



**Fourth Edition**  
**“NATURAL HAZARDS AND  
CULTURAL HERITAGE”  
PRESERVATION STRATEGIES**  
**19 - 26 July 2026**



LANDSLIDE DAY landslide management in historic urban environments

# Landslide Risk Management in Italy

---

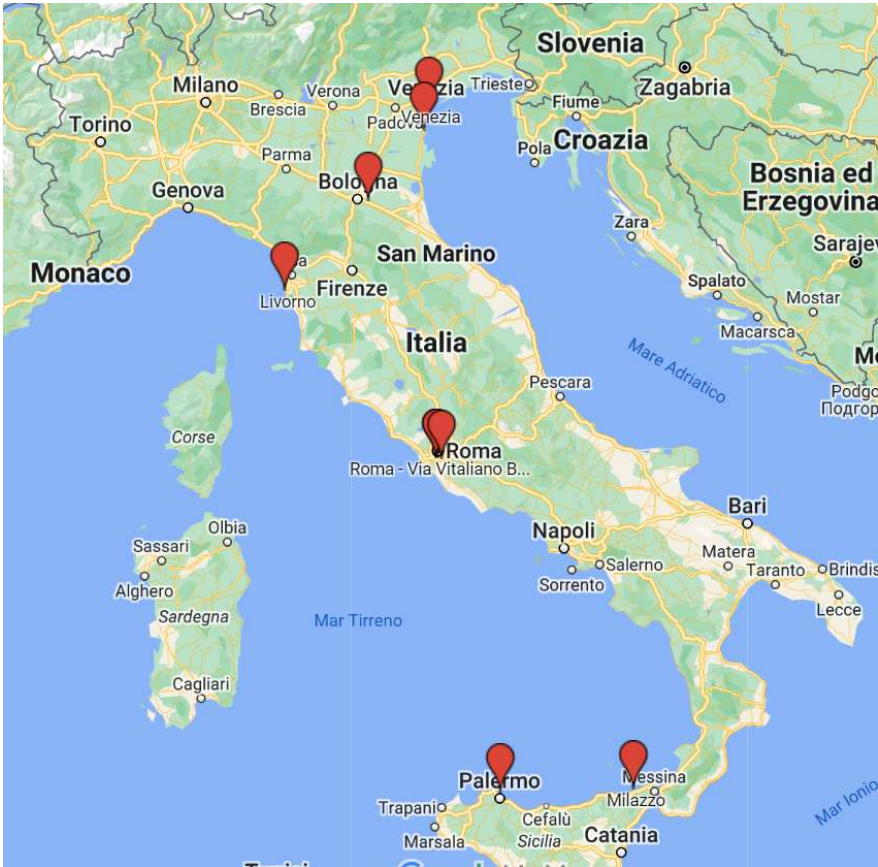
General overview and selected cases

Daniele Spizzichino  
ISPRA – Department for the Geological Survey of Italy  
[daniele.spizzichino@isprambiente.it](mailto:daniele.spizzichino@isprambiente.it)

*Civita di Bagnoregio*  
**21 July 2026**

# ISPRA Italian Institute for Environmental Protection and Research

- 1. National Agency for the monitoring natural and anthropogenic pressures of all the environmental matrices
- 2. Technical governmental body support to Environmental, Industry, Cultural and Foreign Affair Ministry
- 3. Copernicus USER Forum National Focal Point
- 4. Centre of competence for the national civil protection – emergency and crises
- 5. Department of National Geological Survey
- 6. Guideline, Regulations, Technical standard, Plan for the environmental issue (e.g. National Plan for Climate change adaptation)





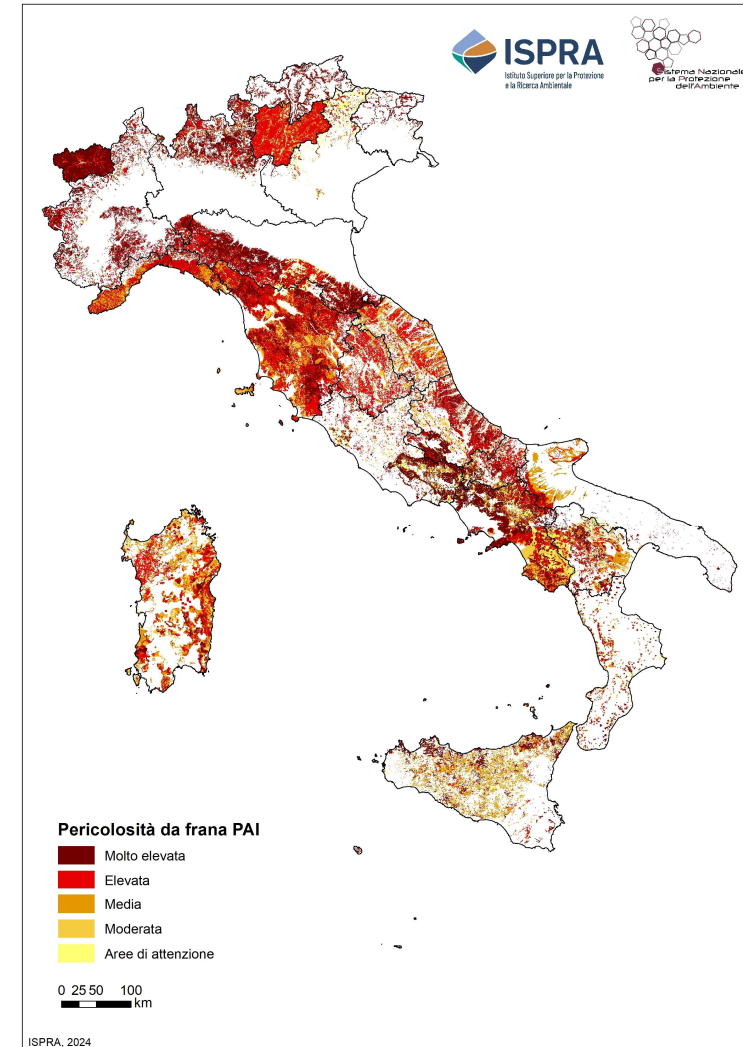
**The core challenge is not only to map hazards, but to transform evidence into priorities, maintenance, emergency planning and long-term adaptation.**



## Why Italy is a landslide-risk laboratory

- A mountainous and hilly territory with complex geology, active tectonics and highly variable rainfall regimes;
- Dense settlement, transport networks, cultural heritage and economic activities often occupy valley floors, hilltops and coastal slopes;
- Landslide risk management is therefore both a geoscientific and a public-policy challenge.

The Italian approach combines official hazard zoning, inventories, monitoring, funded mitigation works and civil-protection planning.







## The national picture: hazard, exposure and risk indicators

**69,530 km<sup>2</sup>**

territory classified as PAI  
landslide hazard areas and  
attention areas

**23%**

of the national territory within  
landslide hazard or attention  
areas

**28,801 km<sup>2</sup>**

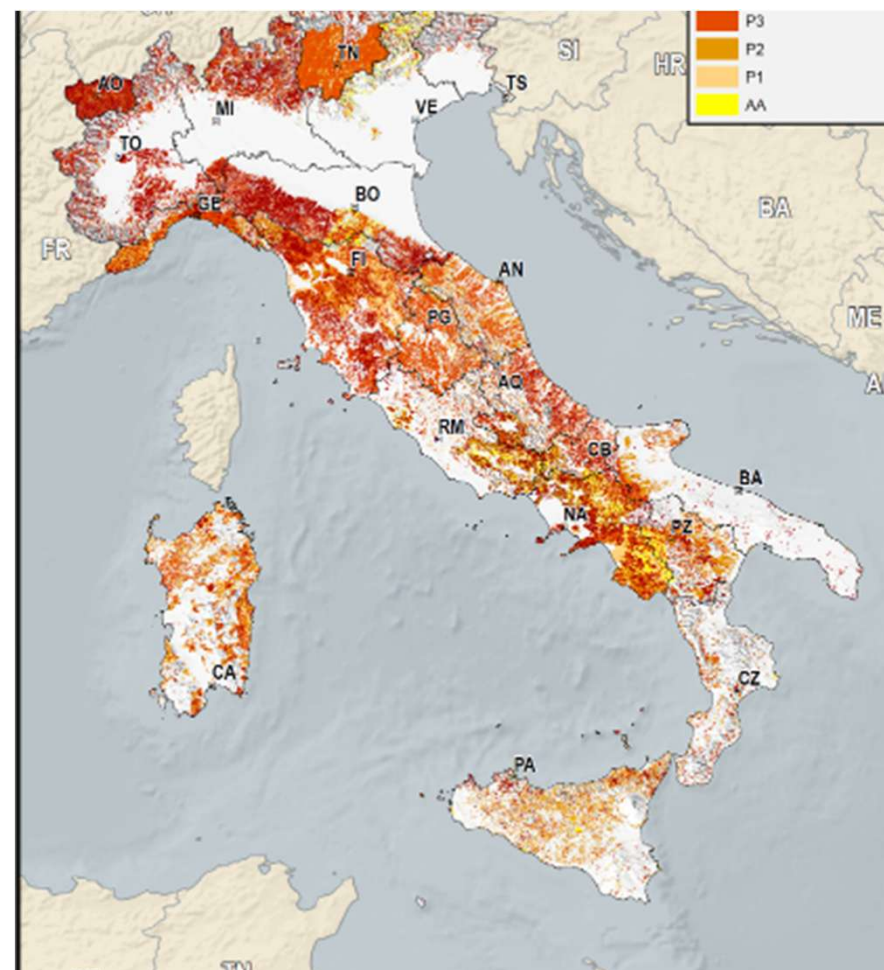
areas with high or very high  
landslide hazard (P3 + P4)

**5.7 million**

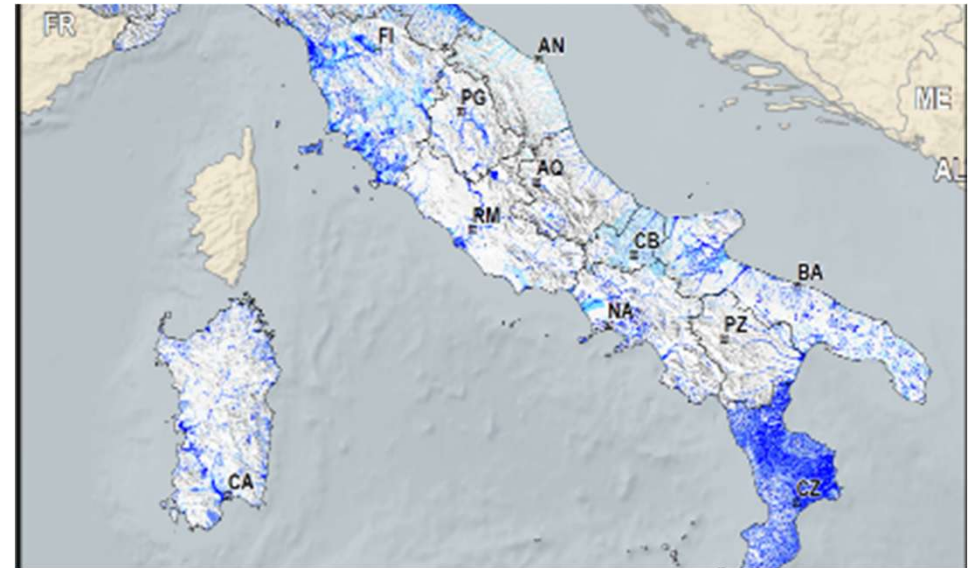
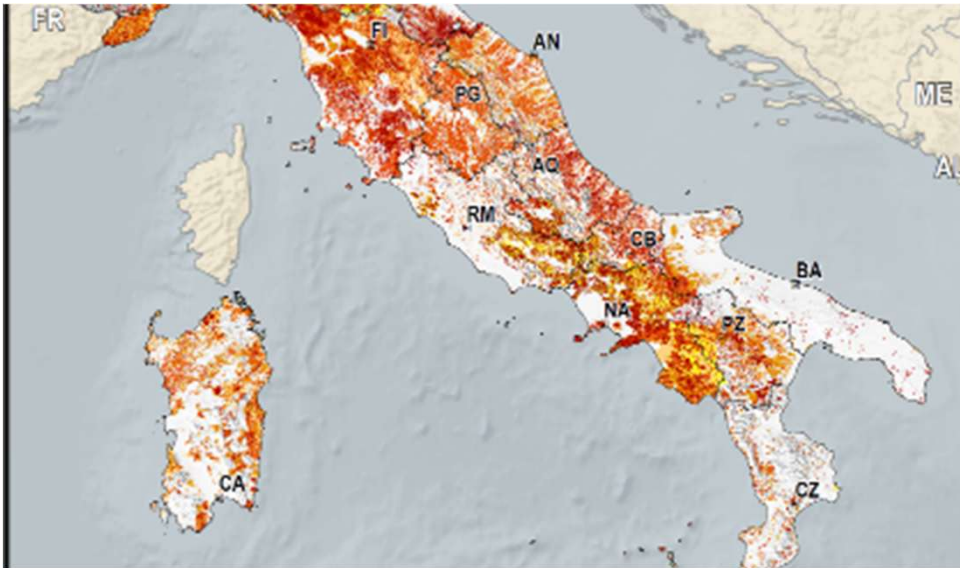
people living in landslide-risk  
areas in 2024

**≈14,000 cultural assets**

located in high or very high landslide-hazard areas (P3 + P4)

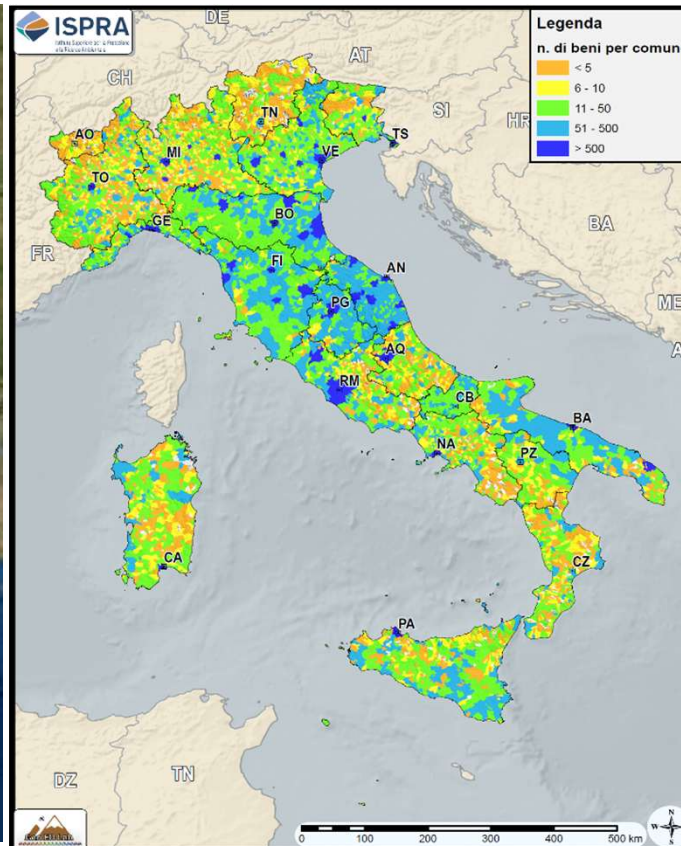


## PAI hazard classes as a baseline for planning and prioritisation

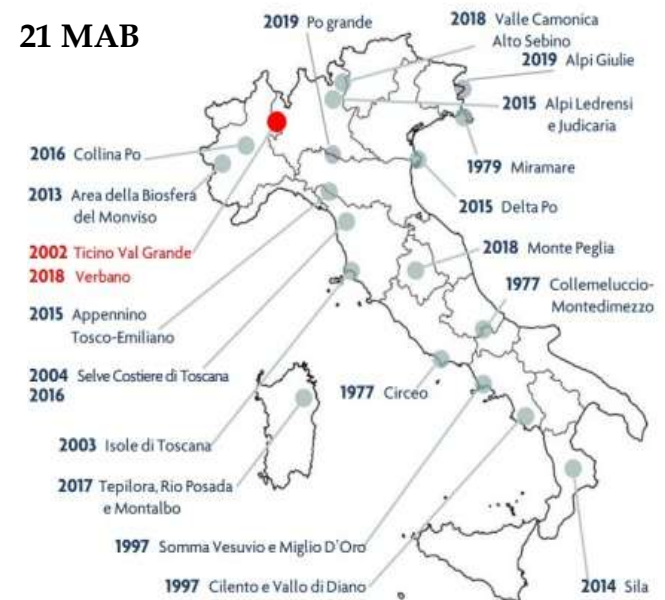


The map gives a harmonised first-level national view, but local planning must use the official detailed maps and field validation. Risk management starts with hazard, but must also quantify exposed people, buildings, infrastructure, services and cultural assets.

# ITALIAN NCH VERY HIGH EXPOSURE, VULNERABILITY and FRAGILITY



21 MAB



Cultural heritage at  
municipal level

Tot. 229530

*sources:*

*banca dati VIR e CdR,*

*elaborazione ISPRA*



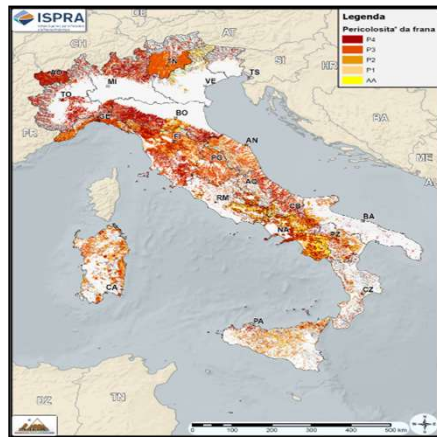
12 Geo-parks

Italian distribution of  
Natural & Cultural Heritage  
**61** UNESCO site



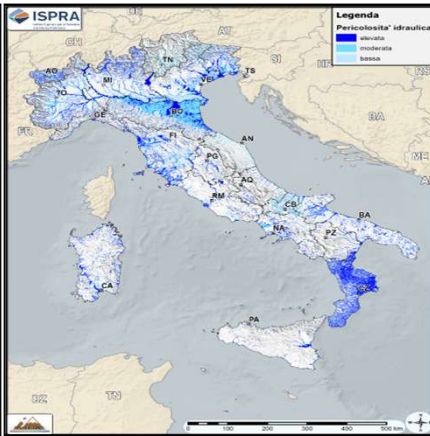
# Natural Hazards threatening NCH

## LANDSLIDE



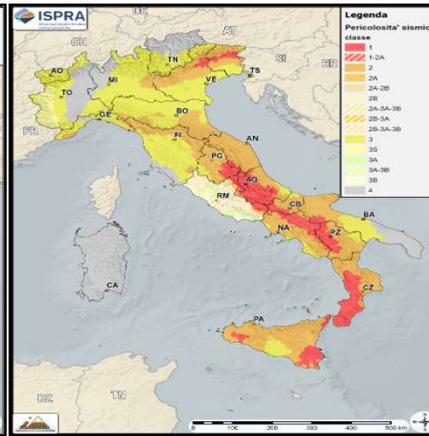
**IFFI Inventory - Landslide Index (%)**  
Source: Rapporto ISPRA su Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio - Edizione 2021

## FLOODS



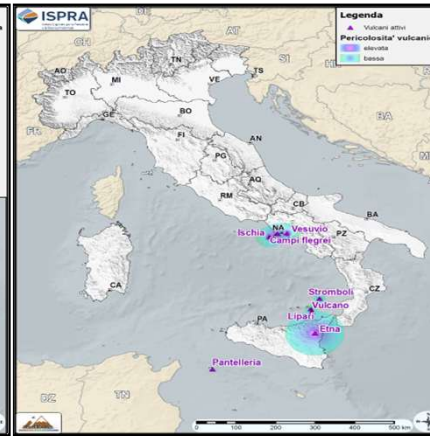
**PAI hydraulic hazard mosaic**  
Source: Rapporto ISPRA su Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio - Edizione 2021

## EARTHQUAKE



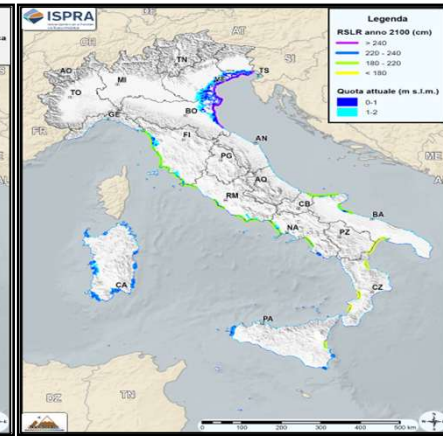
**Seismic classification on a municipal basis**  
Source: Fonte dati : Dipartimento Protezione Civile - INGV; elaborazione grafica ISPRA  
Riferimento Annuario Dati Ambientali , ISPRA 2020

## VOLCANO



**Pericolosità da vulcani attivi**  
Fonte dati : Dipartimento Protezione Civile - INGV; elaborazione grafica ISPRA.  
Aggiornamento 2016.

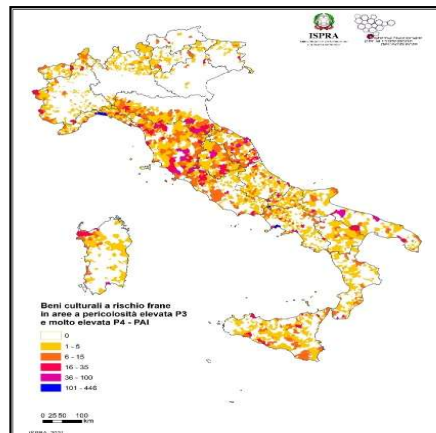
## COASTAL



**Sea level rise scenarios over some coastal areas**  
Source: Fonte dati: UNIBA; Assetto Costiero Italiano. Elaborazione grafica ISPRA.

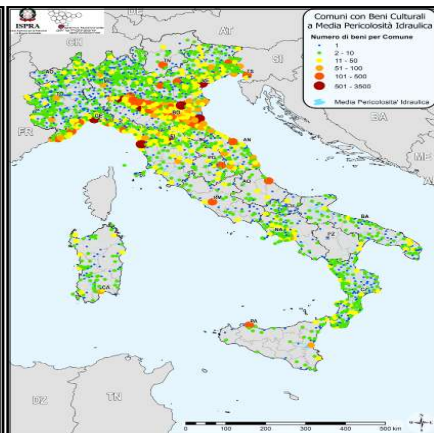
# National Simplified risk of CH Vs Natural hazards

## LANDSLIDE



CH at risk landslides on a municipal basis  
Rapporto ISPRA su Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio - Edizione 2021

## FLOODS



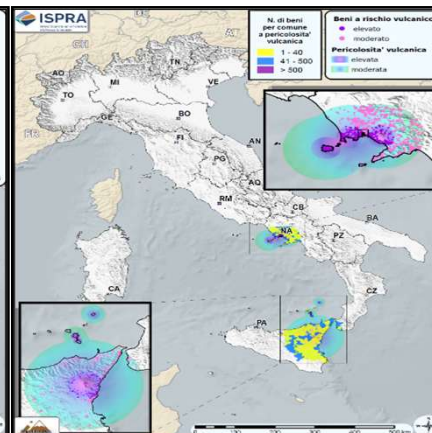
CH at risk of flooding on a municipal basis  
Fonte dati: Banca dati ViR e CdR ISCR, IdroGEO  
Elaborazione grafica ISPRA - 2022.

## EARTHQUAKE



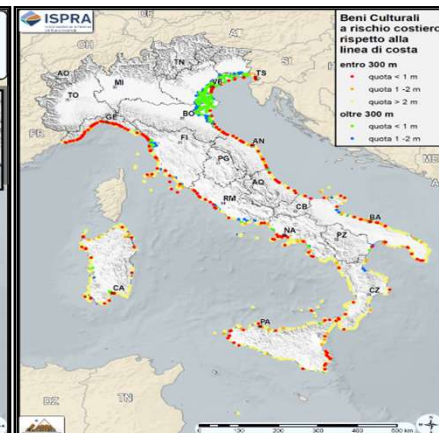
CH by seismic class on a municipal basis  
Fonte Elaborazione ISPRA su dati ISPRA, ISCR e Protezione Civile.  
BBCC in comuni in classe sismica 1 o 2: 92384.  
Riferimento Annuario Dati Ambientali - ISPRA 2020

## VOLCANO



CH and volcanic risk, total  
Fonte: Elaborazione ISPRA su dati ISPRA e ISCR. BBCC a Pericolosità Elevata: 4083 (1.9%) BBCC a Pericolosità moderata 7264 beni (3.4%). Riferimento: Annuario Dati Ambientali - ISPRA 2020

## COASTAL



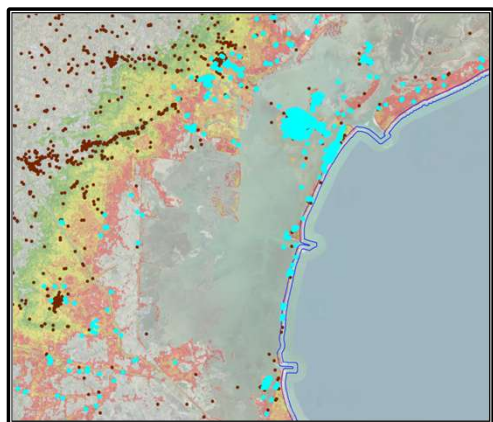
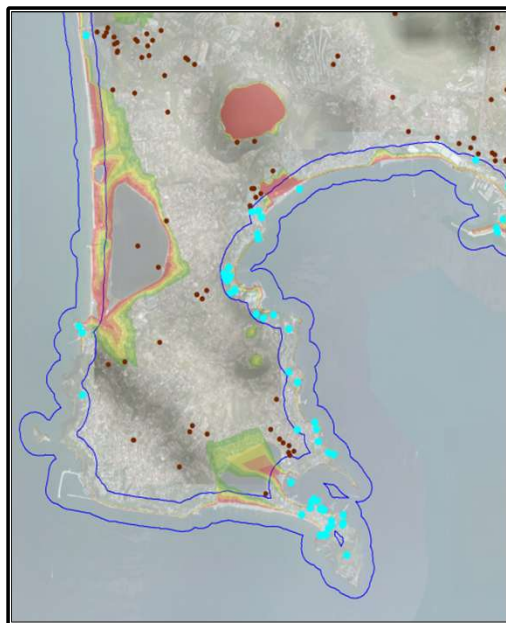


# Detail of coastal erosion and stability at national level

## CH located at:

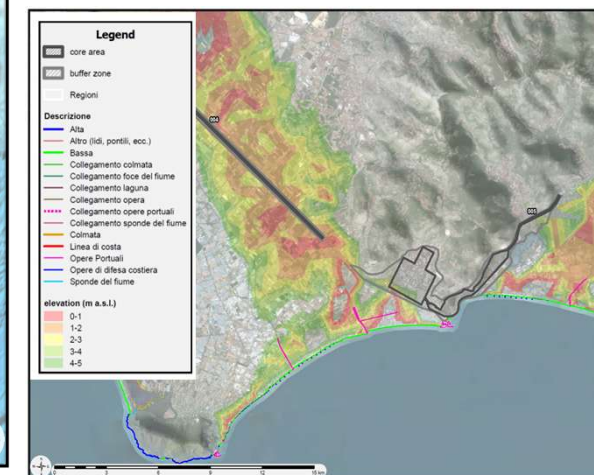
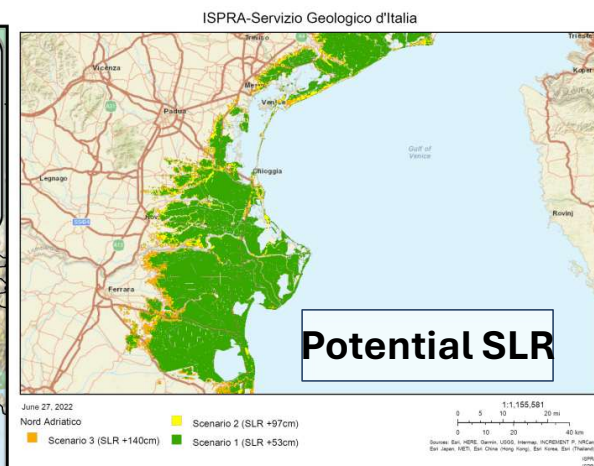
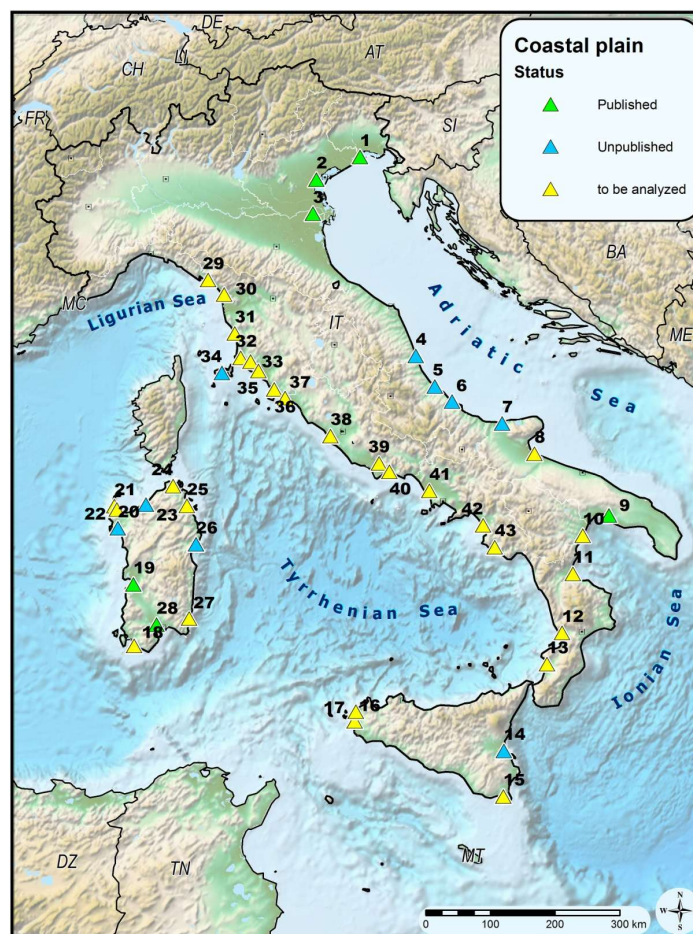
- 200 m from coastline
  - <1 m a.s.l.
- = 10726 CH (5%)

- 200 m from coastline
  - <2 m a.s.l.
- = 12595 CH (6%)



M. di Procida

Laguna Veneta



Terracina



# Part 1 — Understanding the problem

---

Processes, triggers and exposed systems





## From hazard to risk: the four variables to manage



### HAZARD:

type, intensity, frequency, velocity and expected spatial footprint of landslides.



