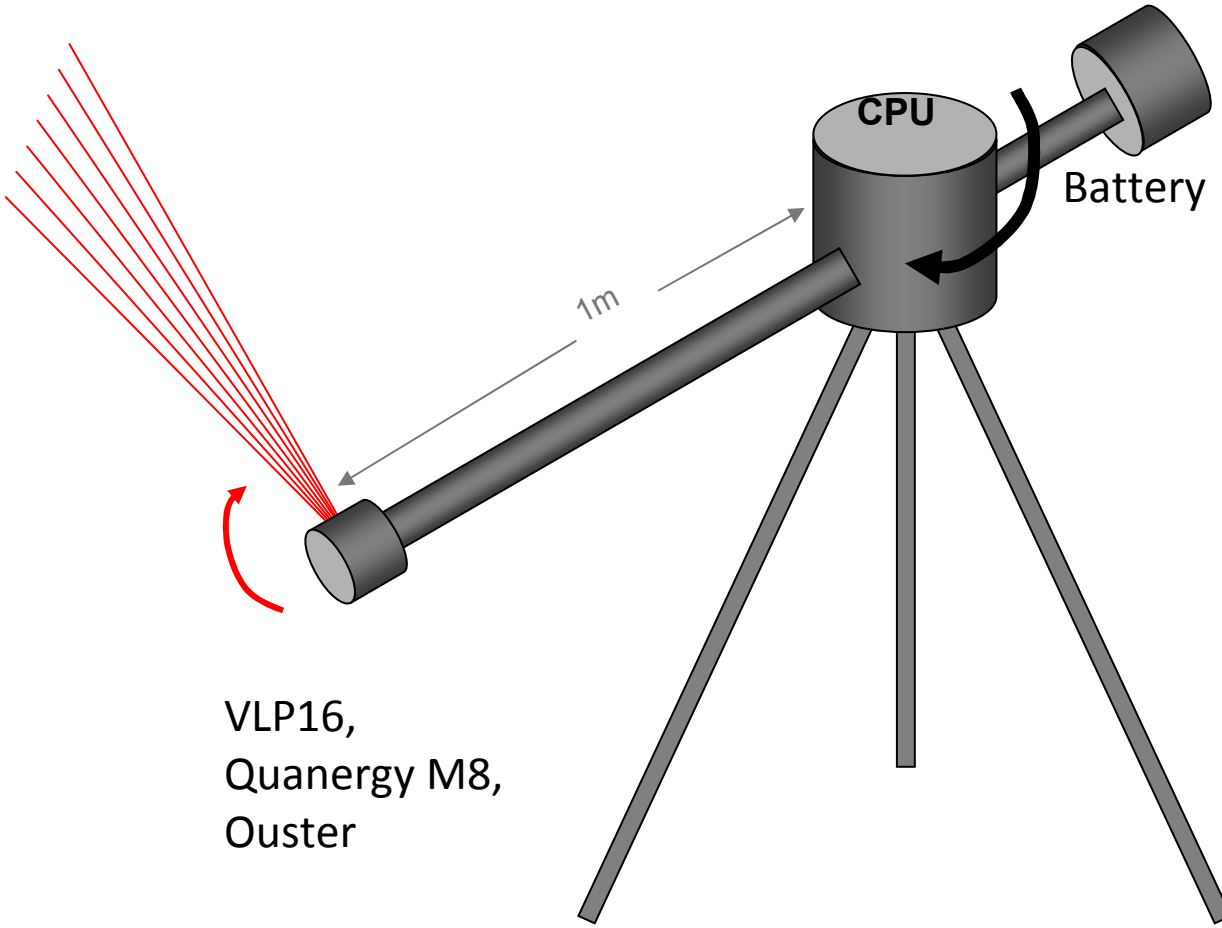
How to avoid occlusion in single station TLS measurements



VLP16,
Quanergy M8,
Ouster

Günther Bronner
Umweltdata AUSTRIA

Martin Wieser

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Günther Bronner g.bronner@umweltdata.at

Professional background and experiences

- **Austrian State Forest Agency, 1983-2000**
  ForestManagementPlanning, Inventory, GIS and Remote Sensing
- **Head of Umweltdata ltd. Since 2001**
  Forest Sustainability :Monitoring :Mapping :Modeling :Management
- **>100 Forest Inventory projects, >70,000 sample plots**
- **>200 Forest Management Planning projects >1000ha**
- **Operational usage of ALS data since 2006**
- **Rapid forest inventories for land acquisition decisions**
- **Monitoring of wildlife influences and damages**
- **Growth models and monitoring on plantations (Brazil)**
- **Permanent Optimization of FI and FMP based on RS**
- **Several R&D projects, Drones in Forest Inventory**
- **Silvilaser 2010, 2012, 2013, 2017; ForestSAT 2016, 2018**

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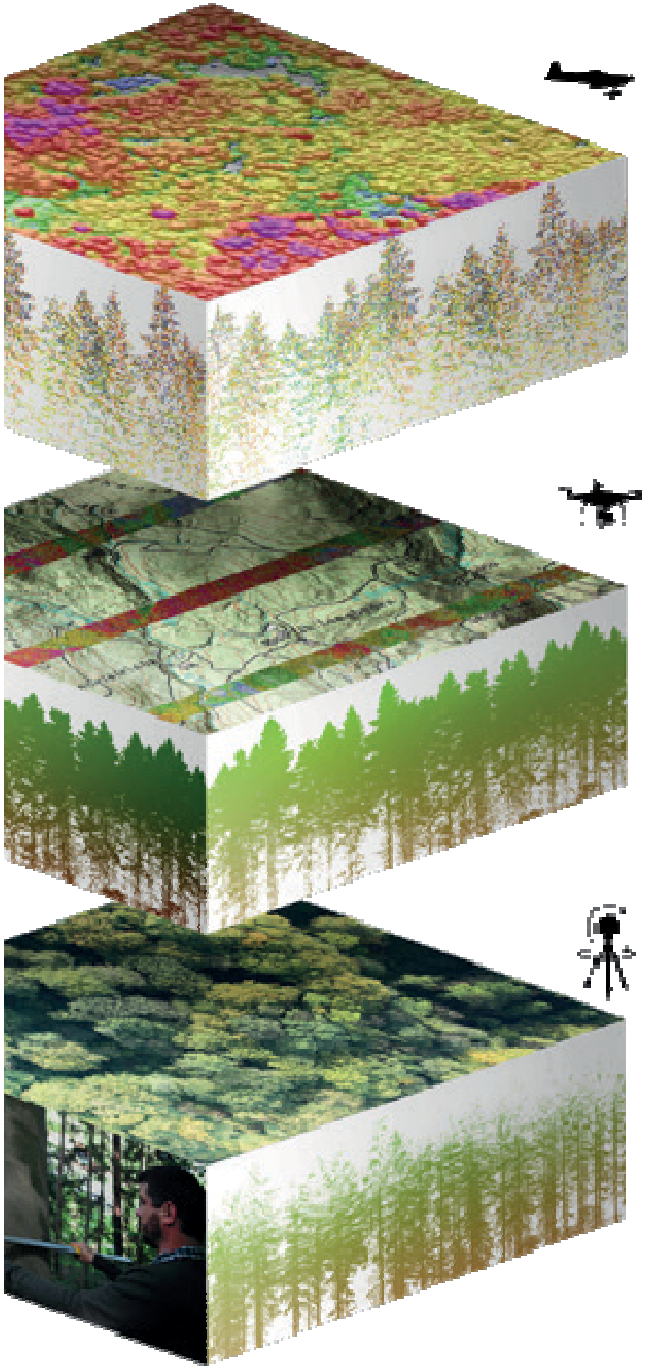
Cooperation Partners (Austria)

