Post-K&C – First Report

Retrieval of forest biomass and biomass change using PALSAR, PALSAR-2 and PALSAR-3 data

Johan Fransson
Swedish University of Agricultural Sciences (SLU)

Co-Is
Henrik Persson, Jörgen Wallerman – SLU
Lars Ulander – Chalmers University of Technology
Maurizio Santoro – Gamma Remote Sensing

Post-KC Science Team meeting #1
Tokyo, Japan, January 20-24, 2020

Project outline and objectives

Project objectives

To investigate L-band SAR applications in boreal forests with focus on new methods (e.g., enhanced Water Cloud Modelling) and algorithms to estimate biomass and biomass change (using backscatter observations) including clear-cuts, thinning and growth, in northern Sweden.

The project can be seen as a continuation of the K&C Initiative activities performed in the previous K&C Phases 1-4, however, ALOS-4 PALSAR-3 data will also be included besides ALOS PALSAR and ALOS-2 PALSAR-2 data. Also, this project will focus on regional-scale biomass and biomass change mapping (instead of national-scale as before).

Project outline and objectives

Project objectives (cont.)

The biomass maps covering all of Sweden previously derived using PALSAR-2 data for the year 2015 and PALSAR data for the year 2010 will be further used for change detection (each map was validated with inventory data from the Swedish National Forest Inventory (NFI) and compared with county statistics from the Swedish NFI).

The project supports the post-KC project “Decadal forest biomass changes with ALOS-1 and ALOS-2 L-band SAR observations” (Maurizio Santoro, PI) and vice versa.

Project outline and objectives

Project area(s) – its geographical location(s) and special characteristics.

The project area include boreal forests within the test site Krycklan and the county of Västerbotten, Sweden.

Project outline and objectives

Indicate how the project aims to supported one or more of *the 4 K&C thematic drivers* (**C**arbon cycle science, **C**limate Change, International **C**onventions, Environmental **C**onservation).

All 4 K&C thematic drivers are addressed.

Satellite and auxiliary data

Satellite data

ALOS PALSAR, ALOS-2 PALSAR-2 and ALOS-3 PALSAR-4 path data (“slant range strips”), best one-year coverage of the region.

Other data sources

Field data (~500 plots with 10 m radius from 2015/2016 and 2019/2020 and ~40 plots with 40 m radius from 2015 and 2020 – Krycklan).

LiDAR data (~20 pulses m^{-2} from 2015 and 2019 – Krycklan, ~1-2 pulses m^{-2} from 2009-2016 and 2018-202? – Västerbotten).

NFI data (~1000 plots with 10 m radius, colllected in 5 years cycles – Västerbotten).

Estimation of biomass and biomass change

- Biomass estimation for Krycklan and a region in Västerbotten will be performed using PALSAR, PALSAR-2 and PALSAR-3 data from the years 2010, 2015 and 2018, and 2021/2022, respectively. The approach will be to use a similar methodology as developed in Phase 4 within the Kyoto & Carbon Initiative project.
- Multi-temporal observations are very important to increase the accuracy of biomass estimates (therefore, mosaic data are not optimal to use).
- For thinning and growth analysis the above datasets will also be used (differencing biomass vs. backscatter observations).

Estimation of biomass and biomass change

For Krycklan, the biomass and biomass change will be evaluated using:

i) field plots within the test site (~500 plots)

ii) biomass maps based on laser scanning data

For the region of Västerbotten, the biomass and biomass change will be evaluated using:

i) statistics from the Swedish NFI

ii) Skogliga grunddata (based on laser scanning data)

