

The background is a solid blue color with a pattern of faint, light blue geometric shapes, including rectangles and lines, and small arrows pointing in various directions. The main title is centered in white, bold text.

# Forest monitoring system by combining wall-to-wall and a sample of VHR imagery

Tuomas Häme



## Challenge

- Forest maps and reliable statistical data with known confidence intervals needed
- Wall-to-wall mapping presently is using medium resolution data - Map reliability estimation without accurate reference data difficult
- Ground reference data difficult and costly to collect

## Suggested solution

- System that combines different data sources to produce maps with statistical accuracy information
- The system concept is based on the experiences from a ESA GMES Service Element project in French Guiana\*
- It is presently further developed and tested in Lao PDR as part of project SUFORD (SUstainable FOrestry and Rural Development)

\*Häme, T., Rauste, Y., Sirro, L., Stach, N. 2009. Forest Cover Mapping in French Guiana since 1992 Using Satellite Radar Imagery. ISRSE 33 Proceedings.

\*Project funding ESA, coordination GAF AG, French Guiana service providers VTT & IFN

## Results of forest mapping in French Guiana

- Forest cover monitoring from early 1990's until 2006 using radar data
- Purpose to support to fulfill the reporting obligations of the Kyoto Protocol

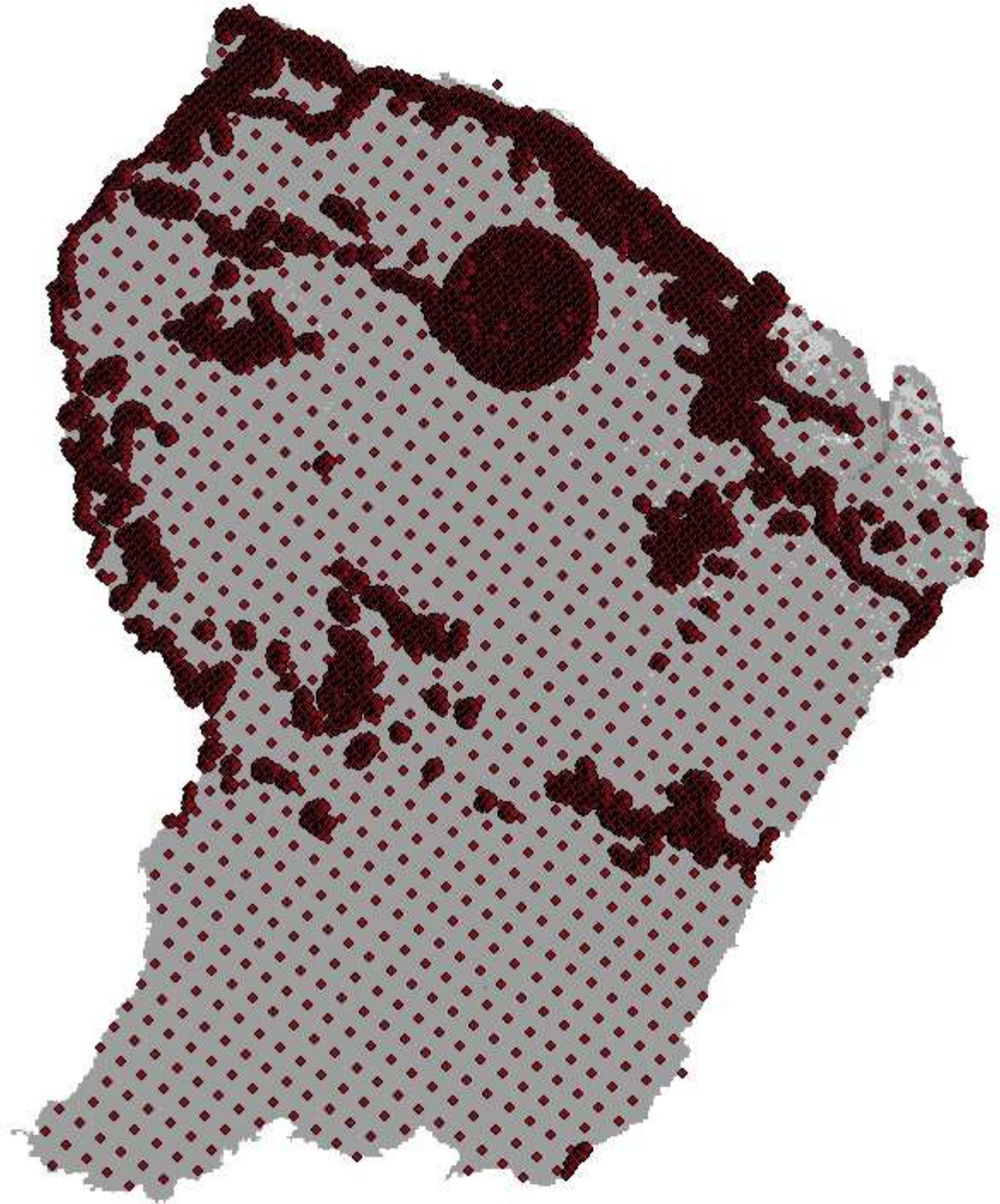
## Data

- C-band VV polarization (wavelength 6 cm, frequency 5.3 GHz) Synthetic Aperture Radar (SAR) images
  - ERS SAR 1992-1993
  - Envisat ASAR 2003-2004 and 2006-2007
- Digital Elevation Model from Shuttle Radar Topography Mission (SRTM) of 90 m pixel size
- Reference data: sample of 16787 points located at optical satellite imagery and visually interpreted by Inventaire Forestier National (IFN) (Stach et al., 2007)
  - Reference years 1990 and 2006
  - One half for class labeling the other half for validation

