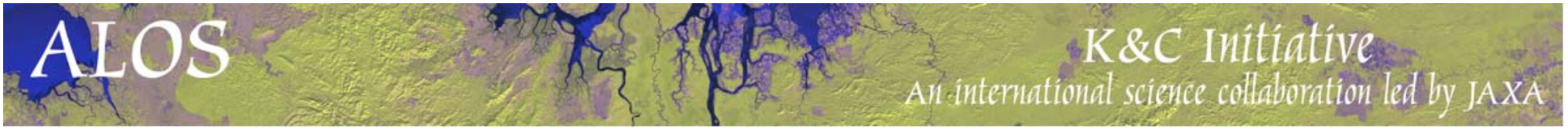



# Report on Kyoto & Carbon Initiative Project

# National clear-cut mapping in Sweden with ALOS PALSAR

Johan Fransson, Andreas Pantze, and Håkan Olsson

*Swedish University of Agricultural Sciences, Sweden*

Leif Eriksson and Lars Ulander

*Chalmers University of Technology, Sweden*

Maurizio Santoro

*GAMMA Remote Sensing, Switzerland*

Anders Persson

*Swedish Forest Agency, Sweden*

# Introduction

## Project objective

To further develop and evaluate methods for nation-wide mapping and monitoring of clear-cuts for the entire Sweden using PALSAR data

## Project region

Sweden

*NOTE: Sweden + Norway + Denmark + Finland + would have been nicer in view of targeting a geographic region but not feasible → PALSAR data are delivered though for this area*


# Schedule – completed

The objective was achieved by refining the methodology developed in Phase 1 and by performing a scientific evaluation of clear-cut detection of Sweden

- Refinement of the developed methodology in Phase 1
- Adaptation of processing chain from regional to national level mapping
- Testing of methodology for change detection at different spatial scales
- Production of yearly clear-cut maps of Sweden from 2008, 2009 and 2010
- Assessment of PALSAR clear-cut detection vs. available databases of clear-felled areas
- Final delivery of the product with a written report to JAXA

# ALOS PALSAR mosaic over Scandinavia and Finland


ALOS PALSAR data used

Fine Beam Dual (FBD34)

