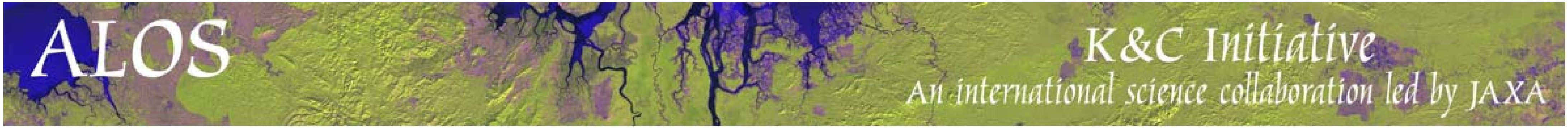


K&C Phase 3 – progress report

Advances in forestry applications using satellite ALOS PALSAR images

&

Coupling radar-based estimates of forest information with biosphere models for improved carbon flux estimation

Johan Fransson (1) & Maurizio Santoro (2)

(1) Swedish University of Agricultural Sciences

(2) Gamma Remote Sensing, Switzerland

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

GAMMA REMOTE SENSING

Max-Planck-Institut für Biogeochemie

SLU

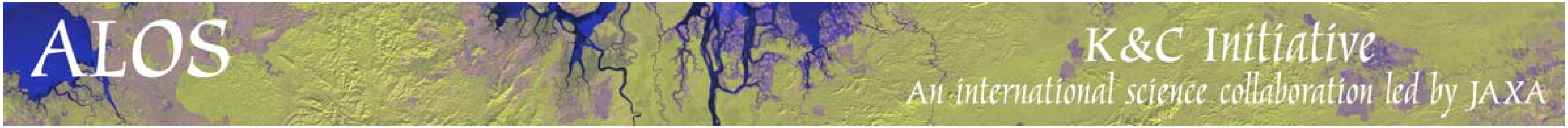
CHALMERS

SKOGSSTYRELSEN SWEDISH FOREST AGENCY

esa

Projects objectives

- To develop and validate methods for large-scale biomass mapping (base year 2010) using PALSAR data
- The methods and algorithms that will be developed aim to demonstrate the large-scale forestry monitoring goals of the JAXA's ALOS Kyoto & Carbon Initiative. Synergy between the two K&C Phase 3 project is explicitely addressed.
- Common project area: Sweden
- Additional areas for carbon flux estimation from PALSAR biomass are located in Finland, Germany, Siberia, Brazil
- Both mosaic and strip data (FB and WB) are used and evaluated for biomass retrieval
- Here we discuss the FB datasets



Input and output

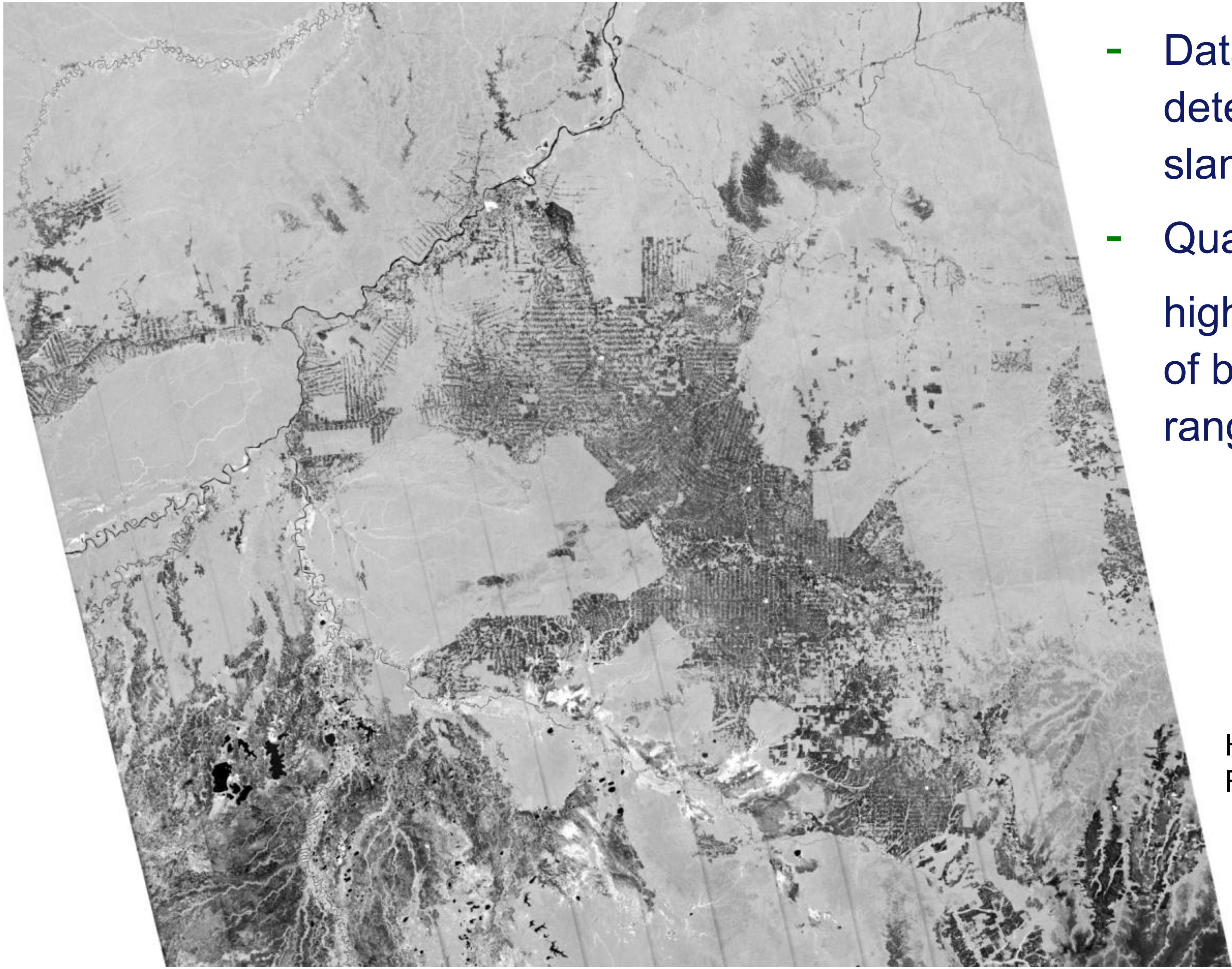
- Both mosaic and strip data (FB and WB) are used and evaluated for biomass retrieval
- We reported at the previous meeting that a one-year dataset of multi-temporal strips is better suited than a yearly mosaic because pixel-wise errors in the estimates can be decreased with a multi-temporal combination
- Here we discuss the retrieval using FB datasets only
- Multi-temporal WB datasets are available over Brazil only

- The output of the retrieval is growing stock volume (GSV, in m^3/ha) a.k.a. stem volume
- Biomass (AGB in Mg/ha) is determined from GSV by means of a biomass conversion and expansion factors (see Thurner et al., Global Ecology and Biogeography, 2013)
- We prefer this approach to preserve the physics behind the SAR backscatter at L-band (which is related to structure)

ALOS PALSAR FB dataset

Study region	Area (Million km2)	# PALSAR strips	Data (Gbyte)
Sweden	1.12	104	89.7
South Finland	0.23	30	10.2
Central Germany	0.25	19	12.8
Central Siberia	0.52	16	16.2
Pará	0.82	63	59.2
Rondonia	0.80	54	56.2
TOTAL	3.74	286	244.3

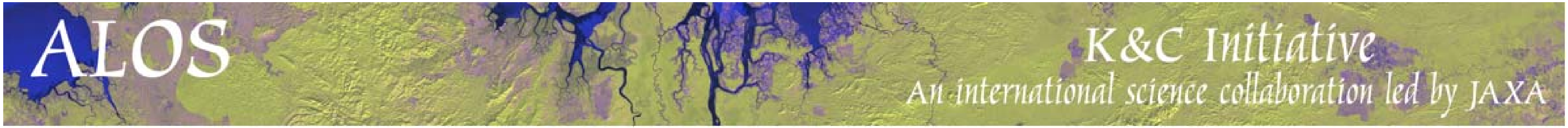
- Data acquired between May and October 2010
- For each RSP, 1-4 acquisitions available
- All data have been terrain geocoded to 25 m pixel size and tiled



- Data requested: detected intensities, slant range geometry
- Quality:

  high except for decay of backscatter in near range (not systematic)

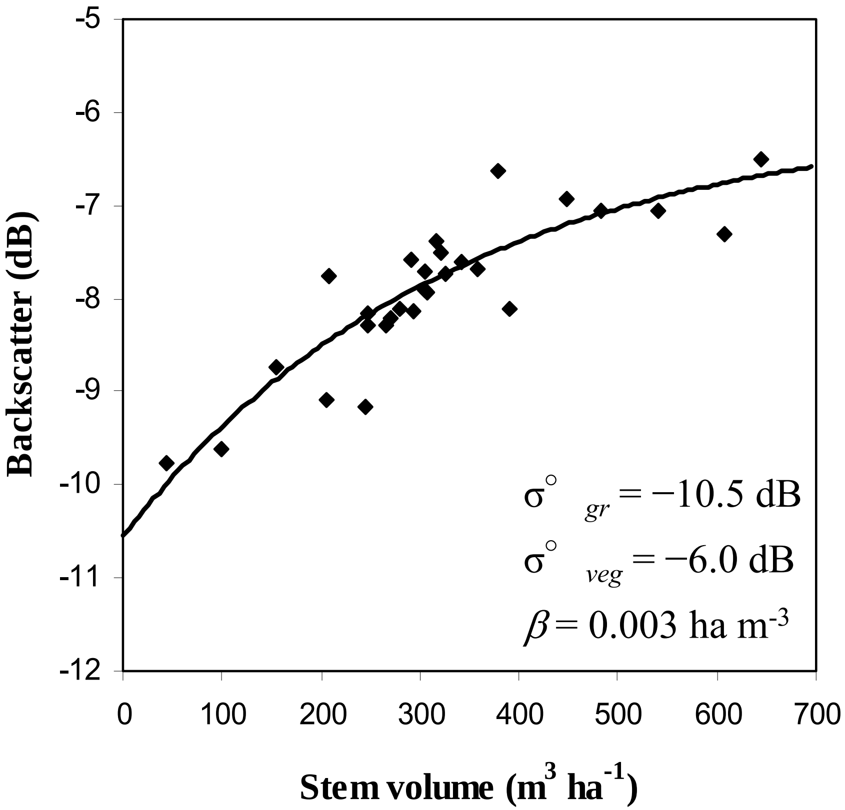
HH SAR backscatter, Rondonia (1021 × 800 km^2)

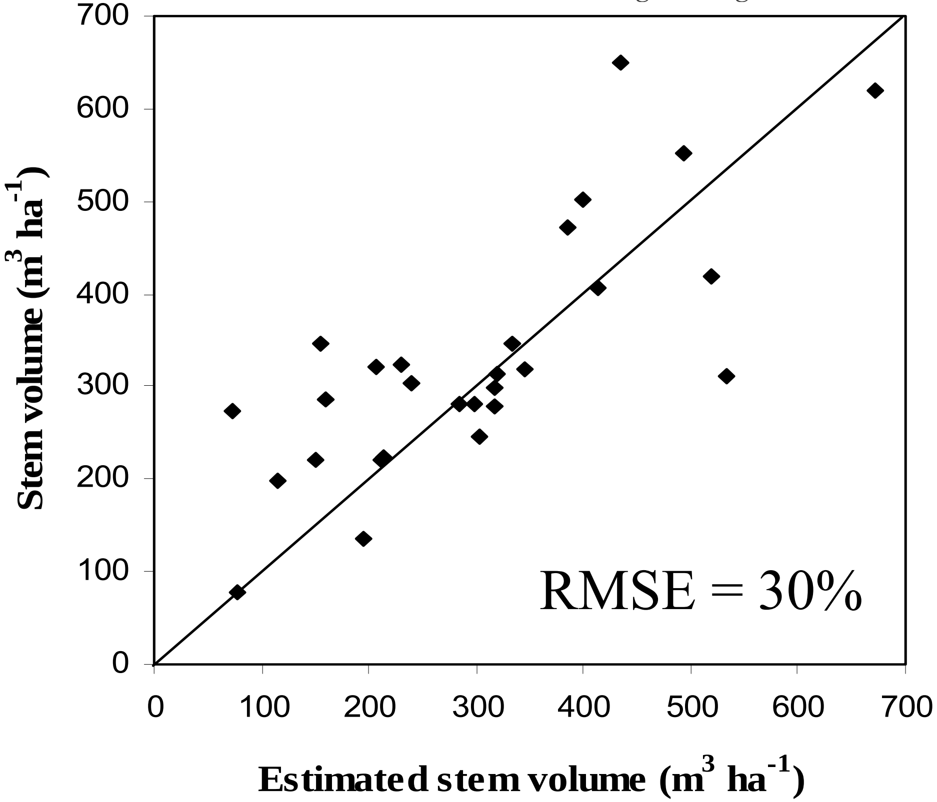


Stem volume estimation from SAR backscatter

$$\sigma^\circ_{for} = \sigma^\circ_{gr} \times e^{-\beta V} + \sigma^\circ_{veg} \times (1 - e^{-\beta V})$$

$$\hat{V} = -\frac{1}{\beta} \times \ln\left(\frac{\sigma^o_{veg} - \sigma^o_{for,meas}}{\sigma^o_{veg} - \sigma^o_{gr}}\right)$$