## SAR data

Satellite & instrument	Year of acquisition	No. of images	Incid. angle, degrees
ERS AMI	1992-1993	60	23
Envisat ASAR	2003-2004	107	33
Envisat ASAR	2006-2007	122	33

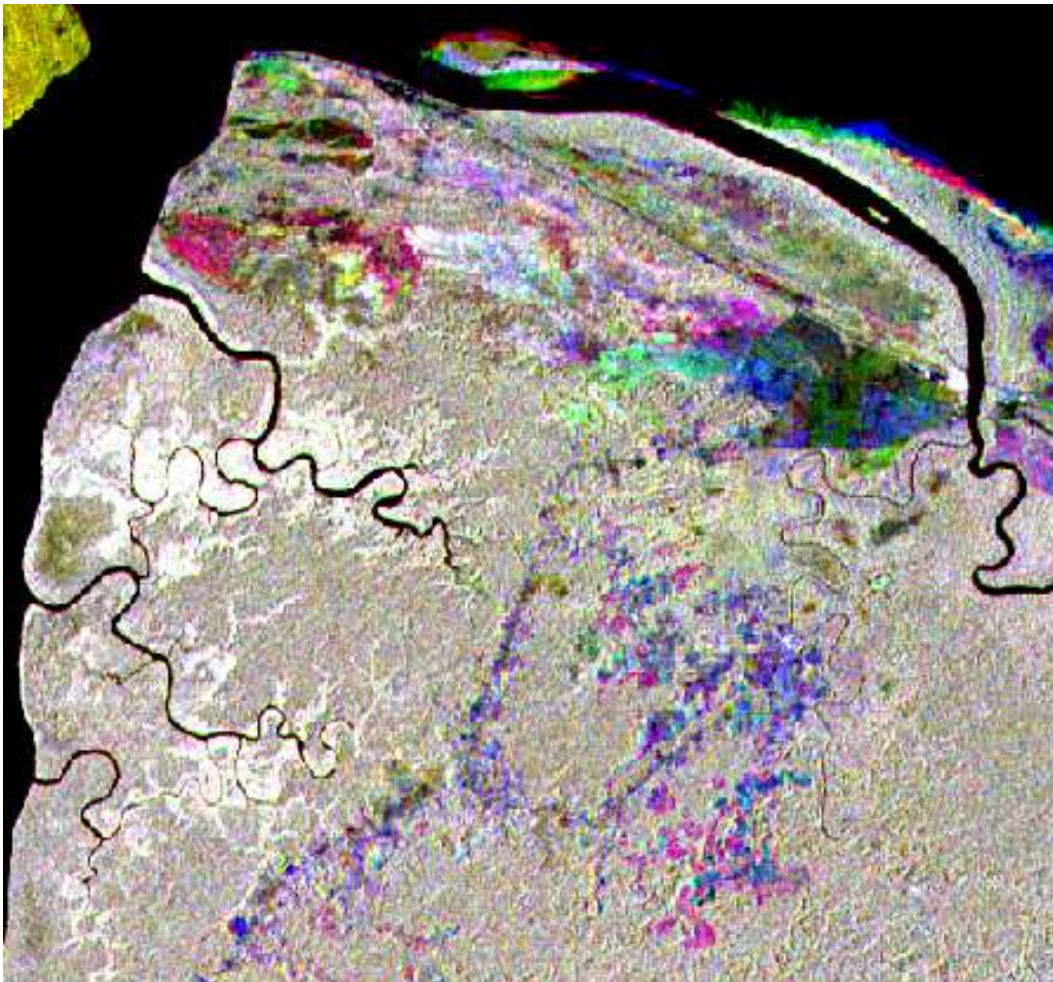
Locations of reference sample plots evaluated from Landsat and Spot satellite data using visual interpretation



