Deformation Monitoring by means of Ground-based and Satellite SAR

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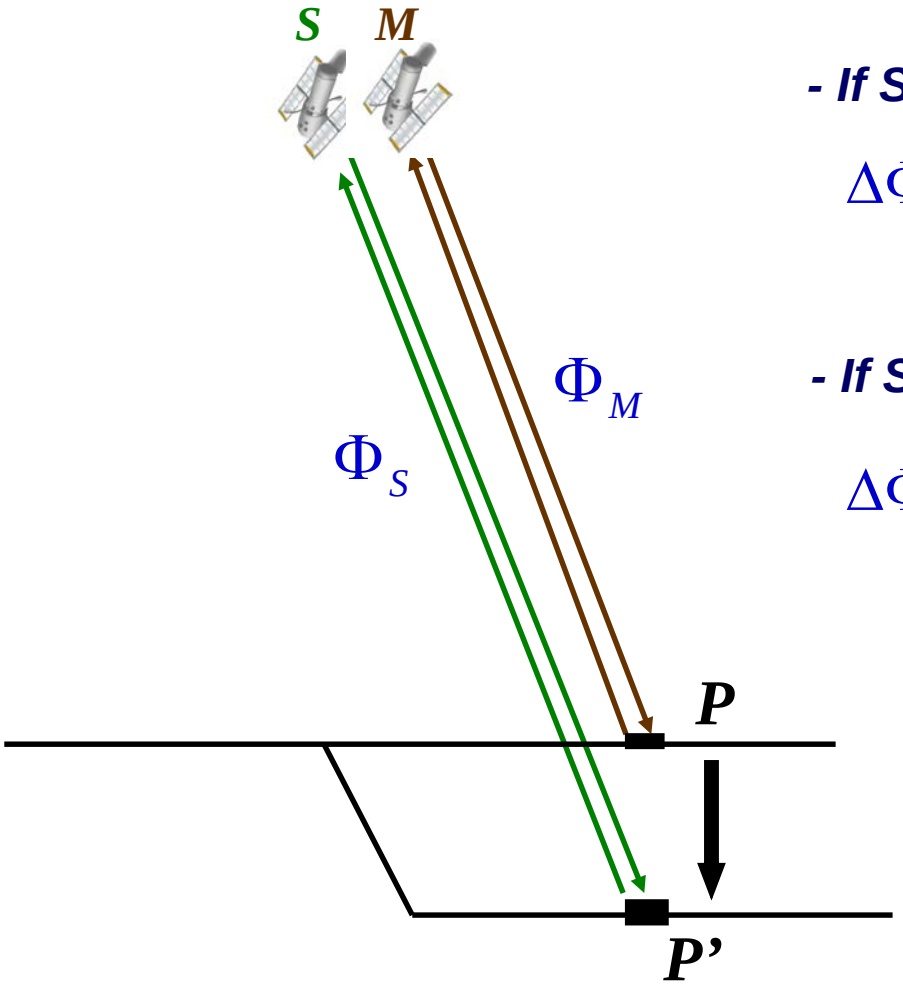
Satellite SAR interferometry
&
Persistent Scatterer Interferometry

SAR interferometry



- If $S \equiv M$:

$$\Delta\Phi_{Int} = \Phi_S - \Phi_M = \Phi_{Mov}$$

- If $S \neq M$:

$$\Delta\Phi_{Int} = \Phi_S - \Phi_M =$$

$$= \Phi_{Topo} + \Phi_{Mov} =$$

$$= \frac{SP - MP}{\frac{\lambda}{4 \cdot \pi}} + \frac{SP' - SP}{\frac{\lambda}{4 \cdot \pi}}$$

Differential SAR interferometry

- If we know the topography (DEM) we can simulate $\Phi_{Topo} \rightarrow \Phi_{Topo\_Simu}$

$$\Delta\Phi_{D-Int} = \Delta\Phi_{Int} - \Phi_{Topo\_Simu} = \Phi_{Mov}$$

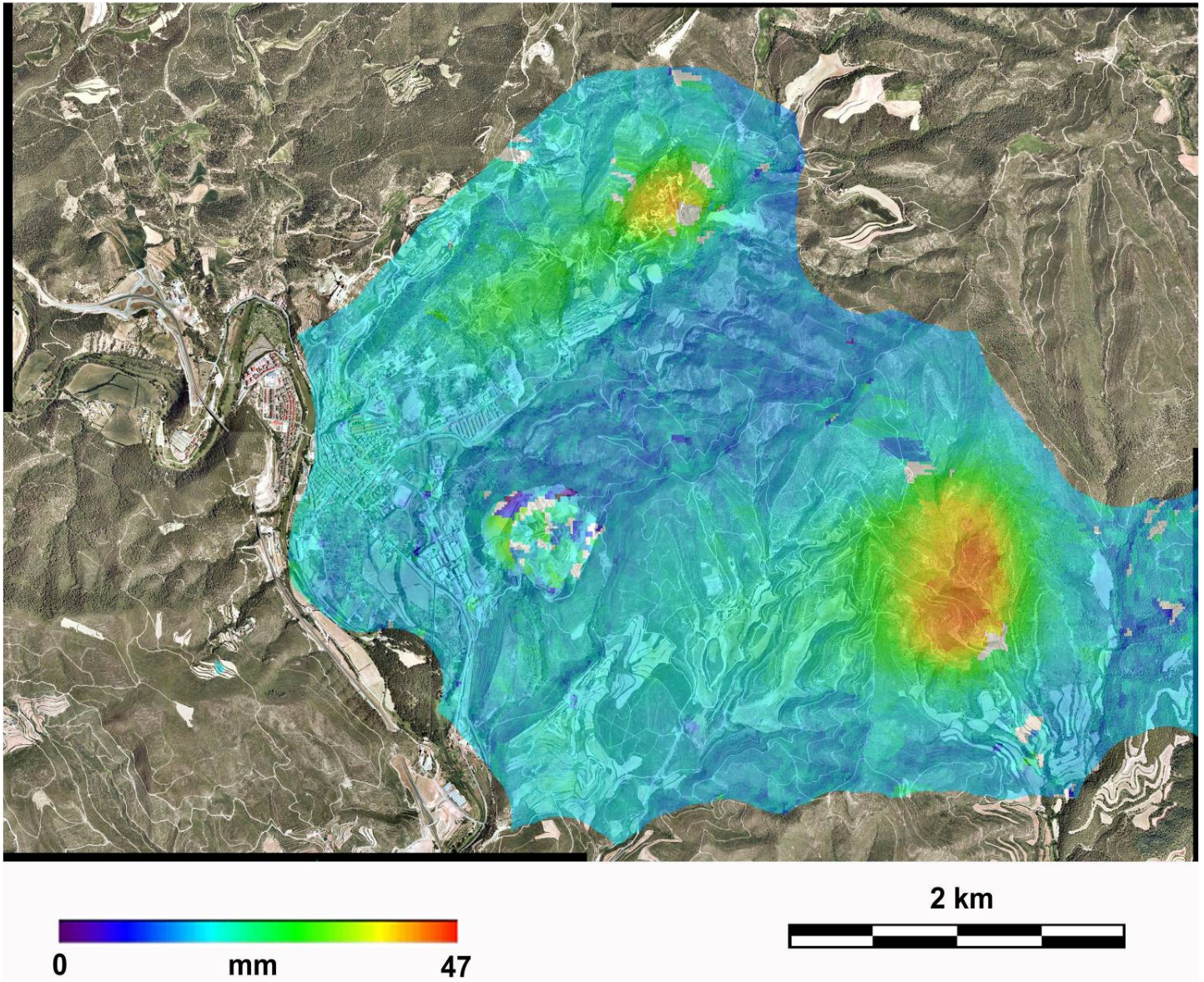
- In reality there are other components:

$$\Delta\Phi_{D-Int} = \Delta\Phi_{Int} - \Phi_{Topo\_Simu} = \Phi_{Mov} + \Phi_{Atm} + \Phi_{Res\_Topo} + \Phi_{Noise}$$

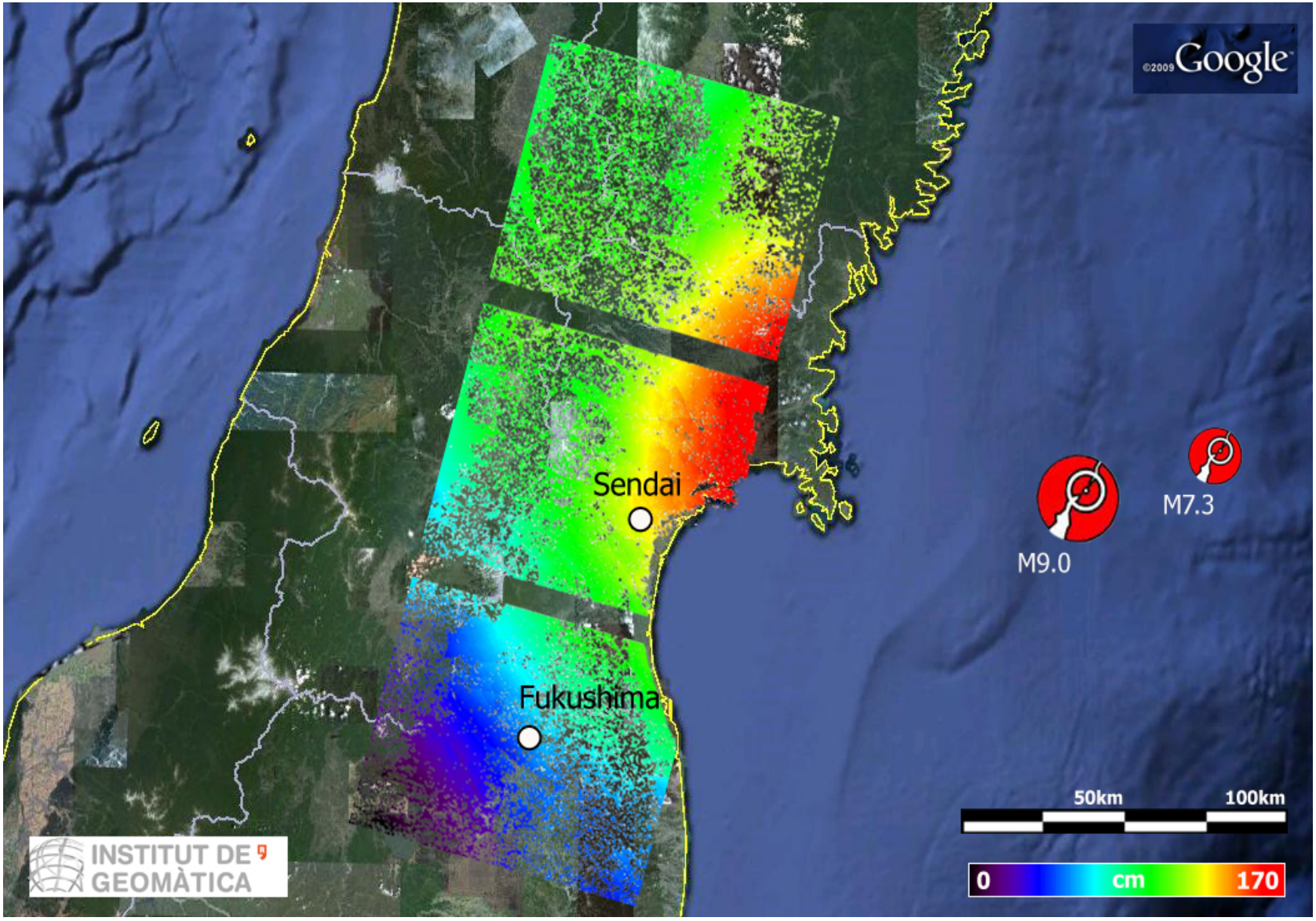
- Comments:

1. The above equation can be exploited if Φ_{Noise} is small enough
   ➔ Persistent Scatterers or coherent pixels.
2. We usually use multiple images.
3. With 2 images we get 1 interferogram, i.e. 1 observation ➔ see ex.

