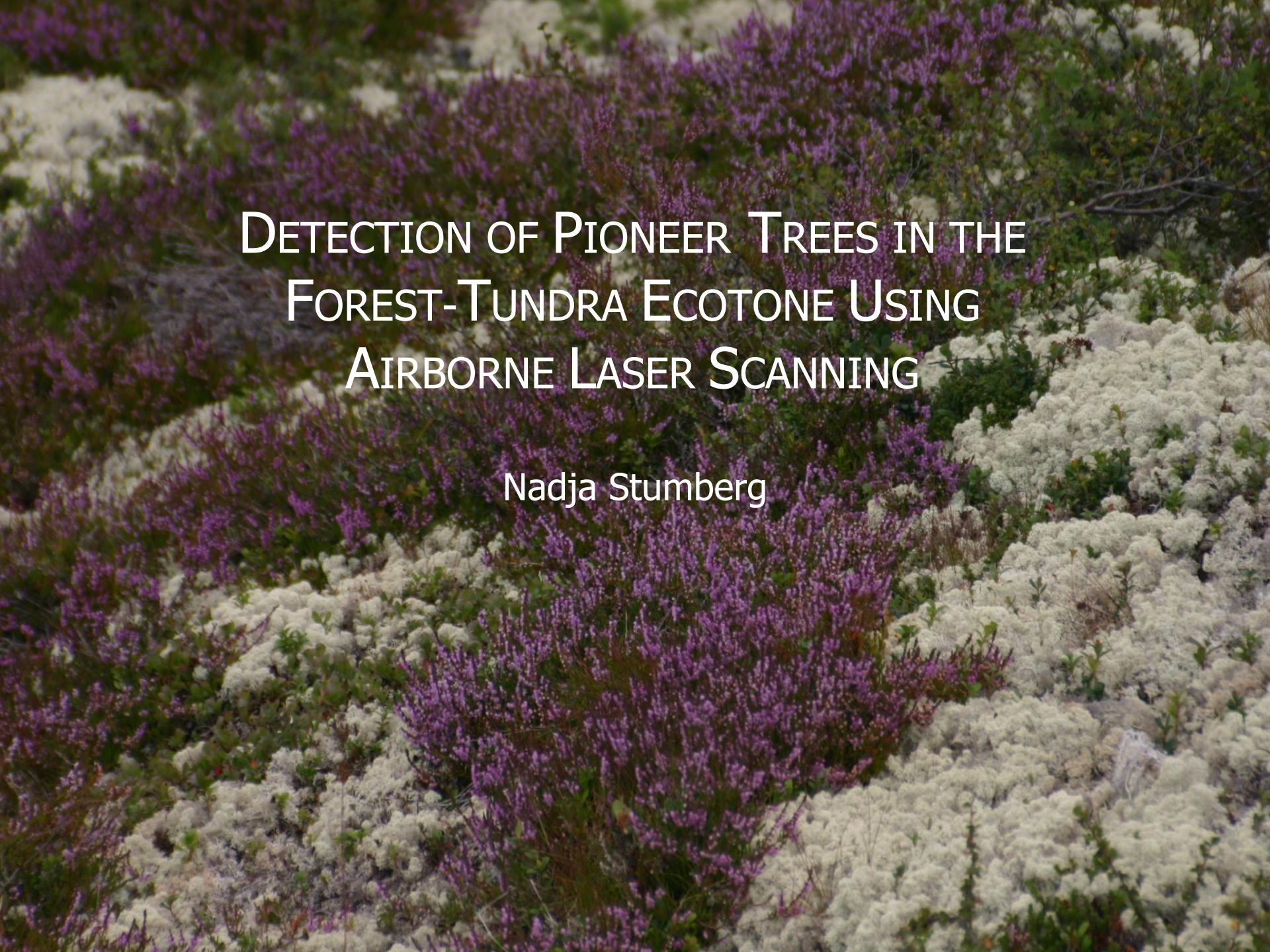


Detection of Pioneer Trees in the Forest-Tundra Ecotone Using Airborne Laser Scanning

