

→ FRINGE 2015 WORKSHOP

**Advances in the Science and Applications of SAR Interferometry
and Sentinel-1 InSAR Workshop**

**The Italian Supersites Volcanoes:
a long-term monitoring experiment in active volcanic areas prone to natural hazard**

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23–27 March 2015 | ESA–ESRIN | Frascati (Rome), Italy

- **October 5, 2013**

Submission of the two Proposals to the SAC (Supersites Scientific Advisory Committee);

- **October 17, 2013**

Positive revision by SAC, inviting CEOS to support data request as new Permanet Supersites;

- **December 10, 2013**

The CEOS Supersites Coordination Team (SCT) requests for clarification on 3 issues of the Proposals;

- **March, 2014**

Submission of the final revision of the Proposals, with clarification to CEOS SCT;

- **May 27, 2014**

CEOS acceptance of the Permanent Supersites “Mt. Vesuvius/Campi Flegreii” and “Mt. Etna”;

- **May 2014 to date**

Implementation of the Supersites initiative for the Italian Volcanoes by each Space Agency, setting up the data access infrastructures.

CEOS acceptance as a Permanent Supersite - “Mt. Vesuvius/CF”



CEOS agencies intend to support the Mt. Vesuvius / Campi Flegreii Supersite with the following data resources:

Agenzia Spaziale Italiana (ASI)	COSMO-Skymed: 150 scenes / year 200 scenes of past acquisitions
Centre National d'Etudes Spatiales (CNES)	Pleiades: 1 coverage per year (up to 40 in case of unrest)
Canadian Space Agency (CSA)	Radarsat-2: 30 scenes / year Archive data
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	TerraSAR-X: 130 scenes / year, plus archive scenes of past acquisitions
European Space Agency (ESA)	ERS-1 / -2 / ENVISAT-ASAR, Sentinel-1, -2: Any available acquisition
Japan Aerospace Exploration Agency (JAXA)	ALOS-2: : 20 scenes / year ALOS-1, JERS: to be determined
National Aeronautics and Space Administration (NASA)	ASTER any available acquisition EO-1 (Hyperion) any available acquisition MODIS: any available acquisition
USGS	Landsat-8: any available acquisition
EUMETSAT	MSG-SEVIRI: any available acquisition

CEOS acceptance as a Permanent Supersite - “Mt. Etna”



CEOS agencies intend to support the Mt. Etna Supersite with the following data resources:

Agenzia Spaziale Italiana (ASI)	COSMO-Skymed: 150 scenes / year 350 scenes of past acquisitions
Centre National d'Etudes Spatiales (CNES)	Pleiades: 1 coverage per year (up to 40 in case of unrest)
Canadian Space Agency (CSA)	Radarsat-2: 30 scenes / year Archive data
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	TerraSAR-X: 130 scenes / year, plus archive scenes of past acquisitions
European Space Agency (ESA)	ERS-1 / -2 / ENVISAT-ASAR, Sentinel-1, -2: Any available acquisition
Japan Aerospace Exploration Agency (JAXA)	ALOS-2: : 16 scenes / year ALOS-1, JERS: to be determined
National Aeronautics and Space Administration (NASA)	SAC-D/Aquarius: any available acquisition ASTER 44 images/year EO-1 (Hyperion) 22 images/year MODIS: any available acquisition
USGS	Landsat-8: any available acquisition
EUMETSAT	MSG-SEVIRI: any available acquisition
NOAA	NPP/Suomi: any available acquisition

Space Agencies	Technical Issues	Data policy	Cons
ESA	Access through the ESA Virtual archive	Open access (registered)	No reporting requested
DLR	Access through a dedicated portal	Open access (registered)	No reporting requested
ASI	Data access through the PoCs	Open access (registered) Co-Is signatures	PoCs responsibility
CSA	Data access through the PoCs	Data availability only for Supersites Users	PoCs responsibility
JAXA	Contacted: No answer	Contacted: No answer	Unknown
EUMETSAT (see table)	Through INGV facilities	Contacted: TBD	Unknown
CNES, NOAA	To be contacted	To be contacted	Unknown
USGS, NASA	Contacted: TBD	Contacted: TBD	Unknown

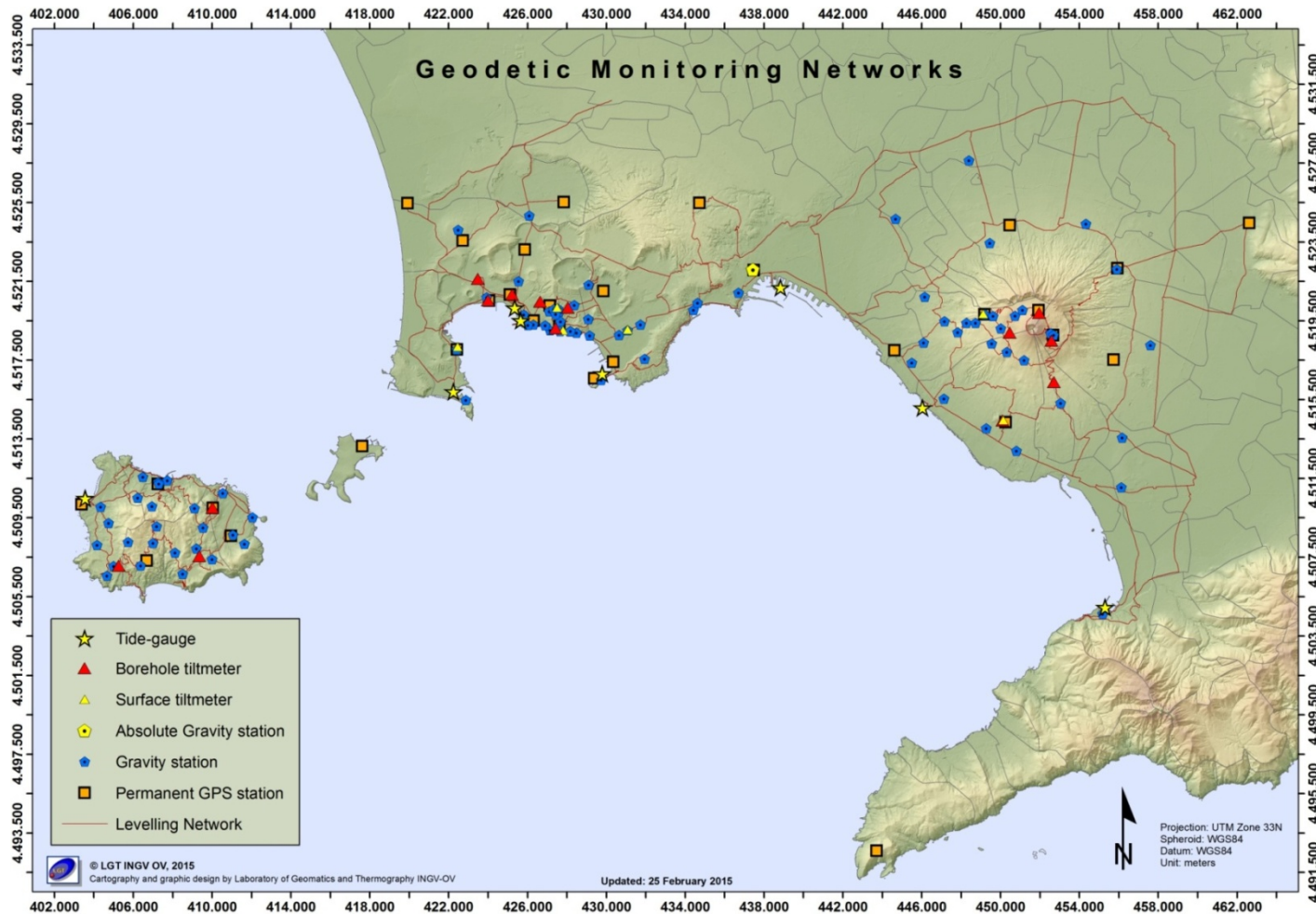
Data	Technical issues	Data Policy
AVHRR	INGV directly acquires data by means of its own antenna	To be defined
MODIS	INGV directly acquires data by means of its own antenna	To be defined
MSG-SEVIRI METOP	INGV directly acquires data by means of its own antenna with EUMETSAT license	To be defined
ASTER	INGV access the data by specific agreement with NASA- JPL	To be defined
LANDSAT	INGV access the data by specific agreement with USGS	Free access
HYPERION	INGV access the data from EROS data centre	Free access
PLEIADES	These data are needed and requested	To be defined
SAC-D	These data are needed and requested	To be defined
NPP	These data are needed and requested	To be defined

From the Supersites Proposals (A.5.5.c “Data policy and vision for data access”)

- **Seismic and GPS data** of Vesuvius/Campi Flegreii and Mt. Etna described in the introduction (...) **are already accessible and available** through the ORFEUS portal (<http://www.orfeus-eu.org>) and the RING (Rete Integrata Nazionale GPS) network (<http://ring.gm.ingv.it/>), respectively.
- **Seismic data can be** openly and anonymously **accessed**.
- **GPS data need the authorization except for selected stations** that are fully open (<ftp://gpsfree.gm.ingv.it/./outgoing/>).
- In both cases, more stations will be implemented in the next future.
- Moreover, **these data** together with other kinds of volcanological observations **will be also accessible in** the framework of **MED-SUV** (the FP7 EU funded Project “MEDiterranean SUPersites Volcanoes”) as soon as the official project portal will be implemented.

The MED-SUV project (INGV as the project leader), with 24 national and international partners and a budget of 6 million Euros, will support the Italian Volcanoes Supersites initiative until May, 2016.

Geodetic Networks in the Neapolitan Volcanic District



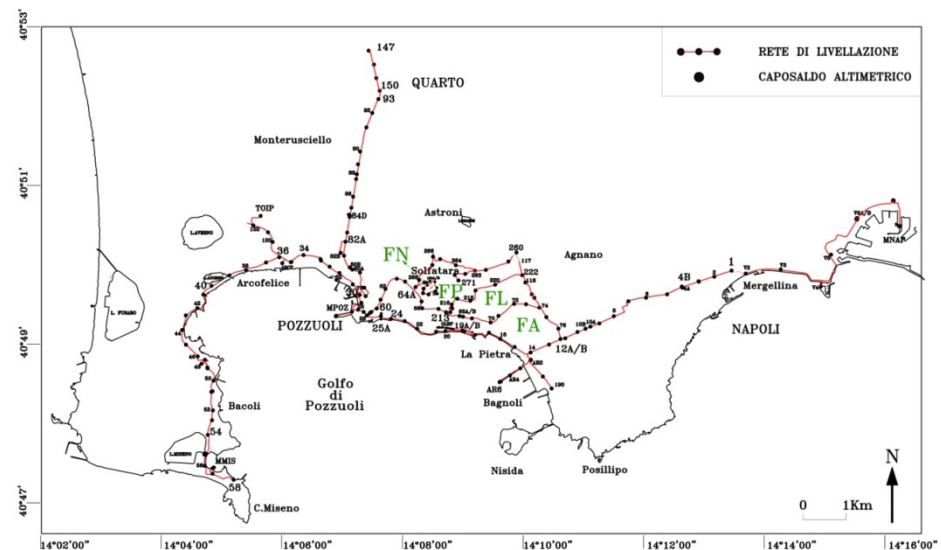


Napoli - Pozzuoli - Miseno line
Pozzuoli - Quarto line

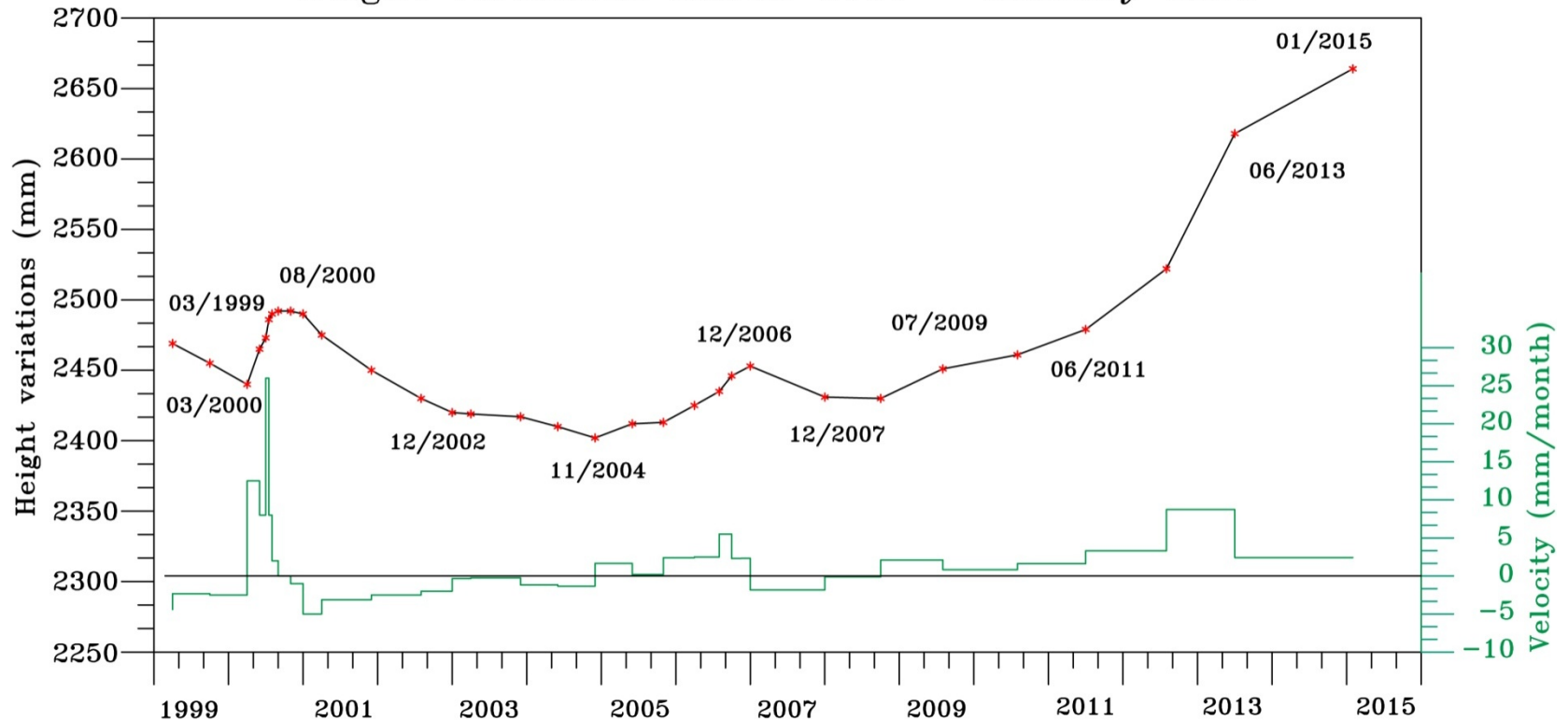
(C. Del Gaudio et al., INGV-OV,
Internal Report)

