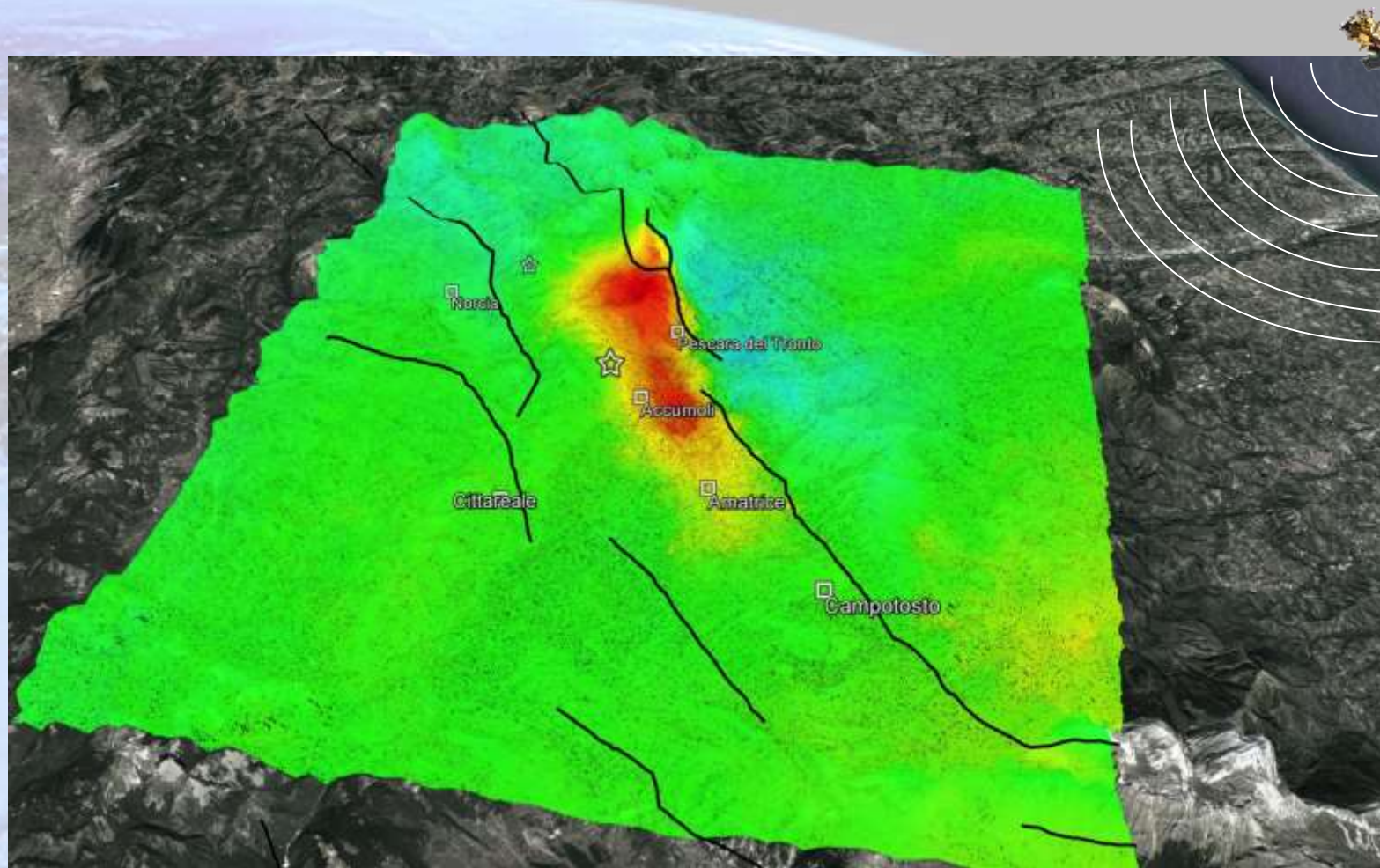


Regional and National Scale Surface Deformation Analysis through Advanced Space-borne Radar Interferometry Techniques

Michele Manunta

**Istituto per il Rilevamento Elettromagnetico dell'Ambiente (IREA)
Consiglio Nazionale delle Ricerche (CNR)
Via Diocleziano, 328, 80124 Napoli, Italy**

Co-seismic DInSAR deformation measurements: Amatrice earthquake (24/08/2016)

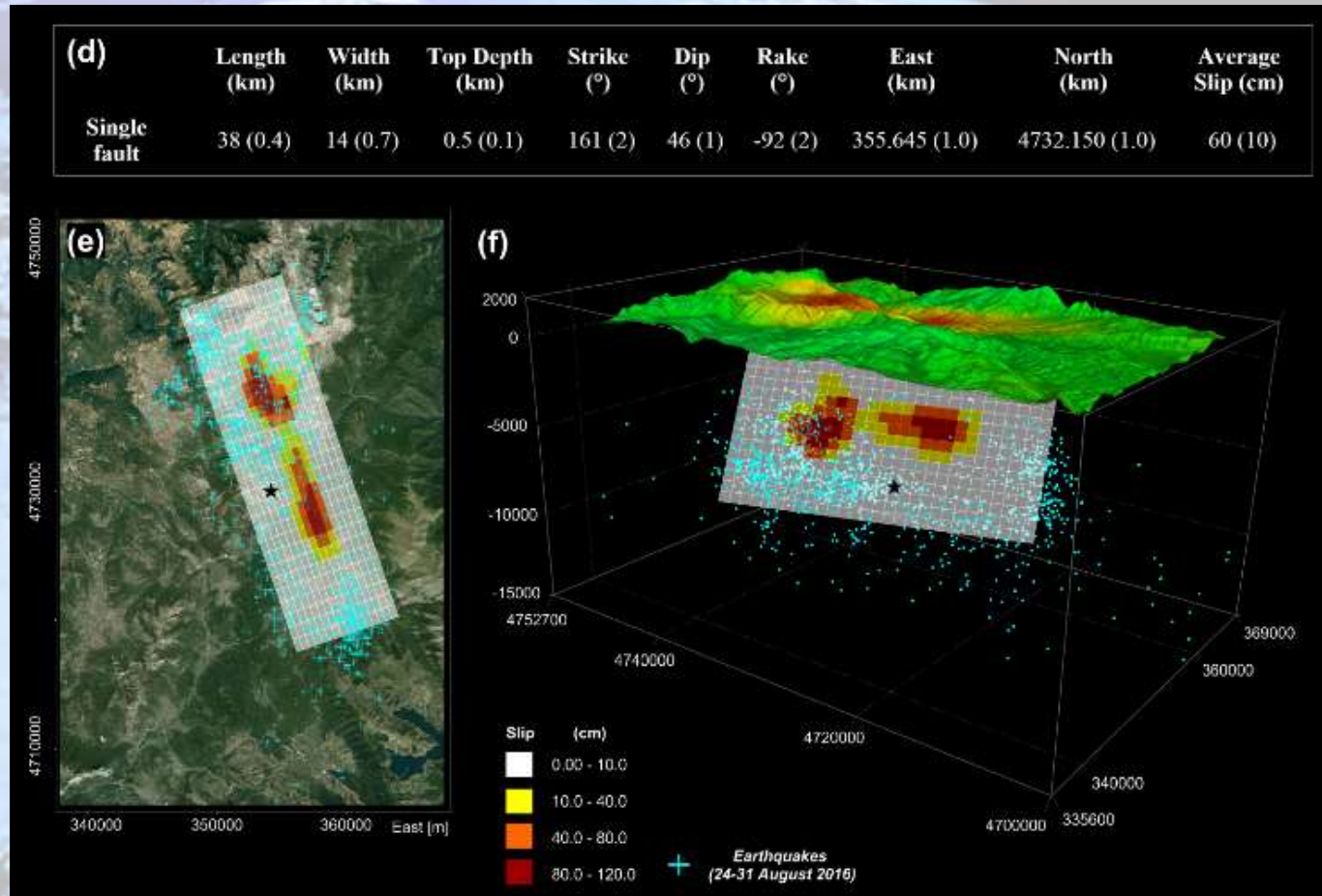


<-20

LOS Deformation [cm]

