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An assessment of multiangular MISR data for tree cover and height mapping in the tundra–taiga transition zone

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Introduction

- Accurate and repeatable land cover characterization is required over the tundra–taiga transition zone
- Low spatial resolution instruments (e.g. MODIS) allow mapping of the whole transition zone regularly
- Tree cover and height are important variables to characterize the ecotone
- The continuous fields of these variables would, for example, enable the delineation of the forest extent according to the different criterion and provide valuable data for monitoring land cover change

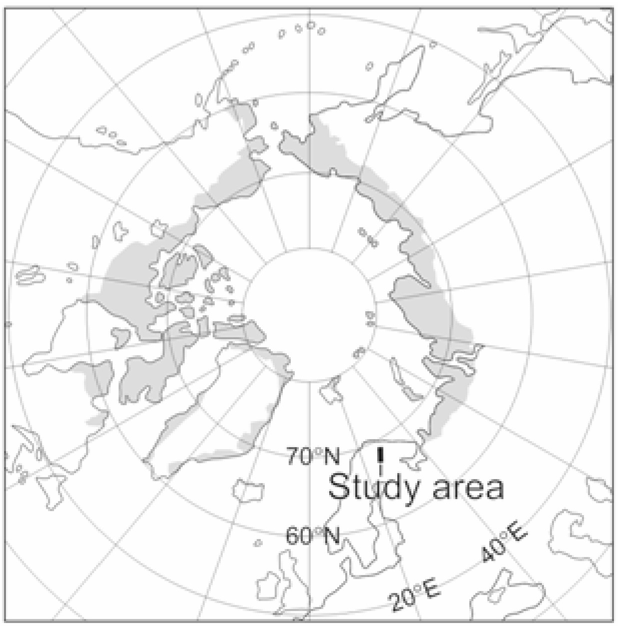
Introduction

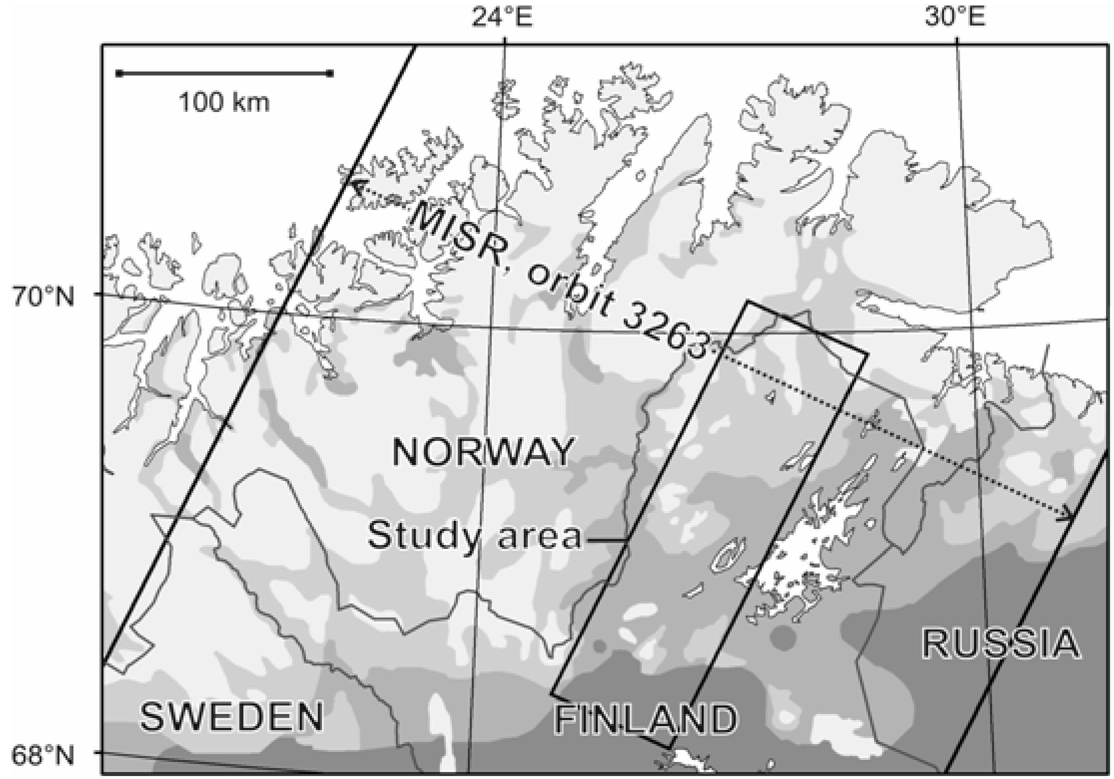
- The applicability of VIS–NIR remote sensing data has been typically hampered by the pronounced reflectance of undergrowth vegetation and by the spectral confusion of the forest and non-forest vegetation
- Directional information (multiangular observations) provides one additional data source that has been used only a little in the land cover mapping
- The sensitivity of BRDF to the canopy- and landscape-level structural variability suggest that multiangular data could be useful in the characterization of tundra–taiga boundary

Aim of the study

- To examine how sensitive MISR reflectance is to the variability in tree cover and height
- To examine how the spectral-angular band combination of MISR data affect to the estimation accuracy of tree cover and height
- The results were compared to the global MODIS continuous fields of tree cover product at 500 m resolution (MOD44B)
- The estimation accuracy was also studied in relation to shrub cover and fractional cover of mire