Estimation of biomass and biomass change

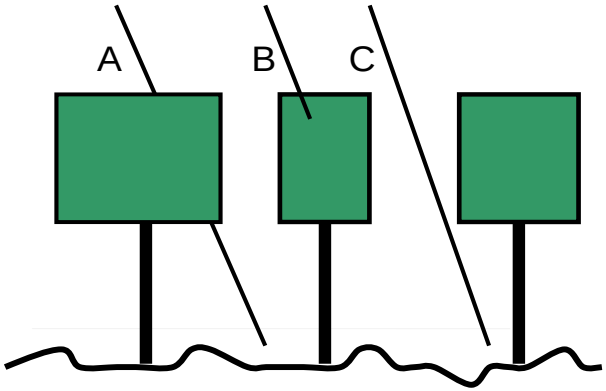
Change detection of the forest cover in terms of detecting and de-lineating clear-felled areas for Krycklan and a region of Västerbotten will be performed using PALSAR, PALSAR-2 and PALSAR-3 data from the years 2010, 2015 and 2018, and 2021/2022, respectively. The approach will be to use a similar methodology as developed in Phases 1 and 2 within the Kyoto and Carbon Initiative project.

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

i) the Swedish Forest Agency (stands),

ii) statistics from the Swedish NFI (plots).

Revisiting the Water Cloud Model



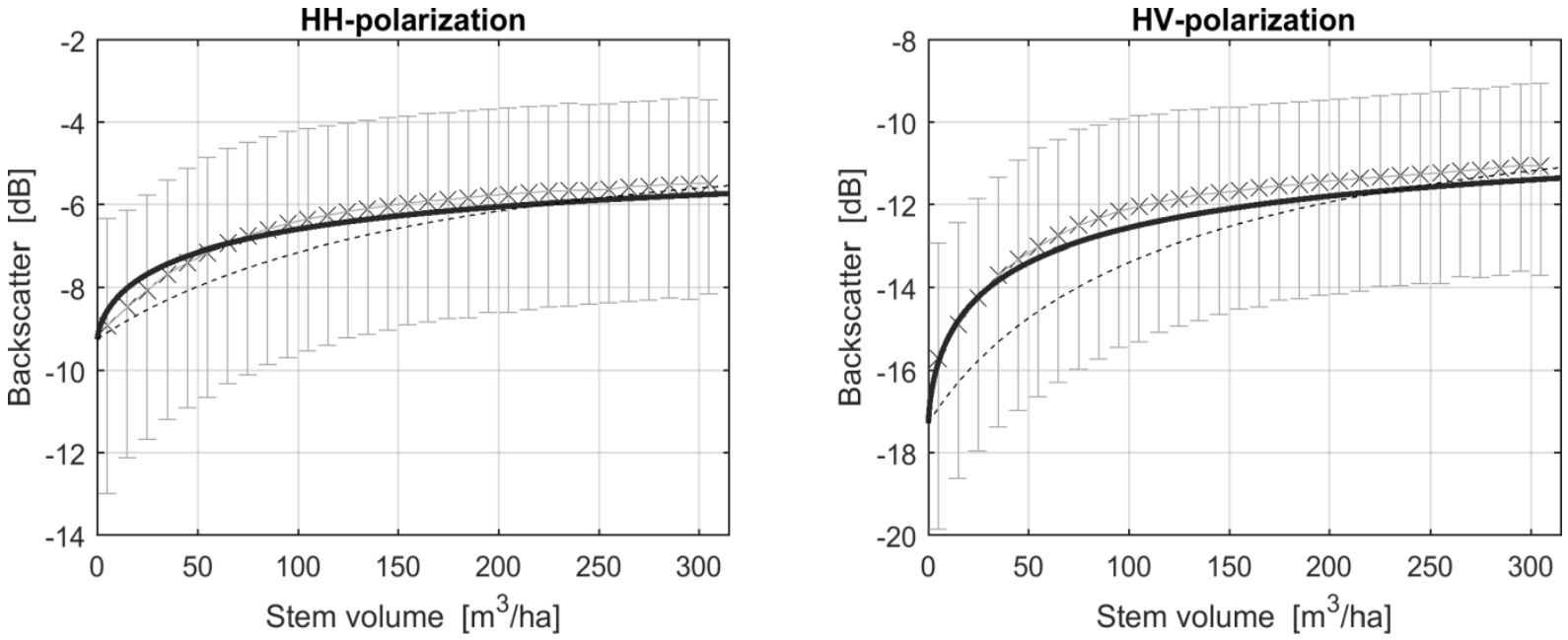
- The original Water Cloud Model expresses the forest backscatter as a function of canopy density (η), vegetation height (h) and two-way tree attenuation (α)

$$\sigma^0_{for} = 1 - \eta\left(1 - e^{-\alpha h}\right)\sigma^0_{gr} + \eta\left(1 - e^{-\alpha h}\right)\sigma^0_{veg}$$

