K&C Phase 4 – Status report

Retrieval of forest biomass and biomass change with spaceborne SAR

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Science Team meeting #23
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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 PALSAR and ALOS-2 PALSAR-2 data are used to further develop and validate methods for large-scale biomass and biomass change mapping.

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

i) the PALSAR 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. To our knowledge this will be the first time forest growth is investigated using spaceborne L-band SAR data in the boreal zone.

An ongoing pilot study is conducted using L-band data from the BioSAR 2007 and BioSAR 2010 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

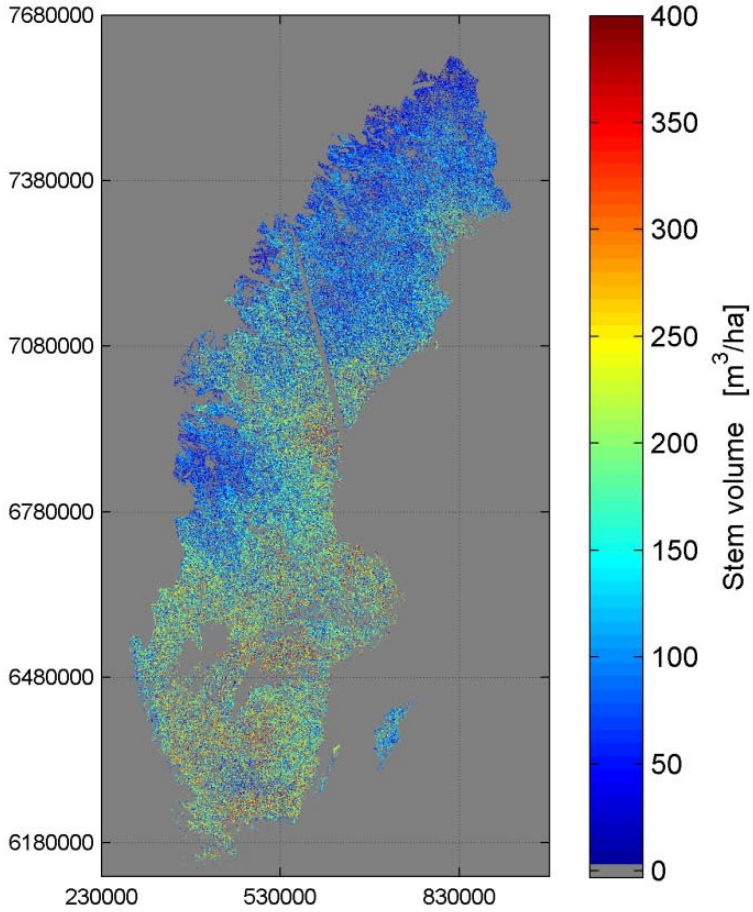
The project will involve analysis of more than 28 million ha of boreal and hemi-boreal forests in Sweden.

The differences in weather conditions, topography and forest properties 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



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

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

Results and significant findings thus far

Forest stem volume estimation using ALOS-2 PALSAR-2 satellite images at plot level (presented at IGARSS 2016)

The enhanced biomass map covering all of Sweden derived using PALSAR-2 data for the year 2015

Estimation of Forest Stem Volume using ALOS-2 PALSAR-2 Satellite Images

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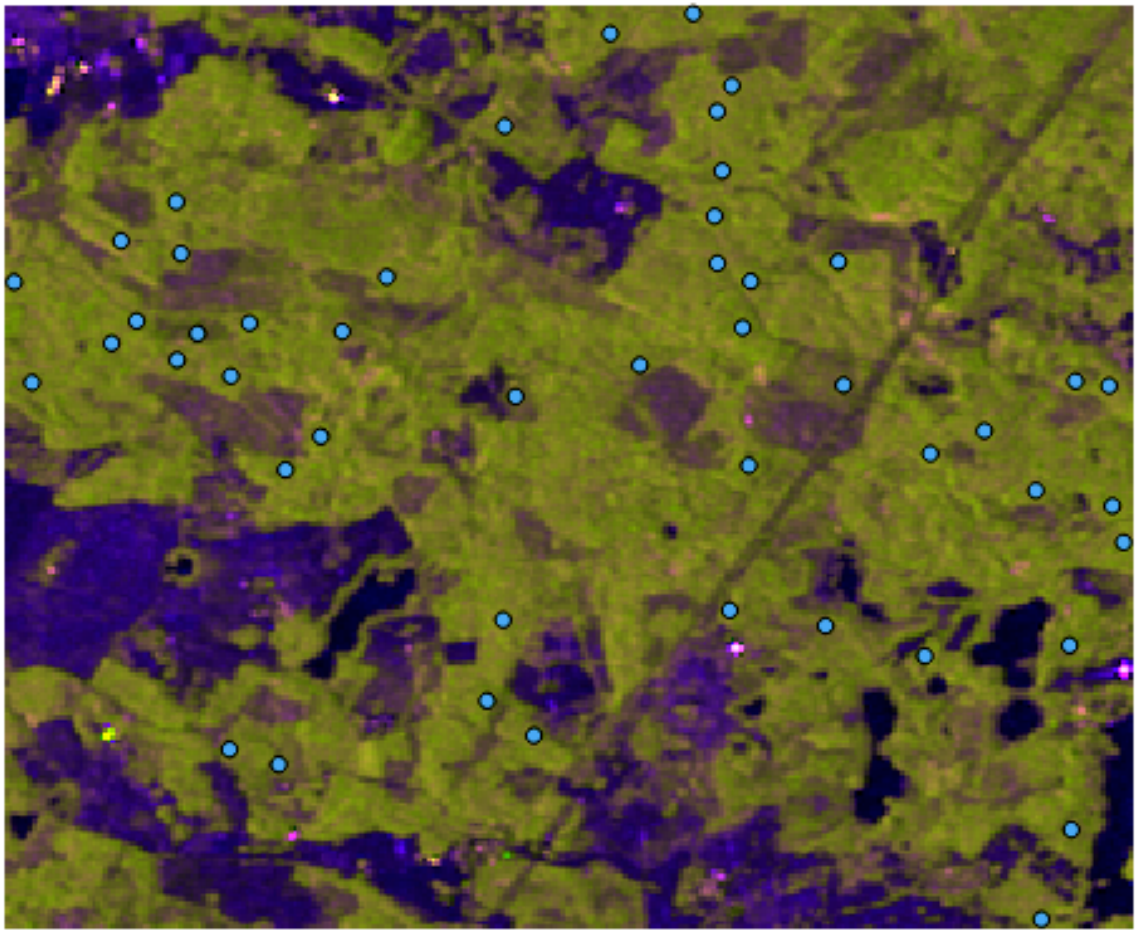
Study site Remningstorp

