NHAZCA SRL
NATURAL HAZARDS CONTROL AND ASSESSMENTS

SAPIENZA
UNIVERSITÀ DI ROMA

SMART Geotechnical Asset Management for Transport Systems

Mazzanti Paolo

Ground Related Risk to Transportation infrastructure Conference

London, UK, 26-27 October 2017

SMART?

"SMART" (adj.): equipped with, using, or containing electronic control devices

Smart….car

Smart….phone

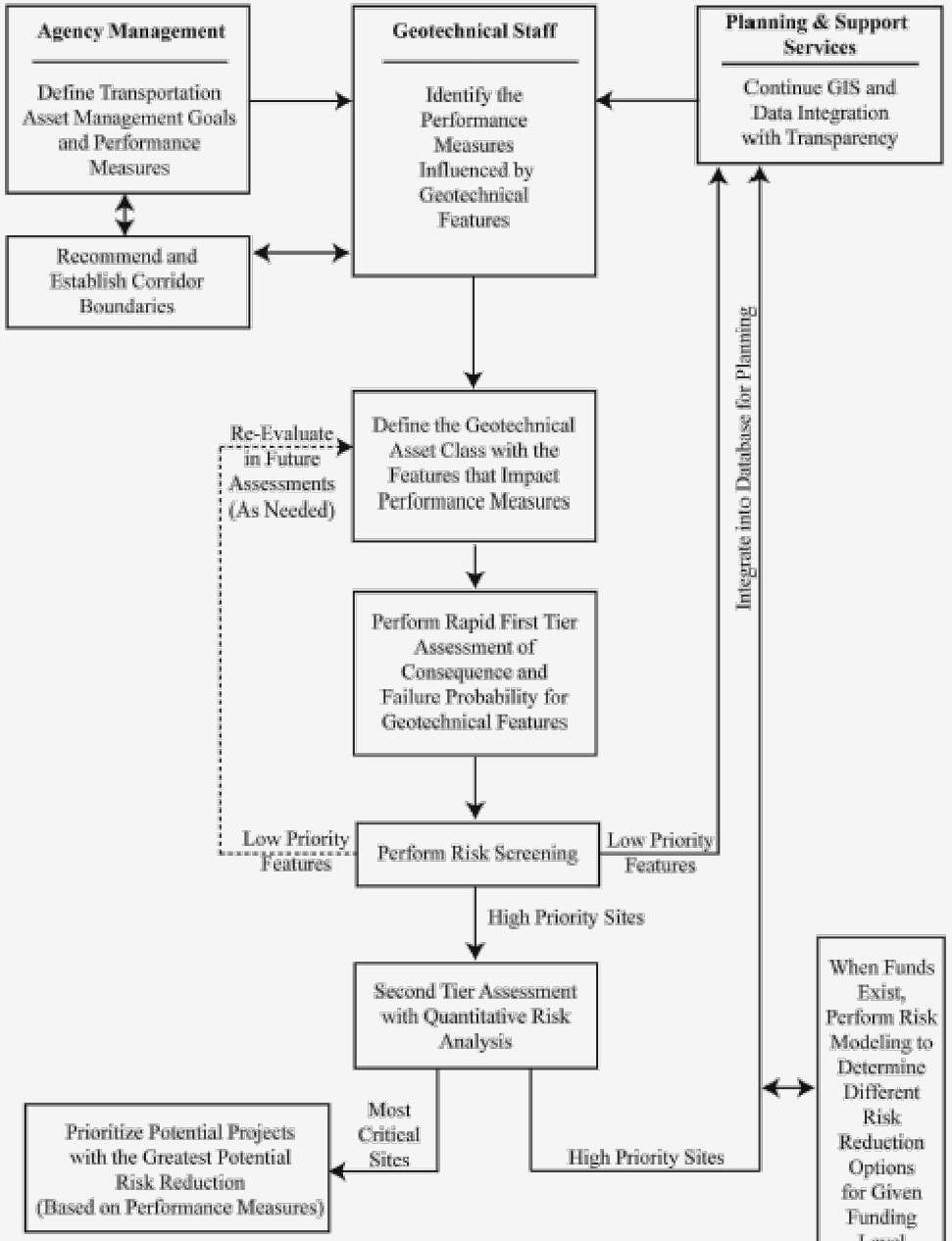
Smart….house

Smart….GAM?

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Geotechnical Assets Management

