The Parallel Implementation of the full resolution SBAS-DInSAR processing chain for surface deformation analysis in extended urban areas

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Outline

✓ Exploited algorithm

- Full Resolution Parallel Small BAseline Subset (FR P-SBAS) DInSAR algorithm

✓ Proposed approach

- Full exploitation of Big SAR Data archives
- Automatic FR P-SBAS chain for large SAR data stacks processing
- Deployment of FR P-SBAS solution on Cloud/HPC architectures

✓ Future perspective

- Mapping the ground displacements at national scale with COSMO-SkyMed
- Integration of FR P-SBAS results for large scale damage assessment analyses

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The FR P-SBAS DInSAR algorithm

- An advanced Differential Interferometry Synthetic Aperture RADAR (DInSAR) algorithm to retrieve deformation time-series and velocity maps both in natural and anthropic hazard scenarios (i.e., seismic events, volcanic unrest, landslides, urban areas and single man-made structures).

- Small Baseline interferometric pairs are only considered in order to minimize the noise effects and maximize the number of detectable (coherent) measure points.

- Full Resolution Interferograms are exploited to retrieve temporal and spatial characteristics of detected displacements at full spatial resolution scale (about 3-10 m).

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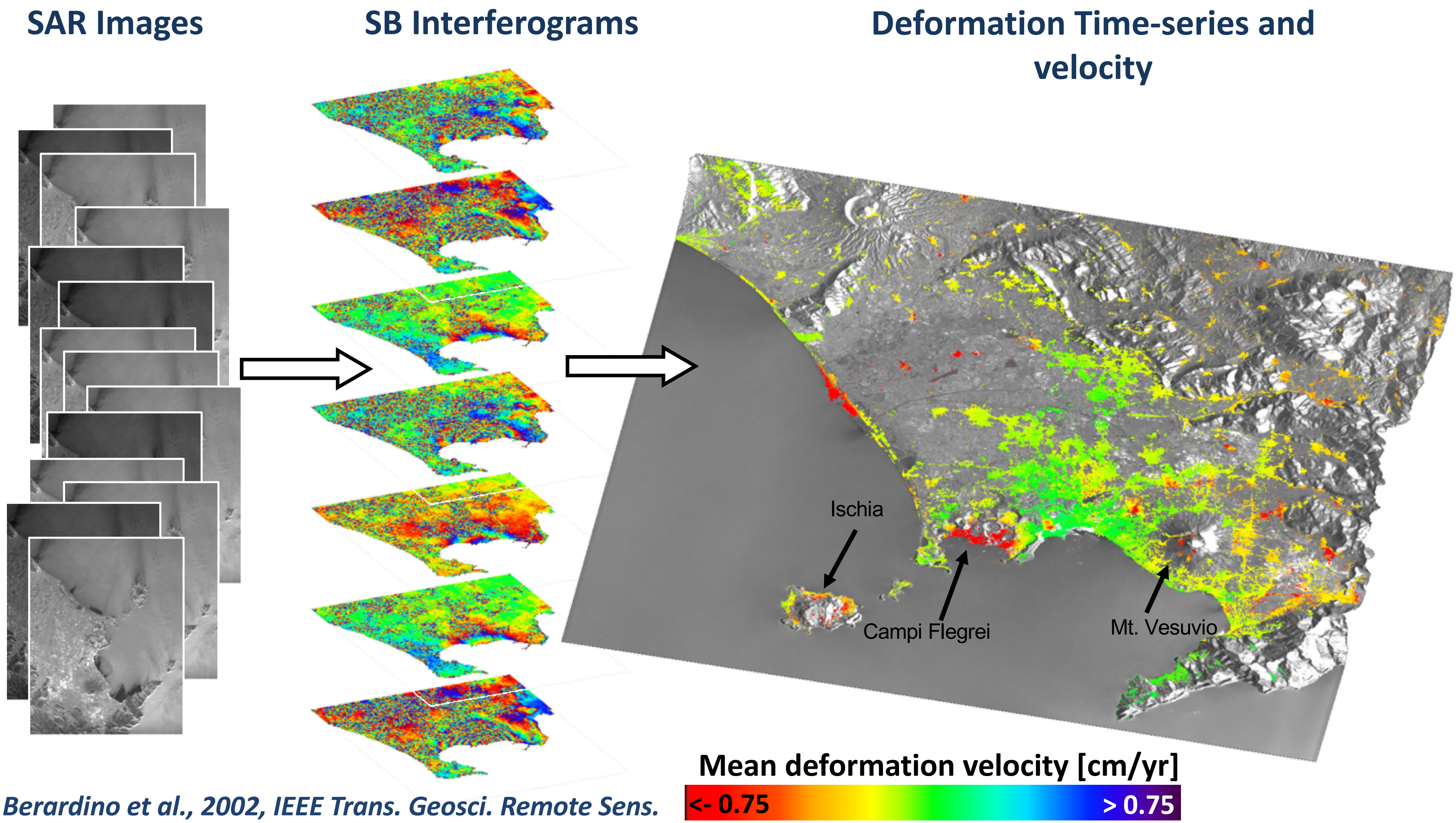
The Small BAseline Subset (SBAS) DInSAR approach



Berardino et al., 2002, IEEE Trans. Geosci. Remote Sens.
Pepe et al., 2005, IEEE Trans. Geosci. Remote Sens.

ERS/ENVISAT images (1992 – 2010)

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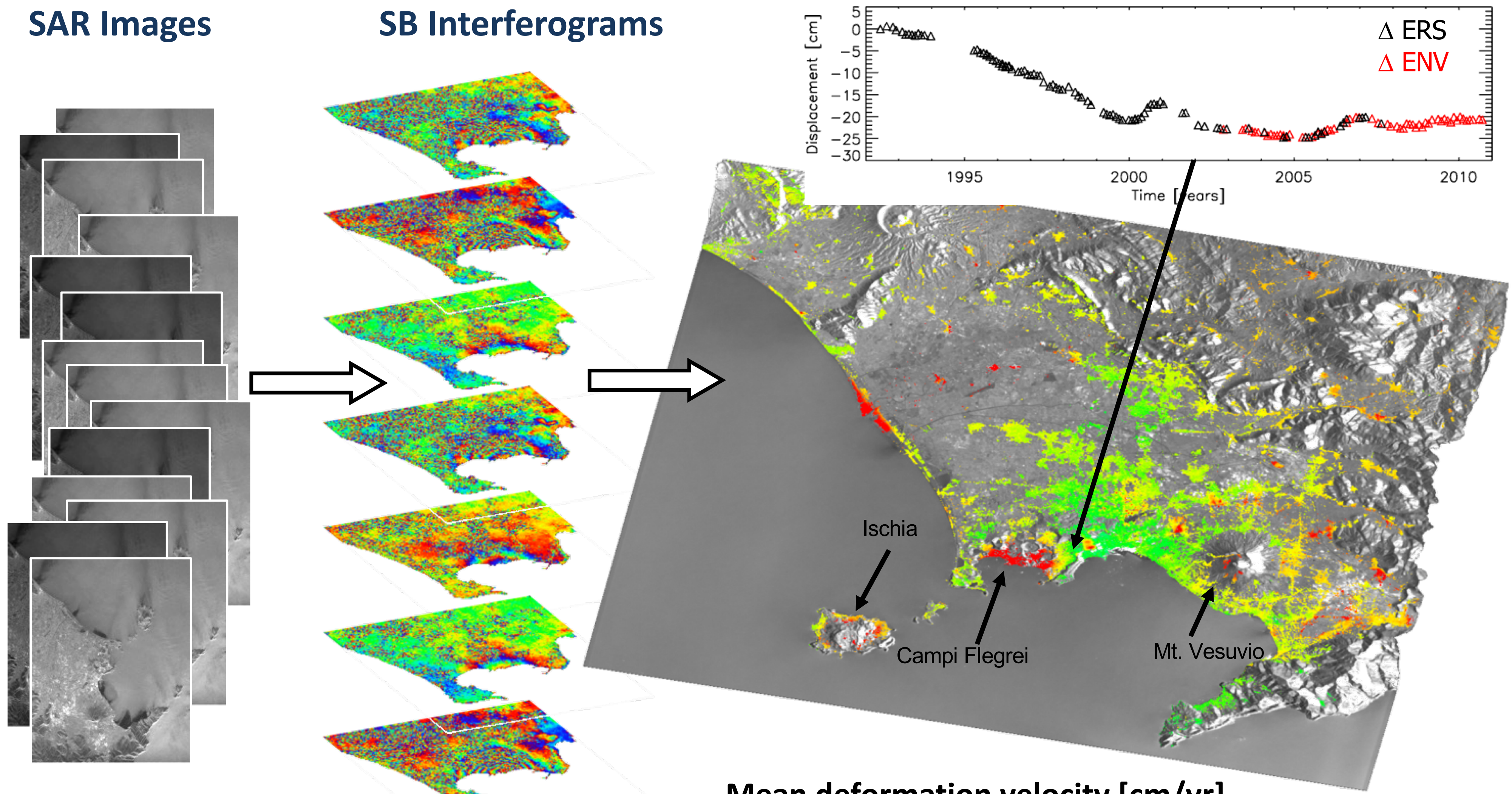
The Small BAseline Subset (SBAS) DInSAR approach



Mean deformation velocity [cm/yr]

<- 0.75 **> 0.75**

Berardino et al., 2002, IEEE Trans. Geosci. Remote Sens.
Pepe et al., 2005, IEEE Trans. Geosci. Remote Sens.

ERS/ENVISAT images (1992 – 2010)

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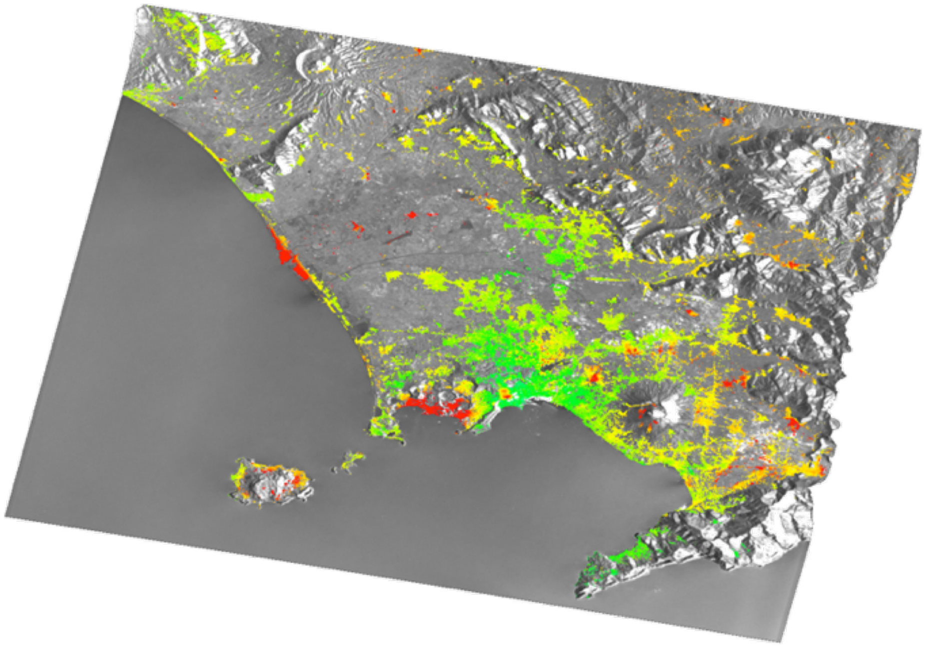
The Full Resolution SBAS technique: multi-scale approach

Regional scale analysis

(pixel size: ~30 m for the CSK stripmap case)



Local scale analysis

(pixel size: ~3 m for the CSK stripmap case)

Lanari et al., 2004, IEEE Trans. Geosci. Rem Sens.
Bonano et al., 2012, Int. Jour. Remote Sensing.