- Southern Sweden
- Prevailing tree species:
  - Norway spruce
  - Scots pine
  - Birch
- Hemi-boreal forest
- 2014 field inventory:
  - 48 plots of radius 40 m (0.5 ha)
  - Stem volume of 10 to 620 m^3 ha^{-1}

Plot locations



Red: average HH backscatter
Green: average HV backscatter
Blue: ratio of average HH / average HV backscatter.

PALSAR-2 dataset

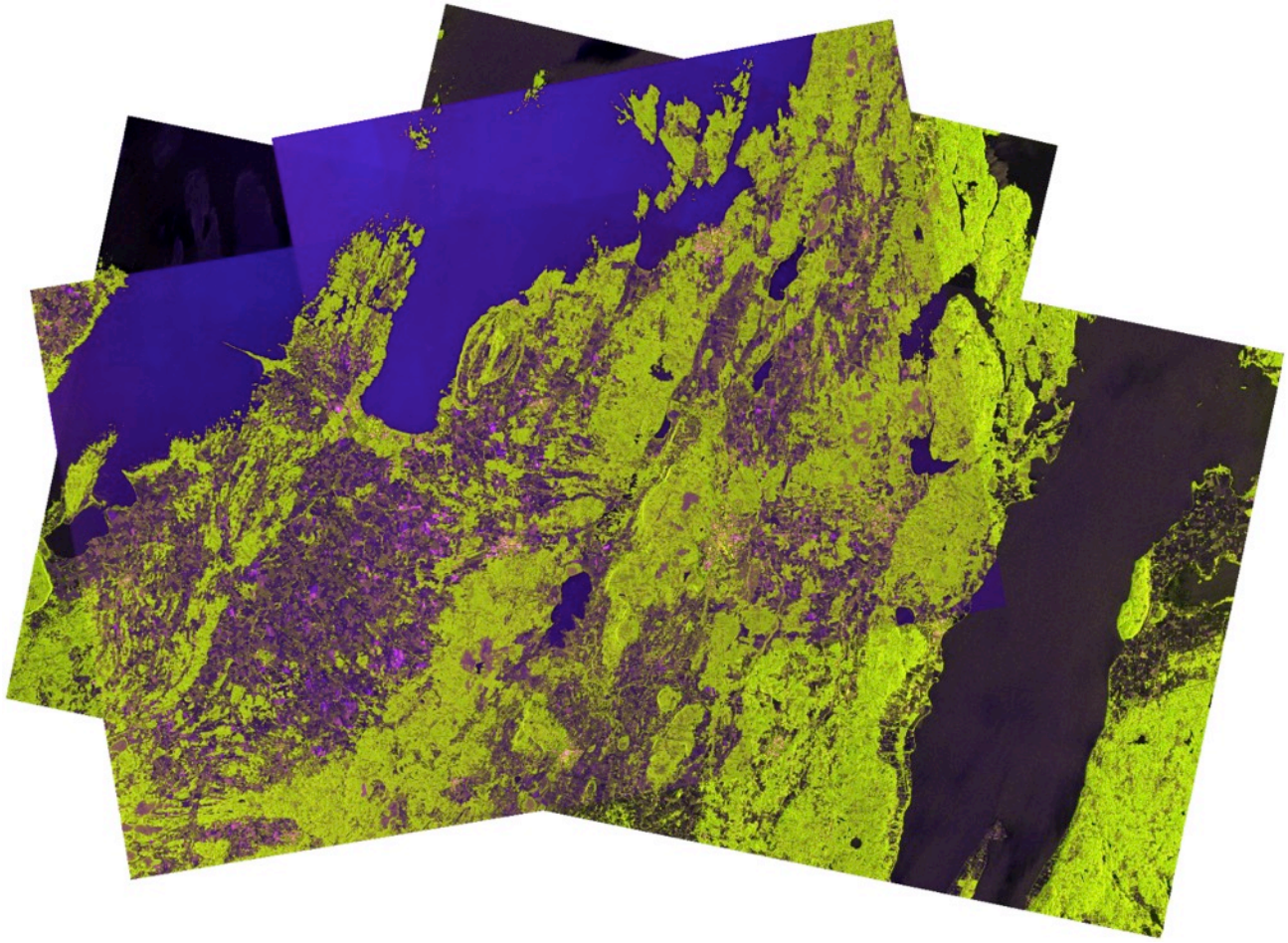
Mode	Quantity	Polarization	Off-nadir angle	Resolution
Fine Beam Dual polarimetric (FBD)	20 acquisitions	HH, HV	28.2°- 36.2°	10 m
Quad-polarimetric	2 acquisitions	HH, HV, VH, VV	25.0°- 34.9°	6 m

- Acquired during 2014-09-18 to 2015-10-06
- Focused on HH and HV images only
- Used both ascending and descending orbits

- Multi-looked to 20 m in range & azimuth
- Geocoding:

  - 20 m resolution (forest plot size)

  - used 50x50 m DTM from Lantmäteriet
- Angular effects and pixel area not compensated for (slope < 2°)



Red: average HH backscatter
Green: average HV backscatter
Blue: ratio of average HH / average HV backscatter.

