AHN4 in drie jaar!
… en daarna?

AHN Congres 2019

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Het Waterschapshuis
Utrecht: 16 April 2019

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History

- AHN1: 1997 – 2004
  - Initiated by Waterboards, Ministery 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

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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 three new sensors:

- Single Photon LiDAR
- Riegl VQ 1560i DW
- Riegl VQ 880 G

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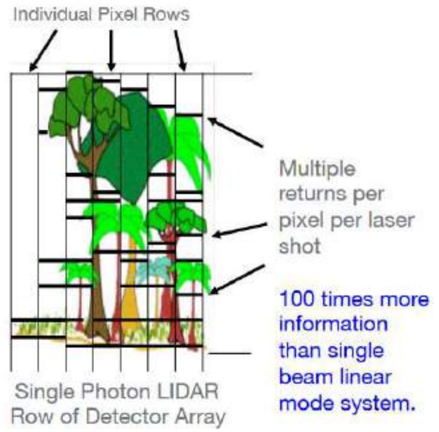
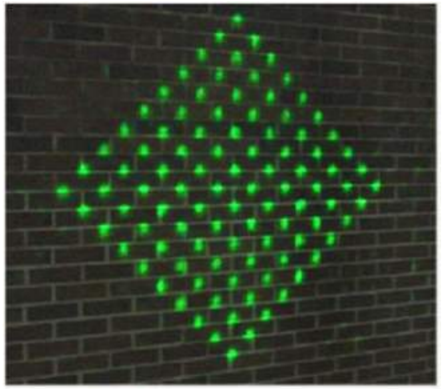
Single Photon LiDAR

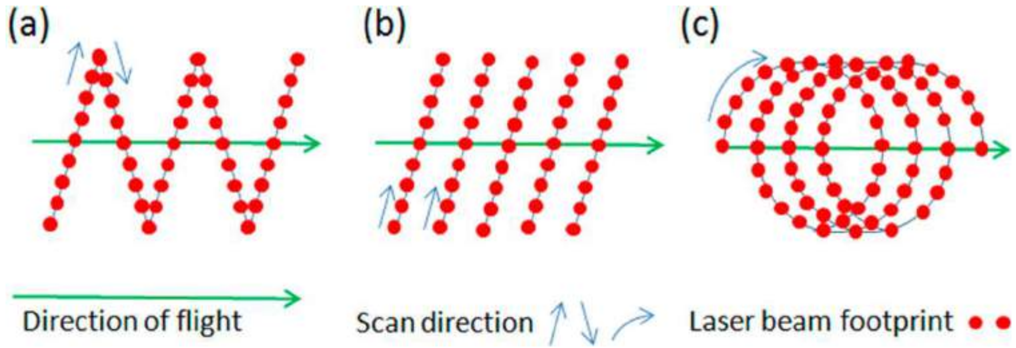
- Laser pulse split into 10x10 beamlets
- Signal strength per beamlet is low, still multiple returns
- 60 kHz → 6mln points/sec
- Conical pattern (c)
- Opening angle 10 – 30 degrees
- Green LiDAR (532 nm), bathymetry?



[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]

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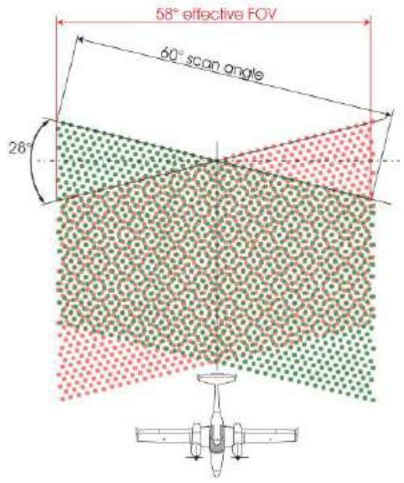
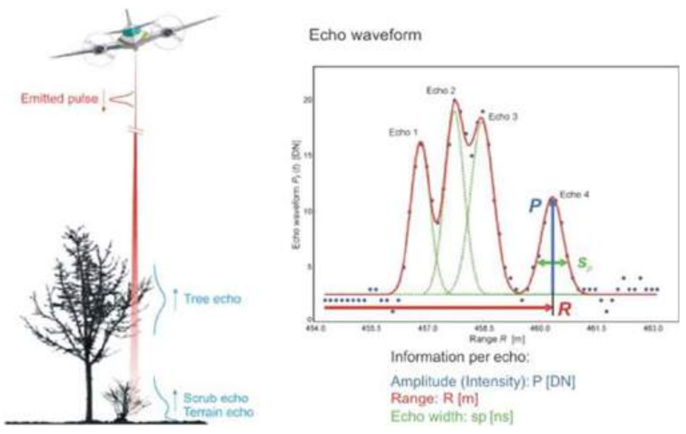


[Riegl]



[http://geo.tuwien.ac.at/opals/html/ModuleFullwave.html, Feb 6th 2018]

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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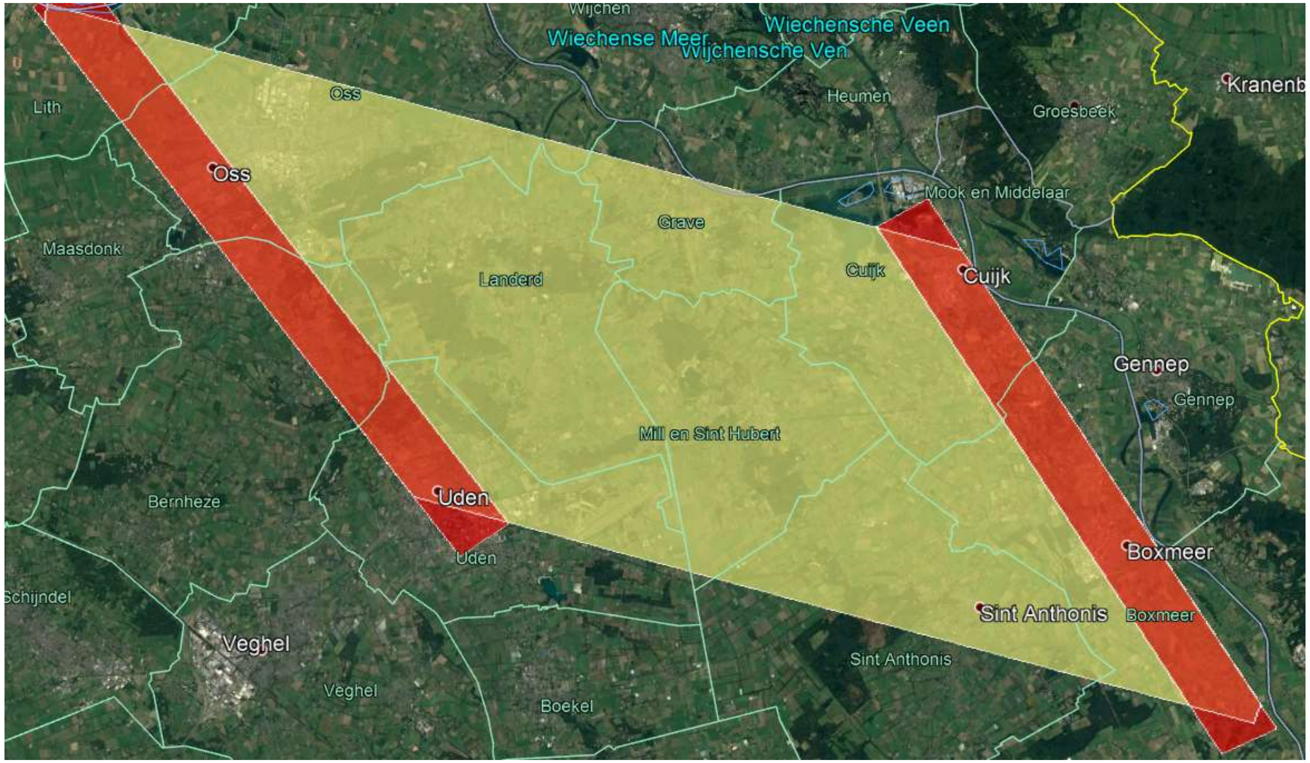

Single Photon LiDAR & Riegl 1560i DW

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Area 1

Characteristics

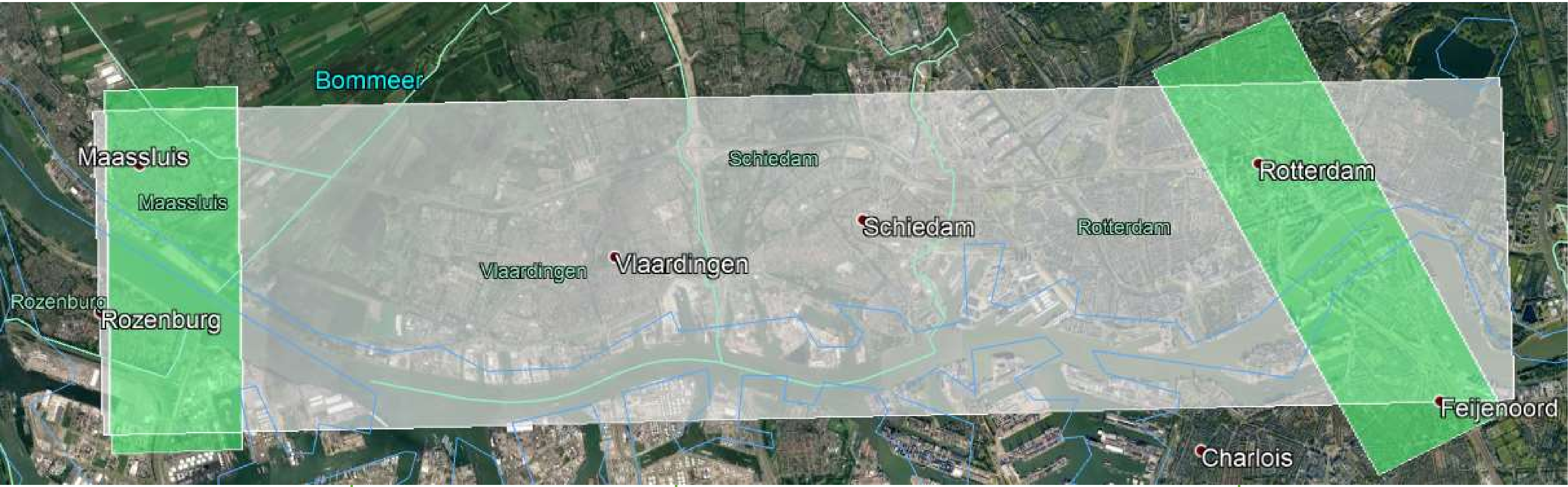
Agricultural area, some medium cities, river, forest

Purpose

Compare to AHN2 / AHN3 data

Aimed point density

8 pts/m2



	Characteristics	Purpose	Aimed pointdensity
Area 2	City, urban canyoning	3D buildings; Ground measurements in urban cannyoning; Compare Rotterdam data	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

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Flight parameters

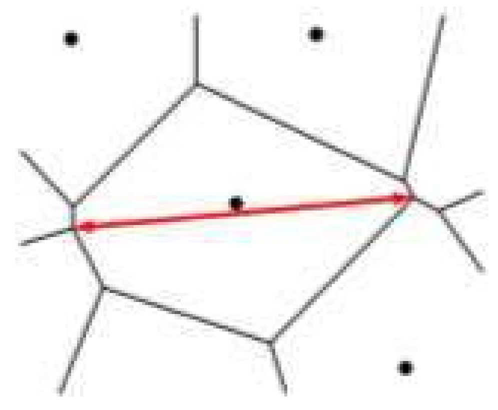
	1: Noord Brabant		2: Rotterdam		3: Westerschelde		3b: Westerschelde low
	Riegl 1560i DW	**SPL100**	**Riegl 1560i DW**	**SPL100**	**Riegl 1560i DW**	**SPL100**	**Riegl 1560i DW**
Point density (pts/m2)	>8	>8	60	60	12	>8	>30
Flight altitude (m)	1500	3750	670	4270	1240	3750	560
Flight speed (knts)	110	160	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	2,1	1,2	0,7	0,5	0,5
Side lap	20%	30%	60%	85%	20%	15%	

