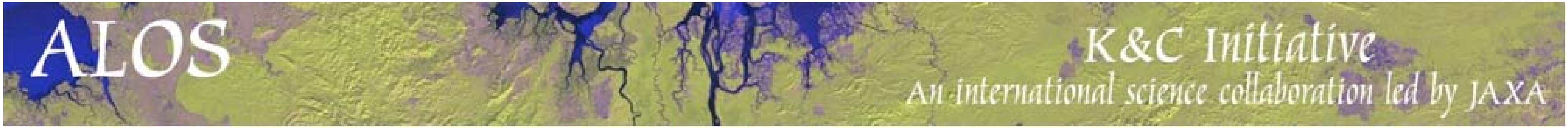
Product Delivery Report for K&C Phase 3

Christian Thiel et al.
Friedrich-Schiller-University Jena, Germany

Science Team meeting #21 – Phase 3 Result Presentations
Kyoto Research Park, Kyoto, Japan, December 3-4, 2014



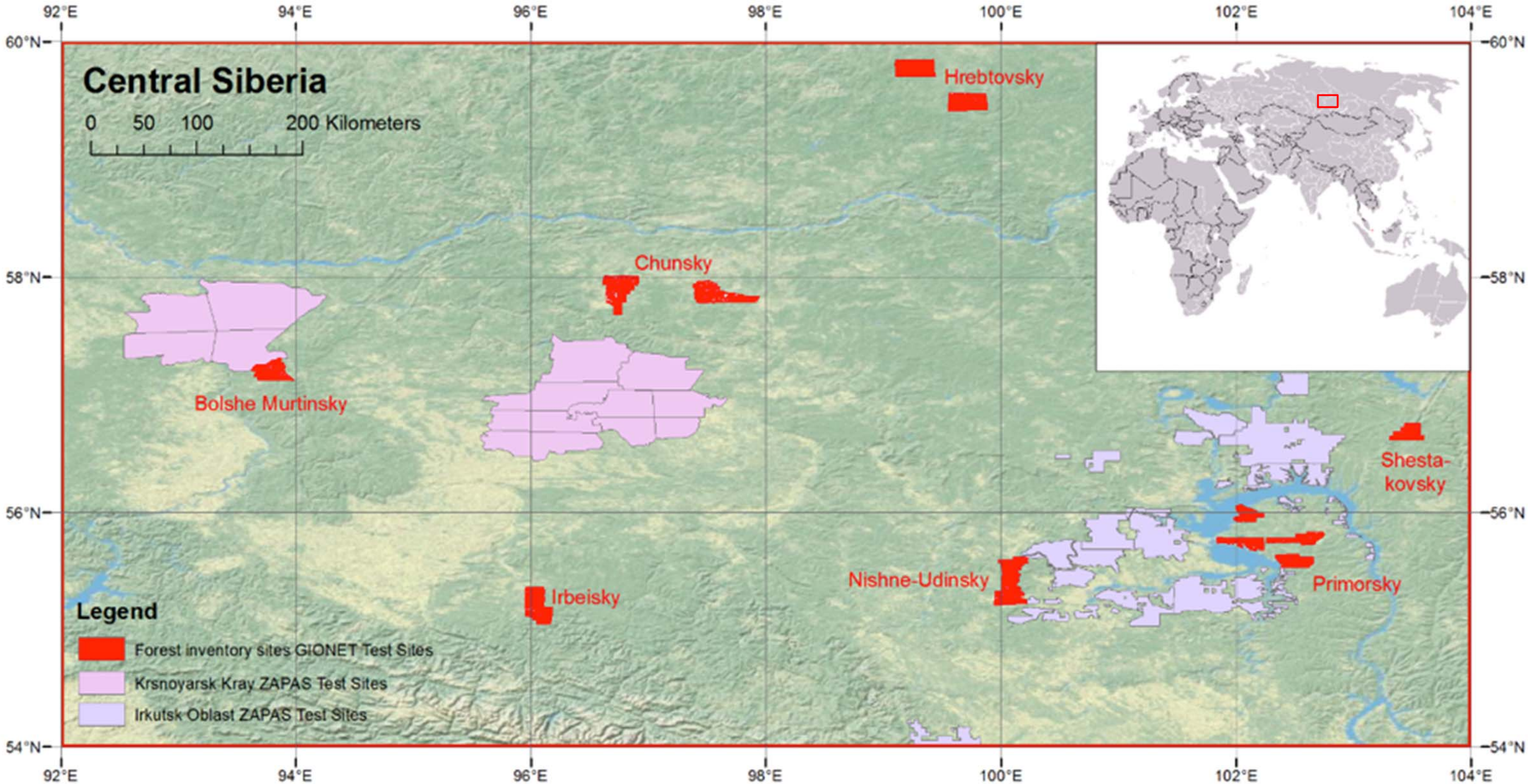
Project objectives

- GSV retrieval using POLSAR data
- GSV retrieval using INSAR coherence and backscatter
- GSV retrieval using multitemporal mosaic backscatter data
- Forest cover and forest cover change mapping using mosaic backscatter data

Results and significant findings

Project objectives

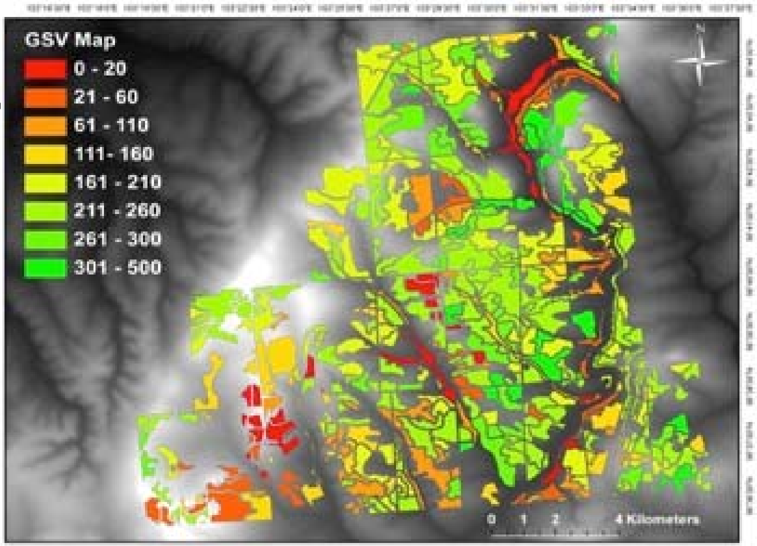
- **GSV retrieval using POLSAR data**
- GSV retrieval using INSAR coherence and backscatter
- GSV retrieval using multitemporal mosaic backscatter data
- Forest cover and forest cover change mapping using mosaic backscatter data

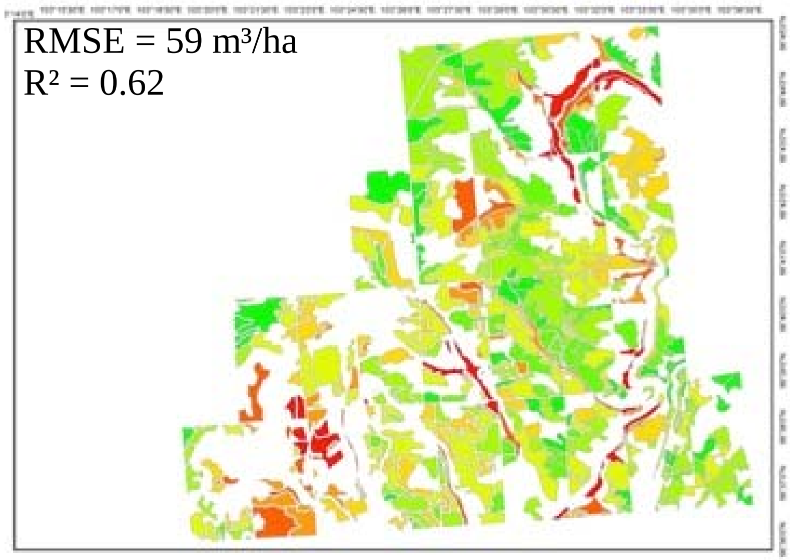

Central Siberia
0 50 100 200 Kilometers
92°E
94°E
96°E
98°E
100°E
102°E
104°E
60°N
58°N
56°N
54°N
Hrebtovsky
Chunsky
Bolshe Murtinsky
Shesta-kovsky
Nishne-Udinsky
Primorsky
Irbeisky
Legend
Forest inventory sites GIONET Test Sites
Krsnoyarsk Kray ZAPAS Test Sites
Irkutsk Oblast ZAPAS Test Sites

