#### K&C Phase 3 – final report

#### Advances in forestry applications using satellite ALOS PALSAR images

Johan Fransson (1) & Maurizio Santoro (2) (1) Swedish University of Agricultural Sciences (2) Gamma Remote Sensing, Switzerland



LOS

GAMMA REMOTE SENSING

Max-Planck-Institut für Biogeochemie

K&C Initiative

An international science collaboration led by JAX.







## **Projects objectives**

K&C Initiative

An international science collaboration led by JAX.

To develop and validate methods for large-scale biomass mapping (base year 2010) using PALSAR data in Sweden → Fulfilled

OS

 The methods and algorithms that were developed aimed to demonstrate the large-scale forestry monitoring goals of the JAXA' s ALOS Kyoto & Carbon Initiative → Fulfilled

### ALOS PALSAR datasets 2010

**K&C** Initiative An international science collaboration led by JAXA

| PALSAR mode | Season        | Pixel size (m) | # PALSAR strips |
|-------------|---------------|----------------|-----------------|
| FBD         | Spring / Fall | 25             | 104             |
| WB          | Winter        | 75             | 17              |

- Data acquired between May and October 2010

- For each RSP, 1-4 acquisitions were available
- All data have been terrain geocoded, normalised and tiled (30 km x 30 km)

#### **K&C** Initiative An international science collaboration led by JAXA



OS

Number of ALOS PALSAR backscatter observations over Sweden in FBD mode (left) and WB mode (right) acquired during 2010

K&C Initiative An international science collaboration led by JAXA



OS

Map of Sweden showing the location of the Remningstorp and Krycklan test sites.

#### K&C Initiative OSAn international science collaboration led by JAX Stem volume estimation from SAR backscatter $\hat{V} = -\frac{1}{\beta} \times ln(\frac{\sigma_{veg}^0 - \sigma_{for,meas}^0}{\sigma_{veg}^0 - \sigma_{ar}^0})$ $\sigma_{for}^{0} = \sigma_{qr}^{0} \times e^{-\beta V} + \sigma_{veq}^{0} \times (1 - e^{-\beta V})$ 20080922 - fbd34hh 20080922 - fbd34hv -12 [dB] -14 Sigma nought [dB] Sigma nought -16 Data Data 2 unknowns 2 unknowns 3 unknowns 3 unknowns -12 500 100 0 200 300 400 500 600 100 200 300 400 600 0 Stem volume [m<sup>3</sup>/ha] Stem volume [m3/ha]

Measured and modelled backscatter for an ALOS PALSAR FBD HH (left) and HV (right) image acquired over the Krycklan test site. The model curves represent a least square fit to the measurements assuming  $\beta$  constant (2 unknowns) and undefined *a priori* (3 unknowns).

#### Multi-temporal retrieval of stem volume

K&C Initiative

An international science collaboration led by JAX.

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

- 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

#### **K&C** Initiative An international science collaboration led by JAXA



LOS

Stem volume maps of Sweden derived from multi-temporal ALOS PALSAR images at 25 m based on FBD data (top left) and at 75 m based on combined estimates of FBD and WB data (top right). The panels in the bottom row show a detail of the maps for a 30  $\times$  30 km<sup>2</sup> at 25 m (bottom left) and at 75 m (bottom right). The color bar has been constrained to 400 m<sup>3</sup>/ha to maximize the contrast.

#### **Comparison of PALSAR- and laser-based retrieval of stem volume**

K&C Initiativ

An international science collaboration led by JAX.



Distribution of PALSAR-based estimates of stem volume with respect to reference laser-based estimates. Black symbols: Remningstorp; red symbols: Krycklan. Crosses and circles refer to the mean value of PALSAR-based stem volume for a given interval of laser-based stem volume. Vertical bars represent the corresponding interquartile range.