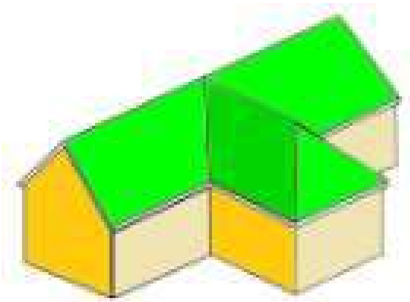
Demands AHN

- 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

Height difference between strips

SPL	Average	Standard deviation
Maximum	0.004	0.065
Minimum	-0.007	0.044
Average	0.000	0.052
Standard deviation	0.003	0.006

Riegl 1560i	Average	Standard deviation
Maximum	0.087	0.029
Minimum	-0.030	0.018
Average	0.002	0.023
Standard deviation	0.030	0.003

- HxMap software minimizes average height differences of SPL very well.
- Standard deviation is clearly higher compared to Riegl
- 100% of all differences fulfil the 1-sigma criterium of AHN3
- 100% of all standard deviations fulfil the AHN3 criteria

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Geometry

Planimetric difference between strips

SPL

Strip overlap	Average dXY	Standard deviation dXY	Average dZ	Standard deviation dZ
Maximum	0.114	0.086	0.027	0.046
Minimum	0.008	0.044	-0.014	0.010
Average	0.042	0.064	0.003	0.029
Standard deviation	0.027	0.011	0.009	0.009

Riegl 1560i

Strip overlap	Average dXY	Standard deviation dXY	Average dZ	Standard deviation dZ
Maximum	0.069	0.044	0.062	0.036
Minimum	0.007	0.027	-0.043	0.013
Average	0.031	0.036	-0.001	0.021
Standard deviation	0.015	0.004	0.026	0.006

- Results of Riegl are slightly better than SPL
- On average resulting pointspacing must be within 2*34.3 for SPL and 2*40.8 for Riegl
- Worst case resulting pointspacing must be within 2*26.1 for SPL and 2*37.2 for Riegl
- Relative height accuracy for SPL is very good on gable roofs as well.

$$\Delta pd + \sqrt{\Delta x^2 + \Delta y^2} + 3\sigma_x \leq 50\ cm$$

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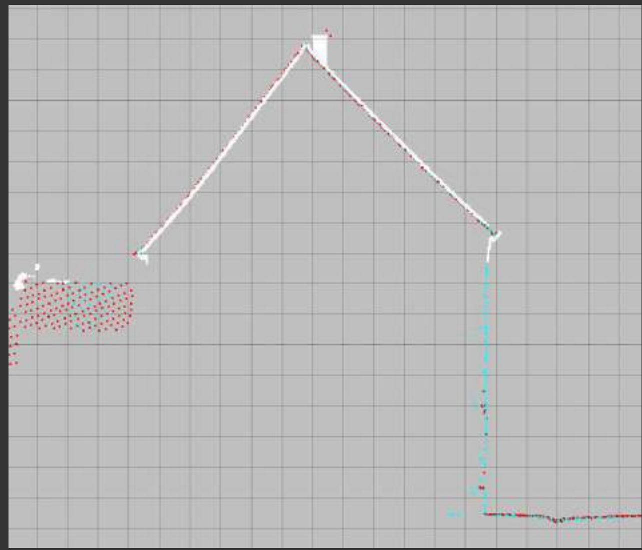
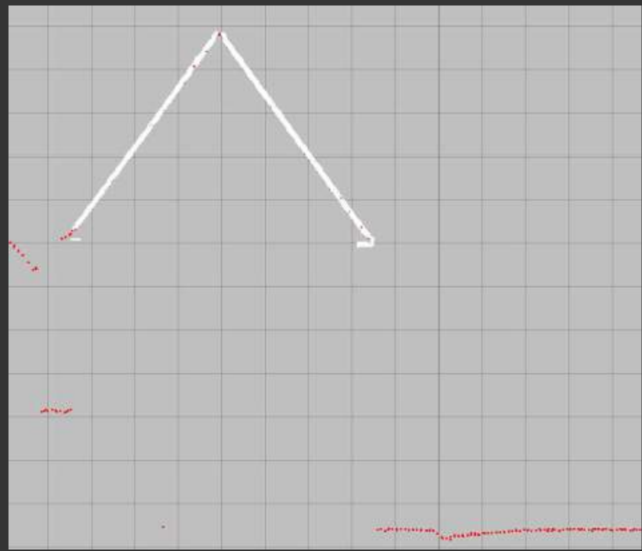
Geometry

- 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)





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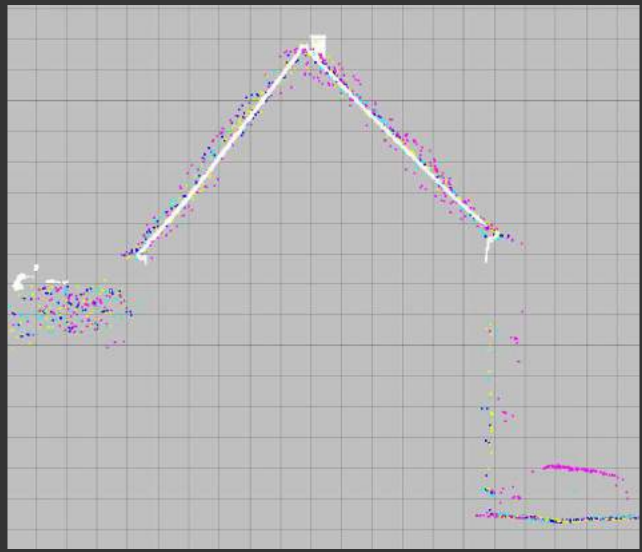
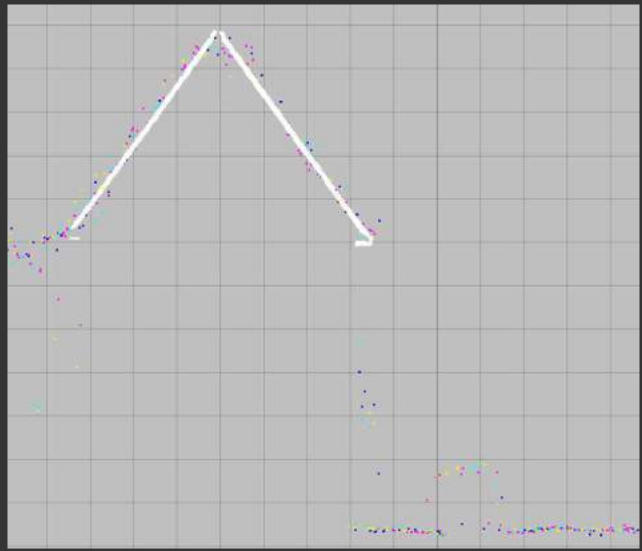
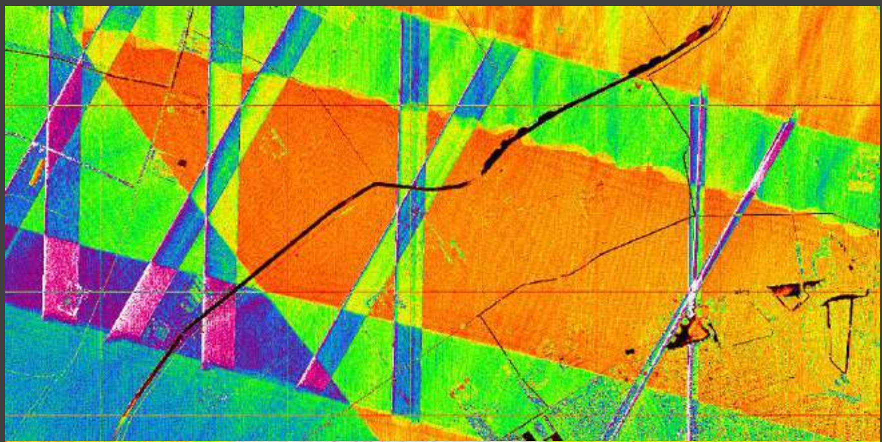
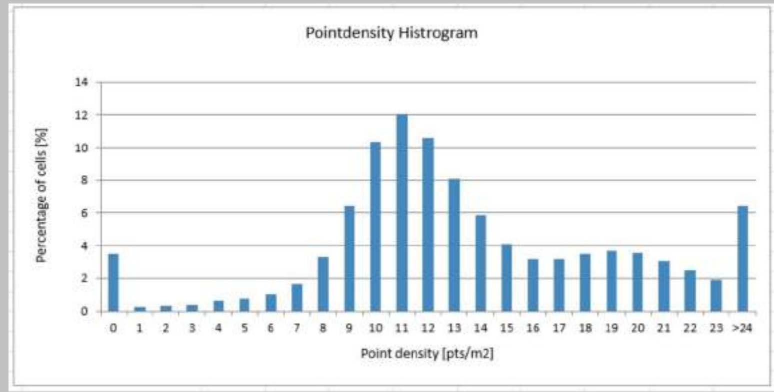


