International Summer School Orvieto-Todi

Third Edition

RISK MANAGEMENT

Knowledge, Forecasting, Prevention, Protection, Planning, Preparedness

20 - 27 July 2025

International Summer School Orvieto-Todi

"Conservation and enhancement of cultural heritage: the Italian experience"

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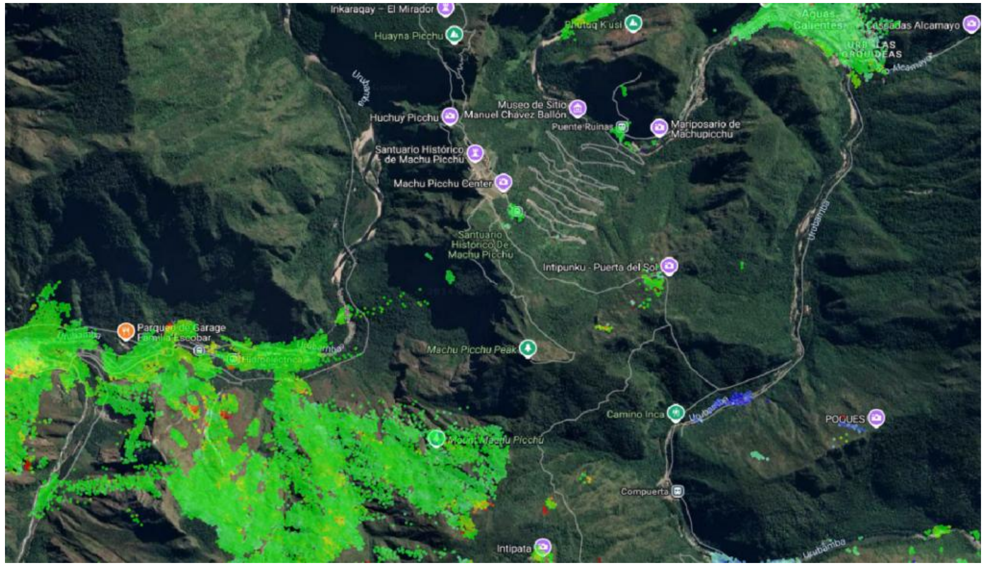


Foligno
21 July 2025

ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale
Sistema Nazionale per la Protezione dell'Ambiente

ISPRA - Italian Institute for Environmental Protection and Research

1. National Agency for the monitoring natural and anthropogenic pressures of all the environmental matrices

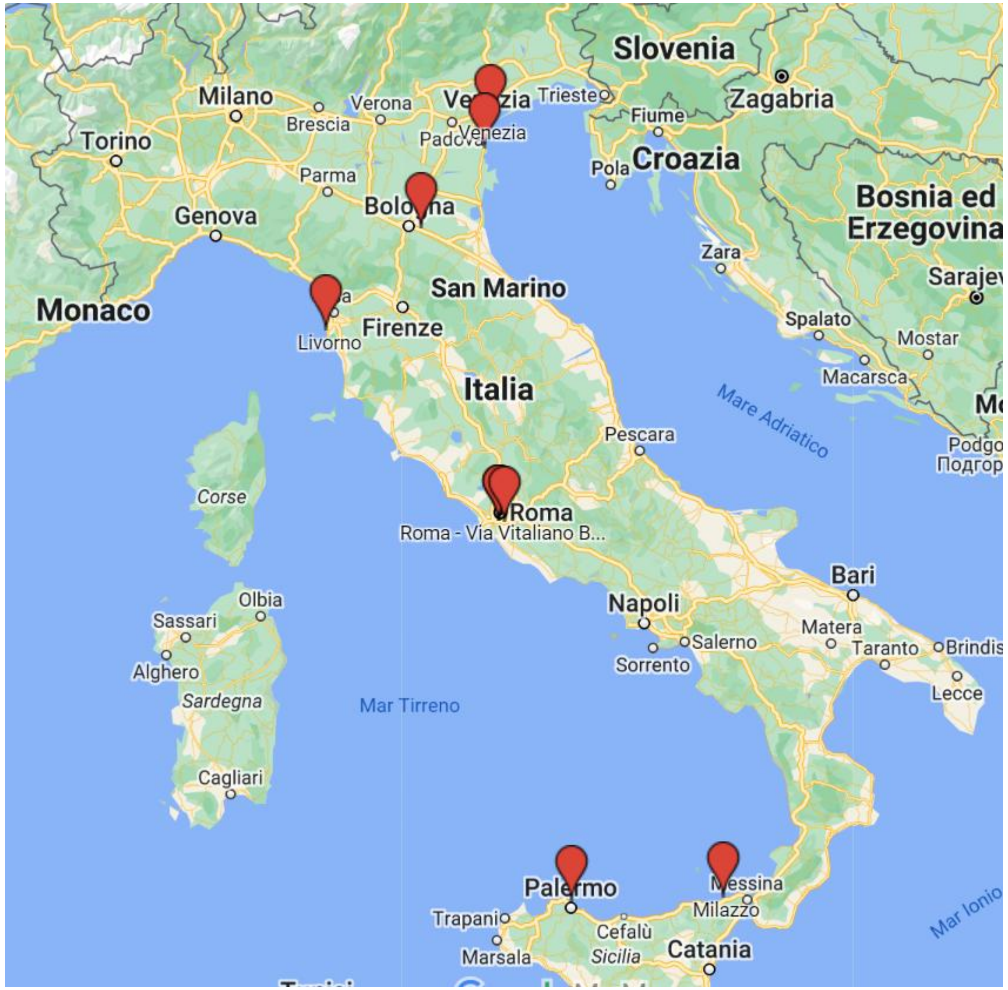
2. Technical governmental body support to Environmental, Industry, Cultural and Foreign Affair Ministry

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 new enemy and threat
Climate Change effects

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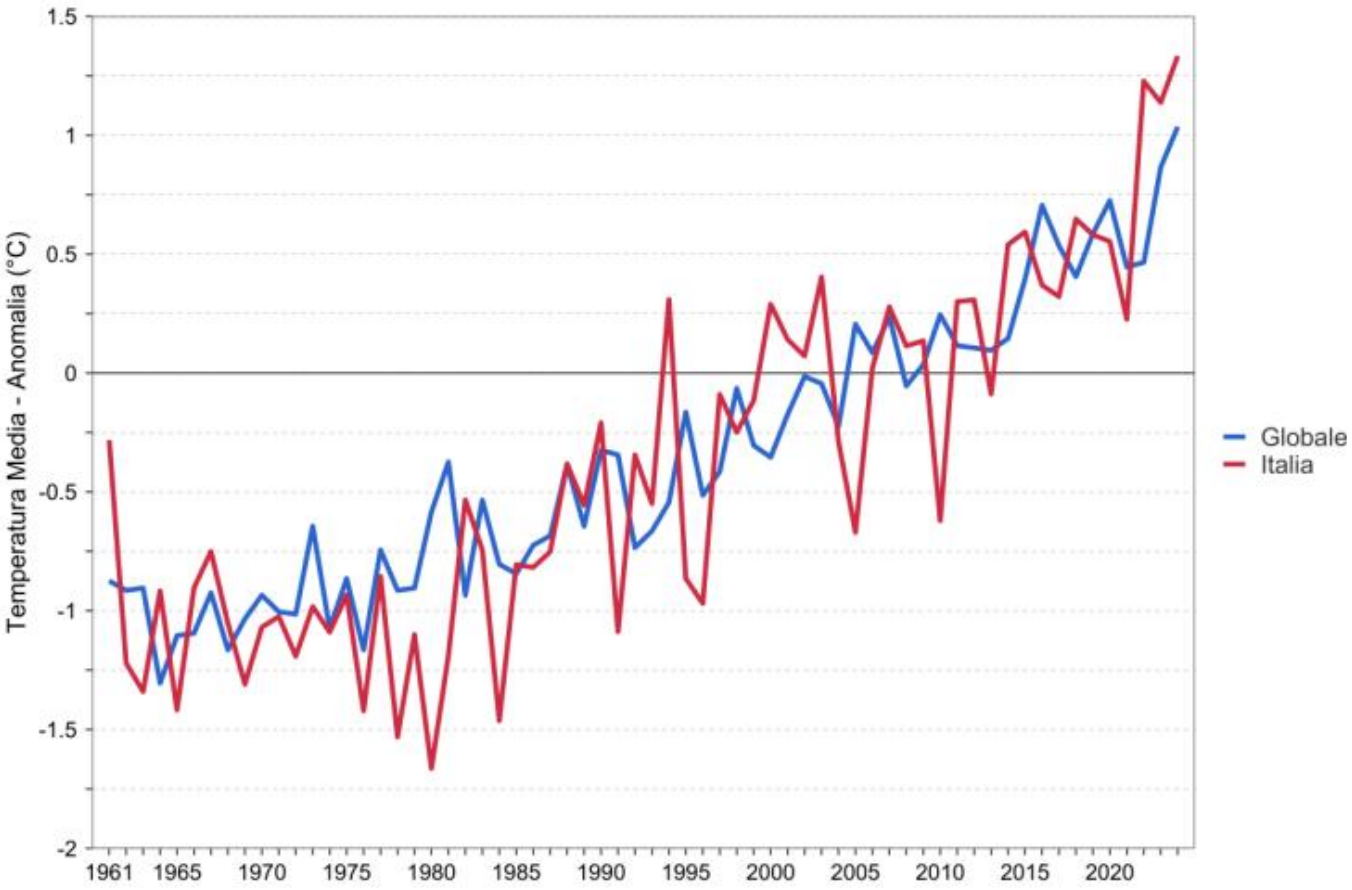

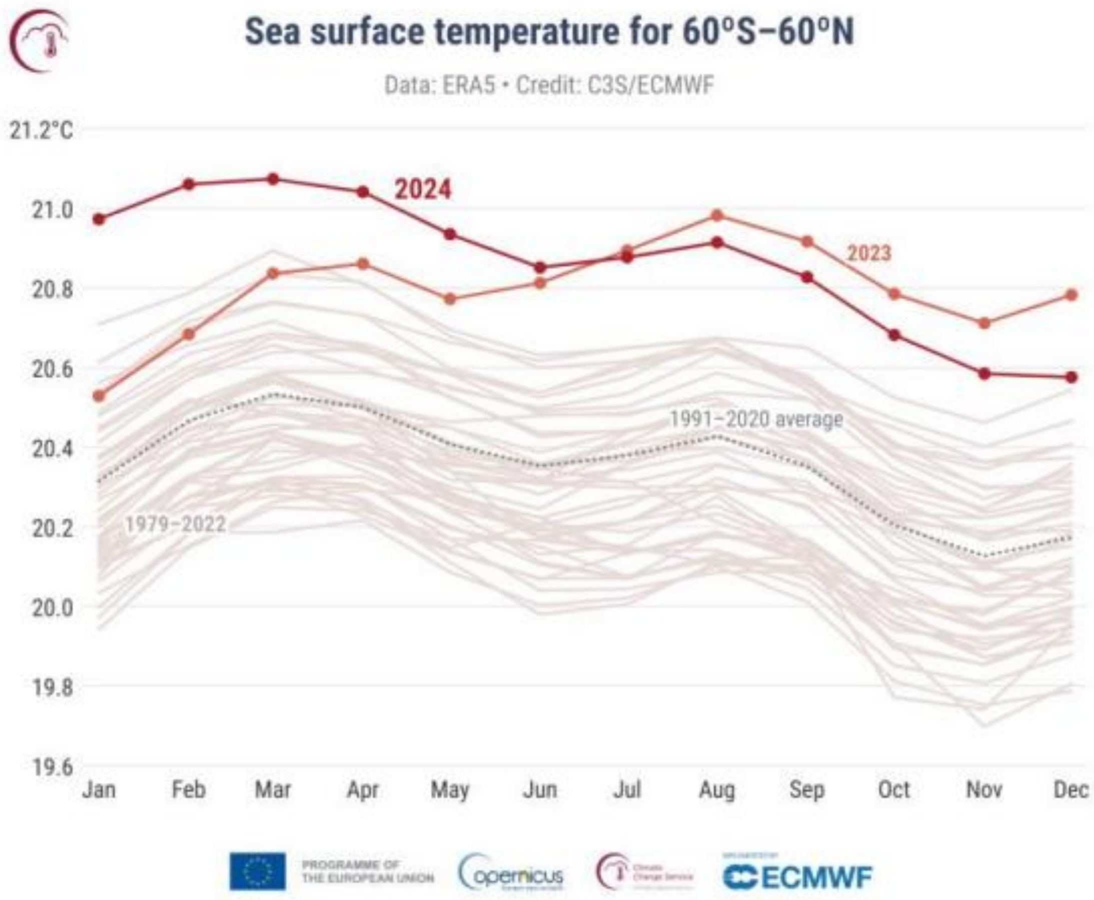

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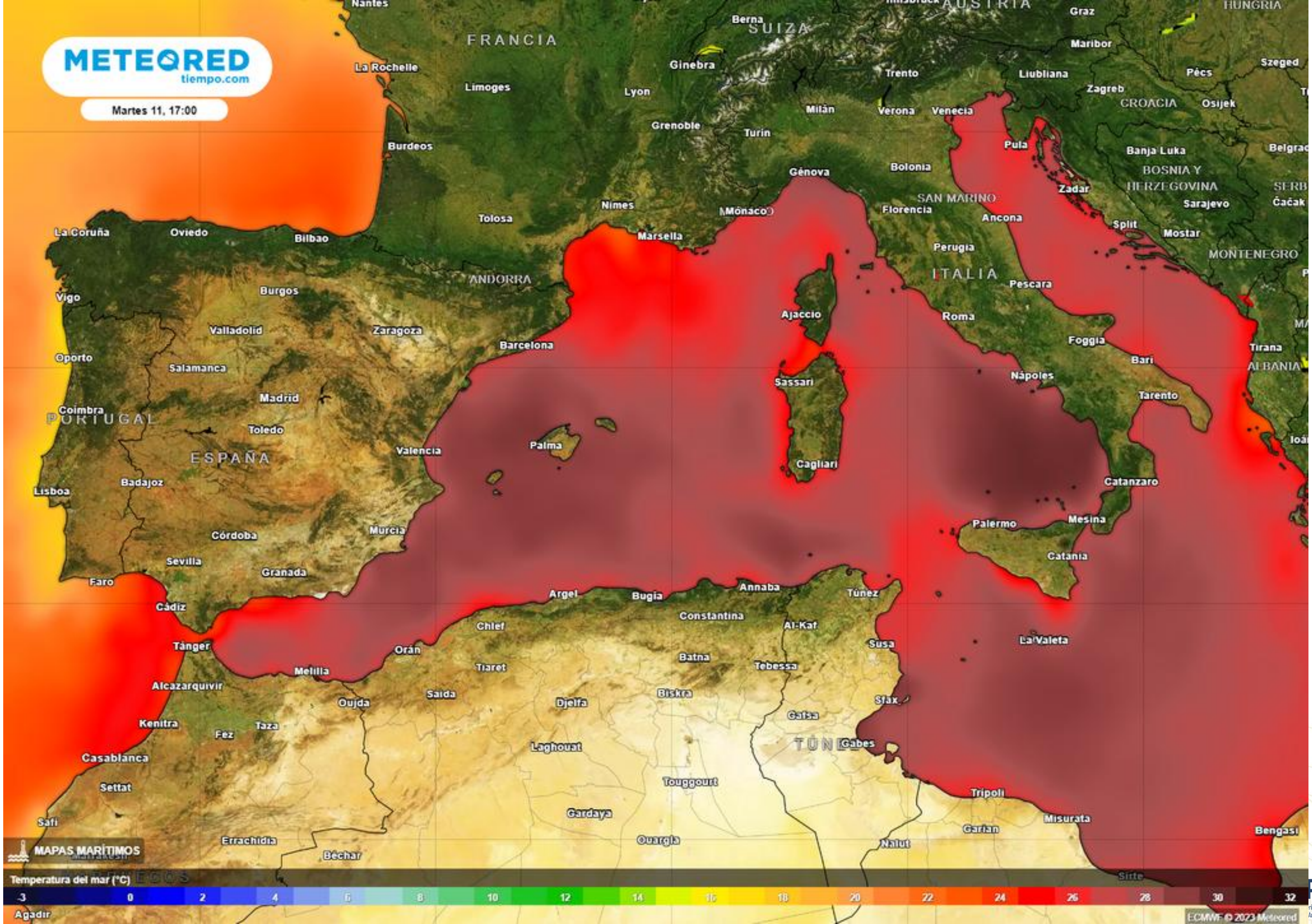

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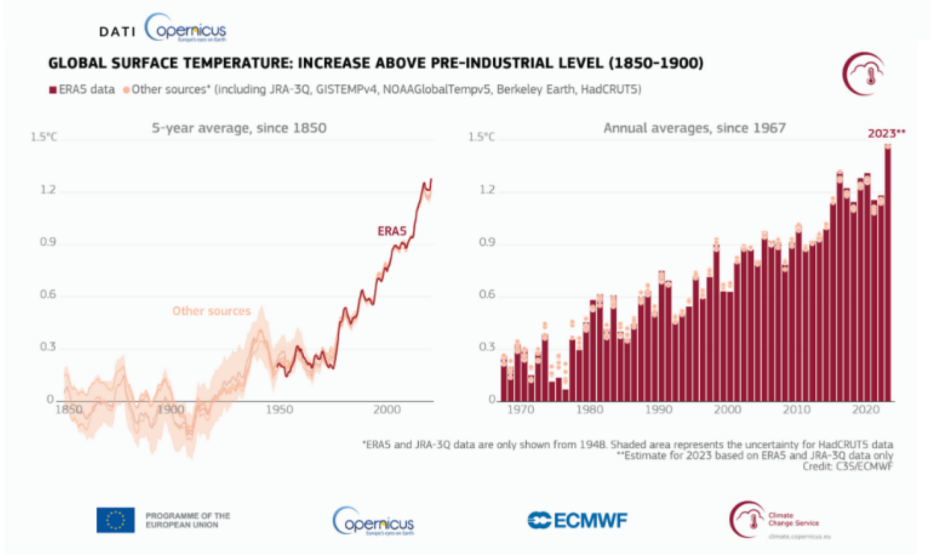
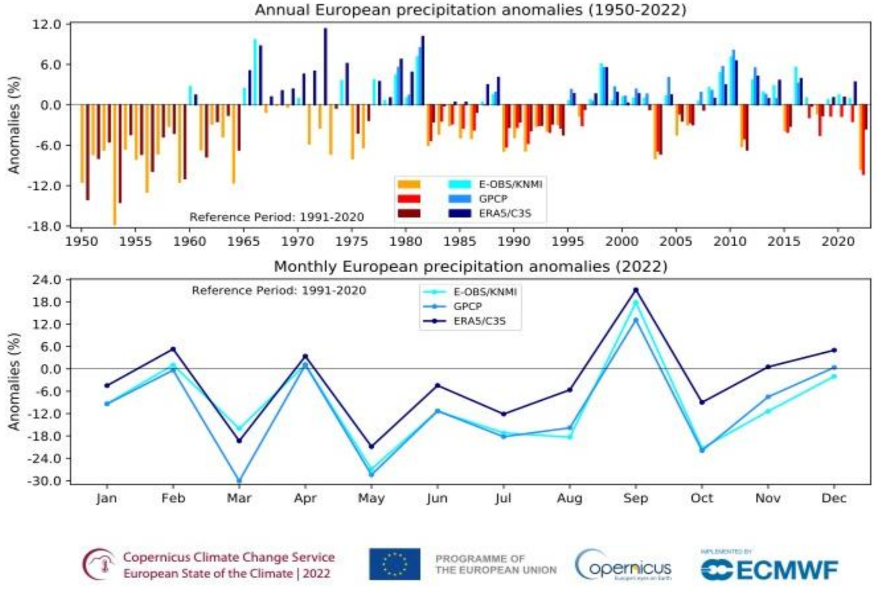
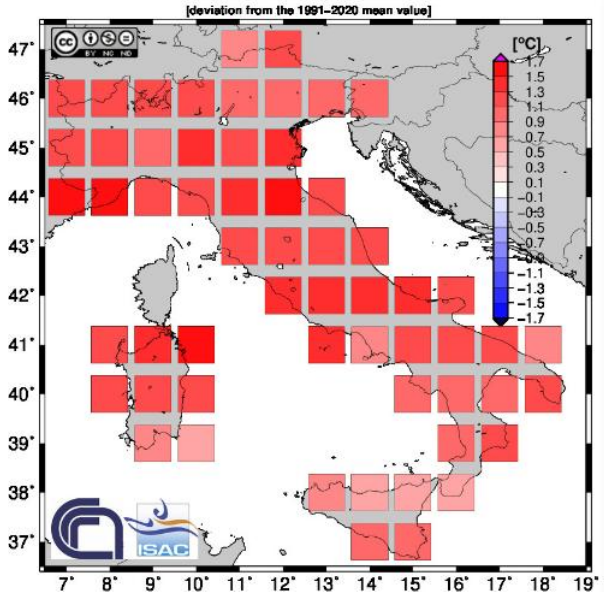
Rationale #1 Climate change in the Mediterranean area and Italy

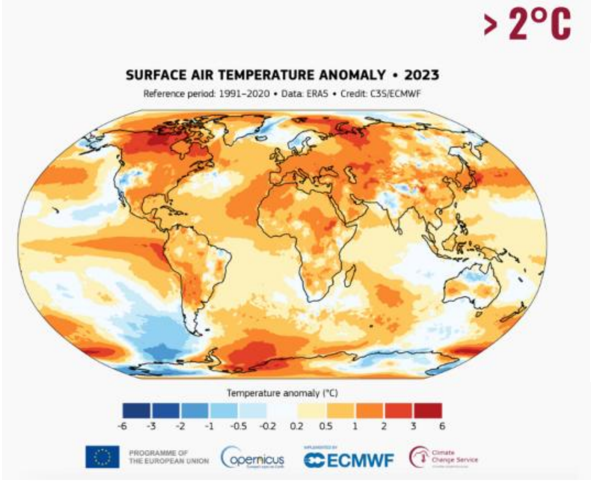


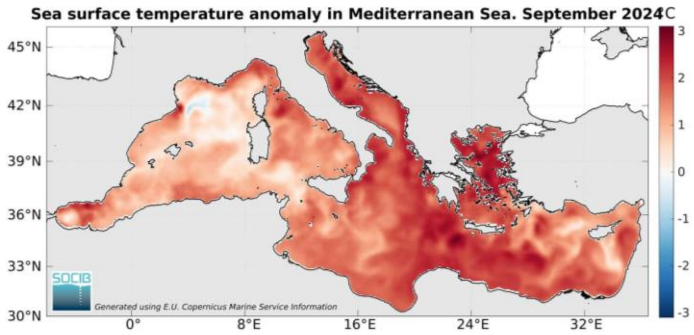
2023 was the hottest year on record (CNR-ISAC, 2024)



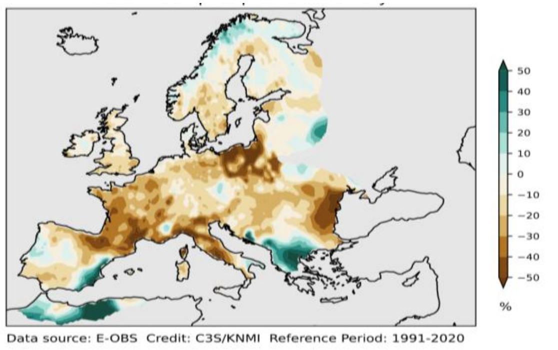


If we consider the 10 warmest years for our country, 8 of these are in the last 10 years

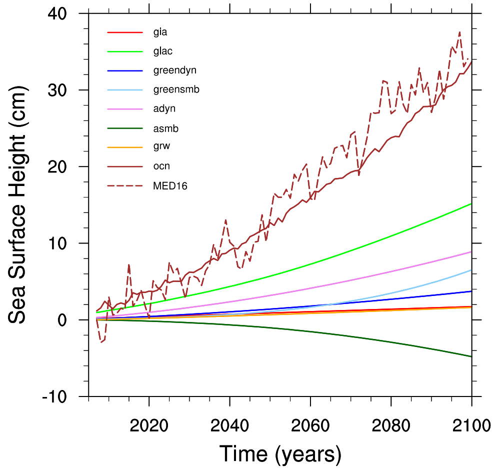




With the hottest month recorded at global level (CNR-ISAC, 2024)



precipitation anomalies at Mediterranean scale and national scale (with 21% less since 1961)

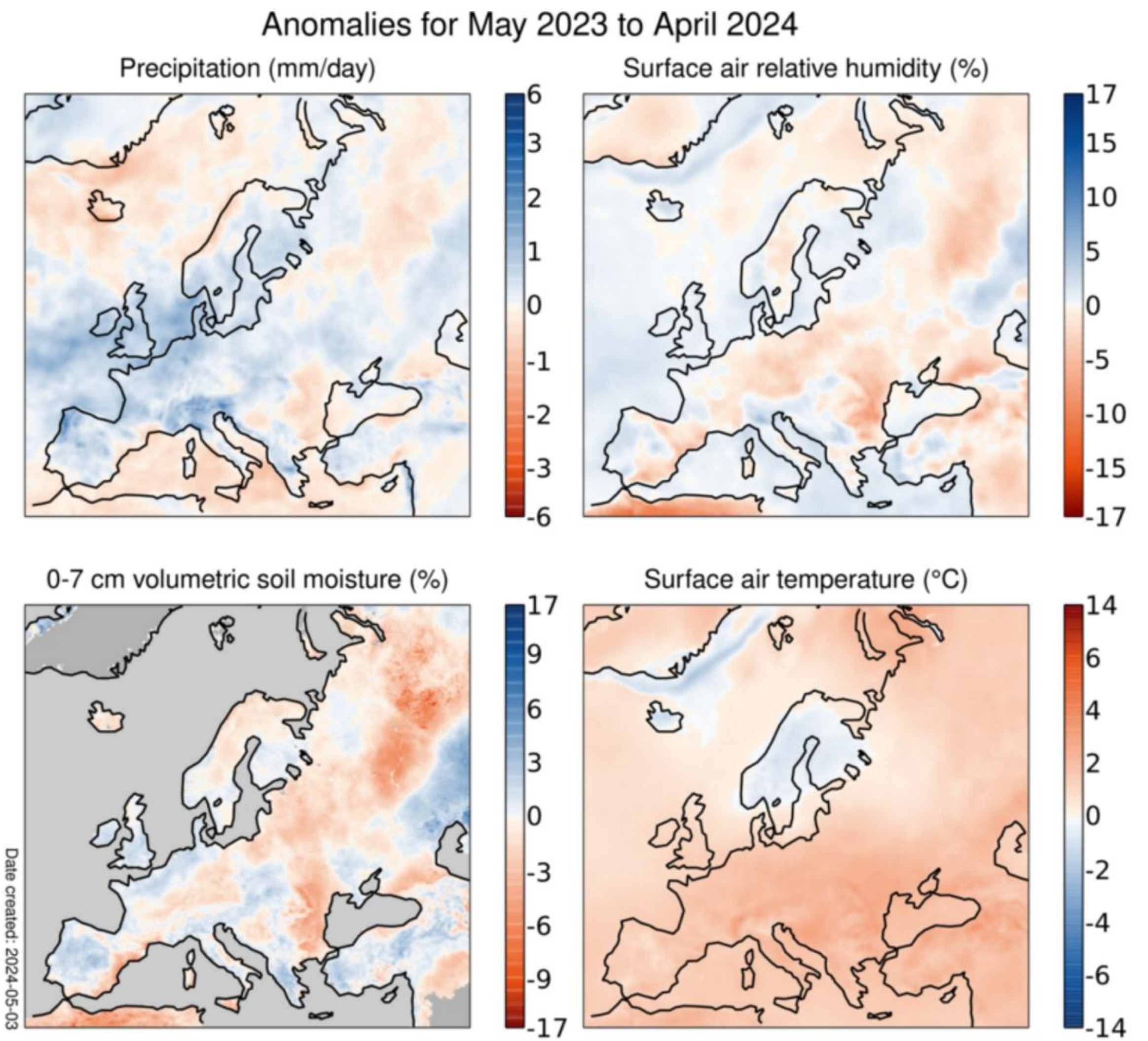


RATIONALE#2 - Rainfall in Europe April anomalies 2023 - 2024

Rainfall in Europe

It is unexpectedly late and early in Europe, all the way to the coast and on the other side of the earth, it is transported to the southern and central areas of the continent.

Most of the time you need to know about agriculture, river transport and energy management. The condition of extreme heat is also subject to an increase in fire risk, resulting in an unexpectedly high fire risk in South-Western Europe, particularly in France and Spain..



(Data: ERA5 / soil moisture ERA5-Land. Reference period: 1991-2020. Credit: C3S/ECMWF)

PROGRAMME OF THE EUROPEAN UNION

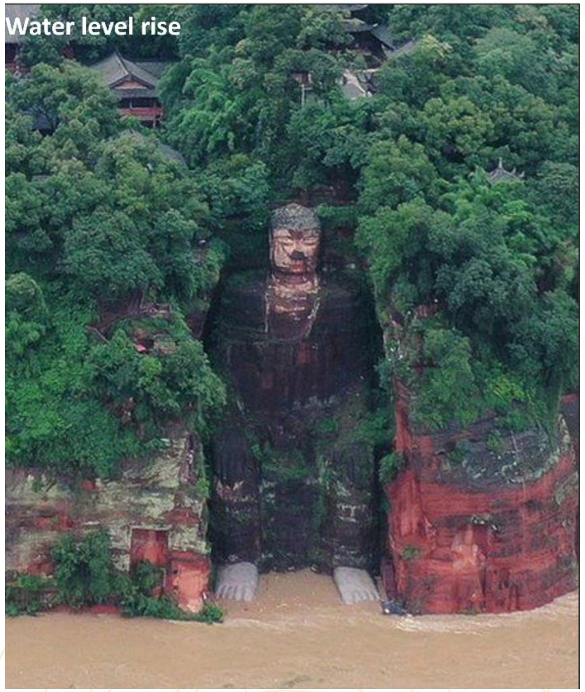
Direct and indirect impacts of natural and anthropogenic effects due to climate change on Cultural Heritage

David Gareja Monastic complex (Georgia) © Spizzichino

Blackening -Vittoriano (Roma)

Surface recession S. Filippo church (Torino)

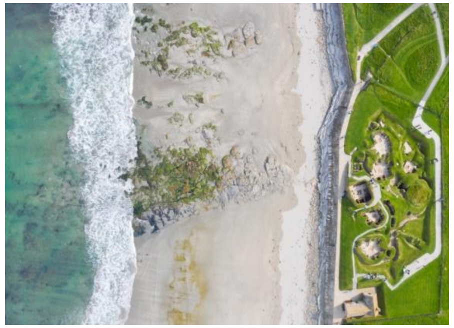
Sea level rise - Venice



Rock facade collapse in Petra (Jordan)

Hegra – Thermal stress, erosion and geomorphological instability in KSA© Spizzichino

Erosion in Akapana pyramid (Bolivia) © Spizzichino



Coastal Erosion Skara Brae © Hist. Env. Scotland

Geo-Morphological Processes

Falls and cave collapses in the monastery of David Garenji (Georgia)

Falls and tombs collapses in the Nabatean site of Petra - Jordan

Falls and tombs collapses in the Nabatean site of AlUla – Kingdom of Saudi Arabia

Erosion Processes

Las Medulas – Spain Ancient Roman Gold Mines

Weathering Processes

Ethiopia, Lalibela

Jordan, Petra

Kingdom of Saudi Arabia, AlUla

Bearing Capacity

Afghanistan, Herat

Afghanistan, Jam

Flood Event

Foto © G. Boccardi

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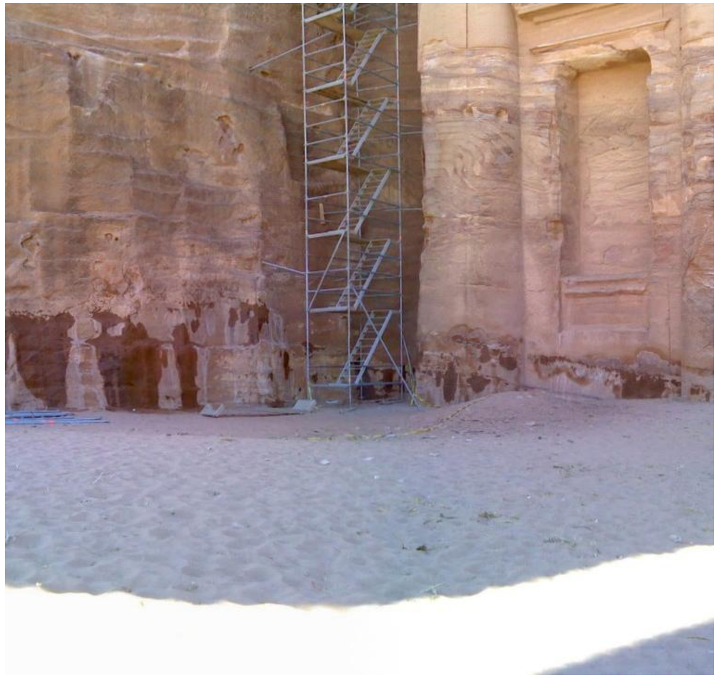
Water and Monuments

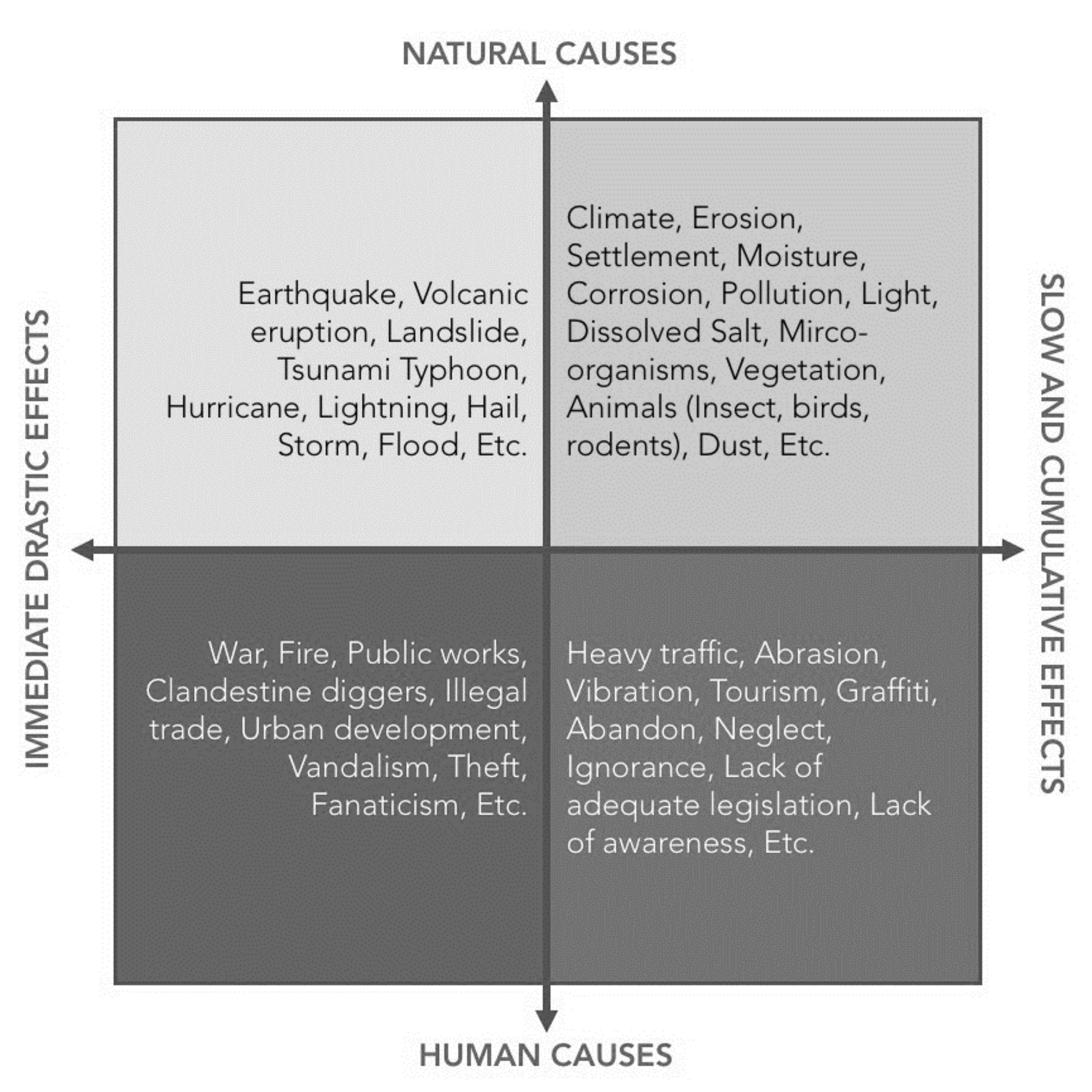
Cambodja (Angkor Watt)
Floods, heavy rainfall (occasionally)

