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Centrum výzkumu globální změny AV ČR, v. v. i.

Airborne LIDAR scanning for assessment of forest site parameters

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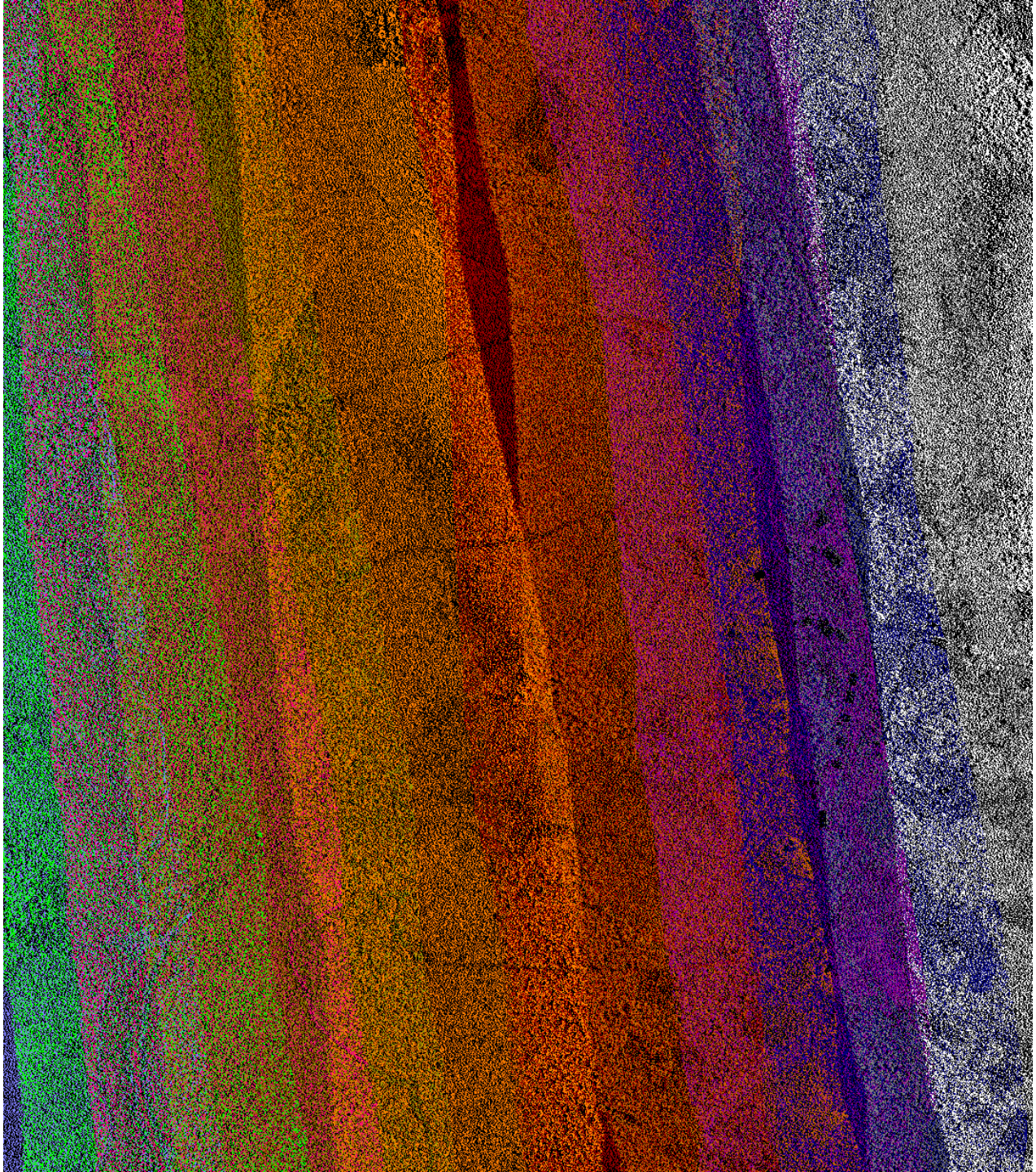
Topics

LiDAR data and their potential/practical application in forestry

Synergy of LiDAR information with other airborne data

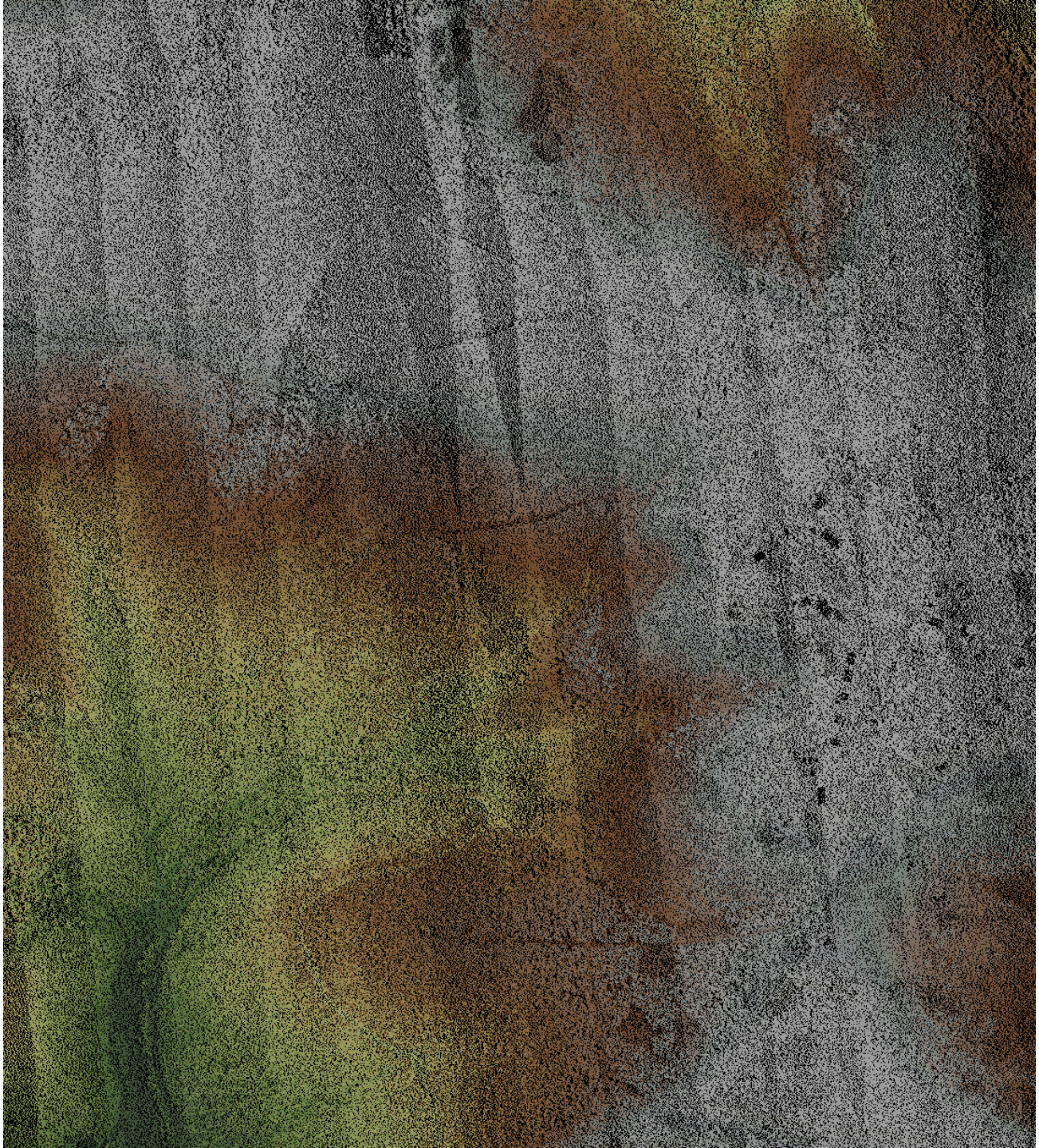
Latest airborne RS infrastructure in CzechGlobe - Czech Republic

What is it?

