UNIVERSITY of GUELPH

CHANGING LIVES
IMPROVING LIFE

LiDAR data processing with Whitebox GAT workshop

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University of Guelph

Introductions

- Who am I?
- Who are you?

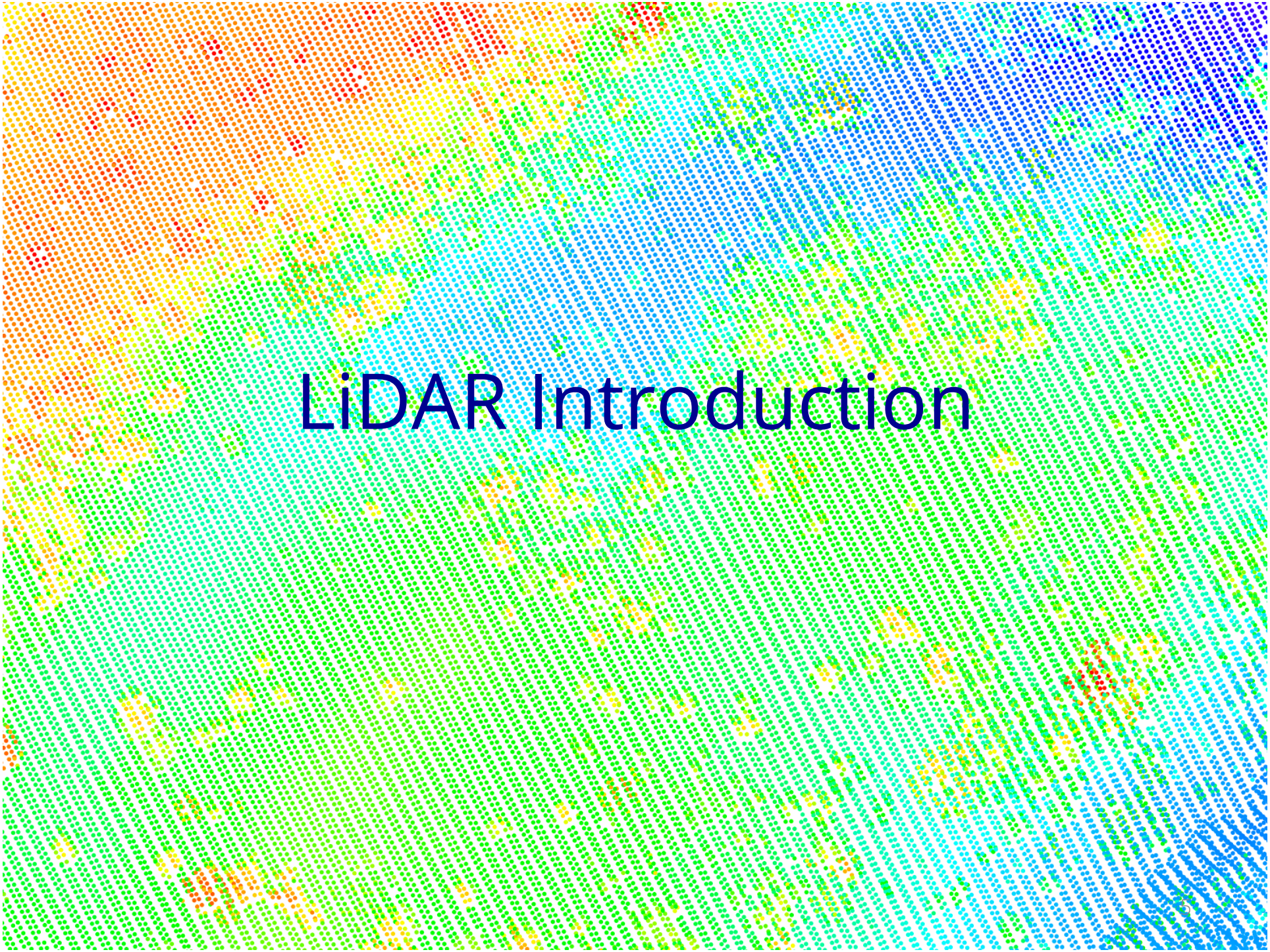
Introductions

- The agenda for today.
  - 9:30-11:00 LiDAR intoduction
  - 11:00-11:15 Short break
  - 11:15-12:00 Discussion: LiDAR acquisition and commons issues
  - 12:00-1:00 Lunch
  - 1:00-4:00(ish) LiDAR technical training with Whitebox GAT

Introductions

- This is meant to be informal, so feel free to ask questions or interject at any point.

- I'll post these slides and other resources for today's workshop for later reference.

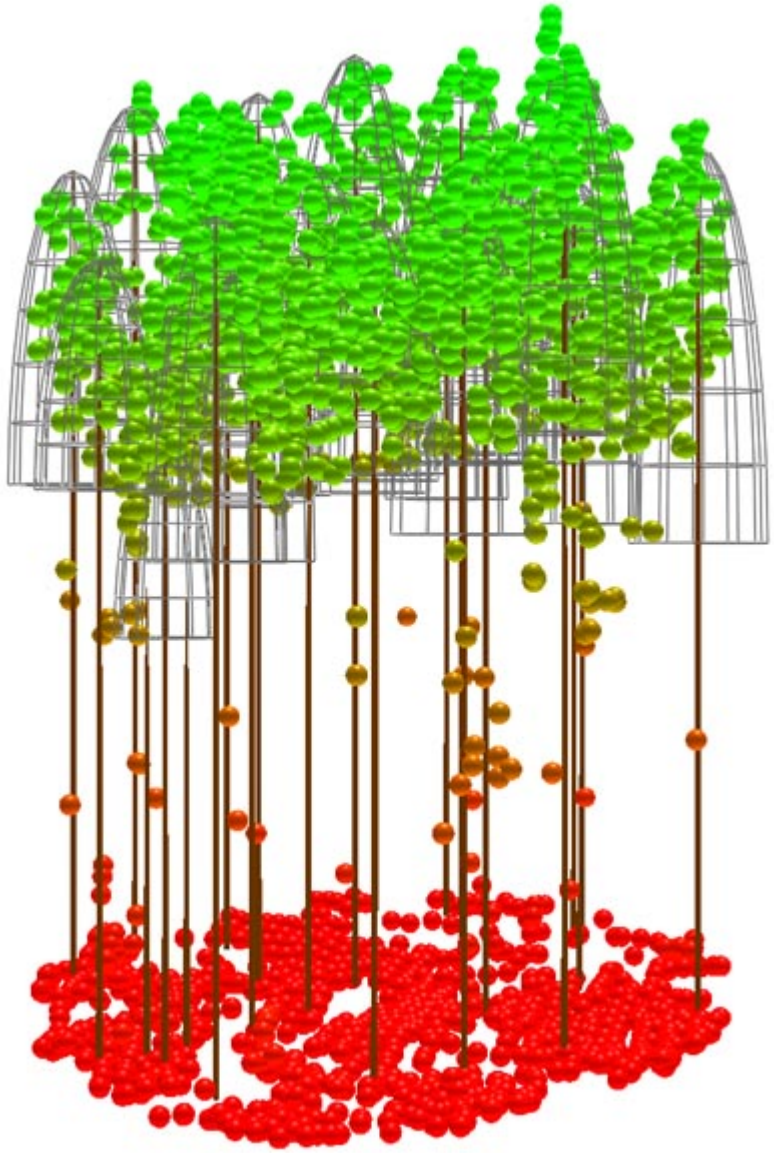

LiDAR Introduction

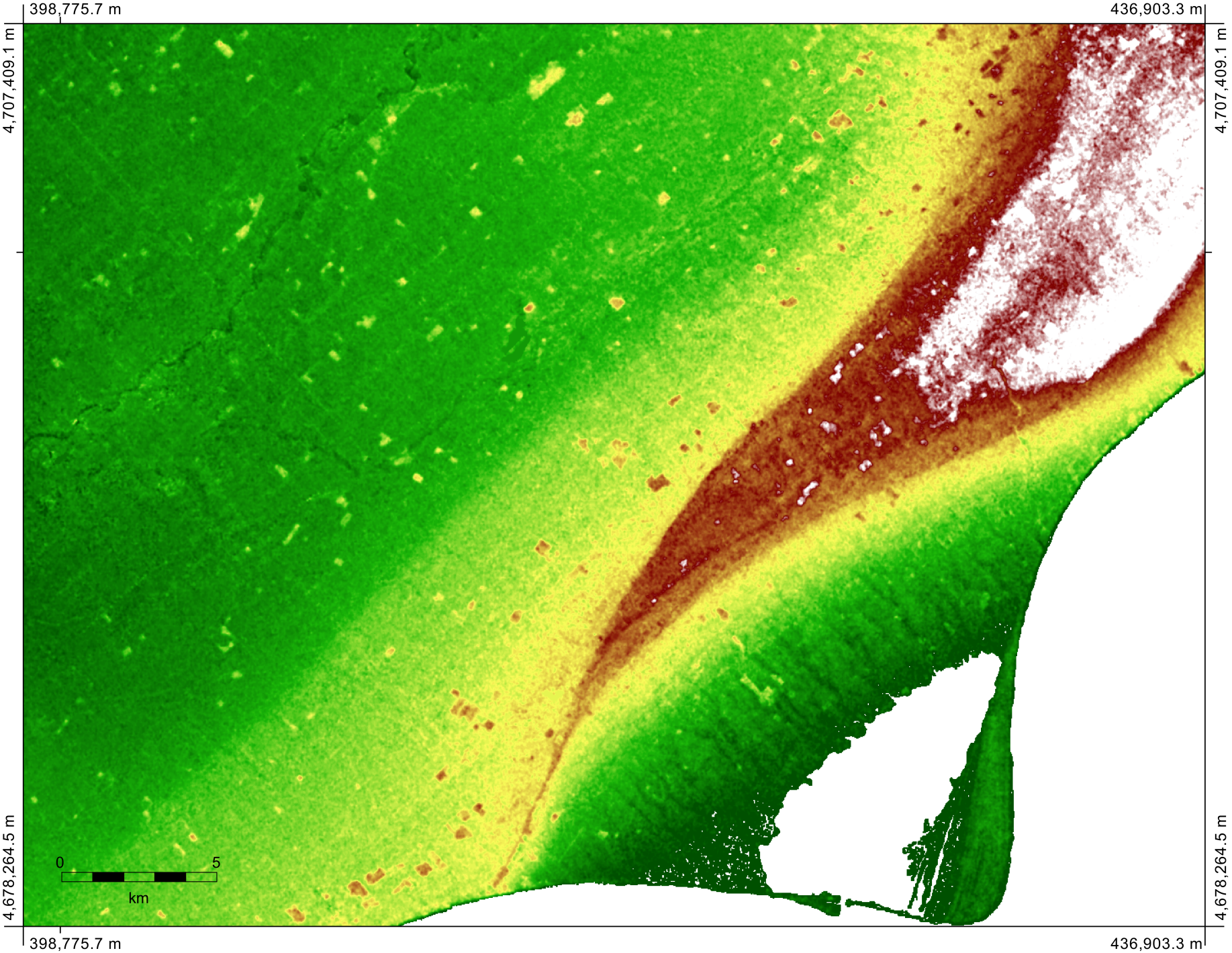
What is LiDAR?

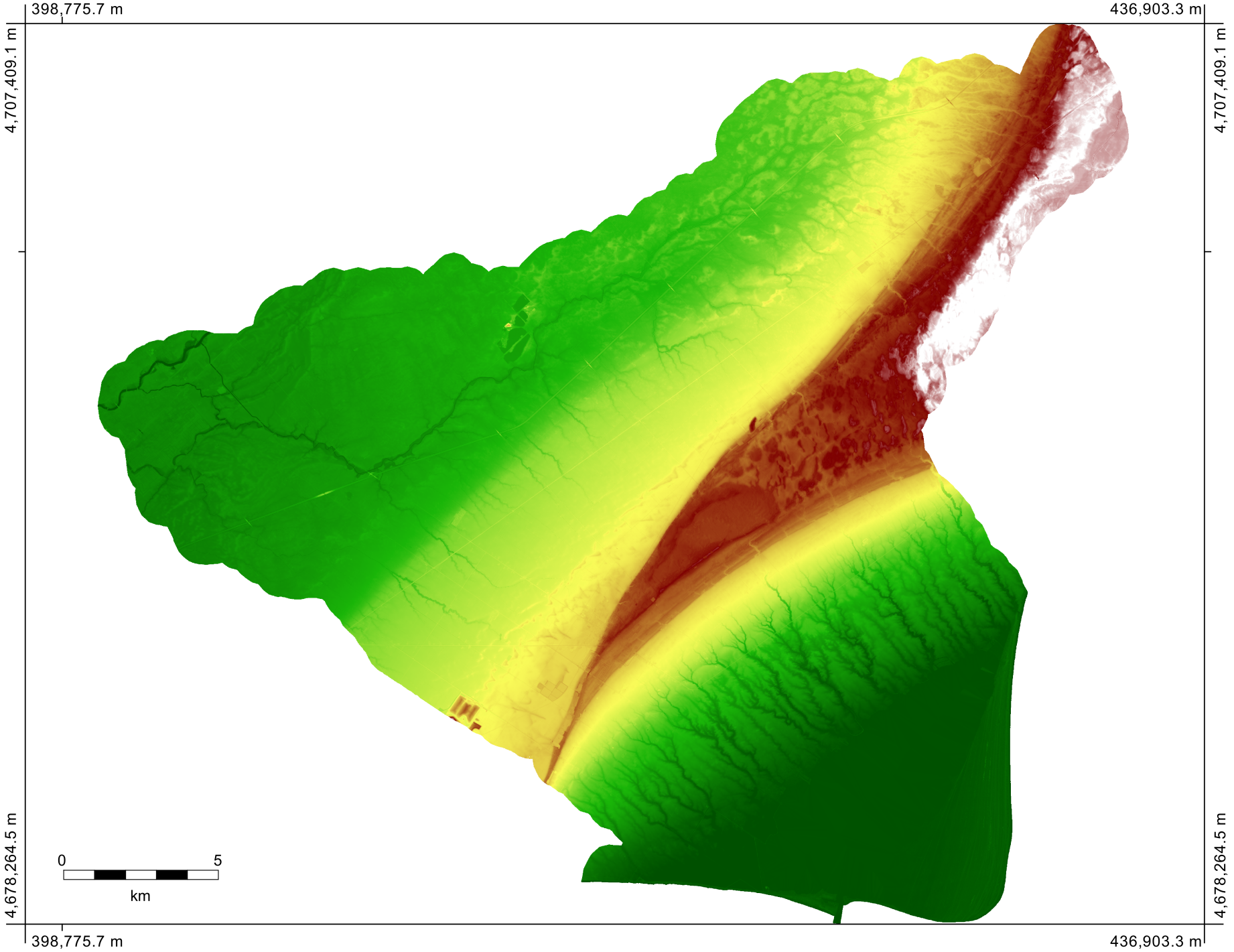
- LiDAR, specifically laser scanning, is a terrain mapping technology.