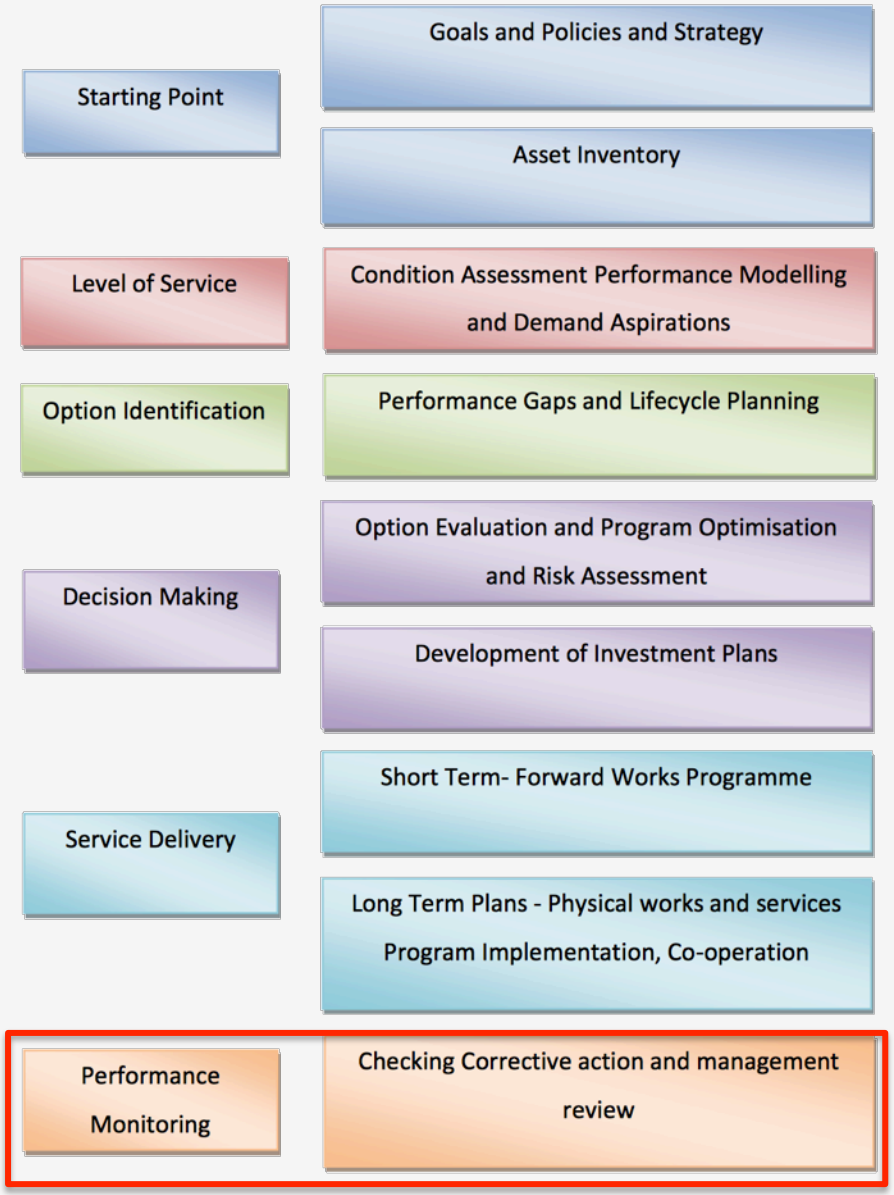


USDOT, 2013

NHAZCA SRL

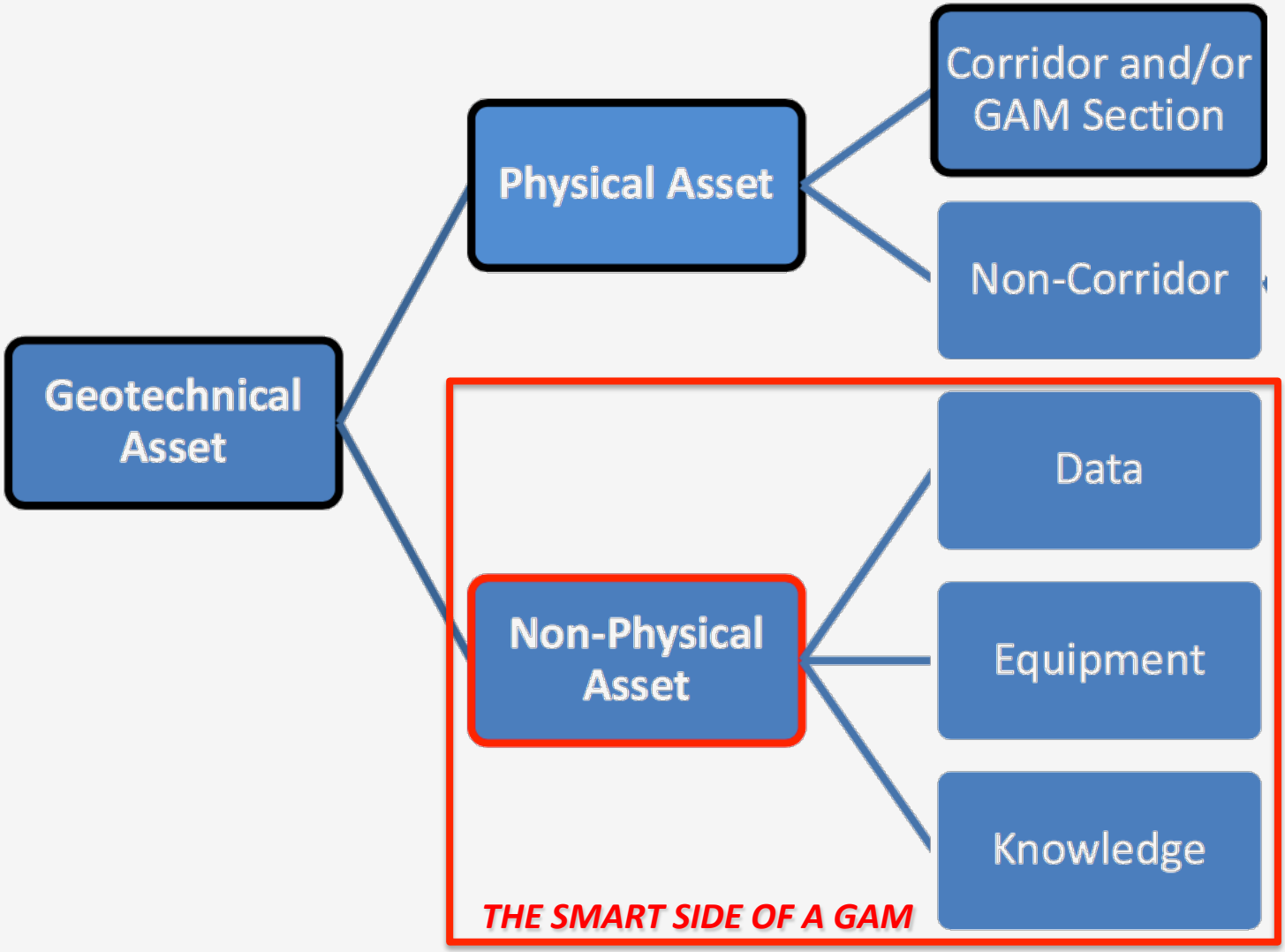
SAPIENZA UNIVERSITÀ DI ROMA

Geotechnical Assets Management



JANVI PANKAJ SHAH, 2014. **Resilient Geotechnical Asset Management**, PhD Thesis, Univ. Birmingham.

"SMART" Geotechnical Assets Management



DATA & KNOWLEDGE ARE CONTINUOSLY UPDATED BY USING SUITABLE MONITORING EQUIPMENT!

NHAZCA SRL

S.A. Anderson, V.R. Schaefer, S.C. Nichols, 2016. **Taxonomy for Geotechnical Assets, Elements, and Features**

SAPIENZA UNIVERSITÀ DI ROMA

The leitmotif

Application of New Sensing and Monitoring Technologies to the Assessment and Control of Natural Hazards and Civil Structures and Infrastructures

THE OBSERVATIONAL METHOD!

Karl Terzaghi 1937

Settlement of structures in Europe and methods of observations. American Society of Civil Engineers. Proceedings, Vol. 63, pp. 1358-1374

Ralph Peck 1969

Advantages and limitations of the observational method in applied soil mechanics. Géotechnique, 19(2), 171-187

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

The need of geotechnical measurement equipment….
….60 years of technological "r"evolution

1950s	1960s	1970s	1980s	1990s	2000s	2010s
Stressmeter			Continuous Monitoring			
Levelling						
Theodolite			US standards	Early Warning Monitoring	European Standards	Digital Image Correlation
Extensometer	Vibration Monitoring		Total Station	GSM data transmission	Laser Scanner	Drones
Piezometer	Submarine Monitoring	Data-logger	Time Domain Reflectometry	Fibre Optics technology	Multi-parametric borehole systems	Web based data management
Load cell	Inclinometer	Laser distance-meter	In place inclinometers	GNSS Technology	Interferometric Radar technology	Wireless monitoring

NHAZCA SRL

Mazzanti P., 2017. Toward transportation asset management: what is the role of geotechnical monitoring? Journal of Civil Structural Health Monitoring. DOI 10.1007/s13349-017-0249-0

SAPIENZA UNIVERSITÀ DI ROMA

What we monitor…

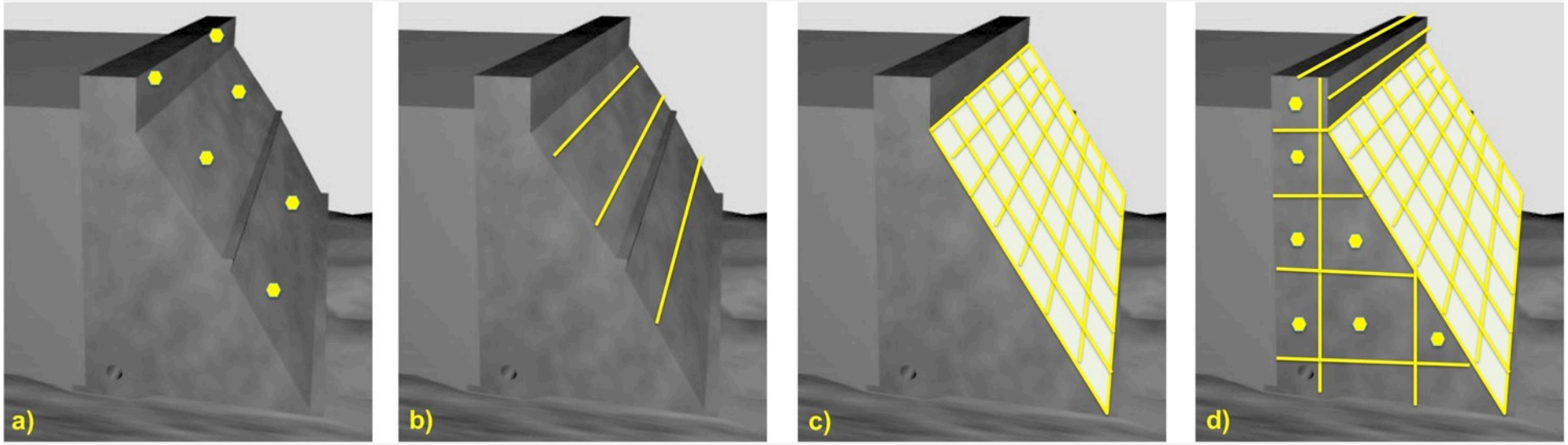
Parameters	Contact instruments	Remote instruments
Displacement (deformation)	Surface and probe tiltmeter, inclinometer, extensometer, liquid level gauge, crack gauge, TDR, fibre optic, pendulum, deflectometer, convergence gauge	GNSS, total station, optical levelling, lidar, satellite SAR interferometry, terrestrial interferometric radar, digital image correlation, photogrammetry
Vibration	Accelerometer, velocimeter, seismometer, geophone	Terrestrial interferometric radar, digital image correlation
Acoustic emission		
Groundwater pressure	Piezometer, observation well	n.a.
Stress	Earth pressure cell, stress-meter	n.a.
Load and strain	Load cell, strain gauge	n.a.
Temperature	Thermometer, thermocouple	InfraRed camera

NHAZCA SRL

Mazzanti P., 2017. Toward transportation asset management: what is the role of geotechnical monitoring? Journal of Civil Structural Health Monitoring. DOI 10.1007/s13349-017-0249-0

SAPIENZA UNIVERSITÀ DI ROMA

Where we monitor…



NHAZCA SRL

Mazzanti P., 2017. Toward transportation asset management: what is the role of geotechnical monitoring? Journal of Civil Structural Health Monitoring. DOI 10.1007/s13349-017-0249-0

SAPIENZA UNIVERSITÀ DI ROMA

Example 1: Monitoring of one Geotechnical Asset

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 1: Monitoring of one Geotechnical Asset

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 1: Monitoring of one Geotechnical Asset

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 1: Monitoring of one Geotechnical Asset

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 1: Monitoring of one Geotechnical Asset

