Multi-temporal/multi-frequency satellite SAR data P-SBAS analysis of natural and built-up environments

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Differential SAR Interferometry (DInSAR)

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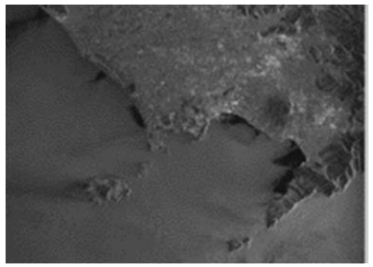
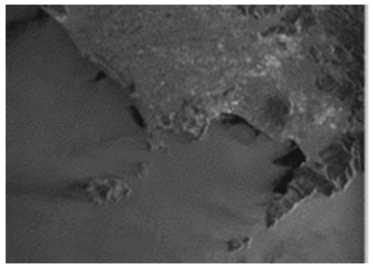
SAR scene @ **T0** MASTER



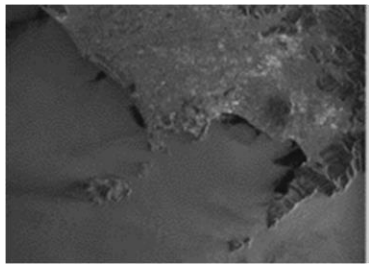
Differential SAR Interferometry (DInSAR)

SAR scene @ **T0** MASTER



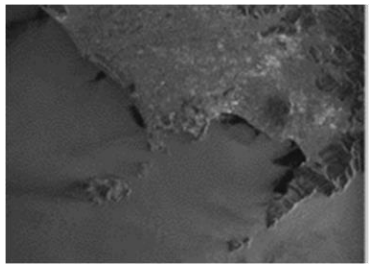
Baseline

SAR scene @ **T1** SLAVE

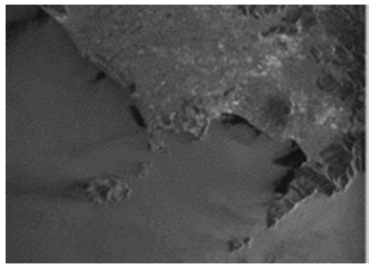


Differential SAR Interferometry (DInSAR)

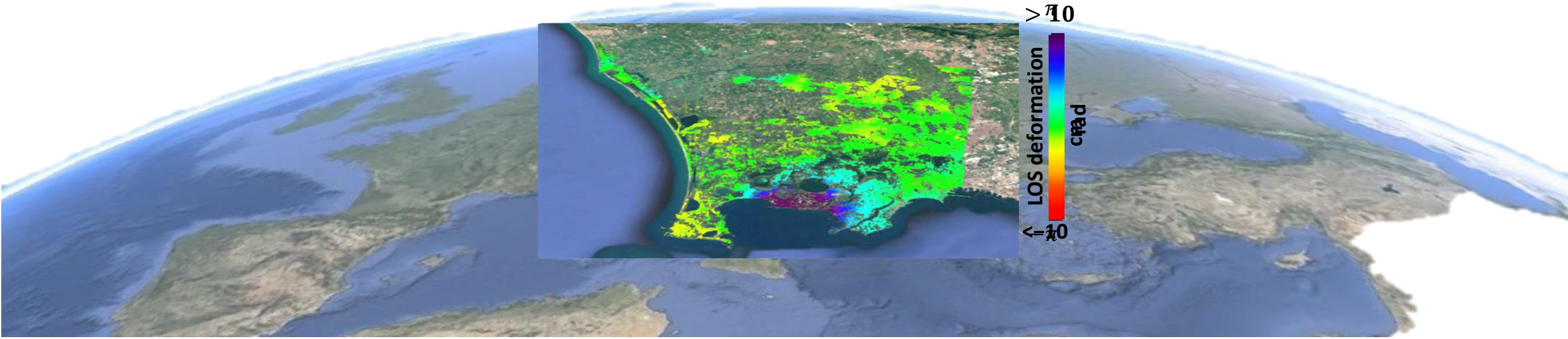
SAR scene @ **T0** MASTER



SAR scene @ **T1** SLAVE

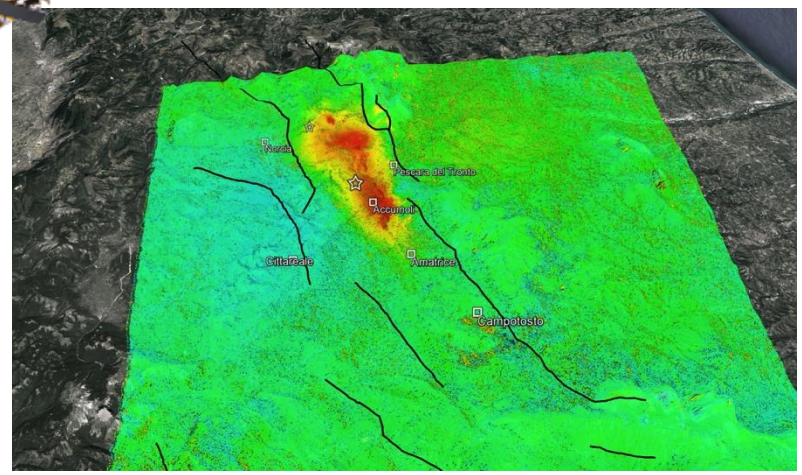


$$\Delta\Phi \cong 4\pi \frac{deformation}{\lambda} \Rightarrow \Delta\Phi = 2\pi \Rightarrow deformation = \frac{\lambda}{2}$$

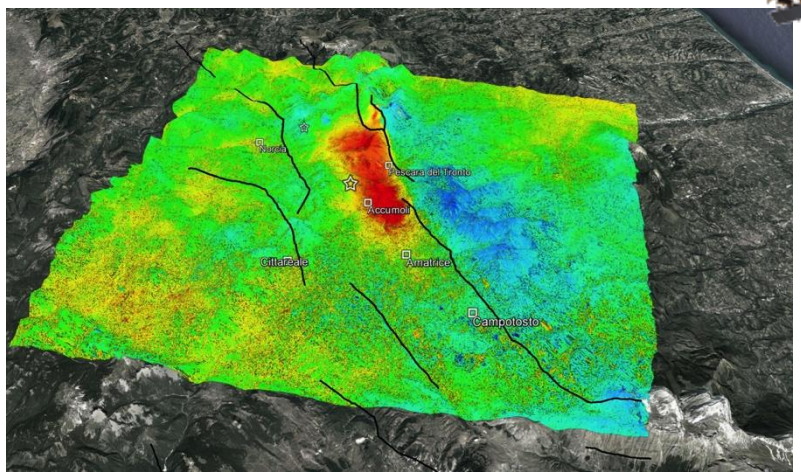


Amatrice earthquake (24/08/2016): DInSAR deformation analysis example

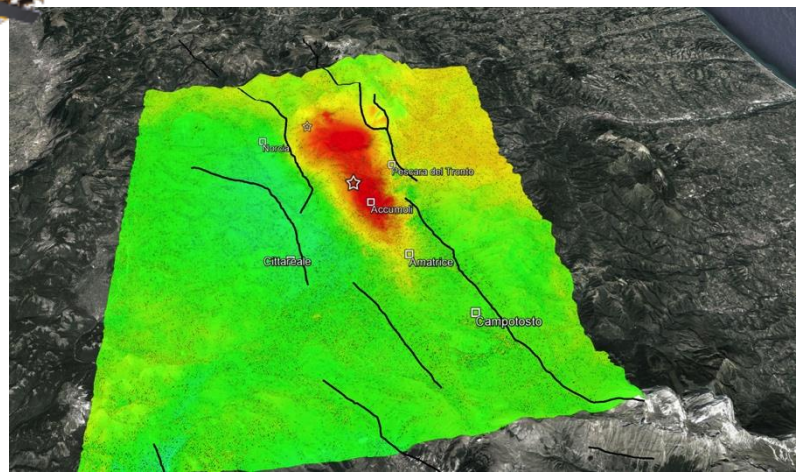
ALOS-2 ASC (09092015 – 24082016)



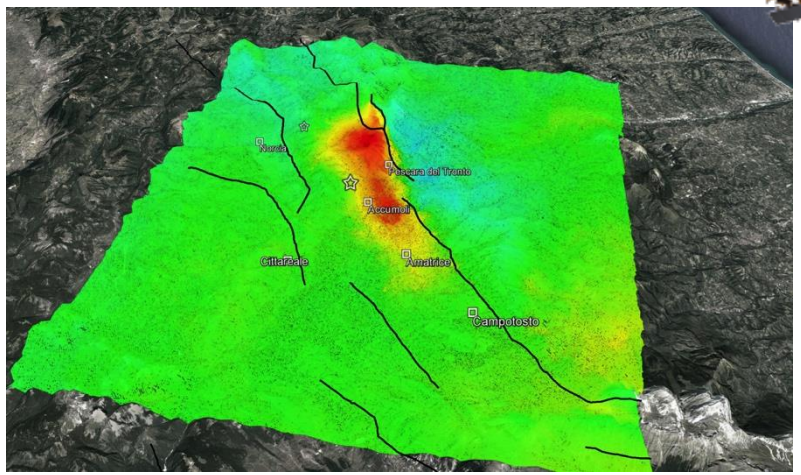
ALOS-2 DESC (25052016 – 31082016)



Sentinel-1 ASC (15082016 – 27082016)

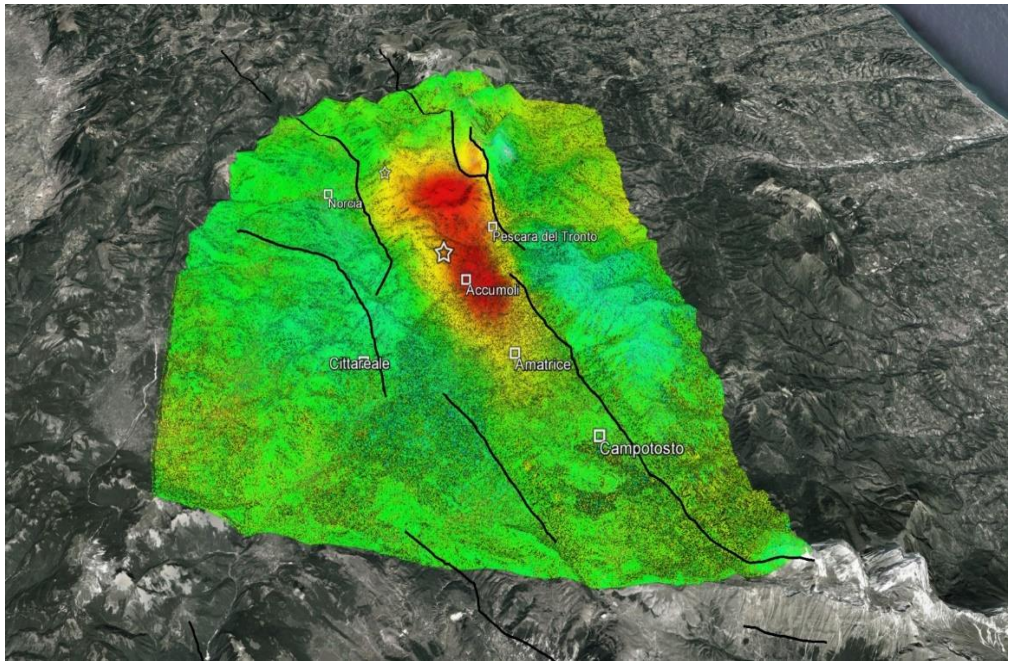


Sentinel-1 DESC (21082016 – 27082016)

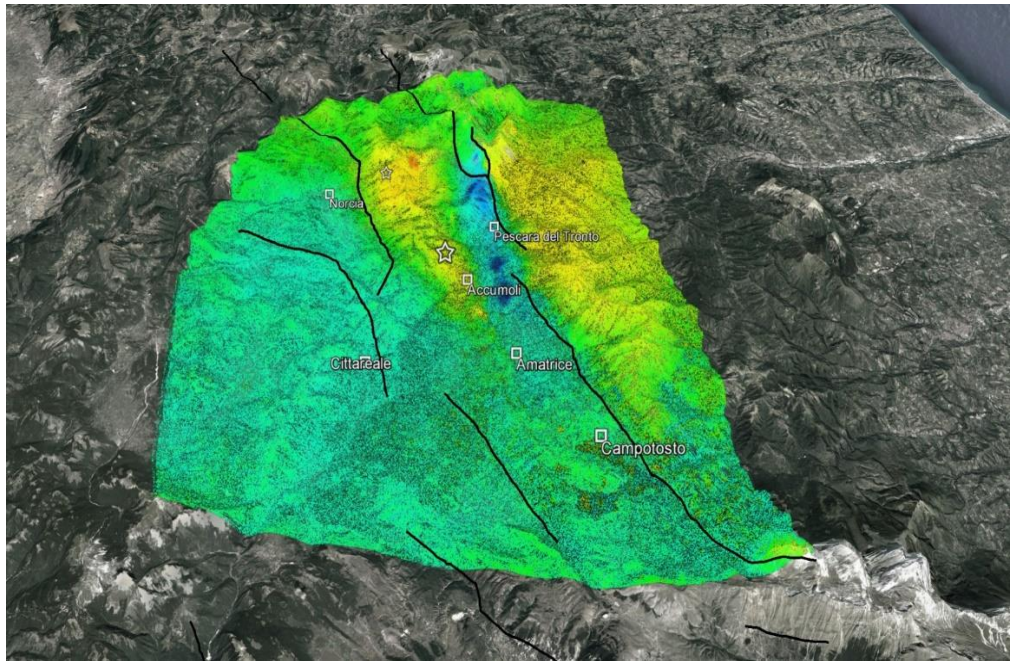


<-20 **LOS Deformation [cm]** **>20**

DInSAR analysis: estimation of the Up-Down and Est-West component



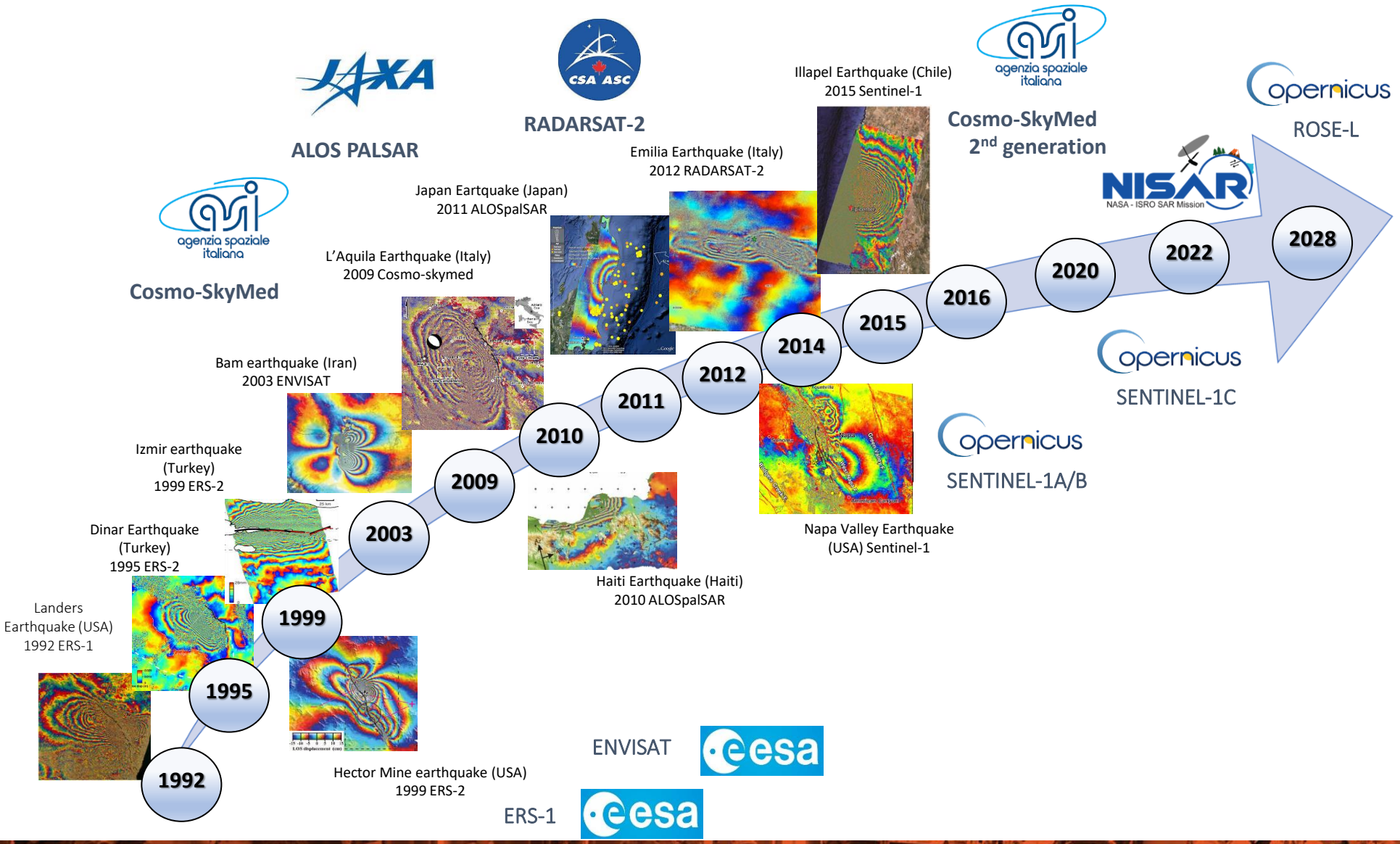
> 20
Up
[cm]
Down
< - 20



> 20
East
[cm]
West
< - 20

It is worth noting that the North-South (N–S) component is not detectable with a significant accuracy, due to the near polar orbit trajectories of the exploited radar satellites.