>20

Amatrice earthquake (24/08/2016): analytical model

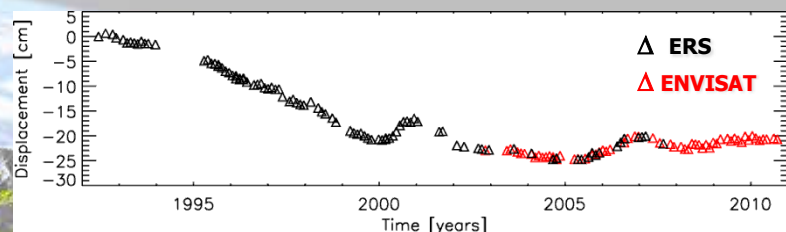
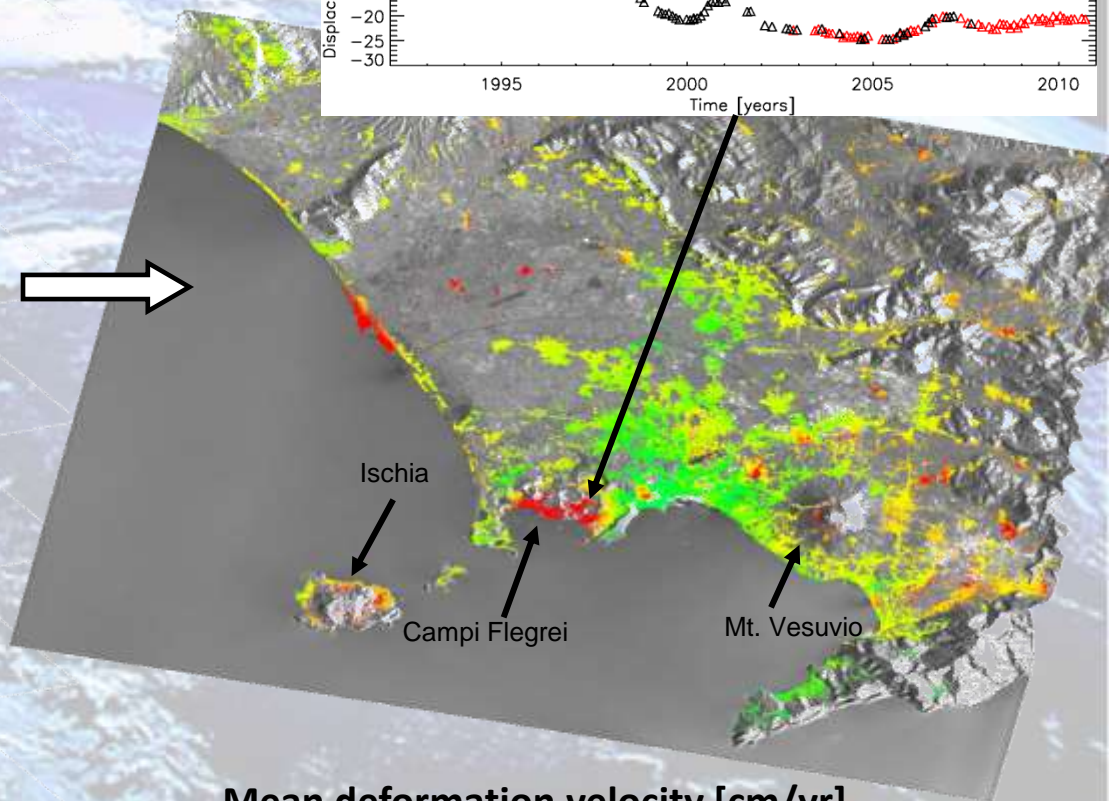
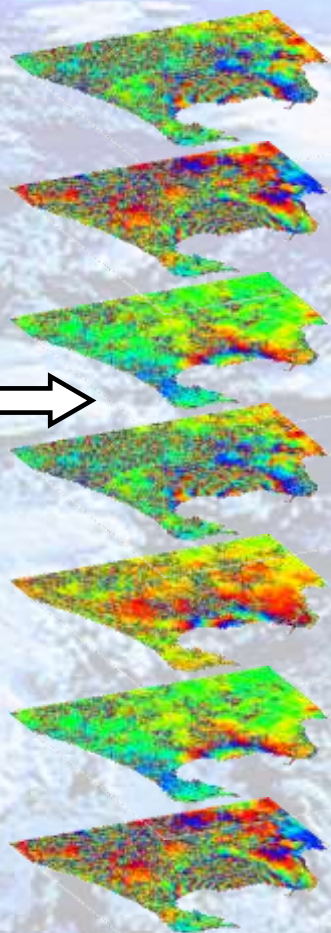
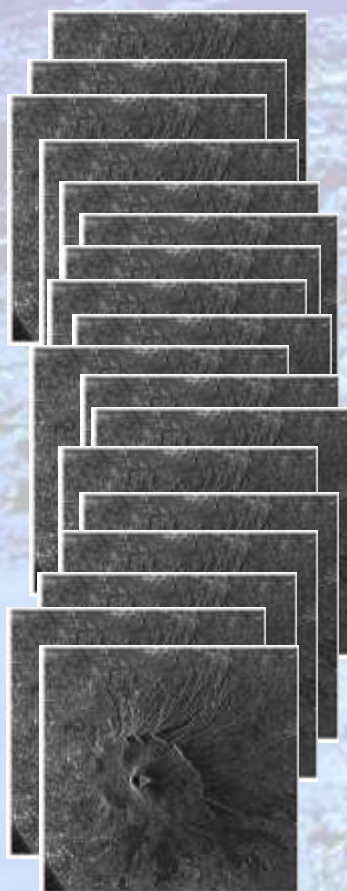


Advanced DInSAR technique: Small BAseline Subset (SBAS)

ERS/**ENVISAT** images (1992 – 2010)

SAR Images

SB Interferograms



Mean deformation velocity [cm/yr]

< - 0.75

> 0.75

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

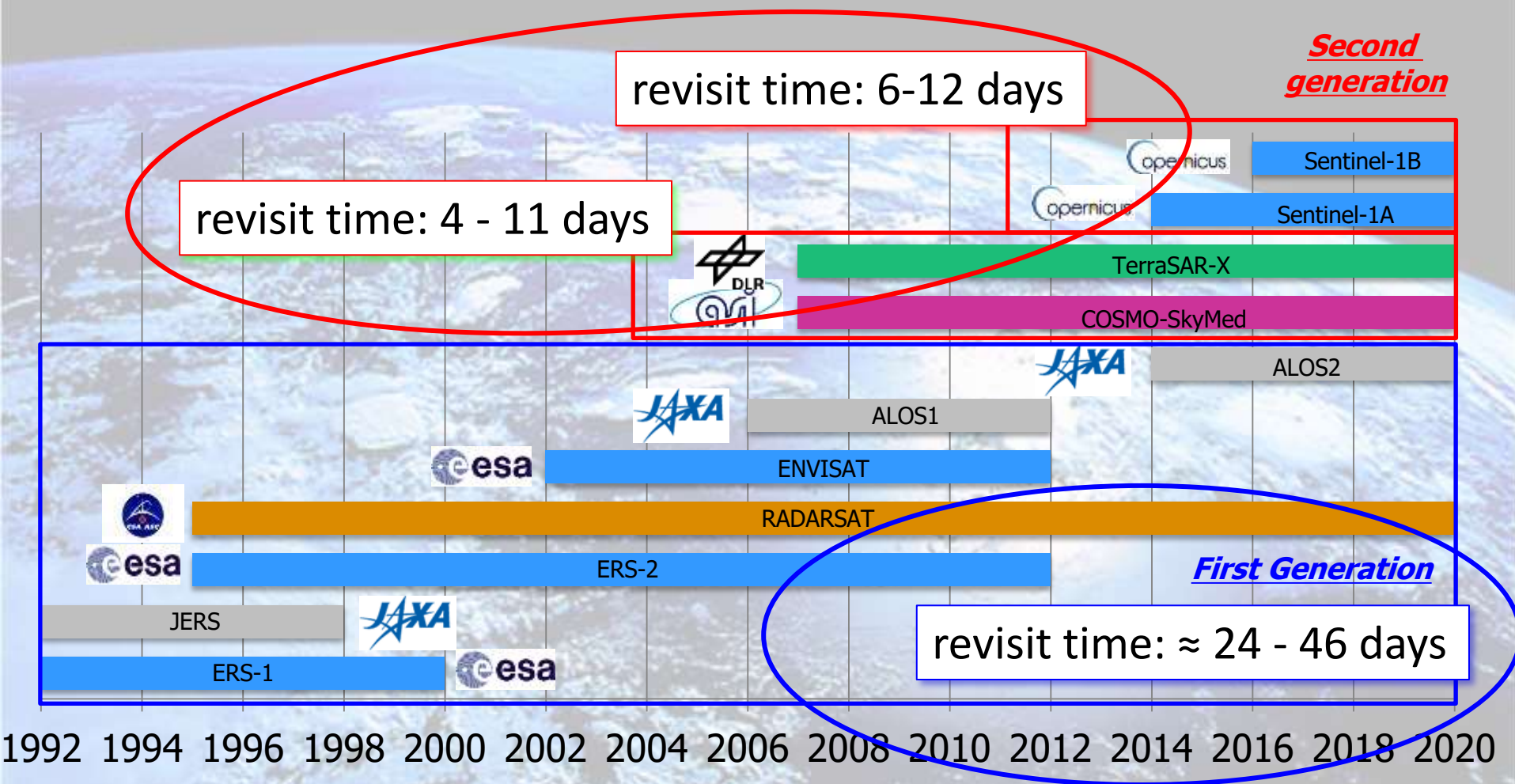
Pepe et al., 2005, IEEE Trans. Geosci. Remote Sens.

