

SPL compared to traditional and other high performance laser systems

EuroSDR 2019

Single Photon and Geiger-Mode LiDAR

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History

- **AHN1: 1997 – 2004**
 - Initiated by Waterboards, Ministry of Infrastructure and Water Management and the Provinces to manage the watersystems and watersecurity
 - 1pt/16m² → 1pt/m²
- **AHN2: 2007 – 2012**
 - Map an object of 2x2m with an accuracy of 50cm from the pointcloud
 - Height accuracy < 5cm stochastic + 5cm systematic
 - Classification: ground – non-ground
- **AHN3: 2014 – 2019**
 - Additional demands on classification: Ground, Water, Buildings, Civil structures, other
 - AHN1, AHN2 and AHN3 Open data

Technical Developments

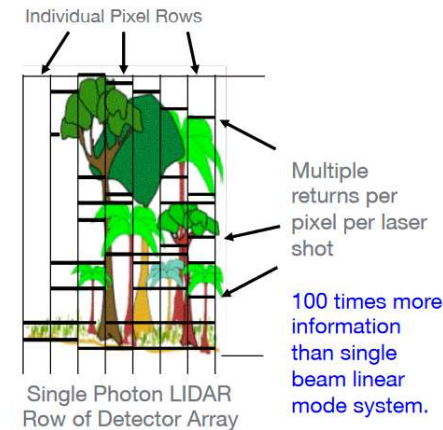
- LiDAR technology
- Dense Matching
- Combined LiDAR – Imagery sensors
- Local point clouds
- Other techniques to indicate changes
- Bathymetric systems

Pilots in three areas with two new sensors:

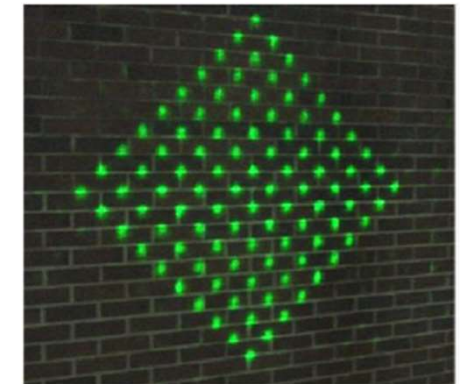
- Single Photon LiDAR
- Riegl 1560i DW

Single Photon LiDAR

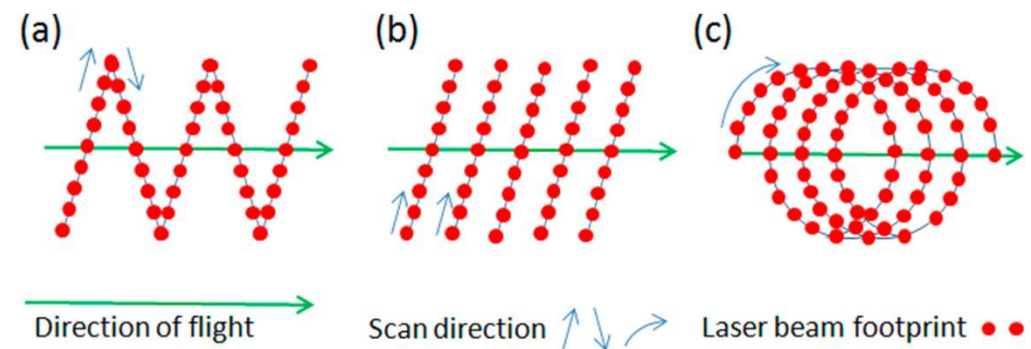
- Laser pulse split into 10x10 beamlets
- Signal strength per beamlet is low, still multiple returns
- 60 kHz → 6mln points/sec
- Conical pattern (c)
- Opening angle 10 – 30 degrees
- Green LiDAR (532 nm), bathymetry?



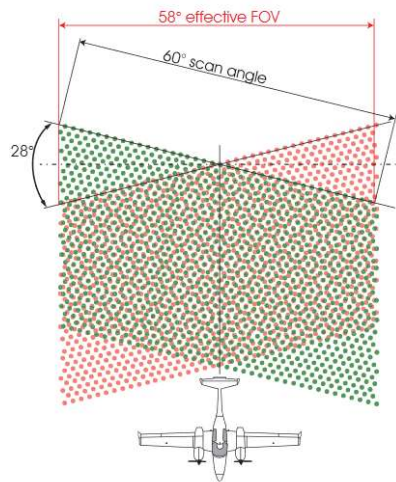
[http://shoals.sam.usace.army.mil/Workshop_Files/2015/Day_01_pdf/1100_Sirota.pdf, Feb 6th 2018]



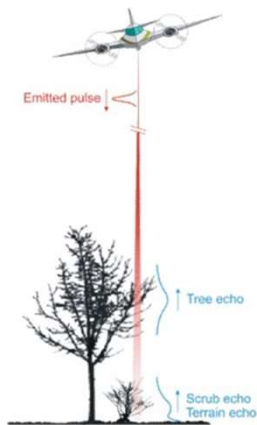
[Sigma Space]



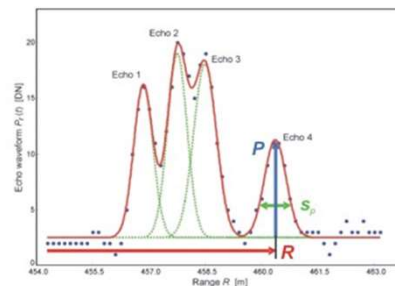
[Juan Carlos Fernandez-Diaz et. al, 2014, Now You See It... Now You Don't: Understanding Airborne Mapping LiDAR Collection and Data Product Generation for Archaeological Research in Mesoamerica]



[Riegl]



Echo waveform



Information per echo:

Amplitude (Intensity): P [DN]

Range: R [m]

