# Feasibility of using UAV-based LiDAR to estimate biomass in Icelandic forests:

## A test case from Fljótsdalur, east Iceland

Sydney Gunnarson[1], Silvia García Martínez[1], Tryggvi Stefánsson[1], Amir Hamedpour[1,3], Arnór Snorrason[2], Björn Traustason[2], Bjarki Þór Kjartansson[2], Lárus Heiðarsson[2]

LANDSSAMTÖK SKÓGAREIGENDA

skógræktin

SVARMI

[1] Svarmi ehf., Árleynir 22, 112 Reykjavík, Iceland
[2] Skógræktin, Mogilsá, is-162 Reykjavík, Iceland
[3] Landbúnaðarháskóli Íslands, Árleynir 22, 112 Reykjavík, Iceland

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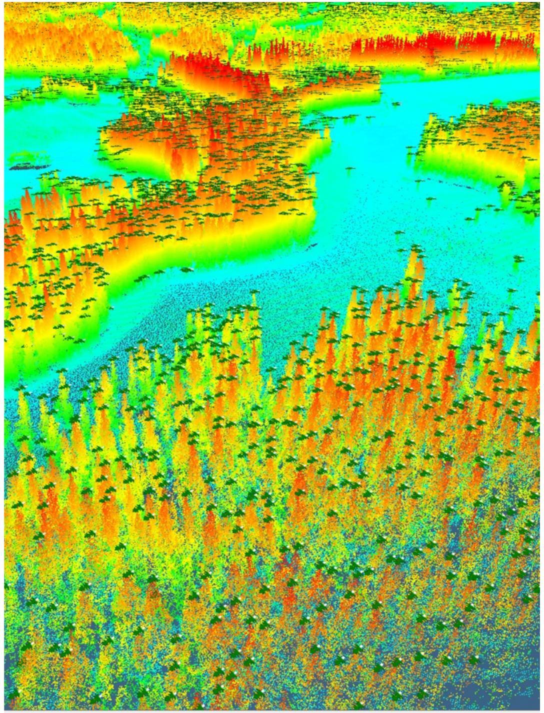
# Yfirlit kynningar


Part 1:
What is Svarmi?

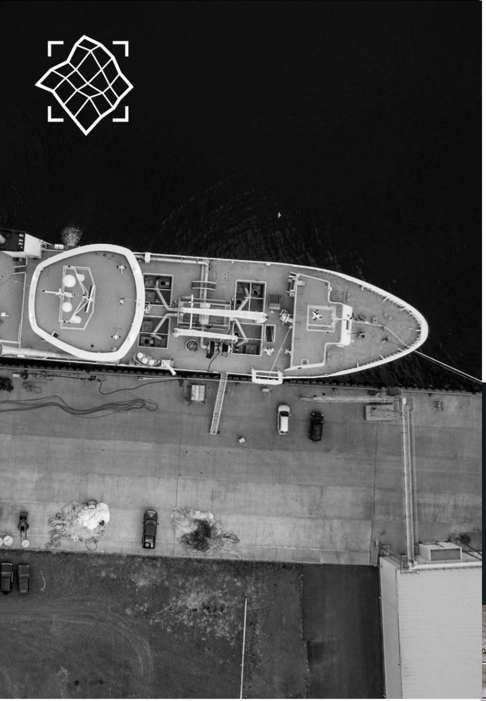


Part 2:
UAV LiDAR Fljótsdalur
Method & Results

Part 3:
Future of UAV LiDAR in
Icelandic forestry

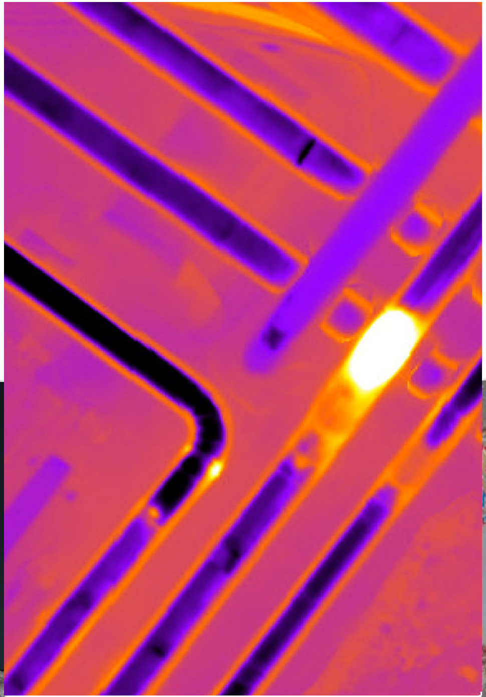
# Svarmi

- **Landlíkön og loftmyndir** þar sem stuðst er við gervitungl og dróna
- **Útdráttur upplýsinga** úr þessum gögnum meðal annars með vélrænum lærdómi
- **DATACT®** hugbúnaður sem eykur yfirsýn og auðveldar aðgengi að háupplausna gögnum í tíma og rúmi
- **Stuðlar að sjálfbærni** með bættri vöktun á umhverfi og innviðum



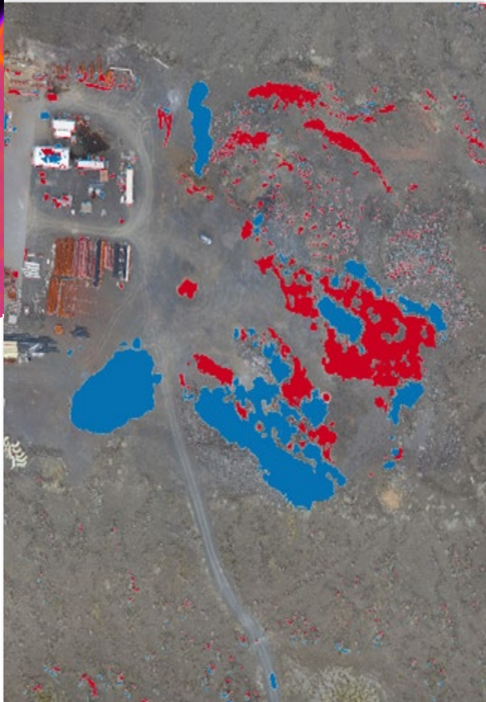
Highest-resolution
Aerial Imagery
& 3d Models