New: integrate allometry to express canopy density and height as function of “biomass”

$$CD = 1 - e^{-qh} \qquad h = (aV)^b$$

Validating the WCM



- Reference: ALS map of Sweden (https://www.skogsstyrelsen.se/skogligagrunddata)
- Observations: ALOS PALSAR

Thick line: "new" WCM (this study integrating allometry)

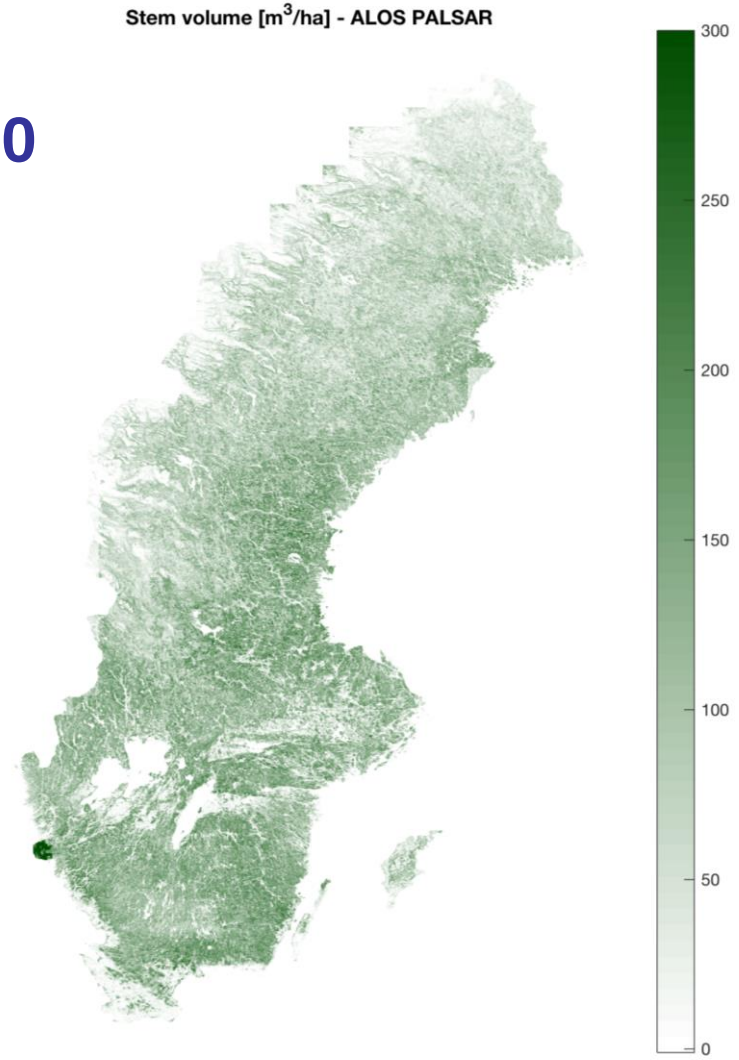
Dashed line: "old" WCM (direct estimation of biomass, see Pulliainen et al., 1994)

