

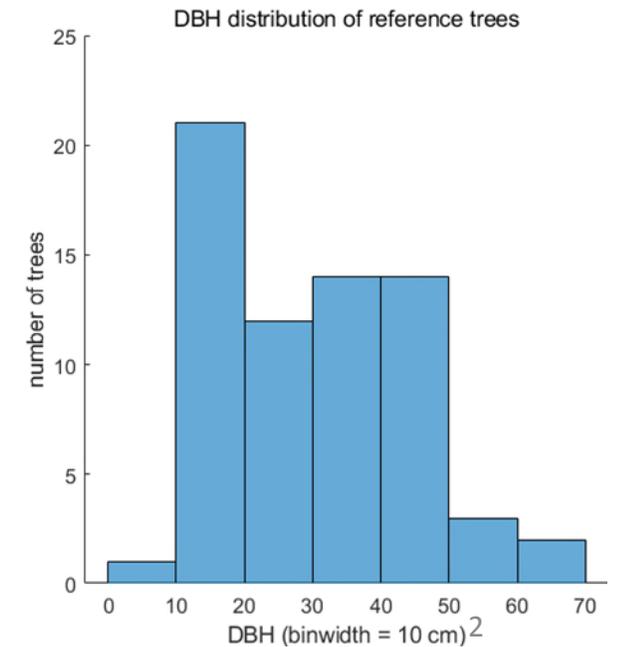
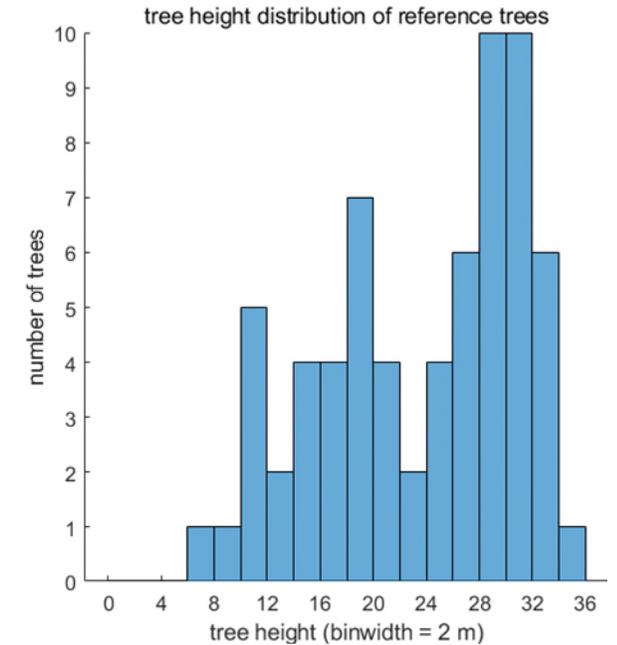
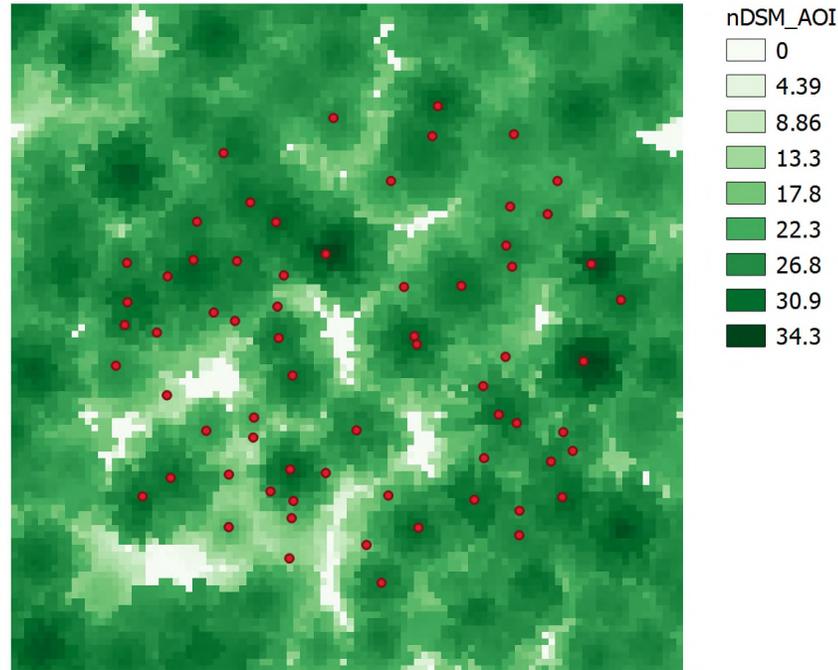
# Influence of ULS data acquisition characteristics on the achievable stem reconstruction accuracies

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# Study area

- Aubergwarte, Austria
- Coniferous forest
- 67 reference trees
- UAV-LiDAR data
  - VUX-1
  - miniVUX



EGU General Assembly, May 4-8, 2020

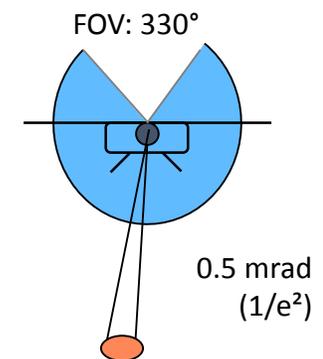
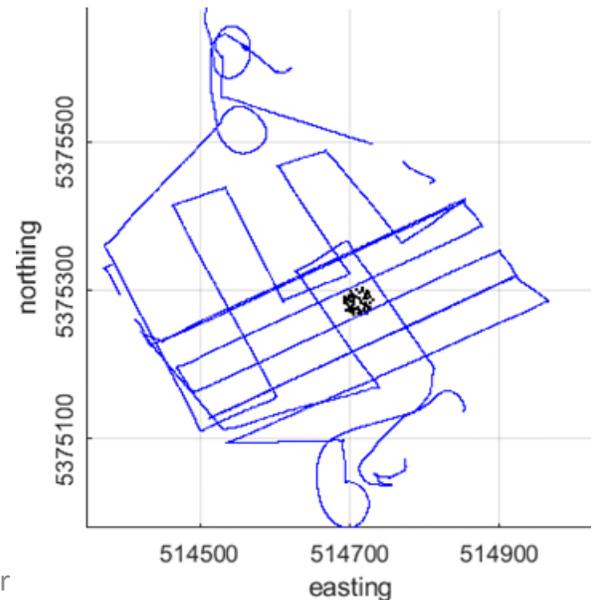
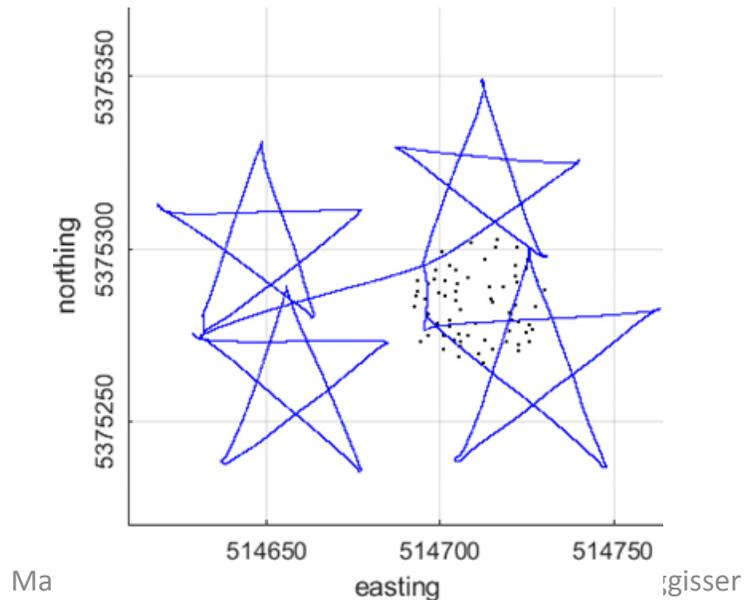
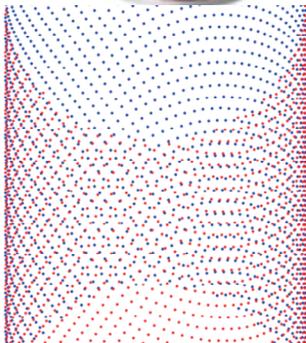