## Radar mosaic from French Guiana; radiometry and geometry corrected using DEM

- Envisat ASAR images © ESA
- Processing VTT

## Color composite of three average back-scattering features from the northwest part of Guiana



- Area size 28 km by 26 km

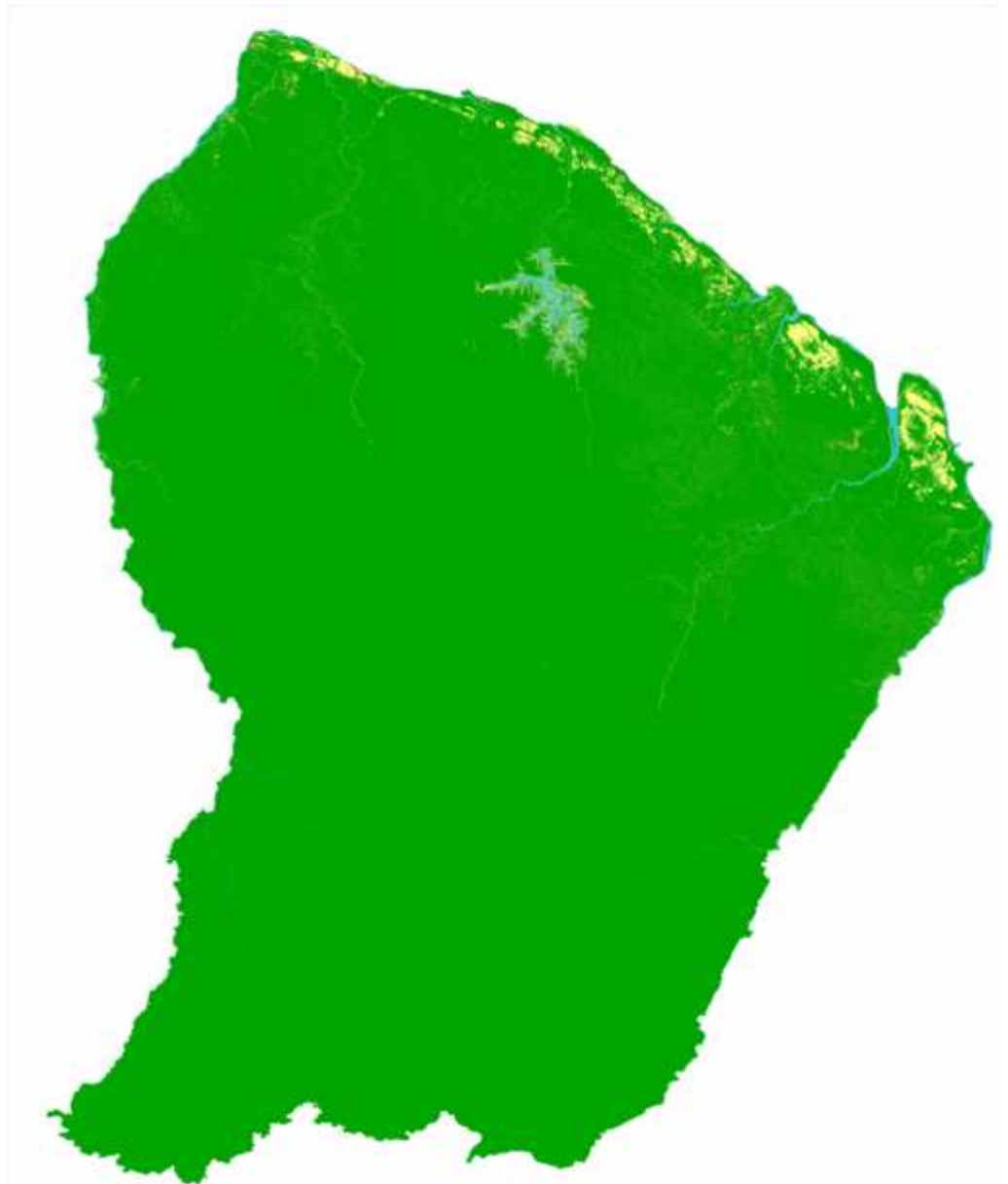
### Channels

- 2003 red
- 2006 green
- 1993 blue

## Land cover and forest cover map from French Guiana including change 2003/2004 – 2006/2007

### 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

## Proportions of classes in the SAR classifications and reference data

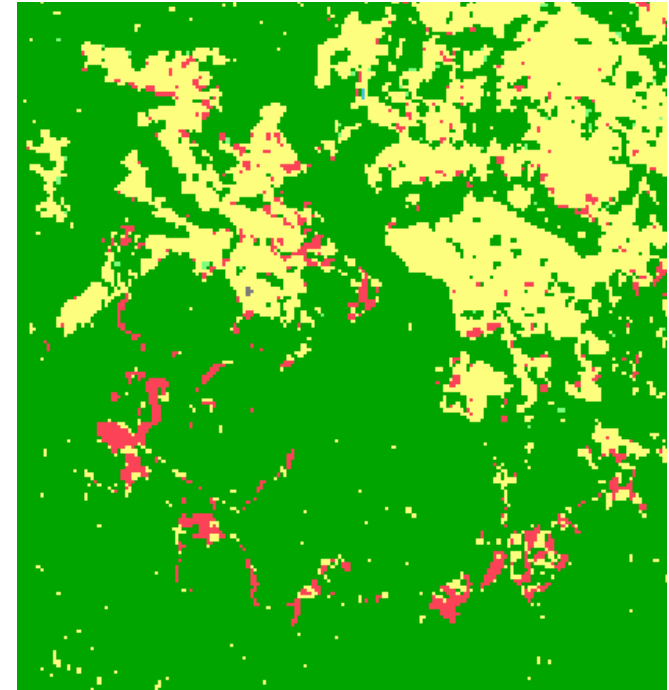
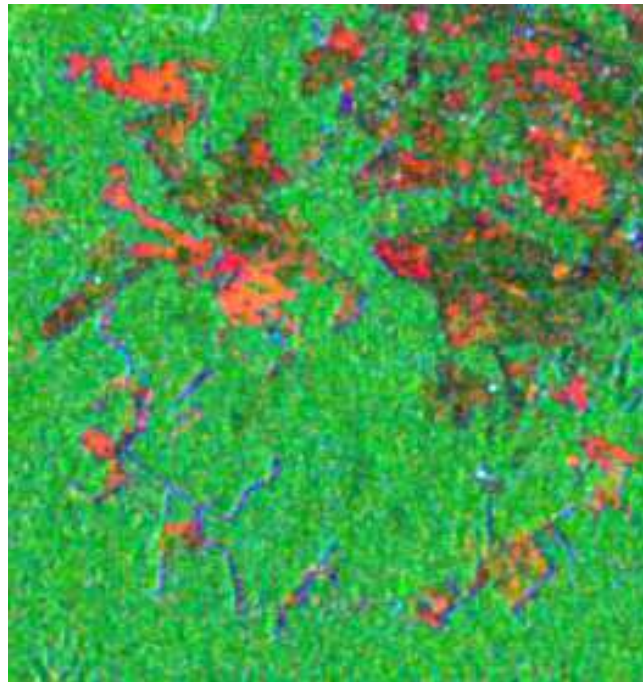
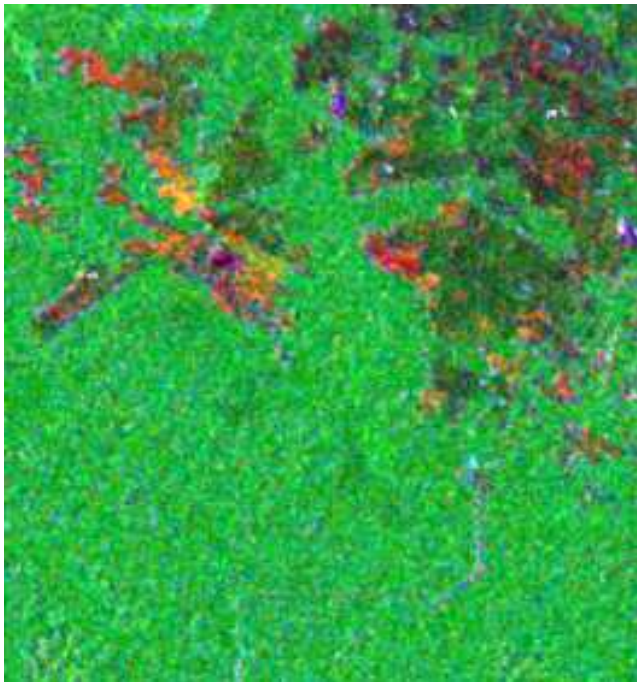
Data set	Forest	Water	Other non-forest
SAR 1993	97.1	0.6	2.3
Ref. ~1990	97.5	0.8	1.7
SAR 2003	96.6	1.0	2.4
SAR 2006	96.8	0.8	2.4
Ref. 2006	96.4	1.3	2.3

