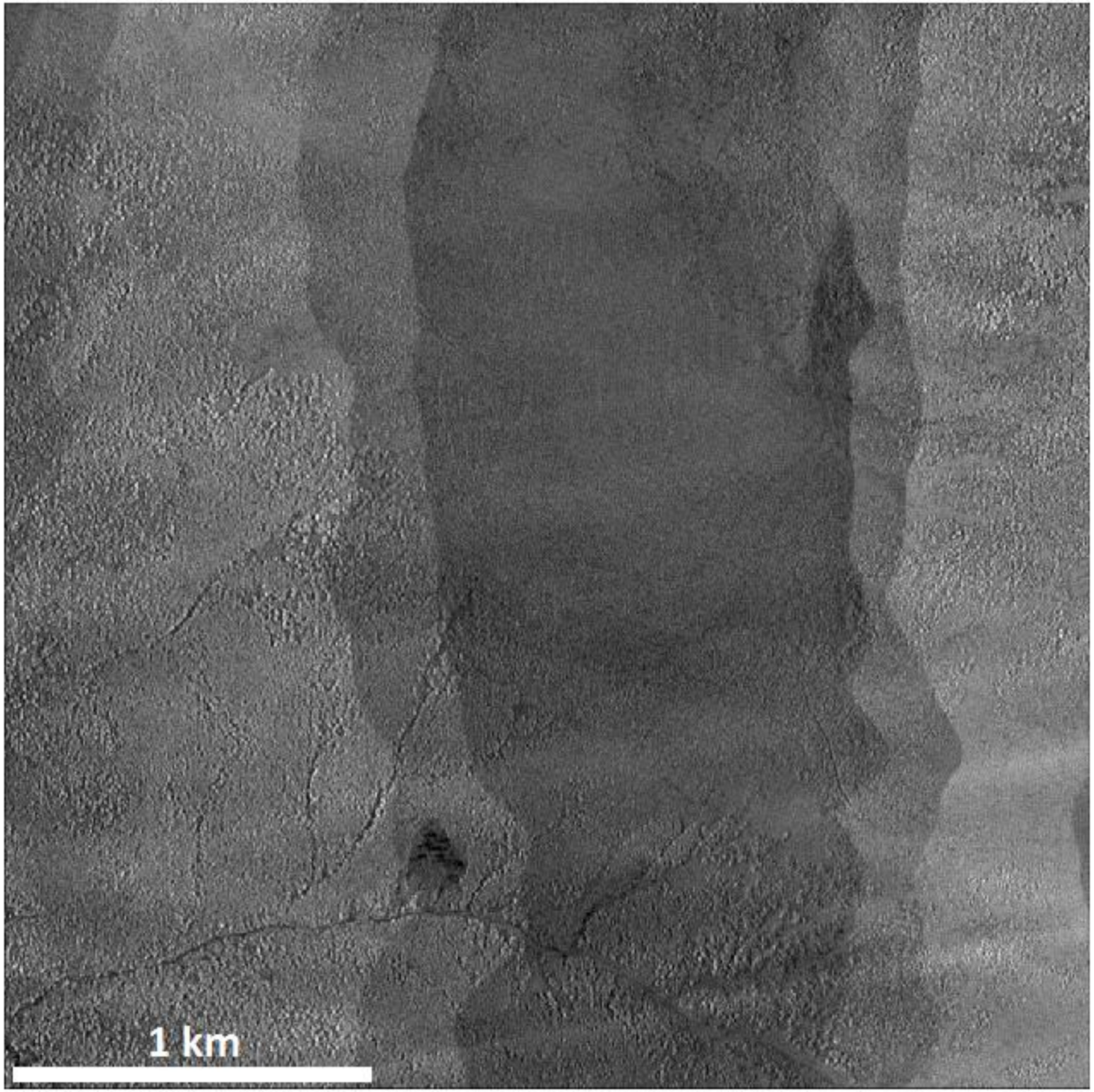


(Currier, n.d.)

