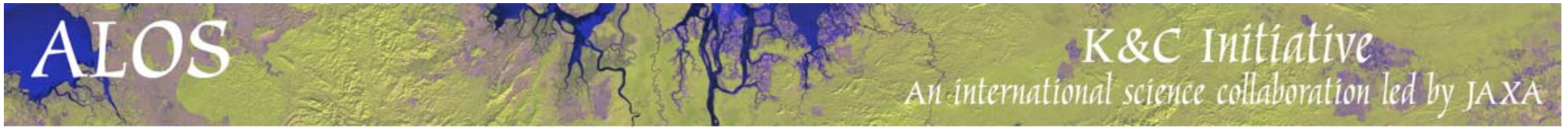


K&C Phase 3 – progress report

Advances in forestry applications using satellite ALOS PALSAR images

Johan Fransson, Andreas Pantze, Håkan Olsson and Jonas Fridman

Swedish University of Agricultural Sciences, Sweden

Maurizio Santoro

Gamma Remote Sensing, Switzerland

Leif Eriksson and Lars Ulander

Chalmers University of Technology, Sweden

Anders Persson

Swedish Forest Agency, Sweden

Malcolm Davidson

European Space Agency

Project objectives

- To further develop and validate the methodology from Phase 2 to detect and delineate forest cover change in terms of clear-felled areas at test site level (and possible for the entire Sweden using PALSAR data from 2008-2010)

- To develop and validate methods for large-scale biomass mapping for the entire Sweden (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. Here, synergy with the K&C Phase 3 project "Coupling radar-based estimates of forest information with biosphere models for improved carbon flux estimation" by Maurizio Santoro will be exploited.

Project areas

Test sites:

- Remningstorp
- Krycklan

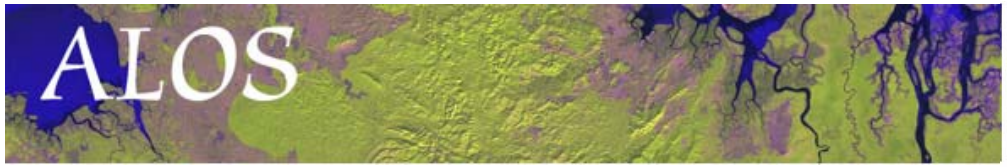
Counties:

- Västra Götaland
- Västerbotten

Country:

- Sweden

(45 million ha – 50% forest)



ALOS PALSAR mosaic over Scandinavia and Finland

ALOS PALSAR data used

Fine Beam Dual (FBD34)

