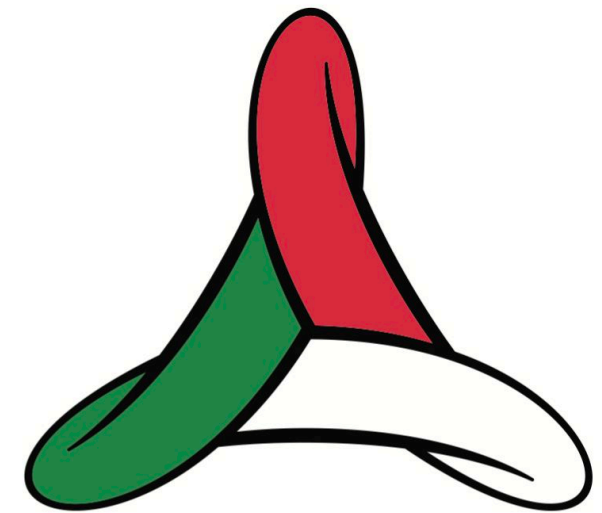




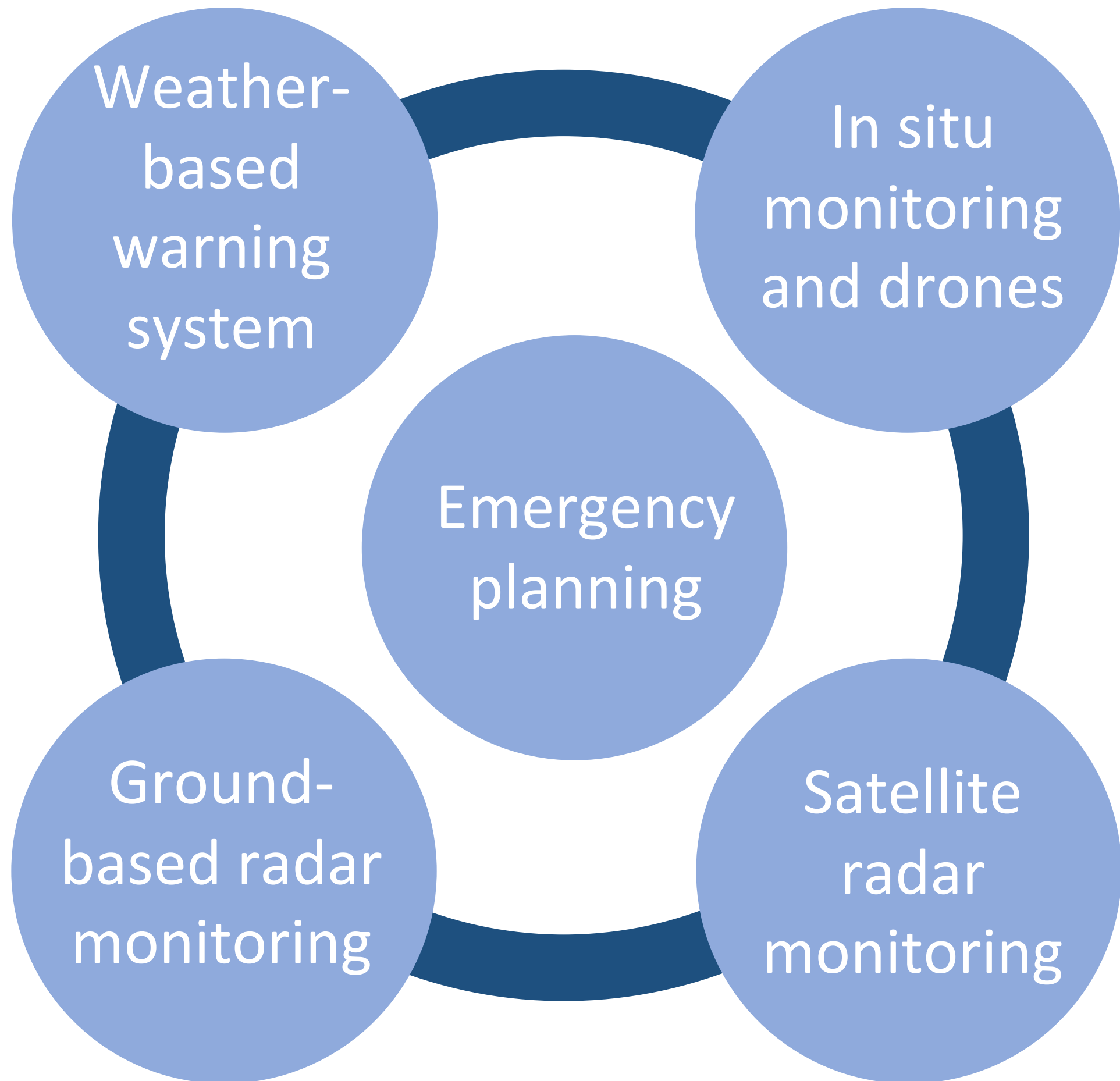
UNIVERSITÀ  
DEGLI STUDI  
FIRENZE



PROTEZIONE CIVILE

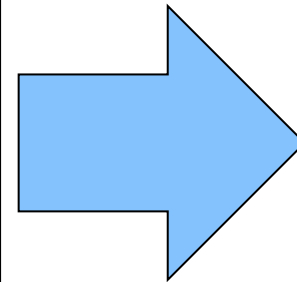
# Monitoring and early warning for disaster risk reduction

N. Casagli, G. Gigli, E. Intrieri



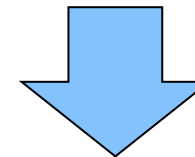
# Landslides

**Rapid long runout landslides**  
**Caused by earthquakes and heavy rainfalls**




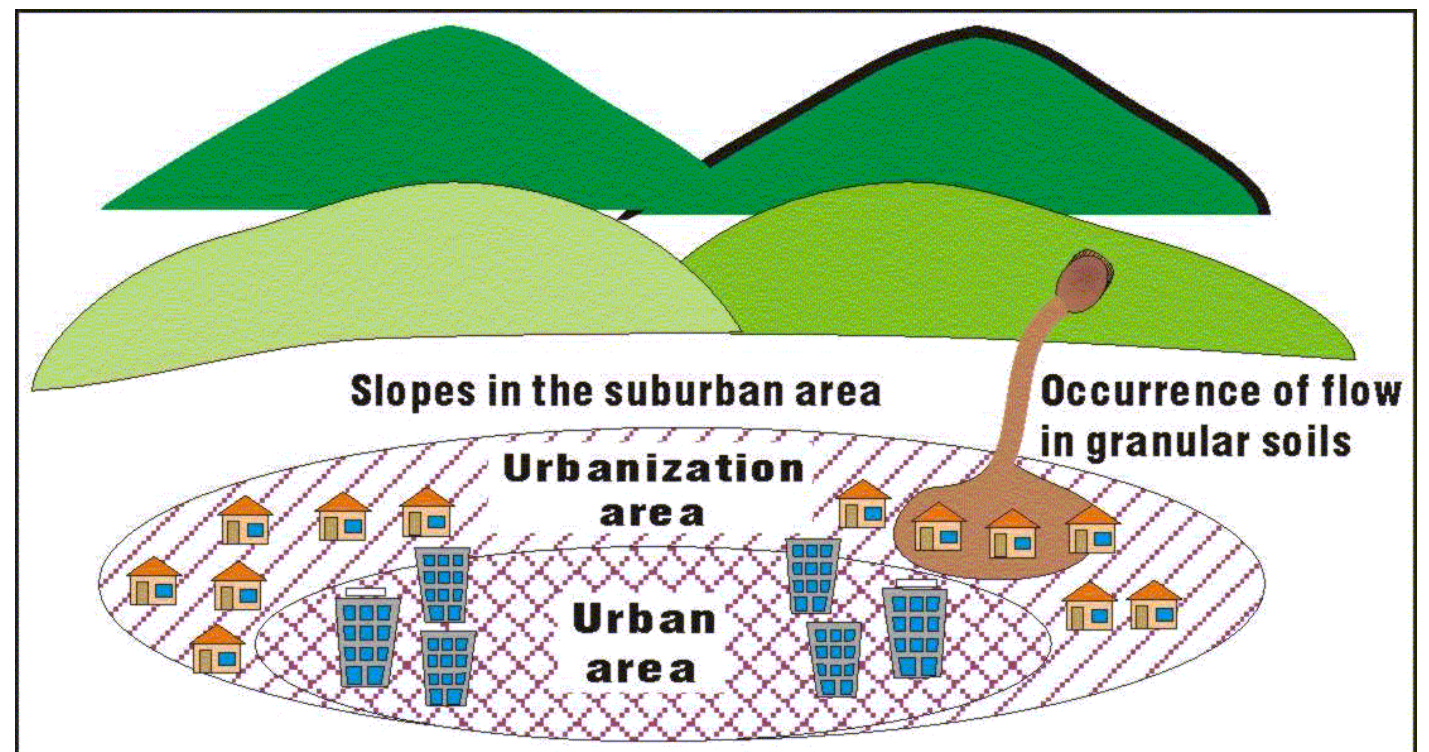
## Characteristics

- Rapid Motion
- Great Impact Force
- Wide Disaster Area



Great number of death

	Rapid - velocity - Slow	
Long run-out distance  short-moving landslides	Rapid long run-out landslides (liquefied slides, etc)	slow long - traveling landslides (Earth flows, etc)
	Rapid short-moving landslides (first-time slides)	Slow short - moving landslides (reactivated landslides)

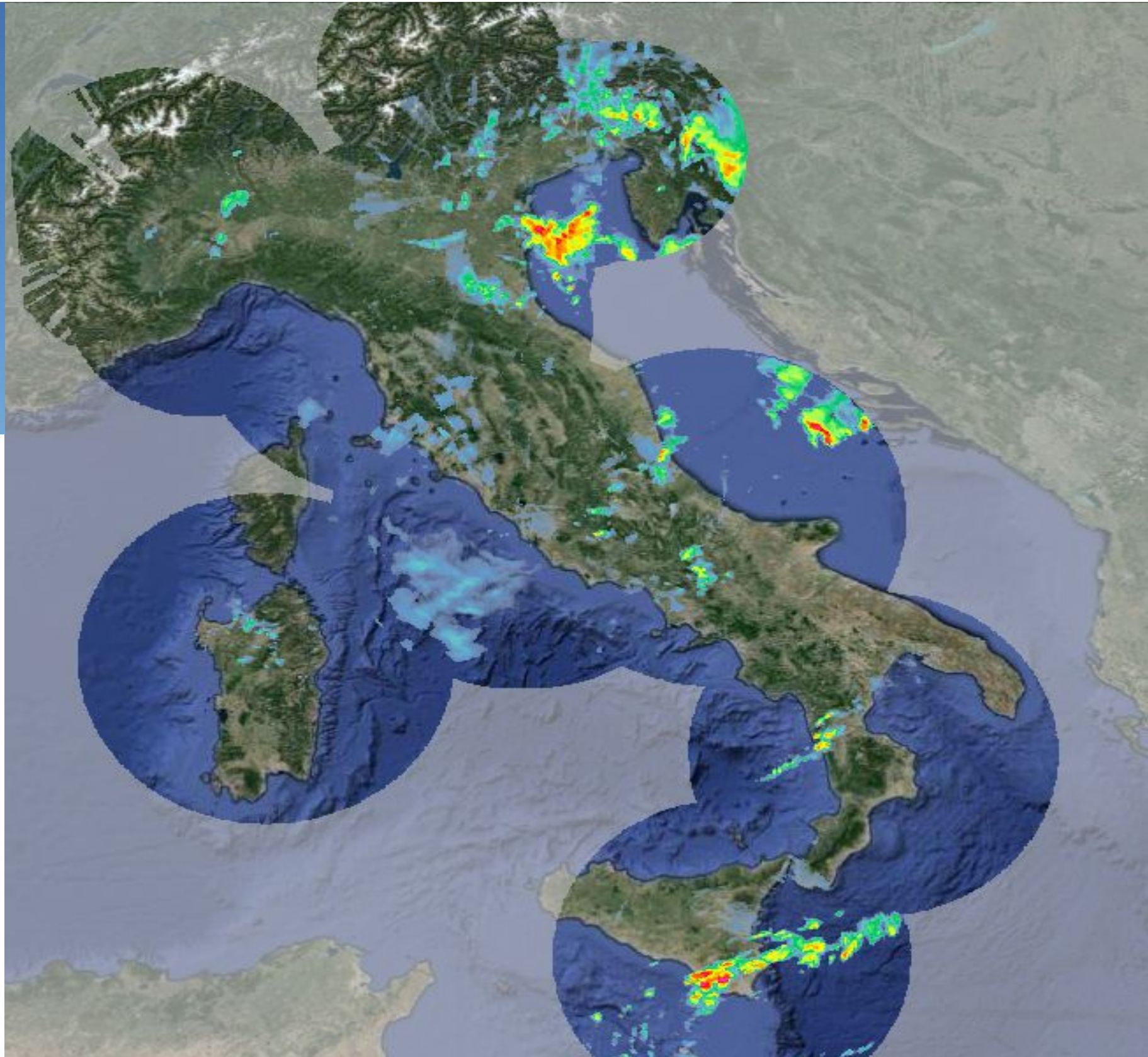


Kyoji Sassa (2001)