### EXPOSURE:

people, buildings, transport corridors, utilities, cultural heritage and productive activities in potentially affected areas.



### VULNERABILITY:

physical fragility, functional dependency, preparedness, redundancy and recovery capacity.



### CAPACITY:

monitoring, warning, maintenance, funding, governance and public awareness.



Managing landslide risk means acting on all four variables in an integrated and coordinated way.



KNOW THE HAZARD



REDUCE EXPOSURE



STRENGTHEN VULNERABILITY



BUILD CAPACITY



# Main landslide processes relevant to Italy



## 1. Rapid shallow landslides & debris flows

Often triggered by intense rainfall on soil or pyroclastic covers.



## 2. Rock falls & rockslides

Typical on cliffs, road cuts, quarries, coastal slopes and rupestrian or hilltop heritage settings.



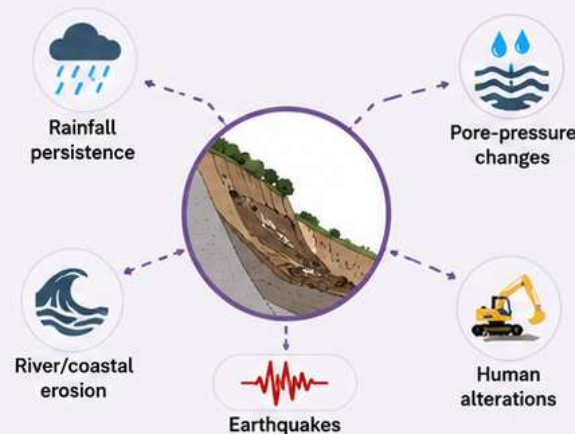
## 3. Slow deep-seated landslides, earthflows & complex movements

Affecting towns, roads and utilities over long periods.



## 4. Reactivations and triggers

Driven by rainfall persistence, pore-pressure changes, river/coastal erosion, earthquakes and human alterations.





# Triggers and time scales

## Different mechanisms require different monitoring and warning strategies

**1. Short intense rainfall:**  
rapid shallow failures and debris flows; warning depends on rainfall thresholds and catchment response.



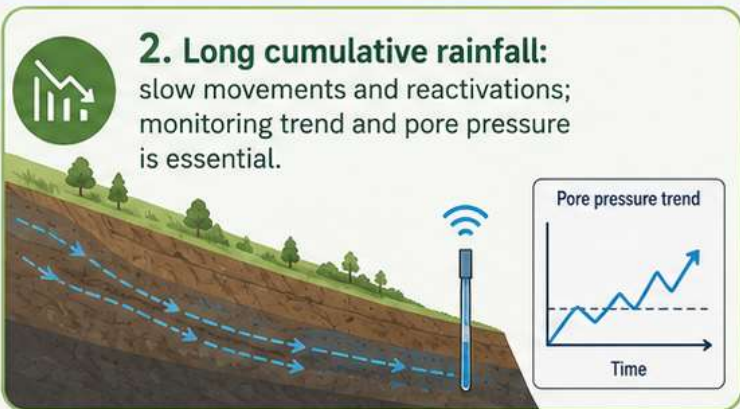
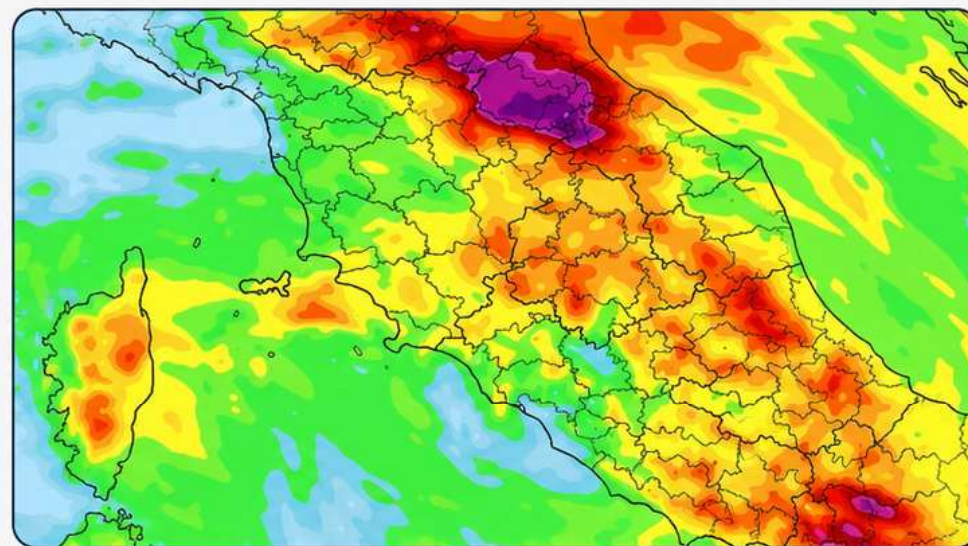
Rapid  
(minutes – hours)



Slow  
(days – years)



**2. Long cumulative rainfall:**  
slow movements and reactivations; monitoring trend and pore pressure is essential.

**3. Heat, drought, fire, freeze-thaw and sea storms can precondition slopes and increase fragility before the triggering event.**



**Monitoring and warning strategies must change depending on trigger type and time scale.**

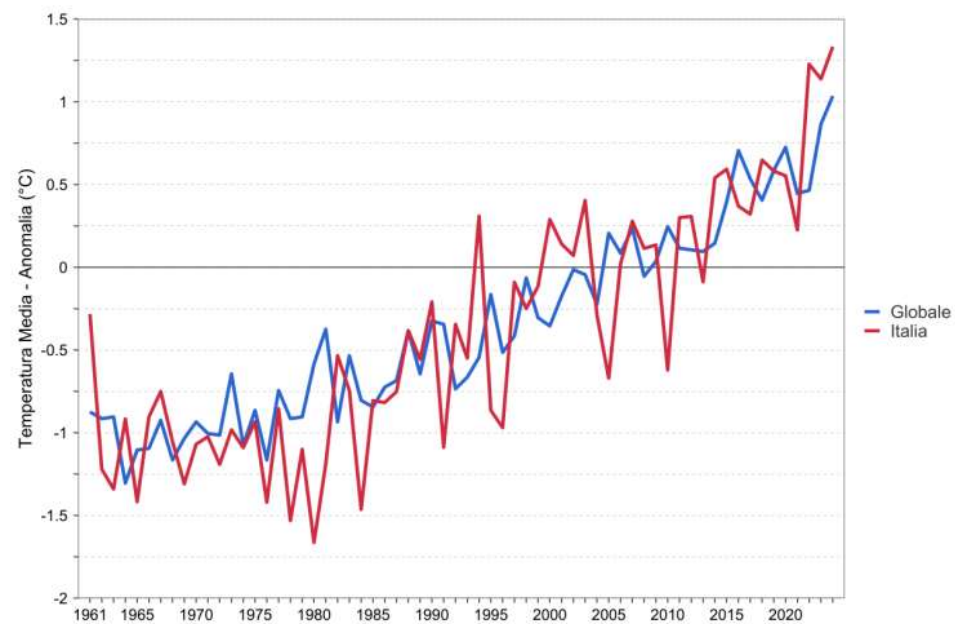
# The new enemy and threat

## Climate Change effects

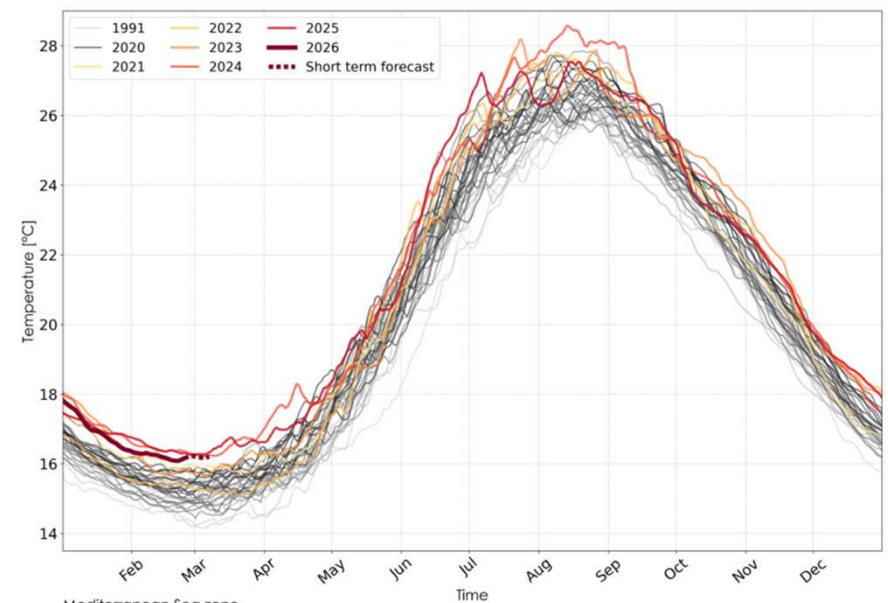
---







Sea Surface Temperature average,  
over Mediterranean Sea zone



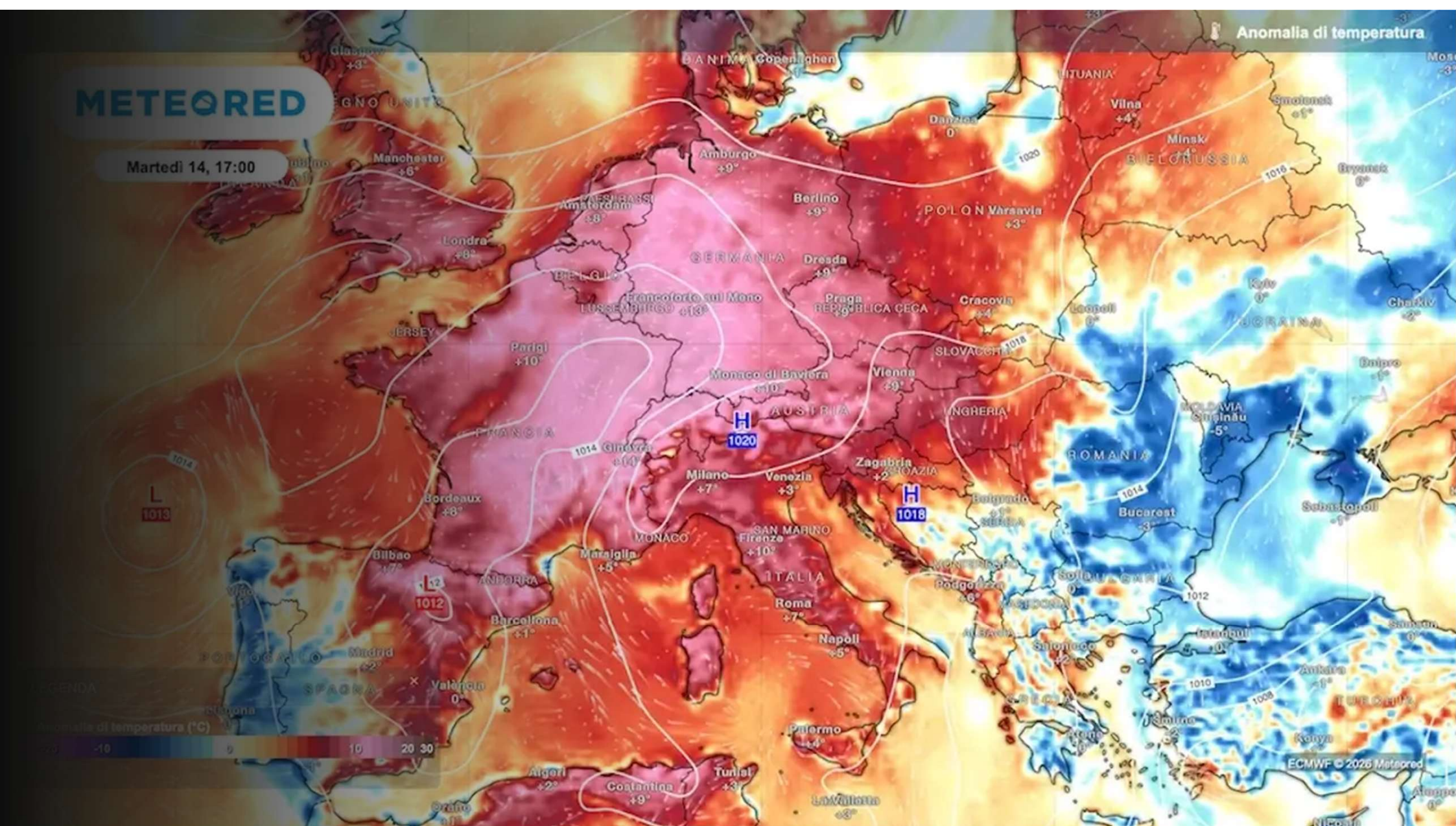
Mediterranean Sea zone  
Gray shades represent ESA CCI data between 1991-2020  
Coloured shades represent Mercator Ocean GLO12 analysis and forecast



# METEORED

Martedì 14, 17:00

Anomalia di temperatura







## Climate pressure: why risk management must be adaptive

Recent years confirm a warmer climate baseline: Copernicus ranked 2025 as the third warmest year globally, after 2024 and 2023.

In the Mediterranean, heat, drought, wildfire, heavy rainfall and sea-level pressure can interact with slope instability.

Risk scenarios should therefore be updated periodically, not treated as static products.

Maintenance of drainage systems, vegetation control and monitoring networks becomes a climate-adaptation measure.



## Part 2 — Managing risk in Italy

---

Governance, datasets and operational workflows





## Italian landslide risk governance: multi-level by design

### EU & National framework

EU Floods Directive, climate adaptation, national funding, Civil Protection system

### Basin District Authorities

PAI landslide-hazard mapping and land-use constraints

### Regions, ARPA/APPA & SNPA

monitoring, local inventories, technical support, datasets

### Municipalities & asset managers

civil protection plans, maintenance, warning, restrictions

### Citizens and local communities

risk awareness, reporting, preparedness and resilience



## National knowledge infrastructure: from data to decisions

### IFFI

Landslide inventory: location, typology, state of activity, damage evidence

### PAI

Official landslide hazard zoning and land-use constraints

### IdroGEO

Public platform for maps, reports, indicators and local queries

### ReNDiS

National register of funded soil-defence and mitigation works

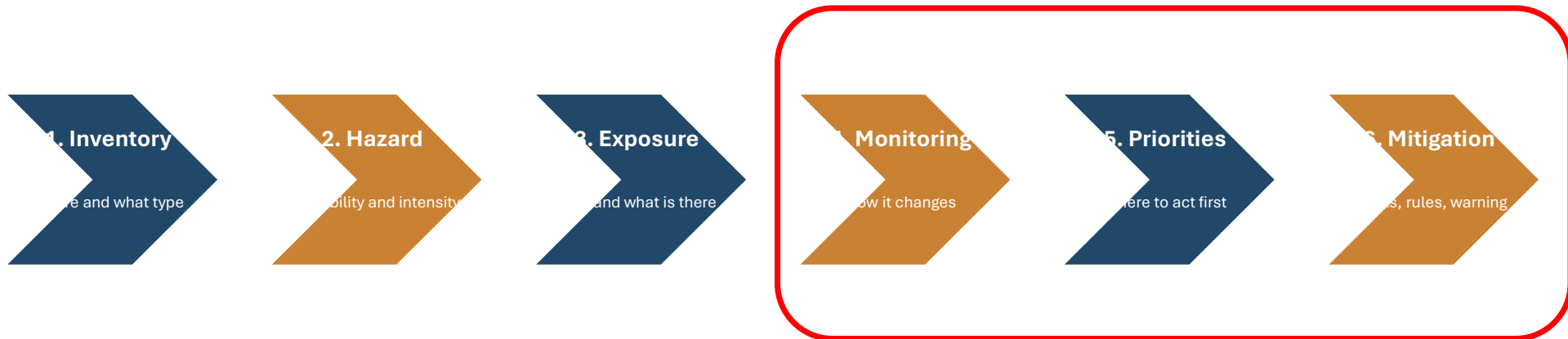
### Monitoring registry

In-situ landslide monitoring systems, stations and sensors

### EGMS / Copernicus

Satellite ground motion for trend screening and prioritisation

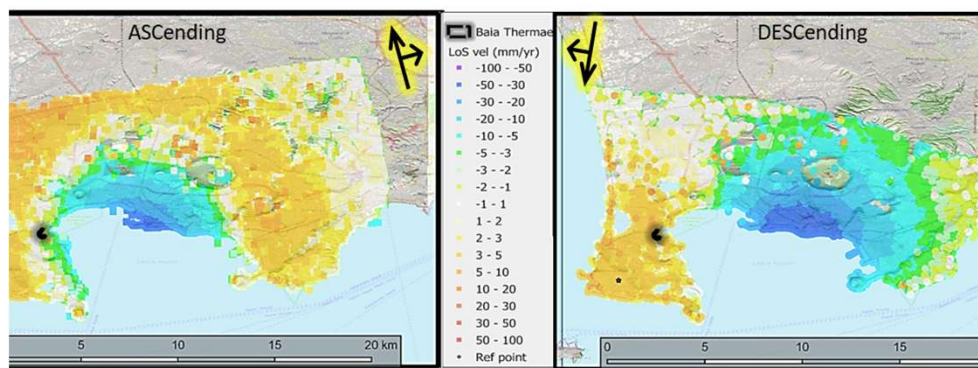




**The core challenge is not only to map hazards, but to transform evidence into priorities, maintenance, emergency planning and long-term adaptation.**



## Monitoring chain: satellite screening + field validation



### Remote sensing

InSAR / EGMS / optical change detection

### Field survey

geomorphology, geomechanics, damage mapping

### In-situ sensors

GNSS, inclinometers, crack gauges, rainfall, pore pressure

### Interpretation

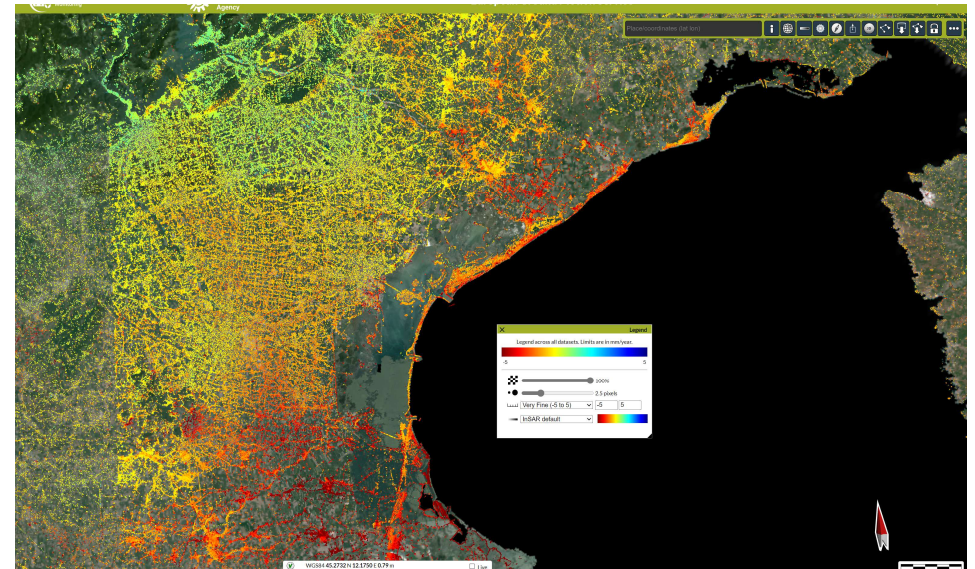
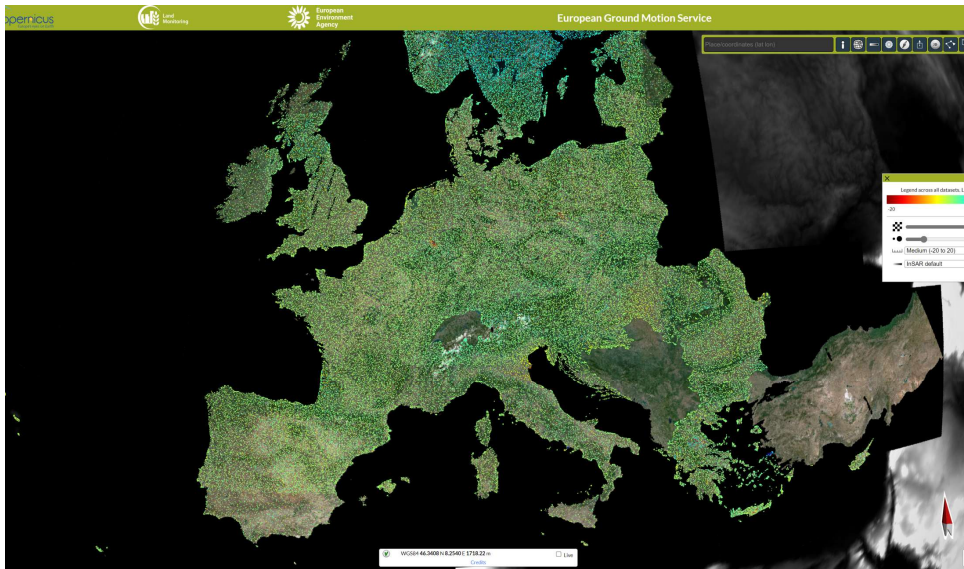
thresholds, scenarios, warning levels and mitigation design

**Principle: no remote-sensing product is “self-explaining”; it must be calibrated, validated and interpreted in the field.**



## European Ground Motion Service: toward dynamic screening

### Sentinel-1 ground motion information supports large-area trend detection

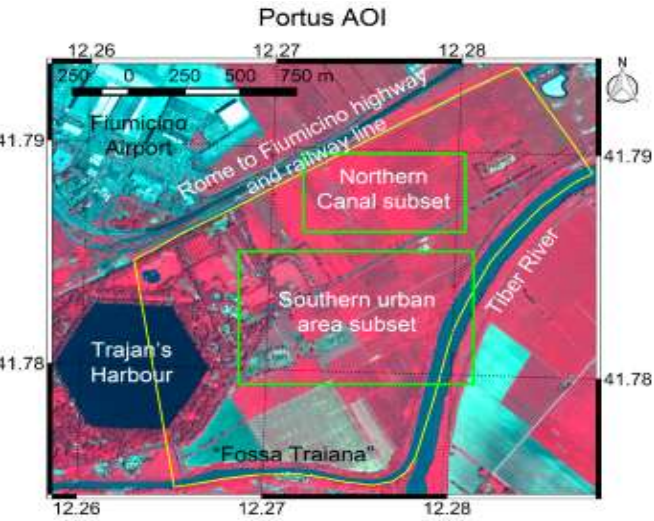
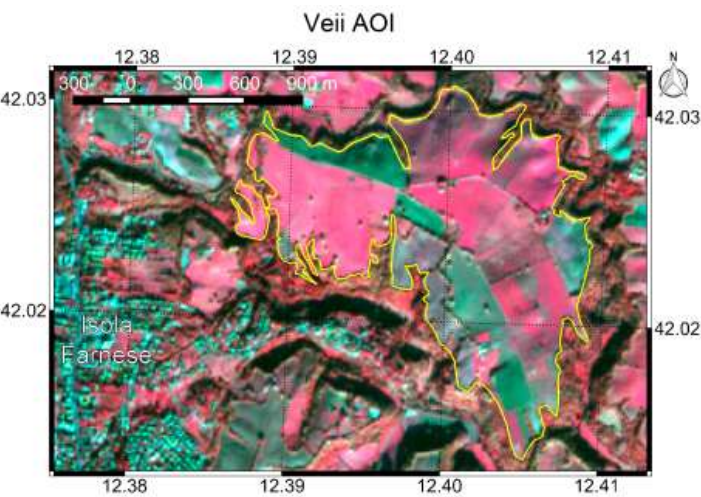


EGMS helps identify deformation trends and prioritise field checks, especially for slow-moving landslides and urban/heritage assets.

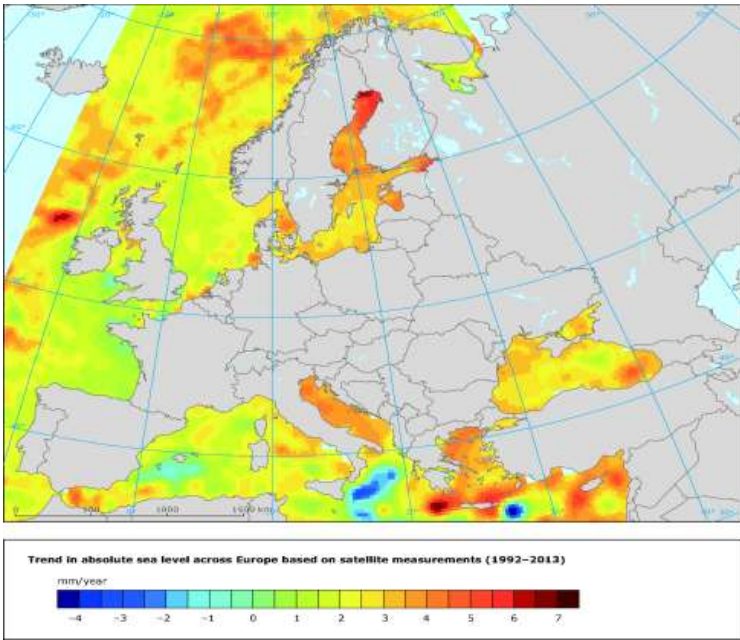
It should be interpreted with geomorphology, geology, land cover, geometry and local evidence before decisions are made.



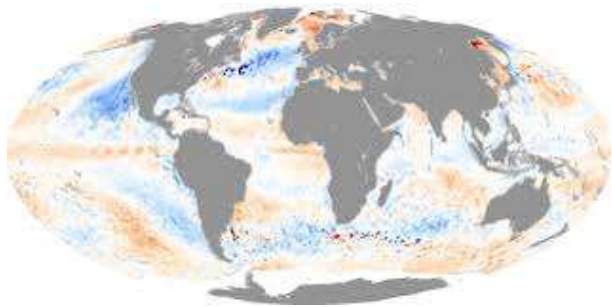
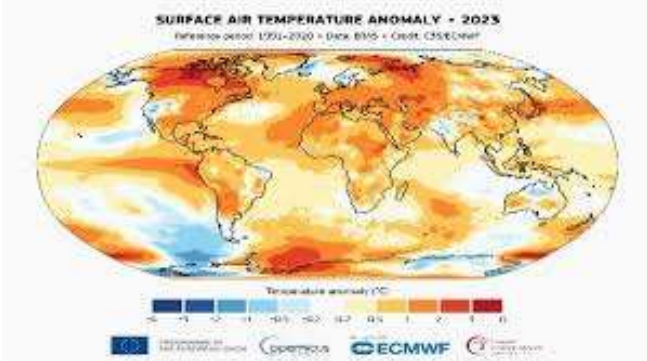
*OPTICAL images, from data to downstream services (e.g. multispectral and Hyper spectral analysis)*



Land use, change detection and buried sites © ESA



sea level rise © EEA

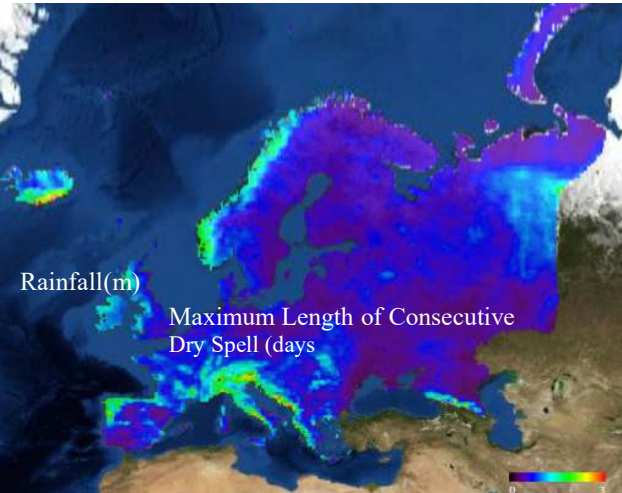
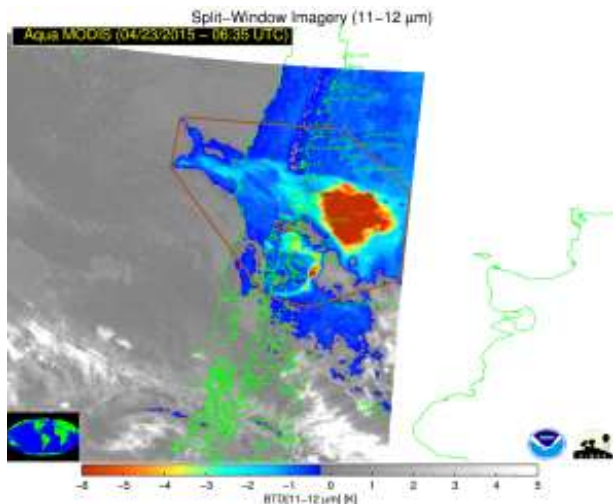


Sea Surface Temperature anomaly © NASA

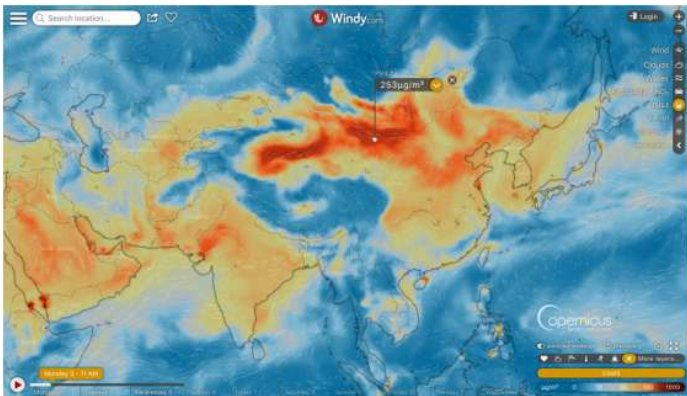


*OPTICAL images, from data to downstream services (e.g. multispectral and Hyper spectral analysis)*

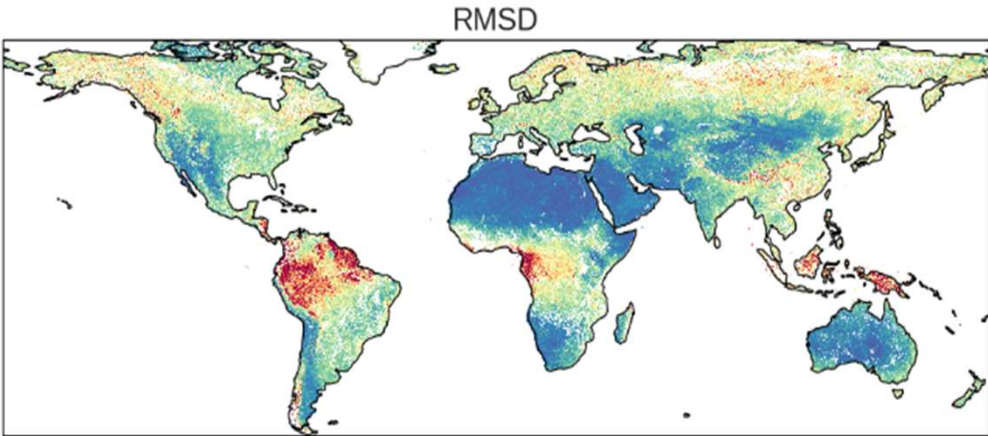
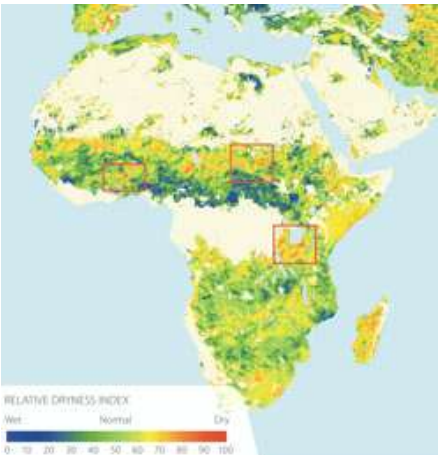
Climate variables and extreme events impact on Cultural Heritage @ ProteCht2save CNR –ISAC Bonazza et al.



