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Ground-Based Synthetic Aperture Radar (GBSAR) and Ground Penetrating Radar (GPR)

Massimiliano Pieraccini





Ground-Based Synthetic Aperture Radar (GBSAR)

Ground Penetrating Radar (GPR)

Environmental, Industrial and Biomedical Sensors



Santa Marta, 1999 approx.



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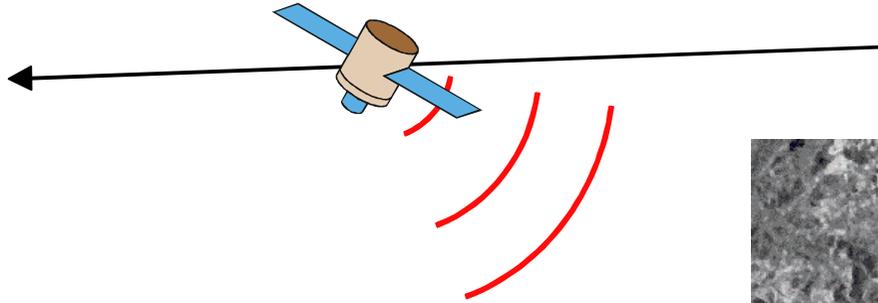
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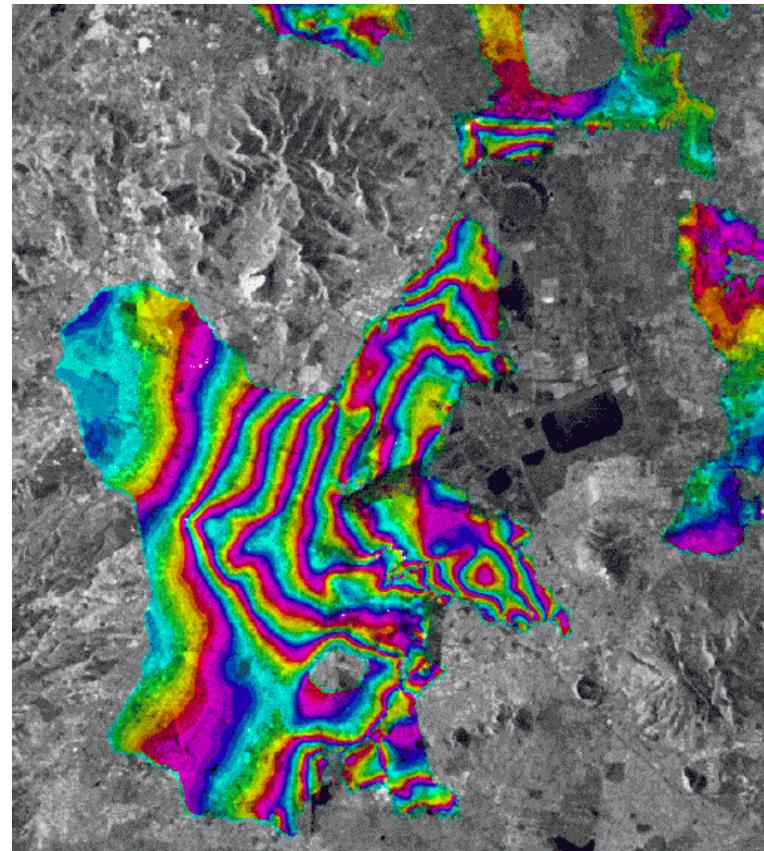
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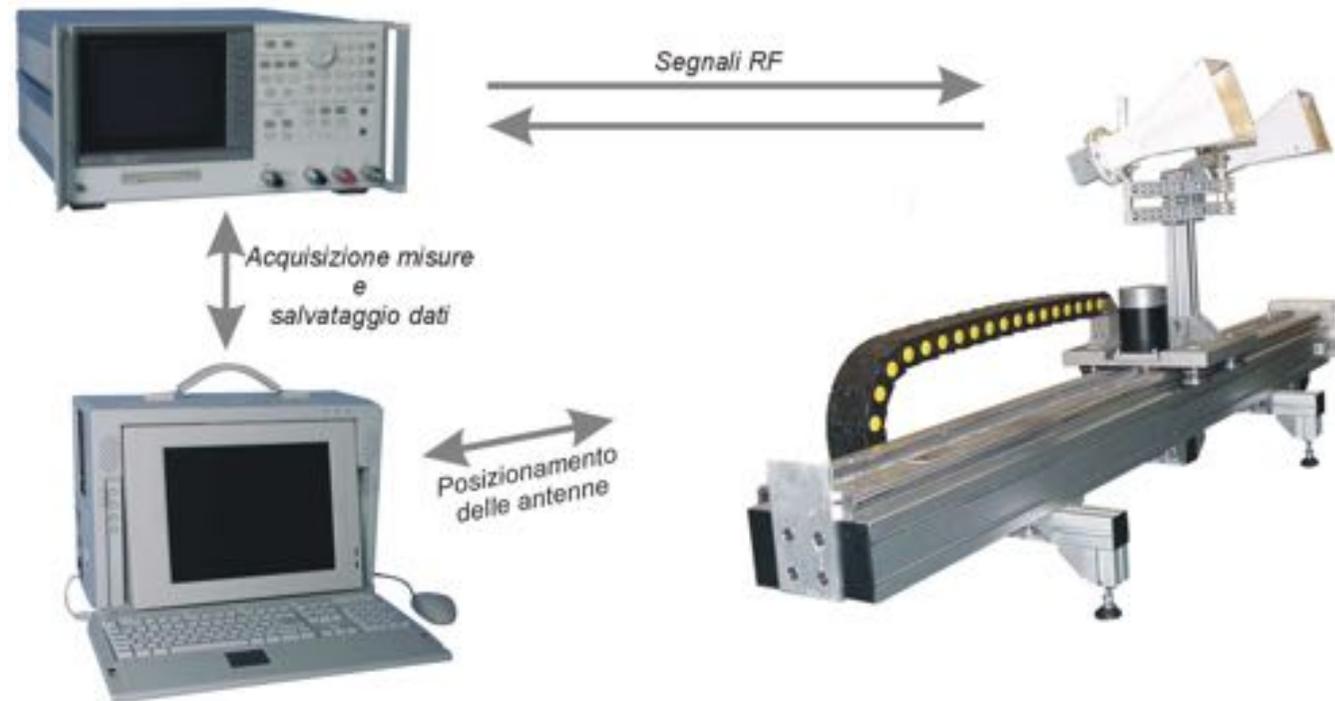
Interferometric Synthetic Aperture Radar (InSAR)



$$\Delta r = \frac{c}{4\pi f} \Delta \phi$$



Mexico City, subsidence

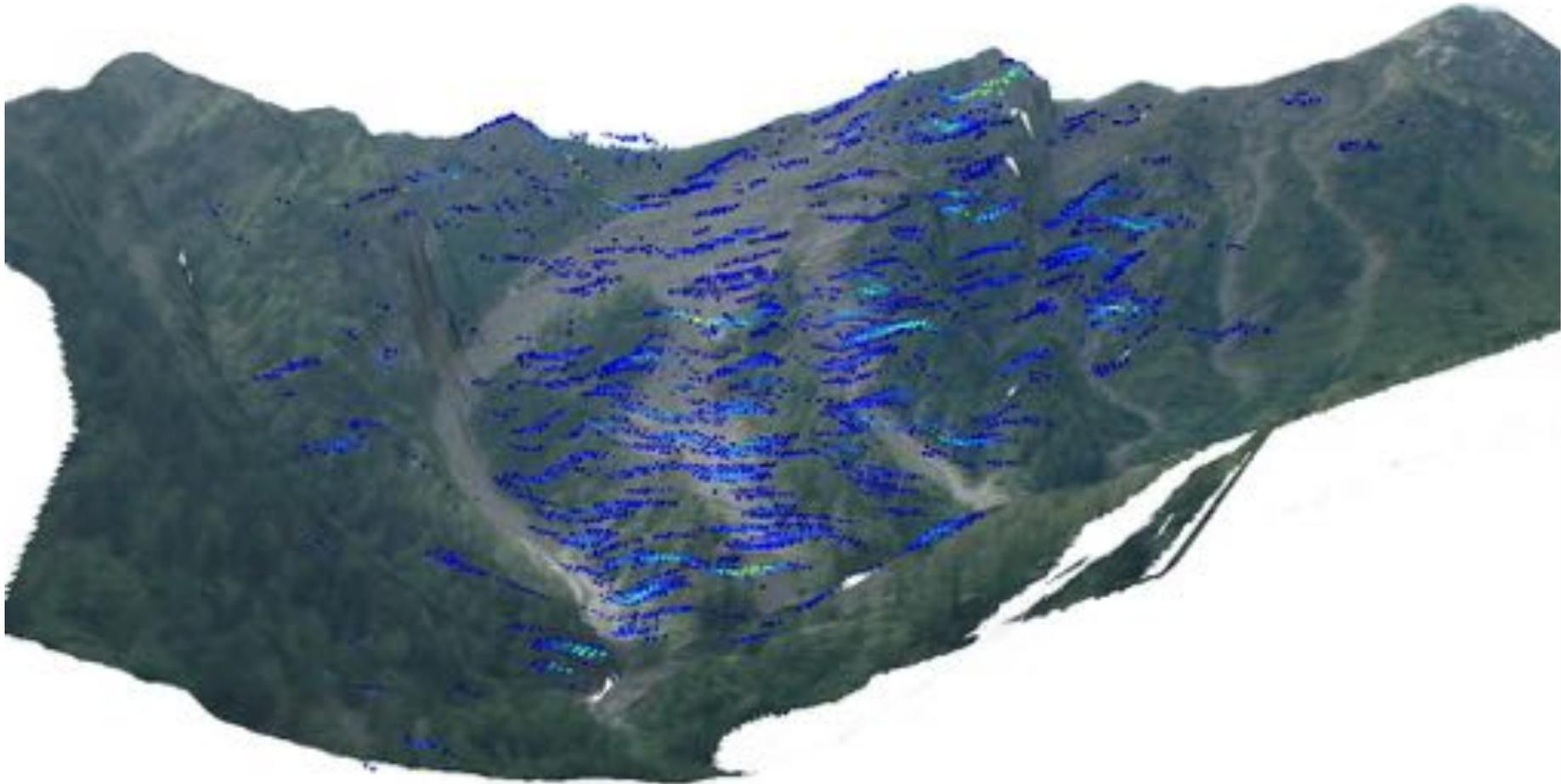




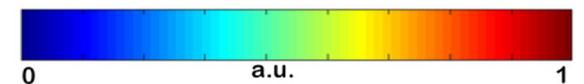
Citrin's landslide (Val d'Aosta 2003-2006)



Citrin's landslide (Val d'Aosta 2003-2006)

