Validation of CARTOSAT-1, TerraSAR-X and CosmoSkyMed imagery for use in field area measurement checks

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The Monitoring Agriculture ResourceS (MARS) Unit Mission

We provide scientific and technical support on EU Agriculture and Food Security policies.

- In Europe, the Unit addresses key issues related to the management and control of the Common Agriculture Policy: Independent crop yield forecasts, agricultural insurances, standard control methods of area based subsidies, compliance with environment, and effect of climate change. It supports EU projects related to Land Administration, the enlargement process, and the GMES Space Component.

- In developing countries, assistance is given to the EU Food Security Thematic Program with special emphasis on Africa, and to providing building blocks for an European capacity for Global Agriculture Monitoring. The activities of the Unit are based on expertise in agro- meteorological crop modelling, sampling methods, econometric, geomatics (GIS, GPS and ICT), and satellite & airborne remote-sensing (the Unit manages the EC Framework Contracts for the provision of Satellite Remote Sensing data and manages the access/dissemination of EU image data archives).

read more>>

Image Acquisition for CAP Control with Remote Sensing

Quickbird "Distributed by EURIMAGE S.p.A. © DIGITALGLOBE [2004]" true colour panmerge, 70cm imagery over Huesca, Aragon, Spain showing small agricultural parcels of mainly corn, rice, and lucern. Irrigations systems (Pivot or Flood) show clearly

Latest News & Events

2009 CAP Control Methods Workshop (06 - 08 April 2009)

The GeoCAP action will host the 2009 Workshop on Control Methods used in the EU Common Agriculture Policy. The workshop will cover the following topics for discussion: - Eligibility definitions for pasture land; validation of measurement tools; Risk analysis / zone definition; control...

New version of the Guidance for Best Practice and Quality Checking of Ortho Imagery

A new version (v. 3.0) of the Guidelines for Best Practice and Quality Checking of Ortho Imagery is available.

4th CGMS Expert Meeting (18-19 March 2009)

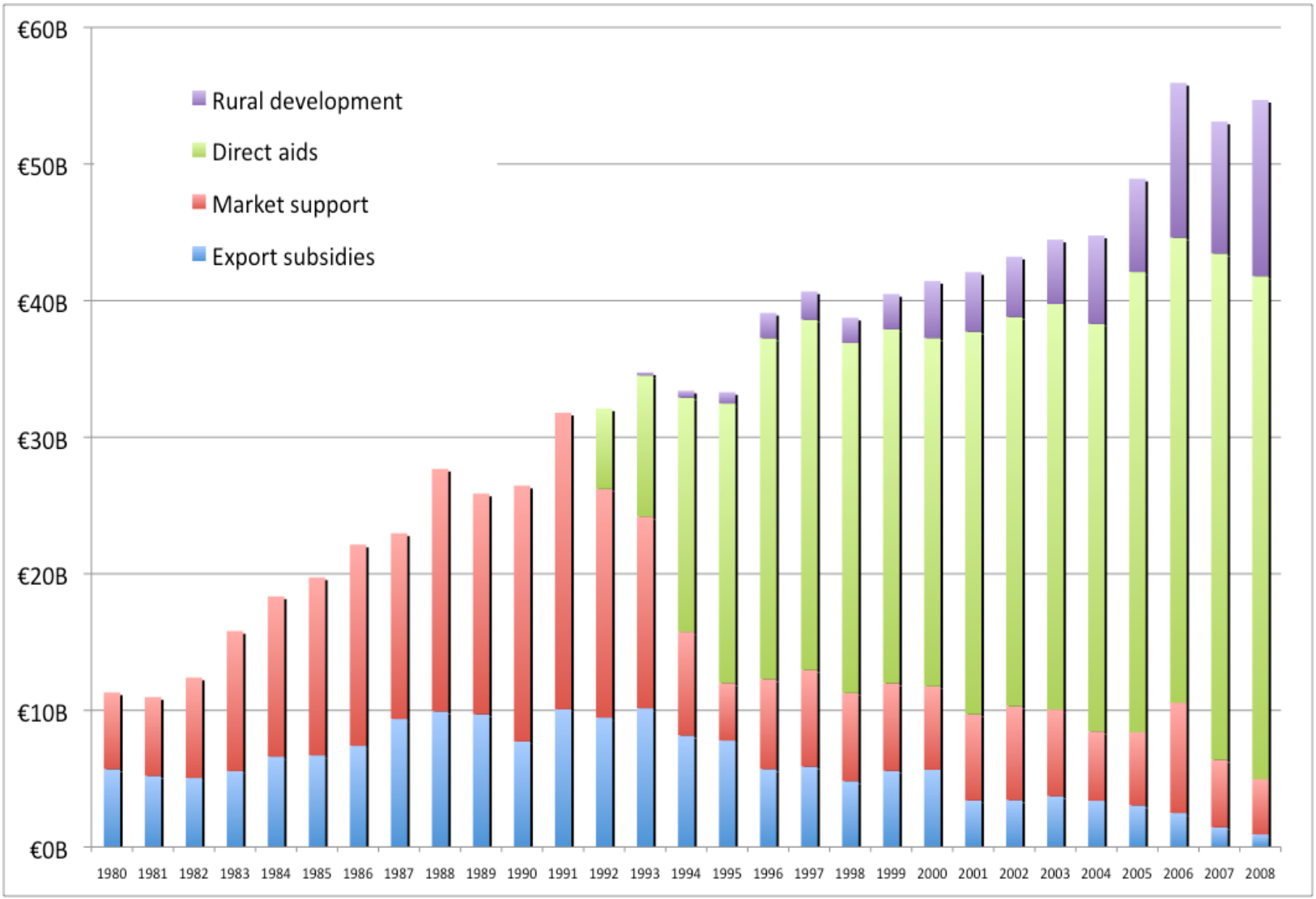
It is organised by The Agriculture Unit of the Institute for the Protection and Security of the Citizen.
The meeting will welcome all the persons who are using and developing the crop growth monitoring system as well who are interested in sharing their knowledge on this subject

Done

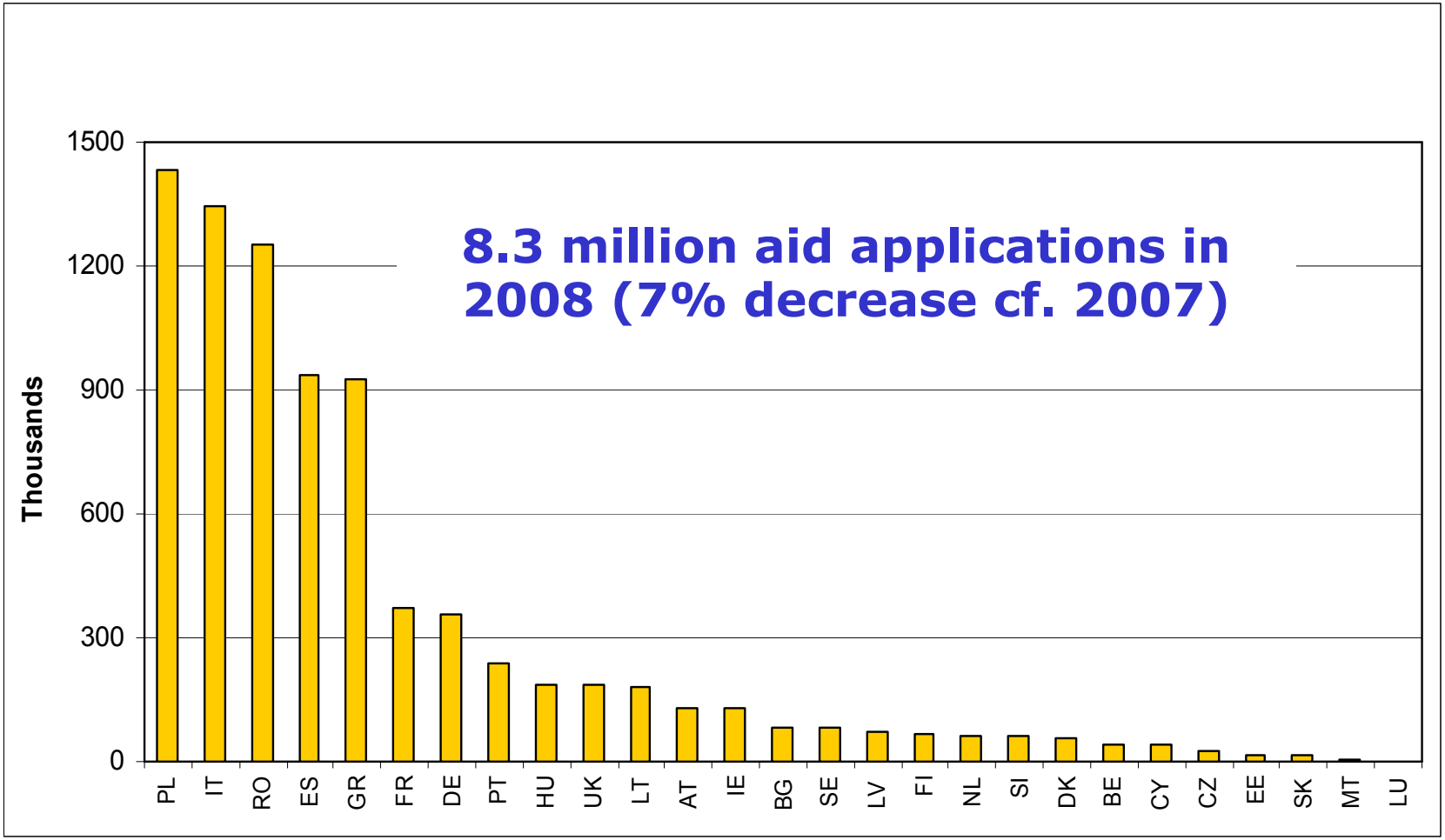
Outline of presentation

- Why? Farm subsidies in the EU
- The instruments and test approach
- Results: field measurement performance on CARTOSAT-1, TerraSAR-X and CosmoSkyMed images
- Conclusions, recommendations