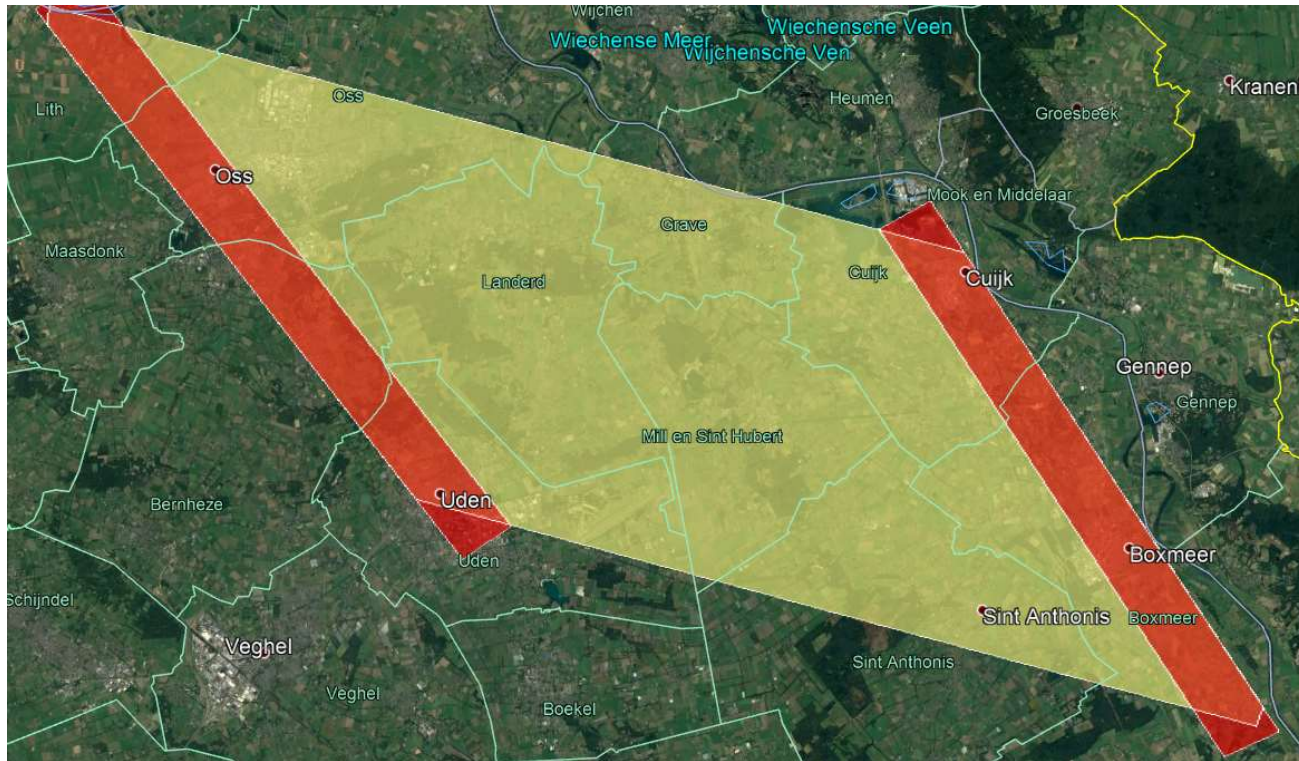
Echo width: sp [ns]

Riegl 1560i DW

- Full wave form analysis
- 2 lasers x 1.000 kHz
- Opening angle 60 degrees
- Effective pulse rate: 1,33 mln points / sec
- Equal point distribution
- Dual wavelength (red 1064nm, green 532nm)



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Area 1

Characteristics

Agricultural area, some medium cities, river, forest

Purpose

Compare to AHN2 / AHN3 data

Aimed point density

8 pts/m²

Single Photon LiDAR & Riegl 1560i DW



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Area 2

Characteristics

City, urban canyoning

Purpose

3D buildings; Ground measurements in urban canyoning; Compare Rotterdam data

Aimed pointdensity

60 points / m2

Single Photon LiDAR &
Riegl 1560i DW



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Single Photon LiDAR & Riegl 1560i DW

Area 3

Characteristics

Water area influenced by tides, dry mud flats, dikes, agricultural landscape with little villages

Purpose

See how instruments perform on dry mud flats and shallow waters

Aimed point density

8 pts/m²



Flight parameters

	1: Noord Brabant		2: Rotterdam		3: Westerschelde		3b: Westerschelde low
	Riegl 1560i DW	SPL100	Riegl 1560i DW	SPL100	Riegl 1560i DW	SPL100	Riegl 1560i DW
Point density (pts/m2)	>8		60		12		>30
Flight altitude (m)	1500	3750	670	4270	1240	3750	560
Flight speed (knts)	110	160	95	175	120	160	115
Total LiDAR pulse repetition rate (kHz)	1400	50	2000	50	2000	50	2000
LiDAR power	100%		100%		100%		100%,25%
Scan rate (lps)	244	21	410	18	340	21	440
FOV (deg)	58	30	58	30	58	30	58
Time over target (hrs)	3		2,1		0,7		0,5
Side lap		30%		85%		15	

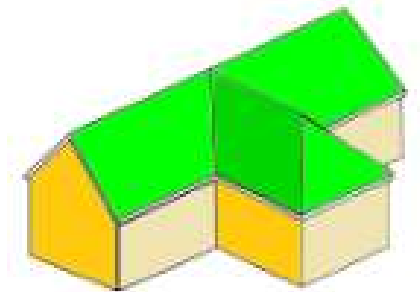
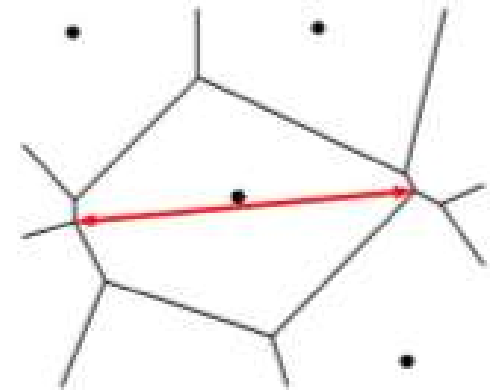


Demands AHN

- Data needs to be suitable to map an object of 2x2m with an accuracy of 50cm.
 - Point density: 6-8 pts/m²
 - Point spacing: Very regular
 - Point precision: High (5cm systematic + 5cm stochastic)
 - Point accuracy: High

Validation

- Height
 - Absolute (ground control fields)
 - Relative (height difference grids strips)
- Planimetry
 - Absolute (reference objects)
 - Relative (gable roofs between strips)
- Point density
- Point spacing



Geometry

Noord-Brabant

Rotterdam

Noord-Brabant	Gemiddelde XY	St.afwijking XY	Gemiddelde Z	St.afwijking Z
Max	0.114	0.086	0.027	0.046
Min	0.008	0.044	-0.014	0.010
Gemiddelde	0.042	0.064	0.003	0.029
Standaardafwijking	0.027	0.011	0.009	0.009

SPL

Gemiddelde XY	St.afwijking XY	Gemiddelde Z	St.afwijking Z
0.069	0.044	0.062	0.036
0.007	0.027	-0.043	0.013
0.031	0.036	-0.001	0.021
0.015	0.004	0.026	0.006