63 strips from

43 orbital tracks

June – October 2009

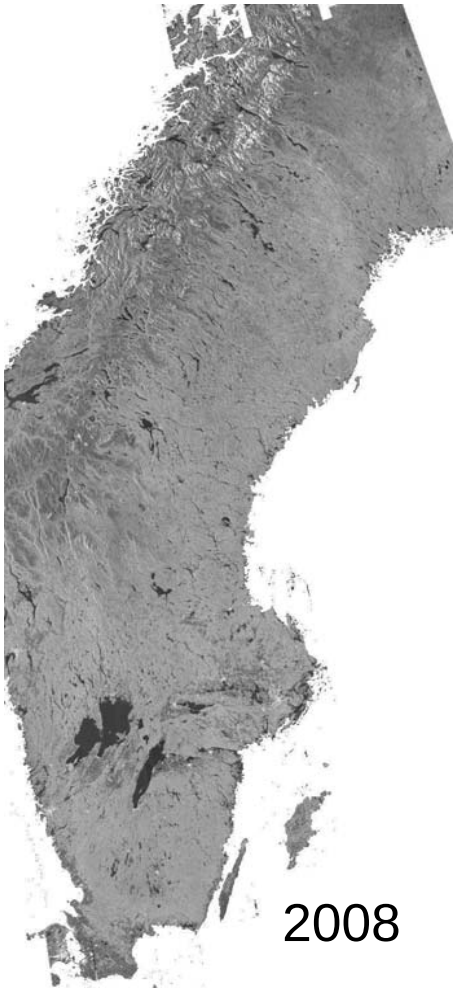
Other data sources

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



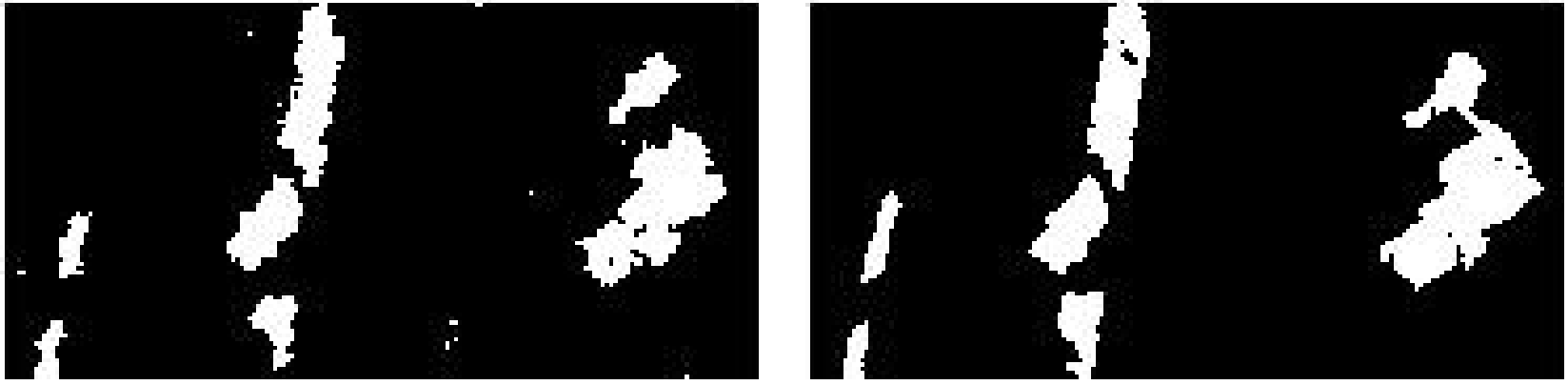
2008

2009

2010

# Improved change detection algorithm

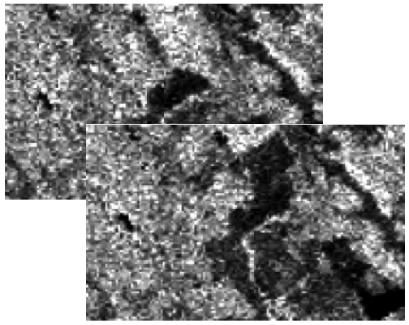
Radiometric normalization and initial change/no change classification were achieved using **histogram matching and automatic image ratio thresholding (GKIT)** (Moser & Serpico, IEEE TGRS, 2006) combined in an iterative manner. As an optional final change/no change classification step the **data fusion based multi-channel change detection (MCD)** method proposed in (Moser & Serpico, IEEE TGRS, 2009) was used. This method is based on Markov random fields and can take into account the spatial contextual information from one or multiple SAR channels.

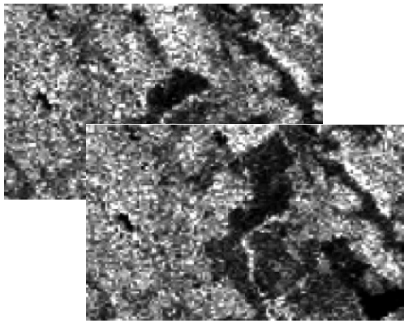


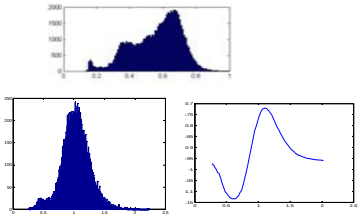
Left: HV channel change map from GKIT+MCD, and right: reference map derived using SPOT-5 SWIR images

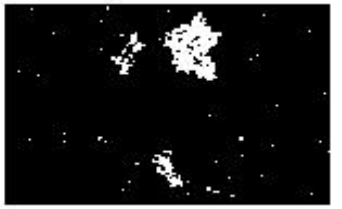
# Change detection approach, part 1

SAR intensity images → (Filtering) → Radiometric normalization + Image ratio thresholding → Change map (initial)









# Change detection approach, part 2

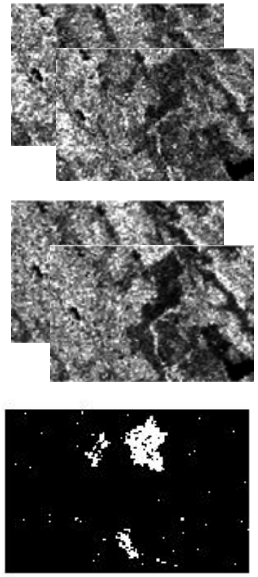
SAR image ratio(s)
+
"Best" initial change map

→

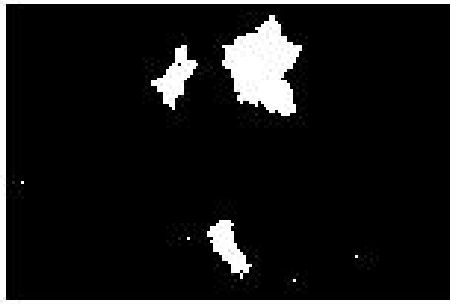
Data fusion based change detection "DF-MCD"