Bruggisser et al.

# LiDAR acquisitions

	miniVUX-DL	VUX-1
Field of View	23° off-Nadir	330°
Scanning pattern	Circular scan pattern (Palmer scan)	Linear scan pattern
Laser beam footprint	160 x 50 mm @ 100 m	50 x 50 mm @ 100 m
Range accuracy	15 mm	10 mm
Pulse repetition frequency	100 kHz	550 kHz
Average flying altitude	65 m	70 m

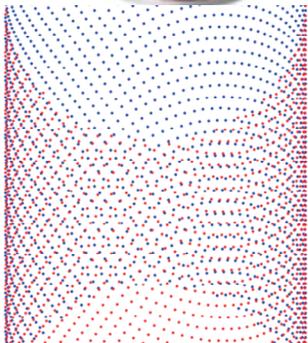
Images from <http://www.riegl.com>



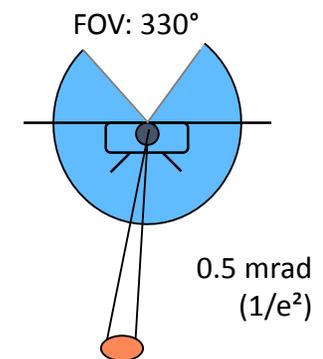
# LiDAR acquisitions

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Scanning pattern	Circular scan pattern (Palmer scan)	Linear scan pattern
Laser beam footprint	160 x 50 mm @ 100 m	50 x 50 mm @ 100 m
Range accuracy	15 mm	10 mm
Pulse repetition frequency	100 kHz	550 kHz
Average flying altitude	65 m	60 m

Images from <http://www.riegl.com>

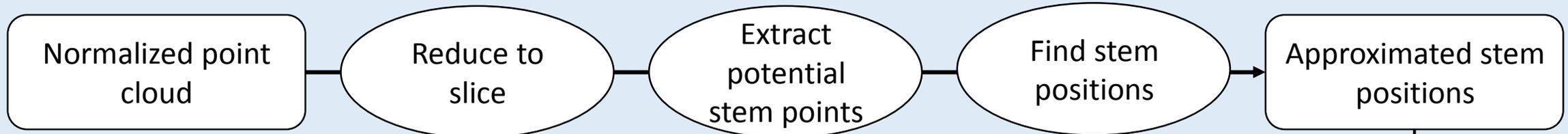


Acquisition	Point density [1/m <sup>2</sup> ]		Pulse density [1/m <sup>2</sup> ]	
	mean	median	mean	median
<b>miniVUX</b>	5716	4974	4044	3382
<b>VUX-1</b>	1831	1407	1402	1058