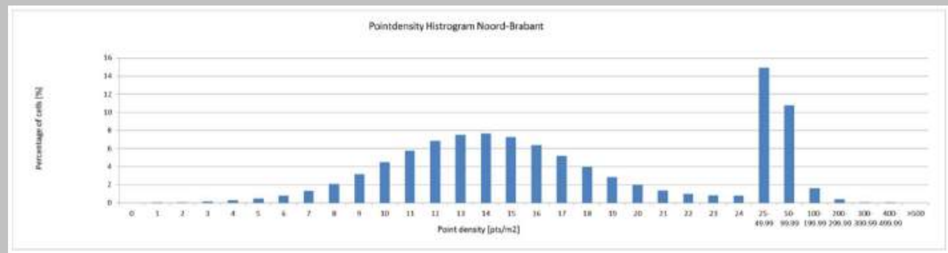


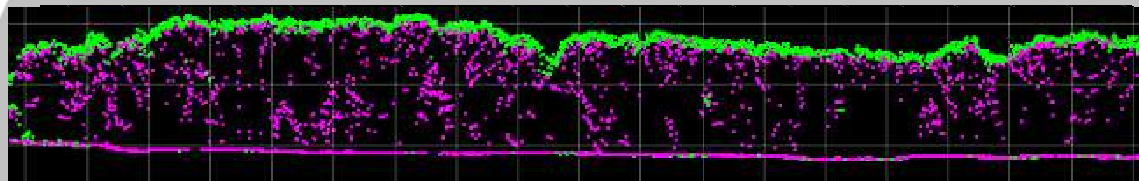
Point density

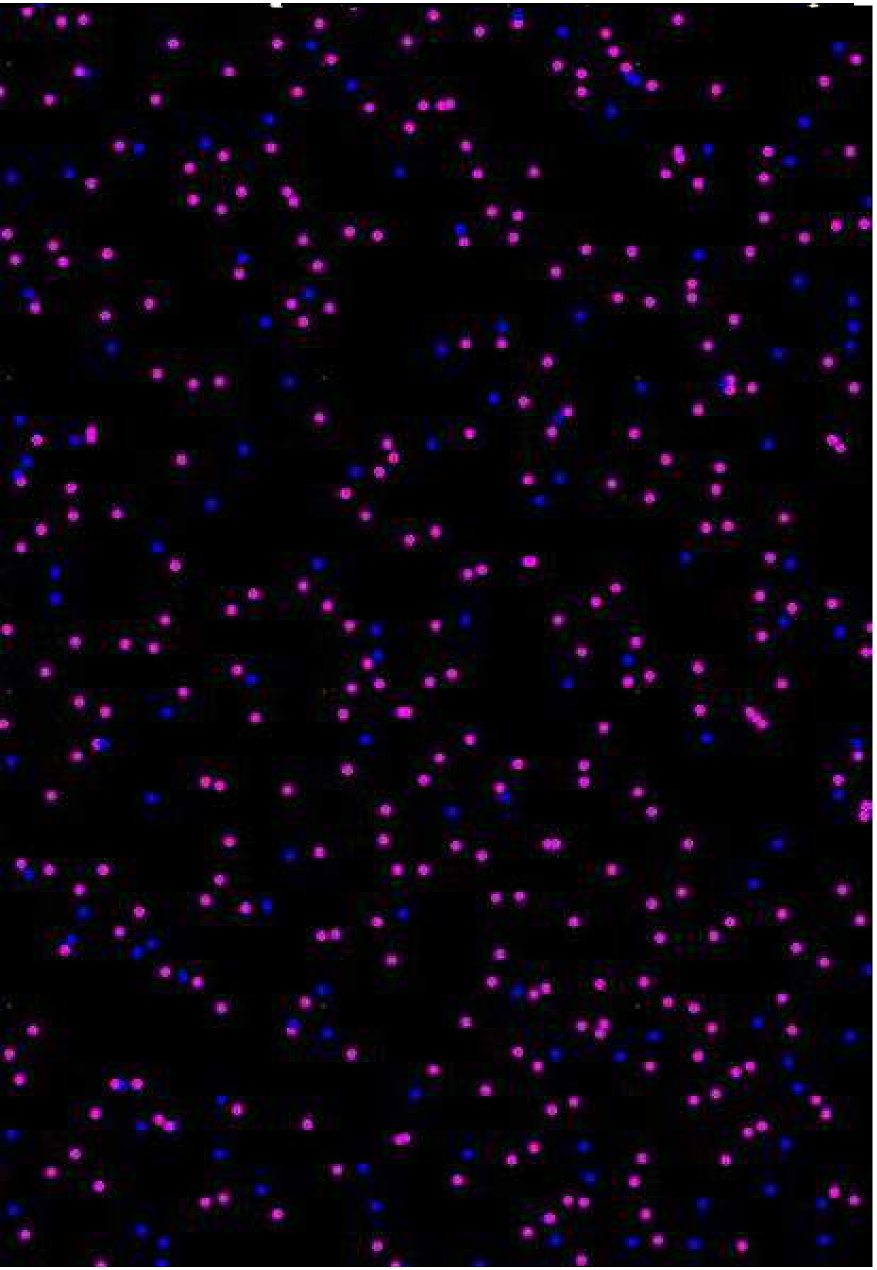
- Point density
  - Riegl average 13.5 pt/m2, 91,5% cells fulfils 8 pts/m2
  - SPL average 25.5 pt/m2 (12.4 in nadir), 96% cells fulfils 8 pts/m2
  - Resulting point density nadir SPL100 30-40% lower than planned
  - Point density SPL100 drops on buildings





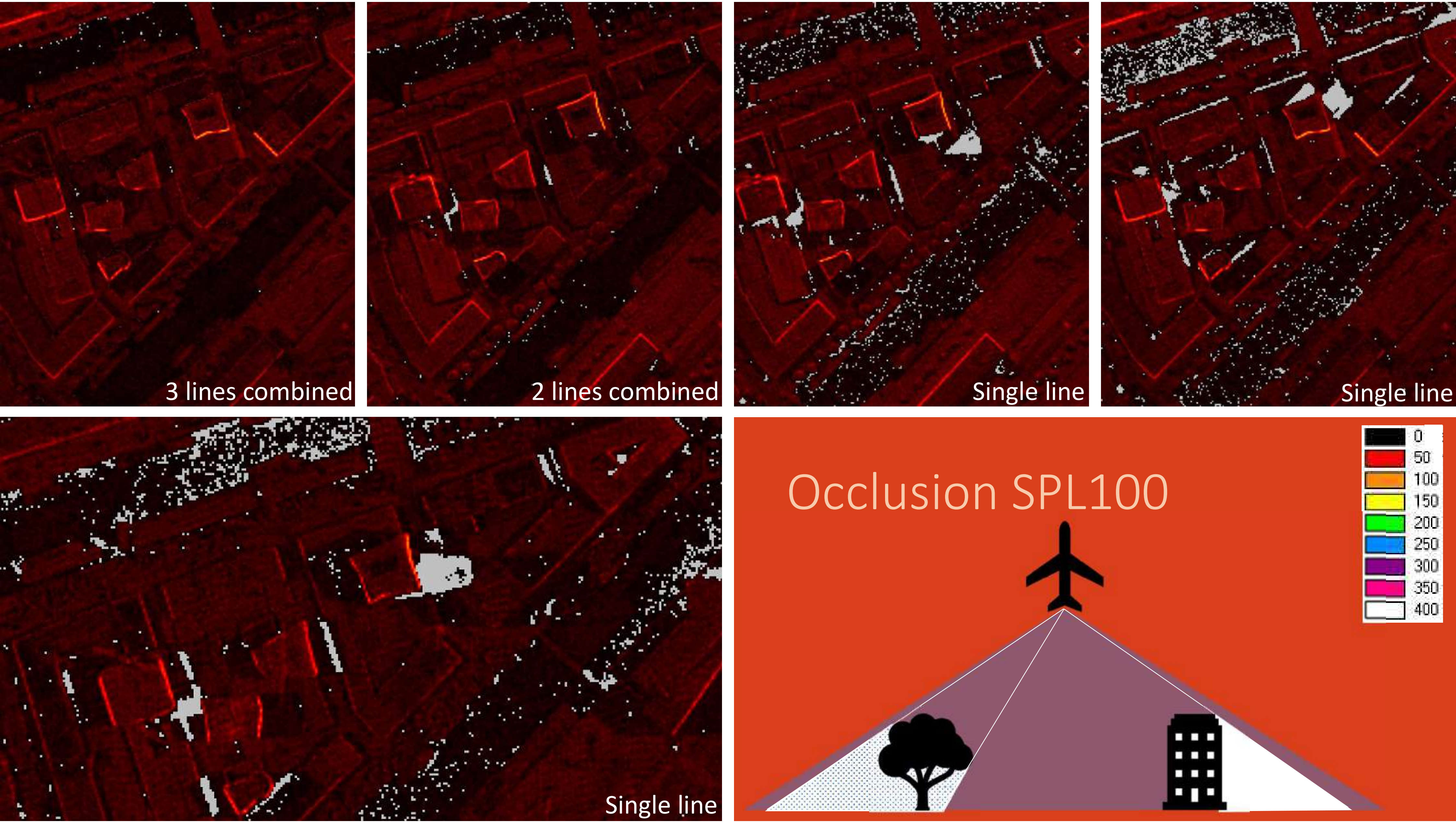


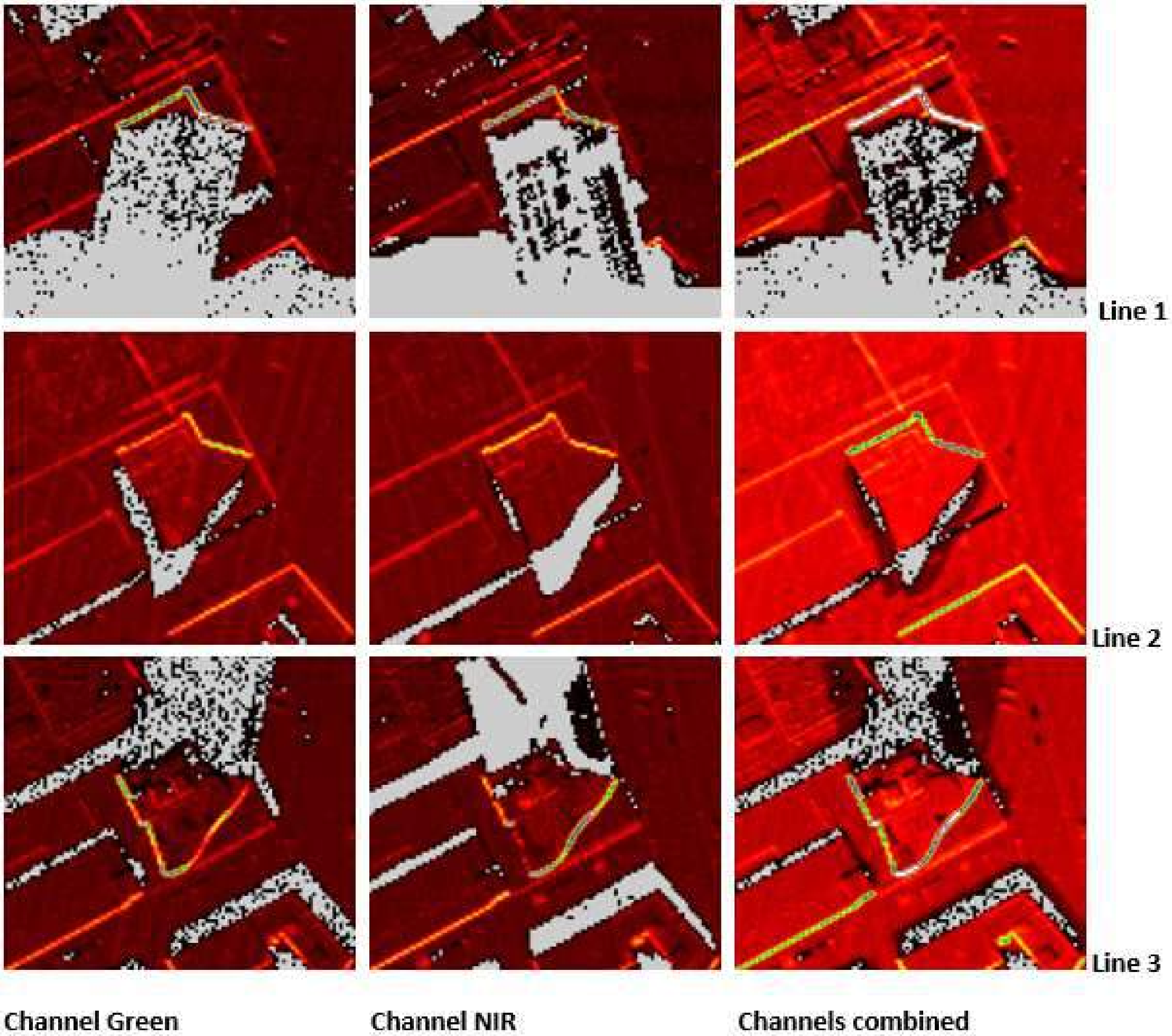


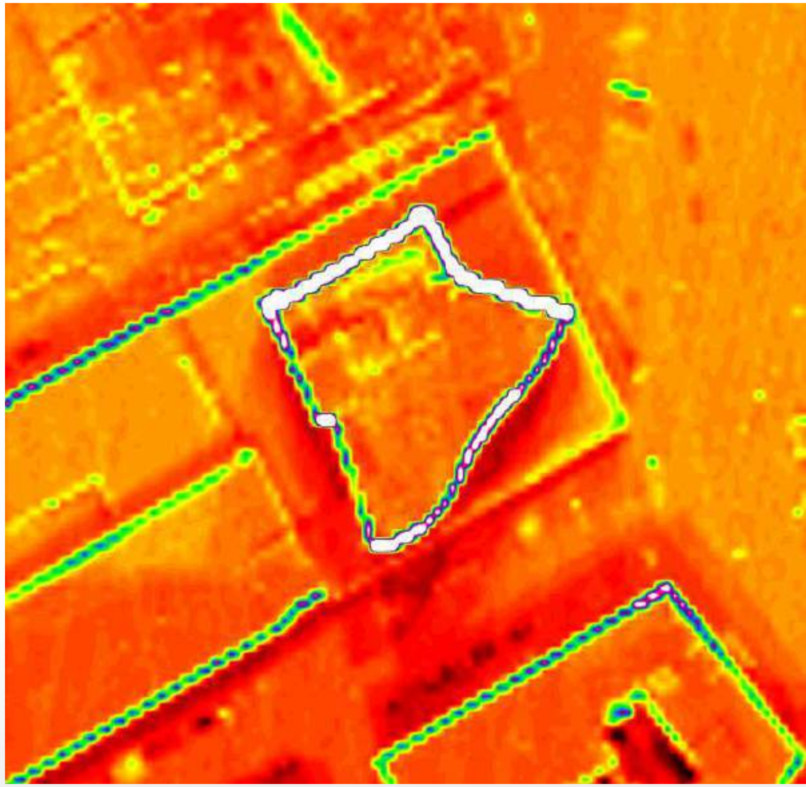


Point spacing

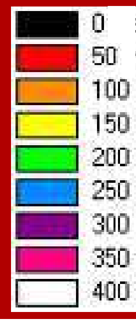
- Riegl 94% fulfils < 54 cm
- SPL100 49% fulfils < 54 cm
- Point spacing for Riegl of each individual channel is within a factor 1.2 from perfect
- The combination of the two channels is random and results in a factor 1.6 from perfect.
- Point spacing for SPL100 is more random due to its scan pattern and is within a factor 1.9 from perfect.