Forest area decrease very small

Reference data: decrease from 1990 until 2006 1.1 %

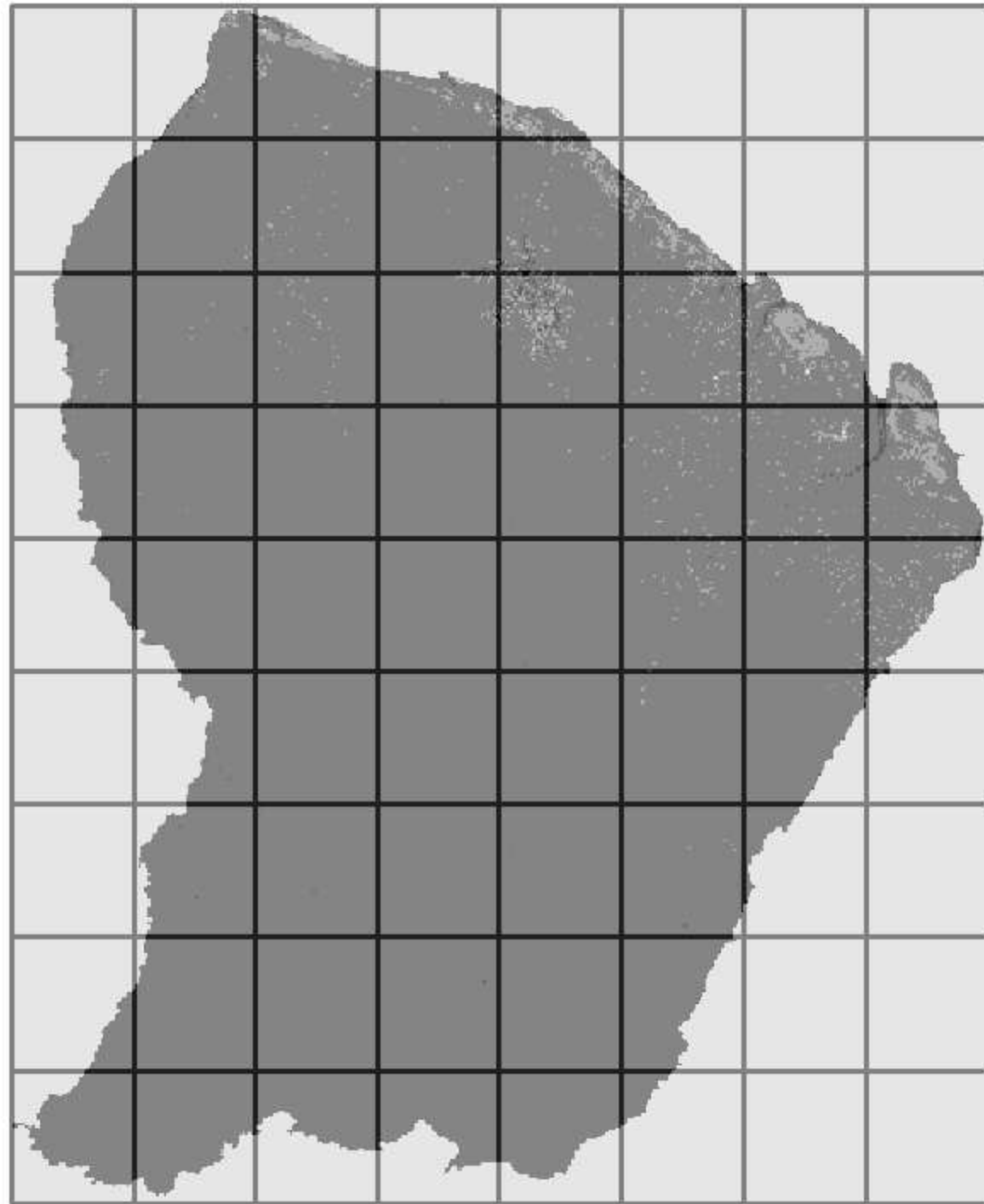
SAR classification: 0.3 %

## A detail from the change classification



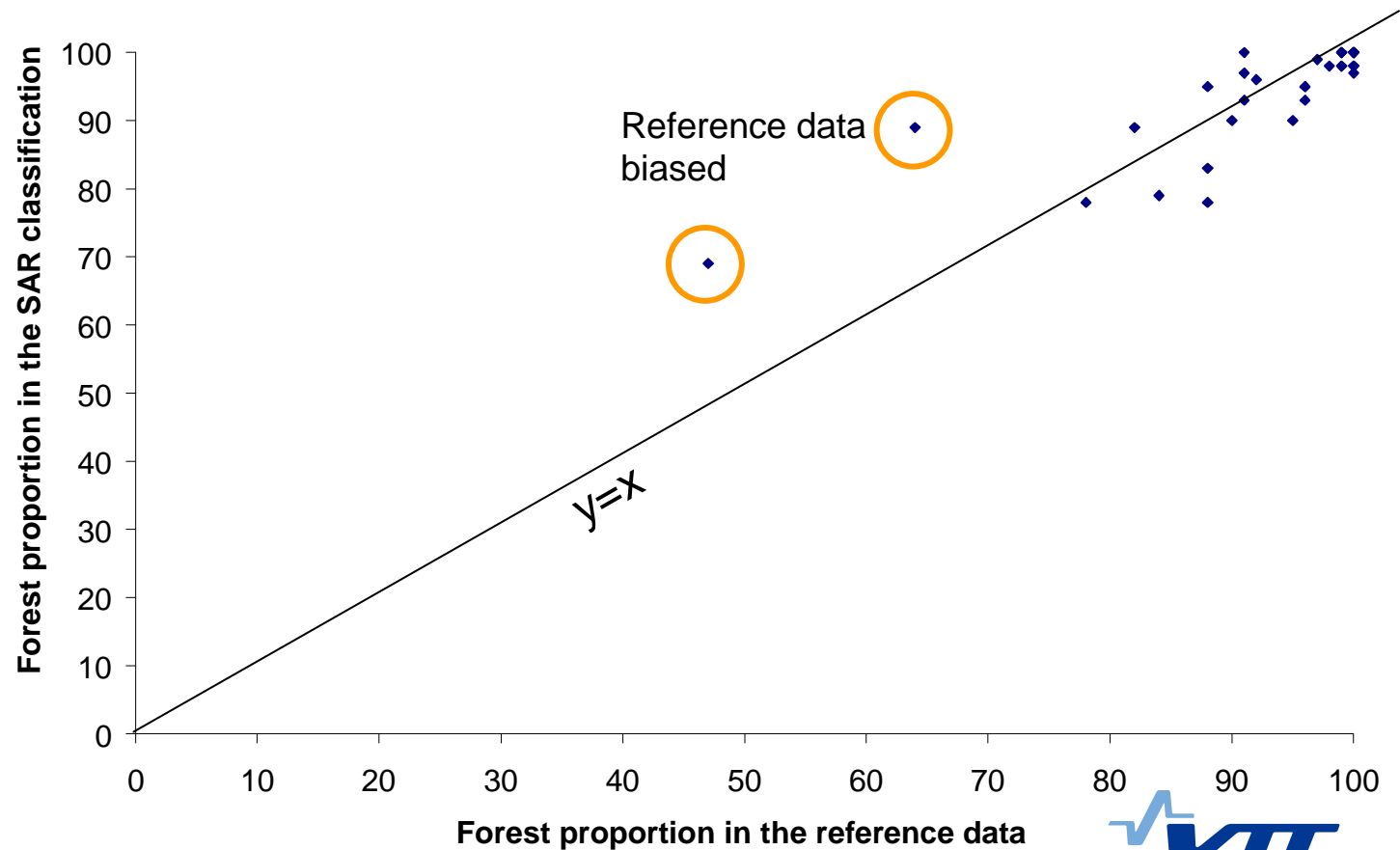
- On the left the mosaic 2003/2004, in the middle the mosaic 2006/2007 and on the right the change map
- Area size 9.5 km x 10 km
- Colors: green – forest/forest; yellow – non-forest/non-forest, red – forest/non-forest; grey- vegetation/water; light blue –water; white – water/water or outside region

45 km by 41.25 km  
rectangles for comparing  
forest areas



## 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.



## Conclusions from French Guiana mapping

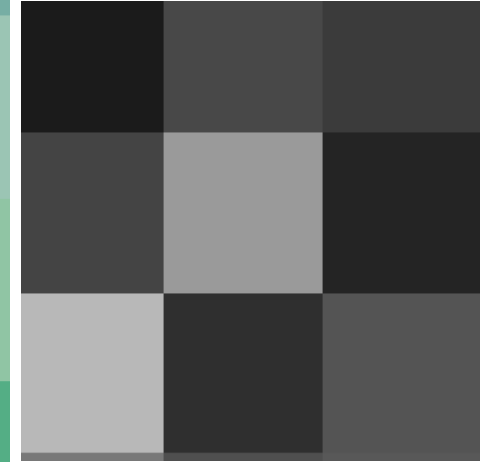
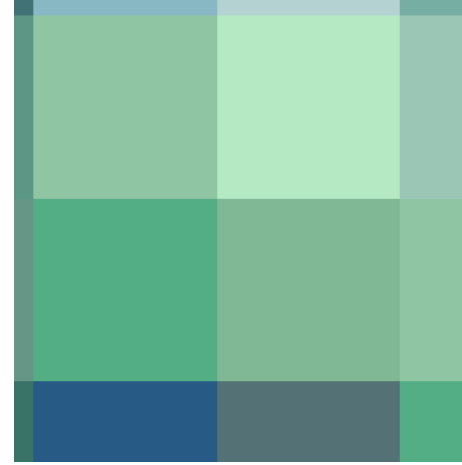
- C-band SAR applicable for forest cover monitoring considering the limitations
  - speckle noise, spatial resolution, high frequency (short wavelength)
  - Would require more accurate DEM than what was available
- Can not be recommended as exclusive remote sensing data, but
  - alert about change occurrence
  - mapping when the changed area size has a significant size
- For the future a multi-resolution approach is proposed:
  - sample of very high resolution (in the order of 0.5 m) optical satellite imagery
  - wall-to-wall SAR (or optical with medium resolution)
  - field plots