# Weather-based warning system



# National radar network

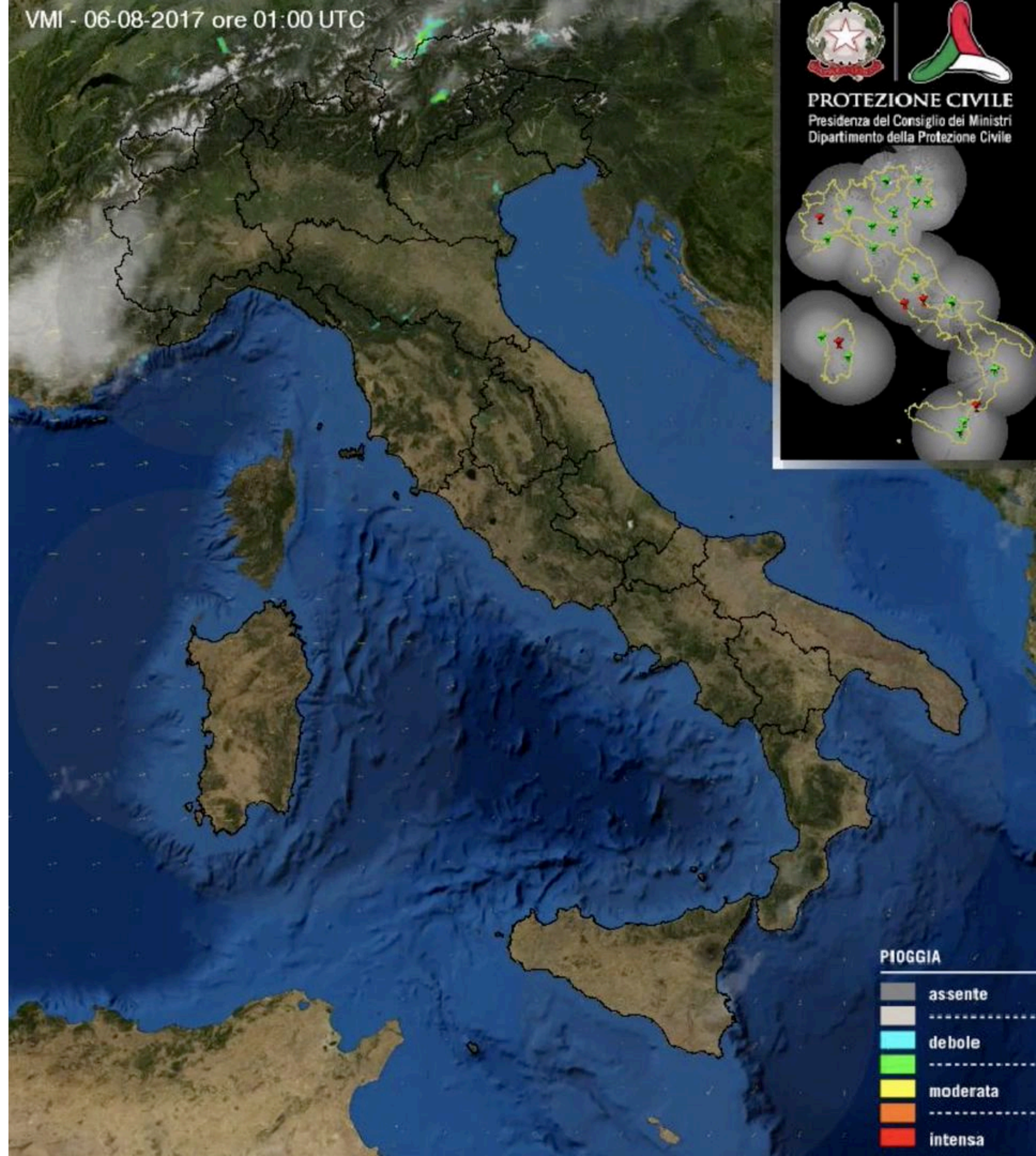


**PROTEZIONE CIVILE**

Presidenza del Consiglio dei Ministri  
Dipartimento della Protezione Civile



# Real-time weather forecasting

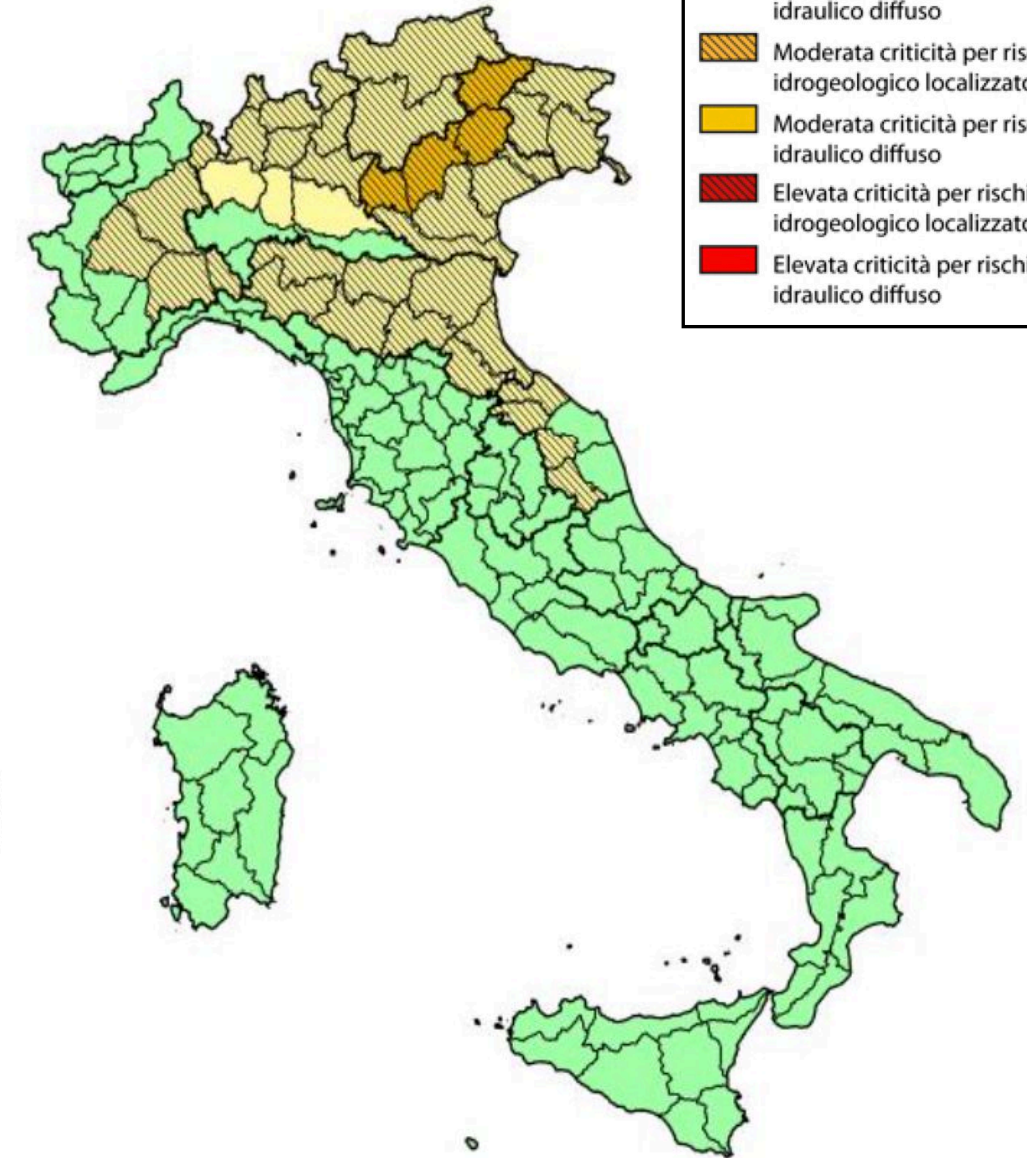
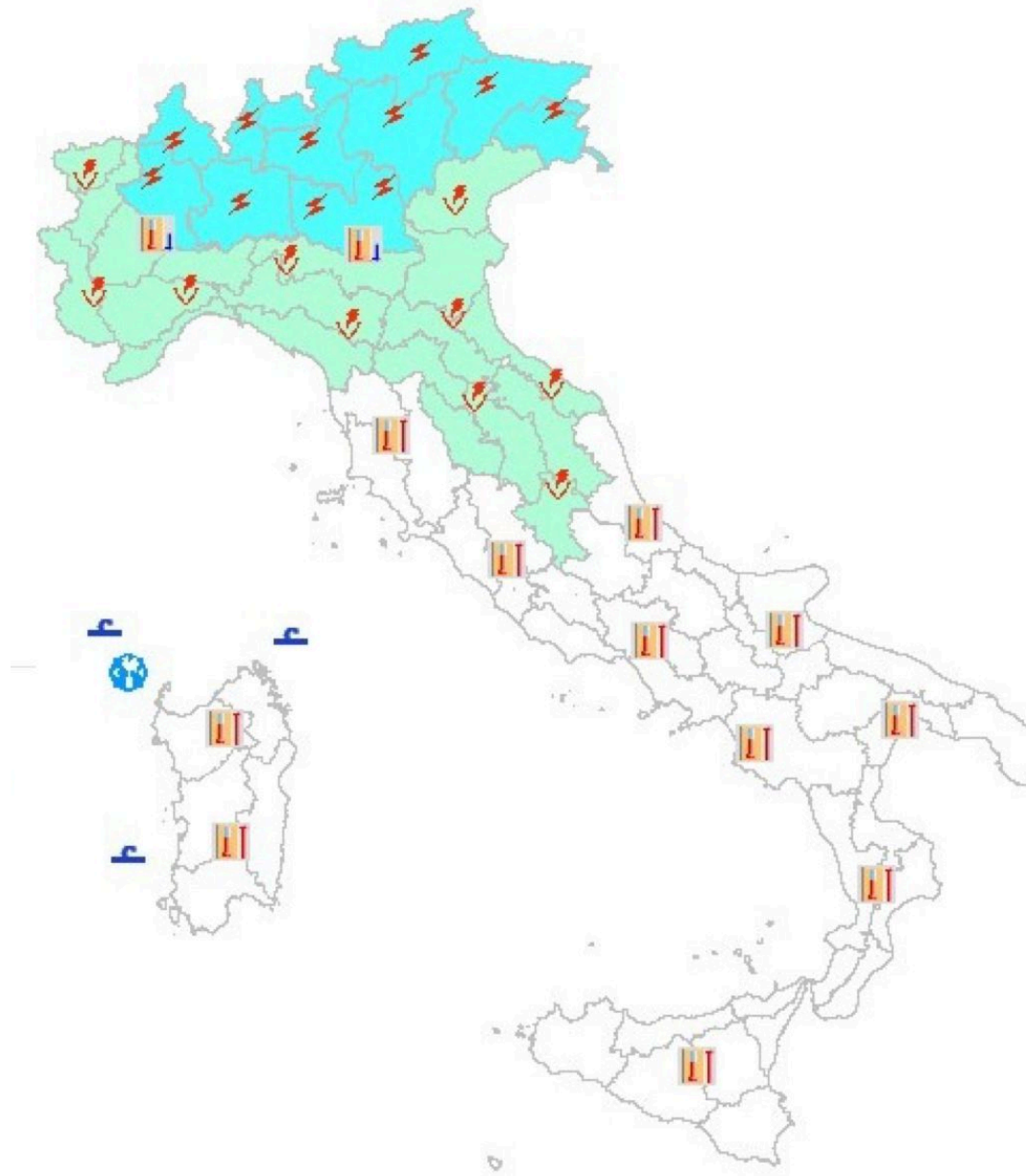




# Warning bulletins

## Meteo forecast

## Criticality/Alerts



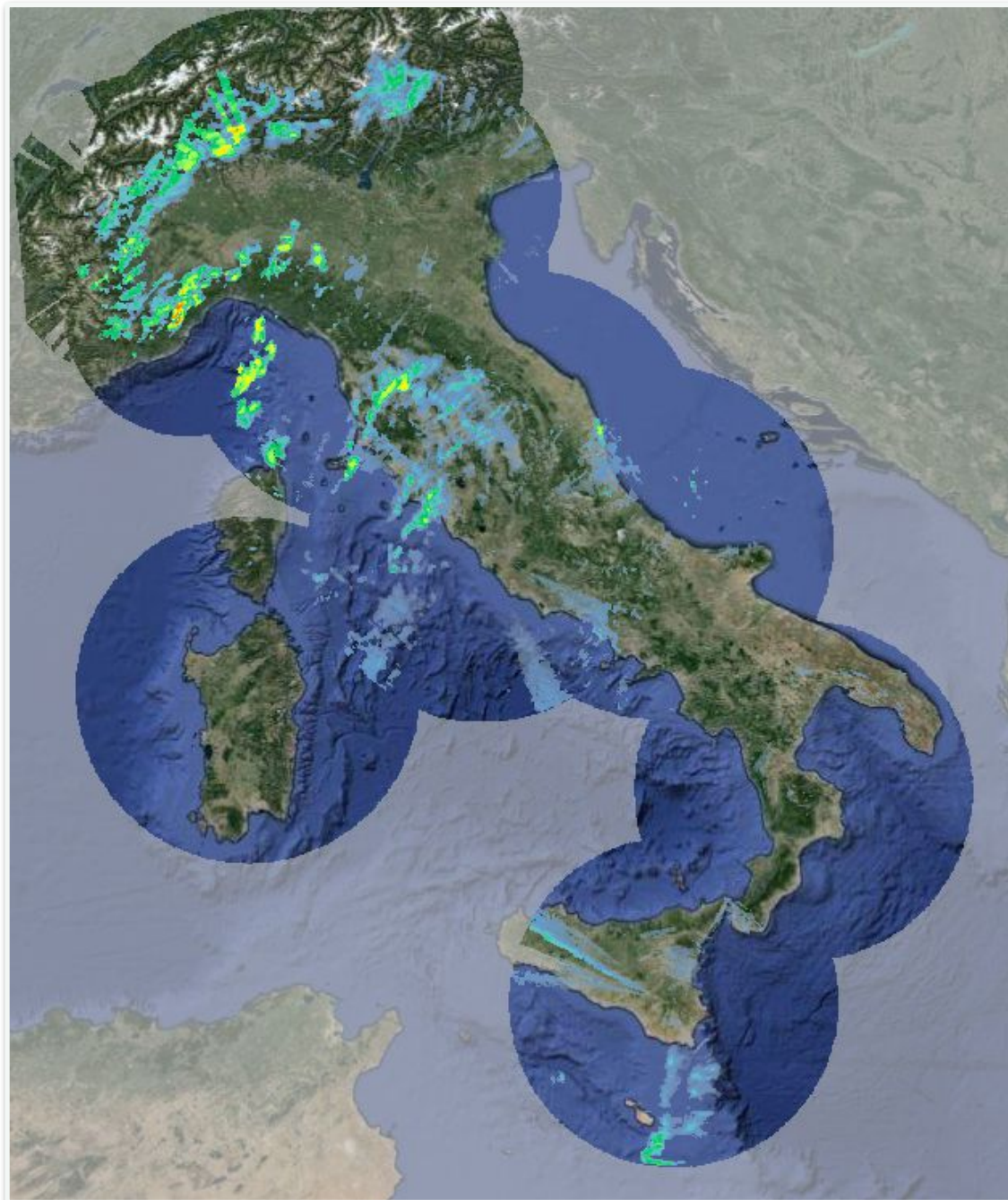
# Criticality/Alert levels

Alert	Criticality	Event scenario	Effects and loss
No alert	No	No predictable significant events	Possible local damages
Yellow	Ordinary	Local events	Possible danger for people safety
Orange	Moderate	Diffused events	Danger for people safety
Red	High	Numerous and widespread events	Severe danger for people safety

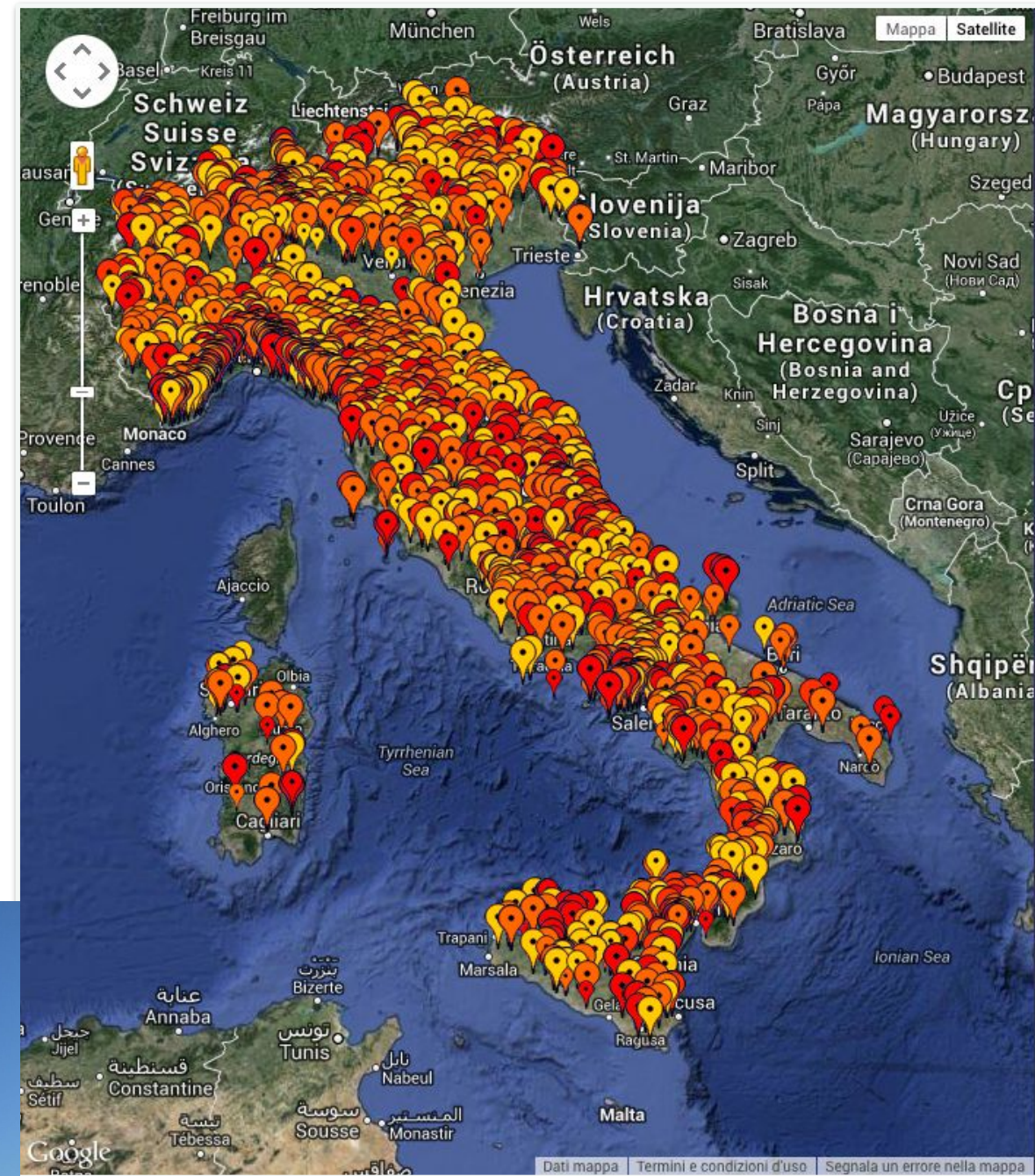


# Landslide prediction

Real-time weather forecasting



National landslide database

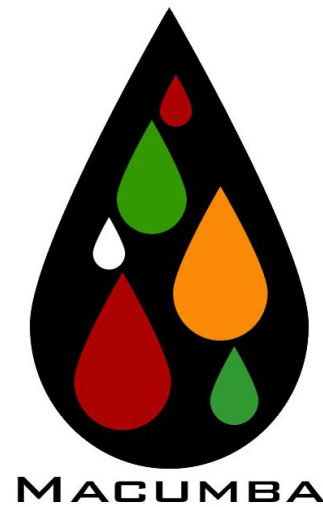
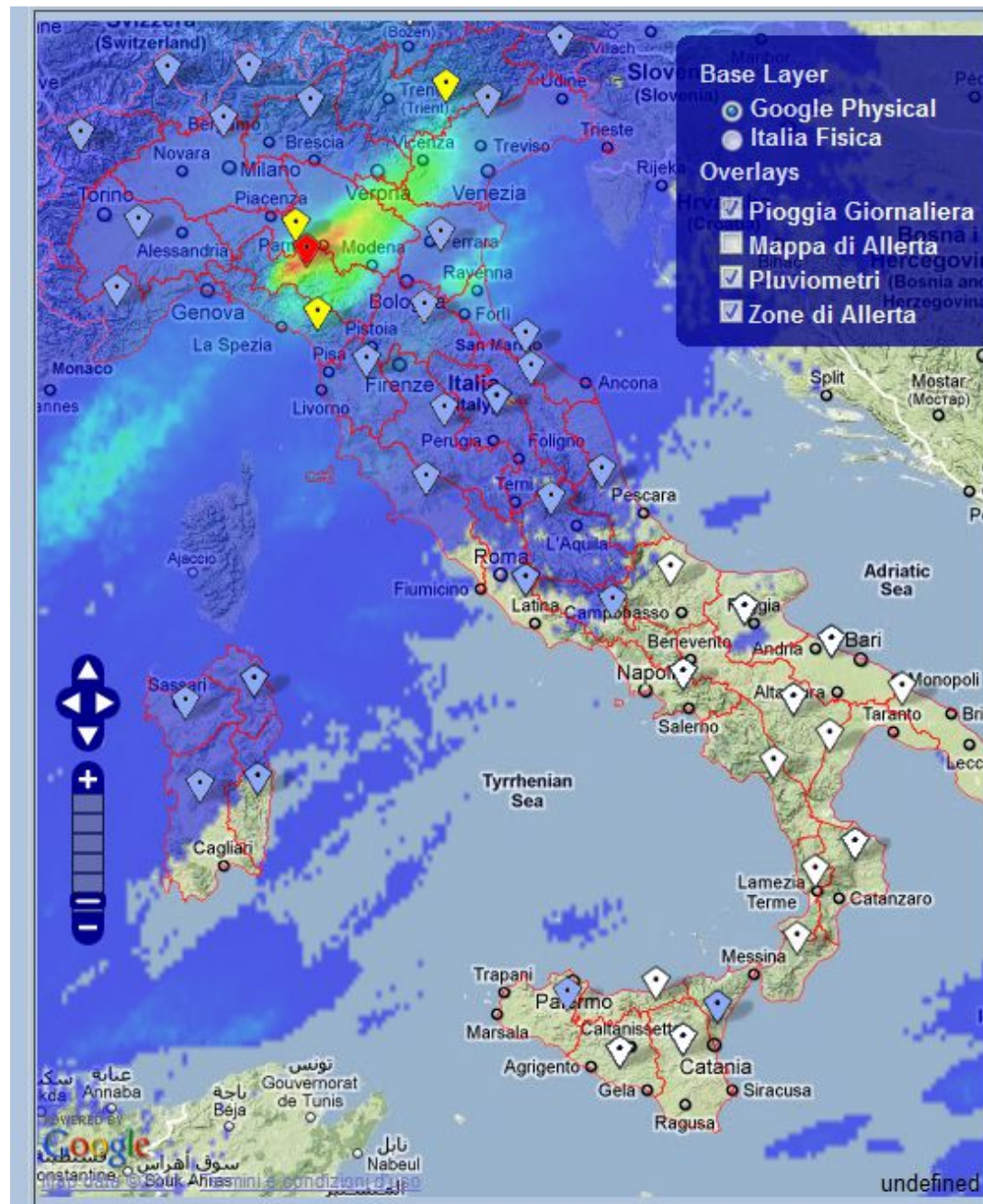


