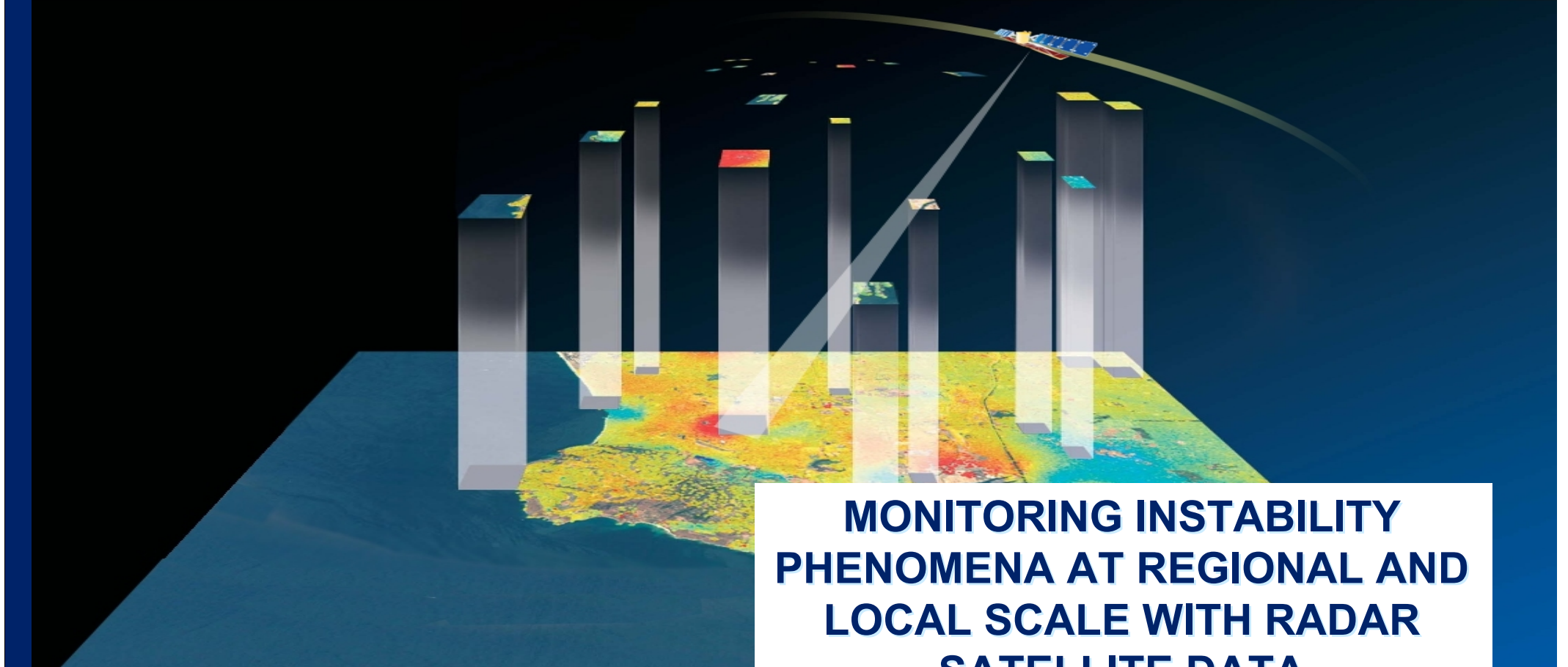




MONITORING INSTABILITY PHENOMENA AT REGIONAL AND LOCAL SCALE WITH RADAR SATELLITE DATA

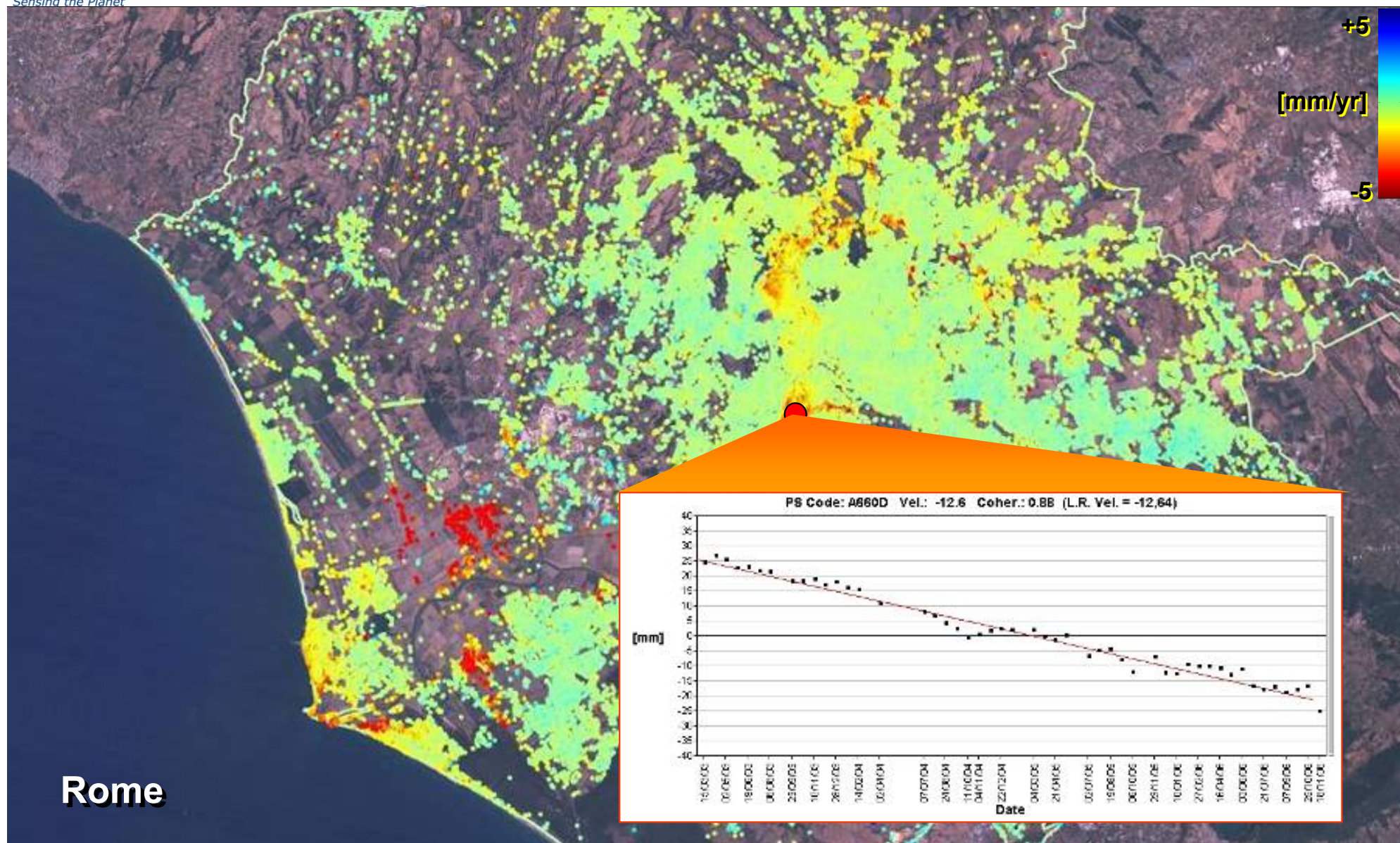
Davide Colombo
Tele-Rilevamento Europa

Cagli, June 2009

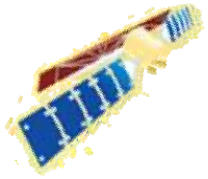


The PSInSAR[™] technology

Measuring displacements from space



The Basic Idea



1st acquisition

2nd acquisition

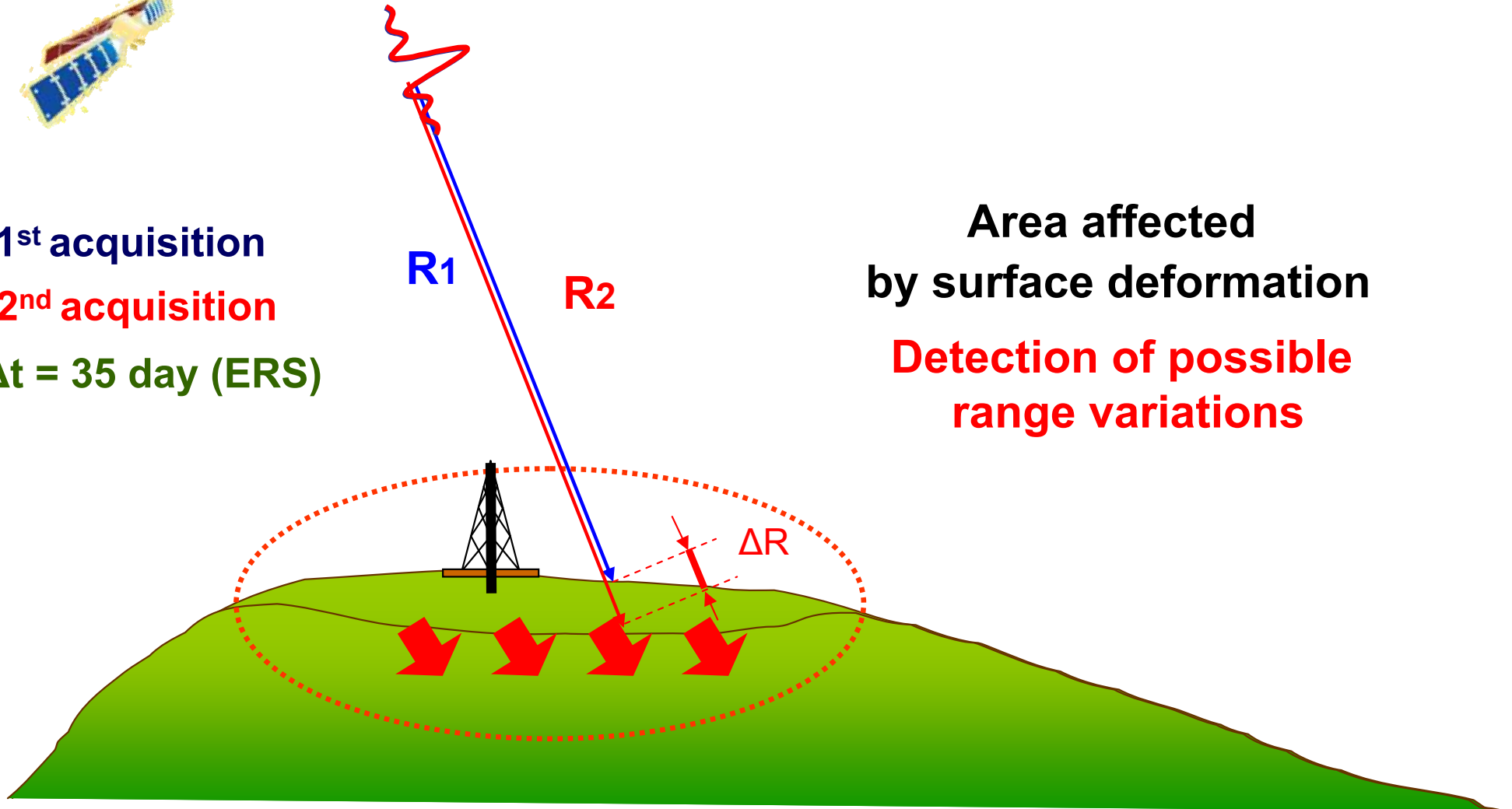
$\Delta t = 35$ day (ERS)

R_1

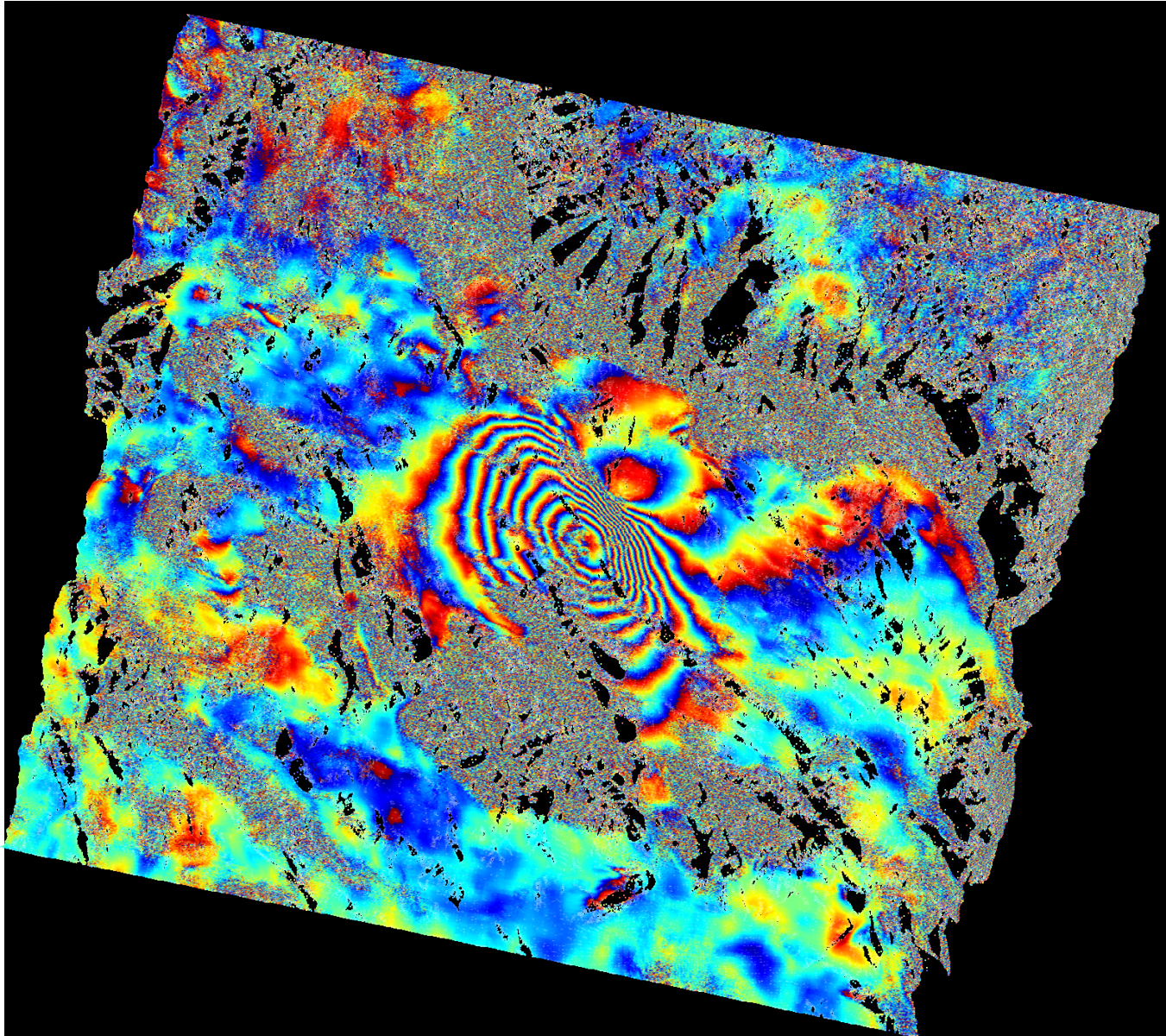
R_2

Area affected
by surface deformation

Detection of possible
range variations



Abruzzo Earthquake , Apr 6th 2009

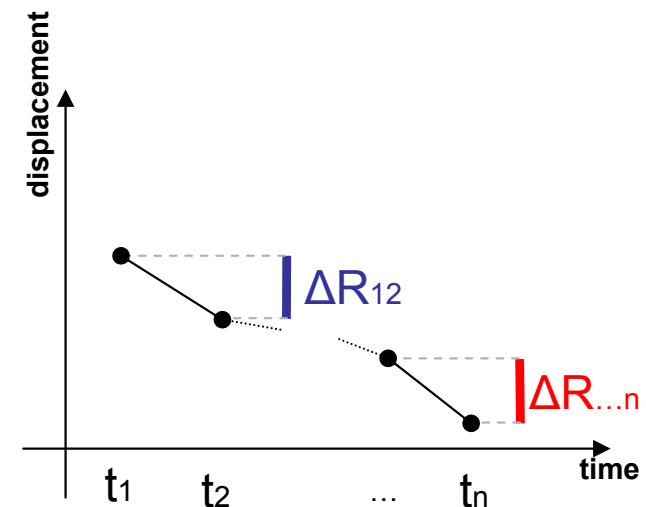
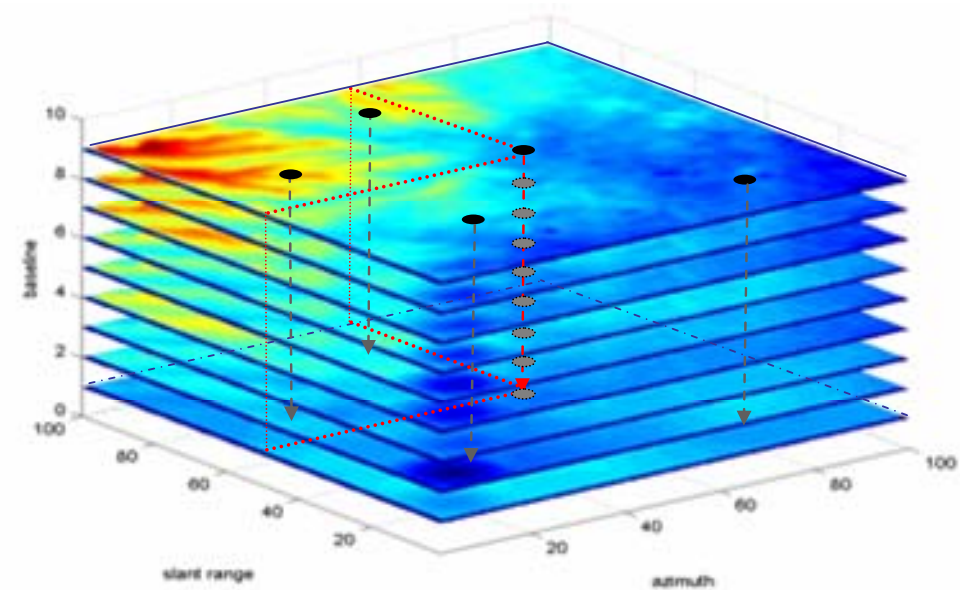
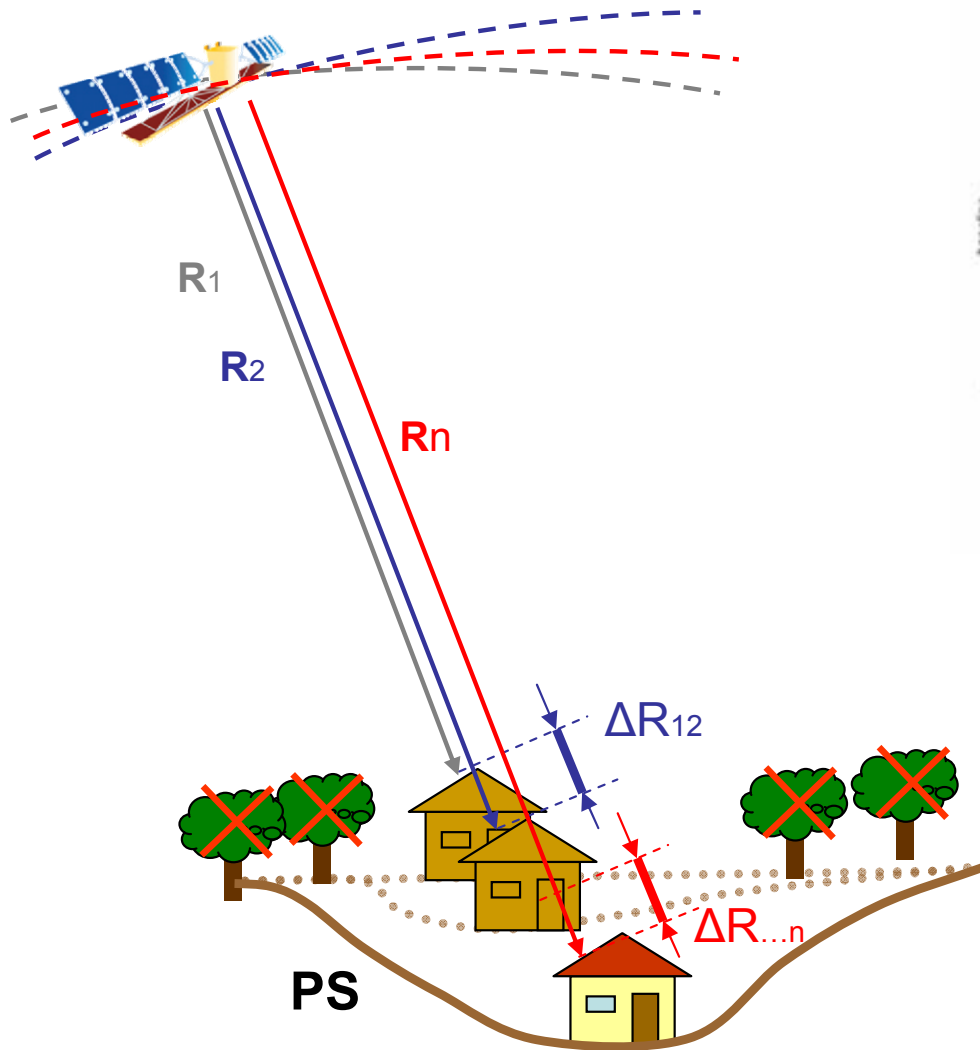


Coseismic
interferogram

ENVISAT satellite

Dates:
20090201 – 20090412

PSInSARTM: multi image approach



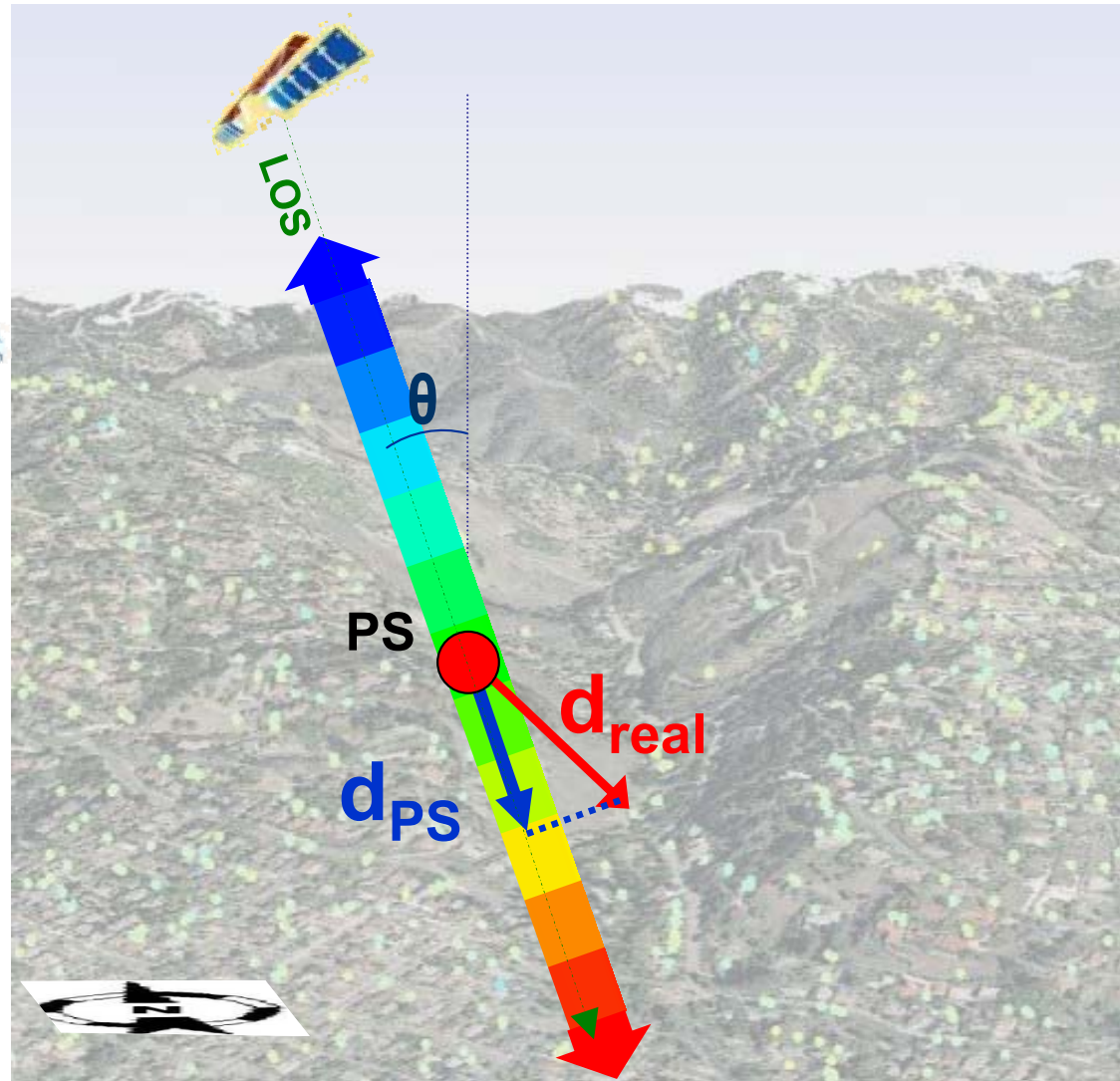
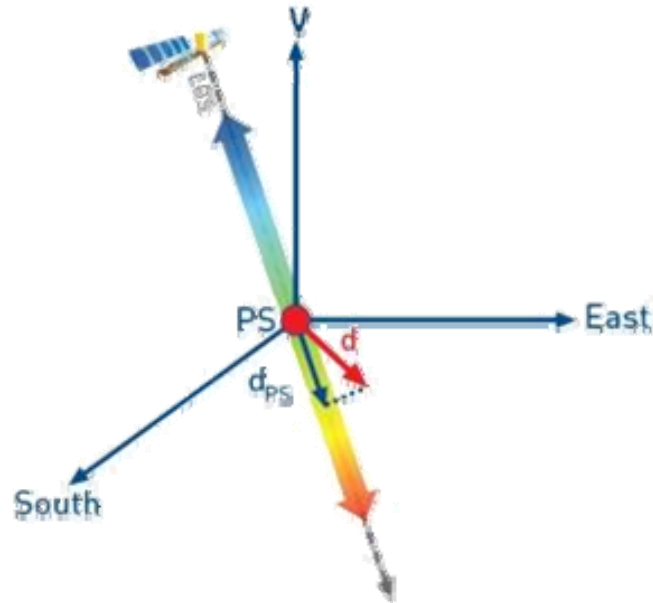
What is a Permanent Scatterer?

