



Misure InSAR: Principi Teorici

Relatore:

Alessandro Ferretti

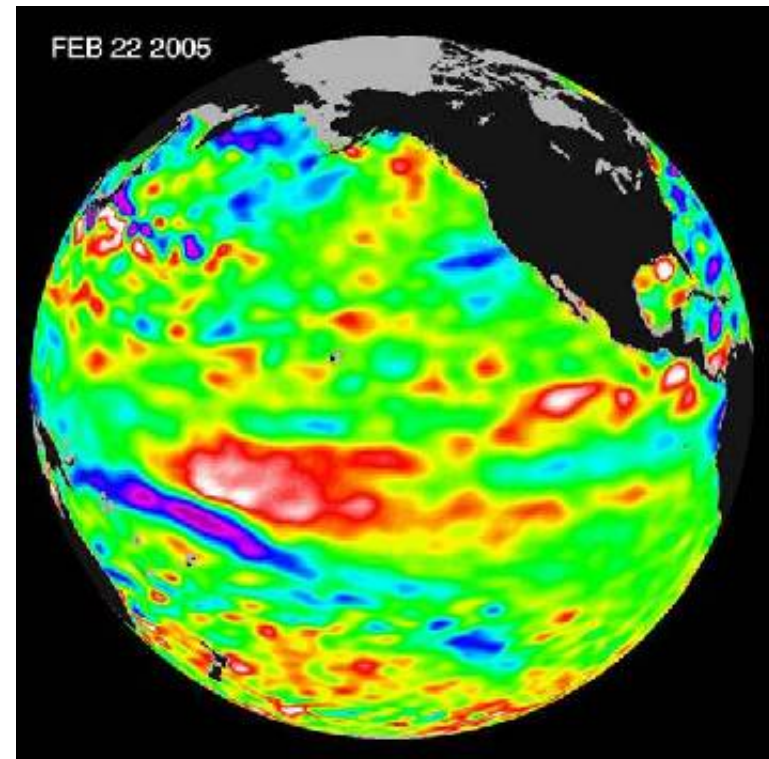
Corso di Formazione - RISKNAT
INTERFEROMETRIA RADAR
SATELLITARE MULTITEMPORALE



L'Osservazione della Terra dallo spazio



La Terra viene costantemente osservata con diversi strumenti montati su satelliti che orbitano ad altezze variabili tra 500 e 36000km



Japanese Tsunami (Geoeye Satellite Data)



Il telerilevamento radar

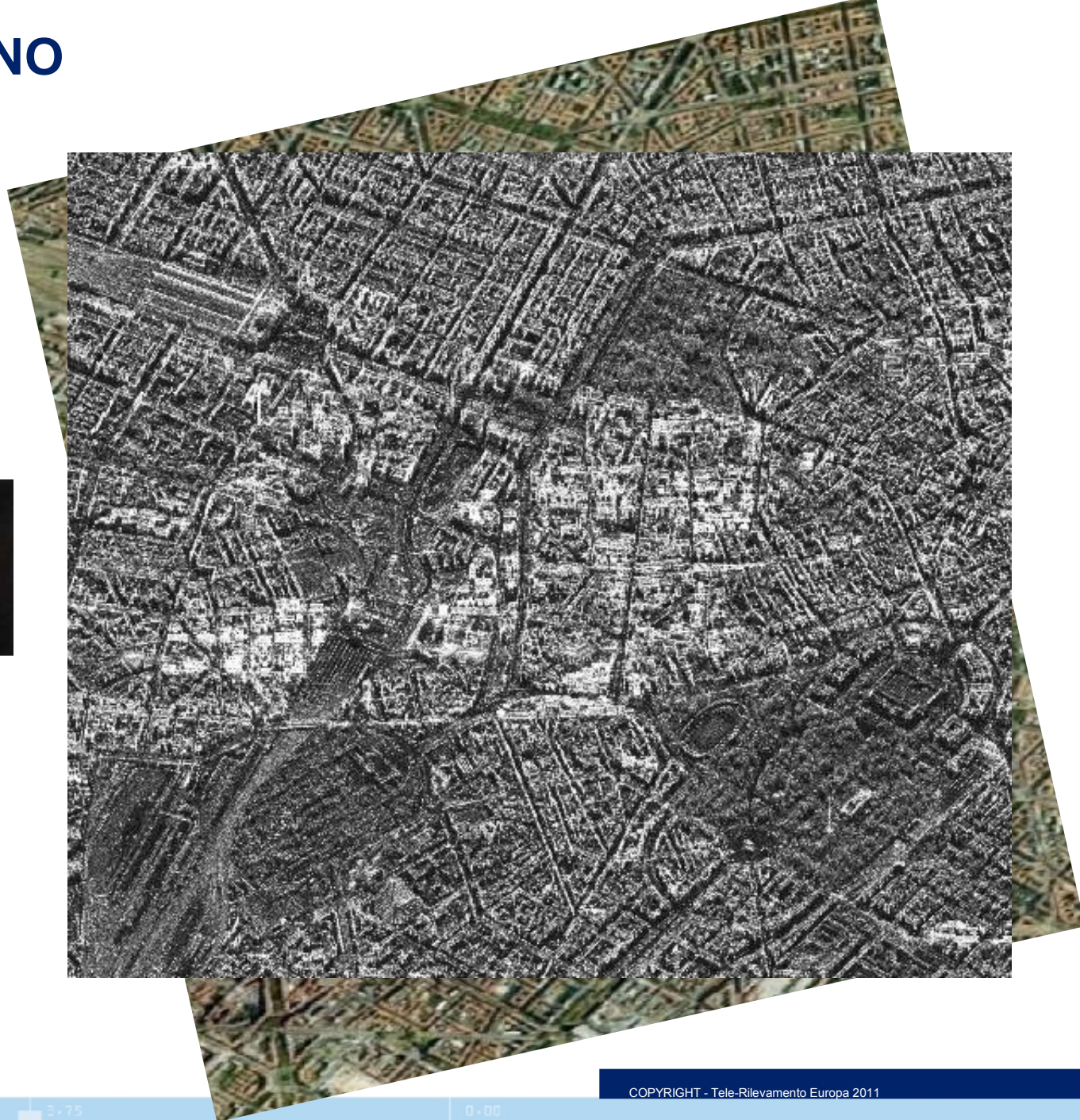
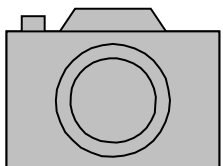


- Vantaggi rispetto all'ottico
 1. È un sistema attivo: *non ha bisogno di sorgenti esterne come il Sole*
 2. Opera alla frequenza delle micro-onde che *penetrano attraverso nuvole e pioggia*
 3. È un sistema coerente: *consente misure molto precise di variazioni di distanza dal radar per mezzo dell'interferometria*

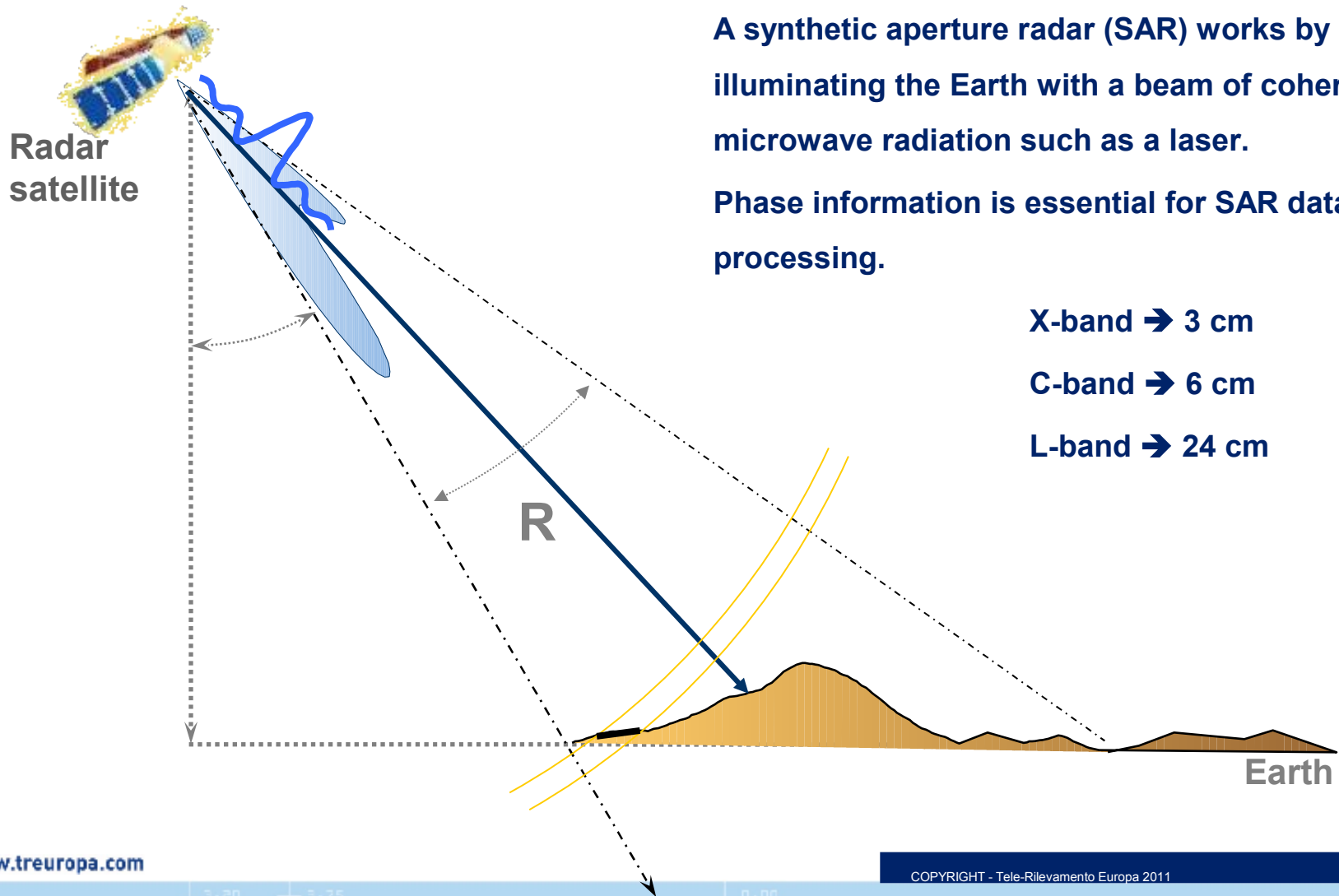


MILANO

TRE
Scanning the Planet



Satellite SAR: a coherent sensor

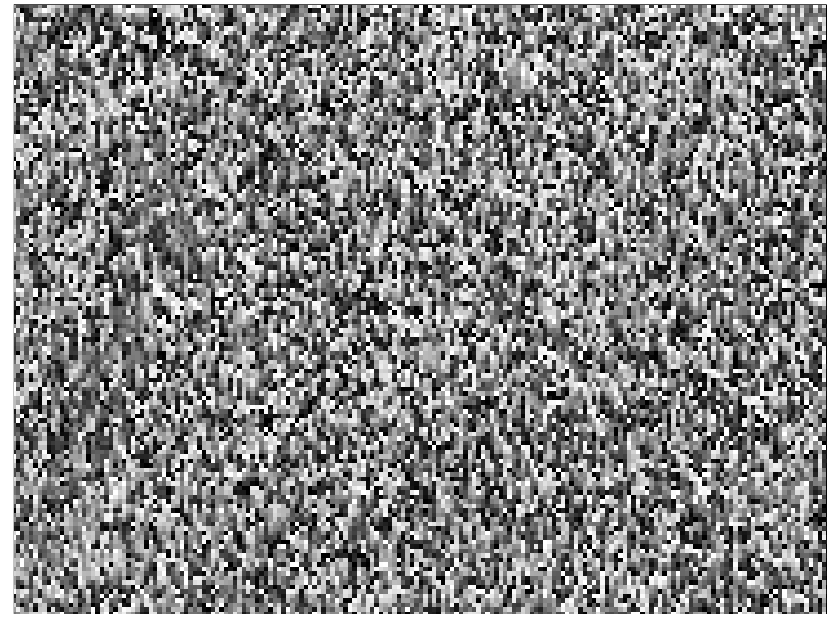


SAR data

A SAR image is a set of pixels characterized by both amplitude and phase values.

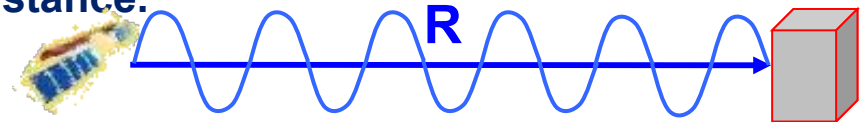


Amplitude



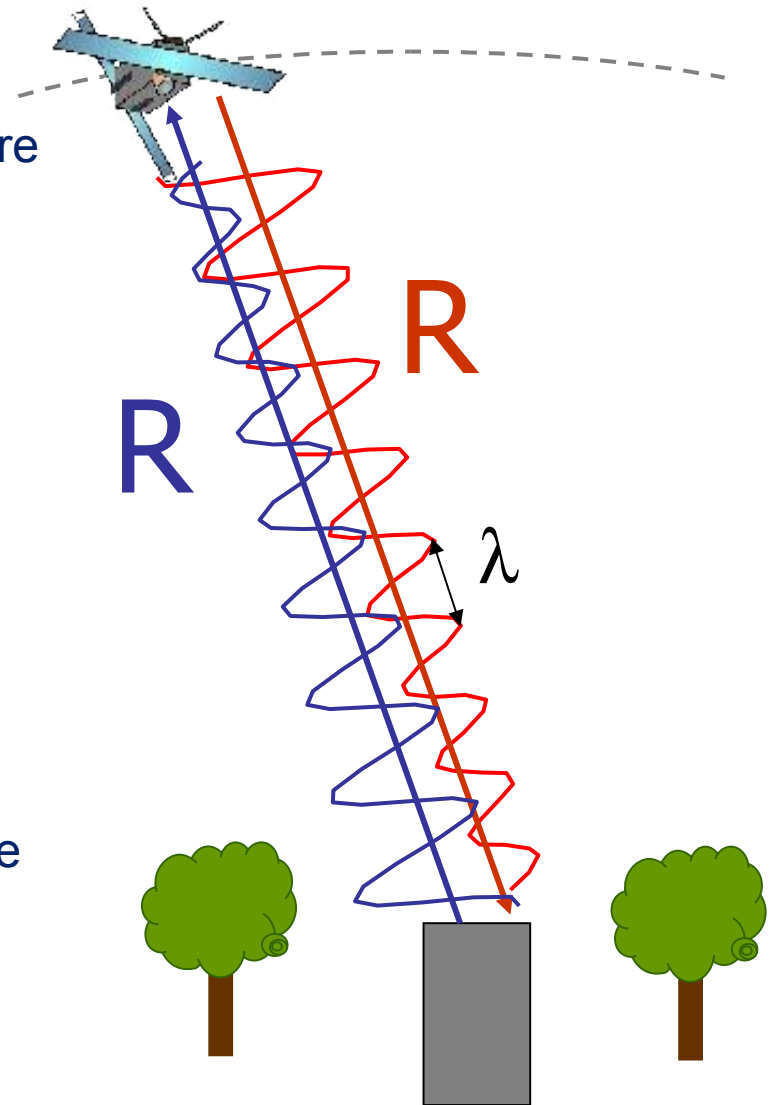
Phase (known modulo 2π)

The phase is related to the sensor-target distance.



L'immagine SAR (fase)

- Il segnale trasmesso dal radar deve raggiungere l'oggetto a terra e quindi tornare indietro fino al radar.
- Oggetti a diversa distanza dal radar introducono un diverso ritardo tra la trasmissione e la ricezione del segnale (tempo di volo).
- Il segnale radar può essere assimilato ad una sinusoide con lunghezza d'onda λ .
- Il tempo di volo fa sì che la fase del segnale ricevuto sia diversa dalla fase del segnale trasmesso.



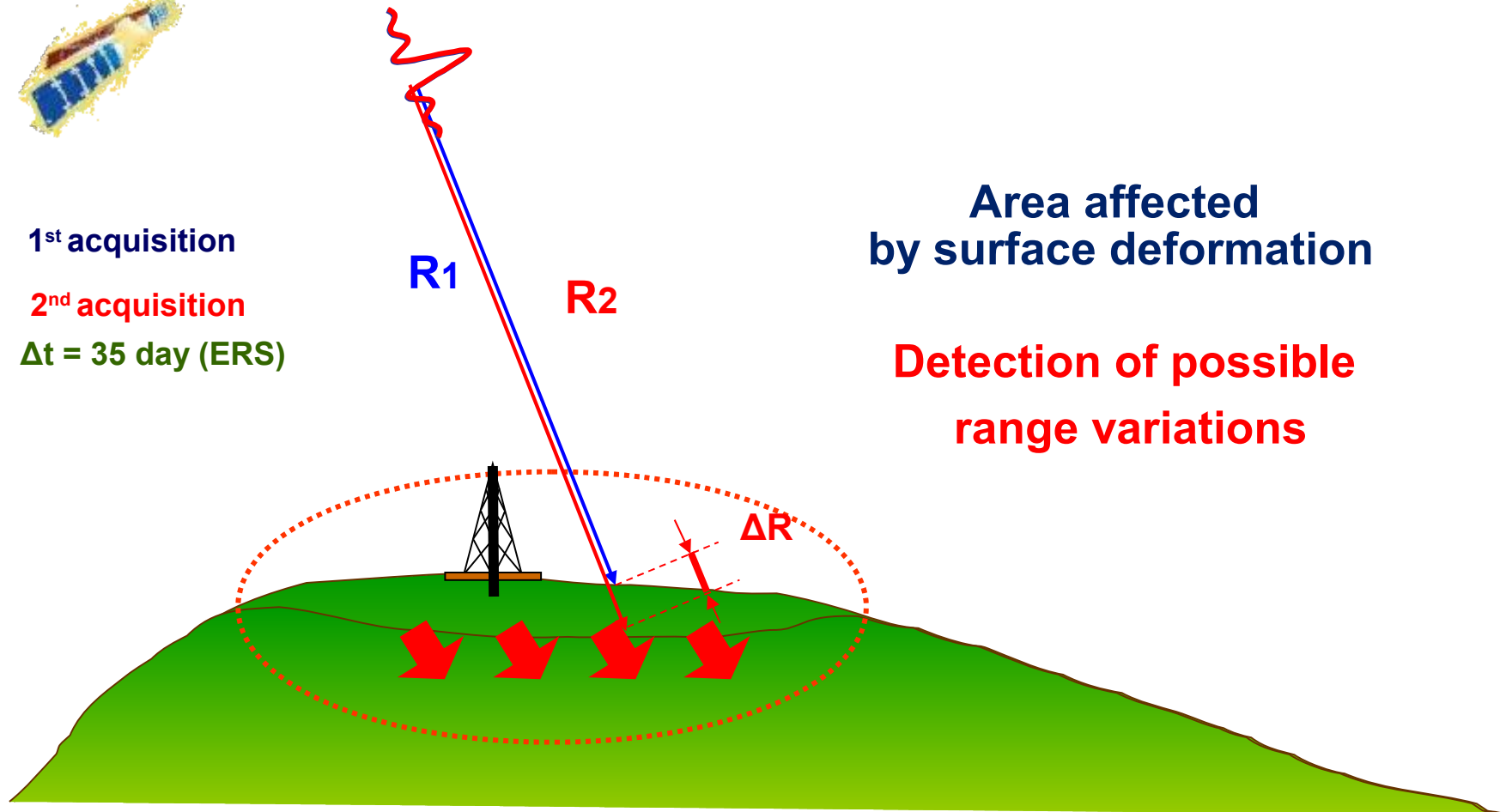
The Basic Idea



1st acquisition

2nd acquisition

$\Delta t = 35$ day (ERS)