The Campi Flegreii leveling network

- 370 benchmarks
- 140 Kms
- 15 loops
- coverage: $\sim 160 \text{ Km}^2$ - mean distance: 400ms

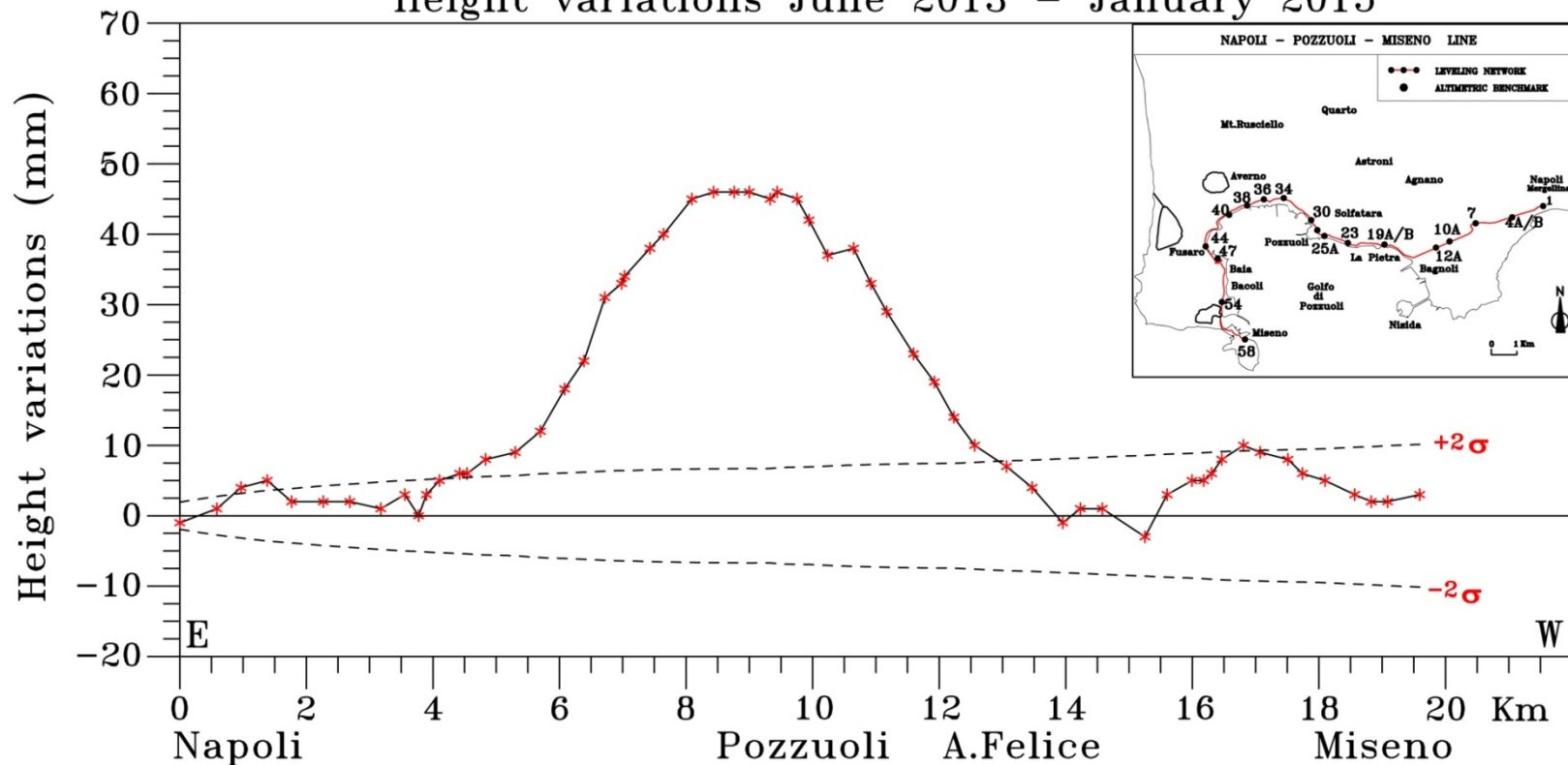


Benchmark n. 25A (Pozzuoli Corso Umberto) Height variations March 1999 – January 2015

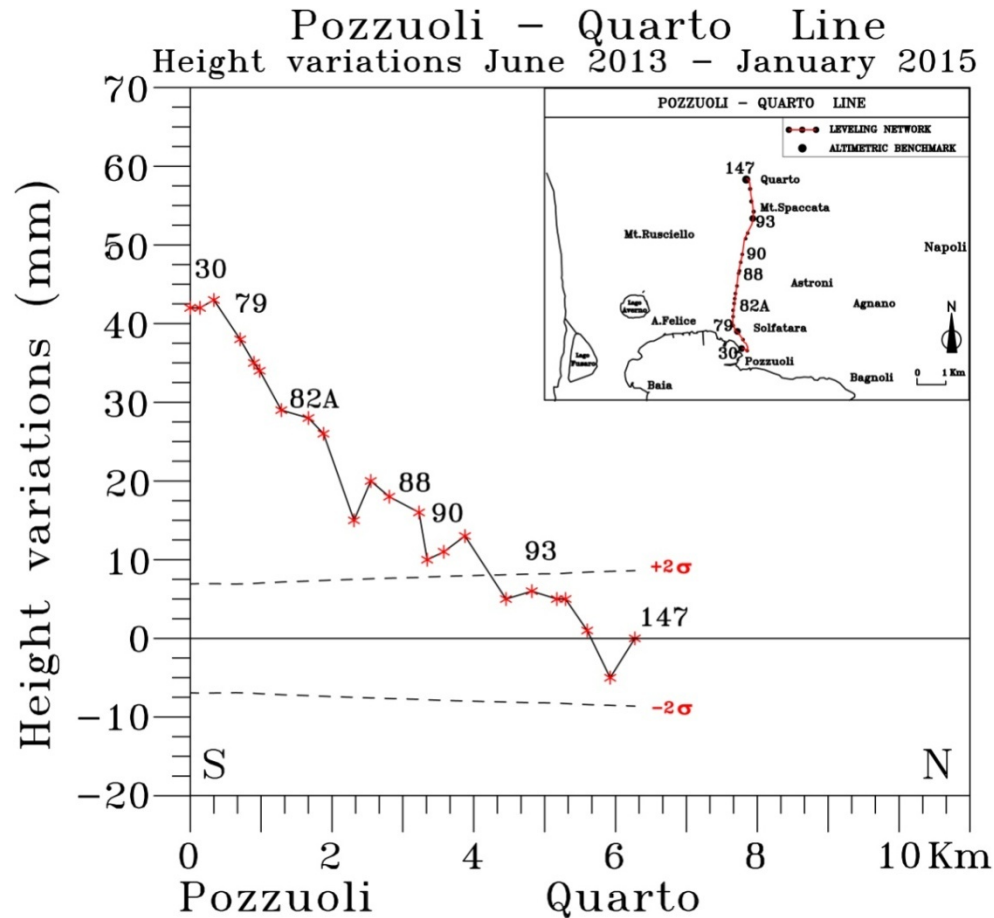


(C. Del Gaudio et al., INGV-OV, Internal Report)

Napoli - Pozzuoli - Miseno Line Height variations June 2013 - January 2015

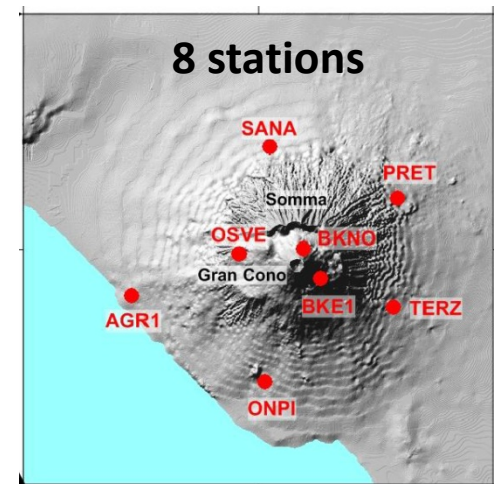
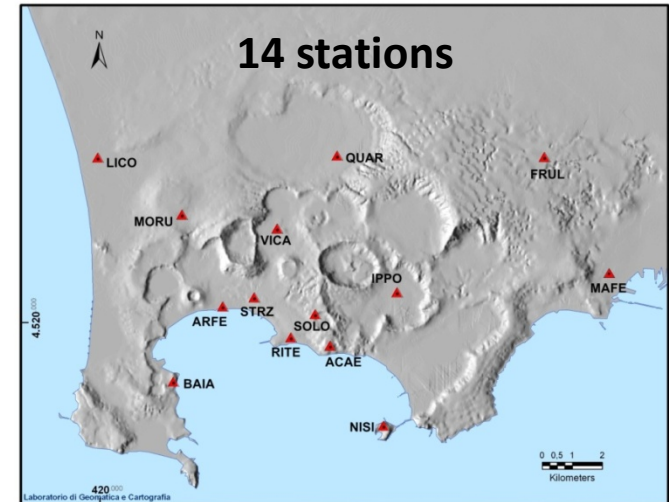
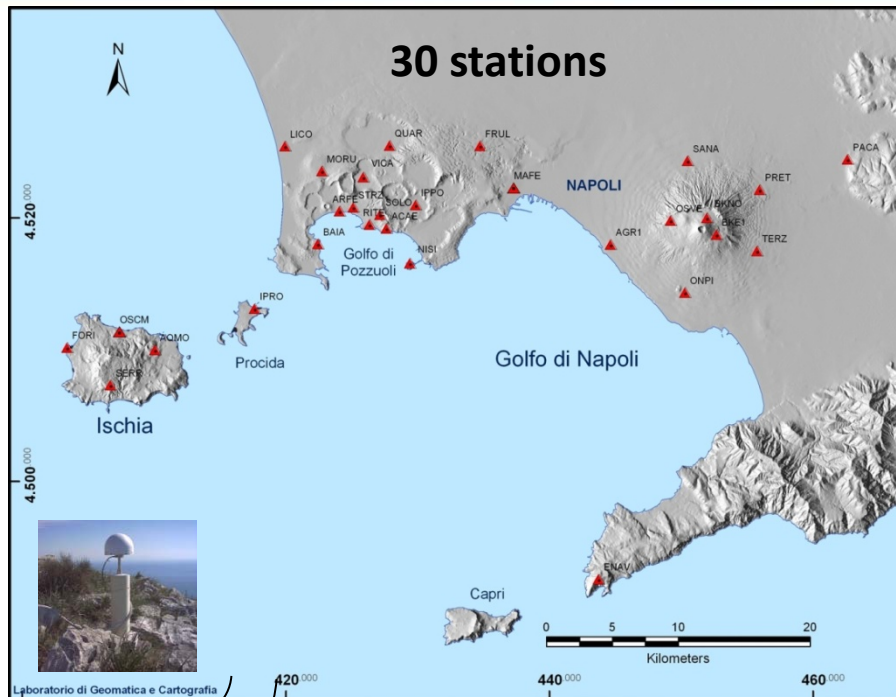
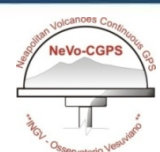


(C. Del Gaudio et al., INGV-OV, Internal Report)



(C. Del Gaudio et al., INGV-OV, Internal Report)

Geodetic Networks (CGPS, Continuous GPS)



