HYBRID POLINSAR: HIGH RESOLUTION & POLARIMETRY APPLIED TO URBAN

ONERA

THE FRENCH AEROSPACE LAB

POLINSAR 2013

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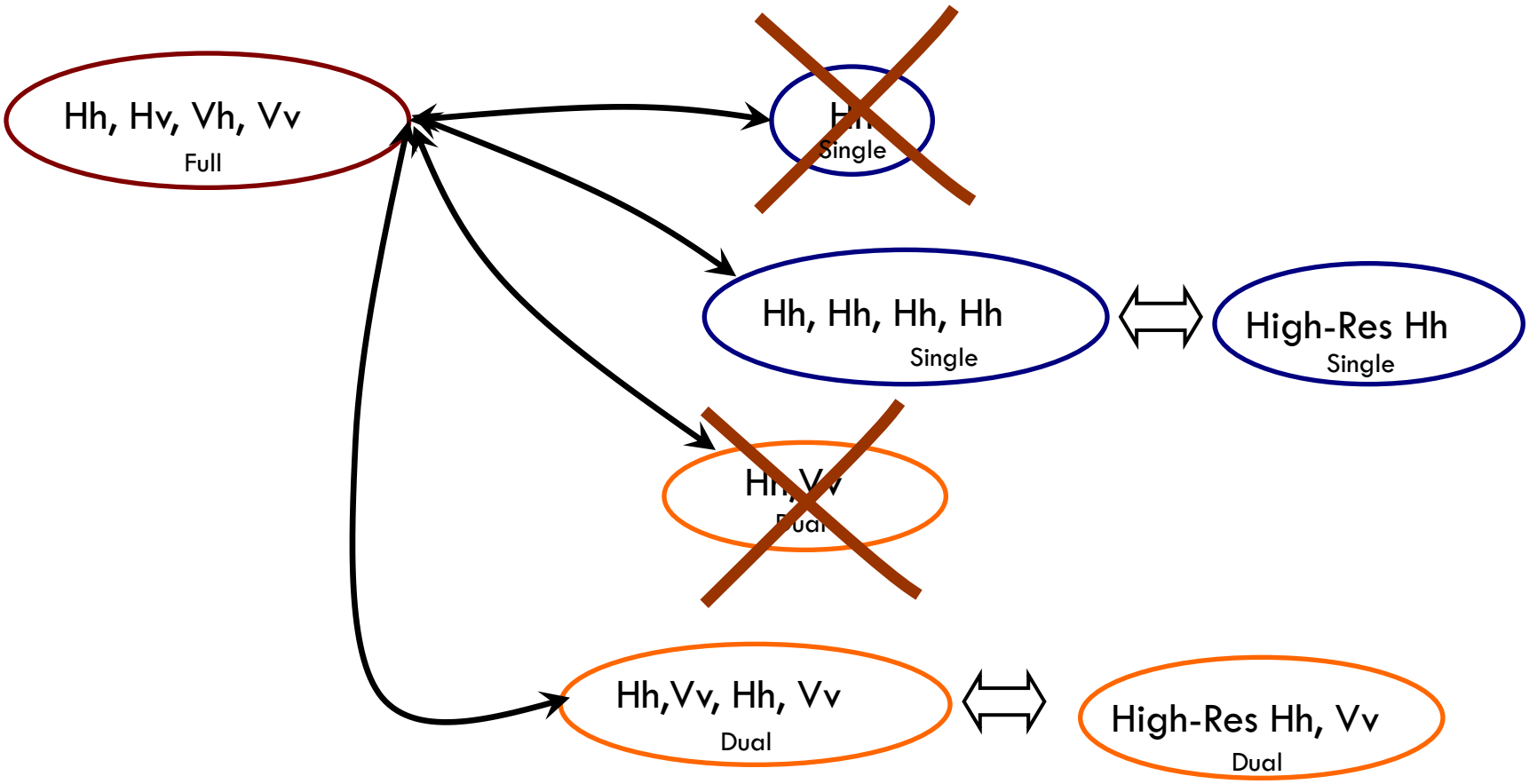
Outline

- **Quantify** the role of polarimetry on a specific application: **Urban classification**
  - Ground Truth for performances comparison
  - Various mode of TerraSAR-X
- On the joint use of:
  - Polarimetry, Interferometry, & Intensity
  - Data fusion
- High resolution versus polarimetry