Water table
(Permanently, seasonally, ephemeral)
Nepal (Lumbini)

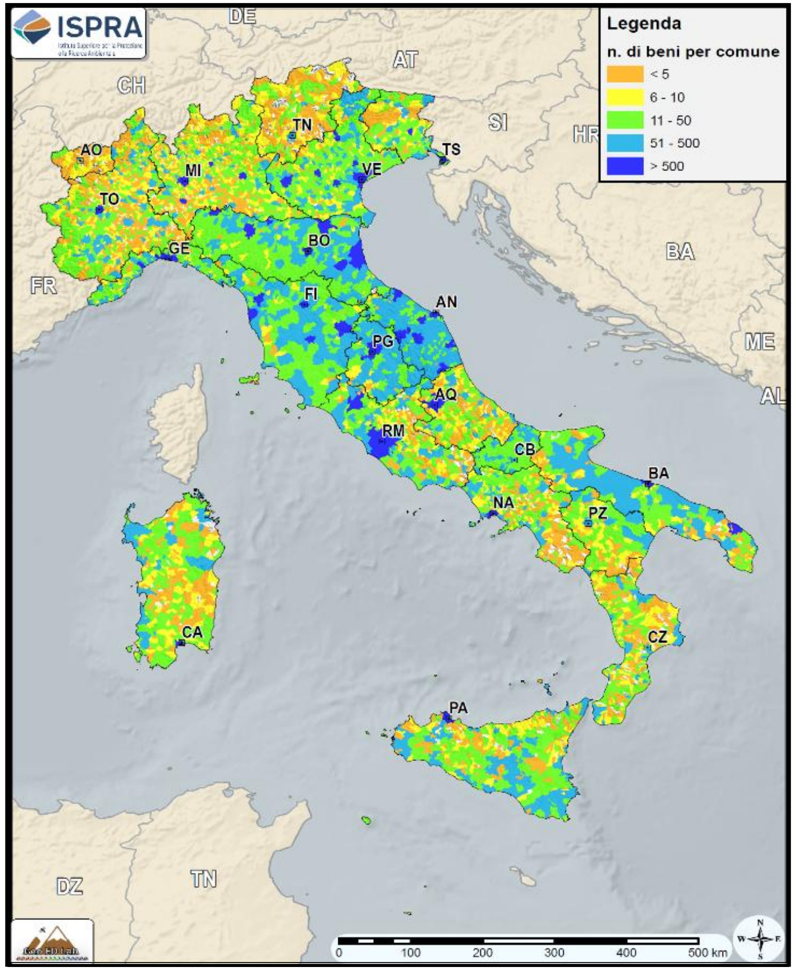


Jordan (Petra)
Rising damp, capillarity
Seepage (seasonally)

Threats facing cultural heritage
(ICCROM, 2006, modified)

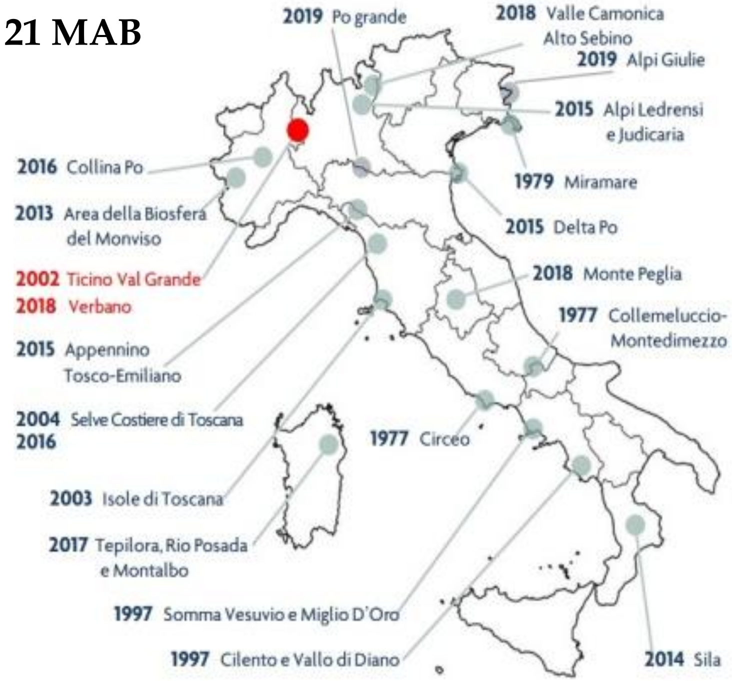


ITALIAN NCH VERY HIGH EXPOSURE, VULENRABILITY and FRAGILITY



Italian distribution of Natural & Cultural Heritage
61 UNESCO site

21 MAB



Cultural heritage at municipal level

Tot. 229530

sources:

banca dati VIR e CdR,

elaborazione ISPRA

12 Geo-parks

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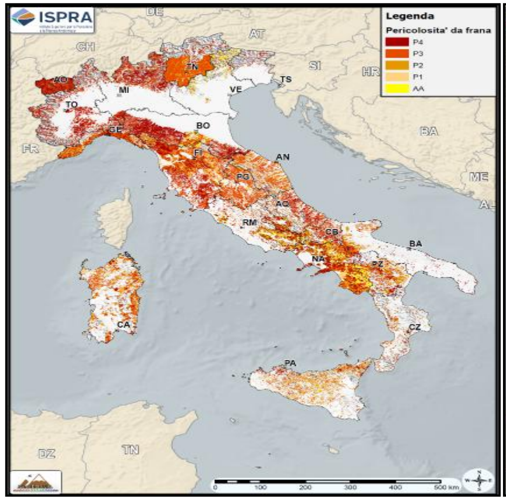
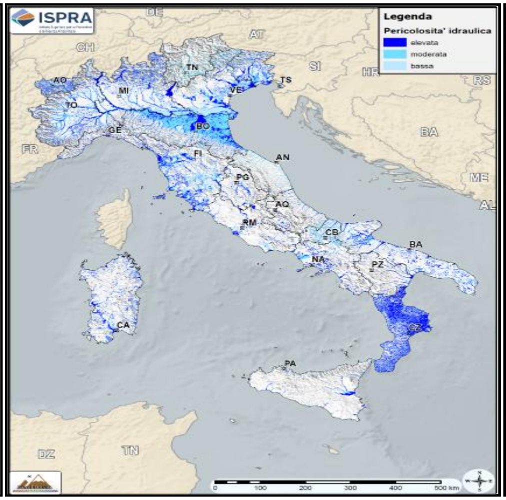
Natural Hazards threatening NCH

LANDSLIDE



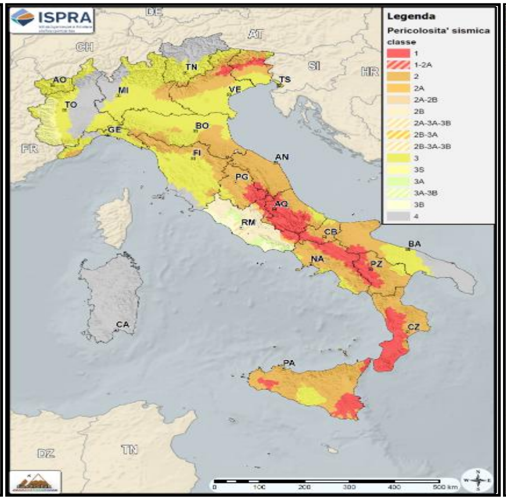
IFFI Inventory - Landslide Index (%)
Source: Rapporto ISPRA su Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio - Edizione 2021

FLOODS



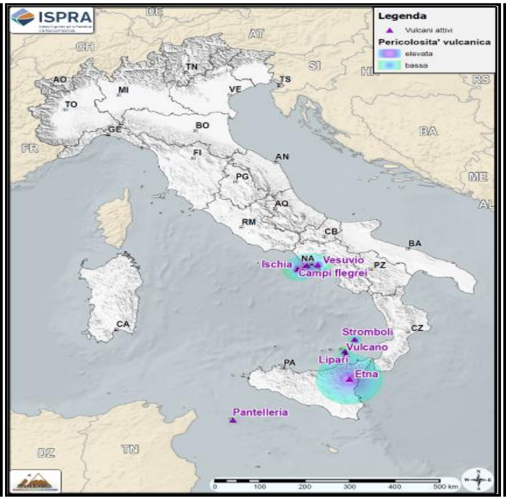
PAI hydraulic hazard mosaic
Source: Rapporto ISPRA su Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio - Edizione 2021

EARTHQUAKE



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

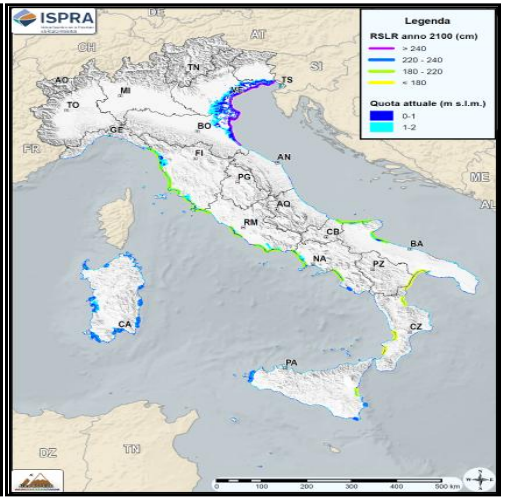
VOLCANO



Pericolosità da vulcani attivi

Fonte dati : Dipartimento Protezione Civile - INGV; elaborazione grafica ISPRA. Aggiornamento 2016.

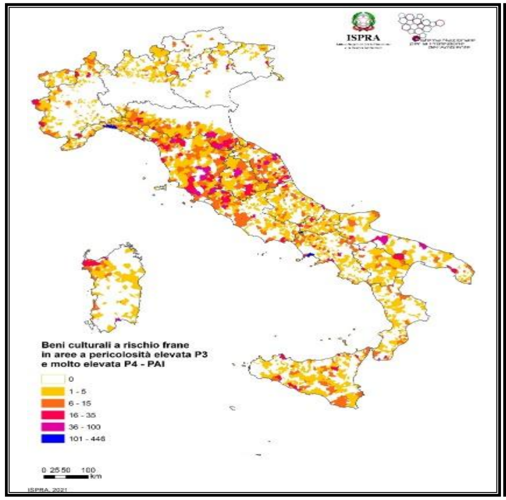
COASTAL

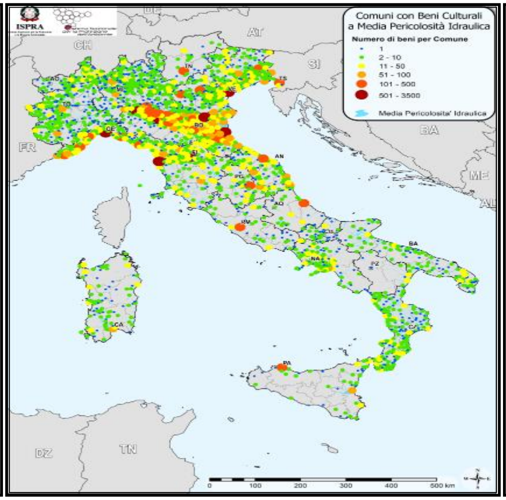


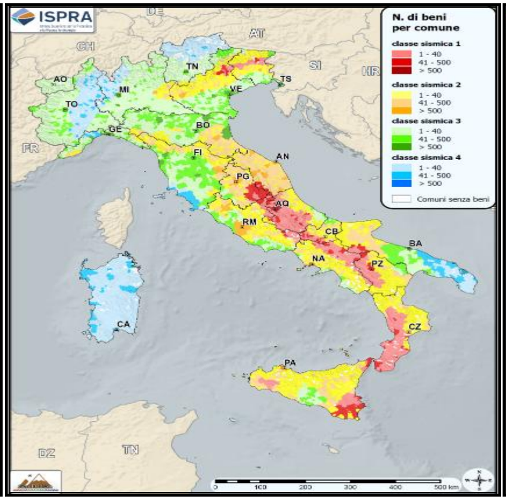
Sea level rise scenarios over some coastal areas
Source: Fonte dati: UNIBA; Assetto Costiero Italiano. Elaborazione grafica ISPRA.

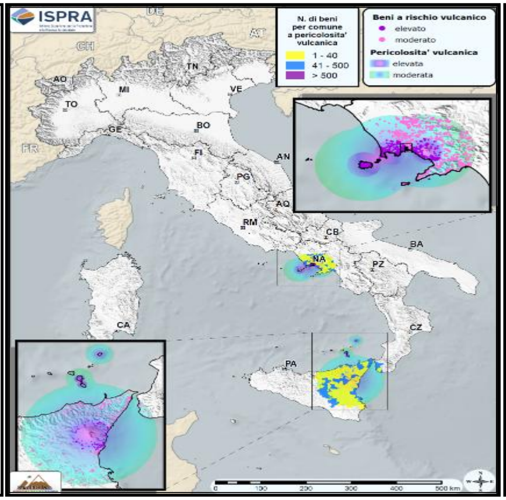
National Simplified risk of CH Vs Natural hazards

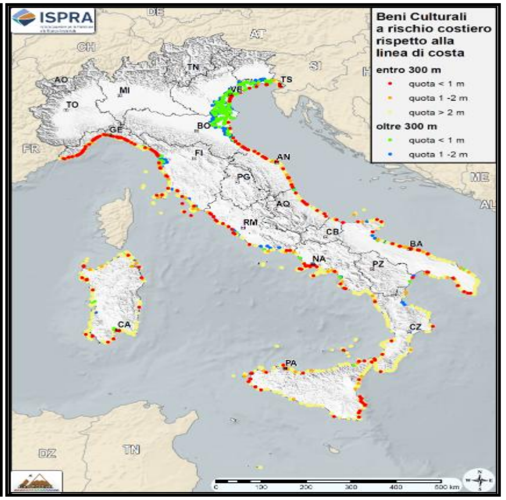
LANDSLIDE	FLOODS	EARTHQUAKE	VOLCANO	COASTAL











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

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

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

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

Detail of coastal erosion and stability at national level

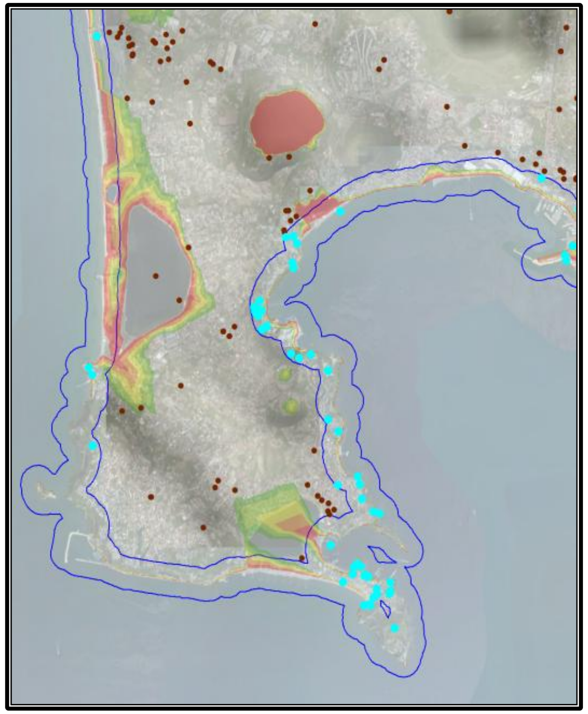
CH located at:

- 200 m from coastline
- <**1** m a.s.l.

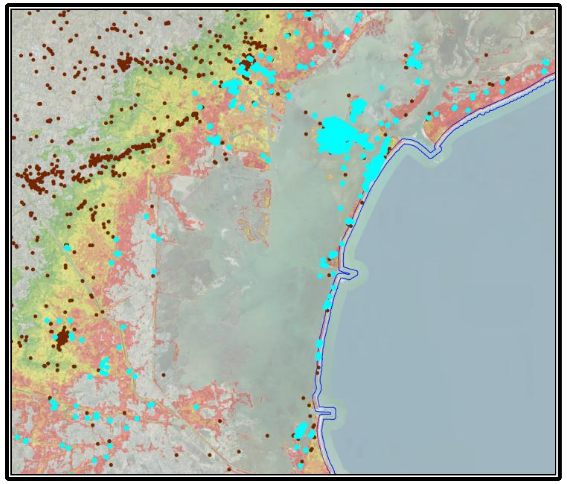
= 10726 CH (5%)

- 200 m from coastline
- <**2** m a.s.l.

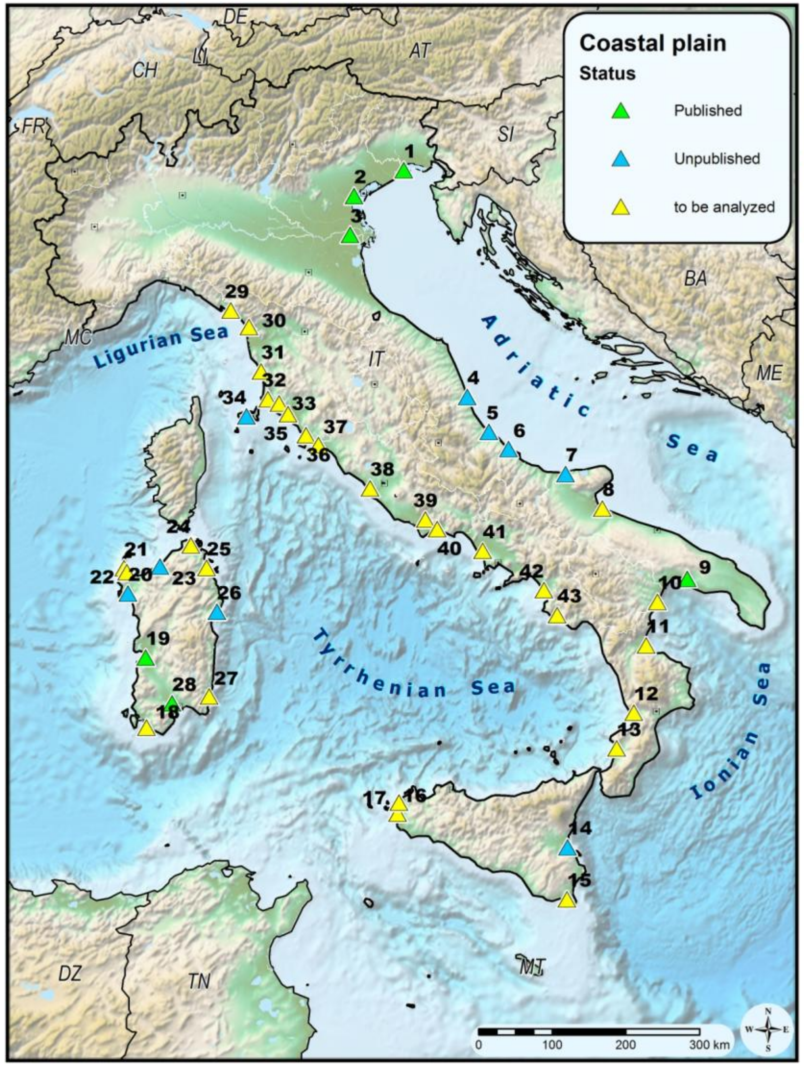
= 12595 CH (6%)

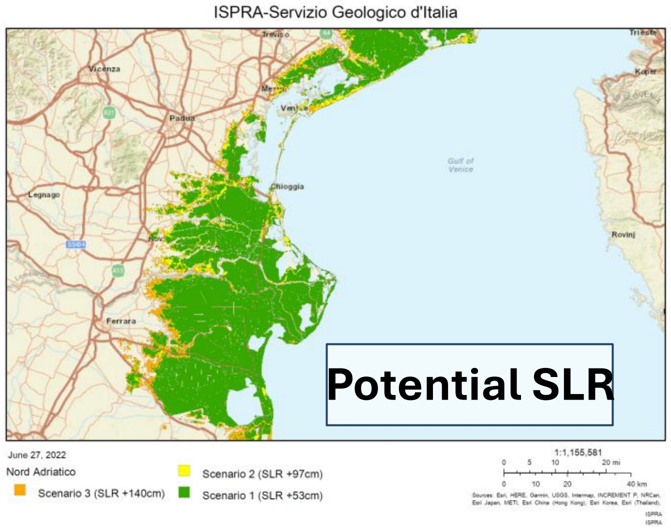


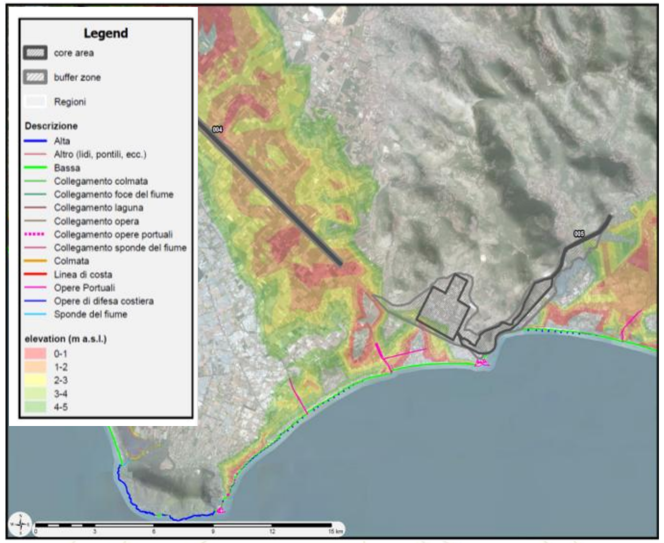
M. di Procida



Laguna Veneta

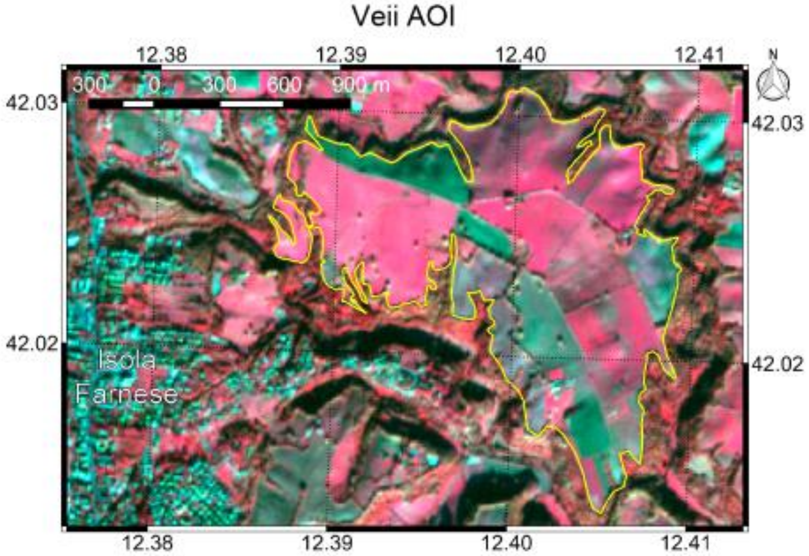


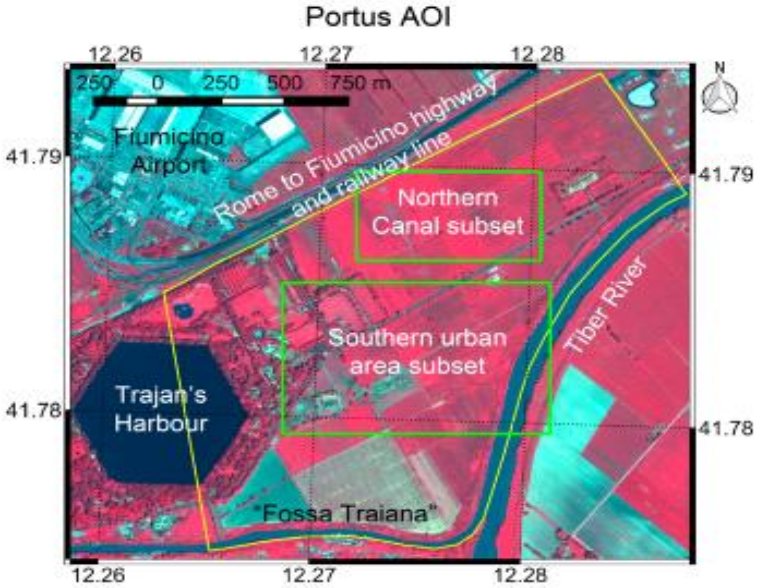




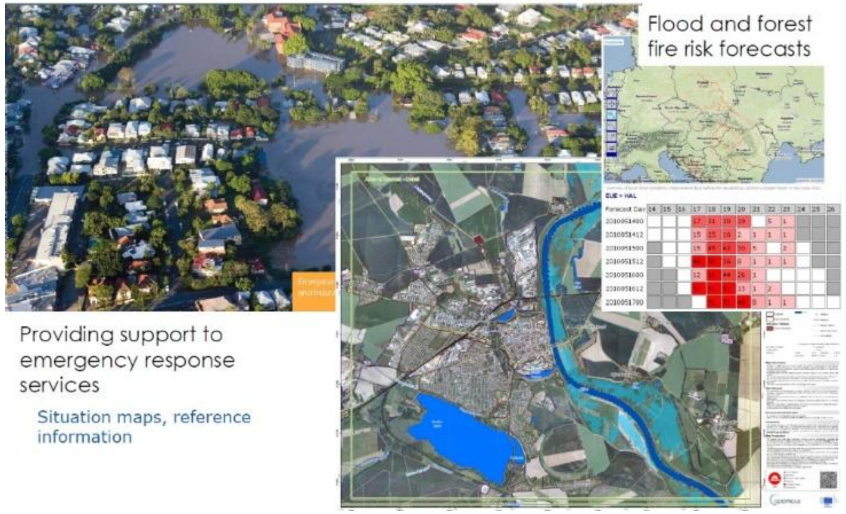
Terracina

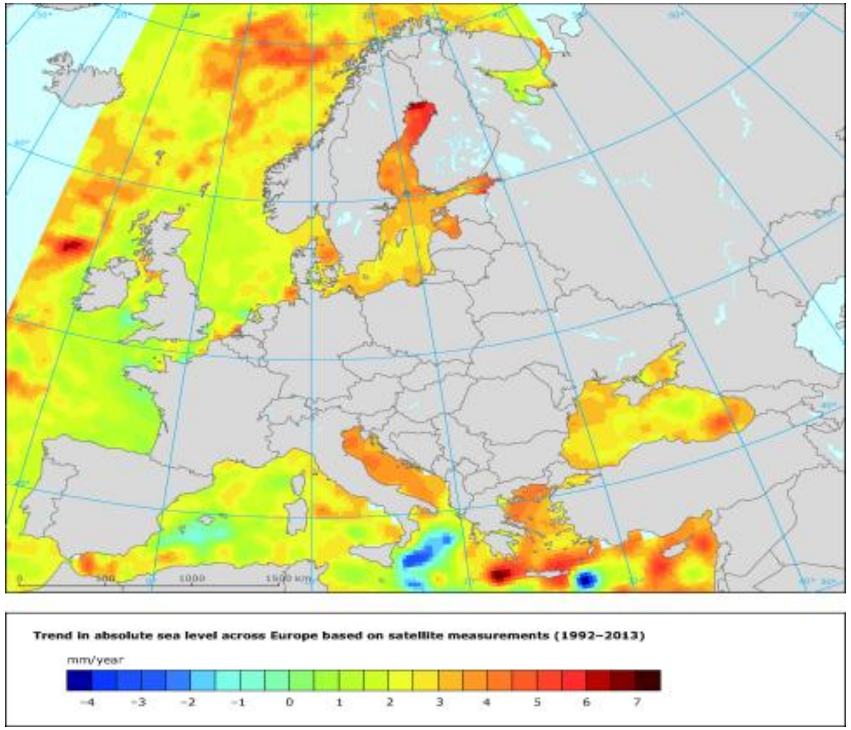
OPTICAL images, from data to downstream services (e.g. multispectral and Hyper spectral analysis)



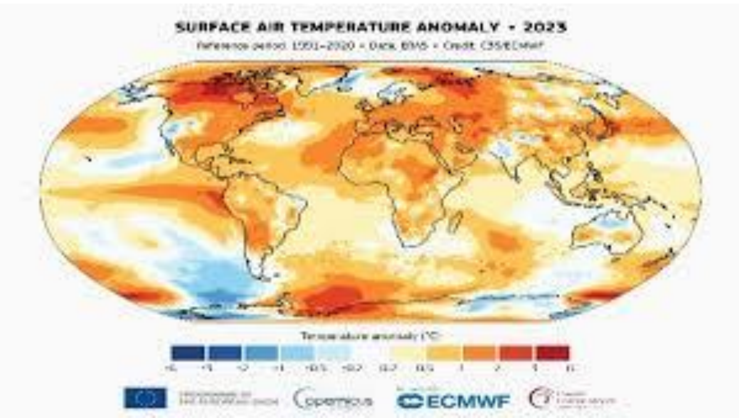


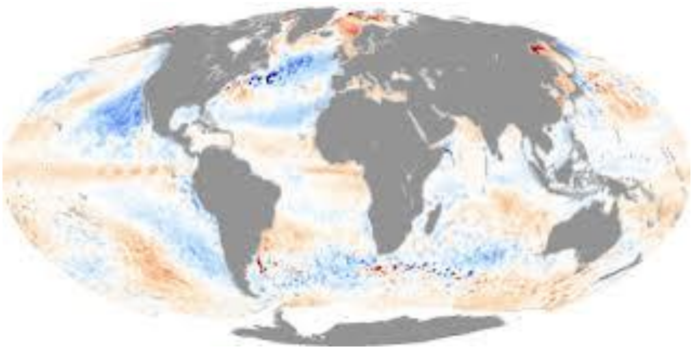
Land use, change detection and buried sites © ESA





sea level rise © EEA





Sea Surface Temperature anomaly © NASA

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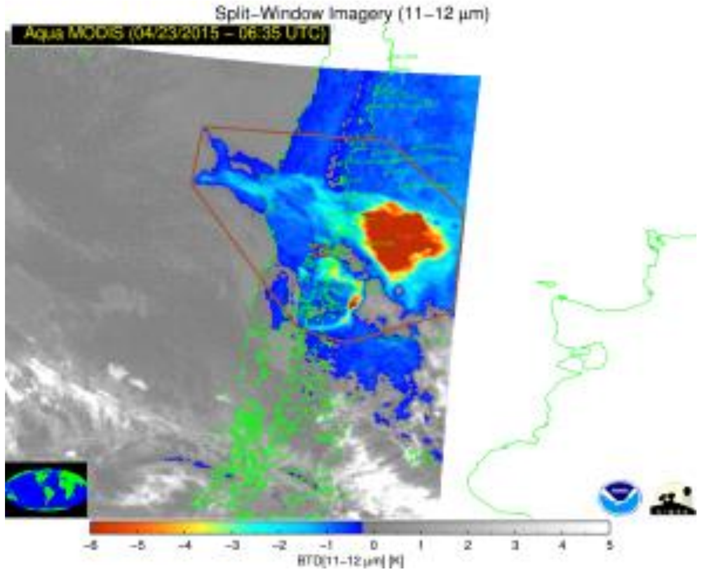
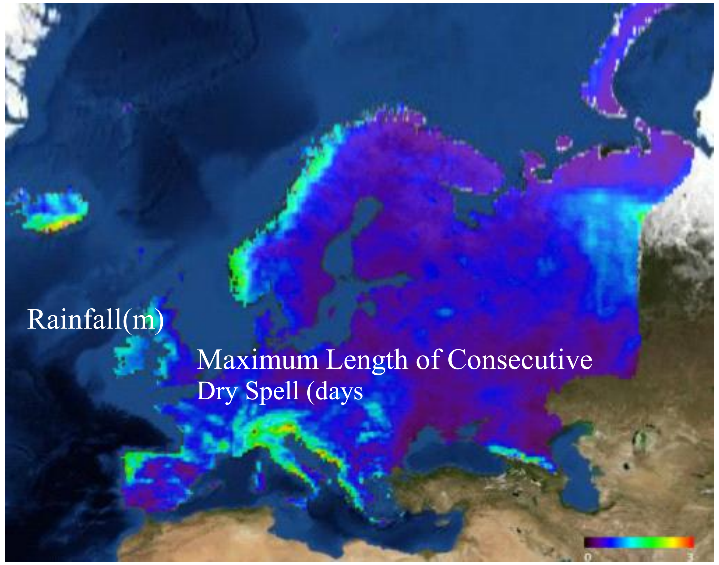
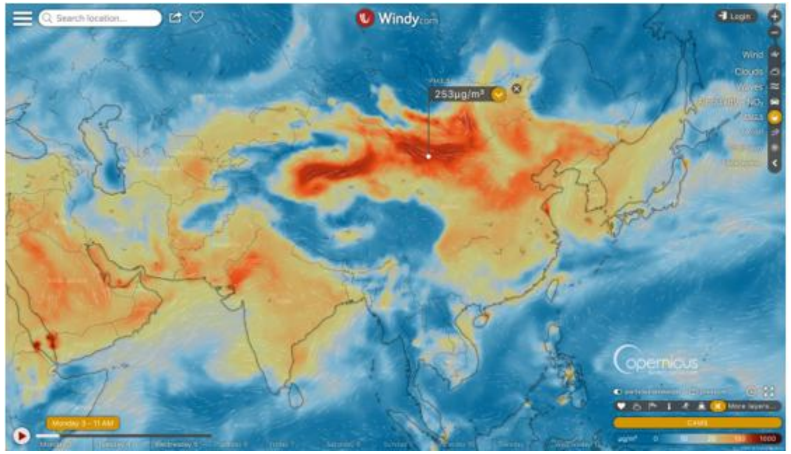
OPTICAL images, from data to downstream services (e.g. multispectral and Hyper spectral analysis)



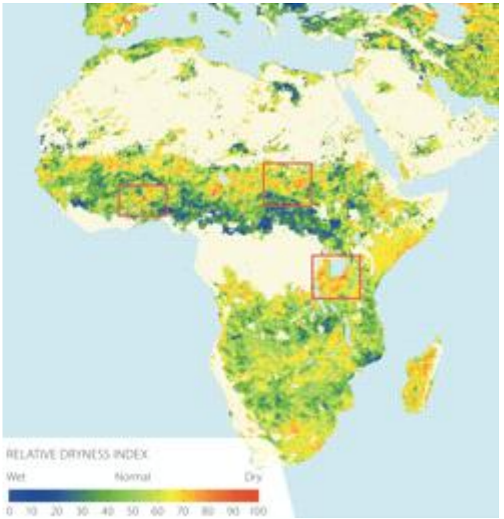
Volcanic Cloud Monitoring website.