Big data analysis



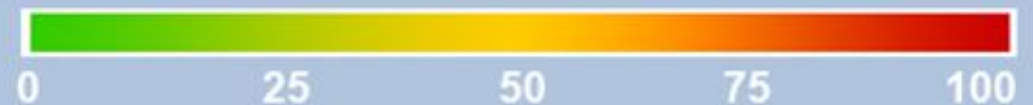
# Prediction of local effects

Real-time weather forecasting



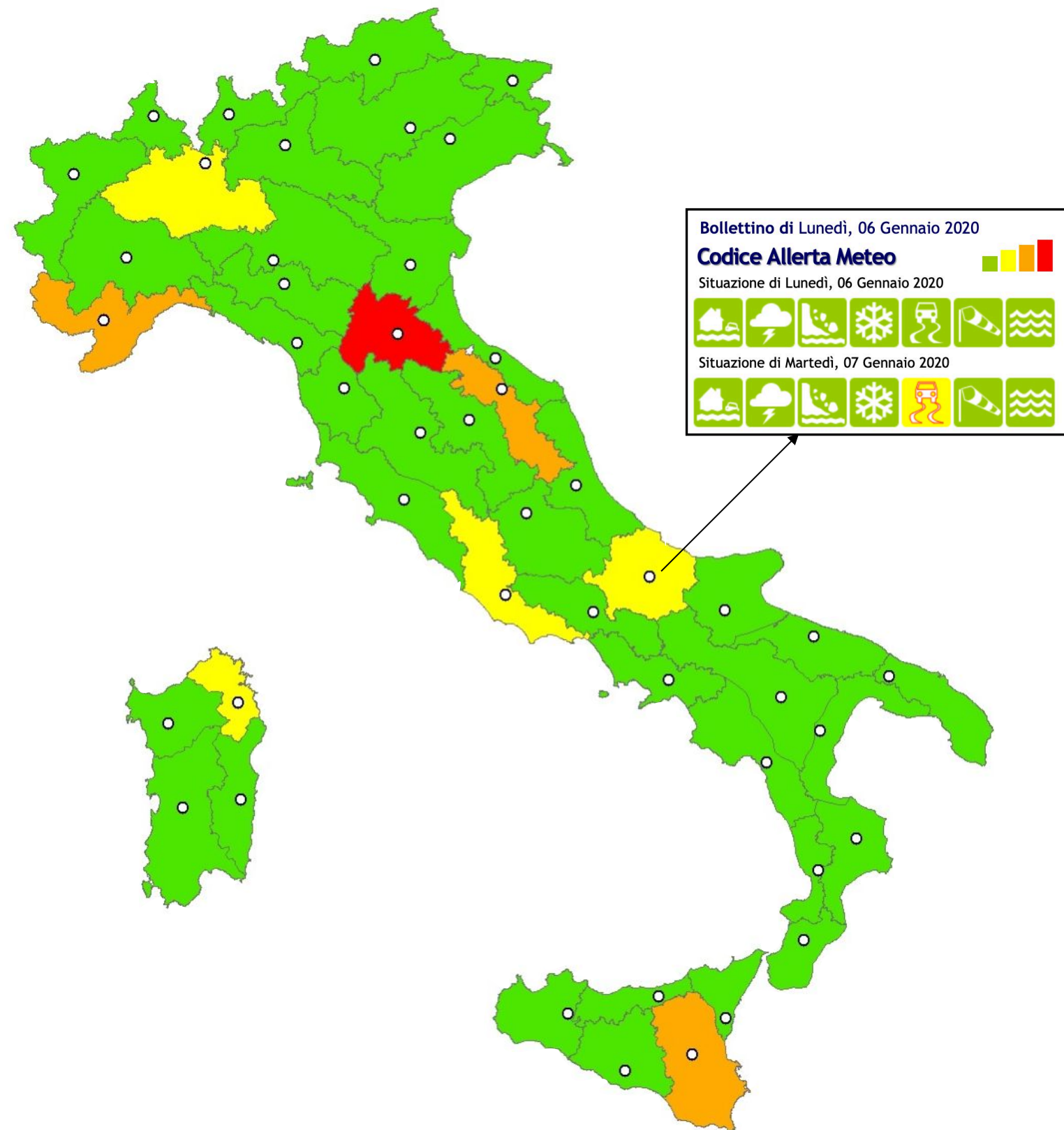
**PROTEZIONE CIVILE**  
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Dipartimento della Protezione Civile

Criticality/alert level





# Daily warning bulletin



Criticality/Alert levels

None

Ordinary

Moderate

High

# In situ monitoring and drones

# Wireless Sensor Network

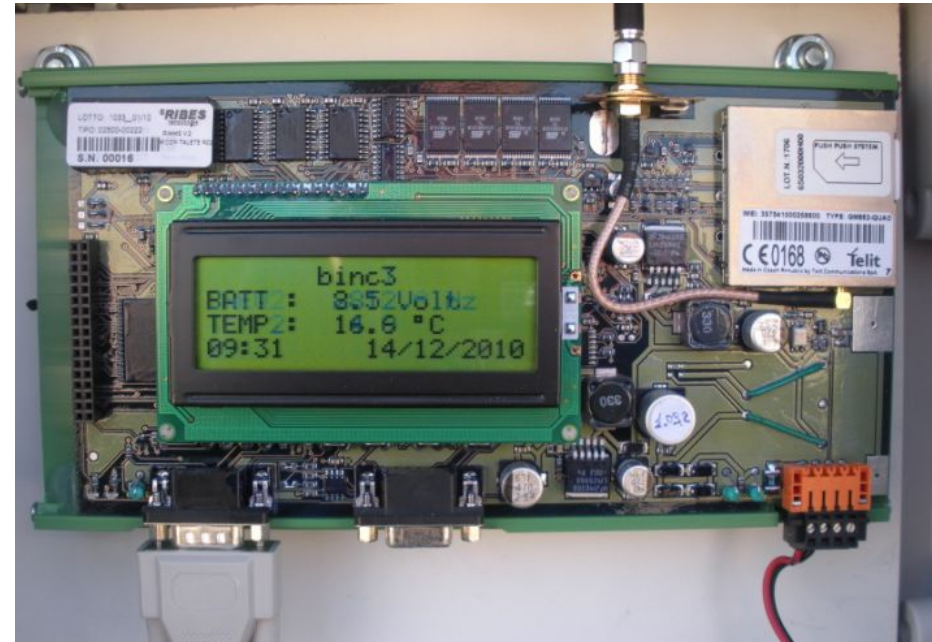




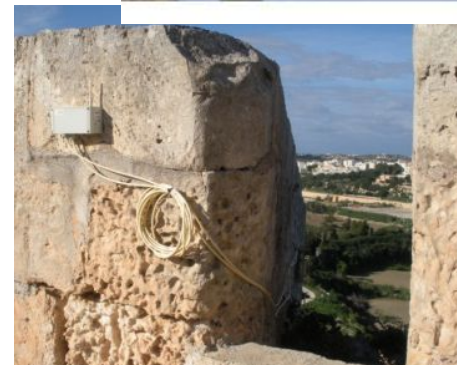
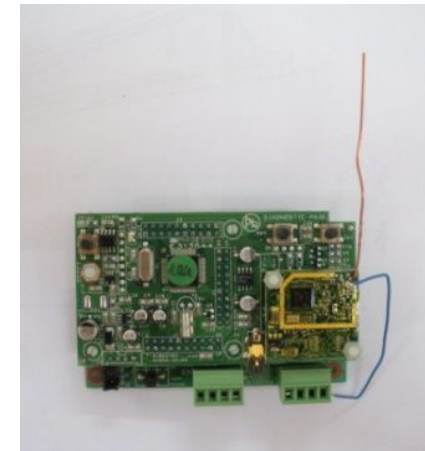
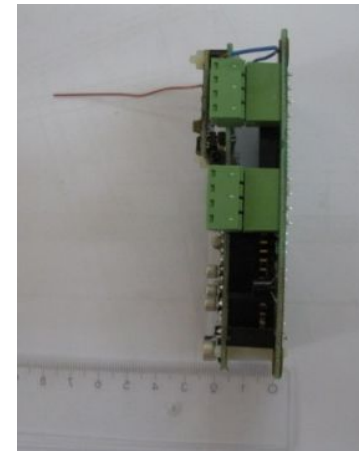
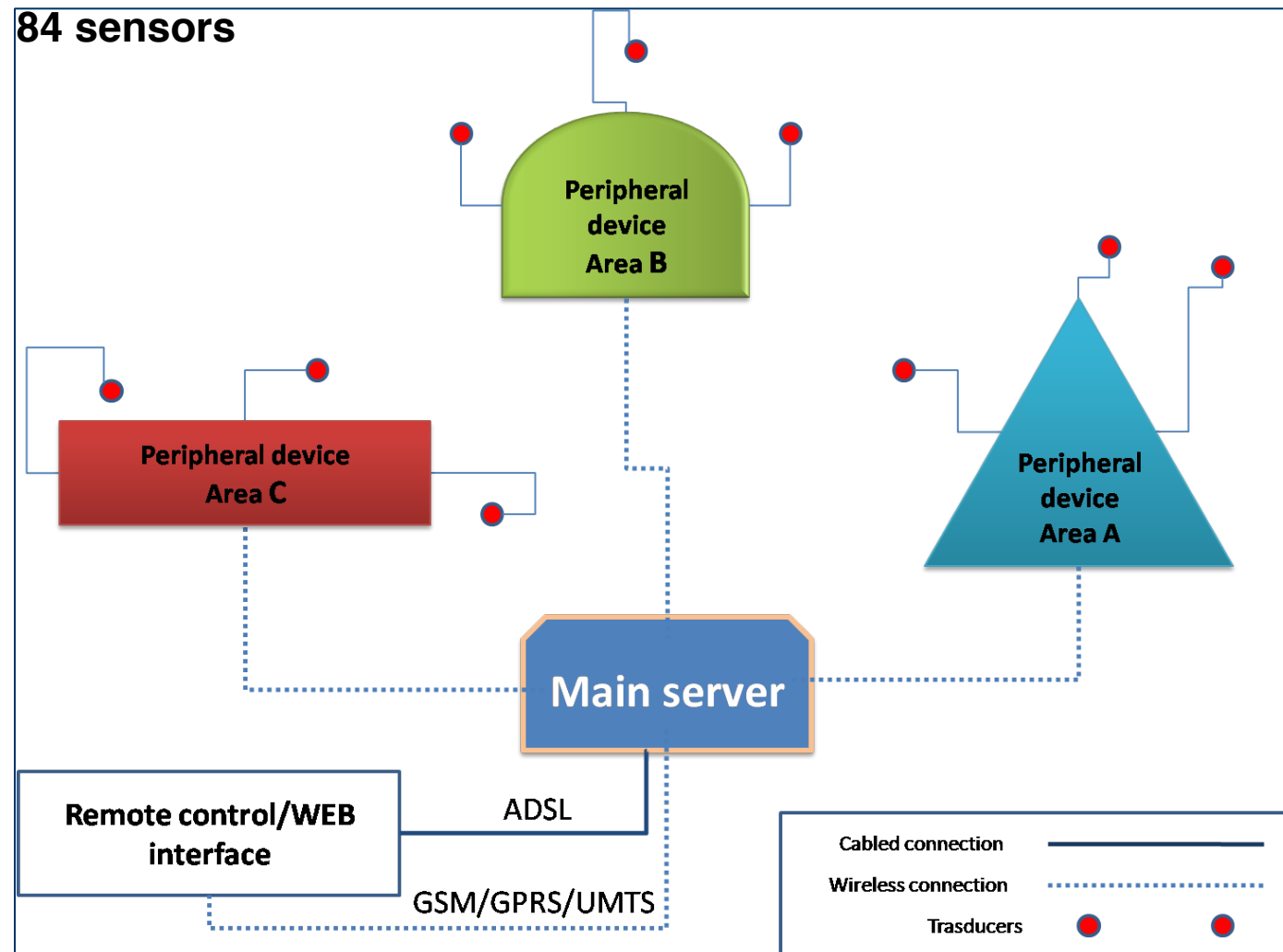
# Monitoring network

## Monitoring network

8 piezometers  
1 pluviometers  
3 termometers  
3 termoigrometers  
56 extensometers  
11 inclinometers

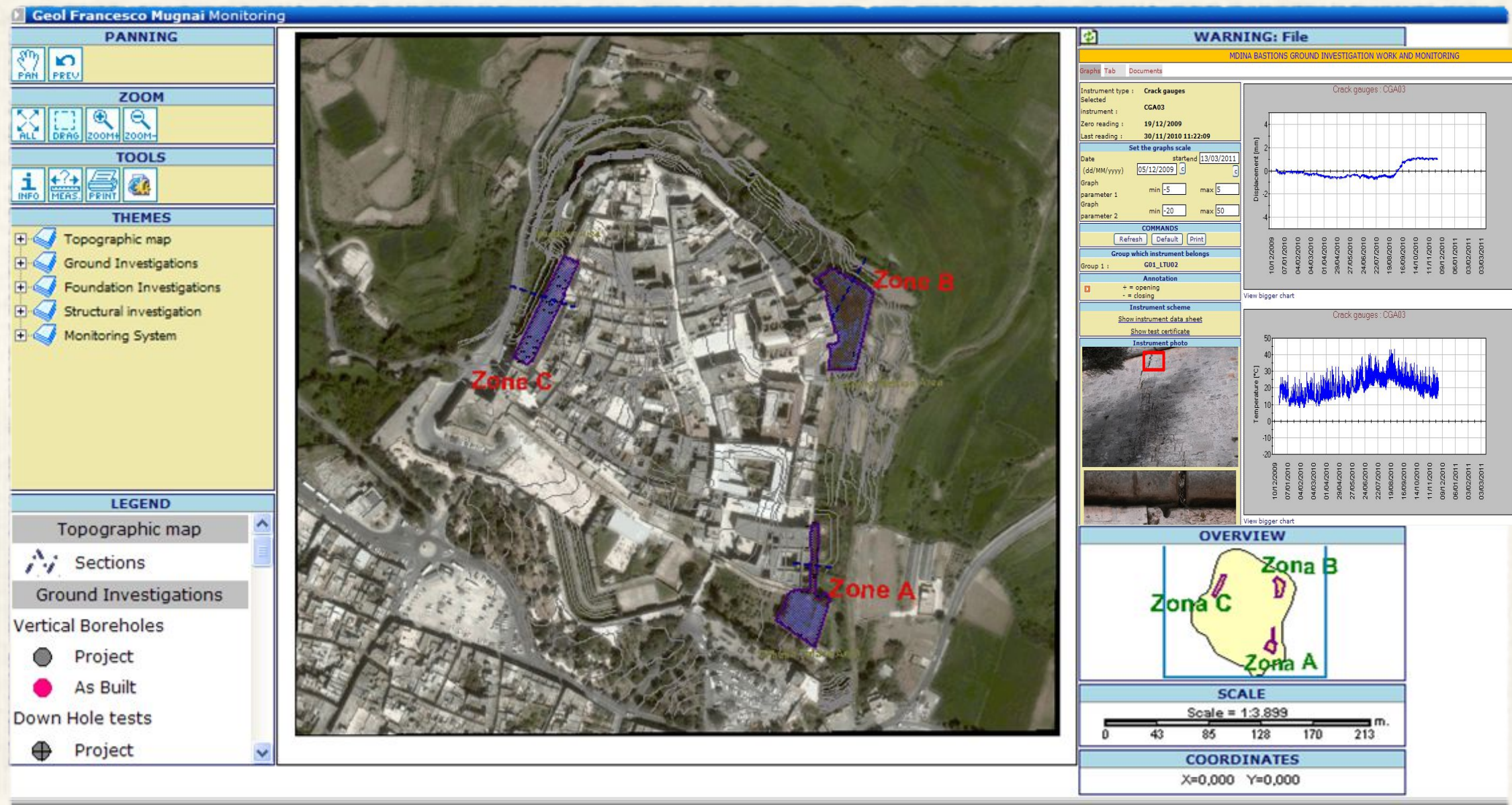


## 84 sensors



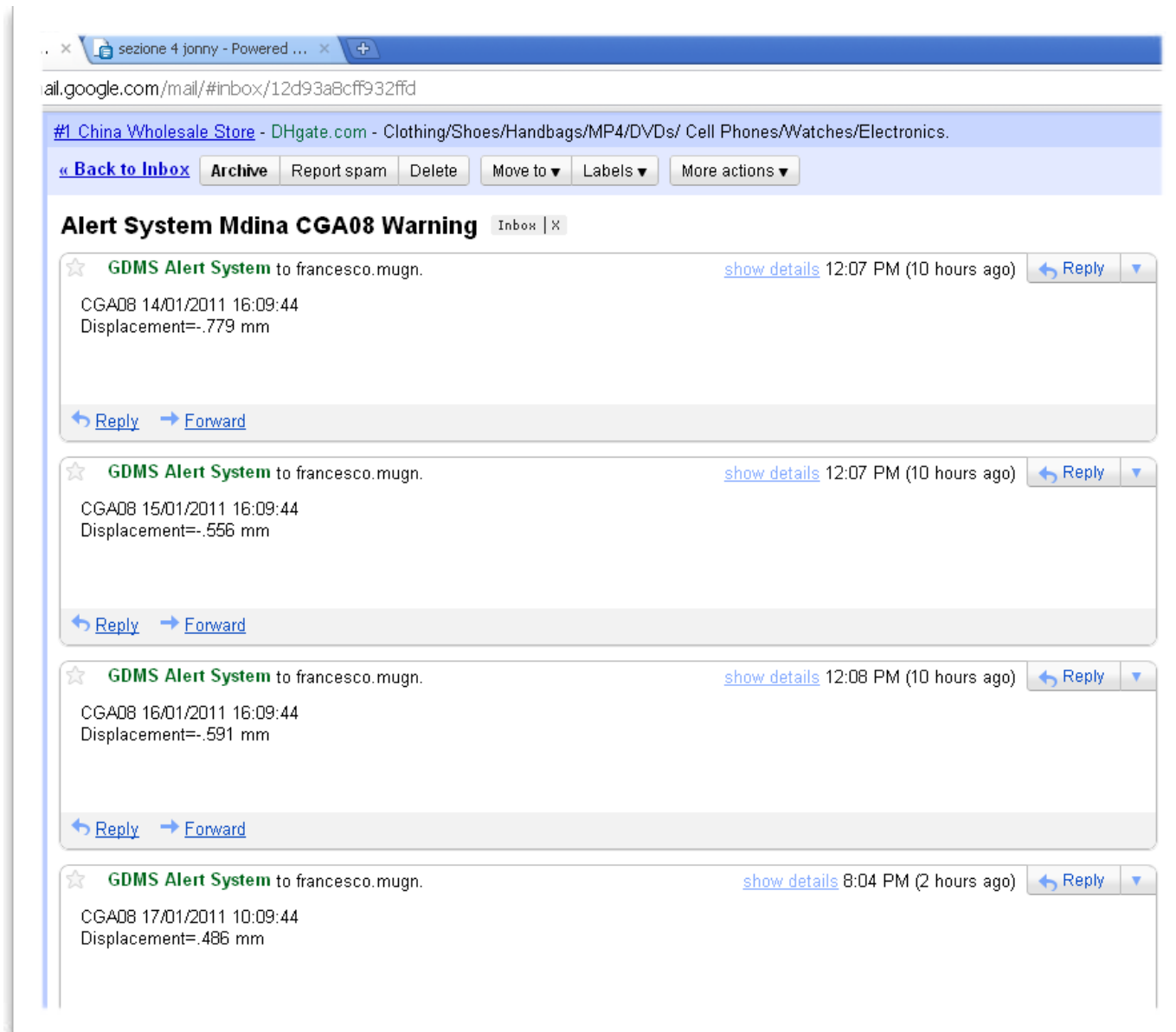


# Web-based control panel



To navigate through the site Java runtime environment is requested on the machine. For installation click here : [JAVA](#)  
© 2006 GD Test - All rights reserved - Legal Informations