Volcanic Cloud Monitoring website.



Pollutant concentration  
© Windy.com



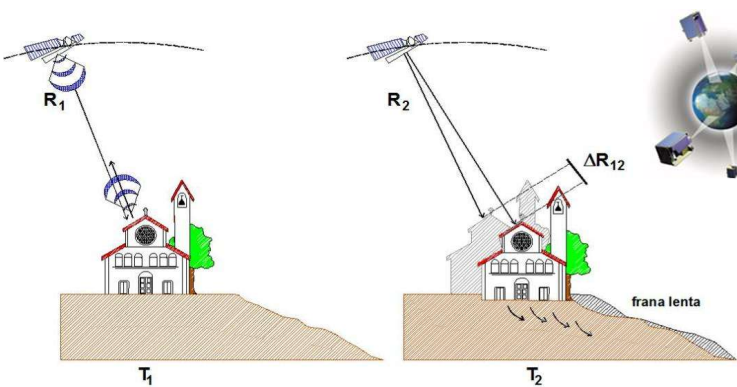
NDVI normalized Vegetation index © Copernicus



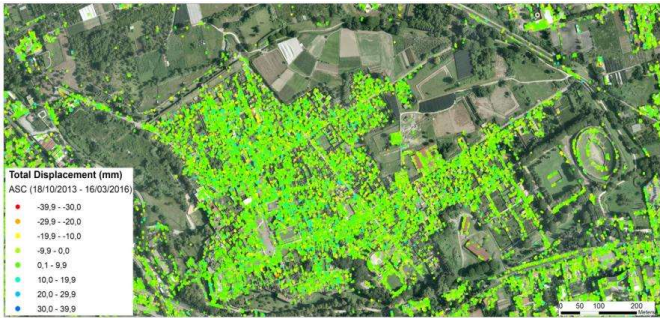
**RADAR images, from data to downstream services (DINSAR analysis)**



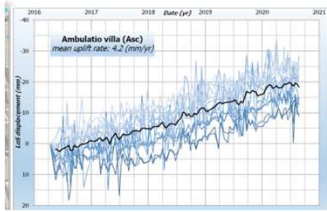
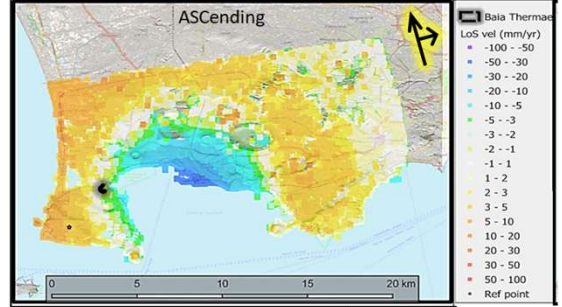
Rome Walls deformation satellite monitoring © Spizzichino



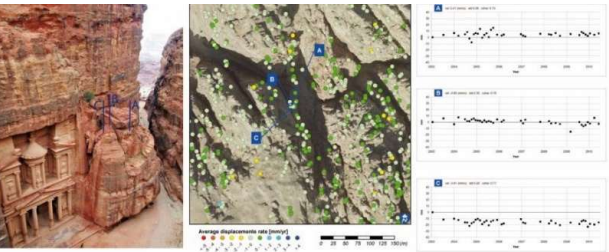
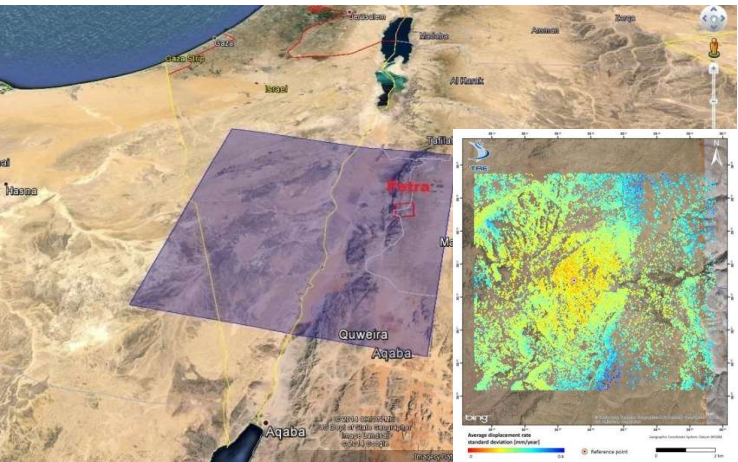
www.prothego.eu collect all the European UNESCO sites where GEO-Hazards and satellite data are already available



Instability processes and SAR data analysis POMPEI



Subsidence and uplift by satellite analysis PACF Park © Spizzichino

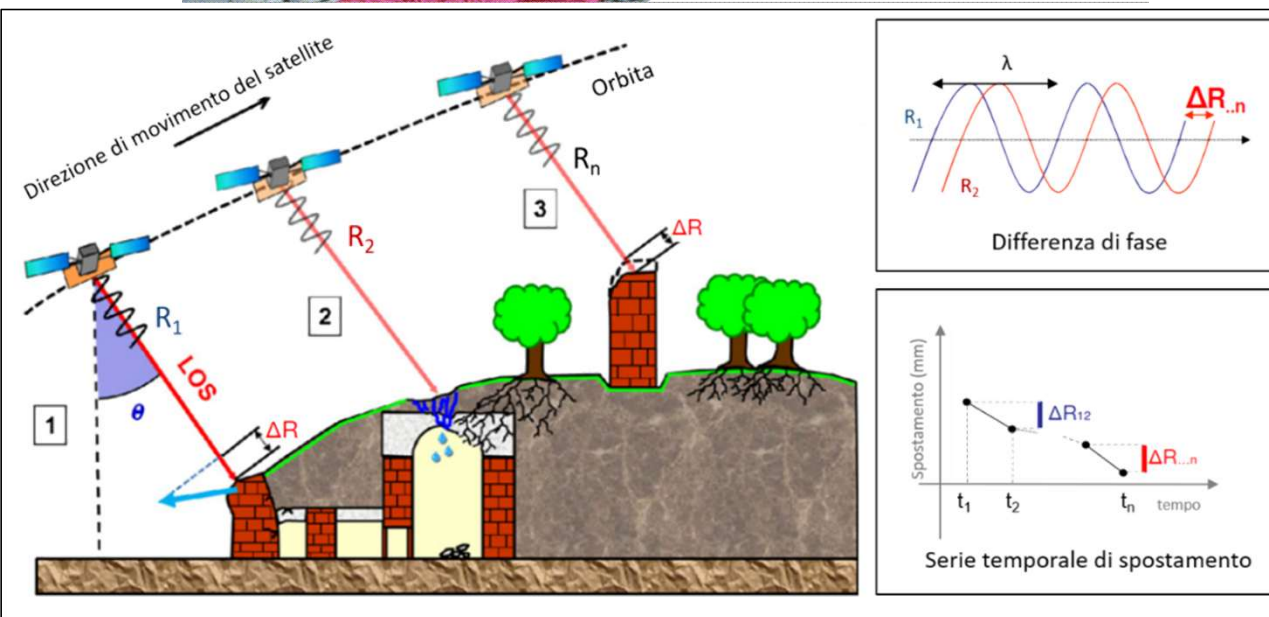
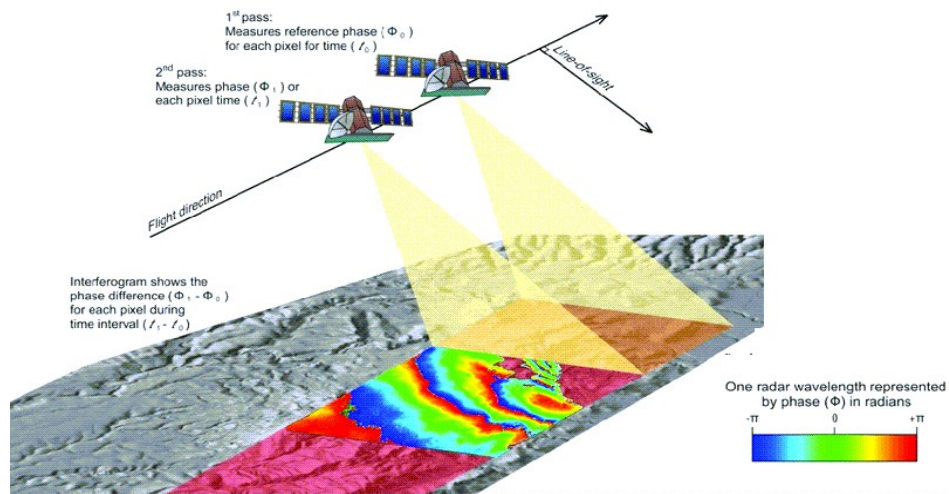


Surface deformation RADAR satellite images Petra © Spizzichino



All data after processing, must be calibrated, validate and interpreted by in situ survey in order to be used as support for the mitigation measures







## Mitigation toolbox: combine works, rules and preparedness

### Avoid / regulate

hazard zoning, land-use constraints, relocation where needed

### Reduce hazard

slope re-profiling, drainage, retaining structures, rockfall barriers

### Reduce vulnerability

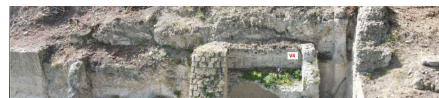
building retrofitting, asset maintenance, protective buffers

### Prepare response

thresholds, warning, evacuation routes and civil protection drills

### Adapt over time

monitoring, maintenance, climate scenarios and periodic review







## Prioritisation: turning evidence into action



**The core challenge is not only to map hazards, but to transform evidence into priorities, maintenance, emergency planning and long-term adaptation.**

## Part 3 — Selected Italian cases

---

From national overview to site-scale management

**Technical Board institution for the national Parks monitoring DM n. 5 del 19/02/2019, still active until 2025**

**National Protocol among Ministry of Culture and ISPRA (26/05/2021)**

**Active agreement:  
Extraordinary National Plan for the monitoring and conservation of CH  
(June 2022 – June 2024) – prolonged till end of 2024.**

**The National Plan for Monitoring and Conservation of Cultural Herit:  
INTEGRATED SATELLITE-TERRESTRIAL MONITORING SYSTEM**

**List of case study and pilots assigned to ISPRA jointly with research center and university (e.g CNR, UNESCO chair UN**





## From satellite screening to field validation and in-situ monitoring

---

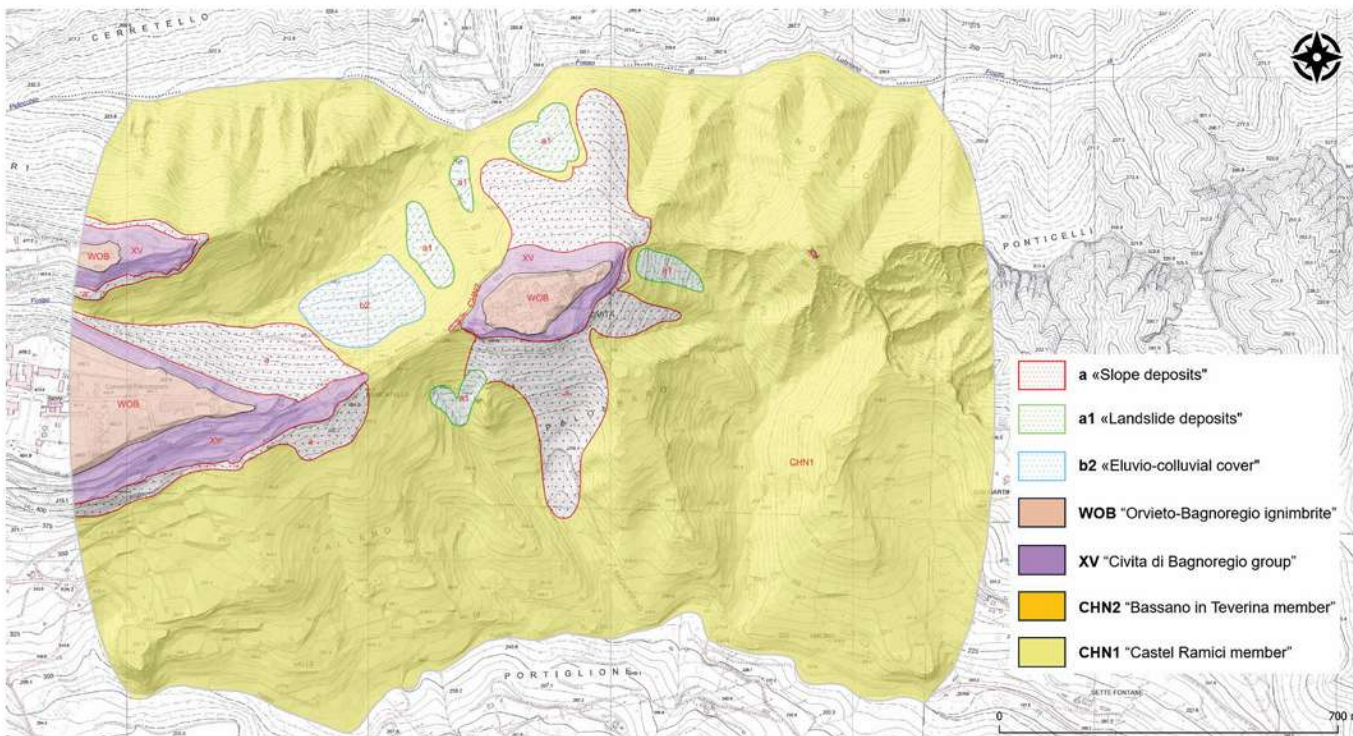
The village is a historic hilltop settlement on a tuff cliff, affected by long-term slope retreat, local failures and access-safety issues.

**Management objective:** preserve an iconic cultural landscape while keeping access, monitoring and maintenance sustainable over time.





## Civita — geological setting controls instability

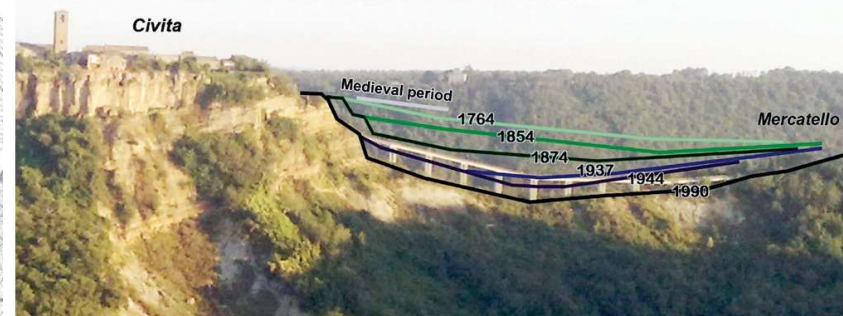
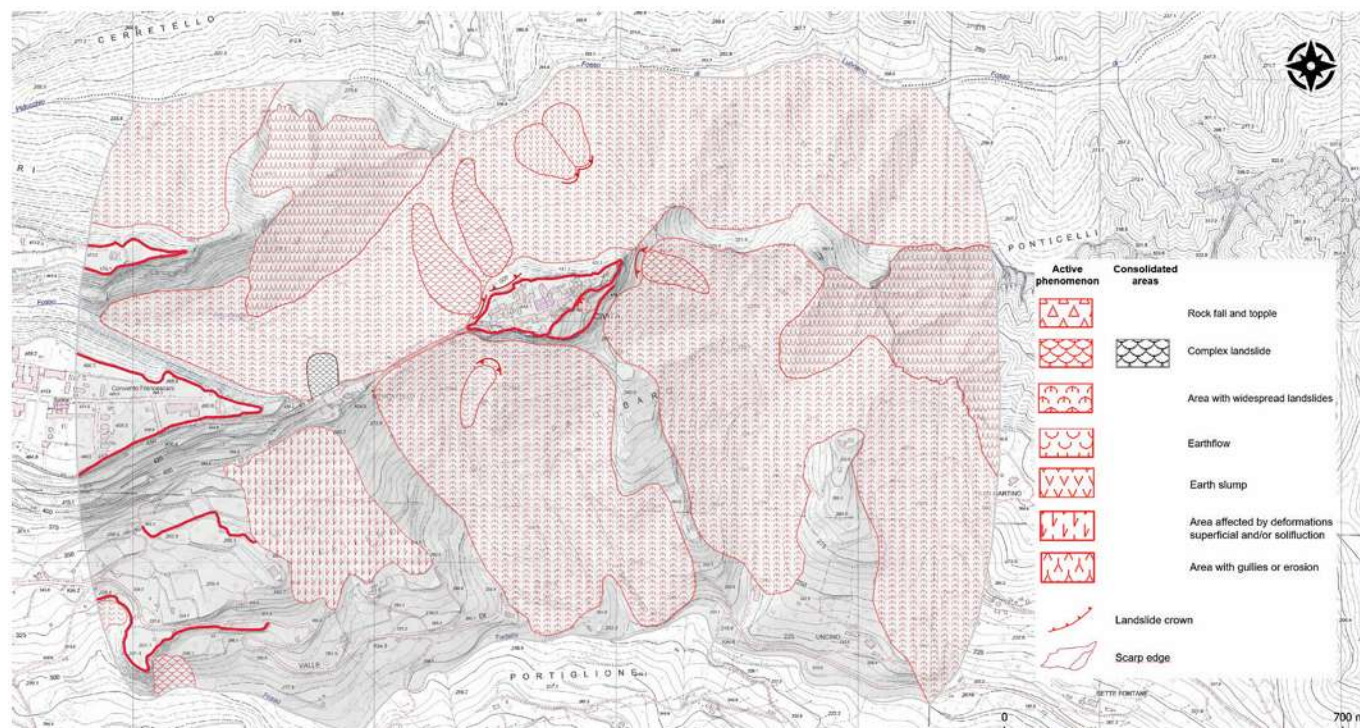


Civita is located at the boundary between the Vulsini volcanic deposits and the Tiber river-valley system, about 100 km north of Rome. The cliff is made of Quaternary pyroclastic units overlying a Plio-Pleistocene clayey succession. A massive tuff cap (about 20–25 m) overlies stratified tuff (about 40–50 m); the clayey basement crops out along the valley slopes. Two main fracture families in the tuff and basal erosion of the clayey slopes govern block instability and cliff retreat.





## Civita — active geomorphological processes

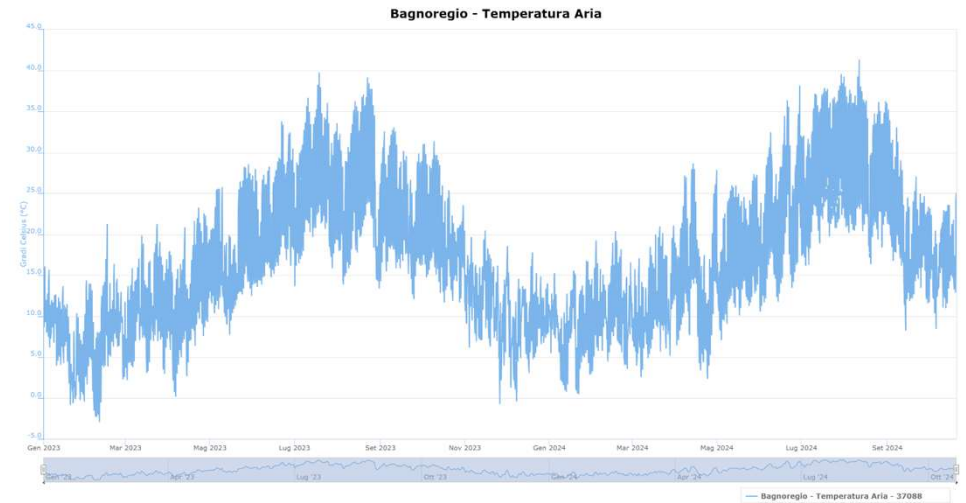
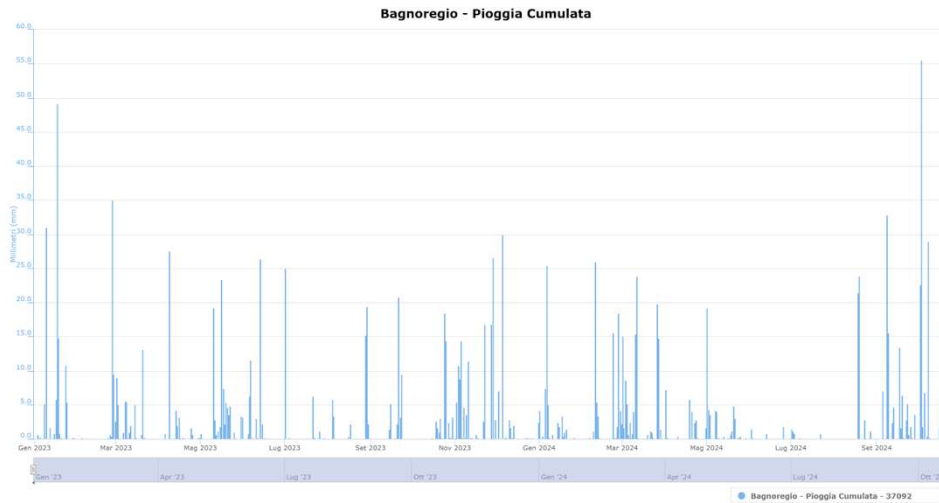


The Valle dei Calanchi is characterised by landscape evolution and a very high density of geomorphological features. Clayey slopes: earth flows, debris flows, solifluction and rotational/translational slides, especially during heavy rainfall. Tuff cliff: rock falls, planar/wedge sliding and toppling triggered by regression erosion, discontinuities and weathering. The north-western sector is historically critical; IFFI maps slow, complex and rotational/translational landslide bodies in this area.





## Civita — climate forcing and trigger conditions

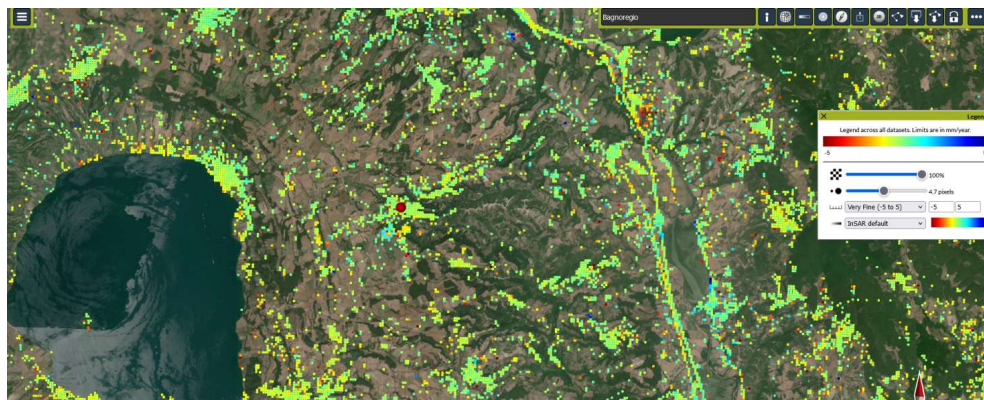


Mediterranean climate with dry summers and wetter autumn–winter periods; autumn 2024 shows a clear rainfall increase in the report data. Daily rainfall peaks above 40–50 mm are highlighted as relevant hydrological stress events for the site. Summer temperatures can exceed 35 °C and locally approach 40 °C, promoting desiccation, cracking and reduced permeability. Freeze–thaw cycles, rainfall after dry periods and seismic shaking act as additional factors that can accelerate slope instability.

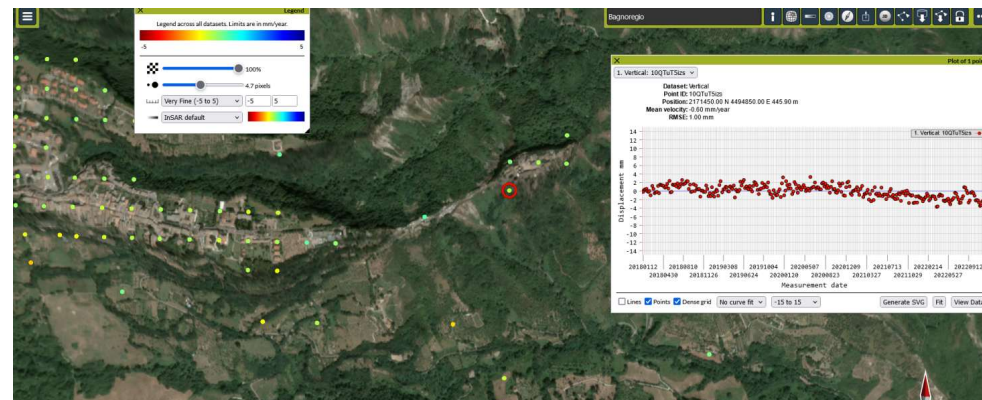
**Operational implication: rainfall, temperature and moisture should be treated as monitoring parameters, not only as background climate information.**



# Civita — satellite ground motion screening



EGMS (Sentinel-1, C-band): broad-area screening and first stability check



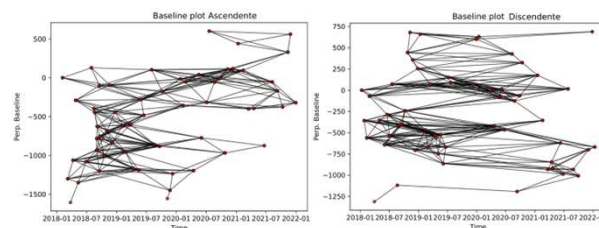
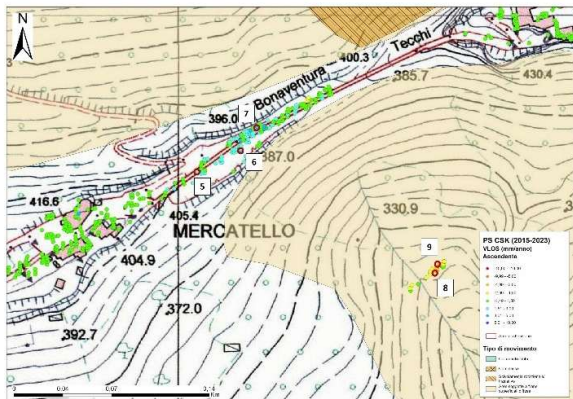
Cosmo-SkyMed (X-band): higher-resolution site analysis processed by UNIFI

**Key interpretation: EGMS supported wide-area screening, while CSK 2015–2023 helped identify two priority clusters for detailed field validation.**





## Civita — field validation: Mercatello bridge and historic centre

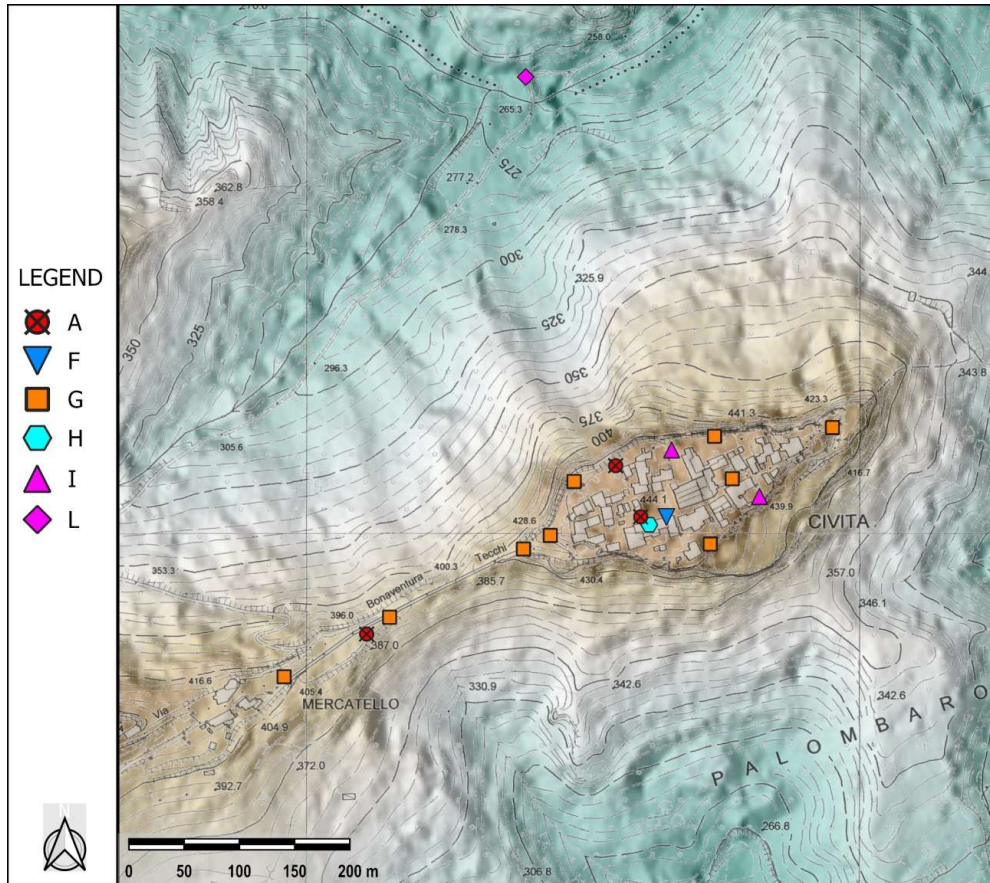


- Stop 1 — Mercatello access bridge: CSK data highlighted an anomalous cluster of monitoring points, with deformation of about 3–5 mm. Field checks confirmed small non-structural cracks and stress concentration near the bridge span; safe access remains a strategic management issue.
- Stop 2 — main square / western buildings: minor cracks and deformations were observed, linked to ageing tuff masonry and recent severe meteo-climatic stress.