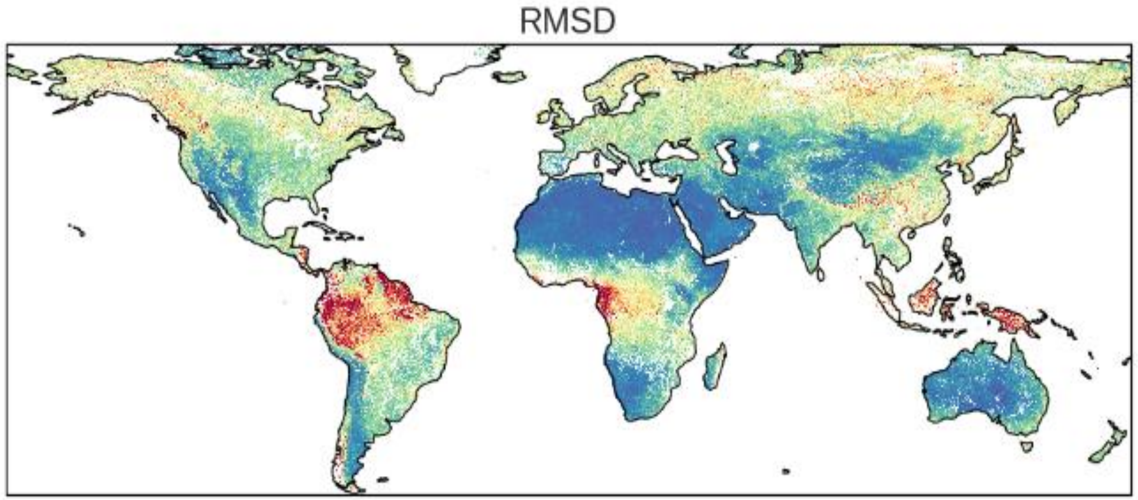
Climate variables and extreme events impact on Cultural Heritage @ ProteCHt2save CNR –ISAC Bonazza et al.





Pollutant concentration
© Windy.com





NDVI normalized Vegetation index © Copernicus

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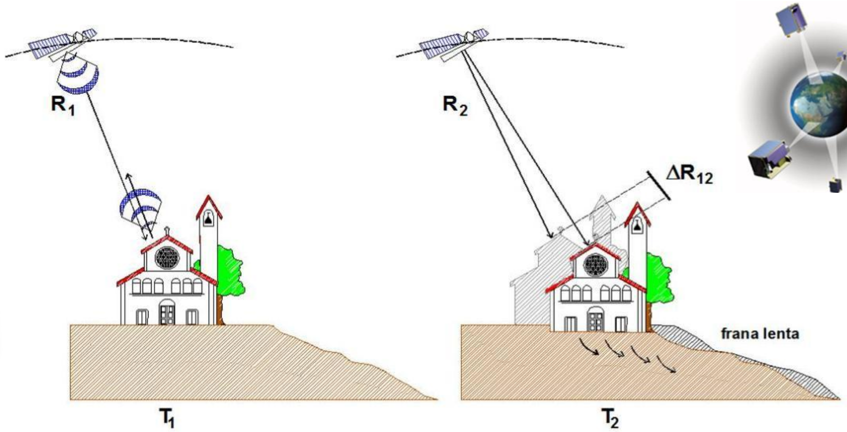
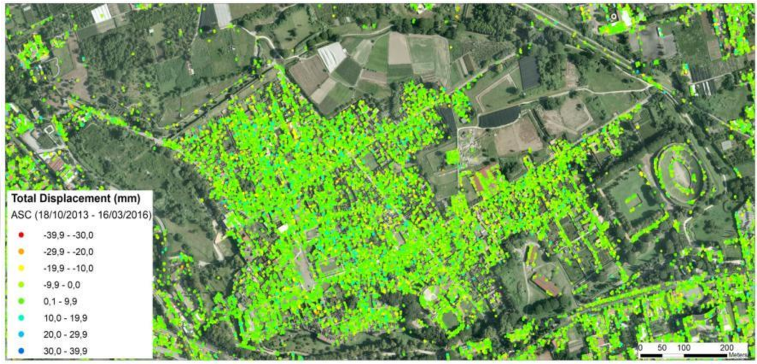
RADAR images, from data to downstream services (DINSAR analysis)

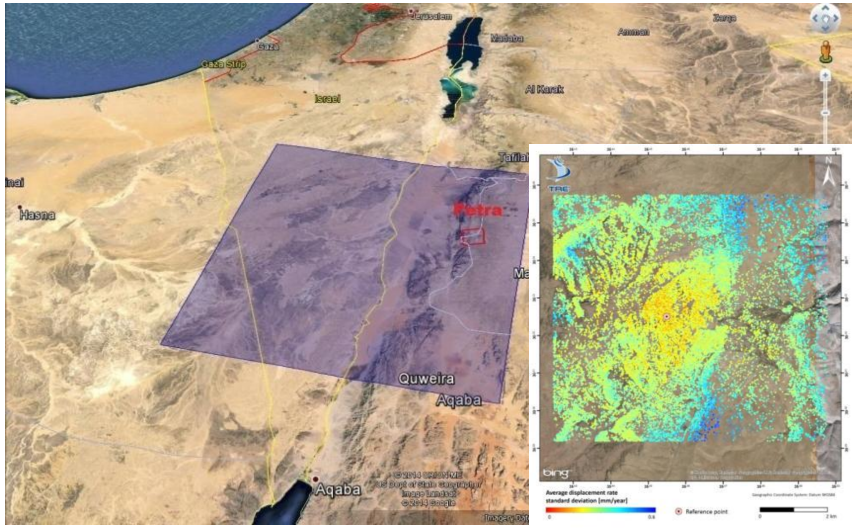
Rome Walls deformation satellite monitoring © Spizzichino

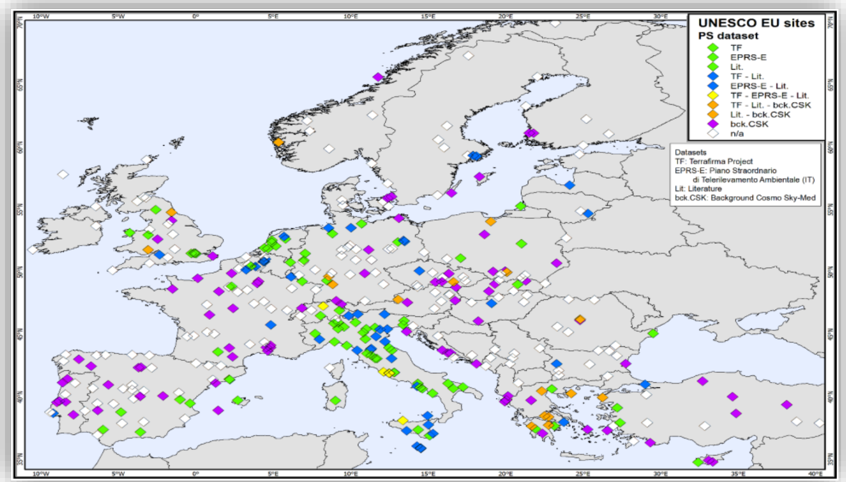


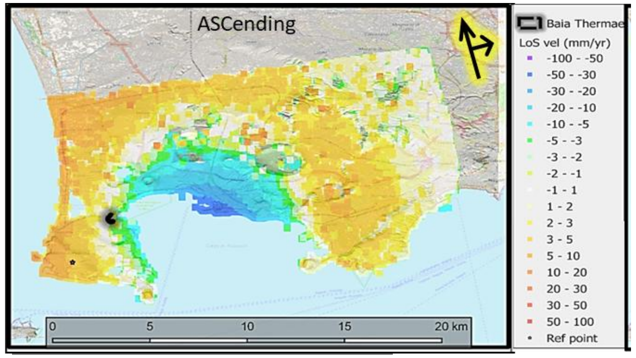
www.prothego.eu collect all the European UNESCO sites where GEO-Hazards and satellite data are already available

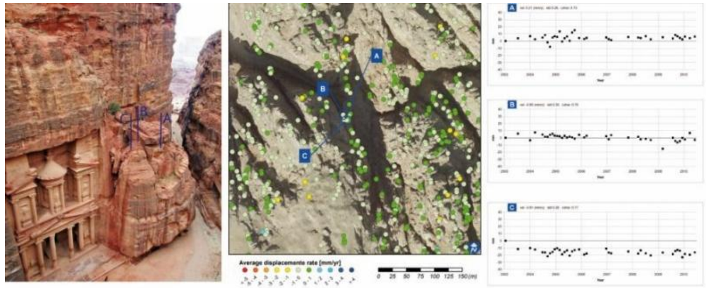


Instability processes and SAR data analysis POMPEI



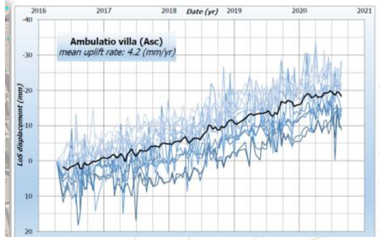






Surface deformation RADAR satellite images Petra © Spizzichino

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



Subsidence and uplift by satellite analysis PACF Park © Spizzichino

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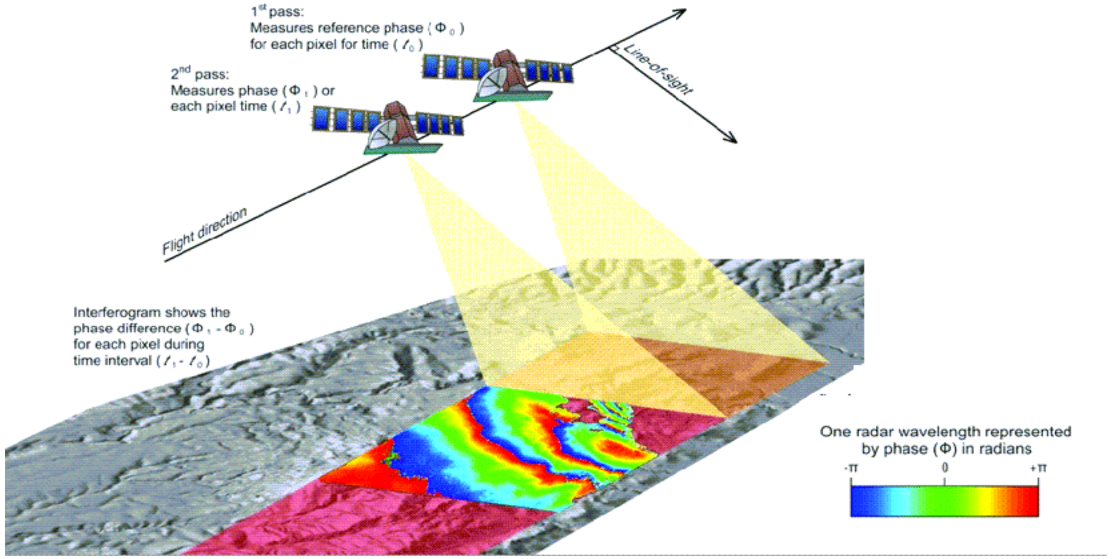
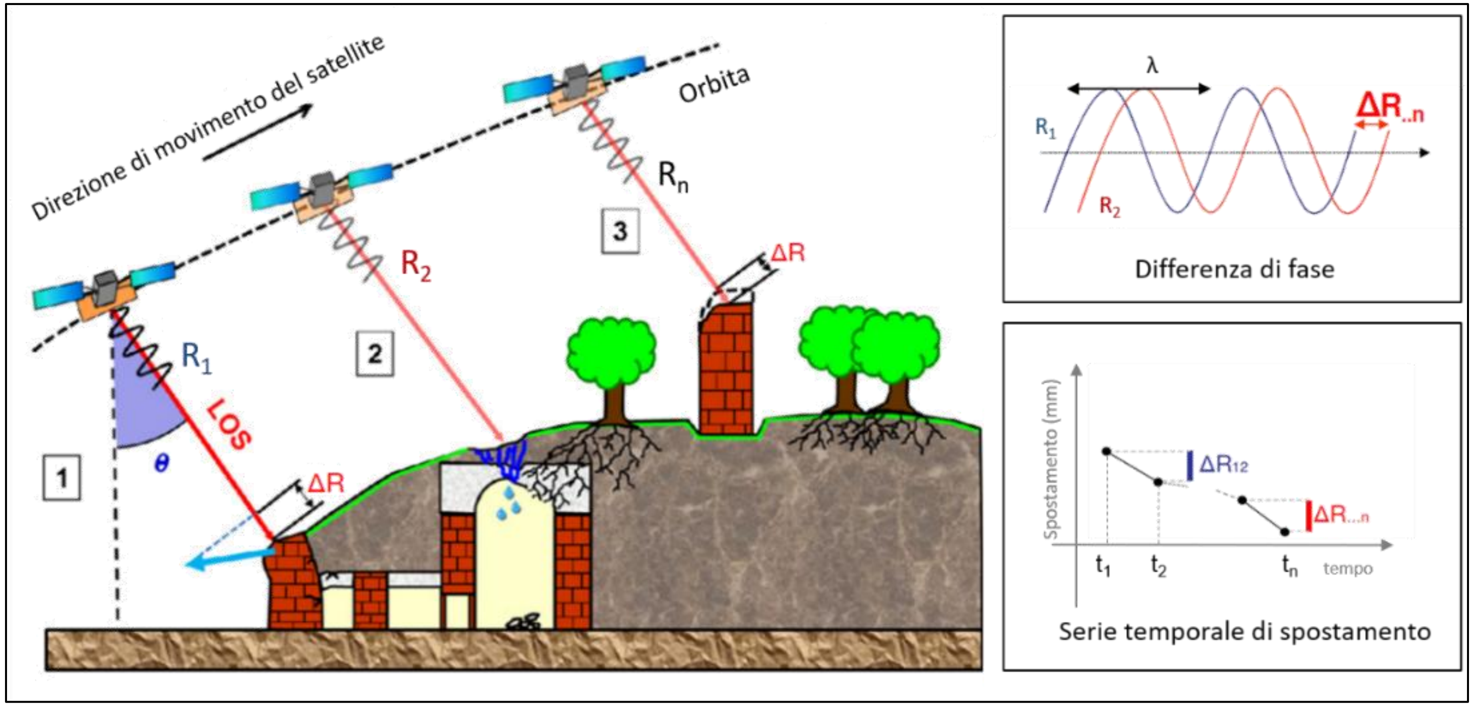

1st pass:
Measures reference phase (Φ₀)
for each pixel for time (t₀)
2nd pass:
Measures phase (Φ₁) or
each pixel time (t₁)
Line-of-sight
Flight direction
Interferogram shows the
phase difference (Φ₁ - Φ₀)
for each pixel during
time interval (t₁ - t₀)
One radar wavelength represented
by phase (Φ) in radians
-π
0
+π


Direzione di movimento del satellite
Orbita
R1
R2
Rn
LOS
θ
ΔR
1
2
3
λ
ΔR..n
Differenza di fase
Spostamento (mm)
ΔR12
t1
t2
tn
tempo
Serie temporale di spostamento

Springer Link

Original Paper | Open Access | Published: 17 November 2020

Multi-risk analysis on European cultural and natural UNESCO heritage sites

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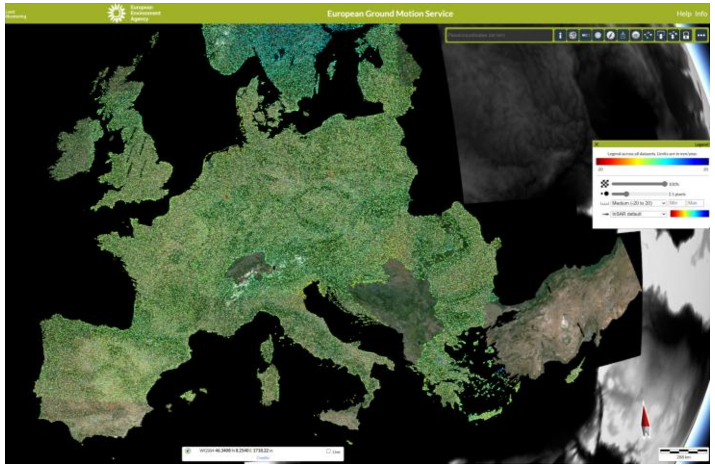
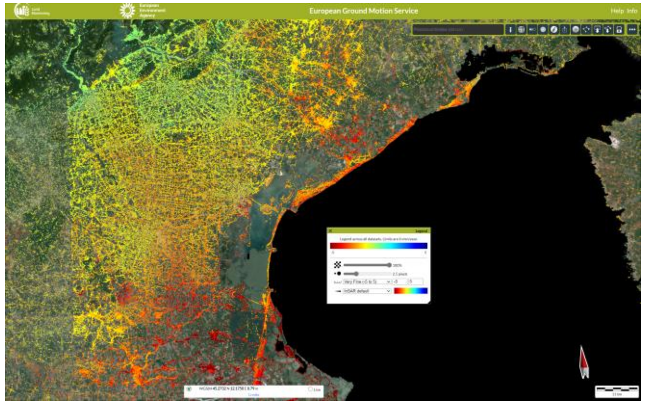
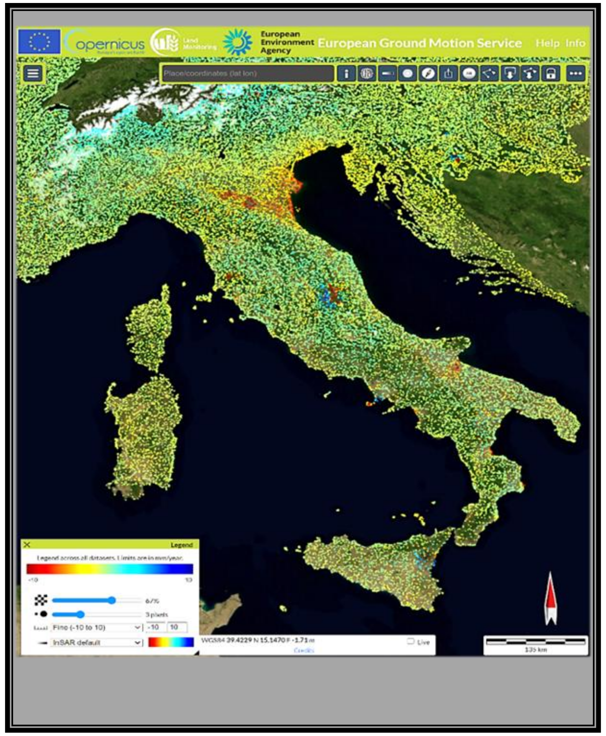
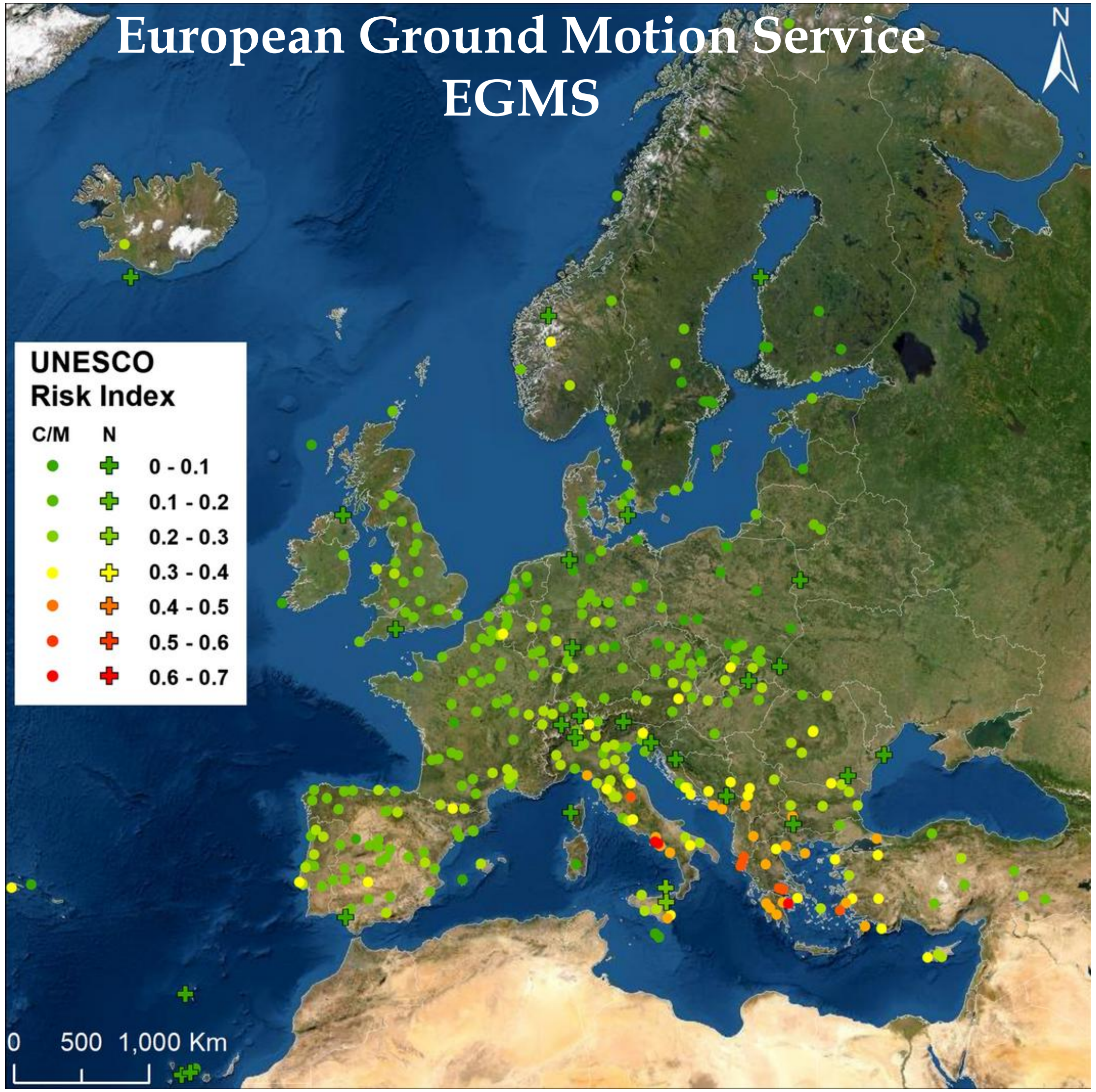
Natural Hazards **105**, 2659–2676(2021) | Cite this article









FROM STATIC TO DYNAMIC RISK ANALYSIS OF NATIONAL CH

https://sgi.isprambiente.it/prothego/

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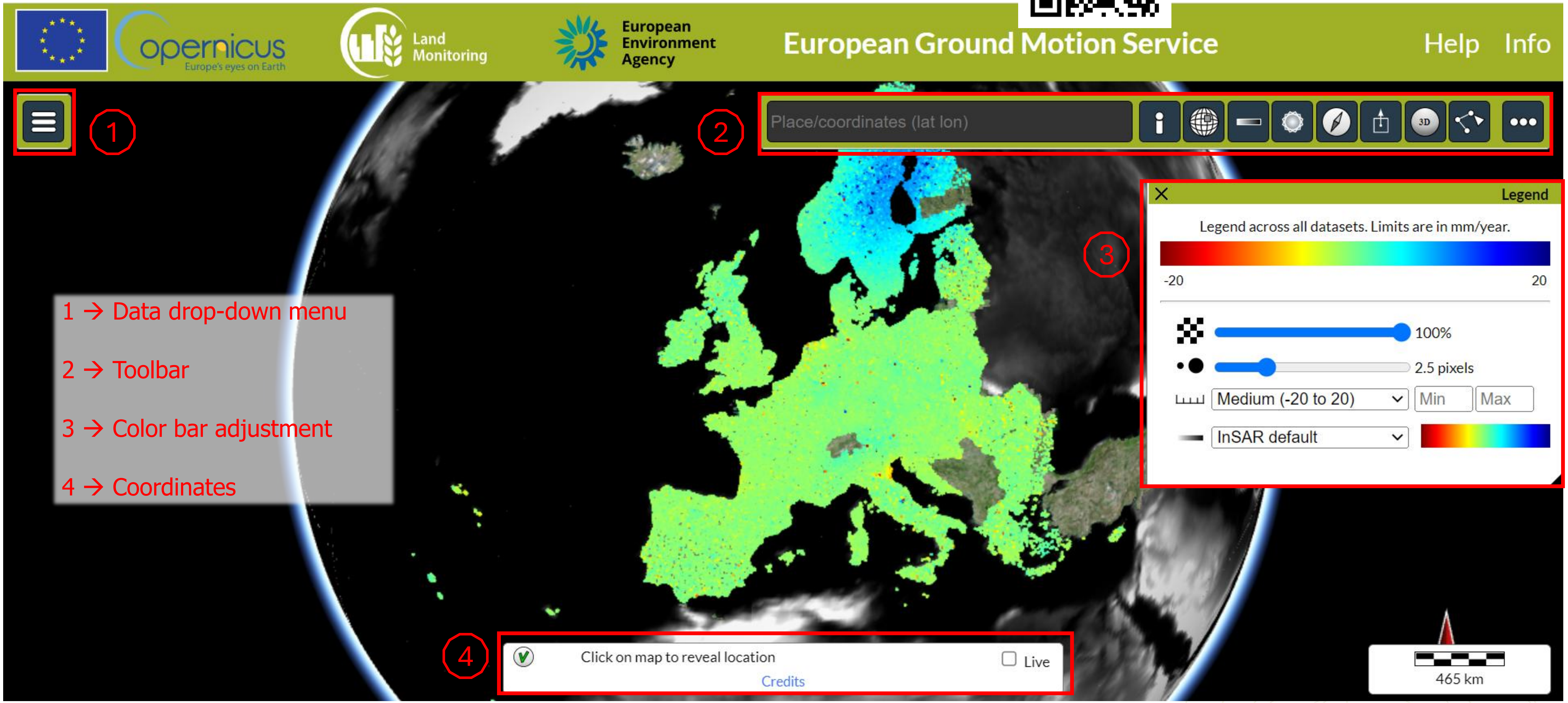
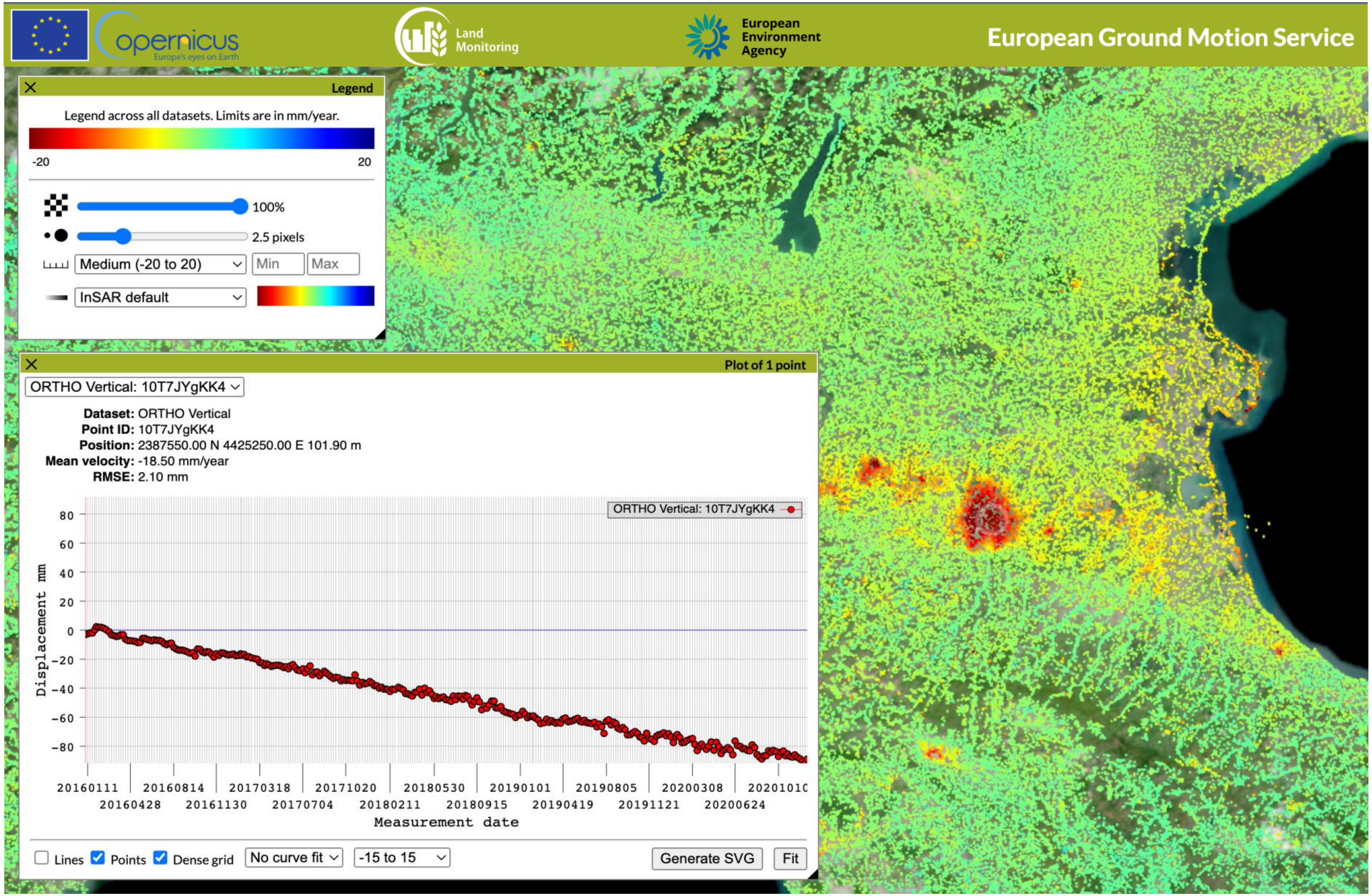
Dati Sentinel-1: EGMS

https://egms.land.copernicus.eu/

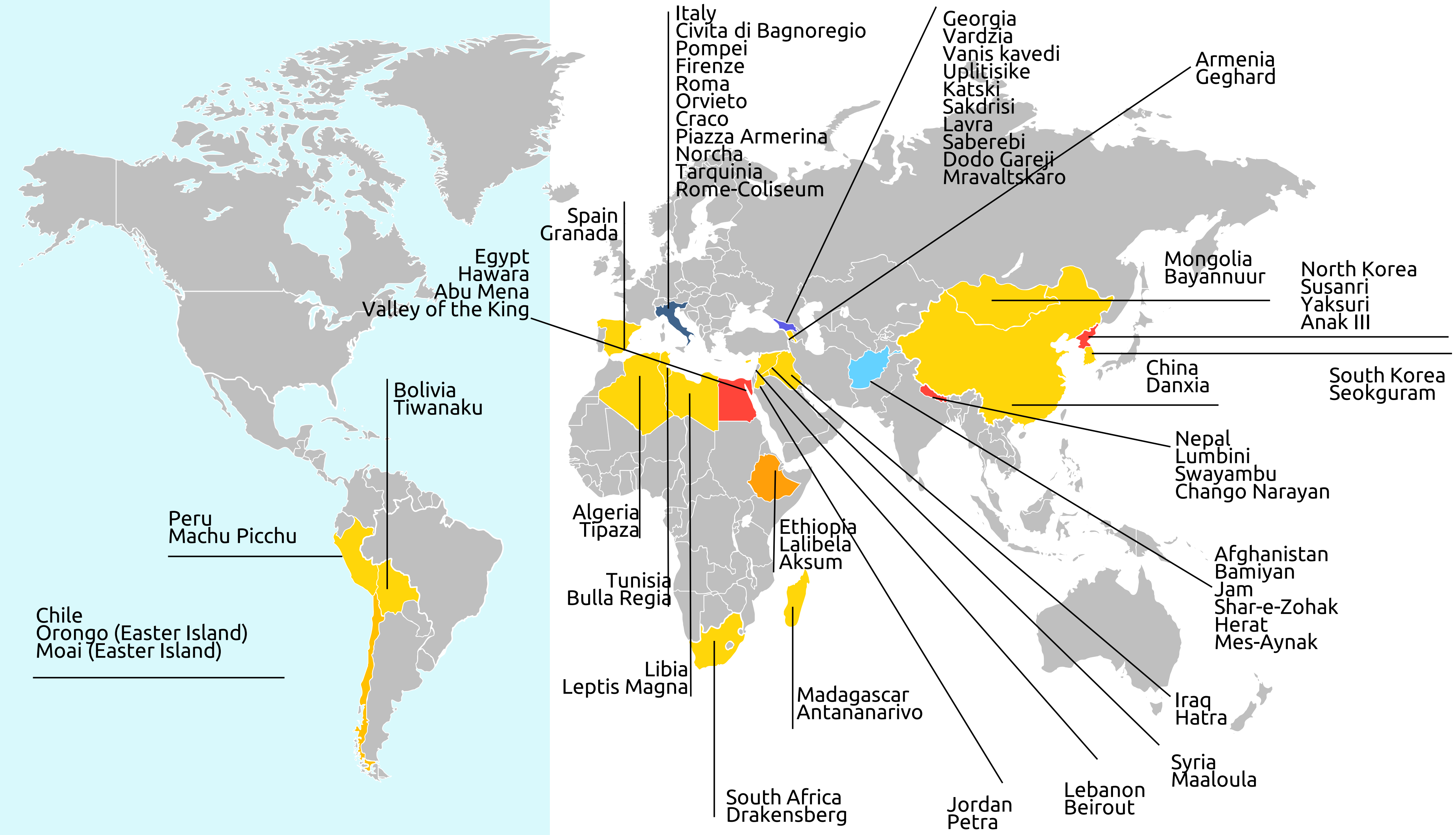


Dati Sentinel-1: EGMS

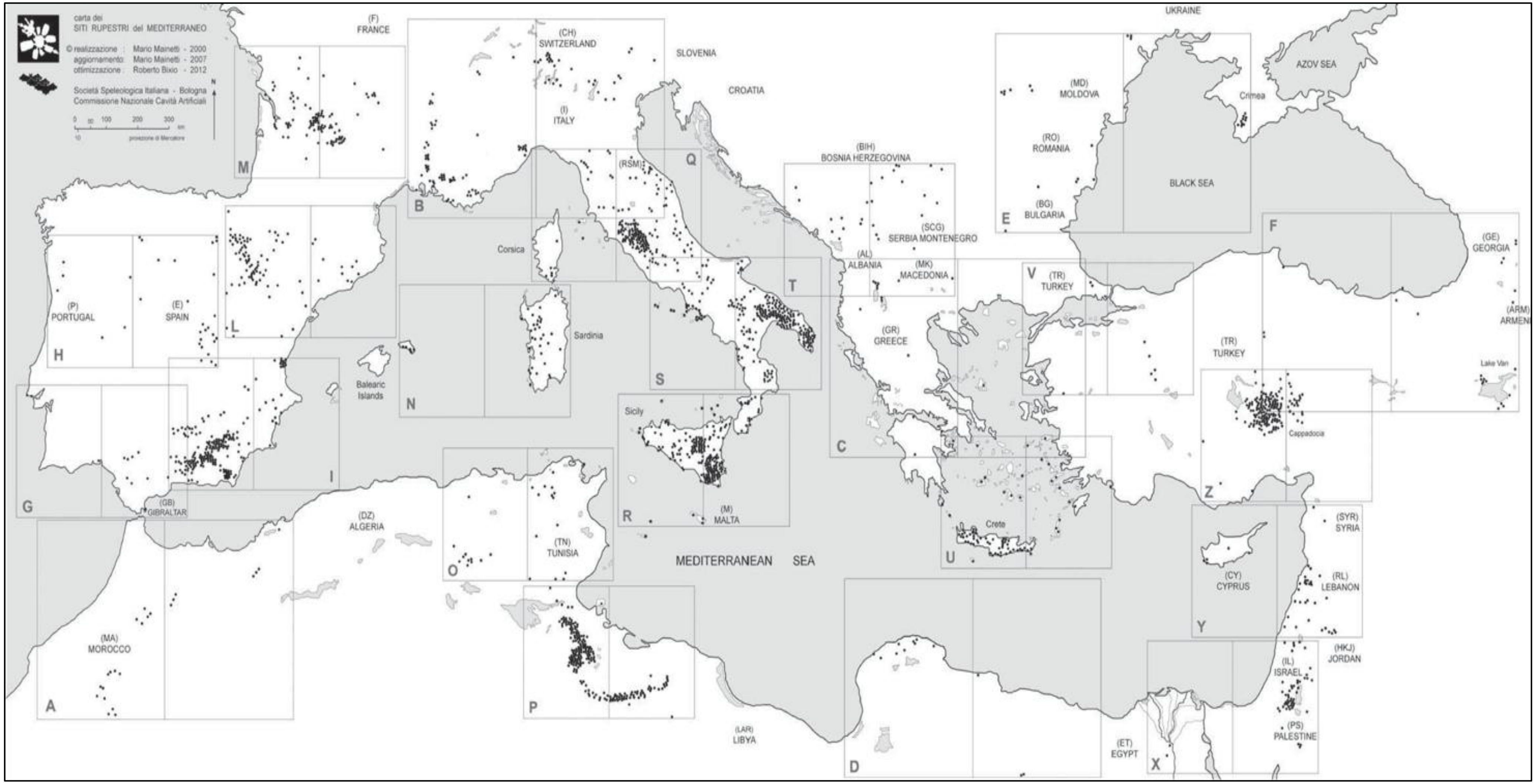


Investigated Heritage site last 20 years

Engineering Geology for the Conservation of Cultural Heritages



The Rupestrian habitat is a distinctive element of the Mediterranean landscape. It is made of structures excavated in the rocks and making benefit from the availability of weak rocks or the presence (in earlier period) of natural hollows and rock shelters



