Business from technology

VTT: Biomassatulkinta tutkakuvista

Paikkatietomarkkinat, marraskuu 4, 2010

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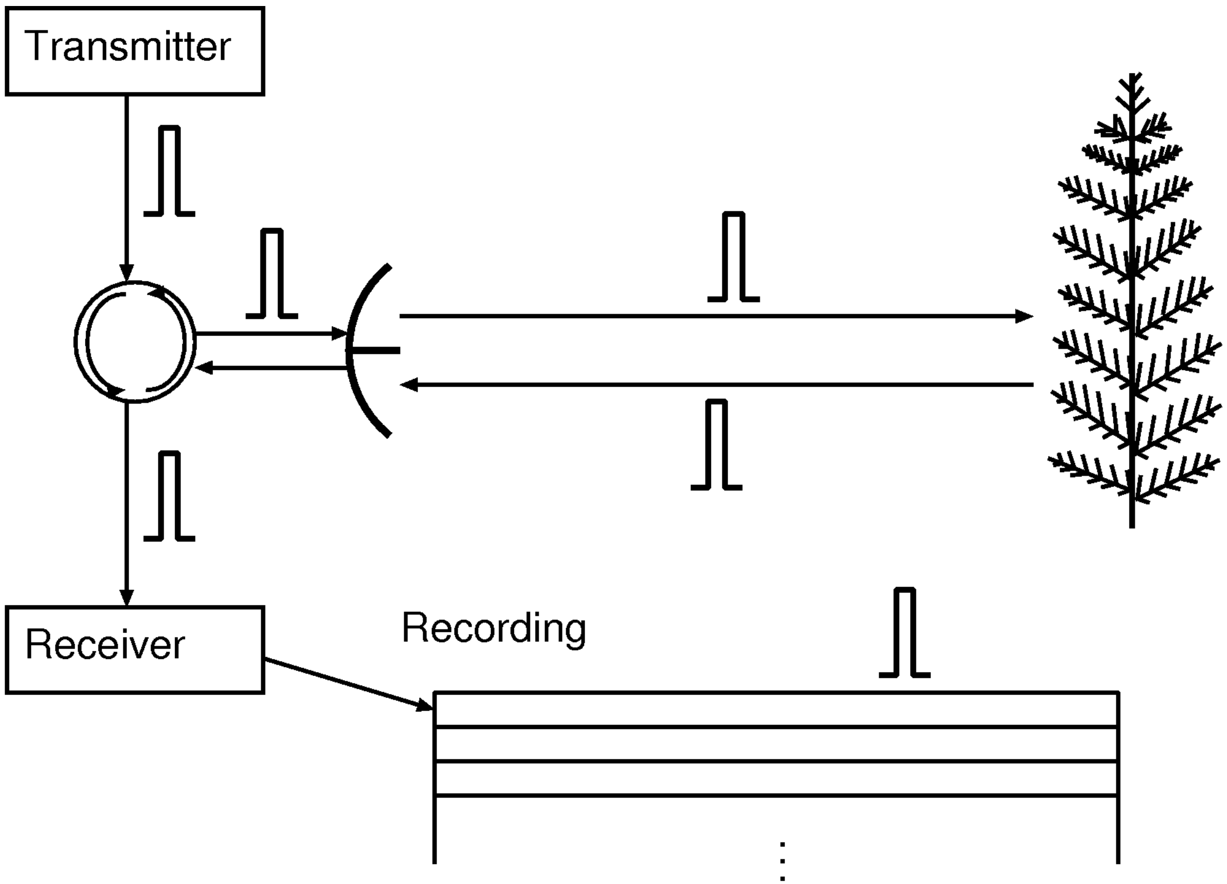
Contents of presentation

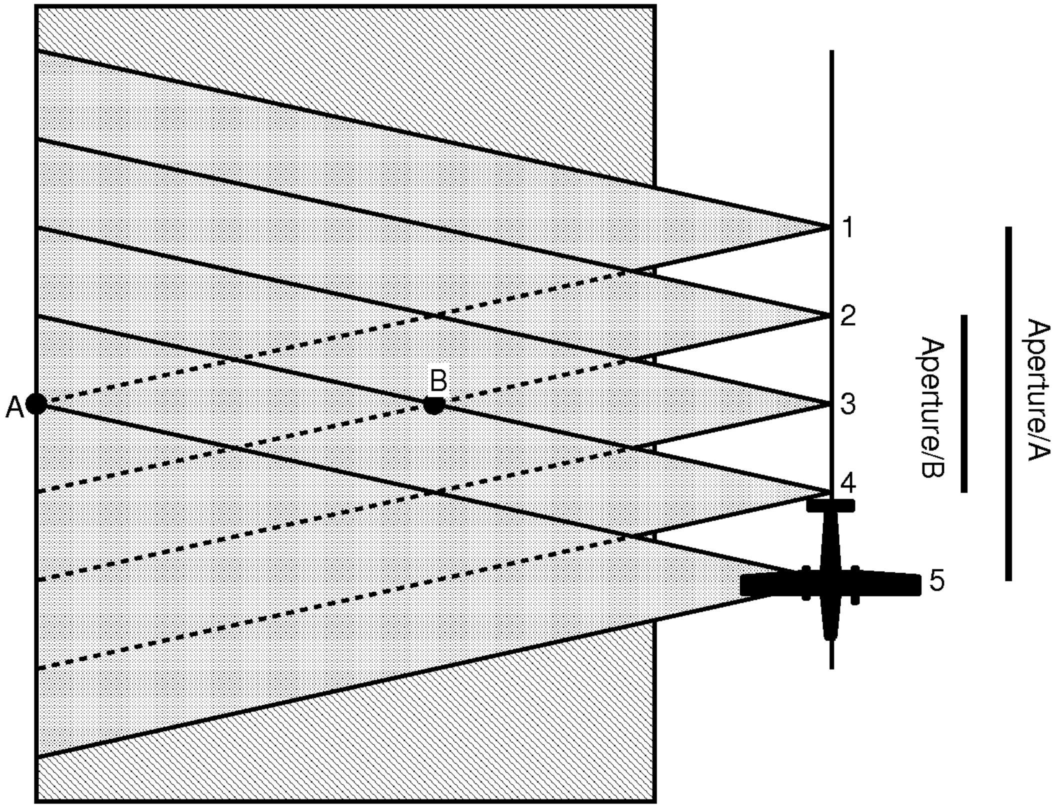
- Imaging radar special characteristics
- Simplest biomass estimation: estimate forest area
- Actual biomass estimation
- Conclusions

What is Radar



- Acronym from words "RAdio Detection And Ranging"
- Implies measurement from the sensor to the target
- A pulse is sent
- The return signal recorded as a function of time
- Intensity of the signal = power, P
- Square root of P = amplitude

Synthetic Aperture Radar

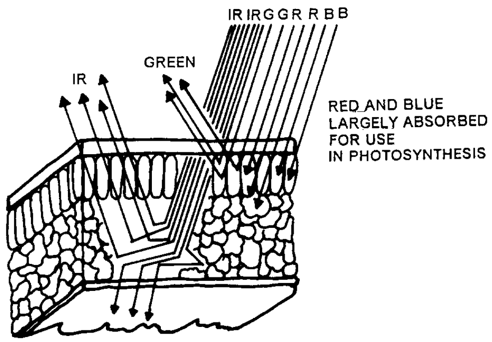


- In real aperture radar, the resolution along track is the better the longer antenna is used
- In synthetic aperture radar (SAR) a long synthetic aperture is constructed by combining the registered echoes from several pulses along the track
- Matched filtering in SAR processing
- Raw data (level 0) is useless without a SAR processor

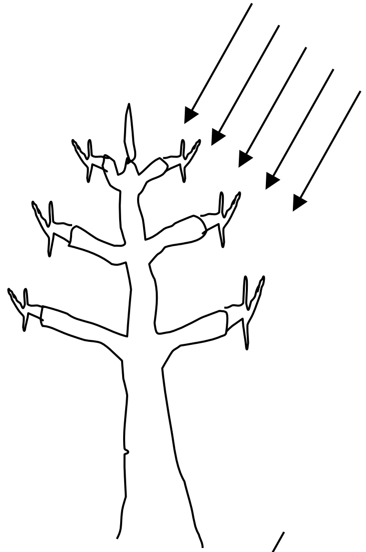
Why Radar in Remote Sensing of Forest

- **Weather independent** => possibility to obtain images when needed, independent of weather obstacles (for monitoring applications with tight schedule requirements)
- **Wide areas** can be covered **in a short period** of time when using space-borne SAR sensors - **without** the **heterogeneity** introduced by atmospheric conditions
- Many acquisitions within a year can be collected from same location – use of seasonal variability
- Biomass mapping with highest wavelengths better than with the optical image data? No space borne data presently available
- Radar sensors from satellites are imaging sensors, space-borne laser altimeters are profiling sensors
- Interferometric (tree height) and polarimetric techniques possible

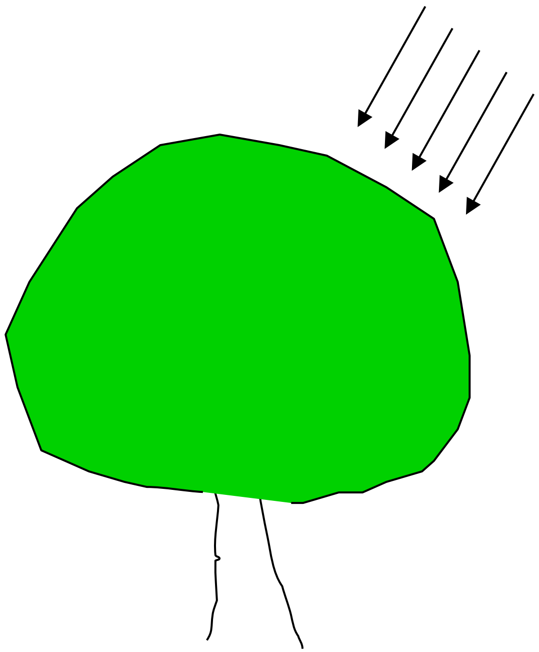
SAR and optical data information content



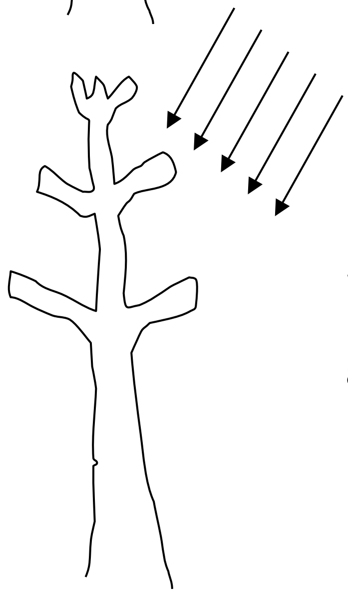
Optical:
cell-level info



SAR 23 cm - L band

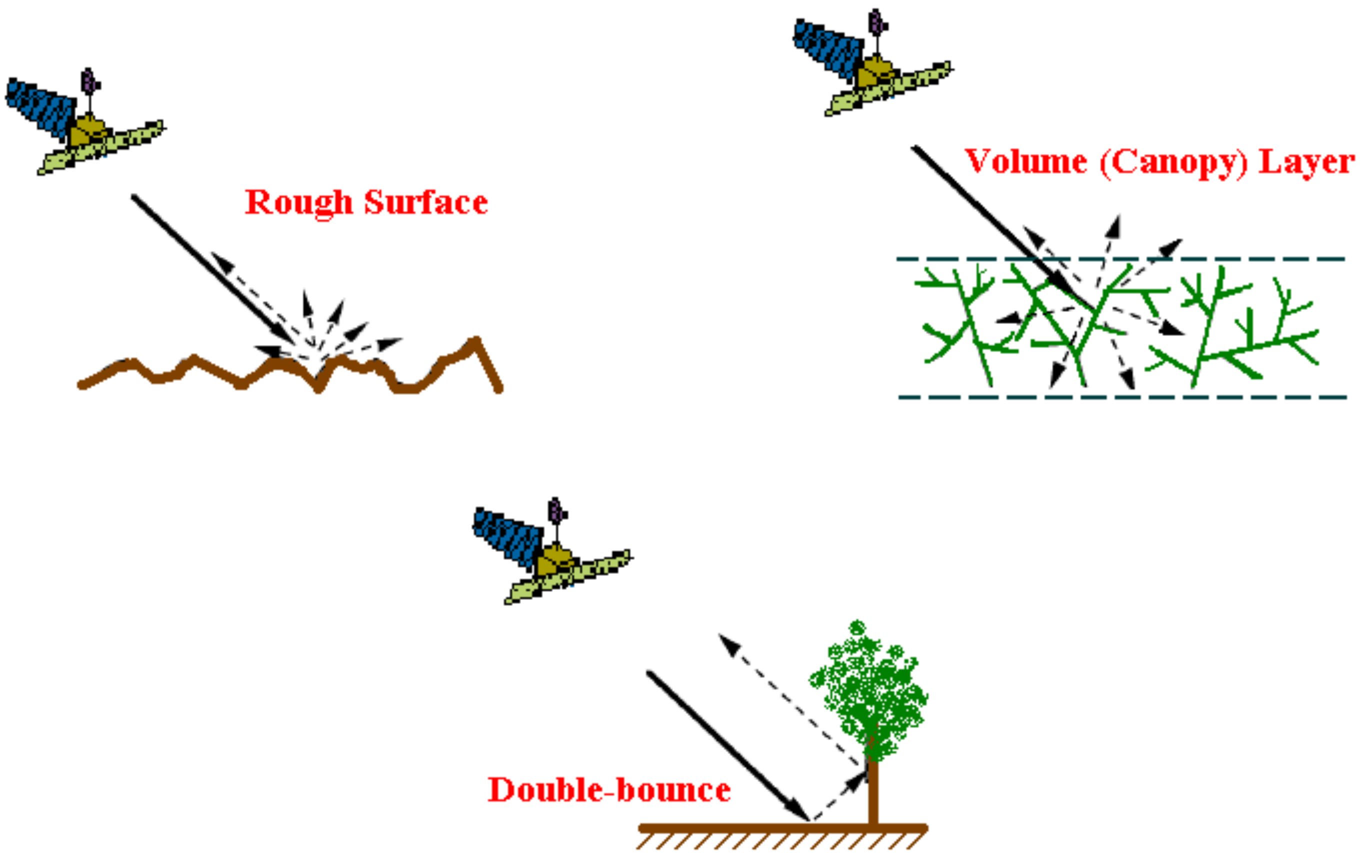


SAR C band - 6 cm
surface structure



SAR 63 cm - P band
(no space-borne available)