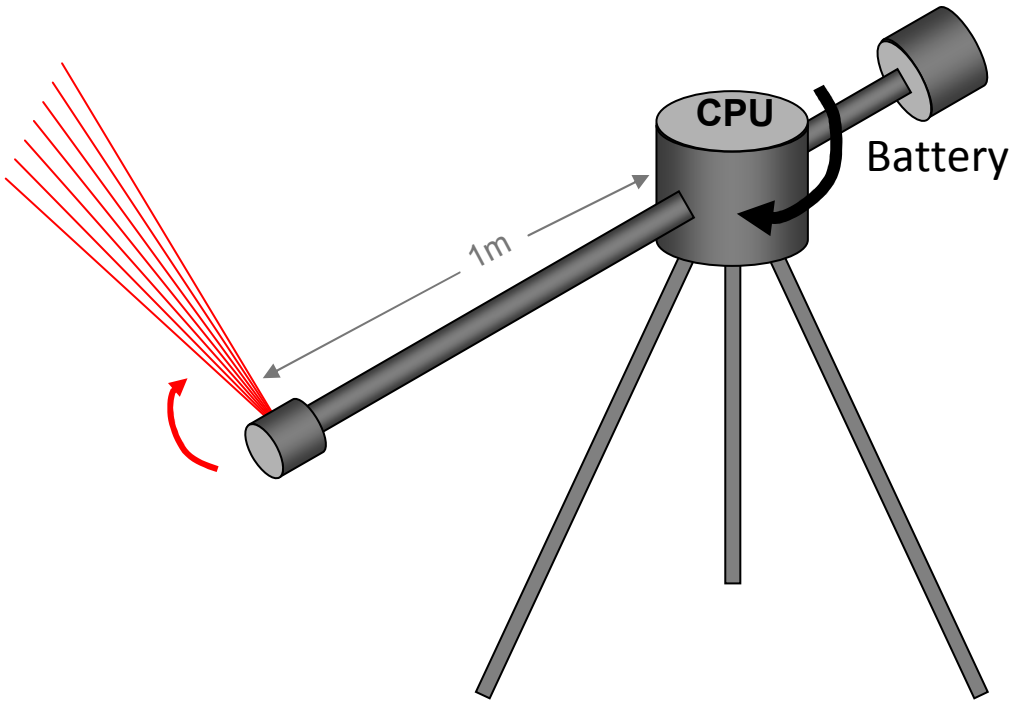
- Umweltdata Ltd. (FI, RS, mapping, FMP)
  Günther Bronner, Boris Jawecki, Martin Keuschnigg
- Joanneum Research (Remote Sensing)
  Mathias Schardt, Manuela Hirschmugl
- TU Vienna, department GEO (photogrammetry)
  Norbert Pfeifer, Markus Hollaus, Martin Wieser
- E.C.O. (Monitoring of Biodiversity, Management of Protection areas) Hanns Kirchmeir, Michael Jungmeier
- Aeromap (Aviation and Aerial Remote Sensing)
  Roland Wack, Thomas Meißl



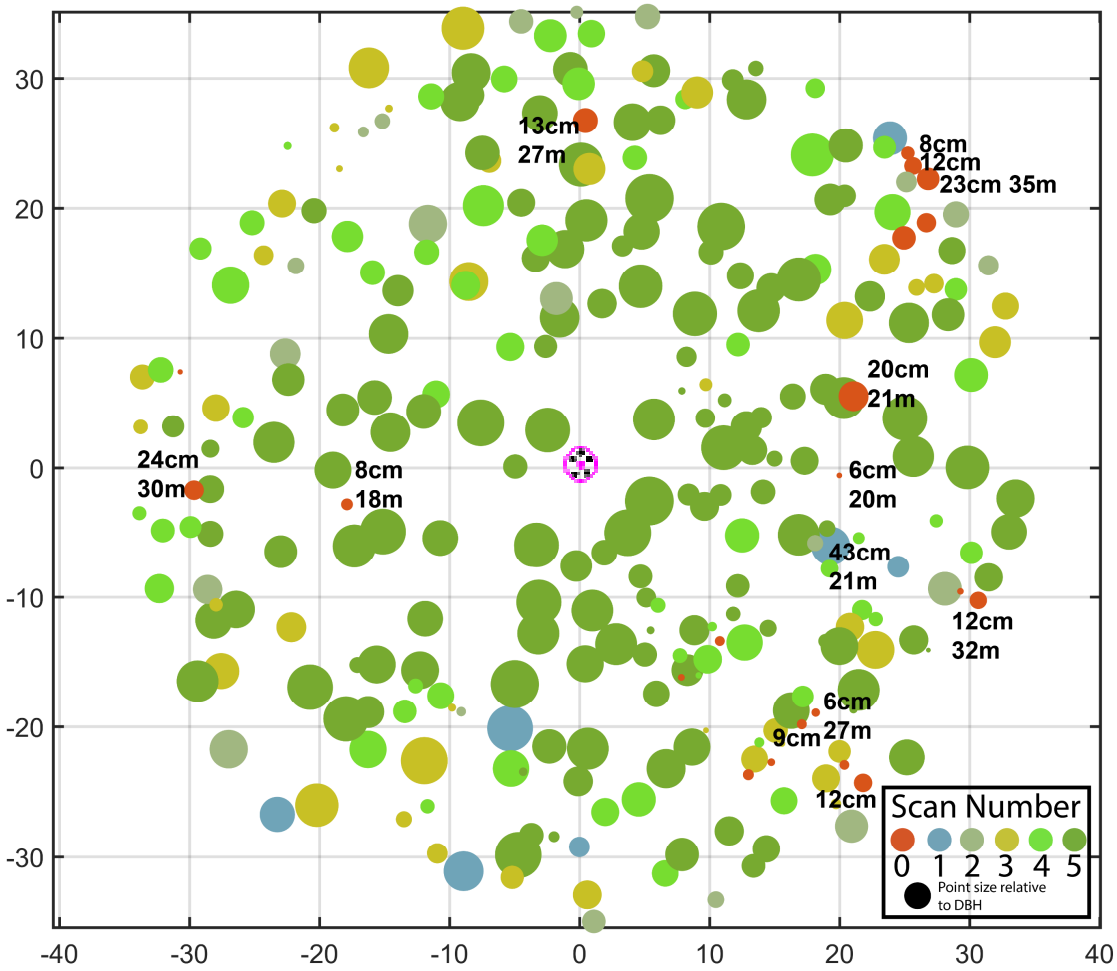
- **Phase I**
  ALS wall-to-wall coverage
- **Phase II**
  VHR ALS stripes in low altitude with ultra-light plane
- **Phase III**
  TLS and / or Fieldwork

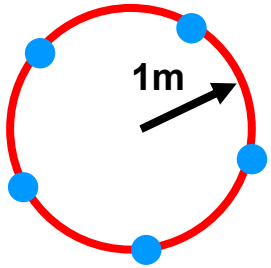
Technical concept:

- Scan-senor mounted on a Rotating arm with 70-100cm
- can avoid >95% of occlusion
- Slow horizontal rotation (1 rot / 10 – 60 minutes)
- Fast vertical rotation 10-60 rot / second
- High angular resolution (horizontal) => accurate DBH
- Combined TLS and photogrammetric approach
- Usage of automotive scanners low-cost, light-weight (VLP16, Quanergy M8, Ouster)
- Usage of Solid State LIDAR



jib-scan-simulation i)