Nadja Stumberg

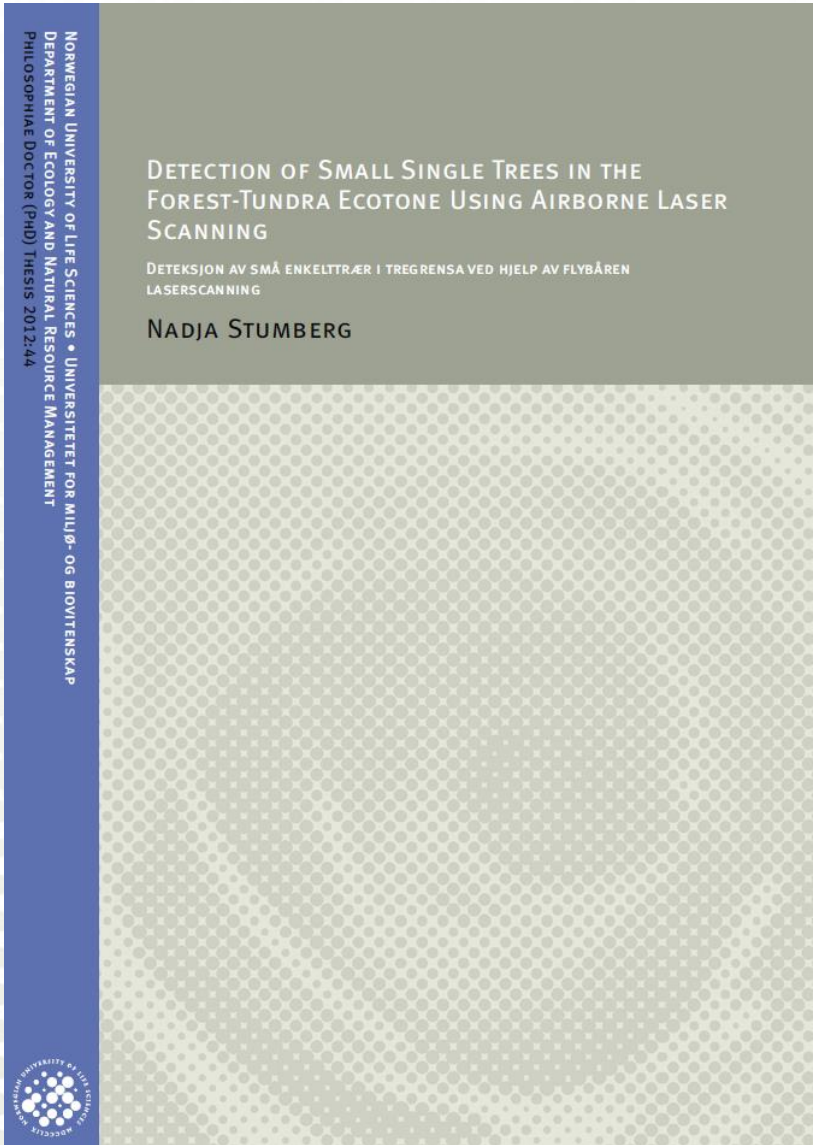
BACKGROUND

» Effects of changing climate on the alpine tree line and mountain forest carbon pools along 1500 km N-S and elevation gradients «

- Development of methods and algorithms for
  - quantification of biomass
  - changes in biomass
- Documentation of changes in biomass in the mountain forest along elevation and latitude gradients
- Detection of changes in the tree line between the boreal and the alpine zone

PhD THESIS

- Supervisors
  - Prof. Erik Næsset
  - Prof. Terje Gobakken
  - Dr. Ole Martin Bollandsås
- Public defence:
  November 16th 2012



MOTIVATION

MOTIVATION