MED2018, ESA-ESRIN, 11-12 December 2018



Consiglio Nazionale
delle Ricerche

Revisit times of radar satellites for Earth Observation



Sentinel-1 Constellation

Sentinel-1A



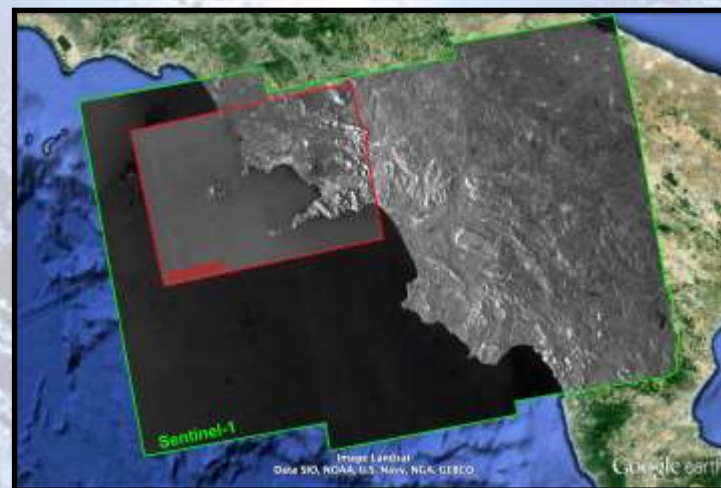
Sentinel-1B



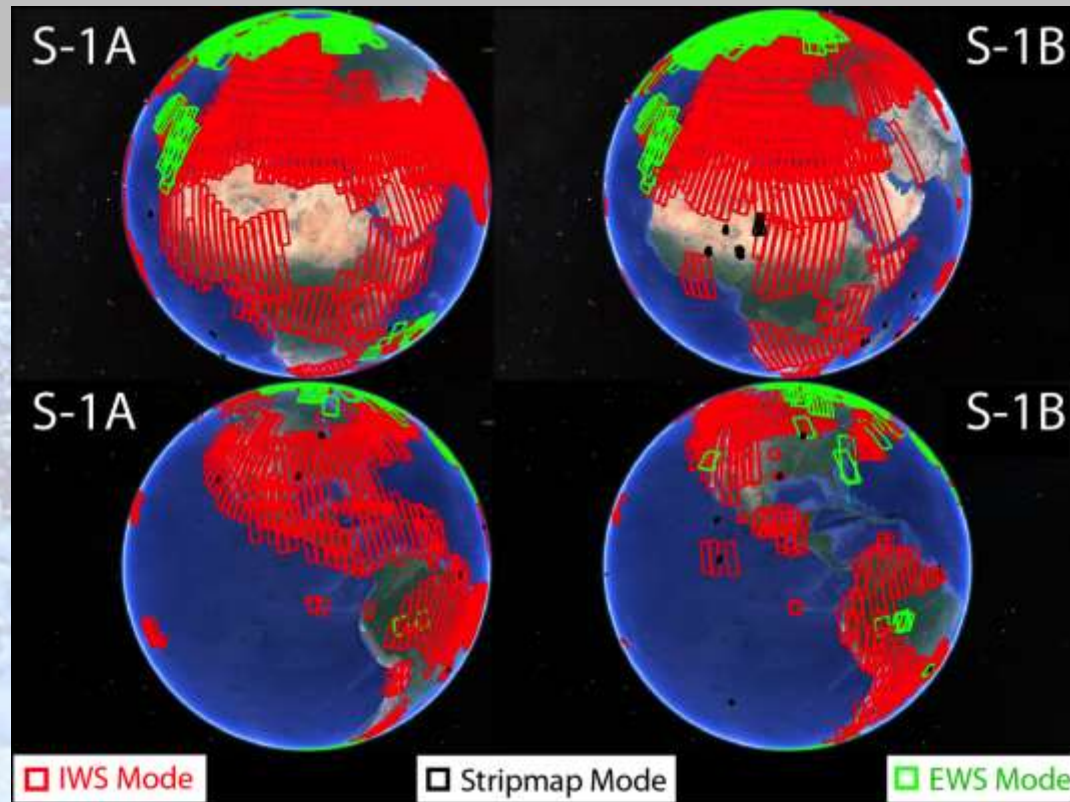
Sentinel-1A



- Sensor spatial resolution: **15 x 4 m**
- Spatial coverage: ~ **250 x 250 km**
- **C-band**
- **Global coverage**
- **Free and open** data access