LiDAR
Scanning



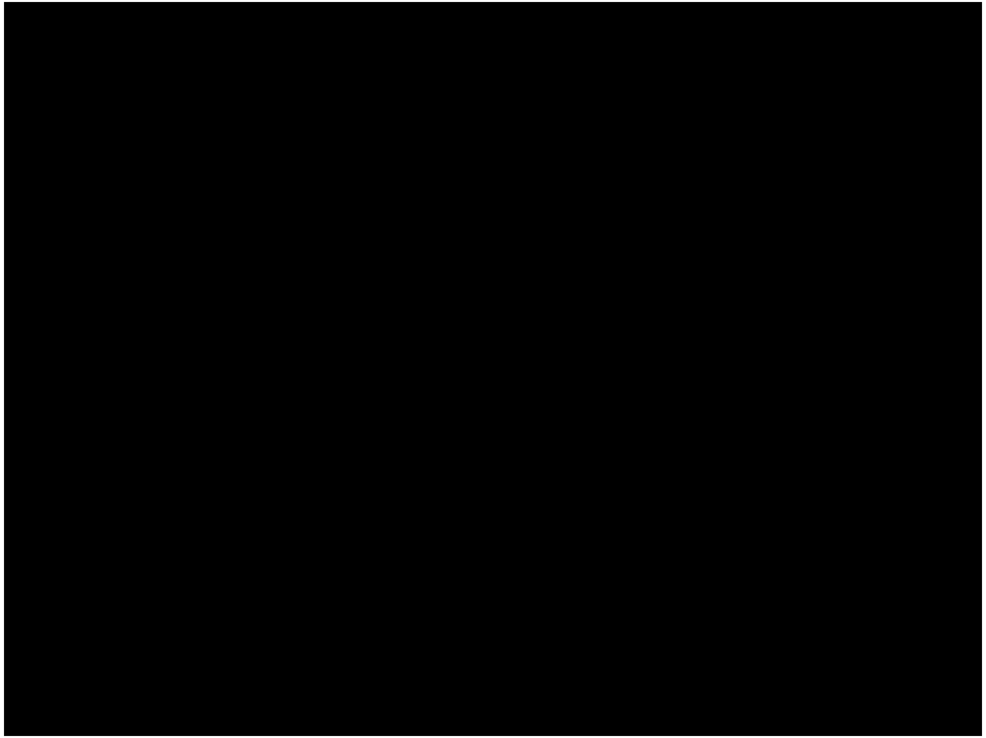
Thermal &
Multispectral
Imagery

Image
Analysis



# UAV LiDAR Flights

- Forested area in Fljótsdalur, East Iceland
- 3 Flights in total
- Total of about half a day of fieldwork
- Mapped about 150 ha in high resolution
- Forest is mainly Siberian Larch (rússalerki)



# LiDAR Pointcloud Of the forest

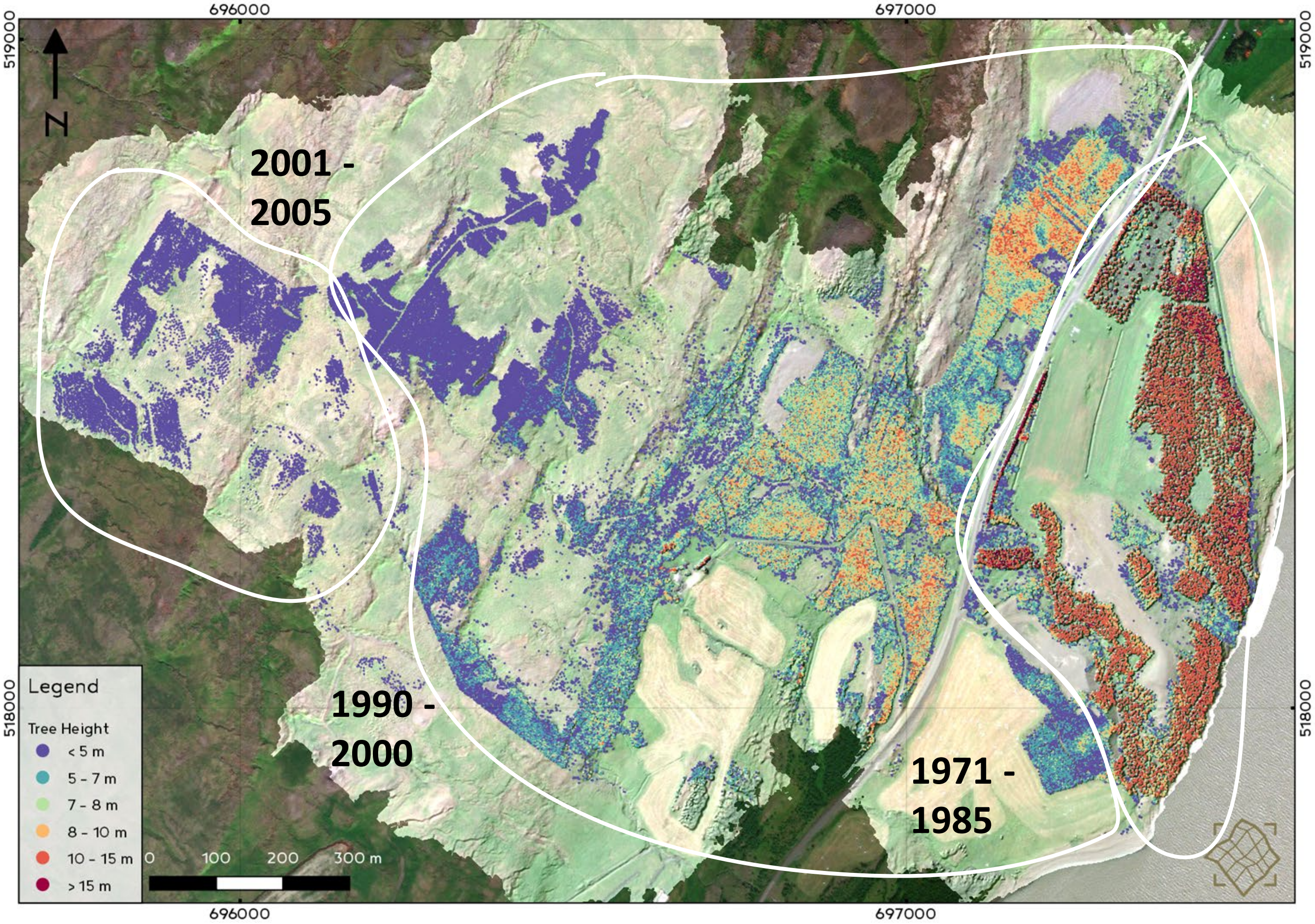
- Took a few hours to produce a pointcloud of the area
- Accuracy +- 3 cm
- 100 - 150 pt/m2 point density
  - Enough to see individual trees, but not to measure DBH