- Annual average temperature increased at almost twice the global rate over the past decades albeit regional variations
  - May influence prevailing tree limit
  - Not just advance but also densification and increased growth

MOTIVATION

- Important need for data collection in low biomass areas by means of carbon accounting
  - Not prioritised by NFIs or other monitoring systems
  - Requirement of efficient monitoring systems
  - Coverage of vast areas
  - High degree of detail at small scales

ALS DATA

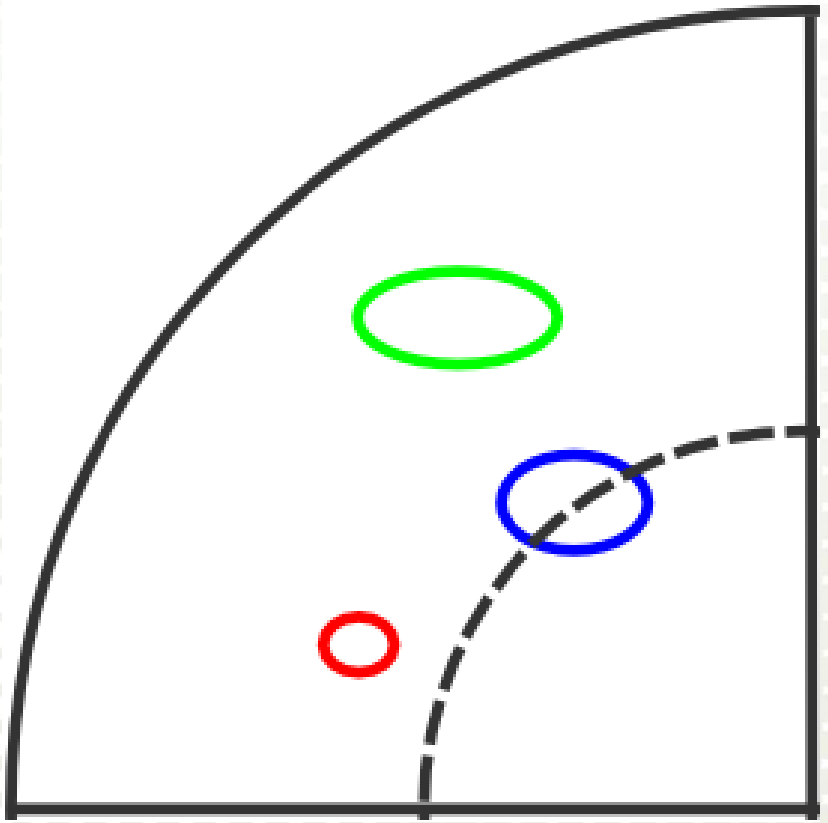
- ALS transect from Tromsø to Tvedestrand
- ~ 1500 km
- Encompasses hundreds of elevation gradients
- Acquisition in summer 2006 and spring 2007
- Overlap zone of about 80 km