Shestakovsky-N

DEM
Value
High : 703.5
Low : 0

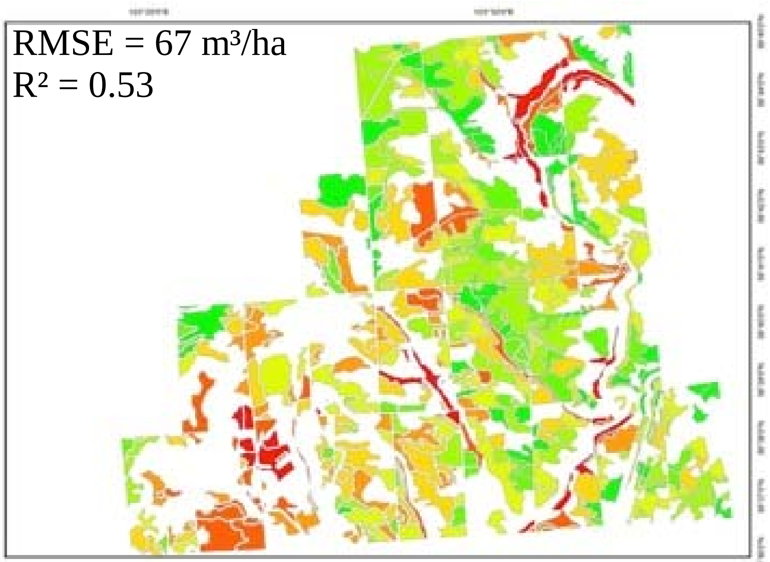
Forest Inventory

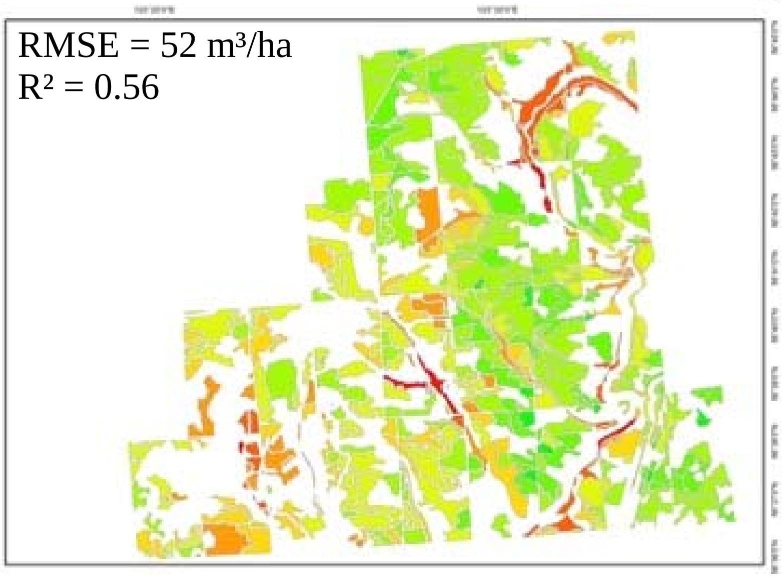




HHVV coherence

Backscatter

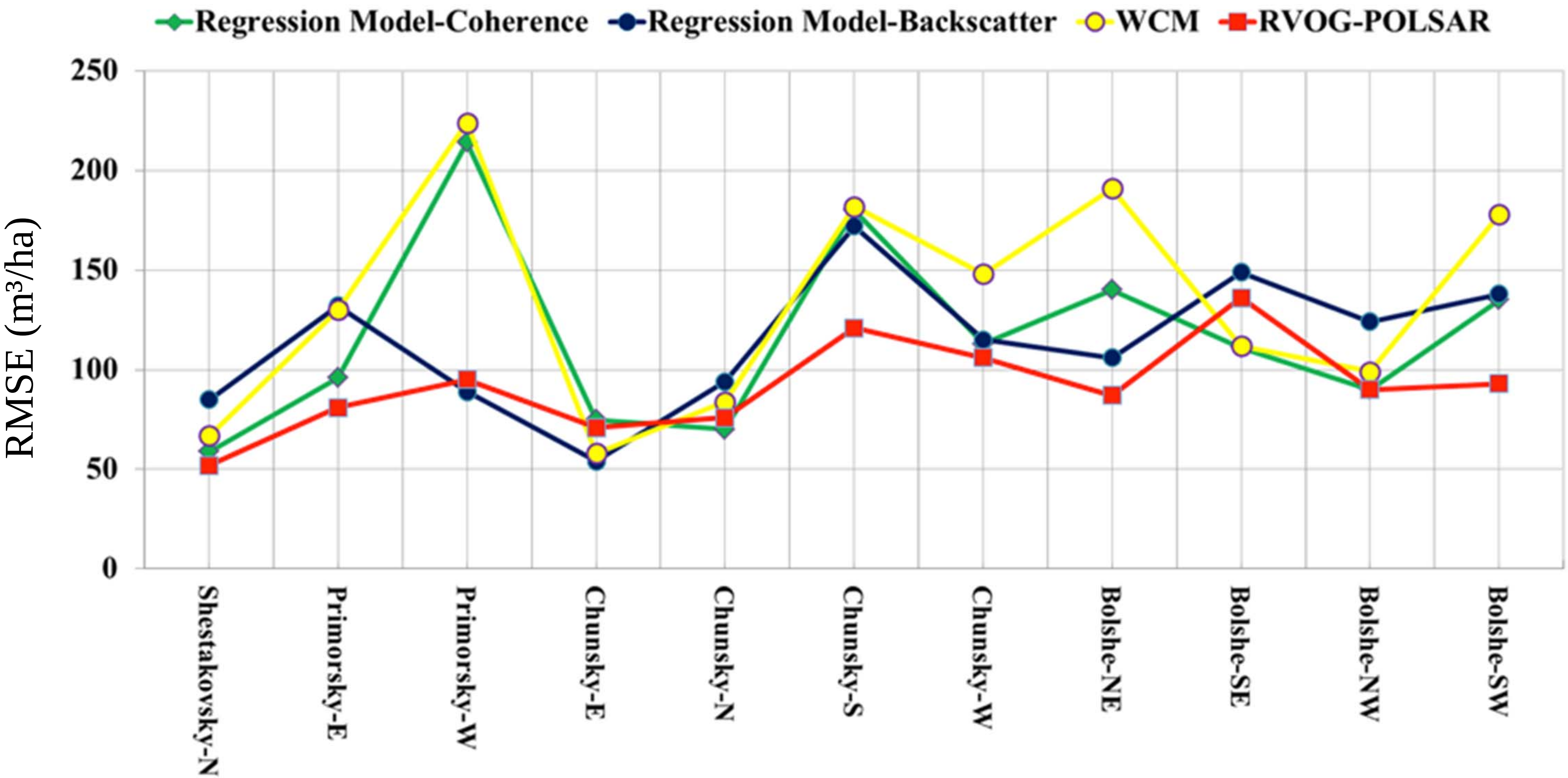




POLSAR Parameters

Test Sites	HV	HH/HV	VV/HV	HHVV coherence	Entropy	Alpha	Freeman Vol	VanZyl Vol	Yamaguchi Vol	Ground/ Volume
Shestakovsky-N	0.75	0.46	0.54	-0.82	0.76	0.76	0.71	0.72	0.72	-0.75
Primorsky-E	0.65	0.29	0.46	-0.59	0.60	0.58	0.61	0.61	0.63	-0.59
Primorsky-W	0.65	0.08	0.05	-0.23	0.25	0.19	0.63	0.64	0.64	-0.24
Chunsky-E	0.81	0.63	0.65	-0.78	0.73	0.76	0.82	0.82	0.82	-0.74
Chunsky-N	0.73	0.60	0.68	-0.72	0.69	0.70	0.75	0.76	0.76	-0.66
Chunsky-S	0.54	0.11	0.12	-0.41	0.38	0.32	0.49	0.50	0.50	-0.35
Chunsky-W	0.51	0.40	0.45	-0.54	0.51	0.52	0.50	0.50	0.51	-0.48
Bolshe-NE	0.86	-0.12	-0.23	-0.72	0.63	0.59	0.85	0.85	0.84	-0.62
Bolshe-SE	0.70	0.30	0.30	-0.68	0.57	0.53	0.67	0.68	0.68	-0.57
Bolshe-NW	0.82	0.21	0.59	-0.80	0.69	0.72	0.75	0.77	0.79	-0.75
Bolshe-SW	0.59	0.07	0.23	-0.48	0.37	0.39	0.50	0.53	0.54	-0.44

Linear Pearson correlation coefficients for growing stock volume against SAR parameters


Regression Model-Coherence
Regression Model-Backscatter
WCM
RVOG-POLSAR
RMSE (m³/ha)
250
200
150
100
50
0
Shestakovsky-N
Primorsky-E
Primorsky-W
Chunsky-E
Chunsky-N
Chunsky-S
Chunsky-W
Bolshe-NE
Bolshe-SE
Bolshe-NW
Bolshe-SW

Summary of findings

- Double-bounce and volume scattering powers show significant correlation with GSV
- The correlation between GSV and surface scattering is highly variable
- The correlation is enhanced if the ratio of volume-to-ground scattering is used

Project objectives

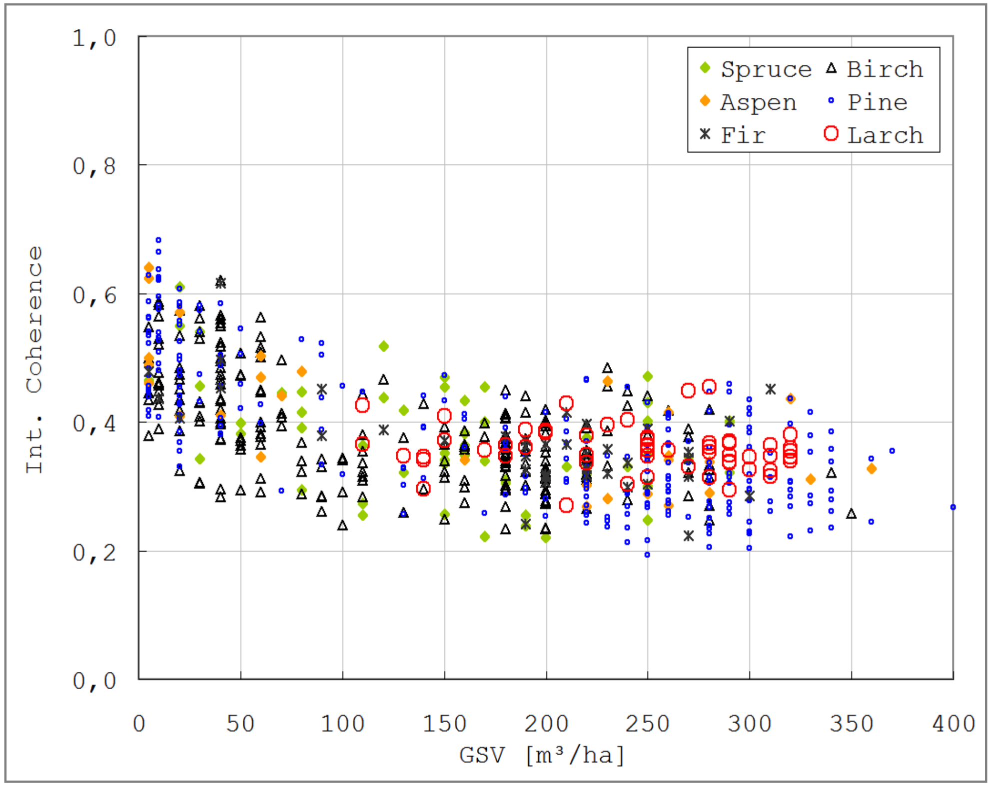
- GSV retrieval using POLSAR data
- **GSV retrieval using INSAR coherence and backscatter**
- GSV retrieval using multitemporal mosaic backscatter data
- Forest cover and forest cover change mapping using mosaic backscatter data

ALOS

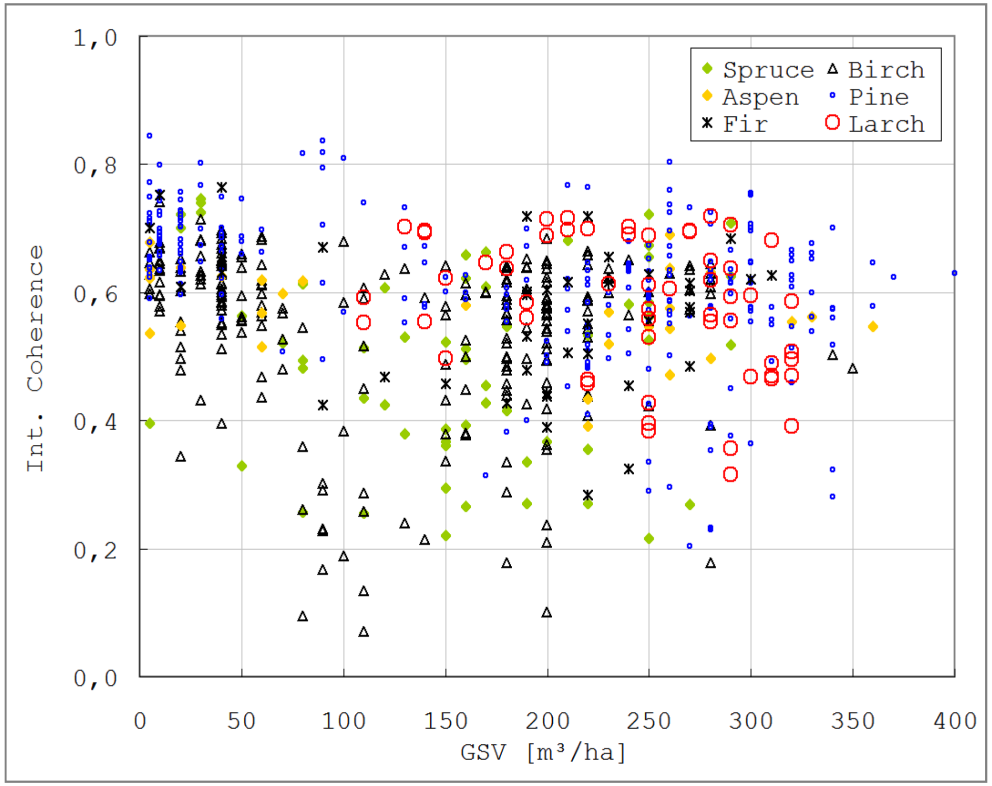
K&C Initiative
An international science collaboration led by JAXA

Impact of Tree Species on PALSAR INSAR Coherence over Siberian Forest at frozen and unfrozen Conditions

