POLSARAP: INVESTIGATING THE BENEFITS OF POLARIMETRY FOR URBAN APPLICATIONS USING X-BAND SAR IMAGES

ONERA
THE FRENCH AEROSPACE LAB

POLINSAR 2011

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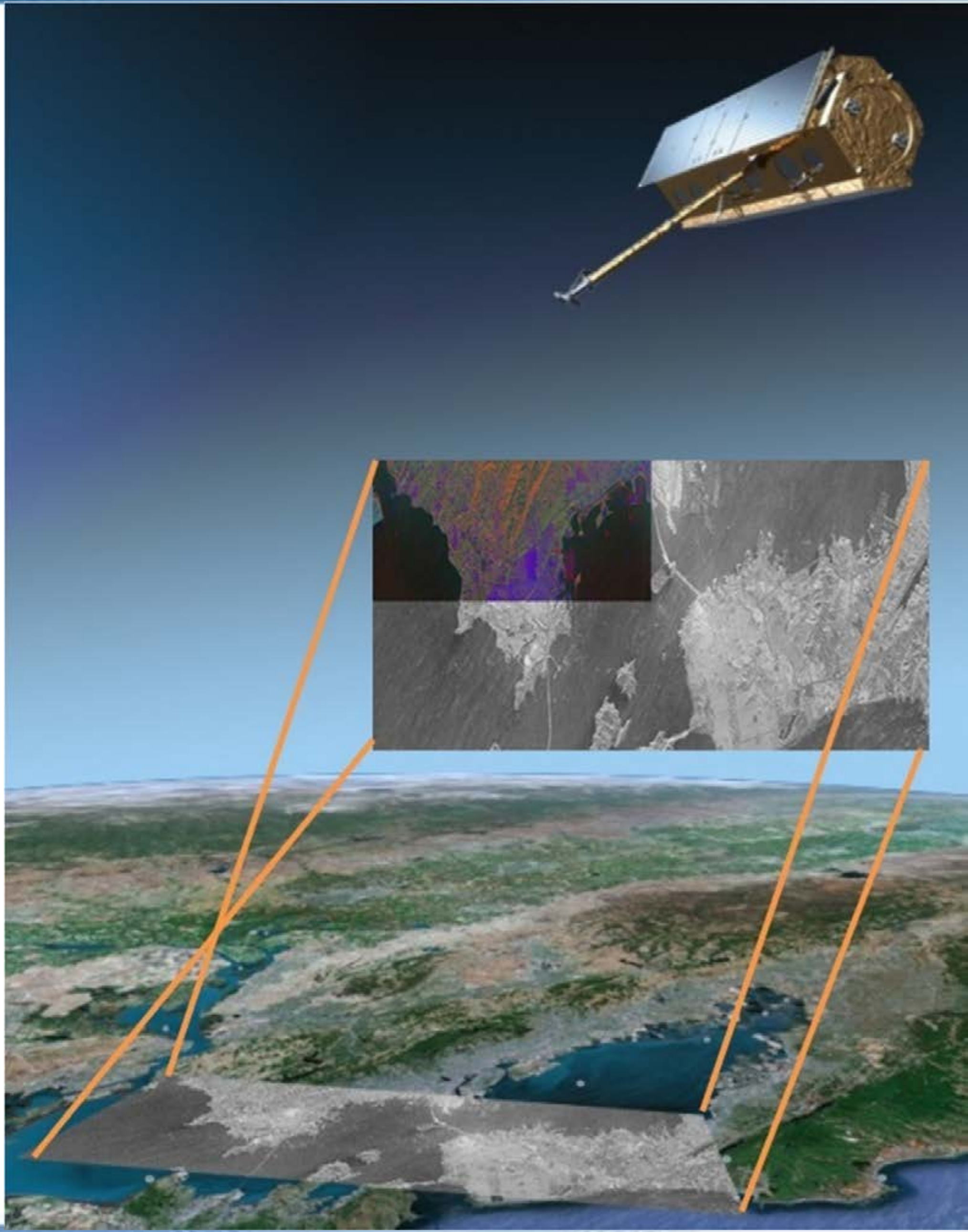
Outline

- Introduction: State of the Art, limitations and questions
- Classification
- 3D rendering
- Results and perspectives.



Introduction

On the use of polarimetry in the context of urban images

"POLSARAp"

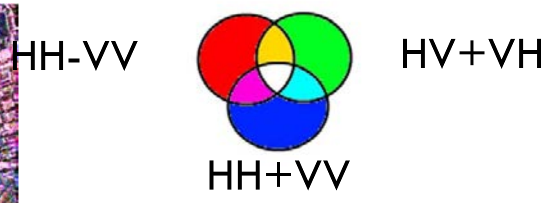
POLSAR Applications over urban

- Determination of three key applications
  - Subsidence
  - Classification
  - 3D rendering
- Determination of test sites and data sets
  - Toulouse
  - San Francisco