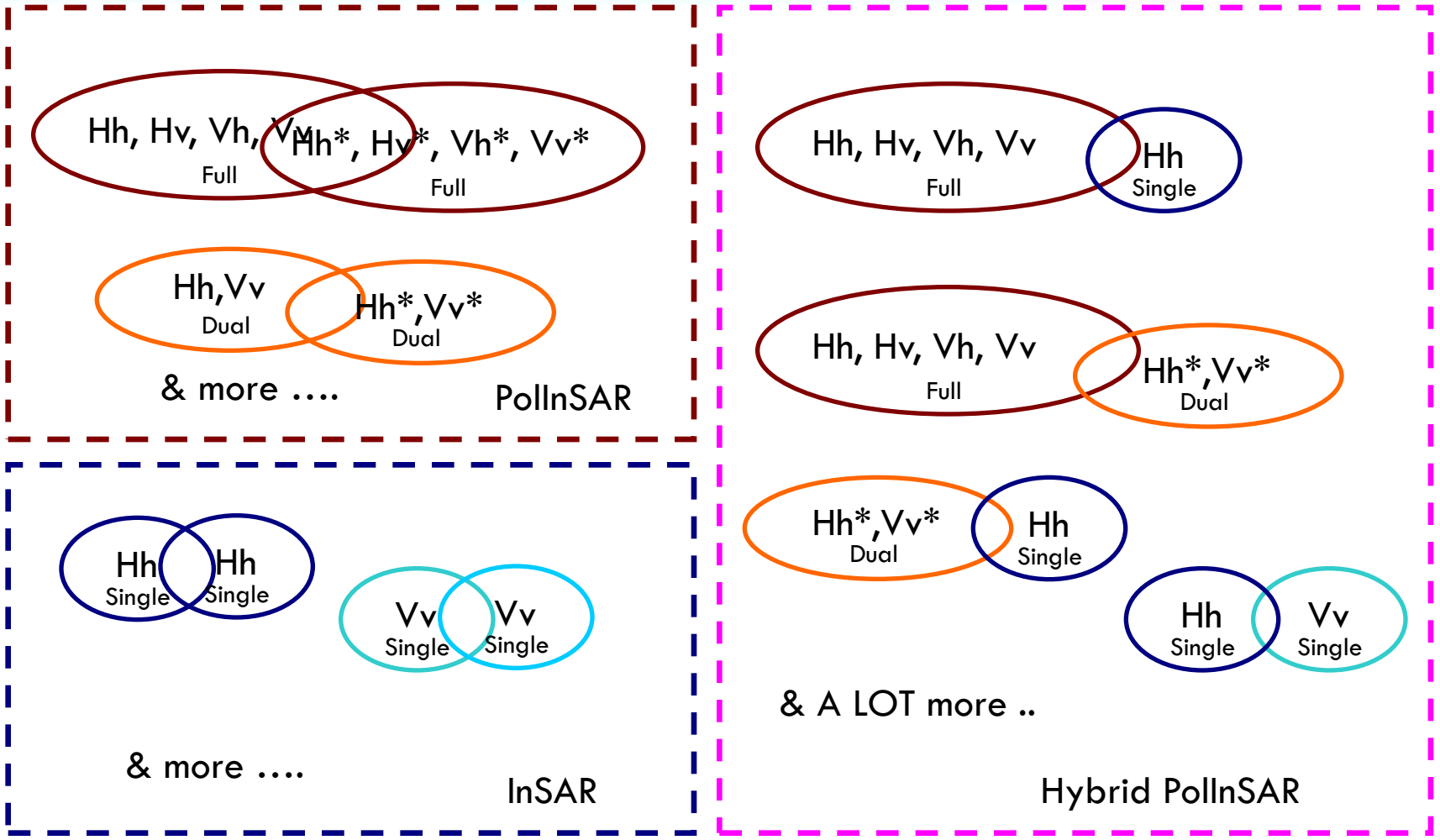
Performances comparison

- How to make a **fair** comparison?



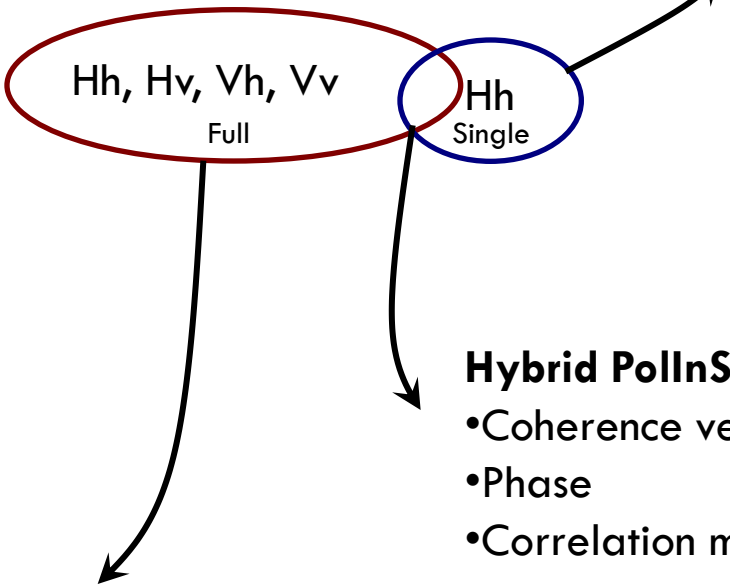
- Not in favor polarimetry in urban…

InSAR, PolInSAR & Hybrid PolInSAR



- Hybrid PolInSAR: intefermetric mode with two distinct polarization mode

Hybrid PolInSAR: information content



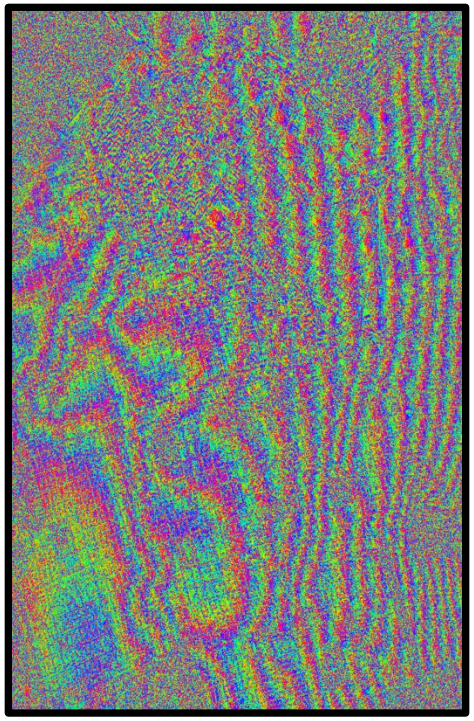
High resolution « power » image:
- Improved SPAN
- HR polarimetry reconstruction

(frequency transfer)

Hybrid PolInSAR:
- Coherence vector
- Phase
- Correlation matrix

Polarimetric coherence matrix:
- Statistical distance (Wishart & co)
- Polarimetric decompositions
- & All existing technics

$$\begin{bmatrix} Hh_{full}.Hh^{*} \\ Hv_{full}.Hh^{*} \\ Vh_{full}.Hh^{*} \\ Vv_{full}.Hh^{*} \end{bmatrix}$$