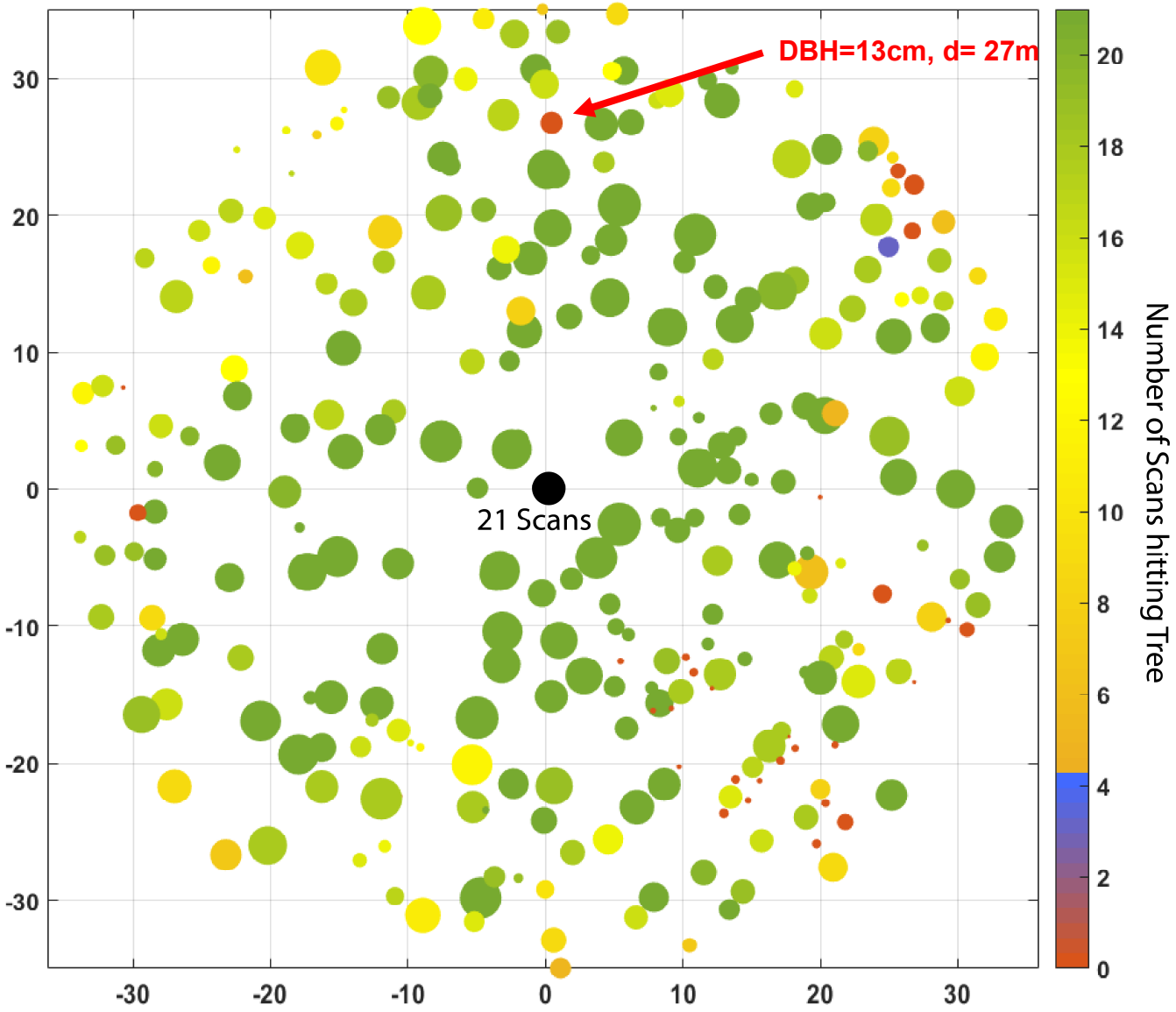


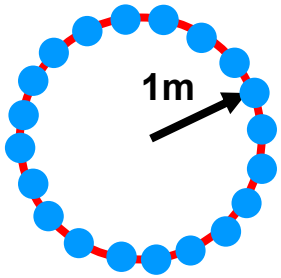


The color indicates, from how many scan positions (one to five) the tree was detected.

With **Bitterlich angle count** basal area factor 1 less than 0.5% of basal area is not detected on stands with basal area ~45m²/ha

Actual Example: 53m²/ha, unevenaged





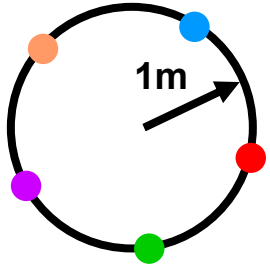
Jib-scan simulation from 21 scan positions on a circle with r=1m

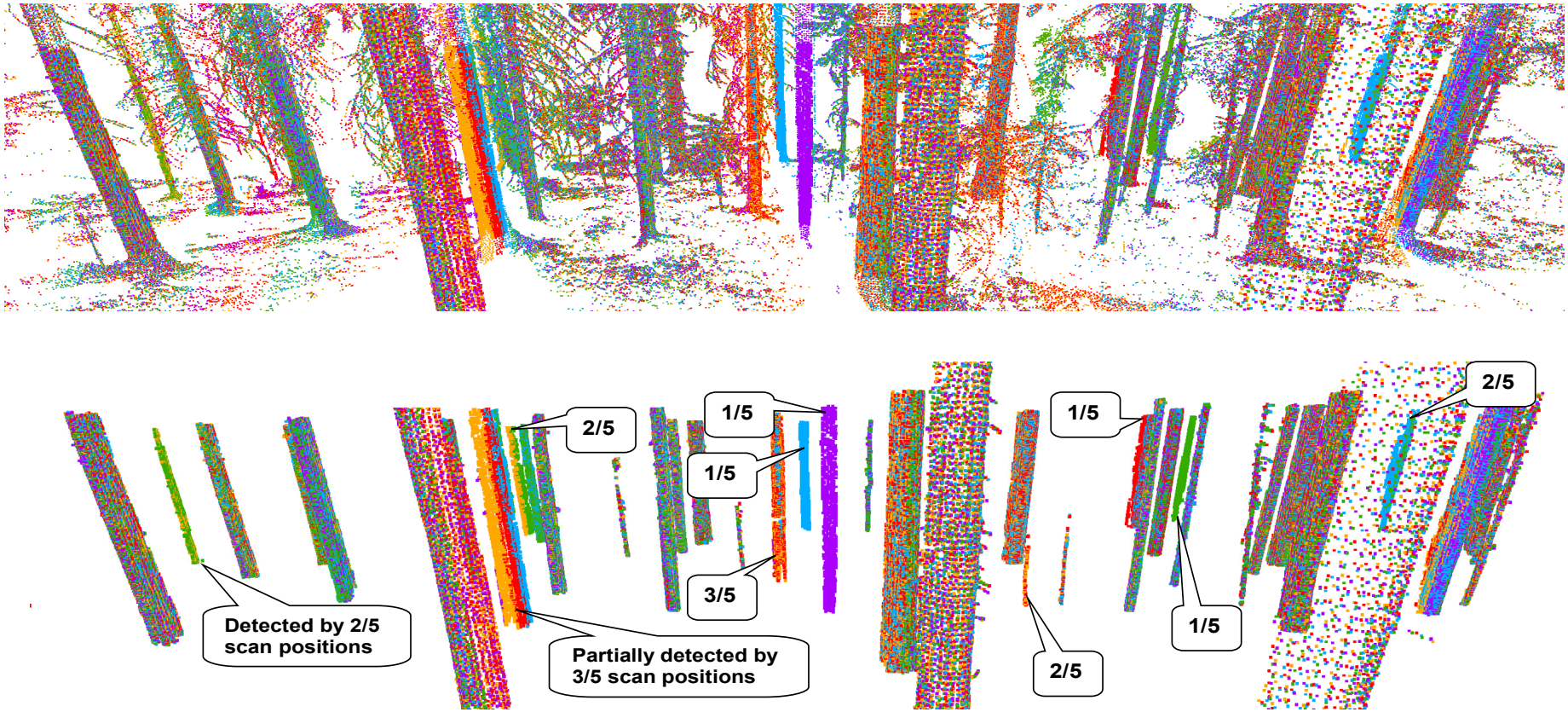
Red trees are not detected, green trees are visible from all positions.