Impact of Species: Results



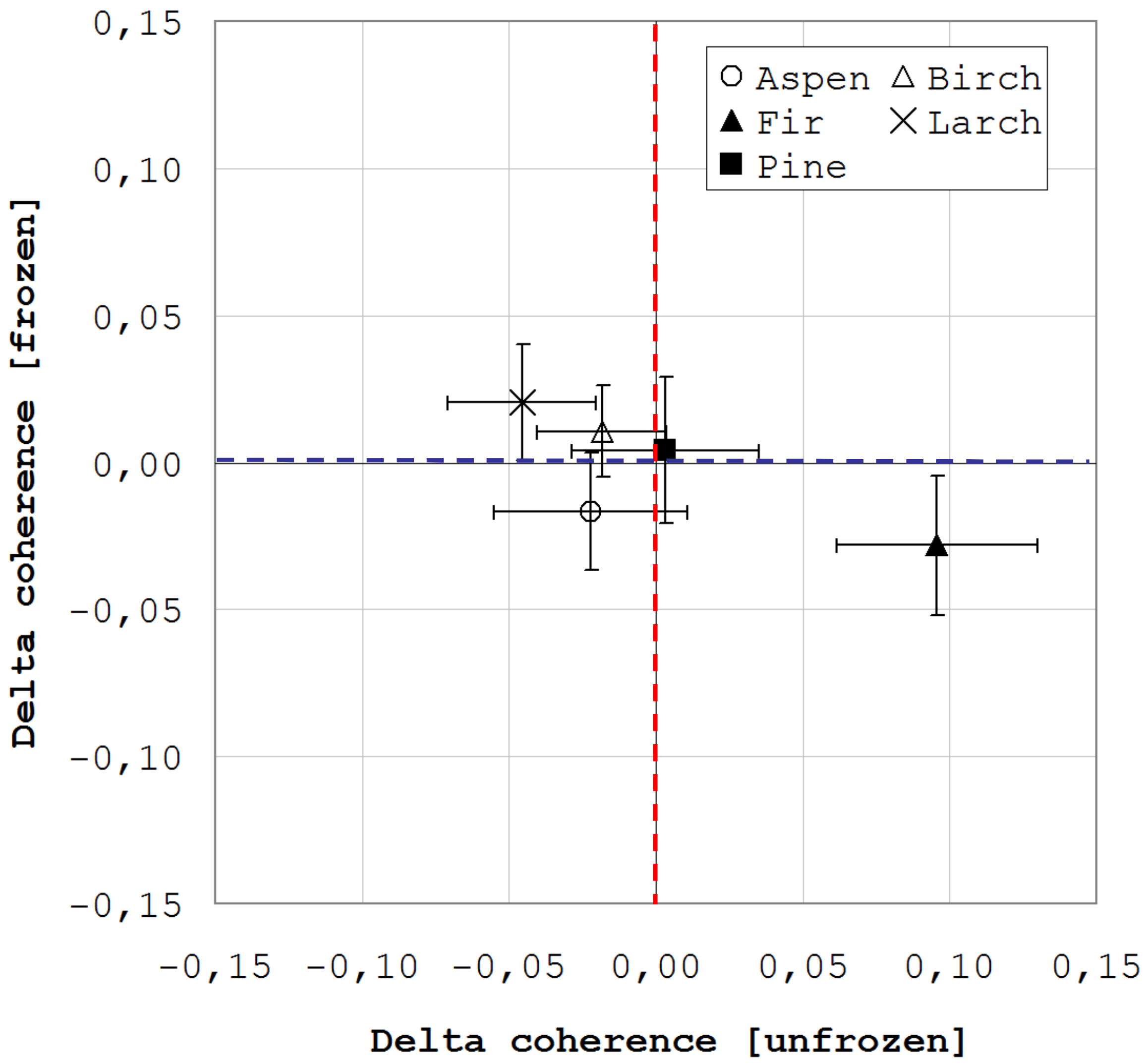
Frozen conditions



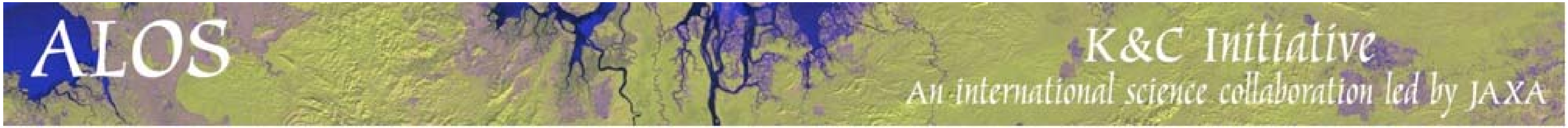
Unfrozen conditions

Magnitude of interferometric coherence vs. GSV for the site Primorsky East

Impact of Species: Results Summary

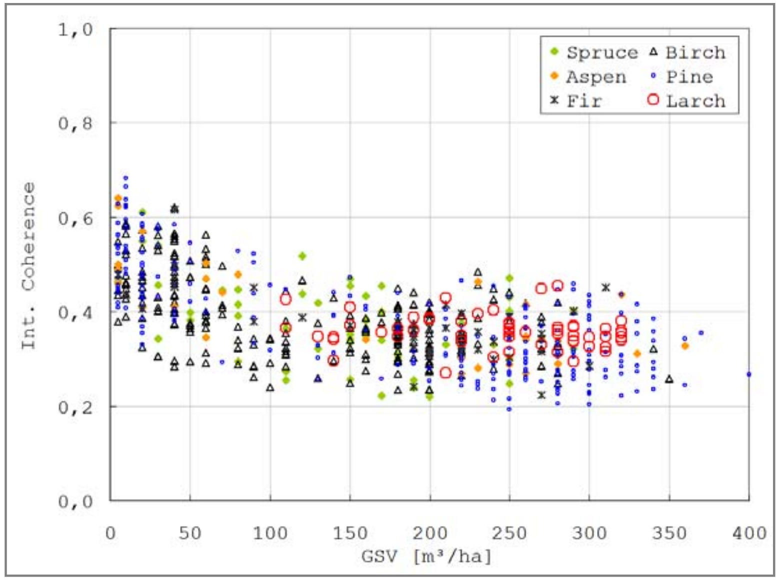


Deviation of tree species specific magnitude of coherence from average – all sites.

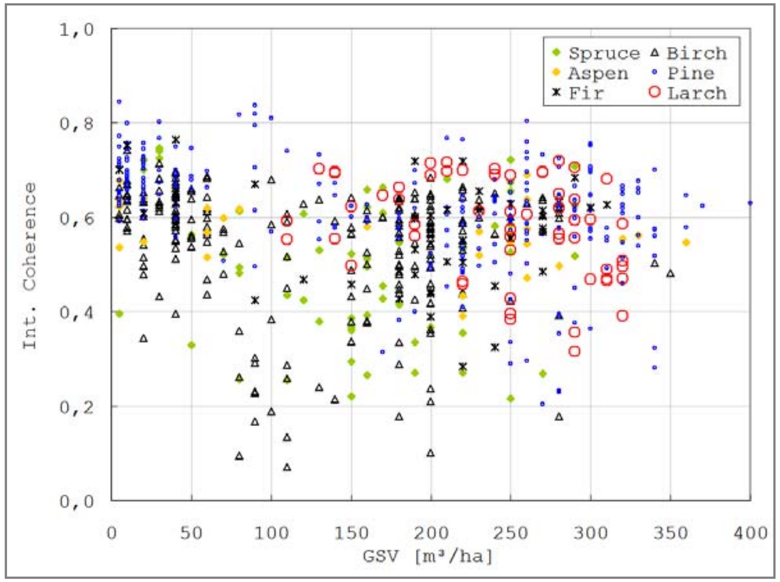


Summary and Conclusions

- Very low impact of tree species on coherence at frozen conditions
- At unfrozen conditions the impact is increased (in particular for fir and larch)
- At unfrozen conditions increased intra-species variance of coherence – most likely caused by spatiotemporal variable environmental conditions



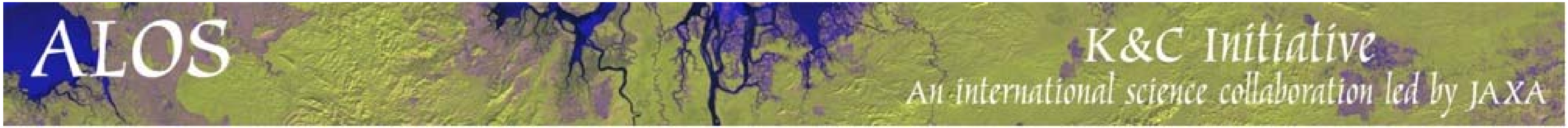
Frozen conditions



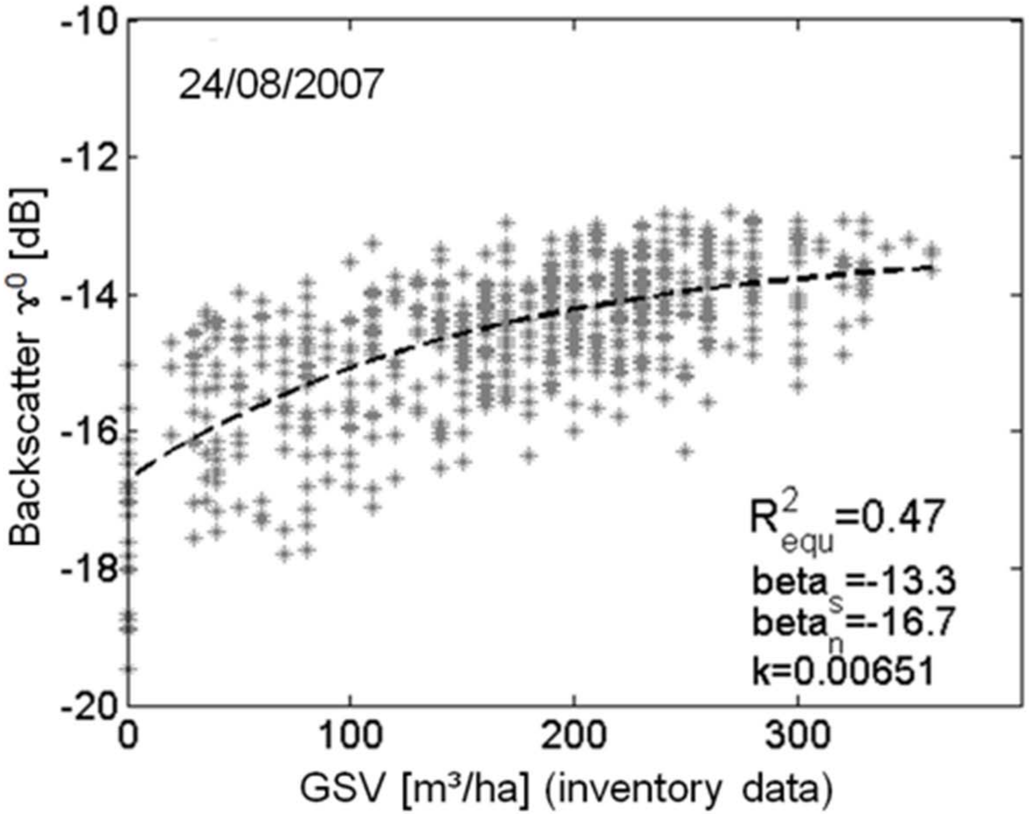
Unfrozen conditions

Project objectives

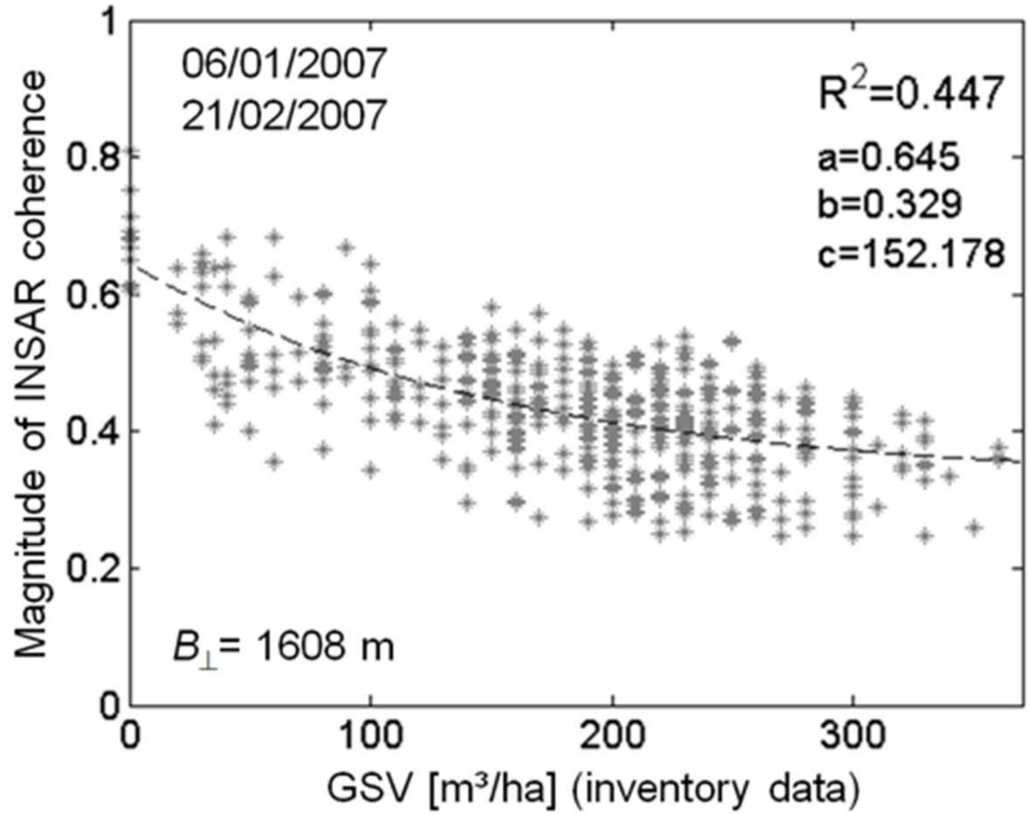
- GSV retrieval using POLSAR data
- **GSV retrieval using INSAR coherence and backscatter**
- Forest biomass retrieval using multitemporal ScanSAR data
- Forest cover and forest cover change mapping



