Istituto Nazionale di Geofisica e Vulcanologia - Sez. di Catania

Volcanic Hazard Reduction at Sicilian Volcanoes by satellite and terrestrial geodetic monitoring

Bonaccorso A., Aloisi M., Bonforte A., Gambino S., Guglielmino F., Mattia M., Palano M., Puglisi G.

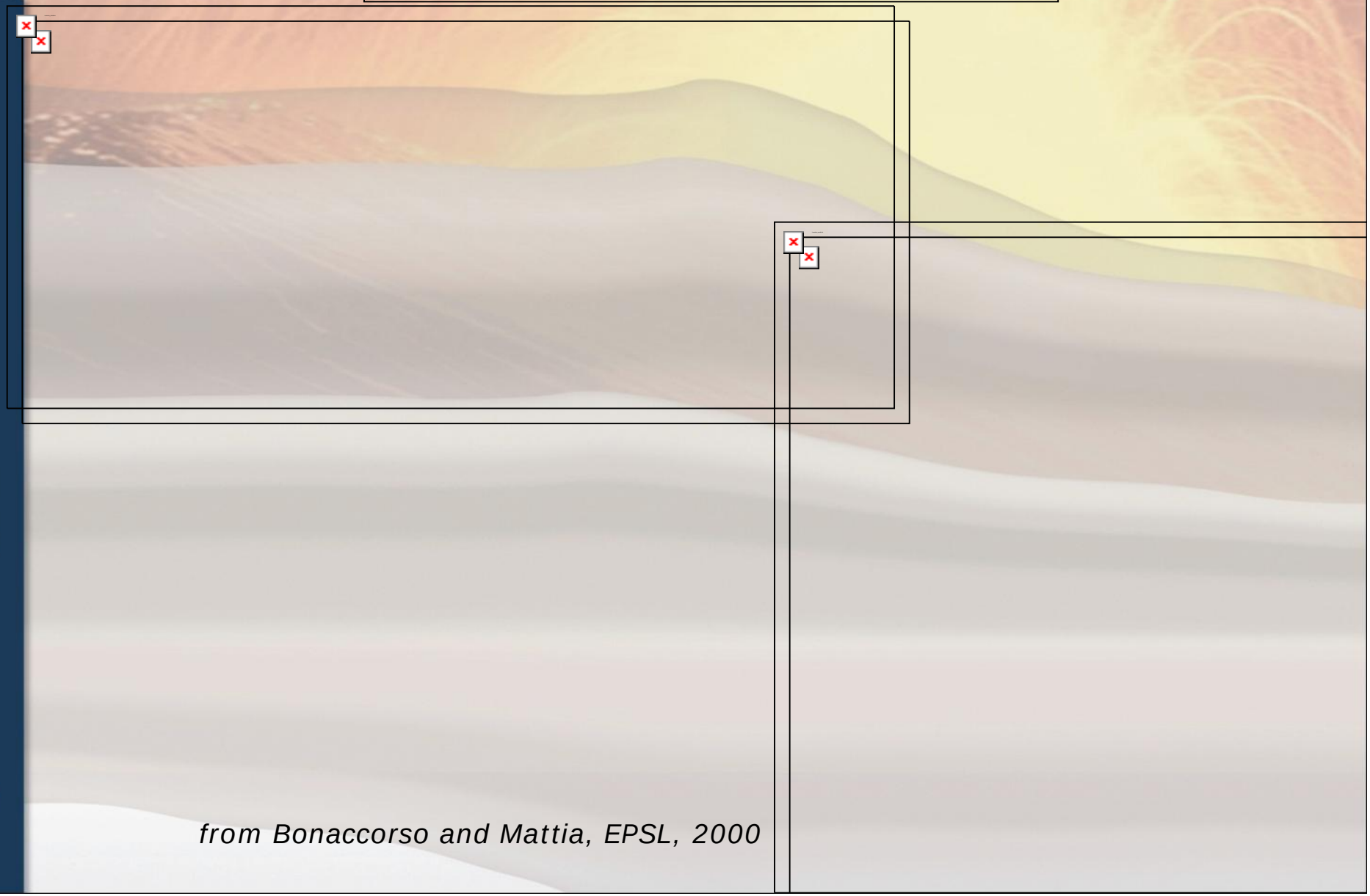
http://www.ct.ingv.it

EDM Network of Pantelleria

First EDM network installed in 1979

17 Benchmarks

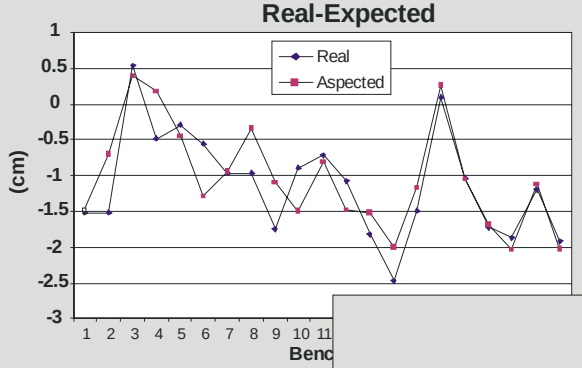
Pantelleria – strain calculation

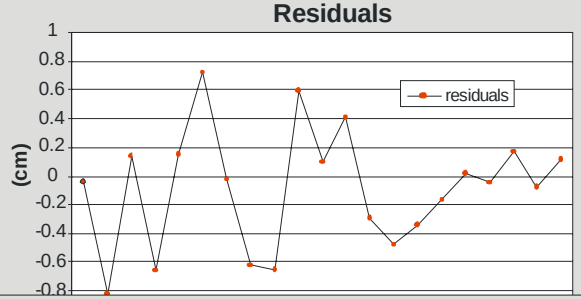


from Bonaccorso and Mattia, EPSL, 2000

Pantelleria – Data inversions

EDM



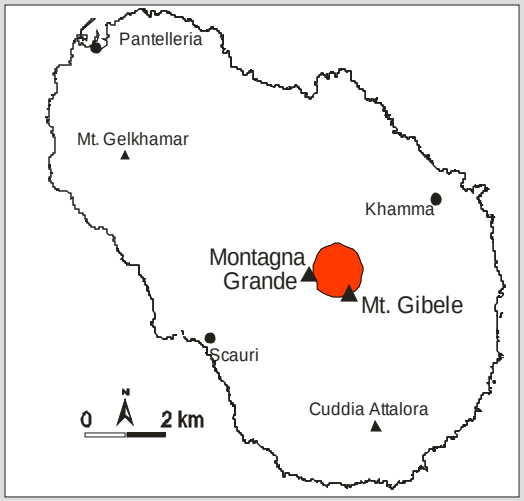


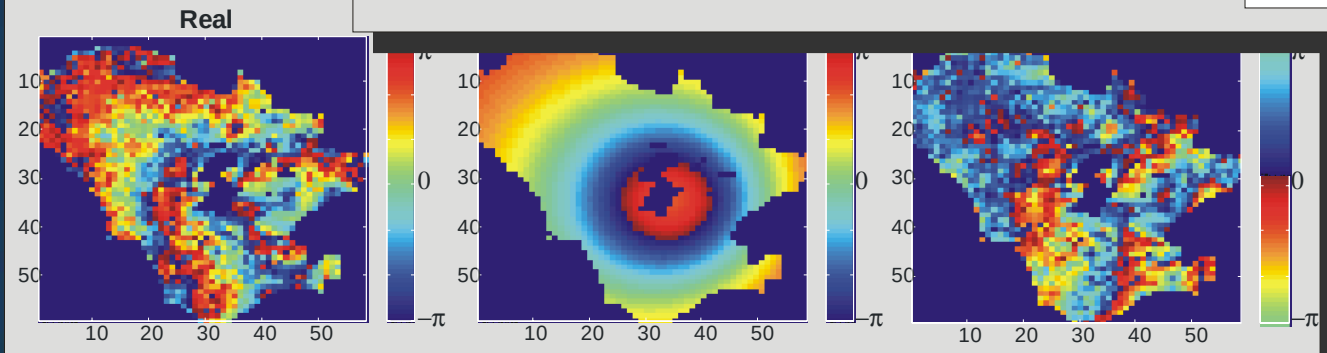
Data inversion by Genetic Algorithms

MOGI(1958) model

Data spanning from 1995 to 1999

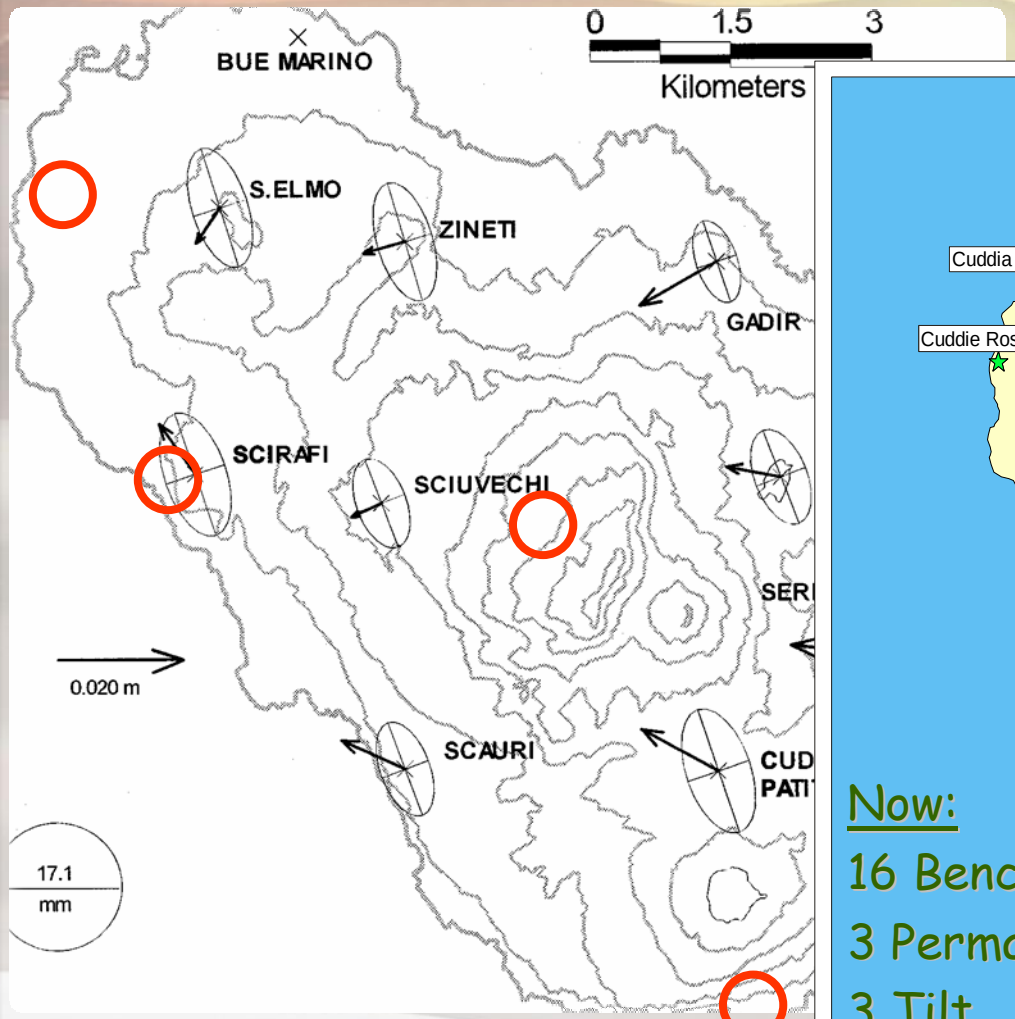
Parameters	Calculated value	Min.	Max.
ΔVolume ($mc*10^6$)	3.0	-1000	1000
Xs - (*m*)	233083	226700	235800
Ys - (*m*)	4074807.75	4072200	4081500
Depth (*m*)	-4456	-8000	-500
Fitness	4.94		