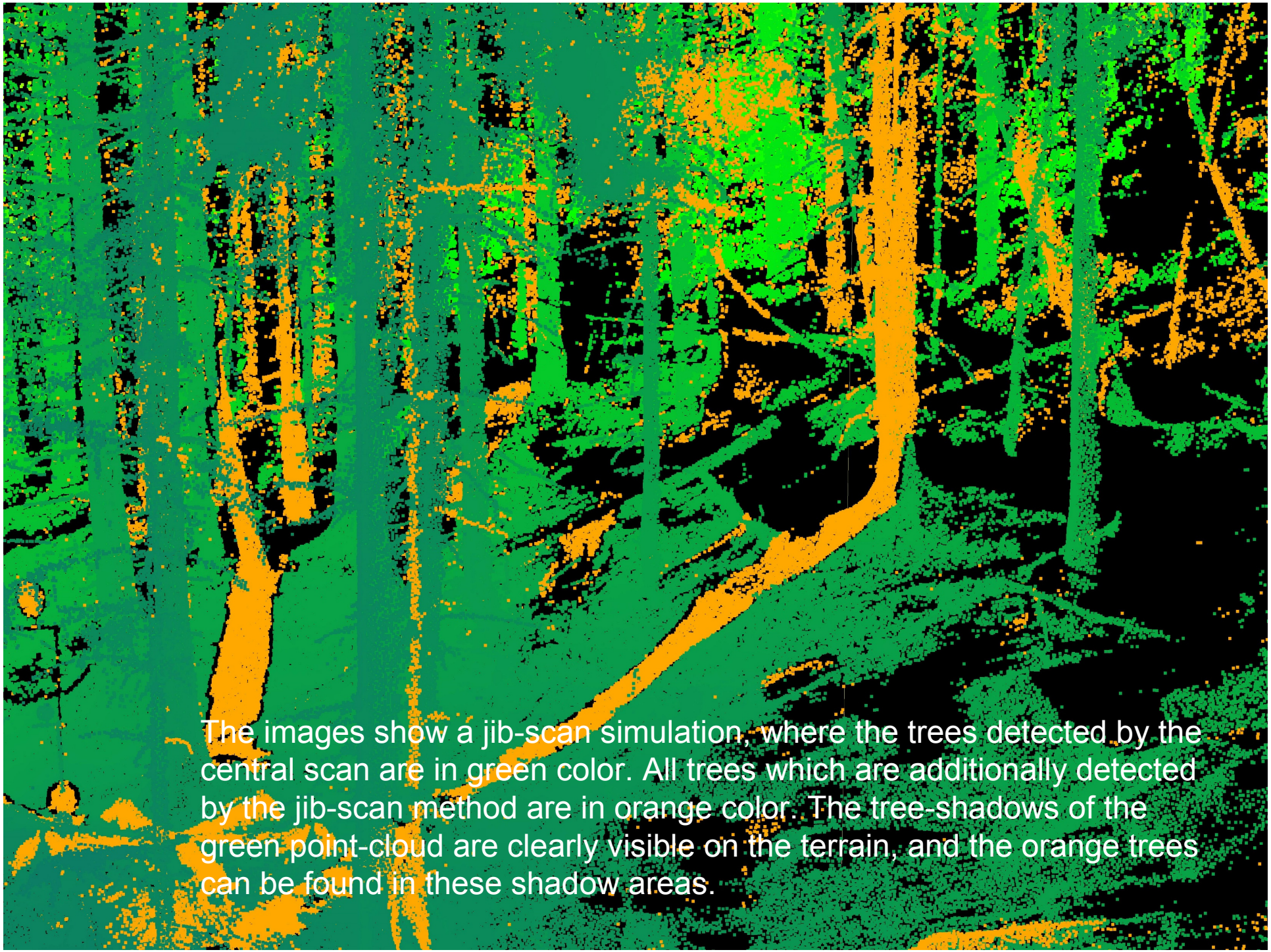
DBH Cylinder-Fitting => Edge Detection ?
Renaissance of Bitterlich Method?

jib-scan-simulation ii)

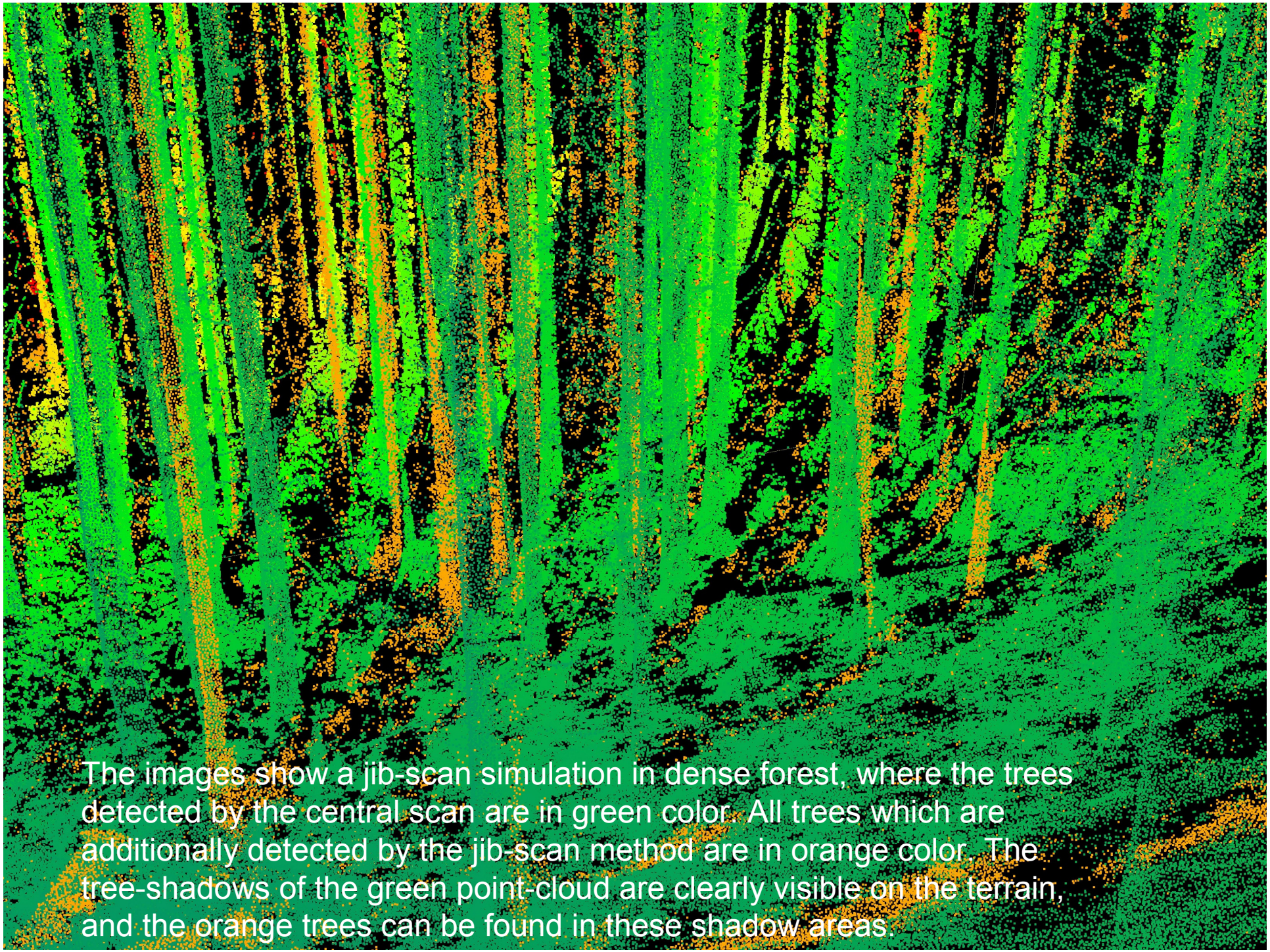
Color indicates visibility by one of five scan positions