Location of the study area





Treeless heath

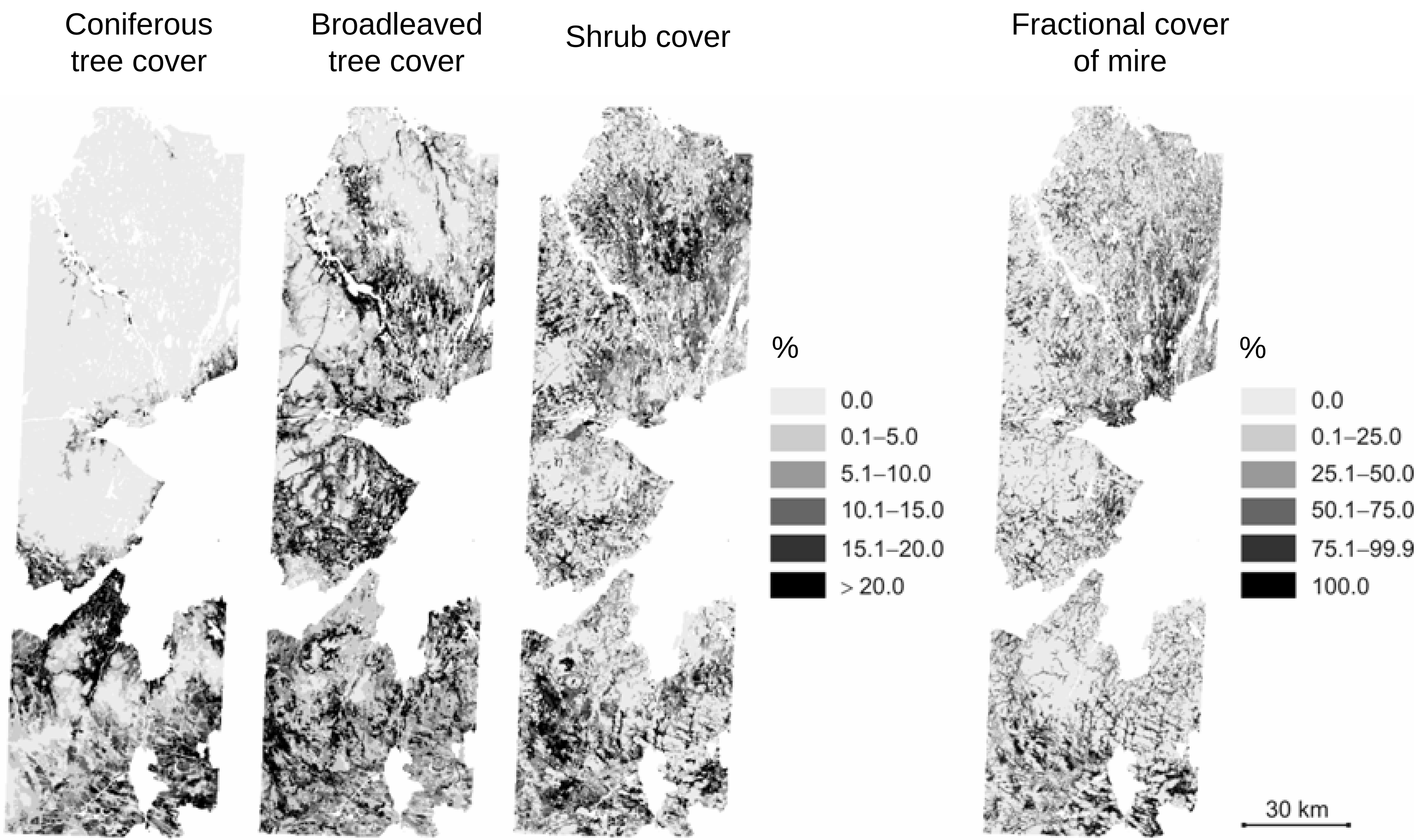
Birch woodland and forest

Pine forest

Mixed coniferous forest

Biotope inventory data

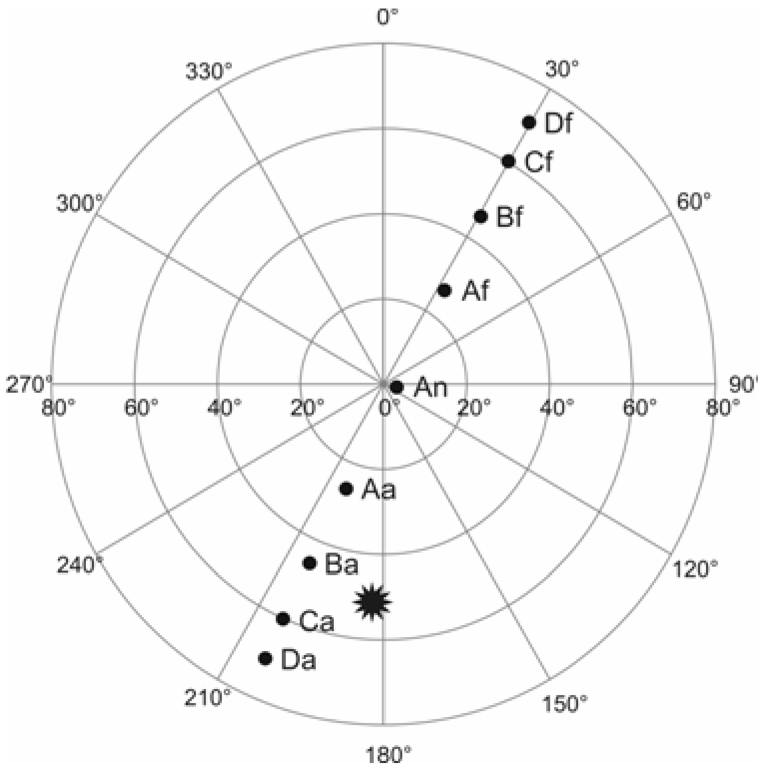
- The reference data consisted of biotope inventory of northernmost Finland that was made between 1996–1999 by Metsähallitus
- Based on colour-infrared aerial photographs and interpretation keys collected in the field
- GIS-database includes also stand-wise forest inventory data, like tree crown cover (also species specific fractions) and tree height
- The data covers only nature reserves, wilderness areas and national parks


Coniferous tree cover
Broadleaved tree cover
Shrub cover
%
0.0
0.1–5.0
5.1–10.0
10.1–15.0
15.1–20.0
> 20.0
Fractional cover of mire
%
0.0
0.1–25.0
25.1–50.0
50.1–75.0
75.1–99.9
100.0
30 km

Multiangle Imaging SpectroRadiometer (MISR)

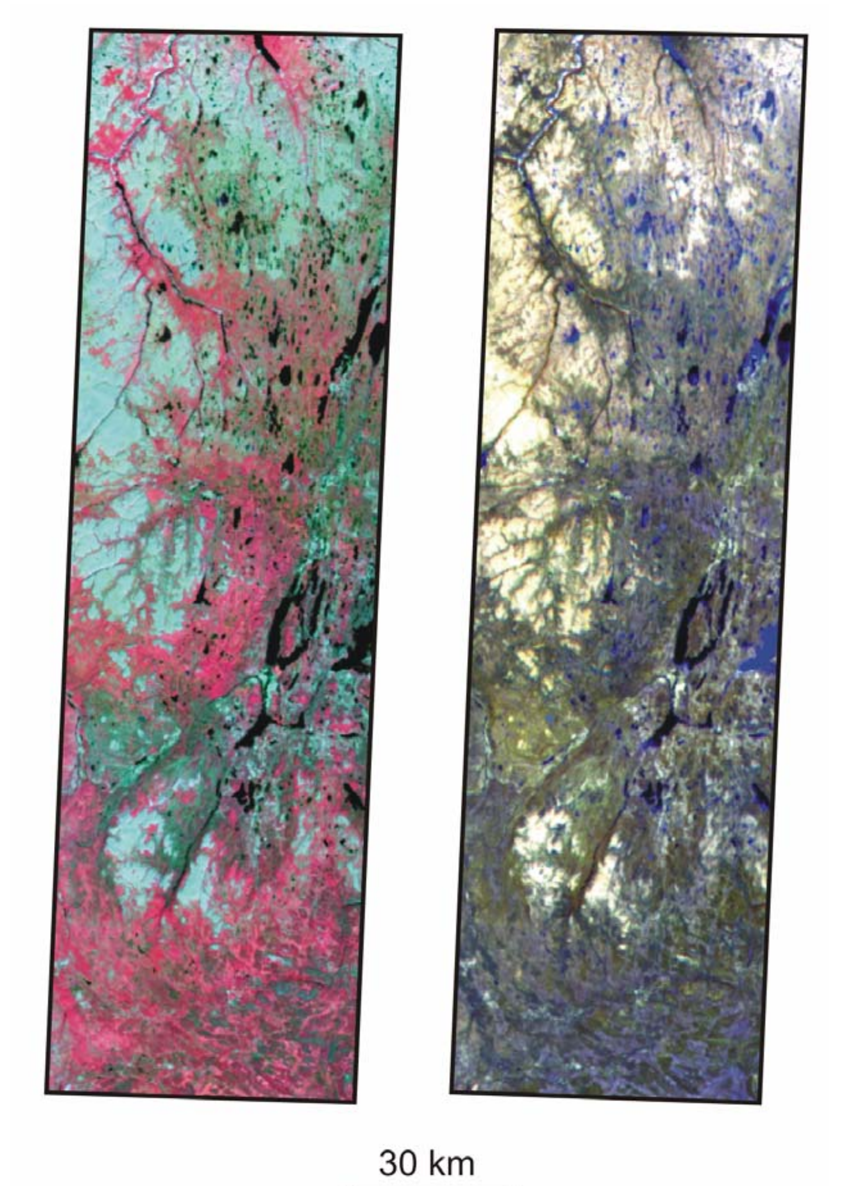
- Nine cameras: 0º, ±26.1º, ±45.6º, ±60.0º and ±70.5º
- Four spectral bands: blue (446 nm), green (558 nm), red (672 nm) and NIR (866 nm)
- In the global mode the red bands and nadir camera are at 275 m resolution, the other bands are averaged to the 1.1 km resolution
- Acquisition date: 29 July 2000 (path 193 and orbit 3263)
- MISR Level 1B2 Terrain data (TOA BRF) and Level 2 Land Surface data (surface BRF) were used
- Da camera was excluded due to coregistration problems

