CoE-LaSR and advanced Laser Scanning for forestry

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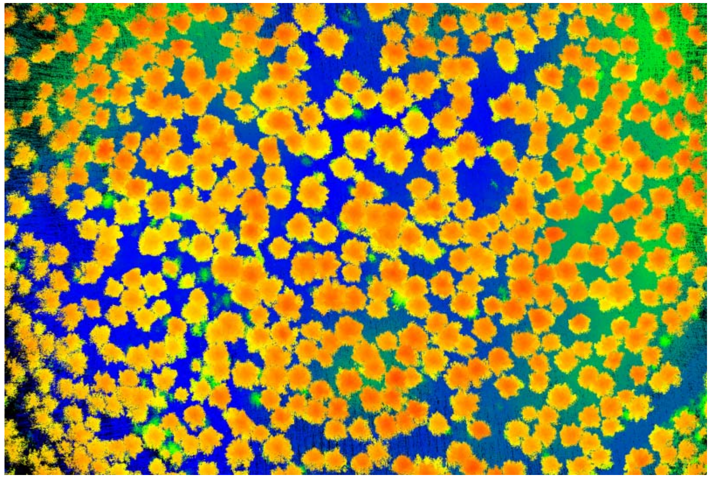
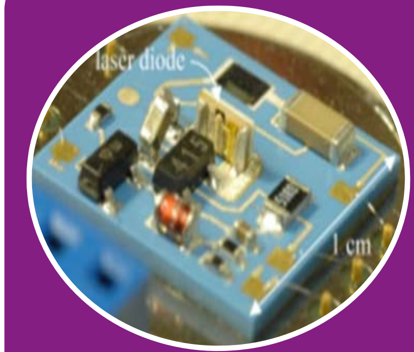
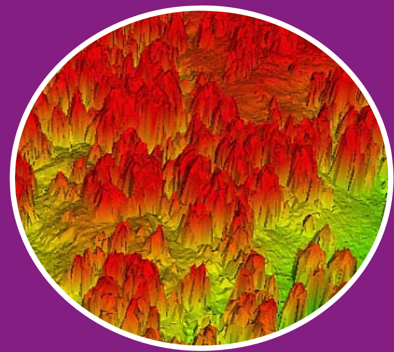


Centre of Excellence
in Laser Scanning Research:
“Together what is otherwise impossible”





Hardware-driven approach

Pulsed time-of-flight laser radar

Juha Kostamovaara
Univ. Oulu

Mobile and ubiquitous Laser Scanning

Juha Hyyppä
FGI

Laser scanning for precision forestry

Markus Holopainen
Univ. Helsinki

Laser scanning for built environment

Hannu Hyyppä
Aalto Univ.

International benchmarking studies

CoE-LaSR Vision

- "**Laser scanning is omnipresent and affecting positively the life of every citizen in modern information society by early 2020s**"
- In the next two decades, new MLS and PLS systems are making LS more ubiquitous in the same sense as the first personal computing was followed by ubiquitous computing. Even autonomous robots using point-cloud-generating perception sensors may be added to the ecosystem during this timeframe. **What can be said for certain is that during the 2020s and 2030s, there will be a great number of laser scanners omnipresent in everyday life. Mobile Laser Scanning is one of the main techniques to create local virtual reality**.
- **We are in the middle of disruptive technologies, multidisciplinary work**

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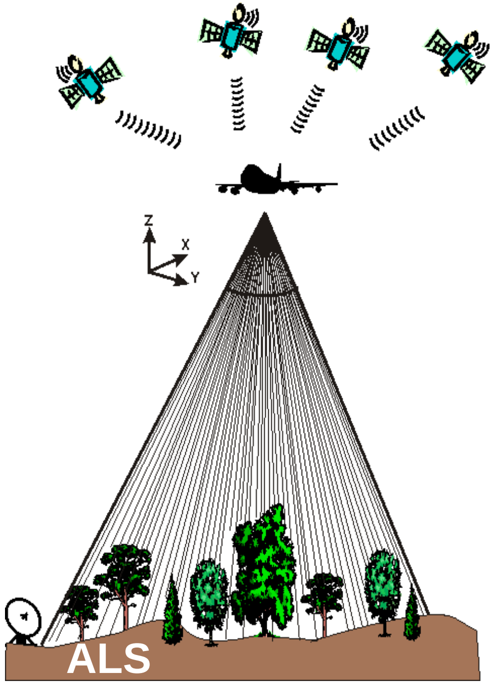
Various Platforms for LS



Airborne Laser Scanning

Terrestrial Laser Scanning

Mobile Laser Scanning

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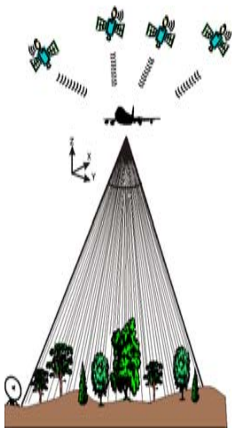
Mobile Laser Scanning

- Autonomous Driving is based on the **same sensors** that has been used for mobile mapping for almost 20 years in the field of **surveying and robotics**, having the following properties: GNSS (GPS) and IMU, Ranging radar, Laser scanner, Camera or Video, Other remote sensing sensors such as ultrasonic, thermal camera etc.
- Autonomous Driving is also based on the following **remote sensing technologies:** Processing of point cloud data, 3D map updating, Object-oriented sensor data processing.
- **Miniaturization of sensor technologies**, cost of sensors rapidly going down

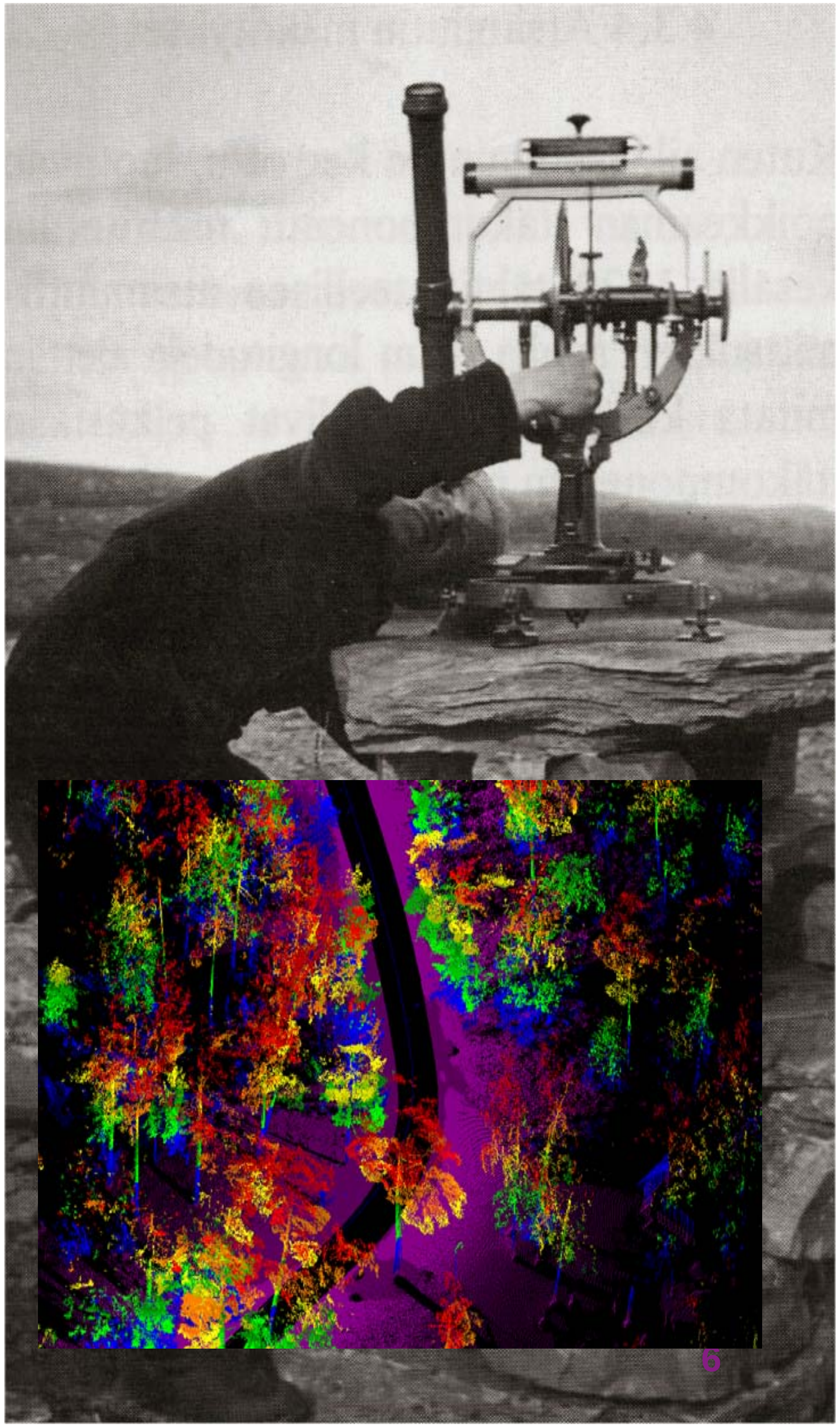


FGI

- Institute was established in 1918 to:
  - establish a coordinate system for Finland
  - determine / calculate geoid for Finland
  - carry out scientific research in geodesy and **related sciences**

- Geodesy (1918)
- **Remote Sensing** (1978)
- Geoinformatics (1987)
- Navigation (2001)

- *“On the World Geodetic System”, published by V. Heiskanen in 1951*
- Satellite positioning is based on WGS84 (World Geodetic System 84)
- **Laser scanning is based on satellite positioning, orientation and laser measurements**.



Web of Science: Lidar&Laser Scanning

Most Citations per Country

1) USA, 2) GER 3) UK, 4) CAN,

5) NOR, 6) FIN

Most Authoring Scientists

1) Hyyppä, J., 6) Kaartinen, H,

11) Kukko, A., 15) Yu, X., 16) Jaakkola, A.

Most Authoring (Mobile Laser Scanning/Lidar)

1) Hyyppä, J., 2) Kukko, A., 3) Kaartinen, H., 4) Jaakkola, A.

Most Citation in Google Scholar

1) Hyyppä, J.,

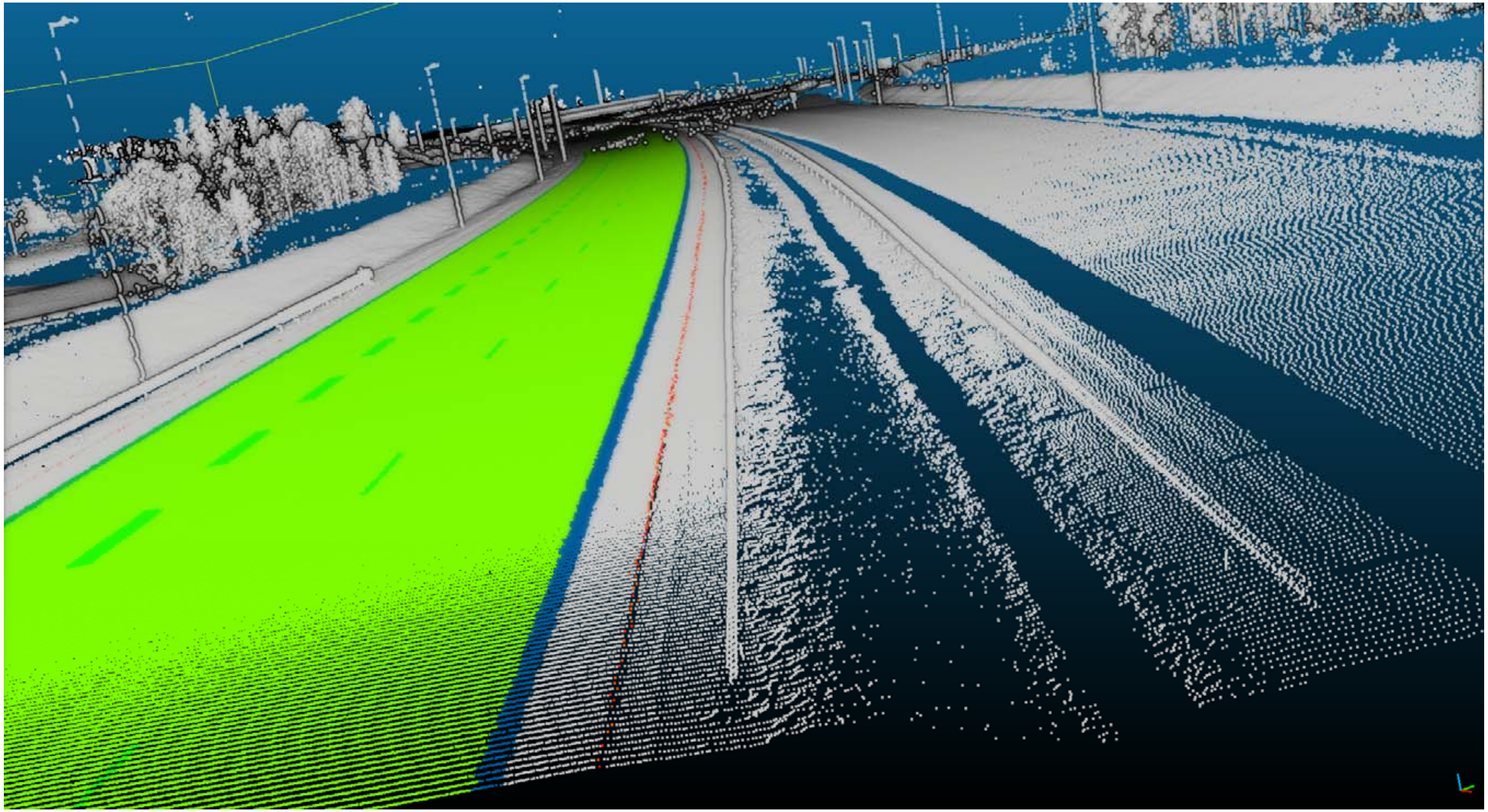
Leading organisations

1) NASA, 2) FGI

Early World Records with Lidar/Laser Scanning

1) Individual tree detection 1999
2) Intensity calibration (-> multispectral lidar)
3) Forest change 2003
4) Integration of lidar and photogrammetric point clouds 2004
5) Hyperspectral Lidar 2007
6) Fastest MLS 2007
7) Mini-UAV Laser Scanning 2009
8) Backpack Laser Scanning 2010
9) MLS+images -> Game Engine + AR+ VR 2010 (Tapiola 3D)
10) Corridor mapping with UAV LS 2013
11) Several multispectral LS records
12) ….

HD maps since 2007



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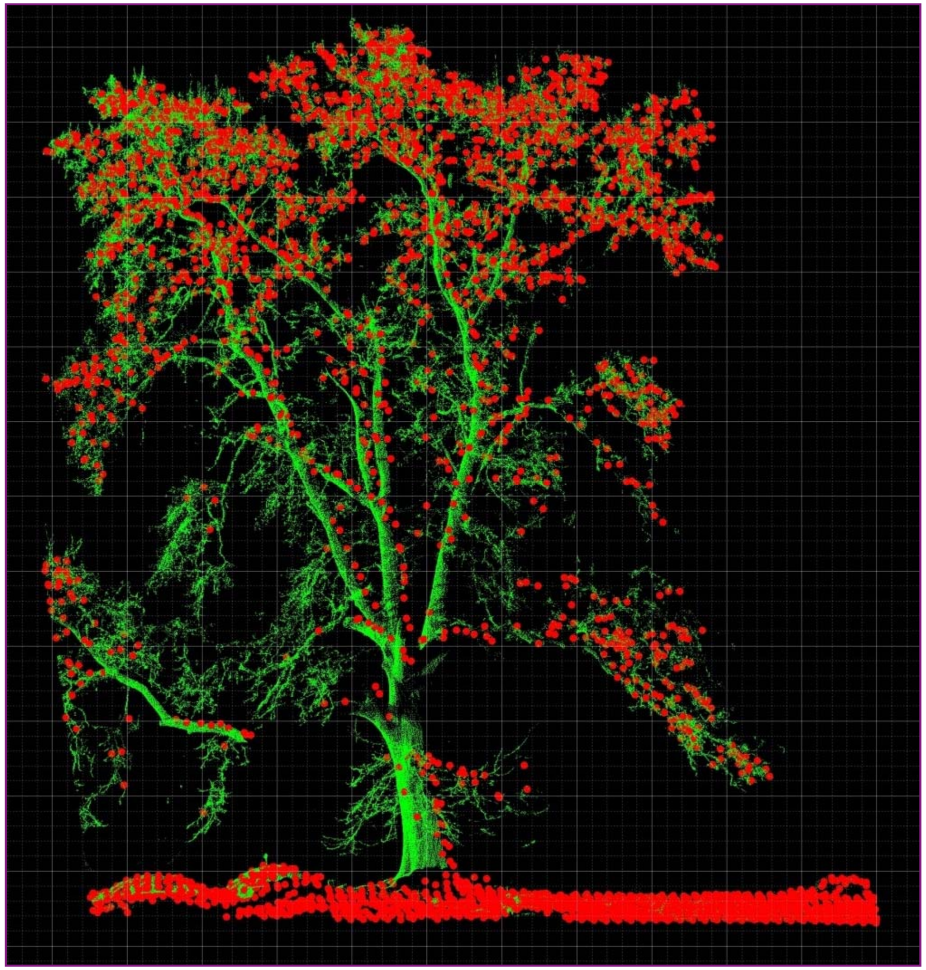
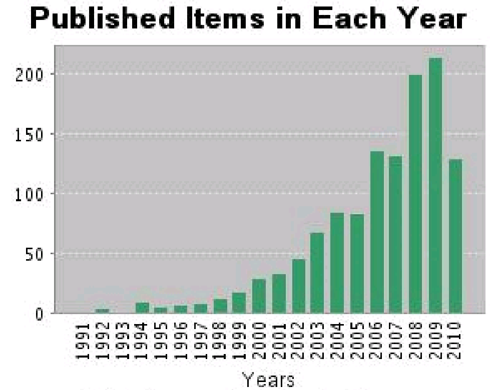
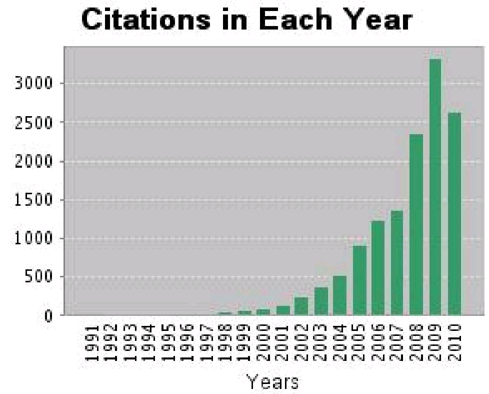
Laser Scanning: A Rapidly Evolving Research Field: especially LS&Forestry