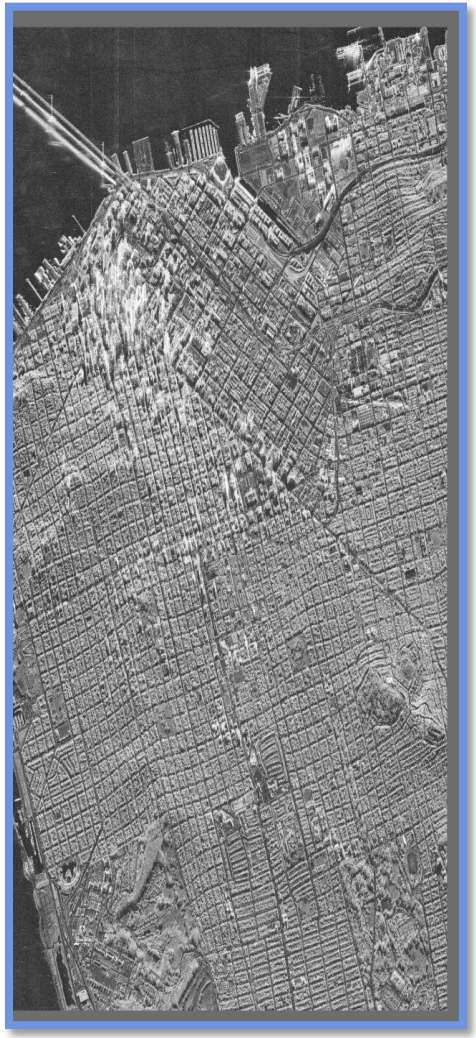


TerraSAR-X Hybrid interference pattern
(Full Pol 2010 & Single Pol 2011)
Corregistration by H.Oriot

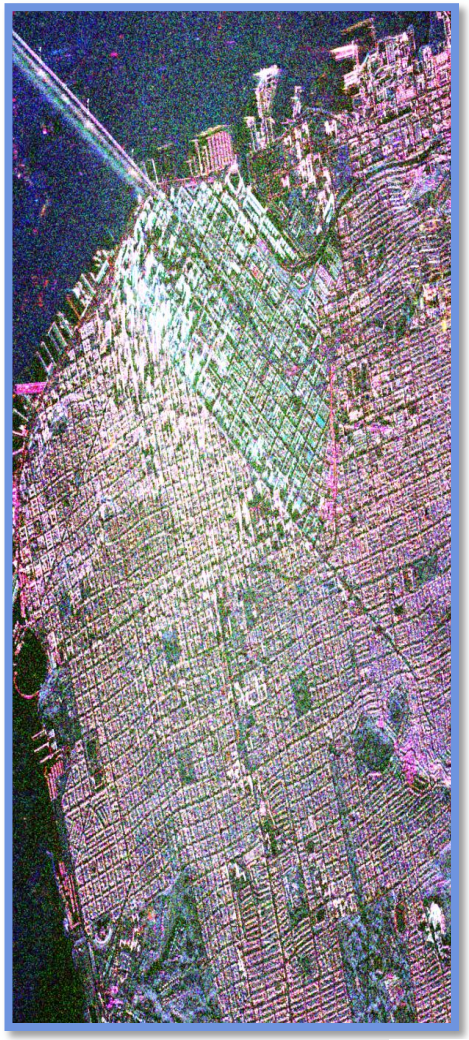
Avaiable Data Set

System	Resolution	Frequency	Interferometric mode	Polarimetric mode
TerraSAR-X	**1 m x 1 m**	**X-band**	**repeat pass** **3 images (2007)** **3 images (2011)**	**HH Single**
TerraSAR-X	**2 m x 2 m**	**X-band**	**repeat pass** **2 images** **11 days**	**HH/VV Dual**
TerraSAR-X	**2 m x 6 m**	**X-band**	**repeat pass** **3 images** **11 days (2010)**	**HH/HV/VV Full**

San Francisco images



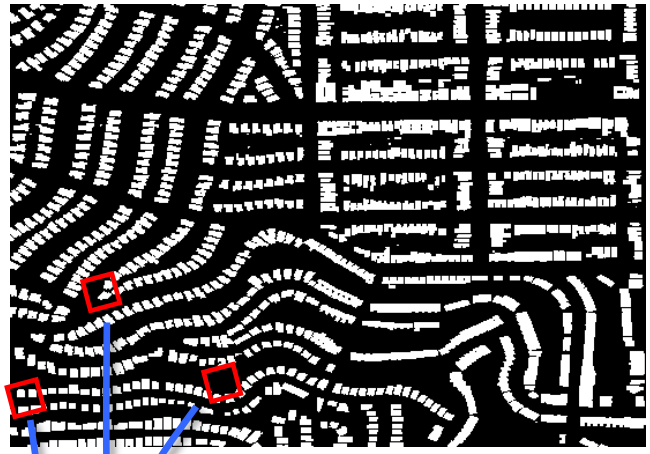
X-band, 1m x 1m
TerraSAR-X



X-band, 2m x 6m
TerraSAR-X

Ground truth (+/- 1m)

Asses performances



Hh, Hv, Vh, Vv (Quad) * 3
HR Hh * 6
Hh Vv (Dual)

- Statistic distances
- Decomposition based distances
- Interferometric coherence

Sample 1 (no building):
- Hh, Hv, Vh, Vv (Quad) * 3
- HR Hh * 6
- Hh Vv (Dual)

Sample 2 (no building):
- Hh, Hv, Vh, Vv (Quad) * 3
- HR Hh * 6
- Hh Vv (Dual)