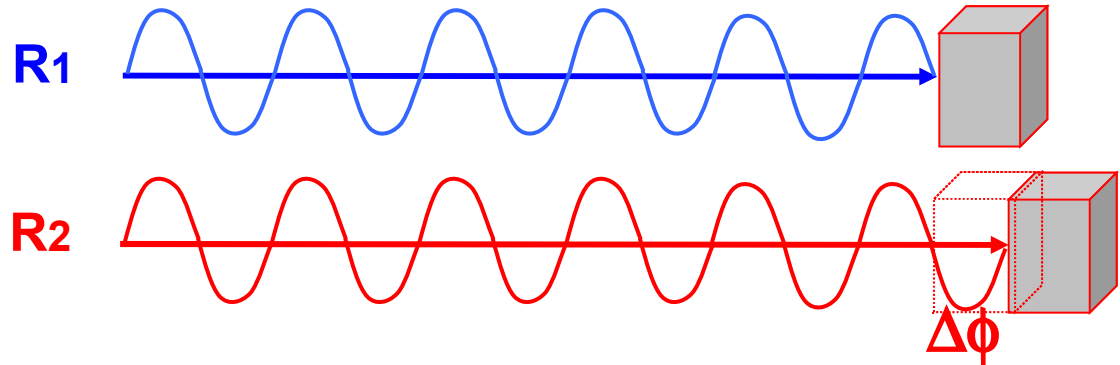


Area affected
by surface deformation

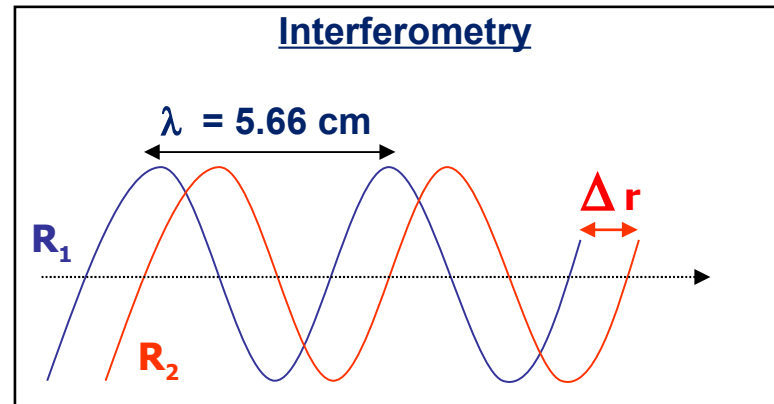
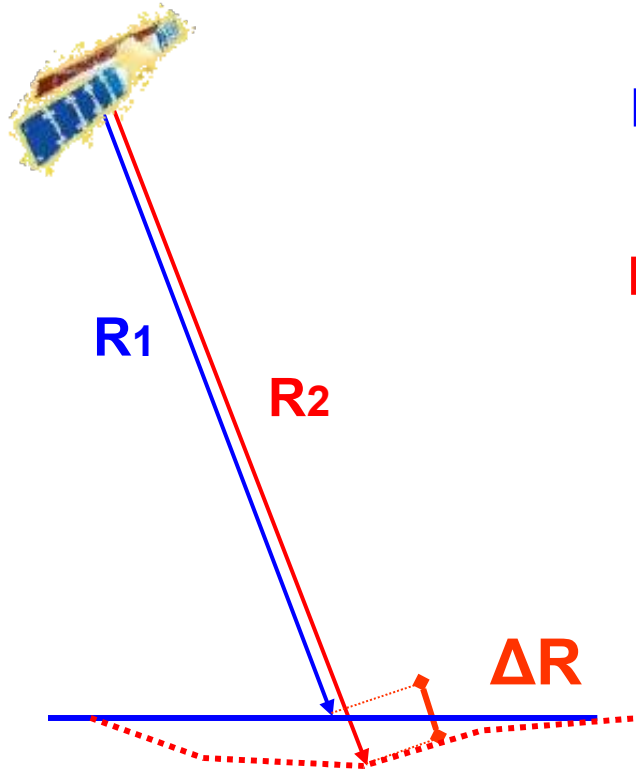
Detection of possible
range variations

The Interferometric Concept

The *unit of length* used in InSAR is the wavelength:



$$\Delta R = c \cdot \Delta\phi$$



Single SAR image: phase contributions

$$\phi = \psi + \frac{4\pi}{\lambda} r + \alpha + v$$

Ψ

Reflectivity of the radar target

$4\pi r/\lambda$

“Propagator”: it depends on the sensor-radar target distance

α

Atmospheric Phase Contribution

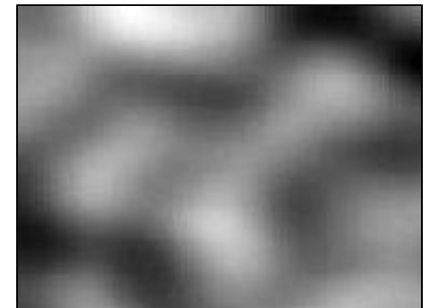
v

Noise

Amplitude



Phase

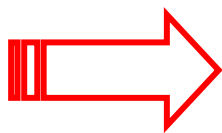


Interferogram: phase contributions

$$\Delta \phi = \cancel{\Delta \psi} + \frac{4\pi}{\lambda} \Delta r + \cancel{\Delta \alpha} + \cancel{\text{noise}}$$

If:

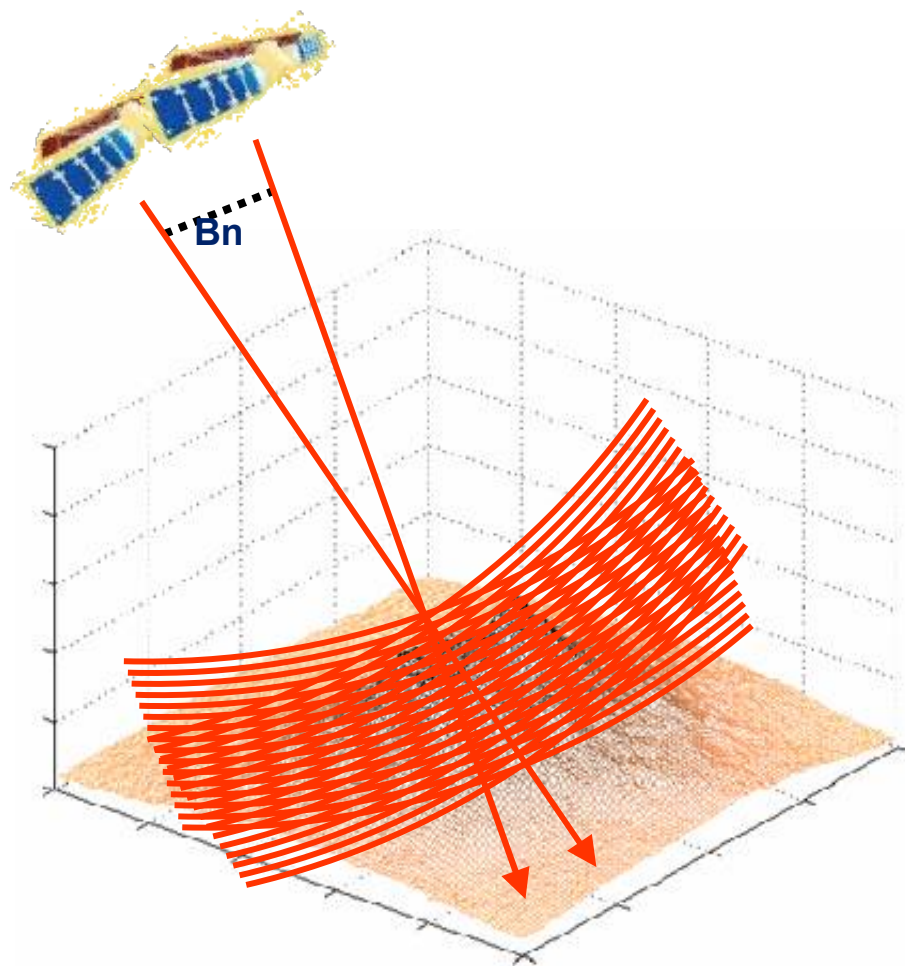
- “nothing” has changed: $\Delta \psi = \Delta \alpha = 0$
- for high SNR: $\nu = 0$



$$\phi = \frac{4\pi}{\lambda} \Delta r$$

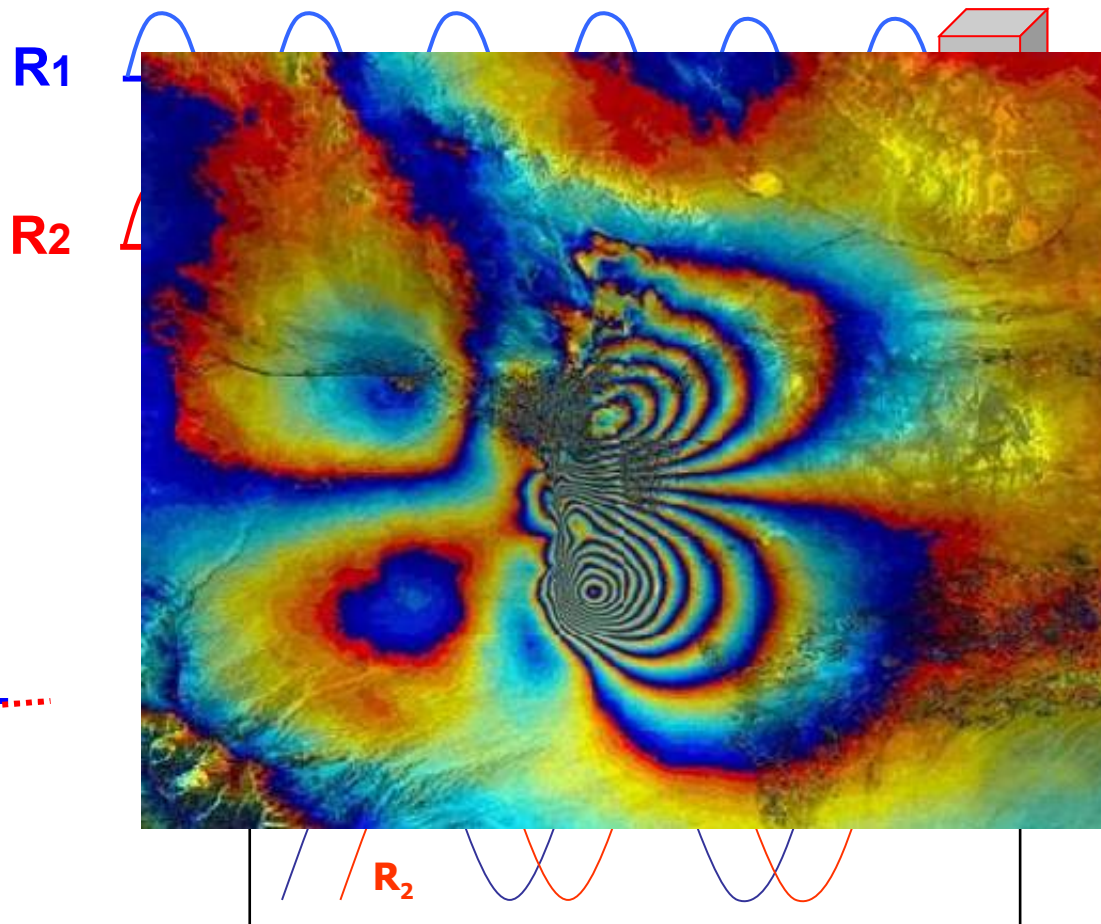
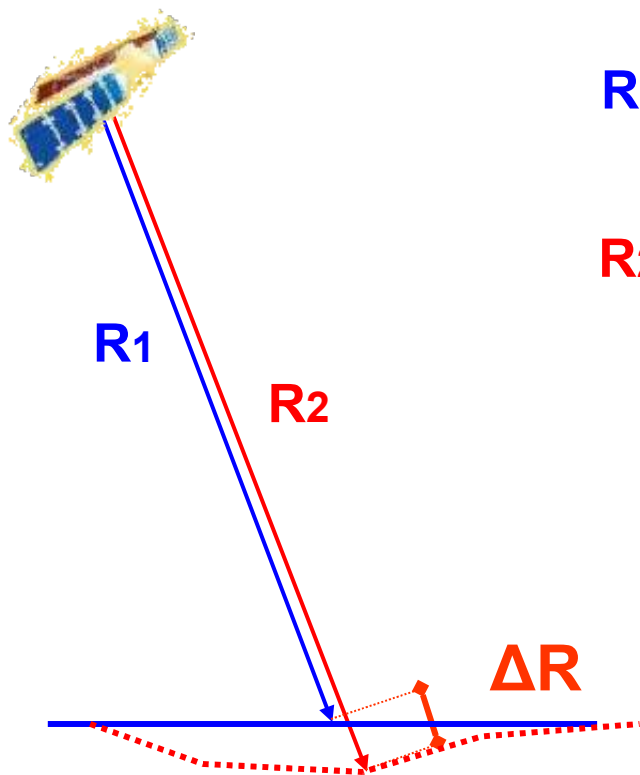
The interferometric phase
is proportional to
range variations

InSAR per la generazione di DEM



InSAR per la stima degli spostamenti

L'unita' di misura nell'InSAR e' la lunghezza d'onda:



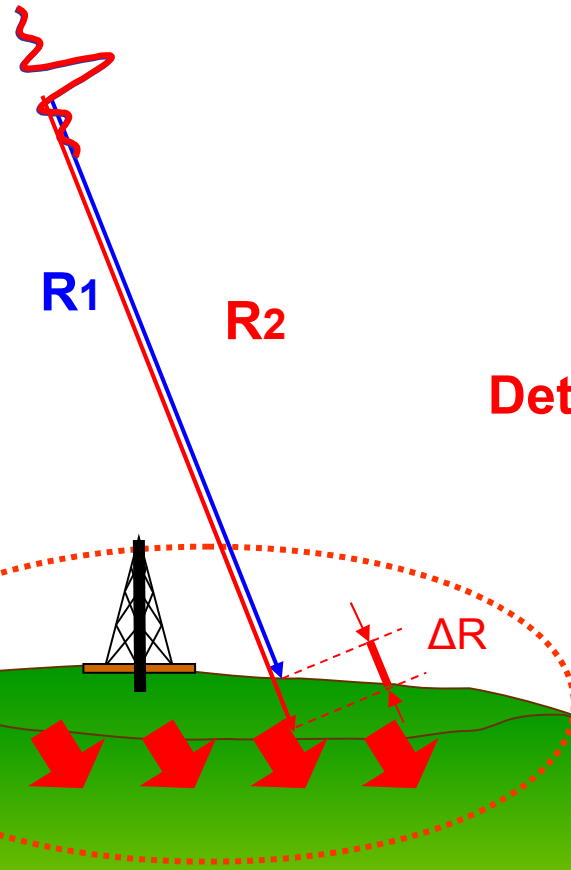
How does it work



1st acquisition

2nd acquisition

$\Delta t = 35/24/11/4$ days



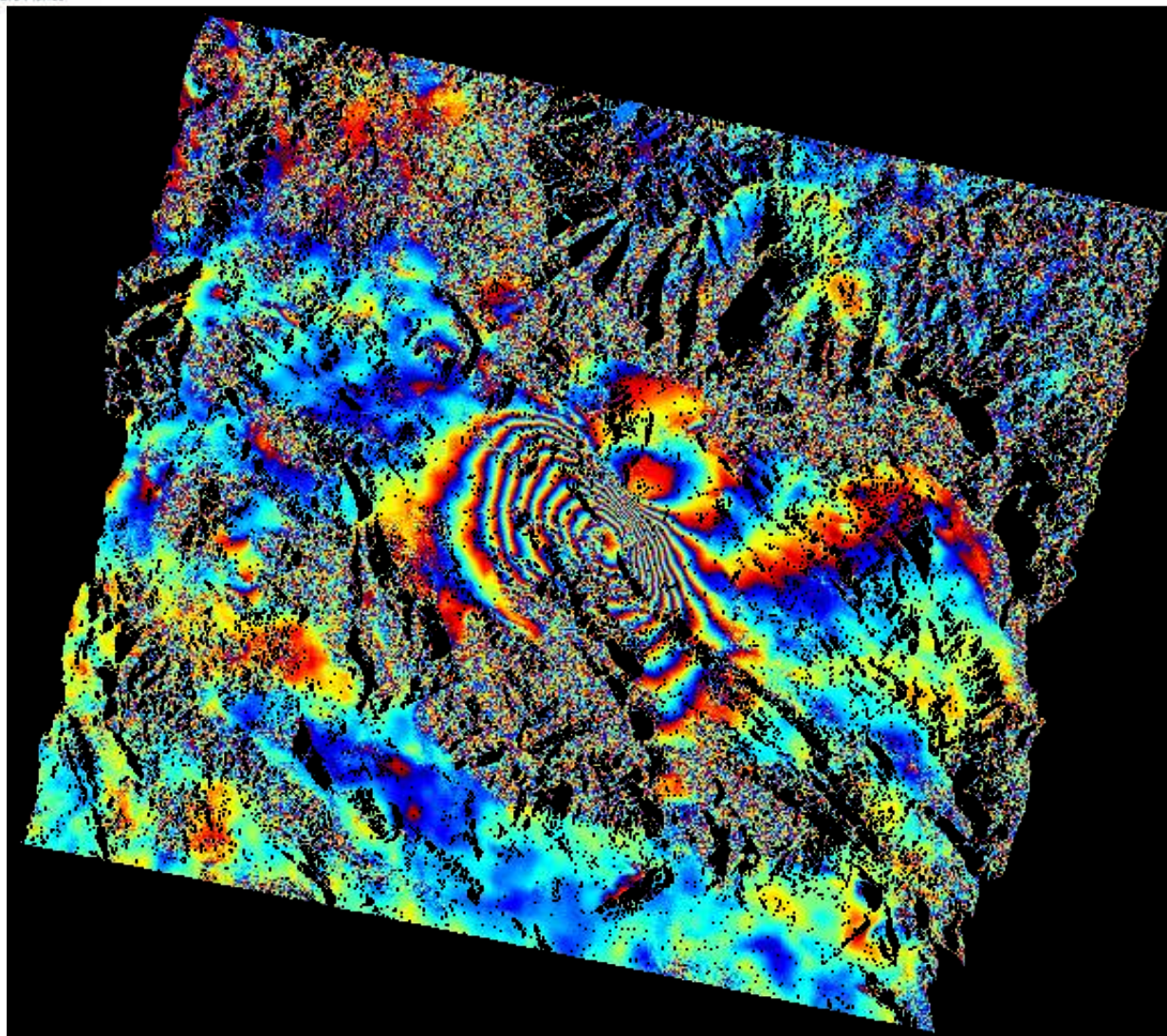
Subsiding area

Detection of displacement (ΔR)