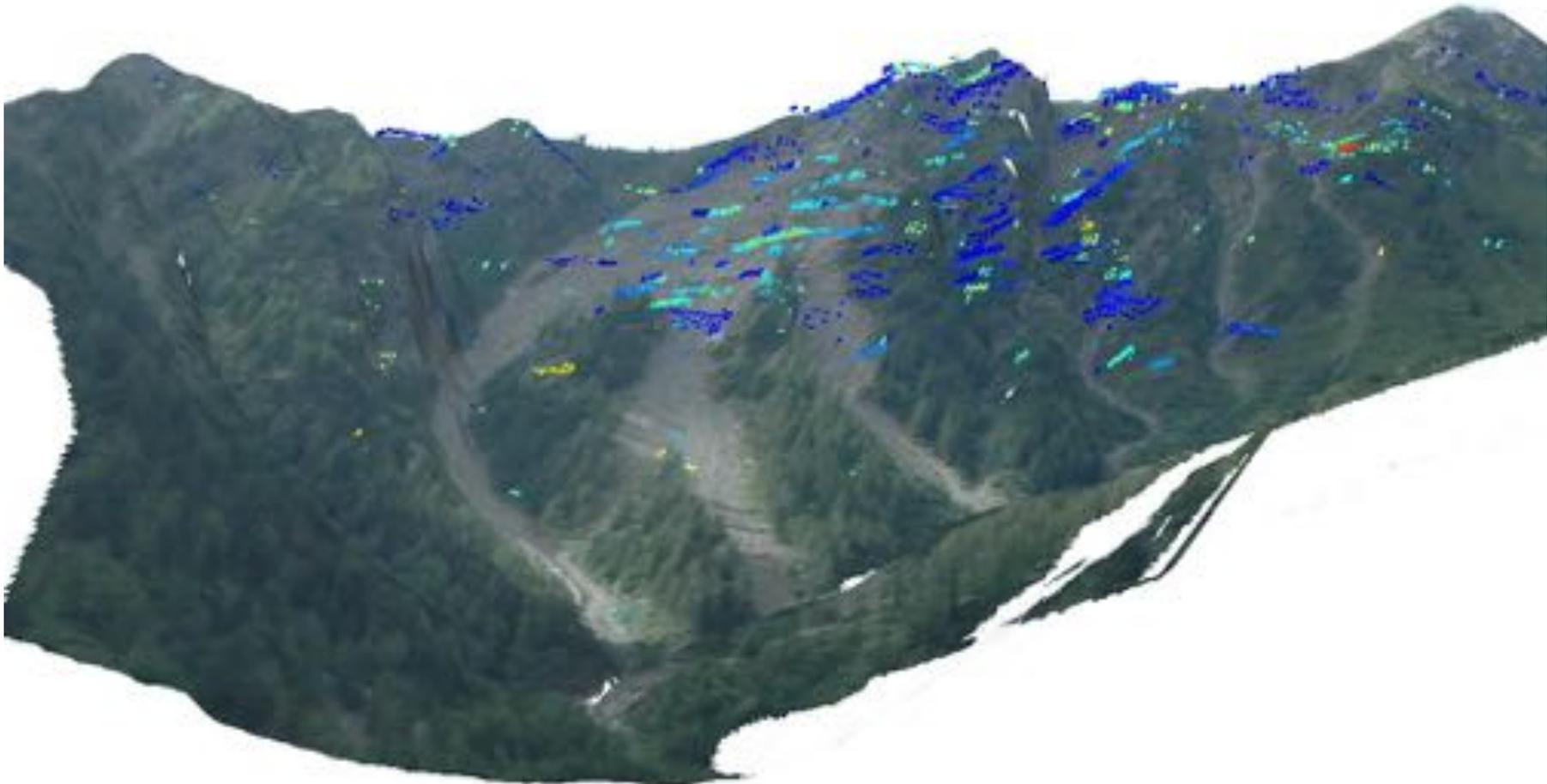


Digital Elevation Model
Photographic image
Radar image



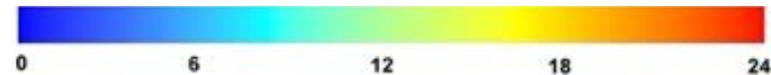


July 2004 - September 2004



Digital Elevation Model
Photographic image
Displacement map

Towards the radar (mm)

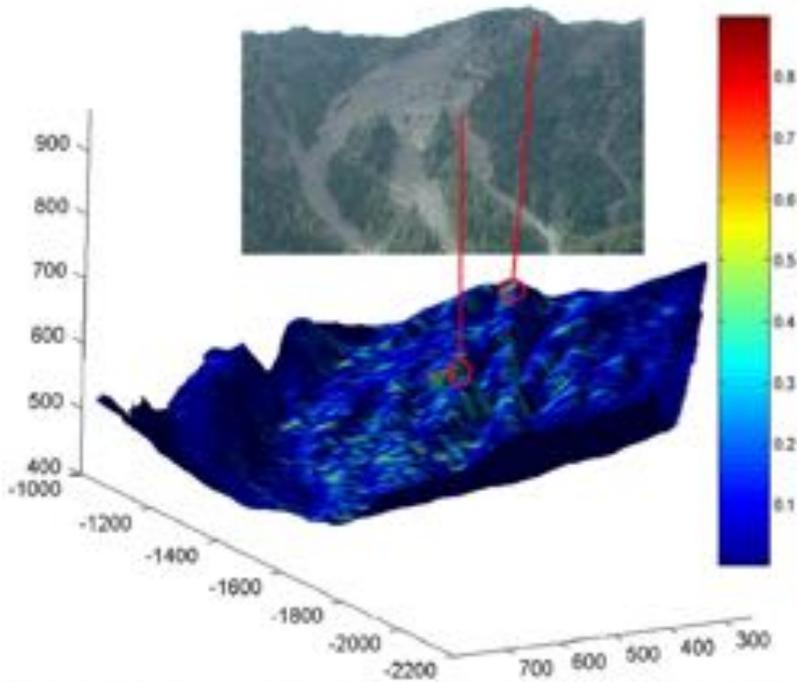




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JULY 2008 VOLUME 43 NUMBER 7 IGRSD2 (ISSN 0196-2892)

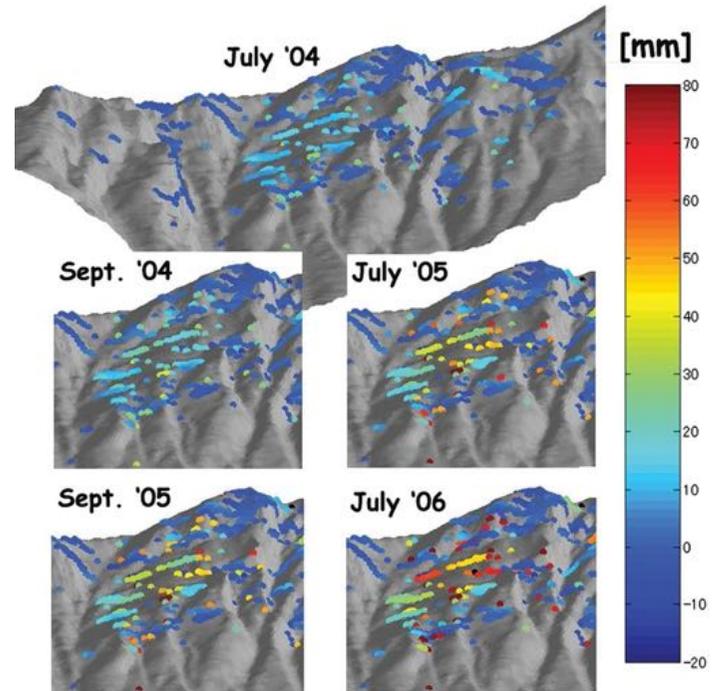


Three-dimensional radar cross-section image (arbitrary units) acquired in C-band by a ground-based interferometric SAR and focused on the DEM of the terrain. Pairs of coherent radar images are employed to detect long-term displacements on the imaged landslide slope.

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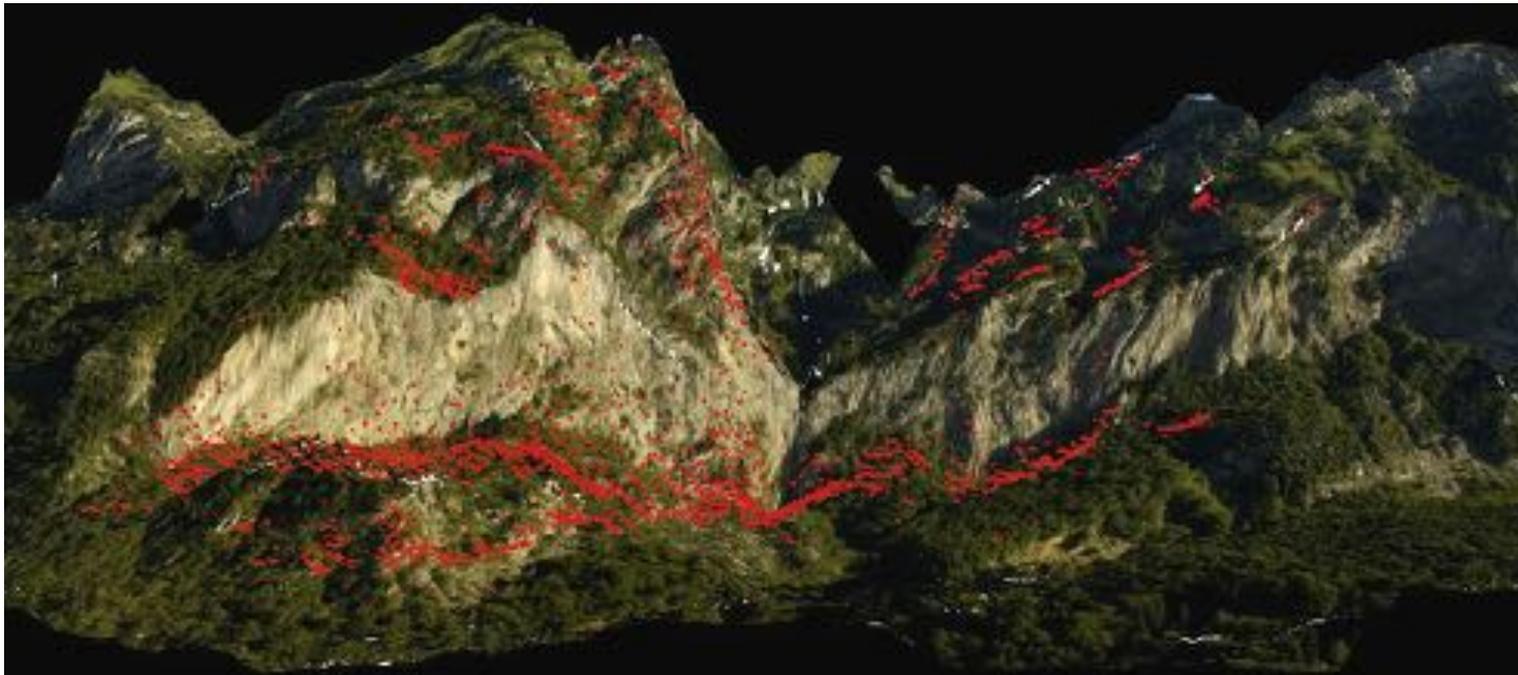


Six different ground-based SAR (GB-SAR) surveys were scheduled for monitoring an alpine landslide over a period of about three years. Here the maps represent the displacements along the line of sight detected at each survey with respect to the first survey in September 2003.

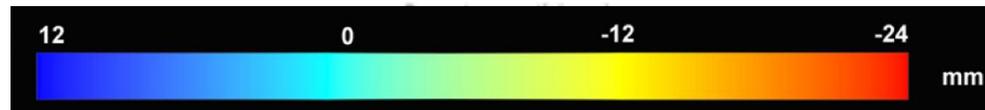
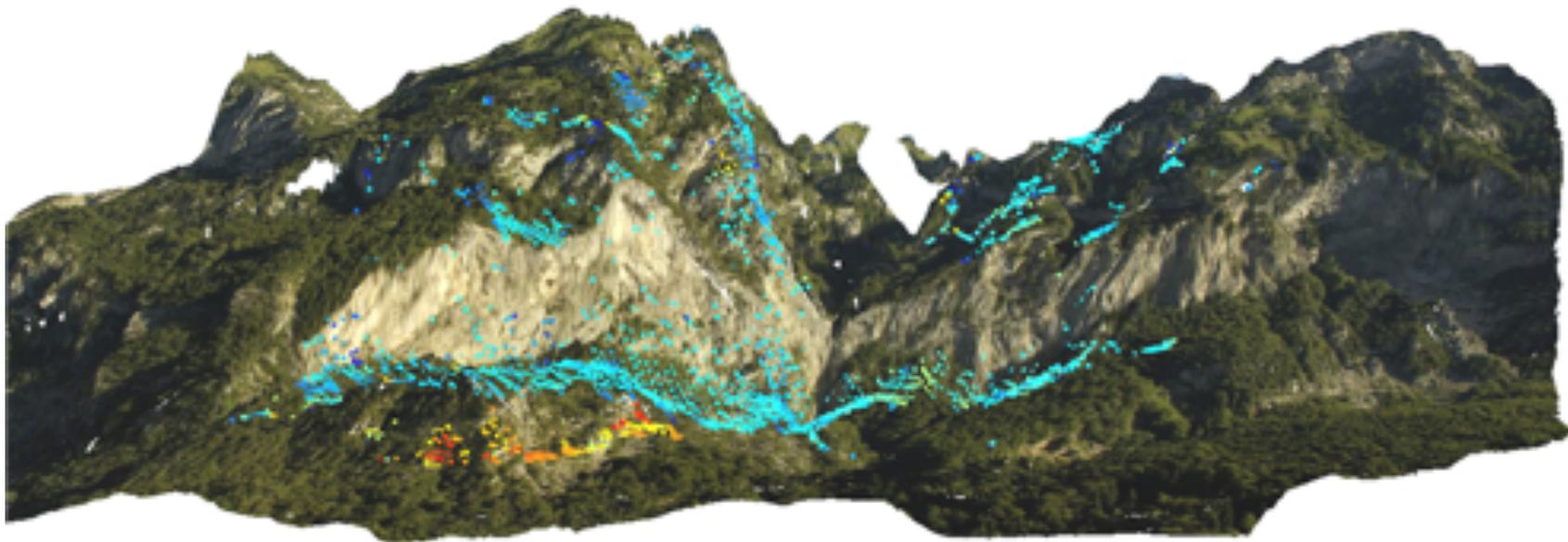


Passo della Morte (Udine)