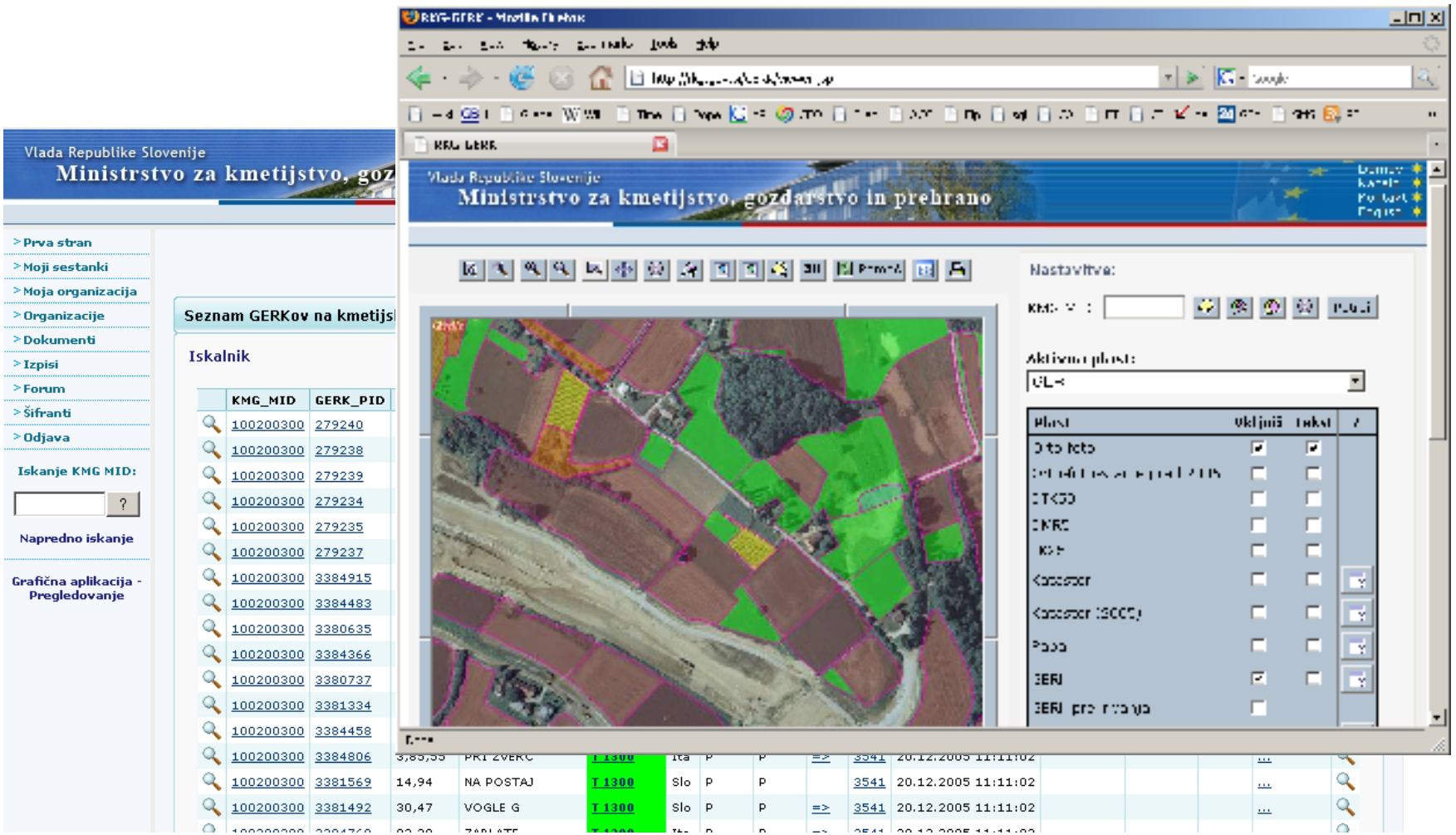
CAP expenditure, 1980-2008



Total number of farm businesses

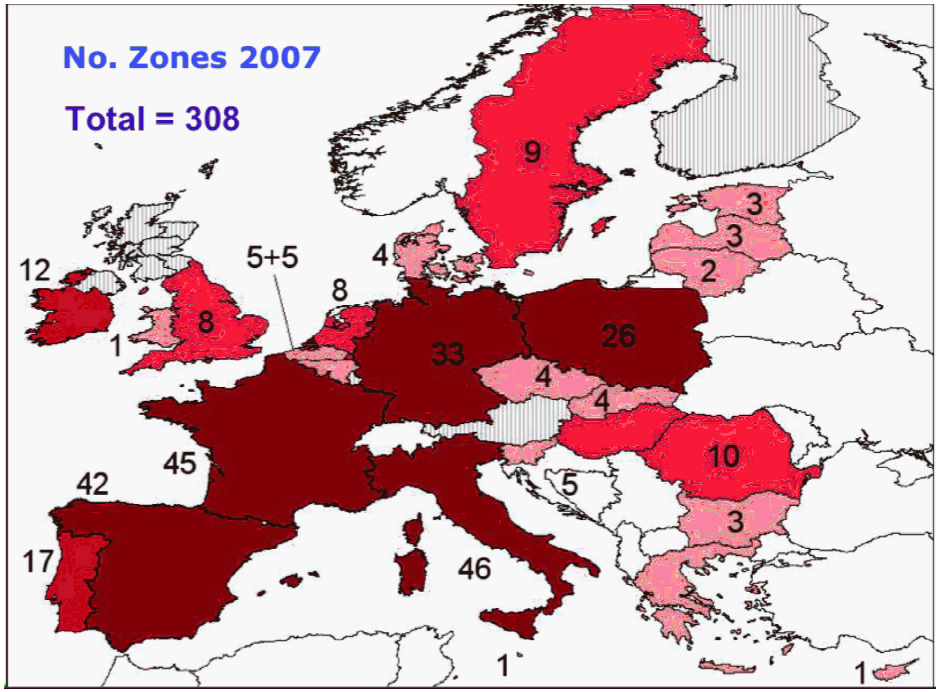


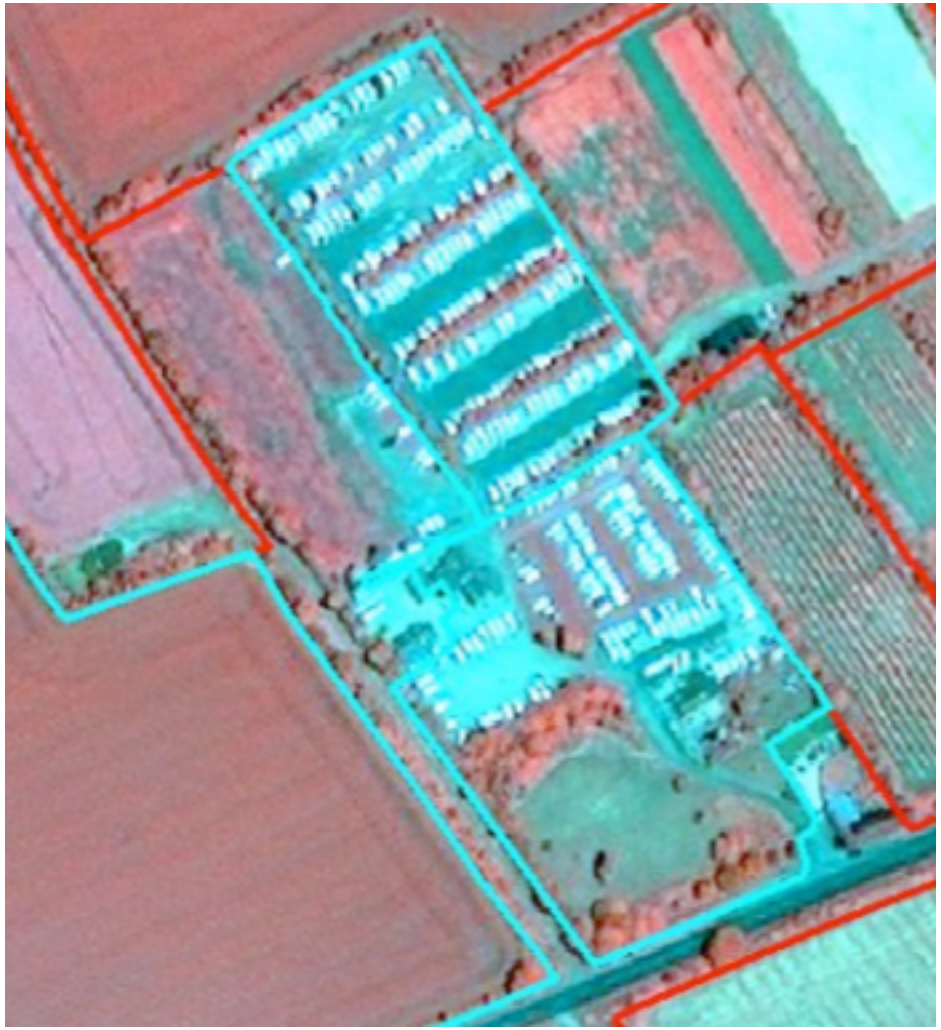
Land Parcel Identification System: Slovenia



EU Control with Remote Sensing, 2008

- 24 Member States involved in the program
  - 30 contractors
  - ~338,000 farms checked (over ½ of all farm checks)
  - ~800 HR images over ~244 zones, (avg. 740km2)
  - VHR: ~170,000km2
  - >4 million ha checked
- Budget for imagery: €6.5M





FEASIBLE STANDARDS TO BE CHECKED USING REMOTE SENSING (IX)

STANDARD GAEC08: MAINTENANCE OF RETAIN TERRACES, KEEPING THEIR DRAINAGE CAPACITY AND AVOIDING THE RISK OF SILTING UP AND GULLY FORMATION

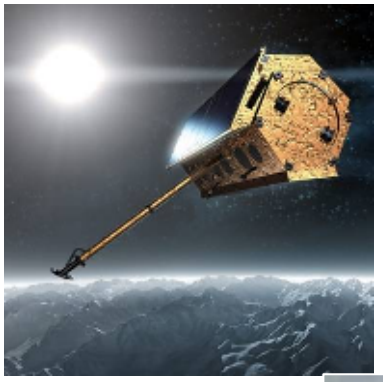
ARCHIVE ORTHOPHOTO

VHR IMAGE OF THE CURRENT YEAR

NON ELIMINATION OF TERRACES, BOUNDARIES, ETC IS CHECKED BY COMPARISION BETWEEN THE ORTHOPHOTO AND THE VHR IMAGE [Ref. Sardon, MARS PAC Annual Conf. 2007]

TerraSAR-X

First commercial 1m resolution radar satellite

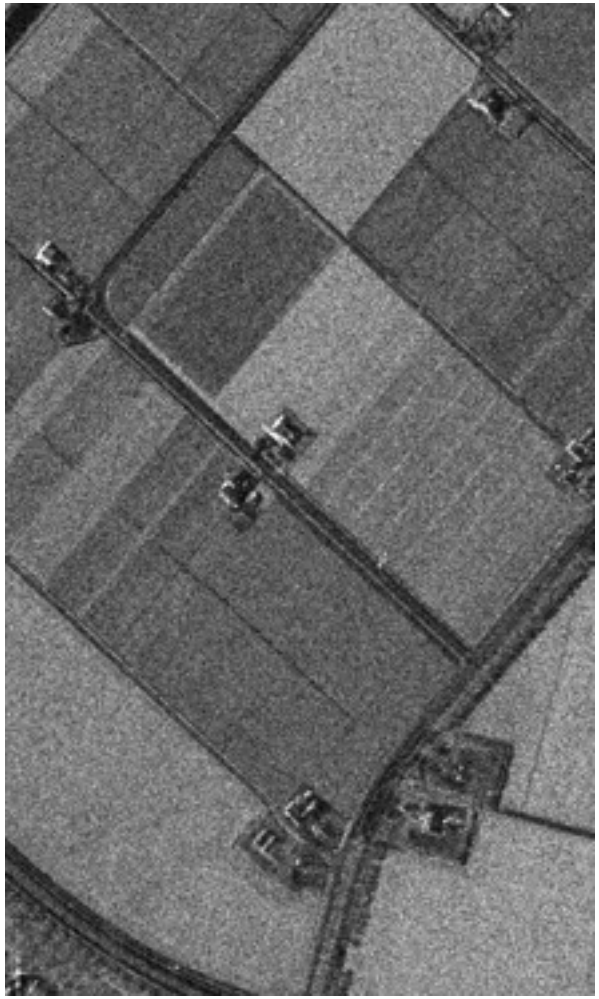


- Launched June, 15th 2007
- Weather independent acquisition, worldwide
- High acquisition flexibility
- Quick site access of 2.5 days maximum (2 days at 95% probability)
- Unique agility: rapid switches between imaging modes and polarisations
- Unrivalled geometric pixel location accuracy
- 2009: highly accurate DEM generation from twin satellite constellation with TanDEM-X

Source: T Schrage, Infoterra GmbH

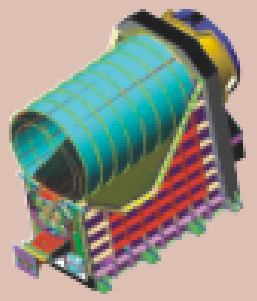
CosmoSkyMed

- COnstellation of small Satellites for Mediterranean basin Observation
  - Commissioned and funded by Italian Space Agency (ASI) and Italian Ministry of Defense (MoD),
  - Dual-Use (Civilian and Defence) Earth Observation System relevant to a wide range of applications
- Constellation of four Low Earth Orbit mid-sized satellites, each equipped with a multi-mode high-resolution Synthetic Aperture Radar (SAR) operating at X-band



