Performance Comparison between Dual Polarimetric and Fully Polarimetric data for DInSAR Subsidence monitoring

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Introduction

- **Spaceborne DInSAR: Technique widely used to survey terrain deformation from large areas with high resolution.**
  - ➔ **SINGLE-POL Data Oriented → Unavailability of PolSAR data**

- **Polarimetric Data availability**
  - ➔ **Old and Current Missions**
    - **L-Band: ALOS**
    - **C-Band: Envisat, Radarsat-2**
    - **X-Band: TerraSAR-X, Cosmo_Skymed, Tandem-X**
  - ➔ **Future Missions**
    - **L-Band: ALOS-2**
    - **C-Band: Sentinel, Radarsat Constellation**
    - **X-Band: TerraSAR-X2, PAZ**

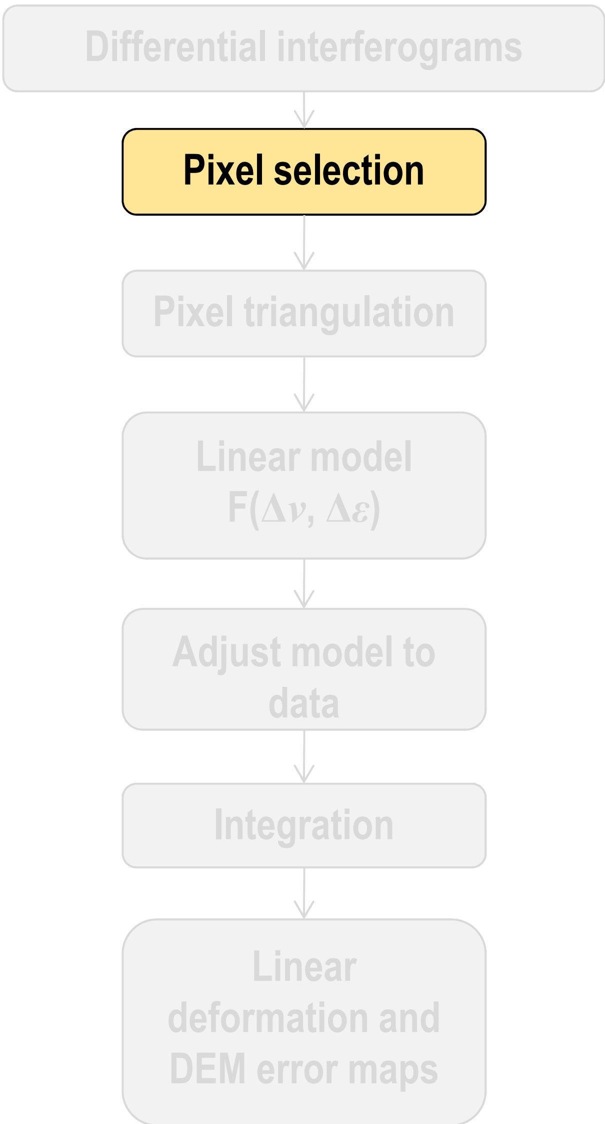
- **Providing Both DUAL-POL and FULL-POL data**

DinSAR processing

Differential interferograms
↓
Pixel selection
↓
Pixel triangulation
↓
Linear model $F(\Delta v, \Delta \varepsilon)$
↓
Adjust model to data
↓
Integration
↓
Linear terrain displacement and DEM error maps

- **Differential Phase:** Phase information about terrain deformation between acquisitions.
- **Pixel Selection: Pixel Candidates** with high phase quality. **Indirect estimators**.
- **Triangulation:** Work with the relative phase between pixels to avoid unwrapping.
- **Phase Linear model:** Adjust phase increments to a linear model depending on deformation rate and topographic error
- **Integration:** Obtain **terrain deformation rate** and **topographic error** absolute values from the relative values.

DinSAR Processing



- Differential Phase: Phase information about terrain deformation between acquisitions.
- **Pixel Selection: Pixel Candidates with high phase quality. Indirect estimators.**
- Triangulation: Work with the relative phase between pixels to avoid unwrapping.
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Phase Quality Estimation and Optimization

- **Mean Interferometric Coherence**

$$\boxed{\hat{\gamma} = \left\langle \frac{\left| \mathbf{w}^H \boldsymbol{\Omega}_{ij} \mathbf{w} \right|}{\sqrt{\mathbf{w}^H \mathbf{T}_{ii} \mathbf{w} \cdot \mathbf{w}^H \mathbf{T}_{jj} \mathbf{w}}} \right\rangle}$$

- **Characteristics**
  - ➔ **Resolution loss due to multilook**
  - ➔ **Multibaseline Approach**
    - **Preservation of the projection vector $\mathbf{w}$**
    - **Temporal sensitivity given by the mean operator**
  - ➔ **Distributed targets oriented**
  - ➔ **Optimization method**
    - **ESM-MB: Numeric Iterative Solution *(Neumann et al, January 2008)***

Phase Quality Estimation and Optimization

- **Amplitude Dispersion**

$$D_A(\mathbf{w}) = \frac{1}{\left\langle \left| \mathbf{w}^H \cdot \mathbf{k} \right| \right\rangle} \cdot \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(\left| \mathbf{w}^H . \mathbf{k}_i \right| - \left\langle \left| \mathbf{w}^H \cdot \mathbf{k} \right| \right\rangle \right)^2}$$

$$\left\langle \left| \mathbf{w}^H \cdot \mathbf{k} \right| \right\rangle = \frac{1}{N} \cdot \sum_{i=1}^{N} \left| \mathbf{w}^H \cdot \mathbf{k}_i \right|$$

- **Characteristics**
  - ➔ **Preserves full resolution of data**
  - ➔ **Multibaseline nature inherent to the estimator**
  - ➔ **Deterministic targets oriented**
  - ➔ **Optimization method**
    - **ESM: Numeric Parametric Solution *(Navarro et al, April 2010)***

