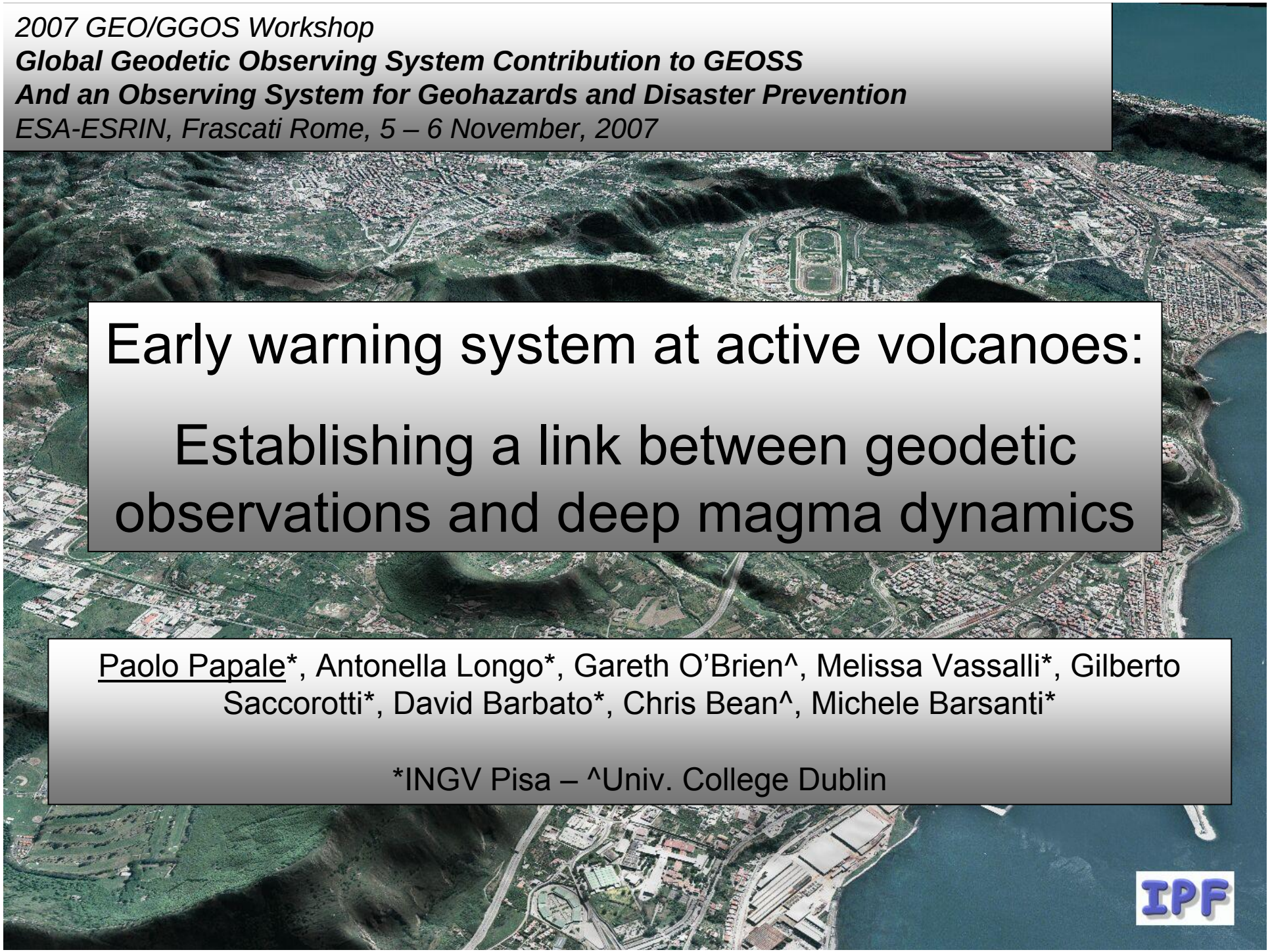
2007 GEO/GGOS Workshop
Global Geodetic Observing System Contribution to GEOSS
And an Observing System for Geohazards and Disaster Prevention
ESA-ESRIN, Frascati Rome, 5 – 6 November, 2007



Early warning system at active volcanoes:

Establishing a link between geodetic observations and deep magma dynamics

Paolo Papale*, Antonella Longo*, Gareth O'Brien^, Melissa Vassalli*, Gilberto Saccorotti*, David Barbato*, Chris Bean^, Michele Barsanti*

*INGV Pisa – ^Univ. College Dublin

IPF

Mass movements and associated stress changes in volcanic systems translate into variations in geophysical quantities commonly measured at the surface

Gravity field, quasi-static and dynamic rock deformation

Question:

• Can we recognize deep magma dynamics from measured quantities?

- Interpretation of geophysical signals
- Short-term volcanic hazard

Forward approach

METHOD

GALES CODE FOR MAGMA FLOW DYNAMICS

(Longo, Vassalli, Papale, Barsanti, GRL 2006)

+

NUMERICAL MODEL FOR WAVE PROPAGATION IN ROCKS

(O'Brien and Bean. GRL 2004)

+

MODEL OF CAMPI FLEGREI ROCKS

(Judenherc and Zollo, JGR 2004)