CARTOSAT-1

CARTOSAT-1 Specifications		
Orbit	:	618 km high, circular Polar Sun Synchronous
Orbit inclination	:	98.87 deg
Orbit period	:	97 min
Number of orbits per day	:	14
Local time of equator crossing	:	10.30 AM
Repetivity	:	126 days
Revisit	:	5 days
Lift-off mass	:	1560 kg
Attitude and orbit control	:	3-axis body stabilised using Reaction Wheels, Magnetic Torquers and Hydrazine Thrusters
Electrical power	:	15 sq m Solar Array generating 1100 W, Two 24 Ah Ni-Cd batteries
Mission life	:	5 years
Payloads	:	Two PAN Cameras (PAN fore mounted with a tilt of +26 deg and PAN aft mounted with a tilt of – 5 deg from the yaw axis to generate stereoscopic imagery)
Instantaneous Geometric Field of View (IGFOV)	:	< 2.5 m
Swath	:	30 km
Spectral Band	:	0.50-0.85 Micron
Data rate	:	105 Mbps for each camera
Solid State Recorder	:	120 GB capacity for image data storage



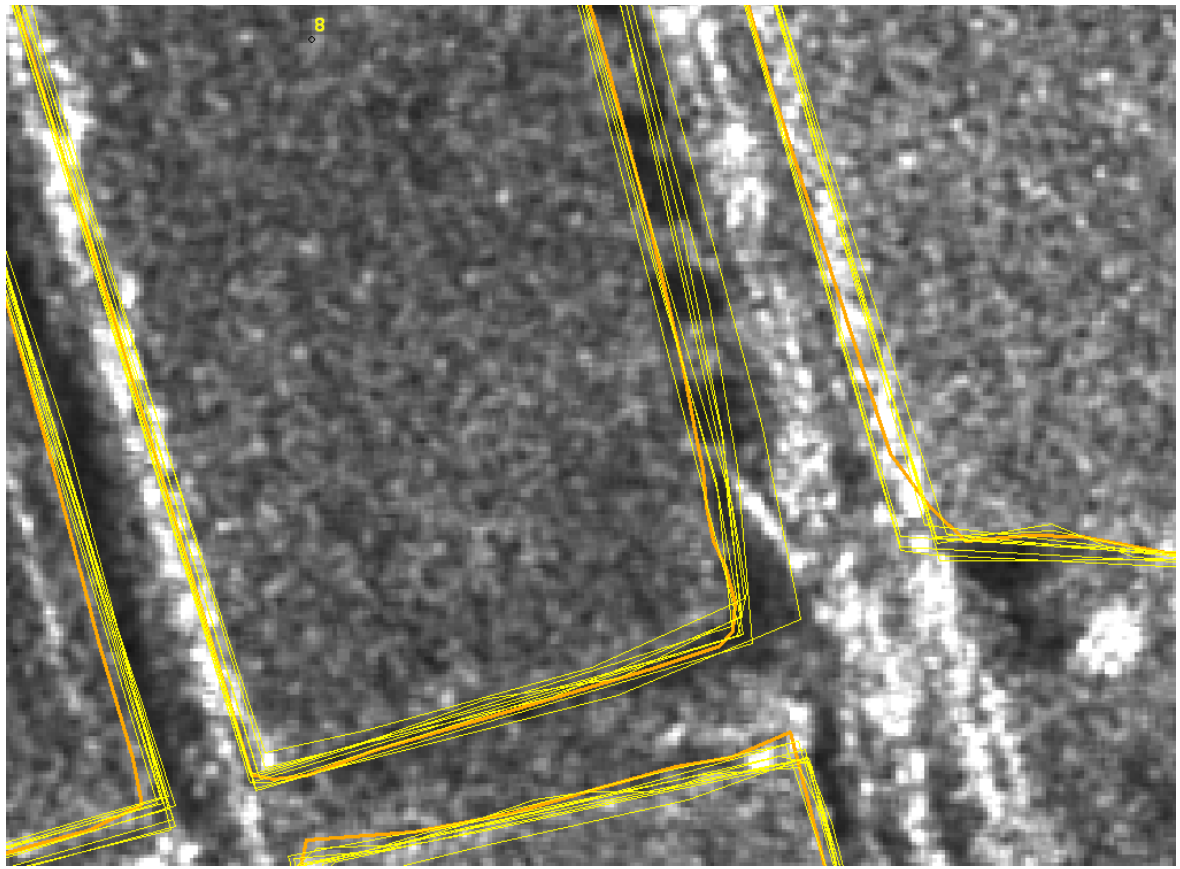
CARTOSAT-1 PAN camera

http://www.isro.org/Cartosat/Page3.htm

Field measurements

measurement performance, variation, and tolerance

…A measurement tolerance shall be defined by a buffer of maximum 1.5 m applied to the perimeter of the agricultural parcel. (Comm Reg 796/04, Art 30(1))



Determination of the tolerance

Tolerance = Reproducibility limit

Reproducibility limit R (ISO 5725*): the value less than or equal to which the absolute difference between two test results obtained under reproducibility conditions may be expected to be with a probability of x% (here 95%).

$$R = f * \sigma_R * \sqrt{n}$$

For normal distribution at 95% probability level, f is 1.96 and f*√2 then is 2.8. The simple "rule of thumb" is applied

$$\Rightarrow R = 2.8 * \sigma_R$$

σ_R (or s_R) is the standard deviation under reproducibility conditions: same method, different operators and conditions

*ISO 5725 (1994) "Accuracy (trueness and precision) of measurement methods and results"

7.4.5.1 The repeatability variance is

$$s_{ri}^2 = \frac{\sum_{i=1}^{p} (n_i - 1) s_{ij}^2}{\sum_{i=1}^{p} (n_{ij} - 1)}$$

7.4.5.2 The between-laboratory variance is

$$s_{Lj}^2 = \frac{s_{Bj}^2 - s_{rj}^2}{\bar{n}_j}$$

where

$$s_{Bj}^2 = \frac{1}{p-1} \sum_{i=1}^{p} n_{ij} (\bar{y}_{ij} - \bar{\bar{y}}_j)^2$$

$$= \frac{1}{p-1} \left[\sum_{i=1}^{p} n_{ij} (\bar{y}_{ij})^2 - (\bar{\bar{y}}_j)^2 \sum_{i=1}^{p} n_{ij} \right]$$

and

$$\bar{n}_j = \frac{1}{p-1} \left[\sum_{i=1}^{p} n_{ij} - \frac{\sum_{i=1}^{p} n_{ij}^2}{\sum_{i=1}^{p} n_{ij}} \right]$$

Test design:
Mausanne les Alpilles, Southern France

- CARTOSAT – 1: Two pairs panchromatic (0.5-0.85µm) images:
  - Aft (-5deg pitch angle) and Fore (+26deg) were acquired on 31.01.2006 with 2.5m of GSD
- VHR X band SAR programmed data over agricultural test sites in Mausanne les Alpilles, Southern France
  - 1 site was imaged with StripMap colour comp (1 image of TerraSAR-X)

    79 parcels on site
  - 1 site was imaged with SpotLight mode data (4 TerraSAR-X, 2 CosmoSkyMed)

    42 parcels on site
- Reference areas & perimeters: derived from orthophoto
  - (ADS40, 0.5m GSD) acquired in May 2003
  - Stability of fields verified in field campaign Feb 2008
- Measurements: 3 independent operators, 3 repetitions, orthophoto as auxiliary material

VHR SAR imagery

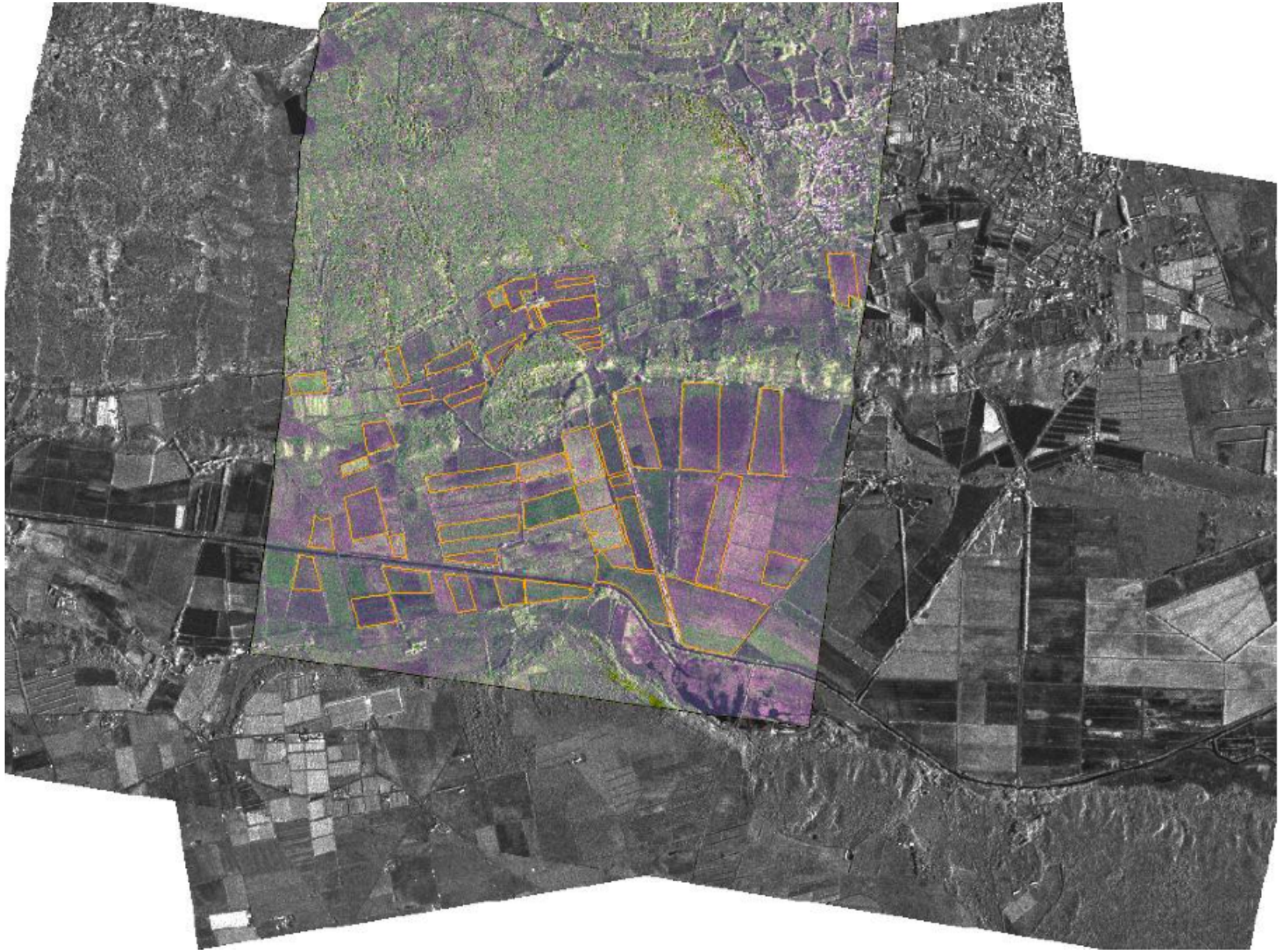
TerraSAR-X

Mode	No	Image file	Incidence angle	Orbit direction	Date Time	Polarization	Approx. GSD	Cell size
SpotLight	1	VV_HSL_1405	34.46	descending	2008-05-14 05:53	VV single	1x1m	1x1m
	2	VV_HSL_2105	52.49	ascending	2008-05-21 17:41	VV single	1x1m	1x1m
	3	HH_SL_0604	47.16	descending	2008-04-06 05:44	HH dual	2x2m	1x1m
	4	cc_SL_0604	47.16	descending	2008-04-06 05:44	Dual: HH, VV, HH-VV	2x2m	1x1m
StripMap	5	cc_SM_1103	42.42	ascending	2008-03-11 17:33	Dual: HH, VV, HH-VV	6x6m	3x3m