1st Return Point Density

Waterhole

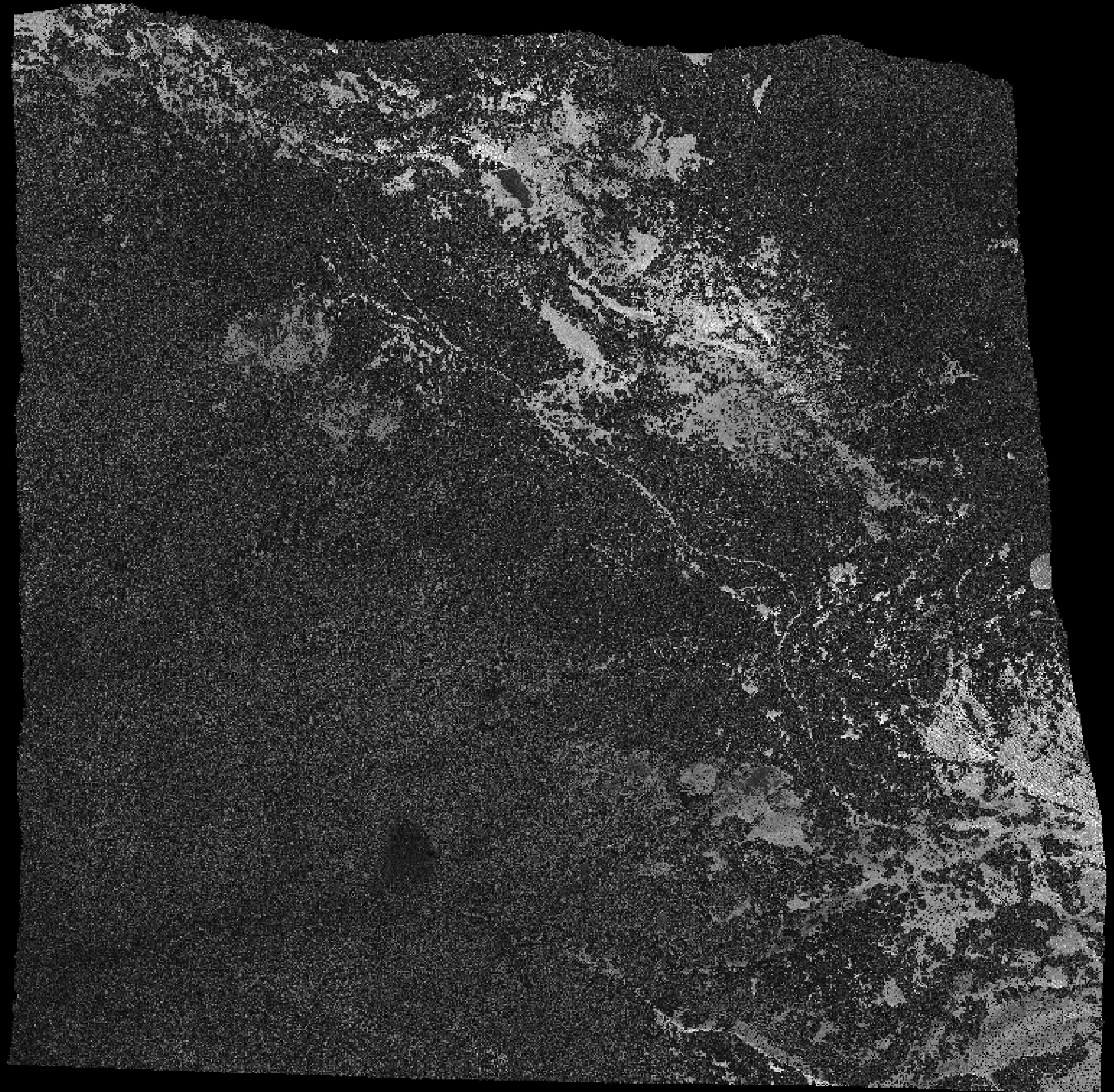
467818.94, 5310943.98 (10T) UTM



Merged LAS File

Waterhole

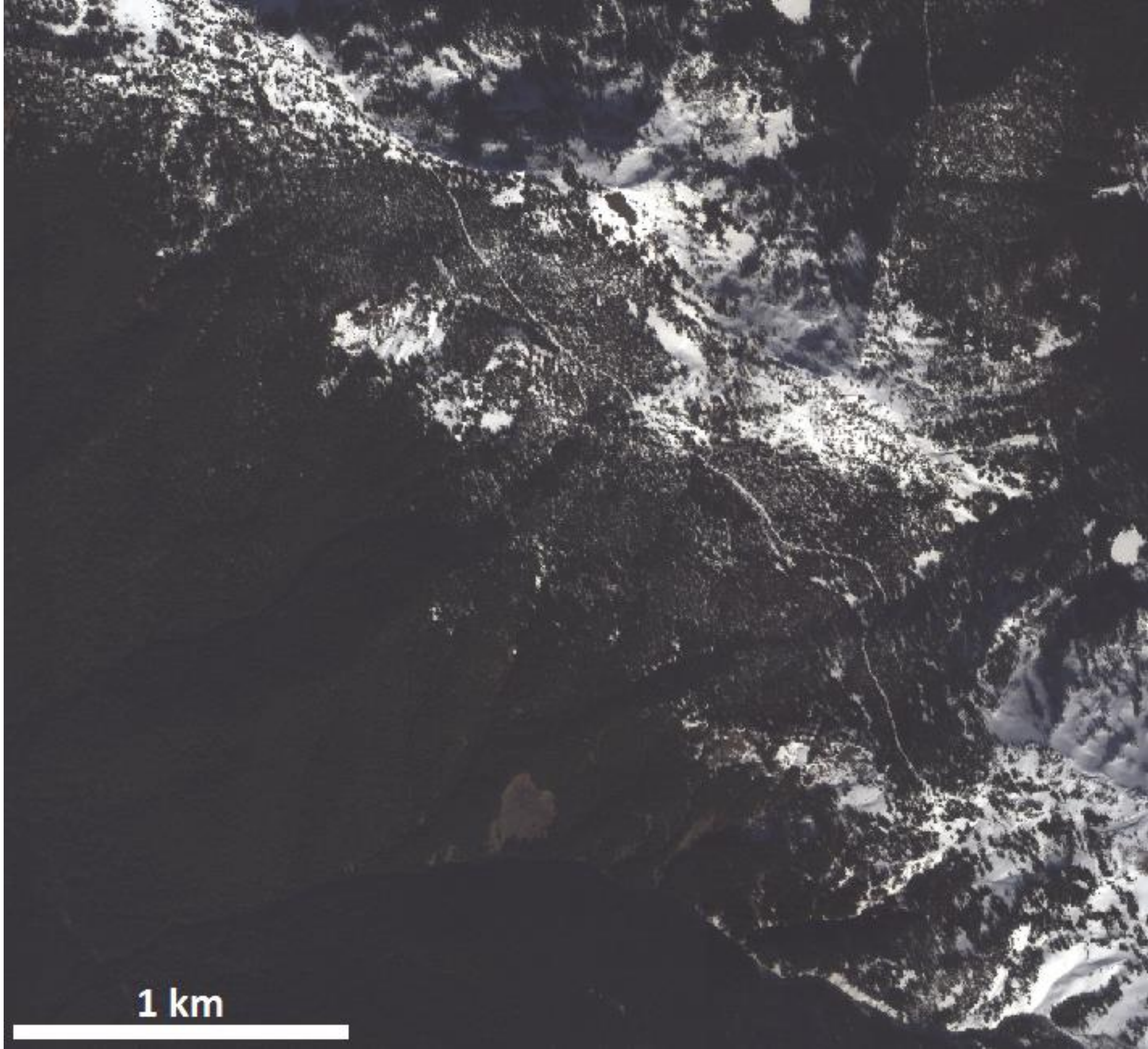
467818.94, 5310943.98 (10T) UTM