Riegl 1560i

Noord-Brabant	Gemiddelde XY	St.afwijking XY	Gemiddelde Z	St.afwijking Z
Max	0.080	0.085	0.035	0.065
Min	0.005	0.022	-0.056	0.009
gemiddelde	0.041	0.054	-0.007	0.030
standaardafwijking	0.020	0.011	0.015	0.012

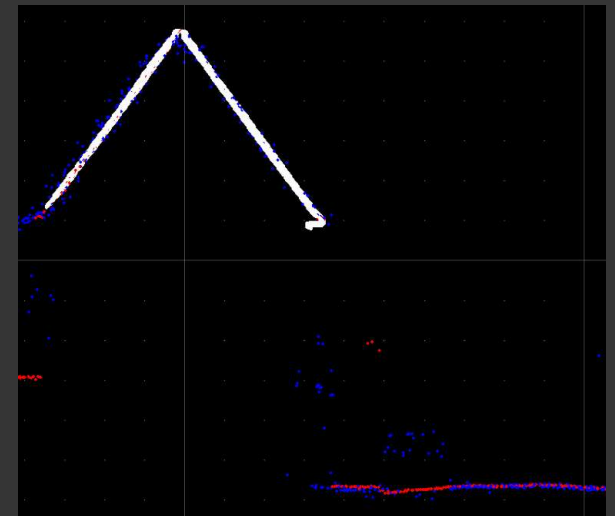
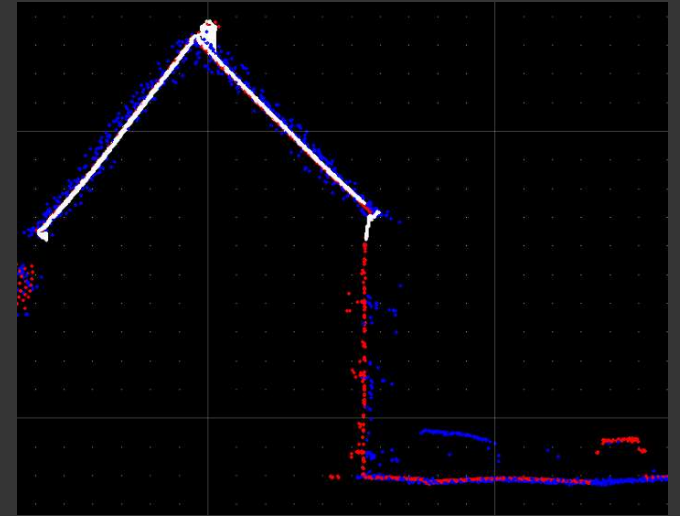
SPL

	Gemiddelde XY	St.afwijking XY	Gemiddelde Z	St.afwijking Z
max	0.065	0.044	0.025	0.020
min	0.006	0.010	-0.017	0.007
average	0.032	0.026	0.002	0.013
st dev	0.013	0.008	0.012	0.003

Riegl 1560i

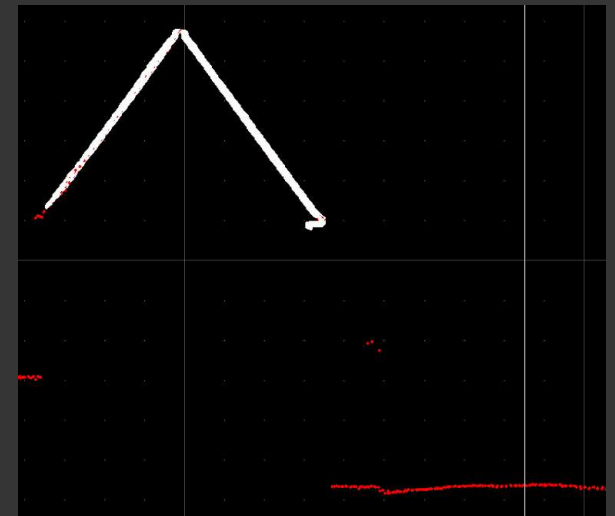
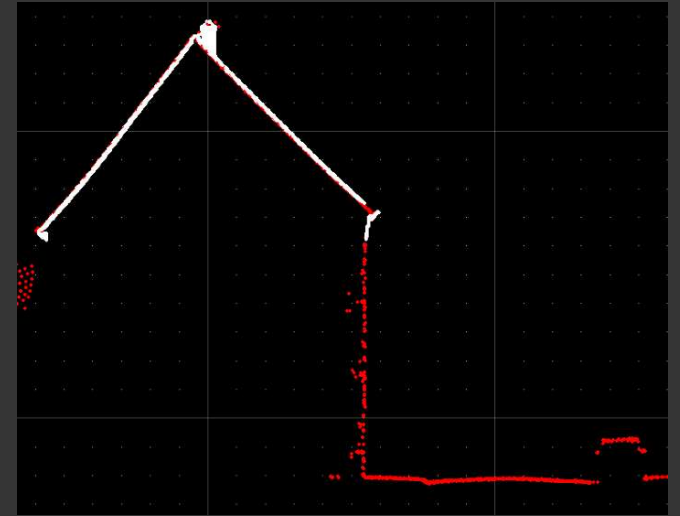
Geometry

- Both systems seem to be able to meet the specifications on:
 - Height (relative and absolute)
 - Planimetry (relative and absolute)
- Although
 - Point spread around roofs is high with SPL100 (angle accuracy at high flight altitude)
 - Software SPL
 - black box (geometry corrections 14 parameters, not only RPH)
 - Not ready yet for big operations (many software updates required)