PS are radar targets exhibiting stable radar returns:
buildings, manufacts, pipelines, antenna, poles, outcrops, exposed rocks...



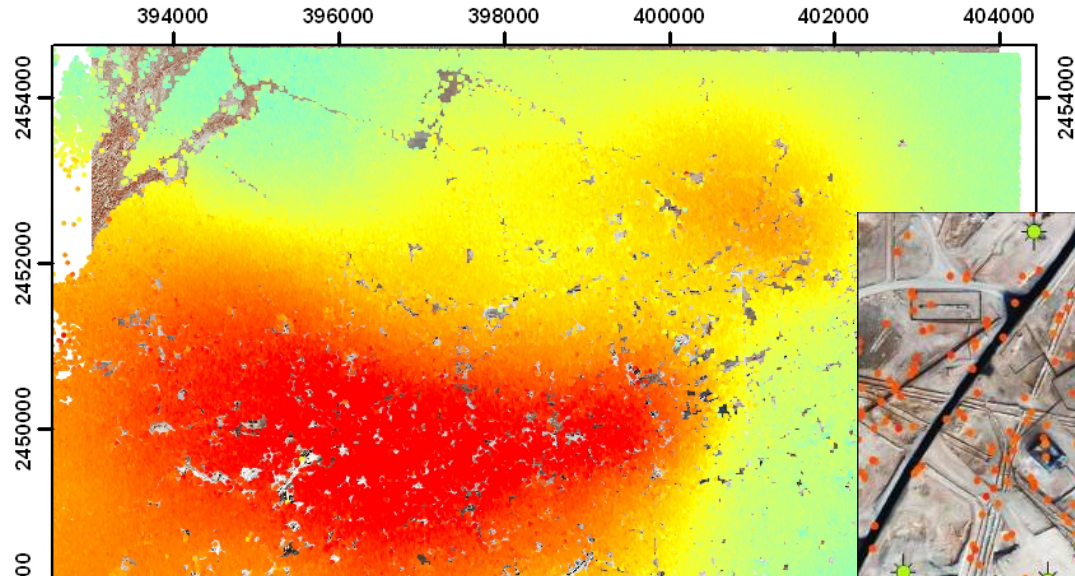
Image courtesy of: Suncor

Measurements along the Line Of Sight (LOS)

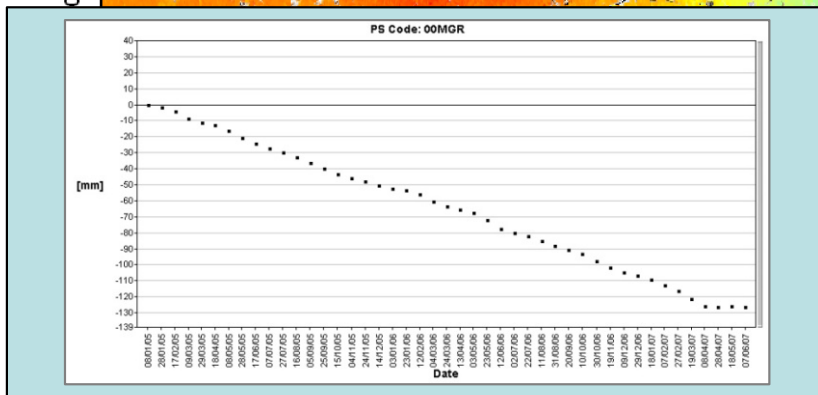


PSInSAR™ Analysis typical output

Deformation field



Close up



Displacement Time Series of a Permanent Scatterer

Accuracy

Common to differential GPS, all PS measurements are **differential** measurements with respect to a reference radar target.

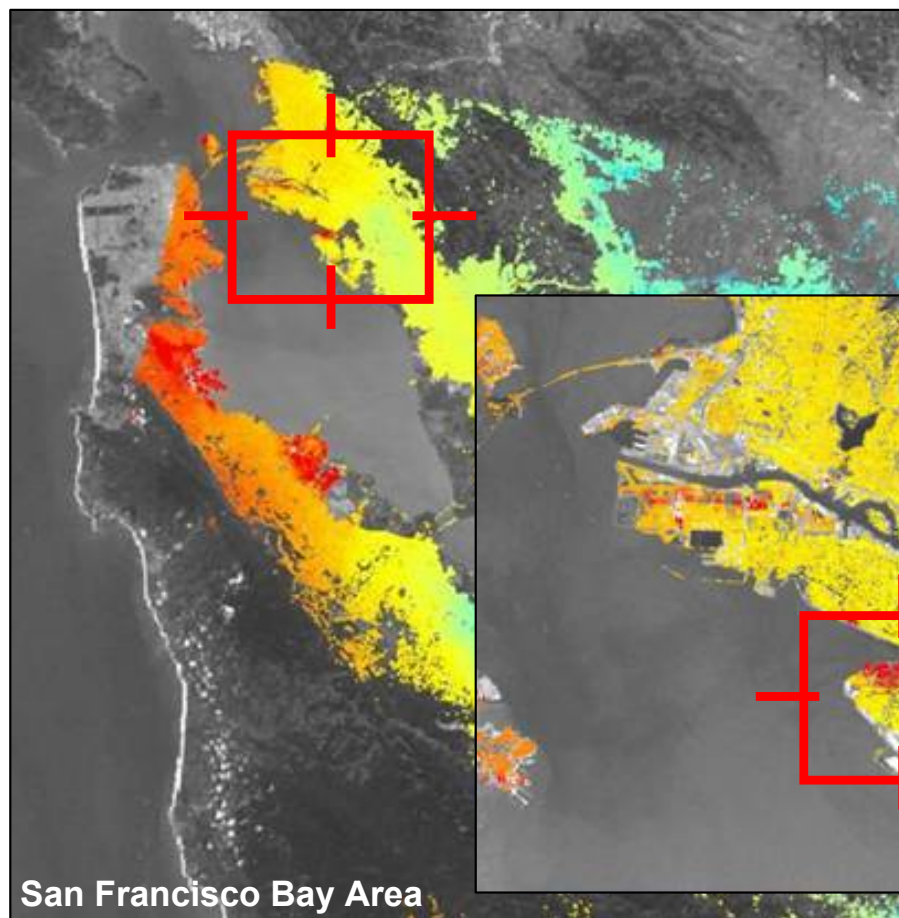
The **accuracy** depends on many factors: # of images, PS density, climatic conditions, distance from the GCP, etc.

Typical values @ < 1 km from the reference point

<u>POSITIONING</u>	Easting	Northing	Height
Precision (1σ)	7 m	2 m	1,5 m

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

PSInSARTM: a multi-scale technology



From a regional scale...



...to the single building!



PSInSAR[™]: main applications

Subsidence



Landslides



Seismic Faults



Single Building

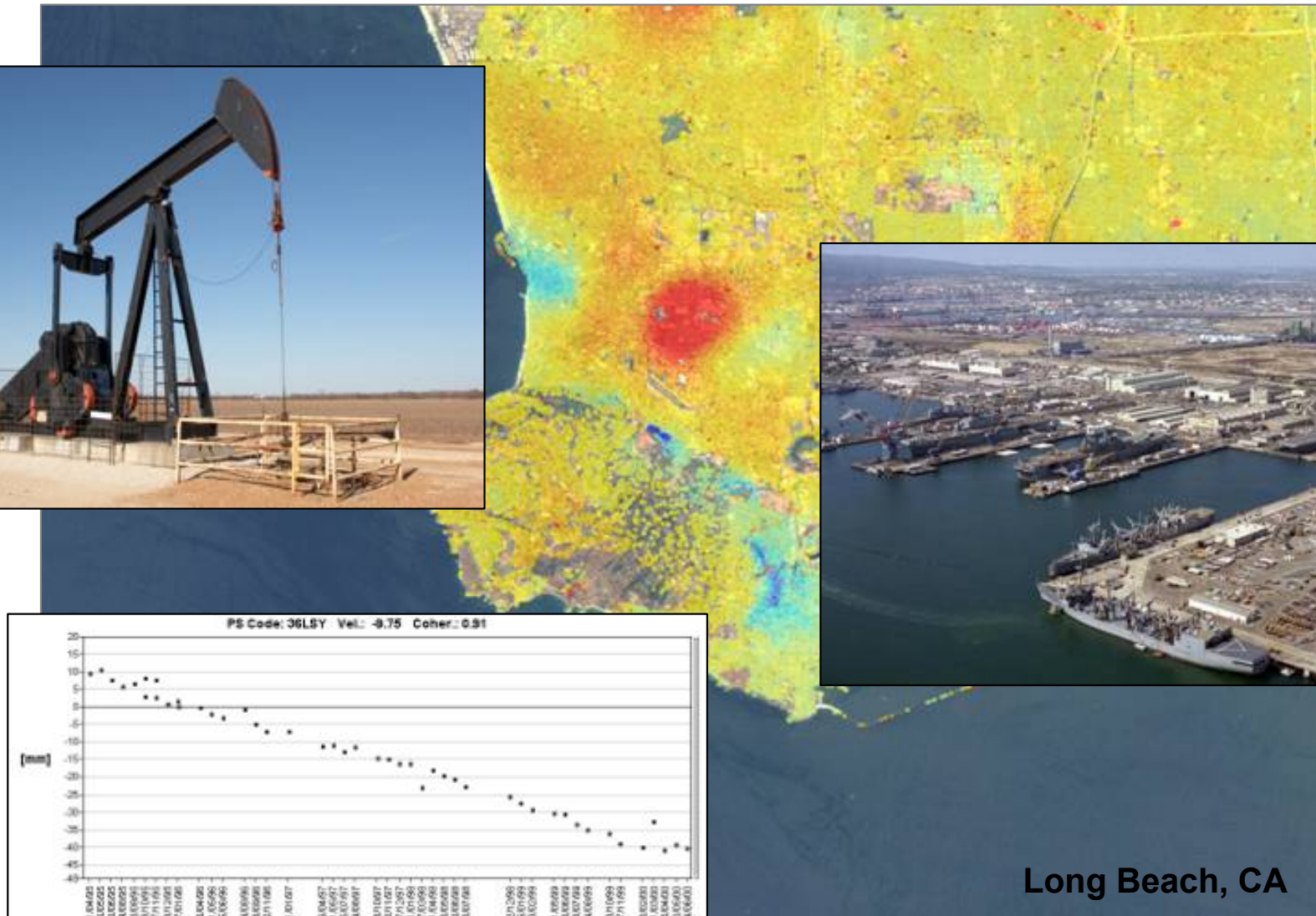




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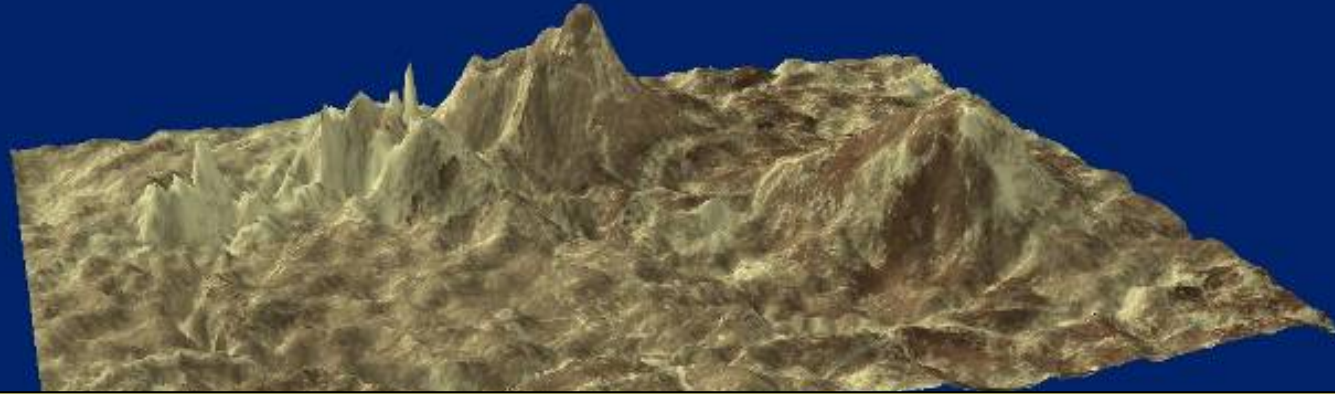
PSInSAR™ APPLICATIONS

Oil field monitoring: Long Beach, CA

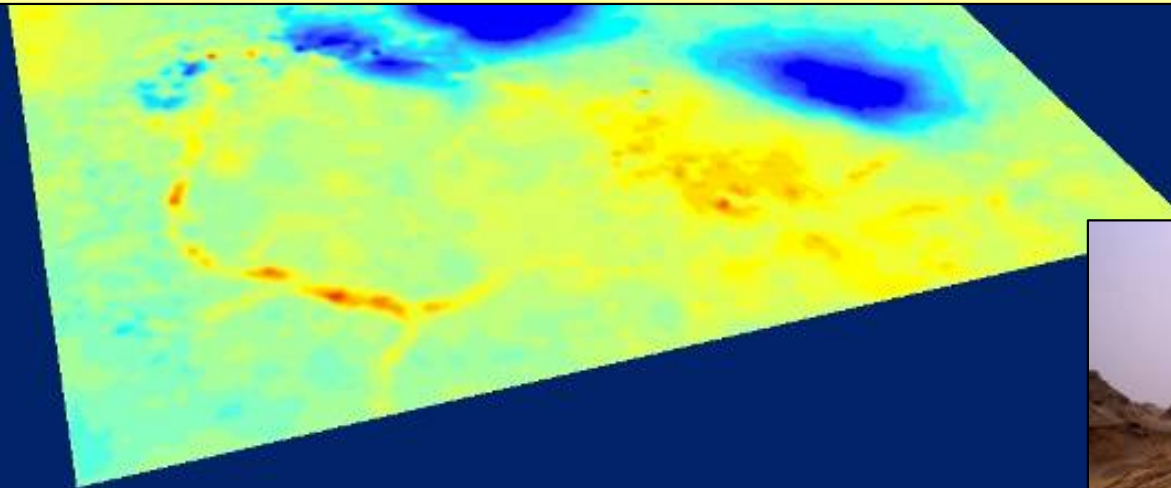


Long Beach, CA

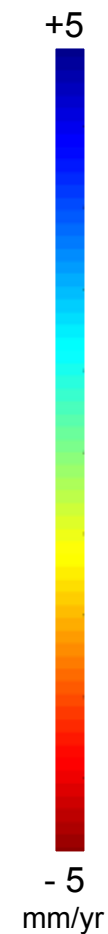
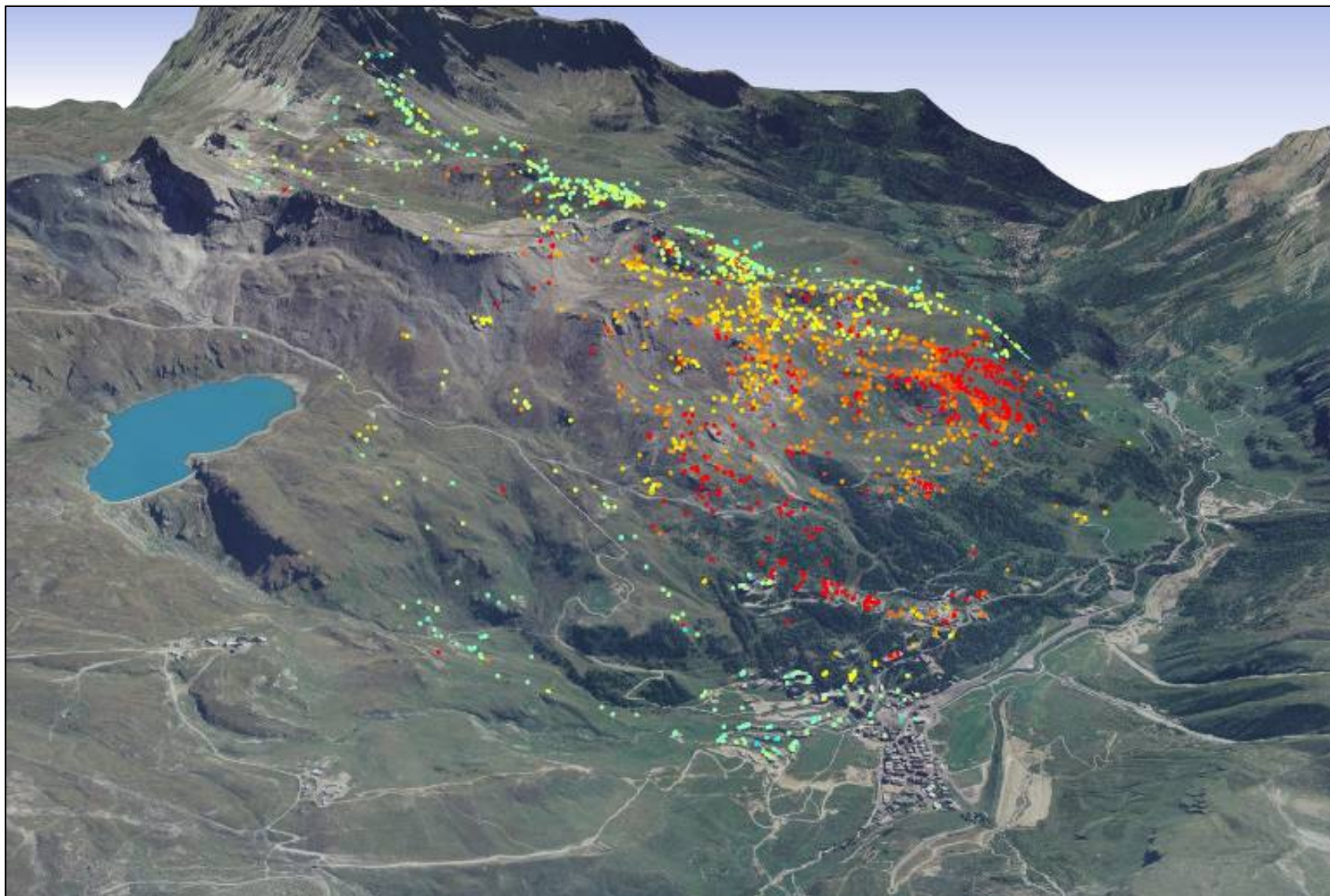
CO2 Sequestration: North Africa



*An in depth analysis of the data will be presented
at the next SEG conference – Las Vegas, Nov. 2008*



Landslide, Alps

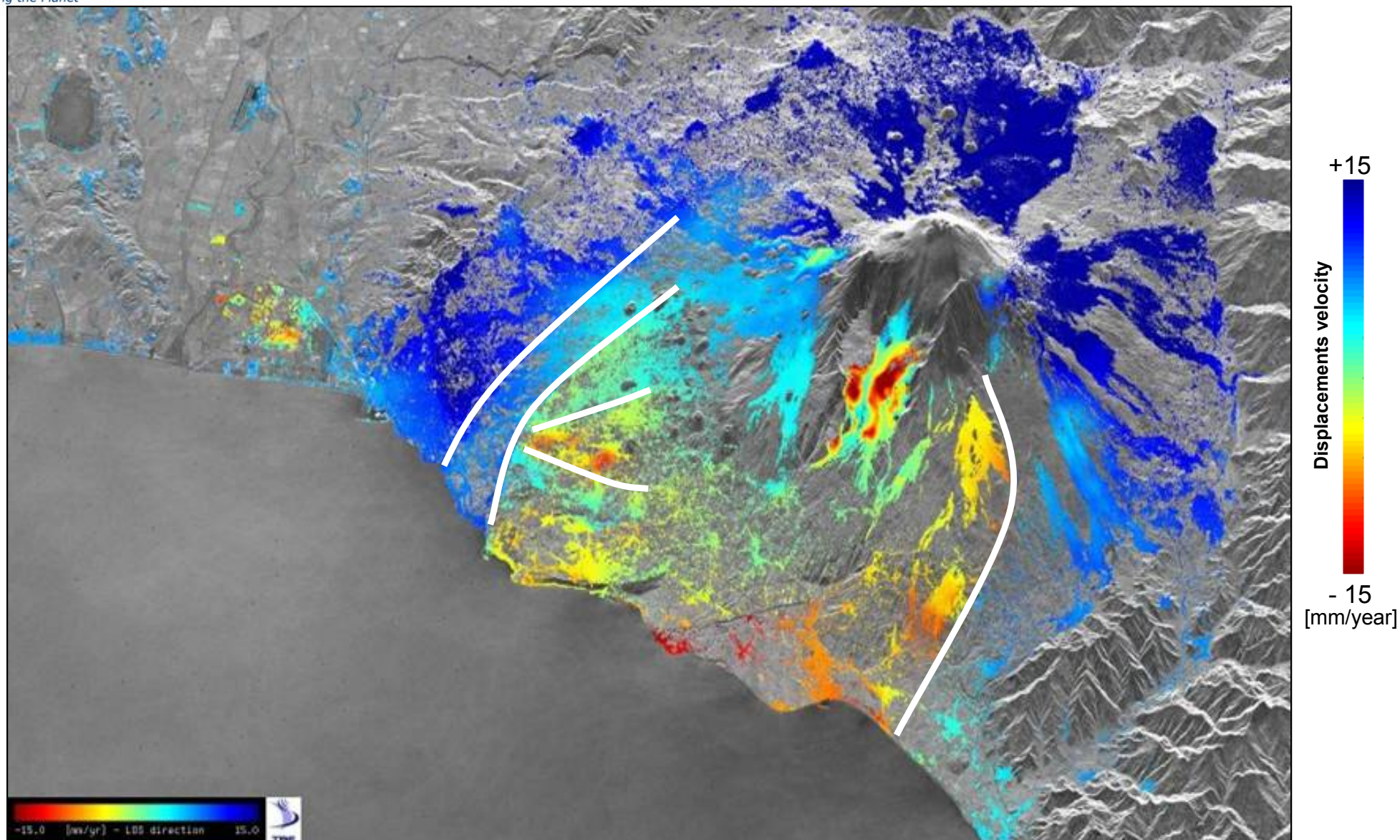




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Seismic Faults and Volcano Etna



