K&C Phase 4 – Status report

Retrieval of forest biomass and biomass change with spaceborne SAR

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Project outline and objectives

In the ongoing project, seen as a continuation of the K&C Initiative activities performed in the previous Phases 1, 2 and 3, multi-temporal ALOS-1 PALSAR-1 and ALOS-2 PALSAR-2 data are used to further develop and validate methods for large-scale biomass and biomass change mapping.

A biomass map covering all of Sweden will be derived using PALSAR-2 data for the year 2015 and compared to:

i) the PALSAR-1 biomass (stem volume) map derived in Phase 3,

ii) statistics from the Swedish National Forest Inventory (NFI), and

iii) the Swedish forest map of 2015 based on airborne laser scanner data.

Project outline and objectives

To derive the PALSAR-2 biomass map, the previously used algorithm based on the Water Cloud Model in Phase 3 is used and further developed and validated (BIOMASAR algorithm).

By comparing the biomass maps of 2015 and 2010, both loss in biomass (i.e., clear-cuts, thinning cuttings, wind-thrown damages) and forest growth can be studied.

An ongoing pilot study is conducted using L-band data from the BioSAR 2007 and BioSAR 2010 BIOMASS campaigns at the test site Remningstorp in southern Sweden (Ivan Huuva et al.).

Project outline and objectives

Furthermore, change detection of the forest cover in terms of detecting and delineating clear-felled areas for all of Sweden will be performed using PALSAR-2 data from the years 2015 and 2016. The approach will be to use a similar methodology as developed in Phases 1 and 2.

The clear-felled areas derived from PALSAR-2 data will be compared to clear-cut maps from:

i) the Swedish Forest Agency and

ii) statistics from the Swedish NFI.

Project outline and objectives

The project will involve analysis of more than 28 million ha of boreal and hemi-boreal forests in Sweden.

The differences in weather conditions, topography, forest properties, time of acquisition, number of observations and incidence angle range make it especially important to develop a robust methodology for future operational use.

It is anticipated that the proposed project will advance the knowledge towards an operational use of high-resolution L-band SAR data in forestry applications.

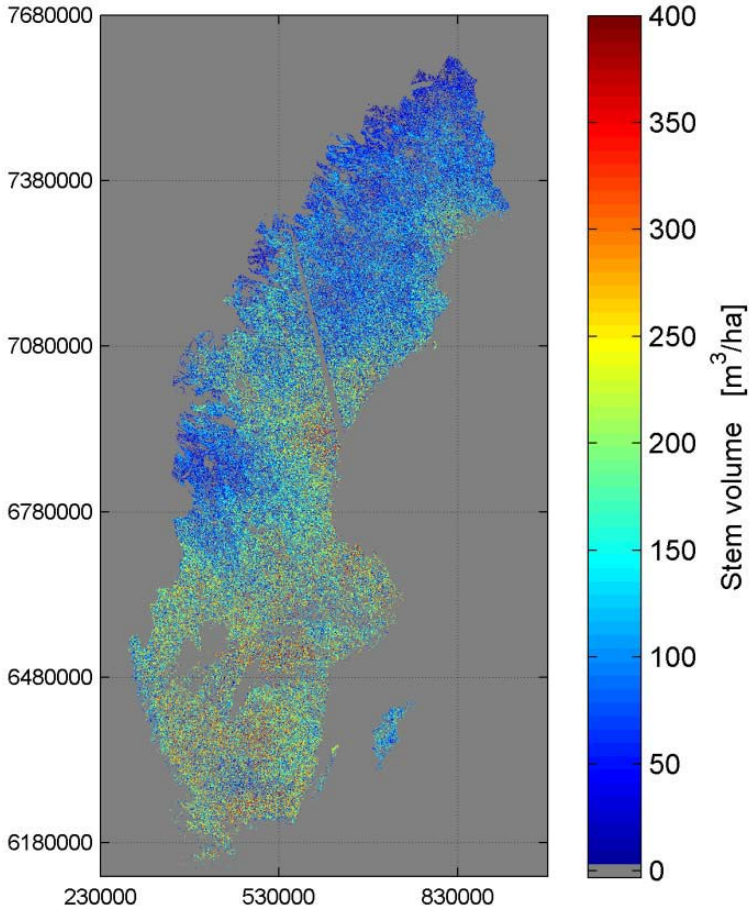
The methods and algorithms that will be developed also aim to demonstrate the large-scale forestry monitoring goals of the JAXA's ALOS K&C Initiative

Project outline and objectives

The project supports the 4 K&C thematic drivers, i.e. **C**arbon Cycle Science, **C**limate Change, International **C**onventions, Environmental **C**onservation.

In this context, for example, there is a synergy with the K&C Phase 4 project “Coupling radar-based estimates of forest information with biosphere models for improved carbon flux estimation” by Maurizio Santoro

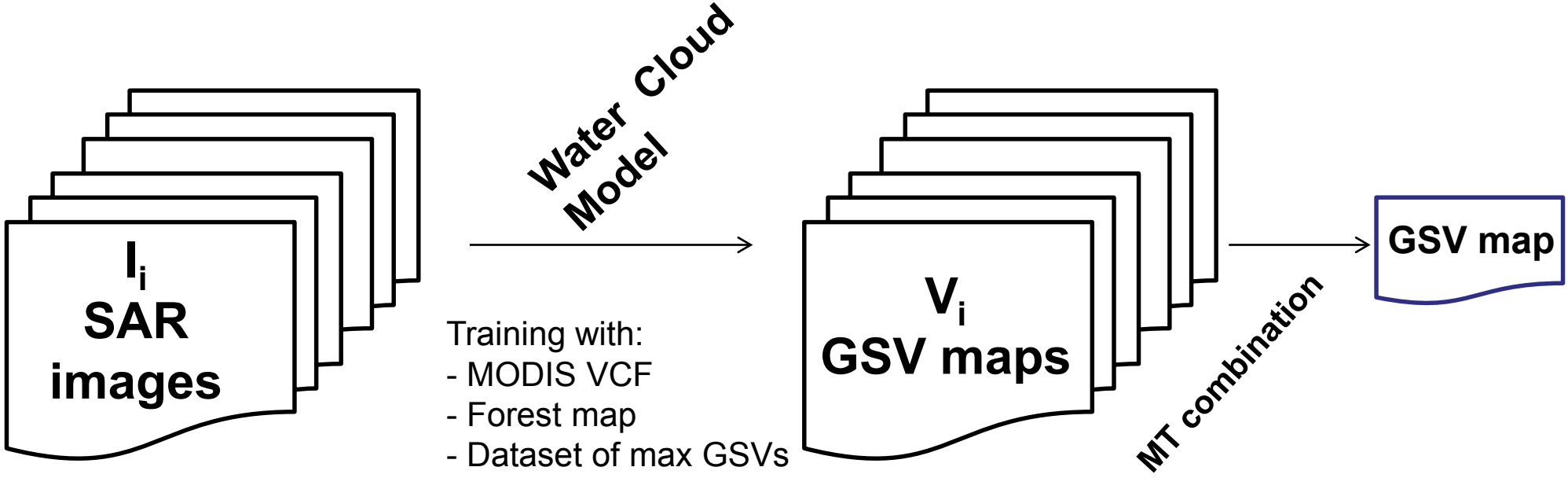
Project outline and objectives



Left: JAXA ALOS K&C Initiative prototype areas and test sites in Sweden. Right: Stem volume map of Sweden from multi-temporal ALOS-1 PALSAR-1 images (25 m resolution).