Crosses: Mean backscatter

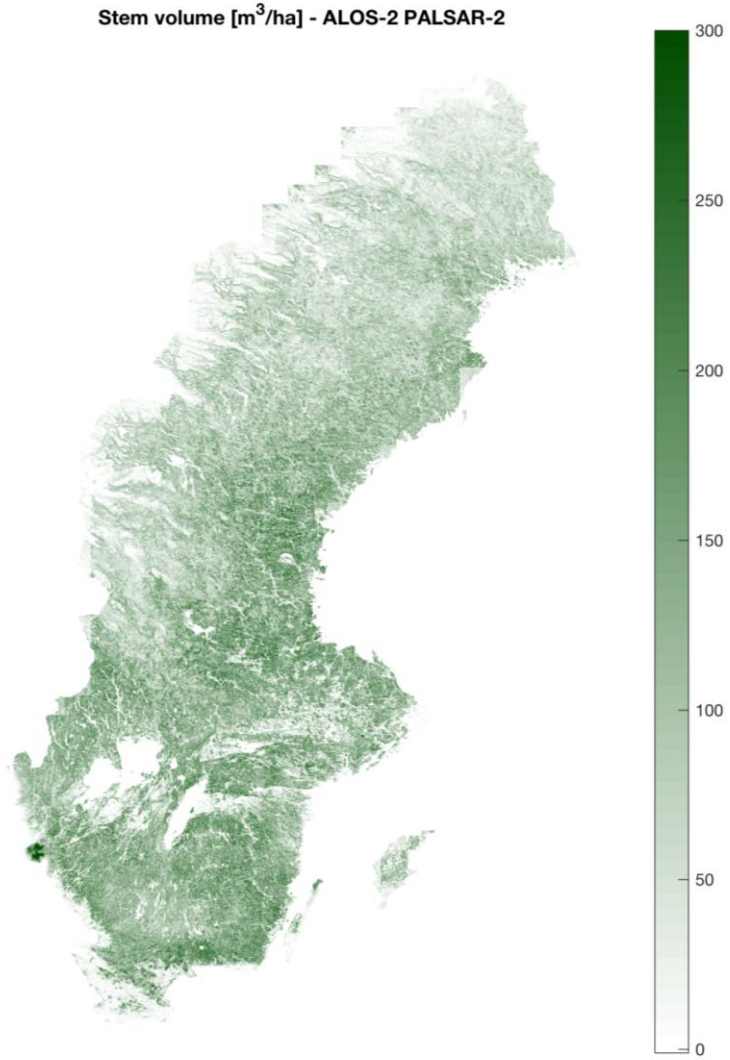
Bars: 5th-95th percentile

L-band stem volume estimates of Sweden

2010

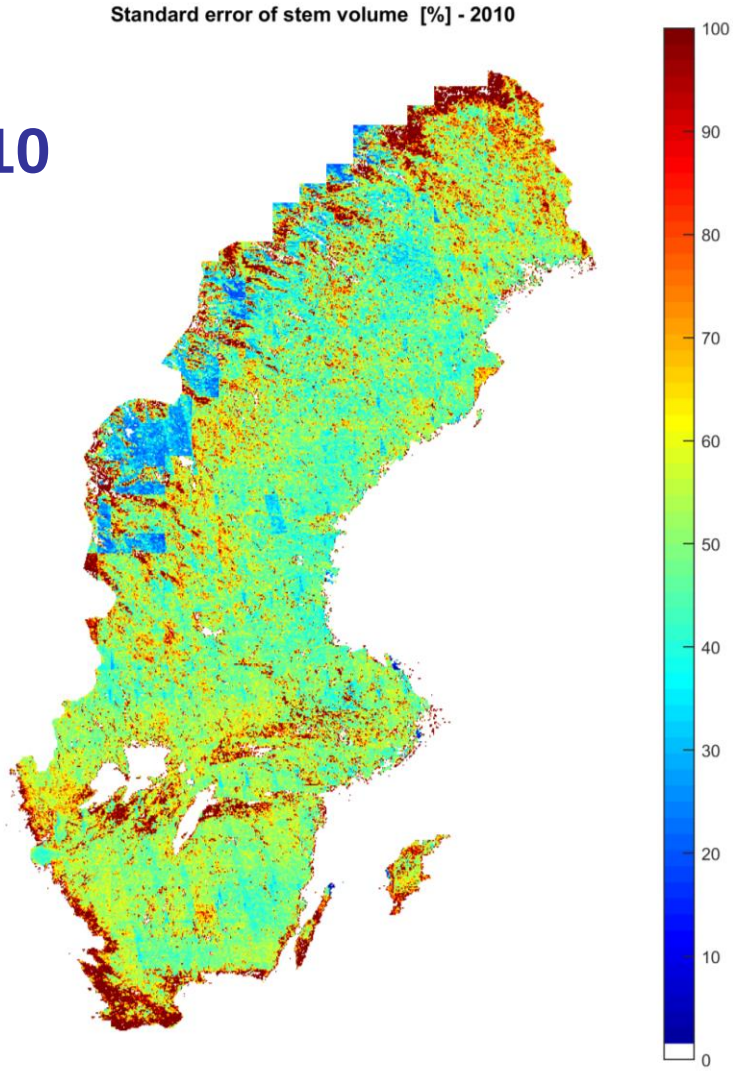


2015

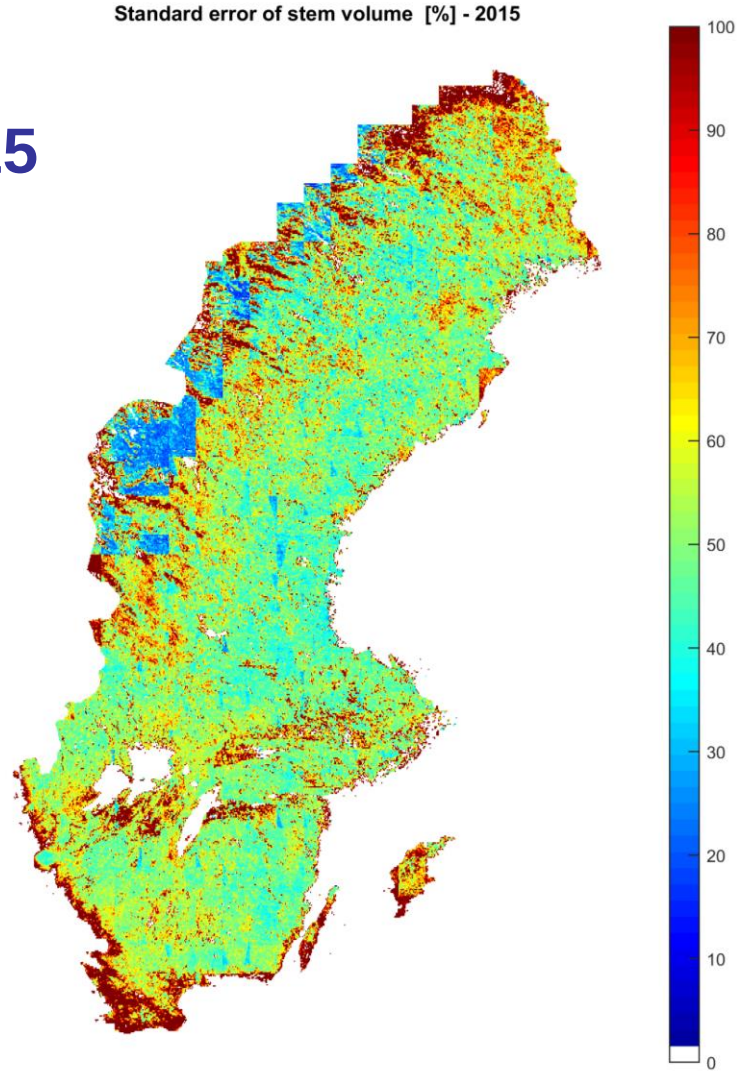


Standard error of the stem volume estimates

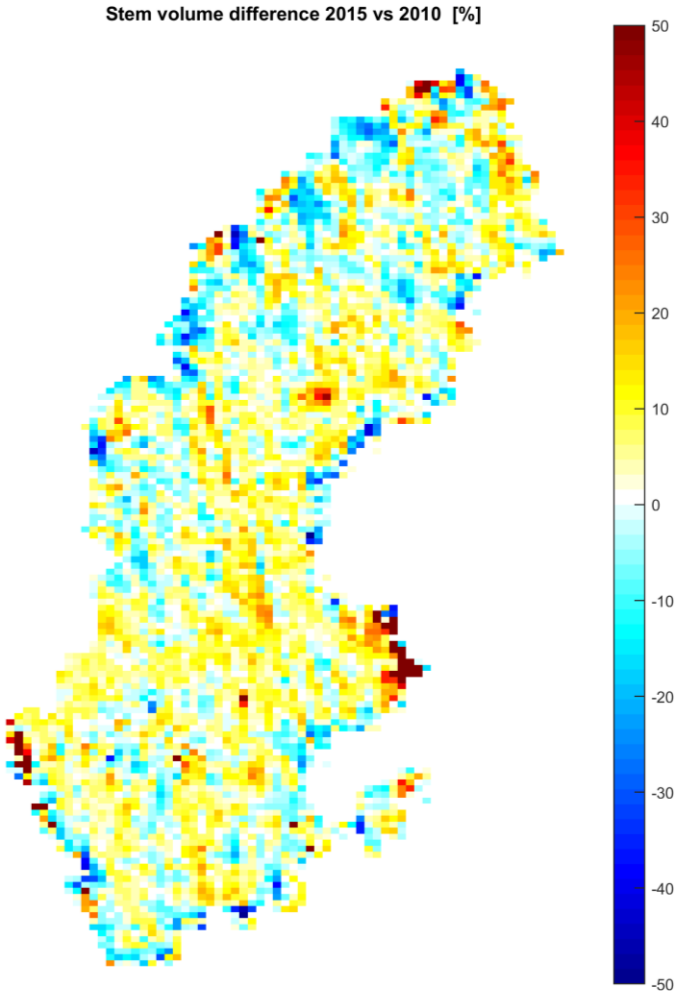
2010

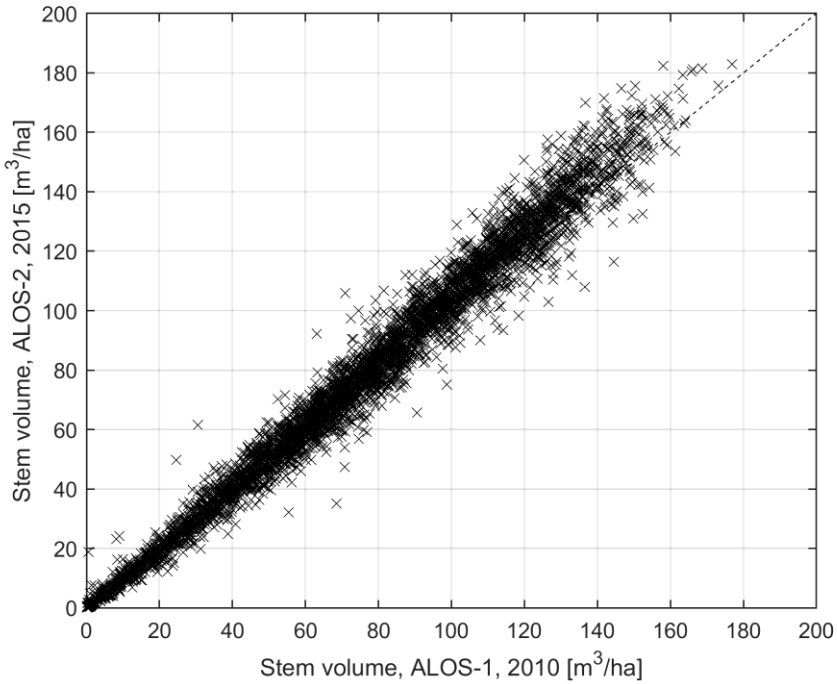


2015



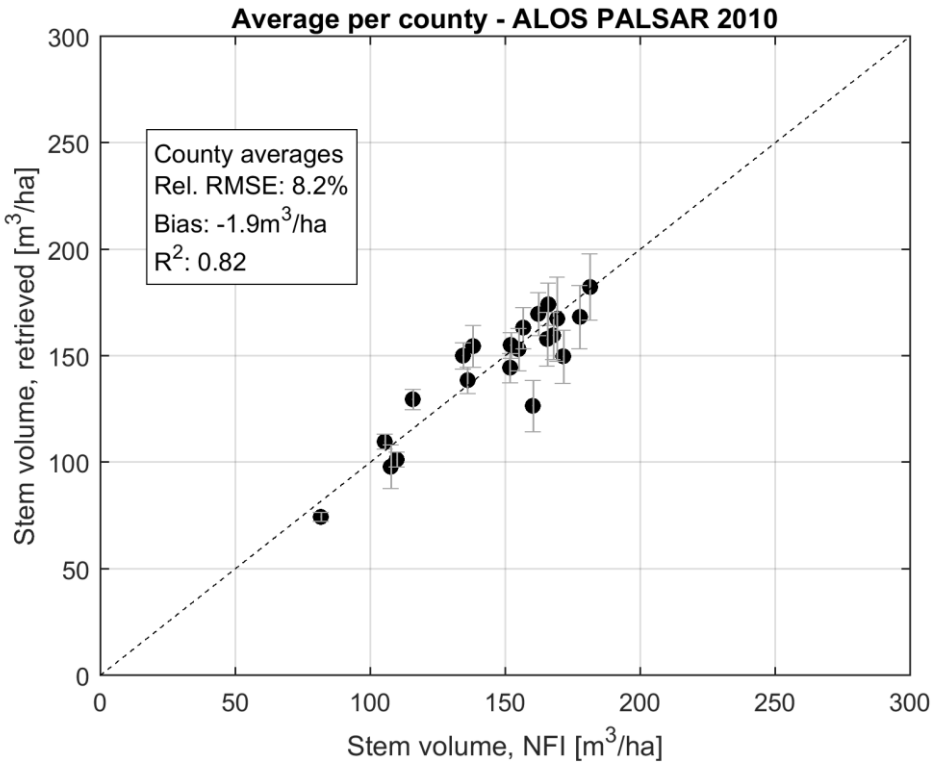
Biomass dynamics between 2010 and 2015

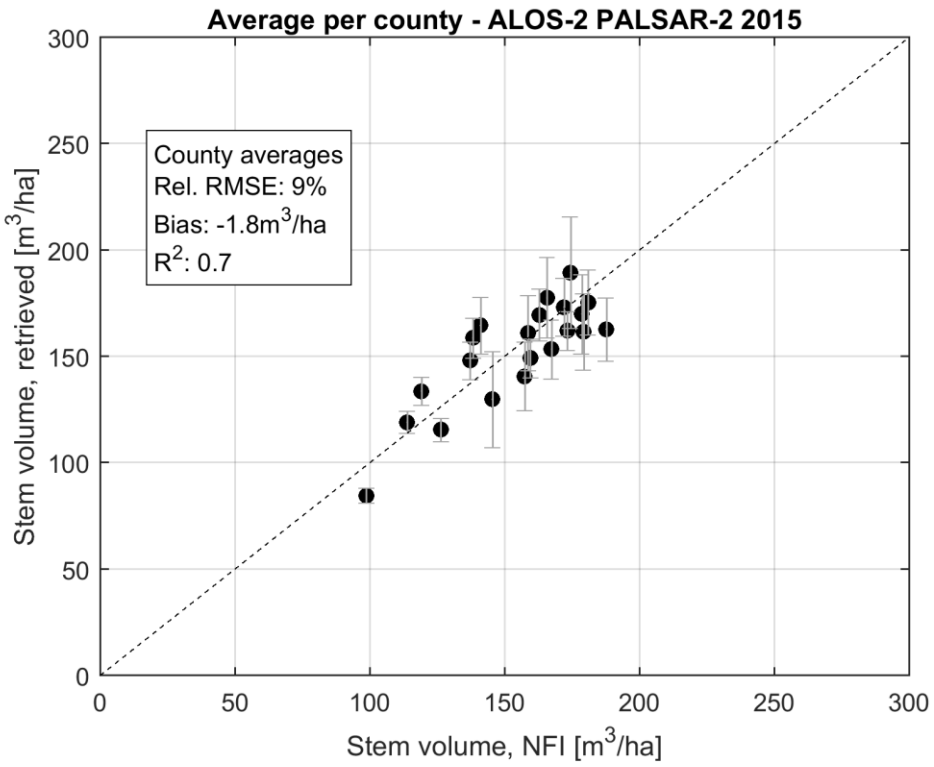




- Comparison done at 10 km to identify spatial trends
- At this scale, the uncertainty becomes negligible

County-wise estimates





