ISTOS
CENTRE FOR NATURAL HAZARD MANAGEMENT

FINAL CONFERENCE
8 February 2024 – Nicosia

Cyprus University of Technology

ARISTOTLE UNIVERSITY OF THESSALONIKI

FREDERICK RESEARCH CENTER

P.LI.N.I.V.S. STUDY CENTRE

Crisis at Campi Flegrei Caldera: risk assessment activities in the emergency planning and management

Prof. Arch. **Giulio Zuccaro**

1987-2006
SEISMIC ANALYSIS AND PLANNING SECTION

L.U.P.T.
Laboratorio di Urbanistica e Pianificazione Territoriale

RESEARCH ACTIVITIES RELATED TO NATURAL HAZARDS IMPACT AND RISK ANALYSES, VULNERABILITY AND MITIGATION MEASURES ASSESSMENTS

EARTHQUAKE

VOLCANIC ERUPTIONS

HYDROGEOL. EVENTS

MARINE WEATHER EVENTS

SINCE 2006
PLINIVS STUDY CENTRE

CENTRO STUDI
P.LIN.I.V.S.

PLINIVS Study Centre

for Hydrogeological, Volcanic and Seismic Engineering

National Competence Centre for Italian Civil Protection
Department for volcanic risk
Interdepartmental Centre of Research
Laboratory of Urban and Territorial Planning
Raffaele d'Ambrosio (LUPT)
University of Naples Federico II, ITALY

- Decreto del Capo Dipartimento della Protezione Civile n. 1922 del 15 Maggio 2006
- Decreto Presidenza del Consiglio dei Ministri, Dipartimento della Protezione civile, n.20 luglio 2011 *Identificazione dei centri di competenza utili alla rete dei centri funzionali - Aggiornamento elenco anno 2011*.

Volcanic Emergency Management

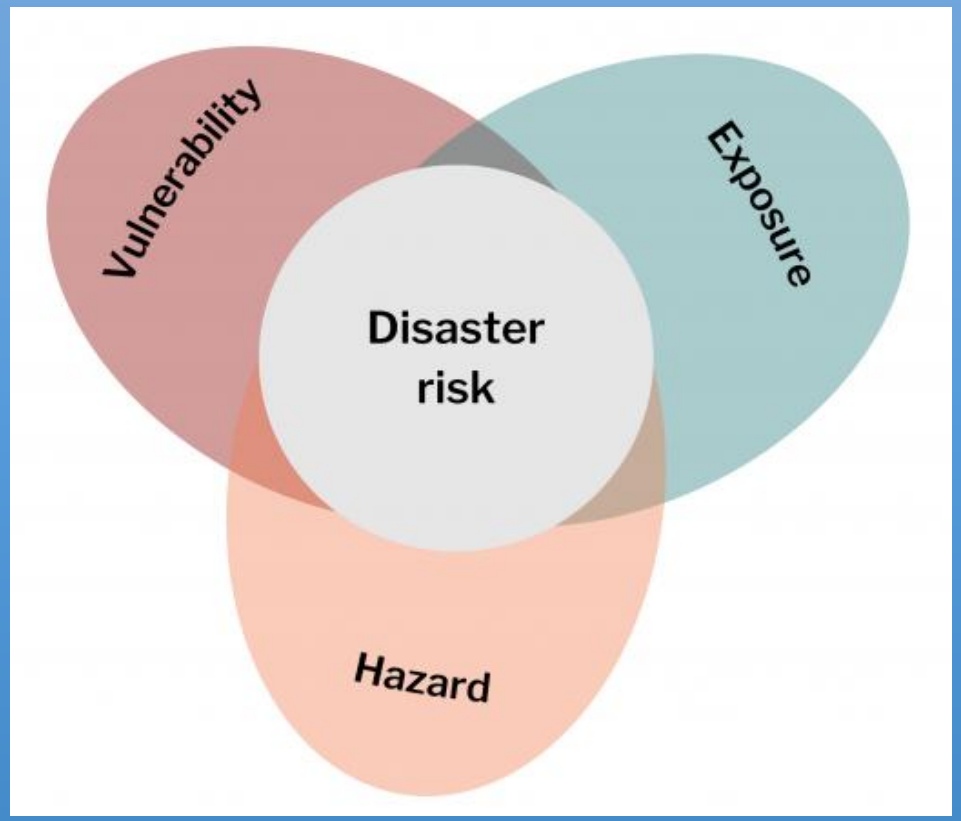
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

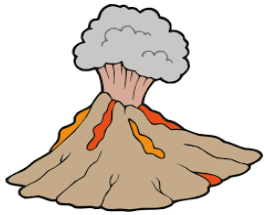
INGV

irea
istituto per il rilevamento elettromagnetico dell'ambiente

CENTRO STUDI P.LIN.I.V.S.