The BIOMASAR approach

Retrieving forest growing stock volume from SAR backscatter



Training with:
- MODIS VCF
- Forest map
- Dataset of max GSVs

e.g., one year of ASAR data or PALSAR mosaics

- No *in situ* data required to train the model

Water Cloud Model

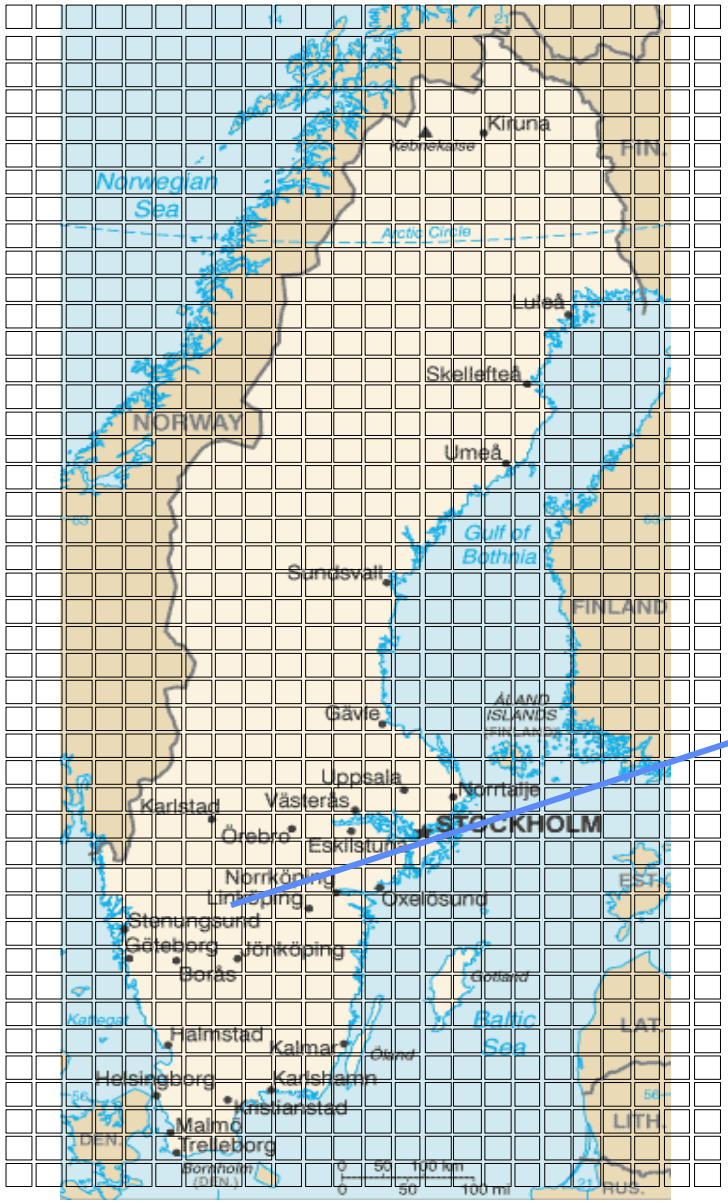
Semi-empirical model:

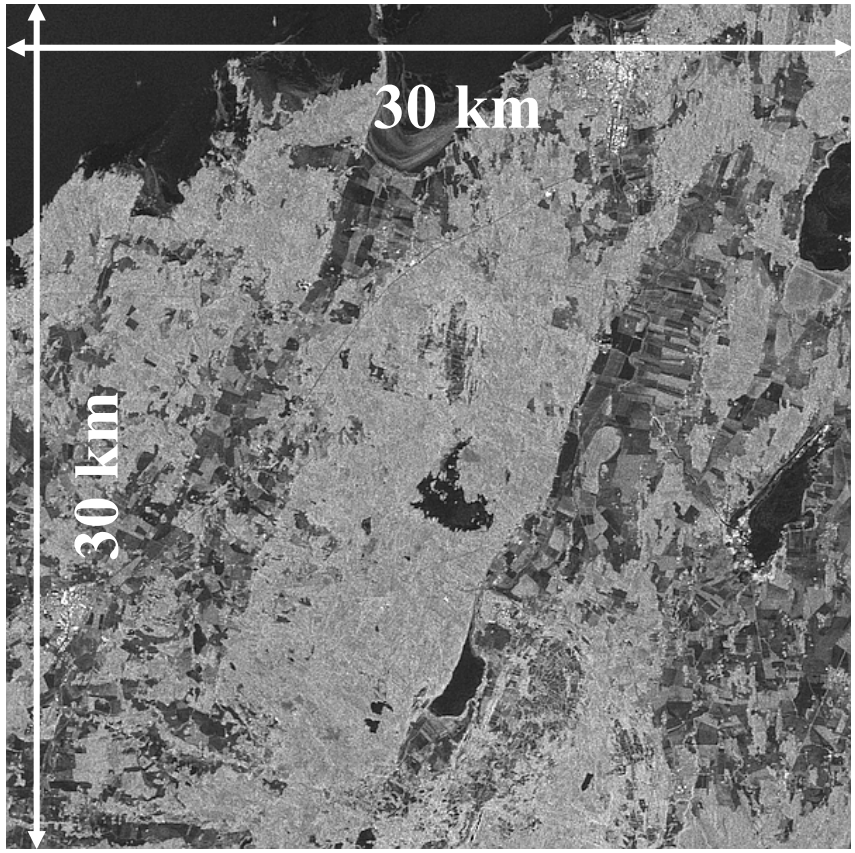
$$\sigma^{\circ}_{for} = \sigma^{\circ}_{gr} \times e^{-\beta V} + \sigma^{\circ}_{veg} \times (1 - e^{-\beta V})$$

Inverted model for stem volume estimation:

$$\hat{V} = -\frac{1}{\beta} \cdot \ln\left(\frac{\sigma^0_{veg} - \sigma^0_{for,meas}}{\sigma^0_{veg} - \sigma^0_{gr}}\right)$$

- β - attenuation coefficient, depends on forest structure & dielectric props.
- V - Stem volume
- σ^0_{veg} - Vegetation backscattering coefficient
- σ^0_{gr} - Ground backscattering coefficient
- σ^0_{for} - Forest backscatter intensity
- $\sigma^0_{for,meas}$ - Measured backscatter