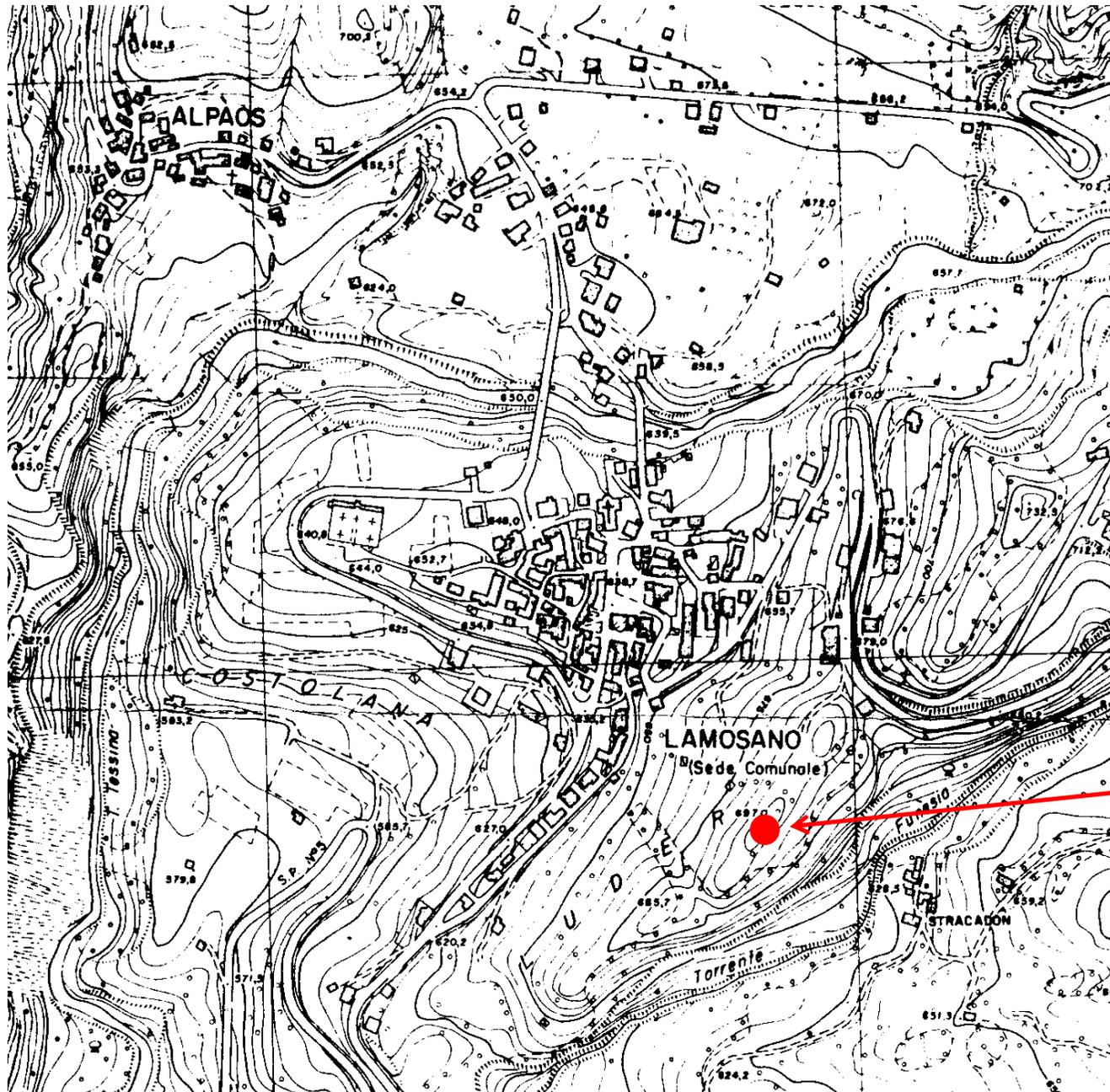
December 2005 – June 2006

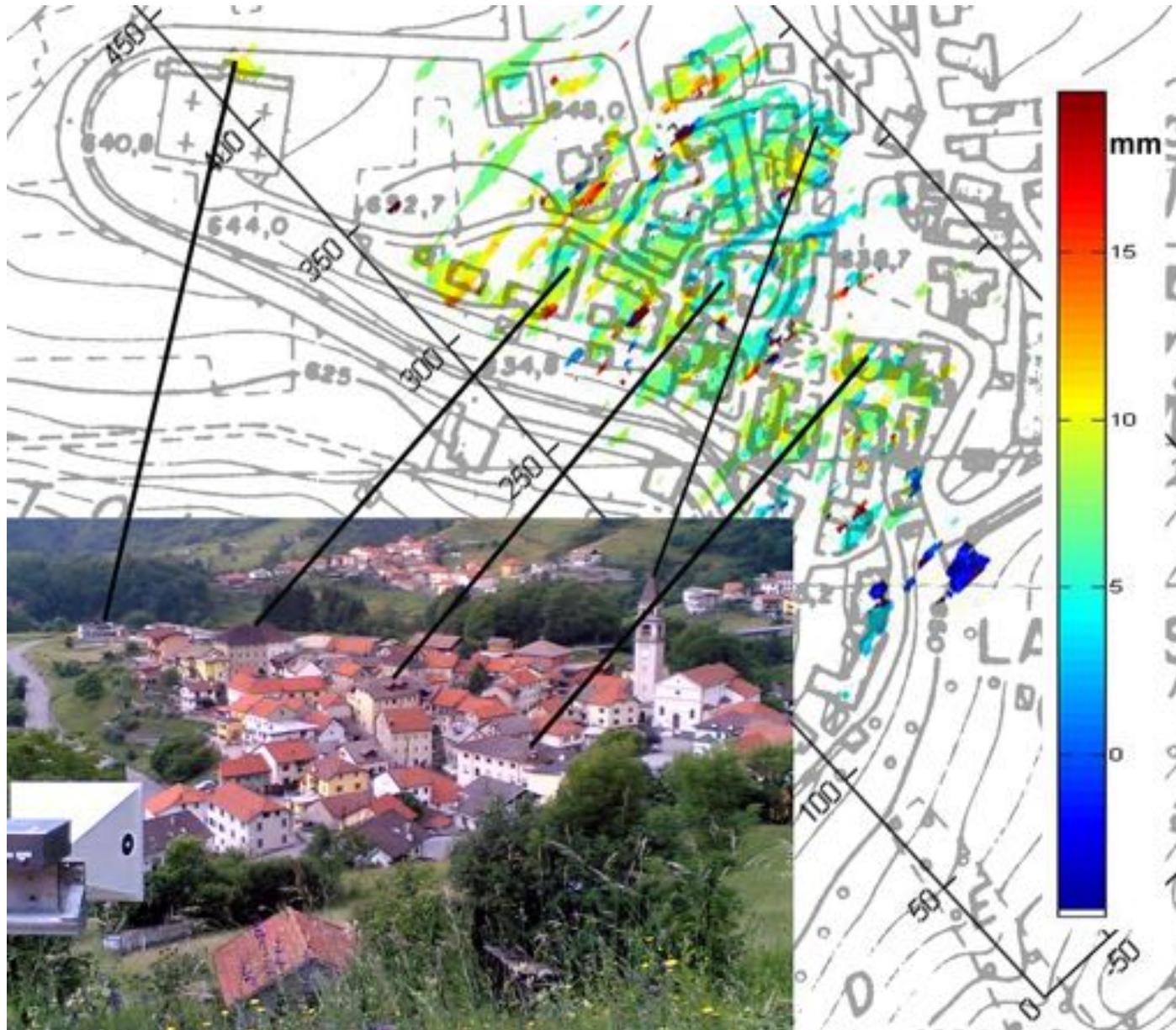


December 2005 – June 2006



Lamosano, Belluno





June 2004 – June 2005



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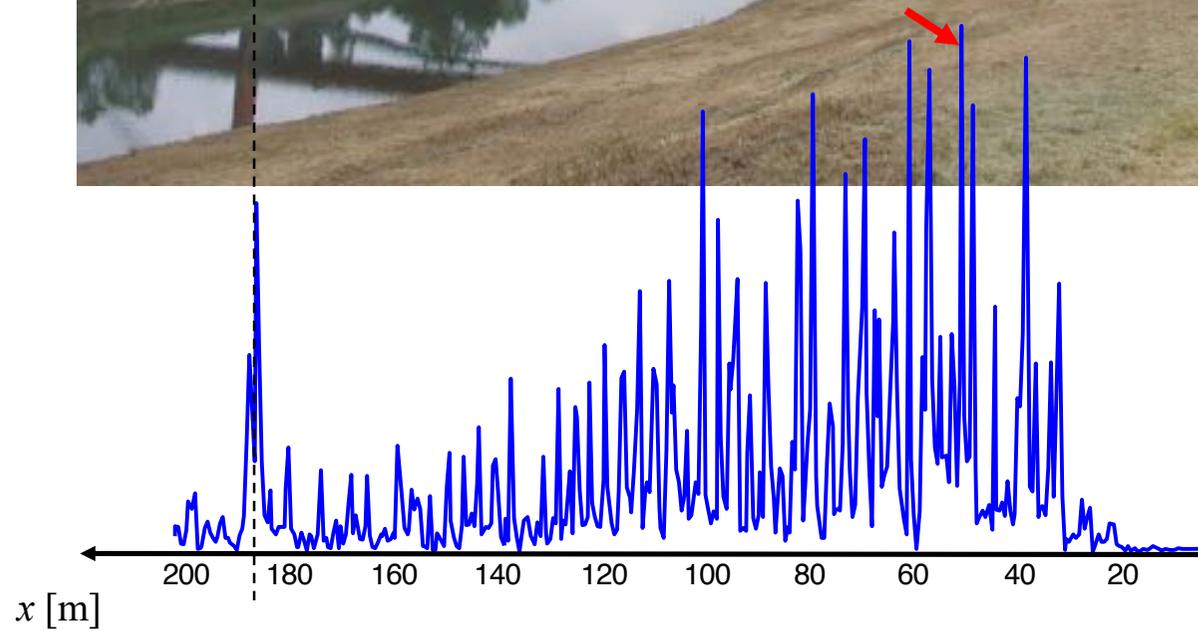


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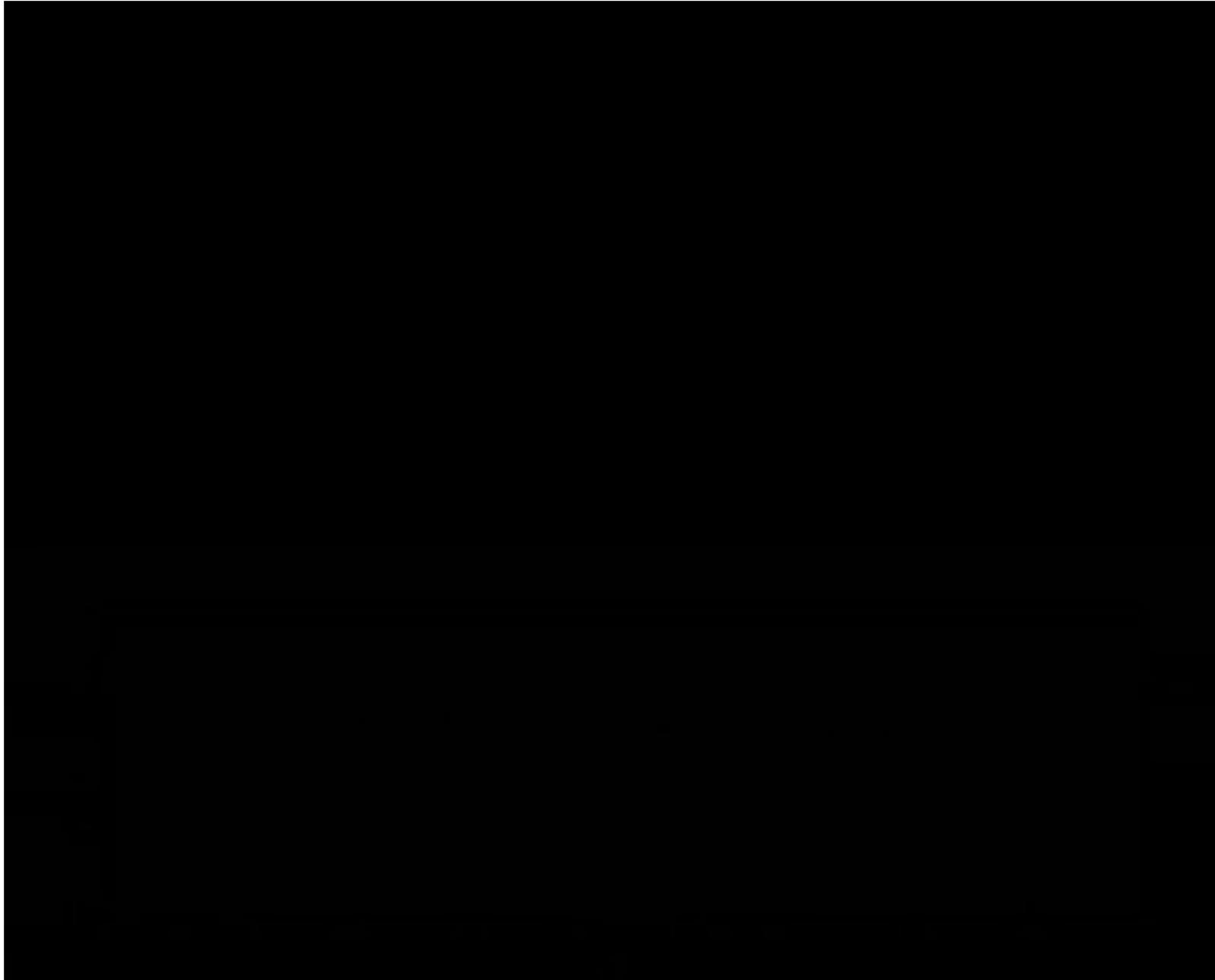