Mean viewing angles of the MISR cameras and Sun position during the acquisition



Nadir
NIR, red, green

60º, nadir, -60º
Red



Data analysis

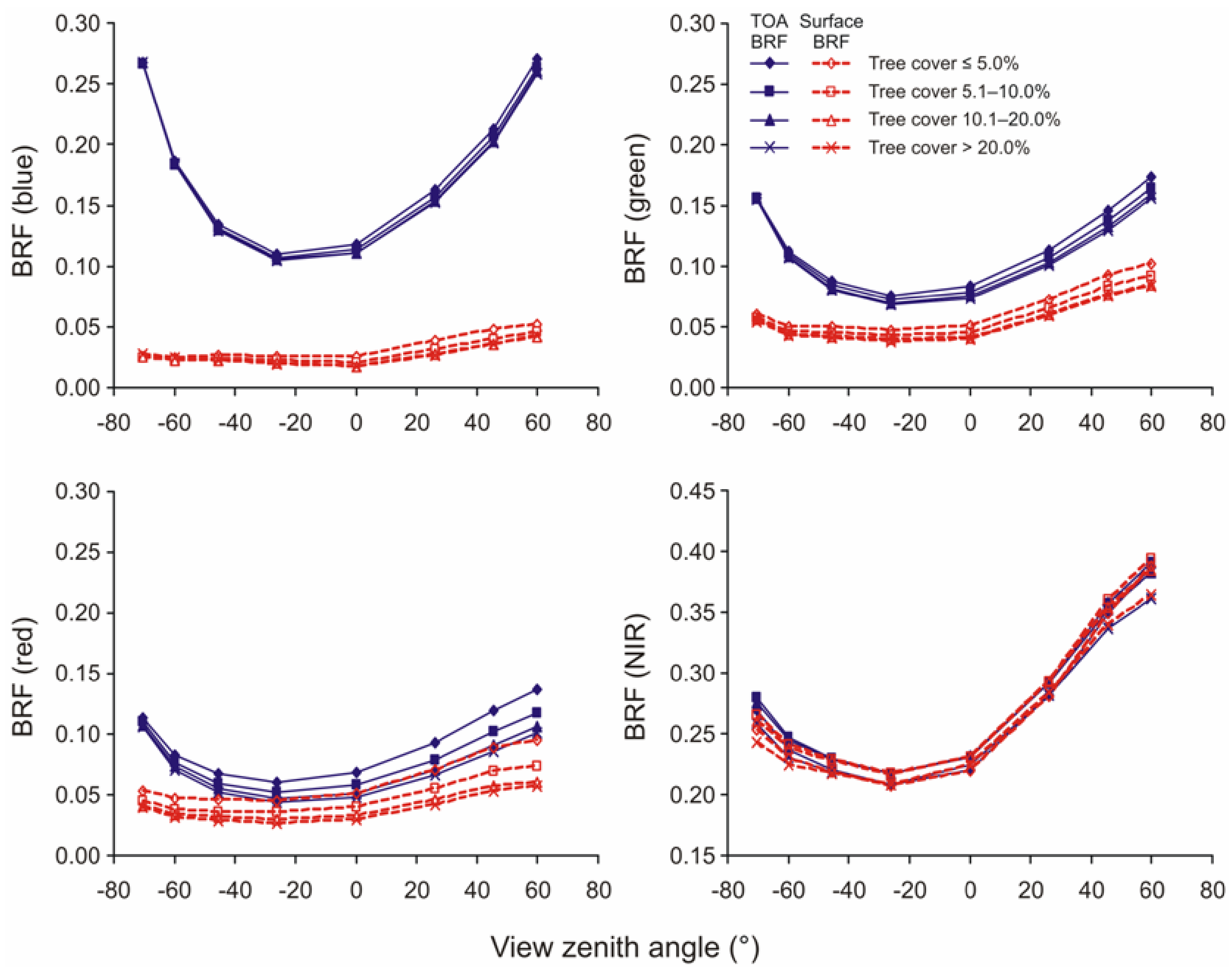
- Mean tree cover, coniferous and broadleaved tree cover, and tree height were calculated for MISR pixels
- The target variables were estimated by feed-forward multilayer neural networks using different spectral-angular band combinations
- Training was performed by Levenberg-Marquardt algorithm and early stopping was used in order to avoid overfitting
- Half of all the data were allocated to the training set and half to the testing set by random sampling
- The estimates were assessed by RMSE and bias statistics

Descriptive statistics

Variable	Resolution	n	Range	Mean	Median	S.D.
Tree cover (%)	275 m	123512	0.0–79.1	11.5	8.5	11.4
	1.1 km (TOA BRF)	6998	0.0–47.9	11.0	9.6	9.3
	1.1 km (surface BRF)	5760	0.0–47.9	11.6	10.8	9.6
Coniferous tree cover (%)	275 m	123512	0.0–50.0	3.6	0.0	7.0
	1.1 km (TOA BRF)	6998	0.0–38.4	3.4	0.0	6.0
	1.1 km (surface BRF)	5760	0.0–38.4	4.0	0.0	6.3
Broadleaved tree cover (%)	275 m	123512	0.0–76.8	7.7	4.4	9.0
	1.1 km (TOA BRF)	6998	0.0–46.6	7.4	5.9	6.8
	1.1 km (surface BRF)	5760	0.0–46.6	7.4	5.8	6.9
Tree height (m)	275 m	123512	0.0–17.8	5.3	4.3	3.7
	1.1 km (TOA BRF)	6998	0.0–16.0	5.1	4.3	3.3
	1.1 km (surface BRF)	5760	0.0–16.0	5.4	4.4	3.5

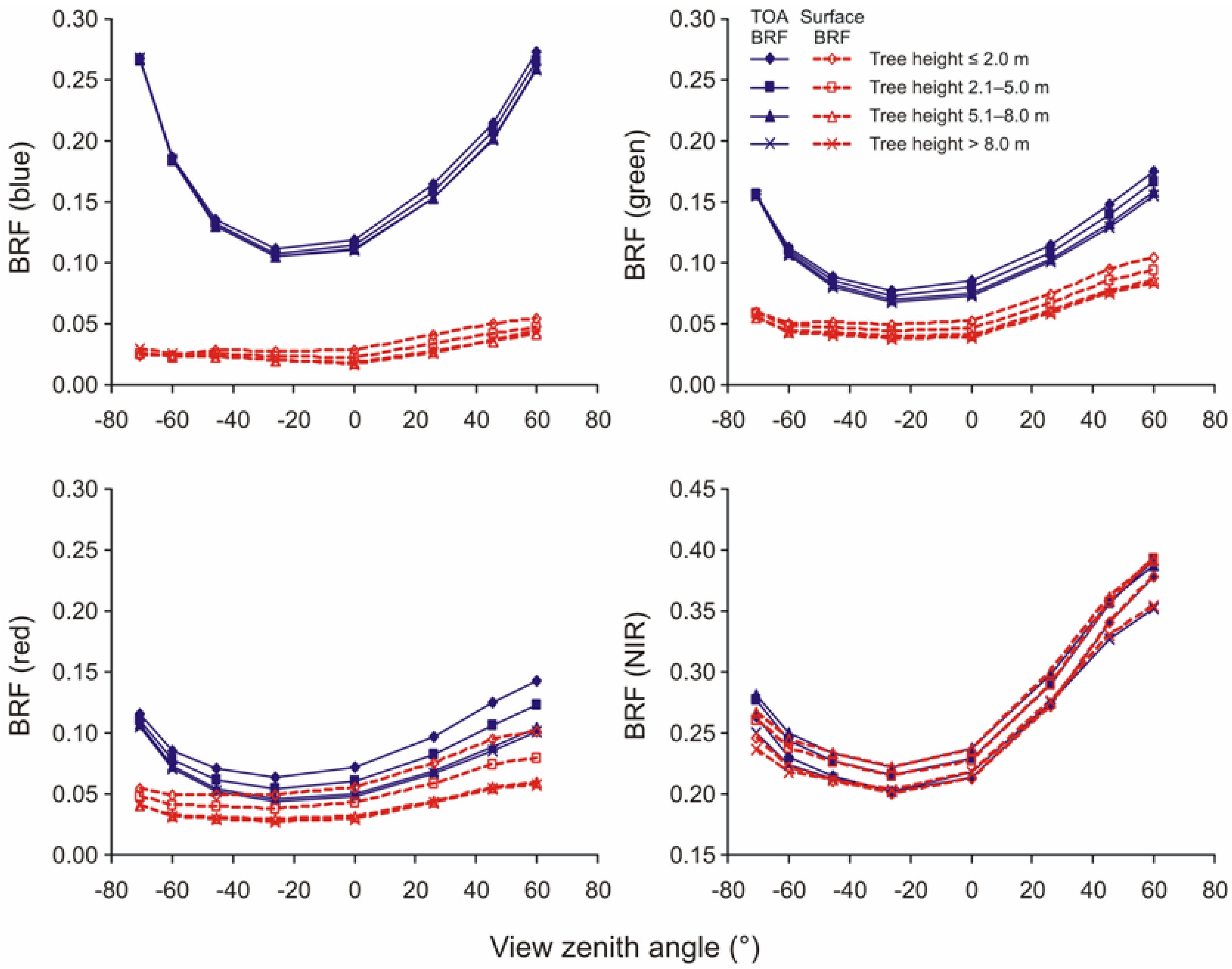
- Shrub cover and fractional cover of mire were used as ancillary data

Mean BRFs of the tree cover classes in MISR viewing angles (-70.5–60.0º)



- Strong dependence of BRF on the view zenith angle
- The atmospheric correction has a major effect, particularly in the shorter wavelengths and in the largest off-nadir view angles
- However, differences between the classes are approximately equal

Mean BRFs of the tree height classes in MISR viewing angles (-70.5–60.0º)

