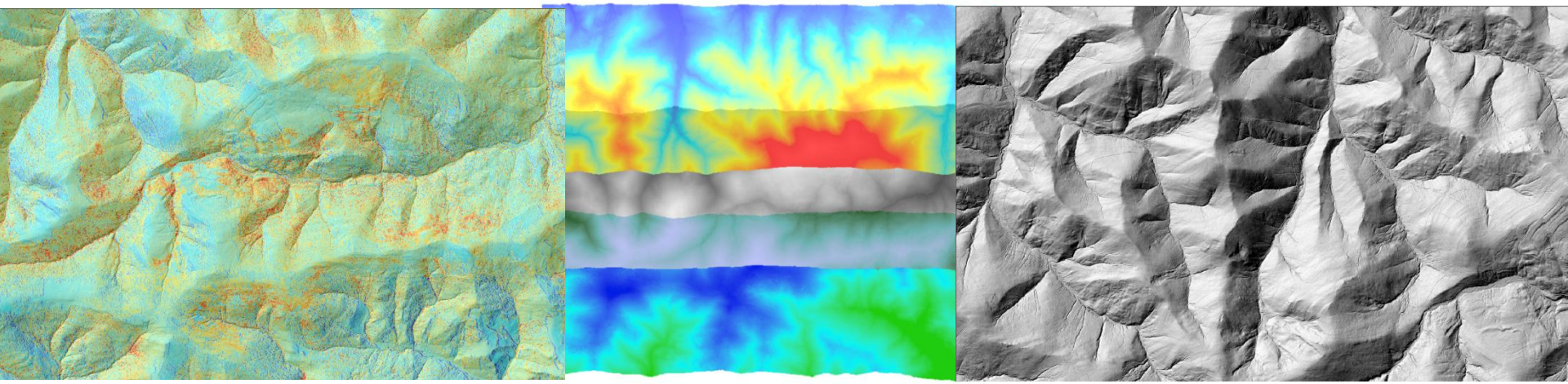
Airborne Laser Scanning versus Stereomatching of aerial photos based approach



Piotr Wężyk Assoc. Prof., Paweł Hawryło M.Sc.
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SCERIN-3 Capacity Building Workshop (CBW)
Brasov, July 13-17, 2015

GOFC-GOLD GLOBAL OBSERVATION OF FOREST AND LAND COVER DYNAMICS

START global change SysTem for Analysis, Research & Training

LiDAR - basic

LiDAR (ang. ***Li**ght **D**etection **A**nd **R**anging)*

- LiDAR - **active** remote sensing systems based on EM energy Near InfraRed (**NIR**) or green band (**Green**);
- Scanner LED generates pulses of radiation (or continuous wave) and the calculation module determines the time of transmission of the pulse until it returns to the device;

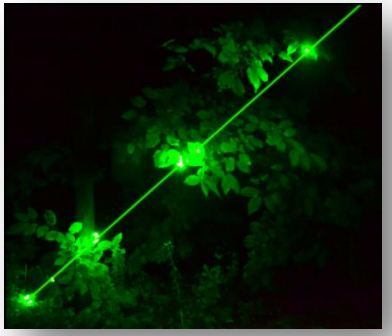


photo. K. Zięba

- the measurement of the laser deviation, relative to the device and determine the position of the scanner in 3D space (airplane, helicopter, car's – INS (INS + GNSS) allow to determine the coordinates (XYZ) of the target (echo /return's) with accuracy: mm-dm);
- laser signal partly reflected from the objects (part of the laser beam) - form echo's (eg. First Echo, Second Echo… Last Echo) - building a 3D point cloud.

LiDAR – how it works

- **Time of Flight (ToF) scanners**

$$\Delta l = \frac{c \times \Delta t}{2}$$

where: Δl - distance
c – speed of light
Δt – time difference

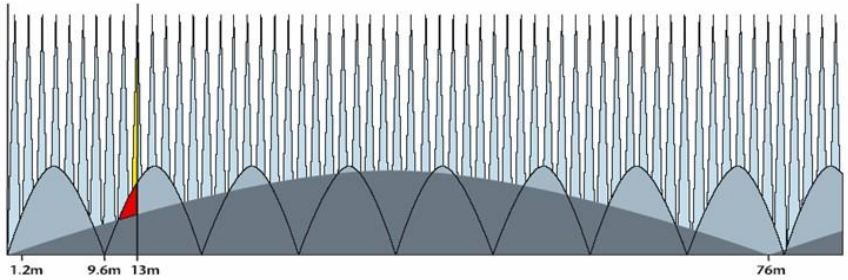
c = 299 792 458 m/s

Example:
Distance: 2 x 400m = 800 m
ToF = 2.64 ms

www.leica.com

velodynelidar.com

- **Continous Wave (Phase) Scanres**



www.faro.com

$$l = \frac{1}{4\Pi} \times \frac{c}{f} \phi$$

photo. P. Wężyk

- **Triangulation scanners (2 cameras + Laser)**

www.konicaminolta.com

www.faro.com

creaform3d.com

LiDAR system classification

LiDAR - classification based on the device location in the space:

- **SLS –** Satellite Laser Scanning;
- **ALS -** Airborne Laser Scanning;
- **ALH** – Airborne Laser Hydrography;
- **ULS** – Unmanned Laser Scanning;
- **TLS -** Terrestrial Laser Scanning or Ground Based Scanning;
  - **MLS** - Mobile Laser Scanning;
  - **ILS** - Industrial Laser Scanning;
  - **HLS** – Handy Laser Scanning

source:RIEGL

photo. P. Wężyk

Source: FARO

photo. P. Wężyk

photo. P. Wężyk

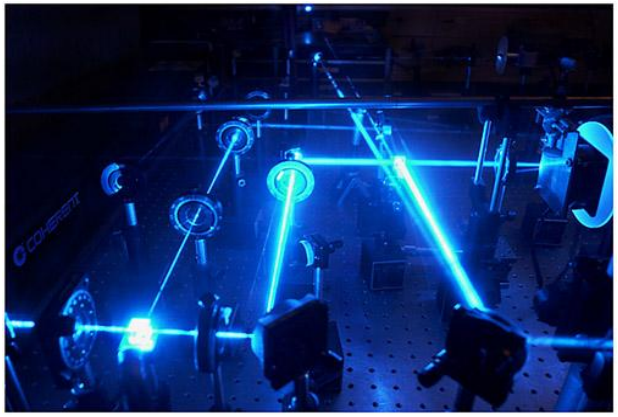
What LiDAR can see ?

Question: Can You see the LiDAR?

Blue - Yes

Red - Yes

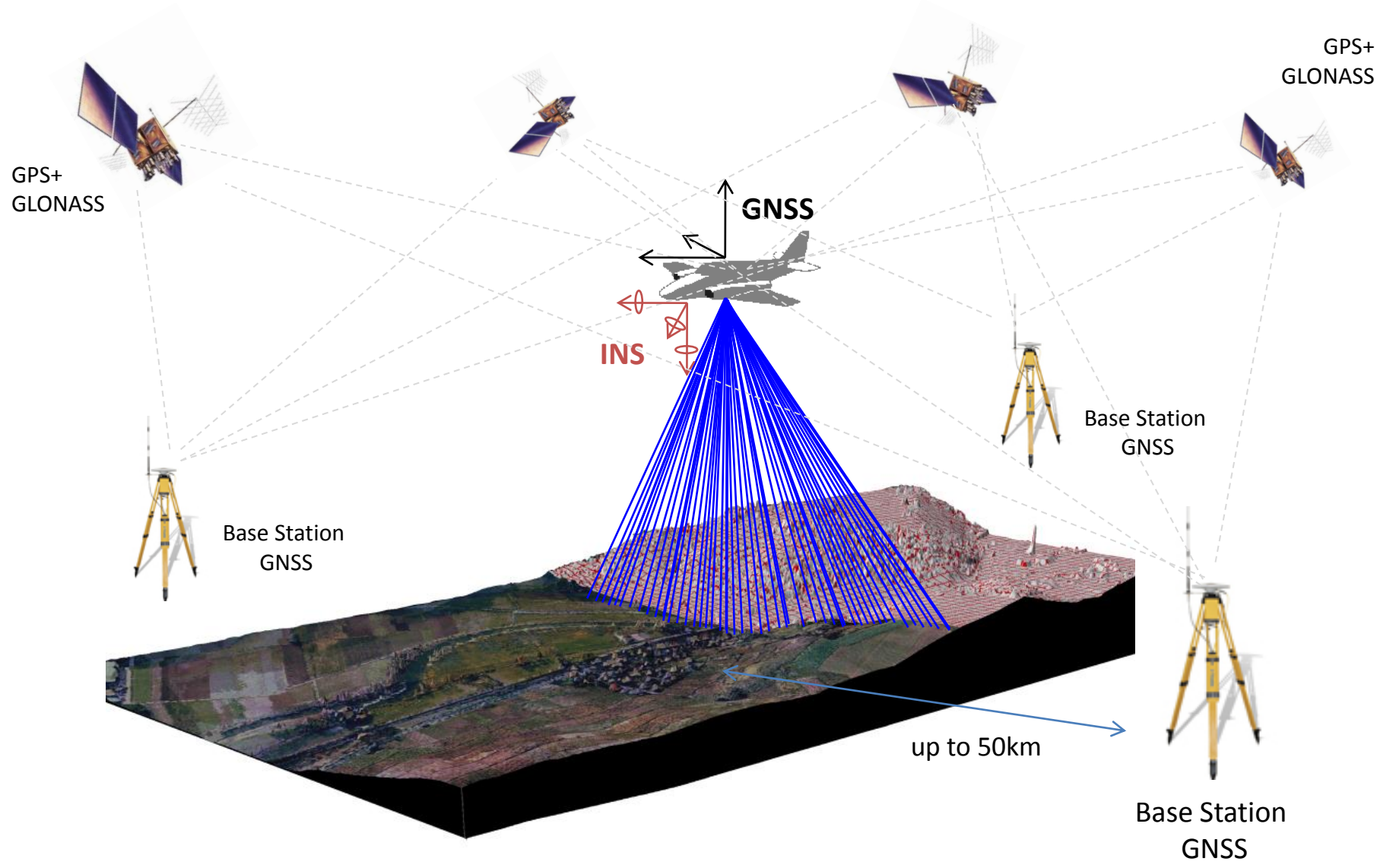
Green - Yes



?

Near InfraRed – No !!!

ALS - components



ALS – modern systems

LMS-Q1560

VUX-1 (UAV)