# Data Segmentation & Classification

- DTM (ground terrain model below trees) also created
- Tree canopy height model created, isolating tree points from ground

**Strata Segmentation:**

- Divided into 3 categories (strata) by age
- Growth rates and filters were applied differently to each strata area



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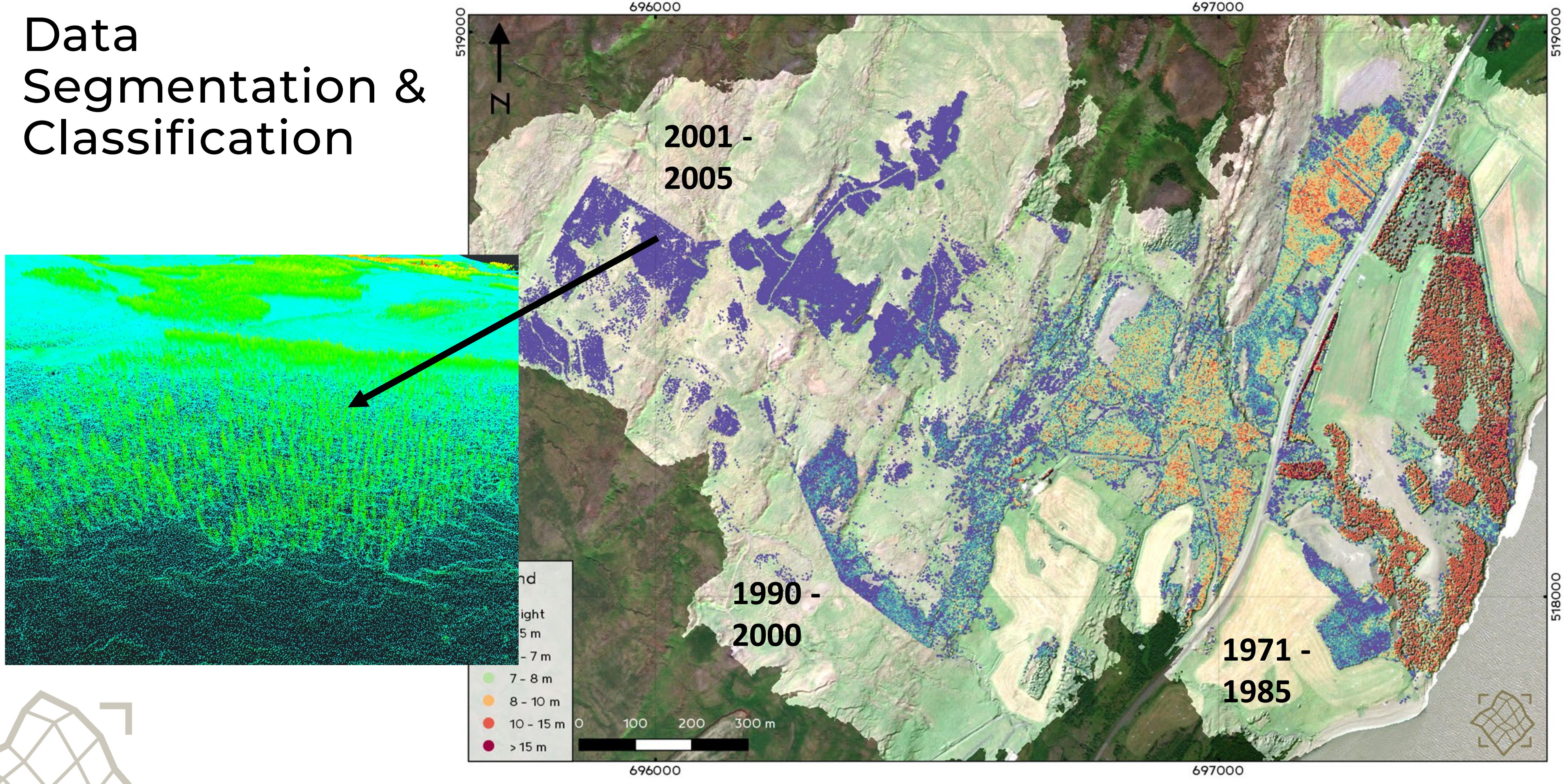

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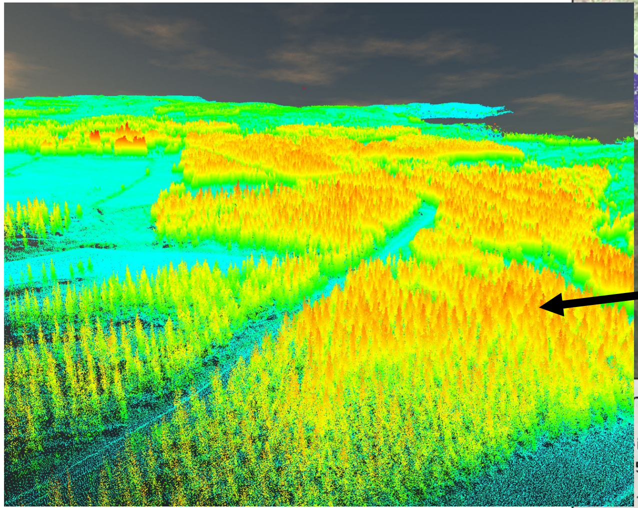