Why LiDAR?

- LiDAR is the gold standard of modern terrain mapping.
- It can characterize surfaces with a very high point measurement density and positional accuracy.
- It is the only terrain mapping technology that works reasonably well under heavy vegetation cover.
- Also useful for feature extraction and vegetation structure modelling.




398,775.7 m
436,903.3 m
4,707,409.1 m
4,678,264.5 m
0
5
km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398,775.7 m
436,903.3 m
0
5
km

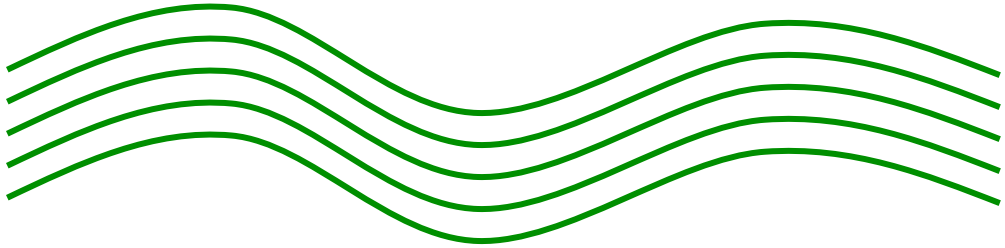
What is LiDAR?

- Light Detection And Ranging (LiDAR)
- An active remote sensing technology much like radar.
- The light that LiDAR emits/detects is in the visible to NIR range just like other forms of remote sensing…but it's laser light.

Laser Light

- A laser is a beam of highly pure (a single wavelength), highly focused (i.e. it does not diverge significantly), and coherent light

Regular light



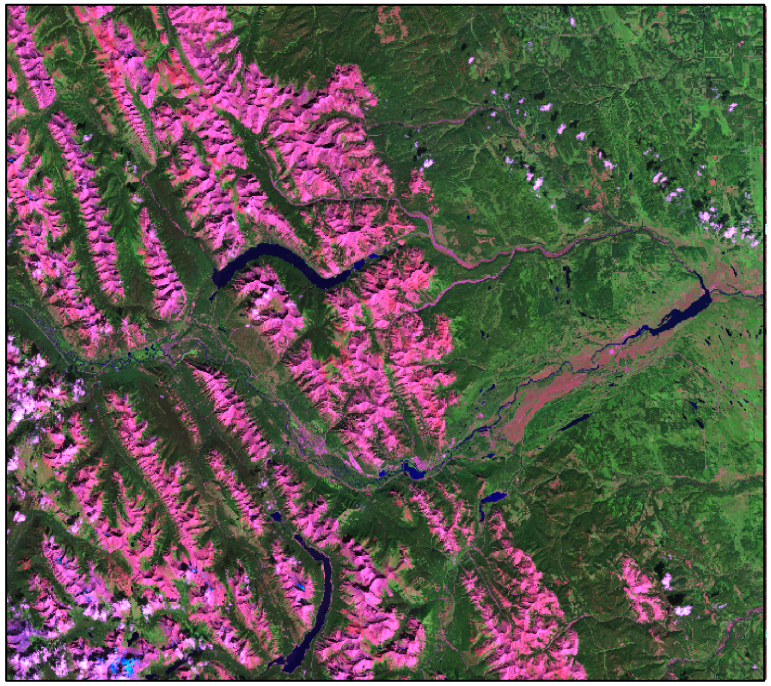
Coherent laser light

LiDAR is not an imaging sensor

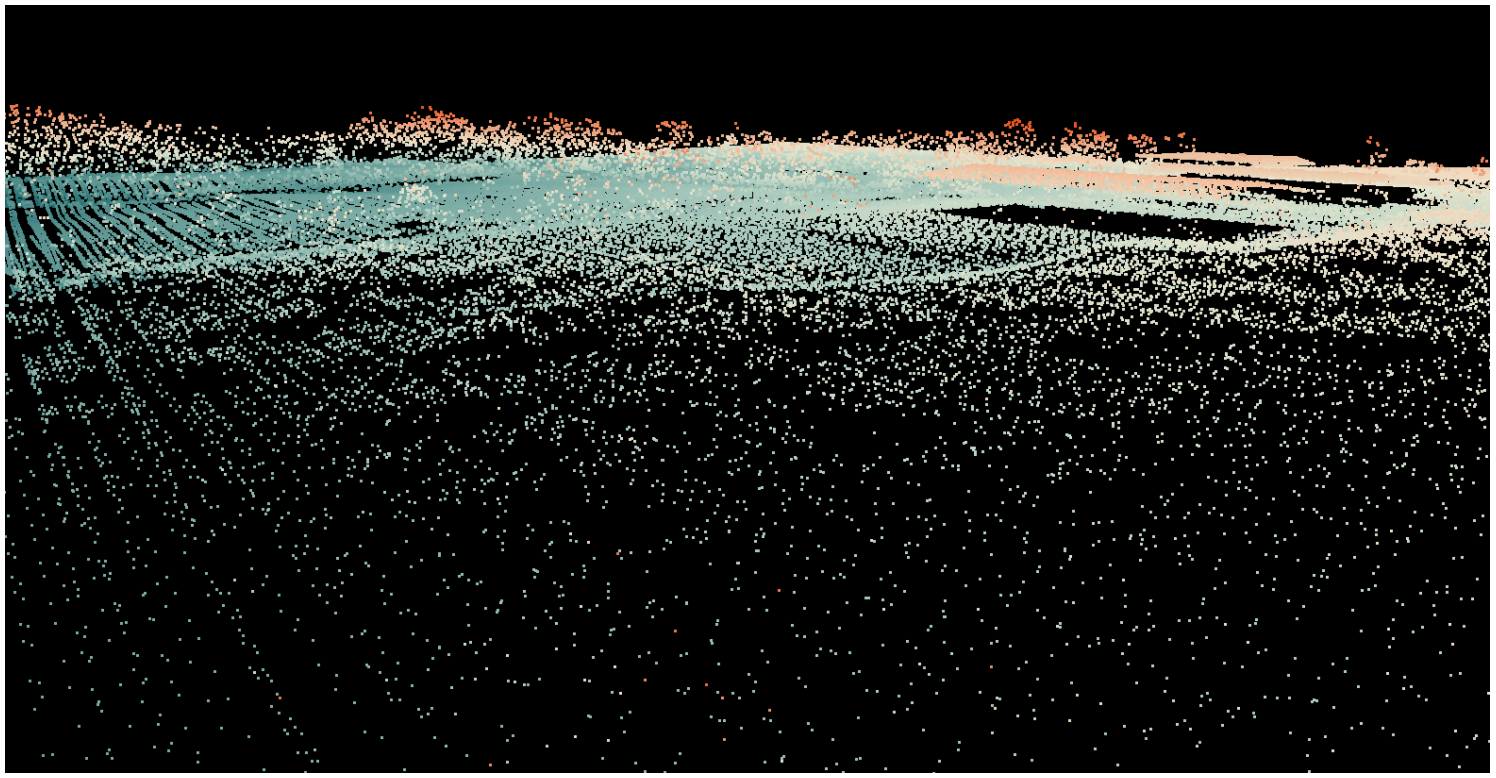
- Unlike most remote sensing devices, a LiDAR's end product is not an image.
- LiDAR is a ranging device not an imaging sensor.

Imaging vs. ranging

- What is the inherent property of the surface that is being measured in this image?
- A LiDAR sensor is instead measuring the distance to the surface and can be used to characterize surface topography.



LiDAR sensors create point clouds



The colours associated with each point in this figure are measures of surface height and not the intrinsic brightness of the reflecting surfaces.

Scanning LiDAR

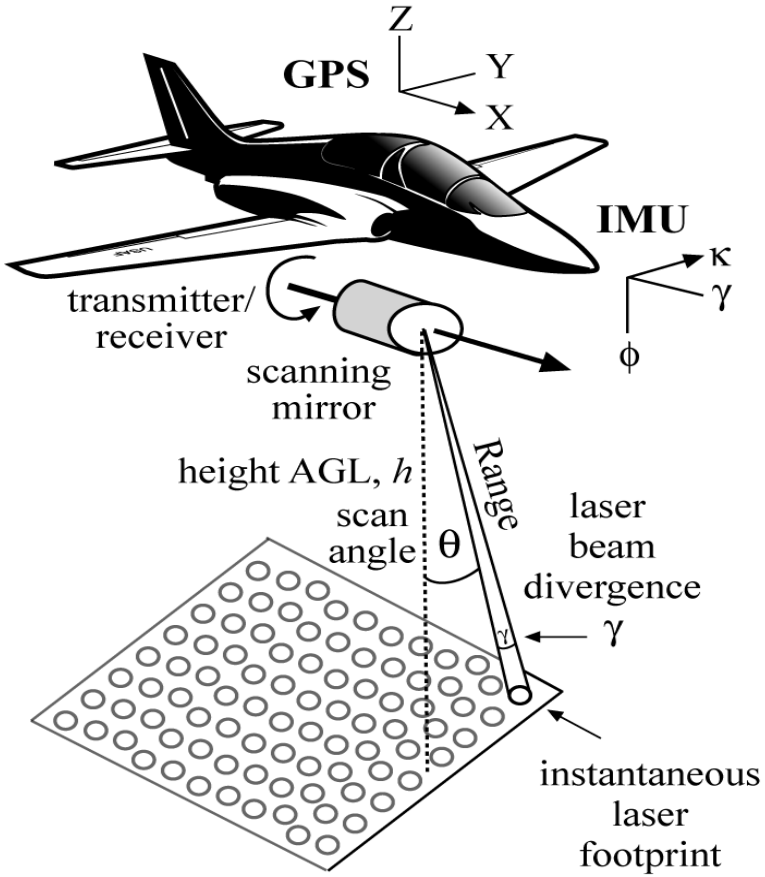
- Primarily used for topographic surveying, i.e. creation of digital elevation models (DEMs).
- Similar to deriving DEMs from photogrammetry except you cannot select the points measured, e.g. breaklines.
- It's a brute force technique.
- Avoids the need to orthorectify because each point is individually georeferenced from the time of measurement.

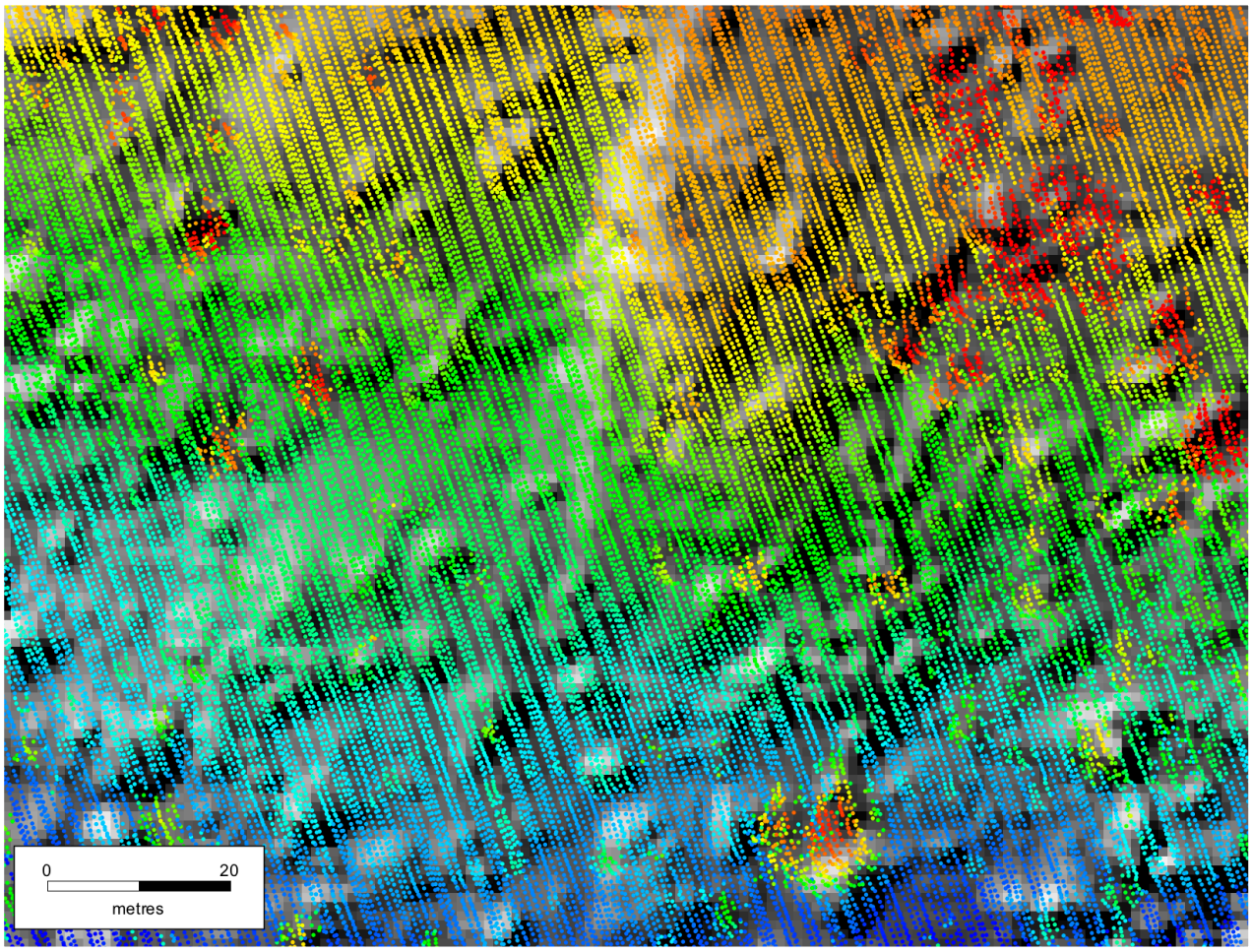
How does it work?