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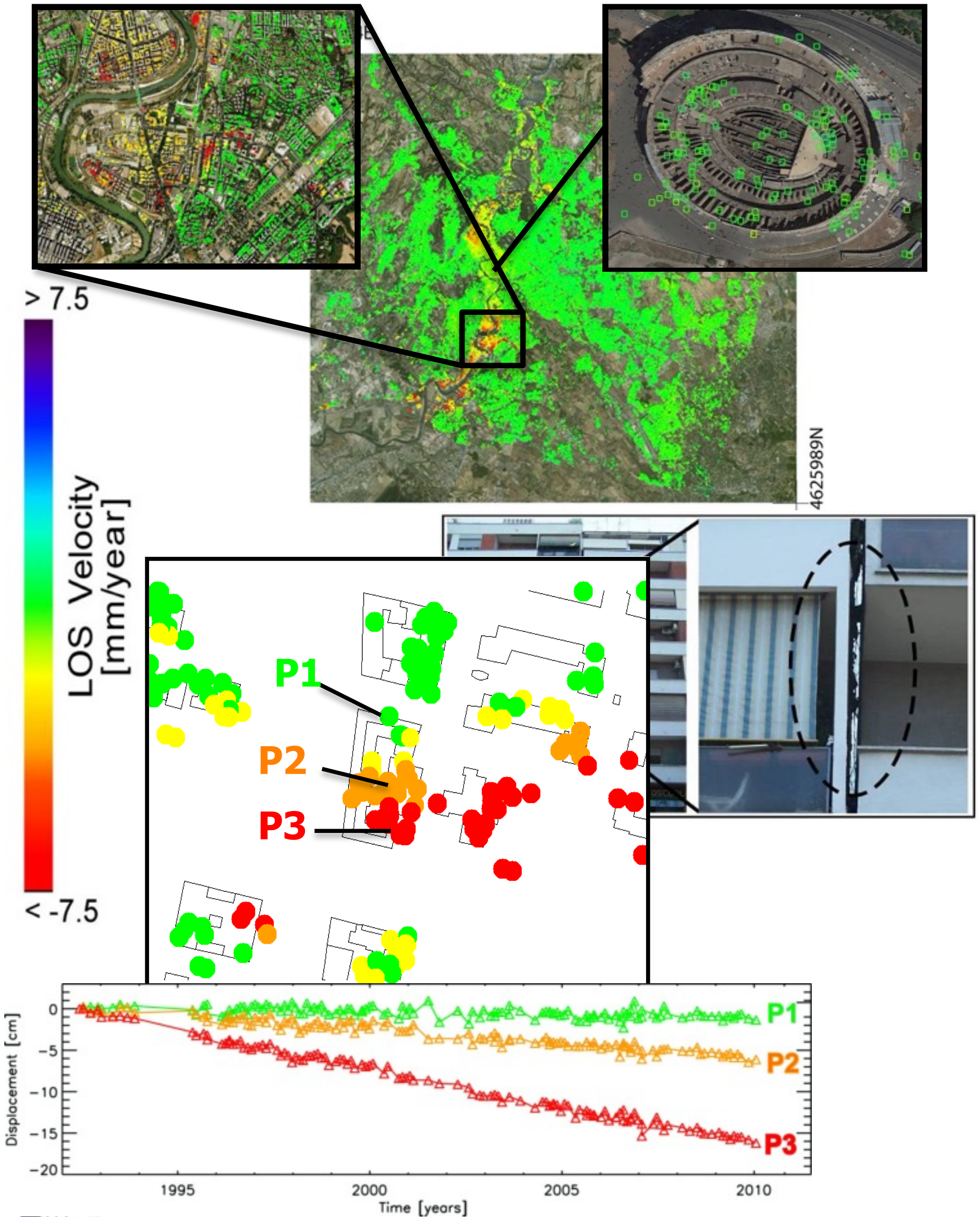
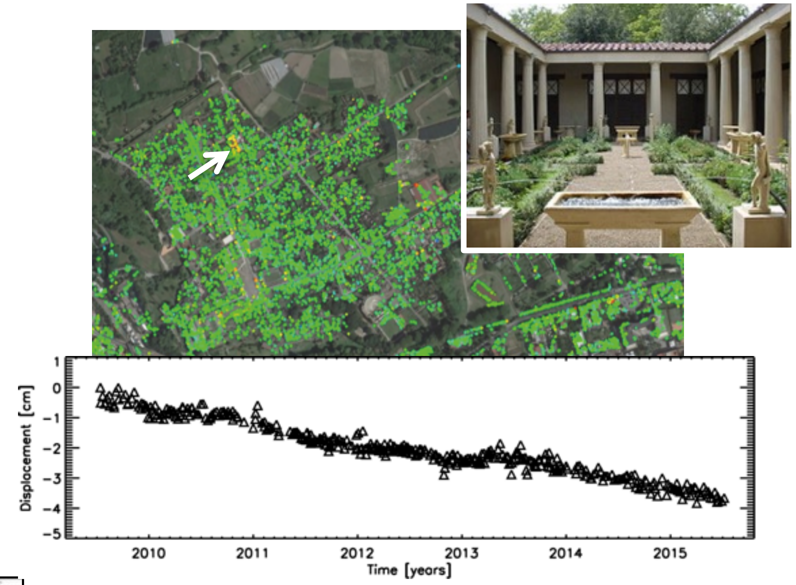
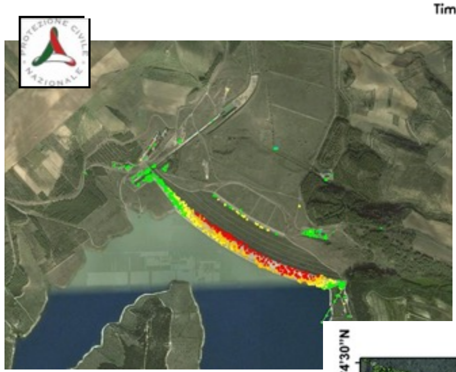
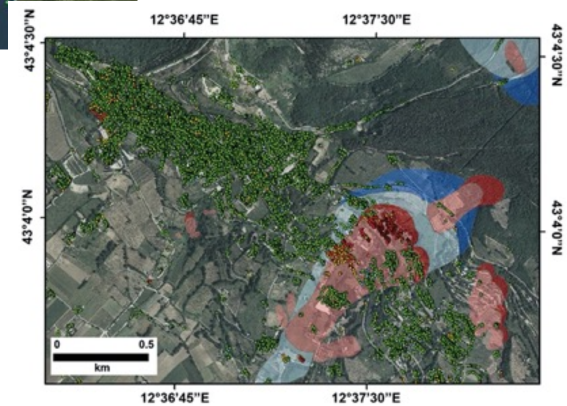
The Full Resolution SBAS technique: main applications









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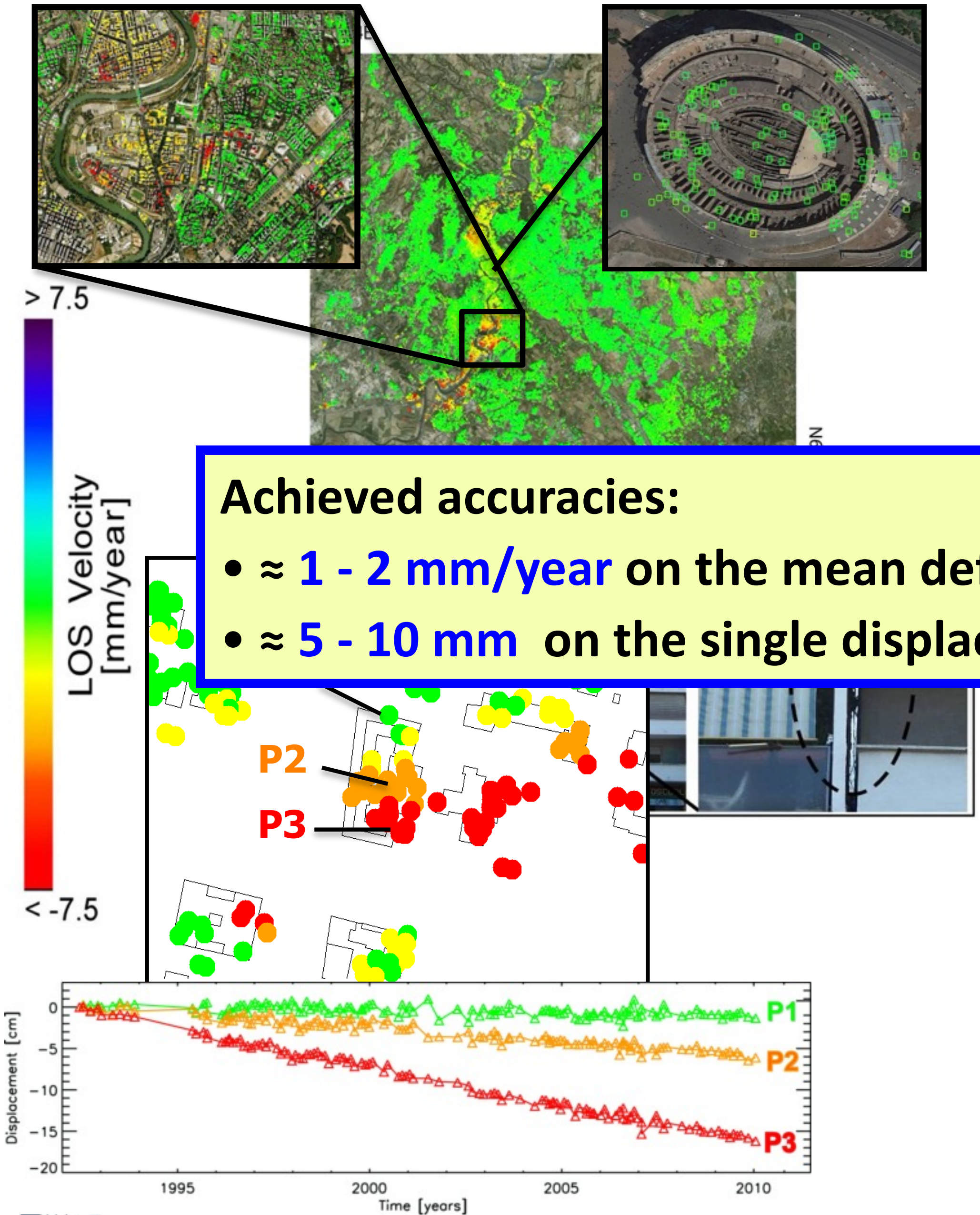
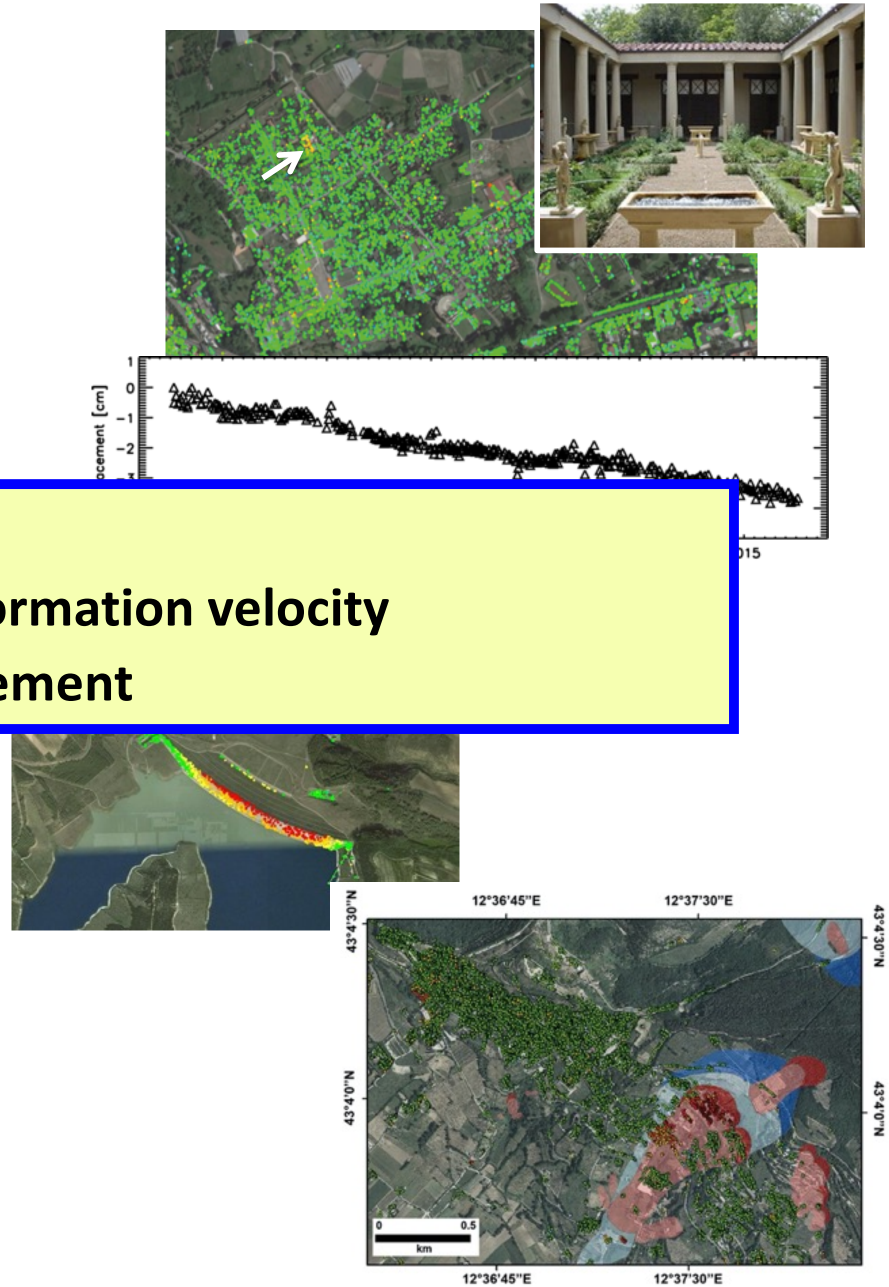
The Full Resolution SBAS technique: main applications





Achieved accuracies:

- ≈ **1 - 2 mm/year** on the mean deformation velocity
- ≈ **5 - 10 mm** on the single displacement

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The Full Resolution P-SBAS algorithm: block diagram

- FR-SBAS deals with low and full resolution interferograms. FR-SBAS processing starts with the retrieval of the residual interferometric phase by subtracting modulo-2π the low resolution phase from the full resolution one.

- The residual interferometric phase is then processed to estimate the linear phase components:

    - Mean deformation velocity, $v(x,r)$
    - Residual topography, $\Delta z(x,r)$
    - Azimuthal position, $\Delta x(x,r)$
    - Thermal dilation coefficient, $K(x,r)$

- Once the linear components are filtered out from residual phase, the non-linear deformation phase $\beta(x,r)$ is finally retrieved.

- Last step carries out the combination of v and β deformation components with the corresponding low resolution ones to retrieve the full resolution signals.