# Different images from the same location

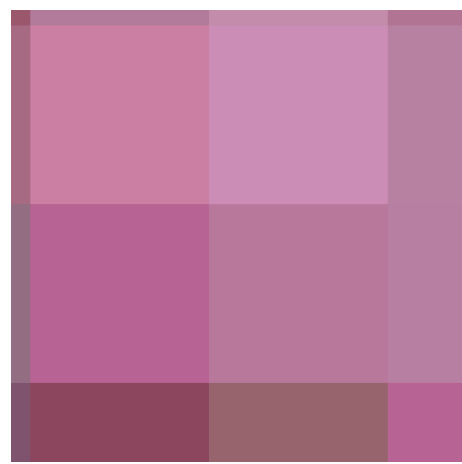
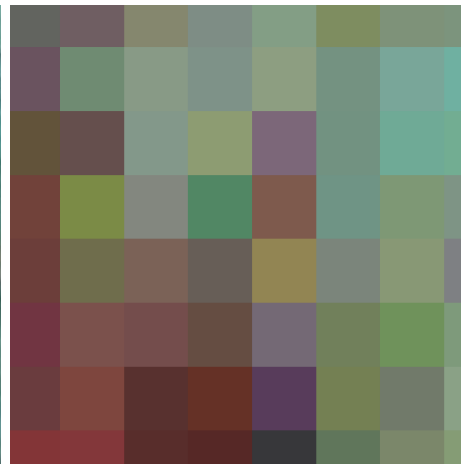
Image size 70 m x 70 m

PALSAR, HV-polarization

Natural color



Color infrared



Quickbird-2  
0.5 meter resolution

AVNIR-2  
10 meter resolution

Landsat-5 (GeoCover)  
30 meter resolution

Kompsat-2 (another location)

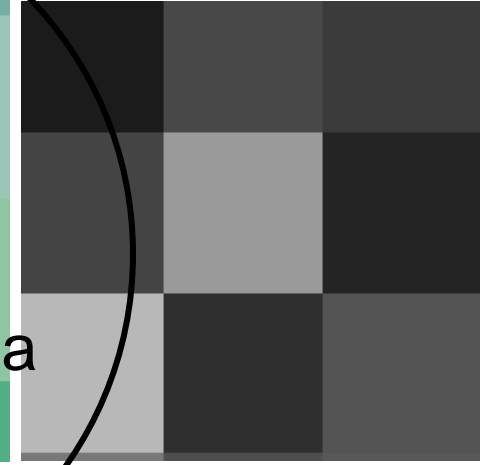
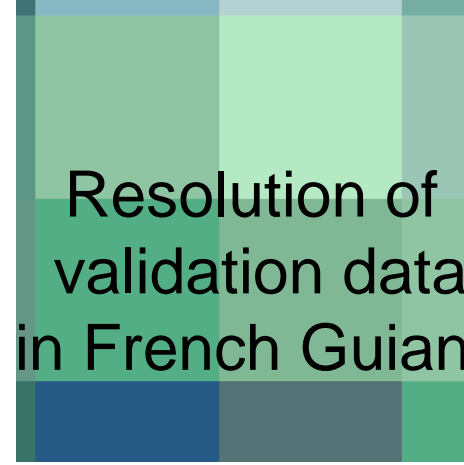


## Proposed inventory concept

# Different images from the same location

Image size 70 m x 70 m

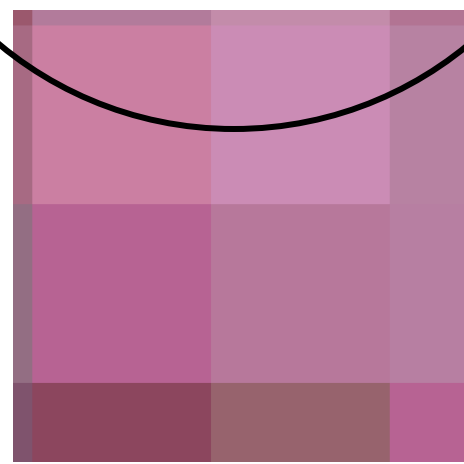
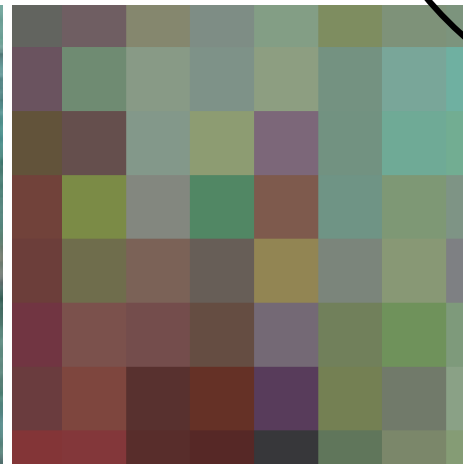
Natural color



PALSAR, HV-polarization

Resolution of validation data in French Guiana

Color infrared



Quickbird-2  
0.5 meter resolution

AVNIR-2  
10 meter resolution

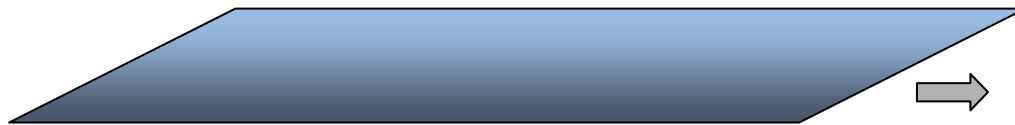
Landsat-5 (GeoCover)  
30 meter resolution

Kompsat-2 (another location)