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Serving the Planet

L'Aquila Earthquake, 6 Apr. 2009



Co-seismic
Interferogram

Satellite: ENVISAT

Date:
20090201 –
20090412

Bn = 148m
Bt = 70gg

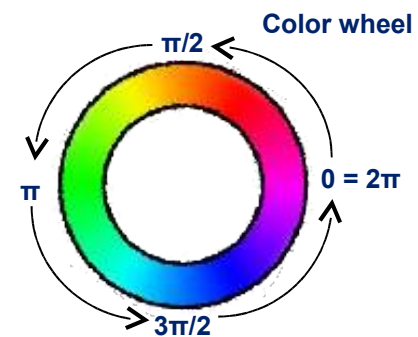
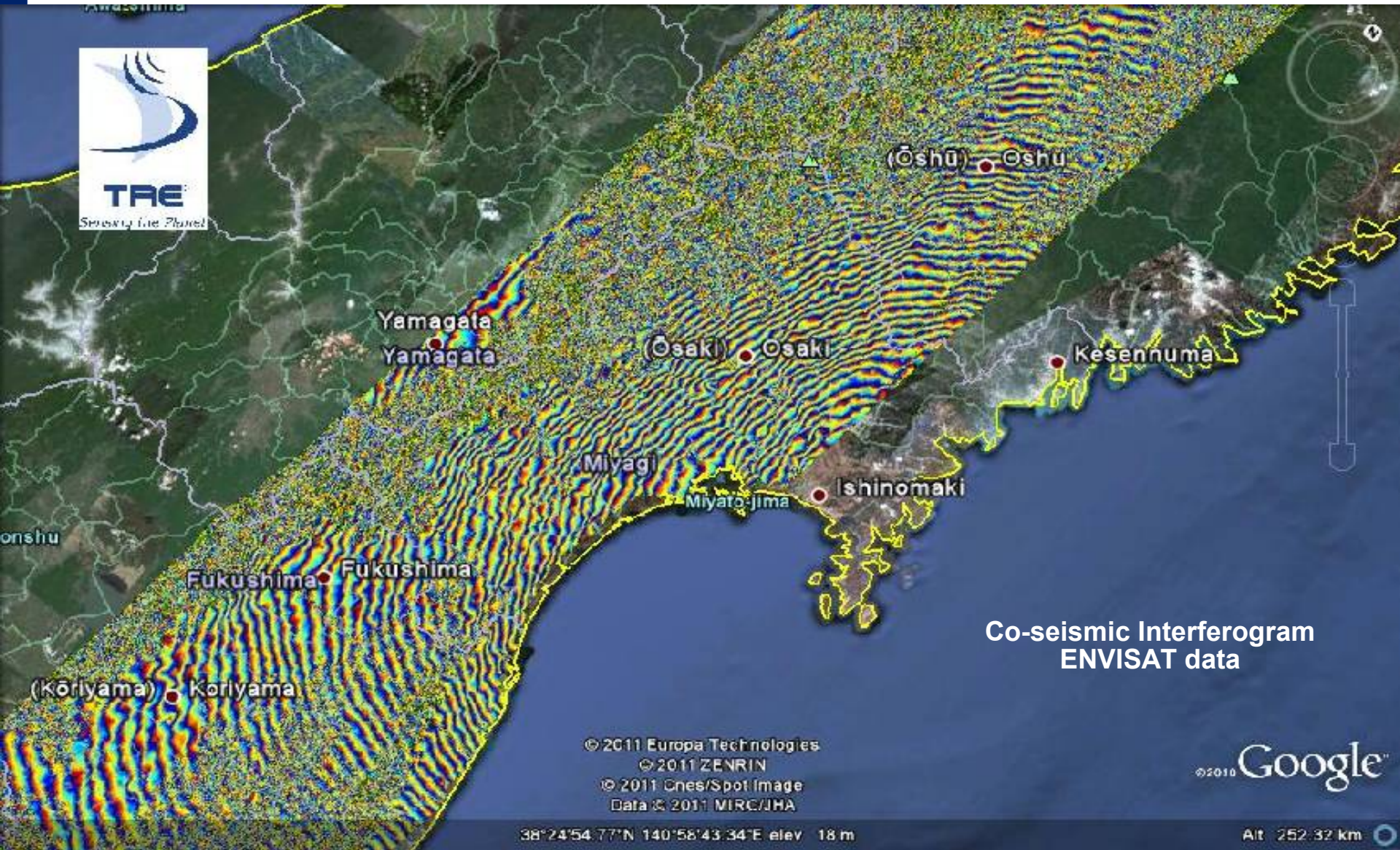
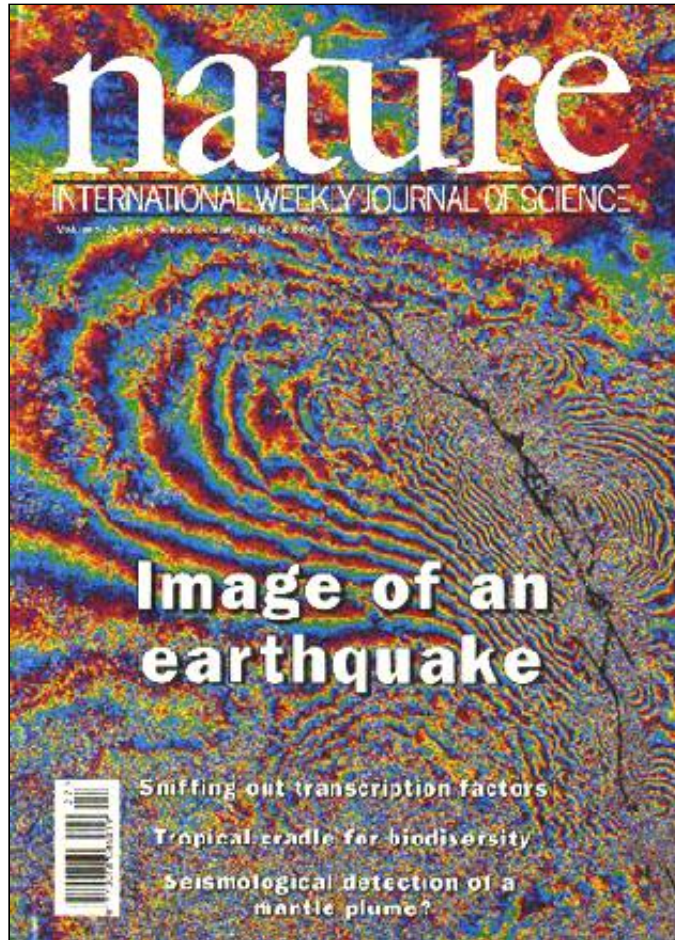


Image of an earthquake: Tohoku, Japan (2011-3-11)



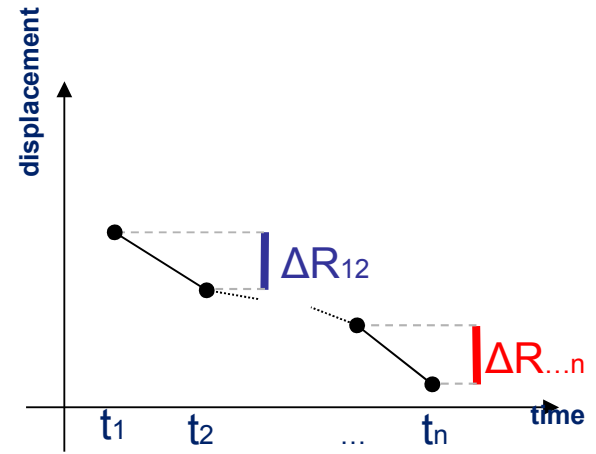
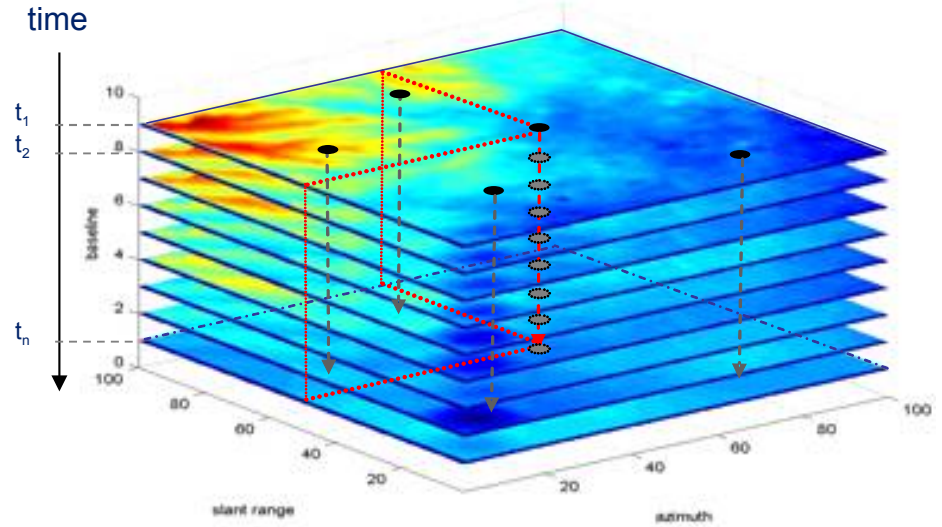
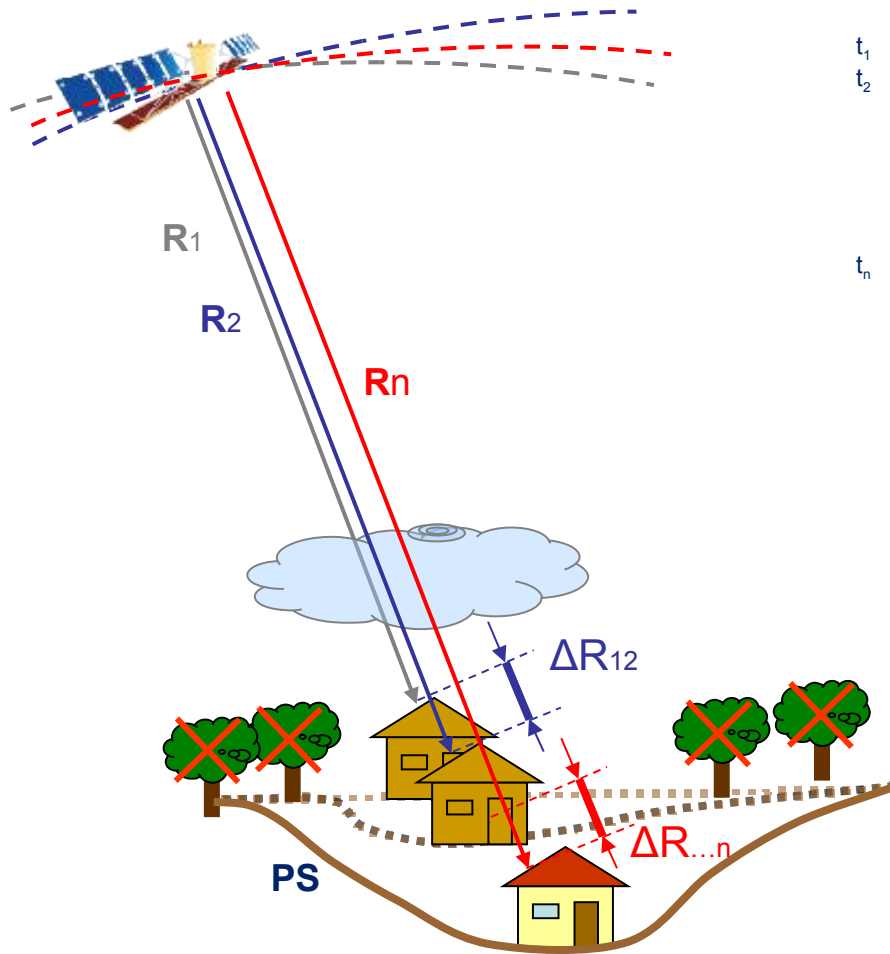
Limits of conventional DInSAR Analysis



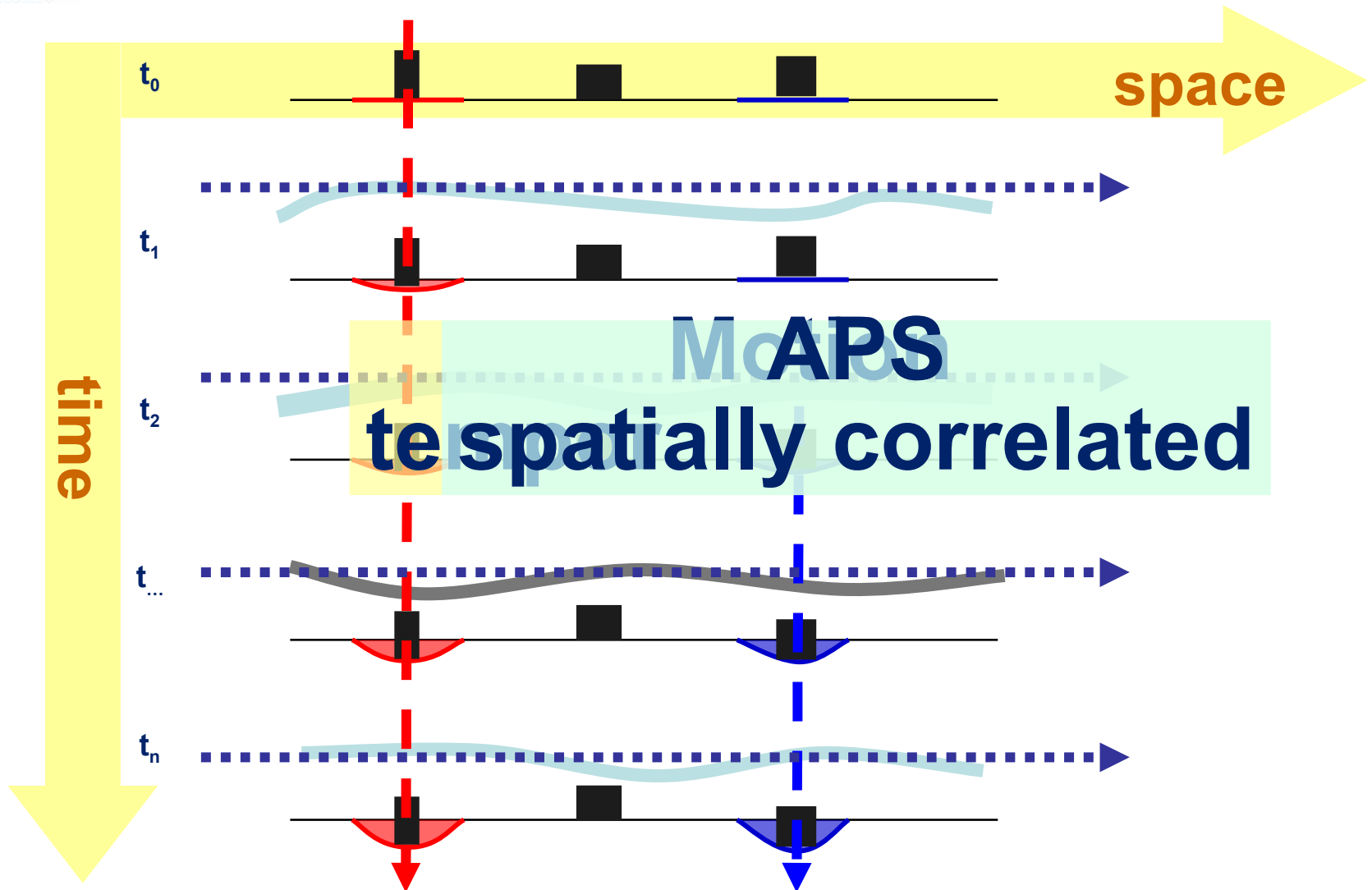
Thanks to ESA archive, since 1993 a growing gallery of examples of DInSAR interferometry started being available.

While more and more InSAR examples were generated, the presence of atmospheric artefacts and problems due to phase decorrelation (temporal and/or geometrical) became more and more evident

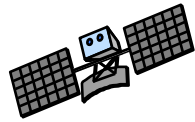
PSInSAR™: approccio multi-immagine



Motion - APS



Looking for good radar targets



2nd acquisition

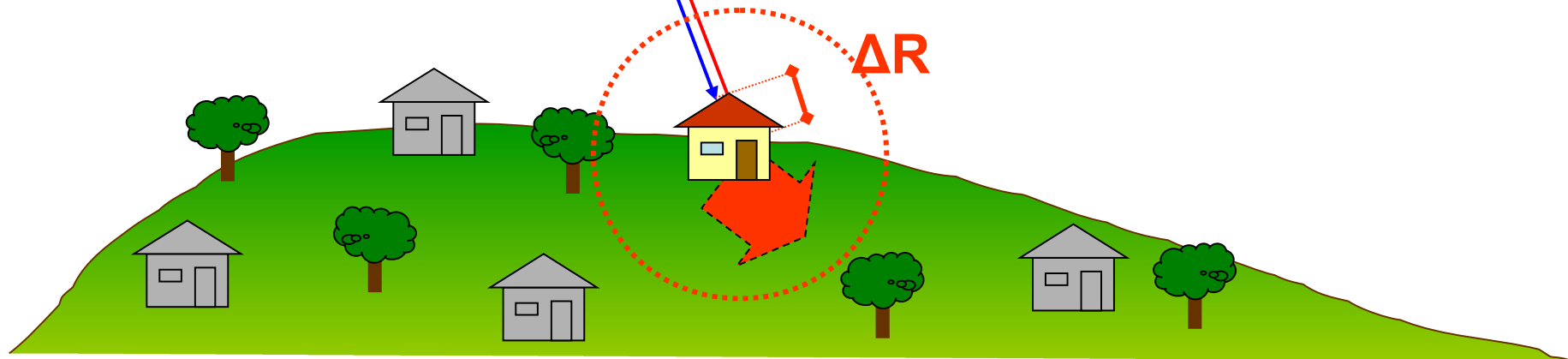
$\Delta t = 35$ days (ERS)

R_1

R_2

Permanent Scatterer
Range variation
affected by motion
[mm]