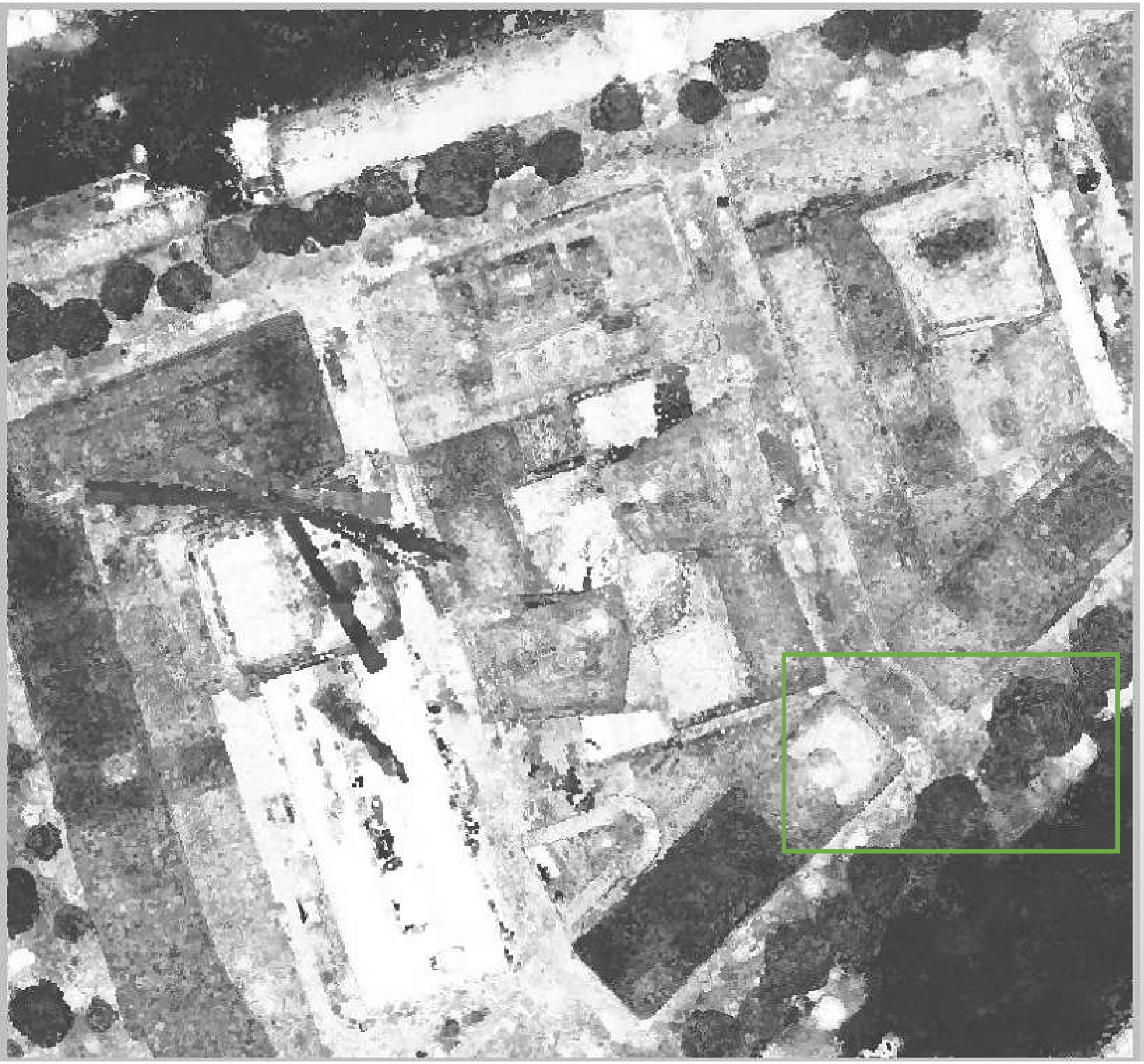

3 lines combined
2 lines combined
Single line
Single line
Single line
Occlusion SPL100
0
50
100
150
200
250
300
350
400