TerraSAR-X San Francisco images

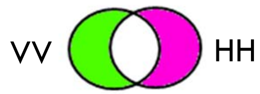
X-band, 1m x 1m

TerraSAR-X



X-band, 2m x 6m

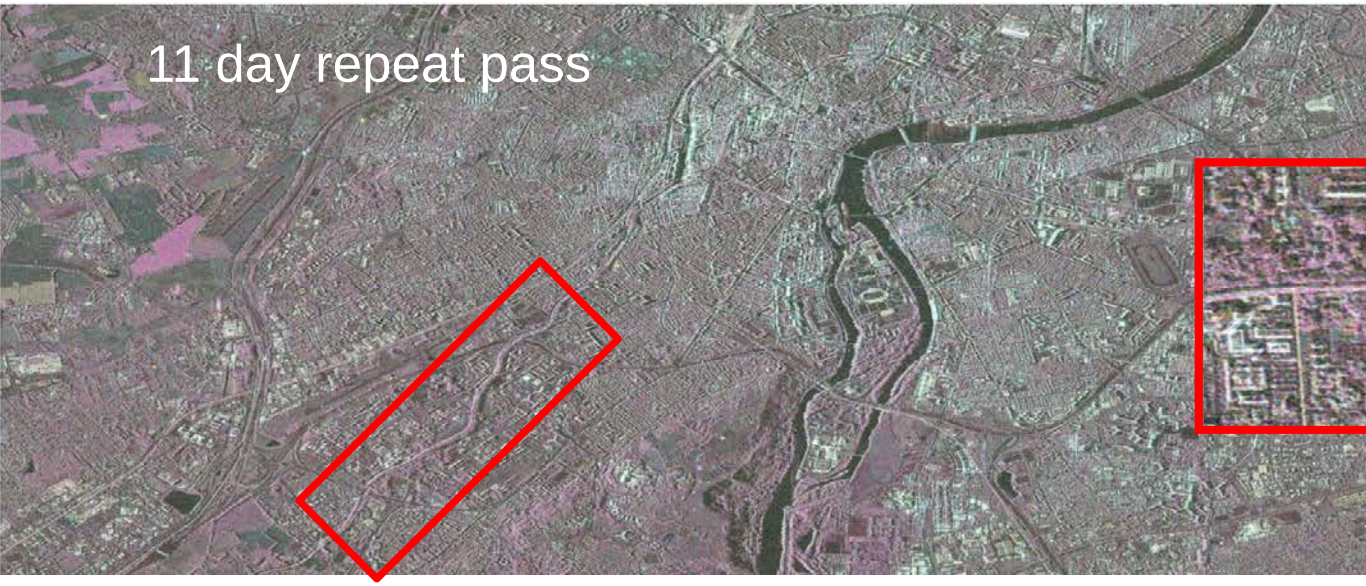
TerraSAR-X

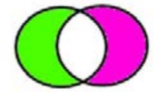


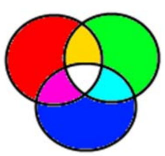
X-band, 2mx2m

Toulouse images

TerraSAR-X

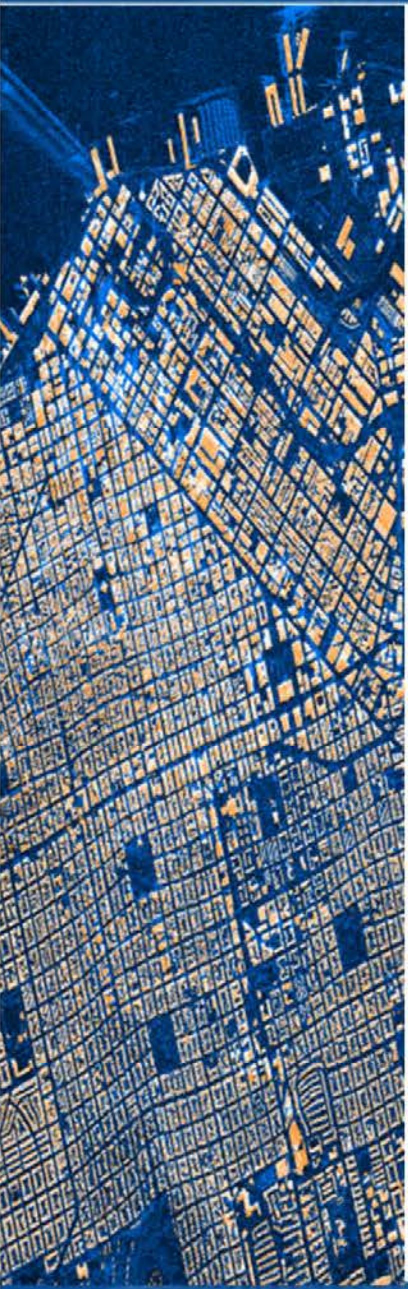




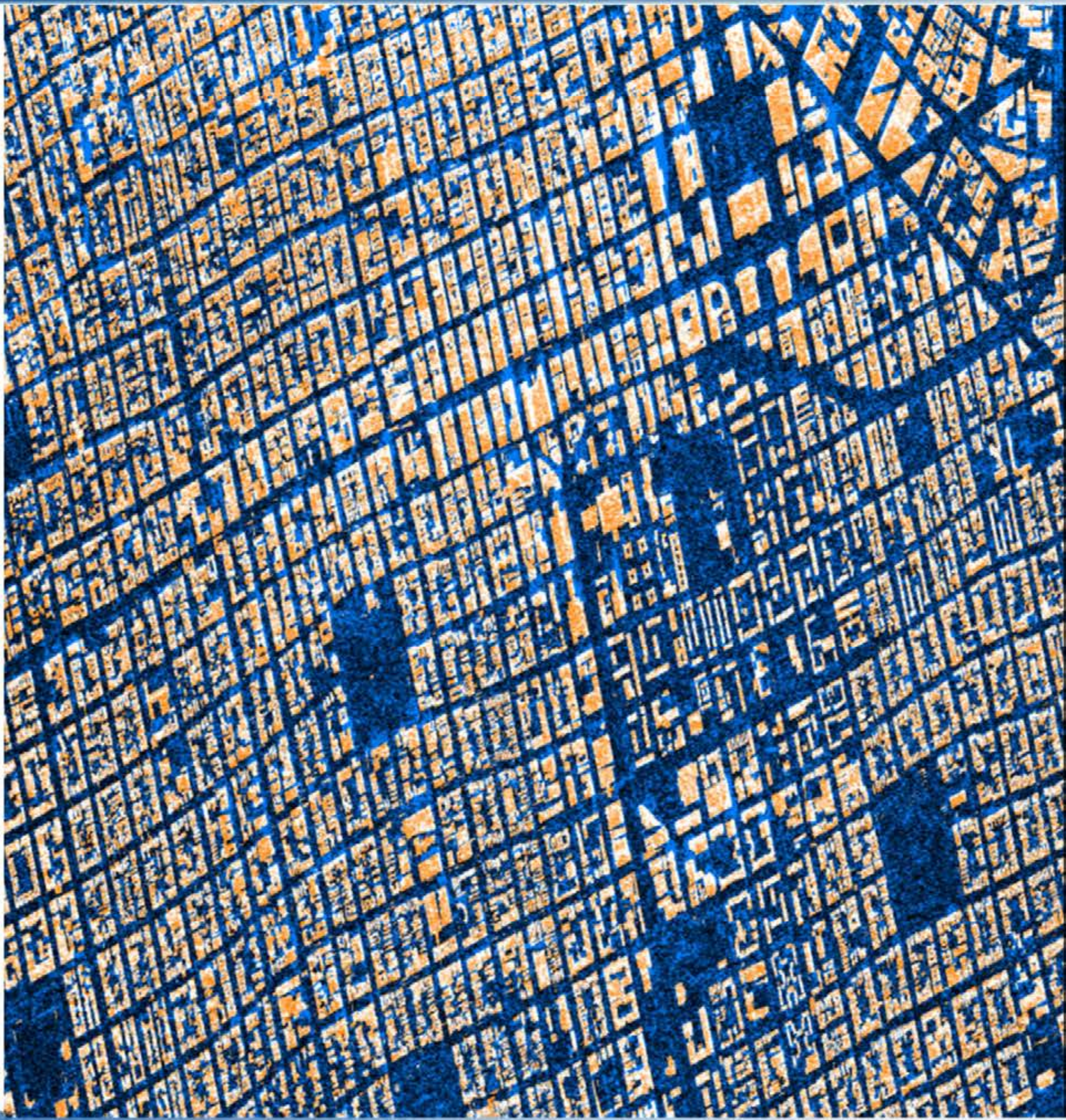


RAMSES (ONERA) airborne

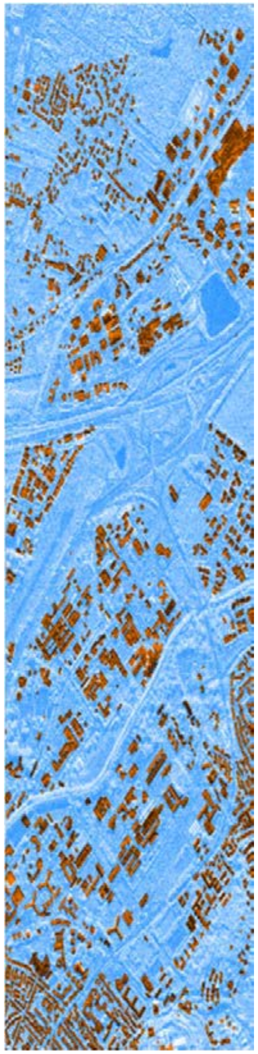
Registering of ground truth over San Francisco



- Geographical reference transformation
- Take into account the radar projection
- Projection of building footprints on the SAR image

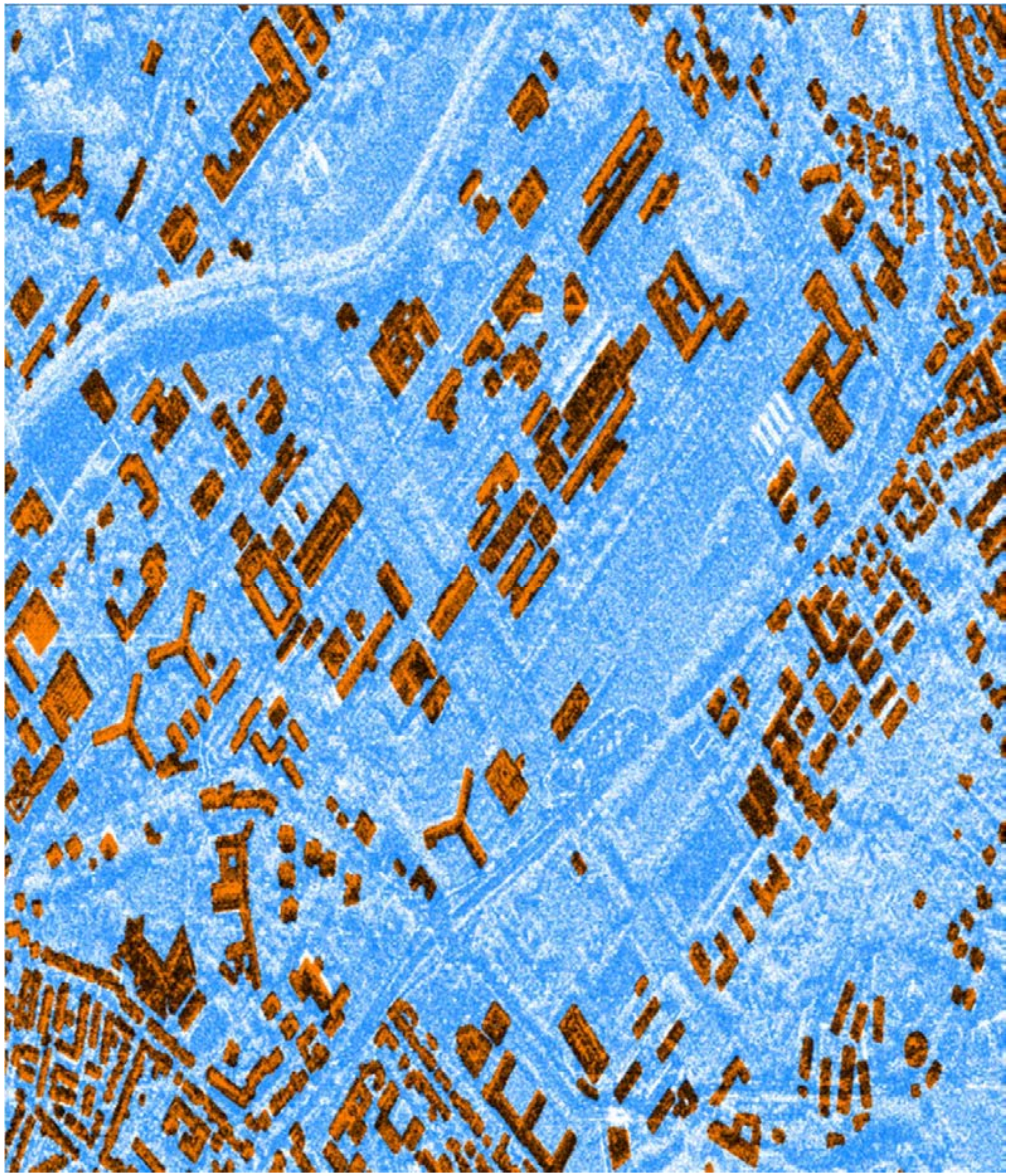


Registering of ground truth over Toulouse



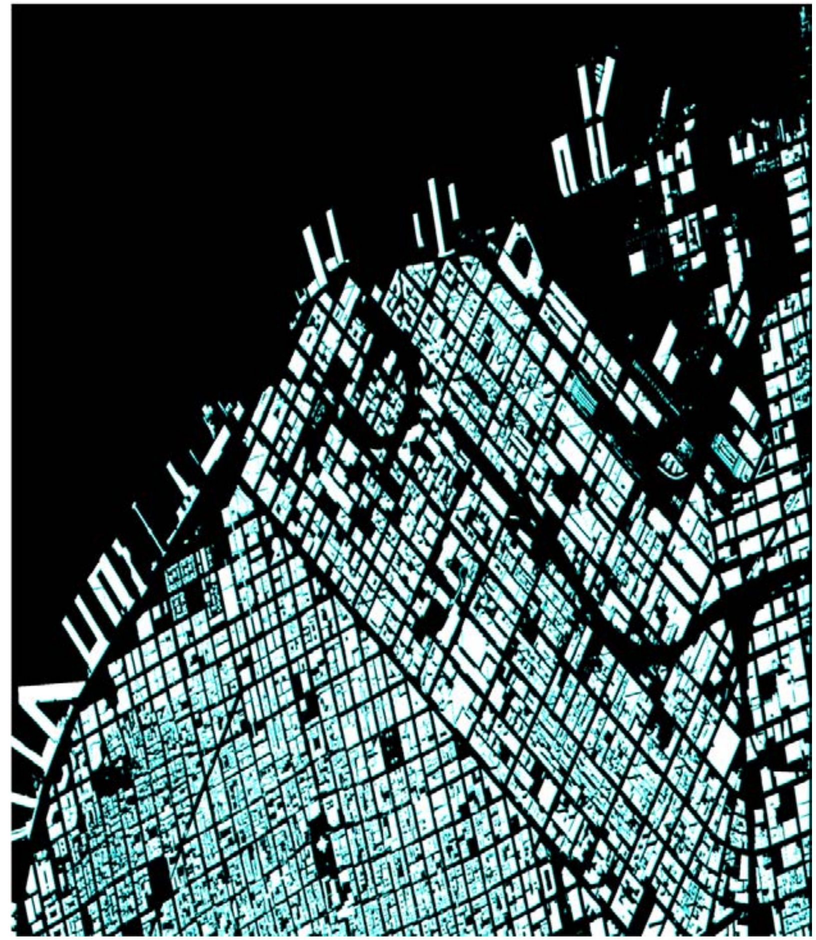
Intensity image

Building footprint given ground truth



Use of the ground truth for building detection purpose

Initial ground truth is transformed in a 3 class image



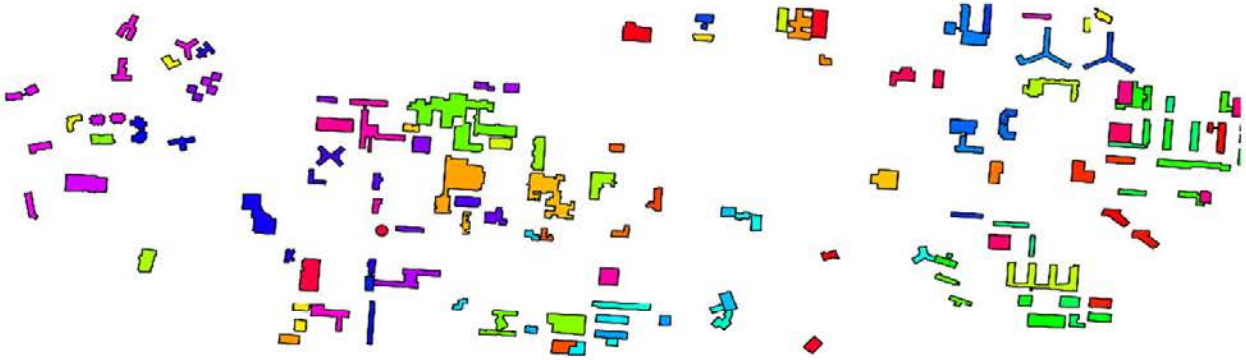
Natural targets
Built-up
Pixels non used

Classification results will be quantified thanks to ROC curves bases on this ground truth

[See Nicolas Trouvé next presentation]