Sample 3 (building):
- Hh, Hv, Vh, Vv (Quad) * 3
- HR Hh * 6
- Hh Vv (Dual)

- **H0 hypothesis:**
-False Alarm Probability/ Threshold

- **H1 hypothesis:**
-Detection Probability/ Threshold

10^n runs

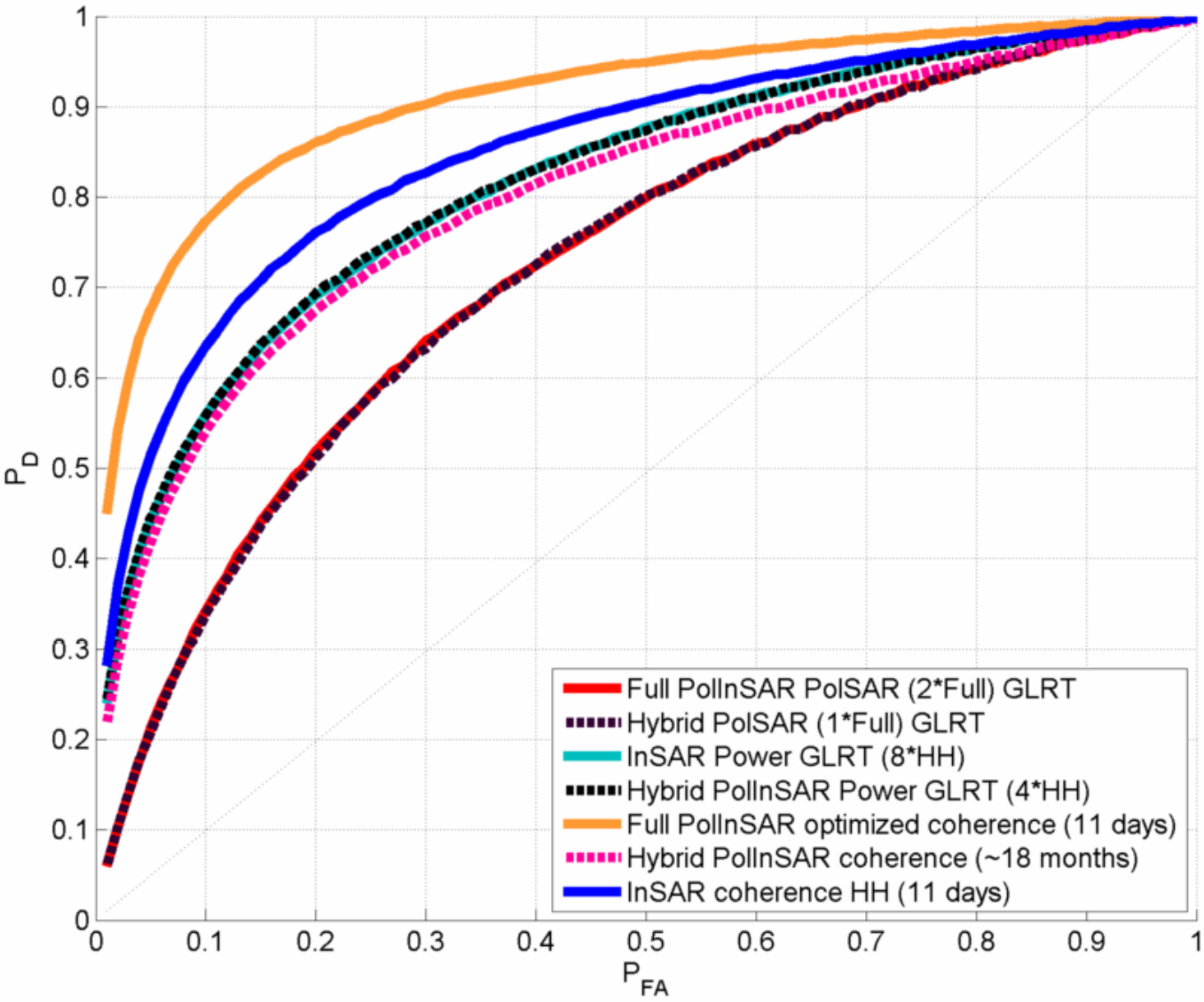
Criteria tested

- **Polarimetry :** Statistical Gaussian-based distance (GLRT)
  - From two pass for Full-PolInSAR (averaged matrices, polarimetric stability hypothesis)
  - From a single pass for Hybrid
- **Intensity :** 1D based distance (GLRT)

  4 sub-bands HH images from each pass are generated to match ground truth resolution
  - 8 intensity images for InSAR
  - 4 intensity images from a single pass for Hybrid
- **Phase :** Interferometric coherence
  - Optimized coherence for Full-PolInSAR
  - 1 HH coherence for Hybrid
  - 4 HH coherence for InSAR