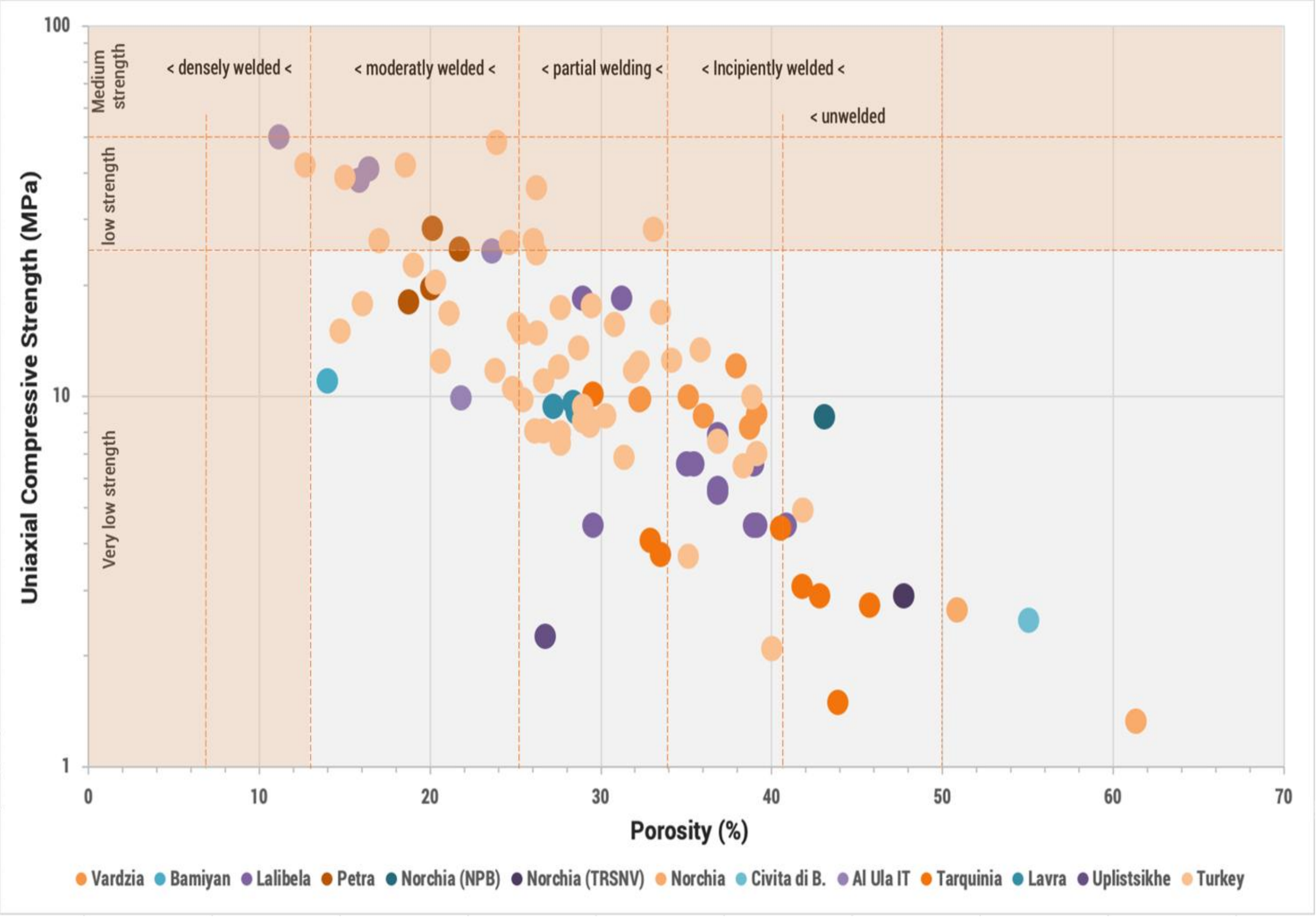
Rock-cut sites in the Mediterranean region (Polimeni at al., 2019)

Name and location	Typology	Geomorphology	Geology	Average UCS σn (MPa)	Average Tensile stress σt (MPa)	Threats
Norchia (Italy)	Necropolis	Vertical cliff	Piroclastic rock	2.65	0.48	Rock fall; water runoff; vegetation
Tarquinia, Monterozzi (Italy)	Necropolis	Vertical cliff	Organic-detritic limestone	10.9	0.94	Rock slide; lateral spread & toppling
Petra (Jordan)	Necropolis	Vertical cliff	Sandstone	22.85	2.84	Rock fall; flash flood; weathering
Hegra (Saudi Arabia)	Necropolis	Vertical cliff	Sandstone	9.9	0.5	Rock fall; weathering
Dadan (Saudi Arabia)	Necropolis	Vertical cliff	Sandstone	41.2	6.46	Rock fall and slide
Vardzia (Georgia)	Monastic centre	Vertical cliff	Tuff	8.7	2.8	Rock fall and slide; weathering
Katski (Georgia)	Monastic centre	Isolated pillar	Limestone	153*		Rock fall and slide
Lavra (Georgia)	Monastic centre	Vertical cliff	Sandstone	9.26	3.5	Wedge failure; rock fall; surface erosion
Uplistsikhe (Georgia)	Political and religious centre	upper plateau with vertical cliff	Sandstone	2.26	0.4	Rock fall; weathering
Vanis Kvabebi (Georgia)	Monastic centre	Vertical cliff	Tuff	7.73	0.31	Rock fall; weathering
Sabereebi (Georgia)	Monastic centre	Vertical cliff	Conglomerate, Sandstone, Siltstone	0.67		Wedge failure; rock fall; surface erosion
Natlismcemeli (Georgia)	Monastic centre	Vertical cliff	Sandstone	0.49		Wedge failure; rock fall; surface erosion
Bamiyan (Afghanistan)	Monastic centre	Vertical cliff	Conglomerate	6.8		Rock fall; upper soil erosion;
Orongo (Easter Island, Chile)	Religious centre		Weathered basalt	32	4.0	Rock slide
Abu Oud (Saudi Arabia)		Vertical cliff	Sandstone	38.5	7.7	Rock fall; flash flood
Jabal Ikmah (Saudi Arabia)		Vertical cliff	Sandstone	24.8	2.7	Rock fall; flash flood
Shar-e-Zohak (Afghanistan)	Fortress	Upper plateau with vertical cliff	Marl and conglomerate			Surface erosion
Mes Aynak (Afghanistan)	Religious centre on copper mine	Flat valley with gentle slopes	dolomite marble, carbonaceous quartz schist and quartz-biotite-dolomite schist			Mining
Lalibela (Ethiopia)	Religious centre	Rock-hewn churches	Weathered basalt	6.4		Weathering; rock slide

Geomechanical proprieties of the Rupestrian sites

COMMON ELEMENTS

Porosity versus UCS plot data from authors investigations and Ince et al, (2019) for Turkey data. A classification of strength (Deere and Miller, 1966) and welding (Quane and Russell, 2005) are reported for reference.



MORPHOLOGICAL PROCESS VS TRIGGERING FACTORS

landslides induced by climate weather events

- *short- and medium-term variation*

MICRO SCALE

Thermo-clastism

Cryo-clastism

Weathering due to humidity

Erosion

Freeze-thaw cycle

MACRO SCALE

Prolonged and accumulated rains → Rock, Slow, Deep

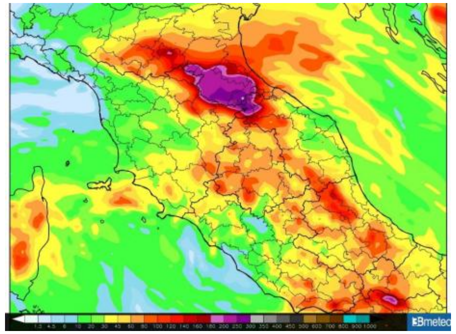
Short and heavy rains → Soil, rapid, shallow

Permafrost dissolution

Cyclones

Sea storm (coastal cliff stability)

Hot wave and prolonged dry period → Slow Creep and



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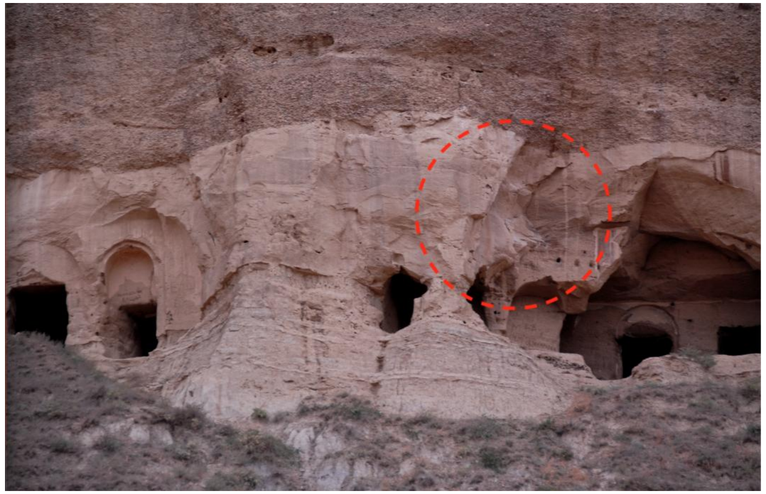
SABEREEBI - GEORGIA

Slow on set Geo-Morphological Processes

2022



2012

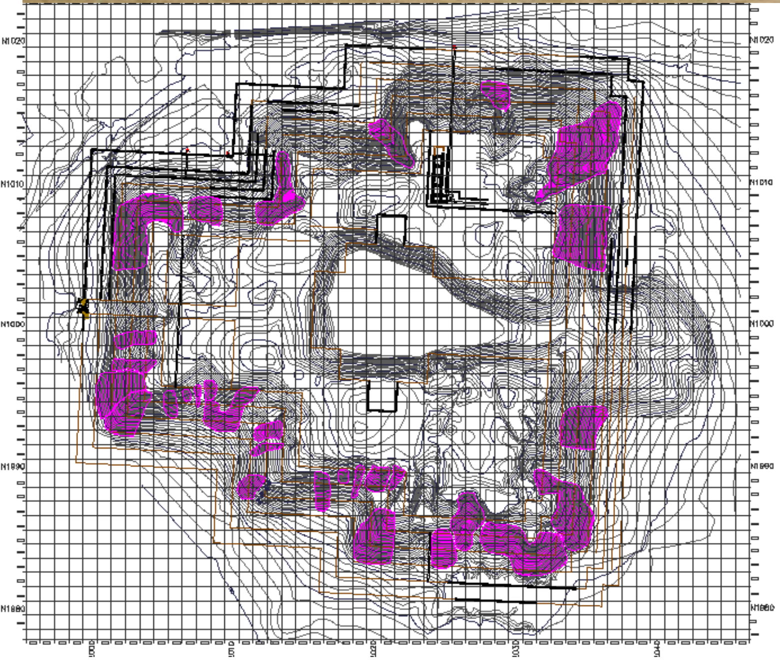
2016

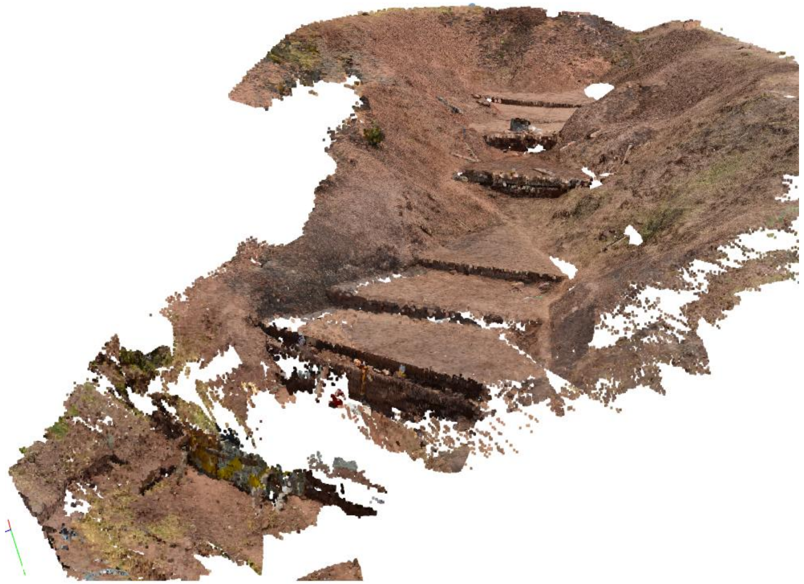
2019

AKAPANA PYRAMID IN TIWANAKU - Bolivia

Tiwanaku, Bolivia (rotational slide, Earth flow, Solifluction, Rill erosion)

For these particular morphological processes affecting the pyramid, the most suitable mitigation measure is to control the deepening of the small watersheds, due to accelerated linear erosion

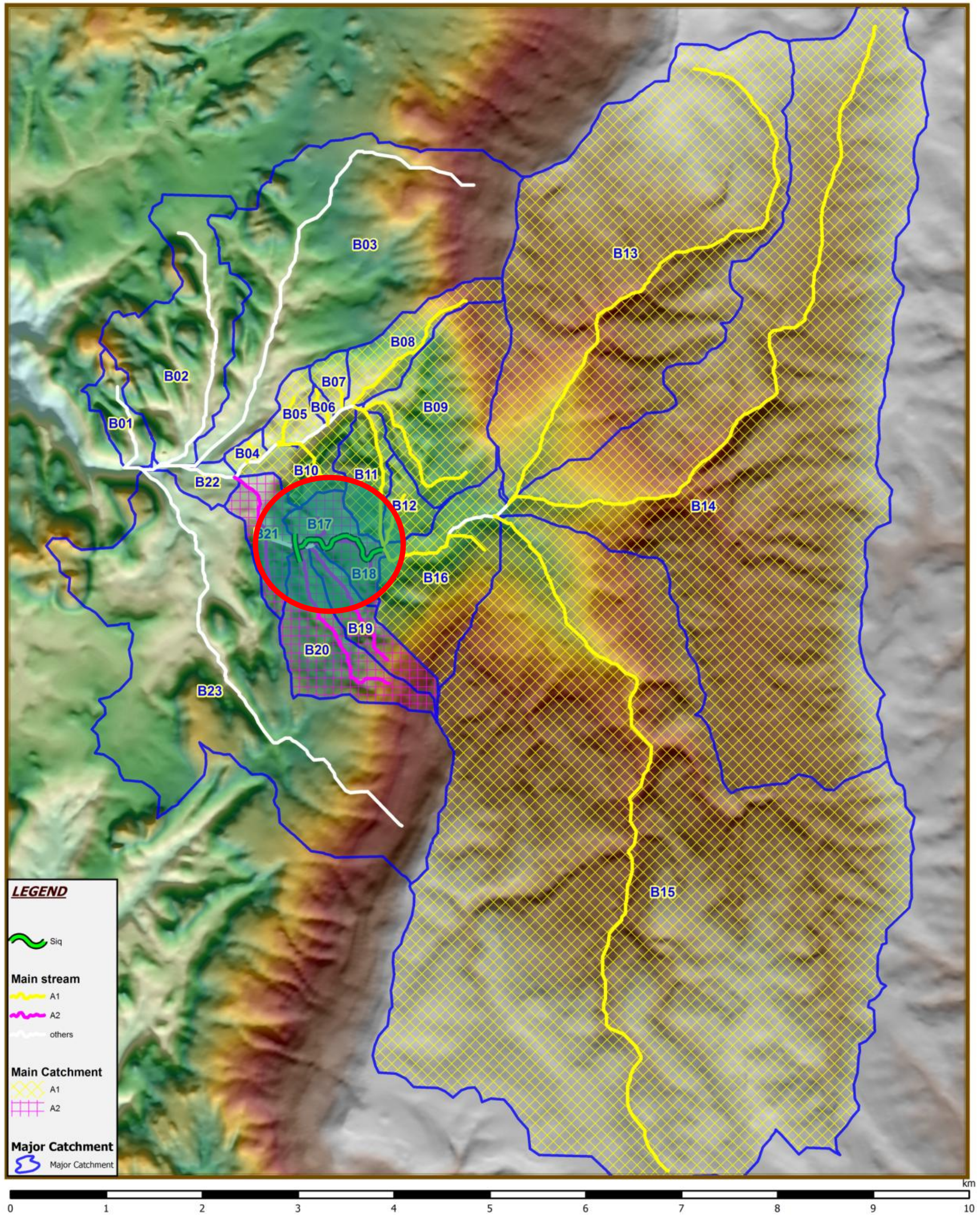




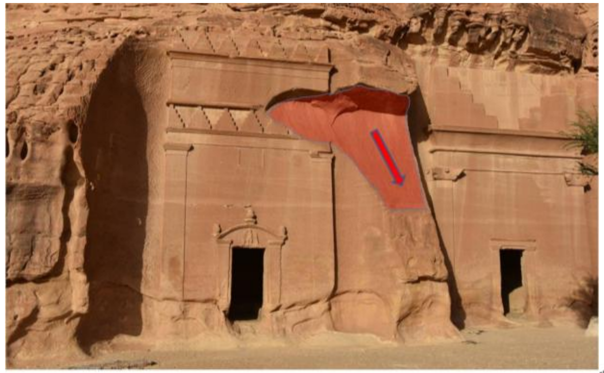
2023 Summer

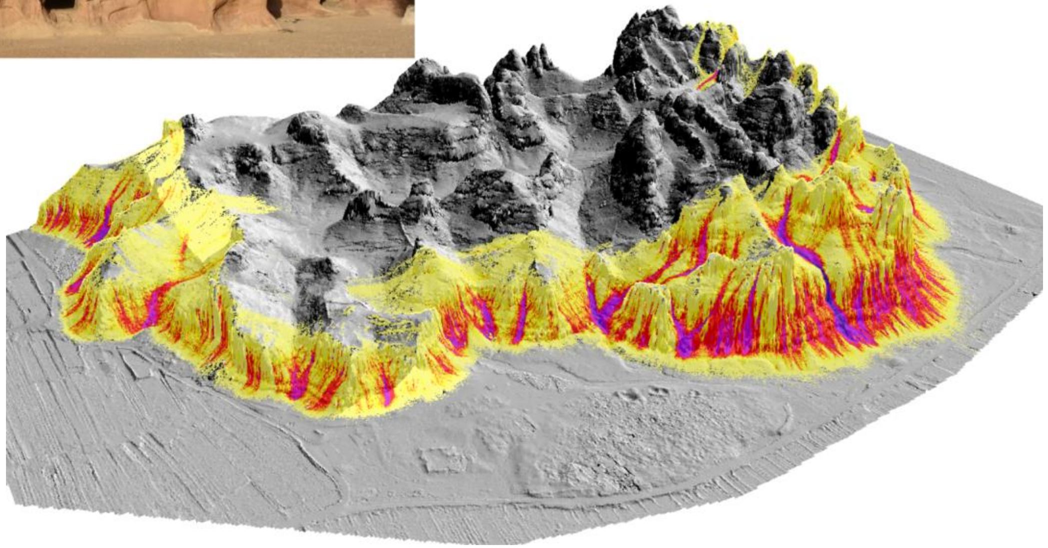
PETRA - Jordan

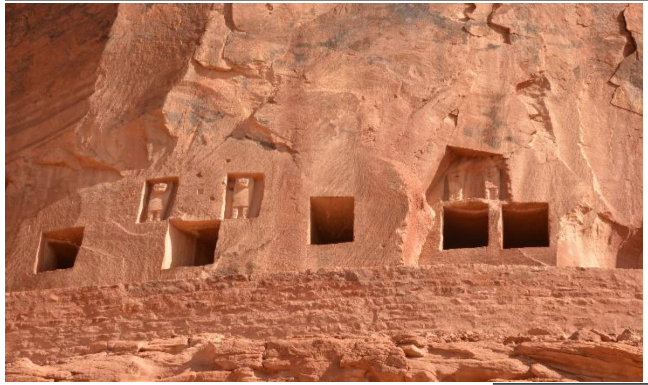
Rapid on set Geo-Morphological Processes



ALULA - KSA







MINISTERO DELLA CULTURA

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 other institution, research center and university (e.g CNR, UNESCO chair UNIFI)

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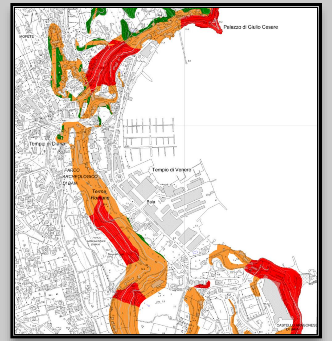
Four *steps*

A

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

B

Geohazard assessment
Hazard and risk map analysis

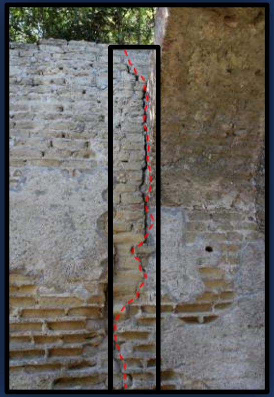


C

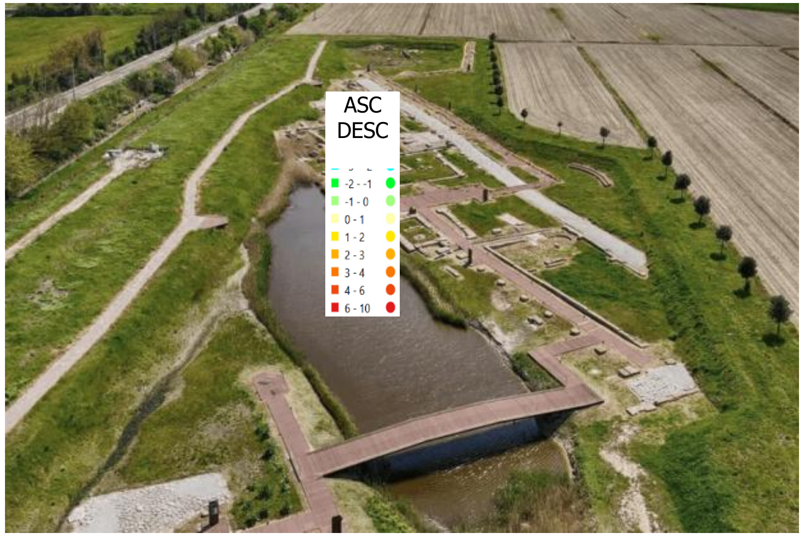
SAR Interferometry
Data integration and services

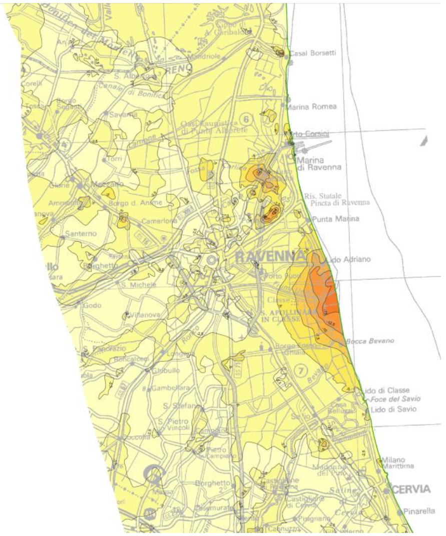
D

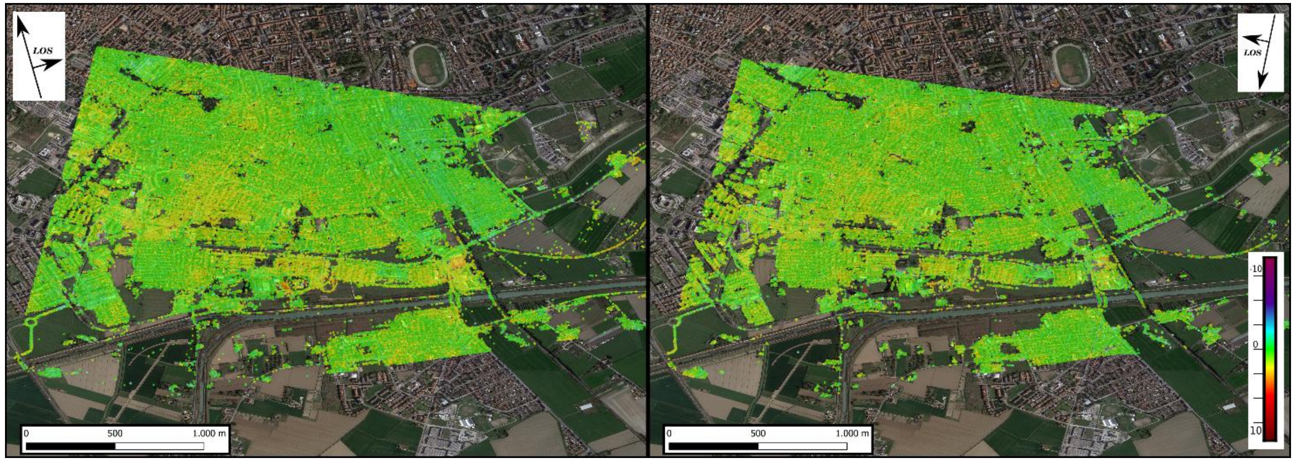
Ground motion monitoring
Field survey and risk mitigation plan

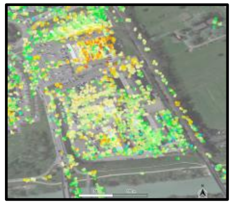


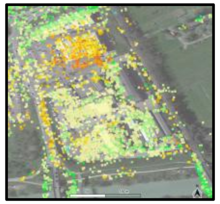
Ravenna pilot: “Archaeological harbor of Classe”
Threats: historical subsidence/differential deformation SAR Techniques analyses

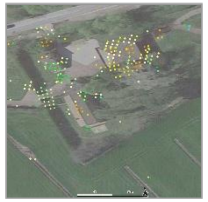


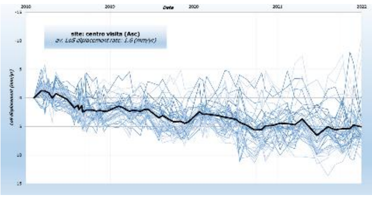




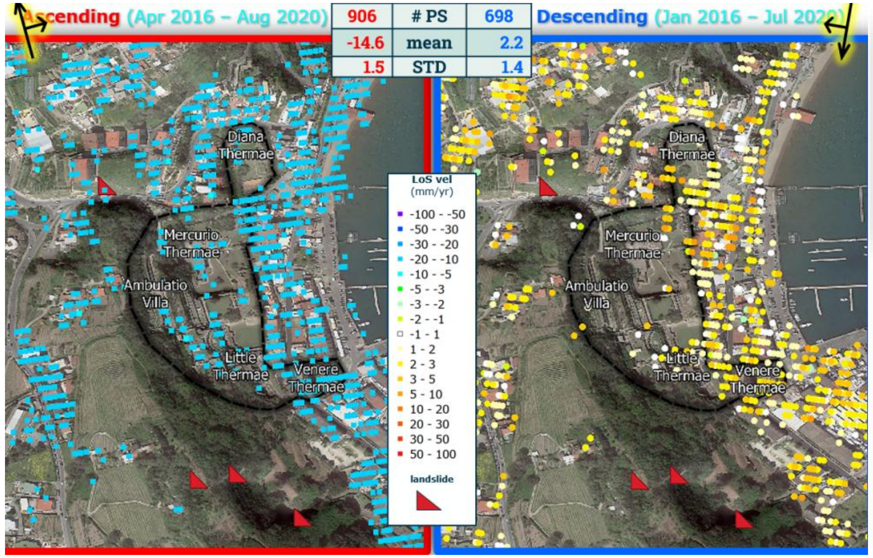


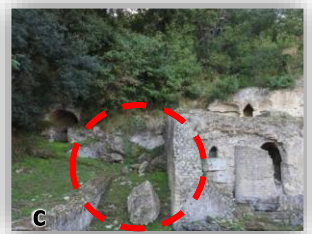


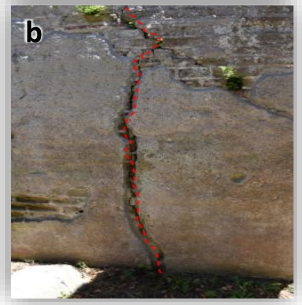


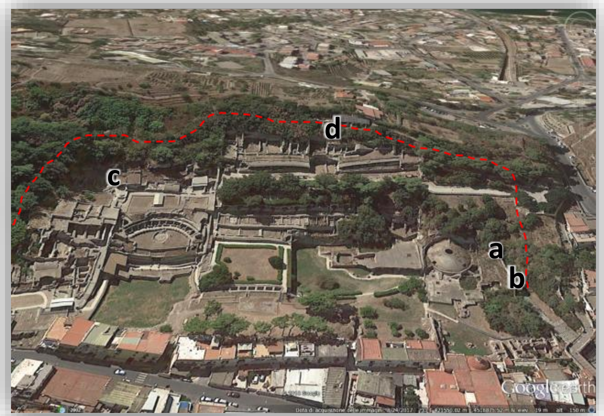


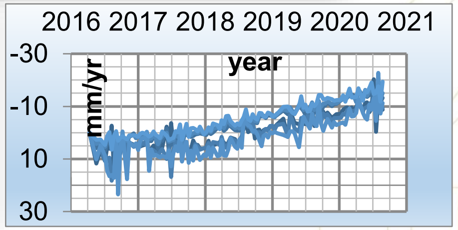
Campi Flegrei pilot: “Archaeological thermae of Baia”
Threats: uplift, rock fall and sea level rise
SAR Techniques analyses











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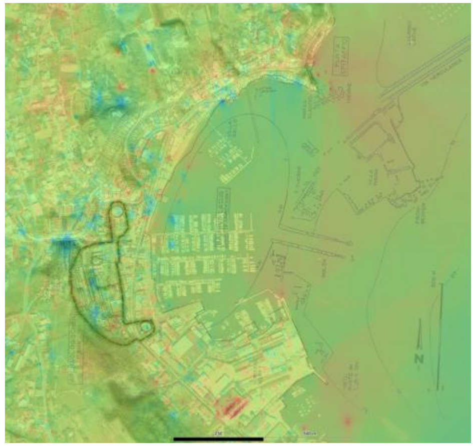
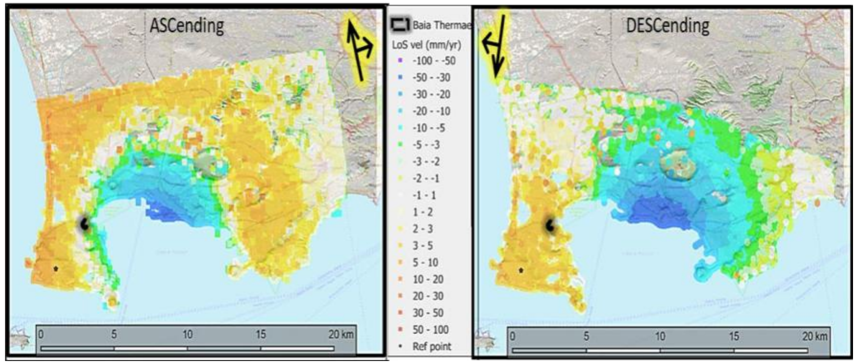
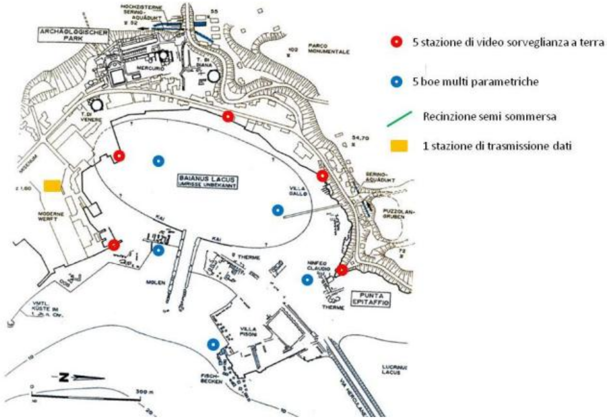
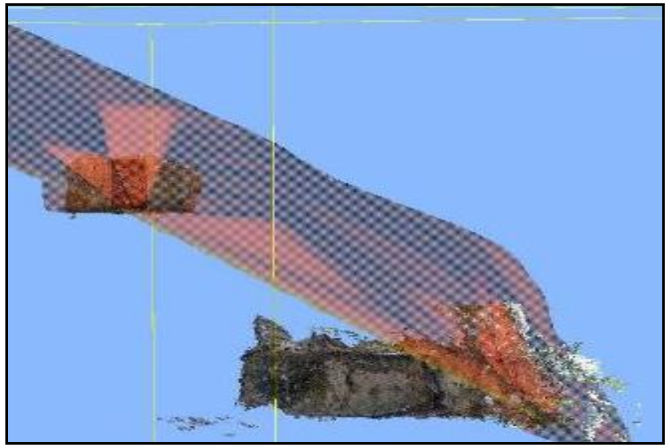
Parco sommerso di Baia pilot: “Archaeological submarine area”
Threats: subsidence and bradism, co-seismic effect morphological phenomena,
SAR Techniques analyses