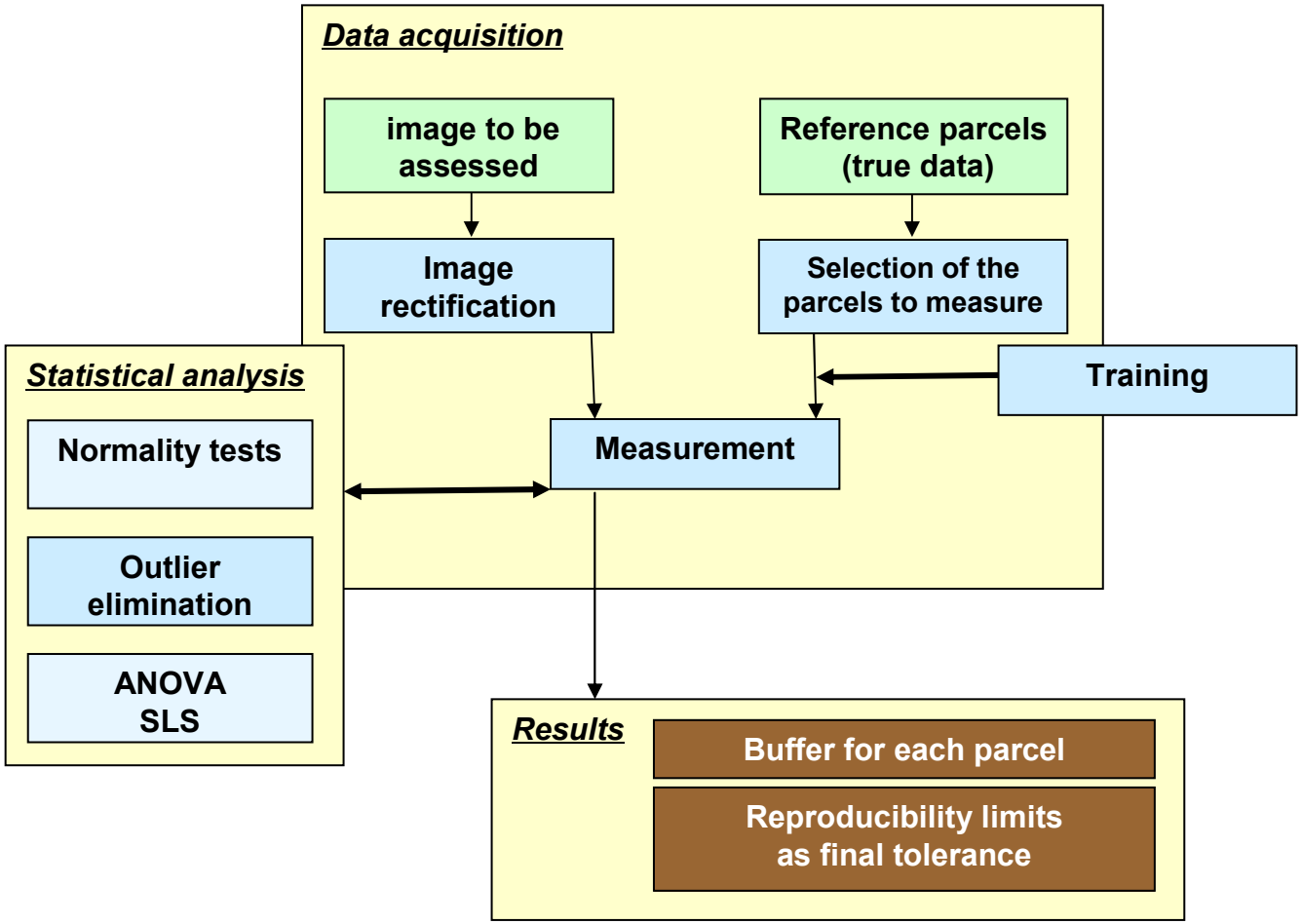
CosmoSkyMed

SpotLight	6	CSK_1207	40.83	descending	2008-07-12 17:56	HH single	1x1m	1x1m
	7	CSK_1407	55.40	ascending	2008-07-14 05:58	HH single	1x1m	1x1m

All TerraSAR-X data pre-processed and provided by Infoterra GmbH and CosmoSkyMed data by Agenzia Spaziale Italiana

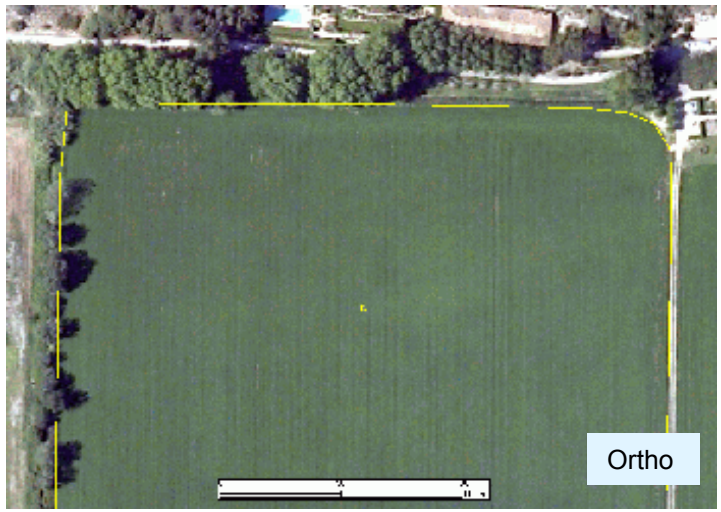


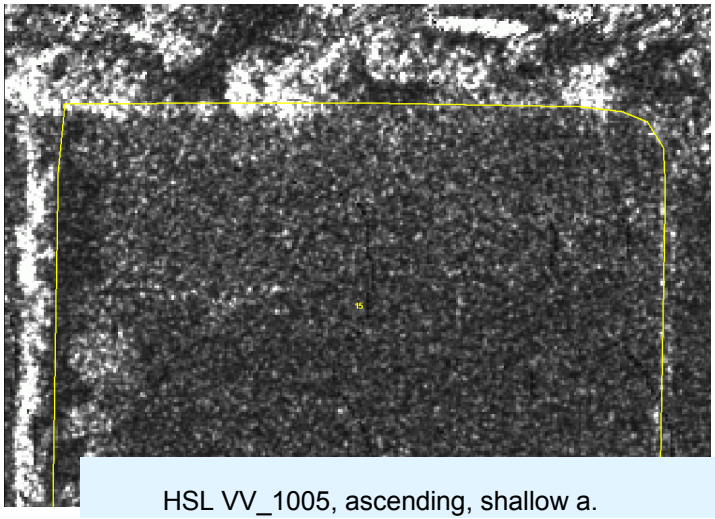
Workflow of the accuracy assessment of parcel area measurement



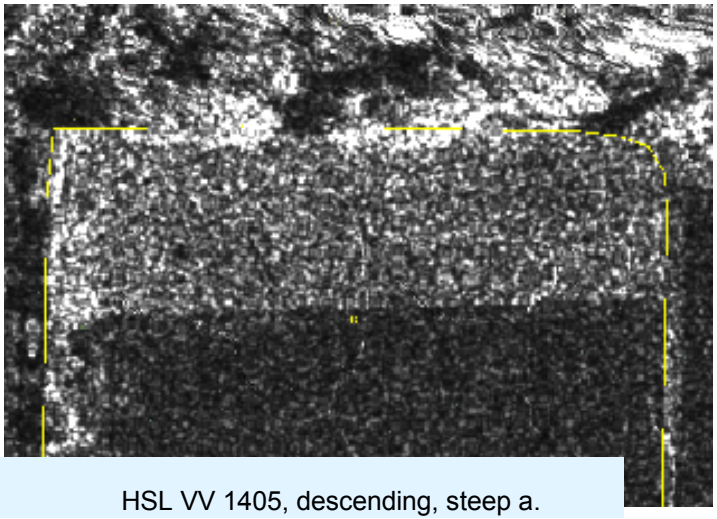
Area measurement methodology

- Photointerpretation key for the most common features
- Self-training course
- Measurement instruction
  - First measurement on orthophoto (parcels memorized by operator)
  - ortho as auxiliary materials for SAR interpretation





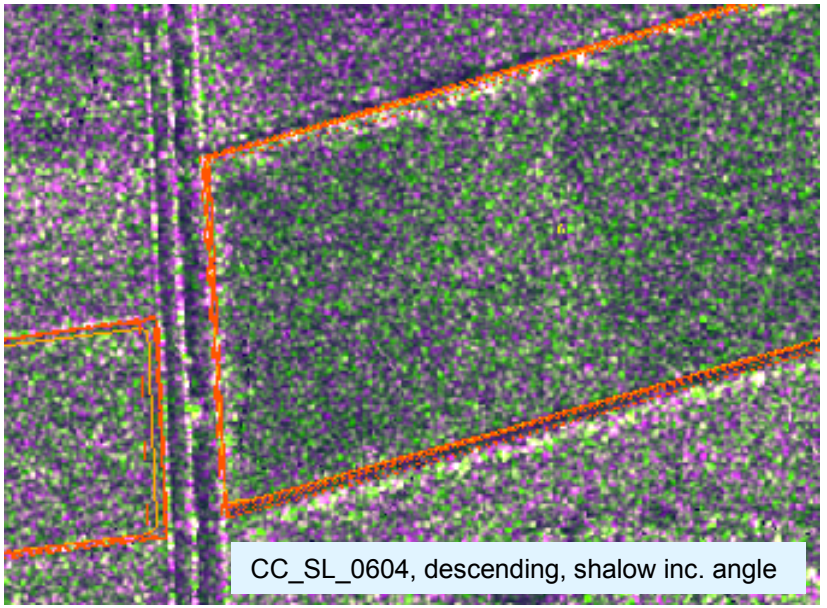
HSL VV_1005, ascending, shallow a.

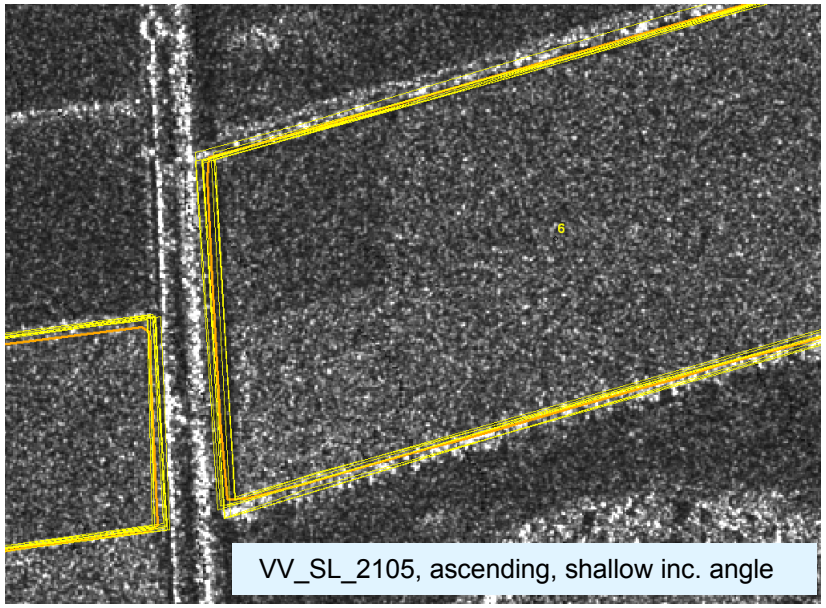


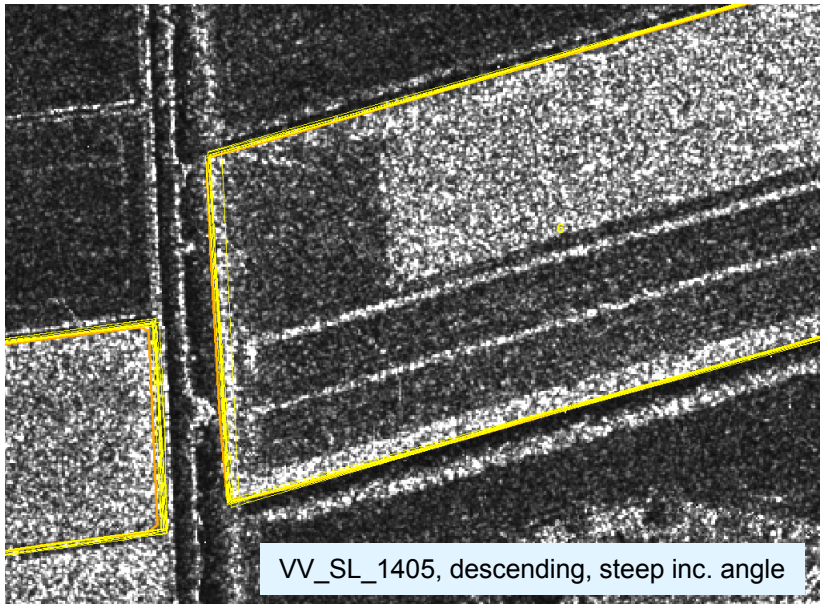
HSL VV 1405, descending, steep a.