RISK ASSESSMENTS





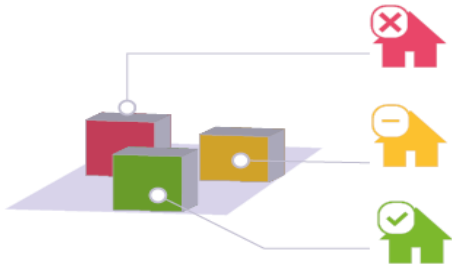
Hazard

X

Exposure

People and buildings in the area

X



Vulnerability

Behaviour of people and buildings with respect to the event

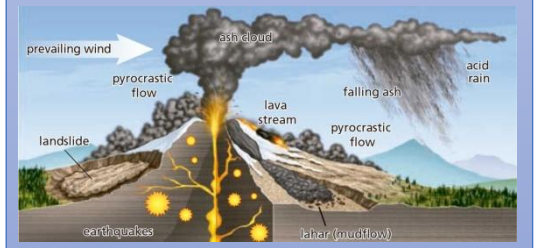
Probability to be destroyed

Probability to be damaged

Probability to not be damaged

TOOL PLINIVS

- **EASE. Ashfall.**
- **EASE. Earthquake/Buildings.**
- **EASE. Earthquake/Roads.**
- **DEB. Bradiseism**



HAZARD

EXPOSURE

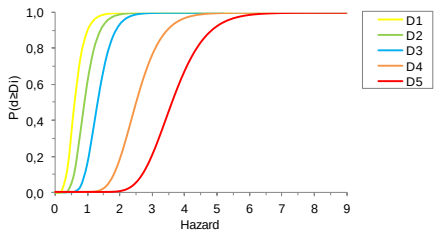
VULNERABILITY

INGV

istituto per il rilevamento elettromagnetico dell'ambiente

CENSIMENTO 2001

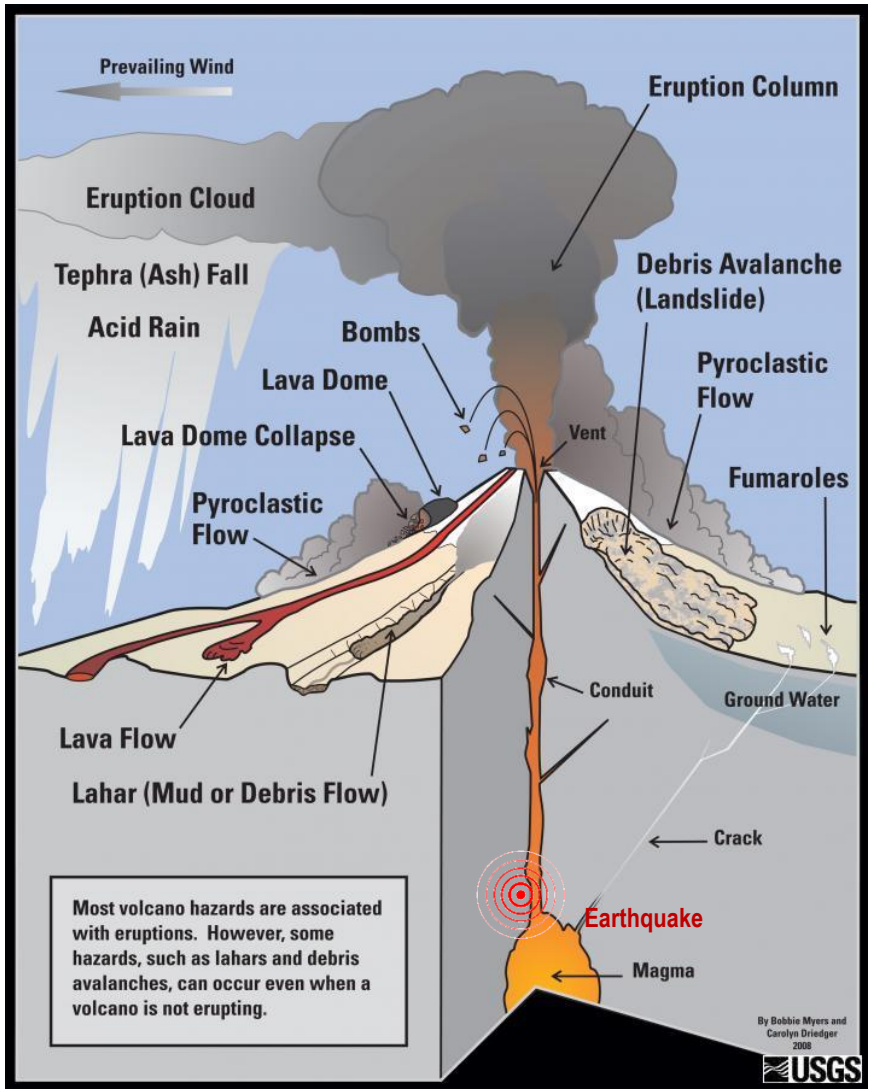
NATIONAL CENSUS DATABASE + DATA COLLECION



Vulnerability Curves

RISK ASSESSMENT | Hazard

EXPLOSIVE ERUPTIONS



- Precursor earthquakes
- Ash Fall
- Pyroclastic flows
- Landslides
- Lahars (Vesuvius)
- Tsunami
- Bombs and Missile
- Bradyseism (Campi Flegrei)

ACTIONS CONSIDERED IN THE PLANNING OF VOLCANIC EMERGENCIES AT VESUVIUS AND CAMPI FLEGREI

RISK ASSESSMENT| Exposure

EXPOSURE. Quantitative and qualitative geographical distribution of risk elements (people, buildings, infrastructure, activities and cultural heritage, etc.) within an area. The condition and/or operation of the elements may be damaged, altered or destroyed as a result of the natural event.