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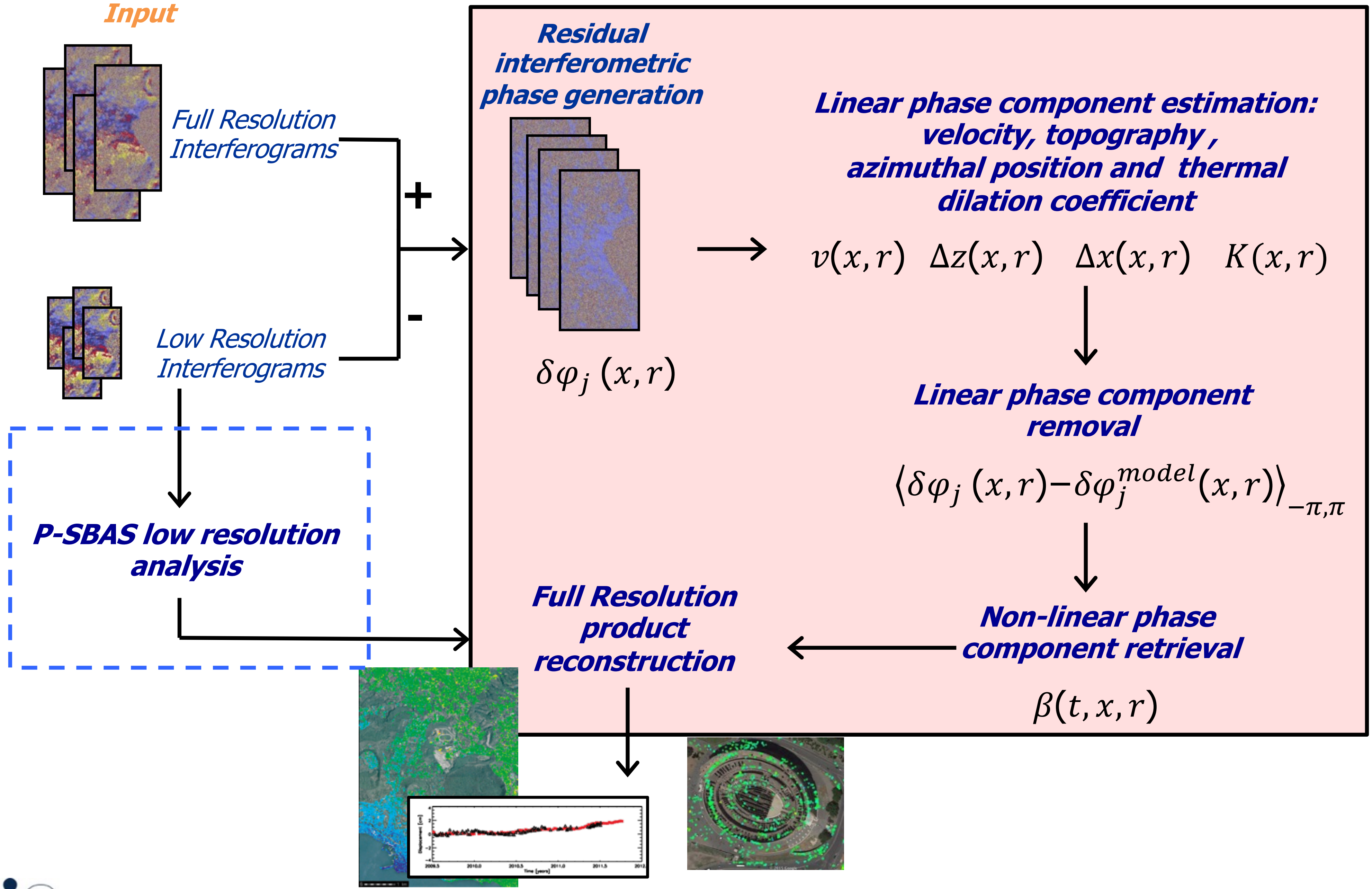
The Full Resolution P-SBAS algorithm: block diagram



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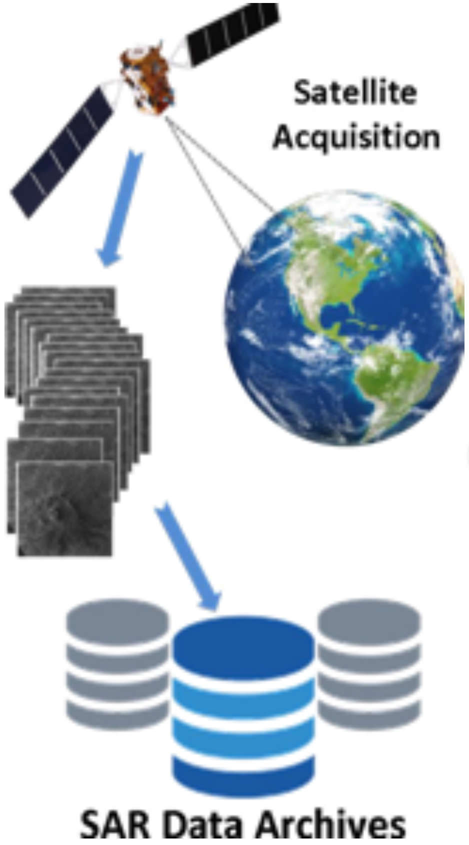
The Full Resolution SBAS-DInSAR analysis: a Big Data challenge



FR SBAS-DInSAR
results:
MILLIONS OF POINTS TO PROCESS!!!

Parallel hardware architectures based on
GPU and **multi-core** processing

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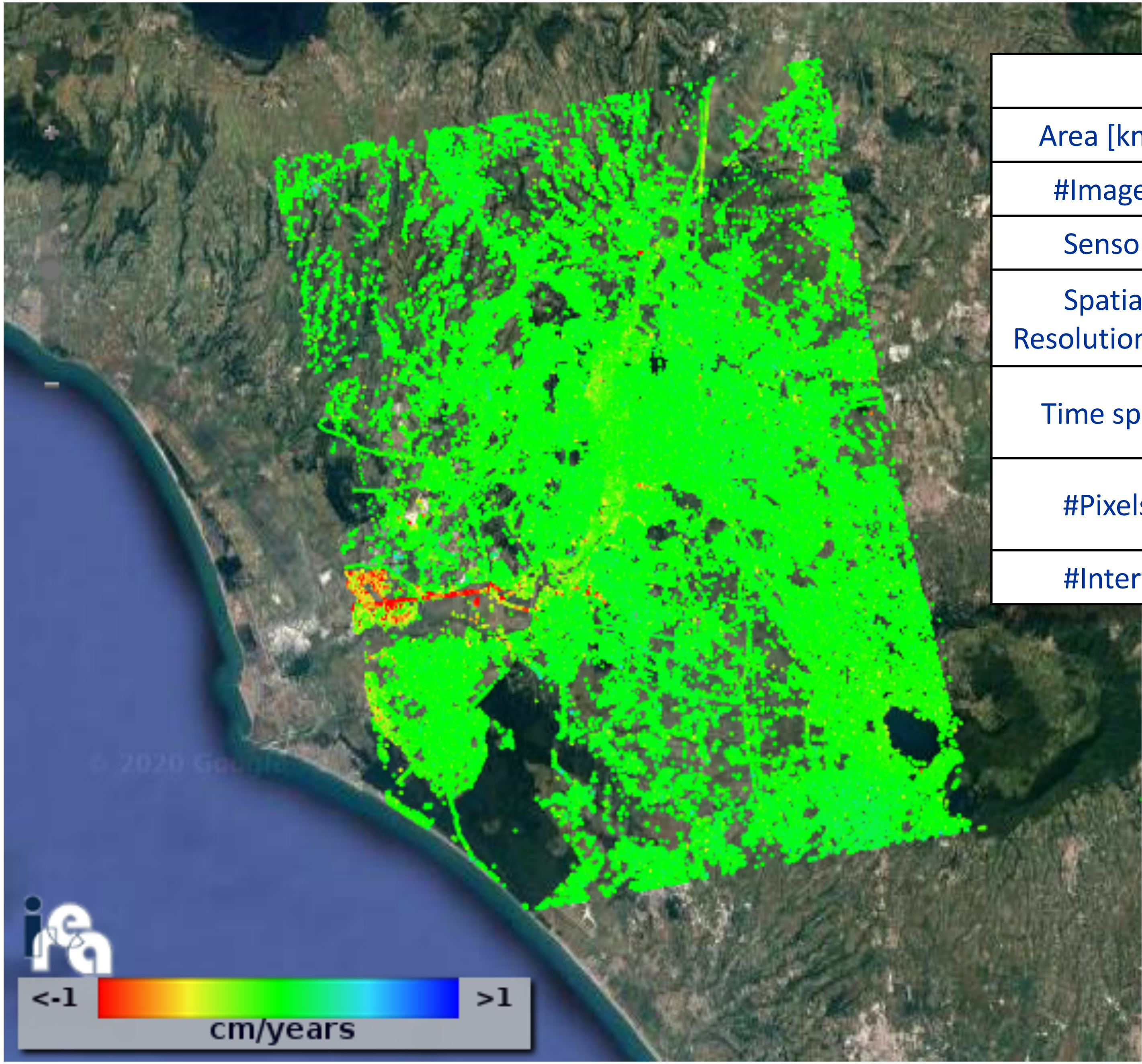
The FR SBAS technique: sequential implementation



Area of Roma	
Area [km^2]	40x40
#Images	129
Sensor	CSK
Spatial Resolution [m]	3x3
Time span	03/2011 – 03/2019
#Pixels	21000x15000 (> 300 M)
#Interf	392

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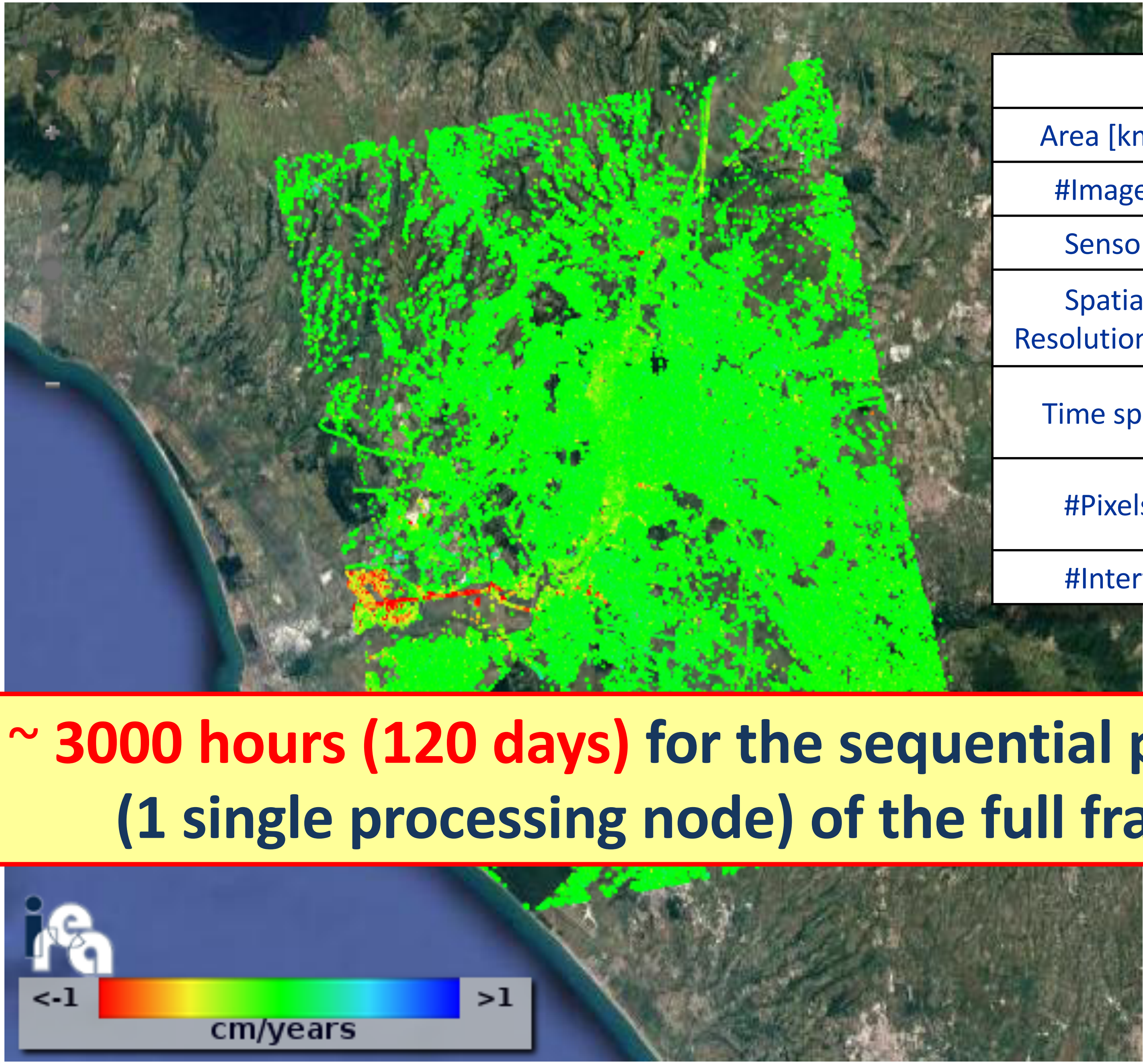
The FR SBAS technique: sequential implementation



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~ 3000 hours (120 days) for the sequential processing (1 single processing node) of the full frame!!!