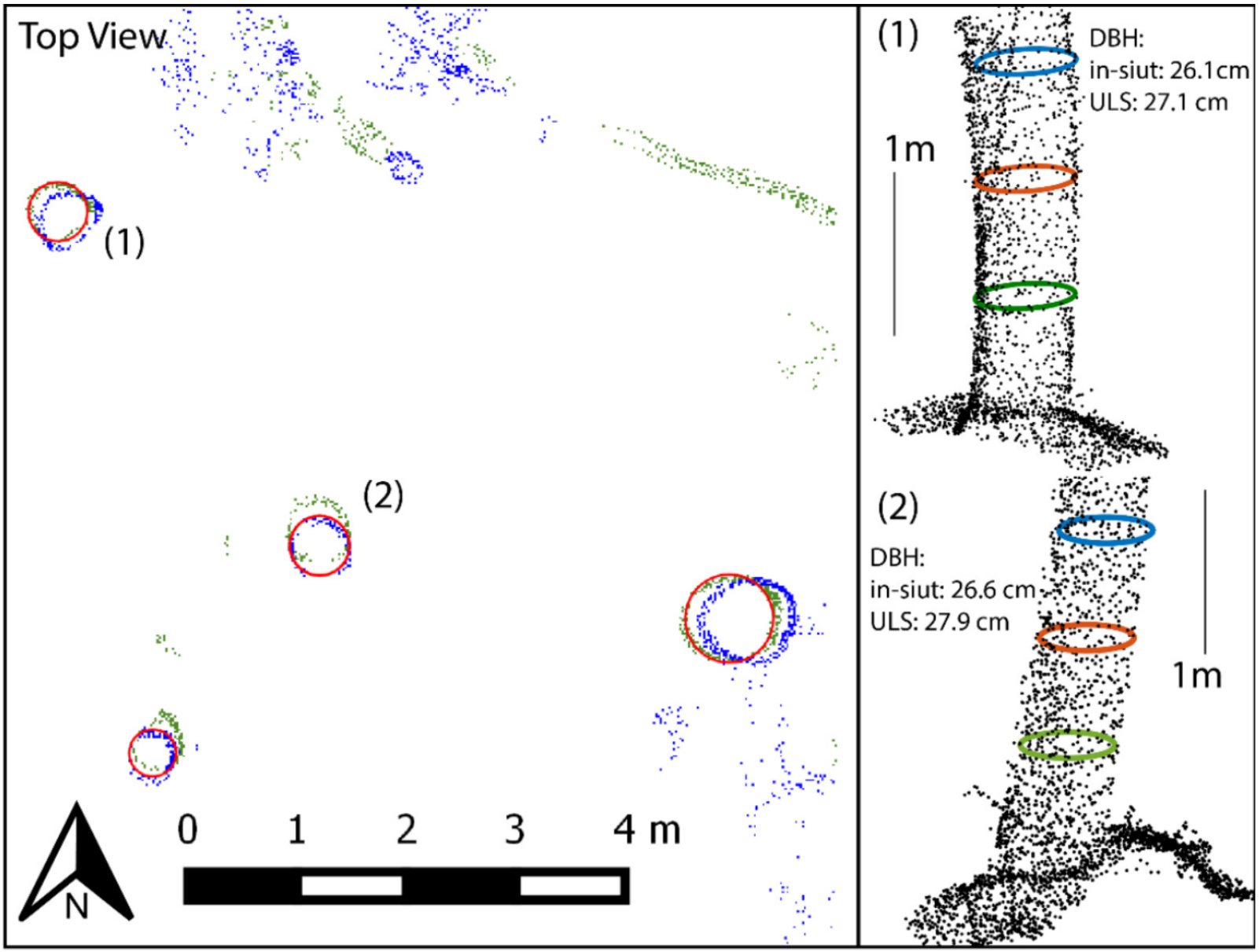


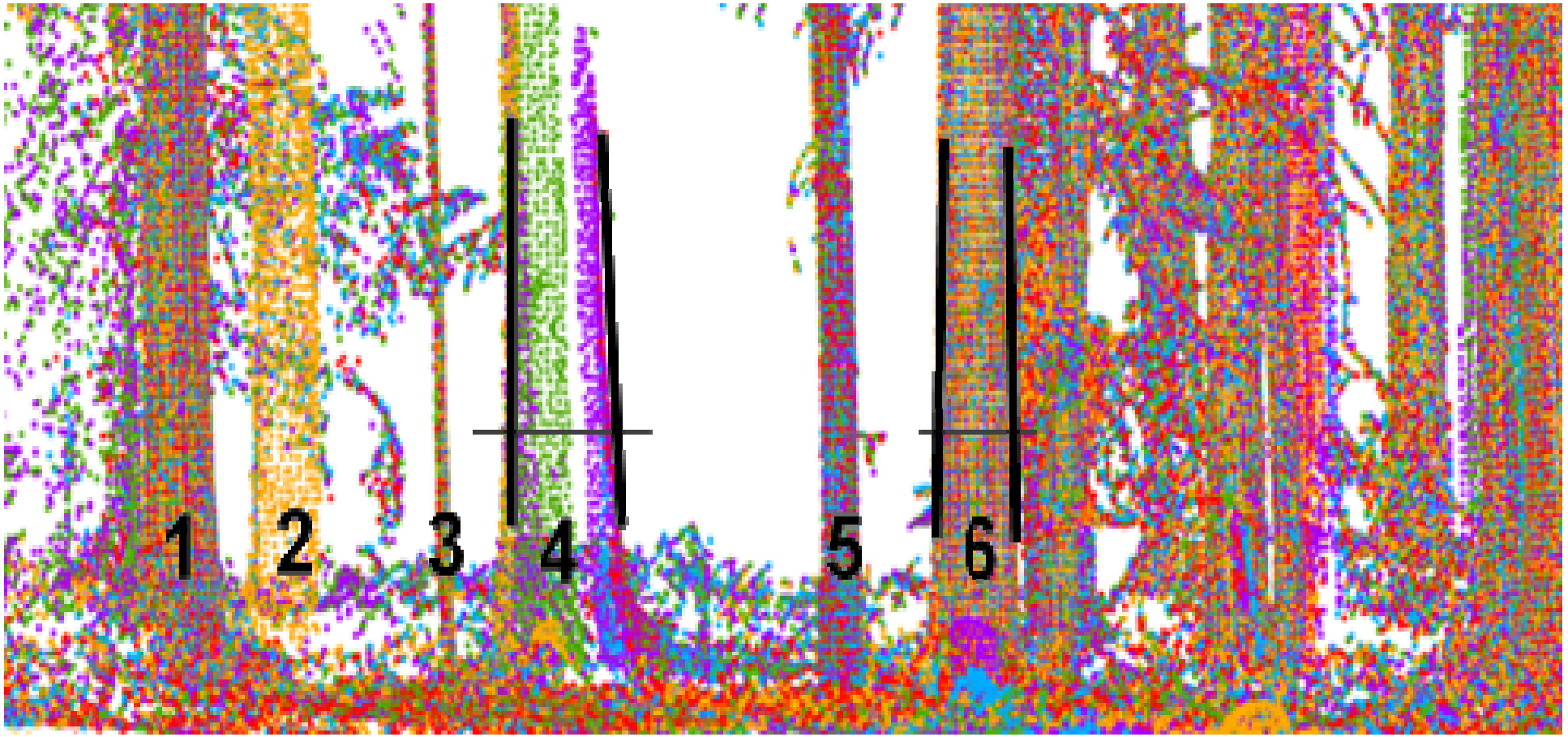
The images show a jib-scan simulation, where the trees detected by the central scan are in green color. All trees which are additionally detected by the jib-scan method are in orange color. The tree-shadows of the green point-cloud are clearly visible on the terrain, and the orange trees can be found in these shadow areas.



The images show a jib-scan simulation in dense forest, where the trees detected by the central scan are in green color. All trees which are additionally detected by the jib-scan method are in orange color. The tree-shadows of the green point-cloud are clearly visible on the terrain, and the orange trees can be found in these shadow areas.

DBH Cylinder-Fitting => Edge Detection ?