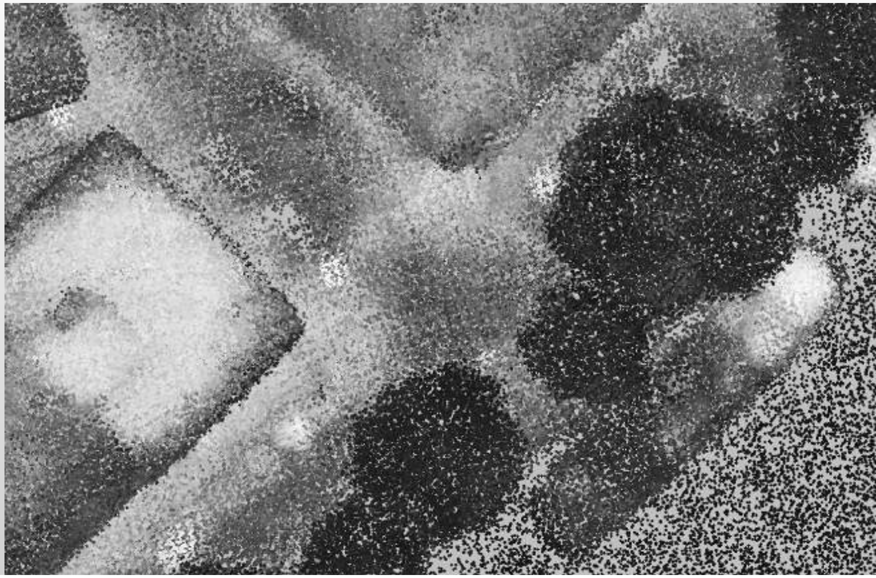


Occlusion
Riegl 1560i_DW

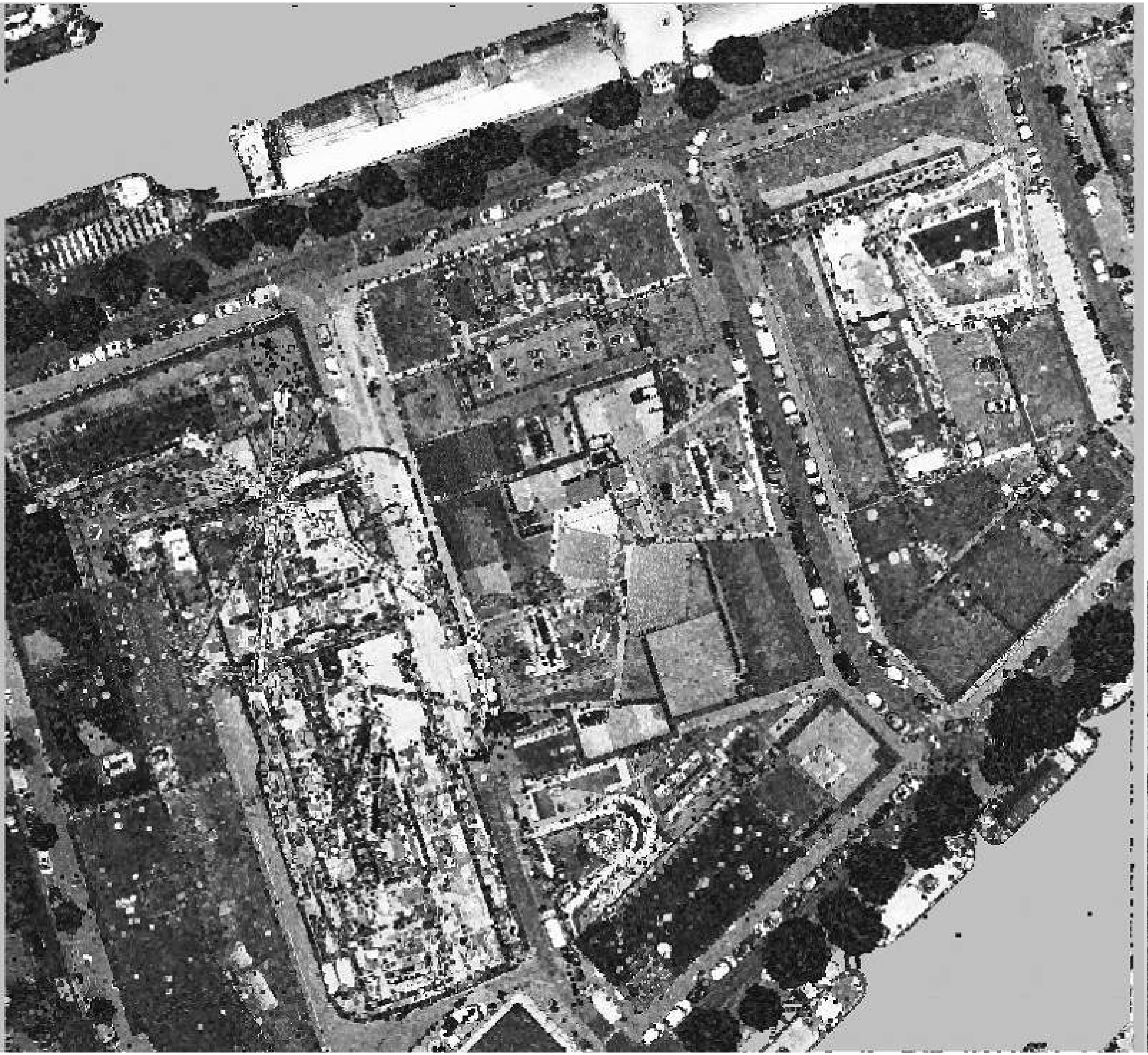




Intensity SPL100

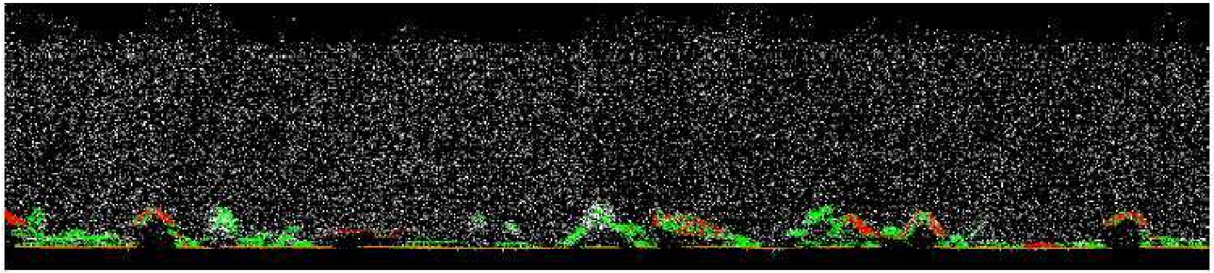


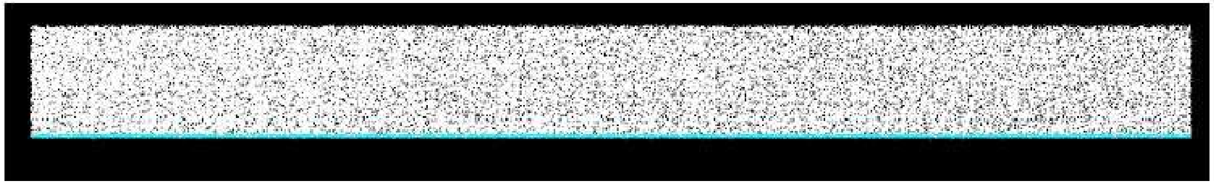
Intensity Riegl 1560i_DW

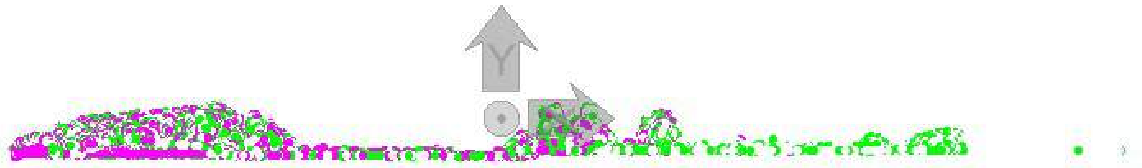


Green vs NIR LiDAR

- 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
- Green LiDAR does not give much more information, but more noise
- Point density is quite regular, NIR gives better results than Green LiDAR, 2 NIR serve purpose better
- To meet current AHN specs a slightly higher point density is required, mainly due to point spacing requirements

Concluding remarks – SPL100

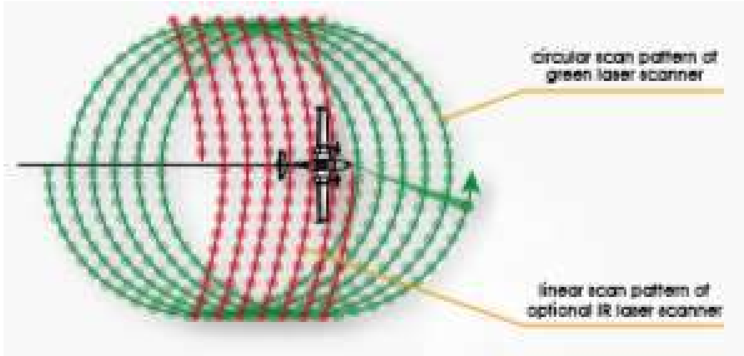
- Geometry is surprisingly good
  - Software uses many parameters to get this done
- Point spread around roofs indicates a weaker angular precision (increased by flight altitude)
- Point density is good but varies much throughout the flight strip
  - Reflectance on roofs is weak
  - Point density is much lower than according to planning (30-40%)
  - Vegetation penetration seams less
- Point spacing is much weaker
- To meet current AHN specs a much higher point density is required (factor 3-4)
- SPL100 is promising, especially for restricted areas like CTR Schiphol

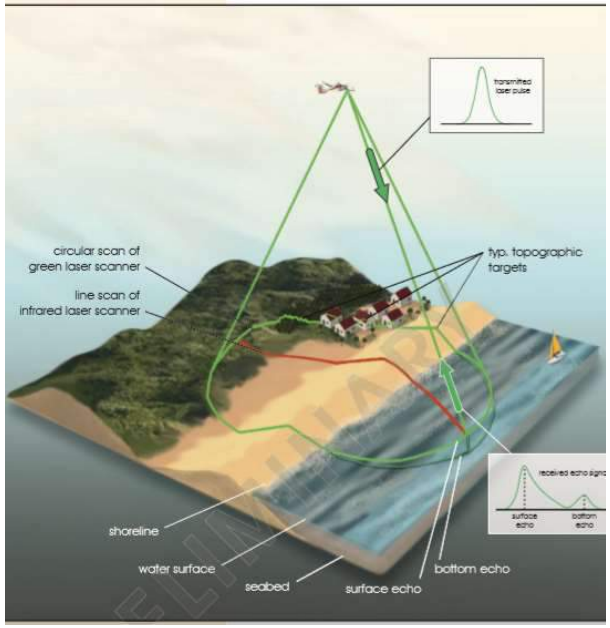
Specifications AHN4

- Vertical accuracy stays the same (5+5 cm)
  - Also on horizontal and tilted planes (f.e. roofs, dikes)
- Planimetric accuracy was:
  - Map an object with 50cm accuracy
- Becomes:
  - Same or: Point density > 10 pts/m2; > 5 pts/m2 below vegetation; no demands on point spacing
- Maybe some demands on normalized intensity

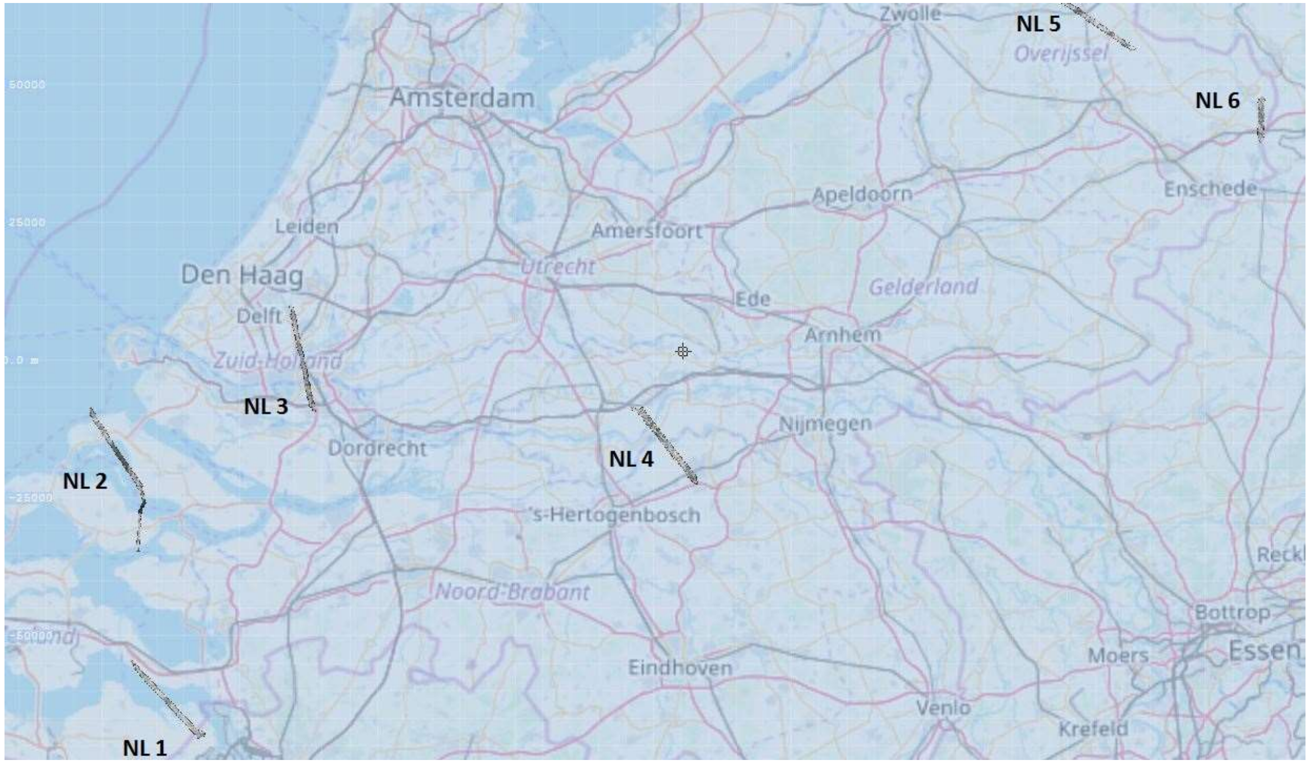
Riegl VQ 880 G

- Bathymetric LiDAR (532 nm)
- Conical pattern
- Opening angle 40 degrees
- Altitude AGL: 400m
- Laser beam divergence: 1.1mrad
- Field of view: 5-175° and 185-355°
- Scan speed: 80 lines per second
- Pulse repetition rate: 550kHz
- Flight speed 80knts





[Riegl]



Area of Interest Bathymetric pilot

6 locations throughout the country

Different soil types

Area size 500-750m x 6-16km

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Doelstelling

- Waar kan de waterbodem gemeten worden en welke factoren hebben daar invloed op?
  - Grondtype
  - Waterdiepte
  - Tijdstip van meten
    - Binnen het jaar ivm vegetatiegroei in het water
    - Binnen een periode ivm stroming door neerslag
- Hoe goed zijn de metingen
  - Validatie met gronddata

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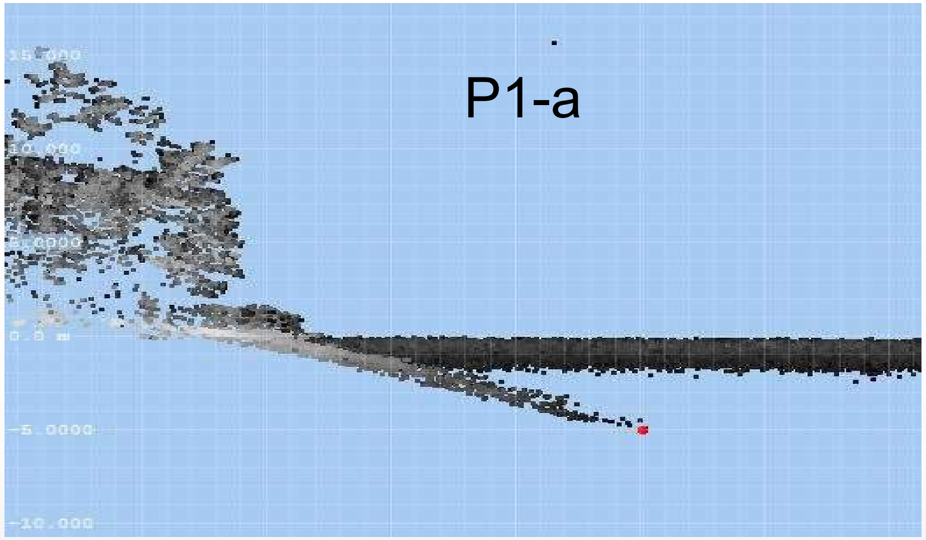