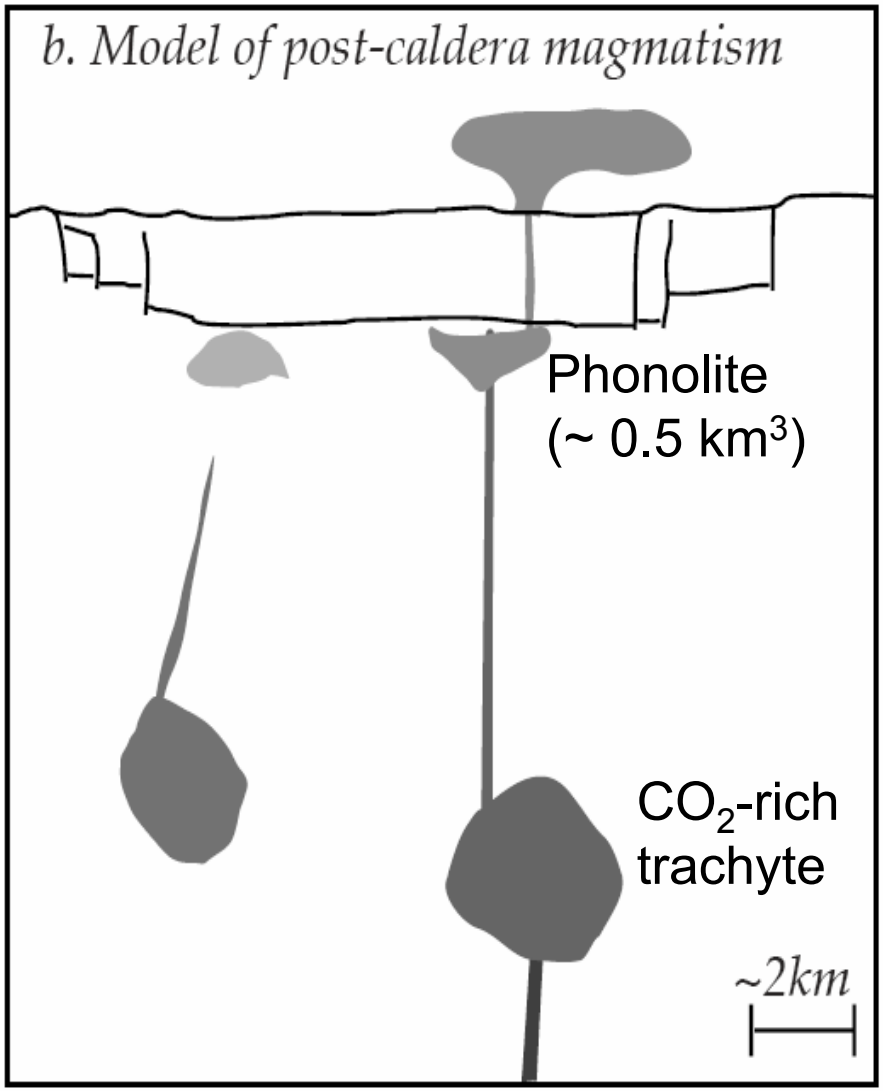
GALES

Developed at INGV Pisa

Finite Elements Method
Galerkin Weighted Residuals
Stabilization: Least Squares (streamwise direction)
Discontinuity Capturing (solution gradient direction)
Double discretization in space and time
Primitive variables (y, p, $\mathbf{u}$, T)
Locally defined properties
C++ programming language
Parallel computation (Linux cluster)

Suitable for the simulation of the space-time evolution of magmatic systems in a wide domain
(from the deep regions of magma chamber to the volcanic crater)

Campi Flegrei

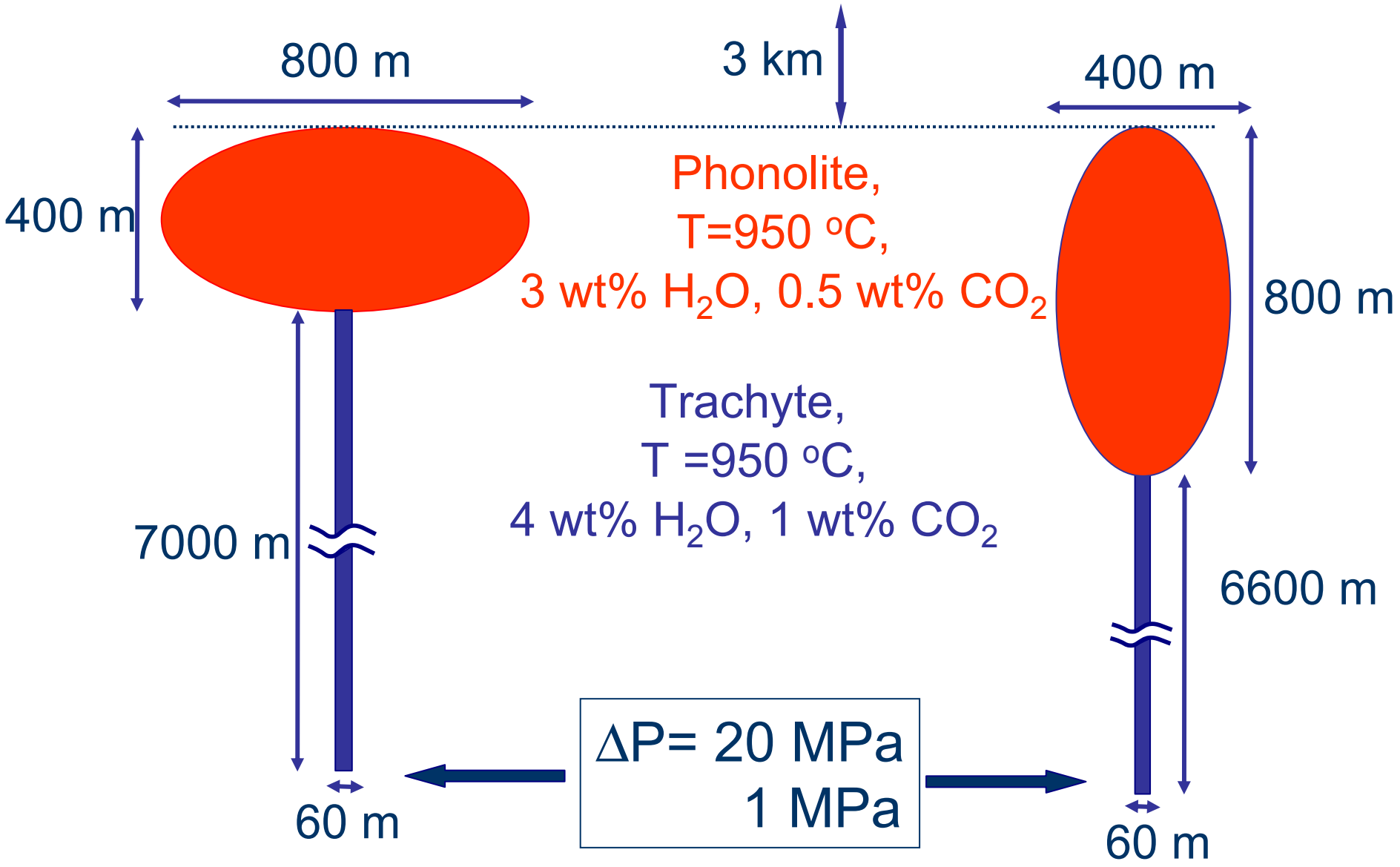


Model based on the petrology of the Agnano Monte Spina and Monte Nuovo eruptions of the C.F. system

(*INGV-DPC Project V3_2 "Campi Flegrei"*)