Ground Classification

Waterhole

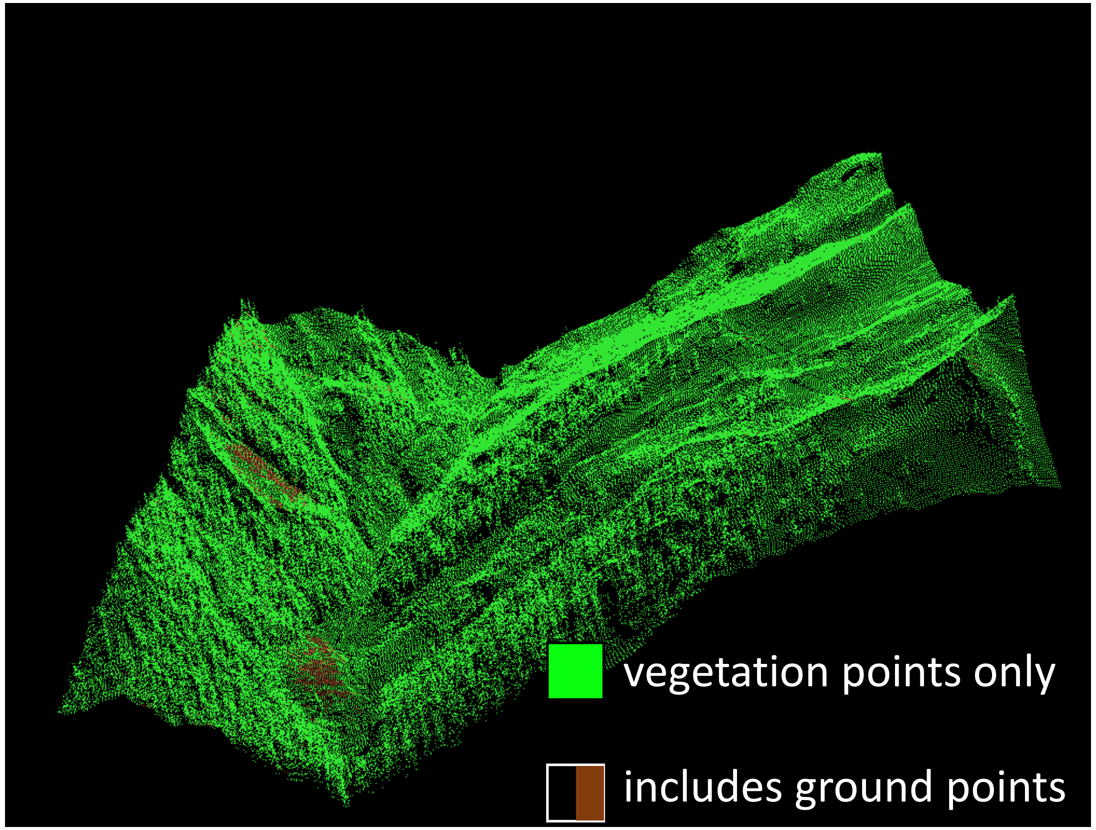
467818.94, 5310943.98 (10T) UTM

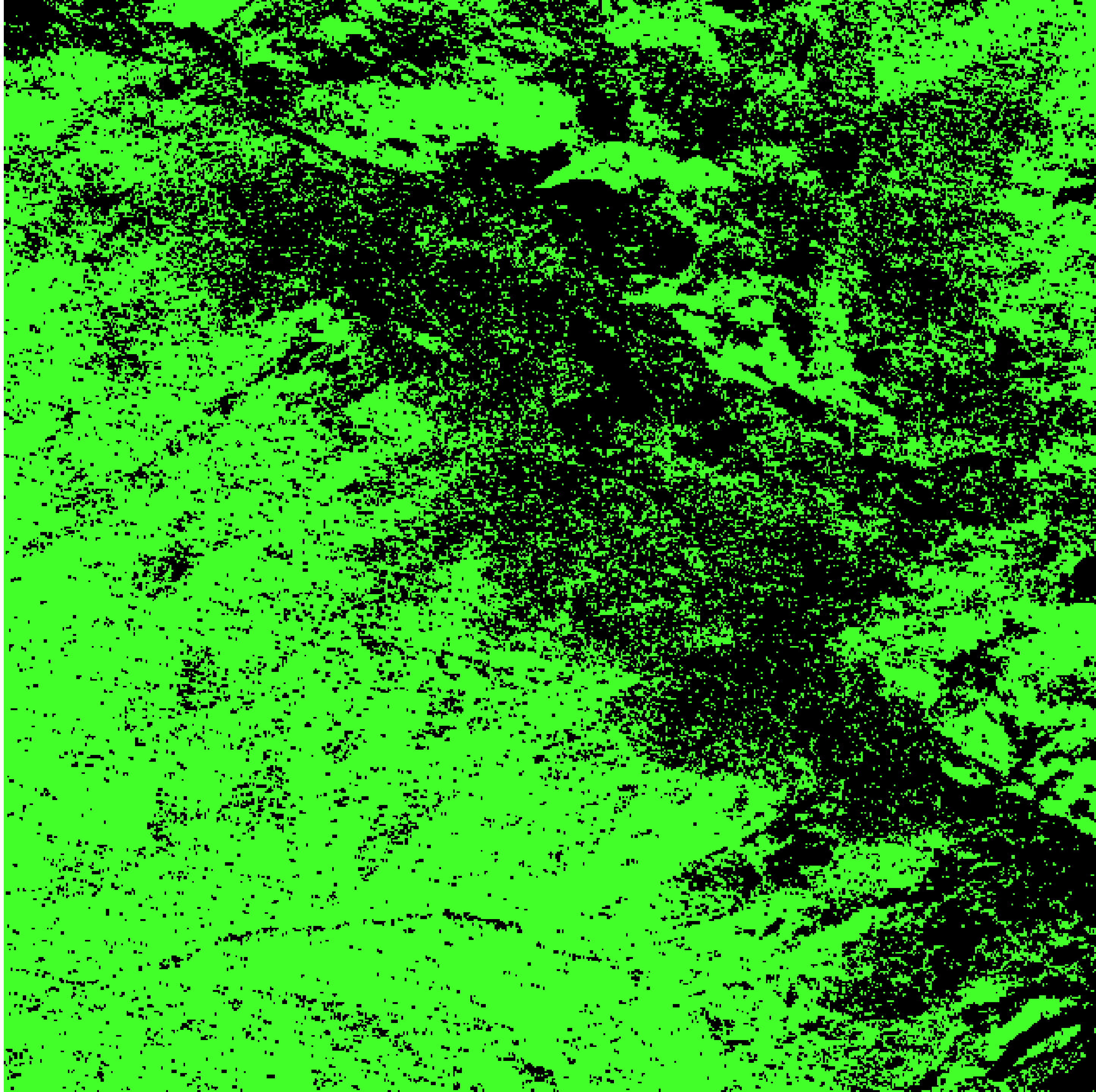


Ground Classification

- ASO LAS files:
  - Classified individual flightline LAS files