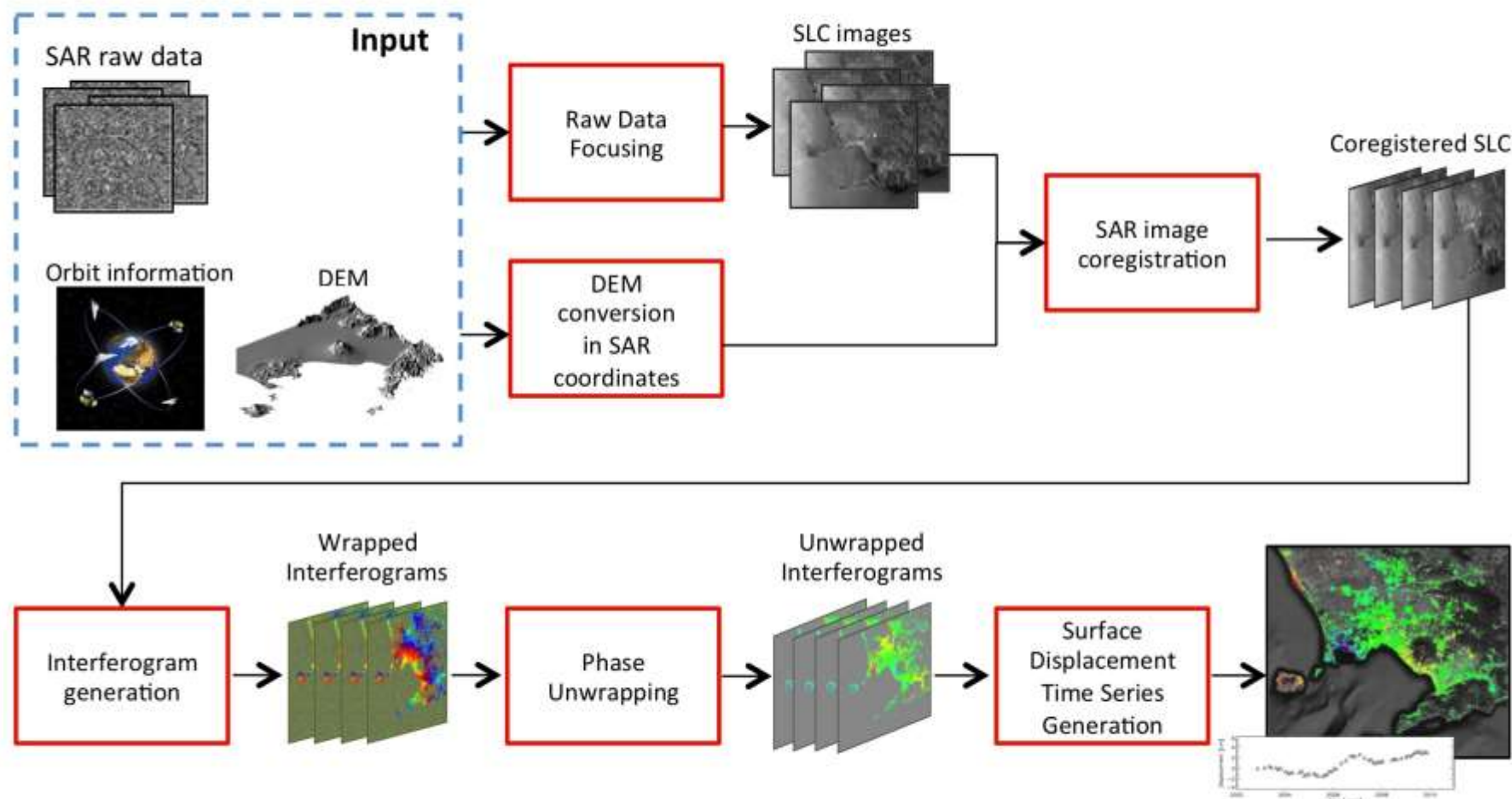


Sentinel-1A and Sentinel-1B spatial coverage and data volumes



*Courtesy of
ESA*

Parallel SBAS (P-SBAS) workflow



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

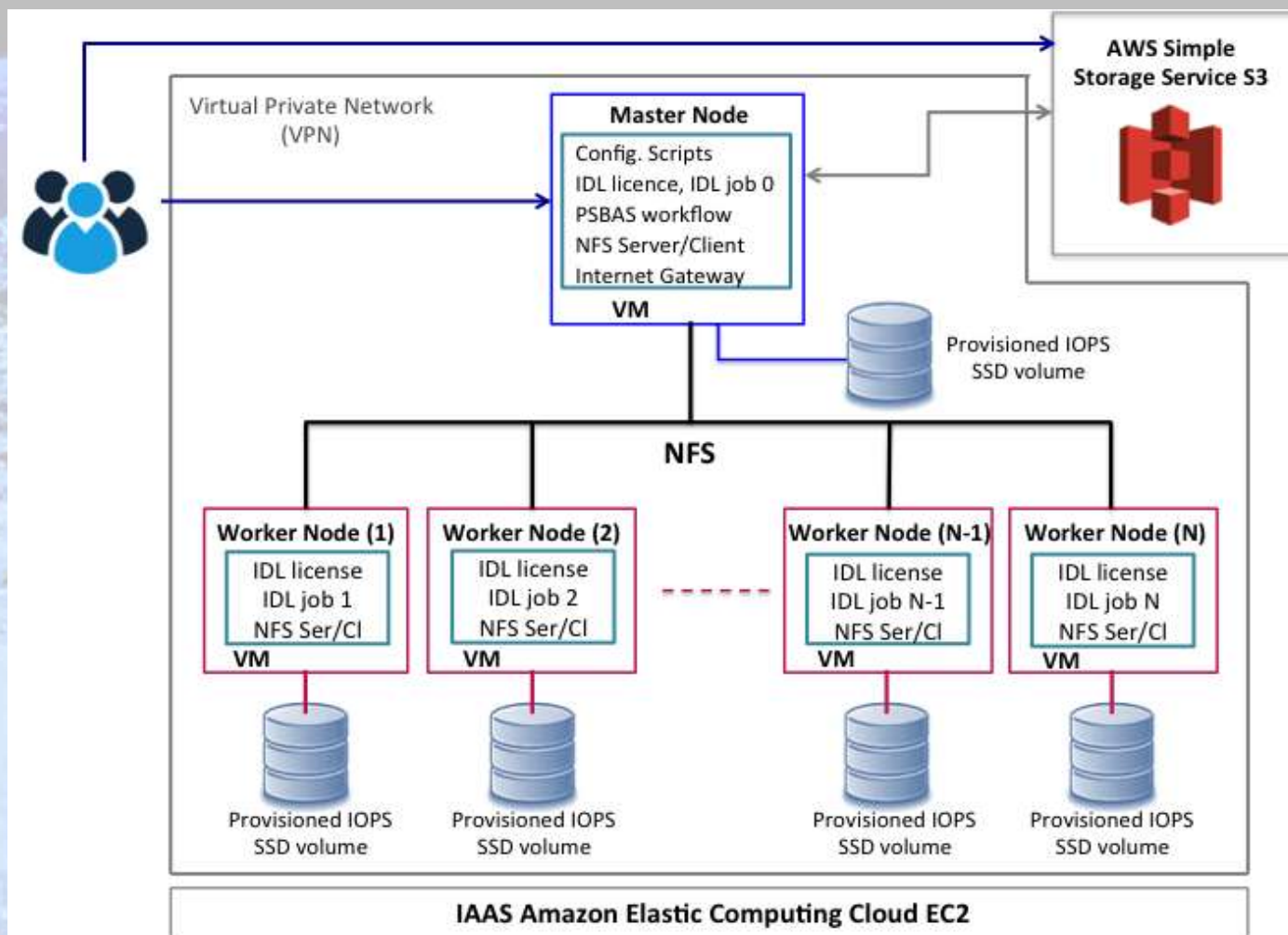
Casu et al., 2014, *IEEE JSTARS*

Zinno et al., 2015, *IEEE JSTARS*

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

MED2018, ESA-ESRIN, 11-12 December 2018

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

MED2018, ESA-ESRIN, 11-12 December 2018

Campi Flegrei caldera: Sentinel-1 SAR data

250 km

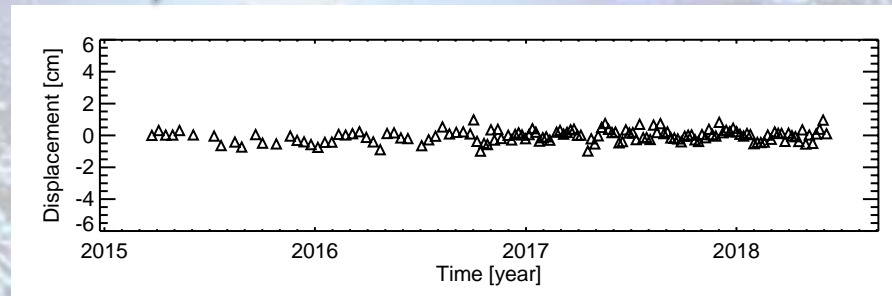
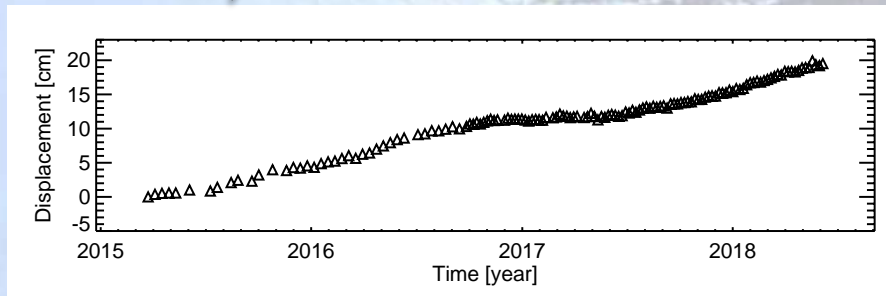
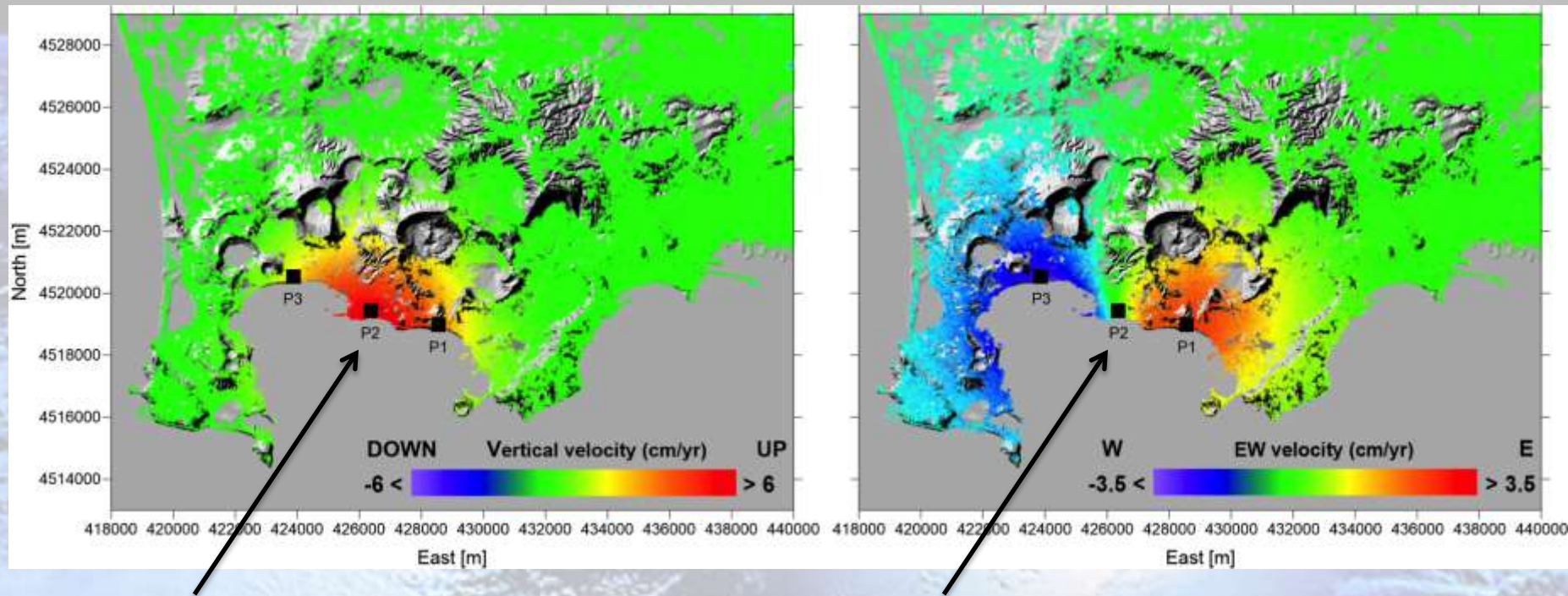
Main characteristics of the exploited Sentinel-1 SAR datasets

	Ascending	Descending
Wavelength	5,5 cm	
Acquisition mode	Terrain Observation by Progressive Scans	
Average look angle	~39°	
Spatial resolution of the interferometric data	~30 m x 30 m	
Track	44	22
Time interval	25/03/2015 – 07/06/2018	24/03/2015 – 06/06/2018
Number of acquisitions	145	143

with

Campi Flegrei caldera: Sentinel-1 DInSAR analyses

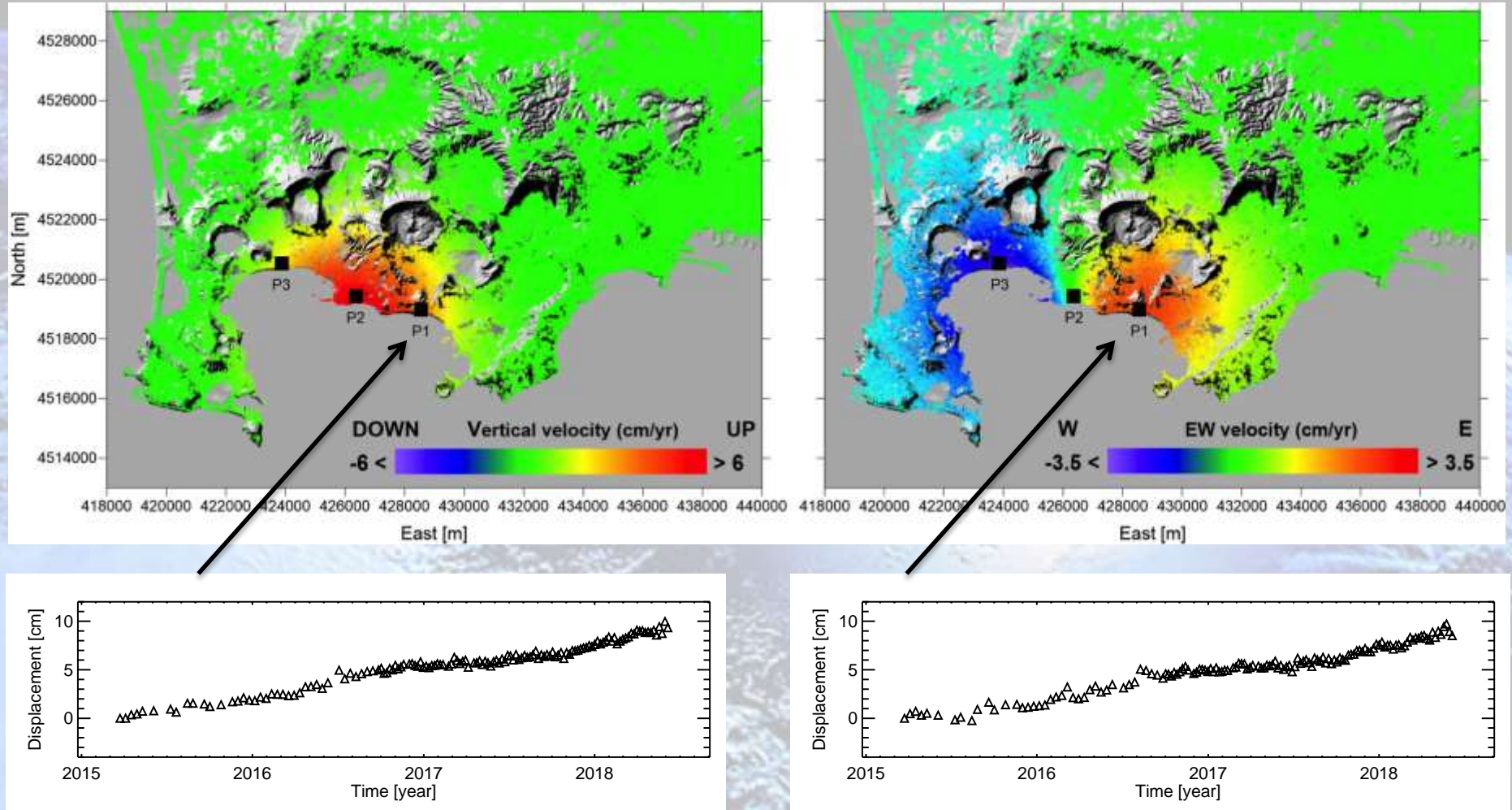
Vertical and East-West deformation components