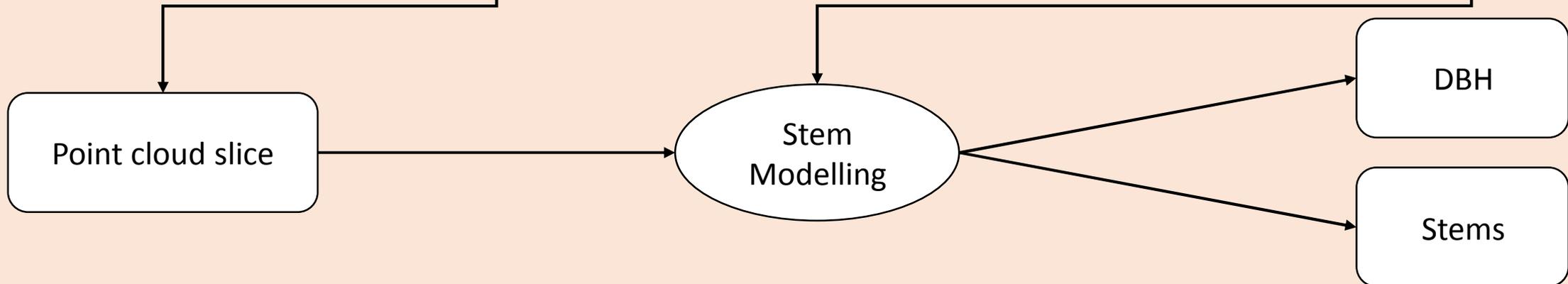


# Method – Overview

## 1. Detection of potential stems



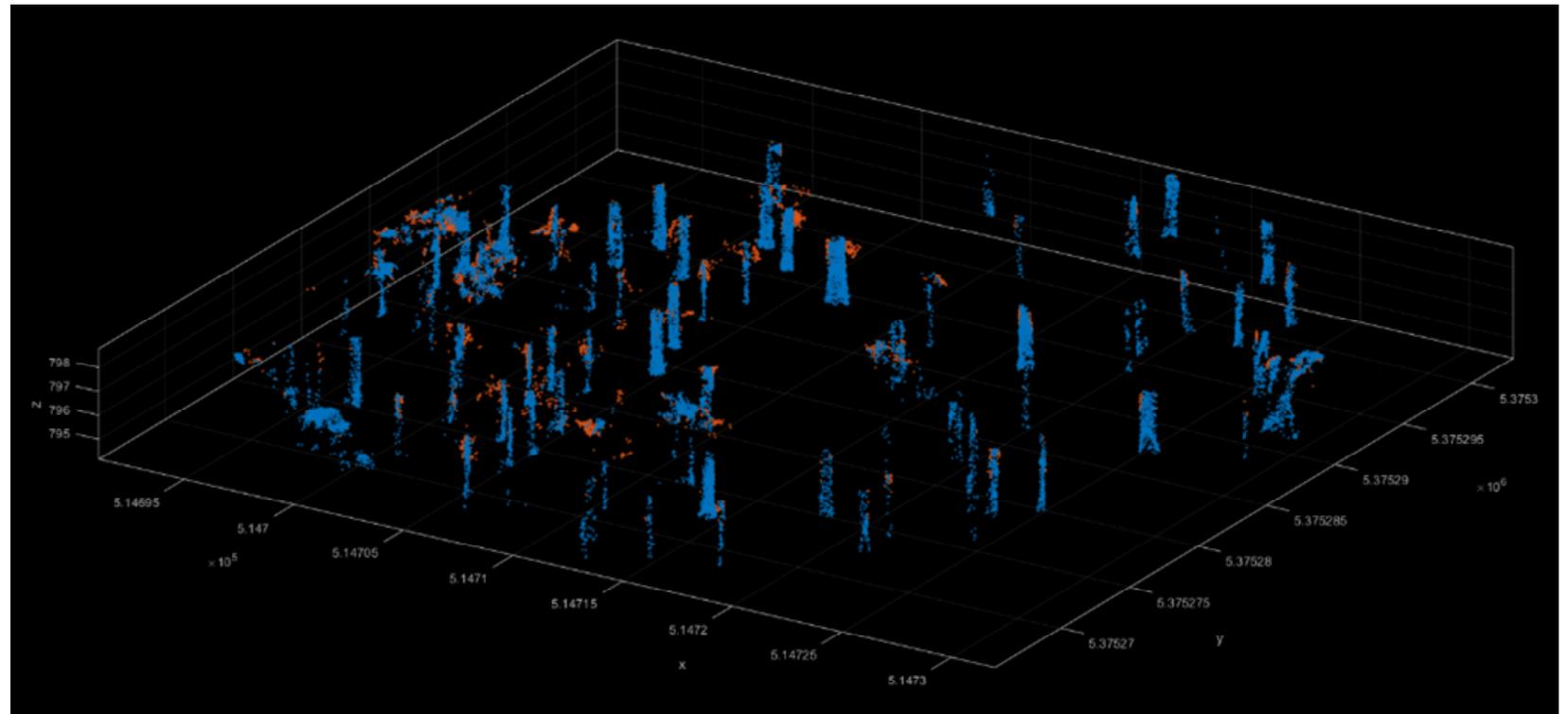
## 2. Stem modelling



# Method – Stem detection

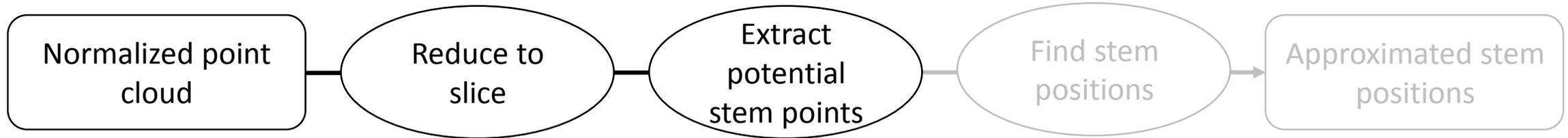


Criterion	Value
Normalized height	[0.4 m 3.0 m]
Return type	last echoes



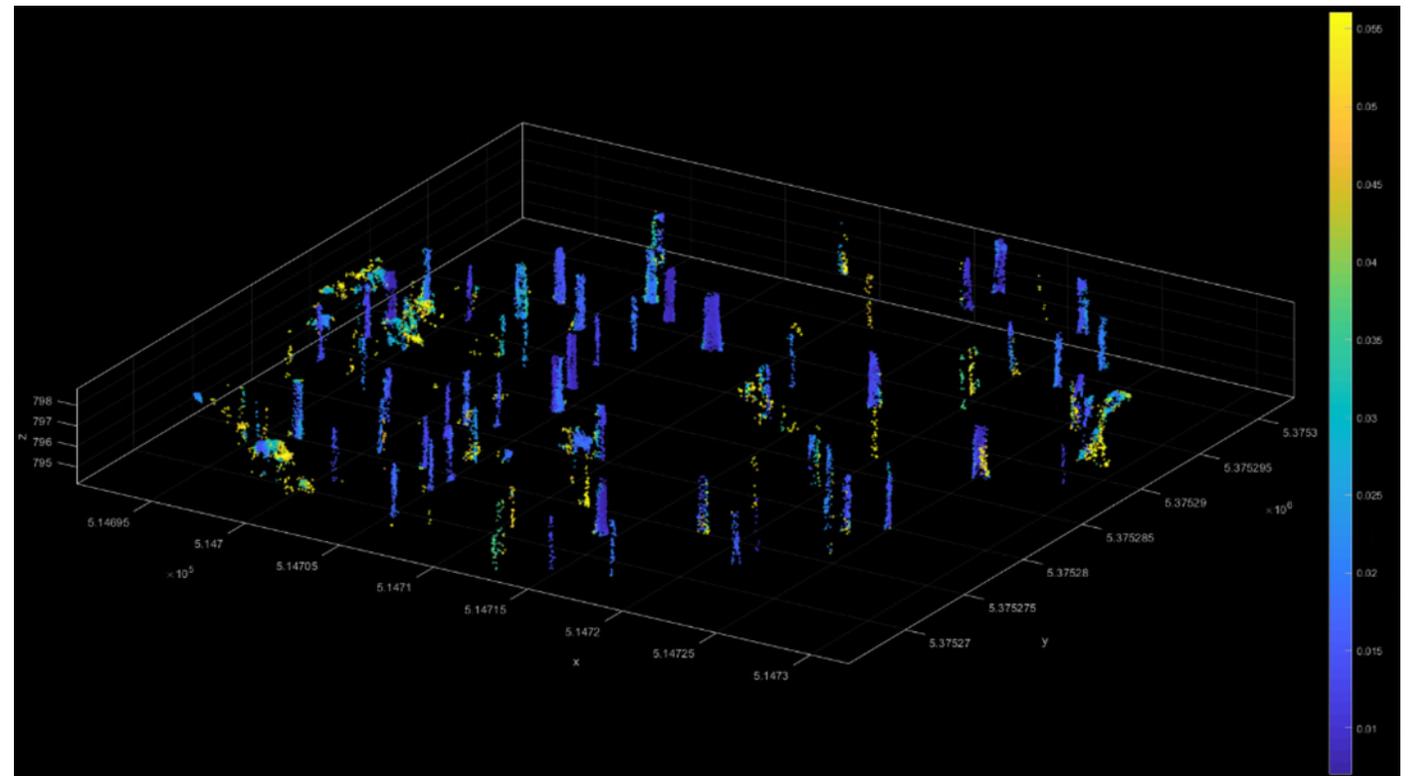
Point cloud slice with last returns (blue) and lower ranked returns (orange)