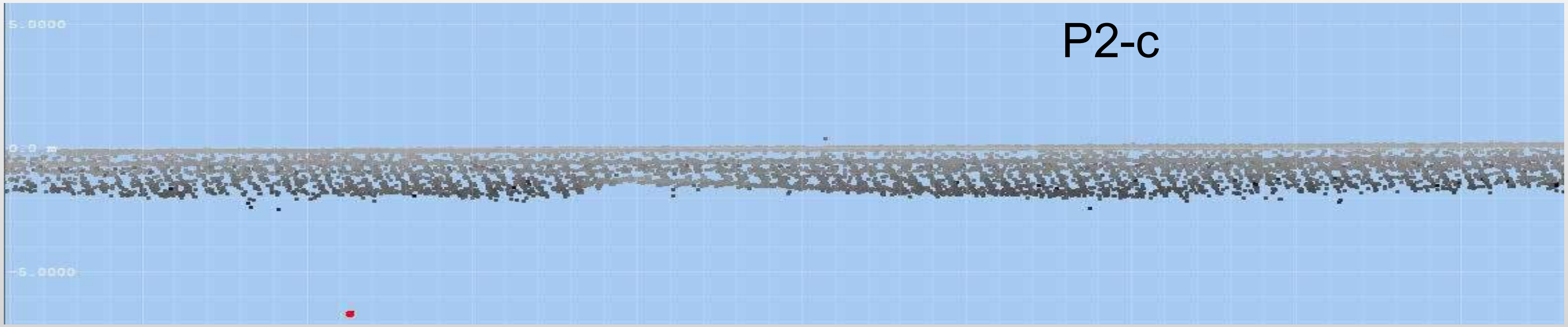

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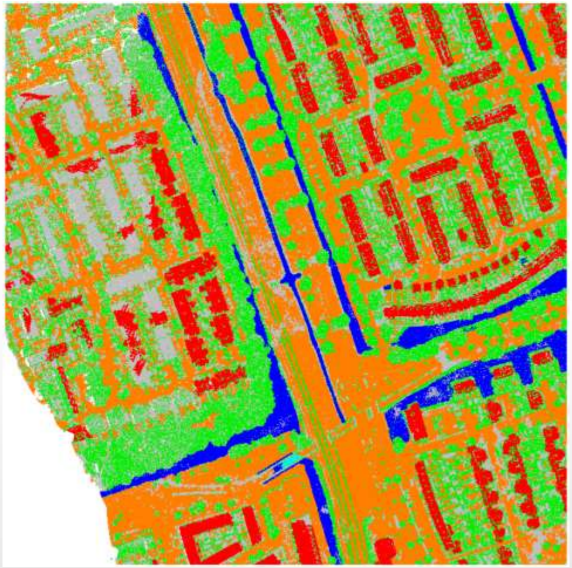
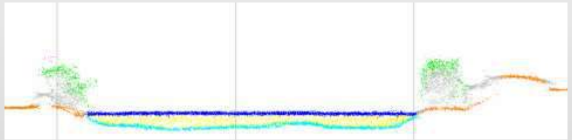
Automatische Classificatie

- Classificeren van de data liefst zo automatisch mogelijk.
- Stappen die zijn uitgevoerd:
- Echo (1st)
- Intensiteit
- Hard surface
- Hoogte tov referentie
    - -10cm tot + 10cm toevoegen aan water
    - -7m tot 0m naar water
    - -7m tot 0m naar "natte grond"waterbodem





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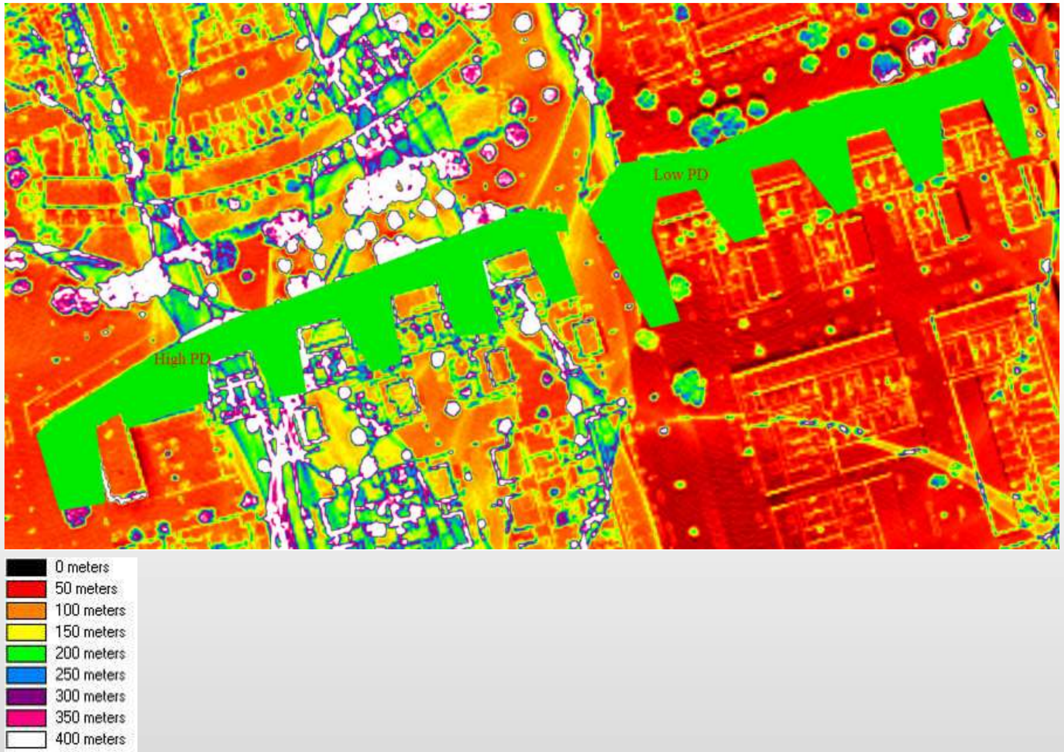
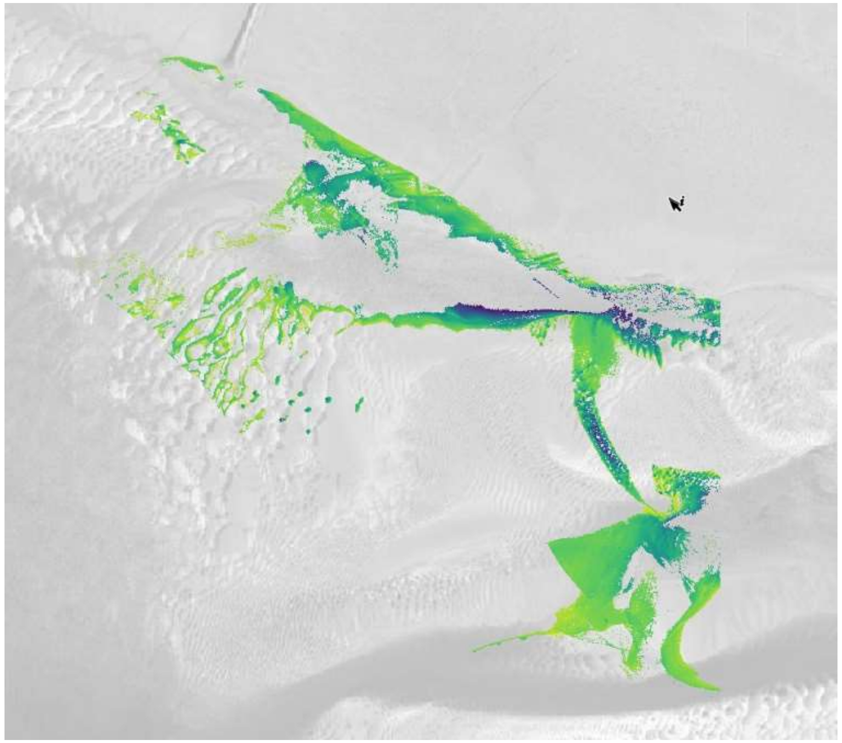
Handmatige controle en correctie

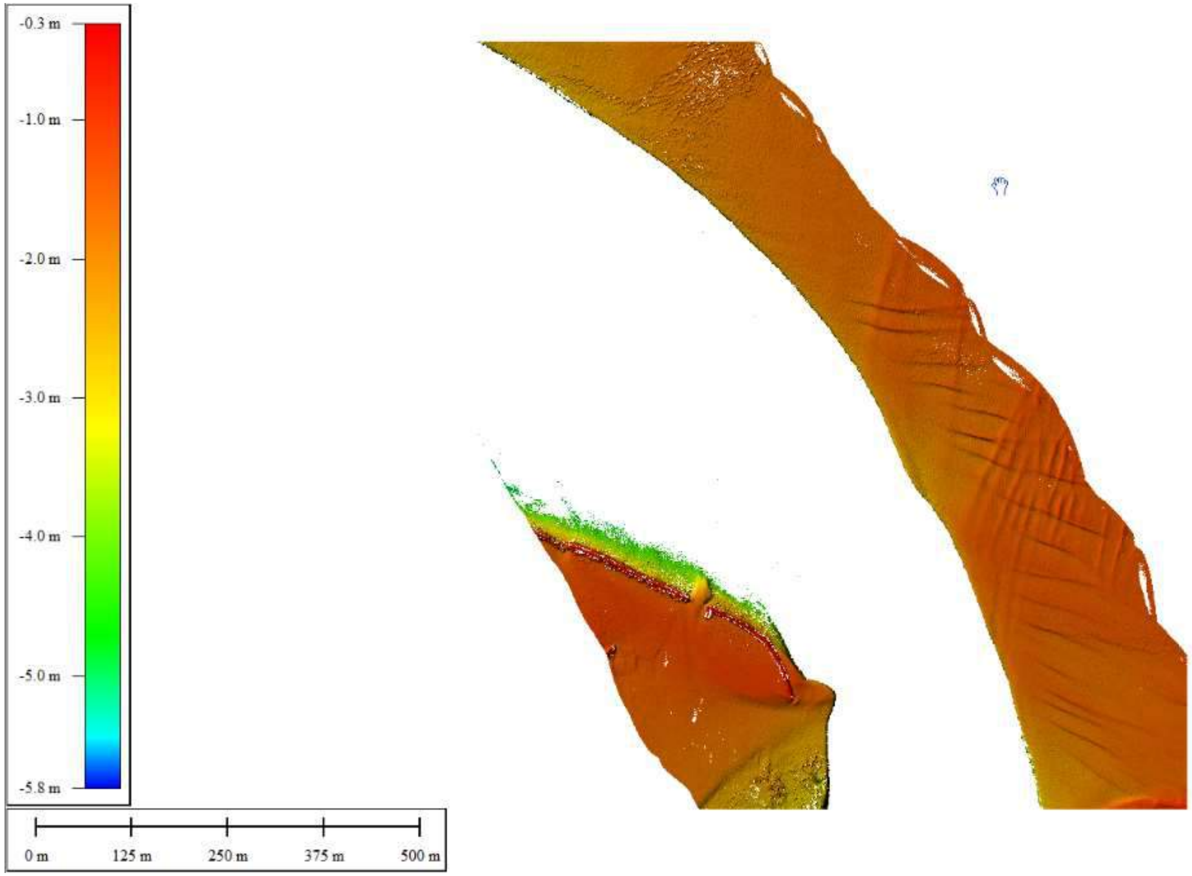
- Resultaat automatische classificatie
- Puntdichtheidseis
- Relatie met ingewonnen puntdichtheid