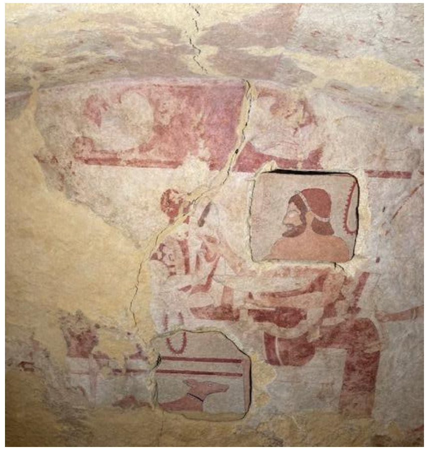


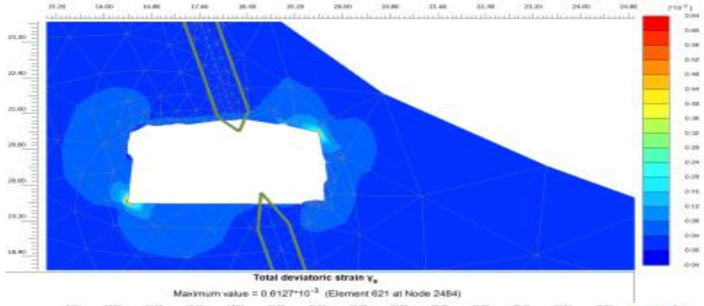


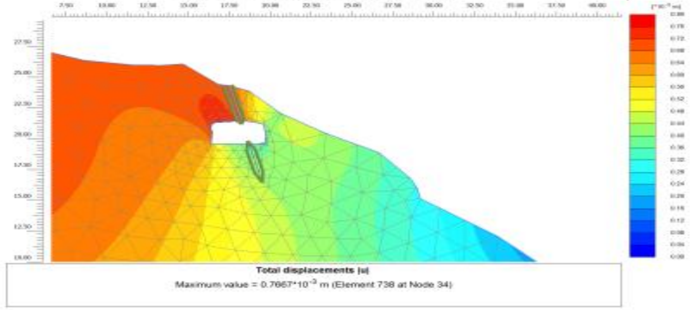


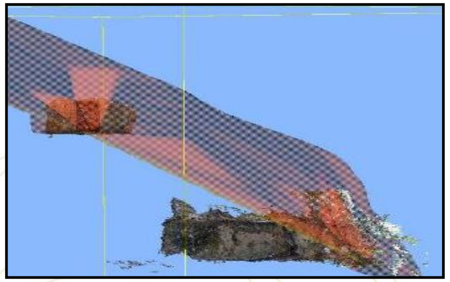
Tarquinia pilot: “Archaeological Etruscan Necropolis”
Threats: Drought, weathering, lateral spreading
Crack gauges monitoring





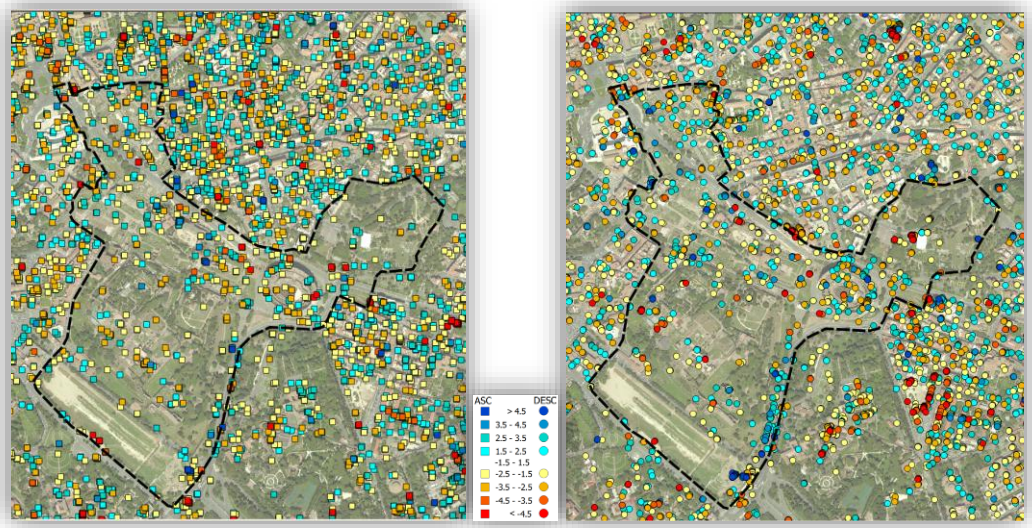


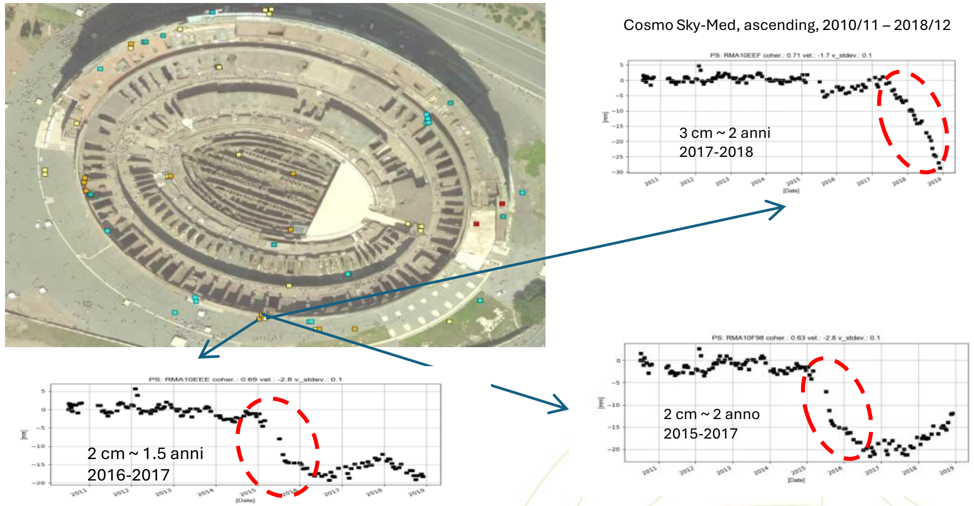




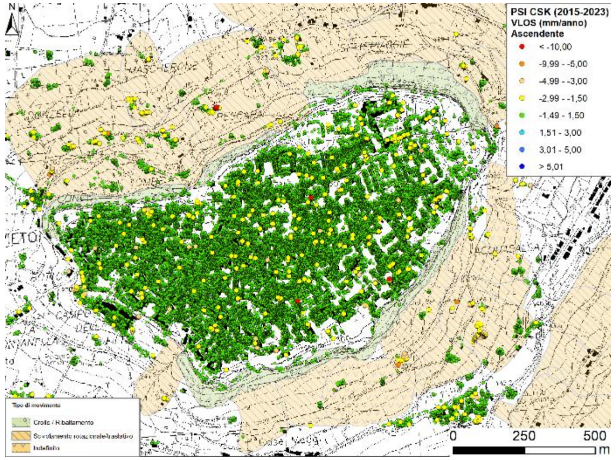
Paestum pilot: "Archaeological roman Park"
Threats: water table fluctuation, weathering, SAR Techniques analyses

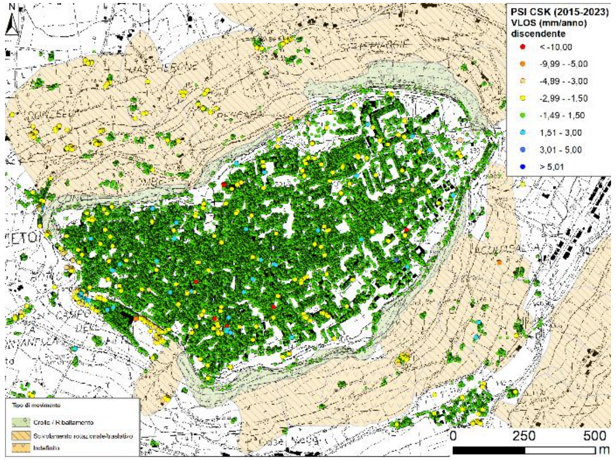
Rome pilot: "Colosseo Park & Aurelian Walls "
Threats: weathering, transportation dynamic interaction, collapses. **SAR Techniques analyses**

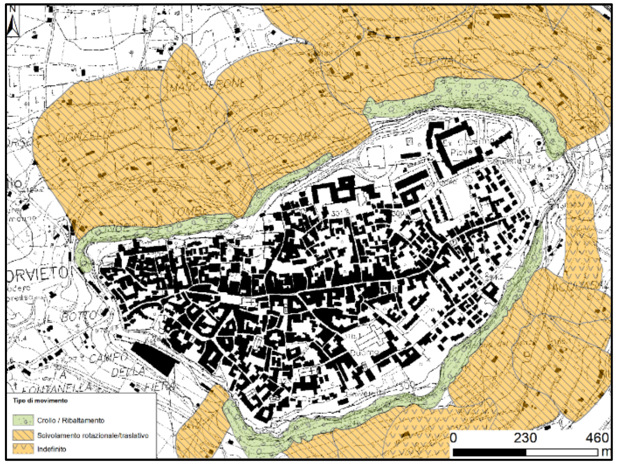




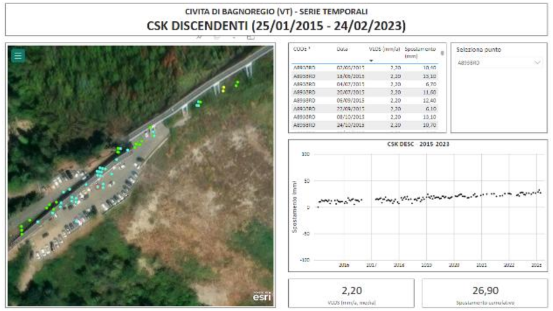
Orvieto pilot: "Historical small town"
Threats: slow landslide; water table fluctuation
SAR Techniques analyses

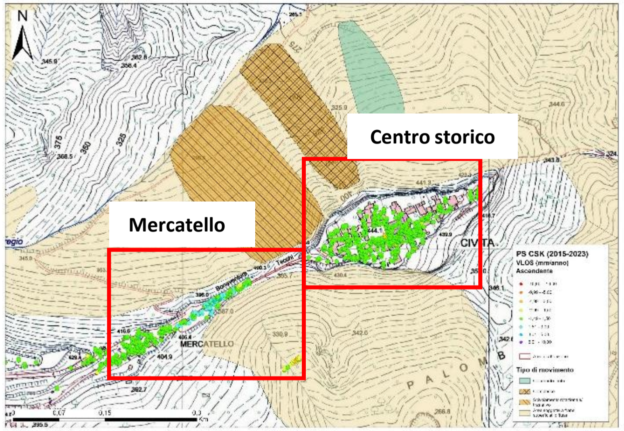


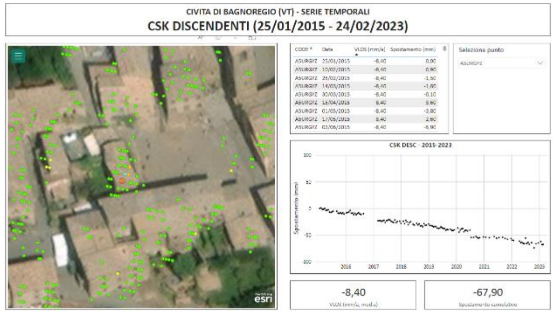


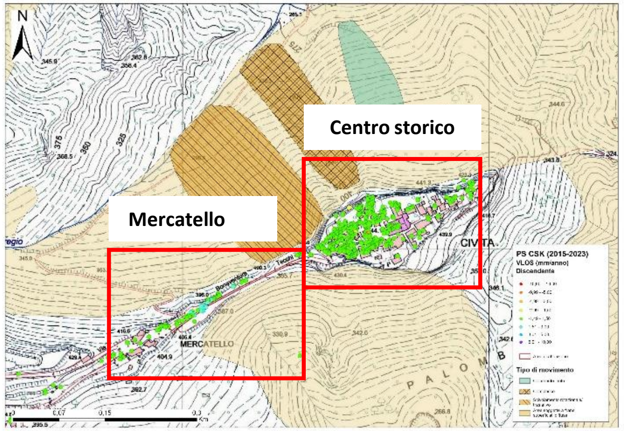


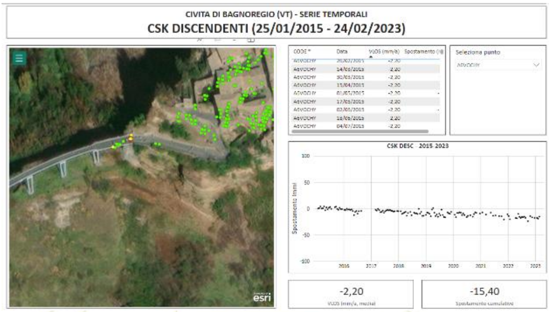
Civita pilot: "Historical village"
Threats: slow landslide & ground deformations
SAR Techniques analyses











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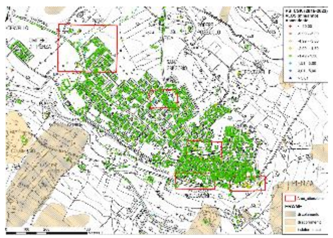
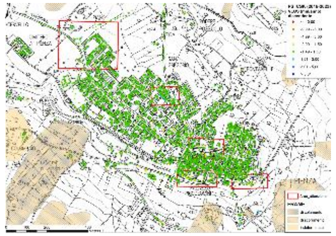
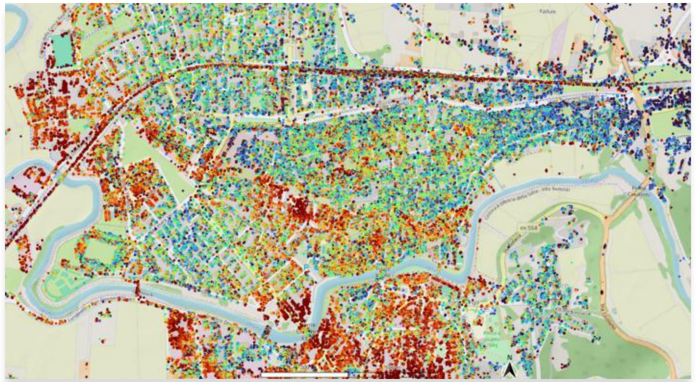
Pienza pilot: “Historical small town”
Threats: DGPV/regional fault; sructural damage: SAR Techniques analyses

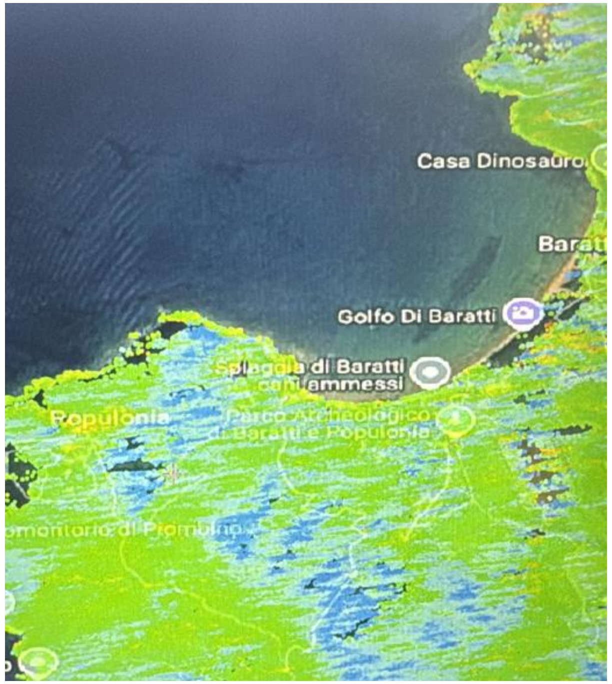




RIETI pilot: “Historical center”
Threats: slow landslide; water table fluctuation SAR Techniques analyses



Baratti&Populonia pilot: “Archaeological area”
Threats: subsidence and morphological phenomena ground motion, SAR Techniques analyses



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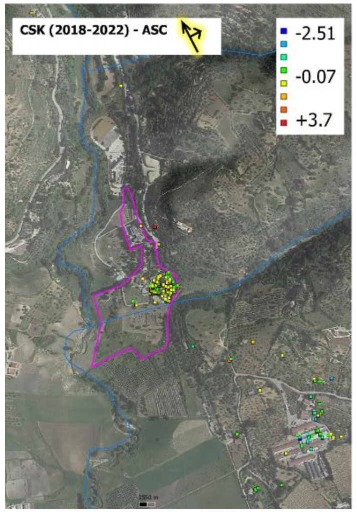
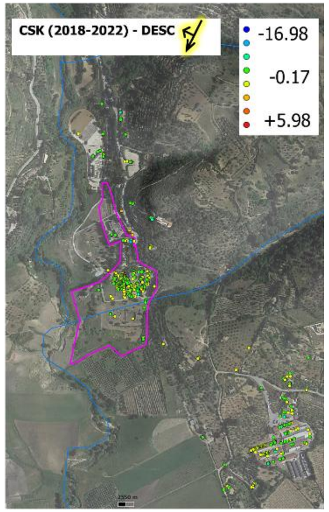
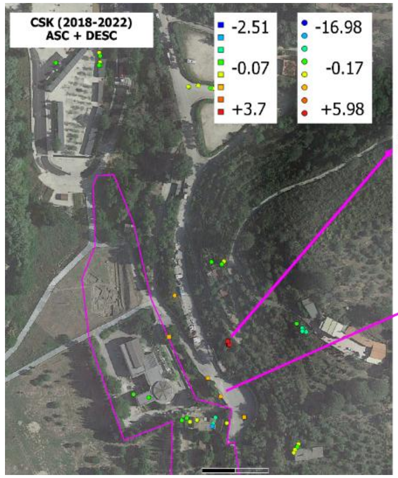
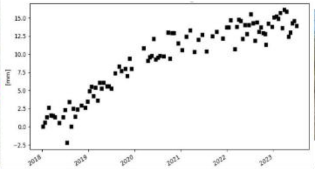
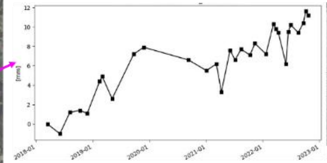
Piazza Armerina pilot: “Roman mosaic”
Threats: slow and rapid landslide; water table fluctuation
SAR Techniques analyses



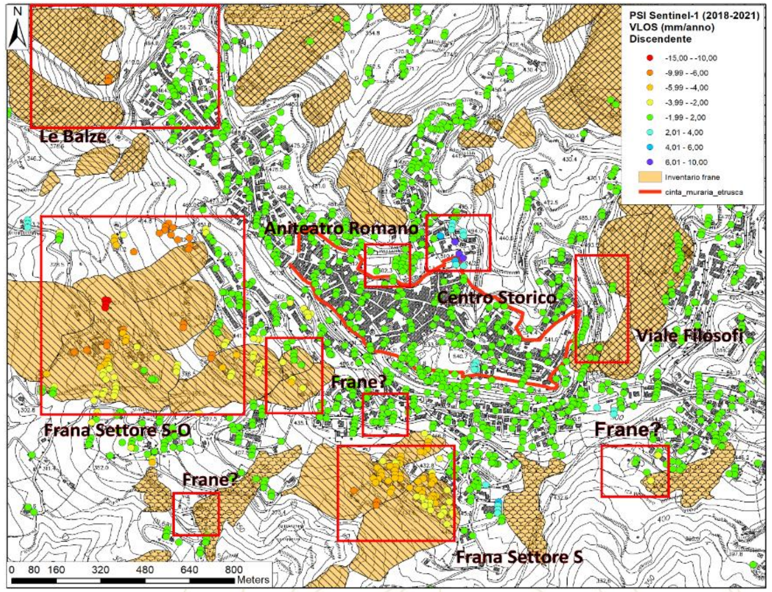




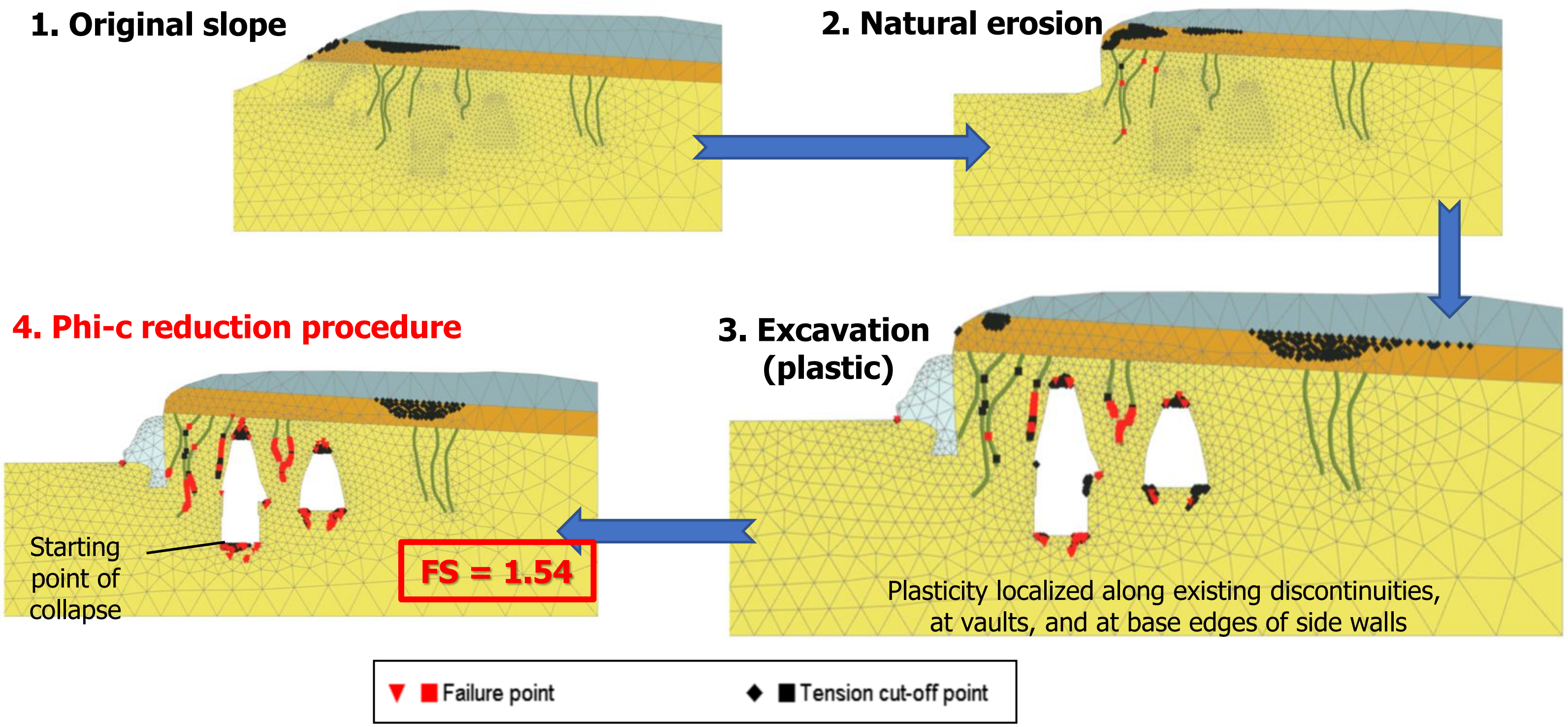


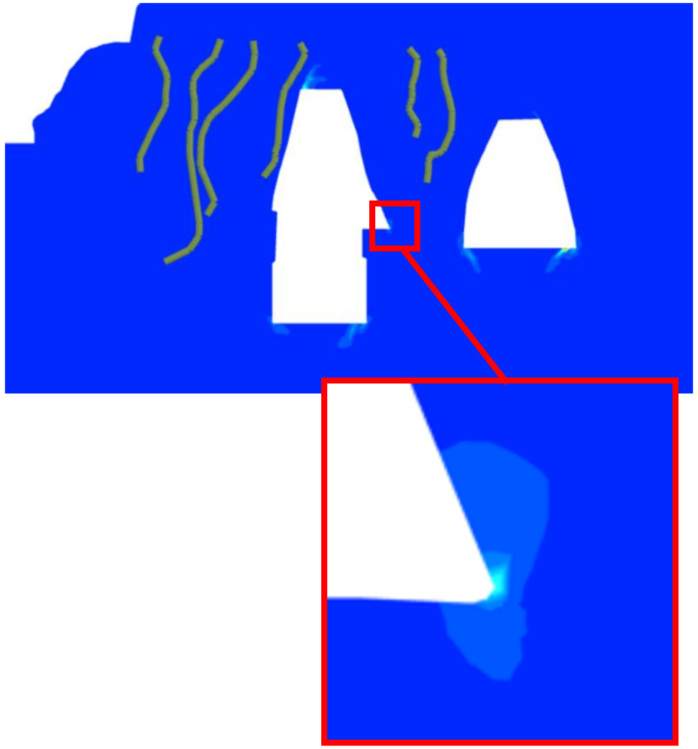


Volterra: “Historical village and medieval walls”
Threats: slow landslide
SAR Techniques analyses

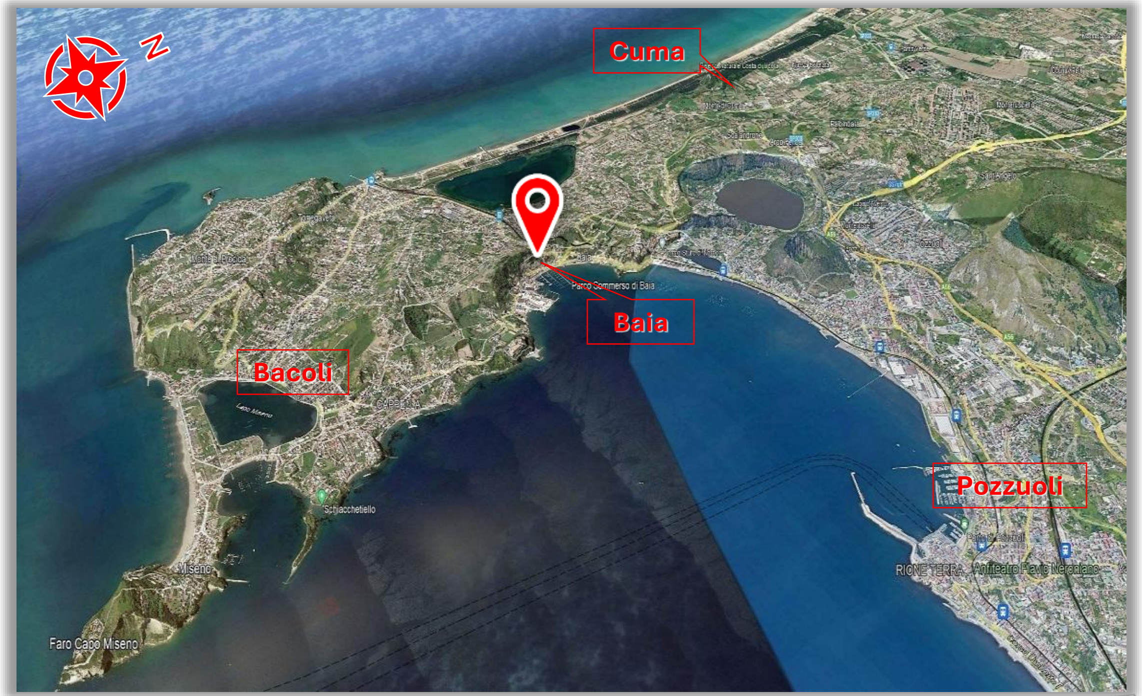


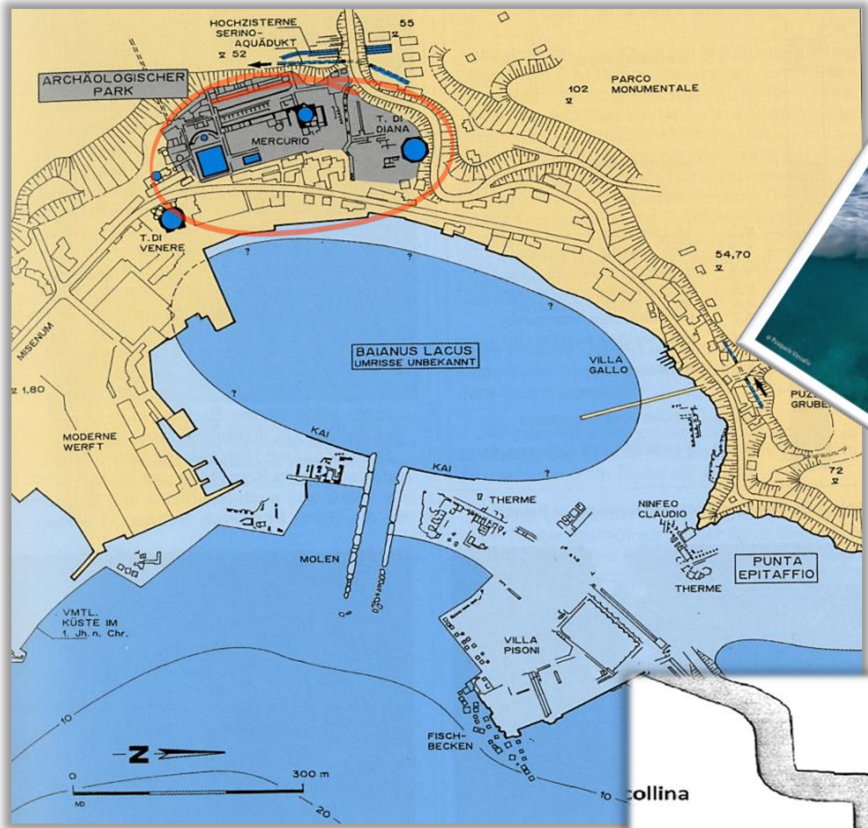
CUMA: evolution of the Antro della Sibilla

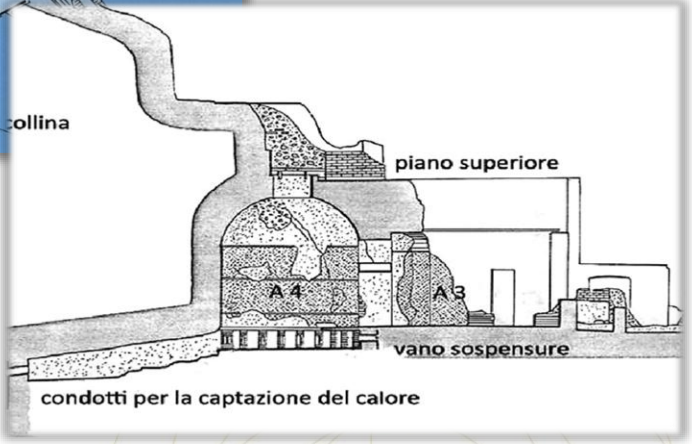




Parco Archeologico dei Campi Flegrei: Terme Romane di Baia







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Step 1

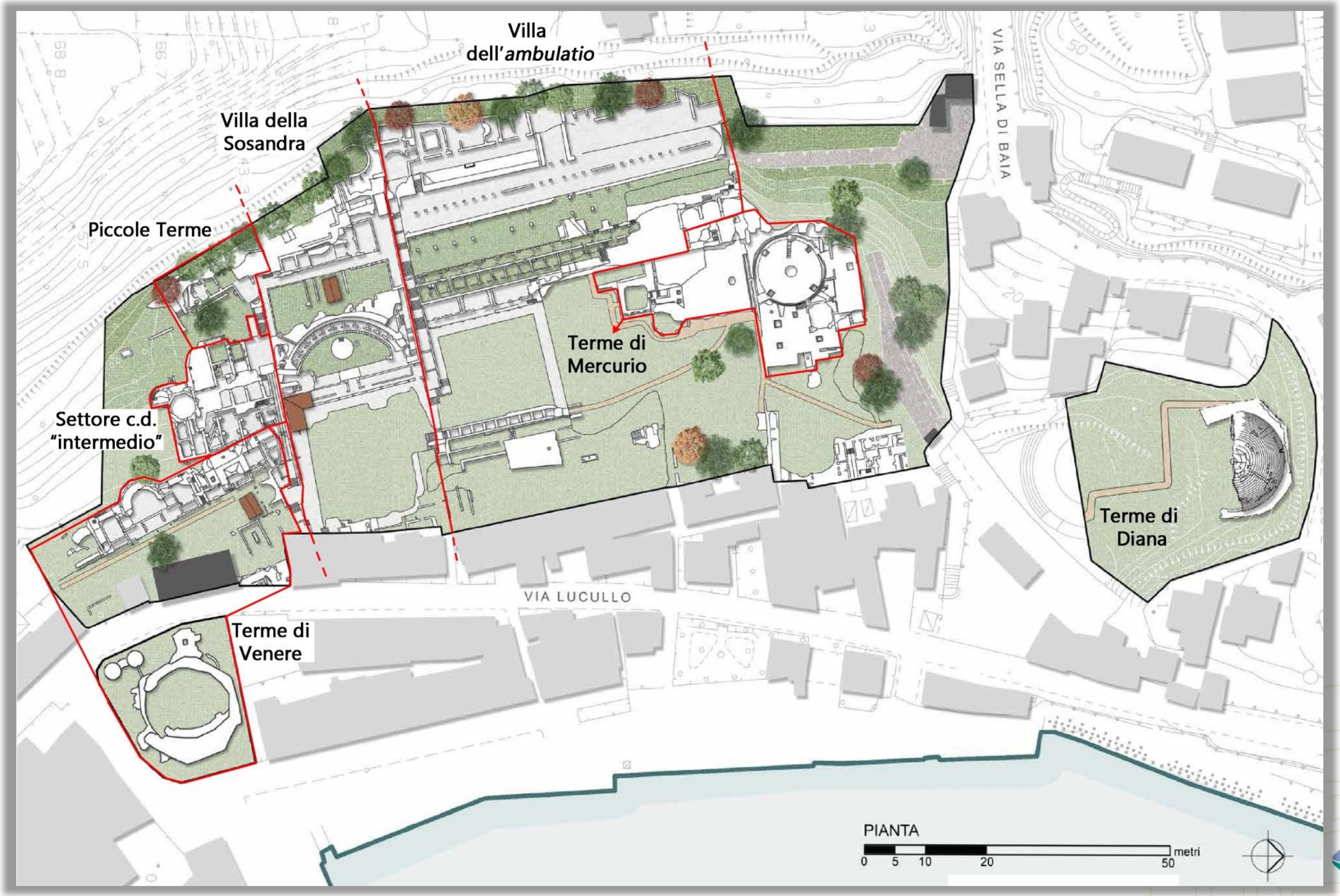
CH Background (desk and field study):
investigating the origin, typology, construction techniques, restoration history, evolution in time, etc.