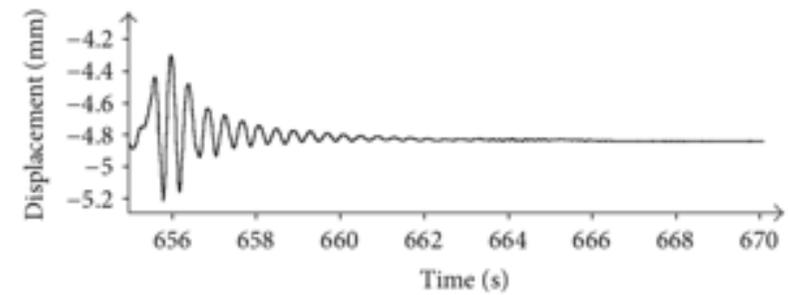
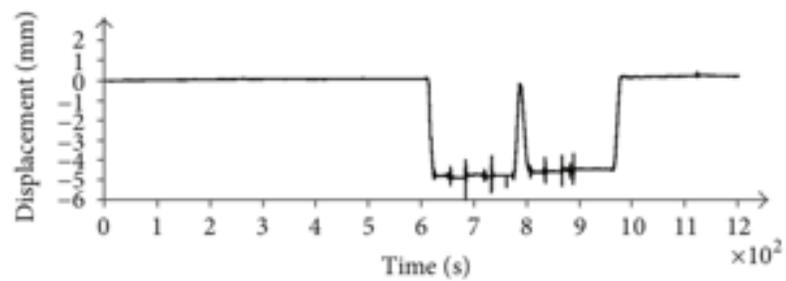


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Tramway bridge, Scandicci, Italy

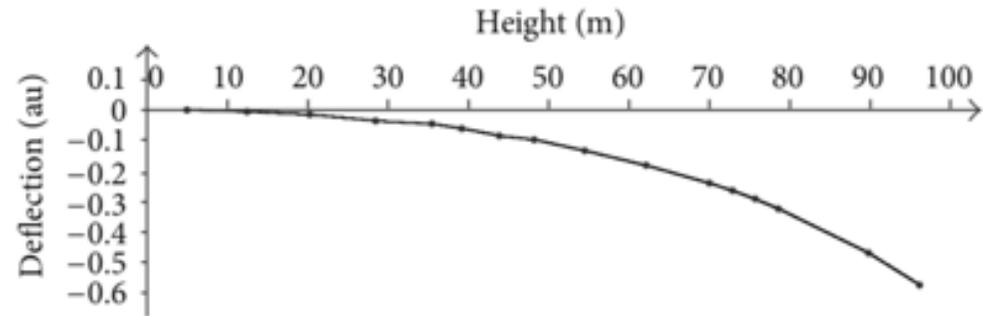


FIGURE 9: Modal shape at 0.43 Hz.

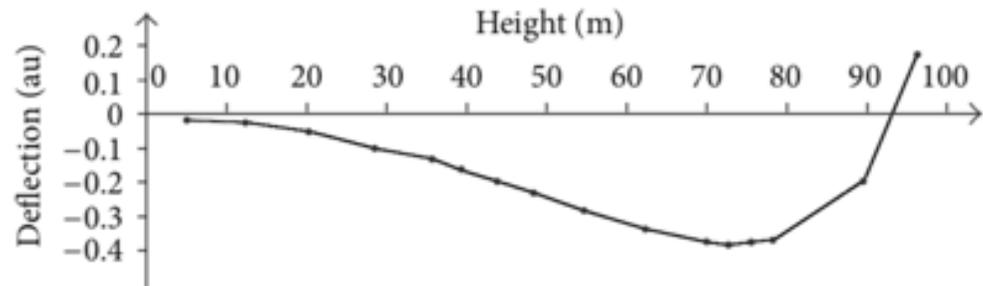
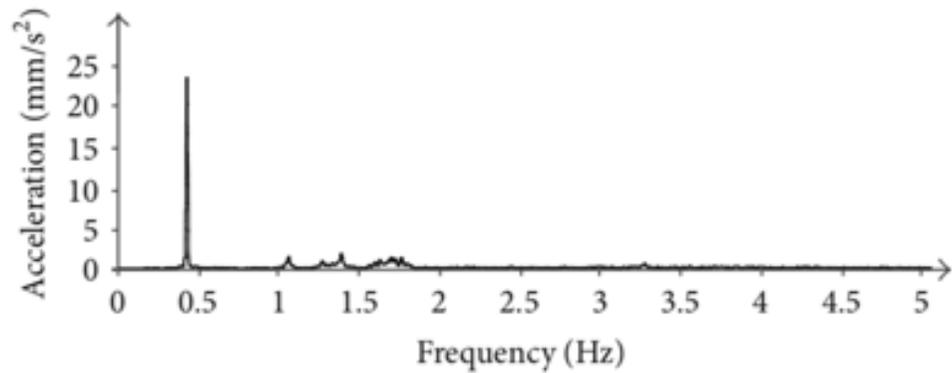


FIGURE 10: Modal shape at 1.06 Hz.



Arnolfo's Tower, Florence

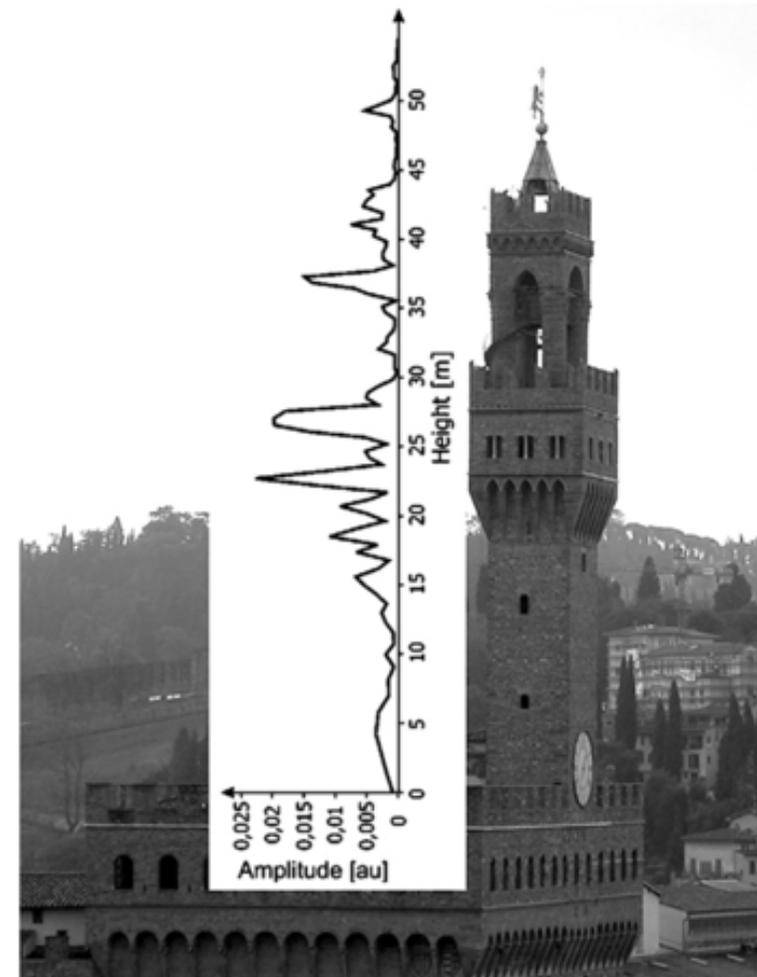


Fig. 9. Profile of radar echoes versus Arnolfo's tower height (east side) superimposed onto the picture of the tower.

Arnolfo's Tower

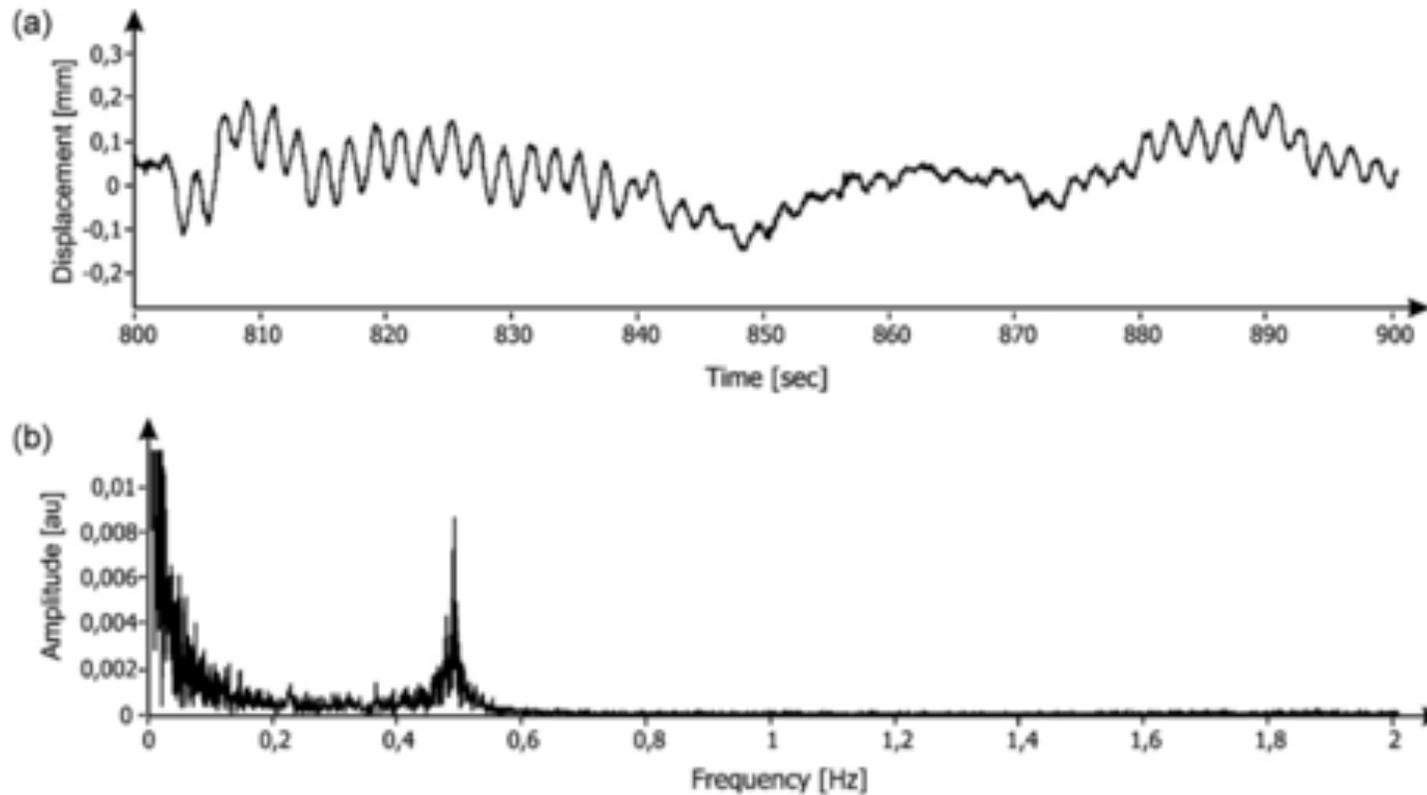


Fig. 10. Arnolfo's tower oscillation detected at 23 m height, east side (a); and its frequency analysis (b).

Tower of Pisa

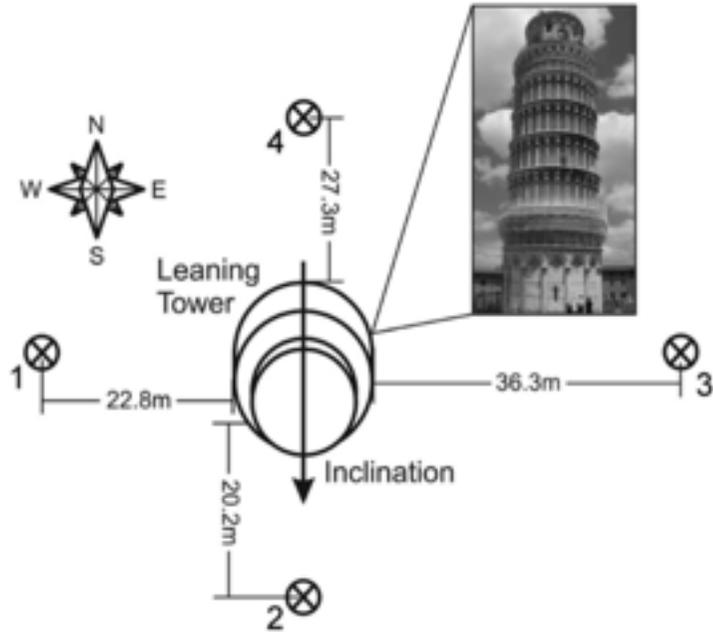


Fig. 2. Top view of the four different sensor's positions around the Tower and a picture of the leaning Tower of Pisa.