## Civita — proposed integrated in-situ monitoring system



### Recommended architecture

Flexible, low-impact and remotely readable system, designed to evolve from monitoring to warning if needed.

Local Knowledge Hub hosted by municipality or competent authority; local and external nodes linked to a central MIC platform.

Priority controls: rainfall, temperature, humidity, GNSS, crack opening, tilt, and radar targets.

### Proposed sensor package

3 crack gauges · 12 thermo-hygrometric sensors · 15 GNSS stations · 2 corner reflectors · 1 full rain station · 1 data processing centre · **1 ground-based radar**

**Total: 26 instruments connected and visualised through the CED.**

**Report recommendations: quarterly inspections for the Mercatello bridge sector and the west-side building in the main square.**



## Case study — Orvieto and hilltop towns

# Urban heritage on a volcanic cliff

---

A historic town built on a limited tuff plateau, where natural instability, underground cavities, monuments and tourism coexist in a compact urban system.

**Management focus: integrated screening, field validation and low-impact monitoring for prevention and maintenance.**





## Orvieto — exposure concentrated on a small cliff plateau



**≈1.3 km**

limited extension of the tuff cliff plateau hosting the historical centre

**IX–VIII c. BC**

Etruscan origin of the town, later transformed by medieval and papal phases

**>1,200**

underground caves, tunnels, wells and cisterns excavated over about 2,500 years

**1977**

Cannicella landslide renewed attention on the stability of the cliff and underground system

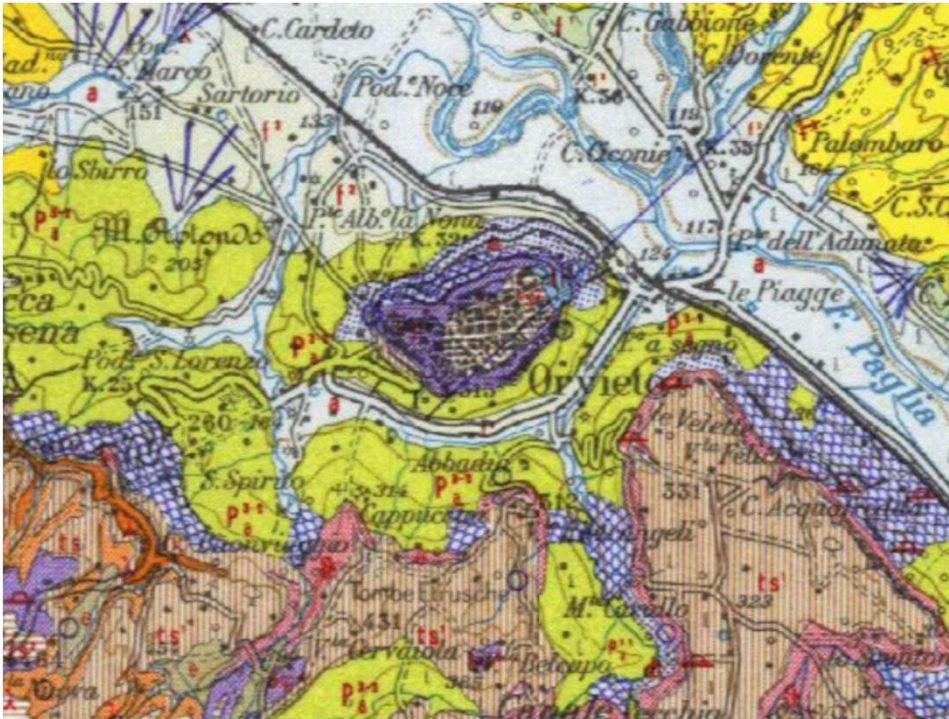
**The main risk-management issue is the overlap between cliff-edge instability, dense urban fabric, iconic monuments, underground cavities and critical access routes.**

A historical town cannot be treated as a single “object”: different sectors require different monitoring and maintenance priorities.





## Orvieto — geology explains the instability pattern



The city lies on the northern edge of the Quaternary volcanic plateau of Alfina, produced by the Vulsini volcanic system. The stratigraphic sequence includes Pliocene marine clays, a thin fluvio-lacustrine “Albornoz series” and the overlying tuff plate.

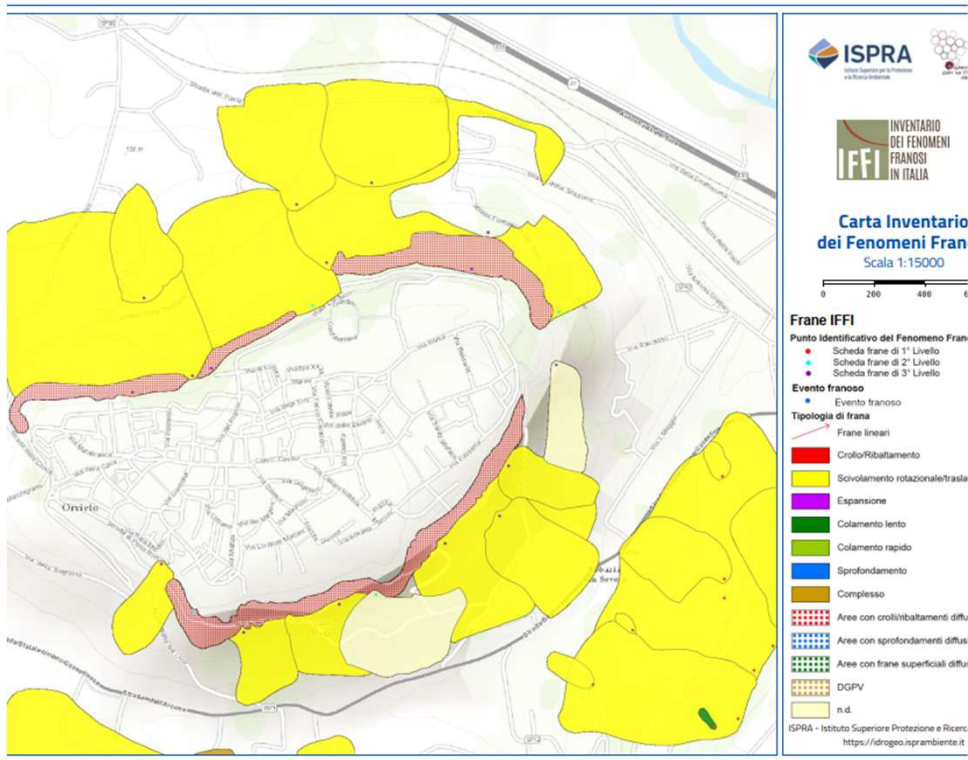
The tuff cliff is a relic of selective erosion by the Paglia River and tributary drainage, with ongoing retrogressive erosion along the margins.

Mechanical contrast between stiff tuff and clayey substratum is a key control on slope deformation and cliff-edge instability.

Read the site from the bottom up: clays → Albornoz series → tuff slab → urban fabric.



## Orvieto — landslide mechanisms around the cliff



### Clayey slopes

Rotational and translational slides in basal clays and detrital covers; possible combined movements.

### Tuff perimeter

Block lowering at the upper edge, rock falls/topples, basal fracturing of prisms.

### Controls

Cooling fractures, different deformability between tuff plate and clays, toe stress and weathering.

### Human factors

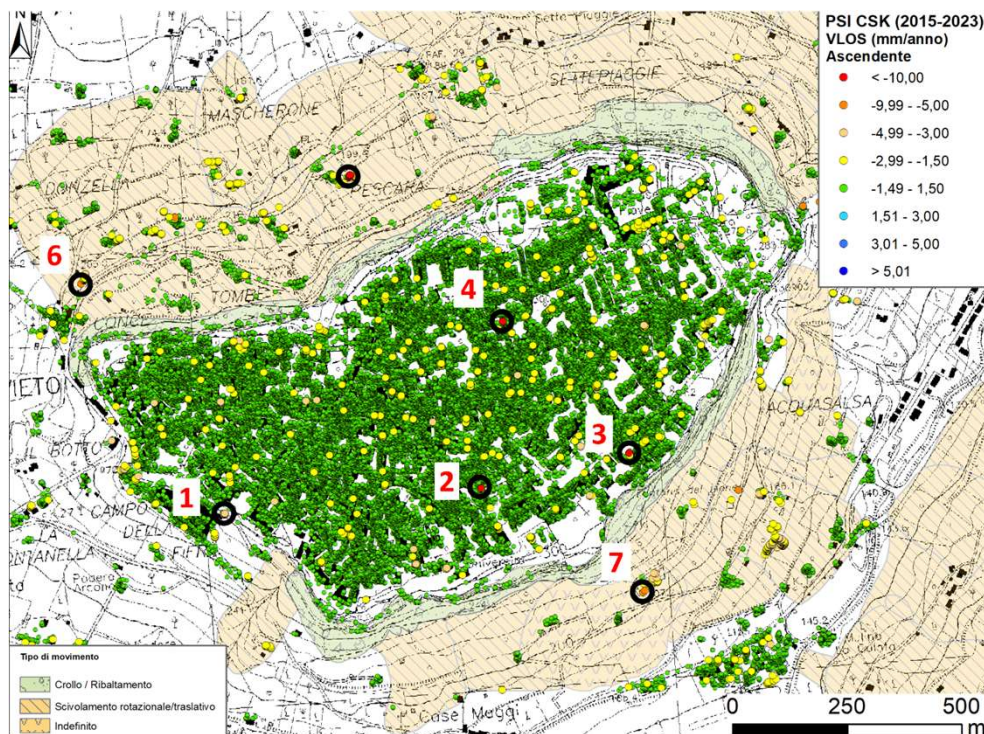
Caves, quarrying and long-term urban use of the tuff mass can locally modify stability conditions.

**IFFI mapping provides the inventory baseline, but interpretation must be updated with cliff-sector inspection, underground knowledge and monitoring evidence.**

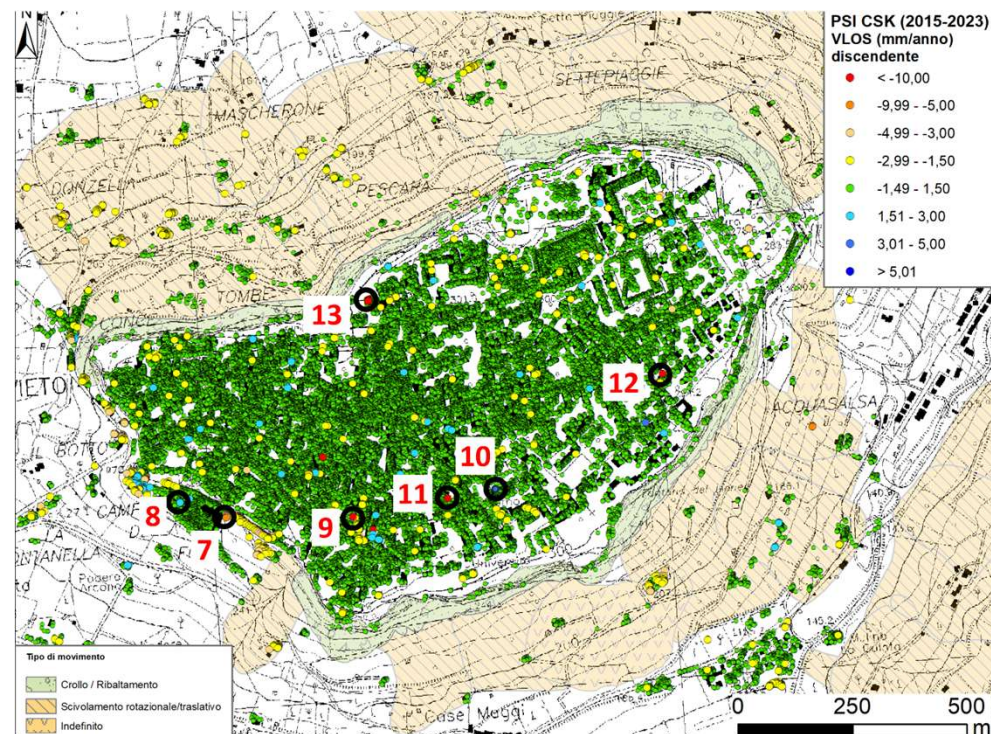




## Orvieto — COSMO-SkyMed results (2015–2023)



Ascending geometry



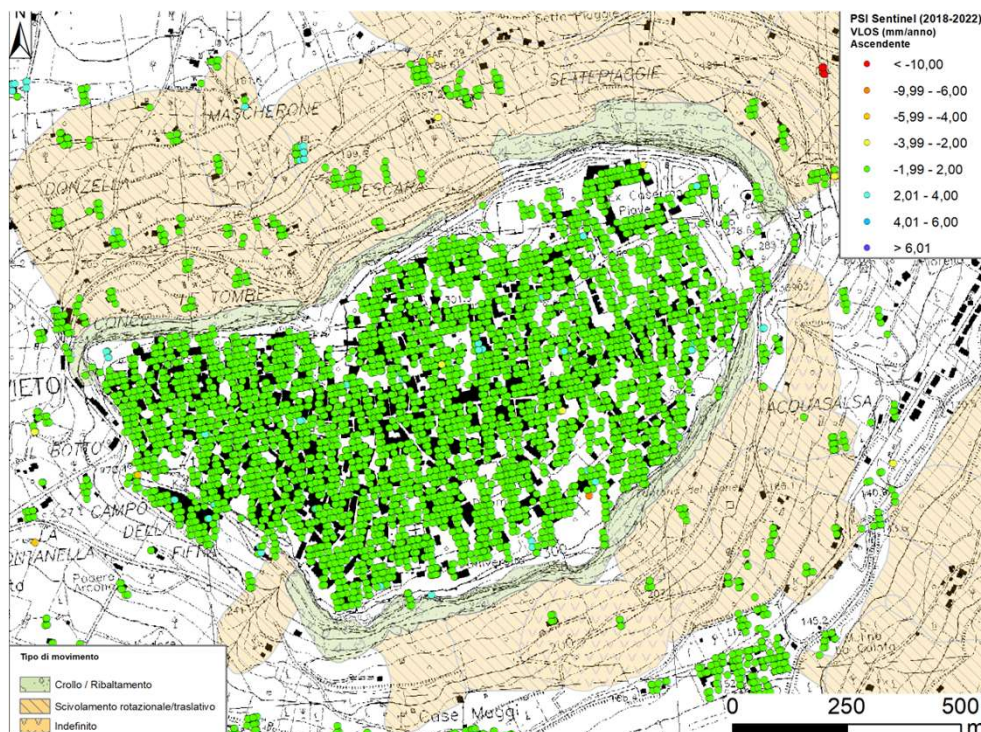
Descending geometry

The CSK maps were used to identify the sectors of greatest interest for targeted field checks and to compare motion patterns along different viewing geometries.

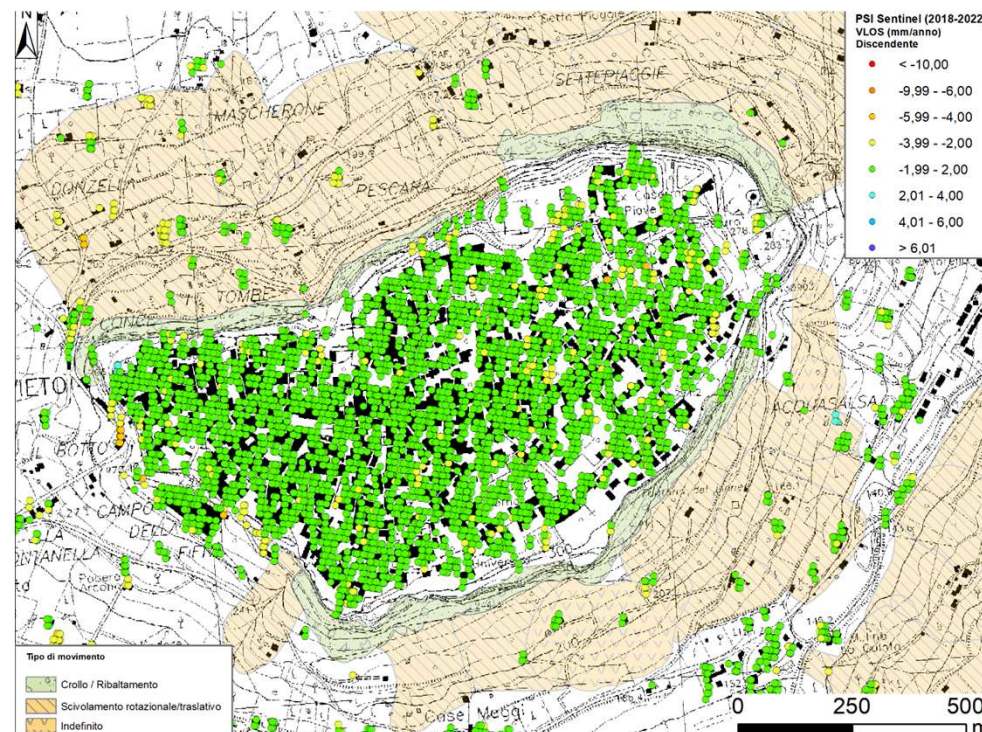




## Orvieto — Sentinel-1 results (2018–2022)



Ascending geometry



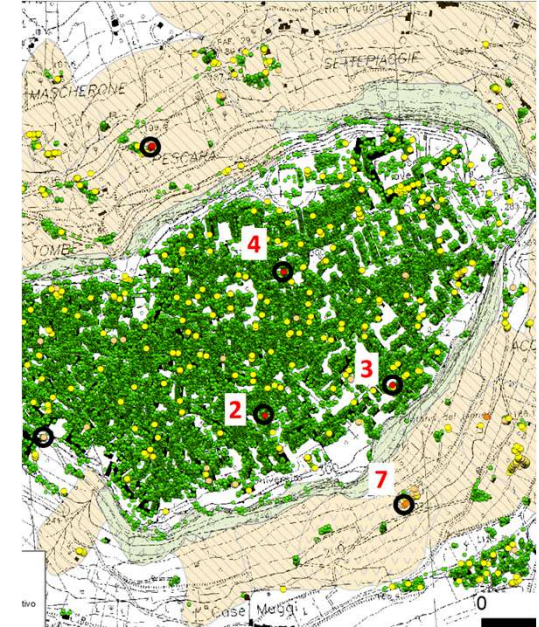
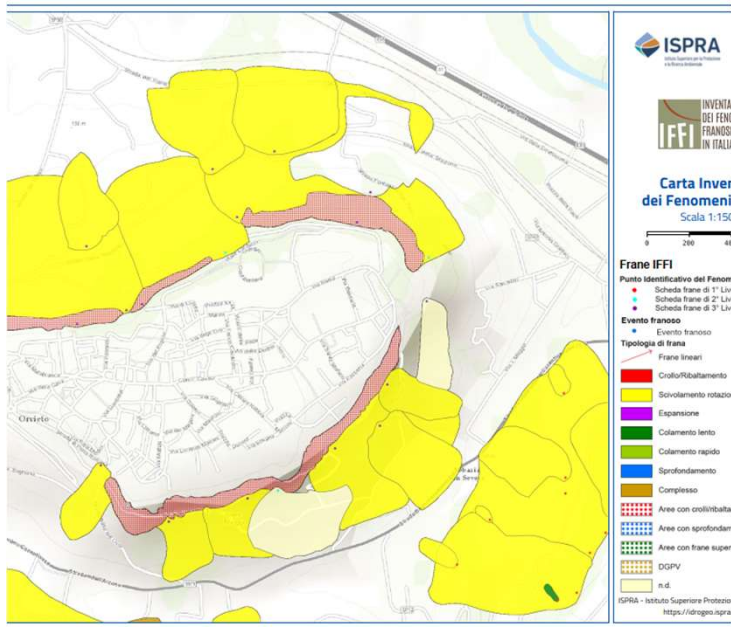
Descending geometry

**Sentinel-1 supports wider-area continuity and comparison with national or European ground-motion services; local decisions still require site-scale interpretation.**





## Orvieto — field validation and preliminary interpretation



The 18 March 2024 survey focused on the areas highlighted by the interferometric analyses.

Objectives: verify site conditions, validate deformation hypotheses and refine the limits of potentially affected sectors.

The report states that the InSAR analyses did not show anomalies attributable to possible deformation phenomena, and field evidence confirmed this preliminary hypothesis for the analysed period.

Some local points still require additional checks to distinguish natural from anthropogenic deformation trends.



## Case study — Volterra: historical village and medieval walls

### Slow landslides, cliff retreat and heritage exposure

---

Volterra is a hilltop town on a fragile Pliocene mesa. Its cultural heritage includes Etruscan walls, the Roman Theatre and a historic urban fabric affected by slow slope deformation and local instabilities.

**Management focus: integrate InSAR screening, field validation and low-impact in situ monitoring.**







## Volterra — cultural heritage exposure

### A long-lived hilltop settlement with archaeological assets at the slope margin



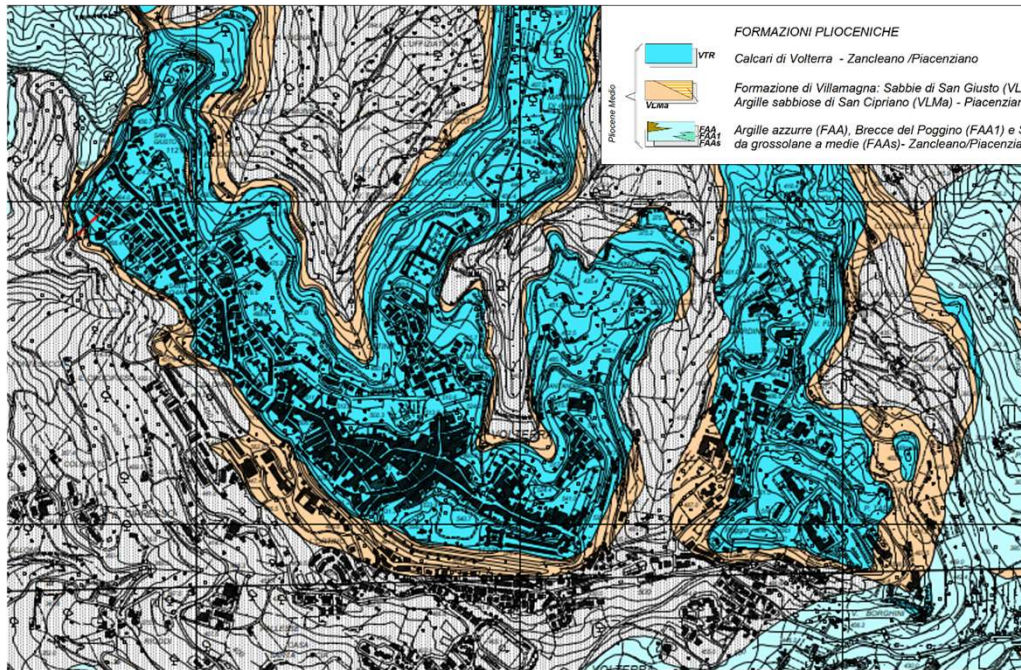
Volterra preserves major Etruscan and Roman evidence: city walls, Roman Theatre and acropolis. More than 1,500 m of Etruscan walls are still standing, although only a fraction of the original circuit. The hilltop position concentrates heritage exposure along steep and retreating slope margins.



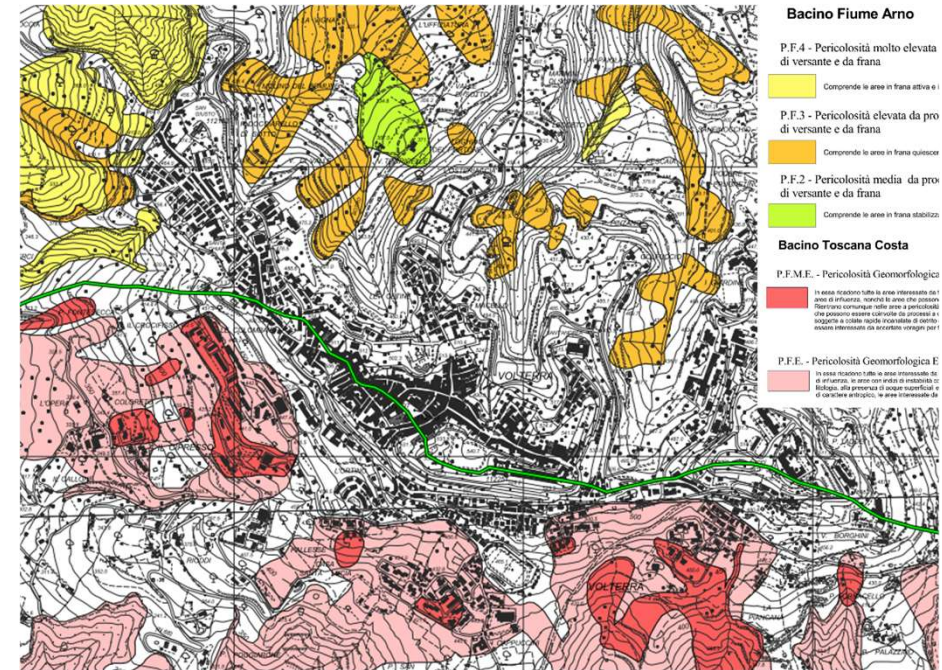


## Geology and geomorphology: the Volterra mesa

### A sedimentary sequence with strong geotechnical contrasts controls slope behaviour



Stratigraphic sequence: Blue Clays at the base, Villamagna sands/conglomerates in the middle, and Volterra Calcarenites on top.



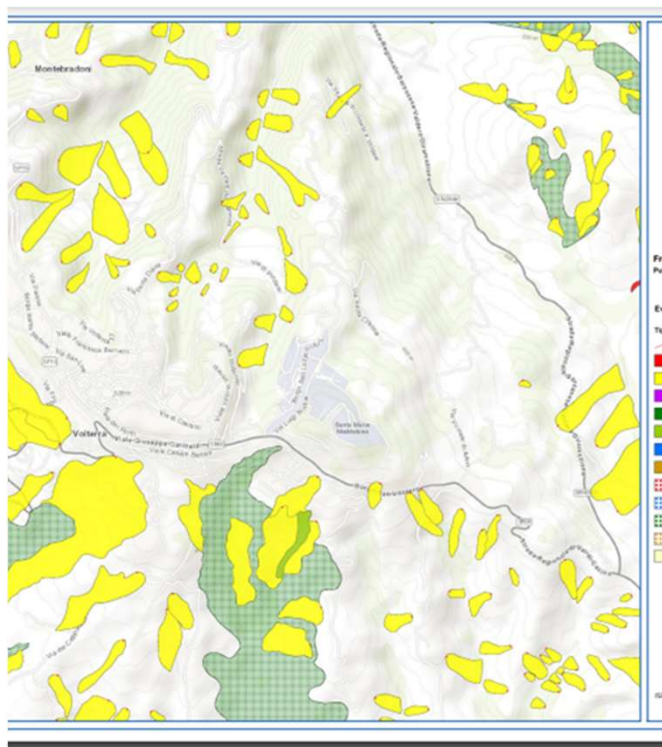
Process control: clay erosion and undercutting generate retrogressive slope failures and the sub-vertical cliffs known as “Le Balze”.