PERSONE

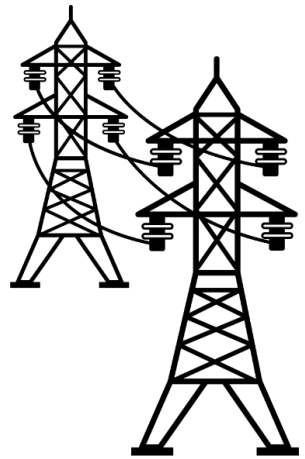
- Eartquake (**EQ**)
- Ash fall (**AF**)

EDIFICI

- Earthquake (**EQ**)
- Ash fall (**AF**)
- Bradisismo (**BR**)

STRADE

- Earthquake (**EQ**)



RETI

- Eartquake (**EQ**)
- Ash fall (**AF**)

RISK ASSESSMENT | Exposure

SCHEDA DI RILIEVO PLINIVS

dati tipologici sugli edifici per la classificazione di vulnerabilità rispetto ai fenomeni multi-hazard (Geologici & Cambiamenti Climatici)

CENTRO STUDI PLINIVS

SEZIONE 1 – ATTIVITÀ DI RILIEVO

ID RILEVATORE: ☐☐☐☐☐ DATA: ☐☐☐☐☐☐☐☐ ACCESSO RILIEVO: A ○ diretto B ○ indiretto

COMPLETAMENTO DELLA SCHEDA: A ○ completata B ○ parzialmente completata C ○ vuota

SEZIONE 2 – IDENTIFICAZIONE

CODICE ISTAT REGIONE: ☐☐ CODICE ISTAT PROVINCIA: ☐☐☐ CODICE ISTAT COMUNE: ☐☐☐

N. AGGREGATO: ☐☐☐☐☐☐☐ N. EDIFICIO: ☐☐☐ COMUNE_____

PRESENZA DELLA GEOMETRIA DELL'EDIFICIO SULLA CTR: ○ sì ○ no

SEZIONE 3 – INFORMAZIONI GENERALI

TIPO DI EDIFICIO:

A	☐	edificio ordinario	B	☐	baracca o assimilabile	C	☐	capannone
D	☐	impianto sportivo	E	☐	cabine balneari, strut. temp.	F	☐	gazebo, pensilina, tettoia
G	☐	edificio abbandonato, rudere	I	☐	edificio leggero in legno	L	☐	edificio leggero in lamiera
S	☐	serra	U	☐	deposito pesante	V	☐	box, garage
Z	☐	altro: spogliatoi, bungalow,..	ZZ	☐	non class. come edif. autonomo			

DESTINAZIONE D'USO:

A	☐	struttura agricola	ND	☐	negozi al dettaglio	NI	☐	negozi all'ingrosso
OM	☐	officine meccaniche	ST	☐	servizi tecnici professionali	B	☐	banche
H	☐	ospedali	HP	☐	cliniche e ambulatori	R	☐	intrattenimento e ricreazione
T	☐	teatri	PK	☐	parcheggi	S	☐	scuole
U	☐	università	P	☐	uffici pubblici	PI	☐	uffici per il pronto intervento
IP	☐	industrie pesanti	IL	☐	industrie leggere	IK	☐	industrie chimiche
IM	☐	industrie metallurgiche	IT	☐	industrie alta tecnologia	IE	☐	industrie per l'edilizia
CH	☐	chiese e organizzazioni no profit	RE	☐	residenza	RT	☐	alloggi temporanei
DD	☐	dormitori pubblici	HP1	☐	casa di cura	H1	☐	struttura ricettiva
DP	☐	deposito	NN	☐	non noto			

UTILIZZAZIONE:

A ☐ abbandonato NU ☐ non utilizzato PU ☐ utiliz. parzialmente U ☐ utilizzato

ESPOSIZIONE:

S ☐ strategico (caserme, ospedali, scuole, prefetture, ecc.) P ☐ caratterizzato da particolare esp. (industria a rischio e simili) O ☐ ordinario

SEZIONE 4 – STATO

EPOCA DI COSTRUZIONE:

A ☐ prima del 1919 B ☐ 1919-1945 C ☐ 1946-1960 D ☐ 1961-1971

E ☐ 1972-1981 F ☐ 1982-1991 G ☐ 1992-2001 H ☐ dopo il 2001

STATO DI CONSERVAZIONE DELLA STRUTTURA:

A ☐ scadente B ☐ mediocre

C ☐ buono D ☐ eccellente

TIPOLOGIA DELLE FINITURE:

E ☐ economiche O ☐ ordinarie

L ☐ lussuose

CENTRO STUDI PLINIVS

DATA COLLECTION (field survey)

BUILDINGS: EXPOSURE

DB ISTAT

Censimento 2001

DATI AGGREGATI
E DISAGGREGATI

DB PLINIVS:
Building-by-building collection

PLINIVS VULNERABILITY DB

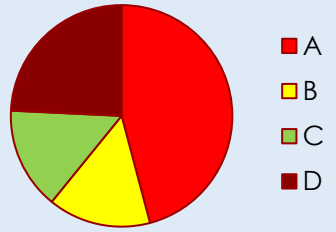
IN TIMES OF PEACE*(approx. 95,000 buildings in approx. 250 municipalities)*
- *Typological features*

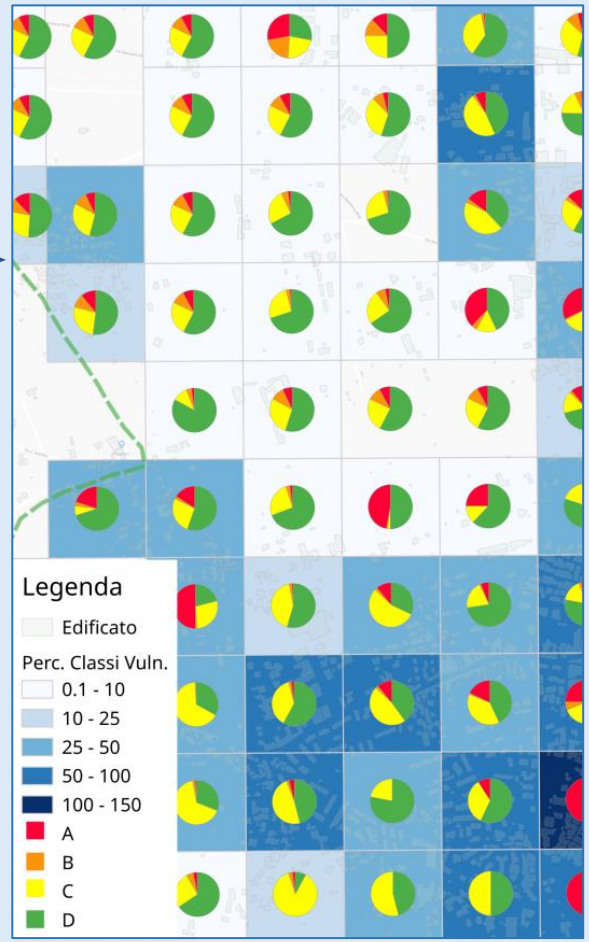
PLINIVS POST SEISM DAMAGE DB

POST SEISMIC DAMAGE *(approx. 170,000 buildings in approx. 500 municipalities)*
- *Typological characteristics*
- *Description of the damage*

INVENTORY AT LOCAL SCALE

DISTRIBUTION OF VULNERABILITY CLASSES BY CELL





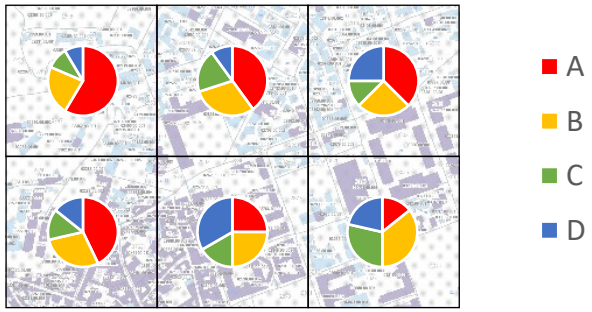
RISK ASSESSMENT | Exposure

INPUT data

- **database ISTAT** – provides aggregated data on buildings belonging to a specific census section;
- **PLINIVS FORMS** – provide typological and structural data of the buildings belonging to the investigated area.

OUTPUT data

- **Vulnerability distribution** on each cell



TOOLS

S.A.V.E. – Seismic Assessment of Vulnerability Expectation

It allows you to assign the vulnerability class of the buildings in the database considered based on their structural and typological characteristics;

B.I.N.C. – Building Inventory at National scale for Census area

It allows you to define the distribution in vulnerability classes of a specific geographical area belonging to the national territory.