Past and present SAR satellites

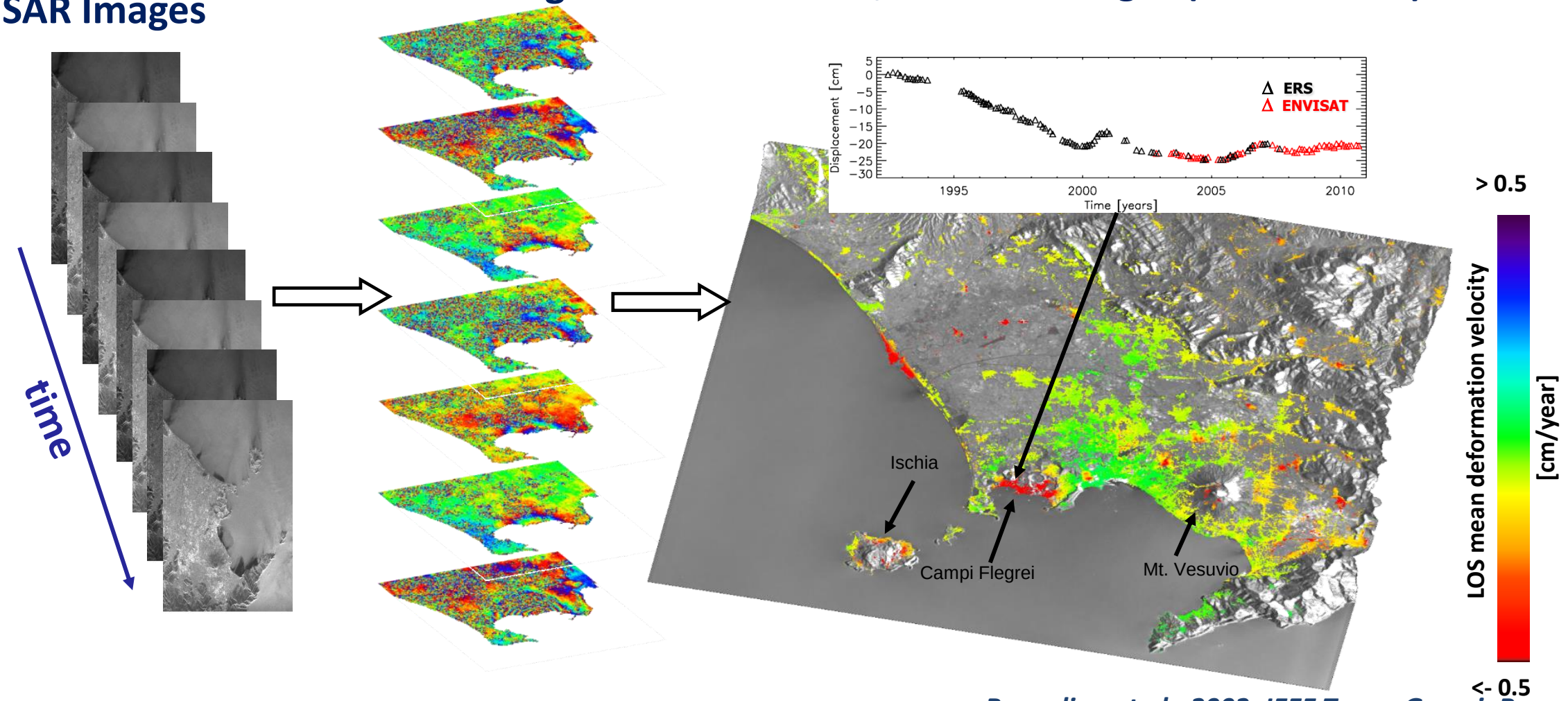


Advanced DInSAR techniques: the Small BAseline Subset (SBAS) approach

SAR Images

SB Interferograms

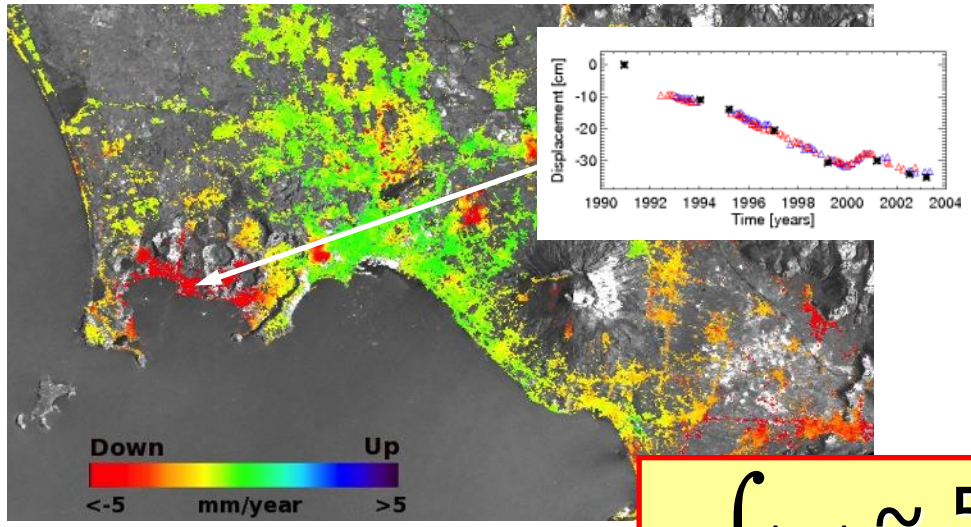
ERS/ENVISAT images (1992 – 2010)



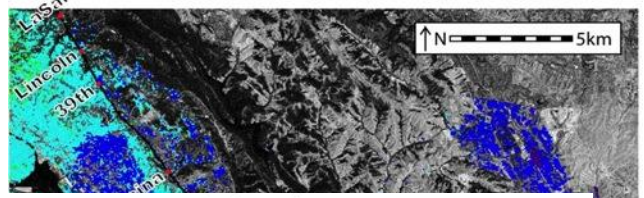
Berardino et al., 2002, IEEE Trans. Geosci. Remote Sens.
Pepe et al., 2005, IEEE Trans. Geosci. Remote Sens.