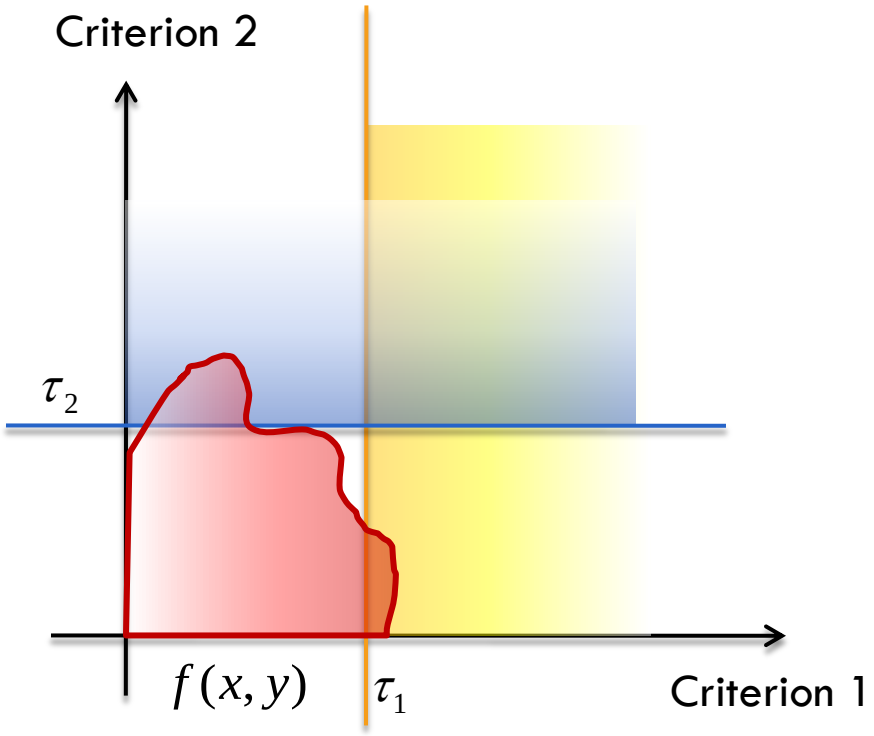
Scattering Vector stacking:
Phase information overwhelmed by power information : need to process it independantly at first

Separated ROC curves



- Interferometric Coherence:
  - Highest performances
  - Greatly improved by polarimetric optimization (low contribution of HV…)
- Intensity:
  - Second highest performances
  - Barely benefits from increased number of sample (Hybrid vs InSAR)
- Polarimetry
  - Barely benefits from increased number of sample (Hybrid vs Full-PolInSAR)

Data Fusion : And threshold example



$$P_{FA} = f(\tau_1, \tau_2)$$

$$\left.\begin{array}{l} P_{FA} = f(\tau_1, 0) \\ \quad\vdots \\ P_{FA} = f(0, \tau_2) \end{array}\right\}$$ Infinite amount of solution : Double threshold ambiguity

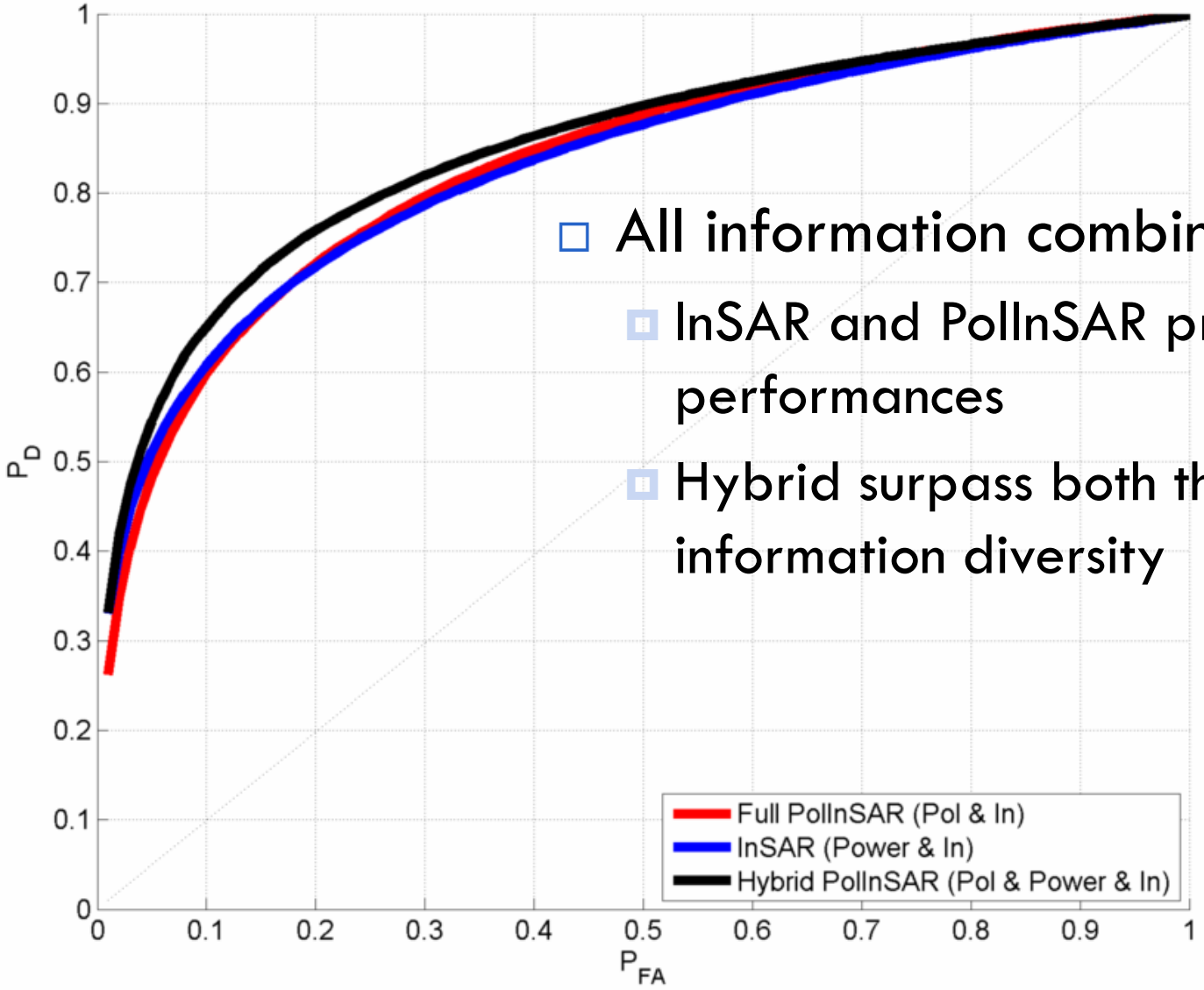
Equalized partial false alarm : as many false alarm from each Criterion