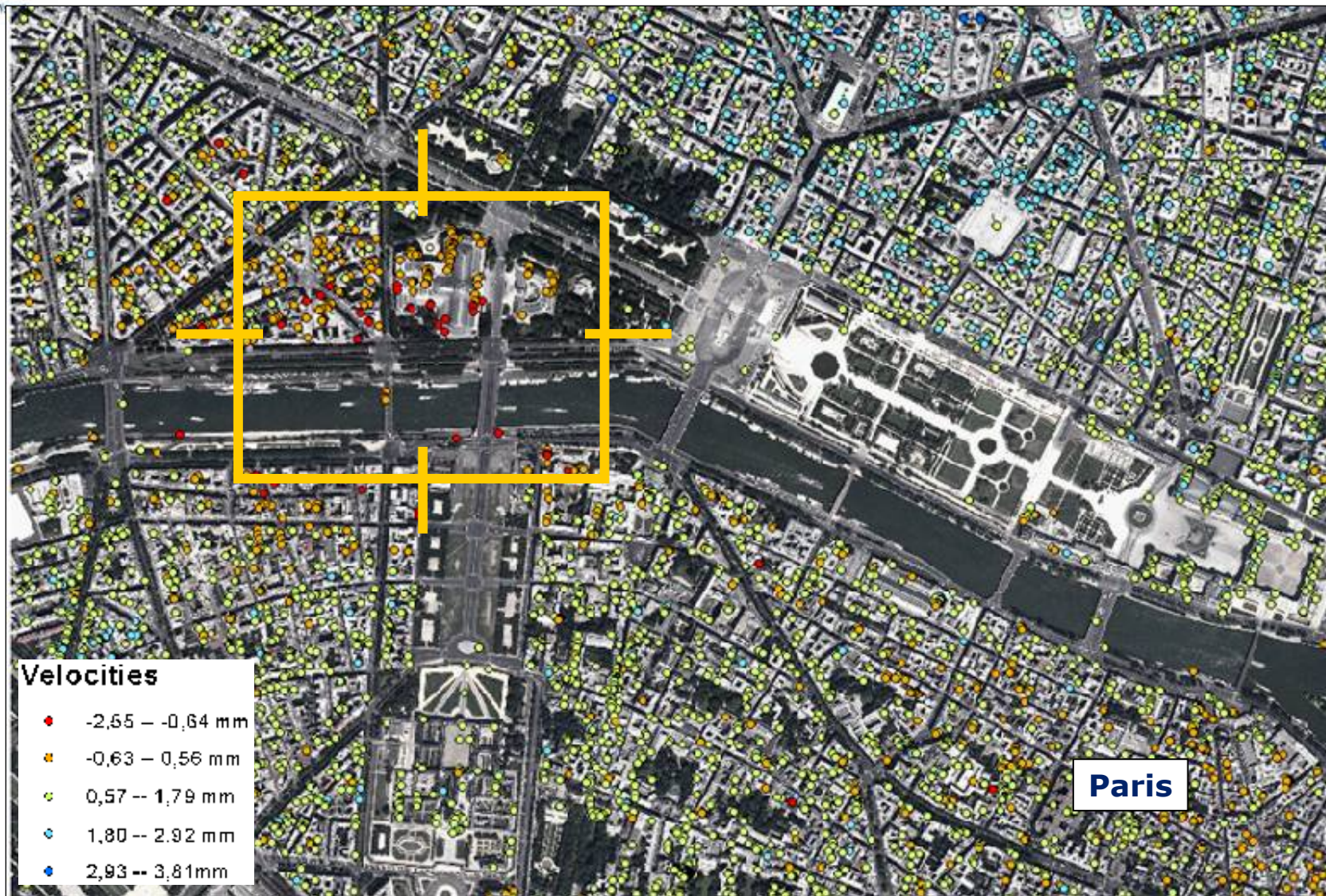
ΔR



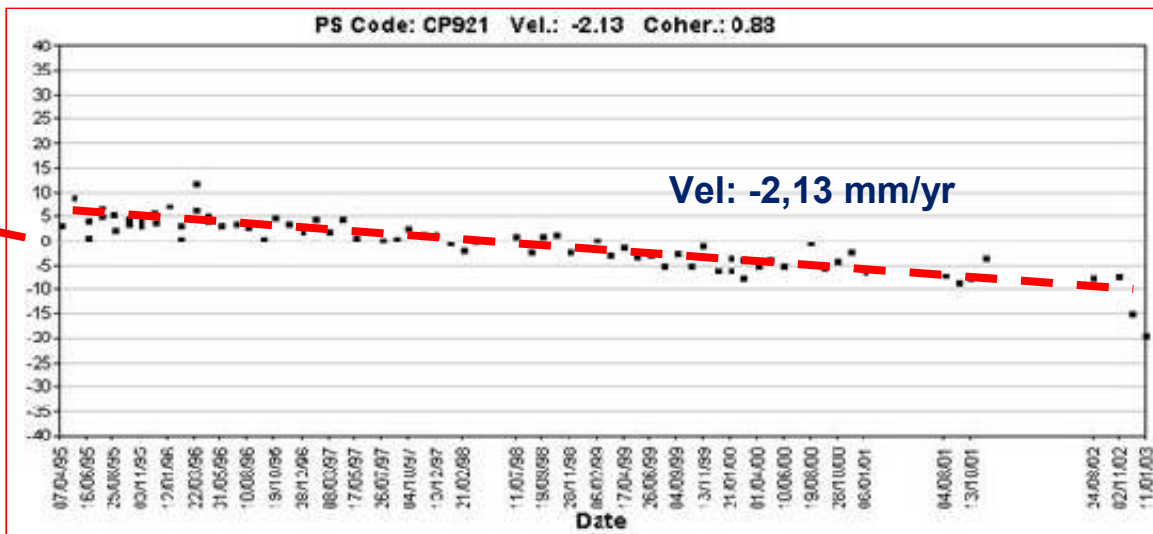
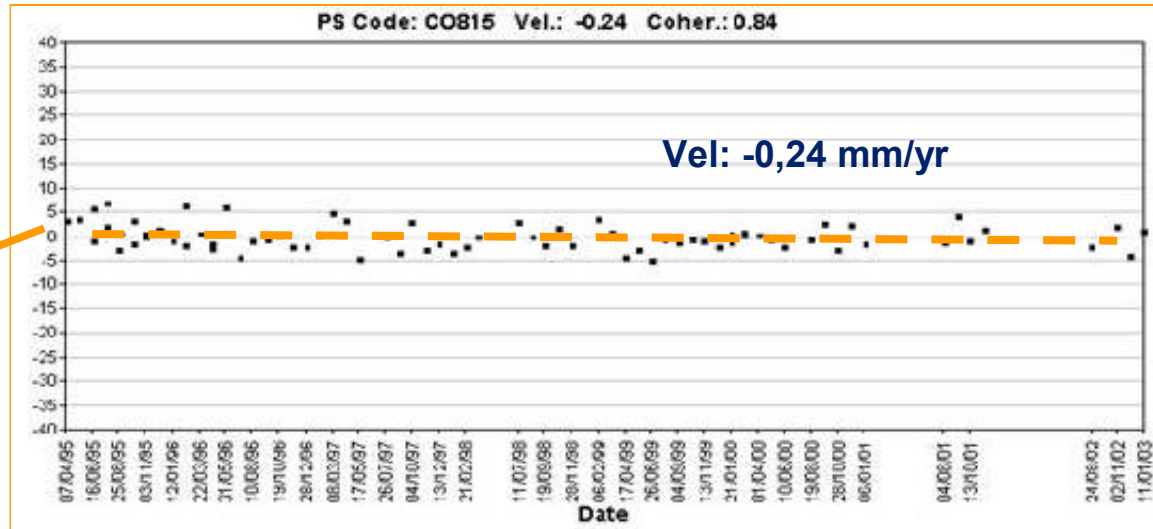
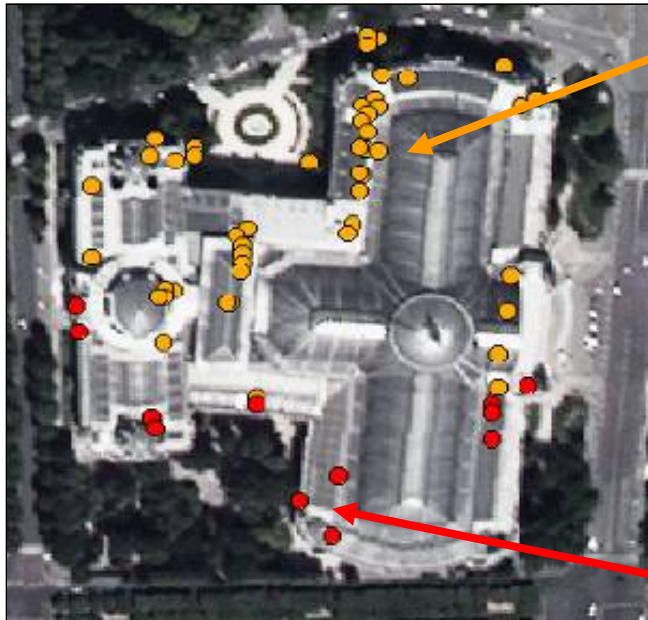


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Setting the P

A first example of PS Analysis



Gran Palais – differential movements

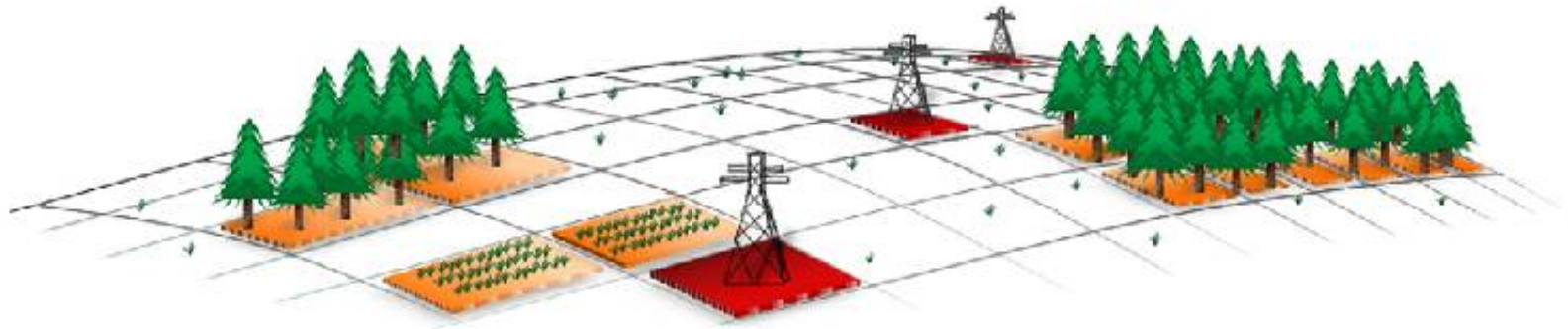
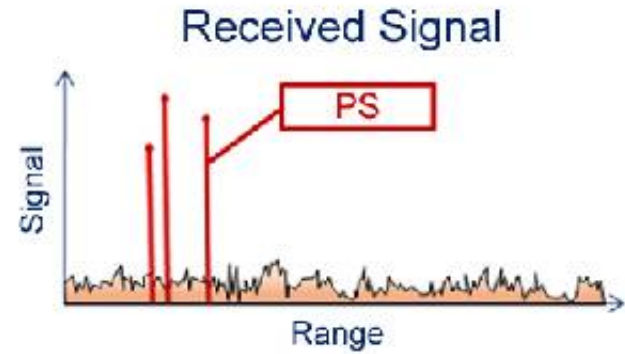


PSInSAR™ Schematic



 No Data

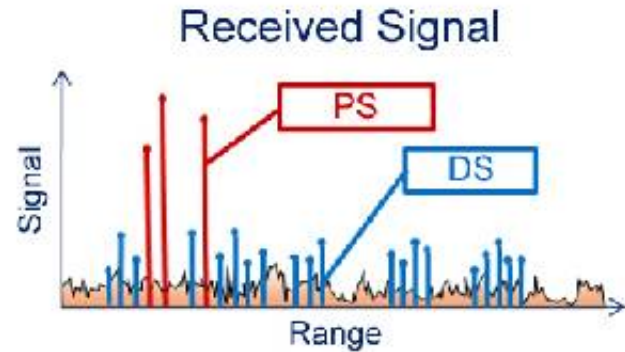
 PS (Permanent Scatterers)



SqueeSAR™ Schematic



-  No Data
-  PS (Permanent Scatterers)
-  DS (Distributed Scatterers)



Accuracy (PSInSAR™ data)

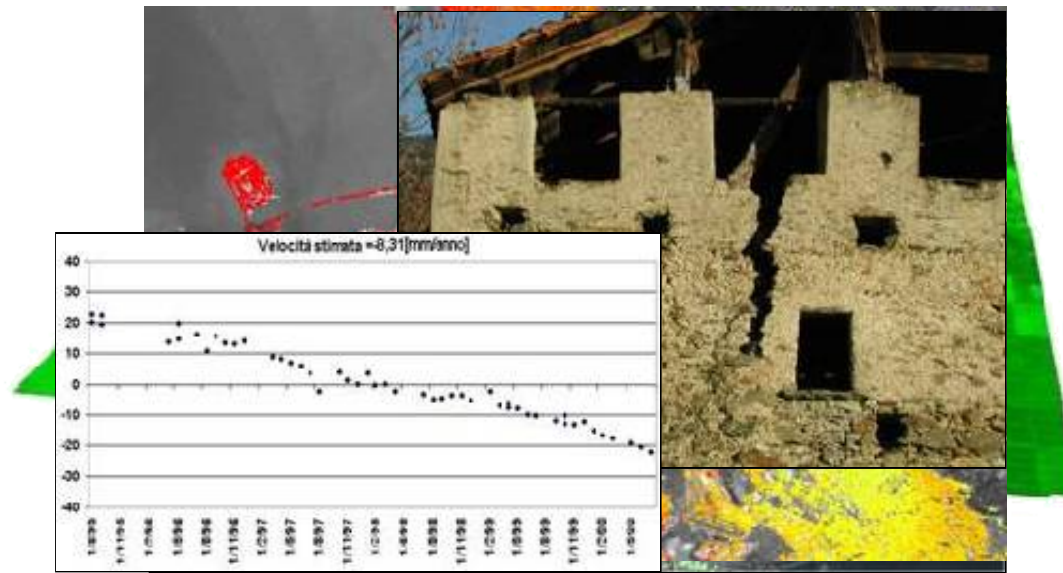
Typical values @ < 1 km from the reference point
>40 images – ERS and ENVISAT satellites (C-band)

<u>Displacement (LOS)</u>	Average Displacement Rate	Single Measurement
Precision (1s)	<1 mm/yr	5 mm