→

Change map



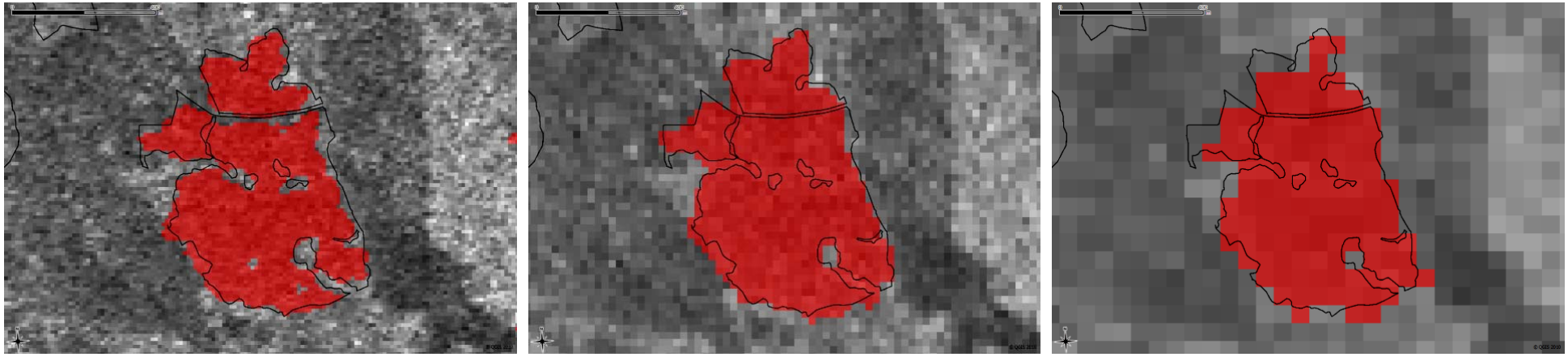
- Spatial contextual information from one or multiple SAR channels
- Markov random fields
- "Energy functions"



G. Moser and S. B. Serpico, "Unsupervised change detection from multichannel SAR data by Markovian data fusion," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 47, no. 7, pp. 2114-2128, Jul. 2009.