$$P_{FA} = f(\tau_1, \tau_2) \qquad f(0, \tau_2) = f(\tau_1, 0)$$

Unique solution

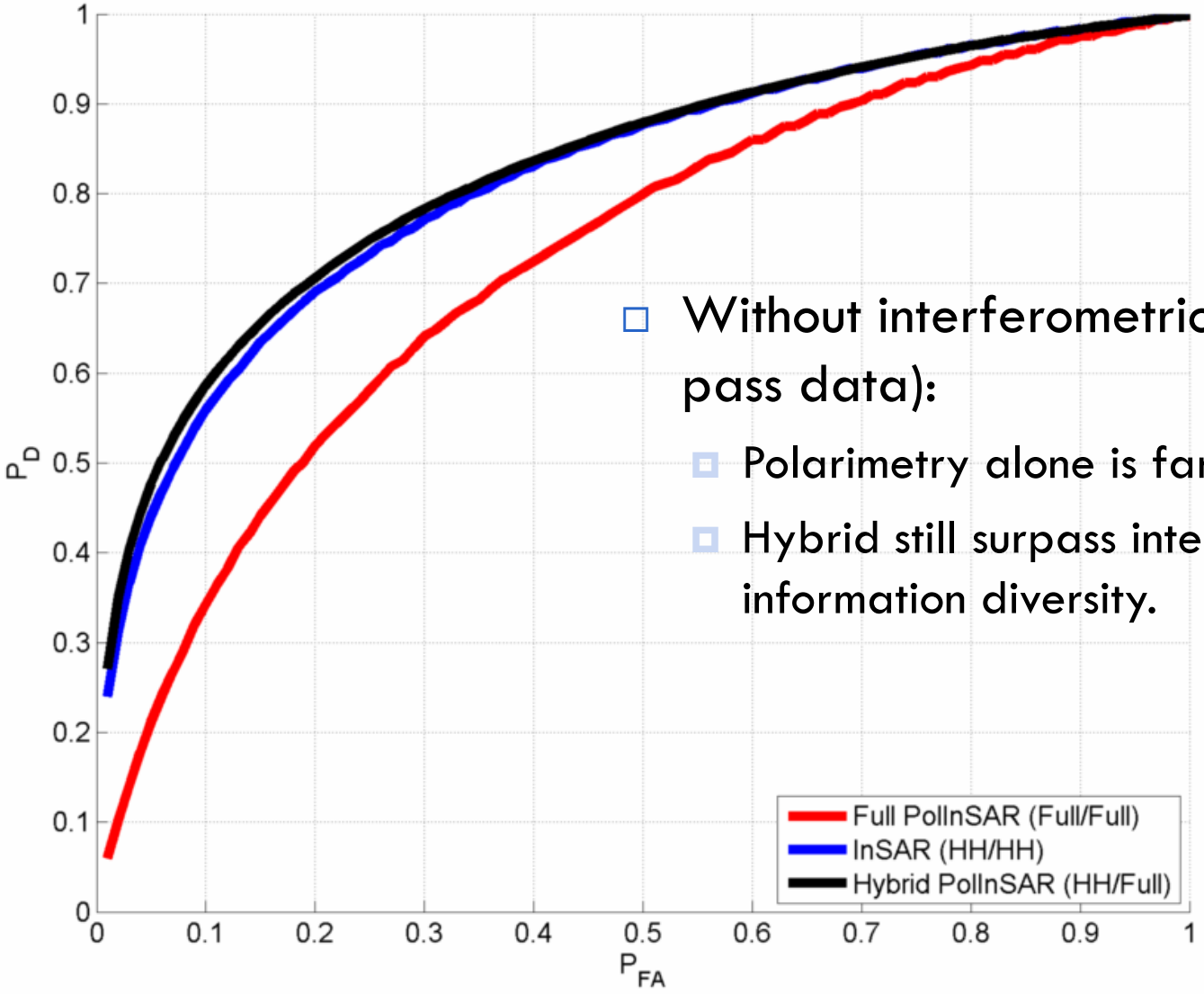
- Criteria fusion:
  - Polarimetry & Interferometry (Full PolInSAR)
  - Power & Interferometry (InSAR)
  - Polarimetry & Power & Interferometry (Hybrid) (3 criteria fusion)