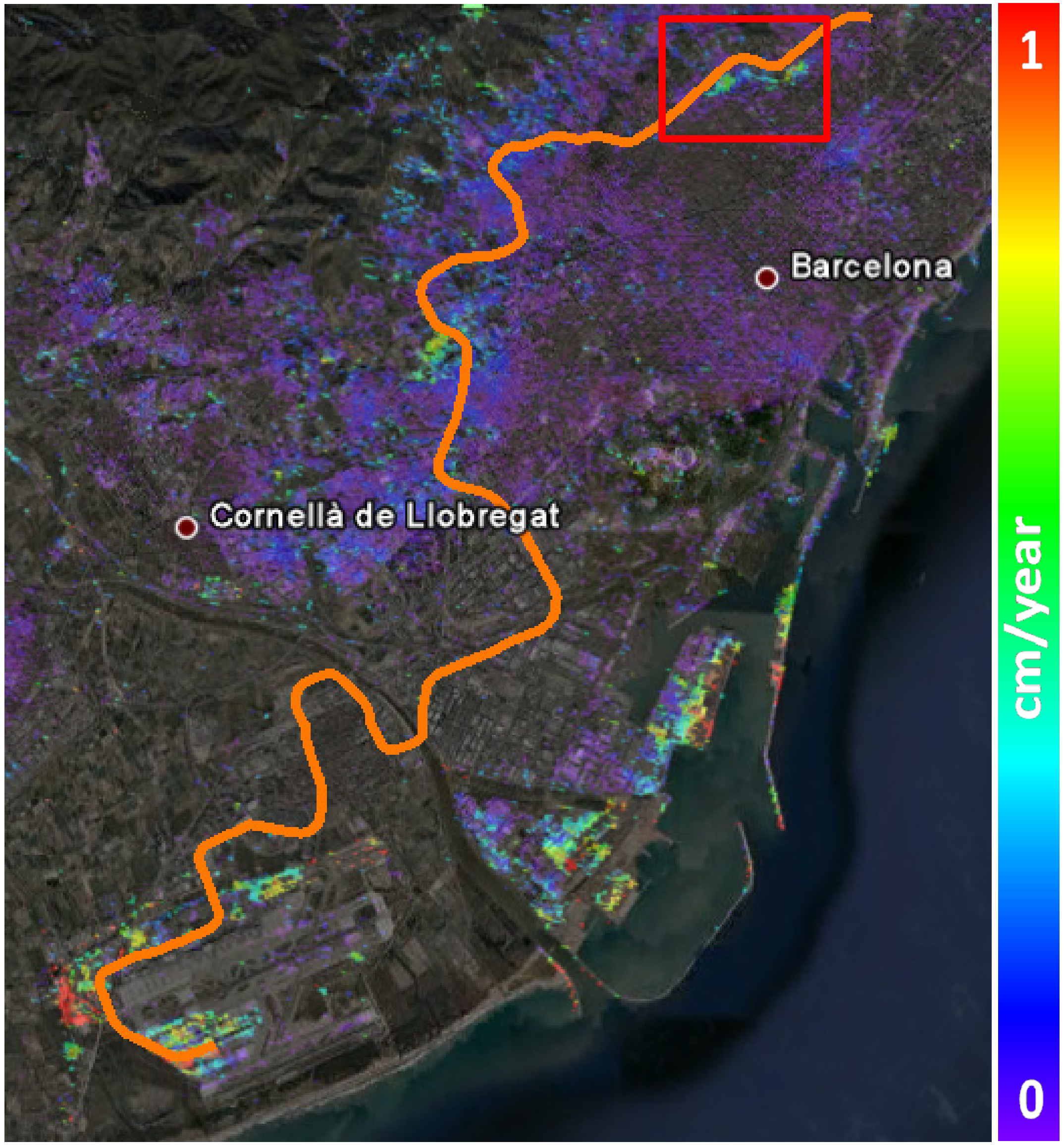
$$\mathbf{w} = \begin{bmatrix} \cos\alpha \\ \sin\alpha \cos\beta e^{j\delta} \\ \sin\alpha \sin\beta e^{j\gamma} \end{bmatrix}$$

DUAL-POL VS QUAD-POL in Polarimetric Optimization

- **FULL-POL characteristics**
  - ➔ **Channels available**
    - **HH, VV, HV**
  - ➔ **Phase Quality Optimization**
    - **Able to reach the absolute optimum value** ✔
    - **Higher complexity** ✘