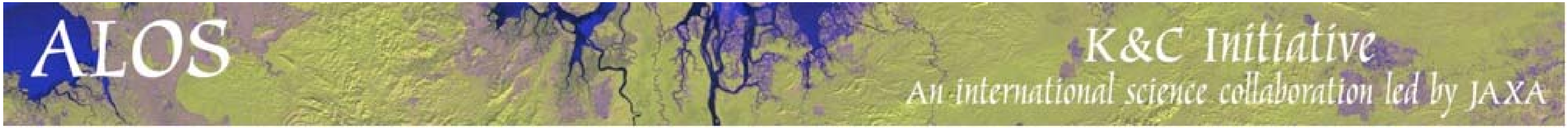
Backscatter

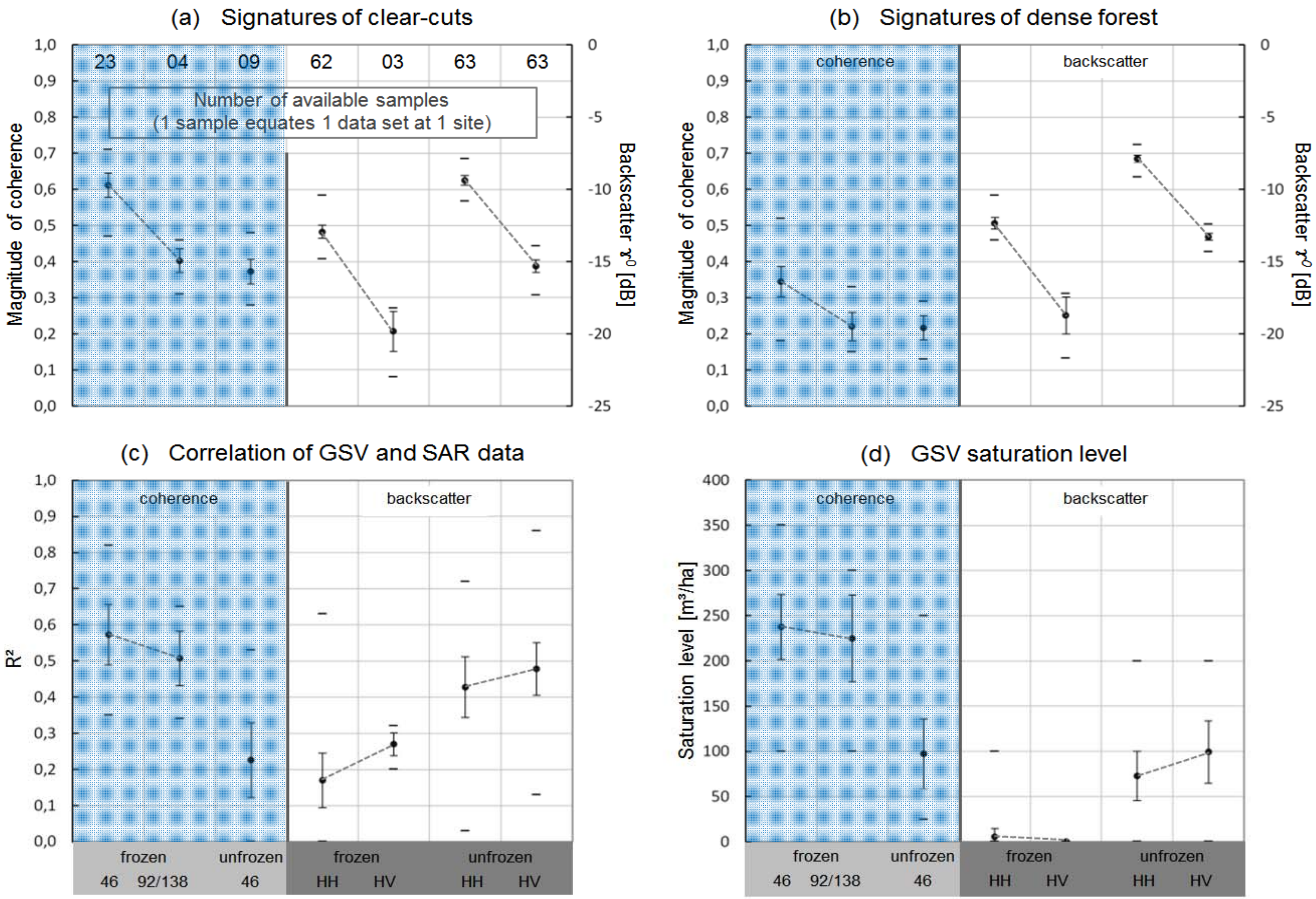


InSAR Coherence



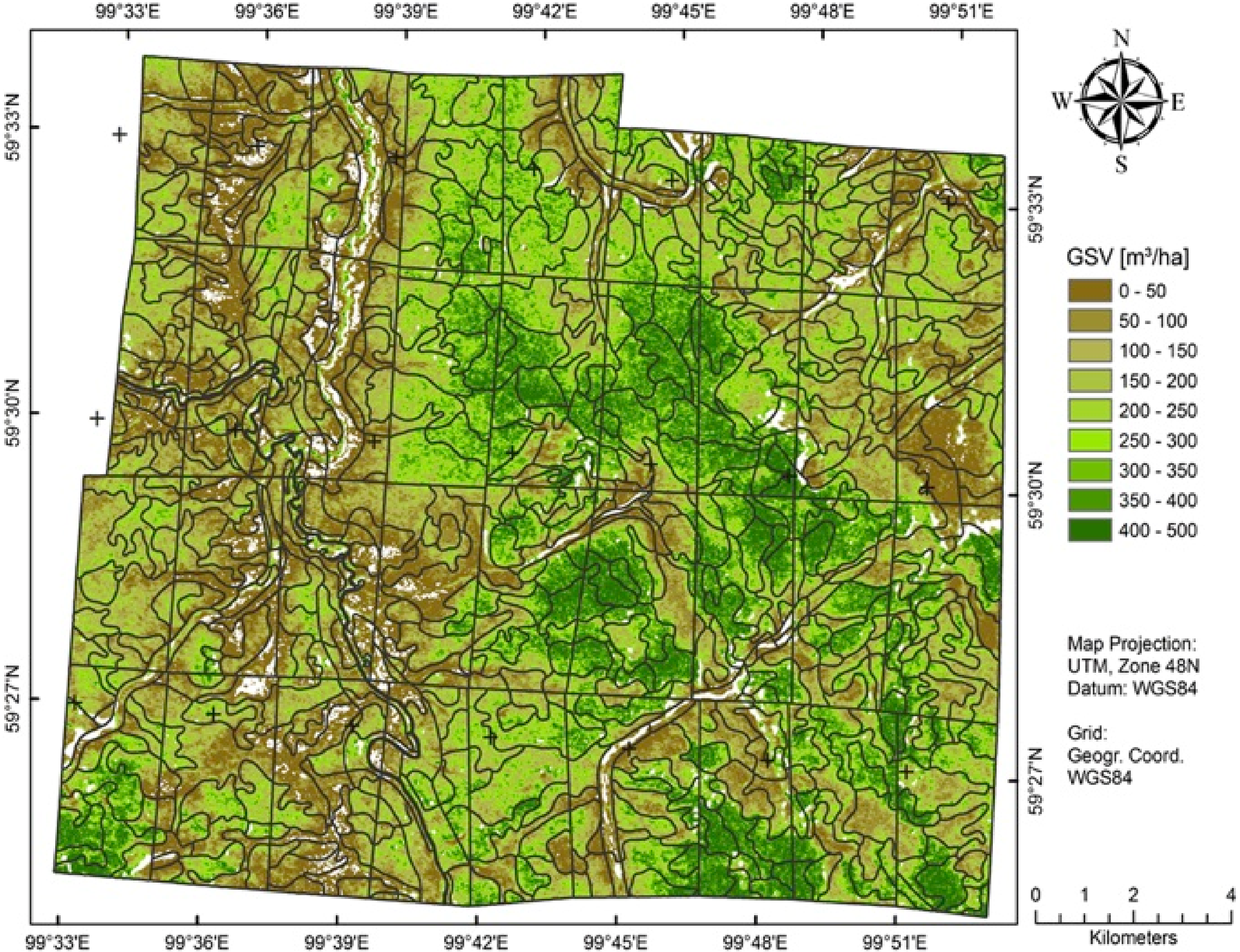
Radar backscatter and coherence as function of GSV for the inventory site Hrebtovsky S. The backscatter image (HV) polarisation was acquired at unfrozen conditions, while the data for the coherence image was acquired at frozen conditions.

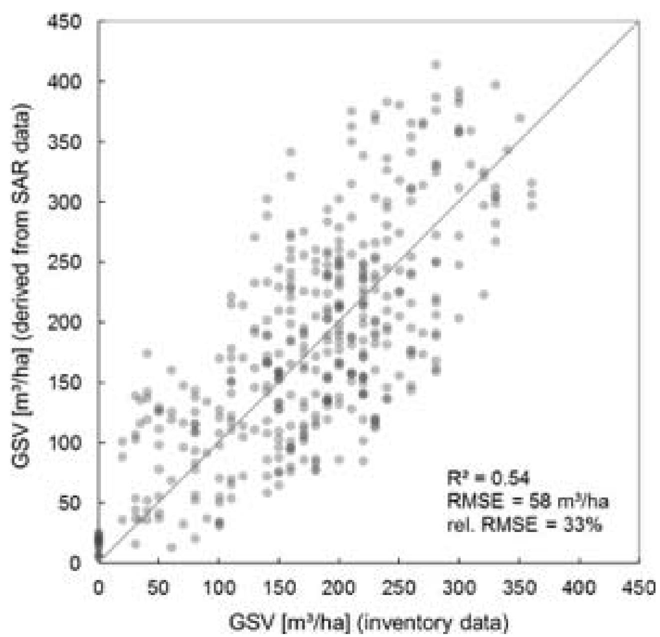




• = average; ⌶ = standard deviation; ⁻₋ = minimum/maximum; 46, 92,138 = temporal baseline [d]

Example for delineation of GSV Map using multi-temporal backscatter & coherence (Hrebtovsky site)





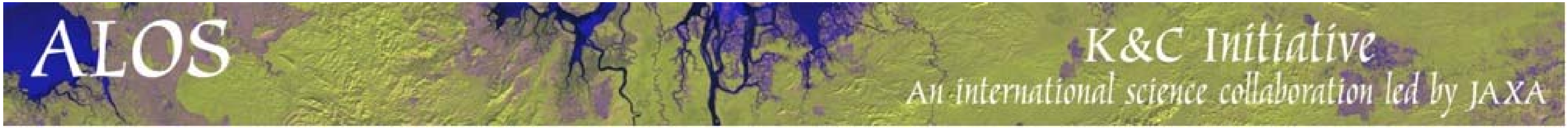
Results for the other sites

	Chunsky E	Chunsky N	Shesta	Hrebt S	Nishni
R^2 coh + int	**0.79**	**0.79**	**0.54**	**0.57**	**0.83**
R^2 coh	0.80	0.78	0.37	0.55	0.82
R^2 int	0.67	0.70	0.56	0.50	0.82
RMSE [m^3/ha] coh + int	**56.6**	**41.2**	**50.4**	**57.4**	**48.9**
RMSE [m^3/ha] coh	56.4	42.4	52.7	61.9	50.7
RMSE [m^3/ha] int	71.1	50.3	56.2	59.1	56.1