63 strips from

43 orbital tracks

June – October 2009

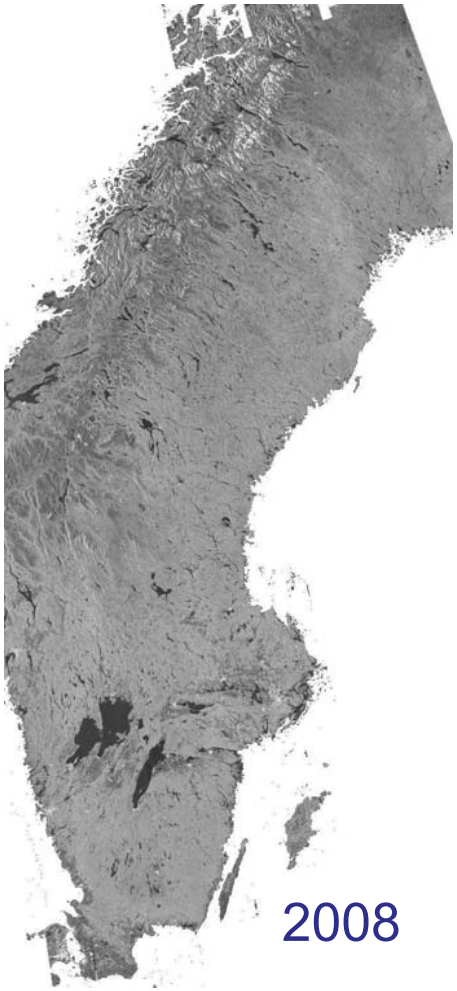
Other data sources

Digital Elevation Model

PALSAR strip dataset

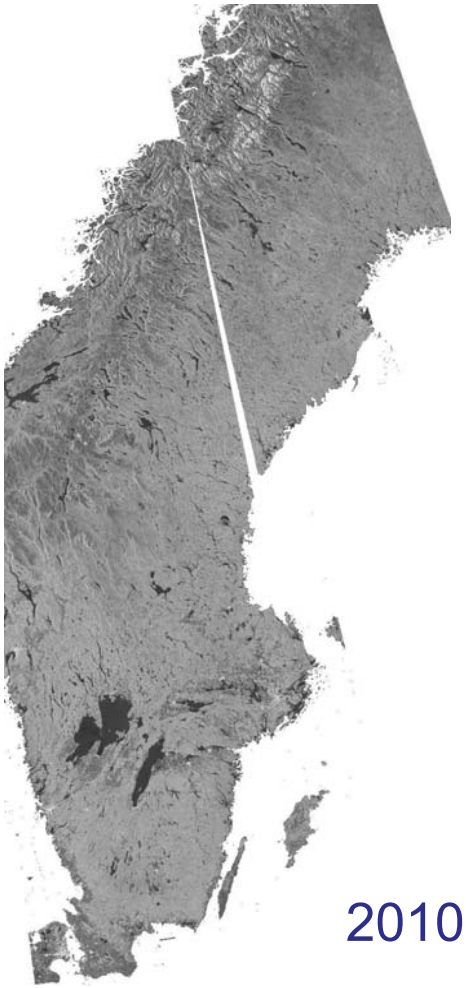
	2008			2009			2010	
RSP	Date	Cycle	RSP	Date	Cycle	RSP	Date	Cycle
613	20080622	20	615	20090613	28	615	20100801	37
615	20080726	21	633	20090713	28	634	20100802	37
634	20080727	21	625	20090715	28	607	20100803	37
607	20080728	21	631	20090725	28	626	20100804	37
626	20080729	21	634	20090730	29	618	20100806	37
629	20080803	21	626	20090801	29	629	20100809	37
621	20080805	21	621	20090808	29	621	20100811	37
605	20080809	21	613	20090810	29	613	20100813	37
624	20080810	21	632	20090811	29	632	20100814	37
627	20080815	21	605	20090812	29	605	20100815	37
619	20080817	21	624	20090813	29	635	20100819	37
611	20080819	21	619	20090820	29	627	20100821	37
630	20080820	21	611	20090822	29	619	20100823	37
603	20080821	21	622	20090825	29	611	20100825	37
622	20080822	21	617	20090901	29	630	20100826	37
633	20080825	21	609	20090903	29	622	20100828	37
625	20080827	21	628	20090904	29	633	20100831	37
617	20080829	21	620	20090906	29	625	20100902	37
609	20080831	21	623	20090911	29	617	20100904	37
620	20080903	21	607	20090915	30	609	20100906	37
631	20080906	21	629	20090921	30	628	20100907	37
623	20080908	21	627	20091003	30	631	20100912	37
632	20080923	22	630	20091008	30	624	20101001	38
628	20081017	22	603	20091009	30	623	20101030	38

Yearly mosaics of PALSAR strip images covering Sweden



2008

2009



2010

ALOS

K&C Initiative

An international science collaboration led by JAXA

PALSAR mosaic 2009

Clear-cuts 2008-2009

Counties (21)

Estimation of clear-felled areas 2008-2010 (on average)

Table 5. County and national level average statistics of clear-felled areas for the time period 2008–2010 from ALOS PALSAR K&C strip data (PALSAR), the Swedish Forest Agency (SFA), the National Forest Inventory (NFI) and the notified areas of final fellings recorded by the SFA (Notified) [11,16,17]. For Västerbotten, Västra Götaland and Jönköping, a three-year average value between 2007 and 2010 is reported. For details on individual years, please refer to Table 4.