<u>Positioning</u>	E - W	N - S	Height
Precision (1s)	6 m	2 m	1,5 m

PSInSAR™ - SqueeSAR™ applications

Single buildings



Applications

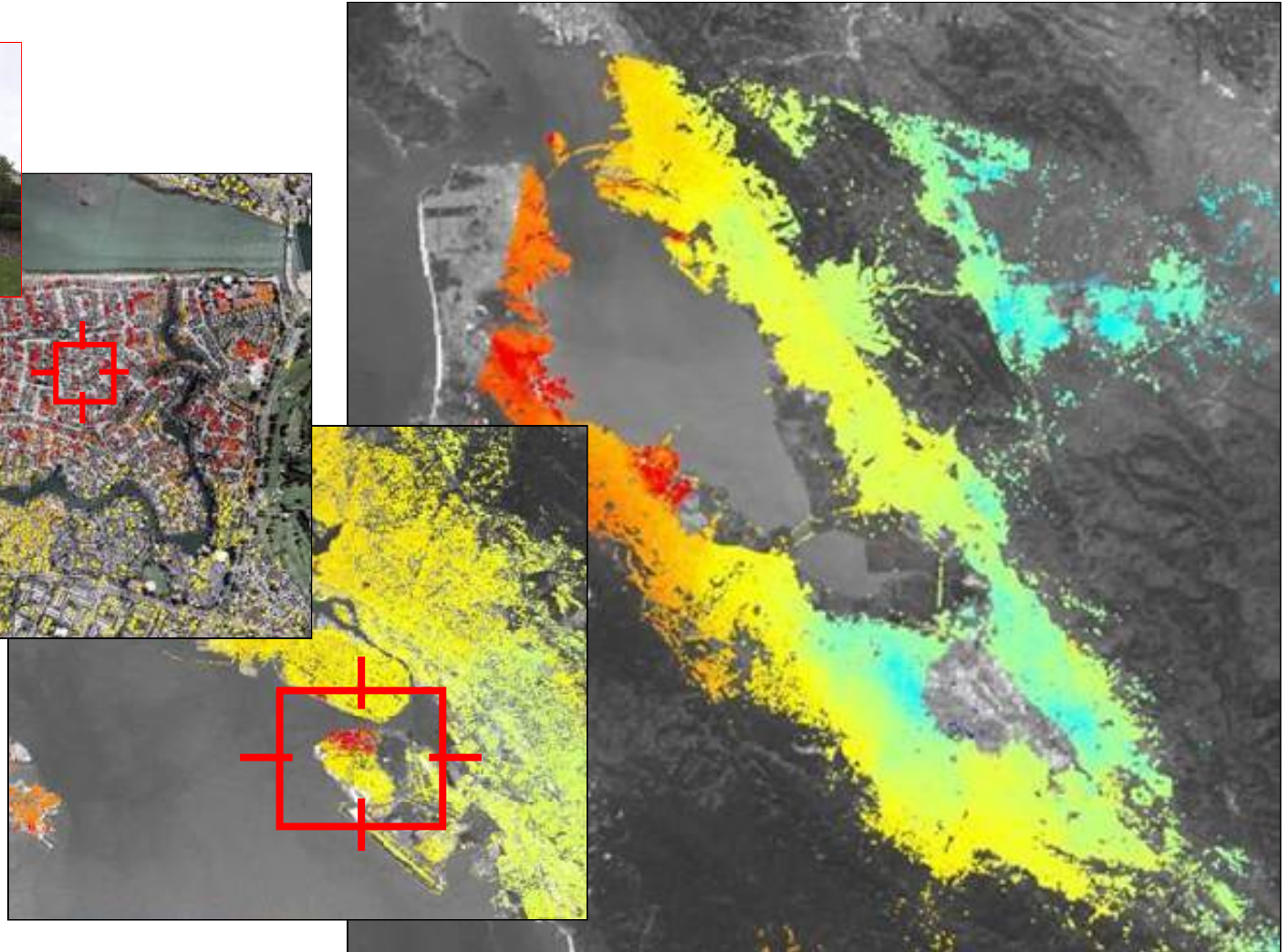
Subsidence

Landslides

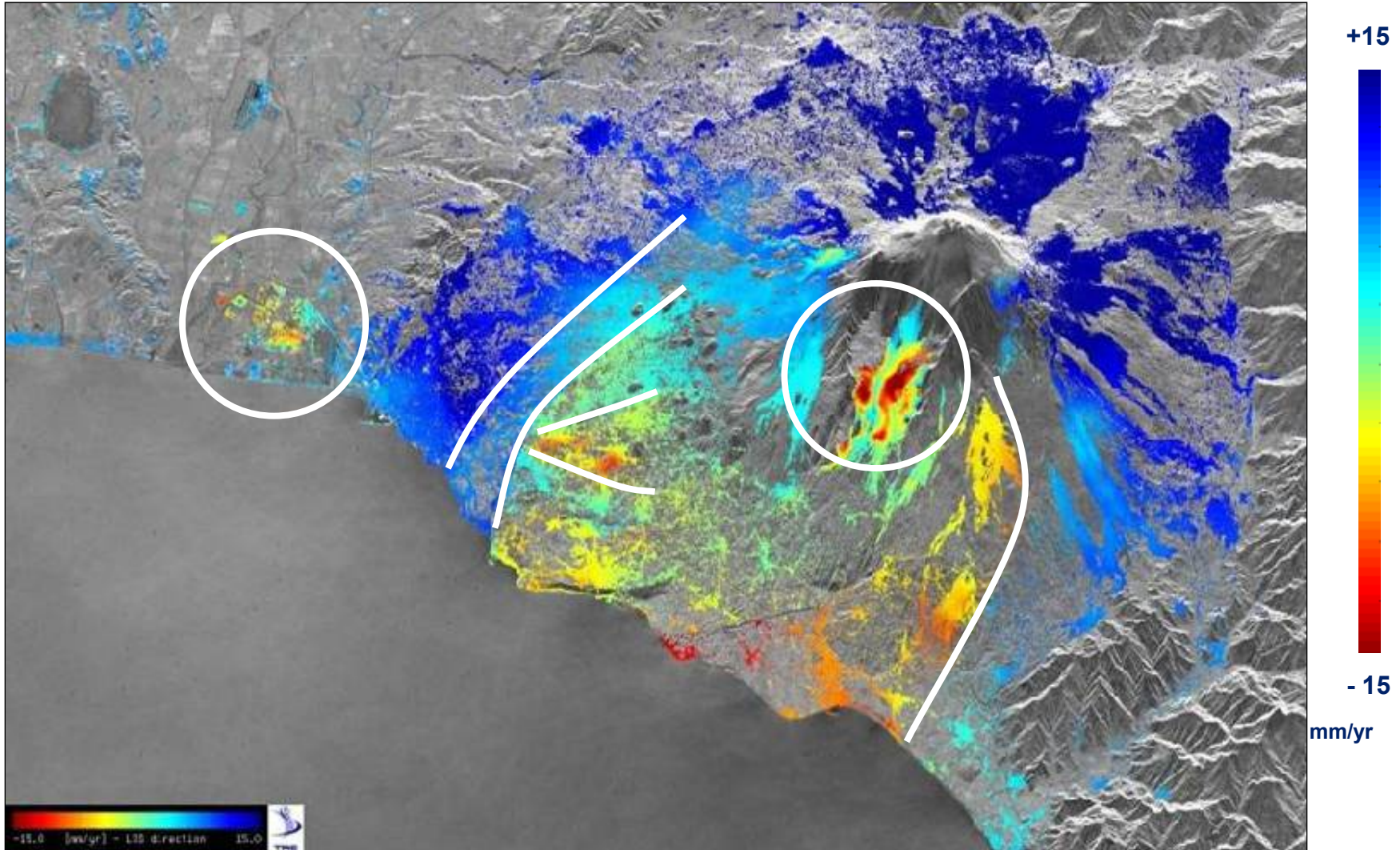
Seismic faults

Single building

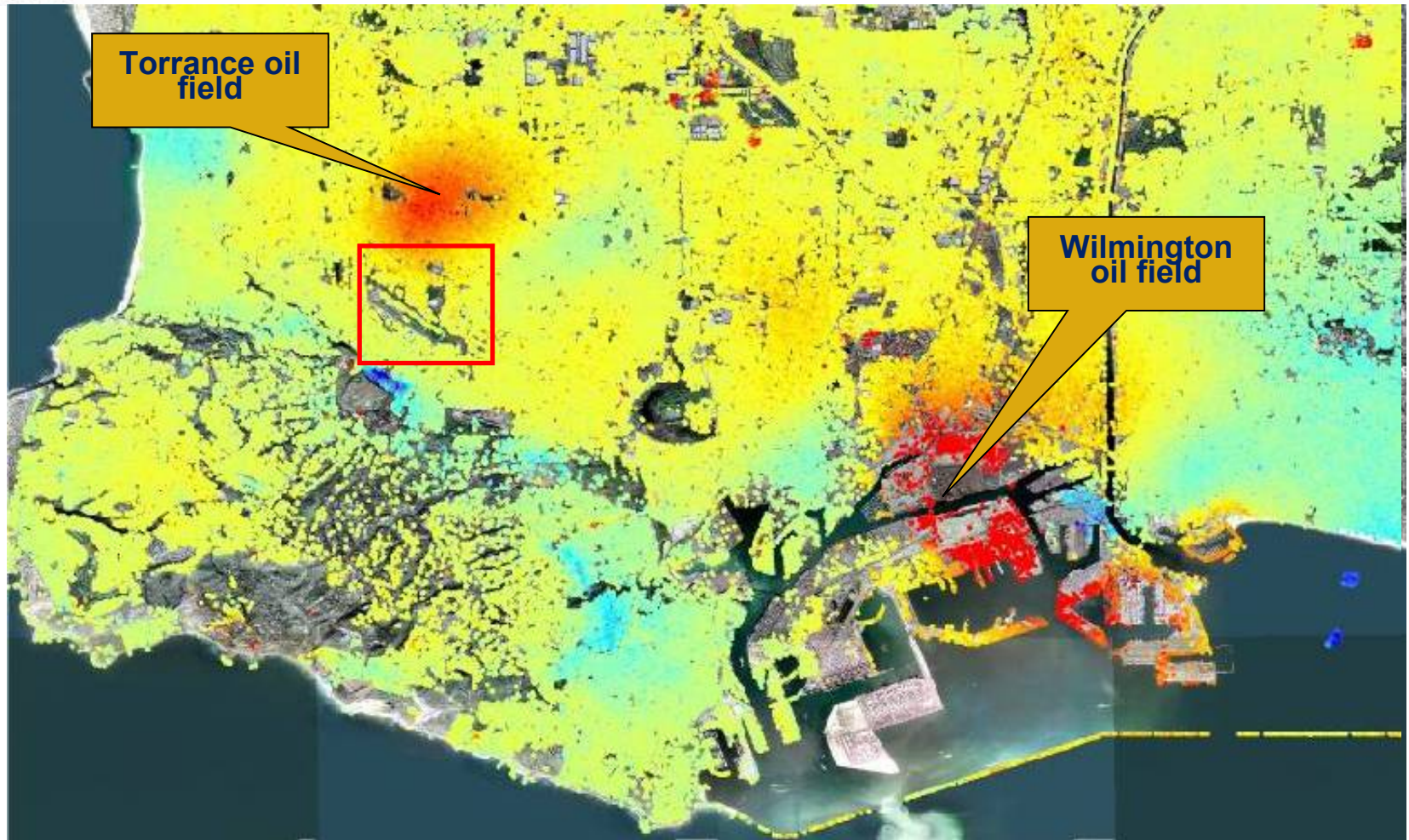
Una tecnologia multi-scala



Sicilia - Etna



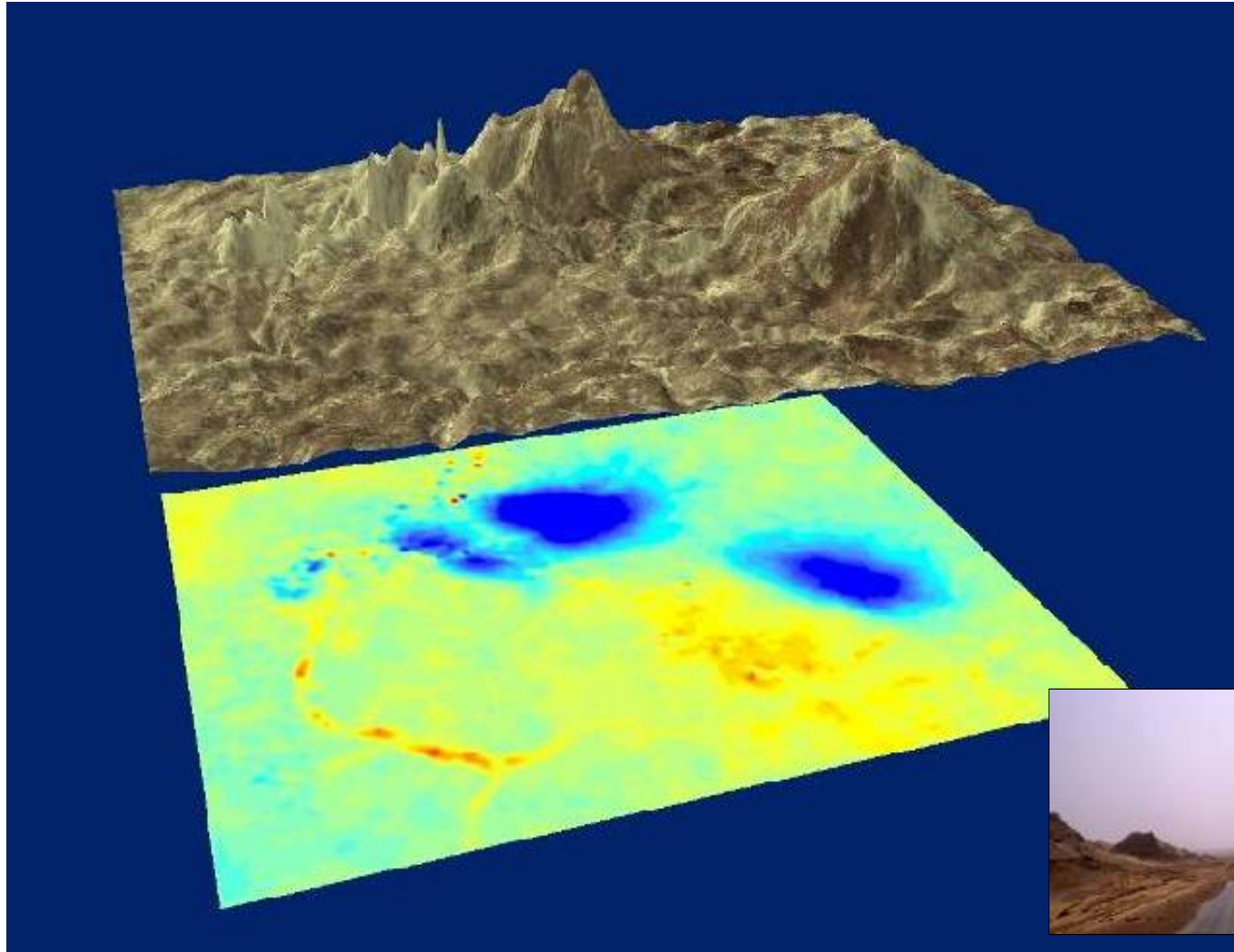
Long Beach



Dati ERS Discendenti 1992-2000

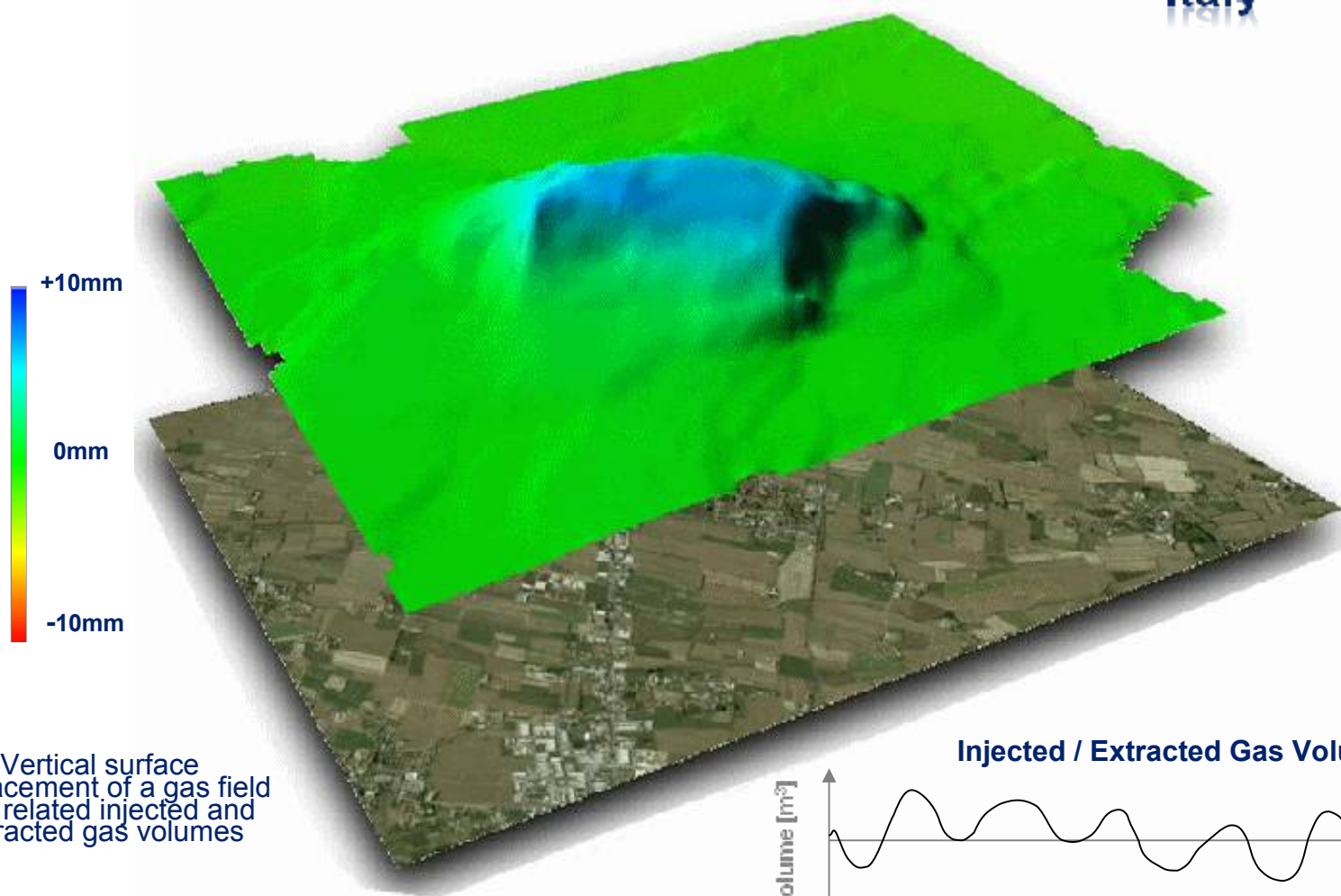


CO2 Sequestration: North Africa

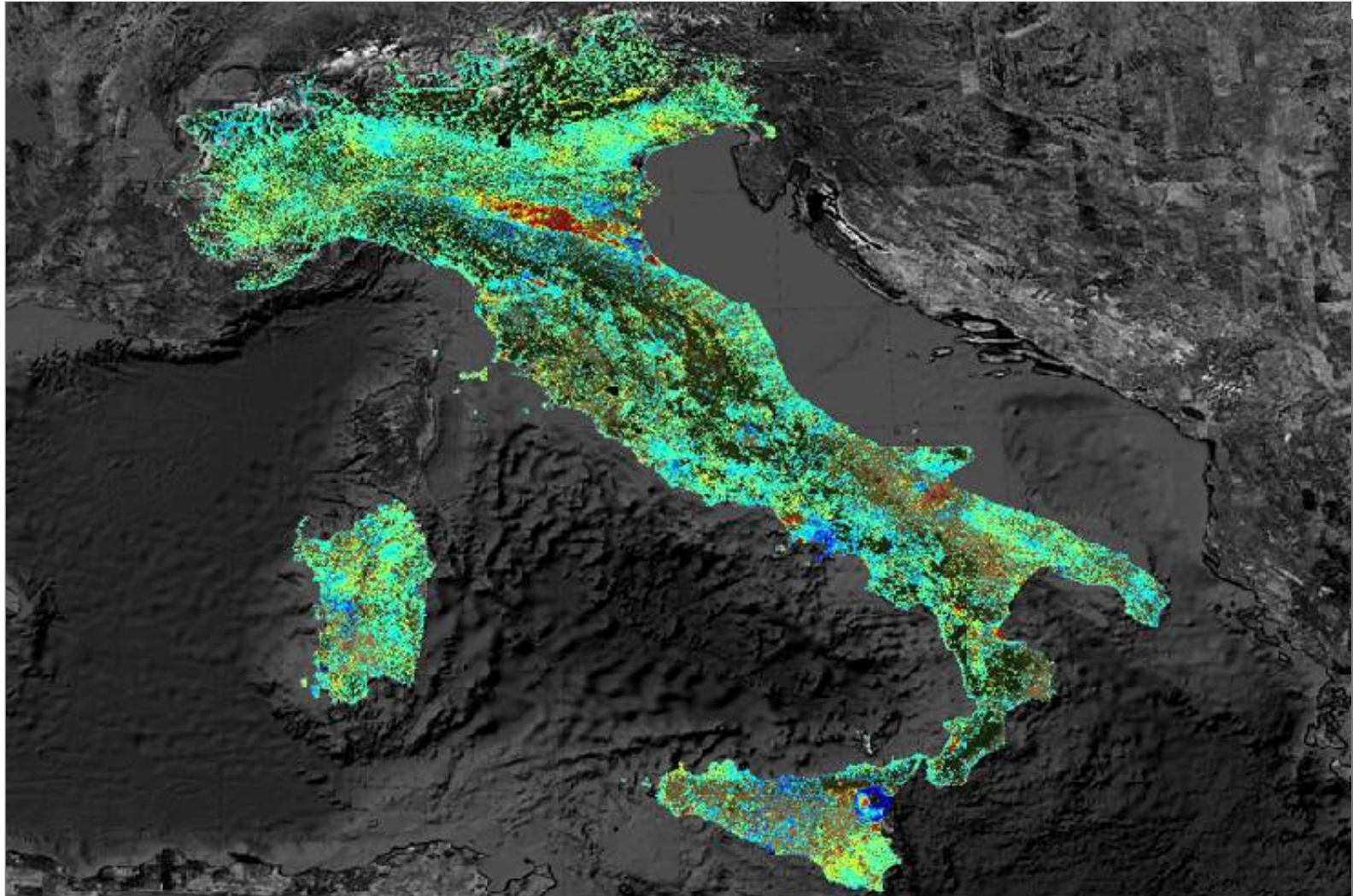


Underground Gas Storage

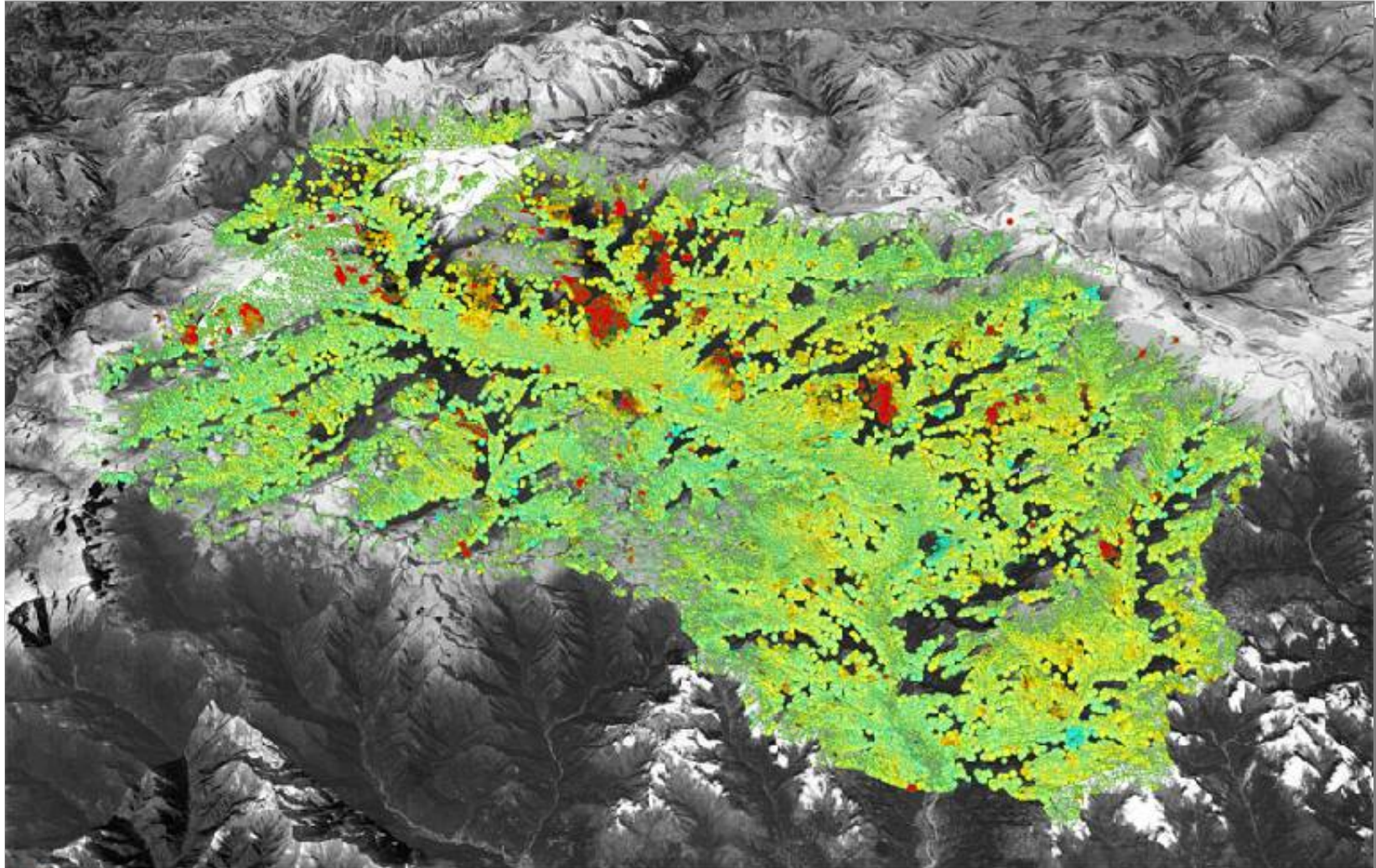
Italy