Scattering mechanisms

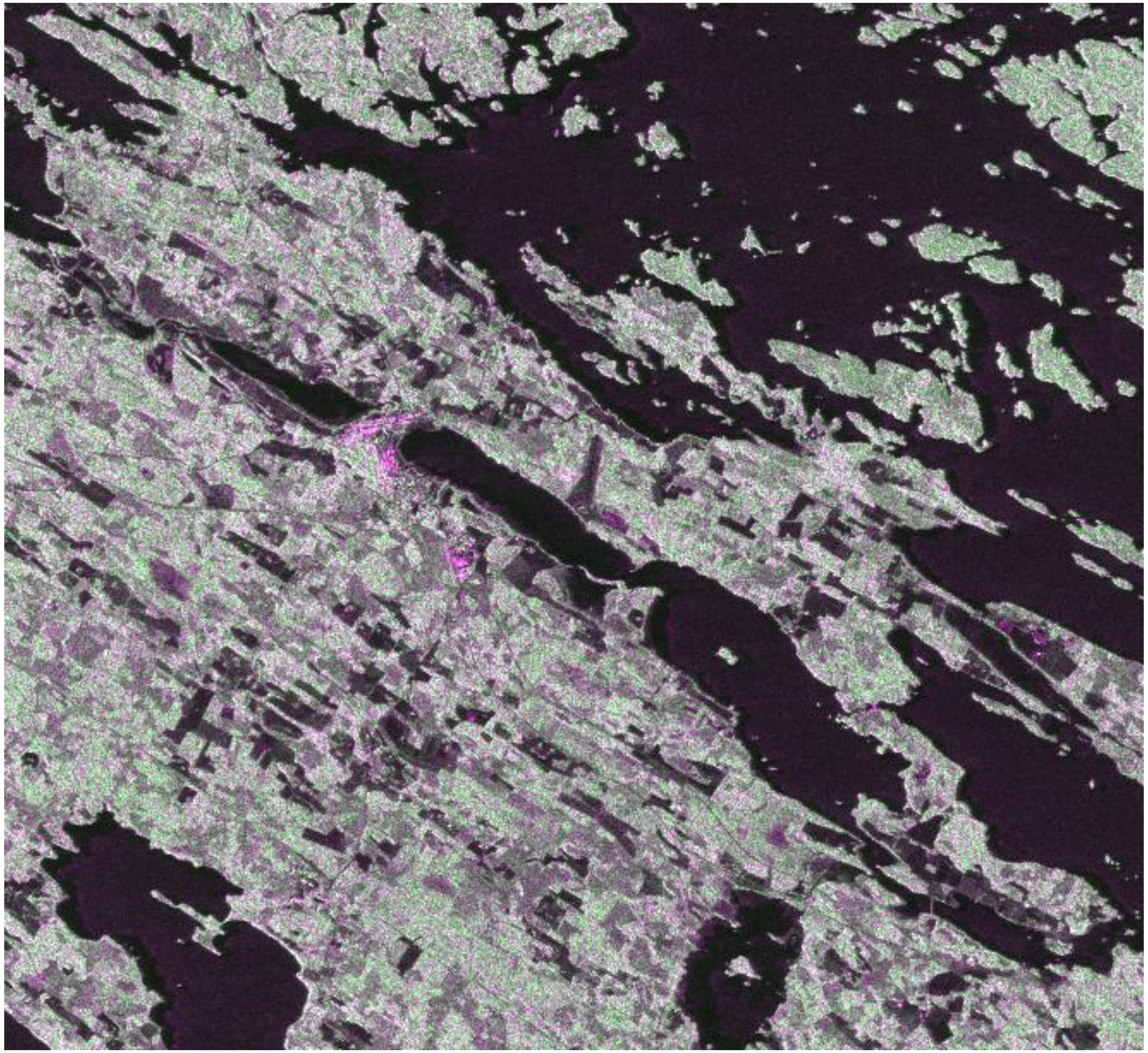


Flying and near future space borne radar satellites

Satellite/Sensor	Band	Ground resolution (m)	Image size (km)
ERS	C 5 GHz, 6 cm	30	100
Envisat ASAR	C 5 GHz, 6 cm	25	100
Radarsat	C 5 GHz, 6 cm	3 – 160	8 - 500
ALOS PalSAR	L 1.3 GHz, 23 cm	25 - 100	70 - 250
TerraSAR X	X 10 GHz, 3 cm	1 – 16	5 - 100
Cosmo Skymed	X 10 GHz, 3 cm	1 – 100	10 - 200
Sentinel 1 Launch 2013	C 5 GHz, 6 cm	5 – 40	80 - 400
Biomass (proposed)	P 0.5 GHz, 50 m	50	> 100 km

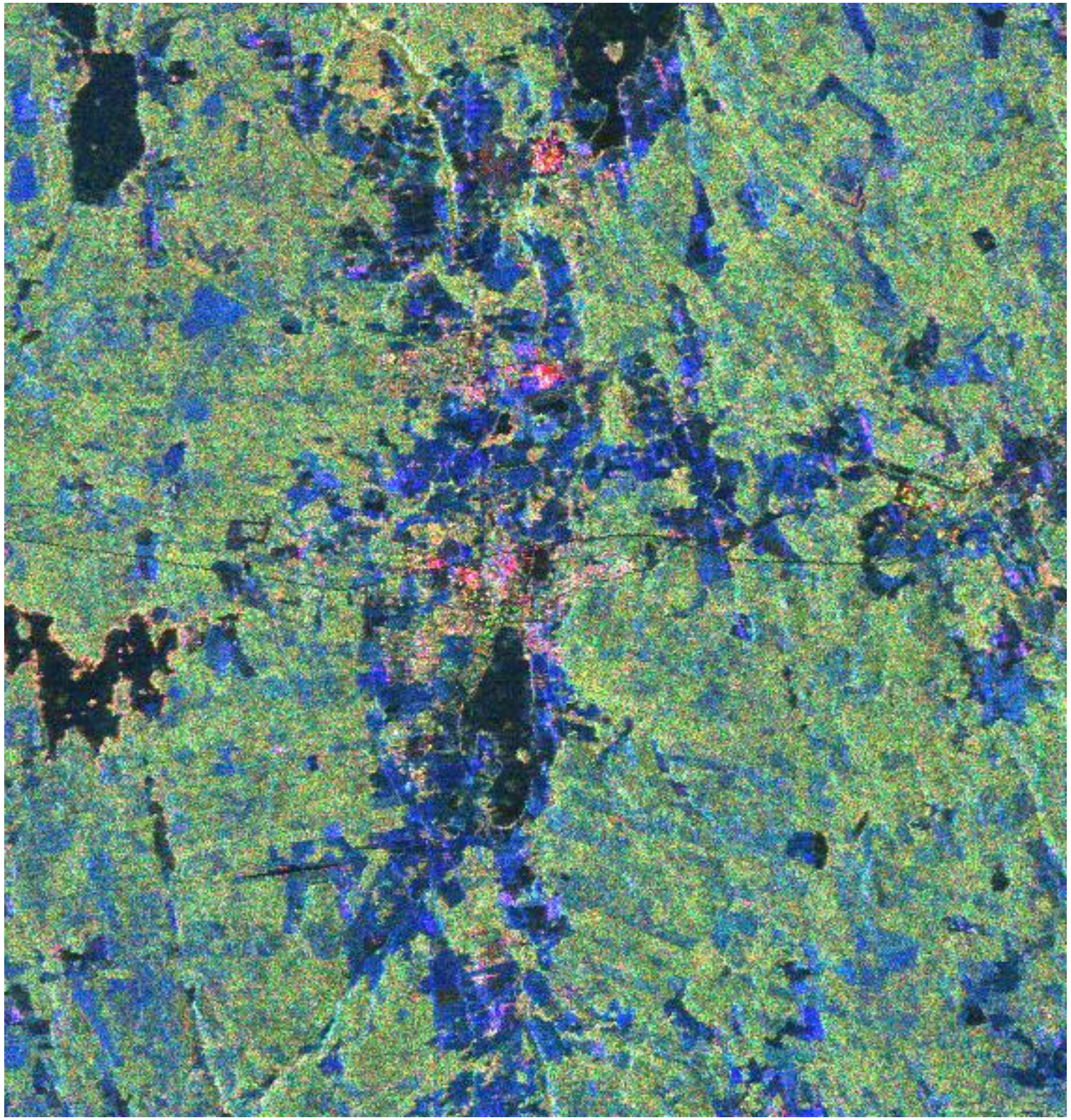
Note: due to the many imaging modes the figures on resolution and image size are only indicative

Sample Palsar Dual-Pol/HH+HV Scene



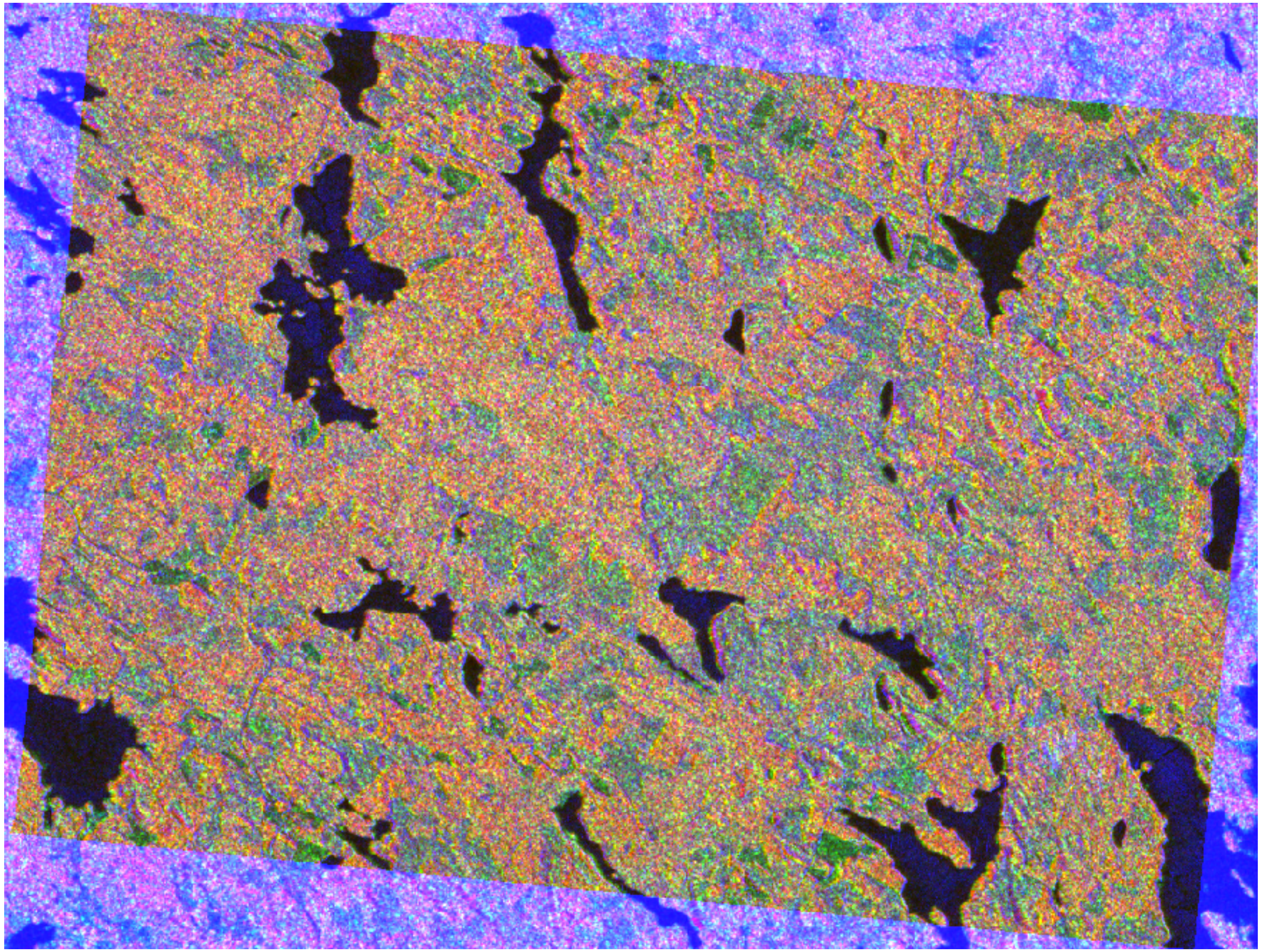
- Colours: Red = HH, Green = HV, Blue = HH
- Around Rantasalmi
- Averaged and rectified to pixel size of 25 m