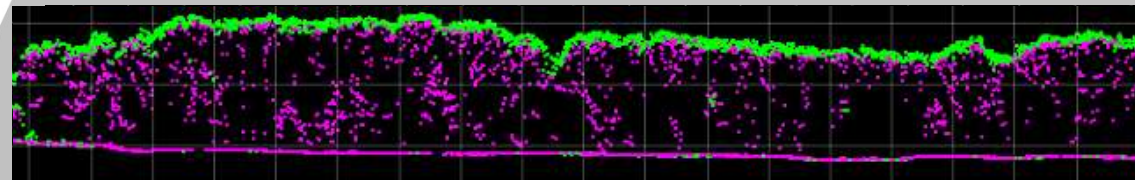
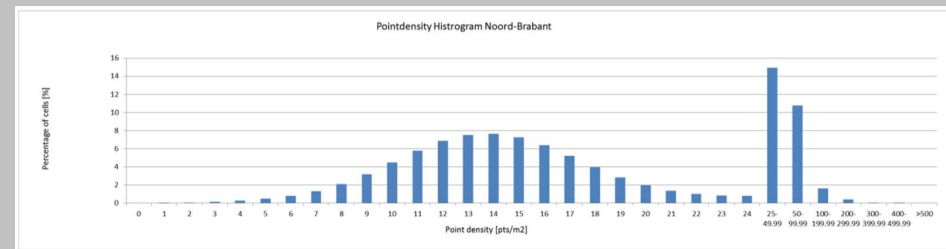
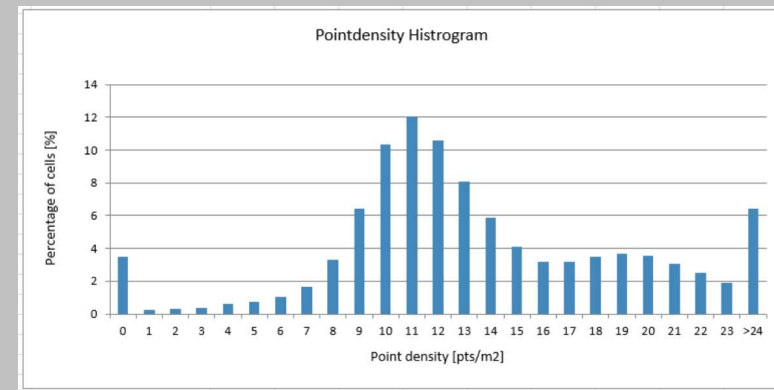
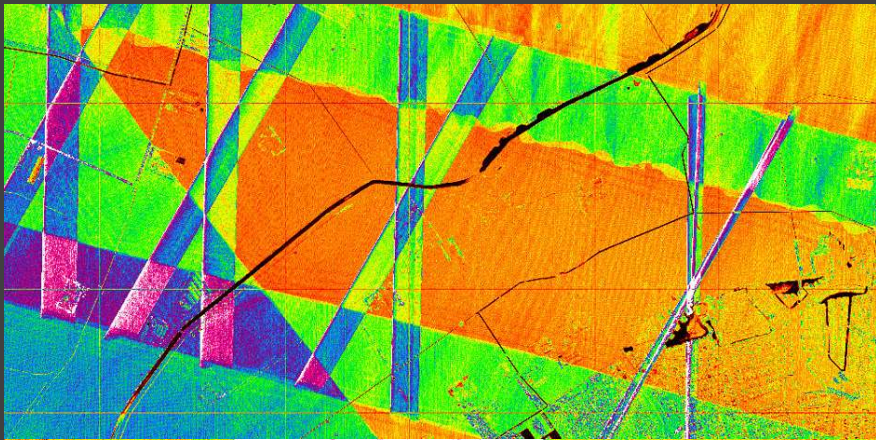
Geometry

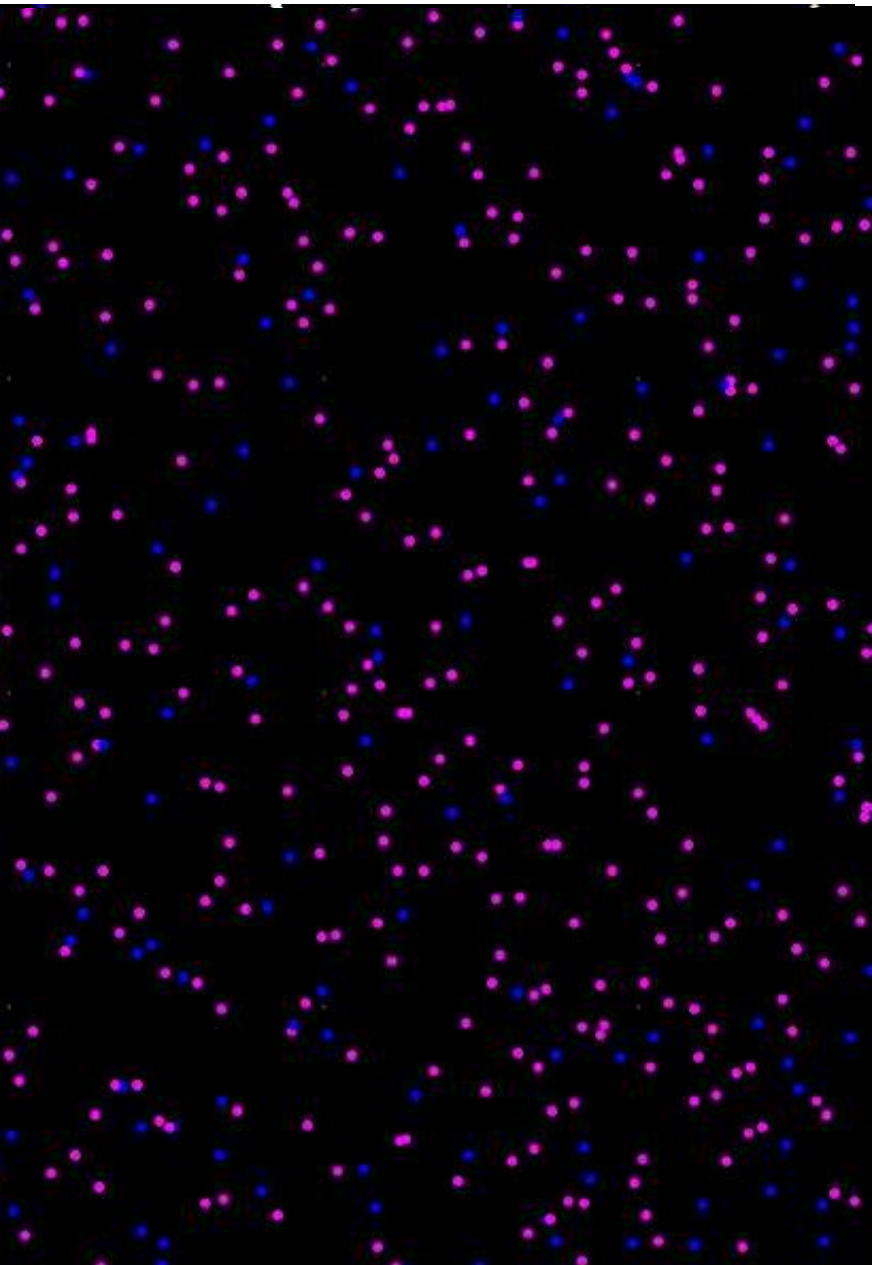
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 - Height (relative and absolute)
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Point density