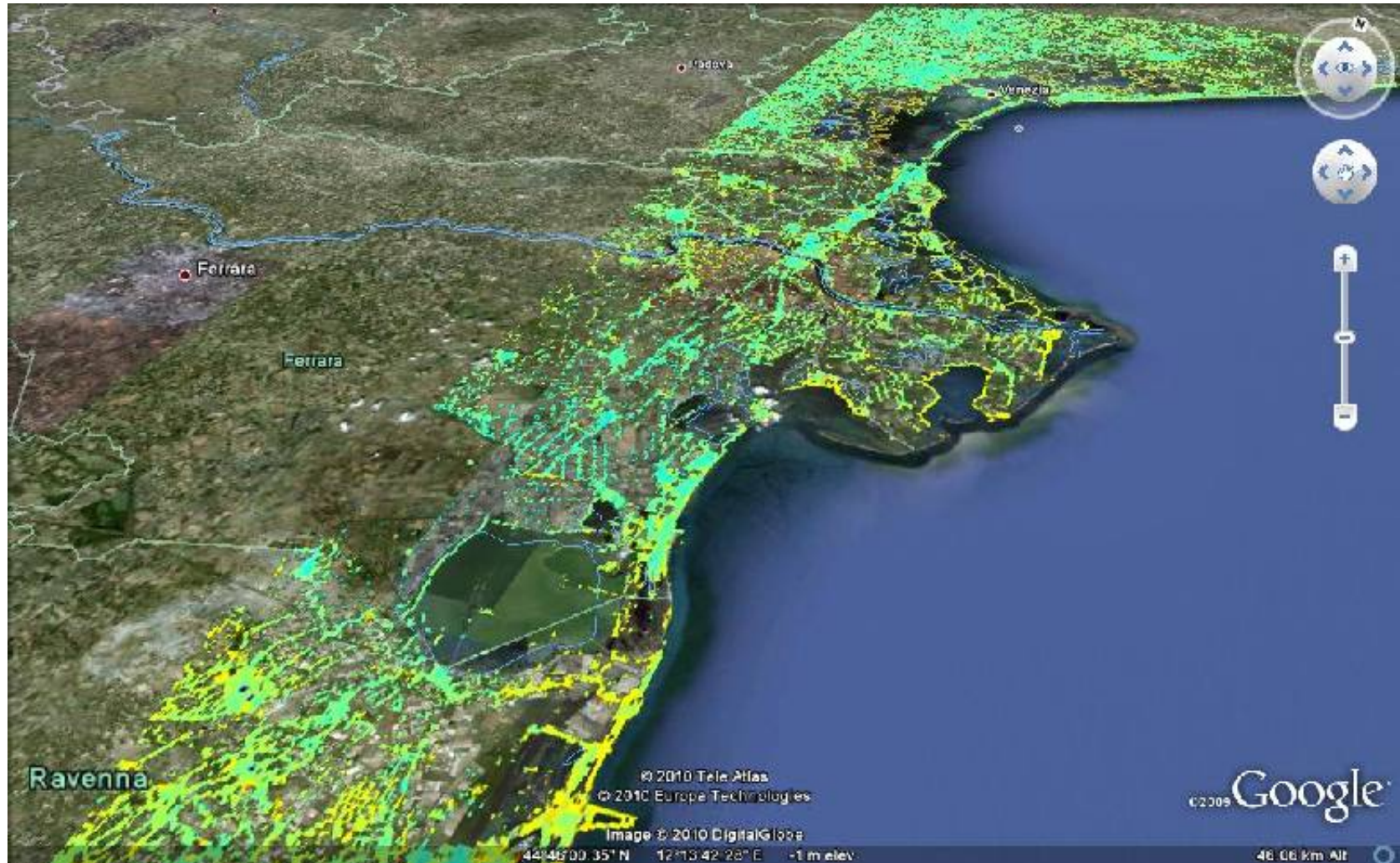
Wide Area Mapping



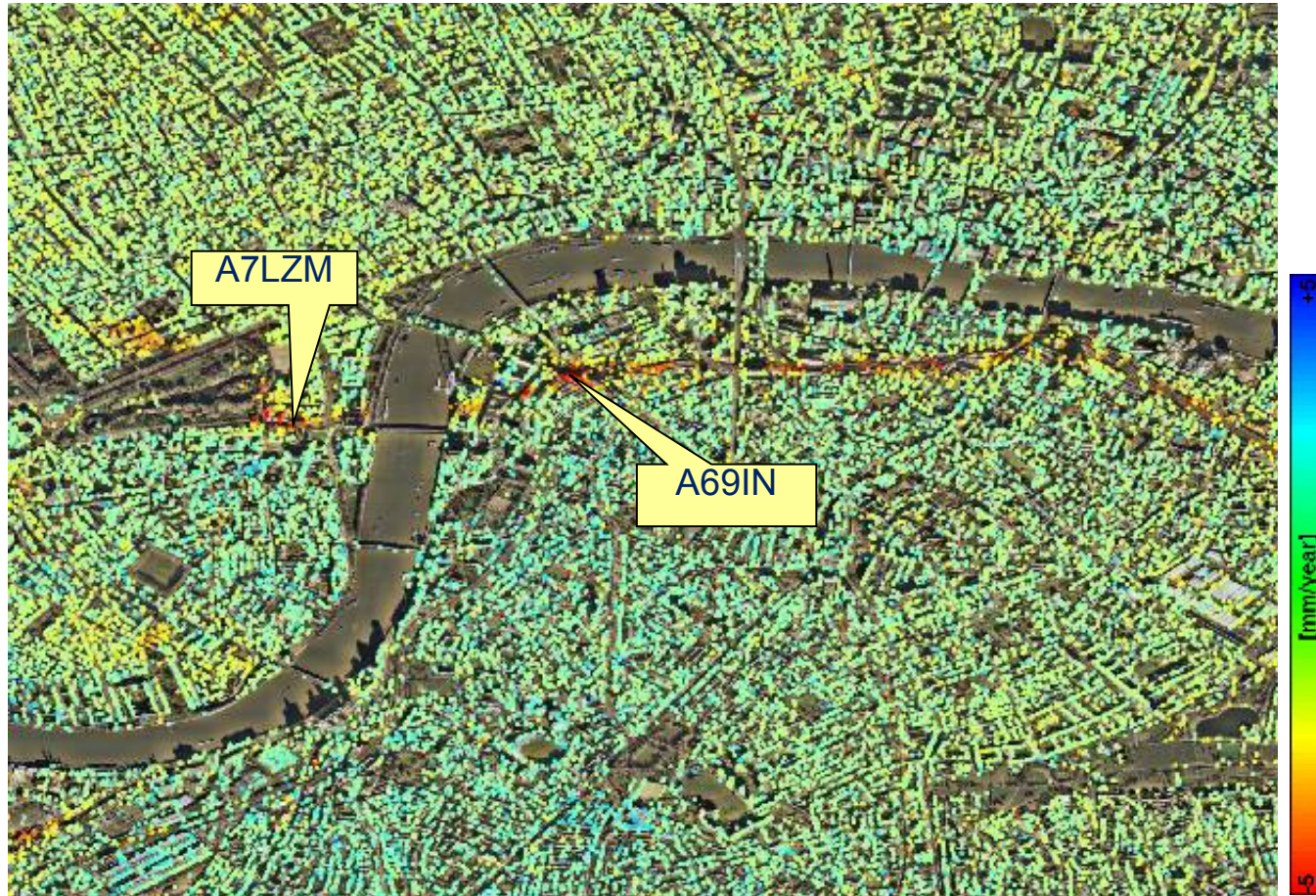
Wide Area Instability Mapping



Subsidence Analysis – Coastal Areas

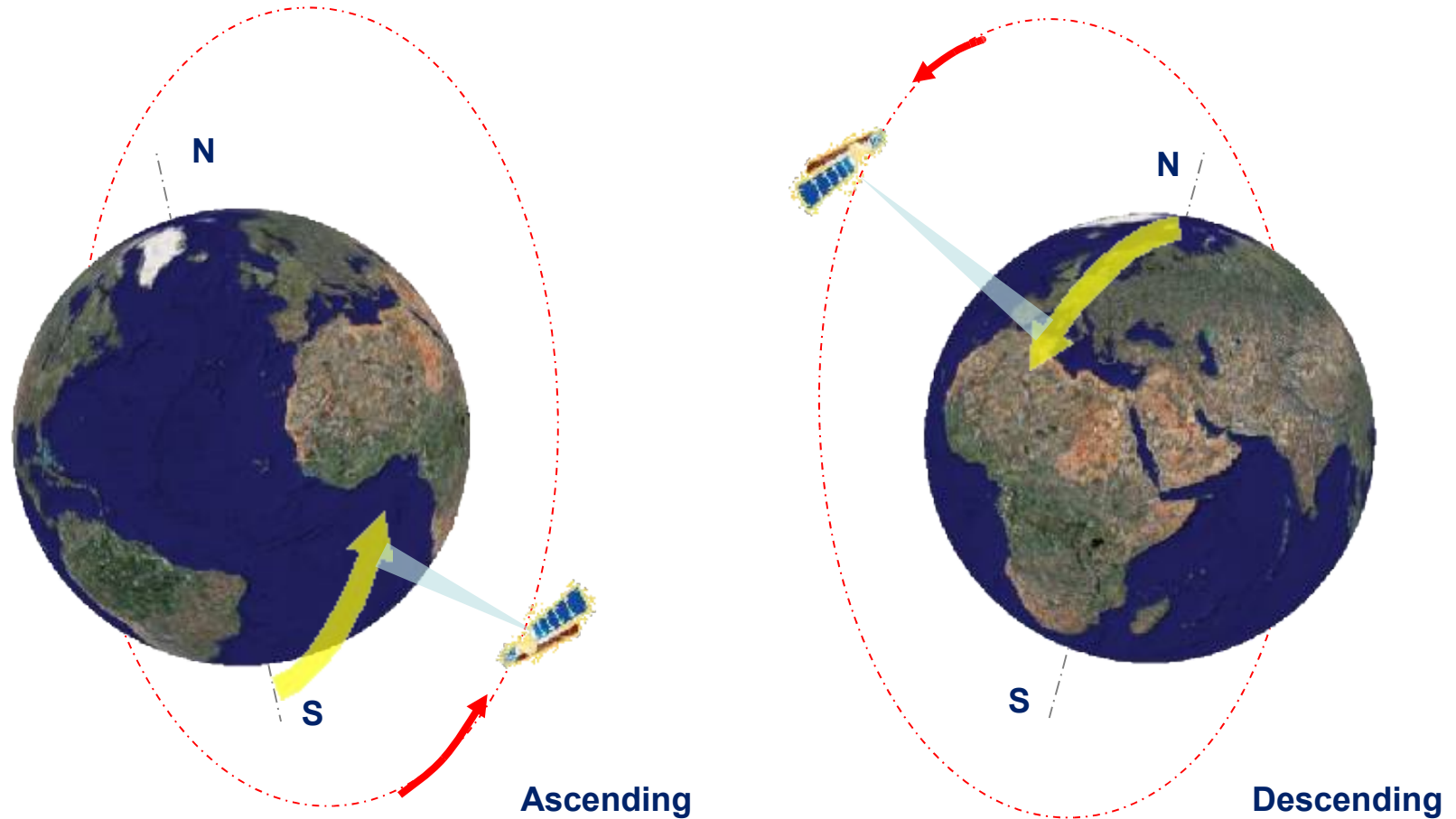


Londra, la nuova “Jubilee Line”



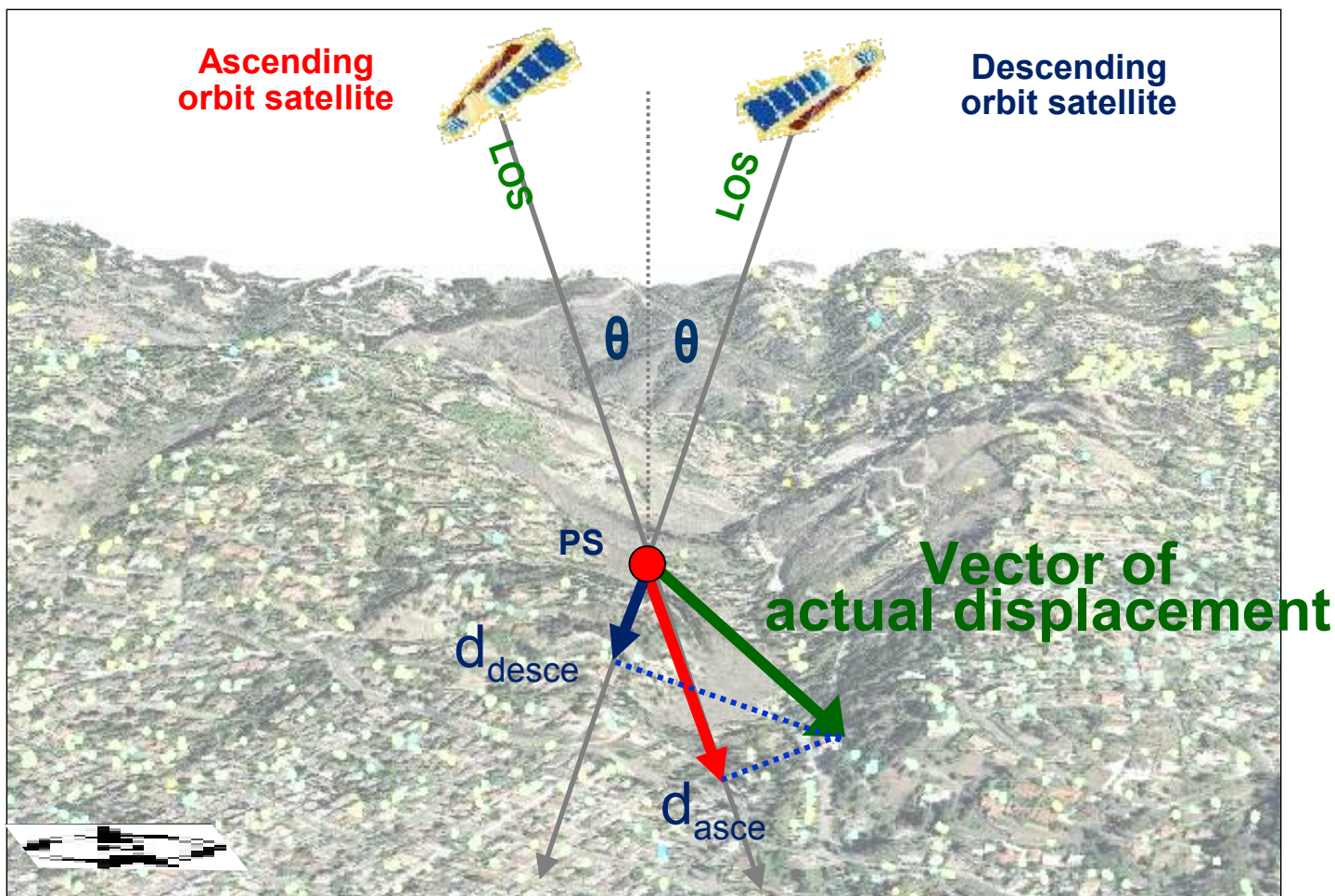
Geometria di acquisizione

Ascending and Descending Geometries

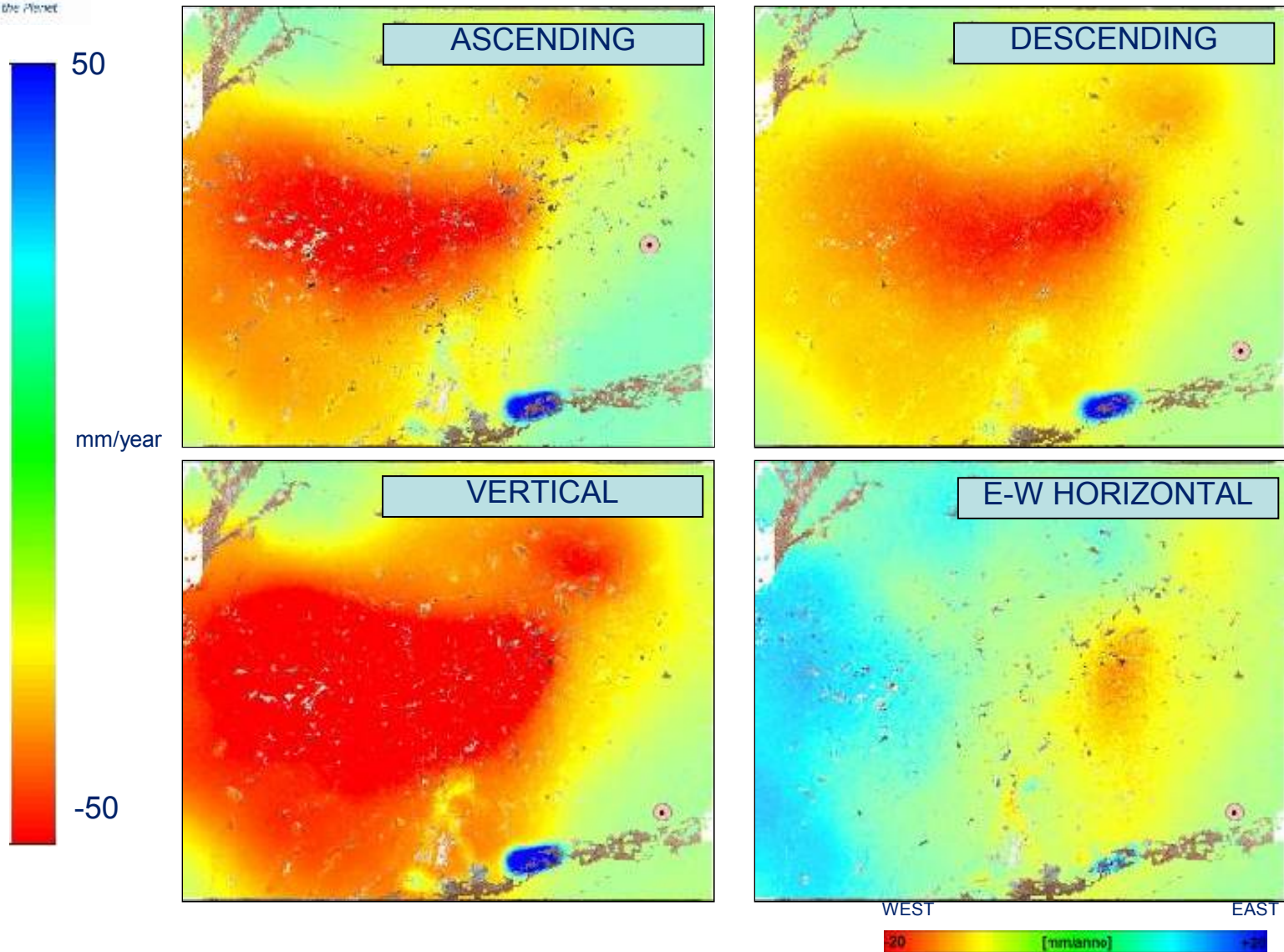


By combining the rotation of the Earth and the orbital paths of the satellites, the entire surface of the Earth is illuminated by two different satellite geometries.

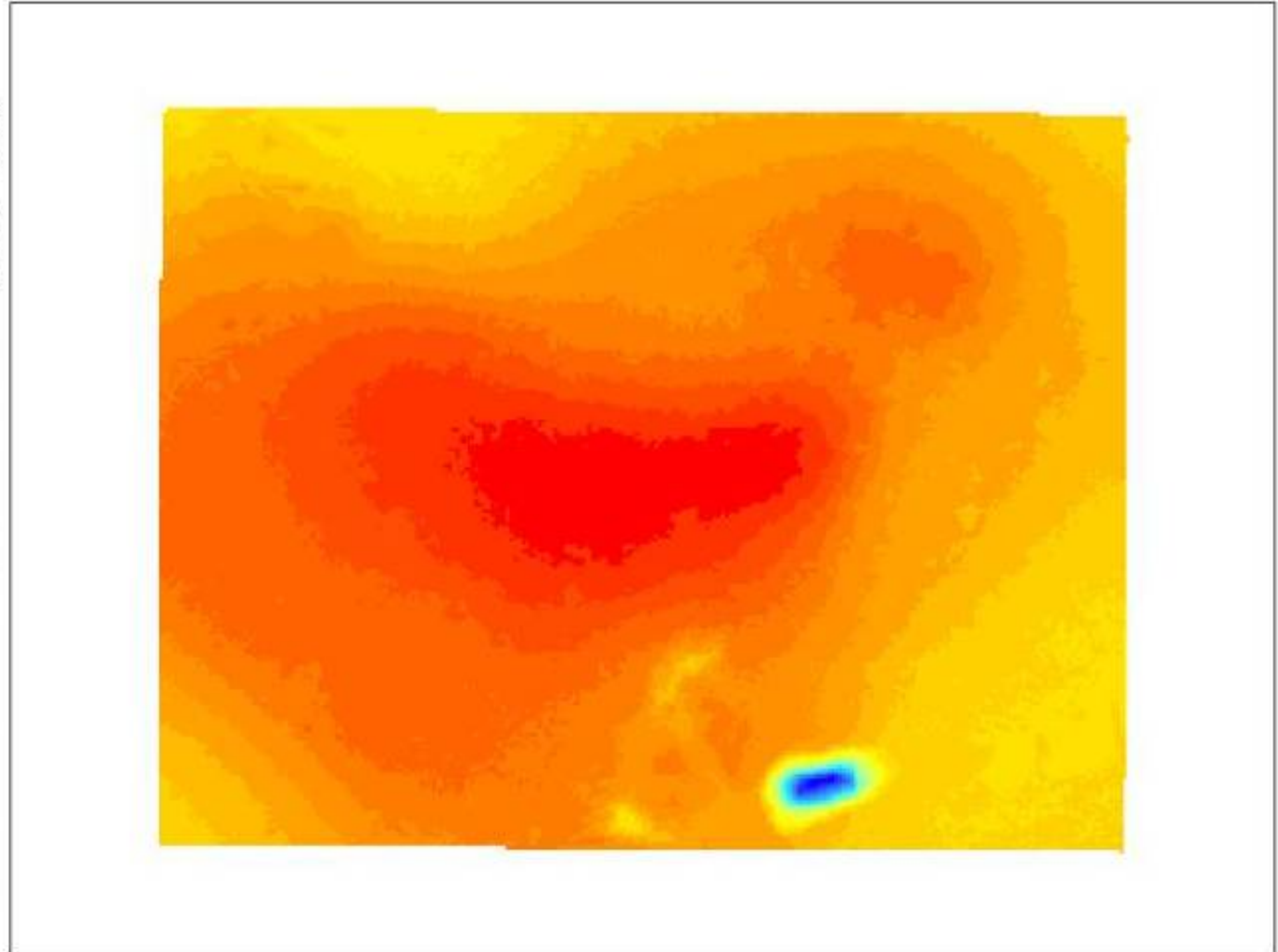
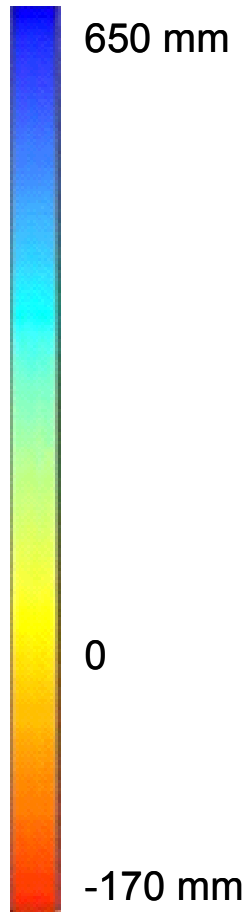
Measuring two components (x,z)