FIELD DATA

- Sample plots in the transect
- June till September 2008
- Both in the mountain forest and the transition zone between forest and alpine zone

FIELD DATA

- Modified version of the PCQ method
- Precise tree positions
- dGNSS
- Three tree height classes
  - I: < 1 m
  - II: 1 – 2 m
  - III: > 2 m



FIELD DATA

- Tree height
- Stem diameter at root collar
- Crown diameter in the cardinal directions
- Tree species

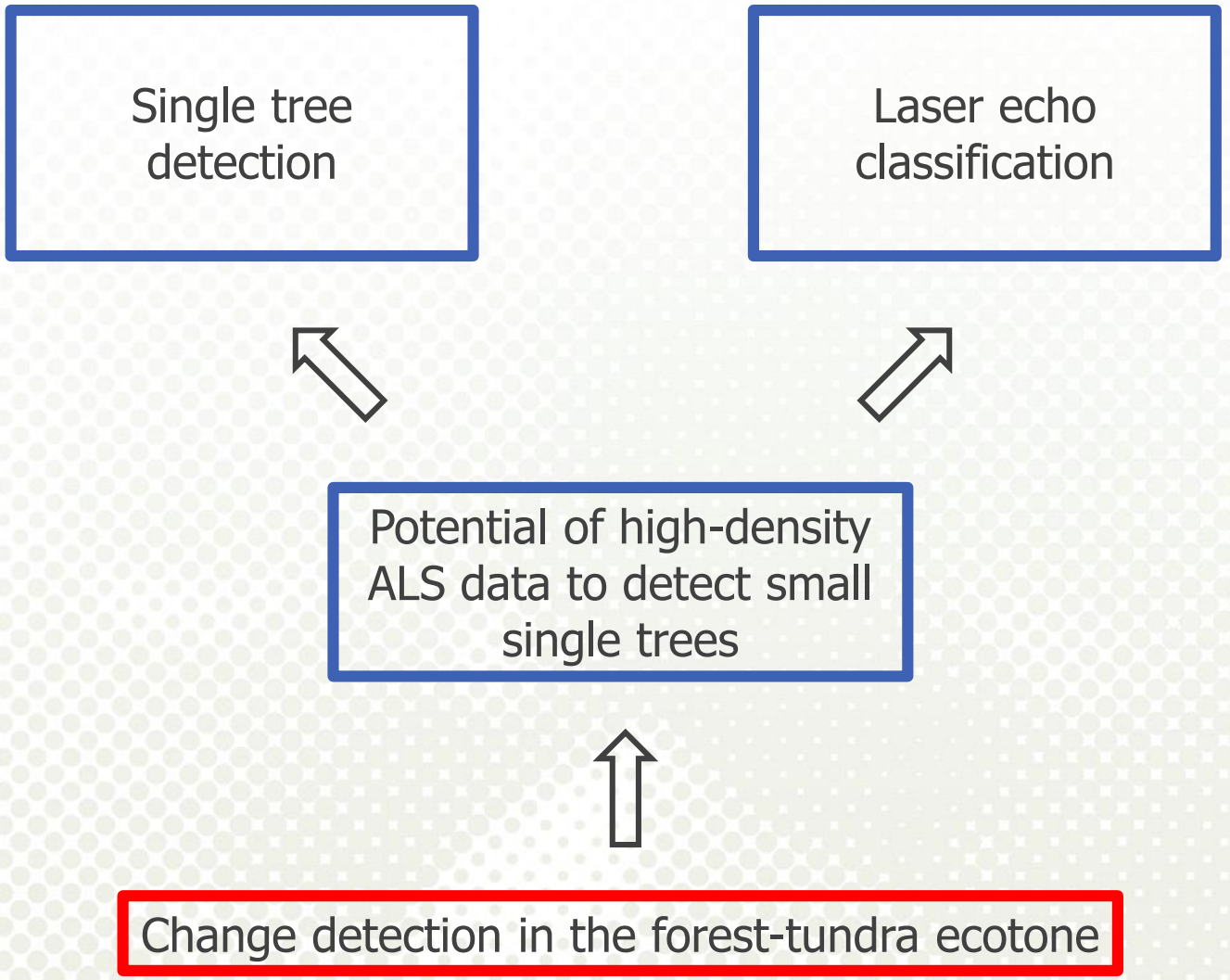
Photo: Erik Næsset

FIELD DATA

Table 1. Summary of field measurements of trees.

Tree species	Characteristics	*n*	Mean	Min.	Max.
Mountain birch	Height (m)	623	1.28	0.02	7.80
	Diameter (cm)	622	3.65	0.10	34.00
	Crown area (m^2)	623	0.90	0.001	19.54
Norway spruce	Height (m)	68	1.66	0.07	7.00
	Diameter (cm)	66	6.53	0.20	19.10
	Crown area (m^2)	68	1.43	0.006	5.69
Scots pine	Height (m)	53	1.33	0.10	5.10
	Diameter (cm)	53	5.00	0.30	18.90
	Crown area (m^2)	53	0.81	0.002	7.28

ANALYSES


Single tree detection
Laser echo classification
Potential of high-density ALS data to detect small single trees
Change detection in the forest-tundra ecotone

SENSOR ANALYSIS

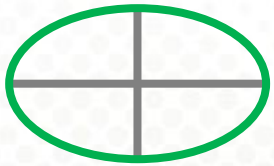
- Methods
  - Testing the null hypothesis for a significant difference between the two data acquisitions using equivalence tests
  - Applied for different tree height categories and individual trees
- Results
  - No significant difference for single trees and for small- and medium-sized height categories
  - No data adjustment

SINGLE TREE DETECTION – METHODS

- Tree detection
  - Binary response (detected/not detected)
  - Modelling of the relationship between the binary response variable and explanatory variables (GLM)
  - Extension of model with random effects in addition (GLMM)