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:

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

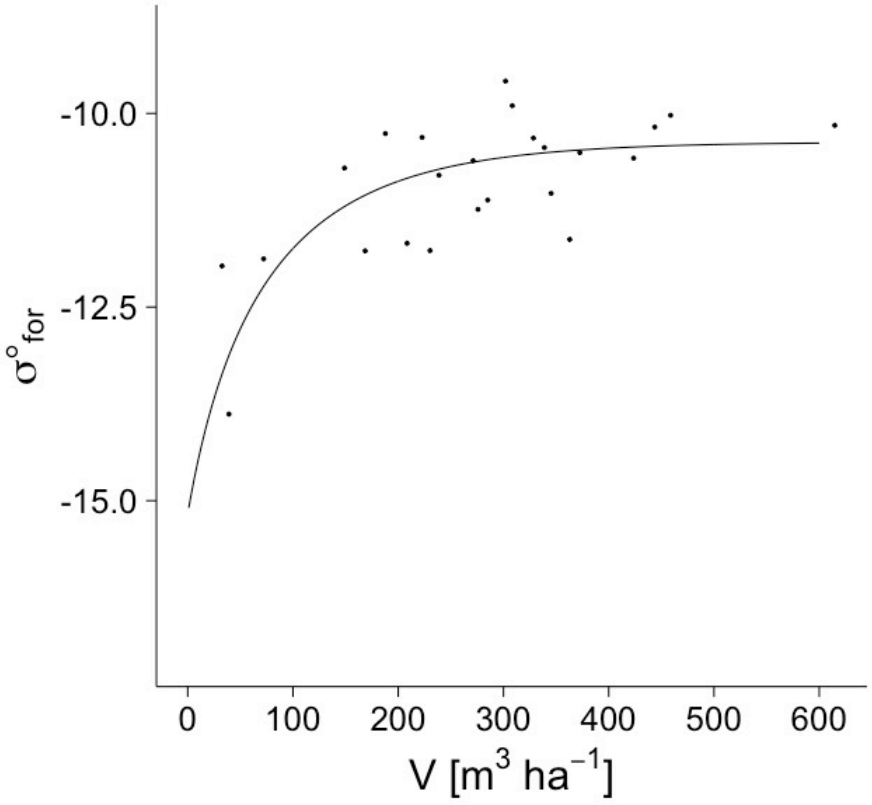
- β - Attenuation coefficient, depends on forest structure & dielectric props.
- V - Stem volume
- σ^0_{veg} - Vegetation backscattering coefficient
- σ^0_{gr} - Ground backscattering coefficient
- σ^0_{for} - Forest backscatter intensity
- $\sigma^0_{for,meas}$ - Measured backscatter

Regression analysis

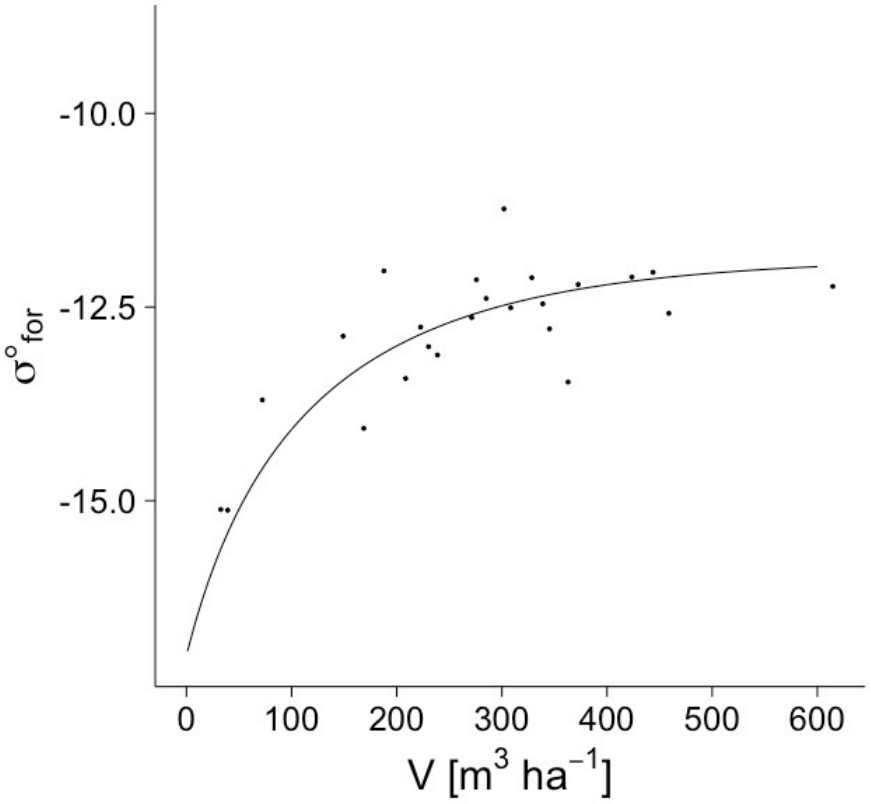
- Sort plots according to stem volume
  - every second plot = training plots
  - remaining plots = validation plots
- Fit WCM using non-linear least squares
- Calculate stem volume