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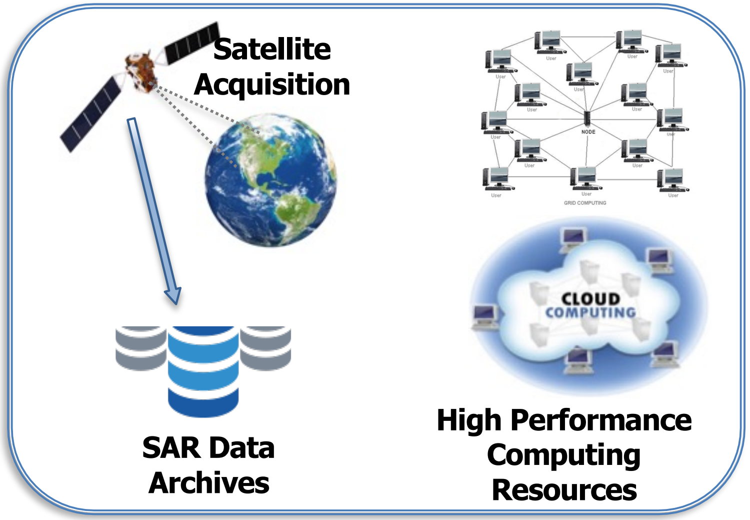
Full exploitation of large SAR data archives

Computing Resources & Data Proximity:

Availability of distributed HPC

infrastructures and data proximity



Efficient Processing Tools:

Development of parallel algorithms for HPC

platforms to cut down the processing times

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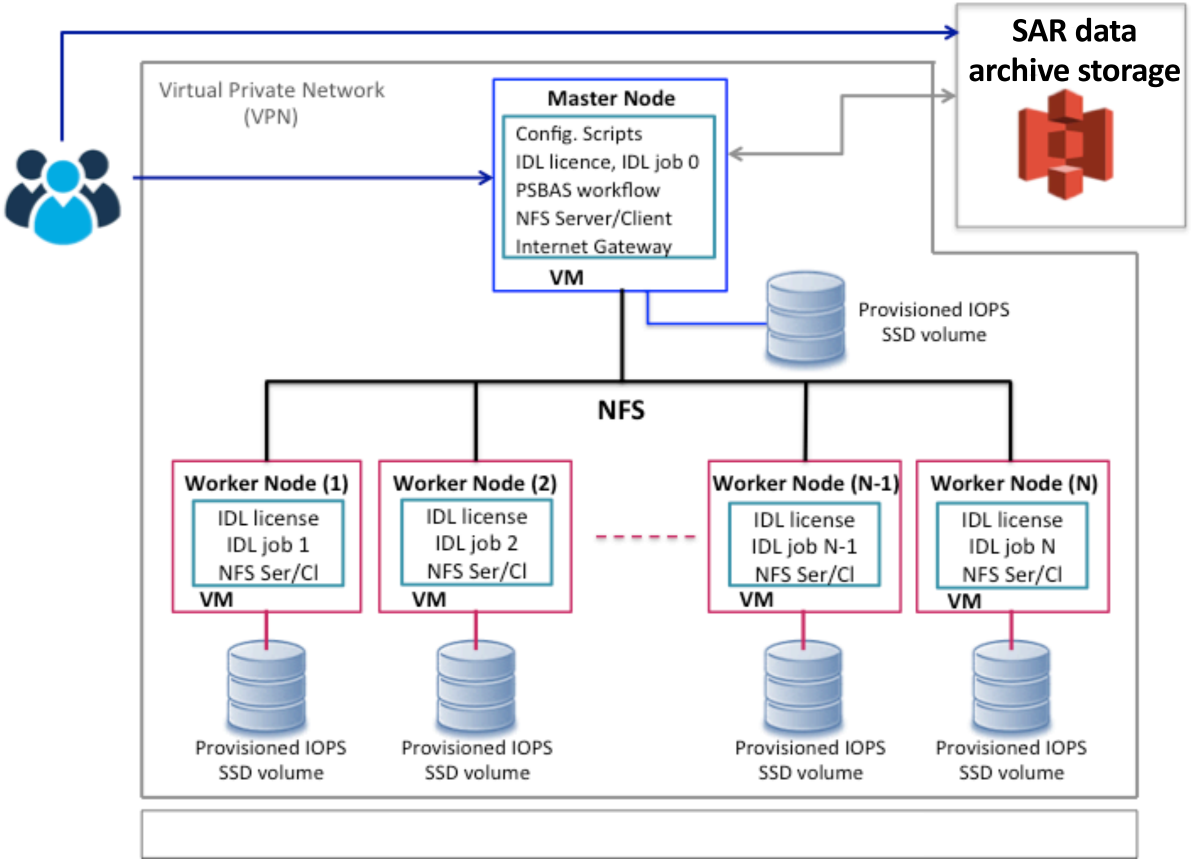
Implemented Computing Architecture



- ✓ All working nodes are controlled by a single Master Node
- ✓ The working nodes are connected with each other via NFS and acts as client and server at same time
- ✓ High I/O performance is obtained thanks to dedicated storage volumes shared among the nodes
- ✓ Final results are transferred to a long-term persistent storage

NFS-based distributed storage implementation designed to minimize the I/O and data transfer overhead

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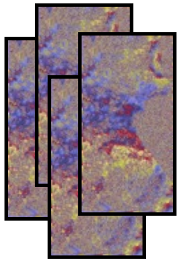
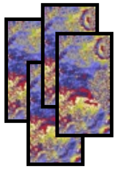
The Parallel Full Resolution P-SBAS algorithm: block diagram

Input



Full Resolution Interferograms



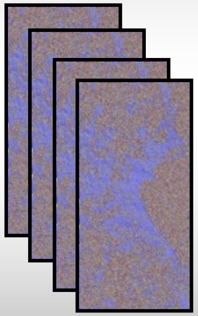
Low Resolution Interferograms

+

-

A

Residual interferometric phase generation



$$\delta\varphi_j^{(HP)}(x,r)$$

B

Linear phase components estimation: velocity, topography, azimuthal position and thermal dilation coefficient

$$v(x,r) \quad \Delta z(x,r) \quad \Delta x(x,r) \quad K(x,r)$$

C

Linear phase component removal

$$\left\langle \delta\varphi_j^{(HP)}(x,r) - \delta\varphi_j^{model}(x,r) \right\rangle_{2\pi}$$

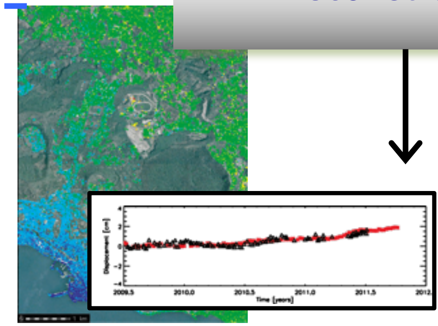
Non-linear phase component retrieval

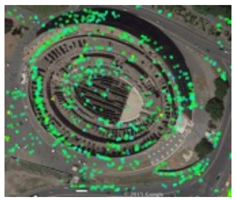
$$\beta(t,x,r)$$

P-SBAS low resolution analysis

D

Full Resolution product reconstruction





GPU CUDA STEPS

MULTI-CORE STEPS

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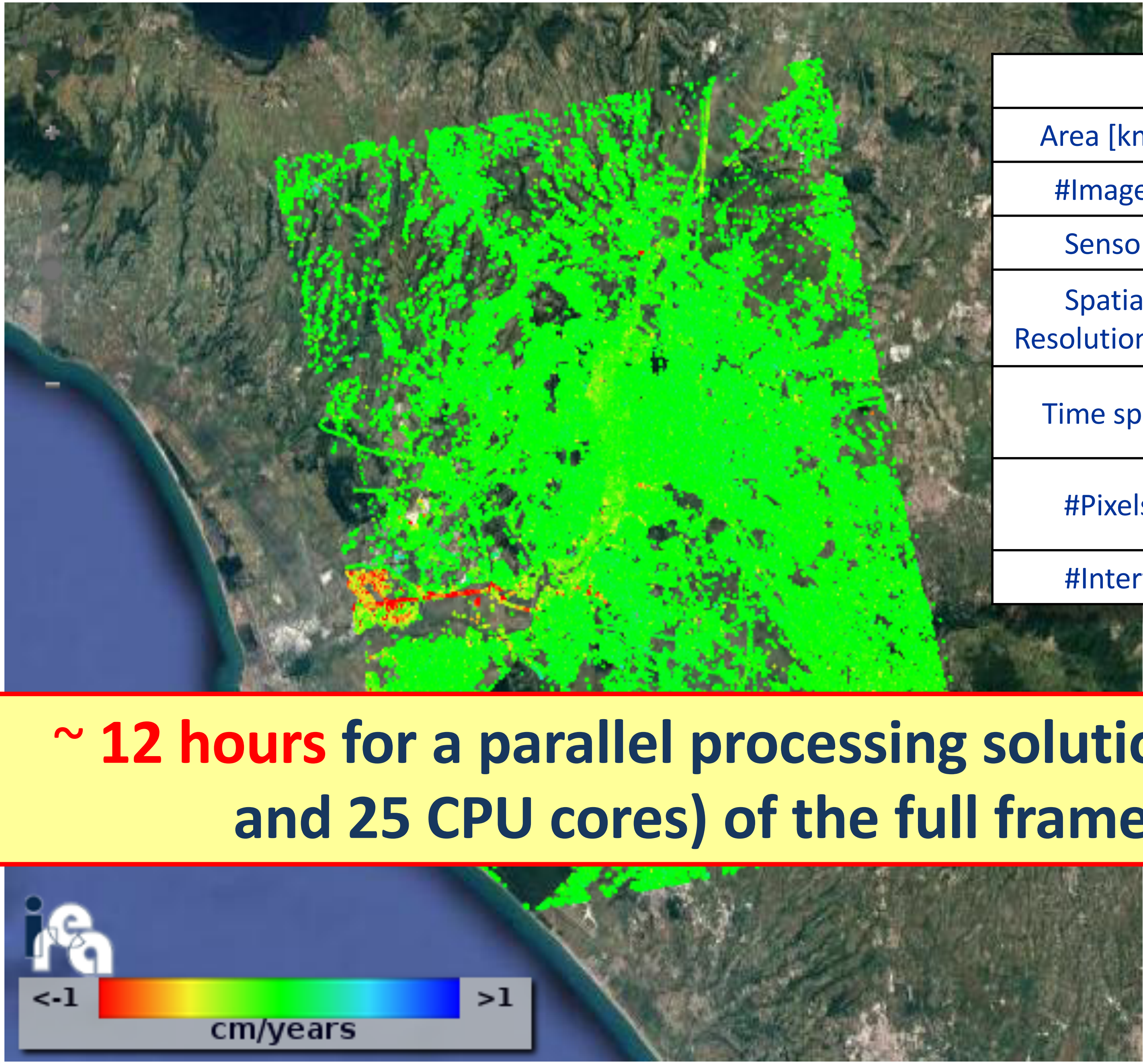
The Full Resolution P-SBAS: parallel implementation



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Sensor	CSK
Spatial Resolution [m]	3x3
Time span	03/2011 – 03/2019
#Pixels	21000x15000 (> 300 M)
#Interf	392

~ 12 hours for a parallel processing solution (4 GPU and 25 CPU cores) of the full frame!!!

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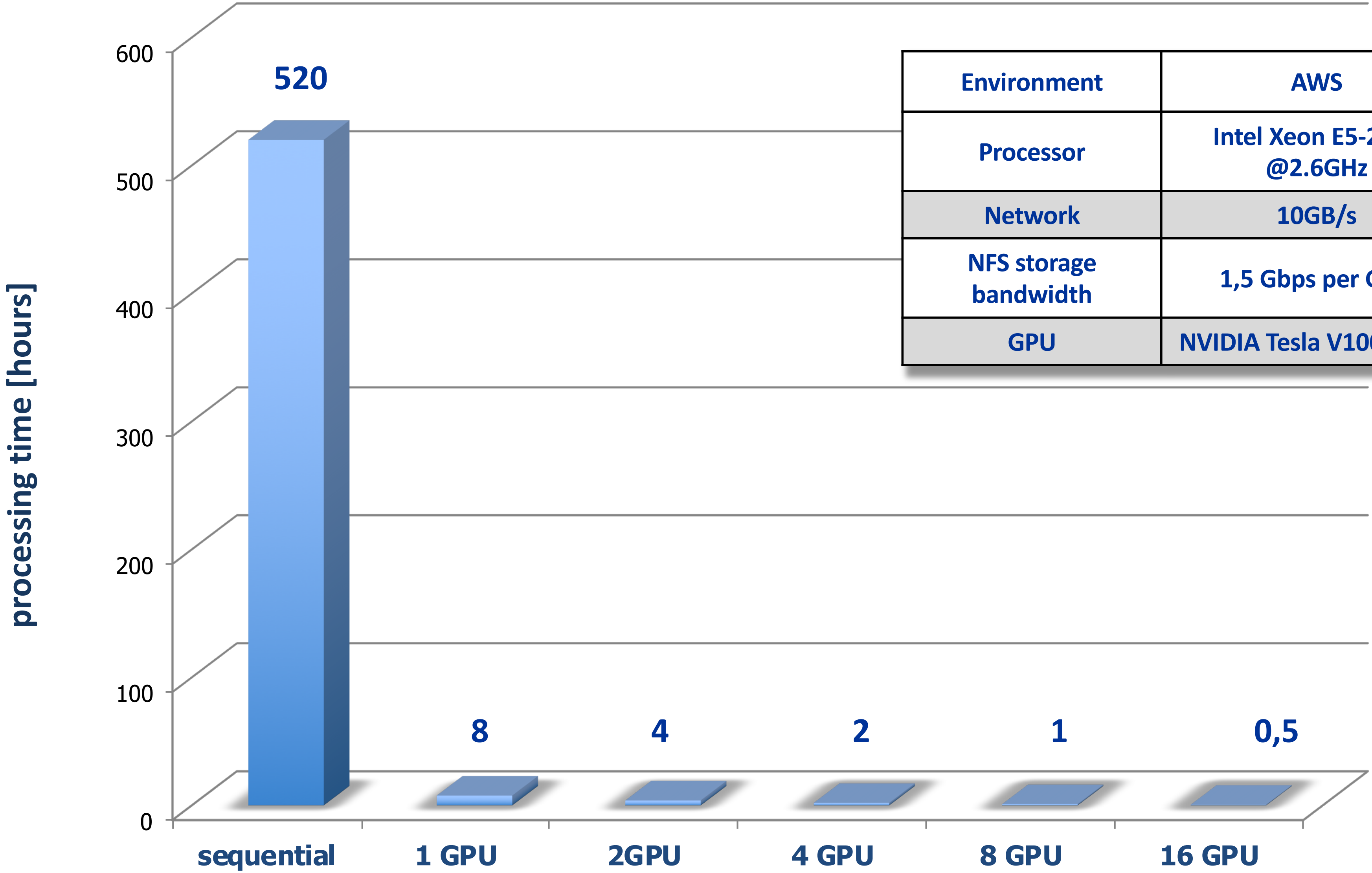
Sequential vs. Parallel FR SBAS processing chain: computing time for linear phase components estimation (step B)