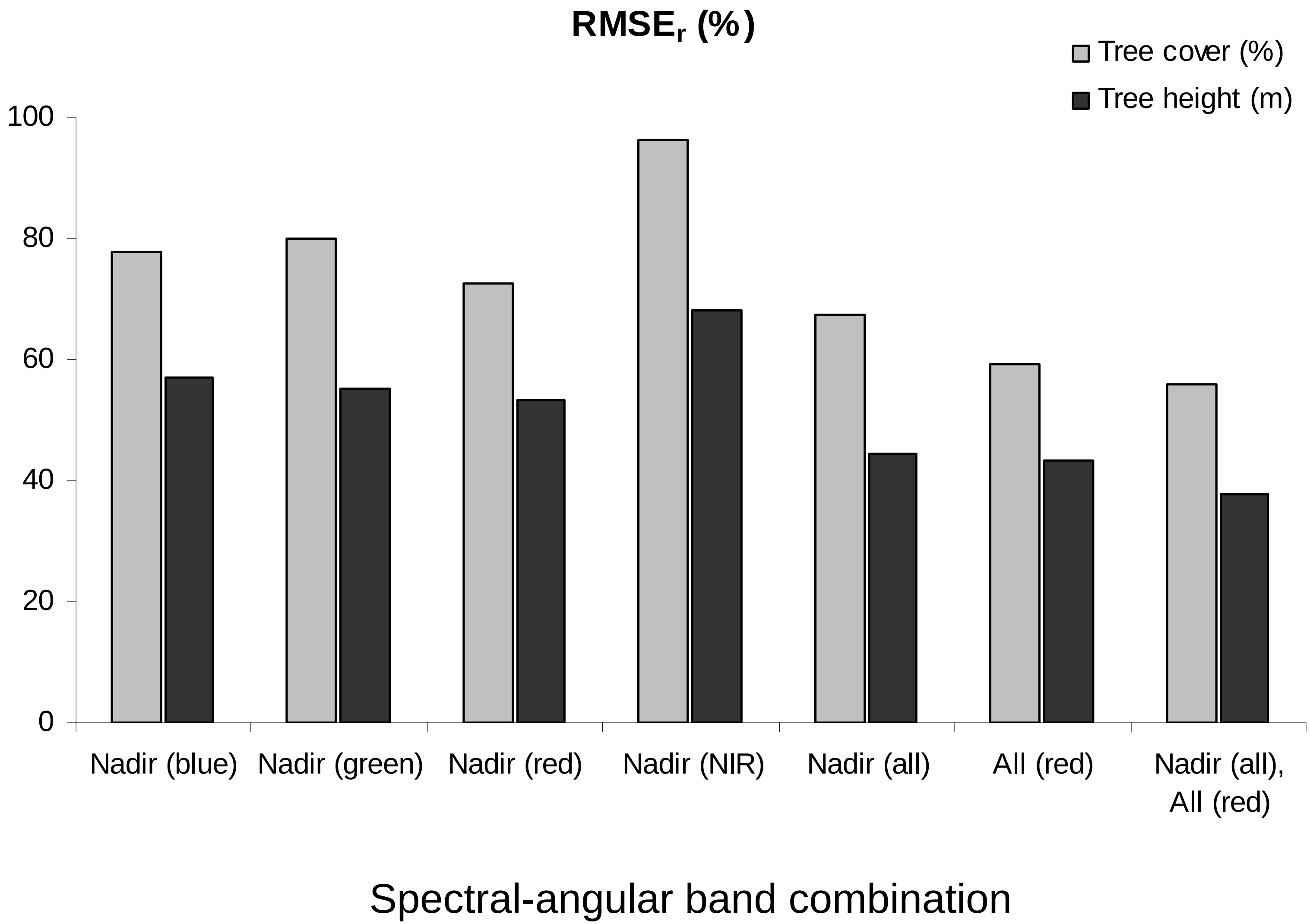


- Red band seem to be the most sensitive band to the tree cover and tree height
- Differences between the classes are greatest in the backscattering direction

Accuracy of the tree cover and height estimates at 275 m resolution

Target variable	View-angle (spectral band)	Number of bands	RMSE	$RMSE_r$ (%)	Bias	$Bias_r$ (%)	r
Tree cover (%)	Nadir (red)	1	8.41	72.7	**-0.08**	-0.7	0.67
	Nadir (all)	4	7.80	67.4	-0.11	-1.0	0.73
	All (red)	8	6.85	59.2	-0.03	-0.3	0.80
	Nadir (all), All (red)	11	6.49	56.1	-0.05	-0.4	0.82
Tree height (m)	Nadir (red)	1	2.81	53.3	0.00	0.0	0.64
	Nadir (all)	4	2.33	44.3	0.00	0.0	0.77
	All (red)	8	2.29	43.5	0.02	0.4	0.78
	Nadir (all), All (red)	11	1.98	37.6	0.01	0.2	0.84

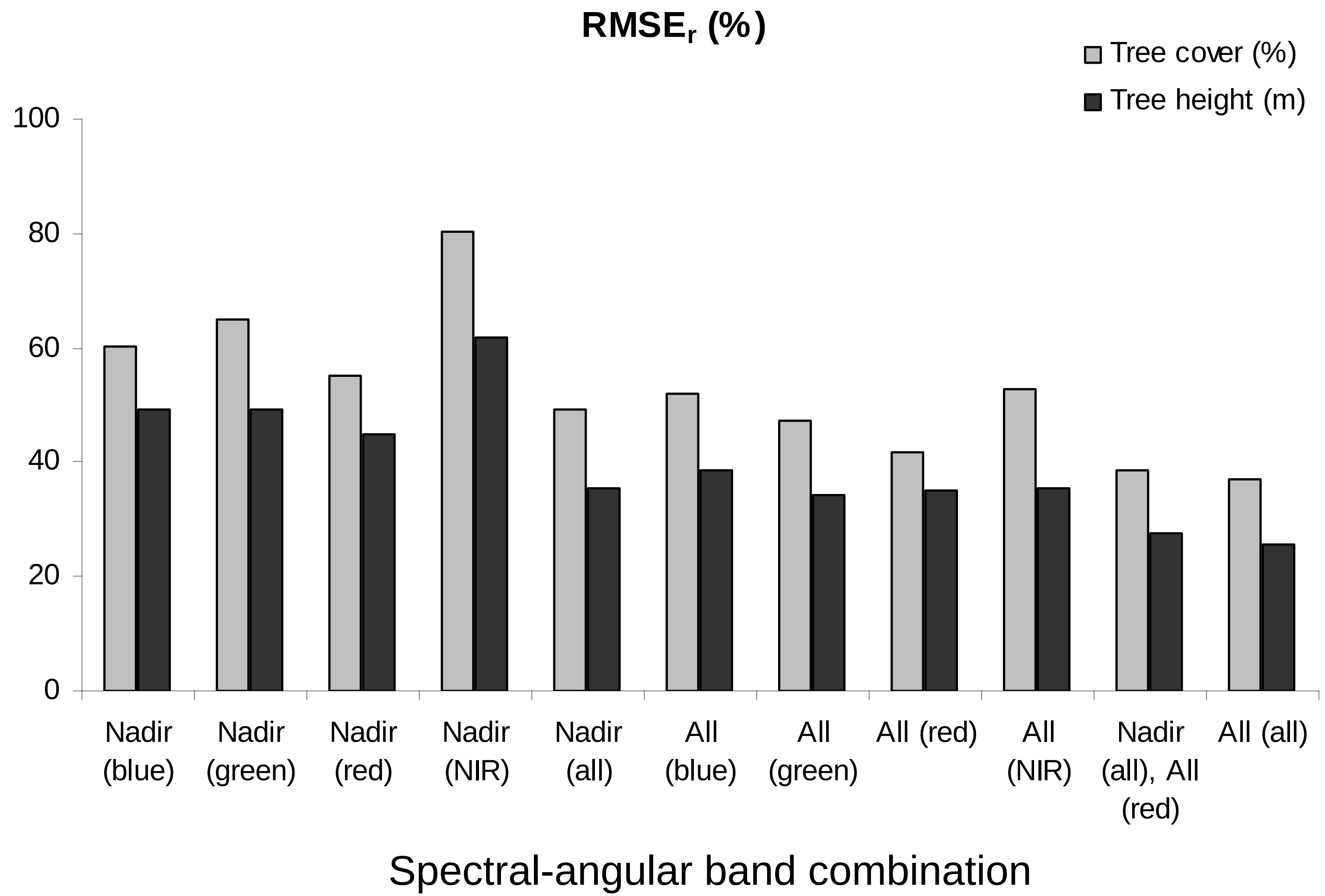
- RMSE of the best coniferous tree cover estimates was 3.85% ($RMSE_r$ 106.5%)
- RMSE of the best broadleaved tree cover estimates was 6.43% ($RMSE_r$ 83.2%)


RMSE$_r$ (%)
Tree cover (%)
Tree height (m)
100
80
60
40
20
0
Nadir (blue)
Nadir (green)
Nadir (red)
Nadir (NIR)
Nadir (all)
All (red)
Nadir (all), All (red)
Spectral-angular band combination