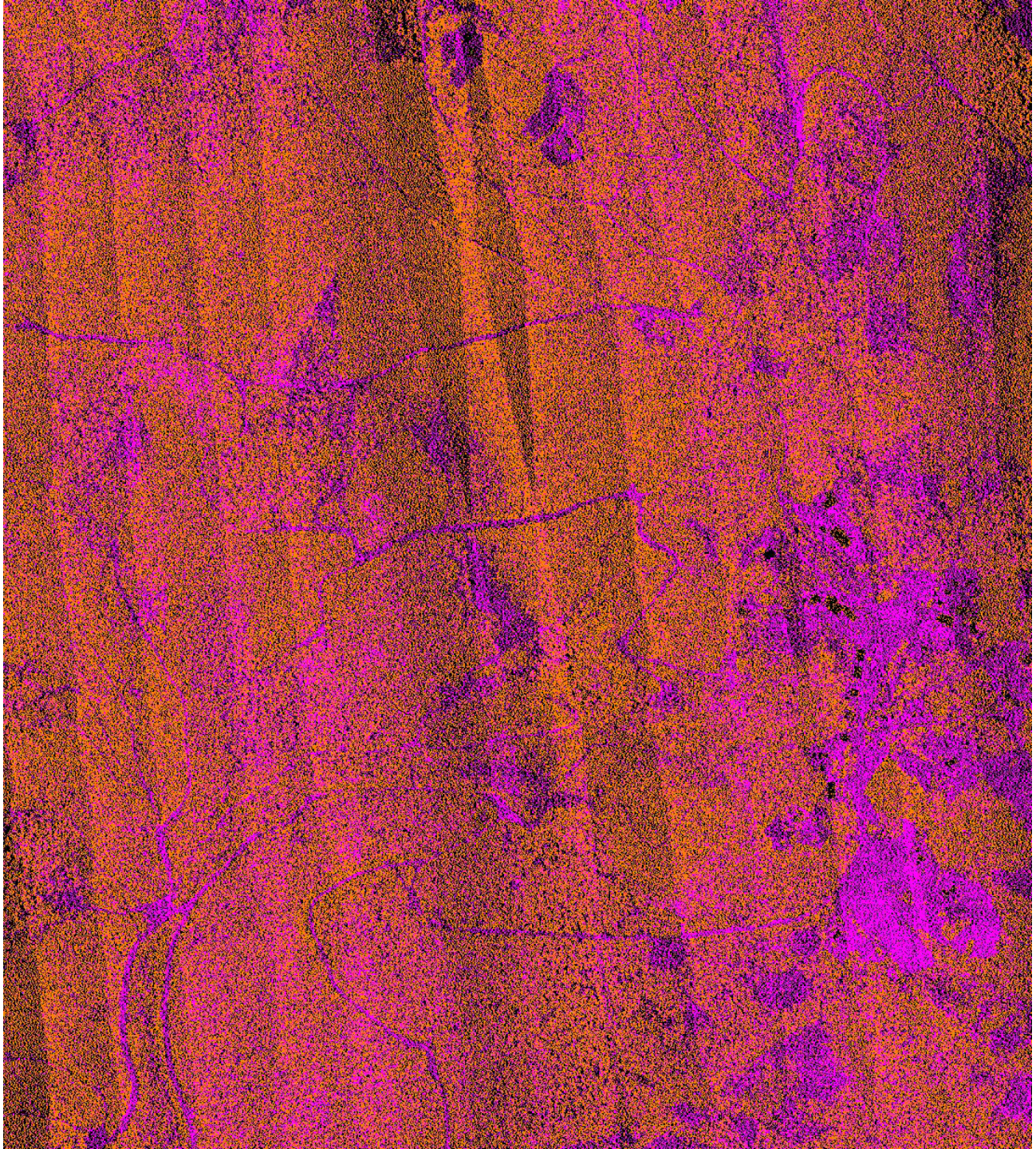


RGB aerial photo

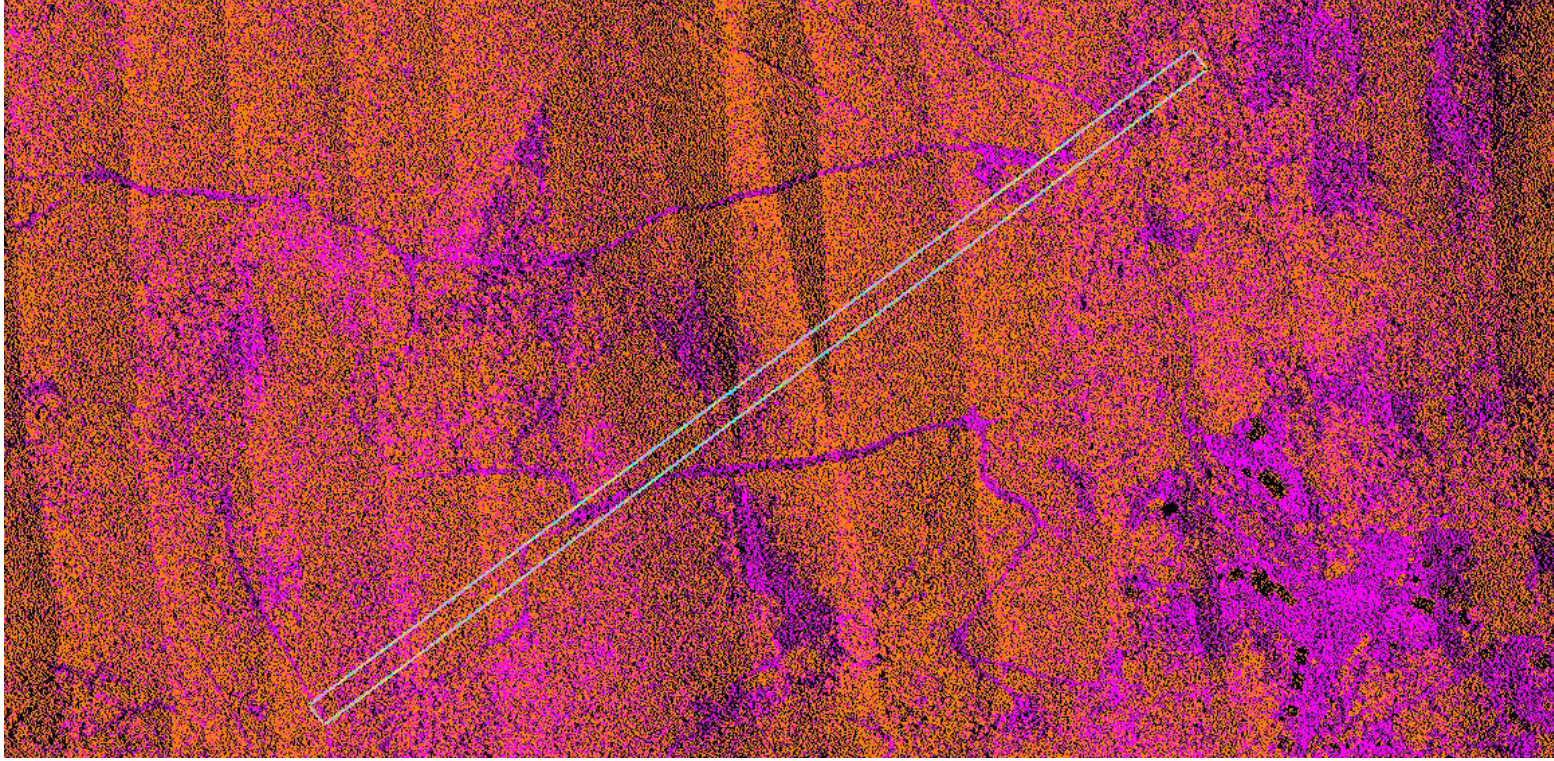
Elevation value - all points

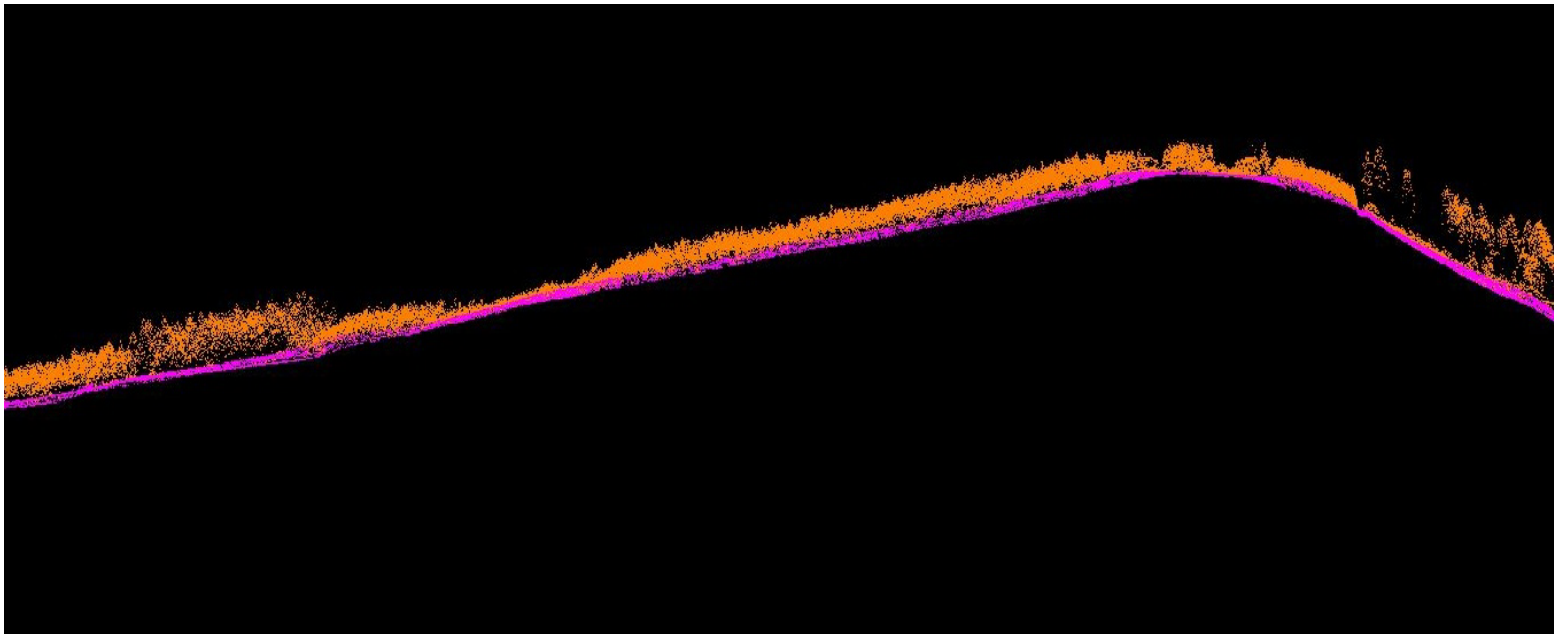


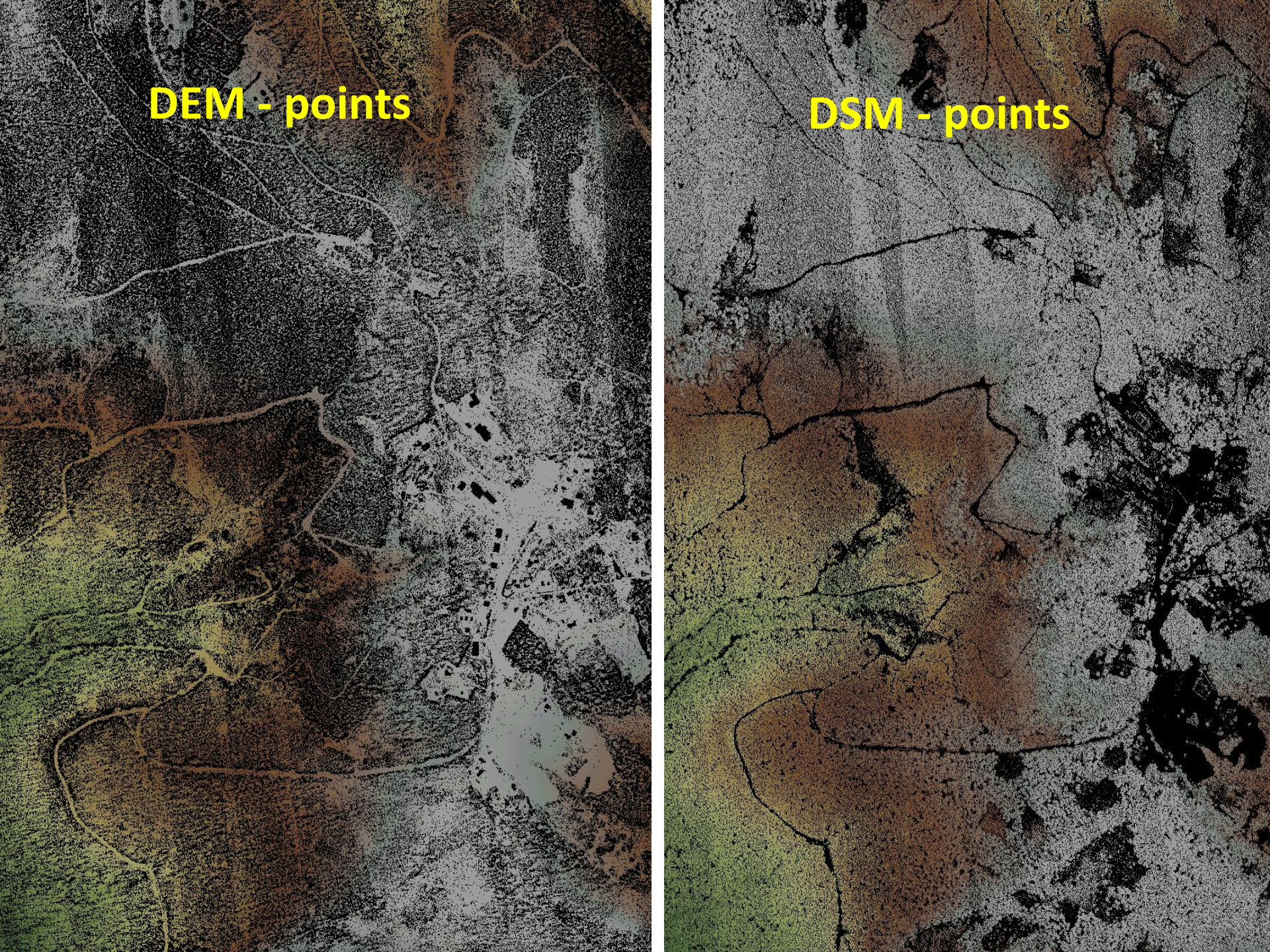
Separation for DEM and DSM

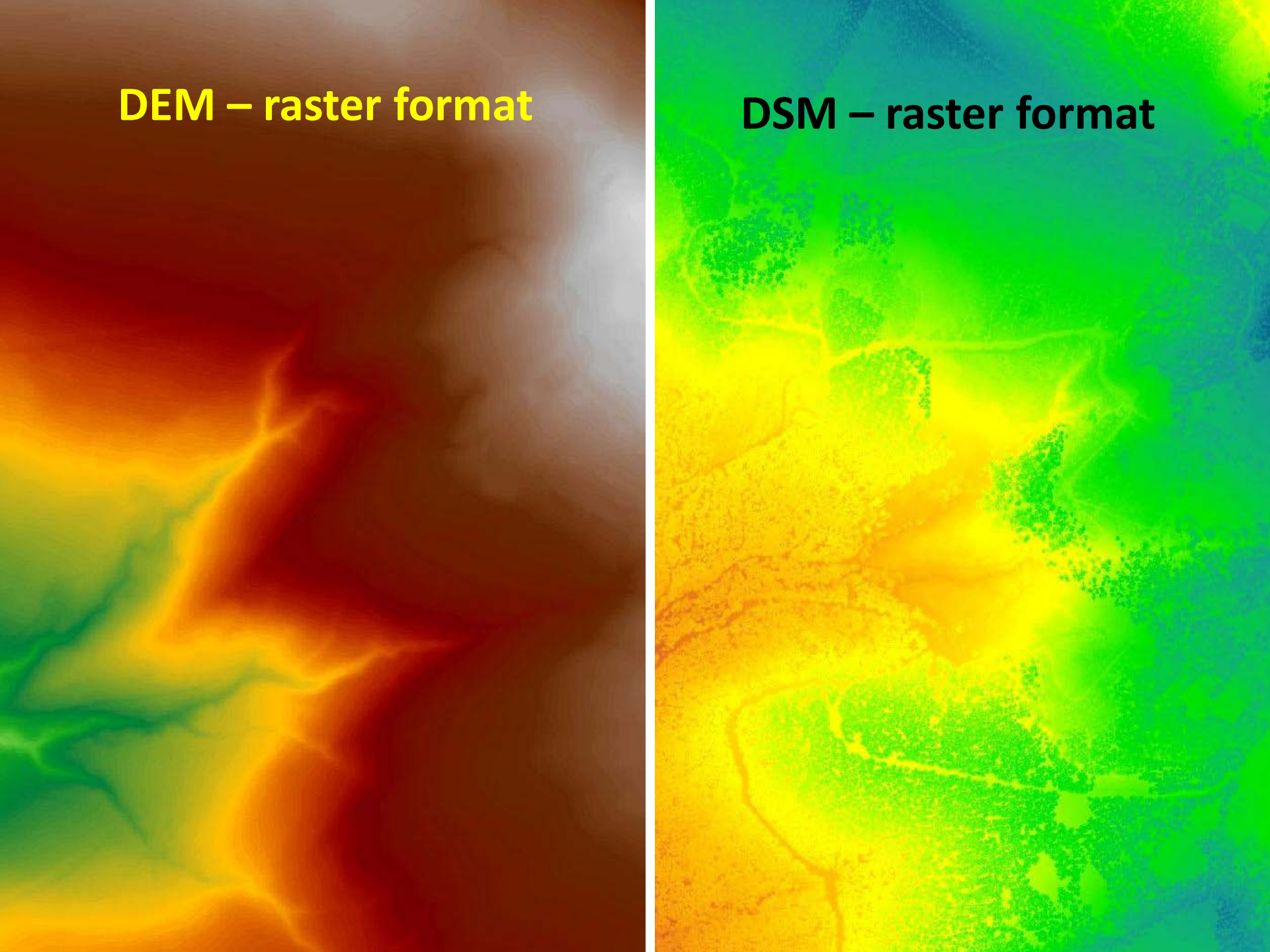


Separation for DEM and DSM

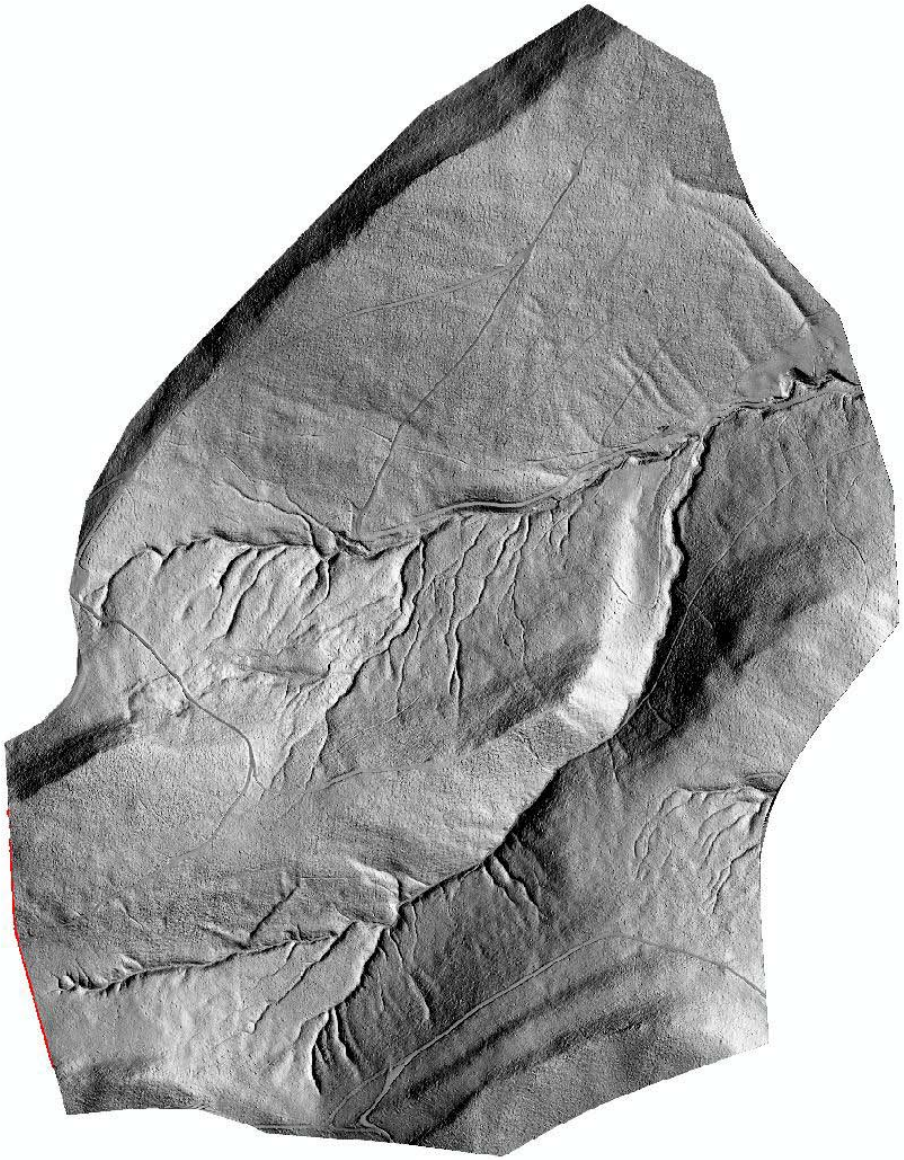




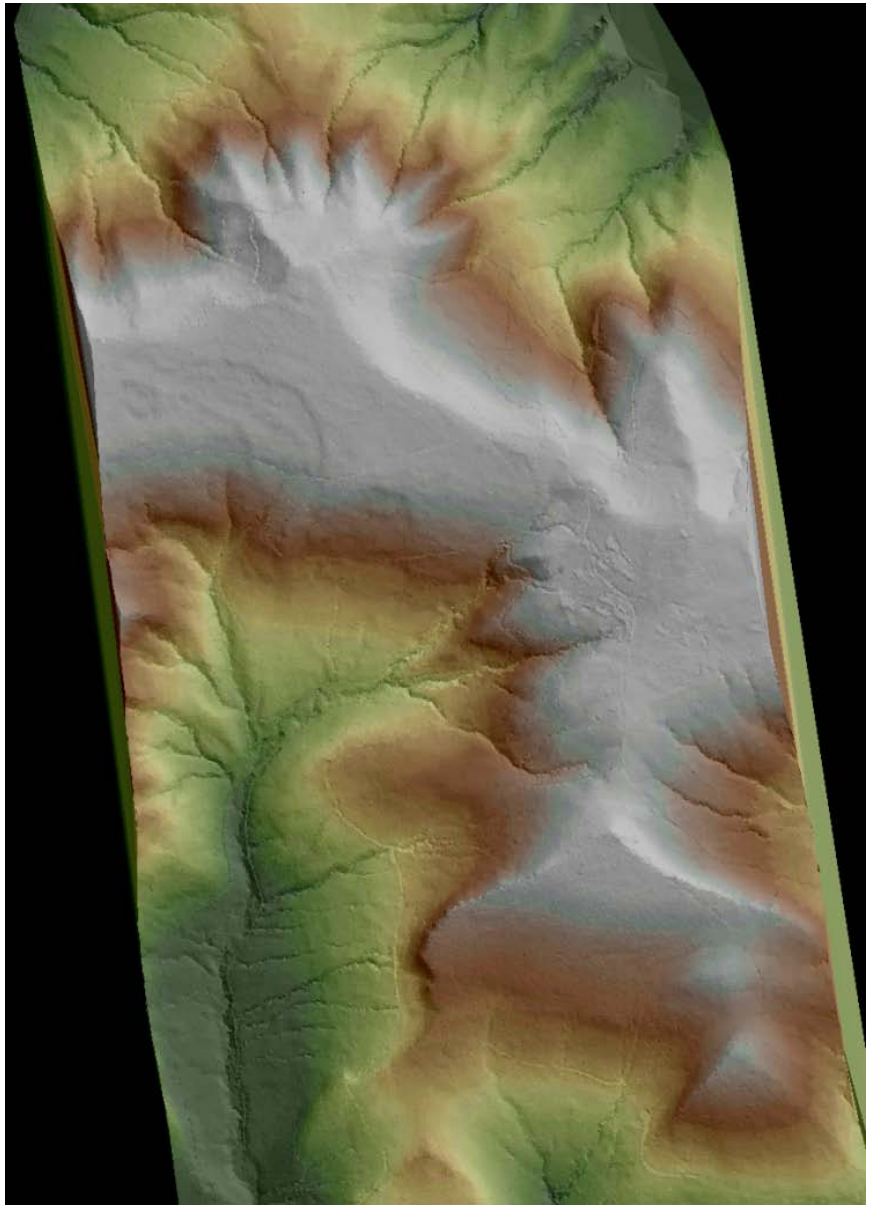

DEM - points
DSM - points