The slightly worse agreement for 2015 should be related to the patchiness in the ALOS-2 dataset compared to ALOS (see presentations at KC23 and KC24)

The L-band datasets used for 2010 and 2015

Slant range geometry, SAR backscatter, Fine Beam Dual mode path data

All data acquired over Sweden requested

ALOS-1 PALSAR-1 (2010 biomass map)

- 104 FBD image strips, spring-to-fall 2010
- 36 AUIG frames to fill a 1% gap, summer 2008 (closest date to 2010)

ALOS-2 PALSAR-2 (2015 biomass map)

- 218 FBD image strips,
- October 2014 – October 2017
- Finally, only the spring-to-fall data used (~50% of the data obtained)

Research schedule

T0-15 to T0+20	Analysis of archived PALSAR and PALSAR-2 data
T0	Launch of ALOS-4 (preliminary in 2021)
T0+6 to T0+12	Data analysis
T0+9 to T0+15	Initial evaluation of algorithms
T0+15	Interim report
T0+15 to T0+20	Continued evaluation of algorithms
T0+24	Final report
T0+24	Journal publication

Deliverables and other output

Project deliverables

- Biomass maps for the 2010, 2015, 2018, 2021/2022.
- Biomass change maps across epochs (time series).
- Biomass and biomass change estimation algorithms.

Deliverables and other output

Peer-reviewed publications

Santoro, M., Cartus, O., and Fransson, J.E.S. Integration of LiDAR metrics and allometry in the Water