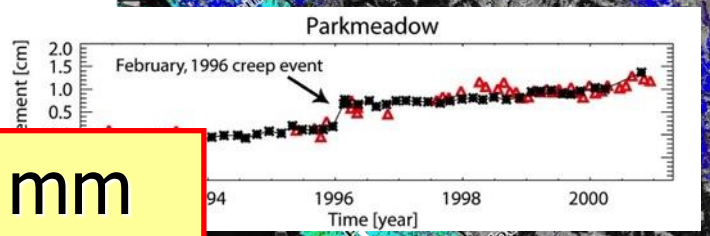
SBAS-DInSAR result accuracy

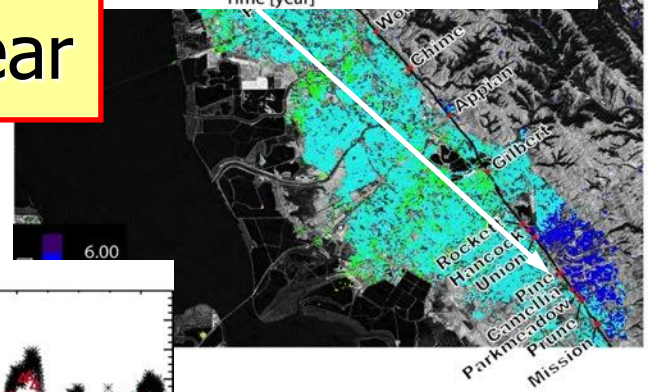
SBAS vs. Leveling: Napoli Bay



SBAS vs. Alignment array: San Francisco Bay

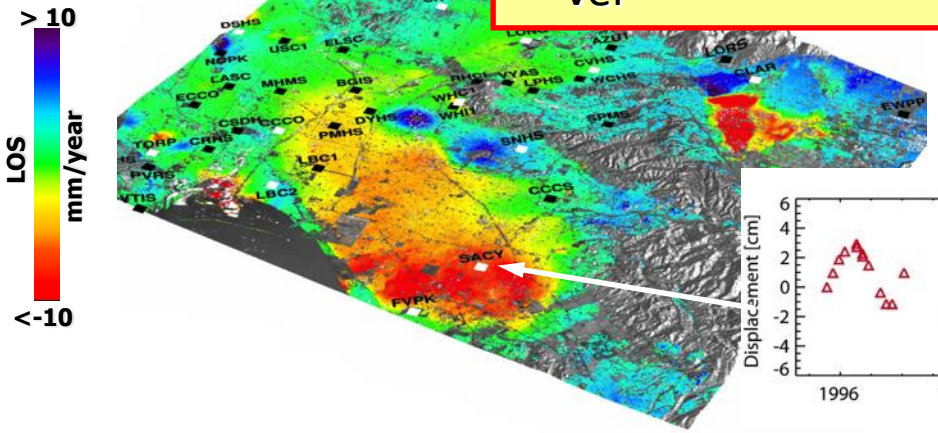


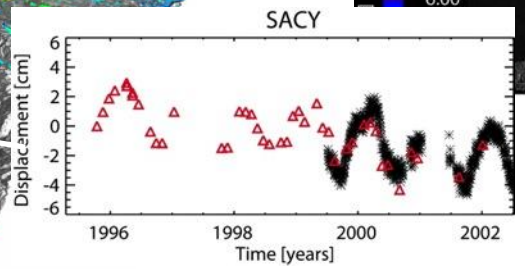




Γ_{displ} ~ 5-10 mm

Γ_{vel} ~ 1-2 mm/year

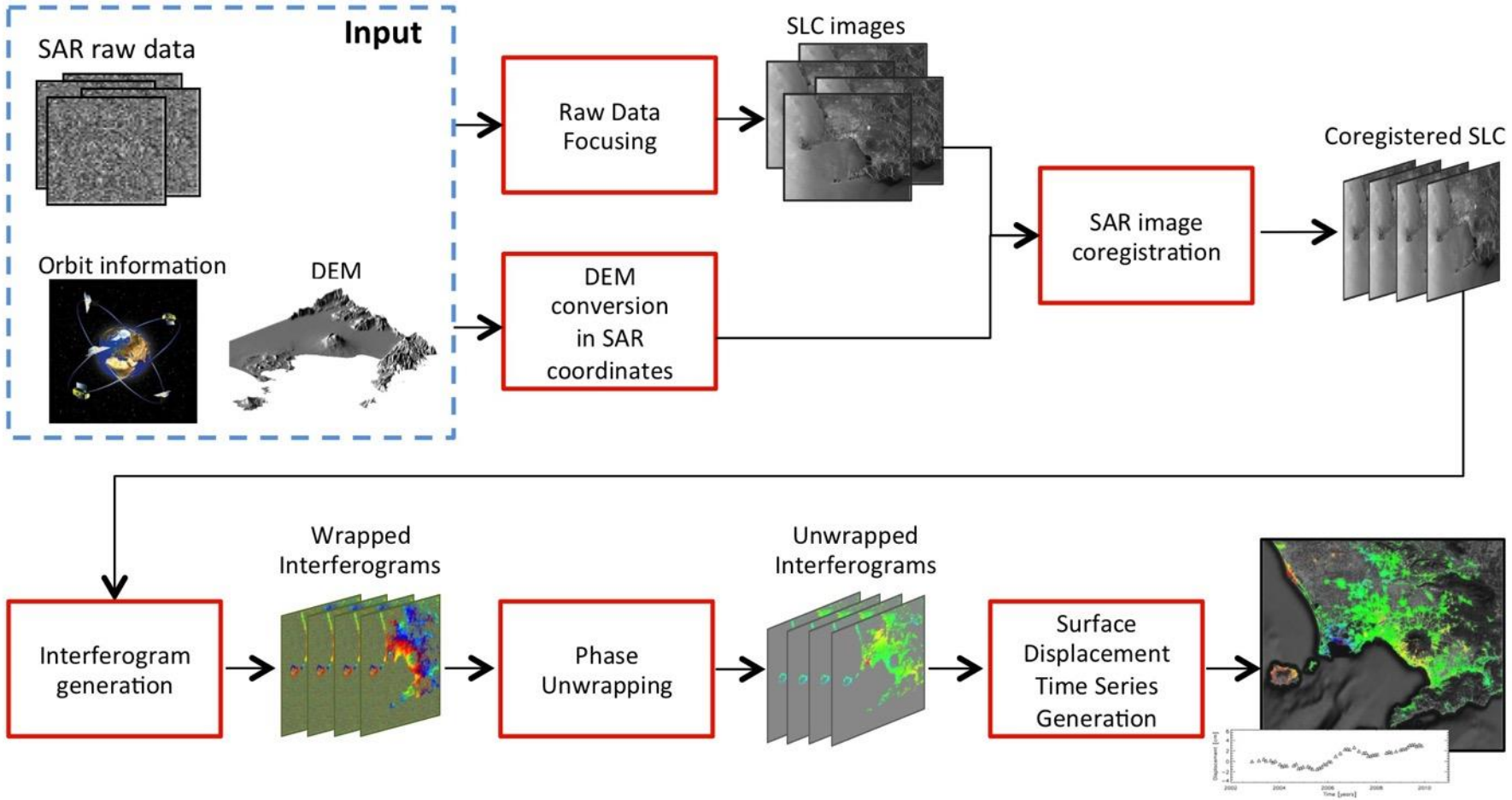




Casu et al., 2006, RSE

SBAS vs. GPS: Los Angeles

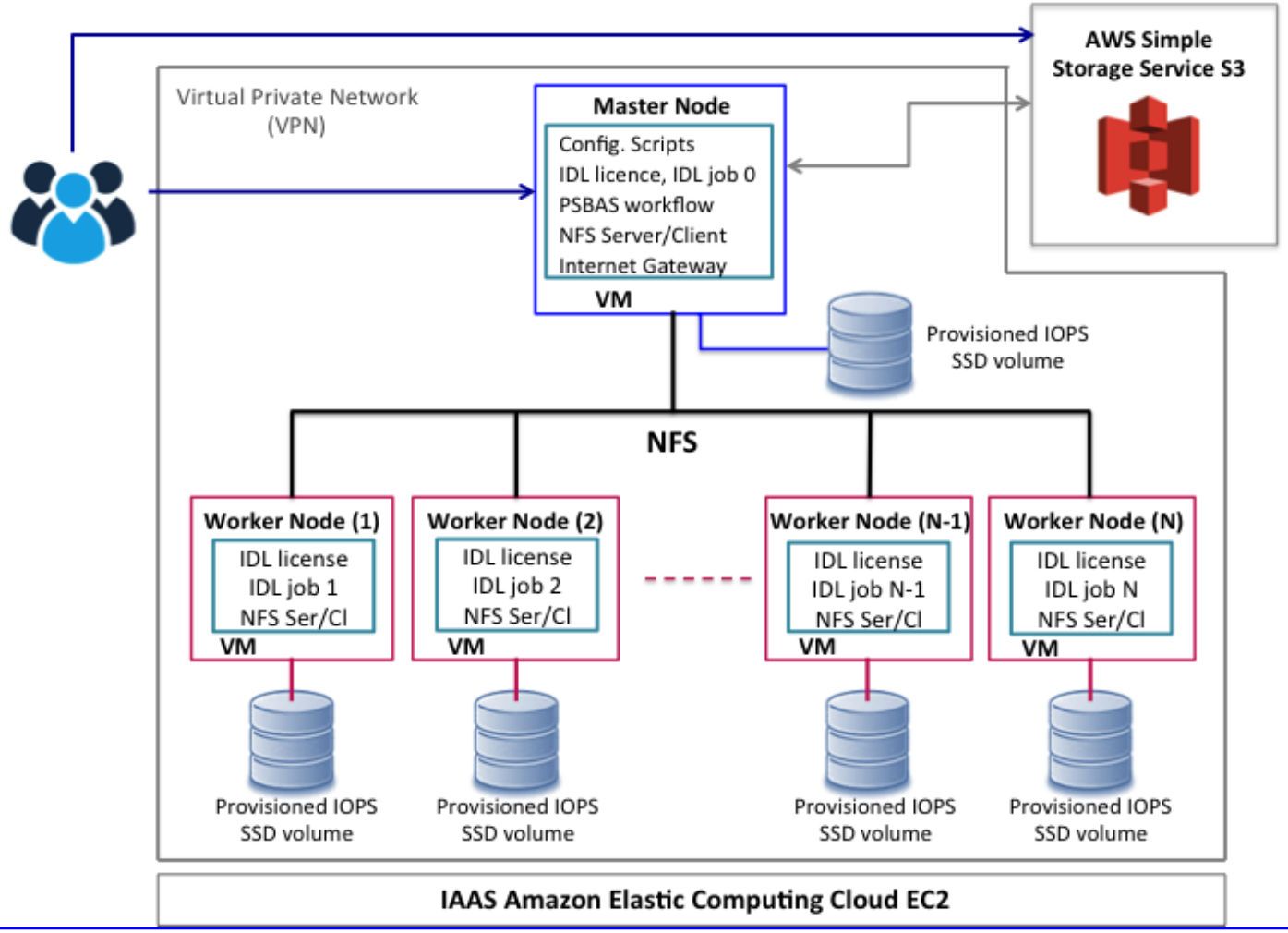
Parallel SBAS (P-SBAS) workflow



DUAL LEVEL PARALLELISM FOR MULTI-NODE AND MULTI-CORE ARCHITECTURES

Casu et al., 2014, IEEE JSTARS
Zinno et al., 2015, IEEE JSTARS
Zinno et al., 2015, IEEE Transaction Cloud Computing

P-SBAS Cloud solution: Amazon Web Services (AWS)



Zinno et al., in *IEEE* Transaction on Cloud Computing 2015

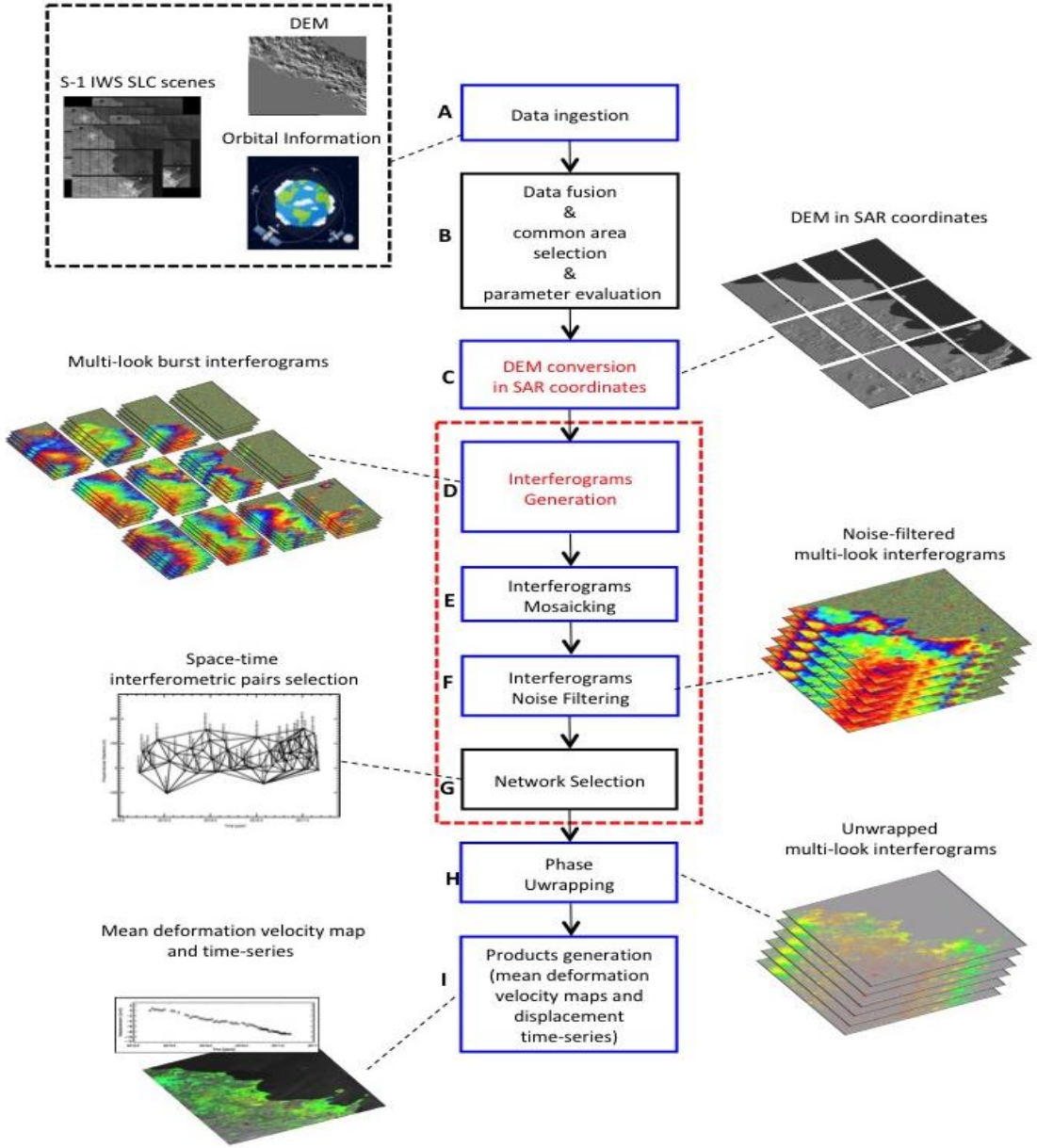
Zinno et al., in *IEEE* JSTARS 2015

Zinno et al., in *IEEE* JSTARS 2016

Sentinel-1 characteristics

- Spatial Resolution (TOPS): **15 x 4 m**
- Ground Coverage (TOPS): **250km**
- **C-Band**
- Quad-Pol: HH, VV, HV, VH
- **2014 - present**
- **Global coverage**
- **Free & open access**

Sentinel-1 Parallel SBAS (P-SBAS) workflow



The parallelization strategy is based on Multi-Node and Multi-Core architectures

The granularity is essentially based on two level:

- Burst Level
- Interferograms Level

The PhU step uses a dedicated parallelization strategy (Open MP)

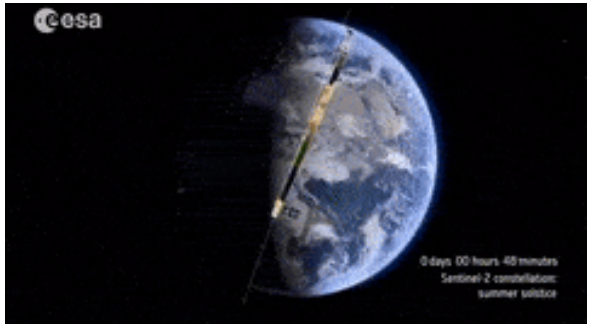
Casu et al., 2014, IEEE JSTARS

Zinno et al., 2015, IEEE JSTARS

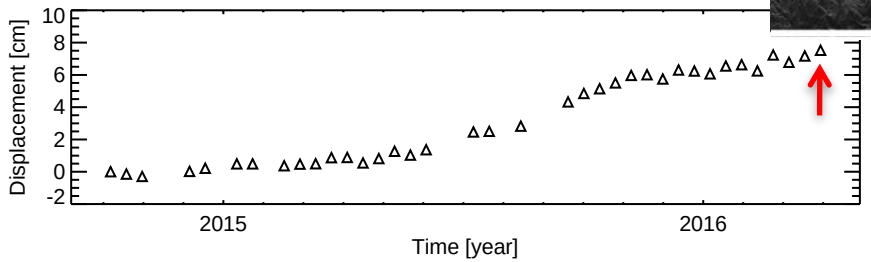
Zinno et al., 2015, IEEE Trans. Cloud Computing

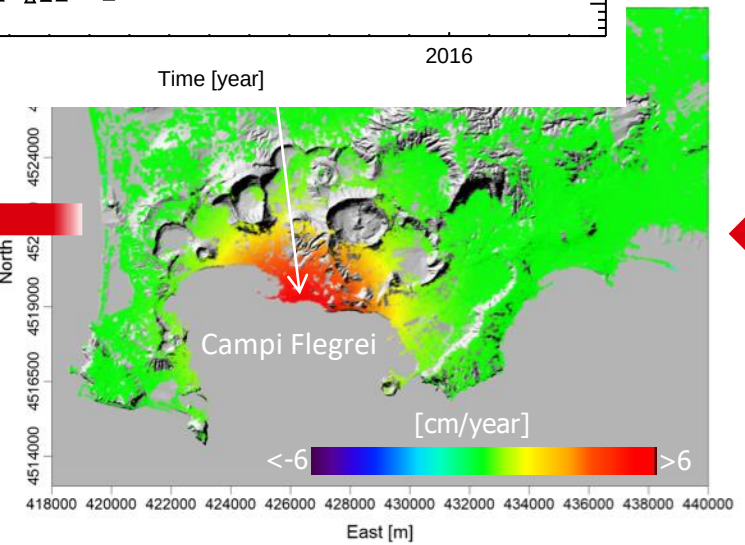
Manunta et al., 2019, IEEE TGRS

DInSAR monitoring of volcanic areas



Sentinel-1 6 days repeat pass





PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Monthly reporting

P-SBAS

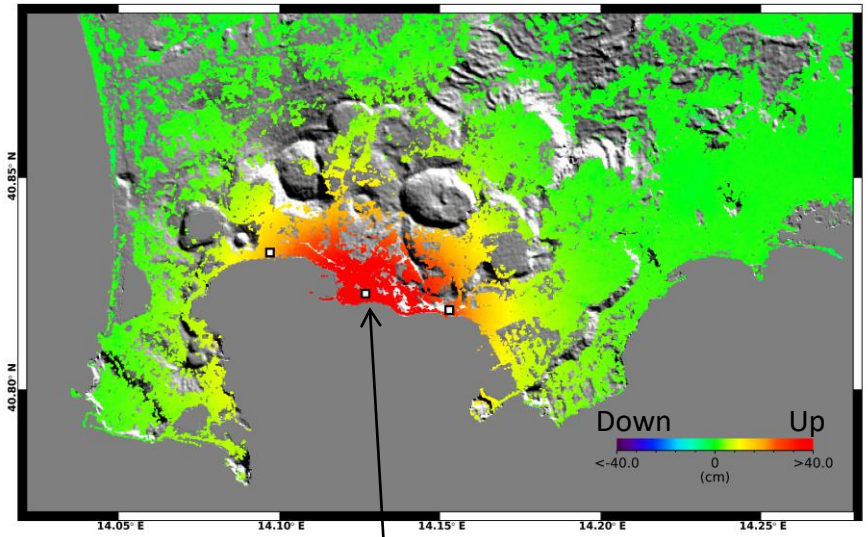
processing...

Parallel Small Baseline Subset

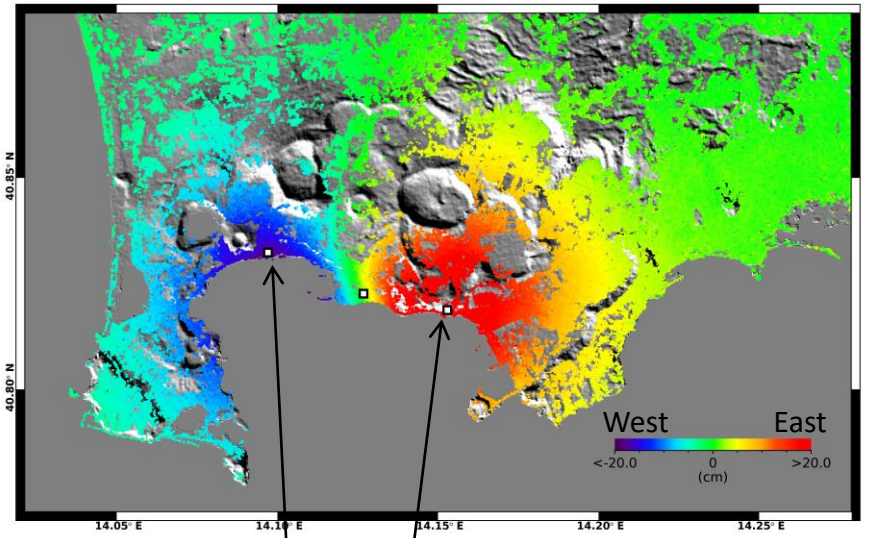
P-SBAS Monitoring of Campi Flegrei via Sentinel-1