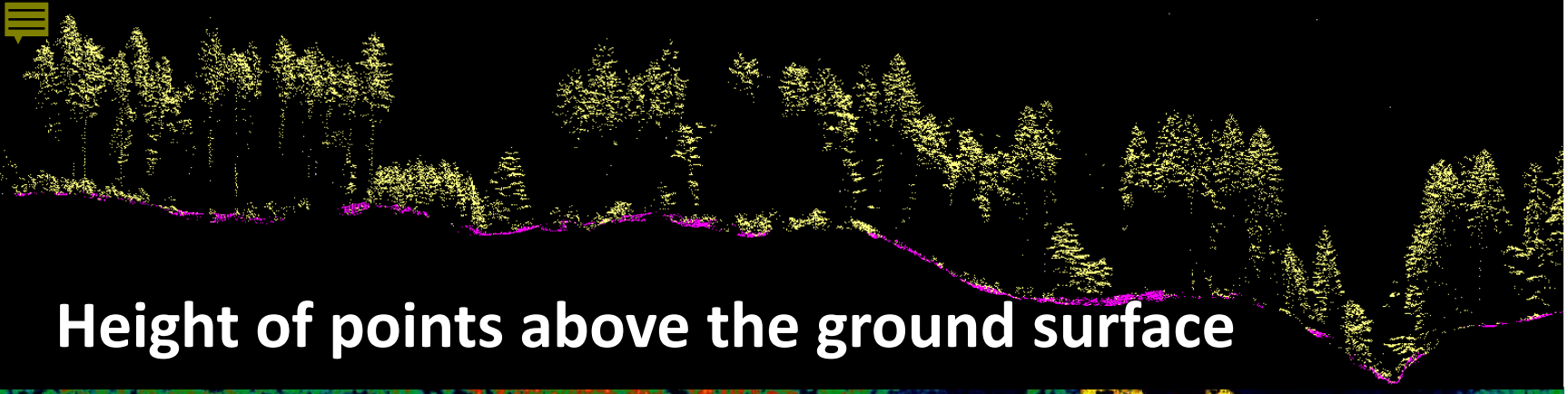

DEM – raster format
DSM – raster format

DEM – sun lighted

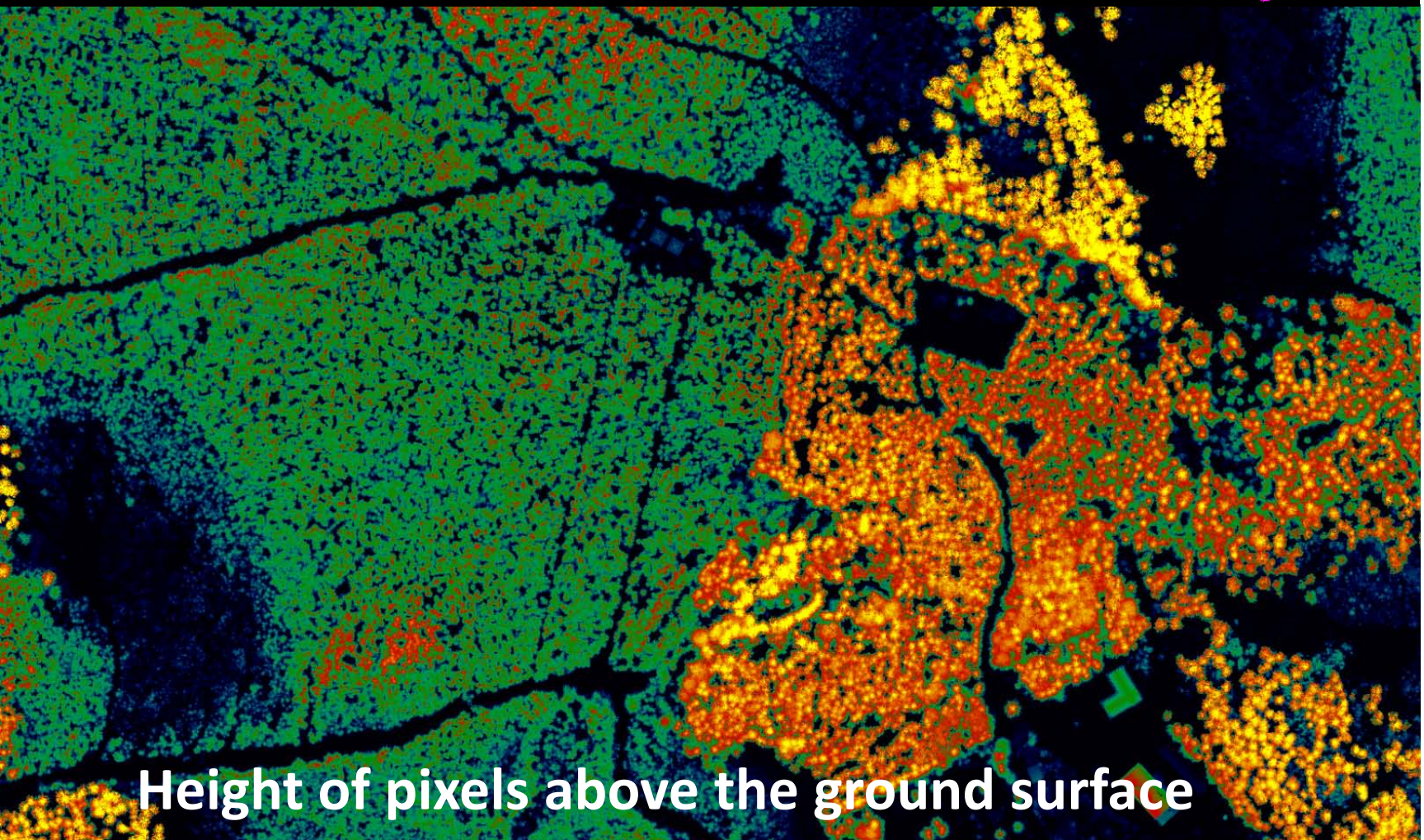


3D view of DEM





Height of points above the ground surface

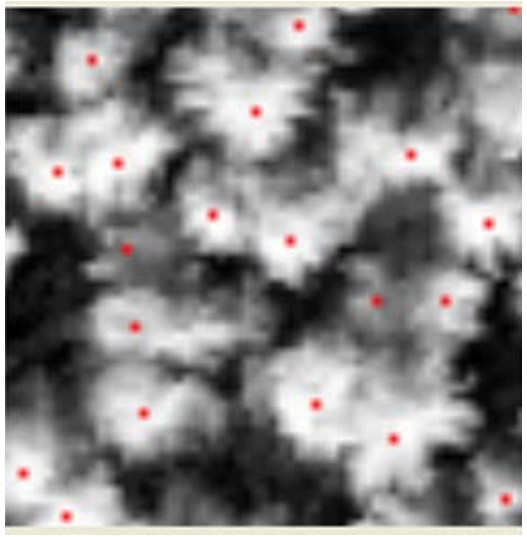


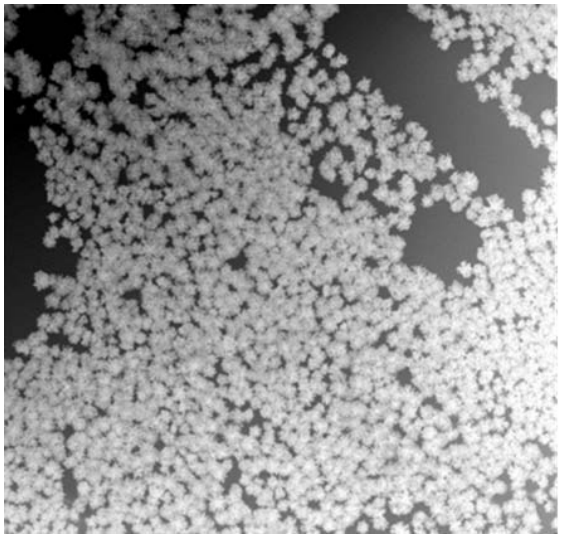
Height of pixels above the ground surface

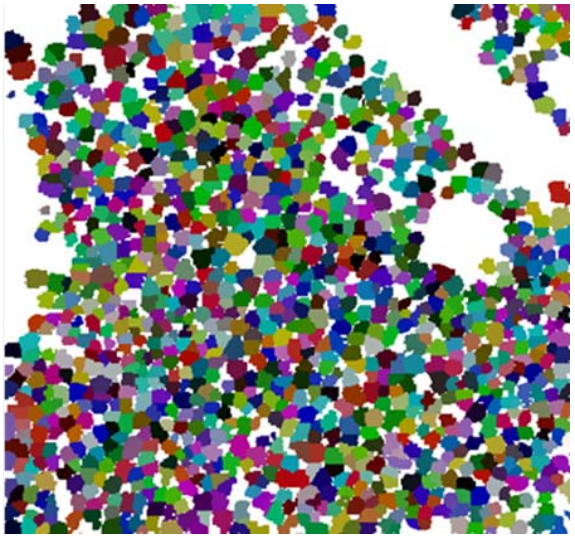
What information can we get about individual trees? How to do it?