Environment	AWS
Processor	Intel Xeon E5-2686 @2.6GHz
Network	10GB/s
NFS storage bandwidth	1,5 Gbps per GPU
GPU	NVIDIA Tesla V100 16 GB

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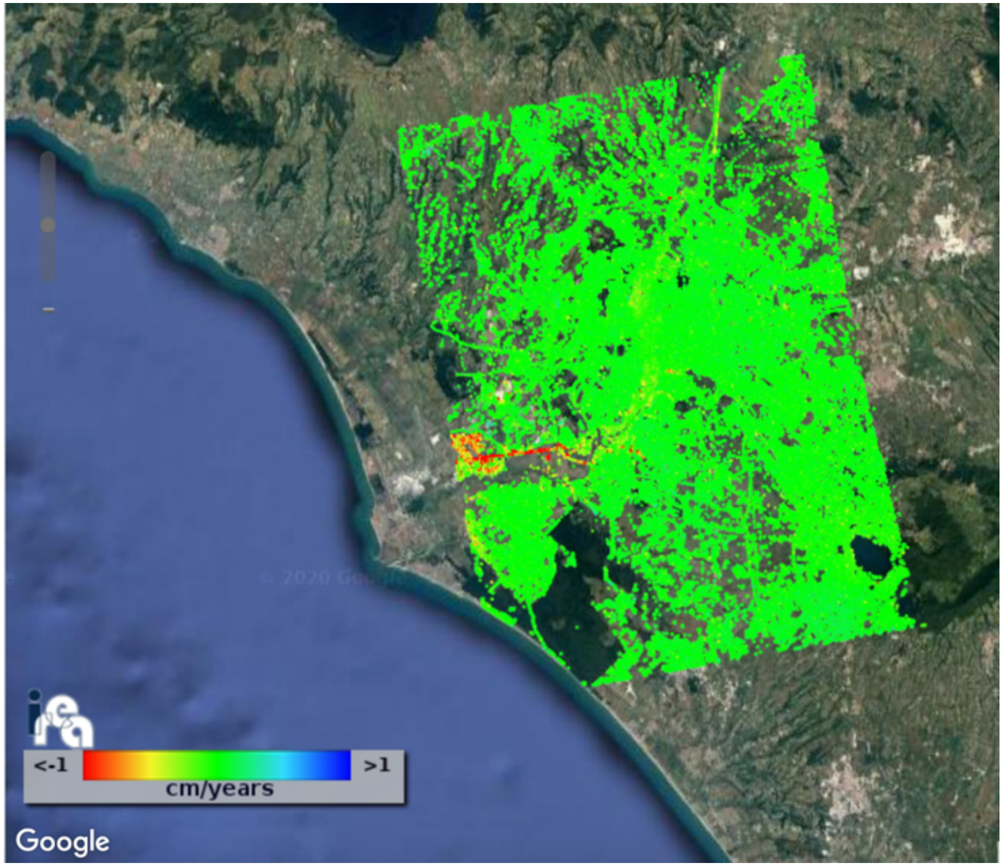
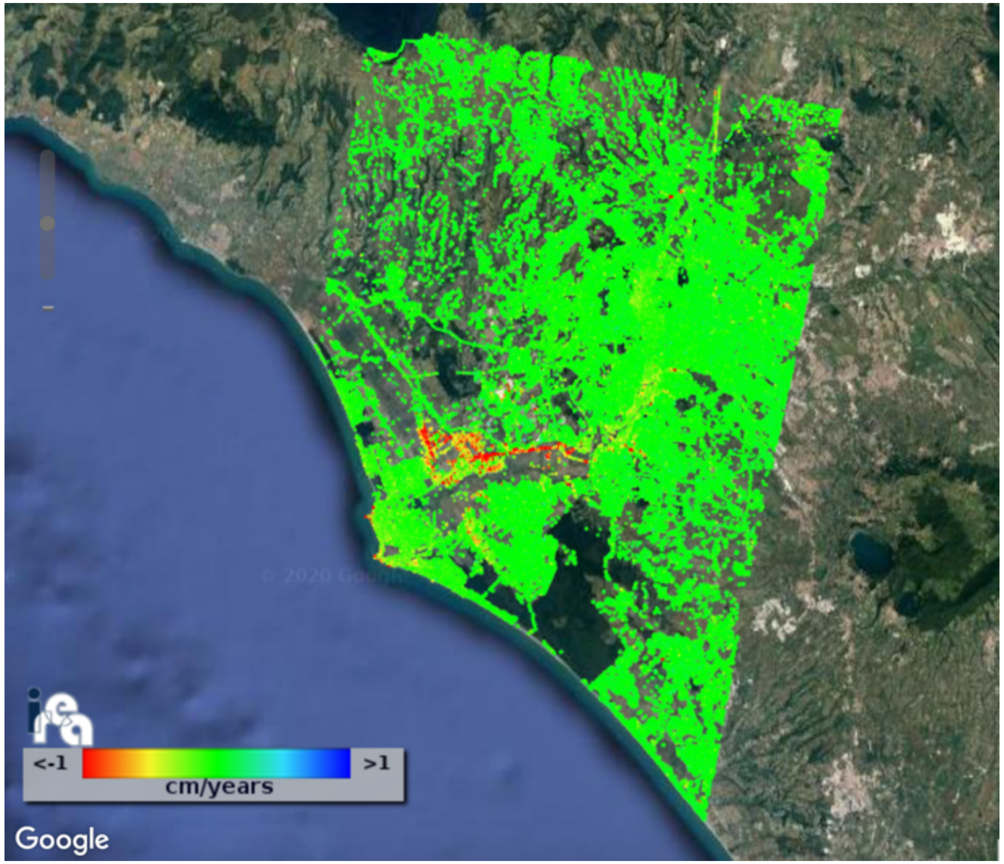
The FR P-SBAS results: the case study of Rome (Italy)





Ascending orbits
Time span: 03/2011 - 03/2019
129 acquisitions

Descending orbits
Time span: 07/2011 - 03/2019
107 acquisitions

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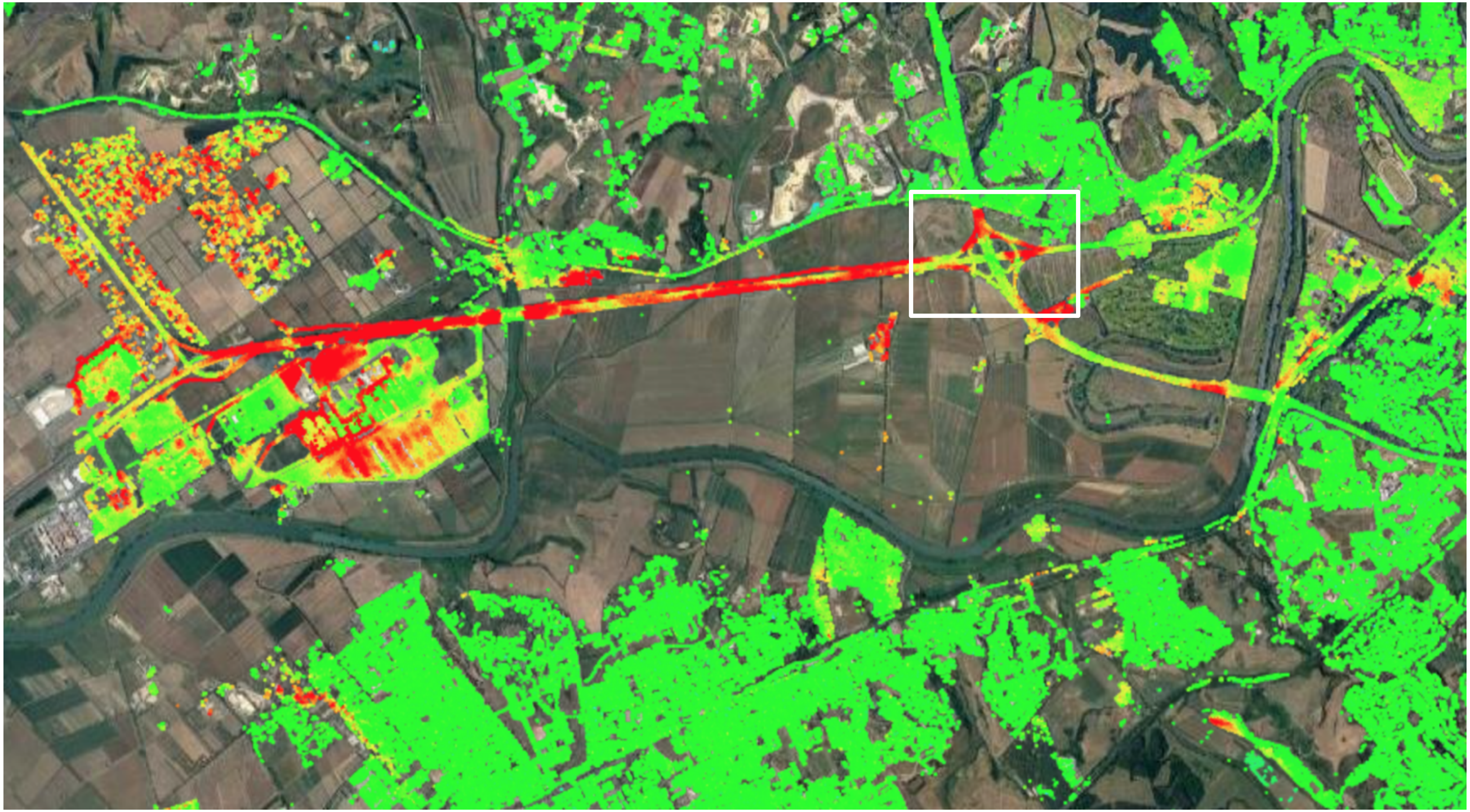
The FR P-SBAS results: the case study of Rome (Italy)