RIEGL LASER MEASUREMENT SYSTEMS

Źródło: www.riegl.com

ALS70

Leica Geosystems

Źródło: www.leica.com

Leica ALS70CM

Chiroptera II

AHAB Airborne Hydrography AB

Źródło: www.airbornehydro.com

Optech ALTM PEGASUS

Optech Lidar Imaging Solutions

Źródło: www.optech.com

Trimble

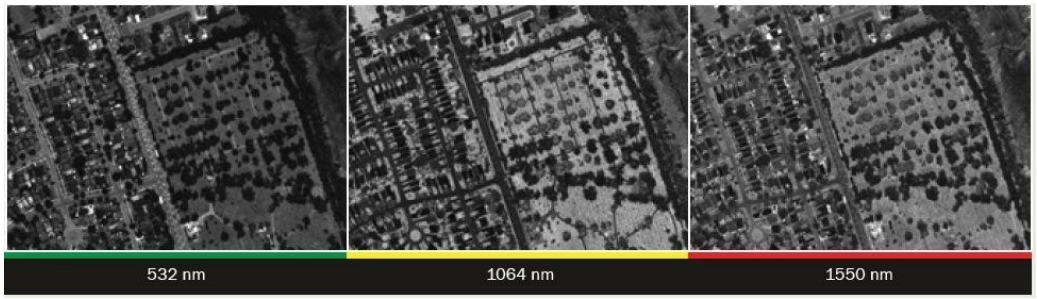
Trimble AX60i oraz AX80

ALS – technical revolution

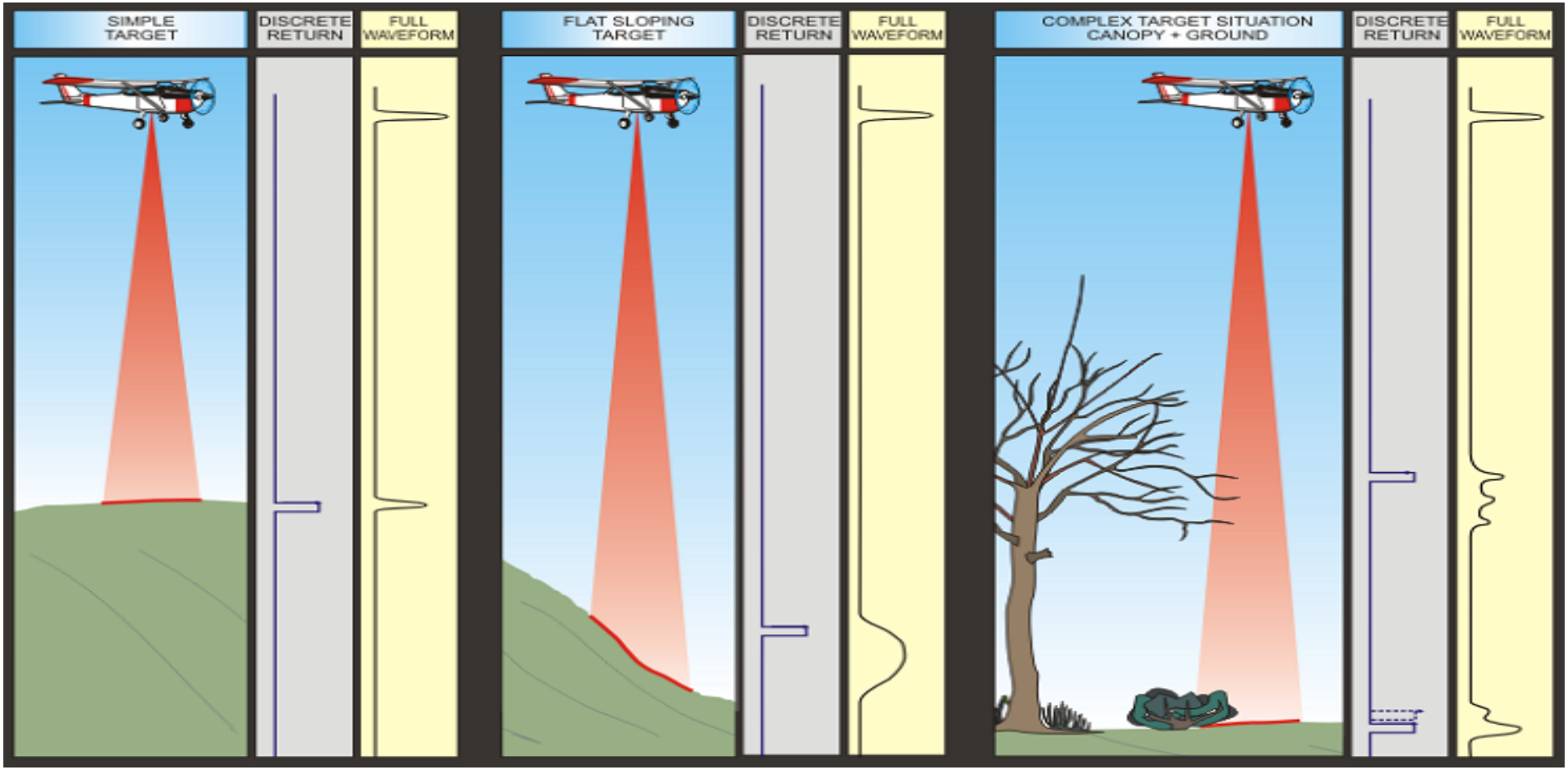
Optech

Parameter	Specification
Laser Configuration	
Channel 1	1550 nm IR
Channel 2	1064 nm NIR
Channel 3	532 nm visible
Beam divergence	Channel 1 & 2: ≈0.35 mrad (1/e) Channel 3: ≈0.7 mrad (1/e)
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Operating altitudes [1,2]	Topographic: 300 - 2000 m AGL, all channels Bathymetric: 300 - 600 m AGL, 532 nm
Depth performance	Dmax (m) ≈ 1.5/K_d, where K_d is the diffuse attenuation coefficient of the water
Effective PRF	Programmable; 50 - 300 kHz (per channel); 900 kHz total
Point density [4]	Bathymetric: >15 pts/m2 Topographic: >45 pts/m2
Scan angle (FOV)	Programmable; 0 - 60° maximum
Effective scan frequency	Programmable; 0 - 210 Hz
Swath width	0 - 115% of AGL
Horizontal accuracy [2,3]	1/7,500 × altitude; 1 σ
Elevation accuracy [2,3]	< 5 - 10cm; 1σ

- Three independent active imaging channels that support 532, 1064, and 1550 nm wavelengths for multispectral mapping of the earth's surface, day or night
- A high-resolution "green" channel that ensures high point density for shallow water mapping applications
- Narrow pulse widths, state-of-the-art receiver and timing electronics guarantee the highest range precision possible for maximum data quality
- A fully programmable scanner enables huge increases in point density at narrower FOVs for maximum target resolution and detail over competing sensors
- A 29 MP high-resolution, fully electronic QA camera provides passive imagery support.
- Optional embedded 80 MP RGB orthometric camera with forward motion compensation enhances image quality and improves classification. Also available with imbedded multispectral, thermal or NIR sensor options

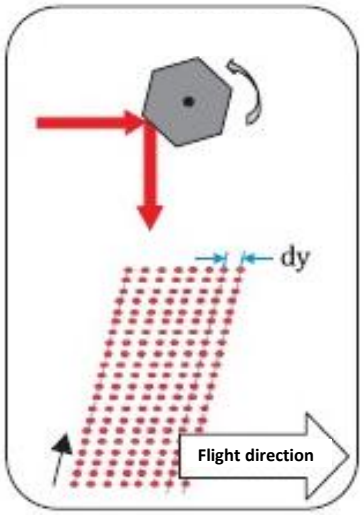


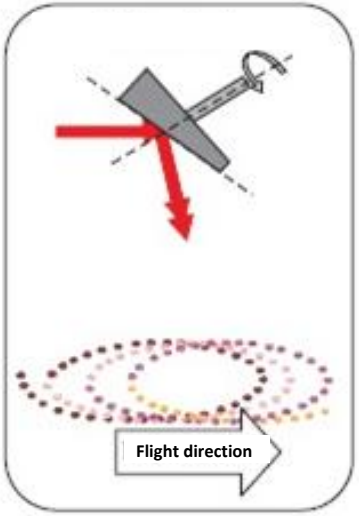
ALS - Full waveform

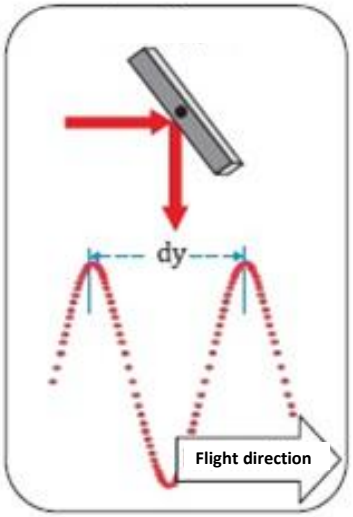


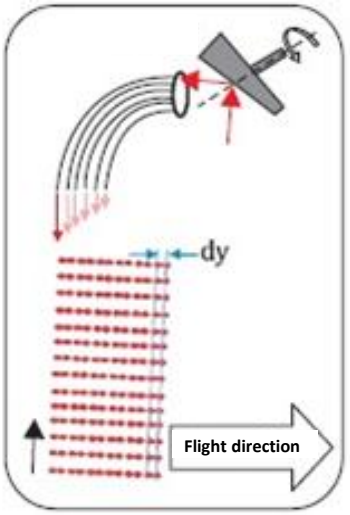
www.riegl.com

ALS – beam patern









Vosselman, Mass 2010

Parallel lines

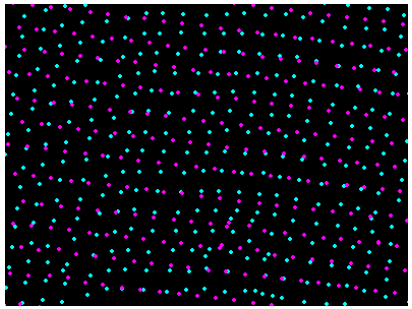
Ellipsoidal shape
Palmer's scanner

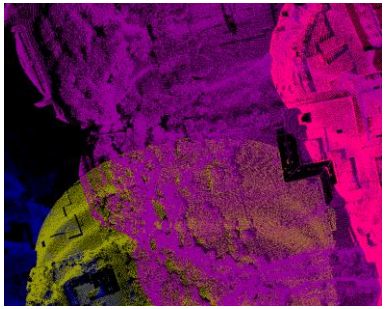
Sinusoid Z

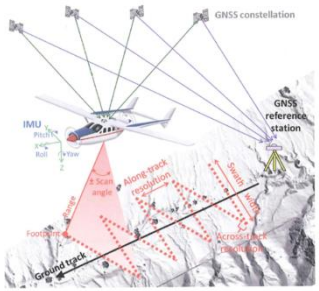
Osciliting scanner

Parallel lines

Fiber optic scanner

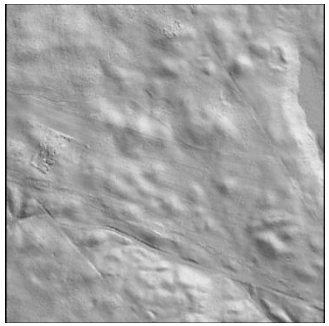




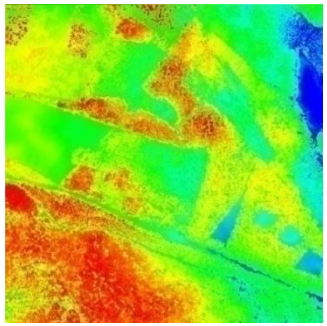


ALS – Height models

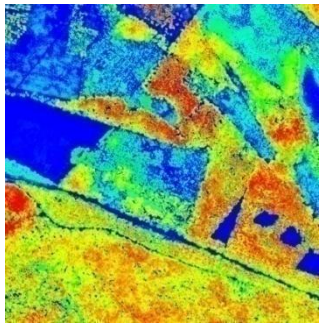
Information hidden in the woods….



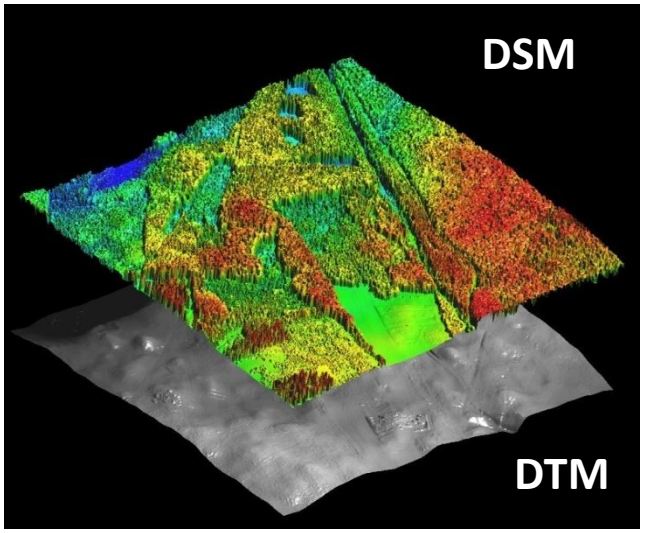
DTM (H + shaded relief)