FBS 34.3° HH, 2007-01-29 (best case – Remningstorp test site)

Multi-temporal retrieval of stem volume

$$\hat{V}_{mt} = \frac{\sum_{i=1}^{N} \frac{w_i}{w_{\max}} \hat{V}_i}{\sum_{i=1}^{N} \frac{w_i}{w_{\max}}}$$

- With one observation, biomass retrieval is less accurate compared with using many observations
- Having available many observations implies that random fluctuations can be filtered out to obtain an estimate that is more closely related to the true value

BIOMASAR algorithm (Santoro et al., 2011; Santoro et al., 2013)

- Implements the WCM + multi-temporal combination in an automated approach
- Estimates of model parameters are pixel-based and derived in a window
- Approach developed, validated and applied to Envisat ASAR ScanSAR data

- *In theory dependent on dielectric properties and forest structure*
- *A constant value does not affect the retrieval performance → 0.004 ha/m³ (e.g. for boreal/temperate forest, L-band)*

1

$$\sigma^o_{for} = \sigma^o_{veg}\left(1 - e^{-\beta V}\right) + \sigma^o_{gr} e^{-\beta V}$$

2

- *Identify in the window „ground“ pixels: pixels with canopy cover < threshold (e.g. 20%)*
- *Parameter estimate: median of backscatter*

3

- *Identify in the window „dense forest“ pixels: pixels with canopy cover> threshold (e.g. 70%)*
- *Median of backscatter represents the backscatter of dense forests (does not represent sigmaveg)*
- *Compensate for residual ground backscatter, (V_{df} = GSV of dense forest, estimated from auxiliary dataset)*

$$\sigma^o_{veg} = \frac{\sigma^o_{df} - \sigma^o_{gr} e^{-\beta V_{df}}}{1 - e^{-\beta V_{df}}}$$

Extending BIOMASAR to ALOS PALSAR

- Cartus et al. (2012) demonstrated that the algorithm performs at L-band as well, with minor adaptations (backscatter → AGB for Northeast U.S.)

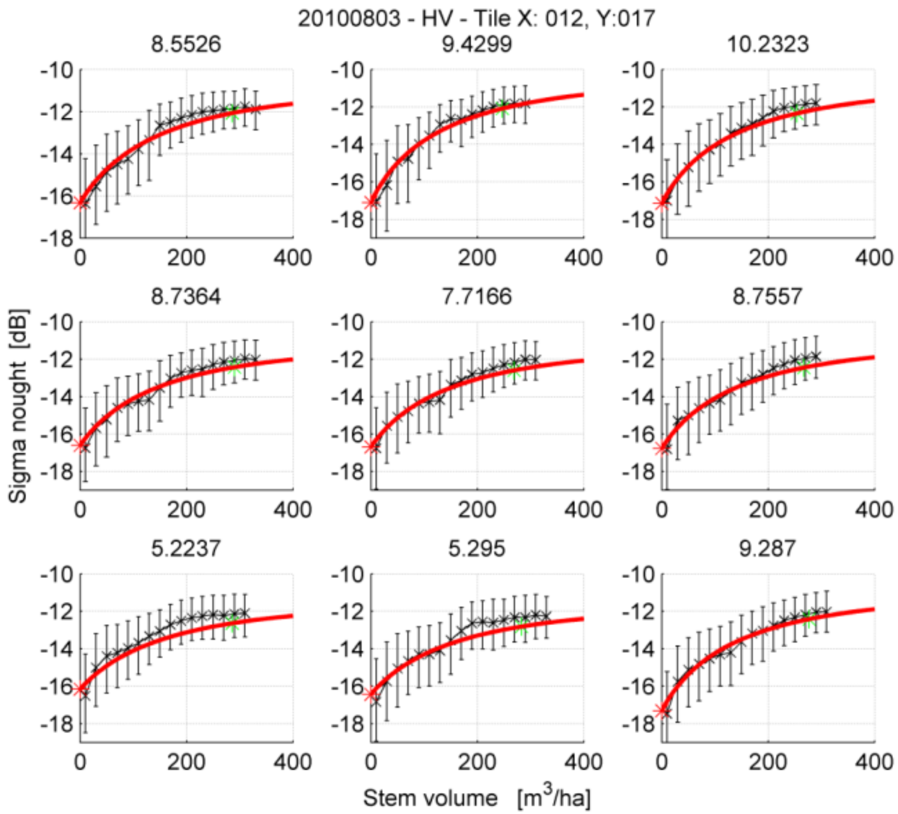
- To come up with a single retrieval approach that would work in all selected regions, there were a few points to be taken care of in first place

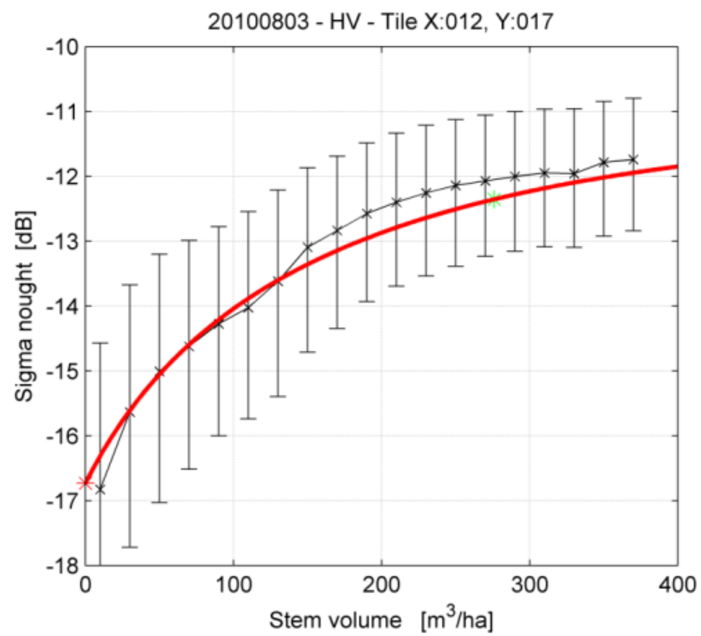
    - Does the WCM represent the relationship between ALOS PALSAR backscatter and GSV
    - **How can we reconcile the model training proposed with a global dataset of canopy cover (e.g., VCF) with a model training based on a detailed measure of canopy cover but only available locally (as done in Cartus et al.)?**
    - Which parameters in the retrieval approach need to be adapted when implementing the retrieval approach at L-band and for high resolution data?

Relationship between ALOS PALSAR backscatter and GSV

• Comparing PALSAR backscatter to GSV derived from “kNN Finland 2011” (1) dataset and to modelled backscatter using the BIOMASAR algorithm and the canopy cover from the kNN dataset.

• Comparing model vs. measurements for two modelling units (estimation window) (10 km vs. 30 km)

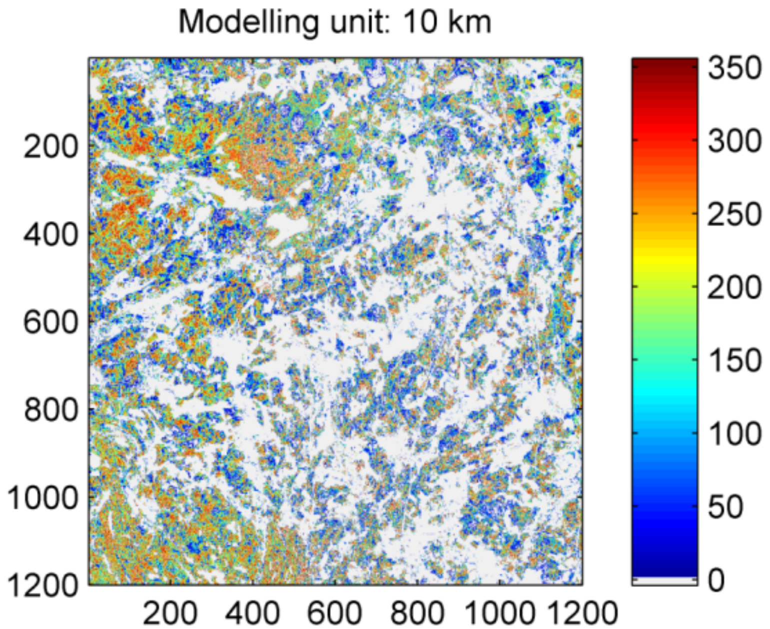


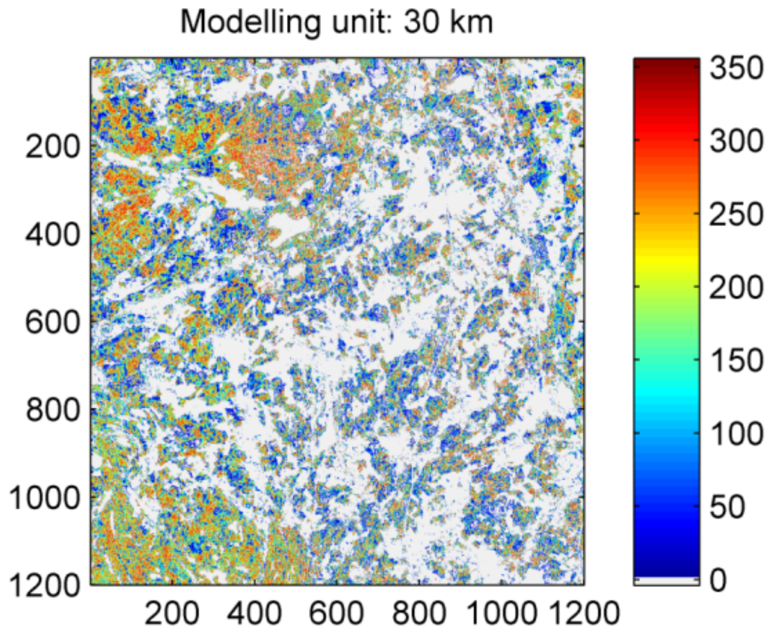


(1) http://www.metla.fi/ohjelma/vmi/vmi-moni-en.htm

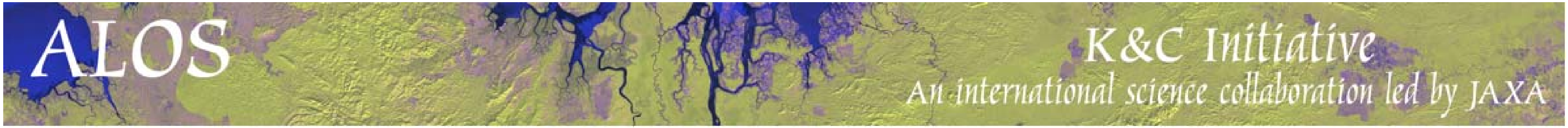
Comparison of retrieved GSV w.r.t. modelling unit