- ✓ 2 years of monitoring whose aims are:
  - ✓ *"Knowledge" the landslide features and behaviour*
  - ✓ *"Control" the evolution of the slope during re-contruction*
  - ✓ *Re-activate the transit of the highway by "emergency monitoring"*
- ✓ Monitoring is performed by:
  - ✓ *Periodic and continuous inclinometer monitoring in some boreholes*
  - ✓ *Continuous monitoring by 3 Robotic Total Stations*
  - ✓ *Continuous monitoring by 2 Terrestrial SAR Interferometers*
  - ✓ *Data managed by a suitable web based data distribution platform*

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Example 2: Monitoring of one Geotechnical Asset

NHAZCA SRL

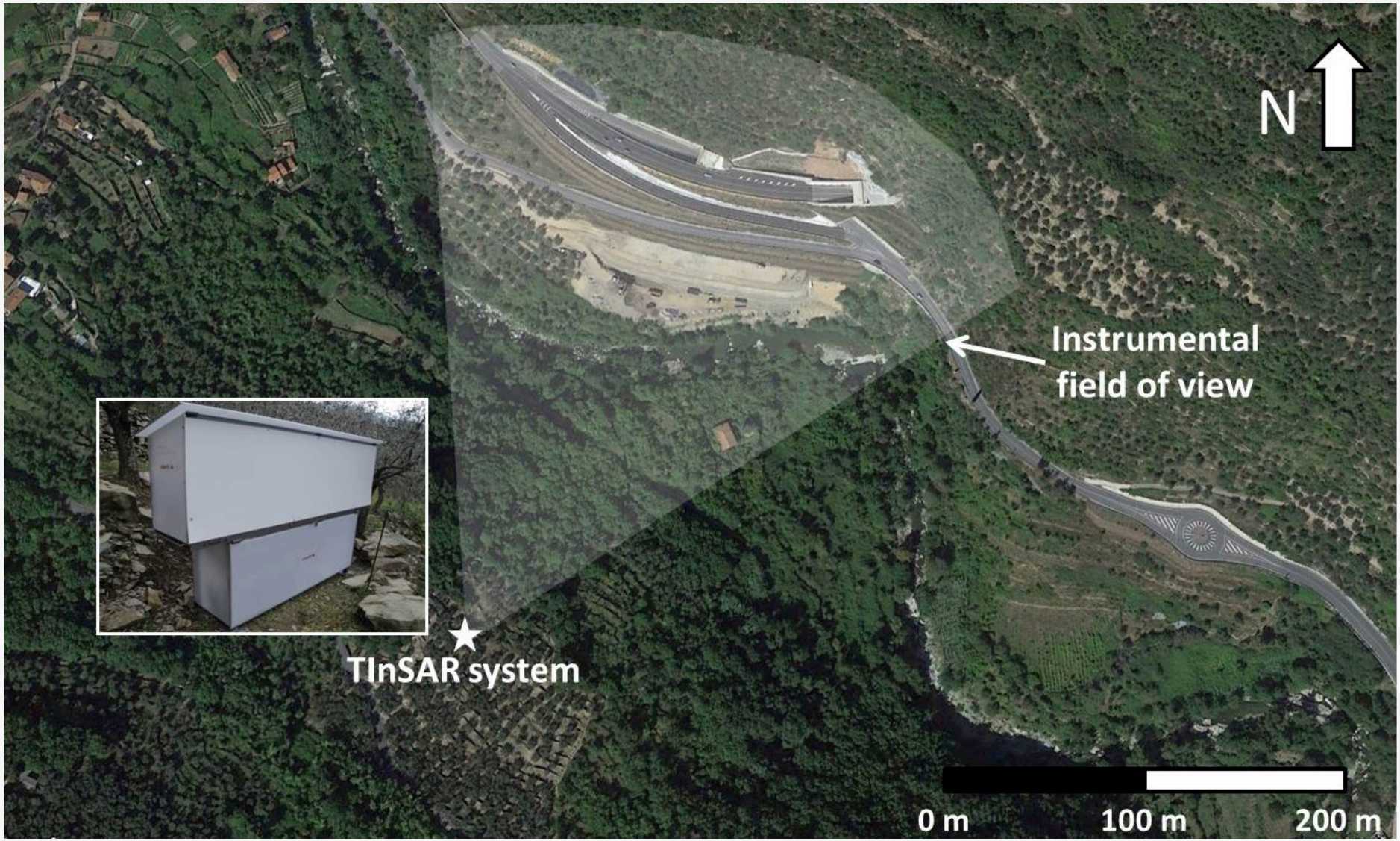
SAPIENZA
UNIVERSITÀ DI ROMA

Example 2: Monitoring of one Geotechnical Asset

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 2: Monitoring of one Geotechnical Asset