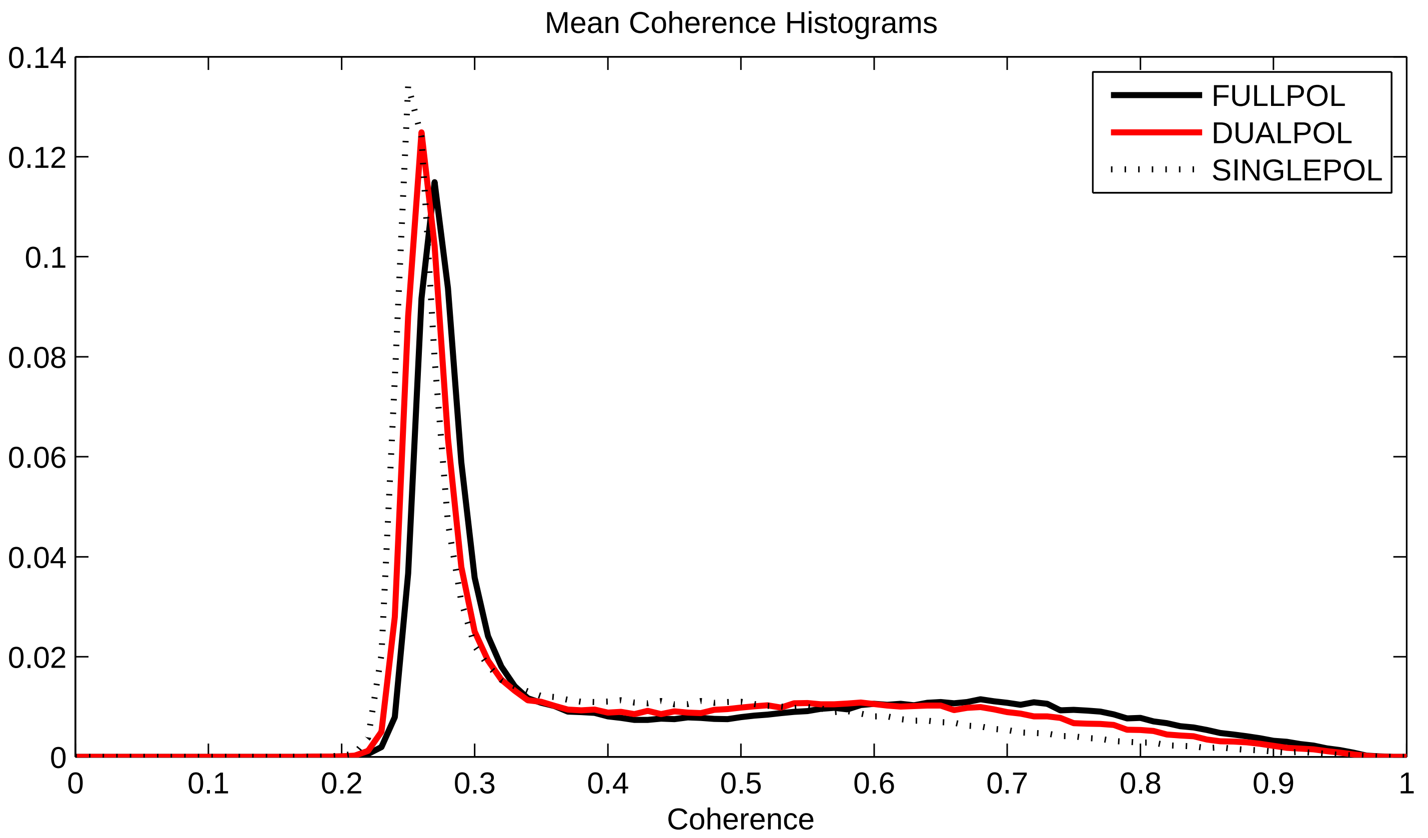
- **DUAL-POL characteristics**
  - ➔ **Channels available**
    - **Direct Channels: HH&VV**
    - **Direct and Cross Polar Channel: HH&HV, VV&VH**
  - ➔ **Phase Quality Optimization**
    - **Not able to reach the optimum value** ✘
    - **Lower complexity and computational cost** ✔

Dataset



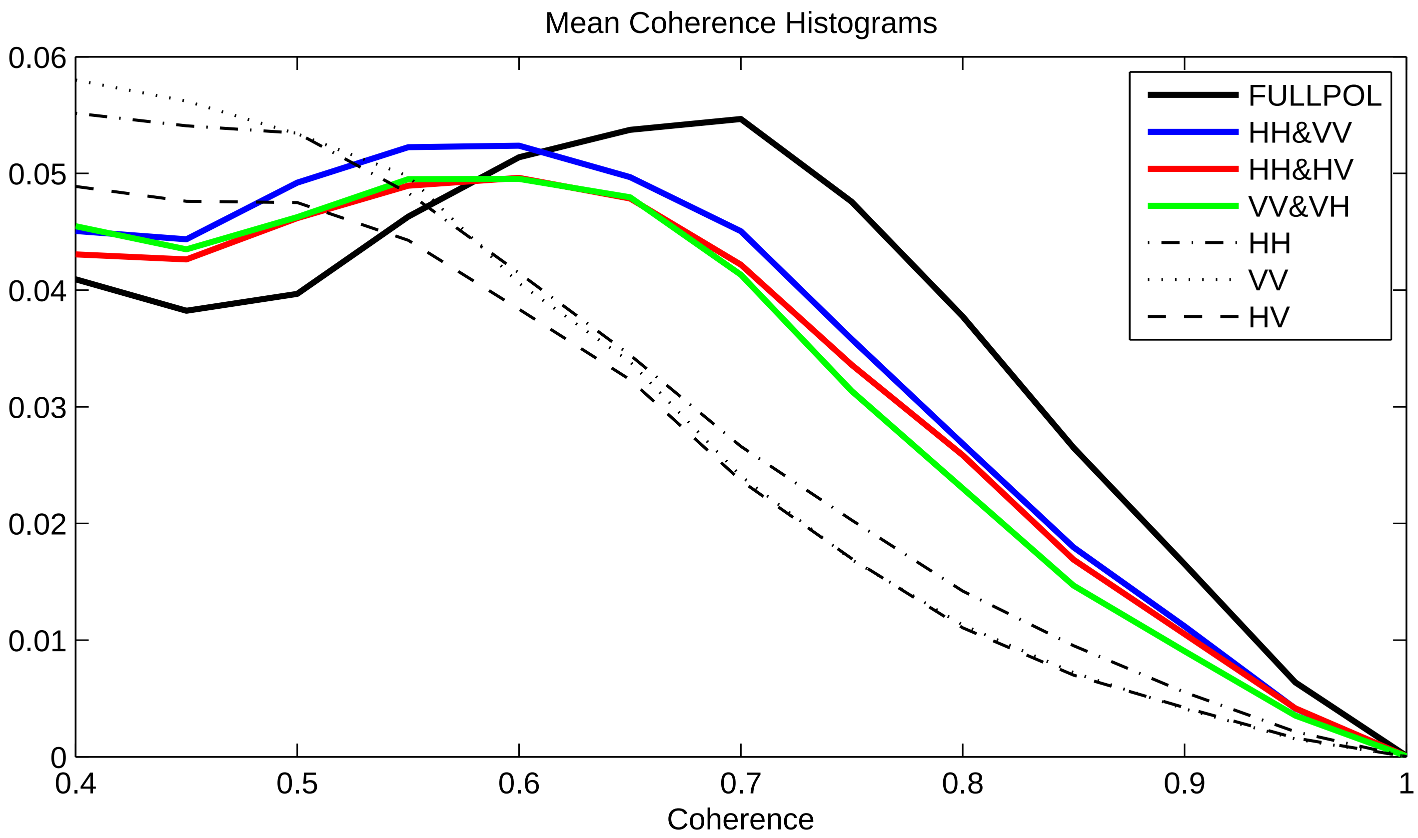
- **Location: Barcelona**
- **Sensor: Radarsat-2**
- **Band: C**
- **Dataset: 37 Fine Quad-Pol Acquisitions**
- **Temporal span: From January 2010 to July 2012**
- **Diagnosis: Subsidence due to underground construction**
- **Generation of DUAL-POL datasets narrowing down the FULL-POL dataset**