  - Classified as “**ground”** and “**not ground”**
  - Used MCC (Multiscale Curvature Classification)

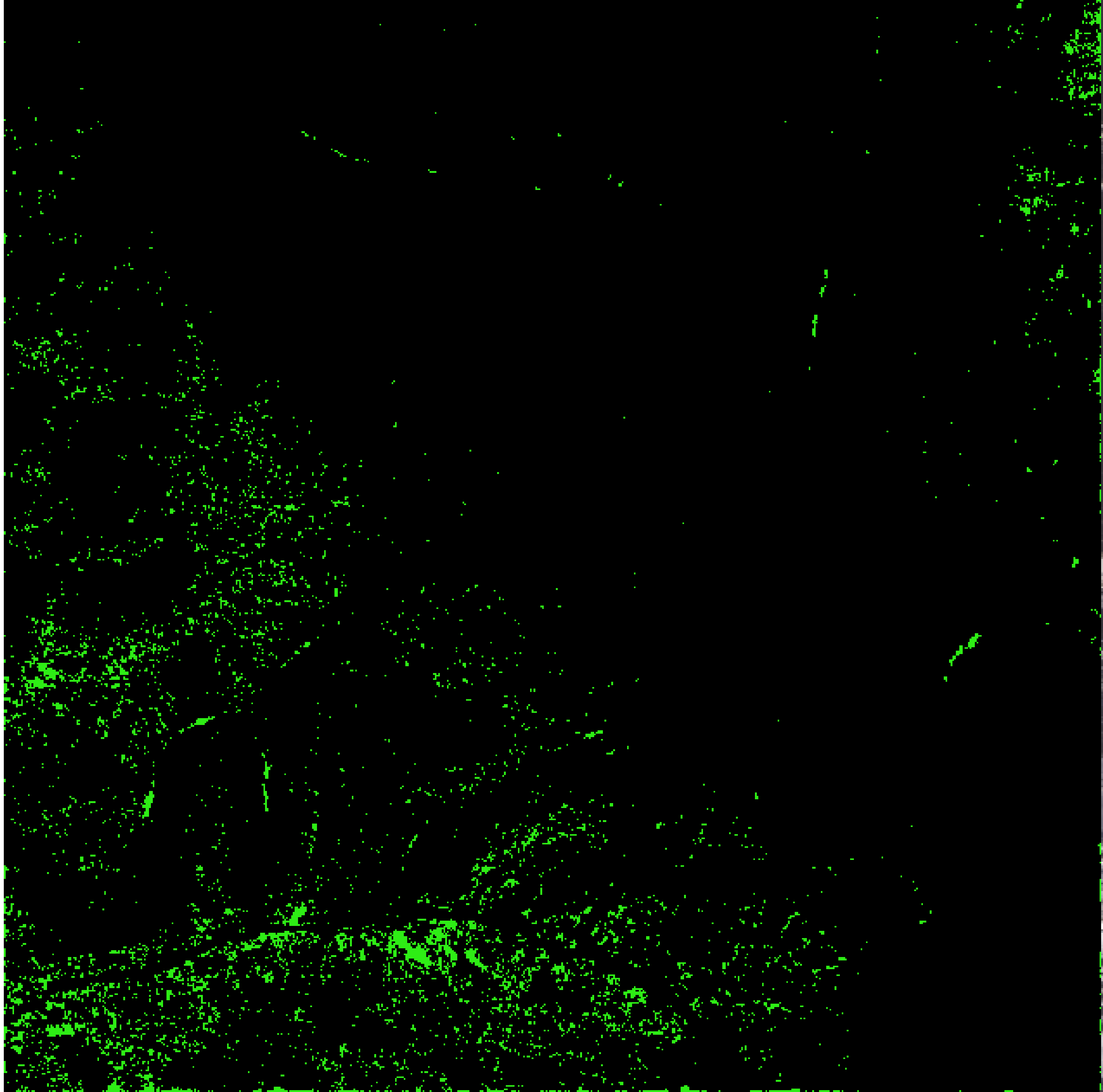
I want to try and get more ground points (snow surface in this case)