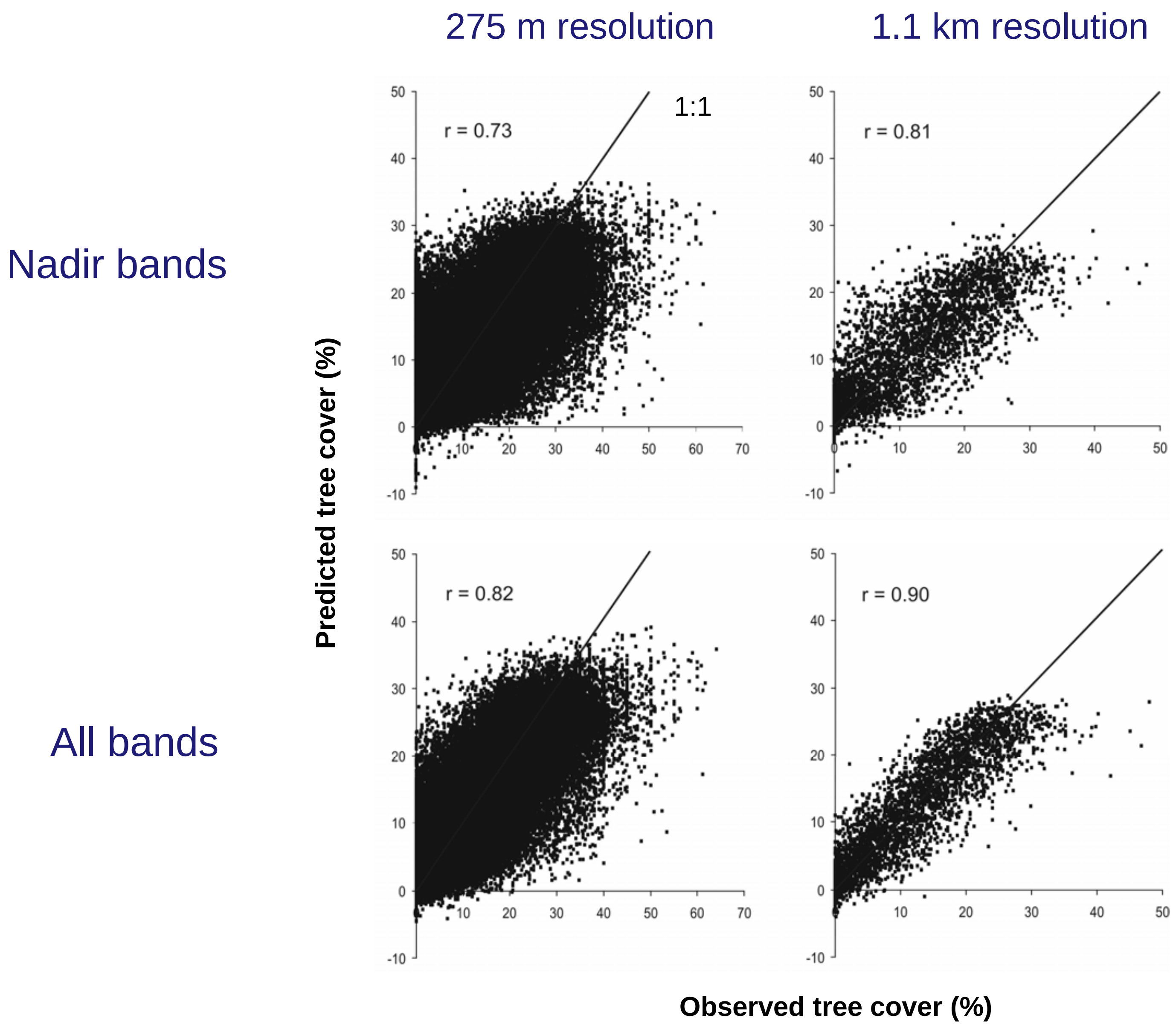
Accuracy of the tree cover and height estimates at 1.1 km resolution (TOA BRF)

Variable	View-angle (spectral band)	Number of bands	RMSE	$RMSE_r$ (%)	Bias	$Bias_r$ (%)	r
Tree cover (%)	Nadir (red)	1	6.07	55.0	0.07	0.6	0.75
	Nadir (all)	4	5.42	49.2	-0.14	-1.3	0.81
	All (blue)	8	5.74	52.0	**-0.26**	-2.4	0.78
	All (green)	8	5.21	47.2	-0.09	-0.8	0.83
	All (red)	8	4.62	41.9	0.05	0.4	0.87
	All (NIR)	8	5.80	52.6	-0.21	-1.9	0.78
	Nadir (all), All (red)	11	4.27	38.7	-0.07	-0.6	0.89
	All (all)	32	4.06	36.9	-0.11	-1.0	0.90
Tree height (m)	Nadir (red)	1	2.28	44.7	0.03	0.6	0.70
	Nadir (all)	4	1.80	35.4	-0.02	-0.4	0.83
	All (blue)	8	1.96	38.5	0.01	0.1	0.79
	All (green)	8	1.74	34.1	0.00	-0.1	0.84
	All (red)	8	1.80	35.2	0.06	1.2	0.83
	All (NIR)	8	1.81	35.6	-0.07	-1.3	0.83
	Nadir (all), All (red)	11	1.40	27.5	0.00	0.1	0.90
	All (all)	32	1.29	25.4	-0.01	-0.2	0.91

- Smaller errors than at 275 m resolution
- RMSE of the best coniferous tree cover estimates was 2.23% ($RMSE_r$ 68.9%)
- RMSE of the best deciduous tree cover estimates was 3.96% ($RMSE_r$ 52.5%)

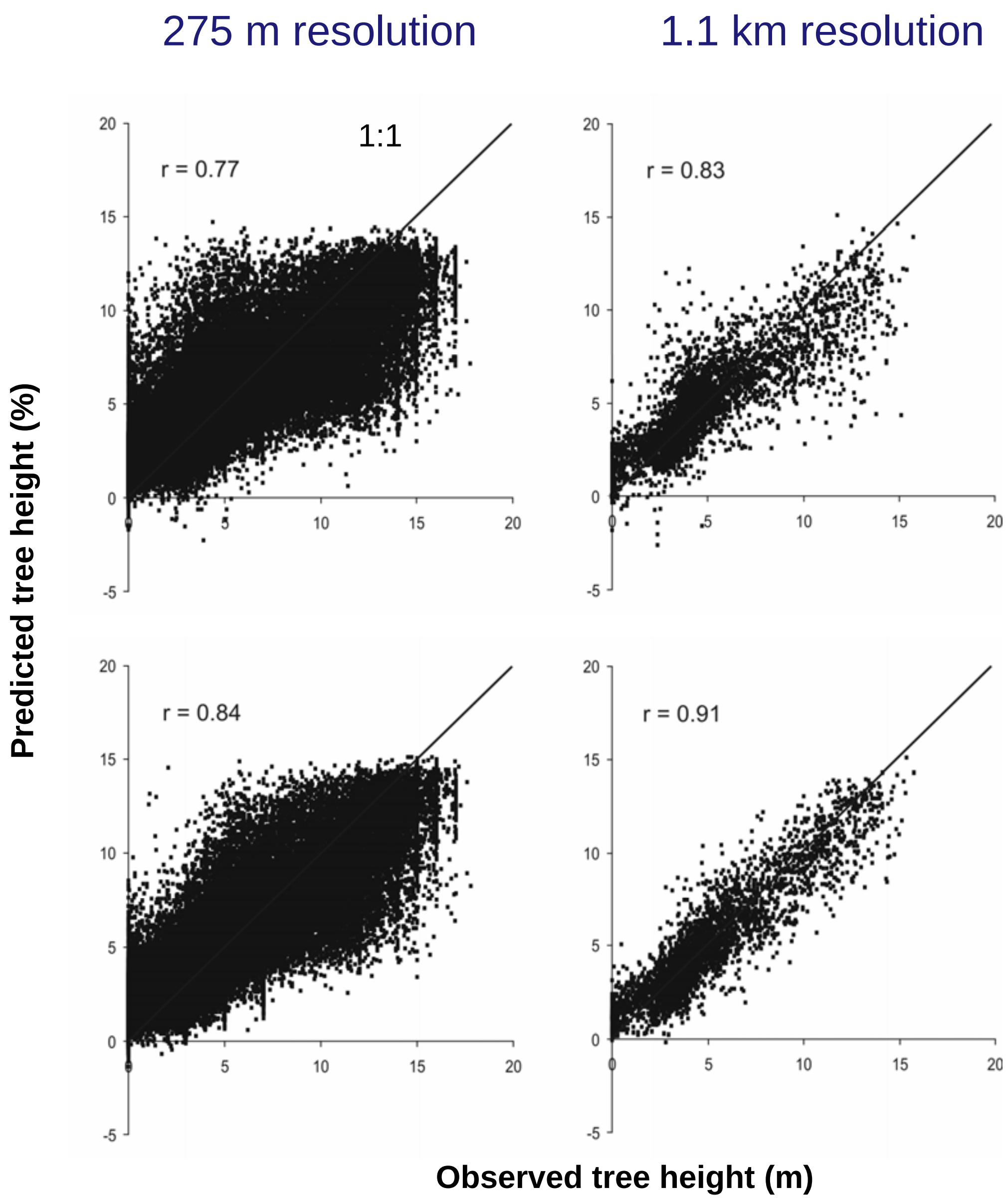


RMSE$_r$ (%)
Tree cover (%)
Tree height (m)
100
80
60
40
20
0
Nadir (blue)
Nadir (green)
Nadir (red)
Nadir (NIR)
Nadir (all)
All (blue)
All (green)
All (red)
All (NIR)
Nadir (all), All (red)
All (all)
Spectral-angular band combination