Ground truth for 3D rendering of airborne data

Top height is given with a **precision of 1 meter**

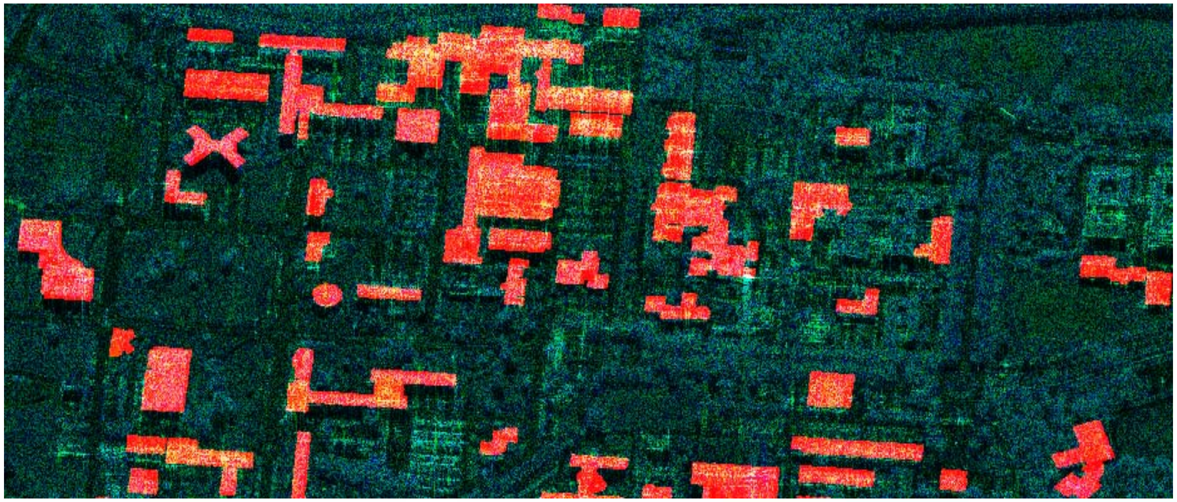


Selection of buildings

Present in the airborne POLINSAR image

- Whose height is > 6 m
- Whose size is > 10 m^2

140 buildings

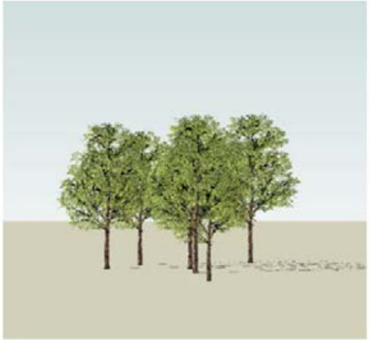


Classification

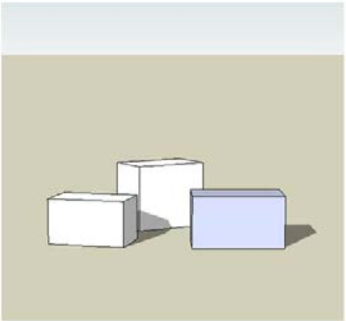
- Polarimetry
- POLINSAR

Polarimetric speficity over urban

- Deterministic / non deterministic targets ?
- Lack of azimuthal symmetry



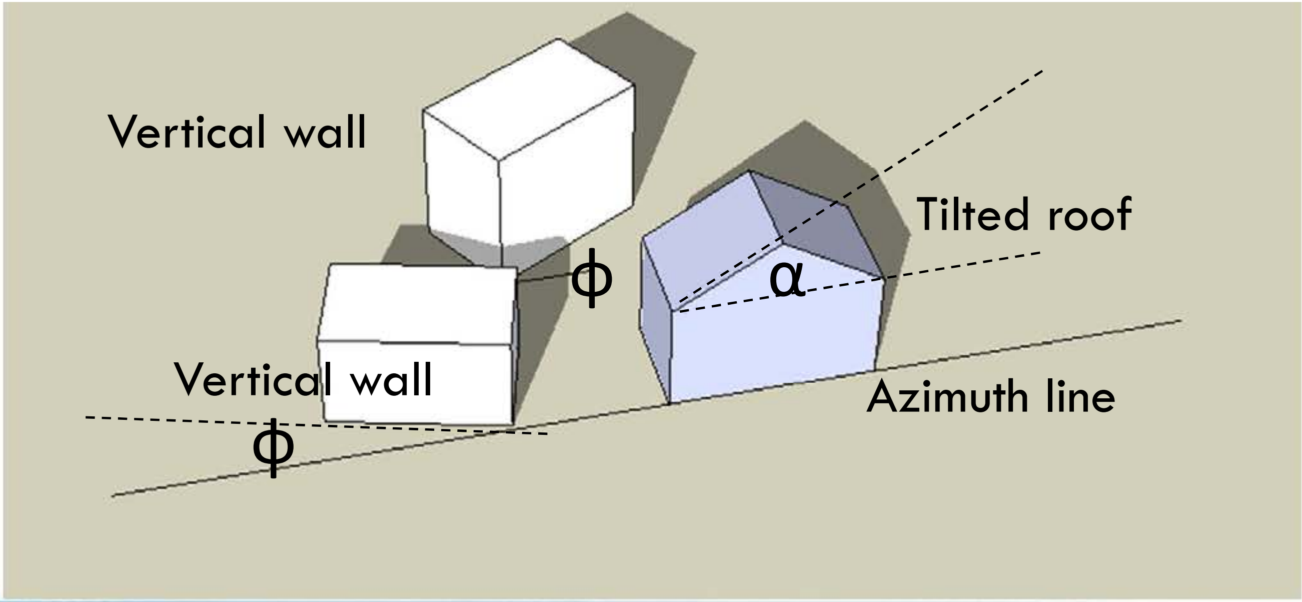
$< S_{HH}S_{HV}^* > = < S_{HV}S_{VV}^* > = 0$



$< S_{HH}S_{HV}^* > \neq 0, < S_{HV}S_{VV}^* > \neq 0$

- Orientation angle

Induced either by:
- tilted roof
- dihedral effects non aligned with the azimuth



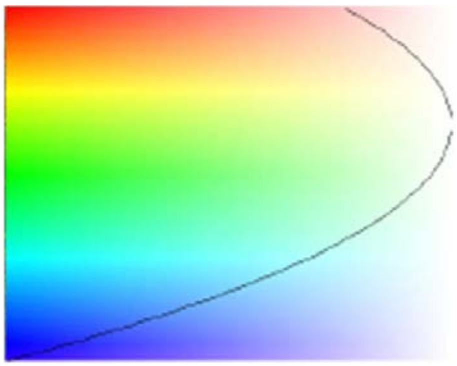
San Francisco

Contains:

- see
- buildings
- vegetated areas

Entropy – alpha - span

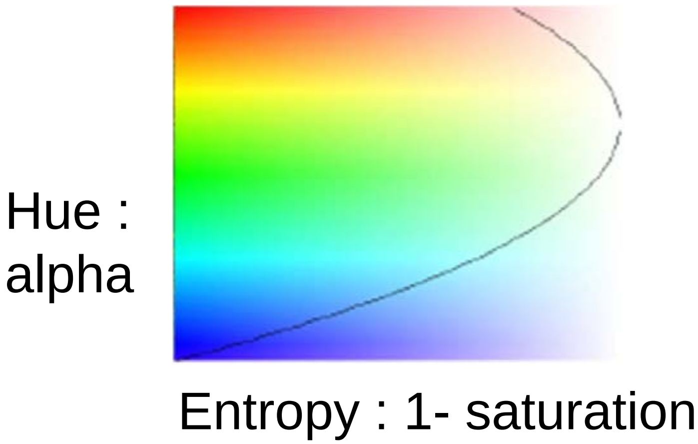
Hue : alpha



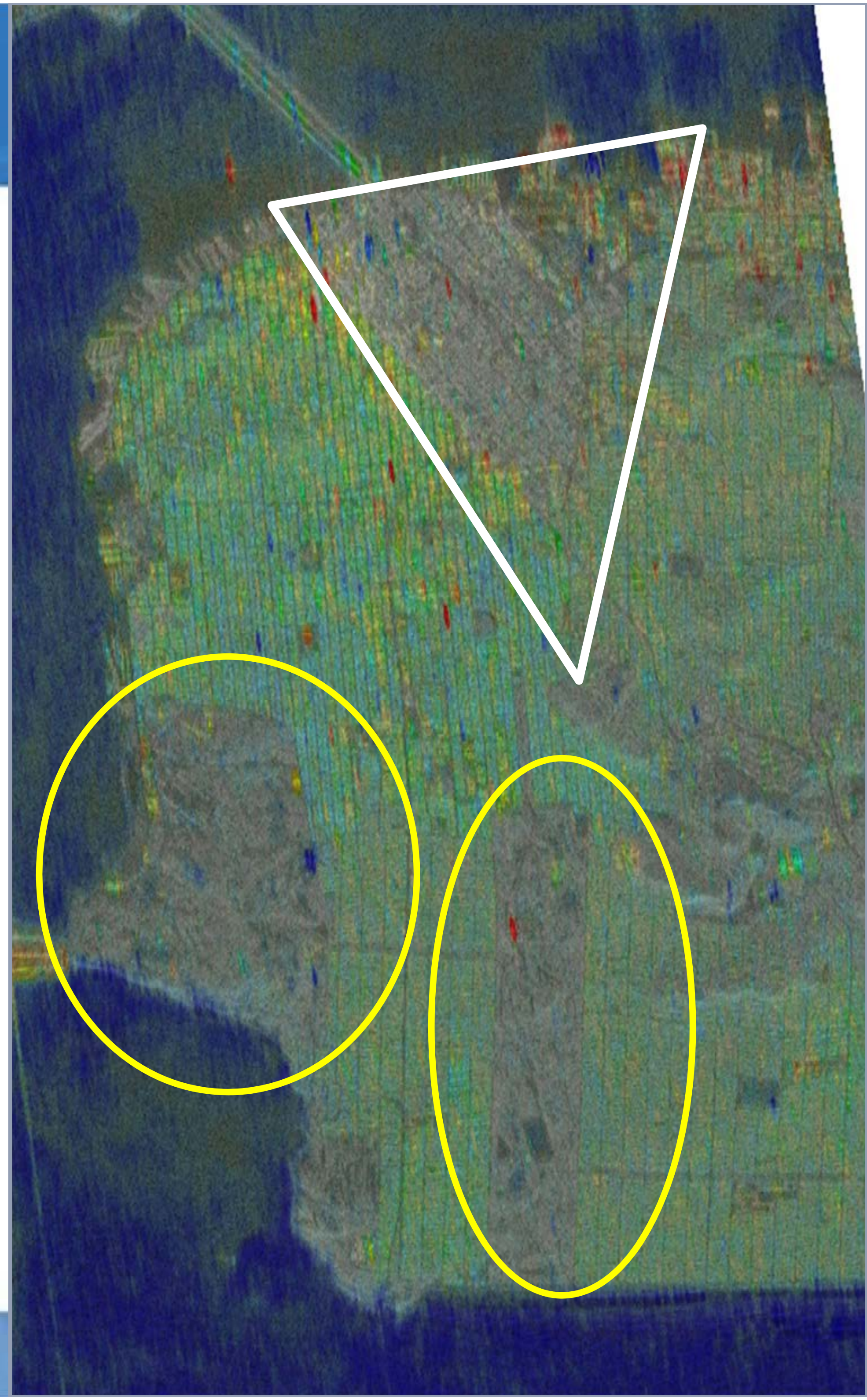
Entropy : 1- saturation

AIRSAR L-band

Entropy – alpha - span

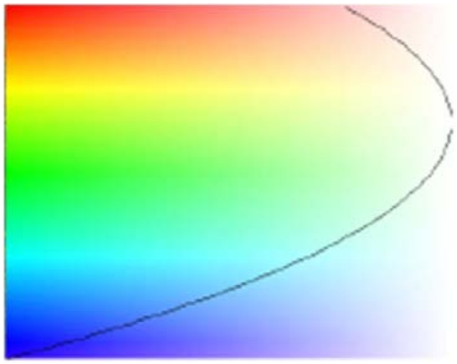


ALOS
L-band



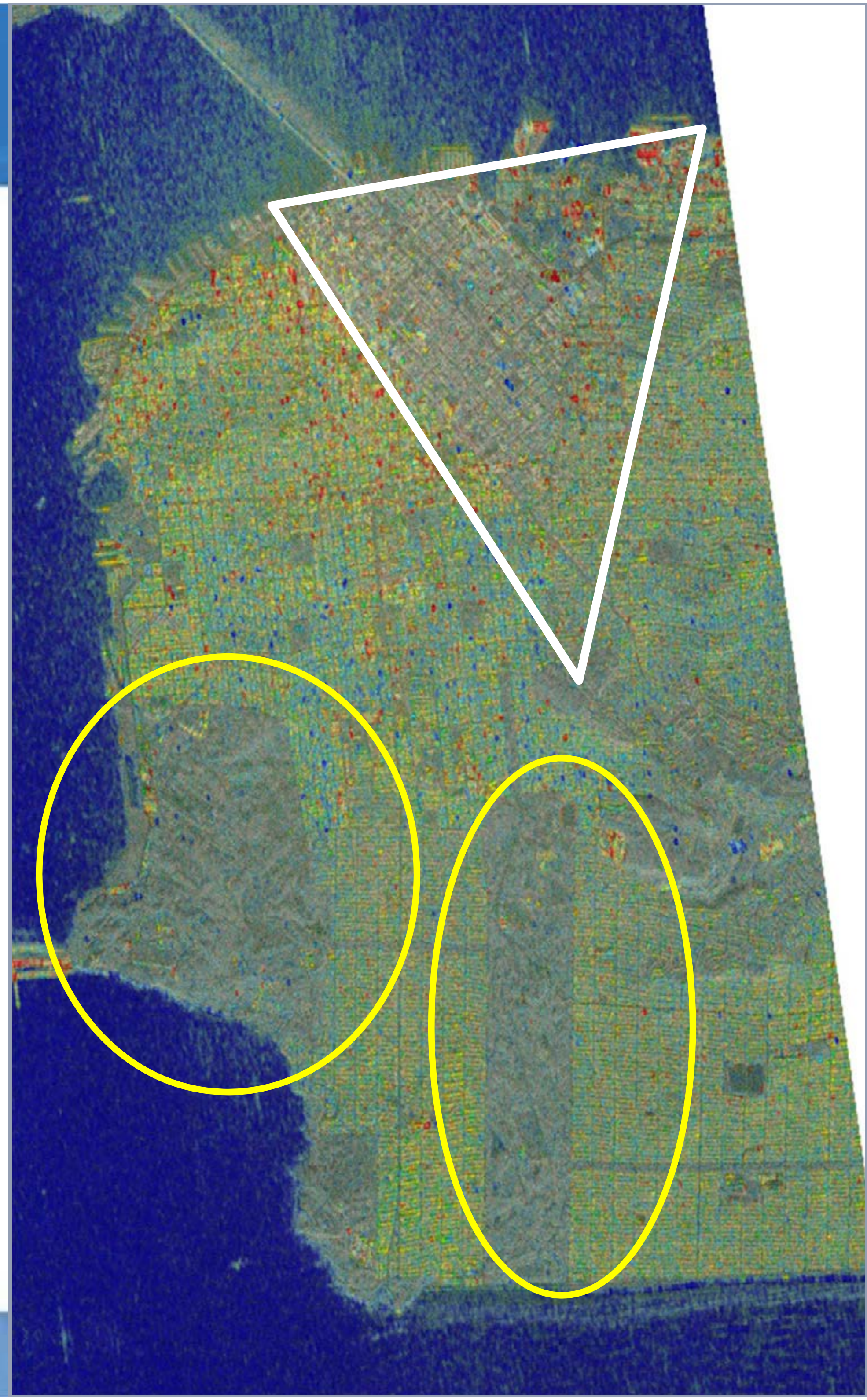
Entropy – alpha - span

Hue : alpha



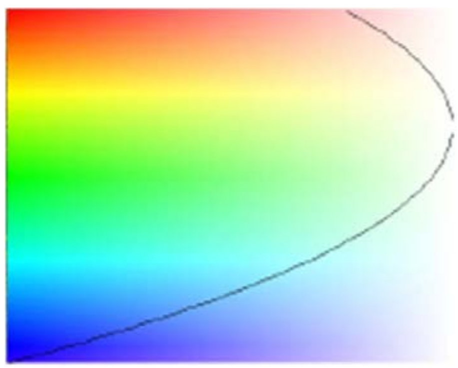
Entropy : 1- saturation

RADARSAT-2
C-band

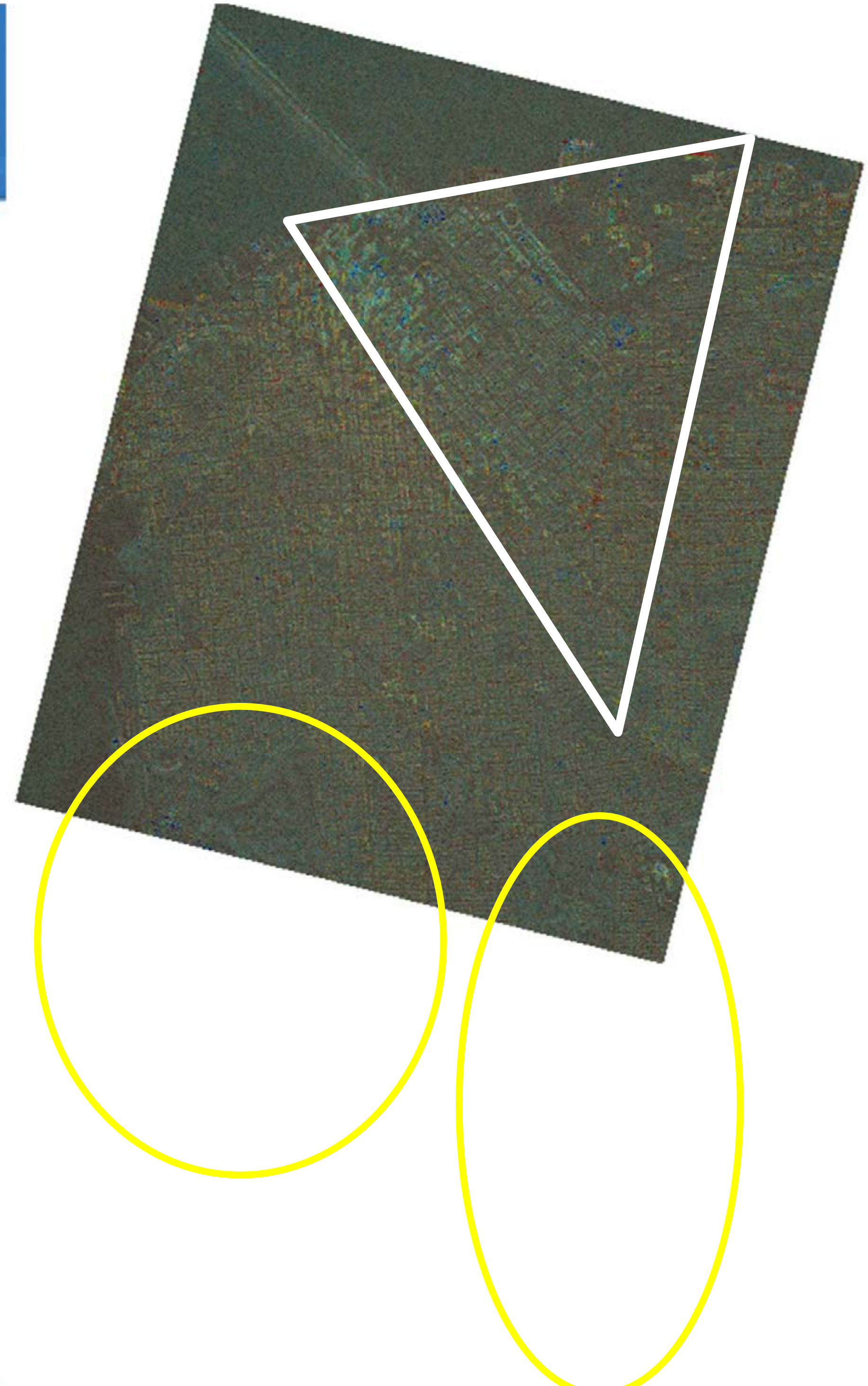


Entropy – alpha - span

Hue : alpha

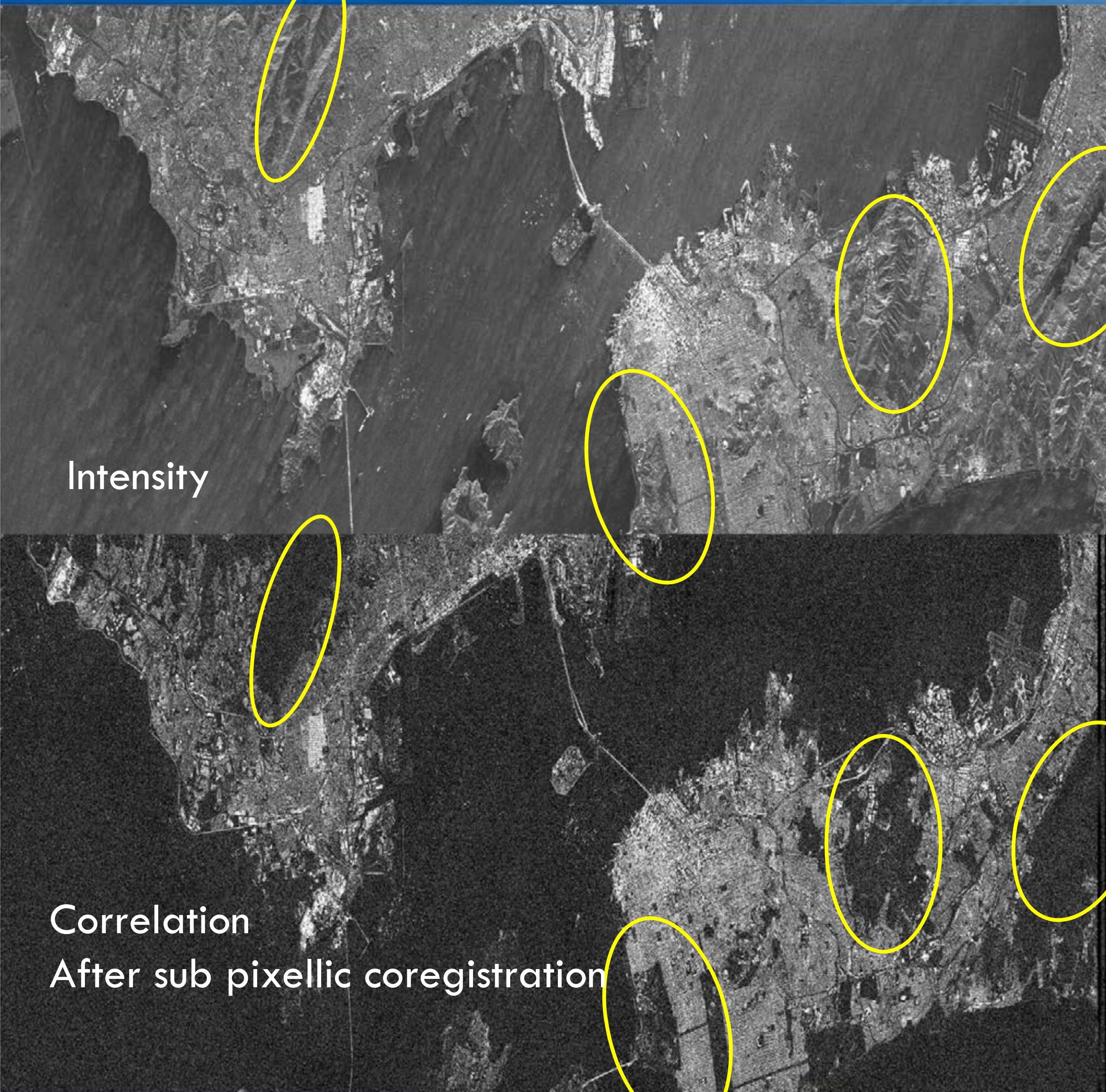


Entropy : 1- saturation