SINGLE TREE DETECTION – DATA

- Tree height *H*
- Tree crown area defined as polygons *CA*

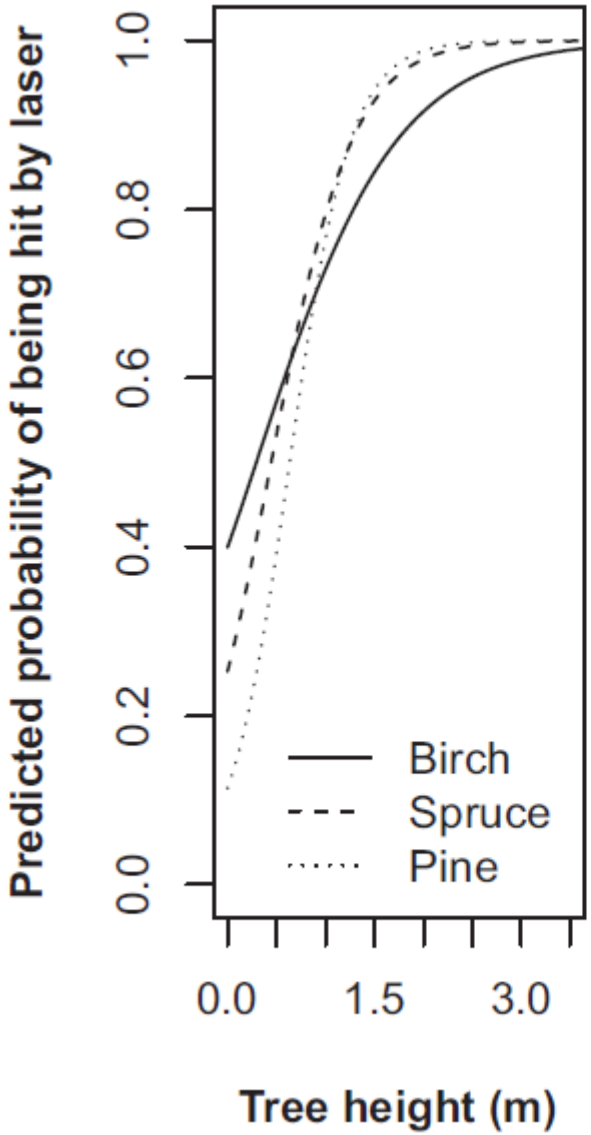


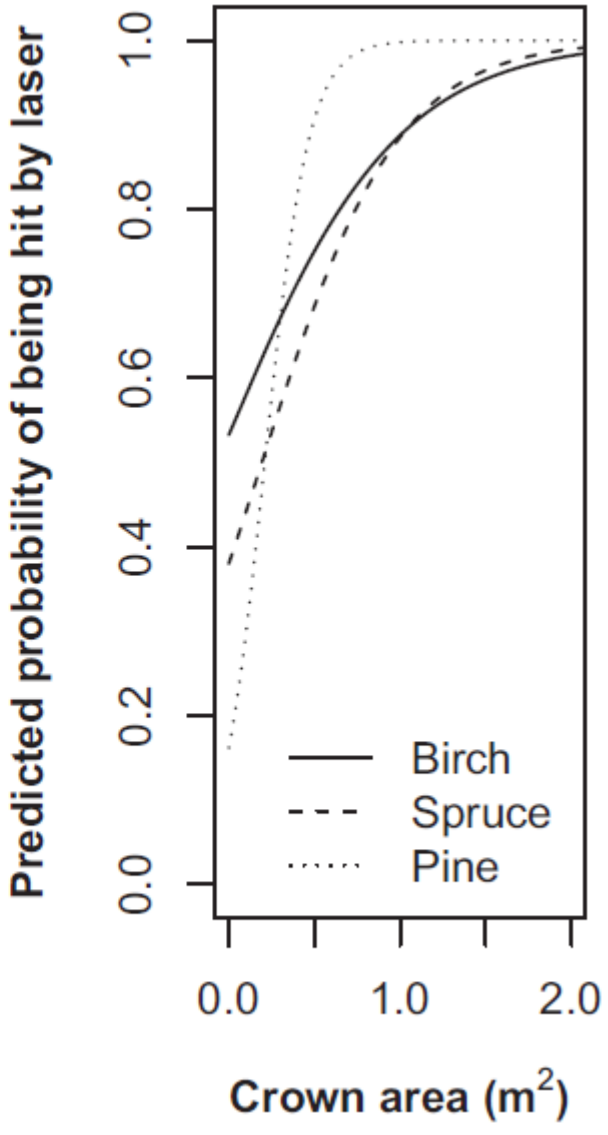
- Tree species *TS*
- Latitude *LAT*
- Region *R*

SINGLE TREE DETECTION - RESULTS

Tree species	Height class	n	Detected	$h_{max} = 0$	No hits
			n (%)	n (%)	n (%)
Mountain birch	< 1 m	293	147 (50)	134 (46)	12 (4)
	1-2 m	199	167 (84)	21 (11)	11 (5)
	> 2m	131	127 (97)	3 (2)	1 (1)
	total	623	441 (71)	158 (25)	24 (4)
Norway spruce	< 1 m	20	9 (45)	11 (55)	0 (0)
	1-2 m	24	22 (92)	1 (4)	1 (4)
	> 2m	24	24 (100)	0 (0)	0 (0)
	total	68	55 (81)	12 (18)	1 (1)
Scots pine	< 1 m	30	11 (37)	19 (63)	0 (0)
	1-2 m	12	12 (100)	0 (0)	0 (0)
	> 2m	11	10 (91)	1 (9)	0 (0)
	total	53	33 (62)	20 (38)	0 (0)
Total	total	744	529 (71)	190 (26)	25 (3)