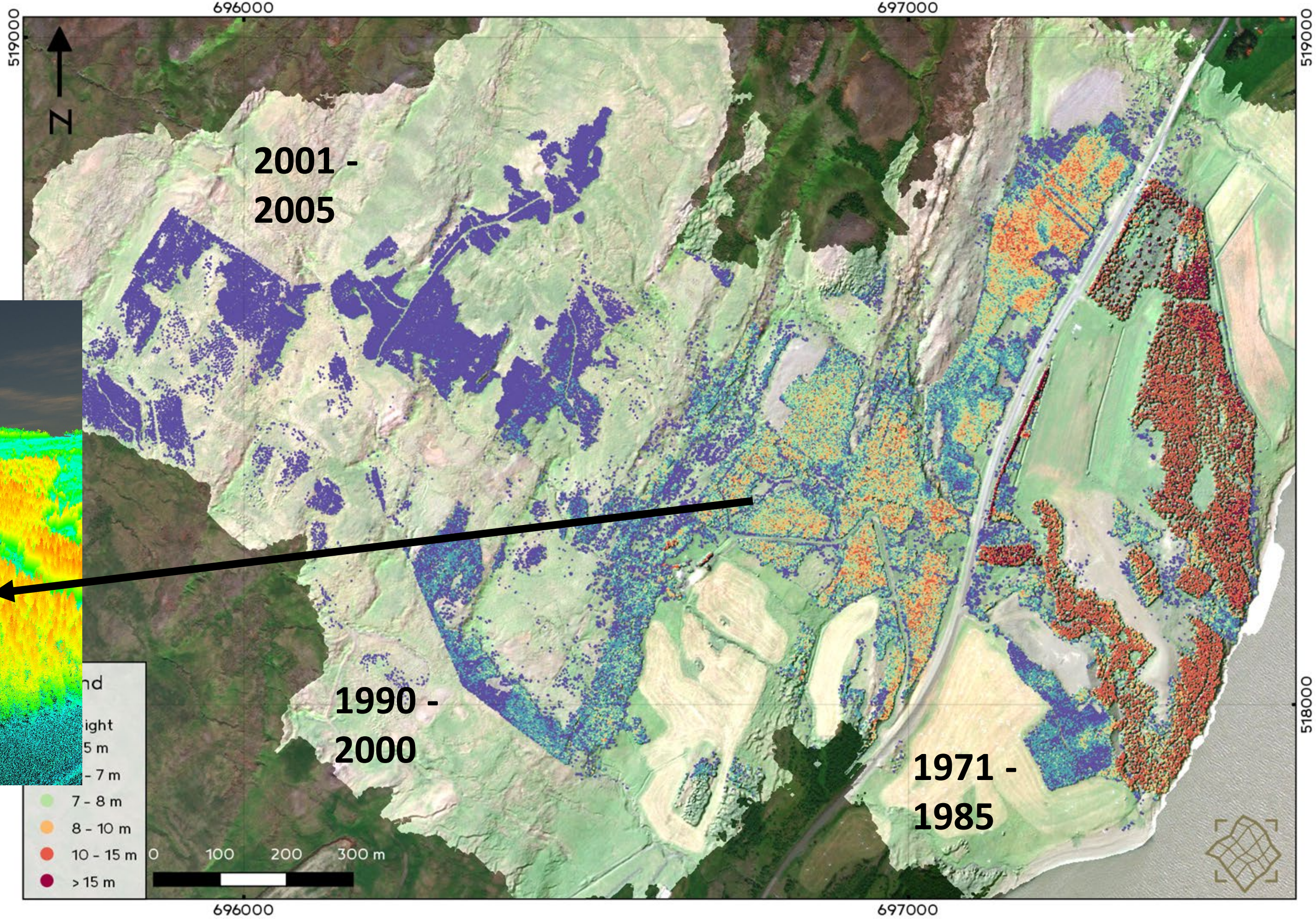

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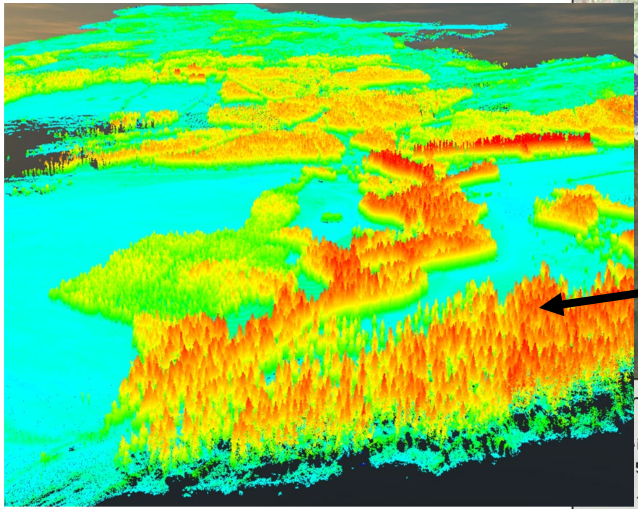
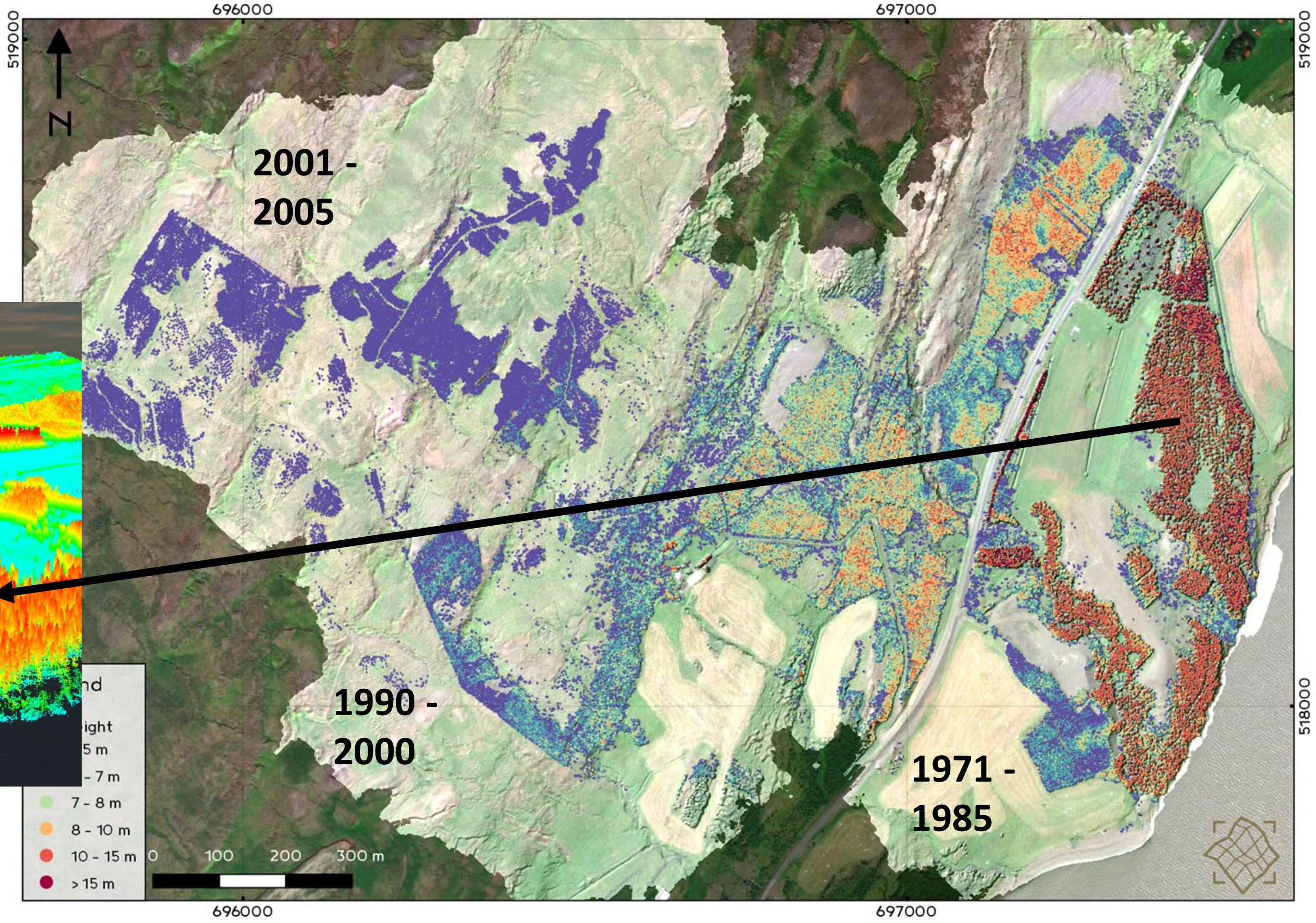
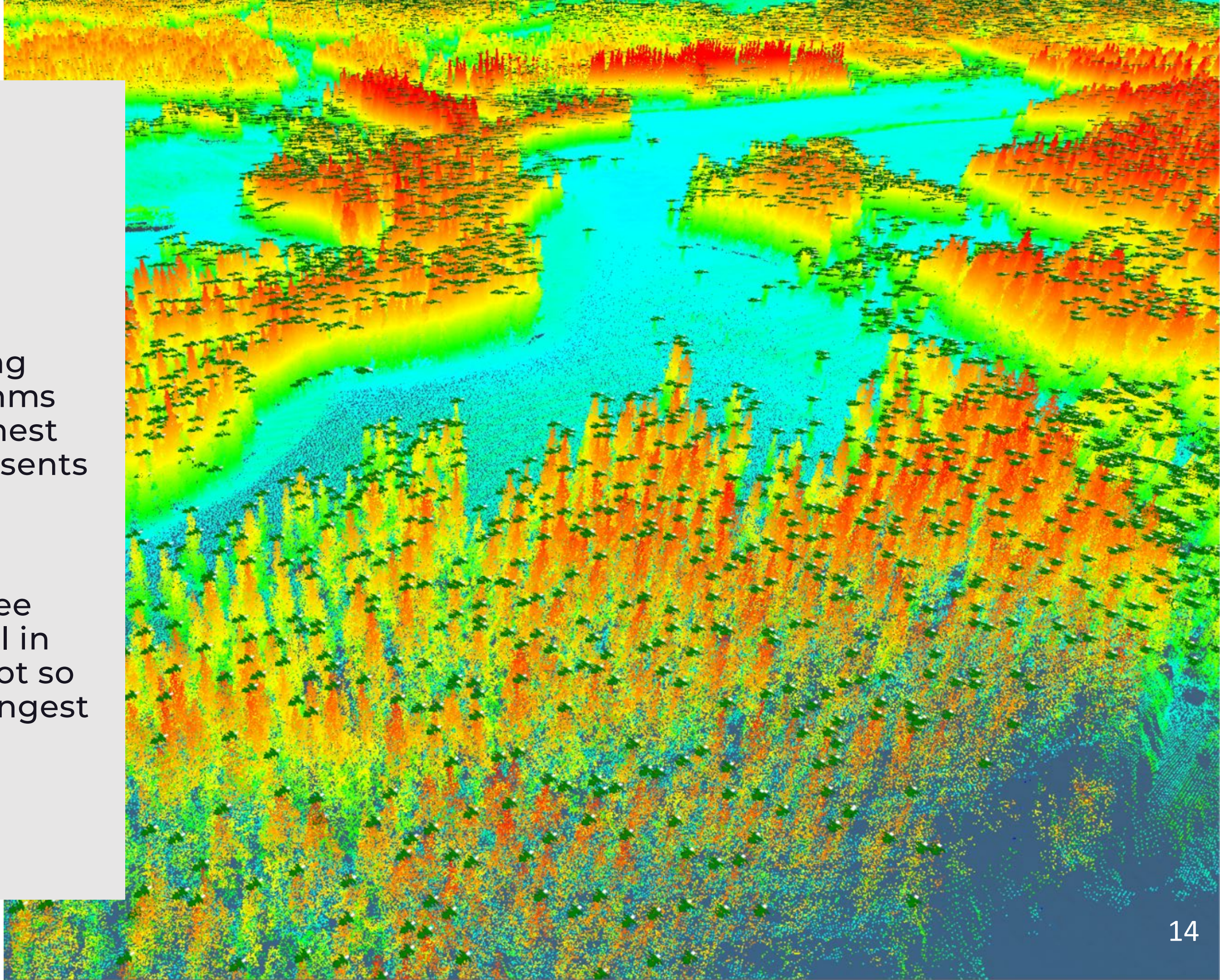




# Processing LiDAR data

- Trees were identified using machine learning algorithms developed at Svarmi, highest point in tree cluster represents tree height

- Visual analysis showed tree identification worked well in areas where trees were not so dense (i.e. oldest and youngest strata)



# Linear Regression Model

## Predicting DBH/Biomass from tree height

- Used field data from rússalerki in east Iceland to create a regression model relating tree height to DBH

- Applicable in this case on mostly single-species forest in the same area, altitude, etc.