Ground Classification

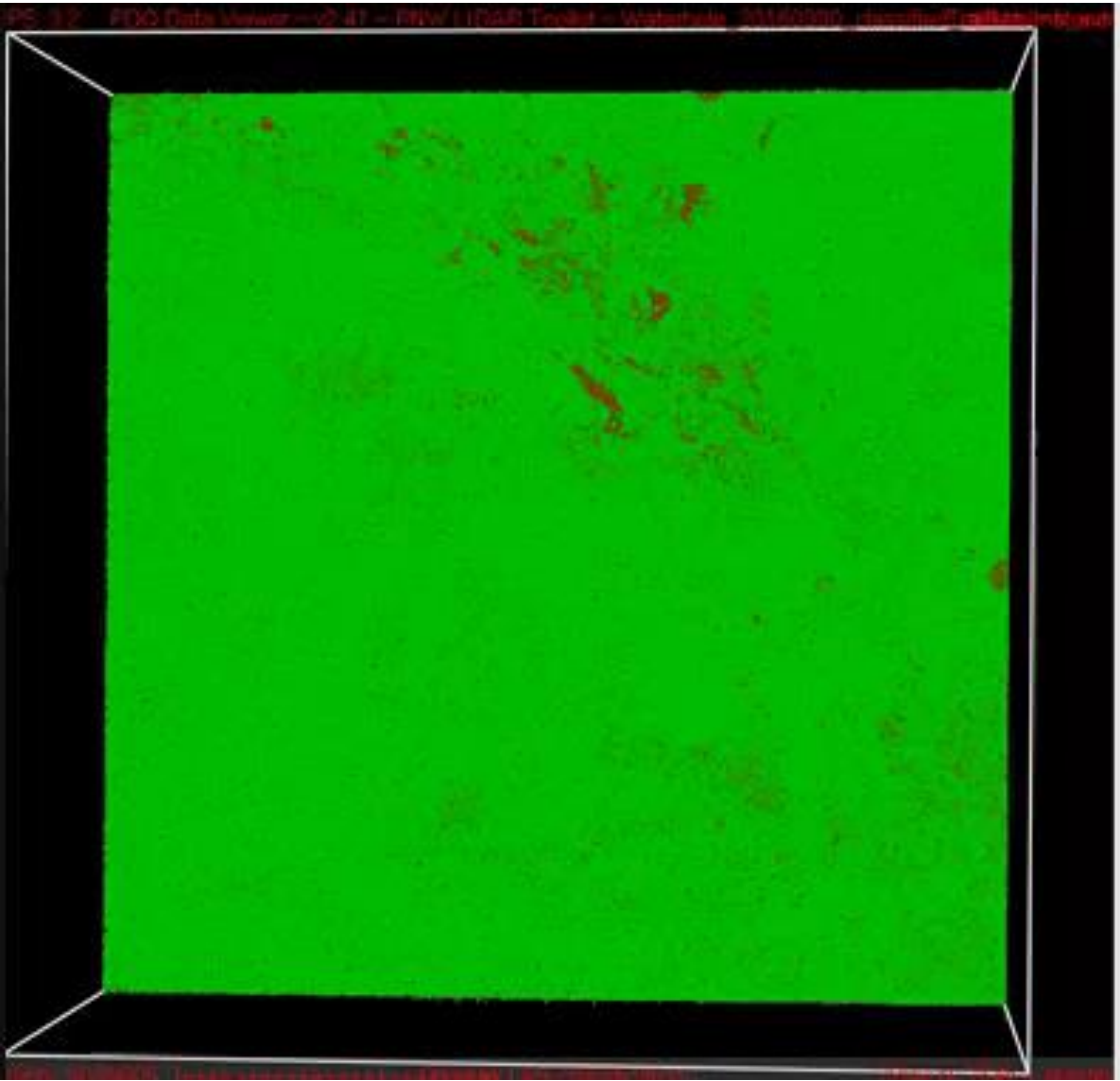
- **lasground**
    - Classifying layered/merged
    - Using all returns