PALSAR-2 backscatter vs. stem volume

PALSAR-2 FBD HV backscatter

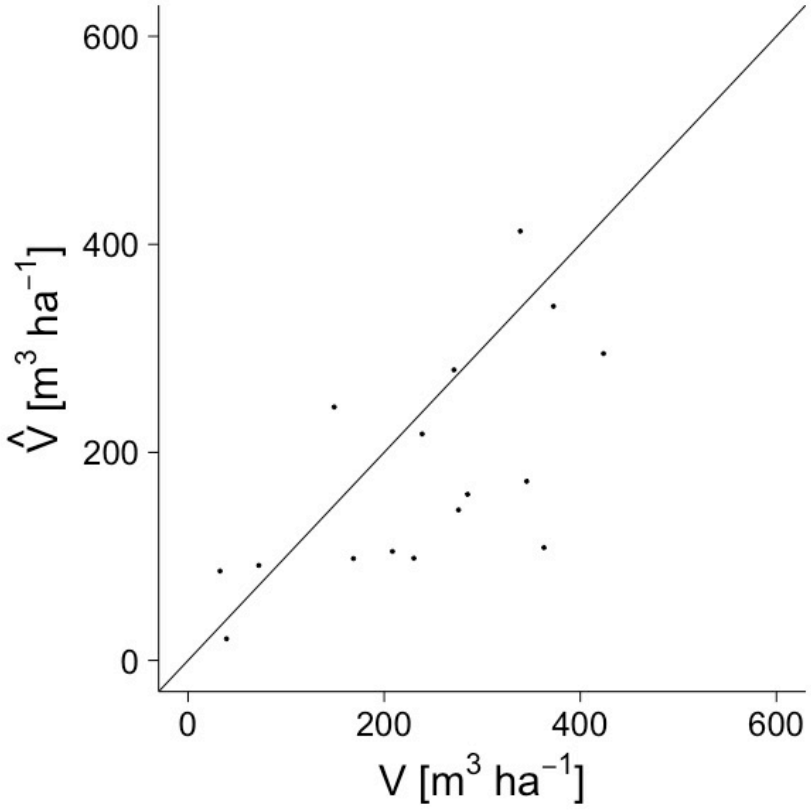


PALSAR-2 Quad-pol. HV backscatter

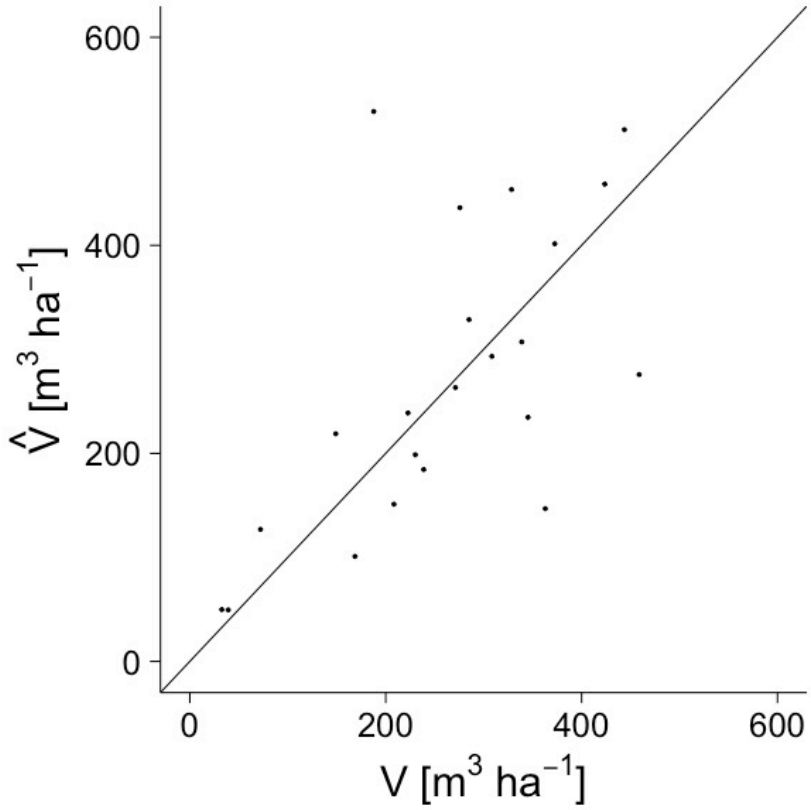


Stem volume estimation

PALSAR-2 FBD HV backscatter



PALSAR-2 Quad-pol. HV backscatter



Results

- RMSE results:

FBD HV	FBD HH	Quad-pol HV	Quad-pol HH
39.8%	43.9%	43.1%	66.1%

- Best case for FBD HV-polarized images
  - RMSE of 39.8%
  - Bias of -21.1 m^3 ha^{-1}

Conclusions

- Large temporal variations in estimation accuracy
  - 40% to 115% RMSE
  - -80 to 30 m^3 ha^{-1} bias
- Likely due to seasonal & weather effects
- Future work:
  - Analyse meteorological data
  - Multi-temporal combination of images
  - Study temporal change & decorrelation in boreal forests (BorealScat)

Acknowledgements

ALOS-2 PALSAR-2 strip data were provided by JAXA EORC within the ALOS Kyoto & Carbon Initiative. This project was funded by the Swedish National Space Board, the EU-project “Advanced_SAR” and the ESA-project “GlobBiomass”.

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European Commission

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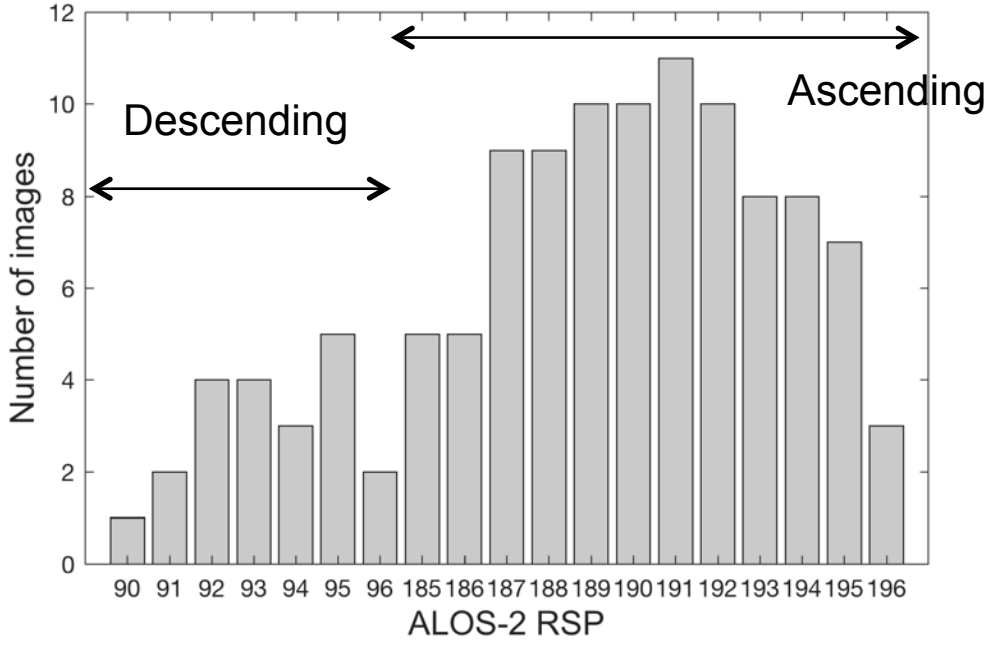
ALOS-2 PALSAR-2 dataset