# Notification system

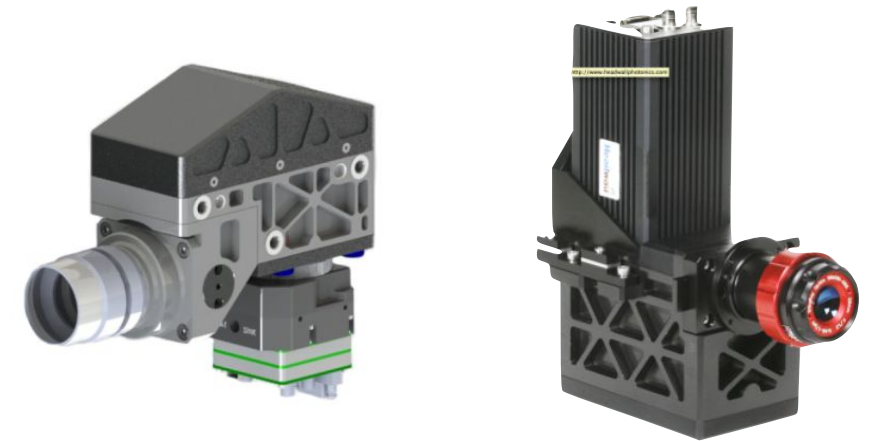




# Multi-sensor drones



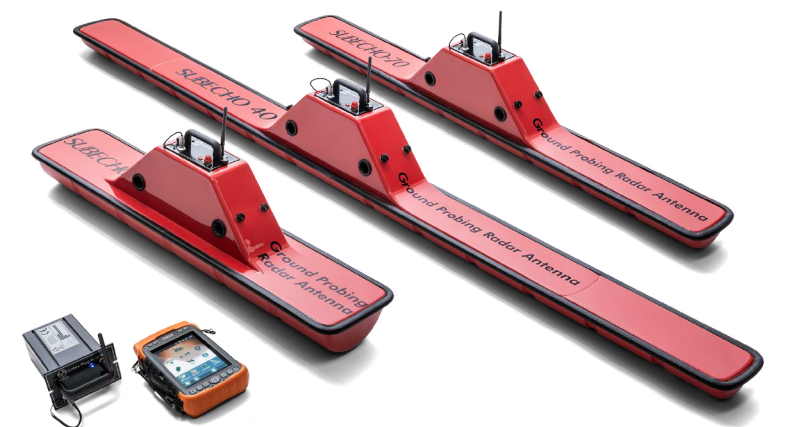
Multi and Hyper Spectral



Laser scanner



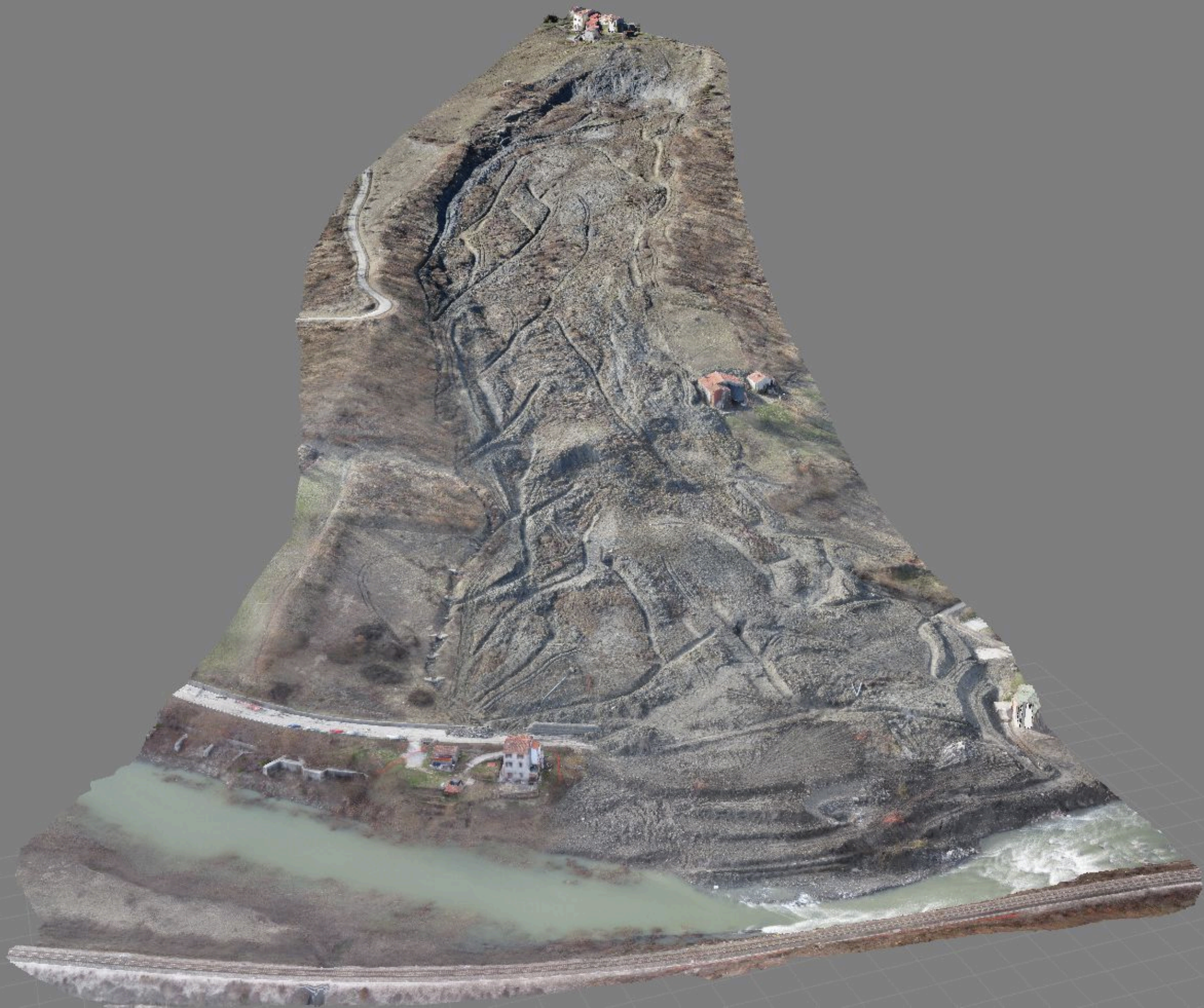
Ground penetrating radar



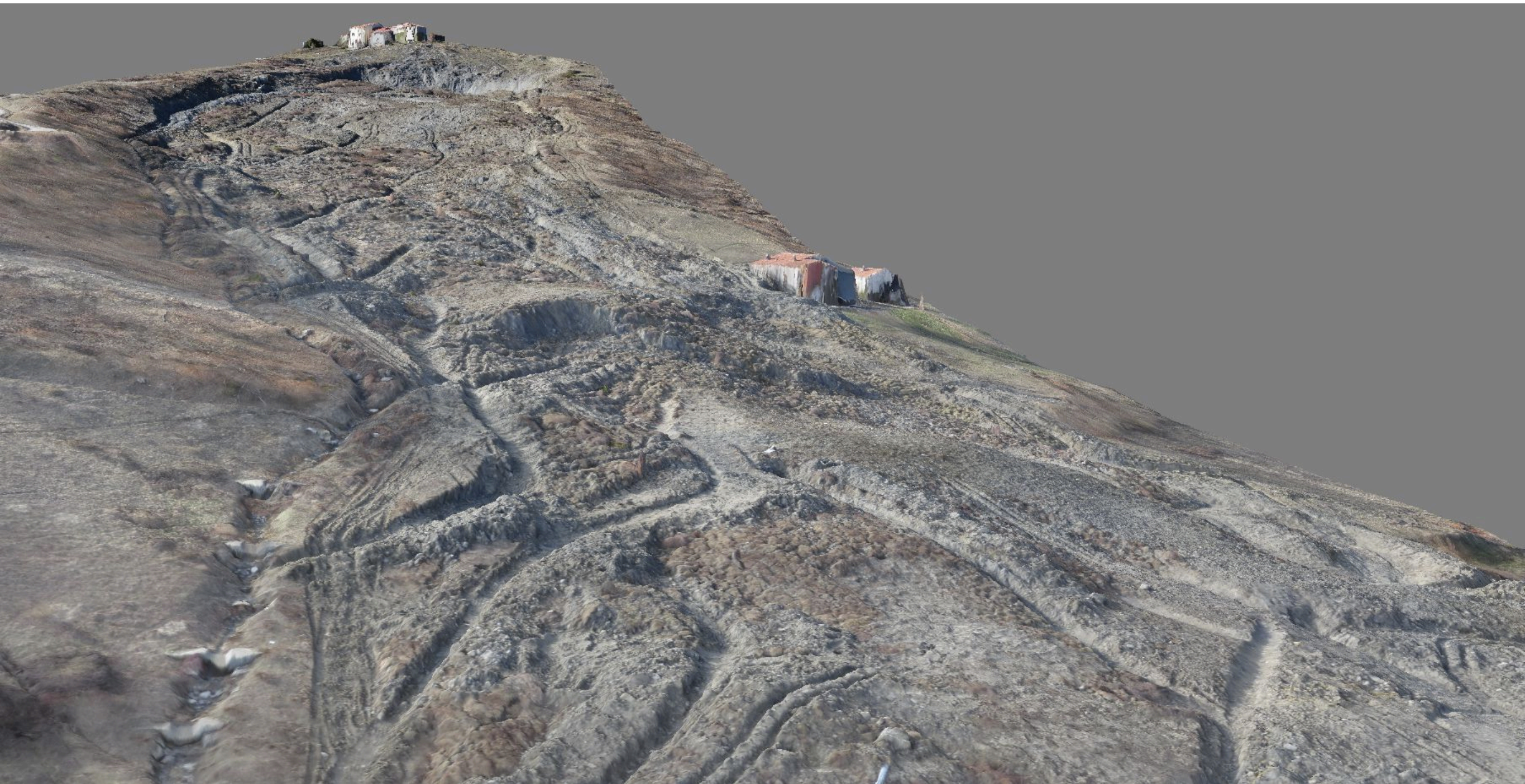




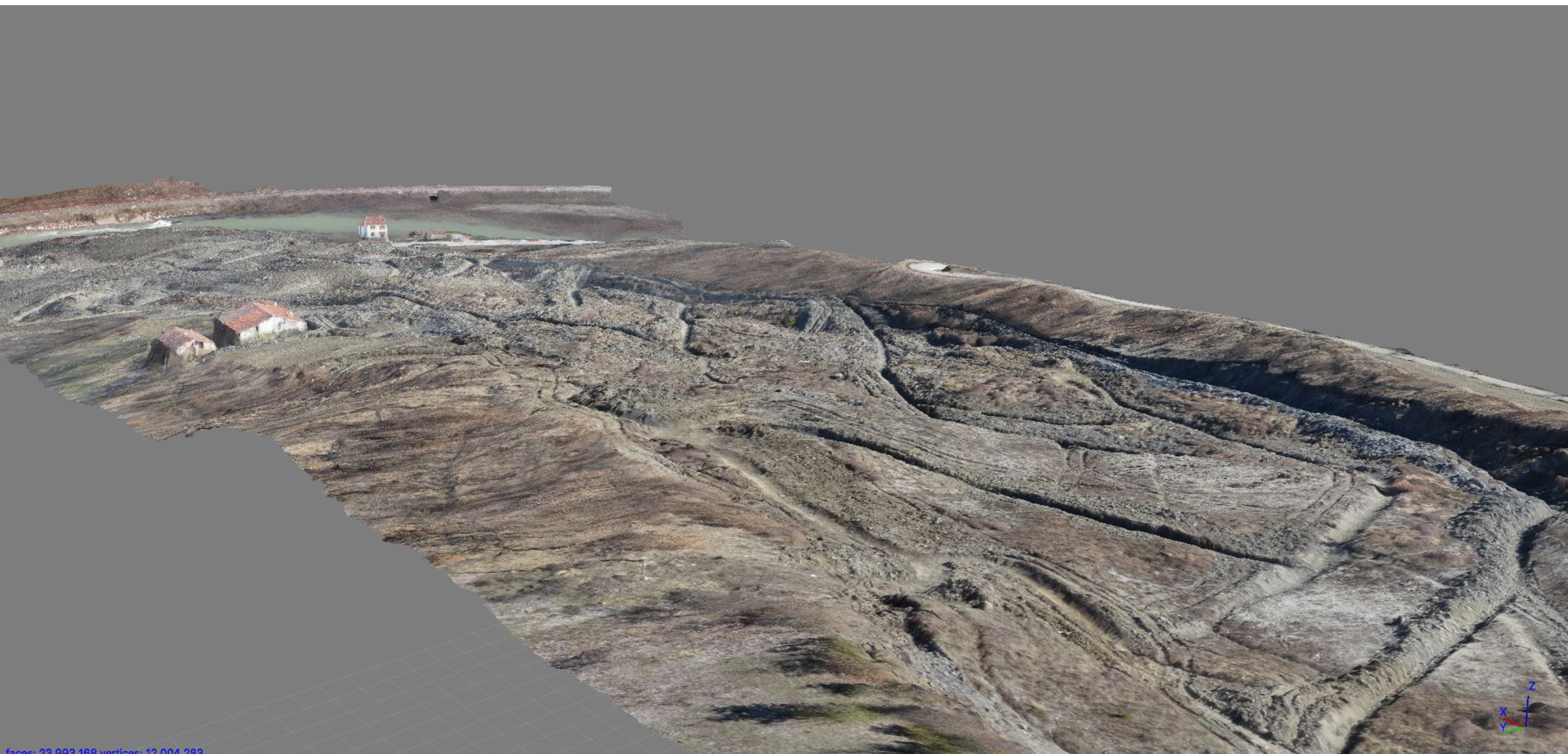












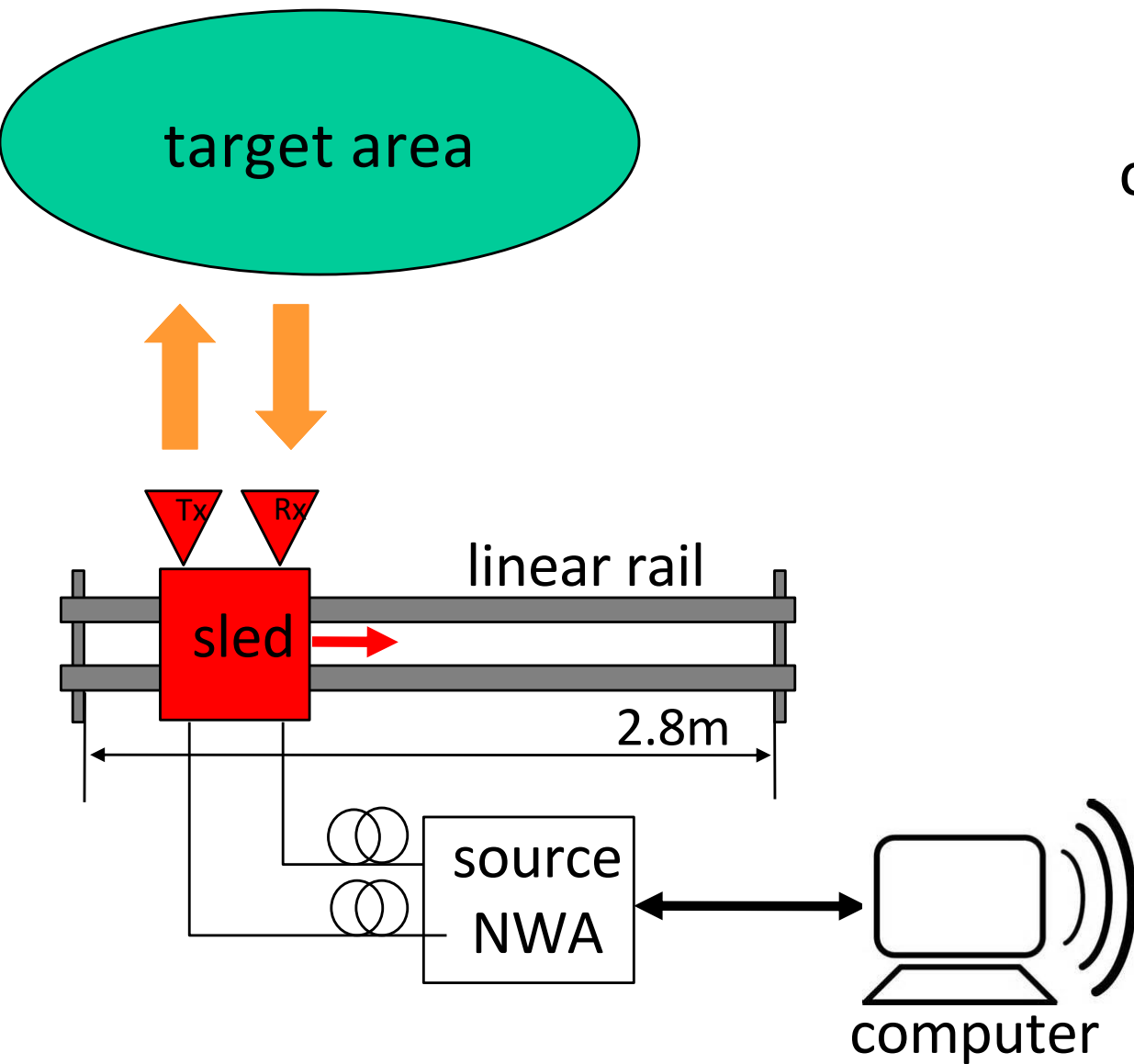
faces: 23,993,168 vertices: 12,004,283

# Ground-based radar monitoring



# GB-InSAR hardware

Continuous-wave stepped-frequency (CW-SF)  
radar based on a Network Analyser (NWA)  
operating in the frequency band 17.0-17.1 GHz