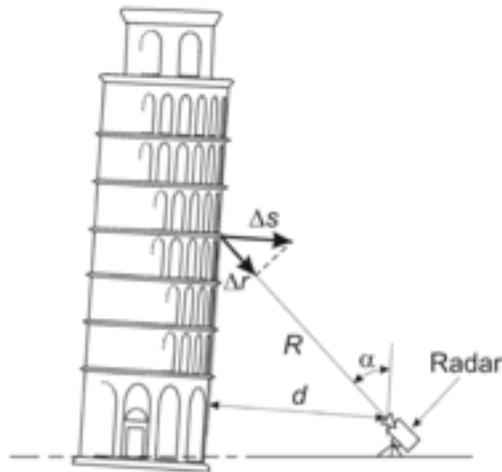


Fig. 3. Orientation of the radar antennas and geometric relationship between the assumed tower displacement Δs and the range shift Δr along the radar line of sight.

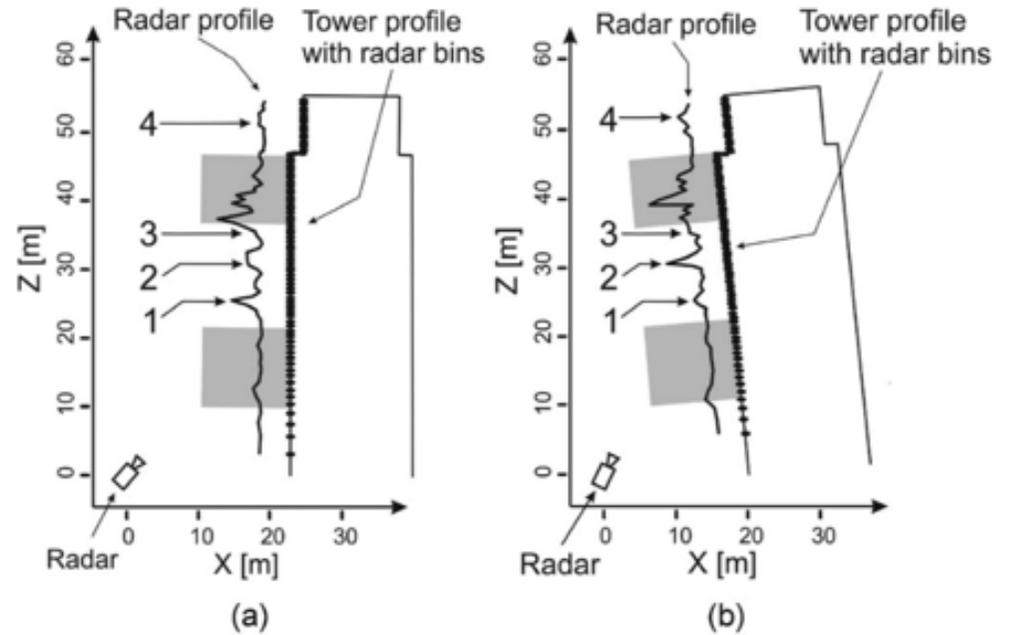


Fig. 4. Radar profiles from positions (a) 1 and (b) 2, projected onto the Tower side; the grayed zones indicate the position of maintenance-work apparatus. The pixels from 1 to 4 of positions 1 and 2 are selected for FDD analysis.

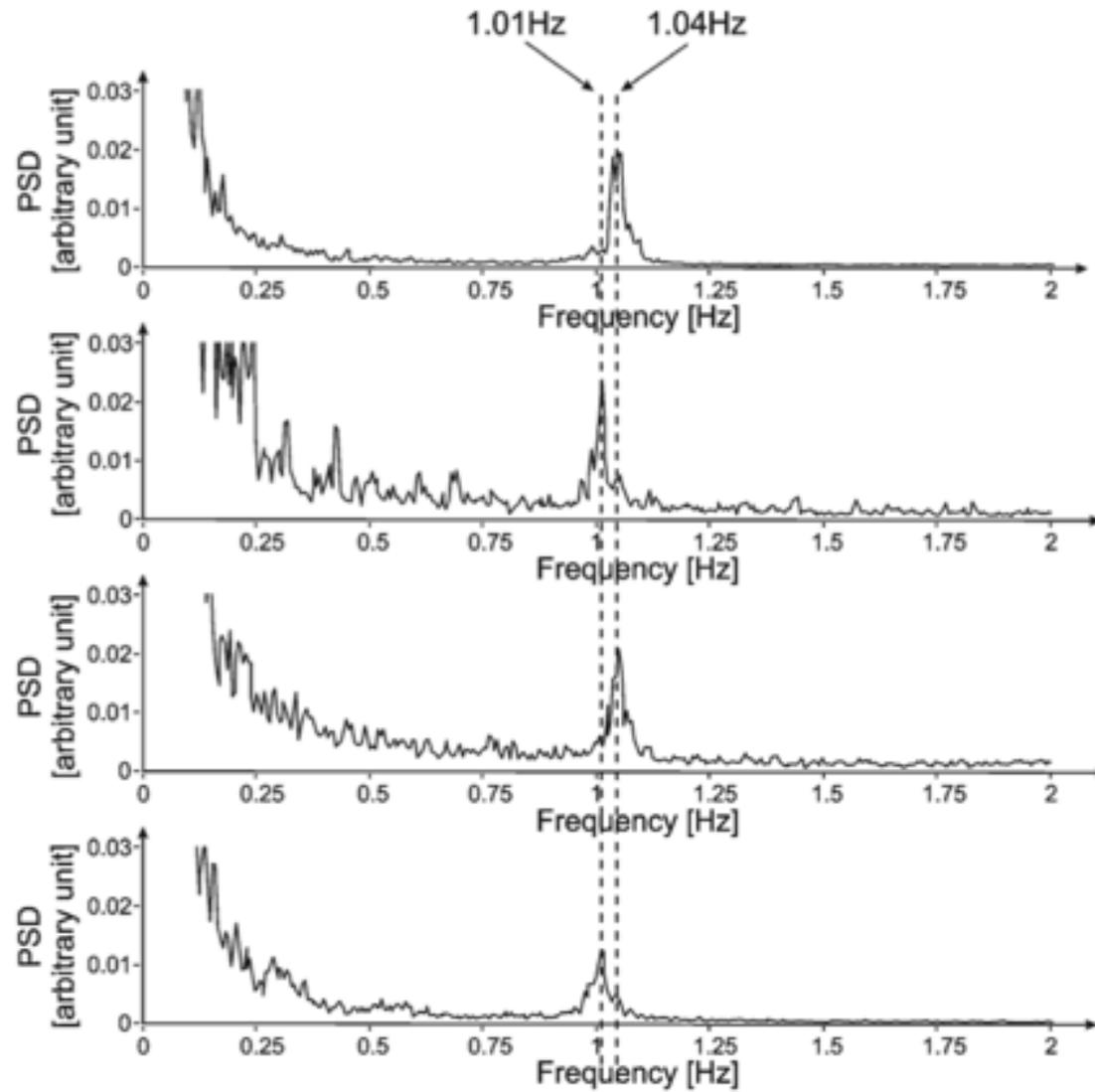
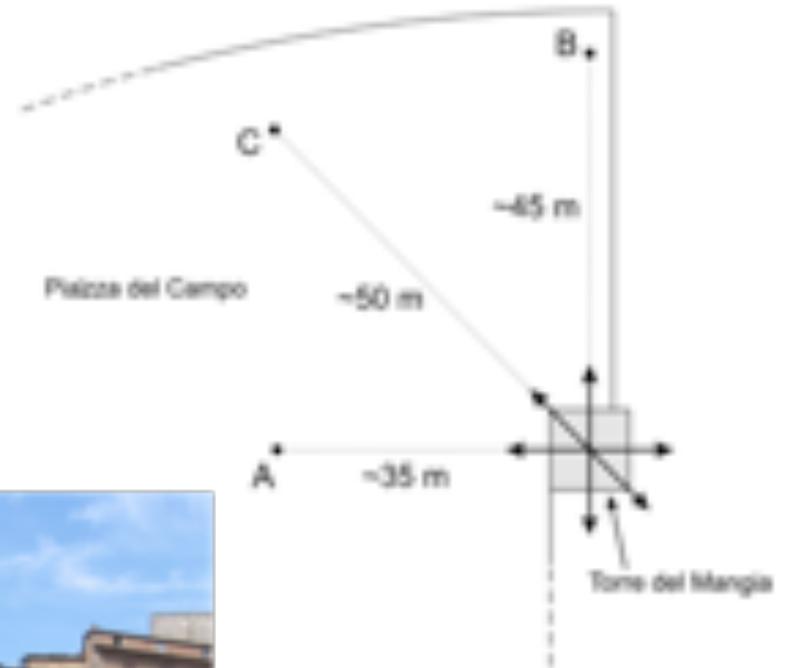


Fig. 6. PSD functions of displacements detected from positions 1, 2, 3, and 4, respectively.

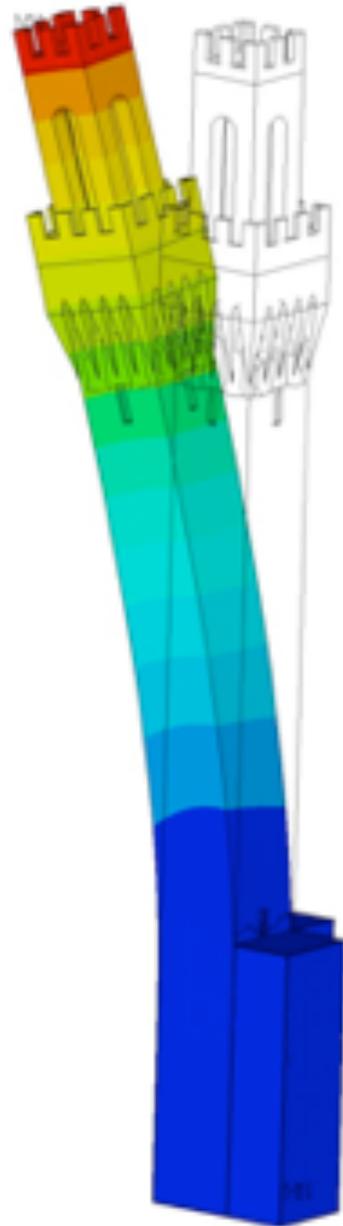


Mangia's Tower, Siena





0.35 Hz



0.37Hz





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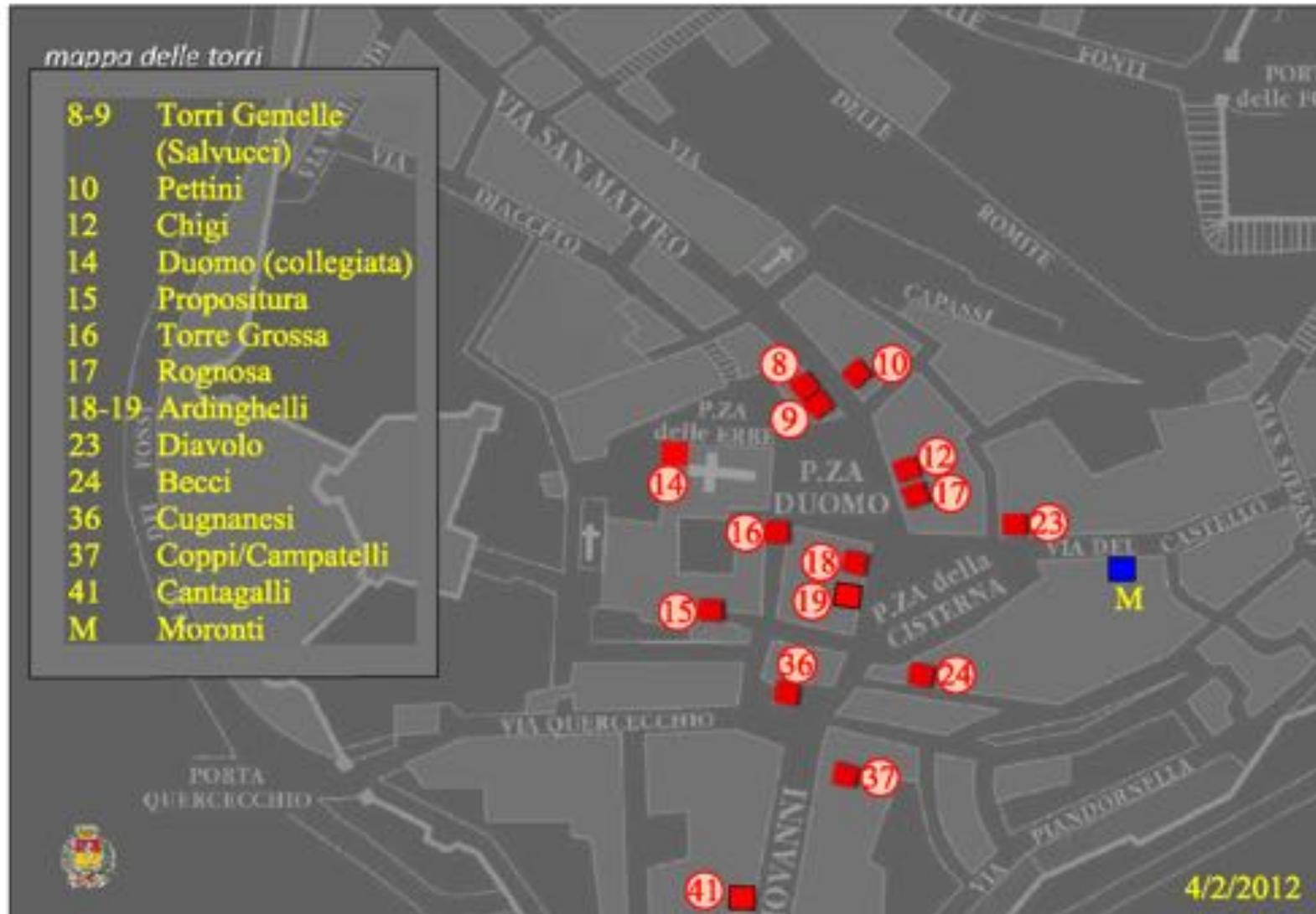
San Gimignano, Italy