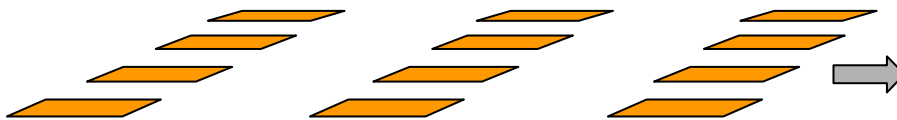


## Information from different data sources

"Wall-to-wall" radar satellite data  
- medium to low resolution



Sample of very high resolution images



Ground measurements



Statistical data and map data of limited number of variables

Statistical data of high number of variables

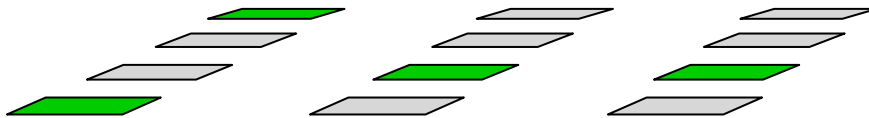
Statistical data and map data of high number of variables

## Phase 1: Map of subsample of VHR images

"Wall-to-wall" radar satellite data  
- medium to low resolution



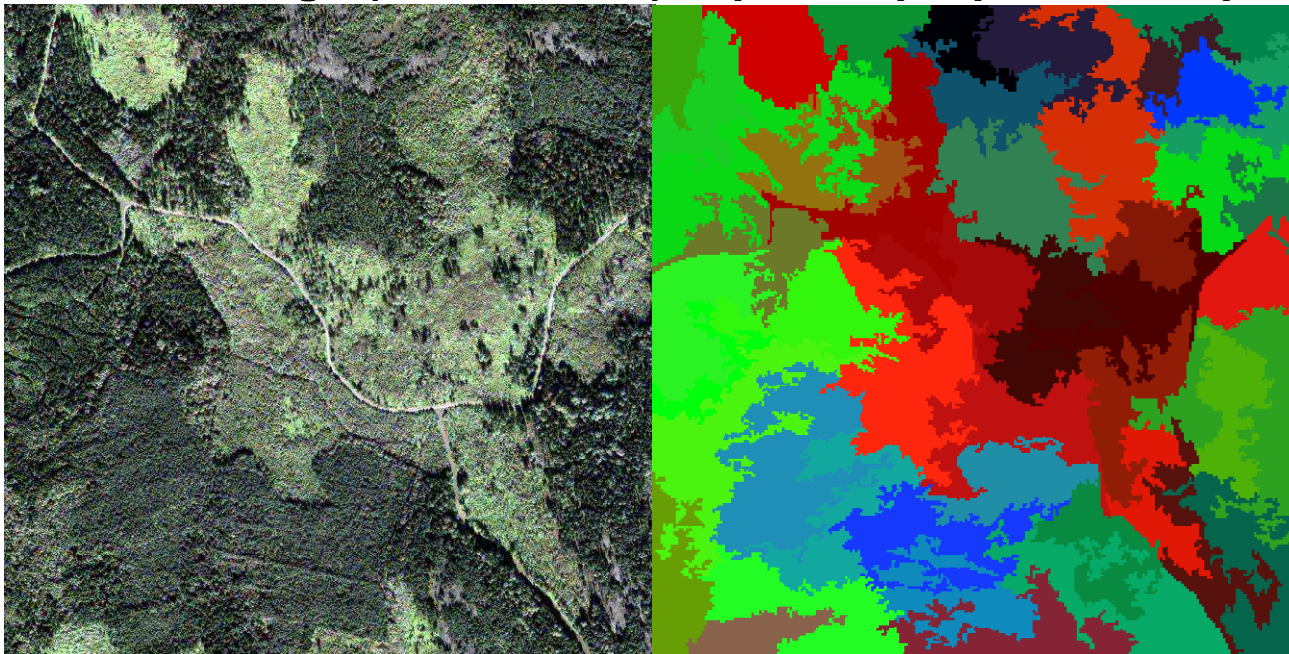
**Sample of very high  
resolution images**



Ground measurements



## Ikonos-2 image (1 km x 1 km) Species proportion map



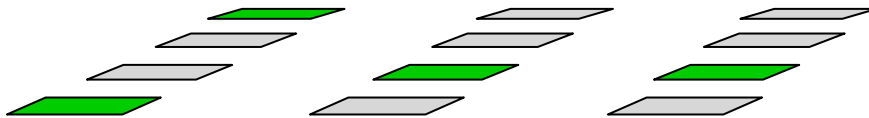
red = deciduous, green = spruce,  
blue = pine (stem numbers)

## Phase 2: Use VHR maps to train mapping of wall-to-wall data

"Wall-to-wall" radar satellite data  
- medium to low resolution



**Sample of very high  
resolution images**



Ground measurements



-  Spruce dominated forest
-  Pine dominated forest
-  Mixed coniferous forest
-  Mixed forest
-  Broadleaved forest
-  Regenerating area
-  Clear cut
-  Agricultural land
-  Bare soil
-  Urban, clouds