- Each time the laser is pulsed:
  - Laser generates an pulse
  - Pulse is reflected off an object and returns to the system receiver
  - High-speed counter measures the time from the start pulse to the return pulse and its intensity
  - Time measurement is converted to a distance
  - The distance to the target and the position and orientation of the aircraft is then used to determine the elevation and location
- Typically 100,000+ pulses/second

How does it work

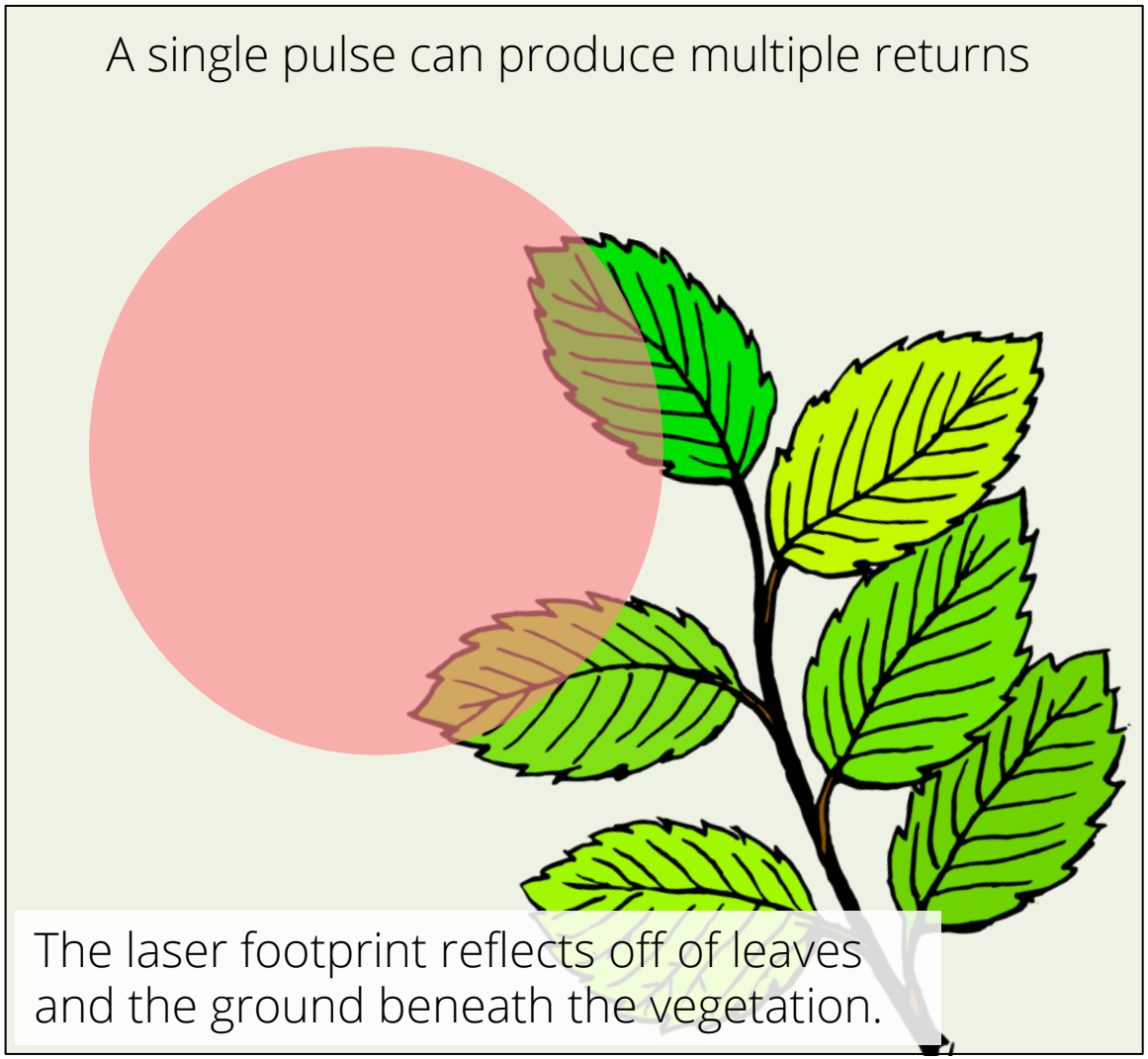
- It is reliant on several technologies:
  - Powerful lasers
  - Global positioning system (GPS)
  - Inertial measurement unit (IMU)
  - Highly precise clocks



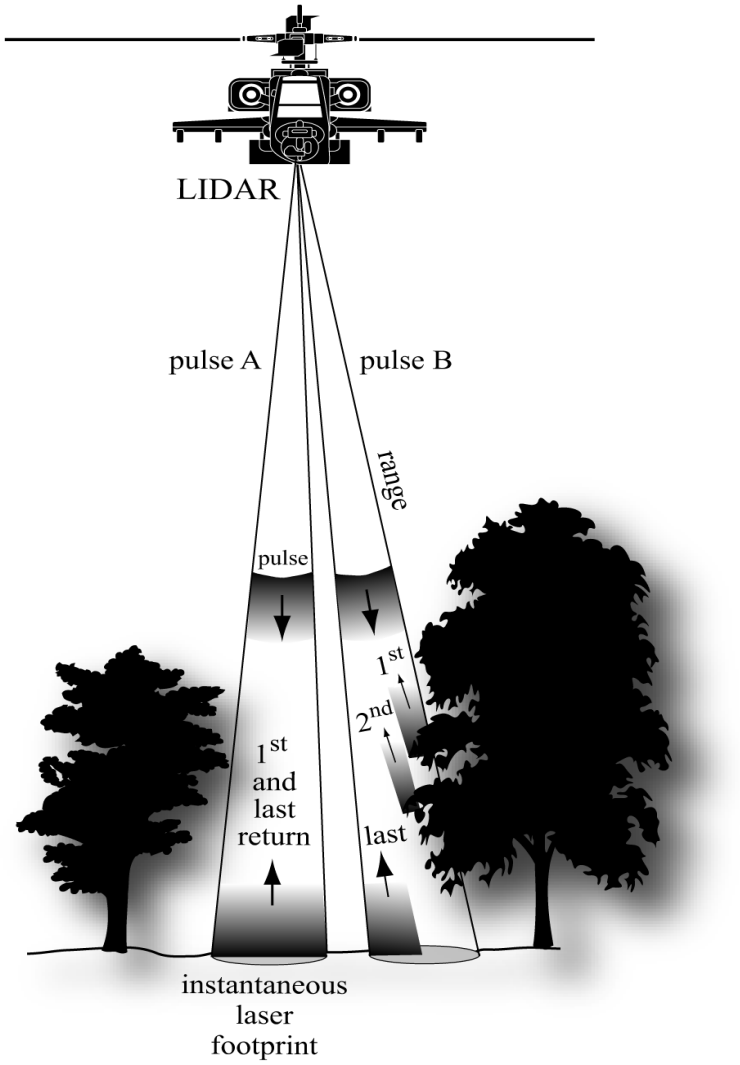


Point density can vary spatially, but an average of at least 1 point m^{-2} is quite common➔ upwards of 20 points m^{-2}

Multiple LiDAR returns



Multiple LiDAR returns



- 1st return
- *n* intermediate returns
- Last return

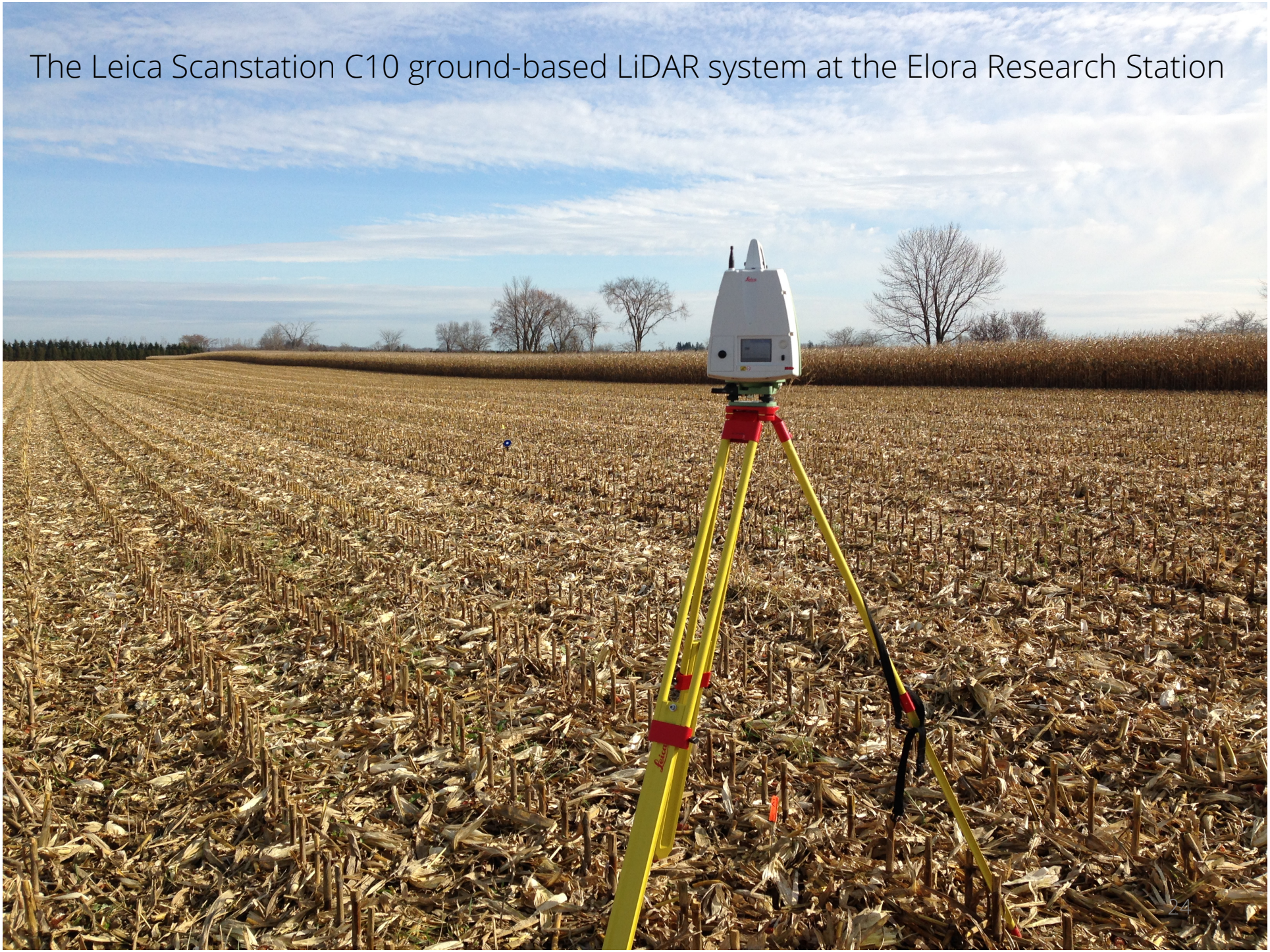
- The last return will be closest to the ground.
- This is what is known as a *discrete LiDAR system.*
- There are also full-waveform LiDAR systems.

LiDAR Platforms

- Airborne platforms provide much of the LiDAR data currently used.
- Usually collected by commercial data providers, much like aerial photography.
- Requires precise positioning (location and orientation) of the aircraft at all times during the survey.
- Drones are becoming an increasingly important airborne platform.

LiDAR System Platforms

- Terrestrial (ground-based) LiDAR system are used for very detailed (<cm) topographic surveys.
- Can be mounted on a tripod (static) or on a mobile platform like a car.

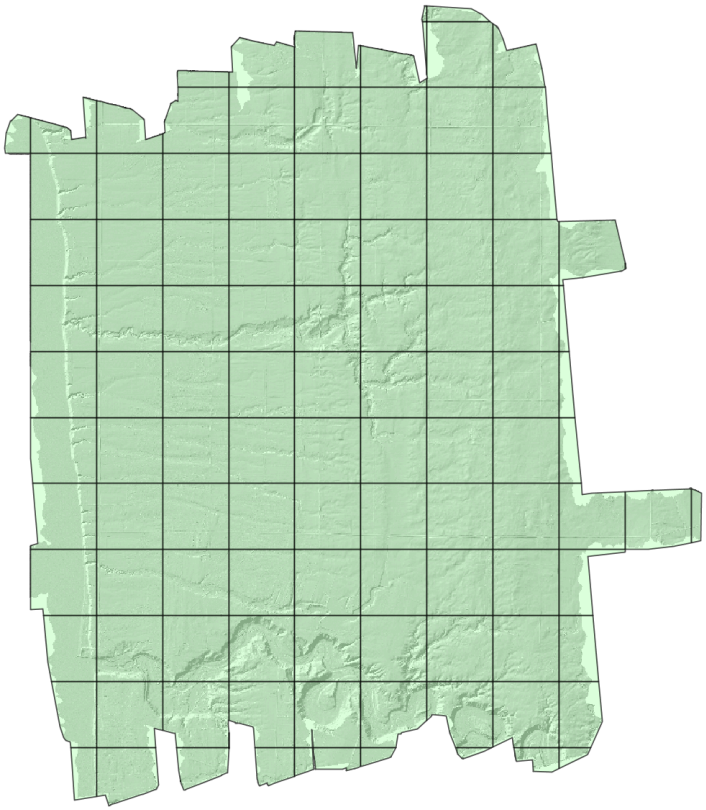


The Leica Scanstation C10 ground-based LiDAR system at the Elora Research Station


Point cloud from a terrestrial LiDAR system
Shadow areas are more extensive

Point cloud data storage

- The millions of LiDAR points in a project are usually broken up into regular tiles.



The Gully Creek LiDAR data set was broken into 108 1.0 km^2 tiles, with each tile containing around 2.5 million points from one or more overlapping flight-lines.

At some stage in the workflow, you need to mosaic the individual DEMs.