# Method – Stem detection



Attribute	Threshold
Point count 0.4-2.0 m	> 1
Point count 2.0-3.0 m	> 1
Average 2D point distance 0.4-2.0 m	< 0.1
Average 2D point distance 2.0-3.0 m	< 0.1

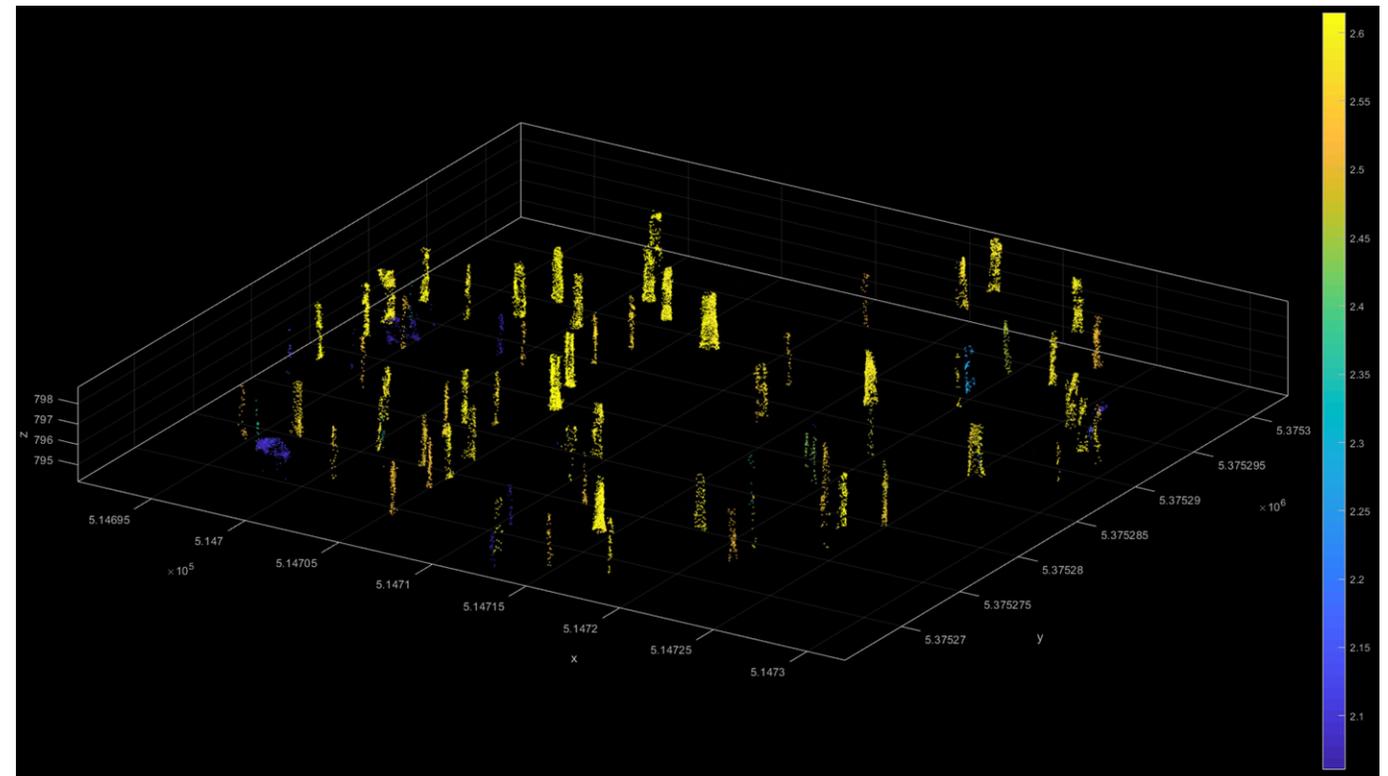
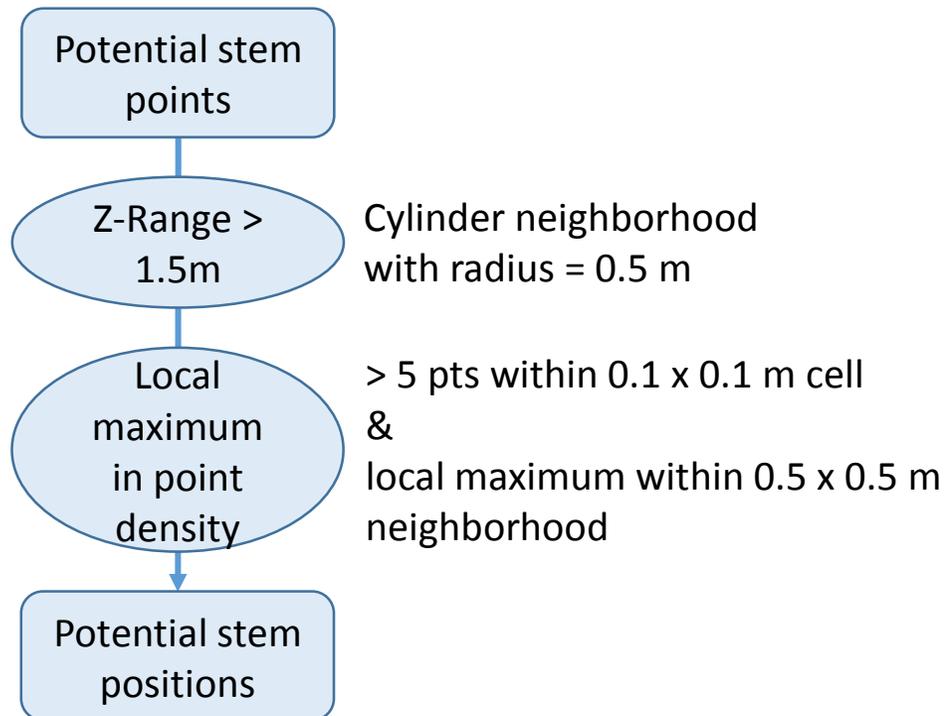
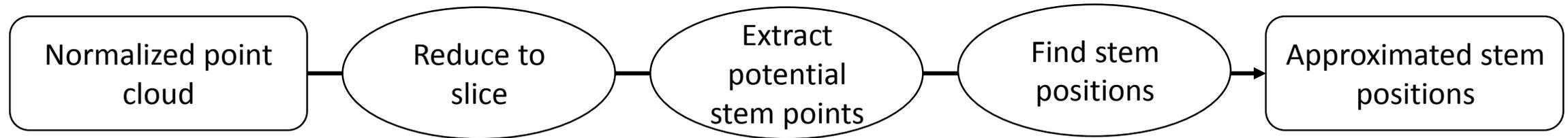
Considered point neighborhood: cylinder with radius = 0.2 m