Geohazard assessment
Hazard and risk map analysis and field survey

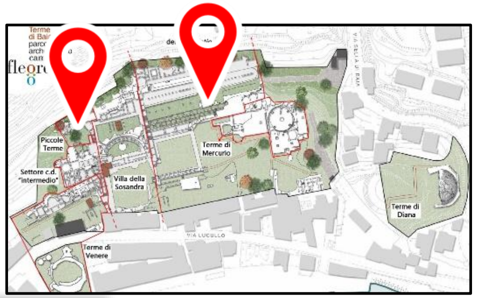
SAR Interferometry
Data integration and services

Ground motion monitoring
Field survey and risk mitigation plan

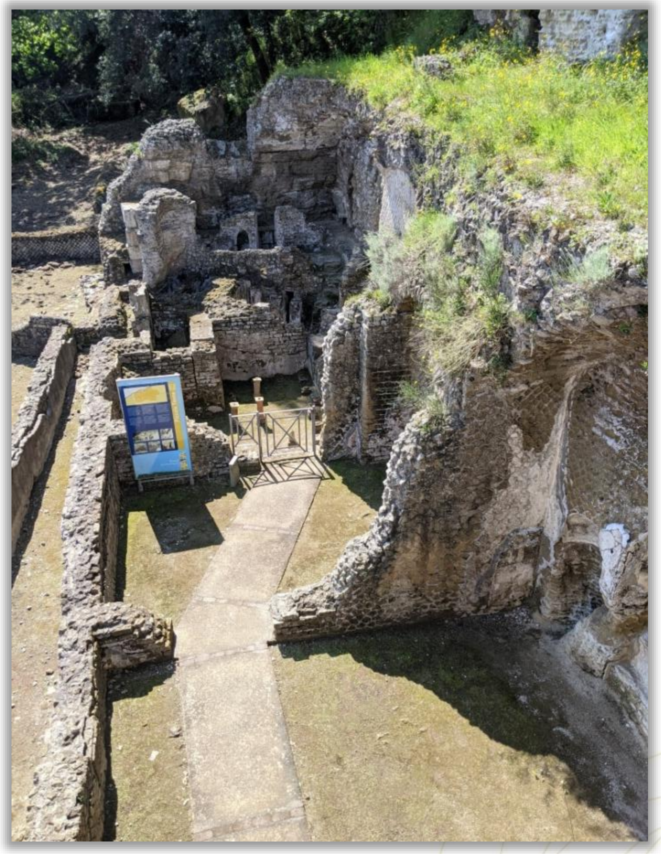
Roman Bath of Baia



Roman Bath of Baia

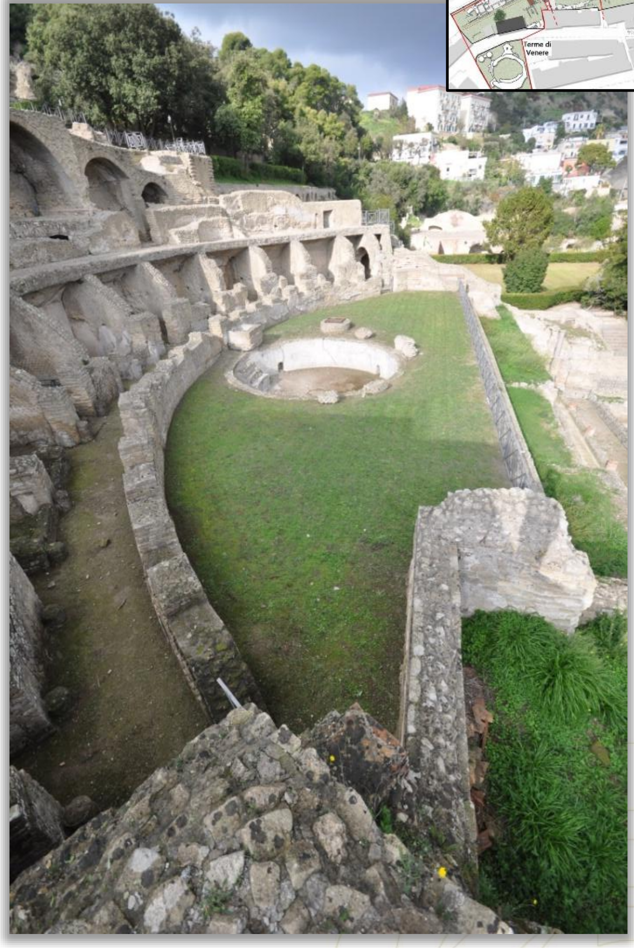


Ambulatio Villa and Little Thermae are the older complexes, originally connected: a small thermal bath serving a majestic residence built on seven terraces.



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

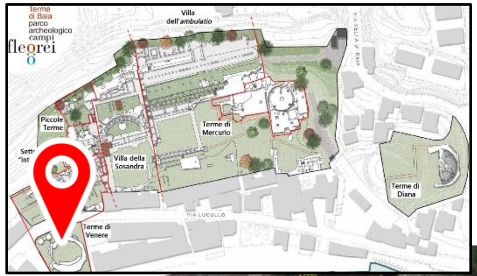
The wealth of thermal resources led to the the rise of majestic thermal complexes, with large domed halls.

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.

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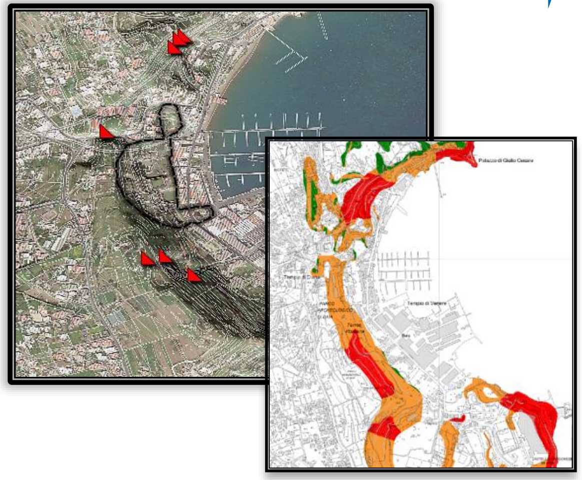
Step 2

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

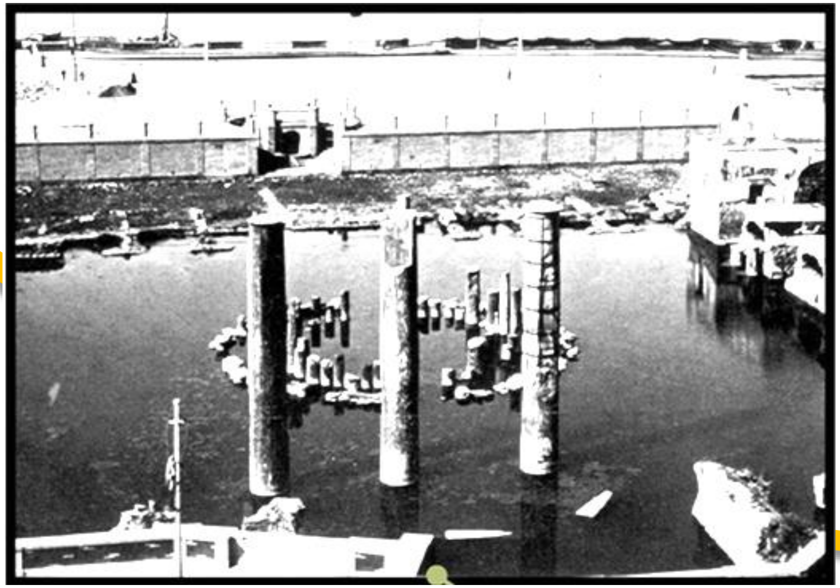
Ground motion monitoring

Field survey and risk mitigation plan

Bradisism phenomena ed effect

1830

1953



2000

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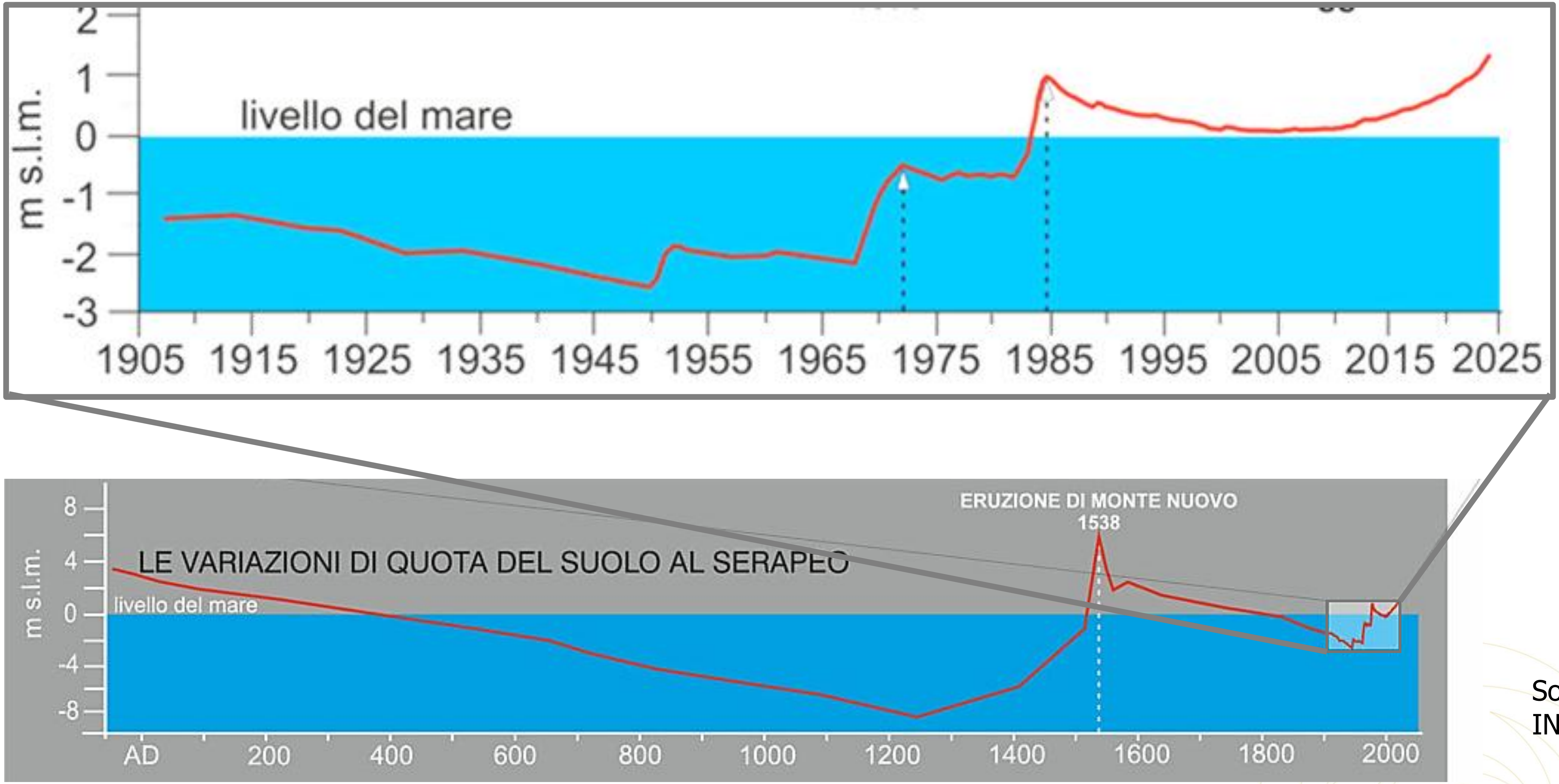
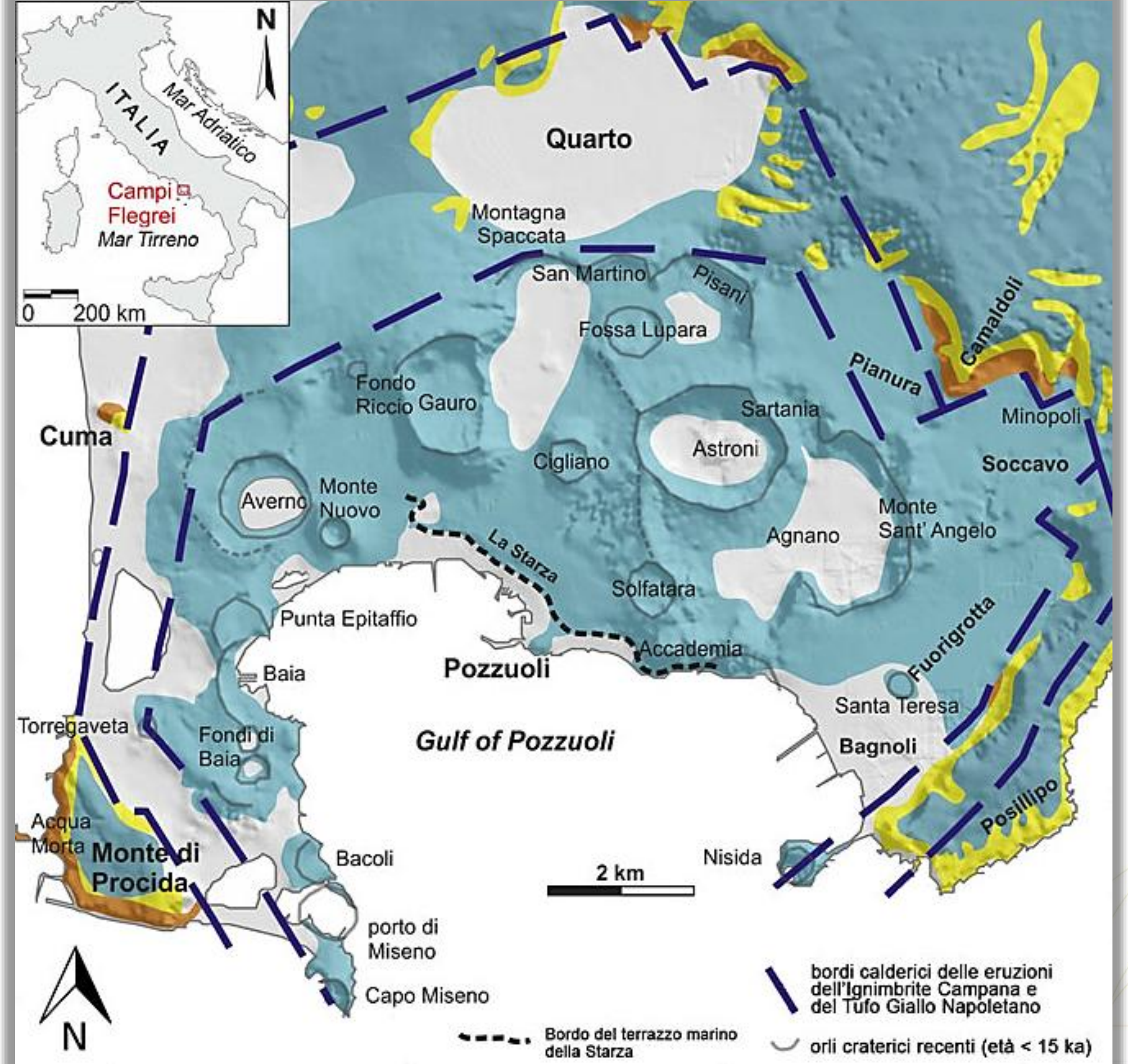
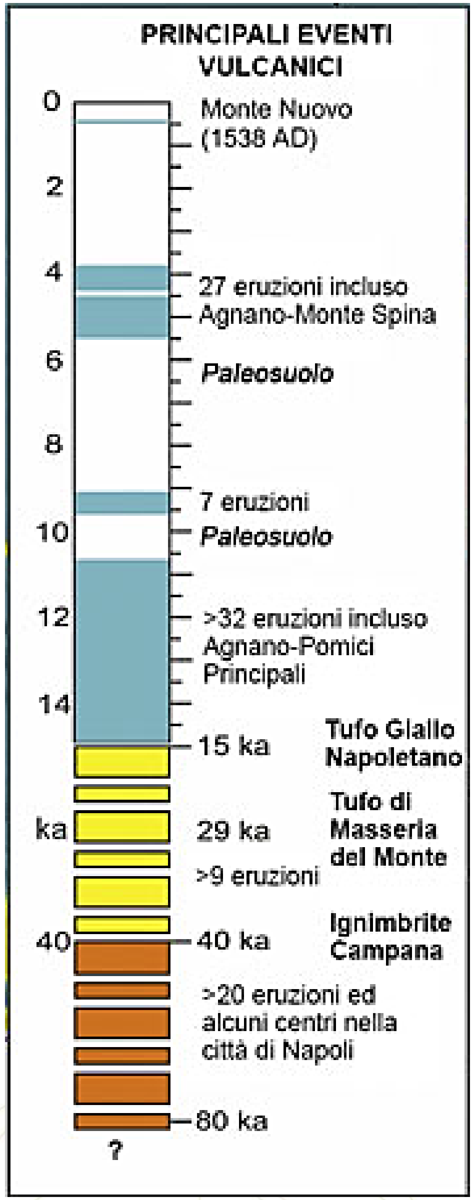
Bradisism phenomena ed effect



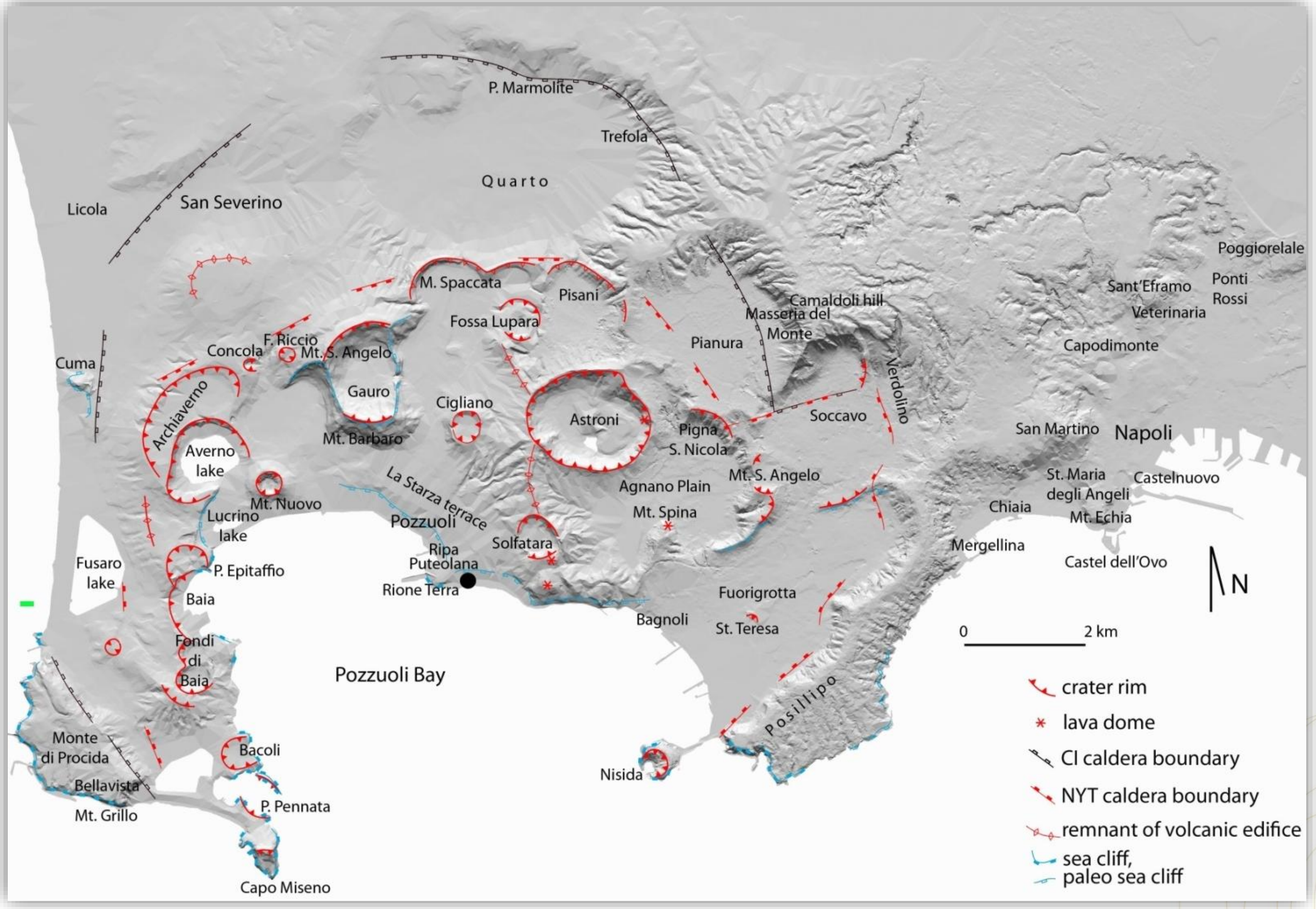
Source: INGV-OV

Geological setting





GEO – HAZARD Assessment



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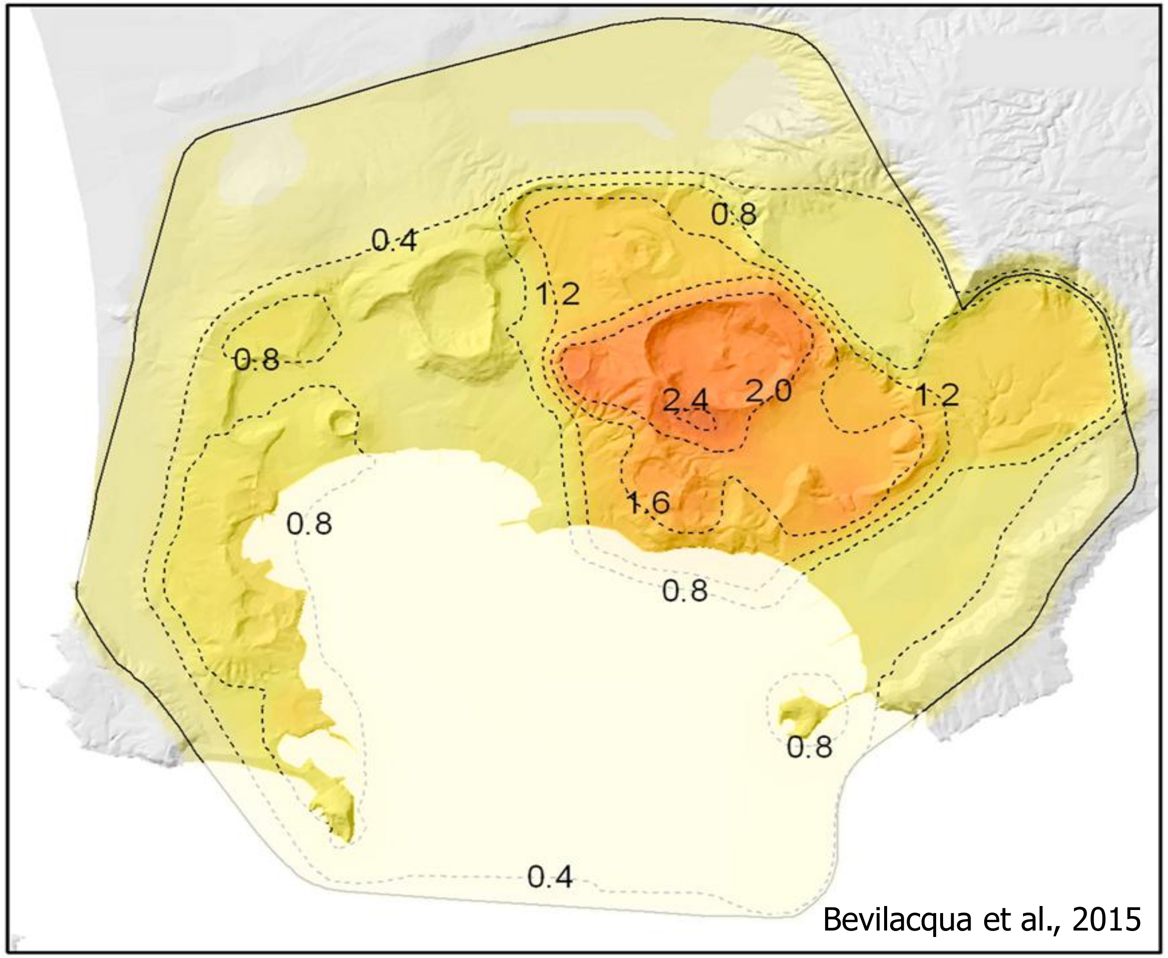
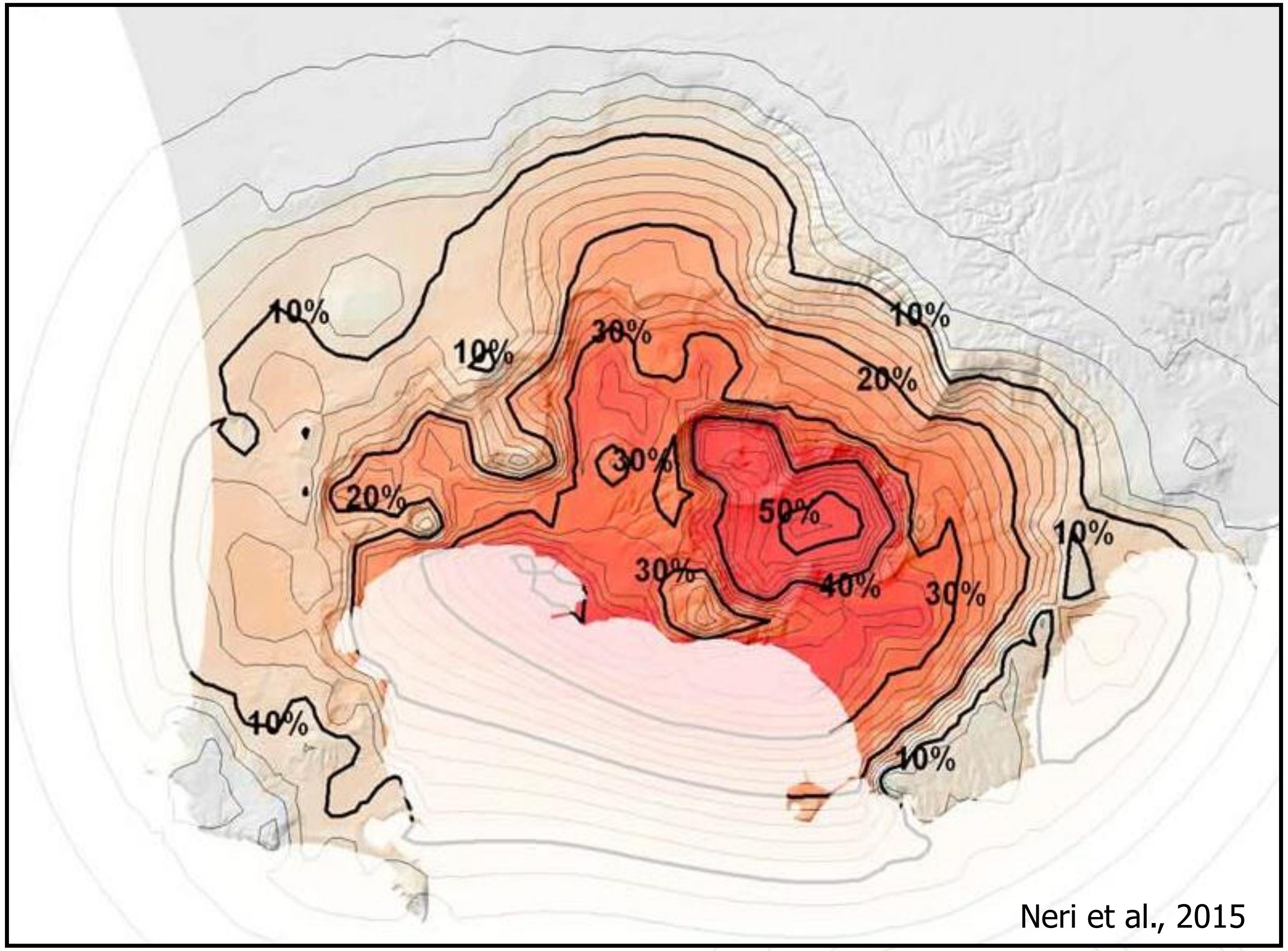
Volcanic hazard map