DSM



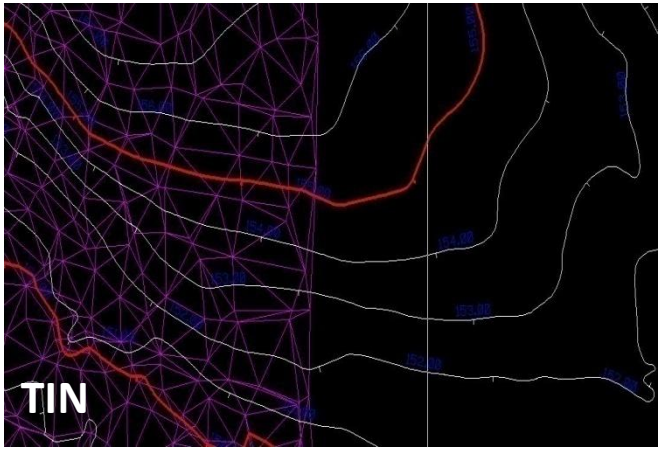
nDSM



ORTHO

nDSM + ORTHO

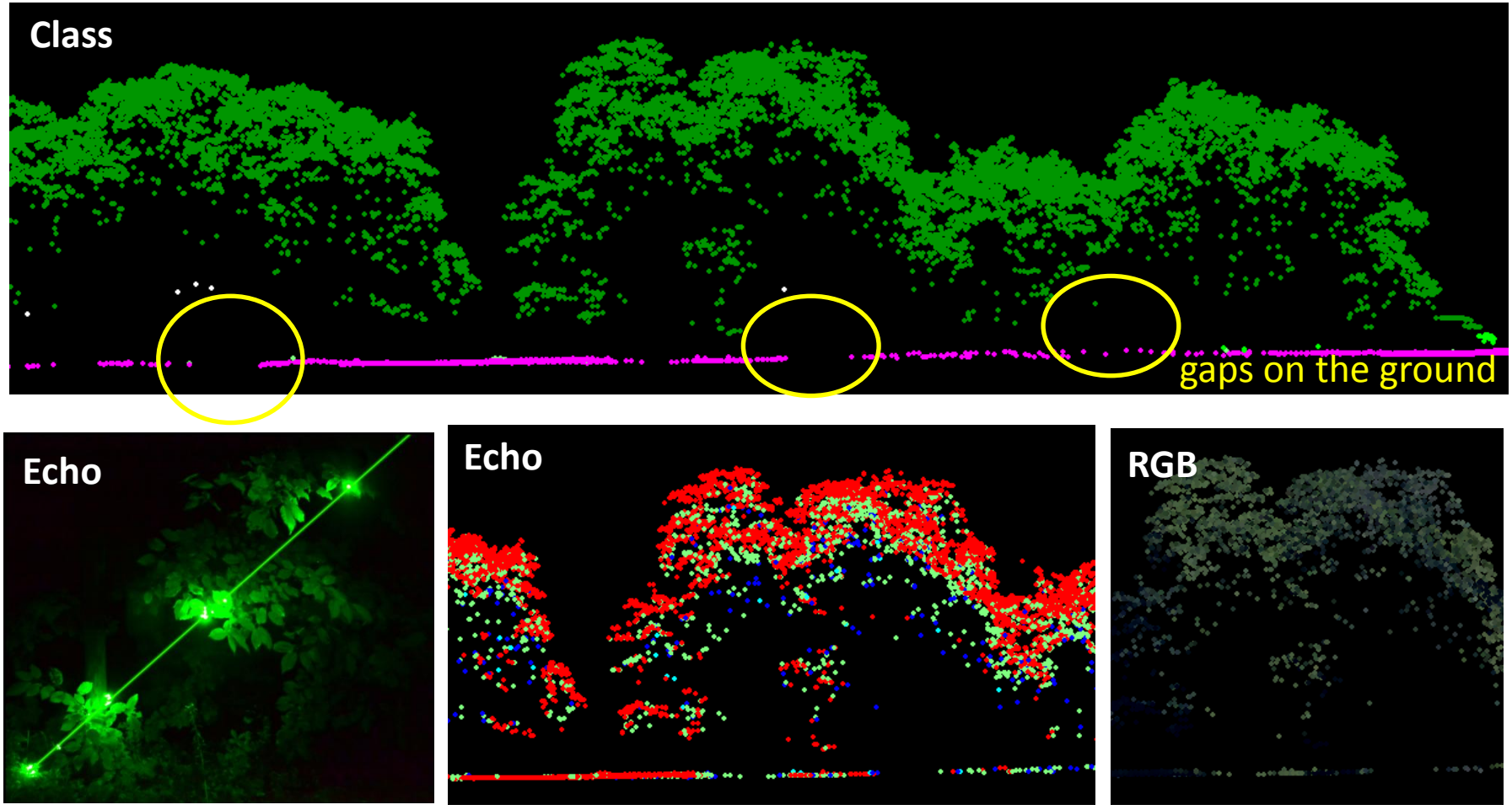
nDSM + vector maps



DTM – after *low point* and *ghost points* filtration , the last echo (or first = last) is used for generation of TIN using active triangle method (Axelsson 2000).

ALS – Echo / Return

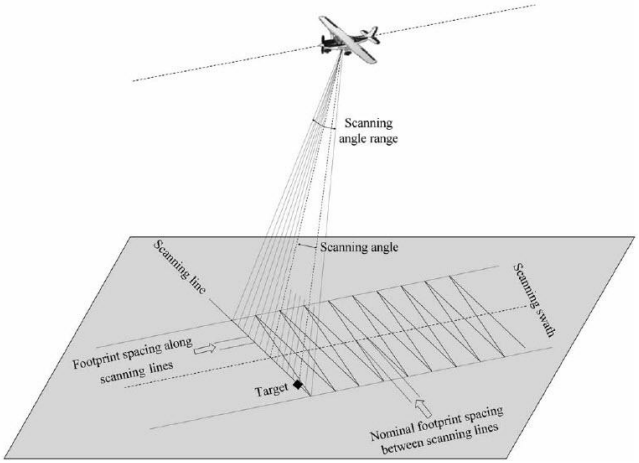
Information hidden in the woods….

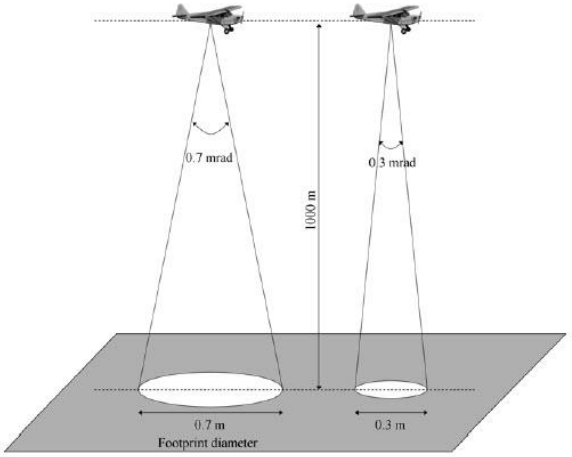


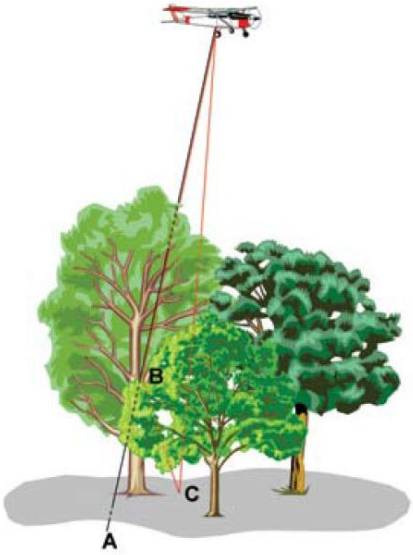
In case of vegetation structure mapping – **the returns are very important.**
In **case of DTM modelling** the Last *returns* or *first = last returns* are used.

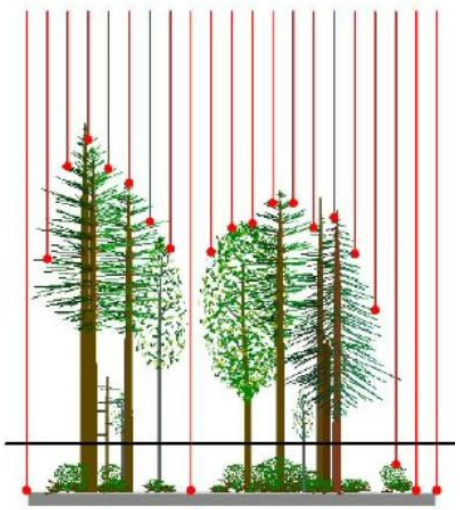
Complex environment - Forest

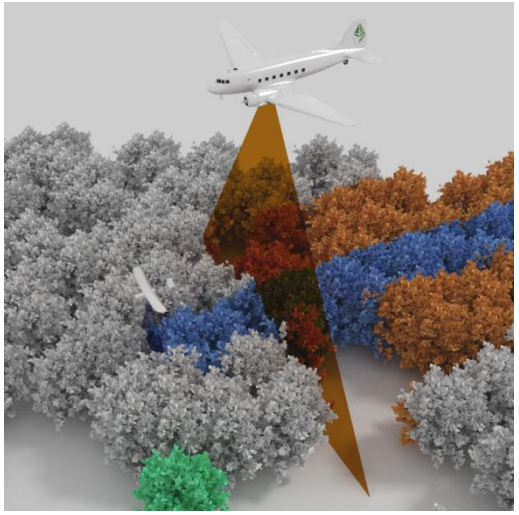
Information hidden in the woods….







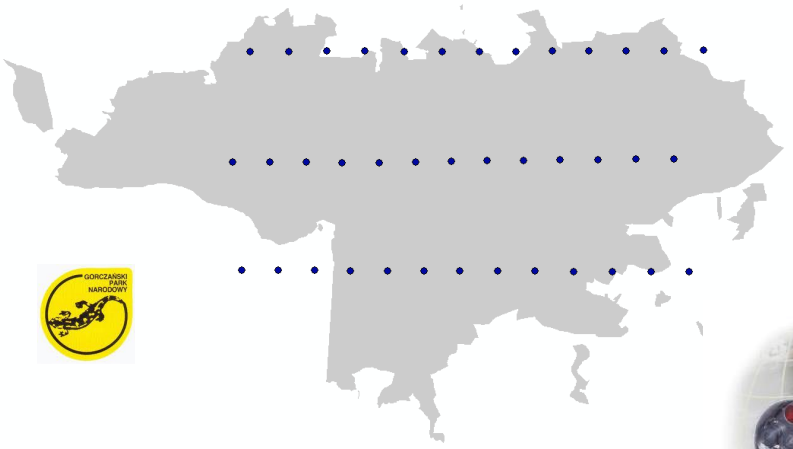


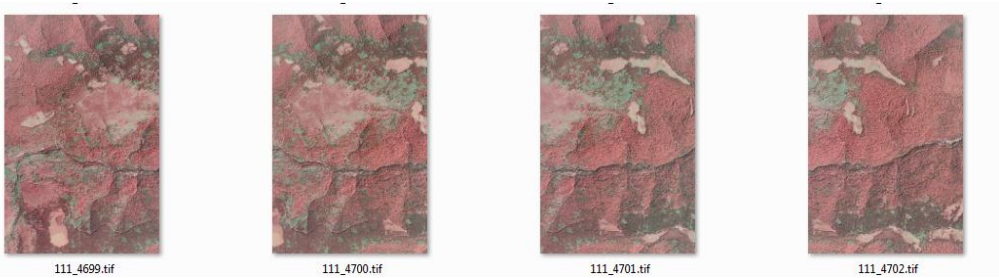


Stereomatching approach - SGM

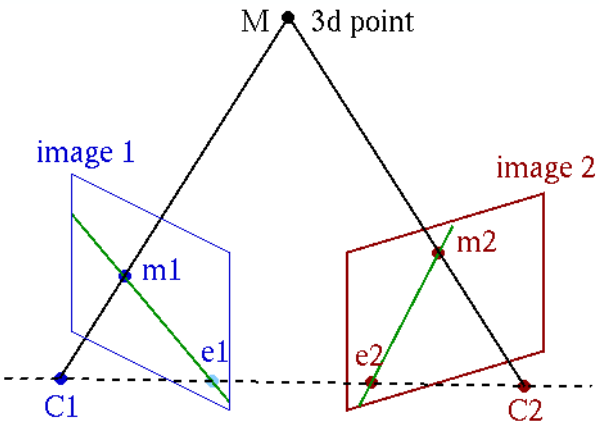
Semi-Global Matching (Aug. 2009)

main point's of CIR single digital aerial photos (R, G, B, NIR) from Aug. 2009;
8 bit ; GSD 0.17 m, UltraCam Xp, VEXCEL





LPIS – aerial photos campaign 2009

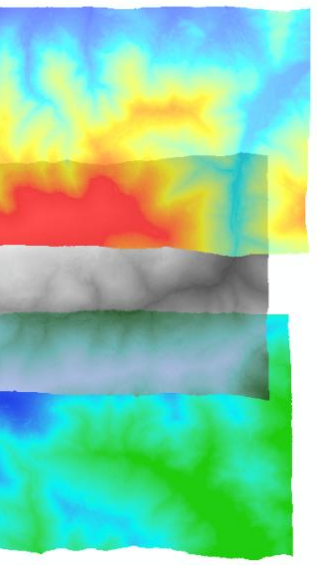


generation map of disparity using Semi-Global Matching (SGM)