Campi Flegrei

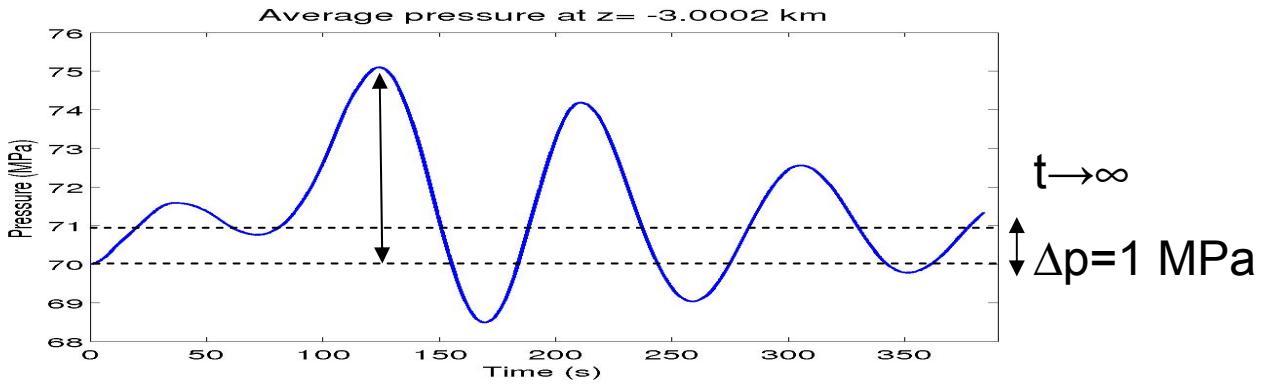
magma chamber + feeding conduit

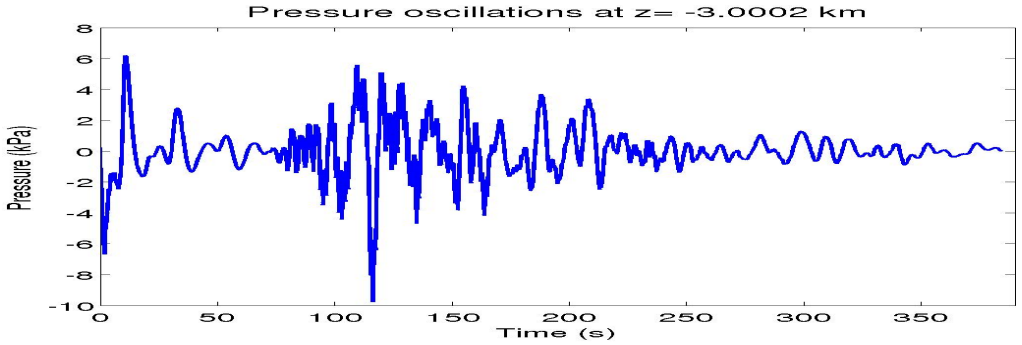


Horizontal, 20 MPa

Pressures changes in the chamber

Driving pressure at dyke base: 1 MPa → Δp max in the chamber = 5 MPa





What geophysical signals are expected at surface?

GALES, CODE FOR MAGMA FLOW DYNAMICS

(Longo, Vassalli, Papale, Barsanti, GRL 2006)

+

NUMERICAL MODEL FOR WAVE PROPAGATION IN ROCKS

(O'Brien and Bean. GRL 2004)

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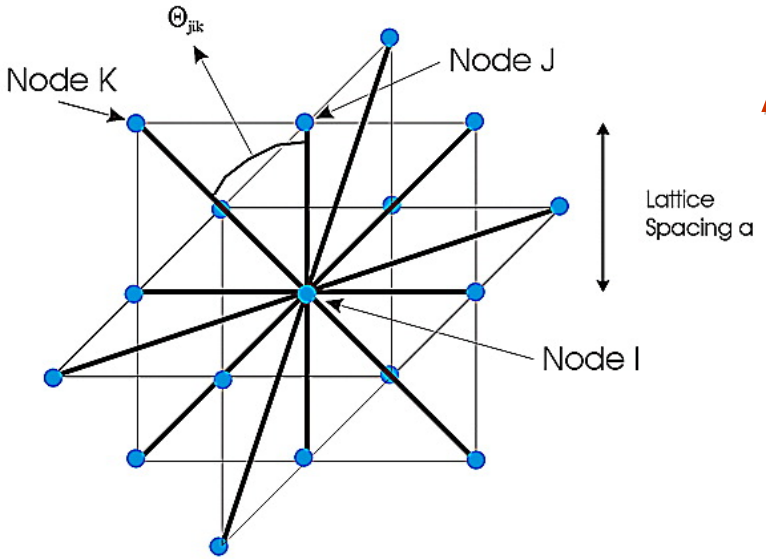
MODEL OF CAMPI FLEGREI ROCKS

(Judenherc and Zollo, JGR 2004)

DISCRETE ELASTIC LATTICE METHOD
(O'Brien and Bean, GRL 2004)

elastic solid represented by a series of interconnected springs arranged on a cubic lattice.

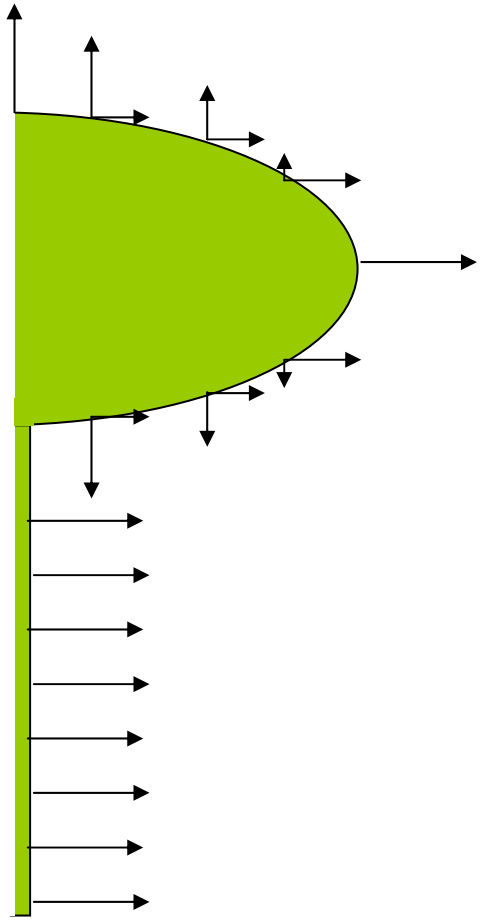


Accounts for:

- Free surface
- Heterogeneous rock properties
- Sharp discontinuities
- Topography

spring elastic constant is a function of rock properties (v_p, v_s, ρ)