RISK ASSESSMENT | Exposure

DEFINITION OF THE INTERESTED AREA

GRID CONSTRUCTION: 250 m x 250 m

DEFINITION OF THE BUILDINGS' ALLOCATION ON THE CELLS

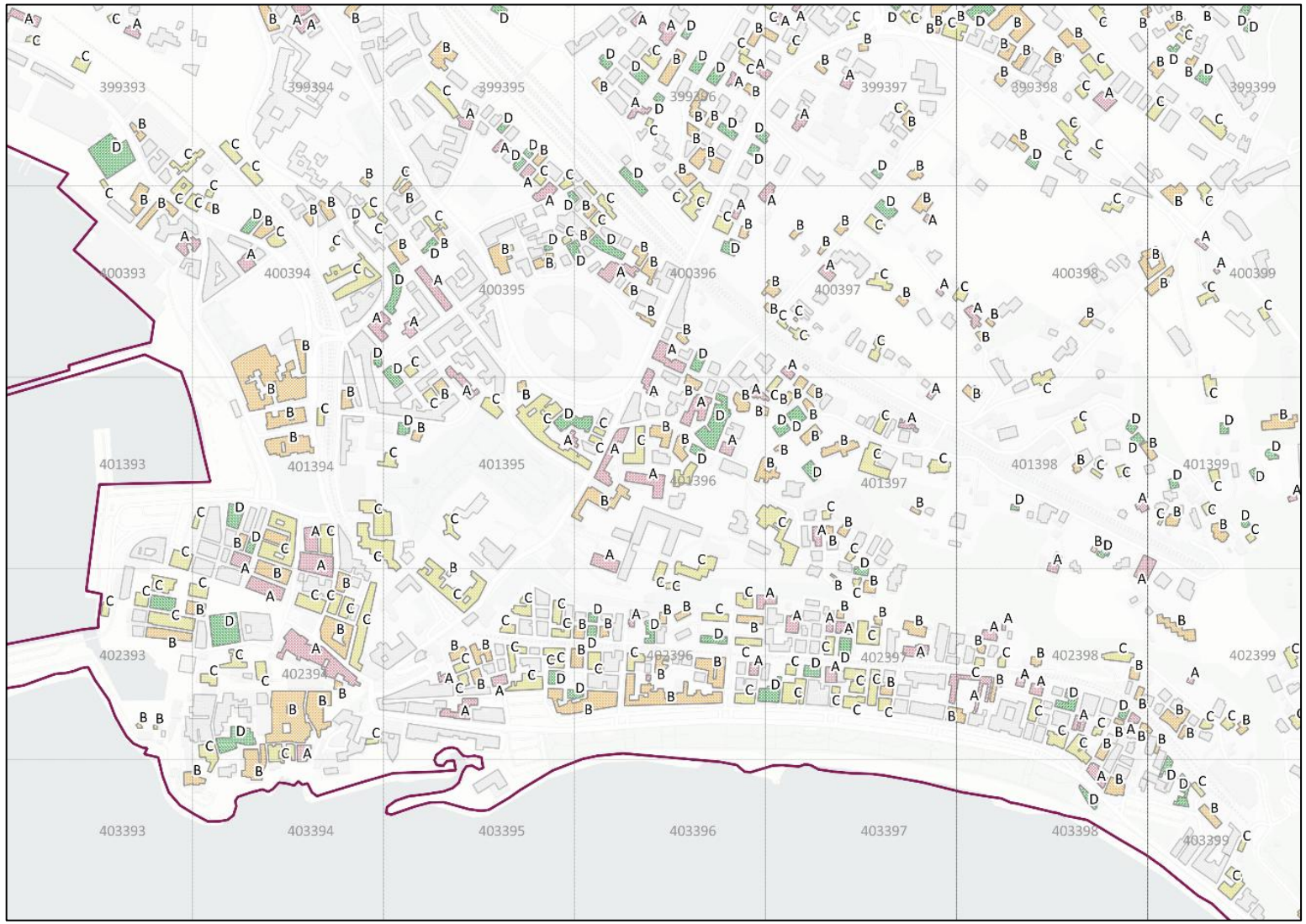
ESTIMATION OF THE VULNERABILITY CLASS FOR THE BUILDINGS SURVEYED

S.A.V.E. method

is a procedure developed by the PLINIVS Study Center to define the seismic behavior of a building with known typological characteristics