- Point density
 - Riegl average 13.5 pt/m², 91,5% cells fulfils 8 pts/m²
 - SPL average 25.5 pt/m², 96% cells fulfils 8 pts/m²
 - Resulting point density nadir SPL100 30-40% lower than planned
 - Point density SPL100 drops on buildings



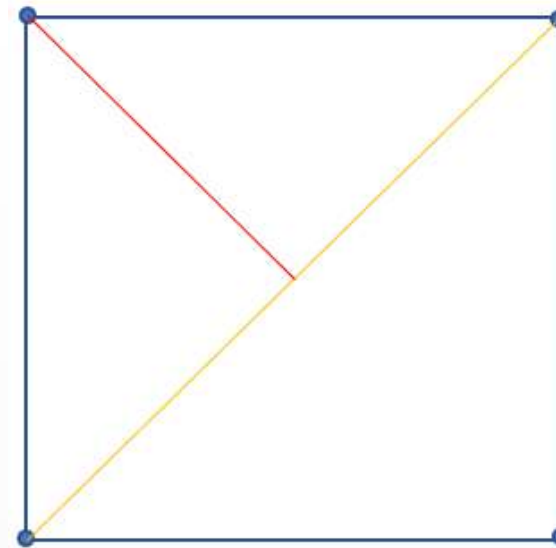


Point spacing

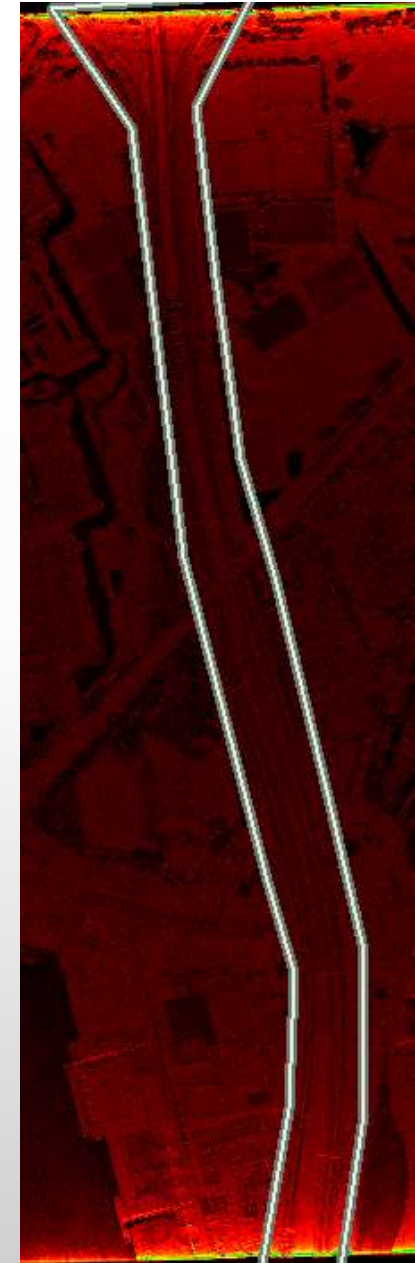
- Riegl 94% fulfils < 54 cm
- SPL100 49% fulfils < 54 cm