MAGMA-ROCK ONE-WAY COUPLING



GALES

output

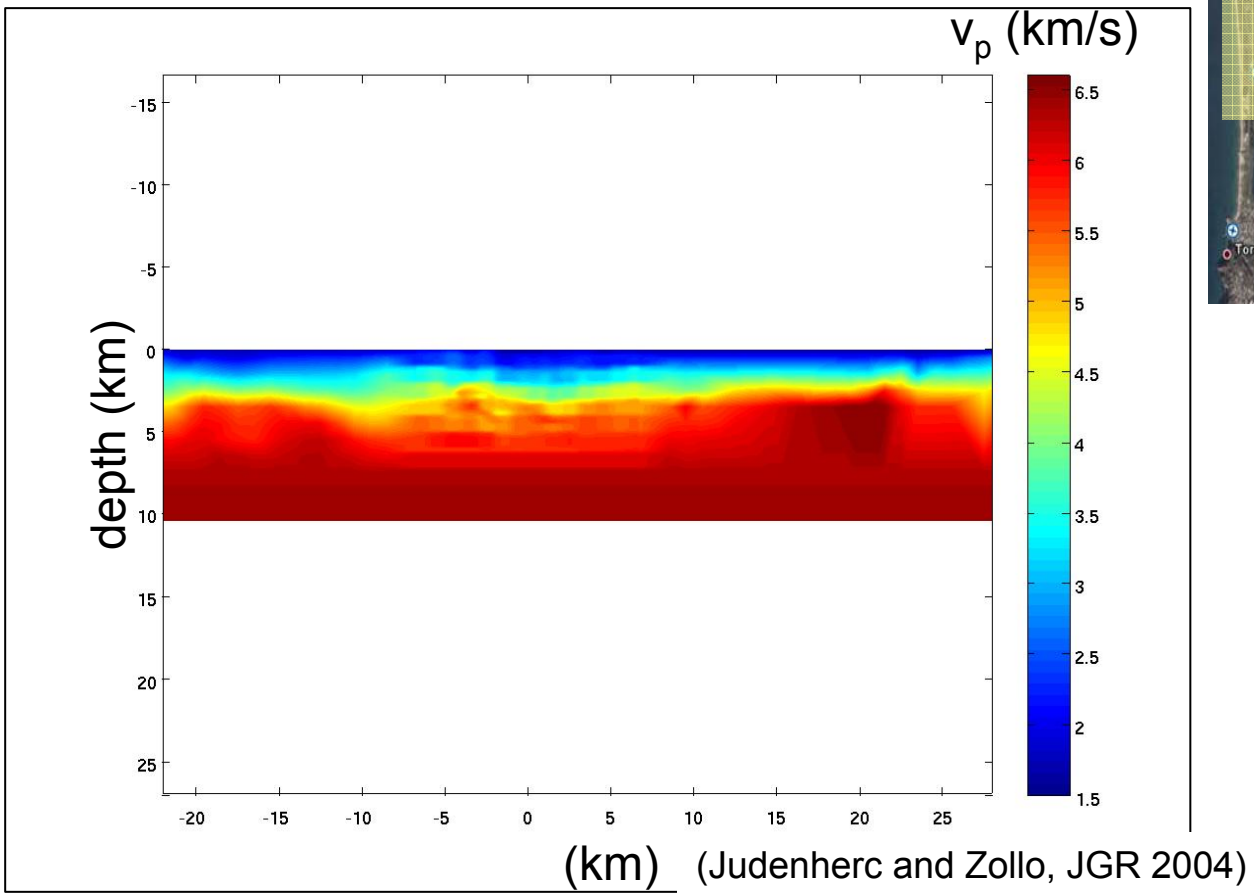
Pressure

Deviatoric stress

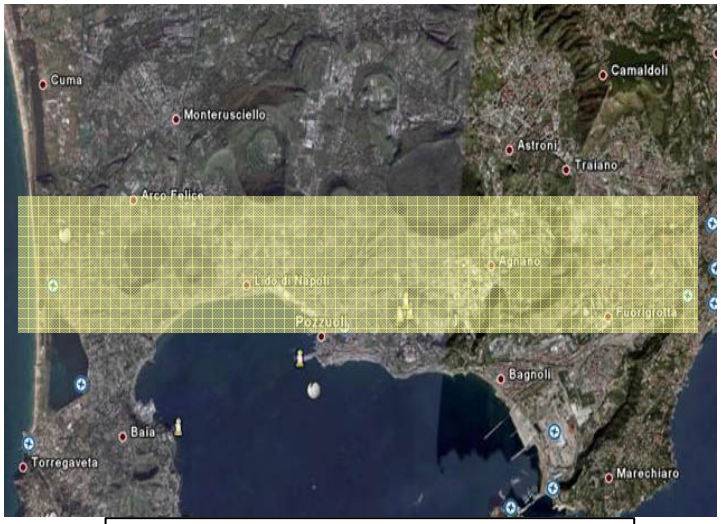
input

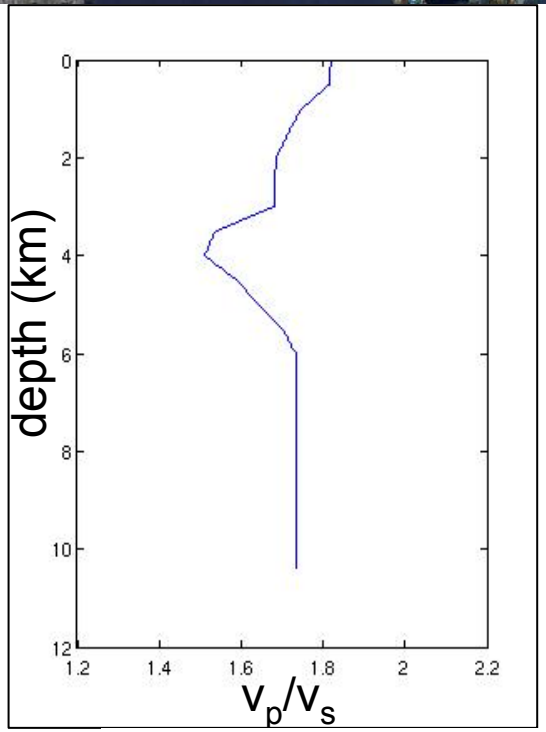
DISCRETE ELASTIC
LATTICE METHOD

Rock model from active and passive tomography

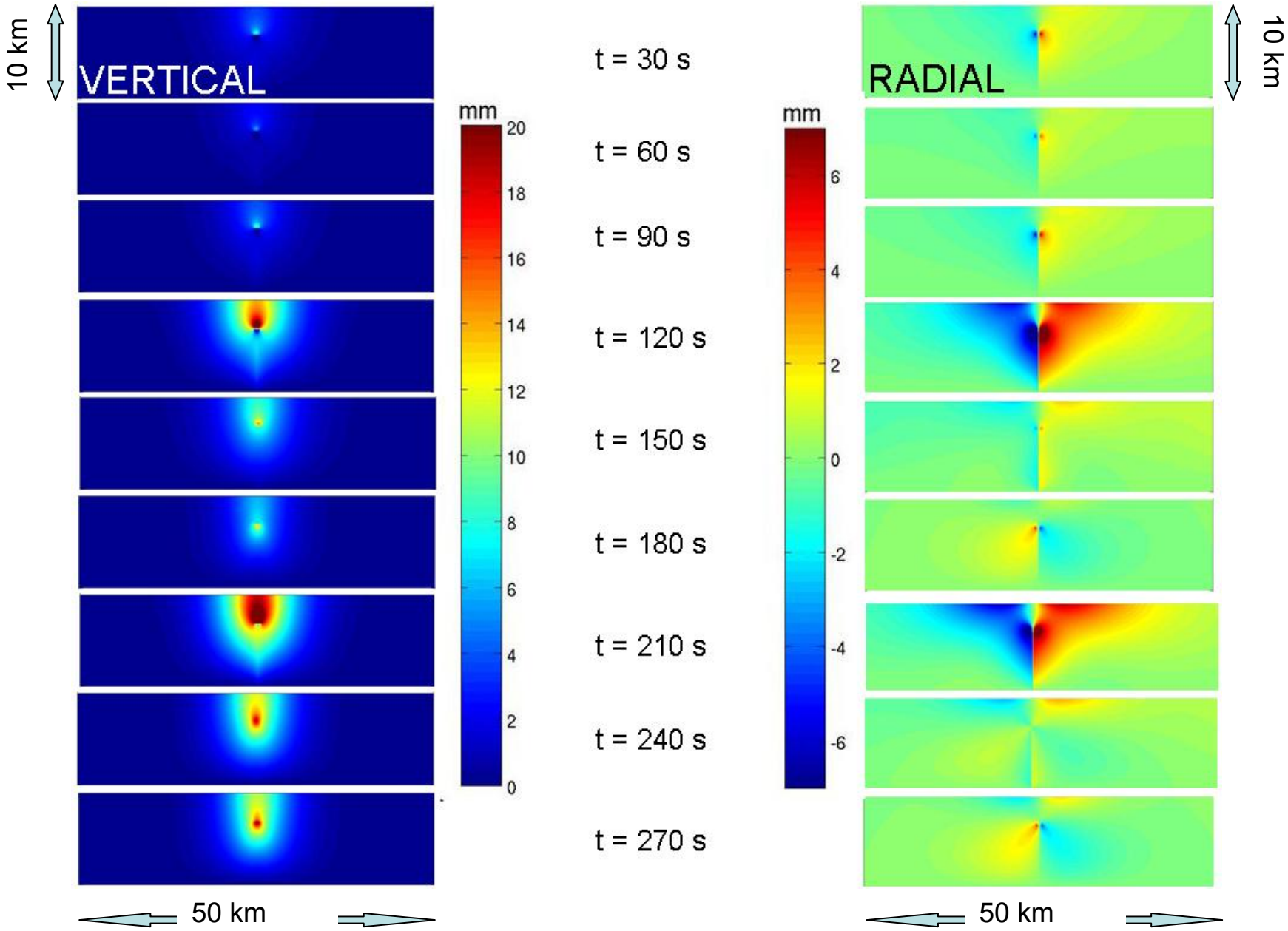