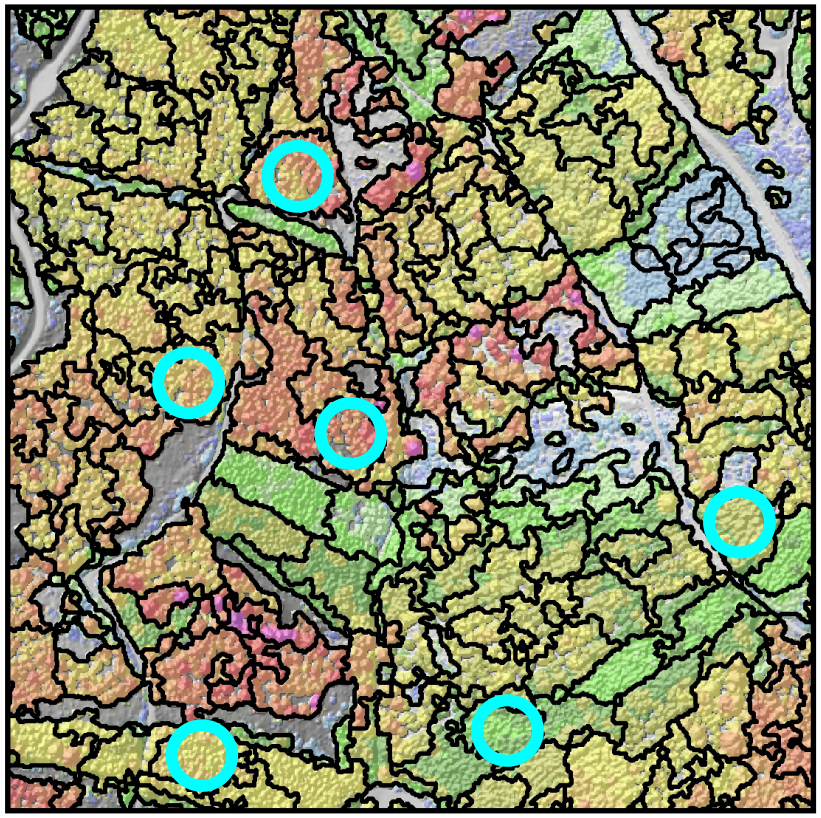




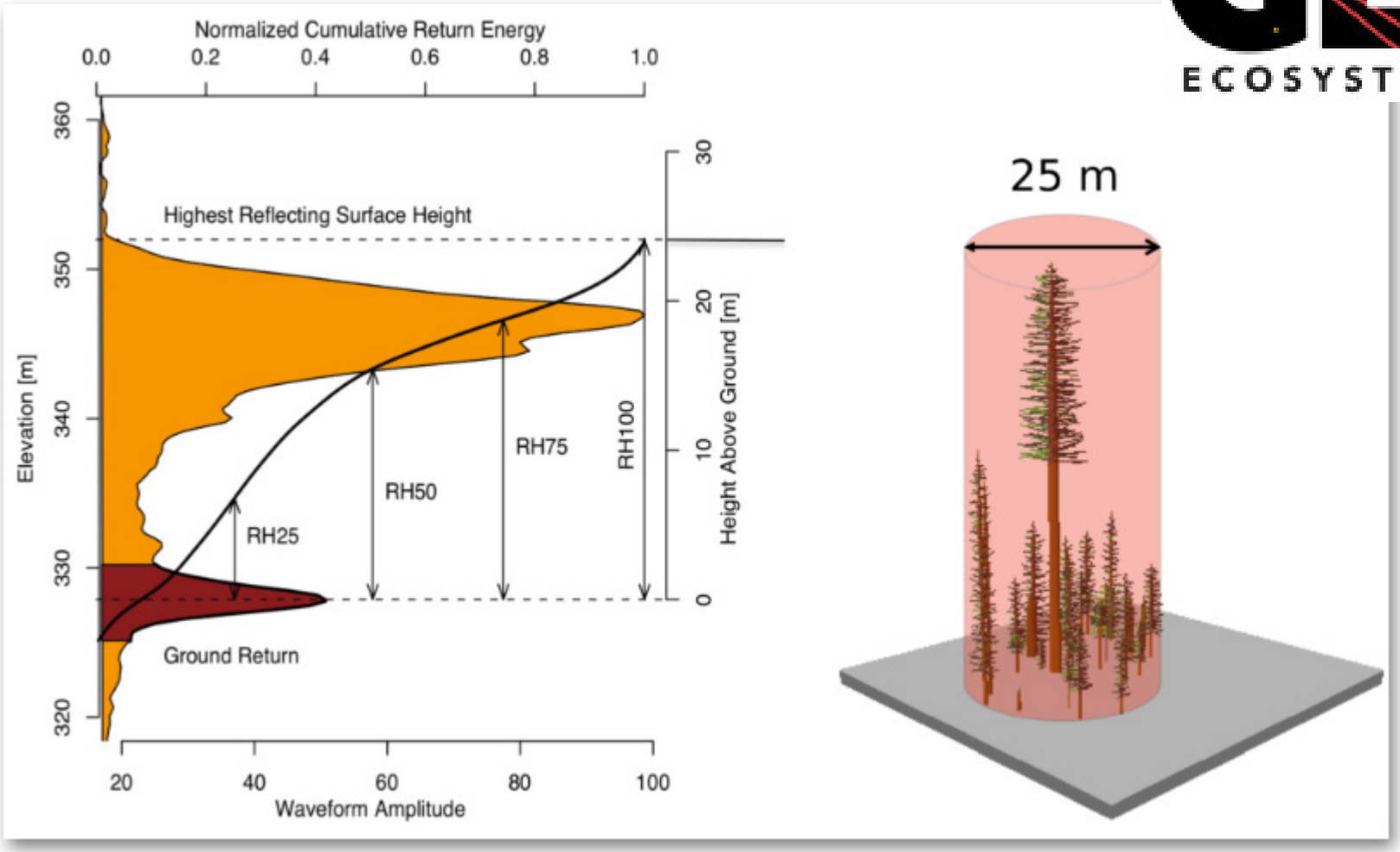
Diameter extraction and the derivation of taper functions by edge detection would most likely be more stable than diameter extraction from cylinder-fitting or cone-fitting. It is less sensible regarding noise from i) sensor, ii) bark, iii) small branches, iv) point cloud fusion.
Using a permanent sample plot design with marked sample plot center points, the increments can be derived from identical geometric setup of measurement time series.

Design of sample plots on ALS-segments

- Temporary design
- Stratification of segments by LIDAR-metrics
- Reduction of fielwork effort by 75% with given accuracy expectation
- Wall-to-wall interpolation of inventory results