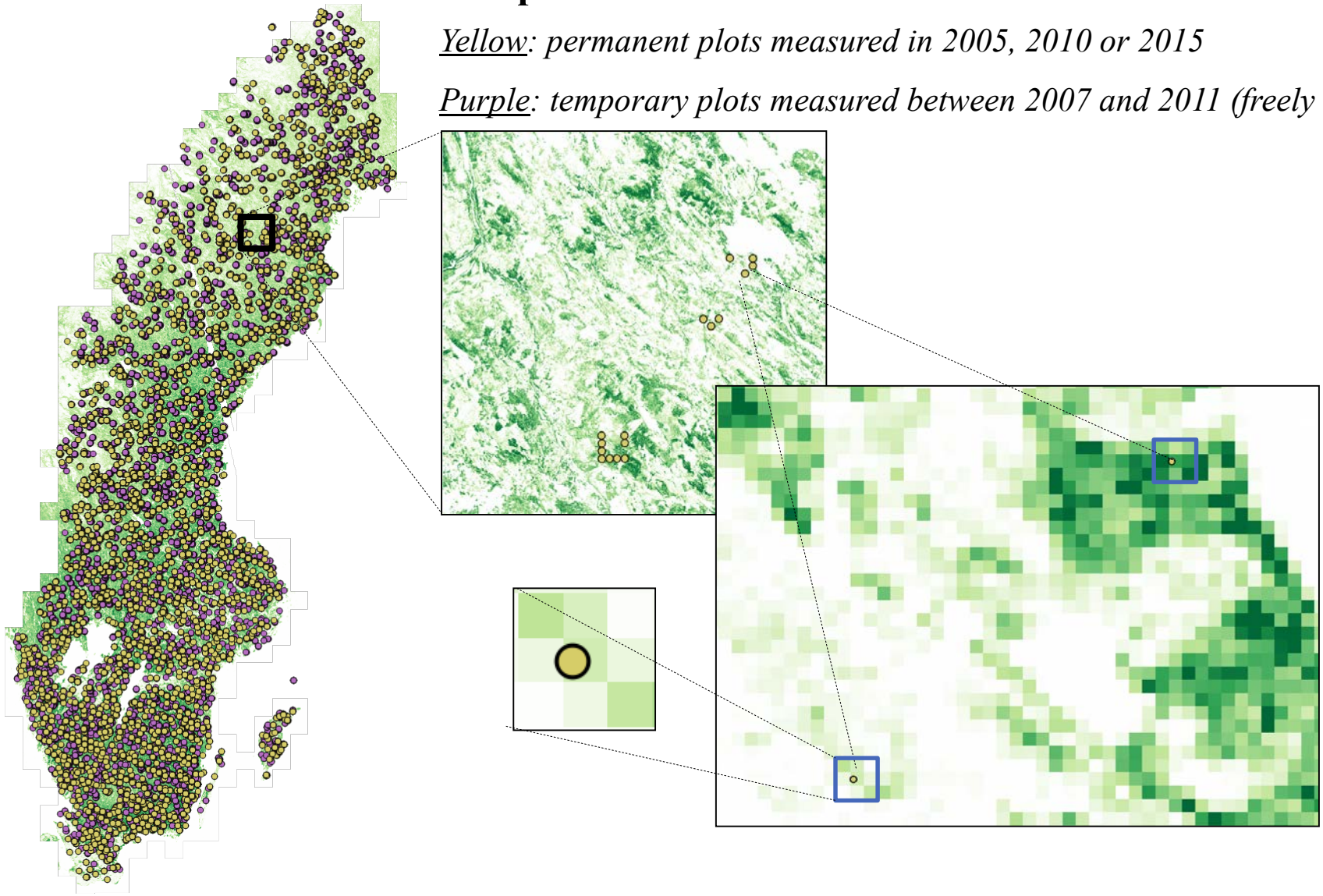


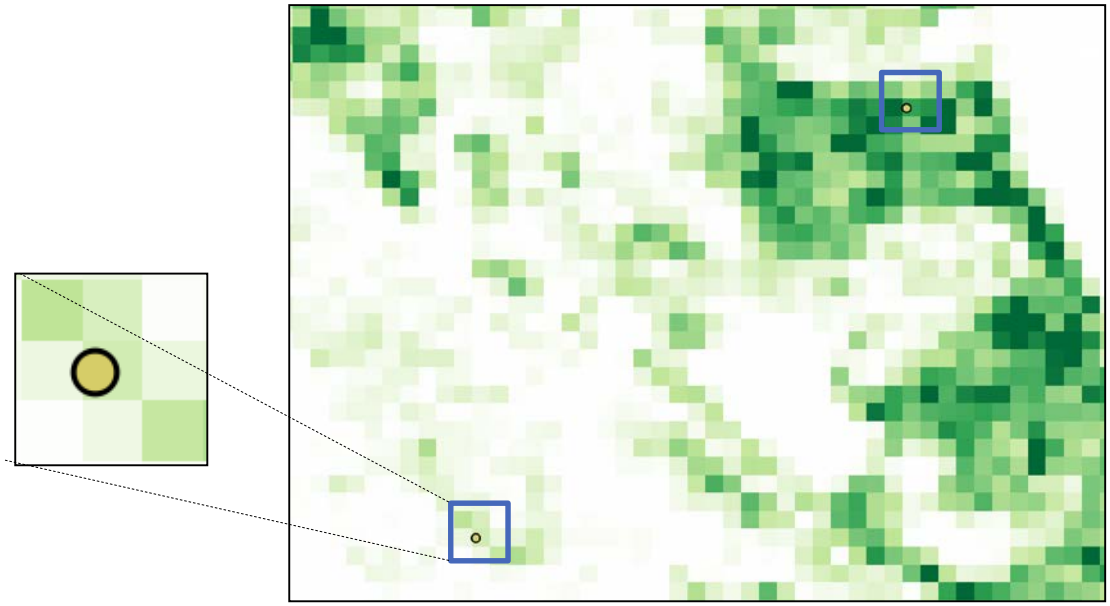
Example of a tiled SAR backscatter image
006_039_20150205_193_FBD_HV.ortho.norm

NFI plots available for validation

Yellow: permanent plots measured in 2005, 2010 or 2015

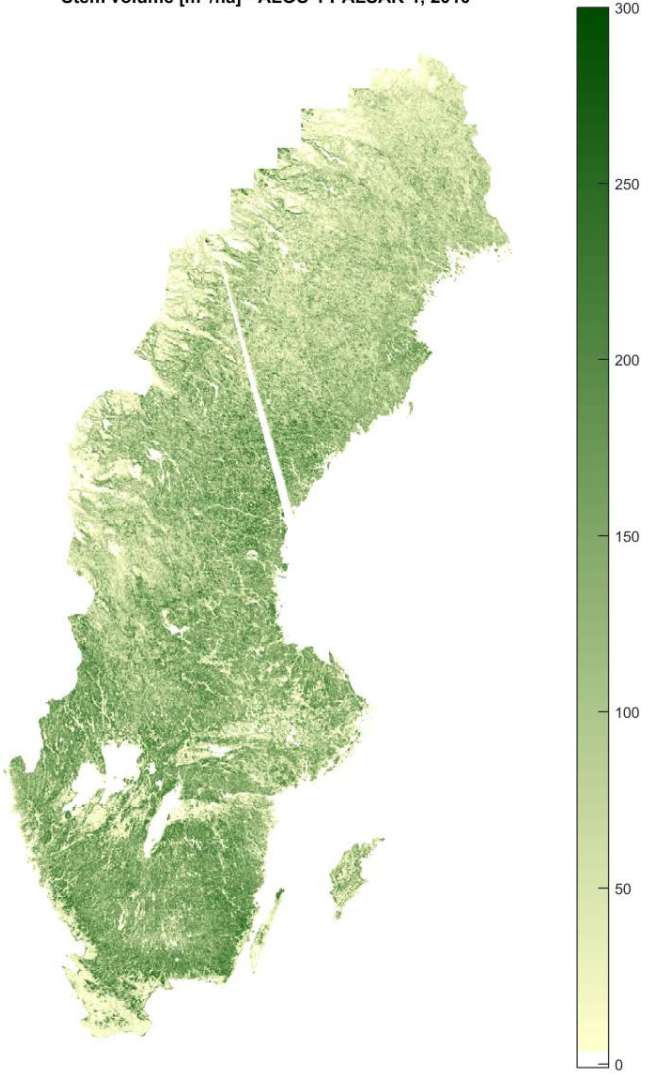
Purple: temporary plots measured between 2007 and 2011 (freely available)



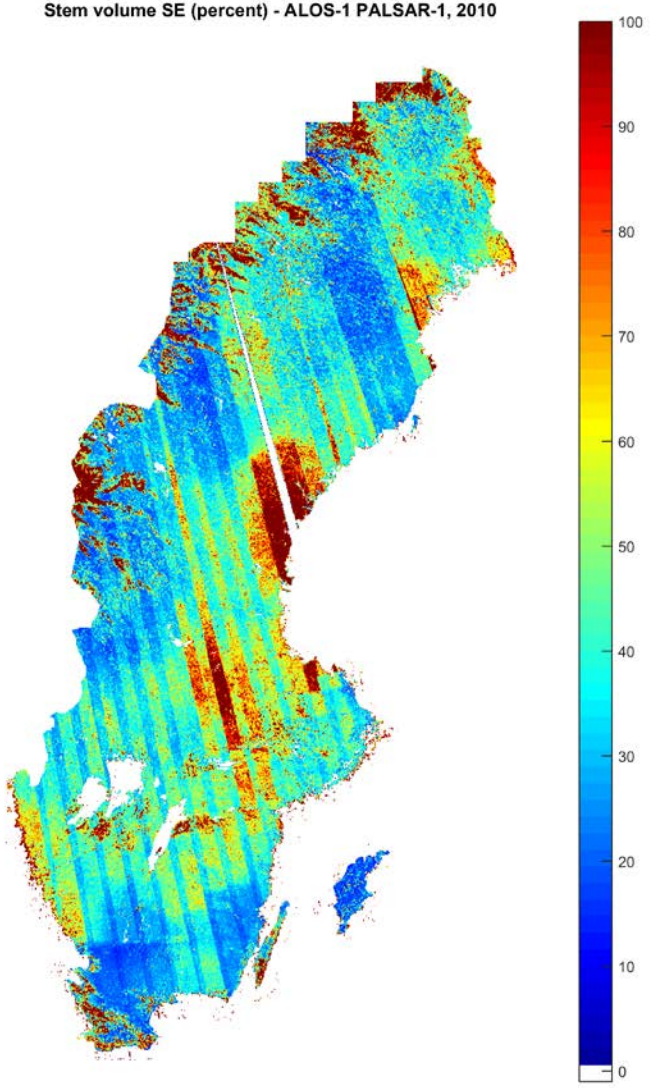


- The size of NFI plots (10 m or 7 m radius) is comparable to the size of an ALOS pixel (25 m)
- A plot, however, may not fall exactly within a pixel
- In addition, the forest represented in a plot does not match with the forest seen by the radar
- Plot vs. pixel assessment is appealing, but bears complications that limit the understanding of the retrieval
- Plot vs. pixel neighborhood assessment is more indicative of the quality of the retrieval, but retrieval statistics need to be well interpreted
- Plots are meant to derive statistics → it is more correct to assess retrieved biomass by looking at spatial averages