# Testing of methodology for change detection at different spatial scales

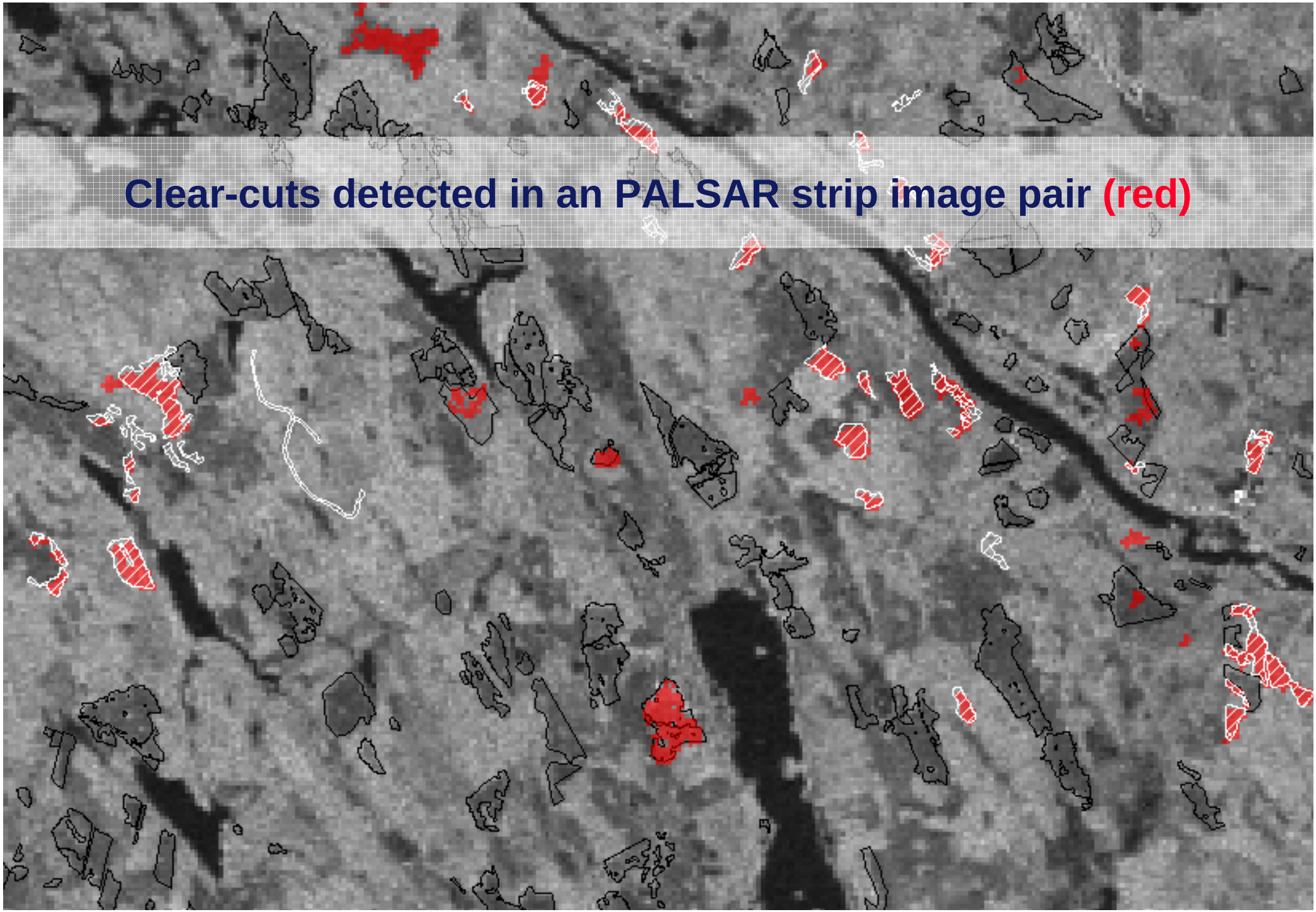
10 m | 20 m | 50 m



Example of a detected clear-cut using PALSAR data (red) at 10 m, 20 m and 50 m pixel size. For reference, the border of the clear-felled area is outlined as reported in a GIS database provided by the forest company Sveaskog. As background, the PALSAR image acquired after clear-felling has been used.

# Testing of methodology for change detection at different spatial scales

| Pixel size (m) | Correctly detected pixels (original / edge-eroded) | |
|---|---|---|
| | Average (%) | 10th and 90th percentile (%) |
| 10 | 62.7 / 71.5 | 34-87 / 38-95 |
| 20 | 79.4 / 90.6 | 56-96 / 67-100 |
| 50 | 72.5 / 85.9 | 33-98 / 52-100 |
| 50* | 58.0 / 78.8 | 22-88 / 41-100 |


Clear-cuts detected in an PALSAR strip image pair (red)

# Likeliness of agreement between pixels detected as change from PALSAR images and Swedish Forest Agency's clear-cut polygons

| Tile ID | County | Likeliness of detection | | |
|---|---|---|---|---|
| | | Not verifiable (%) | Errone-ous (%) | Correct (%) |
| 130 640 | Västra Götaland | 11 | 10 | 79 |
| 165 715 | Västerbotten | 12 | 12 | 76 |
| 150 690 | Gävleborg | 18 | 9 | 73 |
| 165 735 | Norrbotten | 20 | 8 | 72 |
| 160 670 | Uppsala | 17 | 14 | 69 |
| 135 680 | Dalarna | 31 | 15 | 54 |

# County-wise statistics of clear-felled areas between 2008 and 2009 in Sweden

| County | Swedish Forest Agency (ha) | Swedish National Forest Inventory (ha) | ALOS PALSAR (ha) | Notified areas of final fellings (ha) |
|---|---|---|---|---|
| Stockholm | 1,568 | 0 | 2,209 | 1,488 |
| Uppsala | 2,997 | 10,688 | 5,383 | 5,520 |
| Södermanland | 811 | 4,288 | 1,427 | 2,930 |
| Jönköping | 1,693 | 5,125 | 3,708 | 9,623 |
| Halland | 690 | 0 | 891 | 3,518 |
| Västra Götaland | 6,430 | 13,041 | 6,400 | 17,306 |
| Värmland | 5,218 | 6,750 | 7,750 | 15,295 |
| Örebro | 2,880 | 1,838 | 5,235 | 7,868 |
| Västmanland | 3,205 | 876 | 2,585 | 4,173 |
| Dalarna | 12,107 | 5,836 | 17,503 | 18,313 |
| Gävleborg | 14,804 | 3,531 | 15,282 | 17,356 |
| Västernorrland | 5,647 | 14,136 | 15,536 | 20,412 |
| Jämtland | 24,412 | 19,665 | 19,077 | 20,435 |
| Västerbotten | 23,046 | 38,305 | 26,649 | 20,394 |
| Norrbotten | 15,424 | 16,509 | 25,355 | 15,804 |
| Total | 120,931 | 140,590 | 154,990 | 180,435 |