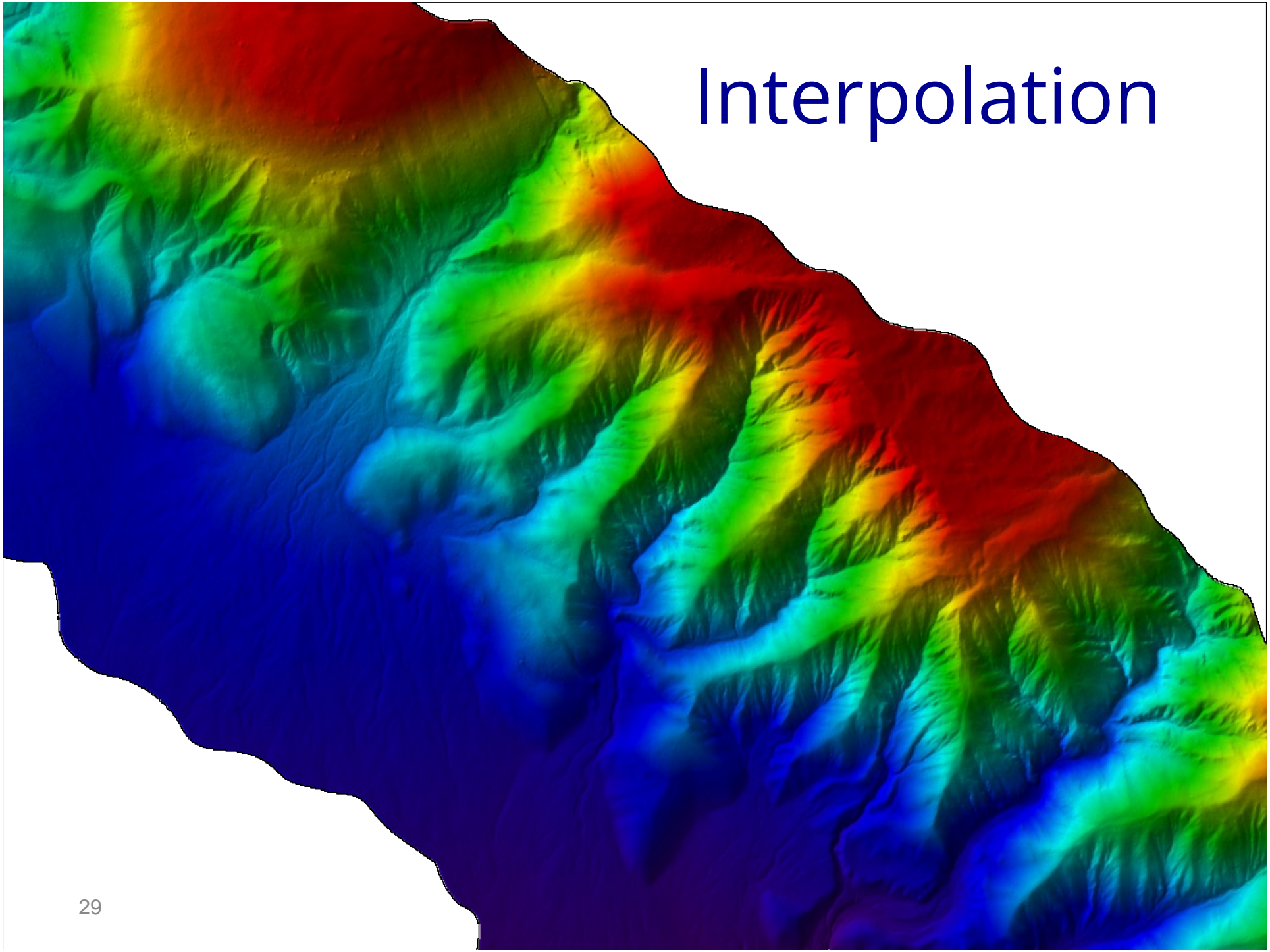
Point cloud data storage

- LiDAR data are often stored in a LAS file format.
- A public file format created by the ASPRS for the interchange of LiDAR data between vendors and customers.
- This binary file format is an alternative to proprietary formats or a generic ASCII file interchange format.
- There is a compressed LAS (LAZ) format too.

Point cloud data storage

- LAS files store much more than just point xyz coordinates:
  - Return number (e.g. 1st of 4 returns)
  - Scan angle
  - Point classification
  - Return intensity
  - (GPS time)
  - (RGB colour)
- Many of these variables can be lost when LAS files are converted to ASCII formats.

Interpolation

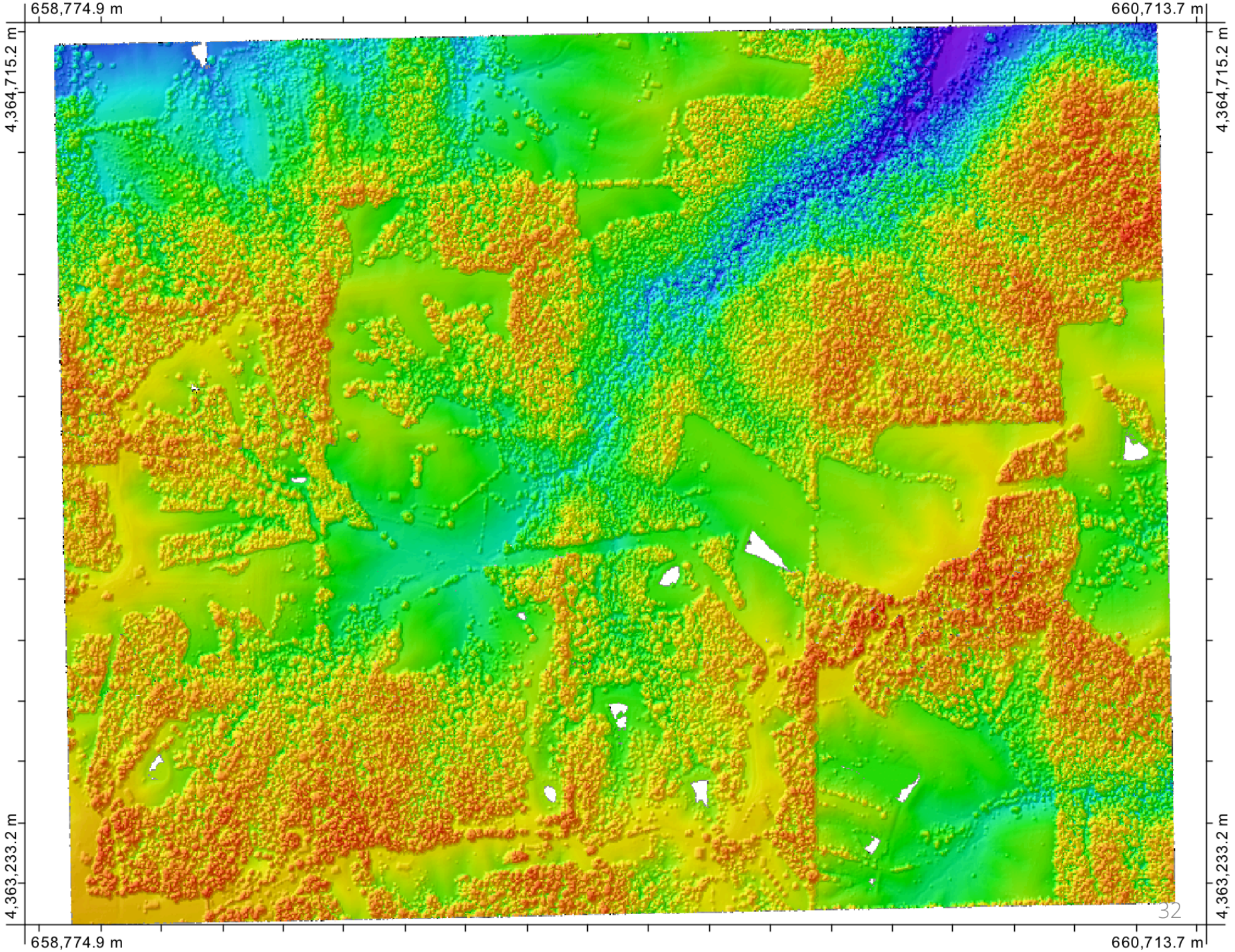


Interpolation

- What's the difference between a digital elevation model (DEM), digital surface model (DSM) and digital terrain model (DTM)?
- Dammed if I know! Everyone has a different interpretation. All of these terms are ambiguous.
- Maybe we should be using 'ground model' and 'bird's eye model' instead?

Interpolation

- First-return DEM: model includes buildings, vegetation canopy, other off-terrain objects (OTOs).
- Last-return DEM: semi-transparent OTOs will largely be stripped off. Residue and buildings will remain.
- Bare-earth DEM: All OTOs have been removed. Usually requires post-processing of the last-return DEM.


658,774.9 m
660,713.7 m
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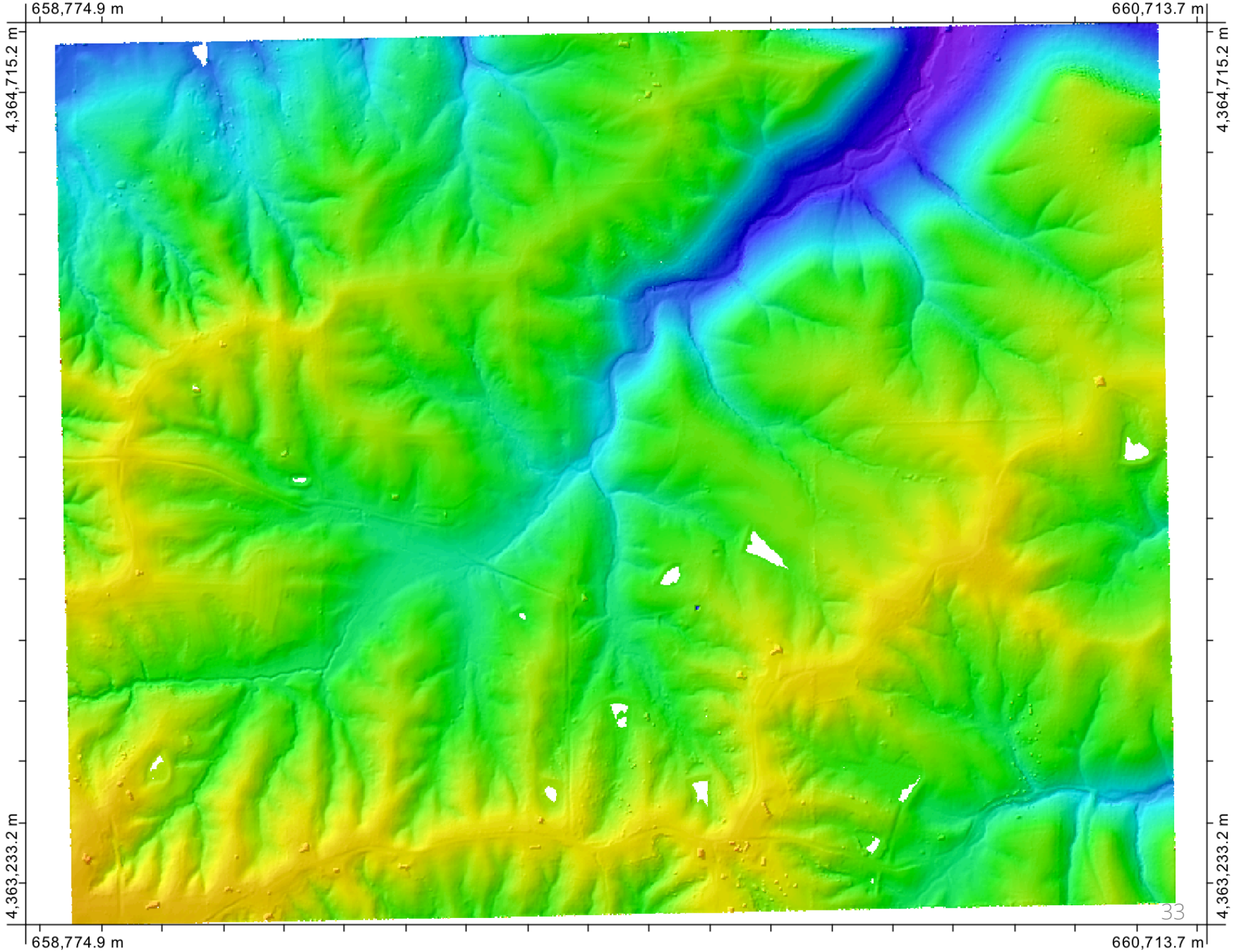
658,774.9 m
660,713.7 m
4,364,715.2 m
4,363,233.2 m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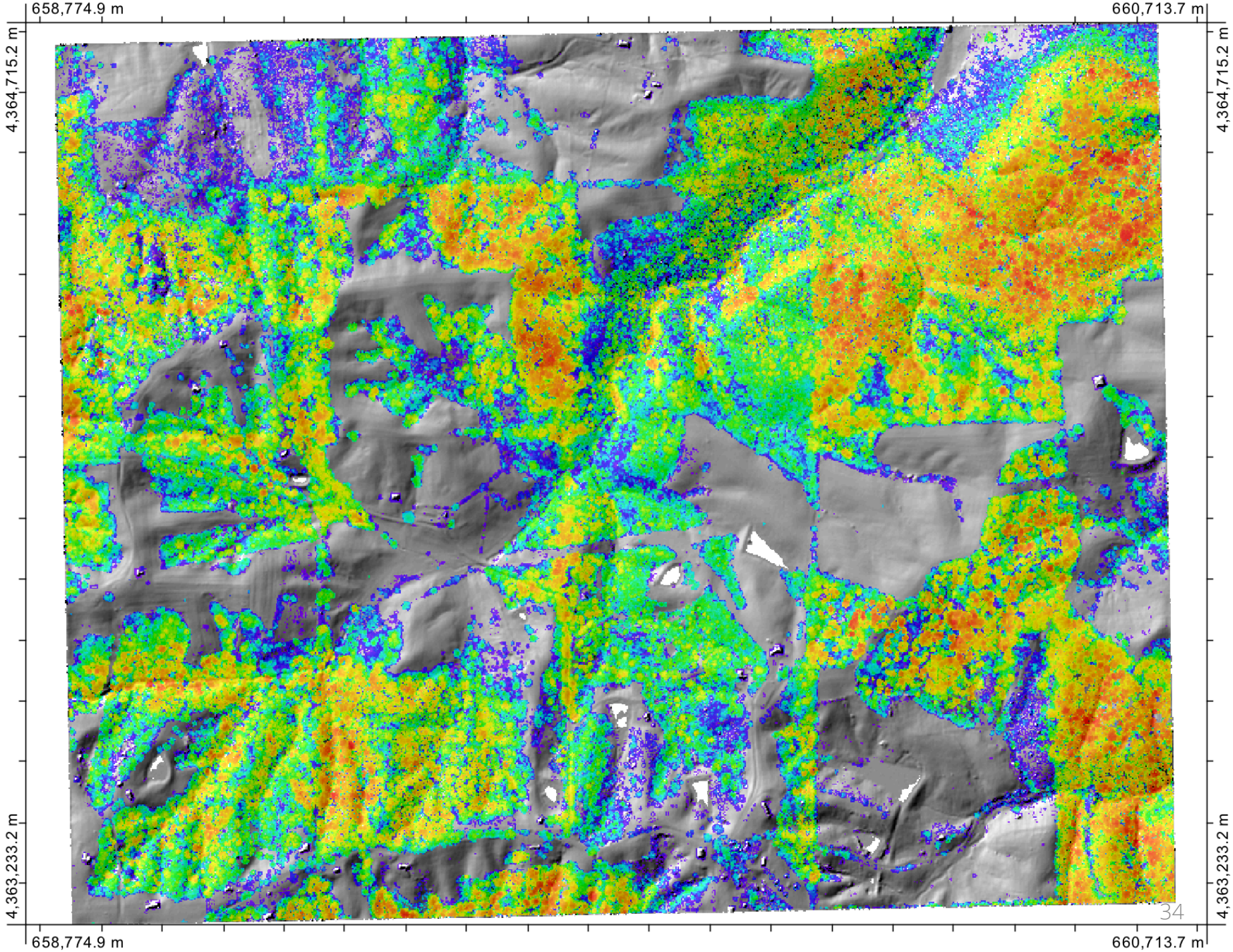
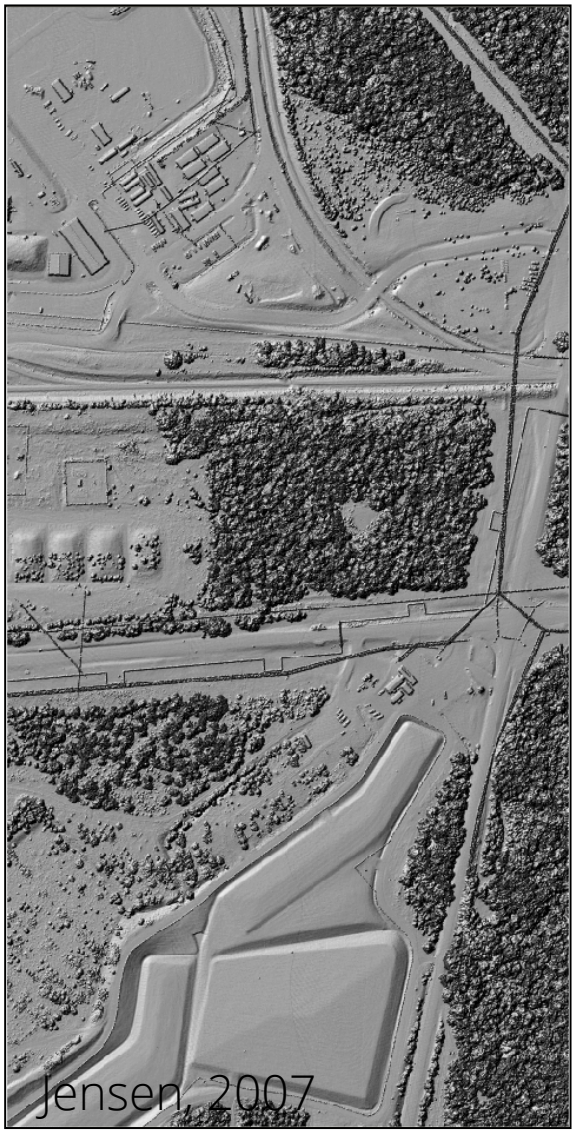
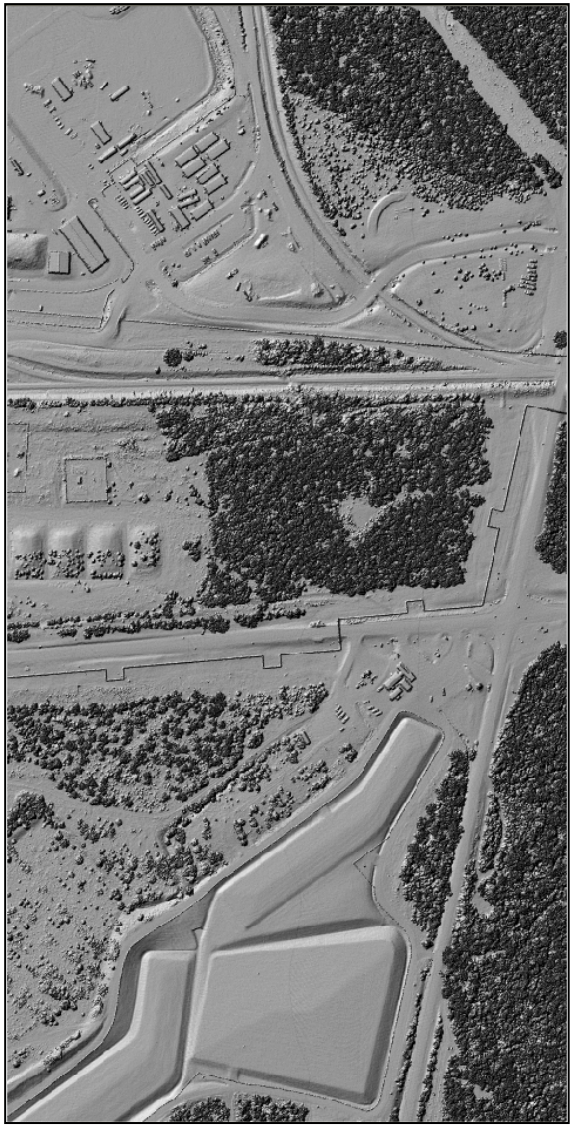