The A90-A91 Roma-Fiumicino Highway



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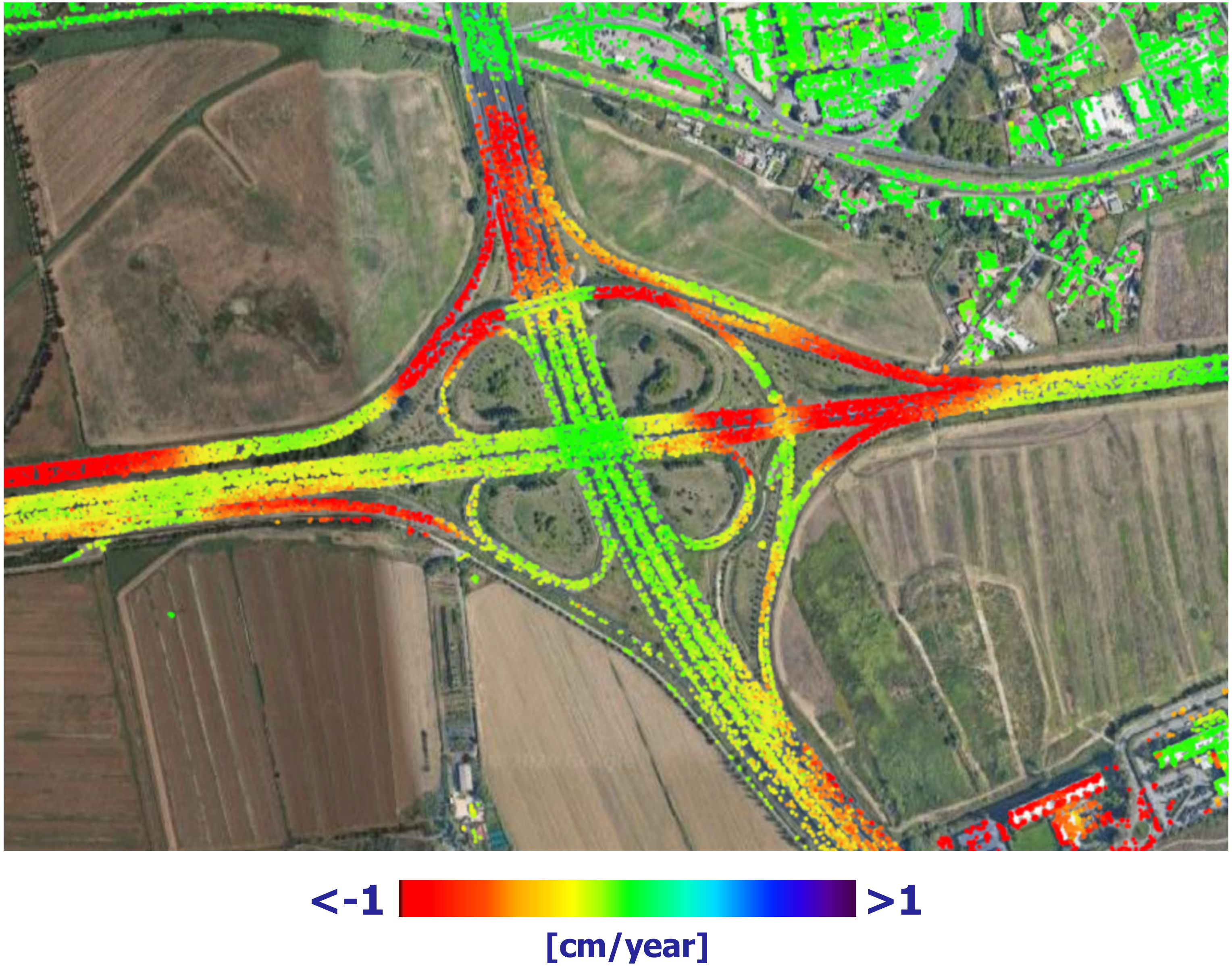

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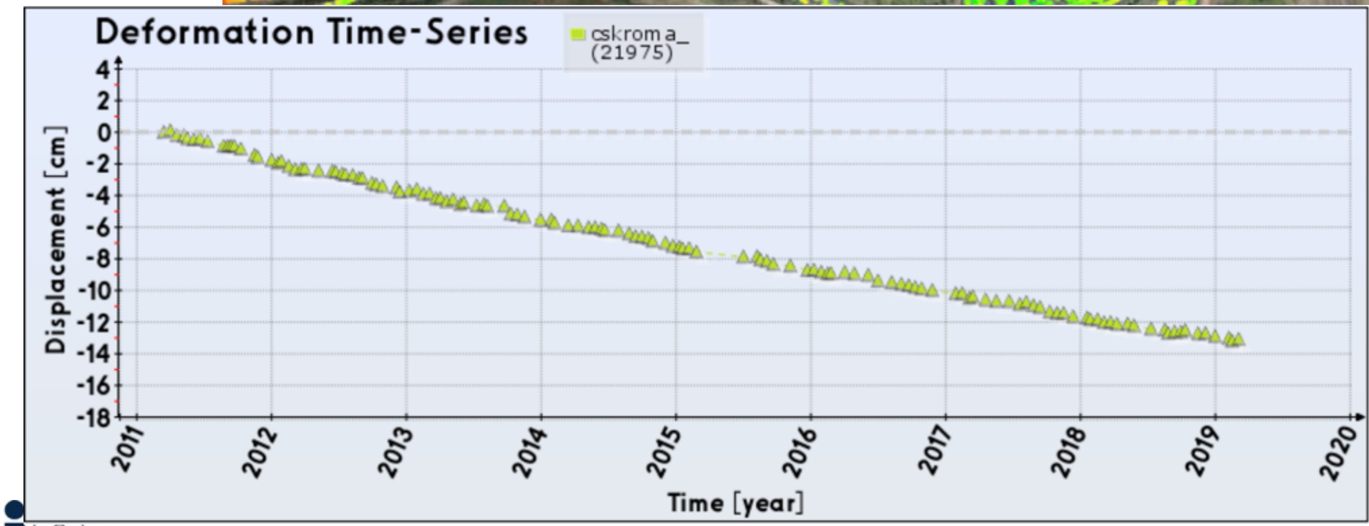

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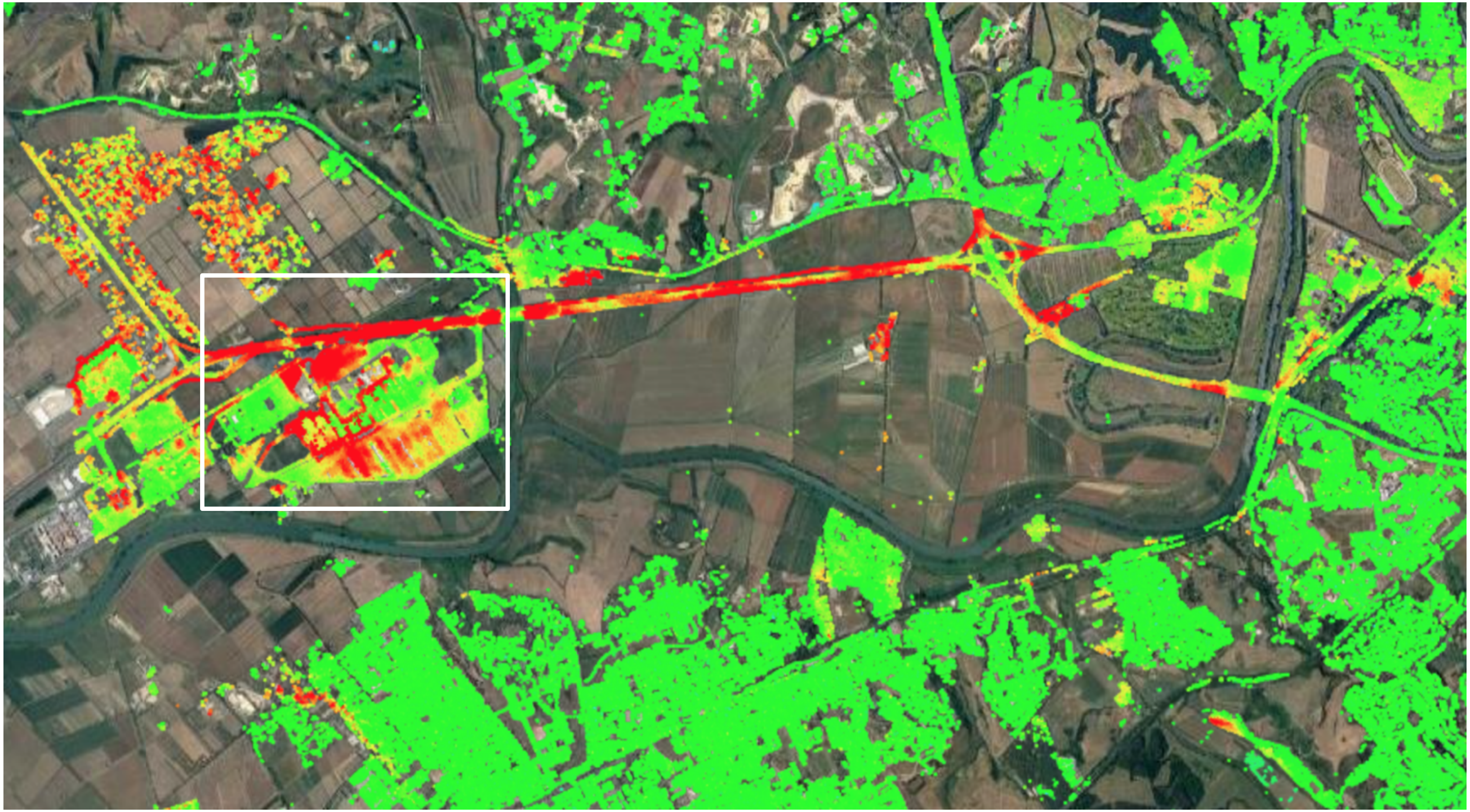
The FR P-SBAS results: the case study of Rome (Italy)

The Fiera di Roma area



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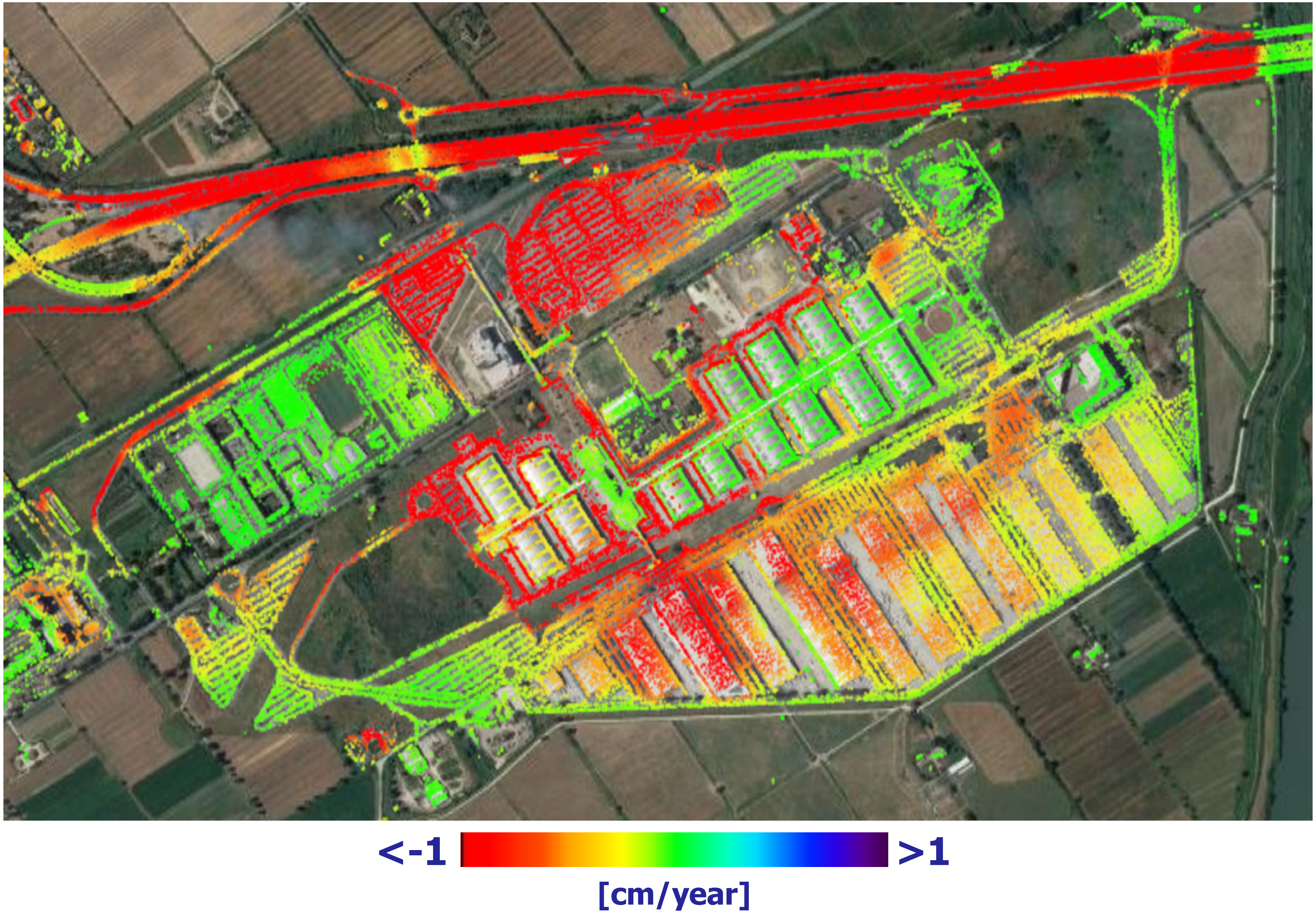
The Fiera di Roma area