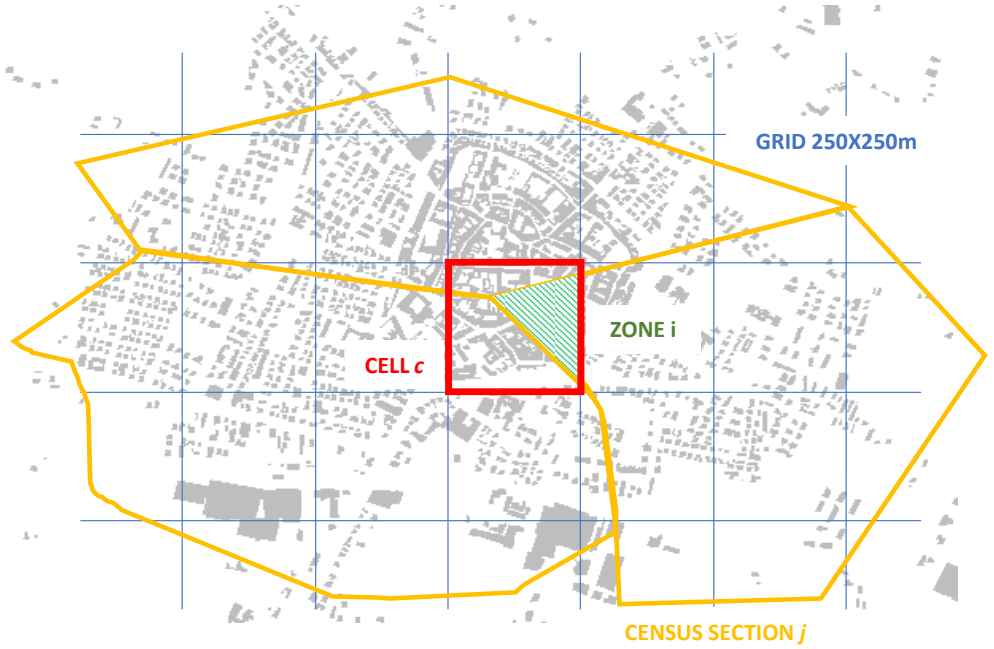
ESTIMATION OF THE VULNERABILITY CLASS FOR THE UNSURVEYED BUILDINGS

DEFINITION OF THE EXPOSURE ON THE CELLS



RISK ASSESSMENT| Exposure

B.I.N.C. METHOD is a procedure developed by the PLINIVS Study Center to estimate a distribution of relevant buildings on the vulnerability class by exploiting thedataset ISTAT (dataset CENSUS)



buindings of the zone *i* and census zone *j* with vulnerability class *k*:

$$E_{ij}^{k} = \begin{cases} E_{ij}^{k,R} & \text{when } E_j^{ISTAT}/E_j^R \leq 1 \\ E_{ij}^{k,R} + E_{ij}^{k,R} = E_{ij}^{k,R} + E_j^k/E_j^{ISTAT} \cdot (E_{ij} - E_{ij}^R) & \text{when } E_j^{ISTAT}/E_j^R > 1 \end{cases}$$

buildings of the cell c and vulnerability class k: $E_c^{k,\,ISTAT} = \sum_{i=1}^{n} E_{i,j}^{k,ISTAT}$

c	cell
j	census section
i	zone, intersection of the grid with the census section
k	vulnerability class (k = A, B, C, D)
n	number of zone in the cell c
$E_{i,j}^{k,ISTAT}$	ISTAT buildings in the zone i belonging to the census zone j having class k
$E_j^{k,ISTAT}$	ISTAT buildings with vulnerability class k of the census section j
S_{ij}	built area of the zone i belonging to census zone j
S_j	built area of the census zone j
$E_c^{k,ISTAT}$	ISTAT building having vulnerability class k belonging to the cell c