Linear Infrastructure Motorway, Northern Italy



Settlement of Buildings

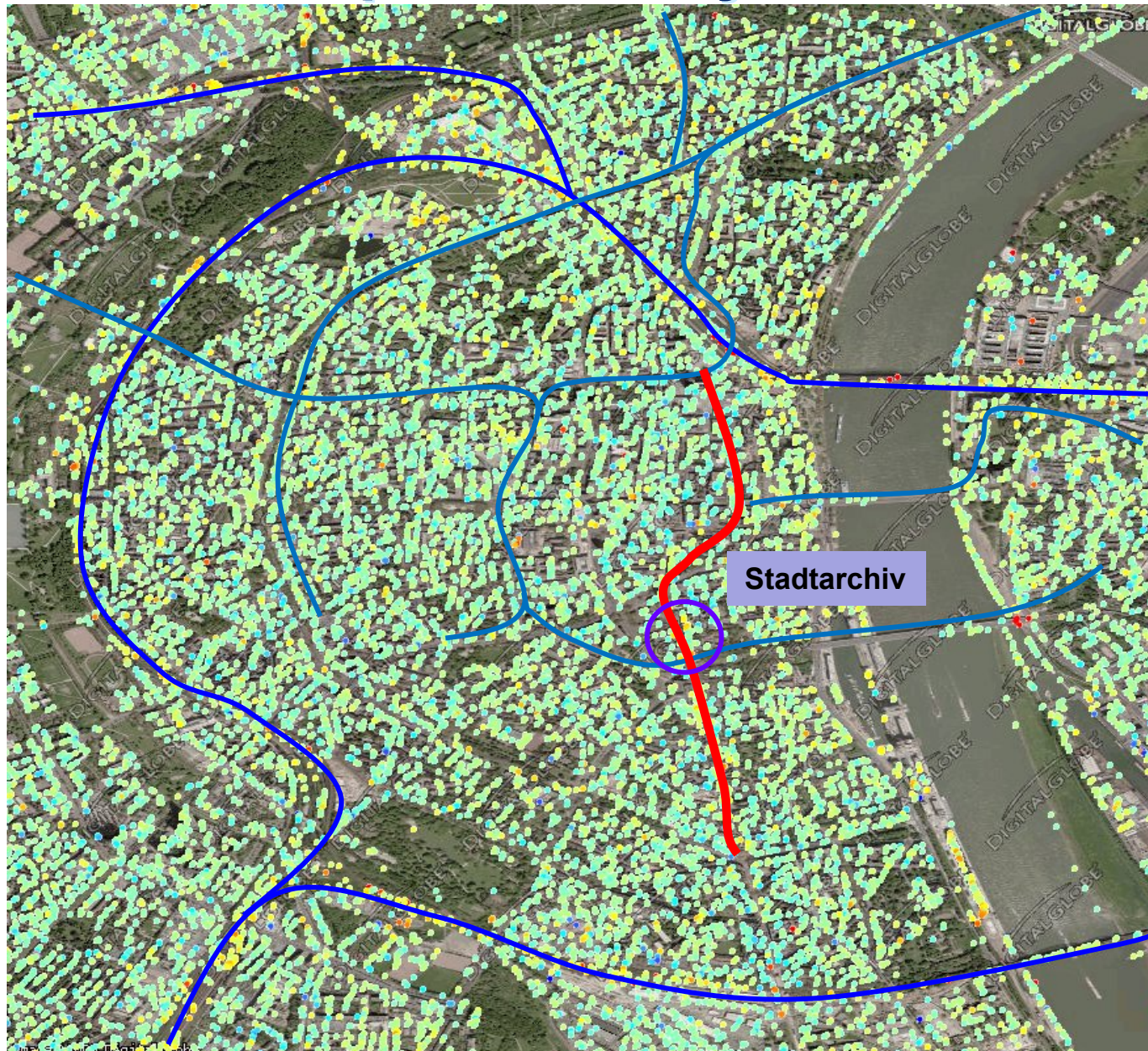
The Palm, Dubai



Collapse of Kölner Stadtarchiv – 3/3/2009

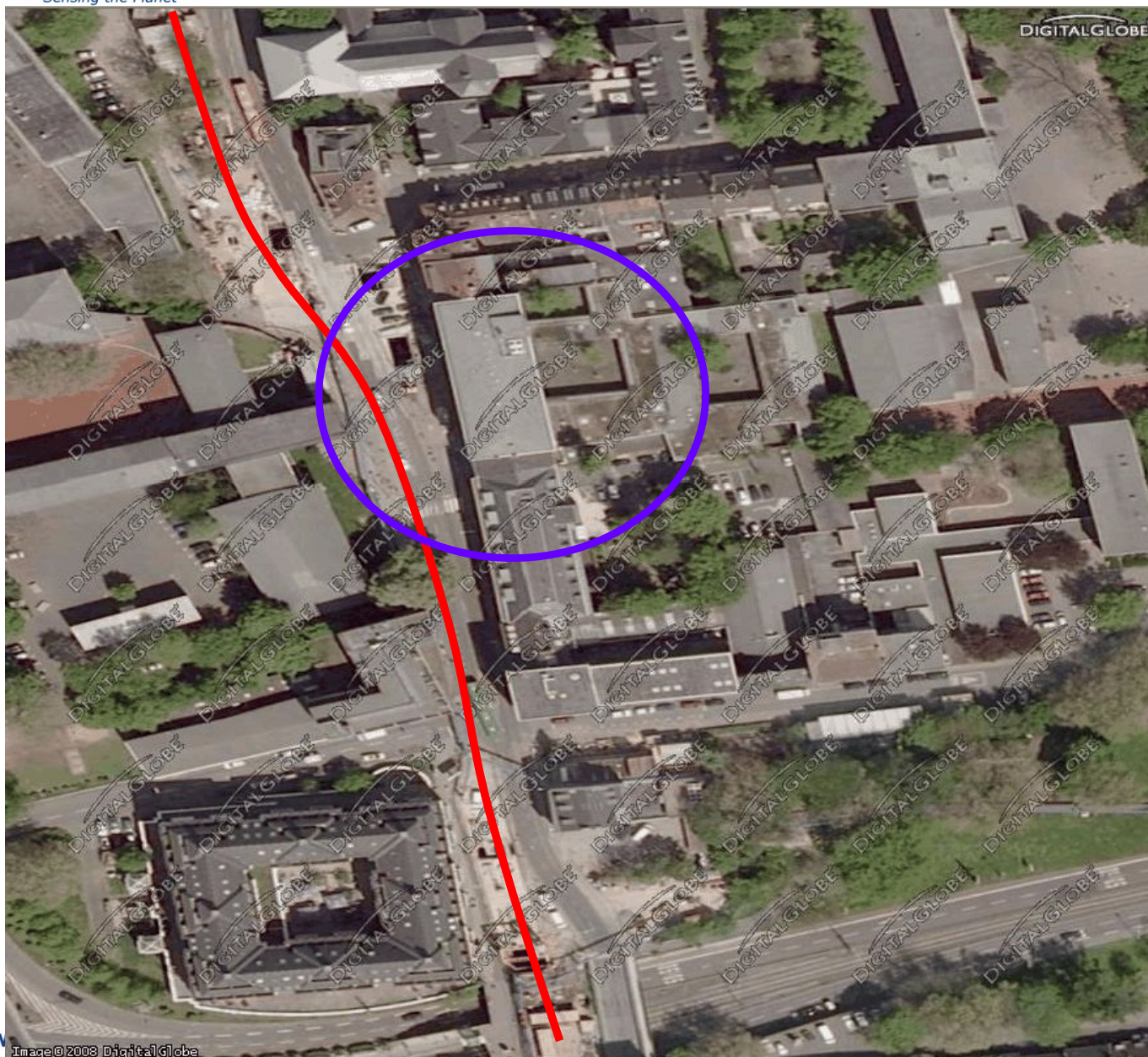


Köln Transportation system and PS data



- Railroad
- Underground metro line
- Underground new tunnel

Kölner Stadtarchiv - Severinstrasse 222-228

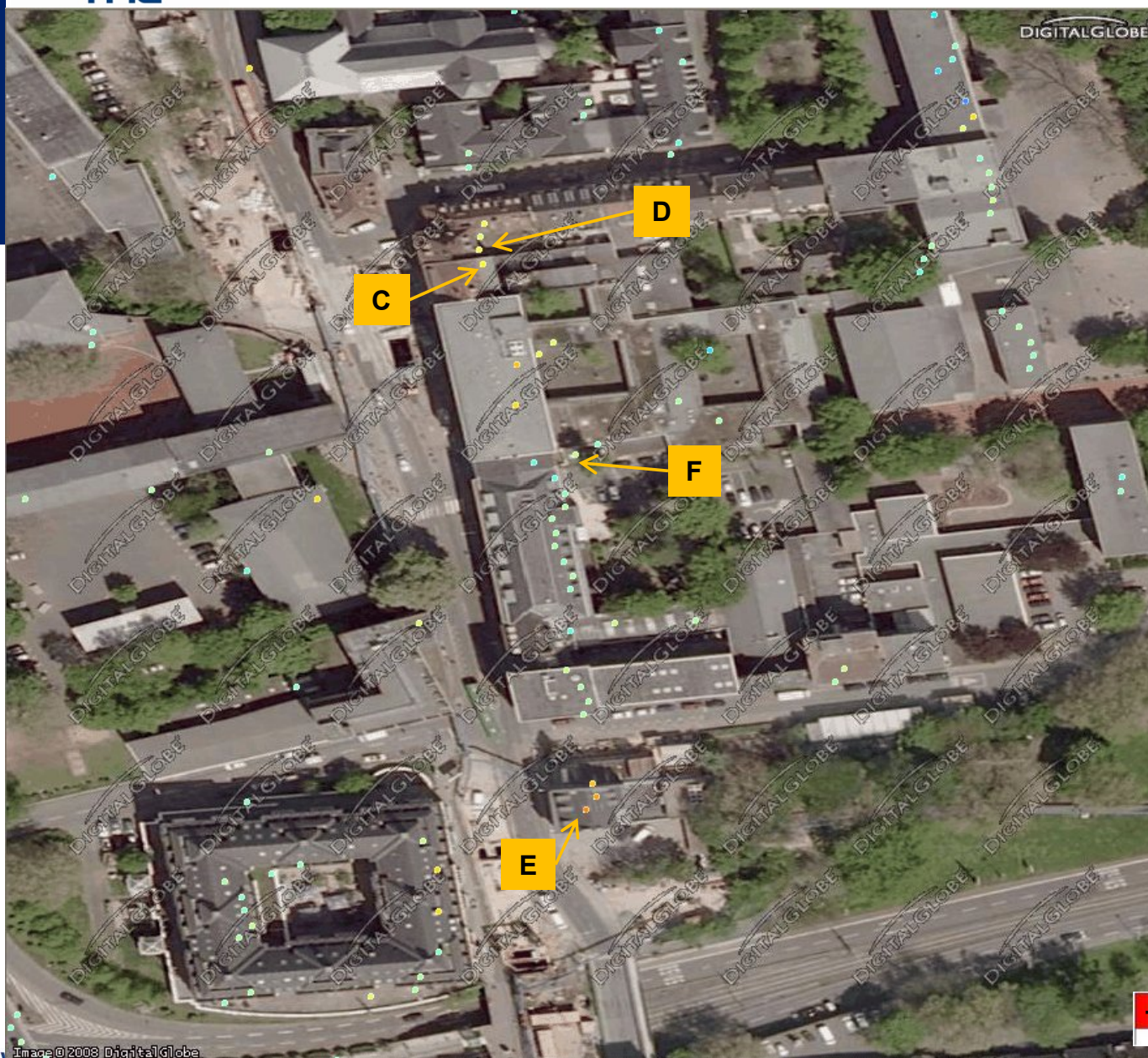


March 3rd, 2009, at approximately 14:00, the Kölner Stadtarchiv collapsed. The building was inaugurated in 1971.

It was a highly sophisticated building purposely built with the needs of a modern archive in mind.

The nearby high school across the street had dismissed its' students at around 13:00.

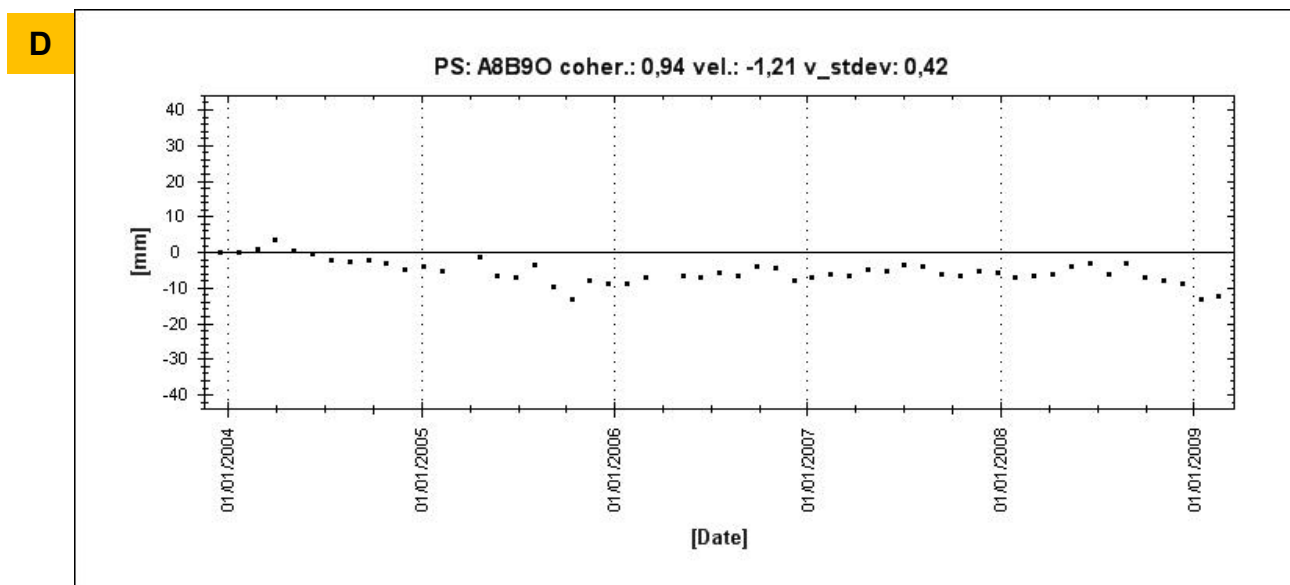
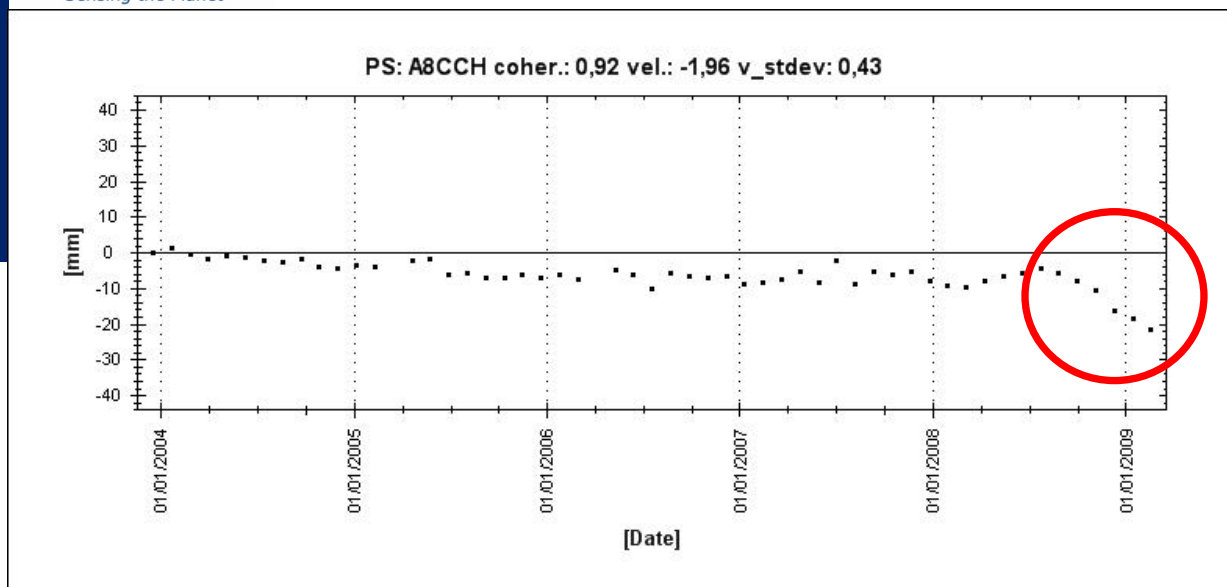
Kölner Stadtarchiv - Severinstrasse 222-228



PS map

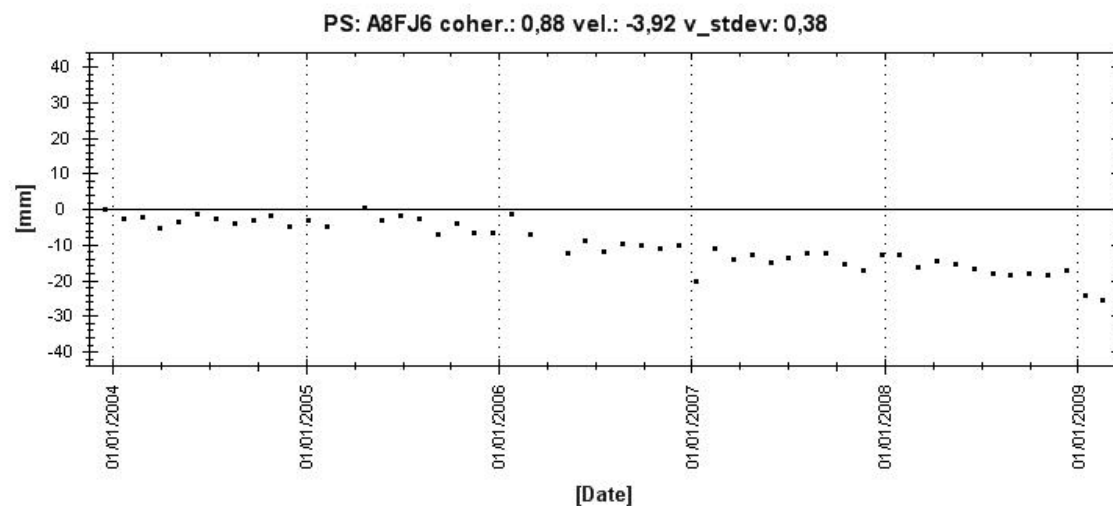


Deformation Time Series

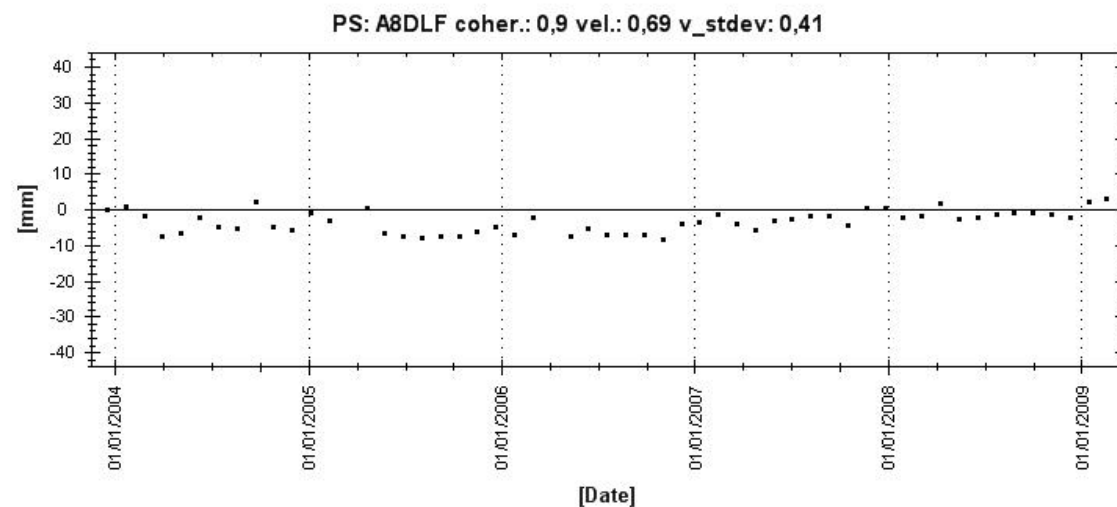


Deformation Time Series

E



F





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EMILIA ROMAGNA CASE STUDY

EMILIA ROMAGNA case study

Customer:

ARPA Emilia Romagna - Ingegneria Ambientale– IT

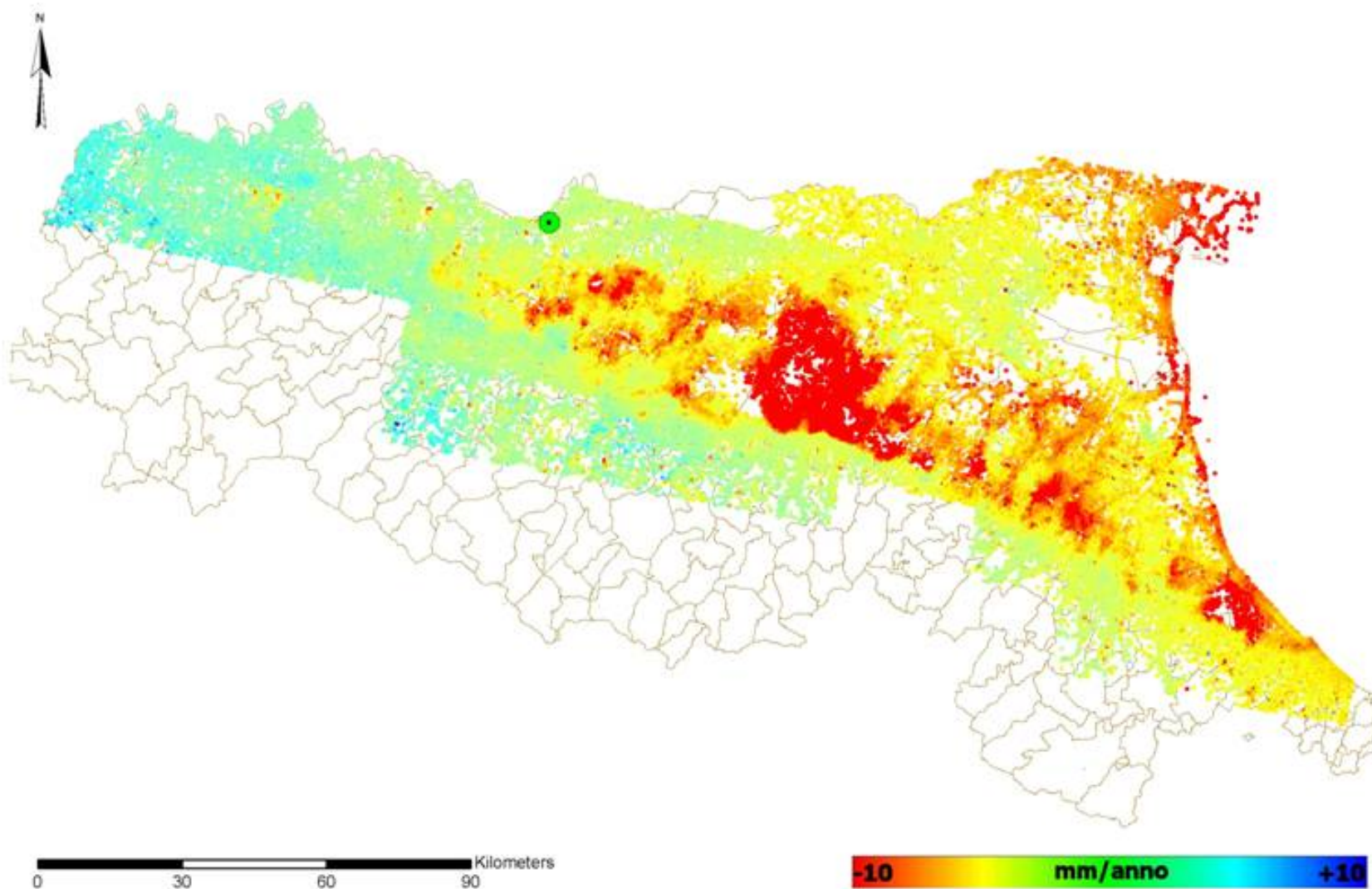
Delivery Date: 31/01/2007

ERS :