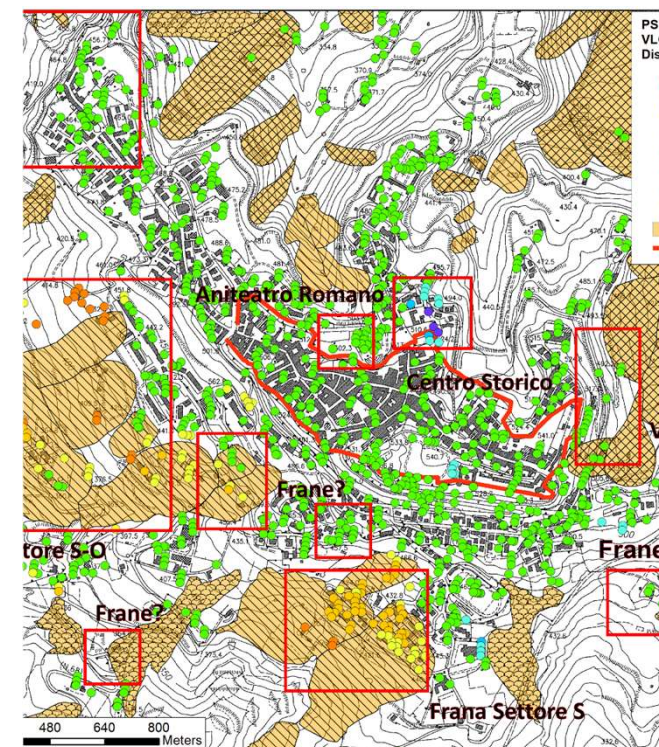
# Hazard inventory and InSAR screening

## Satellite analysis distinguishes stable urban sectors from active/quiescent landslide bodies



| Satellite           | Time Interval | revisit time (days) | Band-Wavelength | Orbite     | Resolution (Range x Azimuth) (m) | Processing | LOS inclination with respect to the vertical (°) |
|---------------------|---------------|---------------------|-----------------|------------|----------------------------------|------------|--------------------------------------------------|
| ERS                 | 1991 - 2000   | 35                  | C               | Desce      | 15 x 4                           | PSInSAR™   | 23                                               |
| Envisat             | 2003 - 2009   | 35                  | C               | Asce/Desce | 15 x 4                           | PSInSAR™   | 22                                               |
| Cosmo-SkyMed (CSK)  | 2011 - 2014   | 16                  | X               | Asce/Desce | 3 x 3                            | SqueeSAR™  | 34                                               |
| Sentinel Toscana    | 2018 - 2023   | 12                  | C               | Asce/Desce | 15 x 4                           | SqueeSAR™  | 38                                               |
| Cosmo Sky Med (CSK) | 2014 - 2023   | 16                  | X               | Asce/Desce | 3 x 3                            | SqueeSAR™  | 34                                               |

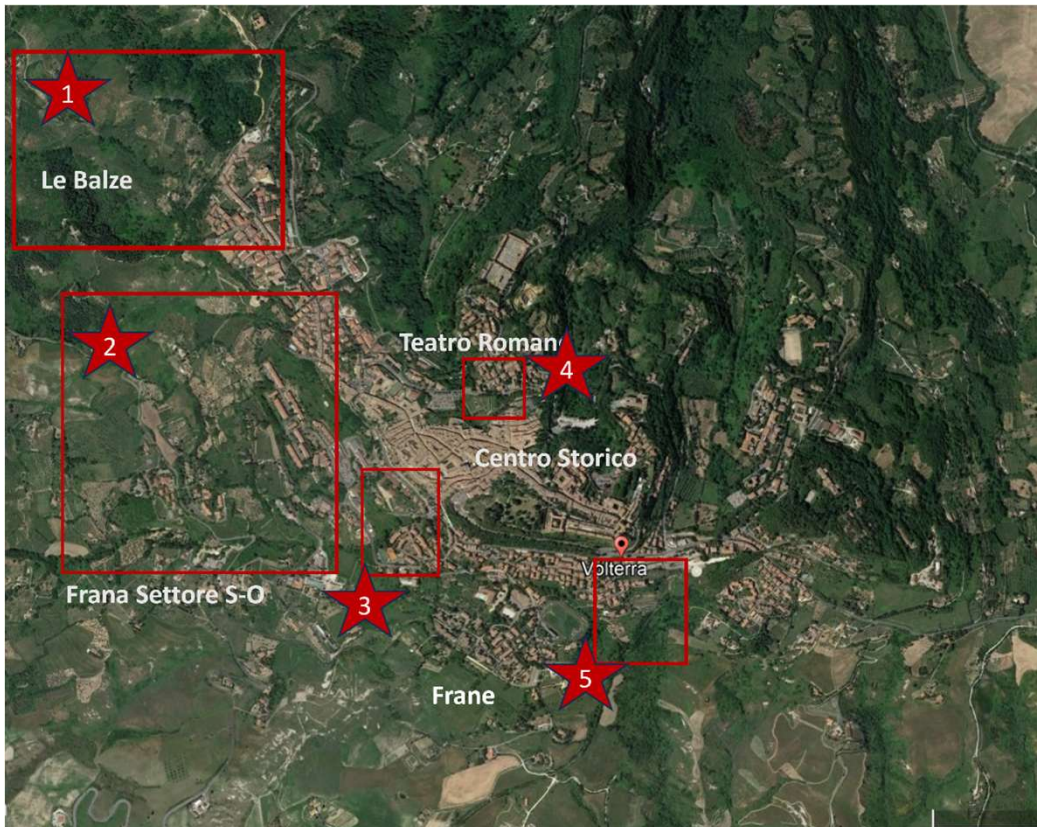
InSAR was used as a first screening layer for deformation anomalies. Mapped landslide areas show ground deformation rates of about 10–15 mm/year. The historic centre is generally stable; peripheral sectors require field checks.





## Field validation strategy

### A rapid survey translated satellite anomalies into site-specific evidence



The field survey focused on the historic centre and immediately outside the walls, where InSAR and previous events suggested potential instabilities.

Stop 1: Le Balze and Etruscan-wall sector.

Stop 2: SIAF area and SP Monte Volterrano deformation sector.

Stop 3: Viale Giusto Landini and Largo Giuseppe Di Vittorio.

Stop 4: Roman Theatre archaeological area.

Stop 5: Via dei Cappuccini and Via Francesco Gioli.

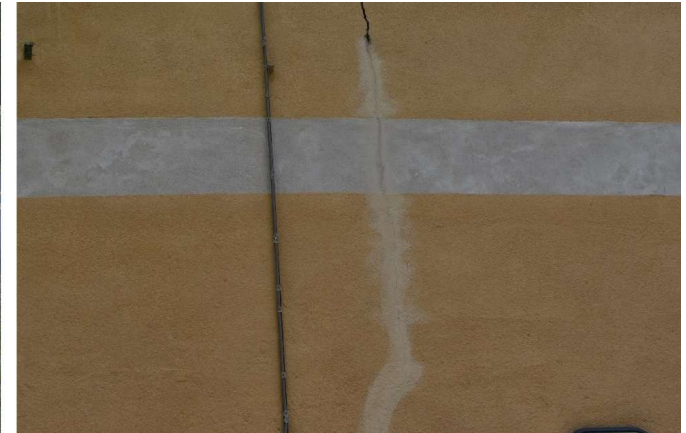
Purpose: validate the extension and limits of deforming zones and define where in situ monitoring should be integrated or upgraded.





## Le Balze and Via Comunale della Frana

### Cliff retreat, 2010 rockfall and local ground–structure evidence



Le Balze: active selective erosion, but no evident update to the known hazard setting from the rapid inspection.

Via Comunale della Frana: 2010 rockfall with sliding component and rolling blocks.

Event geometry: ~16 m front and ~22 m height difference from road to detachment niche.

Residual evidence: road cracks, retaining works and minor cracks in nearby buildings.

Risk-management message: cliff retreat and past rockfall events require periodic inspection and photographic documentation.



## Built-up deformation sectors outside the core

## SIAF, SP Monte Volterrano and Largo Di Vittorio show evidence of damage and deformation



SIAF sector: residual wall cracks, pavement deformation and non-structural detachments after consolidation works.

SP Monte Volterrano: road deformation, wall cracks and mitigation structures indicate interaction with landslide bodies.

The landslide boundary may need revision using geomorphology + InSAR evidence.

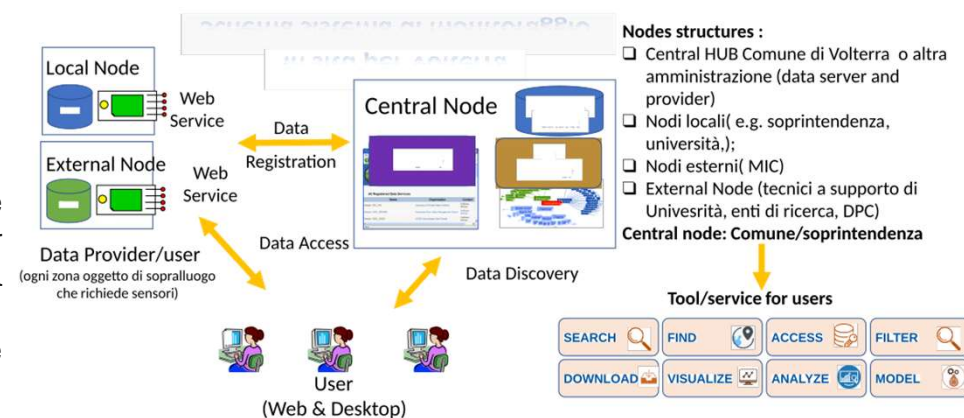
Largo Di Vittorio: strongly cracked houses linked to landslides; some were evacuated in 2013.





## From inspection to monitoring priorities

### A low-impact, flexible monitoring architecture for cultural heritage and slope risk



Suggested architecture: central municipal/superintendency hub, local sensor nodes, external technical nodes and shared data services.



## Case study — Niscemi 2026: managing a mega-landslide

### When a whole urban edge moves

A large, active landslide system affected the western and southern margins of Niscemi in January 2026. The case is not only a geotechnical problem: it is a complex crisis-management problem involving evacuation, red zones, infrastructure, communication, monitoring and long-term relocation.

**350 M m<sup>3</sup>**

estimated mobilised  
volume

**~4–4.7 km**

overall unstable front

**>1,500**

evacuated people  
reported







## Event chronology and operational escalation

### From local collapse to national emergency management in less than two weeks

15–16 Jan



First paroxysmal phase:  
western slope and SP12  
collapse



18 Jan



Severe weather wave  
affects Southern Italy

25 Jan



Major southern landslide:  
red zone and immediate  
evacuation



27–30 Jan



National Service support:  
coordination centres,  
monitoring, road access



Feb 2026



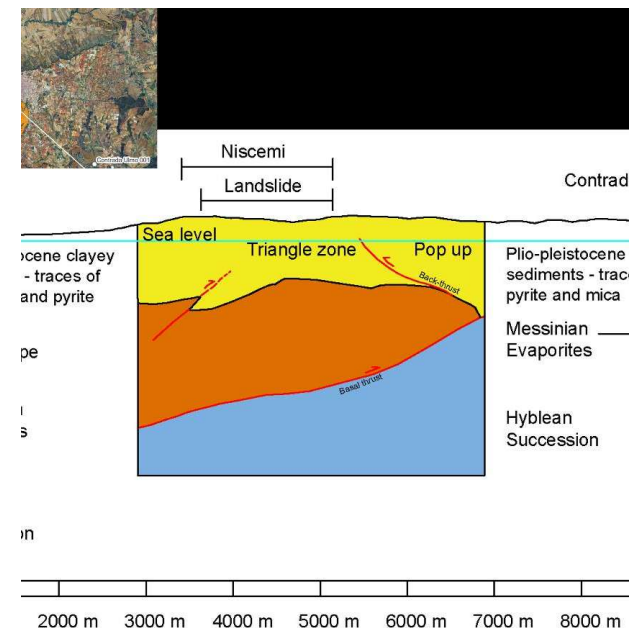
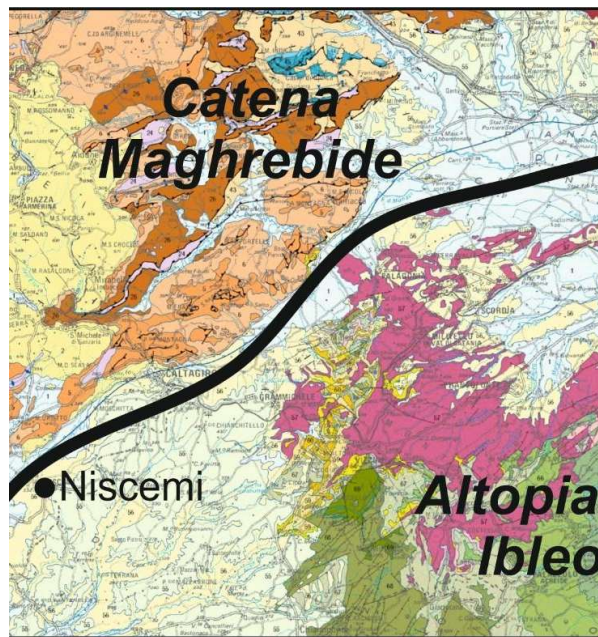
Stabilisation, assistance  
requests, cultural asset  
recovery and longer-term  
planning

**Key management lesson:**  
when the landslide is still  
active, operations must be  
dynamic — boundaries,  
access routes and  
priorities change as new  
evidence arrives.



## Why Niscemi was predisposed to large instability

A plateau town on sands over weak clays, above a tectonically complex foredeep



Niscemi sits on a small plateau at about 330 m a.s.l., bordered by steep slope margins.  
Local sequence: yellow sands / silty sands over sandy silts and highly plastic blue-grey marly clays.  
Historical landslides in 1790 and 1997: 2026 reactivated and enlarged a known deep system.  
The structural setting may favour deep discontinuities, fluid pathways and long-term stress accumulation.



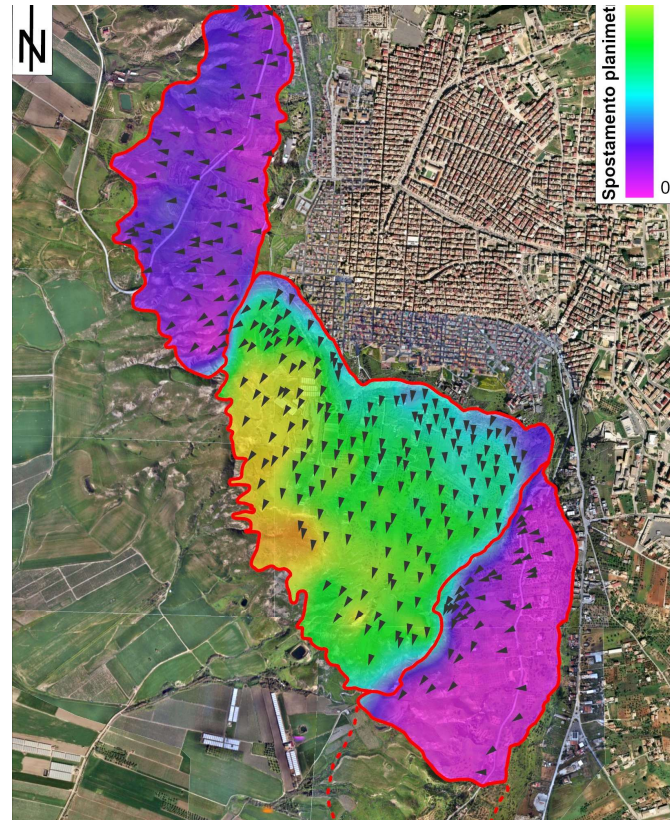


## Scale and kinematics of the 2026 landslide system

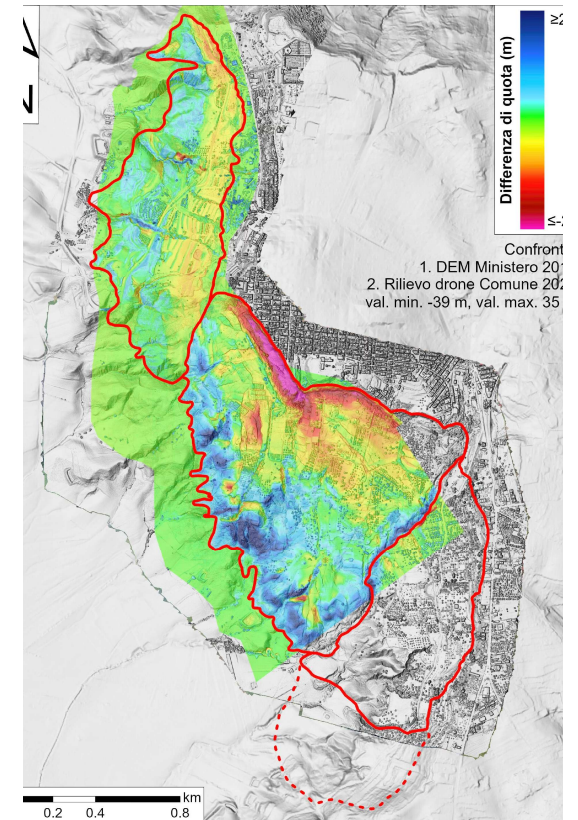
### Three coalescent sectors, different displacement magnitudes and a moving urban edge



North sector: SP12 collapse; >12 m displacement



Central sector: main body; >50 m SW displacement

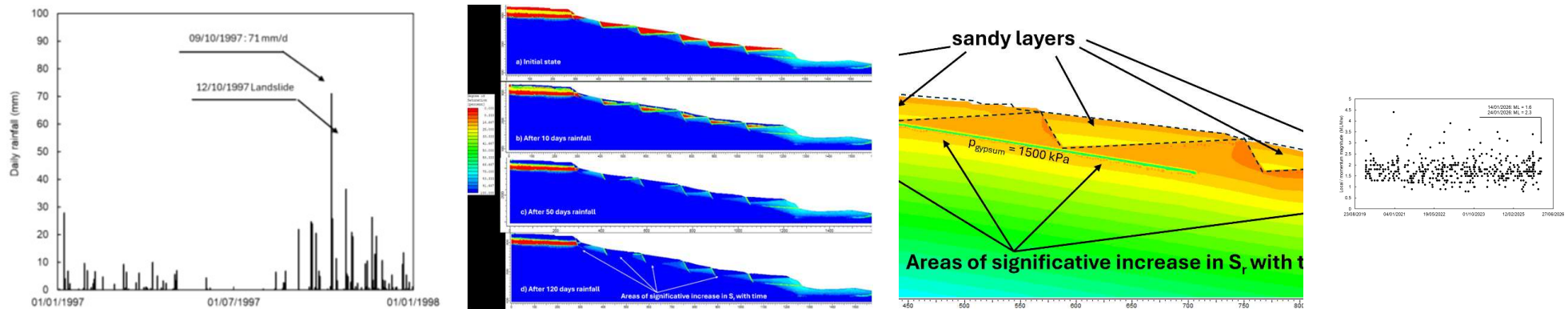


South sector: SP10 damage; >7 m W-SW displacement



## Triggering hypotheses: not a single-cause event

### Rainfall mattered, but the preliminary modelling points to combined mechanisms



Rainfall was not exceptional but followed very dry years that may have promoted shrinkage cracking in high-plasticity clays. The preliminary modelling tested rainfall, swelling / pressurised fluids, toe erosion, seismic effects and combined scenarios. The lowest FS for a deep surface was obtained when swelling pressure of gypsum-bearing minerals / fluids was combined with rainfall. Local seismicity appears too low to be considered the primary trigger.

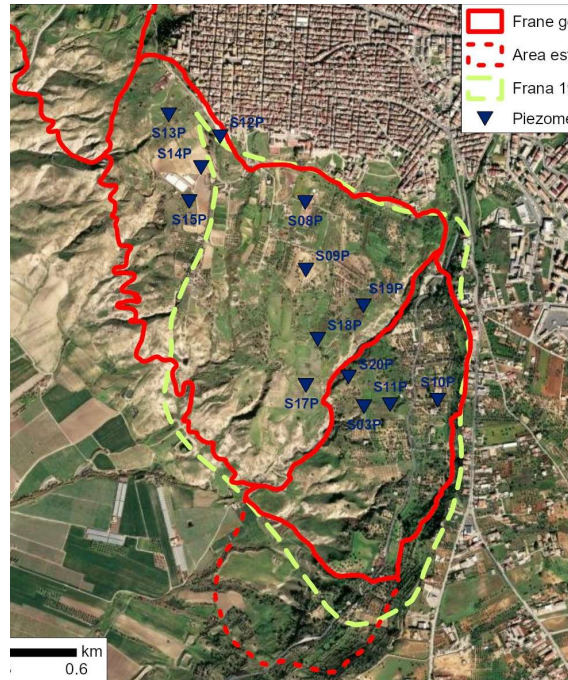
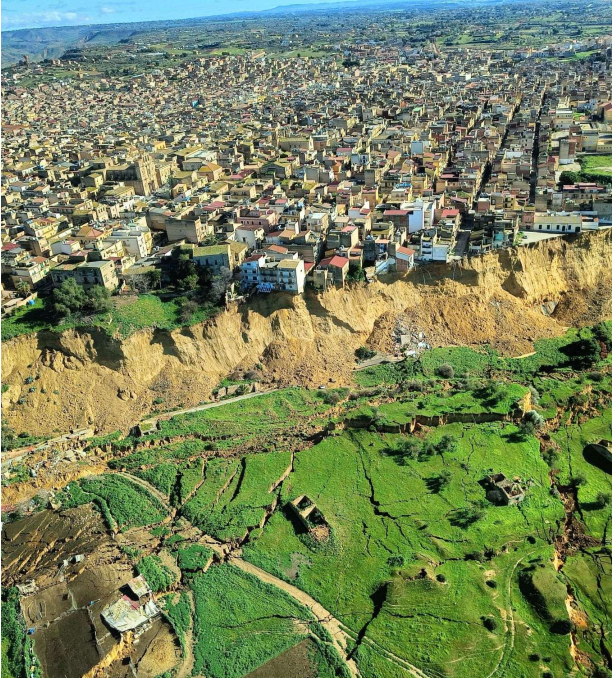
**Operational consequence: crisis management must monitor hydro-meteorology, pore pressures, deep movement and slope toe evolution together — not as isolated variables.**





## Managing the emergency: people first, then assets and services

### The event required rapid conversion from technical assessment to civil-protection operations



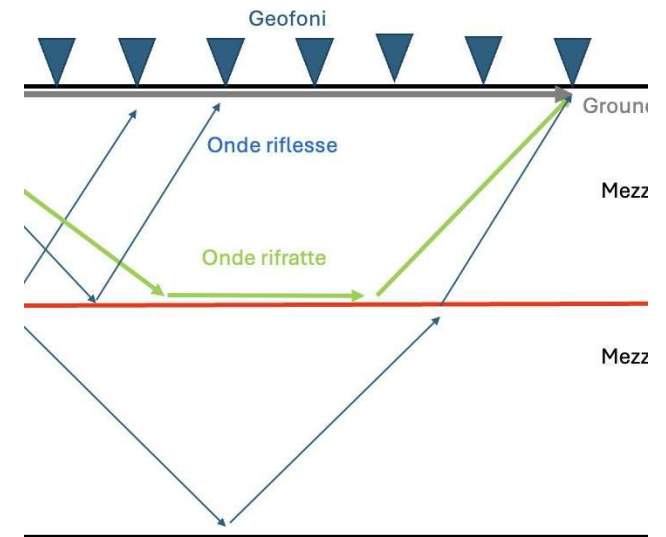
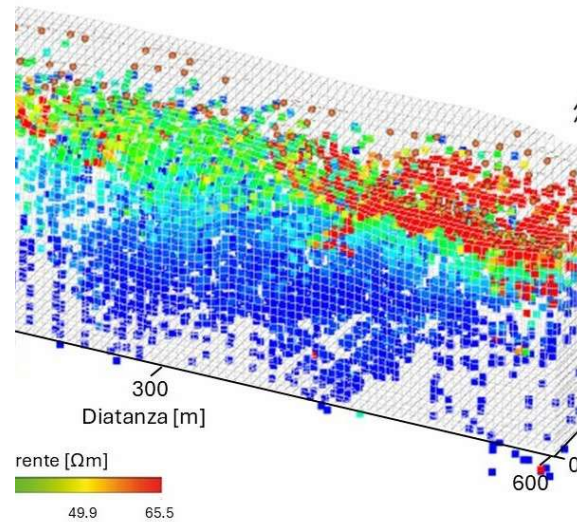
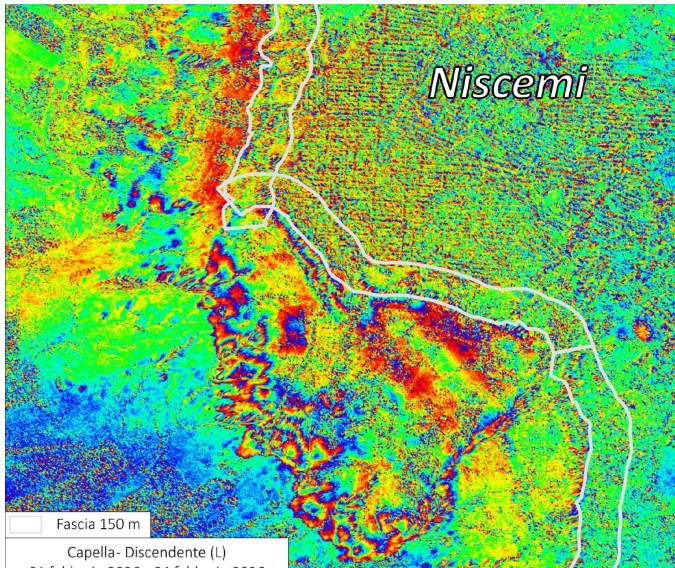
Define and enforce red / no-go zones while the ground is still moving.  
Evacuate residents and maintain assistance, housing and welfare channels.  
Keep road access and lifelines under continuous review; use alternative routes when main roads fail.  
Run building inspections only when monitoring confirms acceptable short-term safety.  
Communicate uncertainty: intervention design is constrained until movement slows and boundaries stabilise.

**Media interviews amplified the key message: several houses on the landslide edge cannot be safely reoccupied and permanent relocation has to be planned.**



## Monitoring and decision support during an active landslide

### Multi-source observations support zoning, access control and recovery planning



Pre-event: IFFI/IidroGEO, historical archives, geological mapping and susceptibility knowledge.  
Co-event: drone surveys, orthophoto comparison, DInSAR / Pixel Offset Tracking and rapid field checks.  
Post-event: Sentinel-1, COSMO-SkyMed, SAOCOM and VHR products support deformation tracking.  
Ground network: piezometers, inclinometers, GNSS, extensometers and dashboards reduce model uncertainty.

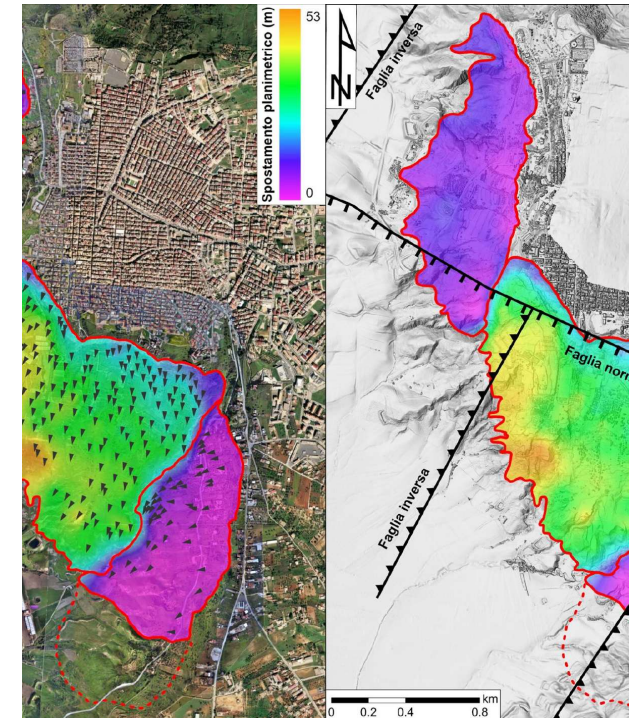
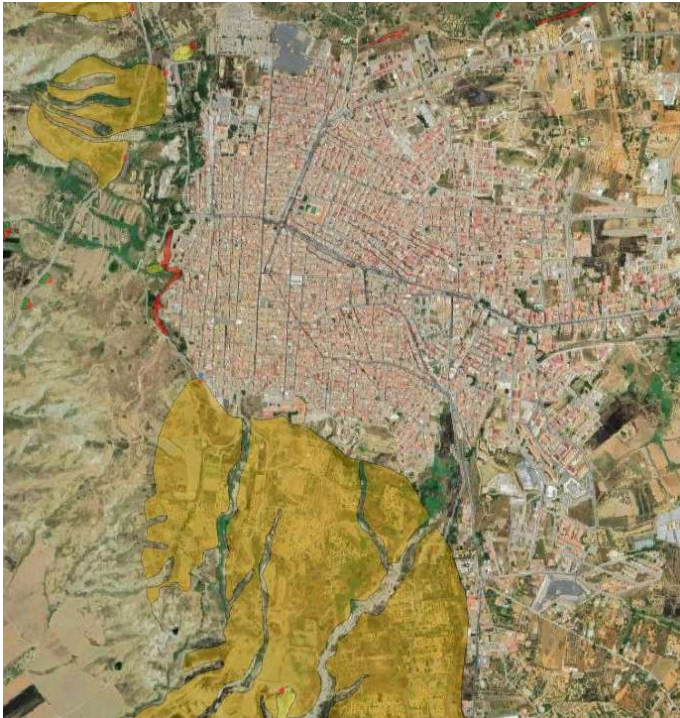
**Decision objective: turn monitoring into operational thresholds for access, evacuation review, works planning and long-term land-use restrictions.**





## From emergency to risk governance

### The Niscemi case is a stress test for Italian landslide-risk management



Short term: life safety, red-zone enforcement, displaced-family assistance, access and communication.

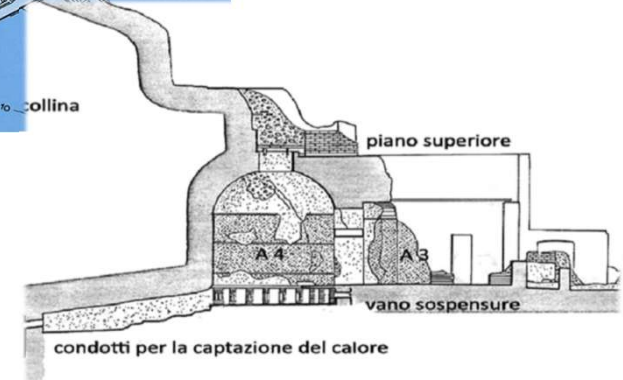
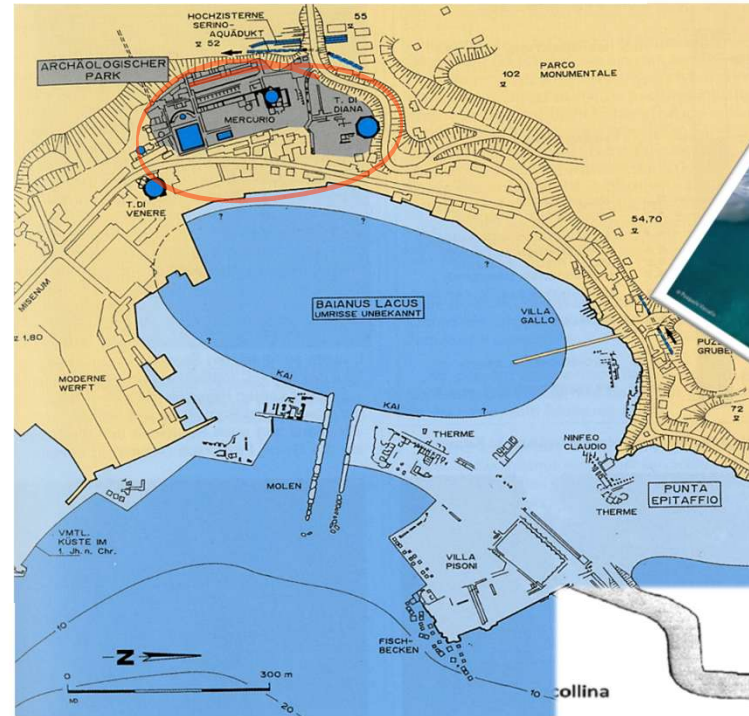
Medium term: complete geognostic/geotechnical characterisation and repeat modelling with lower uncertainty.

Long term: relocate exposed residents, revise planning rules, update zoning and design works where justified.

System lesson: permanently bridge scientific evidence, civil-protection command and political decisions.



# Parco Archeologico dei Campi Flegrei: Terme Romane di Baia





# Step 1

**CH Background  
(desk and field study):**  
investigating the origin,  
typology, construction  
techniques, restoration history,  
evolution in time, etc.