Panchromatic Camera

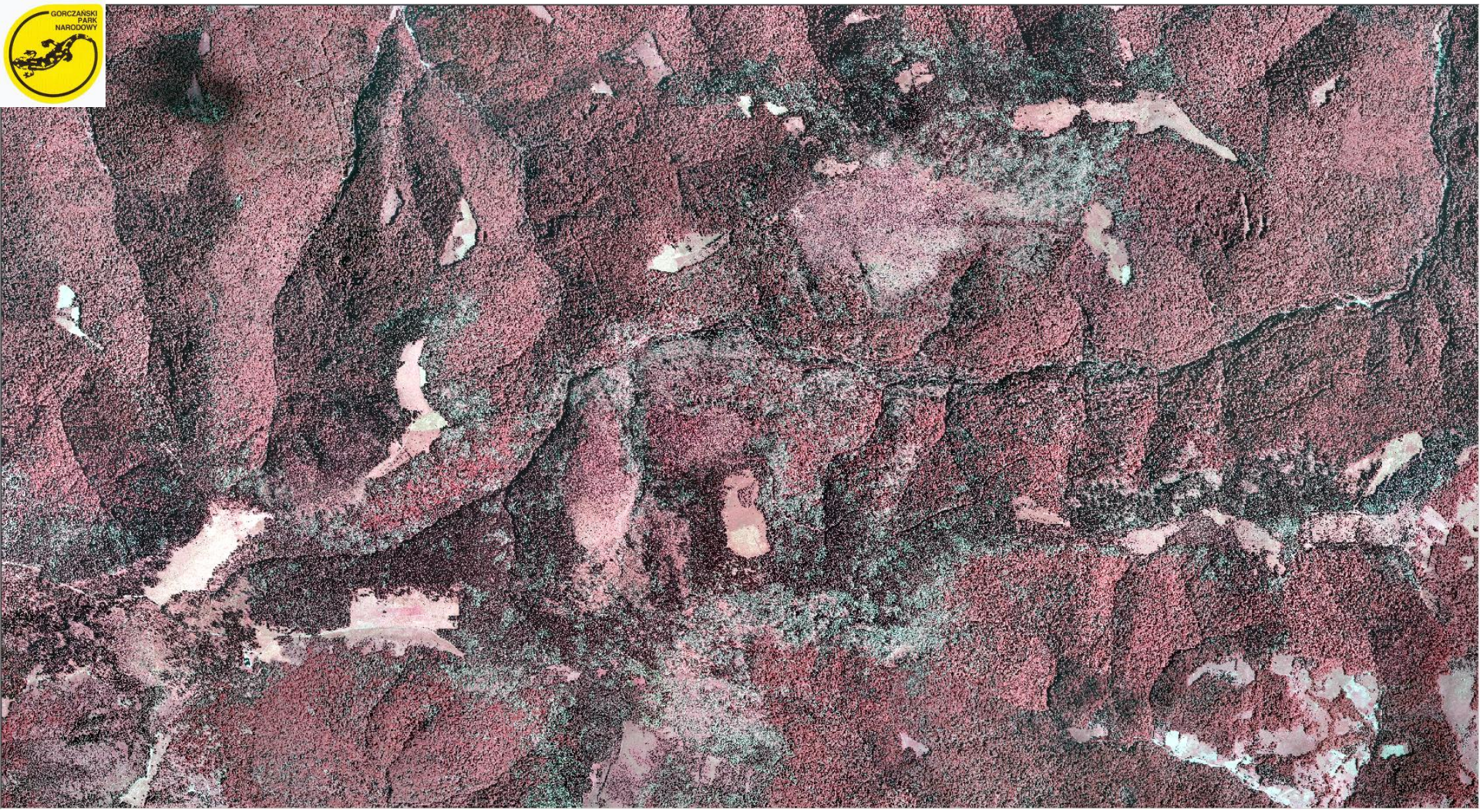
Large Format Panchromatic Output Image

Image Format	long track	67.860mm	11310pixel
	cross track	103.860mm	17310pixel
Image Extent		(-33.91, -51.95)mm	(33.91, 51.95)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.120 mm	± 0.002mm
	Y_ppa	0.180 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



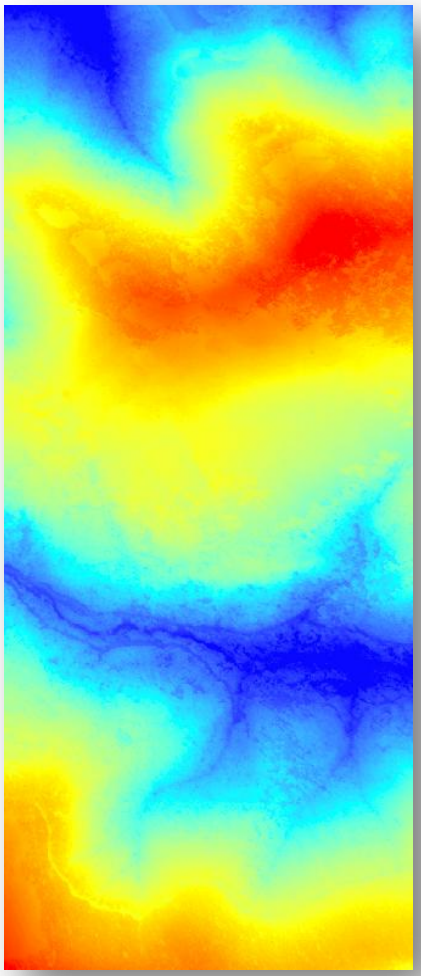
Stereomatching - DSM mosaick

Test area – Gorce NP



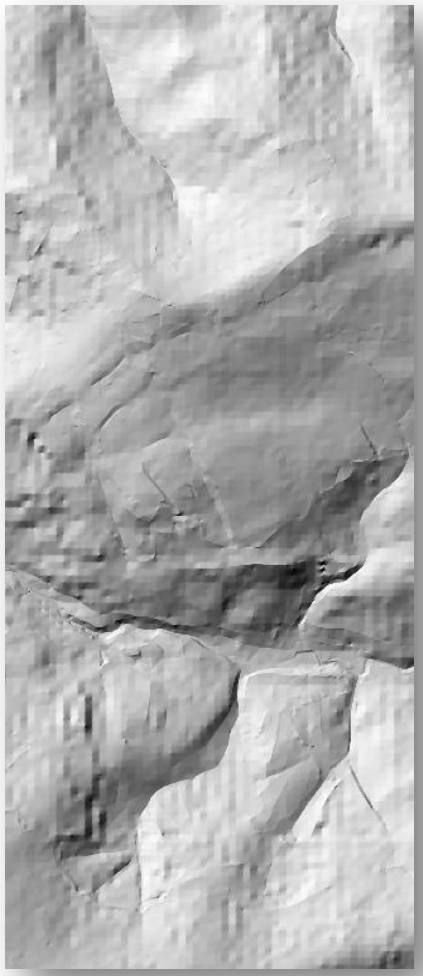
SGM - Derriving nDSM from stereomathing

(reference DTM)



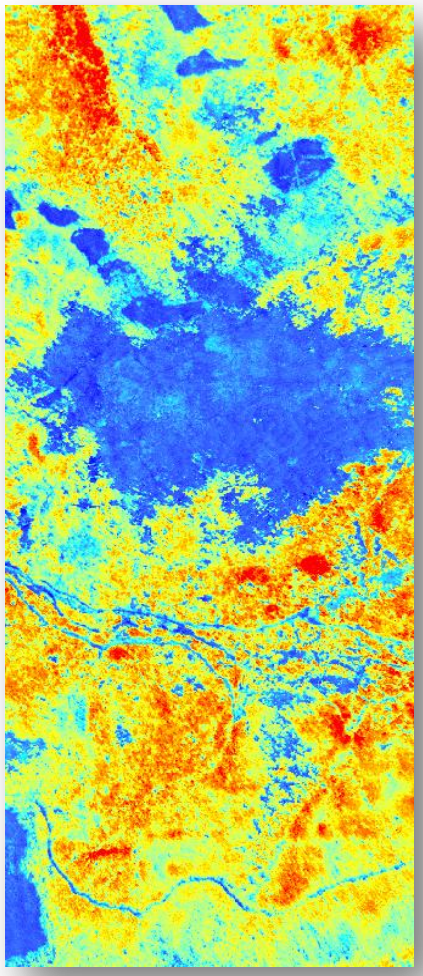
DSM stereo-machting
(882-1288 m a.s.l.)

DSM
minus
DTM



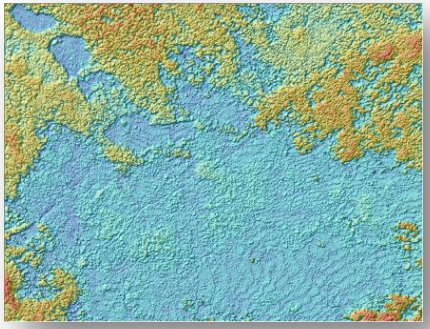
DTM (Photo - LPIS)
(864-1273 m a.s.l.)

=

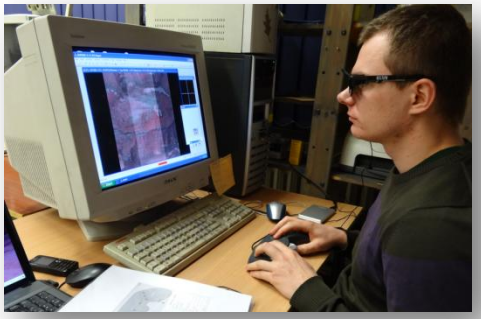


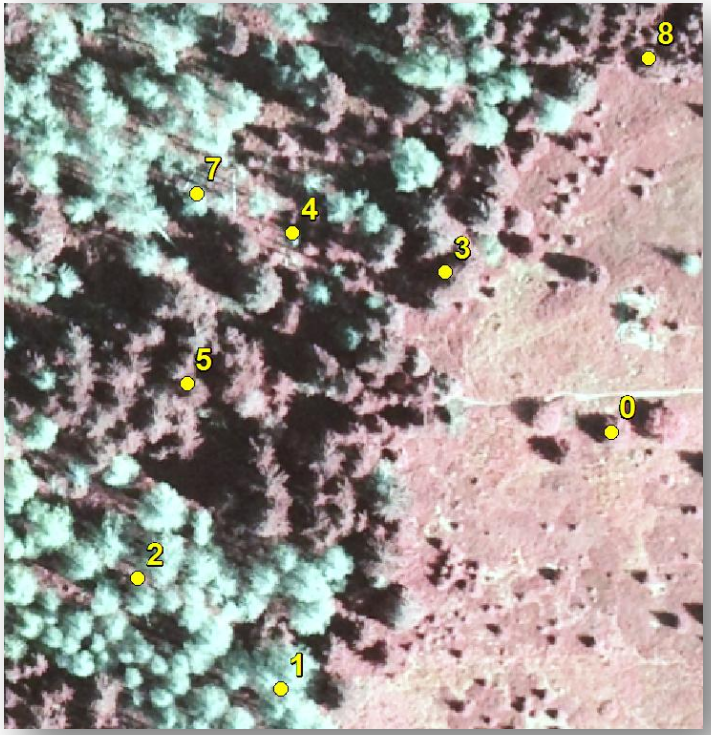
nDSM normalised Digital Surface Model (fom stereomatching 0-42m)

SGM - DSM Quallity Control



The Quallity Control was performed using the 3D photogrammetric workout based on the DEPHOS SoftCopy Station and the stereopairs.