Tree detection and position
=> Local Maxima Approach

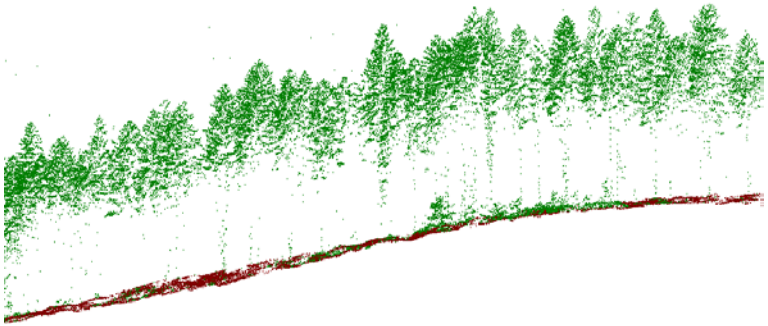
Projected tree crown area delineation => 3 algorithms



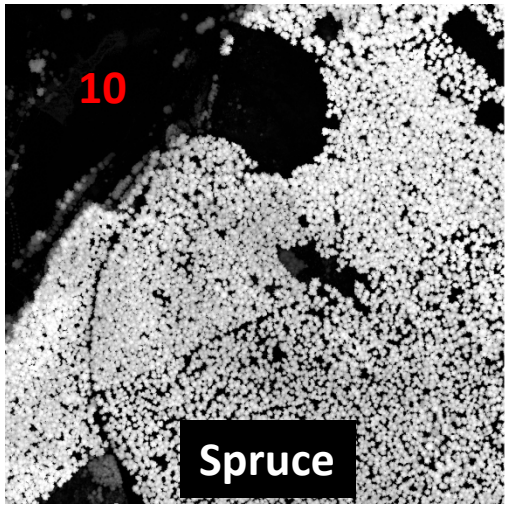


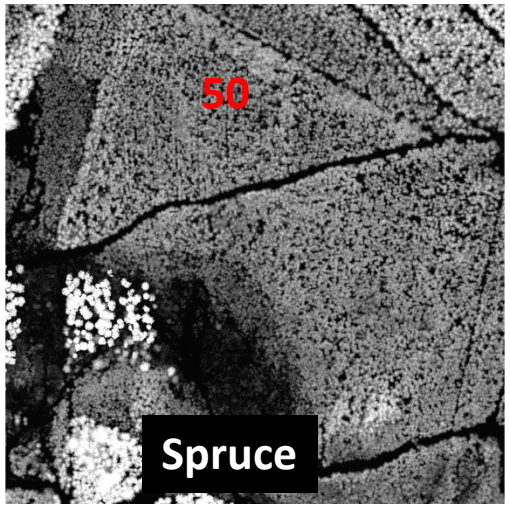


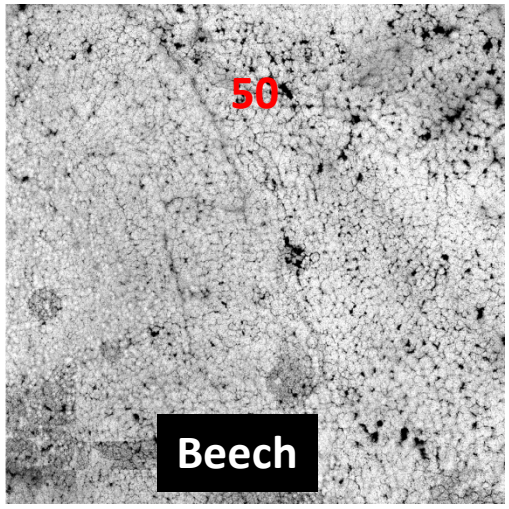
Data input

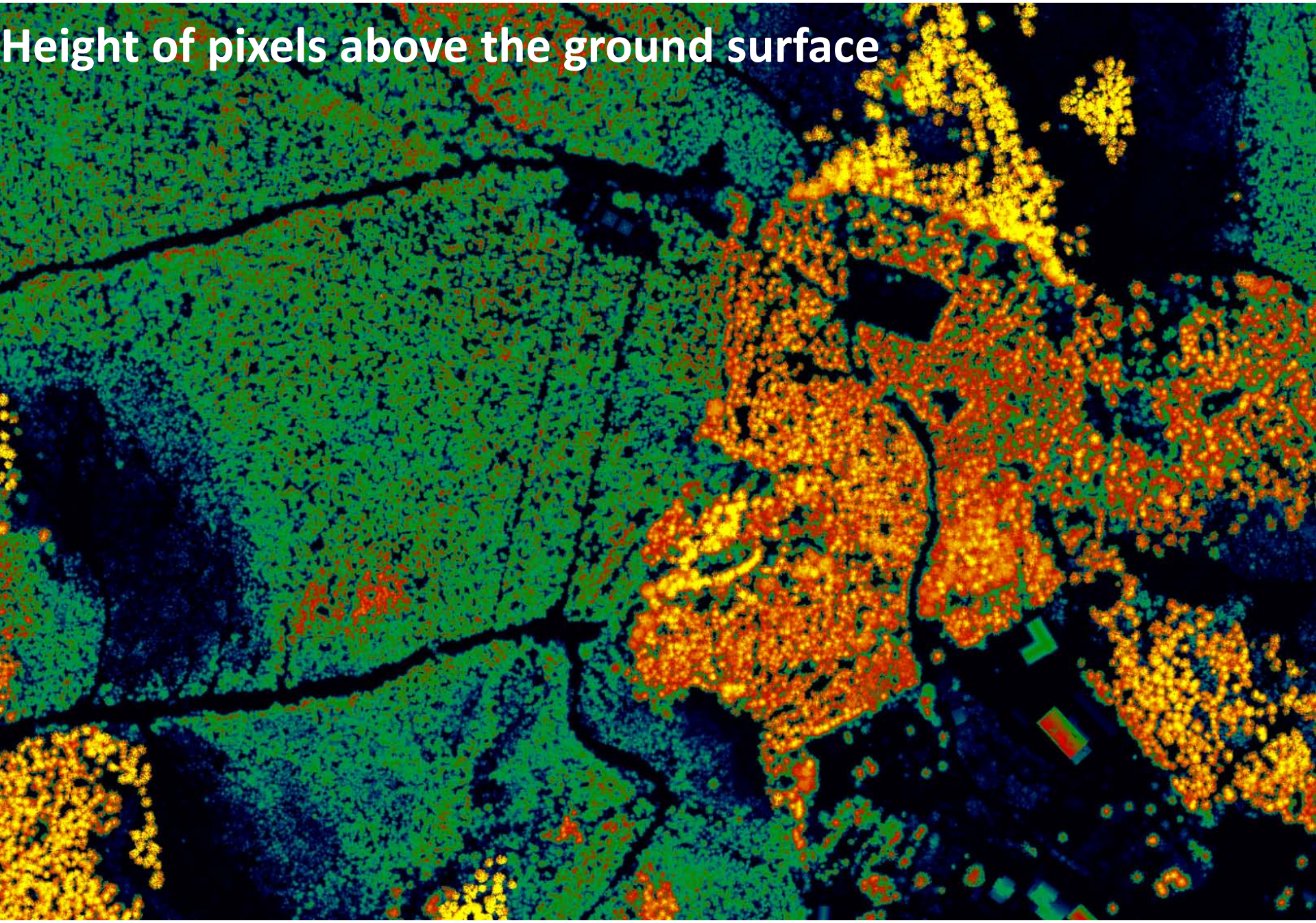


- Riegl Q680 instrument; 10/50 points per m^2
- DEM - triangulation/interpolation of ground X,Y,Z points
- DSM - triangulation/interpolation of above ground X,Y,Z points
- nDSM = DSM - DEM



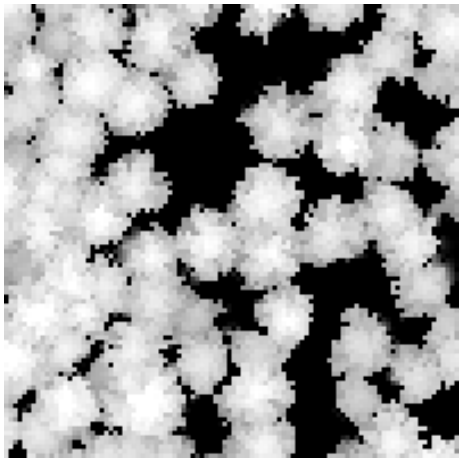


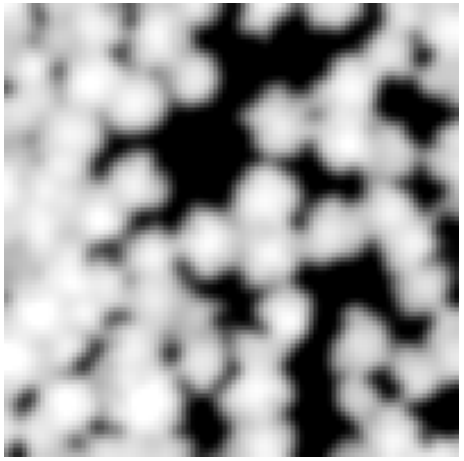


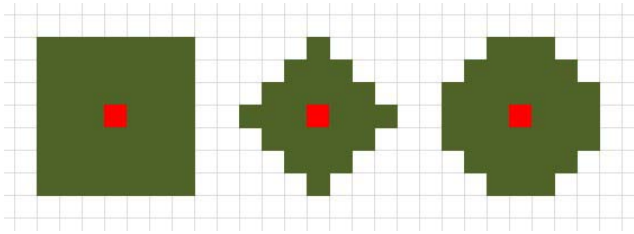

Height of pixels above the ground surface

Tree Detection

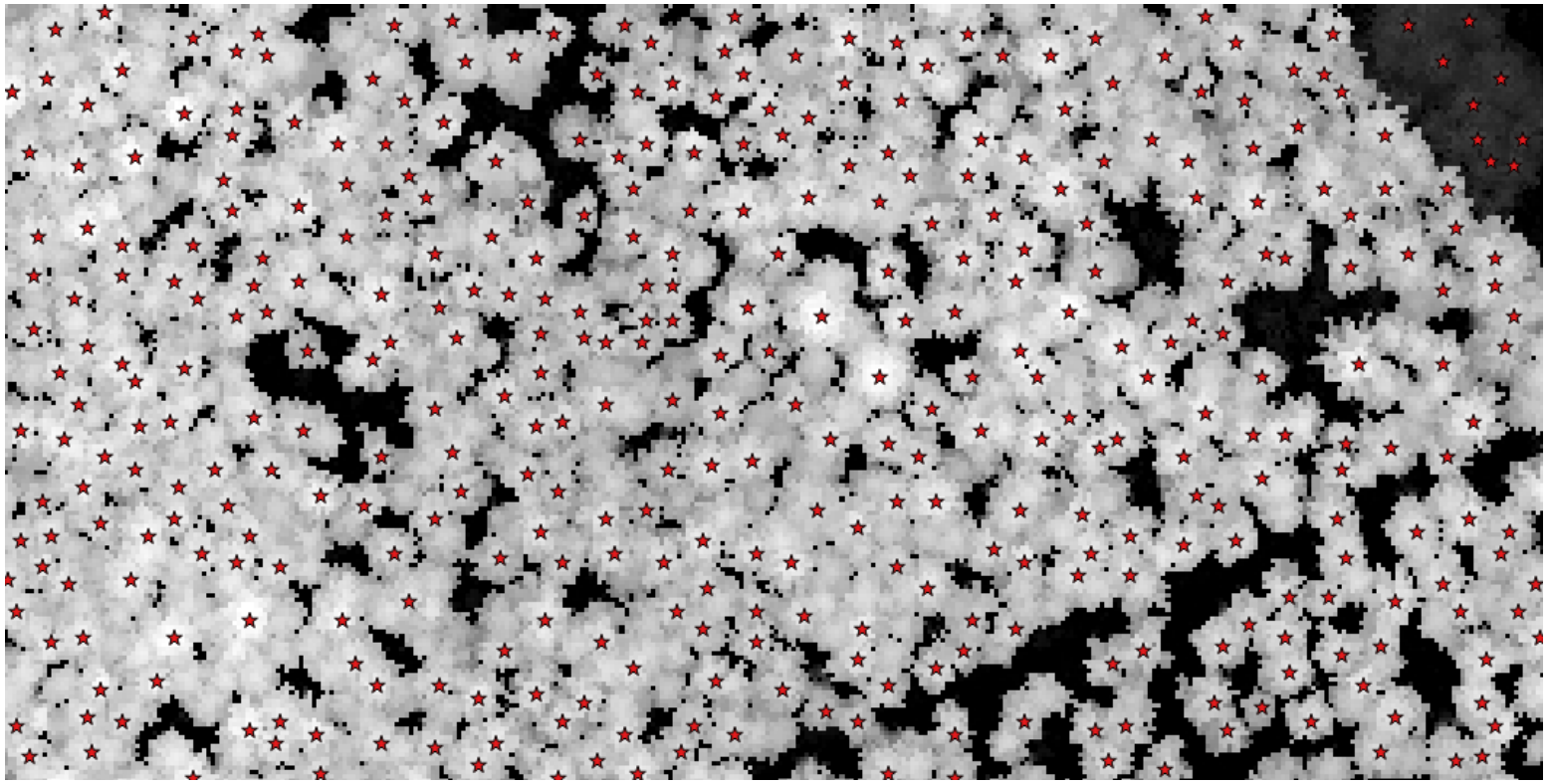
- Local Maxima Approach
- Preprocessing = Gaussian filtering
- Local maxima detection
  - Size of a neighborhood
  - Shape of a neighborhood
  - Minimum height threshold





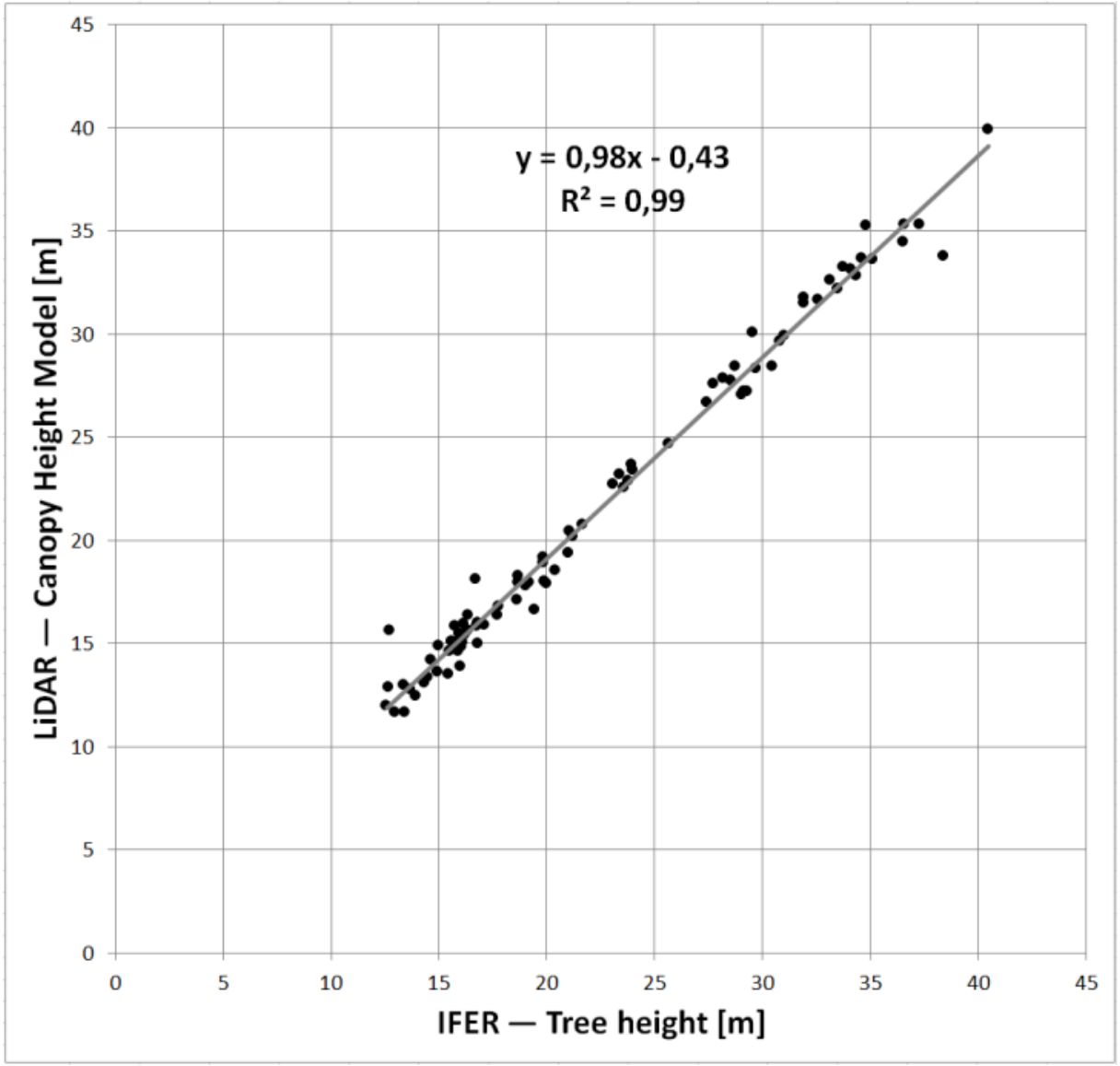


Results: Tree Detection



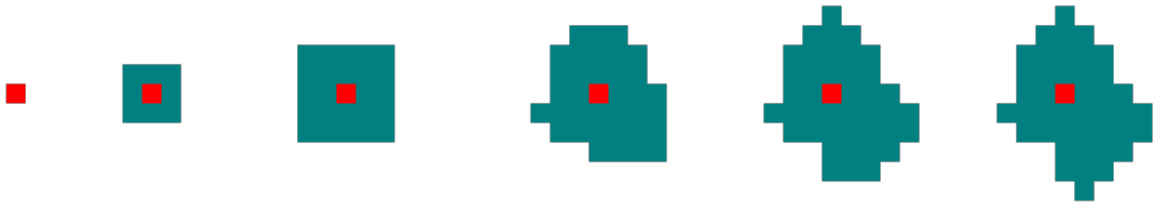
Locality	correct	omitted	efficiency	Locality	# of trees	height stats
Bílý Kříž	315	59	85.1 %	Bílý Kříž	5305	11.9 ± 3.8 m
Rájec	372	53	87.5 %	Rájec	4538	27.6 ± 4.1 m
Štítná	405	80	83.5 %	Štítná	6204	26.9 ± 2.6 m