Sample Polarimetric Palsar Scene



- Colours: Red = HH-VV, Green = HV, Blue = HH +VV
- Around Alavus
- Averaged and rectified to pixel size of 25 m

Combination of SAR sensors



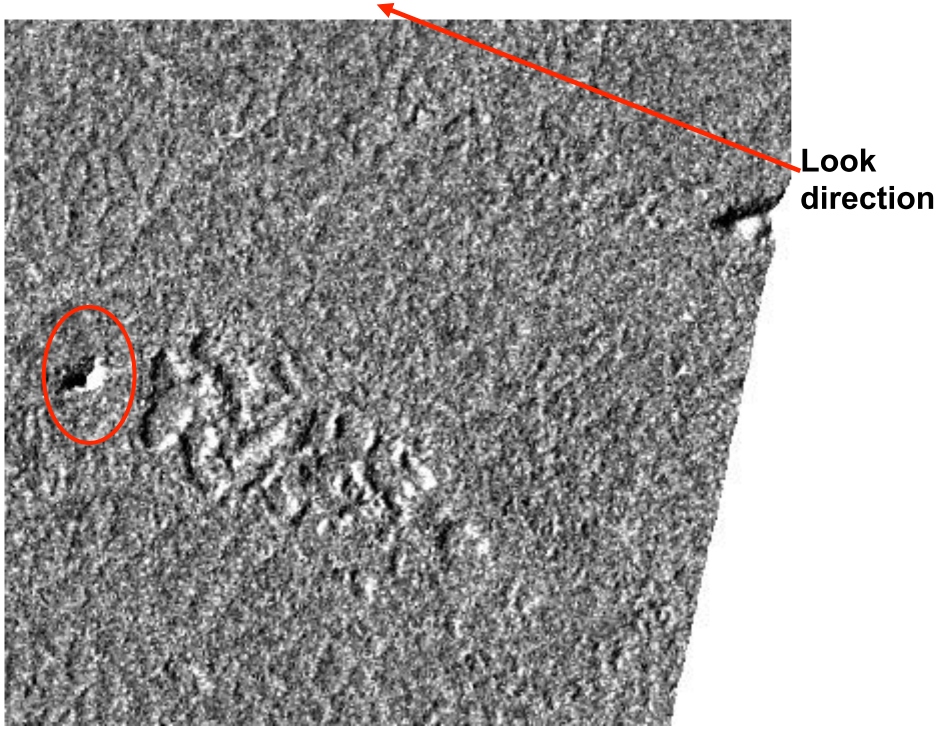
- Palsar (dual 2007-07-28) HV in red
- Radarsat-2 (Fine-Quad 2008-08-28) HV in green
- TerraSAR-X (SpotLight 2008-02-05) HH in blue
- Displayed in 12.5 m pixel spacing for the area of the TerraSAR-X scene
- Synergy of radar wavelengths

Sample SpotLight Scene (HH)

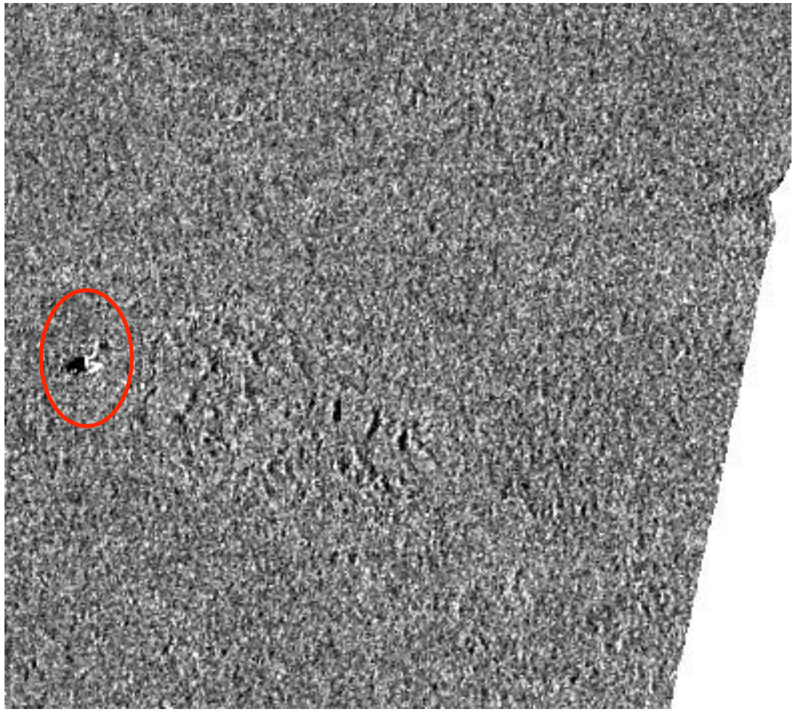
- Nördlinger Ries
- FromInfoterra WWW site
- down-averaged (pixel about 3 m, full resolution 1 m)

Source: http://www.infoterra.de/UserFiles/File/20070810_Acq_TSX_GermanyNoerdlingen.jpg

Radiometric and geometric correction/ASAR IS4



No radiometric correction

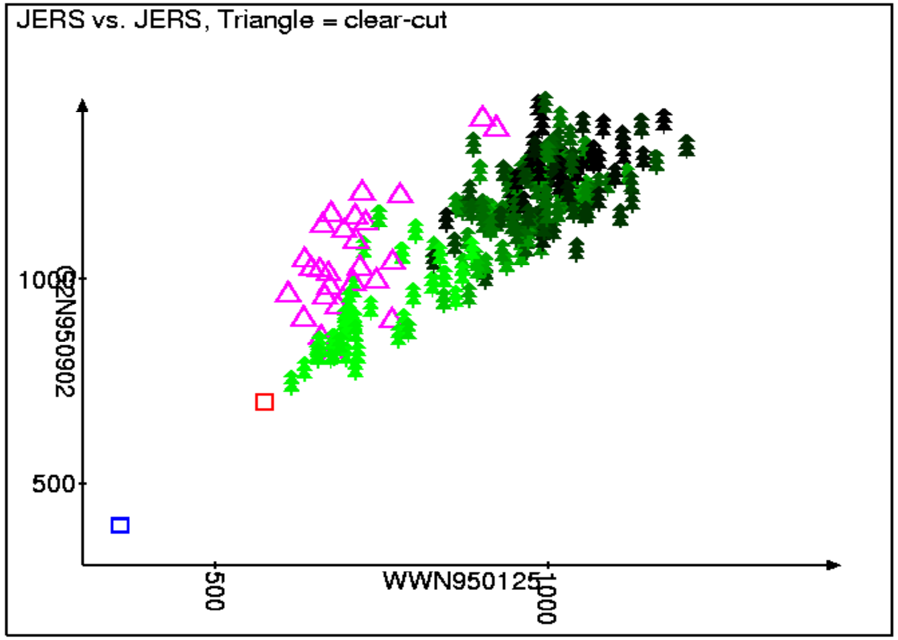


Radiometric correction with shuttle DEM

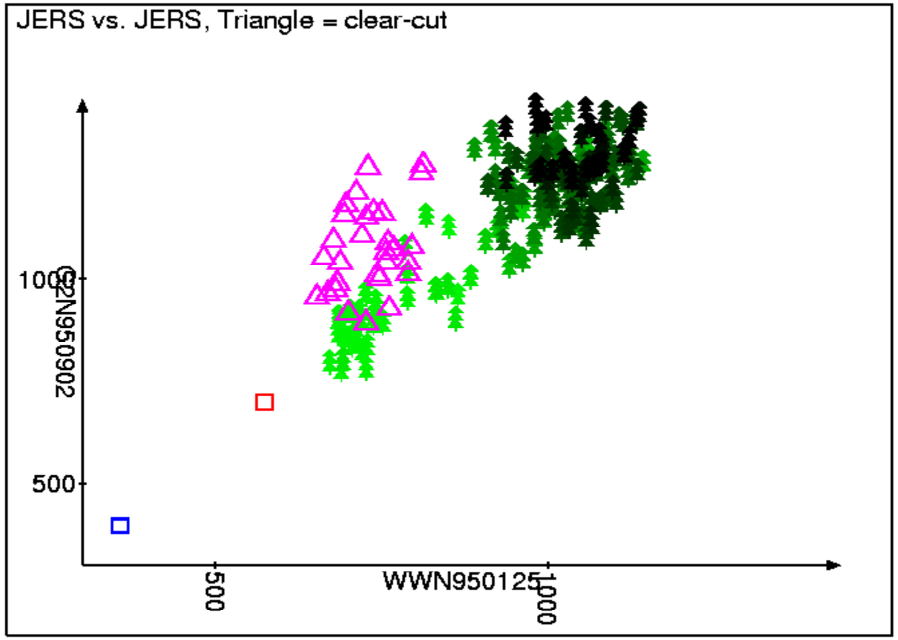
Effect of radiometric correction on analysis:

The 2 outliers (clear-cut stands) that are located on slopes facing the SAR come close to the rest of the clear-cut cluster in the radiometric correction.