Color: Average 2D point distance in range 2.0-3.0 m

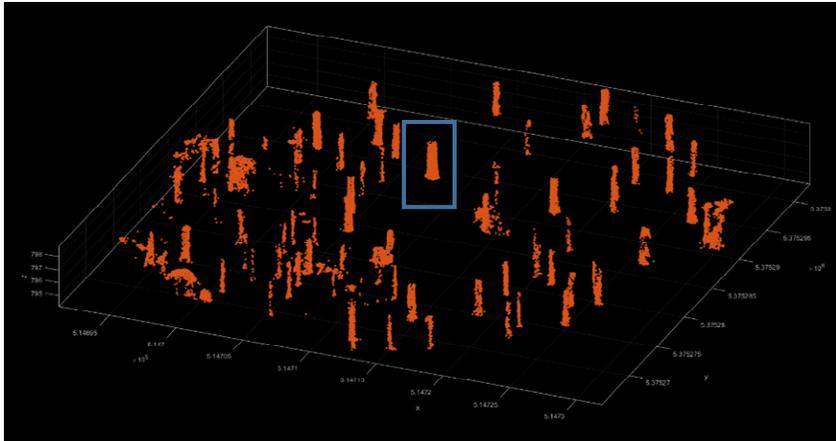
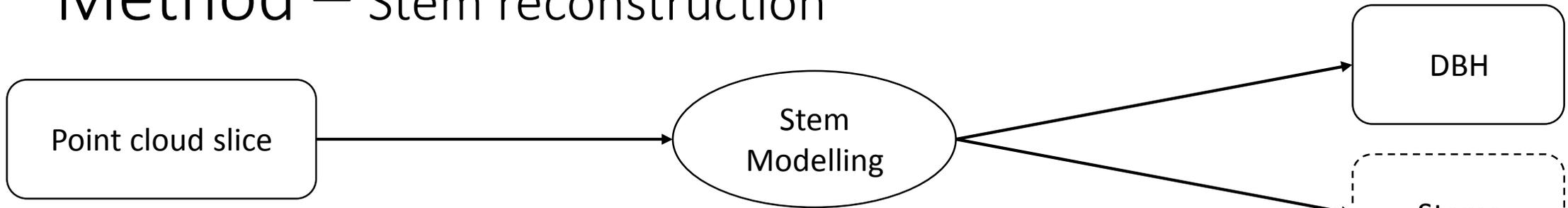
Bruggisser et al.

# Method – Stem detection

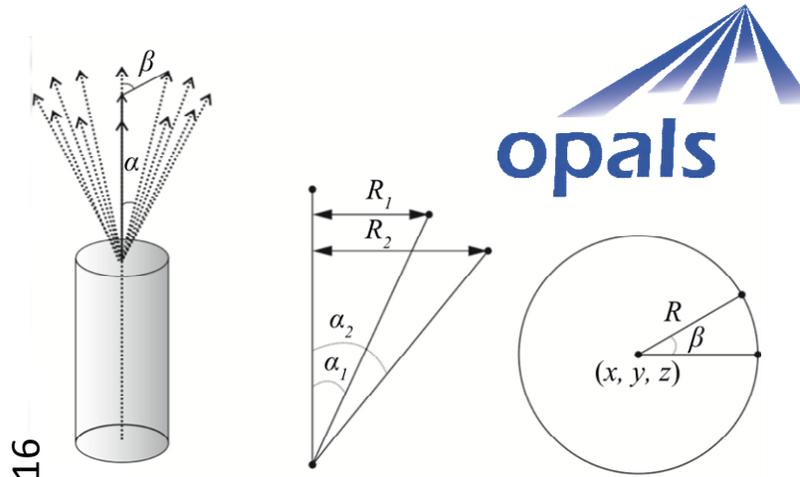


Z-Range  
Bruggisser et al.

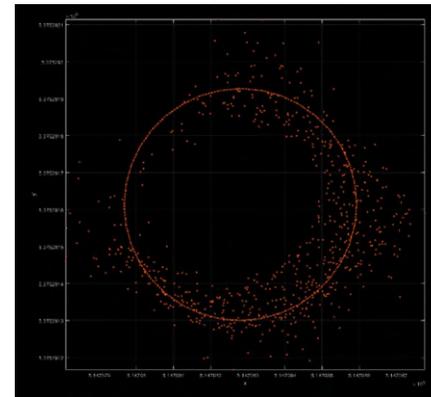
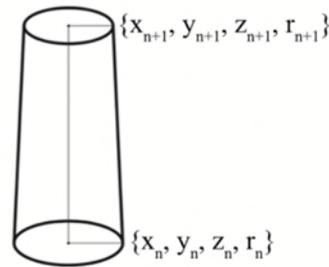
# Method – Stem reconstruction



Point cloud slice, miniVUX

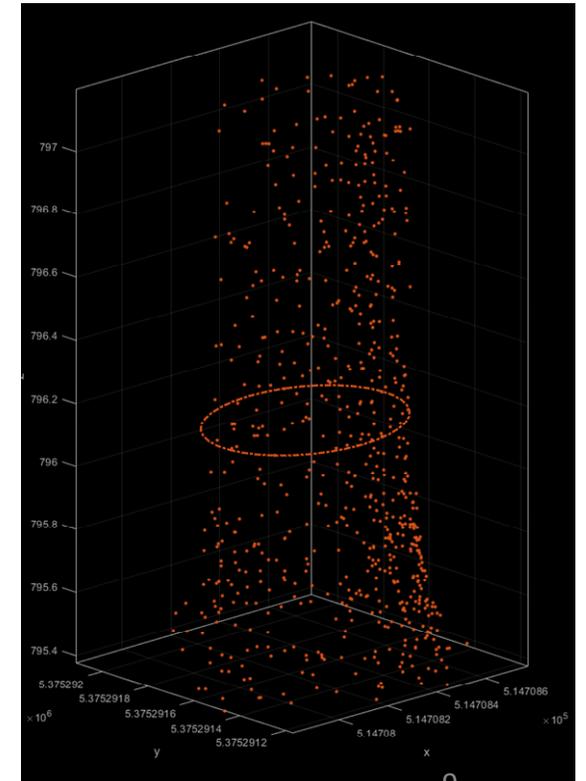


Wang et al., 2016



Bruggisser et al.