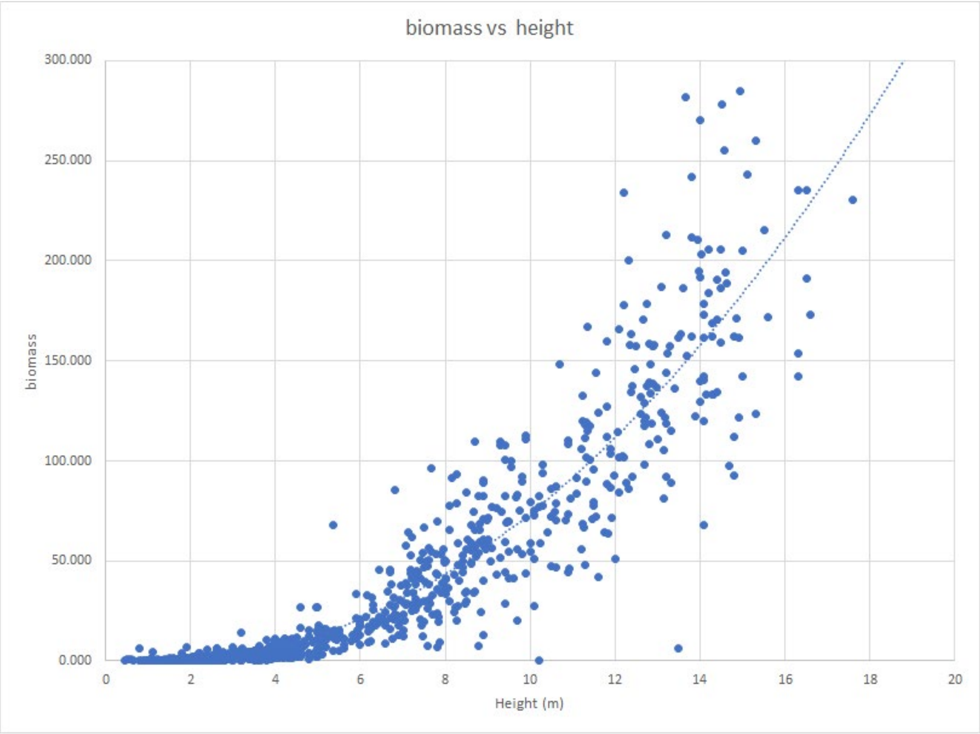
- Each tree assigned a biomass based on height calculated from regression