658,774.9 m
660,713.7 m
4,364,715.2 m
4,363,233.2 m

First return DEM



Jensen, 2007

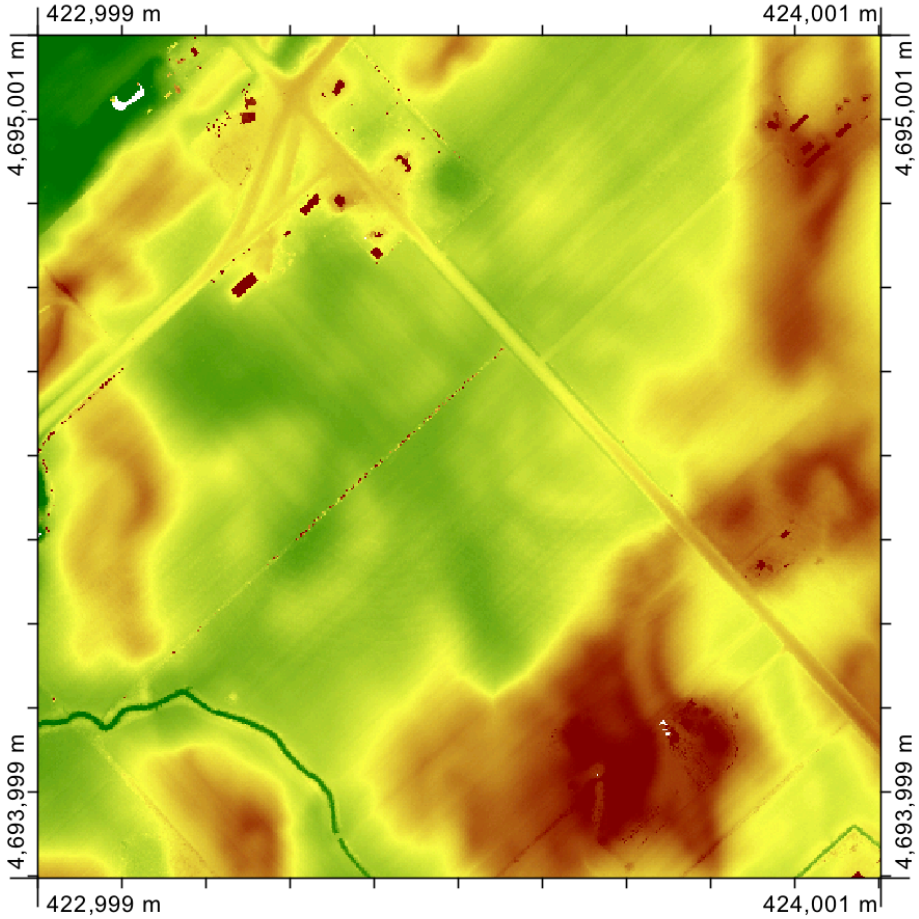
Last return DEM



Bare-earth DEM, achieved with post-processing algorithms to remove OTOs

LiDAR Intensity Data

Elevation



Return Intensity

LiDAR Intensity Data

- Like a perfectly ortho-rectified air photo, although slightly lower resolution.
- Harder to interpret because:
  - Data are often uncalibrated and haven't been radiometrically corrected for scan angle, beam divergence and splitting, atmospheric attenuation, etc.
  - It's the opposite of panchromatic.
  - Generally noisier because each point is effectively independent with no contribution from neighbouring pixels.

LiDAR and Terrain Analysis

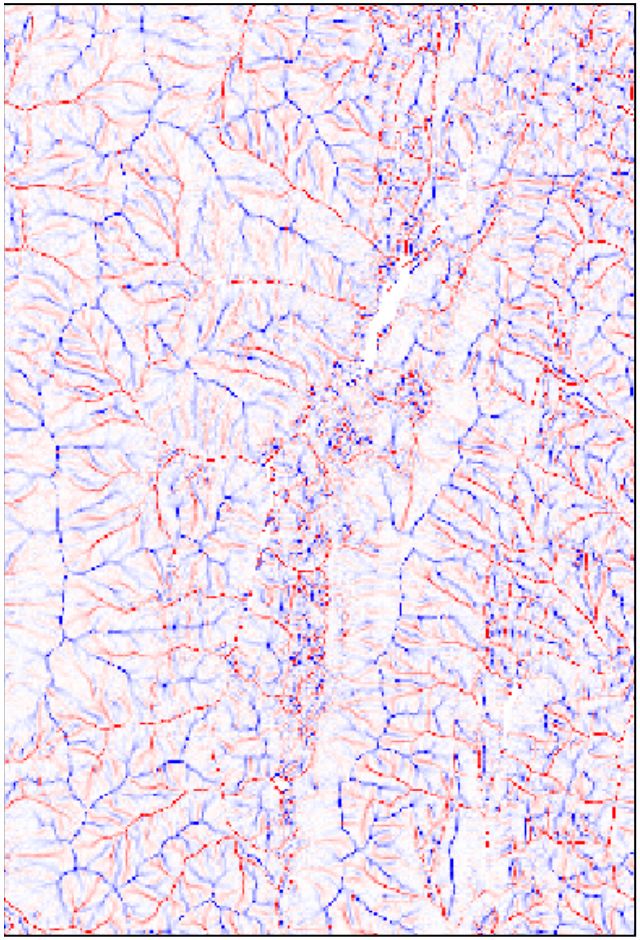
- LiDAR data are often used to extract geomorphometric parameters like slope, aspect, curvature, etc.
- Also particularly well suited to modelling surface hydrology…why?

LiDAR and Terrain Analysis

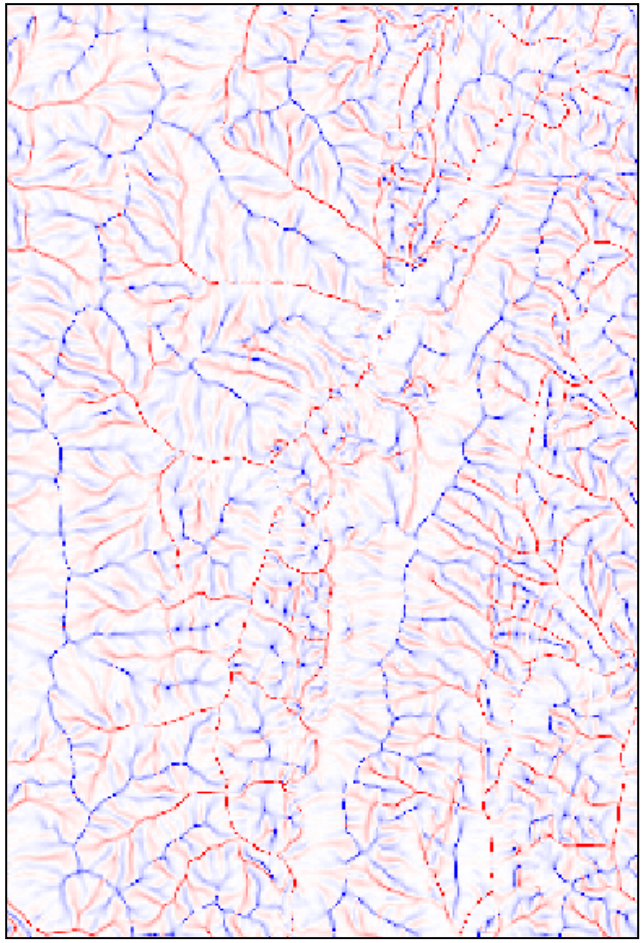
- Main challenges:
  - Many geomorphometry tools weren't designed to work with such large DEMs.
  - LiDAR DEMs have a lot of detail, including road embankments, bridges, etc., that can make hydrological processing difficult.
  - LiDAR DEMs have far greater surface roughness than most other types of DEMs.

LiDAR and Terrain Analysis

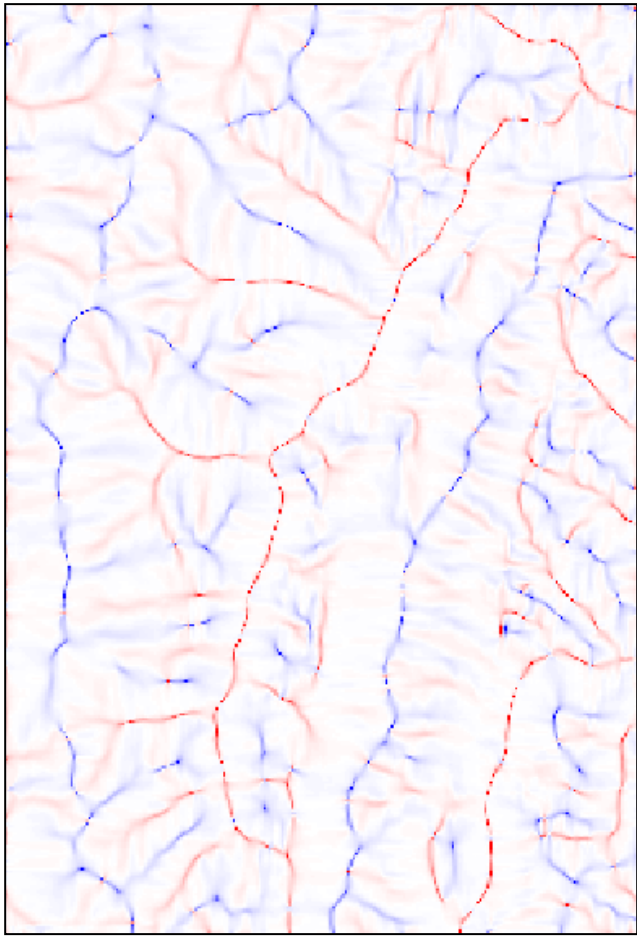
- At 1 m resolution a LiDAR DEM is able to represent micro-topography, i.e. surface roughness.
- The uncorrelated spatial error of LiDAR also magnifies the appearance of surface roughness.
- If you're interested in characterizing topography at the scale of fields, do you really need 1 m resolution? YES!!!!