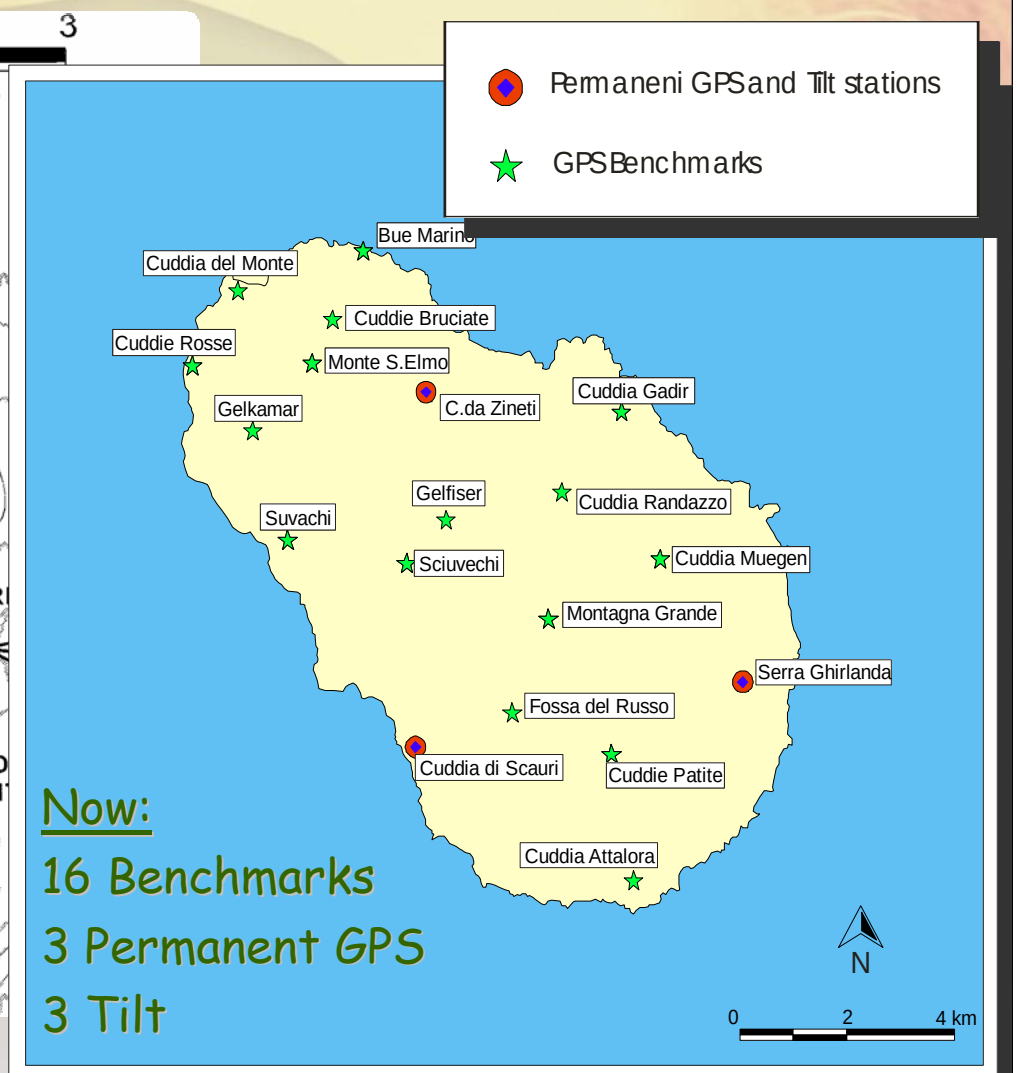


Current GPS Networks of Pantelleria

First GPS network installed in 1996



From Bonaccorso and Mattia, EPSL, 2000



Geodetic Monitoring System of Lipari-Vulcano

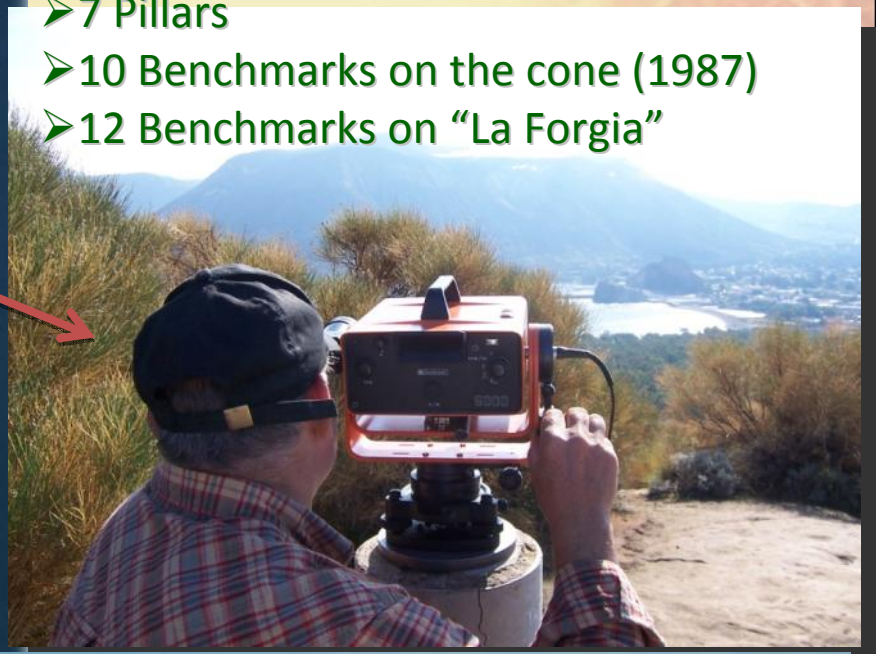
Lipari and Vulcano – GPS networks

First EDM network installed in 1975

- 14 Concrete Pillars
- 7 GPS permanent stations

Vulcano – geodetic networks

- 6 GPS Permanent stations
- 6 Bore-hole Tilt
- 7 Pillars
- 10 Benchmarks on the cone (1987)
- 12 Benchmarks on “La Forgia”



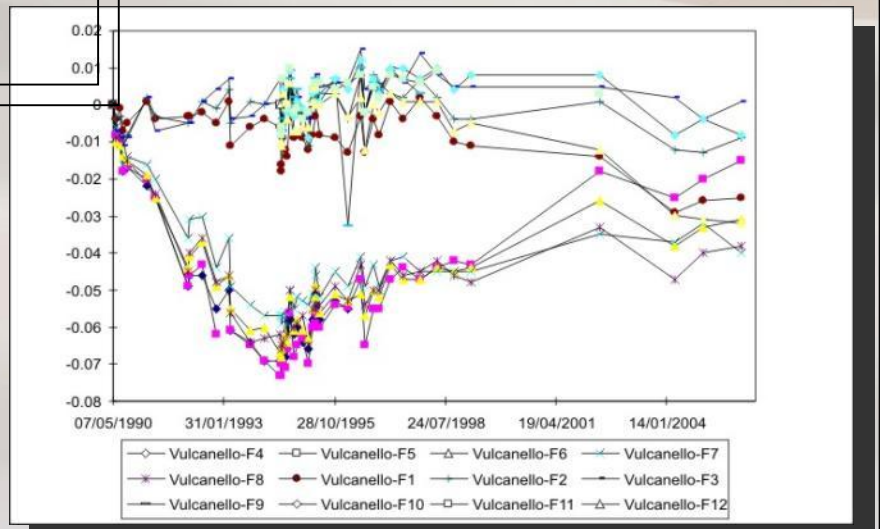
Lipari – Vulcano: ground deformation

Displacements observed from March 2006 to September 2007 (1.5 years)

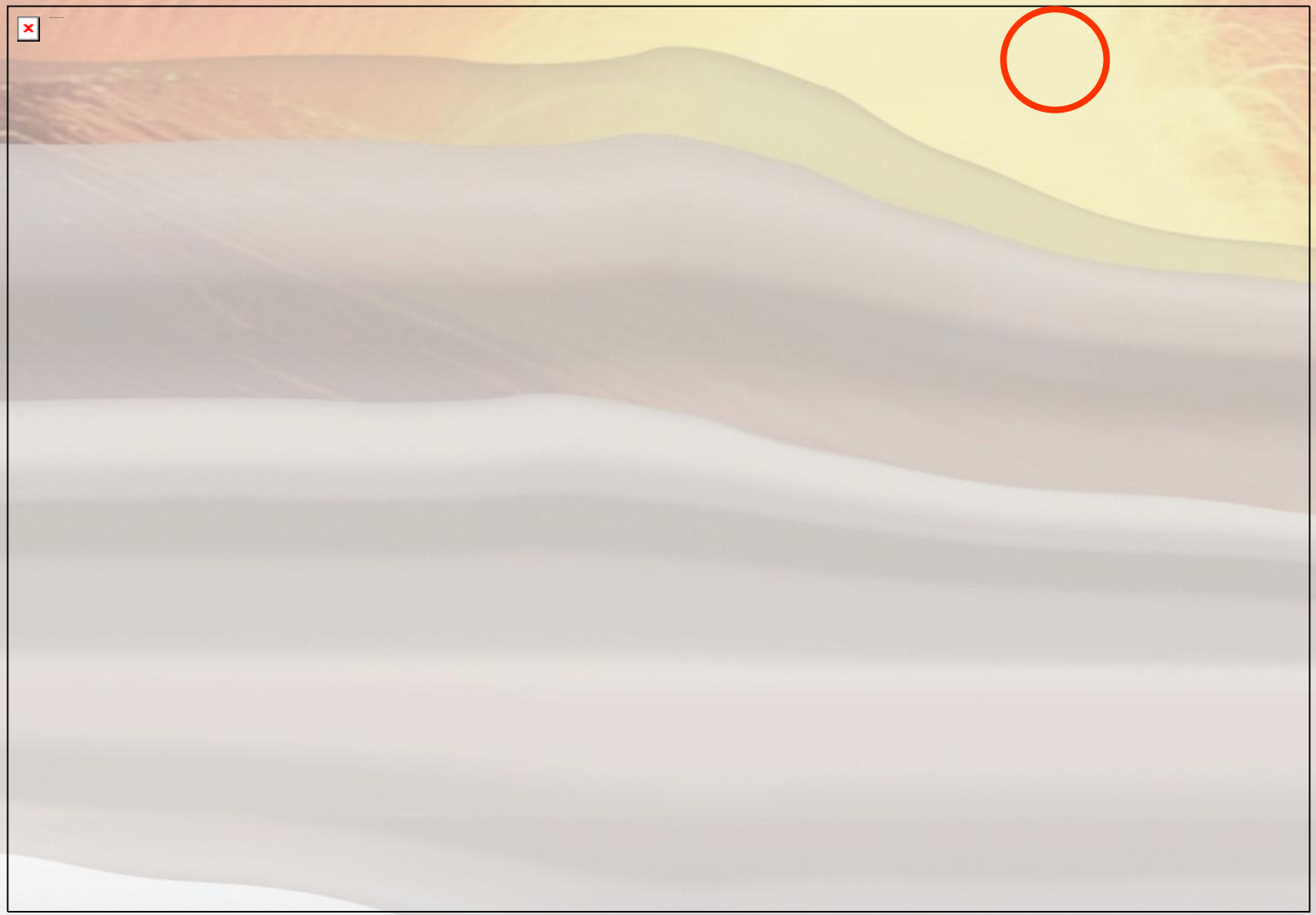
Right lateral kinematics of the NNW-SSE regional fault

Contraction of the “La Fossa” cinder cone inside the caldera at Vulcano

Current stability of the “La Forgia” landslide



Geodetic Monitoring System of Stromboli



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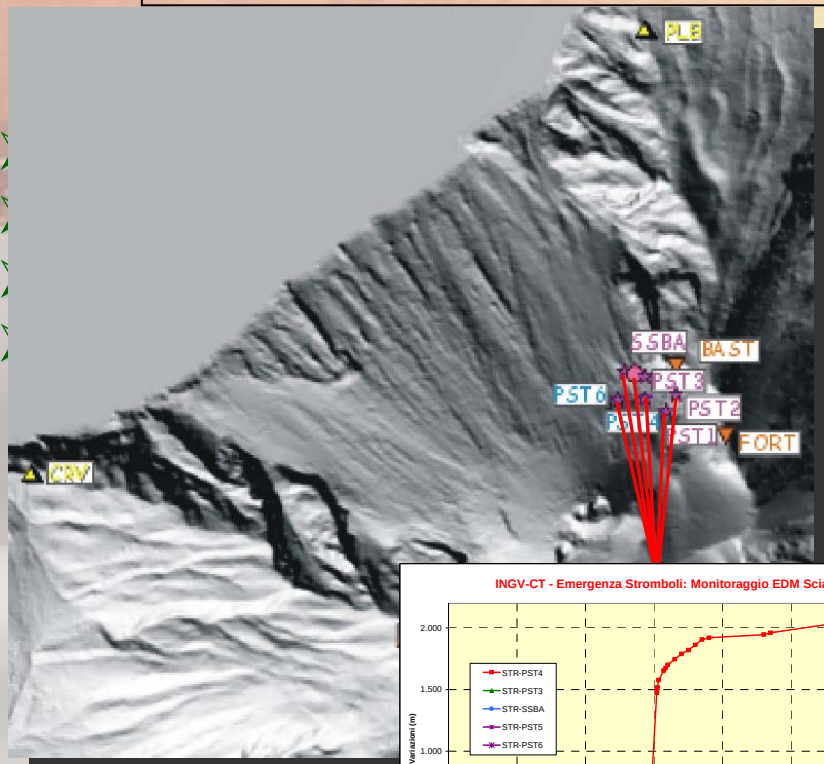
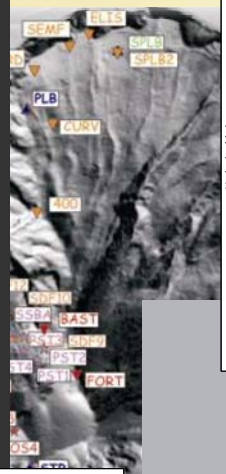
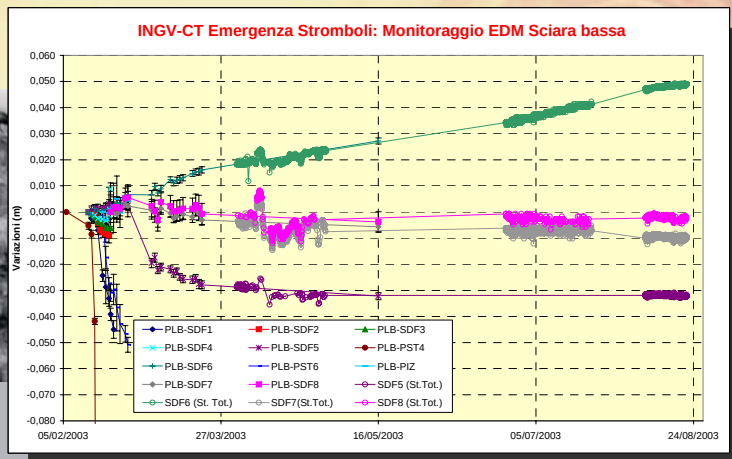
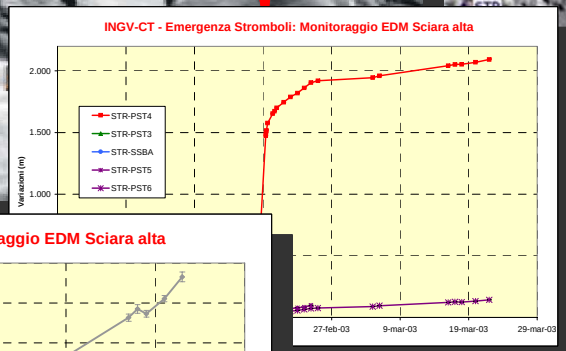
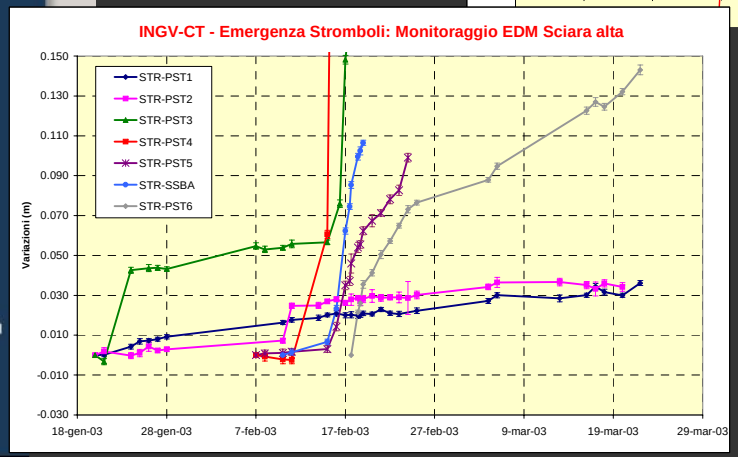
Stromboli 2003: Monitoring the Sciara del Fuoco