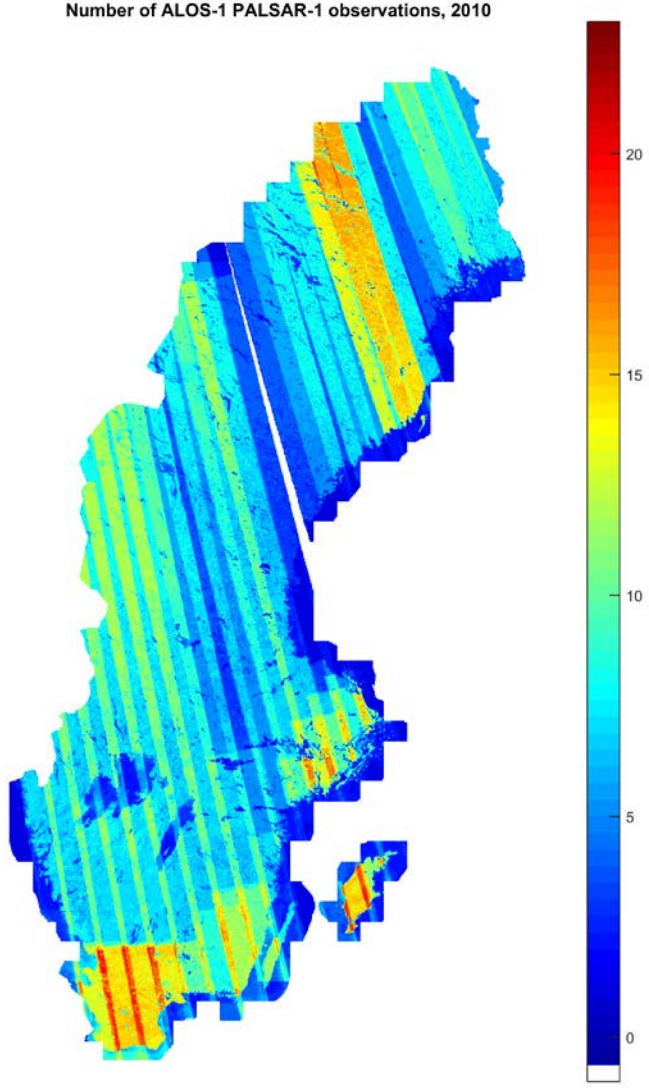
Stem volume [m^3/ha] - ALOS-1 PALSAR-1, 2010



Stem volume SE (percent) - ALOS-1 PALSAR-1, 2010



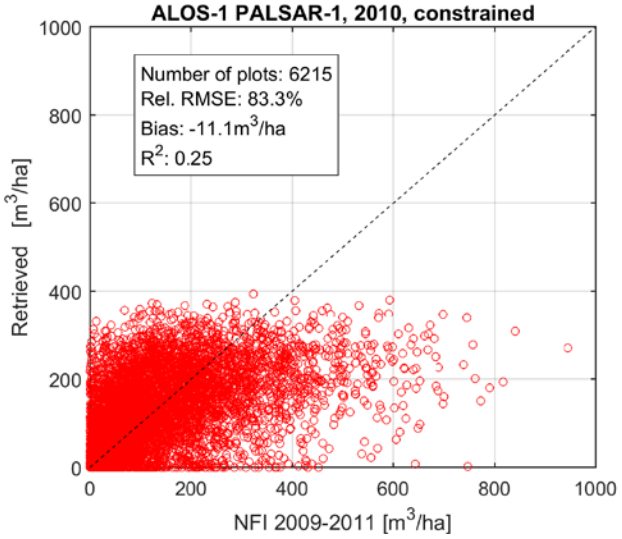
Number of ALOS-1 PALSAR-1 observations, 2010

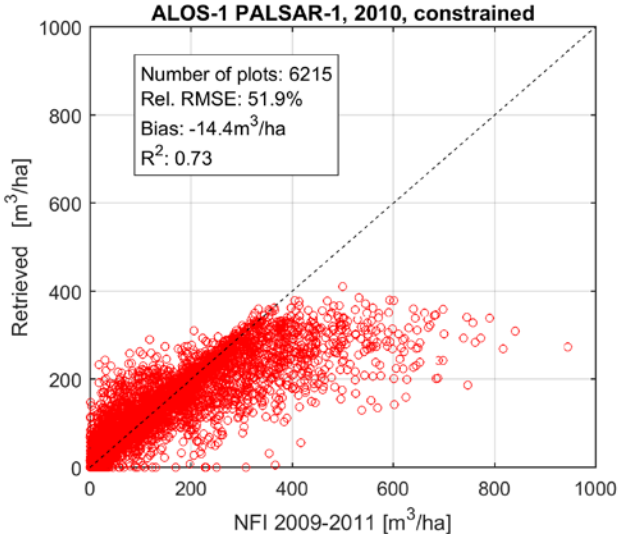


Plot vs. pixel

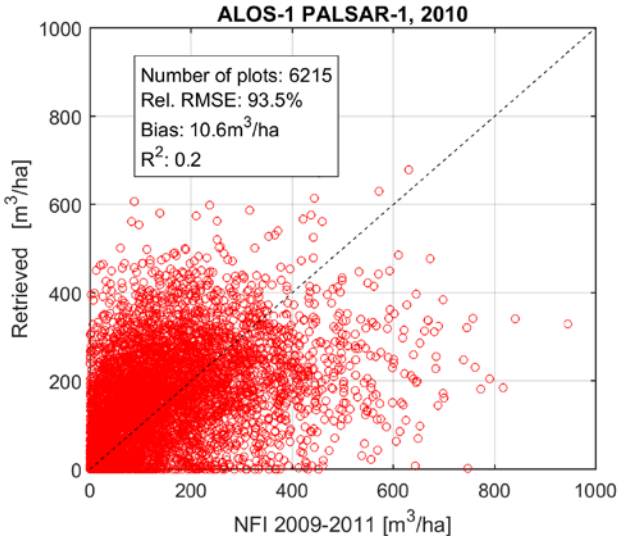
Plot vs. neighborhood (closest estimate)