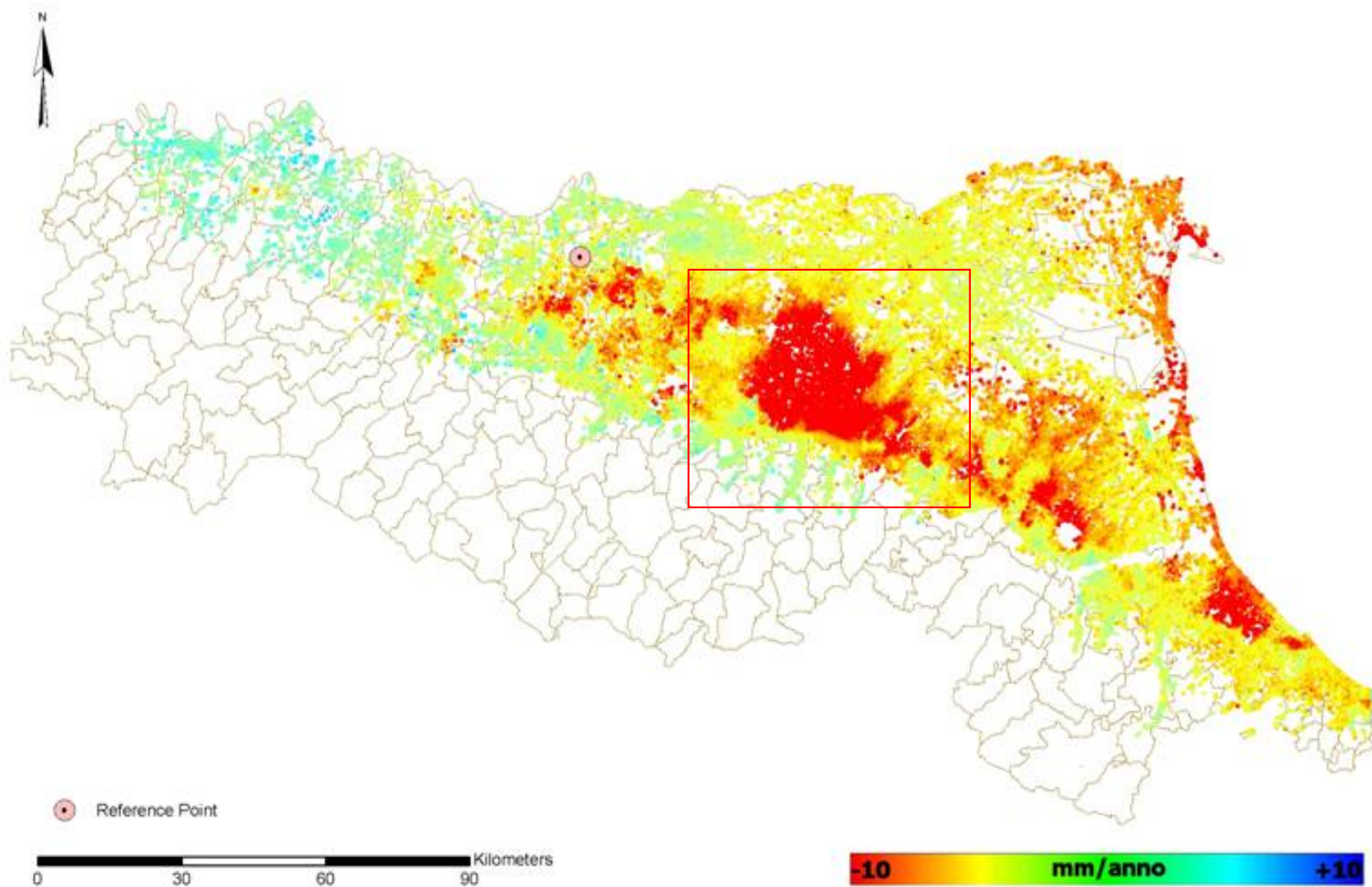
- Satellite: ERS and ENVISAT
- Orbit: Descending and Ascending
- Time range: June 1992 -2006
- Number of Images: >500
- Area of Interest: ~ 10.000 km²
- Number of PS identified: >250.000
- Regional PS analysis 100 m



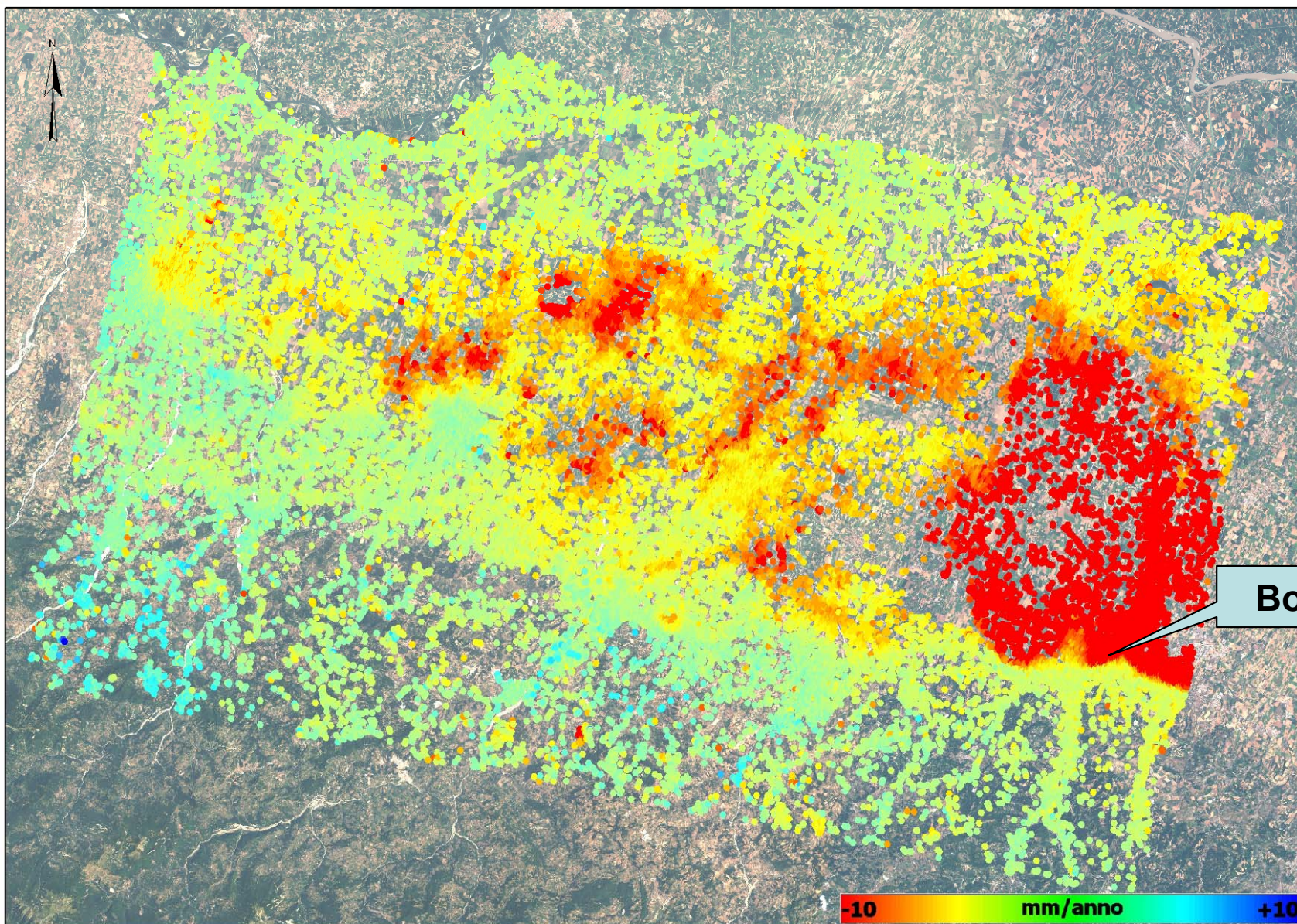
Results: ERS D 1992-2000



Results: ENVISAT A 2002-2006



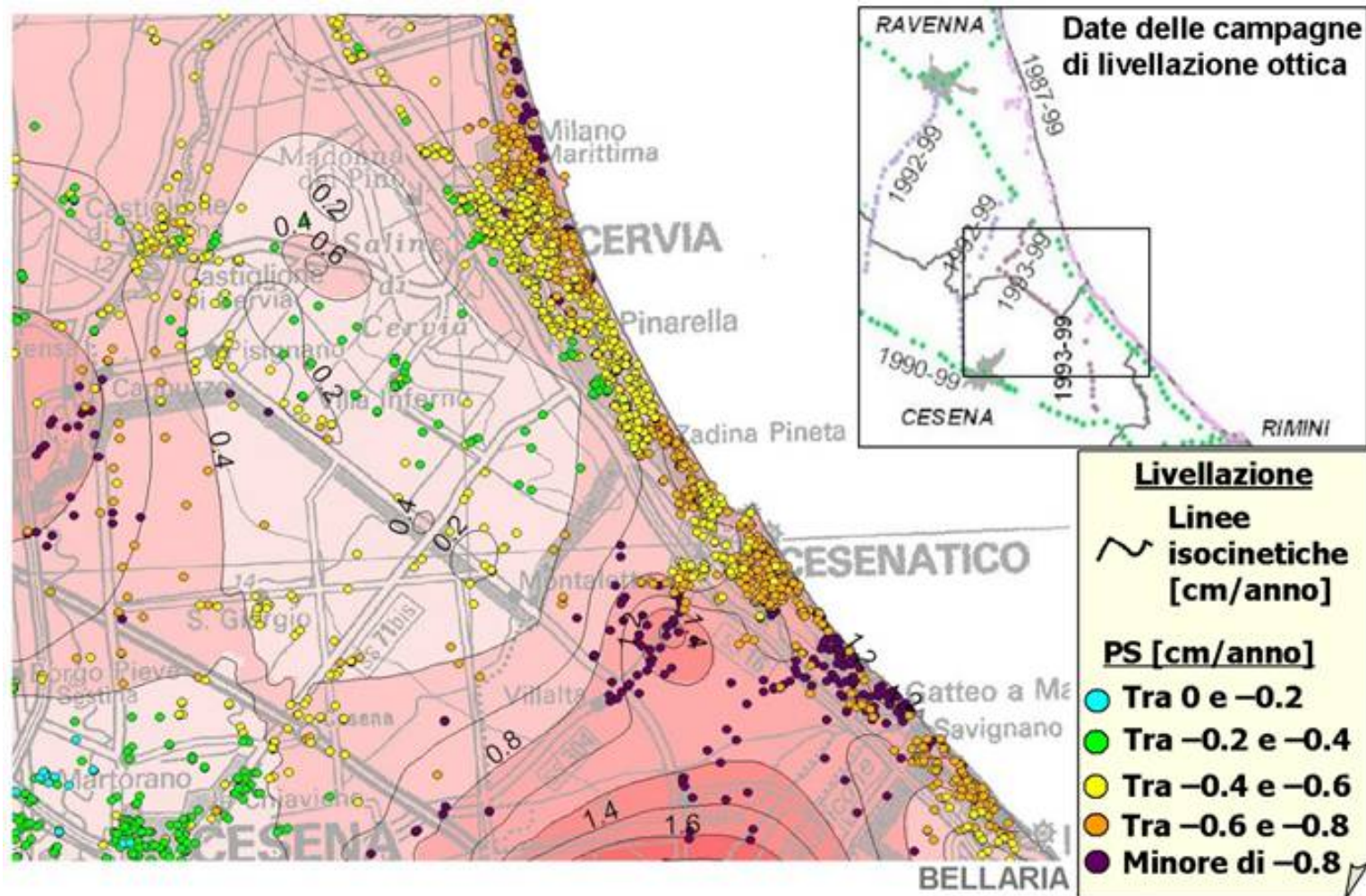
Bologna



Romagna Basins

PS results compared
with levelling surveys

Perfect agreement of
results



Fonte: Alberto Pistocchi, PhD - Autorità dei bacini regionali romagnoli – Poppi
2004



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ALPINE REGION CASE STUDY

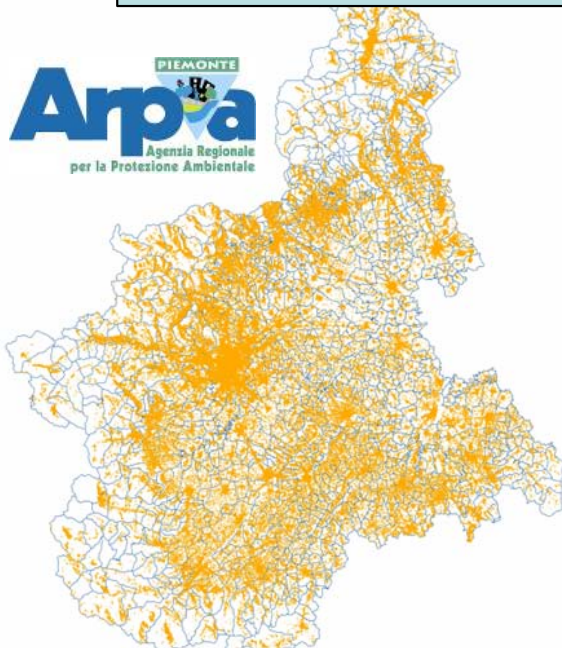


one



- 250 immagini radar processate
- 3.200 Km² elaborati
- > 370.000 PS individuati

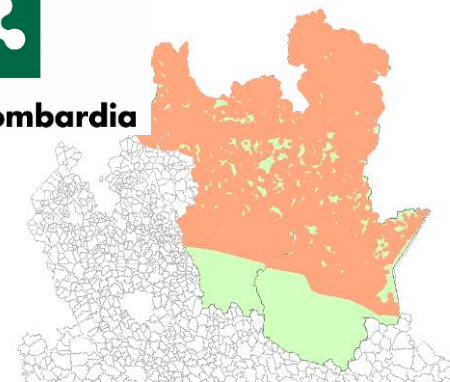
Arpa
PIEMONTE
Agenzia Regionale
per la Protezione Ambientale



- 600 immagini radar processate
- 25.000 Km² elaborati
- > 2.000.000 PS individuati

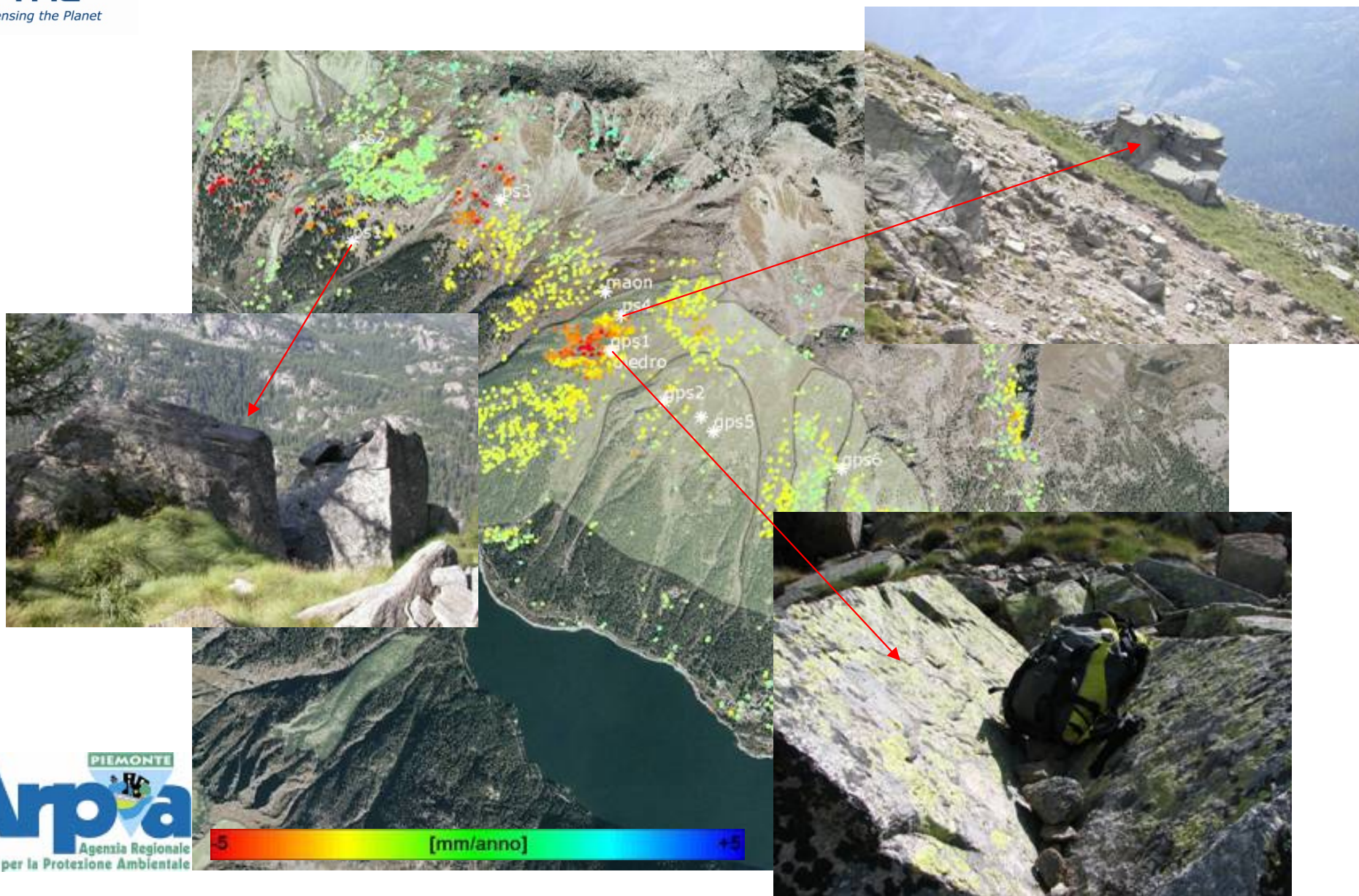


Regione Lombardia



- 400 immagini radar processate
- 8.700 Km² elaborati
- > 600.000 PS individuati

PS in alpin region: validation campaign

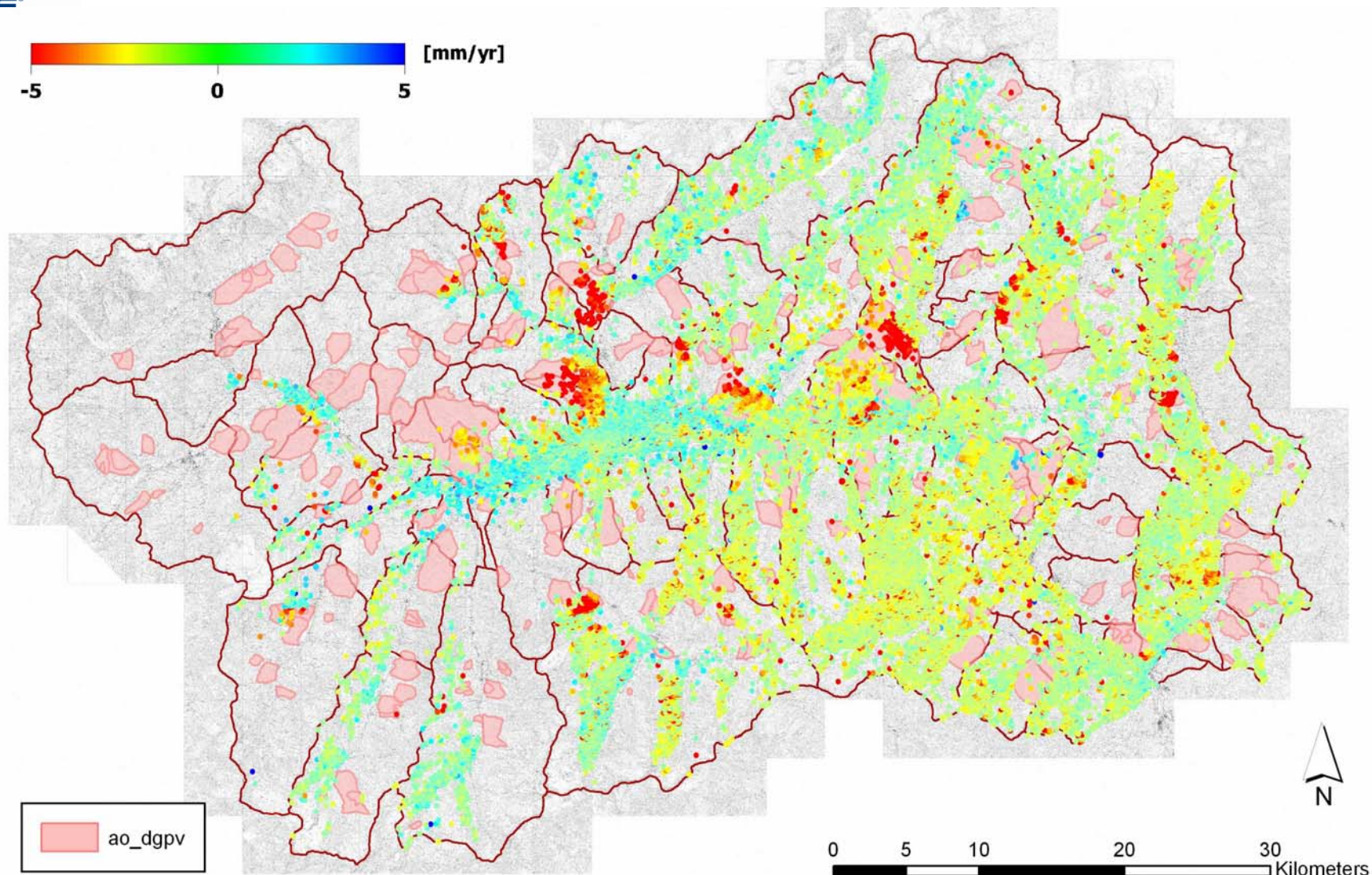


Elaborazione ERS1-ERS2 Valle d'Aosta

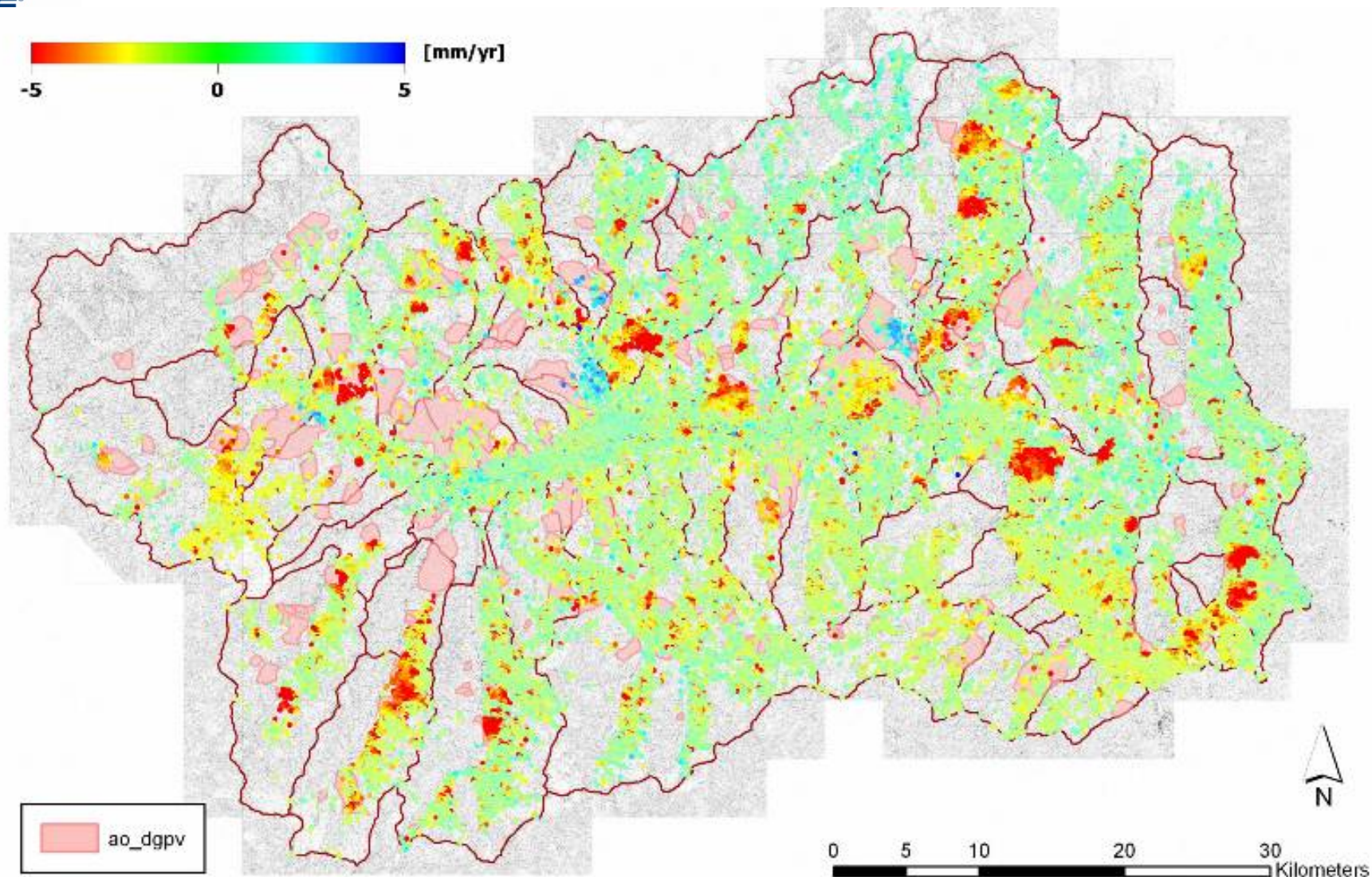
- **Estensione AOI: 3.264 km²**
- **Tipologia di analisi: Standard PS Analysis (SPSA)**
- **Satellite utilizzato: ERS1-ERS2**
- **Geometria di acquisizione: ascendente e discendente**
- **Numero PS individuati: 138095 asce + 234913 desce**
- **Range Temporale e immagini processate asce:**
 - Track 301 – La Salle: immagini 32 (1995-2000)
 - Track 29 – Chatillon: immagini 50 (1993-2000)
- **Range Temporale e immagini processate desce:**
 - Track 294 – Courmayeur - La Thuile: immagini 80 (1992-2000)
 - Track 22 – Cogne - Chatillon: immagini 89 (1992-2001)