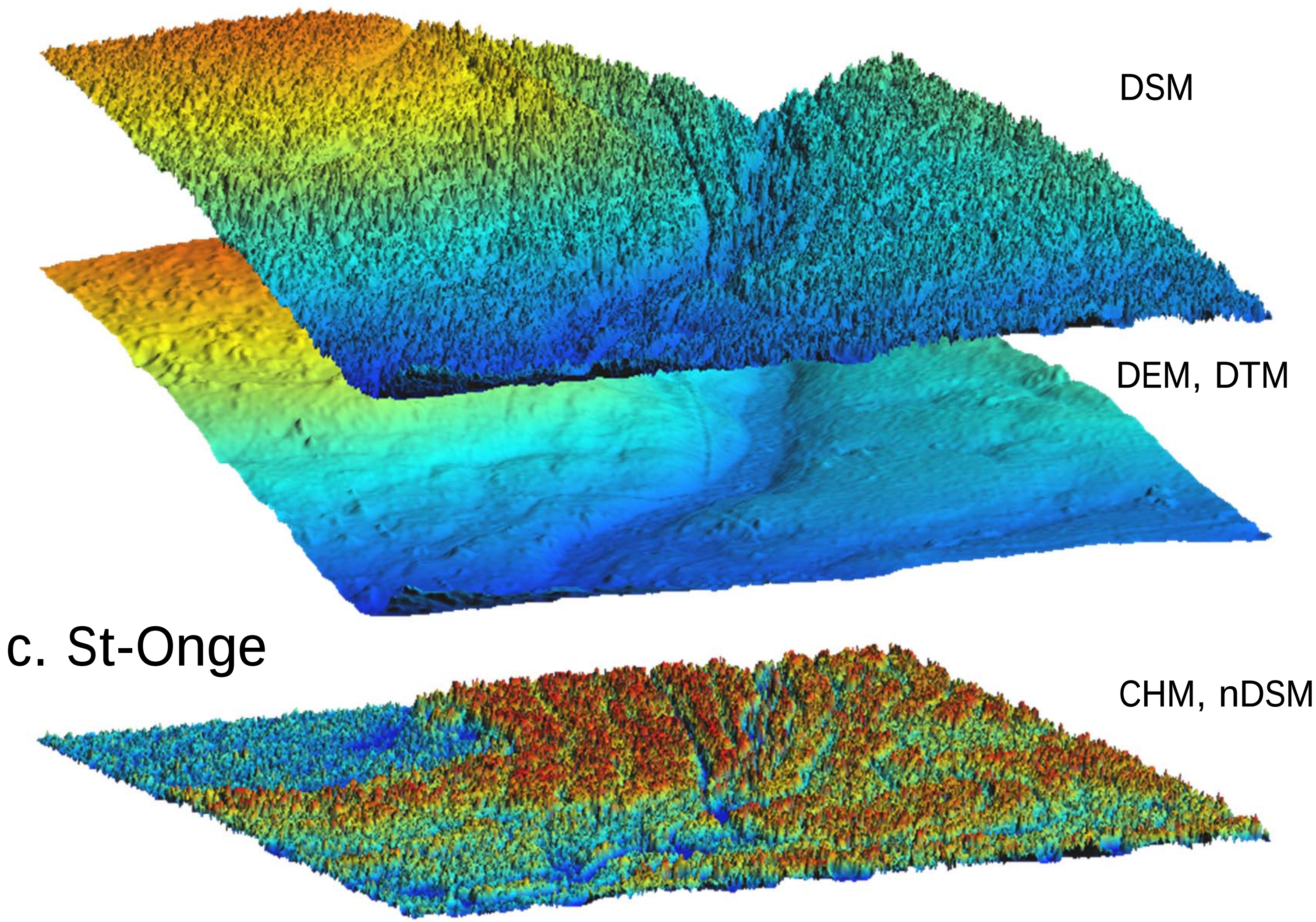
Combined TLS and ALS Point Cloud
© Michael Doneus, Christian Briese, Nikolaus Studnicka



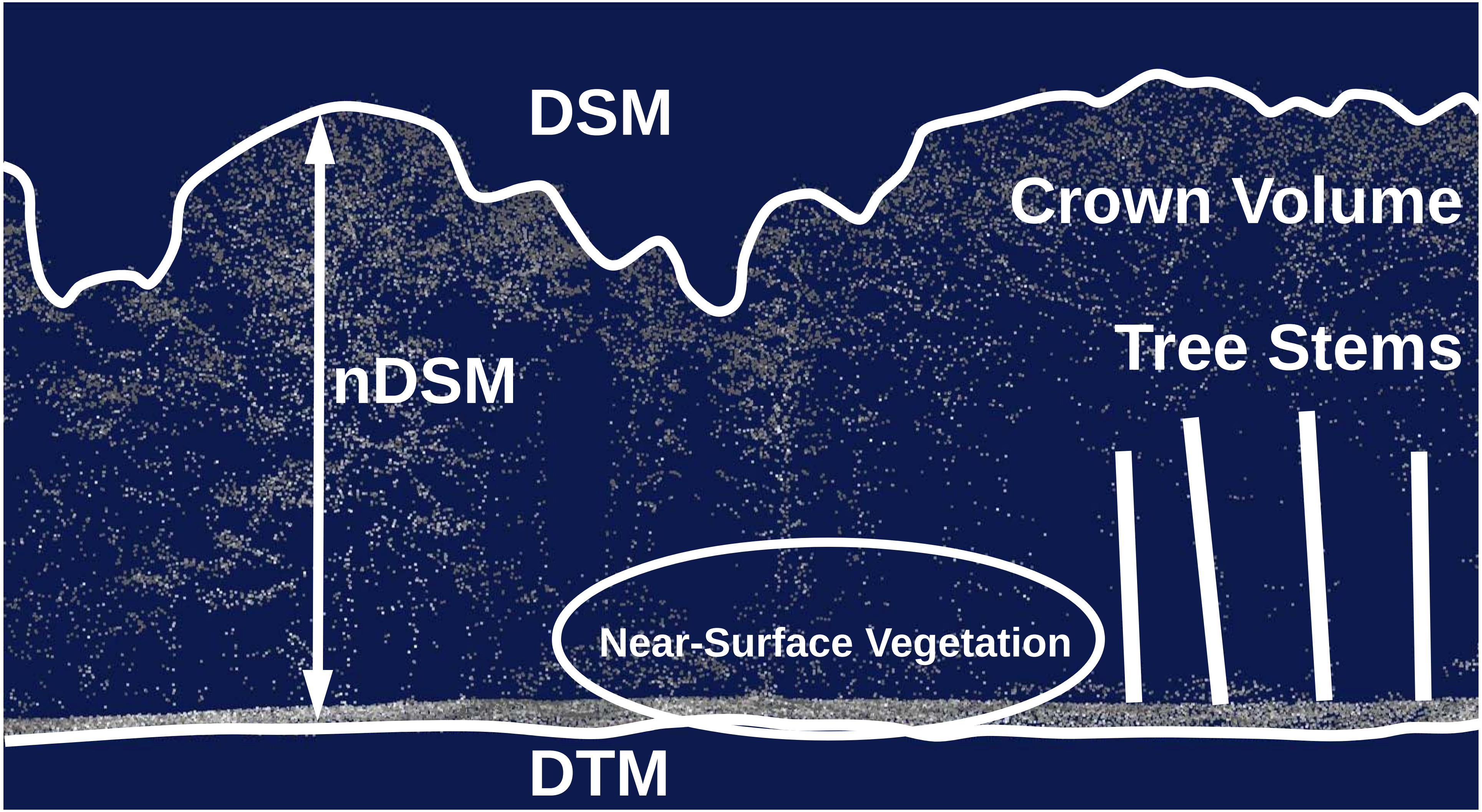


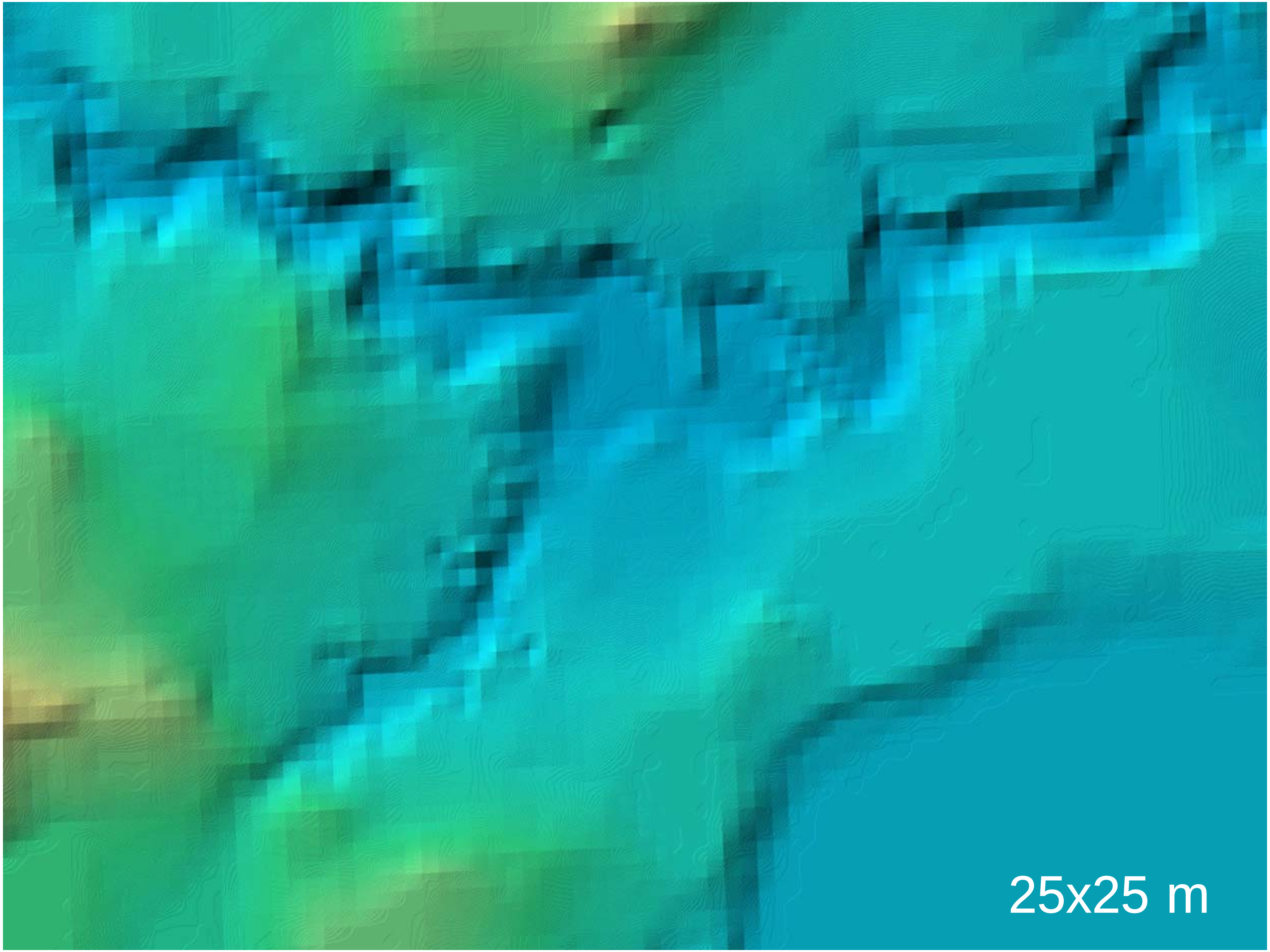
Exponential growth of published papers and citations.
Search on ISI Web of Knowledge, 3/9/2010, Topic=((lidar or laser scanning) and (forestry or forest or vegetation))

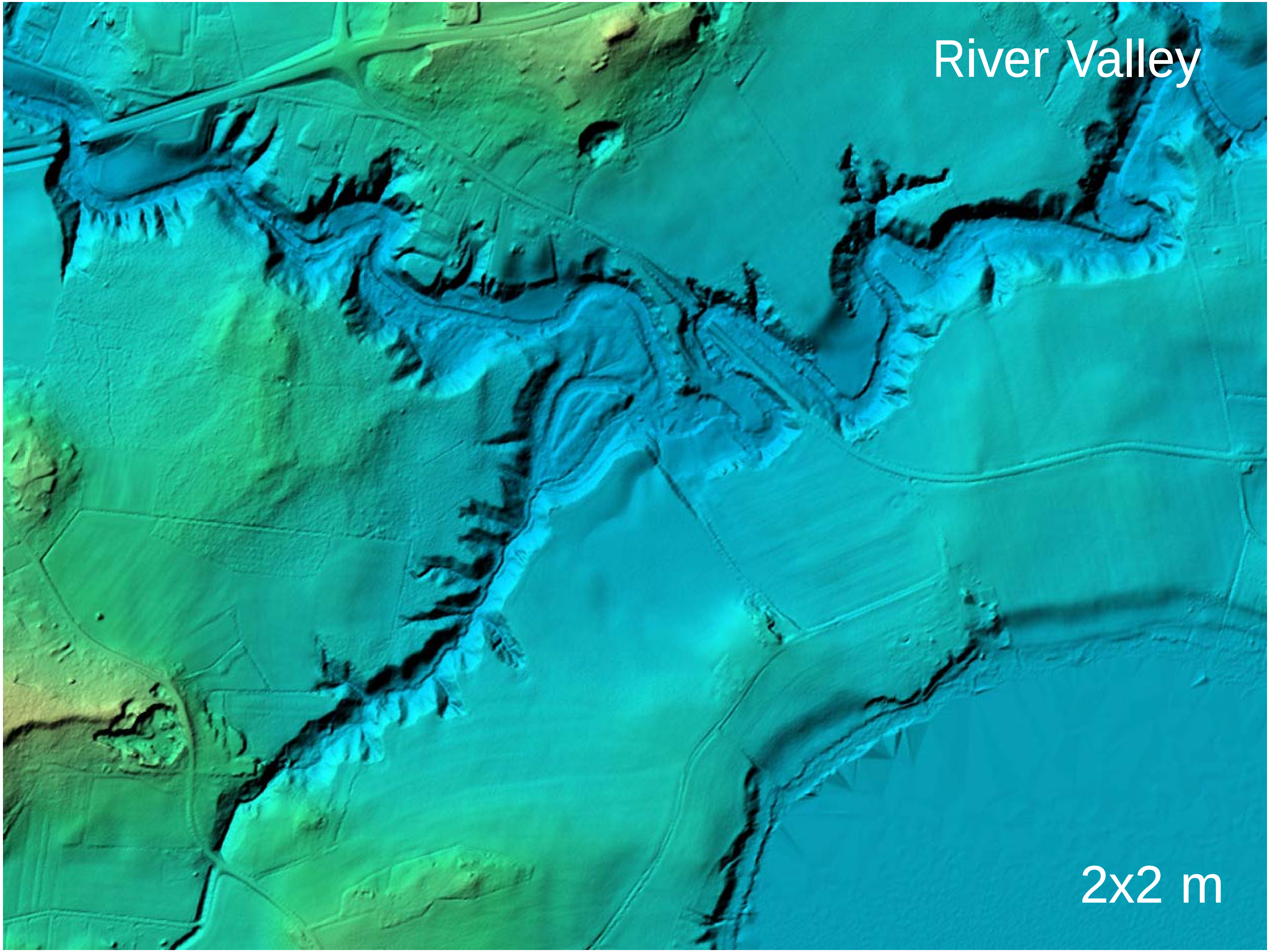
DTM, DSM, nDSM



Interpreting ALS Point Clouds




25x25 m


River Valley
2x2 m

FGI CoE-LaSR spinoffs

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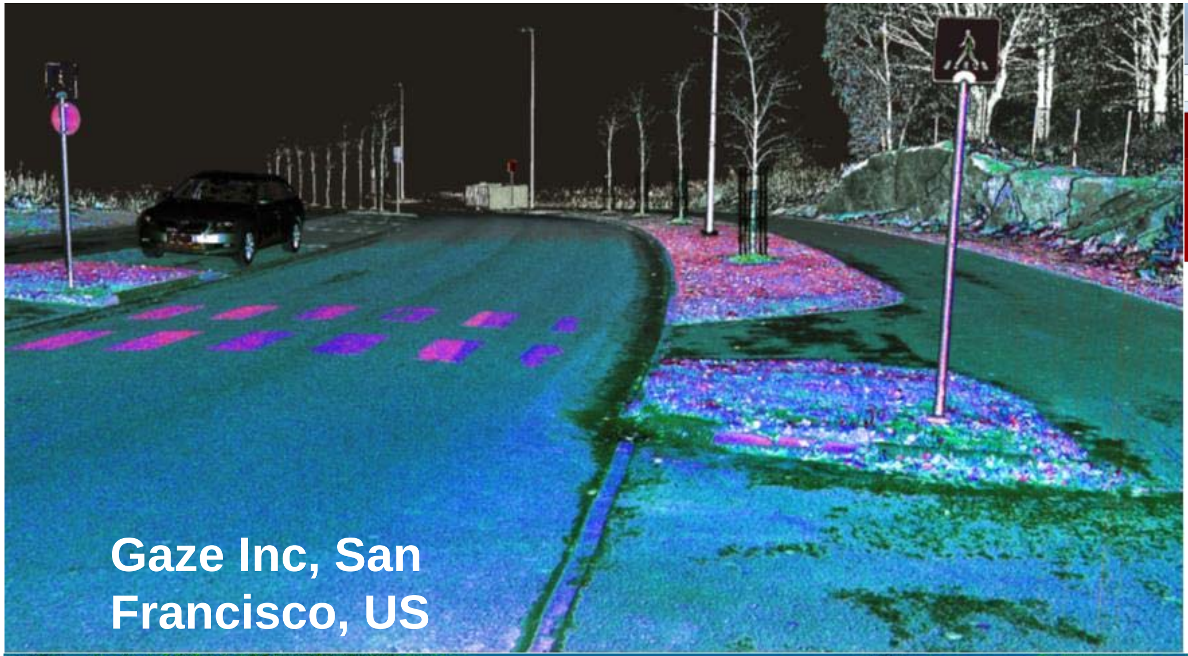
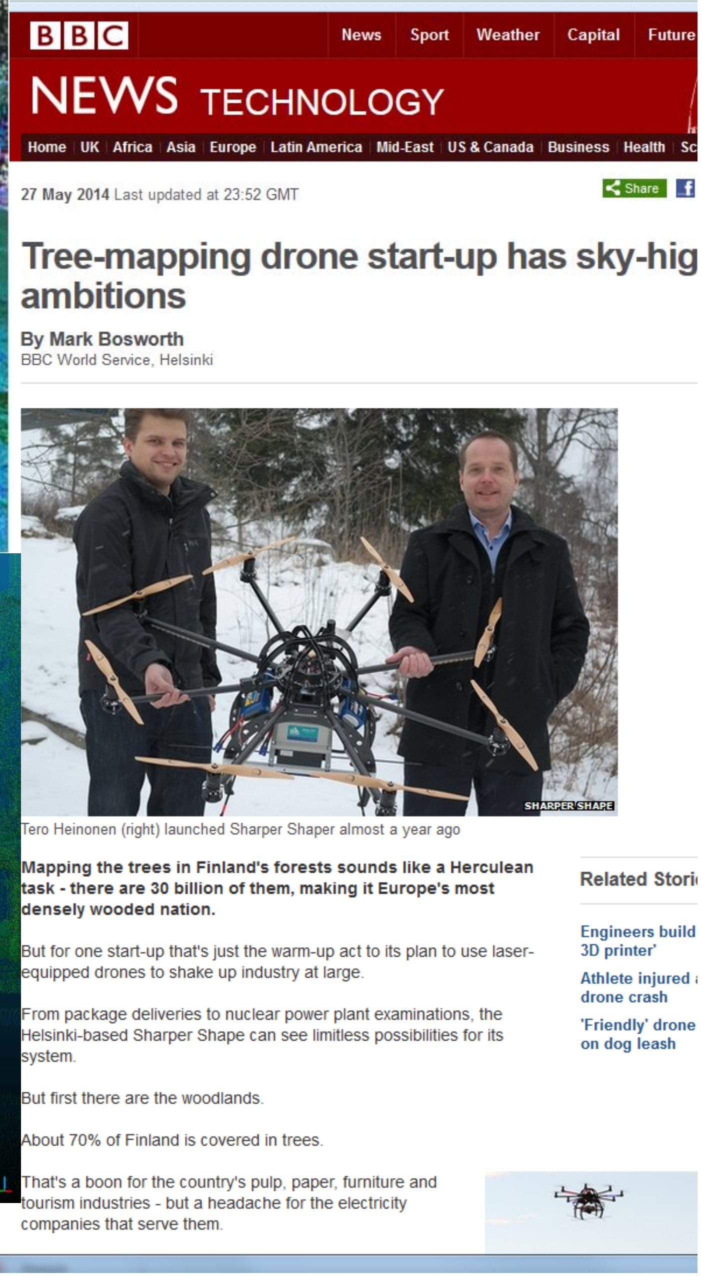
Sharper Shape Group Inc, North Dakota, US





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27 May 2014 Last updated at 23:52 GMT

Share

Tree-mapping drone start-up has sky-hig ambitions

By Mark Bosworth
BBC World Service, Helsinki

SHARPER SHAPE

Tero Heinonen (right) launched Sharper Shaper almost a year ago

Mapping the trees in Finland's forests sounds like a Herculean task - there are 30 billion of them, making it Europe's most densely wooded nation.