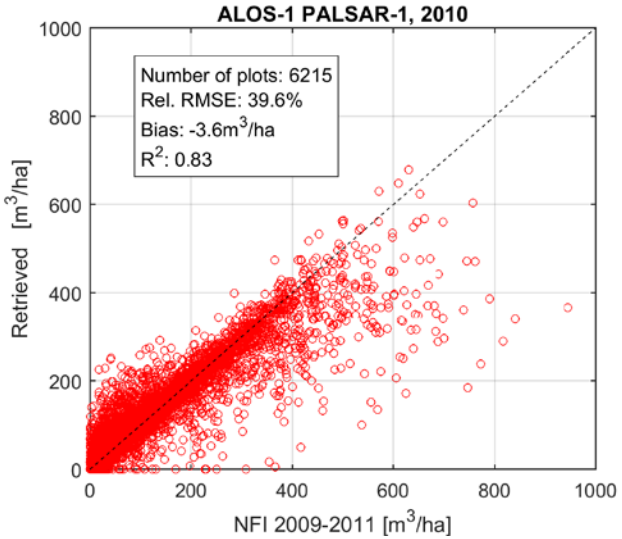
Retrieval constrained with max GSV



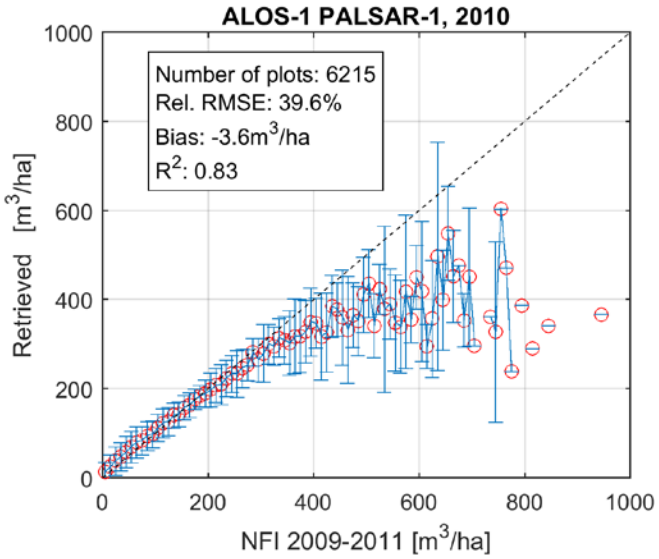


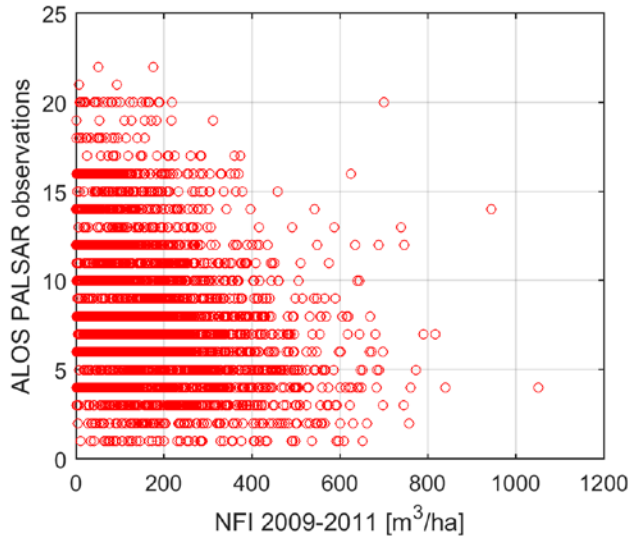
No constraint on max GSV



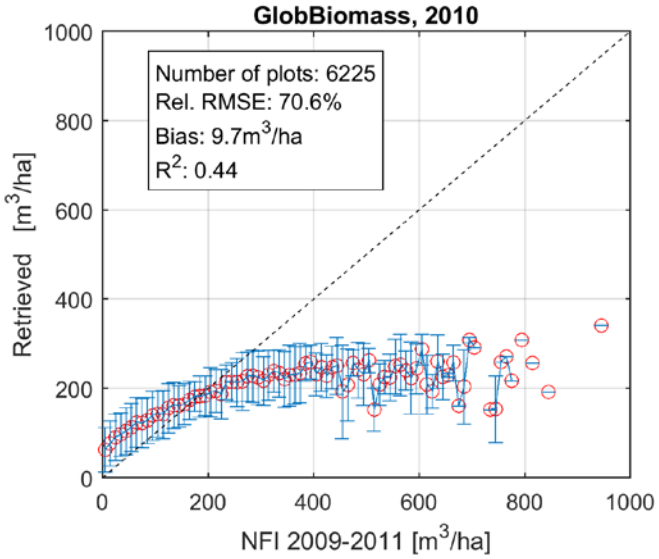


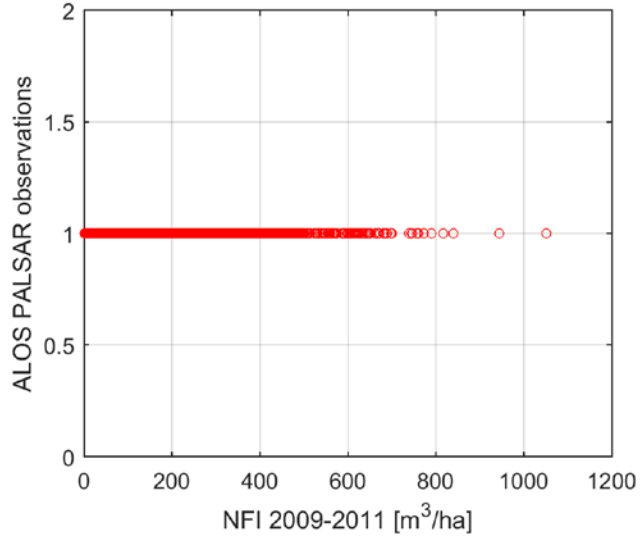
Multi-temporal PALSAR dual-pol dataset

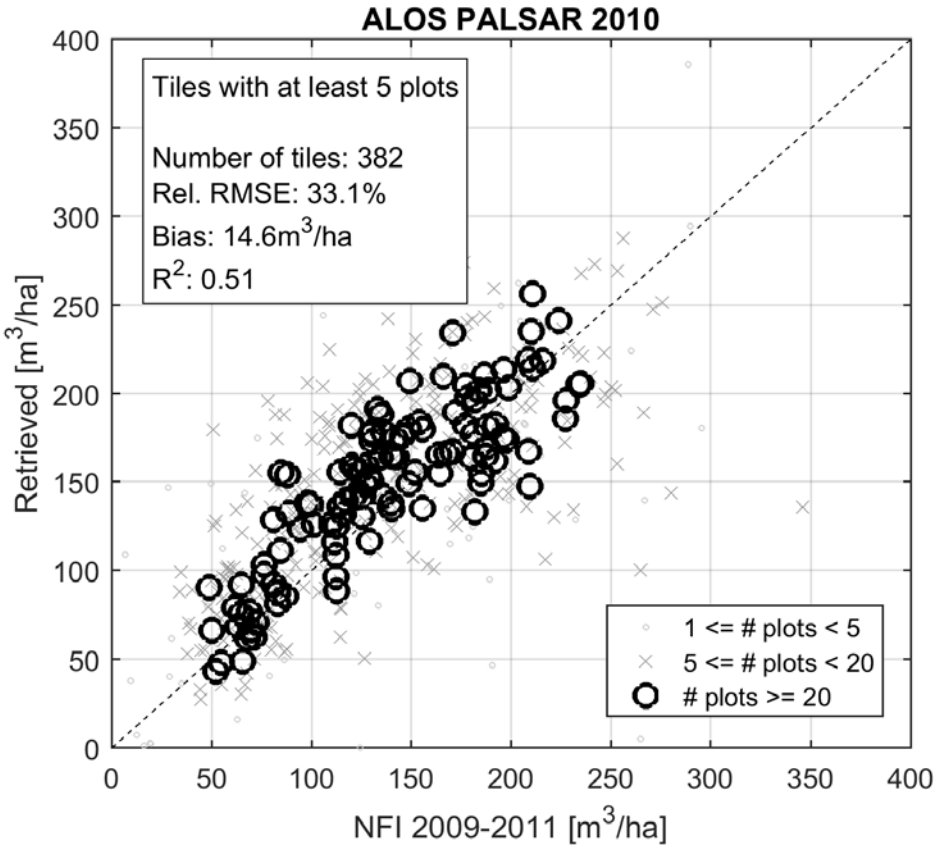


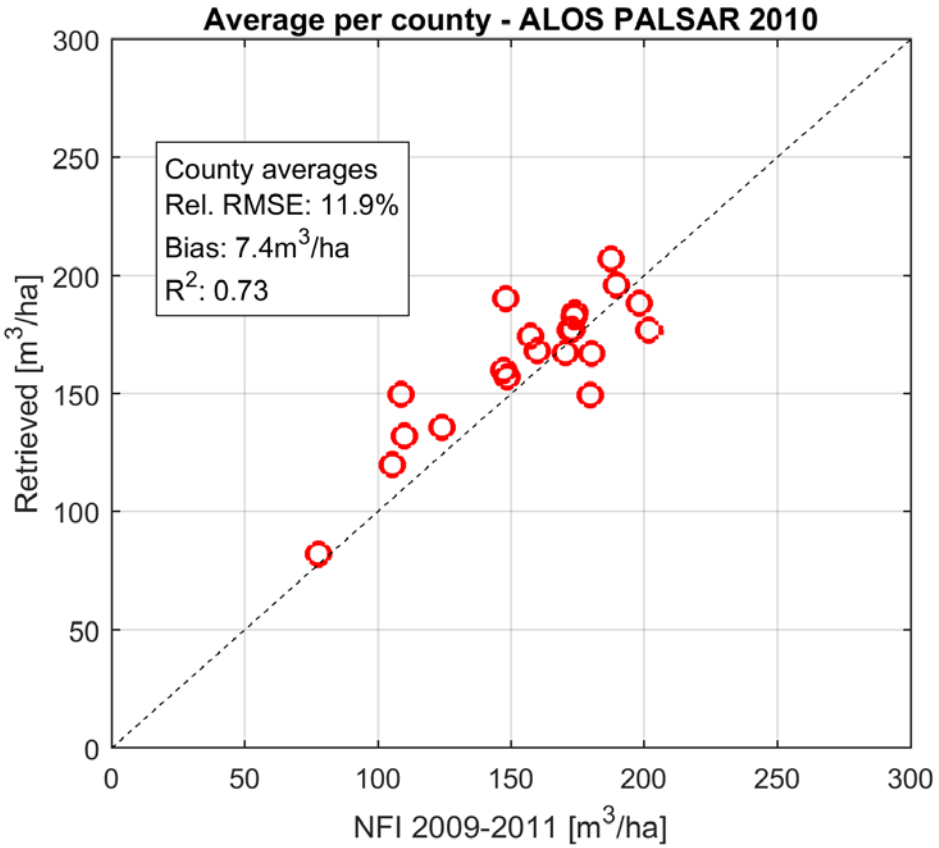


Single PALSAR dataset (HV mosaic)









- Note: averaging over 20 plots, means we are virtually validating a ~ 1 ha area

Retrieval from ALOS-1 PALSAR-1 data: 2010

as of January 2018, not final

- Forest area: 252,415 km^2 (1% of Sweden not covered by ALOS-1 data in 2010)
- Total volume (m^3, constrained retrieval): 2,948 m^3
- Total volume (m^3, unconstrained retrieval): 3,509 million m^3