DInSAR: single interferogram, 35 days



DInSAR: single interferogram



Differential SAR interferometry

- Advanced Differential SAR interferometry, Persistent Scatterer Interferometry (PSI):
  1. Use multiple images
  2. Adopt estimation procedure to derive the parameters of interest

$$\Delta\Phi_{D-Int} = \Delta\Phi_{Int} - \Phi_{Topo\_Simu} = \Phi_{Mov} + \Phi_{Atm} + \Phi_{Res\_Topo} + \Phi_{Noise}$$

model model model

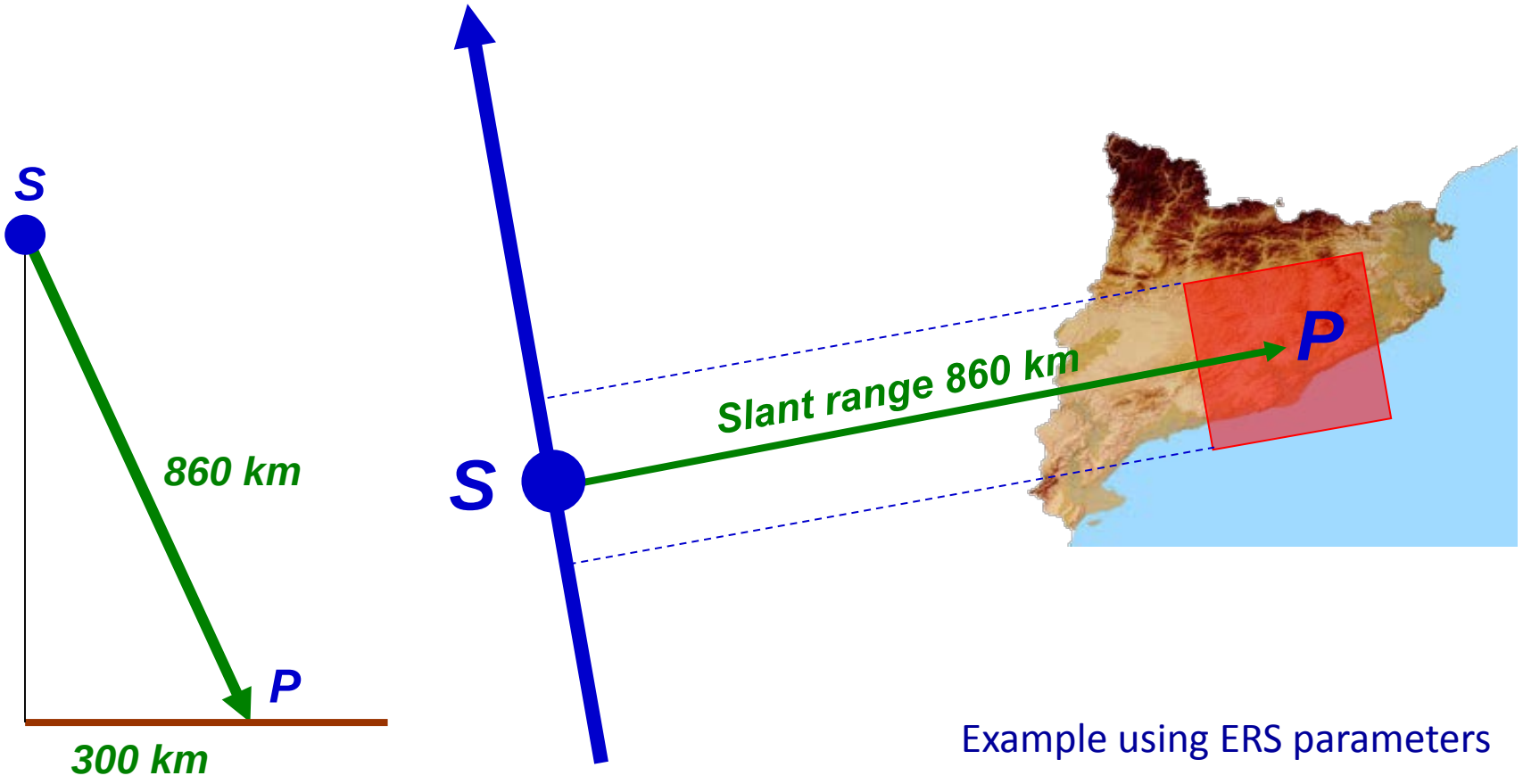
Deformation = F(t) | Atmospheric component | Residual topography

- First remark:

  The main observable $\Delta\Phi_{D-Int}$ is bounded between $\pm\pi$

Second remark

- Deformation is observed along the Line-of-Sight (LOS), which connects S and P



Example using ERS parameters

Third remark

- There is a different sensitivity of the phase with respect to topography and deformation:

  - Φ_{Topo} is a function of the baseline SM: $\Phi_{Topo} = \frac{SP - MP}{\frac{\lambda}{4 \cdot \pi}}$

  - Φ_{Mov} is independent of the baseline: $\Phi_{Mov} = \frac{SP^1 - SP}{\frac{\lambda}{4 \cdot \pi}}$

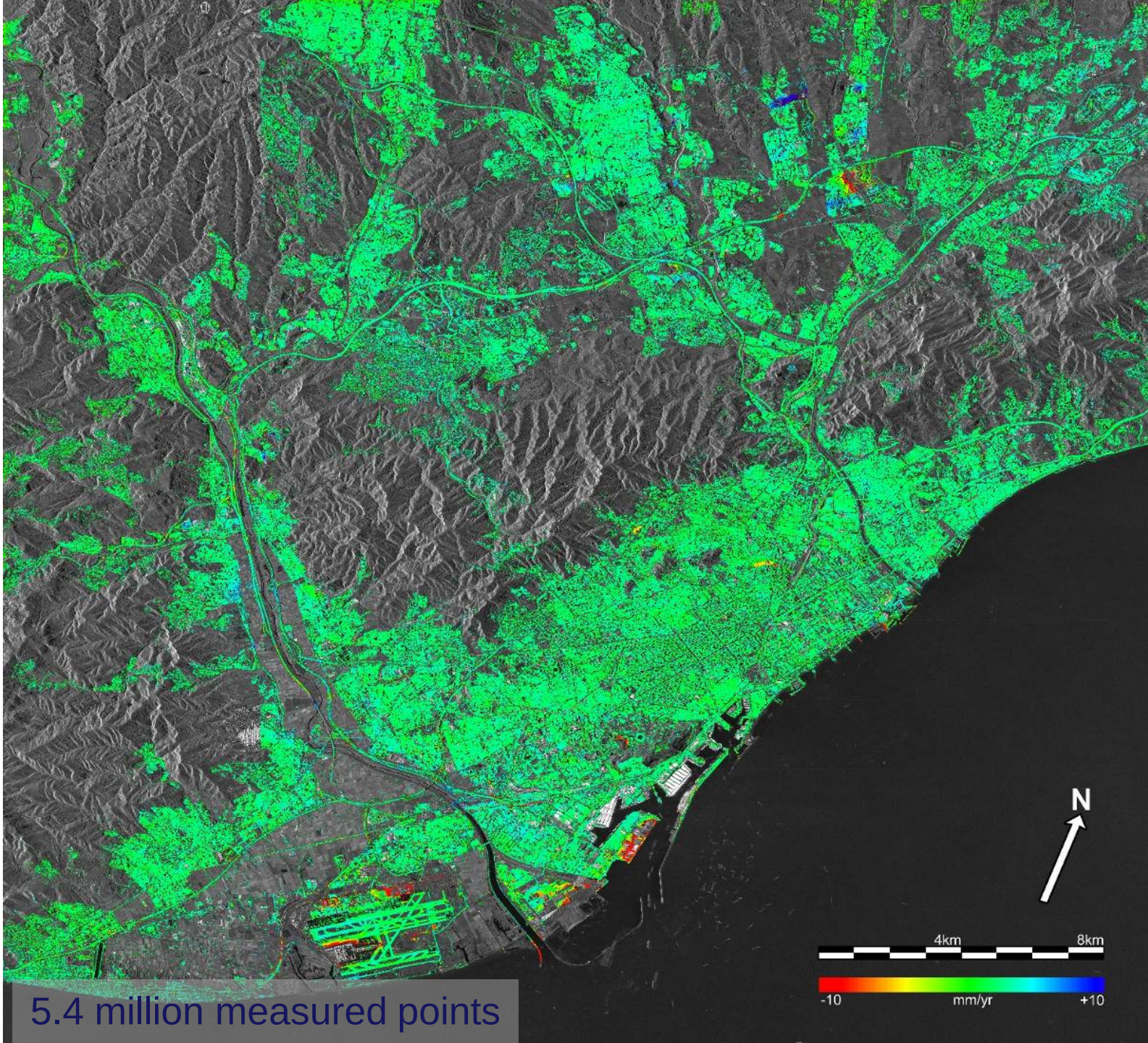
- What does it mean? With ERS:

  1 cm displacement ➔ $\Phi_{Mov} \approx 127^o$

  20 m height difference ➔ $\Phi_{Topo} \approx 43^o$ ($B_\perp$ = 50 m)