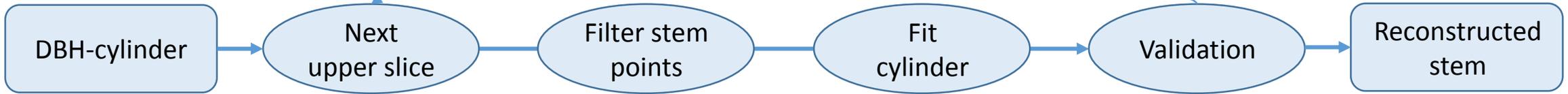
miniVUX, cylinder fit, 0.4-2.2m



# Method – Stem reconstruction

Do while:

1. Stem points above
2. Max skip = 3 heights



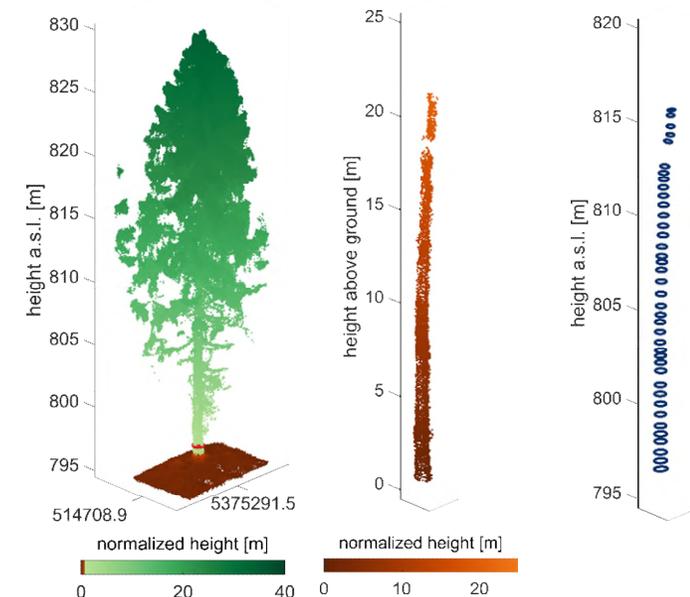
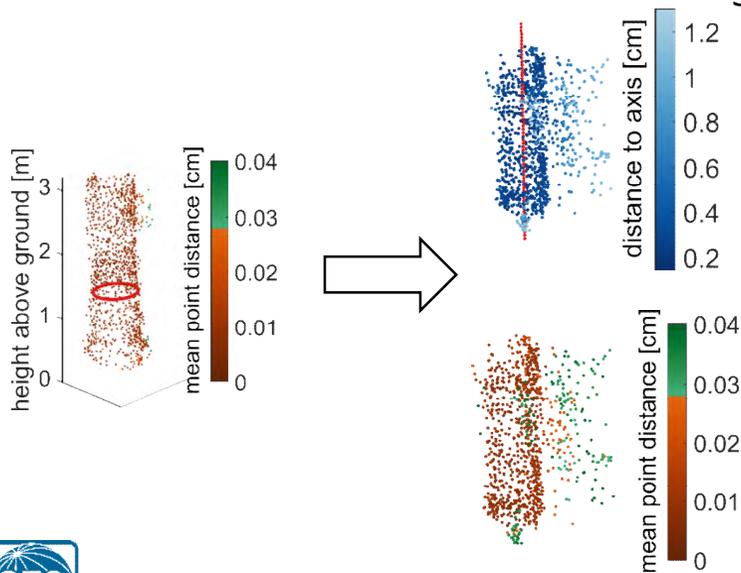
Height interval: 0.5 m  
Slice height: 1.6 m

Stem point criteria:

1. Mean distance to neighbors
2. Distance to stem axis
3. Z-range within neighborhood

Cylinder criteria:

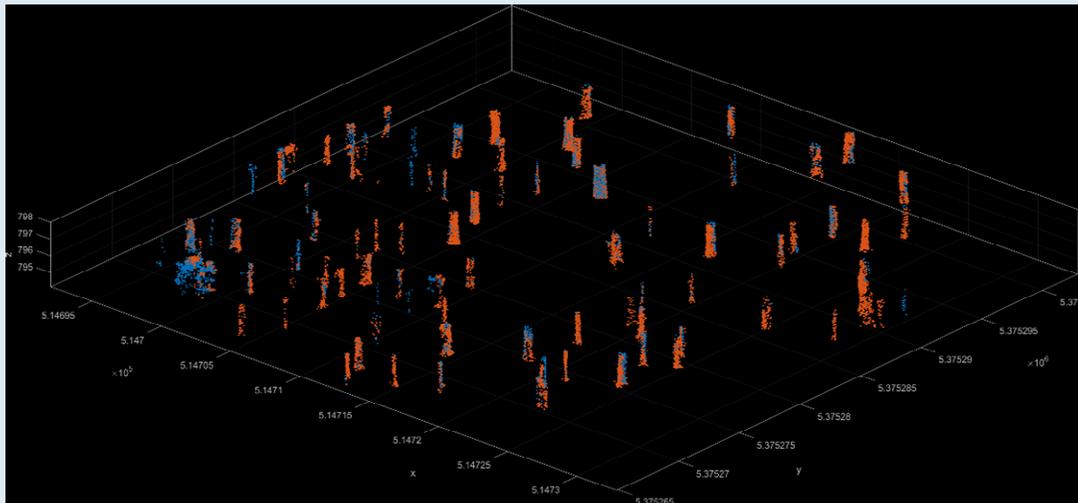
1. Diameter
2. Axis
3. Residuals



# Results – Stem detection rate & DBH retrieval

## 1. Detection of potential stems

	miniVUX	VUX-1
Detected trees	73	63
Correctly detected trees	65	55
Precision	89.0%	87.3%
Recall	97.0%	82.1%