But for one start-up that's just the warm-up act to its plan to use laser-equipped drones to shake up industry at large.

From package deliveries to nuclear power plant examinations, the Helsinki-based Sharper Shape can see limitless possibilities for its system.

But first there are the woodlands.

About 70% of Finland is covered in trees.

That's a boon for the country's pulp, paper, furniture and tourism industries - but a headache for the electricity companies that serve them.

Related Stori

Engineers build 3D printer'

Athlete injured drone crash

'Friendly' drone on dog leash

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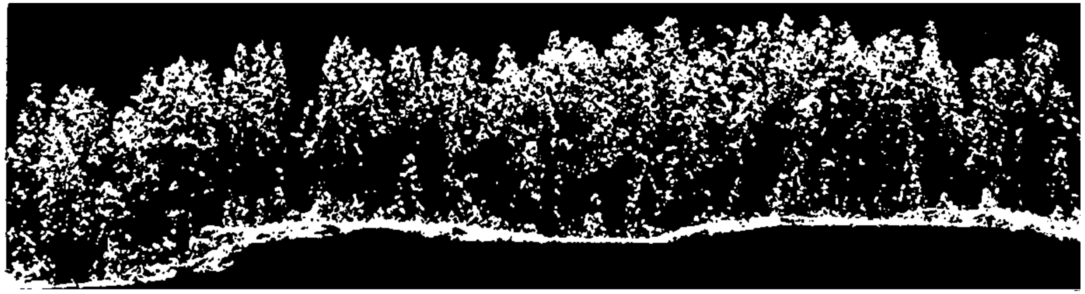
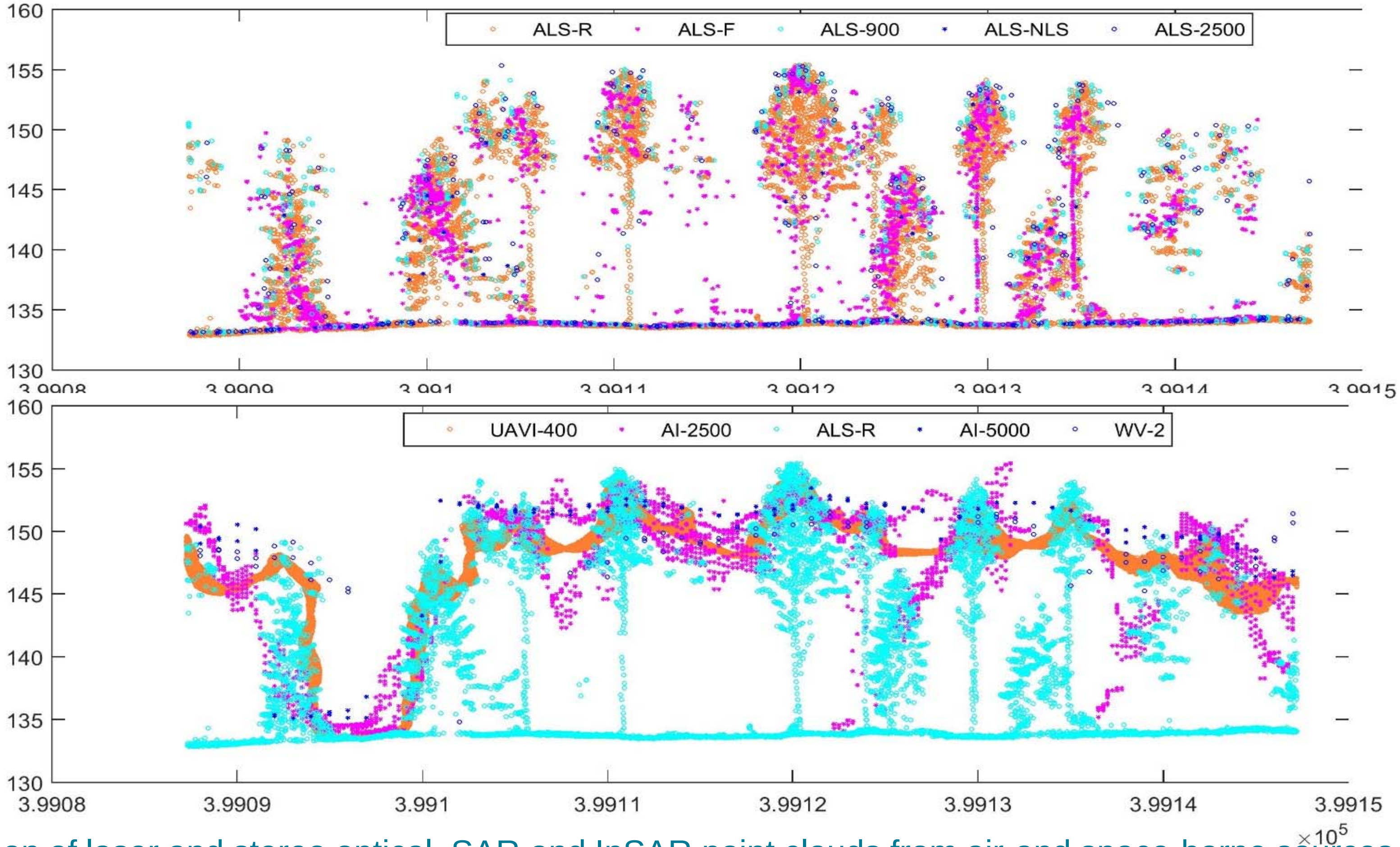
Technologies



- Photogrammetric versus LS Point Cloud
- Airborne Laser Scanning
- Multispectral ALS
- Single Photon Lidar
- Waveform ALS
- UAV LS
- MLS/PLS
- TLS
- Smart-Phone Embedded LS

Photogrammetric vs LS Point Cloud



Comparison of laser and stereo optical, SAR and InSAR point clouds from air-and space-borne sources in the retrieval of forest inventory attributesX Yu, J Hyyppä, M Karjalainen, K Nurminen, K Karila, M Vastaranta, ... Remote Sensing 7 (12), 15933-15954

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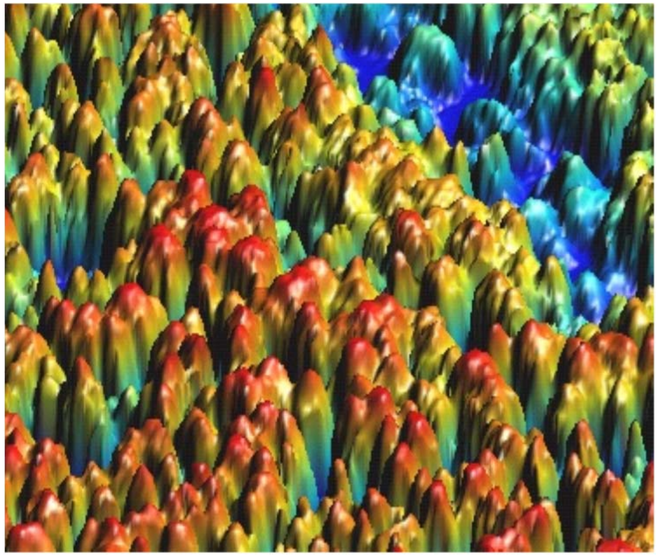
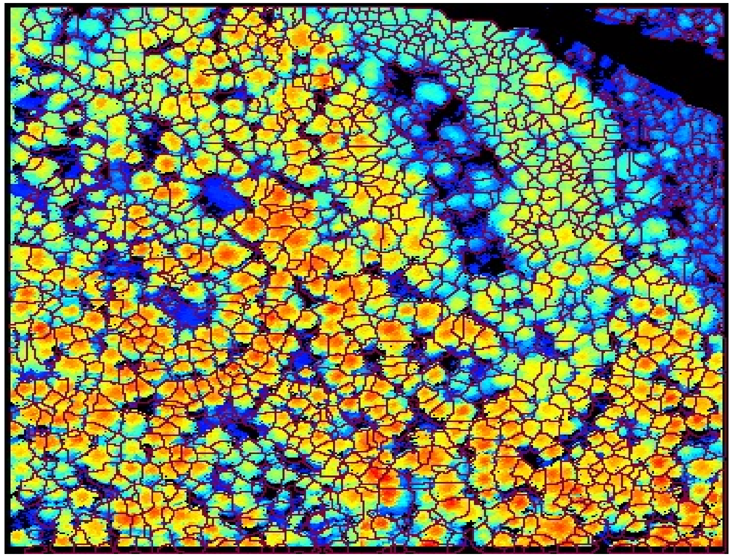
Individual Tree Information from LS for standwise inventory





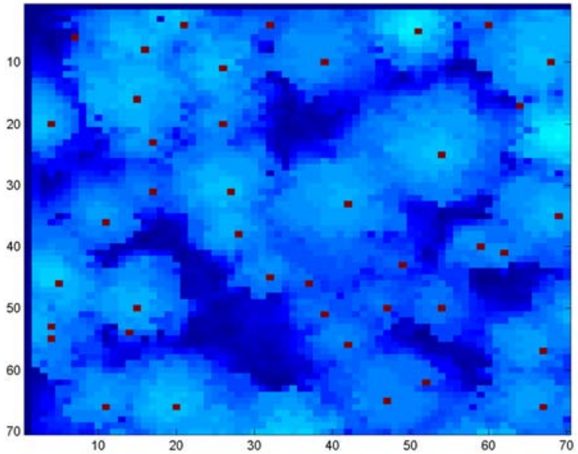
Hyyppä, J., Kelle, O., Lehikoinen, M., and M. Inkinen, 2001. A segmentation-based method to retrieve stem volume estimates from 3-dimensional tree height models produced by laser scanner. *IEEE Transactions of Geoscience and Remote Sensing*, Vol. 39, 969-975. . (Most cited Finnish paper in the journal since 2000)

Hyyppä, J., and M. Inkinen, 1999. Detecting and estimating attributes for single trees using laser scanner. *The Photogrammetric Journal of Finland*, Vol. 16(2), 27-42.

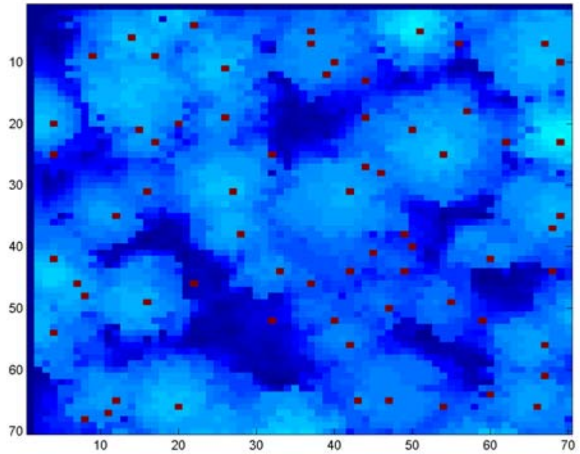
Courtesy to A. Kukko, FGI

Finding Tree Locations

State-of-the-art

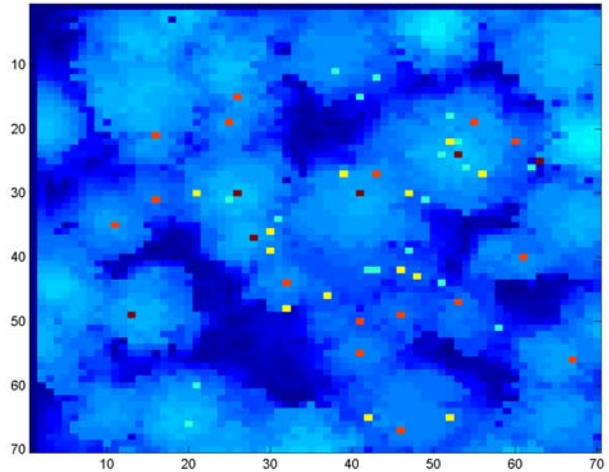


Developed



Advances in forest inventory using airborne laser scanningJ Hyyppä, X Yu, H Hyyppä, M Vastaranta, M Holopainen, A Kukko, ... Remote Sensing 4 (5), 1190-1207

Reference



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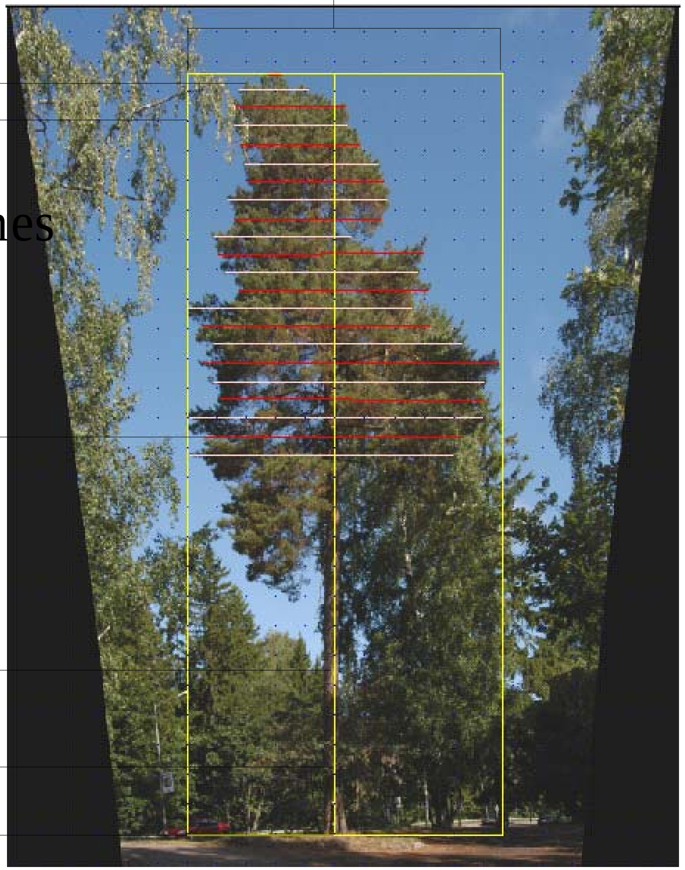
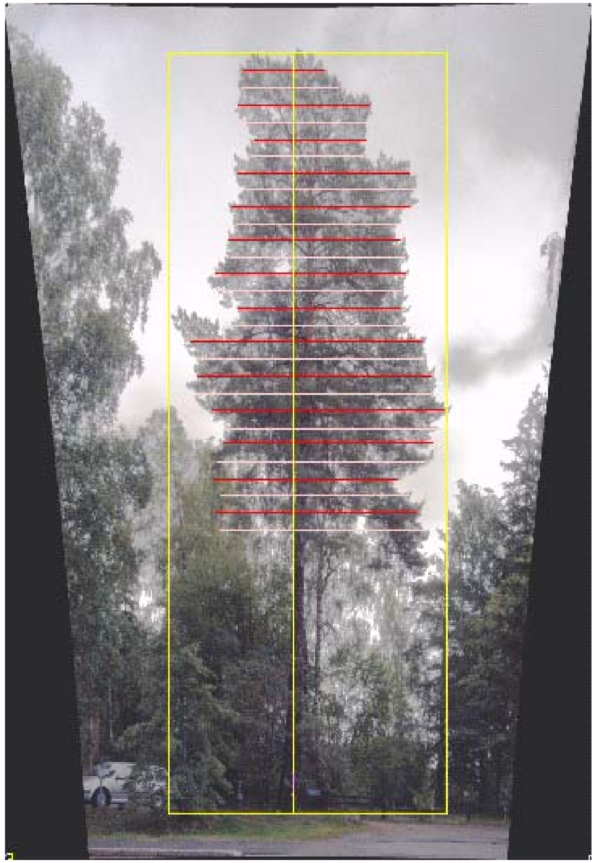
Courtesy to J. Hyyppä, FGI