Id	Rel. hight Photo 3D [m]	Hight nDSM stereomatching [m]	Differences Photo 3D – nDSM [m]
0	6,2	3,2	3,00
1	24,6	21,81	2,79
2	20,7	20,7	0,00
3	13,4	11,32	2,08
4	14,5	11,95	2,55
5	20,2	14,48	5,72
6	20,7	18,74	1,96
7	14,5	11,57	2,93
8	10,5	9,02	1,48

mean difference = 2,51 m

Image-based point clouds
QC : RSG / AGISFOFT - ALS

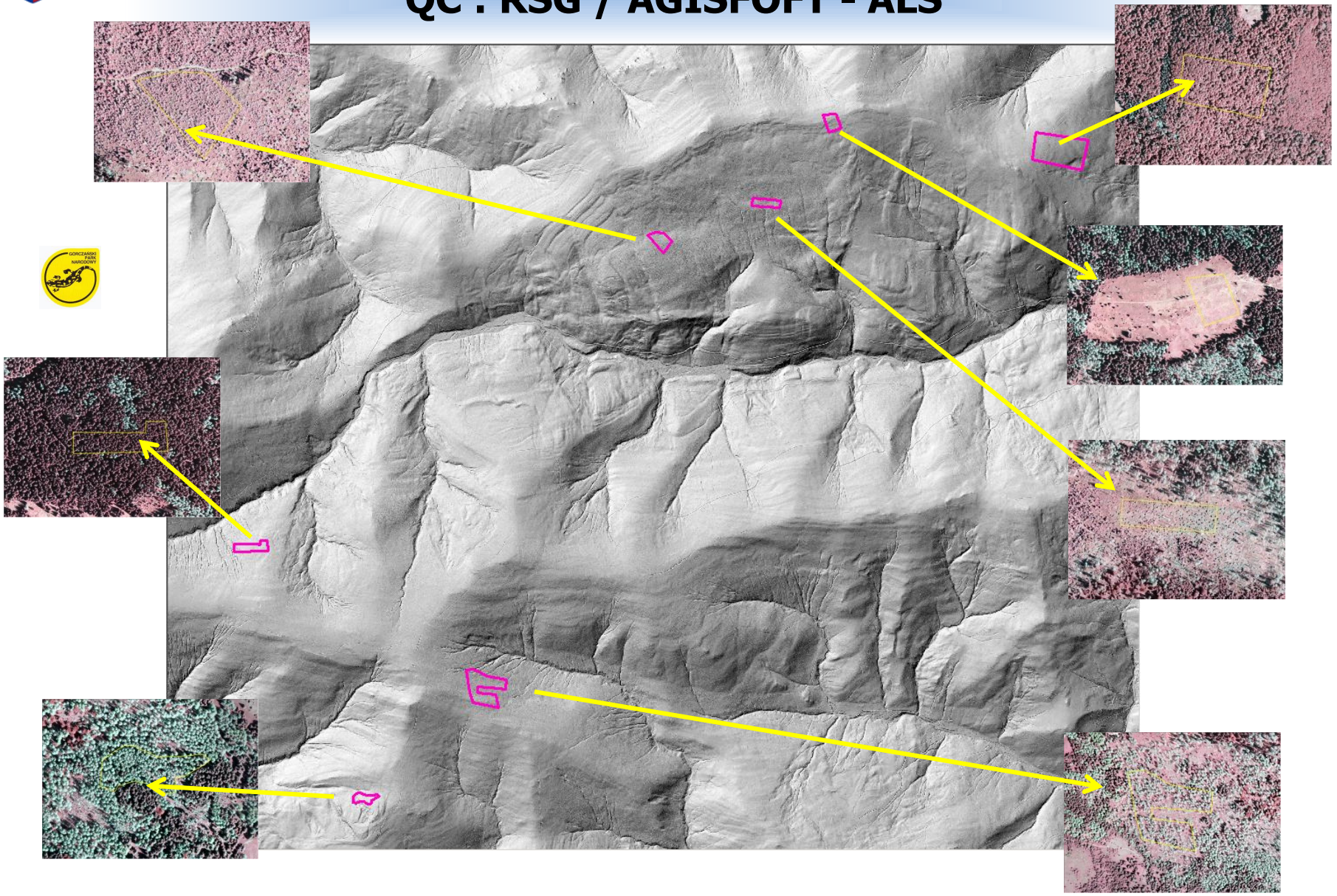
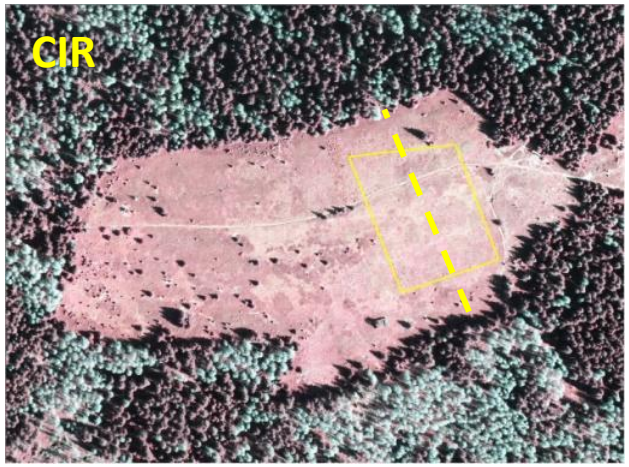
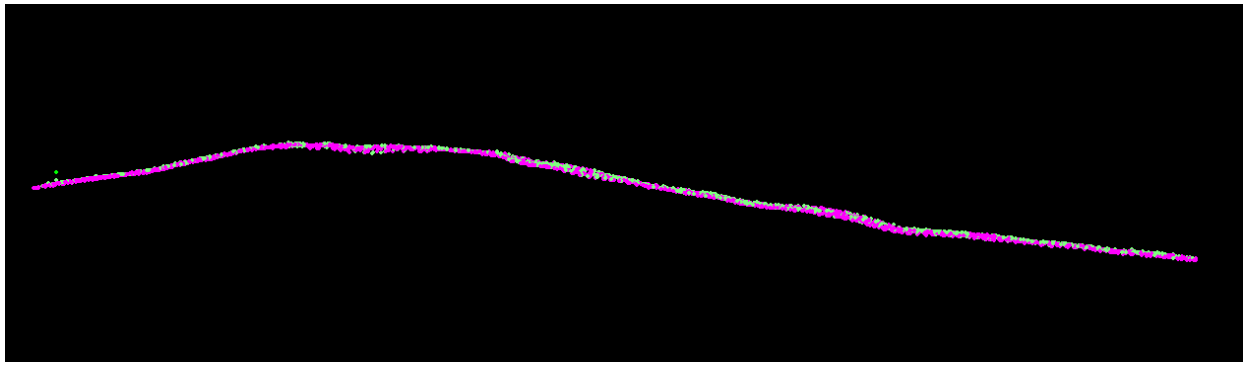


Image-based point clouds
Meadow / open area GNP





LiDAR ALS ISOK point cloud before normalisation

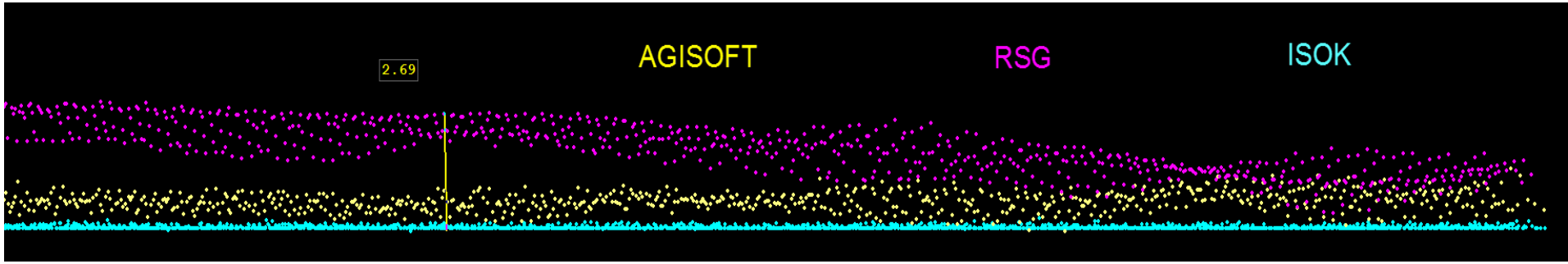
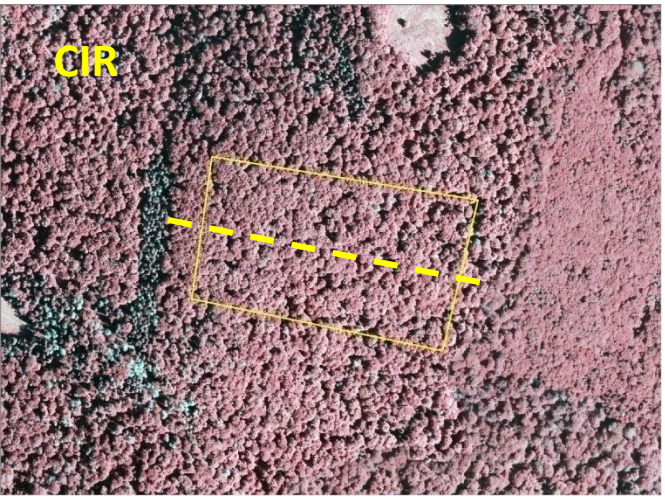
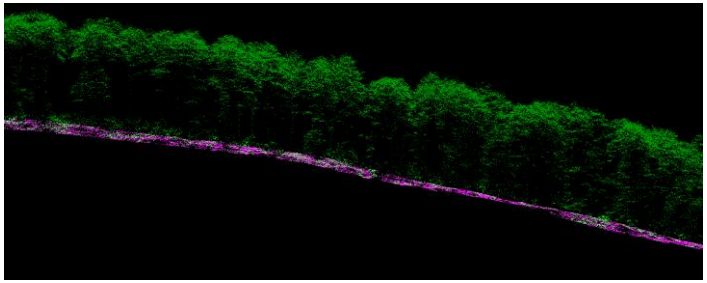
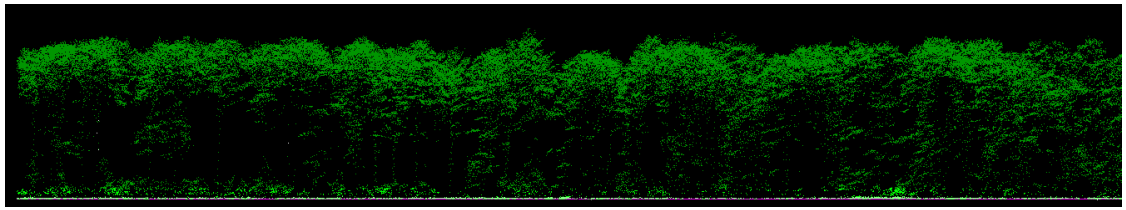


Image-based point clouds
Forest - Decidous stands (Fagus silvatica)





ALS point cloud before normalisation and after normalisation



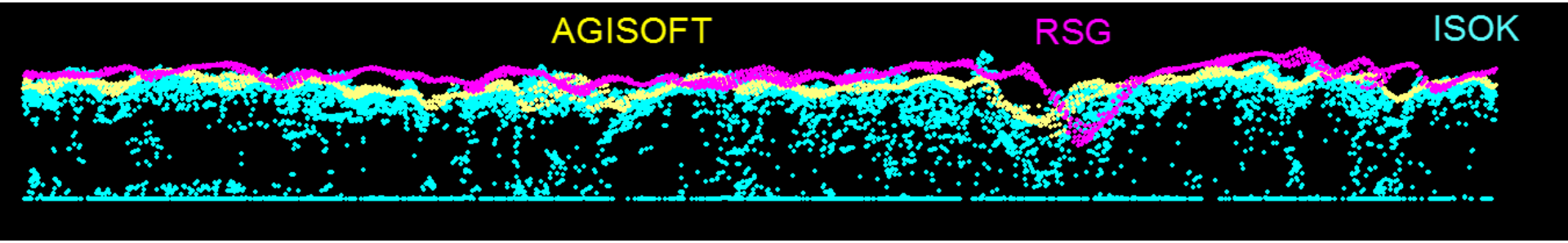
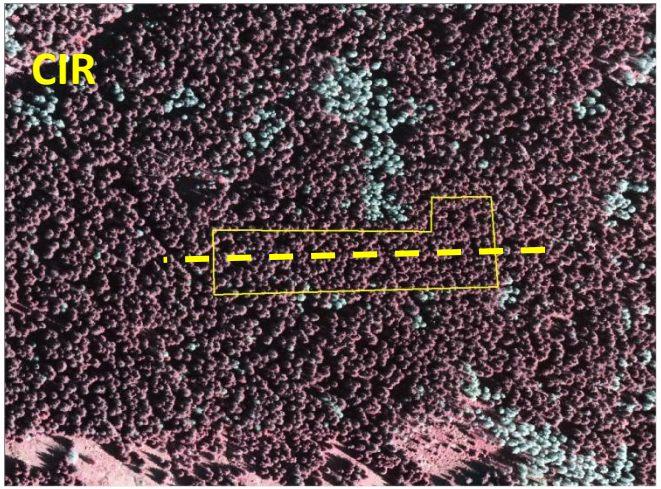
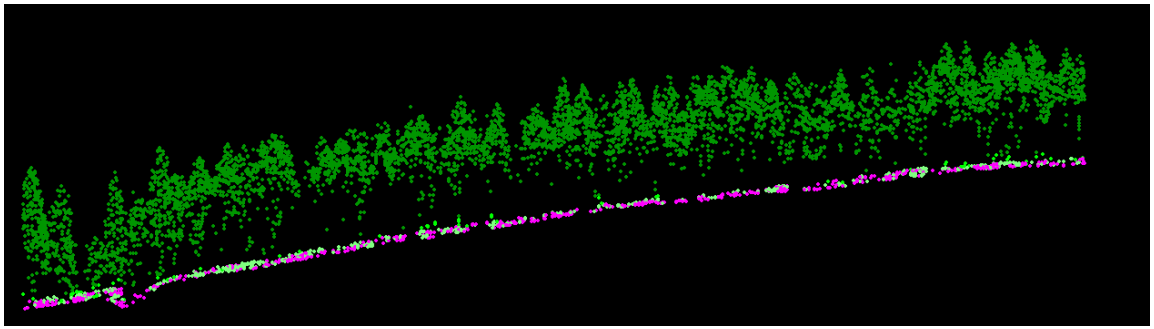