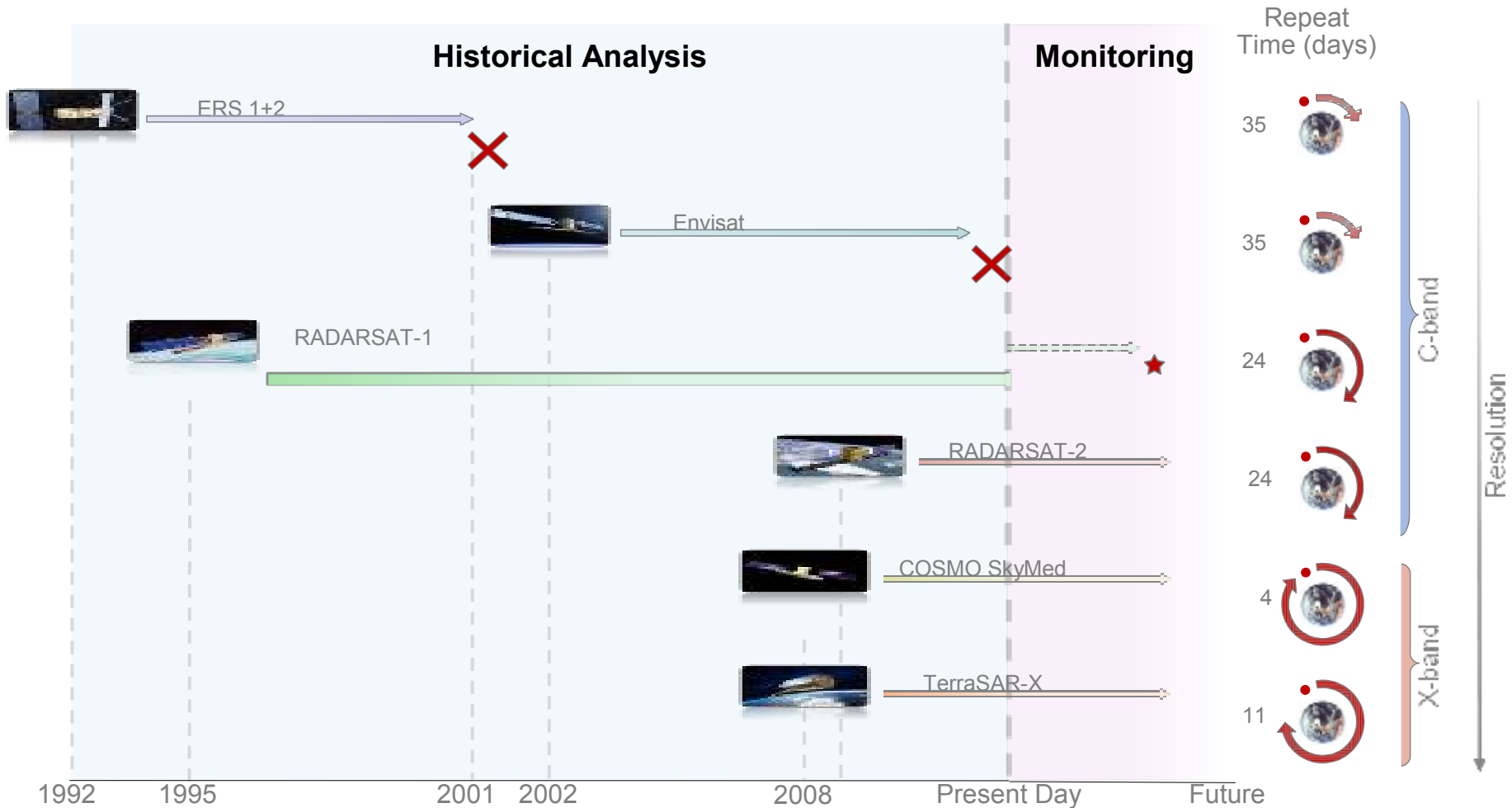
Middle East – deformation rates



Middle East – Vertical displacement evolution



Satellites: Past and Present

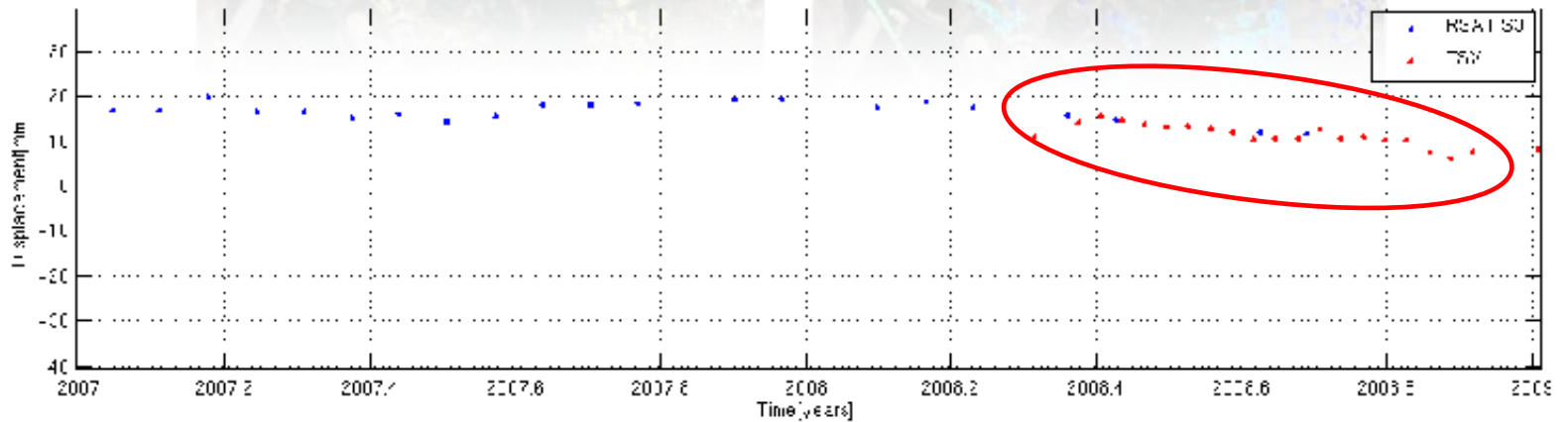
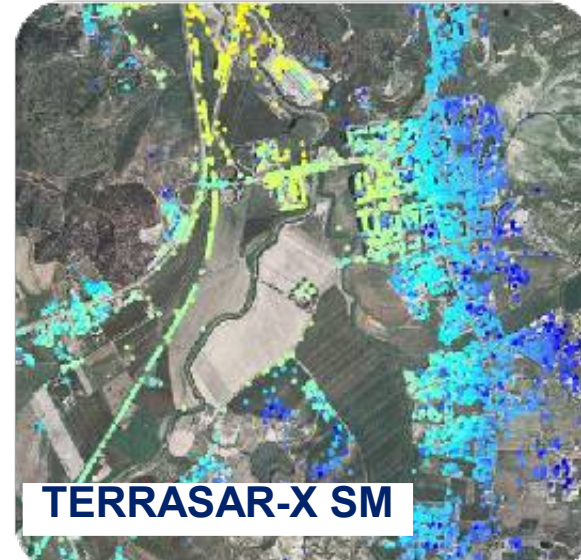


C-band (SB) vs X-band: an example

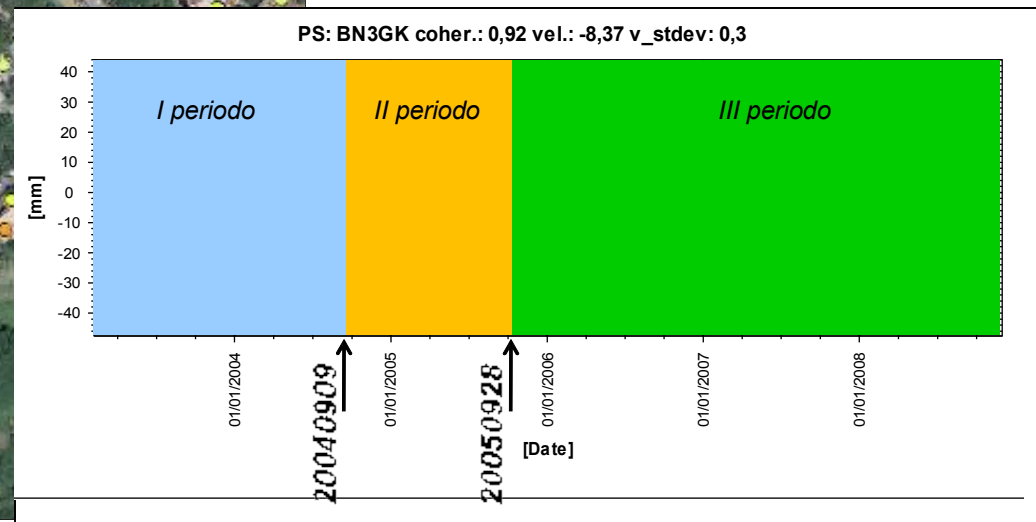
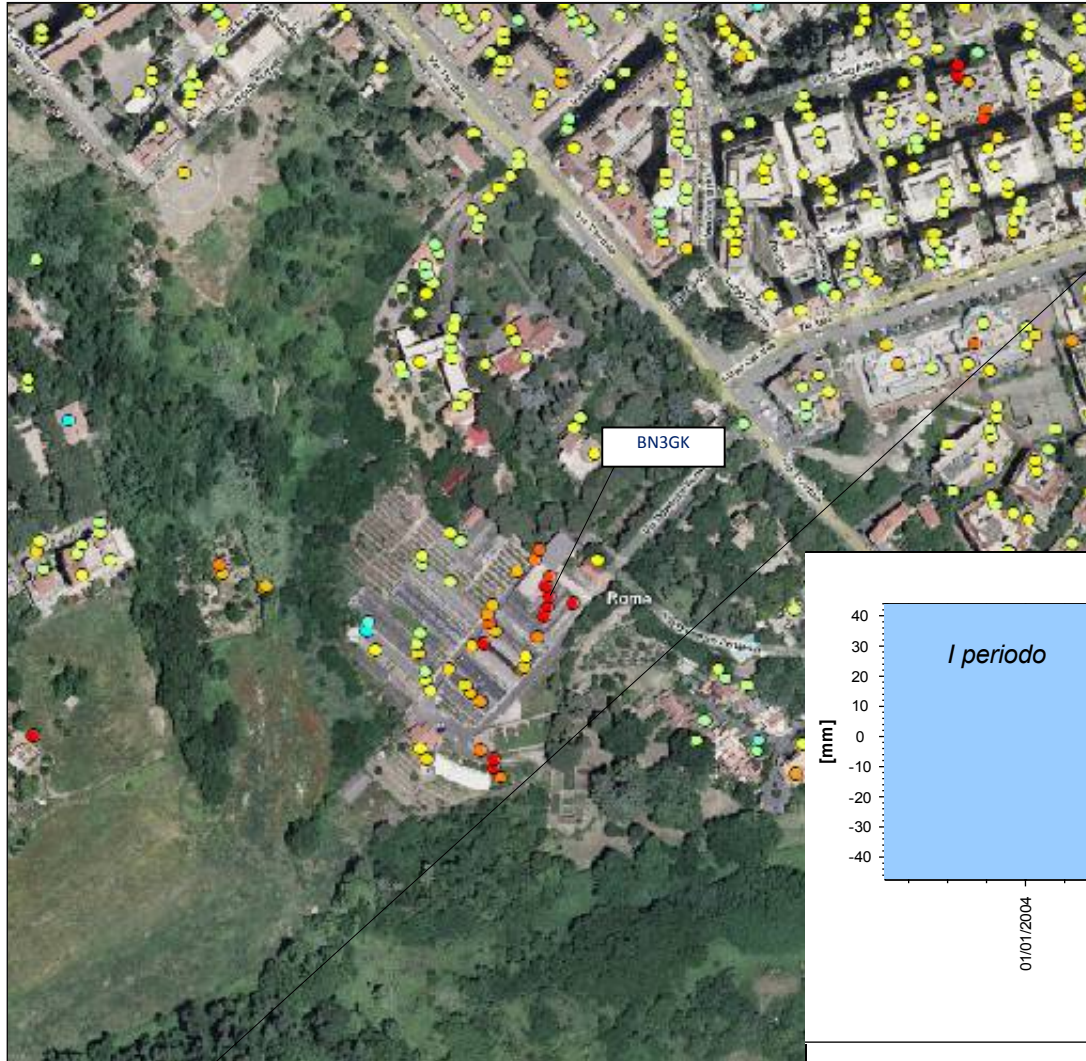
130
PS/km²

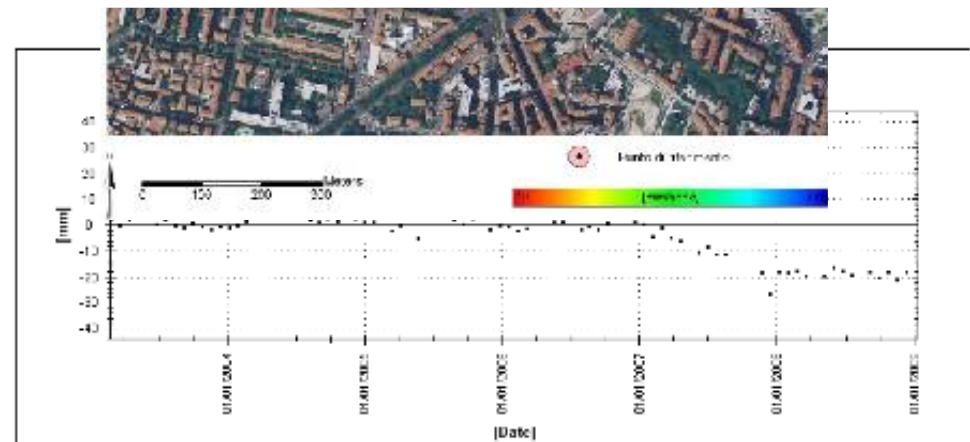
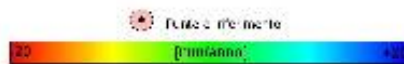
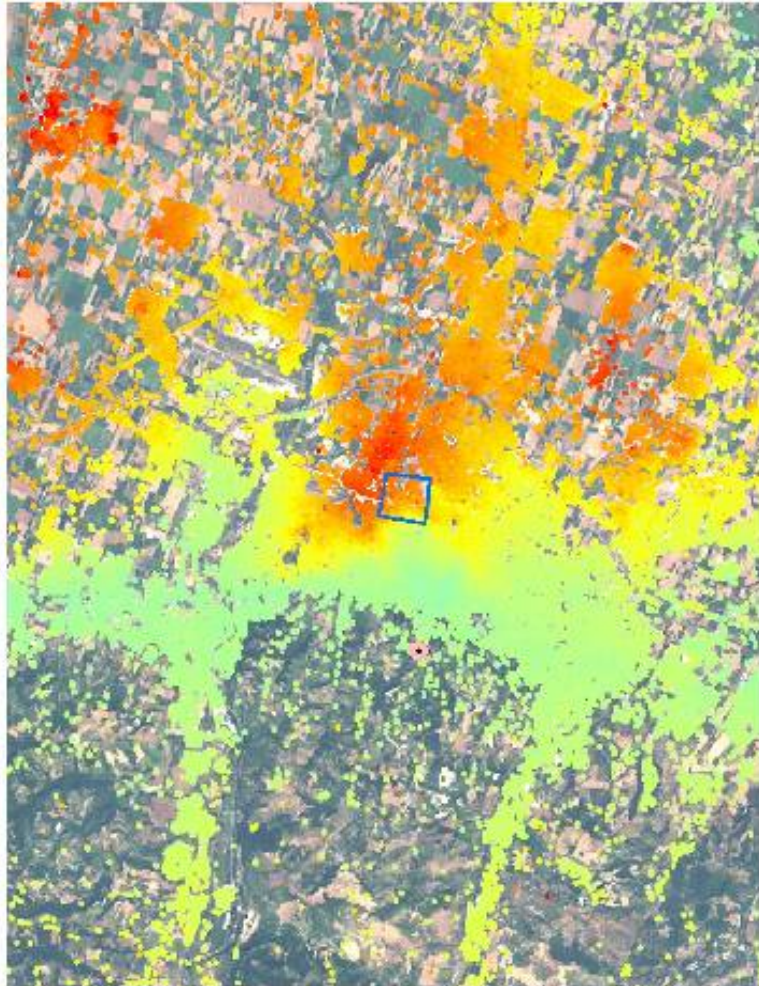