The synthetic aperture is obtained  
sliding the antennas along a linear  
rail



# Interferometry

Image 1

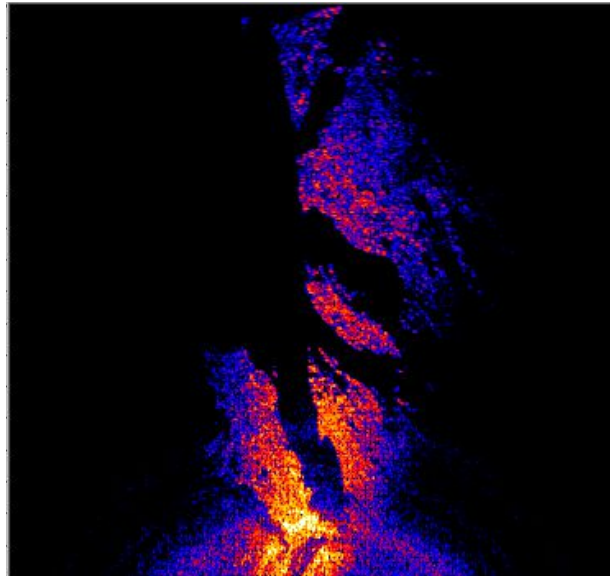
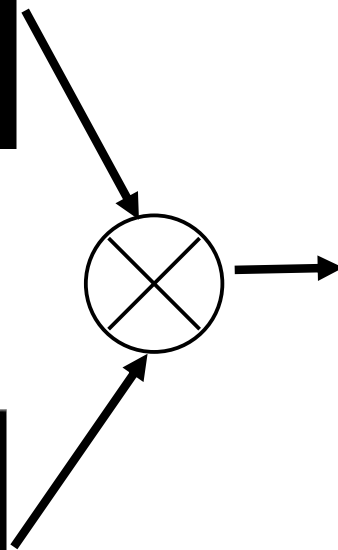
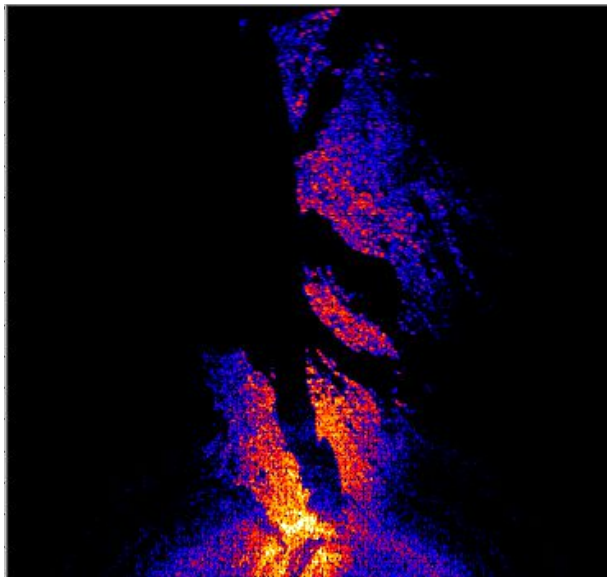
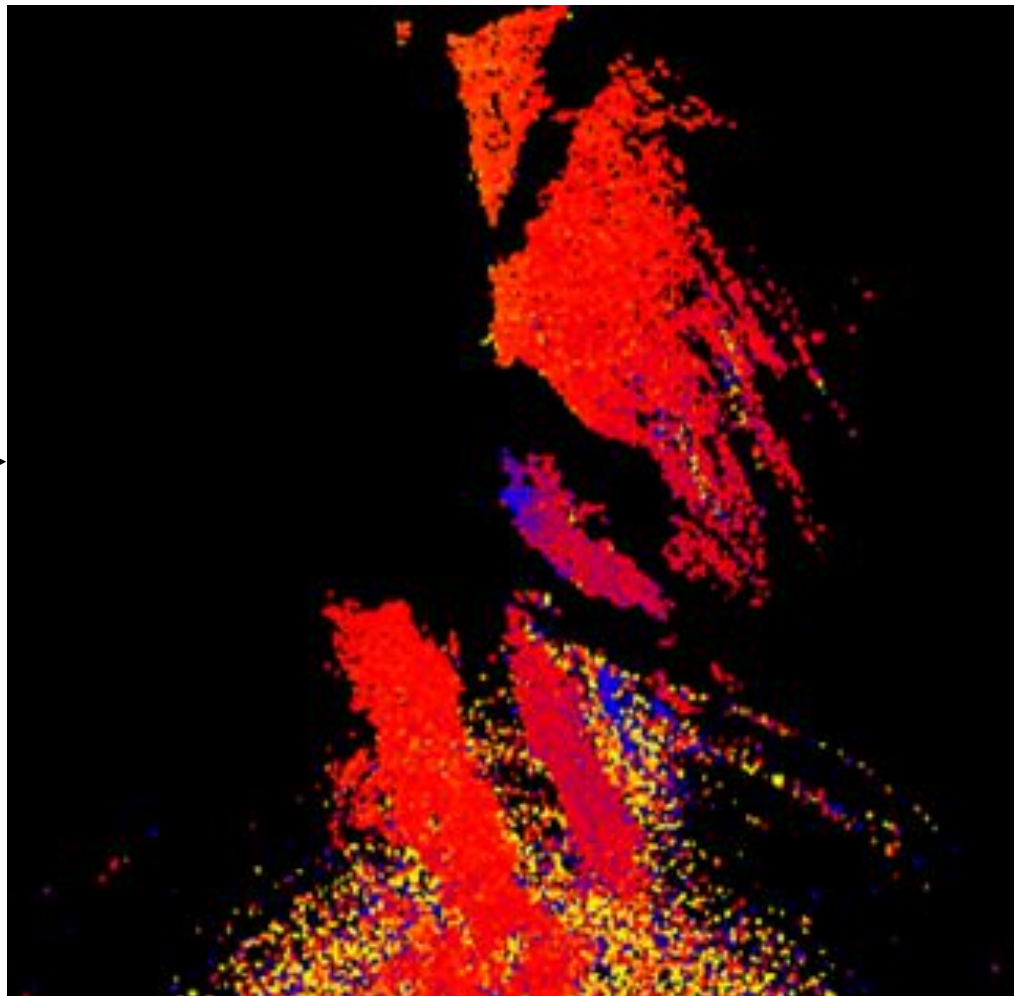


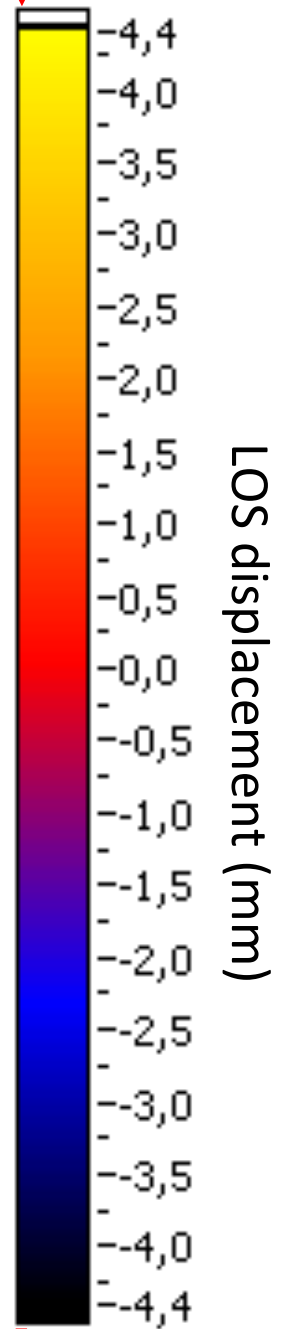
Image 2



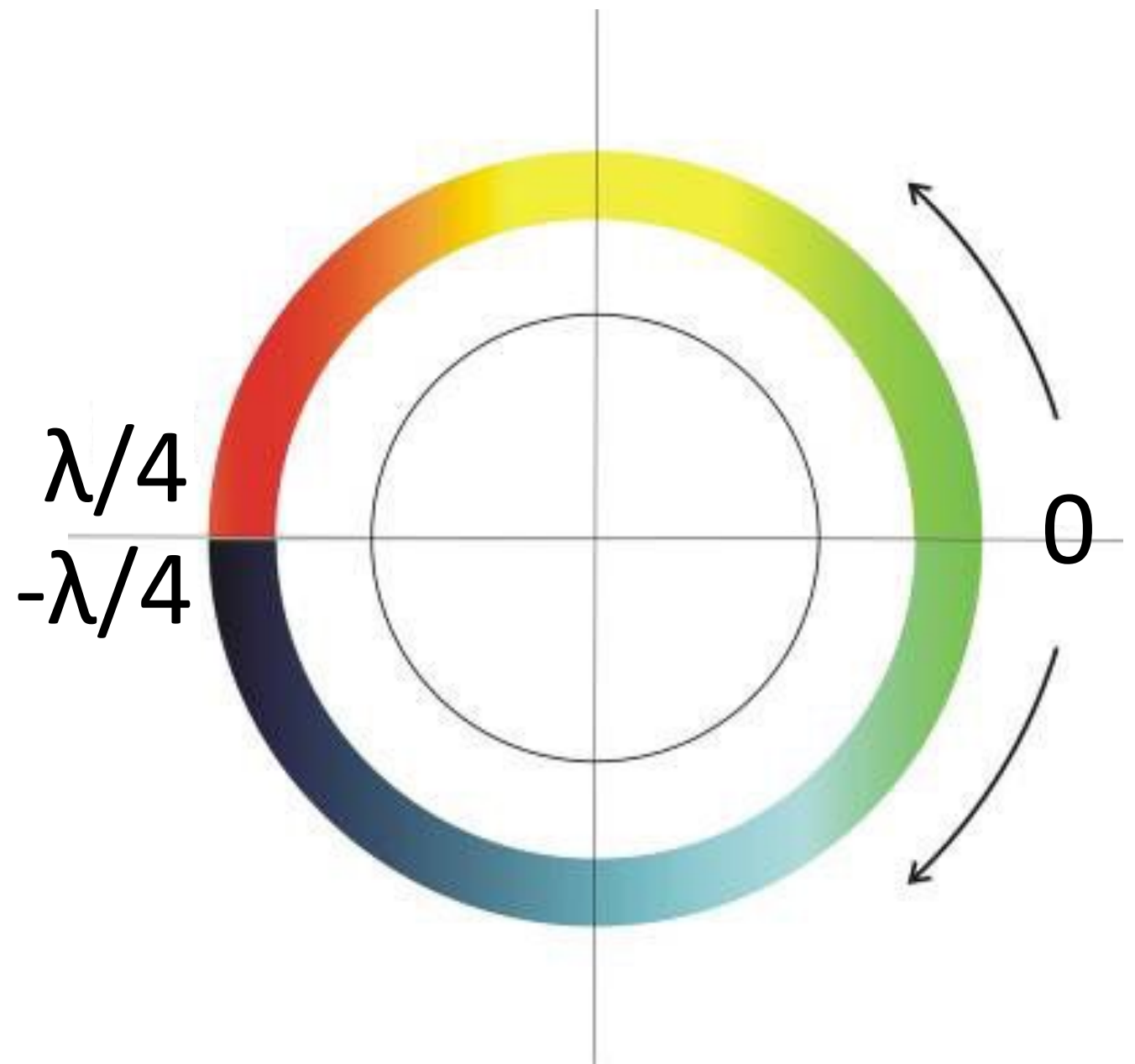
Interferogram  
(phase difference)



phase wrapping



# Phase wrapping



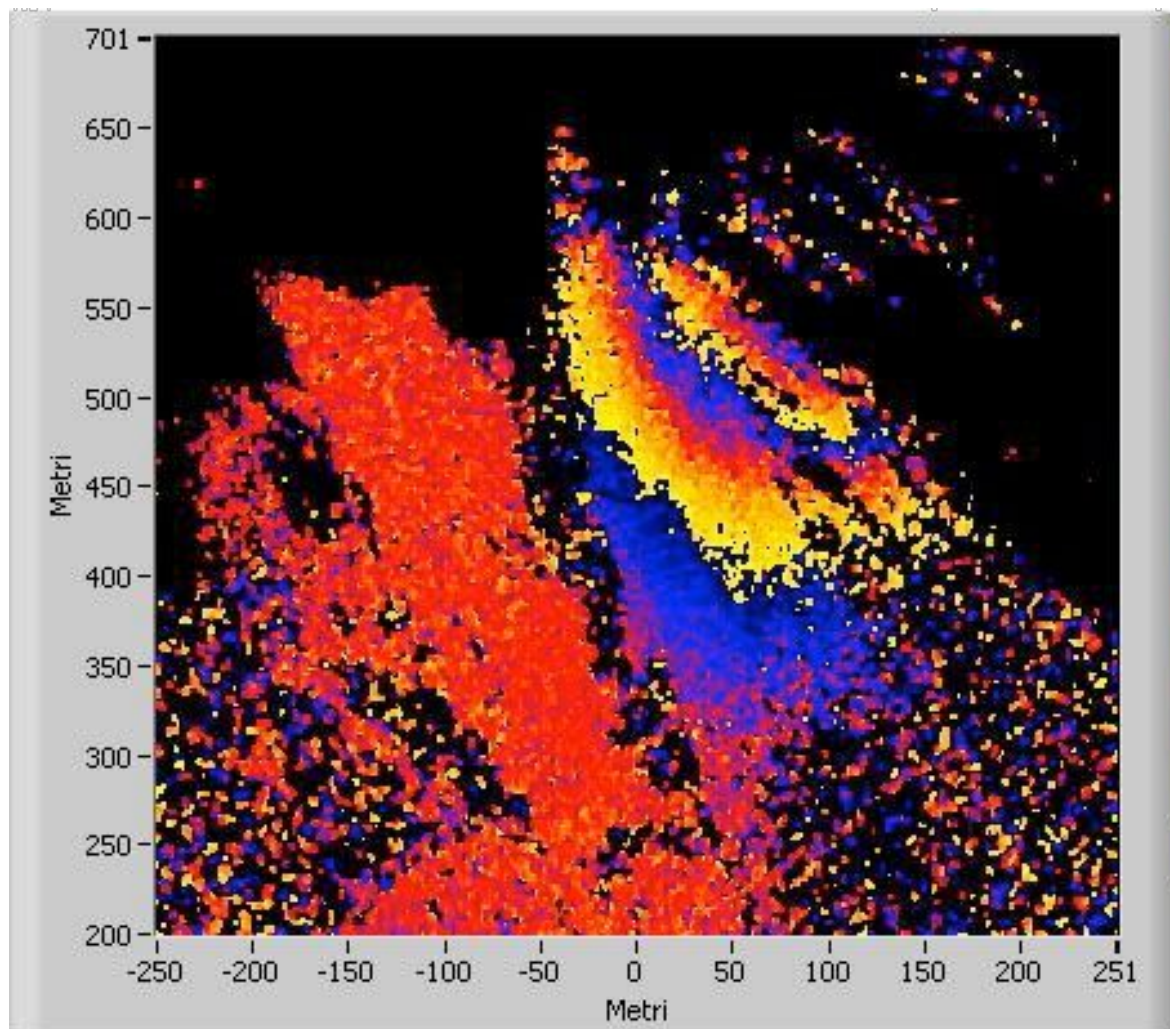
$\lambda = 17,2 \text{ mm}$     -     $\lambda/4 = 4,3 \text{ mm}$



# Phase wrapping and decorrelation

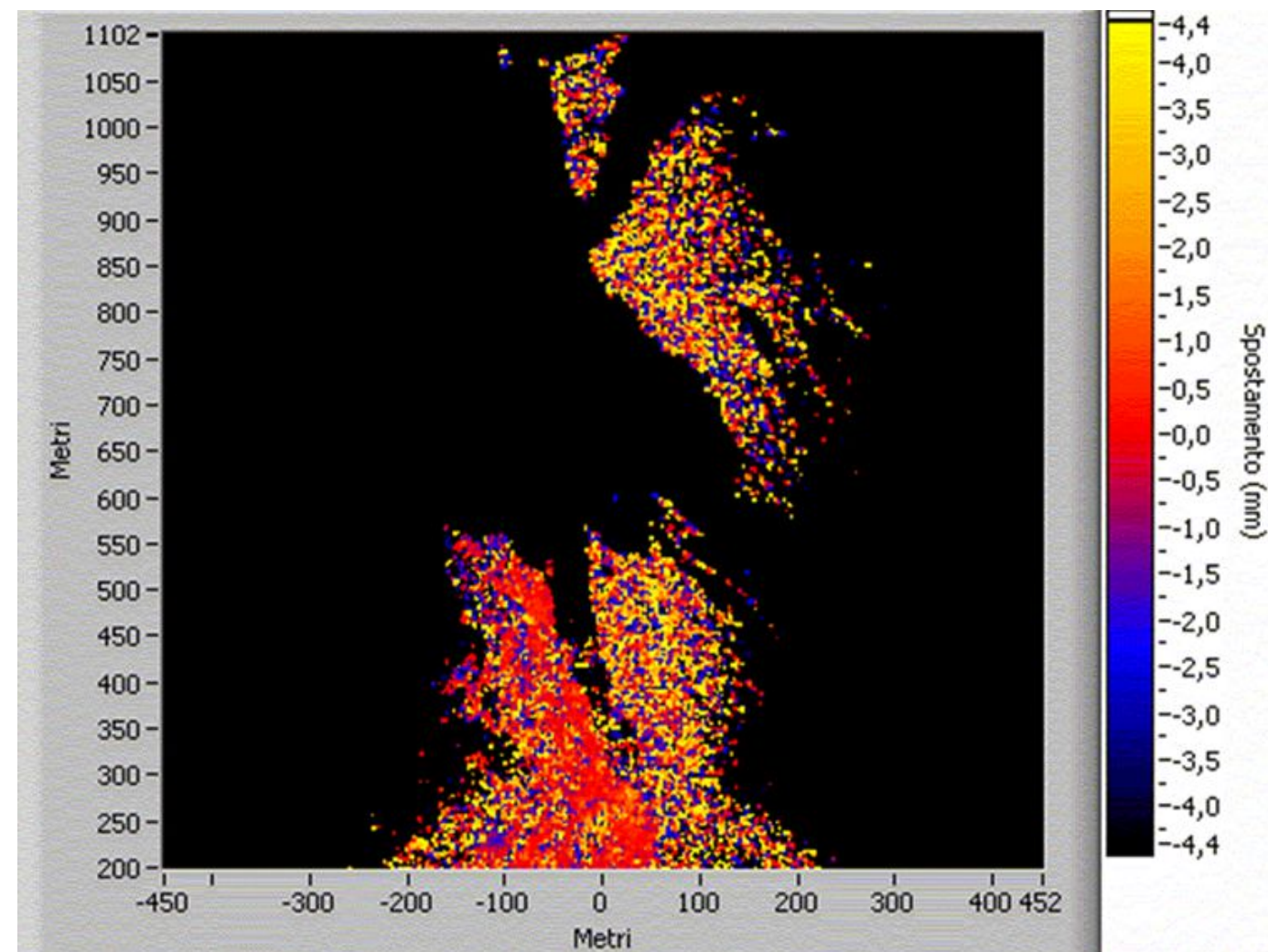
## Phase Wrapping:

Large displacement generates fringes



## Decorrelation:

Rapid motion causes “salt & pepper” texture



Coherence ( $0 < \Gamma < 1$ ) gives an estimate of the error in measured differential phase







Cumulated displacements measured from 15:57:31 2018/03/08 to 15:57:54 2018/03/12  
Elapsed time: 4d 0h 0min 23sec



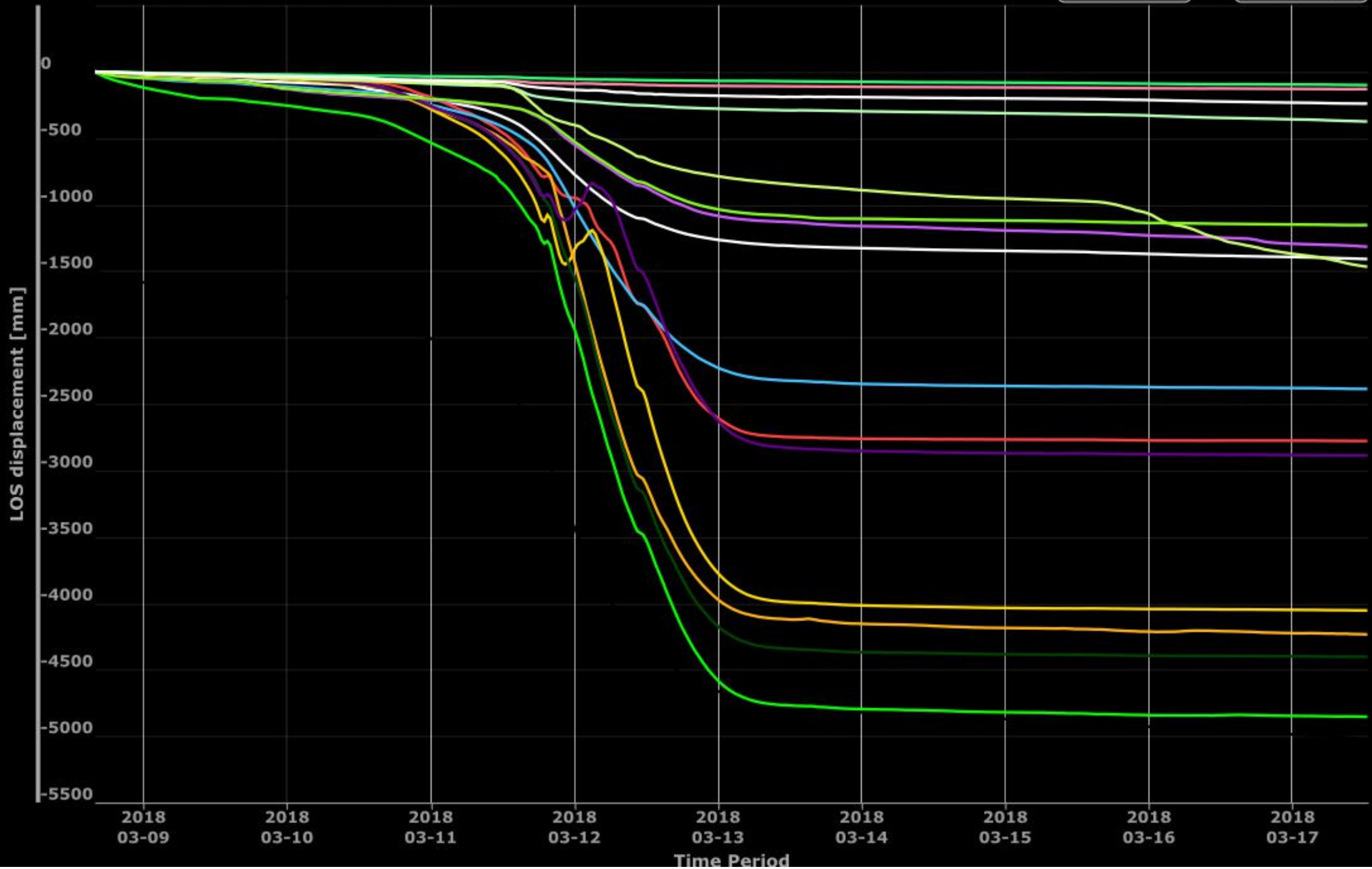


# "Marano Monitoring [GMT+1]"

— Pts\_01 — Pts\_03 — Pts\_04 — Pts\_05 — Pts\_06 — Pts\_08 — Pts\_09 — Pts\_10 — Pts\_11 — Pts\_12 — Pts\_13 — Pts\_14 — Pts\_15 — Pts\_19 — Pts\_16 — Pts\_17