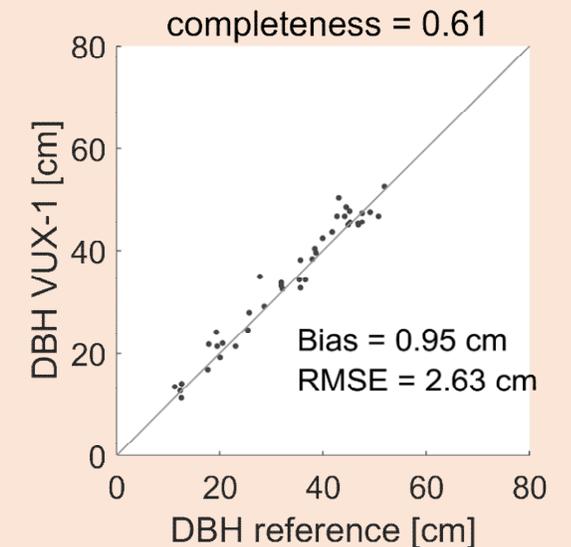
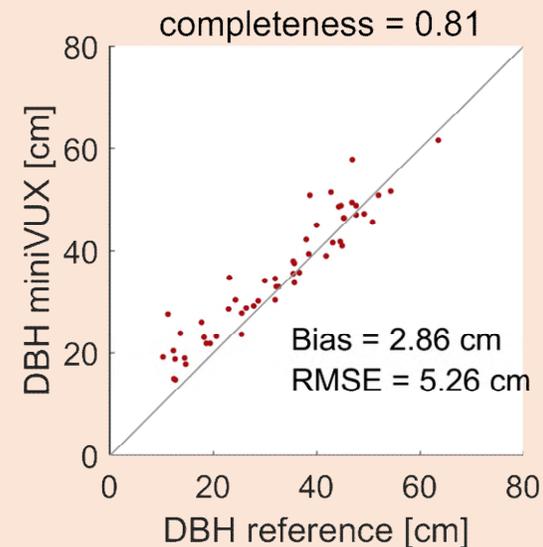


Orange: stem points from miniVUX; blue: stem points from VUX-1

## 2. DBH

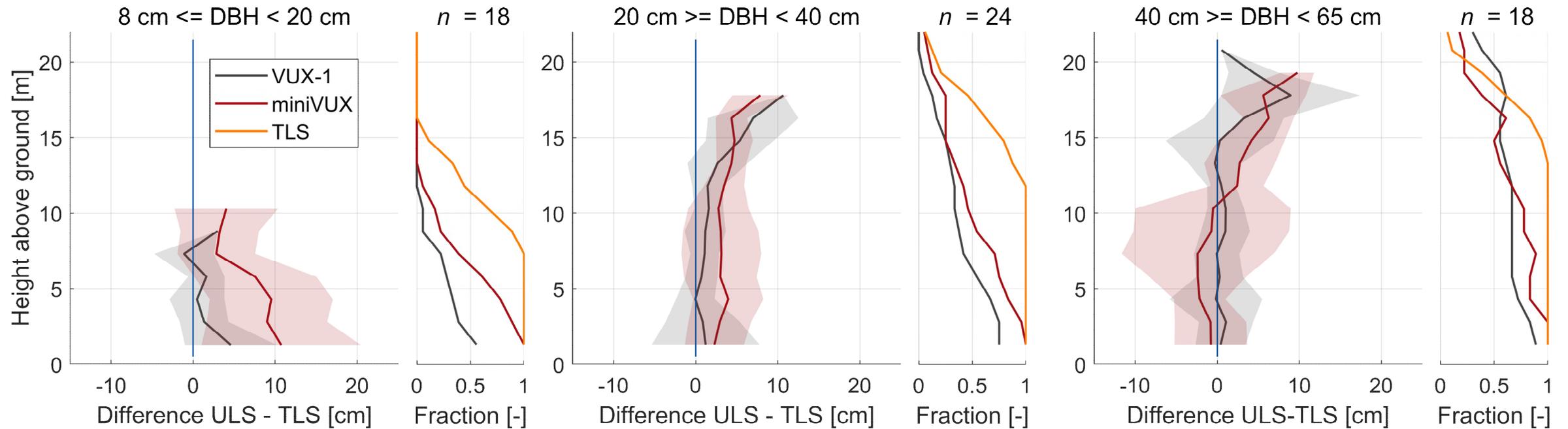
	miniVUX	VUX-1
Fitted and valid stems	54	41

Total number of stems in field reference: 67



# Results – Stem reconstruction

## Differences of diameter estimations from ULS to TLS across tree heights



Number of trees within the three DBH classes.

DBH	8 – 20 cm	20 – 40 cm	40 – 65 cm
Number of trees	22	26	19

# Results – Point density

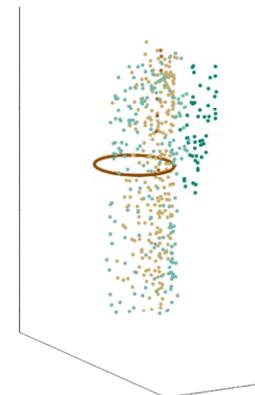
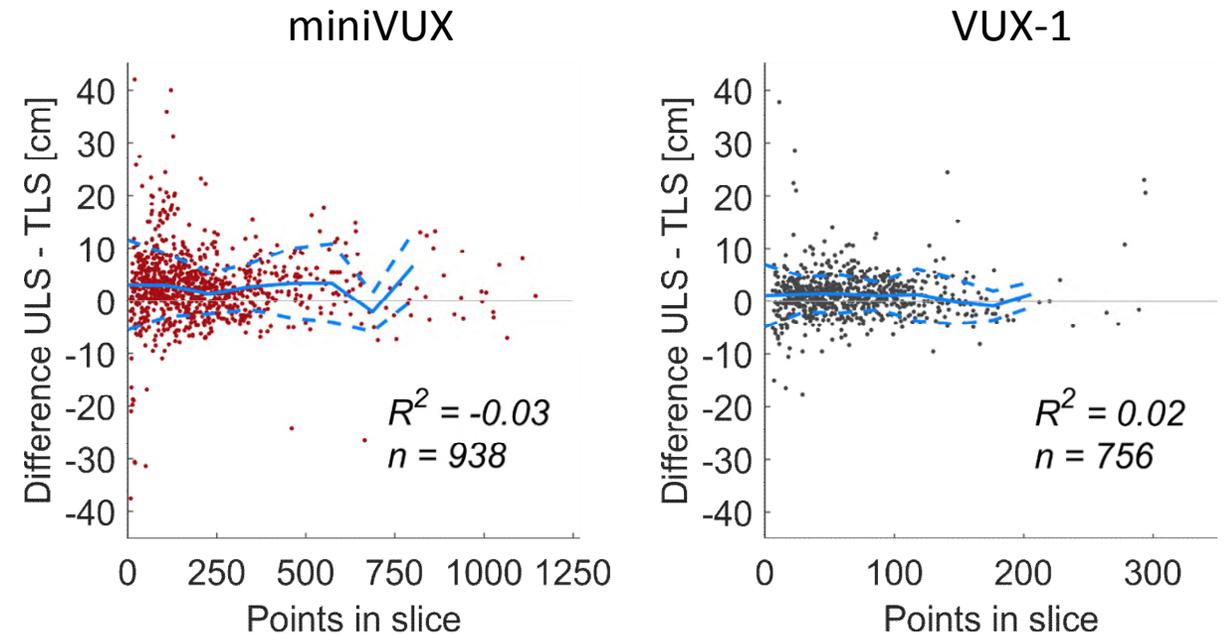
## Provided point densities