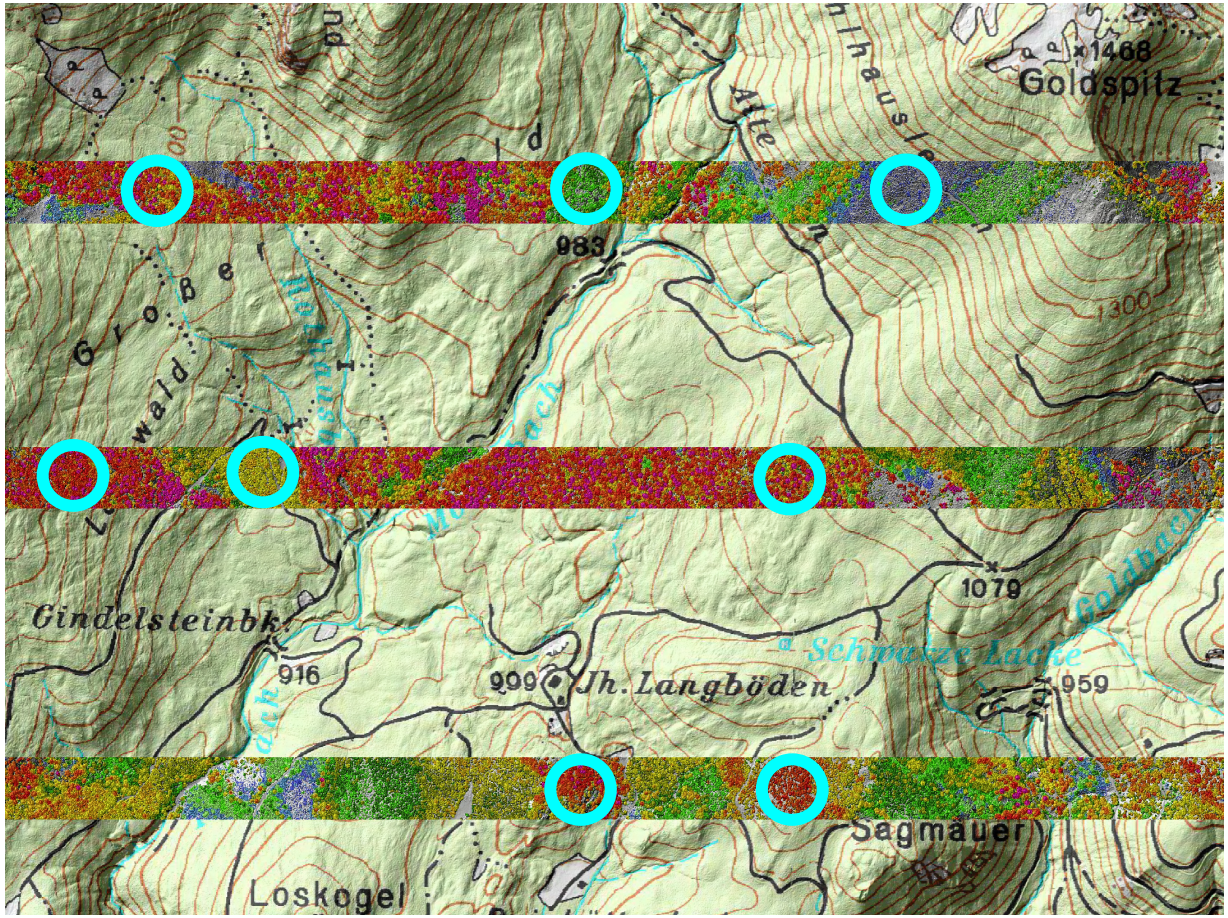


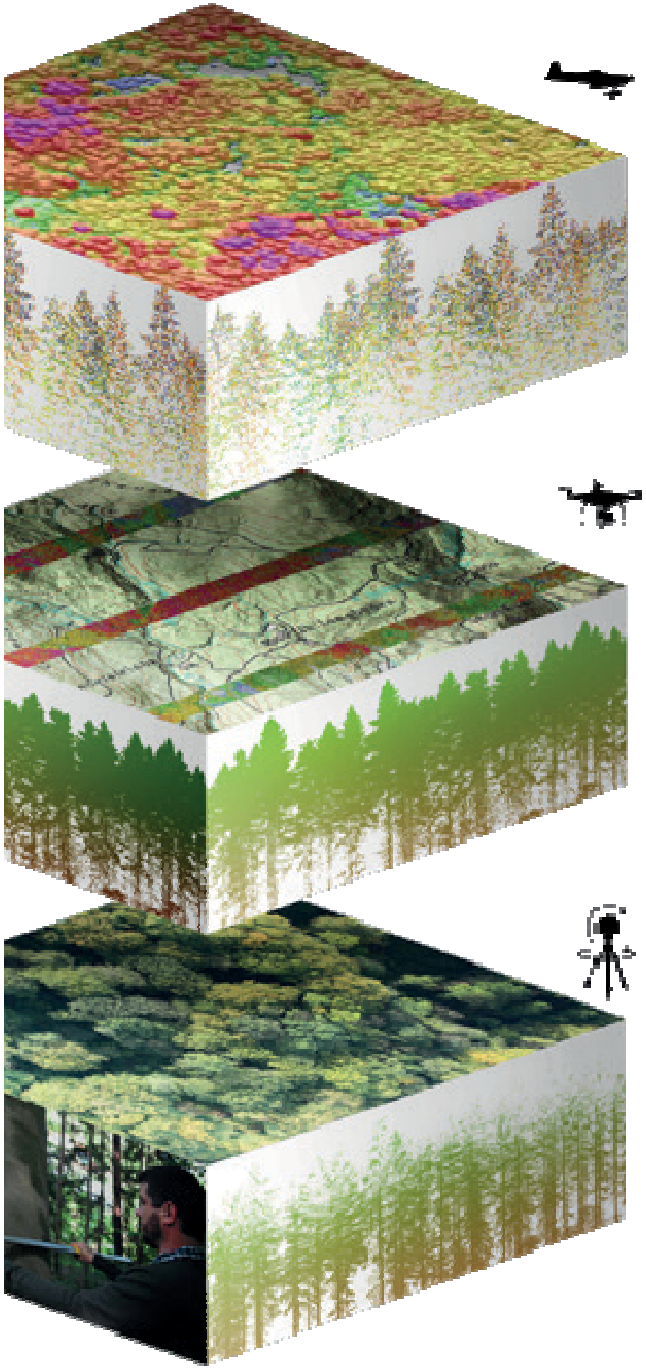
Alternatively:
Temporary sample plots on GEDI footprints



Inventory design on VHR ALS stripes is fully compatible with NFI

Stripes with very high resolution (VHR) ALS data (>100 echos/m²) allow single tree modelling, recognition of vertical structure, dead-wood detection, identification of natural regeneration and the application of advanced tree growth modelling.





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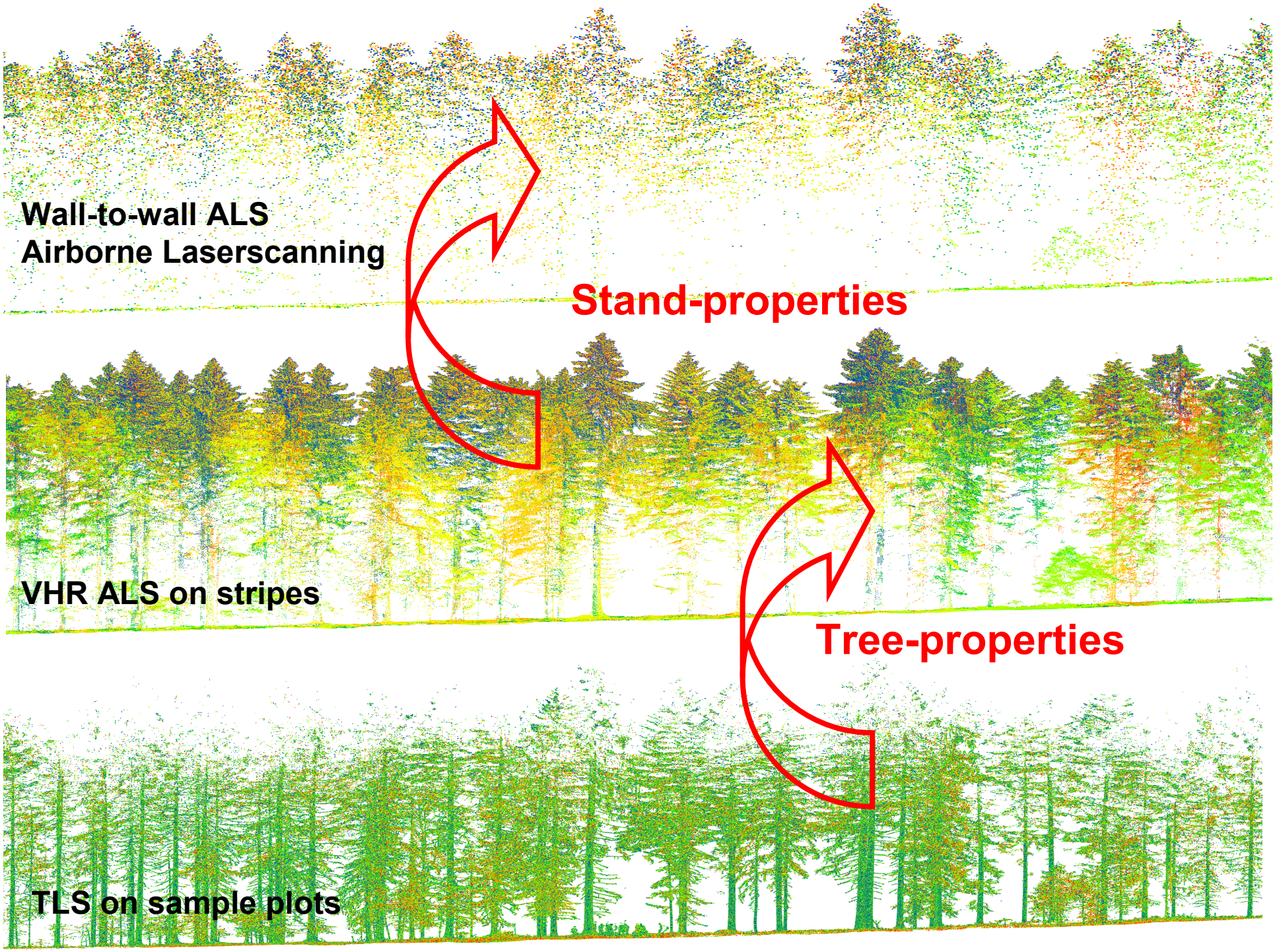
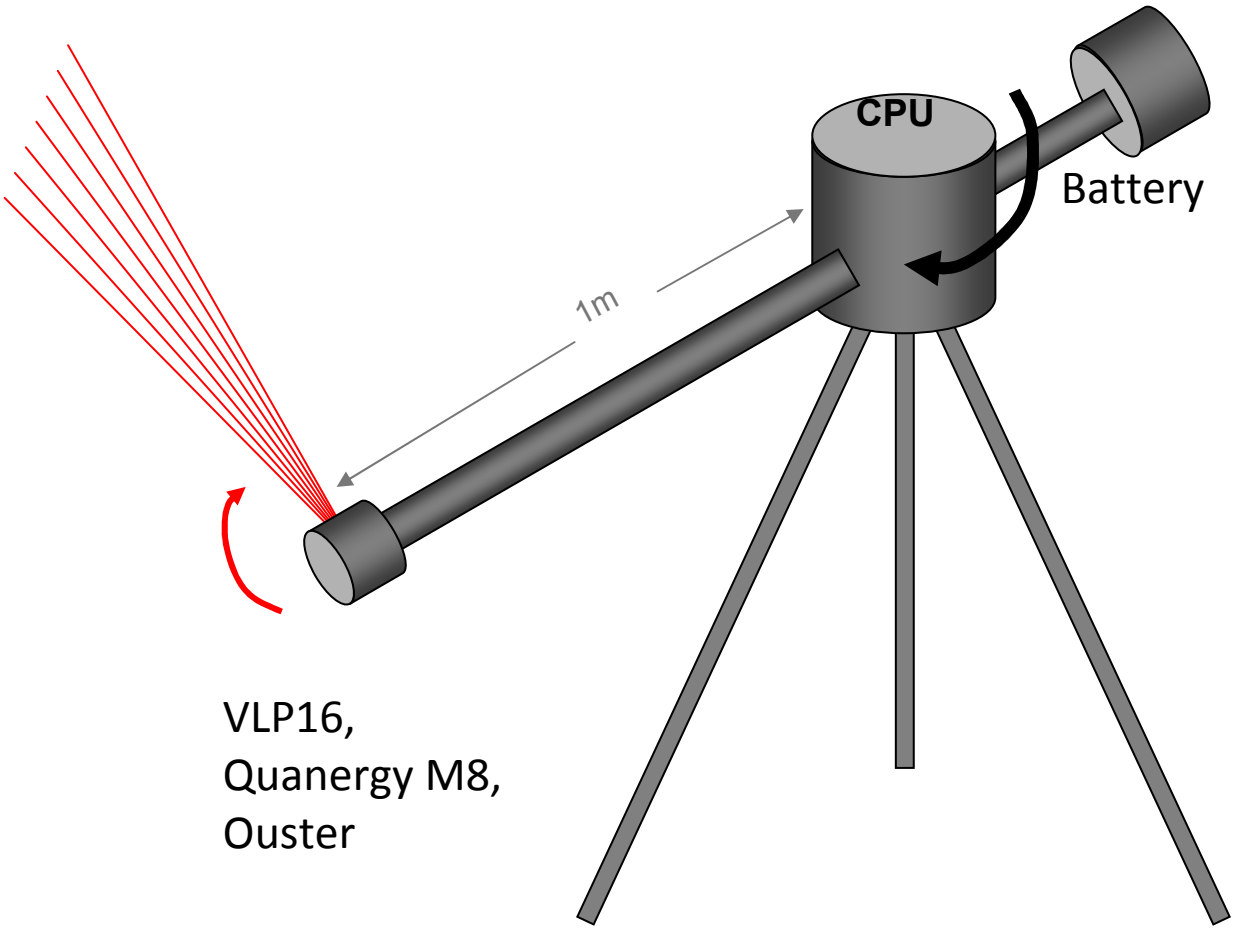