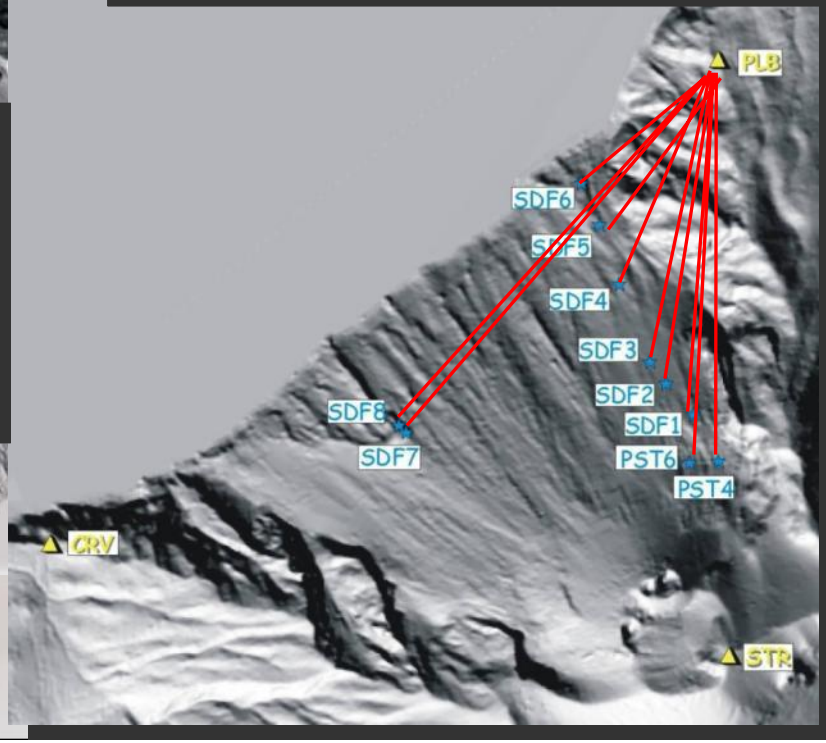












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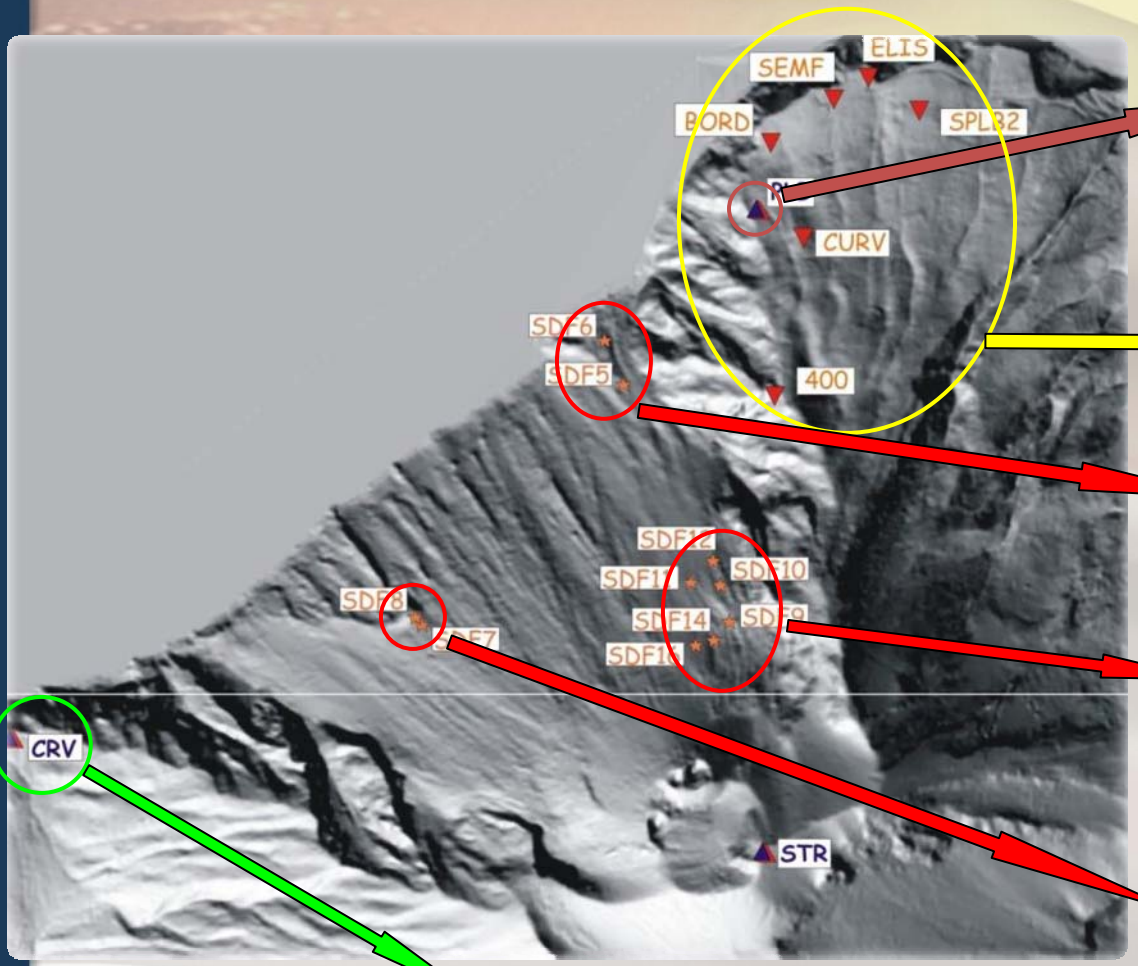
Automatic monitoring system THEODOROS



Total Station (Leica TCA 2003)

6 reflectors of reference system

2 reflectors Low Sciara, N flank (Dic.' 02 lava flows)

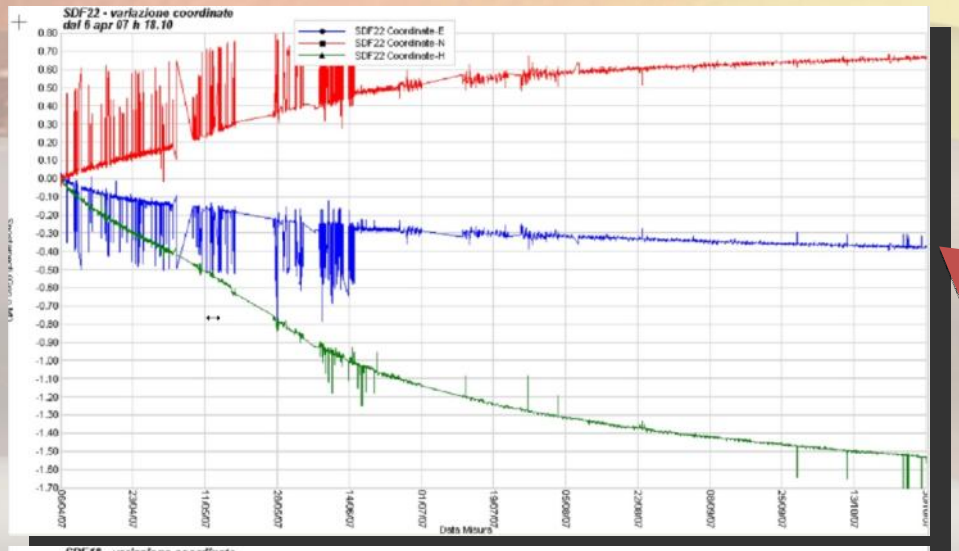
6 reflectors High Sciara (March – July lava flows)

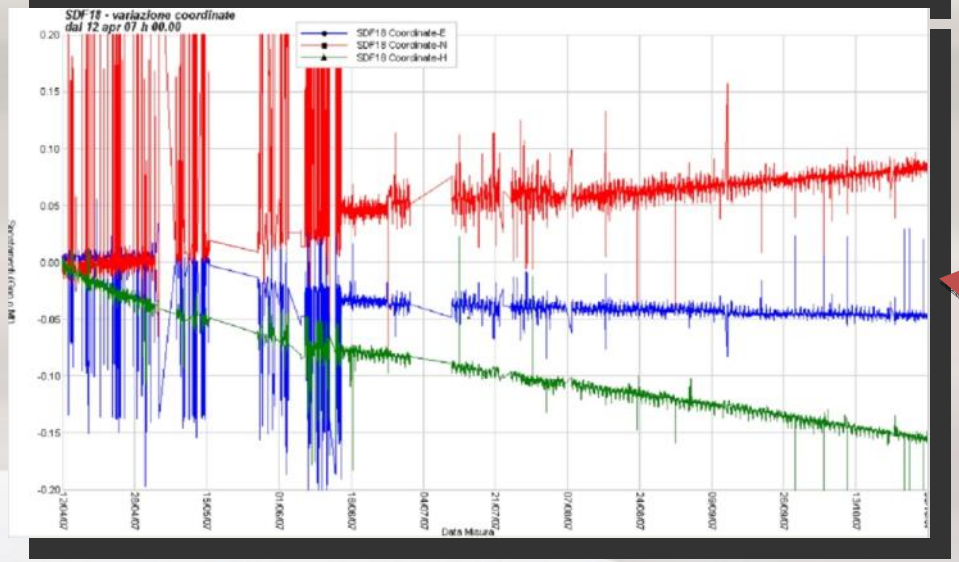
2 reflectors Low Sciara, South-West flank (old lava flows)