Without radiometric correction



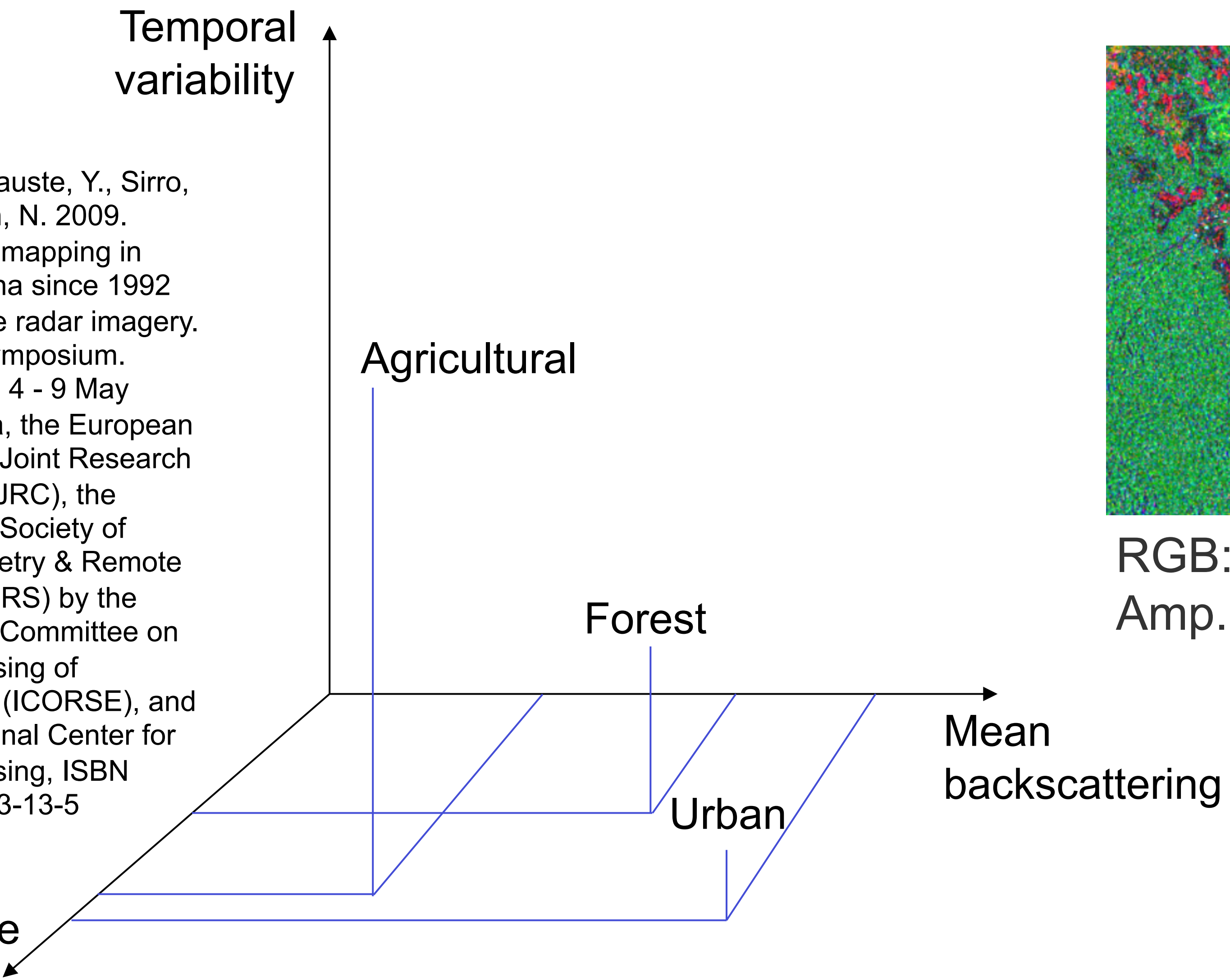
With radiometric correction



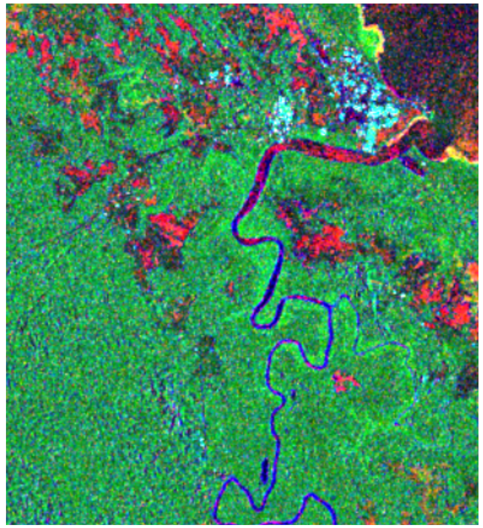
Simplest biomass estimation: estimate forest area

- Biomass estimation by applying a constant value to a land cover class

Sample Forest Area Mapping[1]/SAR features estimation

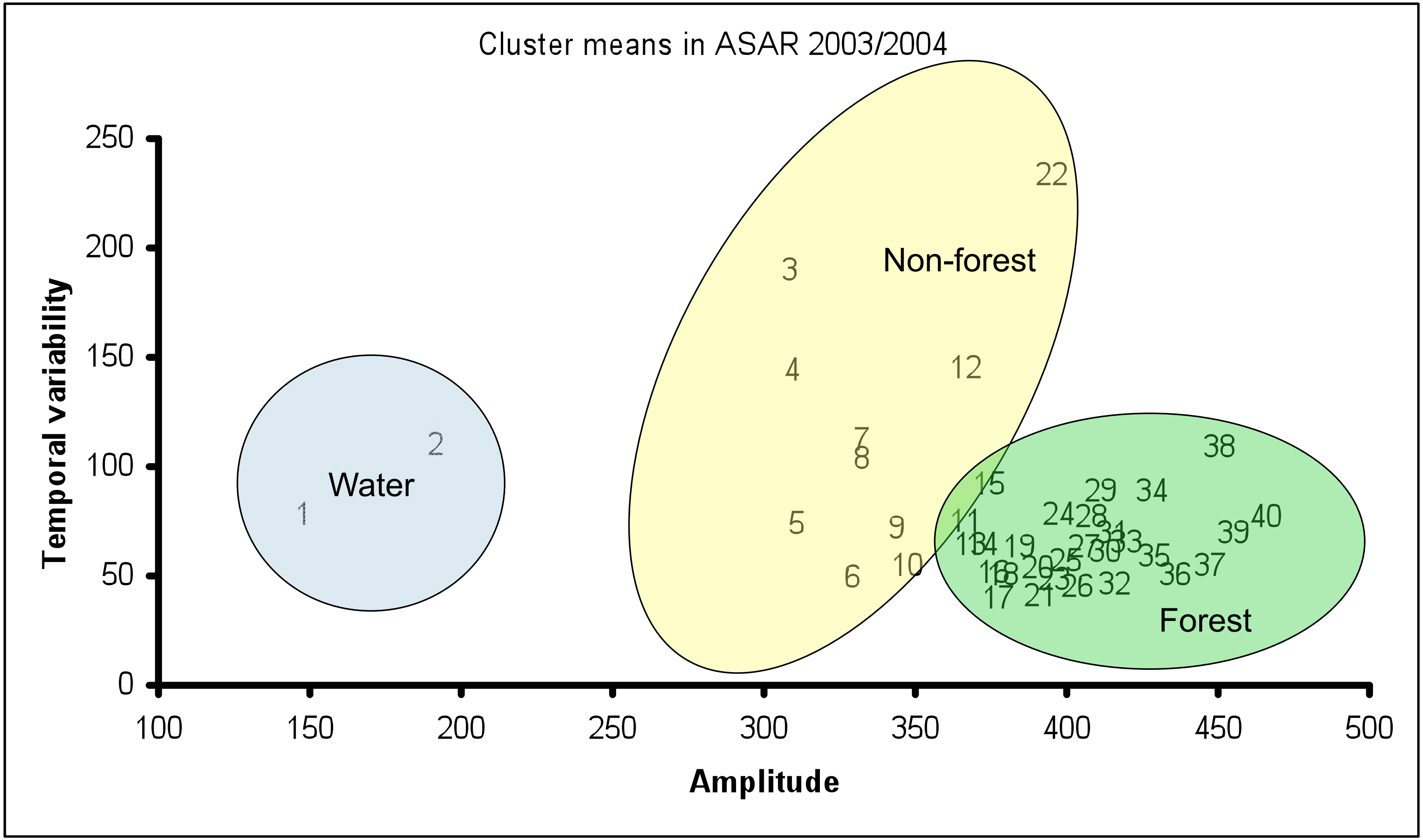


[1]Häme, T., Rauste, Y., Sirro, L., and Stach, N. 2009. Forest cover mapping in French Guiana since 1992 using satellite radar imagery. ISRSE 33 Symposium. Stresa, Italia, 4 - 9 May 2009. Stresa, the European Commission Joint Research Centre (EC- JRC), the International Society of Photogrammetry & Remote Sensing (ISPRS) by the International Committee on Remote Sensing of Environment (ICORSE), and the International Center for Remote Sensing, ISBN 978-0-932913-13-5

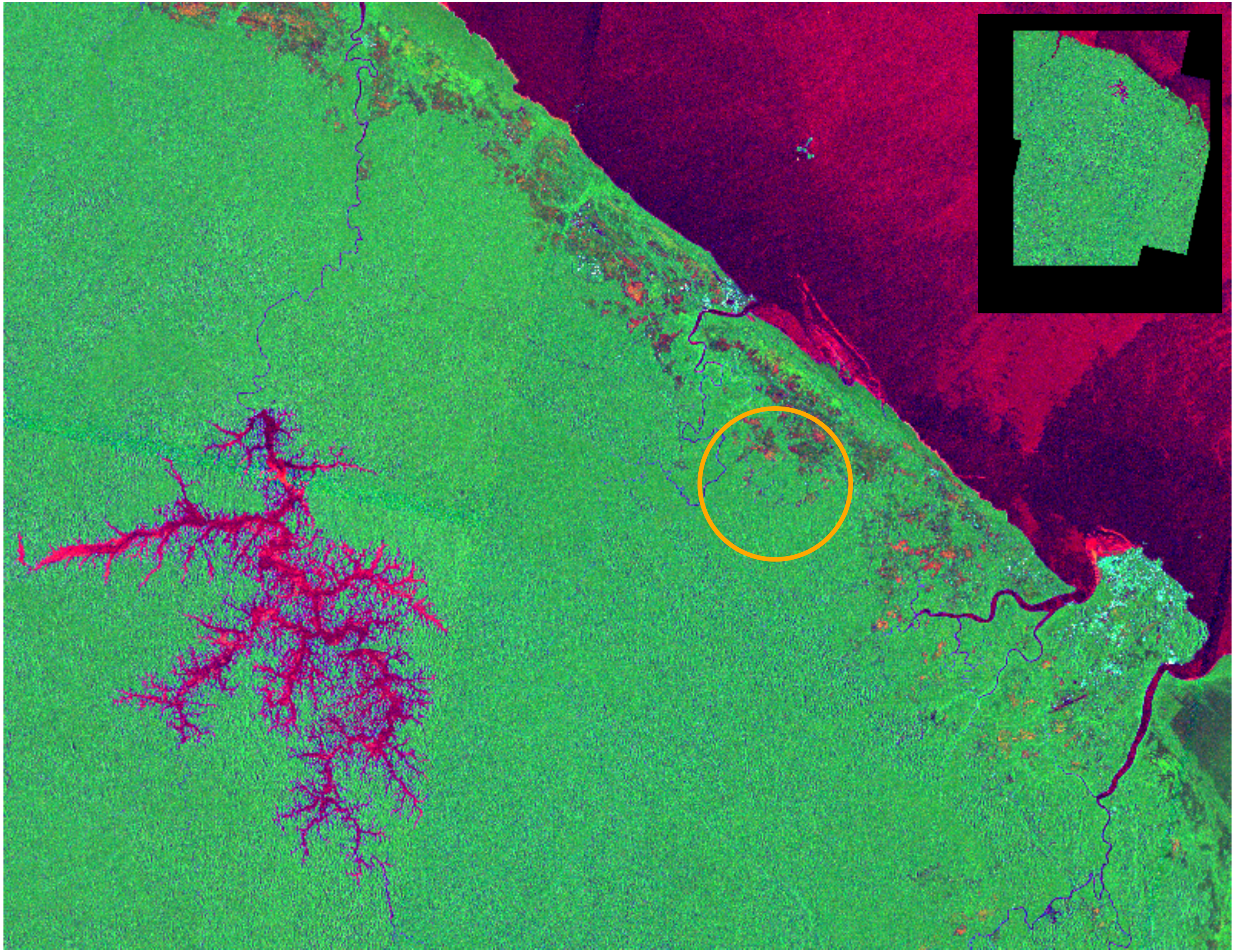


RGB: Temp. Var., Av. Amp., Av. Tex.