All data type: fusion comparison



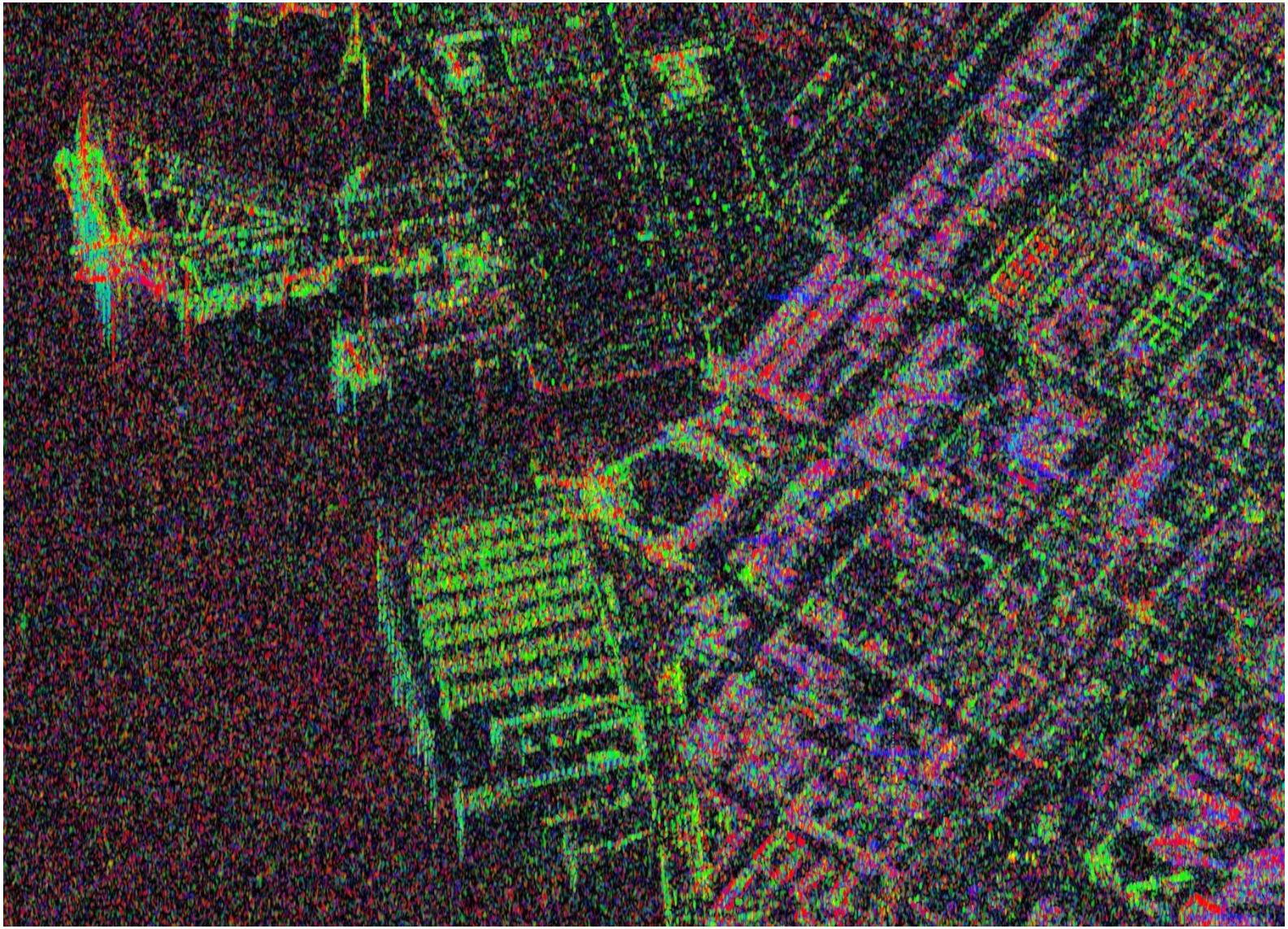
- All information combined:
  - InSAR and PolInSAR provide very close performances
  - Hybrid surpass both thanks to information diversity