RISK ASSESSMENT | Exposure

DEFINITION OF THE AFFECTED AREA

GRILLE CONSTRUCTION:
250 m x 250 m

DEFINING THE ALLOCATION OF BUILDINGS ON CELLS

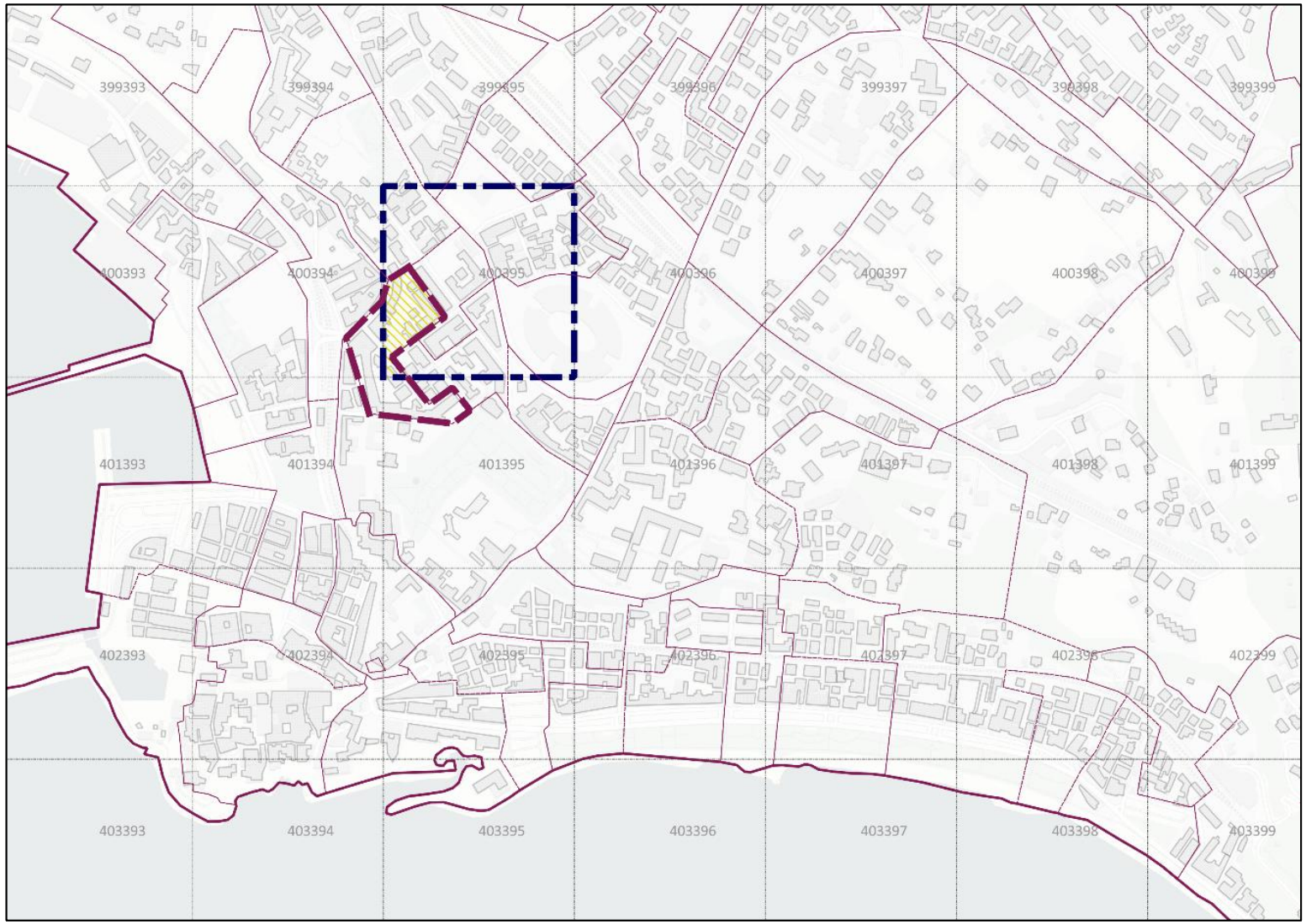
ESTIMATION OF THE VULNERABILITY CLASS FOR THE BUILDINGS SURVEYED

ESTIMATION OF VULNERABILITY CLASS FOR UNDETECTED BUILDINGS

B.I.N.C. method

is a procedure developed by the PLINIVS Study Center to estimate a distribution of relevant buildings on the vulnerability class by exploiting the ISTAT dataset (CENSUS dataset).