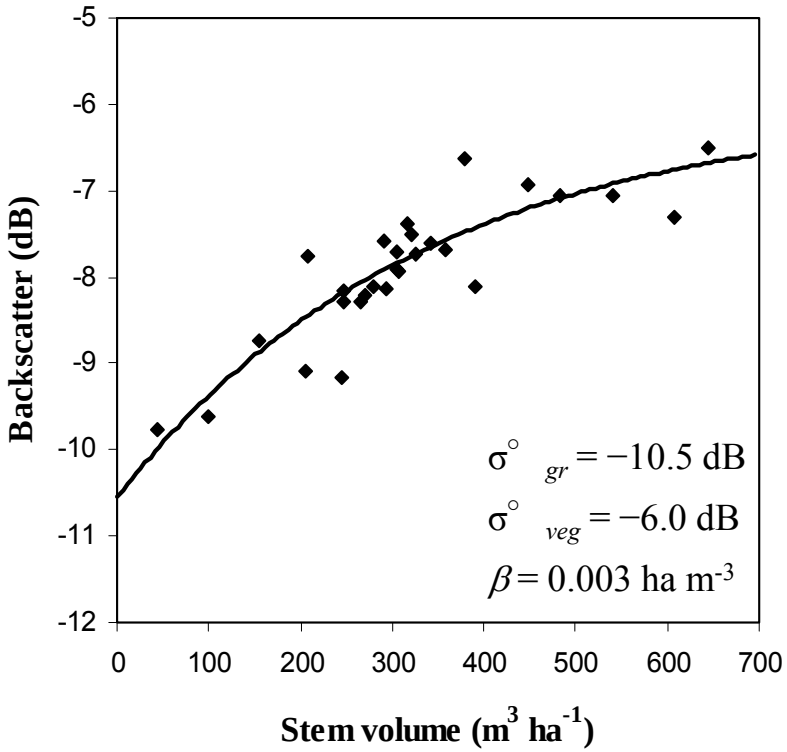
County	PALSAR (ha)	SFA (ha)	NFI (ha)	Rel. RMSE of NFI(%)	Notified (ha)
Norrbotten	20,982	22,343	24,060	50.3	19,414
Västerbotten	21,241	21,220	23,787	45.1	24,717
Jämtland	14,313	21,526	19,230	60.4	24,911
Västernorrland	12,277	14,928	10,923	56.0	23,156
Gävleborg	12,398	15,880	2,453	72.4	18,328
Dalarna	14,115	11,953	21,133	50.5	21,438
Värmland	7,272	10,796	9,368	58.9	15,101
Örebro	3,899	7,644	6,727	62.0	8,619
Västmanland	1,992	4,098	159	100.0	4,499
Uppsala	4,233	3,921	9,313	48.0	6,250
Stockholm	1,490	1,580	1,354	70.3	2,183
Södermanland	1,321	2,068	2,825	63.3	4,089
Östergötland	2,535	2,099	16,579	51.9	8,964
Västra Götaland	6,842	12,828	12,344	57.7	17,947
Jönköping	3,095	5,517	4,050	28.3	8,868
Kronoberg	2,514	4,302	12,930	33.3	8,494
Kalmar	5,067	3,879	9,134	43.2	11,051
Gotland	2,012	832	0	-	0
Halland	714	1,620	854	66.1	3,646
Blekinge	1,137	2,422	3,134	88.9	1,692
Skåne	1,175	3,177	118	132.1	5,816
Total (Sweden)	140,618	172,532	194,586	15.0	239,183

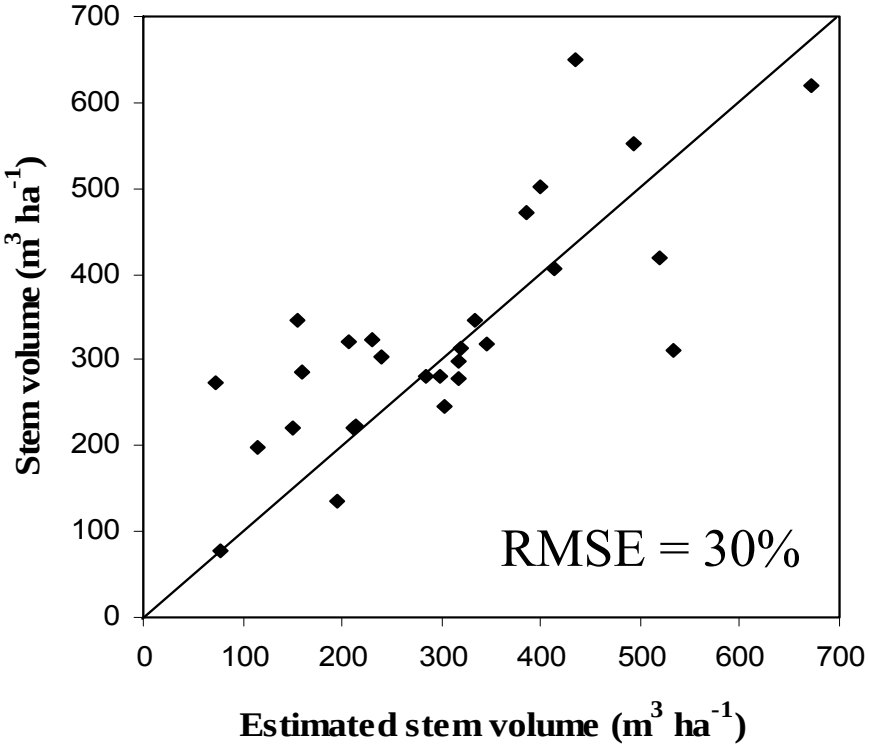
Santoro, M., Pantze, A., Fransson, J.E.S., Dahlgren, J., and Persson, A., "Nation-Wide Clear-Cut Mapping in Sweden Using ALOS PALSAR Strip Images," Remote Sensing, vol. 4, pp. 1693-1715, 2012.

Standwise stem volume estimation

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

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





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

Project schedule

The objectives will be achieved by applying and extend the experiences in Phase 1 and 2 and by performing a scientific evaluation of clear-cut and biomass mapping

Clear-cut mapping:

- Detailed investigation of the algorithm used in Phase 2 and comparison with a new thresholding algorithm developed by Andreas Pantze (2011-2012 → 2013)
- Possible up-scaling and testing of methodology from local to regional to national scale using the processing chain developed in Phase 2 (2013)
- Production of clear-cut maps at the test sites (2013) and possible for the entire Sweden using PALSAR data from 2008-2010 (2013)
- Final delivery of the product with a written report to JAXA (2014)

Project schedule (cont.)