Cloud Model to improve the estimation of stem volume from L-band SAR backscatter, to be submitted to Remote Sensing of Environment.

Santoro, M., Cartus, O., and Fransson, J.E.S. XXXXXX, to be submitted to Remote Sensing of Ecology and Conservation, to be submitted.

Non-peer-reviewed publications (conference papers, reports etc.)

Santoro, M., and Fransson, J.E.S. (2019). Integrating SAR backscatter, ICESat GLAS metrics and allometric functions towards an improved estimation of forest biomass, IGARSS 2019.

PALSAR/PALSAR-2 data access

Please list the PALSAR/PALSAR-2 data you have (1) requested and (2) obtained.

ALOS PALSAR and ALOS-2 PALSAR-2 data (FBD, SLC, asc.) are already available for consecutive years 2008-2018 over Sweden through the Kyoto & Carbon Initiative project. Additional ALOS-2 PALSAR-2 data (FBD, SLC, asc.) will be requested.

Have you had sufficient data to complete your research (according to your K&C agreement)?

If not, which key data sets are missing?

ALOS-2 PALSAR-2 (see above) as well as ALOS-4 PALSAR-3 images will be requested.

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!

RYMDSTYRELSEN
Swedish National Space Board

Skogssällskapet

esa
European Space Agency

SKOGSSTYRELSEN
SWEDISH FOREST AGENCY

European Commission

AVANCEZ 1829
CHALMERS