Statistical Comparison. Mean Coherence



- **Poor improvement FULL-POL / DUAL-POL VS SINGLE-POL**
  - ➔ **Low Coherence peak: Rural area**
  - ➔ **High Coherence peak: Urban area**

Statistical Comparison. Mean Coherence



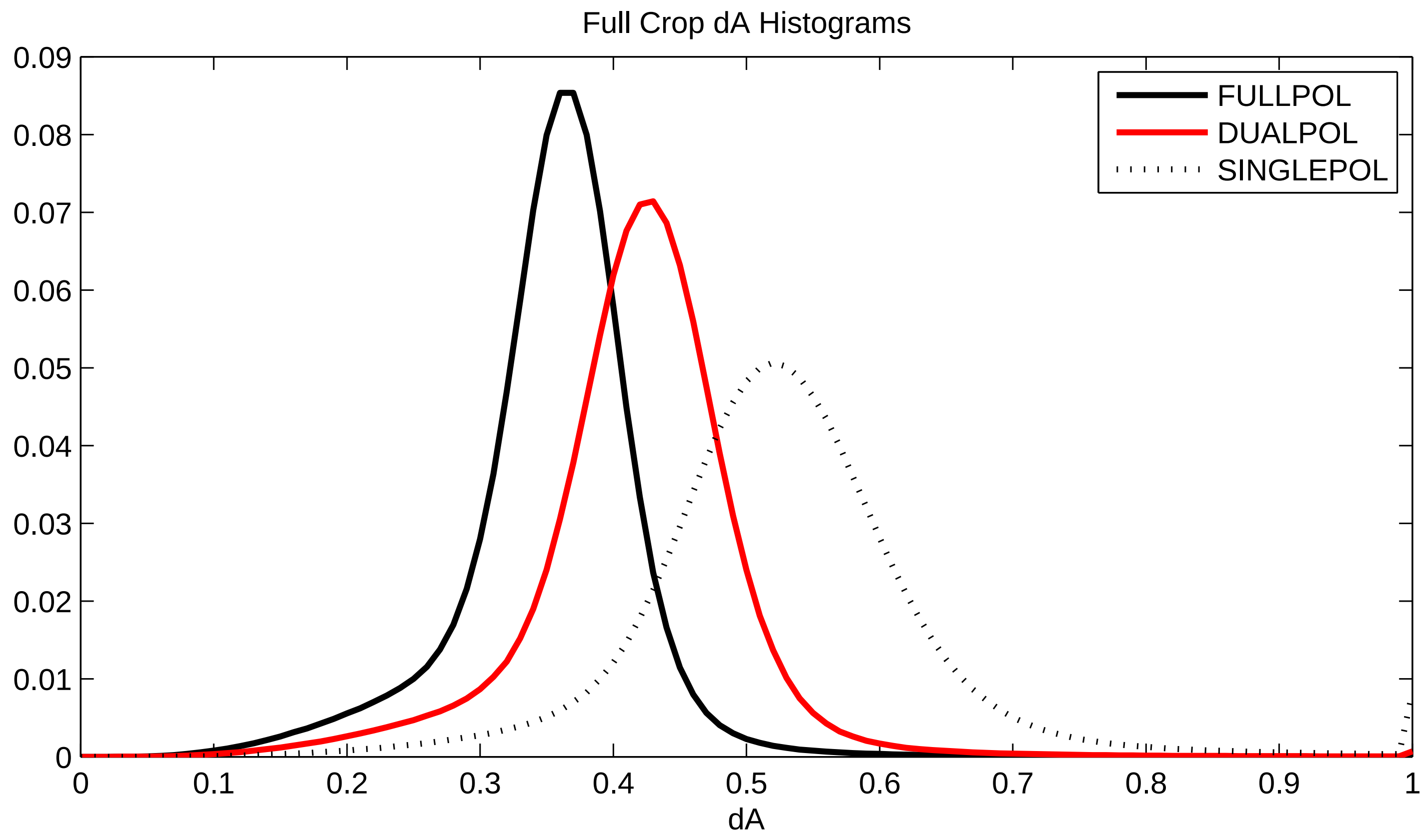
- **Focus on urban area**
  - ➔ **Quality improvement in high coherence points**
  - ➔ **Multibaseline nature of data**

Statistical Comparison. Mean Coherence

PIXEL CANDIDATES	
METHOD	**NUMBER OF PIXELS**
HH	6,060 (**4.0%**)
HV	4,796 (**3.2%**)
VV	4,675 (**3.1%**)
DUAL-POL HH-VV	11,390 (**7.5%**)
DUAL-POL HH-HV	10,961 (**7.2%**)
DUAL-POL VV-VH	9,709 (**6.4%**)
FULL-POL	16,469 (**10.8%**)