Acquisition	Point density [1/m <sup>2</sup> ]		Pulse density [1/m <sup>2</sup> ]	
	mean	median	mean	median
<b>miniVUX</b>	5716	4974	4044	3382
<b>VUX-1</b>	1831	1407	1402	1058

## Detection rates

	miniVUX	VUX-1
Detected trees	73	63
Correctly detected trees	65	55
Precision	89.0%	87.3%
Recall	97.0%	82.1%

## Impact of point density on diameter estimation



Filter point slice, to which a cylinder was fitted.

# Discussion

## ULS in forest inventories

- VUX-1 allows accurate DBH-retrievals, accuracies from miniVUX were lower
- Stems with DBHs  $> 20$  cm can be modelled with differences to TLS below 1.6 cm (VUX-1) and 4.0 (miniVUX) up to 14 m above ground

## Influence of the point cloud quality

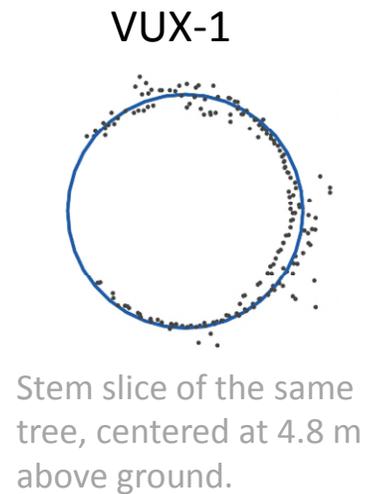
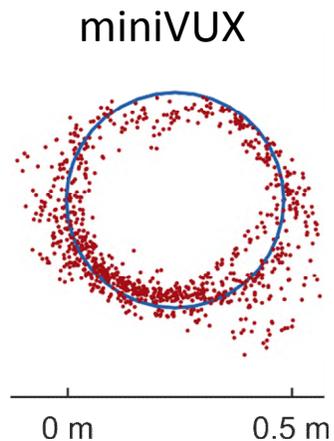
- Point density is relevant for the detection of the stems
  - Higher detection rate for the miniVUX-dataset
- Accuracy of estimated stem diameters is not affected by the local point density

# Discussion – System accuracy miniVUX vs. VUX-1

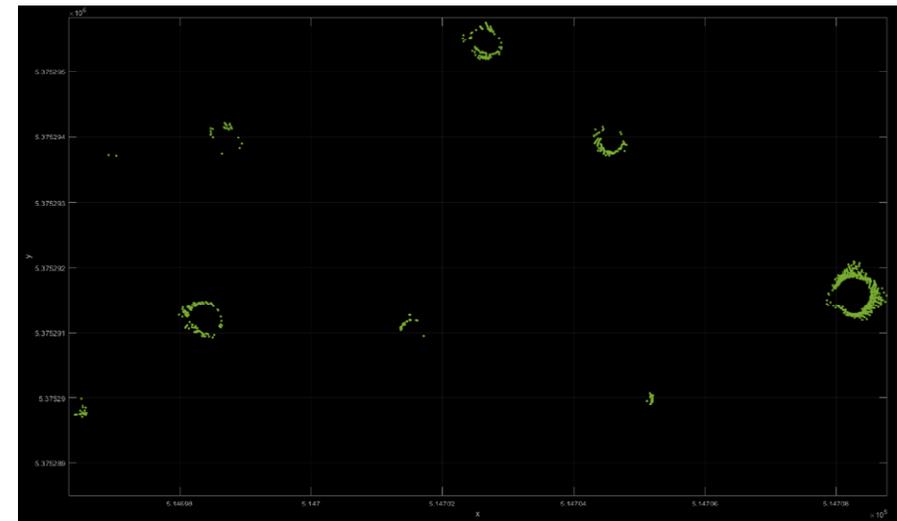
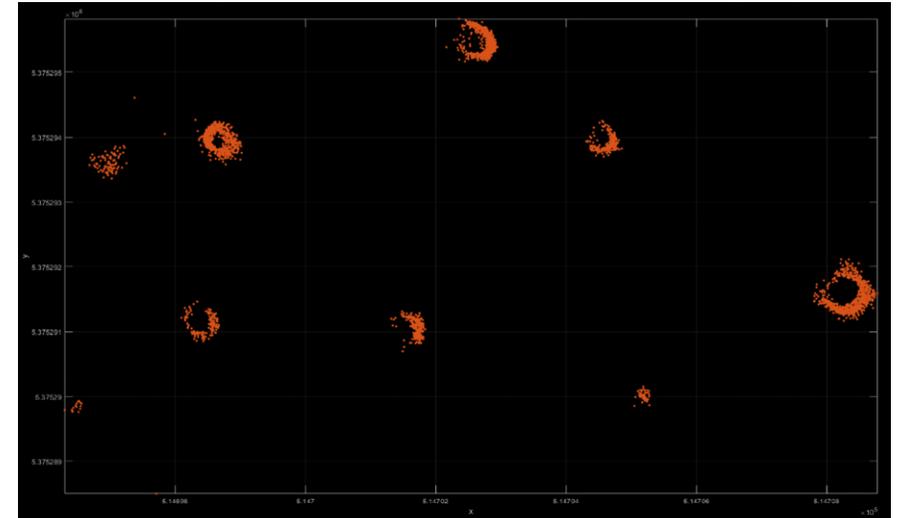
## Point distribution around the stems

- Related to sensor's range accuracy
- Determines accuracy of diameter estimations

	miniVUX-DL	VUX-1
Range accuracy	15 mm	10 mm



Point cloud slice 0.4-2.2m  
Orange: miniVUX  
Green: VUX-1



# Outlook

## Improvements

- Separation of leaf- and wood-points previous to stem detection



Wang, D., Brunner, J., Ma, Z., Lu, H., Hollaus, M., Pang, Y., & Pfeifer, N. (2018). Separating tree photosynthetic and non-photosynthetic components from point cloud data using dynamic segment merging. *Forests*, 9(5), 252.

Thank you for your attention !  
<http://www.geo.tuwien.ac.at/>

### Used software:

**Opals:** Orientation and processing of airborne Laser Scanning Data  
<http://geo.tuwien.ac.at/opals/html/index.html>