30" sampling rate

Automatic system for daily download and processing

REMOTE CONTROL AND DATA DOWNLOAD

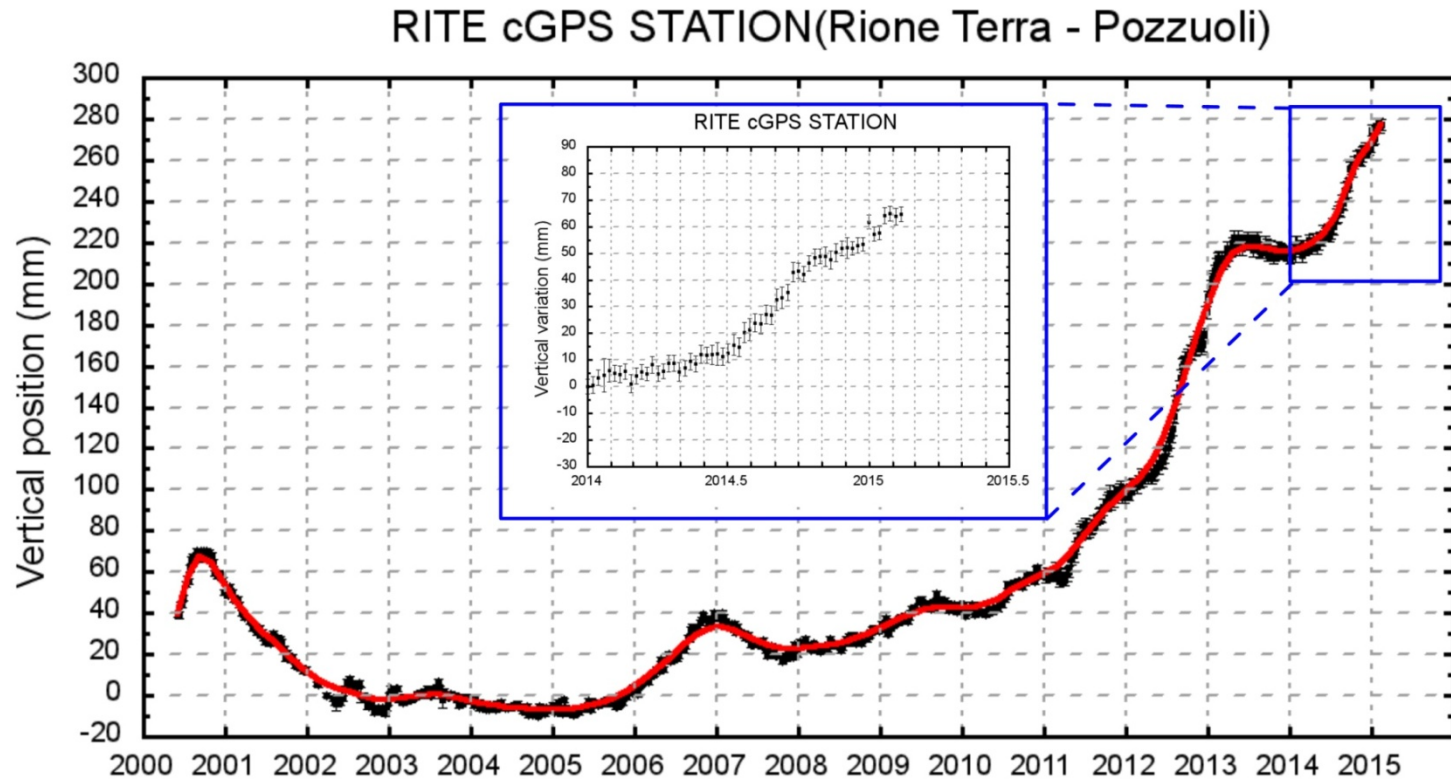
AUTOMATIC DATA DOWNLOAD AND DATA ARCHIVING
CHECK STATION STATUS

DATA VALIDATION AND QUALITY CHECK

CHECK RAW DATA
RINEX AND QUALITY CHECK (TEQC)

DATA PROCESSING

BERNESE GPS SOFTWARE v.5.0 (BPE)
GPS TIME SERIES



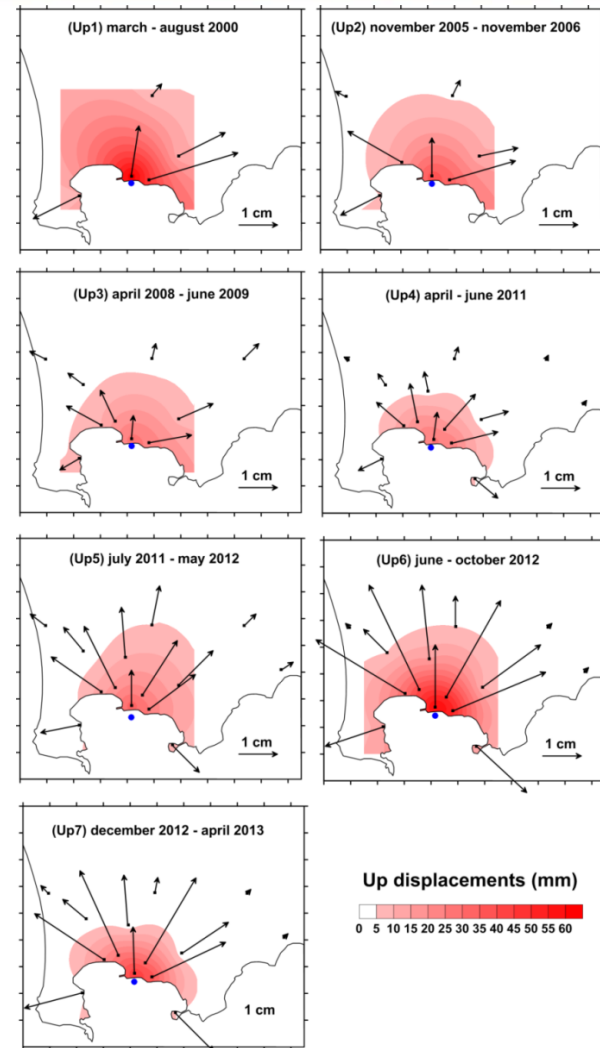
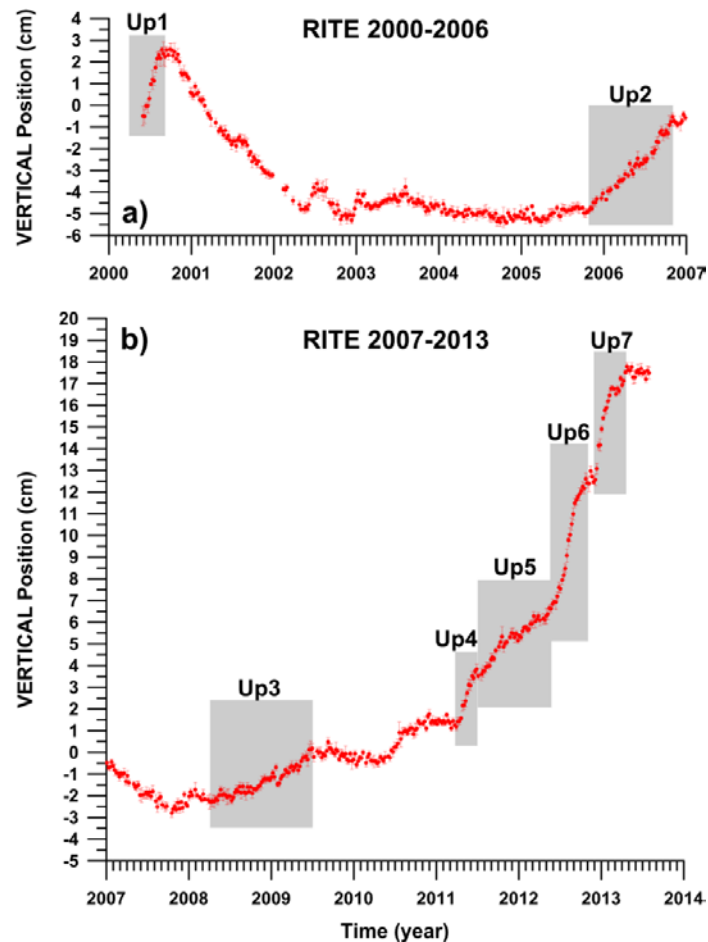
Vertical component of ground deformation for RITE CGPS station (2000-2015)

In the inner box : the detail from 01/2014 to 02/2015

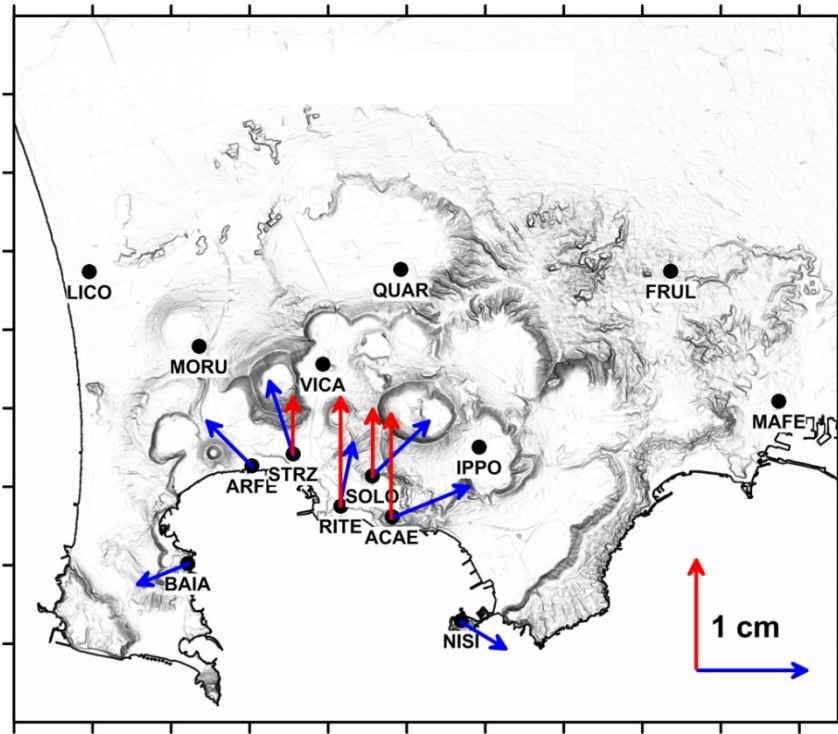
(P. De Martino, INGV-OV, Internal Report)

The Campi Flegreii deformation pattern inferred from CGPS data (2000-2013)

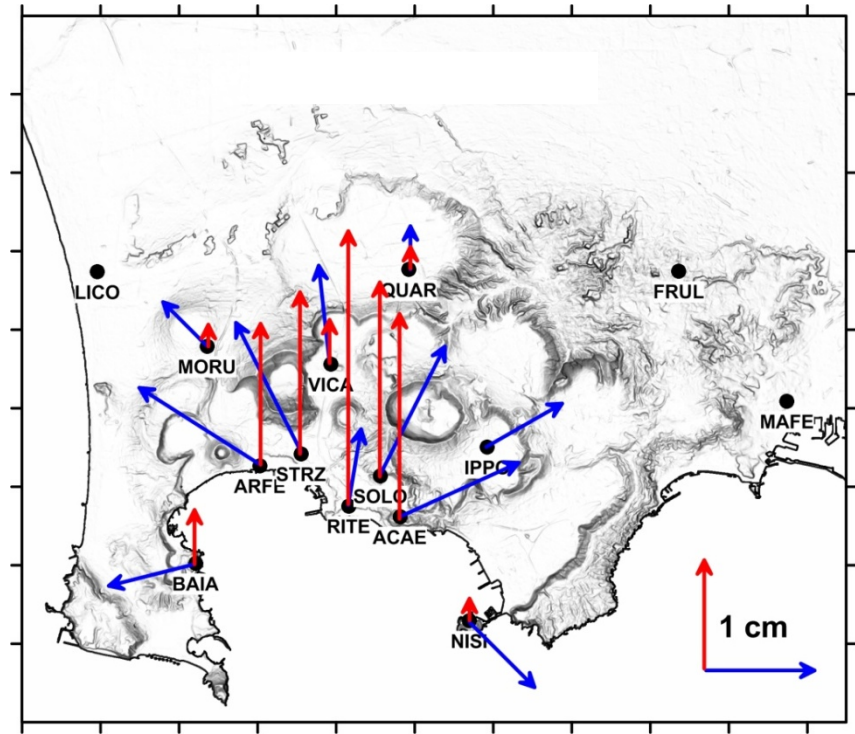
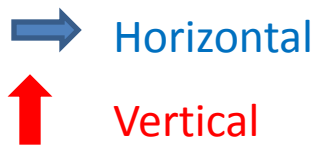
(from P. De Martino et al., 2014)



Horizontal and Vertical GPS deformation pattern (2014)