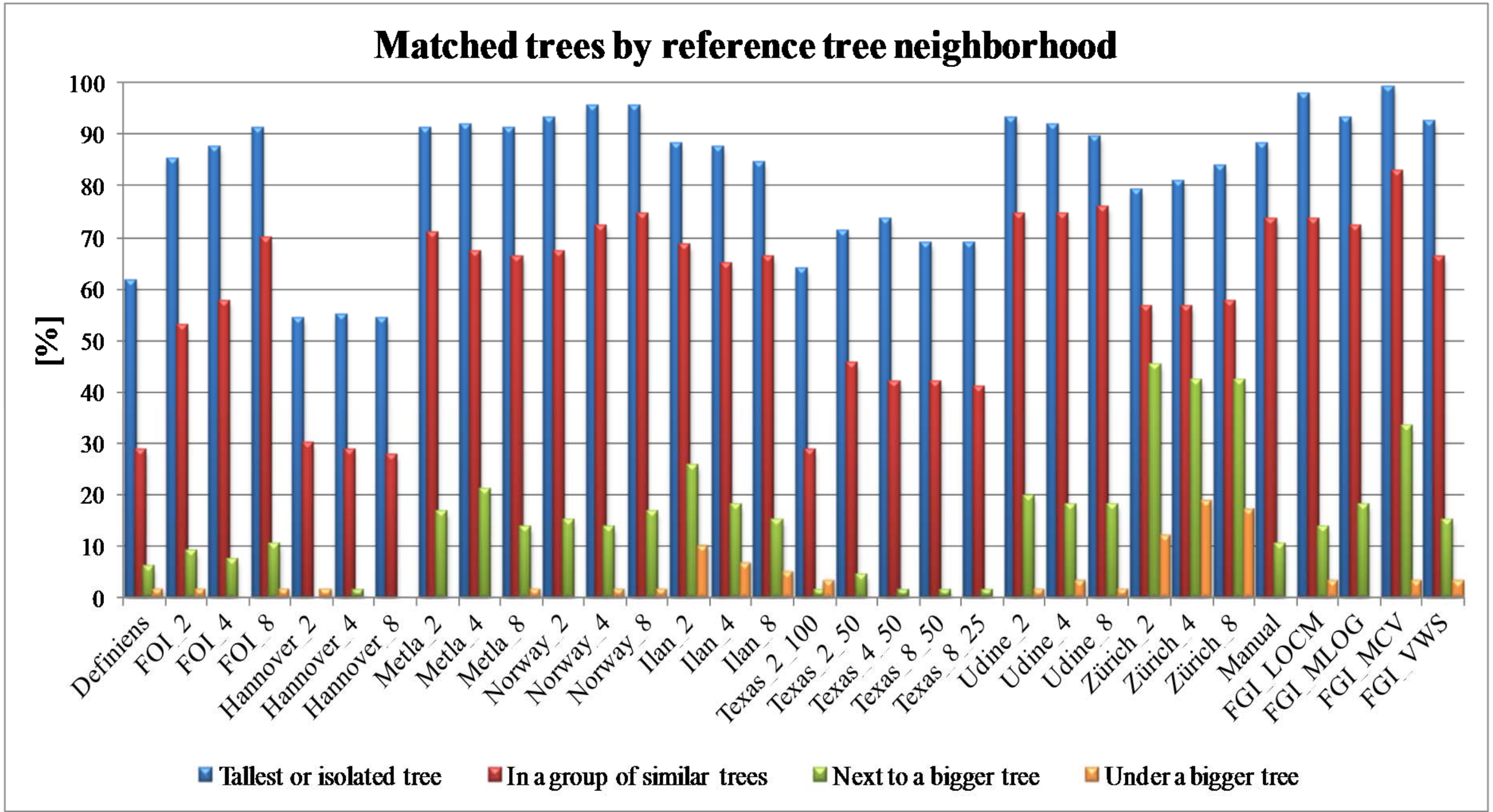
Calibration at Tree and Plot Level





Courtesy to U. Pyysalo,TKK

EuroSDR/ISPRS Tree Extraction Comparison



Kaartinen, H., Hyyppä, J., Yu, X., Vastaranta, M., Hyyppä, H., Kukko, A., Holopainen, M., Heipke, C., Hirschugl, M., Morsdorf, F., Naesset, E., Pitkänen, J., Popescu, S., Solberg, S., Bernd, M. & Wu, J. 2012. An International Comparison of Individual Tree Detection and Exctraction Using Airborne Laser Scanning. *Remote Sensing* 4(4), pp. 950–974. DOI: 10.3390/rs4040950.
http://www.mdpi.com/2072-4292/4/4/950/

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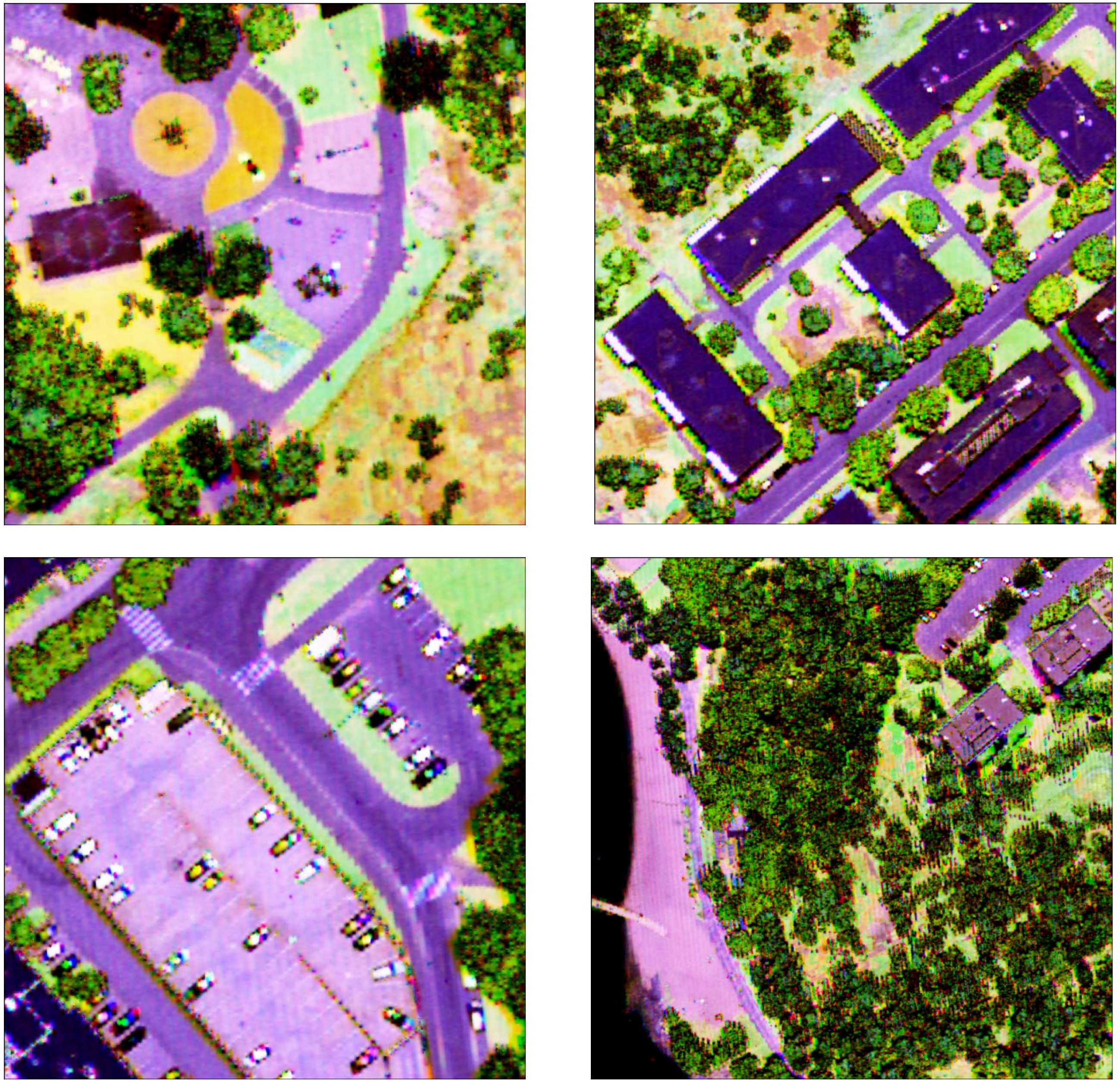
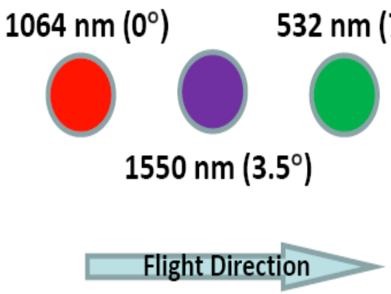
Multispectral LS

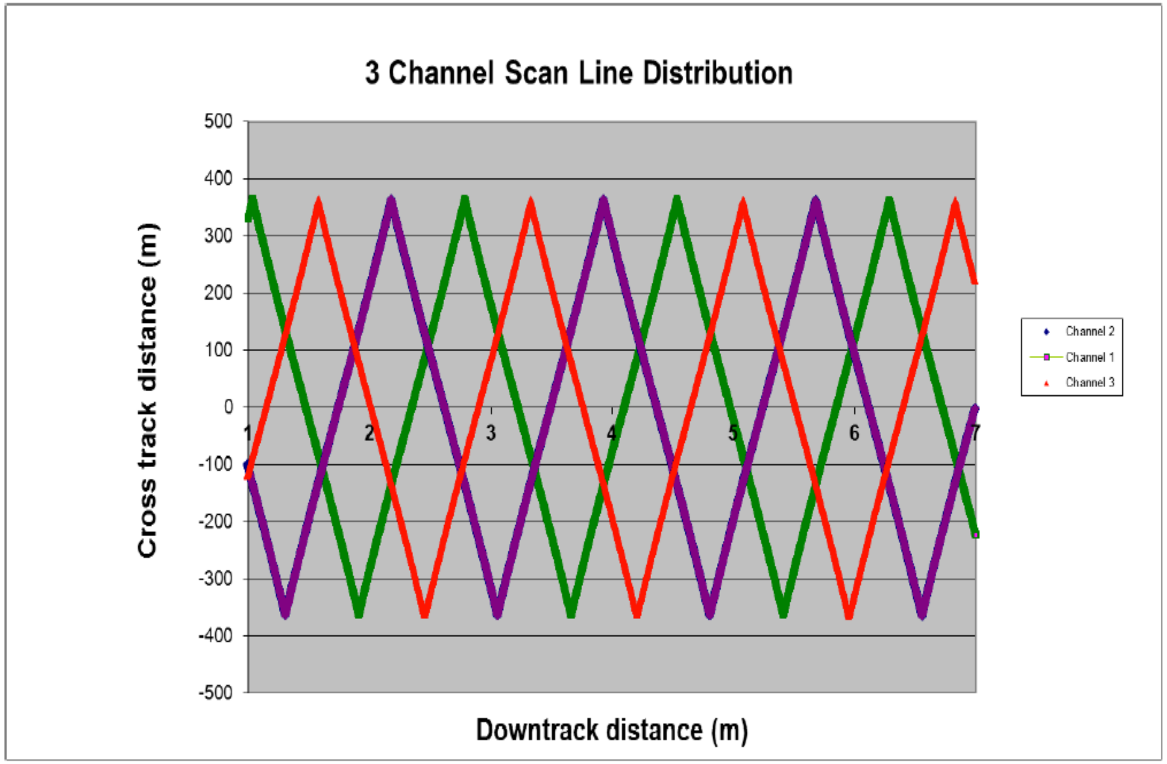
- Matikainen, L., Karila, K., Hyyppä, J., Litkey P., Puttonen, E., Ahokas, E., 2017. Object-based analysis of multispectral airborne laser scanner data for land cover classification and map updating. ISPRS Journal of Photogrammetry and Remote Sensing, 128: 298-313.
- Karila, K, Matikainen, L., Puttonen, E., Hyyppä, J. 2016. Feasibility of Multispectral Airborne Laser Scanning Data for Road Mapping, IEEE Geoscience and Remote Sensing Letters PP(99):1-5 http://ieeexplore.ieee.org/document/7829363/
- Yu, X., Hyyppä, J., Litkey, P., Kaartinen, H., Vastaranta, M., Holopainen, M. Single-sensor solution to tree species classification using multispectral airborne laser scanning. Remote Sensing 2017, *9*(2), 108; doi:10.3390/rs9020108



TITAN – Scan Pattern (MW900)

Forward angle separation = 3.5° (~ 60 mrad)





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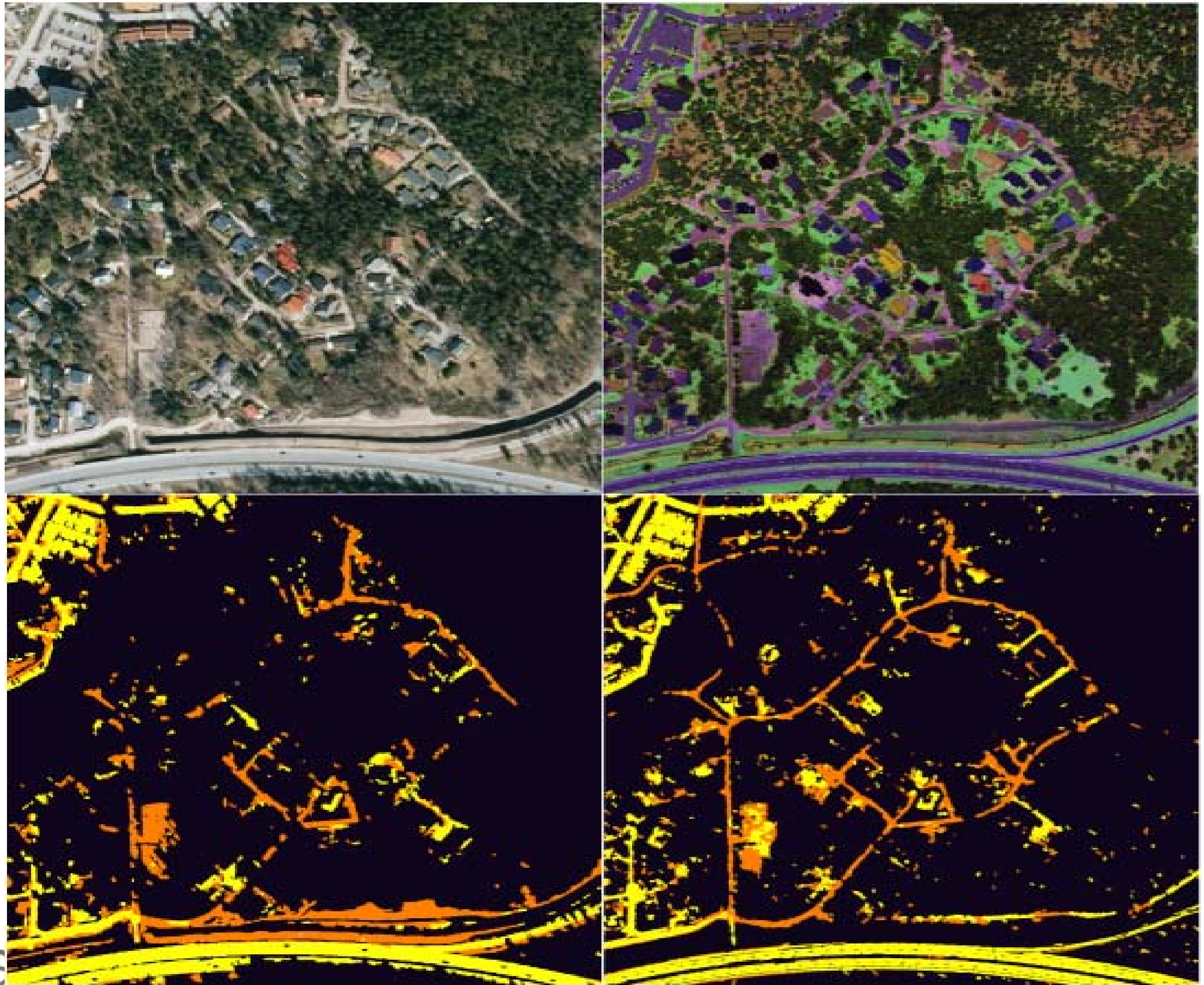

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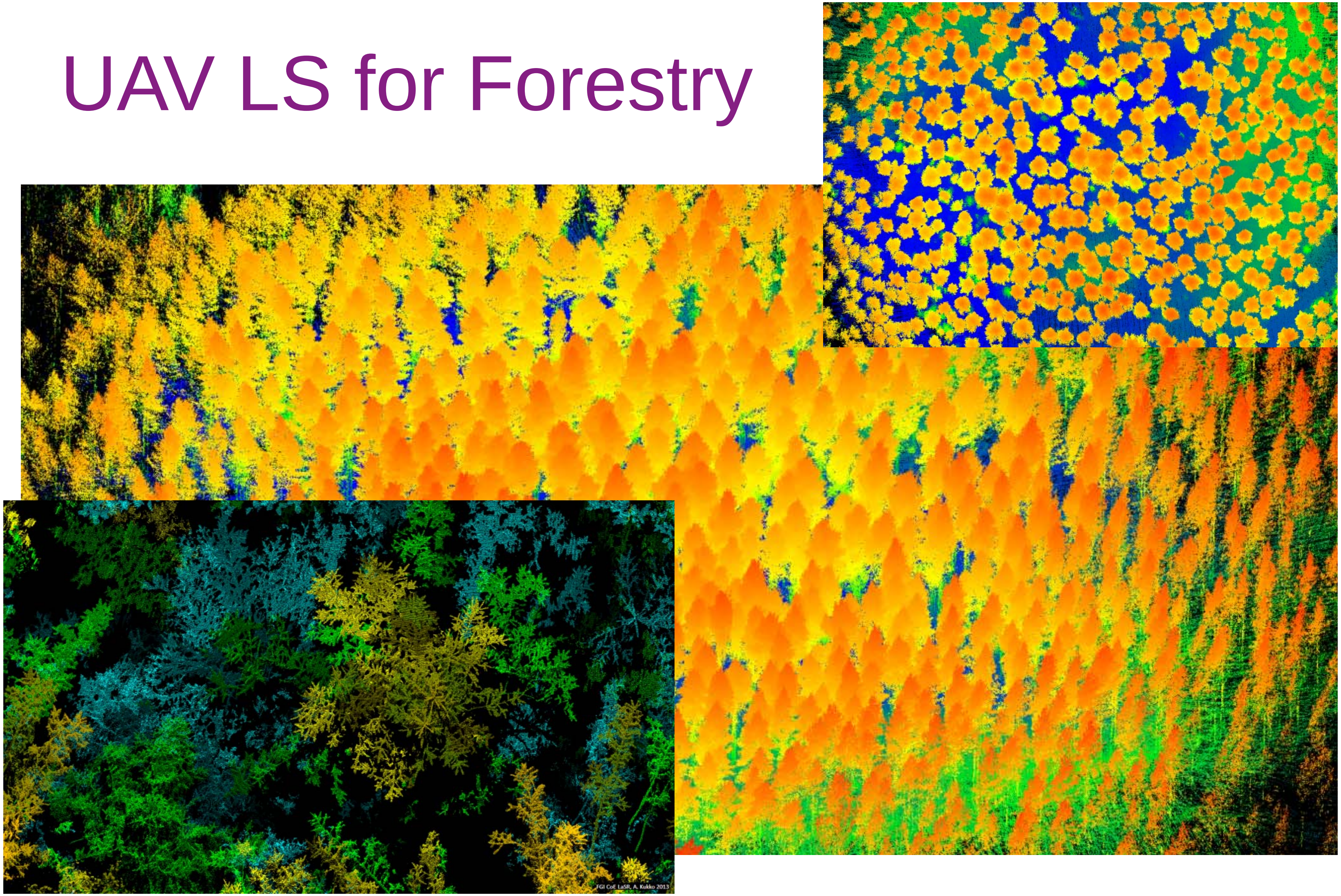
Confusion matrix based on intensity features