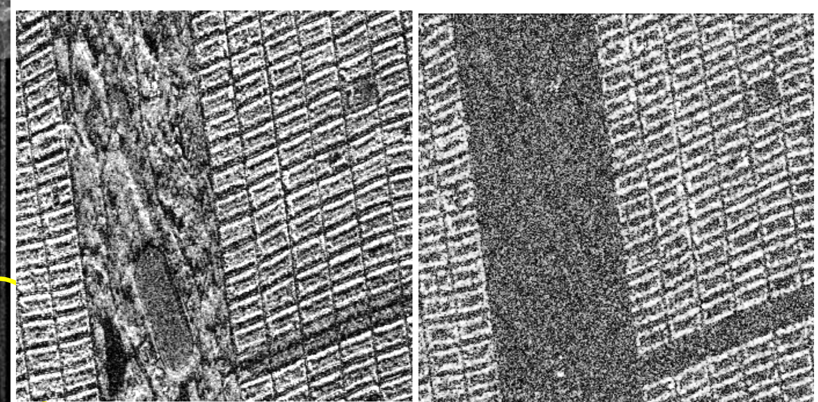
TerraSAR-X
X-band

On the use of interferometric coherence

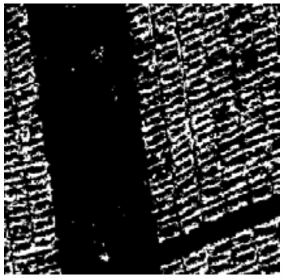


Interferometric coherence in case of temporal decorrelation:

interesting parameter to discriminate deterministic targets!



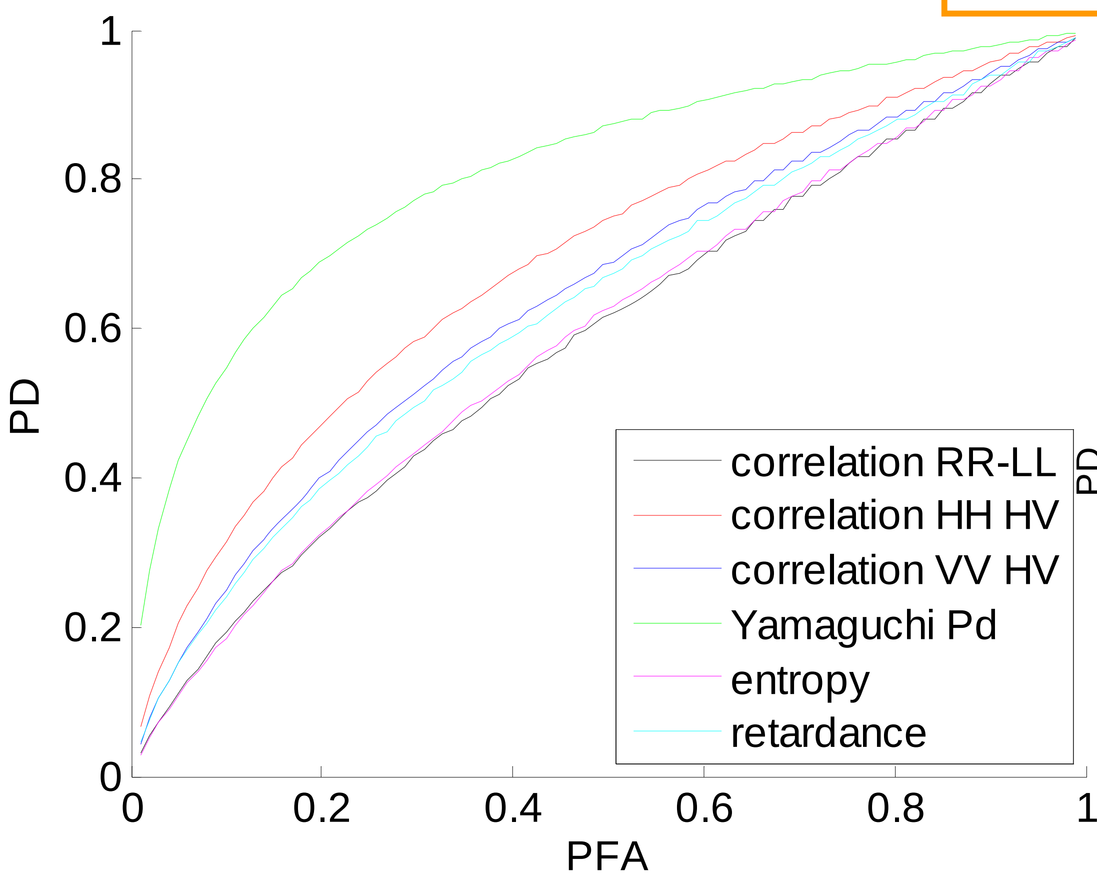
Simple thresholding

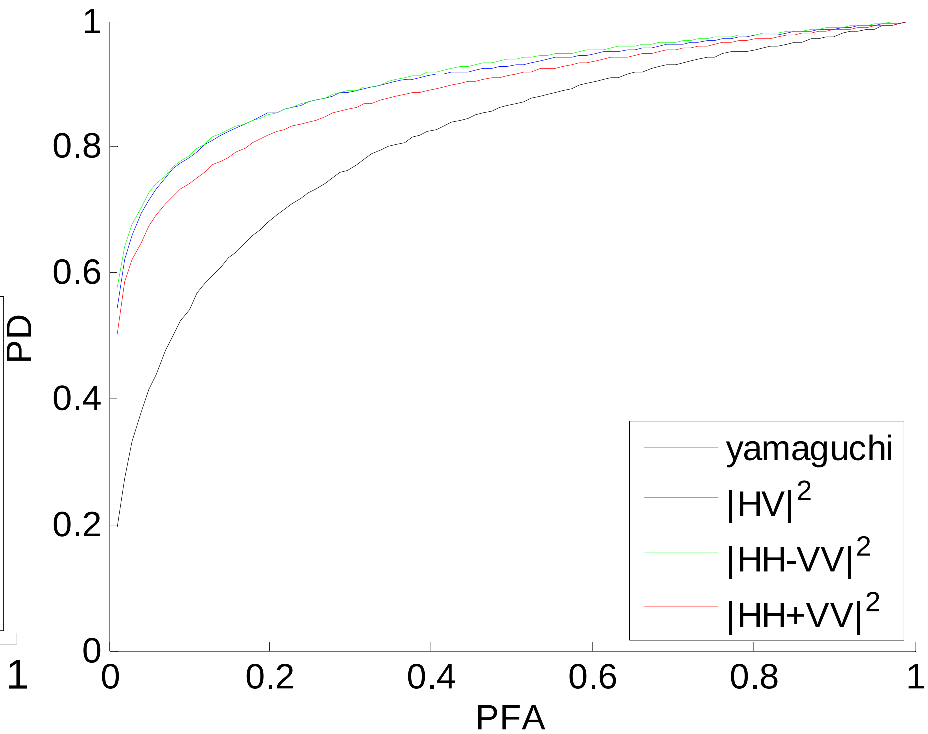


Polarimetry without interferometry

San Francisco

Full polarimetry



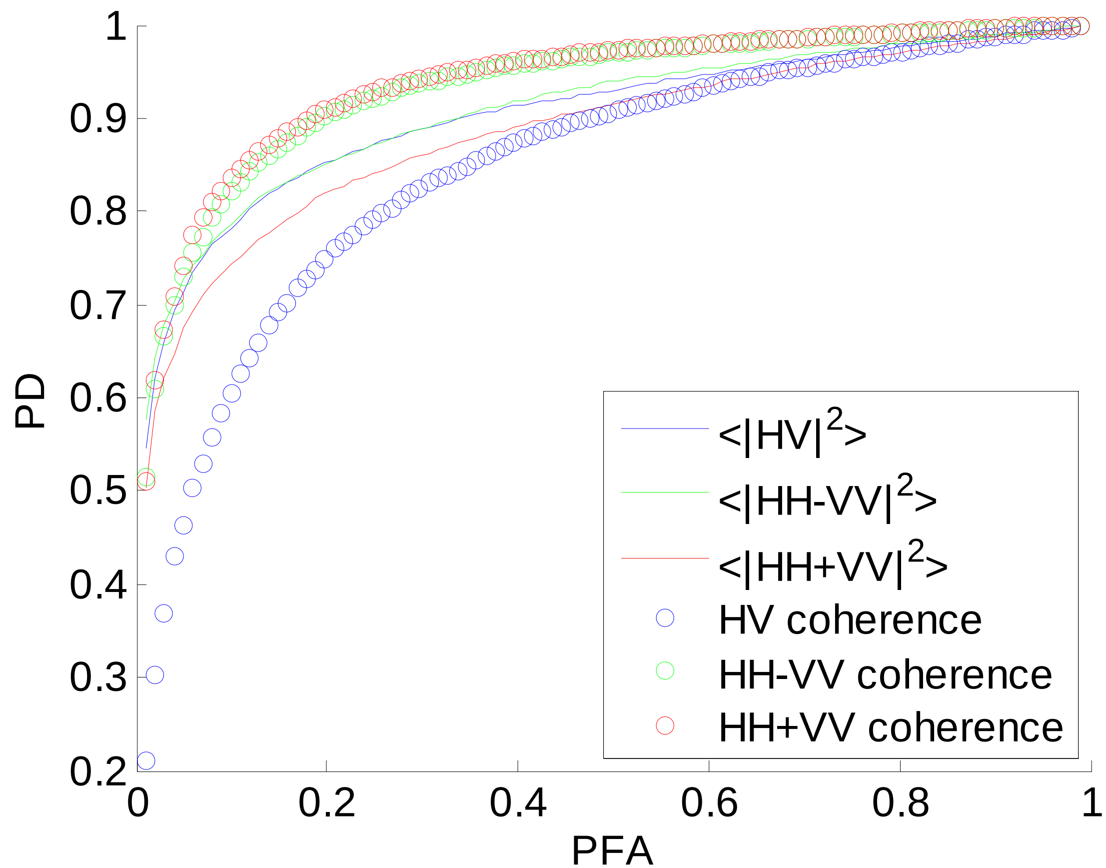


- ➢Good performance of Yamaguchi double bounce component
- ➢Polarimetry alone less informative than intensities