Forest and non forest in Amplitude / Variability space



Northern part of ASAR mosaic 2006-2007 of French Guiana

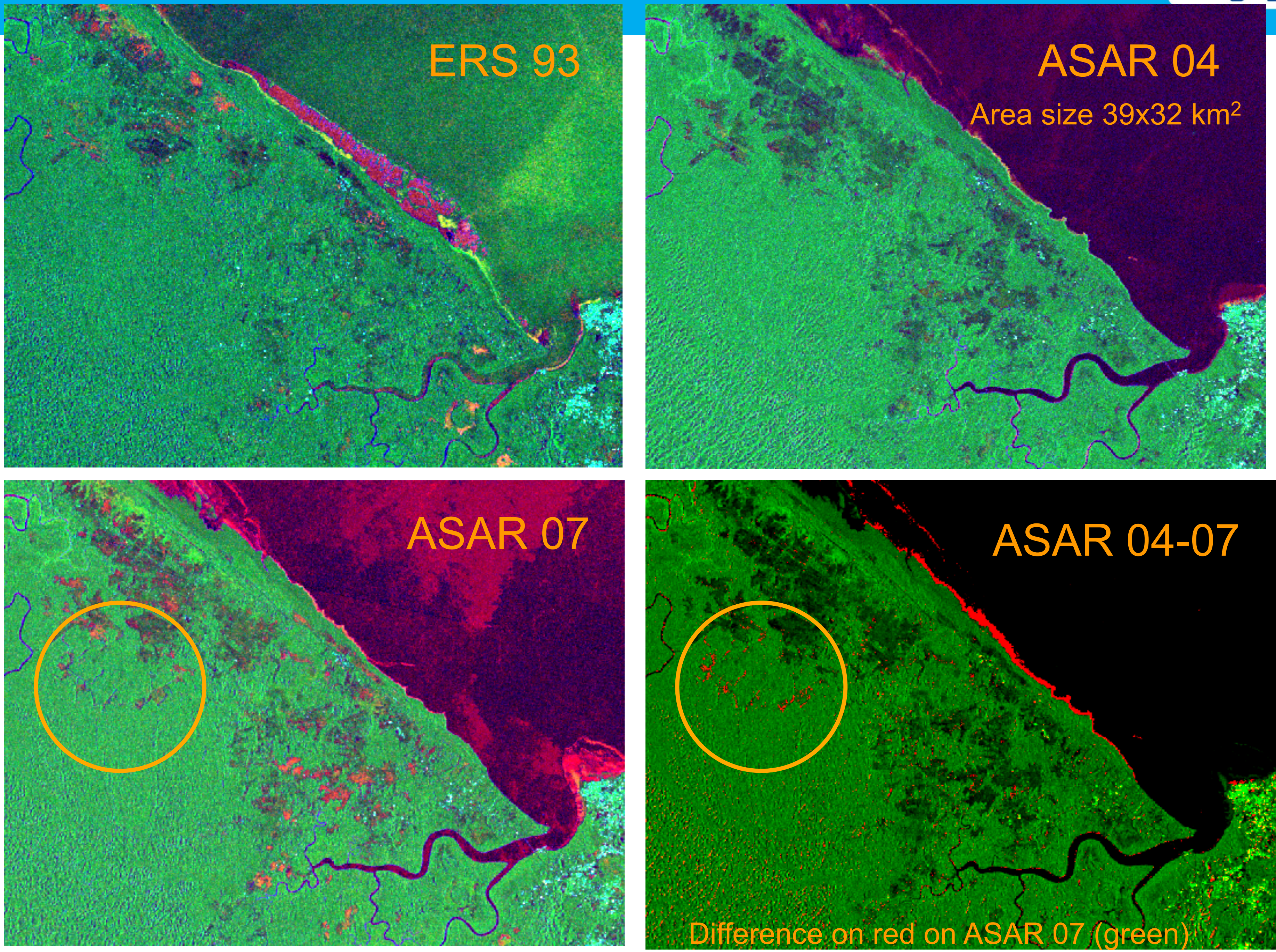


Red: temporal variability

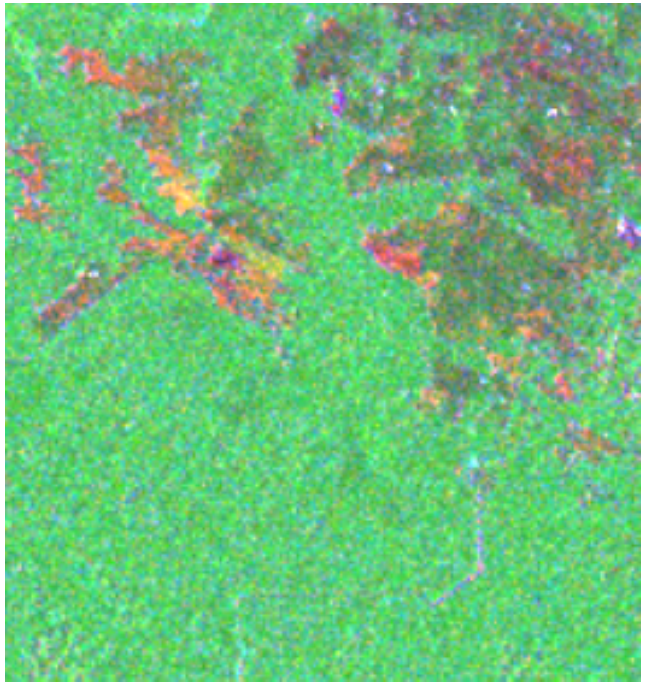
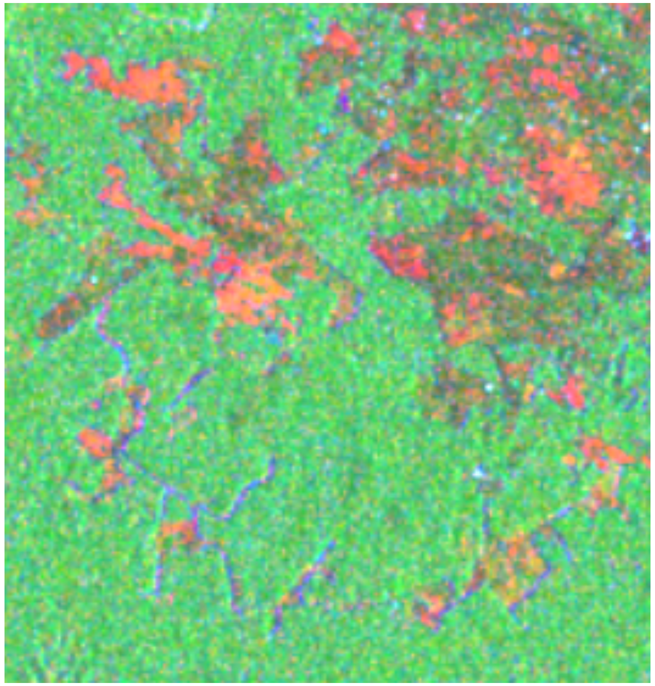
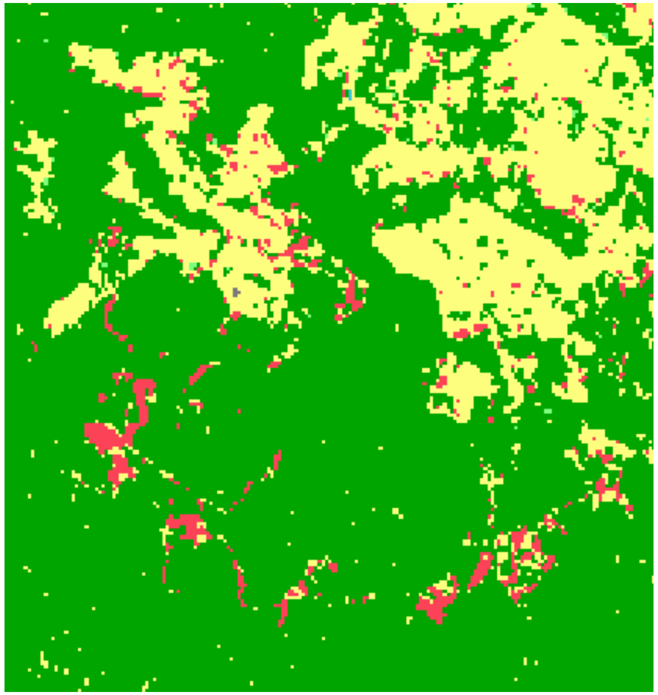
Green: Average amplitude

Blue: Average texture

Area size approximately 115 x 90 km^2

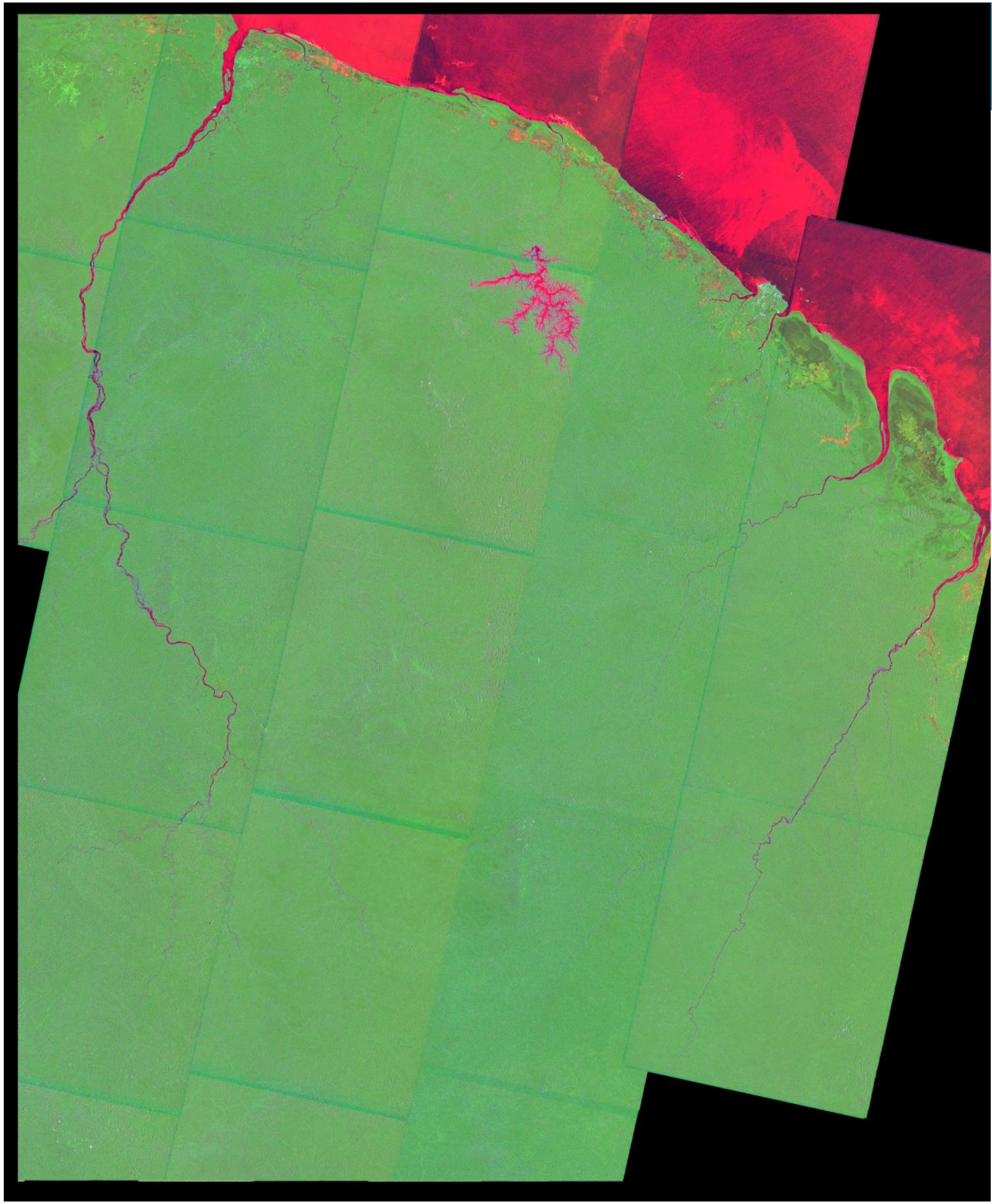

ERS 93
ASAR 04
Area size 39x32 km2
ASAR 07
ASAR 04-07
Difference on red on ASAR 07 (green)

A detail from the change classification

- On the left the mosaic 2003/2004, in the middle the mosaic 2006/2007 and on the right the change map
- Area size 9.5 km x 10 km
- Colors: green – forest/forest; yellow – non-forest/non-forest, red – forest/non-forest; grey- vegetation/water; light blue –water; white – water/water or outside region

Radar mosaic from French Guiana



- Purpose to support to fulfill the reporting obligations of the Kyoto Protocol
- Envisat ASAR images © ESA
- Processing VTT

Land cover and forest cover map from French Guiana

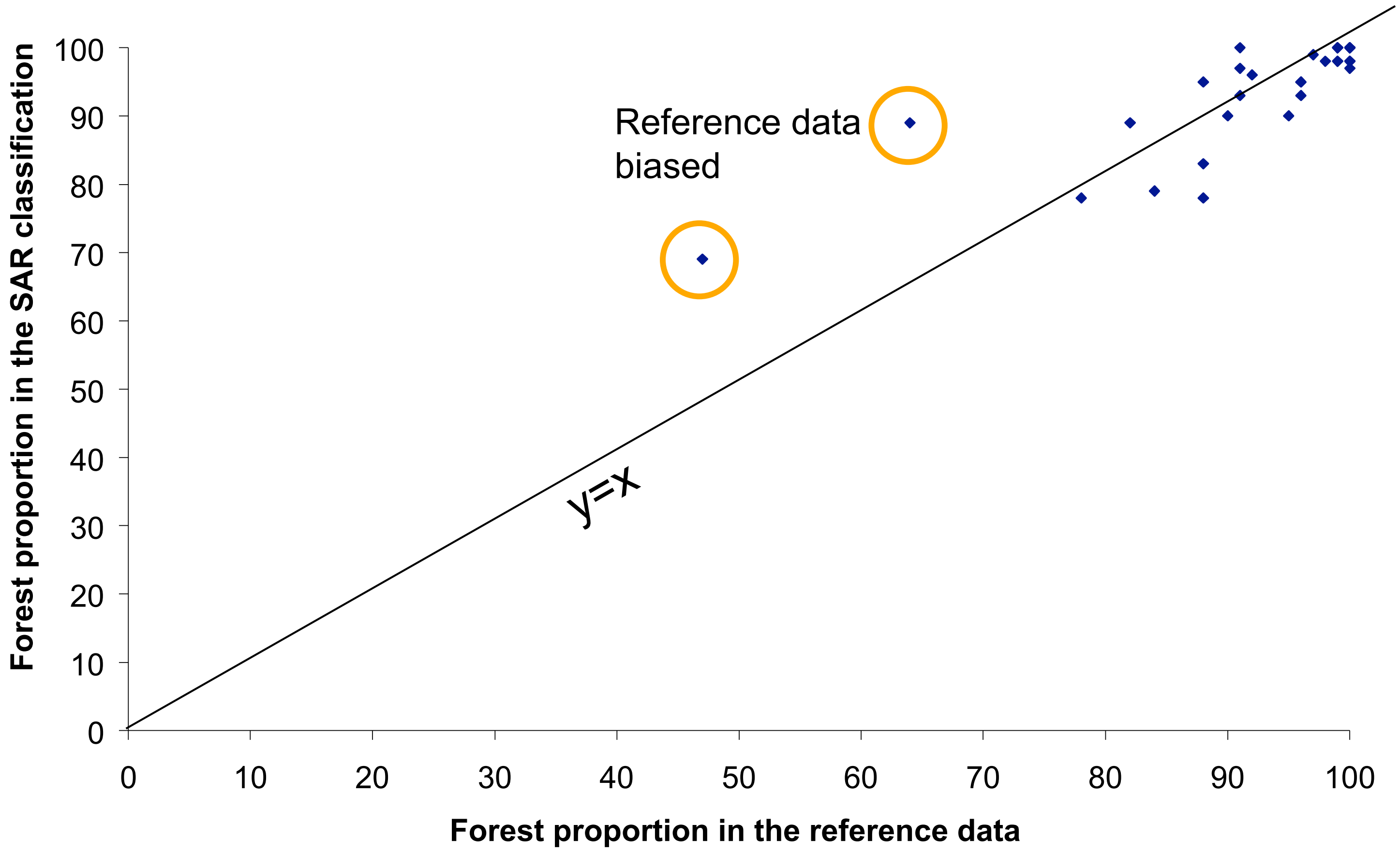
Colors:

- green – forest/forest;
- yellow – non-forest/non-forest,
- red – forest/non-forest;
- grey- vegetation/water;
- light blue –water;
- white – water/water or outside region

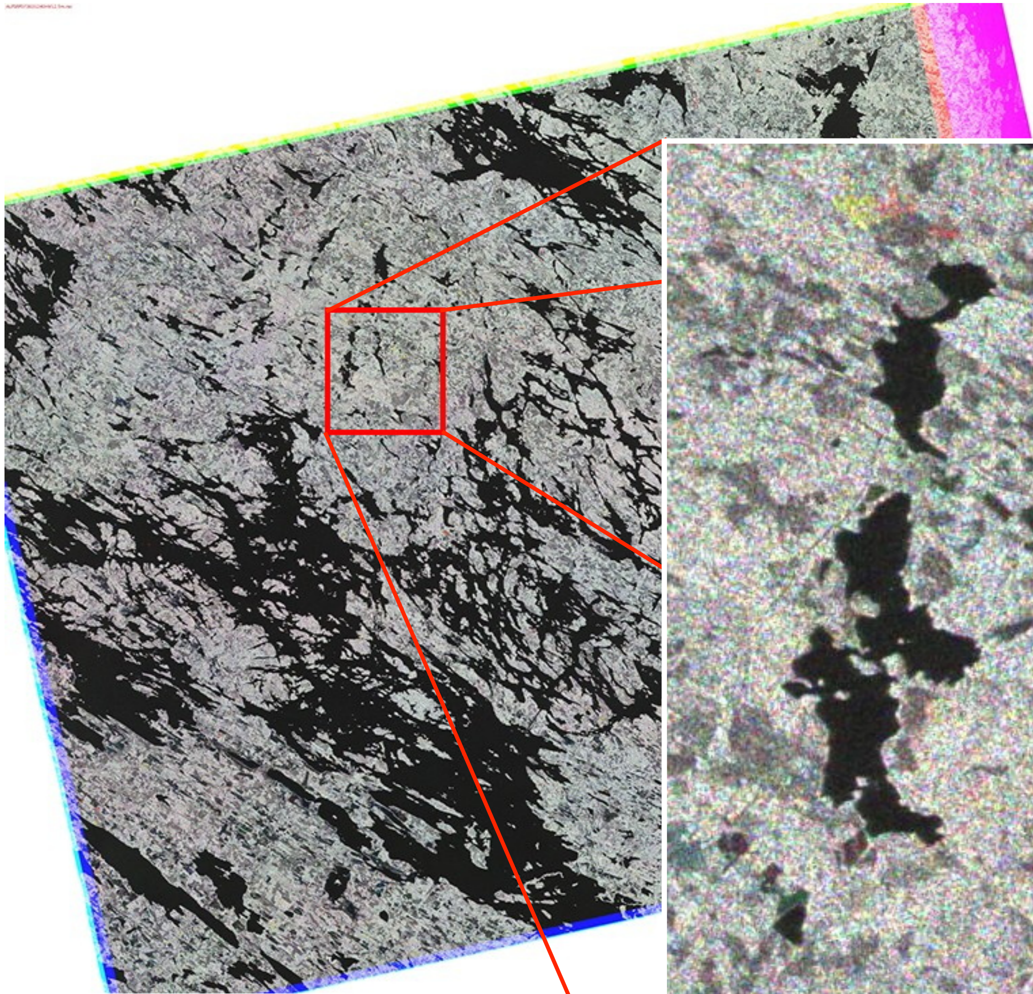
Envisat ASAR data from 2003/2004 and 2006/2007

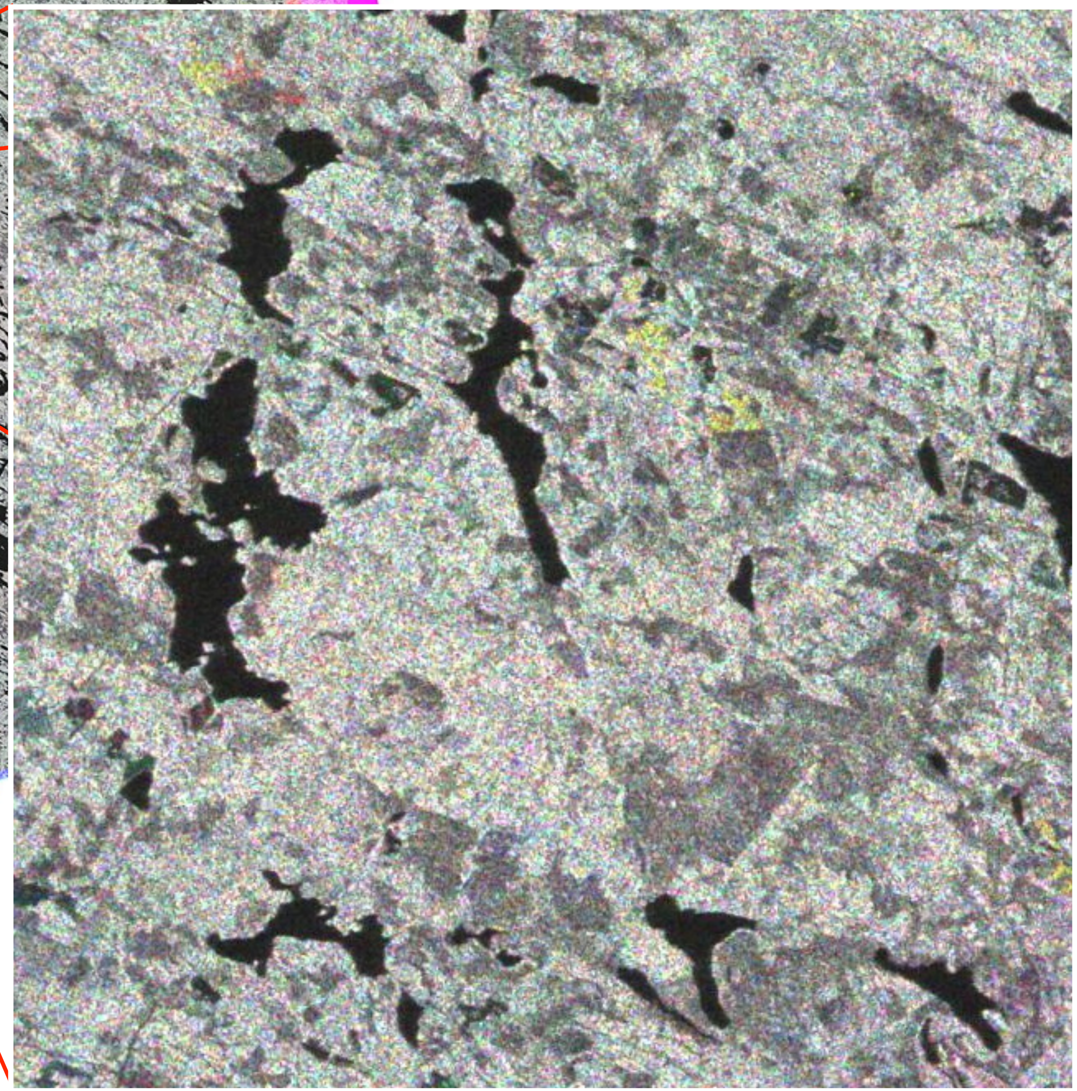
Comparison of forest areas within 45 km by 41.25 km rectangle

Rectangles with at least 50 ground plots are shown
35 rectangles in total.



ALOS/Palsar in Clear-Cut Mapping





R=20070612

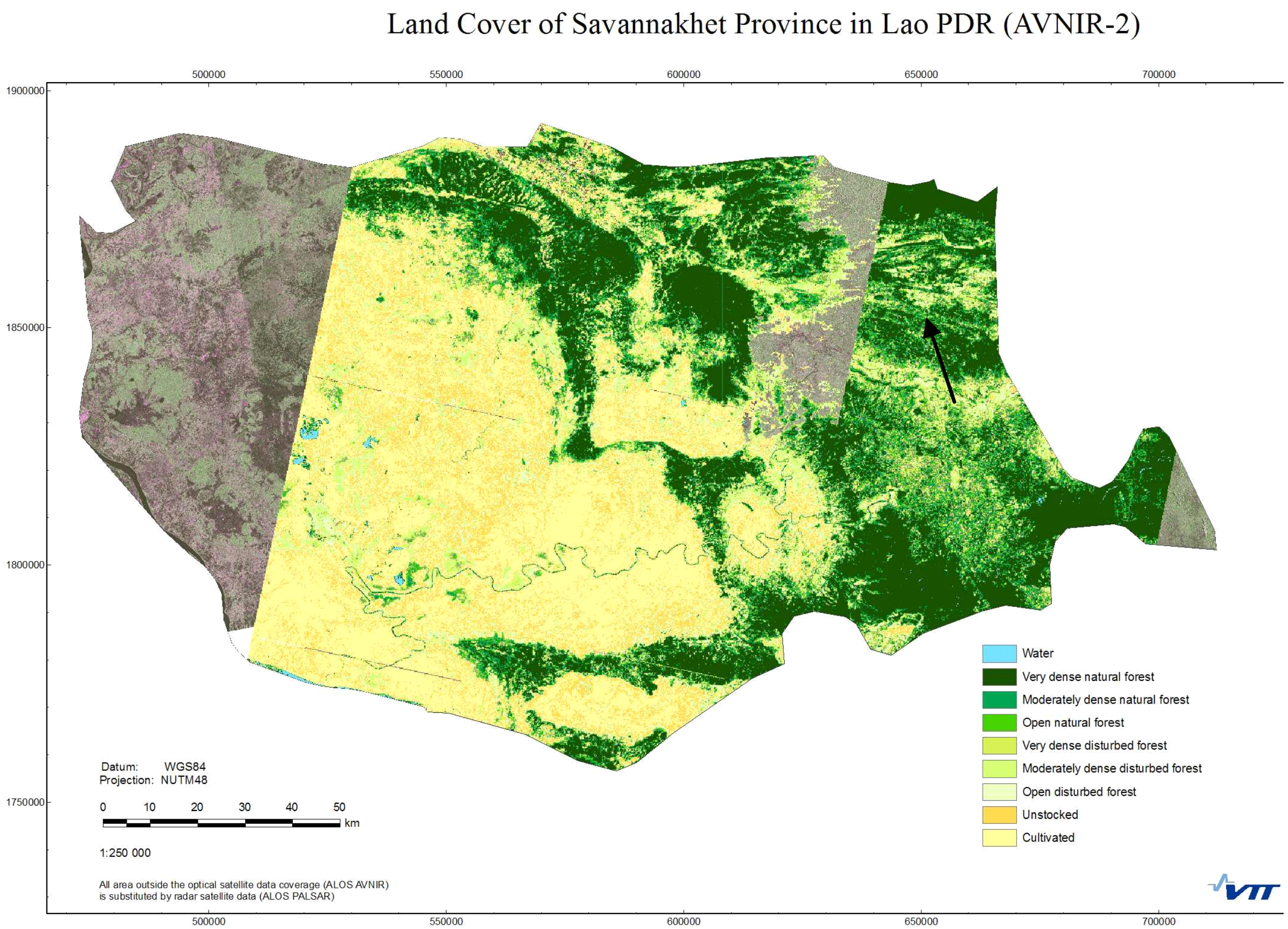
G=20070728

B=20070912

Yellow = logged 28.7.-12.9.