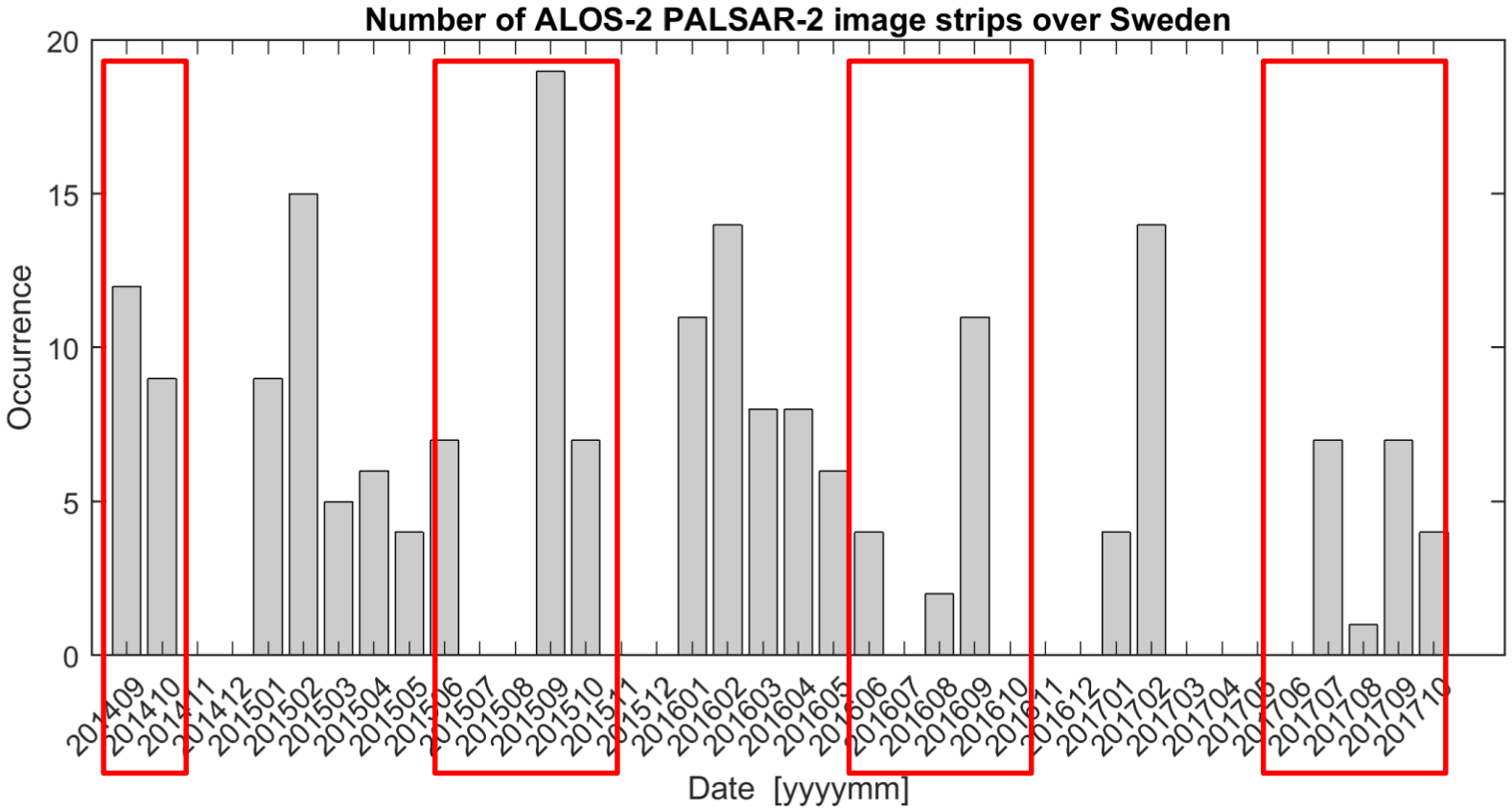
NFI statistics based on plots from 2009-2013

(published in Skogsdata 2014)

- Forest land: 280,680 km^2 (including non-productive forest area)
- Total volume: 3,304 million m^3 (living) + 212 million m^3 (dead wood)

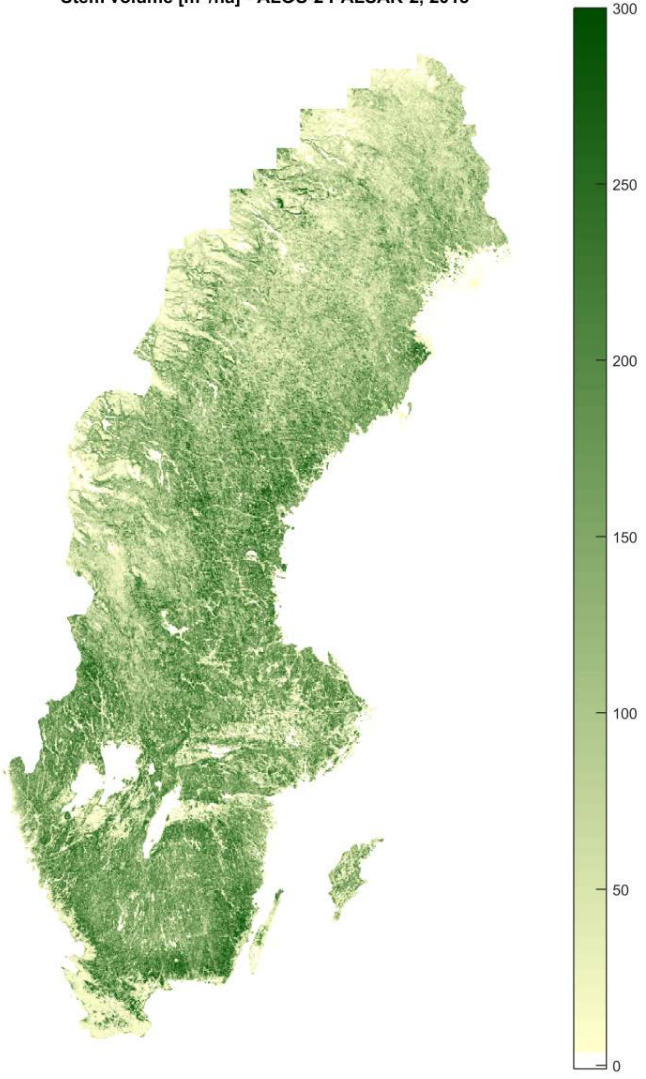
20150610_092_FBD_HH

- In total, 218 image strips, acquired between 2014-09-03 and 2017-10-08
- FBD mode (HH and HV)
- Slant range geometry → calibration, terrain geocoding and topographic correction done with GAMMA software
- Artefacts in near range not compensated for

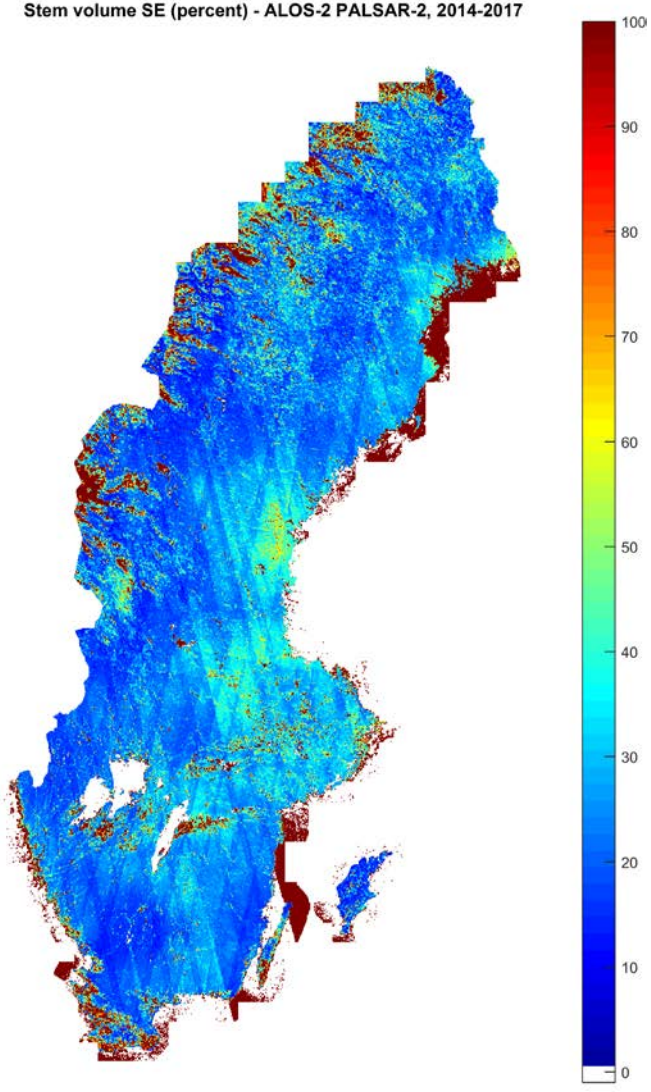


- Temporal distribution of ALOS-2 data slightly skewed towards winter months
- Only 46% of data acquired during spring-to-fall, i.e. under best conditions for biomass retrieval using L-band backscatter