January - June 2014

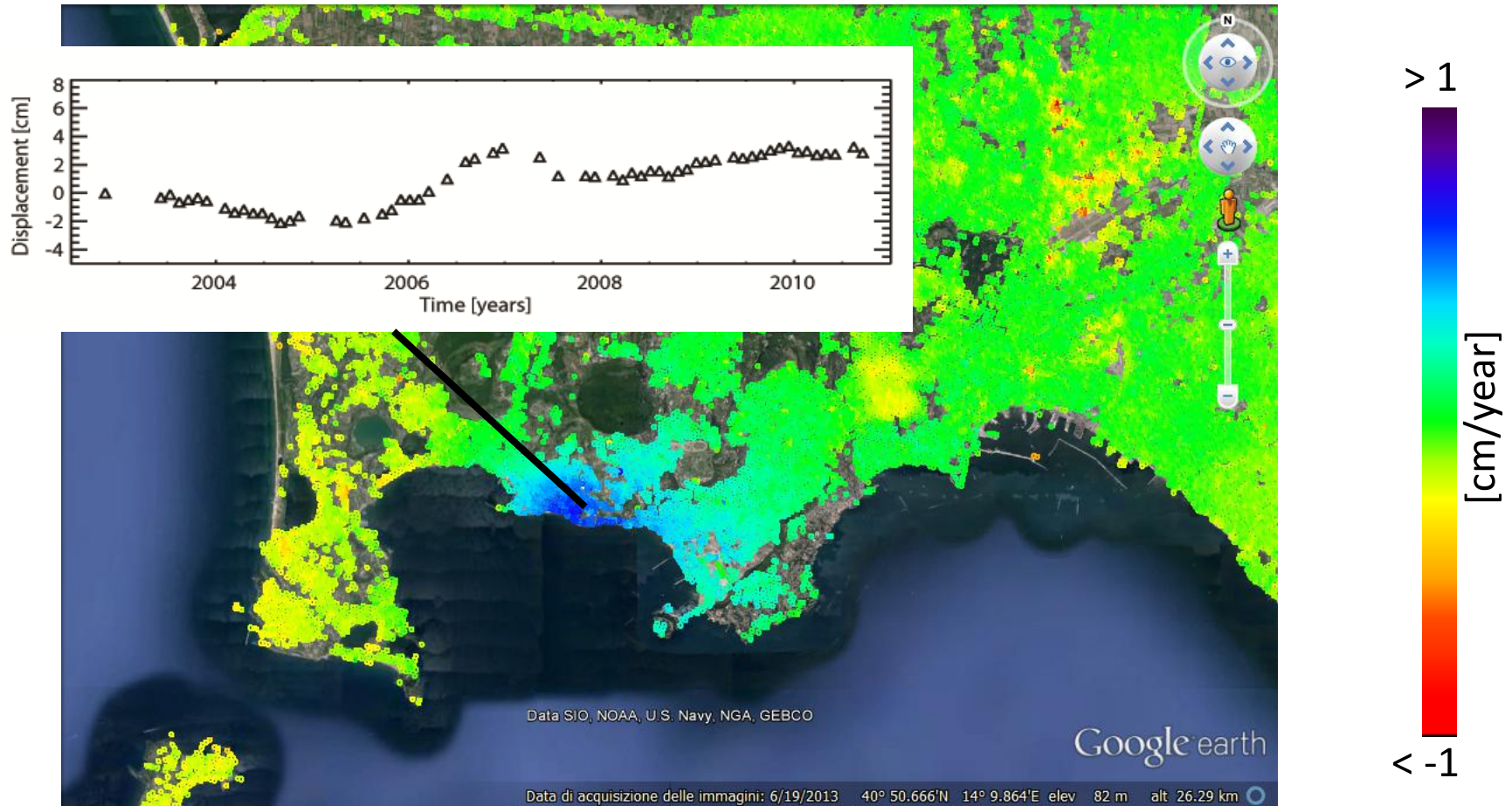


July - September 2014

(P. De Martino, INGV-OV, Internal Report)

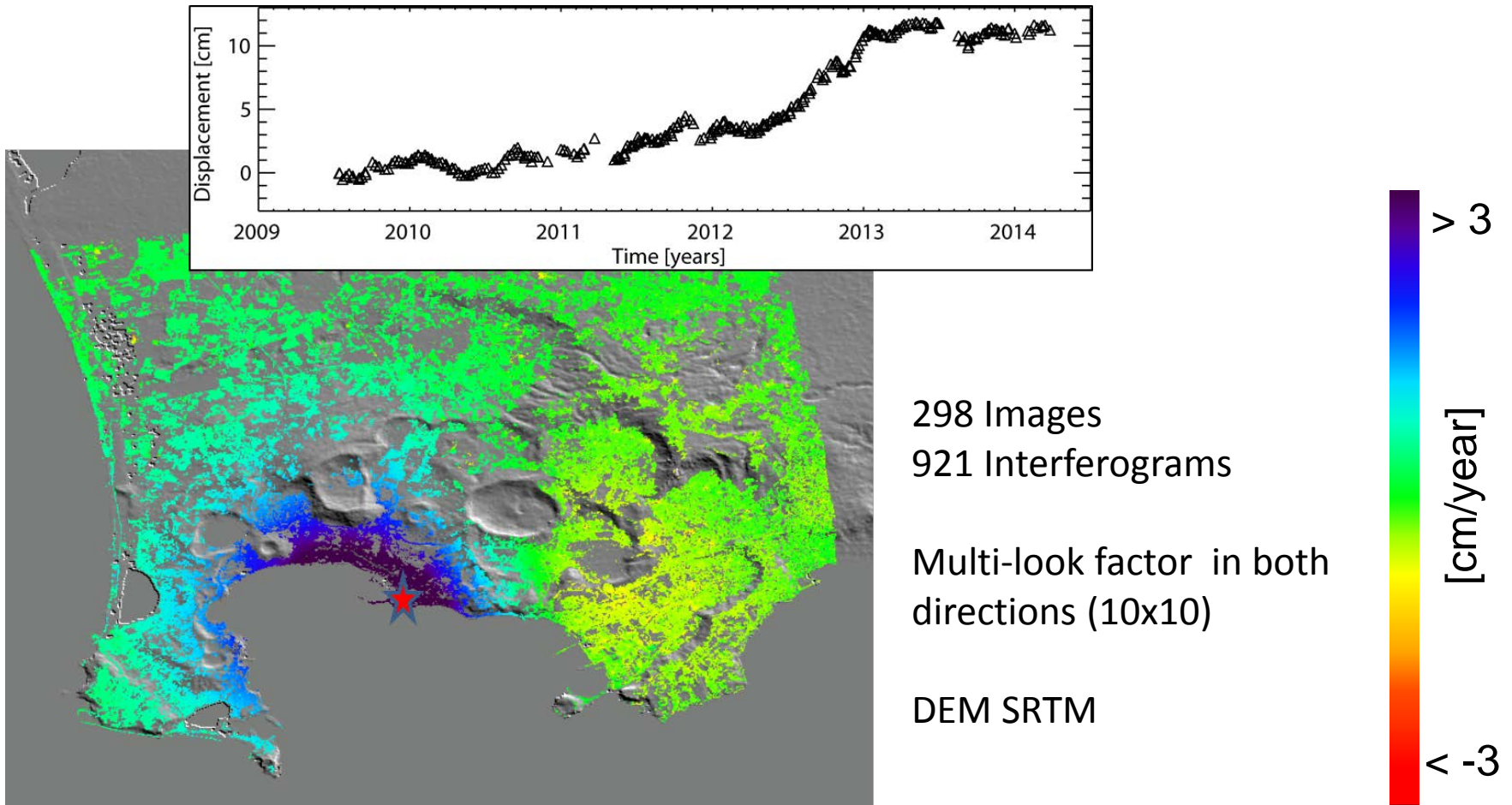
Campi Flegreii

60 ENVISAT Descending SAR images



IREA-CNR, from MED-SUV Project (Task 3.1)

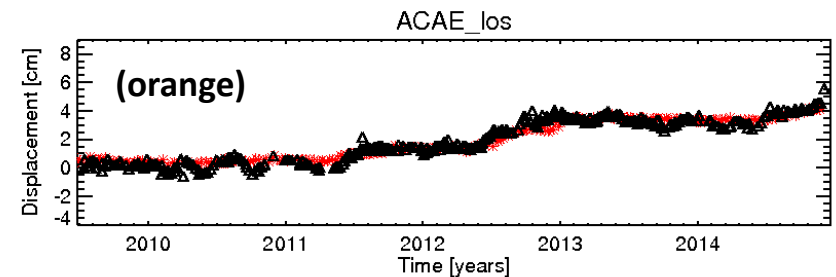
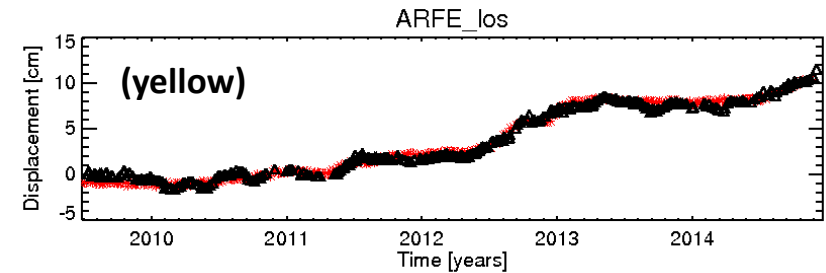
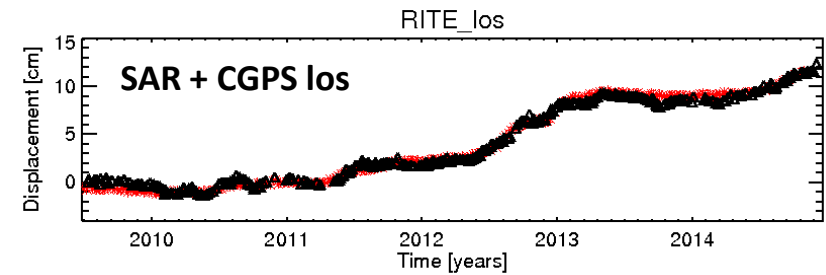
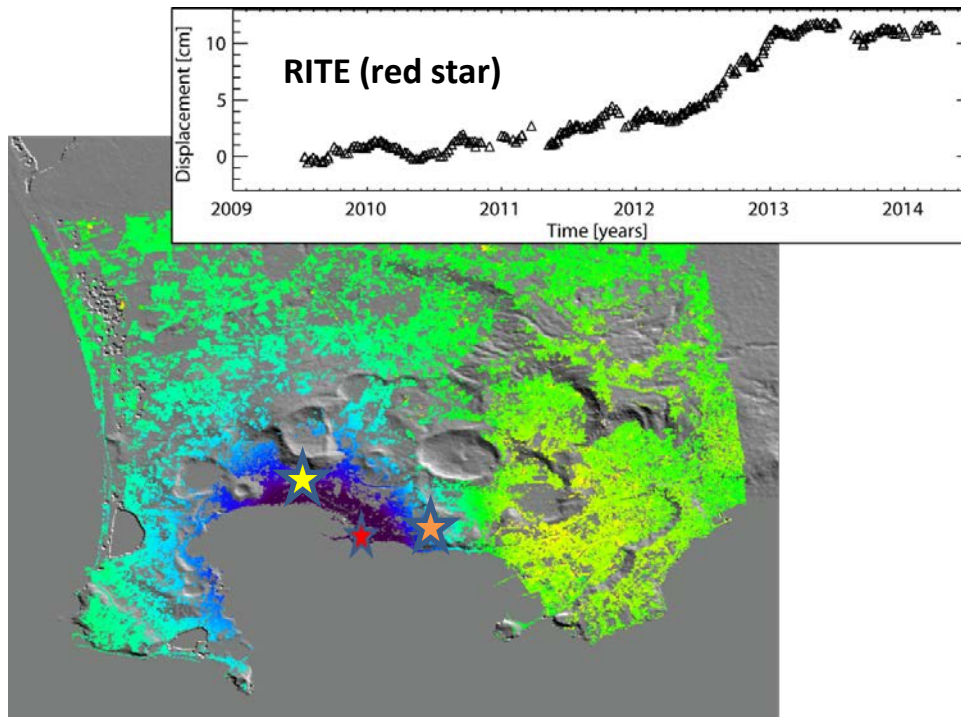
Campi Flegreii CSK Constellation: Ascending Mean Velocity Map (2009-2014)



IREA-CNR, from MED-SUV Project (Task 3.1)