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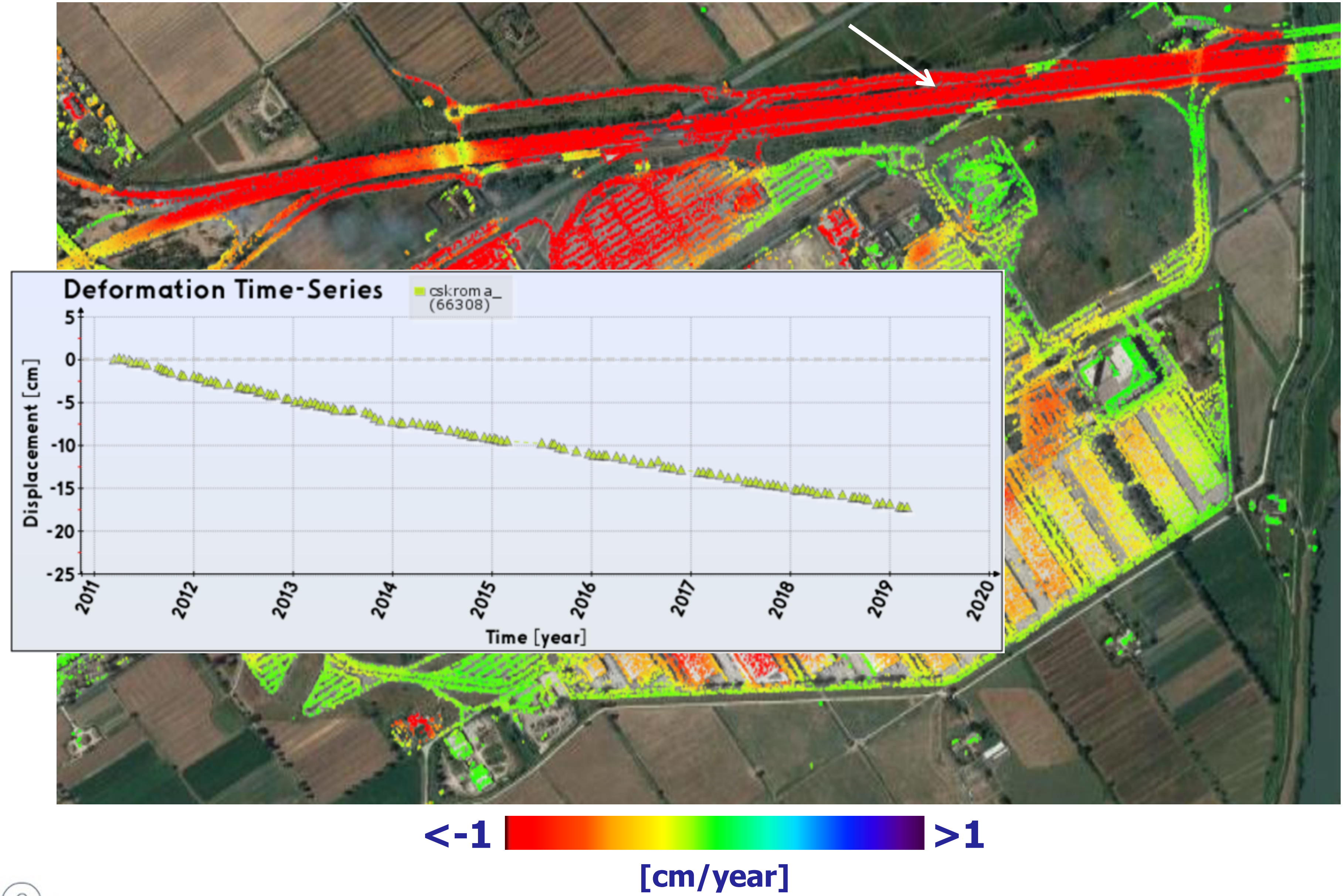
The FR P-SBAS results: the case study of Rome (Italy)

The Fiera di Roma area



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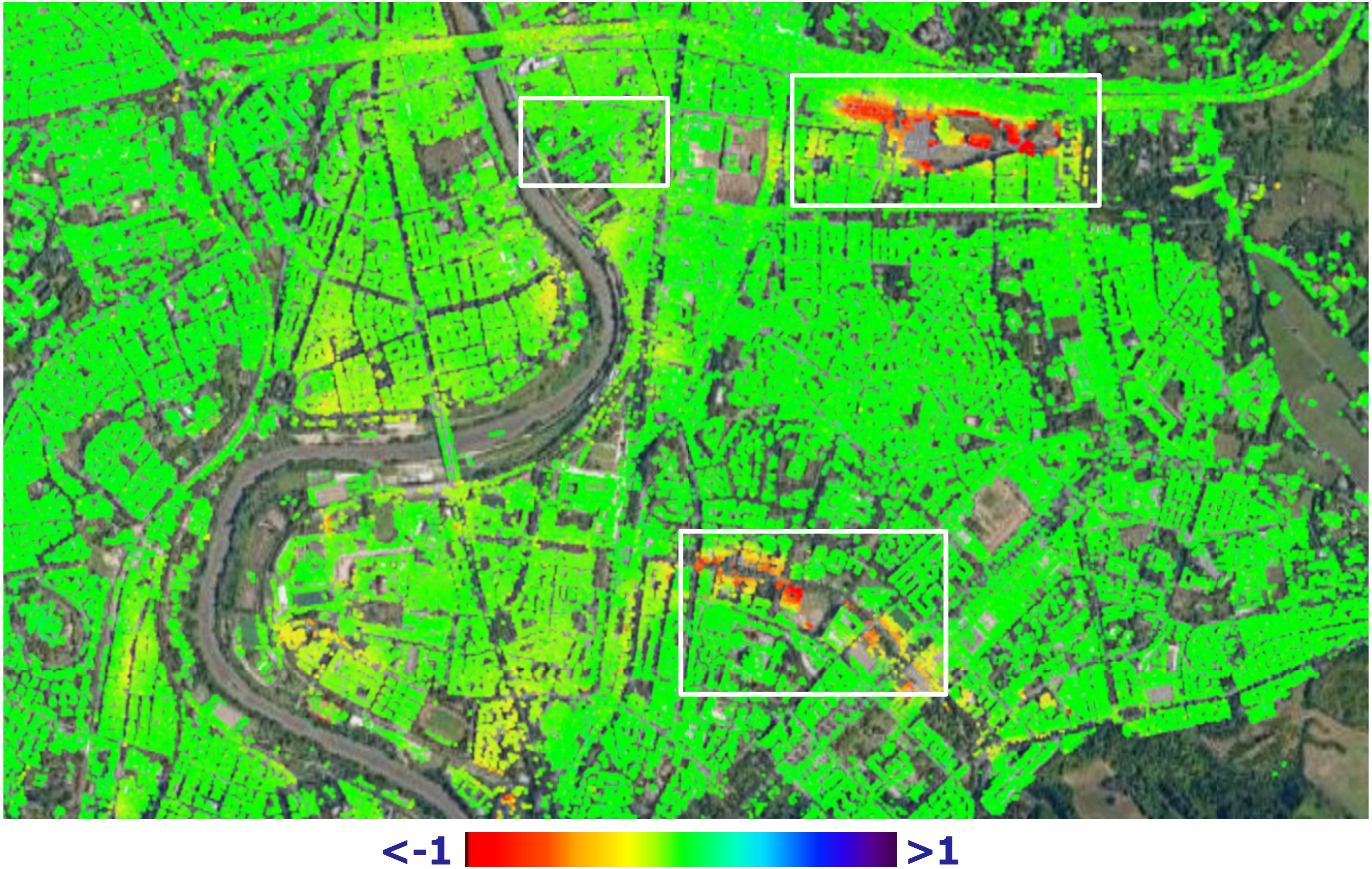
The FR P-SBAS results: the case study of Rome (Italy)

Gasometer, Ostiense railstation and Via Giustiniano Imperatore



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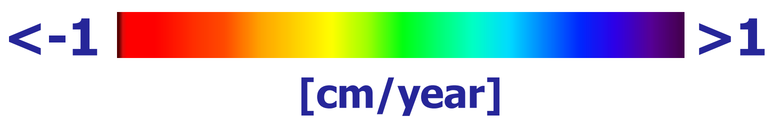
The FR P-SBAS results: the case study of Rome (Italy)

The Gasometer



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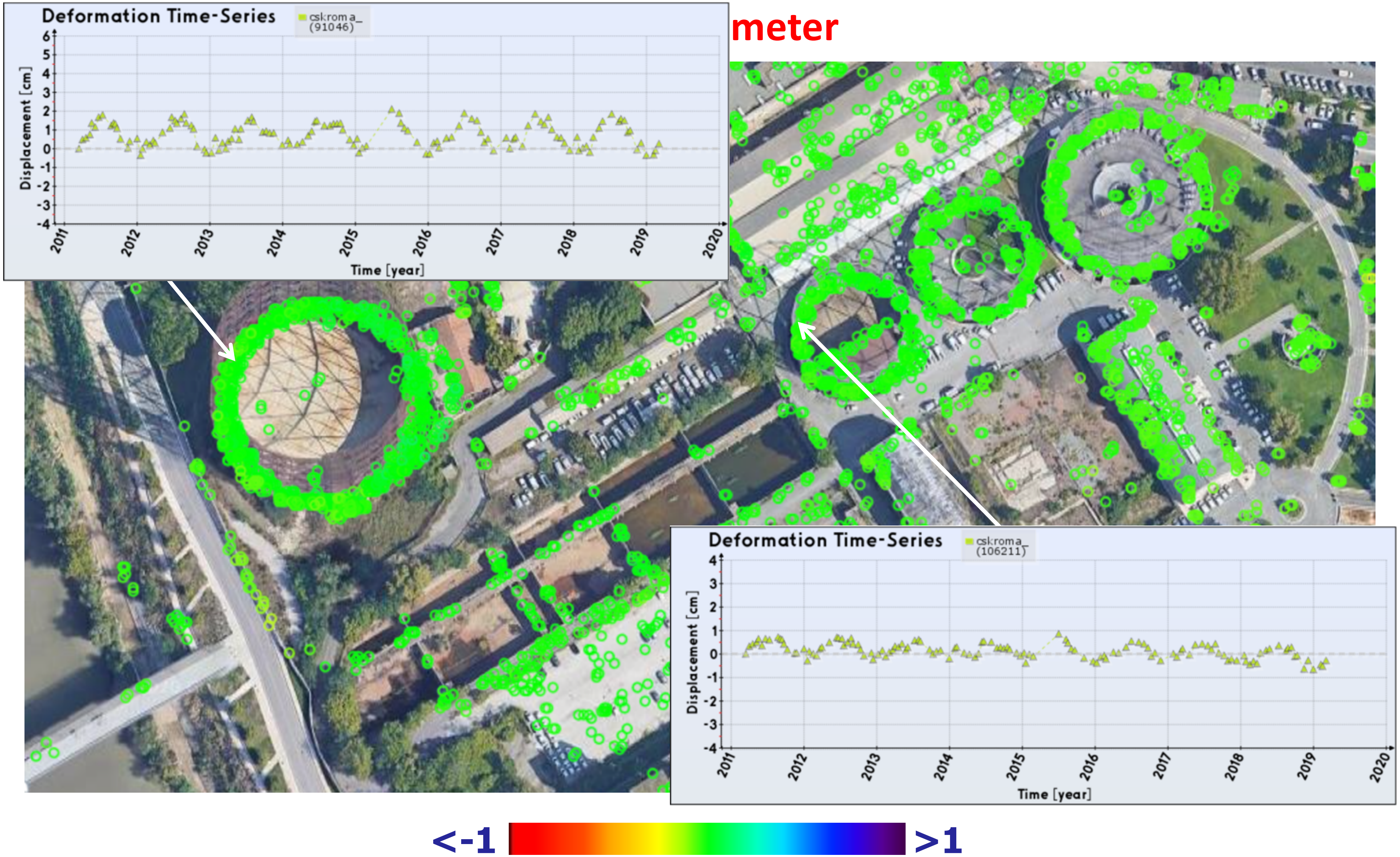

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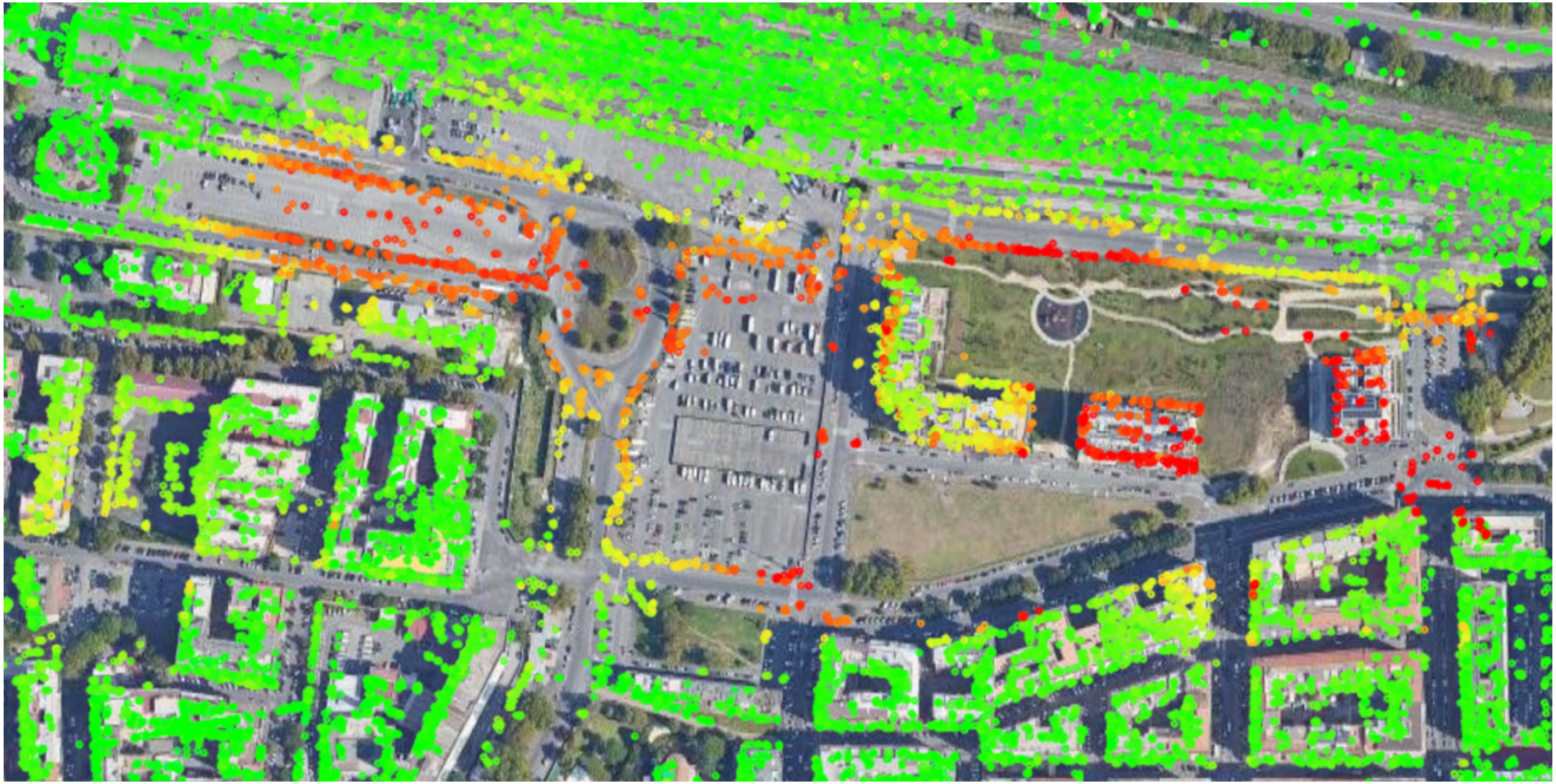
The FR P-SBAS results: the case study of Rome (Italy)