Interferometry vs intensities

San Francisco

Full polarimetry



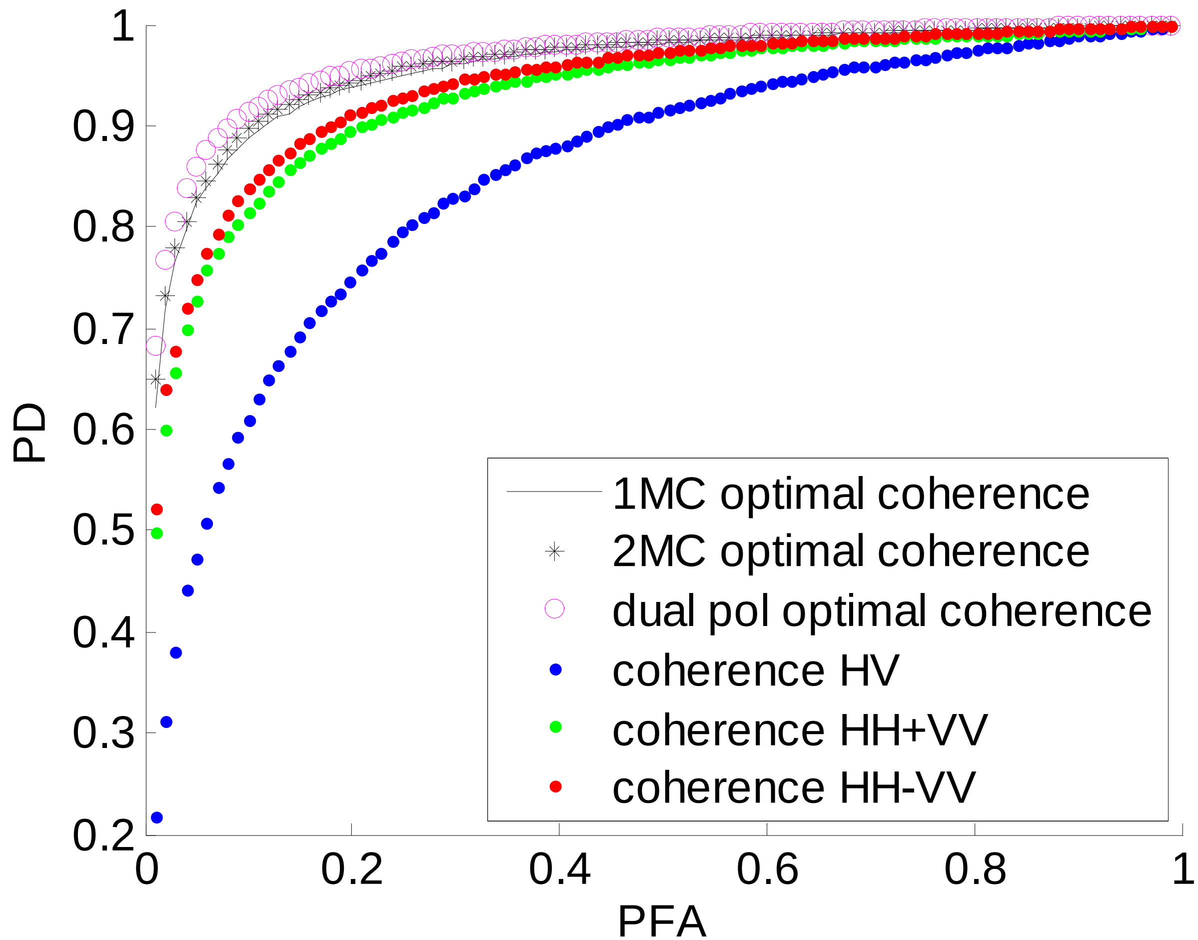
- ➢Use of interferometric coherence is better than use of the intensity

- ➢Except in HV polarization where HV is more informative. <HV> is known as valuable channel for detecting built-up areas because of orientation effects comparing to surfaces (bare soil and ocean)

Single interferometric vs POLINSAR

San Francisco

Full polarimetry

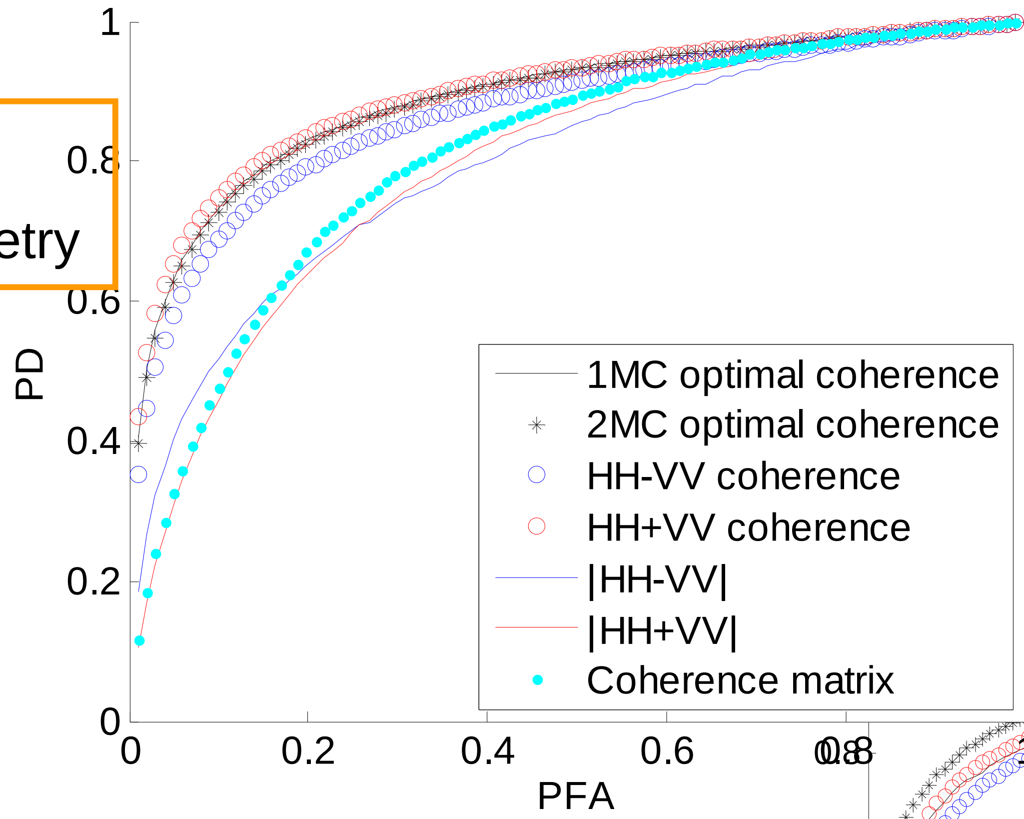


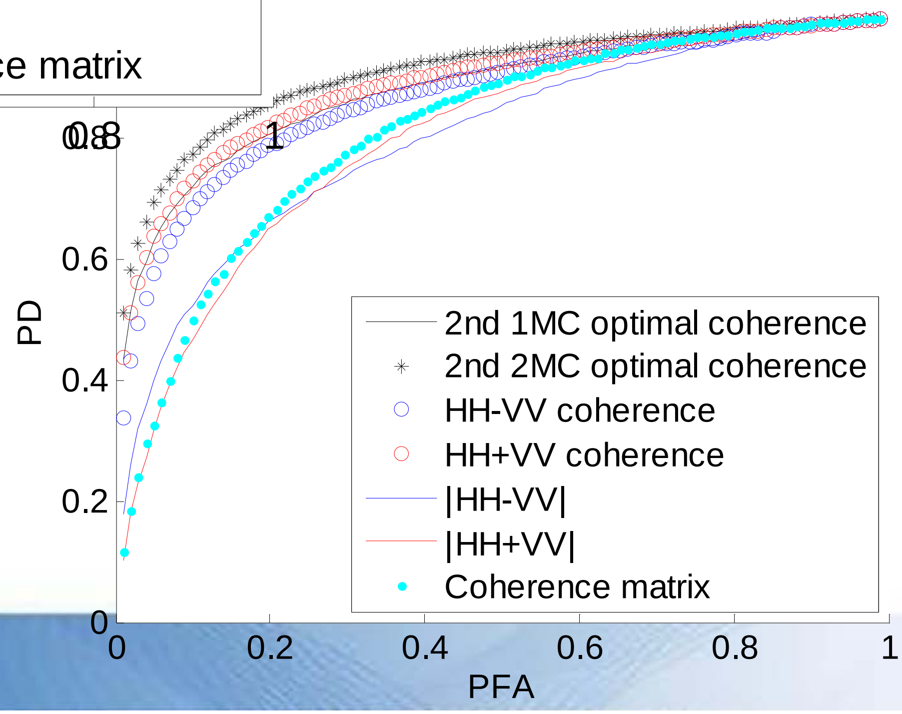
- Benefit of polarimetry using coherence optimization
- Optimization better omitting some of polarization (here: HV)
- Equivalent performance for single mechanism and two mechanism optimization

Dual polarimetry over Toulouse

Toulouse

dual polarimetry





➢Better performance of 2nd optimal coherence: better contrast!