• Ideally one would like to adapt the model as much as possible to the local conditions but there is huge computational effort at high-res. A generalized estimate misses fine-scale differences of the backscatter but the retrieval still performs in a reasonable manner

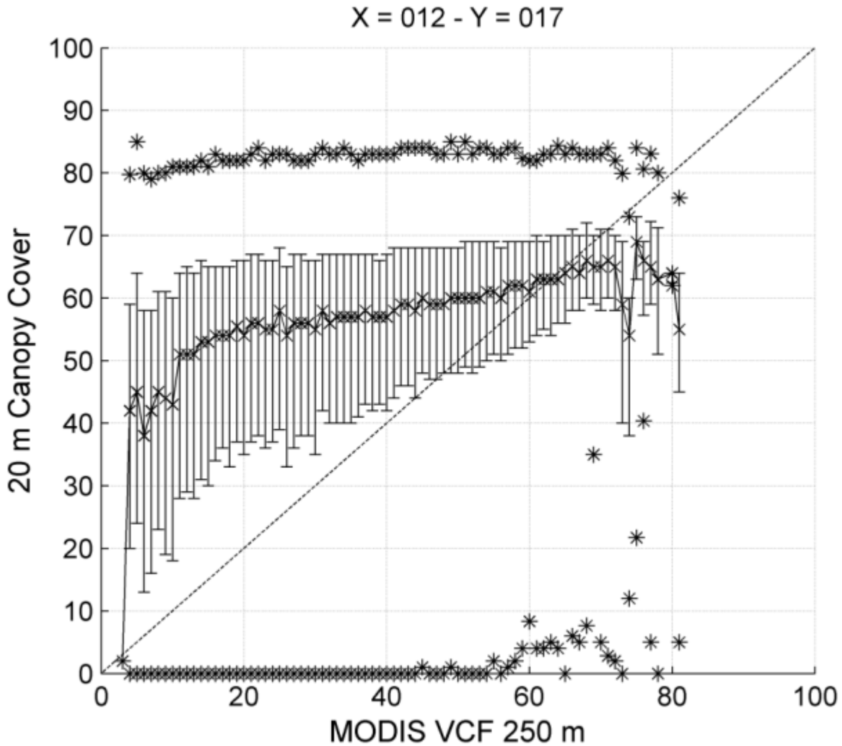


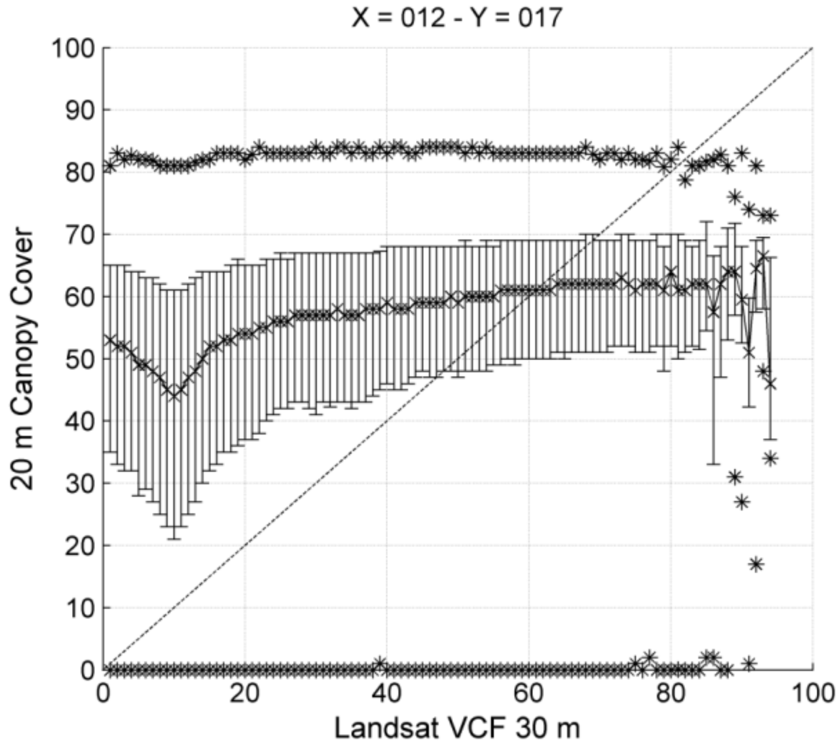


• From here onwards a modelling unit of 30 x 30 km (size of a tile) is used, i.e. a single estimate of each model parameter is considered representative for the area of the tile. Among adjacent tiles values are interpolated (bi-linear interpolation).

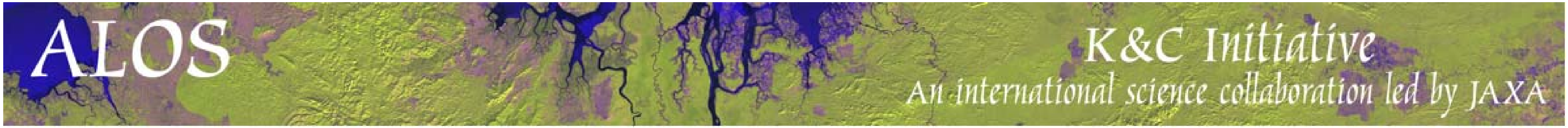


Comparison of canopy cover estimates @ 25 m

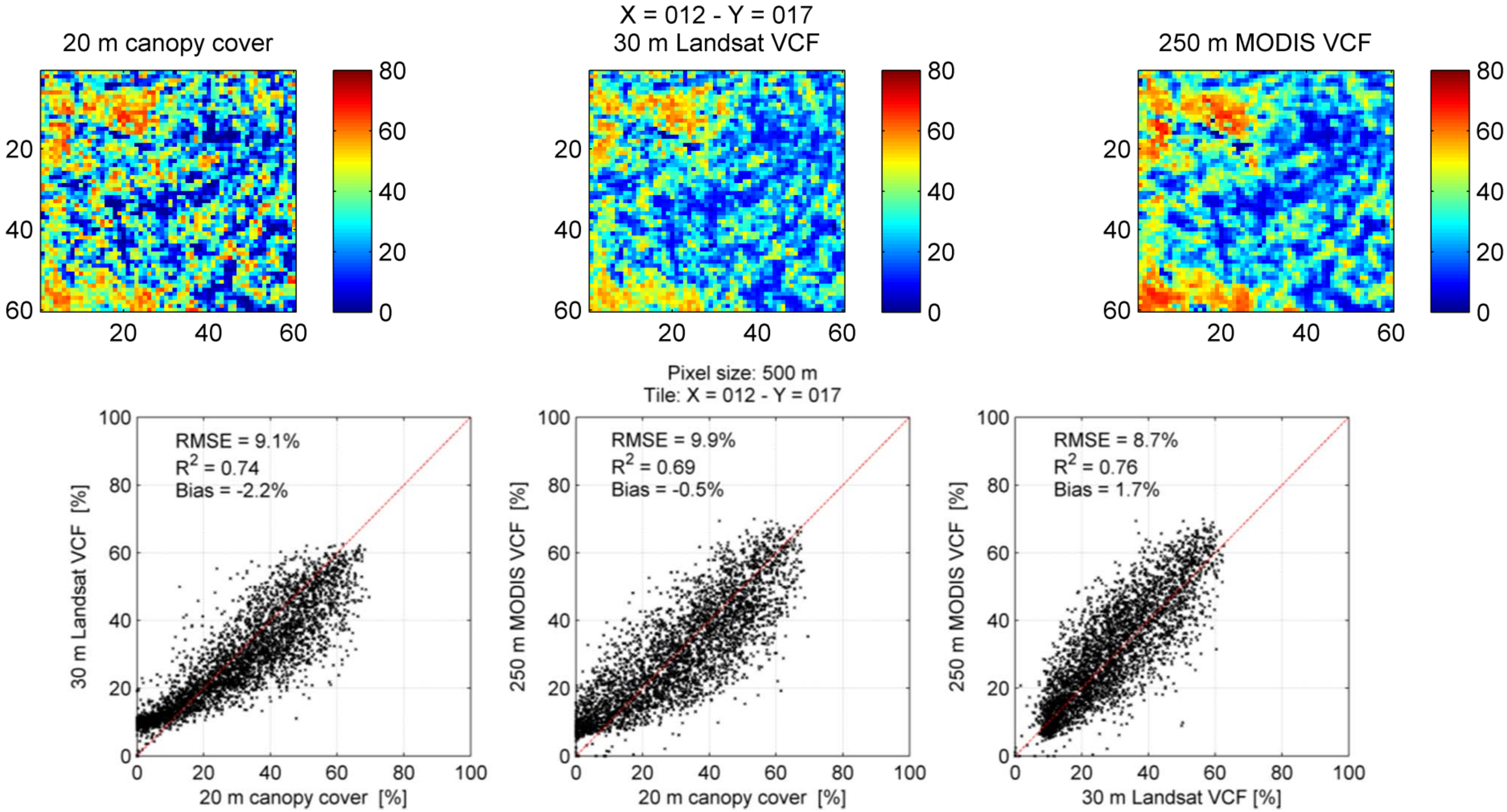




- The new Landsat-MODIS 30m VCF (Sexton et al., 2013) would be a global solution BUT it has significant discrepancies w.r.t. the kNN canopy cover of Finland (considered sufficiently reliable)
- The MODIS VCF 250 m (Hansen et al., 2003) misses fine scale canopy cover, primarily the lowest values.



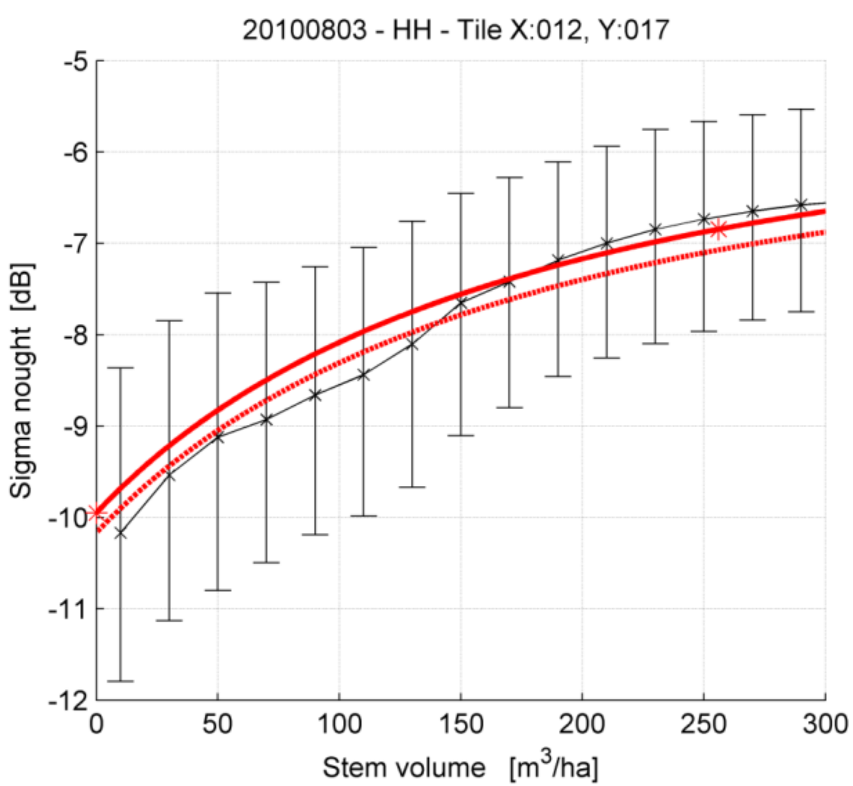
Comparison of canopy cover estimates @ 500 m