Rione Terra

Campi Flegrei caldera: Sentinel-1 DInSAR analyses

Vertical and East-West deformation components

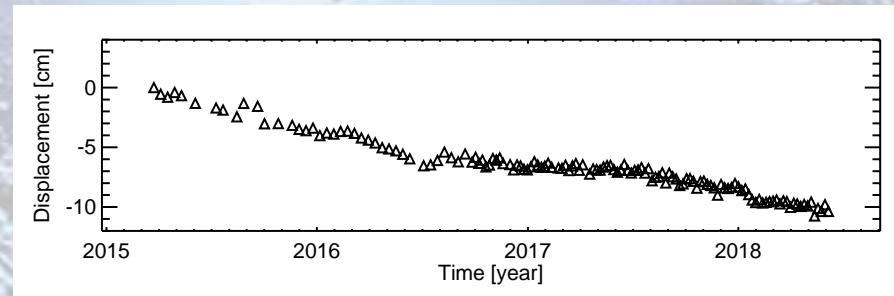
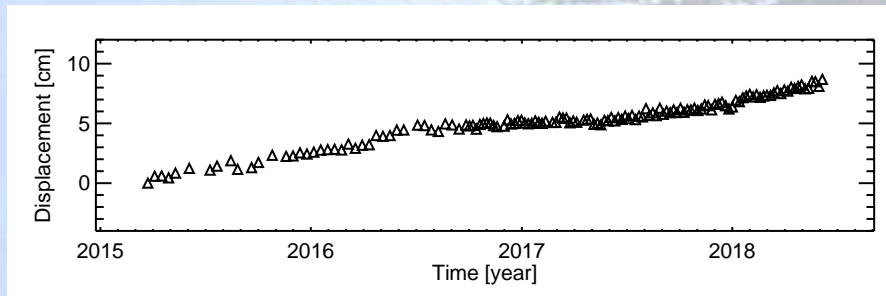
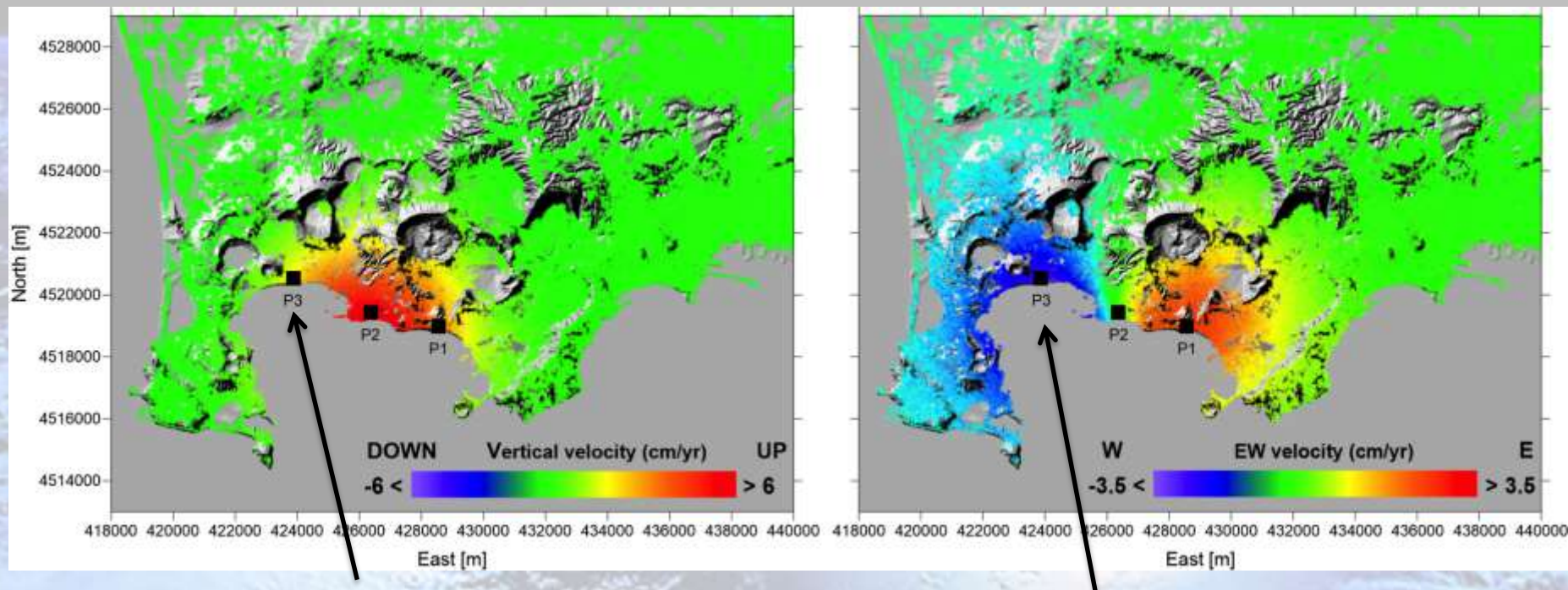


Accademia - Bagnoli

MED2018, ESA-ESRIN, 11-12 December 2018

Campi Flegrei caldera: Sentinel-1 DInSAR analyses

Vertical and East-West deformation components

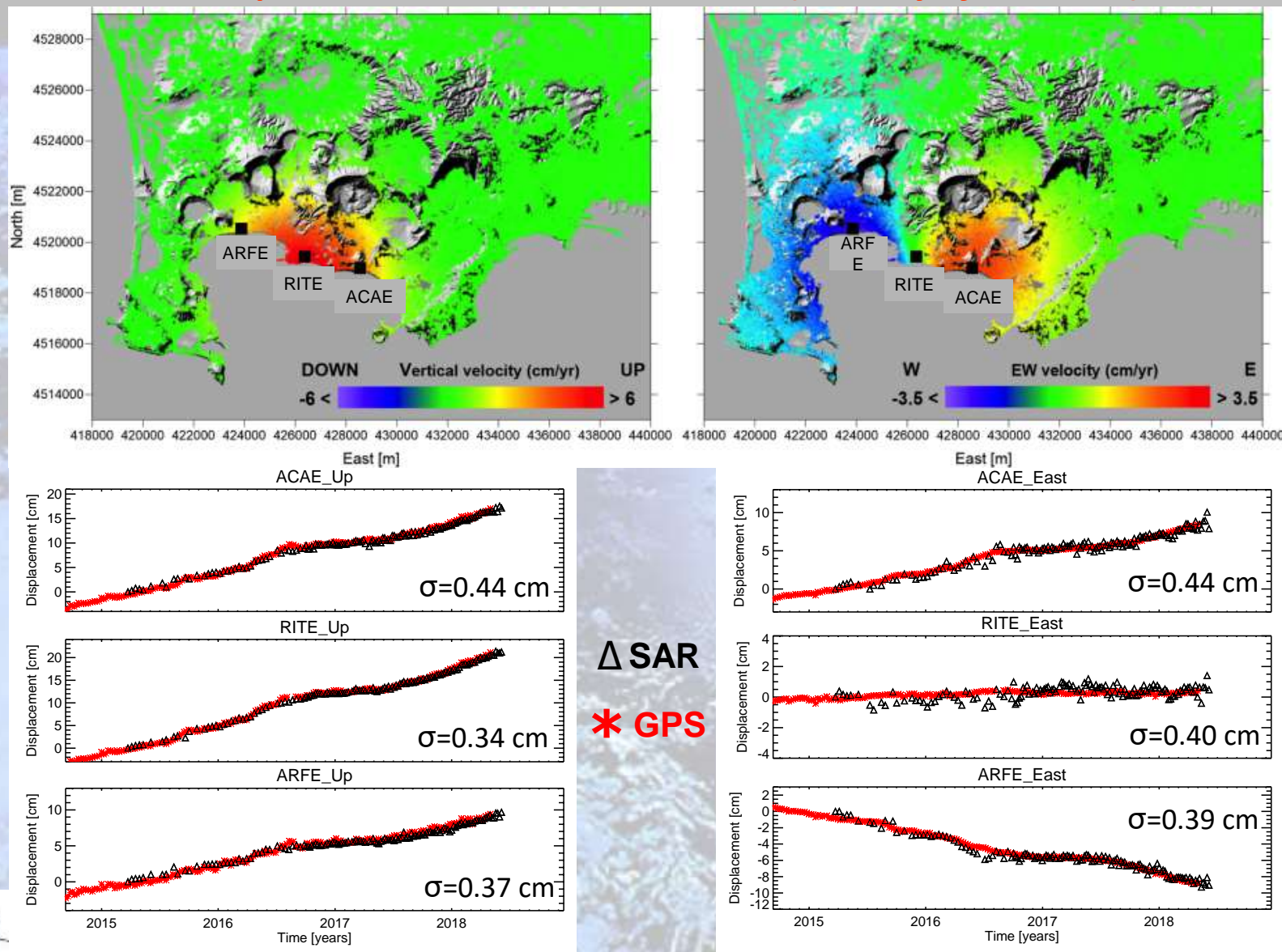


Arco Felice

MED2018, ESA-ESRIN, 11-12 December 2018

Campi Flegrei caldera: Sentinel-1 DInSAR analyses

Comparison with GPS measurements (*courtesy of OV-INGV*)