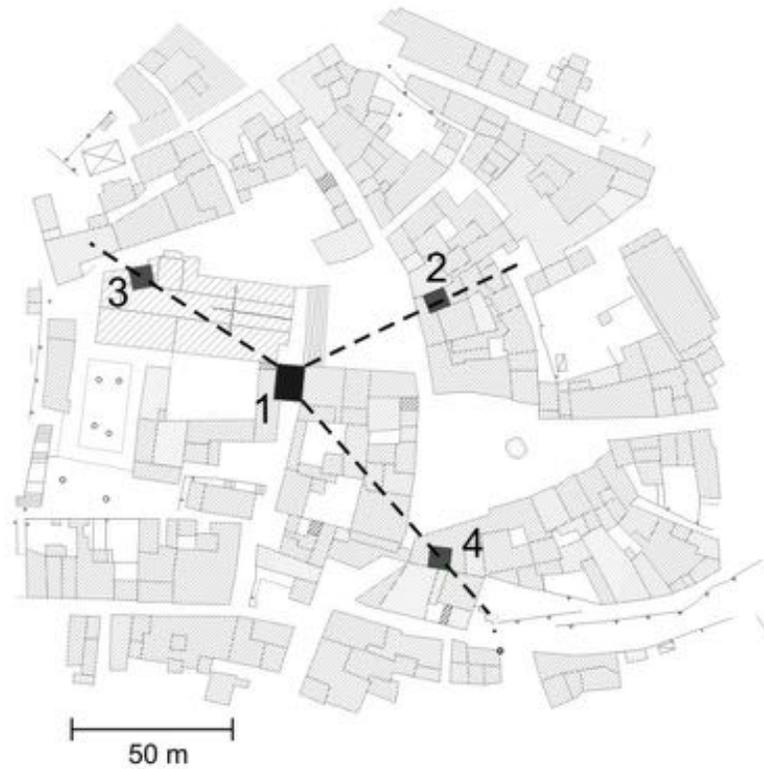


REGIONE
TOSCANA

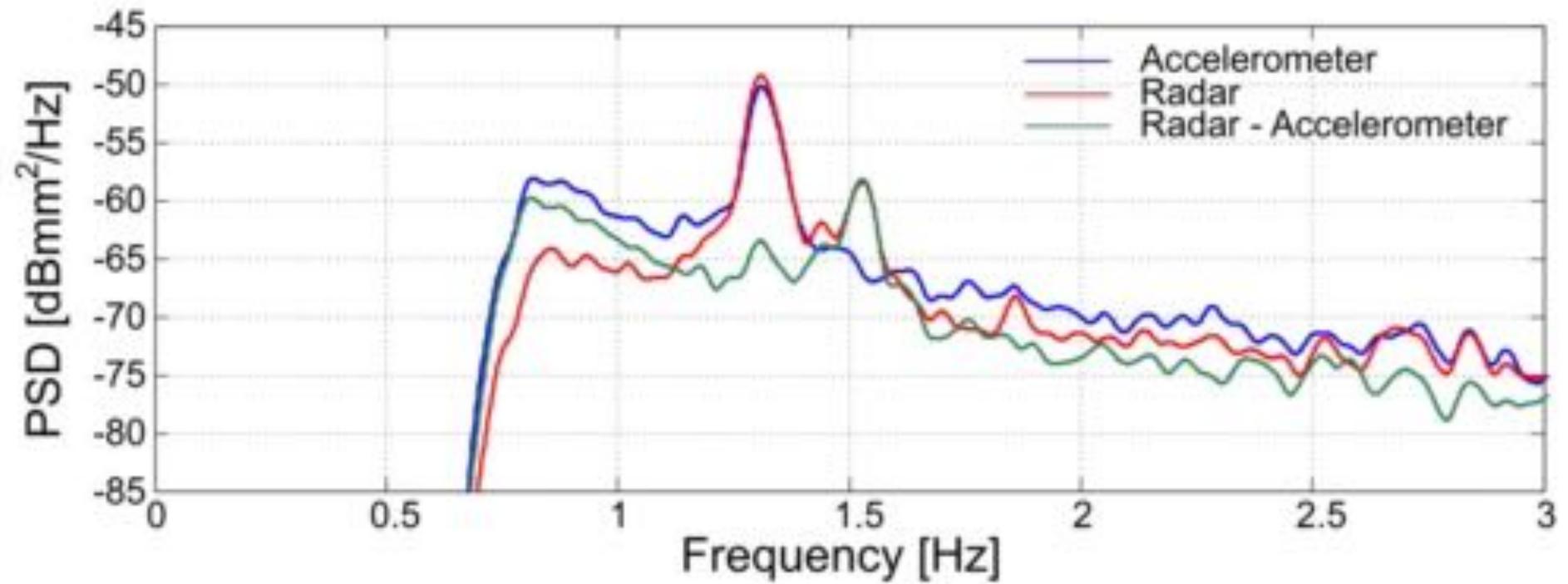


FAS
Fondo Aree
Sottoutilizzate
2007-2013





Radar sulla sommità della Torre Grossa
(torre 1) che punta la Torre Rognosa
(torre 2)



David by Michelangelo, Accademia Museum, Florence, Italy

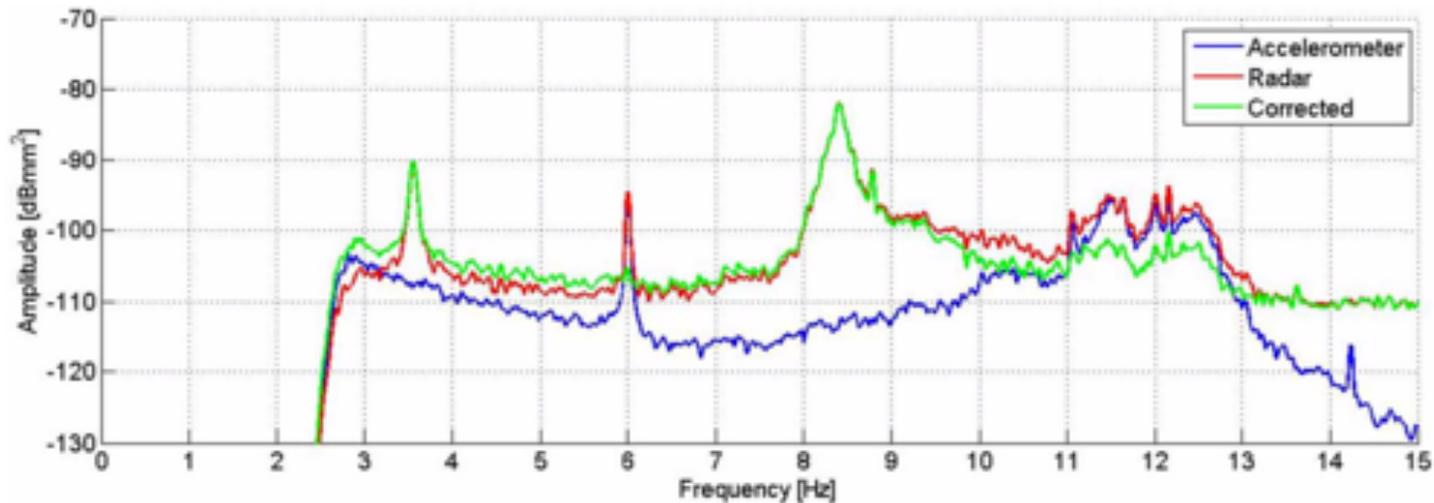
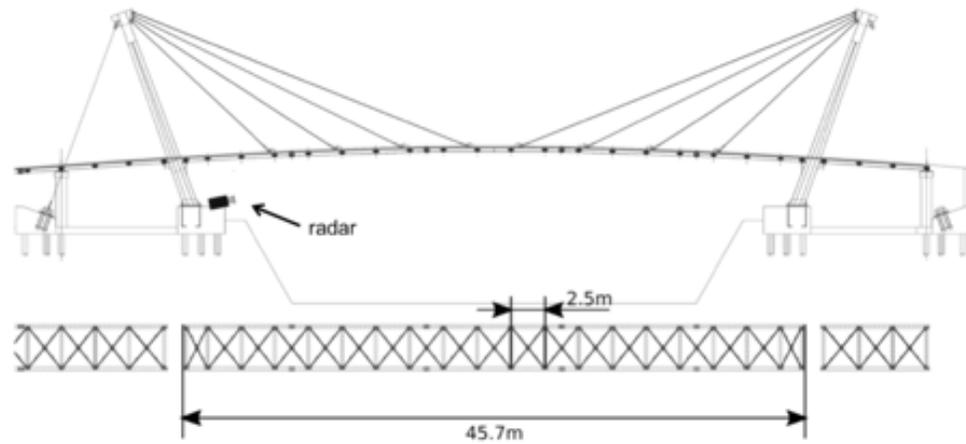


Fig 5. PS of the displacement measured by the radar (red) and the accelerometer (blue), and the result of the correction (green). The peak at 6 Hz disappears in the corrected signal, and the signals between 10.5 Hz and 12.5 Hz are attenuated.

Table 1. Summary of the experimental results.

Lateral position (without visitors)		Frontal position (with visitors)		Lateral position (with visitors)	
Frequency [Hz]	Power [dBmm ²]	Frequency [Hz]	Power [dBmm ²]	Frequency [Hz]	Power [dBmm ²]
3.55	-80	3.55	-72.5	3.54	-76
-	-	5.12	-	-	-
6.00	-	5.94	-	5.92	-
8.40	-69	8.40	-77	8.38	-69
8.79	-	8.79	-	-	-
10.5–12.5	-	11.05–11.88	-	10.5–12.5	-