Dataset ascendente

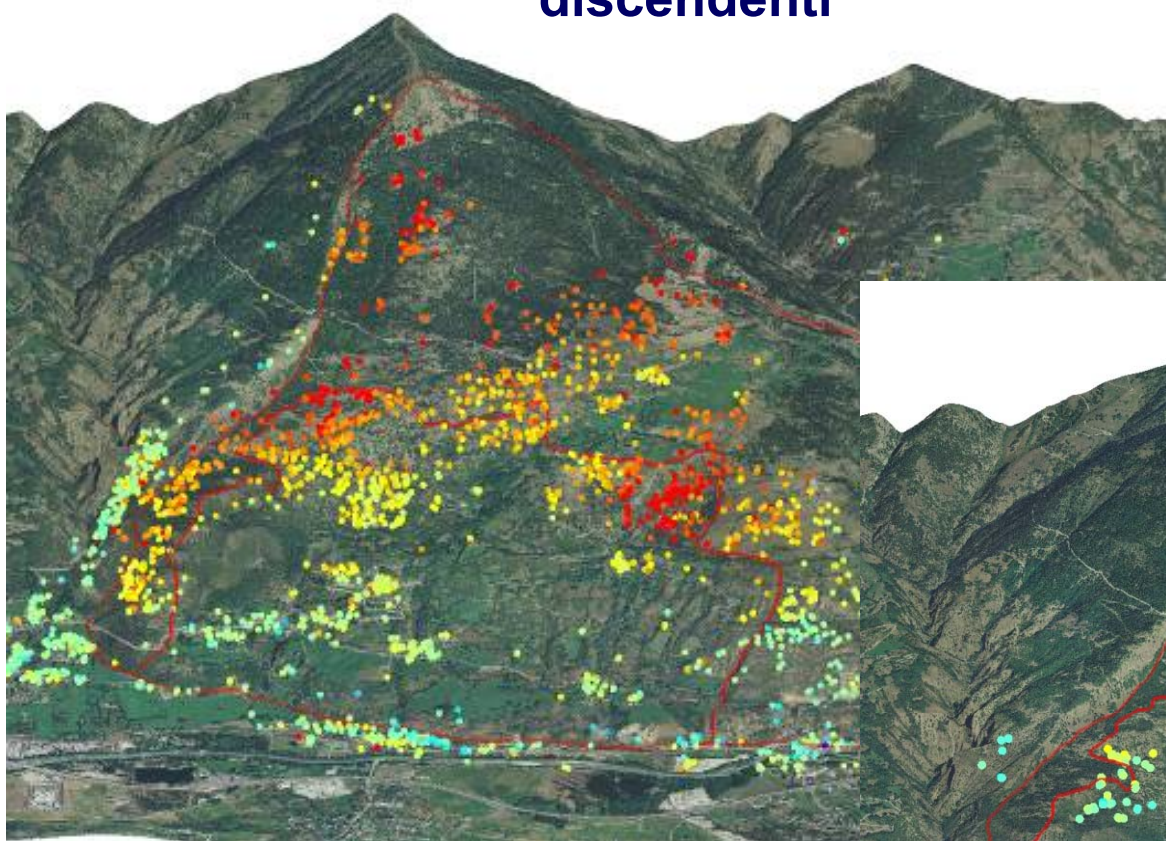


Dataset discendente

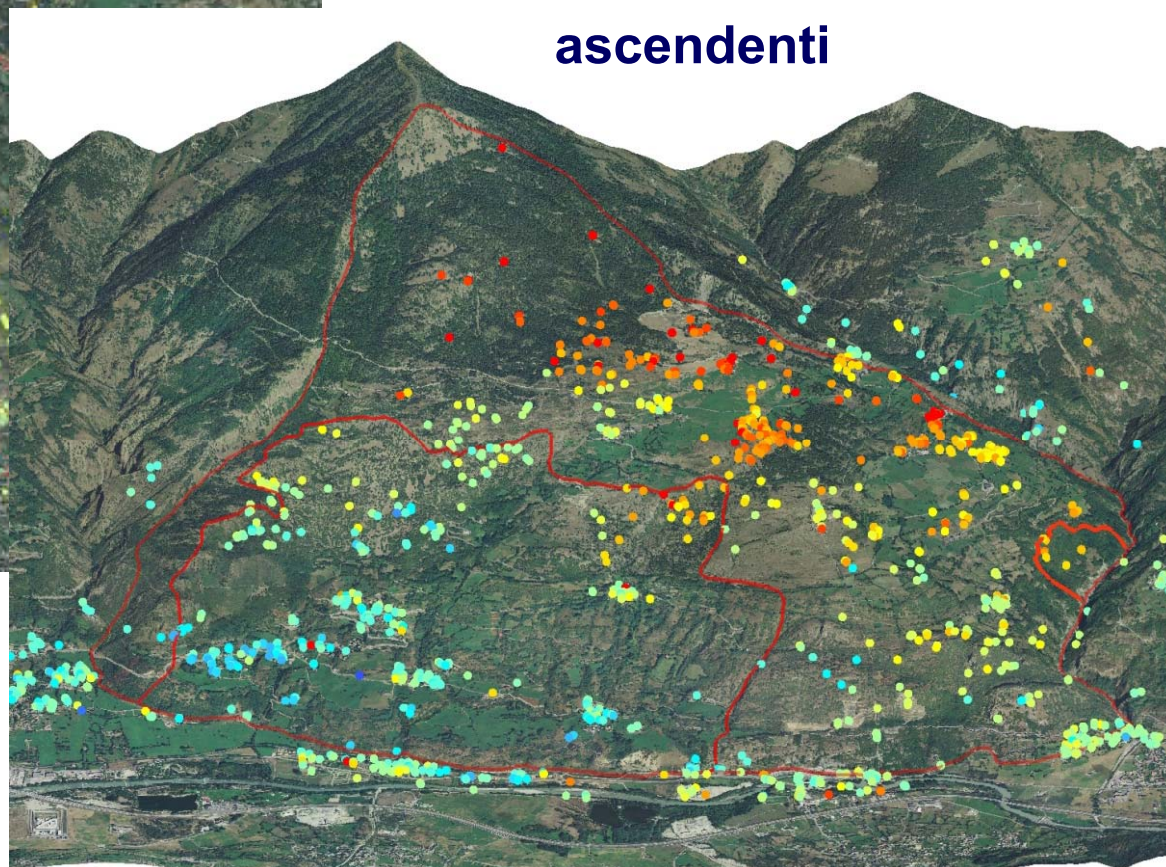


Case history 1: dati PS

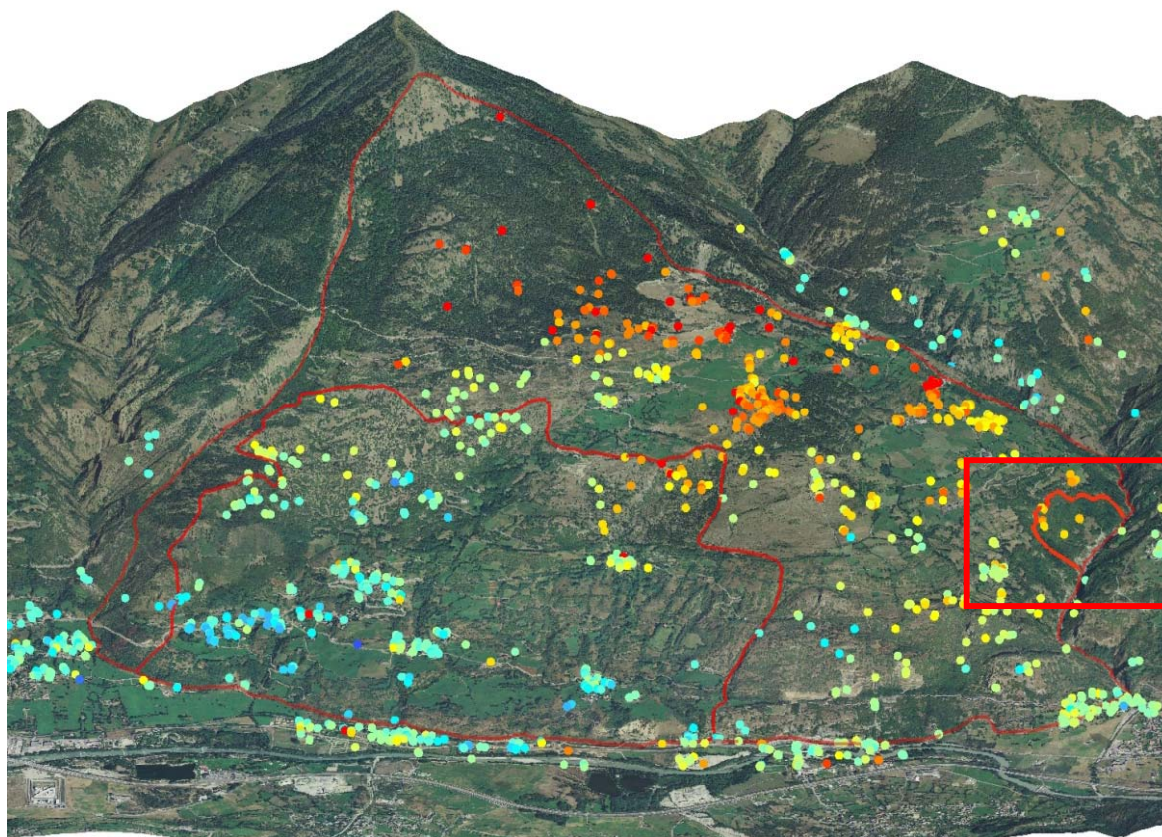
discendenti

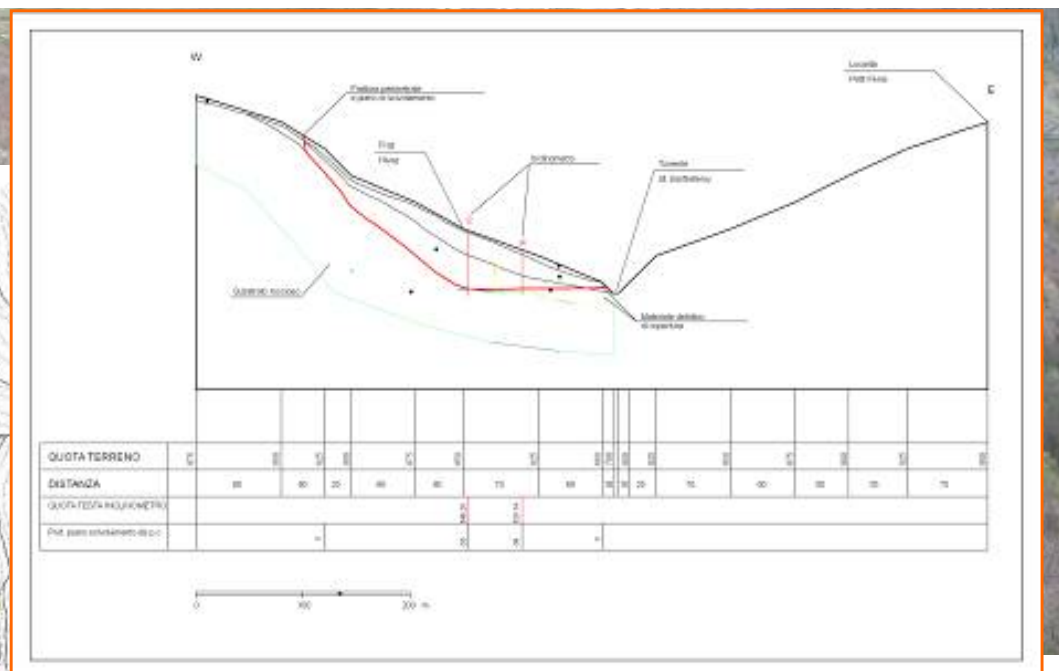
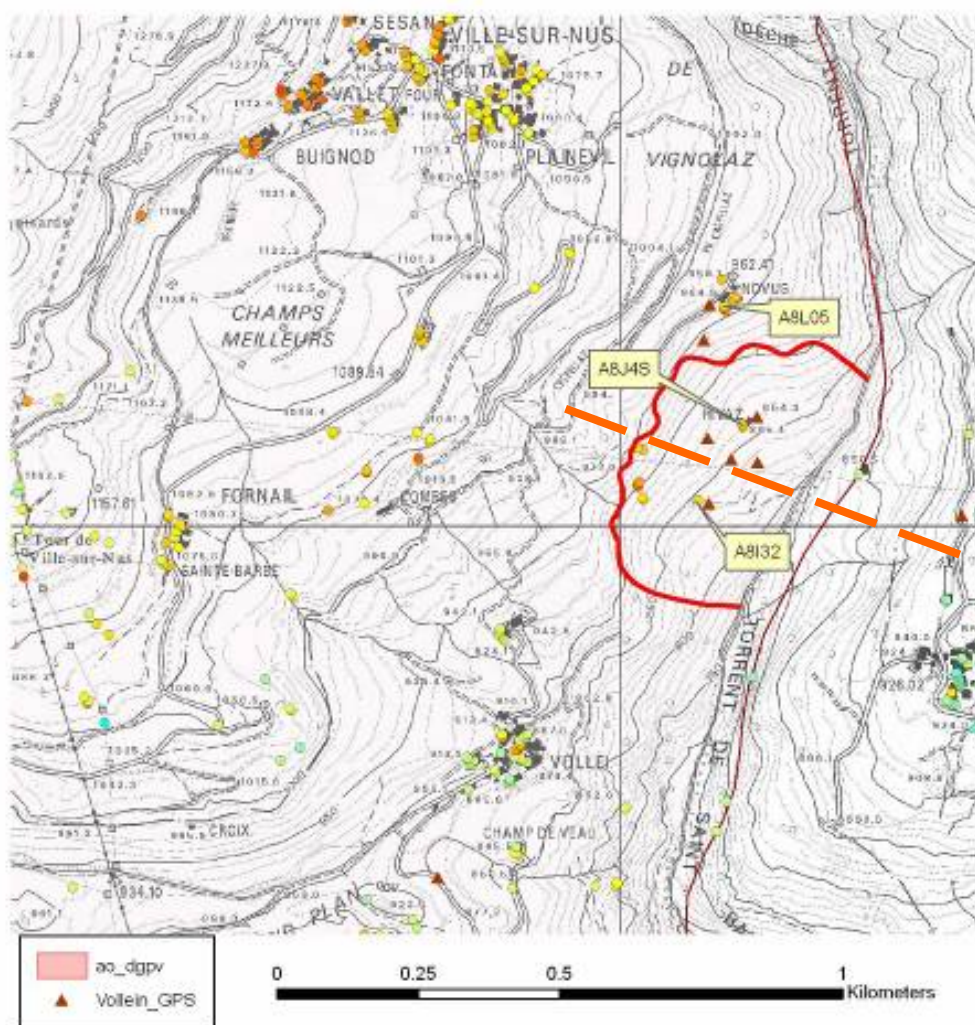


ascendenti

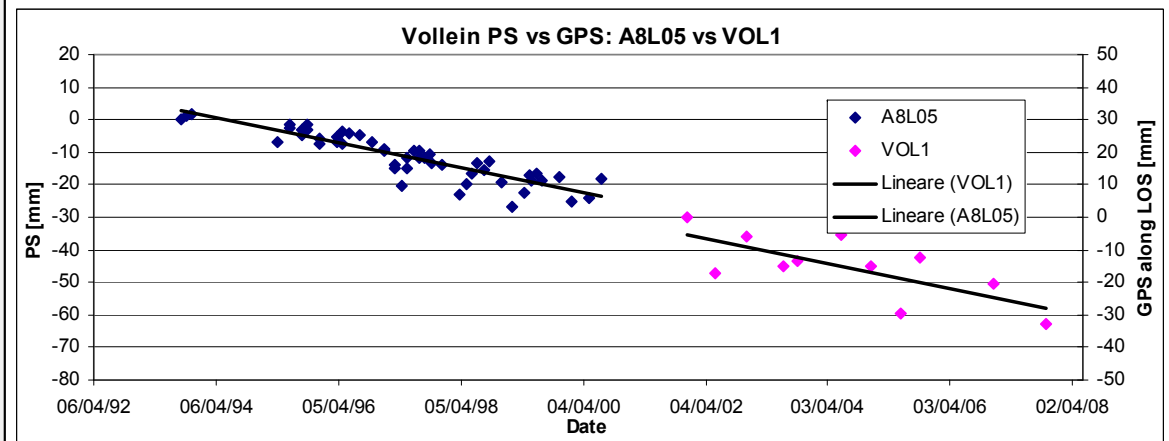
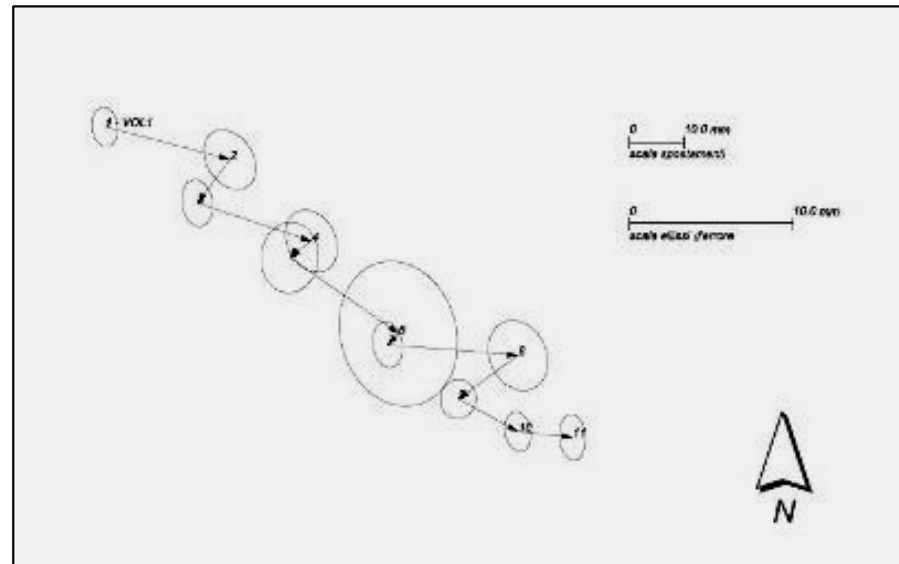
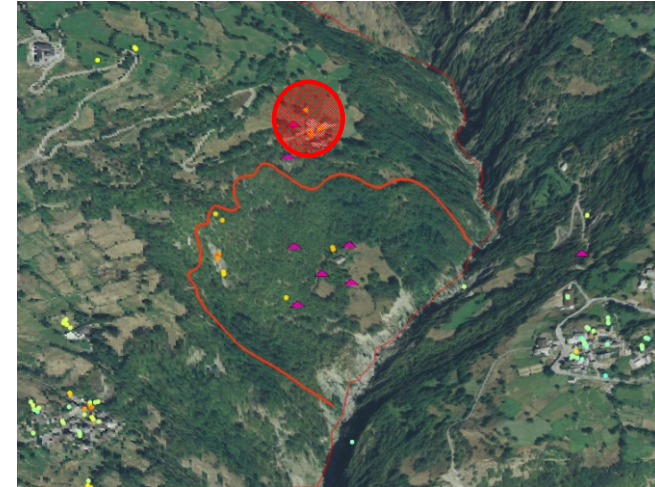
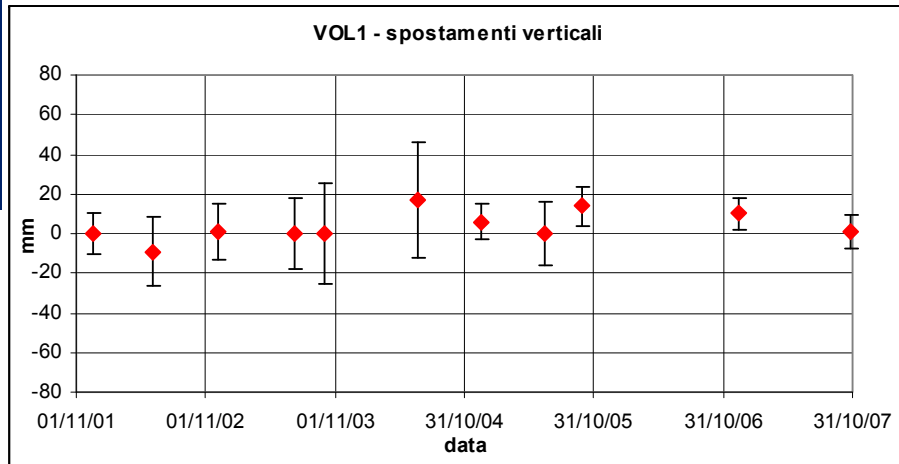


Case history 1: dati PS (dettaglio)