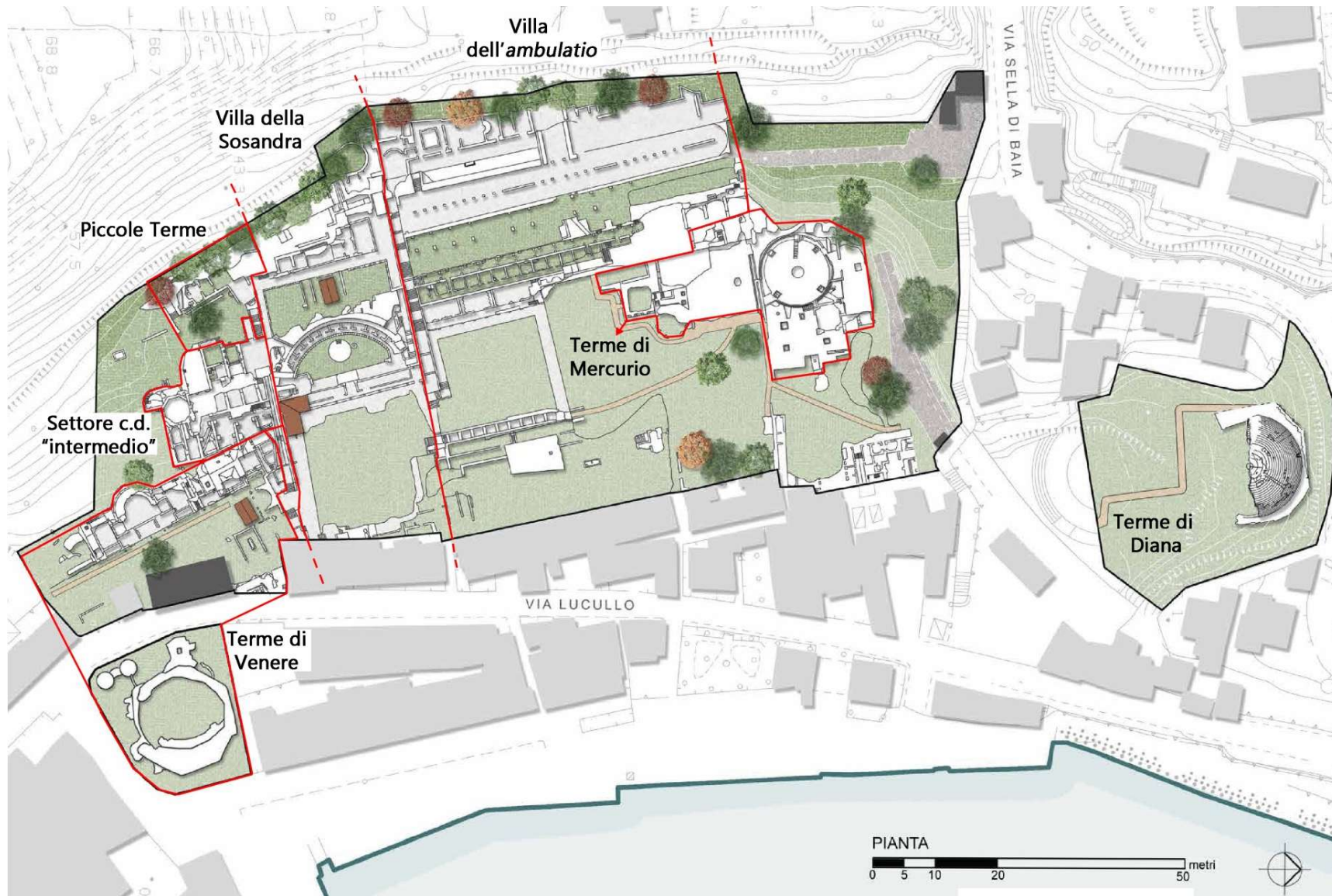
**Geohazard assessment**  
Hazard and risk map  
analysis and field  
survey

**SAR Interferometry**  
Data integration and  
services

**Ground motion  
monitoring**  
Field survey and risk  
mitigation plan



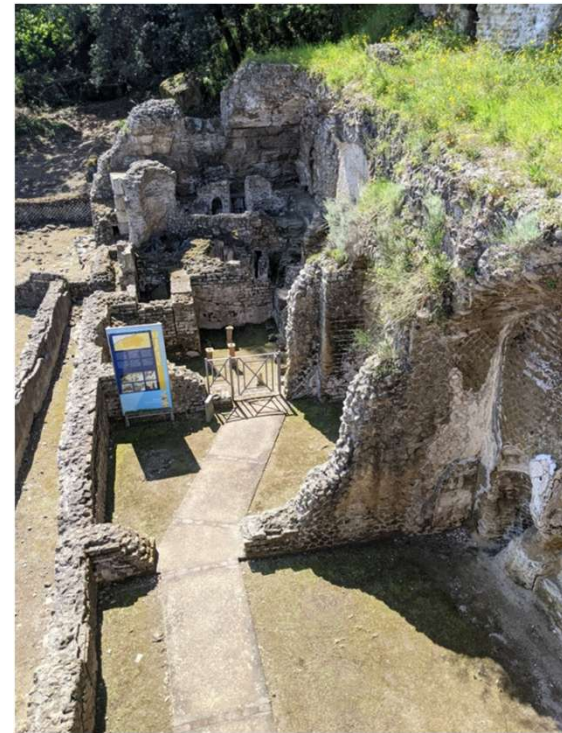
# Roman Bath of Baia





## Roman Bath of Baia

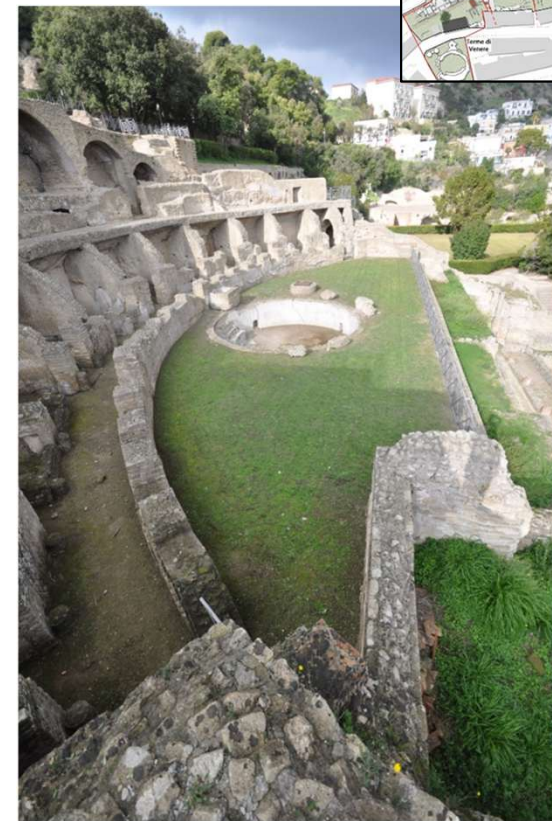
*Ambulatio Villa* and Little Thermae are the older complexes, originally connected: a small thermal bath serving a majestic residence built on seven terraces.





## Roman Bath of Baia

In-between, in the I century A.D., was built the *Villa della Sosandra*, with a wide exedra facing the sea.





## Roman Bath of Baia

The wealth of thermal resources led to the the rise of majestic thermal complexes, with large domed halls.





## Roman Bath of Baia

First came the *Mercurio Thermae*, that took the place of *Ambulatio Villa's* garden.

The complex is well-known for its dome, 20 meters wide; the first built so wide in roman age.





# Roman Bath of Baia

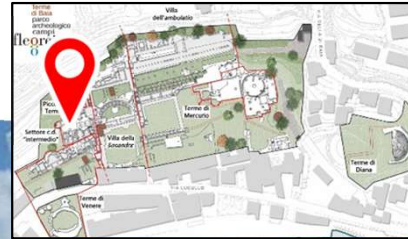
One century later were built the *Venus Thermae* : even this building, divided in two terraces, was domed (nowadays collapsed).





## Roman Bath of Baia

Shortly after the previous, the *intermediate Thermae* arose: their name derives from the position, between *Venus T.* and *little T.* They were built on a single wide and panoramic terrace.





## Roman Bath of Baia

The last are the *Diana Thermae*. Half of the big dome is collapsed, and the rest of the complex is still to be excavated





# Roman Bath of Baia

Le Terme romane di Baia si estendono per 3,5 ettari. Sono costituite dagli scavi archeologici dell'insediamento romano e dai resti del parco archeologico sommerso.





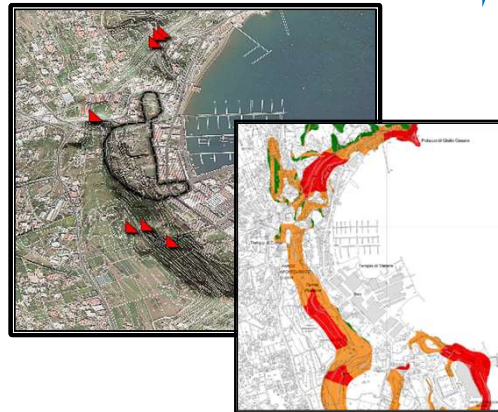
## Step 2

**CH Background**  
(desk and field study):  
investigating the origin,  
typology, construction  
techniques, restoration history,  
evolution in time, etc.

**Geohazard assessment**  
Hazard and risk map  
analysis and field  
survey

**SAR Interferometry**  
Data integration and  
services

**Ground motion  
monitoring**  
Field survey and risk  
mitigation plan



## Bradisism phenomena ed effect

1830



1953

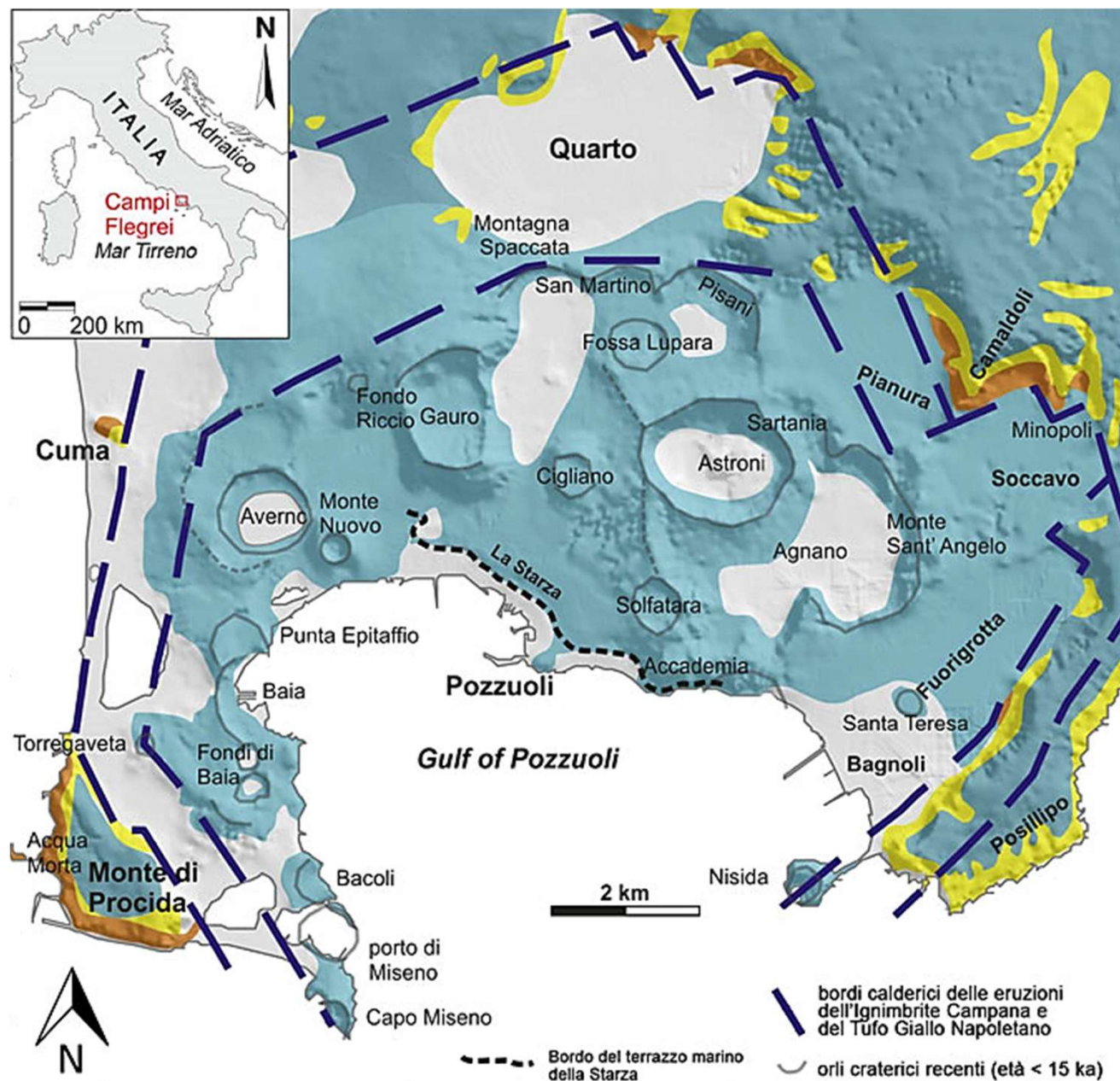


2000

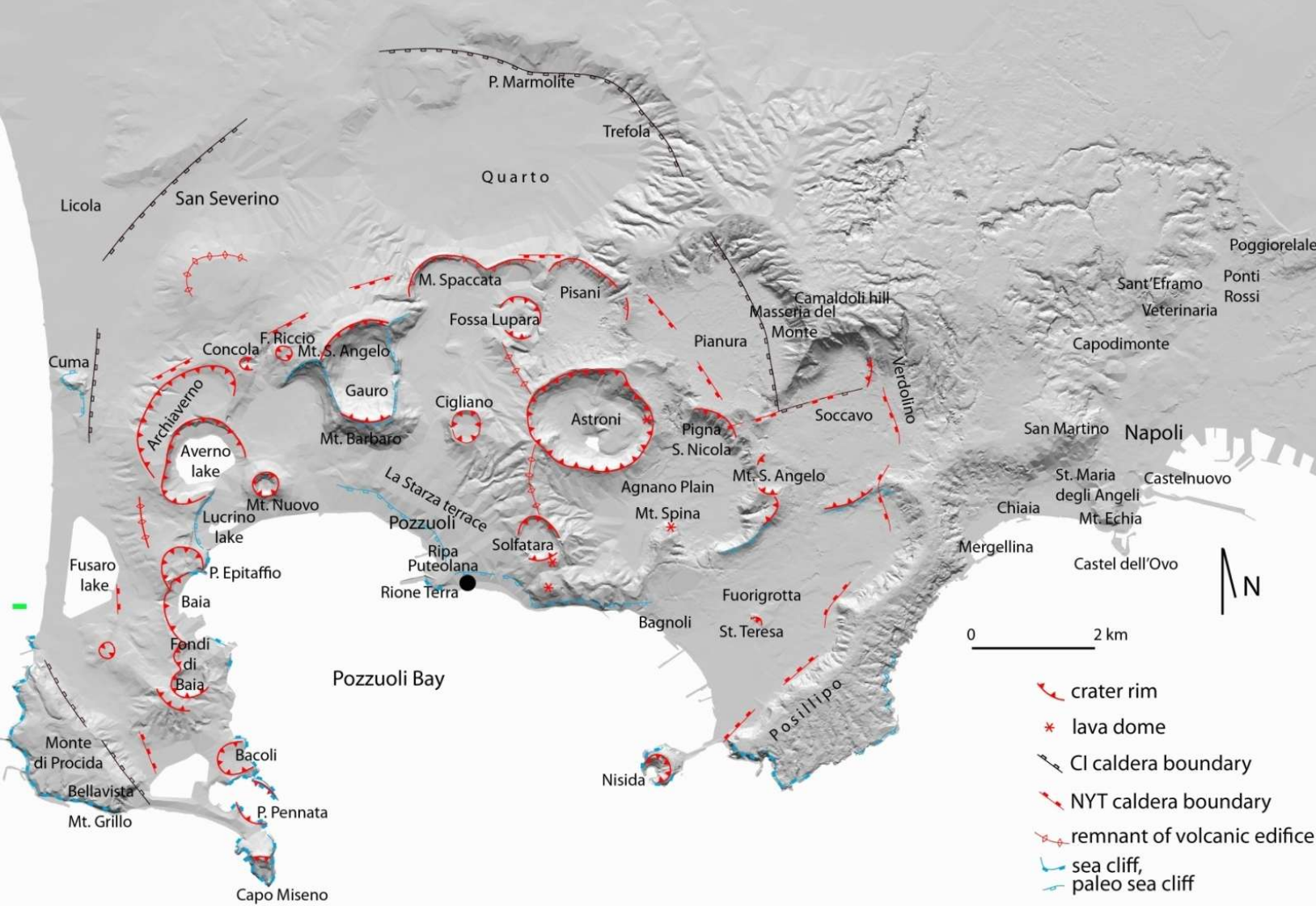




# Geological setting



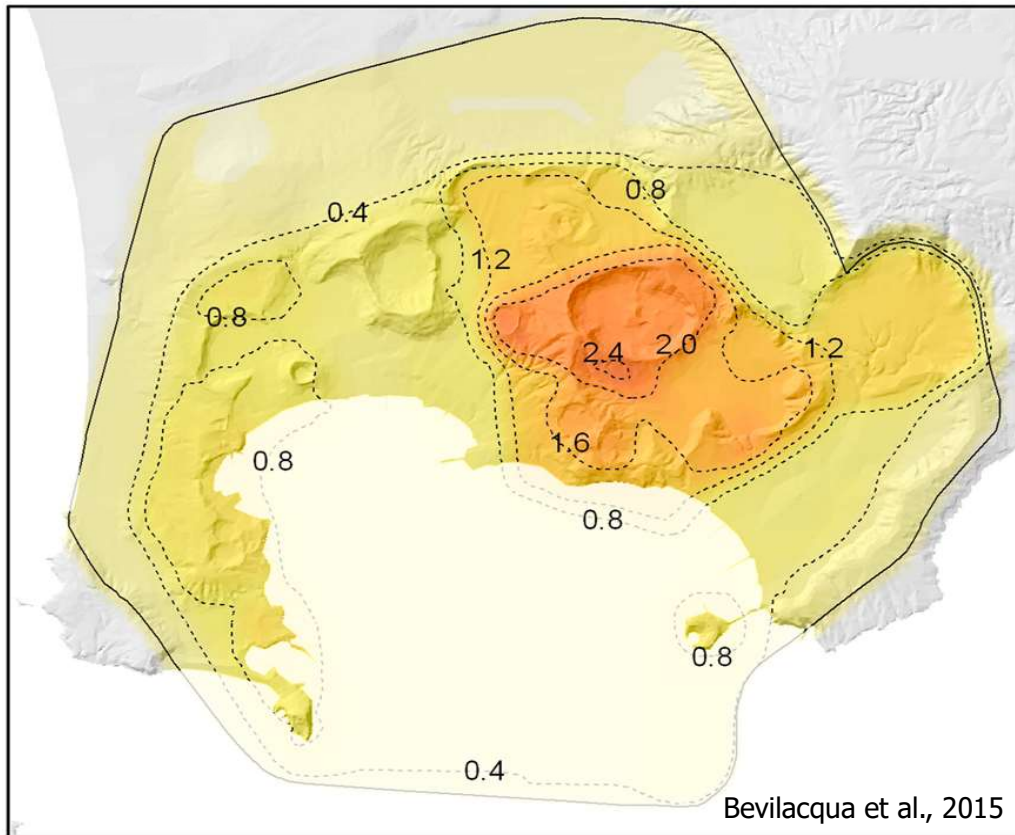
# GEO – HAZARD Assessment



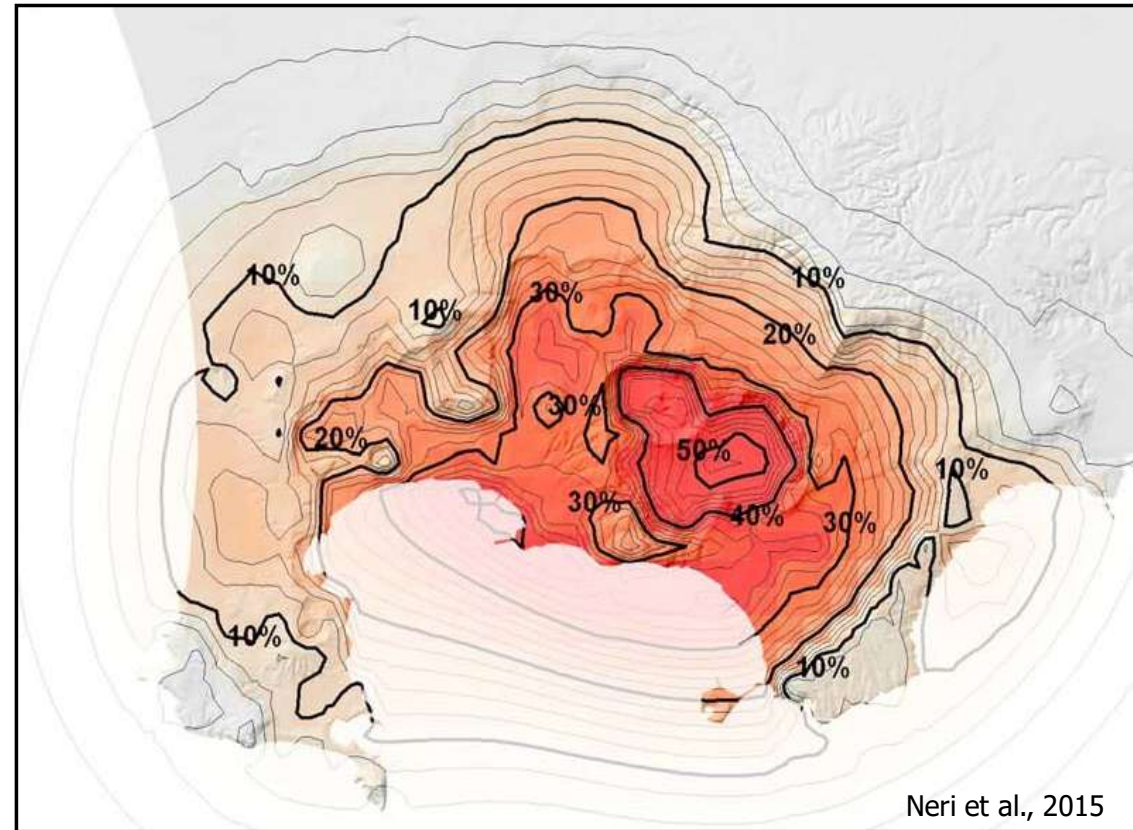


# Volcanic hazard map

New open probability

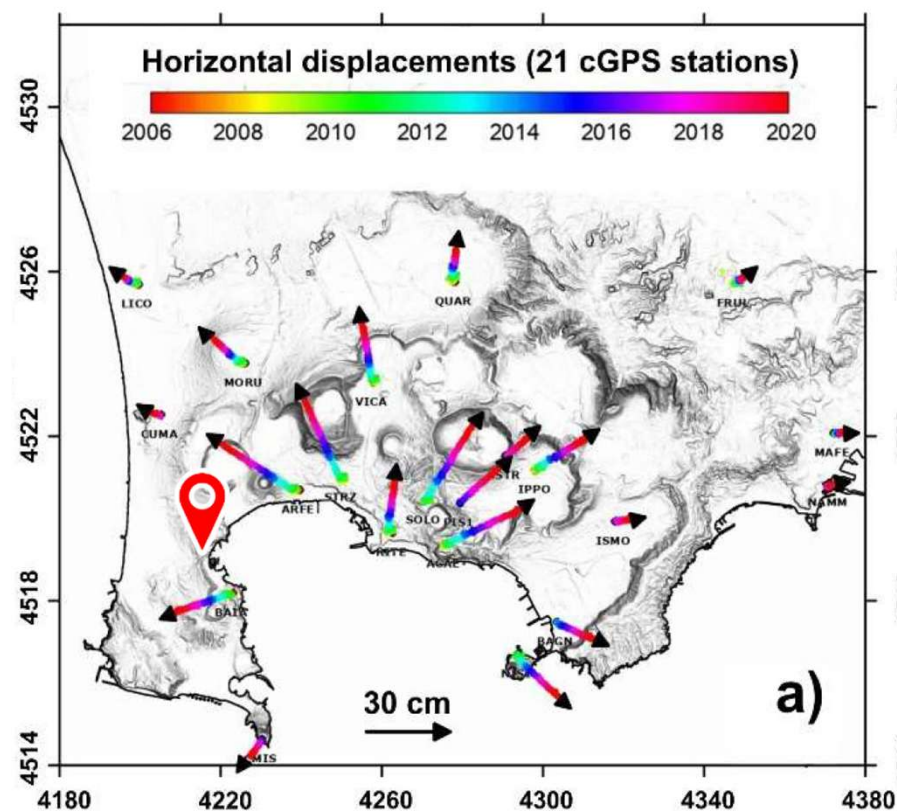


Ash propagation fall probability

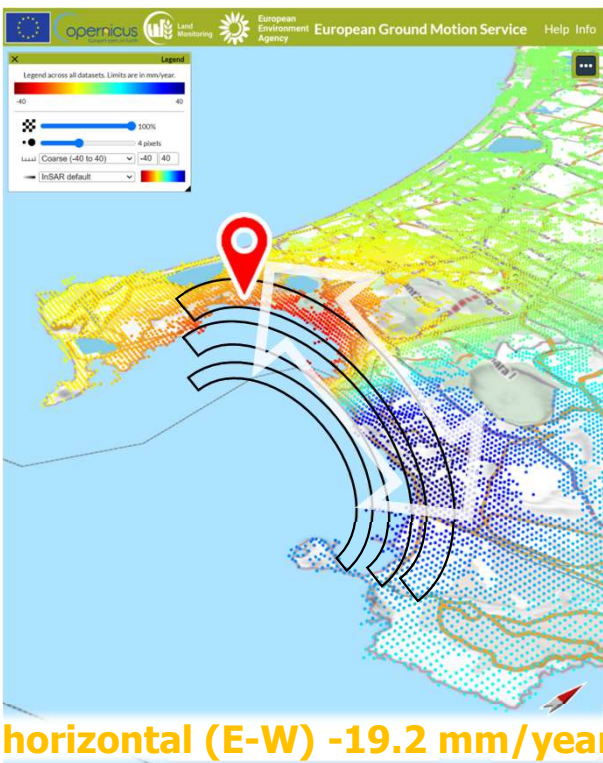
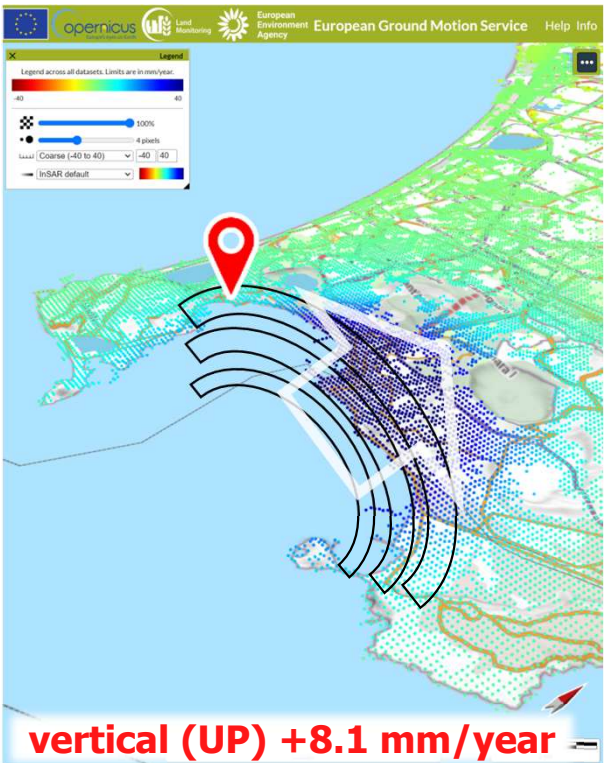


# The monitoring system

GNSS: INGV network



InSAR: European Ground Motion System

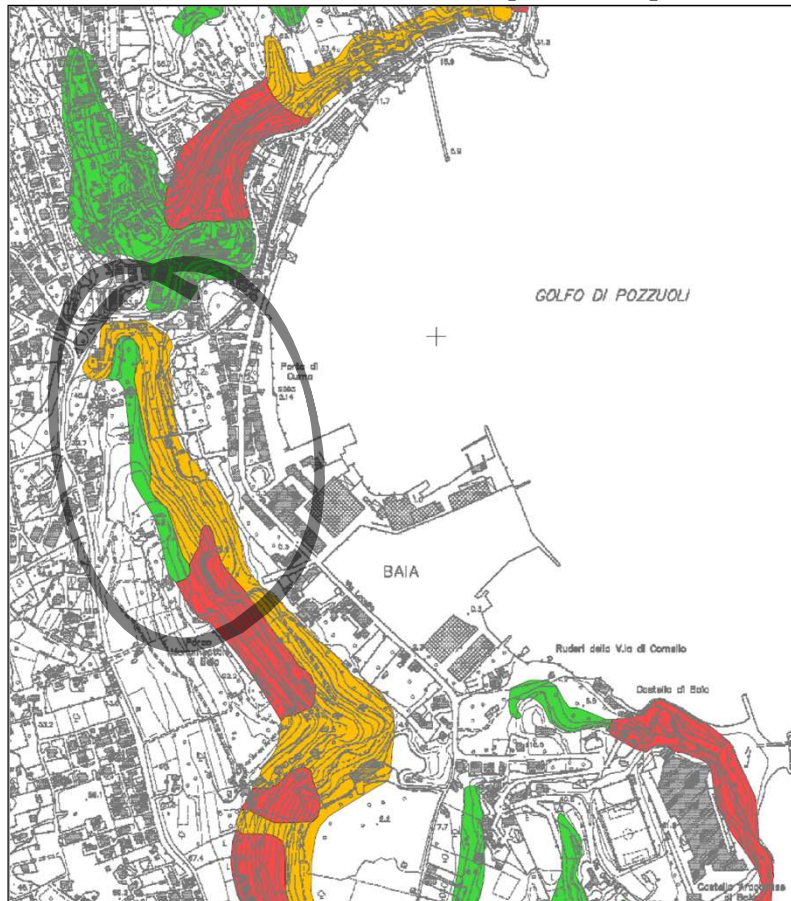
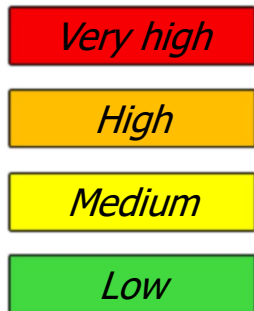