Single tree height accuracy

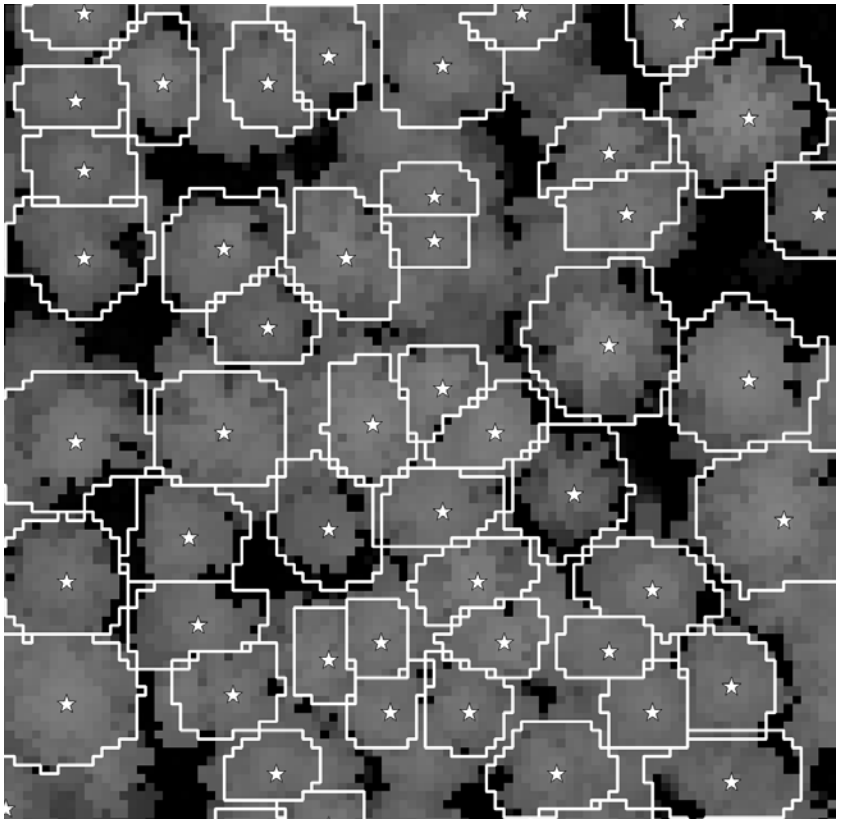


Projected tree crown area delineation

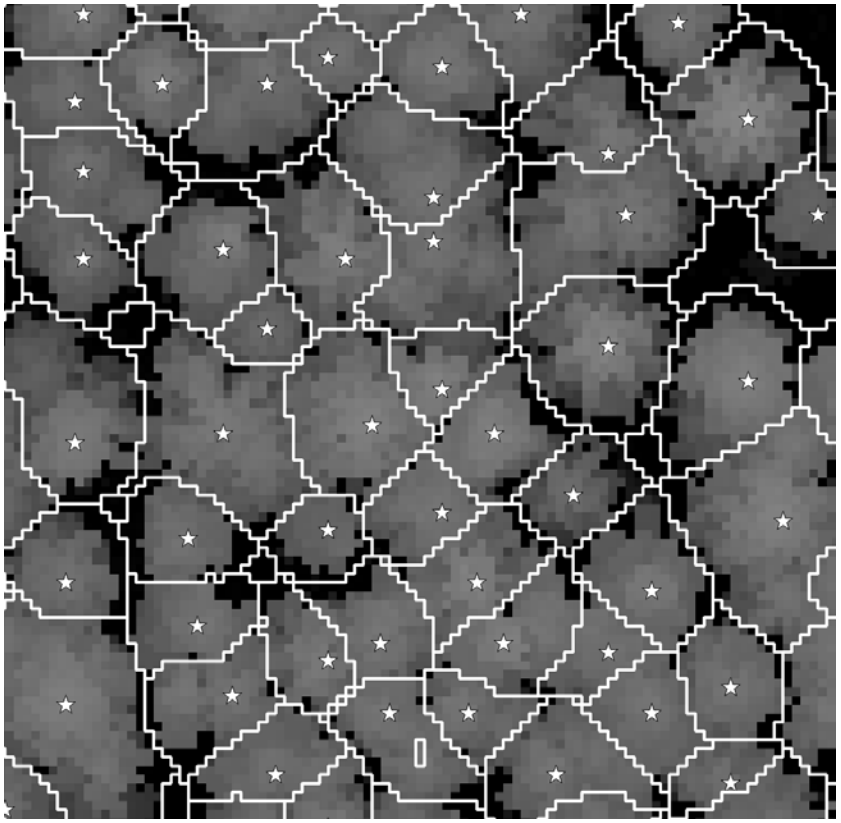
- **Watershed algorithm**
  - flooding of inverted structure from seed points
  - stopped by watershed ridge or height threshold
- **Valley following / Minima network**
  - boundary network built from local minima points
  - innovation: Voronoi diagram as the first iteration, then we move the boundaries down to local minima
- **Seeded region growing**



Comparison: SRG vs. Watershed

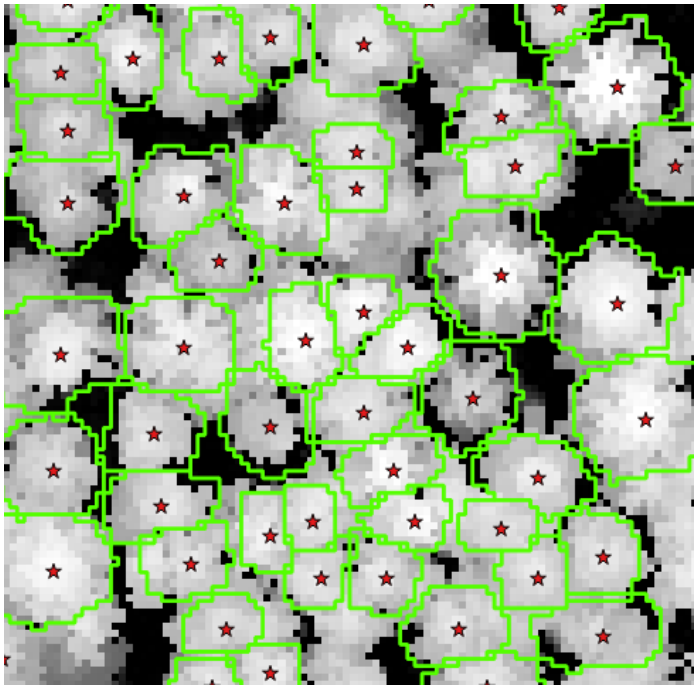


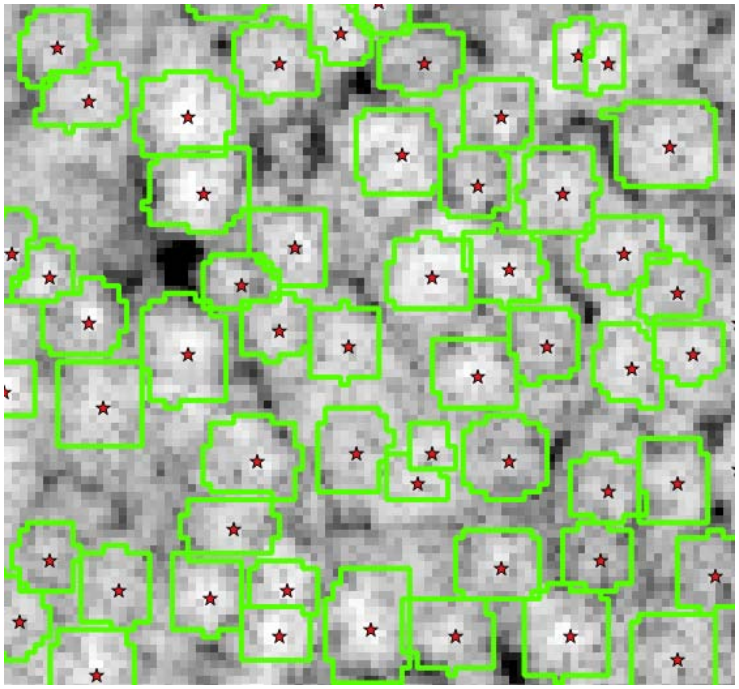
Seeded Region Growing



Watershed algorithm

Results: Crown Delineation



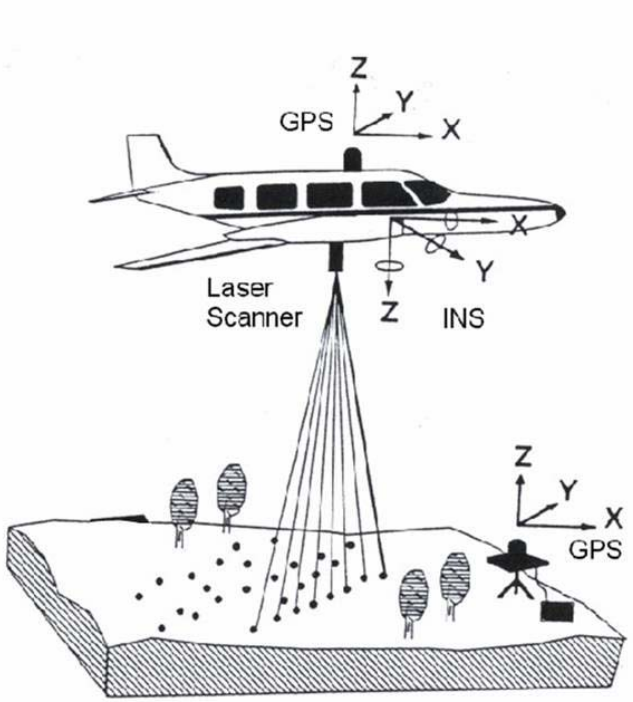


Locality	95 %	75 %	50 %	25 %	accuracy
Bílý Kříž	122	176	54	4	76.8 %
Rájec	177	188	53	10	79.0 %
Štítná	169	294	21	1	80.8 %

What is the source of point cloud data and how does it works?

Components of a LiDAR System

- Laser Rangefinder
  - Determines distance to the ground
  - Includes rotating mirror to scan across the ground
- Inertial Navigational System (INS)
  - Determines orientation of the sensor
- Global Positioning System (GPS)
  - Locates the sensor in absolute space
- Computer and Hard Drive



Source: Kao *et al*., 2005

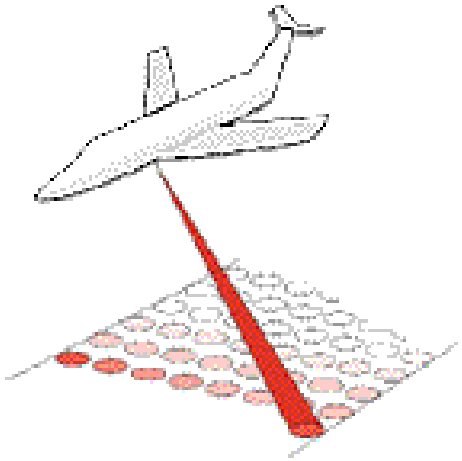
LiDAR system characteristics

- Current systems operate at 100 kHz or more
  - Data builds up quickly (360 million points per hour)
- Commonly at wavelength of ~1064 nm,

  ~ 1580 nm (near-infrared)
  - Good interaction with vegetation
  - Poor interaction with water
- Multiple returns may be recorded