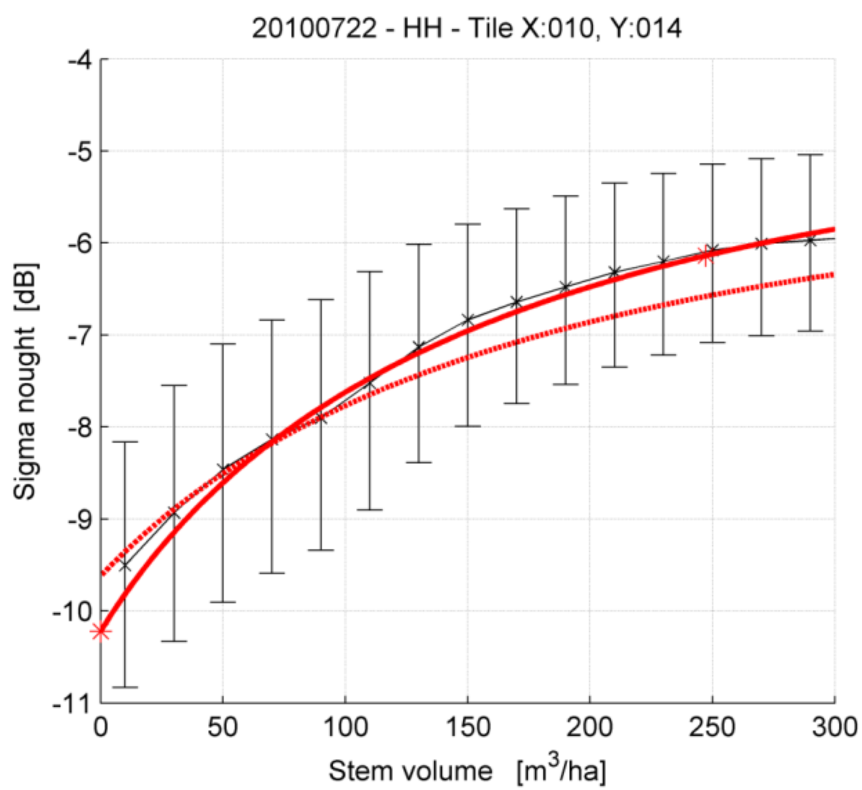


- Much better agreement between national and global canopy cover estimates

- MODIS VCF preferred for model training because (i) truly global, (ii) contemporary to PALSAR data and (iii) consistent correspondence with kNN canopy cover

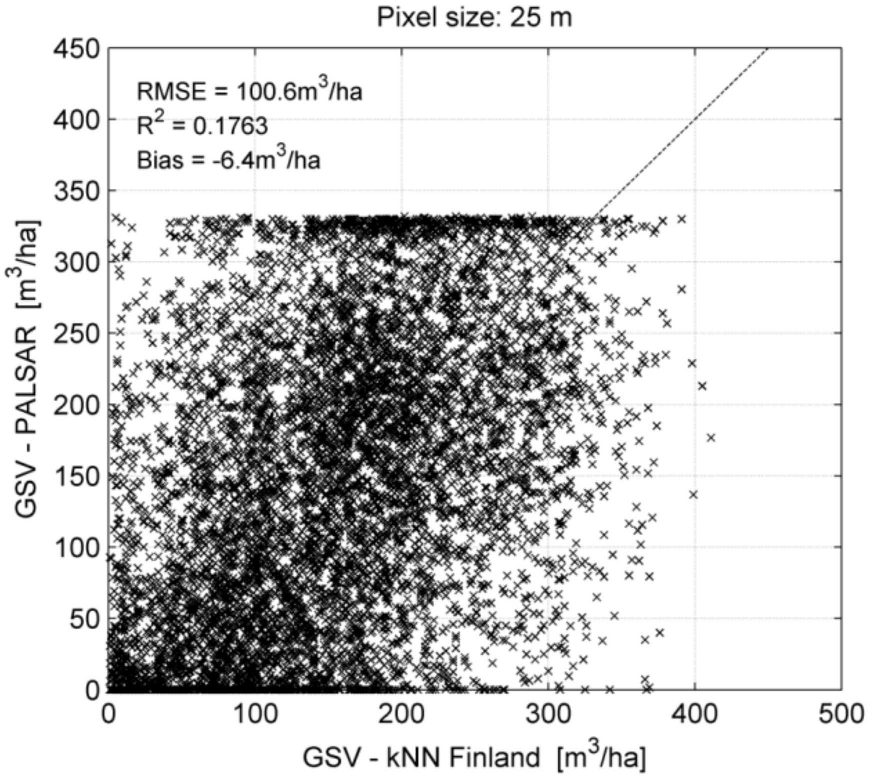
Model training performance





- Modelled backscatter with MODIS VCF (solid curves) satisfactory
- Difference w.r.t. to model trained with kNN canopy cover (dashed curve) small. In some cases, better results obtained when using MODIS VCF as canopy cover reference.

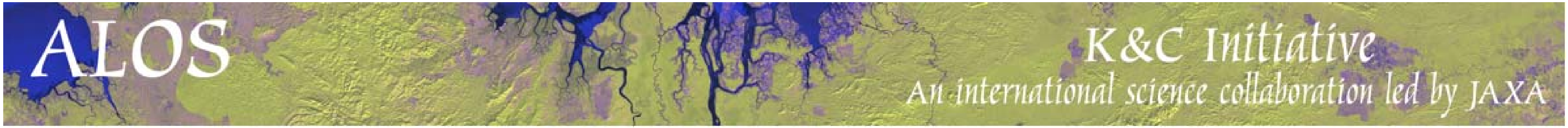
Assessment of GSV retrieval



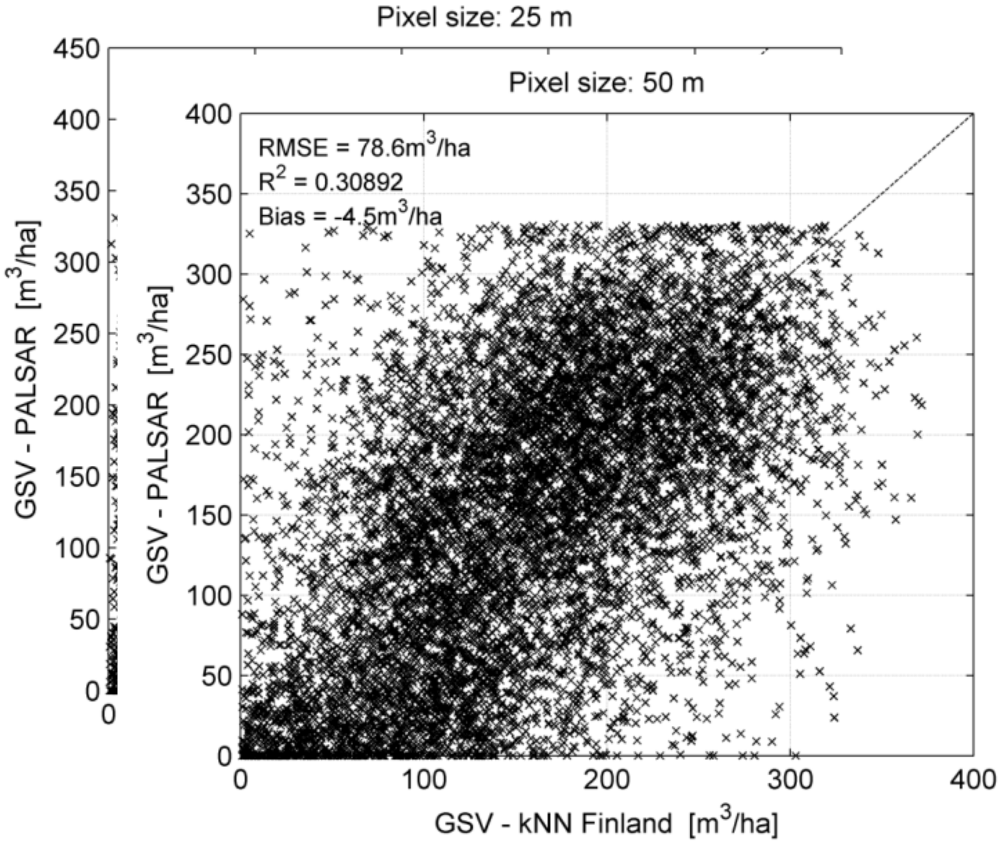
PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area