Image-based point clouds
Forest - Coniferous stands (Picea abies)





ALS ISOK point cloud before normalisation

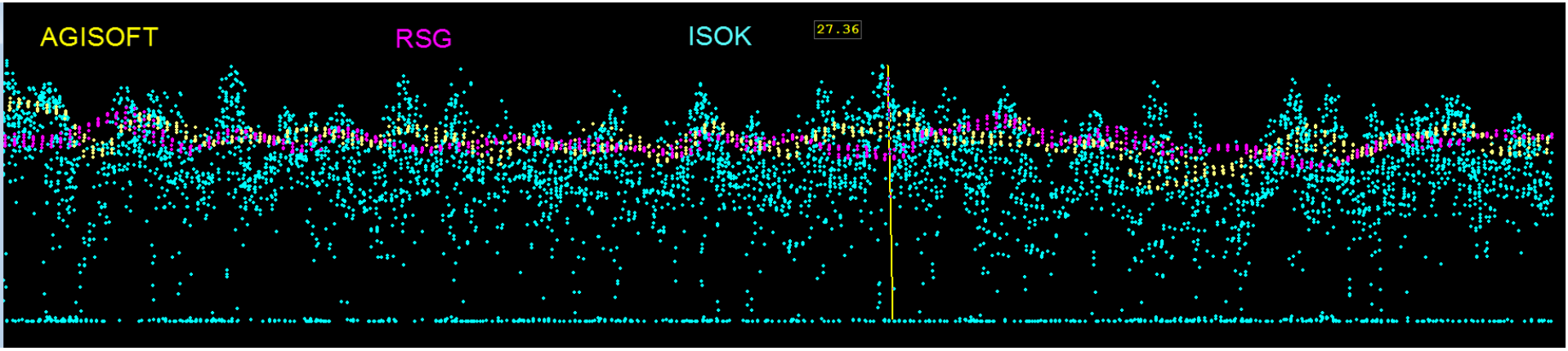
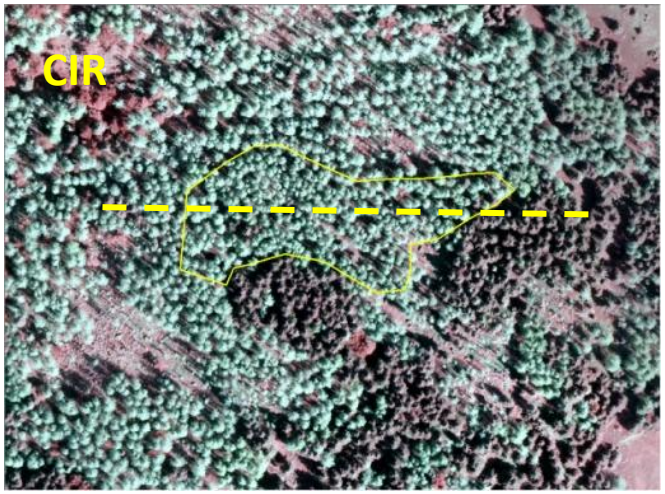
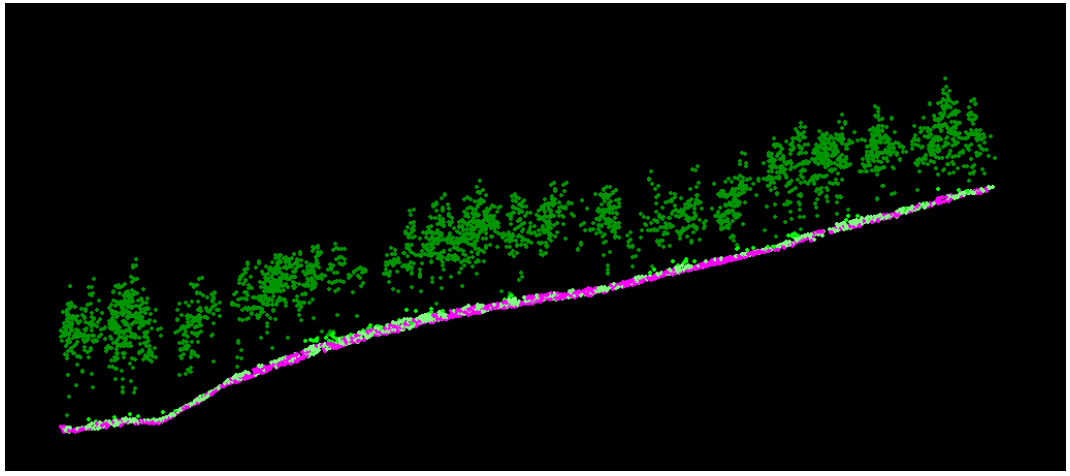


Image-based point clouds
Forest - „Dead trees – dense”





ALS ISOK point cloud before normalisation

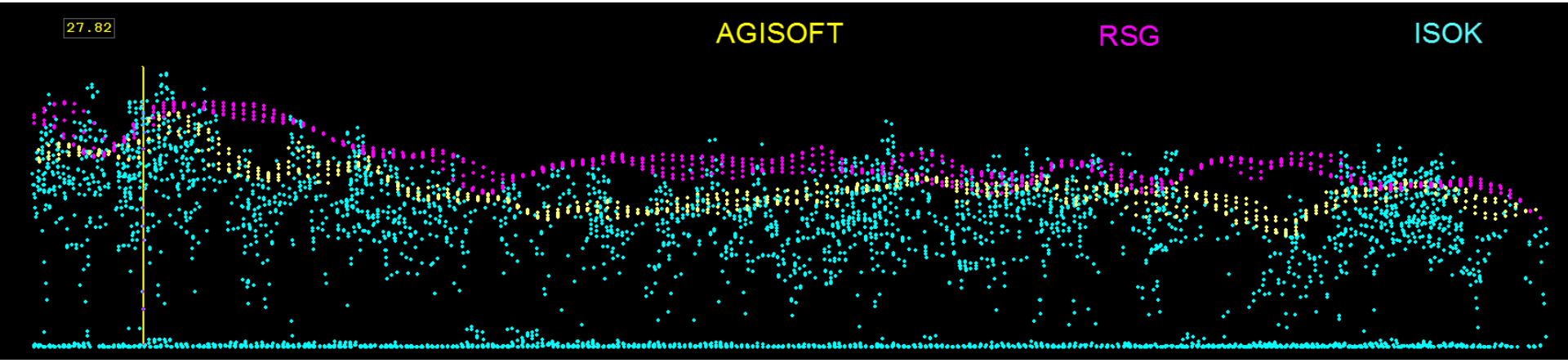
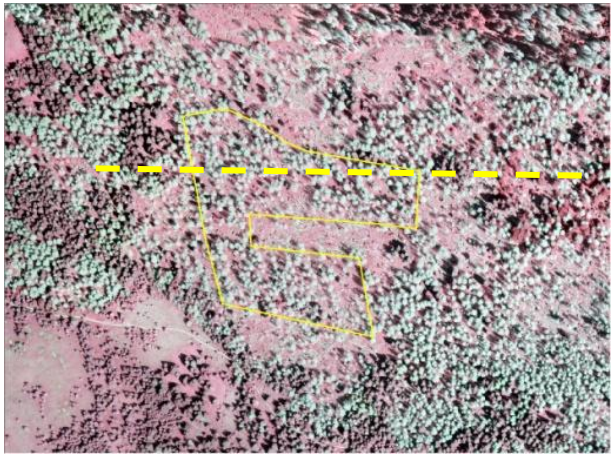
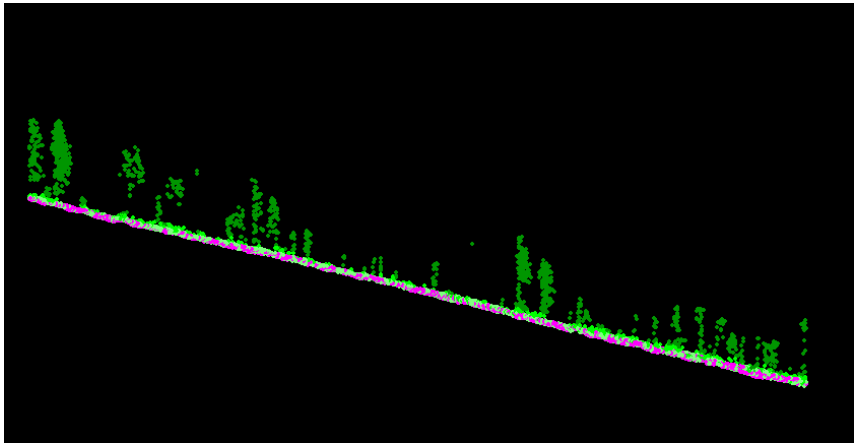
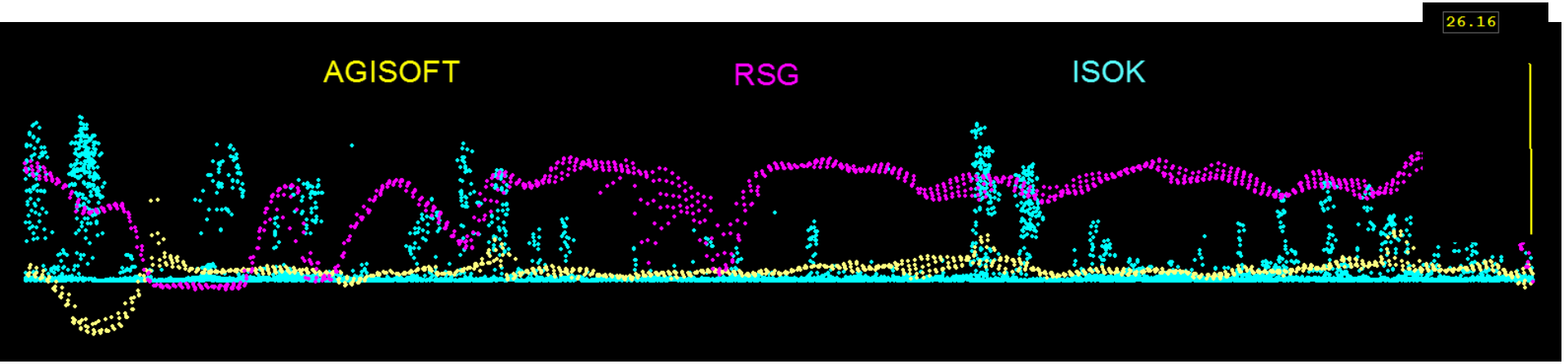


Image-based point clouds
Forest – „Dead trees – sparse”