(Judenherc and Zollo, JGR 2004)

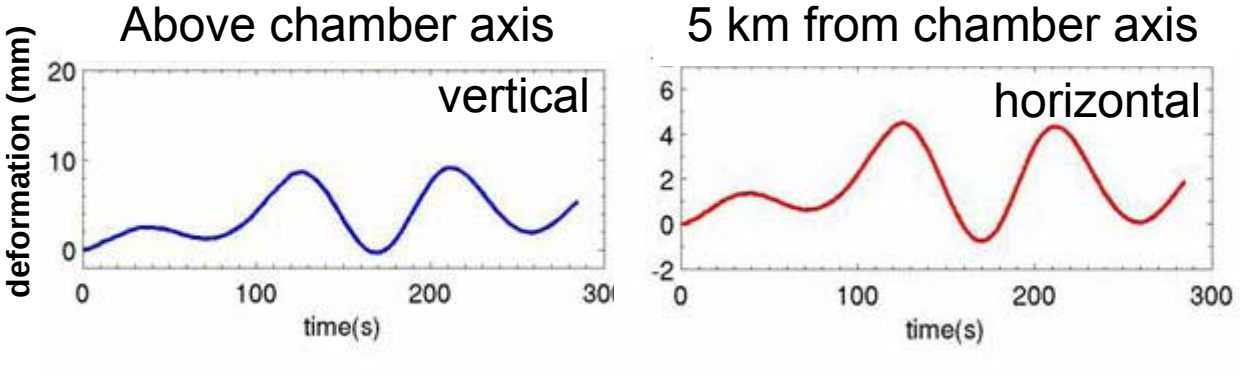




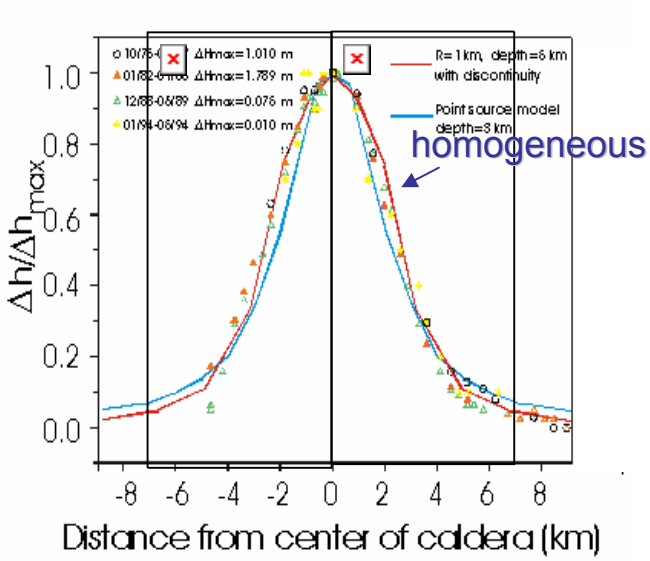
(Vanorio et al, GRL 2005)


10 km
VERTICAL
mm
20
18
16
14
12
10
8
6
4
2
0
t = 30 s
t = 60 s
t = 90 s
t = 120 s
t = 150 s
t = 180 s
t = 210 s
t = 240 s
t = 270 s
RADIAL
mm
6
4
2
0
-2
-4
-6
10 km
50 km
50 km