# Total area detected as clear-felled per growing season from PALSAR and the Swedish National Forest Inventory

| Time period | ALOS PALSAR (ha) | Swedish National Forest Inventory (ha) |
|---|---|---|
| 2008-2009 | 168,279 | 168,645* (170,000) |
| 2009-2010 | 156,910 | Not available |

* In the counties of Stockholm, Halland and Skåne, no field plots were registered as harvested at the time of field inventory

# Conclusions

- The PALSAR strip dataset is of high quality and has been timely delivered for the completion of the project

- Yearly full coverage of Sweden has been achieved for the period 2008-2010

- An improved change detection algorithm has been developed and the performance was proven to be superior to the former algorithm developed in Phase 1

-Yearly maps of clear-cuts for entire Sweden during the period 2008-2010 were produced using PALSAR FBD34 HV-polarized backscatter

- It took about 90 minutes to run the algorithm on a standard computer to produce a clear-cut map over Sweden with 50 m pixel size

- For the period spanning the growing season of 2008-2009, a total of **168,279 ha** were detected as clear-cuts using PALSAR. For the same period, the Swedish National Forest Inventory reported **168,645 ha**

# Conclusions (cont.)

- The results highlight the usefulness of ALOS PALSAR strip data in an operational scenario for clear-cut mapping at a national level.

# List of publications

**International Journals**

- Santoro, M., Fransson, J.E.S., Eriksson, L.E.B., Magnusson, M., Ulander, L.M.H., and Olsson, H. 2009. Signatures of ALOS PALSAR L-band backscatter in Swedish forest. *IEEE Transactions on Geoscience and Remote Sensing 47(12)*, 4001-4019.

- Santoro, M., Fransson, J.E.S., Eriksson, L.E.B., and Ulander L.M.H. 2010. Clear-cut detection in Swedish boreal forest using multi-temporal ALOS PALSAR backscatter data. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 3(4)*, 618-631.

**Proceedings**

- Pantze, A., Krantz, A.H., Fransson, J.E.S., Olsson, H., Santoro, M., Eriksson, L.E.B., and Ulander, L.M.H. 2009. Mapping and monitoring clear-cuts in Swedish forest using ALOS PALSAR satellite images. In *Proceedings of IGARSS 2009 Symposium, Earth Observation – Origins to Applications, Cape Town, South Africa, 13-17 July, 2009*, vol. III, pp. 589-592.

- Pantze, A., Fransson, J.E.S., and Santoro, M. 2010. Forest change detection from L-band satellite SAR images using iterative histogram matching and thresholding together with data fusion. In *Proceedings of IGARSS 2010 Symposium, Remote Sensing: Global Vision for Local Action, 30th Anniversary, Honolulu, Hawaii, USA, 25-30 July, 2010*, pp. 1226-1229.

**Reports**

- Fransson, J.E.S., Olsson, H., Eriksson, L.E.B., Ulander, L.M.H., and Santoro, M., “K&C Science Report – Phase 1, Detection of deforestation in Swedish forest”, In “The ALOS Kyoto & Carbon Initiative, Science Team Reports, Phase 1 (2006-2008)”, Japan Aerospace Exploration Agency, Earth Observation Research Center, 2-1-1 Sengen, Tsukuba-shi, Ibaraki 305-8505, Japan, JAXA EORC, NDX-100003, pp. 58-68, 2010.

- Fransson, J.E.S., Santoro, M., Pantze, A., Olsson, H., Eriksson, L.E.B., Ulander, L.M.H., and A. Persson, “K&C Science Report – Phase 2, National clear-cut mapping in Sweden with ALOS PALSAR”. Submitted.

**Booklet**

- Fransson, J., and Santoro M. 2010. National clear-cut mapping in Sweden. In Global Environmental Monitoring by ALOS PALSAR, Science Results from the ALOS Kyoto & Carbon Initiative, Edited by A. Rosenqvist and M. Shimada, Japan Aerospace Exploration Agency (JAXA reference: NDX-100004), Tsukuba Space Center, 2-1-1 Sengen, Tsukuba, Ibaraki 305-8505, Japan, pp. 44-45.

**Manuscript**

- Pantze, A., Santoro, M., and Fransson, J.E.S. 2011. Forest change detection from L-band satellite SAR images using histogram intense methods and data fusion. Manuscript.

# Acknowledgments


- JAXA EORC and ALOS K&C support team
- Swedish National Space Board
- Hildur and Sven Wingquist's Foundation for Forest Research
- 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)