Green cover

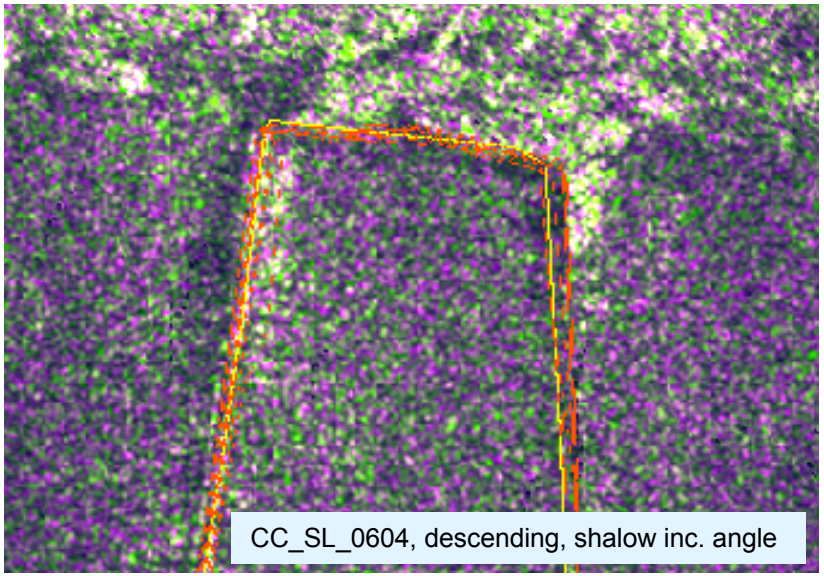

Ortho

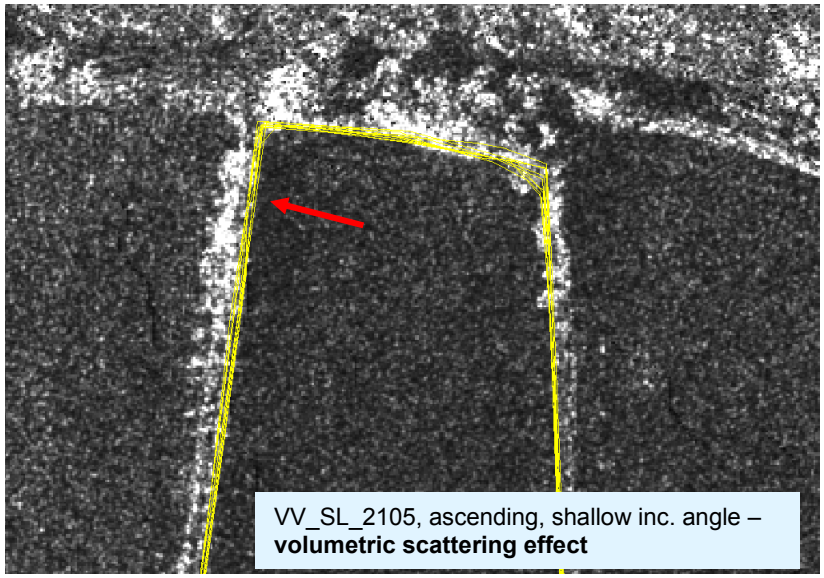

CC_SL_0604, descending, shalow inc. angle

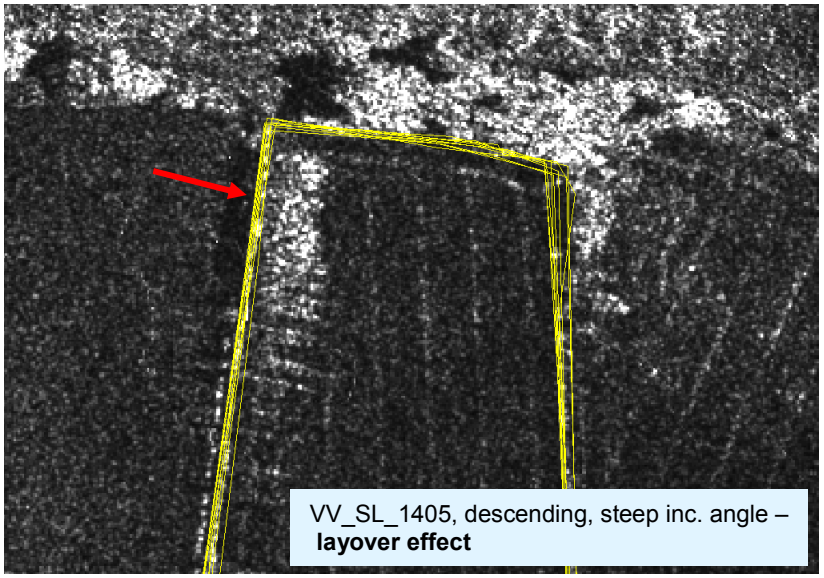

VV_SL_2105, ascending, shallow inc. angle


VV_SL_1405, descending, steep inc. angle

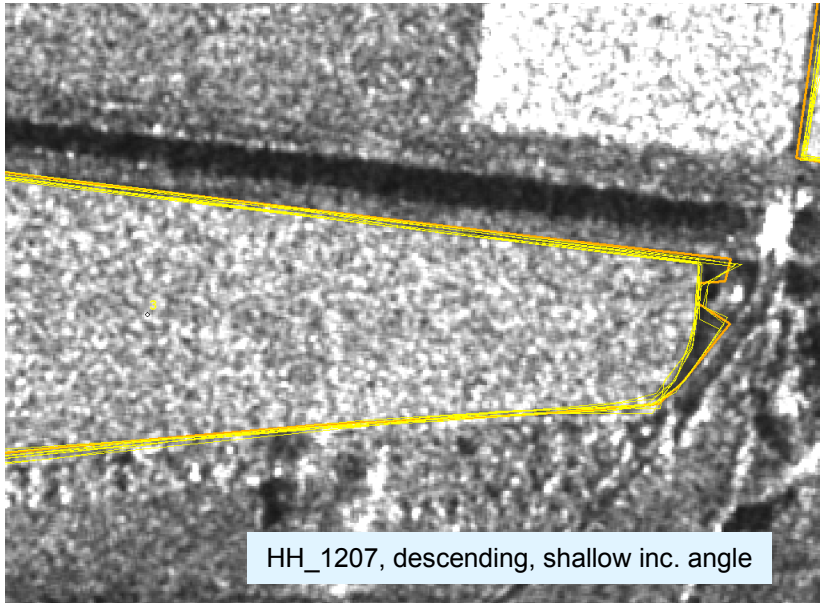
Row trees on the border

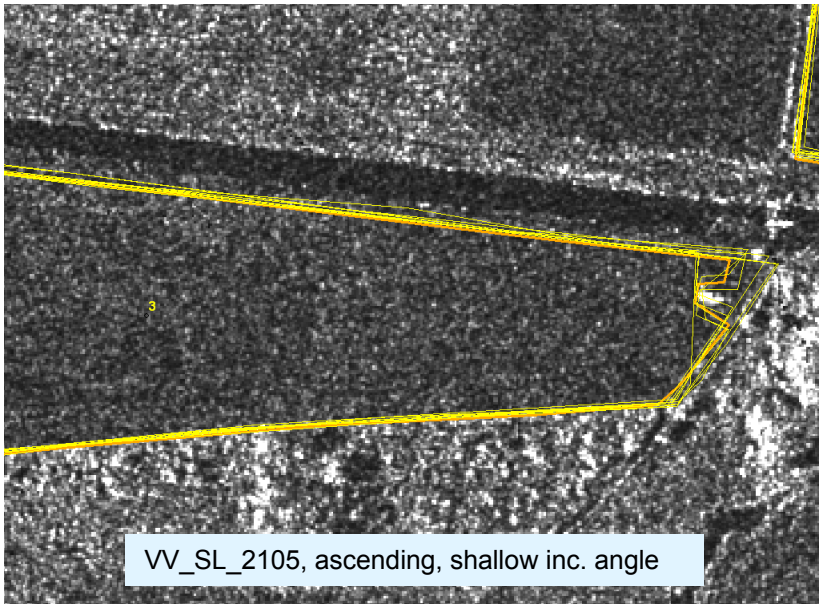


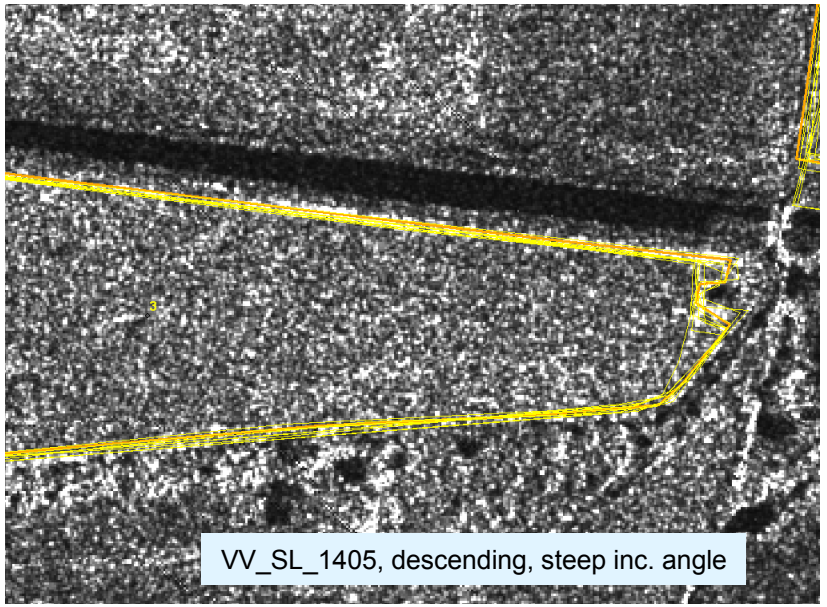




Buildings and roads

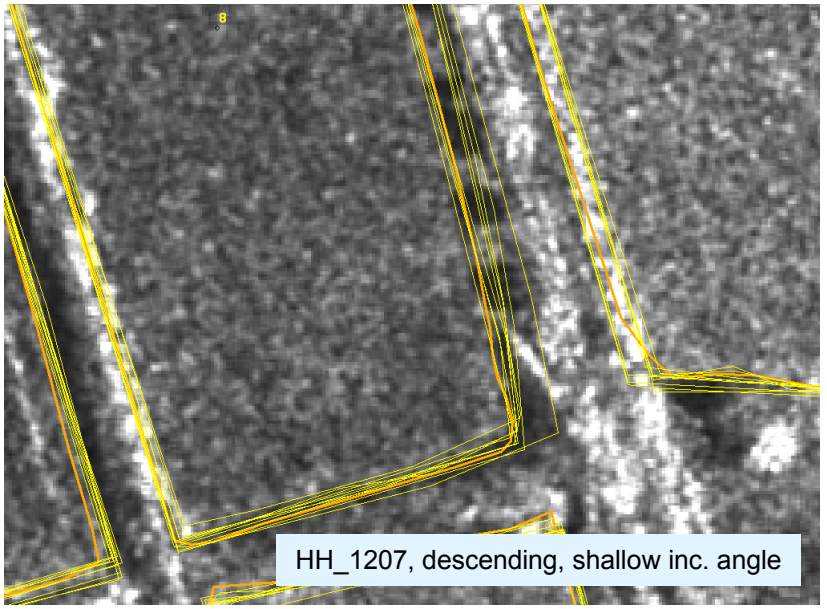




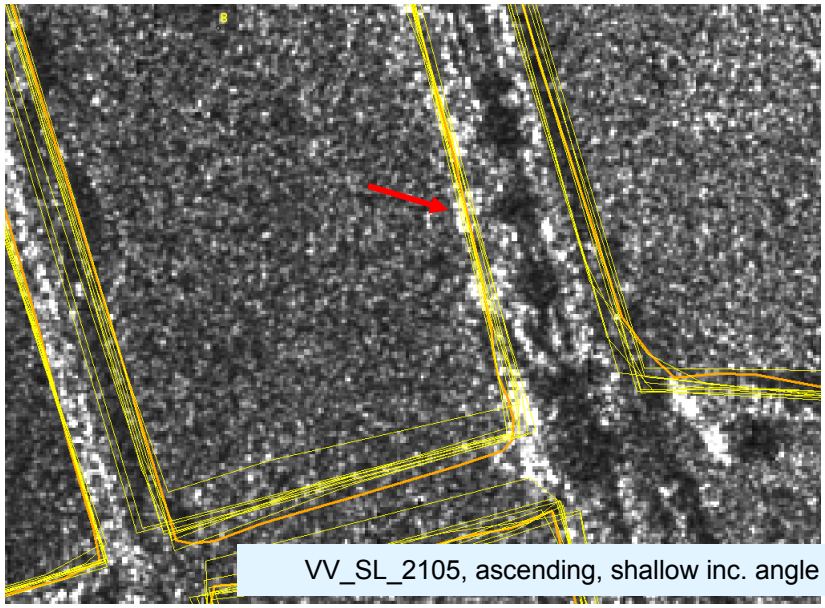


Trees, paths

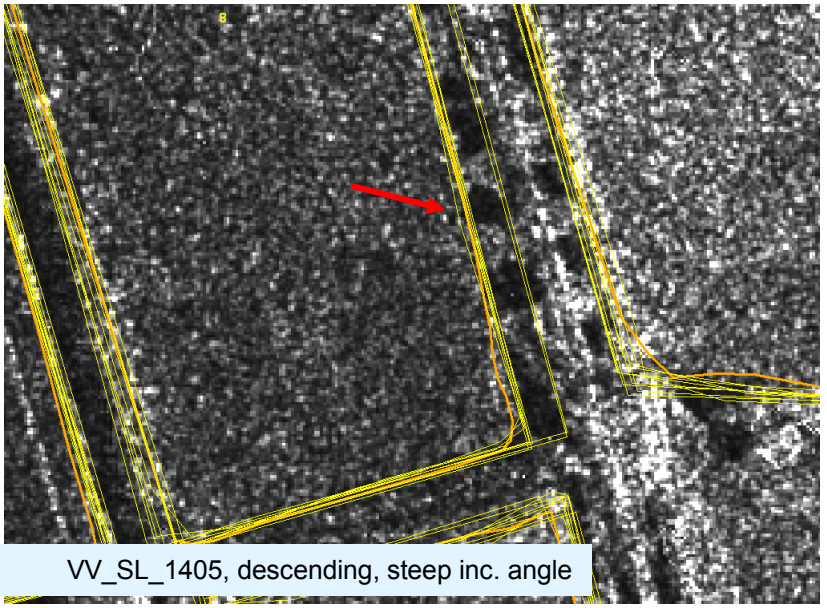
ortho



HH_1207, descending, shallow inc. angle



VV_SL_2105, ascending, shallow inc. angle

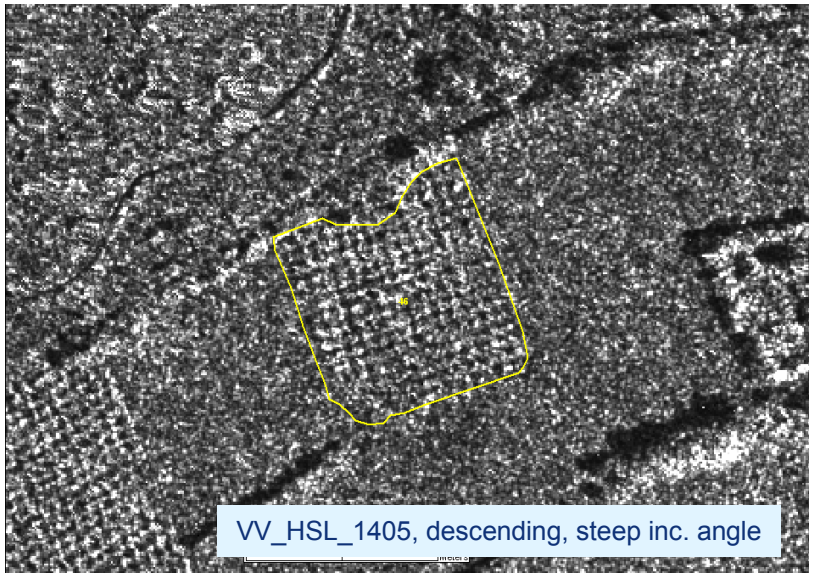