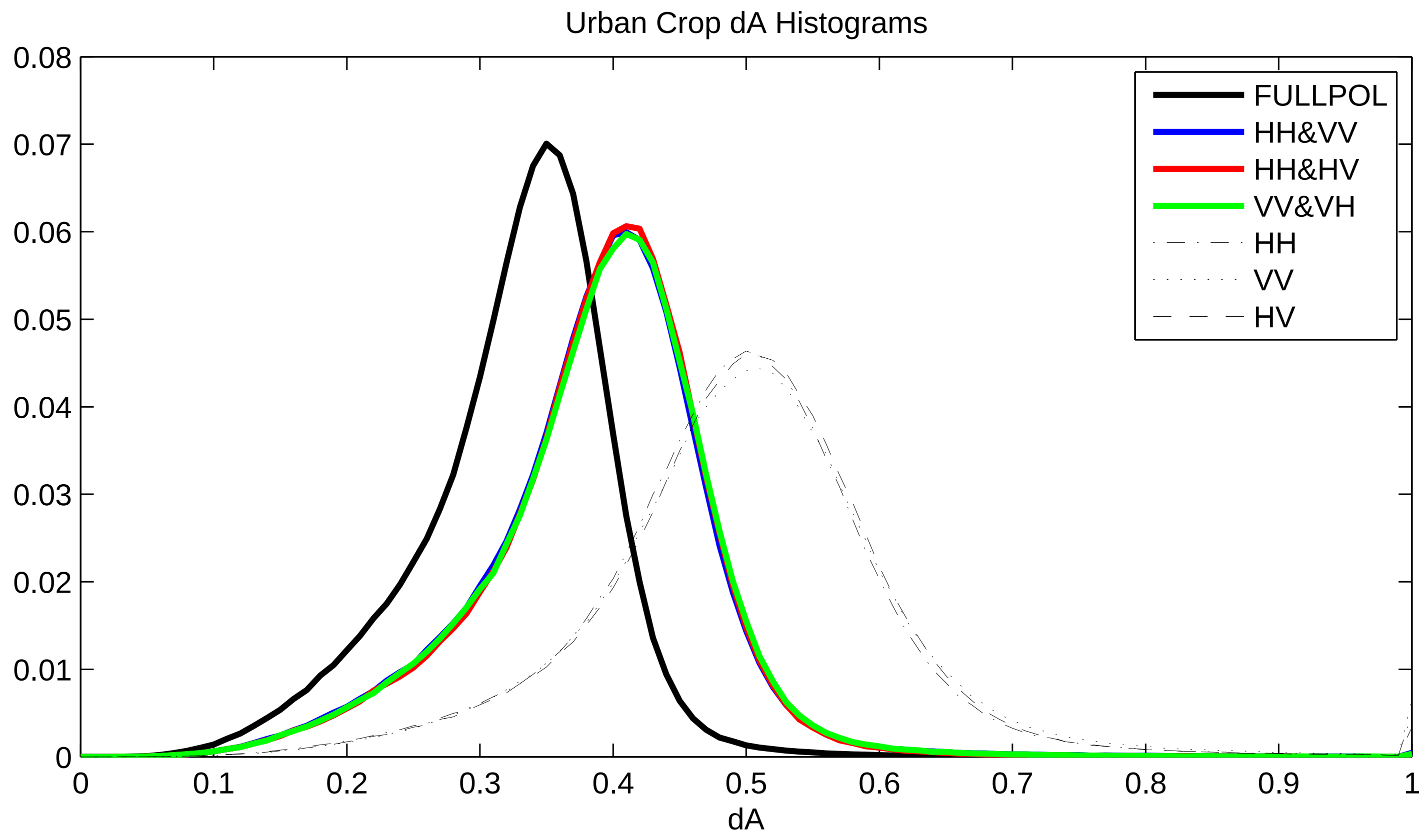
- **Mean Coherence threshold: 0.75 (~5º std. dev. in 9x5 multilook window)**
- **Factor ~1.5-2 between DUAL-POL and QUAD-POL**

Statistical Comparison. Amplitude Dispersion



- **High improvement**
  - ➔ **FULL-POL >> DUAL-POL >> SINGLE-POL**

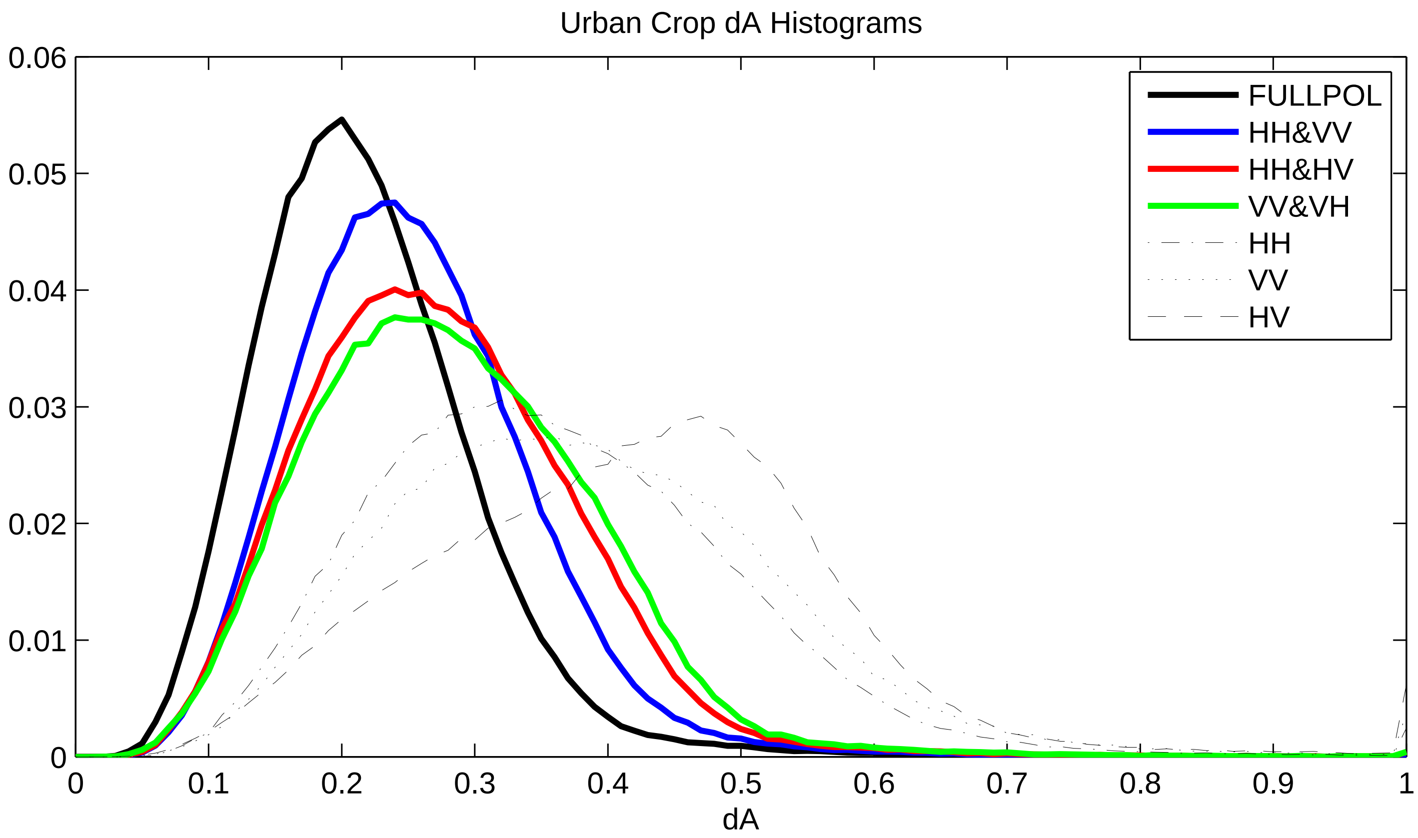
Statistical Comparison. Amplitude Dispersion