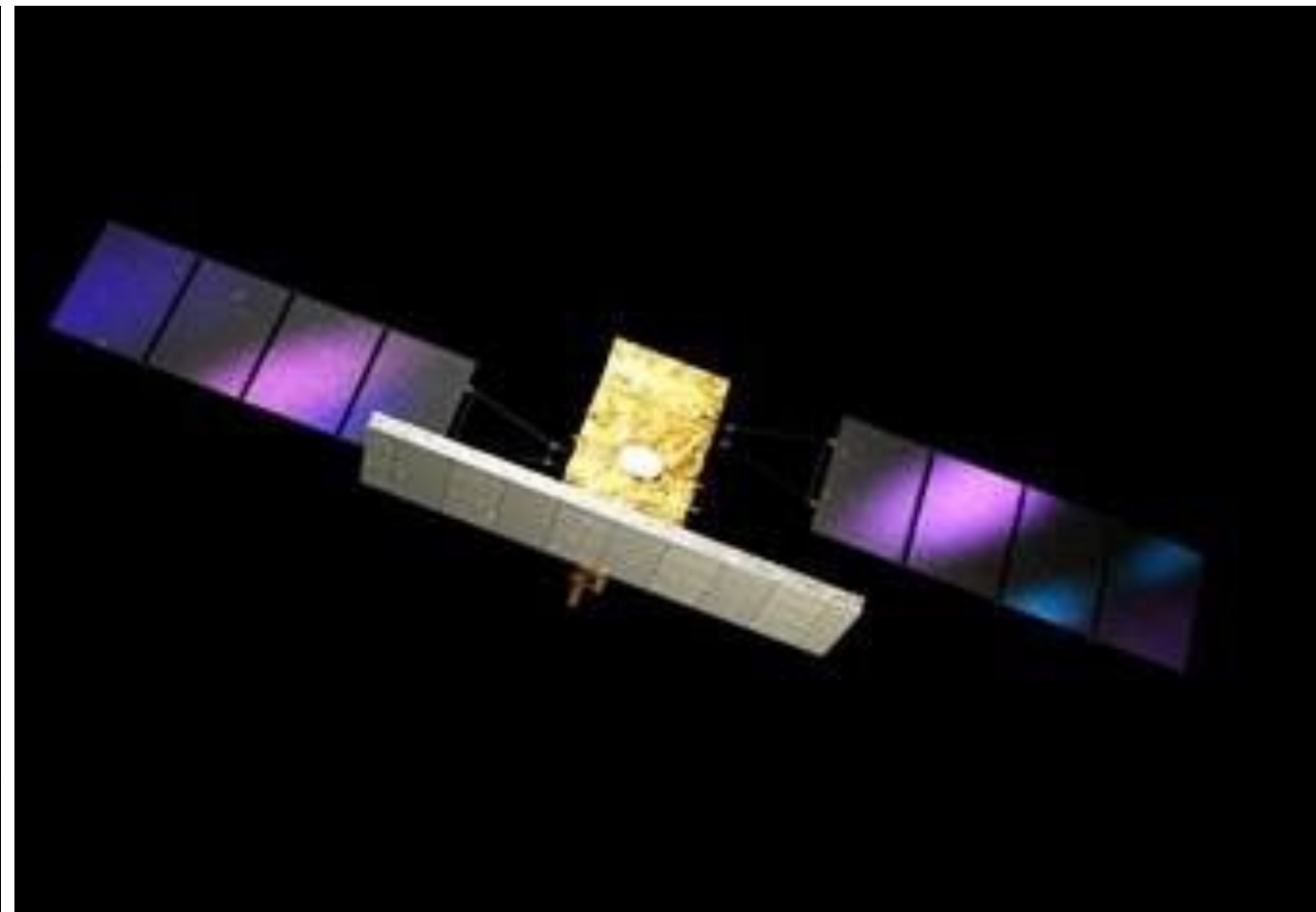
Zoom 1d 1w 1m 3m 6m 1y All

From: Mar 8, 2018 To: Mar 17, 2018



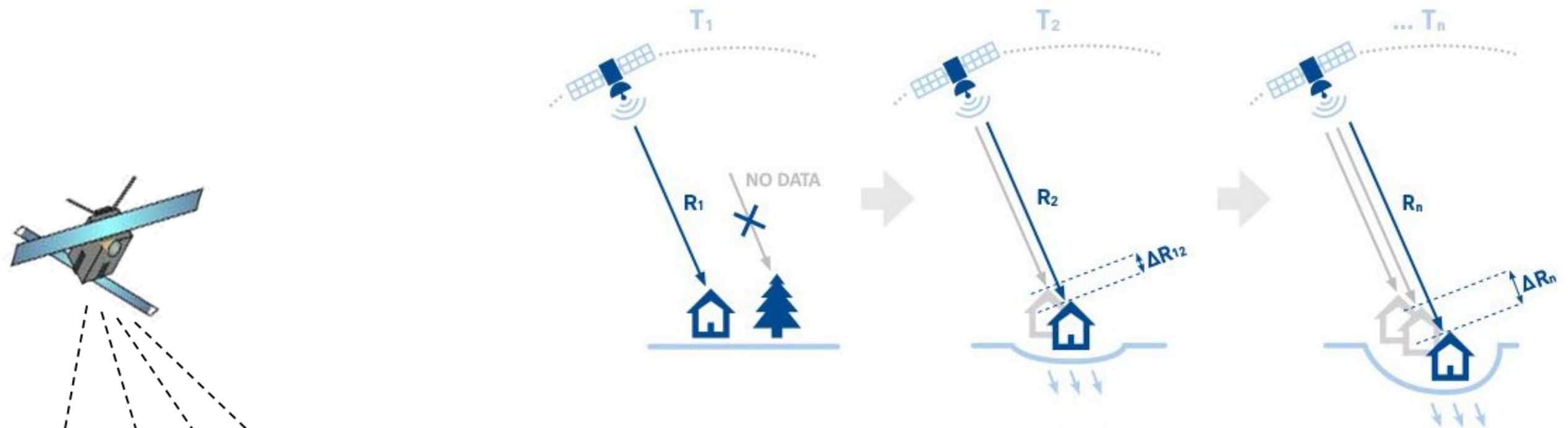
# Satellite radar monitoring

# Radar Satellites

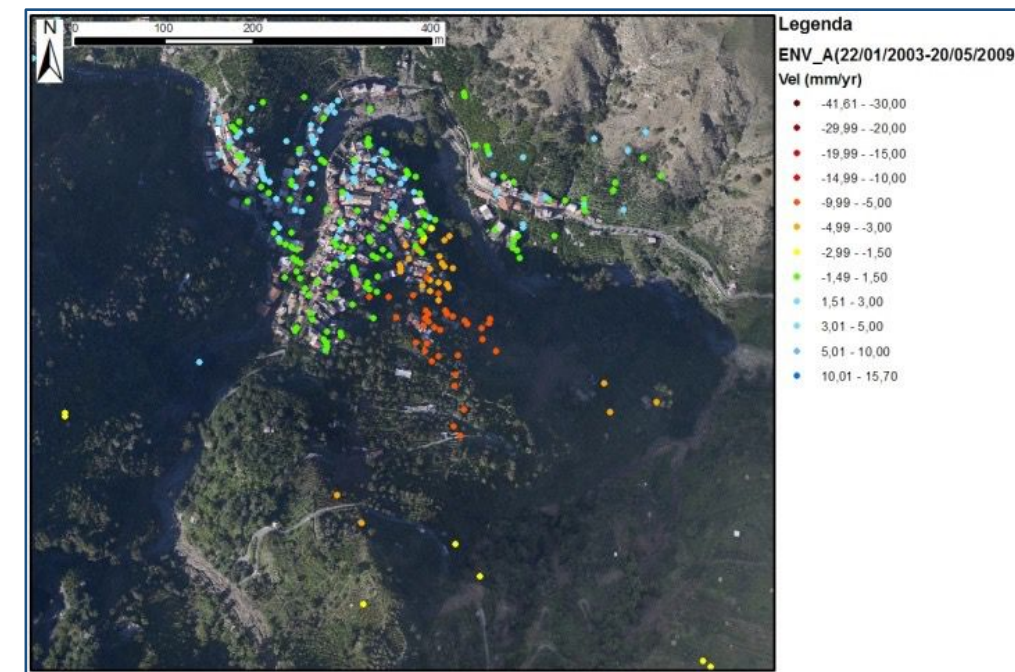




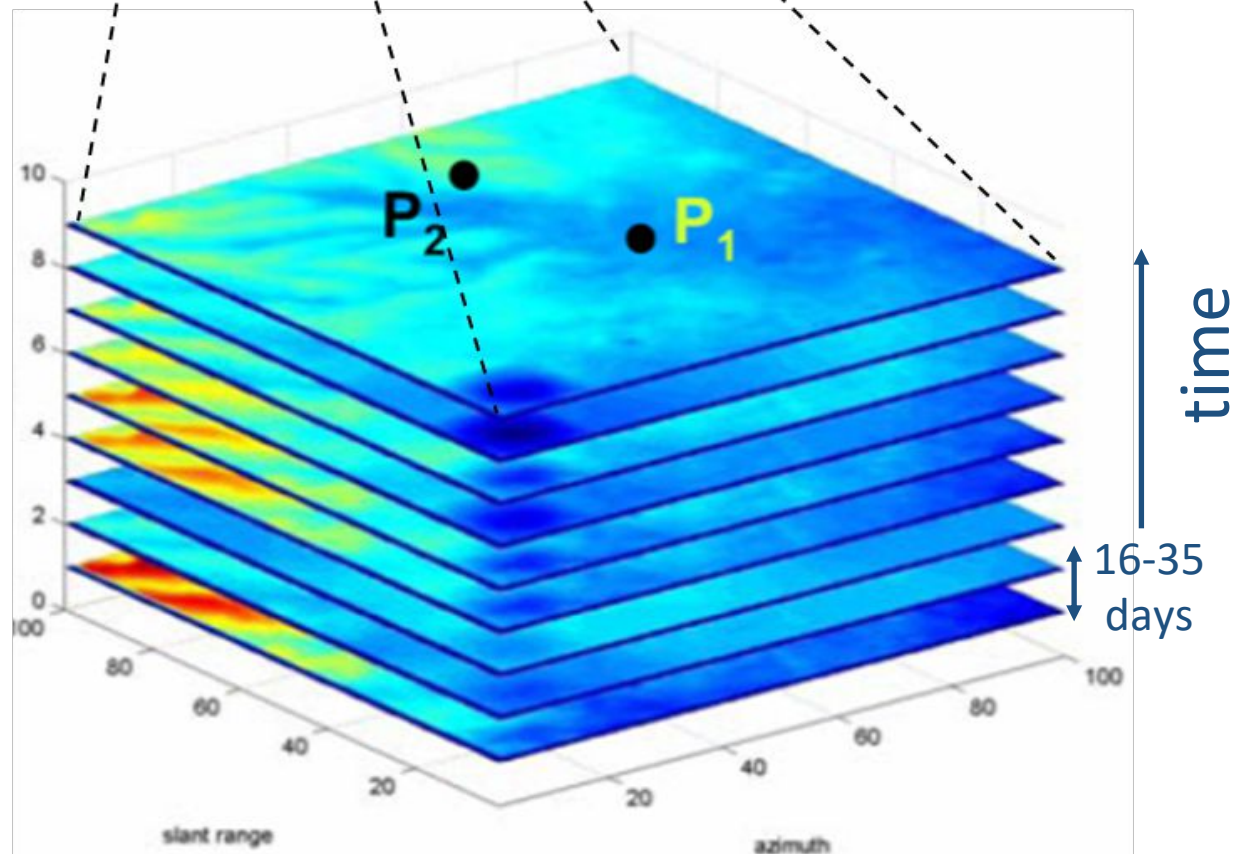
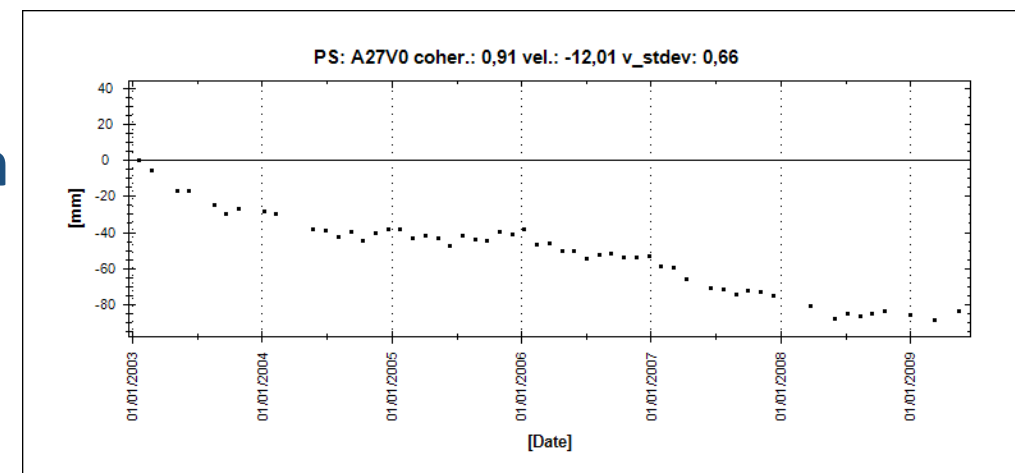
# Persistent Scatterers Interferometry