#### Comparison of PALSAR- and kNN-based retrieval of stem volume



LOS

Scatterplots of stem volume from the kNN dataset and estimated from the PALSAR FBD data for a pixel size of (top left) 25 m, (top right) 100 m, (bottom left) 500 m and (bottom right) 1,000 m for a 30  $\times$  30 km<sup>2</sup> tile.

K&C Initiative

An international science collaboration led by JA2

#### **Comparison of PALSAR- and kNN-based retrieval of stem volume**

OS

K&C Initiative

An international science collaboration led by JAX



Panel showing the retrieval statistics (RMSE, R<sup>2</sup> and bias) as a function of pixel size (for a  $30 \times 30 \text{ km}^2$  tile).

#### RMSE [m<sup>3</sup>/ha] Rel. RMSE [%] 5 10 15 20 5 10 15 20 $R^2$ Bias [m<sup>3</sup>/ha] 0.8 0.6 0.4 -10 -20 0.2 -30

5 10 15 20

-40

LOS

5 10 15 20

Maps of RMSE, relative RMSE,  $R^2$  and bias between PALSAR- and *k*NN-based stem volume for a pixel size of 1,000 m (for all 30 × 30 km<sup>2</sup> tiles in Sweden).

#### **K&C** Initiative An international science collaboration led by JAXA

### Distribution....

OS

**K&C** Initiative An international science collaboration led by JAXA



Histograms of tile-wise (30  $\times$  30 km<sup>2</sup>) RMSE, relative RMSE, R<sup>2</sup> and bias between PALSAR- and *k*NN-based stem volumes for the 1,000 m pixel size.

#### Impact on WB on the retrieval of stem volume

OS

K&C Initiative

An international science collaboration led by JAX.



Comparison of retrieval statistics for different aggregation levels starting from the PALSAR estimates at 25 m (FBD) and those obtained at 75 m by combining FBD and WB data.

#### Large area statistics compared to NFI data

OS

An international science collaboration led by JAXA



County-wise stem volume derived from the PALSAR dataset at 25 m (left, FBD) and 75 m (right, FBD + WB) with respect to values published by the Swedish NFI.

# Deliverables – Papers and reports

K&C Initiative

An international science collaboration led by JAX.

#### 1. Published

• Reports

- Fransson, J.E.S., and Santoro, M., "K&C Science Report Phase 3, Advances in forestry applications using satellite ALOS PALSAR images", In "The ALOS Kyoto & Carbon Initiative, Science Team Reports, Phase 3 (2011-2014)", Japan Aerospace Exploration Agency, Earth Observation Research Center, 2-1-1 Sengen, Tsukuba-shi, Ibaraki 305-8505, Japan, JAXA EORC, NDX-XXXXX, pp. XX-XX, 2014.
- Conference presentations and papers
- Santoro, M., Wegmüller, U., Fransson, J.E.S., and Schmullius, C. 2014. Regional mapping of forest growing stock volume with multitemporal ALOS PALSAR backscatter. In Proceedings of IGARSS 2014, Energy and our Changing Planet, Québec, Canada, 13-18 July, 2014, pp. 2313-2316.

## Deliverables – Papers and reports

K&C Initiative

An international science collaboration led by JAX

#### 1. Published

OS

- Journal papers
- Pantze, A., Santoro, M., and Fransson, J.E.S. 2014. Change detection of boreal forest using bi-temporal ALOS PALSAR backscatter data. Remote Sensing of Environment 155, 120-128.

#### 2. Submitted

- Journal papers
- Santoro, M., Fransson, J.E.S., Eriksson, L.E.B. Reviewing ALOS PALSAR backscatter observations for stem volume retrieval in Swedish forest. Submitted September 8, 2014 to IEEE Transactions on Geoscience and Remote Sensing.

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

**K&C** Initiative An international science collaboration led by JAXA

1. Completed and Delivered to JAXA

- PALSAR-based stem volume (biomass) map of Sweden for 2010
- Ground-truth and laser data from the test sites Remningstorp and Krycklan