Interferometric MIMO radar



Bistatic Interferometric radar

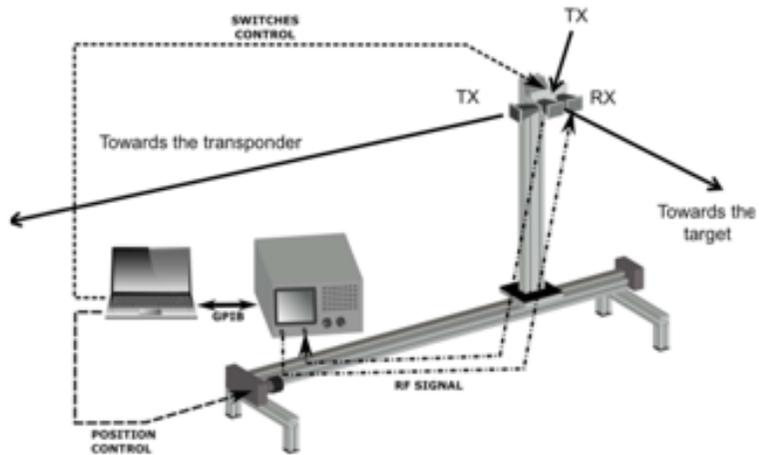
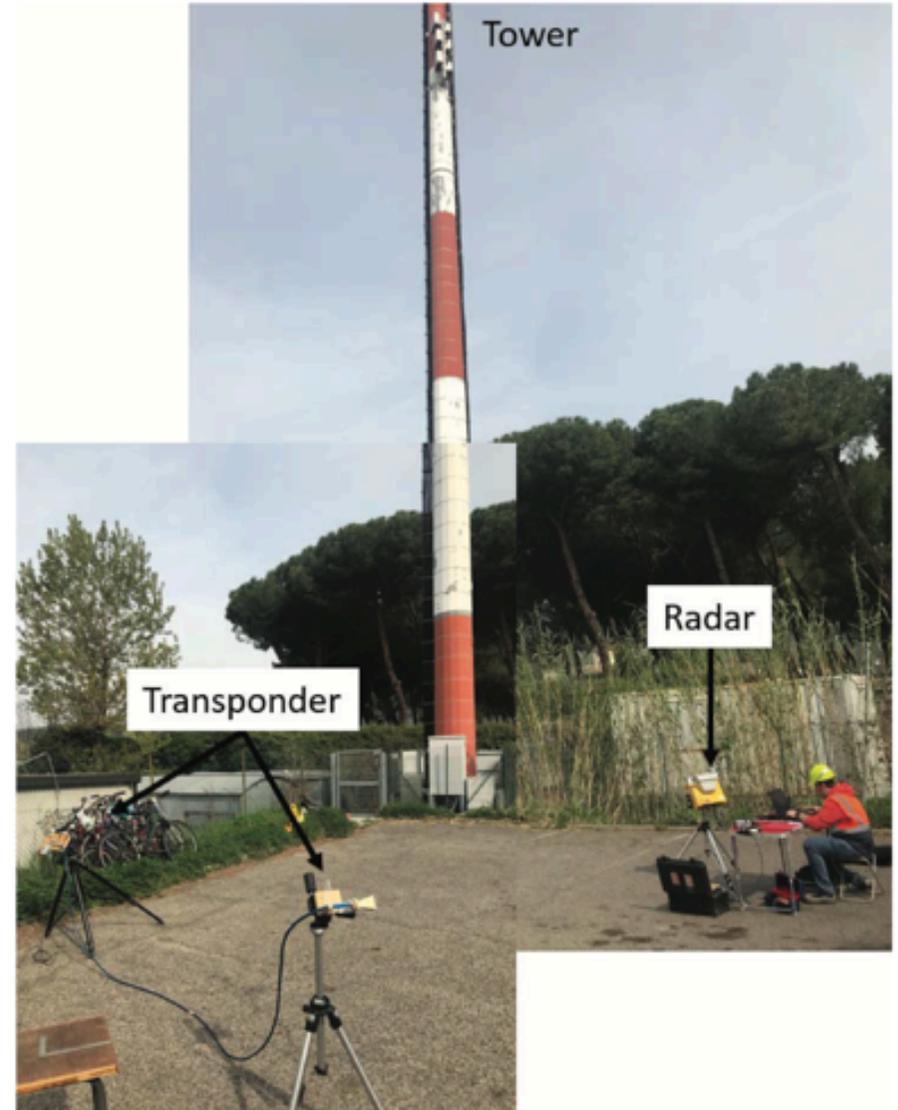
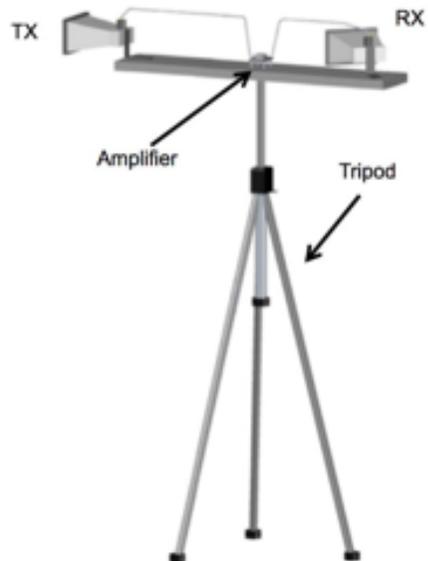


Fig. 4. Radar prototype.





Ground-Based Synthetic Aperture Radar (GBSAR)

**Ground Penetrating
Radar (GPR)**

**Environmental,
Industrial and
Biomedical Sensors**



No-contact High frequency GPR (Ground Penetrating Radar)

Step frequency Continuous Wave (SFCW)

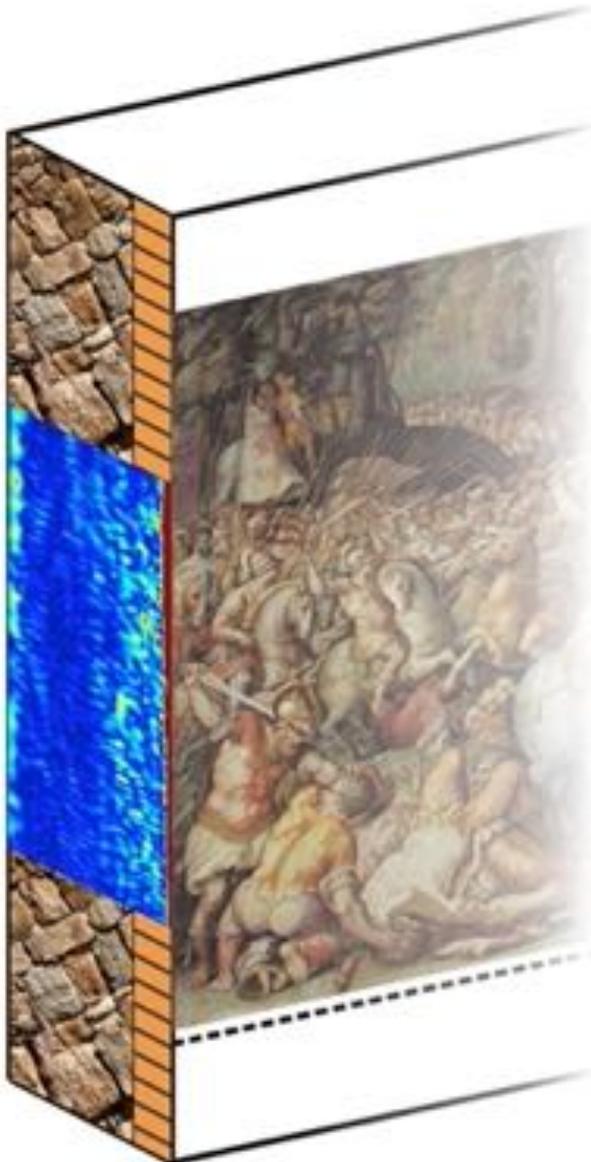
Band: 8 GHz – 12 GHz

Dynamic range: 100 dB,

Transmitted power: 0 dBm

Antennas: 2 horns





West wall



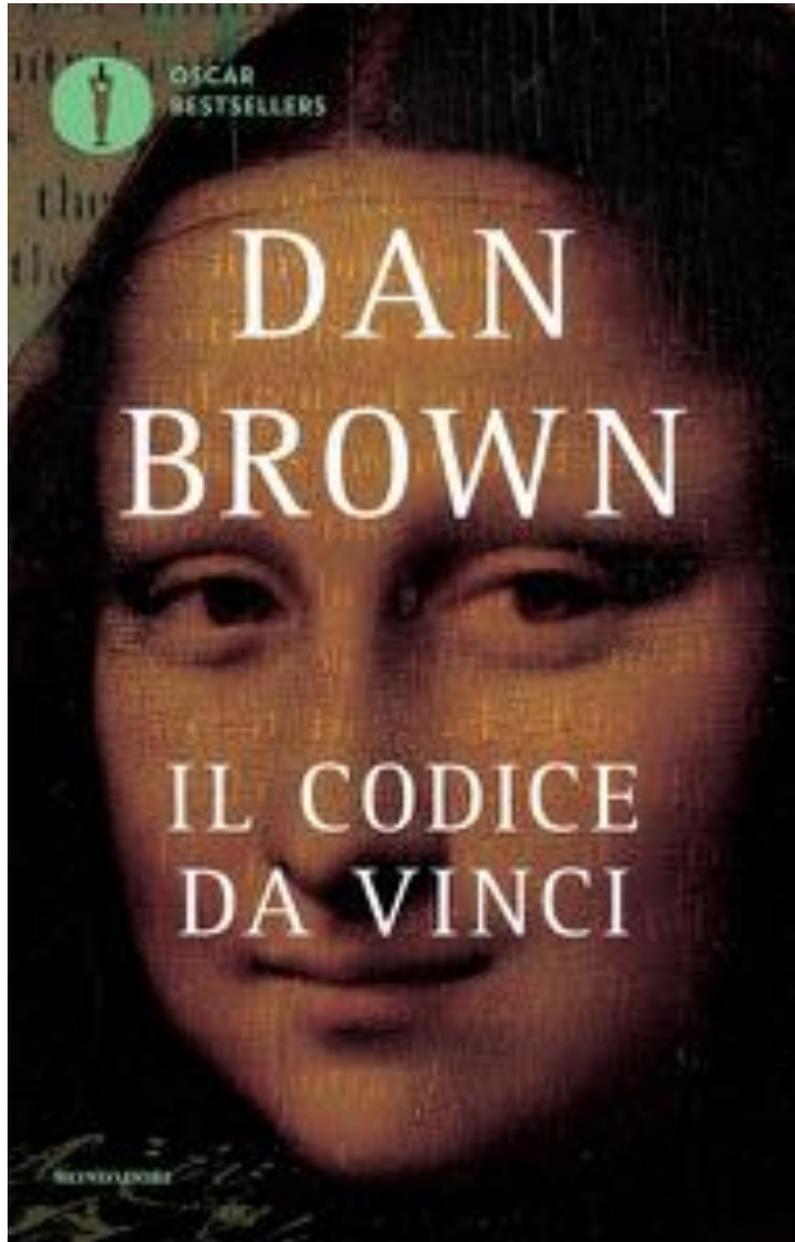
East wall



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Dan Brown, 2003



Firenze, 2007

Il dipinto "La battaglia di Anghiari" forse è nascosto a Firenze, sotto un'altra opera di Palazzo Vecchio. È polemica fra gli studiosi di San Diego e l'esperta Cecilia Frosinini: "Così si danneggia l'affresco attuale"

La caccia a Leonardo che minaccia il Vasari

**MICHELE BOCCI
LAURA MONTANARI**

FIRENZE
La caccia alla Battaglia di Anghiari di Leonardo da Vinci parte con un duello fra studiosi e rallenta subito la sua marcia. L'affresco più misterioso della storia dell'arte italiana potrebbe essere nascosto nell'intercapedine di

Verranno fatti sette, otto buchi per capire se davvero dietro c'è l'affresco del Maestro

un muro del Salone dei Cinquecento di Palazzo Vecchio sotto un'opera del Vasari, "La battaglia di Scannagallo". Per cercarlo un team di ricercatori guidato da Maurizio Seracini, dell'Università di San Diego, avrebbe dovuto iniziare due

Frosinini è tutto fermo. Forse oggi si parte con il primo esame endoscopico. Palazzo Vecchio assicura che non ci sono rischi. Il ministero, interpellato dalla soprintendente fiorentina Cristina Acidini, ha dato il suo ok informale all'operazione, fortemente voluta dal sindaco Matteo Renzi, che è stato anche negli Usa per prendere accordi con il National Geographic. In quell'occasione si decise di abbandonare

l'idea di usare una macchina a raggi gamma per "guardare" dietro al dipinto del Vasari, "La battaglia di Scannagallo", perché si temeva di provocare danni importanti all'affresco. La tecnica è stata sostituita con l'endoscopia, che comporta l'inserimento della micro telecamera attraverso dei fori di circa due centimetri e mezzo da fare nelle zone dell'opera più rovinate, da crepe o cedimenti della pittura. Secondo Frosinini una tecnica invasiva come l'endoscopia potrebbe non essere appropriata per un'opera rea-

lizzata nel 1563, cioè 58 anni dopo la Battaglia di Anghiari. Un parere condiviso anche da Massimiliano Pieraccini, docente di Tecnica dei beni culturali a Firenze che nel 2003 mise a punto il radar utilizzato dallo stesso Seracini per esaminare il dipinto del Vasari. Fu proprio quel radar a scoprire nella parete una discontinuità, qualcosa che poteva essere compatibile con una intercapedine. L'intercapedine che nasconde l'opera leonardiana?