LOS average  
displacement  
rate

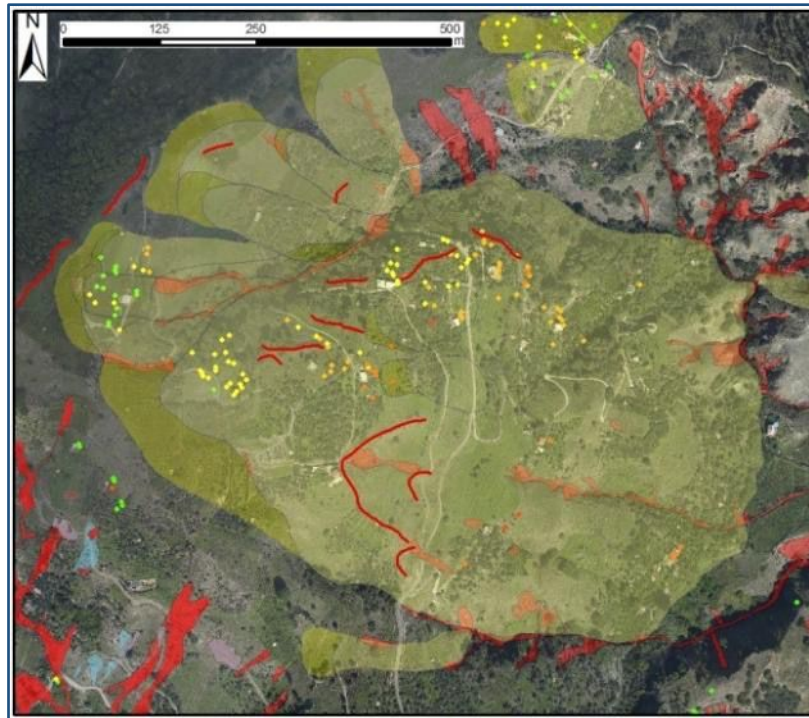


Deformation  
time series

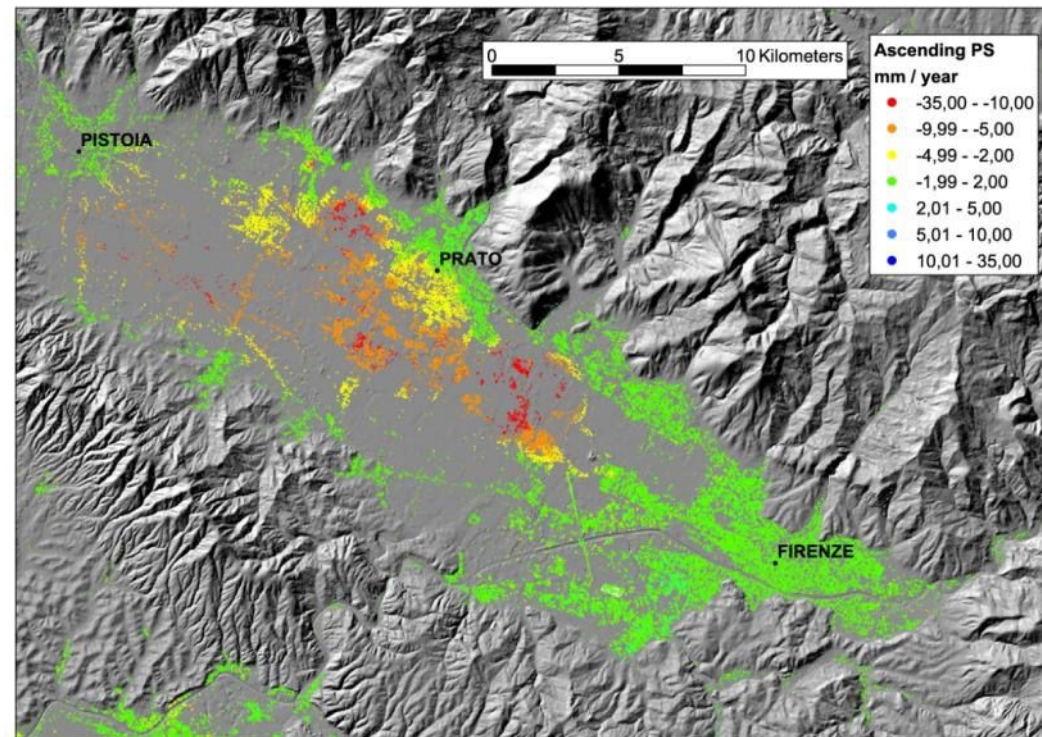




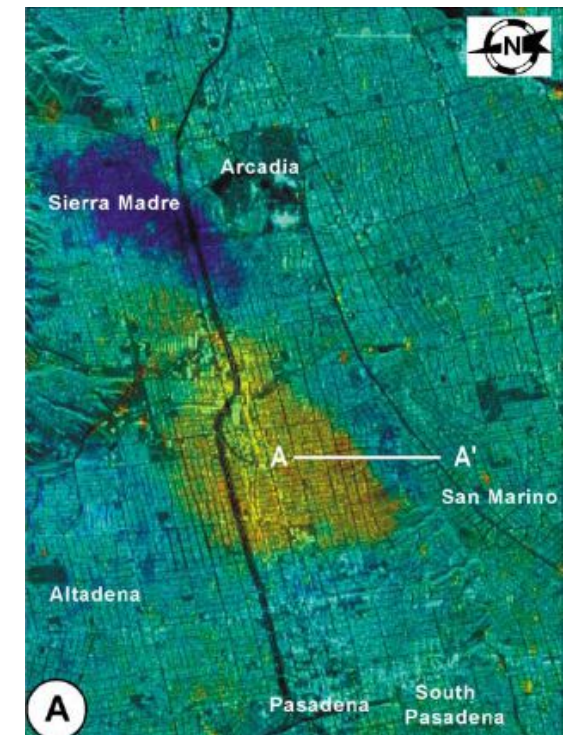
# Fields of application



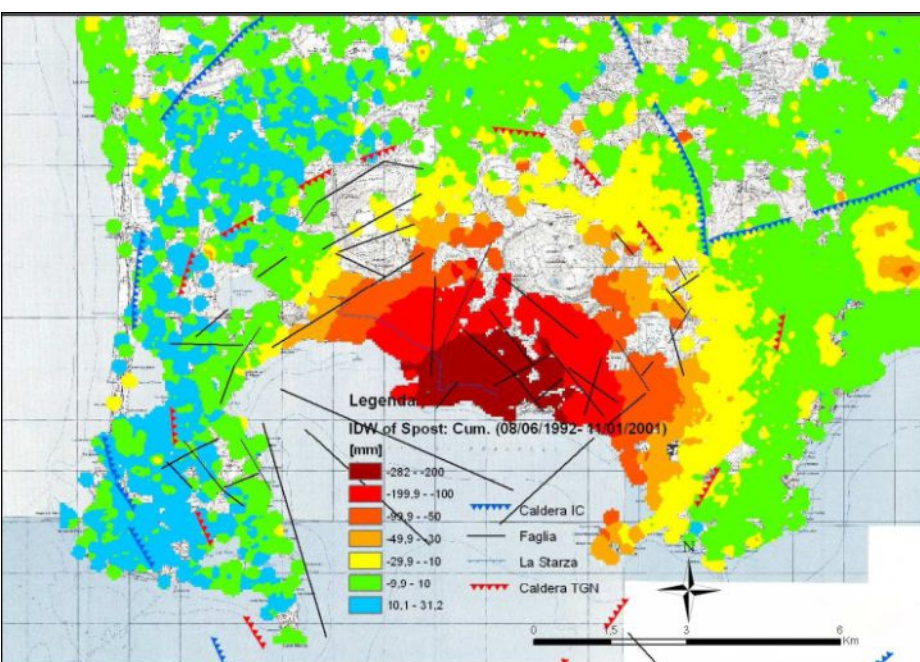
Landslides



Subsidence



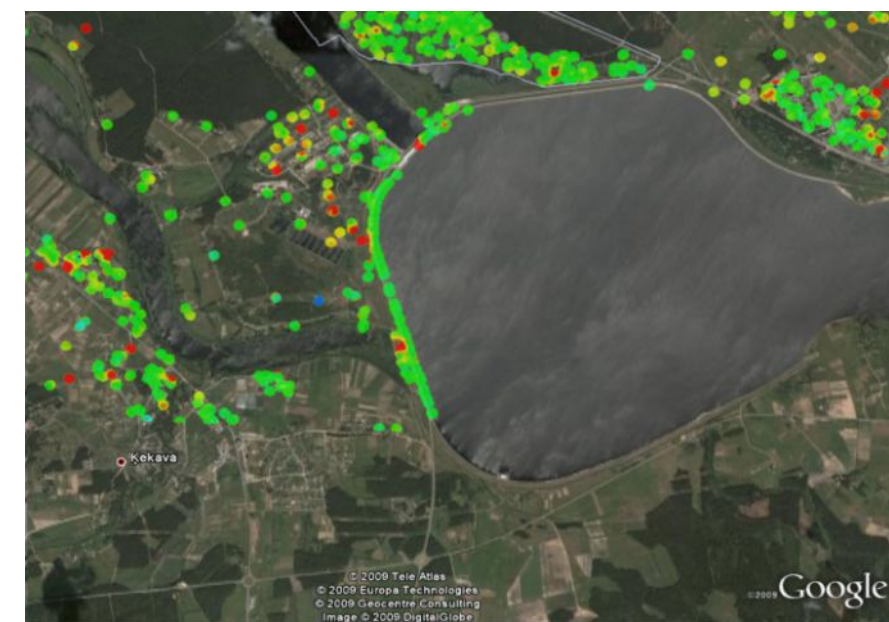
Tectonics



Volcanic activity



Building deformation



Levees and embankments



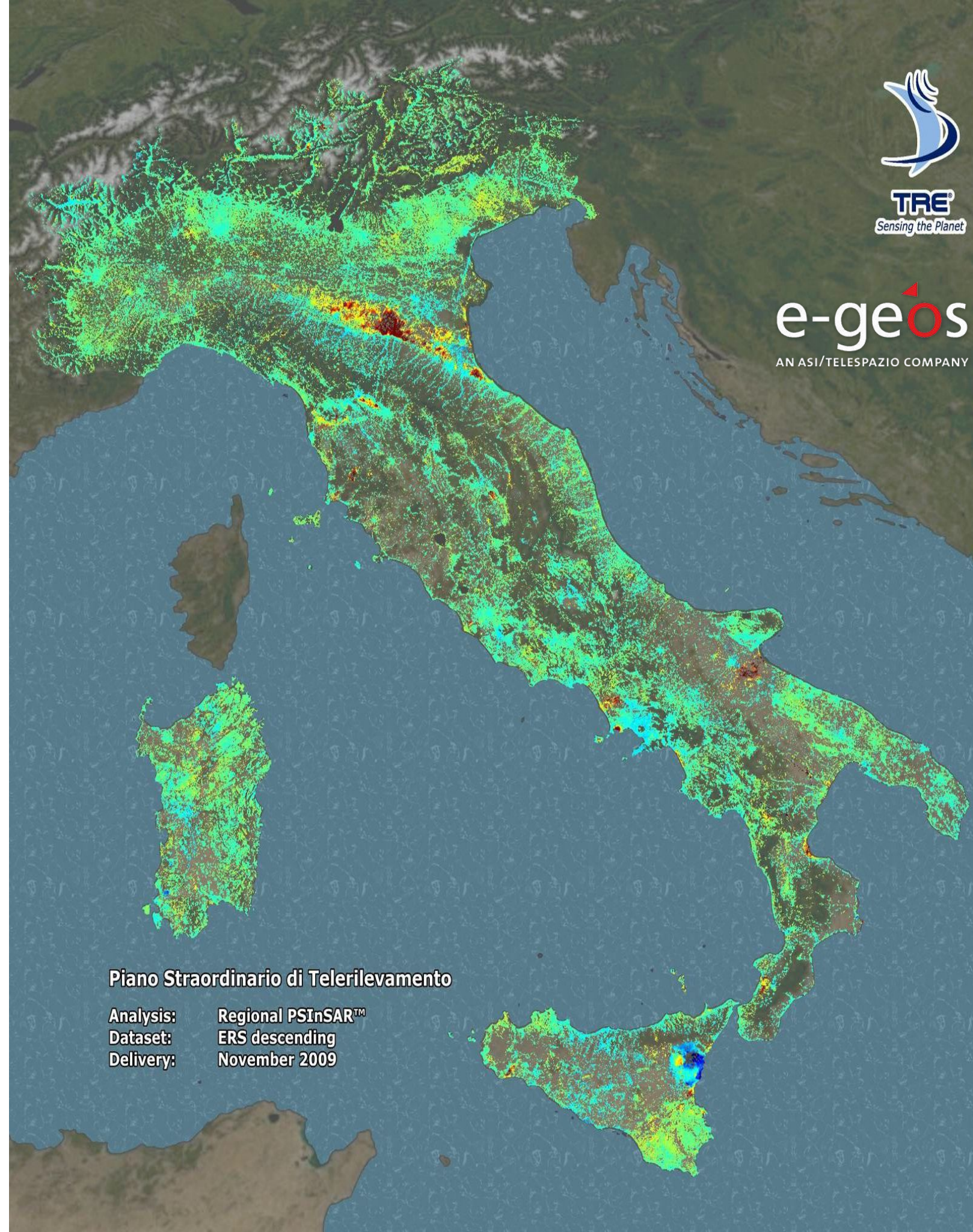
# Multi-risk multi-scale monitoring

Livello	Satellite	Revisiting time	Resolution	Product
National	Sentinel-1	6 days	14x5 m	Hotspot mapping Trend change detection Cluster Risk Classification
Regional	Sentinel-1 / Cosmo SkyMed	6/16 days	14x5 m 3x3 m	Regional warning system Inventory updates
Local	Cosmo SkyMed	16 days	3x3 m	Precision mapping Local warning system
Emergency	Cosmo SkyMed / GB-InSAR	1 minute / 1 day	< 1 m	Residual risk assessment Onsite early warning system



# National coverage PSI

22 million of  
permanent  
scatterers

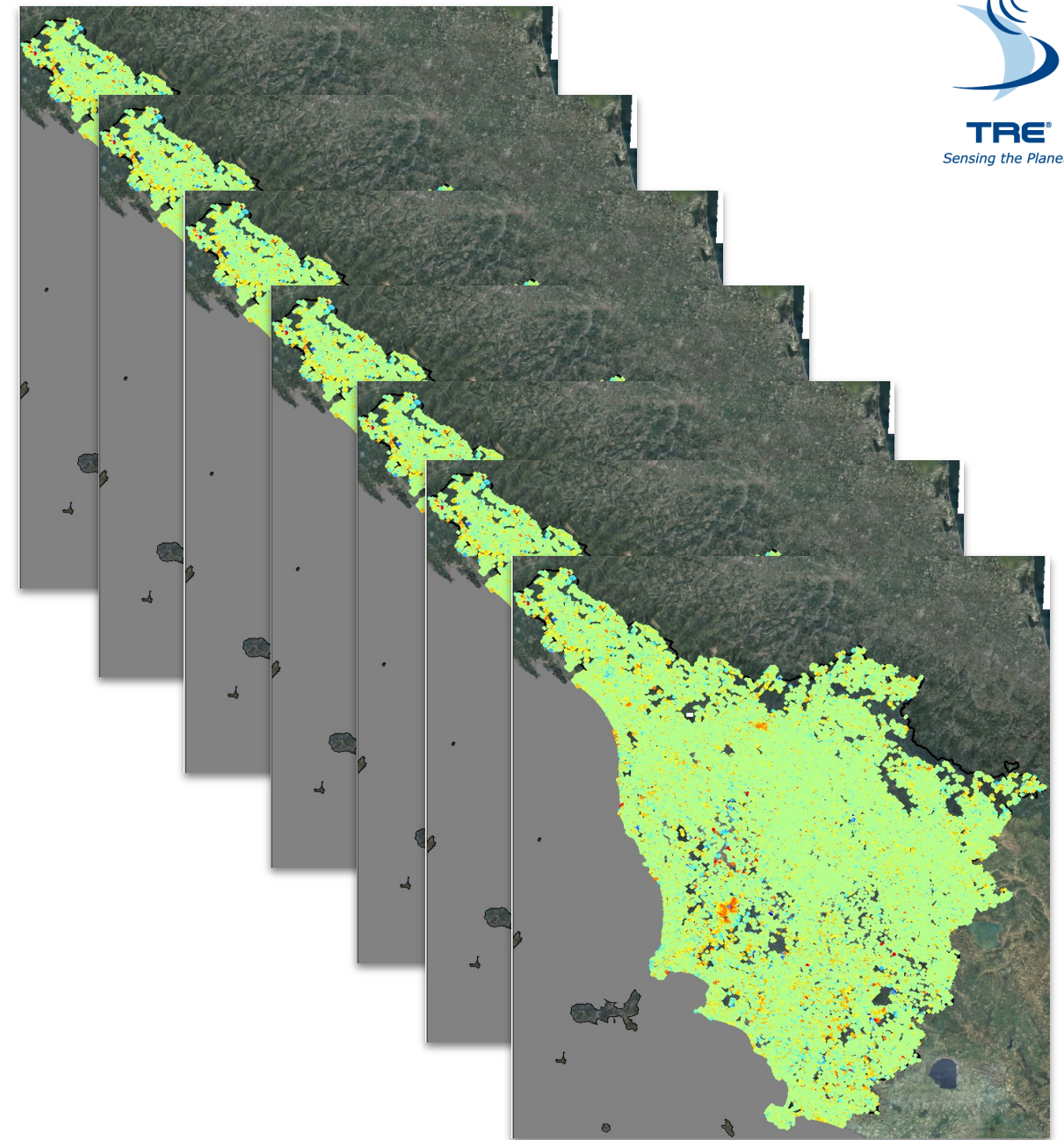




# PS Continuous Streaming



European Space Agency

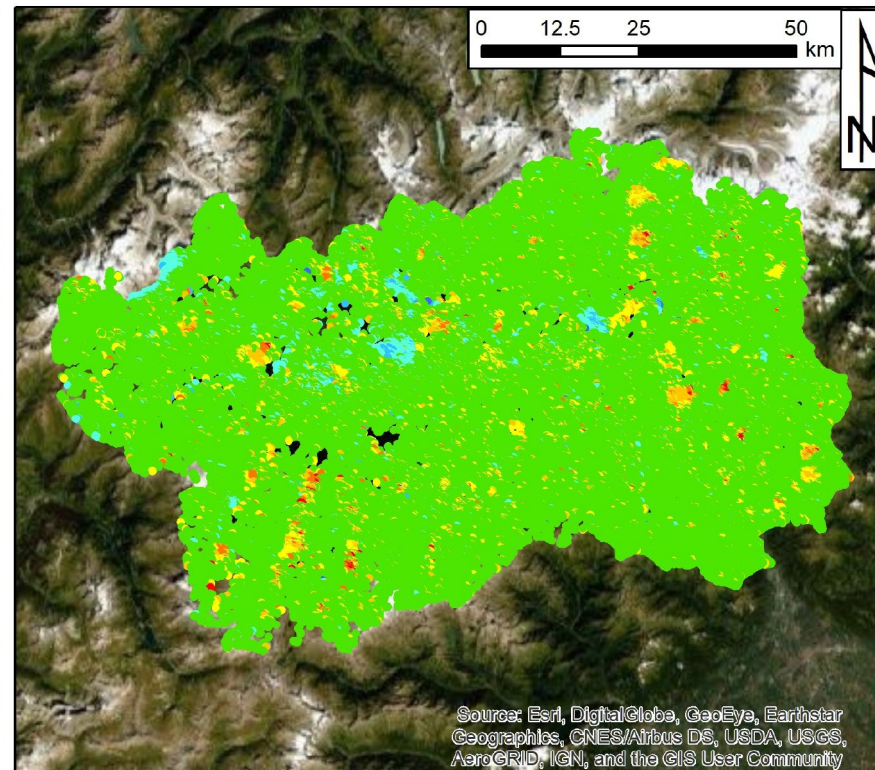
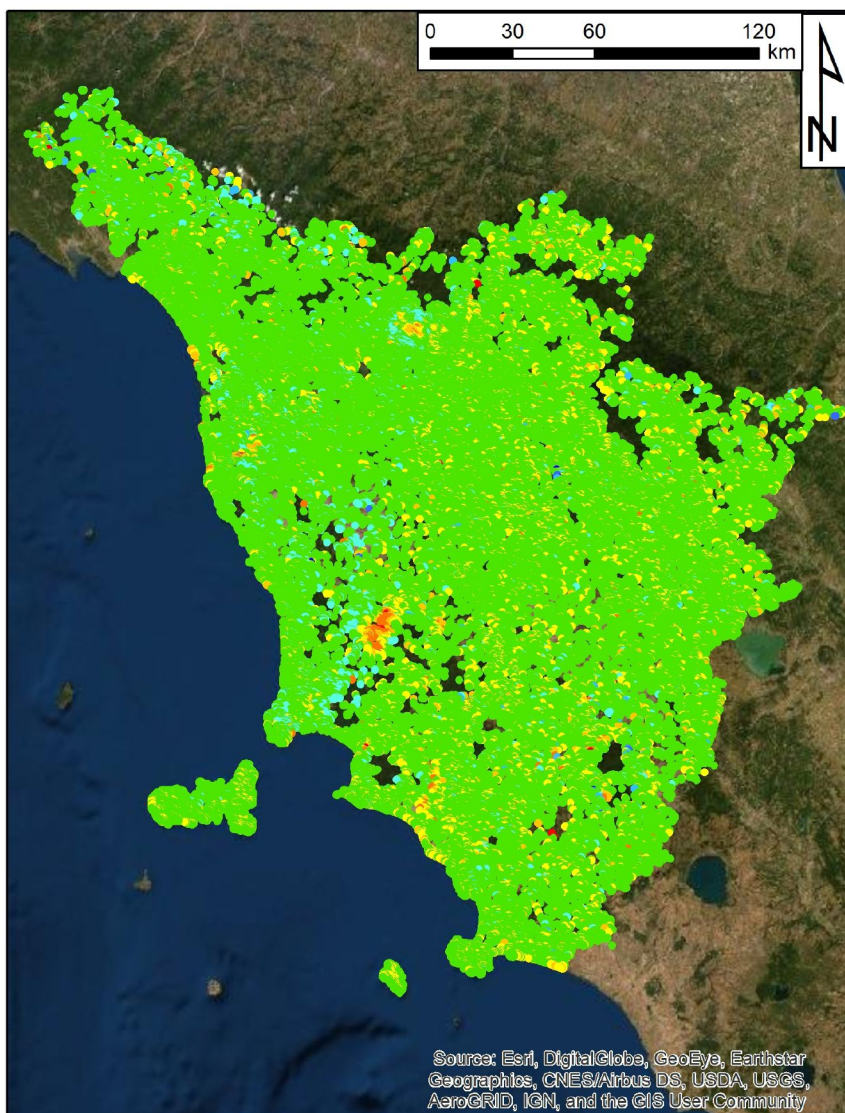