		Predicted			producer
		Pine	Spruce	Birch	
Reference	Pine	623	12	16	95.70
	Spruce	32	180	27	75.31
	Birch	47	18	197	75.19
user		88.75	85.71	82.08	Overall = 86.81%

Confusion matrix based on point cloud and intensity features

	Predicted				producer
		Pine	Spruce	Birch	
Reference	Pine	622	14	15	95,55
	Spruce	18	201	20	84,10
	Birch	46	21	195	74,43
user		90.67	85.17	84.78	Overall = 88.36%

UAV LS for Forestry



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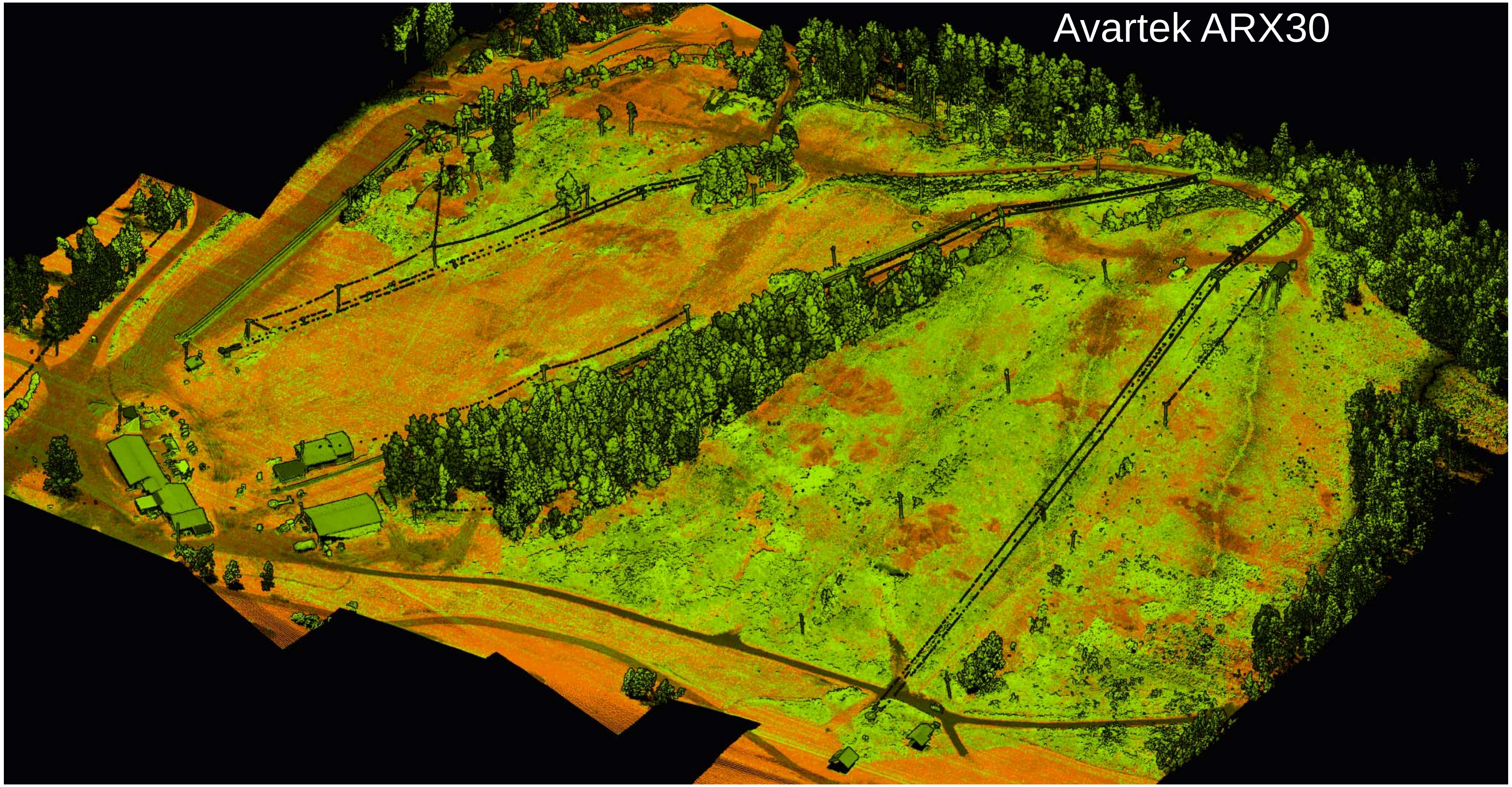
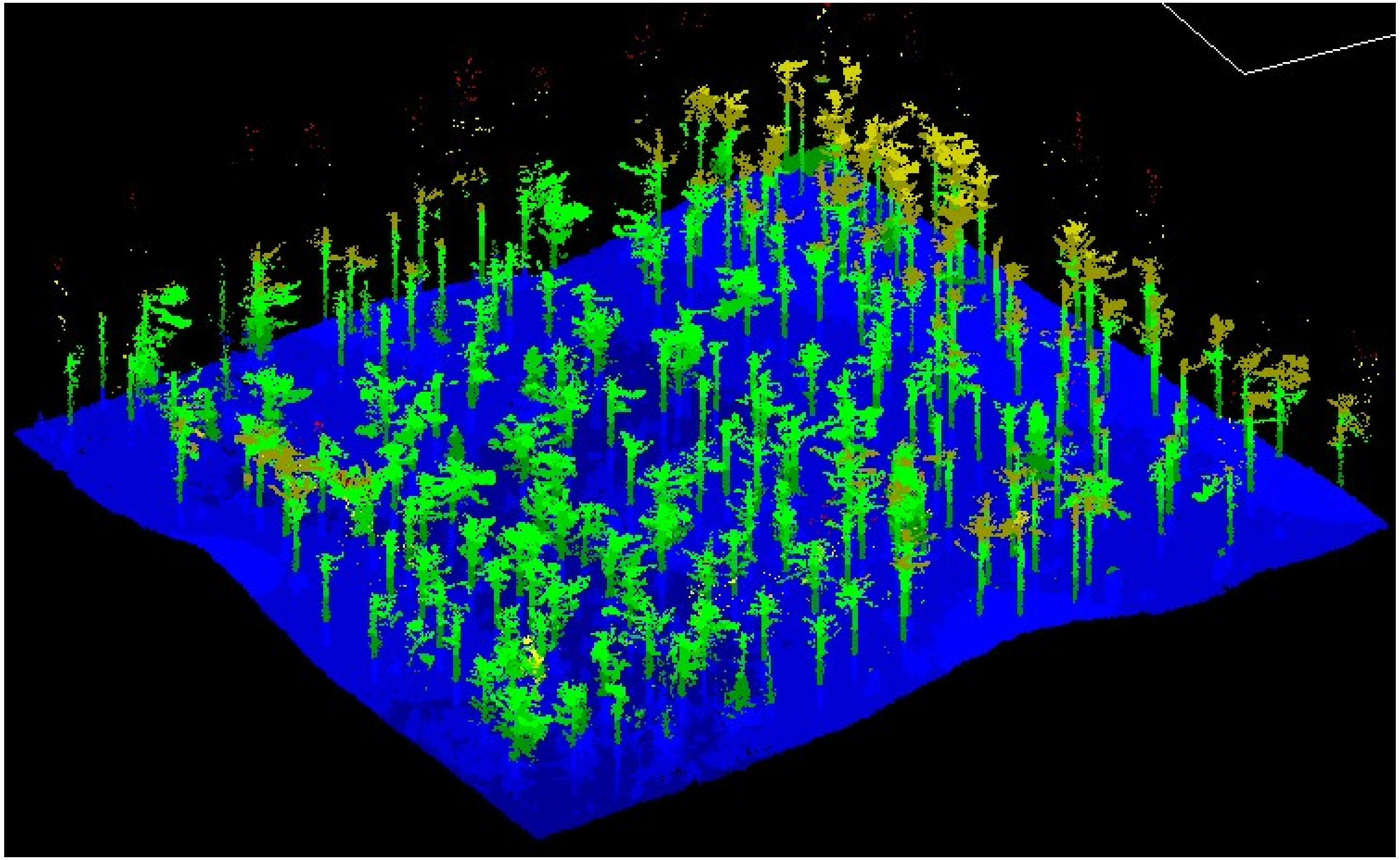
UAV LS

Avartek ARX30



Information below the crowns



Point cloud between 0 and 10 m above ground showing the stem captured by UAV

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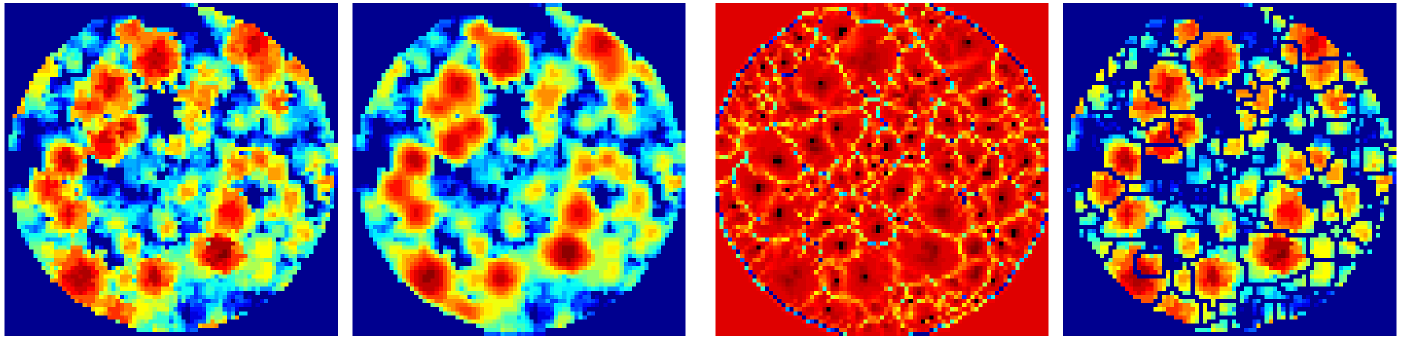
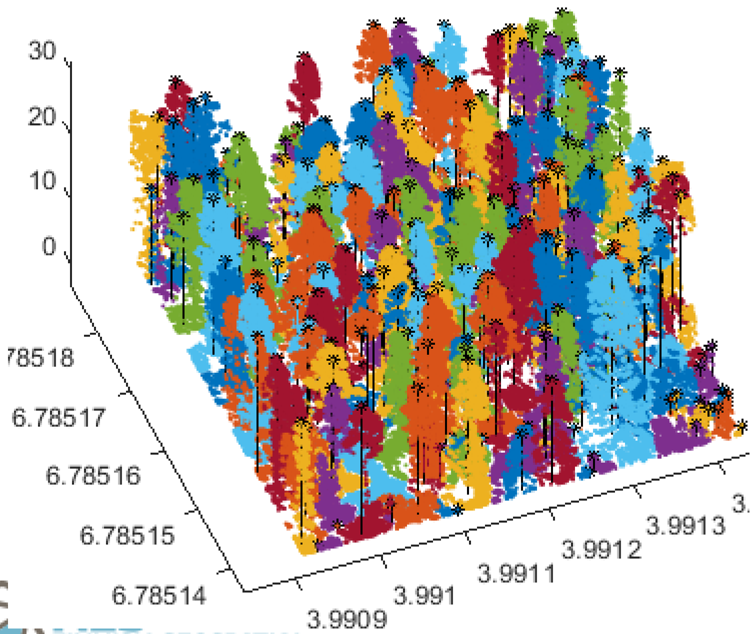
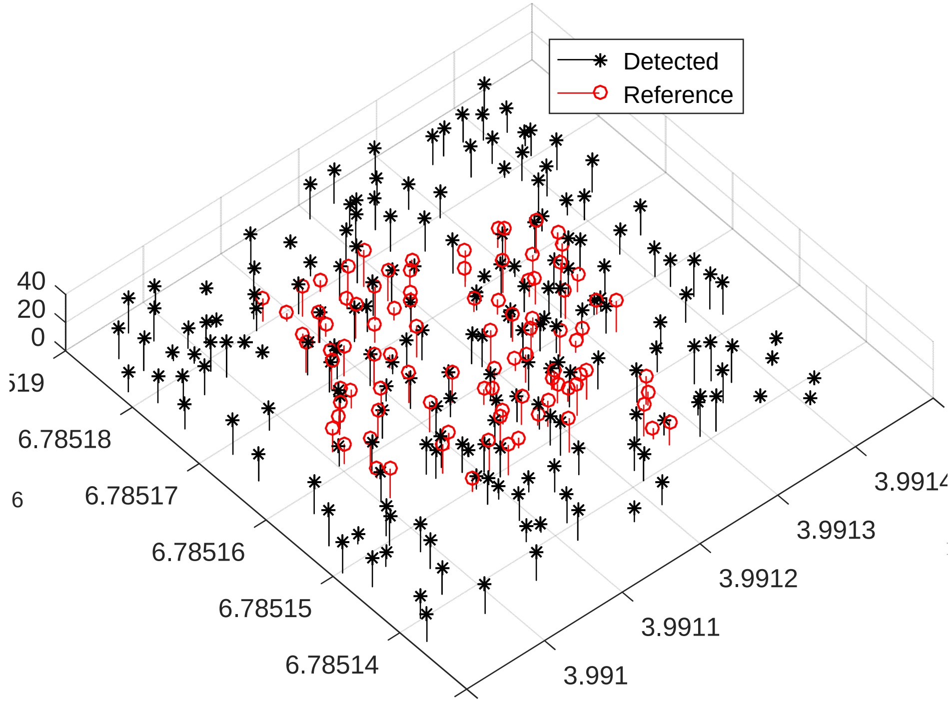
Individual Tree Detection







Low-Cost LiDAR

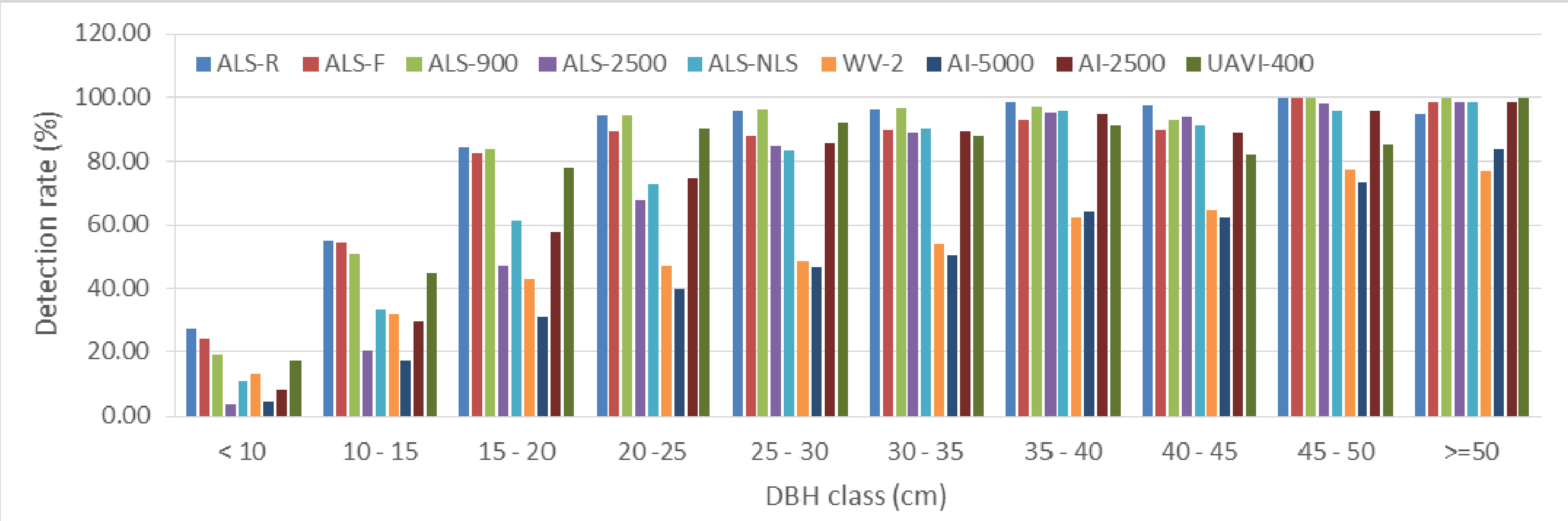
- Velodyne VLP-16 Lite
- Novatel SPAN-IGM S1

- 40 m AGL
- 10 m line spacing
- 8 m/s
- Up to 800 pts/m^2
- Single plot

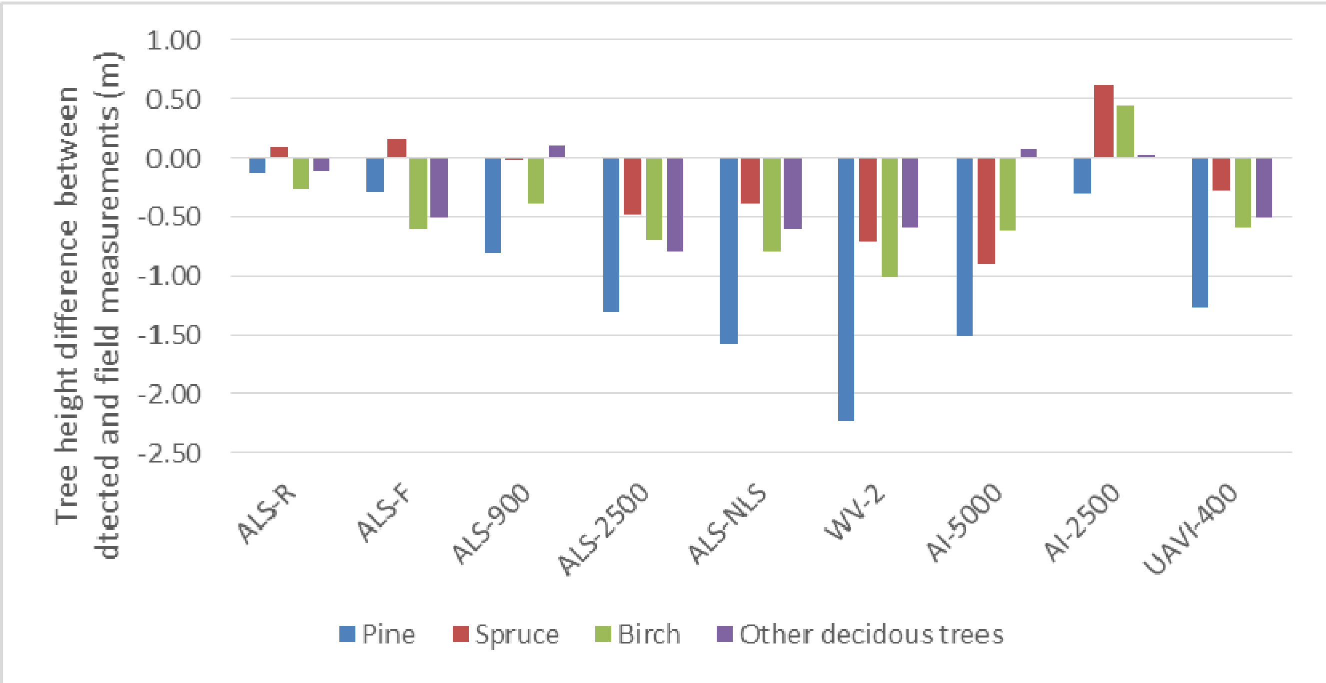
Low-Cost UAV LiDAR

	Bias	Bias (%)	RMSE	RMSE (%)	R
Tree height (m)	0.02	0.08	1.02	5.16	0.92
DBH (cm)	0.02	0.07	2.55	10.40	0.88
Basal area (m^2)	0.00	0.56	0.01	19.73	0.84
Volume (m^3)	0.00	-0.02	0.09	19.26	0.88
Biomass (Mg)	0.12	0.05	40.81	17.35	0.89