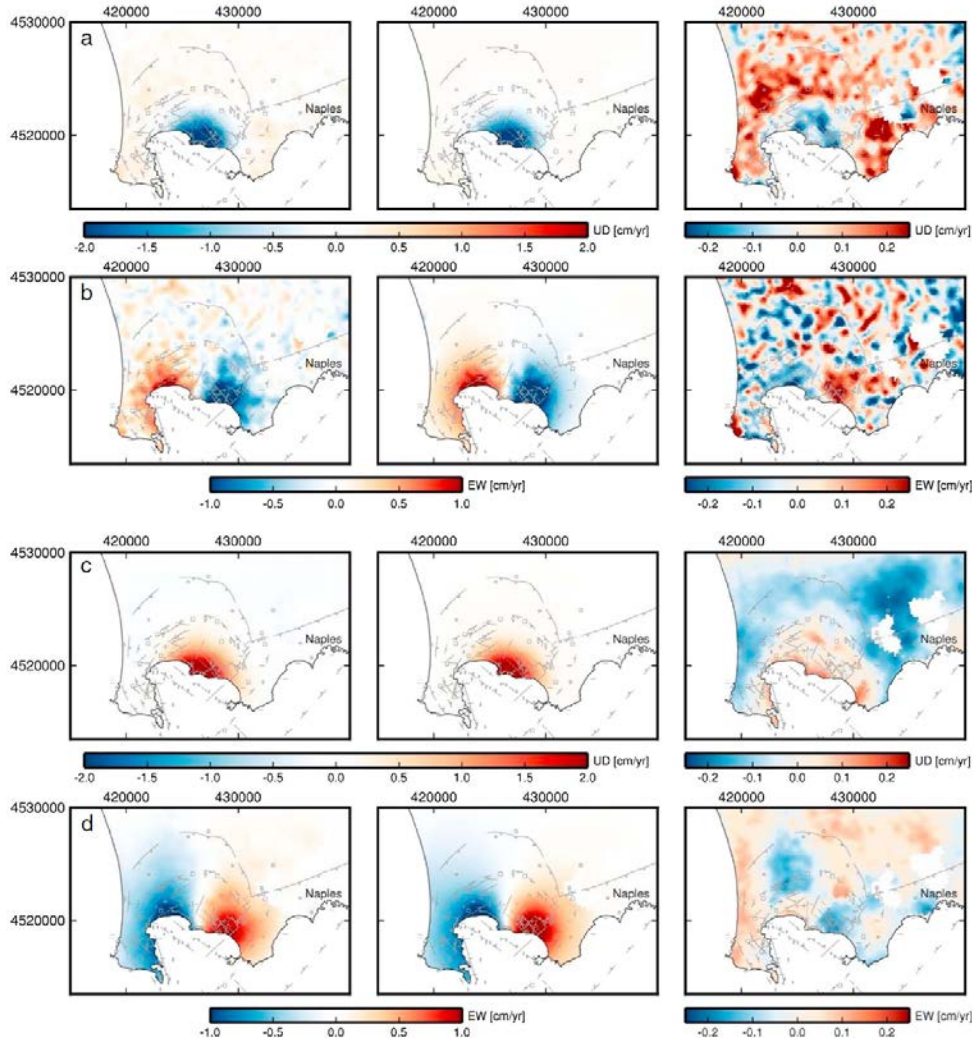
Campi Flegreii

CSK Constellation: Velocity Map + Comparison



△ SAR
★ CGPS

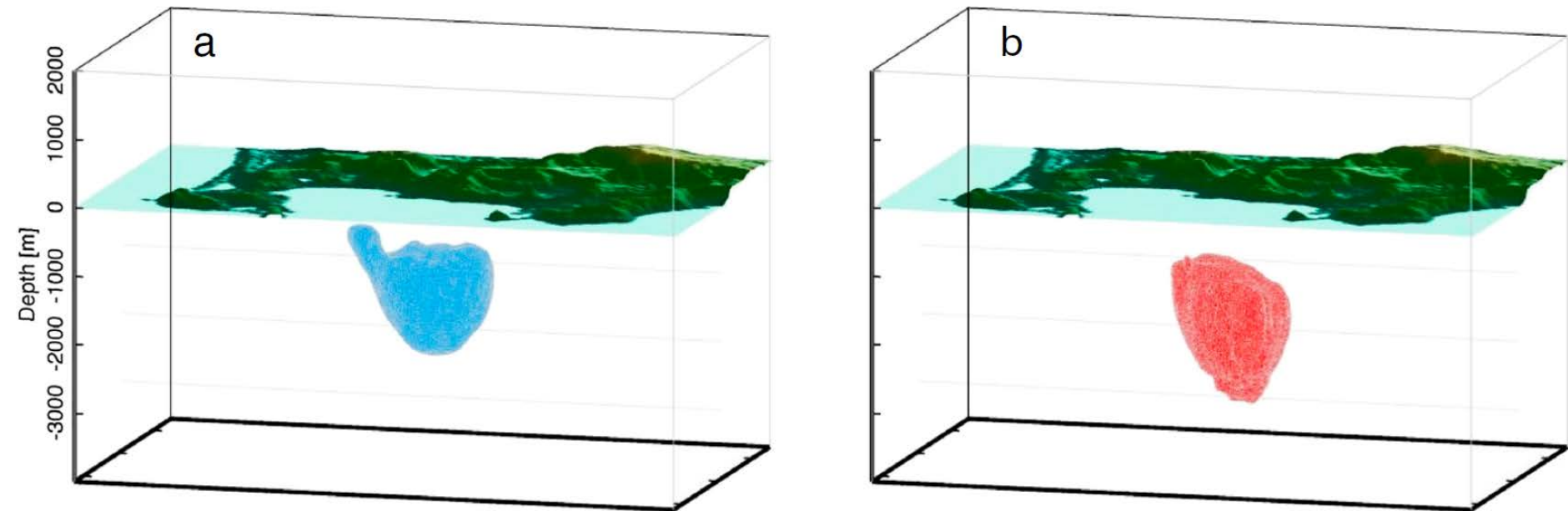
InSAR data processing by IREA-CNR, from MED-SUV Project (Task 3.1)
CGPS data processing by INGV-OV



Nonlinear inversion method from *Camacho et al., 2011* for modeling pressure sources with a free geometry.

- a) observed displacement rate, vertical direction, cm/year, subsidence period **1993-1999** (left), modeled displacement rate, vertical (middle), residual (right);
- b) observed displacement rate, E-W direction, cm/year, subsidence period **1993-1999** (left), modeled displacement rate, E-W (middle), residual (right);
- c) observed displacement rate, vertical direction, cm/year, inflation period **2007-2013** (left), modeled displacement rate, vertical (middle), residual (right);
- d) observed displacement rate, E-W direction, cm/year, inflation period **2007-2013** (left), modeled displacement rate, E-W (middle), residual (right).

(from Samsonov et al., 2014)



a) 3D location and shape of deflation source model for the **subsidence period 1993-1999**

b) 3D location and shape of inflation source model for the **uplift period 2007-2013**

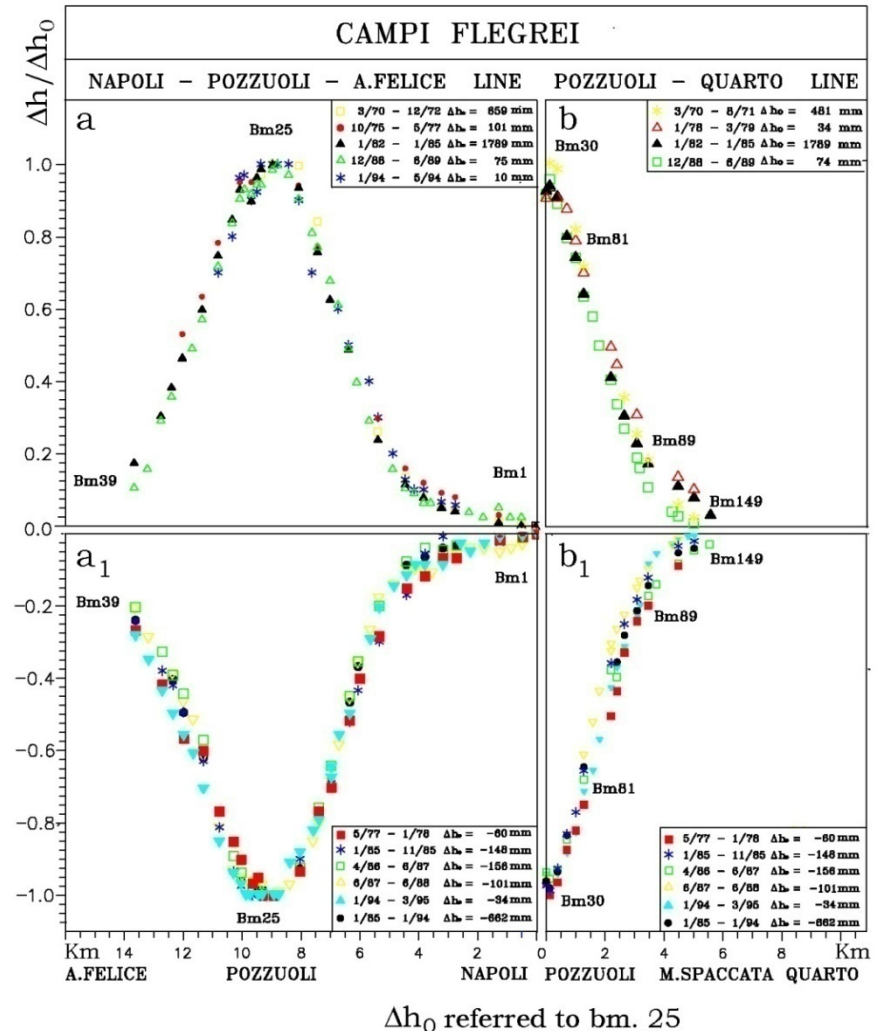
Blue color denotes **negative** pressure changes, **red color** denotes **positive** ones

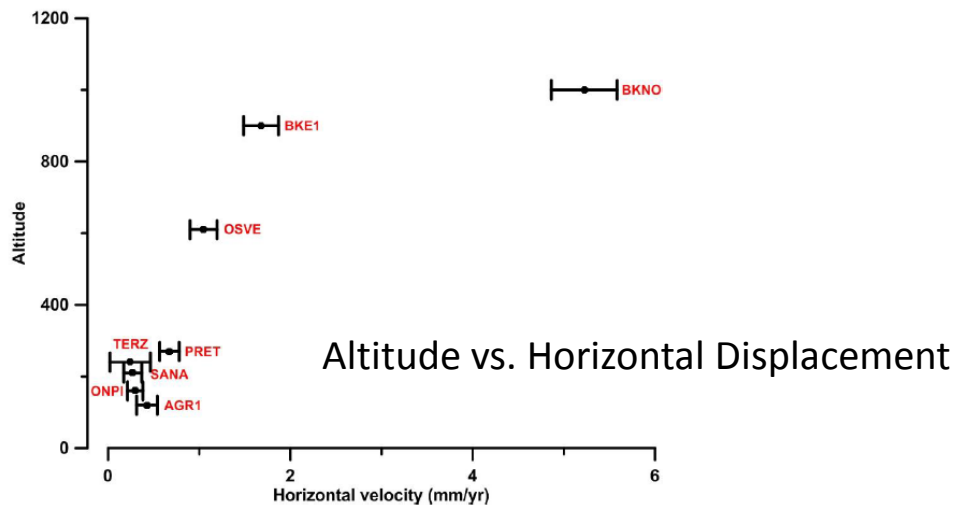
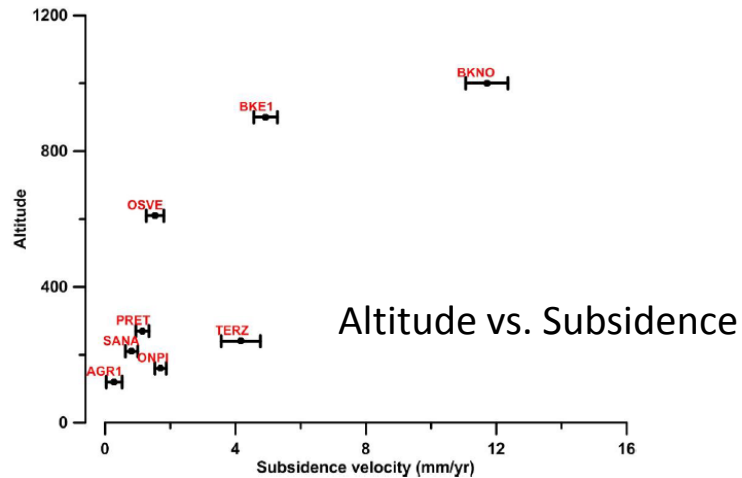
(from Samsonov et al., 2014)

Invariance of the deformation pattern from deflation to inflation

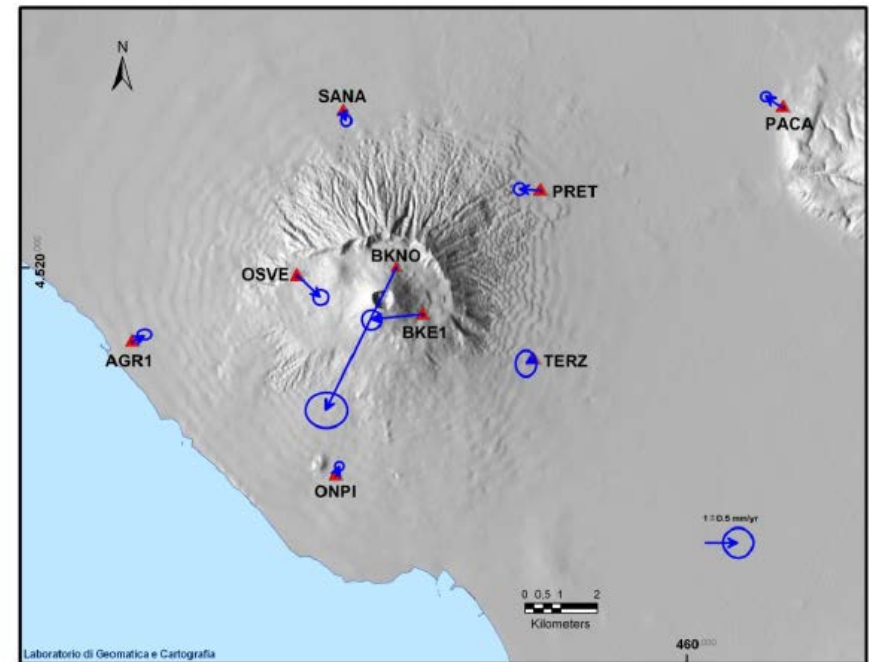
Height variations of single leveling benchmarks along EW and NS profiles during given time intervals, normalized to the maximum deformation value in the same time interval

(from Orsi et al., 1999;
Del Gaudio et al., 2010)