Path data

All strips acquired over Sweden requested

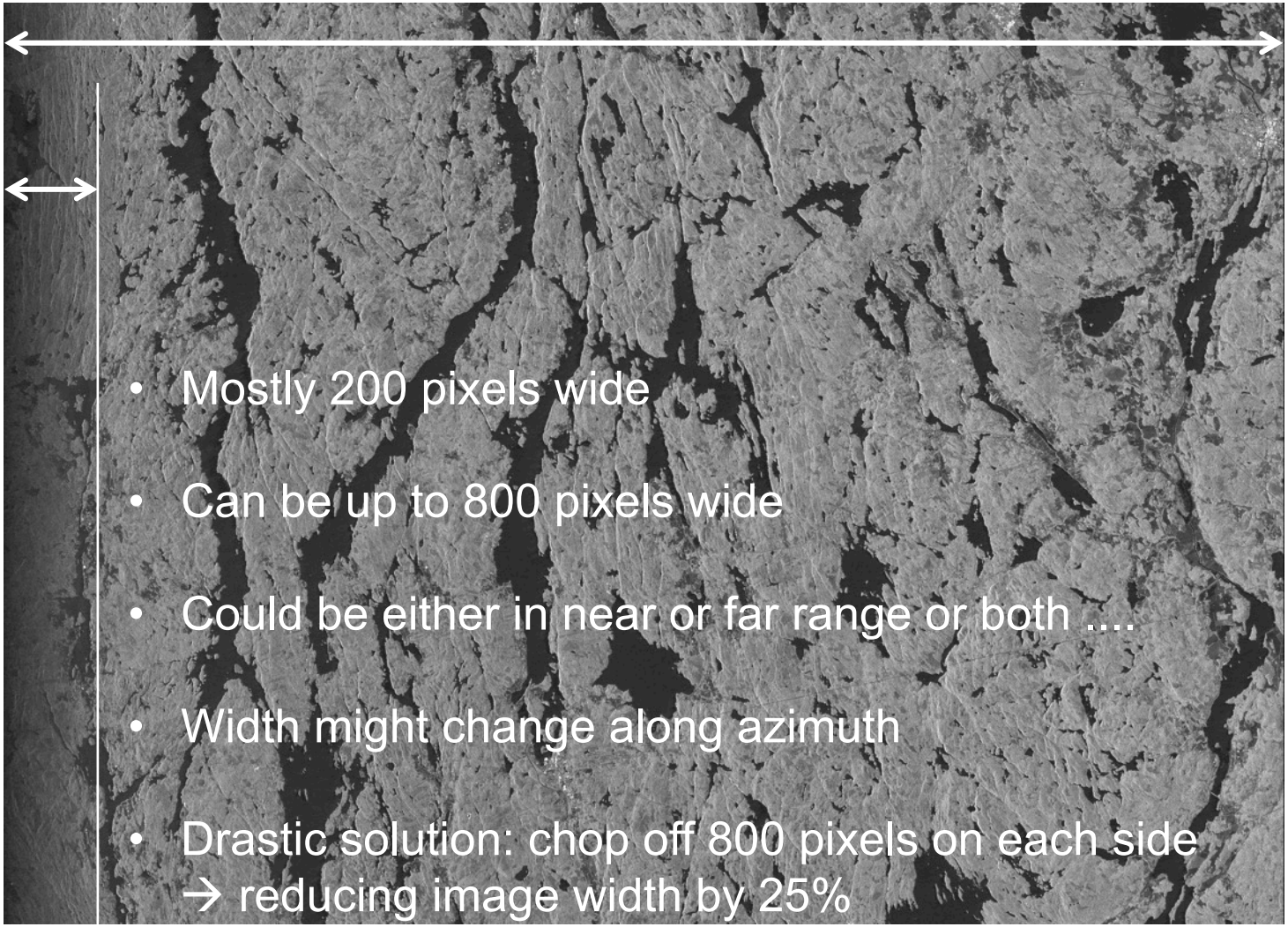
- 116 FBD image strips, mostly ascending orbits
- October 2014 – June 2016 (as of summer 2016)