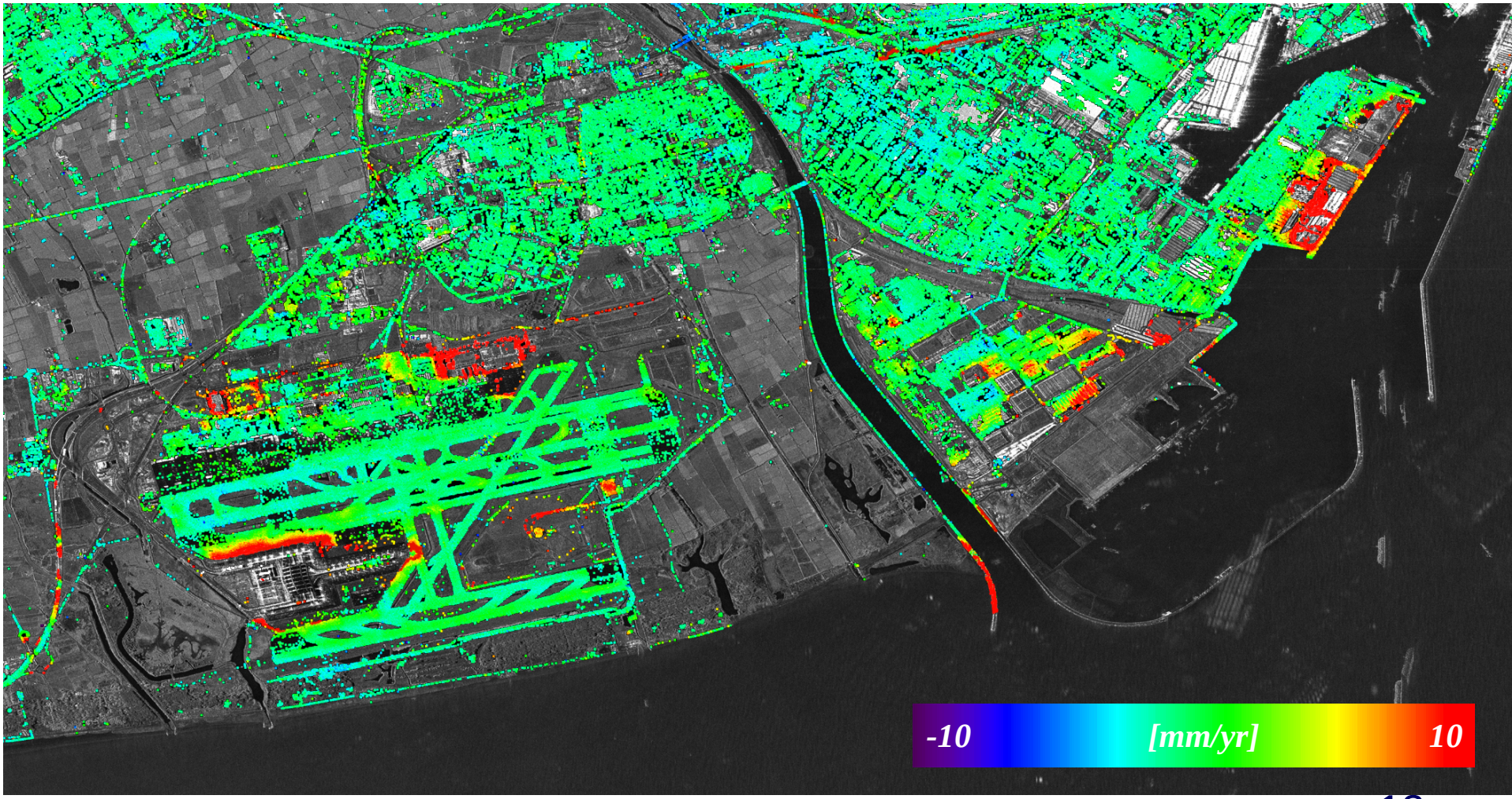
  ➔ $\approx 8.6^o$ ($B_\perp$ = 10 m)