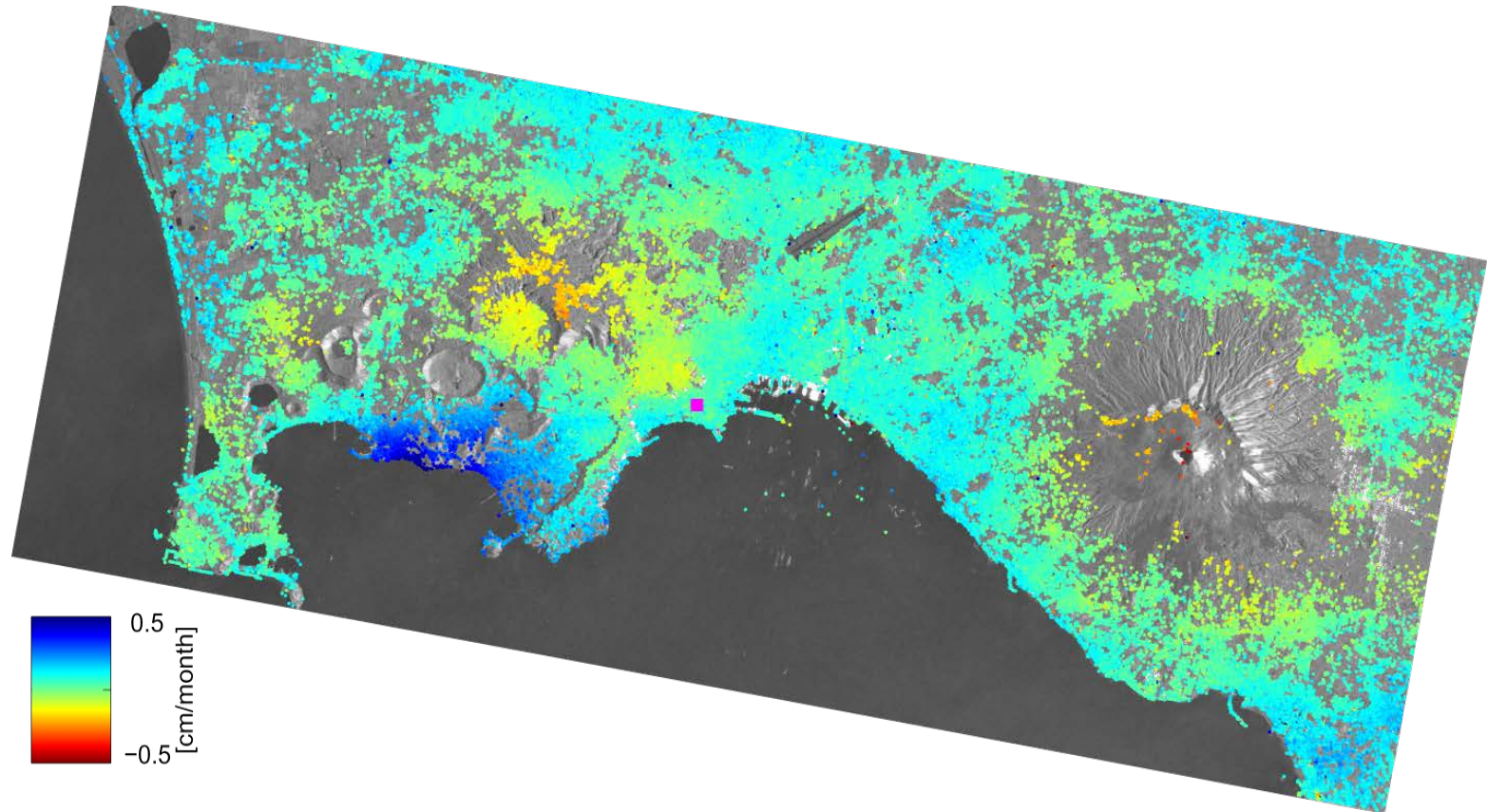




Mt. Vesuvius:
Ground deformations from 2001 to 2012
(from U. Tammaro et al., 2013)



The Neapolitan Volcanic District S1-A Velocity Map (10/2014-03/2015)



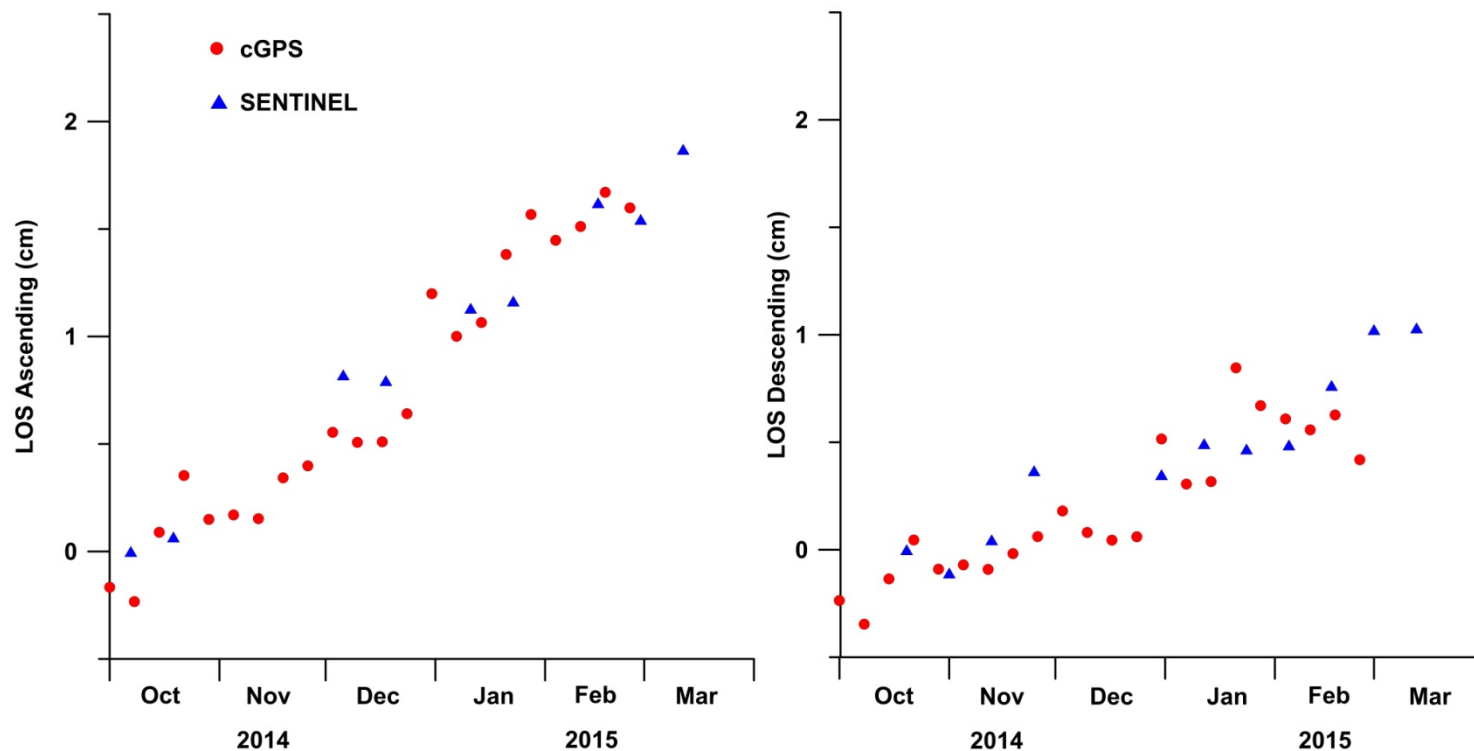
S1-A Descending Velocity Map (10 images – 7/10/2014-12/03/2015)
Copernicus data (2015)/ESA/DLR Microwaves and Radar Institute/e-GEOS/INGV/GFZ
SEOM INSARAP study

Campi Flegreii

S1-A - CGPS Comparison (10/2014-03/2015)



ACAE cGPS Station - SENTINEL Time Series Comparison



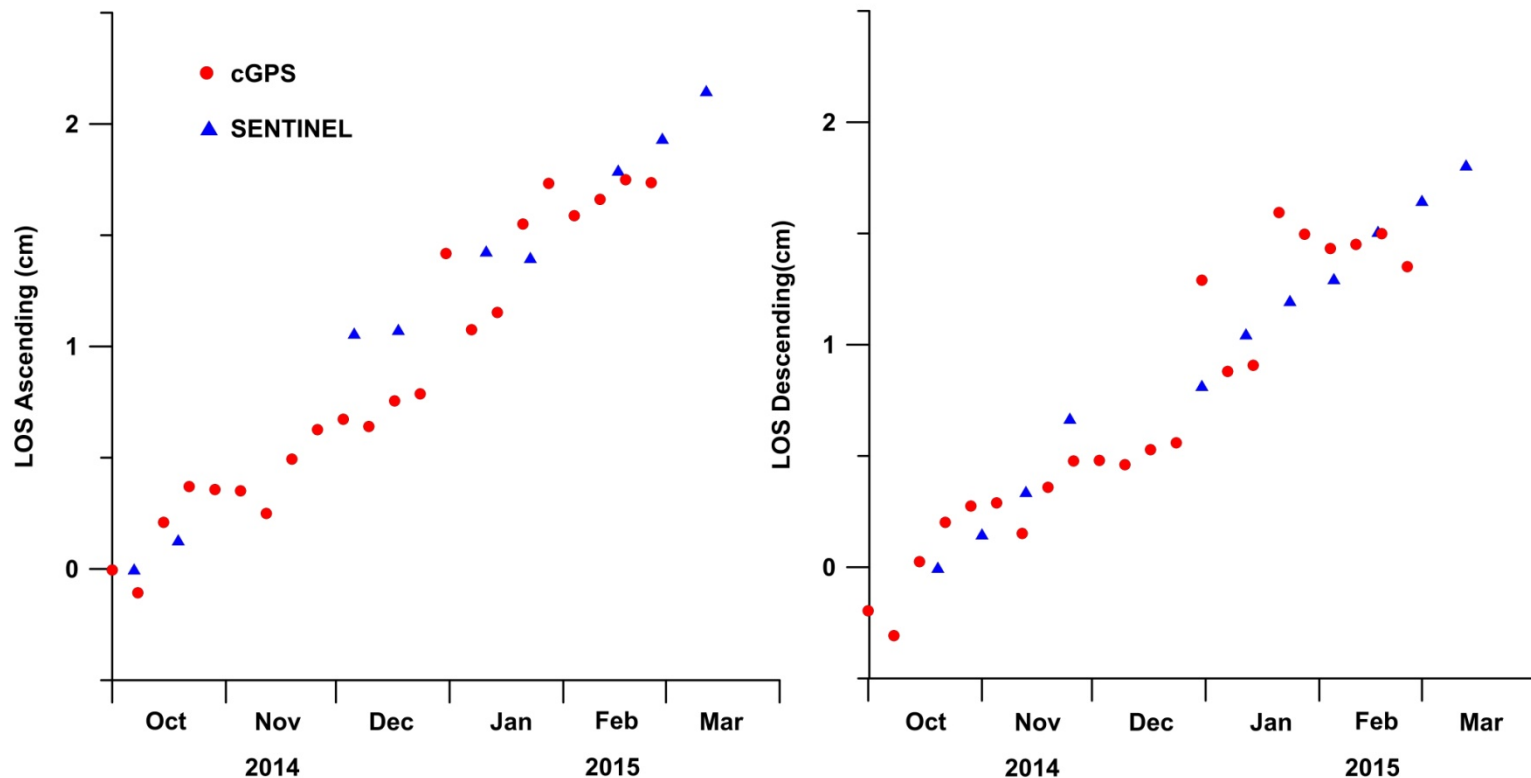
Comparison between S1-A and CGPS LOS data (ACAE station, Campi Flegreii)
Copernicus data (2015)/ESA/DLR Microwaves and Radar Institute/e-GEOS/INGV/GFZ
SEOM INSARAP study

Campi Flegreii

S1-A - CGPS Comparison (10/2014-03/2015) (2)