1,200
PS/km²

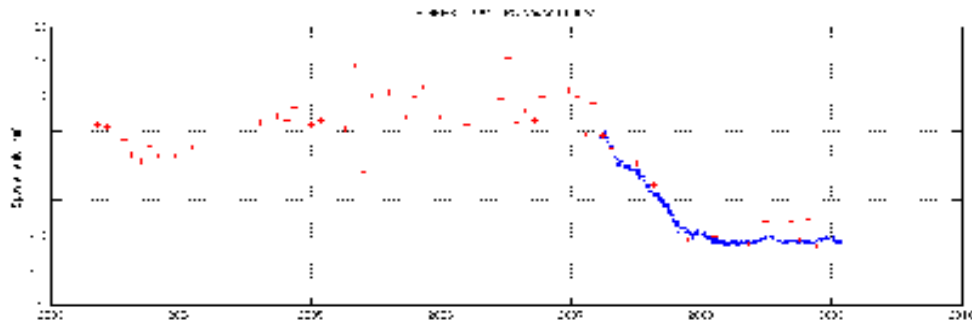


Il caso della galleria Cassia – Monte Mario

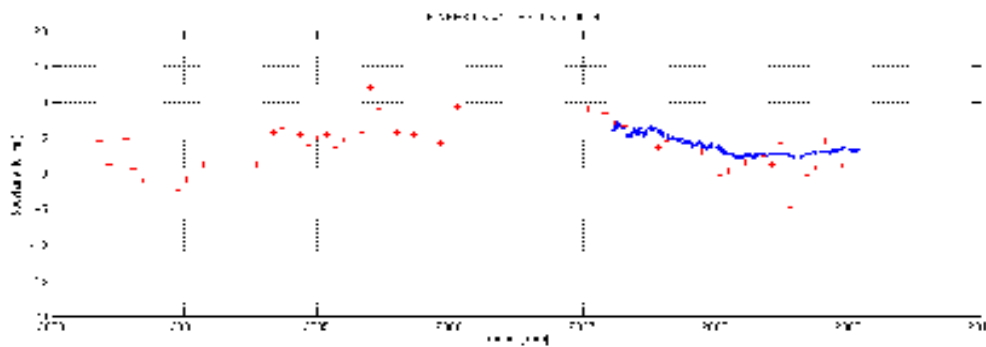




Confronto PS vs leveling

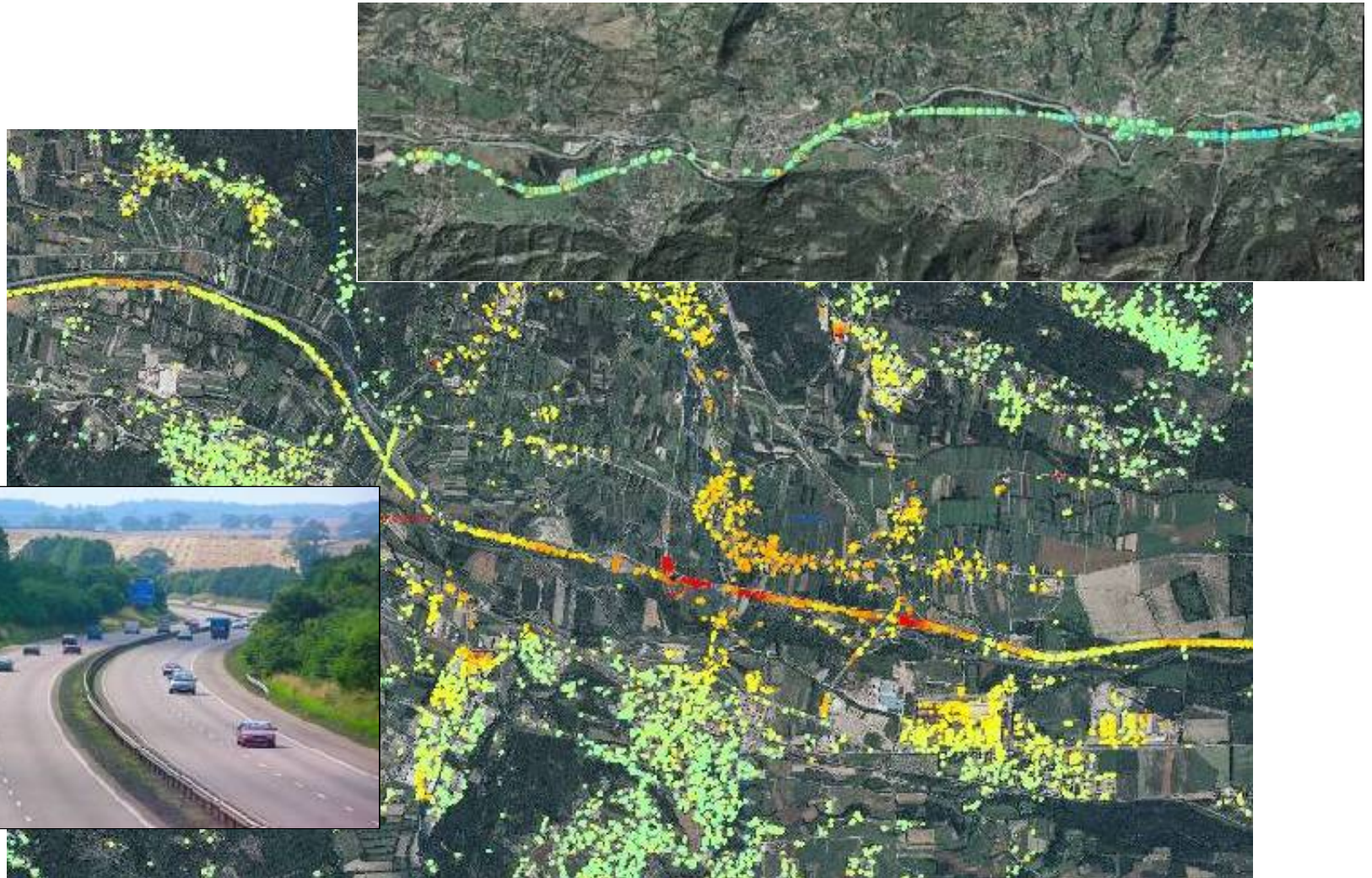


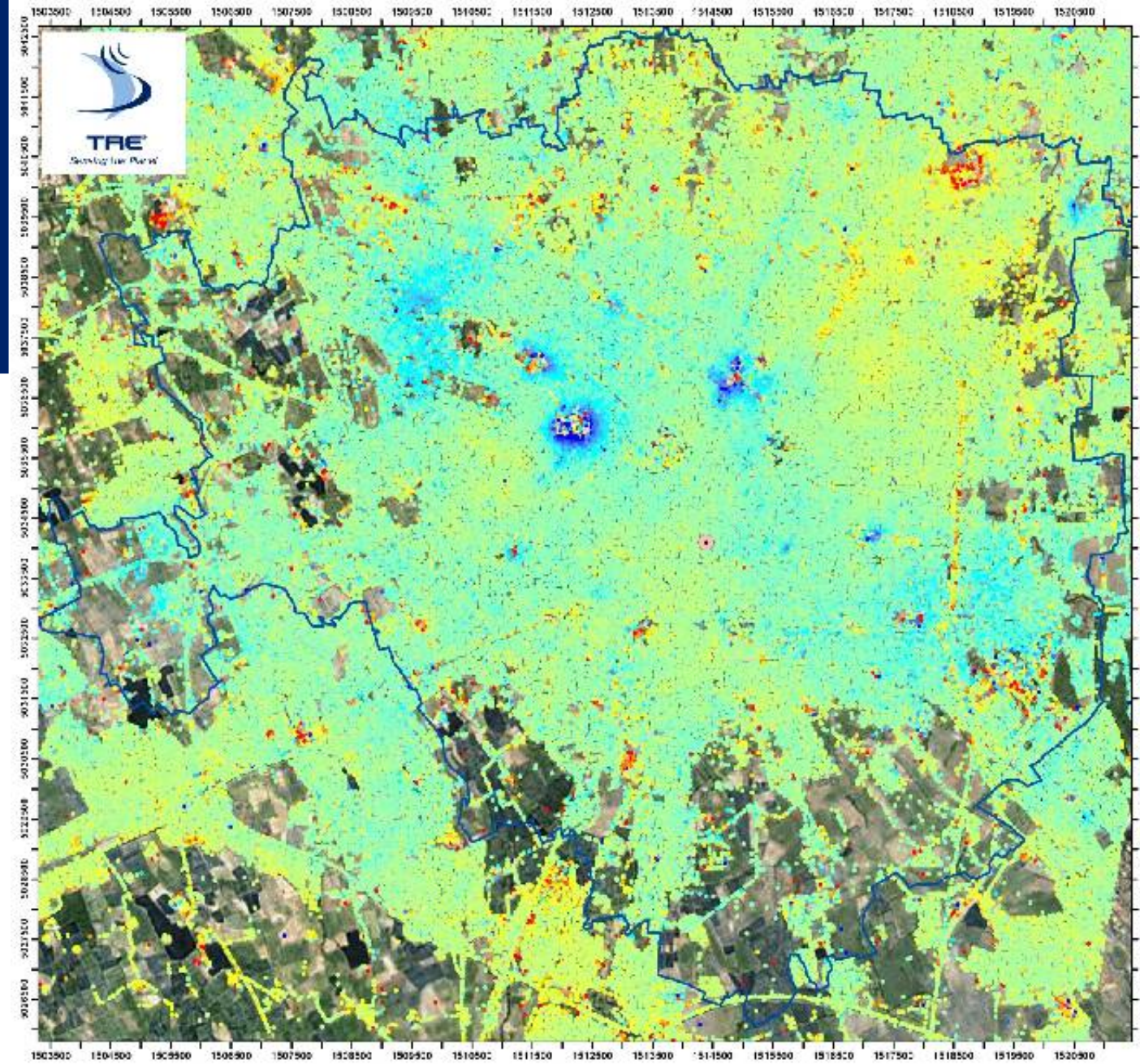
+ Dati Satellitari
• Dati Livellazione ottica



Confidenziale

Autostrada A32





Comune di Milano
PSInSAR™ analysis



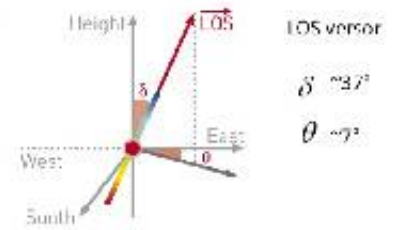
PROCESSING DATA

Satellite	TERRASAR X
Geometry	Descending
Tradi/Frame	78
Number of scenes used	61
Analysis data range	FEB 2008-SEPT 2009

LEGEND

- Reference Point
- MILANO municipality limit

Average displacement rate along LOS direction [mm/yr]



scale 1:65,000



Microsoft Virtual Earth © Microsoft Corporation
© Tele-Rilevamento Europa 2010



TRE
Scanning the Planet

Zona Fiera Milano City

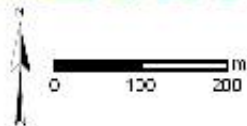


Dicembre 2001

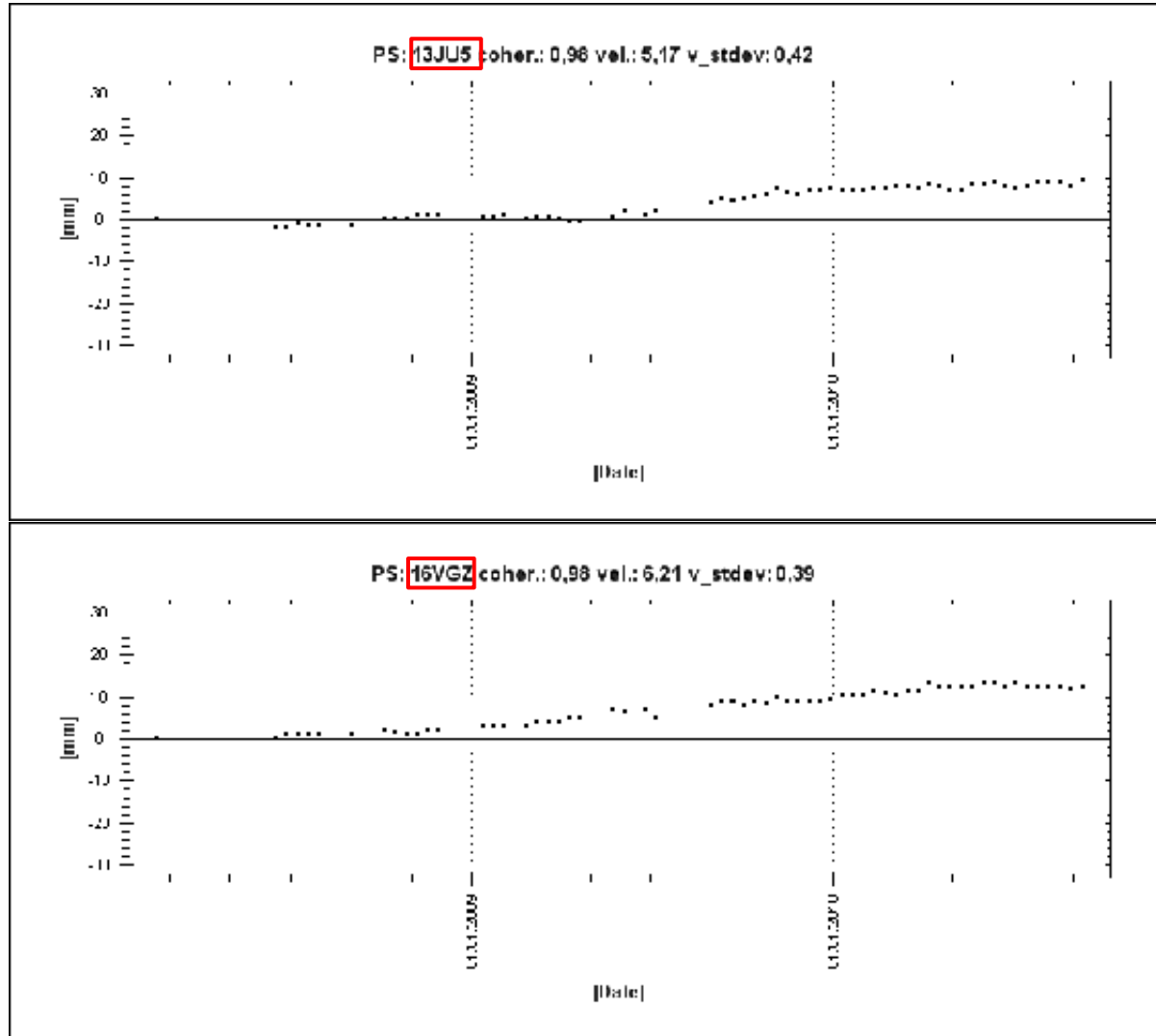


Luglio 2008

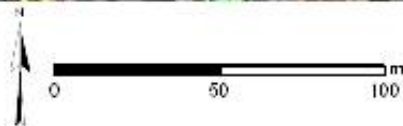
Zona Fiera



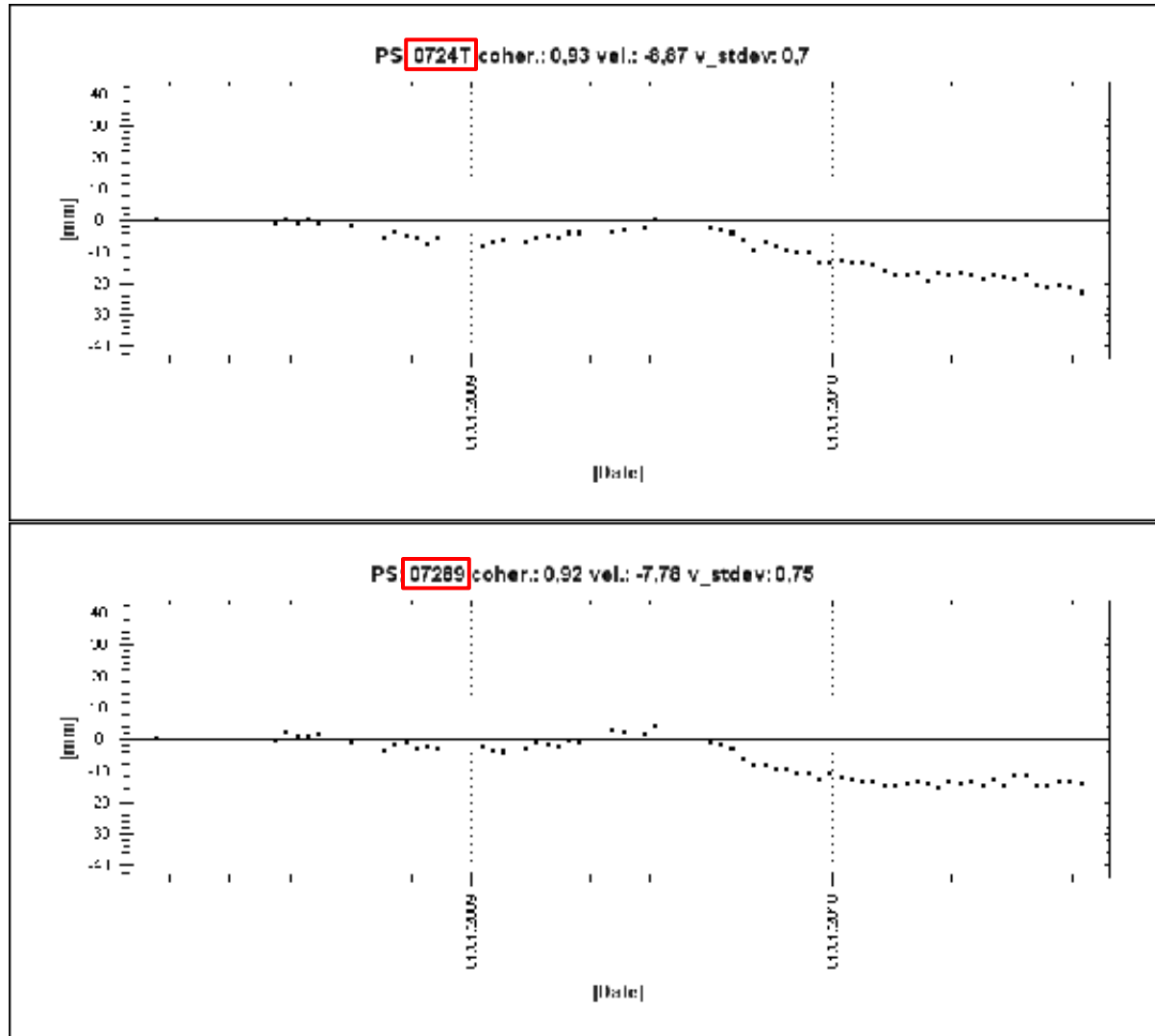
Zona Fiera



Monitoraggio Parcheggi Interrati



Esempi di serie storiche



Monitoraggio di edifici



Venezia, La Giudecca

Milano, Duomo



Visualizzazione via web



Available maps

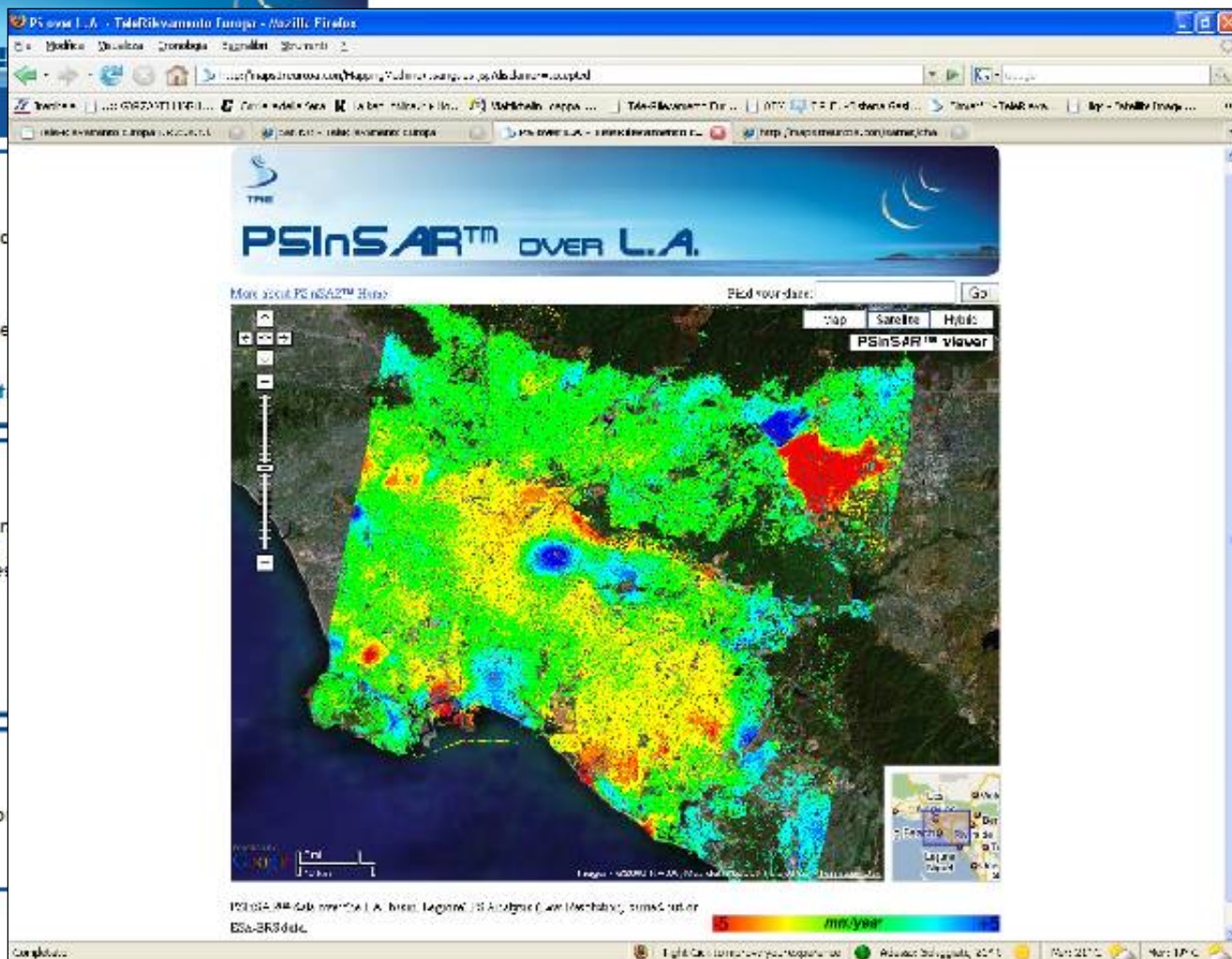
- Las Vegas**
PSInSAR™ data over Las Vegas. Results derived out of ESA-ERS data
- L.A. basin**
PSInSAR™ data over the L.A. basin. Results derived out of ESA-ERS data
- Berkeley Multi-mission PS data**

Applications

- Simcat™ [beta version]**
Search ERS1, ERS2, Envisat and Radar before to start take a look to the HcLP. Write us for suggestions or login request

More on PSInSAR™

- treuropa.com**
The PS Technique is a technology for satellite borne radar imaging



PSInSAR™ OVER L.A.

Max about PSInSAR™ Base: Find your date:

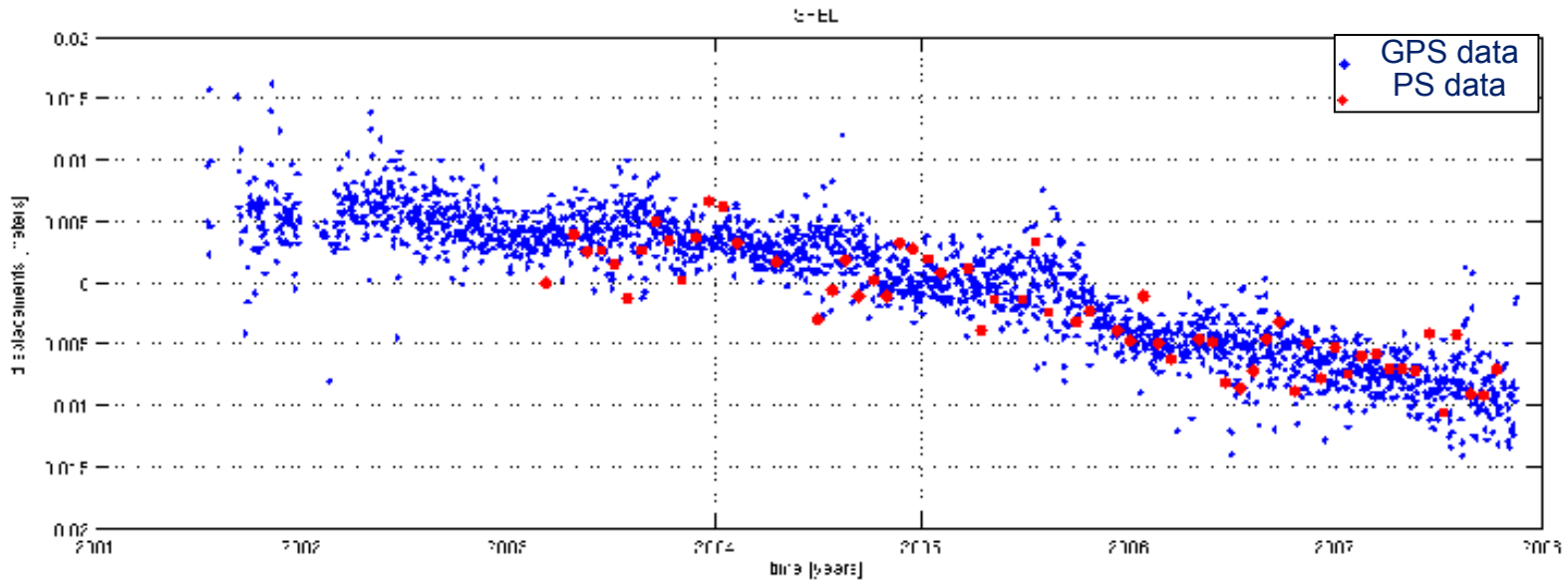
Map | Satellite | Hybrid

PSInSAR™ viewer

Legend: mm/year

PSInSAR™ data over the L.A. basin. Legend: PS Analysis (Cumulative, Simcat) using ESA-ERS data.

Synergy of PS and GPS measurements



- Precise measurements in vertical direction [mm]
 - High spatial density
 - Poor temporal sampling (Monthly updates)
- Optimization of the positions of the GPS stations

PS

- Precise measurements of the horizontal components
 - Low spatial density
 - Very good temporal sampling
- Removal of systematic errors in PS results. Data calibration
- 3D displacement field

GPS

Considerazioni finali

- L'interferometria SAR satellitare costituisce uno **strumento unico** per:
 - densità delle misure,
 - tempi di analisi,
 - precisione,
 - archivio storico,
 - integrazione sistemi GIS,
 - sinergia con altre tecniche,
 - costi e tempi
- L'Italia è all'avanguardia nel mondo per le ricerche e le applicazioni dei dati InSAR
- In futuro si avrà a disposizione un numero di satelliti radar sempre maggiore e tale da rendere le misure InSAR un dato "standard" per la geologia, la geotecnica e l'ingegneria



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