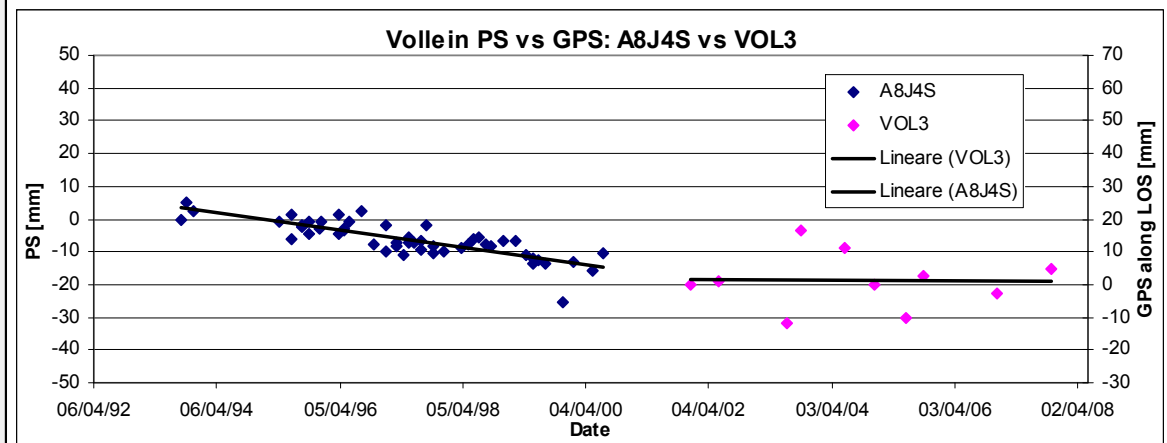
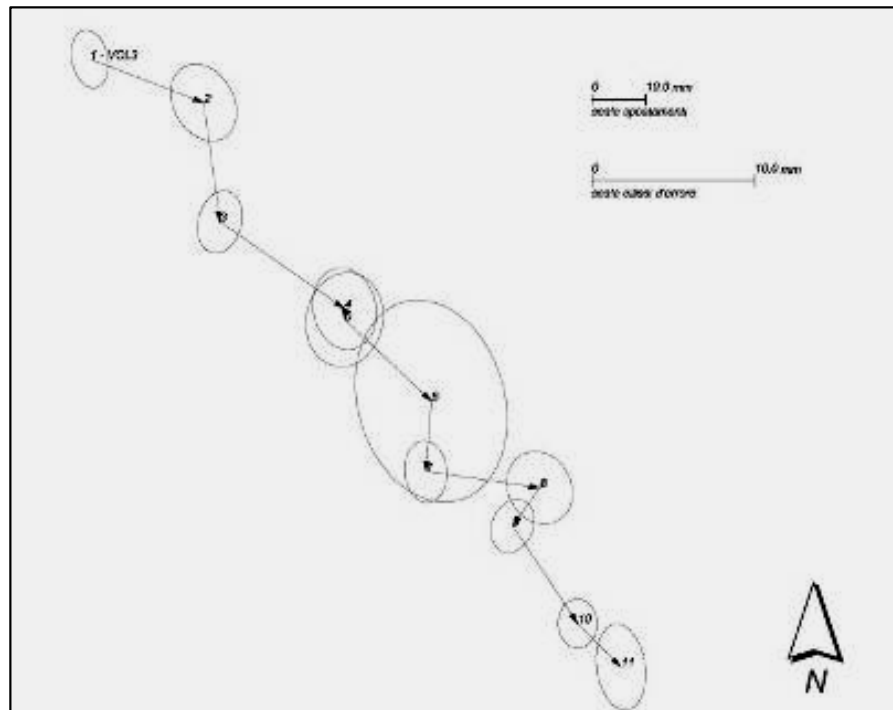
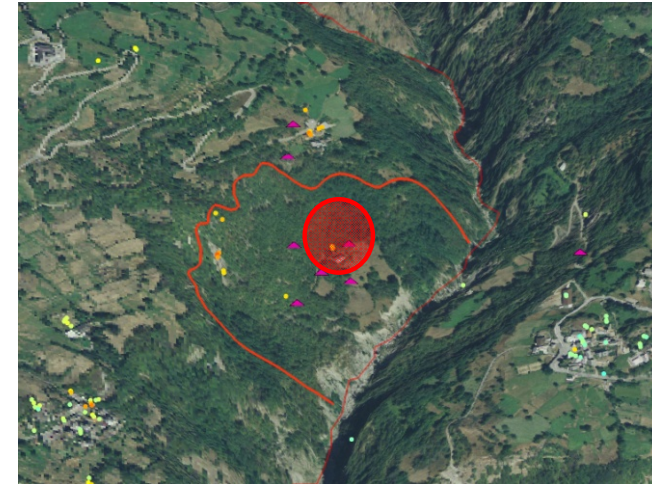
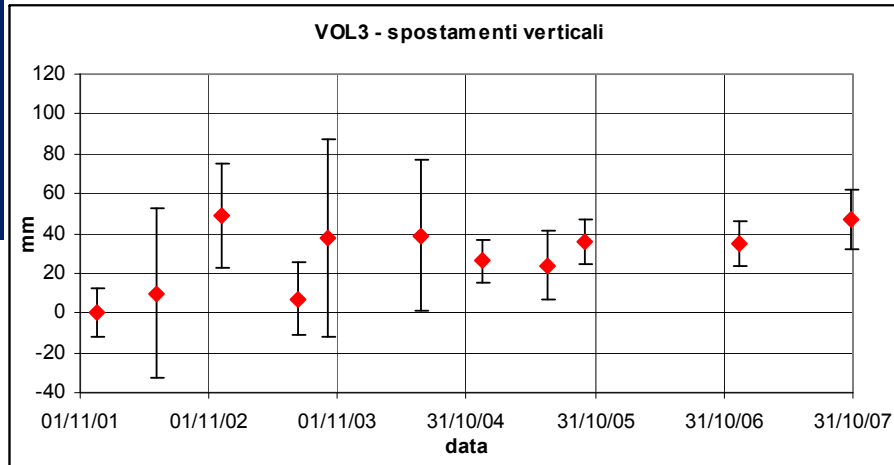


Case history 1: GPS vs PS /1



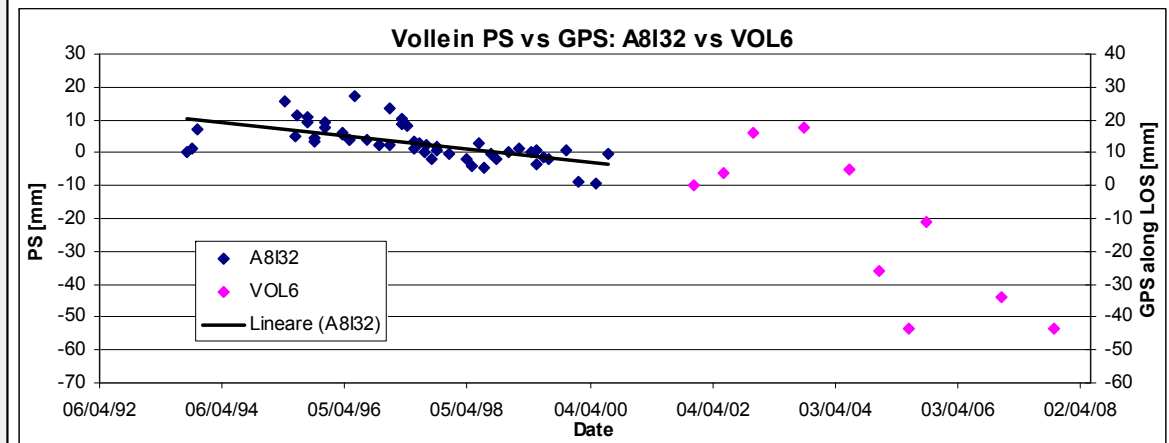
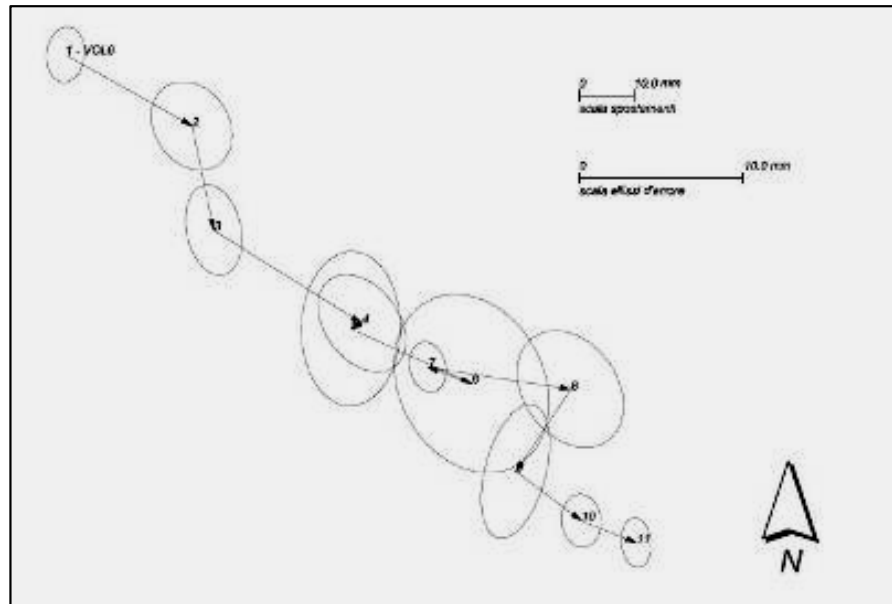
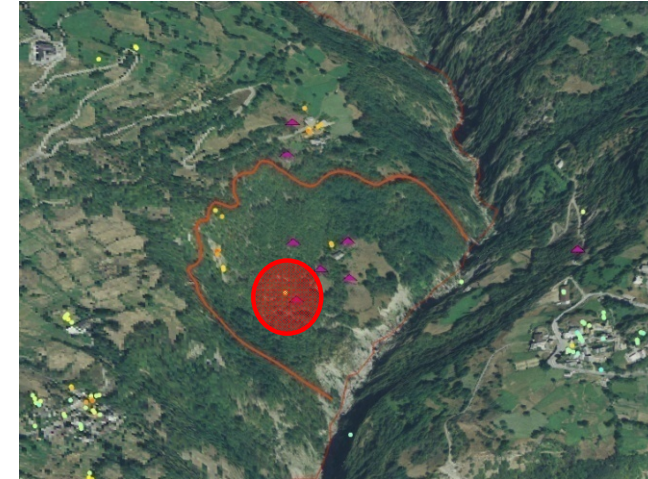
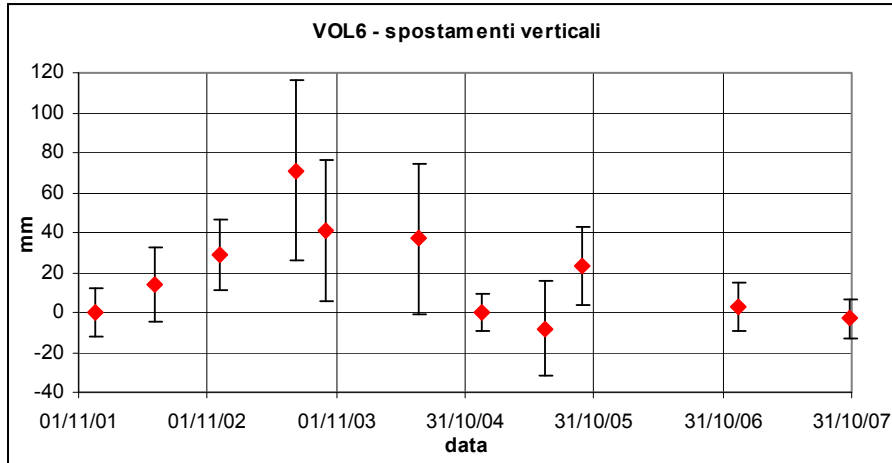
PS time history **GPS projected along LOS**

Case history 1: GPS vs PS /2



PS time history **GPS projected along LOS**

Case history 1: GPS vs PS /3



PS time history **GPS projected along LOS**

Case history 1: considerazioni di sintesi

- La frana, riattivata durante l'evento meteo dell'ottobre 2000, è parte di un'estesa DGPV
- I dati PS consentono di caratterizzare l'evoluzione della DGPV prima dell'evento di ottobre 2000
- Alla scala della frana: il confronto tra i dati PS e le misure GPS proiettate lungo la LOS indicano un incremento della velocità di spostamento dopo la riattivazione di ottobre 2000
- Alla scala della DGPV: il confronto tra dati PS e dati GPS proiettati lungo la LOS non indicano variazioni di velocità di spostamento della DGPV dopo l'evento dell'ottobre 2000

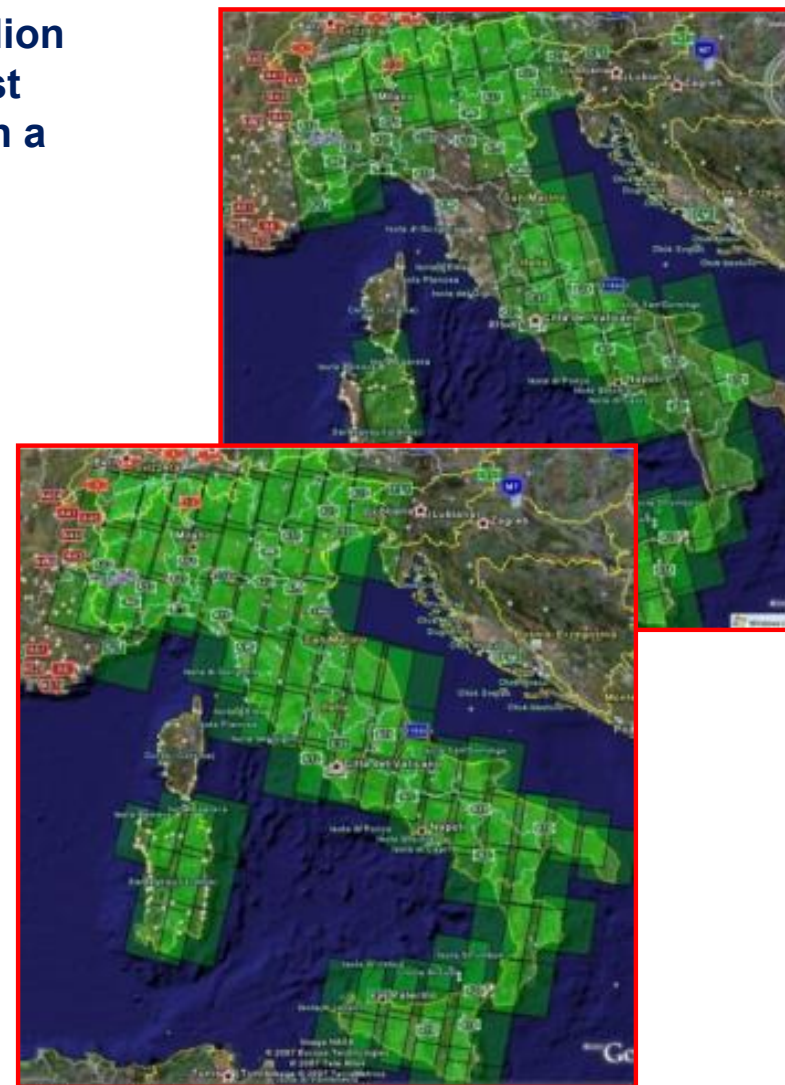
THE ITALIAN INTERFEROMETRIC DATABASE

First Interferometric Database on a National Level

The Italian Ministry of the Environment has awarded a multi-million euro contract to provide the Italian Government with the first interferometric database for surface deformation analysis on a national level.

- > 300,000 sqkm
- > 12,000 ESA data (1992-2001)
- > 24-month project
- > 5,3 M€

TRE will be in charge of the processing of the whole satellite archive acquired over Italy by the ESA-ERS sensors between 1992 and January 2001 (~10,000 radar scenes).

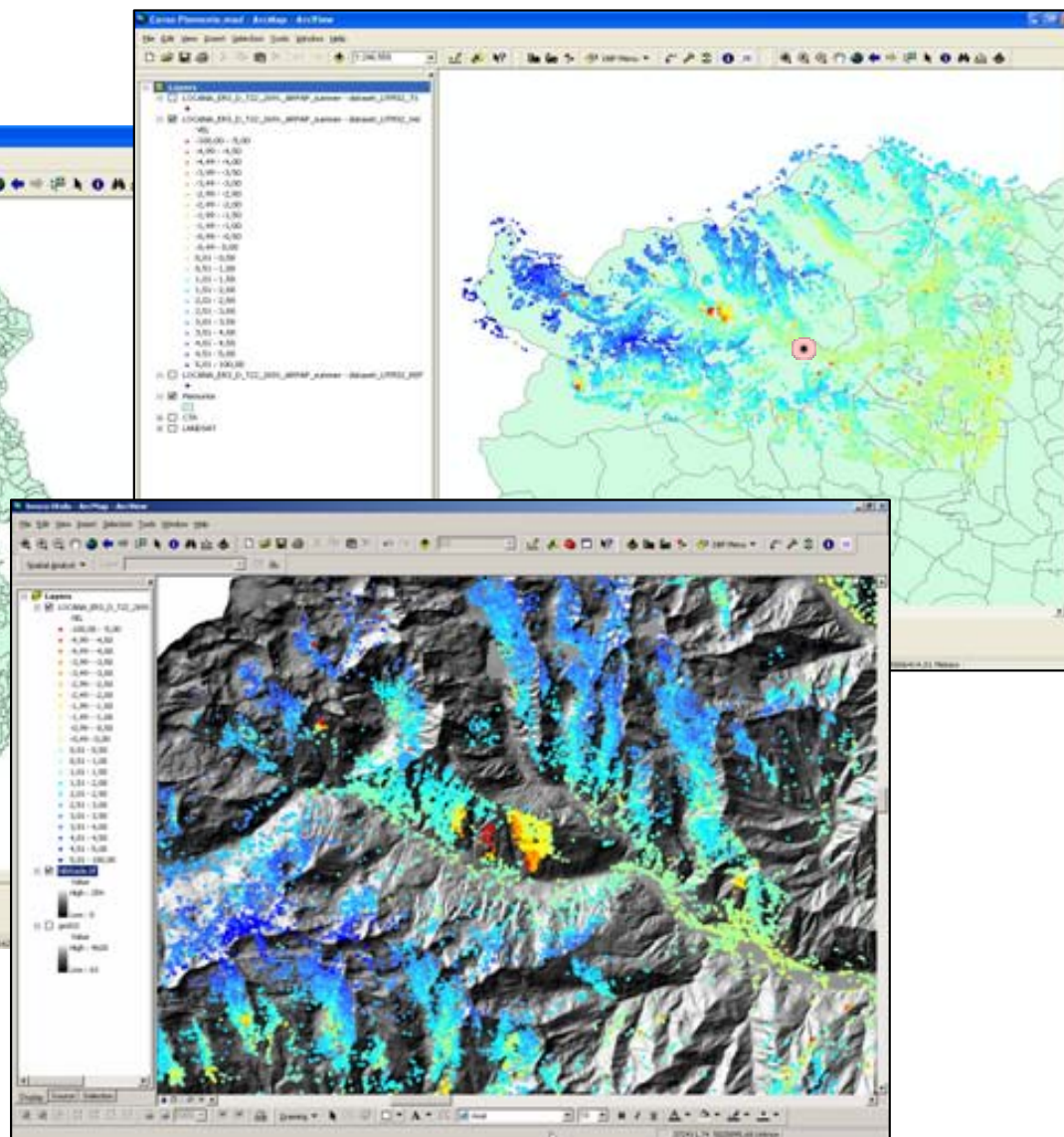
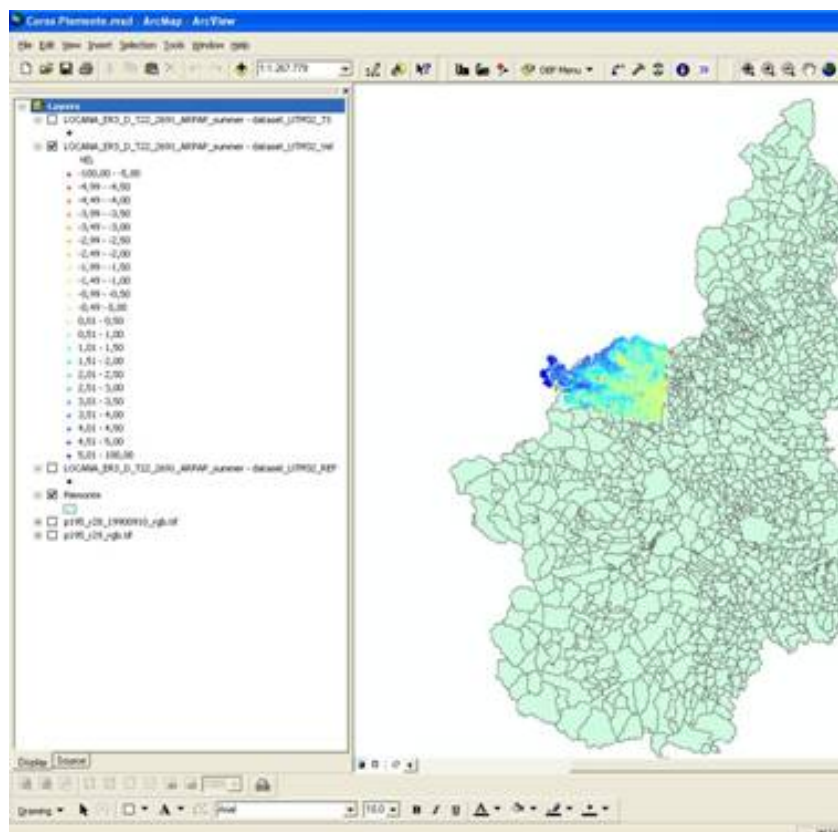




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OUTLOOK and FUTURE DEVELOPMENT

Permanent Scatterers: easy-to-use data



Geographic Information System

Data delivered – dbf file

	A	B	C	D	E	F	G	H	I	J	AH	AI
1	CODE	LAT	LON	V_STDEV	COHERENCE	VEL	D2003040	D2003050	D2003052	D2003061	D2005032	D2005040
2	A4XNS	43,9615964	11,0486399	1,29	0,76	0,82	2,25	-1,27	-5,72	-1,64	0,00	-9,8
3	A4XBX	43,9598439	11,0502158	1,25	0,92	0,29	1,05	0,76	-0,39	-2,18	0,00	-0,7
4	A4RKQ	43,9292916	11,0534296	1,26	0,94	-1,05	4,22	6,41	2,72	-0,65	0,00	-0,2
5	A4X18	43,9651565	11,0539591	1,28	0,92	-0,10	0,69	1,51	-0,62	0,99	0,00	-0,4
6	A4XVZ	43,9639921	11,0536339	1,29	0,81	0,87	0,27	-2,95	-1,06	-1,35	0,00	3,8
7	A4R62	43,9361723	11,0539562	1,21	0,94	1,18	-4,04	0,04	-2,85	-2,23	0,00	0,2
8	A4R7S	43,9364081	11,0540412	1,21	0,94	0,78	-2,49	0,97	-1,36	-0,68	0,00	1,7
9	A4Q20	43,9267158	11,0551989	1,31	0,77	-0,69	2,85	-1,07	2,81	-3,87	0,00	-0,7
10	A4O96	43,9172880	11,0550548	1,27	0,93	-0,07	-2,12	-0,93	0,04	2,76	0,00	0,2
11	A4O6S	43,9168003	11,0550909	1,29	0,84	-0,79	1,86	0,54	2,90	0,76	0,00	-0,4