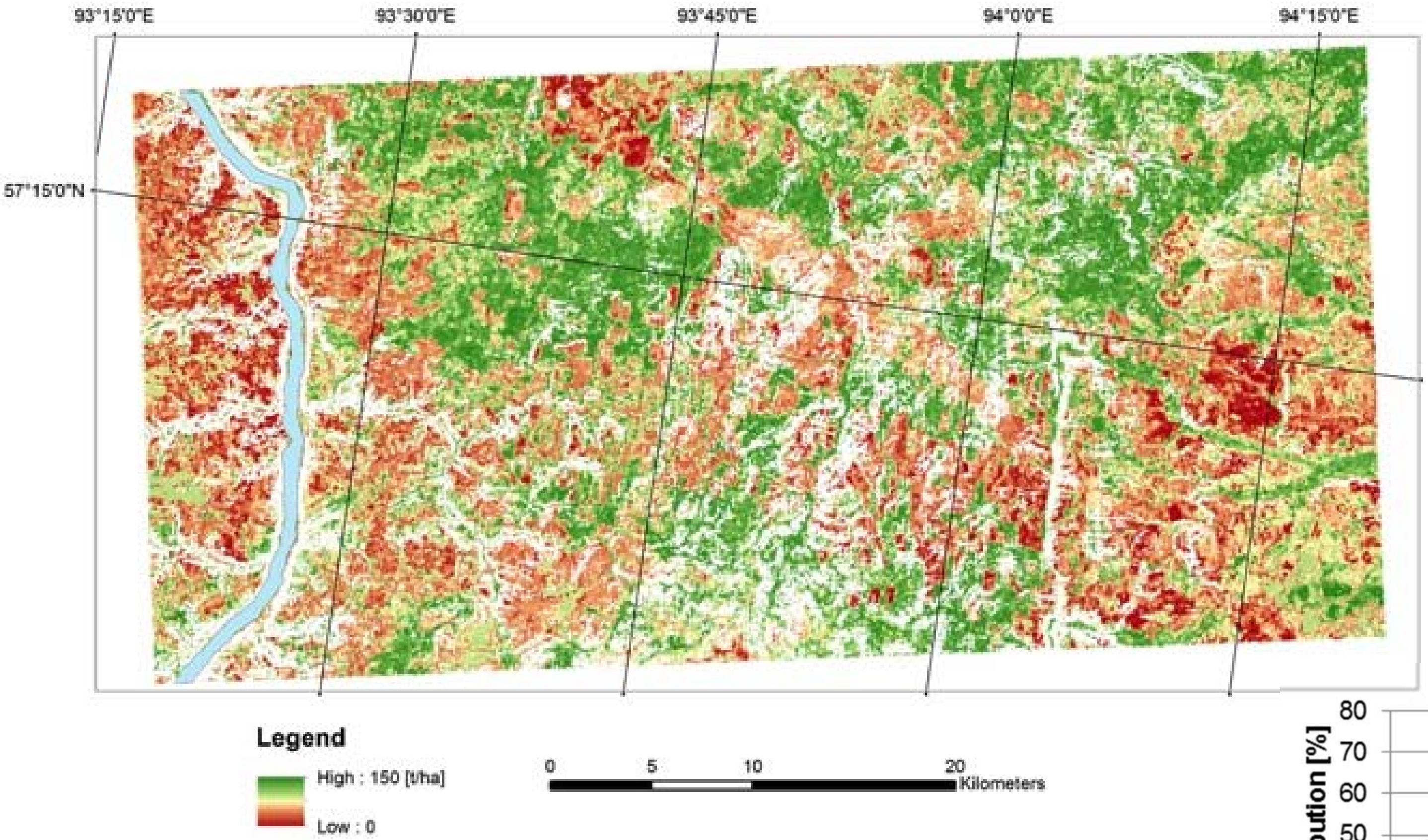
Rel. RMSE approximately 25% for all sites

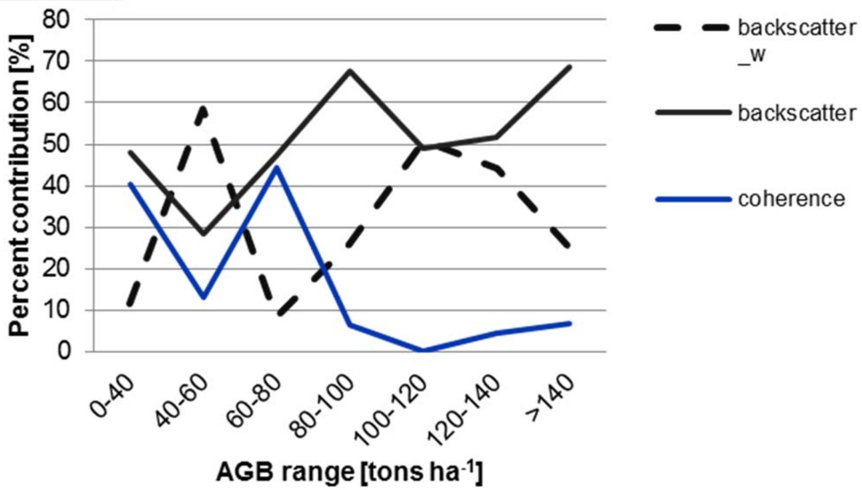
Conclusions

- Coherence at frozen conditions offers the largest potential for *GSV* estimation
    - Saturation at 230 m³/ha, R^2 between coherence and *GSV* is 0.58
    - Comparable results were found in other studies using ERS-1/2 Tandem data
- Backscatter less sensitive
    - Saturation at 75-100 m³/ha, R^2 between backscatter and *GSV* 0.42 (HH) - 0.48 (HV)
- Combination of backscatter and coherence led to improvement of *GSV* estimation, in particular exclusion of areas with contradictory *GSV* (coherence vs. backscatter) helpful
- Demonstrated: Potential of ALOS PALSAR to map the *GSV* of the Siberian forest with a precision close to the accuracy of the conventional forest inventory data (relative RMSE approx. 25%)
- Data availability: At each region in Siberia in average 4 coherence images (temporal baseline 46 days) acquired at frozen conditions and 6 FBD backscatter images acquired at unfrozen conditions are available

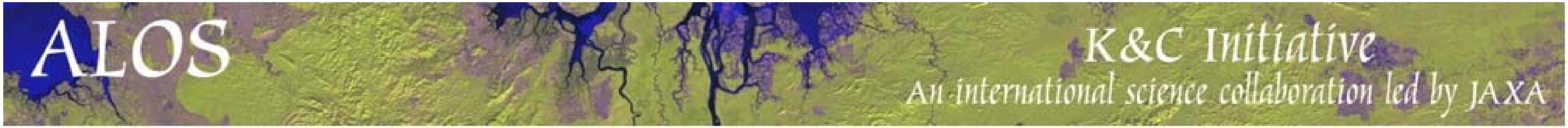


Outlook: Implementation of non-parametric methods (MaxEnt*), Bolshe Murtinsky

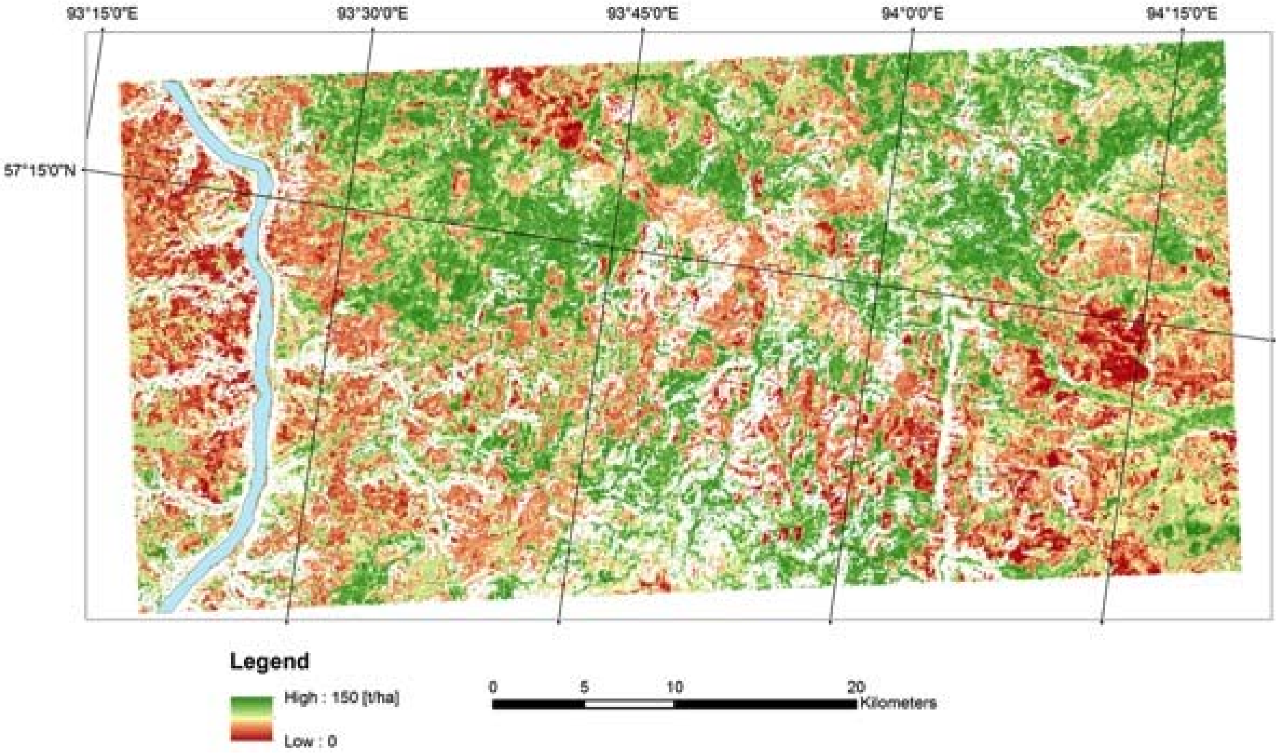


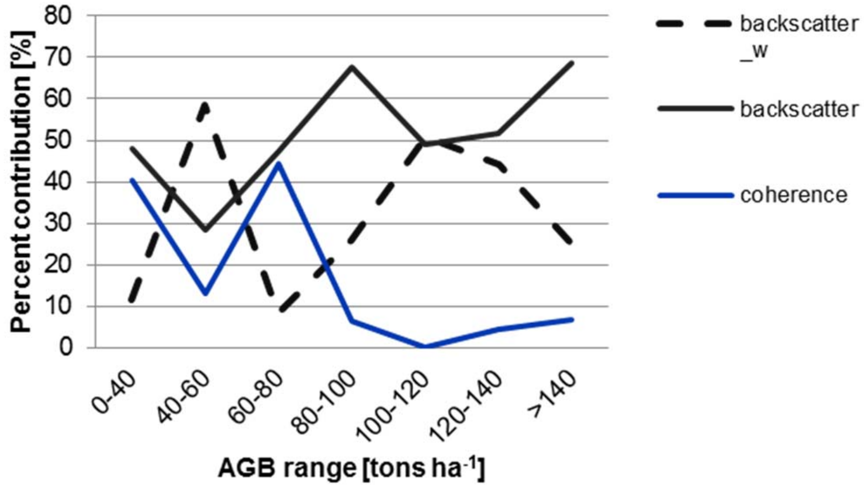


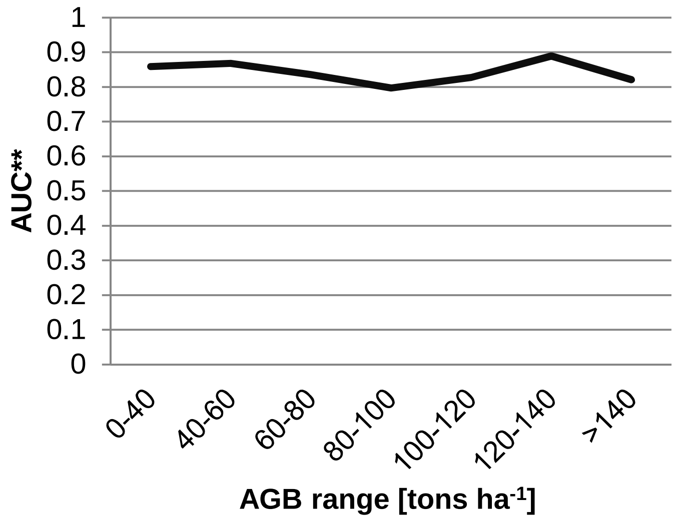
*Cooperation with Centre for Landscape and Climate Research, University of Leicester, UK