1 reflector at Punta del Corvo

http://www.ct.ingv.it

Current configuration of THEODOROS



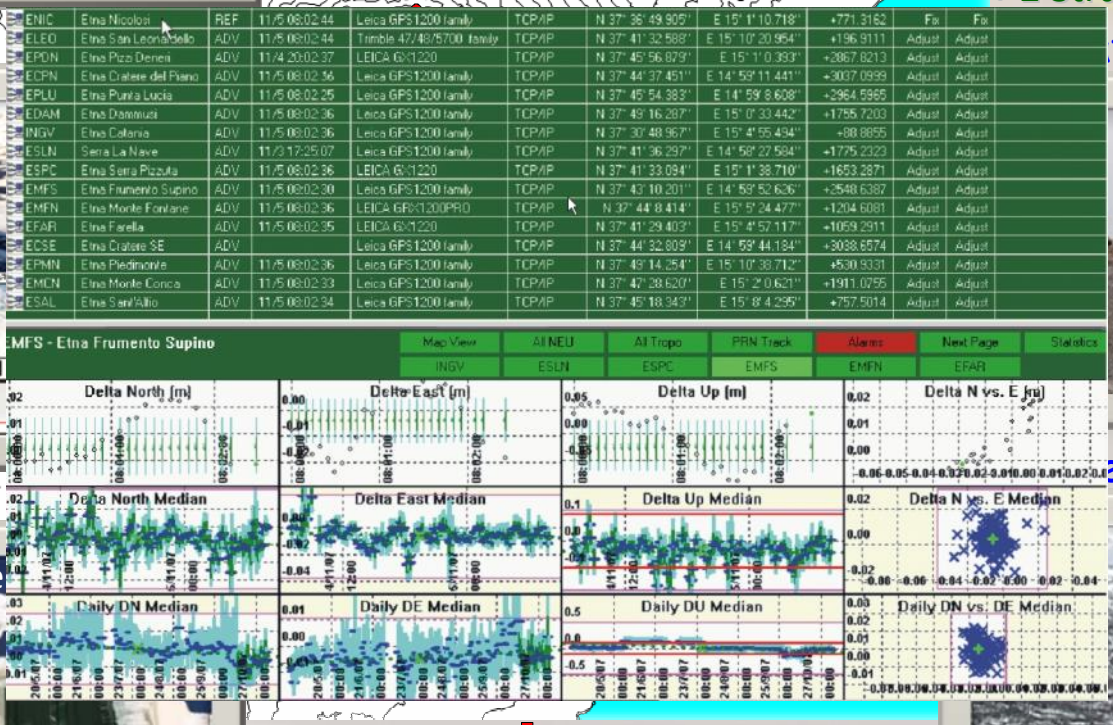


Geodetic Monitoring System of Mt. Etna

Istituto Nazionale di Geofisica e Vulcanologia - Sez. di Catania

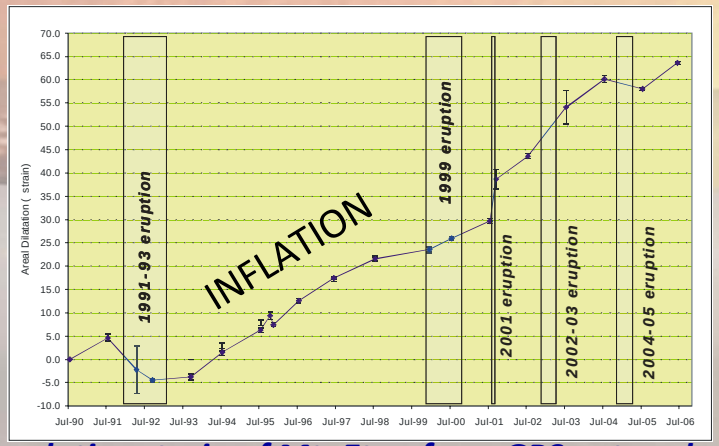
Topographic & GPS networks of Etna

1979: NE EDM network
1980: W EDM network
1983: S EDM network
1988: first GPS network (9 BM)
2000: GPS permanent net
⇒**now**: GPS network (≈ 80 BM)
+ 11 Bore-hole 1 Long-Base Tilt
+ 2 Strainmeters

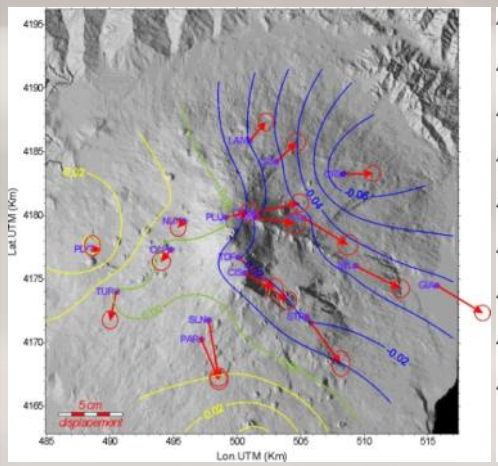


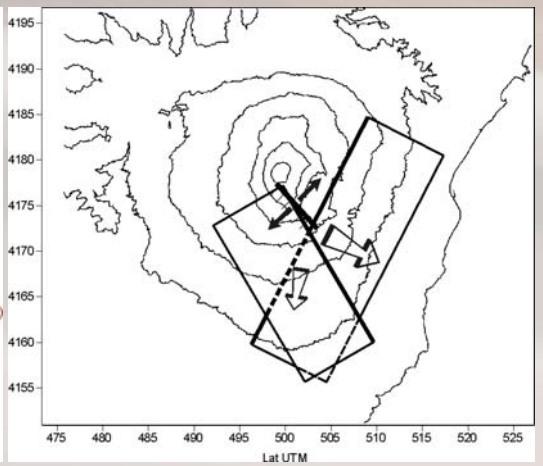
http://www.ct.ingv.it

The results from GPS surveys well describe the dynamics of Mt. Etna during the last 15 years

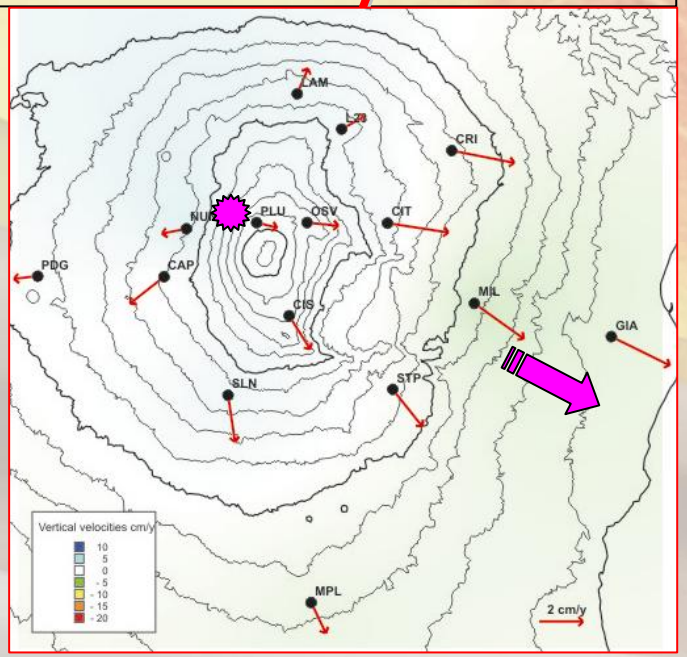


Cumulative strain of Mt. Etna from GPS network.

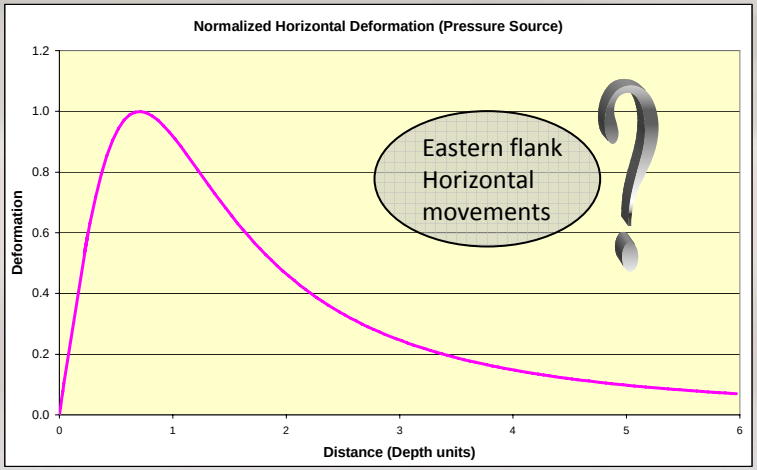




From Bonforte and Puglisi, Journ Geoph Res, 2003



Velocity from 1993 to 2001 (before the eruption)



Inflation is due to two phenomena

Radial inflation (due to the magmatic pressure sources)

+

Flank movements (due to the structural framework)

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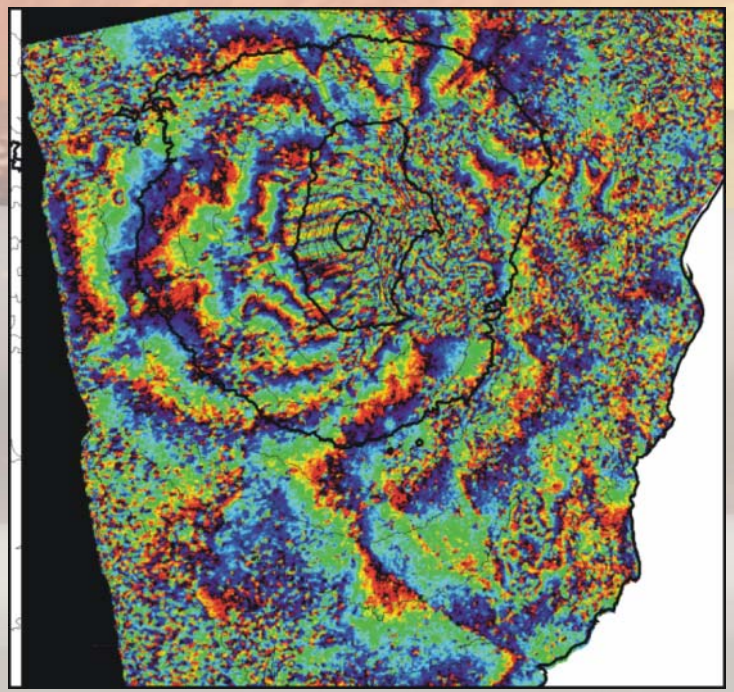
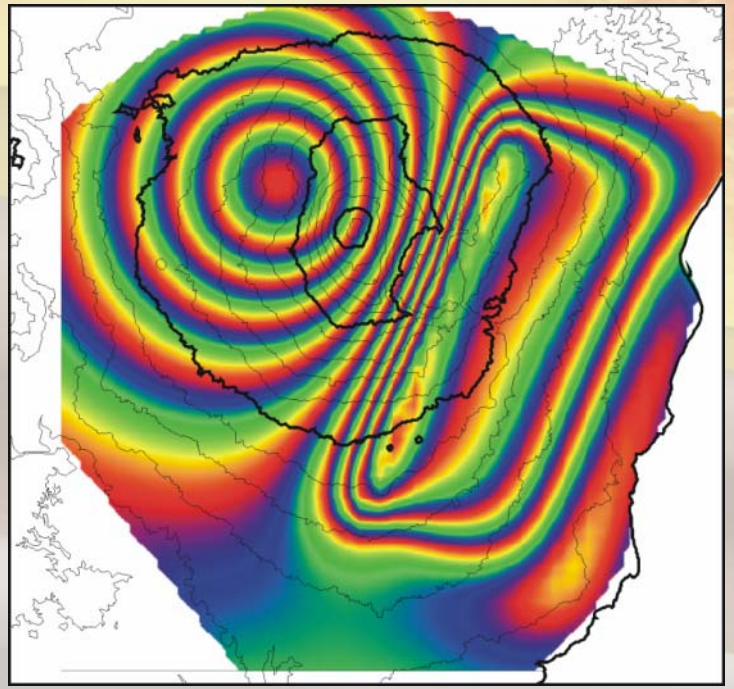
Long-period interferogram (1993-2000)

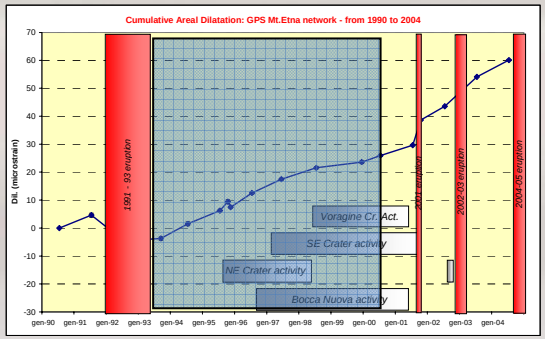




Parameters	Point source	Eastern sub-horizontal plane
Latitude (Km)	496.931	504.200
Longitude (Km)	4181.336	4172.030
Azimuth		N21°E
Depth (Km)	8.1 b.s.l.	1.4 b.s.l.
Length (Km)		26.4
Width (Km)		12.34
Dip		11.6
Strike (cm)		-9.6 ± 0.2
Dip (cm)		25.5 ± 0.2
Opening (cm)		0.3 ± 0.1
$P*a^3$ ($Pa*m^3$)	6.89E+17	