Main PSI products:
Deformation velocity maps
Deformation time series

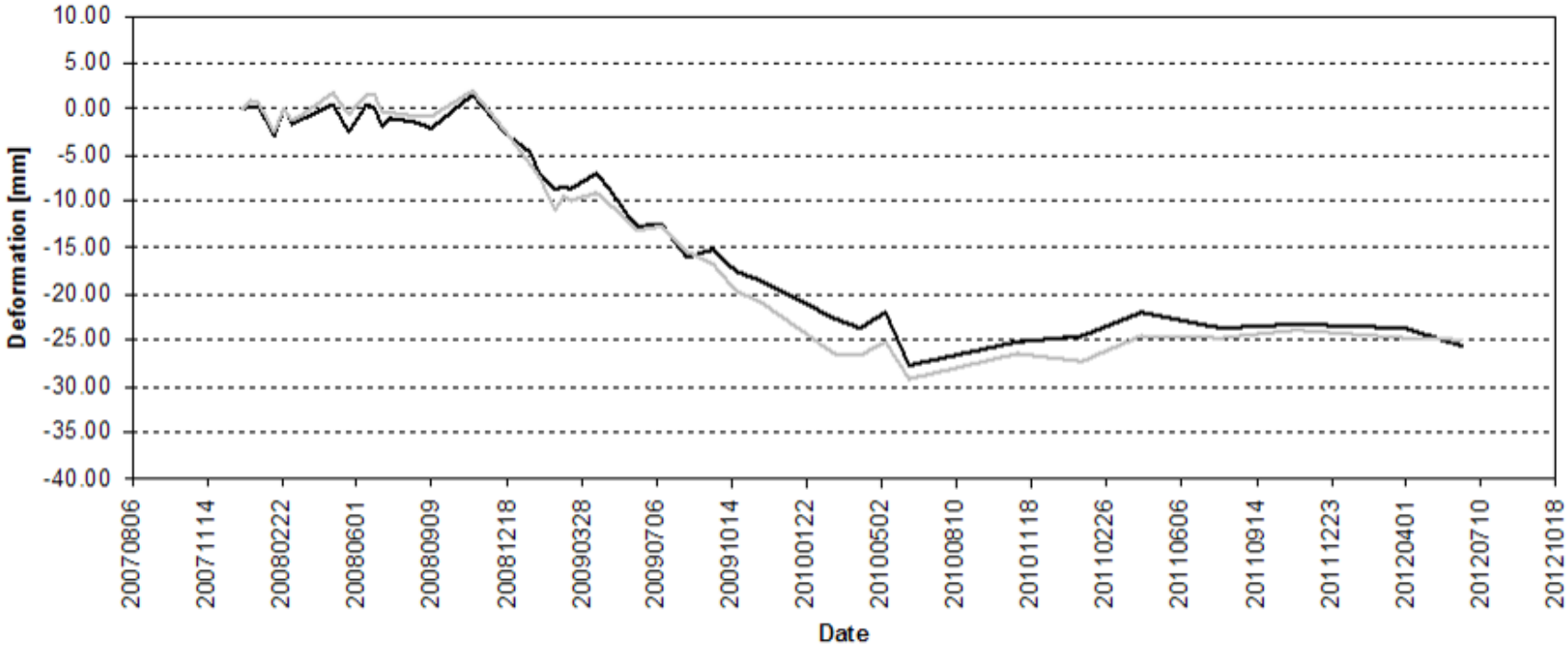


5.4 million measured points

Airport and Port of Barcelona



Deformation time series

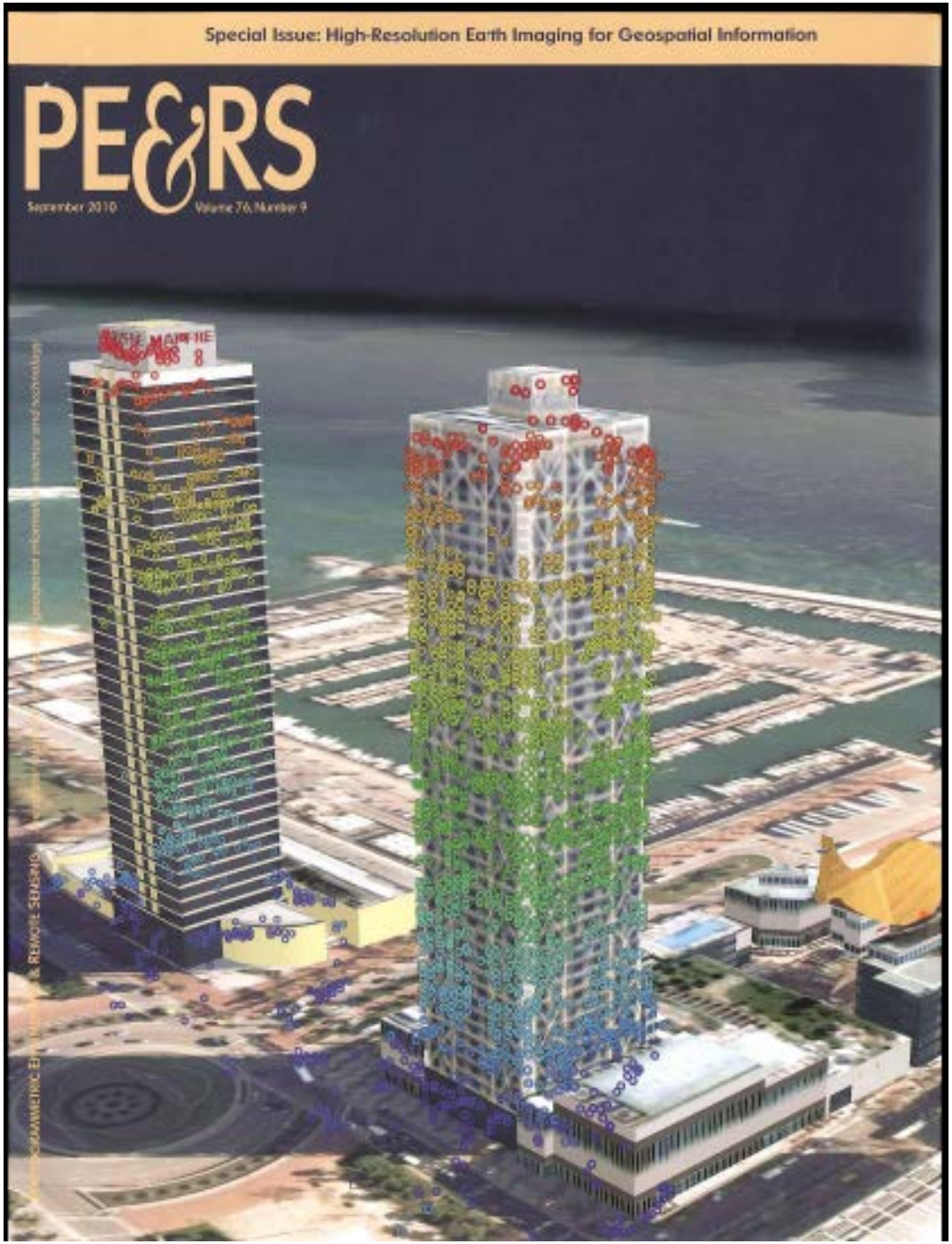


Medium vs. high SAR resolution

Medium vs. high SAR resolution

PSI byproduct:
elevation with respect to a reference DTM or DSM

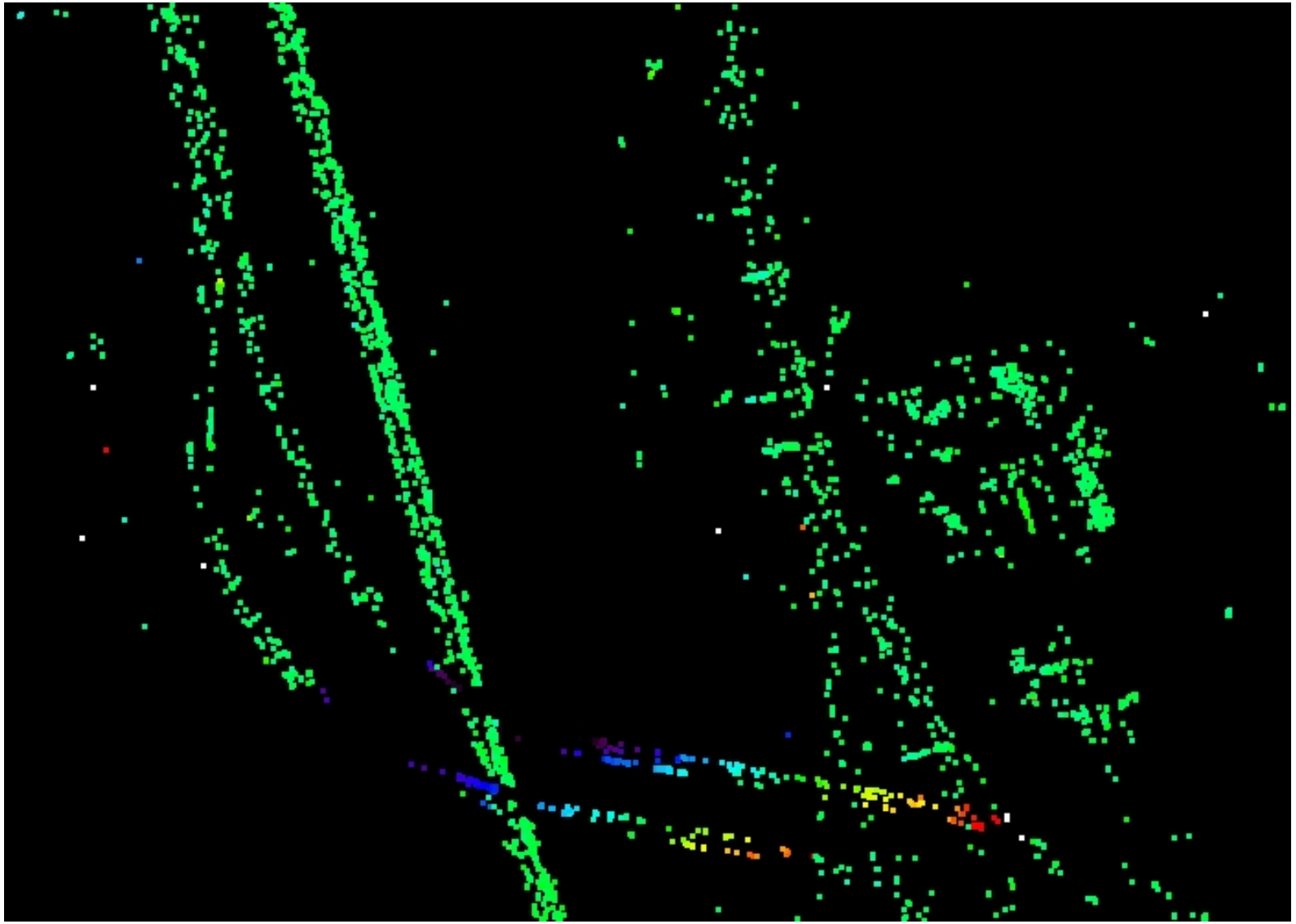

MAPFRE


Special Issue: High-Resolution Earth Imaging for Geospatial Information
PE&RS
September 2010
Volume 76, Number 9

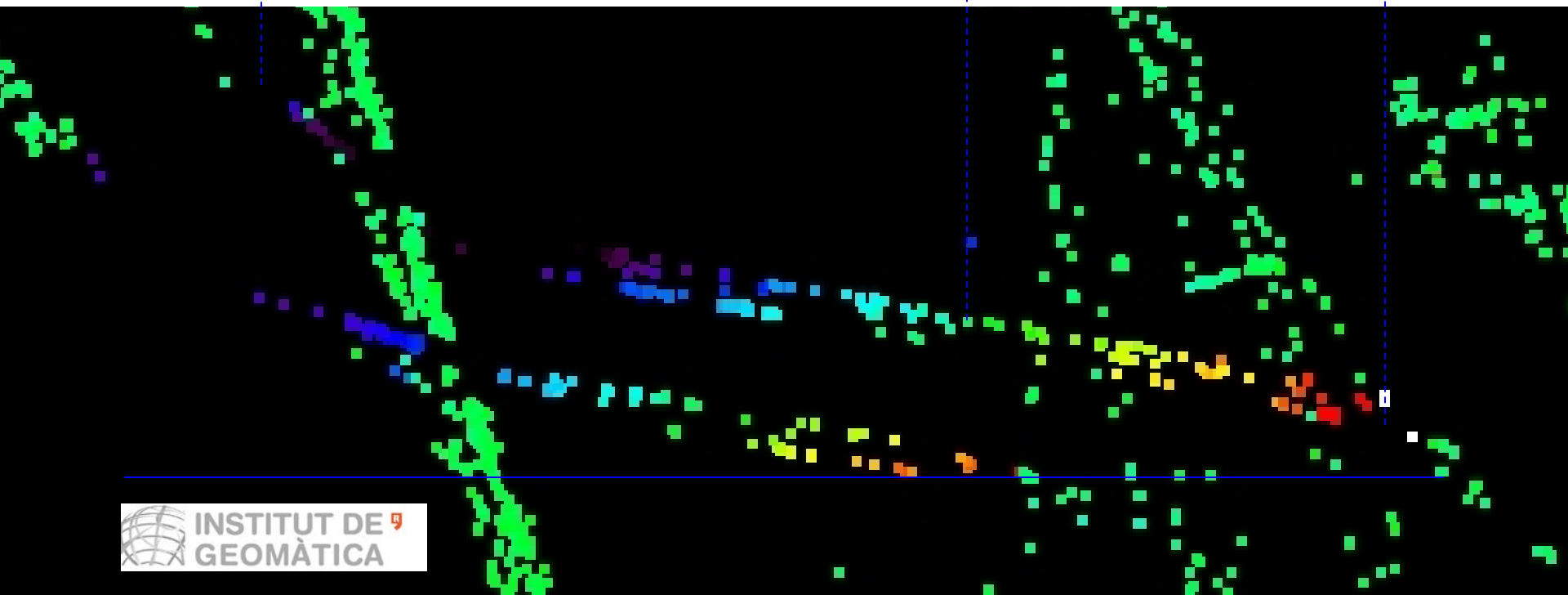
An additional PSI product: thermal dilation maps

Thermal dilation

Thermal dilation



Thermal dilation



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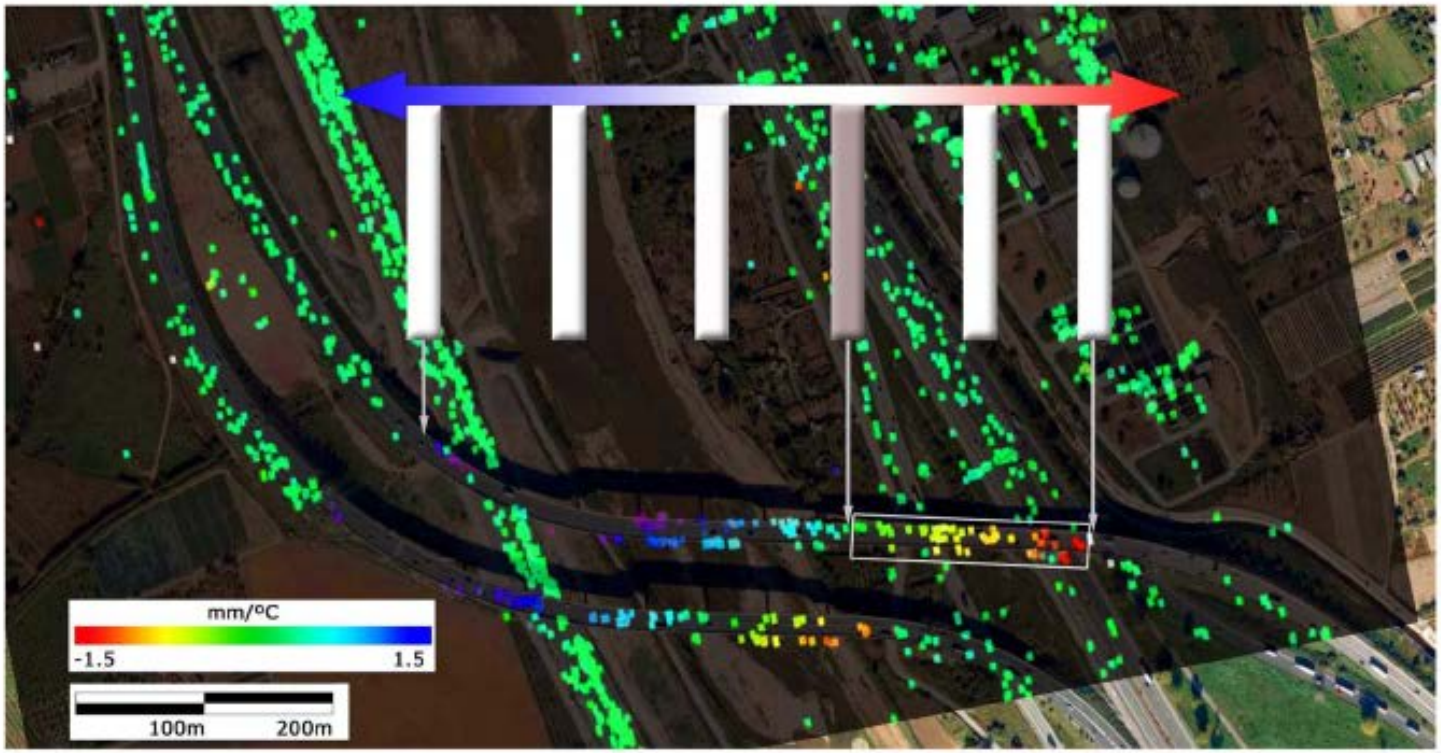
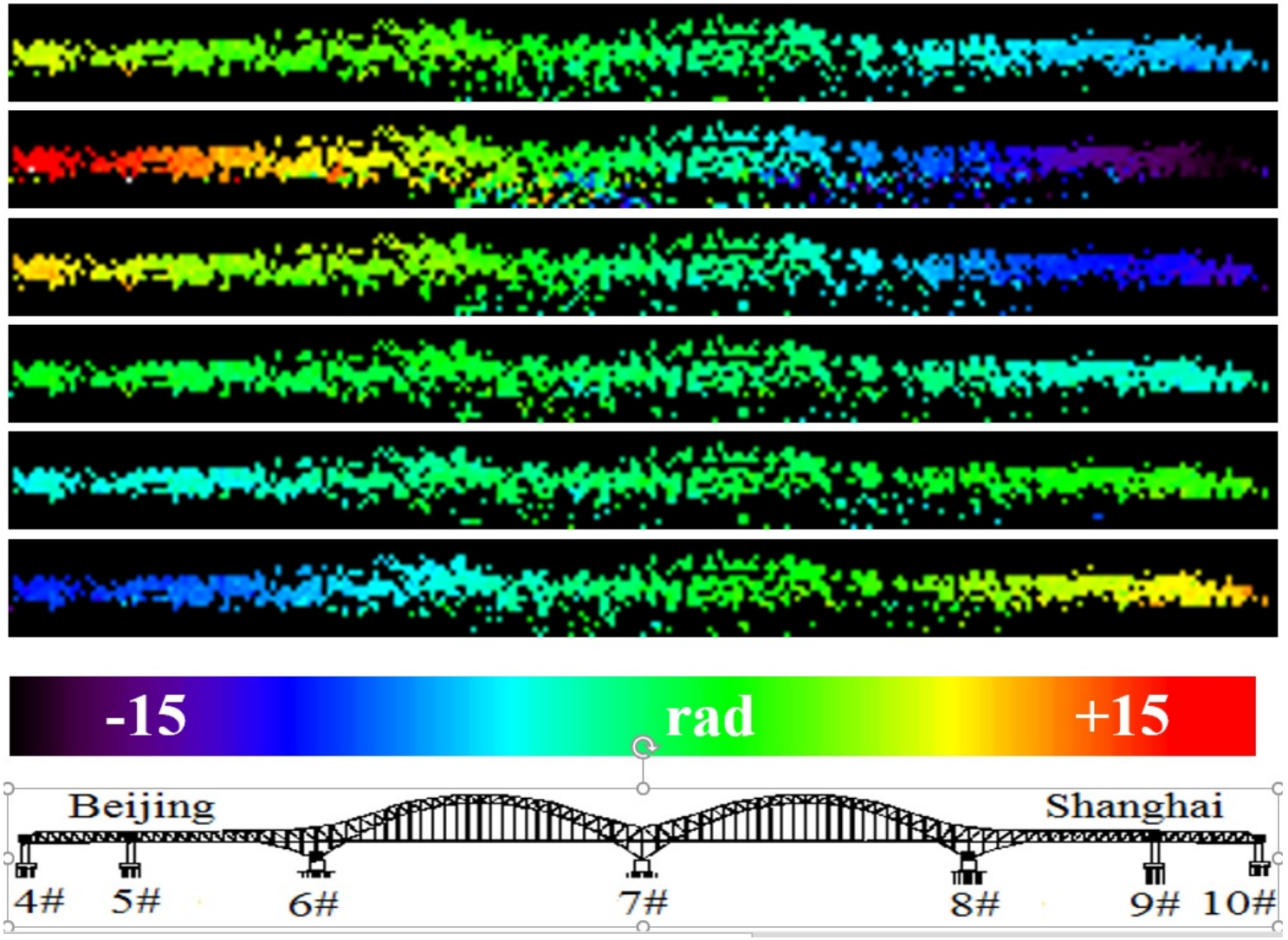
SEPTEMBER 2011 VOLUME 8 NUMBER 5 IGRSBY (ISSN 1545-598X)