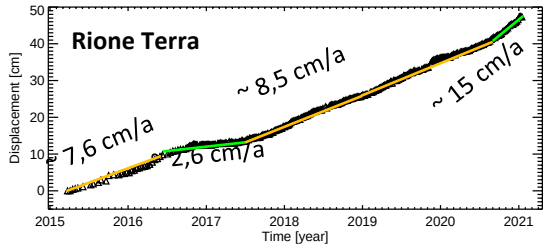
25/03/2015 – 22/01/2021

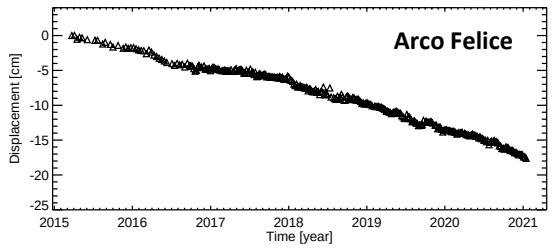
Up Displacement

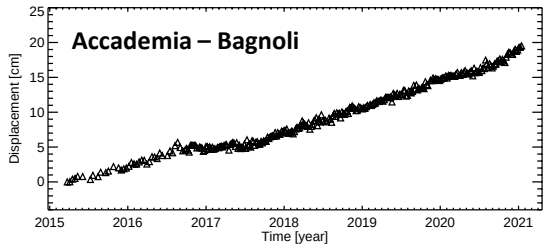


East-West Displacement



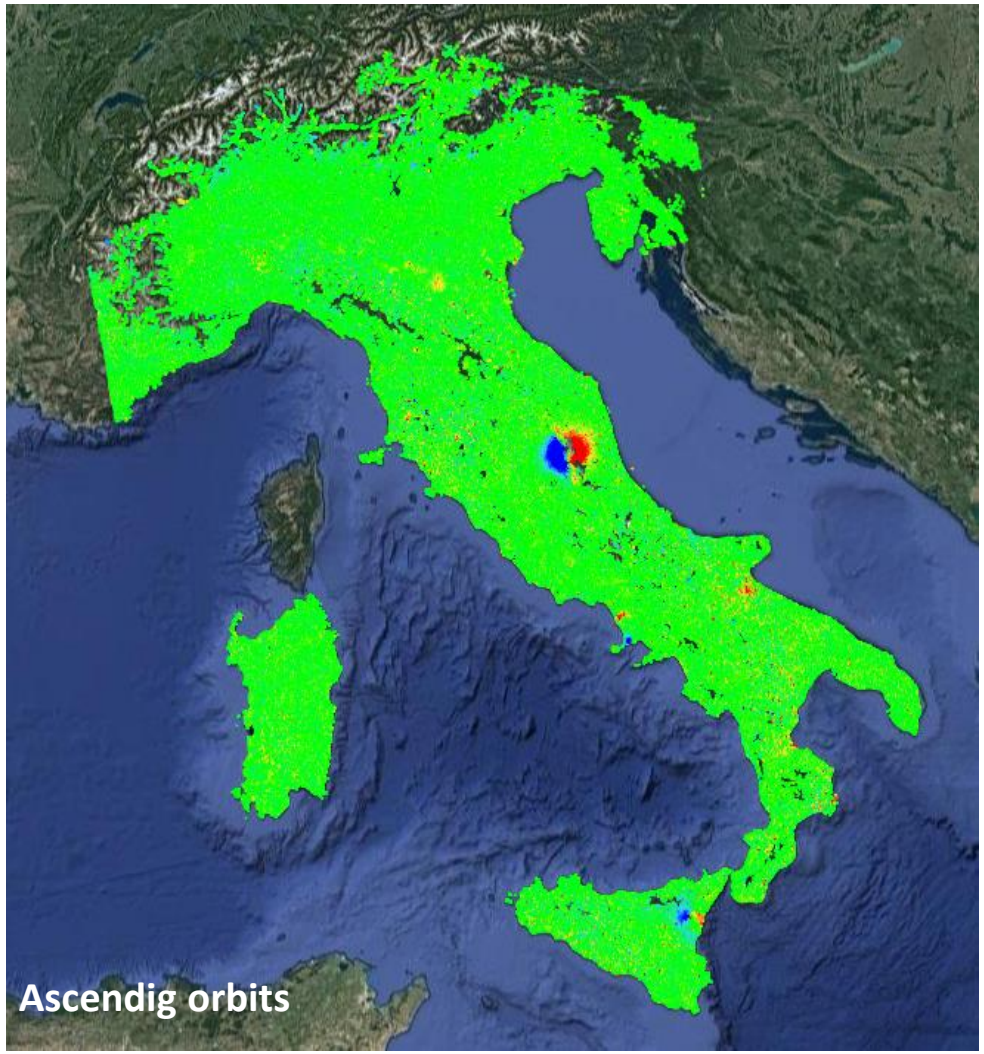


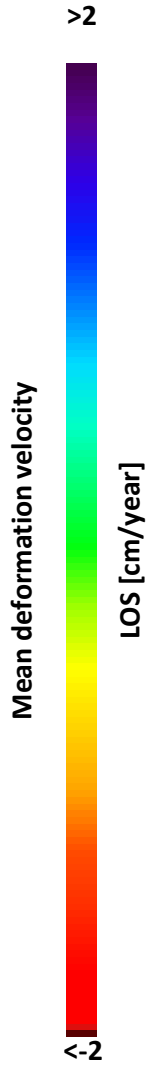


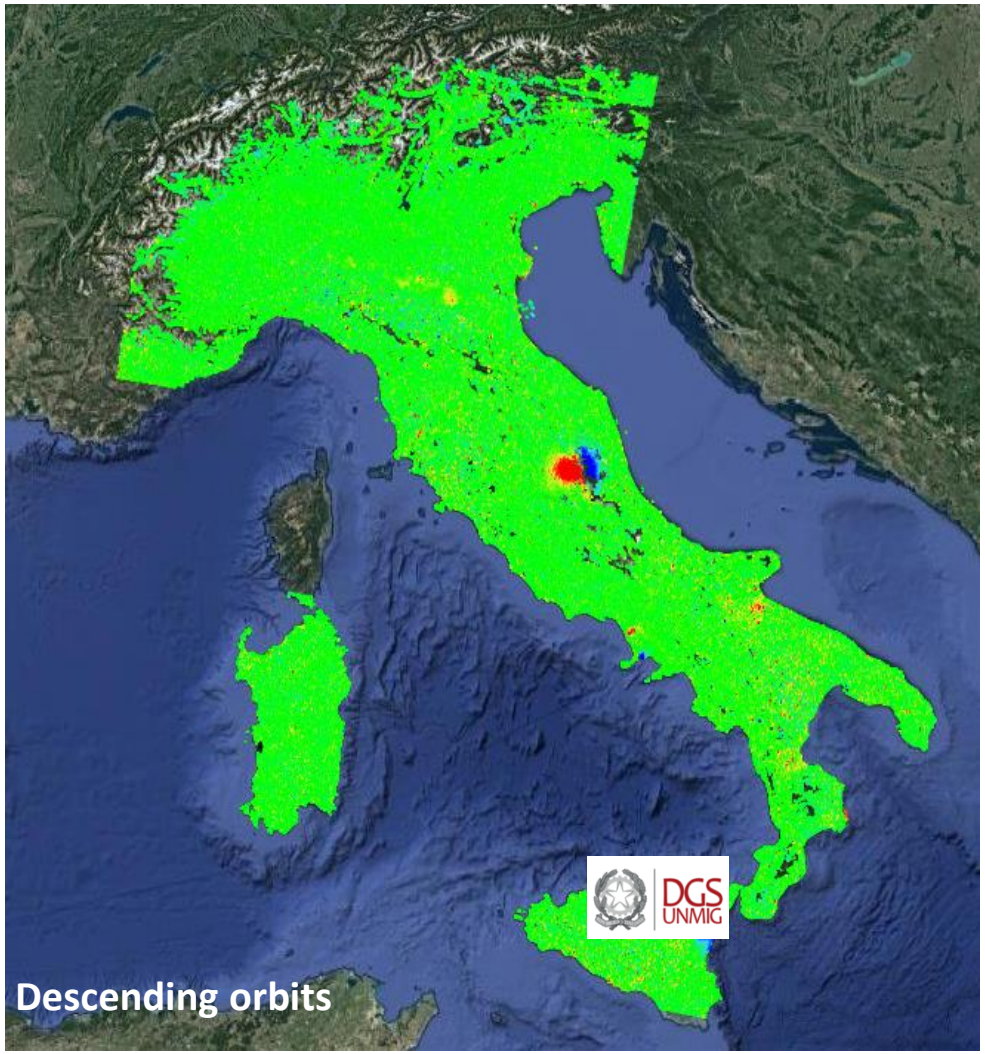


Long term monitoring

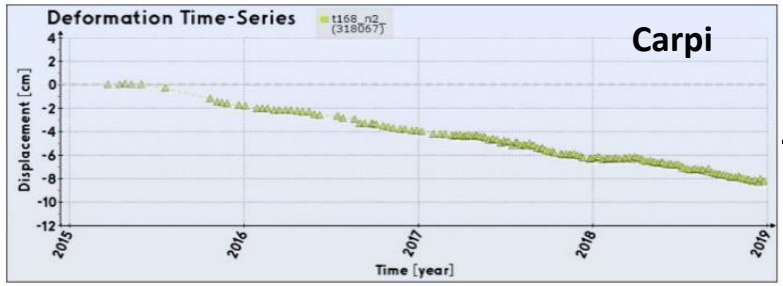
DInSAR analysis at national scale – yearly updates