Plan curvature on raw DEM

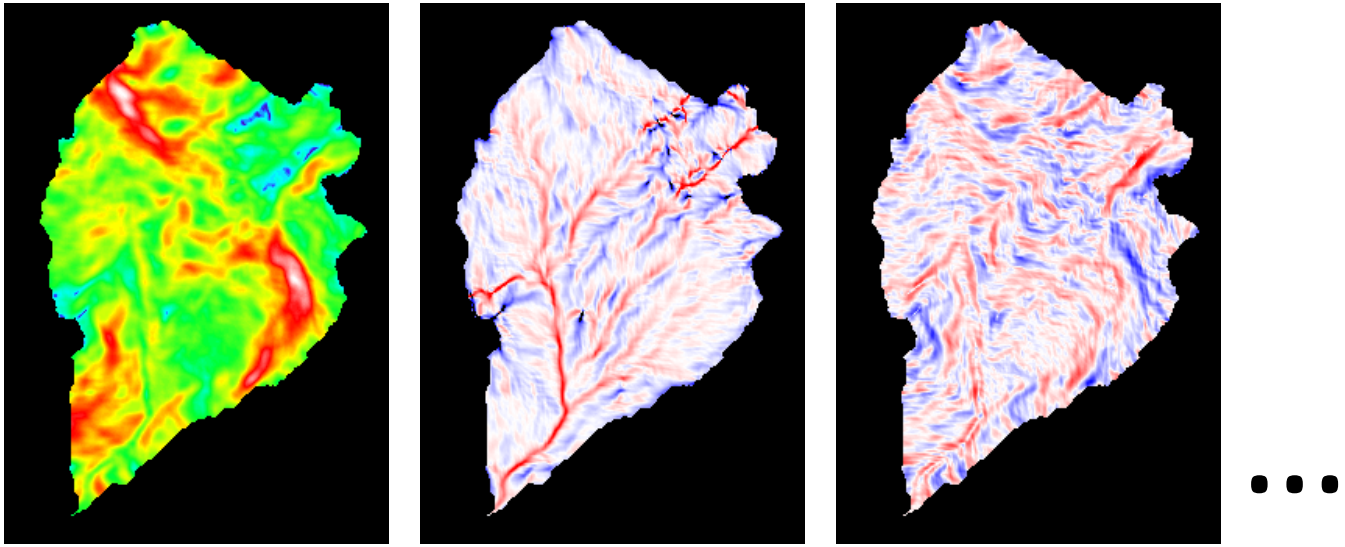


Plan curvature on DEM derived from applying a 3 x 3 mean filter



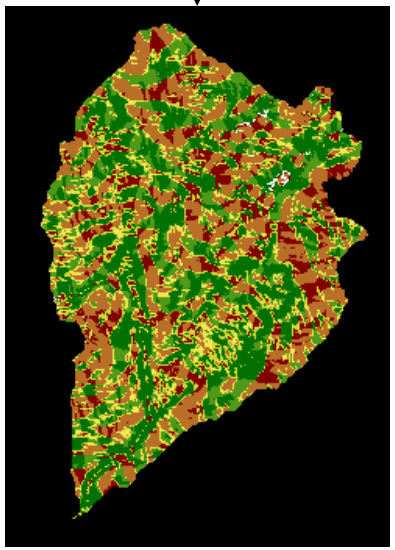
Plan curvature on DEM derived from applying a 11 x 11 mean filter

Terrain parameters



Landform classification system

Landform elements

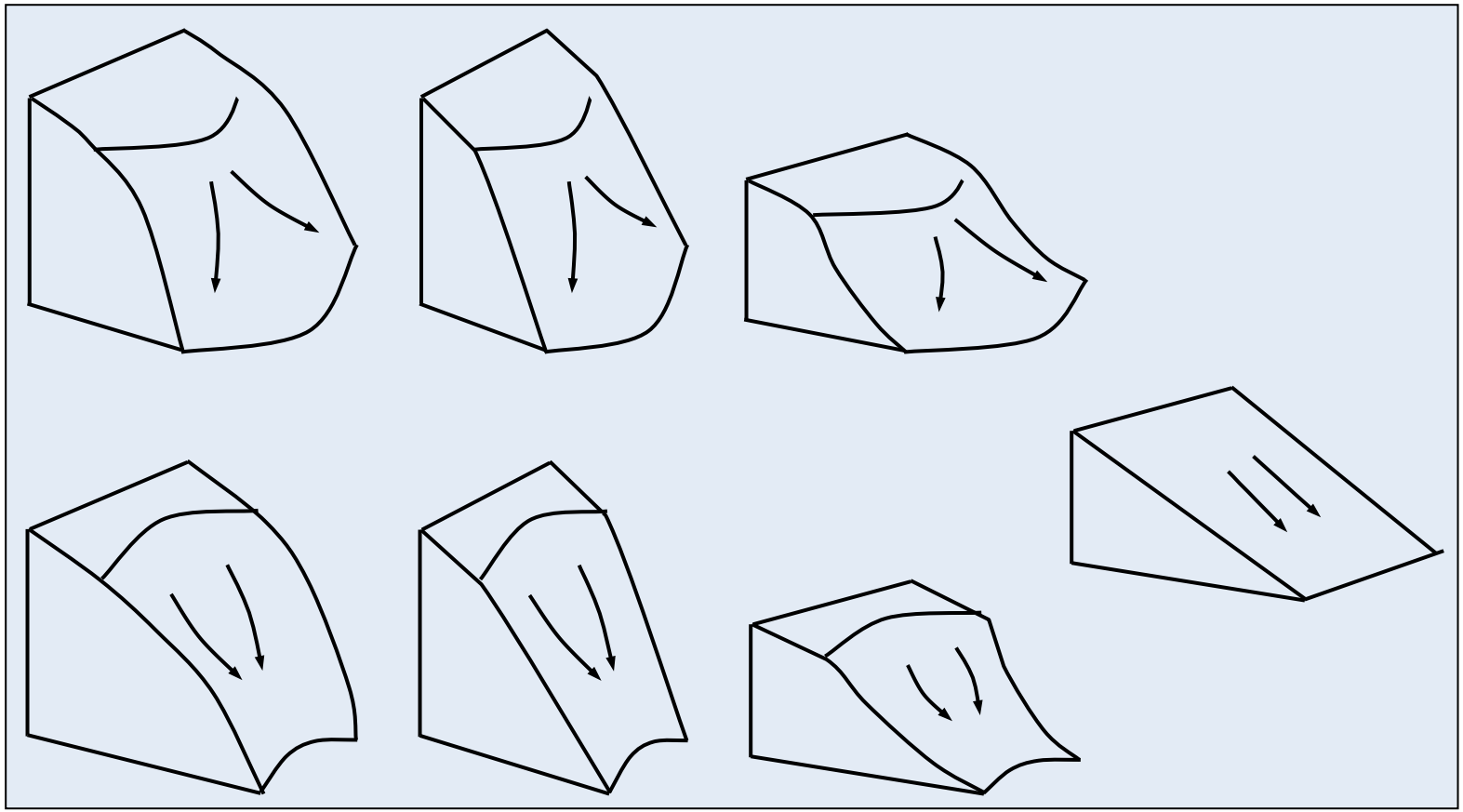


Pennock's Classification

shoulder (convex) | backslope (level-steep) | footslope (concave) | Level (flat)

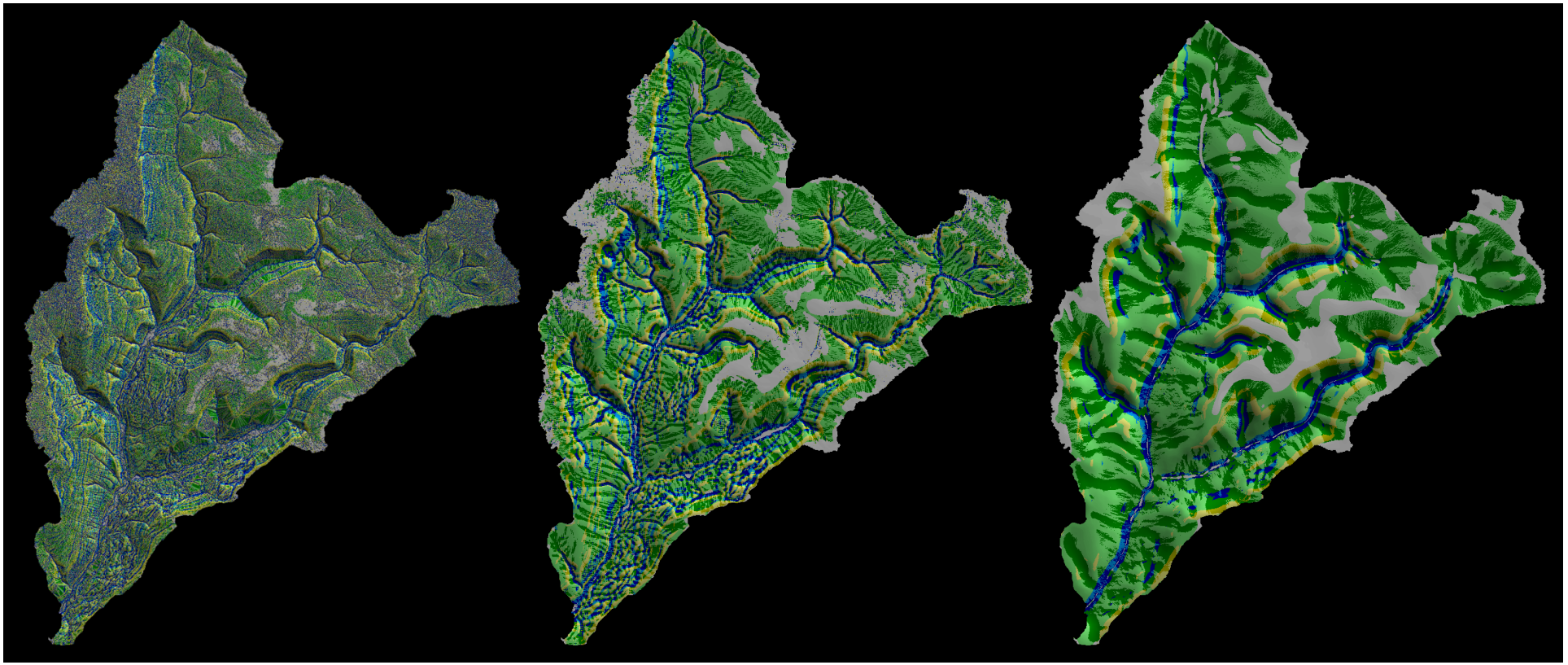
divergent

convergent



Sensitivity to Surface Roughness

No smoothing 3x3 smoothing 7x7 smoothing



Pennock, Zebarth, and DeJong (1987) seven-class landform classification

Issues With LiDAR Acquisitions and Processing

Be forward-thinking at the start of a data acquisition project

- What is your main application for the LiDAR data?
- What other applications could you envision in the future?
- This has major implications for the data acquisition, e.g. point density, time of year of acquisition, LiDAR system, etc.
- Once you've collected the data you can't go back!

Do most of the processing of the DEM data in-house

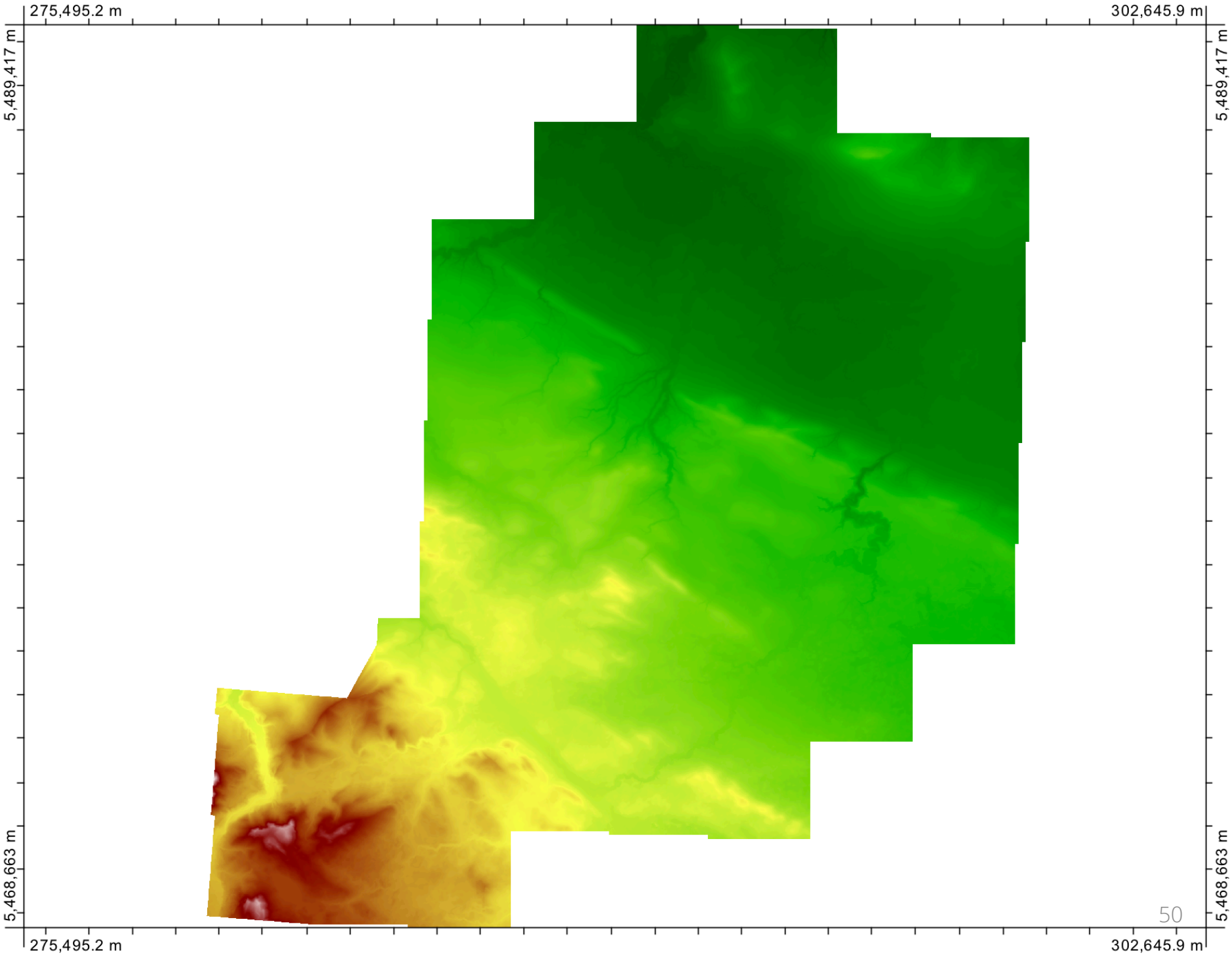
- Different DEMs processed in different ways are more suited to particular applications.
- No method for processing DEMs is suited to all applications.