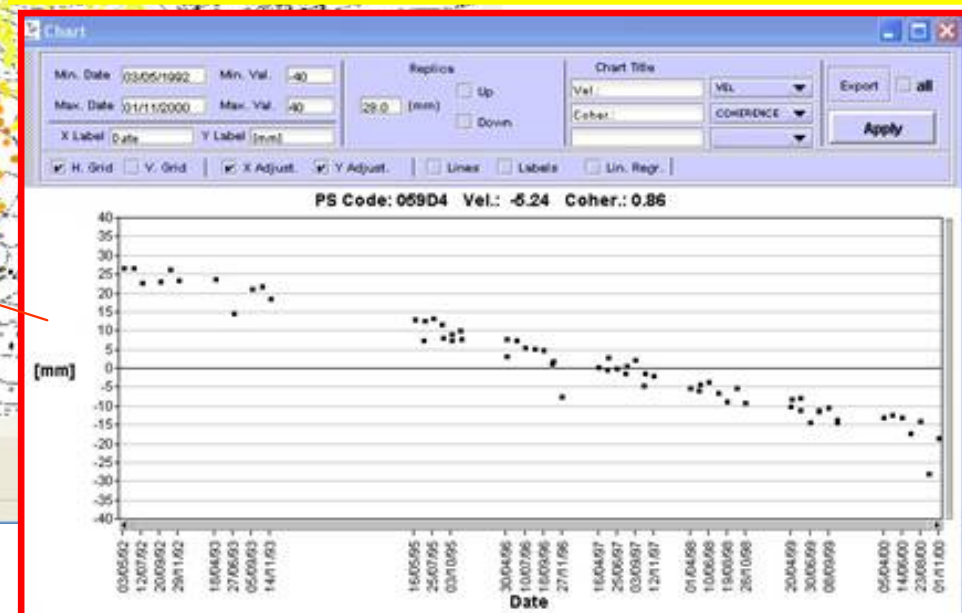
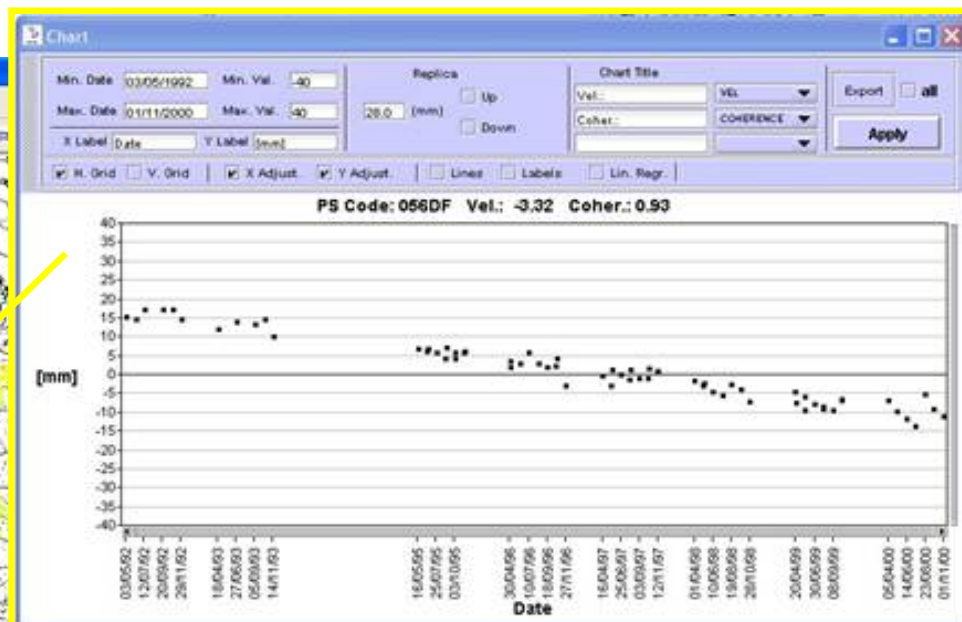
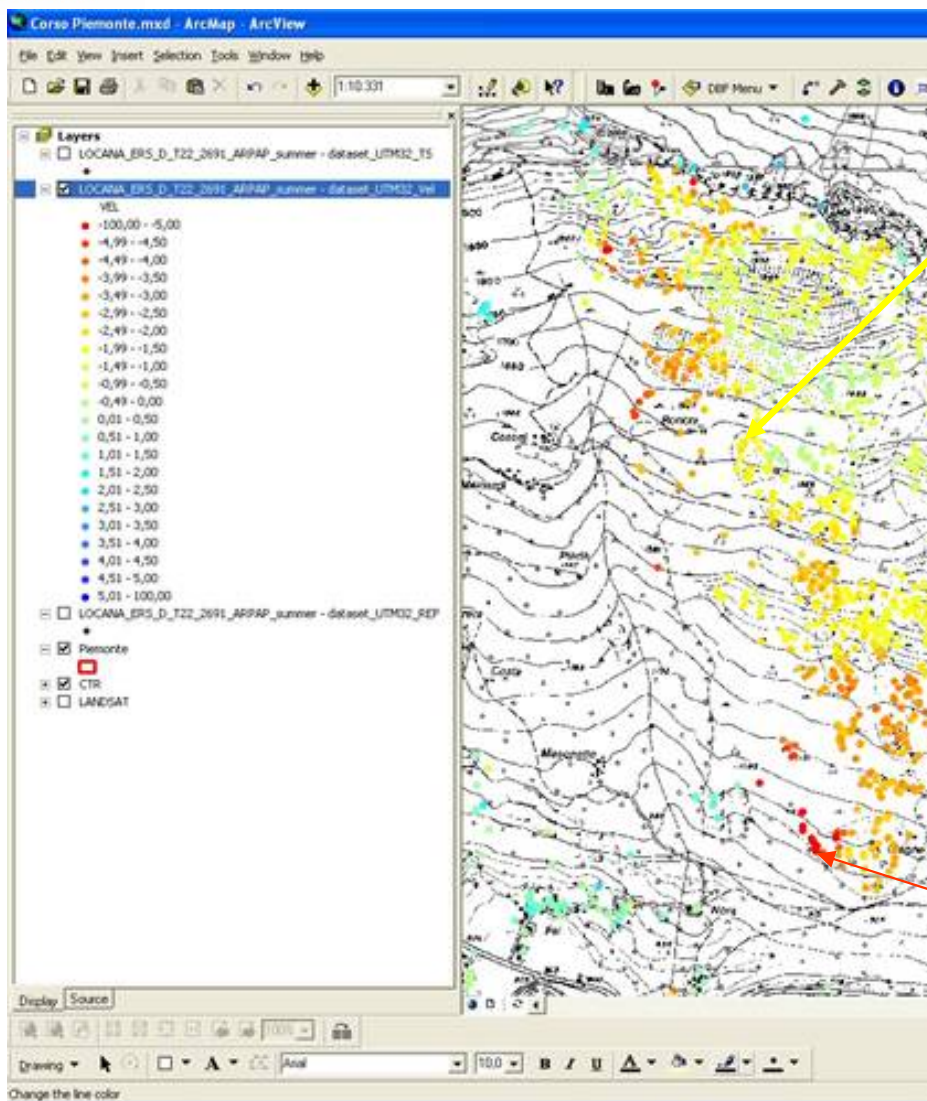
- Code:** PS identification code
- Lat:** PS latitude (elipsoide WGS 84)
- Lon:** PS longitude (elipsoide WGS 84)
- Vel:** PS average velocity in mm/year (with respect to the reference point) (REF)
- V_Stdev:** estimated velocity standard deviation with respect to to the reference point
- Coherence:** quality mesure (between 0 and 1)
- Daaaammgg:** displacement values of successive acquisitions [mm] related to each PS



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Time Series Selection and Visualization in GIS



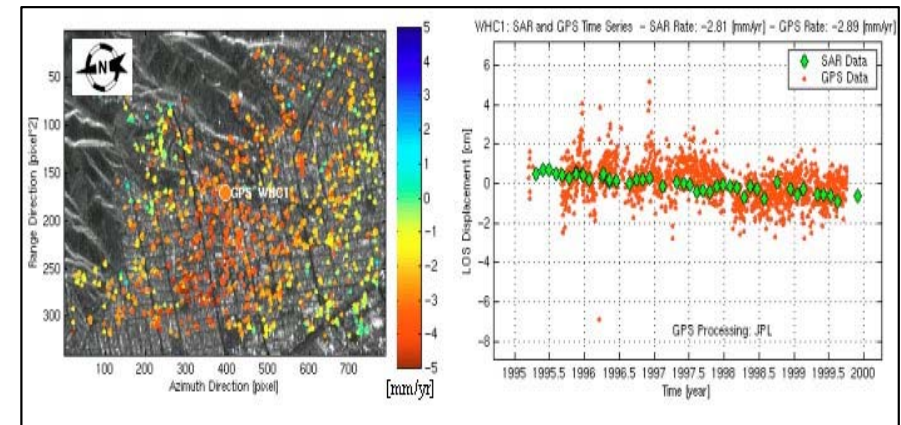
Comparing PSInSAR™ with traditional techniques

PSInSAR™ technique is **complementary with other traditional methods** used for the reconstruction of a fully 3D deformation field:

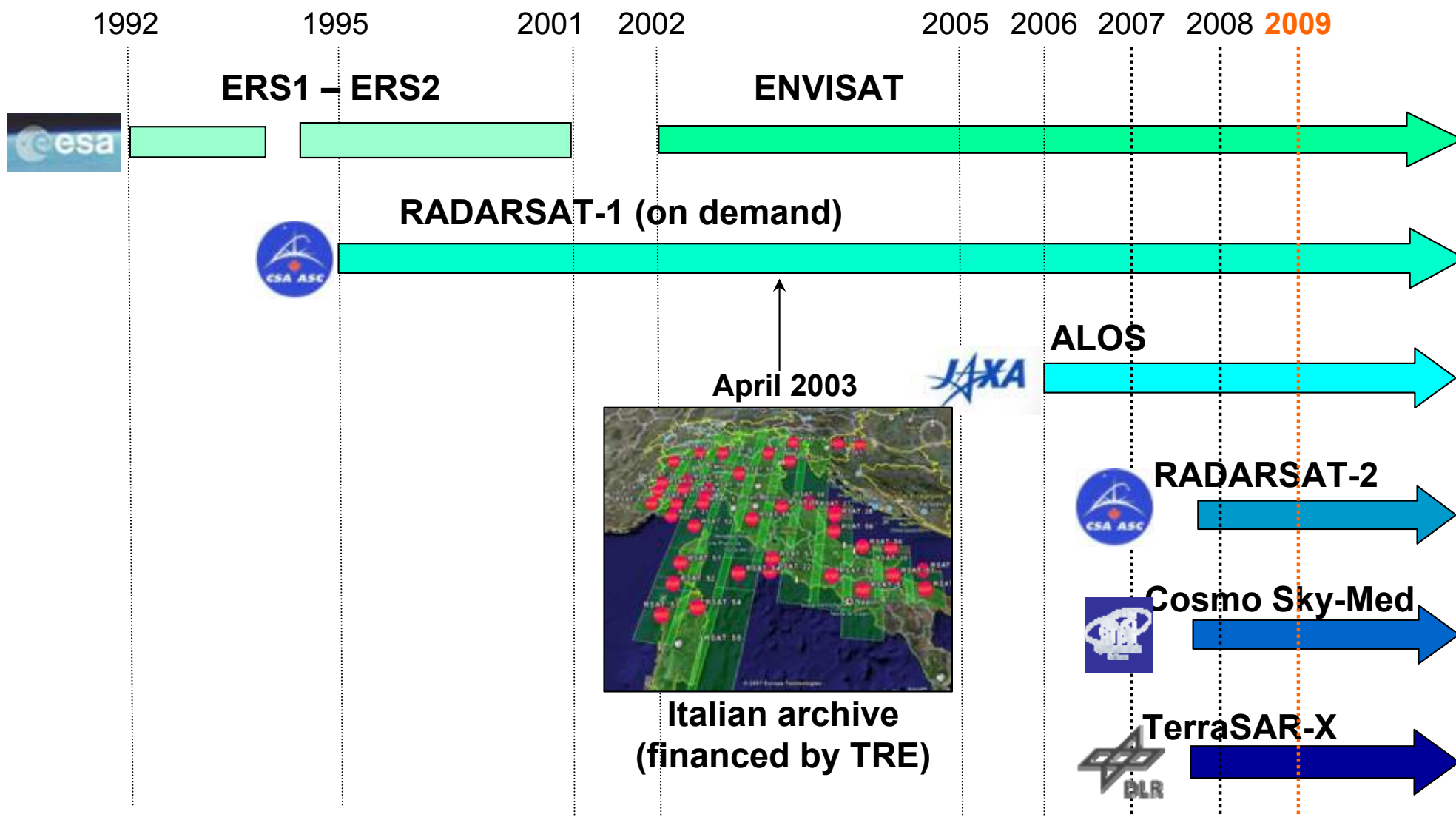
- Valuable help for **appropriate location** of GPS stations
- **Systematic errors** can be removed using permanent GPS
- **Different spatial sampling**



The **accuracy of PS measurements** has been proven by means of comparison with optical levelling, thermal expansion and GPS

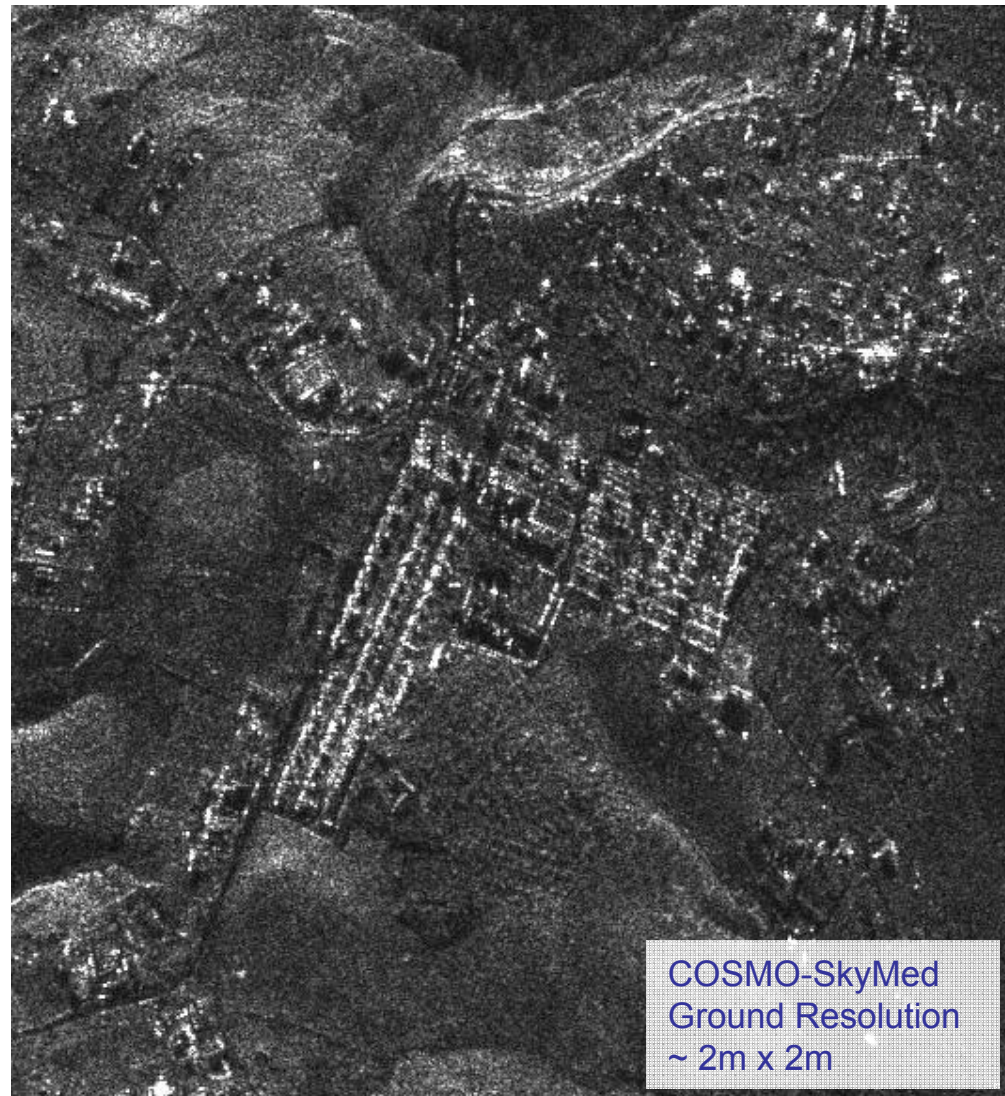
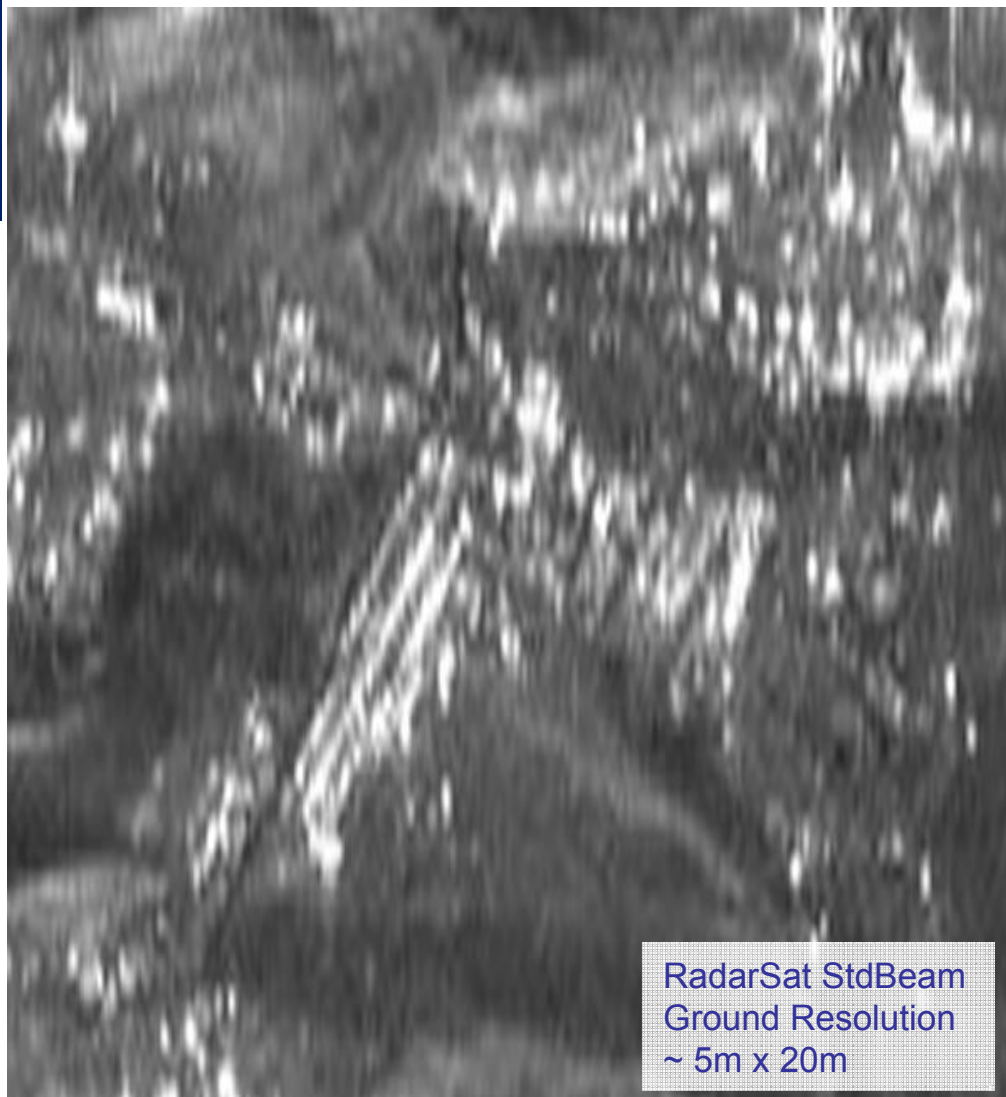


Radar Satellites – Today and tomorrow



High Resolution radar images

HR data vs. “standard” C-band images



Cosmo-SkyMed high resolution images



High-Resolution X-Band TerraSAR data

Venice – PS Position



Venice – Santa Maria della Salute

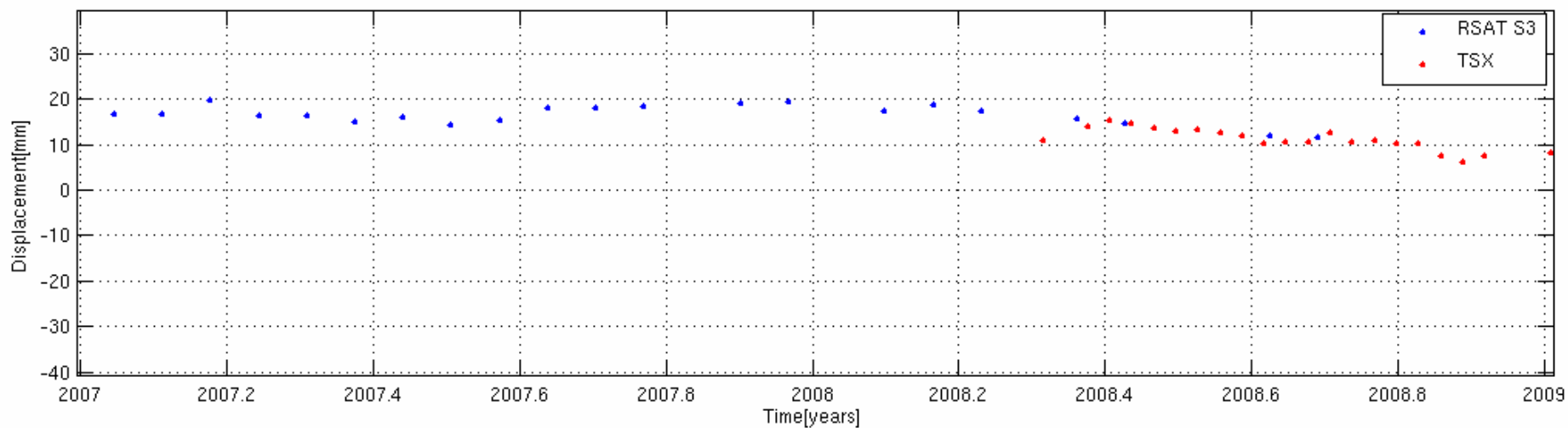
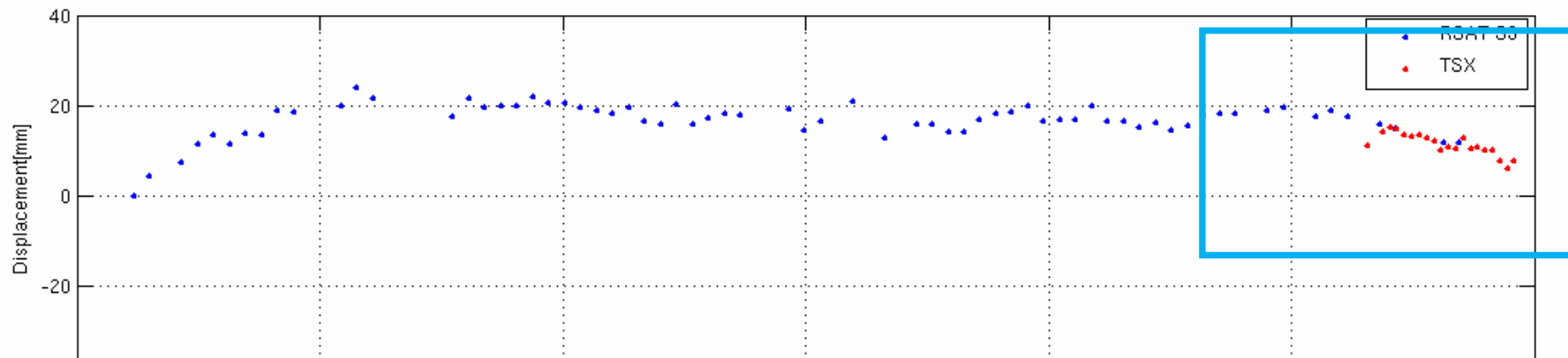
PS HEIGHT [m]



PS VEL [mm/year]



PS Time Series: an example



Conclusions

- **PSInSARTM advantages:**
 - high precision;
 - quantitative and reliable data;
 - fast data processing;
 - regular updates;
 - cost-effective.
- **Historical archives** of radar data can be extremely valuable
- **PSInSARTM** overcomes most of the limitations related to conventional DInSAR.
- **Limitations:** existing satellite radar data archive not available worldwide.
- In the **next future** more and more satellite data will be available and SAR measurements will become a standard monitoring tool.



Tele-Rilevamento Europa

Via Vittoria Colonna, 7
20149 Milano
Italia
www.treuropa.com

TRE Canada Inc.