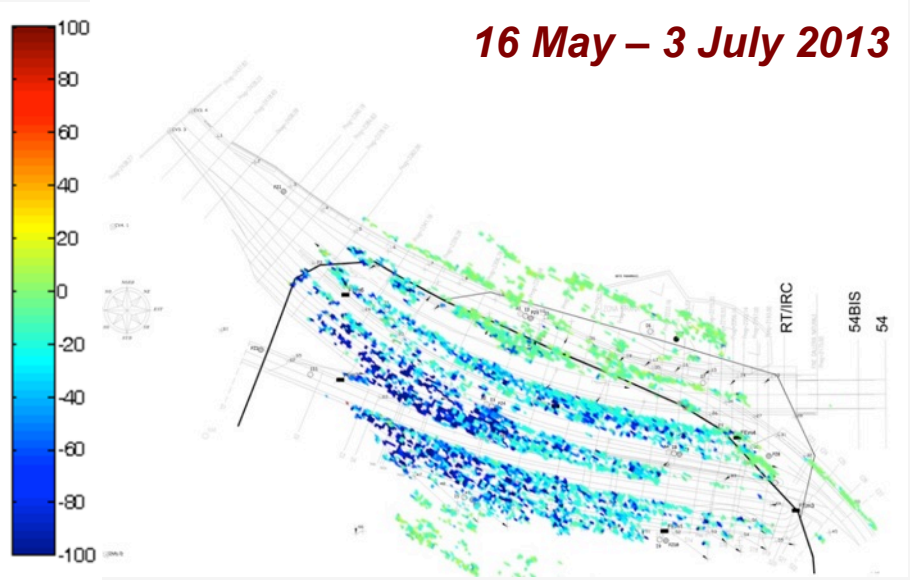


NHAZCA SRL

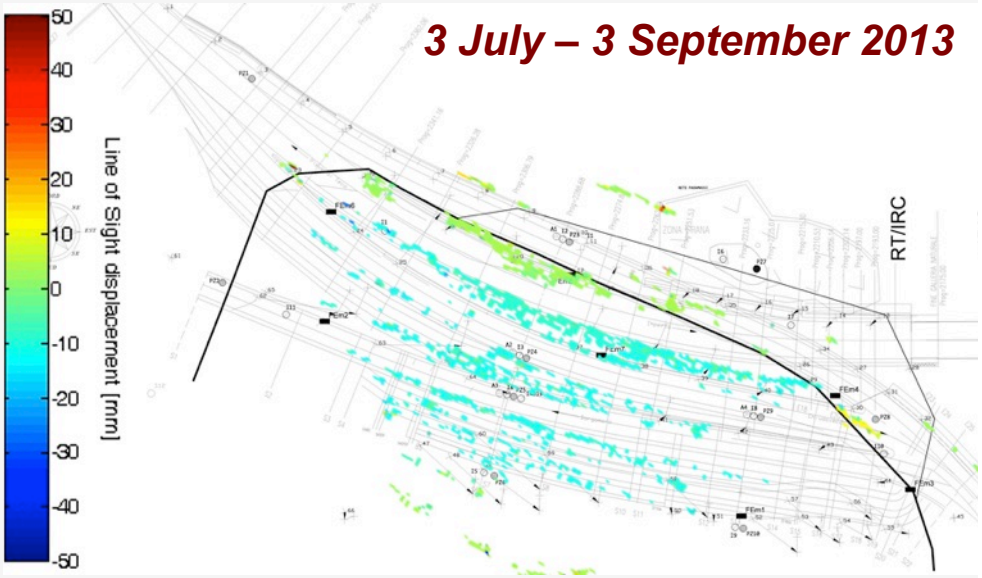
SAPIENZA
UNIVERSITÀ DI ROMA

Example 2: Monitoring of one Geotechnical Asset

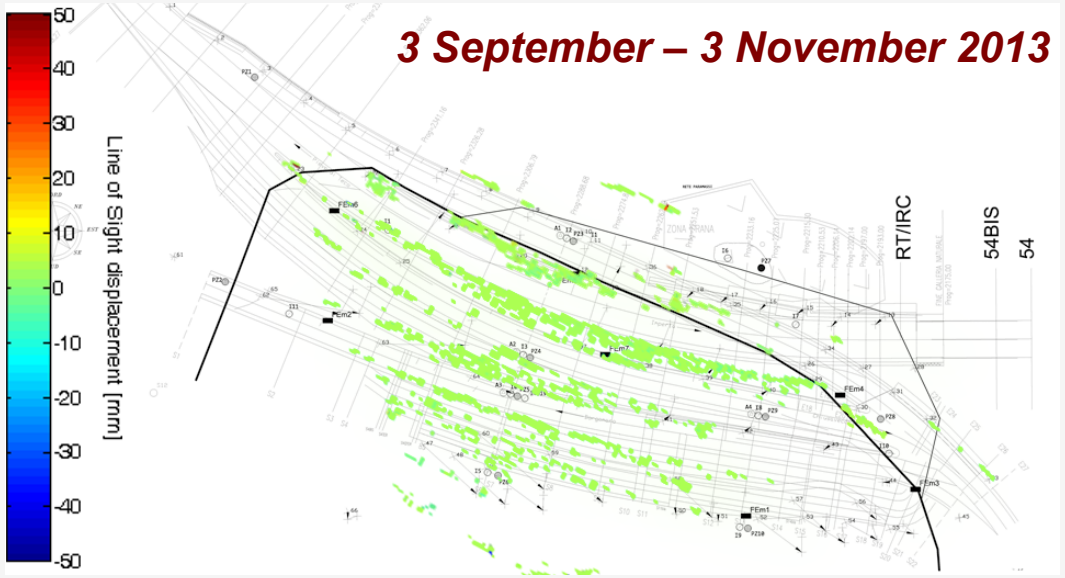
16 May – 3 July 2013



3 July – 3 September 2013



3 September – 3 November 2013

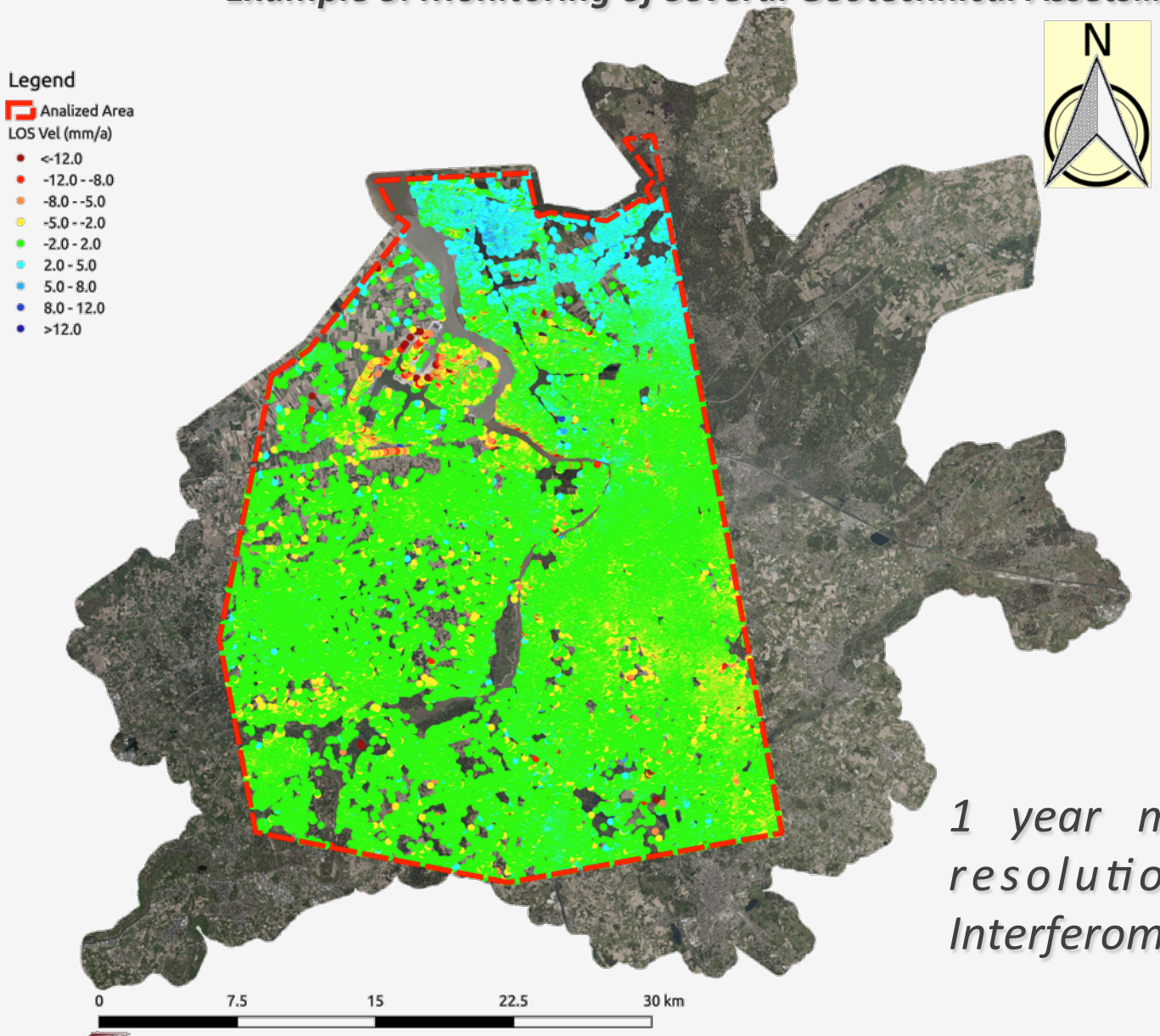


NHAZCA SRL

Mazzanti P., Brunetti A., 2015. Monitoring an unstable road embankment for public safety purposes by Terrestrial SAR Interferometry. In: FMGM 2015, PM Dight (ed.) (p.p. 769-780) Australian Centre for Geomechanics, Perth, ISBN 978-0-9924810-2-5.

SAPIENZA UNIVERSITÀ DI ROMA

Example 3: Monitoring of Several Geotechnical Assets…in Europe

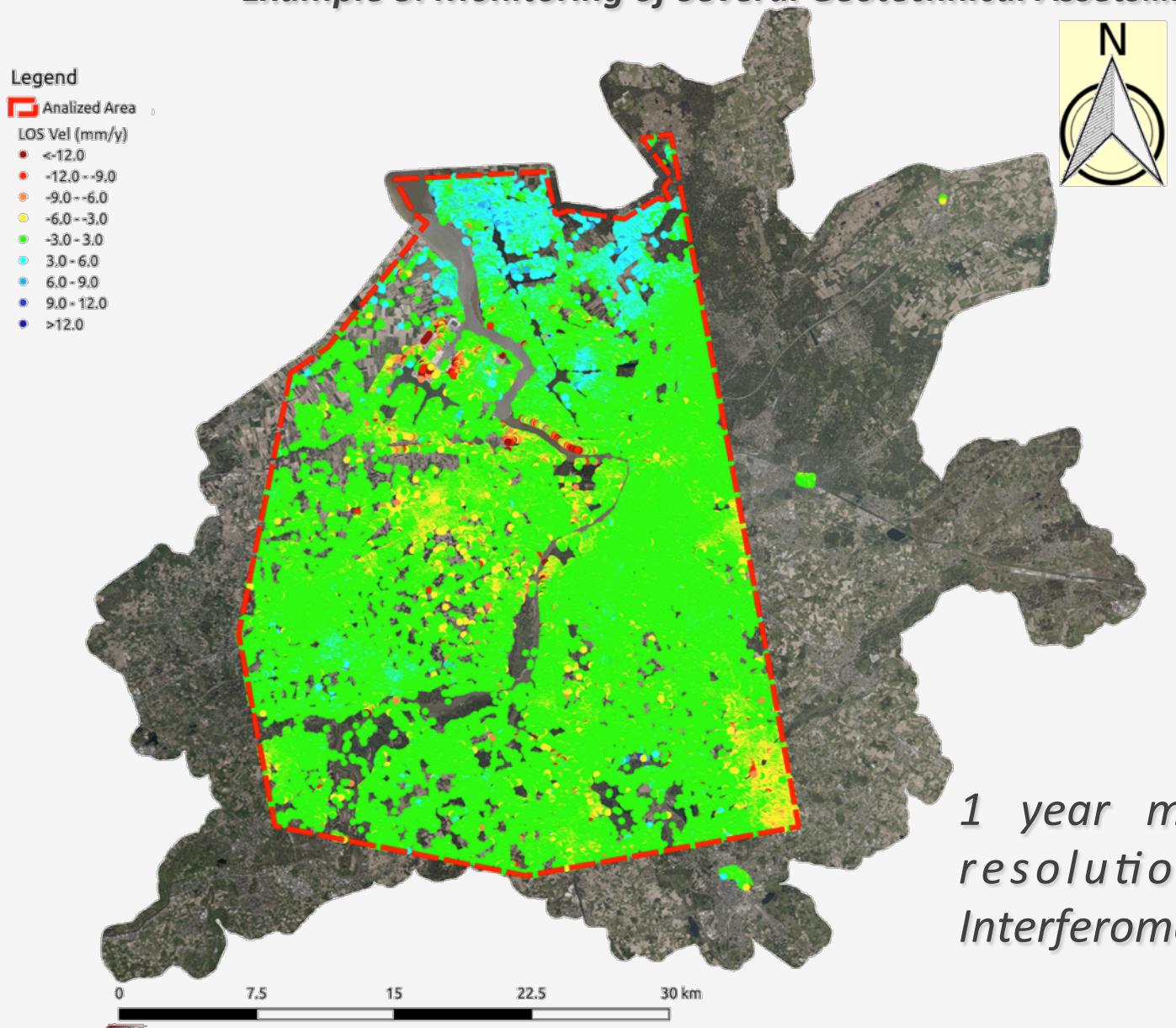


1 year monitoring by high resolution Satellite SAR Interferometry

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Example 3: Monitoring of Several Geotechnical Assets…in Europe



1 year monitoring by high resolution Satellite SAR Interferometry

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Example 3: Monitoring of Several Geotechnical Assets…in Europe

About 100 $ per km²
Few $ for each asset
0,02 $ per monitored point!