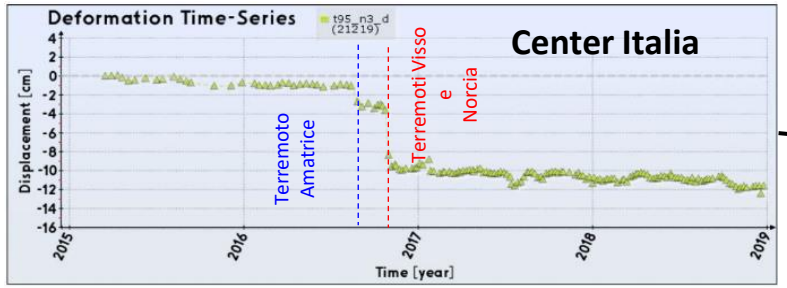


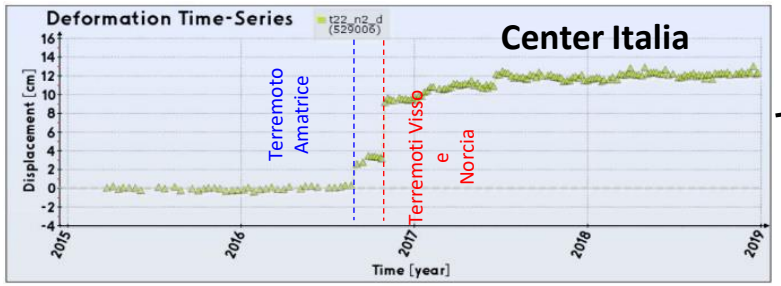


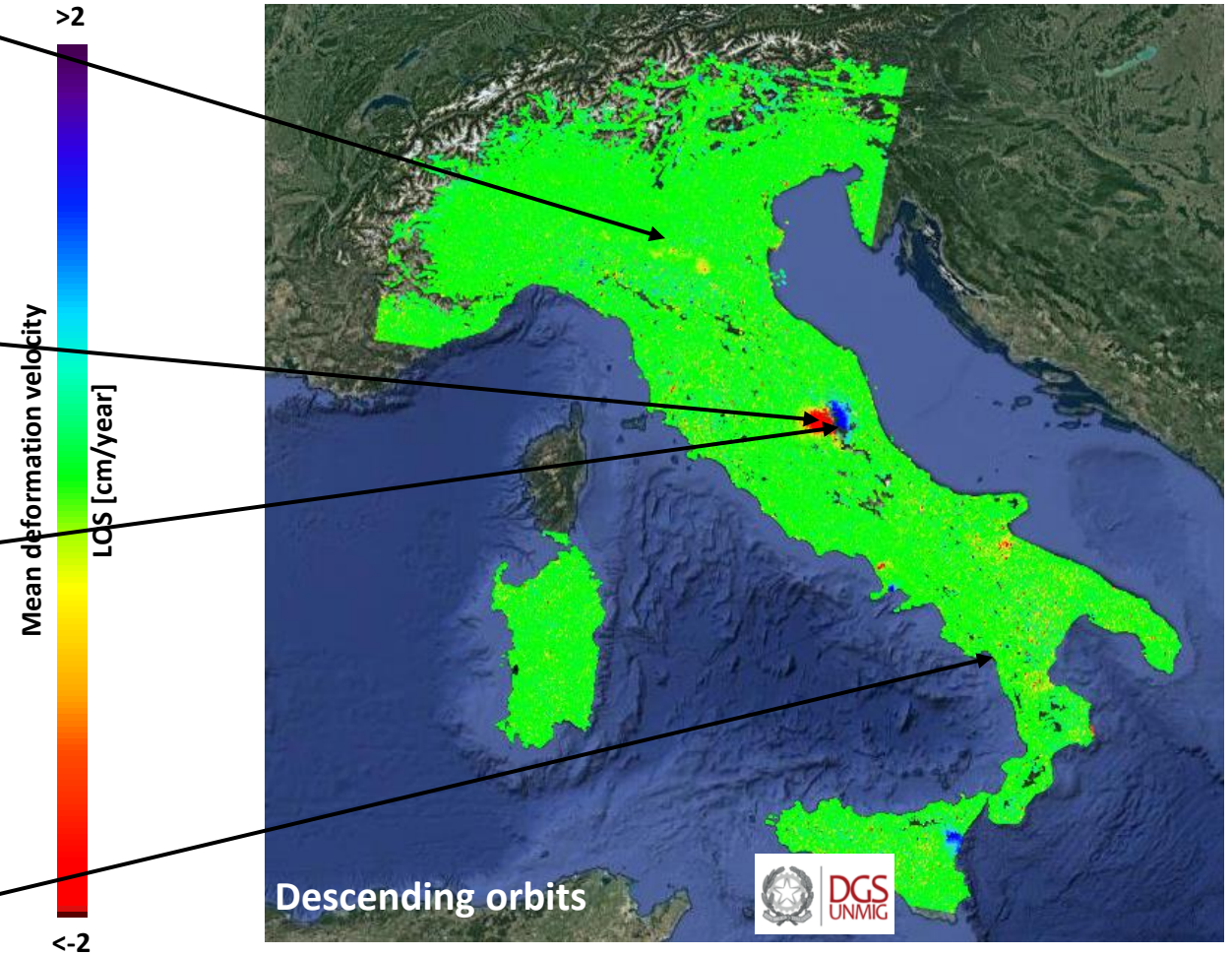


Long term monitoring

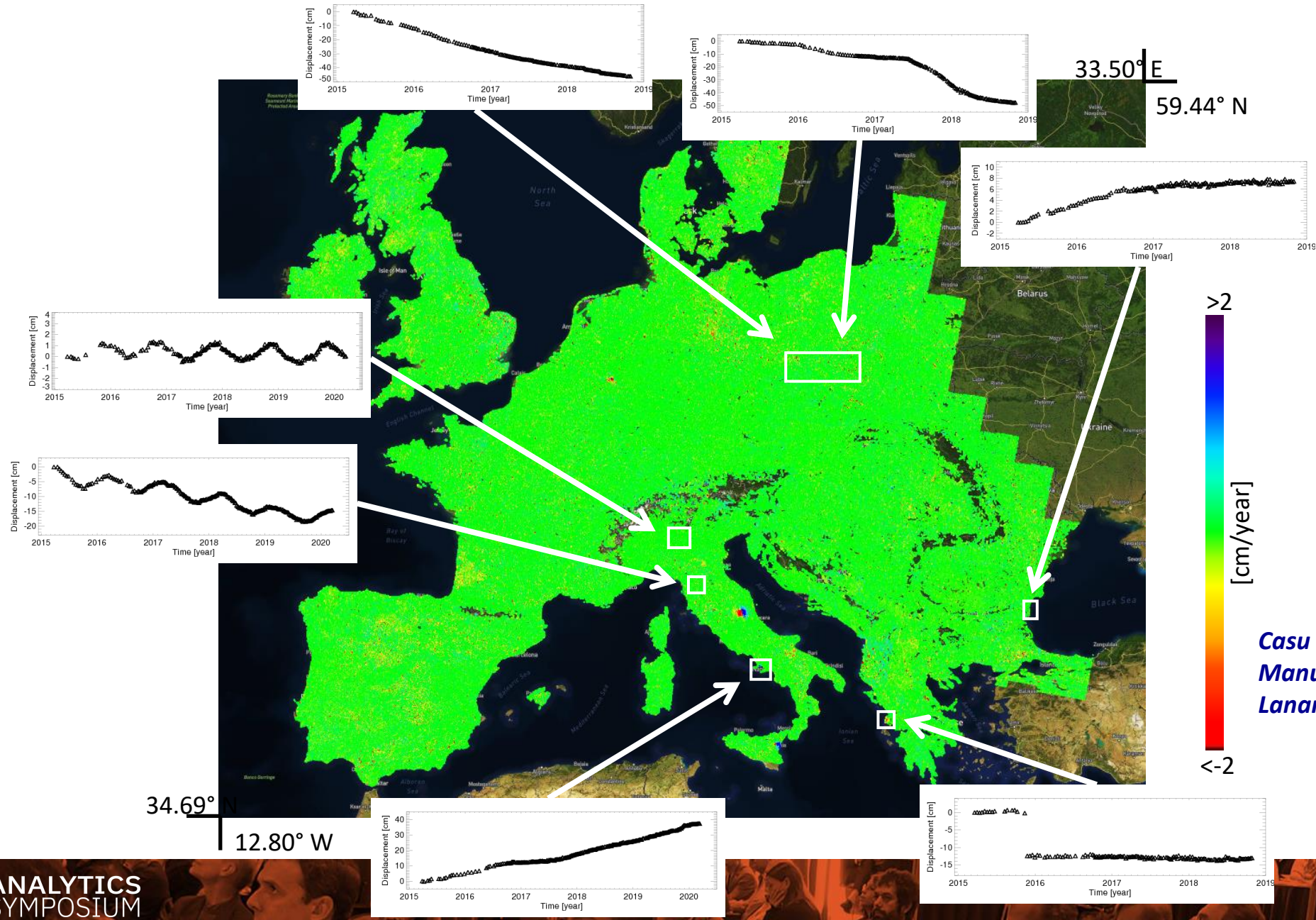








P-SBAS based medium resolution DInSAR analysis at continental scale



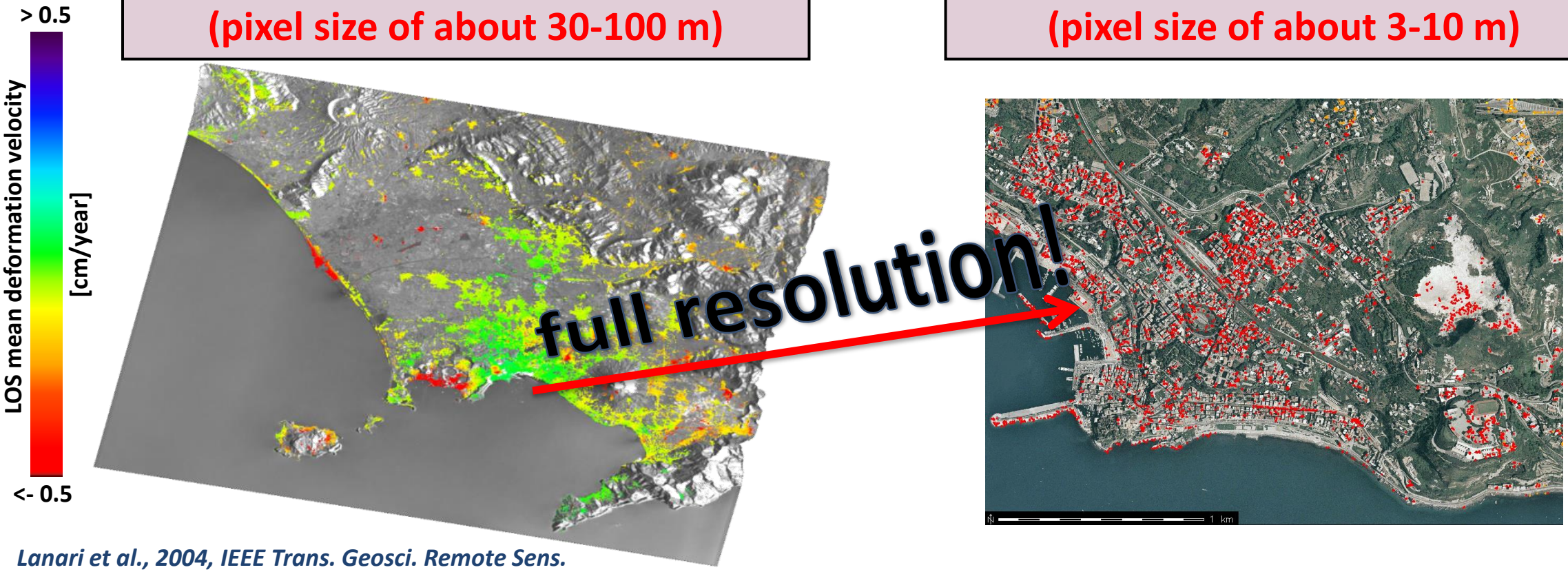
Casu et al., 2014, IEEE JSTARS
Manunta et al., 2019, IEEE TGRS
Lanari et al., 2020, Rem. Sensing

EPOS EUROPEANPLATEOBSERVINGSYSTEM

SBAS-DInSAR analysis at two different spatial scales

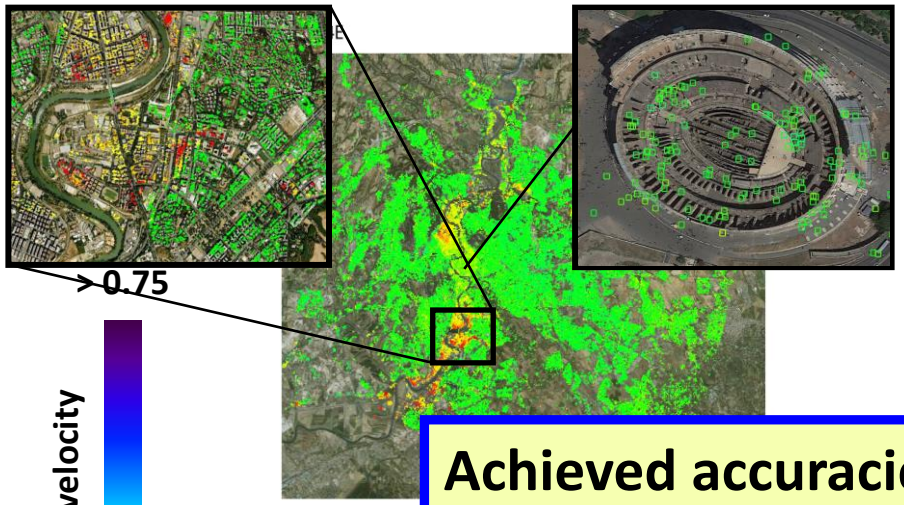
Medium spatial resolution analysis (pixel size of about 30-100 m)

Full spatial resolution analysis (pixel size of about 3-10 m)



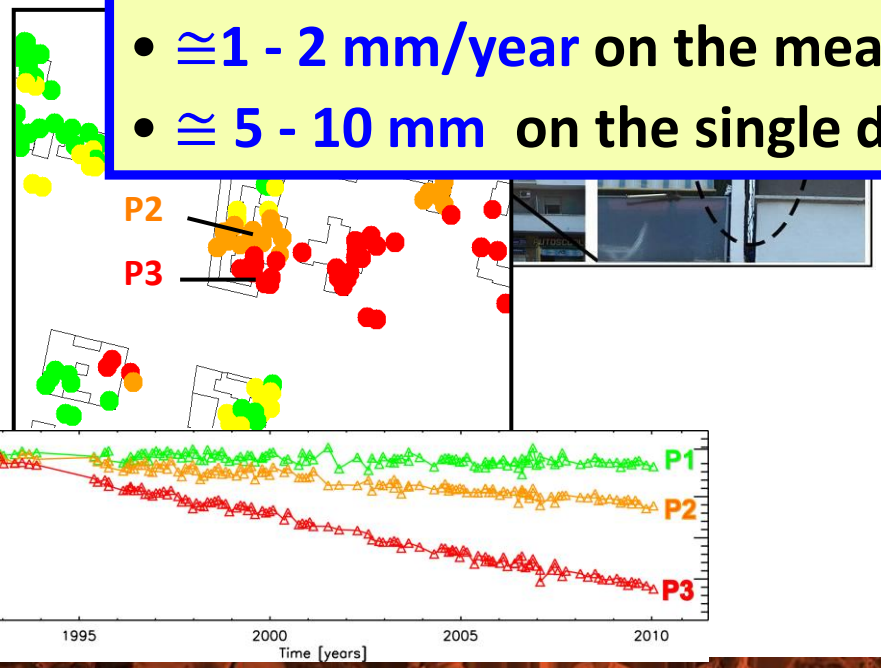
Lanari et al., 2004, IEEE Trans. Geosci. Remote Sens.
Bonano et al., 2012, Int. Jour. Remote Sens.

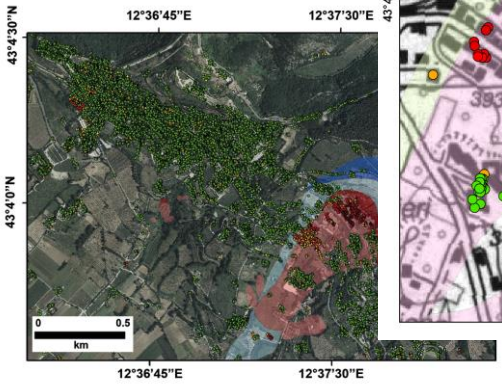
The Full Resolution (FR) SBAS-DInSAR technique: main applications

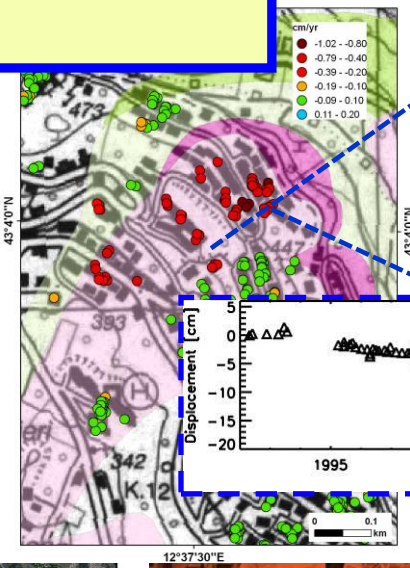


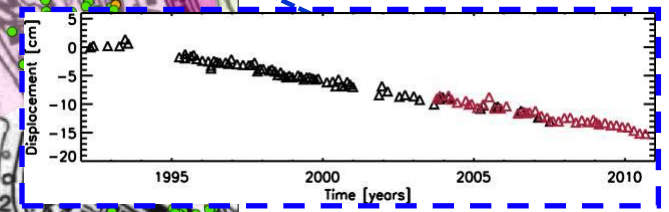
Achieved accuracies:

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

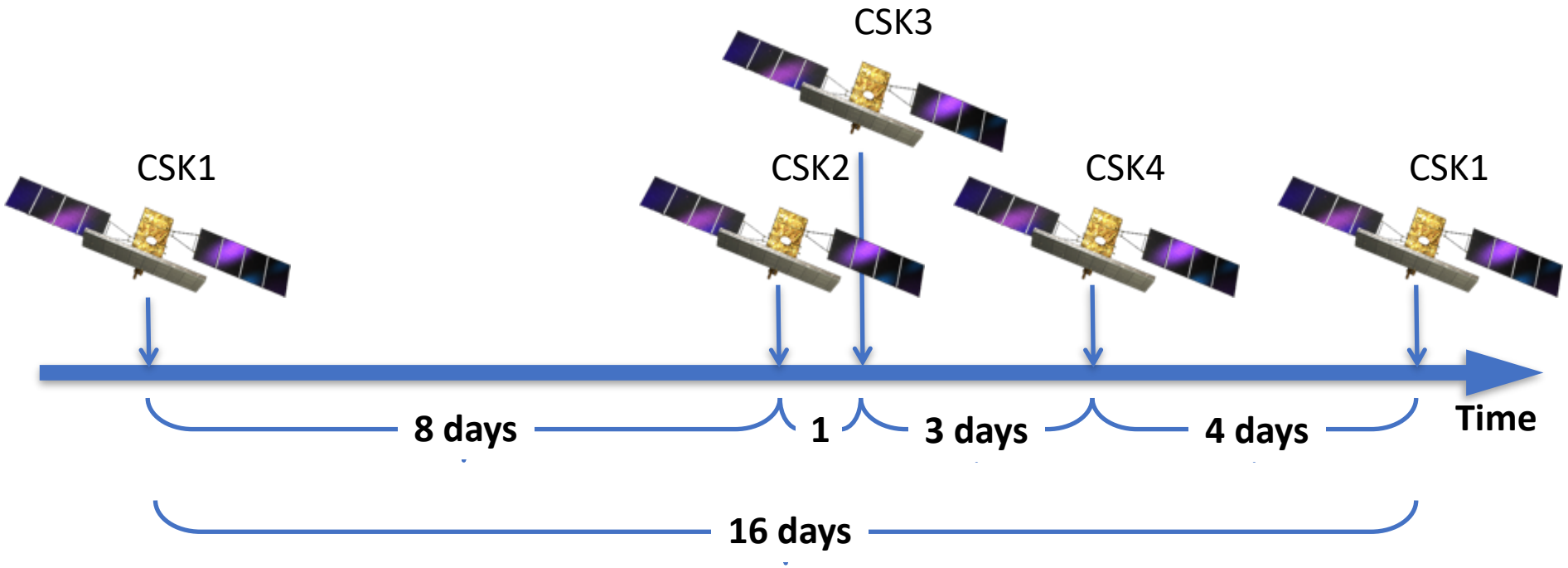






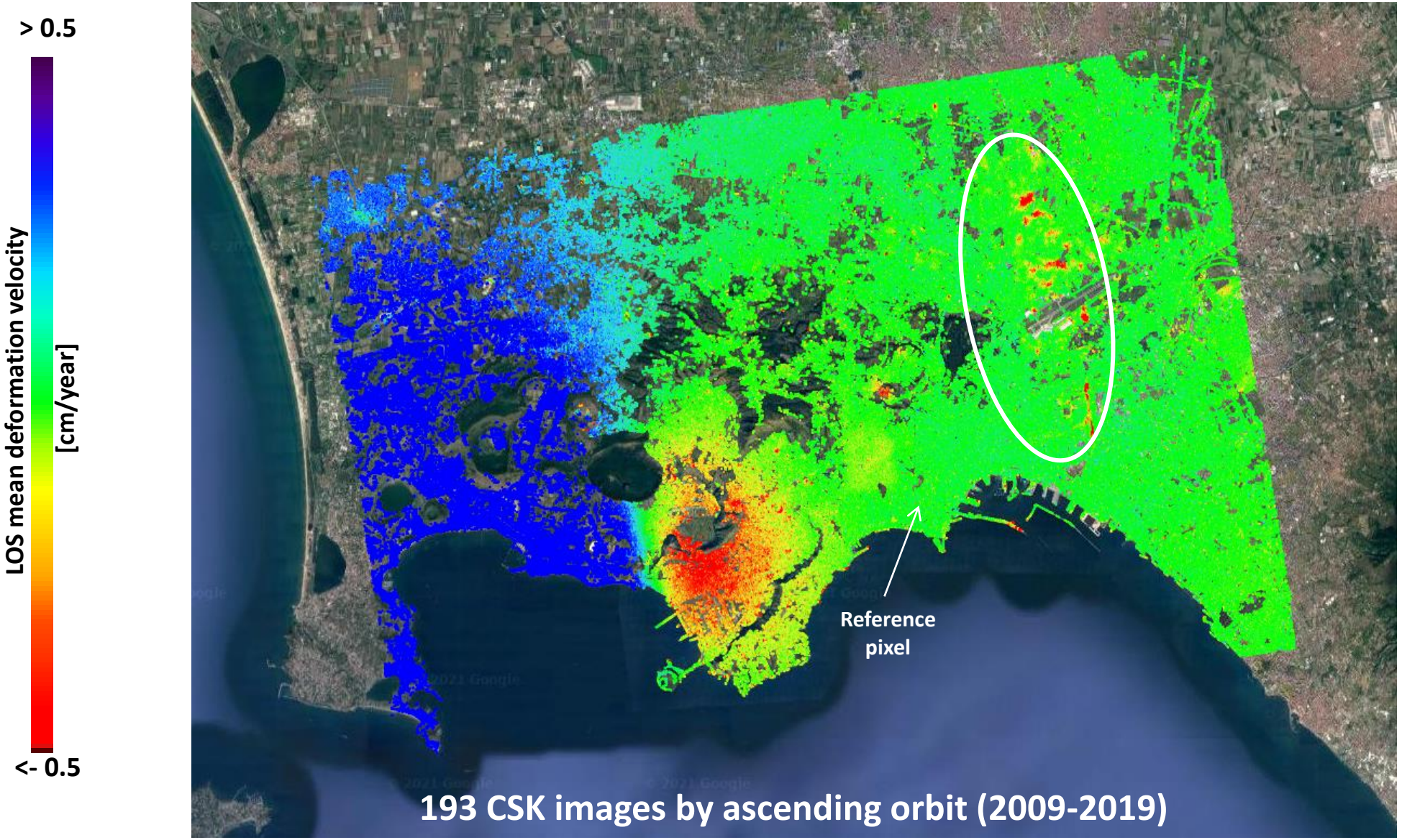


COSMO-SkyMed constellation (CSK)