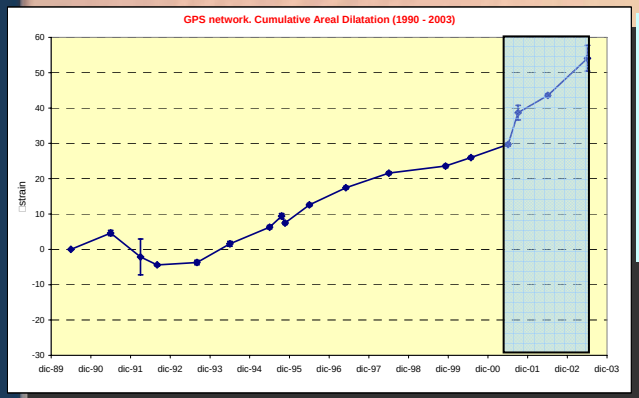
Range change

0 2,83 cm



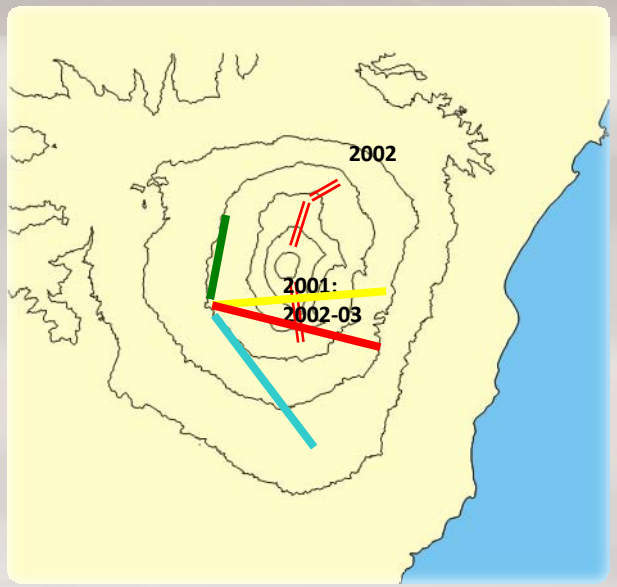
http://www.ct.ingv.it

2001 and 2002-03 eruptions: the application of the permanent GPS network

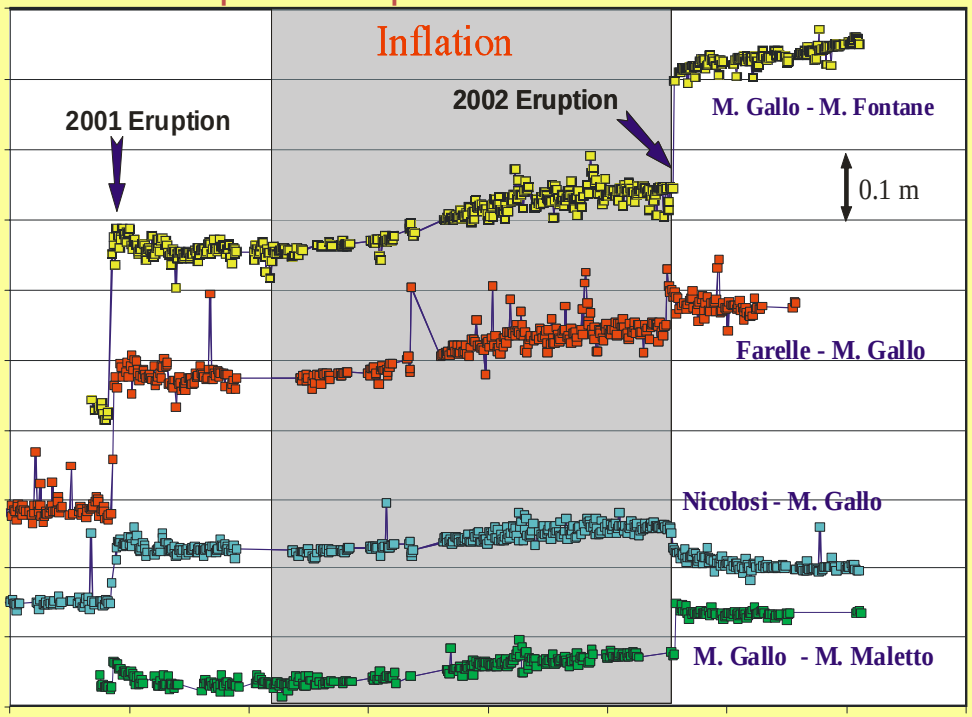


Both on July 2001 and October 2001 the GPS permanent network detected the deformations produced by the onsets of the eruptions.

The GPS permanent network measured the evolution of the inter-eruptive ground deformation pattern.

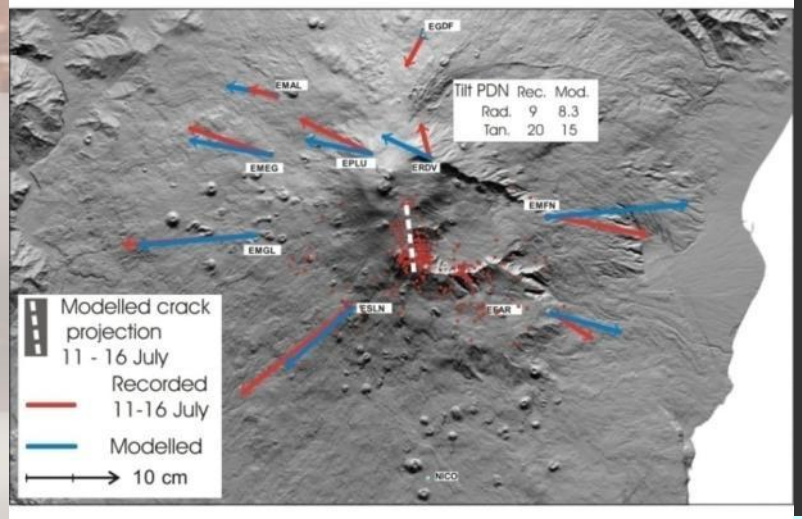


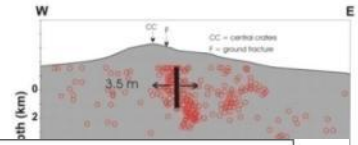
Example of slope distance variations

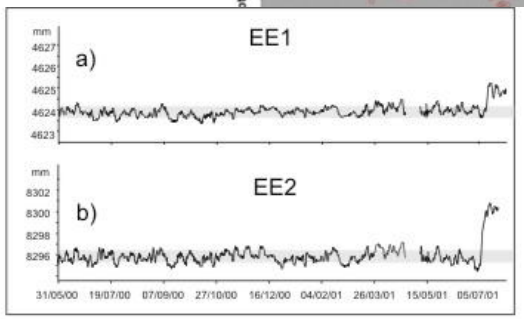


2001 eruption: model from the permanent networks

Ground Deformation pattern
from GPS permanent stations (11-15 July)
and modelling







Distance trends corrected of temperature effects at EE1 (a) and EE2 (b) stations over the period June 2000-August 2001.

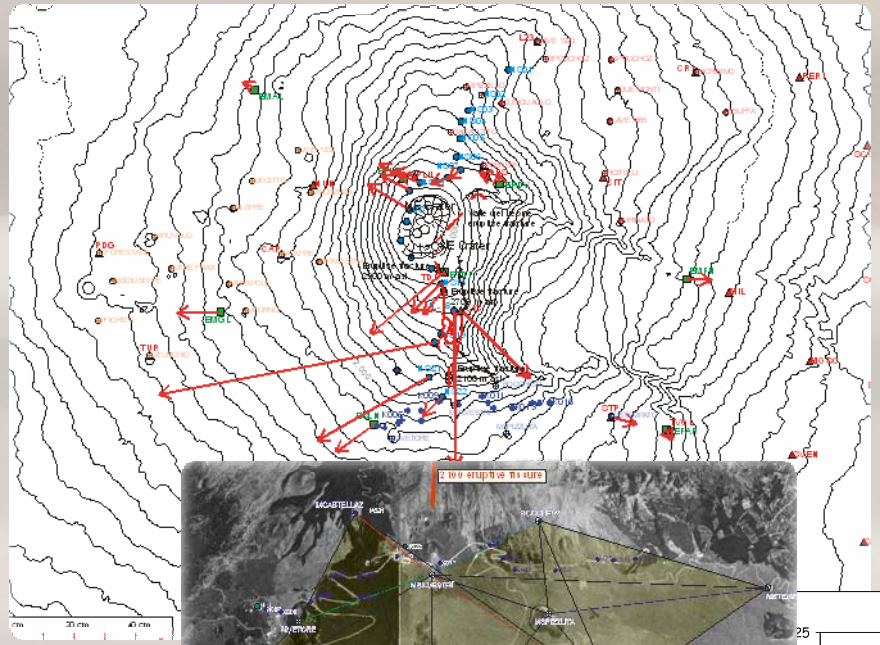
The GPS, Tilt and strain permanent networks allowed defining the dimension of the dyke intruded from 11 to 15 July 2001; i.e. **two days before the opening of the eruptive vents**.

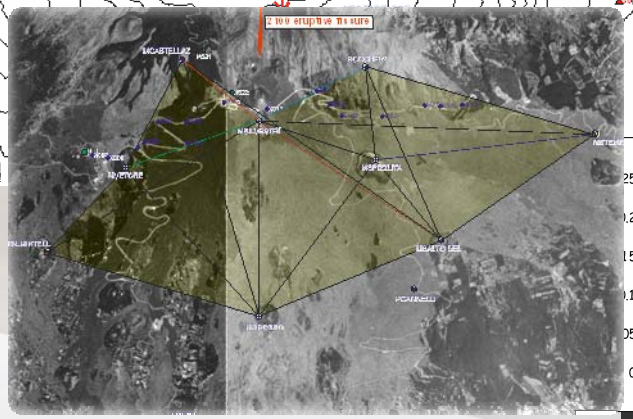
The intrusion of the 3.5 m thick dyke produced thousand of earthquakes beneath and within the volcanic edifice.

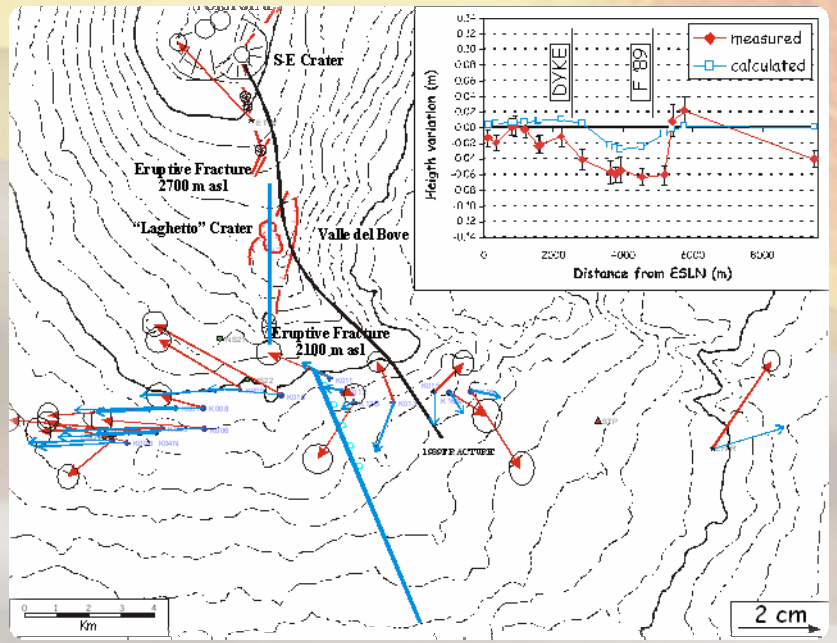
2001 eruption: surveys during the eruption

The surveys carried out during 2001 eruption allowed defining the evolution of the ground deformation pattern both in space and time.