New open probability

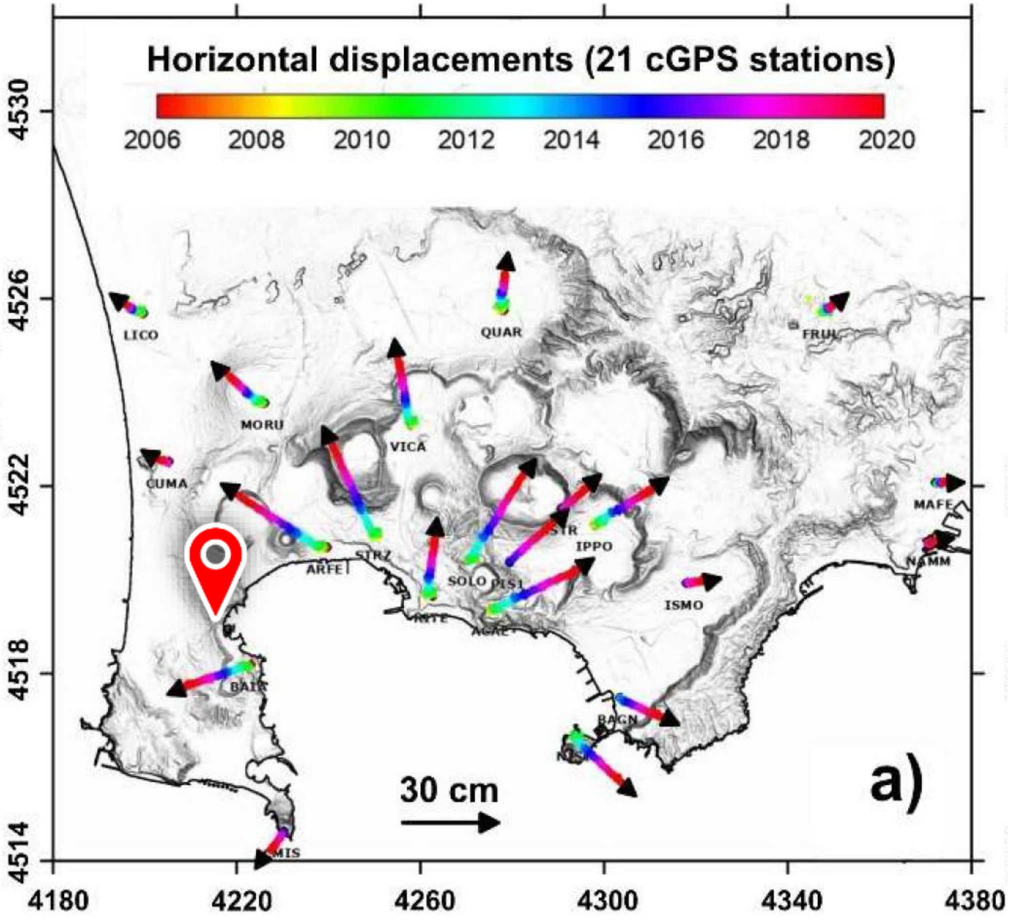


Ash propagation fall probability

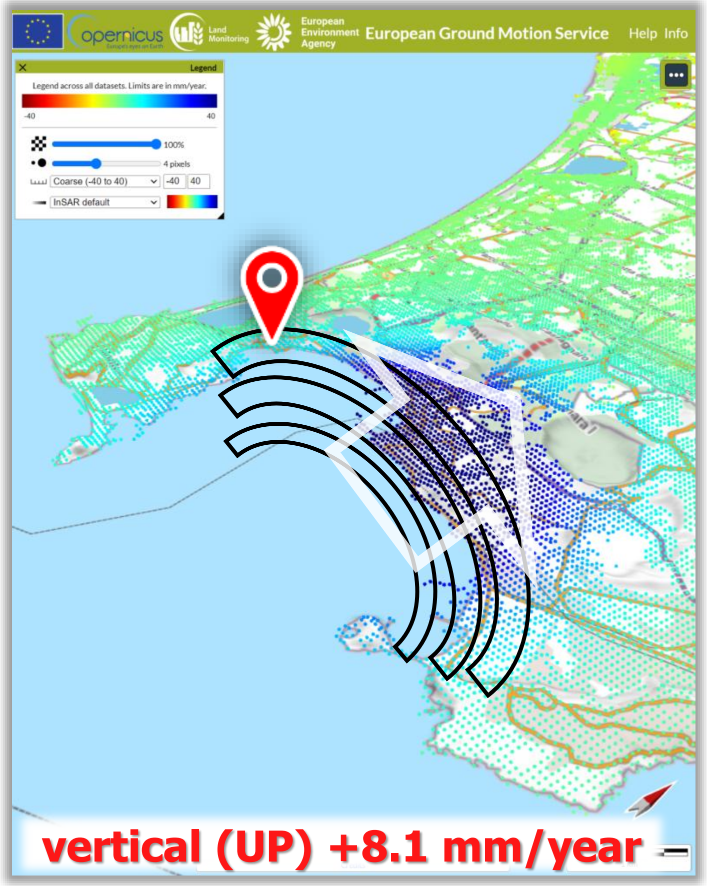


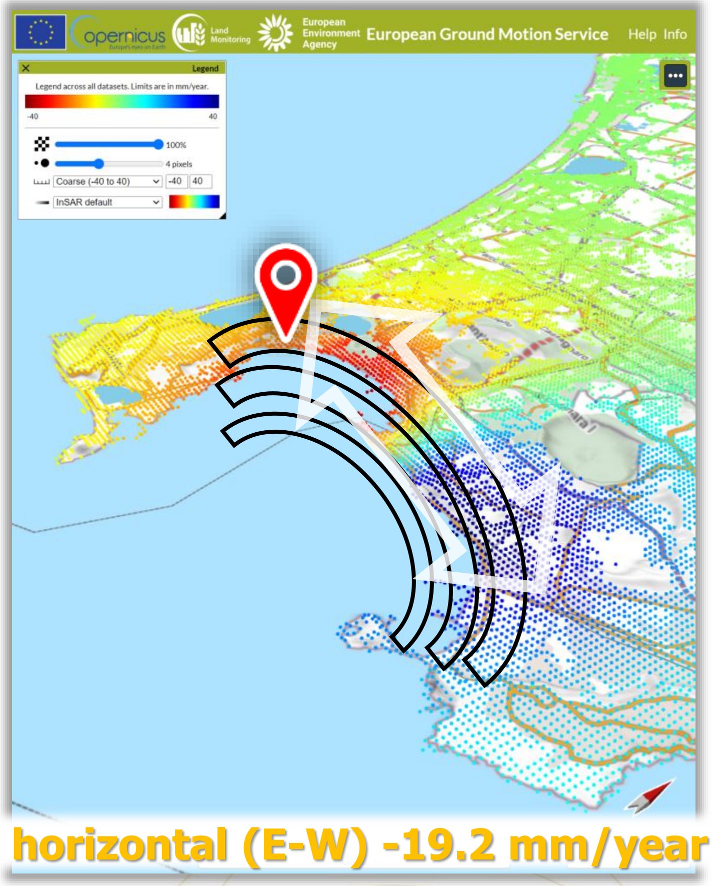
The monitoring system

GNSS: INGV network



InSAR: European Ground Motion System





Landslide hazard map

Piano di
Assetto
Idrogeologico

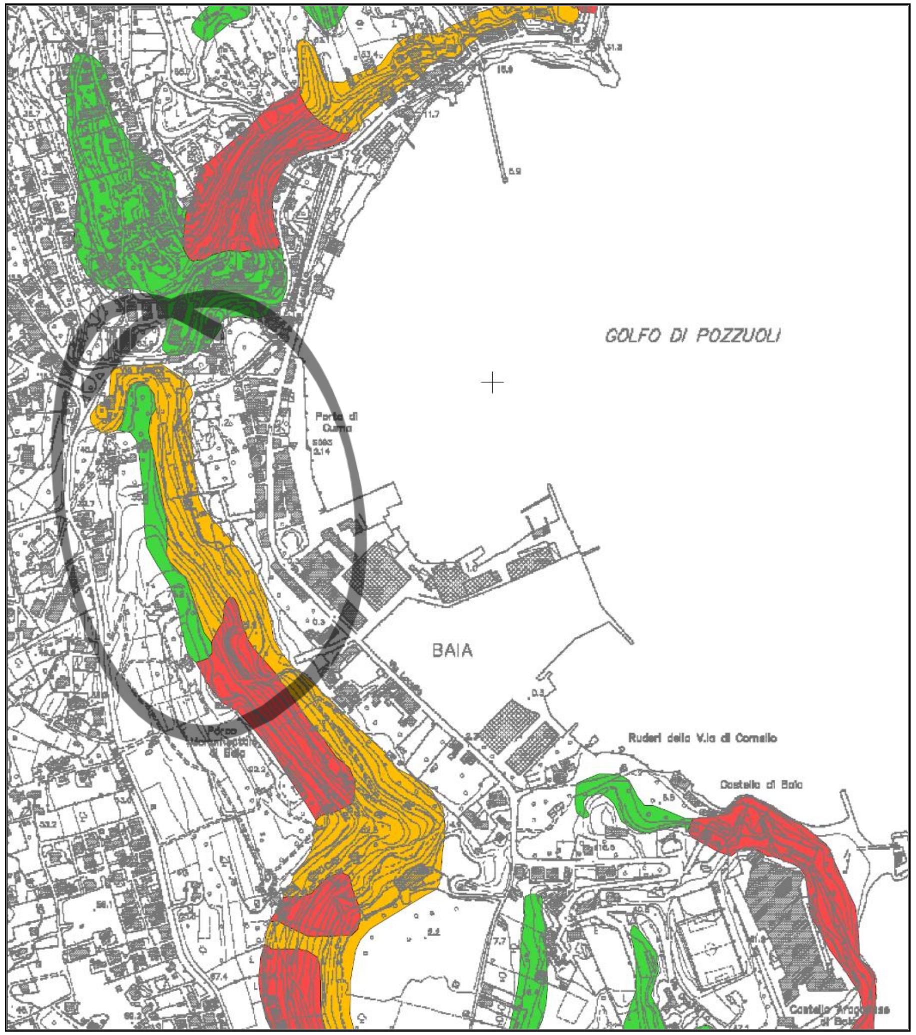
Very high

High

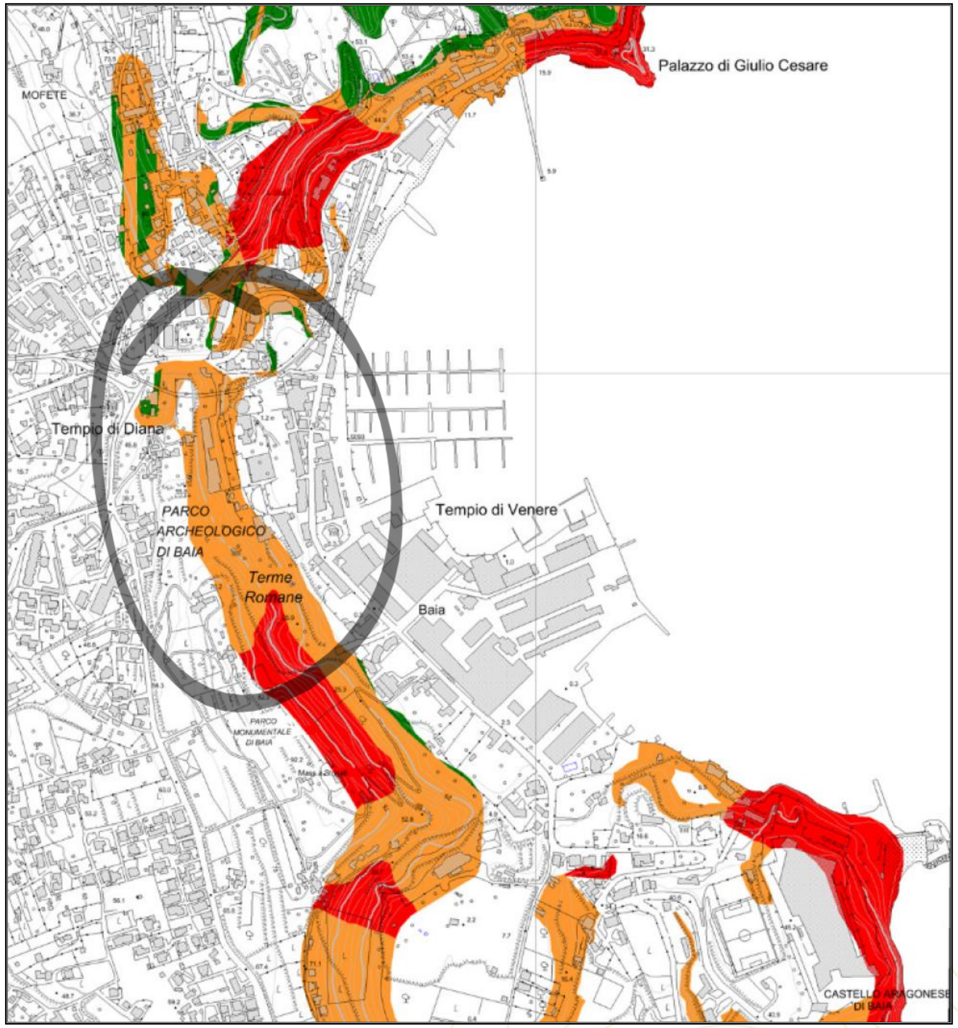
Medium

Low

Landslide susceptibility

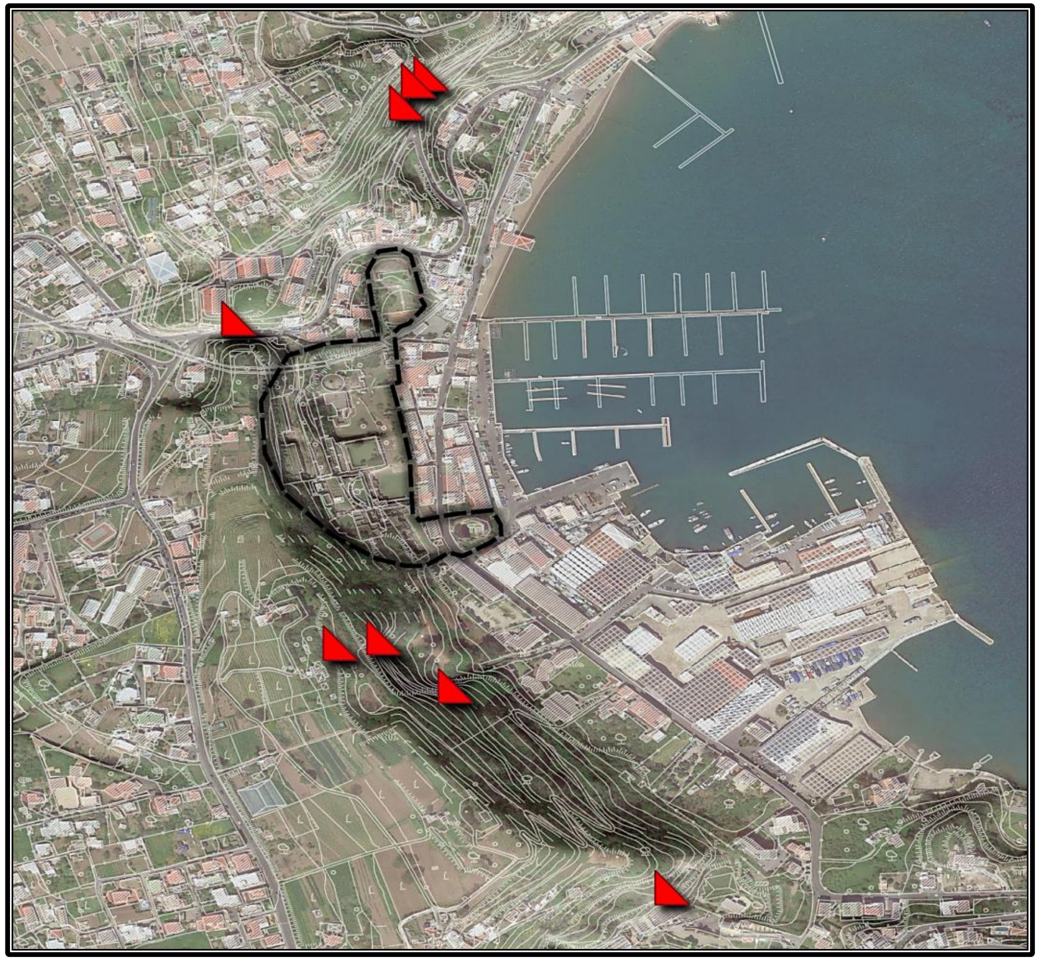


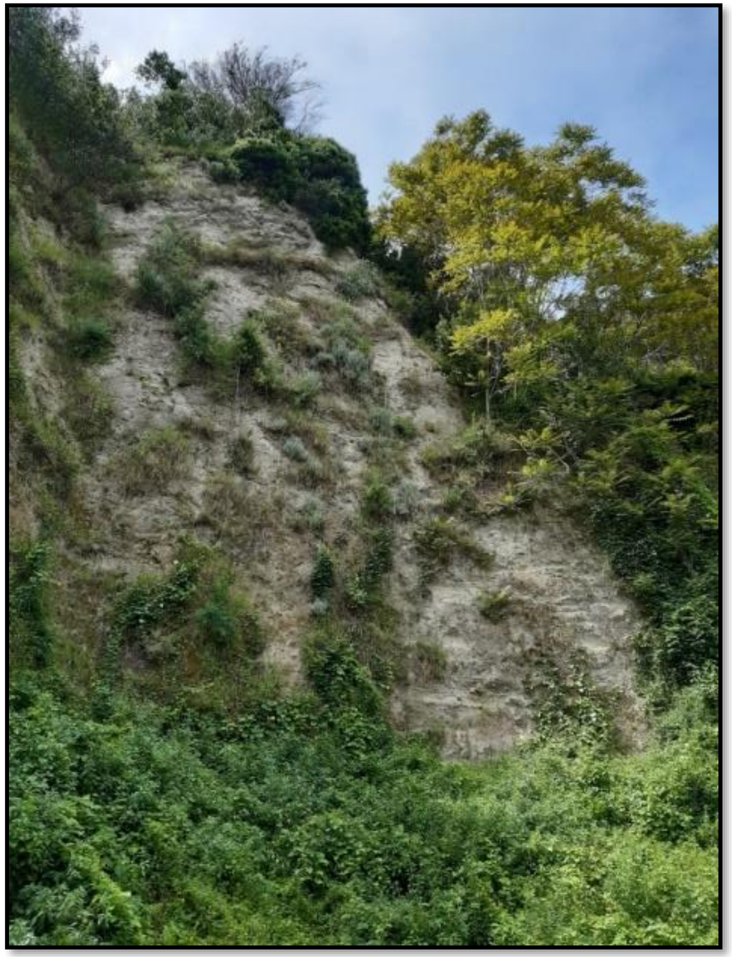
Landslide risk



Landslide local inventory and updated map

Frane





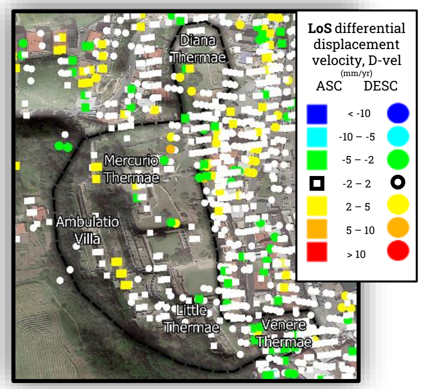
Tipologie prevalenti
- crolli
- caduta di blocchi

Step 3

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

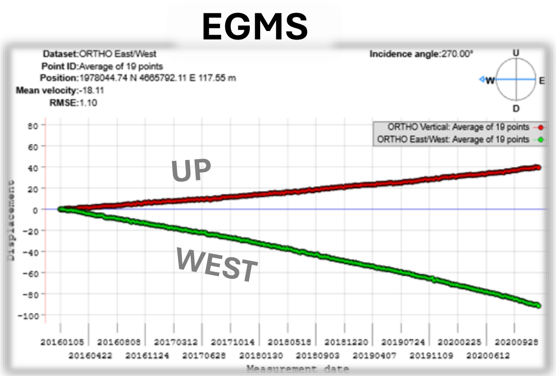
Geohazard assessment
Hazard and risk map analysis and field survey

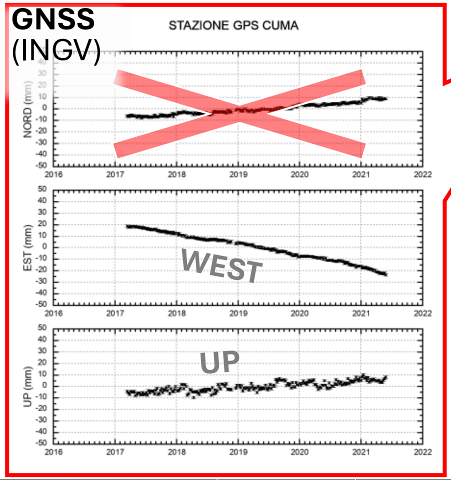
SAR Interferometry
Data integration and services

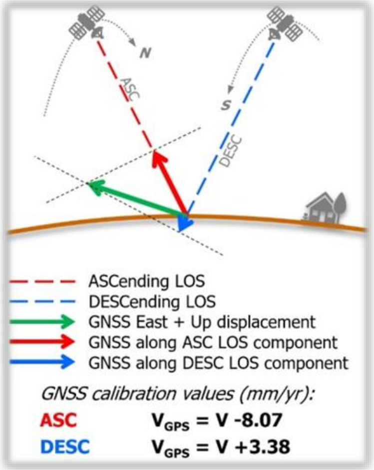


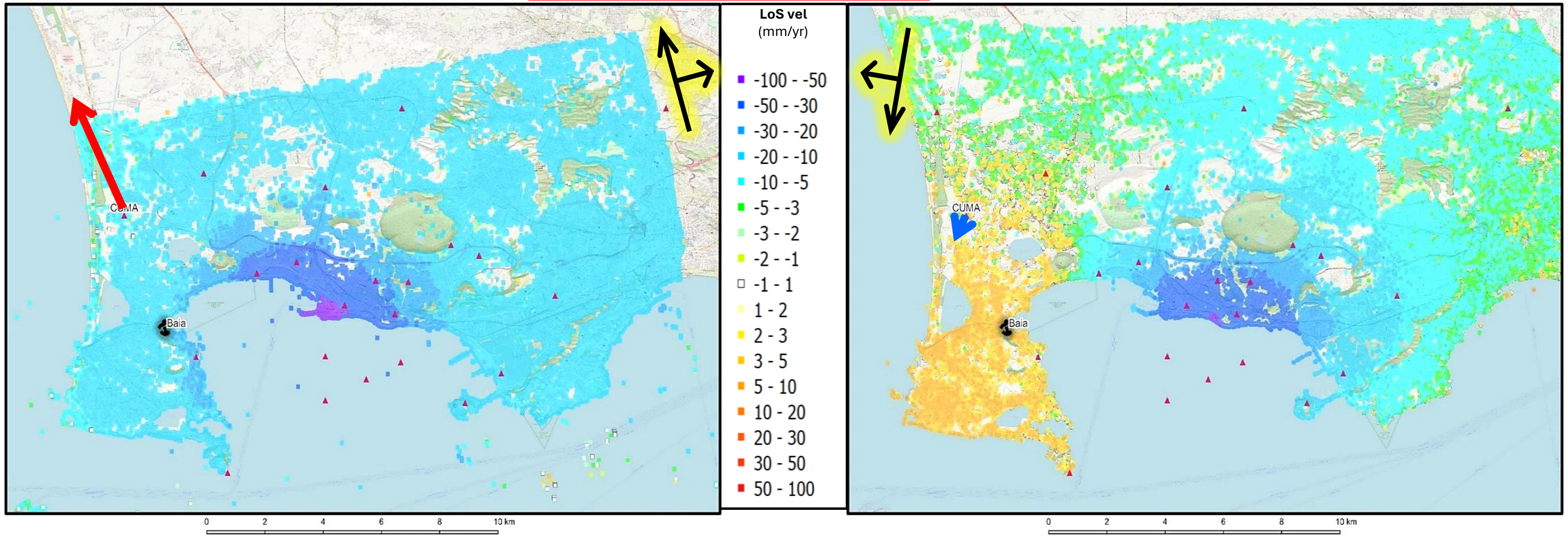
Ground motion monitoring
Field survey and risk mitigation plan

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.

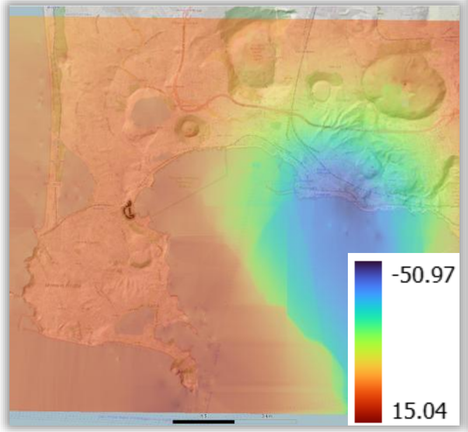
ISPRA and INGV have developed a PS InSAR product calibrated with the GNSS data, in ascending and descending geometry, showing displacements along the respective LoS.

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

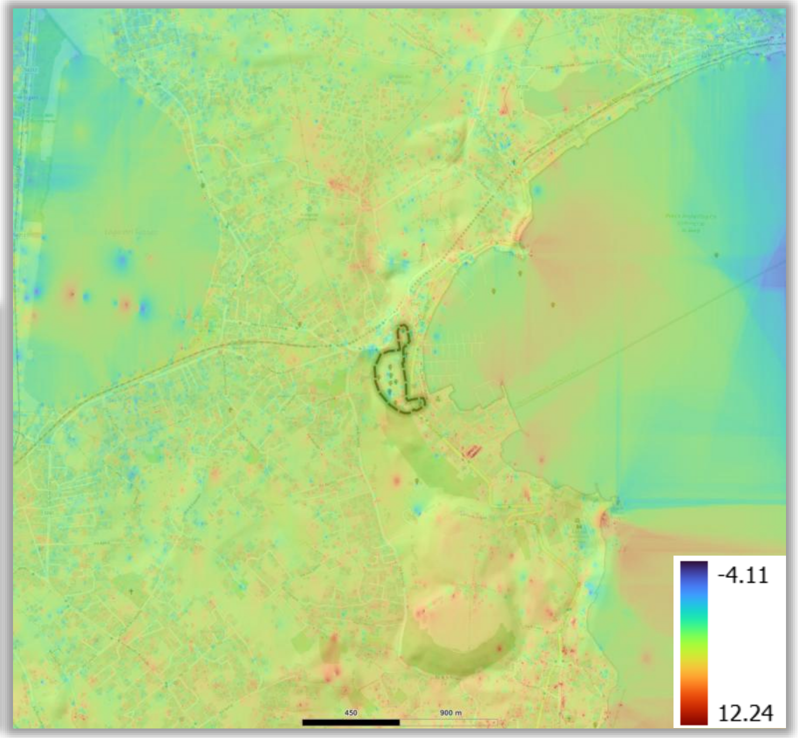
InSAR Analysis: *heatmap analysis*

DESC LoS displacements
(mm/year)

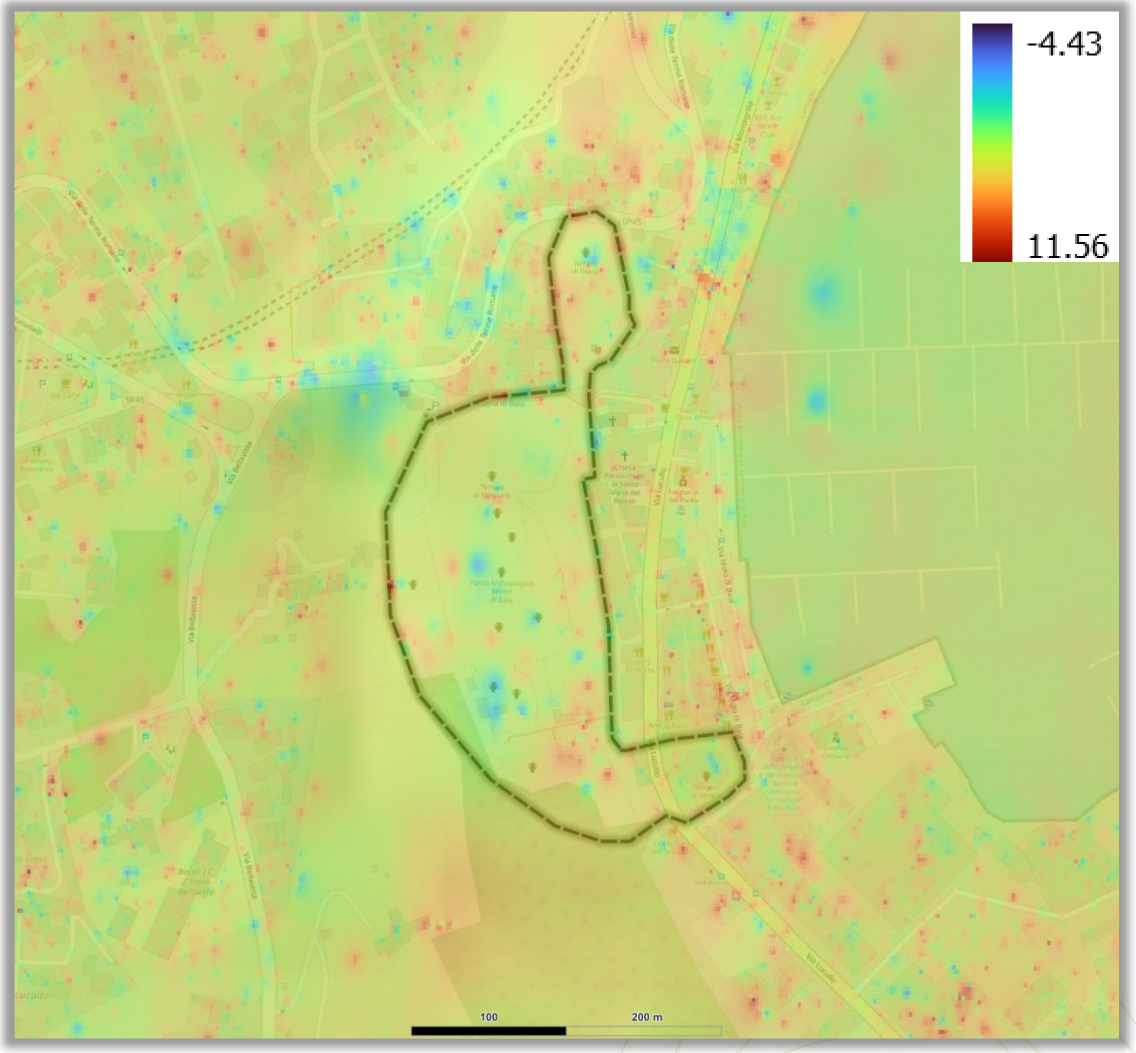
1:25.000



1:10.000



1:2.000



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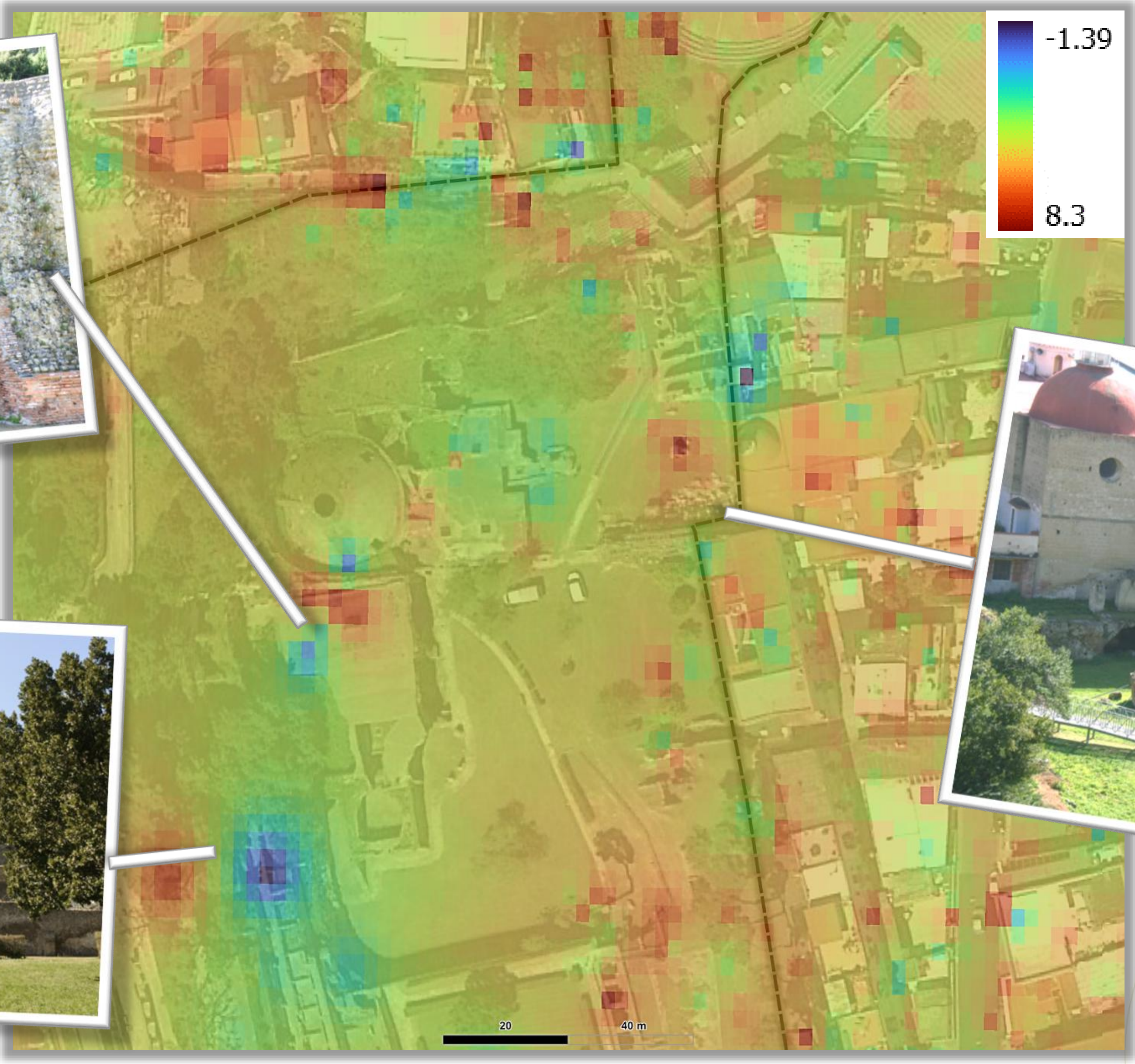
InSAR Analysis: *heatmap analysis*



DESC LoS displacements
(mm/year)
scale 1:500

Step 4

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

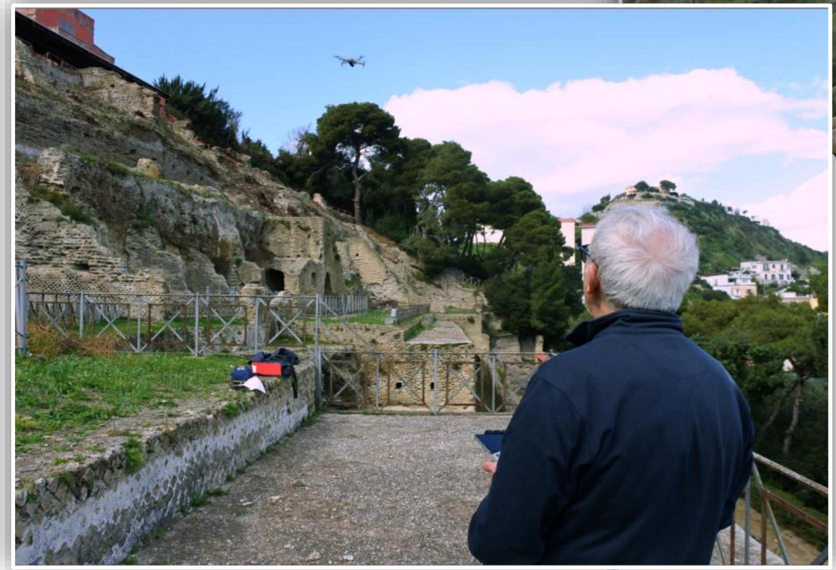
Geohazard assessment
Hazard and risk map analysis and field survey

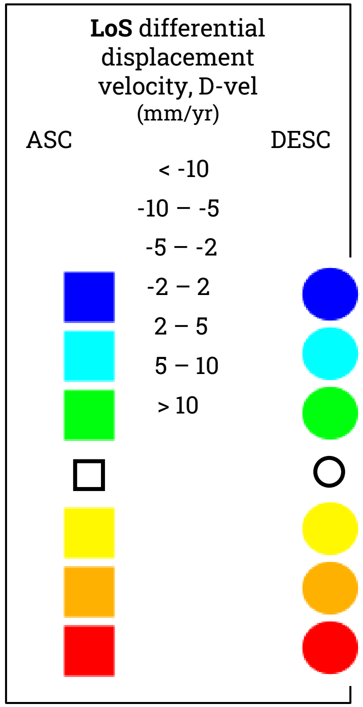
SAR Interferometry
Data integration and services

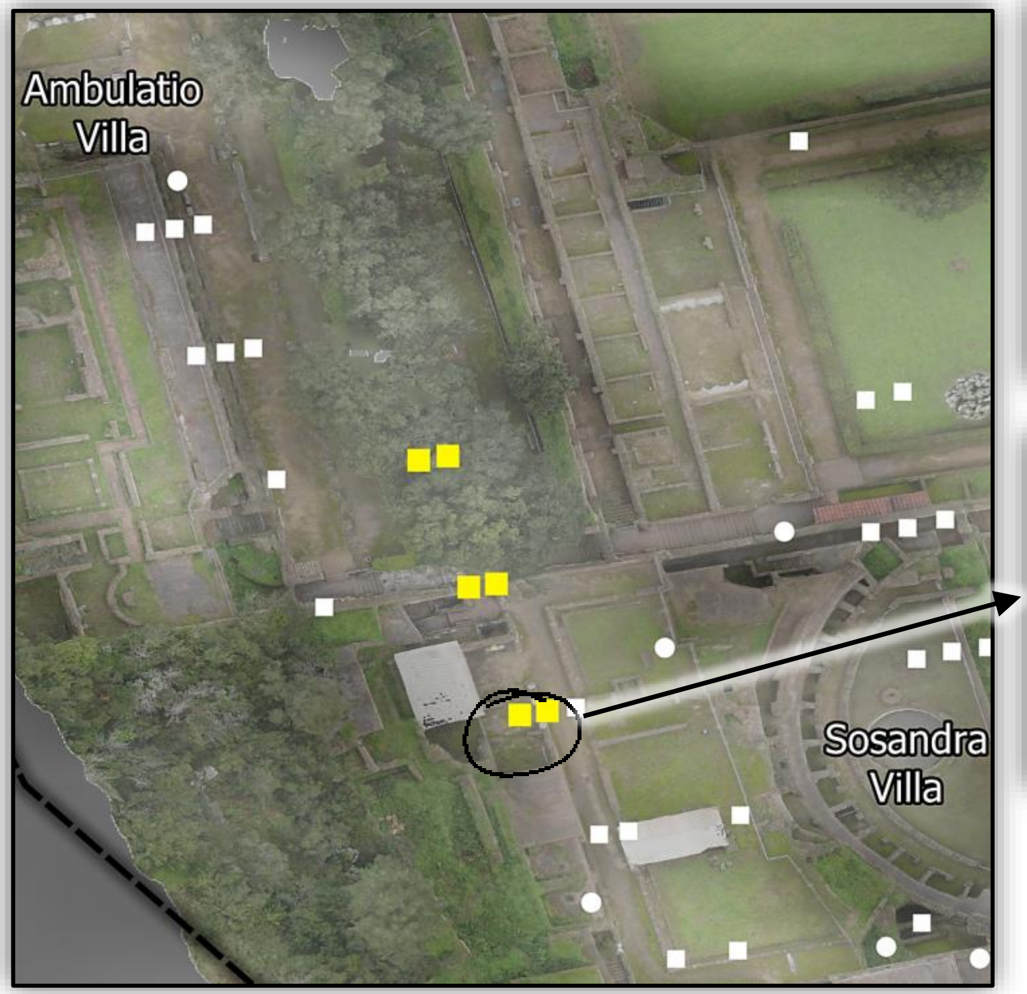
Ground motion monitoring
Field survey and risk mitigation plan

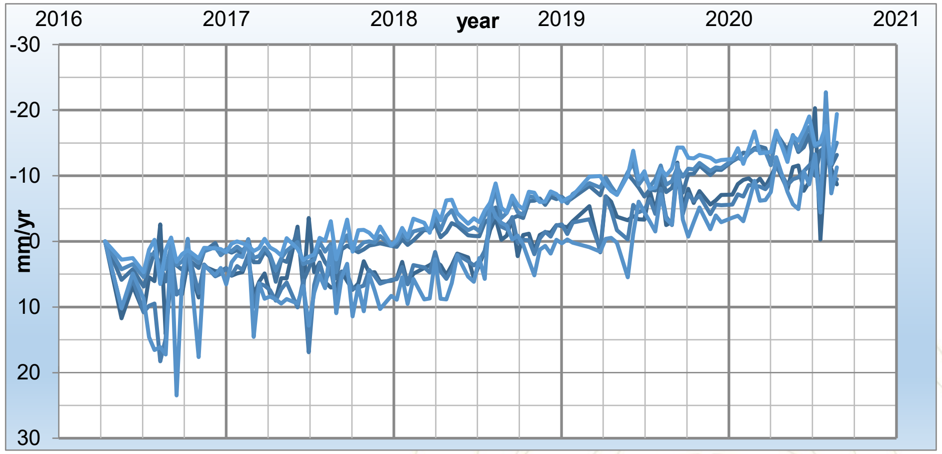
Direct survey

Rilevo 3D







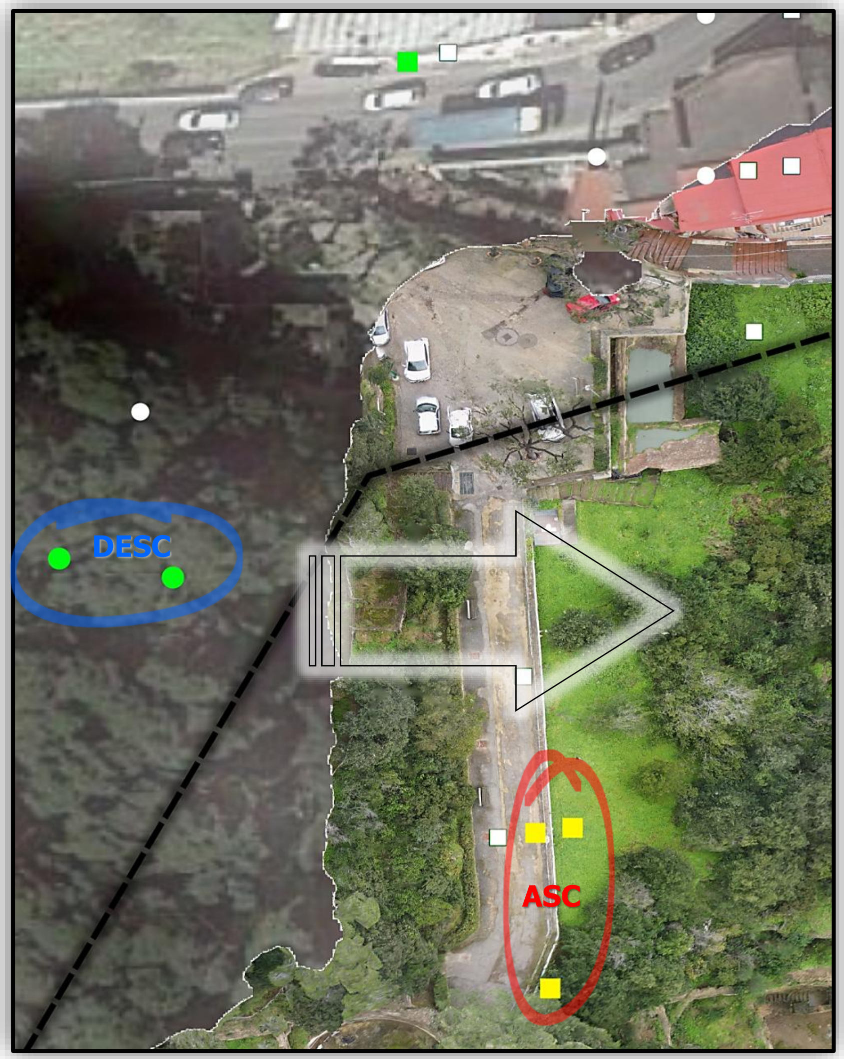


Ascending geometry seems to be more sensitive to radar targets in the site area; this is due mainly to "noise effect", then to East facing geometry of the slope too.