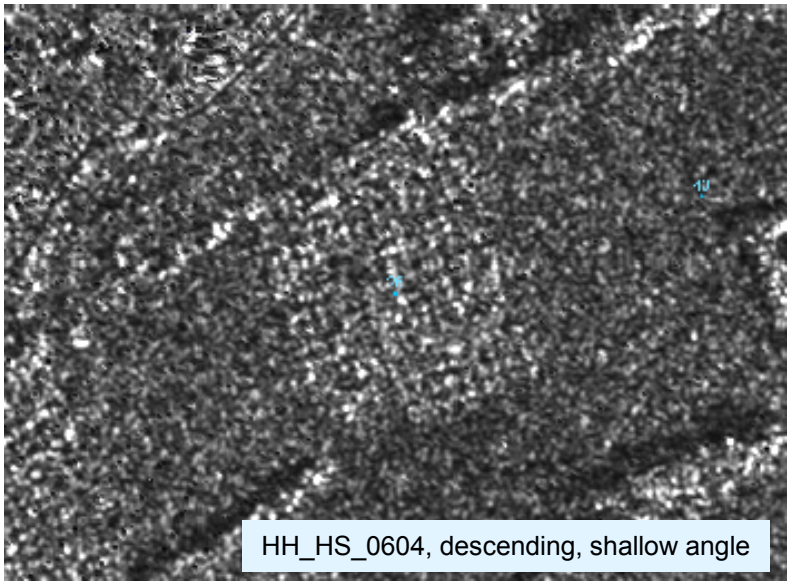
VV_SL_1405, descending, steep inc. angle

Olive trees


ortho


CC_SL_0604, descending, shalow inc. angle

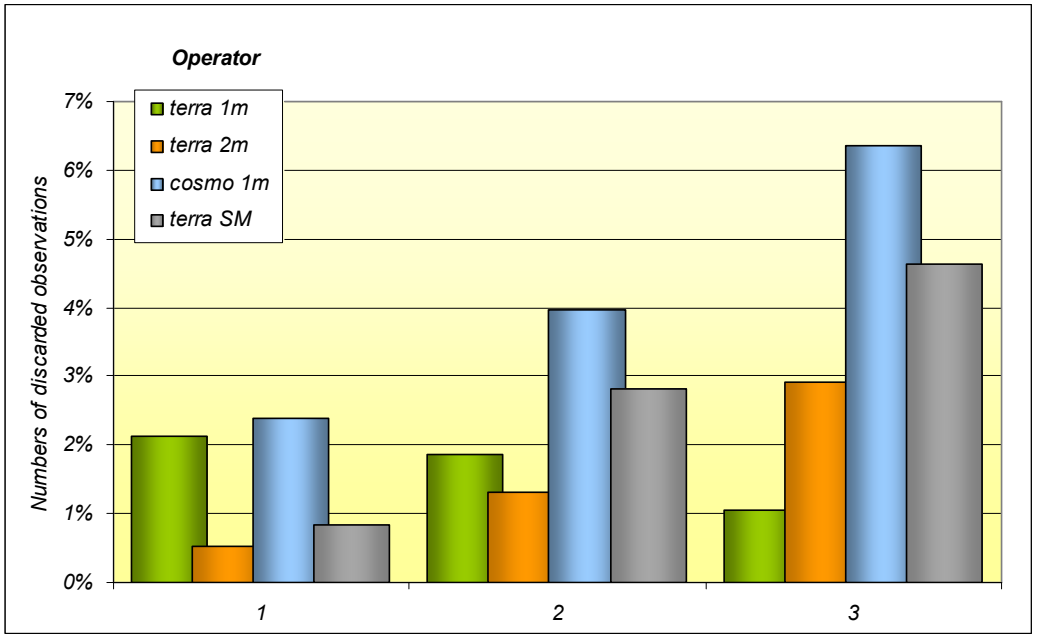

VV_HSL_1405, descending, steep inc. angle


HH_HS_0604, descending, shallow angle

Outlier detection

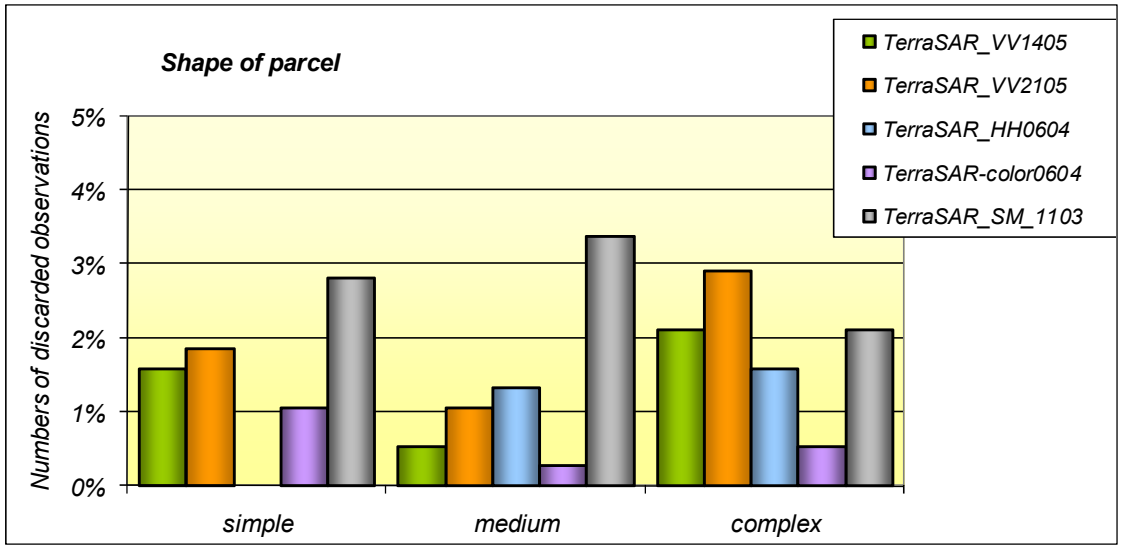
- Grubbs, Cochran tests
- more outliers on StripMap image, less on color SL
- the outliers distribution according to operators, shape and size of parcels

image	No of outliers	%
Terra_VV1405	8 (378)	2%
Terra_VV2105	11 (378)	3%
Terra_HH0604	11 (378)	3%
Terra_CC0604	7 (378)	2%
Cosmo1207	21 (378)	6%
Cosmo1407	27 (378)	7%
SM_CC1103	59 (711)	8%
total	144 (2979)	5%