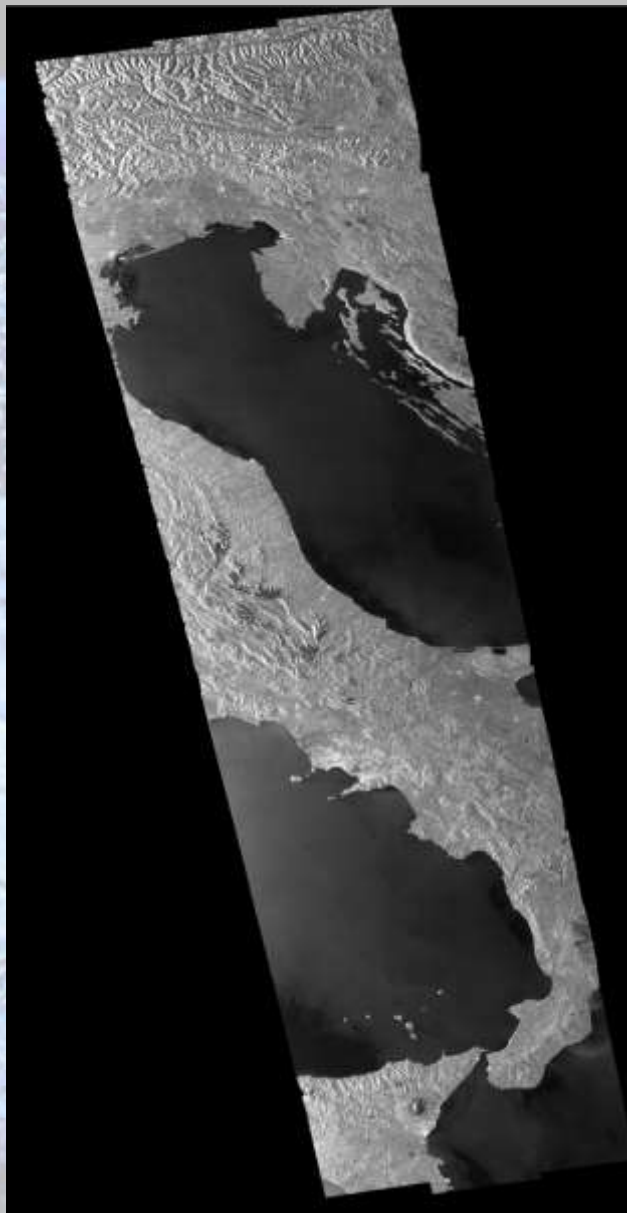


MED2018, ESA-ESRIN, 11-12 December 2018



Consiglio Nazionale
delle Ricerche

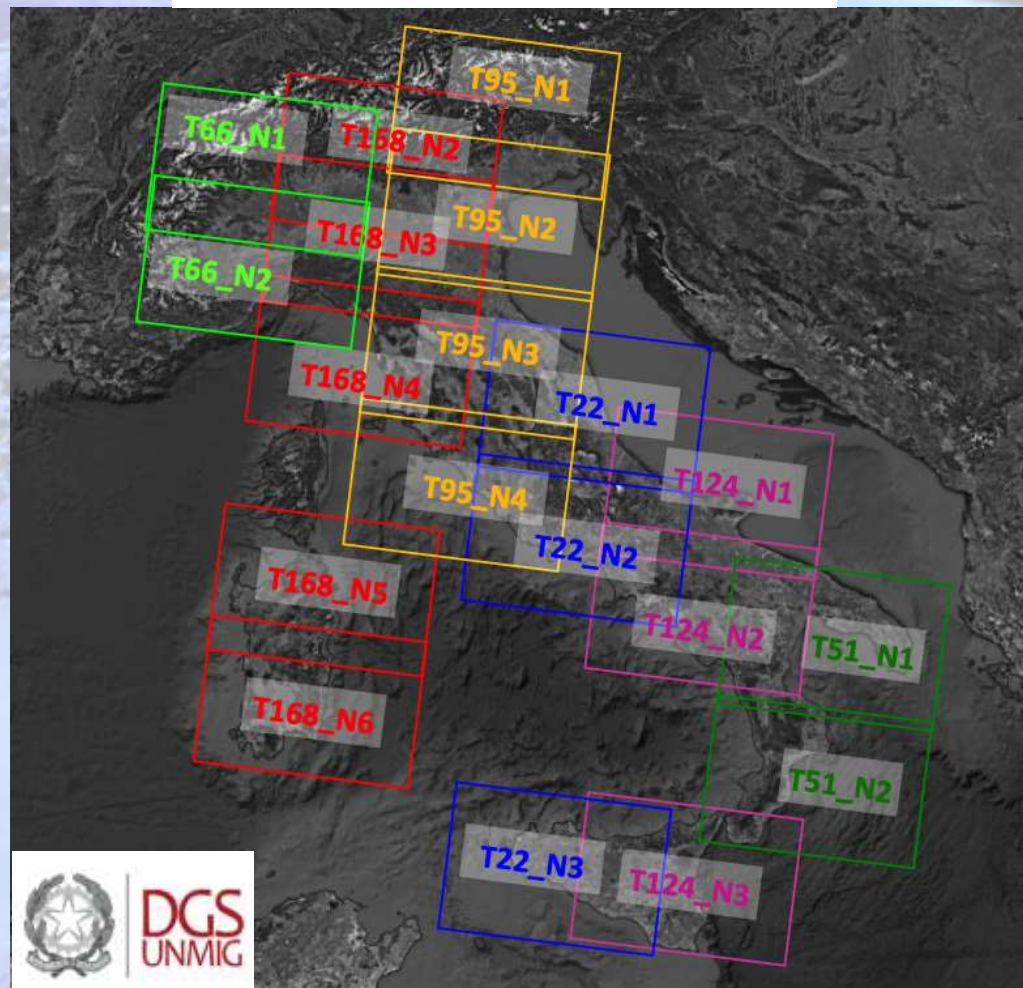
Sentinel-1 constellation: IWS mode area coverage



**Toward a national scale
DInSAR mapping!**

Sentinel-1 for National Scale DInSAR Analyses

Descending Orbits (March 2015 – September 2018)



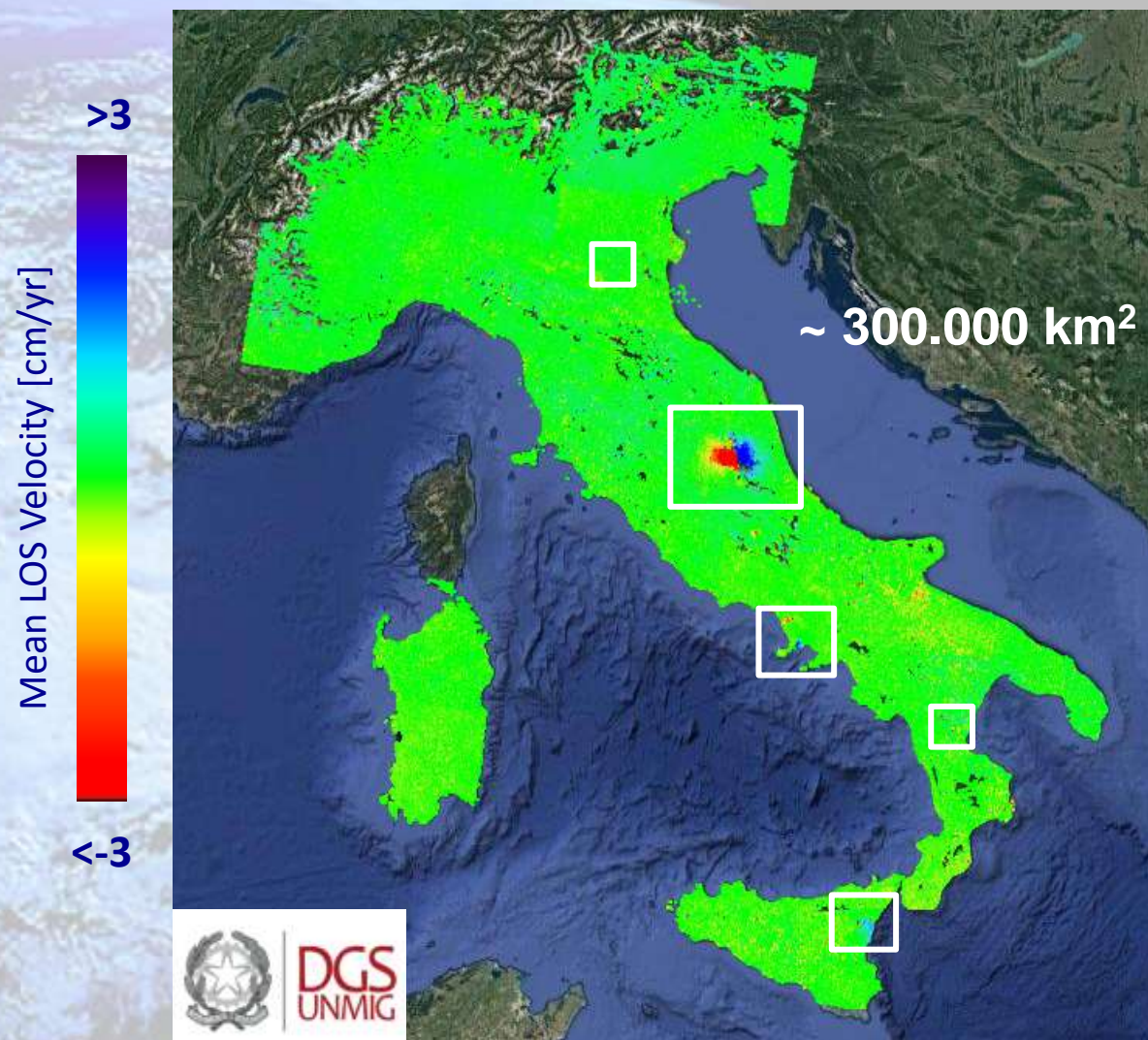
Frame	Number of S-1 slice	Number of S-1 acquisitions
T66_N1	292	139
T66_N2	391	153
T168_N2	286	138
T168_N3	286	150
T168_N4	303	149
T168_N5	319	149
T168_N6	279	128
T95_N1	290	145
T95_N2	308	145
T95_N3	295	144
T95_N4	289	138
T22_N1	327	145
T22_N2	330	145
T22_N3	288	137
T124_N1	300	150
T124_N2	359	150
T124_N3	353	144
T51_N1	361	144
T51_N2	375	144
TOTAL	6031	2737