NHAZCA SRL

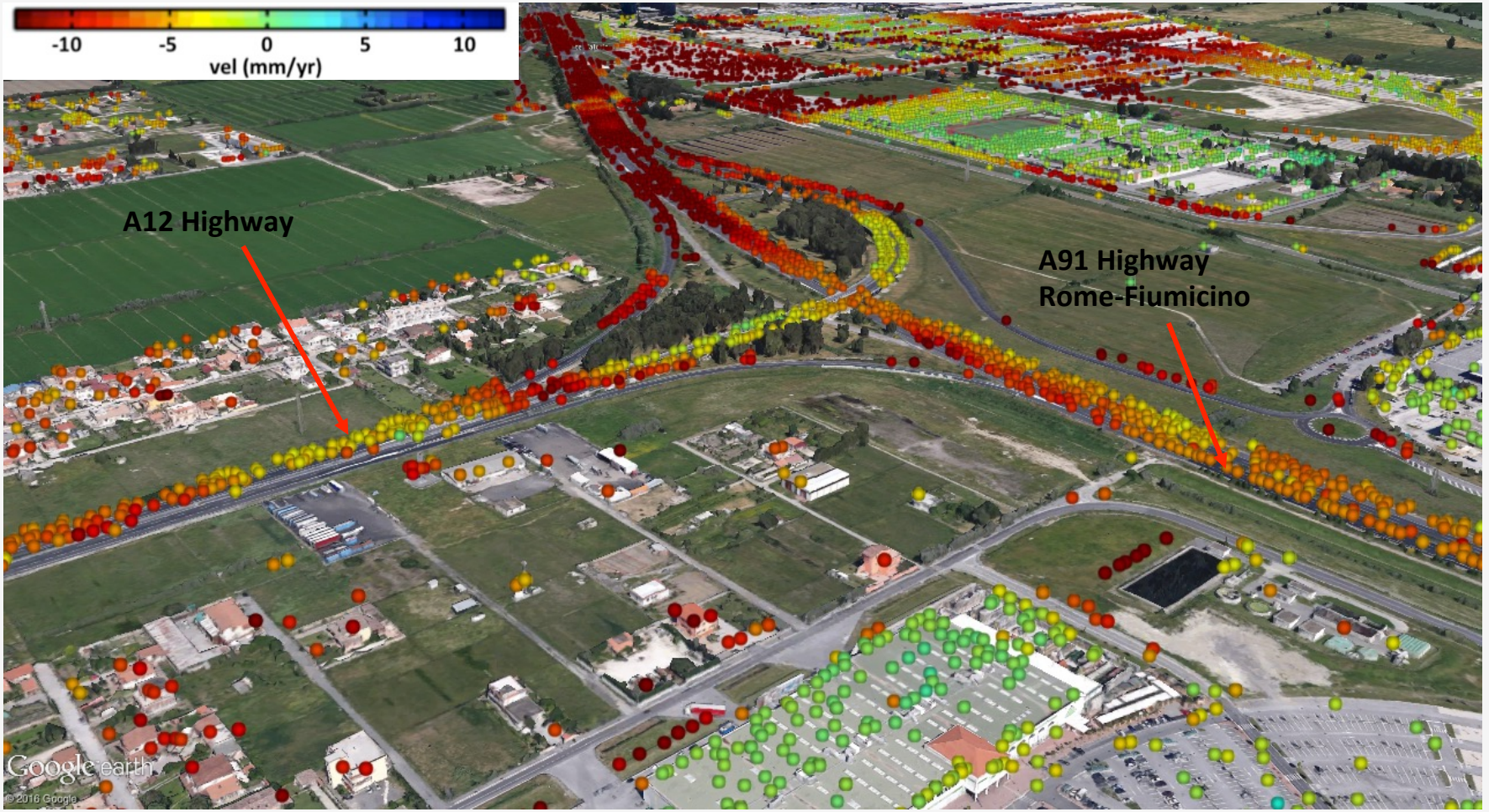
SAPIENZA
UNIVERSITÀ DI ROMA

Example 4: Monitoring Several Geotechnical Assets….in Italy

NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Example 4: Monitoring Several Geotechnical Assets….in Italy



NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

When and why we monitor….

	Common applications	Common instruments
Knowledge monitoring	Design phase Standard maintenance Screening after paroxysmal events (earthquakes, floods, etc.)	LiDAR, satellite SAR interferometry, terrestrial interferometric radar, GNSS, photogrammetry, observation well, piezometer, inclinometer, TDR, earth pressure cell, accelerometer, velocimeter, seismometer
Control monitoring	Construction phase in medium risk areas Advanced maintenance (critical segments) Verification of high risk area	LiDAR, satellite sar interferometry, terrestrial interferometric radar, GNSS, photogrammetry, total station, optical levelling, digital image correlation, observation well, piezometer, inclinometer, TDR, extensometer, earth pressure cell, stress-meter, load cell, strain gauge, fibre optic, pendulum, deflectometer, convergence gauge, surface and probe tiltmeter, liquid level gauge, crack gauge, accelerometer, velocimeter, seismometer
Emergency monitoring	Construction phase in high risk areas Early warning systems for operation in high risk areas	LiDAR, terrestrial interferometric radar, GNSS, total station, piezometer, inclinometer, extensometer, strain gauge, fibre optic, pendulum, surface and probe tiltmeter, liquid level gauge, crack gauge, TDR, convergence gauge, accelerometer, velocimeter, seismometer