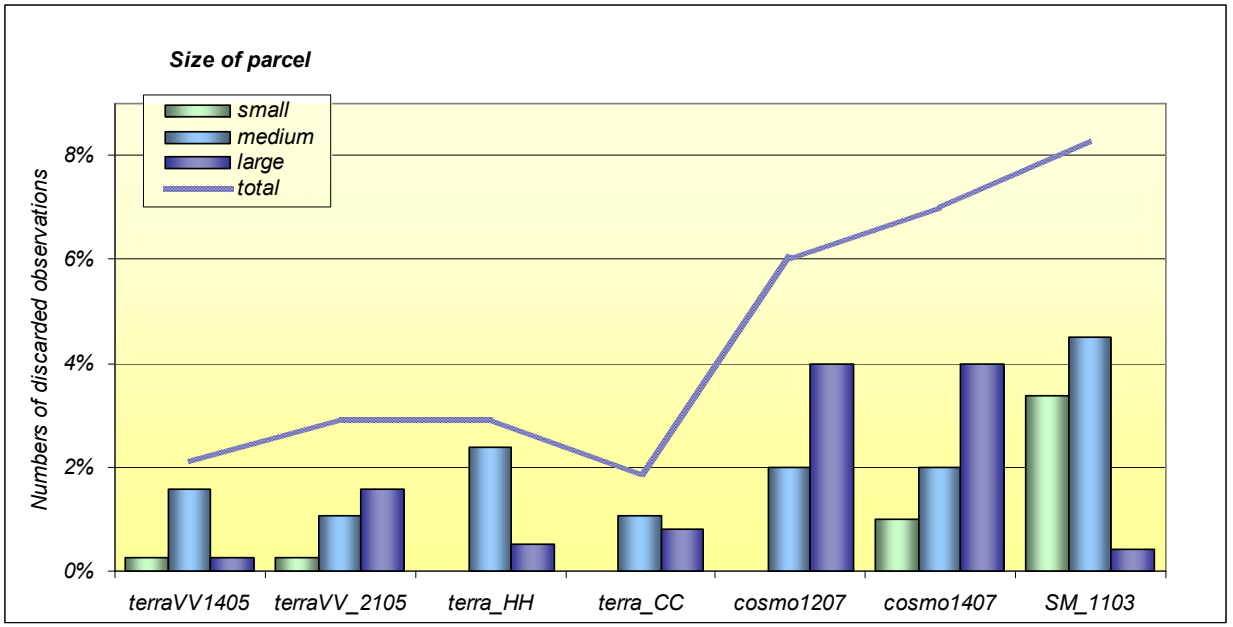


Discarded observations

- more outliers for complex-shape parcels

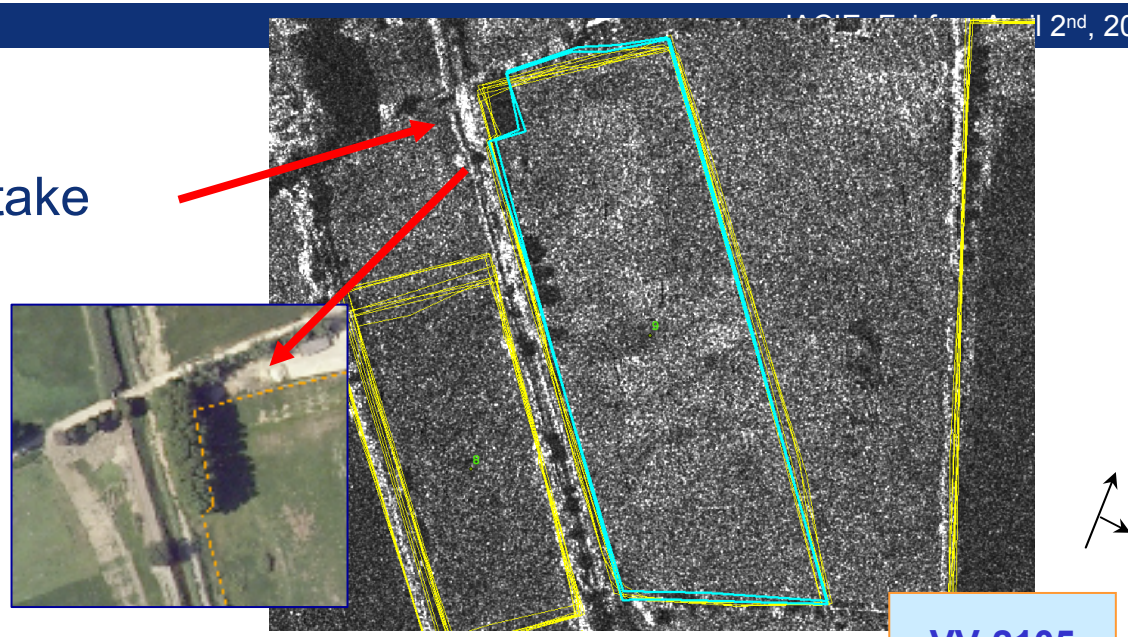


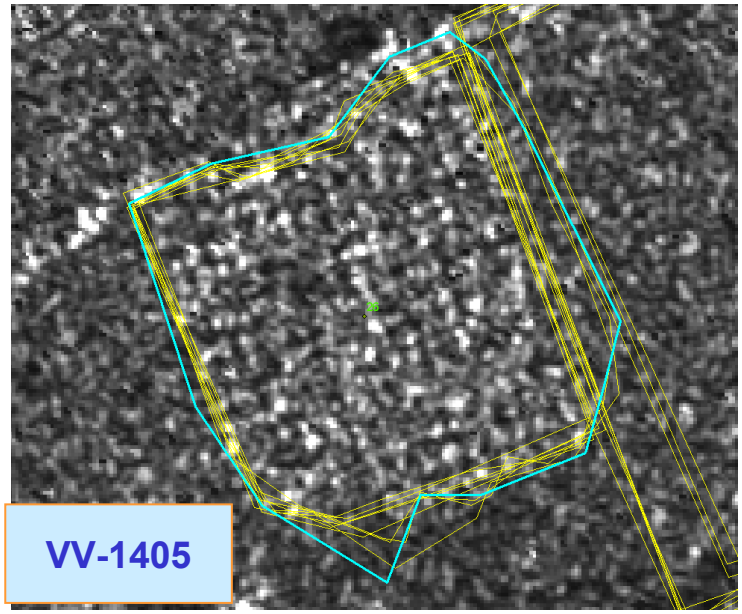
- more outliers on StripMap image for small and medium parcels and less for large
- no outliers on HH0604 for regular and small parcels