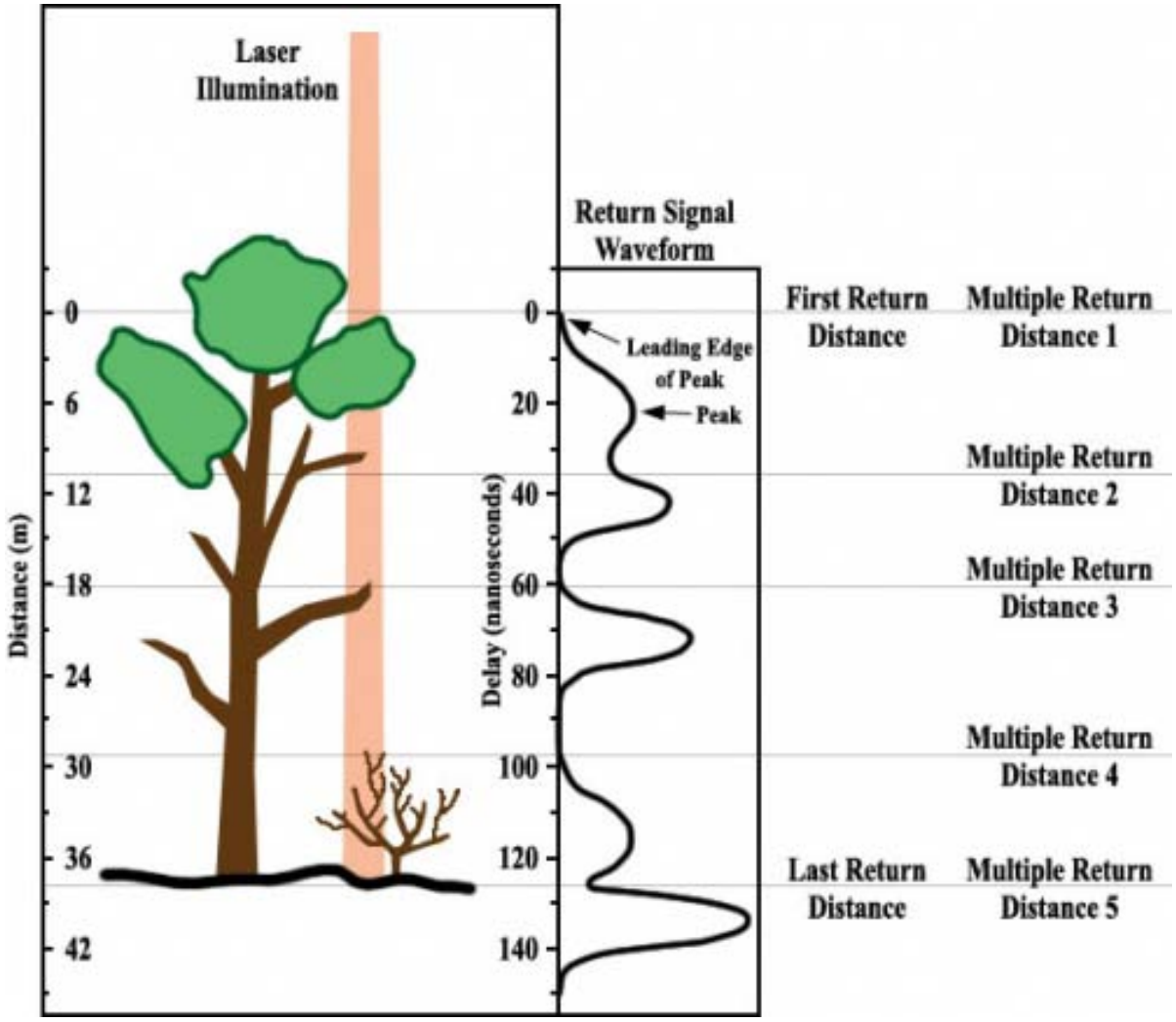
Small Footprint LiDAR

- **Discrete systems**
  - record one, two, or several returns for each emitted laser pulse
  - horizontal sampling is determined by the ground area of the footprint caused by the divergence of the laser pulse and the number of footprints per unit area
- **Full-waveform systems**
  - record the amount of energy return to the sensor over equal time intervals
  - The number of these time intervals determines the detail of data within the laser footprint



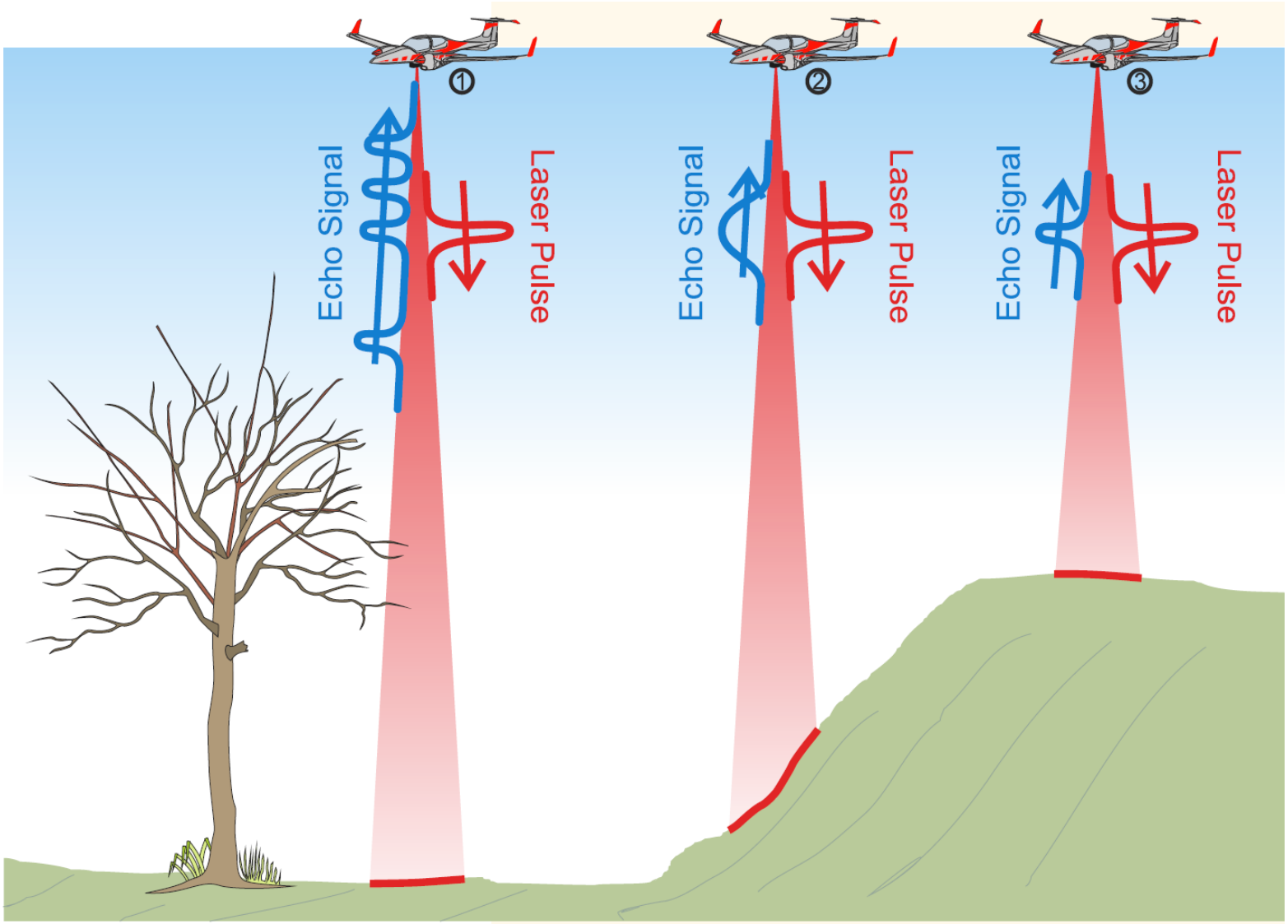
Source: www.geolas.com

Discrete and Waveform LiDAR



Source: Lefsky *et al.*, 2002

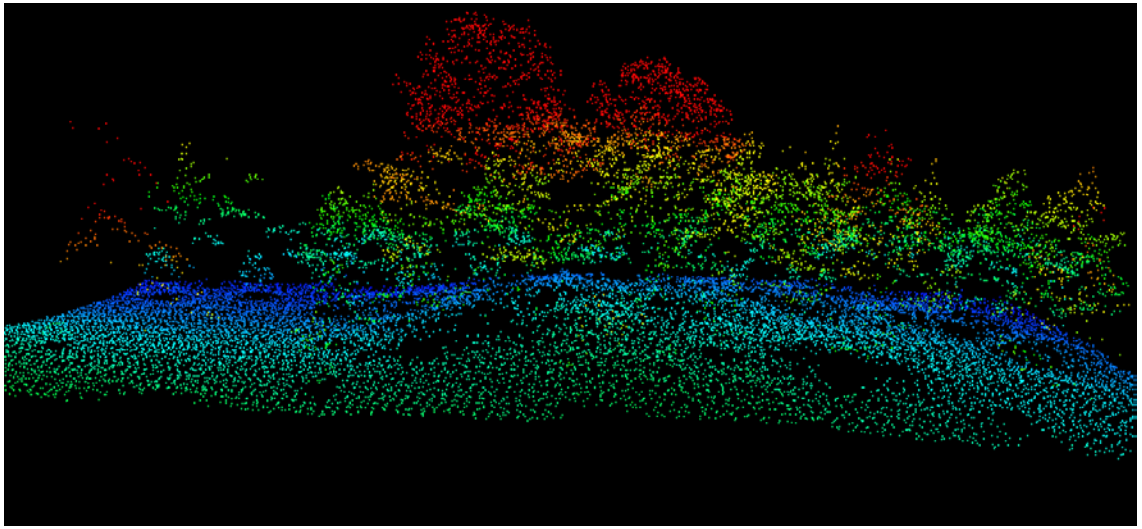
Waveform LiDAR



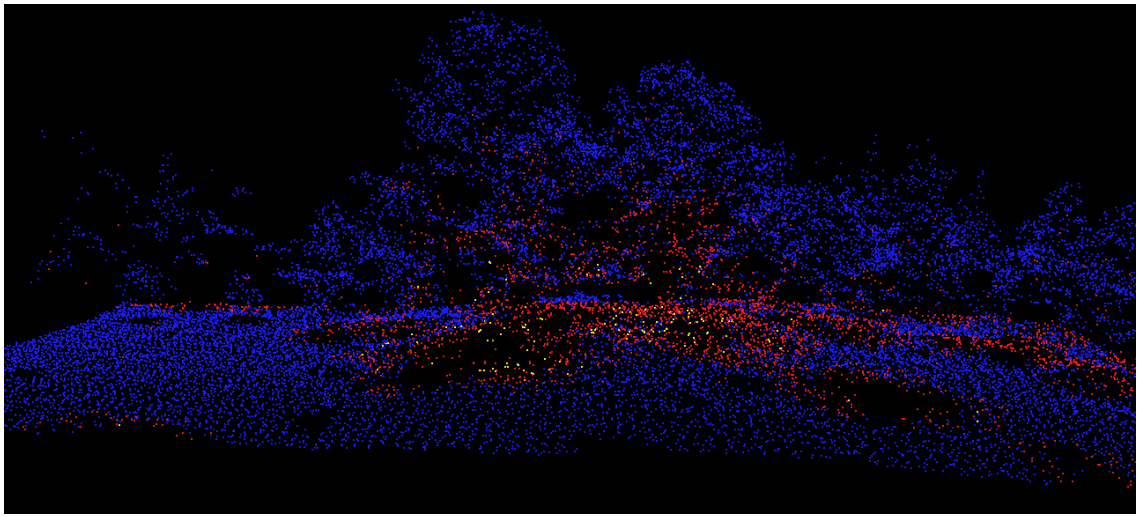
(www.riegl.com)

Multiple Return Lidar

Color represents elevations

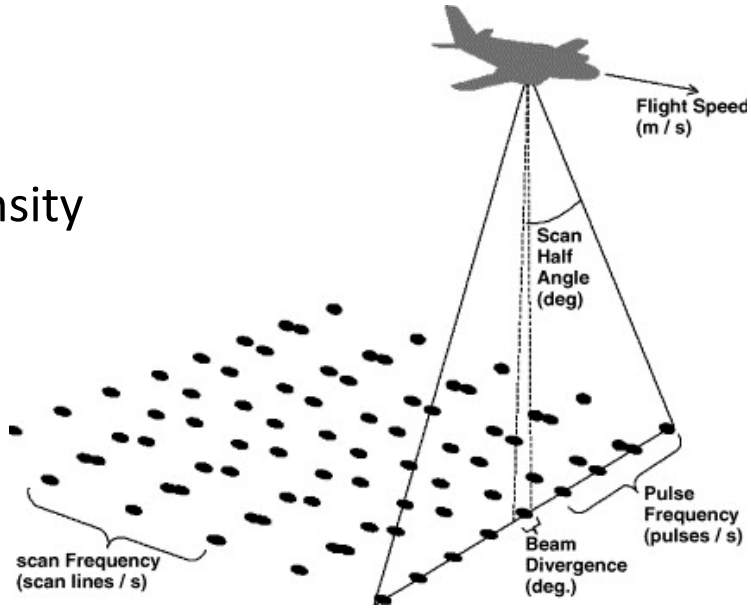


Color represents returns (Blue = 1st, Red=2nd, Yellow = 3rd)



Specifications for data collection

- Altitude
- Wavelength
- Frequency
- Number of returns
- Pulse spacing on the ground / pulse density
- Footprint size
  - Beam divergence/altitude
- Scan angle
  - 0 degrees = nadir
  - Usually < 15 deg
- Flightlines
  - Percent overlap
- X, Y, Z accuracy