During the vent opening: 11-17 July 2001

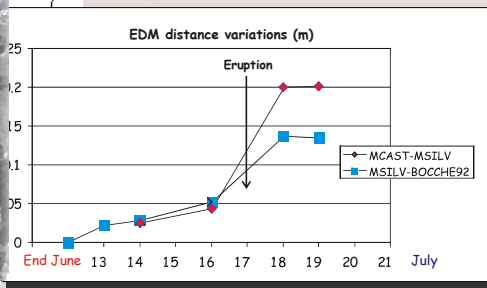


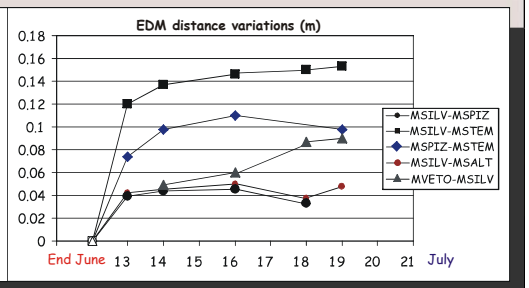




During the eruption: 25-27 July 2001

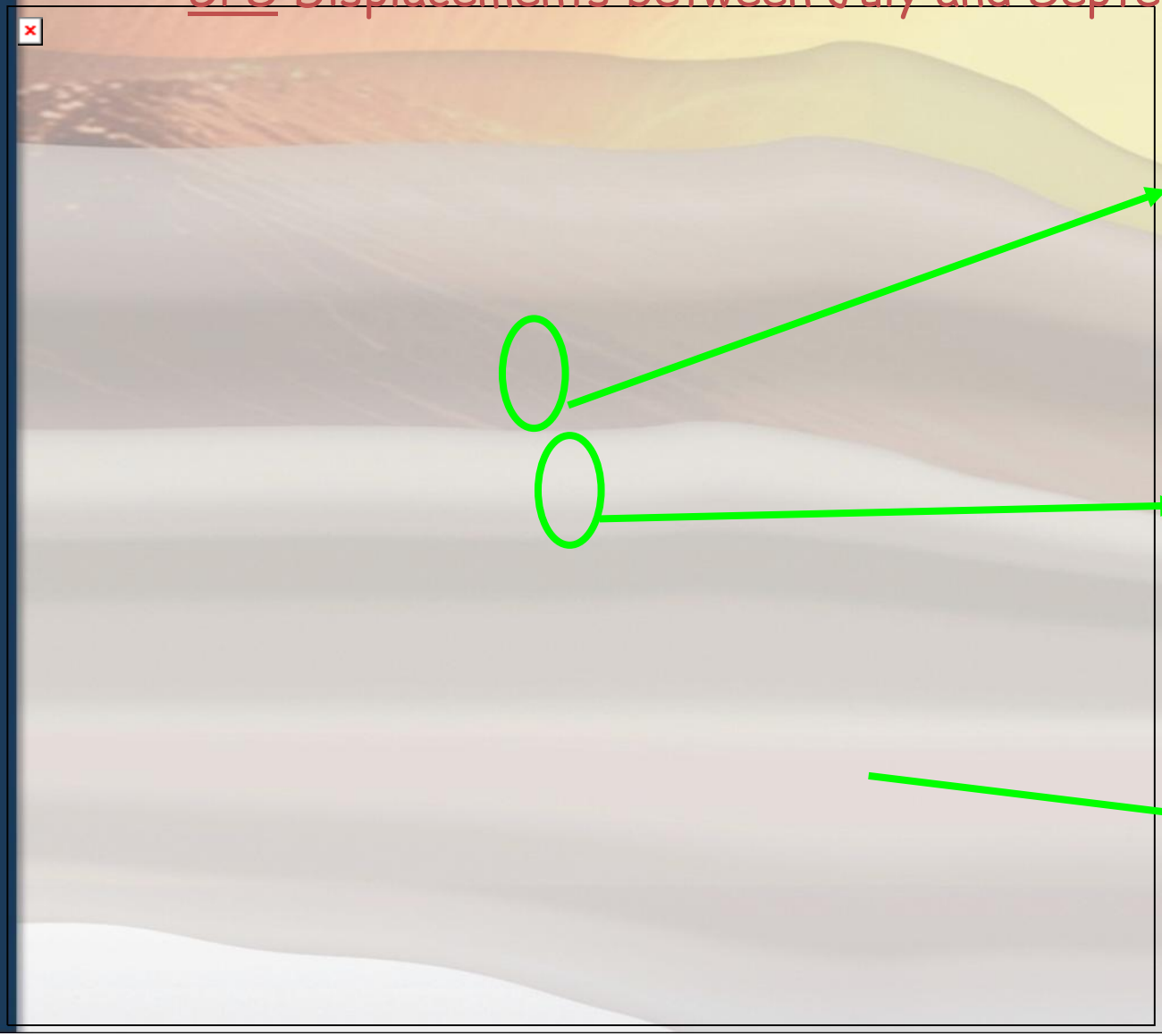
From Bonforte et al., Bull Volcanol, 2004





Entire 2001 eruption (GPS surveys)

GPS Displacements between July and September 2001



Observed displacements
Calculated displacements

Dyke
Depth: 1.6 Km a.s.l.
Dip: 90°
Strike slip: 0
Dip slip: 0
Opening: 251.7 cm

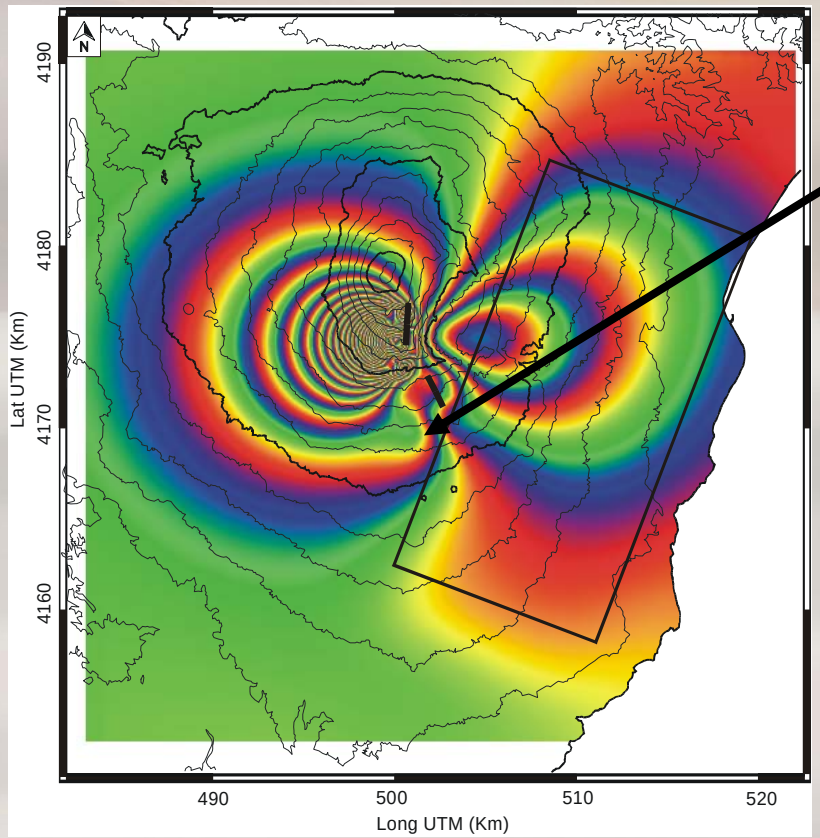
SE fault
Depth: 1 Km a.s.l.
Dip: 73°E
Strike slip: 40 cm dx
Dip slip: 13 cm normal
Opening: 18 cm
(Bonforte et al., 2004)

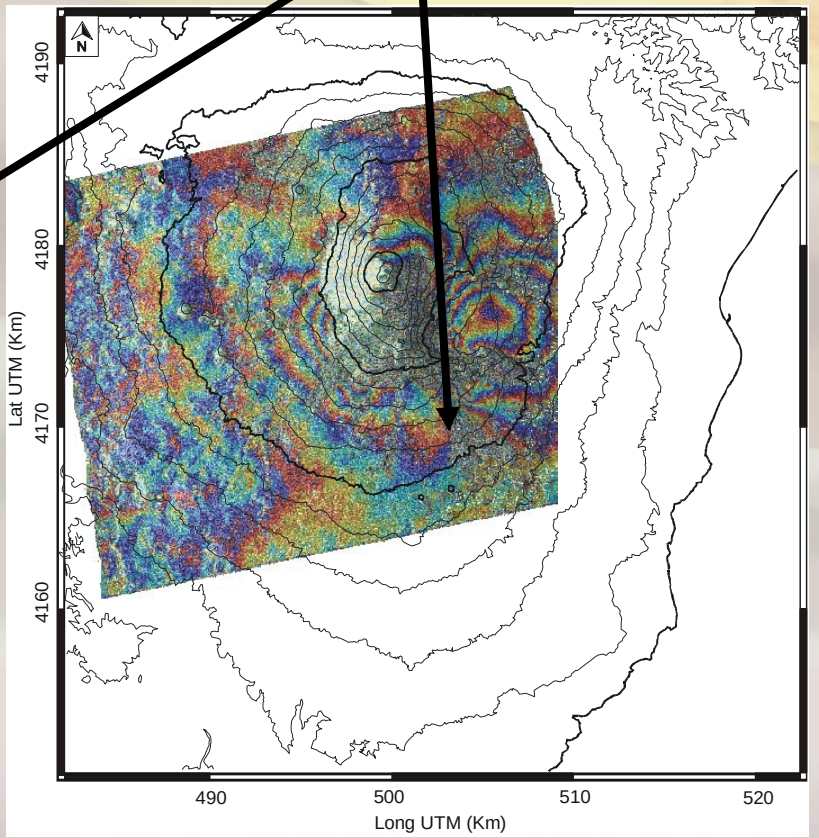
Sub-horizontal plane
Strike slip: 0.8 cm sx
Dip slip: 2.6 cm normal

Entire 2001 eruption (DInSAR)

Synthetic ascending Interferogram from July to August 2001

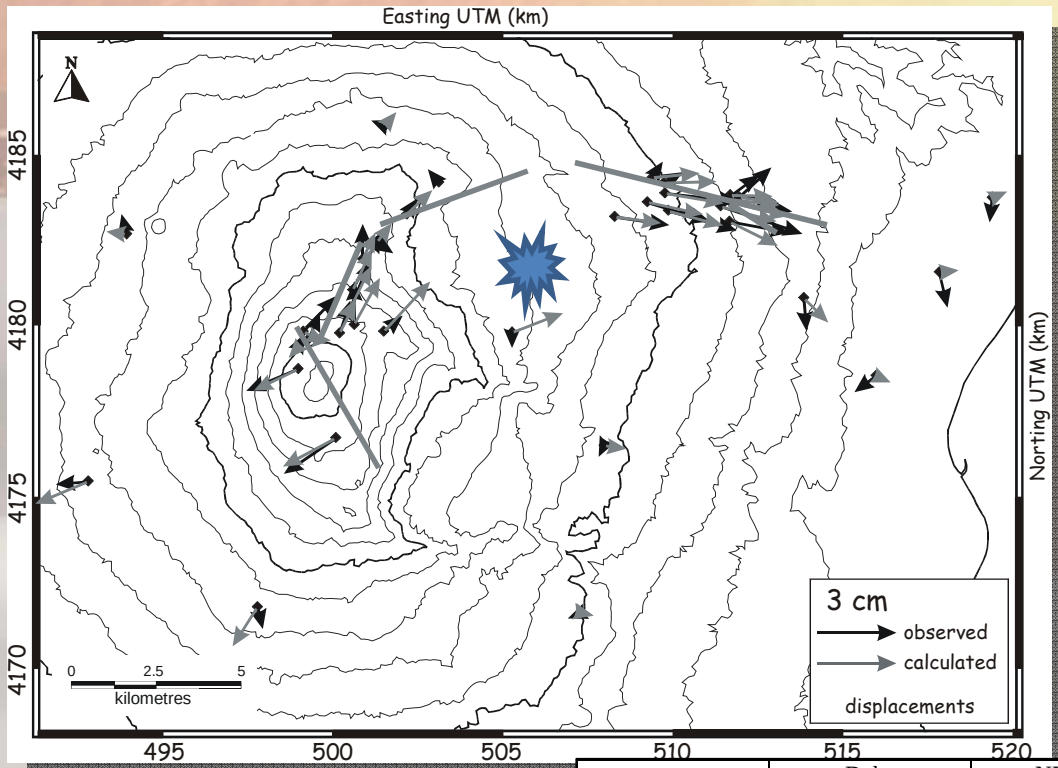
Anomaly produced by the SE fault from Bonforte et al., Bull Volcanol, 2004

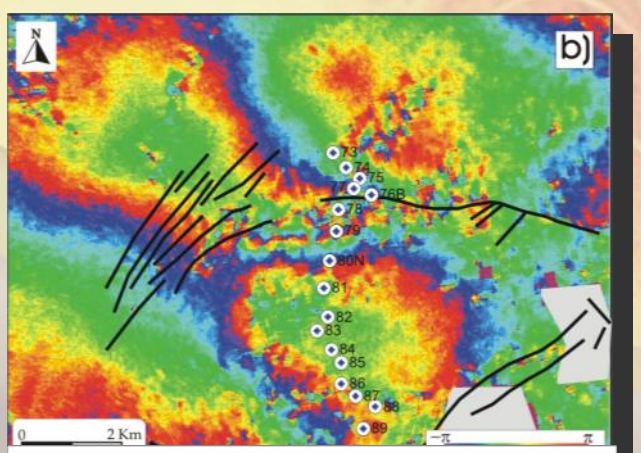


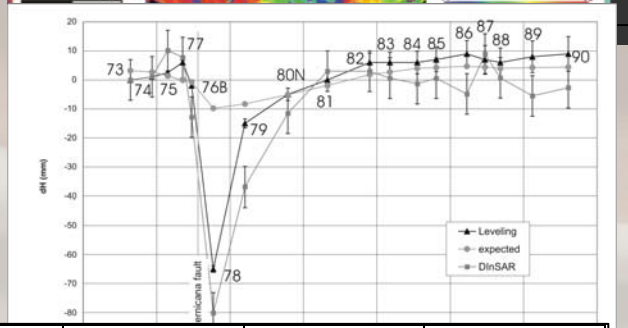


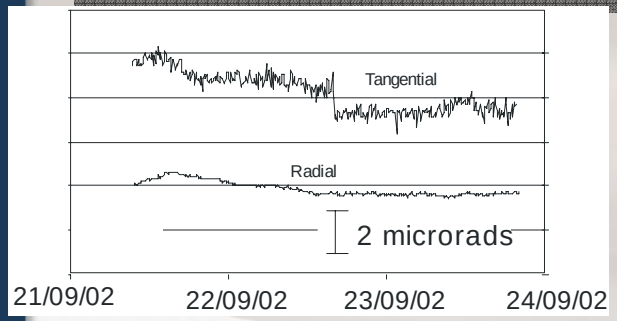
Sources modelled by GPS data from July - September 2001 interval

Before the 2002 eruption (July-September)









	Dyke	NE Rift	Provenzana Fault	Pernicana Fault	Splay Fault
Longitude (Km)	500.200 ± 0.2	499.900 ± 0.2	503.650 ± 0.04	510.590	512.200
Latitude (Km)	4178.100 ± 0.3	4181.300 ± 0.2	4183.890 ± 0.03	4183.930	4183.400
Azimuth	N150°E	N23°E	N70°E	N104°E	N123°E
Depth (Km) (a.s.l.)	0.9 ± 0.3	1.1 ± 0.2	1.2	0.9 ± 0.02	0.96 ± 0.02
Length (Km)	4.8 ± 0.4	3.2 ± 0.3	4.6 ± 0.4	7.6	1.0
Width (Km)	4.7 ± 0.3	1.6 ± 0.2	2.6 ± 0.1	2.3 ± 0.1	1.6 ± 0.1
Dip	77° ± 2°	60.8° ± 3°	60° ± 2°	58° ± 2°	81.8° ± 2°
Strike slip (> 0 if sinistral) (cm)	0	1.6 ± 0.3	0.5 ± 0.2	2.9 ± 0.3	2.9 ± 0.5
Dip slip (> 0 if normal) (cm)	0	3.4 ± 0.4	4.0 ± 0.5	-0.7 ± 0.5	0.6 ± 0.3
Opening (cm)	17.2 ± 2.3	-2.2 ± 0.8	0.5 ± 0.2	1.2 ± 0.3	1.5 ± 0.3