SINGLE TREE DETECTION - RESULTS





SINGLE TREE DETECTION - RESULTS

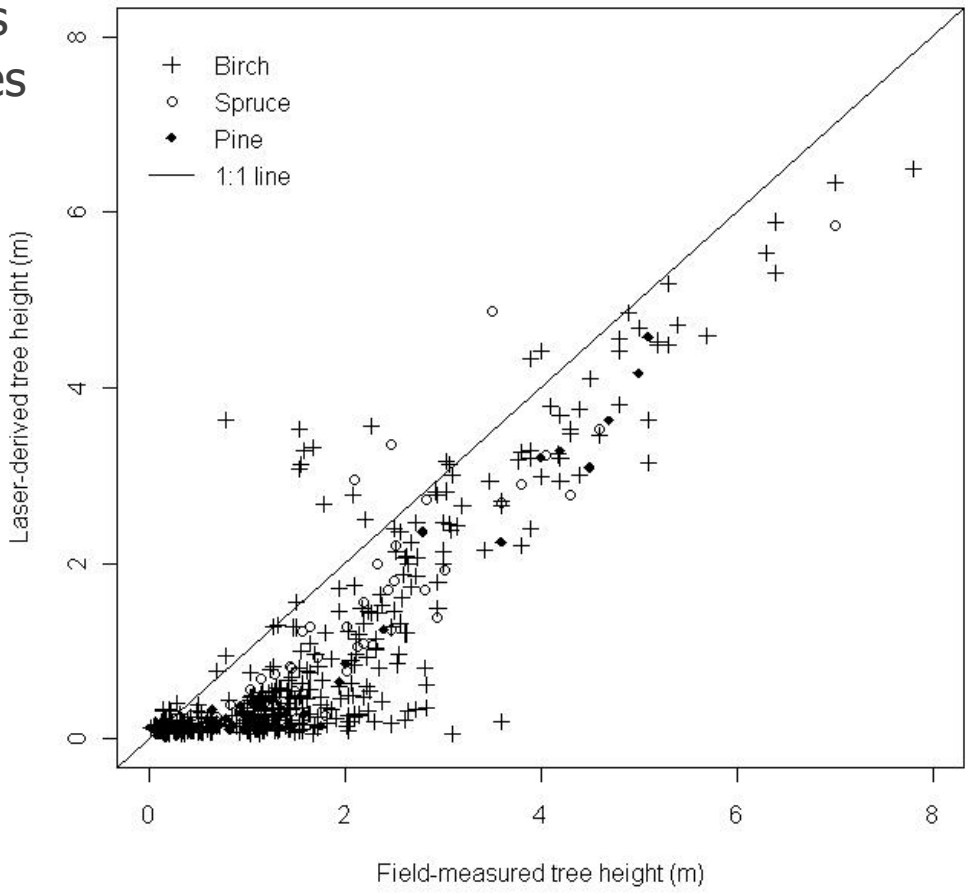
- Significant parameters: *H*, *CA*, *LAT*, *TS* and *R*
- *TS* important explanatory variable: highest success for spruce
- Regional and latitude effect

SINGLE TREE DETECTION – METHODS

- Assessment of laser tree height estimation by comparing laser-derived with field-measured tree height

SINGLE TREE DETECTION - RESULTS

- Assessment of laser tree height estimation
  - Significant underestimation between 0.20 and 1.08 m
  - Large overestimations for some isolated trees



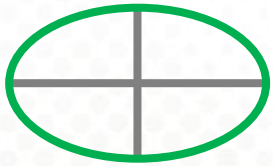
LASER ECHO CLASSIFICATION - METHODS

- Classification methods
  - GLM: classification using the modelled relationship between the binary response variable and explanatory variables
  - Support vector machines (SVM): analysis of data and recognition of patterns for classification

- Assessment of classification performance
  - Leave-one-out cross-validation: single observation from original sample for validation and remaining observations for training
  - Cohen's kappa coefficient: measures inter-rate agreement that is comparable to simple percent agreement but more robust

LASER ECHO CLASSIFICATION – DATA

- Tree crown area defined as polygons



- Treeless areas defined as polygons

LASER ECHO CLASSIFICATION – DATA

Classification I

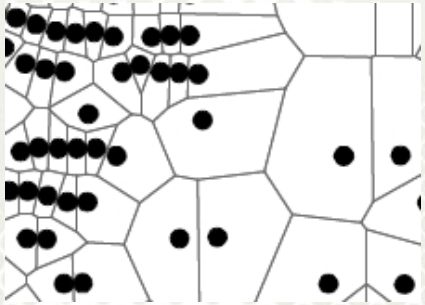
- Laser height
- Intensity of backscattered laser light