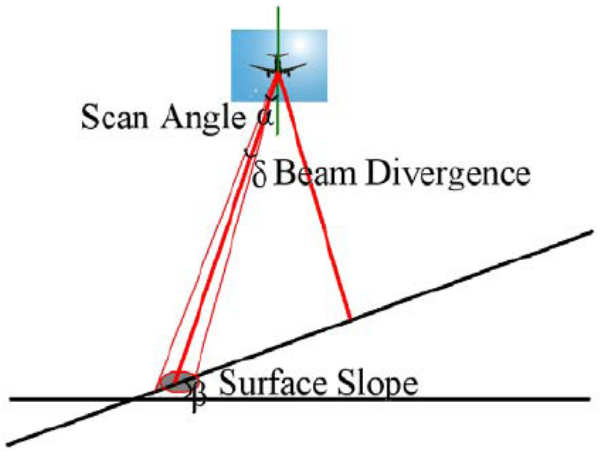
Lovell et al., 2005

Footprint size

- Depends on sensor configuration, altitude, flight velocity, and scan angle
- Calibrate for scan angle distortion over a known area
- Footprint size:

$$= 2h\tan(\delta/2)$$
$$= h\delta$$

h – flying height, δ - beam divergence

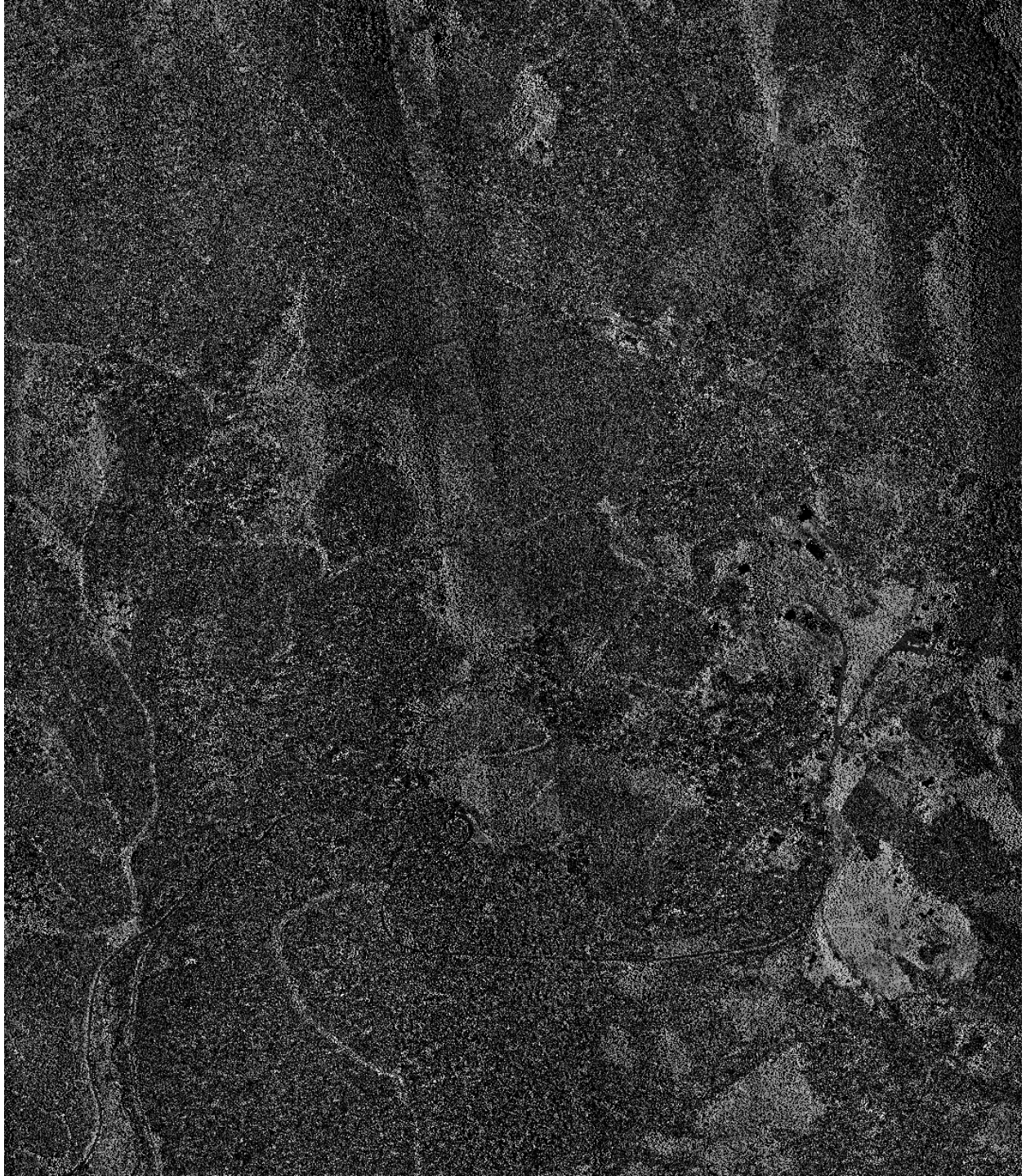


Ussyshkin et al., 2009

Intensity

- LiDAR intensity is the ratio of strength of reflected pulse to that of emitted pulse
- Values varies from 0-255
- Depends on
  - material properties
  - atmospheric attenuation
  - scan angle
  - flying height
  - sensor
- Can be useful for classifying landcover

Intenzity



Point Data Records

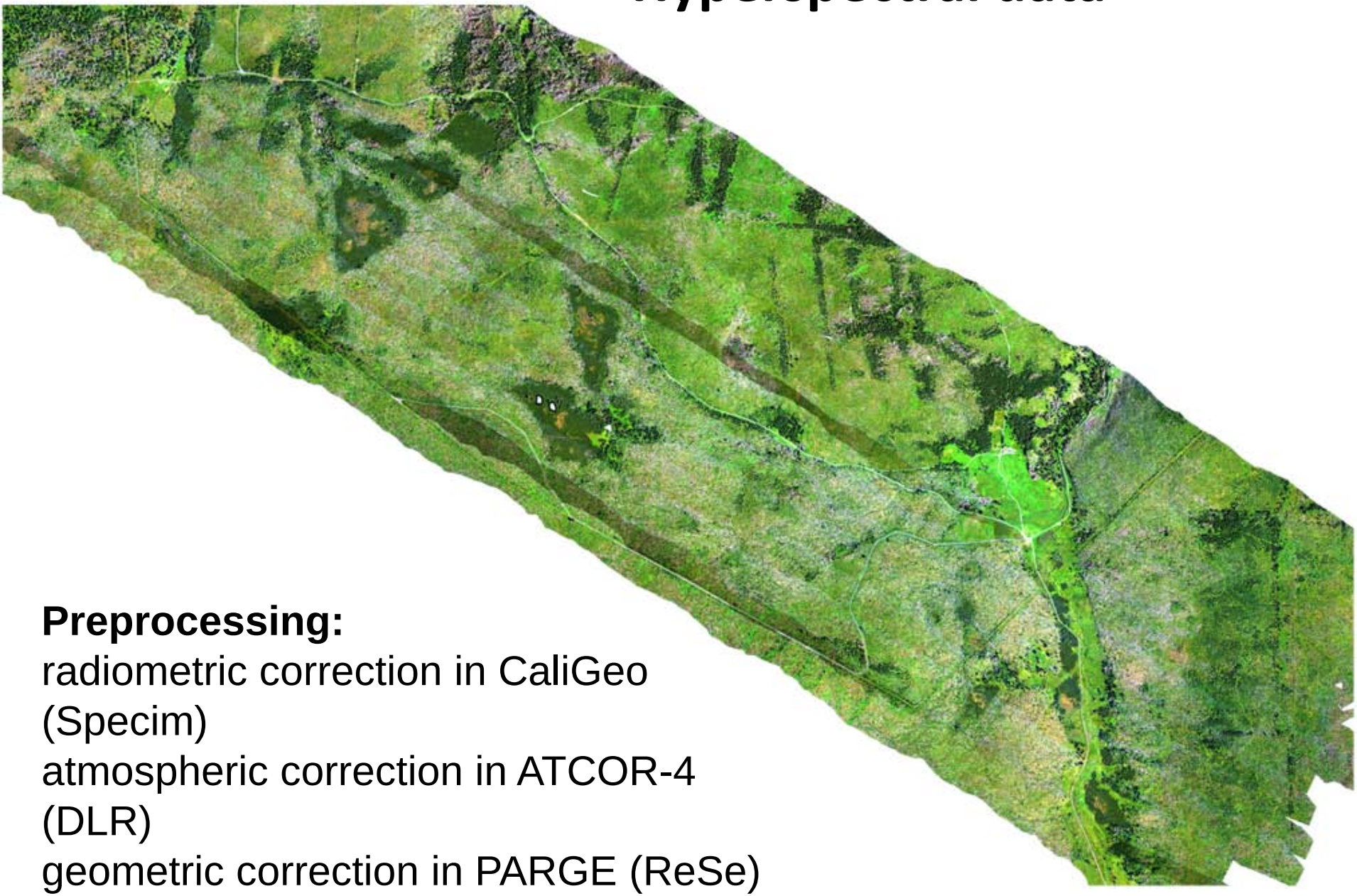
ASPRS Standard LiDAR Point Classes (LAS 1.1 to 1.3)

Classification Value (bits 0:4)	***Meaning***
0	Created, never classified
1	Unclassified[1]
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	*Reserved for ASPRS Definition*
11	*Reserved for ASPRS Definition*
12	Overlap Points[2]
13-31	*Reserved for ASPRS Definition*

LAS 1.0 – user-defined


Combined airborne LiDAR
and hyperspectral data for
forest qualitative and
quantitative assessment

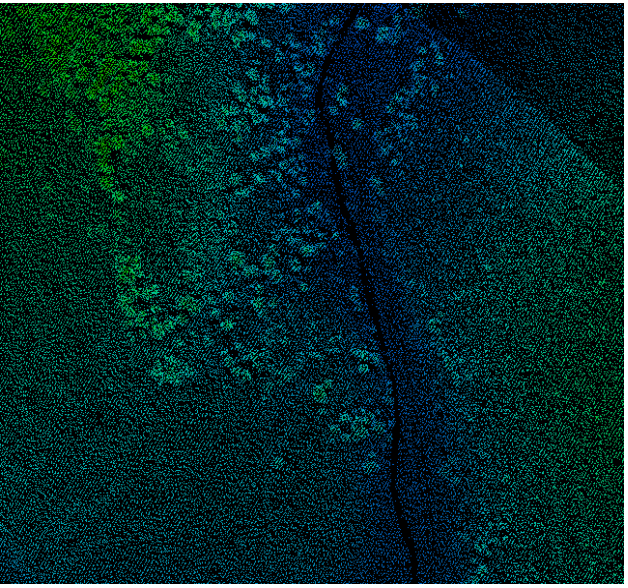
Hyperspectral data



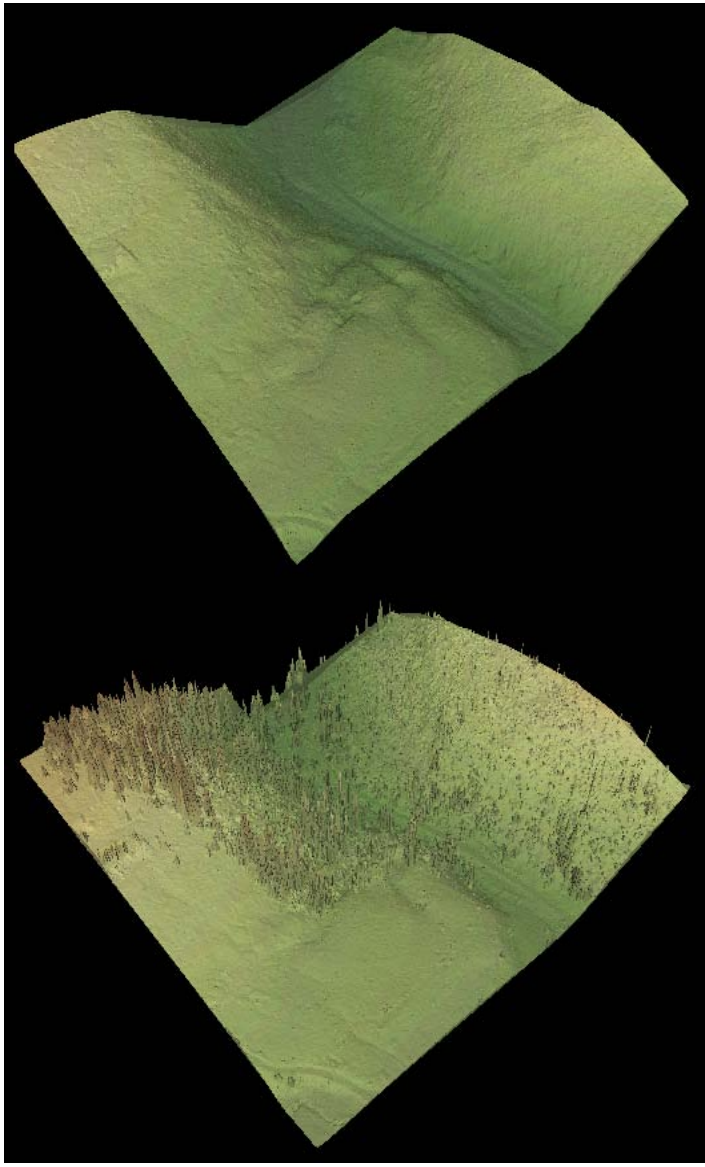
Preprocessing:
radiometric correction in CaliGeo (Specim)
atmospheric correction in ATCOR-4 (DLR)
geometric correction in PARGE (ReSe)