275 m resolution
1.1 km resolution
Nadir bands
All bands
Predicted tree cover (%)
Observed tree cover (%)
1:1
r = 0.73
r = 0.81
r = 0.82
r = 0.90

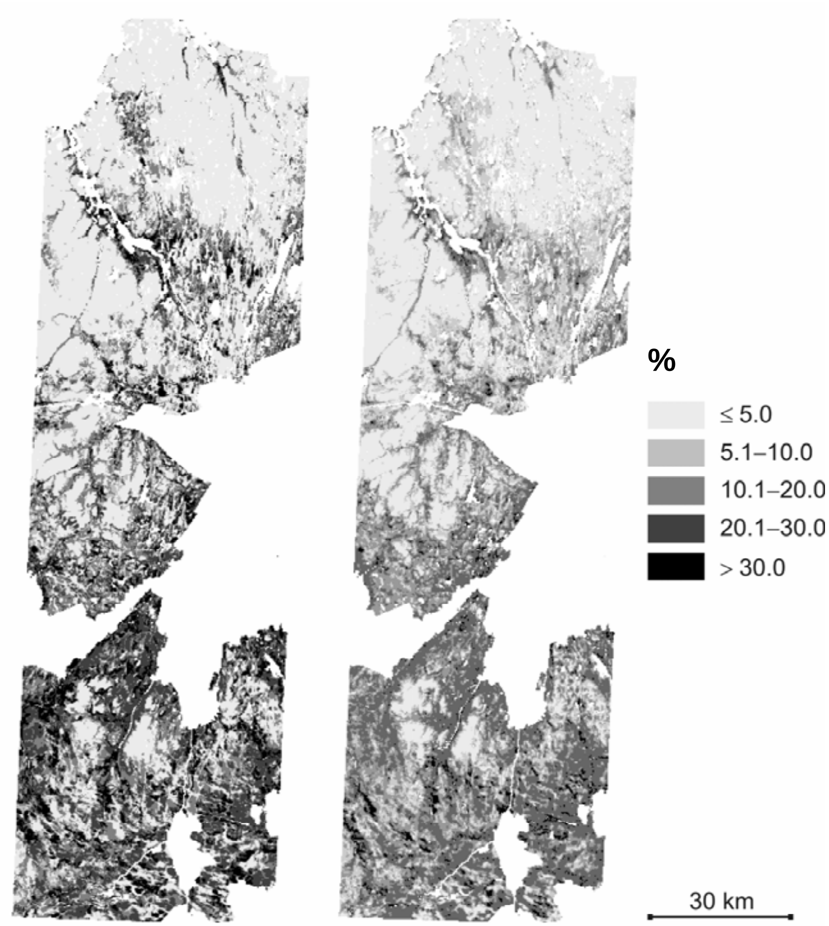
Nadir bands

All bands



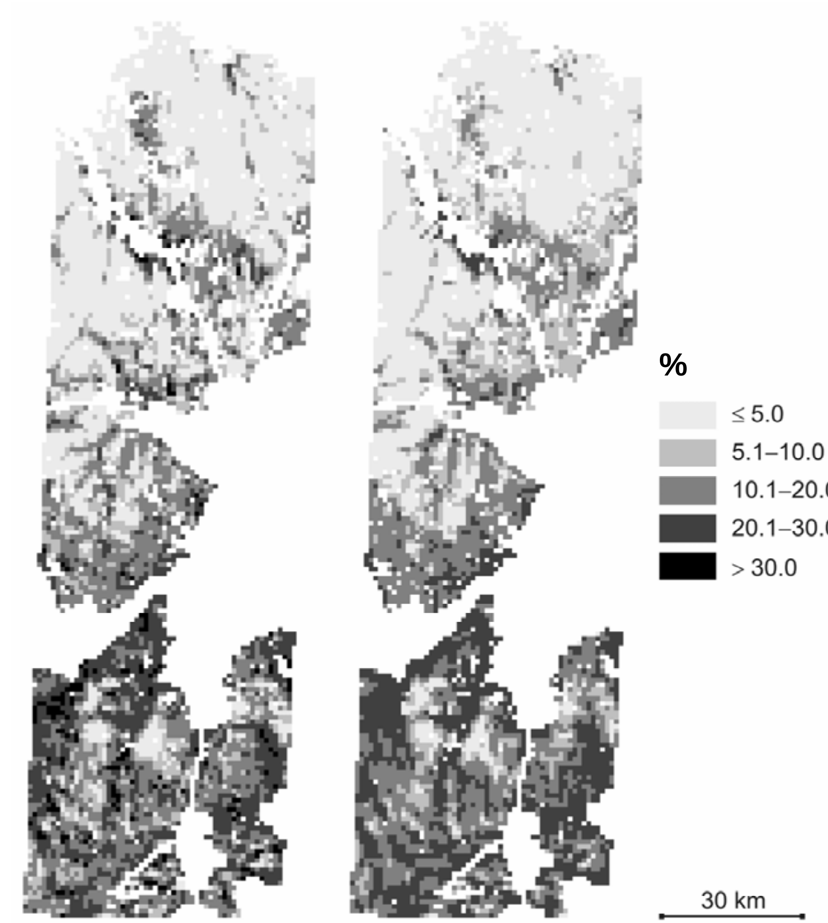
Tree cover surfaces

Observed Predicted



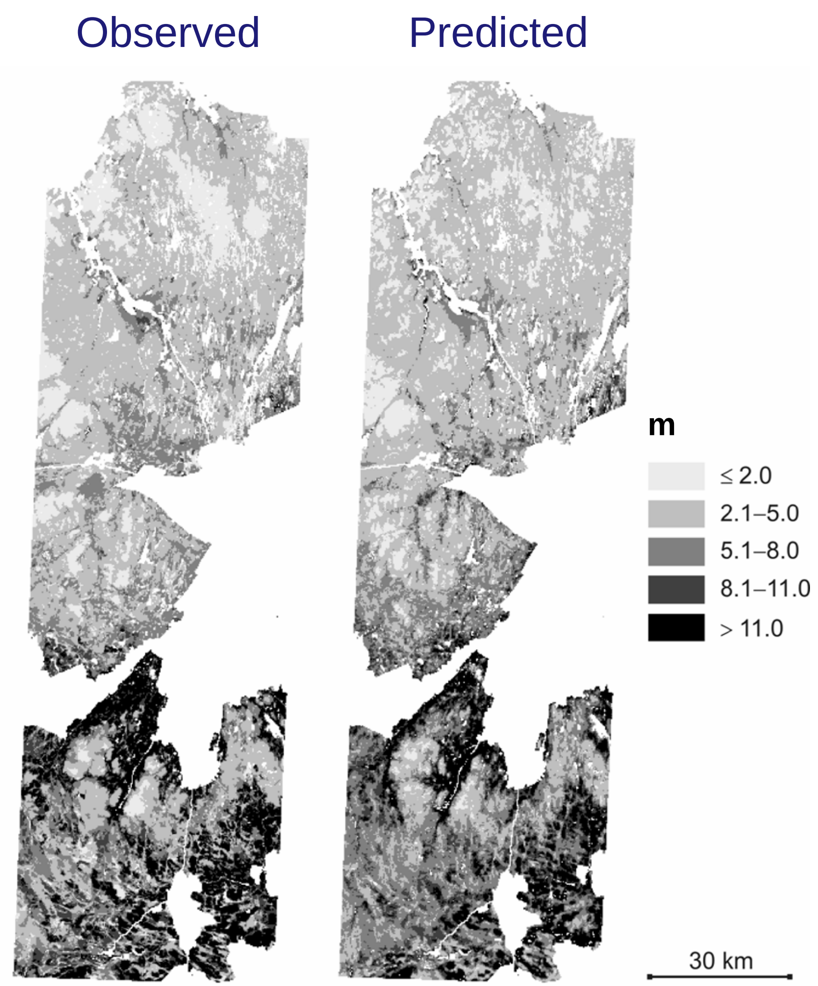
275 m resolution

Observed Predicted

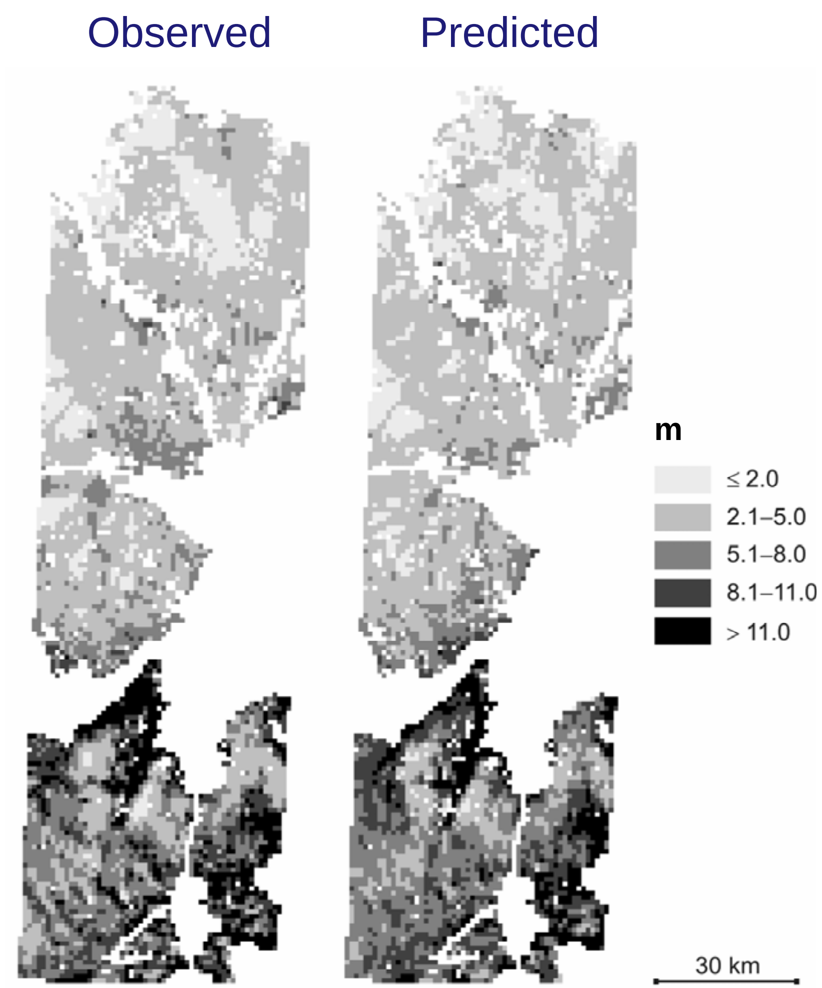


1.1 km resolution

Tree height surfaces



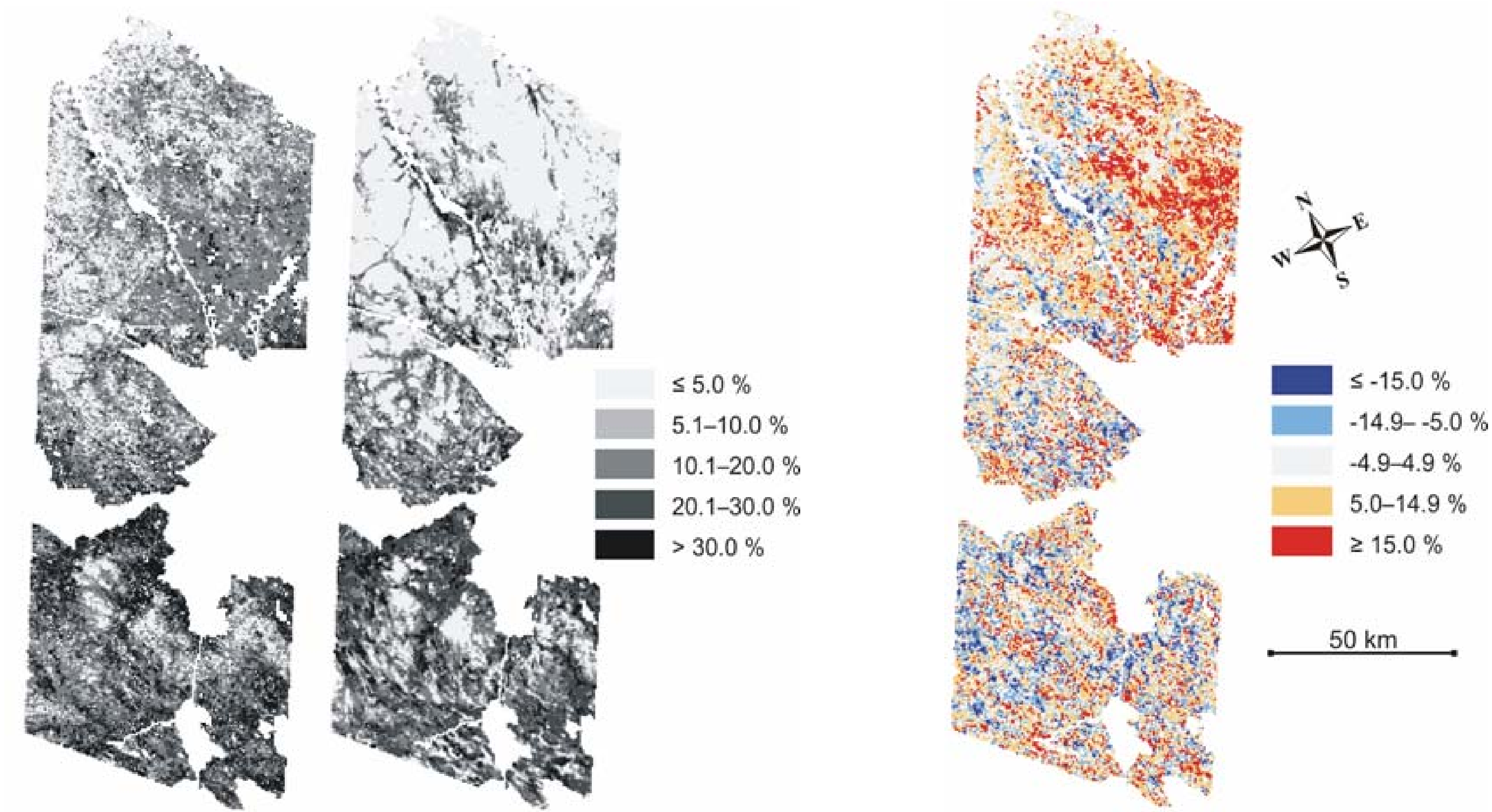
275 m resolution



1.1 km resolution

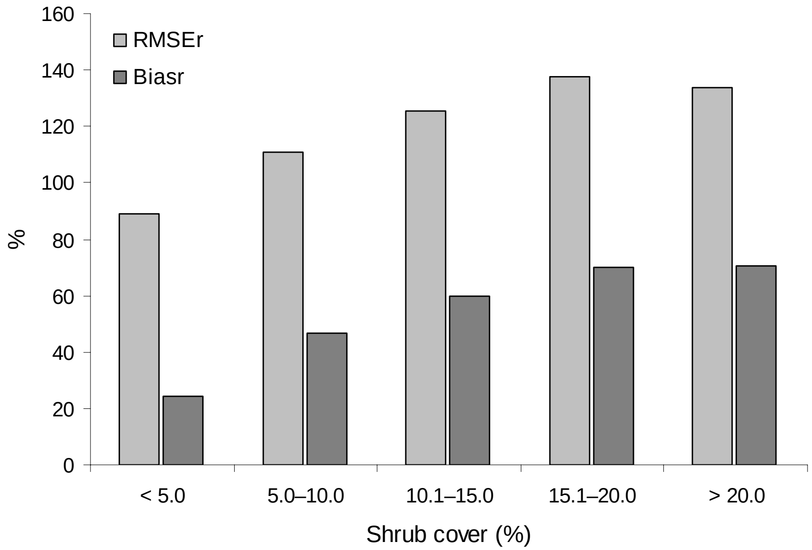
MODIS continuous fields of tree cover