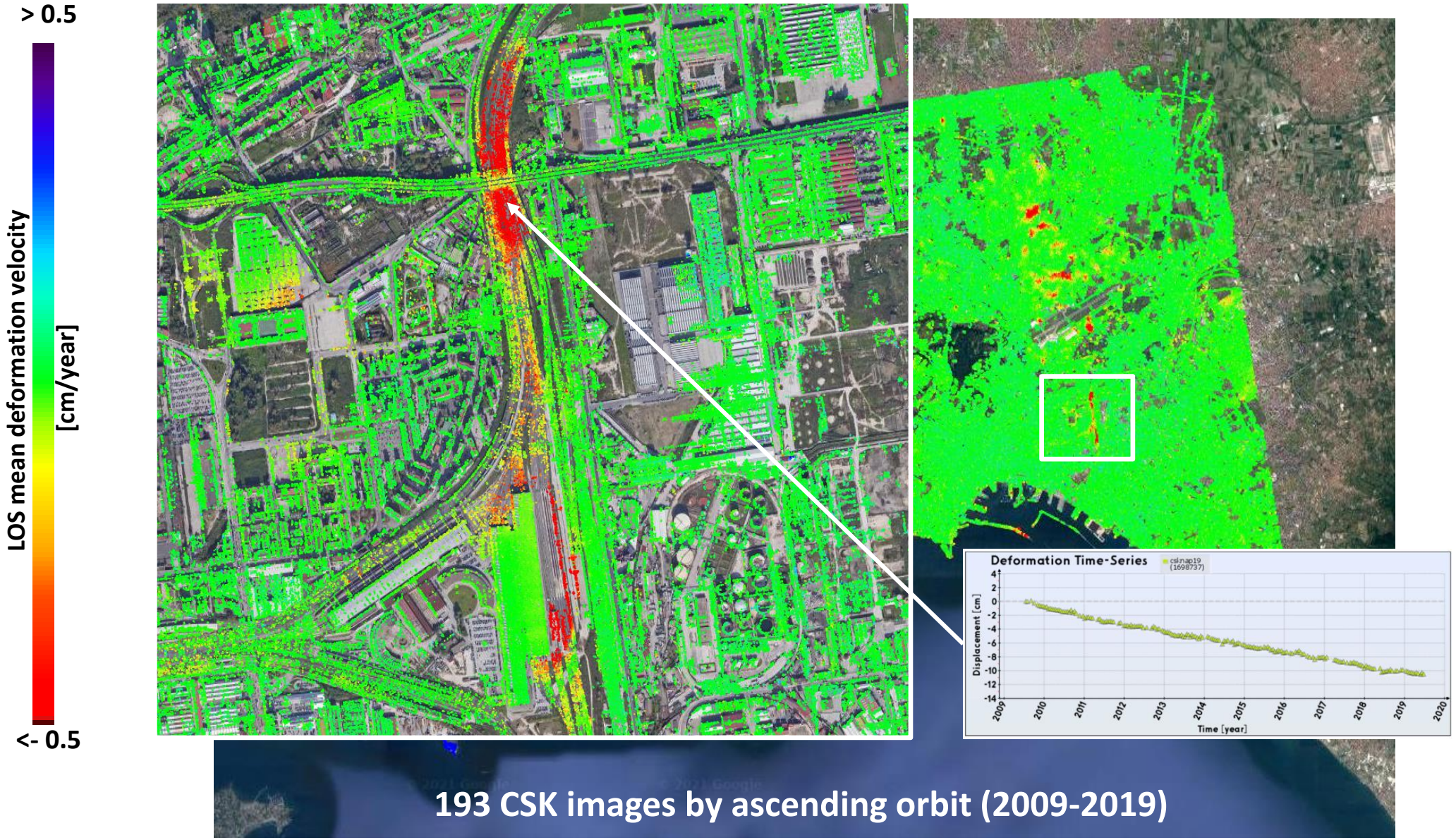


- Spatial resolution (Stripmap/Spotlight): **3 m / < 1m**
- Ground coverage (Stripmap): **40 x 40 km**
- Ground coverage (Spotlight): **10 x 10 km**
- **X-band**
- Quad-Pol: HH, VV, HV, VH
- **2007 - present**

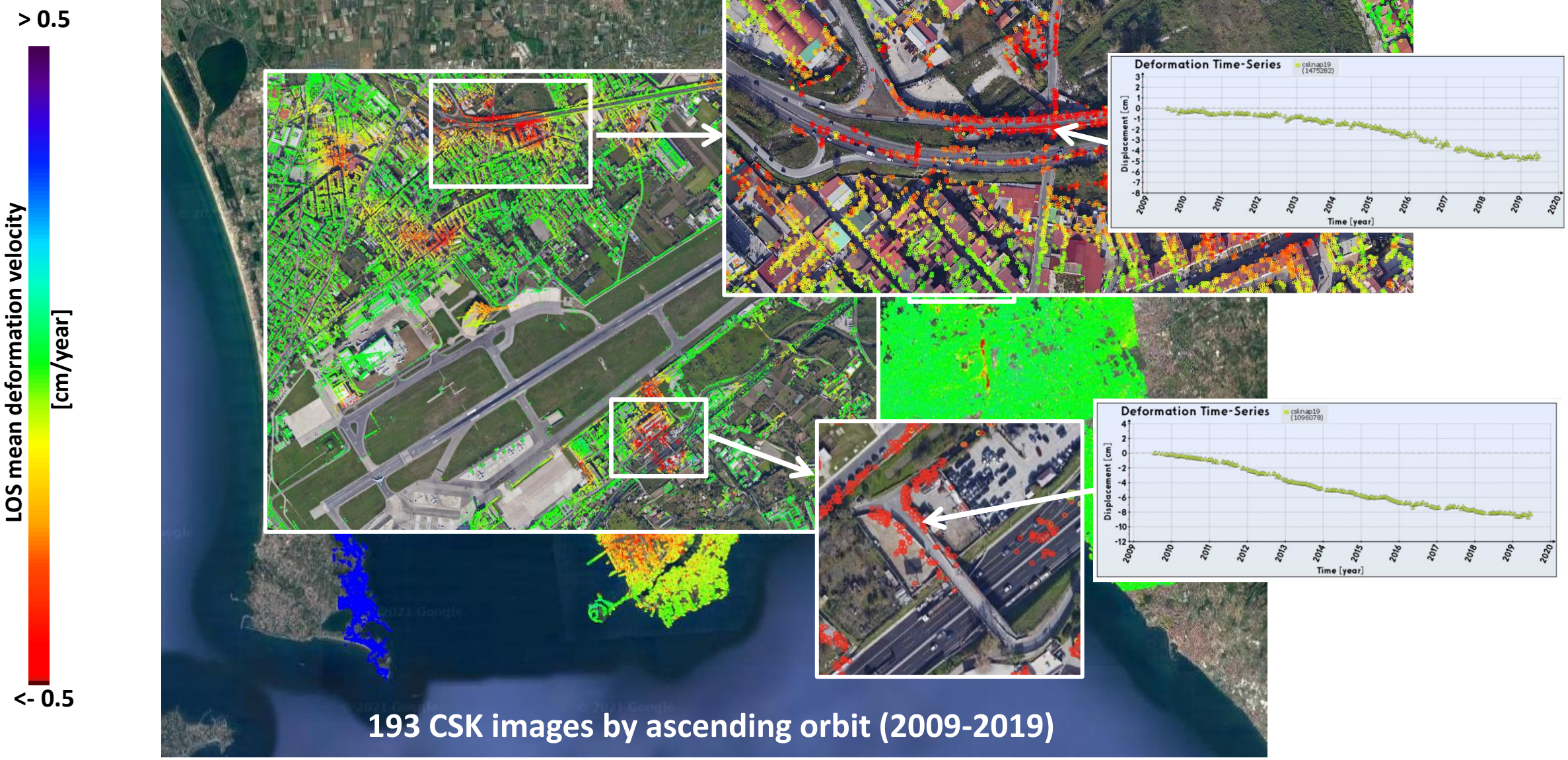
Full resolution CSK SBAS-DInSAR analysis: the Napoli case study



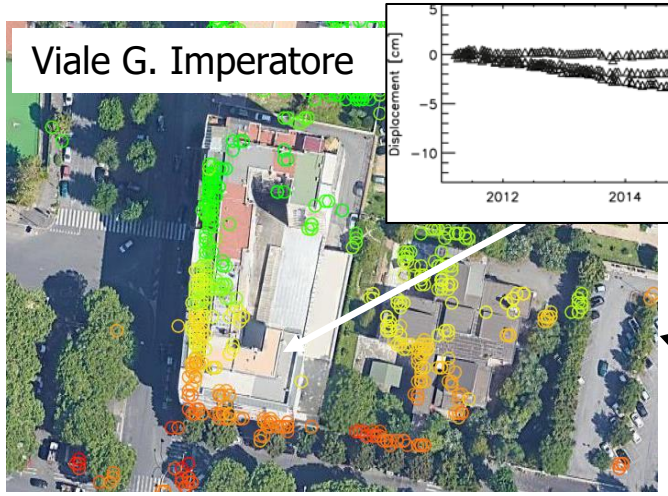
FR SBAS-DInSAR analysis of the built-up environment: the Napoli case study

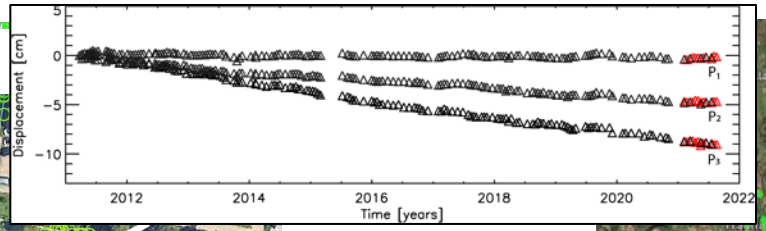


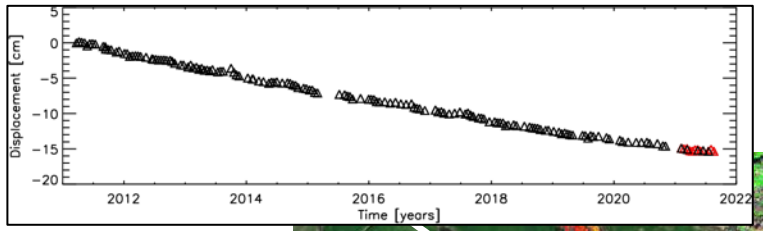
FR SBAS-DInSAR analysis of the built-up environment: the Napoli case study

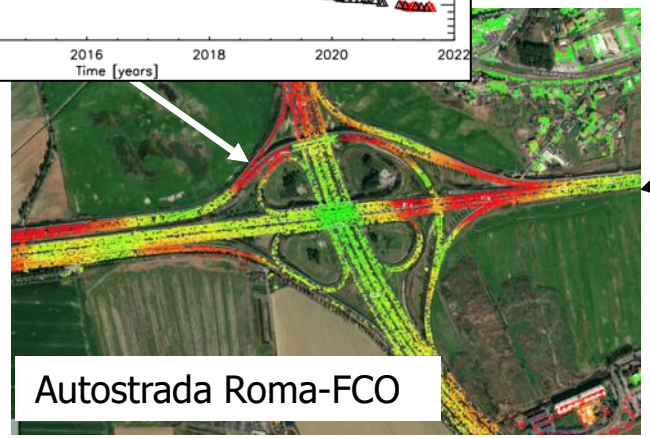


FR P-SBAS DInSAR analysis: CSK+CSG case study over Rome (Italy)