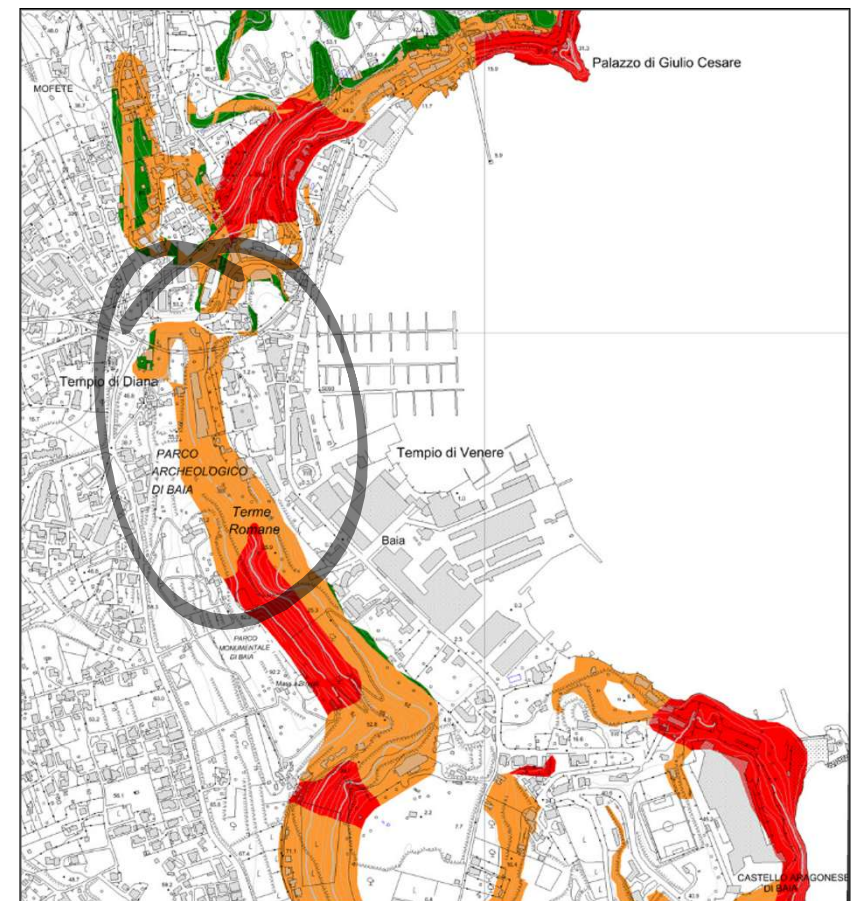
# Landslide hazard map

## Landslide susceptibility

Piano di  
Assetto  
Idrogeologico



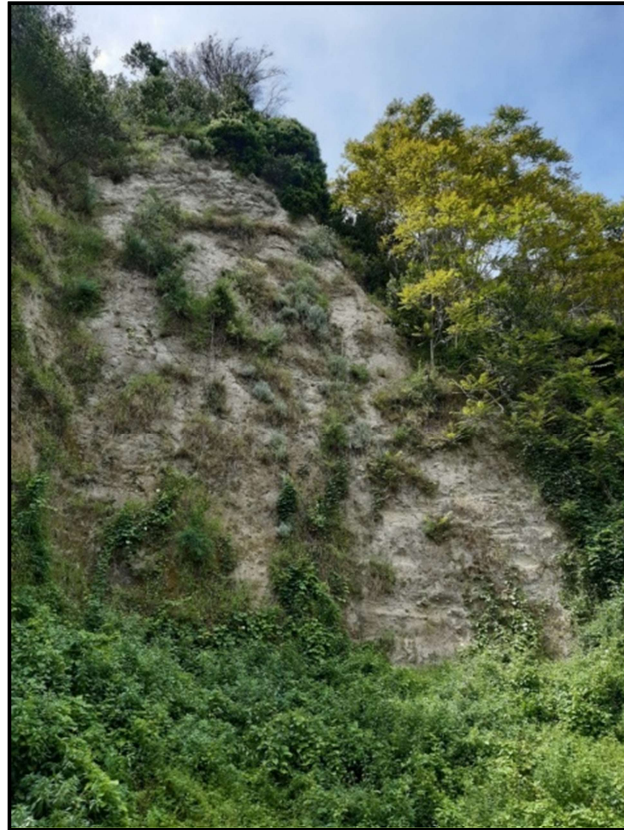
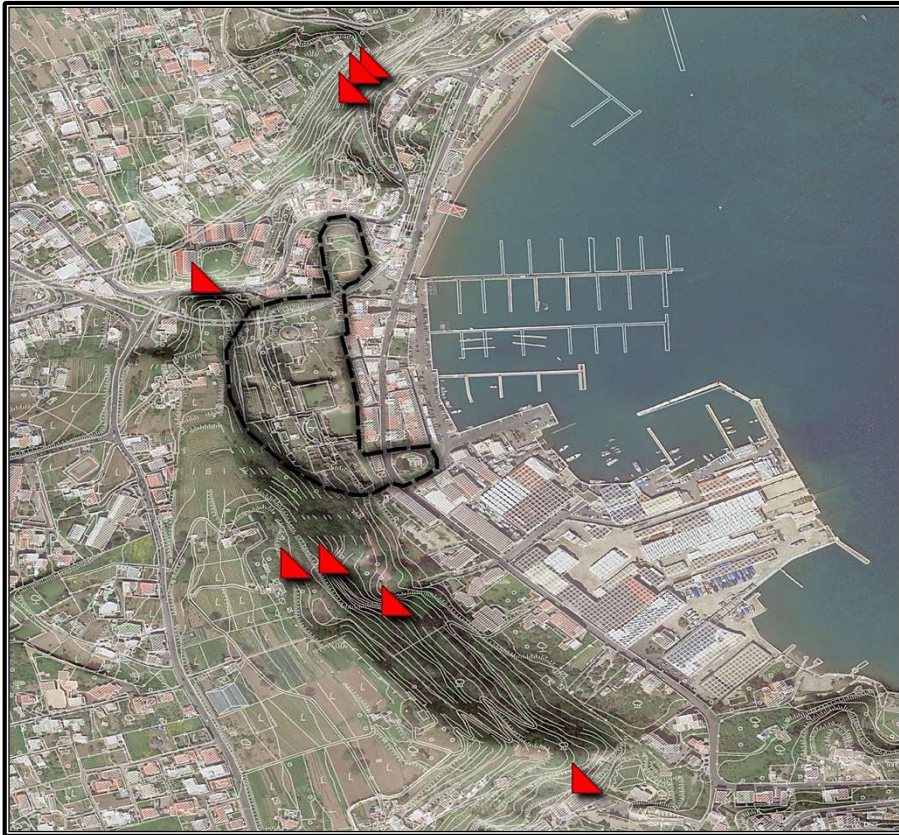
## Landslide risk





# Landslide local inventory and updated map

▲ Frane



Tipologie prevalenti

- crolli
- caduta di blocchi



## Step 3

### CH Background (desk and field study):

investigating the origin,  
typology, construction  
techniques, restoration history,  
evolution in time, etc.

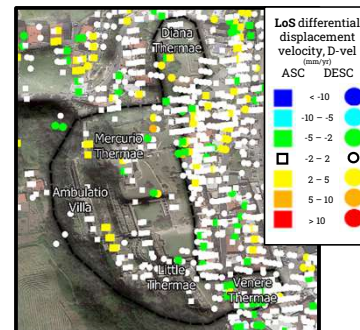
### Geohazard assessment

Hazard and risk map  
analysis and field  
survey

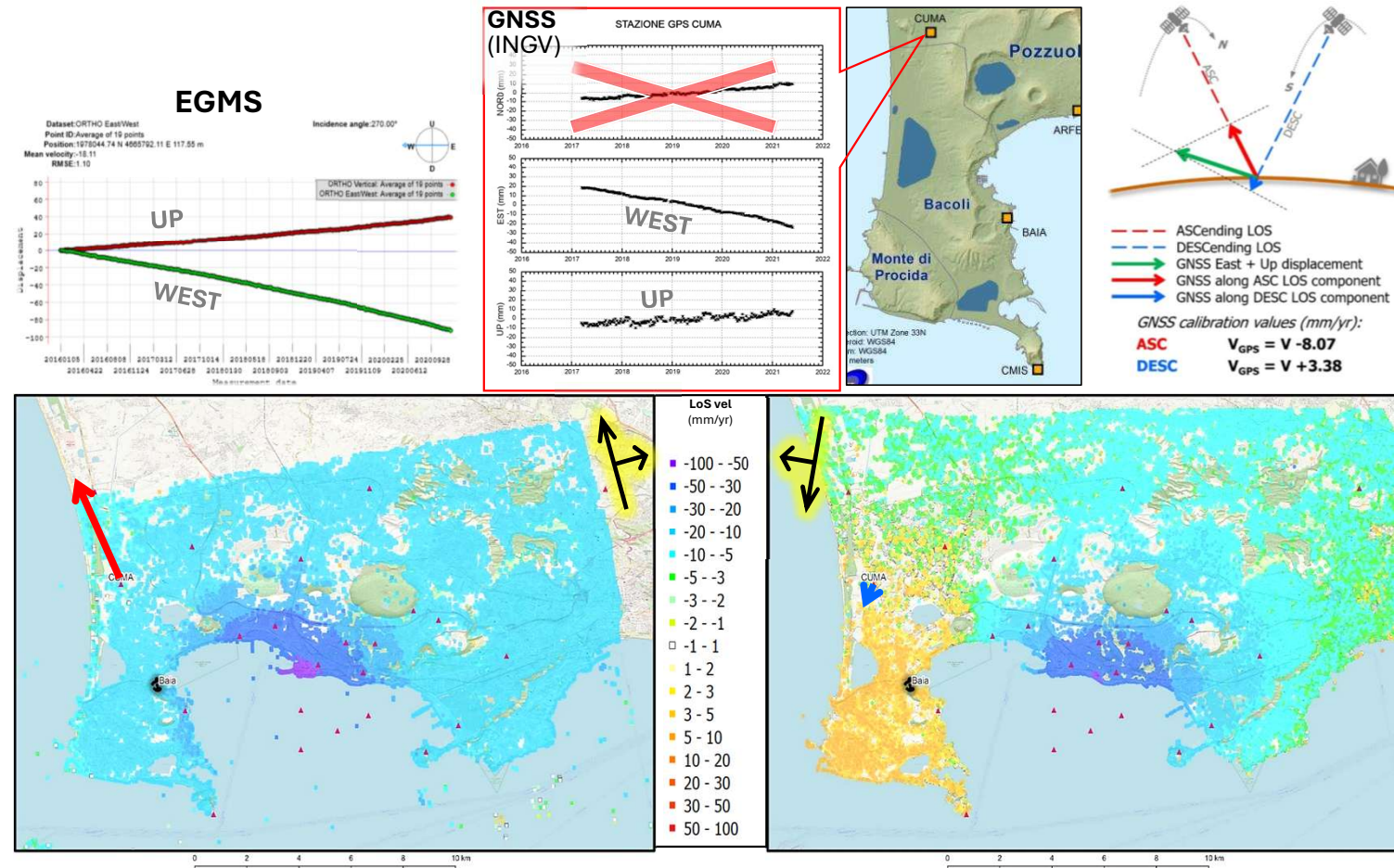
### SAR Interferometry Data integration and services

### Ground motion monitoring

Field survey and risk  
mitigation plan



# InSAR analysis : processing



The Cuma GPS station, belonging to the GNSS monitoring network of the Vesuvius Observatory (INGV), is the nearest of those outside the Campi Flegrei volcanic area. The N-S component of the displacement is not detected by the InSAR technique.

The LoS displacement is calibrated with respect to the regional displacement trend.

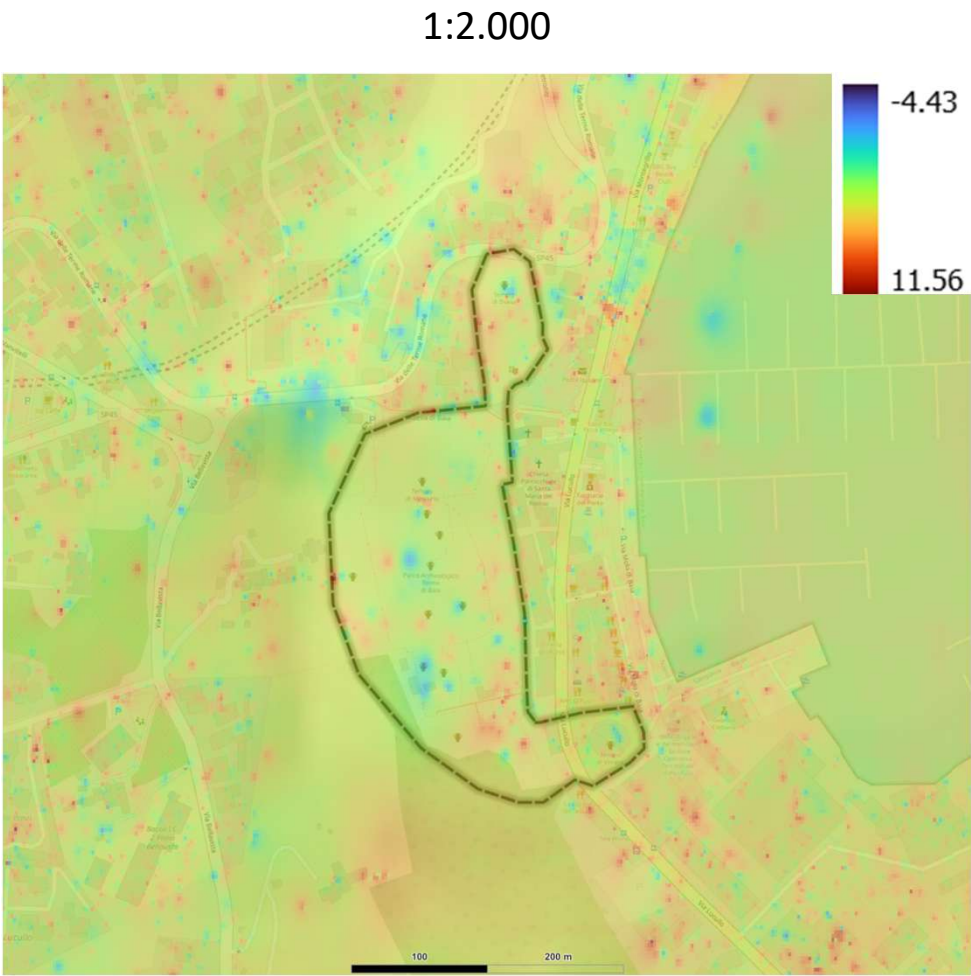
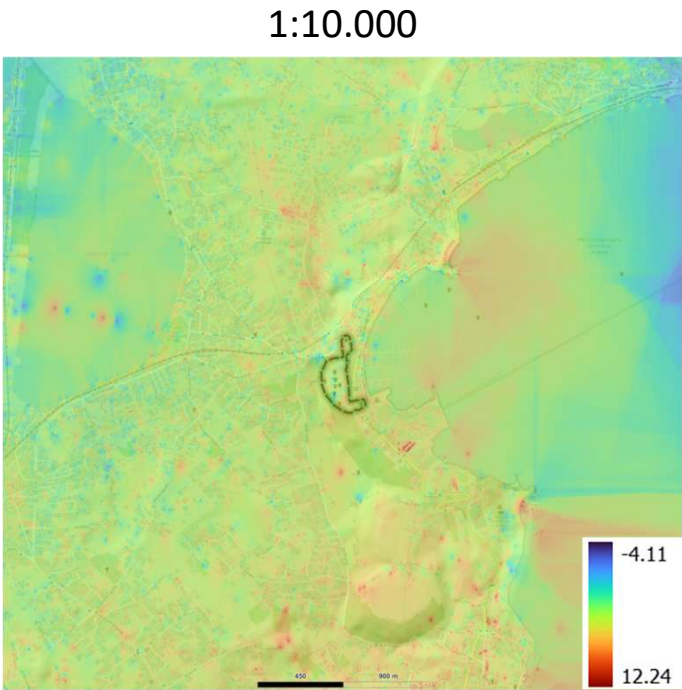
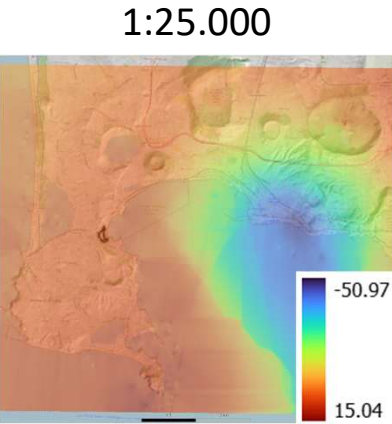
ISPRA and INGV have developed a PS InSAR product calibrated with the GNSS data, in ascending and descending geometry, showing displacements along the respective LoS.

This product is an equivalent of the EGMS Level 2b (calibrated).

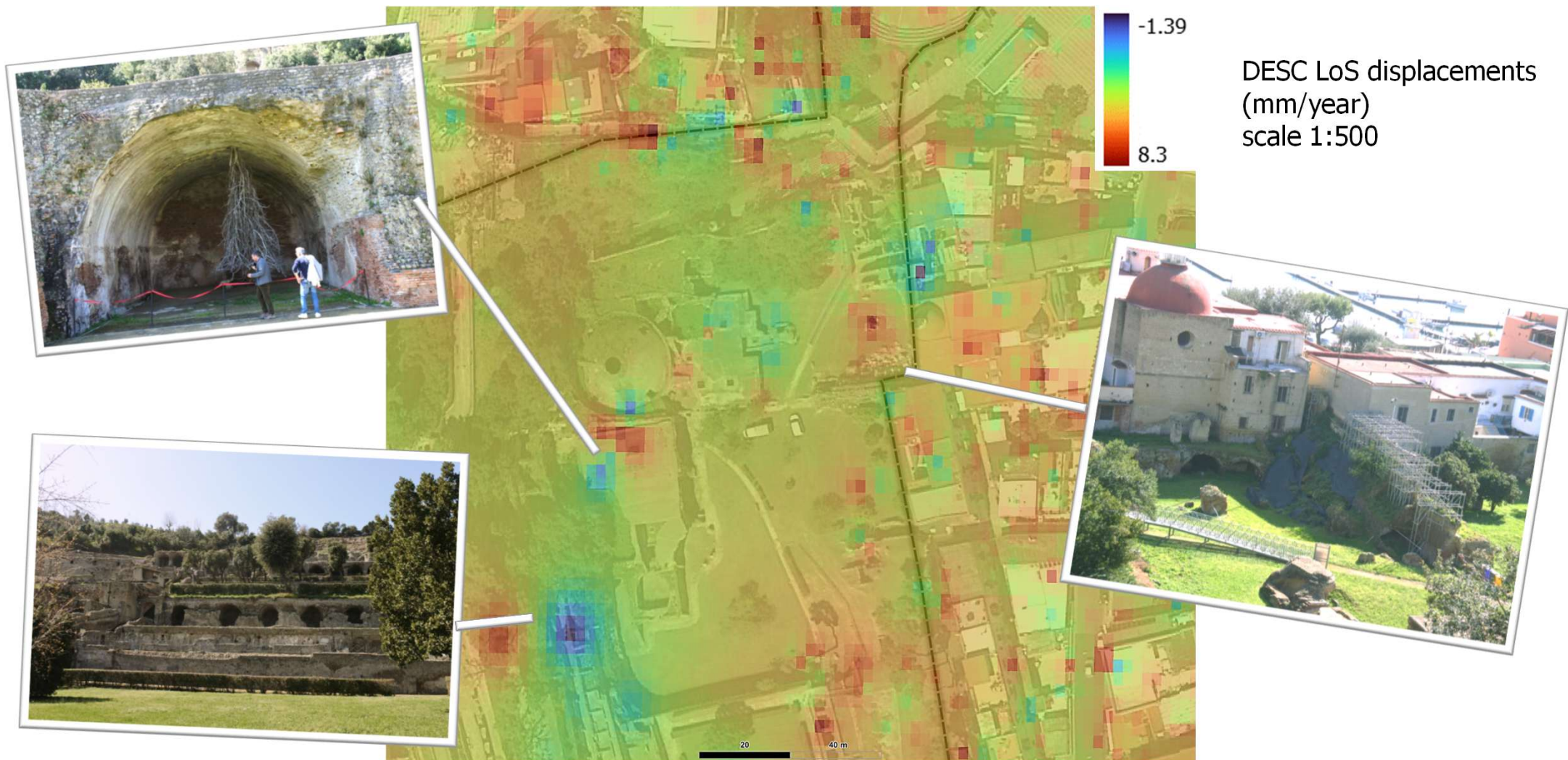


# InSAR Analysis: *heatmap analysis*

DESC LoS displacements  
(mm/year)



## InSAR Analysis: *heatmap analysis*





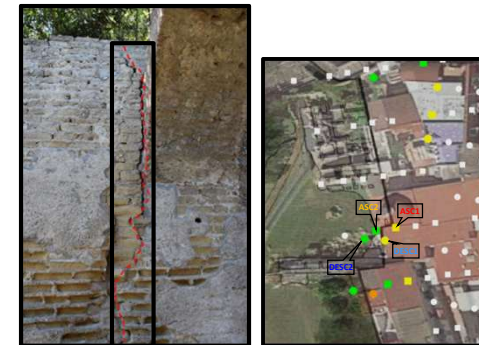
## Step 4

**CH Background  
(desk and field study):**  
investigating the origin,  
typology, construction  
techniques, restoration history,  
evolution in time, etc.

**Geohazard assessment**  
Hazard and risk map  
analysis and field  
survey

**SAR Interferometry**  
Data integration and  
services

**Ground motion  
monitoring**  
Field survey and risk  
mitigation plan

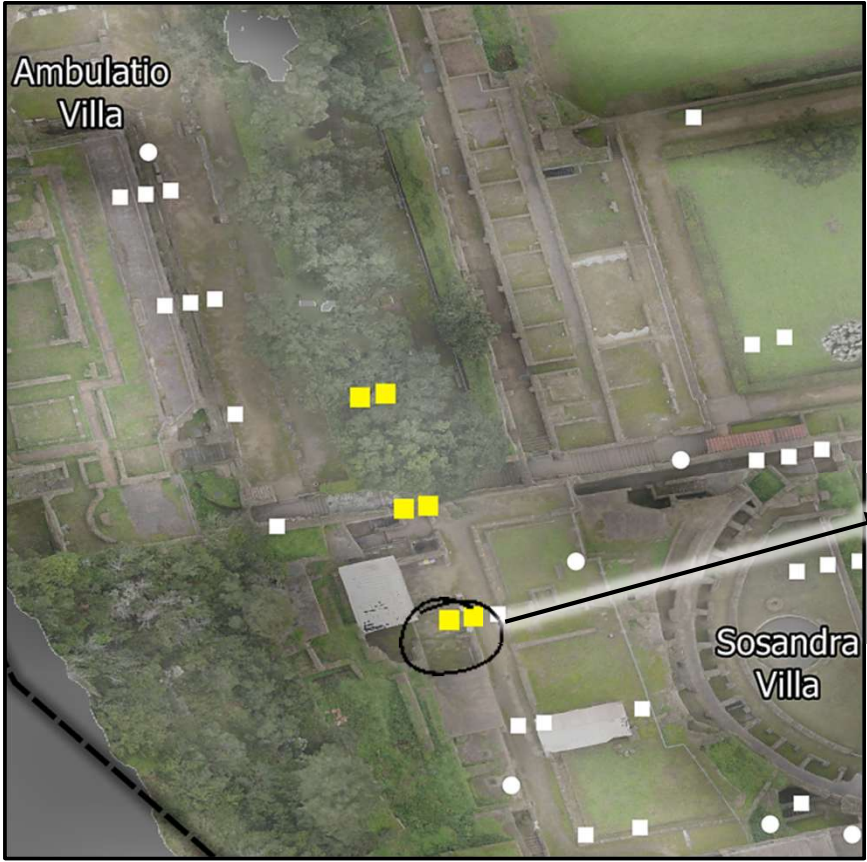
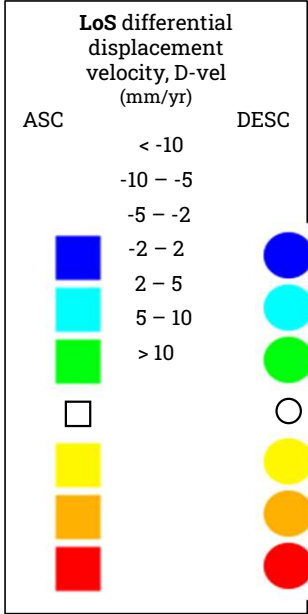


# Direct survey

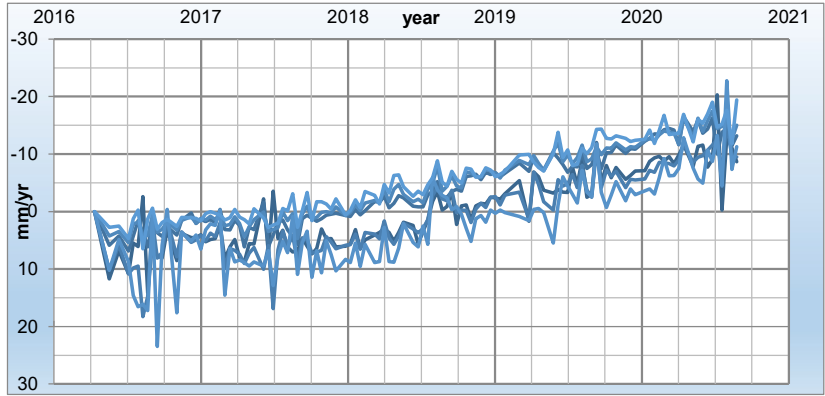
## Rilevo 3D





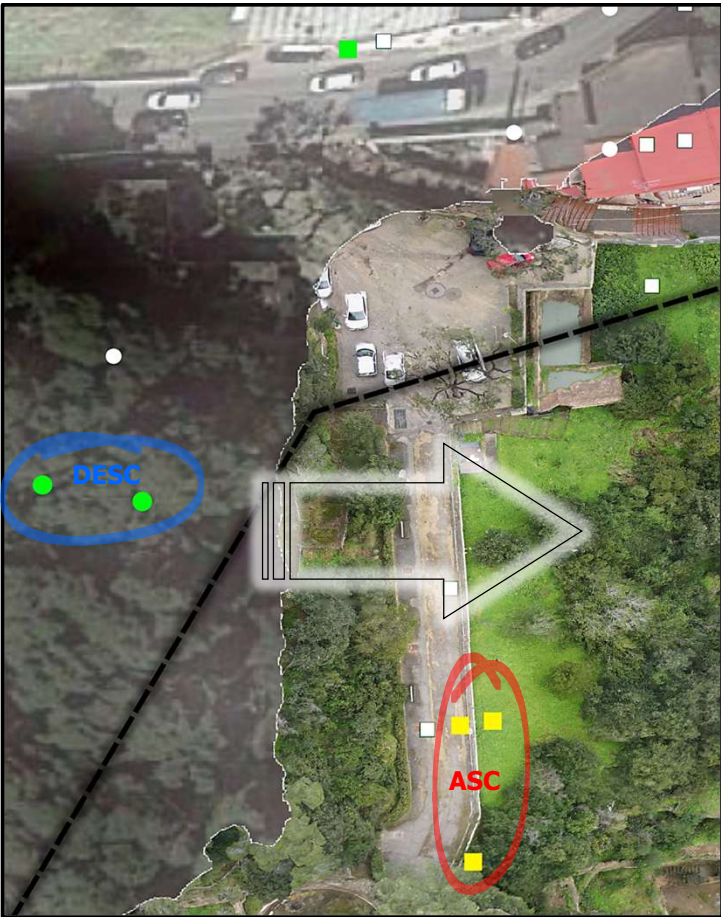


Ascending geometry seems to be more sensitive to radar targets in the site area; this is due mainly to "noise effect", then to East facing geometry of the slope too. At the edge between *Ambulatio* and *Sosandra* villas a cluster of 6 PSs indicates, consistently, a relatively subsiding area. The crack along the sidewall may indicate this masonry weakness, thus needs to be properly monitored.