44 68 53

- Terrain by means of aspect and slope

NS W 7° 23°

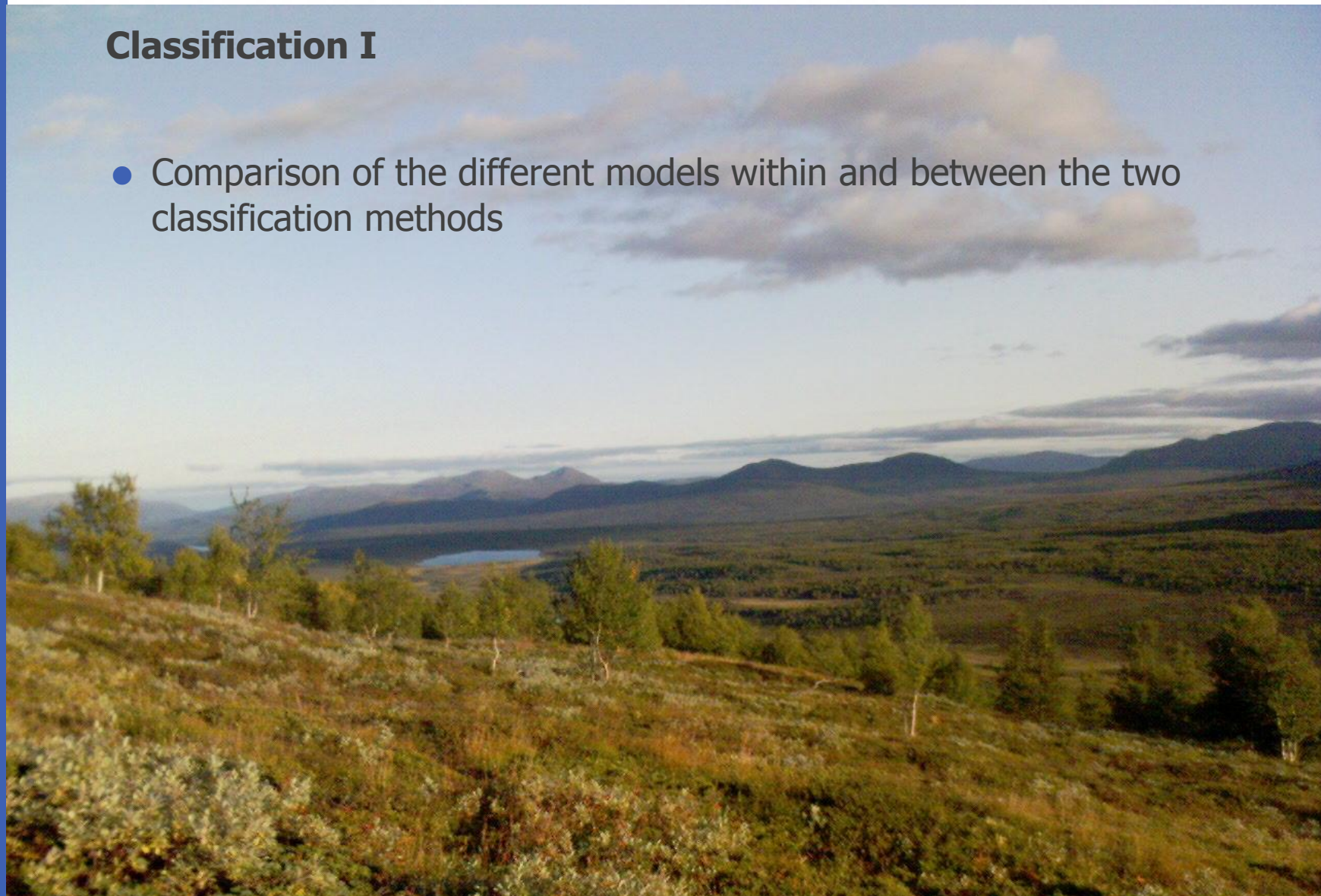
- Spatial distribution and correlation of laser measurements



LASER ECHO CLASSIFICATION – METHODS

Classification I

- Comparison of the different models within and between the two classification methods



LASER ECHO CLASSIFICATION - RESULTS

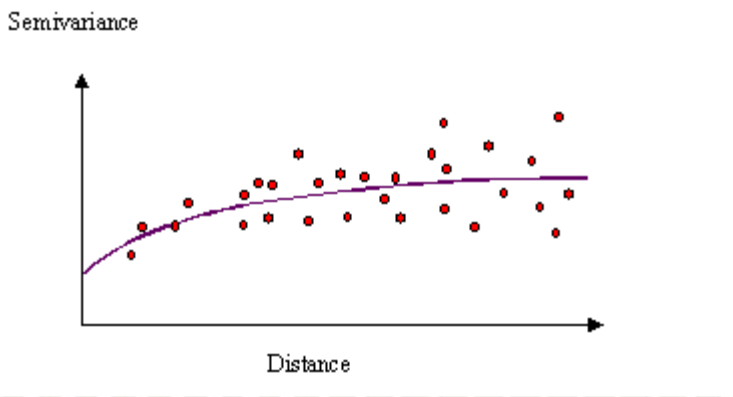
Classification I

- Total accuracy of at least 93% irrespective of classification method or model
- Moderate fits for all models as indicated by kappa coefficient
- Comparison of kappa coefficients between classification methods
  - Similar performances for GLM and SVM for models consisting of different combinations of height, intensity, spatial distribution and correlation, as well as aspect
  - Superior performance when using slope in SVM

LASER ECHO CLASSIFIKATION – DATA

Classification II

- Differences in the behaviour of spatial correlation of laser height and intensity