DGS
UNMIG

Sentinel-1 P-SBAS: national scale DInSAR analysis

Time interval: March 2015 – September 2018, descending orbits

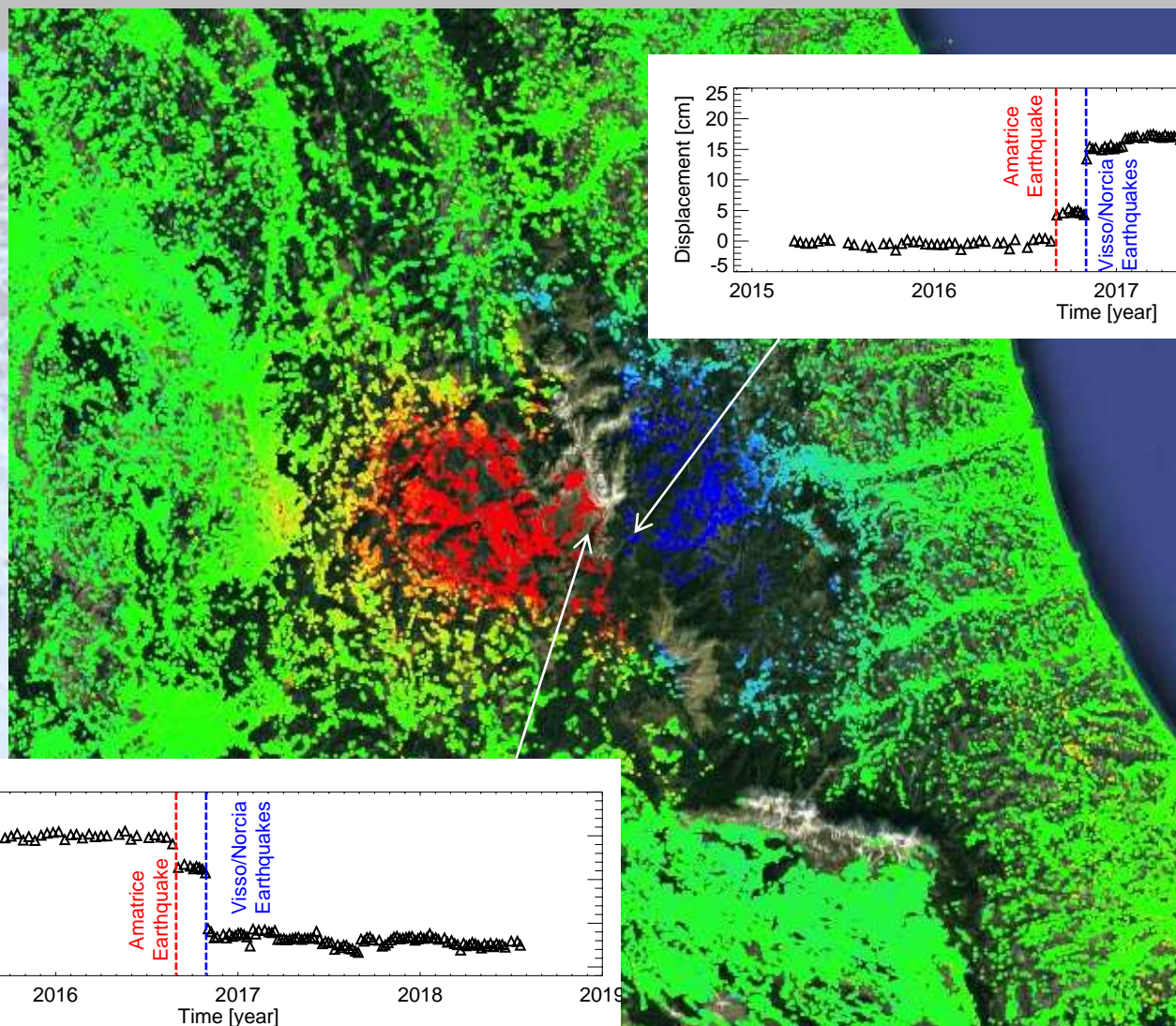


MED2018, ESA-ESRIN, 11-12 December 2018



Consiglio Nazionale
delle Ricerche

Earthquake: Amatrice – Visso/Norcia seismic events (2016)

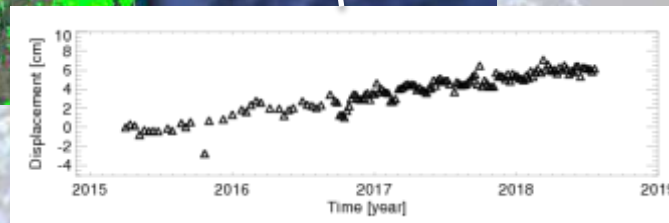
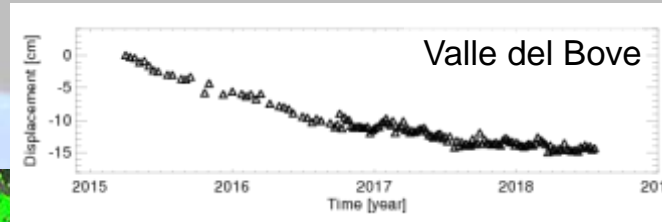
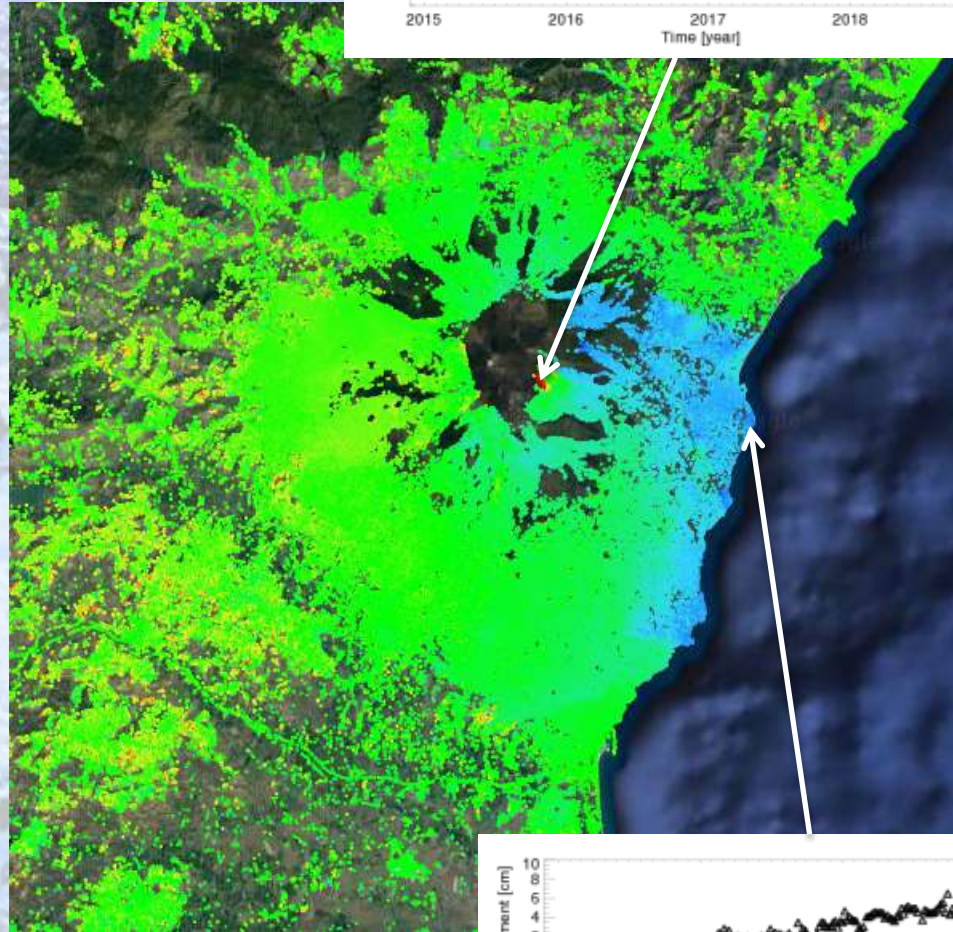


Volcano: Mt. Etna (Sicilia)

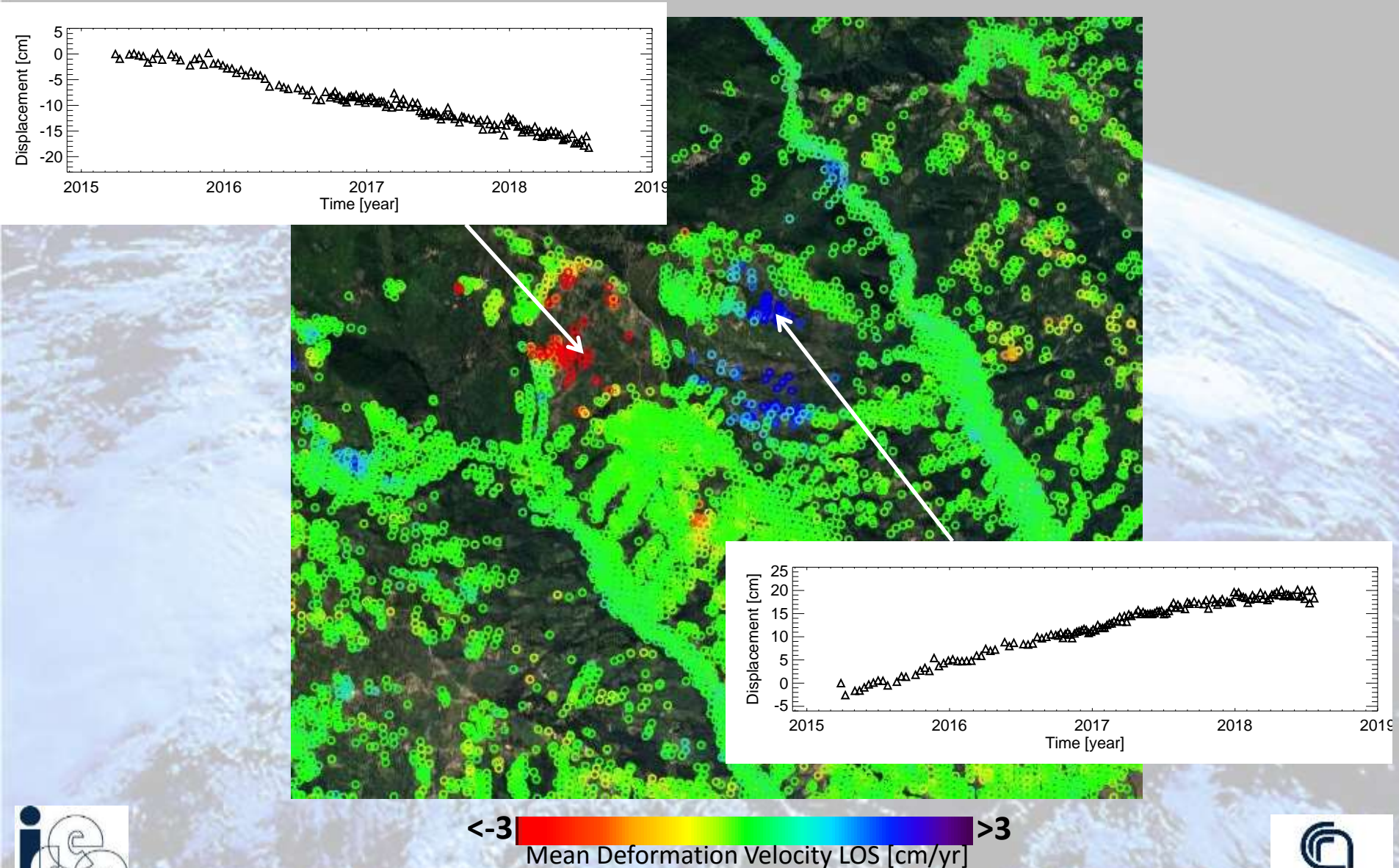
Mean LOS Velocity [cm/yr]