Assessment of GSV retrieval

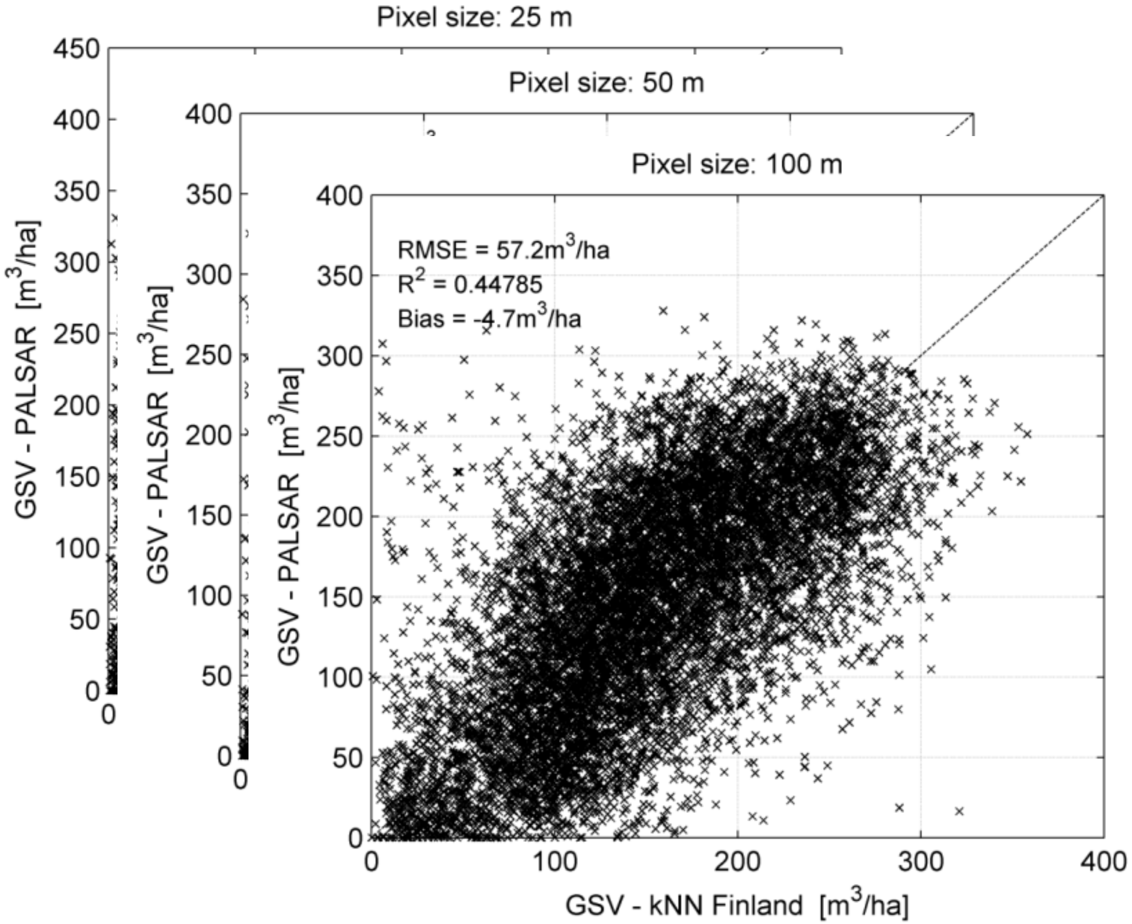


PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area

Assessment of GSV retrieval

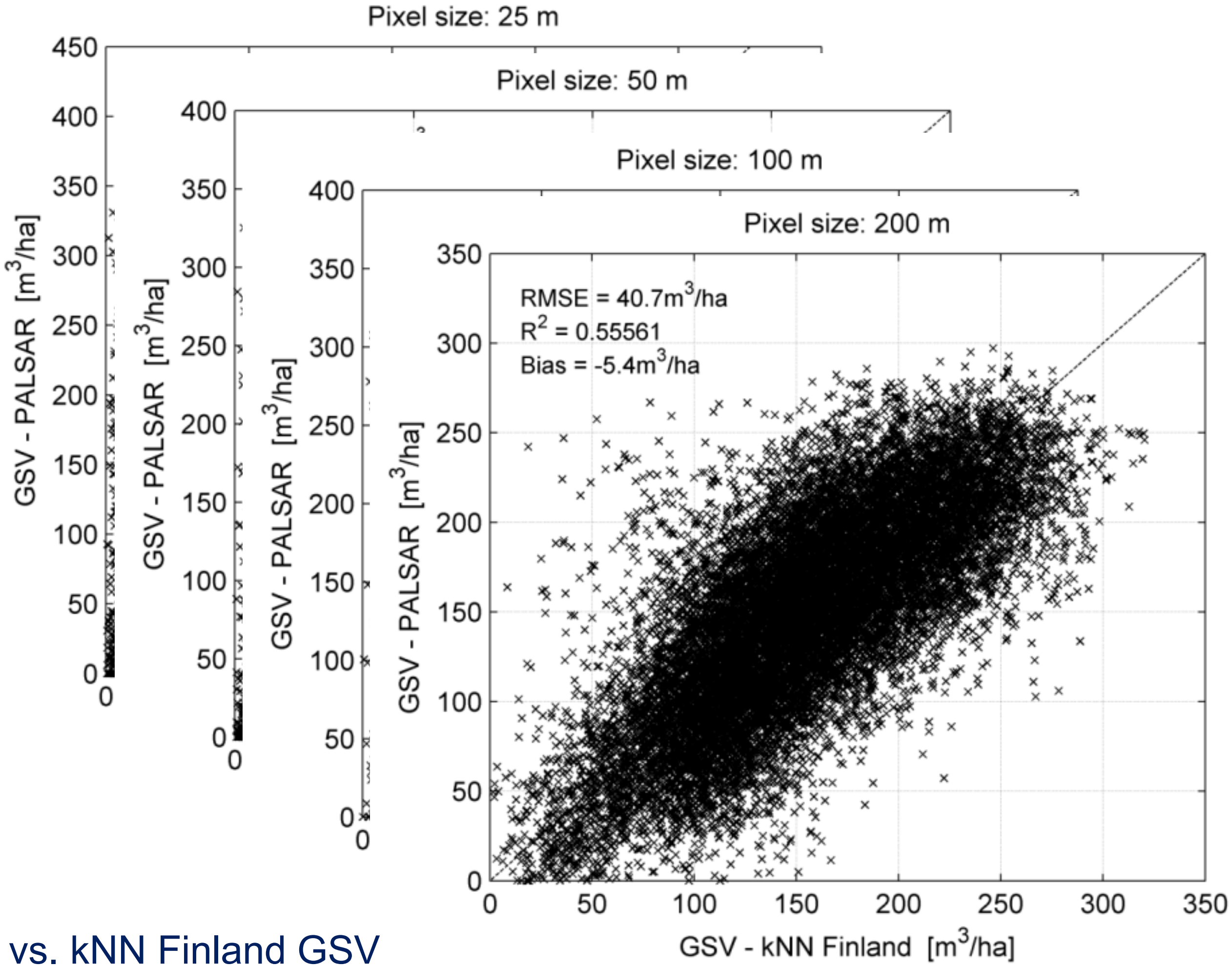


PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area

Assessment of GSV retrieval

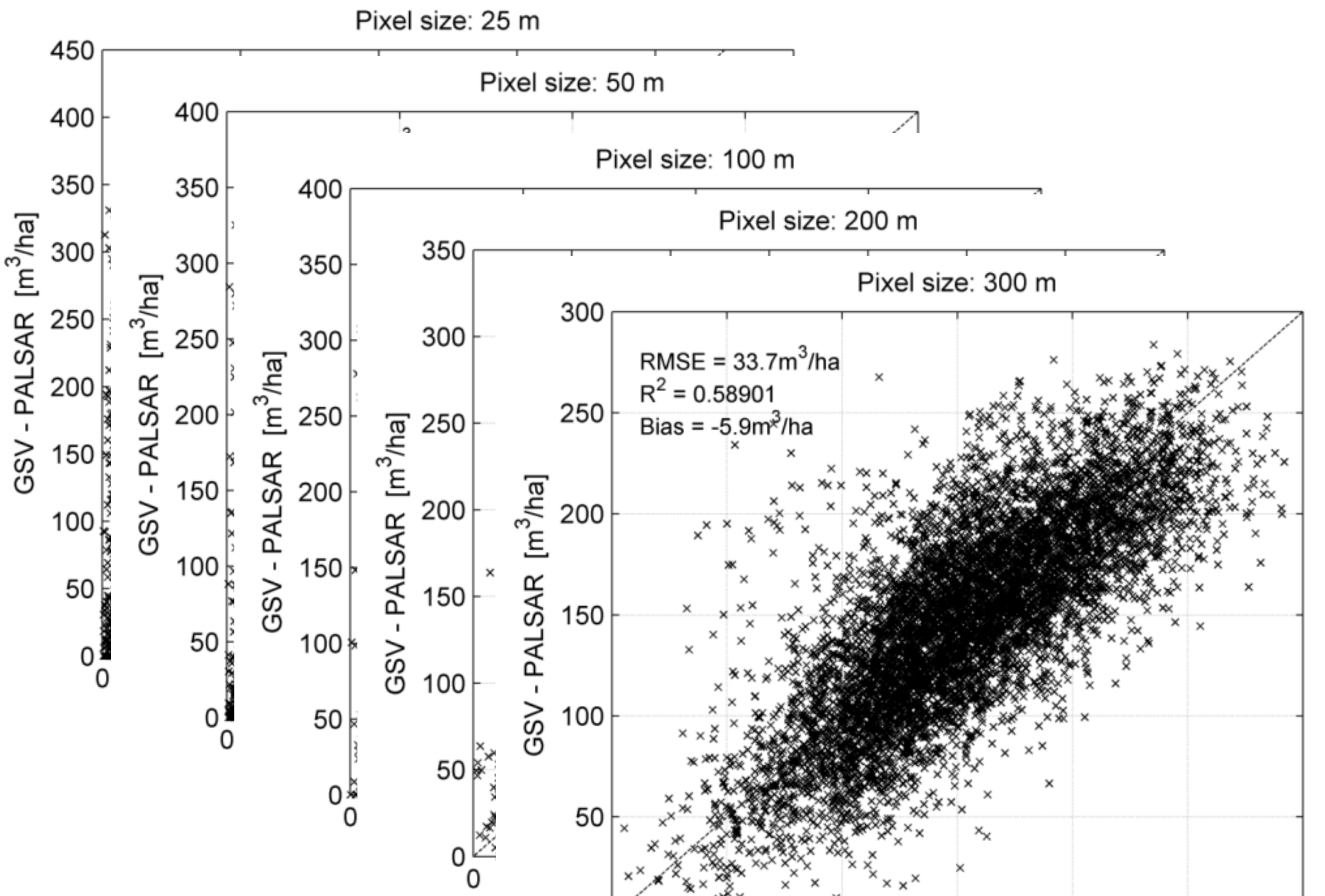


PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area

Assessment of GSV retrieval

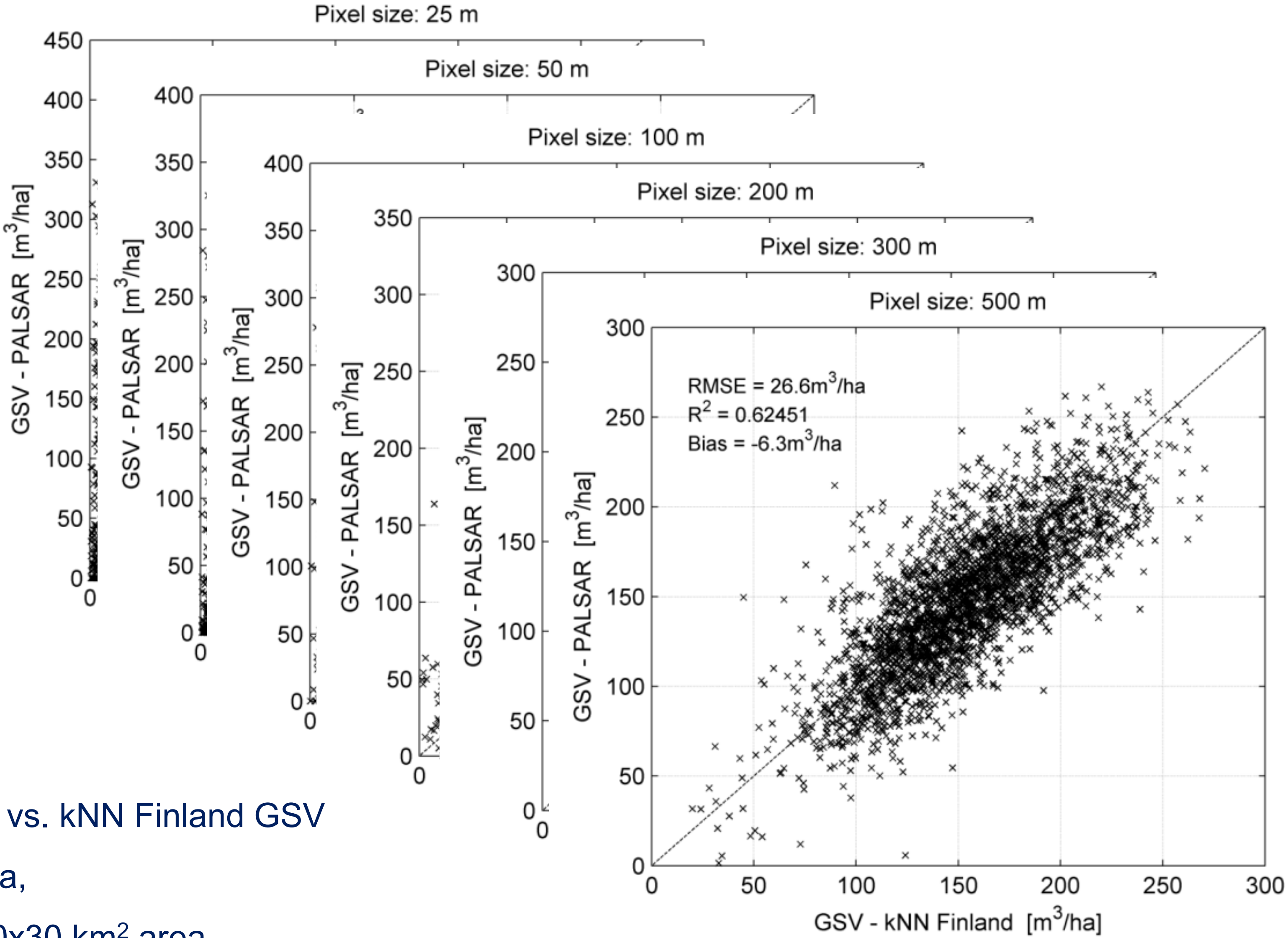


PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area

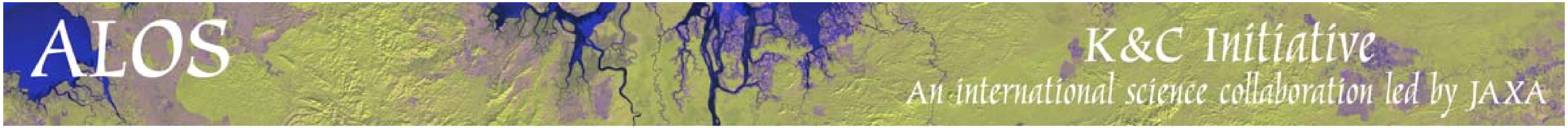
Assessment of GSV retrieval



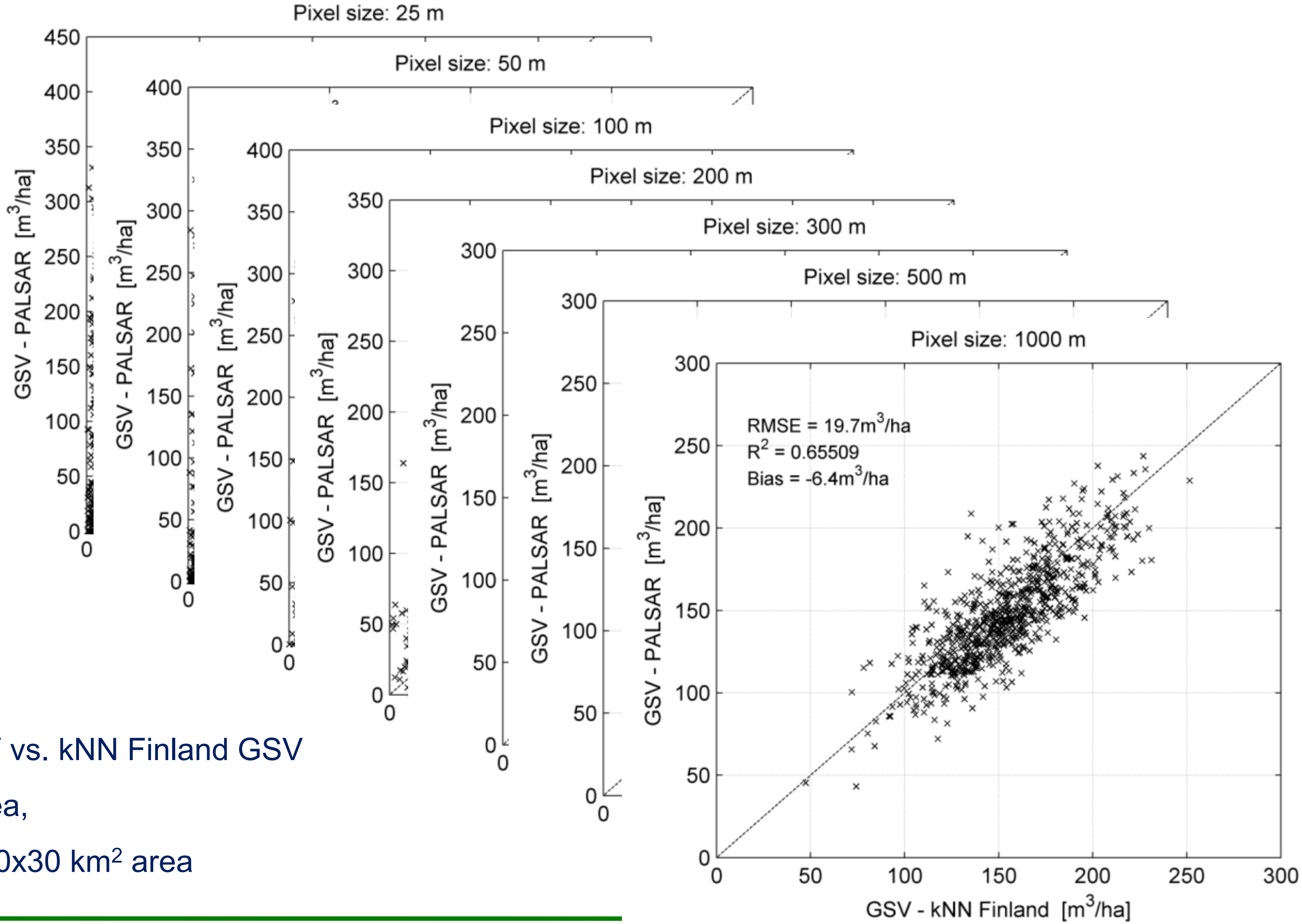
PALSAR GSV vs. kNN Finland GSV

only forest area,