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ORFEUS GPR (Ground Penetrating Radar)

Step frequency Continuous Wave (SFCW)

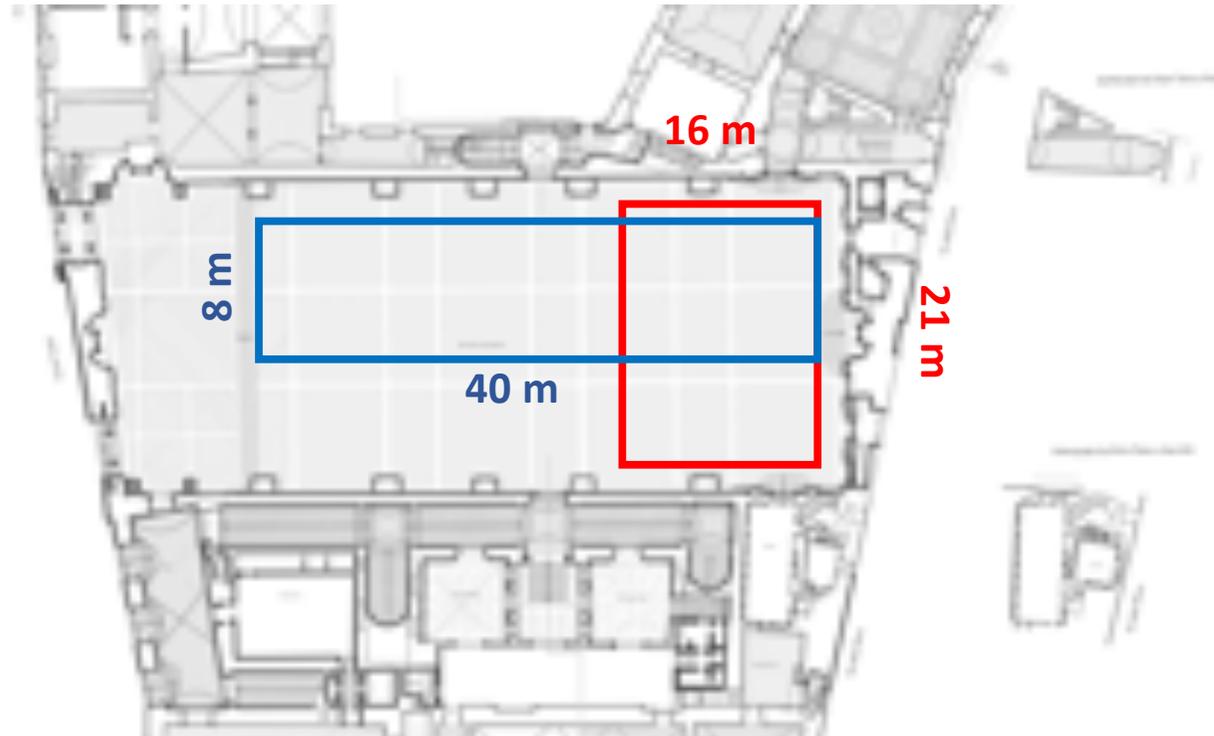
Band: 100 MHz – 1 GHz

Dynamic range: 100 dB

Scan speed: 200 scan/s

Antennas: 2 co-polarized loaded bowties







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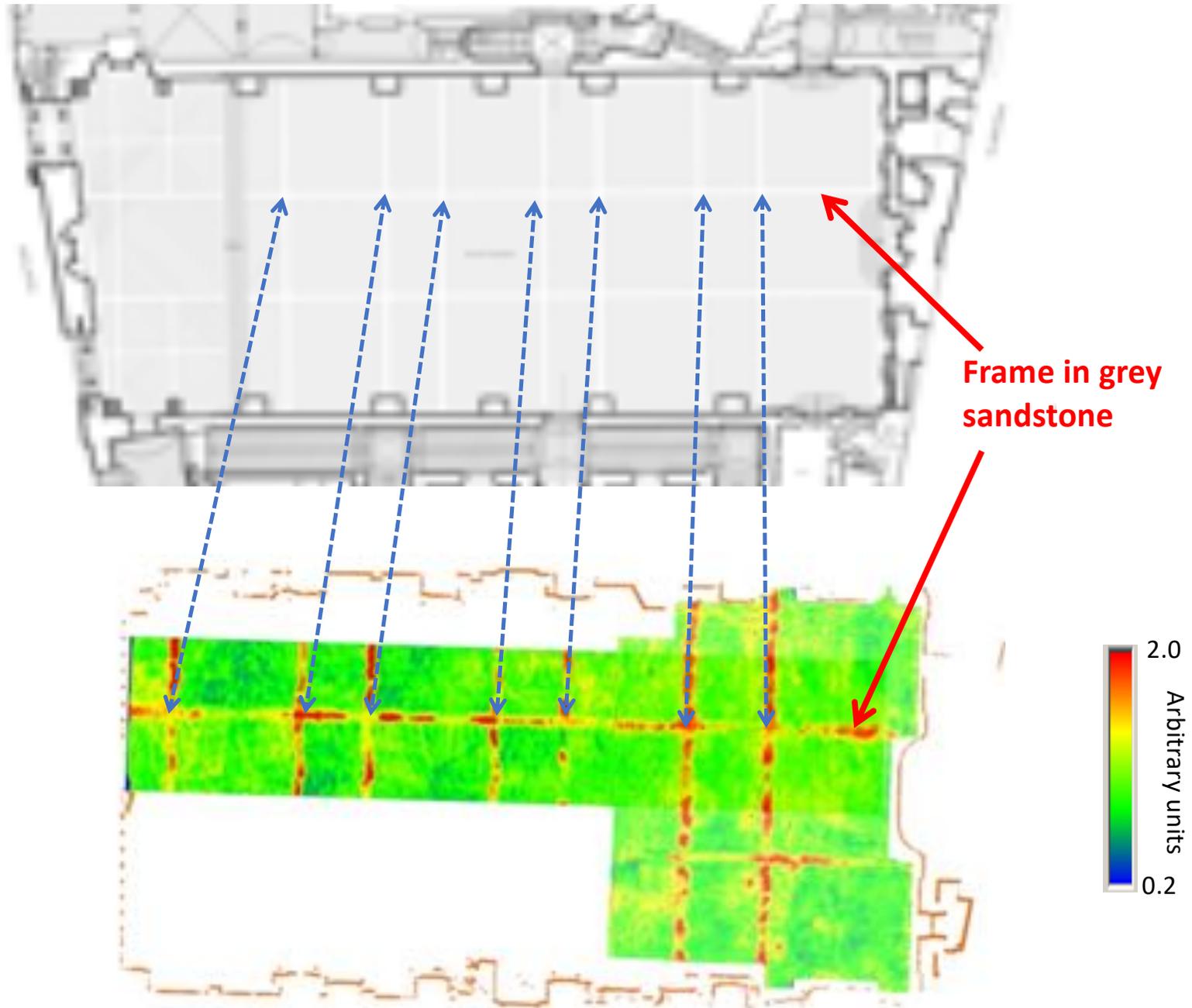
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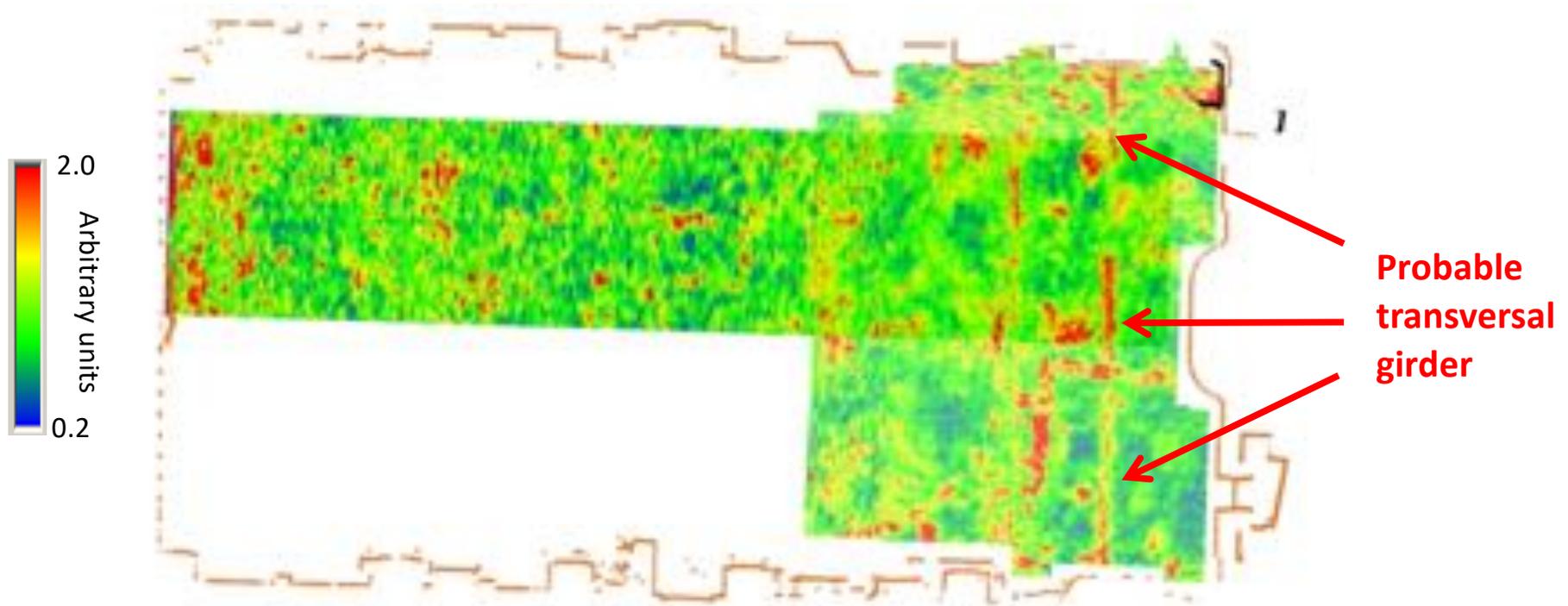
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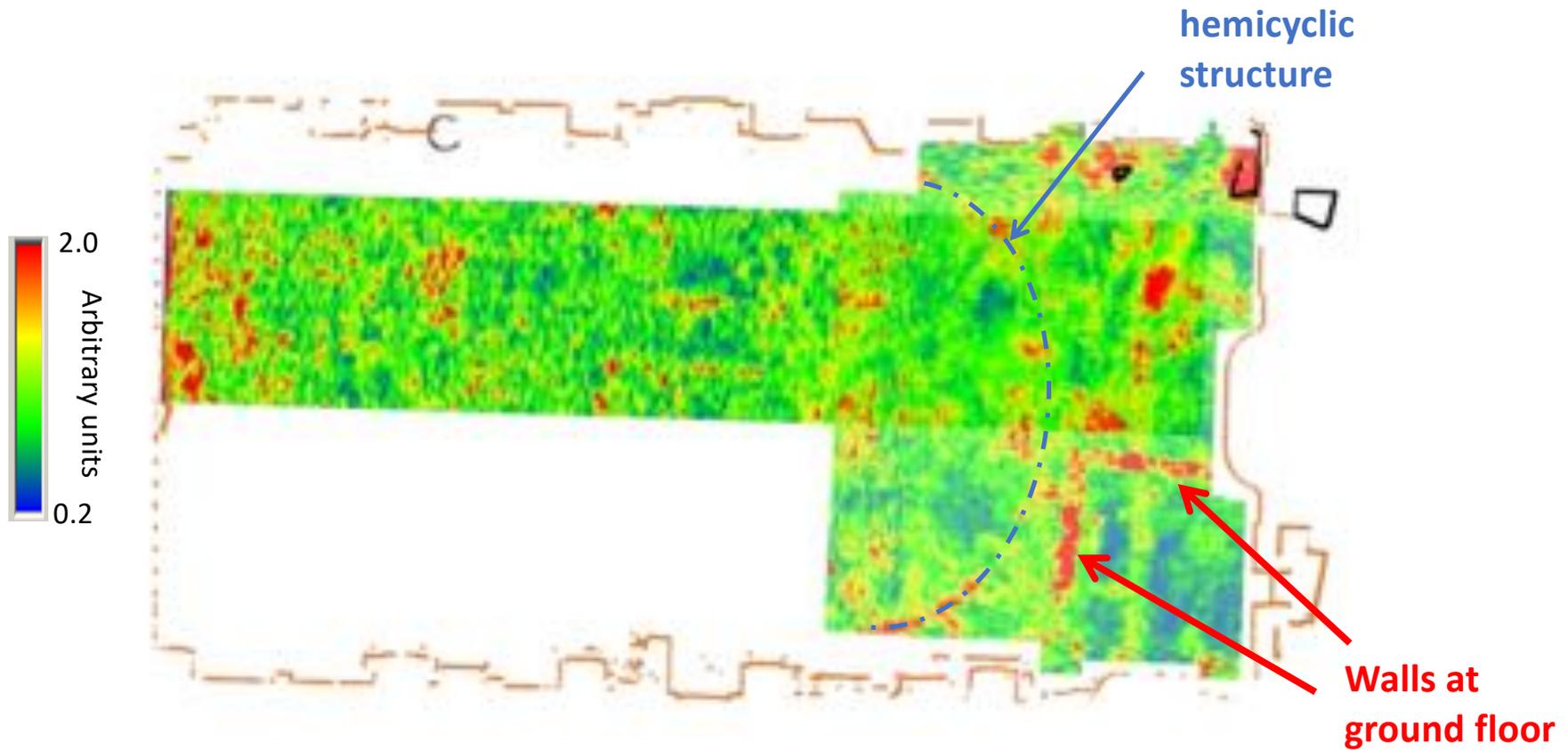


18 cm
below the
floor





44 cm below the floor



54 cm below the floor



hemicycle



1865-1870



Ground-Based Synthetic Aperture Radar (GBSAR)

Ground Penetrating Radar (GPR)

Environmental, Industrial and Biomedical Sensors