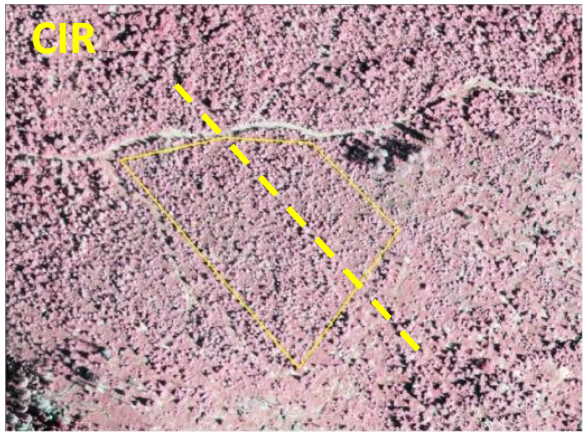


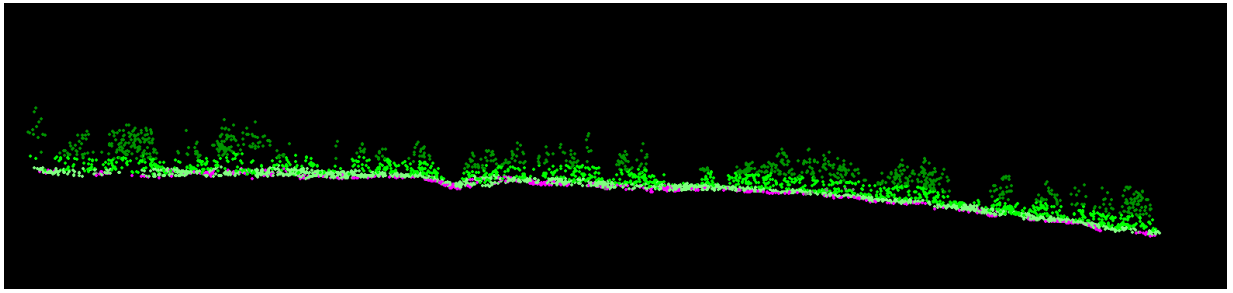
ALS ISOK point cloud before normalisation



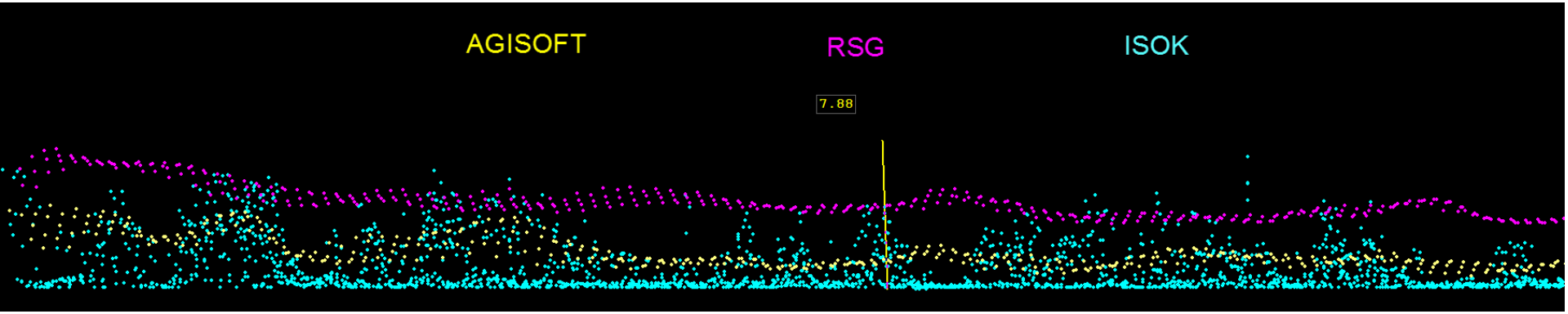
RSG – overestimation; AGISOFT - understimation

Image-based point clouds
Secondary forest succession



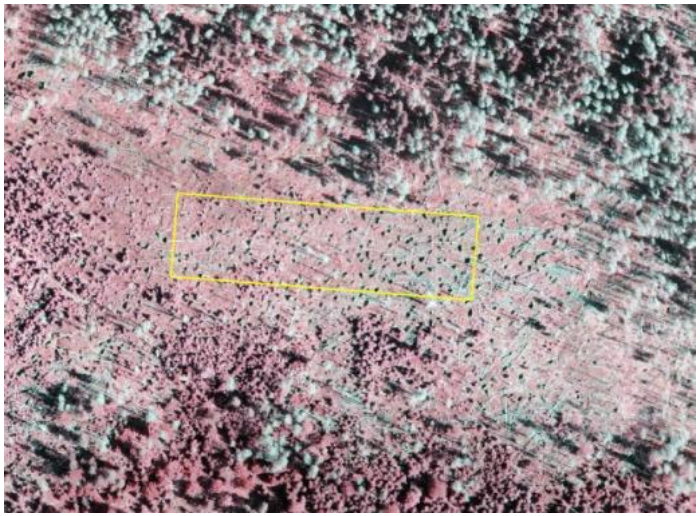


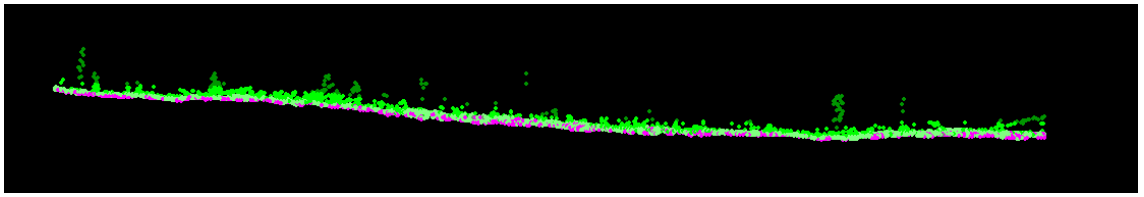
ALS ISOK point cloud before normalisation



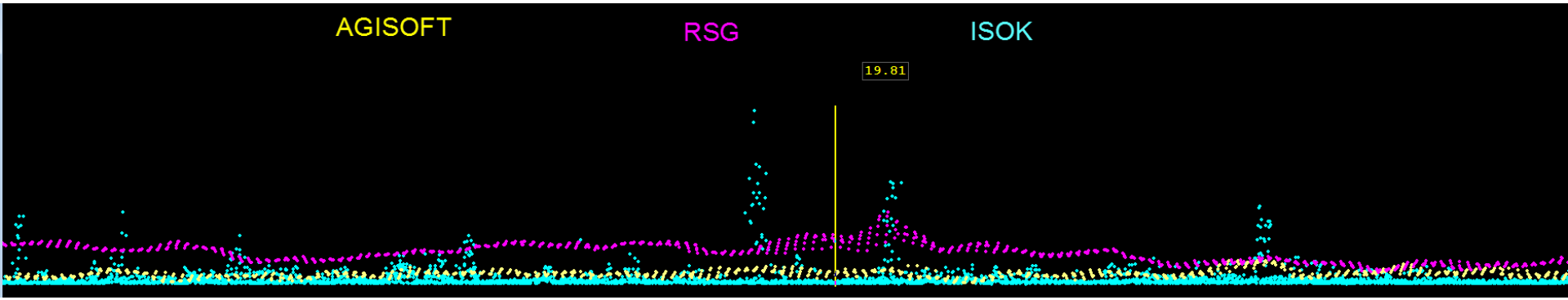
RSG - overestimation

Image-based point clouds





ALS ISOK point cloud before normalisation



RSG – overestimation

Image-based point clouds
AGISOFT nDSM – slightly overestimation

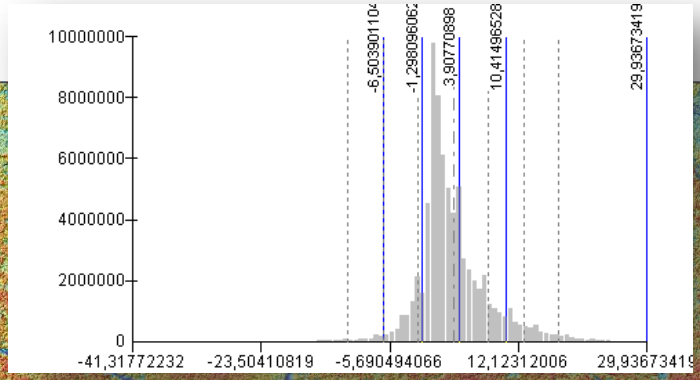
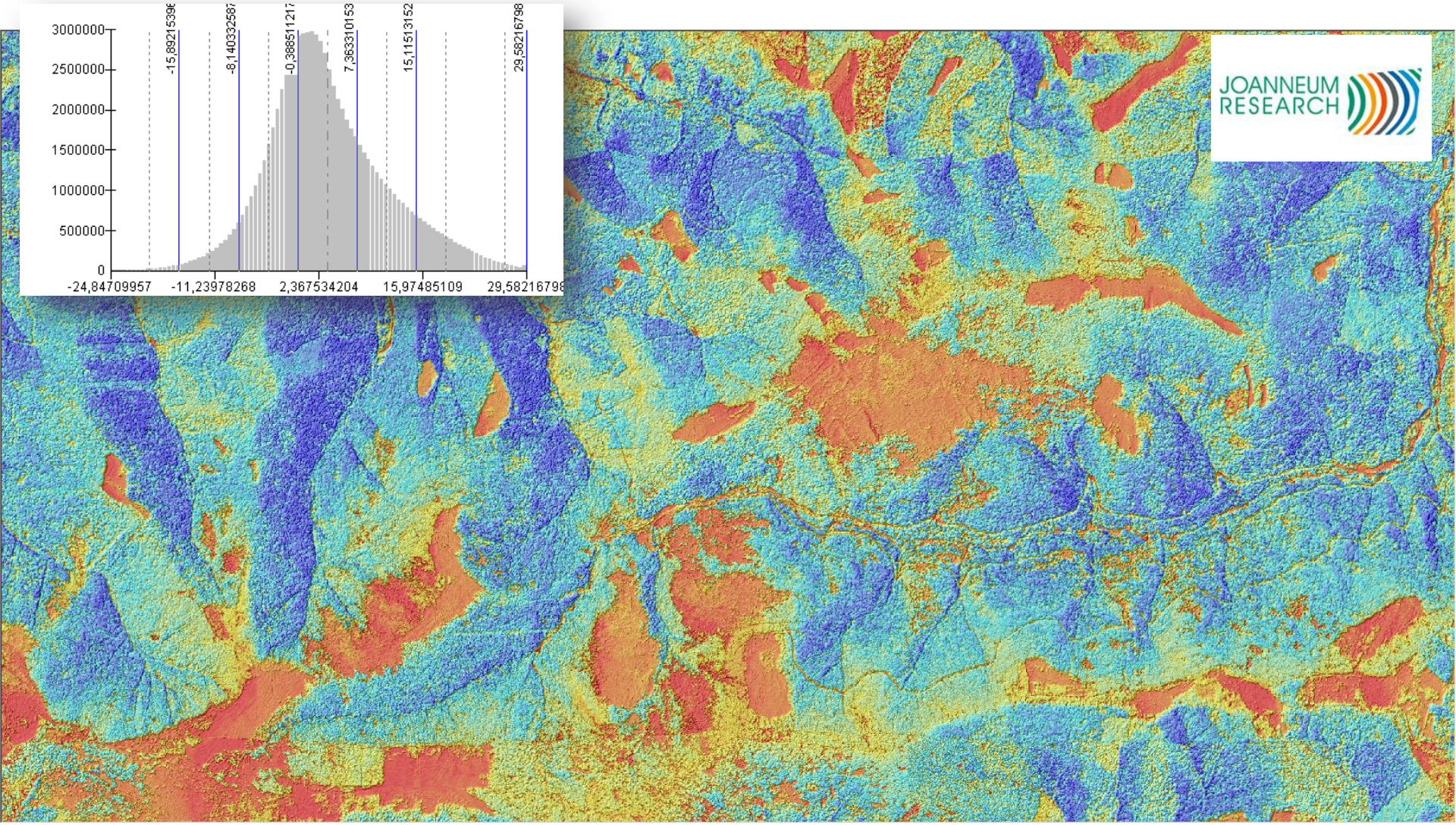
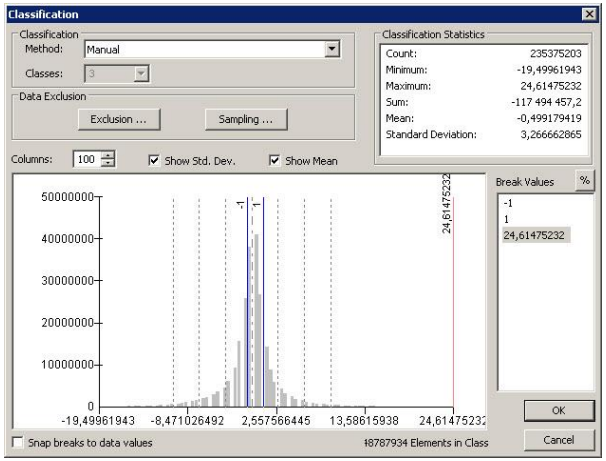