Thermal dilation: C-band Sentinel-1

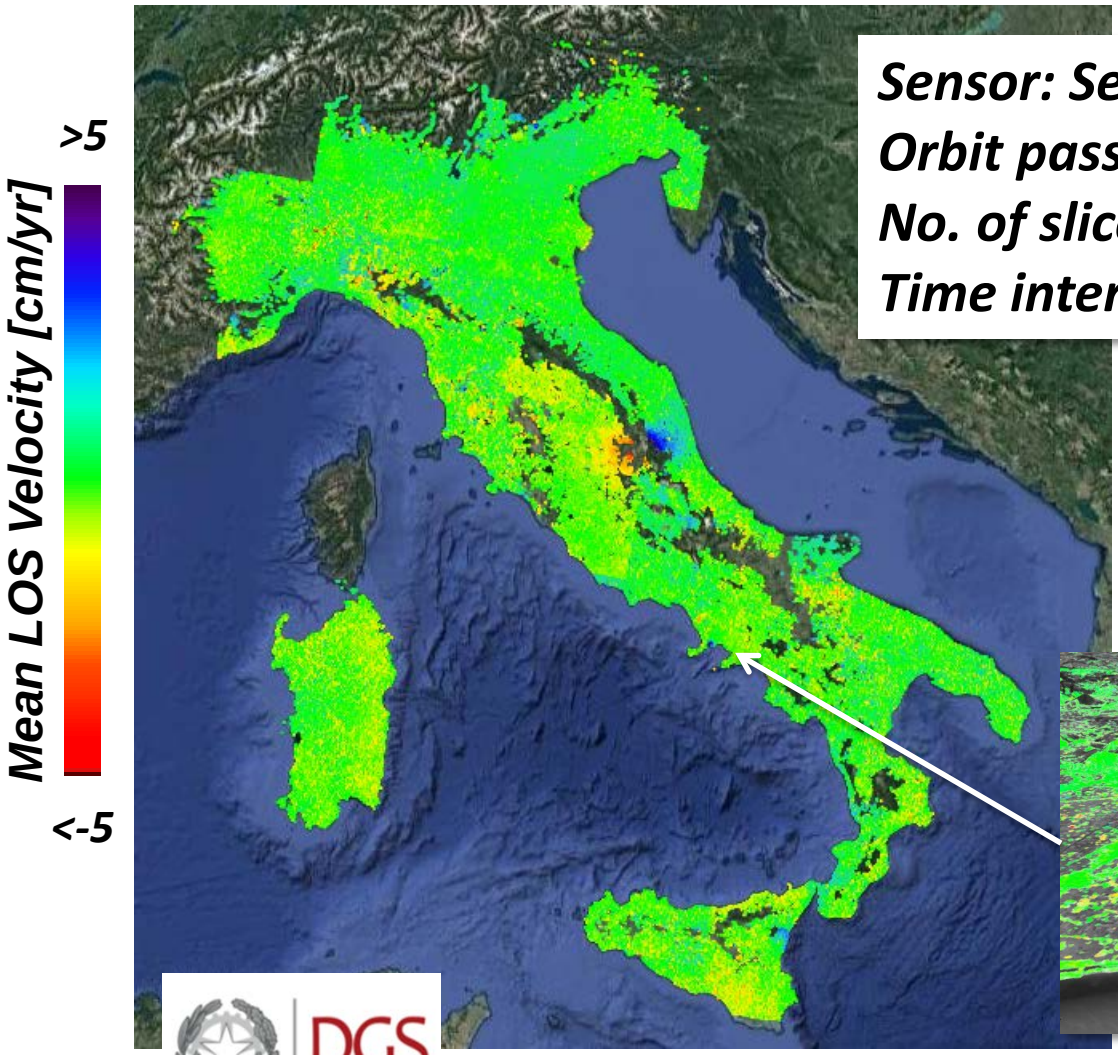


Huang et al. (2017), ISPRS Journal, 128, pp. 204–211

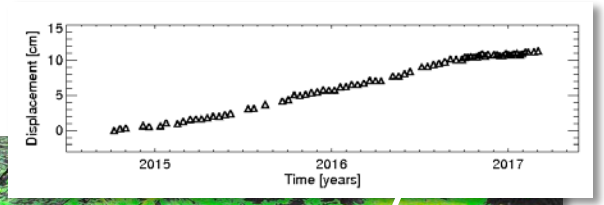
Future:

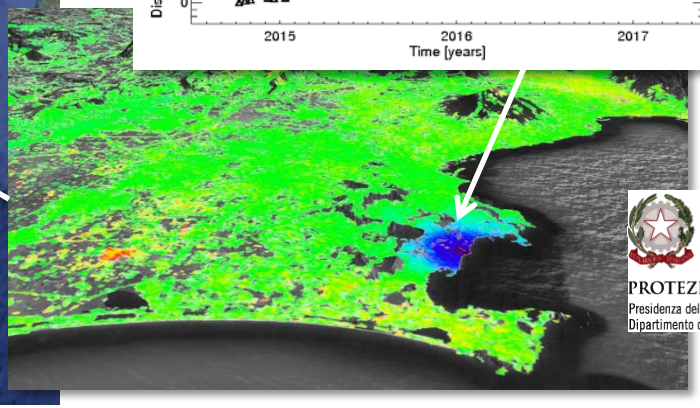
Several SAR missions
Consolidation of the technique

Nation-wide PSI coverage: Italy



Sensor: Sentinel-1
Orbit pass: Descending
No. of slices: 1364
Time interval: Oct 2014 – Apr 2017





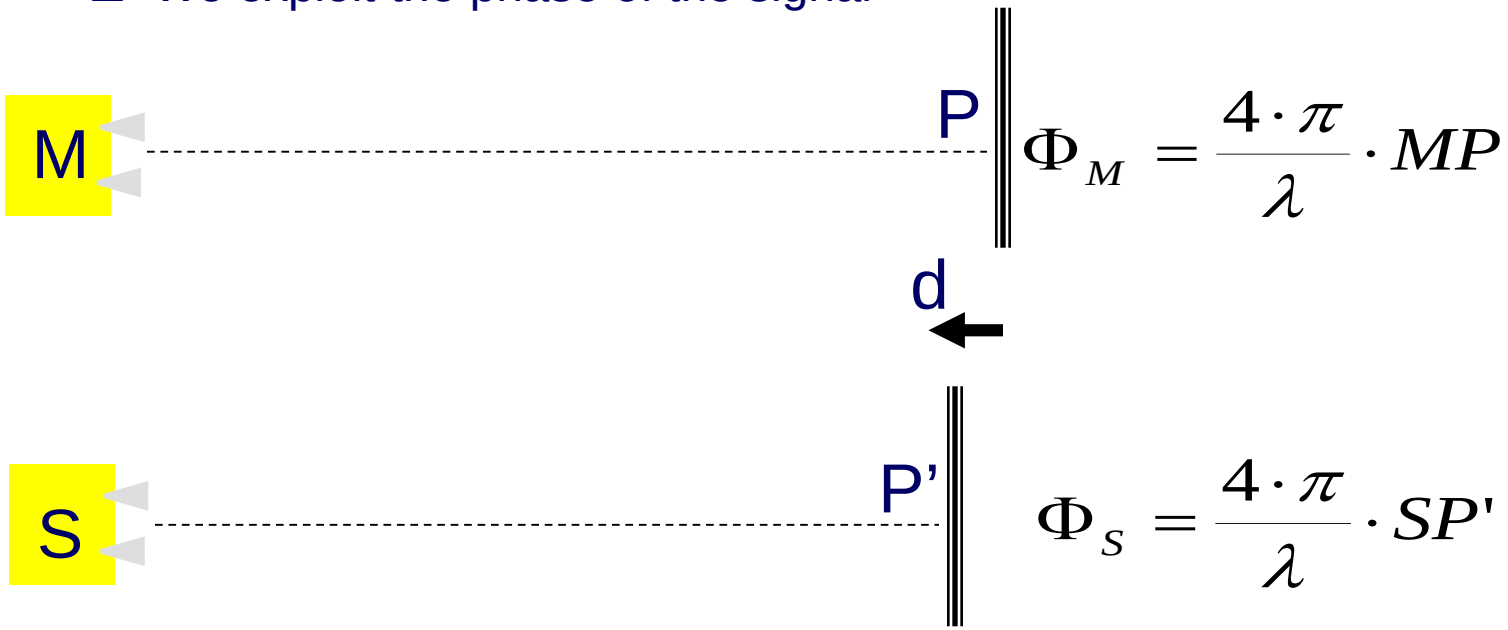
DGS UNMIG

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Ground-based SAR (GBSAR)