**Revisiting time: 6 days**

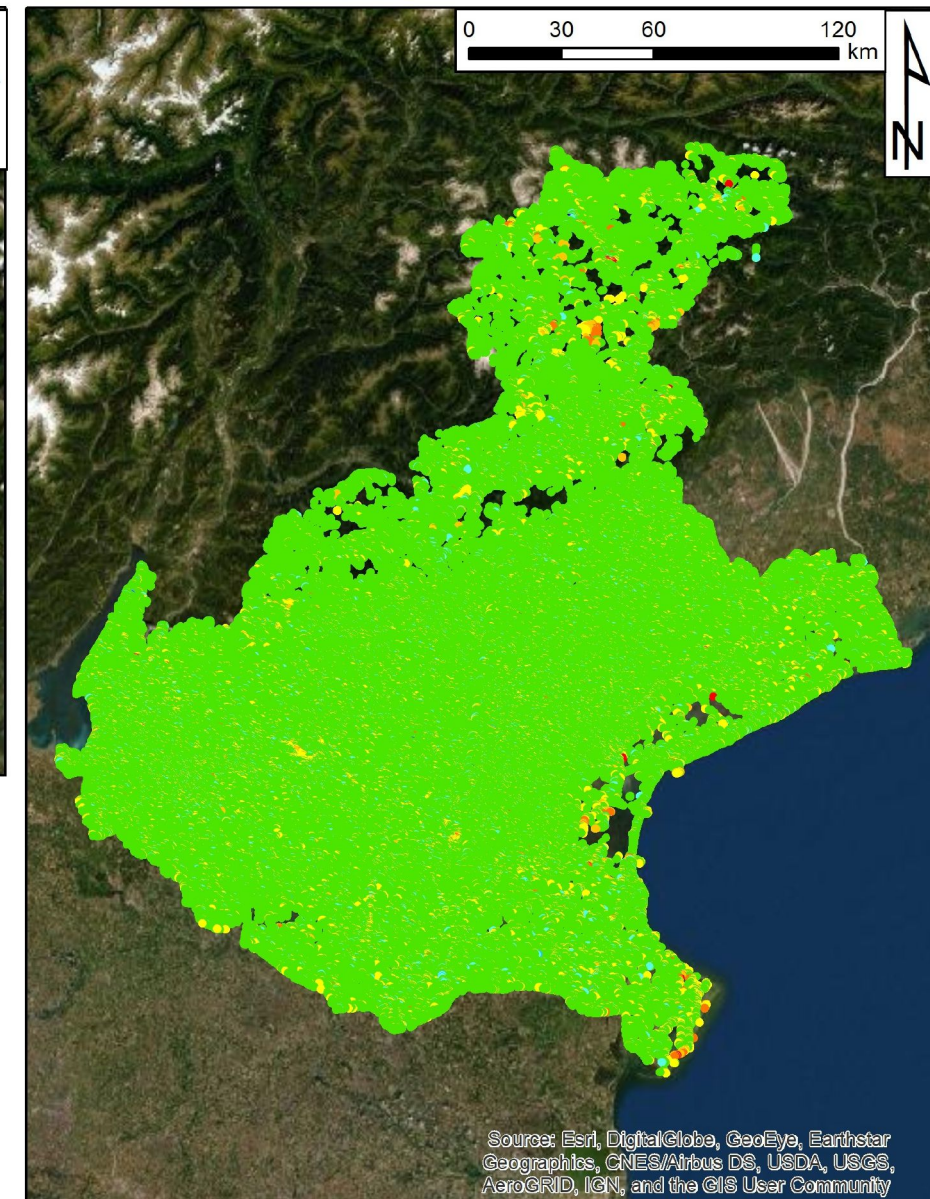
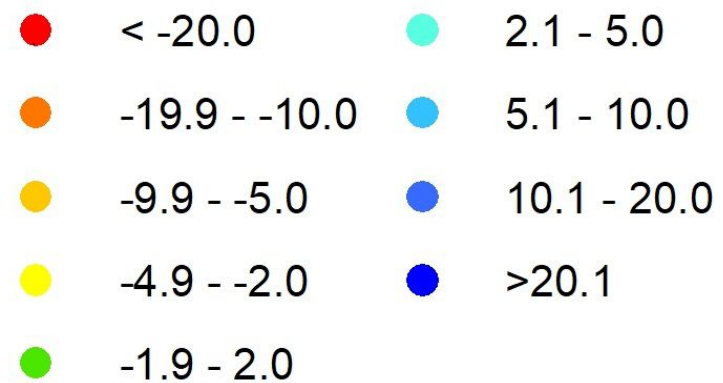
**First application of PS-InSAR Continuous Streaming at regional scale (2016)**



# Regional PS Streaming



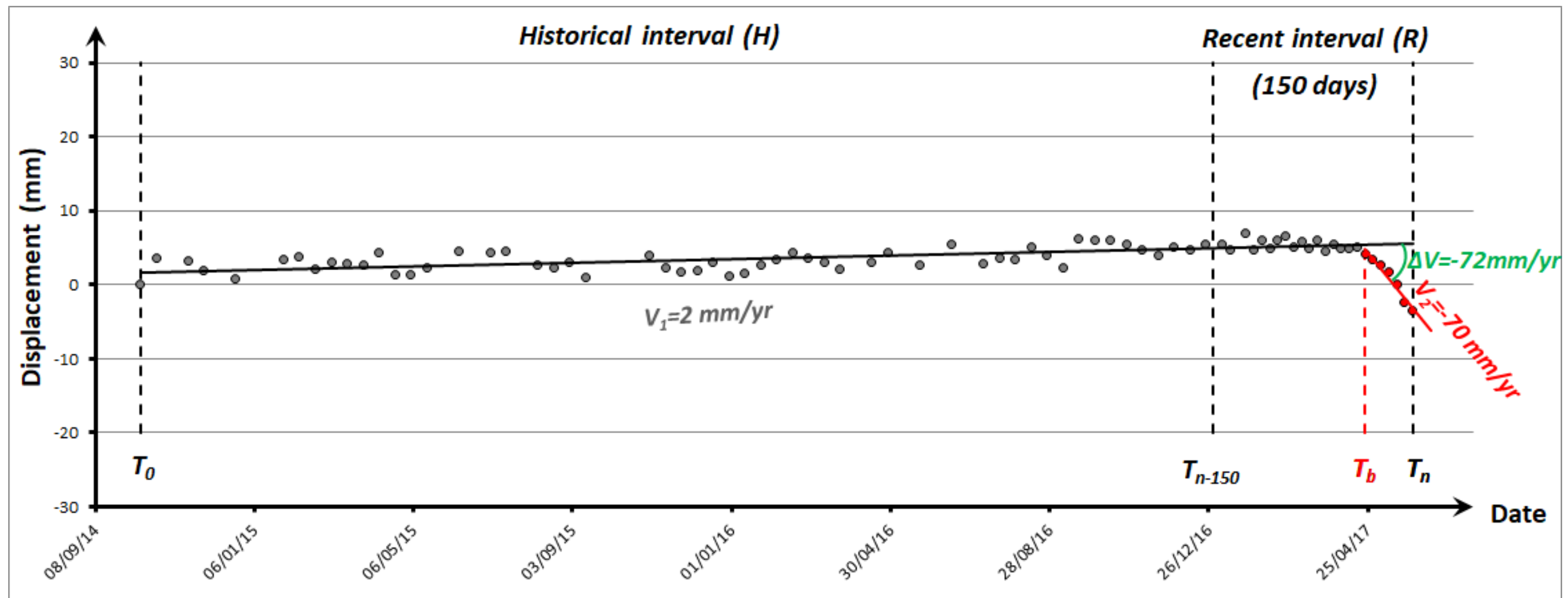
## Sentinel-1 data - Velocity (mm/yr)





# PS Monitoring

## Capturing changes in the deformation pattern through time



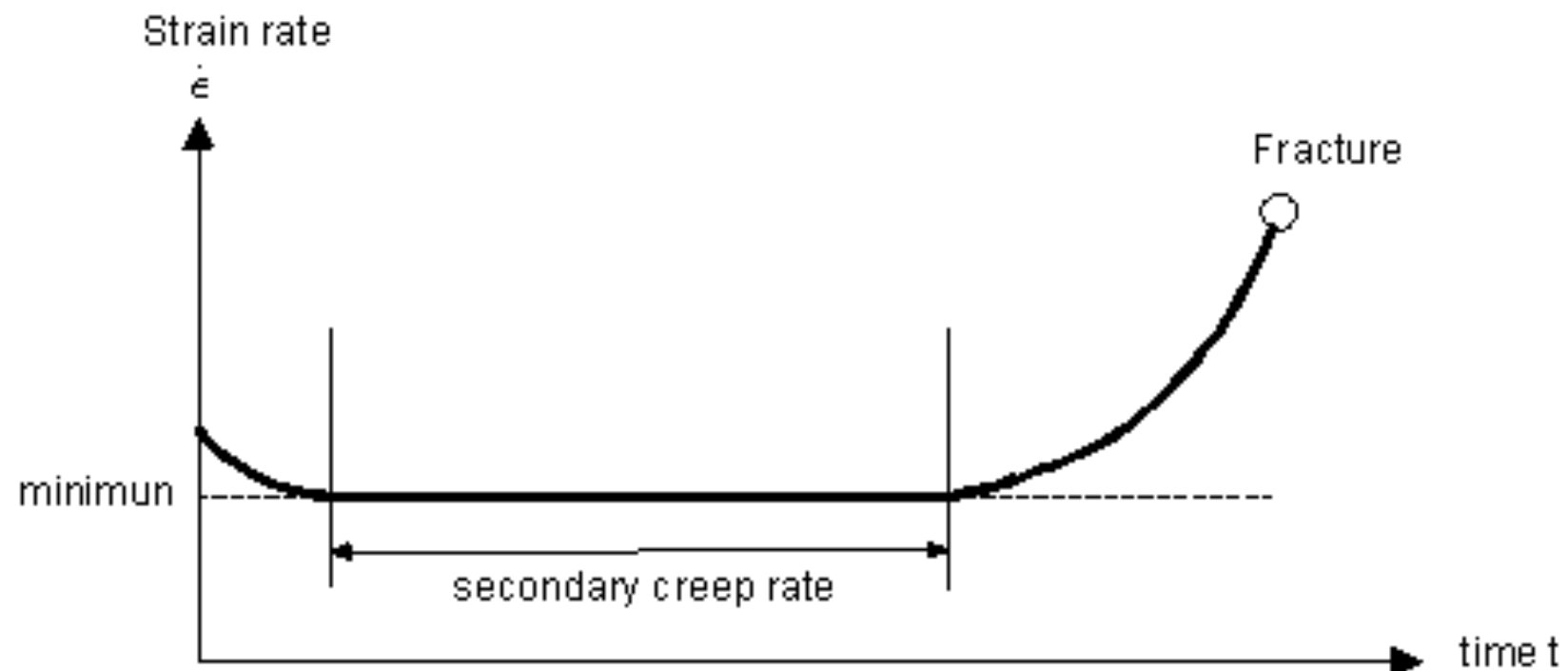
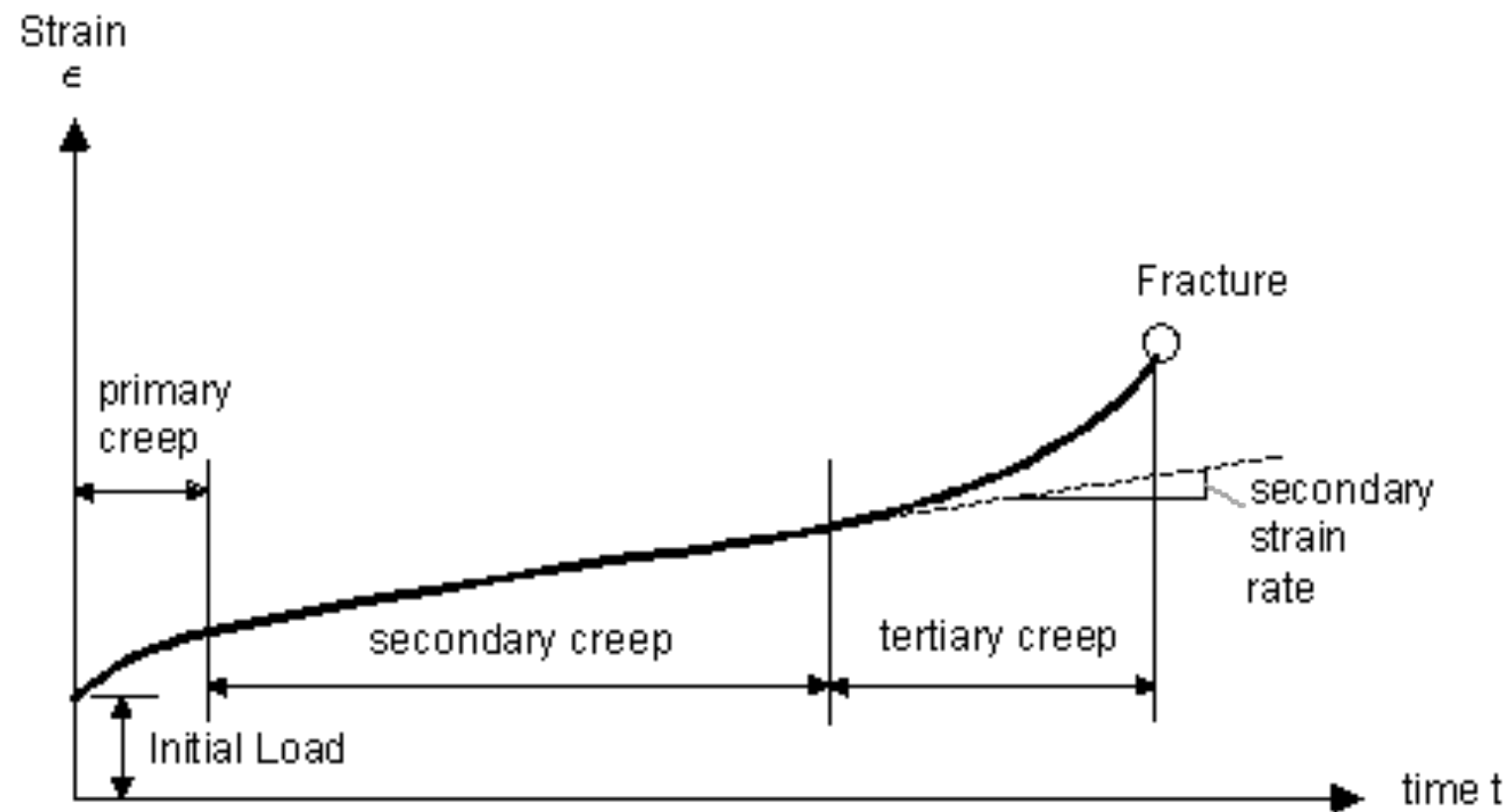
Identification of trend changes within the last 150 days in the displacement time series. An anomalous point is automatically highlighted as the difference between the deformation velocities ( $|\Delta V|$ ) recorded in the two-time intervals ( $T_0-T_b$  and  $T_b-T_n$ ) is  $> 10 \text{ mm/yr}$ .



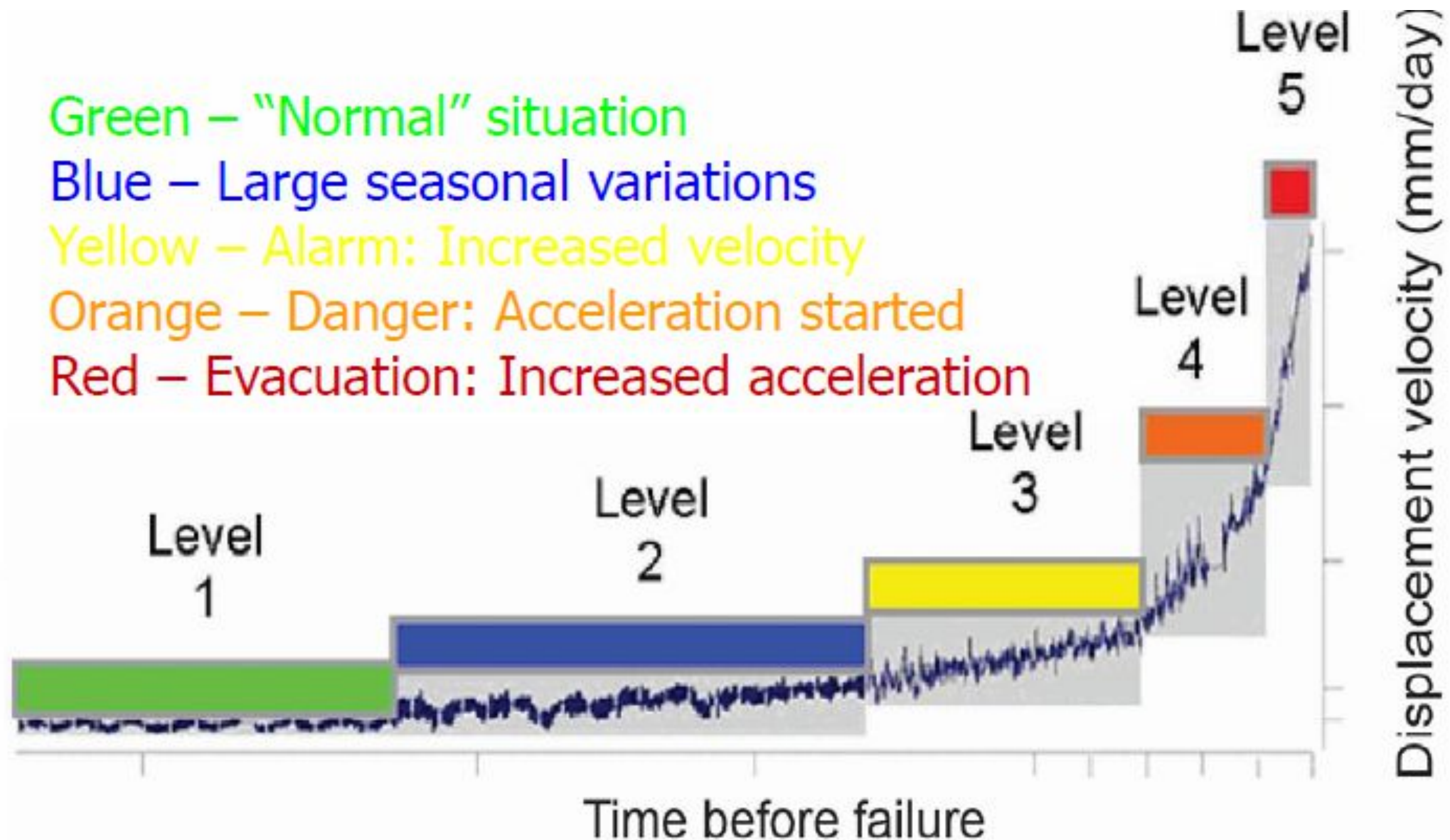
# Emergency planning



# Creep law








Blikra L.H., 2008. The Aknes rockslide. Monitoring, threshold values and early warning. 10th International Symposium on Landslides and Engineering Slopes, 30th June- 4th July, Xian, China, pp. 1089-1094.



NOTHING SPECIAL	BE AWARE	BE PREPARED	TAKE ACTION
Stable or constant velocity	Start of acceleration	Sustained acceleration	Asymptotic acceleration
Weekly reports	Daily reports	Hourly reports	Continuos reports
			



# Soglie e livelli di criticità - 2° fase

ALERT	Weather-based warning	In situ monitoring	Ground-based radar monitoring	Satellite radar monitoring	ALARM
NONE	GREEN	< treshold	< treshold	< treshold	NONE
ORDINARY	YELLOW	> treshold	> treshold	> treshold	ATTENTION
MODERATE	ORANGE	> treshold	> treshold	> treshold	PREALARM
HIGH	RED	> treshold	> treshold	> treshold	ALARM



# Operational phases

Code	ALERT	ALARM	ACTIONS
GREEN	None	None	<ul style="list-style-type: none"><li>- Action 1</li><li>- Action 2</li><li>- Action 3</li></ul>
YELLOW	Ordinary	Attention	<ul style="list-style-type: none"><li>- Action 1</li><li>- Action 2</li><li>- Action 3</li></ul>
ORANGE	Moderate	Prealarm	<ul style="list-style-type: none"><li>- Action 1</li><li>- Action 2</li><li>- Action 3</li></ul>
RED	High	Alarm	<ul style="list-style-type: none"><li>- Action 1</li><li>- Action 2</li><li>- Action 3</li></ul>



NOTHING SPECIAL	BE AWARE	BE PREPARED	TAKE ACTION
Stable or constant velocity	Start of acceleration	Sustained acceleration	Asymptotic acceleration
Weekly reports	Daily reports	Hourly reports	Continuos reports
		