Ground deformation

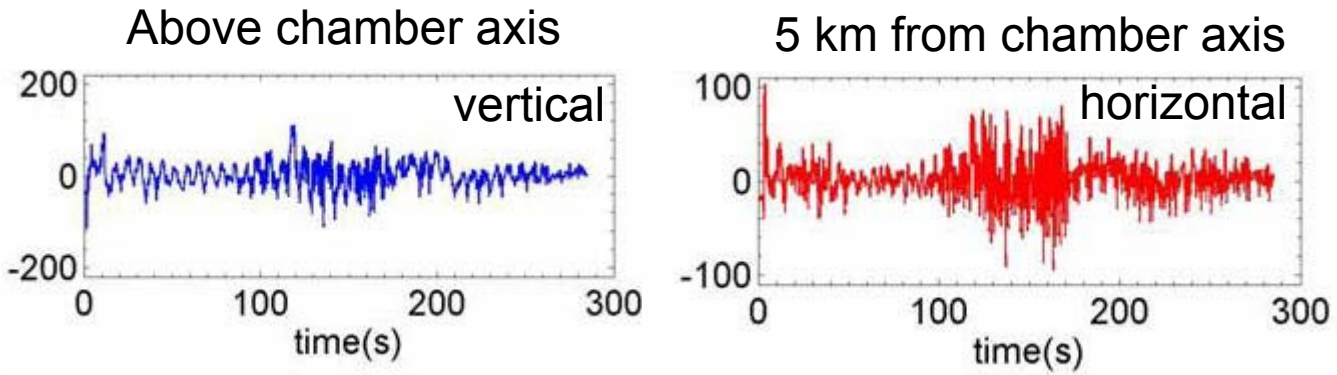


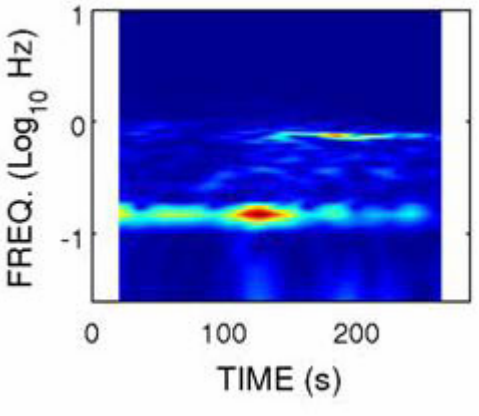
Period: 70 – 80 s up to > 100 s



Seismicity

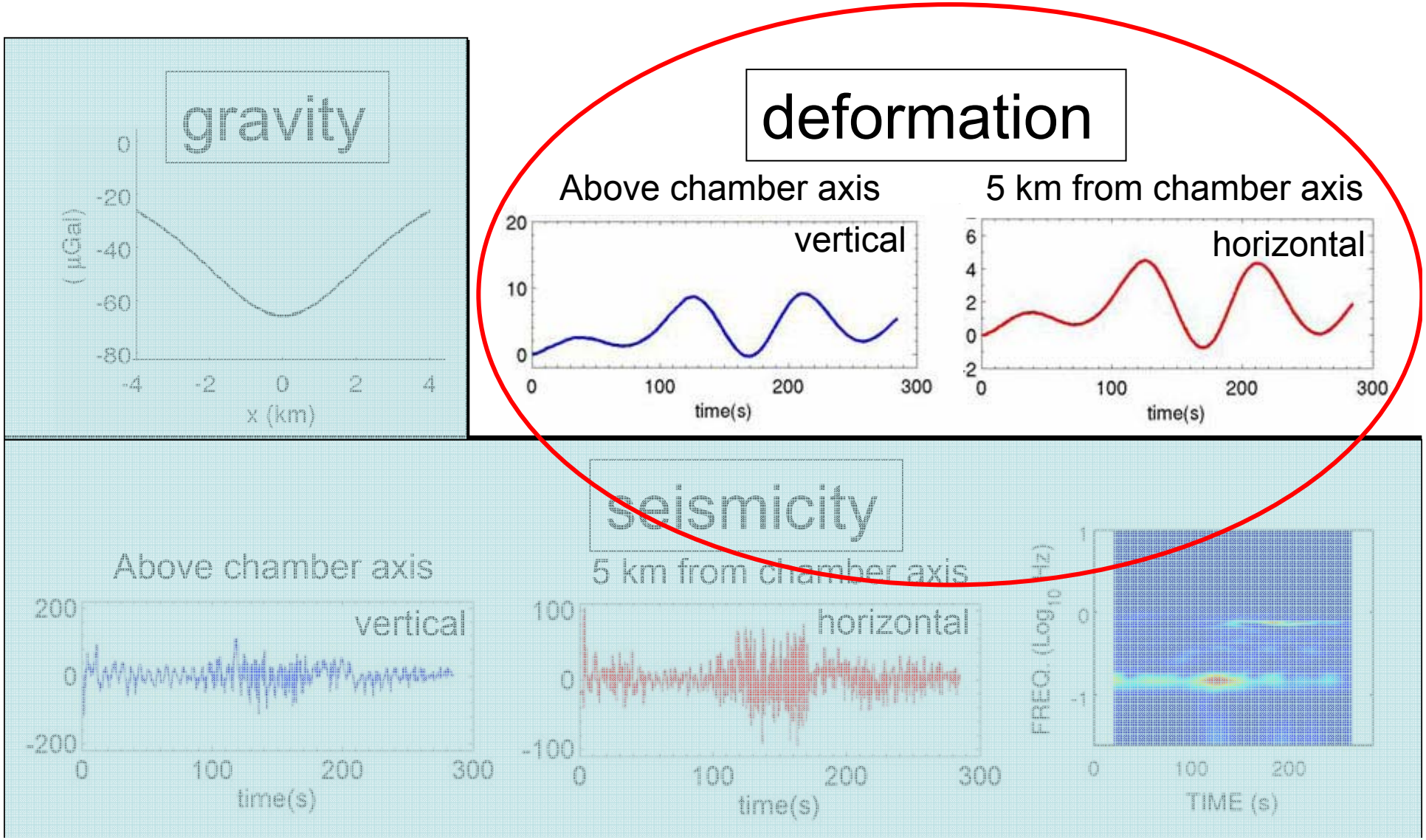
Band-pass filter 0.25 – 10 Hz

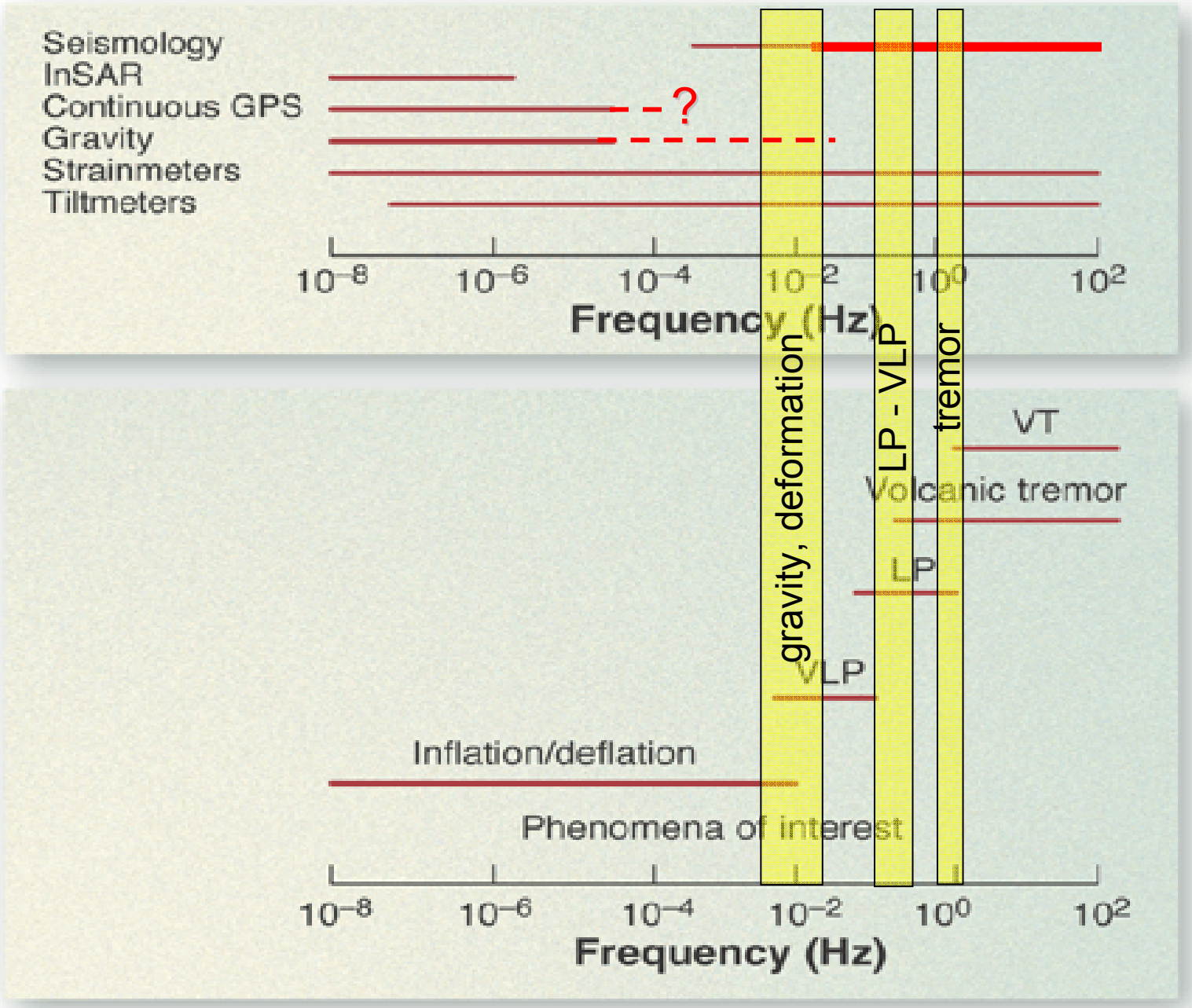




Periods: 1) 6-7 s (LP/VLP); 2) 1 s (tremor)

Expected signals associated with recharge of a shallow magma chamber at Campi Flegrei