Image-based point clouds

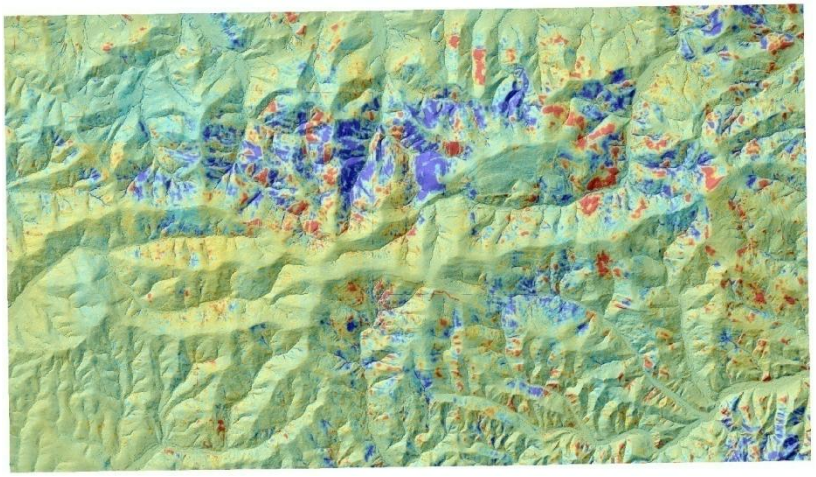
RSG nDSM – clearly overestimation



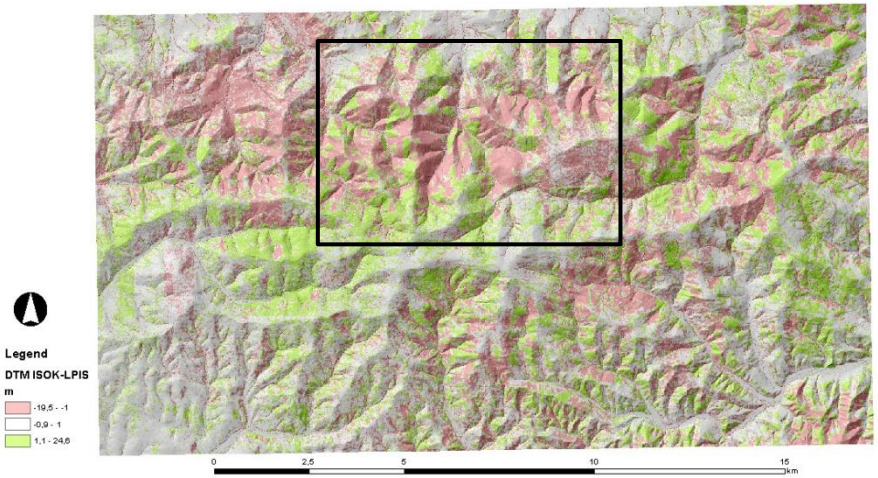
Stereomatching approach – SGM
Difference between DTM $_{ALS}$ - DTM $_{PHOTO\ LPIS}$



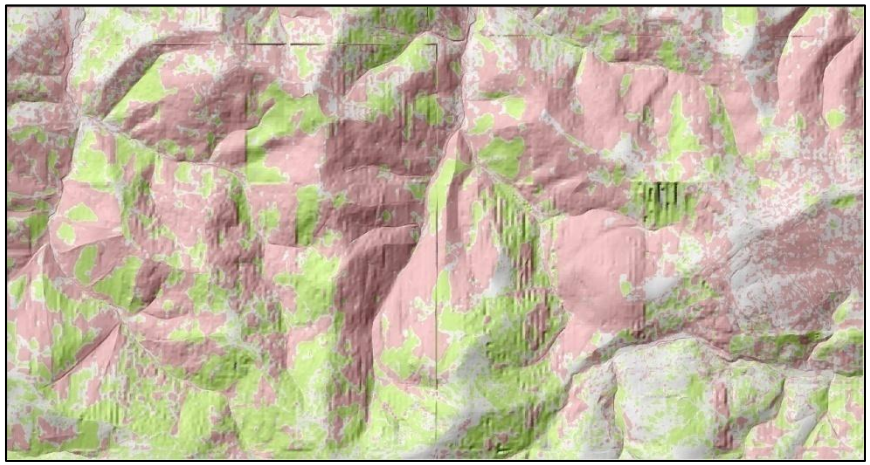
Histogram of errors between DTM ALS and DTM PHOTO LPIS



Map of errors between DTM $_{ALS}$ - DTM $_{PHOTO\ LPIS}$



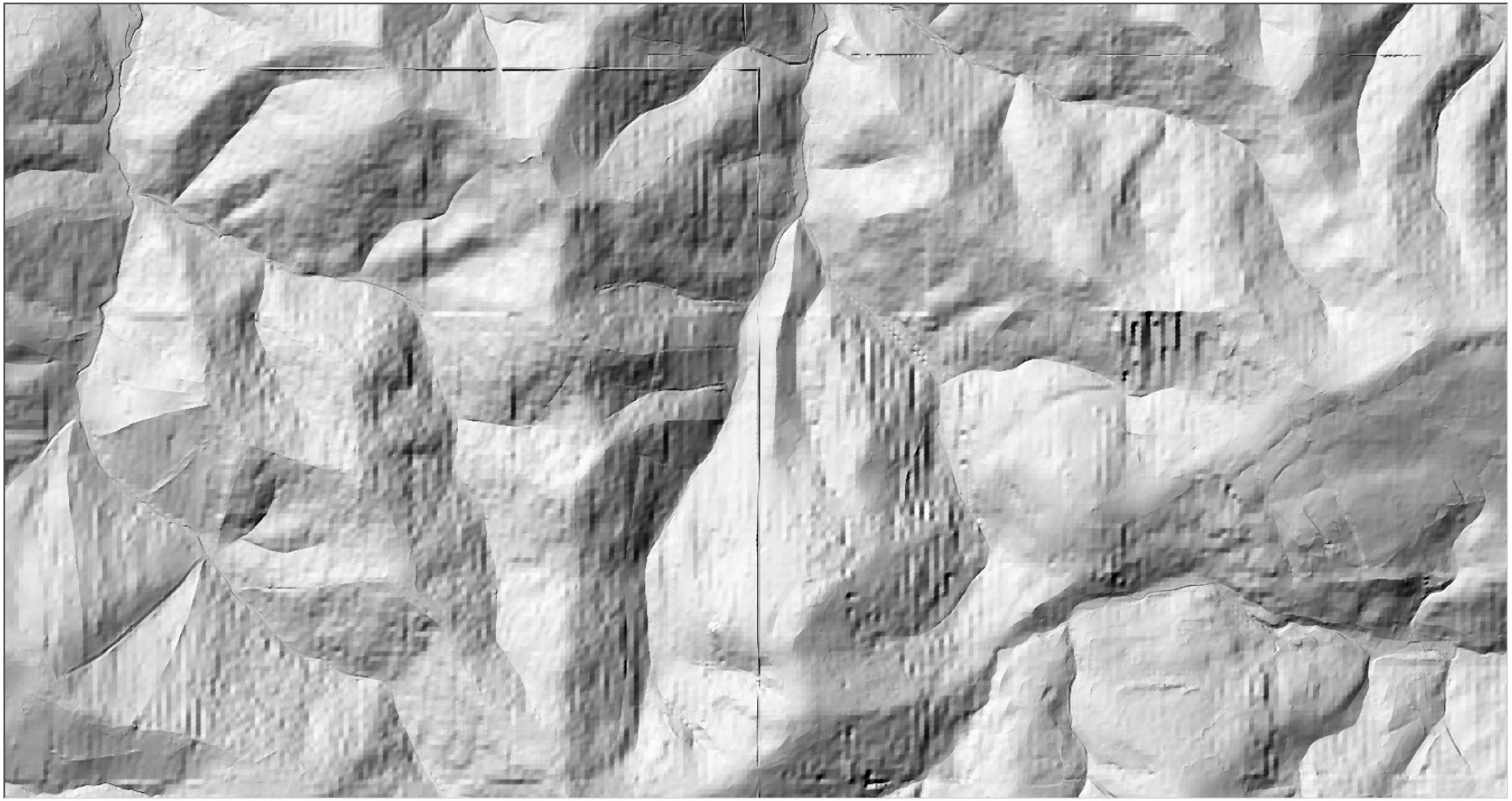
Map of possitive and negative differences between DTM $_{ALS}$ and DTM $_{PHOTO\ LPIS}$



Map of possitive and negative differences between DTM $_{ALS}$ and DTM $_{PHOTO\ LPIS}$

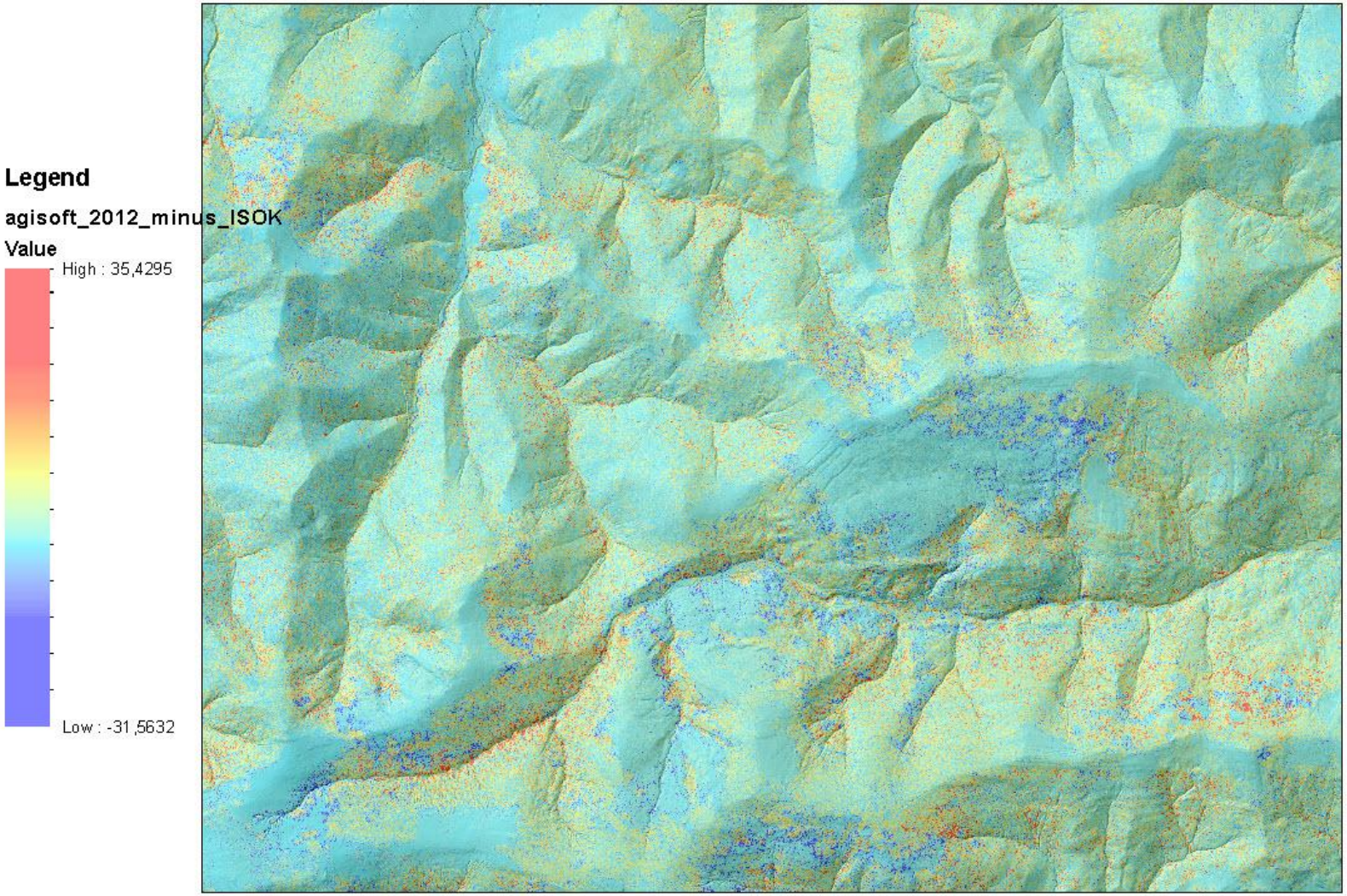
Stereomatching approach – SGM

Difference between DTM $_{ALS}$ - DTM $_{PHOTO}$



Stereomatching approach – SGM

Difference between DSM AGISOFT - DSM ALS ISOK



Stereomatching approach – SGM

Difference between DSM $_{RSG}$ - DSM $_{ALS\ ISOK}$