Outlook: Implementation of non-parametric methods (MaxEnt*), Bolshe Murtinsky







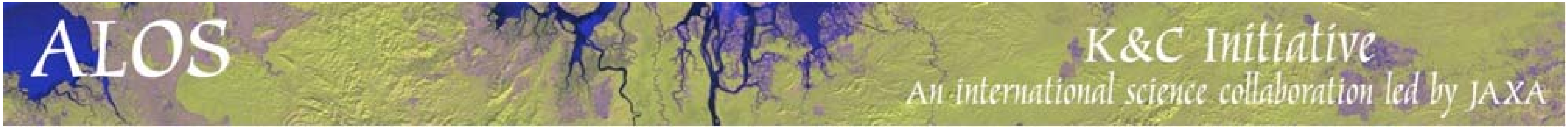
rRMSE = 40.9%

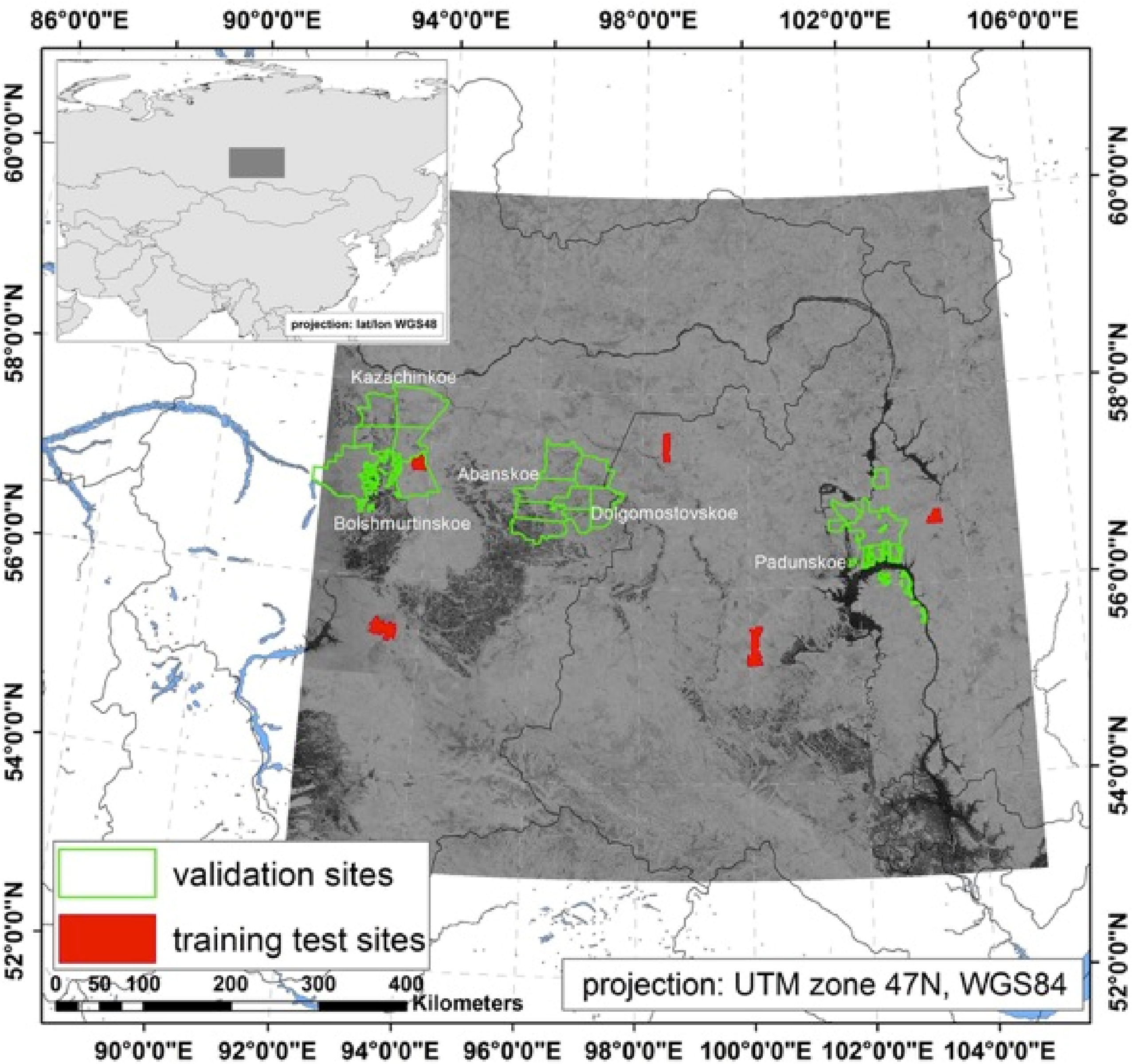
*Cooperation with Centre for Landscape and Climate Research, University of Leicester, UK

** AUC - Area Under the Receiver Operator Curve - AUC (Phillips et al., 2006, Phillips et al., 2004)

Project objectives

- GSV retrieval using POLSAR data
- GSV retrieval using INSAR coherence and backscatter
- **GSV retrieval using multitemporal mosaic backscatter data**
- Forest cover and forest cover change mapping using mosaic backscatter data

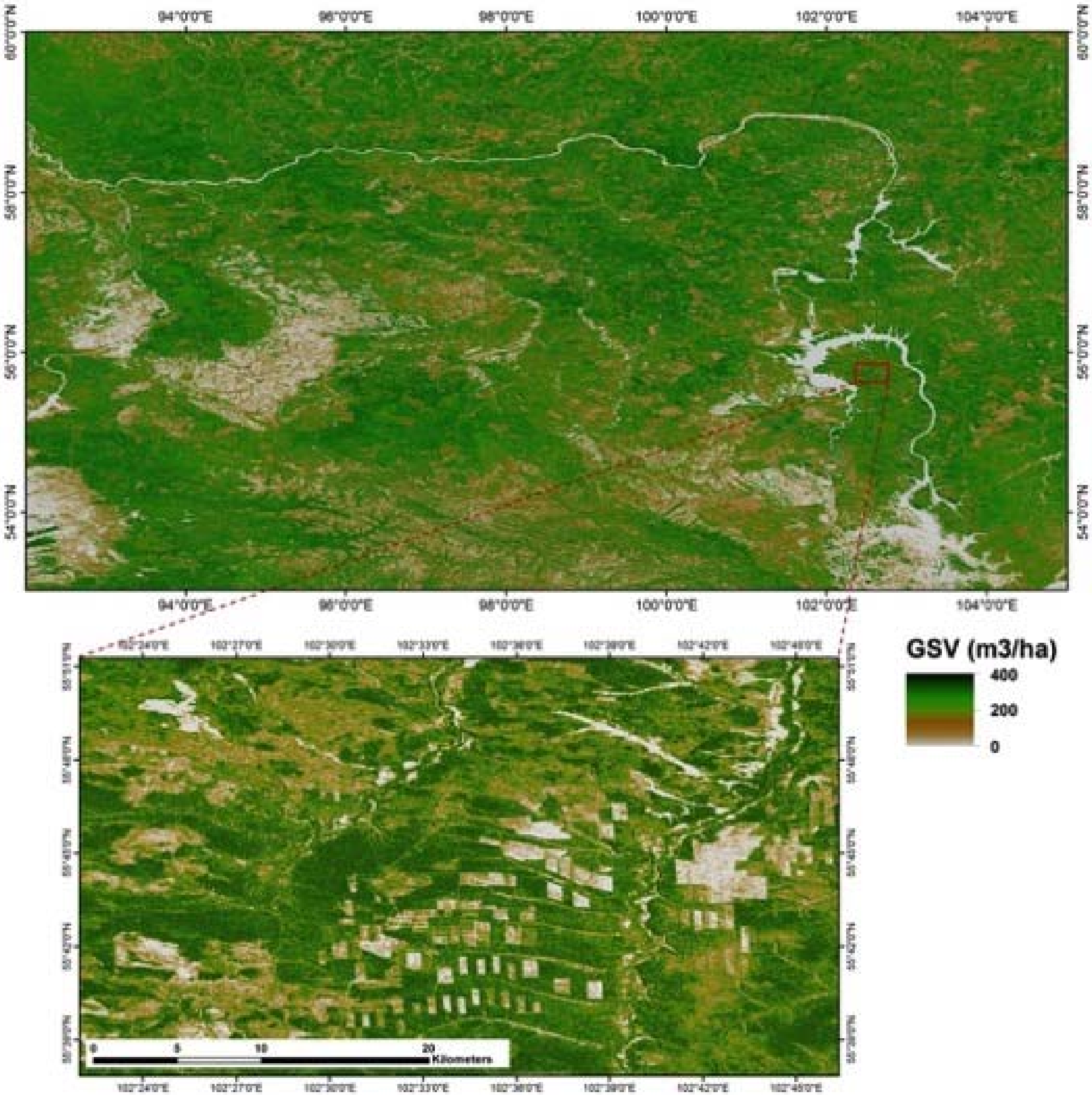




ALOS PALSAR 25 m backscatter mosaic data

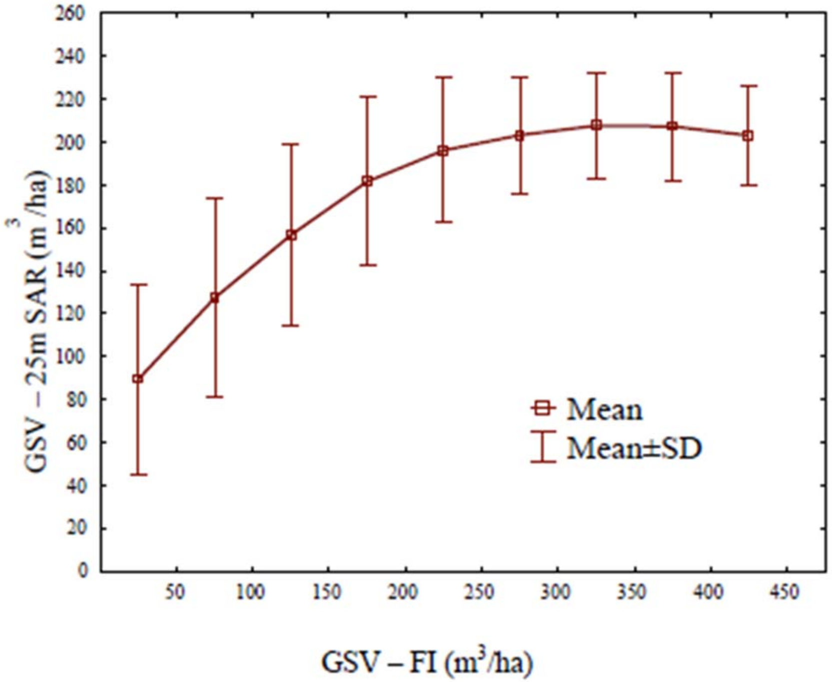
- Annual HH / HV mosaic based on summer acquisitions
- 2007 – 2010
- 25 m spatial resolution
- Covers area of **569.400 km²** in Central Siberia
- GSV mapping using forest inventory and random forest regression

GSV mapping using multi-annual ALOS PALSAR mosaic data (2007-2010)



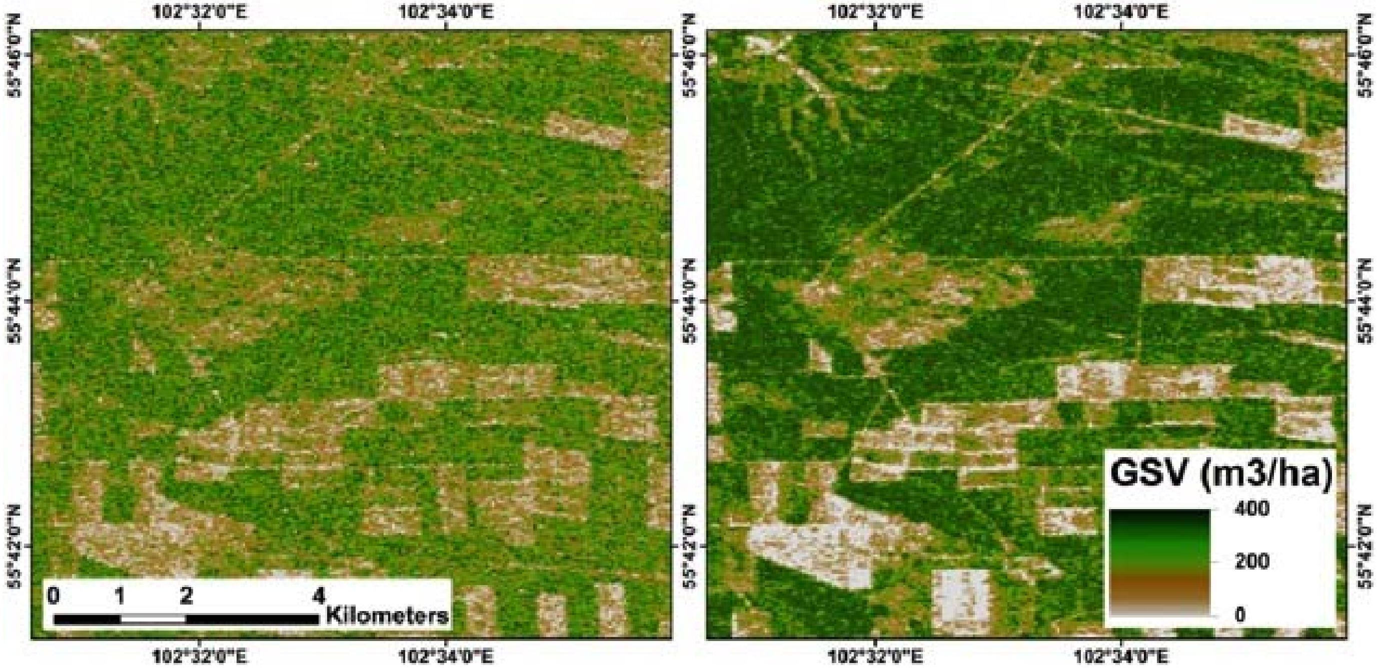
Wilhelm et al. (*Forests*, **2014**, 5)

Relationship between forest inventory and SAR-based GSV estimates



Hüttich et al. (*Forests*, **2014**, 5)

GSV mapping using multi-annual ALOS PALSAR mosaic data (2007-2010)



Annual map 2007

Multi-temporal map (2007-2010)

Table 4. Validation results, overall statistics of SAR and forest inventory (FI)-based GSV comparison (m^3/ha).