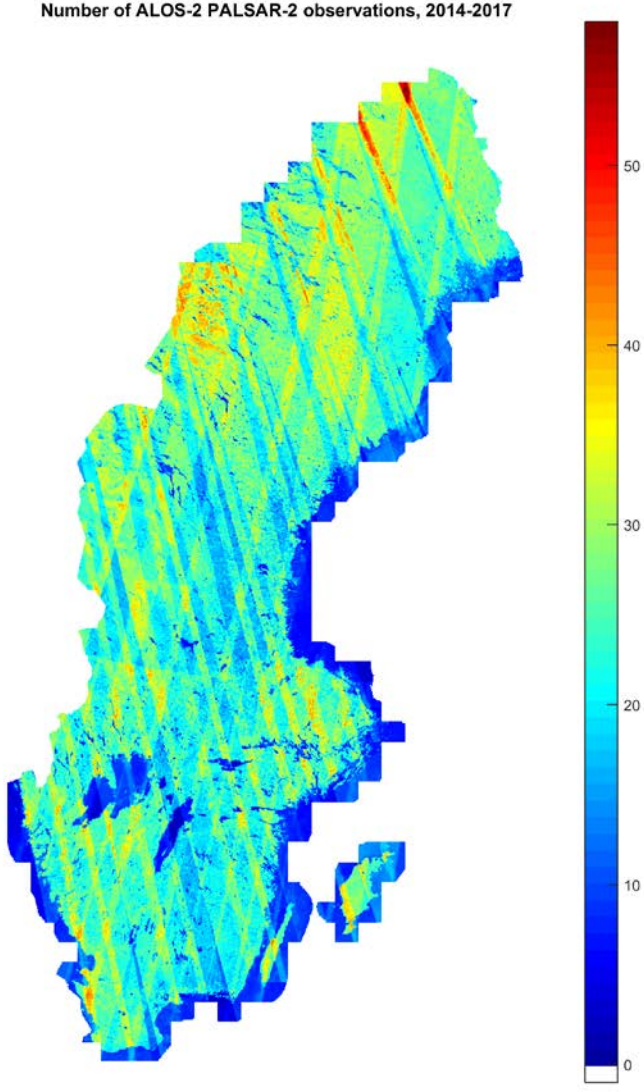
Stem volume [m^3/ha] - ALOS-2 PALSAR-2, 2015



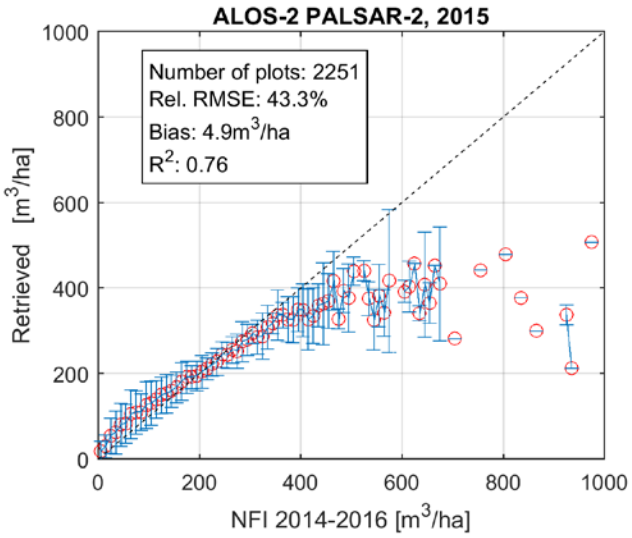
Stem volume SE (percent) - ALOS-2 PALSAR-2, 2014-2017