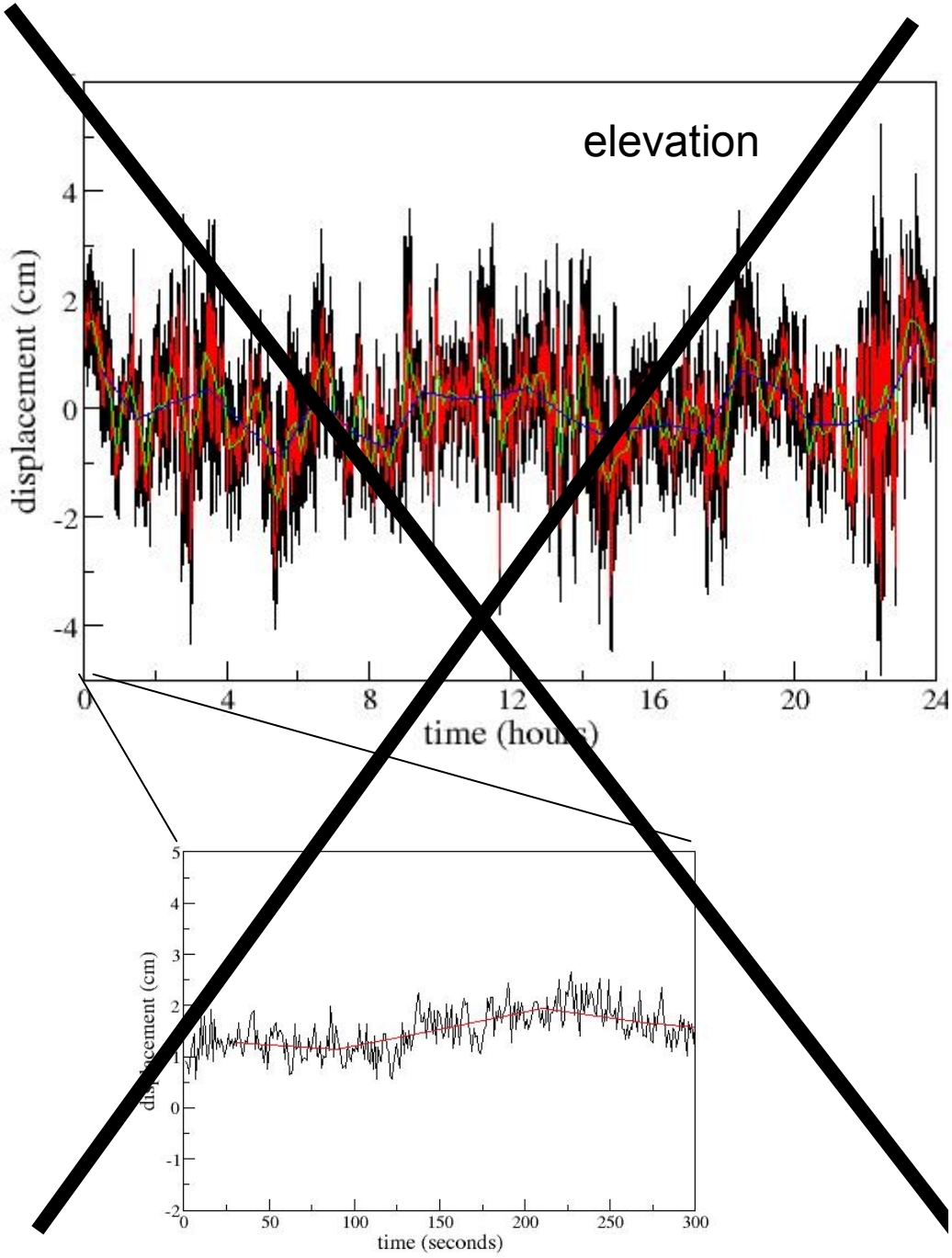
From Scarpa, Science 2003

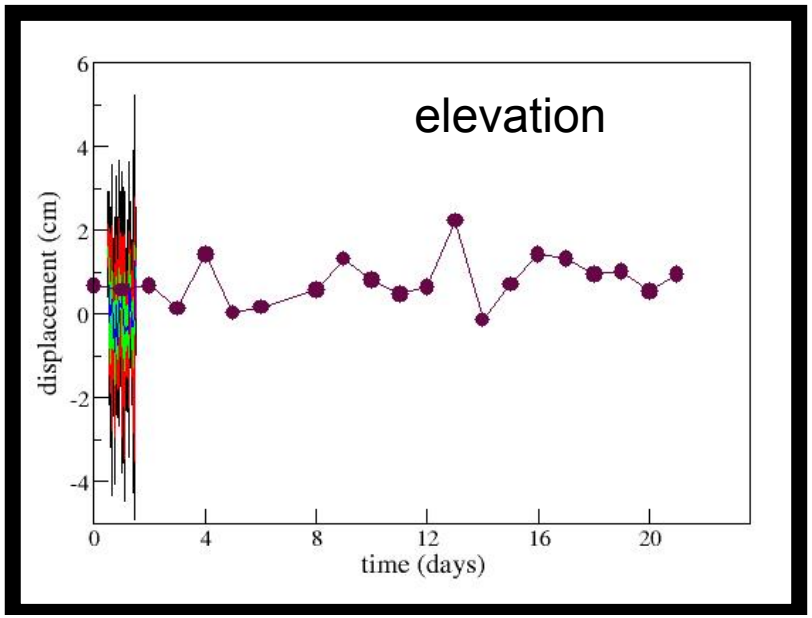
GPS measurements at Timpone del Fuoco – Stromboli volcano

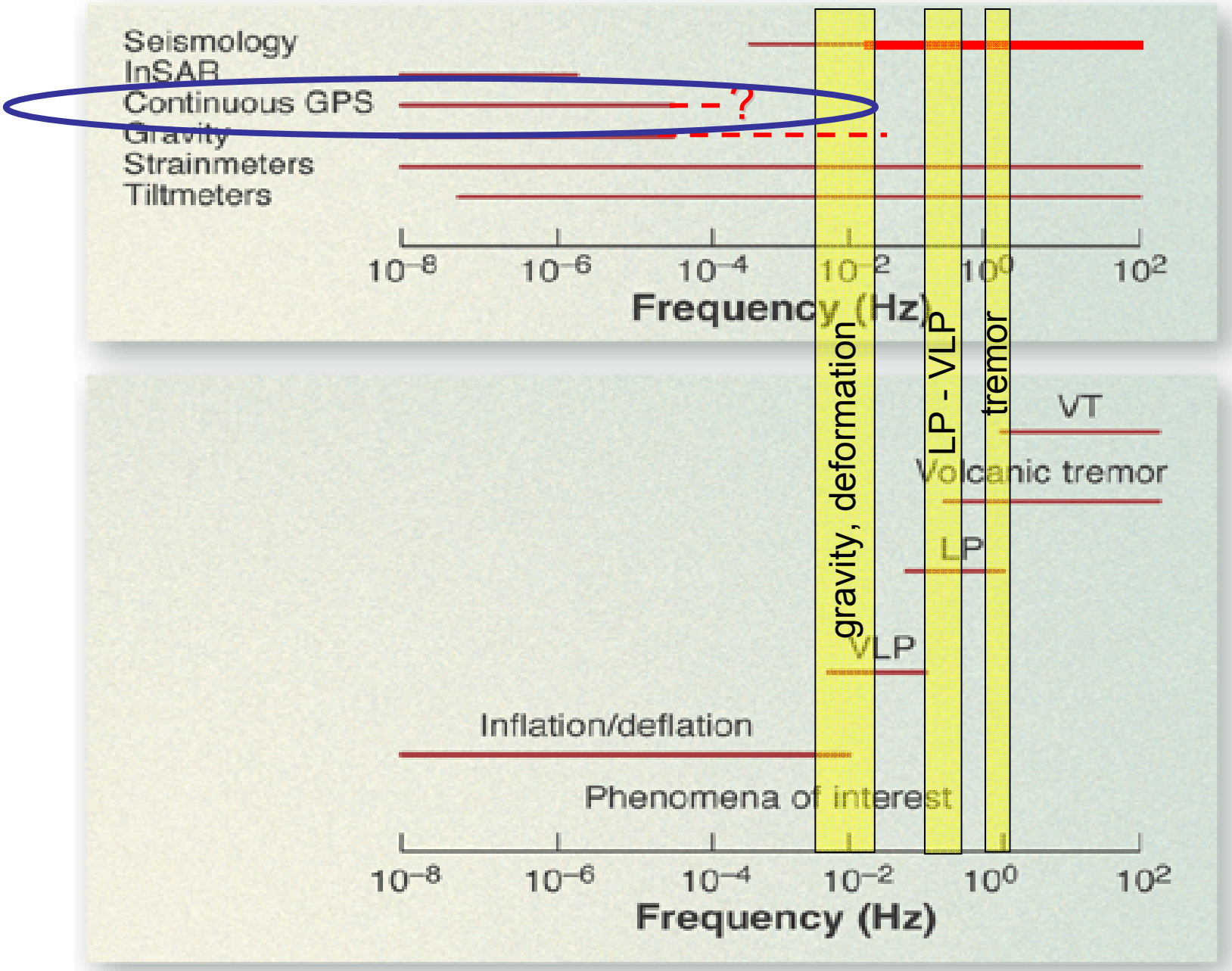
kindly provided by G. Puglisi, INGV-CT

sampling period

- 1 s
- 1 m
- 10 m
- 1 h







From Scarpa, Science 2003

THANK YOU

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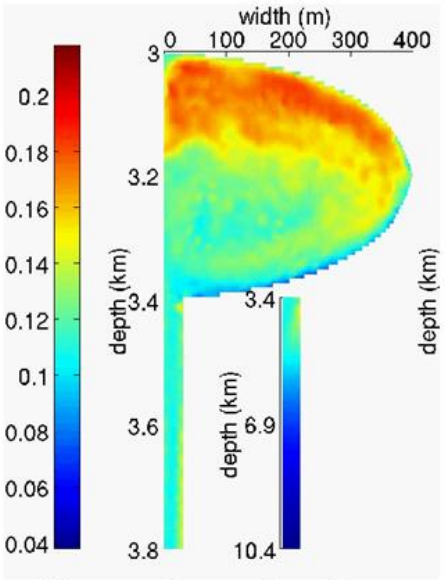
- *Italian Dipartimento della Protezione Civile*
- *MIUR-FIRB*
- *EC Volume Project*
- *Istituto Nazionale di Geofisica e Vulcanologia*

Initial phase of new magma input into a shallow chamber at Campi Flegrei



- Ground deformation: order of 1 cm, oscillations with period around 100 s
- Seismic signal: two main periods, 6-7 s (VLP/ULP) and 1-2 s (volcanic tremor)
- Vertical gravity change: negative, order of tens of μgal