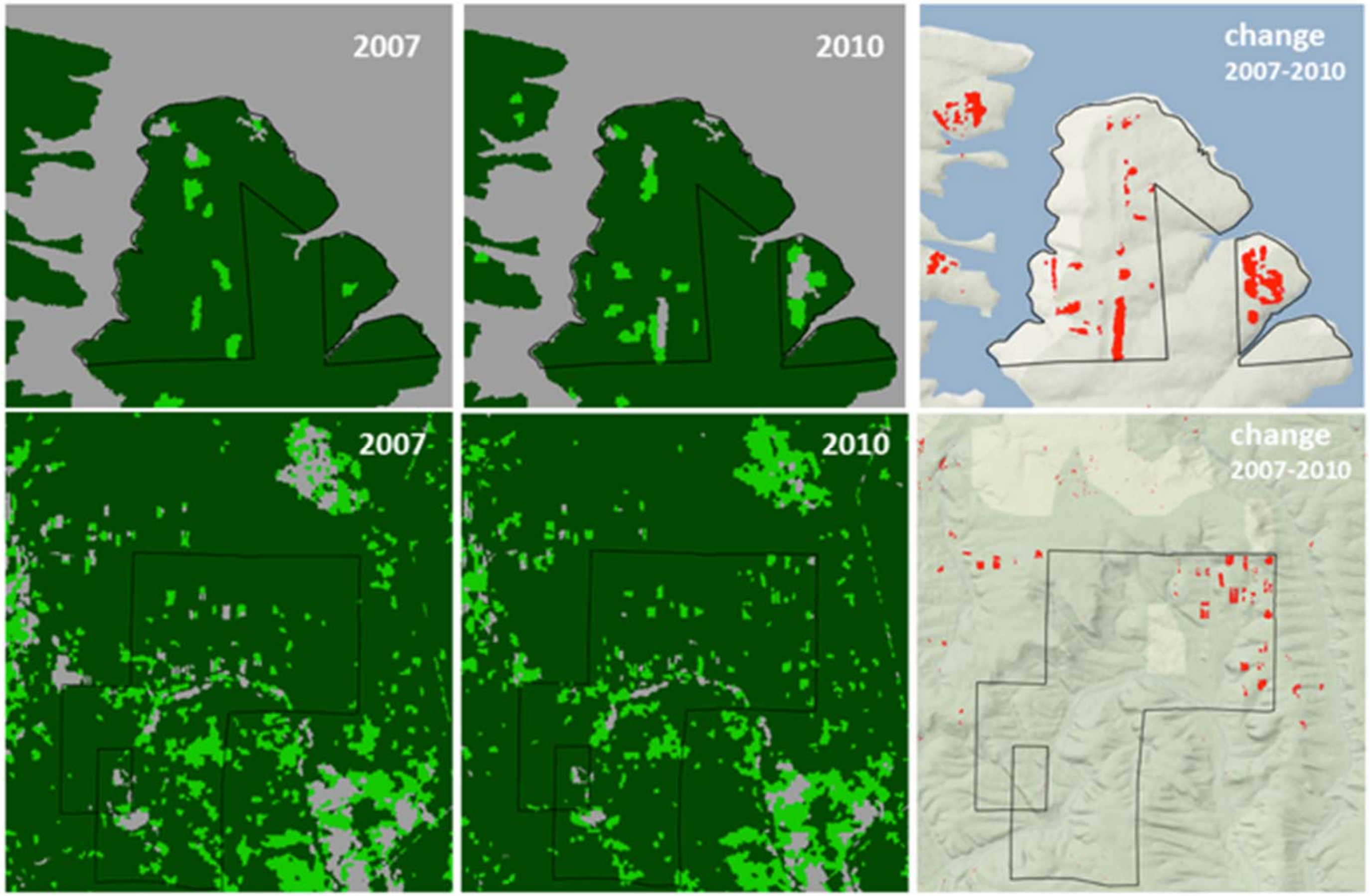
Label	Characteristics	2007	2008	2009	2010	Multi-Temporal
Emin	Δ GSV_{min}	−259.1	−249.6	−264.9	−285.8	−247.9
Emax	Δ GSV_{max}	202.5	216.5	217.6	208	221.2
ME	Mean Δ GSV (SAR-FI)	−1.3	1.4	6.3	−14.6	3.7
SD	Δ GSV SD	55.3	55.2	57.6	61.6	54.3
RMSE	Root Mean Square Error	55.3	55.2	57.9	63.3	54.4

Project objectives

- GSV retrieval using POLSAR data
- GSV retrieval using INSAR coherence and backscatter
- GSV retrieval using multitemporal mosaic backscatter data
- **Forest cover and forest cover change mapping using mosaic backscatter data**

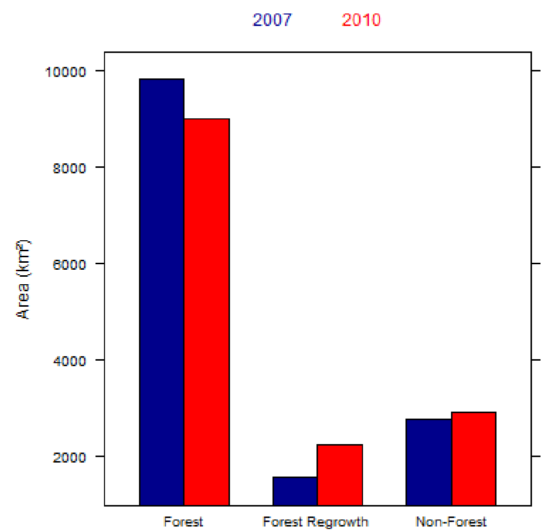
Forest cover and disturbance products

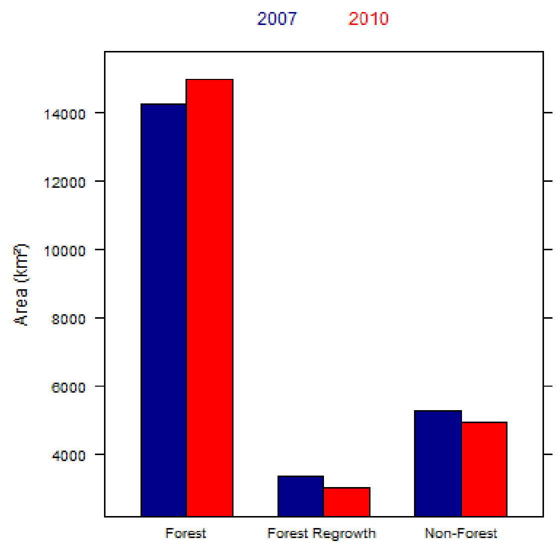
- Forest Cover & Disturbance Maps
  - 2007 and 2010
  - Forest
  - Forest Regrowth
  - Non-Forest
- Change Map
  - Forest cover loss 2007-2010



Mapping different forest cover and disturbance stages

- **Abansk / Dolgomostowsk**
  - Decreasing forest area due to ongoing logging activities
  - Increasing forest regrowth areas due to forest recovery
- **Padunsk**
  - Increasing forest areas due to recovering of old clear cuts
  - Decrease of non-forest and forest regrowth patterns





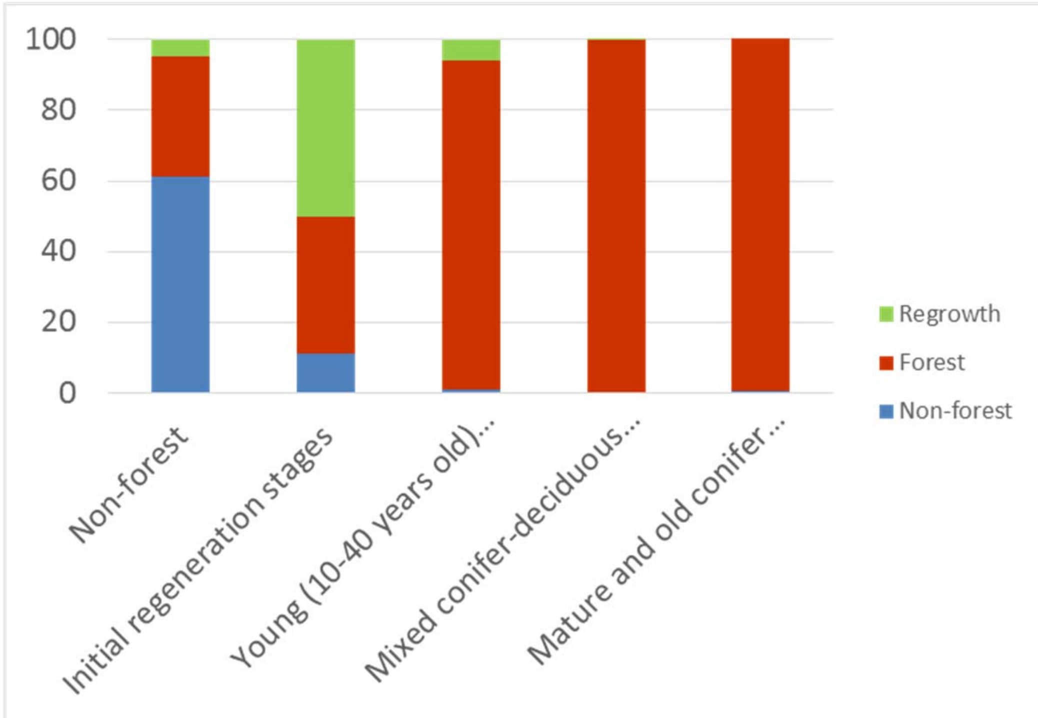
Forest cover map - cross-comparisons

Landsat-based land cover types (2010-2011)

Non-forest
Initial regeneration stages
Young (10-40 years old) deciduous stands
Mixed conifer-deciduous stands aging 40-80
Mature and old conifer stands over 80 year of age

SAR-based land cover (2010 year)