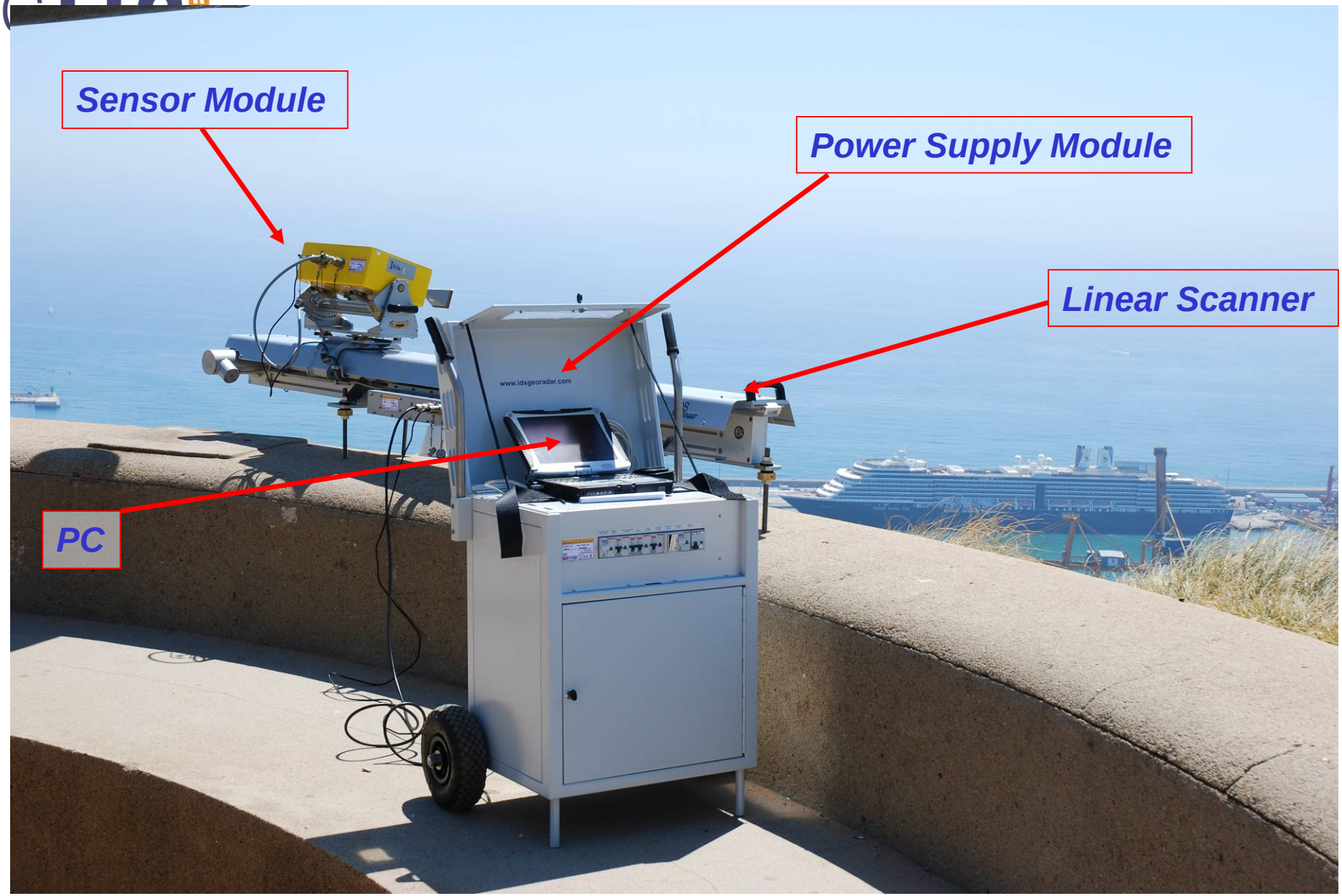
Ground-based SAR

- We exploit the phase of the signal



$$\Phi_{Int} = \Phi_S - \Phi_M = \frac{4 \cdot \pi}{\lambda} \cdot (SP' - MP) \quad \Rightarrow \quad SP' - MP = d$$

The main observable is wrapped

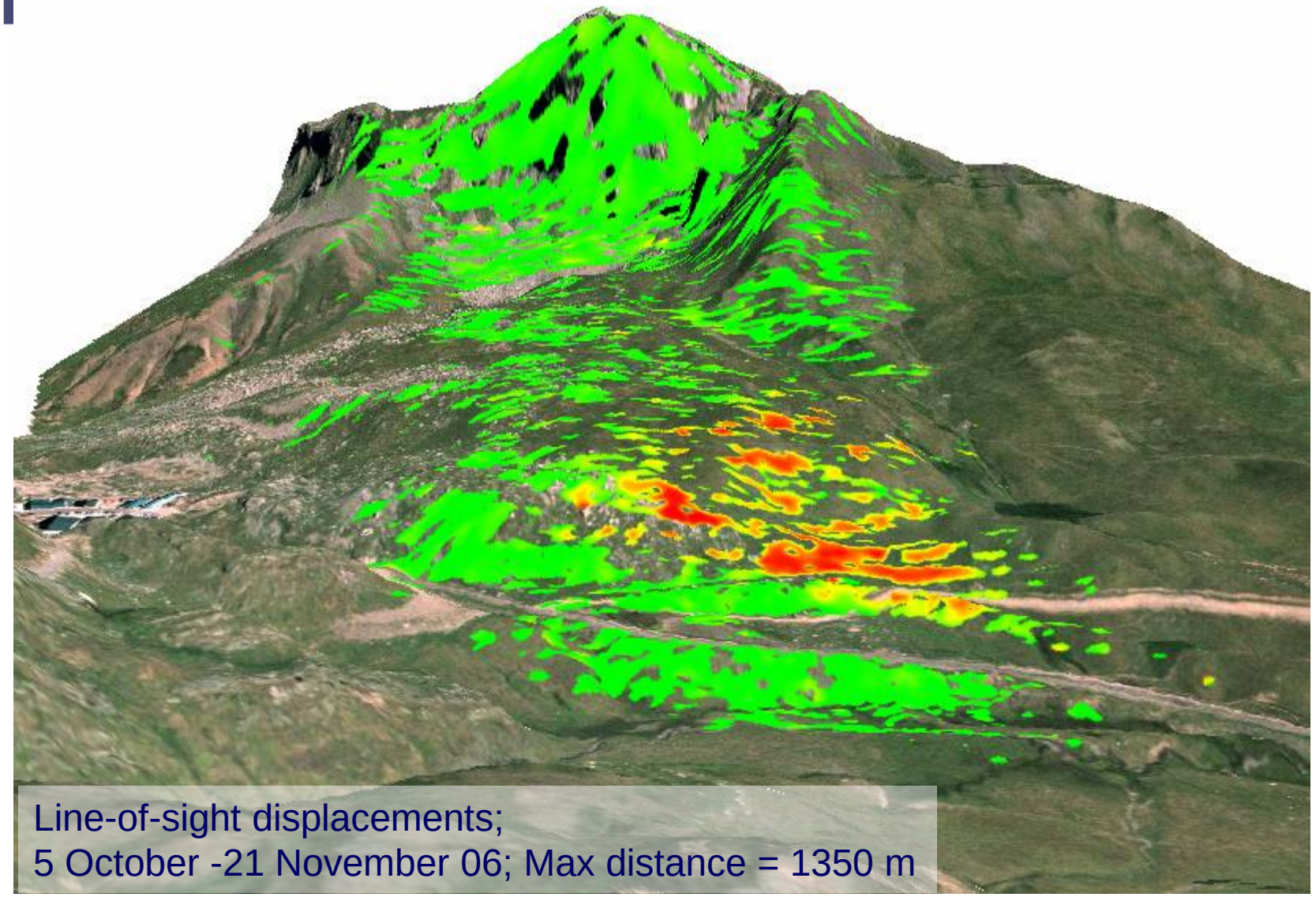

Sensor Module
Power Supply Module
Linear Scanner
PC
www.idsgeoradar.com

Continuous GBSAR

- 3 TLS campaigns
- 1 continuous GBSAR campaign
- Several topographic campaigns: total station & D-GPS