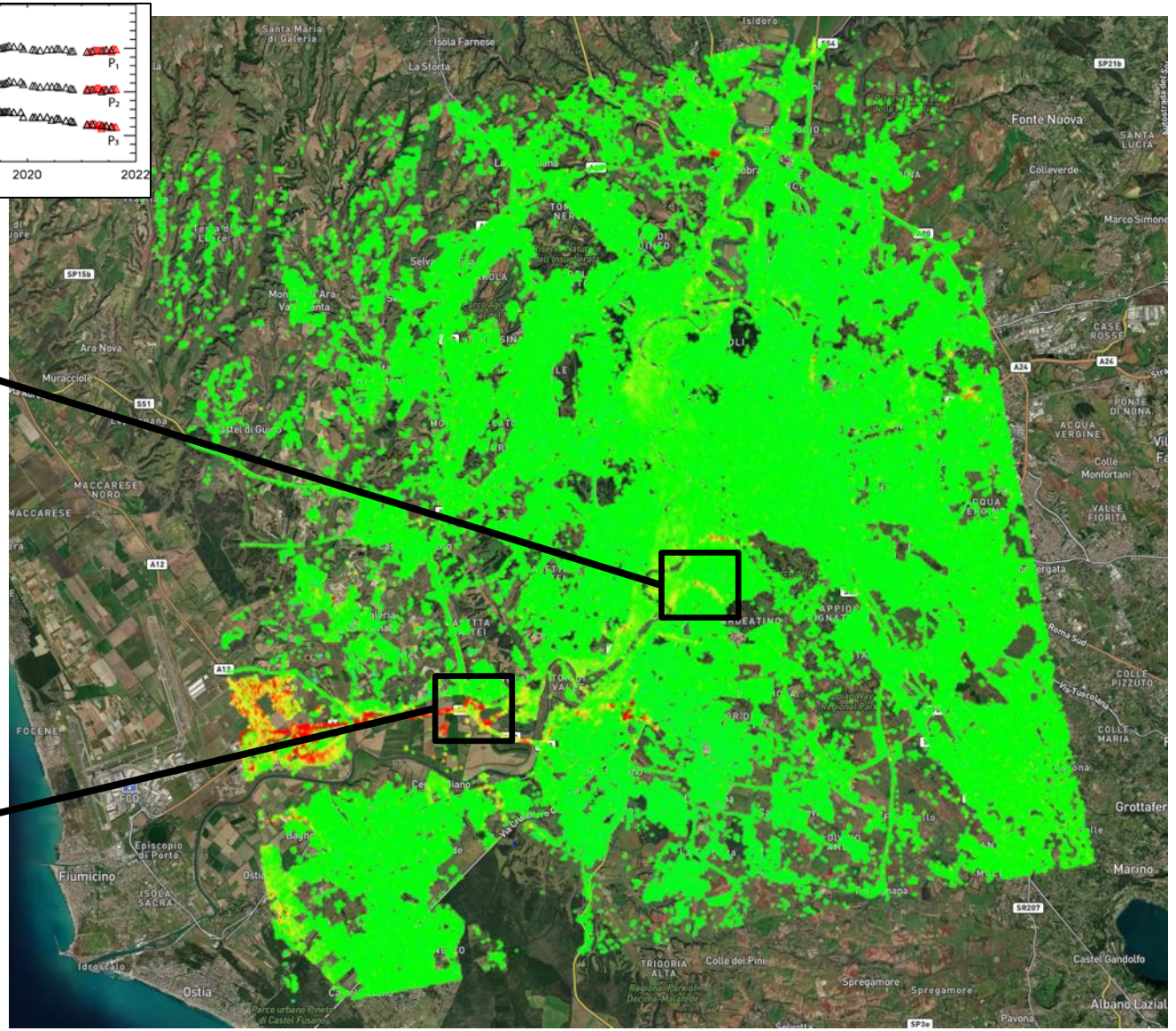


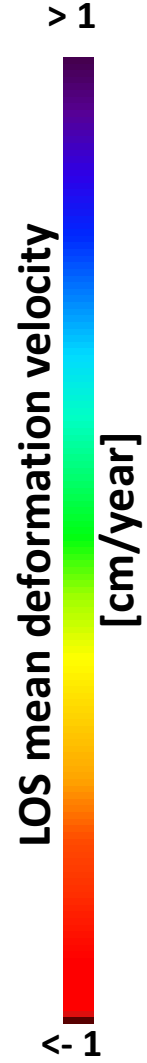




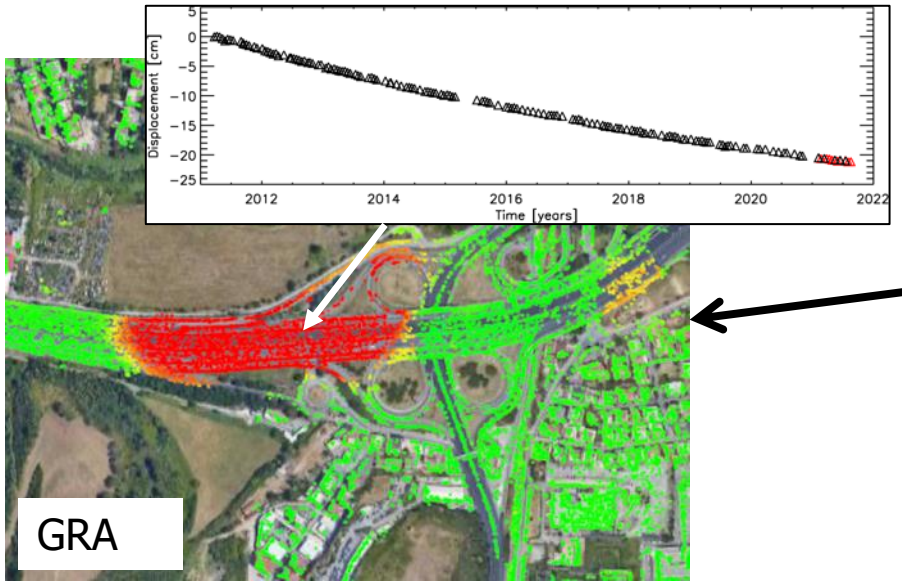
Δ CSK

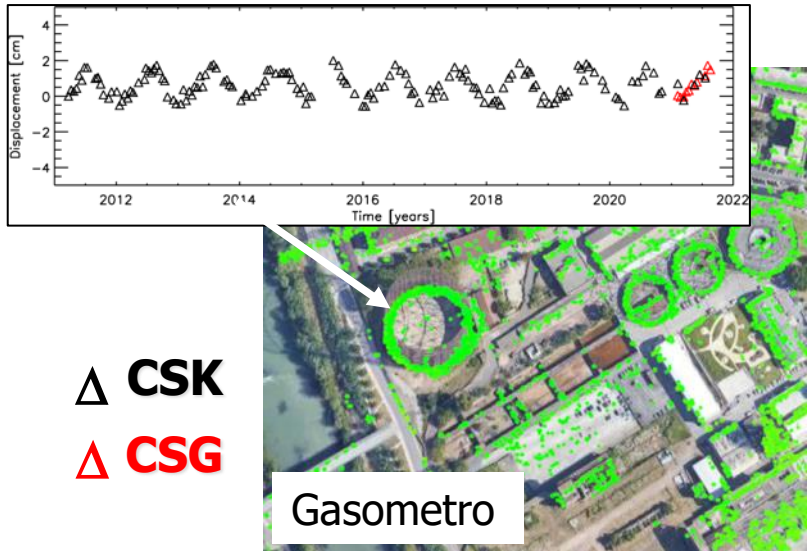
Δ CSG





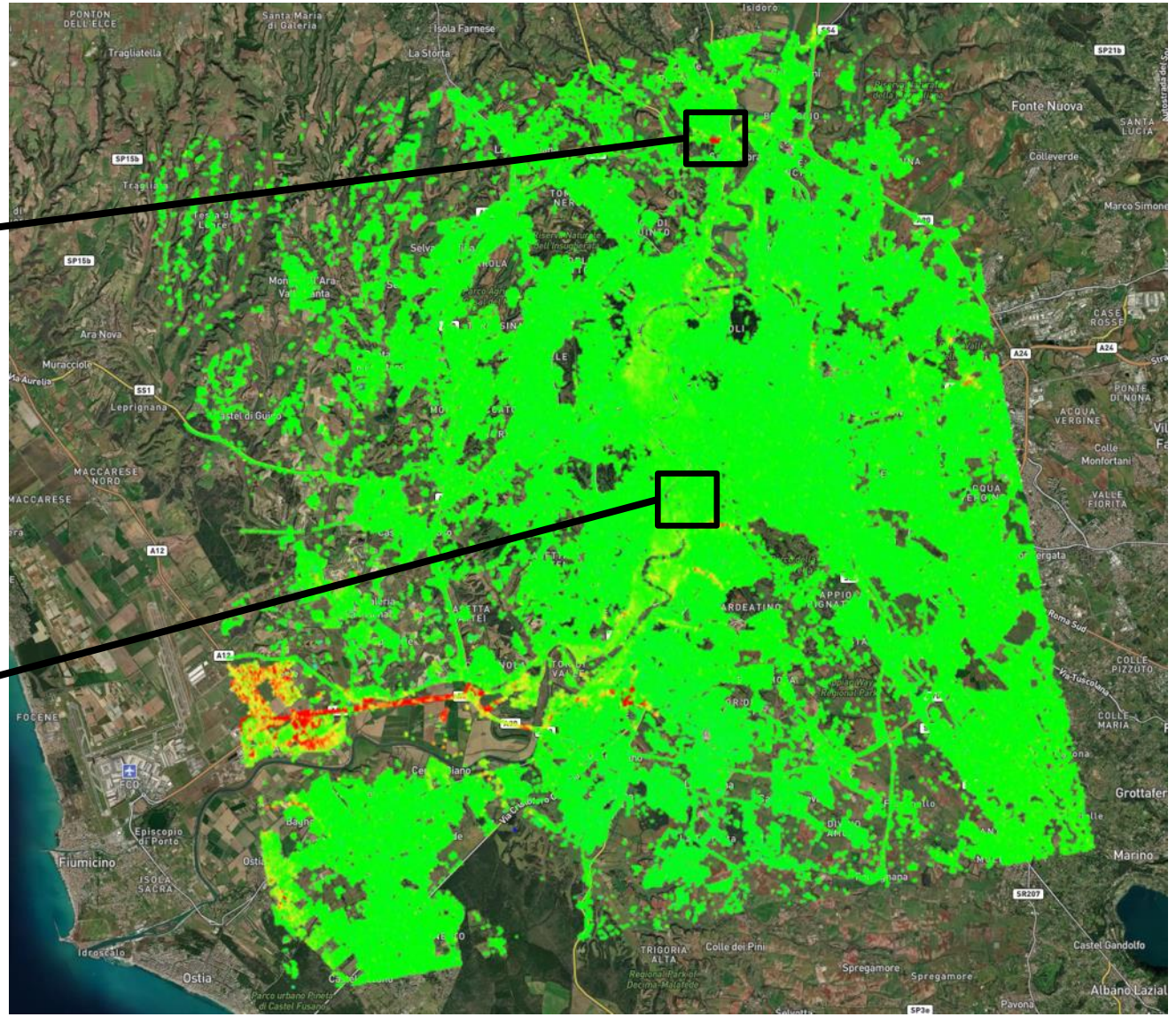
FR P-SBAS DInSAR analysis: CSK+CSG case study over Rome (Italy)



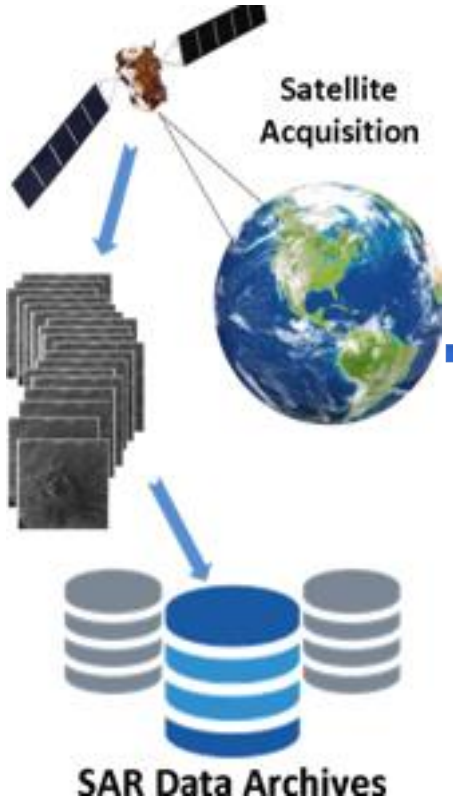


Δ CSK

Δ CSG



How to manage such a Big Data challenge?



FULL RESOLUTION
SBAS-DInSAR ANALYSIS:
MILLIONS OF POINTS
TO PROCESS!!!

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

L-Band SAOCOM Satellite

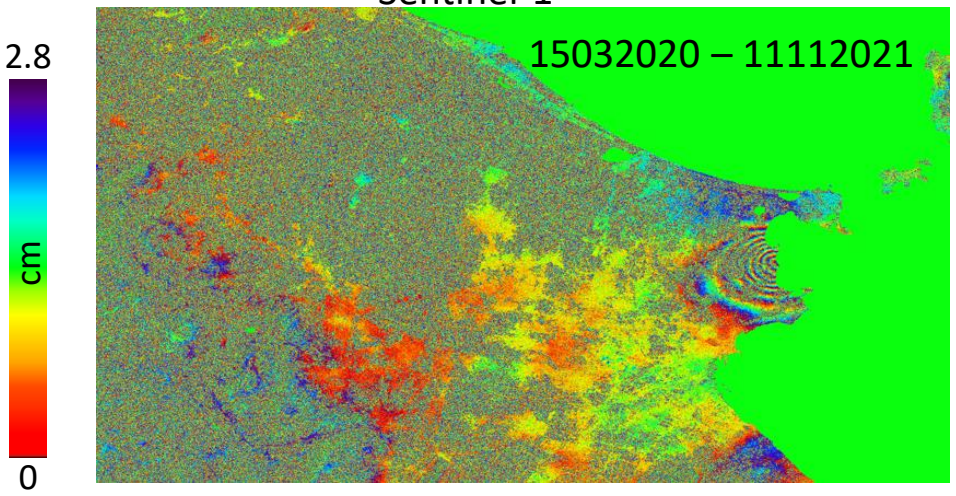
SAOCOM: Satélite Argentino de Observación COn Microondas

- Spatial Resolution: **5m**
- **L-Band**
- Swath width: **~60km**
- **Italy as an exclusivity region**

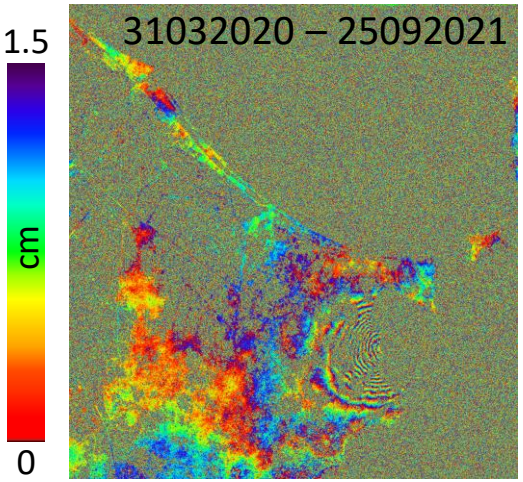
L-band is less sensitive but presents less criticisms, suitable for the analisys of infrastructures