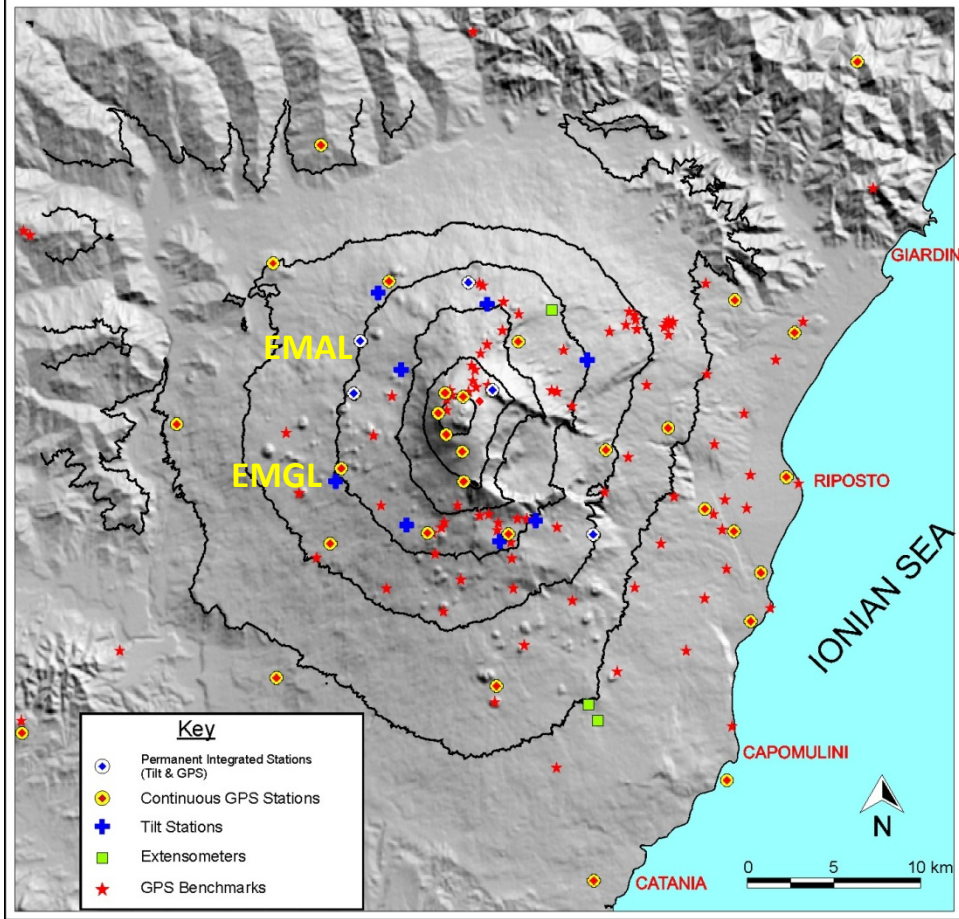


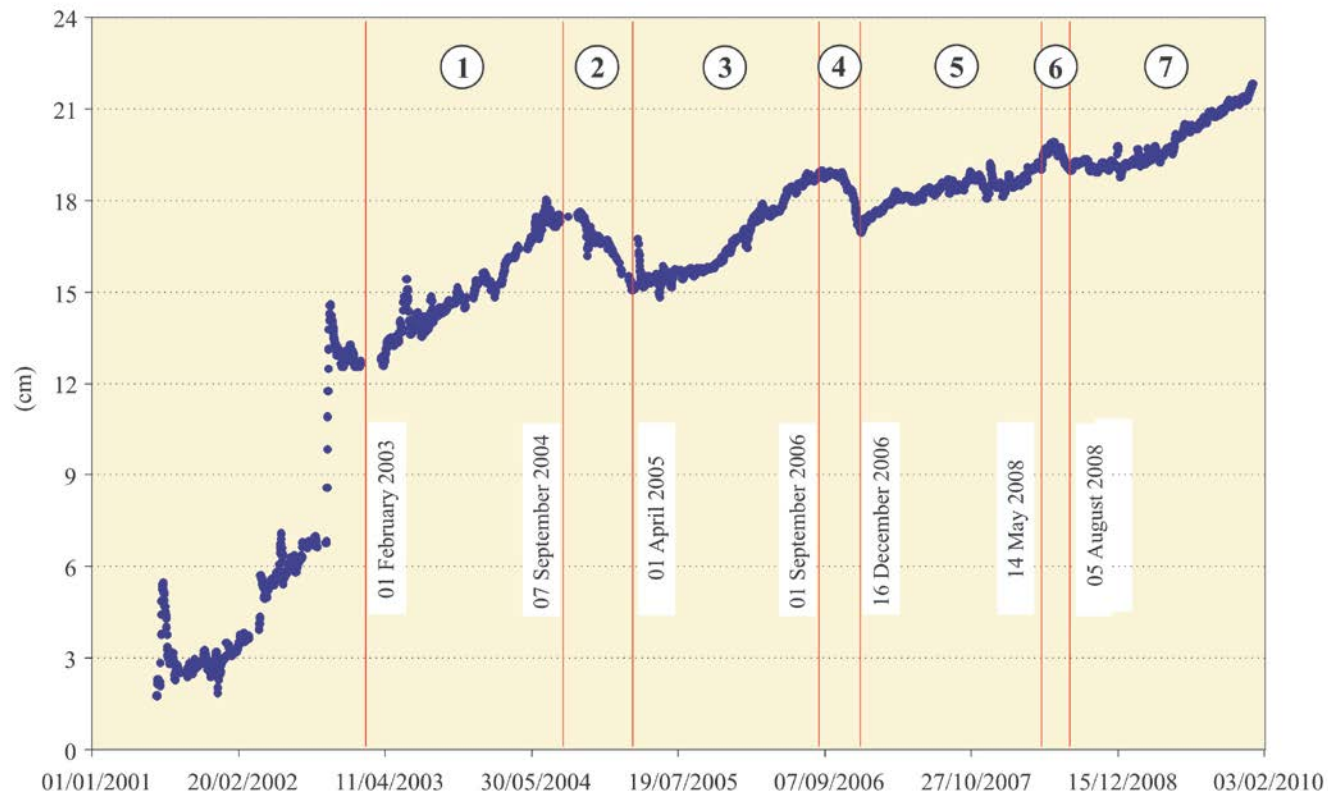
RITE cGPS Station - SENTINEL Time Series Comparison



Comparison between S1-A and CGPS LOS data (RITE station, Campi Flegreii)
Copernicus data (2015)/ESA/DLR Microwaves and Radar Institute/e-GEOS/INGV/GFZ
SEOM INSARAP study

INGV Monitoring Geodetic Networks of M. Etna

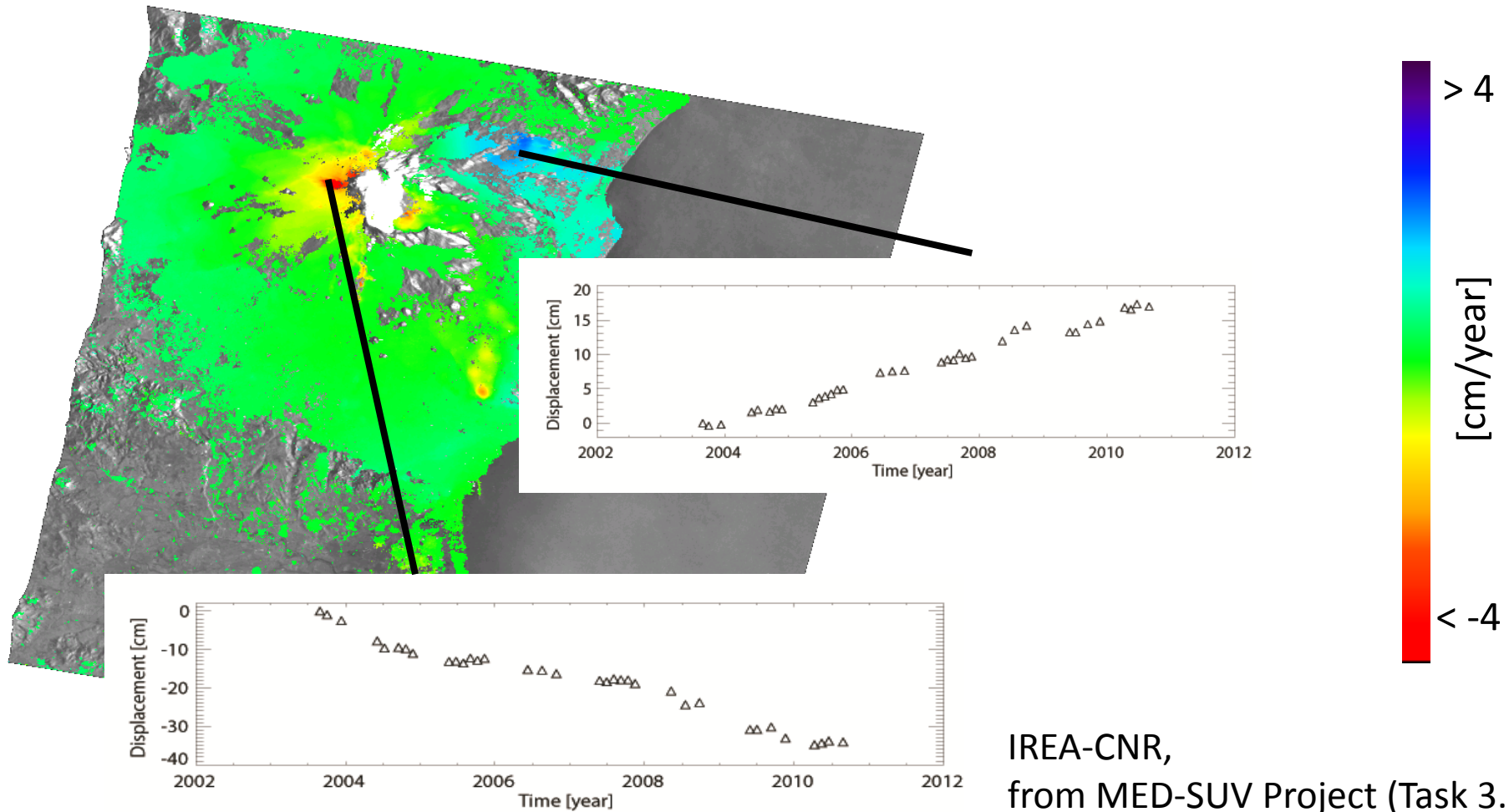




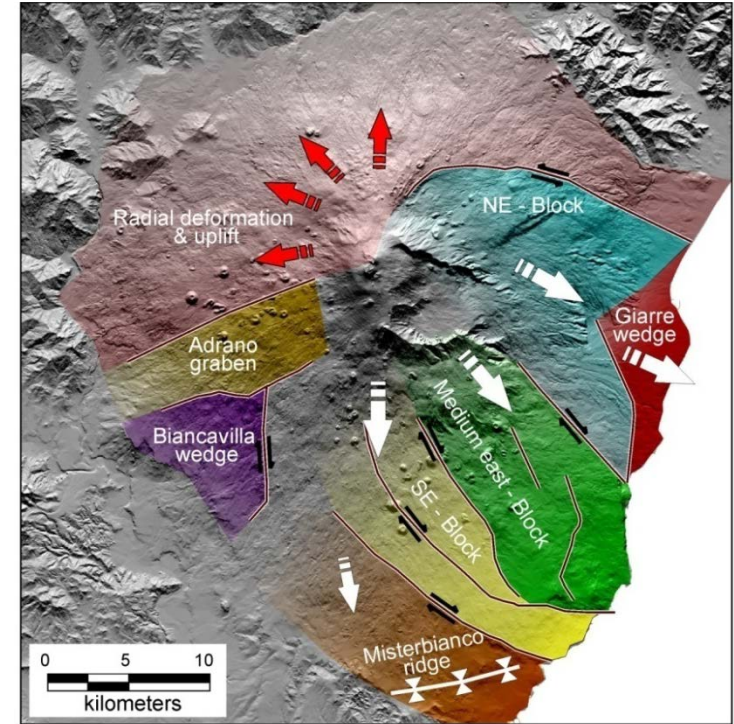
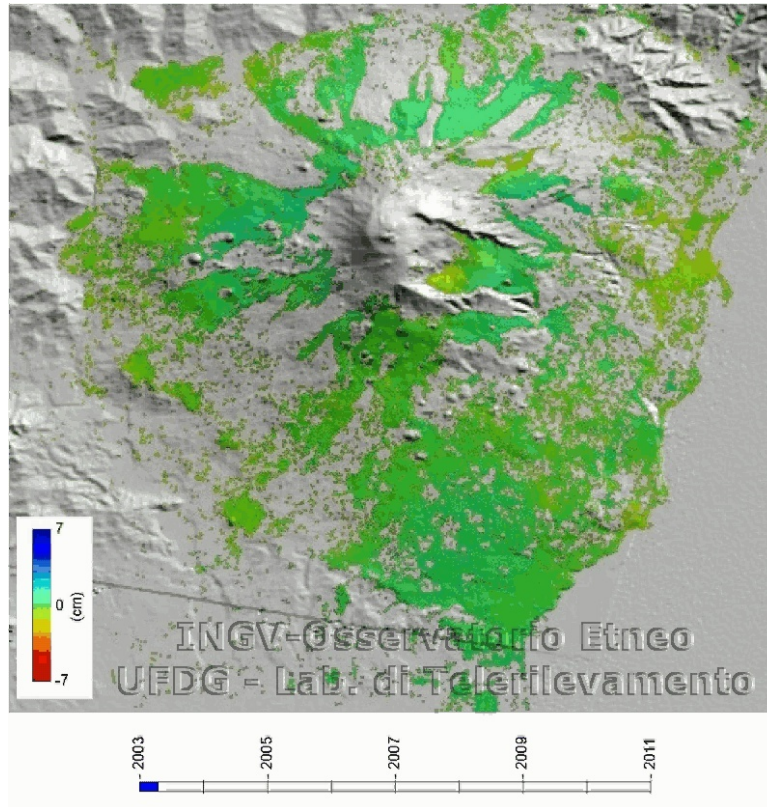
Time-series of the length variations of the baseline between the EMAL and EMGL CGPS stations. Vertical lines separate the seven different periods of volcanic activity, pointed out on the basis of the changes in the slope of the baseline length (INGV-OE)

Mt. Etna

34 ENVISAT Descending SAR images



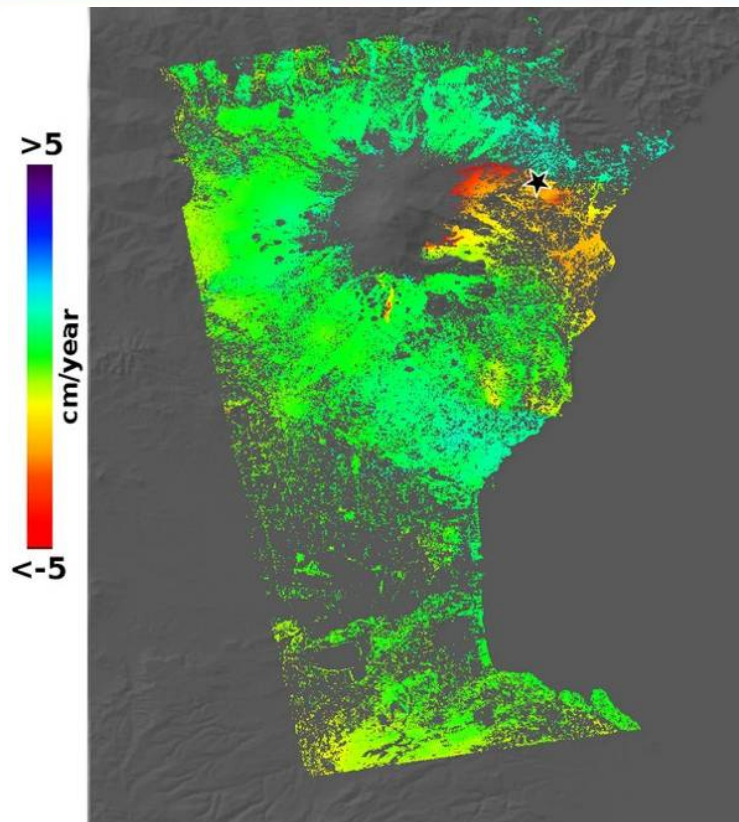
Mt. Etna kinematics revealed by ENVISAT SAR data (2003-2010)



The spatial resolution of InSAR technique allowed a detailed model of the surface displacement: Mt. Etna is dissected into different kinematic blocks, showing different style and intensity of deformation. They are the result of the complex magmatic and tectonic dynamics acting at the same time on the volcano.