Biomass mapping:

- Further investigations of the methodology used in Phase 1 (Water Cloud Model) at the test sites (2012-2013) → Ongoing
- Comparison (after adjustments) with other algorithms found in literature at the test sites (2011-2012-2013) → Andreas Pantze has started this work at the Krycklan test site (also multi-temporal combinations of PALSAR images have been investigated)
- Develop a processing chain at the test sites (2013)
- Adaptation of processing chain from local to regional to national scale (2013)
- Up-scaling and testing of methodology (2013)
- Production of biomass maps (base year 2010) (2013)
- Final delivery of the product with a written report to JAXA (2014)

Biomass mapping – early results

- For 30 boreal stands at the Krycklan test site an RMSE of less than 30% (best case: RMSE = 25%) could be achieved using PALSAR images acquired during the summer applying regression analysis with leave-one-out cross-validation
- A direct inversion of the Water Cloud Model is depending on the choice of the upper bound of biomass possible to retrieve

Water Cloud Model

single $\sigma^{\circ}_{for} = \sigma^{\circ}_{gr} \times e^{-\beta V} + \sigma^{\circ}_{veg} \times (1 - e^{-\beta V}) + \varepsilon$ $\hat{V} = -\frac{1}{\beta} \times \ln\left(\frac{\sigma^{o}_{veg} - \sigma^{o}_{for,meas}}{\sigma^{o}_{veg} - \sigma^{o}_{gr}}\right)$

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

- 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 thus obtaining biomass that is more closely related to the true value
- Models will likely be developed at plot level producing a raster with the same resolution (i.e., 10 m radius corresponding to 20 m × 20 m pixel size)

Support to JAXA's global forest mapping effort

Clear-cut and biomass mapping:

- Original planned to compare the forest/non-forest and biomass product by JAXA with the clear-cut map over Sweden (2008-2010) produced in Phase 2 and the biomass map over Sweden (2008-2010 – base year 2010) that will be produced in Phase 3. However, it is unclear if this activities can be pursued or not.
- PALSAR FBD mosaic data will be delivered by JAXA over Sweden 2008-2010 (2010 already available through the K&C Phase 3 project "Coupling radar-based estimates of forest information with biosphere models for improved carbon flux estimation" by Maurizio Santoro)

Support to JAXA's global forest mapping effort

Ground truth data that will be shared with JAXA:

- Field inventory data and laser data from the test sites (collected through ESA airborne campaigns conducted within the framework of the ESA Earth Explorer mission BIOMASS in cooperation with the Swedish Defence Research Agency (FOI), Chalmers University of Technology) Remningstorp (2007 and 2010) and Krycklan (2008)
- The datasets are available at registration via the ESA PI Portal (follow the "campaign" link under http://eopi.esa.int/esa/esa). The ESA contact person is Malcolm Davidson (Head of Campaigns Section, Mission Science Division at ESA)

Is it preferable that SLU deliver the data or that the data are delivered to JAXA through ESA?

Deliverables

- Clear-cut map for Sweden obtained from PALSAR strip data for the time period 2008-2010 (delivered to JAXA at the end of Phase 2)
- Clear-cut maps for the test sites applying other methodologies than in Phase 2 (possible also for Sweden (2008-2010))
- Biomass map for Sweden (base year 2010) obtained from PALSAR strip data (2008-2010)
- Improved/revised JAXA forest change and biomass maps for Sweden (if JAXA's products are available)
- Ground truth data from the test sites (Remningstorp and Krycklan) including estimates of forest variables (at plot, raster and stand level)
- Yearly feed-back to JAXA on progress

Recent publications

- Pantze, A., Santoro, M., and Fransson, J.E.S., “Boreal Forest Change Detection From L-Band Satellite SAR Images,” Manuscript.
- Santoro, M., Pantze, A., Fransson, J.E.S., Dahlgren, J., and Persson, A., “Nation-Wide Clear-Cut Mapping in Sweden Using ALOS PALSAR Strip Images,” Remote Sensing, vol. 4, pp. 1693-1715, 2012.
- Pantze, A., de Luna, S., and Fransson, J.E.S., “On model selection and finite mixture modeling of SAR intensity data,” Manuscript submitted.

Acknowledgments

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- Forestry Society's Estate Management Company (Skogssällskapet)
- Swedish Meteorological and Hydrological Institute (SMHI)
- Svartberget's research station, SLU
- Swedish National Land Survey
- Sveaskog (Swedish forest company)