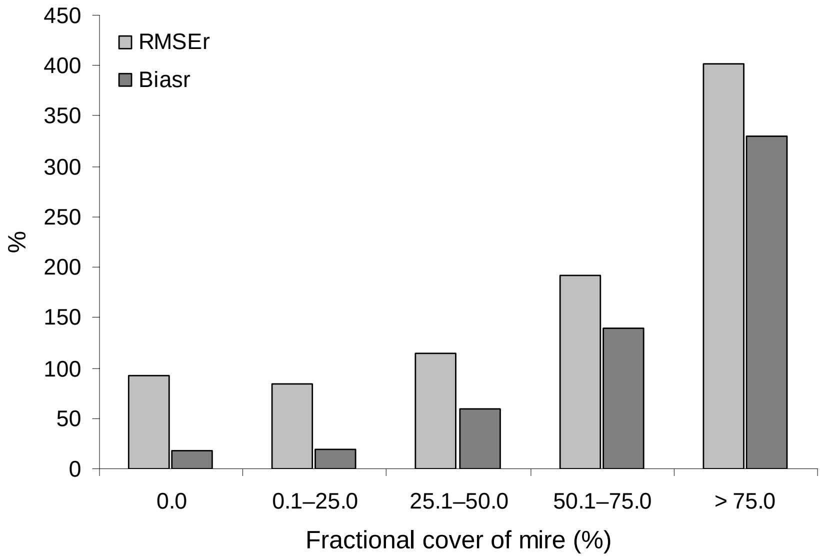
MODIS   Reference data   Difference



n	RMSE	$RMSE_r$ (%)	Bias	$Bias_r$ (%)	r
43631	11.36	101.9	4.13	37.0	0.474

MODIS continuous fields of tree cover



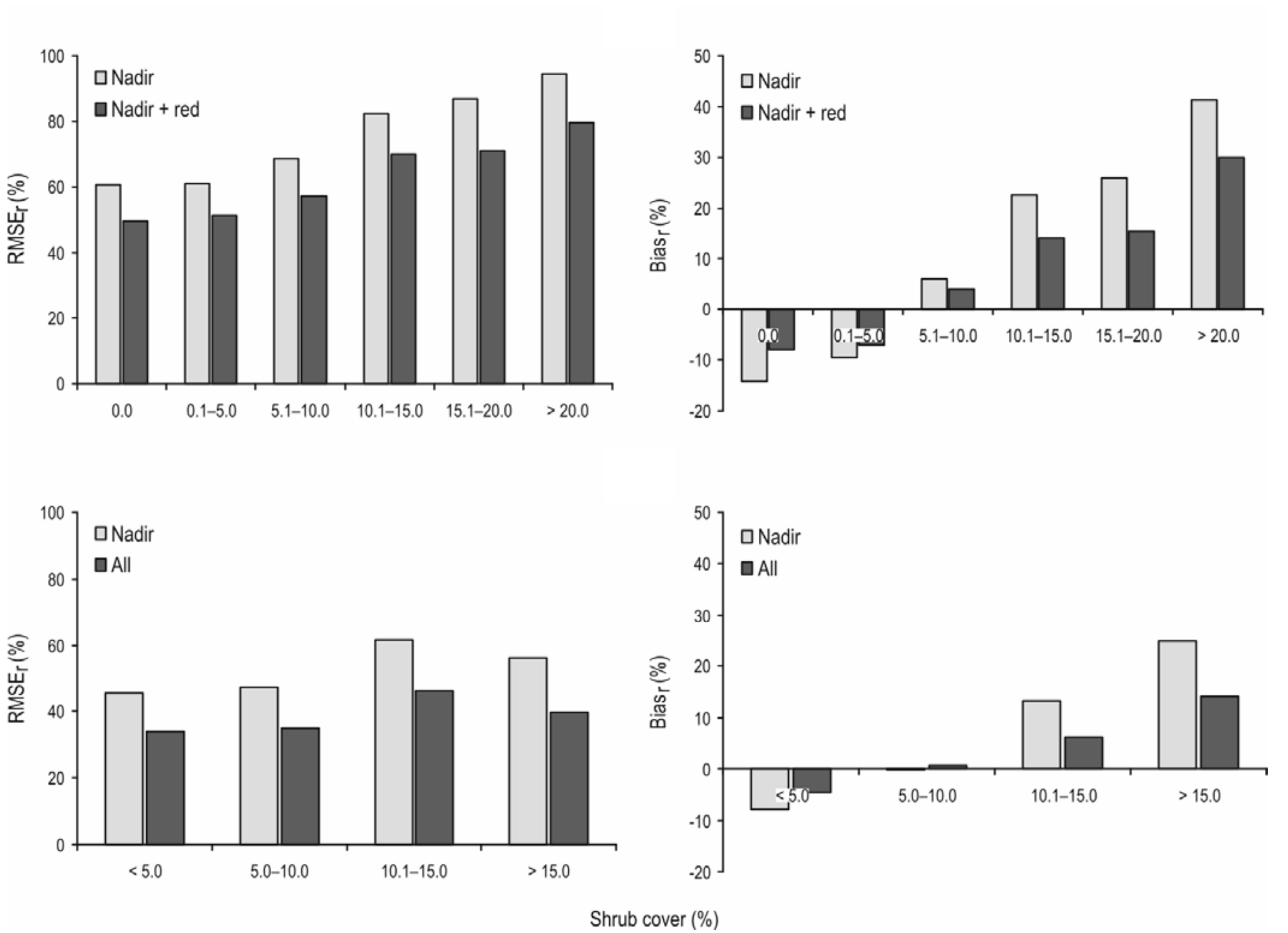


- Tree cover is overestimated in the areas of dense shrub cover and in the mires

Accuracy of the tree cover estimates in relation to shrub cover

275 m

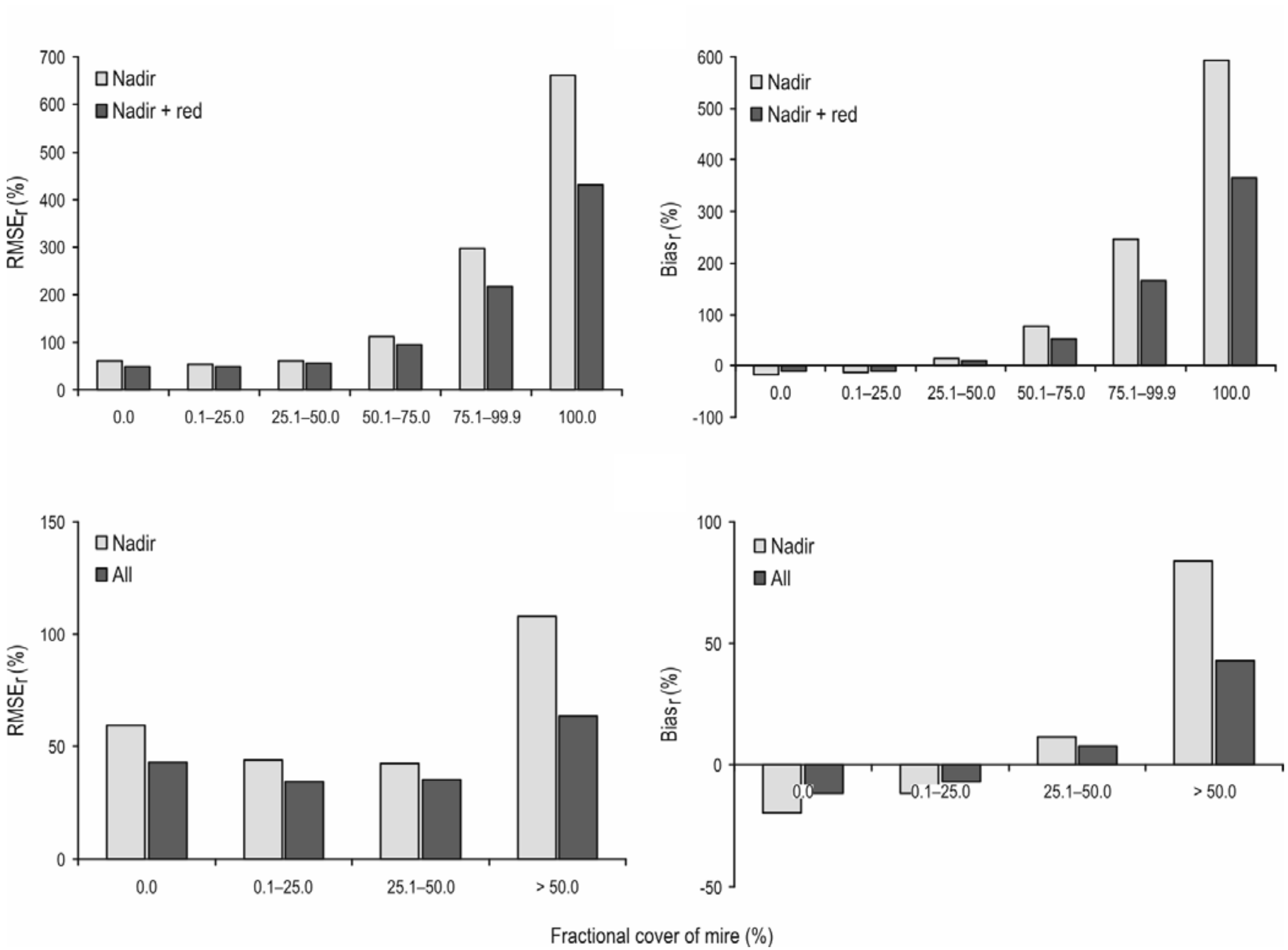
1.1 km



Accuracy of the tree cover estimates in relation fractional cover of mire

275 m

1.1 km



Conclusions

- The results suggest that directional information has potential to improve the tree cover and height estimates over the tundra–taiga transition zone in comparison to VIS–NIR nadir-view data only
- The multiangular data seem to increase sensitivity to the vegetation structure and reduce the effects of undergrowth vegetation
- The largest errors occurred when shrub cover was dense and in mires, but the inclusion of multiangular data improved estimates also in those areas

Conclusions

- So far the use of multiangular data has been somewhat limited in land cover mapping in tundra–taiga transition zone
- For mapping large areas, the atmospheric correction of MISR data and application of an appropriate BRDF model would be necessary

Thank you!