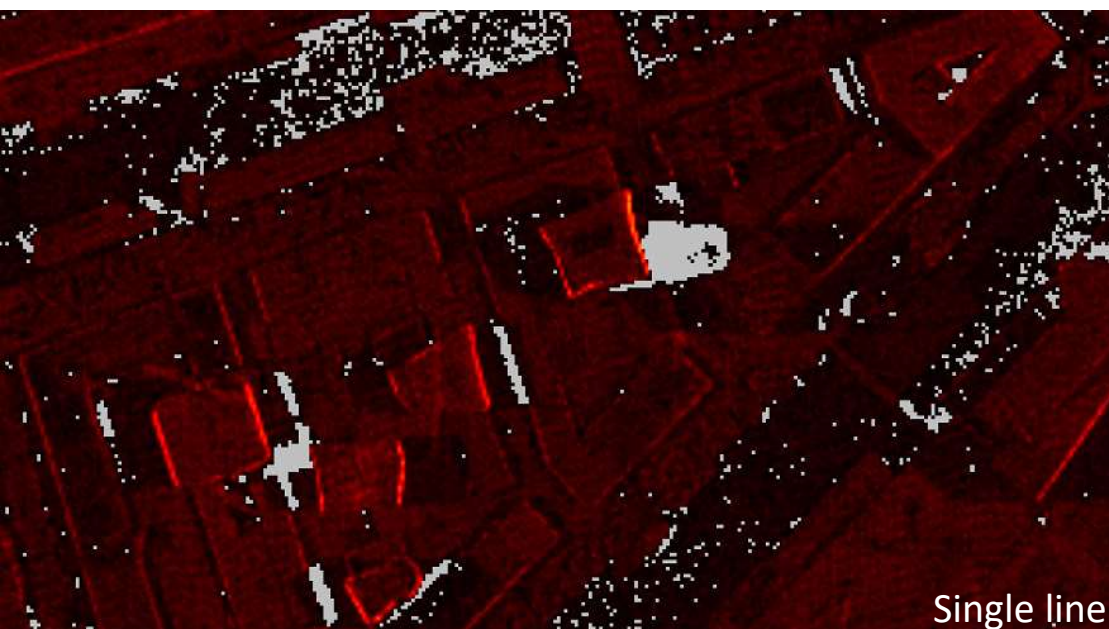
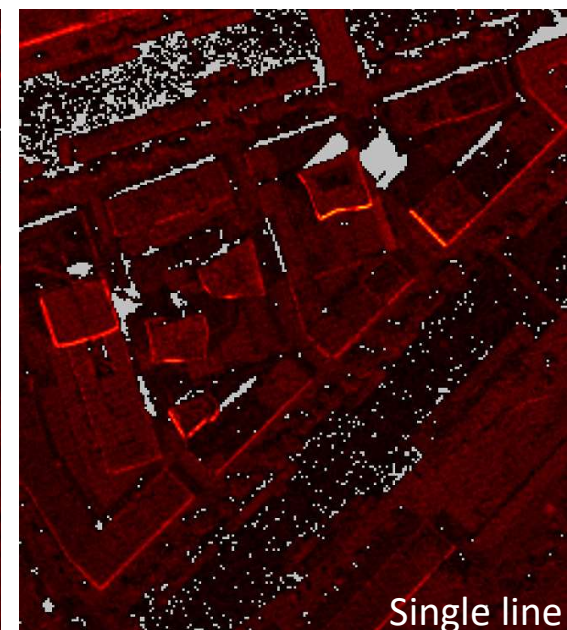
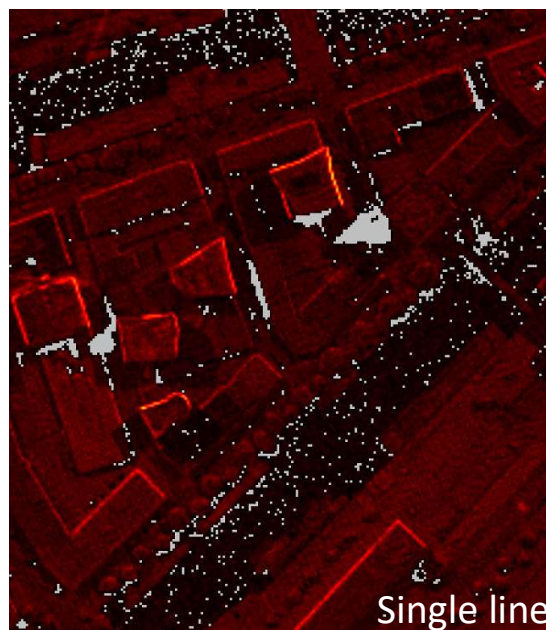
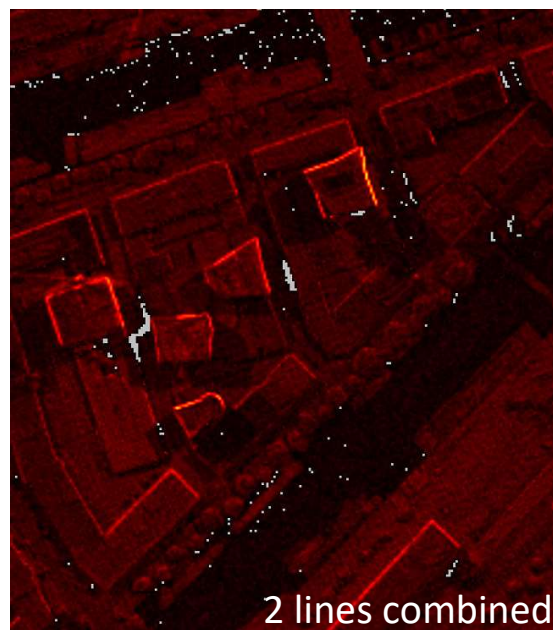
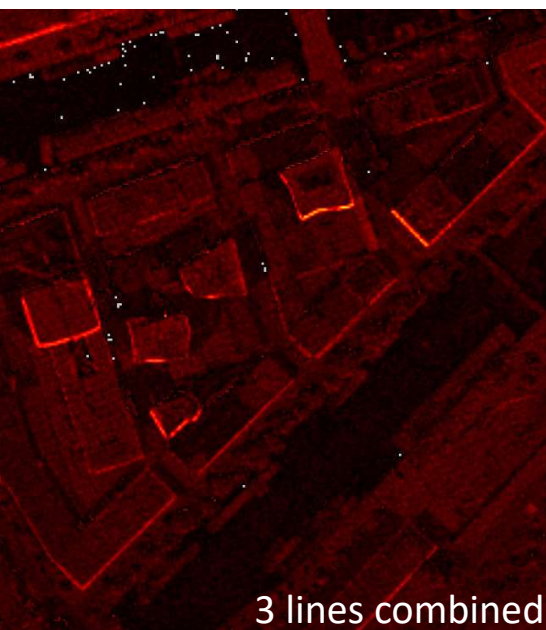
Point density and point spacing on flat surface

SPL100				Riegl 1560 i	
Line 49	Line 50	Line 51	Green	NIR	
Point Density (pts/m2)					
1-sigma (68,3%)	9	9	9	16	17
2-sigma (95,5%)	5	4	5	7	9
3-sigma (99,7%)	3	1	2	1	1
Average	15,1	15,4	14,5	17,5	17,7
Point density 5x5m flat area relative to strip width					
north	67,6	31,0	64,9	20,7	
66% north	9,2	10,0	10,0	18,6	
33% north	8,4	9,5	7,4	20,2	
centre	6,8	8,9	7,4	17,7	
33% south	8,9	9,0	7,0	17,3	
66% south	11,8	10,8	10,0	20,0	
south	40,2	34,5	21,6	19,5	
Point Spacing (cm)					
1-sigma (68,3%)	16	16	16	10	10
2-sigma (95,5%)	28	28	28	16	14
3-sigma (99,7%)	42	40	40	40	40
Average	15,8	15,2	15,6	11,3	10,9



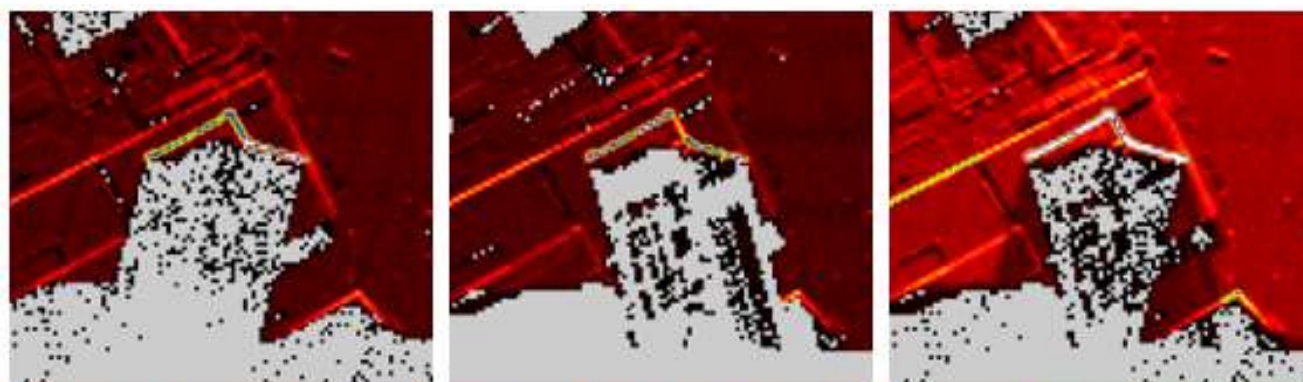
point <u>density</u> (pts/m2)	16
point <u>distance</u> (m) (edge)	0,250
point <u>distance</u> (m) (diagonal)	0,354
longest distance to point (m)	0,177
shortest distance to point(m)	0,000
average distance to point (m)	0,096
Standard deviation distance to point (m)	0,036
1-sigma (68,3%)	0,117
2-sigma (95,5%)	0,151
3-sigma (99,7%)	0,170