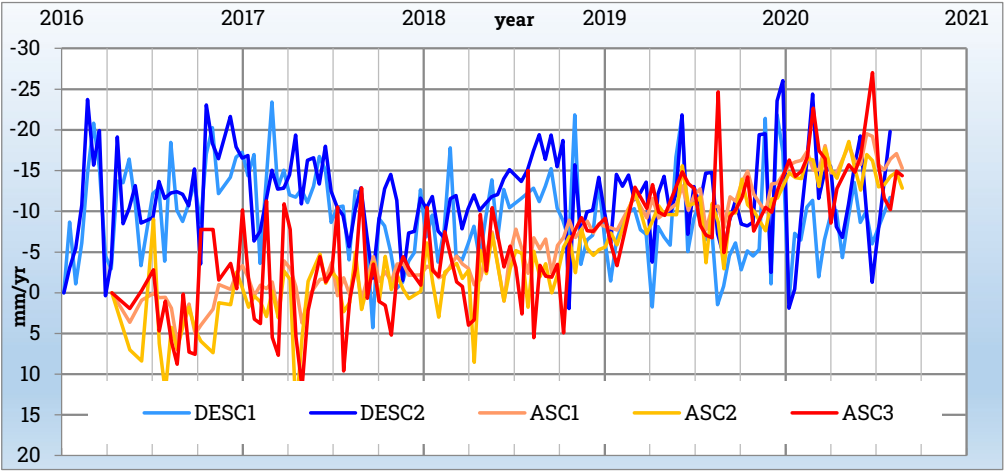
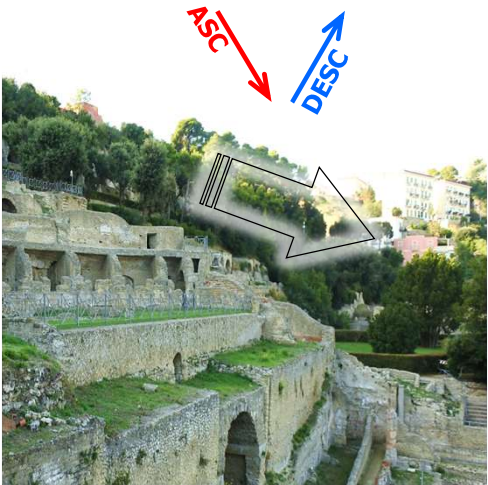
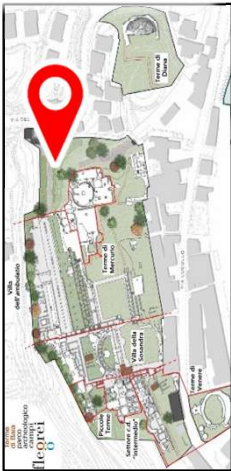
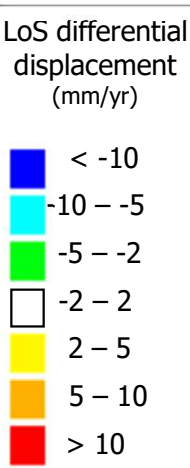




# In situ calibration and interpretation

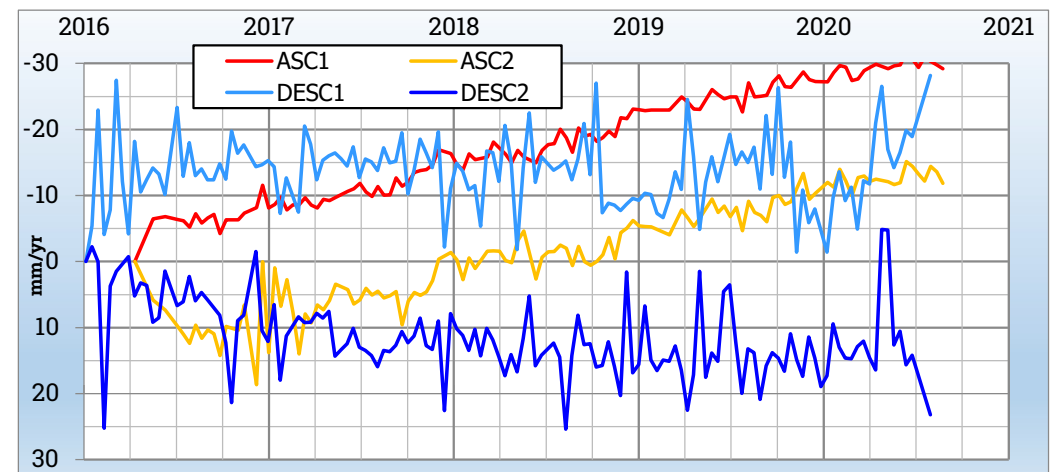
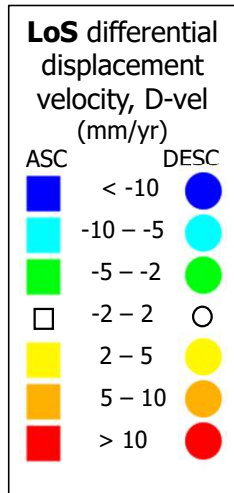


The combined interpretation of the PS, moving away from the ASC satellite and approaching the DESC satellite, shows the prevalence of the horizontal movement of slow slope sliding eastward (i.e. seaward).





# EAST border in situ interpretation and validation

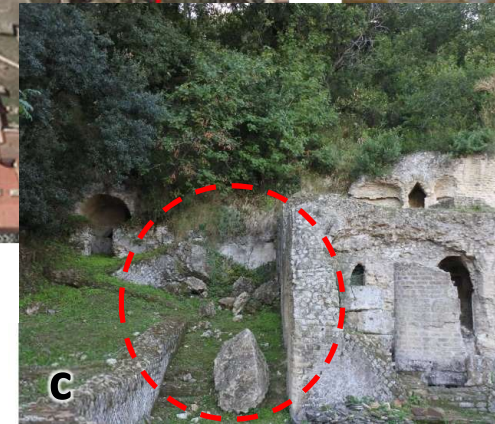
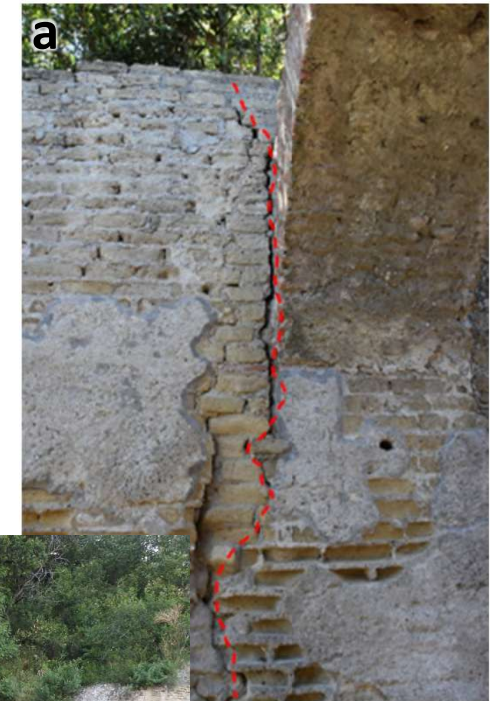
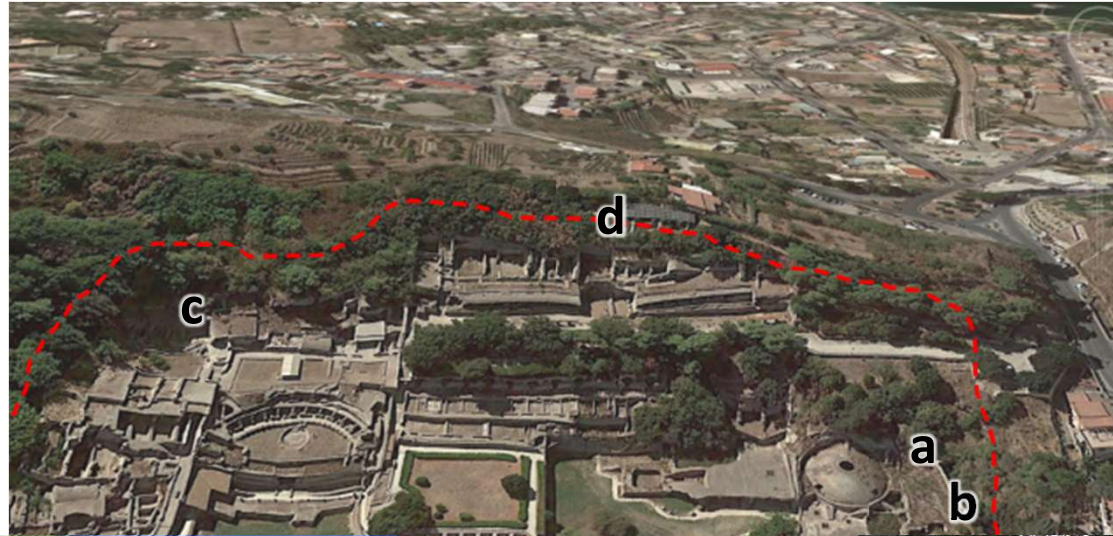




# Structural and damage assessment

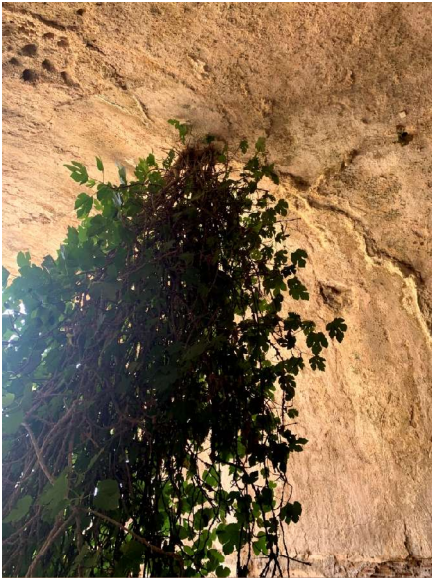
Main critical issues:

- cracks (a,b);
- rocks fall (c);
- invasive vegetation (d).

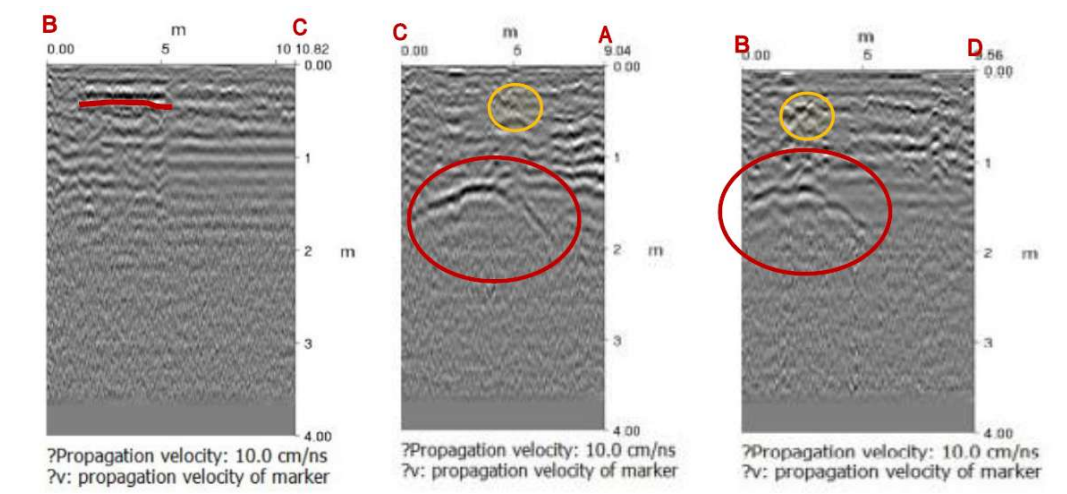
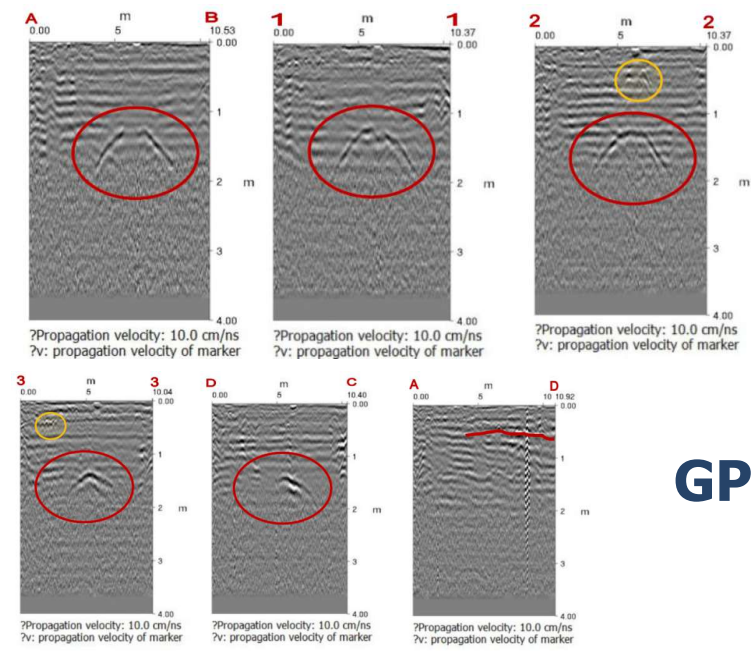
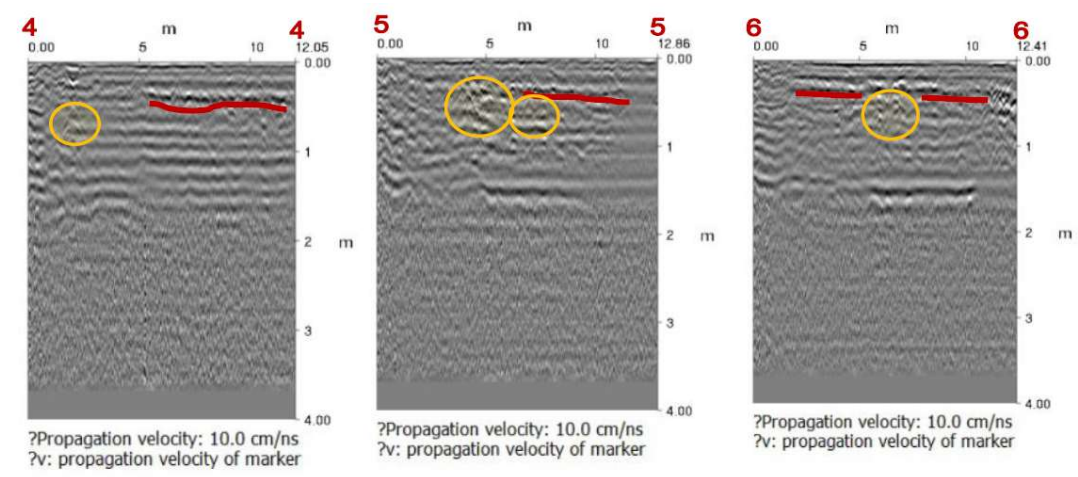
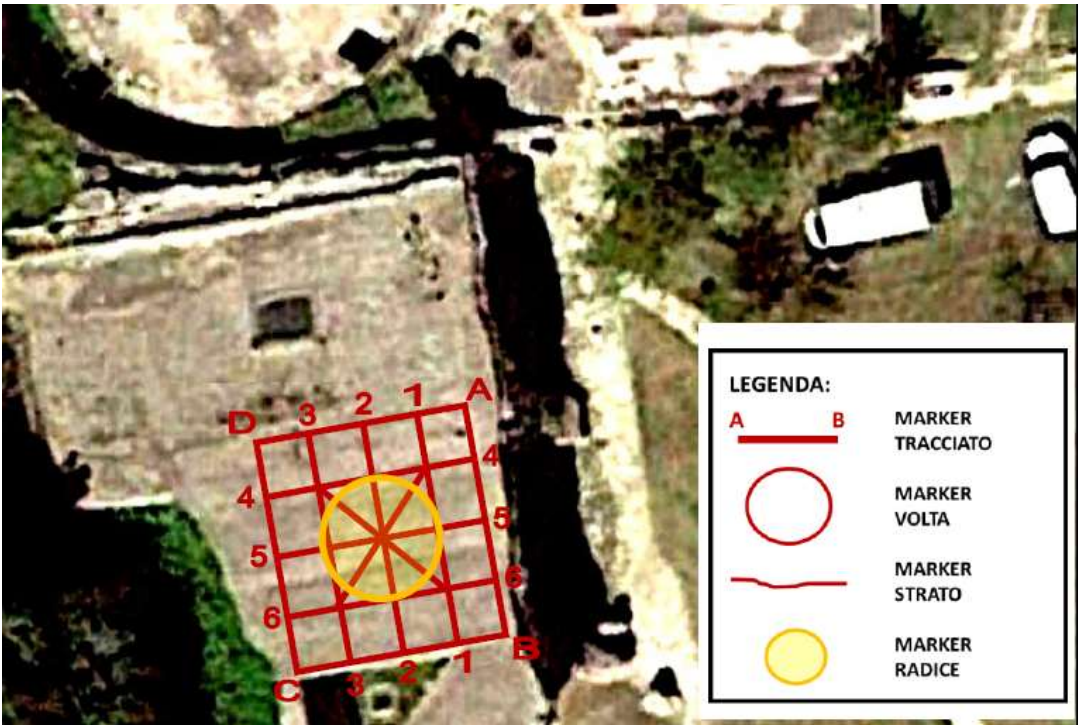




## GPR analysis



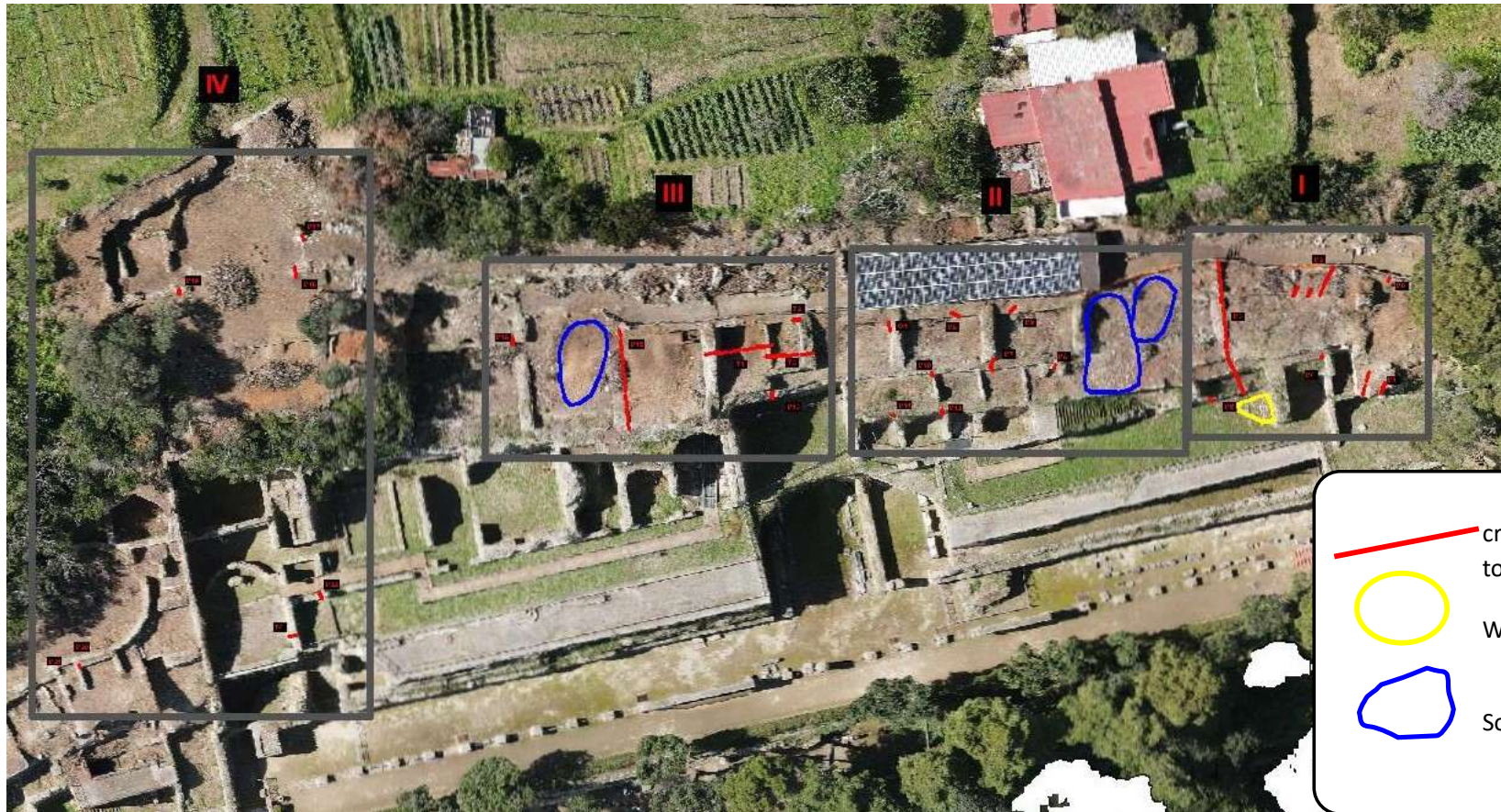




# GPR analysis



# Preliminary mitigation measures

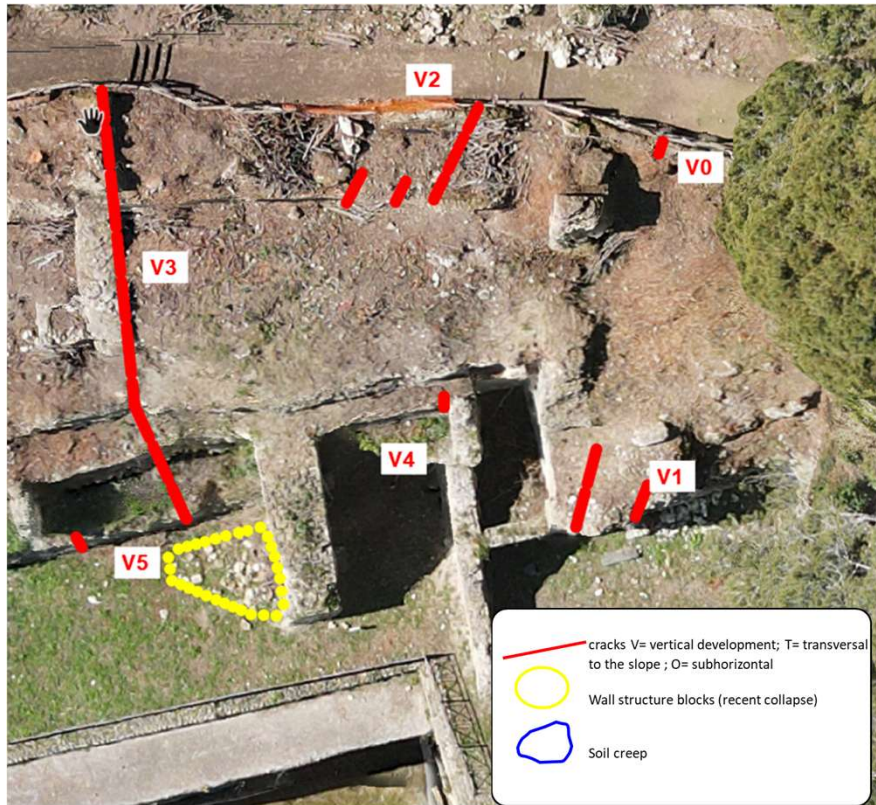


- cracks V= vertical development; T= transversal to the slope ; O= subhorizontal
- Wall structure blocks (recent collapse)
- Soil creep



# Preliminary mitigation measures

## Sector I



## Cleaning the vegetation





- Crack gauges : displacement measurement station (type A) N° 10
- Humidity and Temperature : measurement station (type B) n° 12
- 3D tiltmeter : measurement station of rotation (type C)
- Mitigation measure (type D) N° 1
- Accelerometer/velocimeter: dynamic measurement station (type E) N°1





## Italian landmark events: what they teach risk managers

### Vajont, 1963

Deep-seated rockslide into a reservoir: the defining lesson is governance, uncertainty management and the danger of treating monitoring as a formality.

### Sarno / Quindici, 1998

Rainfall-triggered debris flows on pyroclastic covers: the lesson is rapid onset, warning thresholds, emergency planning and land-use control.

### Casamicciola, Ischia, 2022

Rainfall, volcanoclastic deposits, drainage and urban exposure: the lesson is maintenance, exposure control and local preparedness.

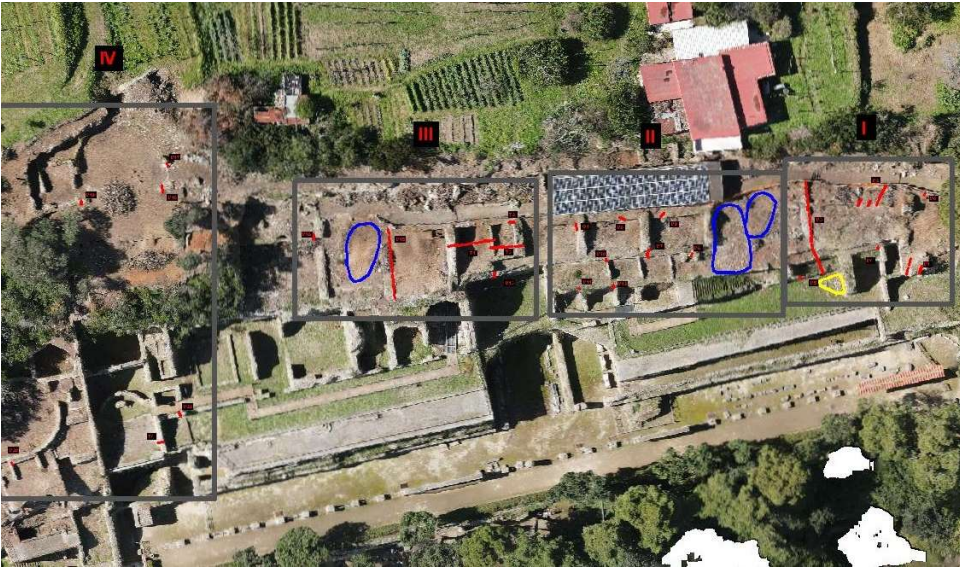
**Common message: risk is produced by the interaction between processes, exposure, decisions and time.**





## From cases to transferable lessons

### Common elements across Italian landslide-risk management



Slow processes need long-term monitoring, maintenance and institutional continuity.  
Rapid processes need rainfall thresholds, emergency planning and clear communication chains.  
Cultural heritage and infrastructure require vulnerability analysis, not just hazard mapping.  
The best outputs are decision-ready: priorities, responsibilities, timescales and funding pathways.



## What an Italian municipality should operationalise

1

### Know the hazard

Use PAI/IdroGEO, local inventories, field checks and historical events

2

### Map exposure

People, critical infrastructure, cultural heritage, schools, roads and services

3

### Rank priorities

Combine hazard, vulnerability, value, feasibility and urgency

4

### Maintain & monitor

Drainage, slopes, retaining structures, sensors and satellite screening

5

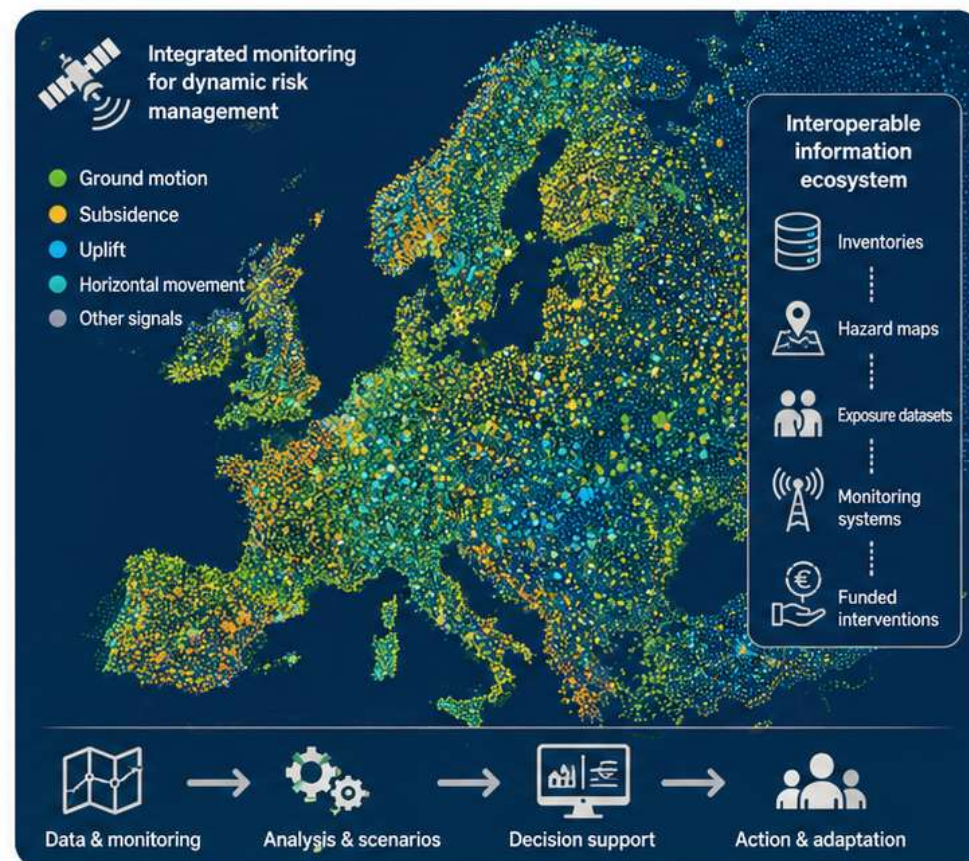
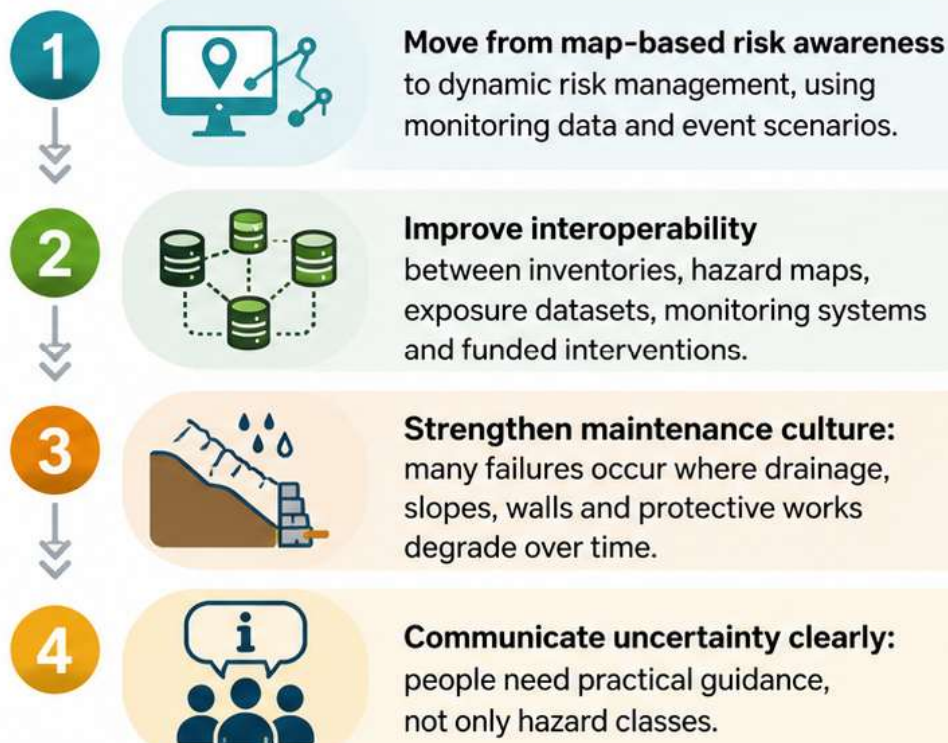
### Prepare response

Thresholds, alert levels, evacuation routes and communication



## Current challenges and opportunities

### From map-based awareness to dynamic risk management



**Opportunity:** integrate monitoring, maintenance and communication into adaptive risk governance.

# Take-home messages

1



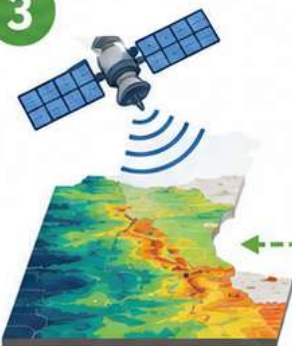
Italy has one of the most advanced knowledge infrastructures for landslide risk, but the decisive step is integration into decisions.



Risk management is continuous: inventory, monitoring, prioritisation, mitigation, maintenance and emergency planning must interact.



3



Satellite data are transformative for screening and trend analysis, but field interpretation remains irreplaceable.

The future is dynamic and adaptive risk management, especially under changing climate and land-use pressures.