Ostiense railstation



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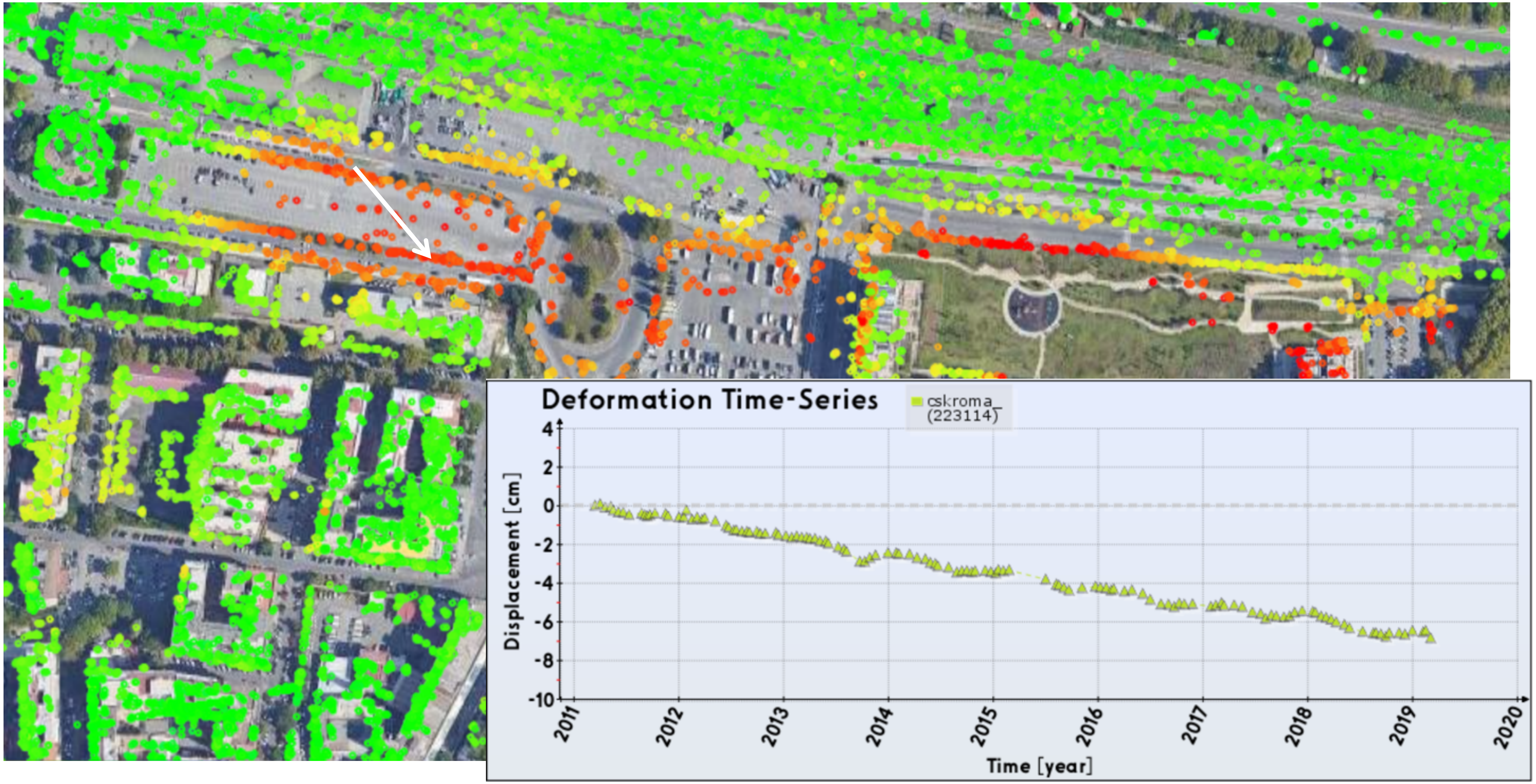
Ostiense railstation



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The FR P-SBAS results: the case study of Rome (Italy)

Via Giustiniano Imperatore

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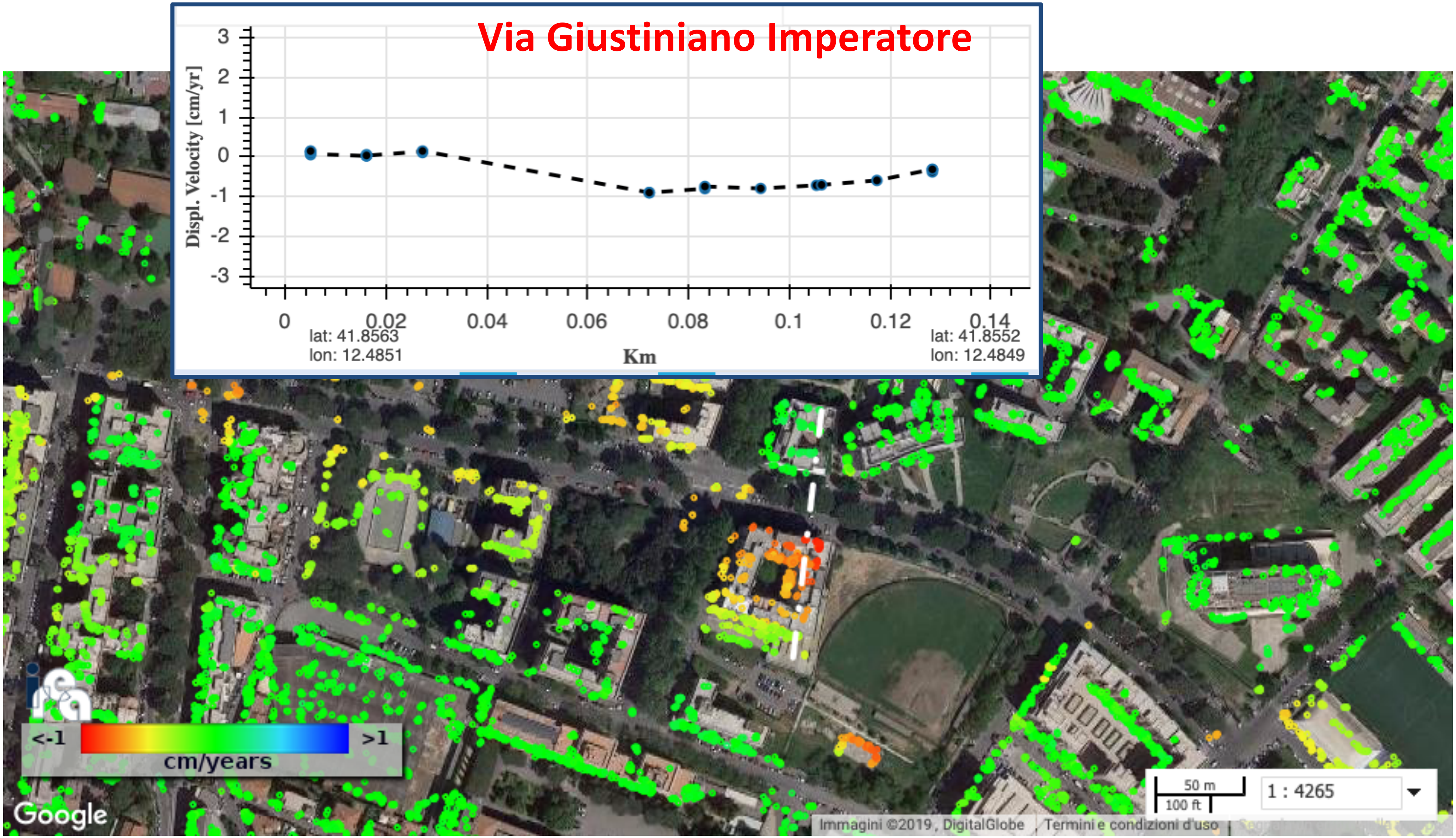
The FR P-SBAS results: the case study of Rome (Italy)



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The FR P-SBAS results: the case study of Rome (Italy)

Descending orbits: Fiumicino airport

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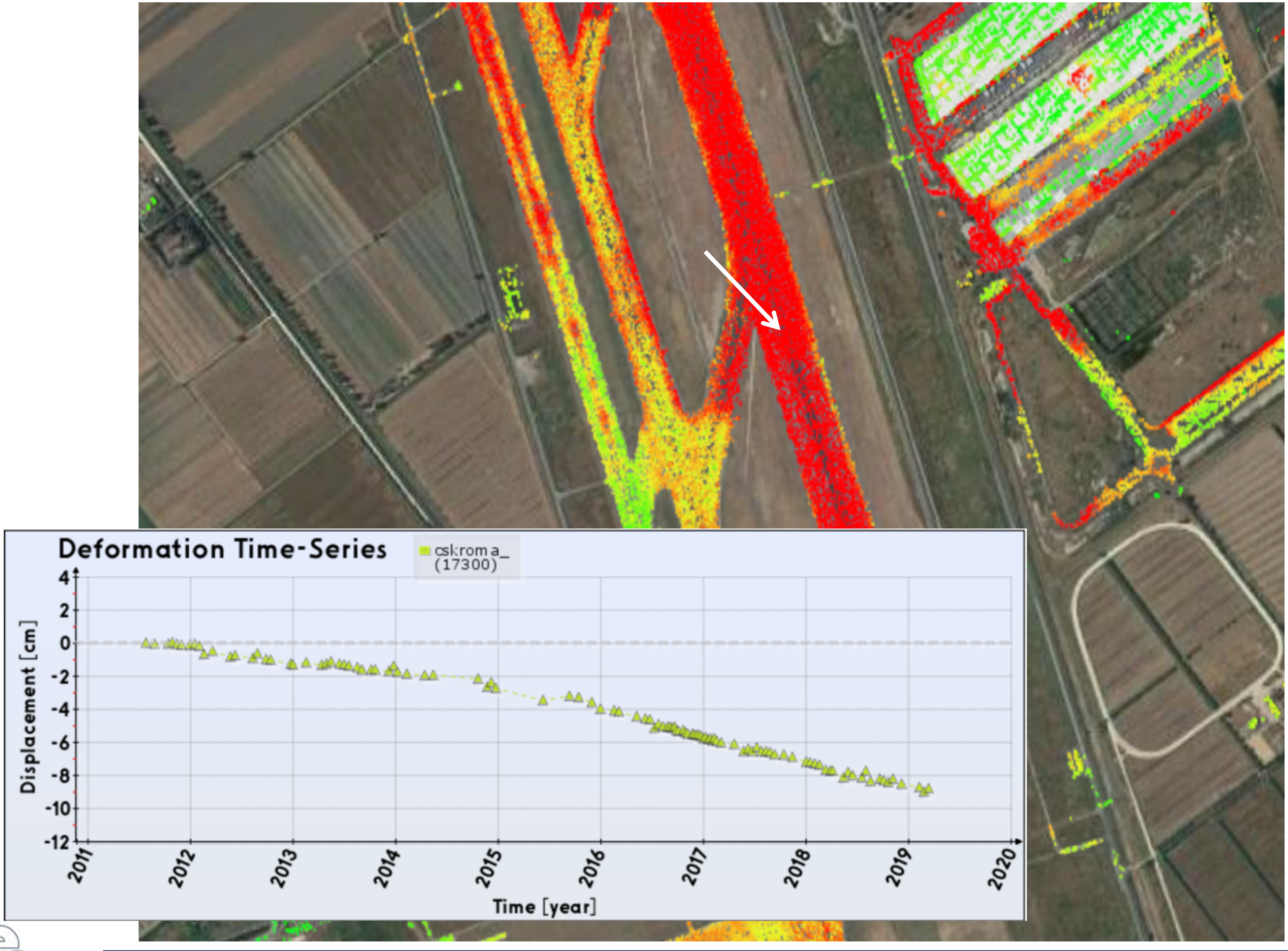
The FR P-SBAS results: the case study of Rome (Italy)

Descending orbits: Fiumicino airport



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Future perspective

- ✓ **Mapping the whole Italian territory by exploiting the full CSK data archive**

- ✓ **Integration of the FR P-SBAS measurements with structural models (FEM, semi-empirical, etc) for large scale damage assessment analyses**

- ✓ **Exploration of Big Data and AI approaches for advanced remote sensing and data interpretation methods**

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Thank you!

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