Occlusion SPL100

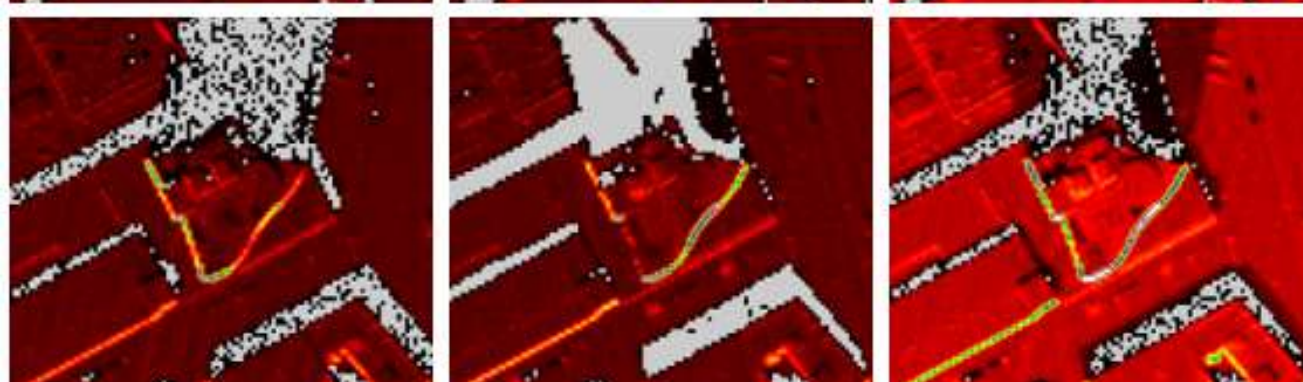




Line 1



Line 2

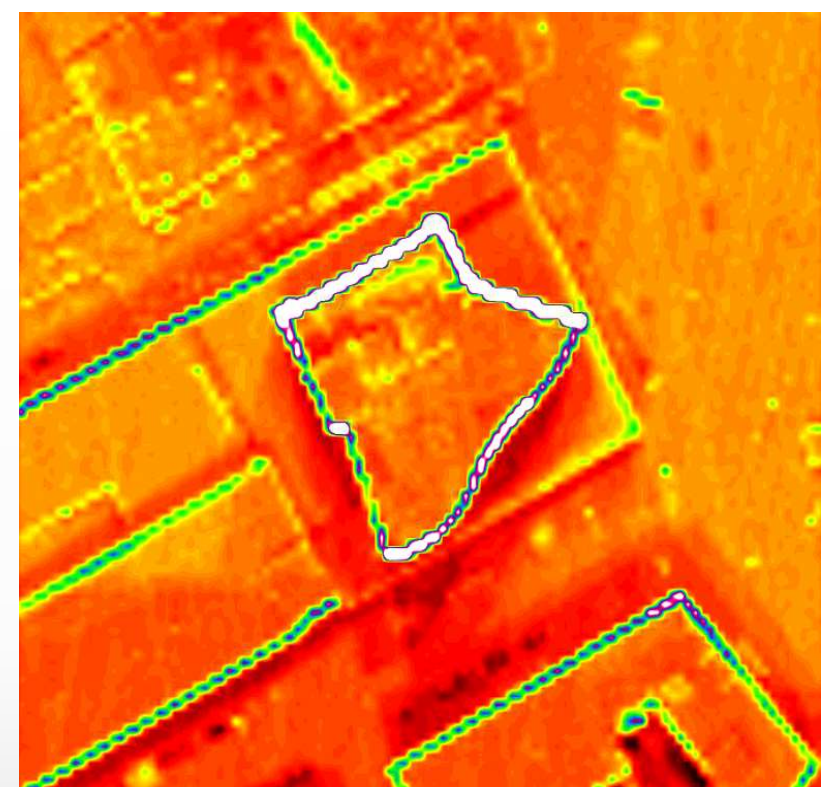


Line 3

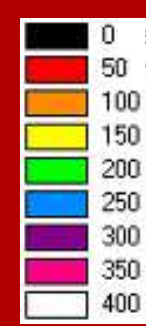
Channel Green

Channel NIR

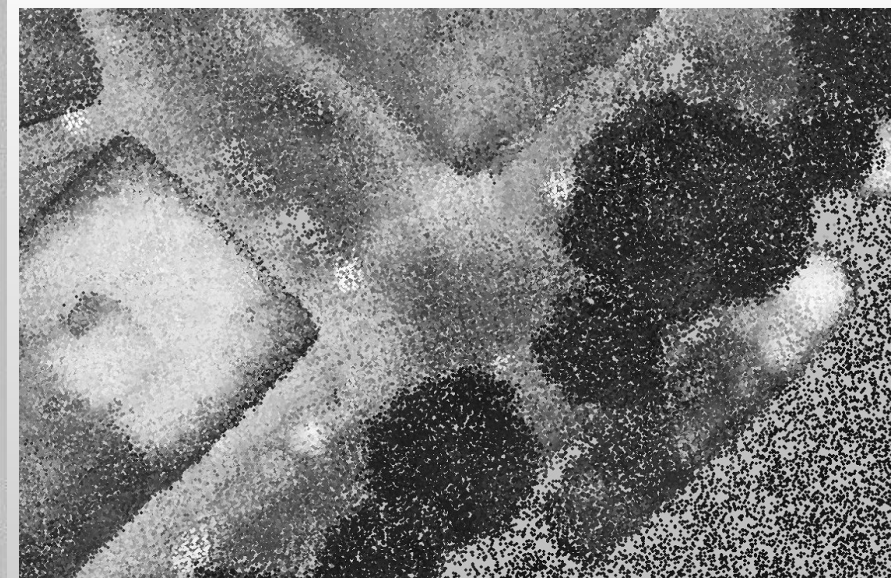
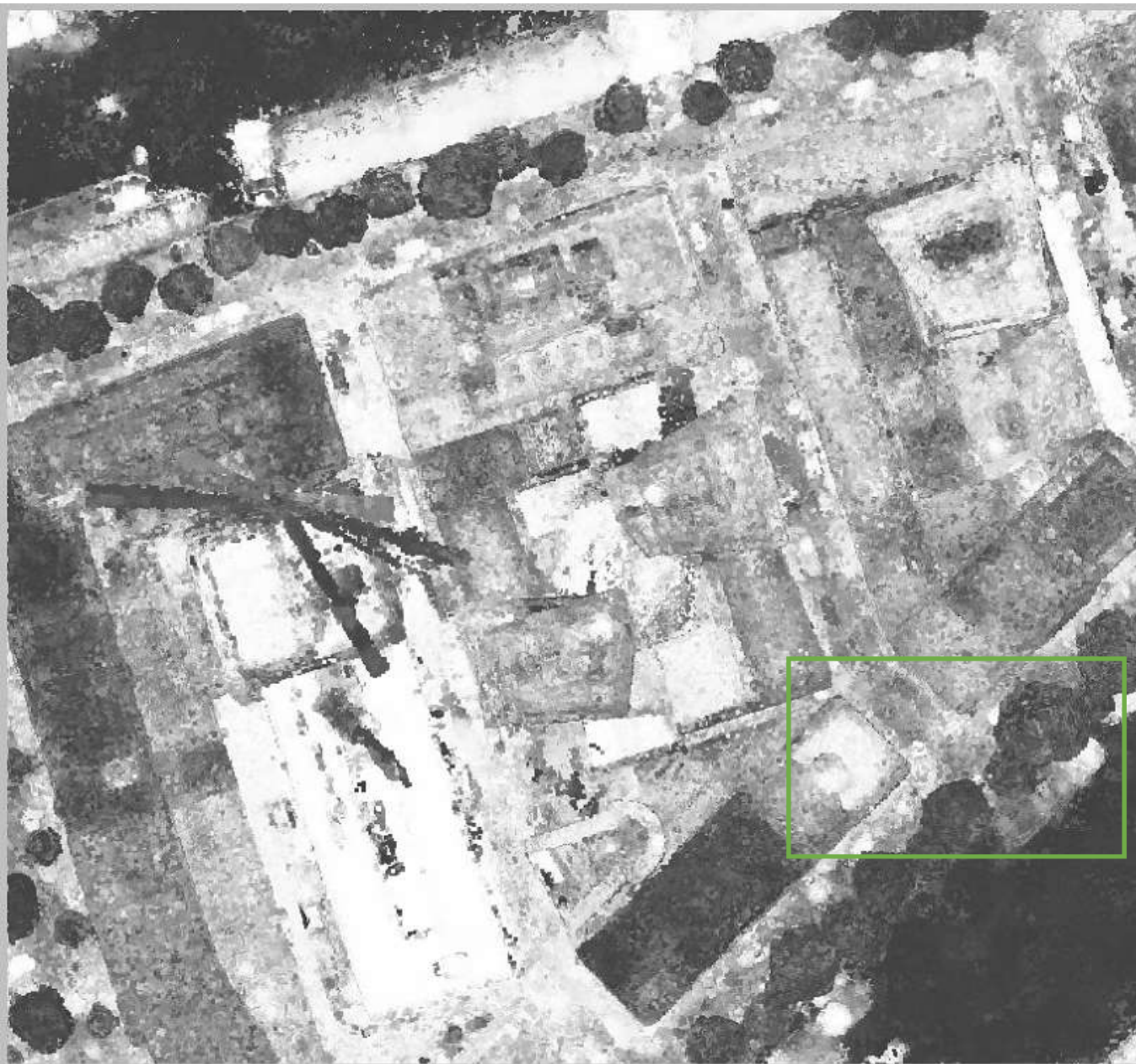
Channels combined



Occlusion
Riegl 1560i_DW



Intensity SPL100



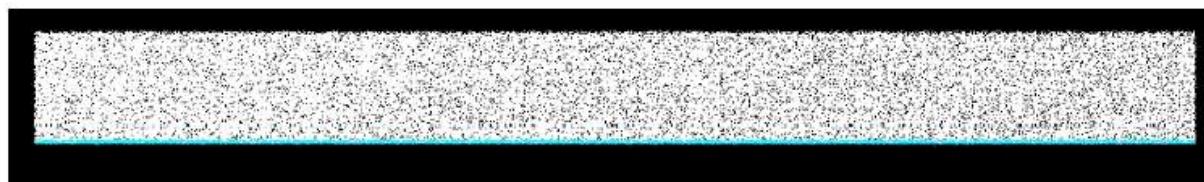
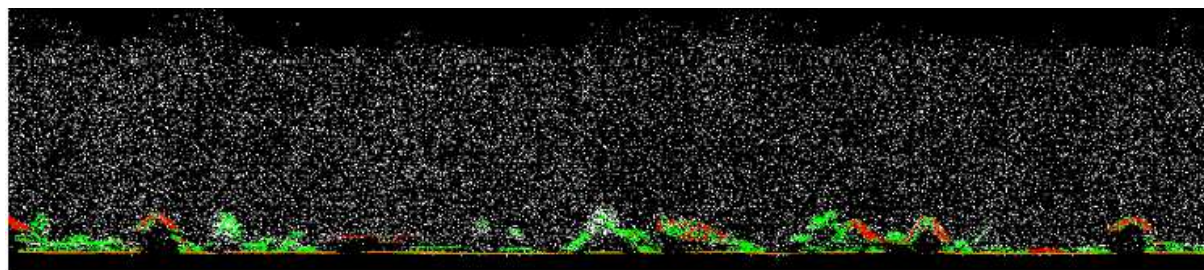


Intensity Riegl
1560i_DW



Green vs NIR LiDAR

- Green LiDAR (532 nm) much more noise compared to NIR LiDAR (1064 nm)





Concluding remarks – Riegl 1560i DW

- Geometry great
- 2 scanners individual perfect point spacing, combined less perfect
- Point density is quite regular, NIR gives better results than Green LiDAR
- To meet current AHN specs a slightly higher point density is required, mainly due to point spacing requirements



Concluding remarks – SPL100

- Geometry is surprisingly good
 - Software uses many parameters to get this done
- Point spread around roofs indicates a weaker angular precision (increased by flight altitude)
- Point density is good but varies much throughout the flight strip
 - Reflectance on roofs is weak
 - Point density is much lower than according to planning (30-40%)
 - Vegetation penetration seems less
- Point spacing is much weaker
- To meet current AHN specs a much higher point density is required (factor 3-4)



Concluding remarks – Pilots

- SPL100 is promising, especially for restricted areas like CTR Schiphol, but needs further development first
- Riegl 1560i_DW is very promising.
 - Green LiDAR does not give much more information, but more noise
 - 2 NIR serve purpose better
 - Due to non-perfect matching of point spacing between two scanners a slightly higher point density is required
- Reconsider strict demands on point spacing



Thanks for your attention

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