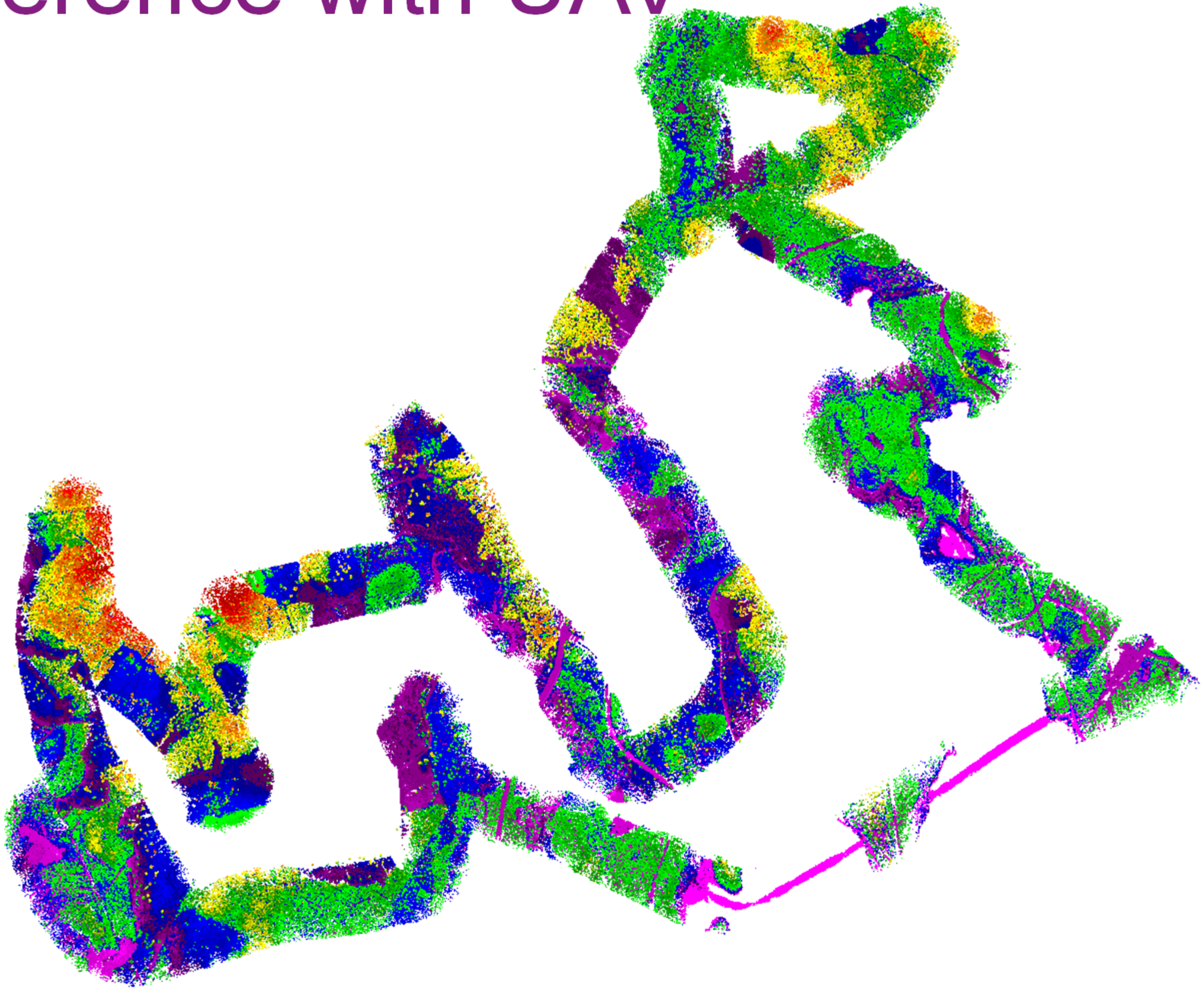
High-End UAV LiDAR



High-End UAV LiDAR



Field reference with UAV



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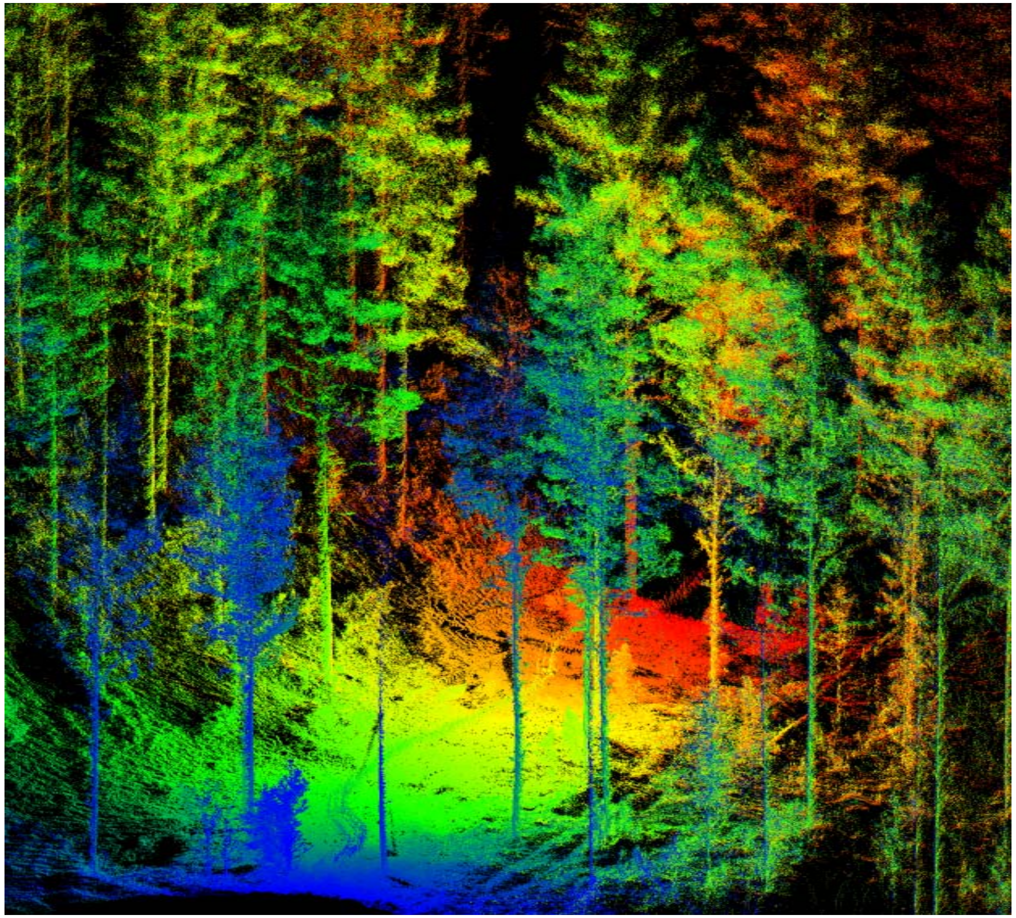
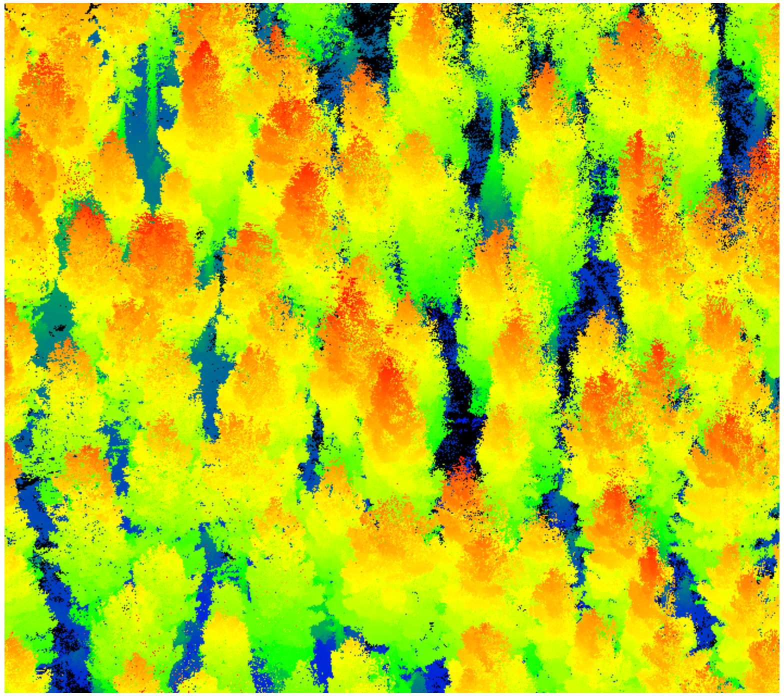
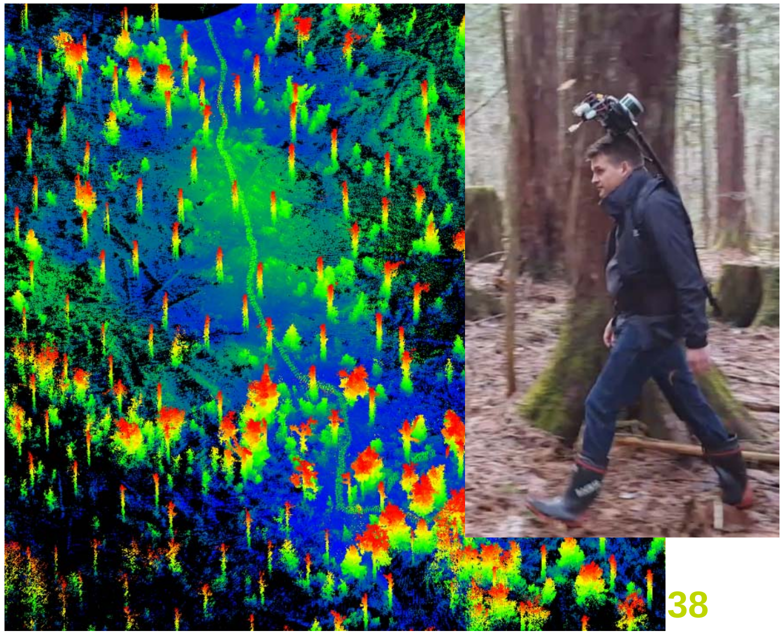
Low-cost Backpack for Forestry (VLP-16)







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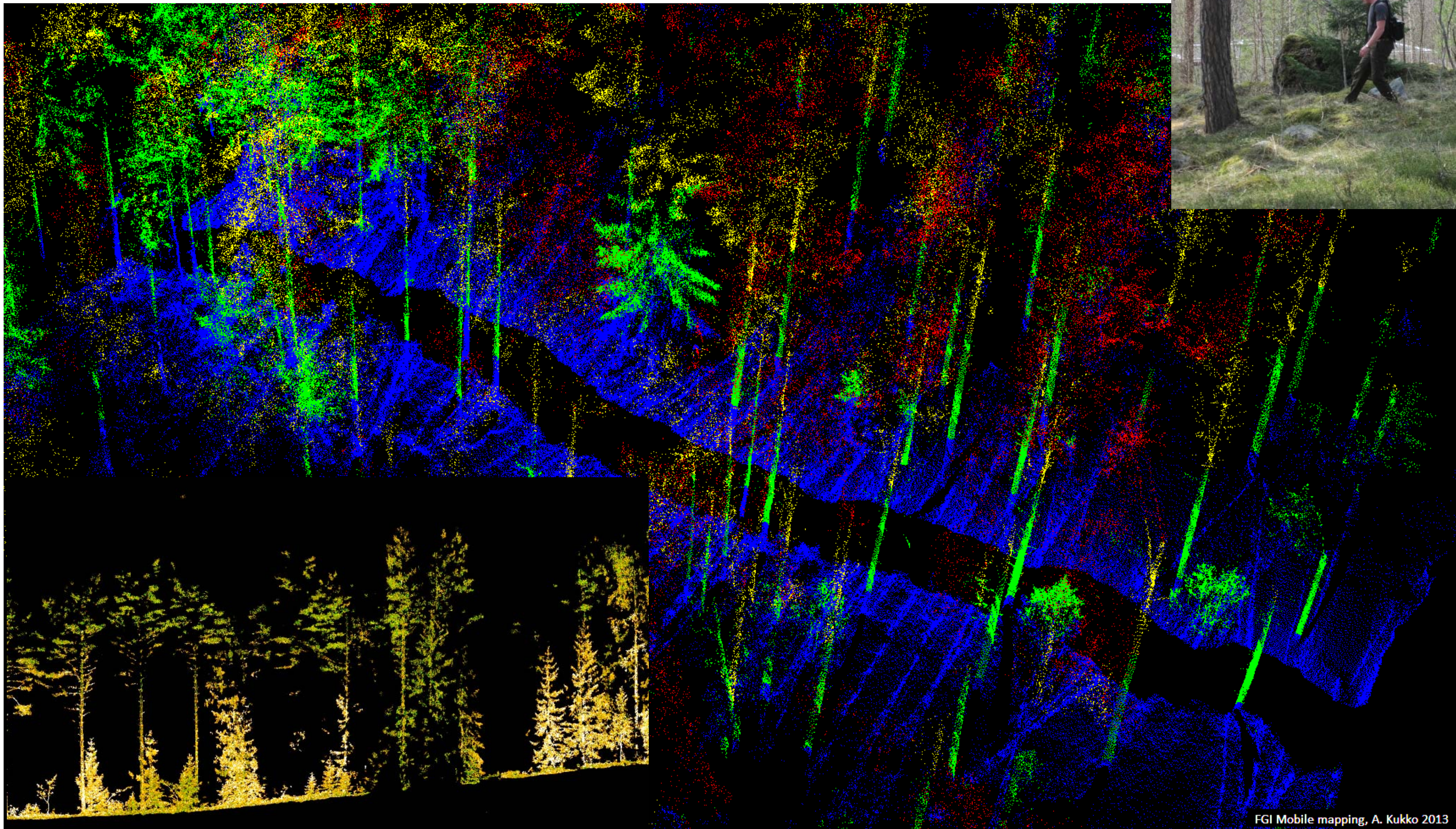
Backpack MLS



ATV MLS + cameras

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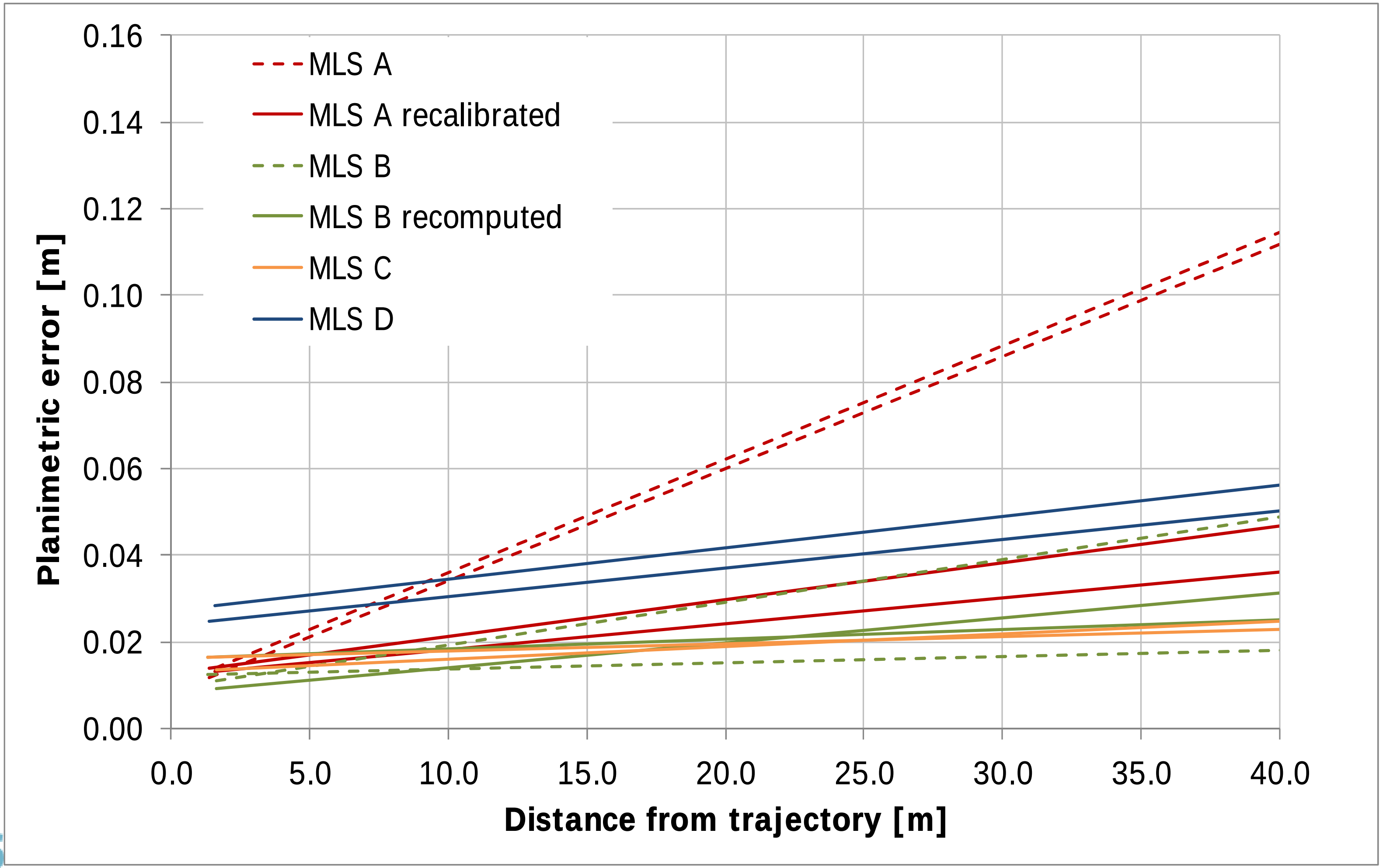
Accuracy as a function of range