From Bonforte et al., Bull Volcanol, 2007

2002 eruption: intrusion on southern and northern flanks

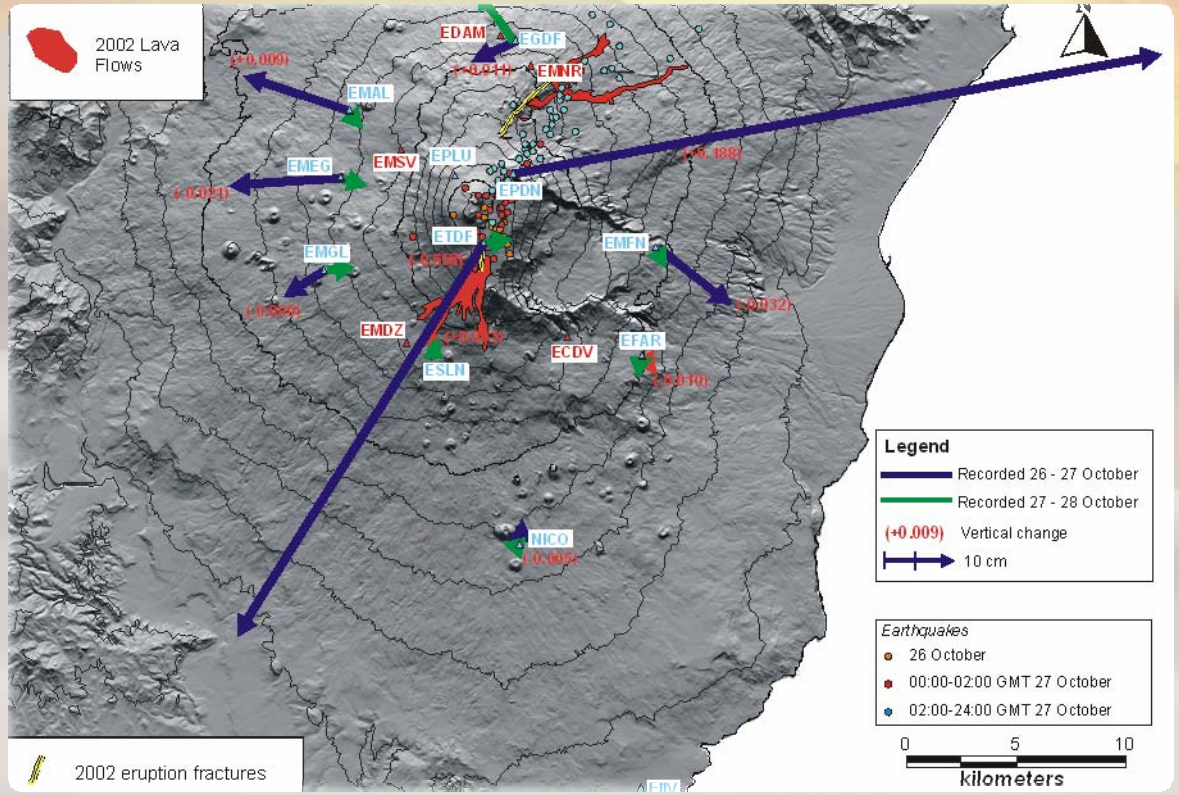
2002 eruption: how the permanent networks imaged the intrusion

The GPS permanent network allowed defining the dimension of the **two dykes intruded during the night** between 26 and 27 October 2002.

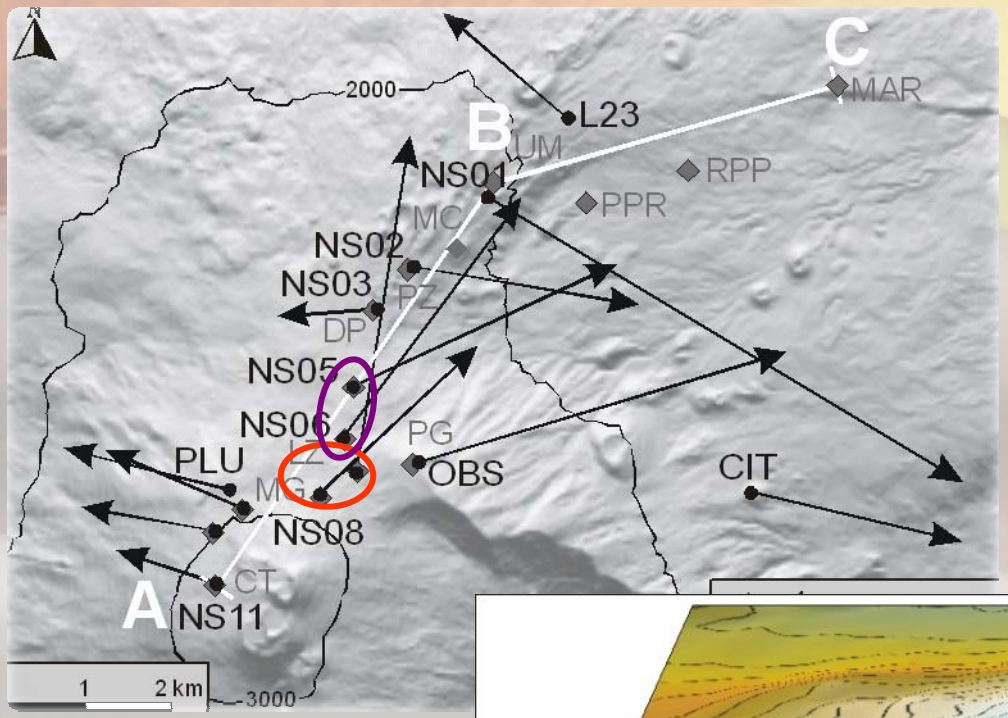
The **southern dyke** "exploited" the path of the 2001 eruption

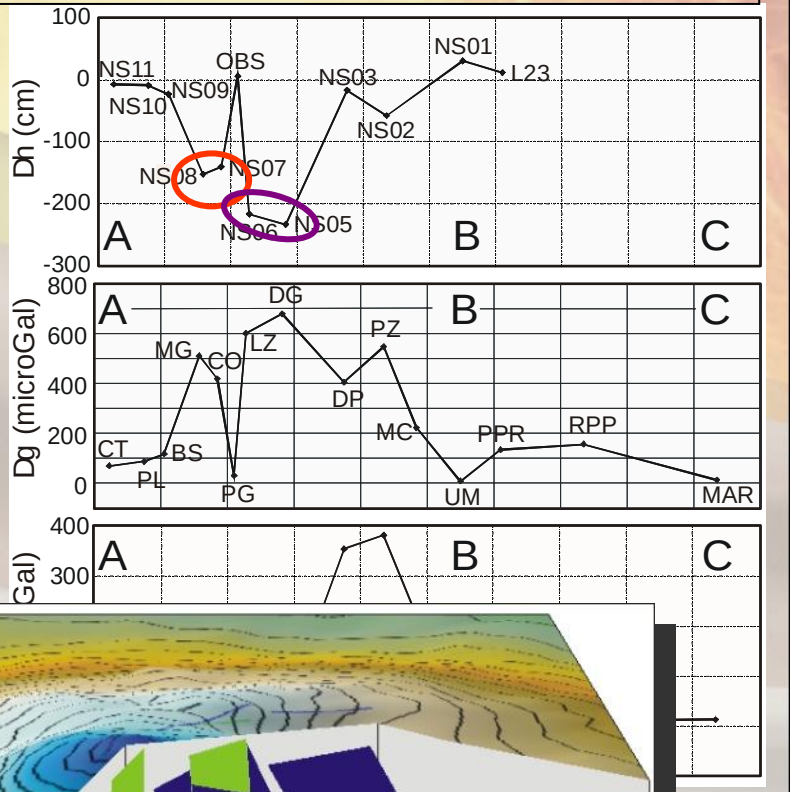
The **northern dyke** intruded along the NE Rift zone (this is new !).

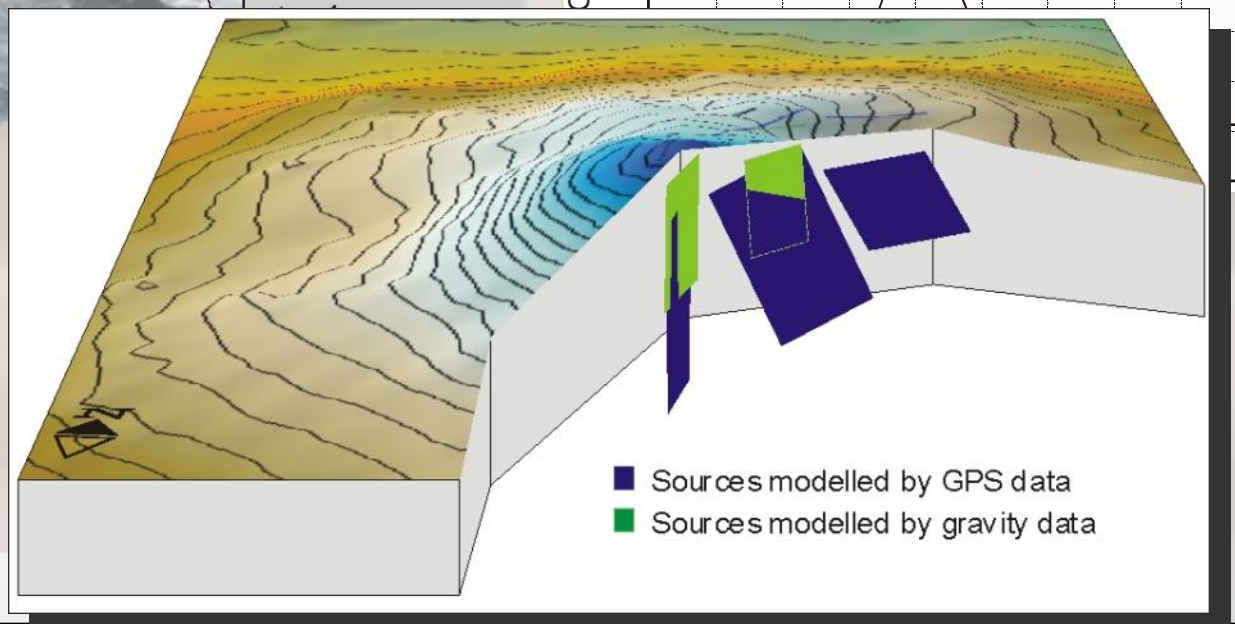
Ground deformations larger on Northern flanks than on Southern ones



Model for 2002 NE intrusion from semi-kinematic surveys



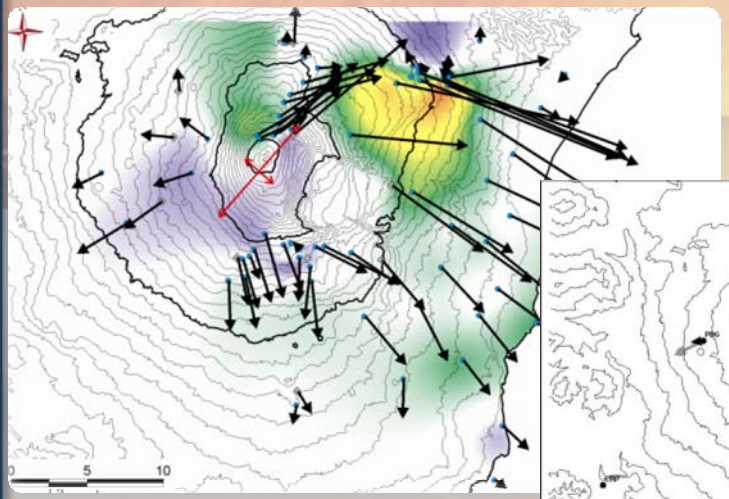




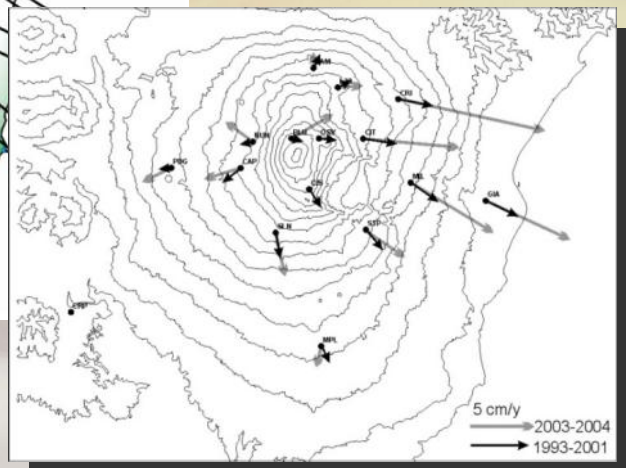
From Bonforte et al., Geoph Journ Int, 2007