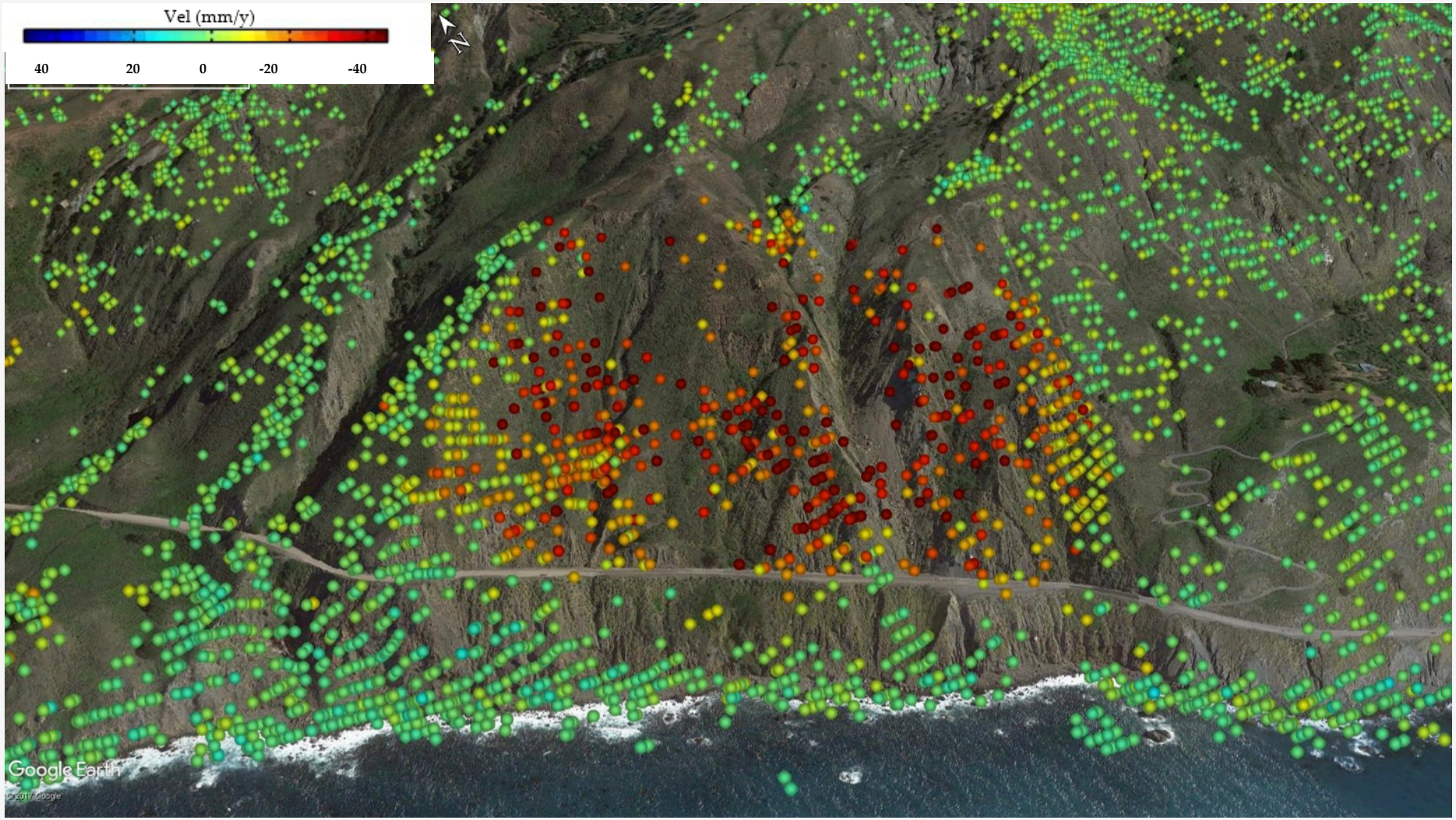
SMART

NHAZCA SRL

Mazzanti P., 2017. Toward transportation asset management: what is the role of geotechnical monitoring? Journal of Civil Structural Health Monitoring. DOI 10.1007/s13349-017-0249-0

SAPIENZA UNIVERSITÀ DI ROMA

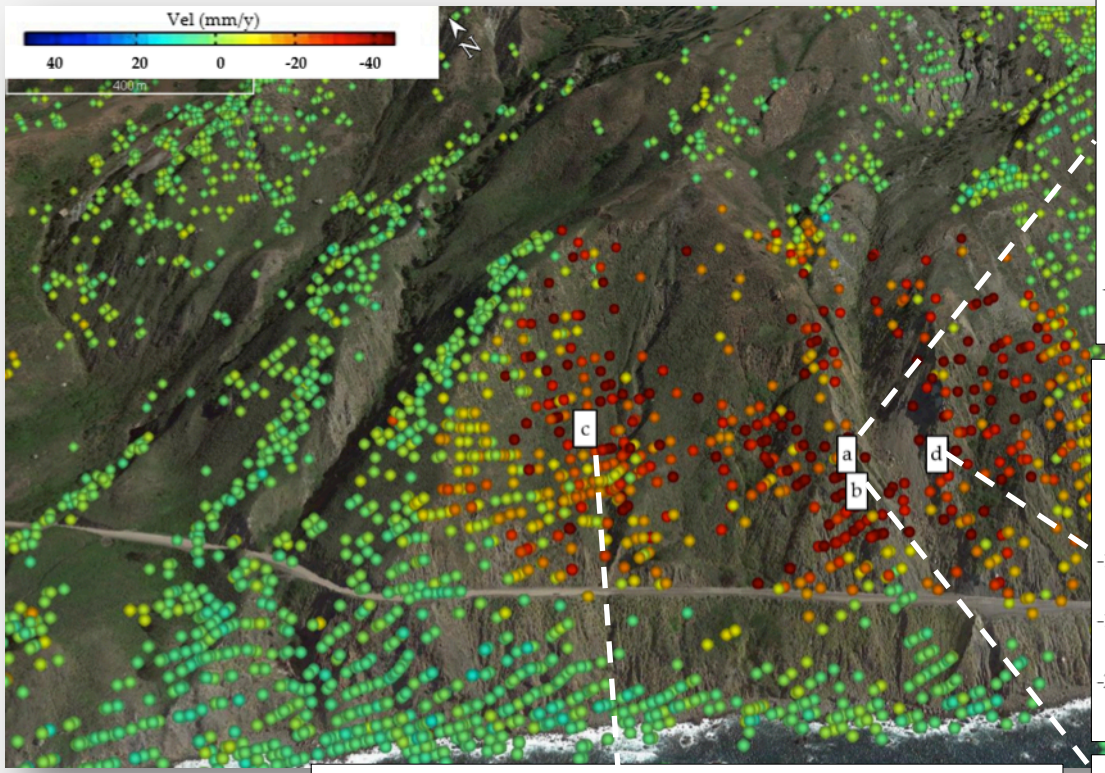
Detection of precursors….is really SMART

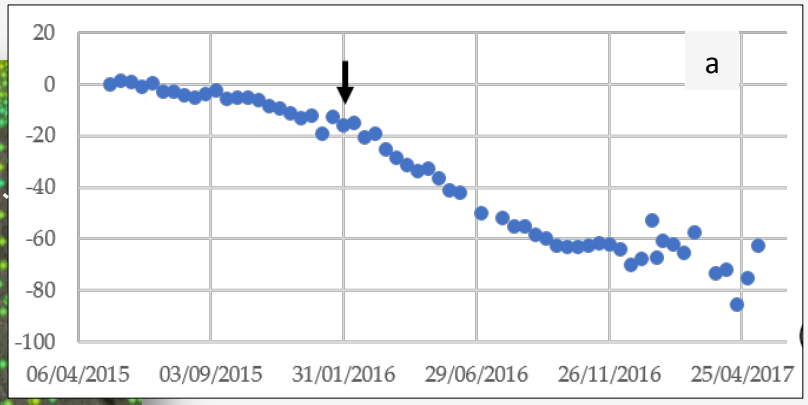


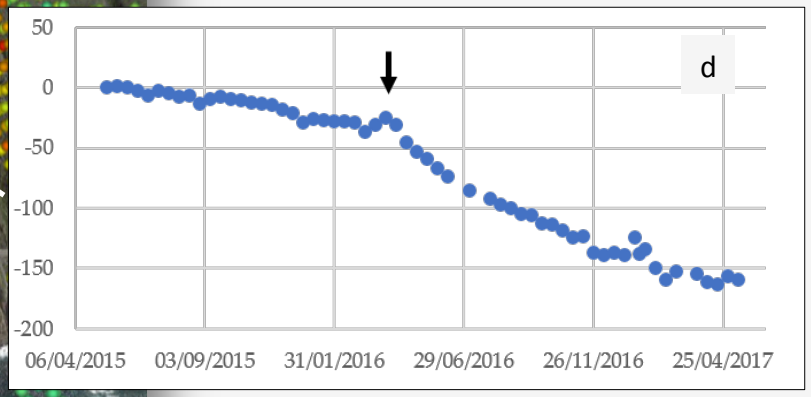
NHAZCA SRL

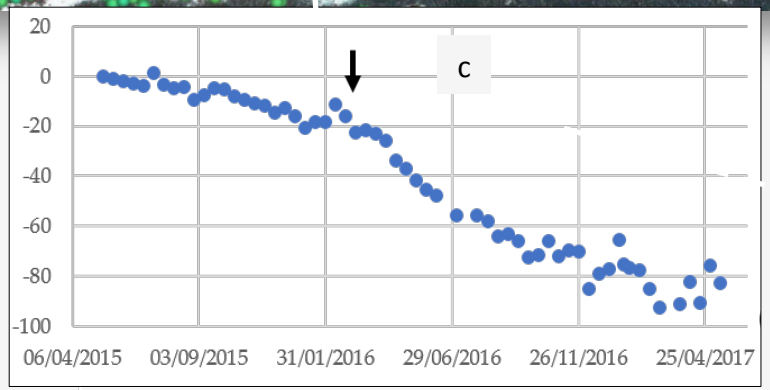
SAPIENZA
UNIVERSITÀ DI ROMA

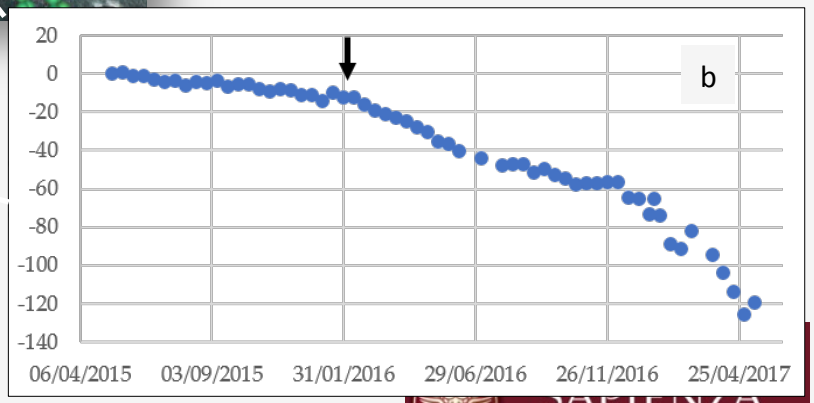
Detection of precursors….is really SMART