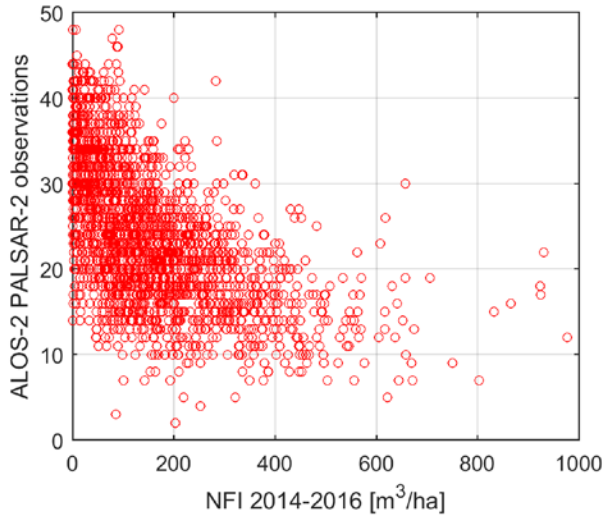


Number of ALOS-2 PALSAR-2 observations, 2014-2017

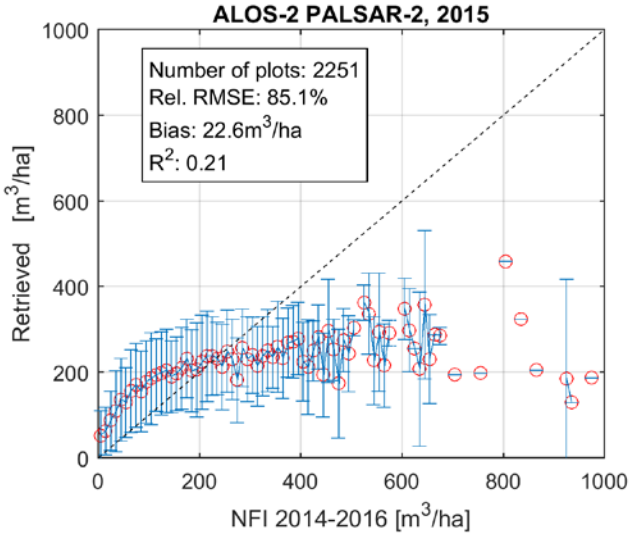


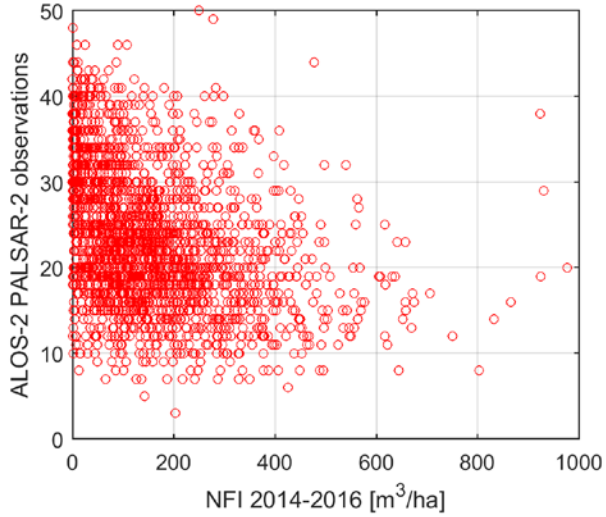
Plot vs. pixel neighborhood

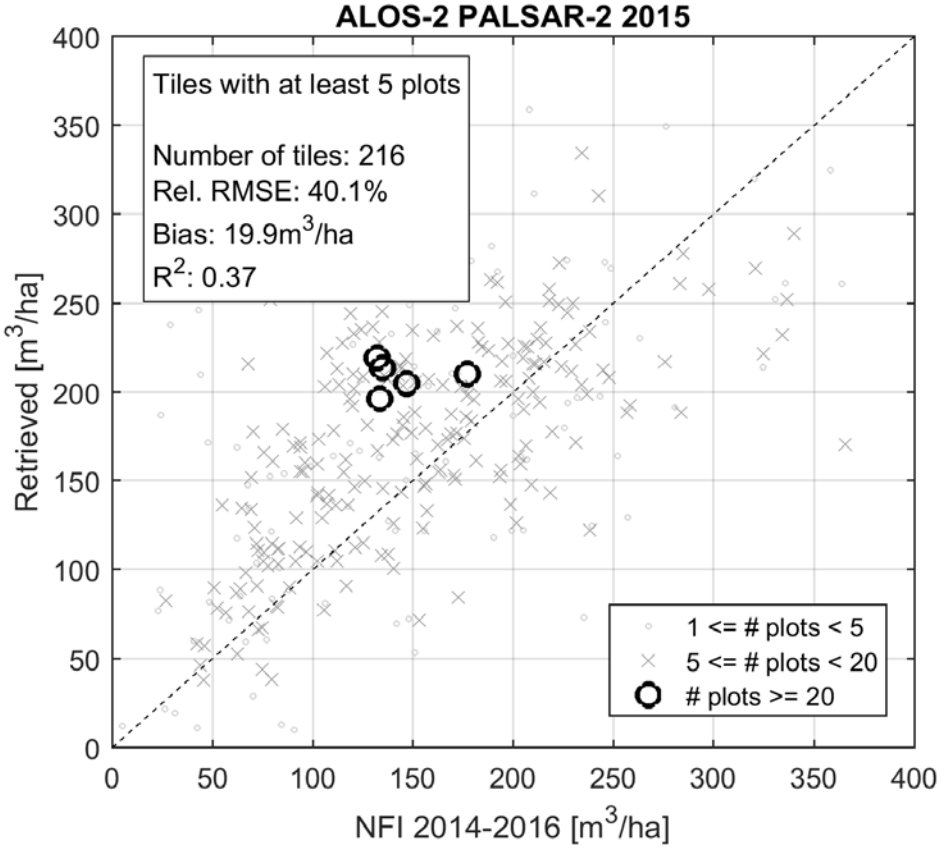


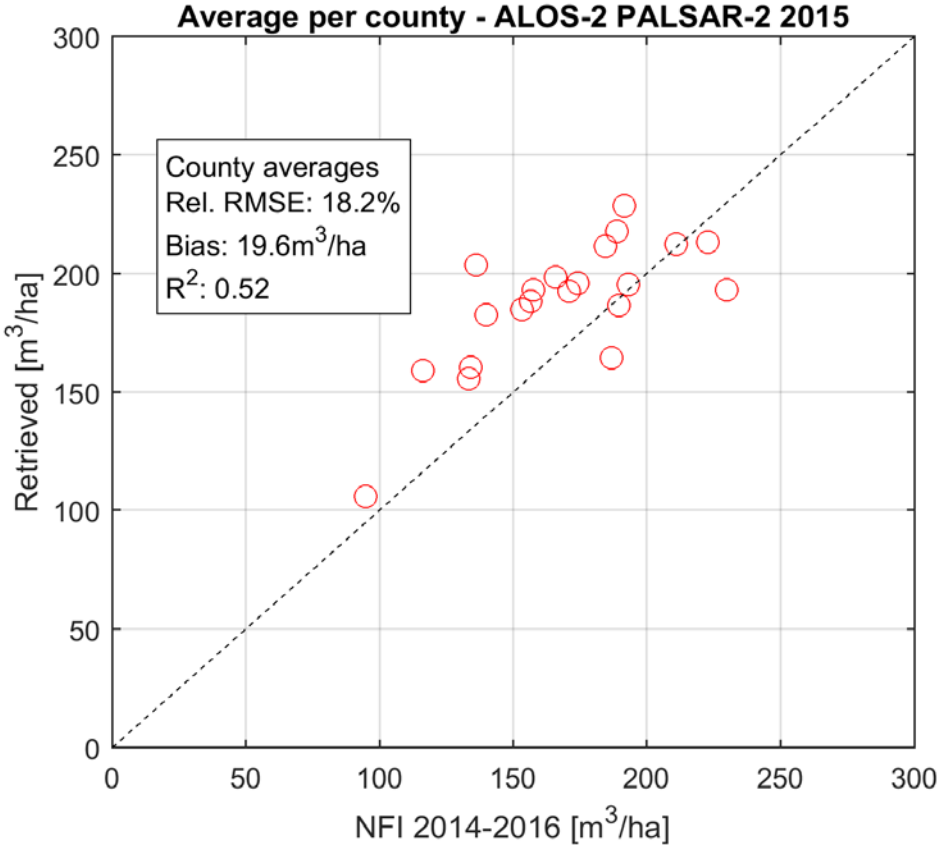


Plot vs. pixel






ALOS-2 PALSAR-2 2015
Tiles with at least 5 plots
Number of tiles: 216
Rel. RMSE: 40.1%
Bias: 19.9m3/ha
R2: 0.37
1 <= # plots < 5
5 <= # plots < 20
plots >= 20
Retrieved [m3/ha]
NFI 2014-2016 [m3/ha]
0
50
100
150
200
250
300
350
400


Average per county - ALOS-2 PALSAR-2 2015
County averages
Rel. RMSE: 18.2%
Bias: 19.6m3/ha
R2: 0.52
Retrieved [m3/ha]
NFI 2014-2016 [m3/ha]
0
50
100
150
200
250
300

Retrieval from ALOS-2 PALSAR-2 data: 2014-2017

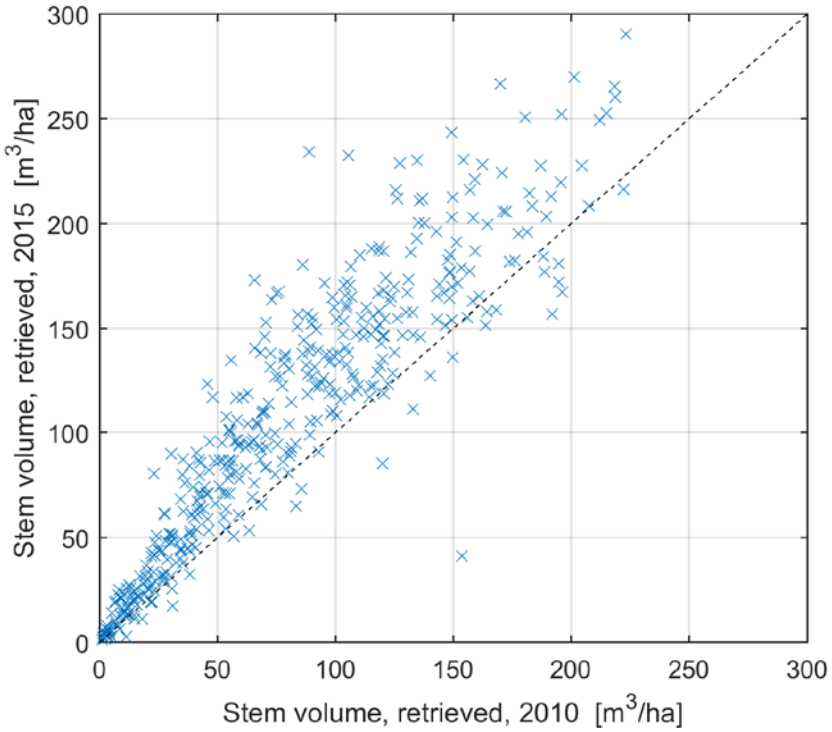
as of January 2018, not final

- Forest area: 254,733 km^2
- Total volume (m^3, constrained retrieval): n/a
- Total volume (m^3, unconstrained retrieval): 4,024 million m^3

NFI statistics based on plots from 2012-2016

(published in Skogsdata 2017)

- Forest land: 282,630 km^2 (including non-productive forest area)
- Total volume: 3,445 million m^3 (living) + 225 million m^3 (dead wood)



- Larger stem volume predicted with the ALOS-2 dataset than with ALOS-1
- Biomass increase is substantially larger than growth factors (3-10 m^3/ha × year → 15-50 m^3/ha)
- Reasons: large proportion of winter data used in 2015 and variable incidence angle range → situations probably not yet well modelled in the BIOMASAR algorithm? Need to do a more in depth analysis of signatures

References

- Fransson, J.E.S., Santoro, M., Wallerman, J., Persson, H.J., Monteith, A.R., Eriksson, L.E.B., Nilsson, M., Olsson, H., Soja, M.J., and Ulander, L.M.H. (2016). Estimation of forest stem volume using ALOS-2 PALSAR-2 satellite images. In Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 5327 - 5330

- Huuva, I., Fransson, J.E.S., Persson, H.J., Wallerman, J., Ulander, L.M.H., Blomberg, E., and Soja, M.J. (2017). Measurements of forest biomass change using L-and P-band SAR backscatter. In Proceedings of IEEE International Geoscience and Remote Sensing Symposium, pp. 5818 - 5821

- Santoro, M., Fransson, J.E.S et al. (2018). Biomass estimation in boreal and tropical forest using multi-temporal L-band backscatter observations.

Project milestones

- Completion of the biomass map of Sweden 2015 (end of JFY 2017) (biomass map for the year 2010 has been delivered to JAXA at the end of Phase 3).
- Completion of the clear-cut maps of Sweden for the time period 2015-2016 (end of 2018 – extension requested).
- Completion of the biomass change map of Sweden for the time period 2010-2015 (end of 2018 – extension requested).
- Yearly feed-back to JAXA on quality of their data products.

Deliverables

The following products will be delivered:

- Biomass map of Sweden for year 2015.
- Clear-cut maps of Sweden for the time period 2015-2016.
- Biomass change map of Sweden for the time period 2010-2015.
- Ground-truth data from the test sites Remningstorp and Krycklan.

ALOS

K&C Initiative
An international science collaboration led by JAXA

SLU
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

JAXA

GAMMA REMOTE SENSING

Thank you!

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Swedish National Space Board

Skogssällskapet

esa
European Space Agency

SKOGSSTYRELSEN
SWEDISH FOREST AGENCY

European Commission

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