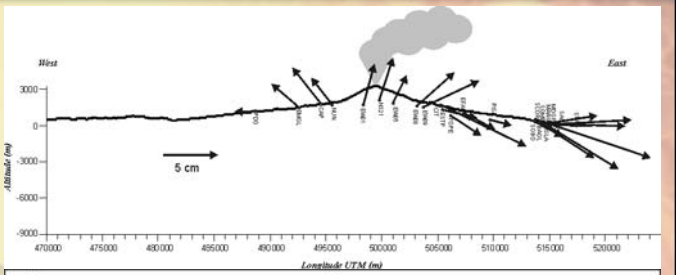
http://www.ct.ingv.it

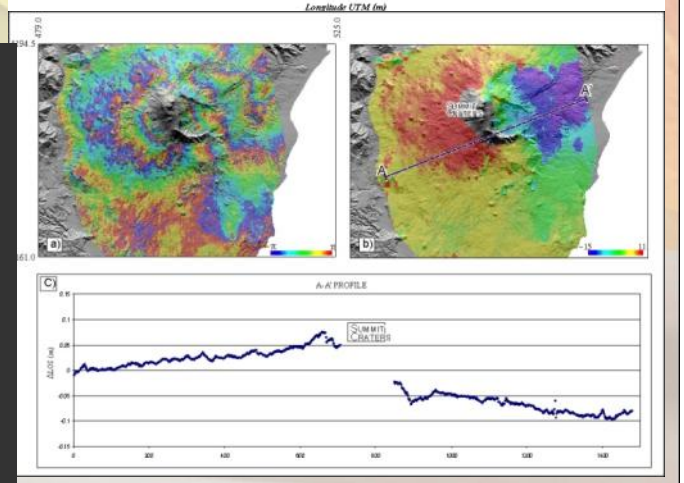
The 2004 and 2006 eruptions

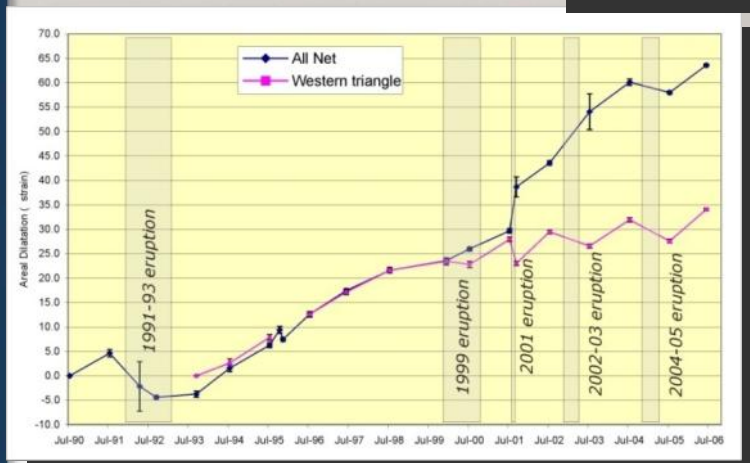


From Bonaccorso et al., Journ Geoph Res, 2006

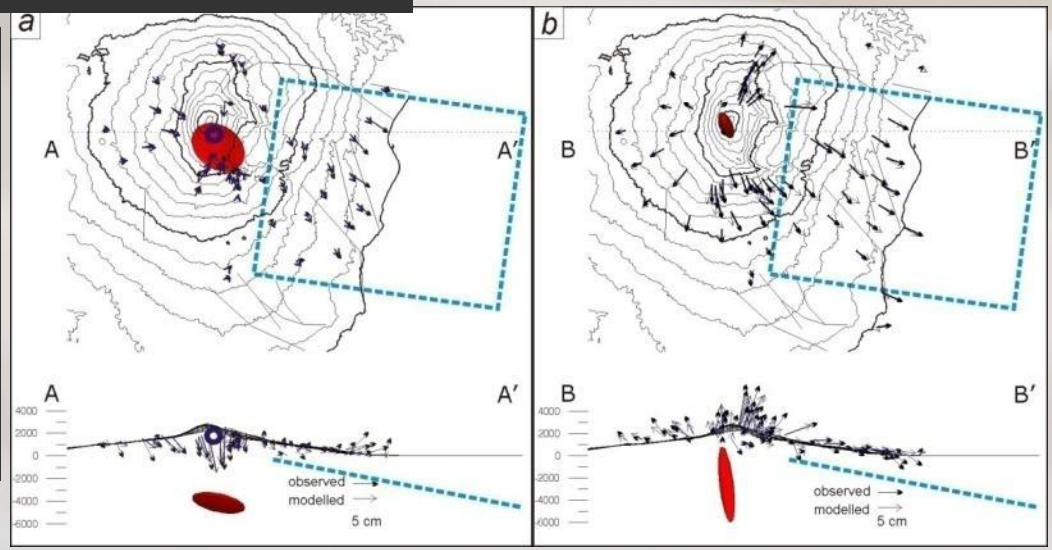






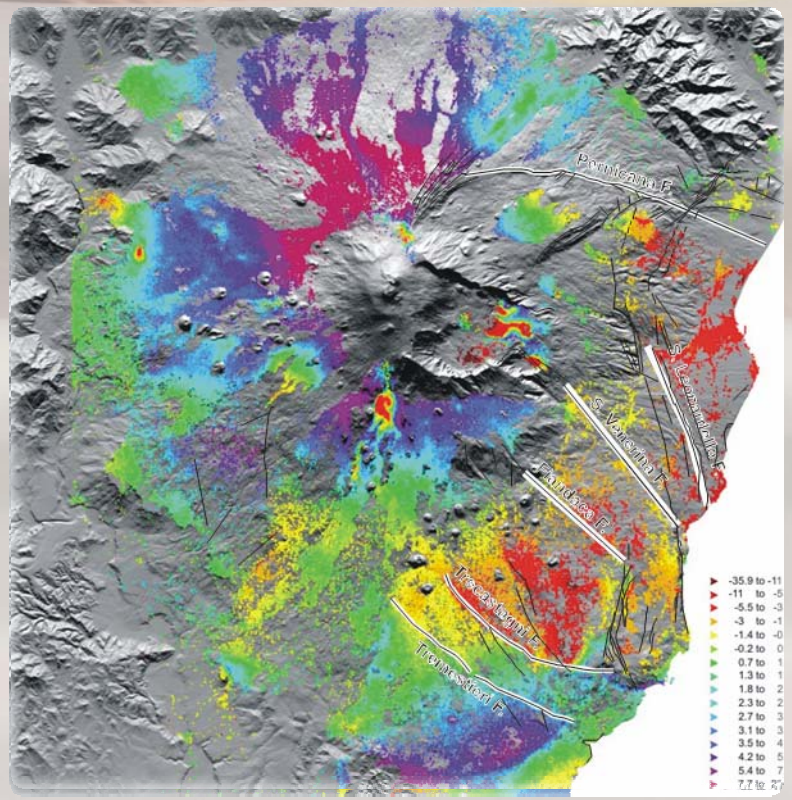


From Bonforte et al., Journ Geoph Res, subm

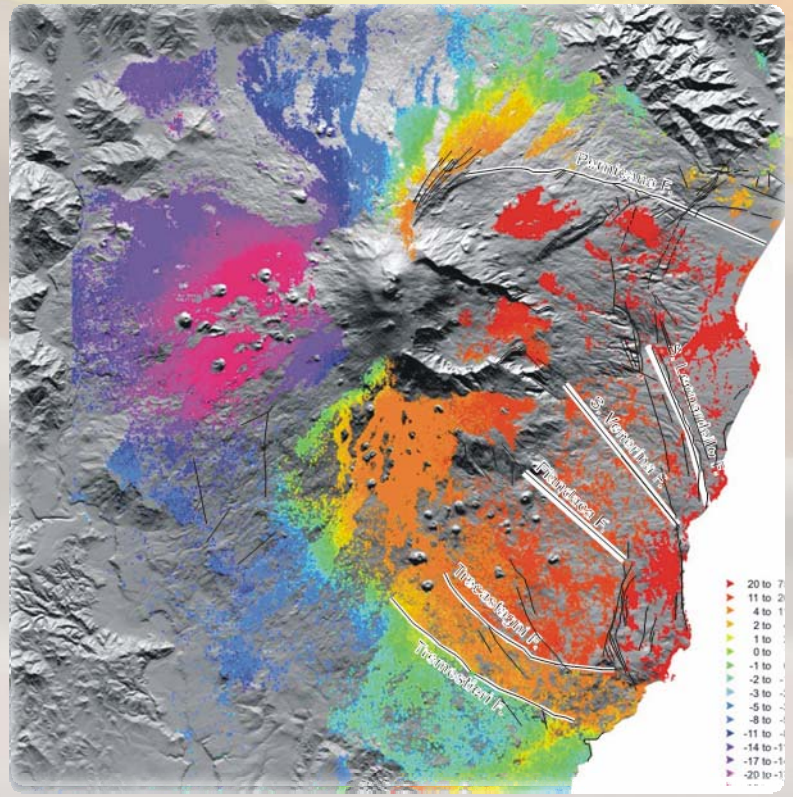


Results of PSA processing from 1993 to 2000

LOS velocities

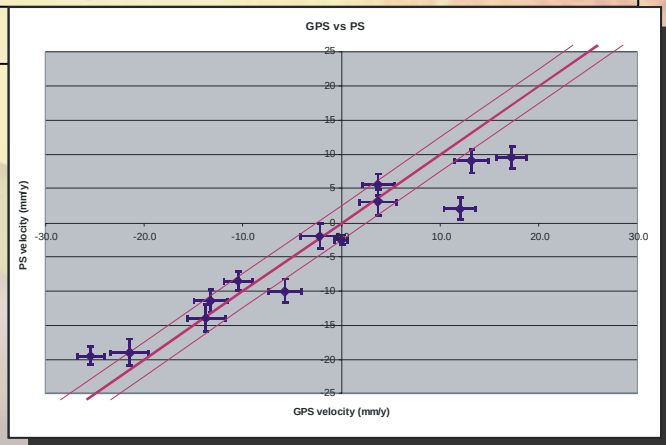


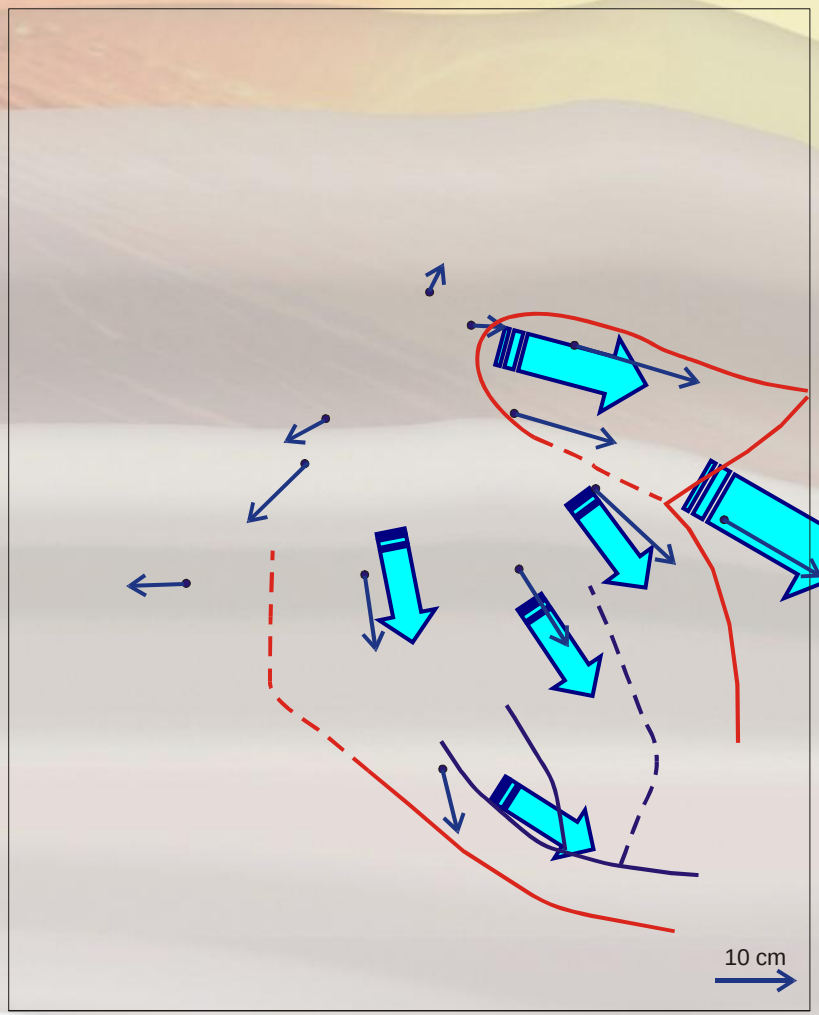
Ascending
Vertical



Descending
Horizontal (E-W)

Analysis of Eastern flank by integrating PS and GPS data





North sector
Large homogeneous horizontal movements;
Vector direction E - ESE
Horizontal Com. > Vertical comp.

Giarre Wedge
Vector direction ESE
Horizontal comp. >> Vertical comp.;

South-East sector
Vector direction from SSE to SE;
Heterogeneous horizontal and vertical movements.