example for 30x30 km^2 area



Assessment of GSV retrieval

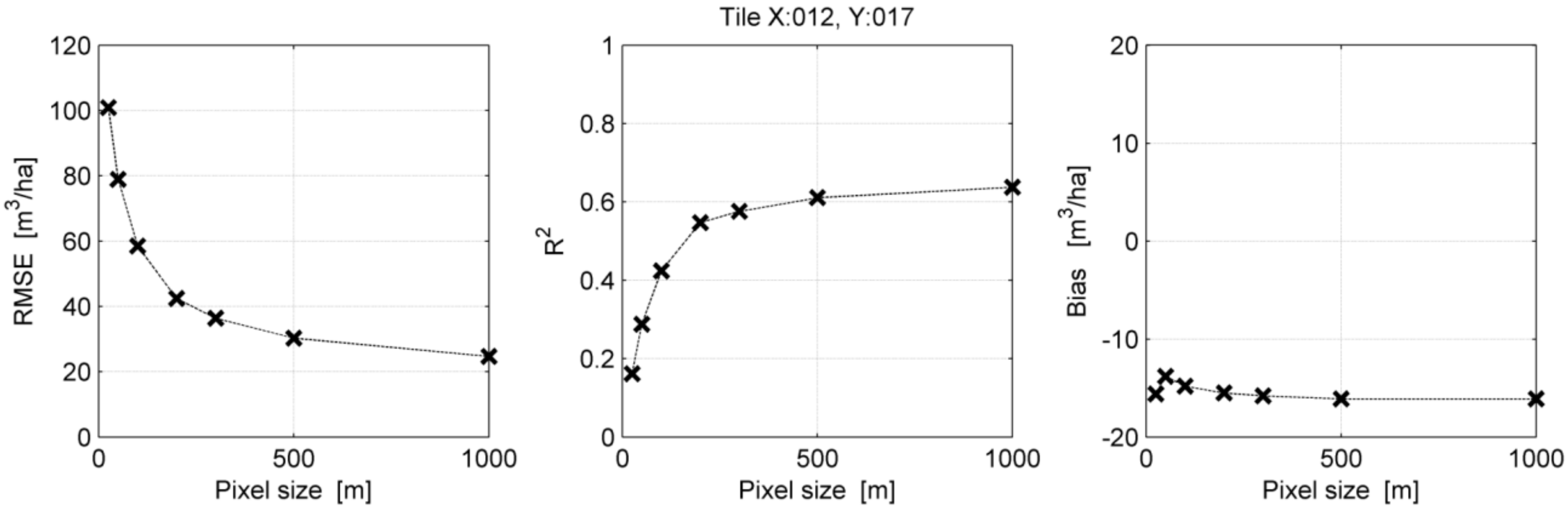


PALSAR GSV vs. kNN Finland GSV

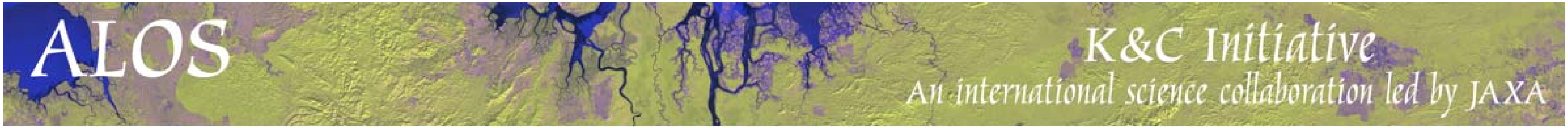
only forest area,

example for 30x30 km^2 area

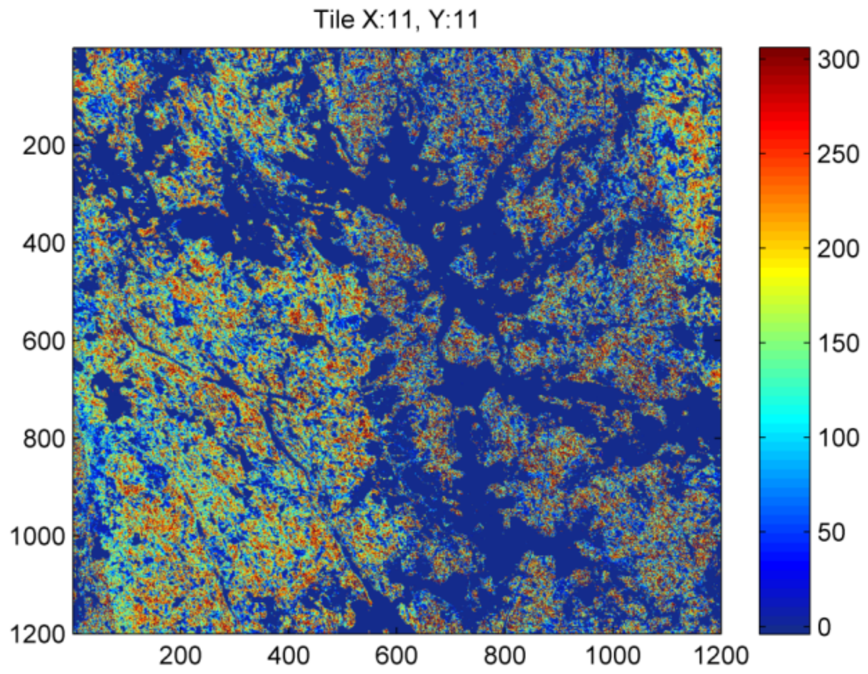
Assessment of GSV retrieval

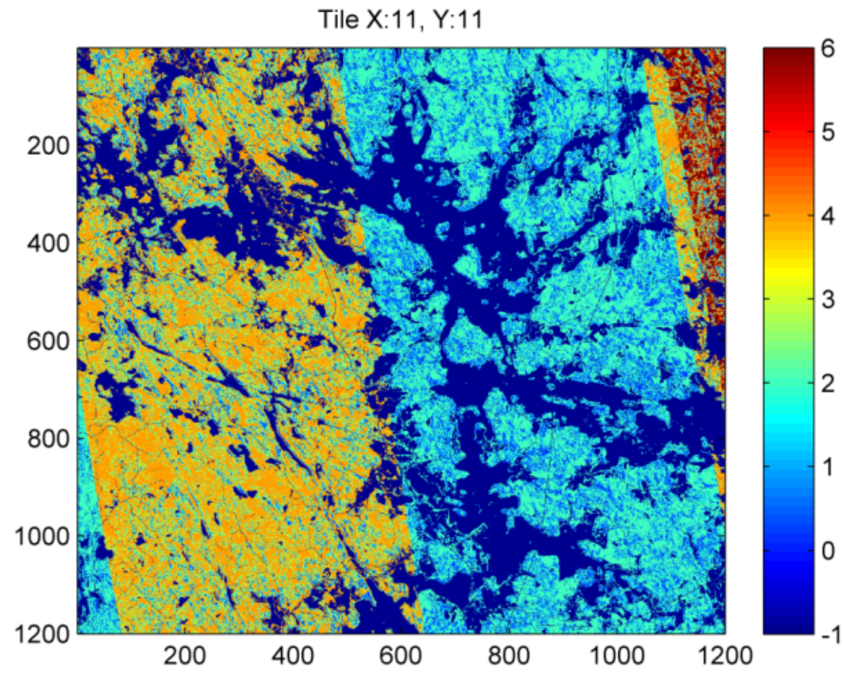


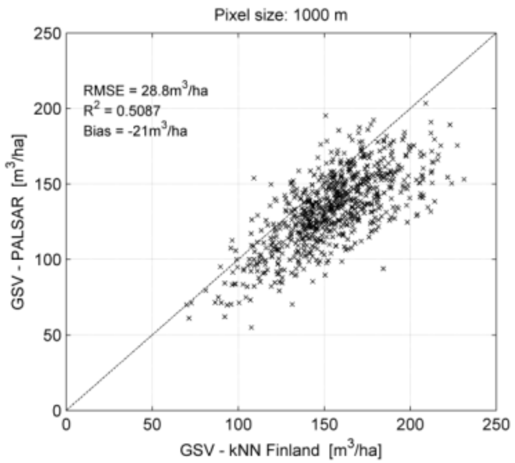
- At full resolution, hardly any agreement between PALSAR and kNN GSV of Finland
- For increasing aggregation, increased agreement.
- At 1 km,
  - RMSE between 10 and 30 m^3/ha (mean: 19.1 m^3/ha)
  - R^2 between 0.25 and 0.85 (mean: 0.60)
  - bias between -11 and 22 m^3/ha (mean: -5.7 m^3/ha)