>3

<-3



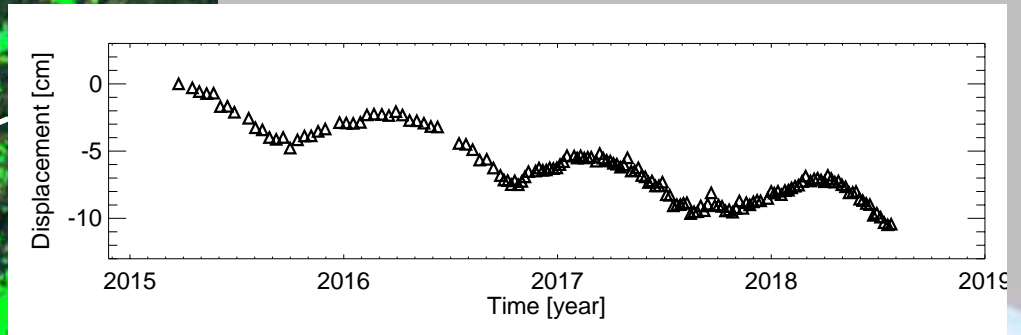
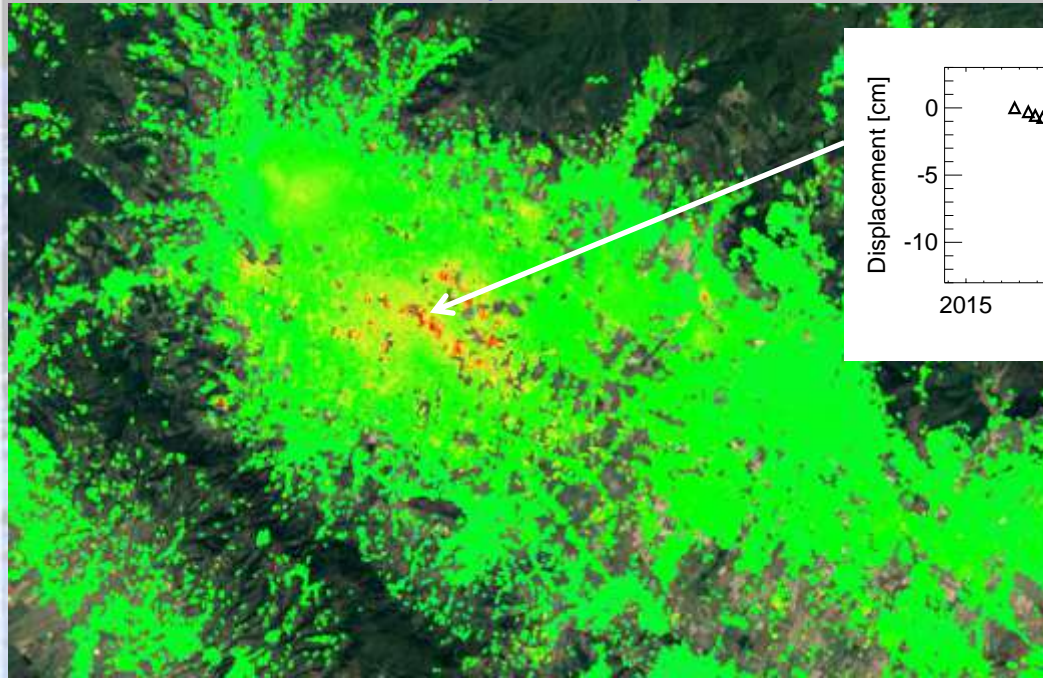
Landslides: Plataci (Calabria) area



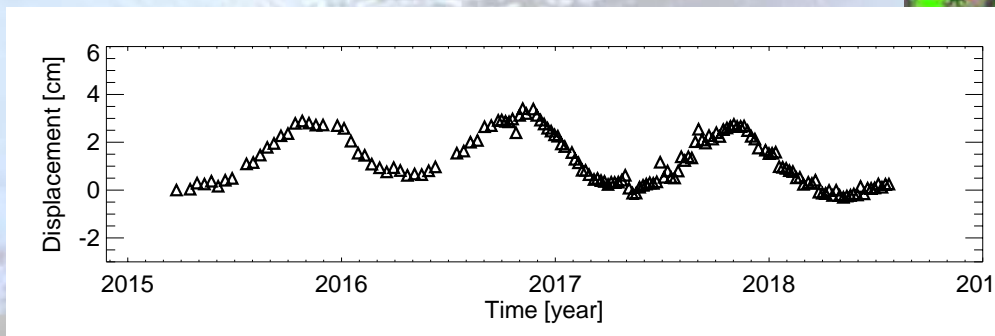
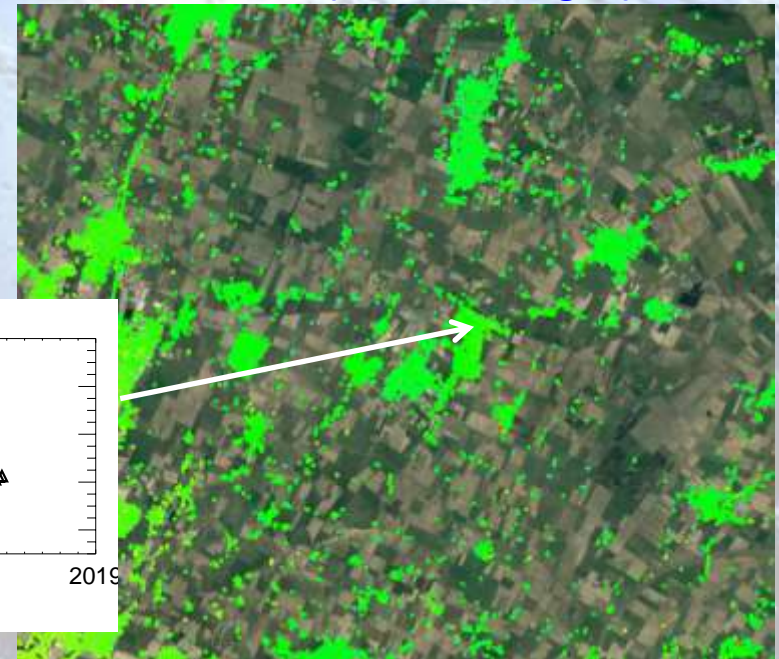
MED2018, ESA-ESRIN, 11-12 December 2018

Aquifer and Oil&Gas Subsidence

Pistoia (Toscana)



Minerbio (Emilia Romagna)

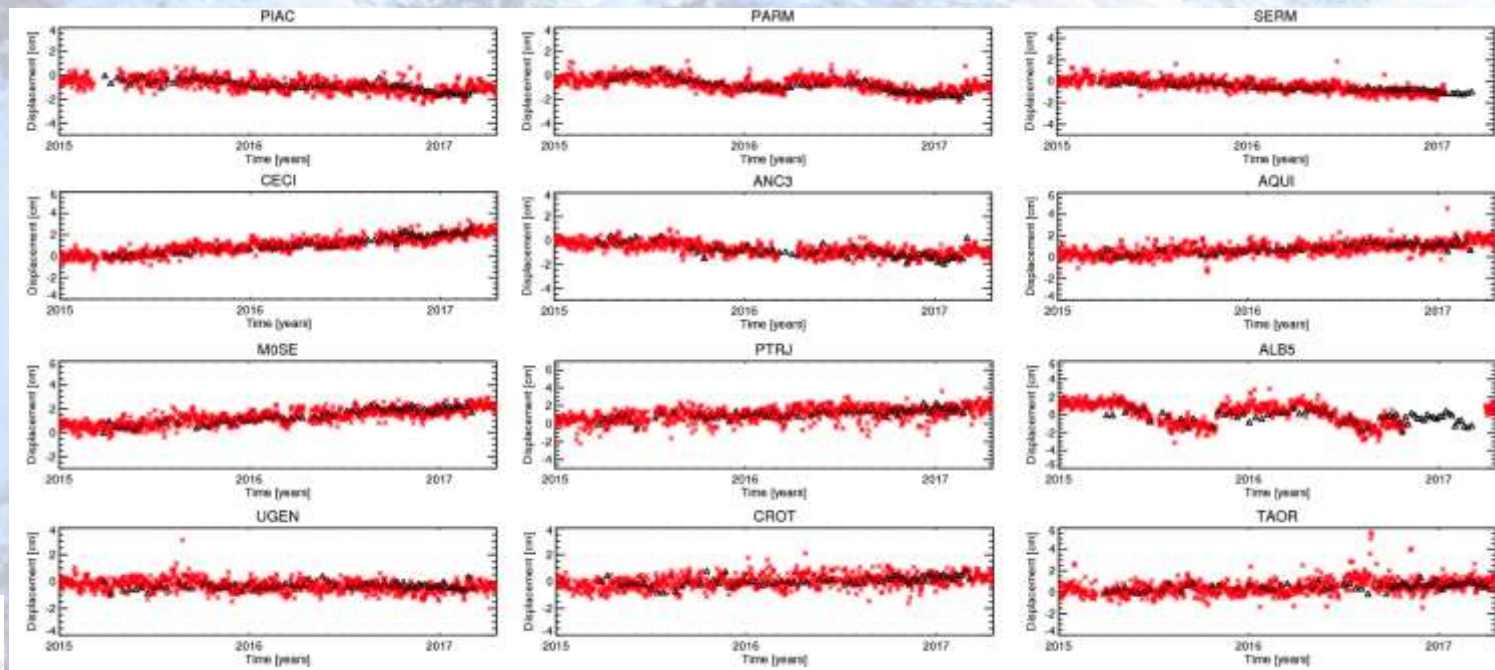


<-3  >3
Mean Deformation Velocity LOS [cm/yr]

MED2018, ESA-ESRIN, 11-12 December 2018

DInSAR vs. 434 NGL GPS Stations

$$\sigma_{\text{def}} \sim 4 \text{ mm}$$



Δ SAR

* GPS

Sentinel-1 national scale P-SBAS processing scenario in the AWS Cloud

S1 ascending orbit

S1 descending orbit

National scale processing: ITALY

Spatial coverage: 38 S1 slices

AWS Cloud i3.16xlarge instance

CPU's	RAM	Storage (SSD)	Bandwidth
64	484 GB	15.2 TB	20 Gb/s

Operational scenario

Processing time: ~18 weeks

Time Series update: 2-3 times/year

Total cost per year: ~ 20.000 USD

(March 2015-September 2018)

Sentinel-1 P-SBAS continental scale processing scenario

P-SBAS processing

How to do that?



4 Nodes each one equipped with:

CPU's: 64

RAM: 512 GB RAM

Storage: 20 TB

Task's Start Date: 01/2019

Time Needed: ~6 months

Continental scale
processing: EUROPE

190 slices

Coverage: 3,200,000 km².



Google Earth

Map Data © 2018 AND
Image copyright / Copernicus
© 2018 Google
US Dept of State Geographic



12-days Interferometric Coherence map of a large part of Europe

June-July 2015

(done in ESA G-POD/GEP)

Thank You!