Wall-to-wall ALS
Airborne Laserscanning
Stand-properties
VHR ALS on stripes
Tree-properties
TLS on sample plots

Technical Challenges



Technical Challenges

- Slow & Undisturbed Rotation of Arm (IMU)
- GNNS-Integration for ALS/TLS Matching
- Tablett Integration for Fieldwork Optimization
- Local Navigation with high Accuracy
- Tree Identification during Fieldwork
- Offline Voice Recognition for Tree Properties
- Diameter Extraction from Depth-Panorama by Edge Detection rather than Cylinder-Fitting?

Desired Inventory Workflow

- Quick-scan for tree detection (~1 min)
- Delivery of tree-map to tablet device
- Precision scan while visual fieldwork assessment is done (scan resolution depending on expected amount of fieldwork)
- Indication of actually scanned area on tree-map to avoid scan-disturbance
- Voice recognition for data entry

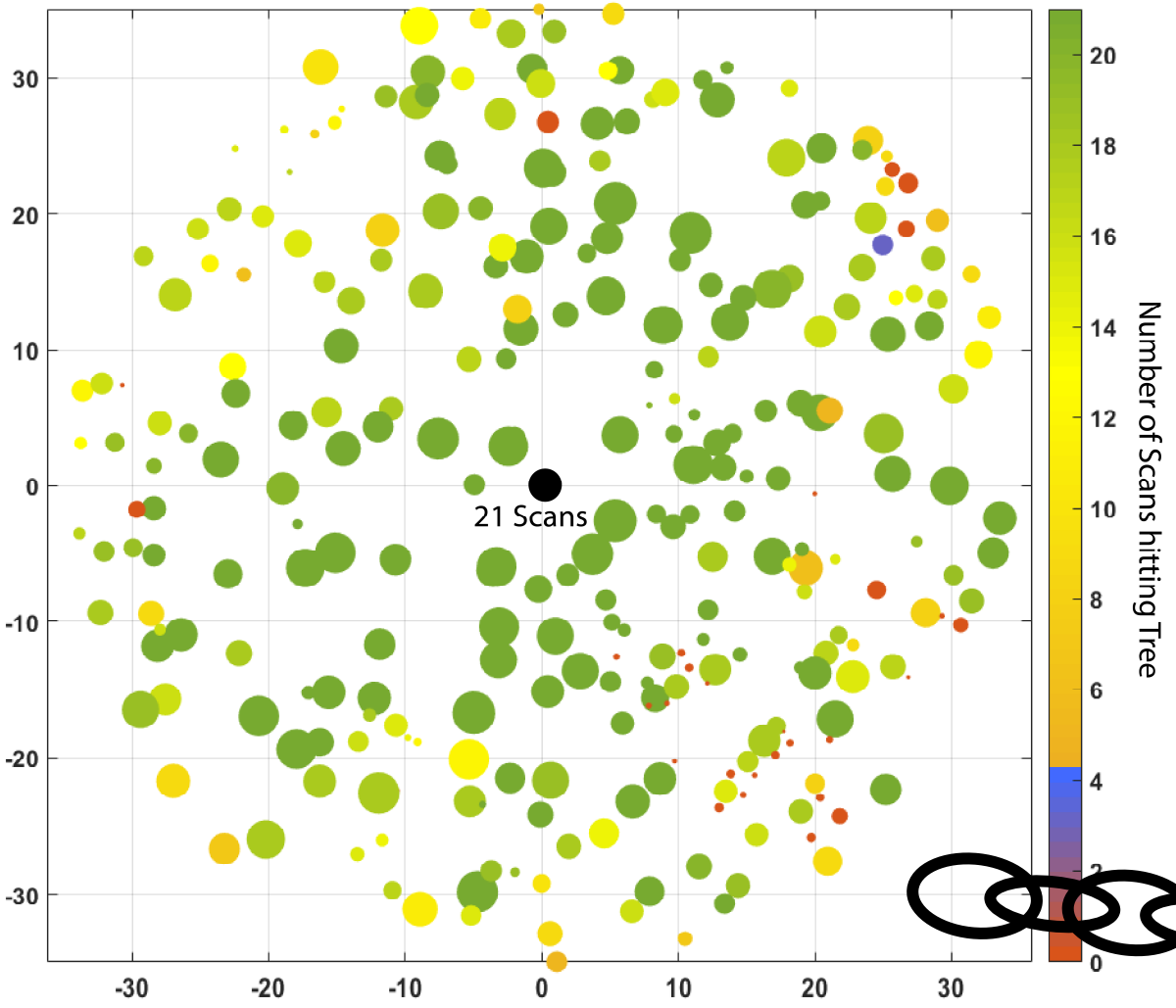
Limitations

- Very thick trees (with diameter >1.5m)
  reduce avoidance of occlusion

- Very dense understory
  would not allow rotation of a protruding arm

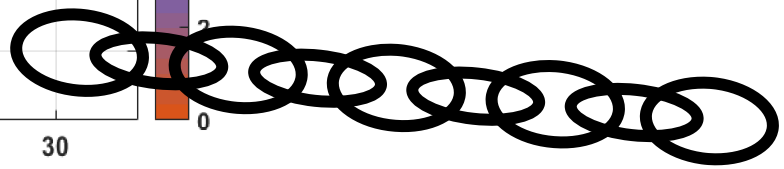
Next Steps

- Prototype under construction
  - rotation arm accomplished
  - sensor integration in process
- Test measurements from Q2/20
- Datasets for download available Q4/20
- Small serial production available in 2021



One single scan delivers
- 50-200 trees
- with accurate position
- DBH, height
- taper function
- QSM+biomass
- tree species from QSM
- dead wood
- regeneration
- micro+meso relief

can be correlated to ALS, GEDI, satellite images



Could such certified snapshots serve as a global standard for REDD+ issues?
- no more NFI compatibility discussion
- can be reprocessed with new methods in the future for monitoring purposes

could be easily certified by block-chain tokens or watermarks.