- **Urban area: Similar histograms as in the full crop**
- **No difference between the different DUAL-POL and SINGLE-POL modes**

➔ **Clutter >> Stable points**

Statistical Comparison. Amplitude Dispersion



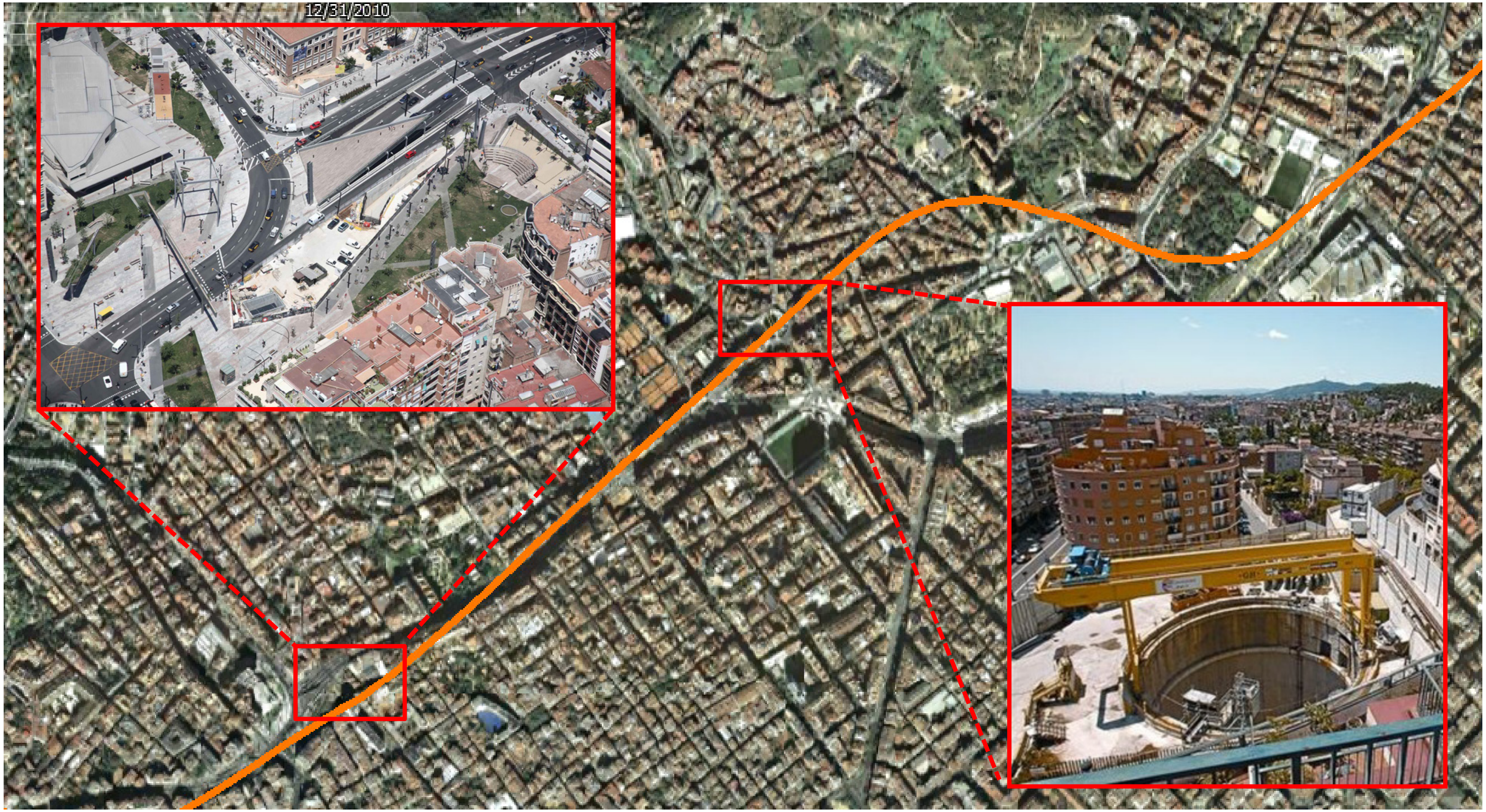
- **Histograms of high amplitude points**
  - ➔ **Lower performance of Cross polar channel and DUAL-POL modes implied**