# Linear Regression Model

Predicting Biomass from tree height

- Each tree assigned a biomass based on height calculated from regression

  **Biomass** (kg carbon) = **0.0978*(height$^{2.7854}$)**

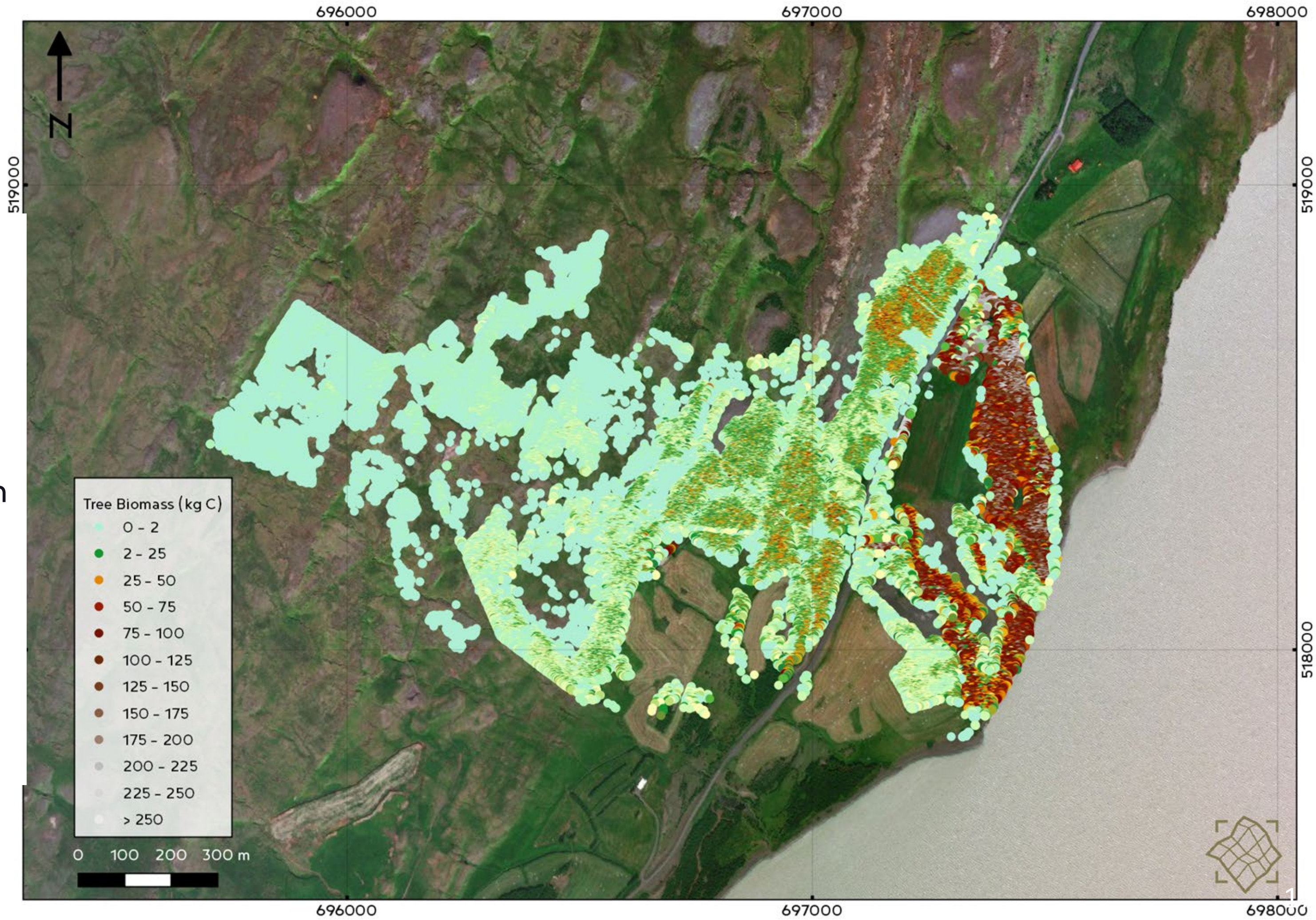



$R^2$= 0.89

# Estimated Biomass

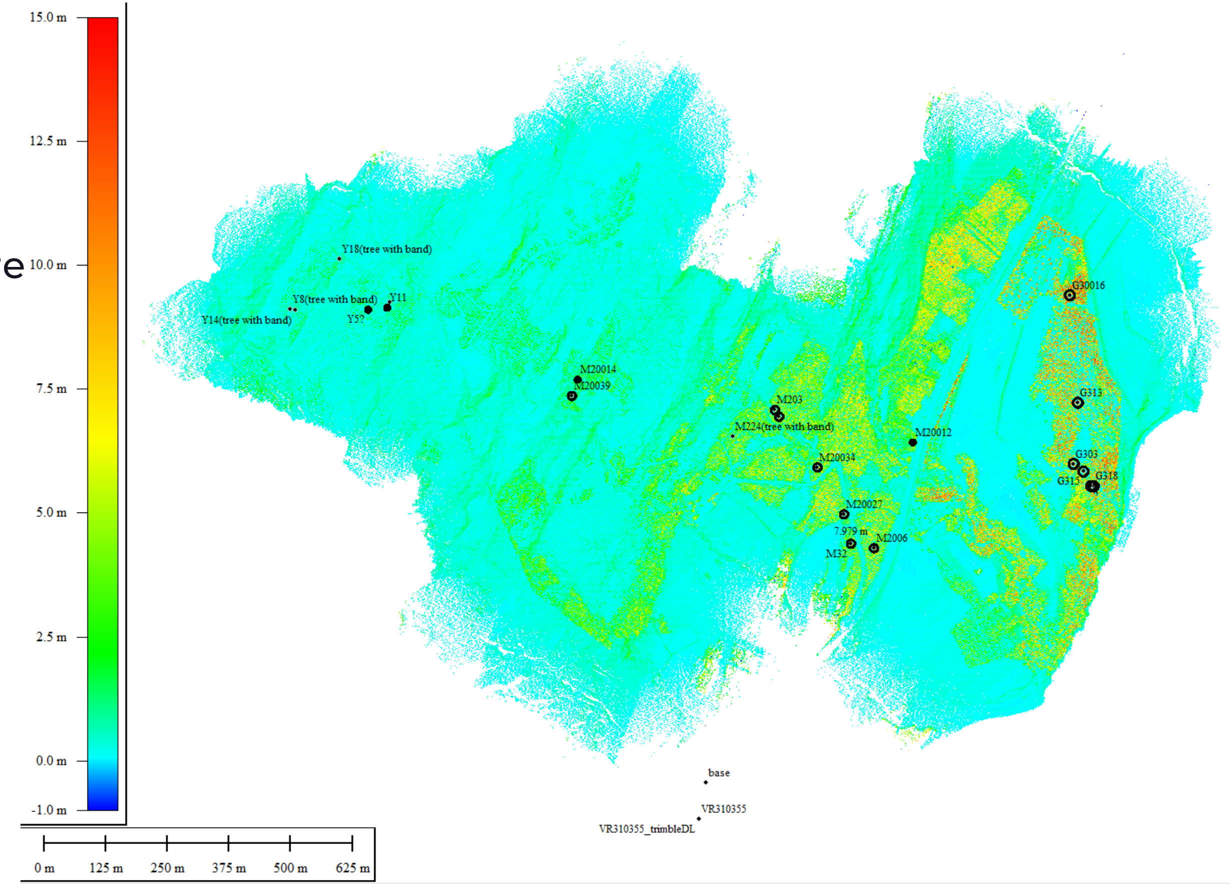
- Each point represents an individual tree

- Biomass estimate can be given for the whole forest in matter of minutes with regression analysis



# Accuracy

- 26 plots measured in situ were compared with the same areas on the pc to estimate accuracy
- Individual trees were compared side-by-side when possible
- Biomass for the entire plot was also estimated