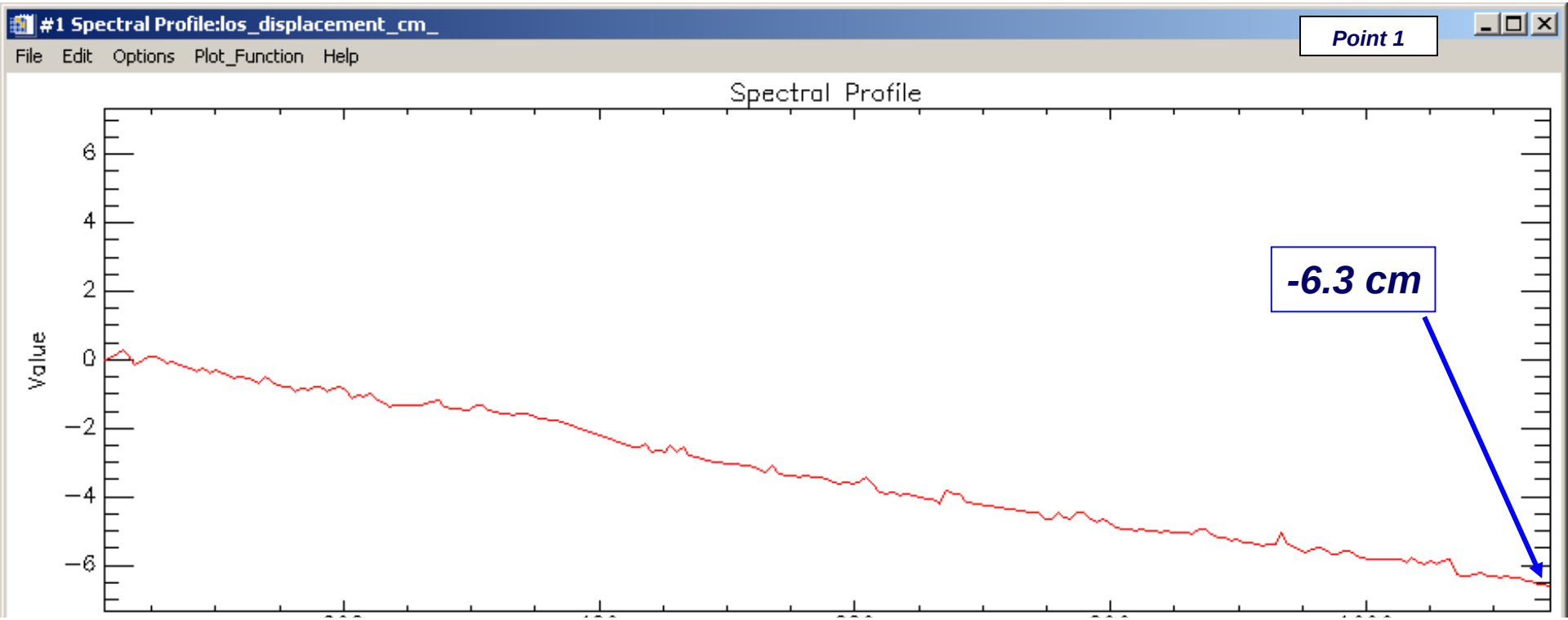
www.galahad.it

Continuous GBSAR



Line-of-sight displacements;
5 October -21 November 06; Max distance = 1350 m

Continuous GBSAR: time series



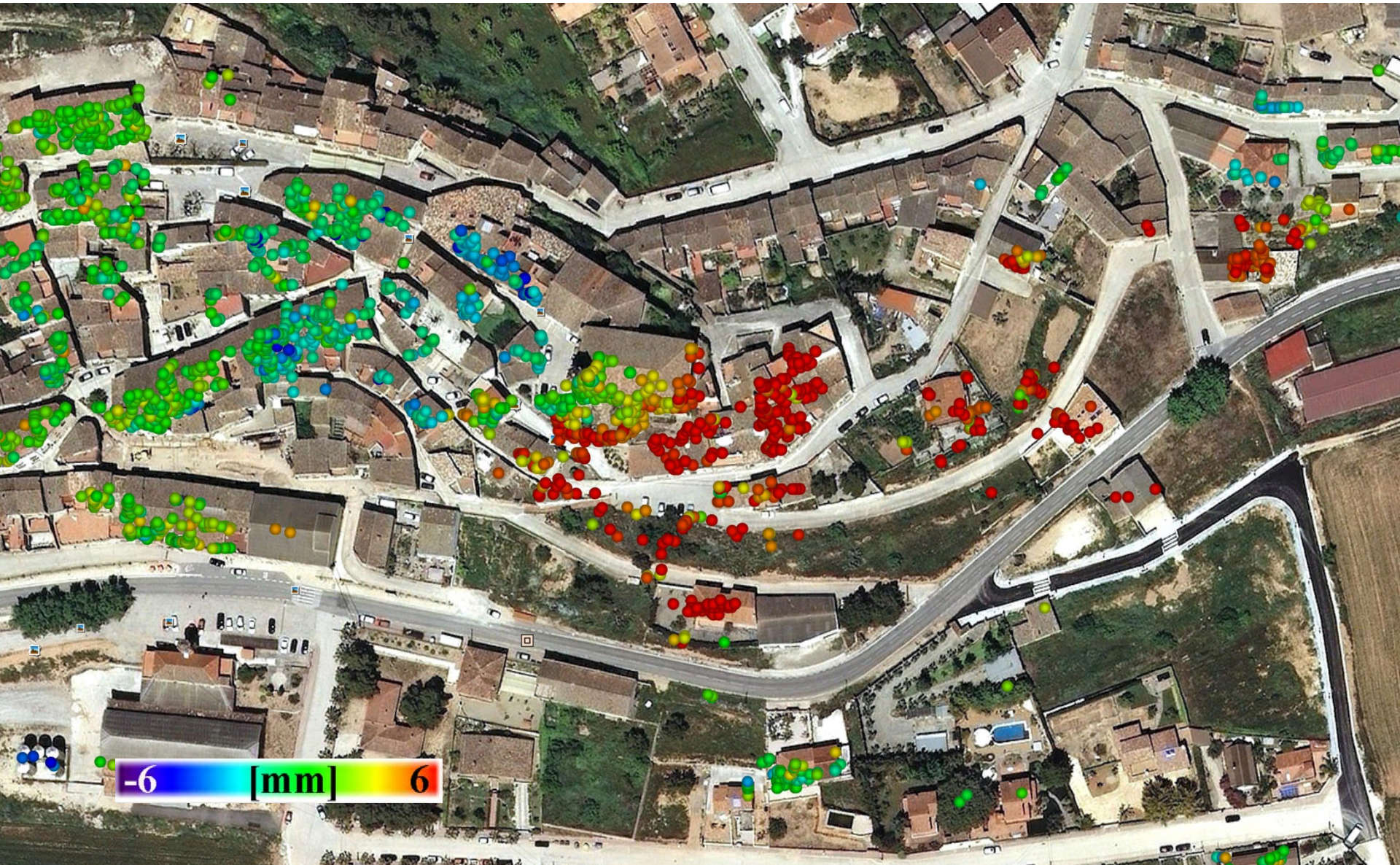
5th October

21st November

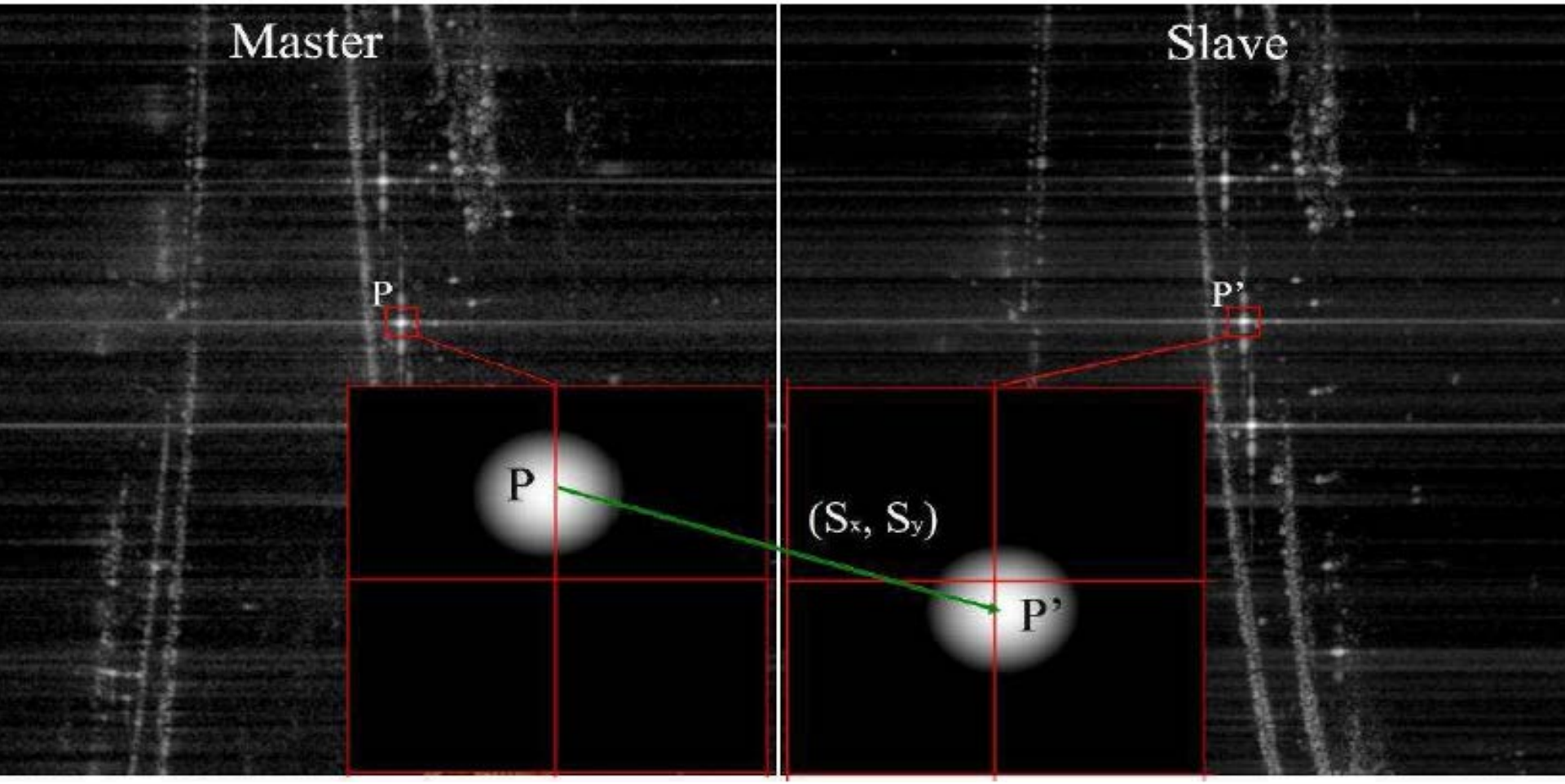
Distance = 550 m

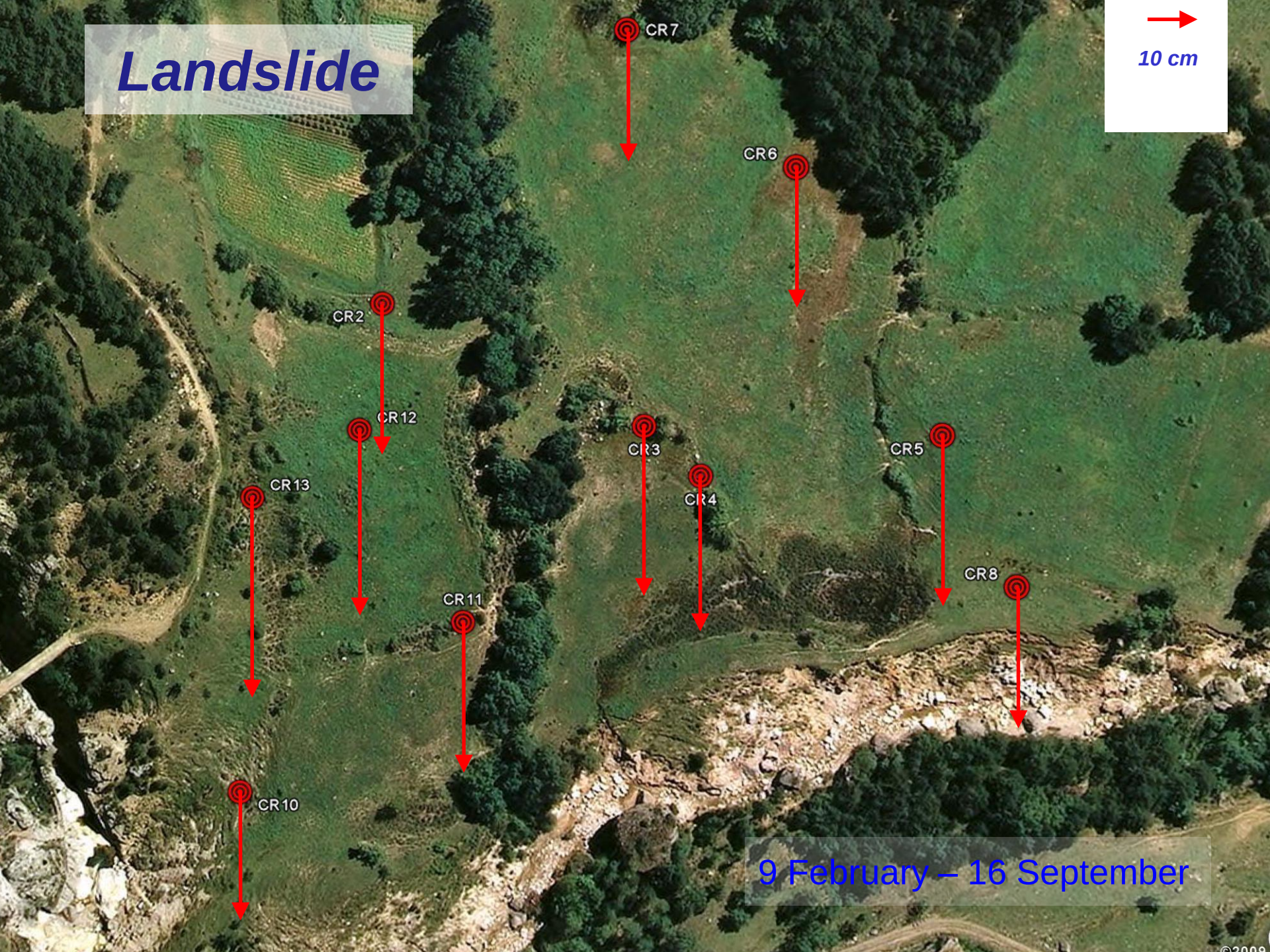
Discontinuous GBSAR

Discontinuous GBSAR



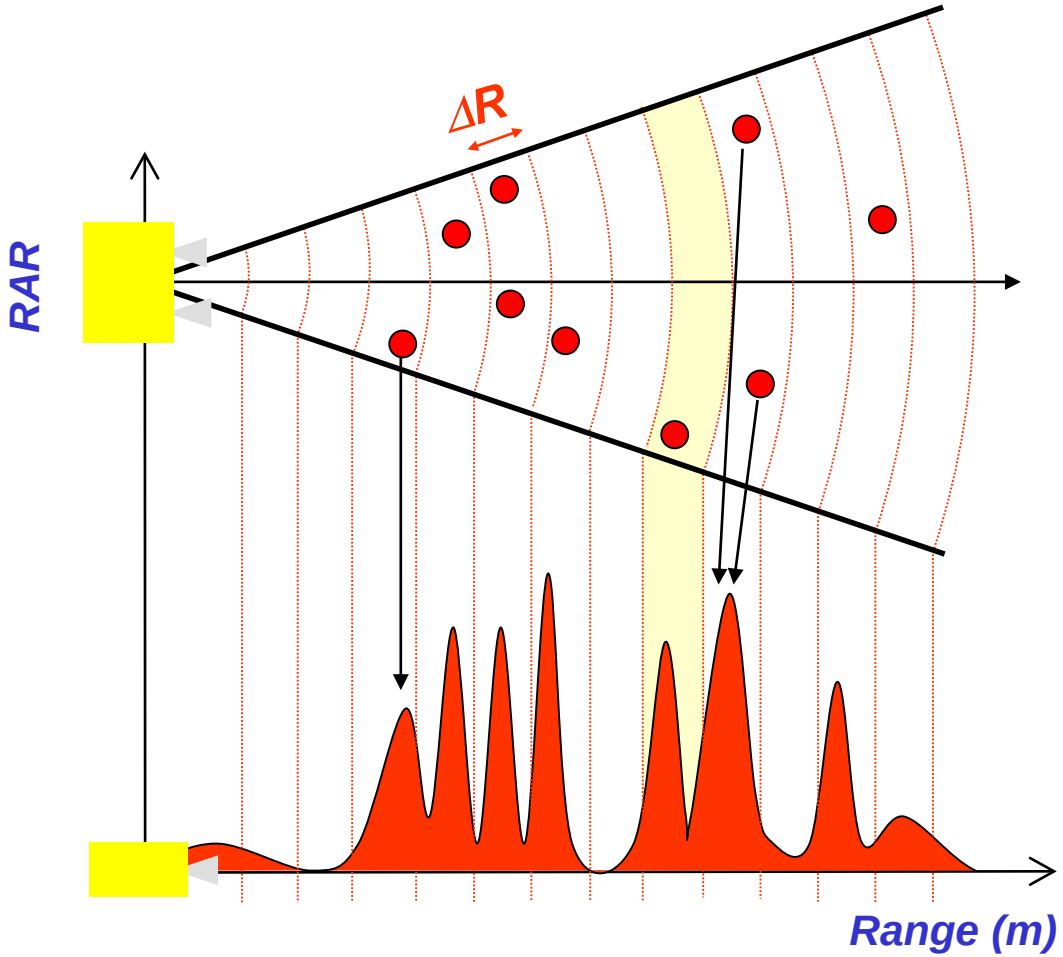
Non-interferometric GBSAR




Landslide