Statistical Comparison. Amplitude Dispersion

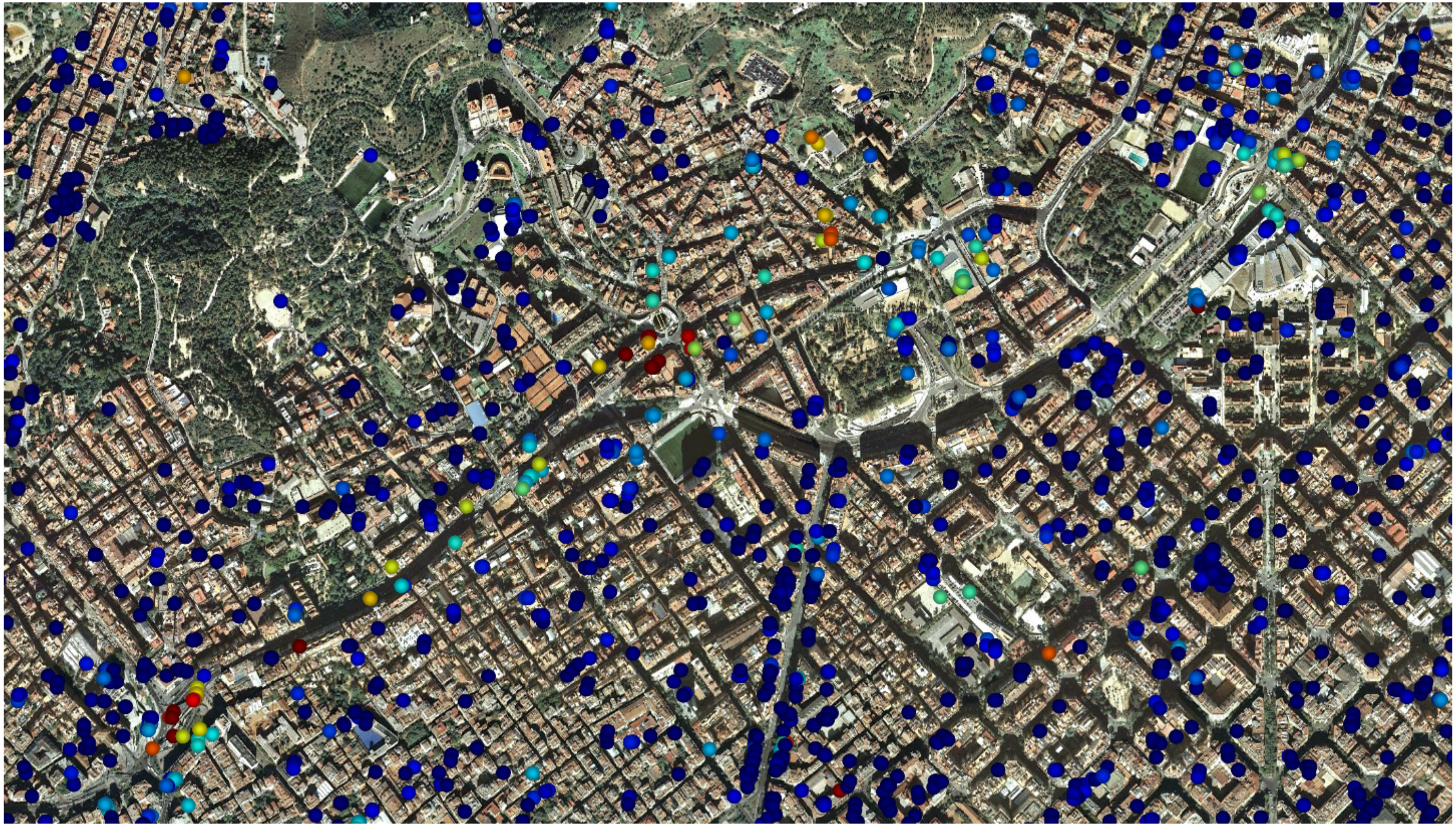
PIXEL CANDIDATES	
METHOD	**NUMBER OF PIXELS**
HH	75,653 (1.1%)
HV	64,815 (0.9%)
VV	66,377 (1.0%)
DUAL-POL HH-VV	228,853 (3.3%)
DUAL-POL HH-HV	217,785 (3.2%)
DUAL-POL VV-VH	214,435 (3.1%)
FULL-POL	463,412 (6.7%)

- **Amplitude Dispersion threshold: 0.25 (~15º std. dev.)**
- **Factor >2 between DUAL-POL and QUAD-POL**
-