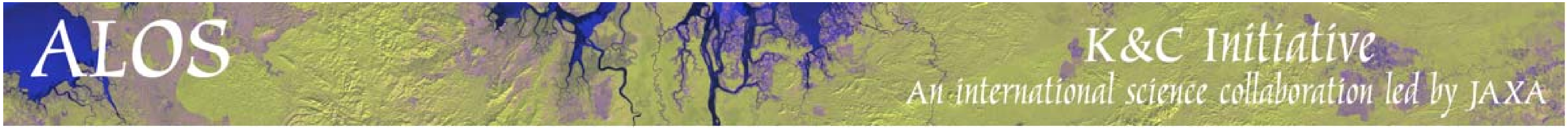
Explaining cases with the largest errors



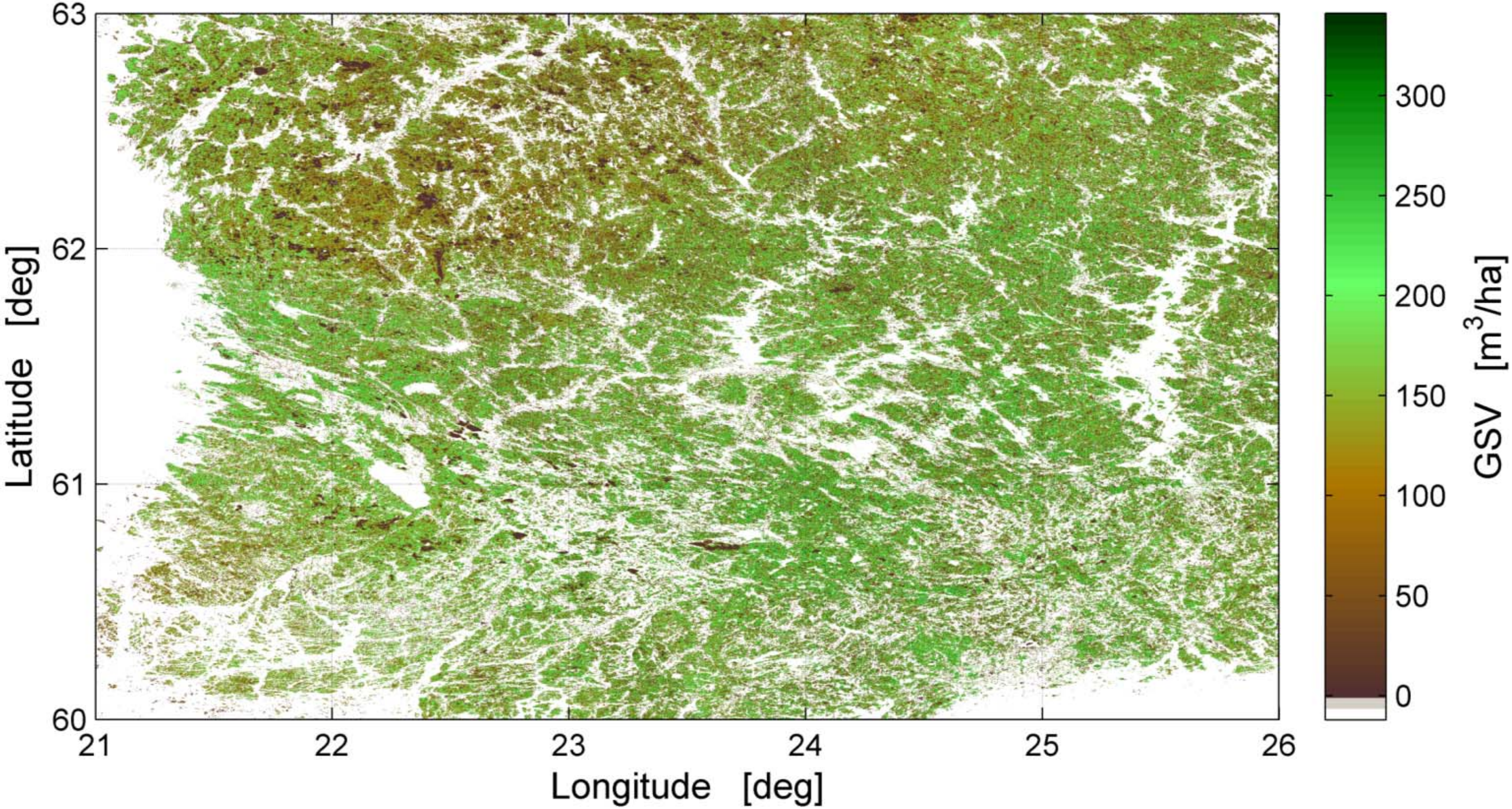




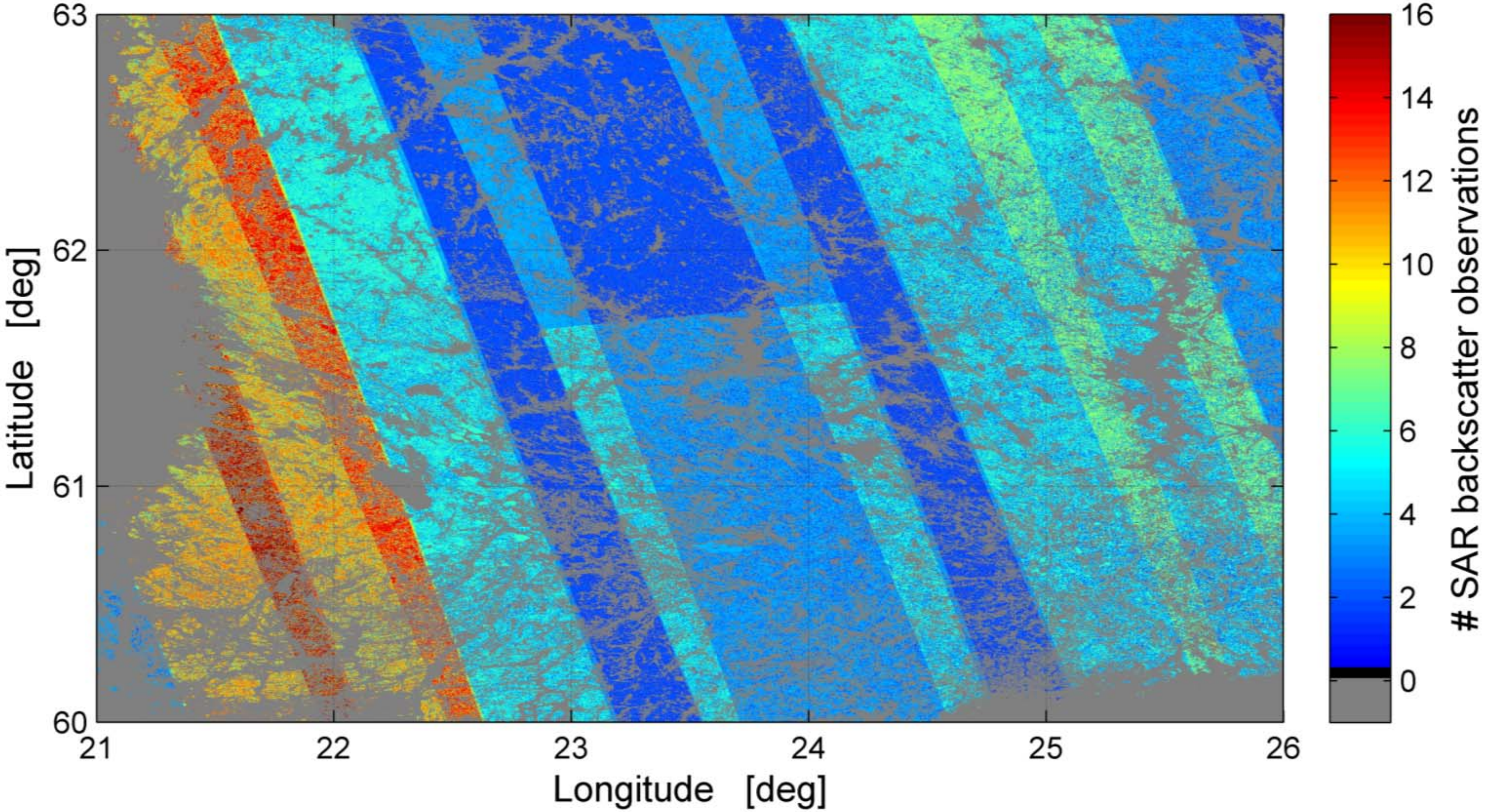
- The retrieval is better where we have more images
- Inhomogeneous number of images impacts overall quality of retrieval thus explaining bias and spread in the scatterplot
- Artifacts more visible when we have a very small number of images



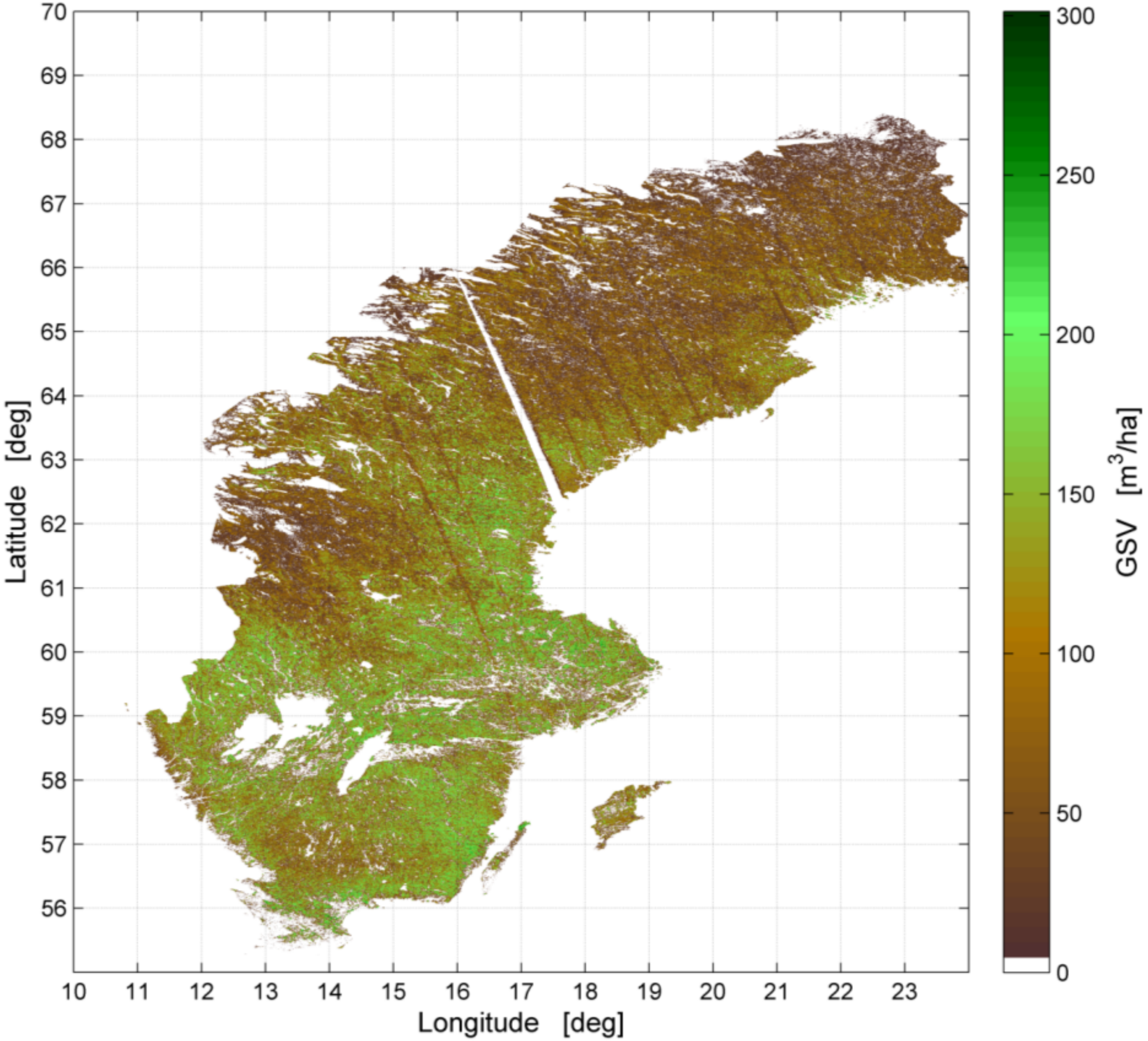
PALSAR GSV map of southwest Finland @ 25 m