Gebied 1: Westerschelde



Gebied 2: Grevelingenmeer



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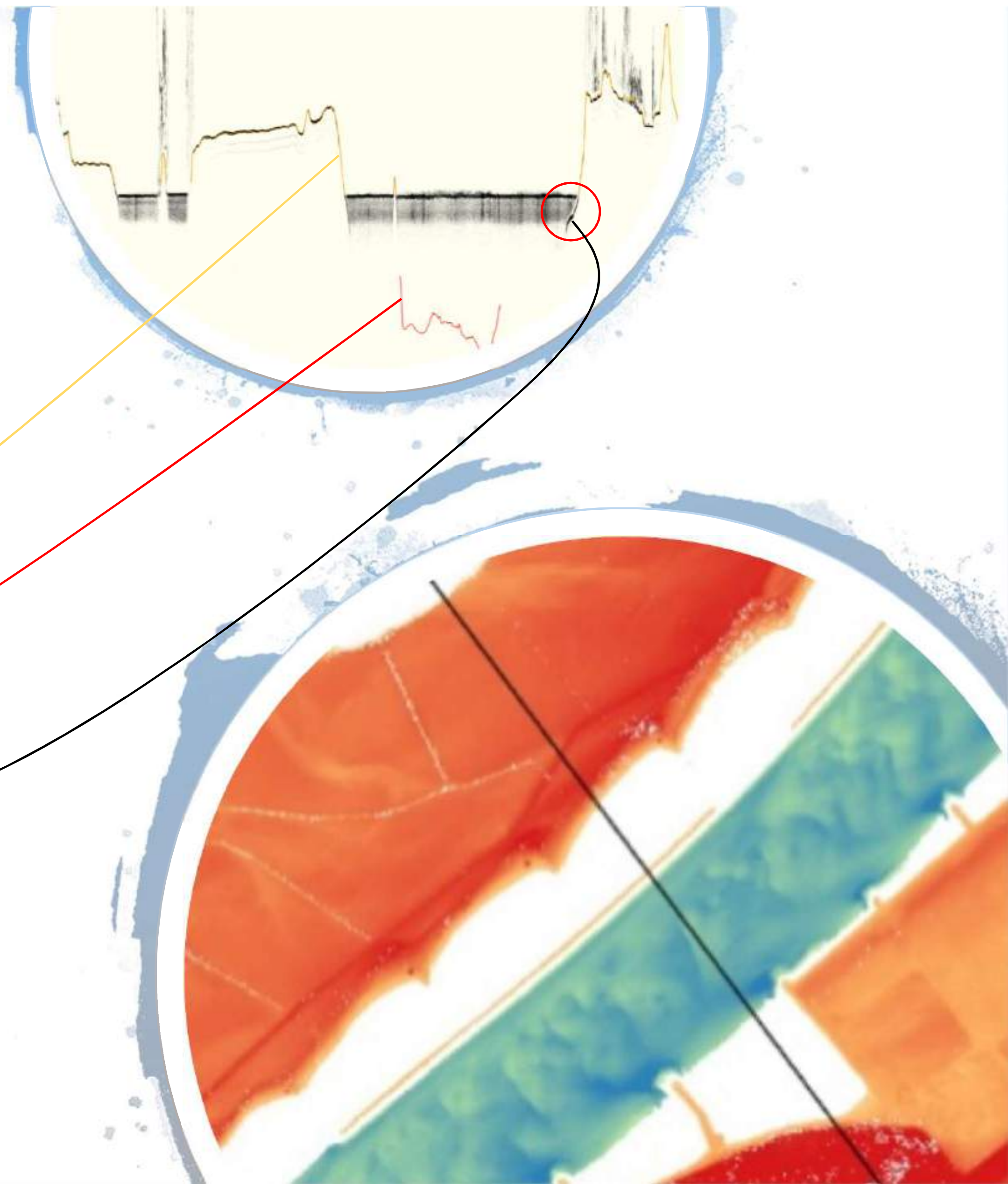
Gebied 3: Rotterdam

Gebied 4: Oss

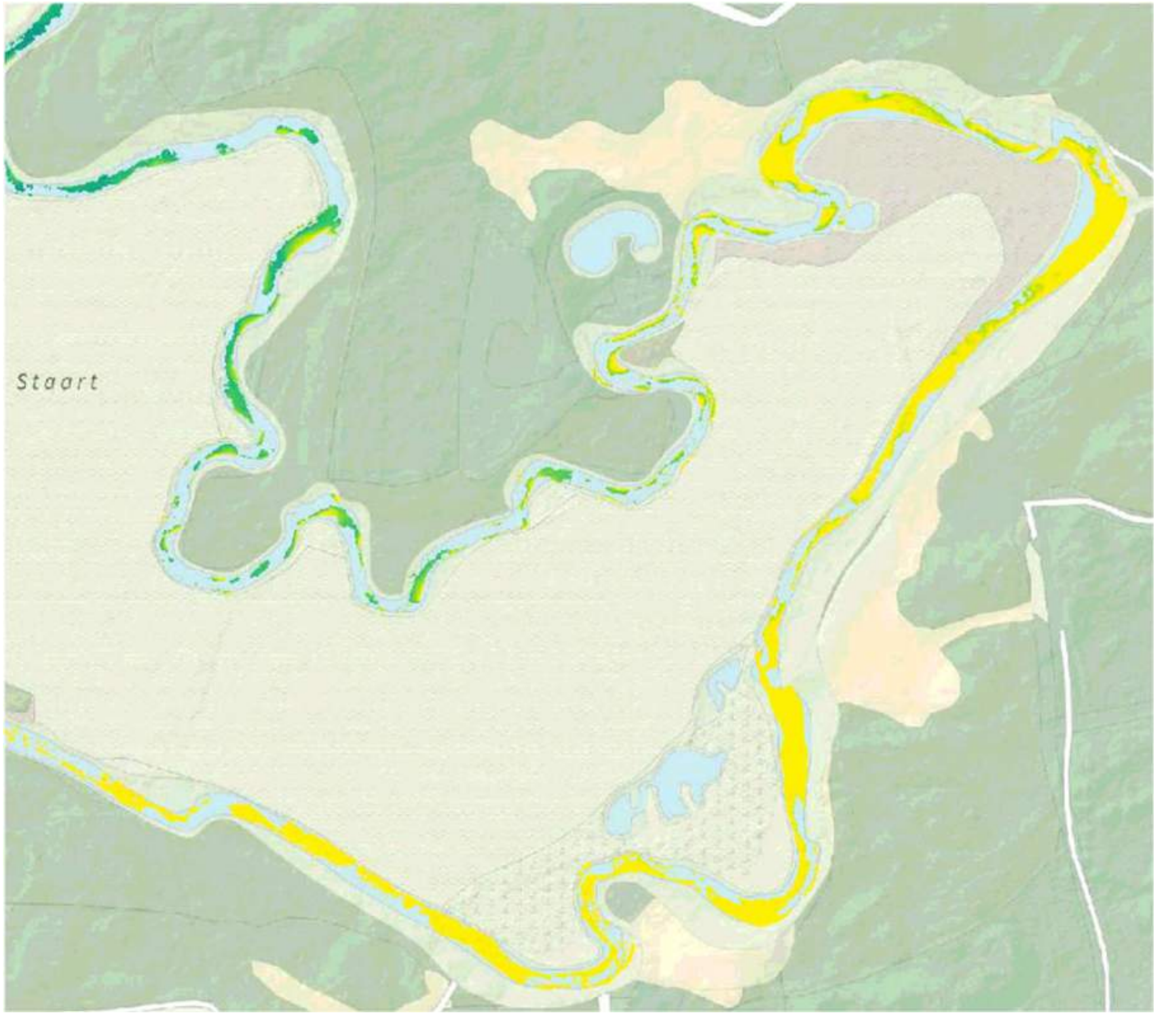
Gebied 4: Oss

- De Waal, gecombineerde dataset:
    - AHN data
    - Multibeam
    - Bathymetric LiDAR



Gebied 5: Ommen

Gebied 6: Dinkel



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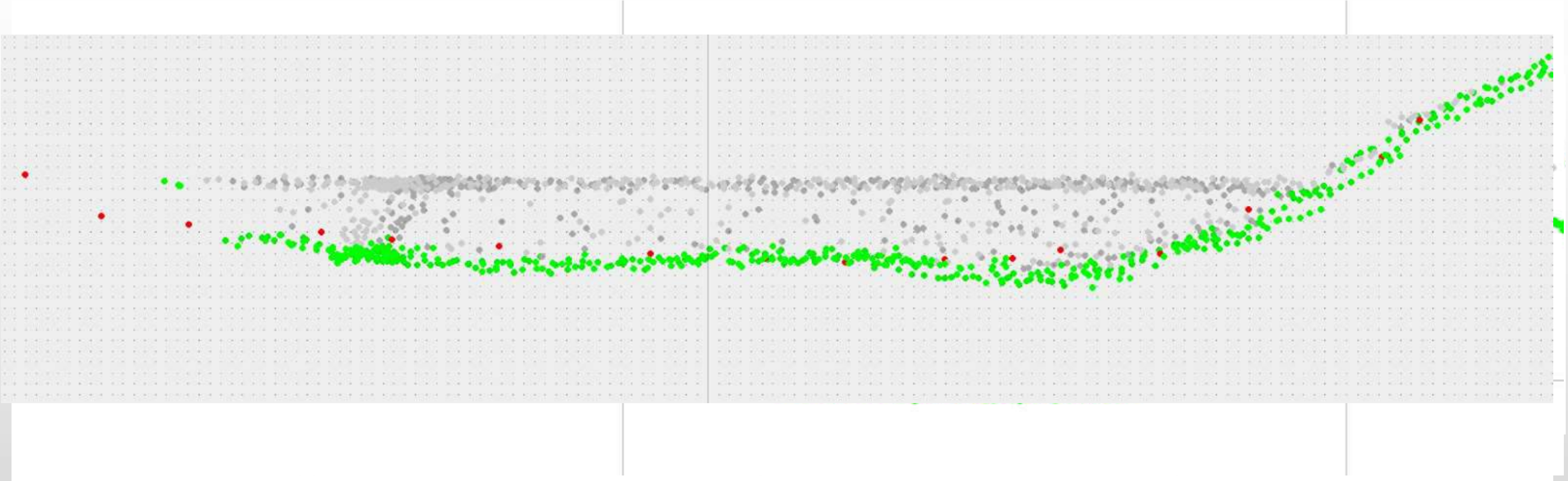
Gebied 6: Dinkel

- Beverborgsebrug
- Groenestaart boven
- Groenestaart onder
- Lutterzandweg



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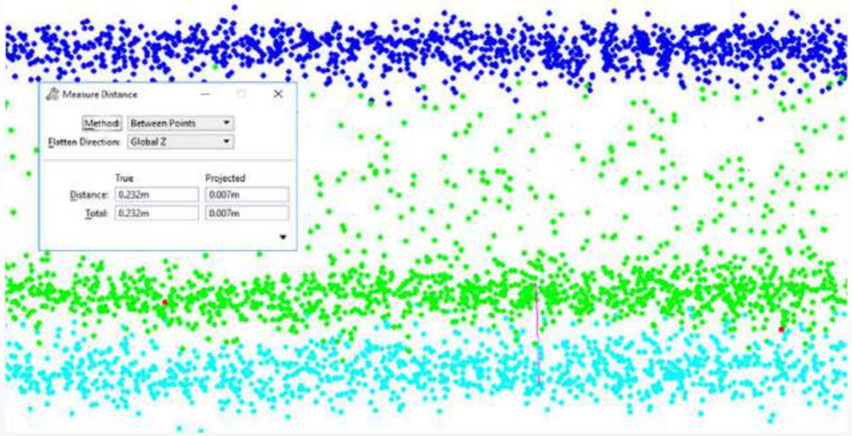
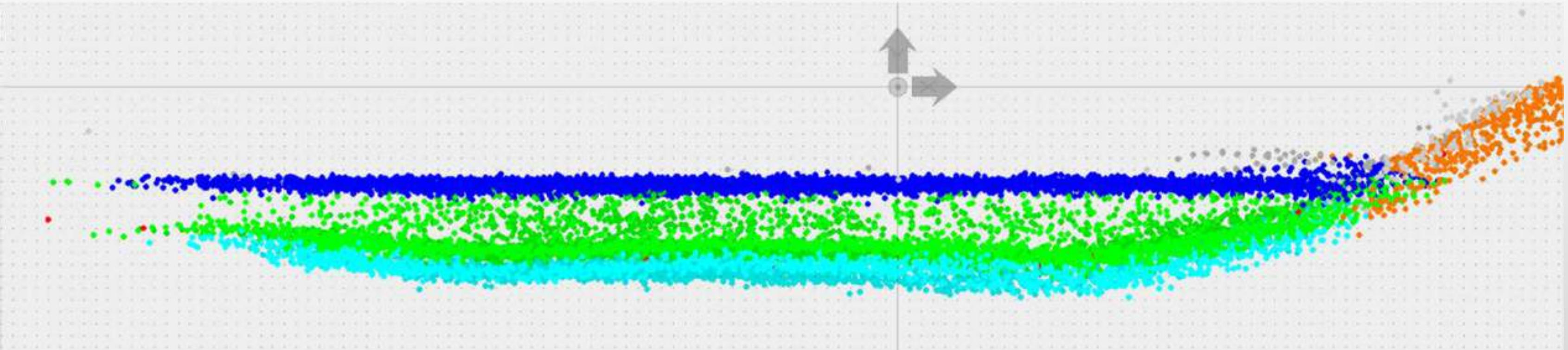
Gebied 6: Dinkel