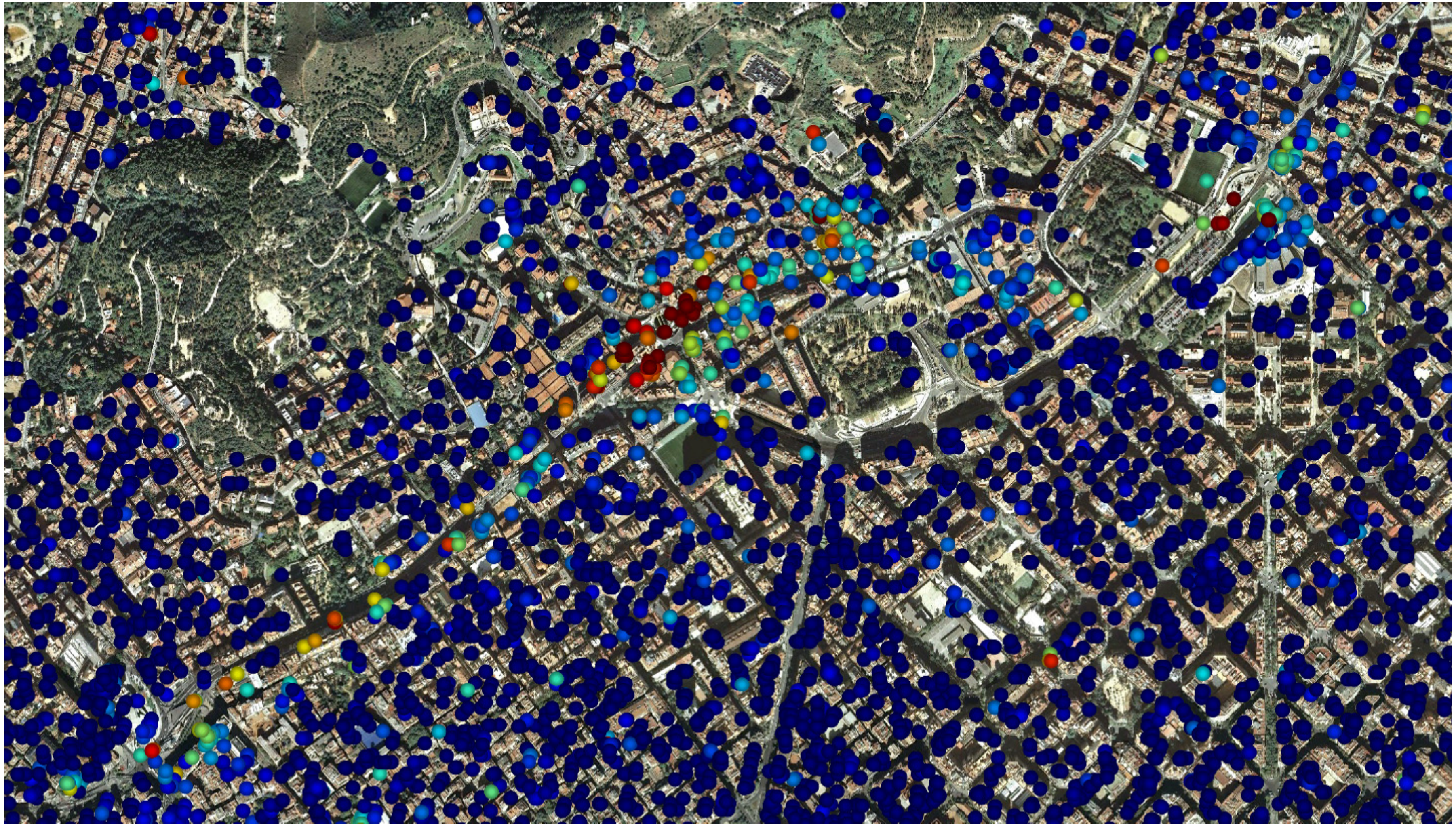
DInSAR Results. Test Area



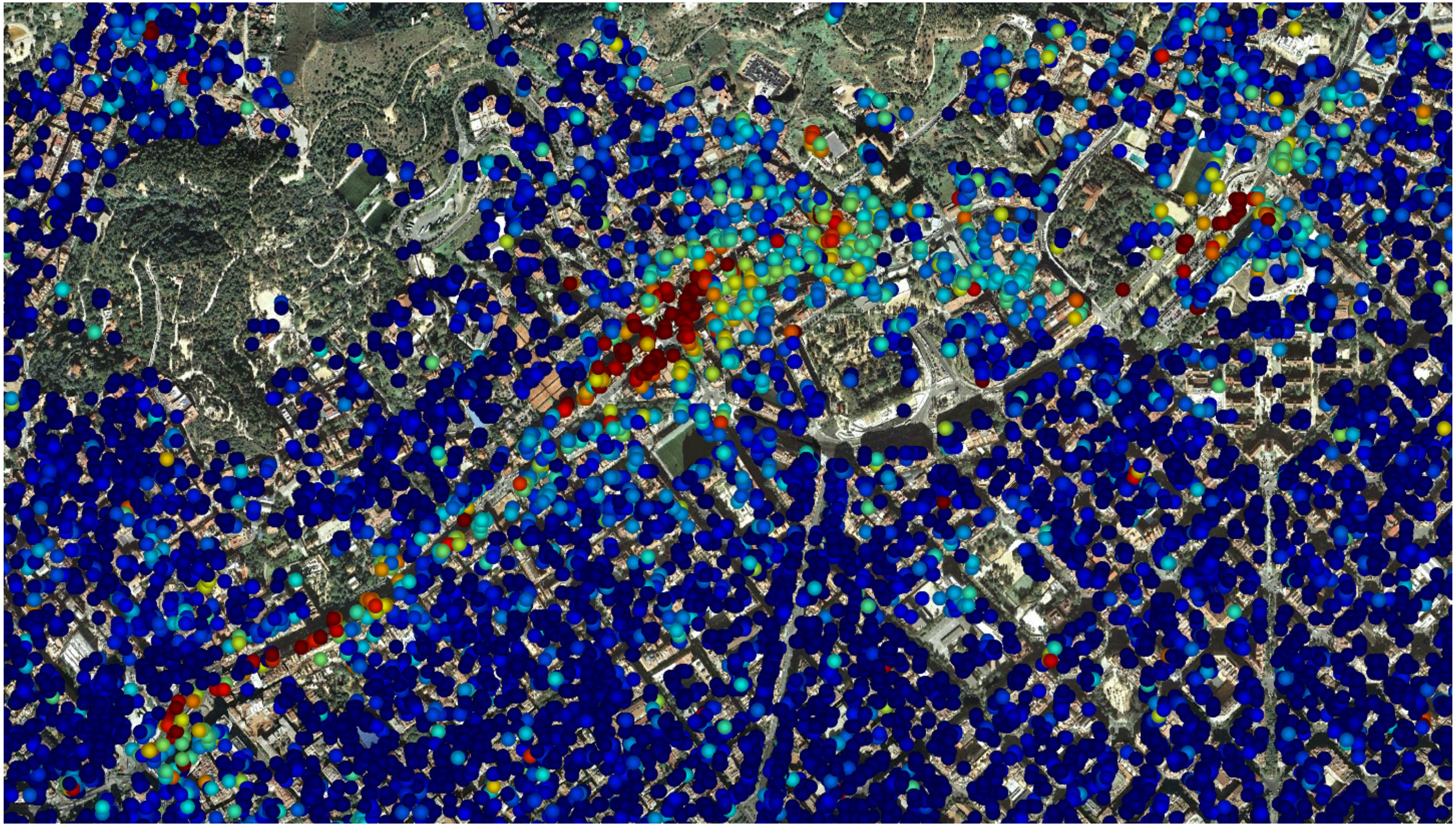
DInSAR Results. Amplitude Dispersion SINGLE-POL



DInSAR Results. Amplitude Dispersion DUAL-POL



DInSAR Results. Amplitude Dispersion FULL-POL



Conclusions

- This work considers the benefits of FULL-POL over DUAL-POL data in the PolDInSAR framework.

- DUAL-POL advantages
  - ➔ Lower computational load
  - ➔ Lower storage size
  - ➔ DUAL-POL modes with direct channels are more suitable for urban areas

- FULL-POL advantages
  - ➔ Absolute optimization
  - ➔ Doubles the performance of DUAL-POL data

THANK YOU
FOR YOUR ATTENTION

QUESTIONS?

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