- Planimetric error vs. target distance



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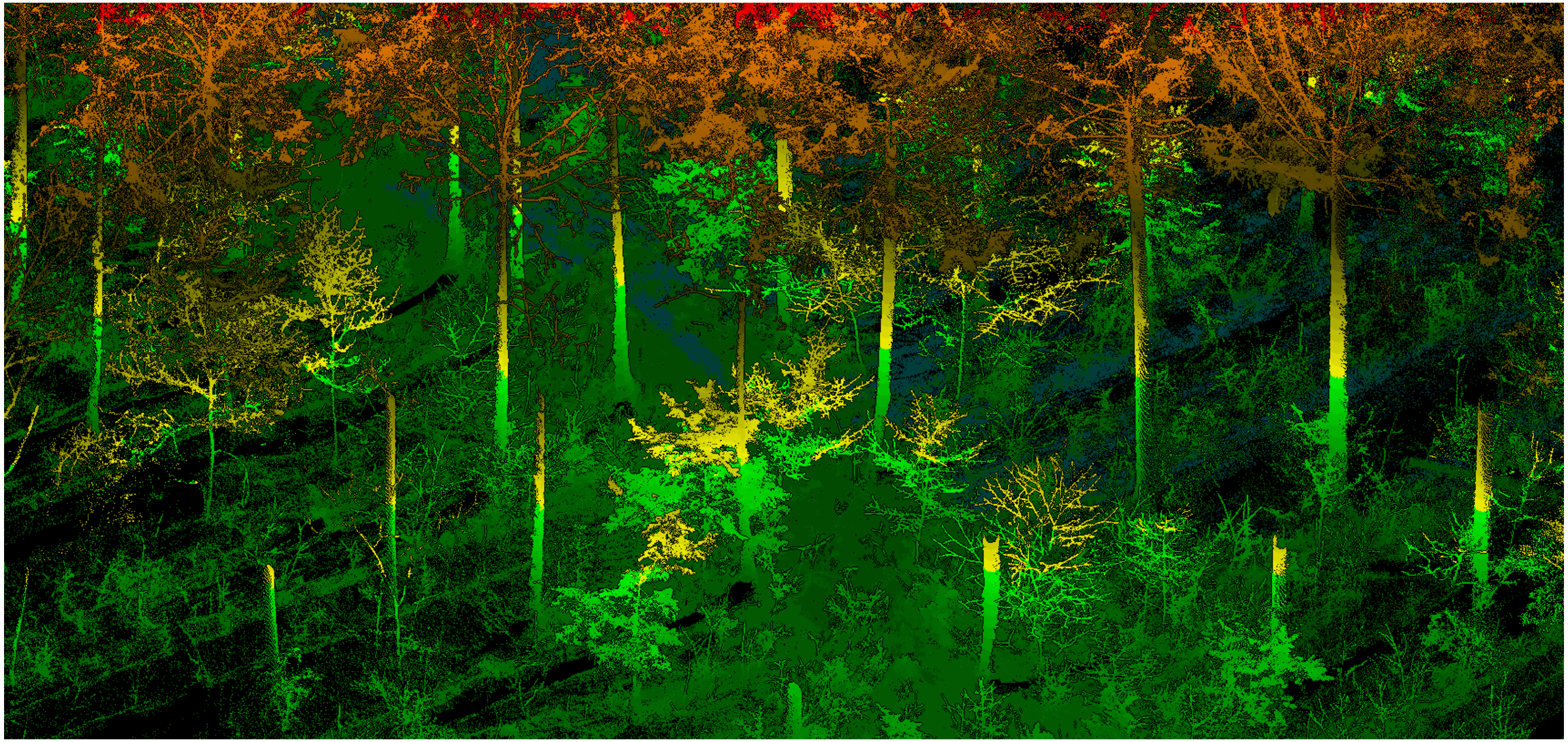
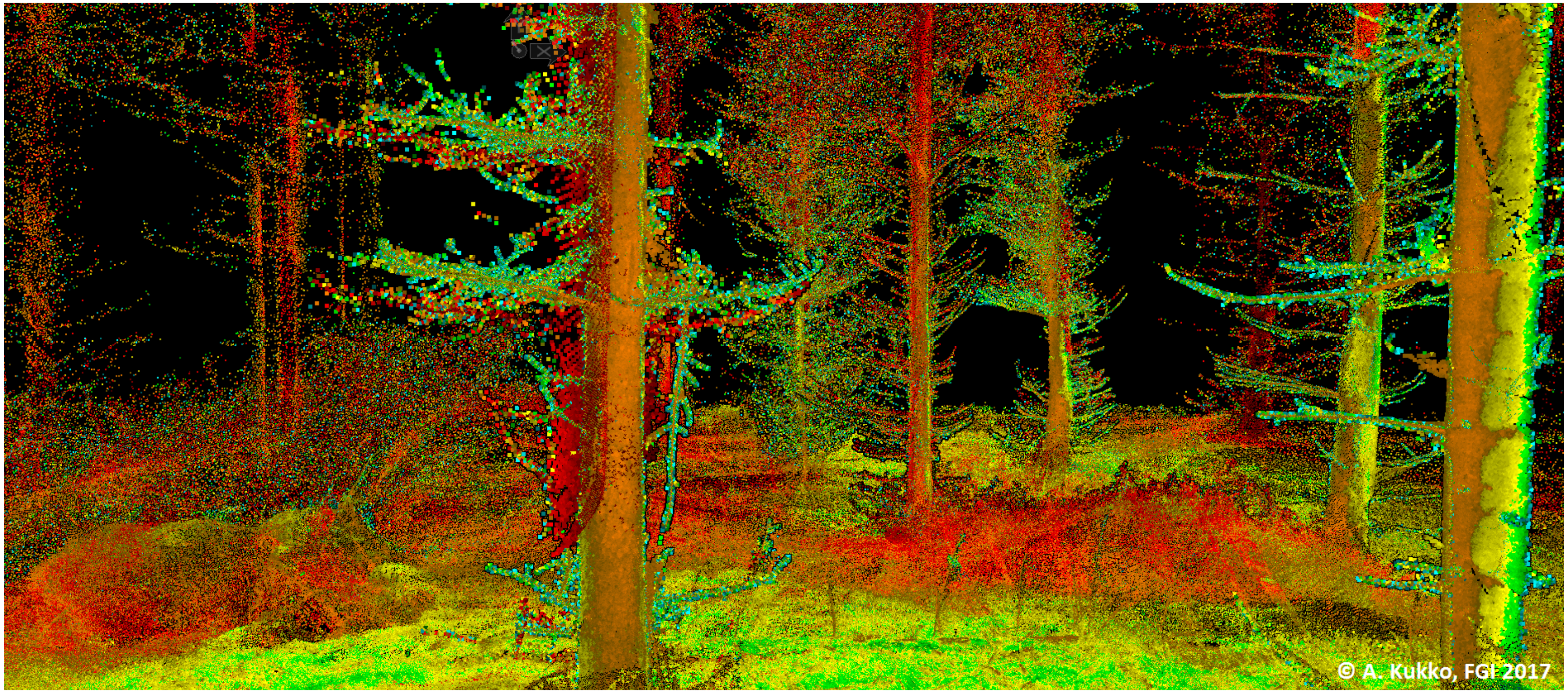
SLAM included



Sub 1 cm accuracy in georefencing



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Use of TLS

- Single scan/Multi Scan
- Trunk location
- Trunk diameters and trunk curves
- Tree Species
- ALS + TLS integration

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Courtesy to H. Kaartinen, FGI

Benchmarking: TLS for forest inventories

Participants

- 23 groups participated
- 18 provided their results
- Europe, Asia, North America

Partner	Country	Abbreviation
Chinese Academy of Forestry	China	CAF
Delft University of Technology / TU Delft	Netherlands	TUDelft
Finnish Geospatial Research Institute	Finland	FGI
Institut géographique national	France	IGN
Institute of Remote Sensing and Digital Earth	China	RADI
Nanjing University	China	NJU
Shinshu university	Japan	Shinshu
Swedish University of Agricultural Sciences	Sweden	SLU
Technical University in Zvolen	Slovakia	TUZVO
Technische Universität Wien / TU Wien	Austria	TUWien
The Silva Tarouca Research Institute for Landscape and Ornamental Gardening	Czech Republic	RILOG
Treemetrics	Ireland	TreeMetrics
University of Lethbridge	Canada	UofL
University of Padova	Italy	UNIPD
University of West Hungary	Hungary	NYME
Wuhan University	China	WHU