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.

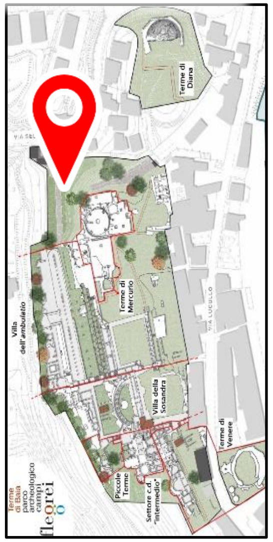
In situ calibration and interpretation

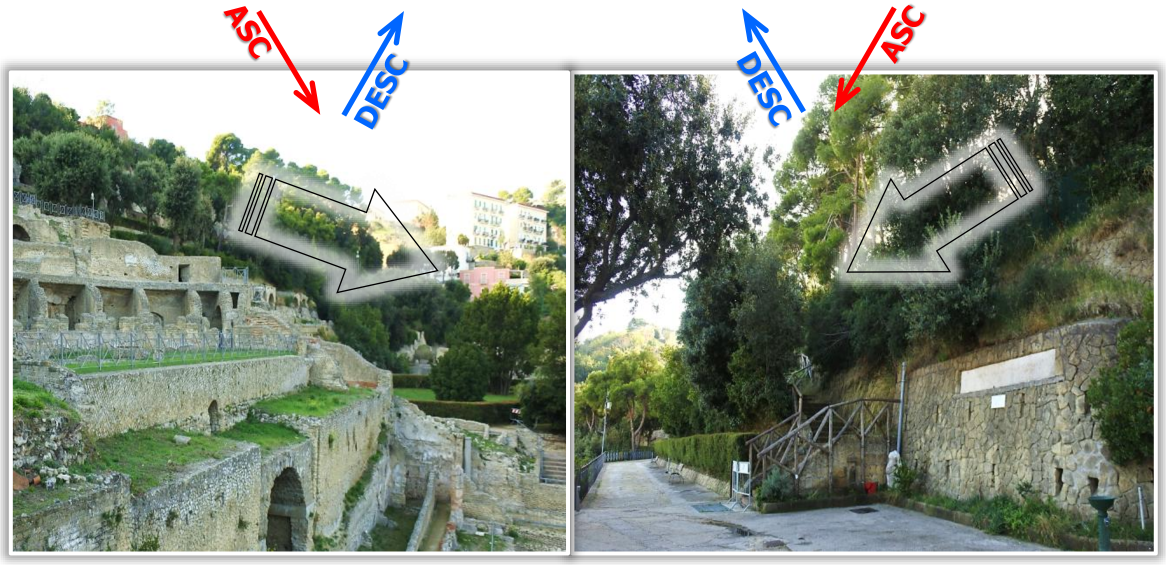


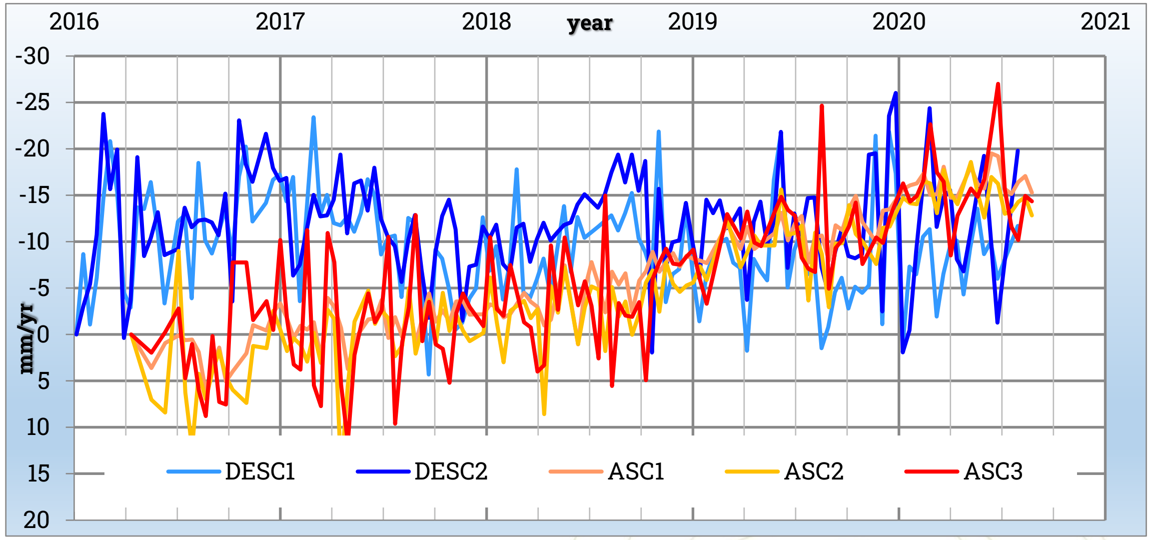
The combined interpretation of the PS, moving away from the ASC satellite and approaching the DESC satellite, shows the prevalence of the horizontal movement of slow slope sliding eastward (i.e. seaward).

LoS differential displacement (mm/yr)

- < -10
- -10 – -5
- -5 – -2
- -2 – 2
- 2 – 5
- 5 – 10
- > 10



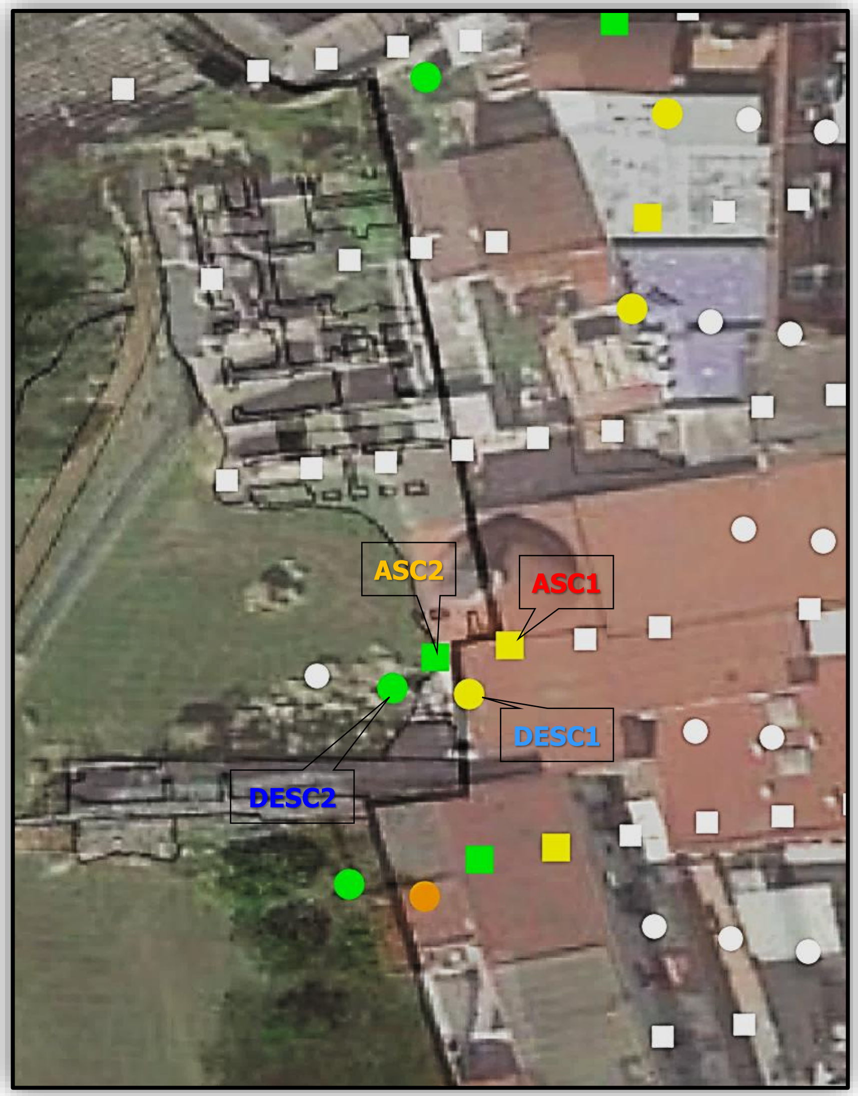


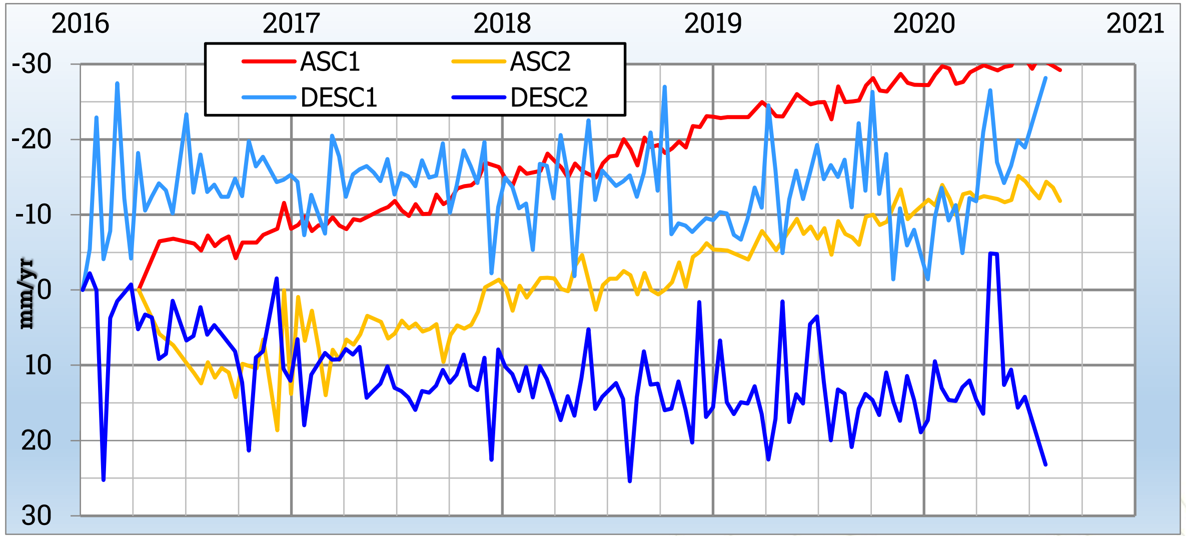


EAST boarder in situ interpretation and validation

LoS differential displacement velocity, D-vel (mm/yr)

ASC		DESC
blue square	< -10	blue circle
cyan square	-10 – -5	cyan circle
green square	-5 – -2	green circle
open square	-2 – 2	open circle
yellow square	2 – 5	yellow circle
orange square	5 – 10	orange circle
red square	> 10	red circle





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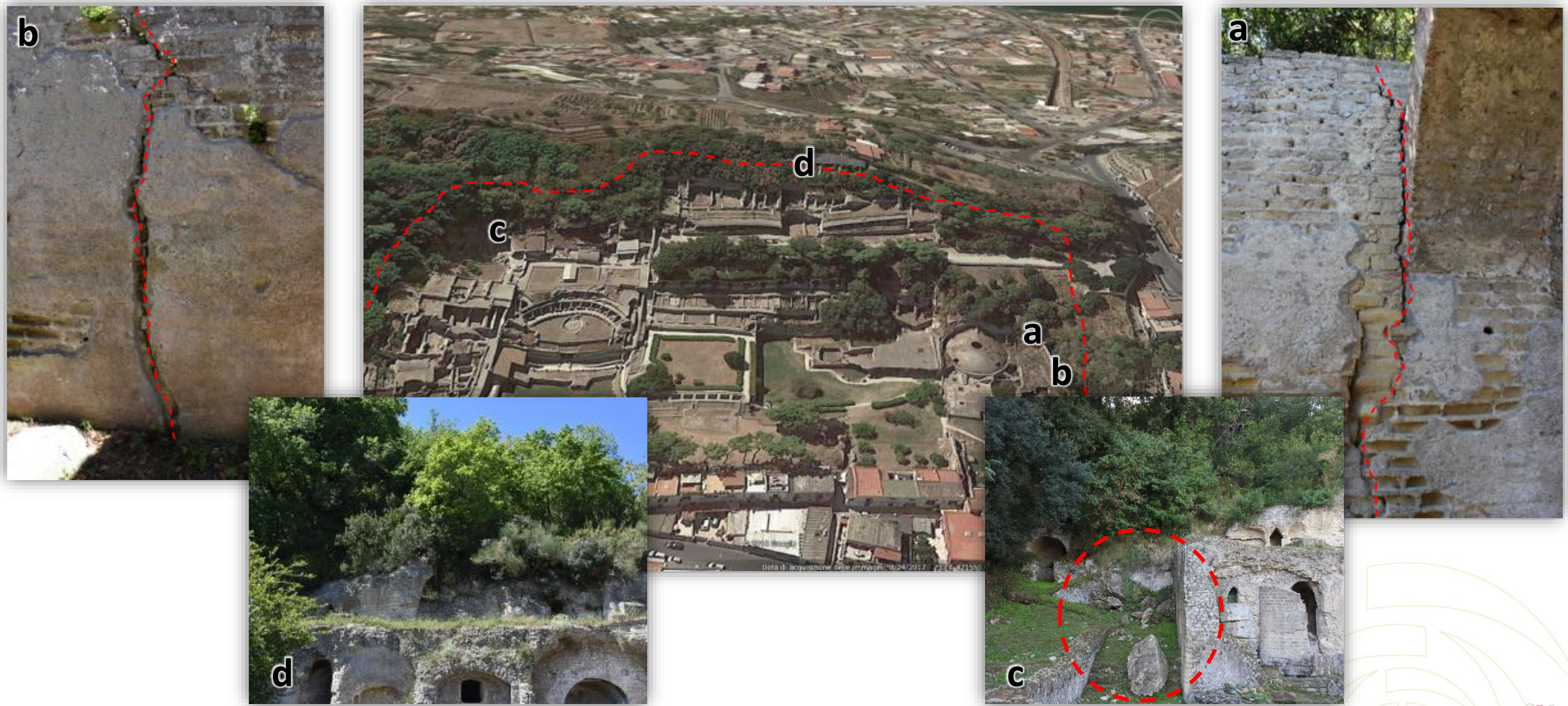
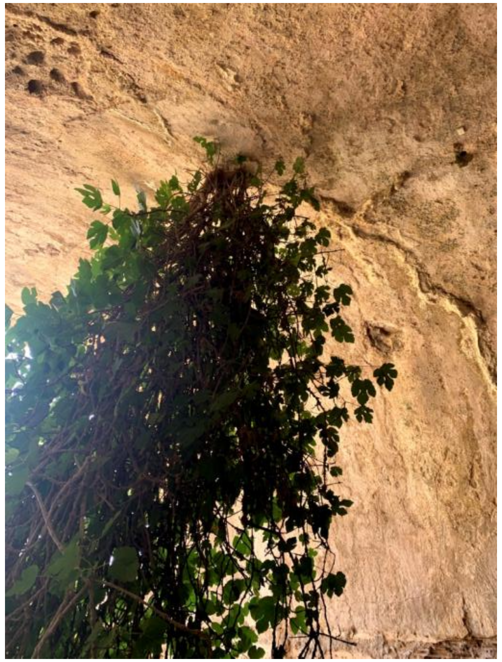
Strucutural and damage assessment

Main critical issues:
- cracks (a,b);
- rocks fall (c);
- invasive vegetation (d).



GPR analysis



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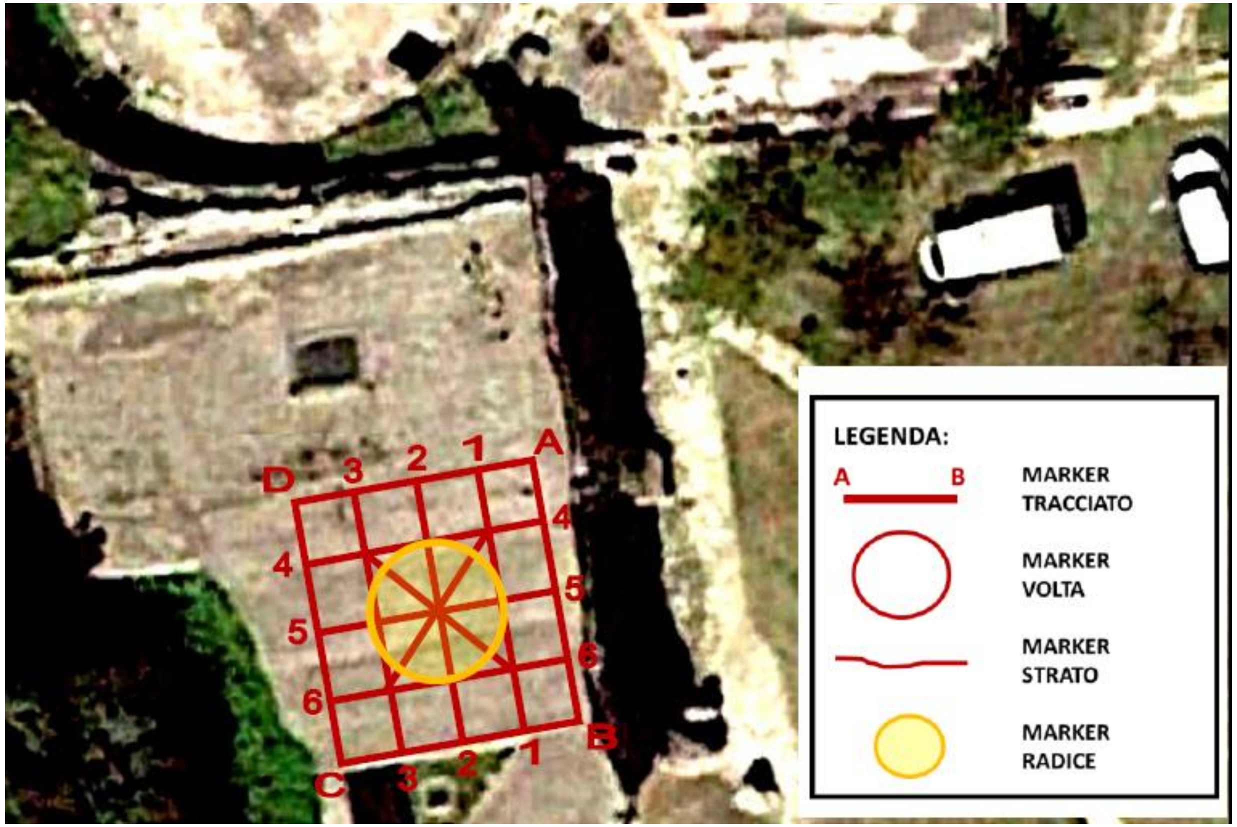
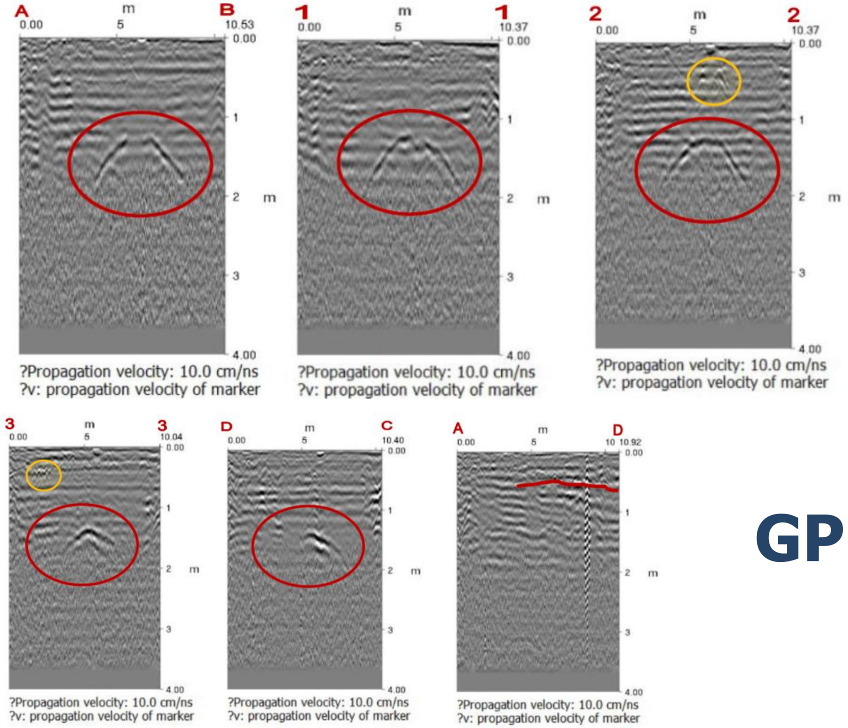
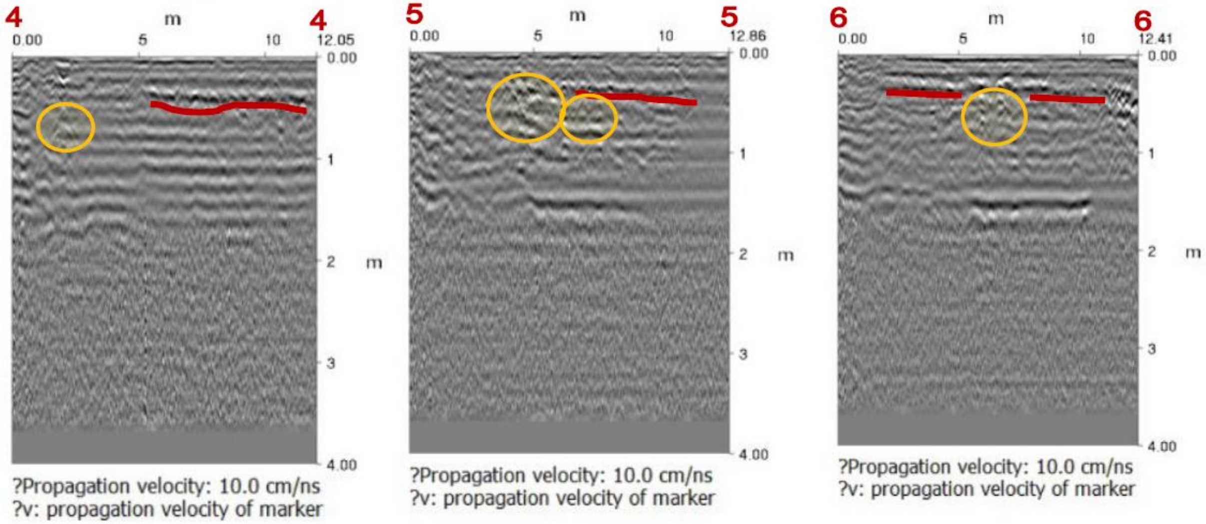
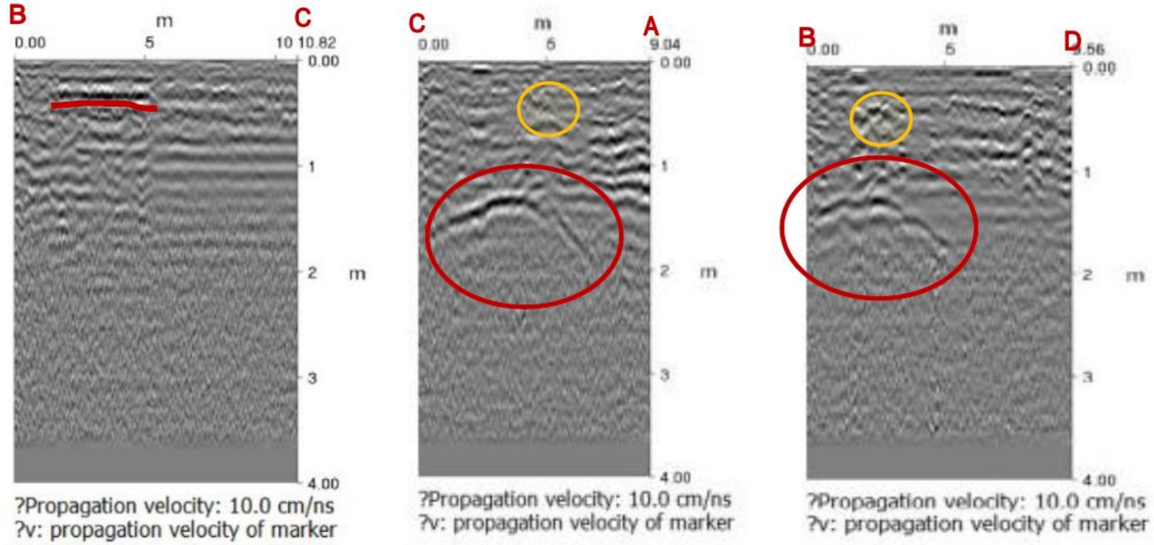
GPR analysis

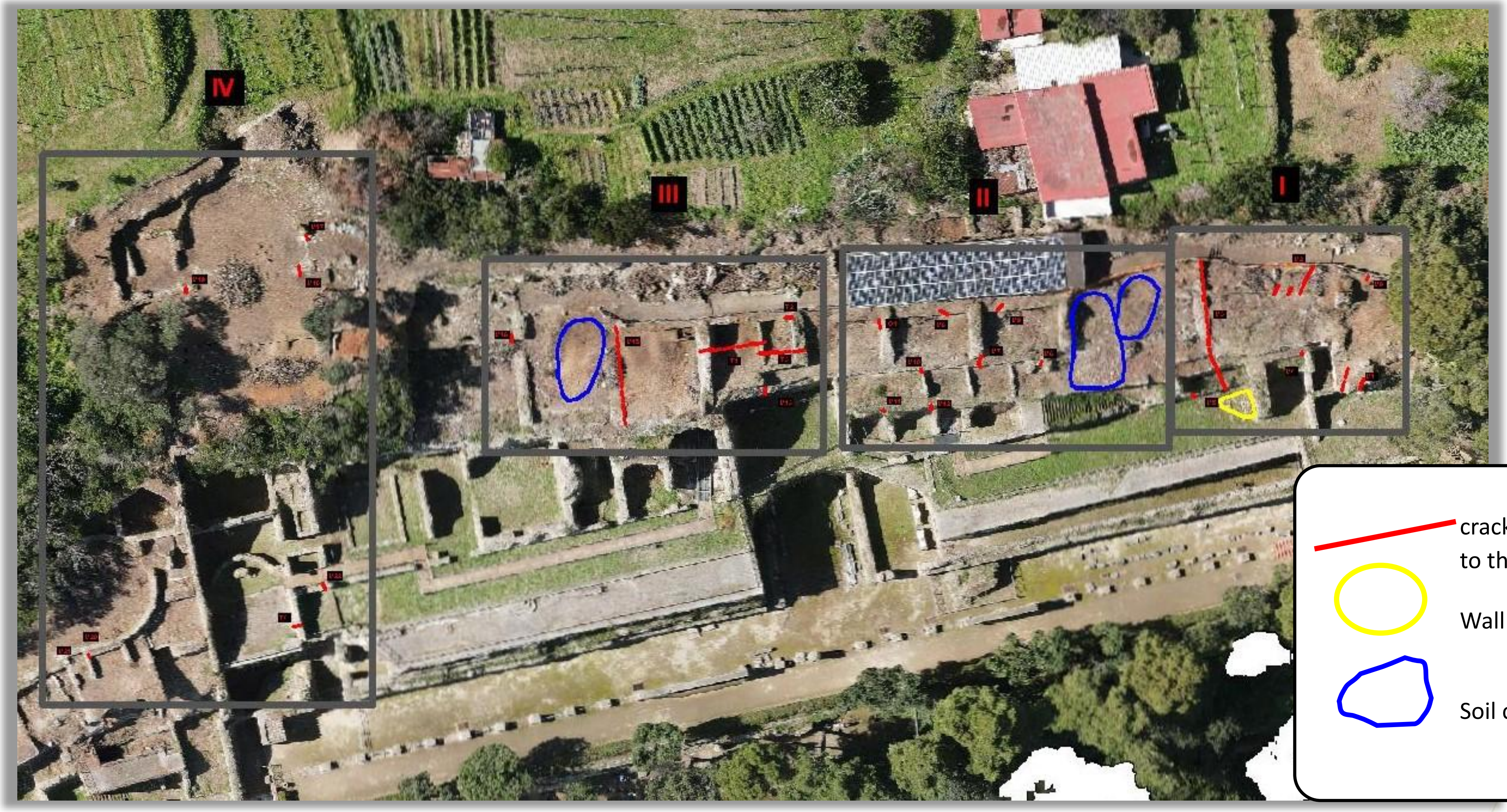








Preliminary mitigation measures



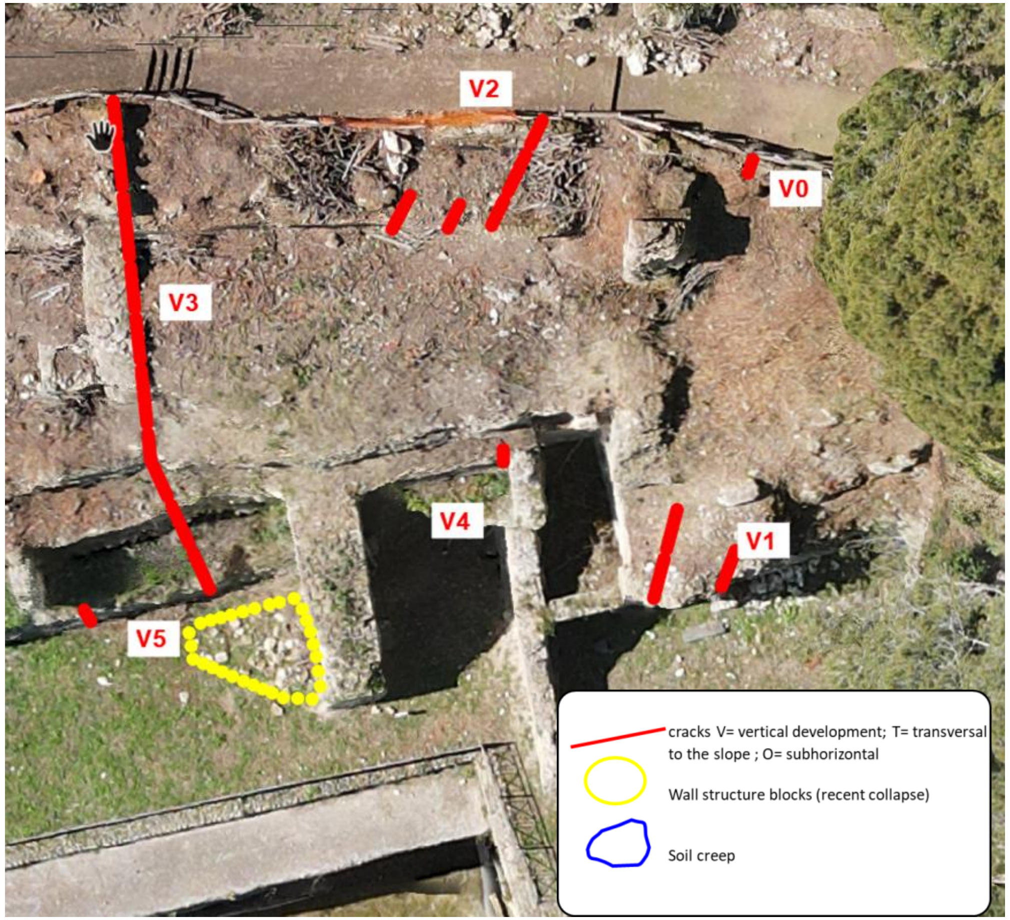
cracks V= vertical development; T= transversal to the slope ; O= subhorizontal

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 an 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**

The HOLISTIC approach and the new paradigm

World strategic assets such as the CH must have "Management and Adaptation Plans" that aim to increase the resilience and decrease the vulnerability to the impacts of geo-hazards triggered by climate change. **We have now the support of Earth Observation and remote sensing data, products and services**. **We need a strong and precise road map**:

1. **Location and typologies of process and their relative meteo climatic triggering**
2. **integrate the approaches that come from earth sciences (hazard and risk maps) and climatic sciences, into local policies - modeling variables and parameters**
3. **policies for the prevention and control of the effects of climate change are now supported by data from earth observation, which can make in some cases reduce the lack of knowledge and calibrate in situ data;**
4. **after the identification of the most vulnerable assets, and thanks to continuous monitoring, the mitigation interventions must be implemented following priorities. The solutions must be green and blue.**