Number of PALSAR observations used: southwest Finland



PALSAR GSV map of Sweden @ 25 m



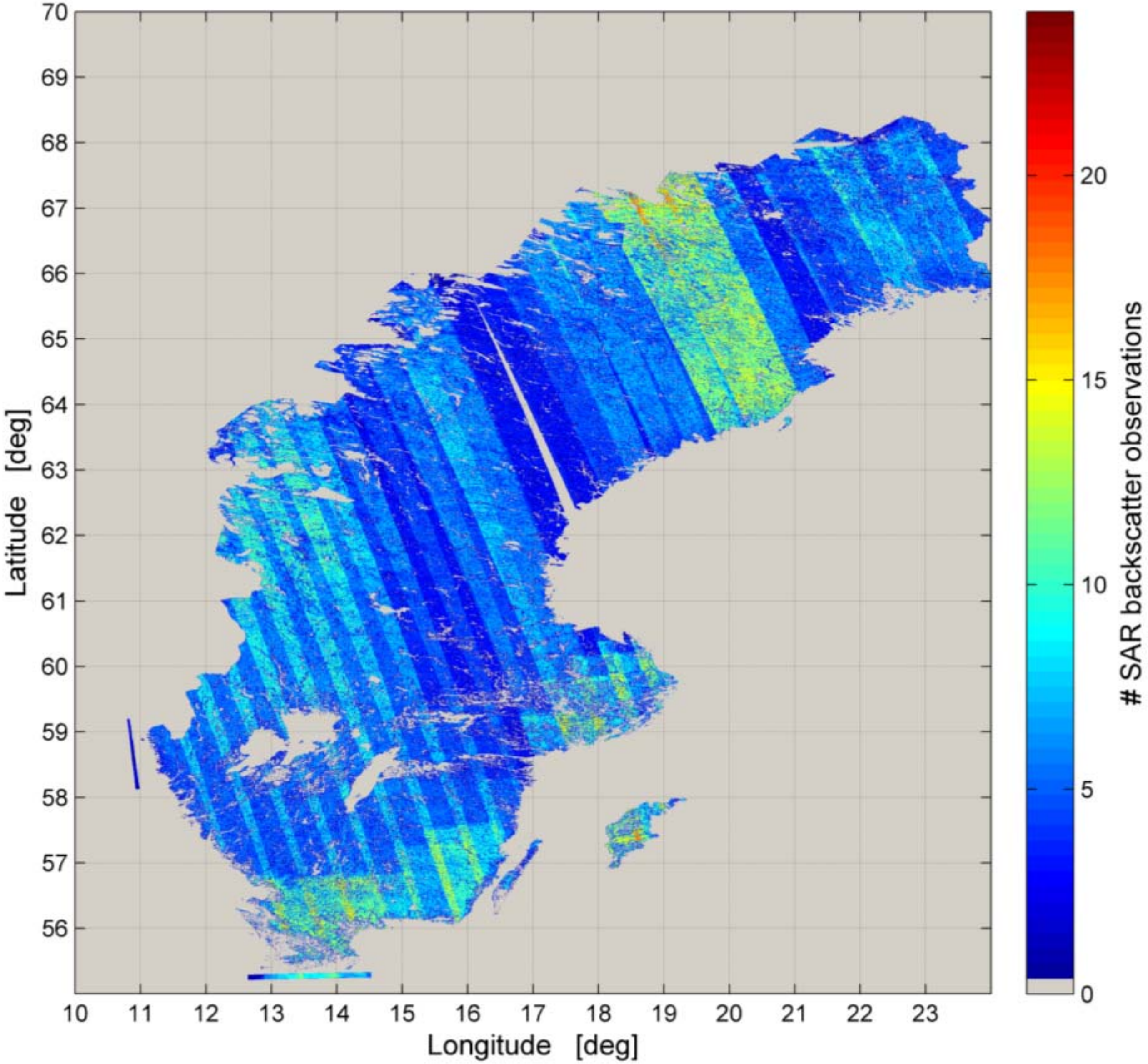
- Preliminary version

  → some artefacts need to be corrected for

  → minor improvement to modelling approach identified (currently implemented)

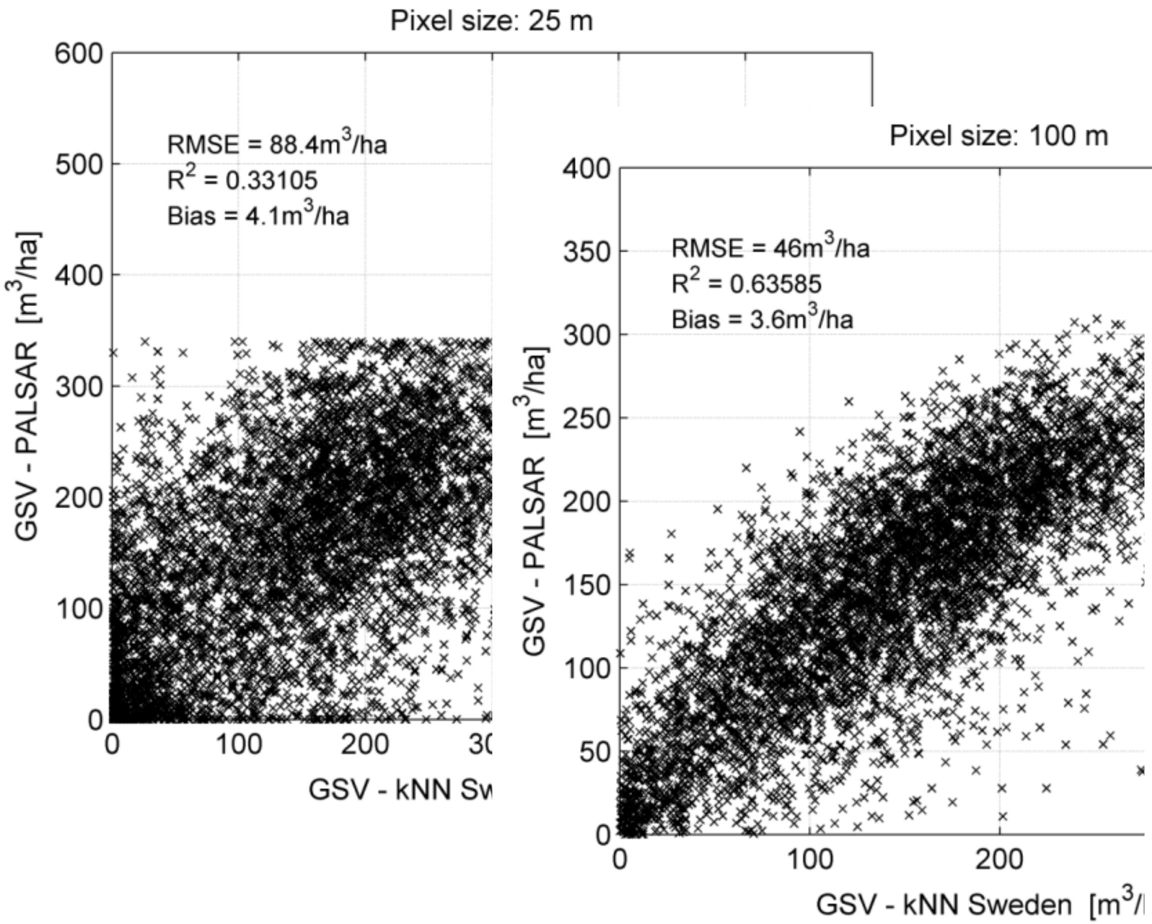
- Gap in correspondence of no PALSAR data for 2010 (possible gap filling with WB @ 75 m)

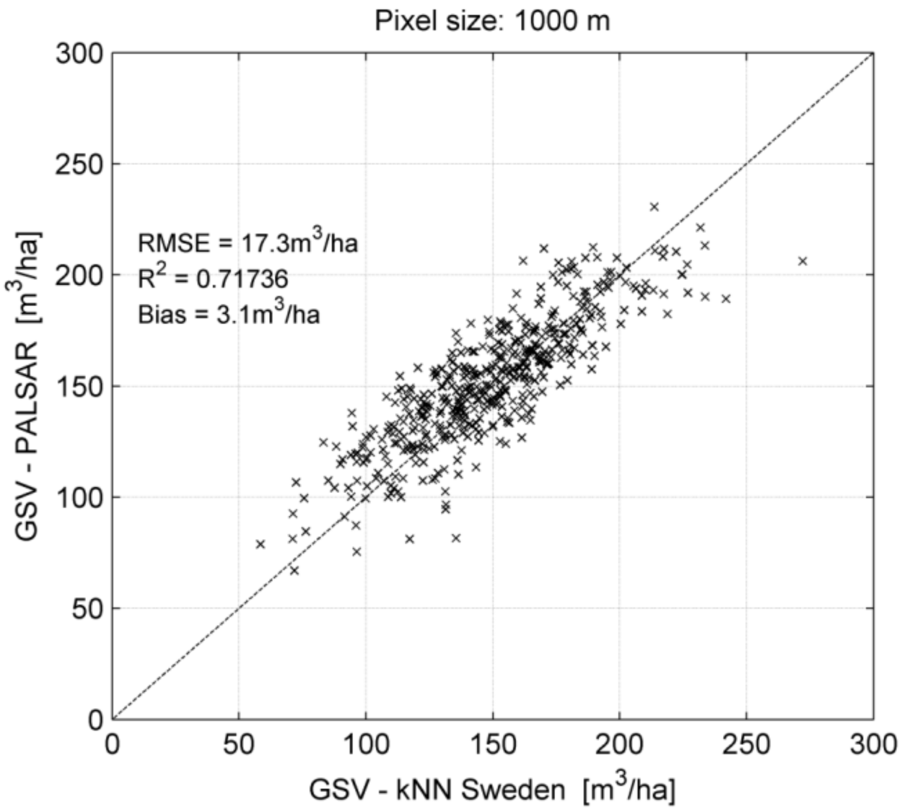
Number of PALSAR observations used: Sweden



- Preliminary version
- The number of observations should increase in the next version (currently being produced)

Assessment of GSV retrieval





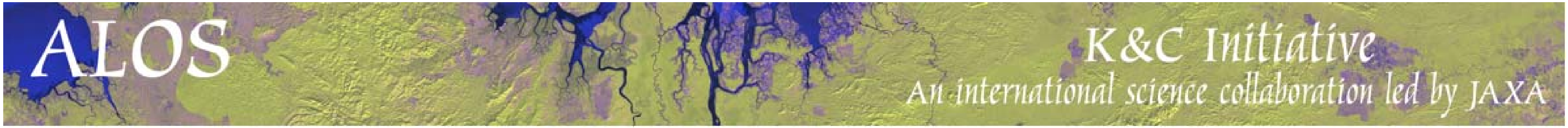
PALSAR GSV vs. kNN Sweden GSV

only forest area,

example for 30x30 km^2 area (containing the Remningstorp test site)

Some observations

- Retrieval profits from multi-temporal observations, see also Cartus et al., 2012 → to be considered in future observations scenarios
- Consider redundant observations in future BOS to avoid data gaps (see results for Sweden)
- HH and HV were found to have similar weight in the multi-temporal combination
- Retrieval at full resolution does not give the right picture of volume/biomass at that scale (too many disturbing factors, both in radar and optical images). With aggregation, the agreement increases because noise in filtered out. Our results confirm indications by Saatchi et al., RSE, 2011.



Project schedule (status)

- Investigations of the retrieval methodology: concluded
  - Water Cloud Model with two unknown parameters and fixed transmissivity
- Automation of retrieval approach (modeling): implemented
  - BIOMASAR algorithm adapted to high-res data
    - Model training @ 500 m using MODIS VCF as mask, retrieval at high-res
- Mapping @ 25 m:
  - Sweden and southwest Finland (refinement foreseen)
  - Other study regions: started
- Future:
  - Combination of FB-aggregated biomass (25 m → 75 m) with WB biomass to enhance accuracy at medium resolution
  - Estimation of regional carbon fluxes