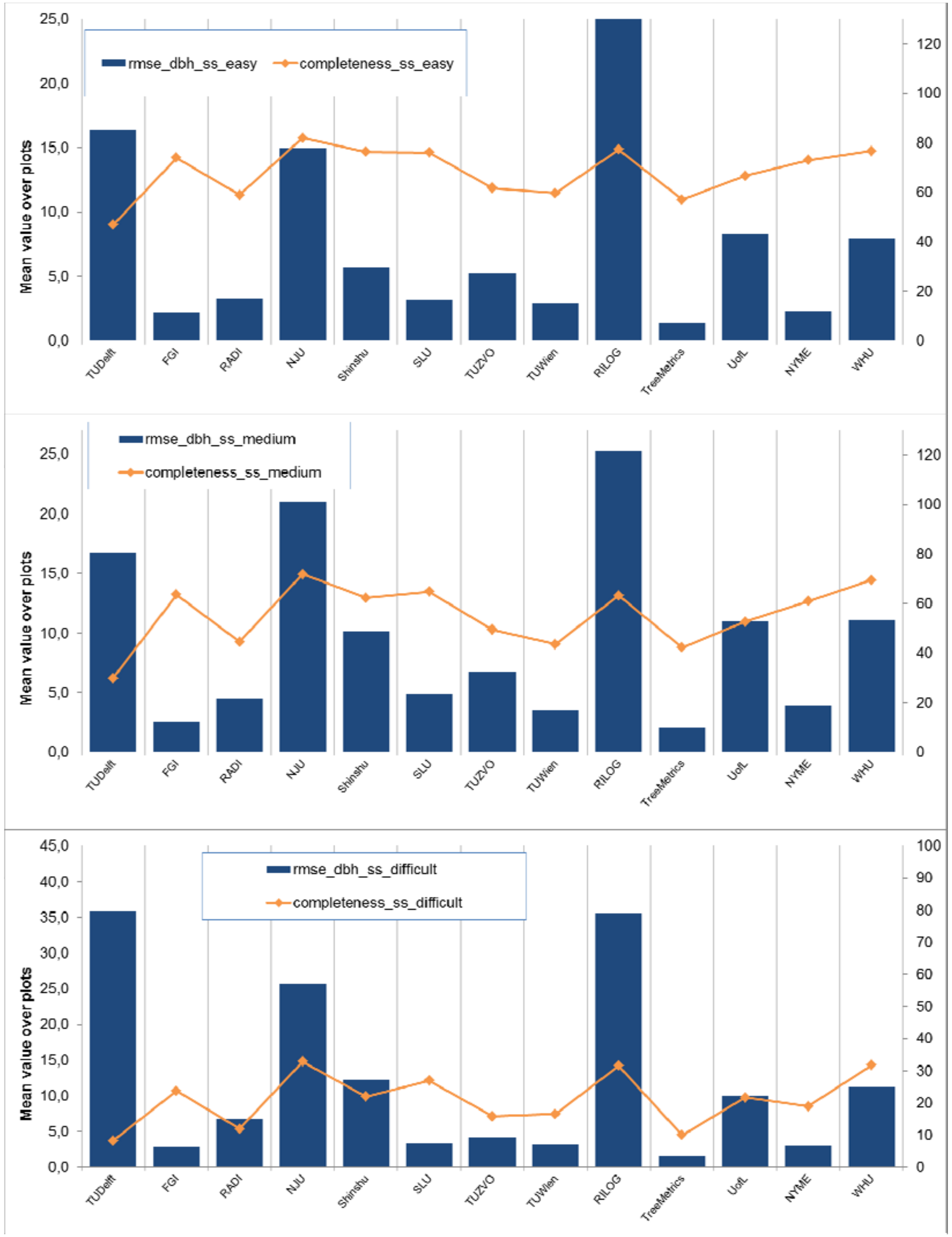
DBH RMSE

Single-scan

easy

medium

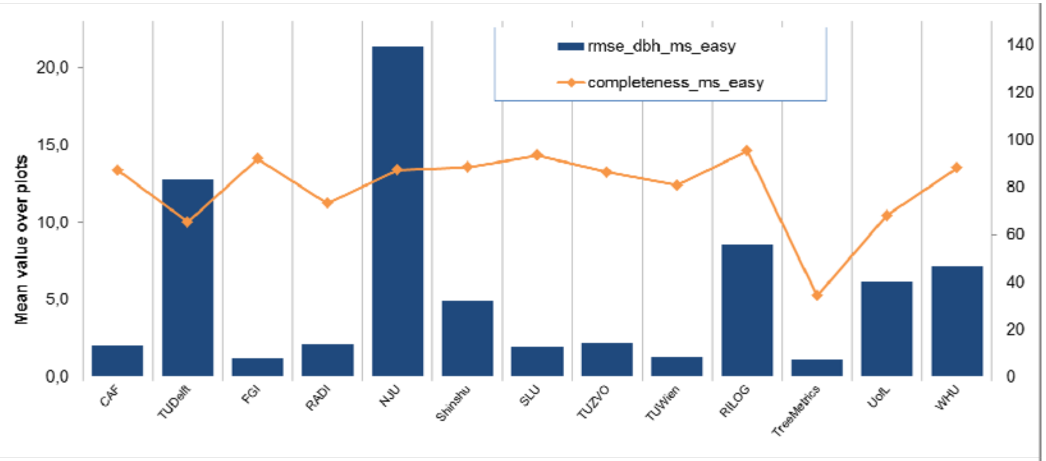
hard



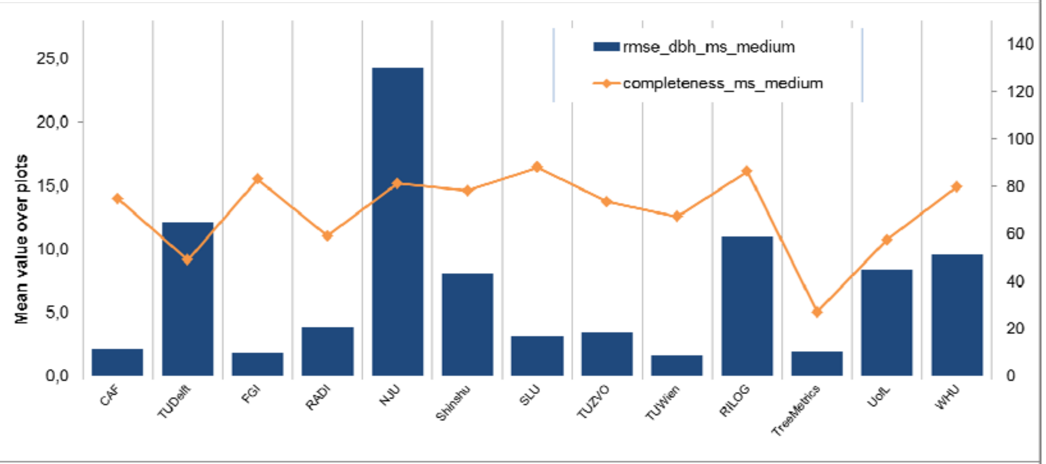
DBH RMSE

Multi-scan

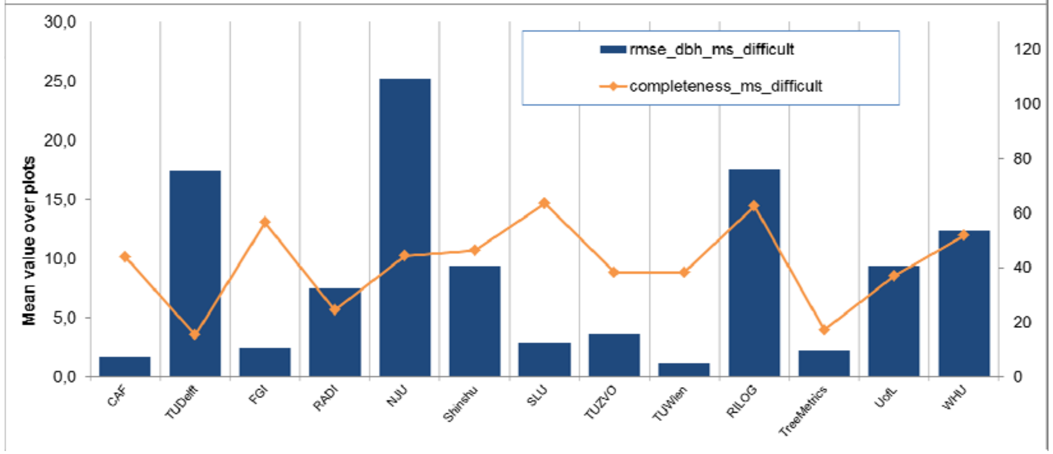
easy



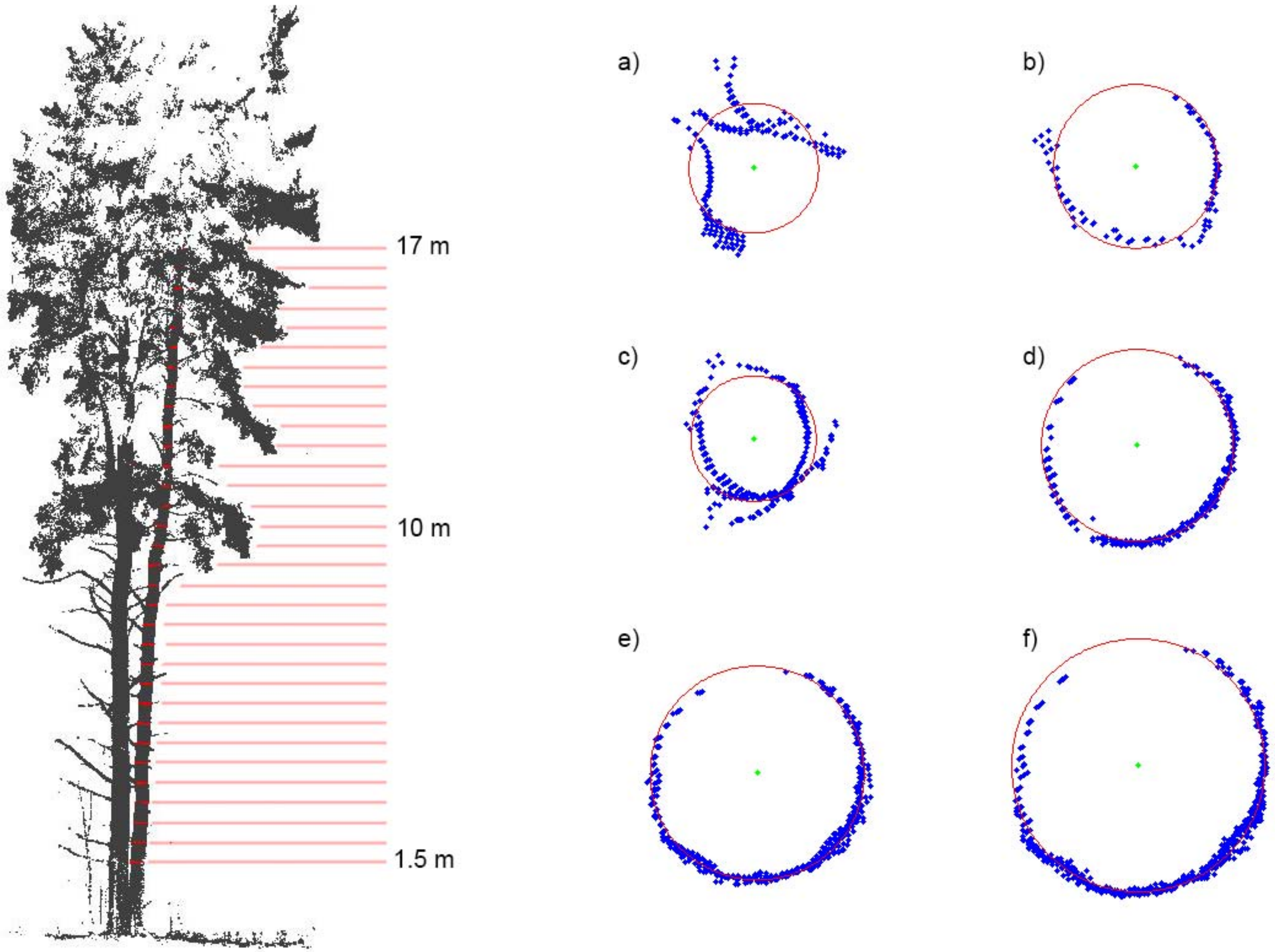
medium



hard



Effect of wind speed and georeferencing problems to the derivation of stem curve



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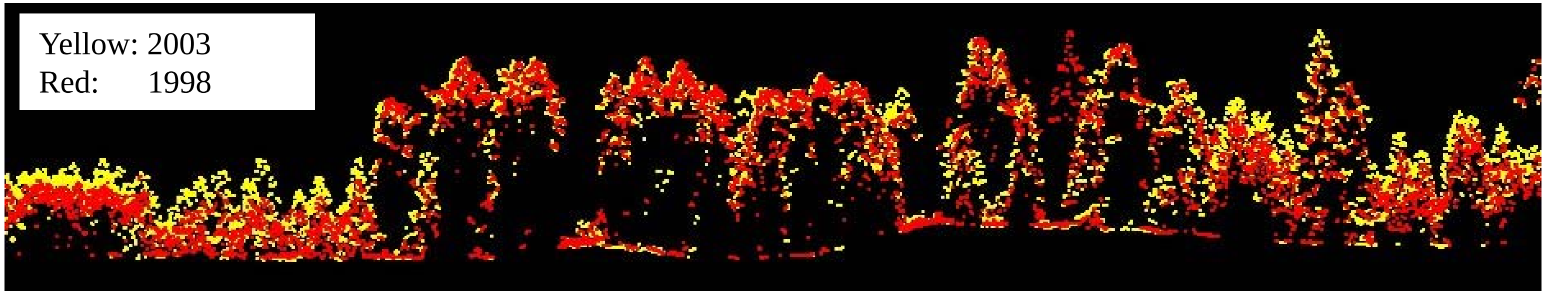
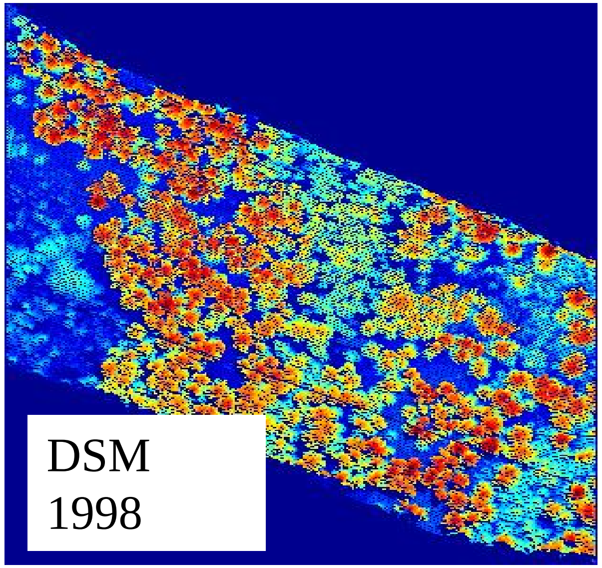
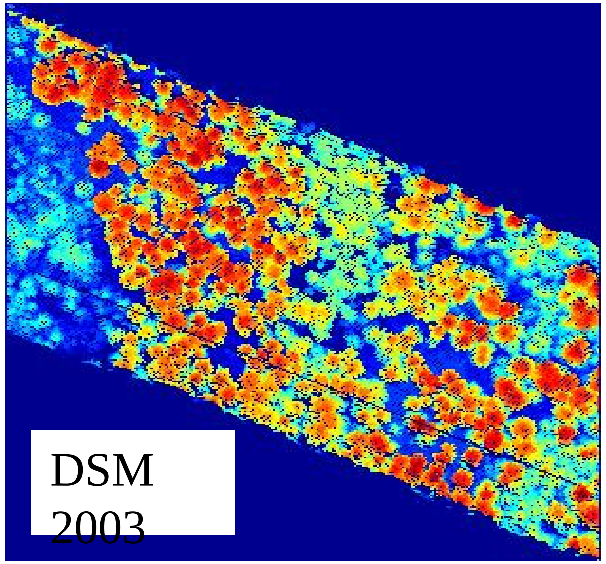
Forest Height Growth from ALS







Hyyppä, J., Yu, X., Rönnholm, P., Kaartinen, H., and H. Hyyppä, 2003. Factors affecting laser-derived object-oriented forest height growth estimation, *The Photogrammetric Journal of Finland,* Vol. 18(2), 16-31.

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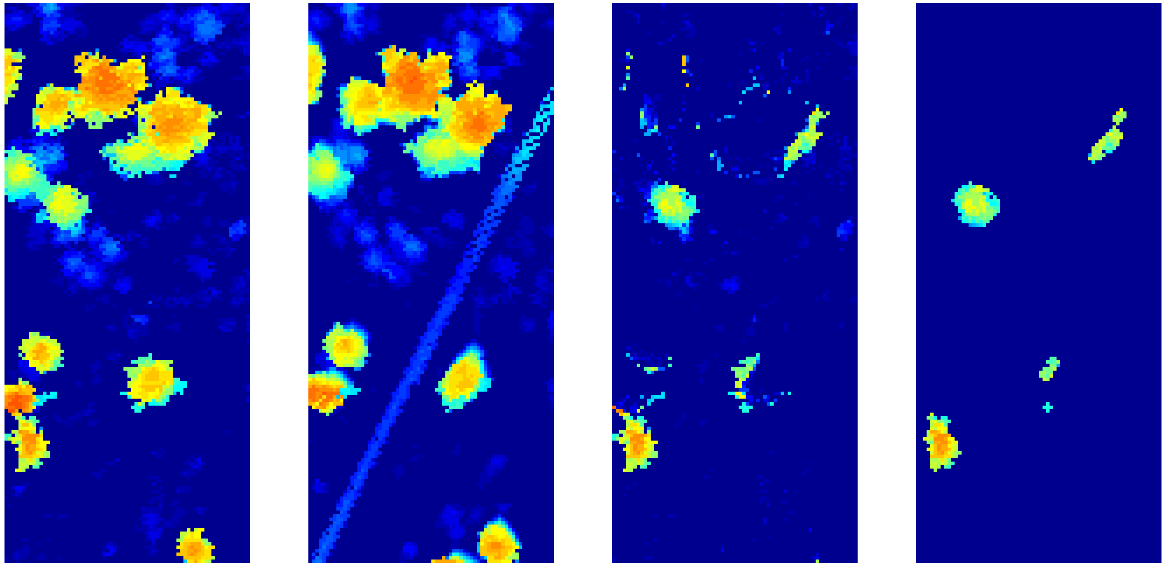
Courtesy to Xiaowei Yu, FGI

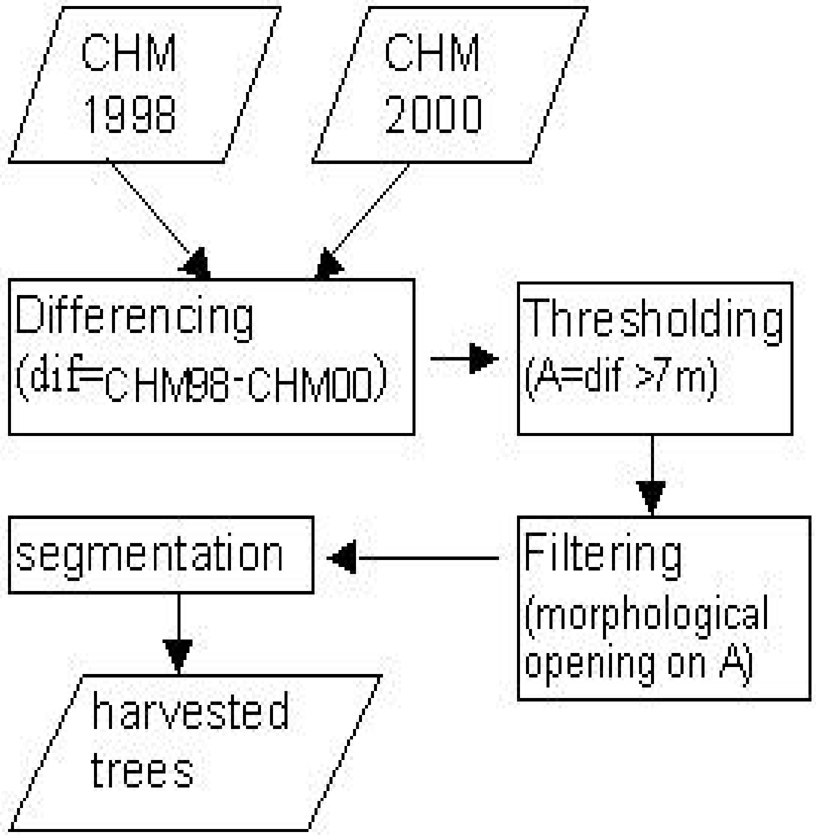
Added value of change detection

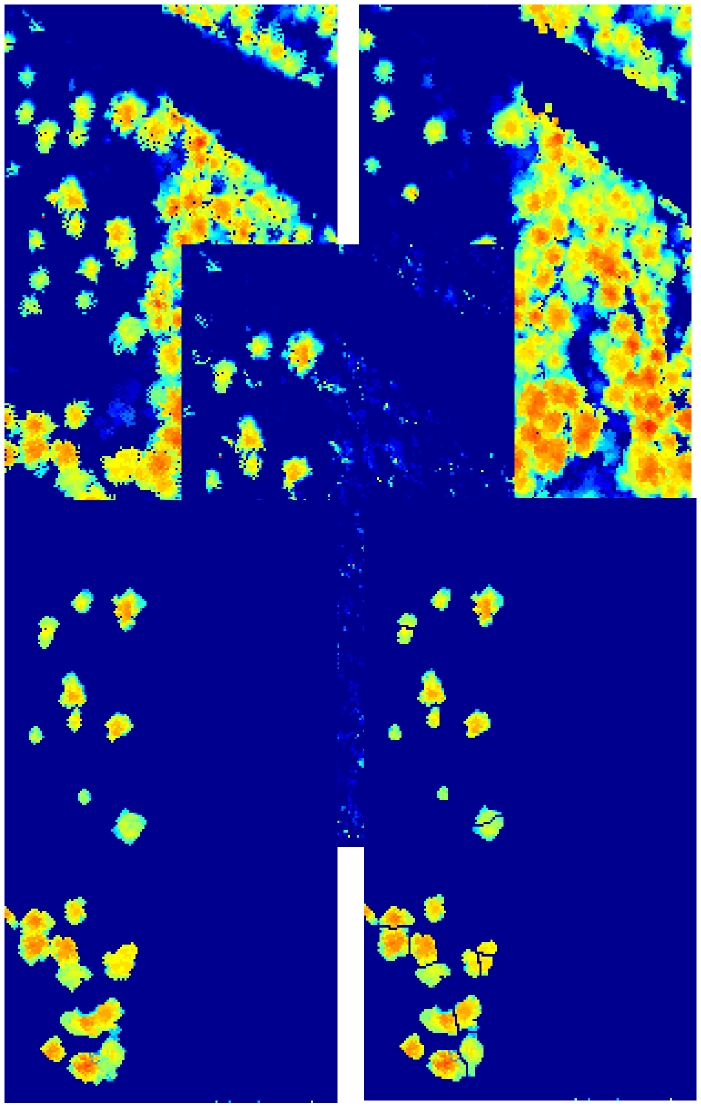


Yu, X., Hyyppä, J., Kaartinen, H., and M. Maltamo, 2004. Automatic detection of harvested trees and determination of forest growth using airborne laser scanning. *Remote Sensing of Environment*, Vol. 90, 451-462

Courtesy to Xiaowei Yu, FGI

Method - Harvested Trees Detection





Yu, X., Hyyppä, J., Kaartinen, H., and M. Maltamo, 2004. Automatic detection of harvested trees and determination of forest growth using airborne laser scanning. *Remote Sensing of Environment*, Vol. 90, 451-462

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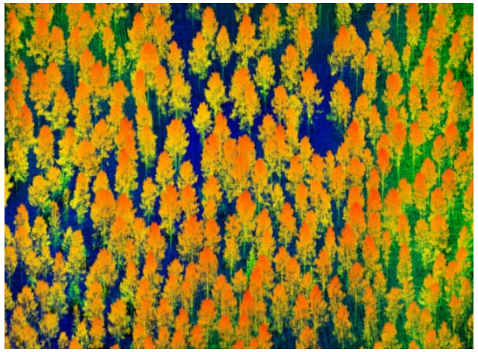
For autonomous driving and UAV merge for field data automizing



Autonomous Collection of Forest Field Reference—The Outlook and a First Step with UAV Laser Scanning
A Jaakkola, J Hyyppä, X Yu, A Kukko, H Kaartinen, X Liang, H Hyyppä, Remote Sensing 9 (8), 785

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Phone-based mapping

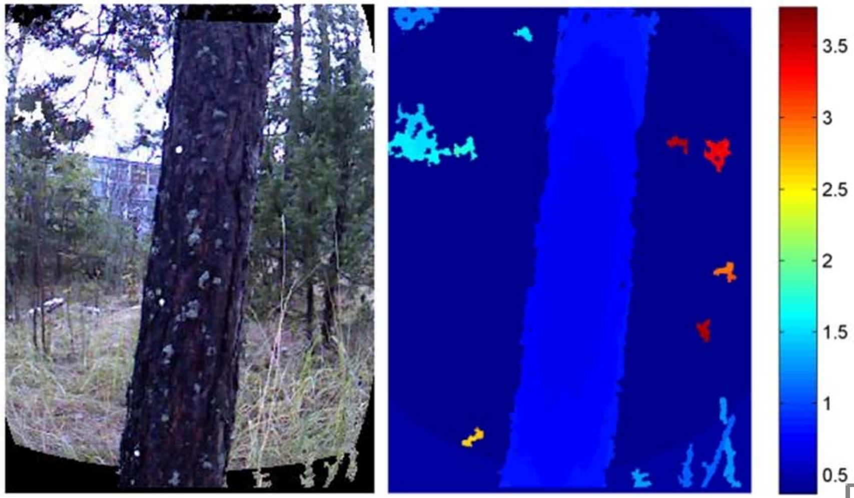
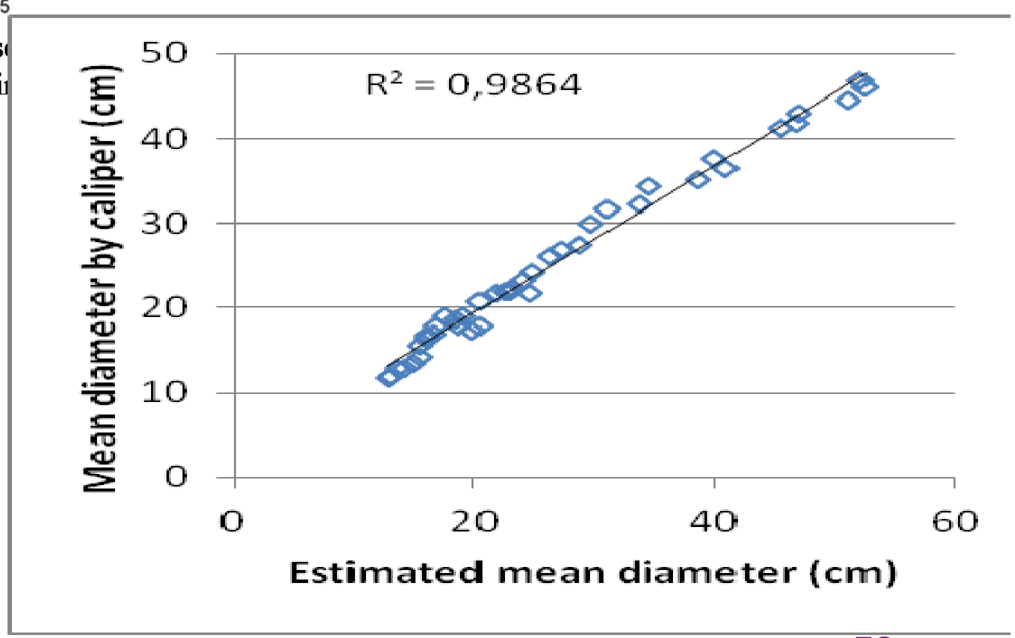


Figure 1. RGB image (left) and range image (right) taken by Kinect s
Markers pinned on the trunk can be visually identified from the RGB i

Feasibility of Google Tango and Kinect for Crowdsourcing Forestry InformationJ Hyyppä, JP Virtanen, A Jaakkola, X Yu, H Hyyppä, X Liang Forests 9 (1), 6



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Laser Scanning is digitalizing the forest information

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