Radiometric issue with ALOS-2 path data

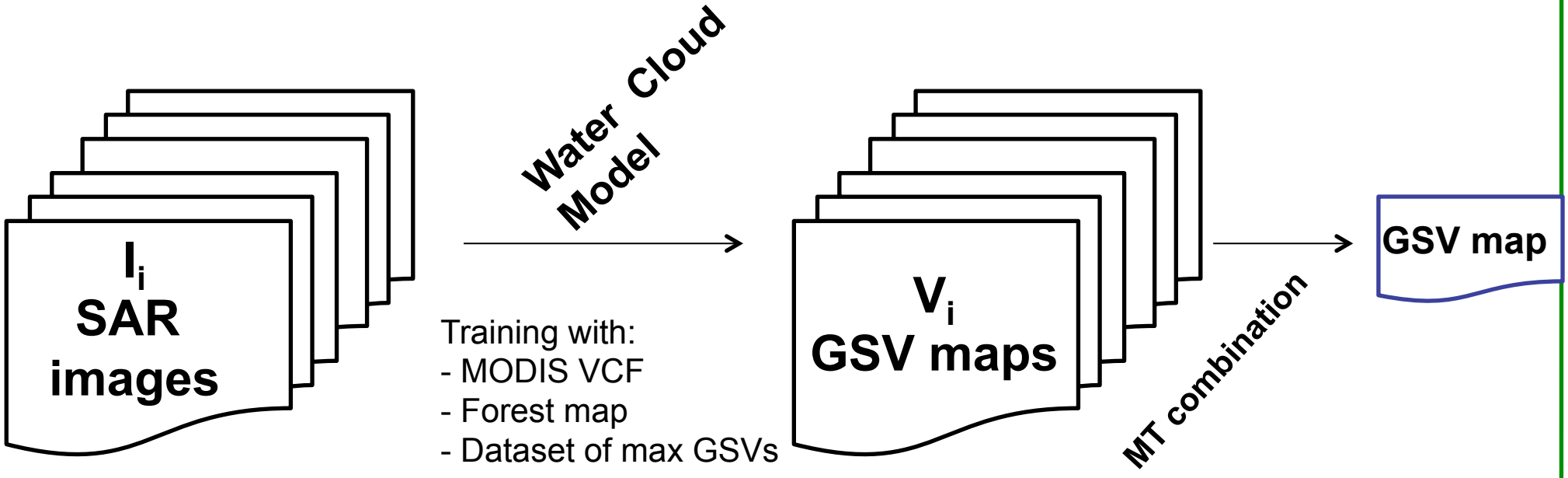
~ 5700 pixels

200 pixels



The BIOMASAR approach

Retrieving forest growing stock volume from SAR backscatter

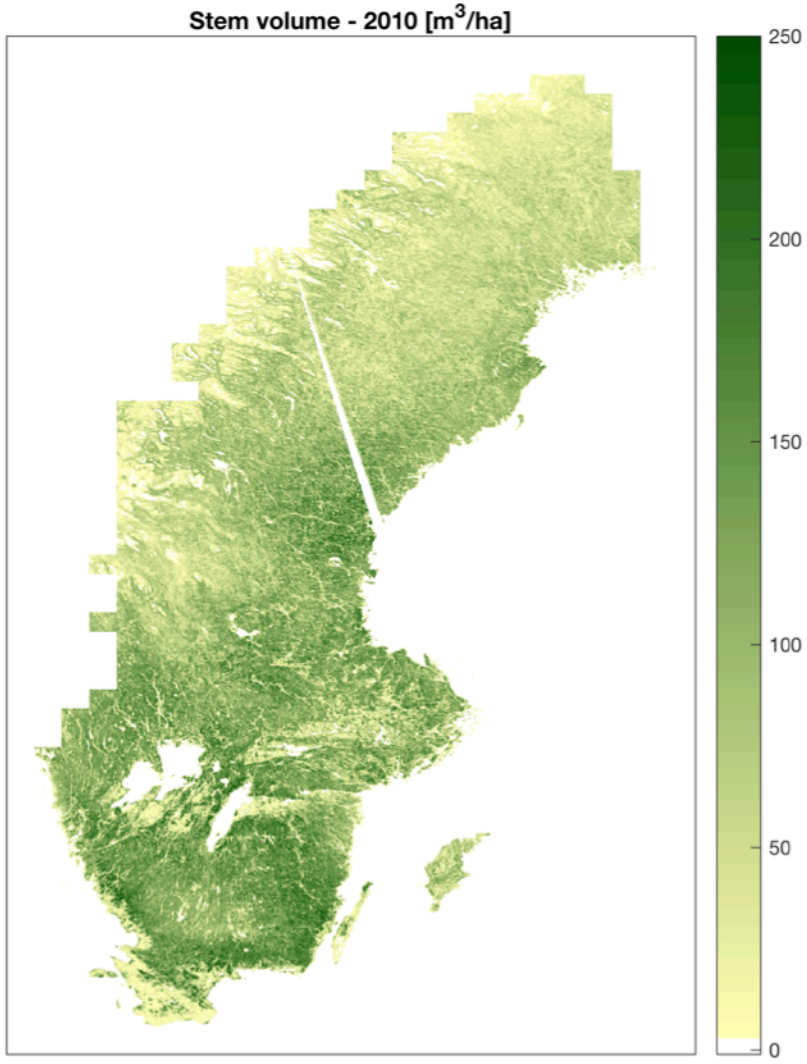


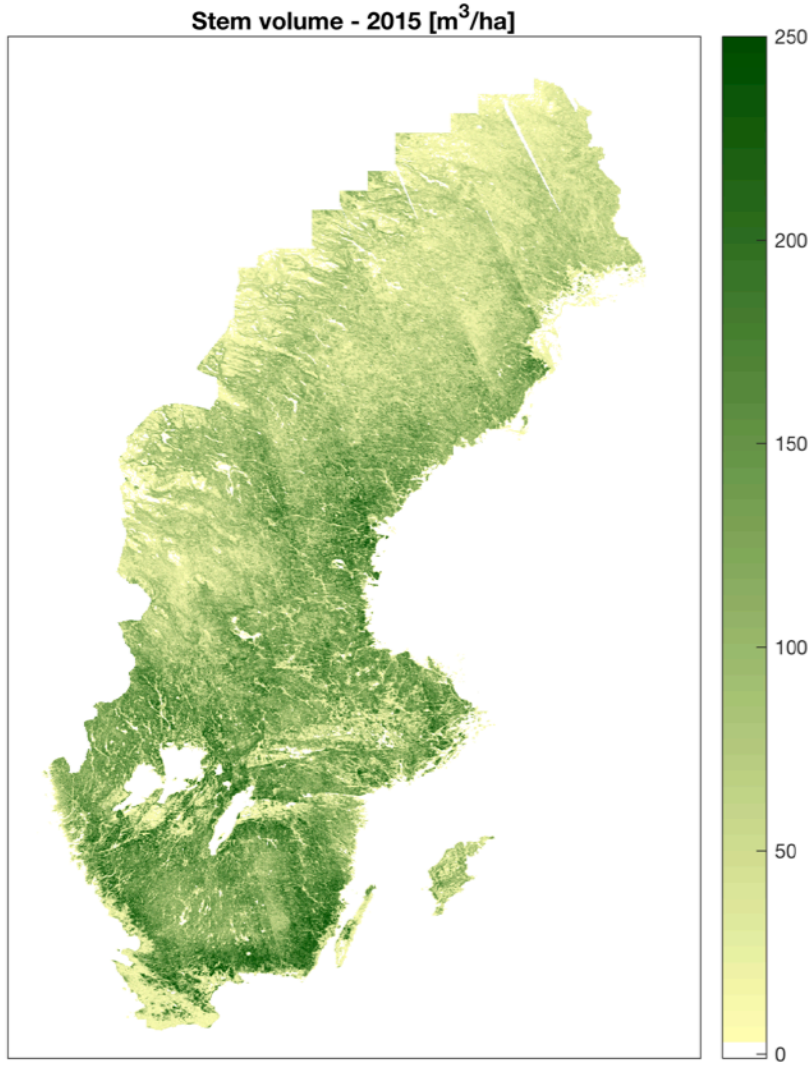
Training with:
- MODIS VCF
- Forest map
- Dataset of max GSVs