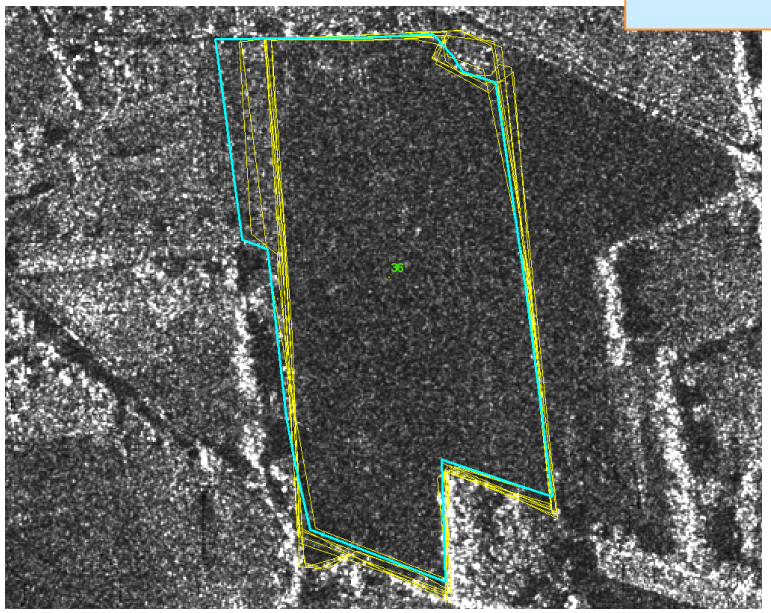
Outliers – examples

- Feature interpretation mistake
- Boundary not clear



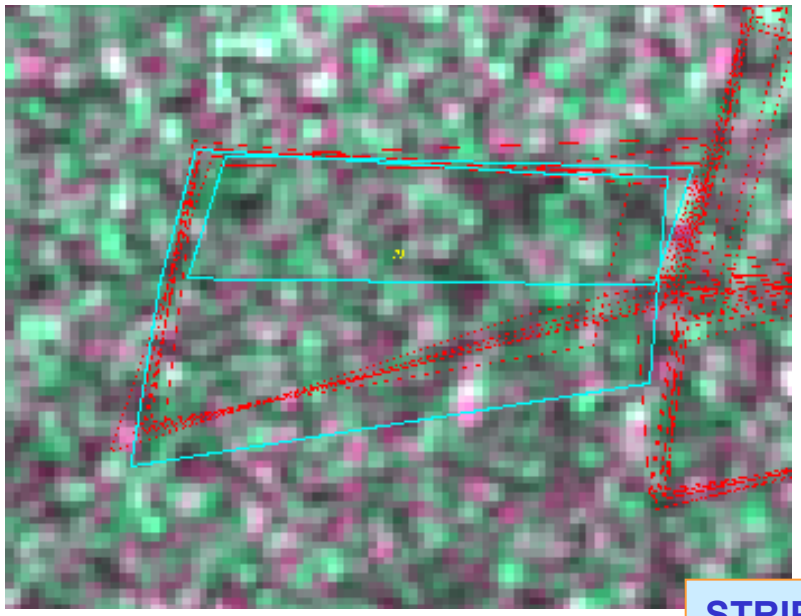


VV-1405

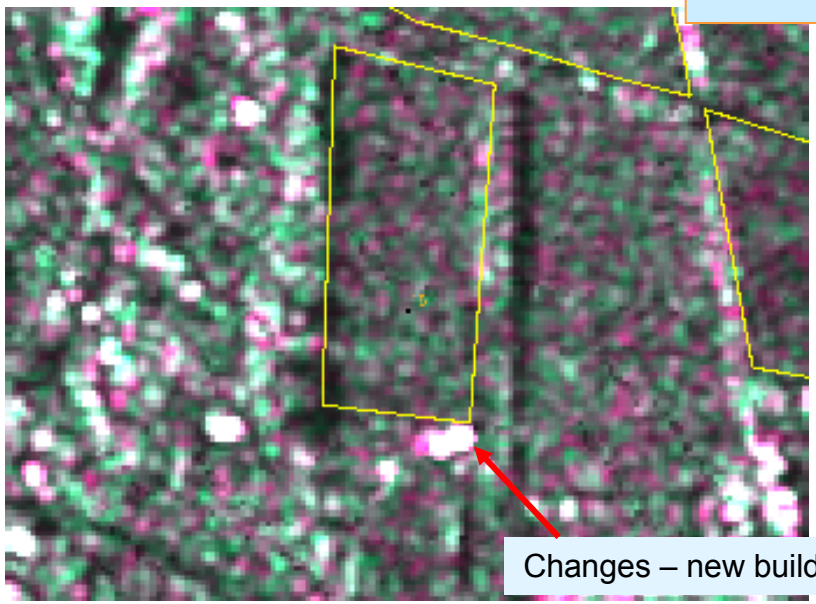


VV-2105

Outliers – examples



STRIP MAP

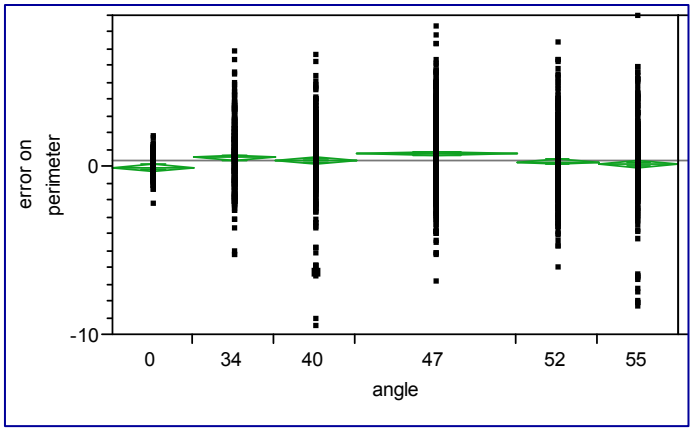


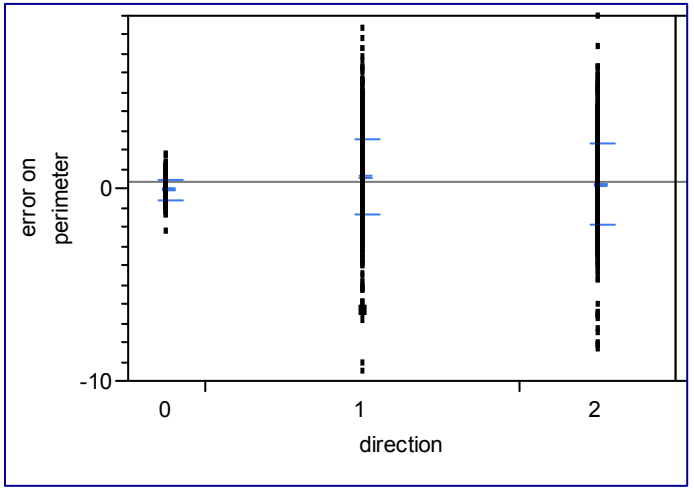
Changes – new buildings

Analysis of variance

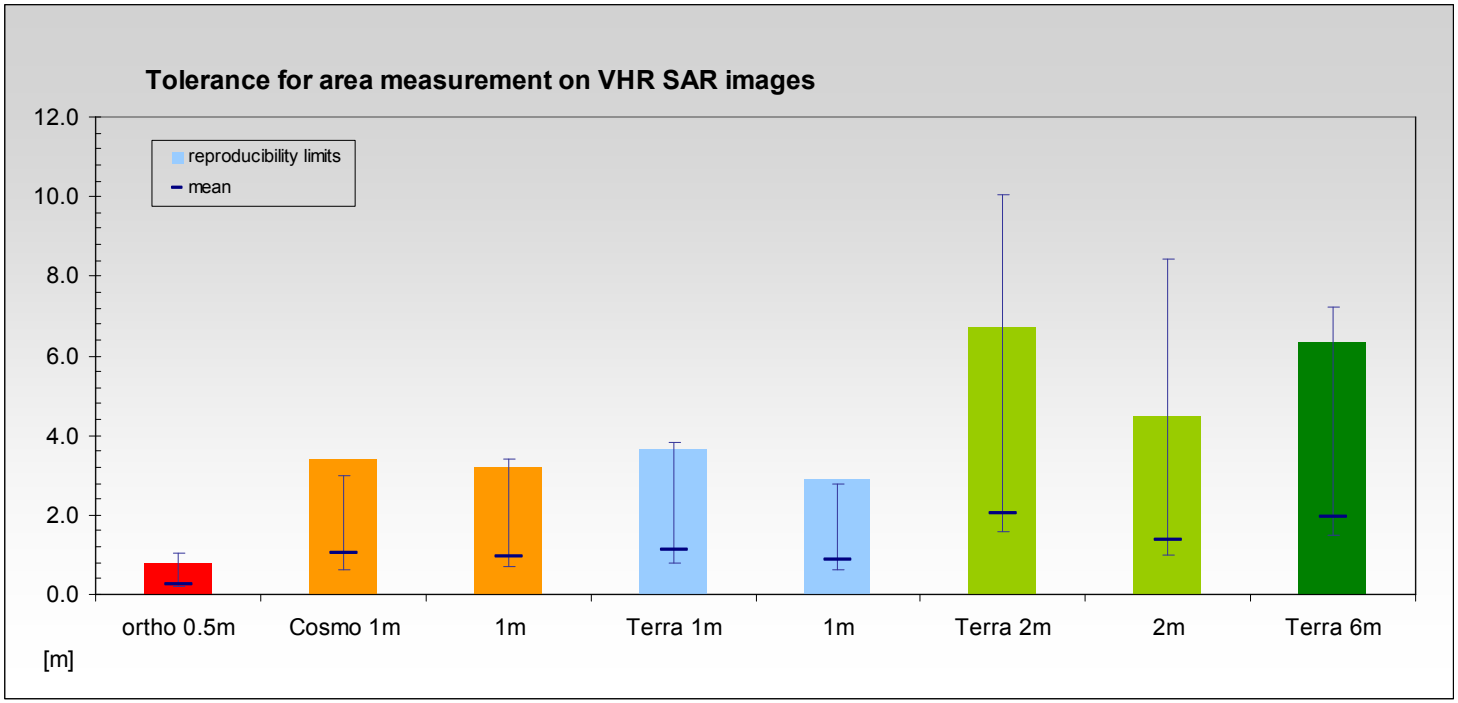
Main factors effected buffer variation

1. incidence angle
   - shallow angle (47-55deg) results with overestimation
   - steep angle (20-40deg) results with underestimation
2. orbit direction
   - descending orbit results with overestimation
   - ascending orbit results with higher variation
3. polarization
   - VV results with higher variation
   - Colour comp results with overestimation
   - the same level of overestimation for both VV and HH





Final results – VHR SAR



buffer	ORTHO 05.2003	Single polarization				Dual polarization		Terra SM CC1103
		Cosmo HH1407	Cosmo HH1207	Terra HSL VV1405	Terra HSL VV2105	TerraSL HH0604	TerraSL CC0604	
Nb observ	360	345	357	370	367	365	371	652
Reproducibility limits [m]	**0.81**	**3.41**	**3.19**	**3.66**	**2.89**	**6.71**	**4.50**	**6.35**
Maximum buffer [m]	0.93	2.27	2.83	3.17	2.21	9.34	8.25	4.55
Min buffer [m]	0.04	0.48	0.31	0.40	0.28	0.55	0.45	0.54

Conclusions from study on SAR images

- 100% of the parcels are recognised on both orthophoto and VHR SAR data
  - 144 outliers out of almost 3000 observations (5%)

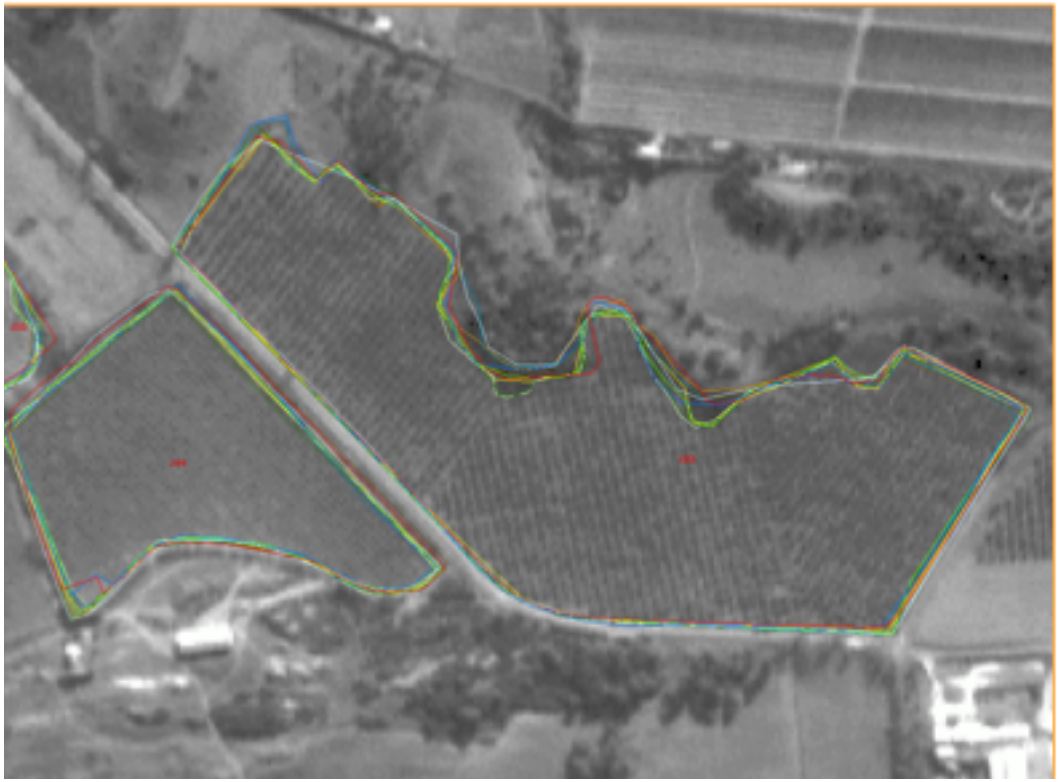
- Estimated tolerances: ~3m on 1m HSL, ~6,7m on 2m SL are higher than the maximum 1.5m obliged by current EU regulations
  - The same tolerance for both sensors: TerraSAR-X and CosmoSkyMed

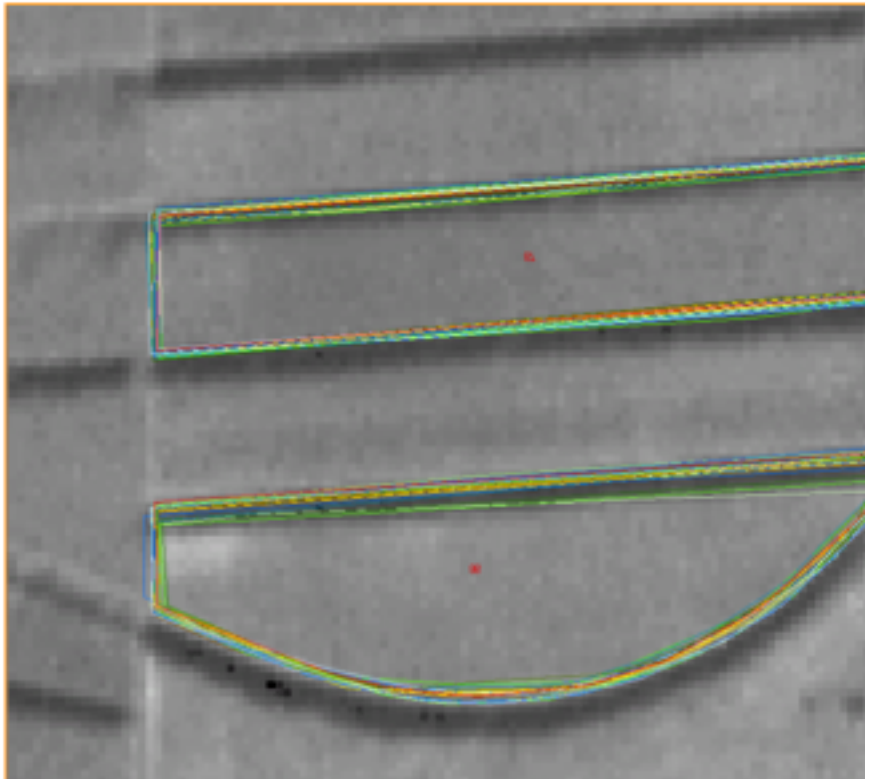
- Compensatiing effect of multipolarized information on lower resolution: ~4,5m on colour SL (2m) and ~6,4m on colour SM (6m) image

- Significant effects on buffer variability: incidence angle and orbit direction,
  - no effect of polarization

CARTOSAT-1: results

Image	Ortho	Cart Fore	Carto Aft
Mean value = bias [m]	-0,06	0,52	0,04
Reproducibility st. dev [m]	1,02	3,13	1.85
Reproducibility Limit [m] 2.81*stdev	2,86	8,76	5,17





Discussion and recommendations

- Photointerpretation on VHR SAR in general more difficult than on optical images of same GSD
  - Advanced training on radar imagery needed
  - Photointerpretation guidelines are very necessary

- Main problems not with parcel identification, but with boundary delineation
  - Difficulties with feature recognition on borders
  - Feature interpretation success depends somewhat on image parameters

- VHR SAR images acquired under the shallow incidence angle and ascending direction are recommended
- The SAR systems tested can be considered as a possible backup solution for CwRS in accordance with European legislative requirements

  - However: CARTOSAT-1: outside usable specification in this test

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