Red = logged 12.6.-28.7.

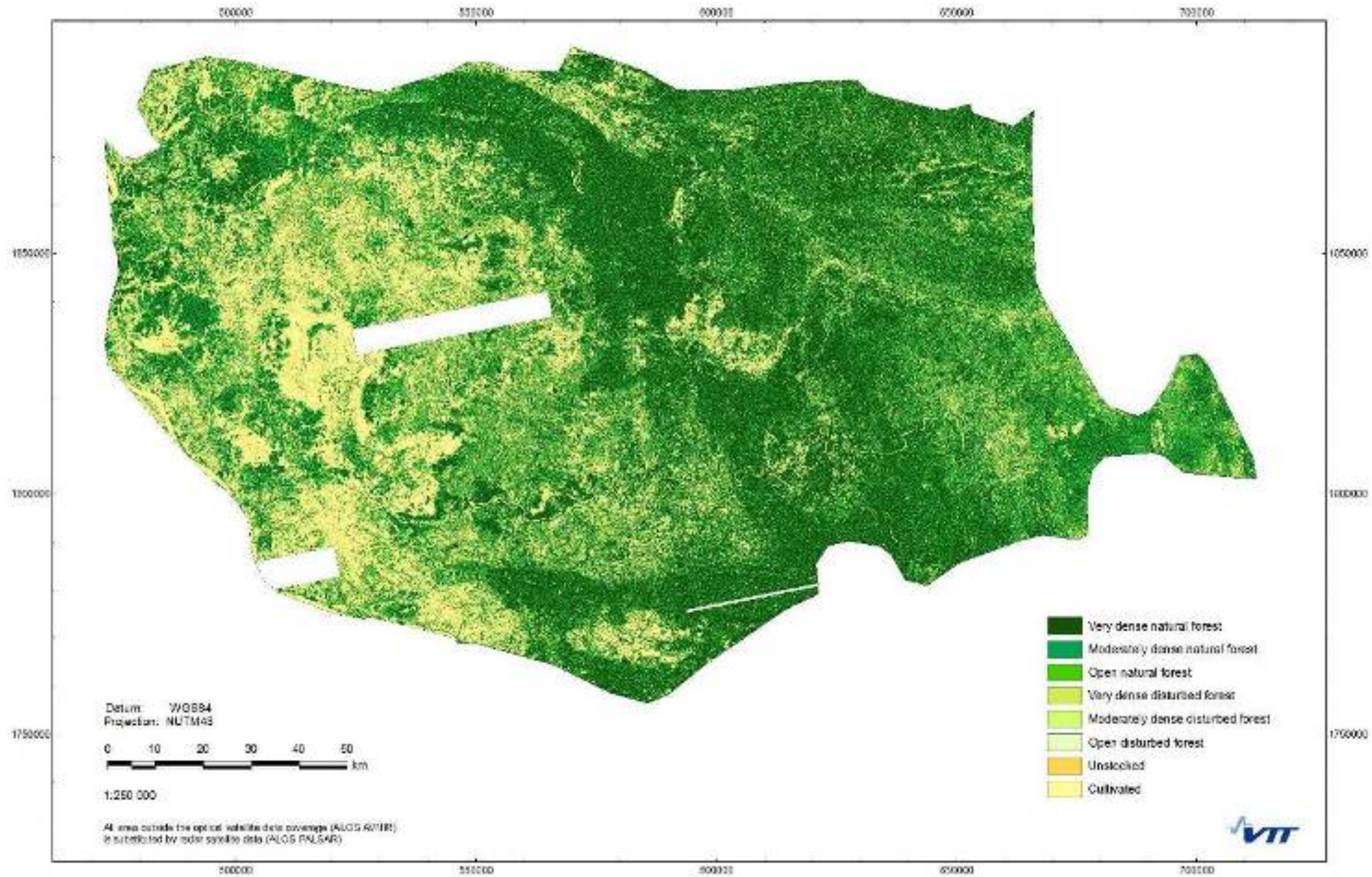
VTT, project NewSAR



Land cover map of Savannakhet province in Lao PDR from AVNIR optical image data. Missing image data are replaced by radar image

Source: Häme, Kilpi, Ahola, Rauste, Sirro 2009.LaosSilva final report, VTT

Land Cover of Savannakhet Province in Lao PDR (PALSAR)



Radar data tend to overestimate forest area

- Sensitivity to surface roughness

Figure 21. Land cover map of Savannakhet province in Lao PDR from PALSAR radar image data.

Actual biomass estimation

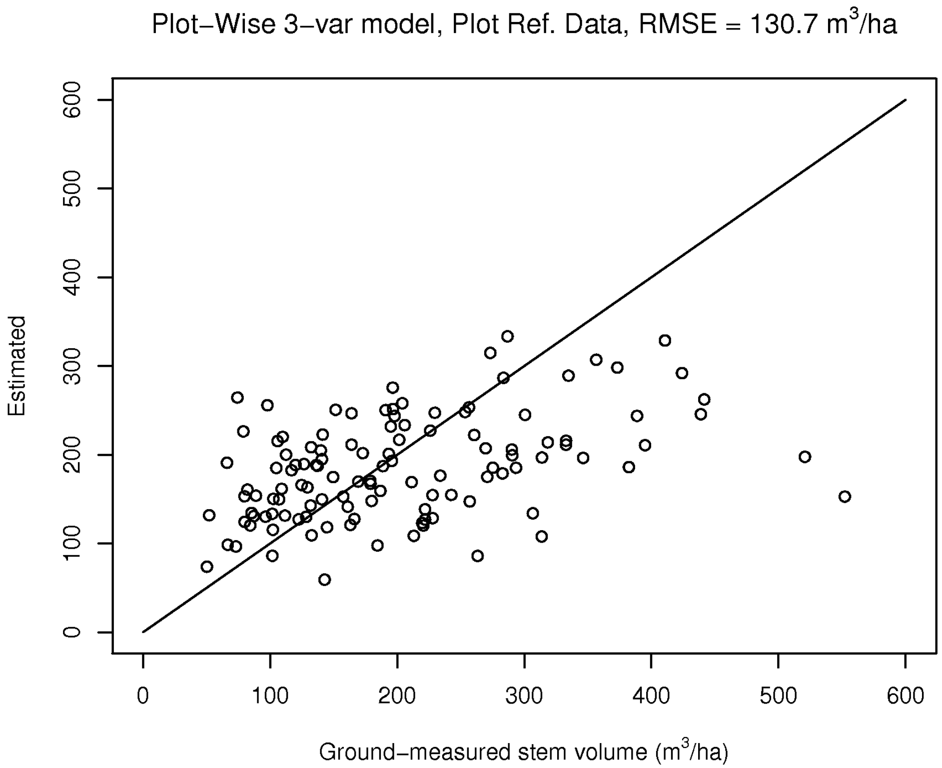
- Usually through growing stock volume because no reference data from the actual biomass available
- Regression analysis using ground stands or plots main method
- Probability method, k-nn
- Physical models – inversion
- Interferometry – tree height

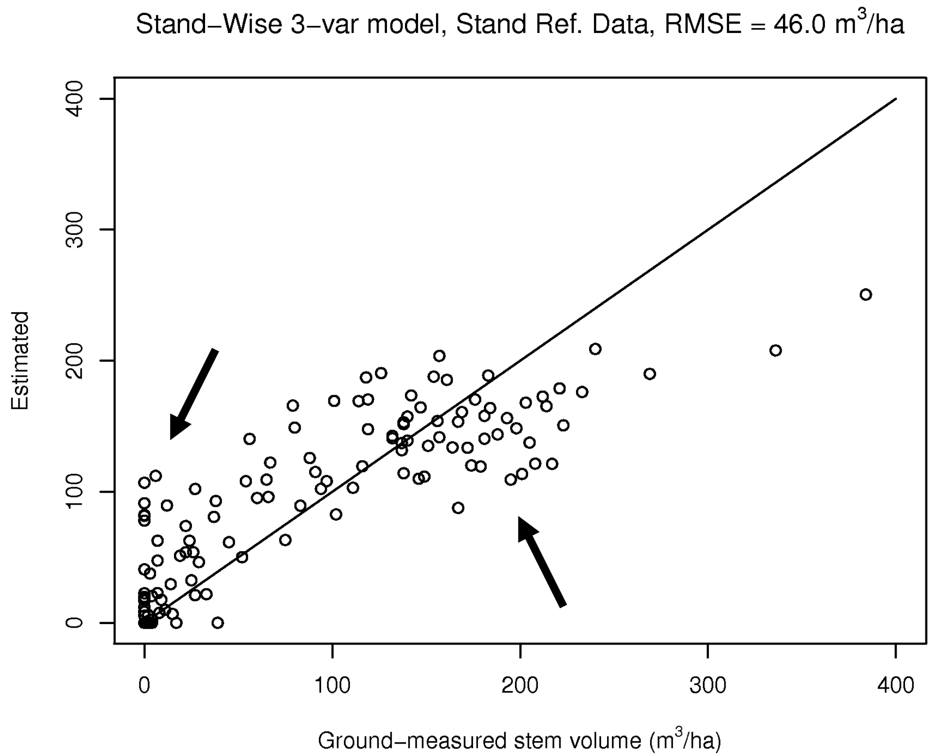
Plot-Wise Stem Volume

- Regression model derived with 95 plots
- Model tested with 119 reference plots
- Both training and testing plots were screened for visible SAR artefacts close to stand boundary
- Without manual screening for SAR artefacts, the RMSE (and R^2) was much worse

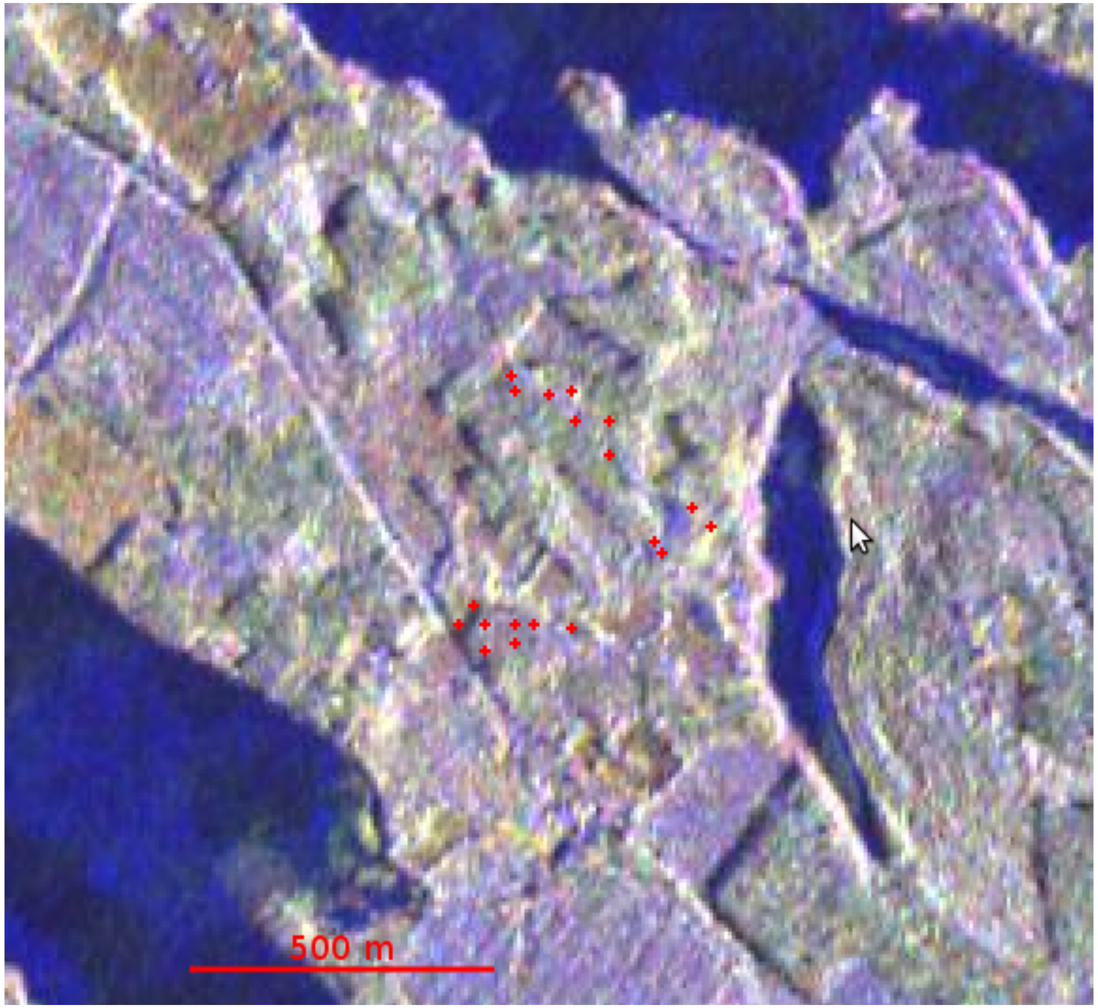
Stand-Wise Stem Volume

- Regression model derived with 128 stands
- Model tested with 127 reference stands
- R^2 computed for the reference stands was 0.70