Mt. Etna

ALOS-PALSAR Ascending Mean Velocity Map (2007-2010)



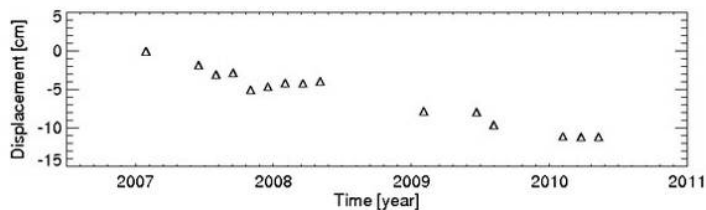
18 Images

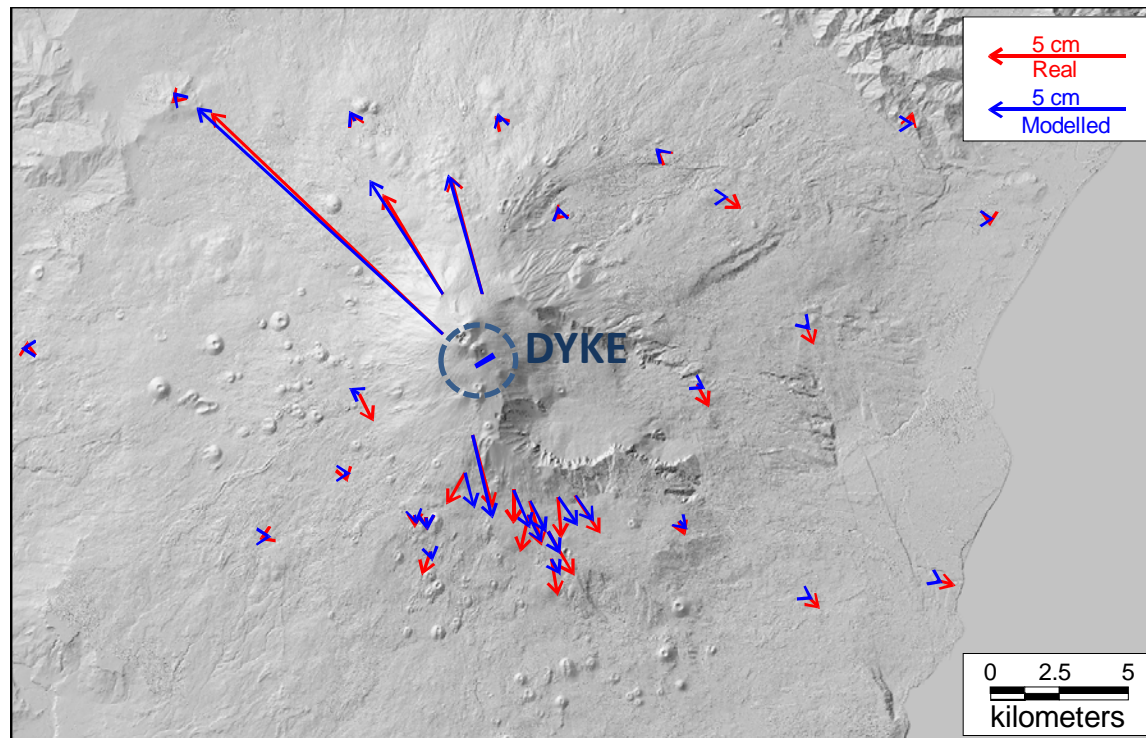
37 Interferograms

Multi-look factor of 16 in azimuth and 8 in range

High resolution DEM (5 m pixel spacing)

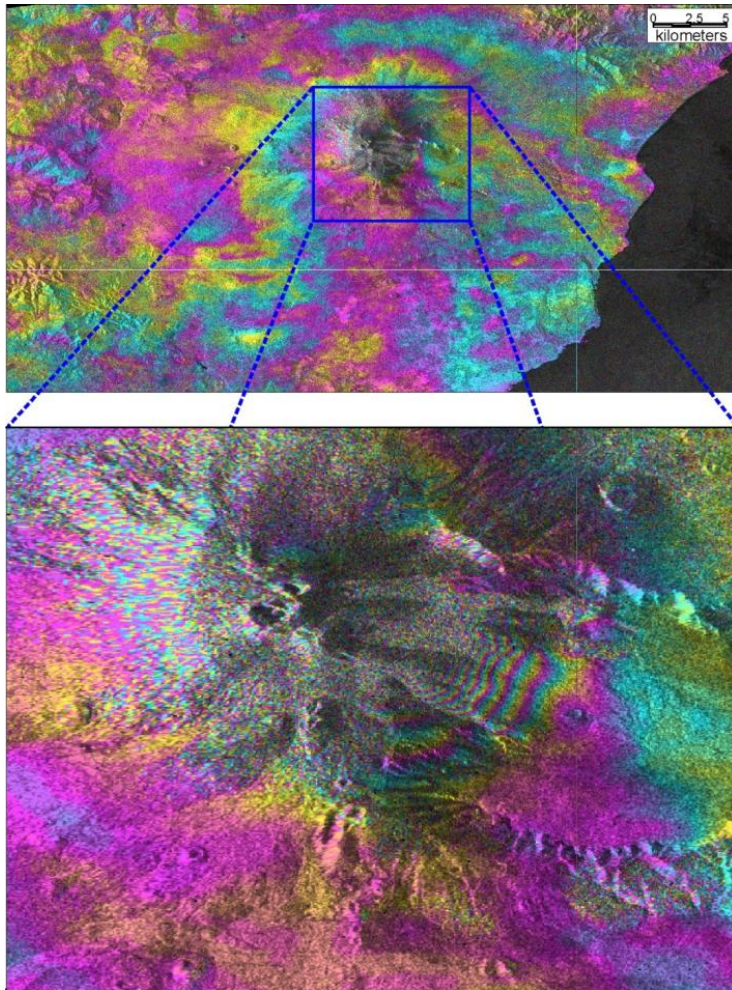
IREA-CNR, from MED-SUV Project (Task 3.1)





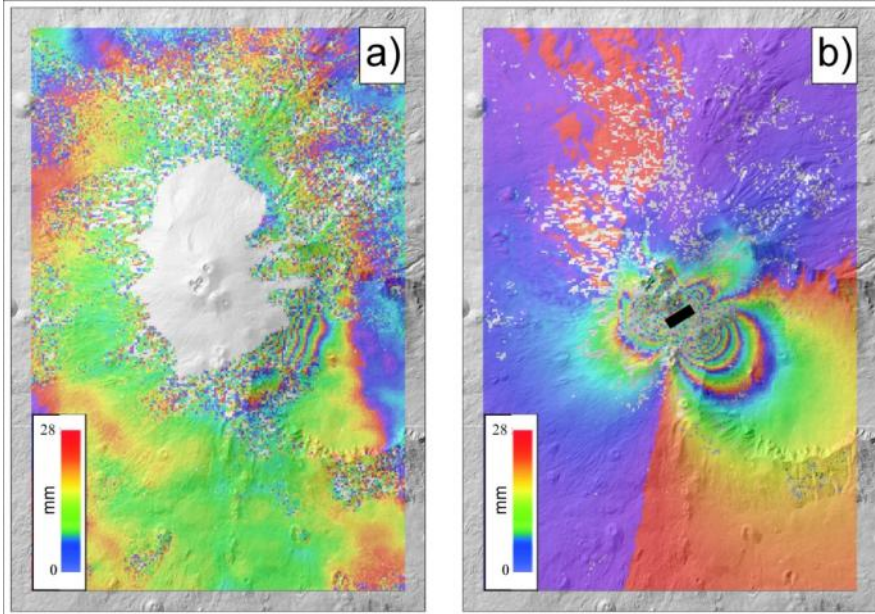
Comparison between July 2014 and January 2015 GPS surveys: a ground deformation pattern mainly affecting the uppermost part of the volcano has been pointed out by the GPS network, above 2000 m of elevation, with a strong decay of the deformation.

This pattern suggests a very shallow source producing the observed displacements: here the position of the arrows suggests that a planar source (a new dyke) probably intruded beneath the SEC and fed this eruption. Indeed, the inversion results indicate a very shallow-subvertical dislocation plane (deep=61m), located beneath the eruptive fissures, NE-SW oriented, with a tabloid geometry (length x width=570x370 m).



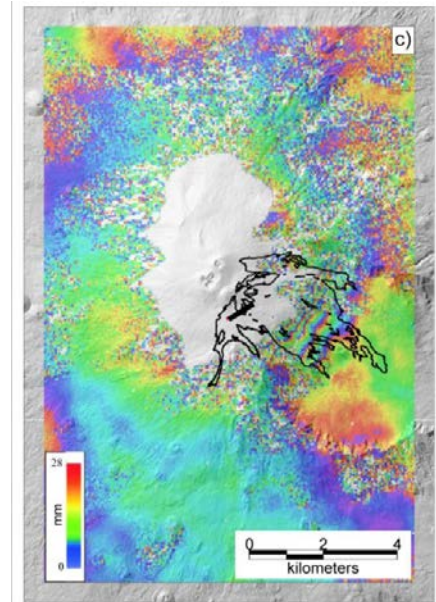
The interferogram shows poor coherence on the summit crater area due to the snow coverage; in spite of this, a clear deformation exceeding 7 interferometric fringes is visible on the upper part of the Valle del Bove area.

The fringe pattern is not regular and reveals a composite ground deformation field. No interferometric fringes are visible north of the summit area, where the maximum GPS horizontal displacement has been recorded.



For validation purposes, a synthetic interferogram (b) has been produced using the model parameters obtained from GPS data inversion. The synthetic interferogram shows a general good agreement with the real one (a), confirming that most of the SAR line of sight displacements are related to the dike intrusion and that they are confined on the summit area and on the upper Valle del Bove

Due to the snow coverage, it is not possible to compare the real and synthetic data on the summit crater area. Anyhow, the residual deformation reveals an area affected by larger displacements than the ones expected by the only dyke intrusion: a good agreement of this deforming area with the lava flow field emplaced in 2014 is visible by superimposing the map of the residual deformation on the map of the lava flows (c)



THE STATE OF THE ART

Data availability

- **ESA**
E1/E2/ENVISAT **data available** at <http://eo-virtual-archive4.esa.int/> (Virtual Archive);
S1-A **data available** at <https://scihub.esa.int/dhus/> (Sentinel Data Hub);
- **DLR**
TSX/TDX **data available** at <https://supersites.eoc.dlr.de/> (DLR Services for Supersites);
- **ASI**
CSK **data available**
 - through the **MED-SUV e-infrastructure** for MED-SUV partners (coming soon);
 - through the **PoCs for other Co-Is** (FTP site, coming soon);
- **CSA**
RS2 **data availability through the PoCs only for the Users listed in the Supersites Proposals;**
- **JAXA**
ALOS-2 **data availability and dissemination to be defined;**

Preliminary results

- Beginning of activities in **2015**, preliminary results already **available through MED-SUV.**

CRITICALITIES/ACTIONS TO BE DONE

- ESA, DLR

Provide the PoCs with the names of the Supersites Users, to be involved in reporting activities requested by both CEOS and Space Agencies;

- DLR

Actually some products missed (Strip, Staring) although requested:
more coordination with the Agency and/or previous Proposals (but still active) requesting data on same areas;

- CSA

Only few archive data available for Supersites:

- is there a chance to get future acquisitions too?
- is there a possibility to include more Users?

- JAXA

ALOS2 data availability and dissemination through CEOS

In conclusion

Interested colleagues can get in touch with the two Points of Contact at:

sven.borgstrom@ingv.it (PoC for Mt. Vesuvius/Campi Flegreii Supersite)

giuseppe.puglisi@ingv.it (PoC for Mt. Etna Supersite)

THANK YOU FOR YOUR ATTENTION