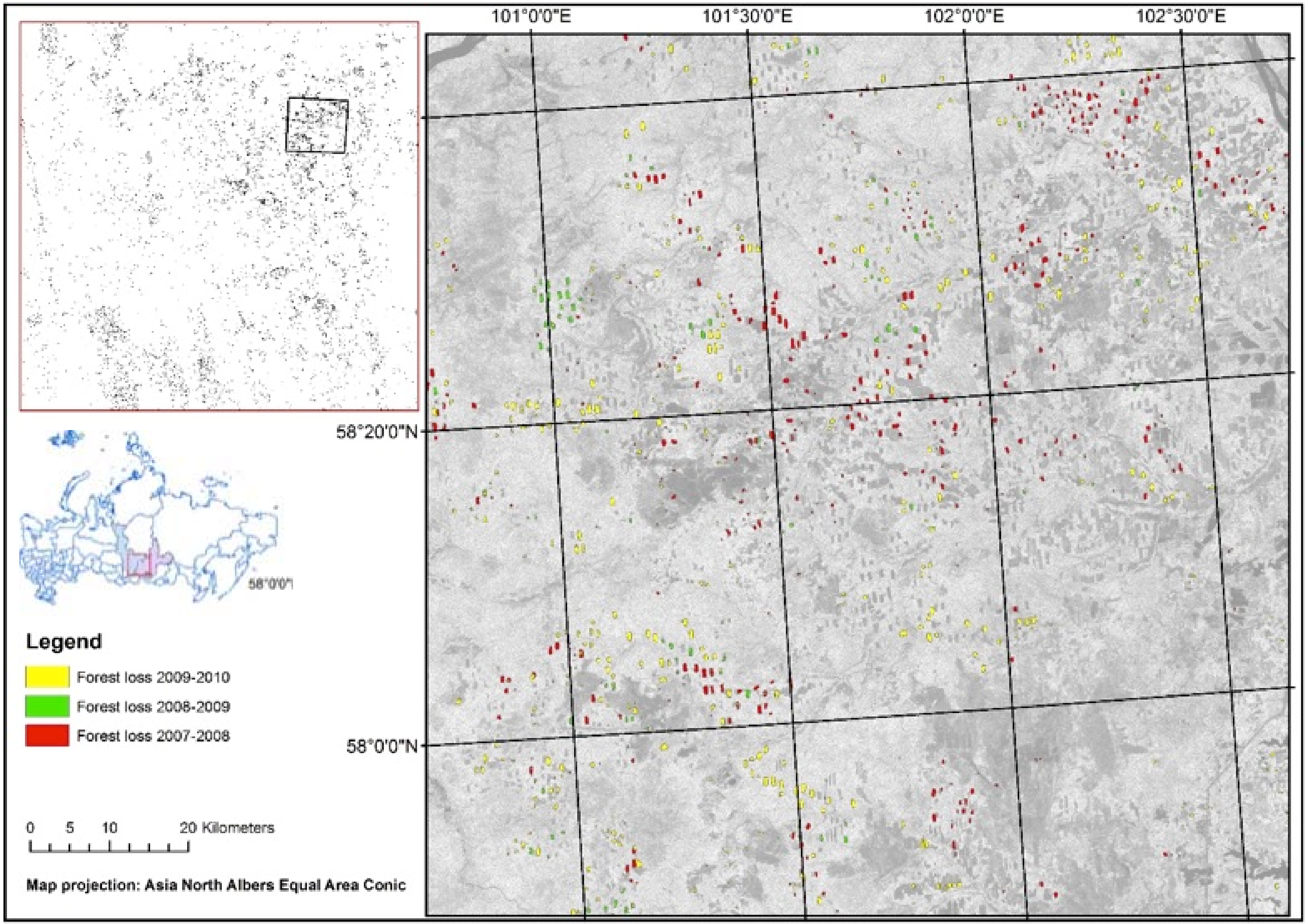
Non-forest
Regrowth
Forest



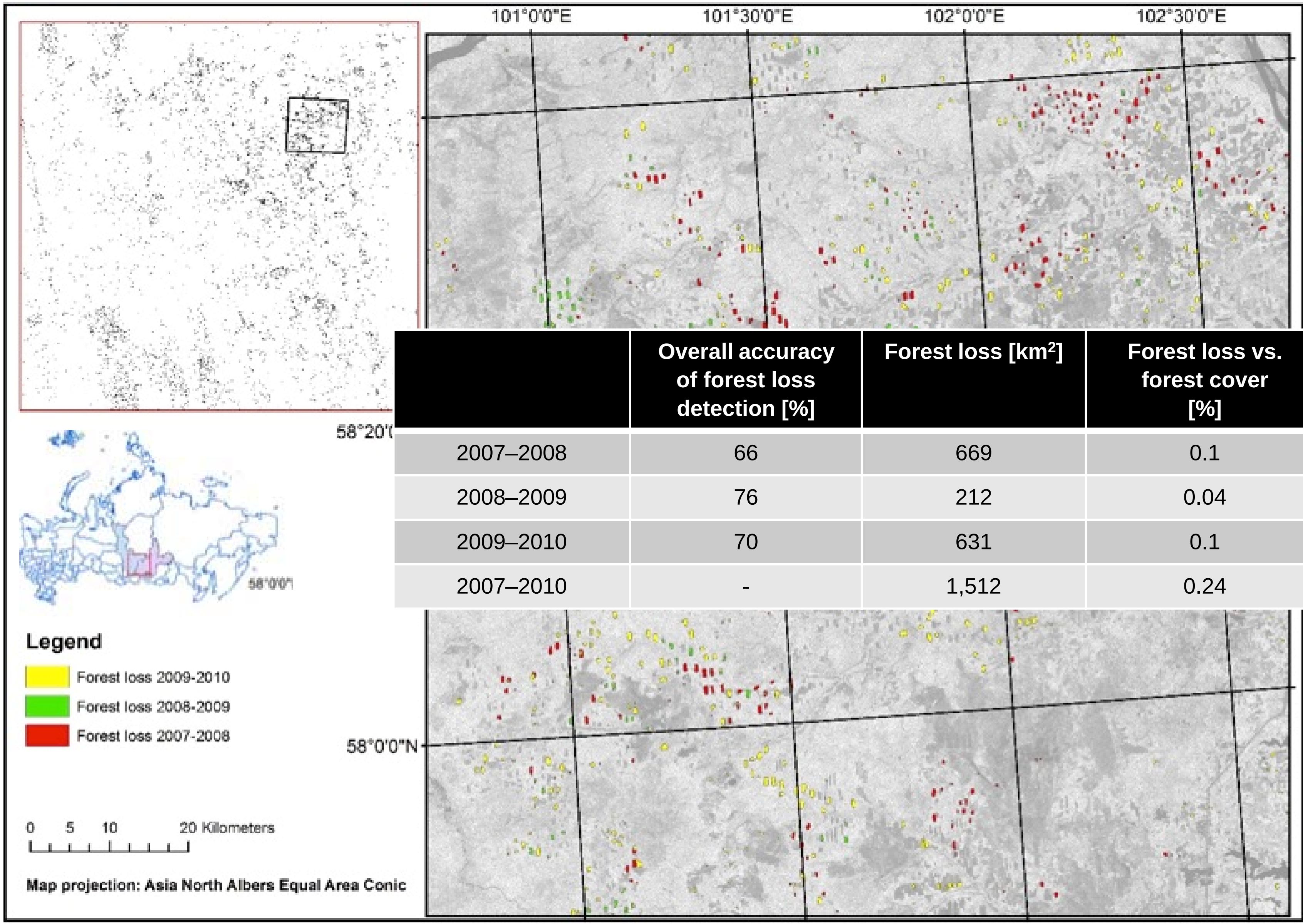
Project objectives

- GSV retrieval using POLSAR data
- GSV retrieval using INSAR coherence and backscatter
- GSV retrieval using multitemporal mosaic backscatter data
- Forest cover and **forest cover change mapping using mosaic backscatter data**

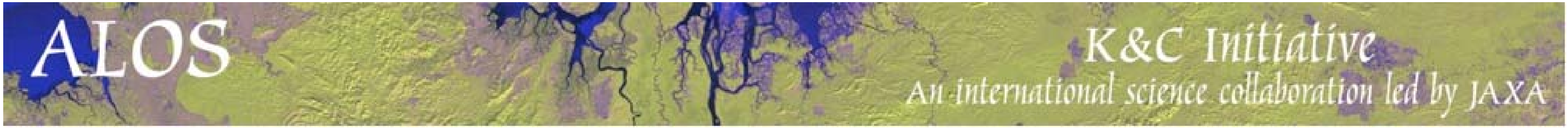
Yearly forest loss mapping



Yearly forest loss mapping



	Overall accuracy of forest loss detection [%]	Forest loss [km²]	Forest loss vs. forest cover [%]
2007–2008	66	669	0.1
2008–2009	76	212	0.04
2009–2010	70	631	0.1
2007–2010	-	1,512	0.24



Deliverables –

Papers and reports (1)

1. Published

- C. THIEL & C. SCHMULLIUS (2013): Investigating the impact of freezing on the ALOS PALSAR InSAR phase over Siberian forests.-In: Remote Sensing Letters 4 (9), pp. 900-909.
- C. THIEL & C. SCHMULLIUS (2013): Investigating ALOS PALSAR interferometric coherence in central Siberia at unfrozen and frozen conditions: implications for forest growing stock volume estimation.-In: Canadian Journal of Remote Sensing 39 (3), pp. 232-250.
- T. A. CHOWDHURY, C. THIEL, C. SCHMULLIUS & M. STELMASZCZUK-GORSKA (2013): Polarimetric Parameters for Growing Stock Volume Estimation Using ALOS PALSAR L-Band Data over Siberian Forests.-In: Remote Sensing 4, pp. 5725-5756.
- C. THIEL & C. SCHMULLIUS (2014): Impact of Tree Species on Magnitude of PALSAR Interferometric Coherence over Siberian Forest at Frozen and Unfrozen Conditions.-In: Remote Sensing 6(2), pp. 1124-1136.
- T. A. Chowdhury, C. Thiel & C. Schmullius (2014): Growing stock volume estimation from L-band ALOS PALSAR polarimetric coherence in Siberian forest.-In: Remote Sensing of Environment, in press.
- C. HÜTTICH, C. SCHMULLIUS, C. THIEL, C. PATHE, S. BARTALEV, K. EMELYANOV, M. KORETS, A. SHVIDENKO, D. SCHEPASCHENKO (2012): ZAPÁS: Assessment and monitoring of forest resources in the framework of EU-Russia space dialogue.-In: European Commission [Ed.], Let's embrace space, Vol. II, pp. 164-171.
- C. HÜTTICH, C. SCHMULLIUS, C. J. THIEL, S. BARTALEV, K. EMELYANOV, M. KORETS, A. SHVIDENKO, V. SKUDIN & L. VASHCKOUK (2012): Assessment and Monitoring of Siberian Forest Resources in the Framework of the EU-Russia ZAPÁS Project.-In: Proceedings of International Geoscience and Remote Sensing Symposium IGARSS, Munich, Germany, pp. 7208-7211.

Deliverables –
Papers and reports (2)

1. Published

- C. THIEL & C. SCHMULLIUS (2012): Effect of Tree Species on PALSAR InSAR Coherence over Siberian Forest at frozen and unfrozen Conditions.-In: Proceedings of International Geoscience and Remote Sensing Symposium IGARSS, Munich, Germany, pp. 190-193.
- C. THIEL & C. SCHMULLIUS (2013): Investigation of the impact of freezing on the scattering phase center in Siberia using ALOS PALSAR FBS and FBD data.-In: Proceedings CD of ESA Living Planet Symposium, 09 – 13 September, Edinburgh, UK.
- C. THIEL & C. SCHMULLIUS (2013): Impact of Freezing on ALOS PALSAR Interferometric Coherence in Central Siberia.-In: Proceedings CD of ESA Living Planet Symposium, 09 – 13 September, Edinburgh, UK.
- M. STELMASZCZUK-GÓRSKA, C. THIEL & C. SCHMULLIUS (2013): Optimisation of the coherence estimation window size aiming at growing stock volume retrieval in Siberian forest using ALOS PALSAR data.-In: Proceedings CD of ESA Living Planet Symposium, 09 – 13 September, Edinburgh, UK.
- C. HÜTTICH, M. STELMASZCZUK-GÓRSKA, J. EBERLE, P. KOTZERKE & C. SCHMULLIUS (2014): Operational forest monitoring in Siberia using multi-source Earth Observation data. –In: Siberian Journal of Forest Science, in press.
- M. STELMASZCZUK-GÓRSKA, C. THIEL & C. SCHMULLIUS (2014): Large-scale forest change monitoring scheme. GIONET deliverable: http://www.gionet.eu/wp-content/uploads/GIONET-deliverable_stelmaszczuk_gorska_corrected_.pdf
- S. Wilhelm, C. Hüttich, M. Korets & C. Schmullius (2014): Large Area Mapping of Boreal Growing Stock Volume on an Annual and Multi-Temporal Level Using PALSAR L-Band Backscatter Mosaics. Forests 5, 8, 1999-2015.
- C. Hüttich, M. Korets, S. Bartalev, V. Zharko, D. Schepaschenko, A. Shvidenko, & C. Schmullius (2014): Exploiting Growing Stock Volume Maps for Large Scale Forest Resource Assessment: Cross-Comparisons of ASAR- and PALSAR-Based GSV Estimates with Forest Inventory in Central Siberia. Forests, 5, 8, 1753-1776.

Deliverables –

Data sets and Thematic products (mosaics, classification maps etc.)

1. Completed and Delivered to JAXA

- *Growing stock volume maps based on forest inventory data from sample sites (delivered: 08/10/2012)*

2. Completed, but not yet delivered (please deliver ASAP)

- *Yearly forest loss map*
- *Forest Cover & Disturbance Maps (2007, 2010)*
- *Forest cover loss 2007-2010*
- *GSV maps using multi-annual ALOS PALSAR mosaic data (2007-2010)*