Summary of coherence optimization gain

- Water, vegetation: more decorrelation than bare soil:

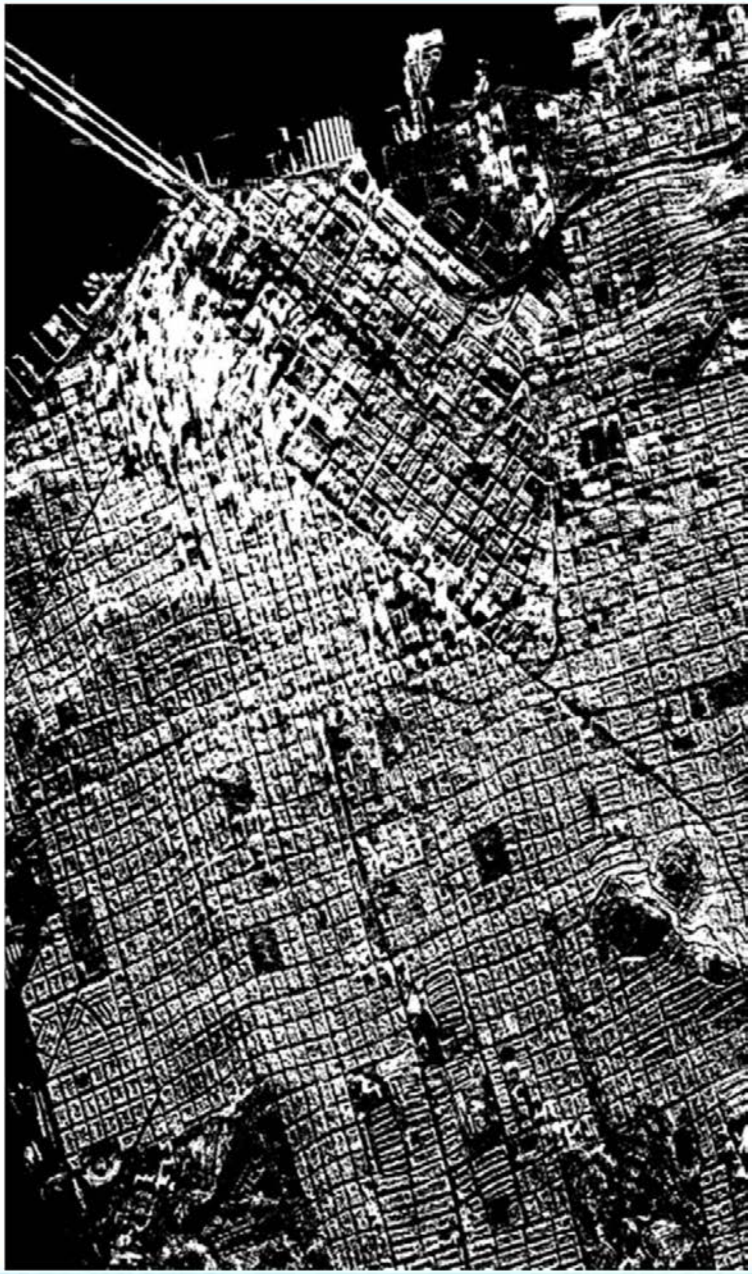
  contrast remains high even after optimization

  coherence optimization very efficient

- Optimization can be sometimes non as efficient as expected,
  - in presence of bare soil whose optimization can improve coherence, or
  - when a polarimetric channel has an inefficient level (HV)

- Adaptative coherence optimization according to maximization of contrast would be better

Results of classification using optimal coherence



3D rendering

-Analysis of the coherence shape

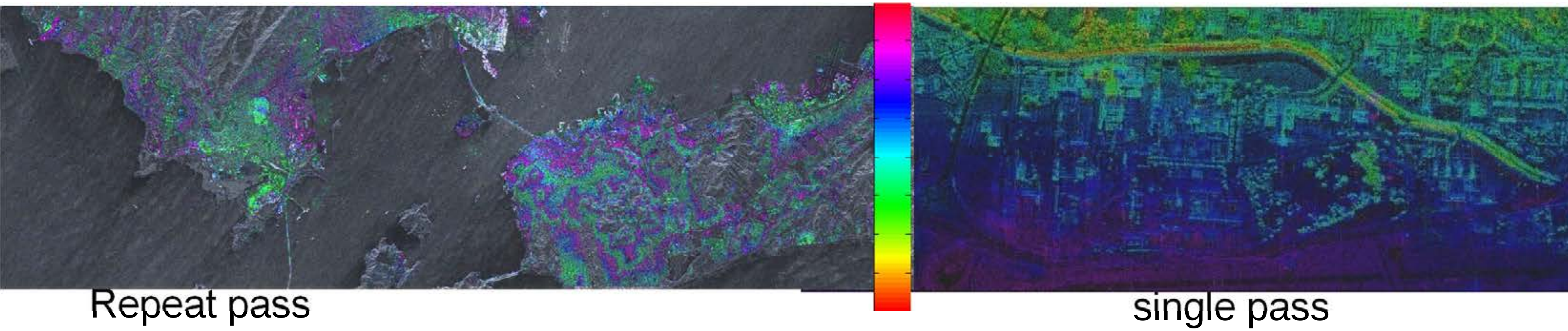
-Proposition of an inversion scheme

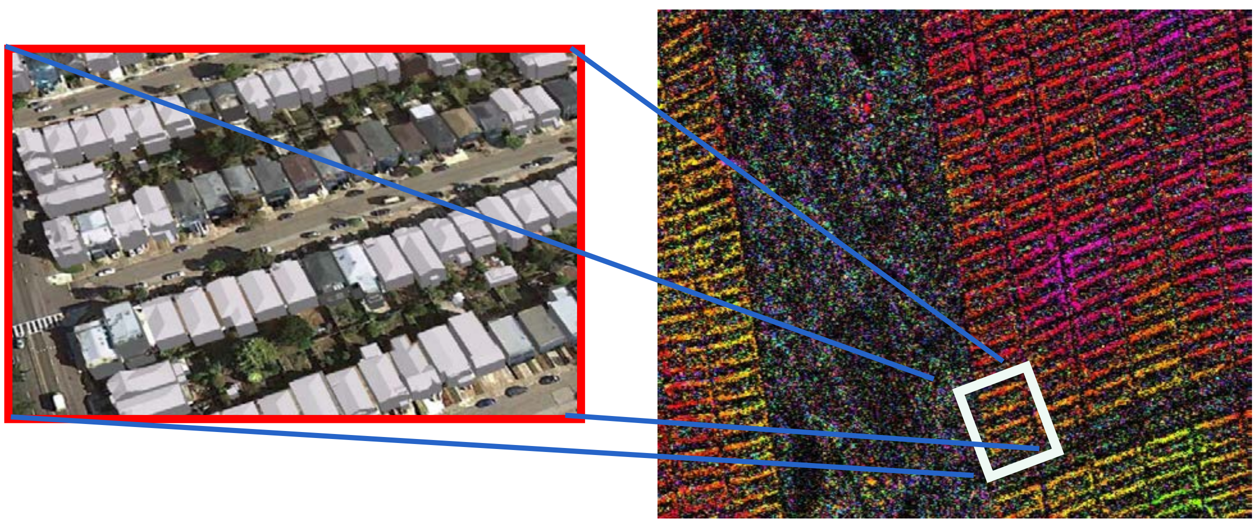
-results

Single pass vs repeat pass

- important criteria: repeat pass or single pass

Hue : interferometric phase Intensity : span Saturation : coherence level



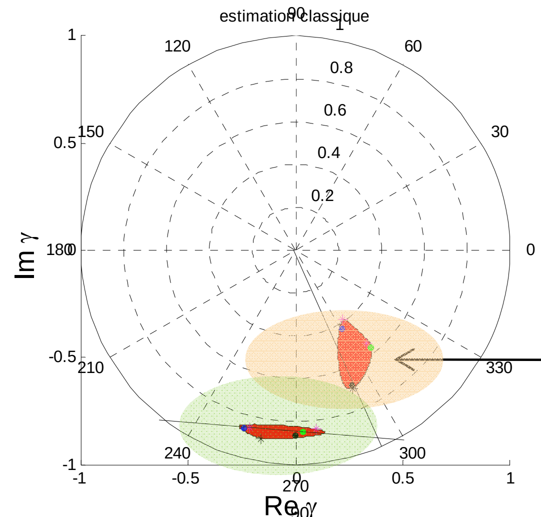


If we want to estimate both ground and building elevation, we need repeat pass acquisition

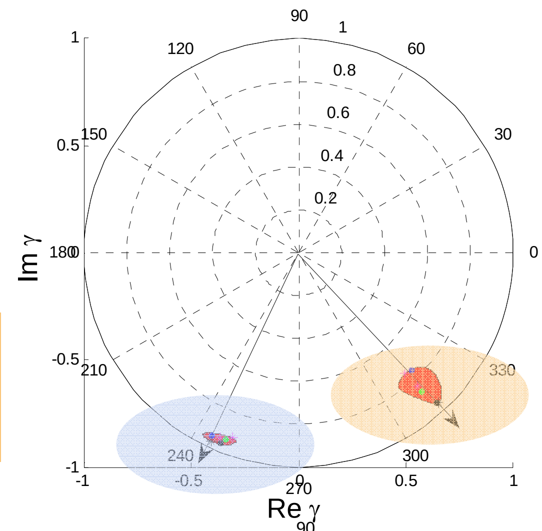
- Repeat pass: Phase information is available only on buildings

Ground segments and building segments

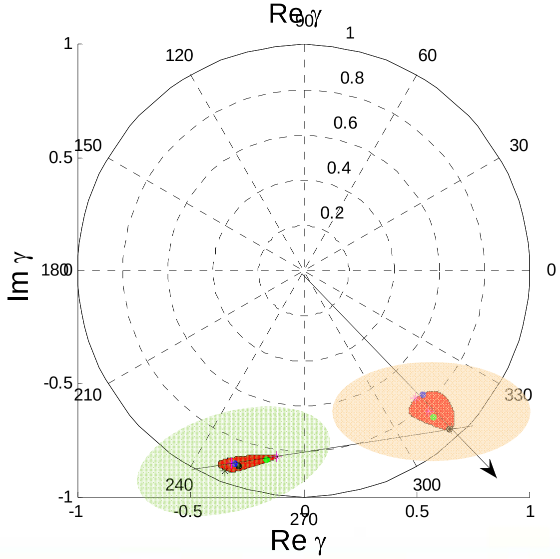
- Analysis presented in POLINSAR 2011



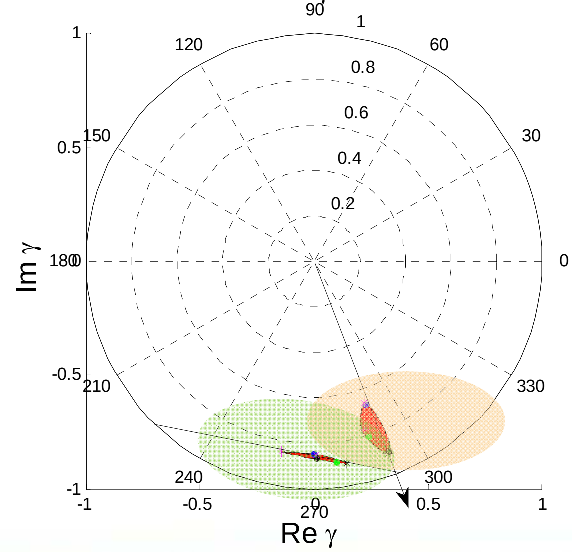
Bare soil segments



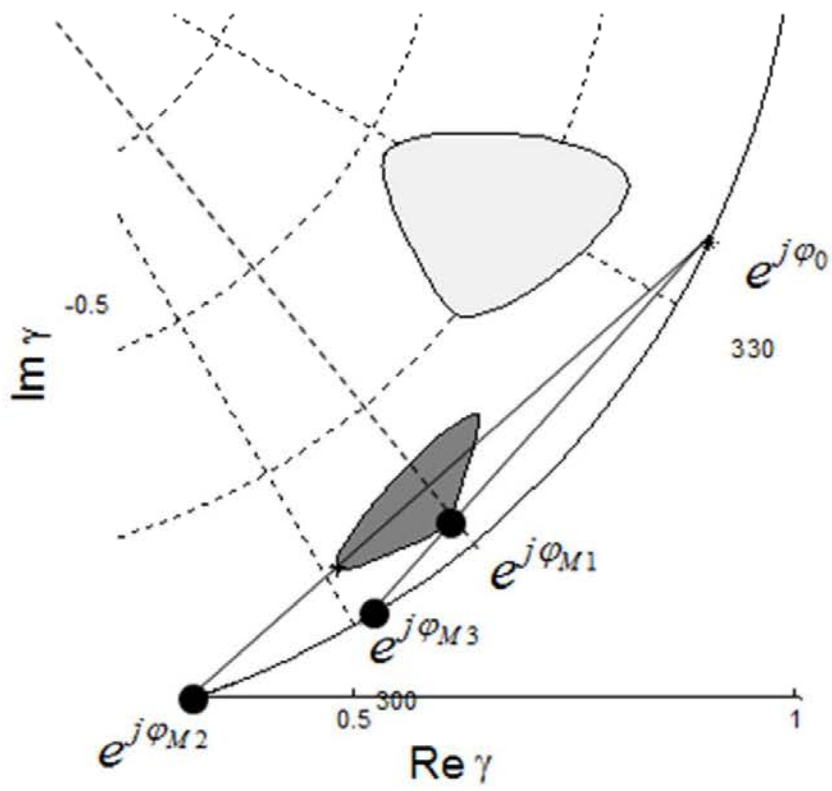
Building segments without internal polarimetric diversity