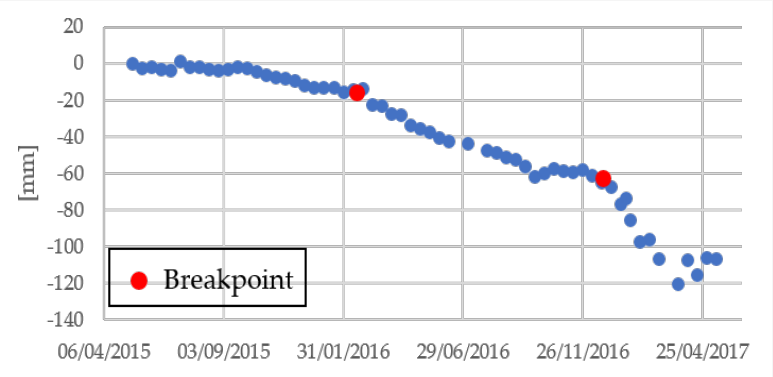
NHAZCA SRL

SAPIENZA
UNIVERSITÀ DI ROMA

Detection of precursors….is really SMART

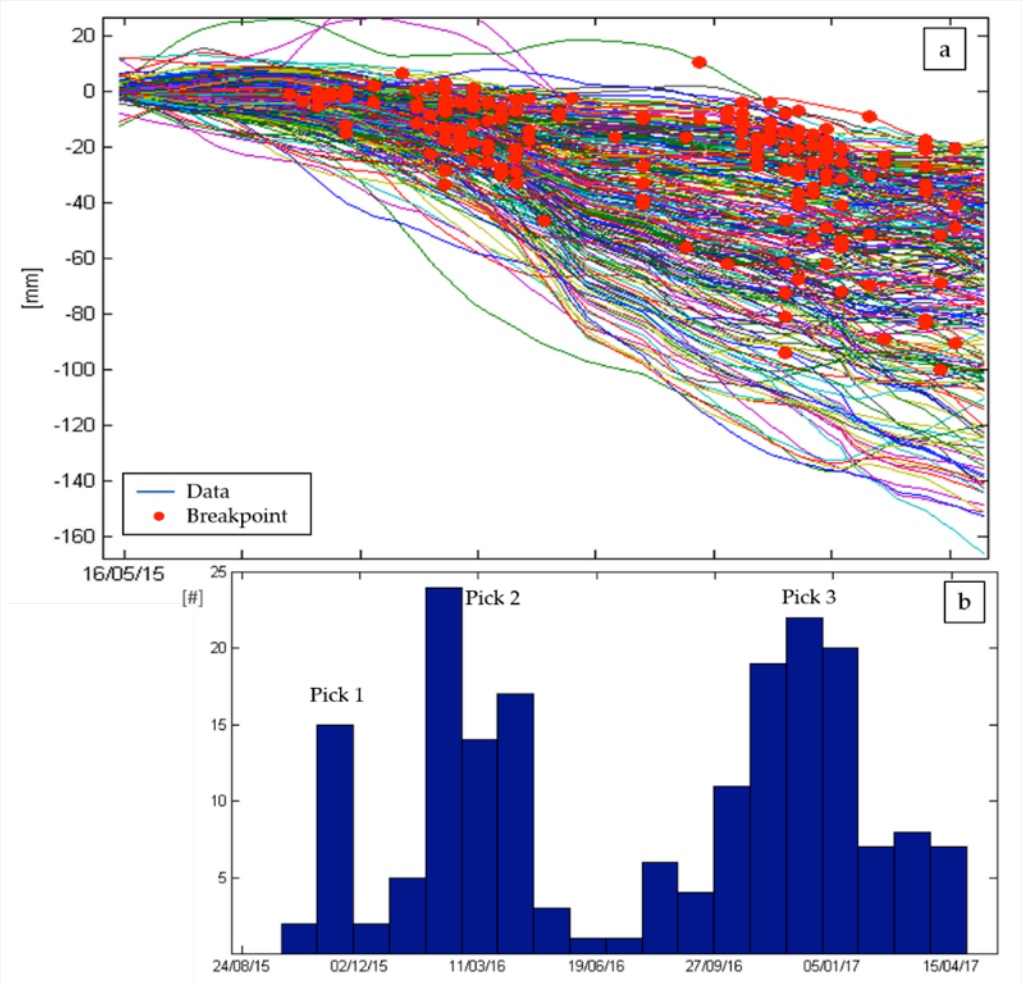
Trend Change Detection (TCD)

Example of breakpoints



***Results**:*

Modified Sliding Window (MSW) segmentation method

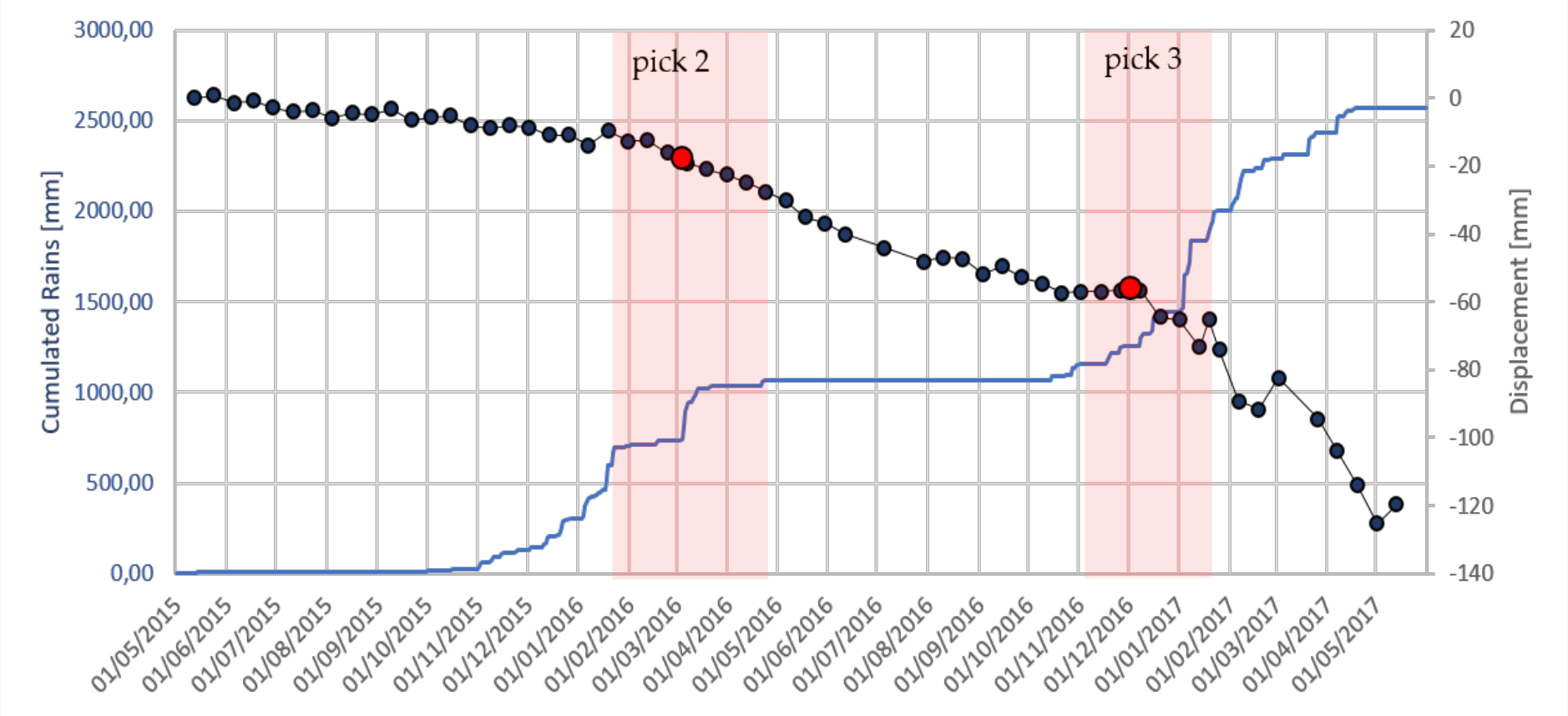


NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Detection of precursors….is really SMART

Trend Change Detection (TCD)

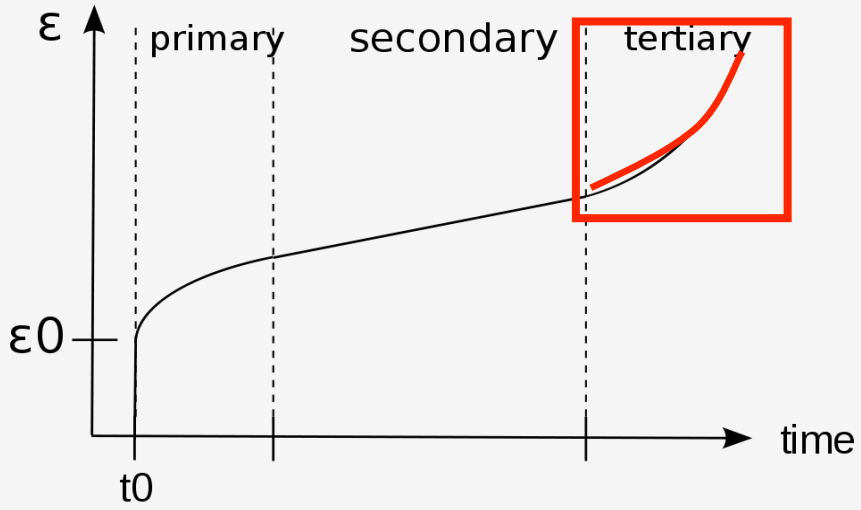


Correlation between the displacements (black dots) and the rainfall records (blue line). Pick 2 and pick 3 correspond to the time intervals detected using the MSW segmentation algorithm.
The red dots represent the computed breakpoints in this time series.