Polarimetry and Intensity, fusion comparison

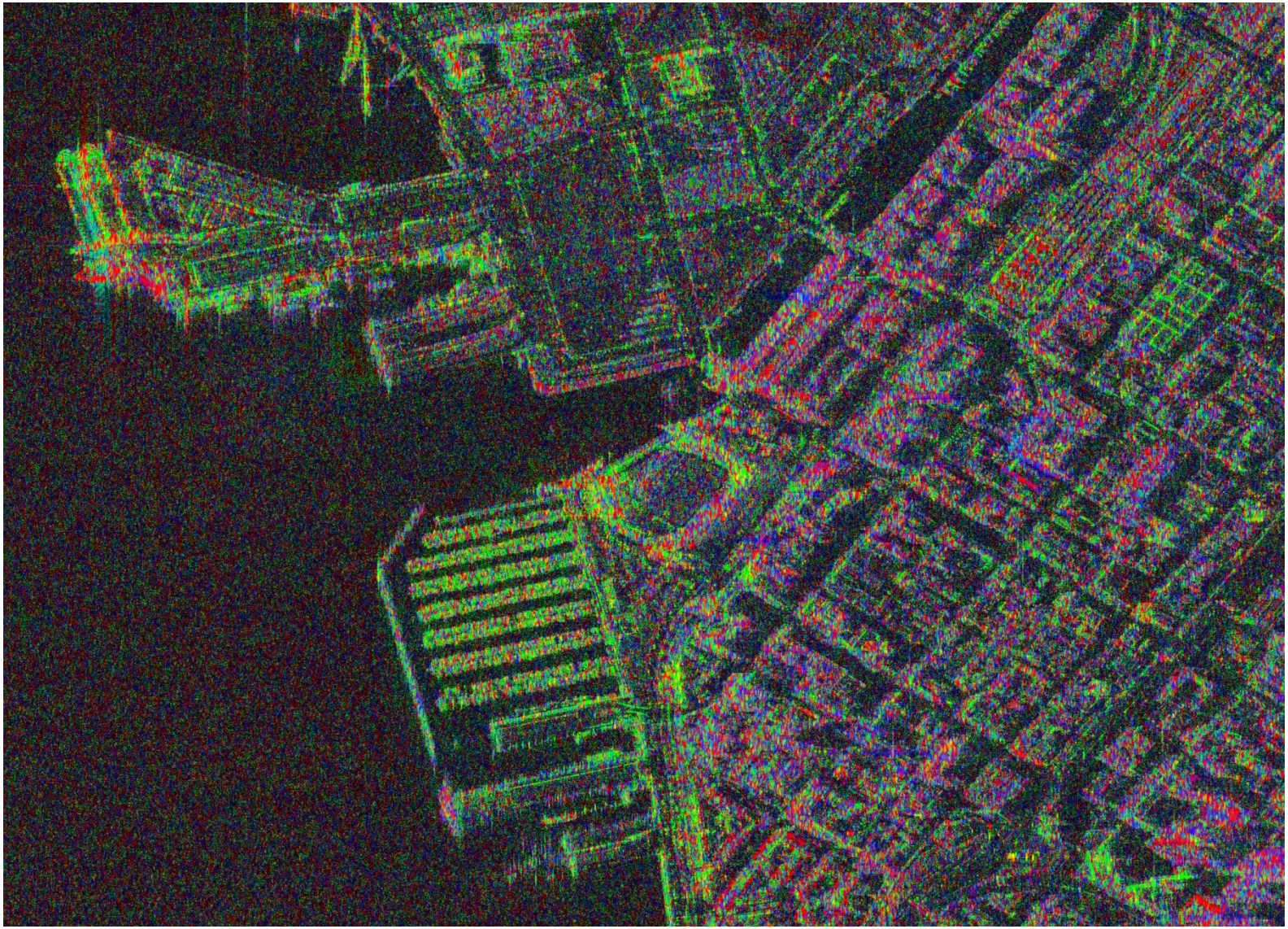


- Without interferometric coherence (2 pass data):
  - Polarimetry alone is far behind
  - Hybrid still surpass intensity only due to information diversity.

High Resolution Polarimetric Reconstruction



High Resolution Polarimetric Reconstruction



Observations

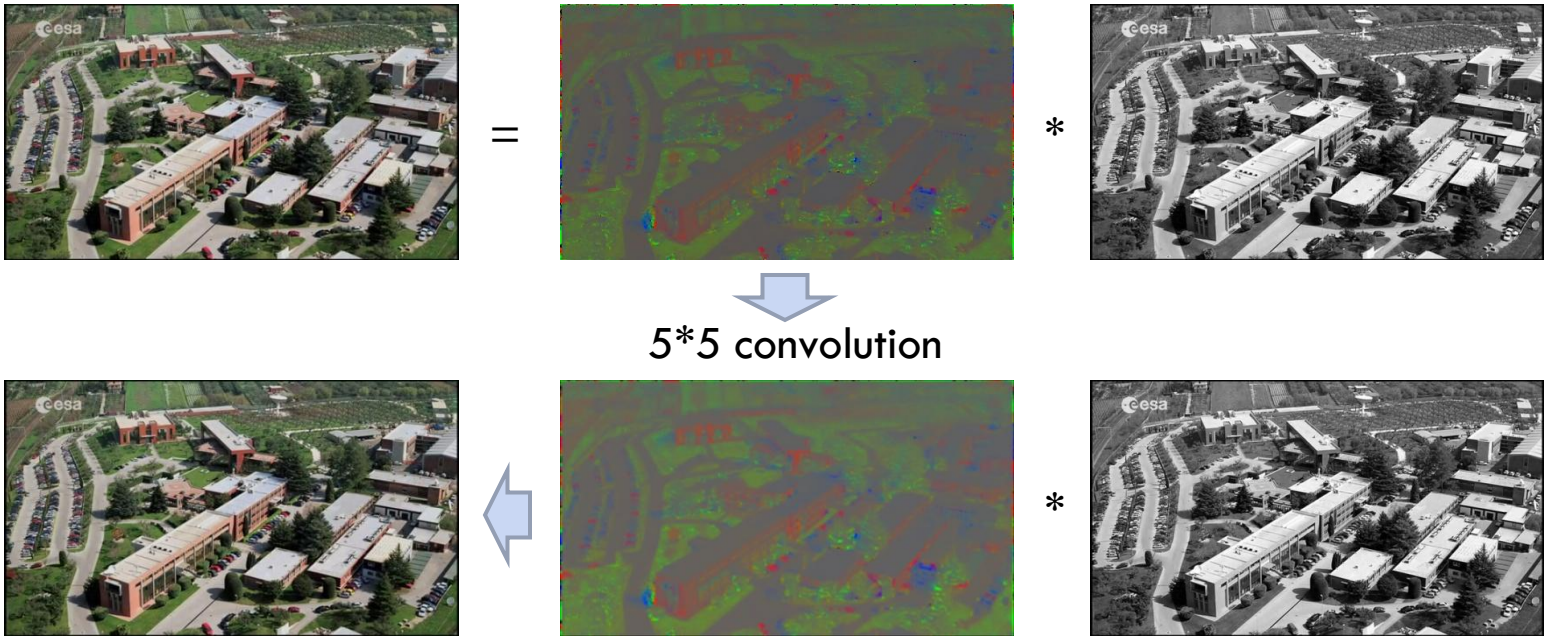
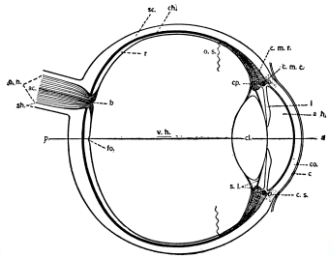
In the very **restricted** field of the application of building vs all classification & the San Fransisco TerraSAR-X data set.

- If only a single pass is used: High resolution Single Pol yield the best performances
- When two passes are used: Hybrid PolInSAR or Full PolInSAR yield the best results
- When three passes can be considered, Hybrid Single+Full+Full will yield the best result thanks coherence optimization

Conclusions

- Ground truth allows to **quantify** performances but in a very precise scope
- Know your information hierarchy: Coherence, Polarimetry, Intensity?
- Even "low" quality information improves performances over more already measured "high" quality information
- **Diversity > Quantity**
- Many hybrid couple to be investigated

An optic/vision parallel



- Do we need resolution for polarimetry as much as we need it for SPAN?
  - Human eye principle:
    - 4.5 M cone cells (color vision) only with bright lighting. Blue cone cells are not even in focus!
    - 90 M rod cells (intensity vision), much more sensitivity, higher SNR, works at night.
  - Highly use of the brain processing power.