#550 – 409 Granville Street
Vancouver, BC, V6C 1T2
Canada
www.trecanada.com



Prodotti PSInSAR™



Local area



Aree da 1 a 100 kmq:

- frane o sinkhole
- pianificazione urbana
- bacini di estrazione
- impianti



Regional area



Aree da 50 kmq

- fenomeni di deformazione estesi
- subsidenze
- faglie sismiche
- giacimenti, miniere



Linear Structures



Strutture lineari presenti sul territorio:

- condotte
- autostrade
- ferrovie
- Metanodotti
- linee elettriche



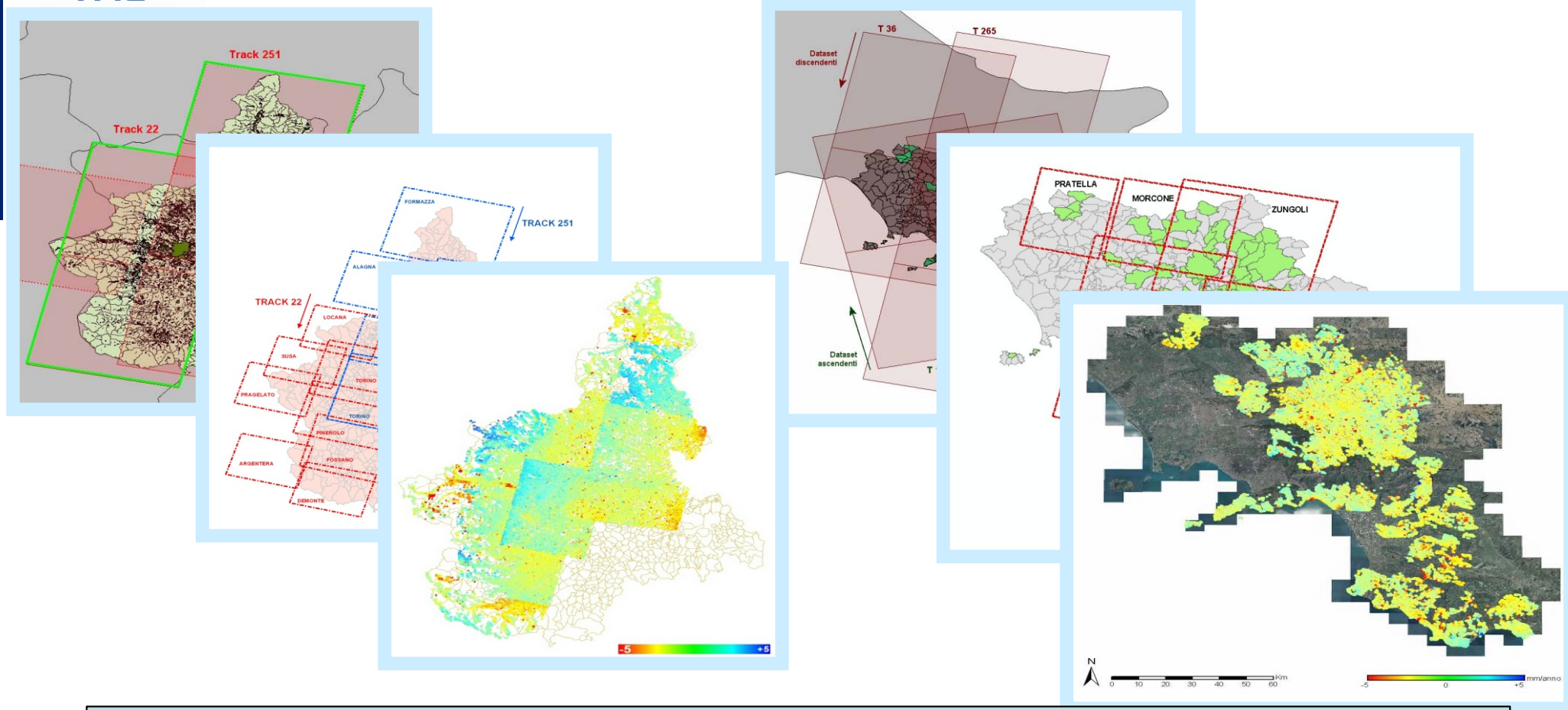
Single building



Analisi circoscritta a singoli edifici in aree urbane

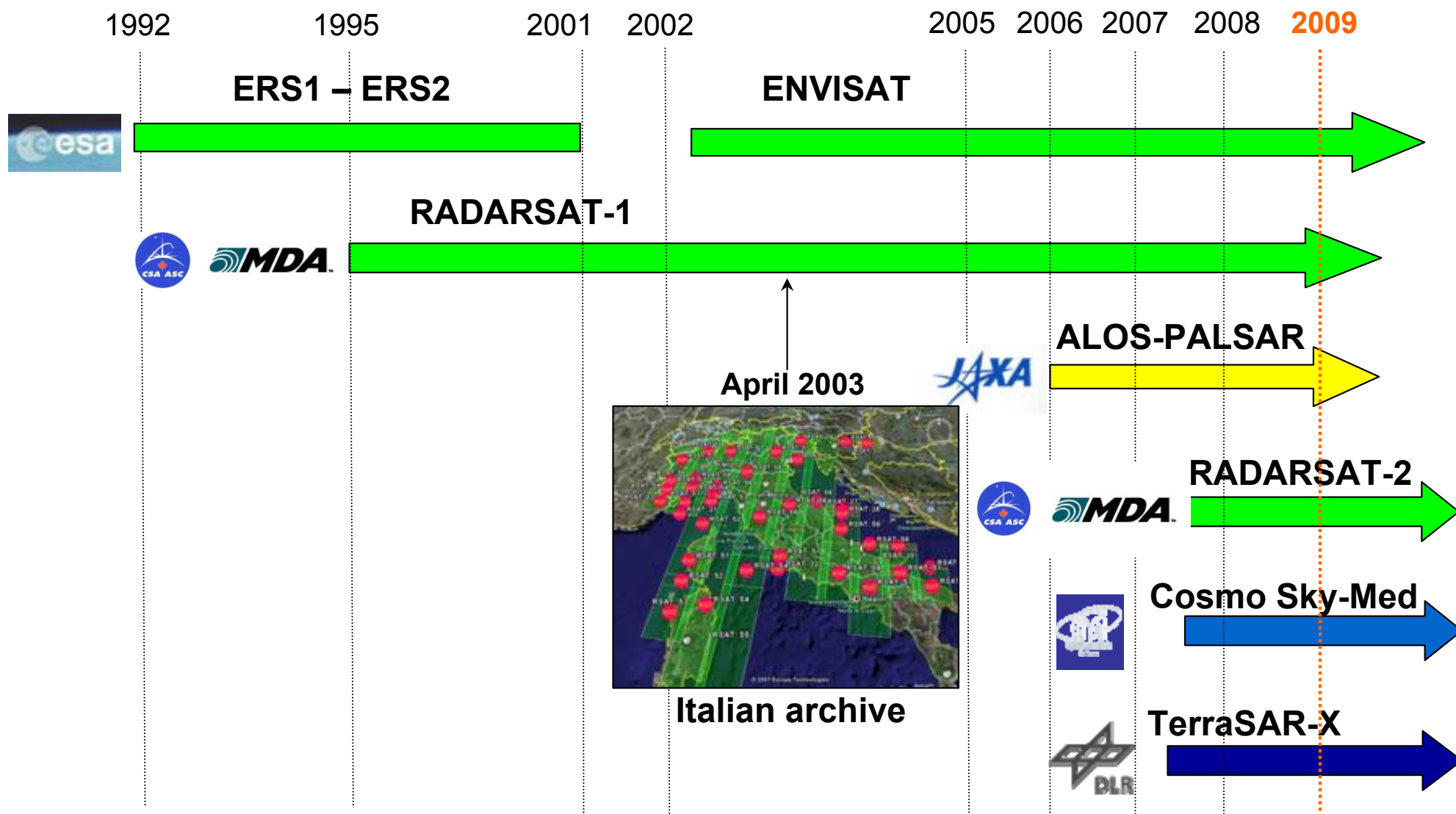
- Attualmente disponibile solo su ROMA

ELABORAZIONE MULTI DATASET



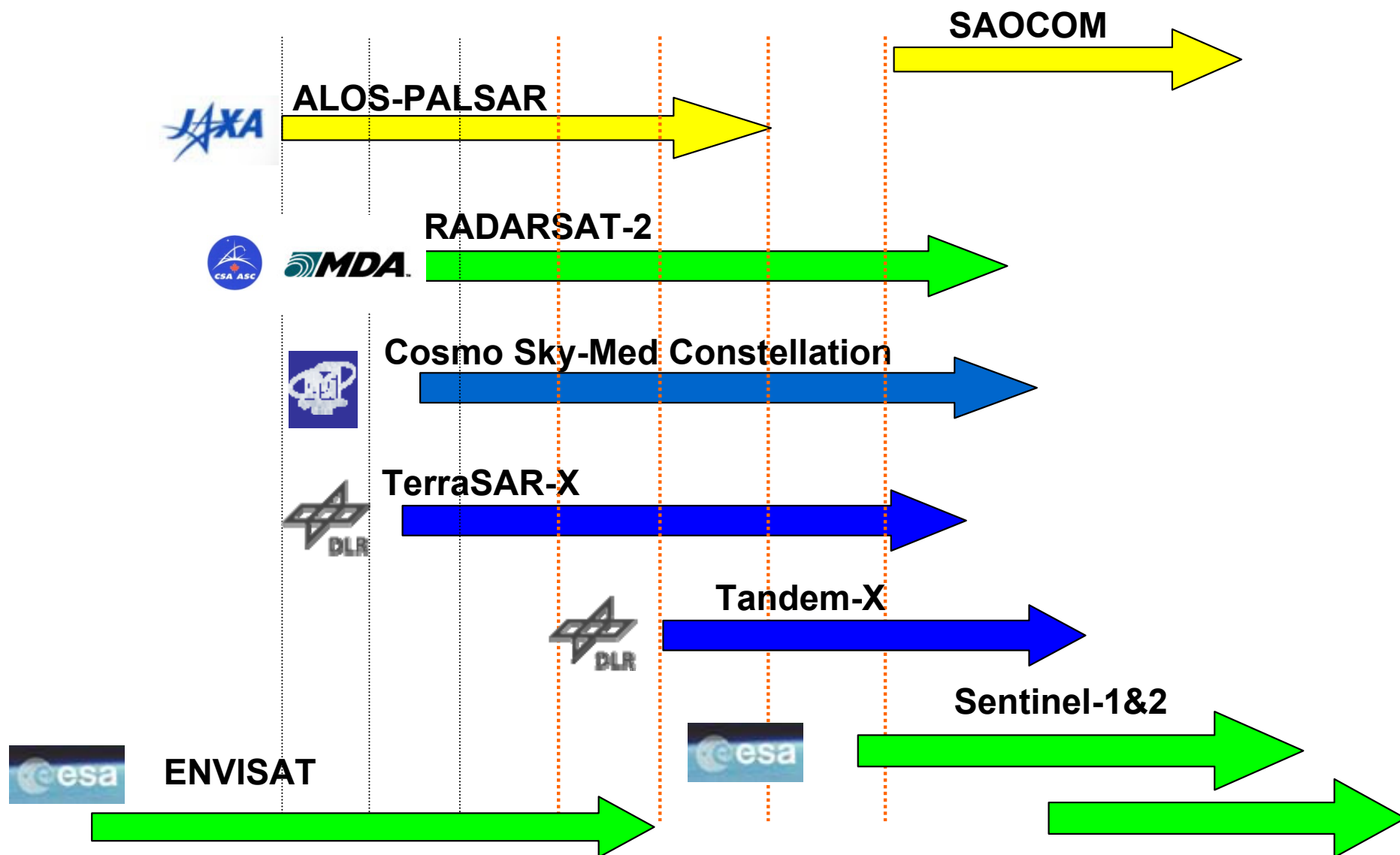
- Individuazione Track/Frame
- Elaborazione per Siti
- Risultato PS

Satellite radar systems available

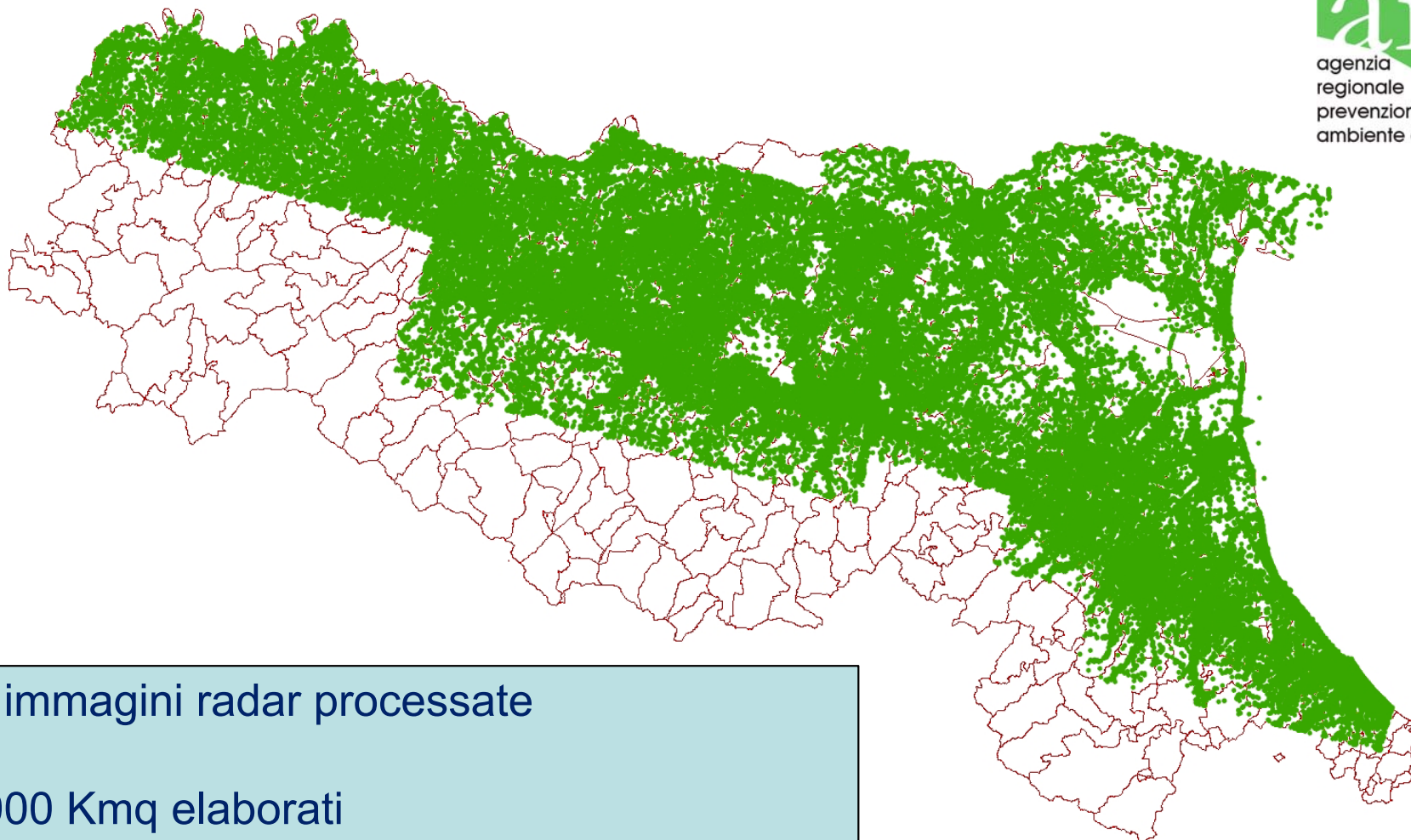


A look at the future

2006 2007 2008 2009 2010 2011 2012



Emilia Romagna: territorio di pianura

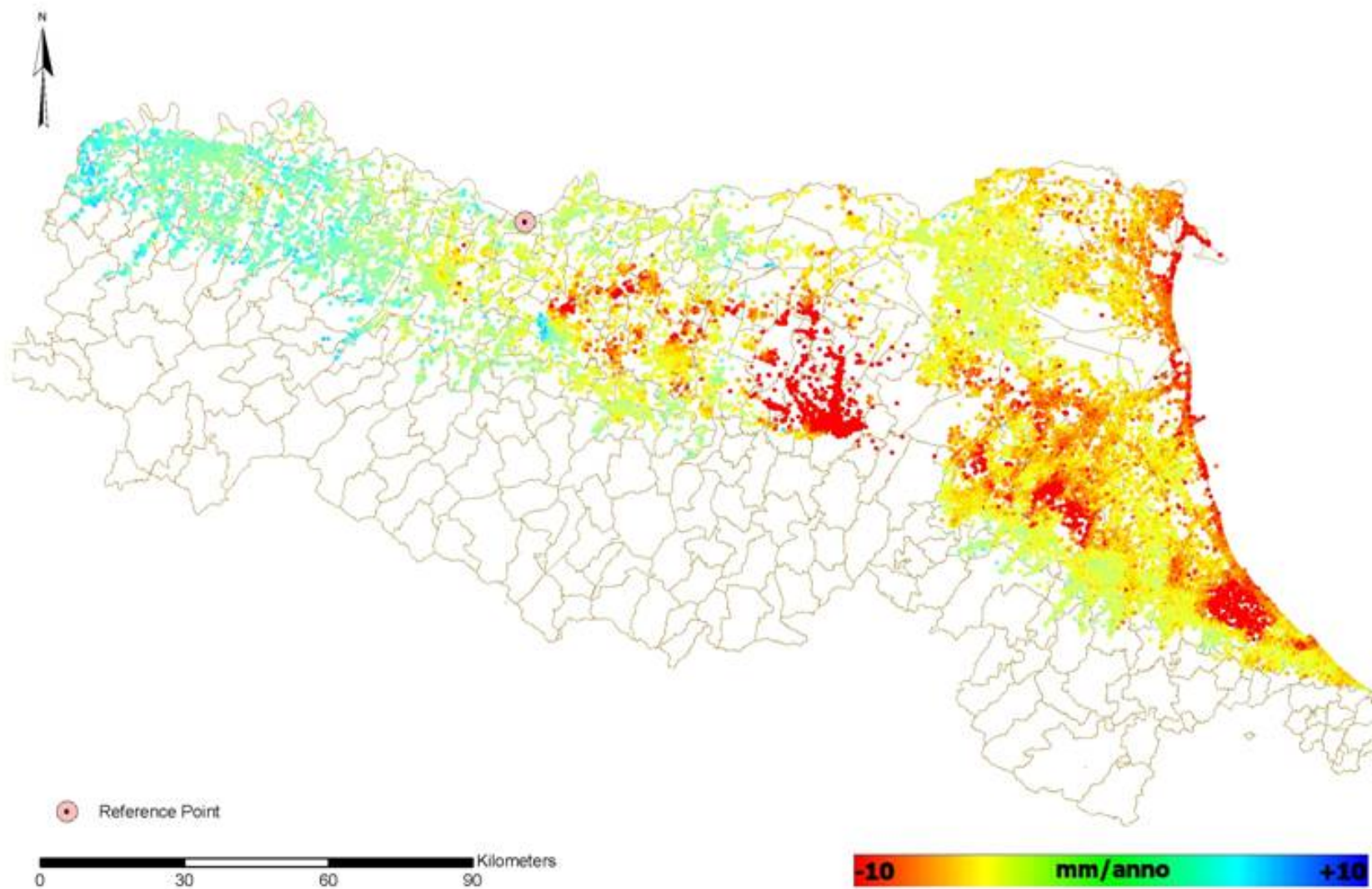


500 immagini radar processate

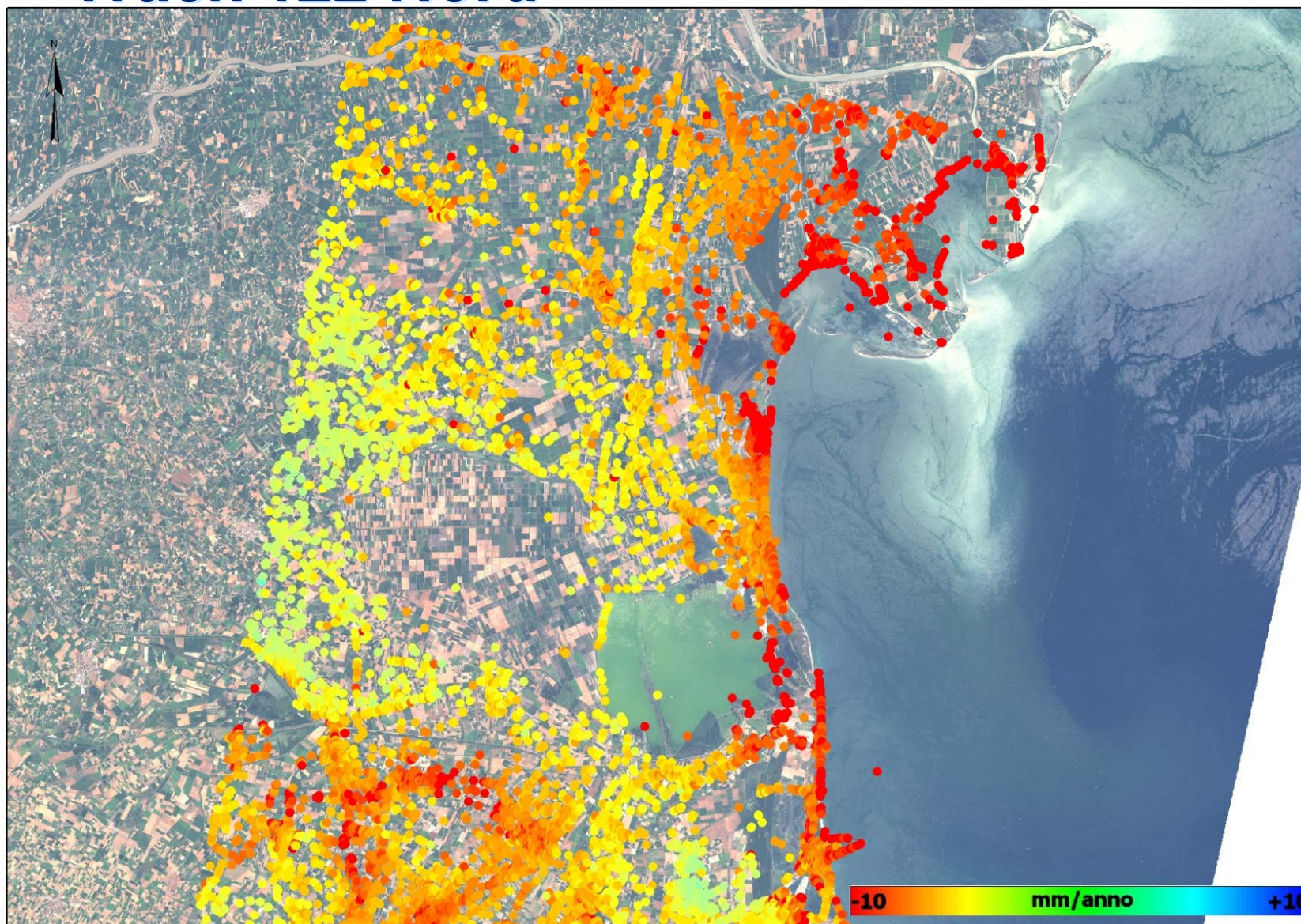
10.000 Km² elaborati

> 250.000 PS individuati (low resolution)

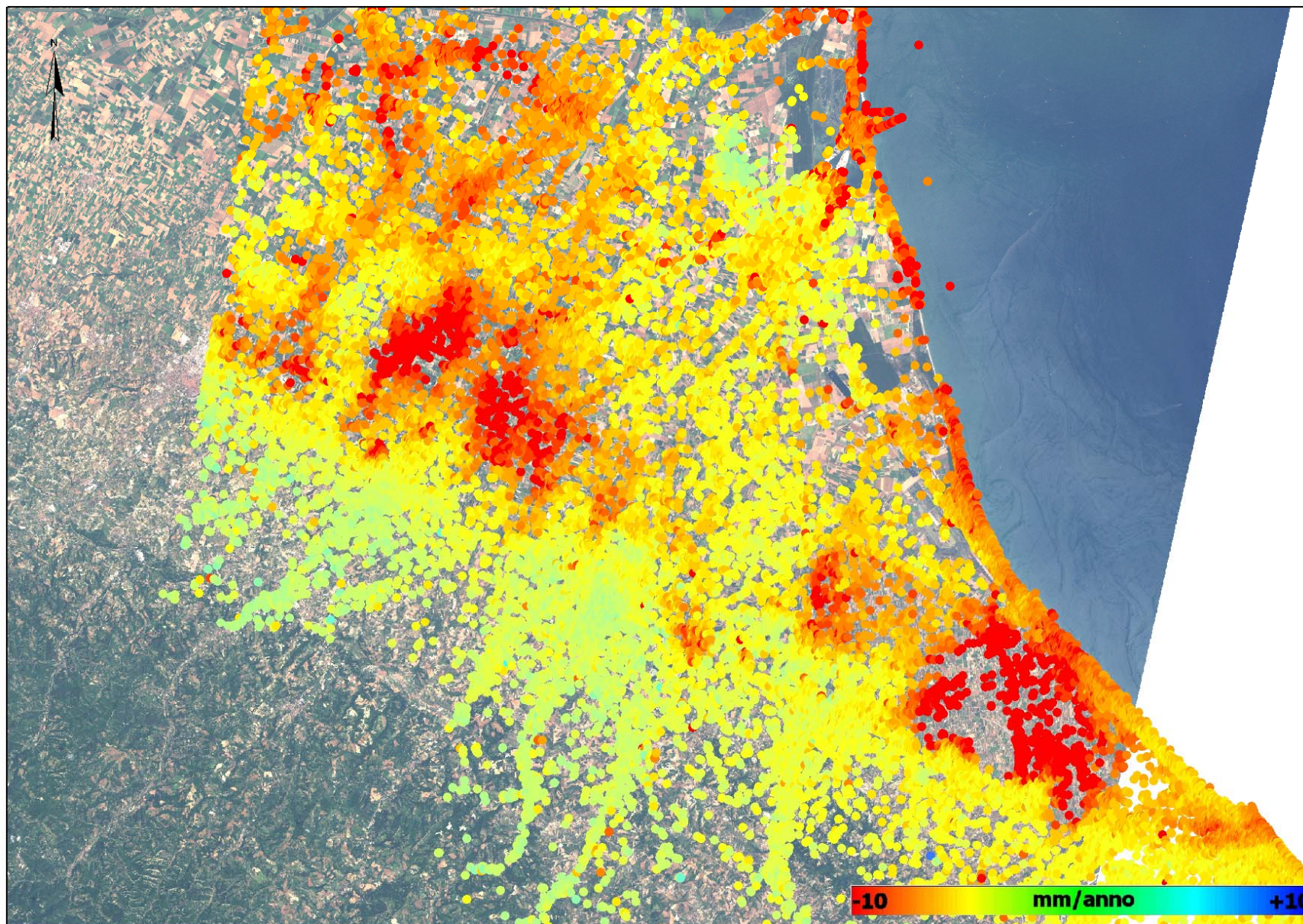
Risultati ENVISAT Discendente -2002-2006



Track 122 Nord



Track 122 SUD



Track 394