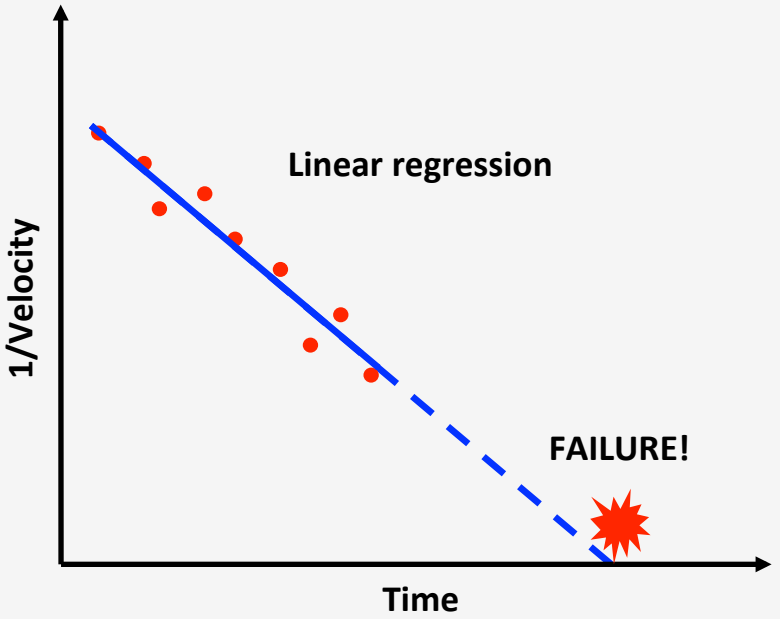
NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

Prediction of failure….is even more SMART



Three-stage **creep** model (*Varnes 1978)*



(Saito 1960; Fukuzono 1985; Voight 1989)

Displacement Monitoring!

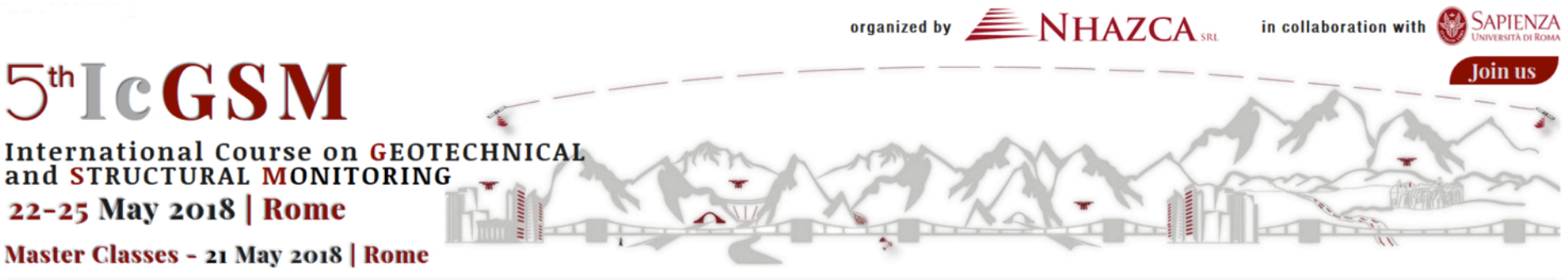
NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA

How we can move forward with the SMART GAM?

Reduce the distance between innovative monitoring solutions and GAM managers:

1) Training



NHAZCA SRL

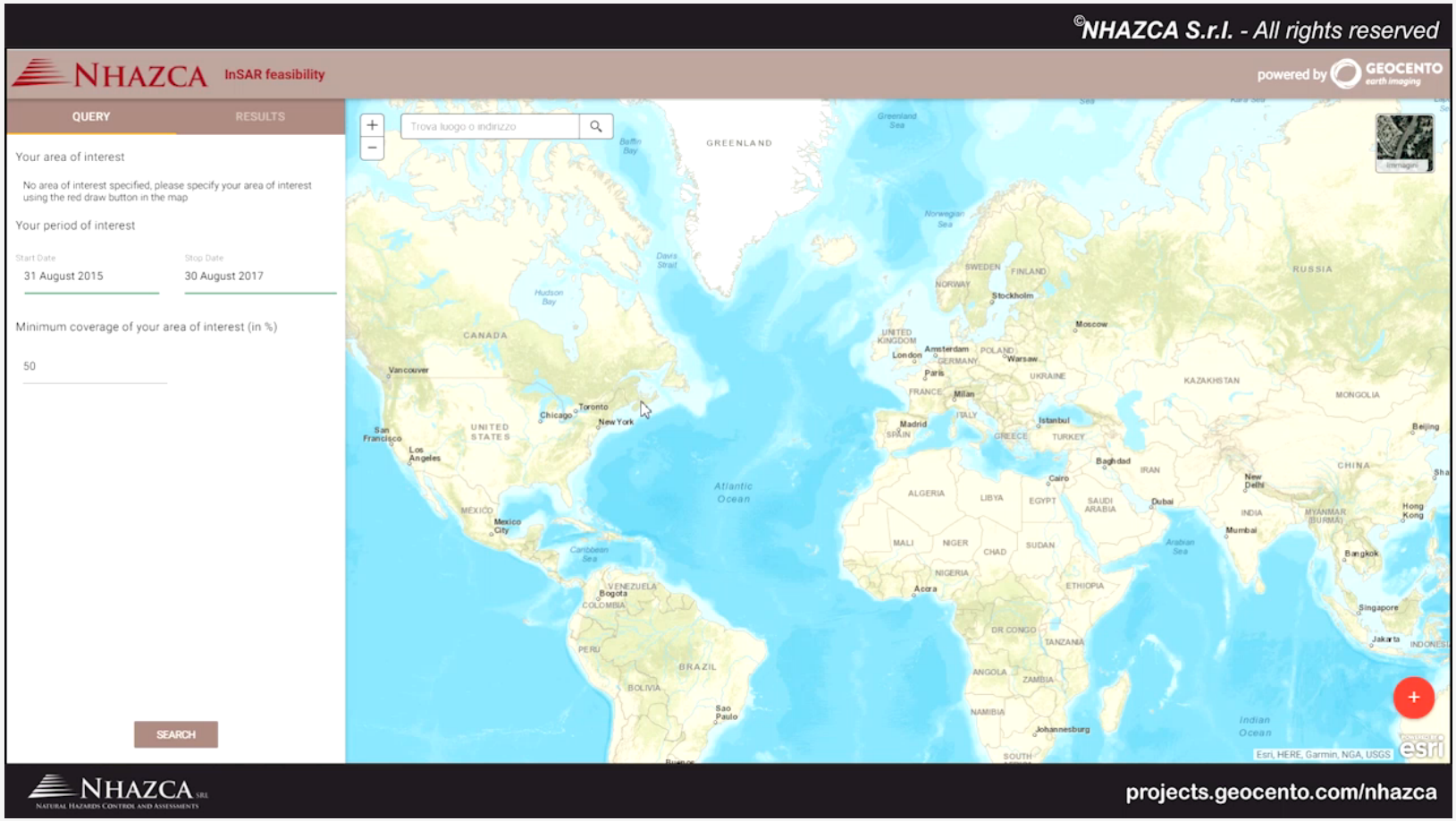
WWW.GEOTECHNICALMONITORING.EU

SAPIENZA UNIVERSITÀ DI ROMA

How we can move forward with the SMART GAM?

Reduce the distance between innovative monitoring solutions and GAM managers:

2) Developing suitable tools



NHAZCA SRL

WWW.SARINTERFEROMETRY.COM

SAPIENZA UNIVERSITÀ DI ROMA

What I hope for the future

- Monitoring will become a key part of each geotechnical asset program and not just an option

- The word “monitorability” will enter in the dictionary of designers and infrastructure owners

paolo.mazzanti@nhazca.com

www.nhazca.com

NHAZCA SRL

SAPIENZA UNIVERSITÀ DI ROMA