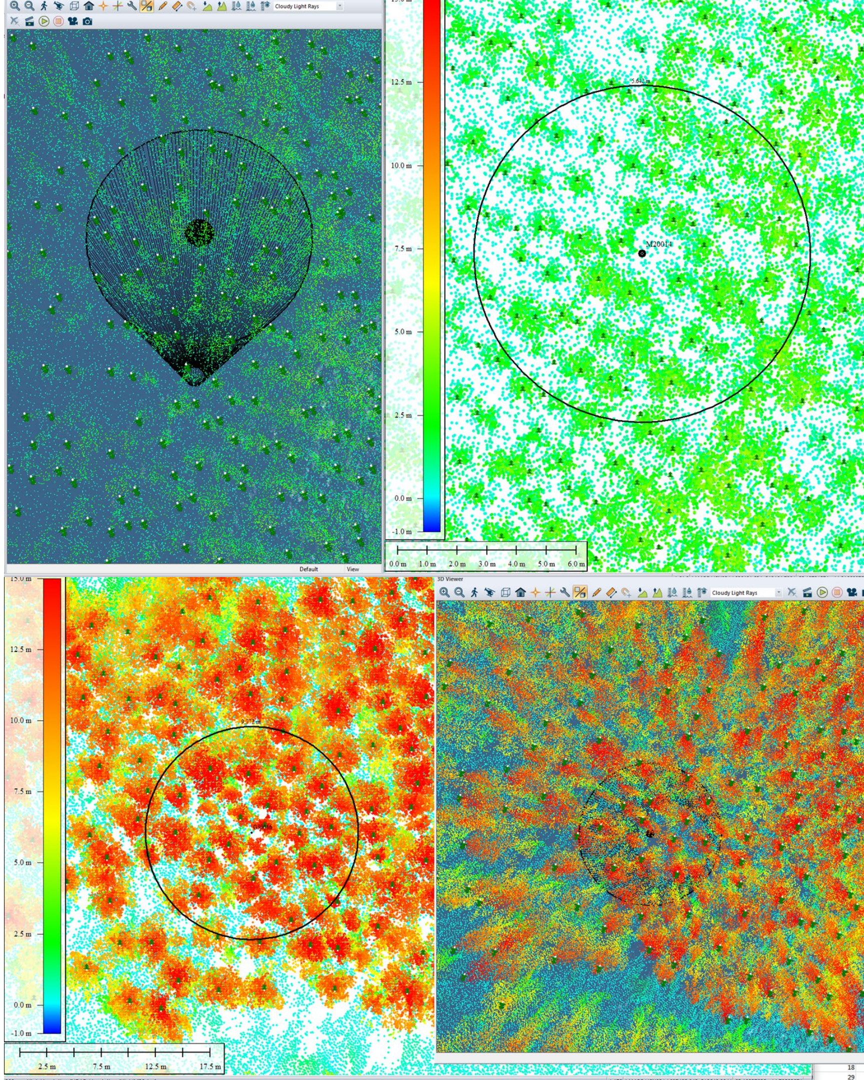


# Accuracy

## Biomass Plot Comparison

- Trees measured in the field were compared for accuracy in each strata

- It was not always possible to compare individual trees, so the biomass of the entire plot was estimated instead



# Accuracy

## In-situ Biomass compared to LiDAR method

- Overall error for all strata within 6%
- Slight overestimate in middle strata, where trees are densely planted
  - Treetops could not be easily identified from branches; too many treetops
- Slight underestimate of biomass in oldest strata
  - Smaller trees in between were likely filtered out by mistake; slight breakdown of the regression model accuracy here as well (high scatter in data)
- Smallest error in youngest strata (under 3%)
  - Individual trees easily identifiable; regression seemed to work well here

| Plot | Biomass Measured | Biomass LiDAR est. | Difference | Error (%) | Measurement |
|---|---|---|---|---|---|
| 10005 | 85.05 | 79.80 | -5.25 | -6.18 | GPS |
| 10008 | 41.70 | 31.30 | -10.40 | -24.93 | GPS |
| 10011 | 39.19 | 27.90 | -11.30 | -28.82 | GPS |
| 10013 | 44.43 | 32.08 | -12.35 | -27.80 | Shifted |
| 10014 | 55.44 | 49.12 | -6.32 | -11.40 | GPS |
| 10018 | 35.55 | 58.16 | 22.61 | 63.59 | GPS |
| 10025 | 160.65 | 159.32 | -1.33 | -0.83 | Shifted |
| 10050 | 48.84 | 56.28 | 7.44 | 15.24 | Shifted |
| 20006 | 1316.37 | 1773.47 | 457.10 | 34.72 | GPS |
| 20012 | 743.05 | 1034.19 | 291.14 | 39.18 | GPS |
| 20014 | 161.92 | 251.35 | 89.43 | 55.23 | GPS |
| 20023 | 682.88 | 923.13 | 240.25 | 35.18 | Shifted |
| 20027 | 1670.64 | 1908.21 | 237.57 | 14.22 | GPS |
| 20032 | 719.41 | 694.38 | -25.03 | -3.48 | GPS |
| 20034 | 1607.68 | 2028.15 | 420.47 | 26.15 | GPS |
| 20039 | 546.30 | 658.21 | 111.91 | 20.48 | GPS |
| 20203 | 1193.67 | 1125.26 | -68.41 | -5.73 | GPS |
| 20222 | 1339.77 | 1574.73 | 234.95 | 17.54 | GPS |
| 20224 | 1388.58 | 1541.69 | 153.11 | 11.03 | GPS |
| 20238 | 1013.99 | 1211.56 | 197.56 | 19.48 | Shifted |
| 20240 | 1231.40 | 1171.51 | -59.88 | -4.86 | Shifted |
| 30016 | 5146.43 | 4058.52 | -1087.91 | -21.14 | GPS |
| 30303 | 2837.24 | 1880.45 | -956.79 | -33.72 | GPS |
| 30313 | 1720.26 | 1789.18 | 68.91 | 4.01 | GPS |
| 30315 | 1267.37 | 810.12 | -457.25 | -36.08 | GPS |
| 30318 | 2414.39 | 2262.18 | -152.20 | -6.30 | GPS |
| | | **Overall Error** | **-12.38** | **5.57** | **% overestimate** |
| | | **Youngest** | **-2.11** | **-2.64** | **% underestimate** |
| | | **Middle** | **175.40** | **19.93** | **% overestimate** |
| | | **Oldest** | **-517.05** | **-18.65** | **% underestimate** |

# Future of LiDAR Remote Sensing in Forestry Applications

# Improvements to LiDAR forest measurement

- Good GPS measurements on field plots important for error estimate

- More imagery types (RGB, MSI) can help to segment out individual trees in densely planted areas as well as help in classifying multiple species

- Regression model could be improved with more field data

# Benefits of LiDAR / Remote sensing data in forestry

- Quick & relatively cheap georeferenced ‘snapshot’ of the forest
  – can be processed later & compared to later datasets
- Inventory of entire forest taken at once
- Measurements are very accurate (+/- 3 cm)
- DTM (terrain model below trees)  can be given as well as ortho
- Tree growth could be measured for entire forest year-to-year
- Forest boundary extent can be easily updated….

# Takk!

tryggvi@svarmi.com

www.svarmi.com