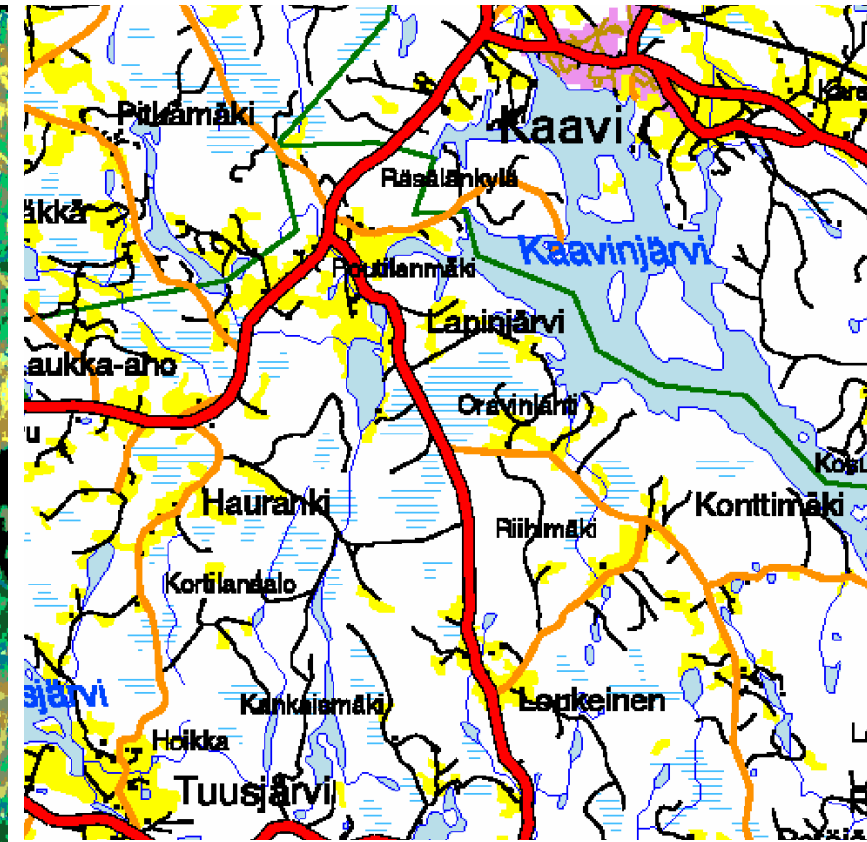
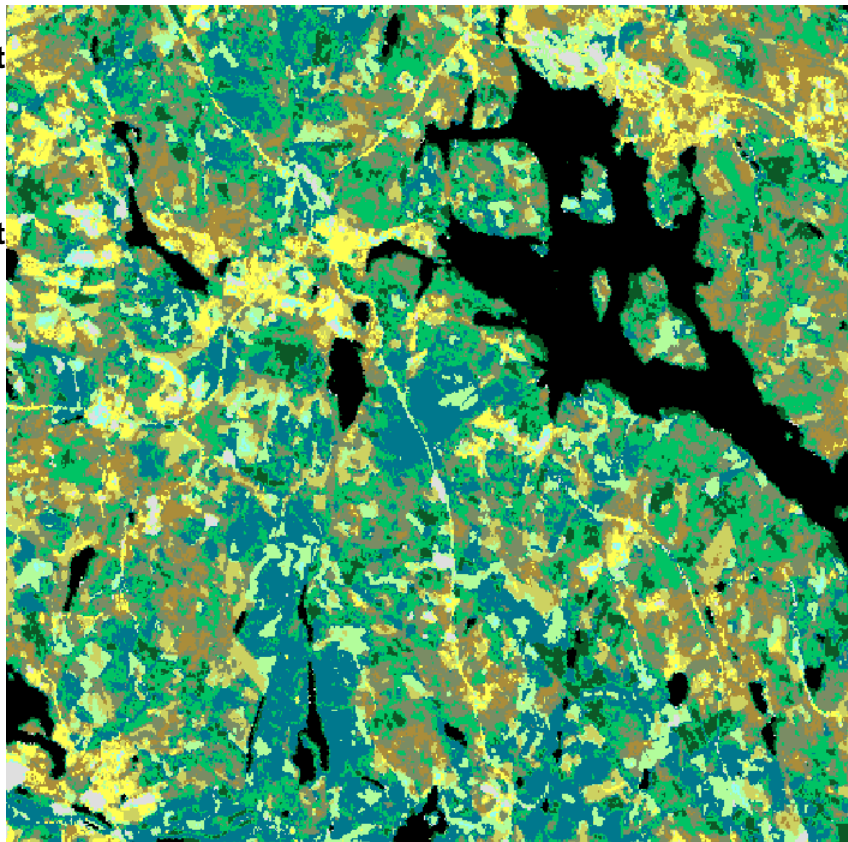


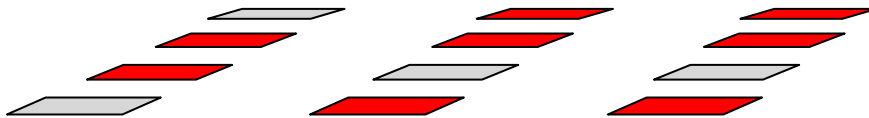
Image area about 13 km by 13 km

## Phase 3: Validate wall-to-wall map with rest of VHR images

"Wall-to-wall" radar satellite data  
- medium to low resolution



**Sample of very high  
resolution images**

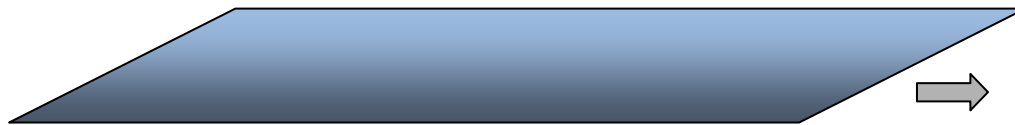


Ground measurements



# Result

"Wall-to-wall" radar satellite data  
- medium to low resolution



Sample of very high  
resolution images



Ground measurements



**Statistical  
data and  
map data  
of limited  
number of  
variables**

(Statistical  
data of  
high  
number of  
variables)

**Statistical  
data and  
map data  
of high  
number of  
variables**

## Conclusions

- Reliable data needed for validation of wall-to-wall data maps
- Field observations, VHR satellite data and airborne lidar data fulfill reliability requirement, depending on variables of interest
- Optical data default data type
- SAR for frequent monitoring to alert on change and to fill in cloudy areas
- Validation data have to be collected using a statistical sampling principle to enable computation of statistical measures for accuracy
- Field data costly to collect, sometimes completely unfeasible
- Access to sampled coverage of VHR data should be ensured
  - Organization of commercial VHR data delivery with nominal costs to users or
  - Launching a specific satellite mission for image sample collection
  - Government or Intl organization contribution to GEOSS?



# VTT creates business from technology