Building segments with polarimetric diversity



Tested methods



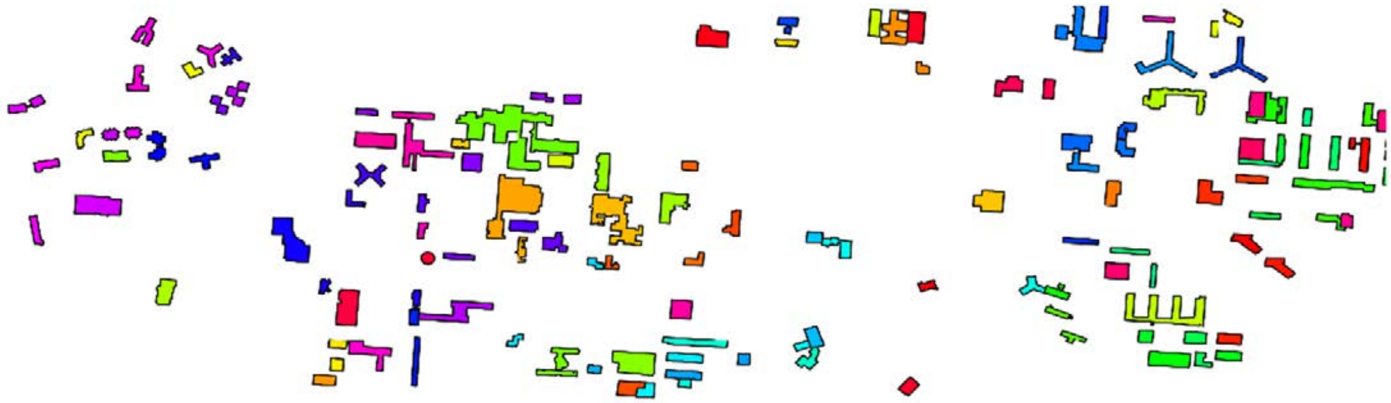
Method #1
Difference between optimal coherence of the ground and optimal coherence of the roof

Method #2
Regression between optimal coherence of the ground and extremal angle of the coherence of the roof

Method #3
Regression between optimat coherence of the ground and optimal coherence of the roof

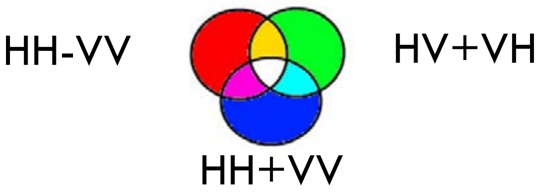
Quantitative results

Method	Difference <Reference Height – Estimated Height >	RMSE
HH+VV	2.57	3.89
HH-VV	2.76	4.60
HV	**2.23**	3.79
Method 1 (diff optimal coherence)	2.47	3.65
Method 2 (linear regression with extremum angle)	-5.65	9.25
Method 3 (linear regression with optimal coherences)	**1.20**	**2.87**

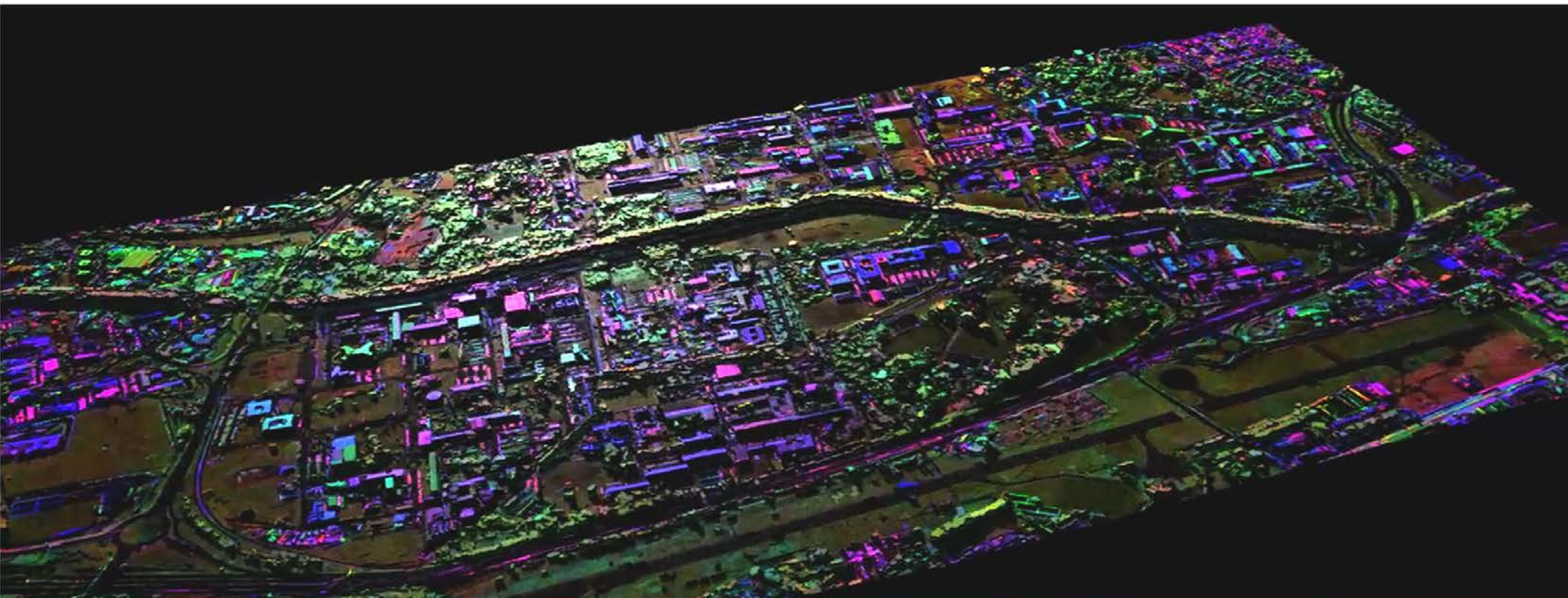


Top height is given with a **precision of 1 meter**

Summary



Mean underestimation: **1.20 m**
RMSE : 2.87 m



Summary

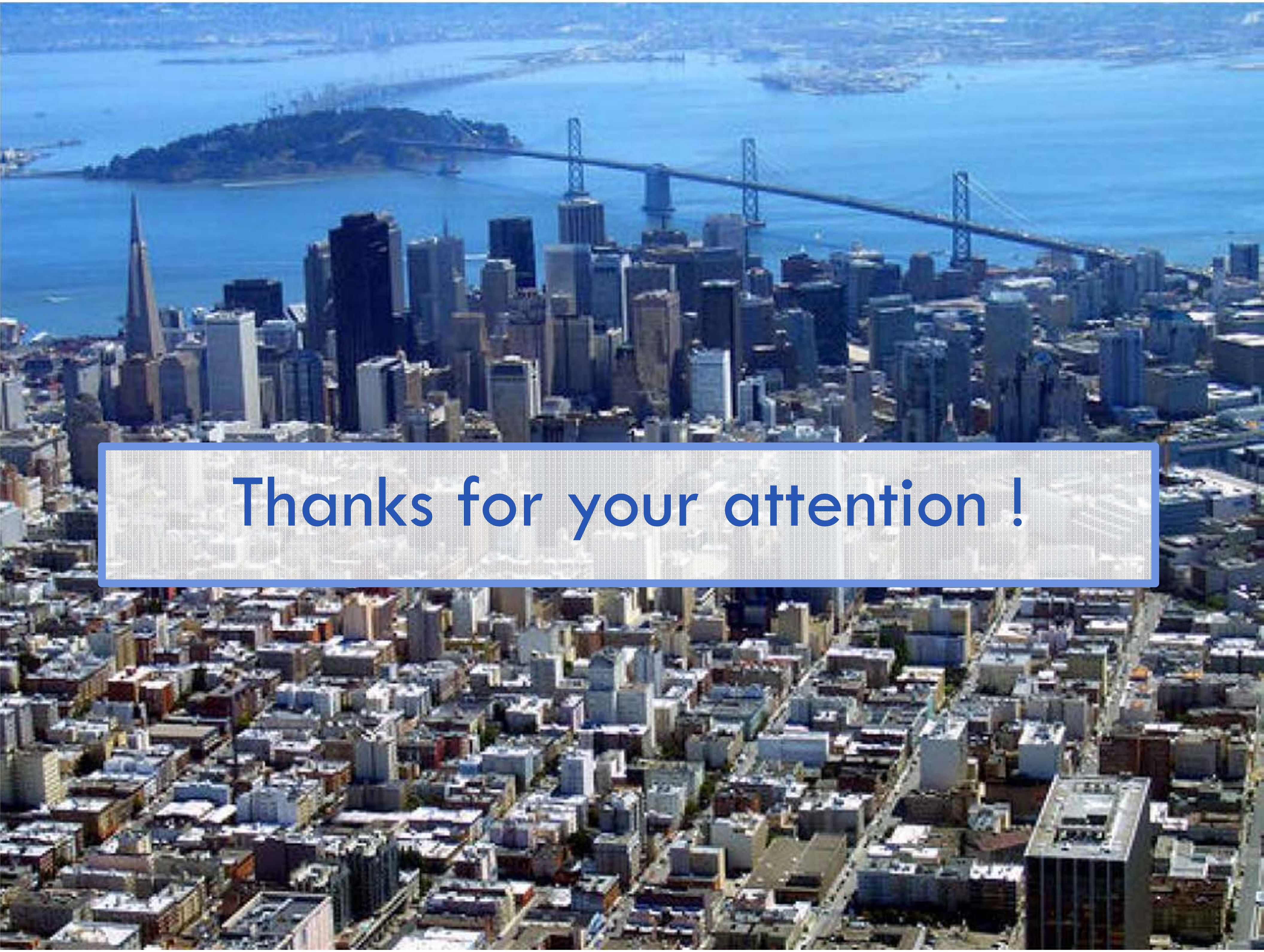
Classification over urban

- **Benefit of polarimetry** in the case of repeat pass data sets. Otherwise, **difficulty at X-band for separating built-up areas and vegetation, even using polarimetry**

- On going work about the analysis of polarimetric mechanisms and their dependancy to frequency and bandwidth / adaptative coherence optimization

3D rendering over urban

- Ideal data set: single pass POLINSAR.
- On going work about the analysis of influence of statistics over the coherence shape.


Thanks for your attention !