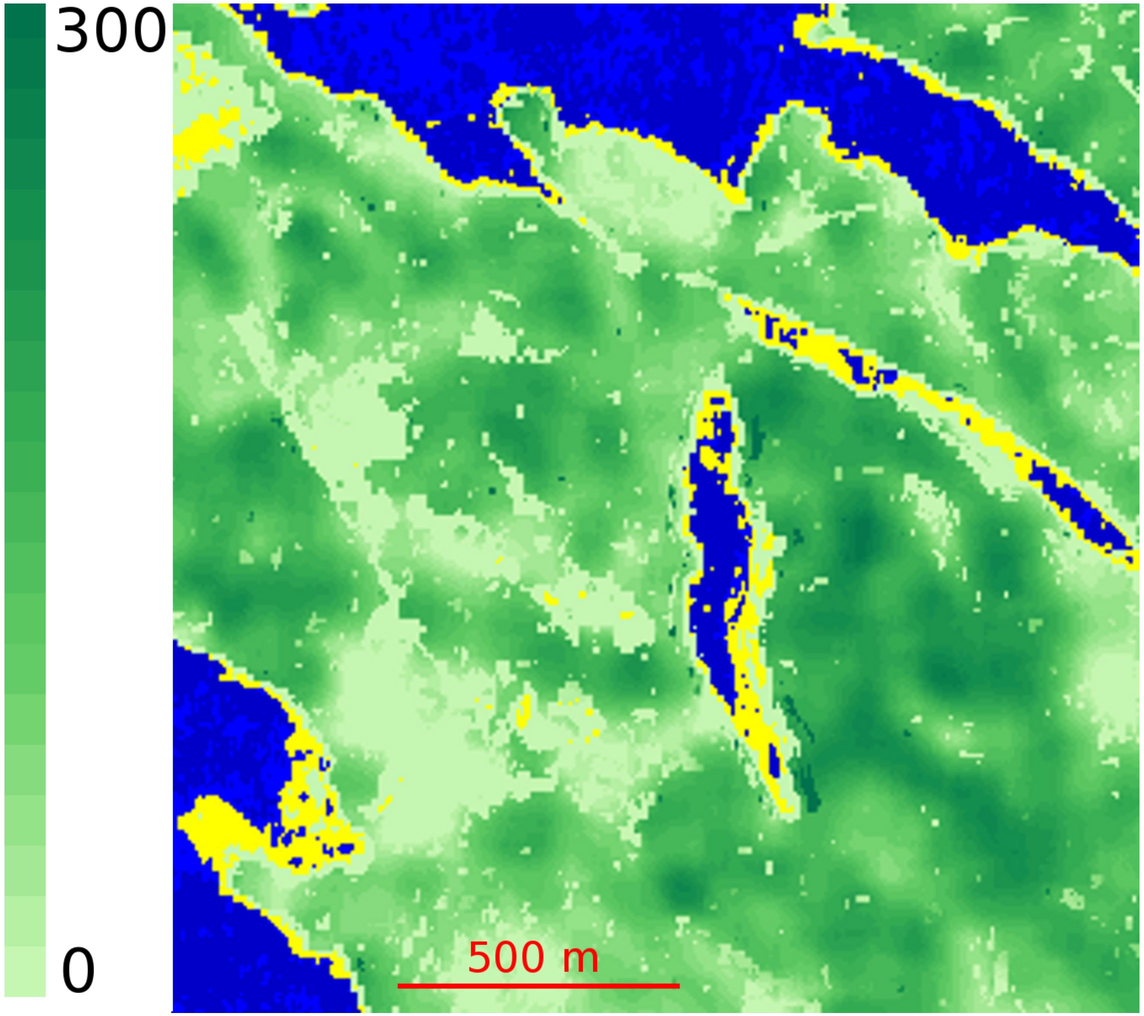


Sample Reference plots on TerraSAR-X Imagery



- Edge effects (some points clearly on a boundary of radar shadow area) give rise to noise in estimates
- If SAR amplitude is used to predict stem volume an extended area is needed to estimate the SAR amplitude in the noisy radar data
- Shadow and other anomalies produce high noise in the estimate
- TerraSAR-X data © InfoTerra GMBH 2009

A SAR-derived Stem Volume Map



- Ortho-rectified TerraSAR-X and ALOS/PALSAR data as input
- Smoothing only within the same or related class (blue = lakes, yellow = open areas)
- A regression model that was derived with stand-wise ground data was applied to the smoothed SAR data

Forest Biomass Mapping

- Strong correlation between biomass and radar backscatter intensity
- Longer wavelengths preferred
- Cross-polarisation (HV of VH) preferred over co-polarisations
- E.g. R^2 between stem biomass and radar backscatter[1]:
  - L-HH: 0.73
  - L-HV: 0.80
  - L-VV: 0.75
  - P-HH: 0.87
  - P-HV: 0.95
  - P-VV: 0.86
- Higher incidence angles (computed from surface normal) preferred

1)Results computed using low-biomass stands only

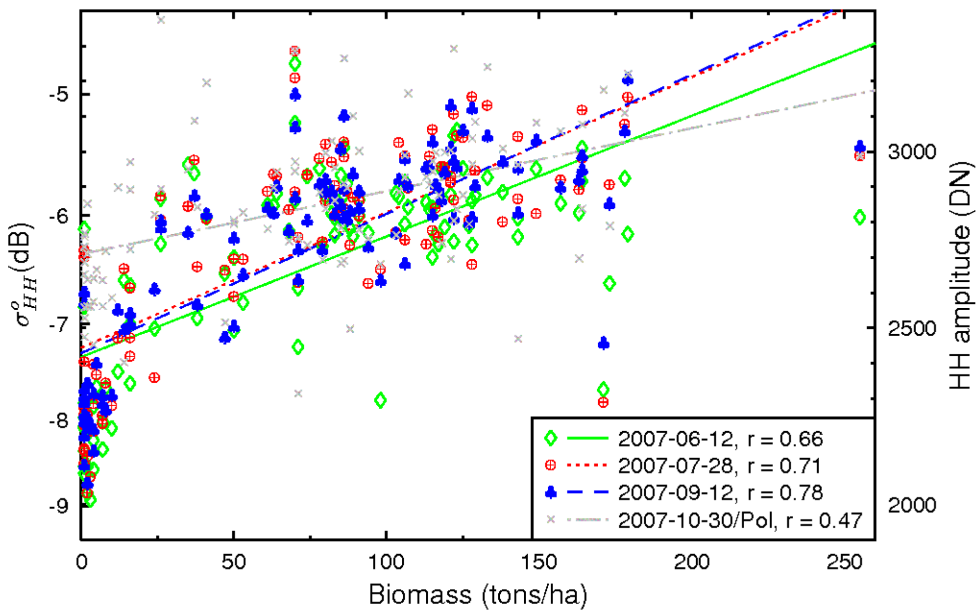
Le Toan, T., Beaudoin, A., Riom, J., and Guyon, D. 1992. Relating forest biomass to SAR data, IEEE Transactions on Geoscience and remote Sensing, Vol. 30, No. 2, p. 403-411.

Forest Biomass Mapping/Sample – L band[1]

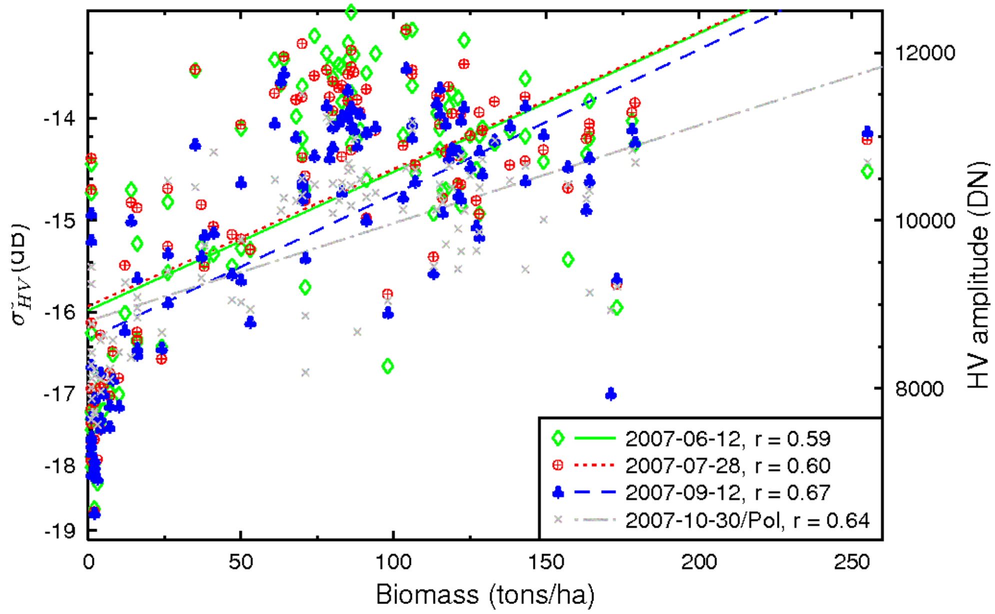
Scene	Polarisation	r	RMSE (tons/ha)
2007-06-12	HH	0.66	42.4
2007-06-12	HV	0.59	45.6
2007-07-28	HH	0.71	39.6
2007-07-28	HV	0.60	44.9
2007-09-12	HH	0.78	35.0
2007-09-12	HV	0.67	41.5
2007-10-30/Pol	HH	0.47	49.9
2007-10-30/Pol	HV	0.64	43.1
All of above	All	0.84	33.0

[1]Rauste, Y., Lönnqvist, A., Ahola, H., 2008. Mapping Boreal forest biomass with imagery from polarimetric and semi-polarimetric SAR sensors, Ambiencia, Vol. 4, Edicao Especial 2008, ISSN 1808-0251, p. 171-180.

Palsar/Heinavesi, HH Amplitude as a Function of Forest Biomass



Palsar/Heinavesi, HV Amplitude as a Function of Forest Biomass



Forest Biomass Mapping/Saturation

- The biomass-radar correlation saturates at a biomass level depending on radar wavelength
- Saturation limits from a combined boreal-temperate-tropical global dataset[1]:
- C-band: 20 tons/ha
- L-band: 40 tons/ha (≈ 66.7 m^3/ha stem volume in boreal forest)
- P-band: 100 tons/ha
- In coniferous study sites, L-band saturation much higher: 85.8[2] tons/ha (143 m3/ha), 72[3] tons/ha (120 m^3/ha), or 100[4] tons/ha (167 m^3/ha, HH and HV)

[1]Imhoff, M. 1995. Radar backscatter and biomass saturation: Ramifications for global biomass inventory, IEEE Transactions on Geoscience and Remote Sensing, 33(2), p. 511-518.
[2]Fransson, J. and Israelsson, H. 1999. Estimation of stem volume in boreal forests using ERS-1 C- and JERS-1 L-band SAR data, International Journal of Remote Sensing, 20(1), p. 123-137.
[3]Rauste, Y., Häme, T., Pulliainen, J., Heiska, K., and Hallikainen, M. 1994. Radar-based forest bio-mass estimation, International Journal of Remote Sensing, 15, p. 2797-2808.
[4]Watanabe, M., Shimada, M., Rosenqvist, Å., Tadono, T., Matsuoka, M., Romshoo, S., Ohta, K., Furuta, R., Nakamura, K., and Moriyama, T. 2006. Forest structure dependency of the relation between L-band σ^o and biophysical parameters, IEEE Transactions on Geoscience and Remote Sensing, 44(11), p. 3154-3164.

Conclusions

- Present space borne radar instruments with L band have approximately the same potential in biomass estimation as Landsat or Spot type optical data (20 – 30 m resolution)
- Biomass saturation point in boreal forest at about 200 m3/ha or 140 t/ha if not lower
- The longer the wavelength (the lower the frequency) the better
- A digital elevation model (DEM) is needed for geo-coding and radiometric correction
- Main use to augment optical data in cloudy regions – tropical areas – many parts of boreal forest
- Through improved land cover classification (seasonal information) potential to improve biomass mapping
- Inherent speckle noise reduces effective ground resolution
- Visual image interpretation has a bigger role than with optical data
- Topographic and surface roughness variations challenge image analysis

*Rauste, Y., Astola, H., Ahola, H., Häme, T., and von Poncet, F. 2010. Dual-band radar estimation of stem volume in Boreal forest, Proceedings of the ESA Living Planet Symposium, Bergen, Norway, 28.6.-2.7.2010, in press.

VTT creates business from technology