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Vergelijking AHN-pilots en bathymetrische pilot

- 3 systemen met een groene LiDAR (532nm)
- SPL
  - Vlieghoogte: Westerschelde 3750m, Rotterdam 4270m
  - Datum: Westerschelde 6 juni, Brabant & Rotterdam 28, 29 juni 2018
- Riegl 1560i-DW (NIR en groen)
  - Vlieghoogte: Westerschelde 1240m en speciaal voor bathymetrie 560m, Rotterdam 670m
  - Datum: 20-22 februari 2018
- Riegl VQ880
  - Vlieghoogte: 400m
  - Datum: 16 april 2018

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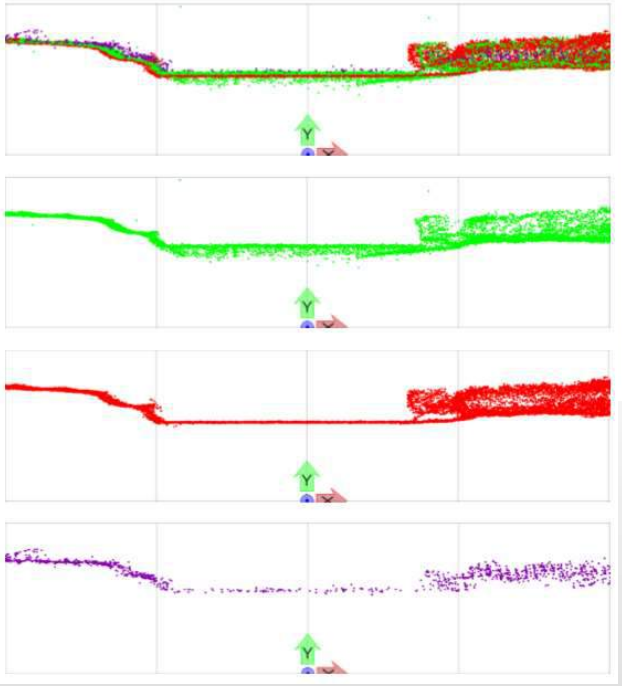
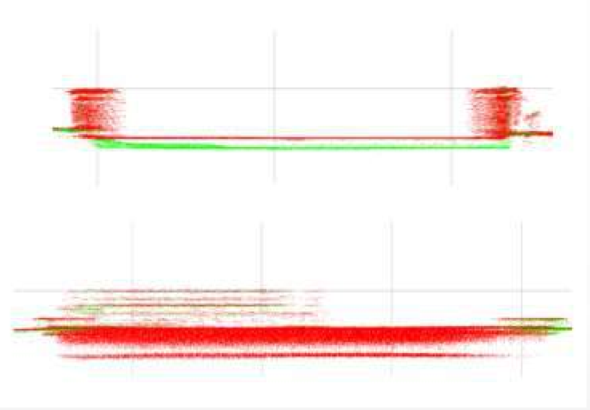
Vergelijking AHN-pilots en bathymetrische pilot





Riegl 1560i DW
Riegl VQ880
Single Photon LiDAR

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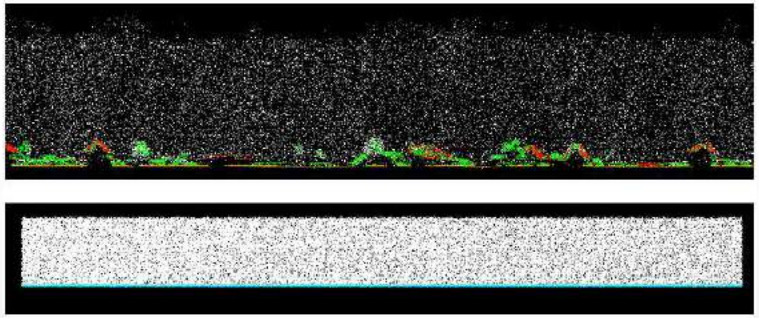
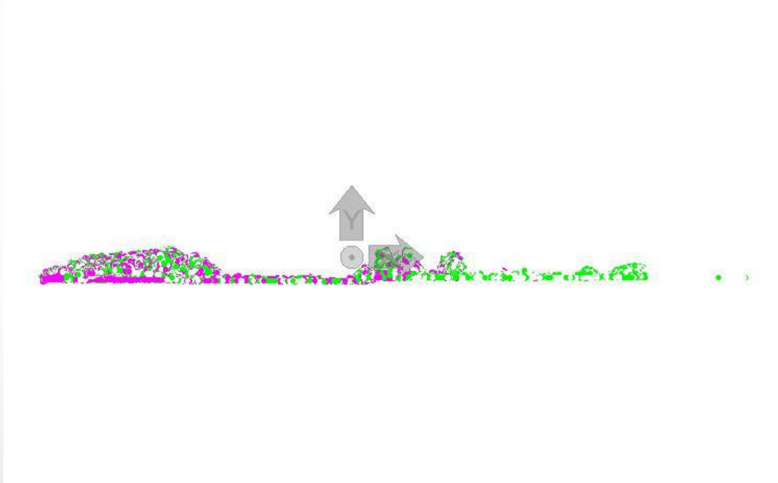
Vergelijking AHN-pilots en bathymetrische pilot



Figuur 13: Voorbeeld van dwarsdoorsneden van de data met in wit punten die als ruis geidentificeerd zijn. (Boven) stedelijk gebied, (Onder) water gebied.



- Ruis in een groene LiDAR (532nm) en NIR LiDAR (1064nm)

Conclusies Bathymetrische pilot vs AHN pilots

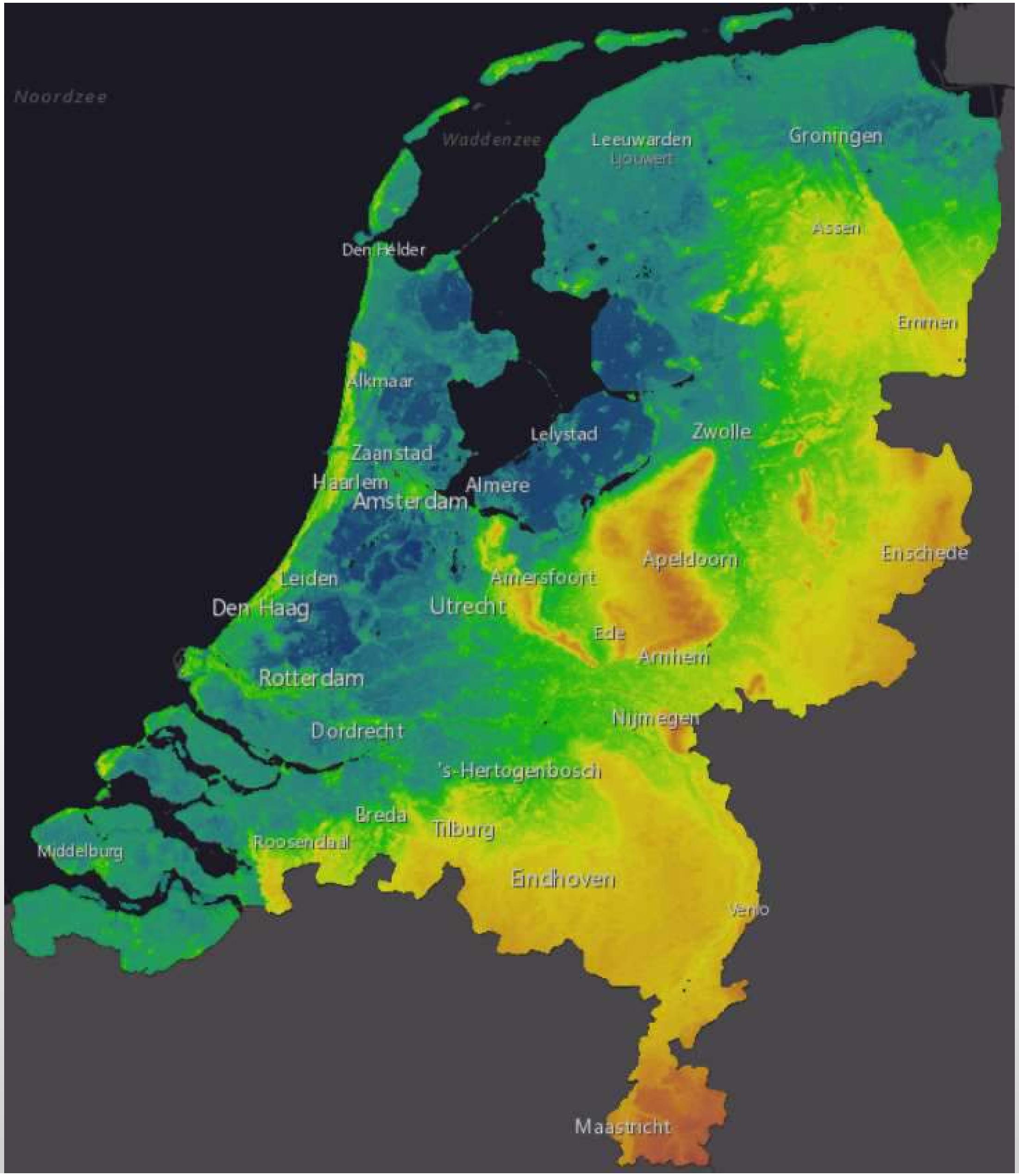
- Voor succesvolle bathymetrische data is een lage vlieghoogte vereist
- De SPL kan waarschijnlijk geen goede data inwinnen op die lage vlieghoogte vanwege het conische scanpatroon
- Groene LiDAR geeft veel meer ruis dan NIR LiDAR
- Voor een grote zekerheid over het meten van de bodem is een extreme puntdichtheid vereist (dus veel overlappende vliegstroken)
- De Riegl VQ 880 geeft door de bank genomen betere resultaten dan de Riegl 1560i-DW, enkele locaties uitgezonderd (verschil in vliegperiode)
- Combinatie van een bathymetrische metingen en het AHN programma lijkt nu nog niet mogelijk

Concluding remarks – Riegl VQ 880 G

- Better results than ever seen before in the Netherlands
- Many waterways with a depth until 1,5-2m can be measured, but also many locations without results
- A very high point density (>100 pts/m2) is required to be able to have certainty about bottom measurements
- Flight altitude with green LiDAR needs to be relatively low compared to SPL100 and Riegl 1560i DW
- Riegl VQ 880 G is interesting but not suitable for AHN
  - Fits for local projects, although it's not really clear why it fails to give results on certain locations. Further research required.

AHN4-en daarna?

- **Track 1: Data**
  - Snellere inwinning: 3 jaar
  - Snellere leveringen: 5-6 maanden na inwinning
  - Meer geautomatiseerde classificatie
- **Track 2: Ontwikkeling**
  - Stimuleren van automatische classificatie
  - Verbeteren van de infrastructuur voor data-analyses en downloads
  - Breder draagvlak creëren voor nog hogere update frequentie
  - Onderzoeken van een "Living Elevation Model"



LiDAR sensor carriers

Actueel Hoogtebestand Nederland

Bedankt voor de aandacht

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