LiDAR input

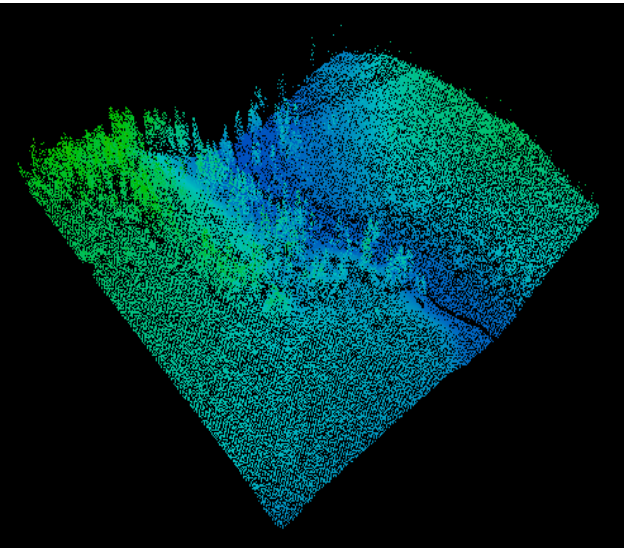
< DEM points



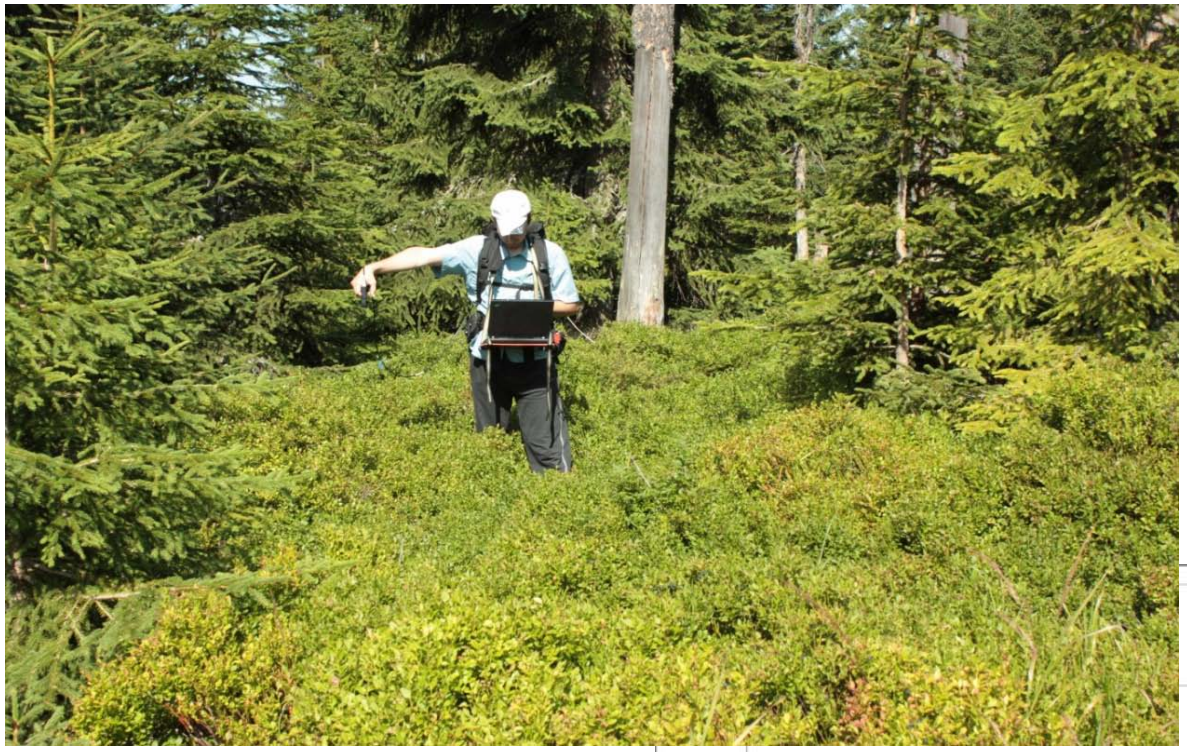
DEM raster >



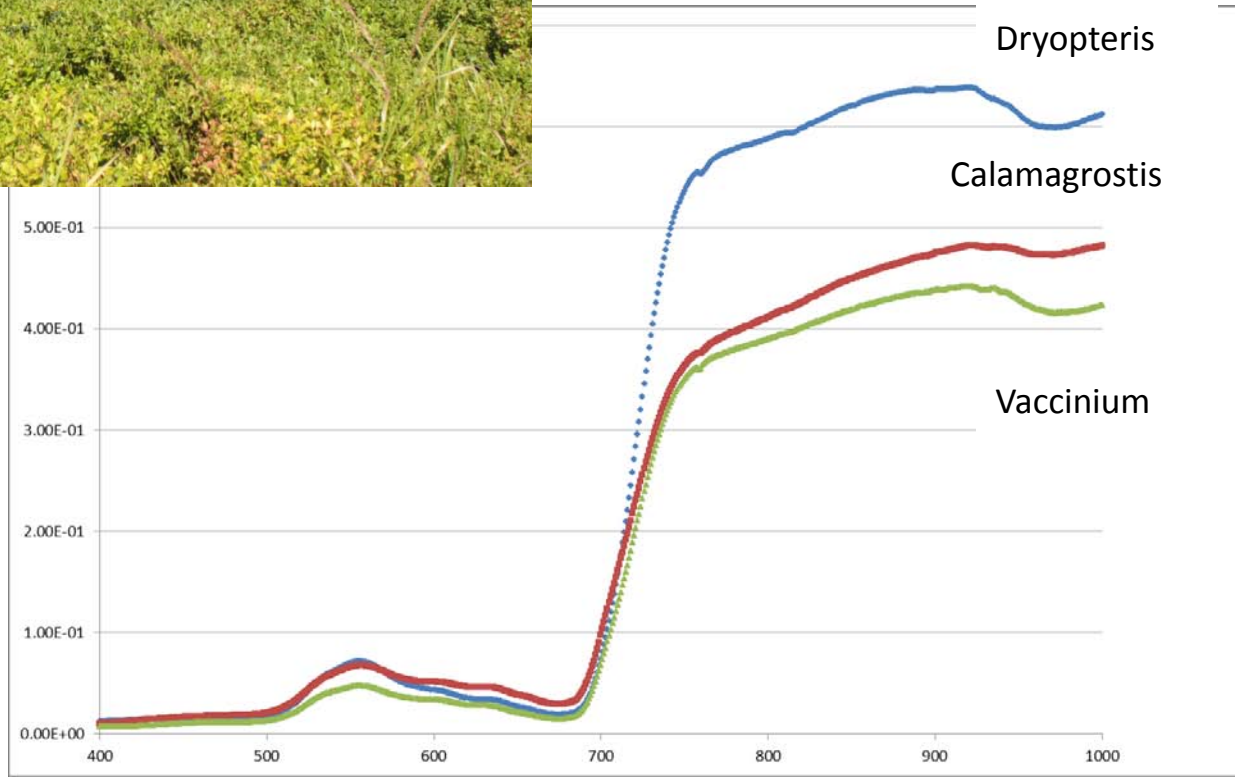
< DSM points



DSM raster >



Field spectral measurements of selected plant species



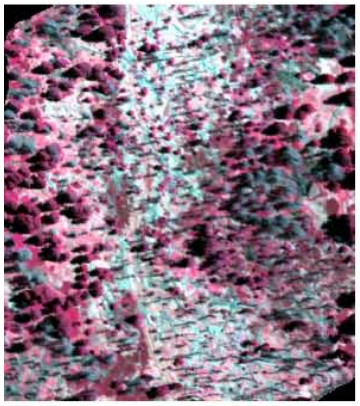
Object oriented classification

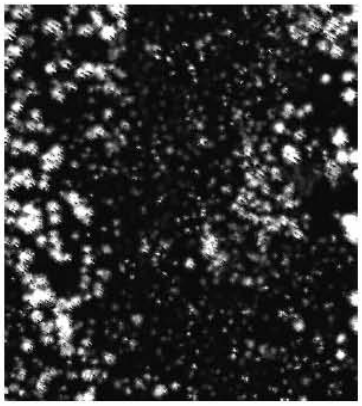
spectral information - from HS data

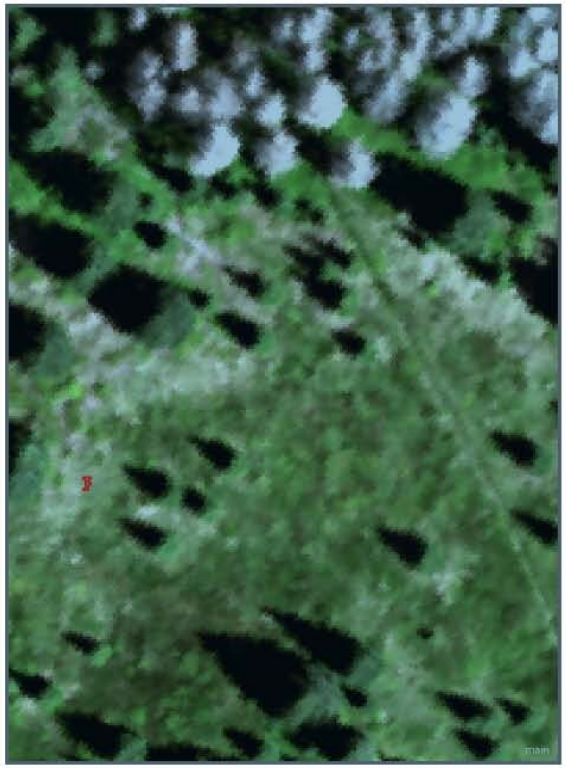
structural information - tree height/crown area derived from LiDAR data

Results of object-oriented classification

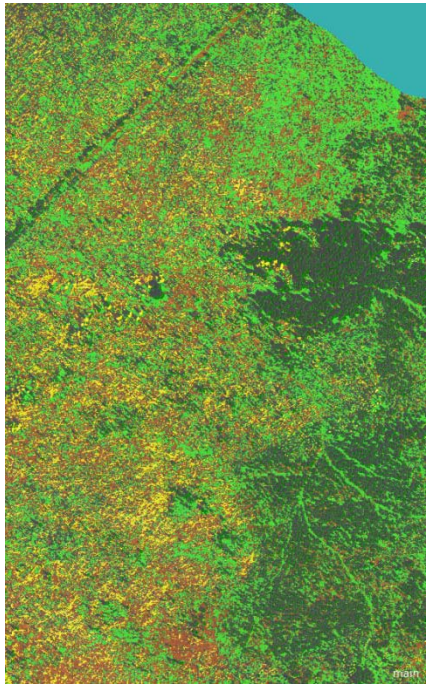
Classification inputs:
hyperspectral data and map of tree heights

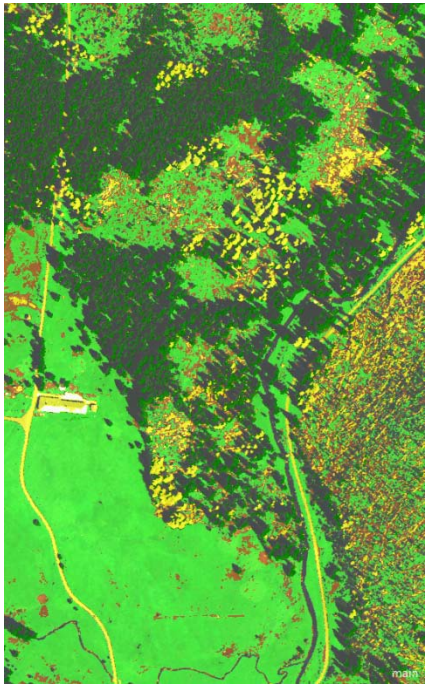




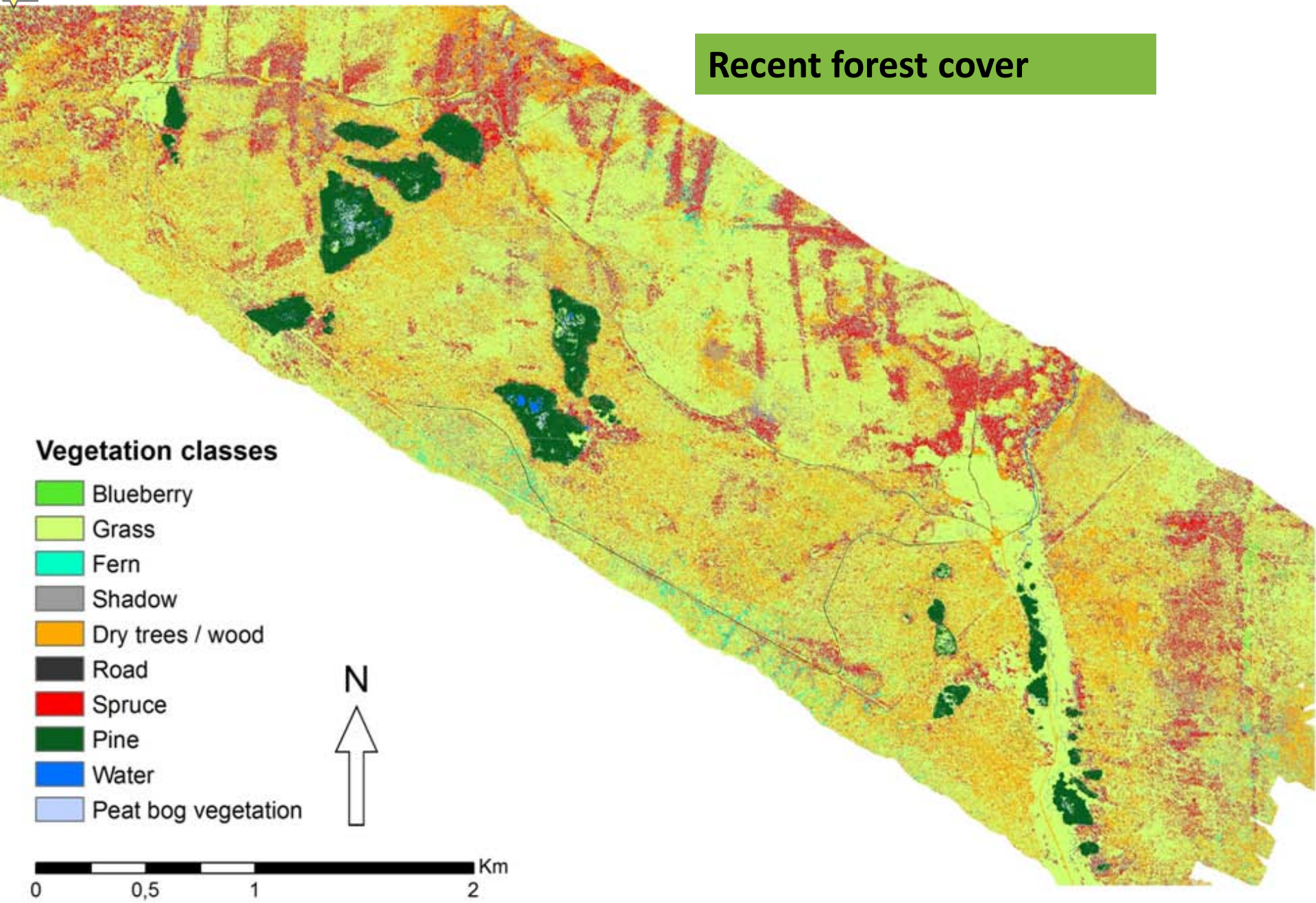


Object oriented classification



Recent forest cover



Latest technical facilities of CzechGlobe for airborne RS

Flying Laboratory of Imaging Systems (FLIS) + field campaign instrumentation

Cessna Caravan 208B

FLIS

- Photogrammetric **aircraft** with two acquisition open slits for imaging RS instruments
- Airborne imaging **spectroradiometers** with sensors in visible and near infrared (**VNIR**), short wavelength infrared (**SWIR**) and thermal infrared (**TIR**) spectral regions
- **IMU/GPS** units
- Full-waveform Light Detection And Ranging (**LiDAR**) airborne laser scanner for mapping the geometrical characteristics of the Earth surface objects (AdMaS)

http://mapserver.czechglobe.cz

CASI-1500 SPECIFICATIONS

FIELD OF VIEW	40° Across-Track over 1500 pixels
SPECTRAL RANGE	650nm between 365 and 1050nm
SPECTRAL SAMPLES	Programmable, up to 288 (<3.5 nm FWHM)
APERTURE	F/3.5 to F/18.0
DYNAMIC RANGE	16,384:1 (14 bits)
NOISE FLOOR	< 2.0 DN
SIGNAL TO NOISE RATIO*	1095:1 peak
DATA RATE (MB/SEC)	20

SASI-600 SPECIFICATIONS

FIELD OF VIEW	40° across-track over 600 pixels
SPECTRAL RANGE	950 to 2450nm
SPECTRAL SAMPLES	100 at 15nm intervals
APERTURE	F/2
DYNAMIC RANGE	16,384:1 (14 bits)
NOISE FLOOR	6.0 DN
SIGNAL TO NOISE RATIO	Contact ITRES for SNR calculations
DATA RATE (MB/SEC)	16 (Mode 1) 9.6 (Mode 2: Preferred data rate for optimal image quality)

TASI-600 SPECIFICATIONS

FIELD OF VIEW	40° across-track over 600 pixels
SPECTRAL RANGE	8 to 11.5µm
SPECTRAL SAMPLES	32 at 0.25µm intervals
APERTURE	F/1.5
DYNAMIC RANGE	16,384:1 (14 bits)
NOISE FLOOR	6.0 DN
SIGNAL TO NOISE RATIO	Contact ITRES for SNR calculations
DATA RATE (MB/SEC)	13.25
NEDT	0.2° at 300K

LiDAR - *RIEGL* LMS-Q680i

waveform airborne laser scanner

Thank you for your attention.