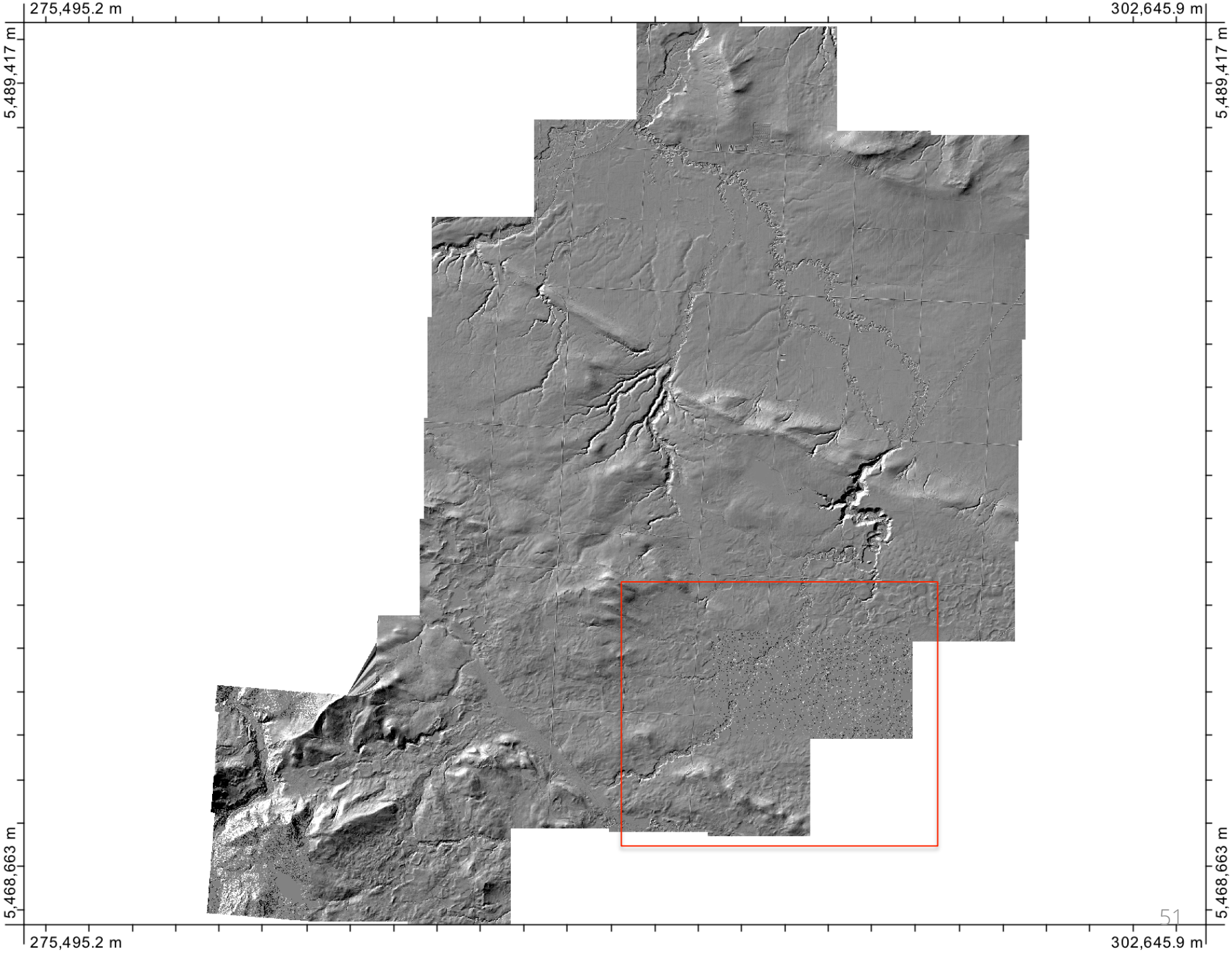
Archive the raw data

- Most LiDAR survey companies want to provide their customers with interpolated DEMs as the end product.
- Be sure to specify that you want the raw LAS files (point clouds).
- Archive the LAS files so that you can always go back to them.

Archive the raw data

- LiDAR data are huge and organizations responsible for these data sets are always looking to reduce the expenses associated with archiving it.
- There is a lot of incentive to delete the source data once you've created the 'final product'.
- This is a mistake.


275,495.2 m
302,645.9 m
5,489,417 m
5,468,663 m
50


275,495.2 m
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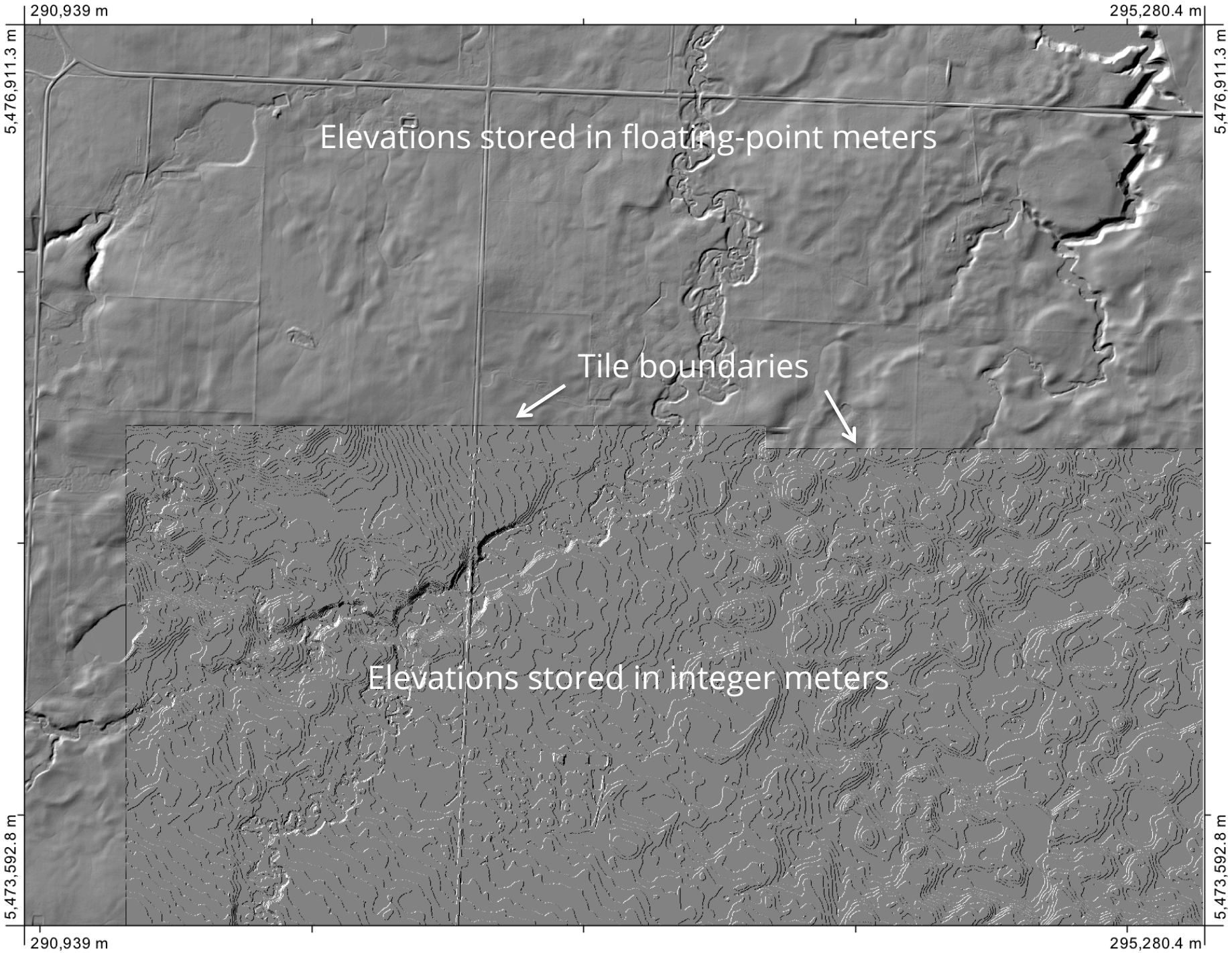
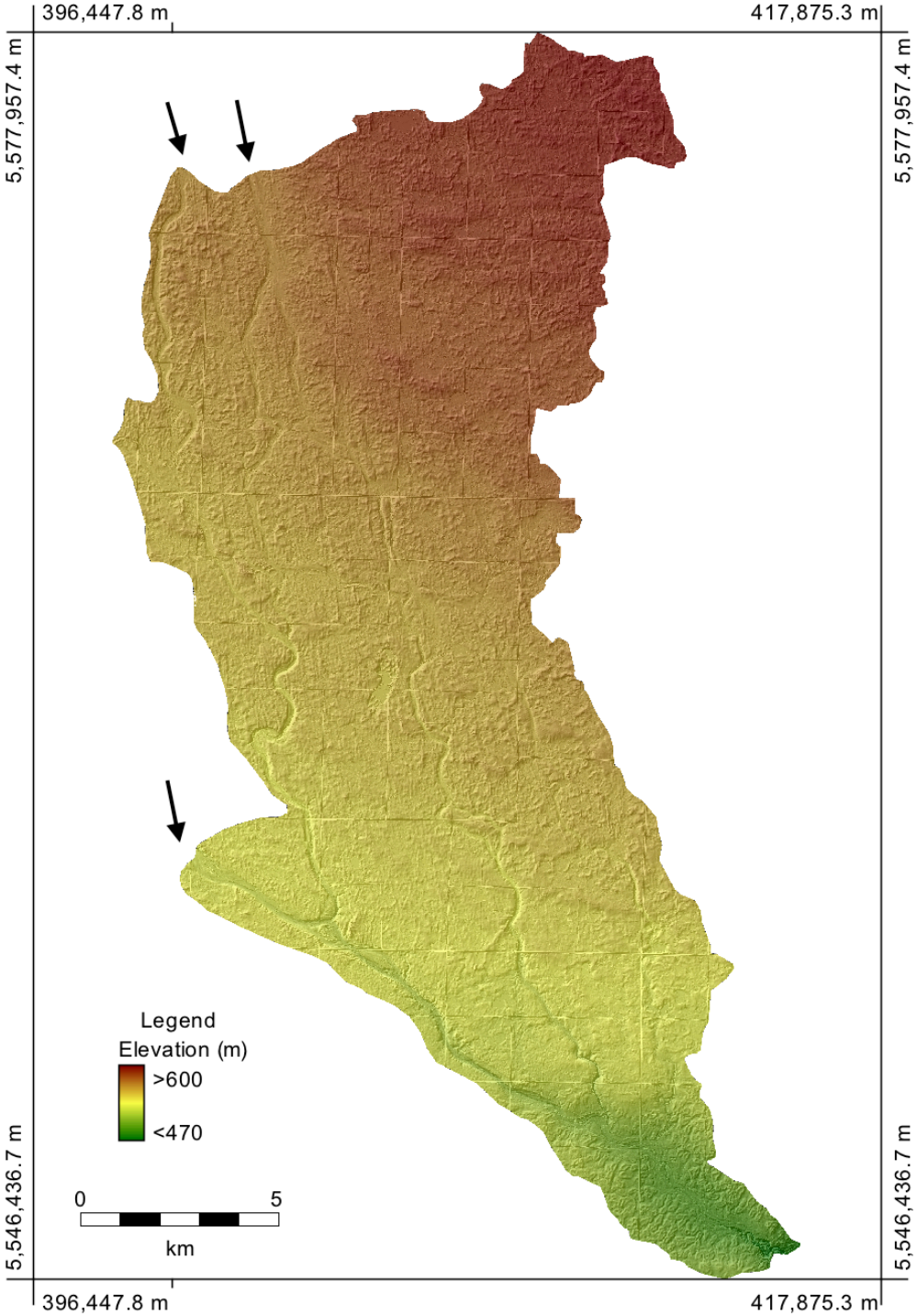

290,939 m
295,280.4 m
5,476,911.3 m
5,476,911.3 m
Elevations stored in floating-point meters
Tile boundaries
Elevations stored in integer meters
5,473,592.8 m
5,473,592.8 m
290,939 m
295,280.4 m

Point cloud classification

- If you have the option to have the data provider classify the points, do so.
- Critical classes include bare ground, vegetation (low, medium, high) and buildings.

Specifying the area of interest

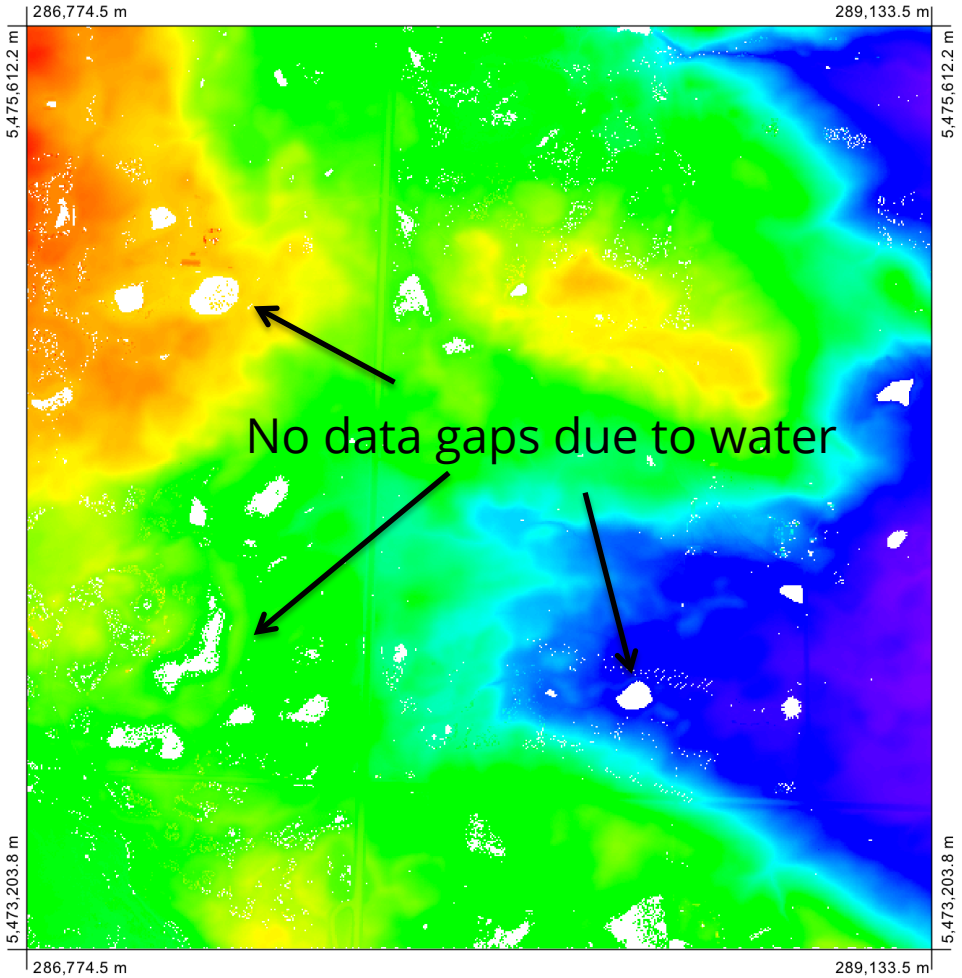
- If you’re interested in a watershed, be sure to buffer the extent of your AOI.