10 cm
CR7
CR6
CR2
CR12
CR3
CR5
CR13
CR4
CR8
CR11
CR10
9 February – 16 September

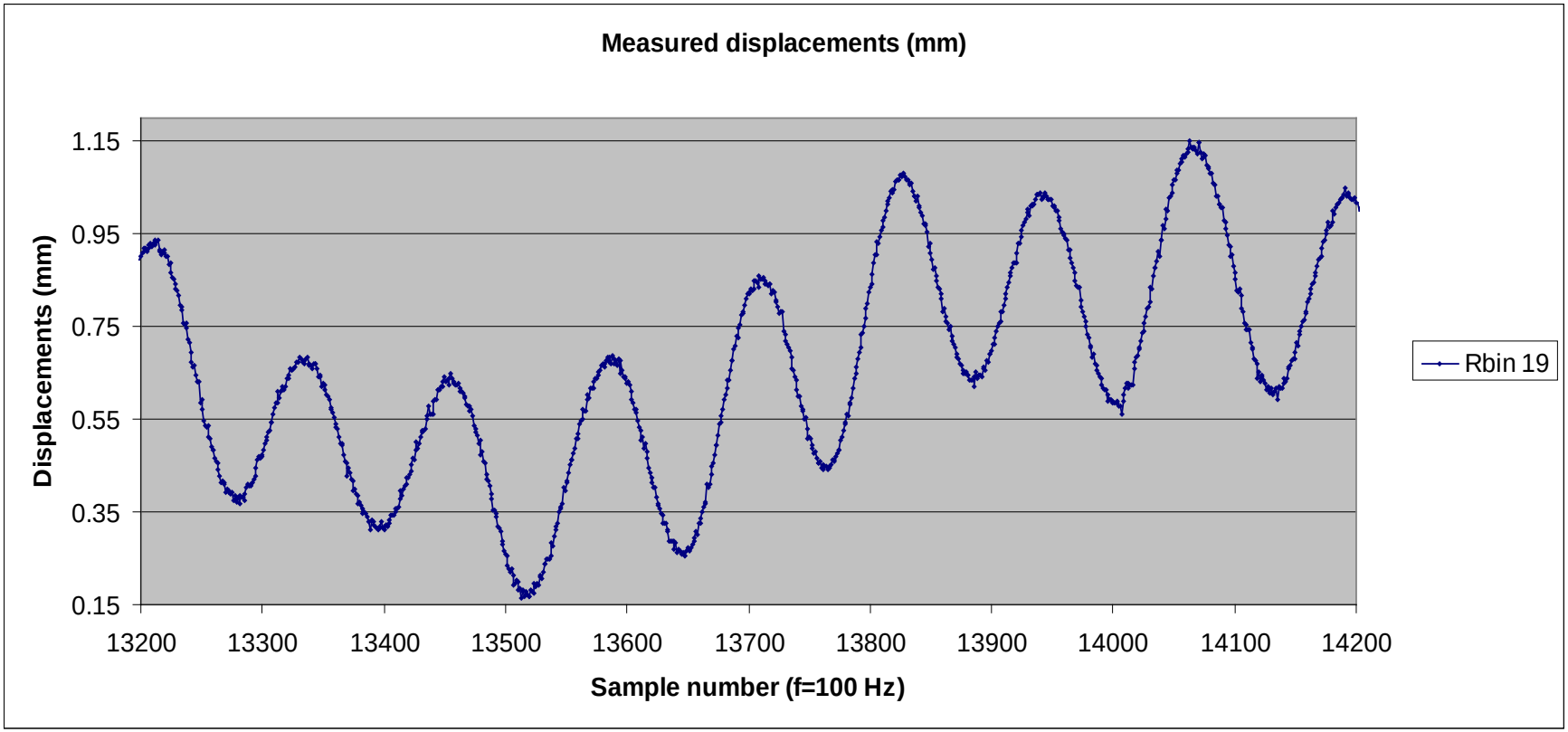
Real-Aperture-Radar interferometry

Real-Aperture-Radar



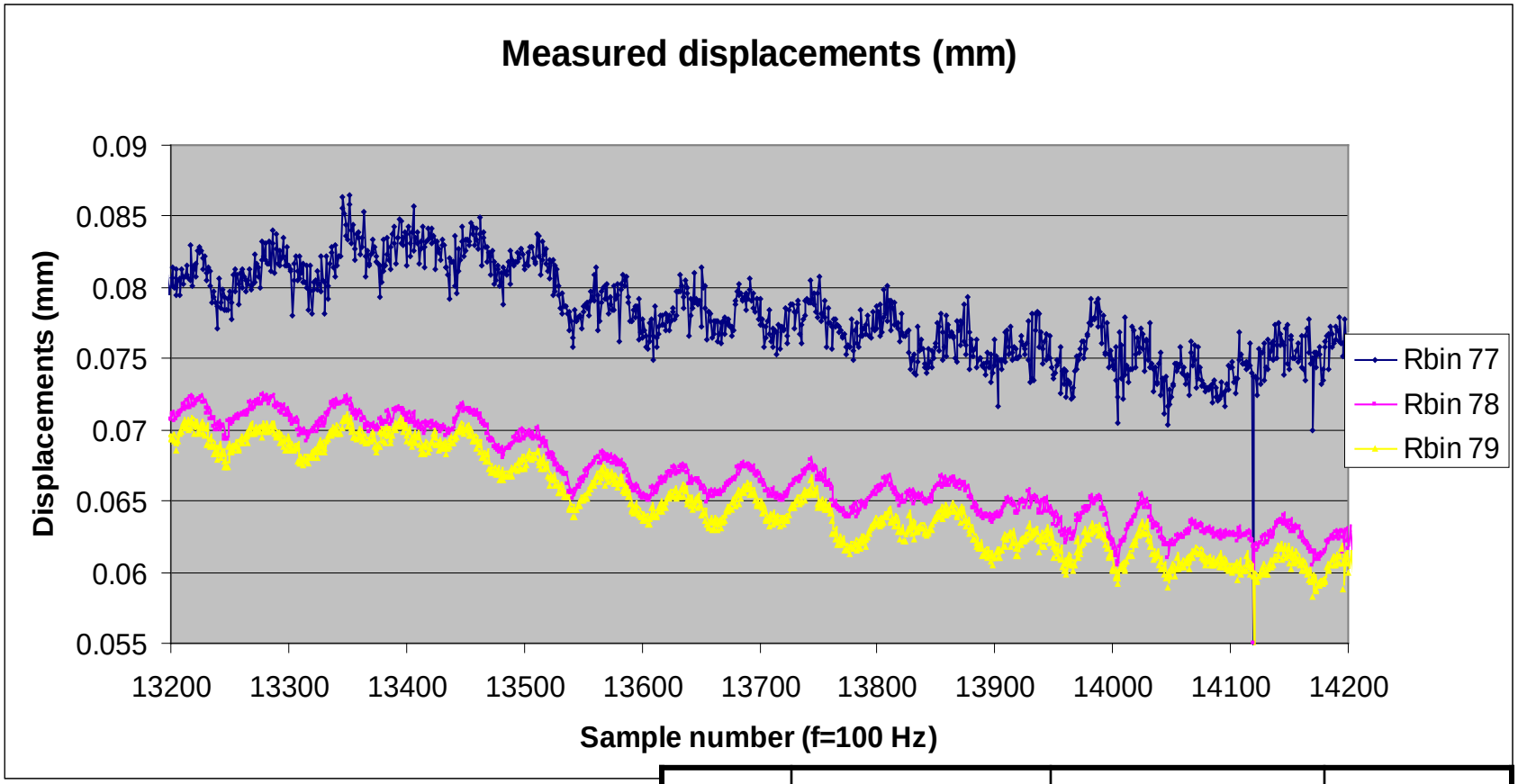
Real-Aperture-Radar: example

Real-Aperture-Radar: light pole



Point	Object	Distance LOS [m]	SNR [db]
19	Light pole	9	49.2

Real-Aperture-Radar: building



Point	Object	Distance LOS [m]	SNR [db]
77	Façade	37.9	**62**
78	Façade	38.4	**78.4**
79	Façade	38.9	**75.4**