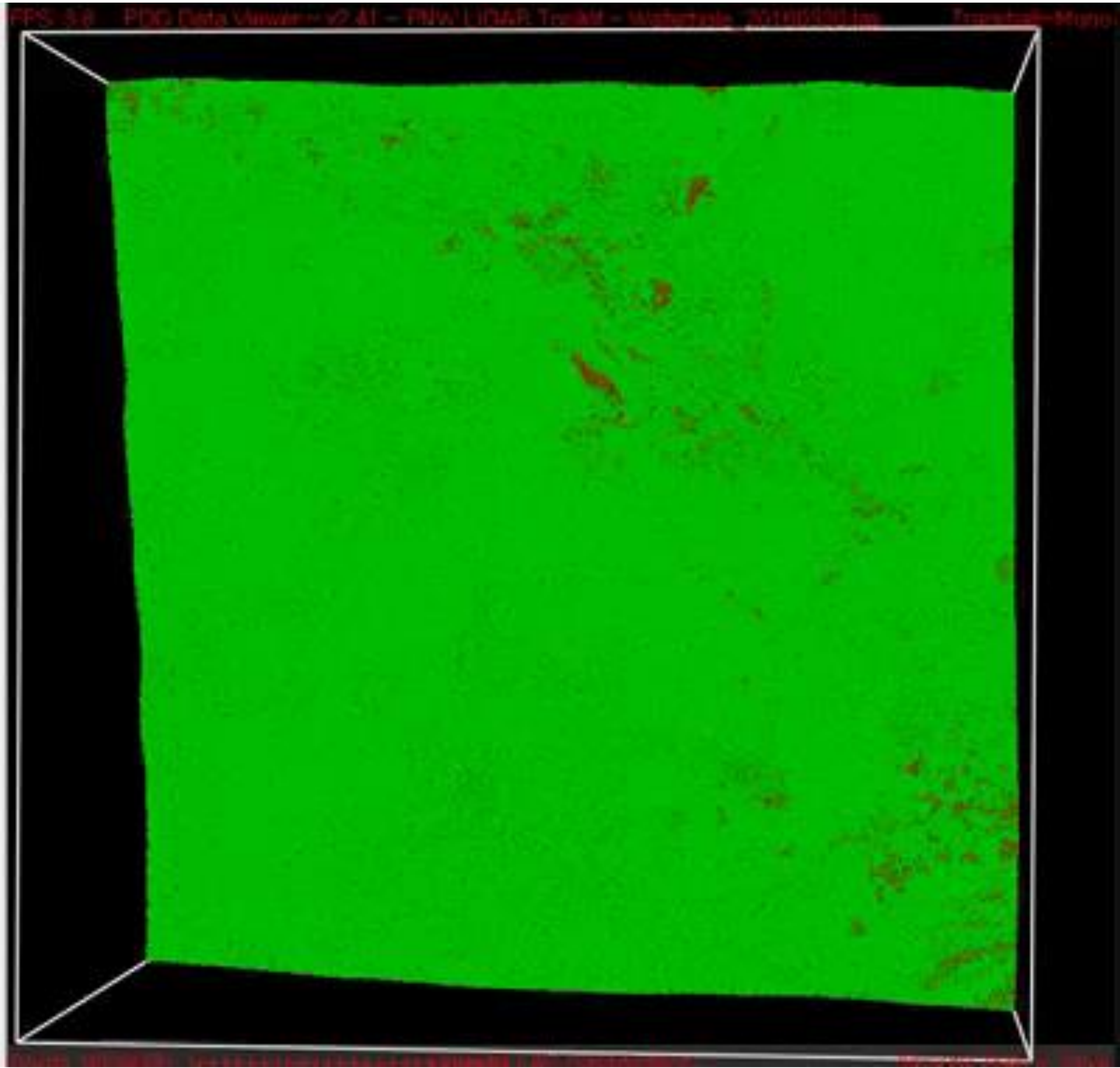


vegetation points only

includes ground points

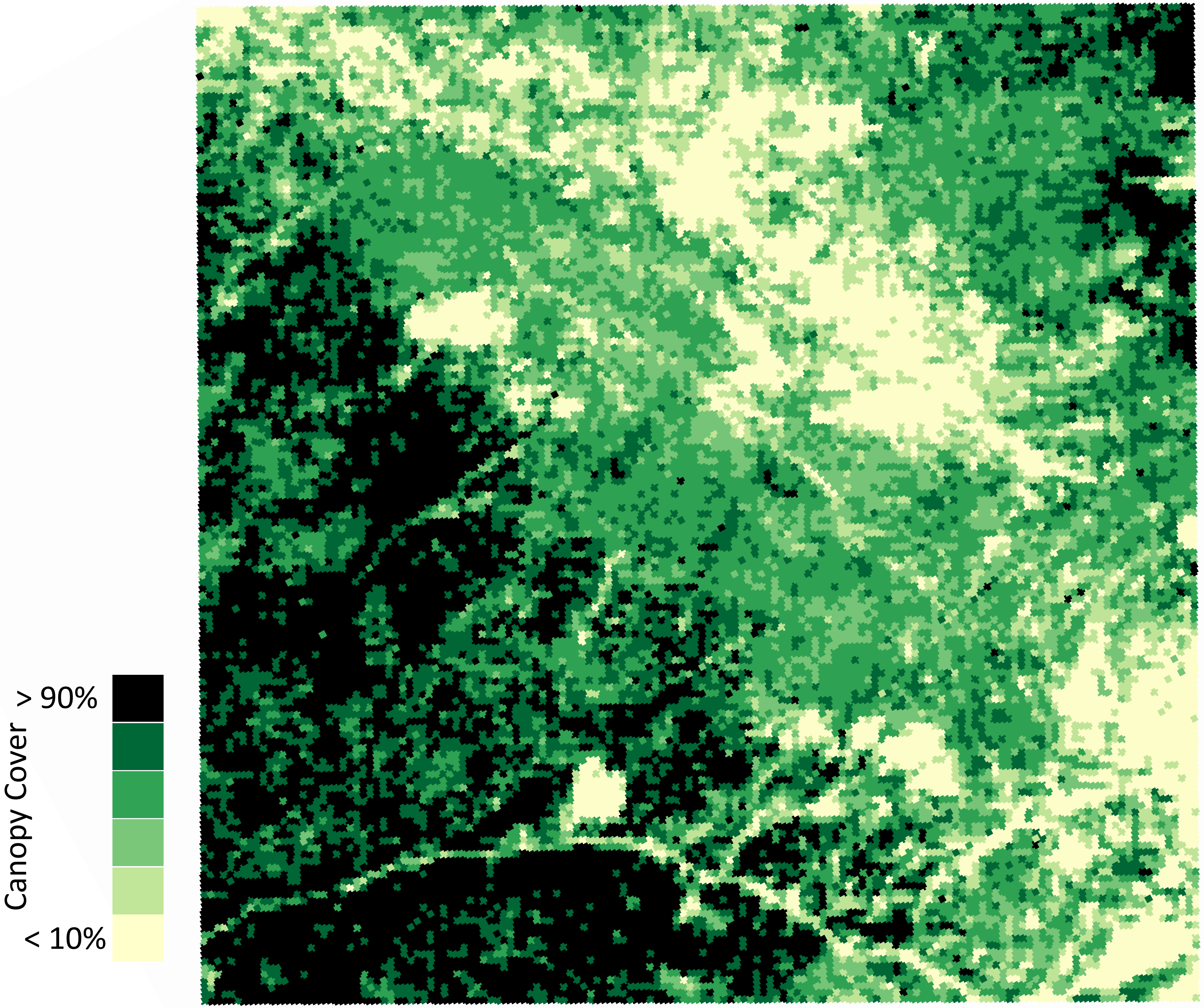
Ground Classification





Forest Metrics

- **lascanopy -**