396,447.8 m
417,875.3 m
5,577,957.4 m
5,577,957.4 m
5,546,436.7 m
5,546,436.7 m
396,447.8 m
417,875.3 m
Legend
Elevation (m)
>600
<470
0
5
km

Do quality checking

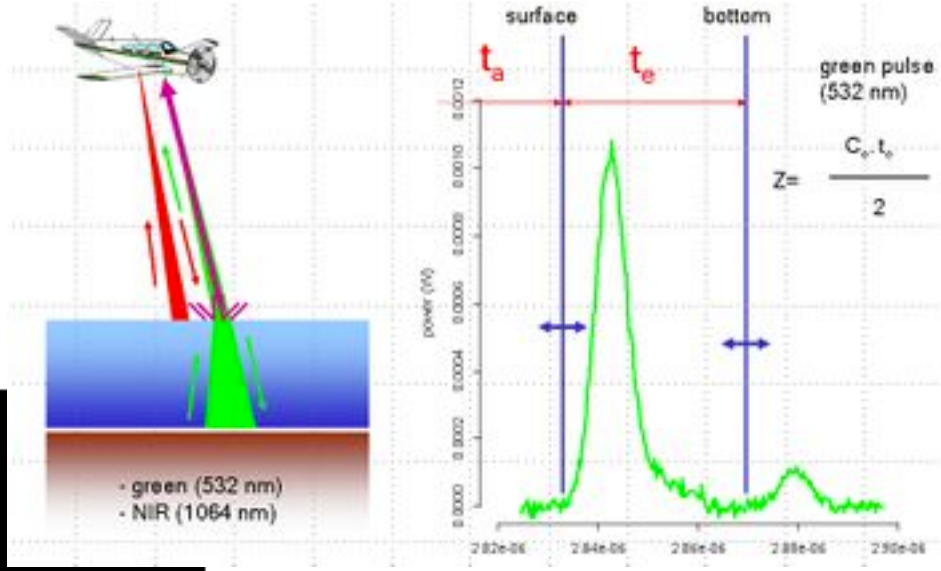
- Be mindful of spuriously high and low points within the point clouds.
- Look at areas of flight-line overlap.

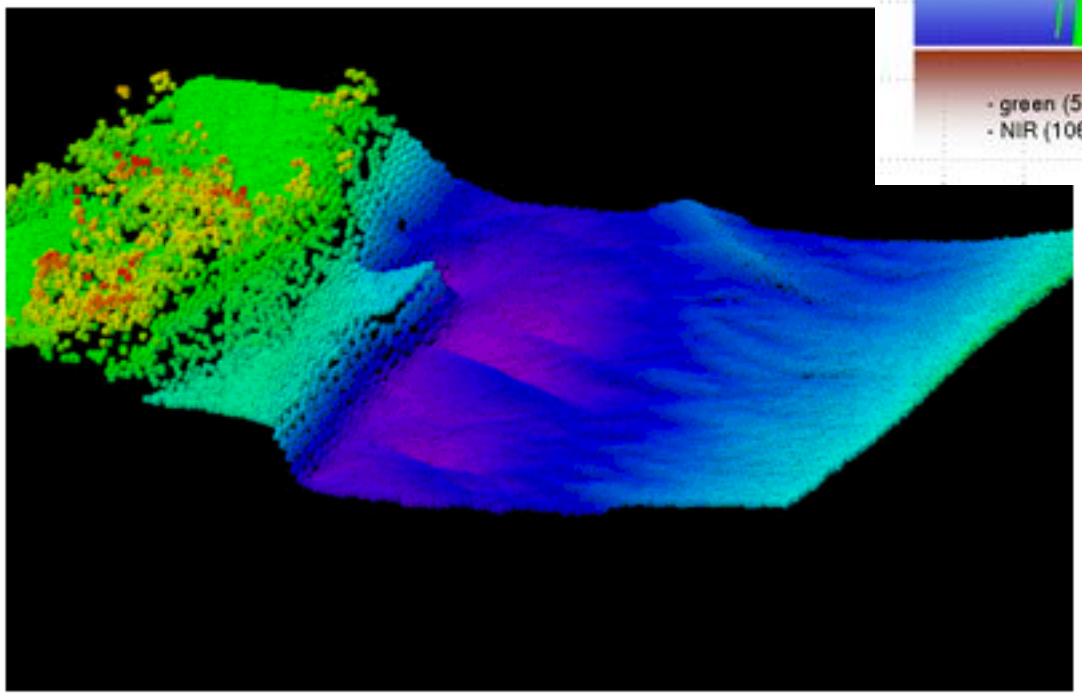
Water bodies pose a problem for most LiDAR systems



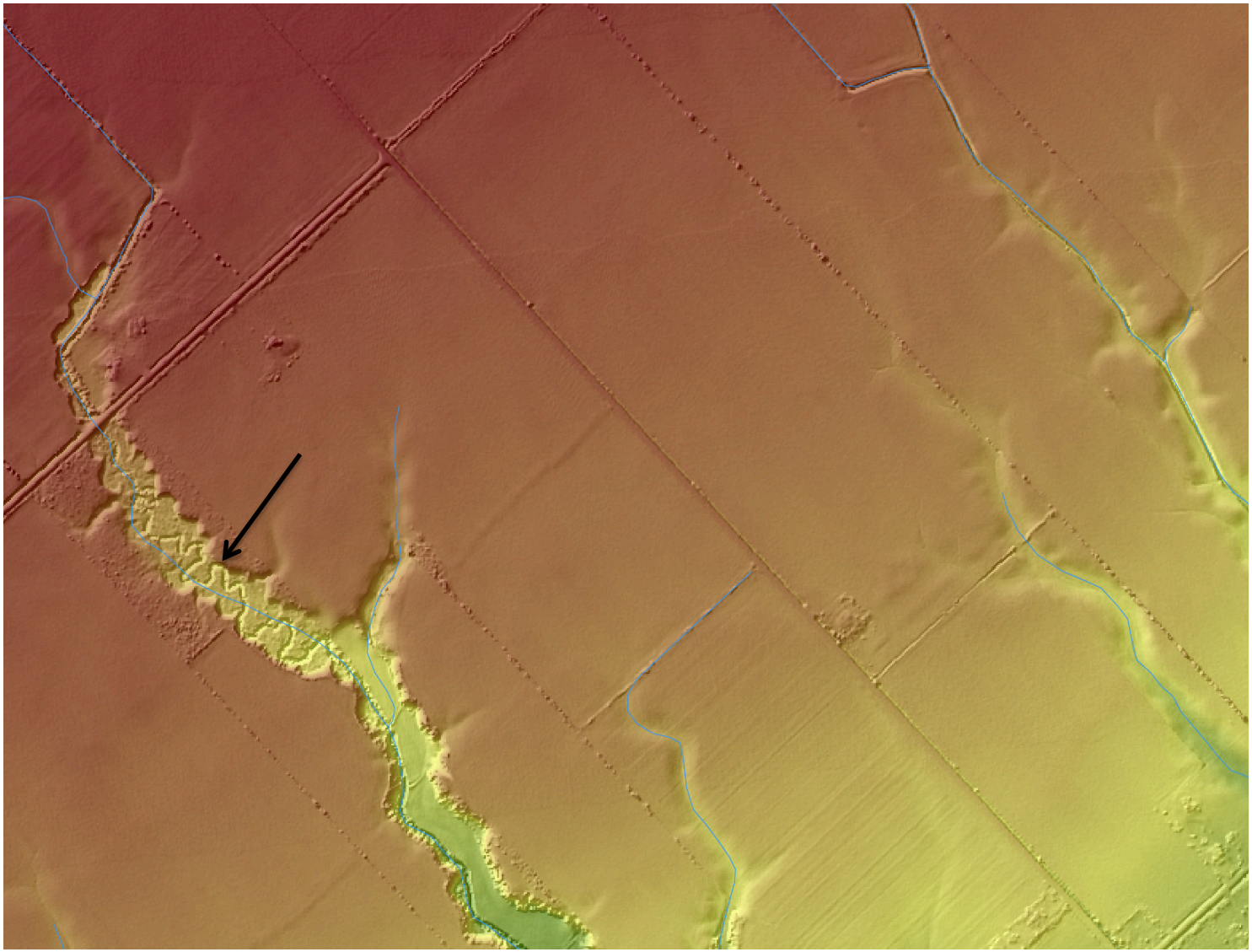
LiDAR can be used for bathymetric mapping of lakes and coastal areas, up to about 50 m in ideal conditions.

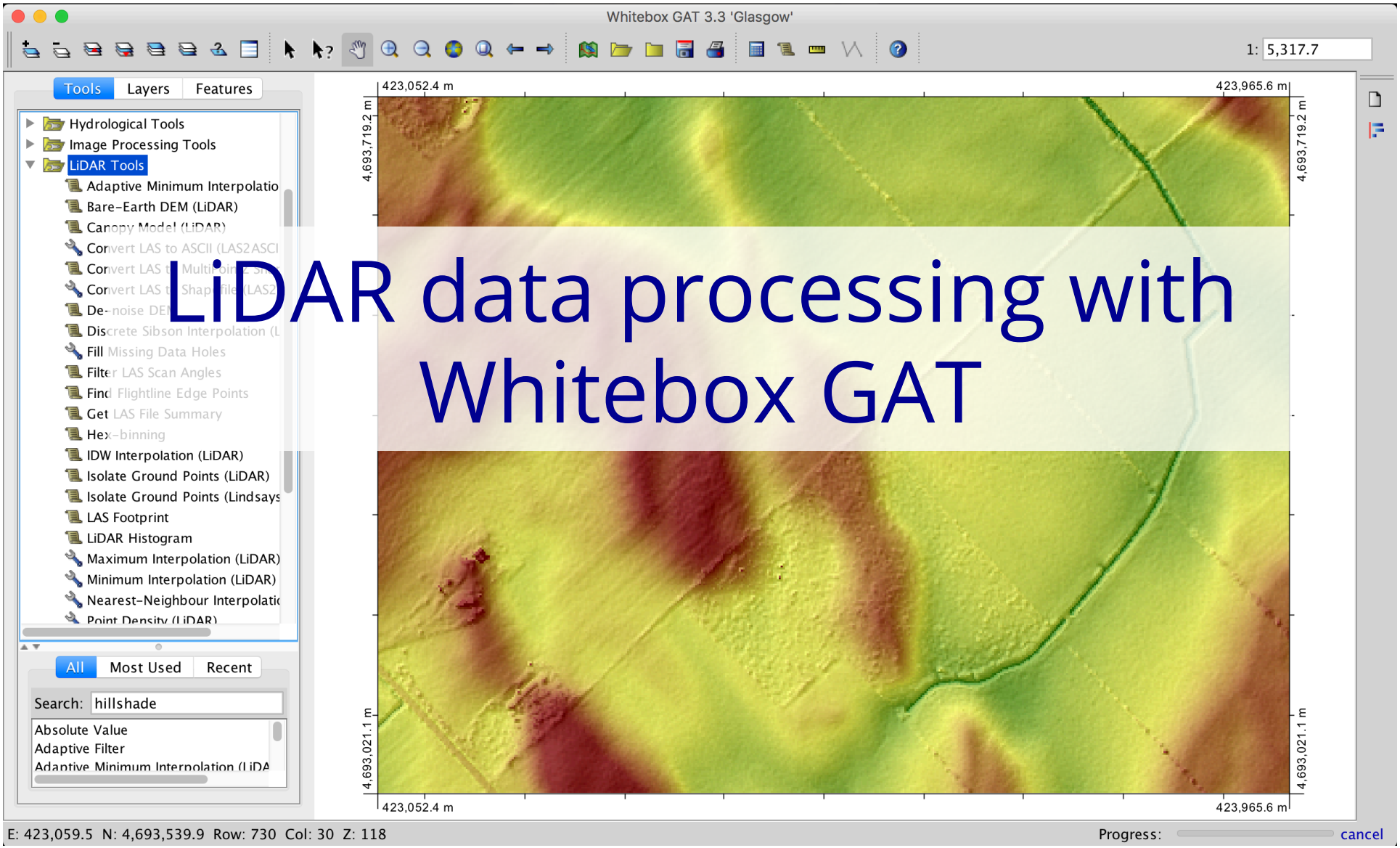
Bathymetric LiDAR systems are fundamentally different than other LiDAR systems.





LiDAR and stream burning





LiDAR data processing with Whitebox GAT

Background

- An open-source desktop GIS and remote sensing software package.
- A platform for advanced geospatial data analysis and visualization.
- Project began in 2009.
- Developed using Java and runs on the JRE.
- Whitebox GAT is particularly powerful for processing LiDAR data and geomorphometric analysis.

GISGeography said of Whitebox…

Here is the **diamond in the rough**. No sarcasm. I see **Whitebox GAT** as the **most underrated** software package on this list. I feel that it is inevitable to move up the rankings in the years ahead. Here's why:

1. It has ***out-of-this world*** LiDAR support. Nobody should run to ArcGIS for LiDAR conversion again. (Esri's LAS dataset was awkward to begin with) The out-of-the-box tools in Whitebox GAT far exceeds Esri ArcGIS.
2. **360** plugin tools to choose from for GIS analysis. Whitebox GAT has tools for conversion, import/export, analysis, hydrology, image processing, LiDAR, mathematical analysis, raster, statistics, stream network and terrain analysis.
3. Developers can create new plugin tools and extensions using built-in Python scripting.
4. It's been translated into 11 different languages
5. And it's only been in development since 2009.

What are the advantages and disadvantages of using Whitebox GAT: Break-neck processing speeds, LiDAR support, maps, terrain analysis, geospatial statistics, vector overlay, image processing, similar look and feel to Esri ArcMap, best-kept secret for open source GIS software

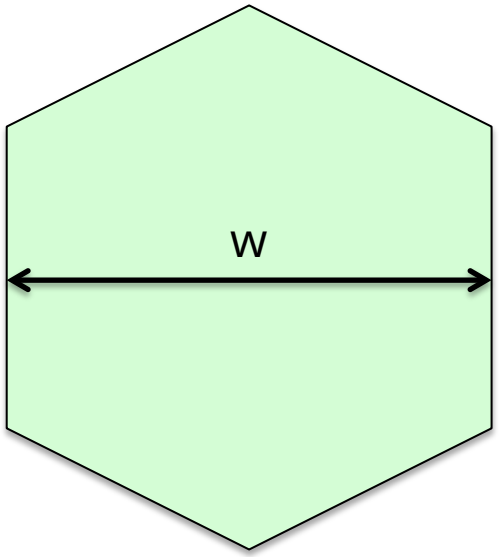
We will cover…

- Installing and using Whitebox GAT
- Working with LAS files
- Creating a DEM
- Workflow automation

- Please download the data from:

http://www.uoguelph.ca/~hydrogeo/Whitebox/WorkshopData.zip

Area of a hexagon from its width



$$A = (3w^2) / (2\sqrt{3})$$