- Arithmetic mean from laser height and intensity

$$arithmetic\ mean = \frac{1}{n}\sum_{i=1}^{n} x_i$$

LASER ECHO CLASSIFICATION – DATA

Classification II

- Standard deviation from laser height and intensity

$$standard\ deviation = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

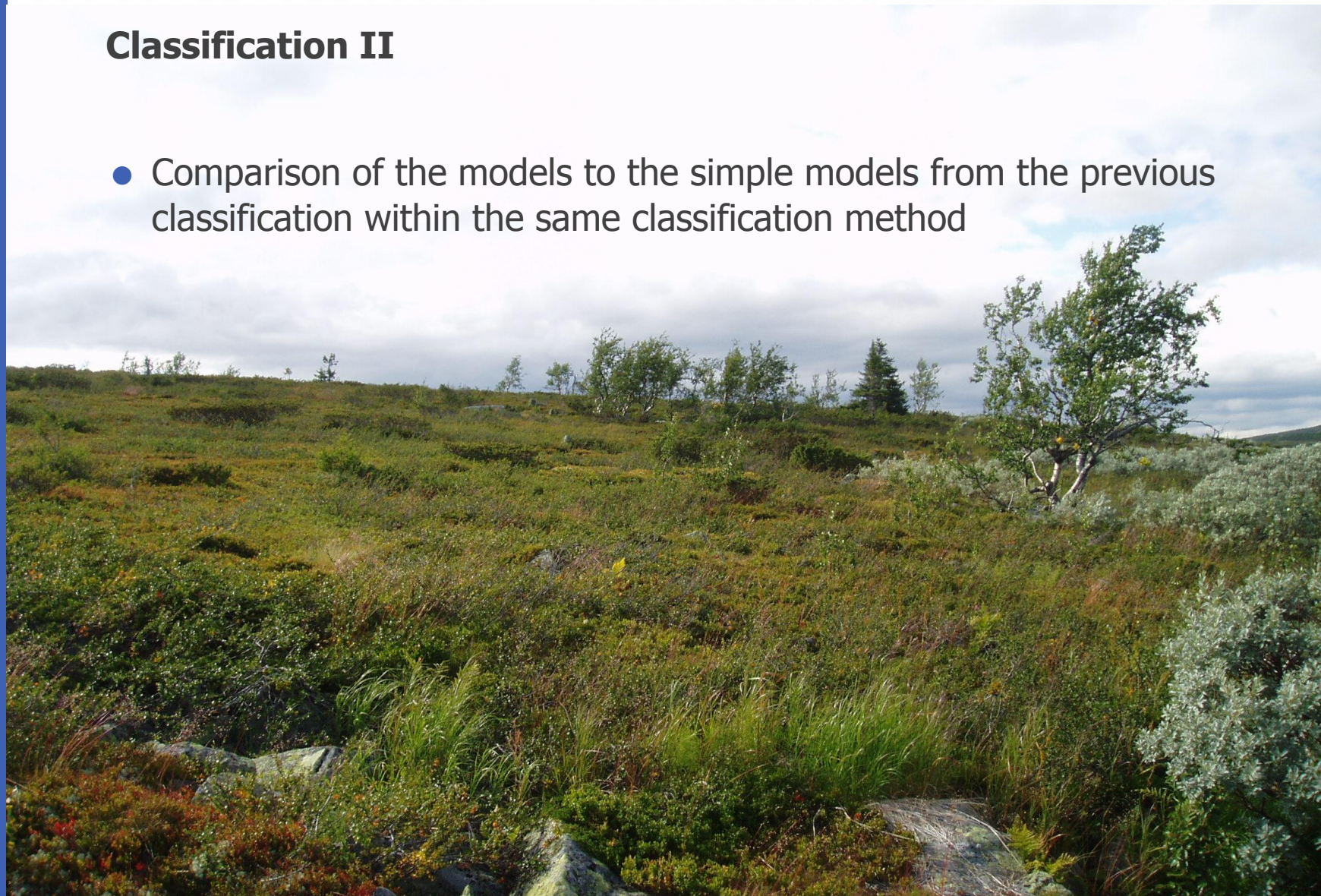
- Coefficient of variation from laser height and intensity

$$coefficient\ of\ variation = \frac{standard\ deviation}{arithmetic\ mean}$$

LASER ECHO CLASSIFICATION – METHODS

Classification II

- Comparison of the models to the simple models from the previous classification within the same classification method



LASER ECHO CLASSIFICATION – RESULTS

Classificatjon II

- Total accuracies similar to previous classification
- Kappa coefficients improved by at least 0.032 for GLM and 0.034 for SVM
- GLM: mean semivariance and arithmetic mean estimated from height were discriminators with highest improvement capability
- SVM: mean semivariance from height revealed highest improvement

CONCLUSION

- In-depth investigation of the potential of high-density ALS data for small single tree detection in the forest-tundra ecotone
- Verification of successful STD using laser height values in combination with tree characteristics and spatial influences for trees > 1 m
- Confirmation of LEC into tree and non-tree echoes using laser measurements, geospatial and terrain variables using two different modelling techniques
- Significant improvement of LEC by extending the classification models with geostatistical and statistical measures


THANKS FOR YOUR ATTENTION