Ground Classification

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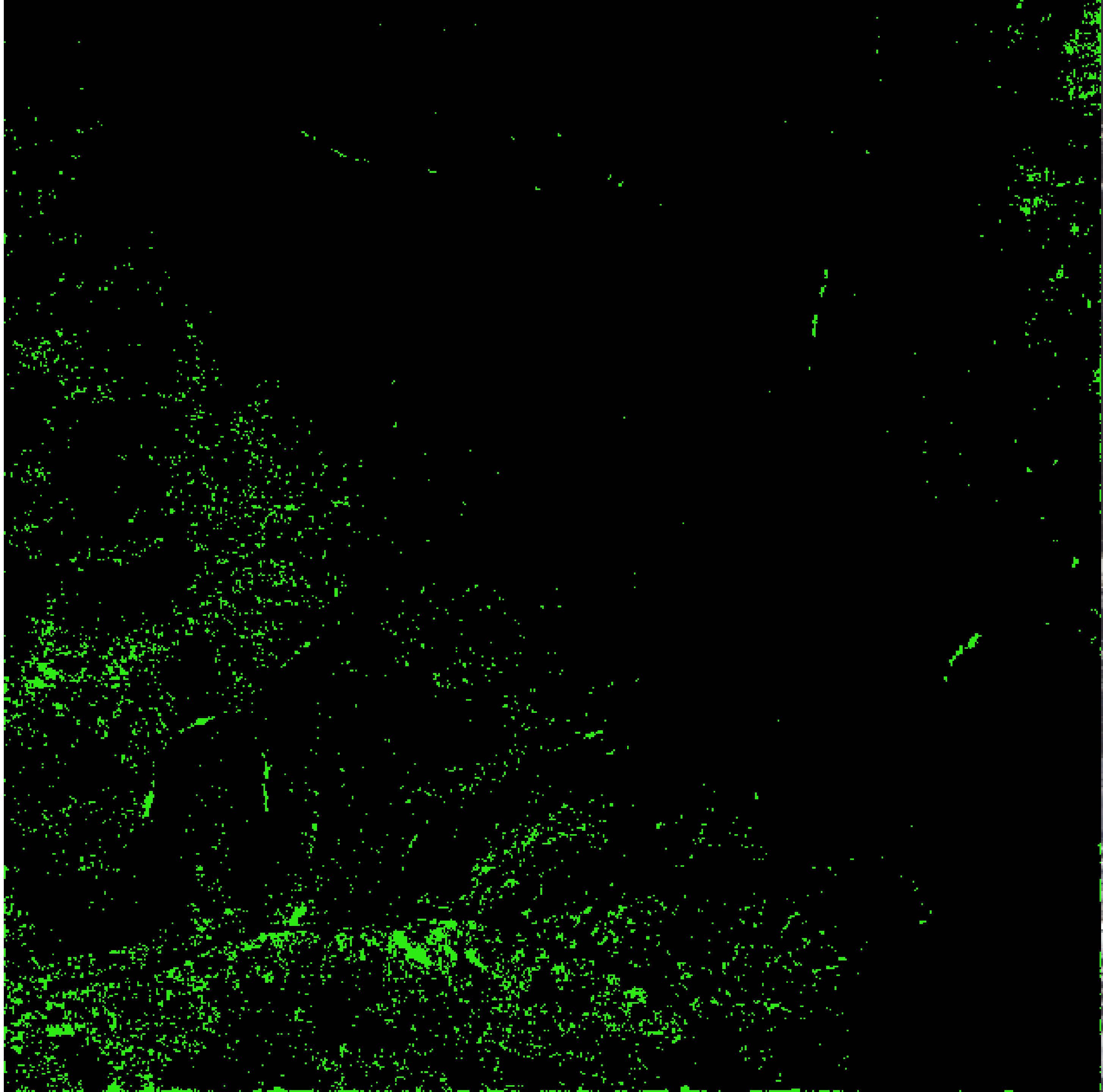
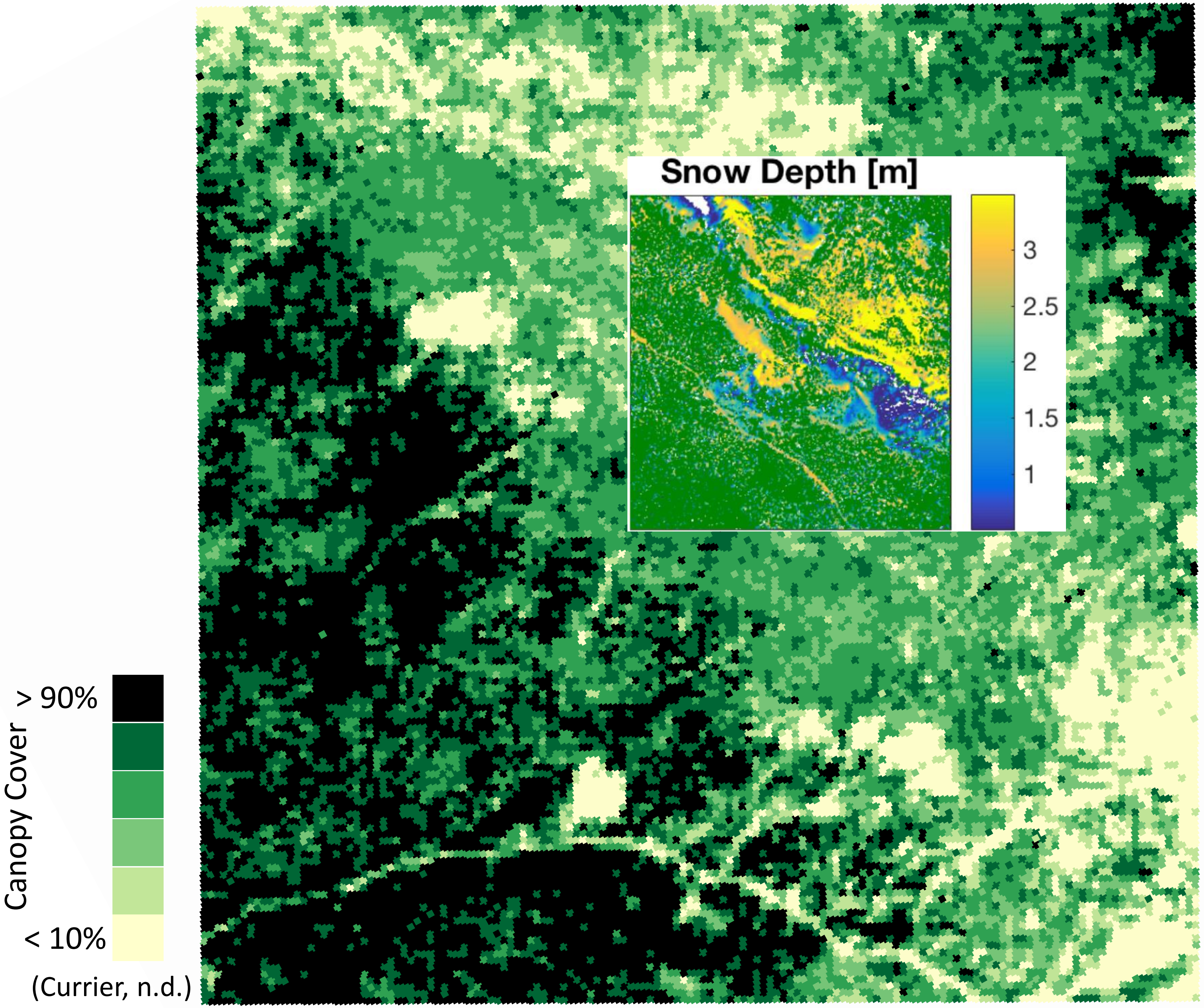


vegetation points only

includes ground points

Forest Metrics



Forest Metrics

- **Canopy Height**

- Hillslope-scale forest stand shape?
  - Linear stands "windbreaks"
  - Dense clusters
  - Sparse clusters