L-Band SAOCOM Satellite examples

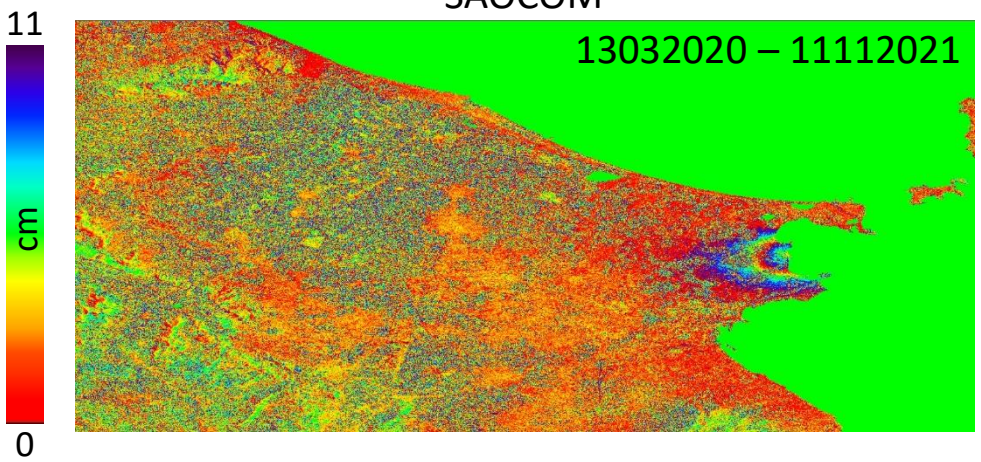
Sentinel-1



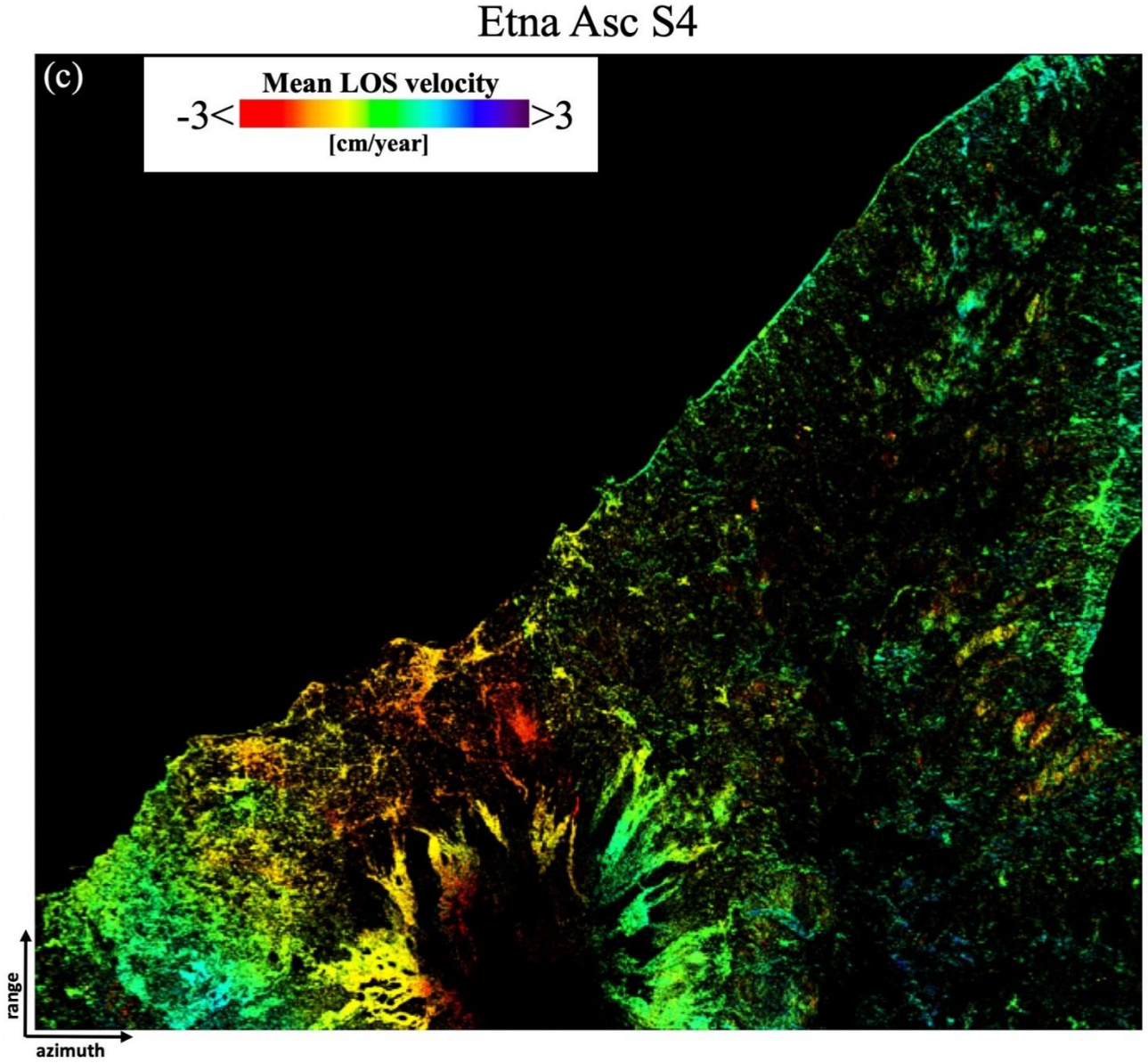
CSK

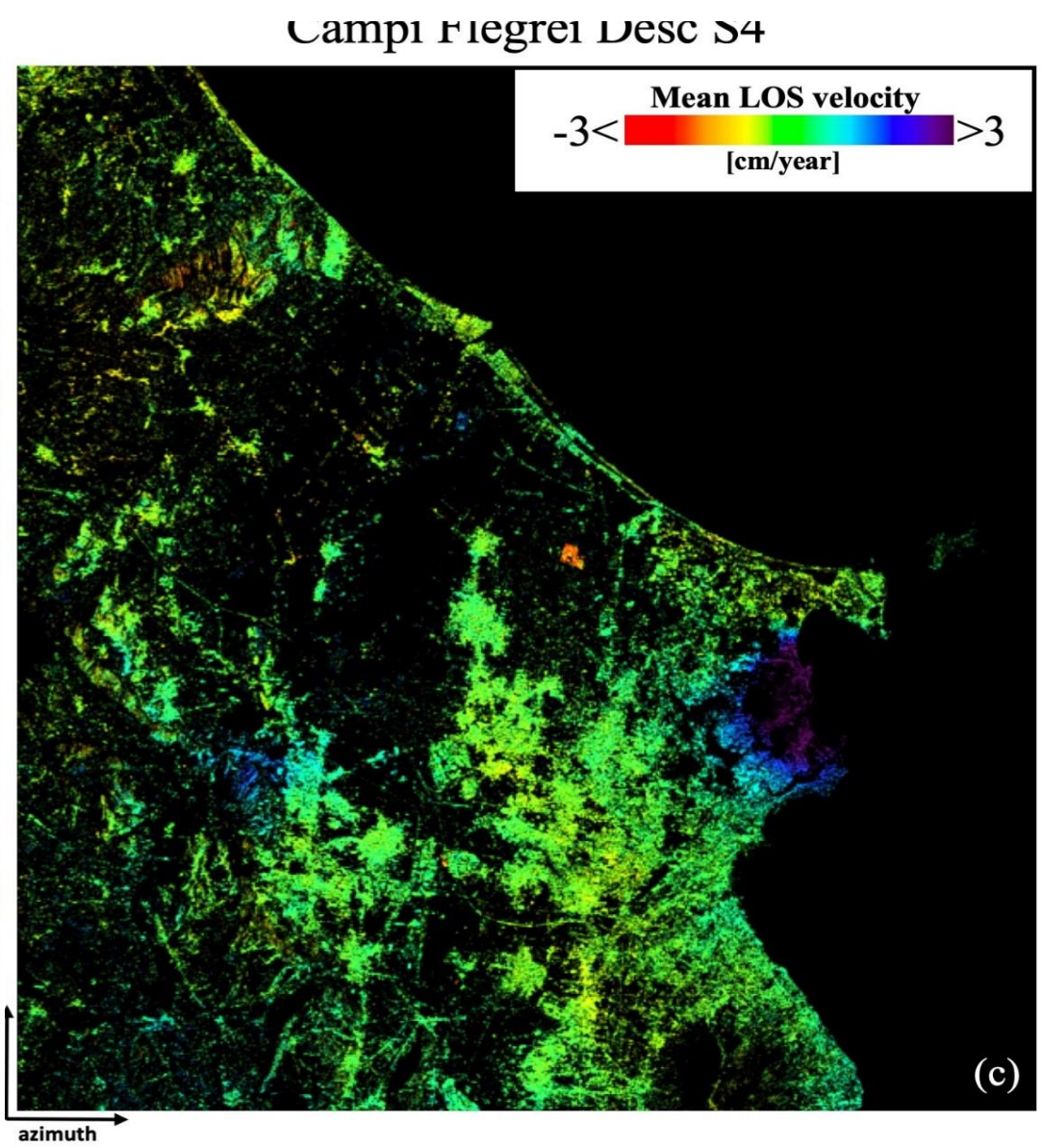


SAOCOM



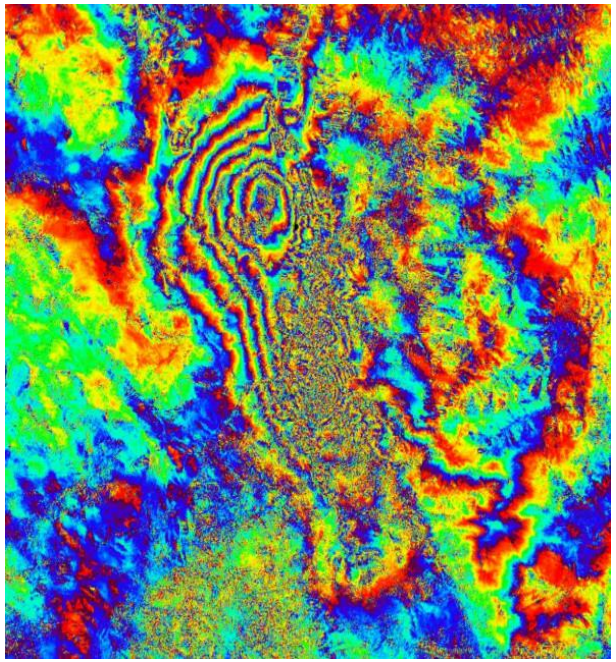
L-Band SAOCOM Satellite examples





Frequency impact on fringe pattern

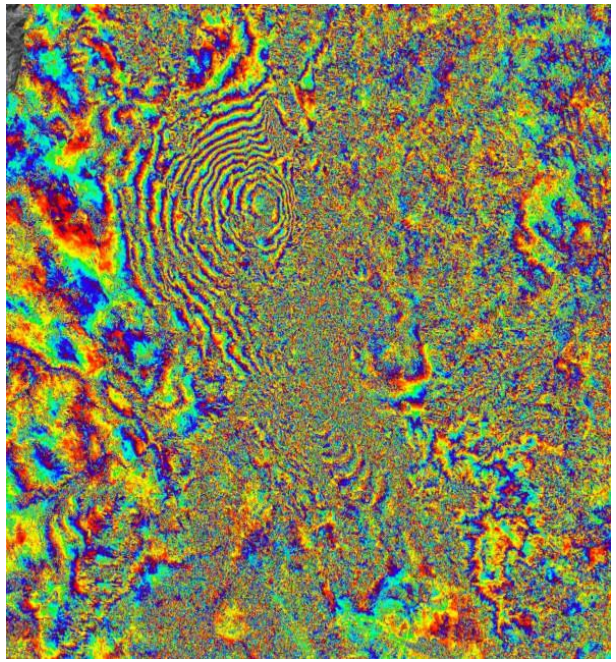
Sentinel-1



0 2.8 [cm]

C-band:
λ = 5.5 cm
Dt = 6 days
$b_\perp$ = 79 m

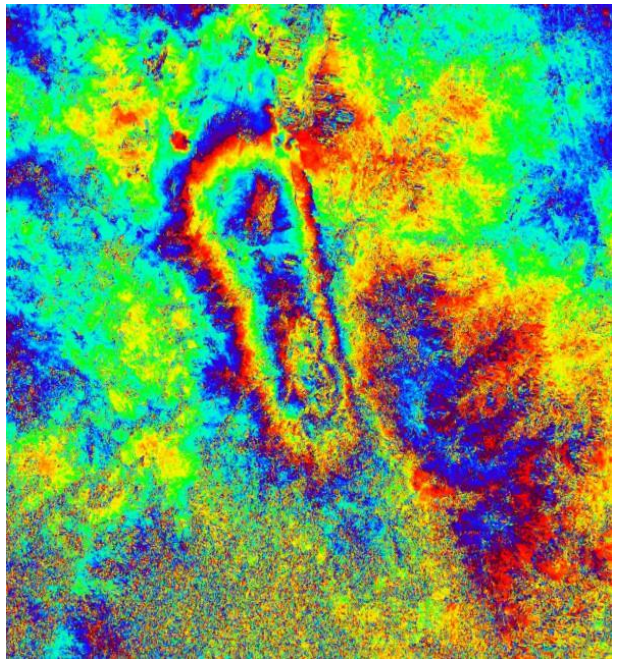
COSMO-SkyMed



0 1.5 [cm]

X-band:
λ = 3.1 cm
Dt = 8 days
$b_\perp$ = 101 m

ALOS-2



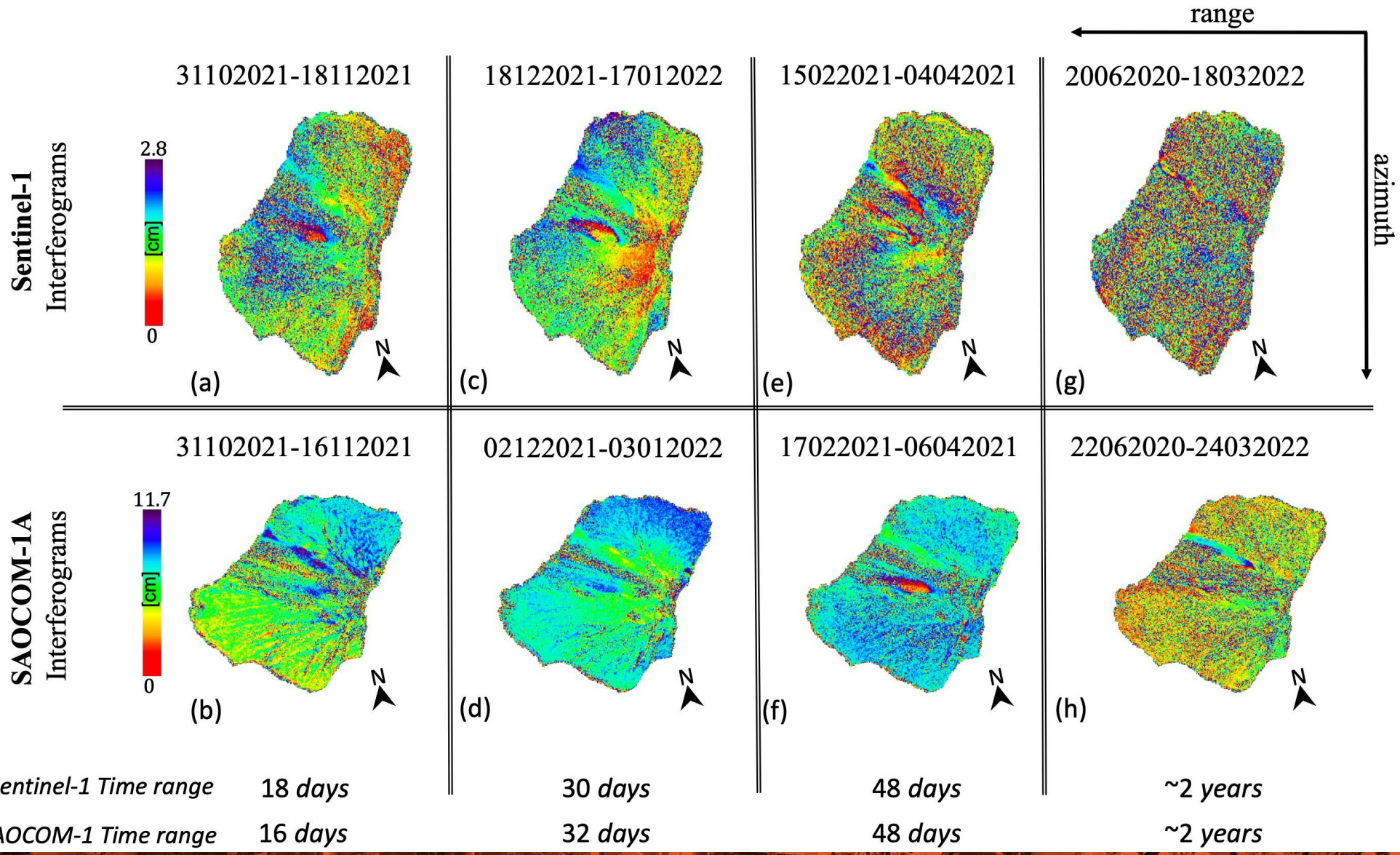
0 11.5 [cm]

L-band:
λ = 23 cm
Dt = 98 days
$b_\perp$ = 88 m

Multi-frequency and multi-platform data integration

Sentinel-1 Data:
- Orbital Pass: Desc
- Track: 124
- Inc Angle: 37°

***SAOCOM-1A* Data:**
- Orbital Pass: Desc
- Sub-mode: S4
- Inc Angle: 35°



Next to come

- Operational **airborn** SAR platform
- **Systematic** DInSAR Mapping/Monitoring at **national scale:**
  - Update rate: 12 – 6 – 3 – 1 months
  - Higher spatial resolution
- CSK/CSG (COSMO Second Generation) **on-demand** at **high resolution**
- **New sensors:** SAOCOM, NiSAR (2023), Rose-L (2028)
- **Mirror Copernicus,** New constellation **PNRR**

Thanks for the attention


2022
SAR ANALYTICS
SYMPOSIUM


2022
SAR ANALYTICS
SYMPOSIUM


2022
SAR ANALYTICS
SYMPOSIUM