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

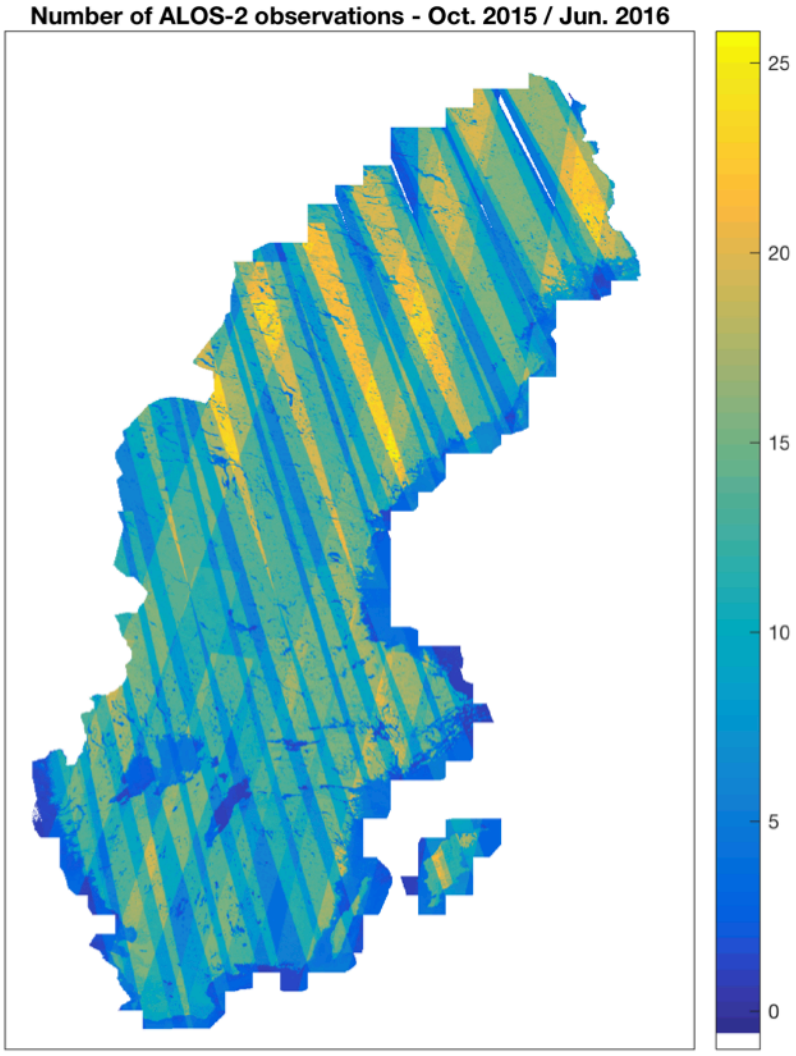
- No in situ data required to train the model

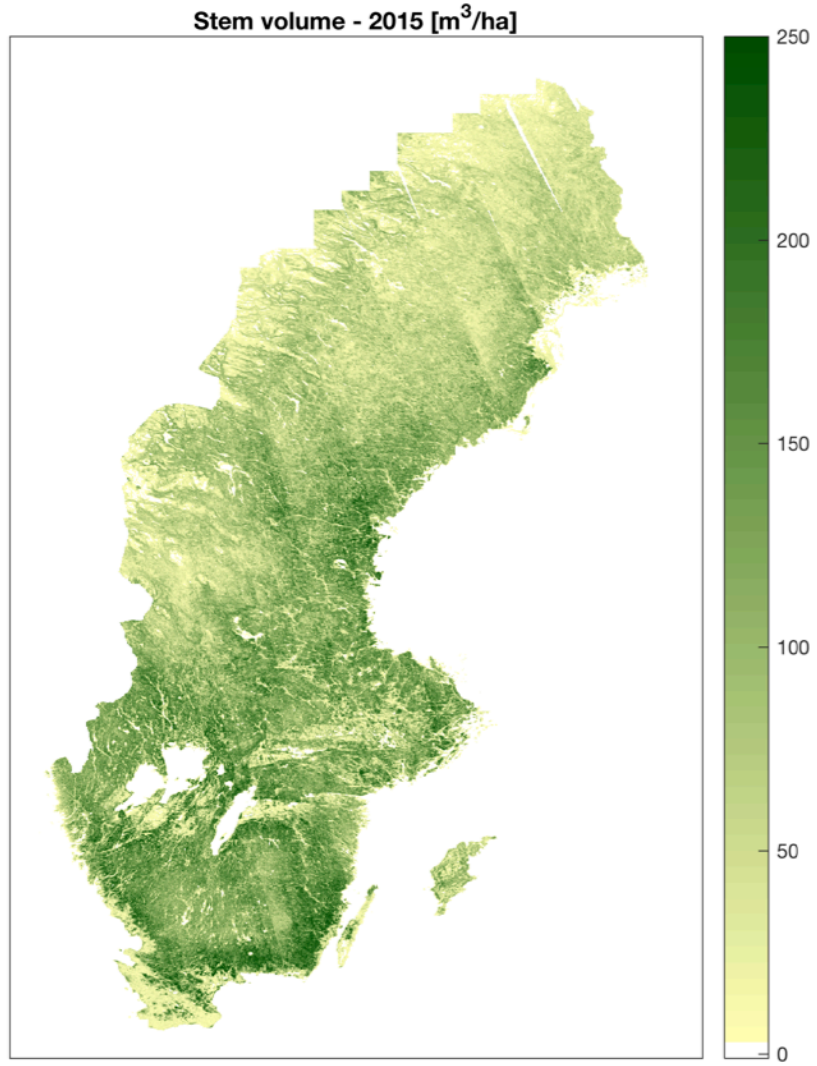
ALOS-1 vs. ALOS-2 stem volume estimates of Sweden



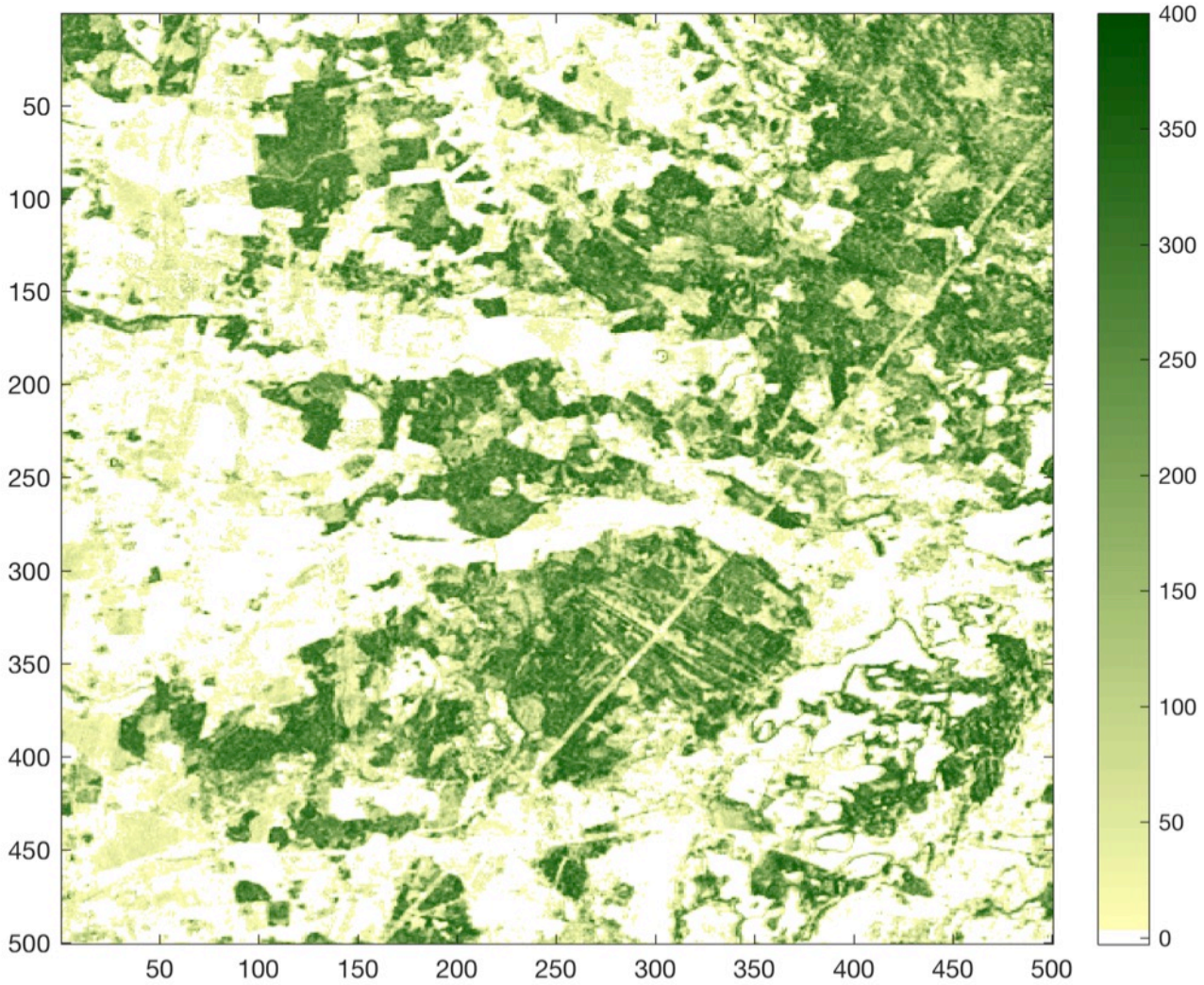


Understanding ALOS-2 stem volume estimates of Sweden





ALOS-2 (Oct. 2014 – Jun. 2016) 25 m stem volume estimates



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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-band SAR backscatter. Abstract submitted to IGARSS 2017.

Santoro, M., Fransson, J.E.S, and Persson, P. (2017). Country-wide estimation of forest stem volume in Sweden derived from spaceborne L-band SAR backscatter observation.

Project milestones

- Completion of the biomass map of Sweden 2015 (end of 2016) (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 2010-2015 and 2015-2016 (mid/late 2017).
- Completion of the forest growth map of Sweden for the time period 2010-2015 (end of 2017).
- Yearly feed-back to JAXA on quality of their data products.

Deliverables etc.

The following products will be delivered:

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

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GAMMA REMOTE SENSING

Thank you!

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