DEFINITION OF THE EXPOSURE ON THE CELLS



RISK ASSESSMENT | Exposure

DEFINITION OF THE AFFECTED AREA

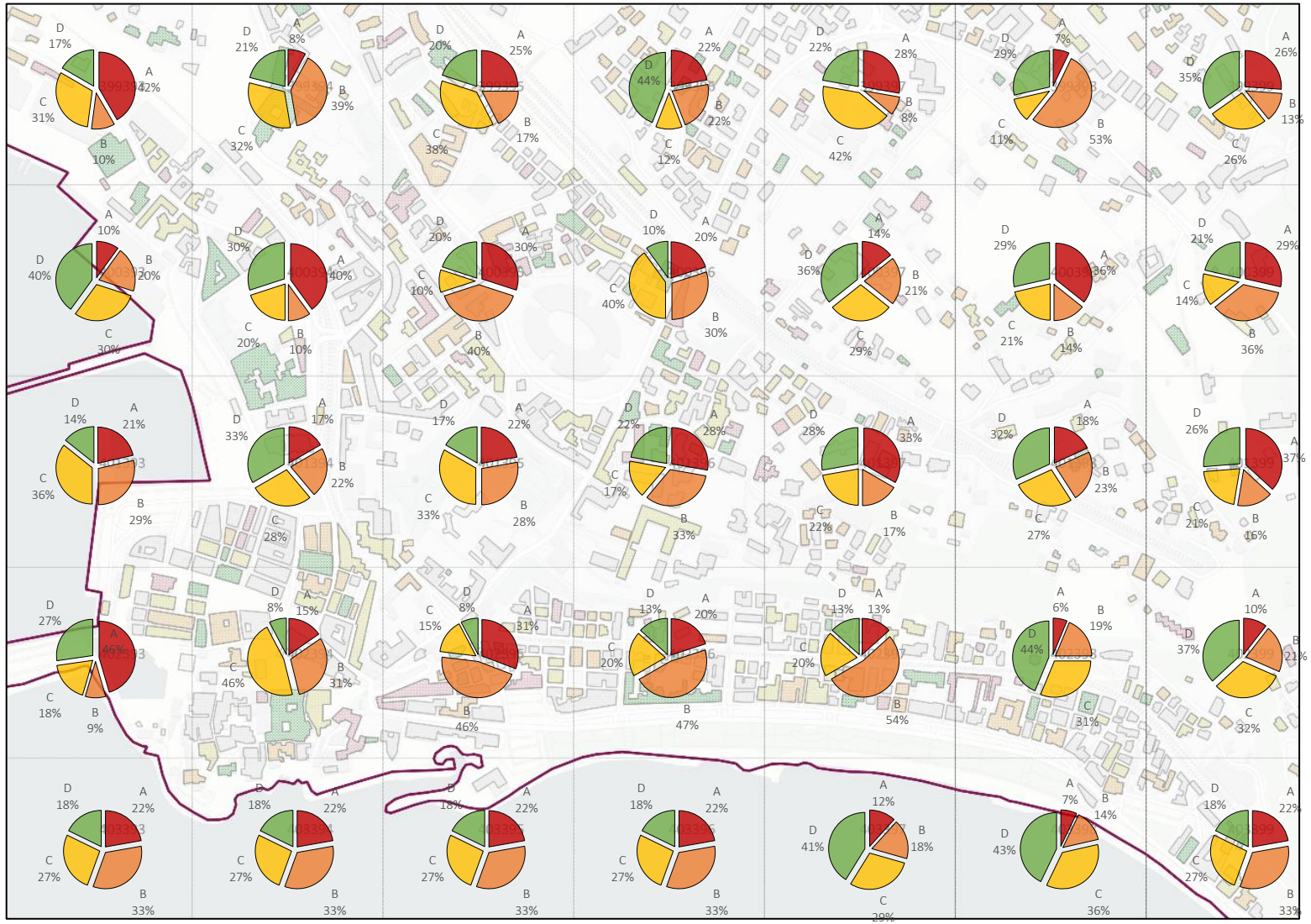
GRID CONSTRUCTION:
250 m x 250 m

DEFINING THE ALLOCATION OF BUILDINGS ON CELLS

ESTIMATION OF THE VULNERABILITY CLASS FOR THE BUILDINGS SURVEYED

ESTIMATION OF VULNERABILITY CLASS FOR UNDETECTED BUILDINGS

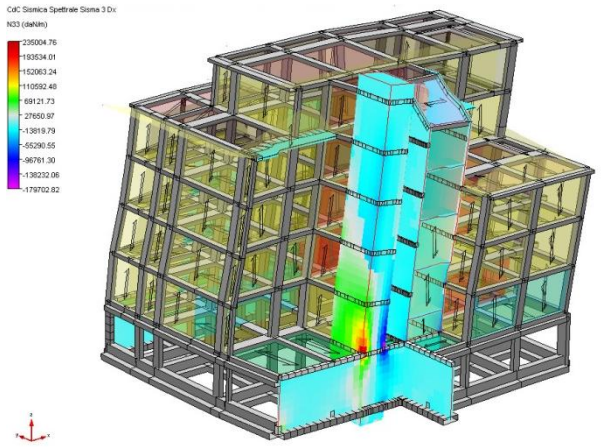
EXPOSURE DEFINITION ON CELLS



RISK ASSESSMENT | Vulnerability

VULNERABILITY. Sensitivity of an element exposed to a natural event. Probability that the exposed element will suffer a certain level of damage or change in status, with reference to an appropriate scale, as a result of the occurrence of natural events of assigned intensity.

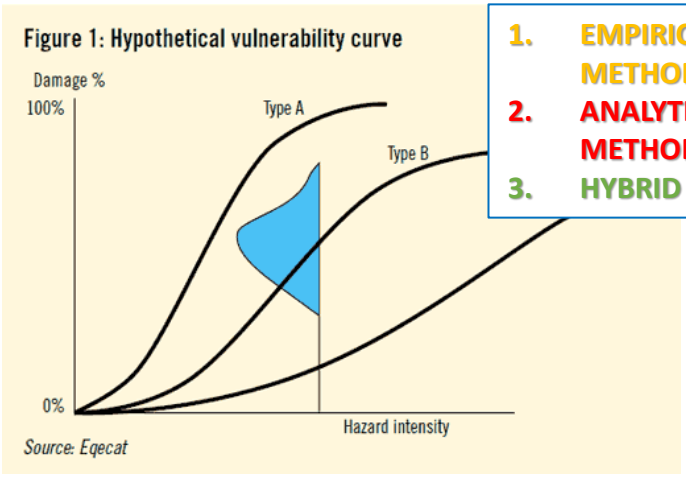
SINGLE BUILDING ANALYSIS



DETERMINISTIC ANALYSIS OF THE CAPACITIES OF THE INDIVIDUAL BUILDING

DESIGN/ BUILDING VERIFICATION

BUILDING CLASS ANALYSIS



1. EMPIRICAL METHODS
2. ANALYTICAL METHODS
3. HYBRID METHODS

STATISTICAL ANALYSIS OF THE CAPACITIES OF A CLASS OF BUILDINGS, CHARACTERIZED BY SIMILAR BEHAVIOR WITH REGARD TO SEISMIC EVENTS

VULNERABILITY

VULNERABILITY. Sensitivity of an element exposed to a natural event. Probability that the exposed element will suffer a certain level of damage or change in status, with reference to an appropriate scale, as a result of the occurrence of natural events of assigned intensity.

EARTHQUAKES: VULNERABILITY OF ORDINARY BUILDINGS

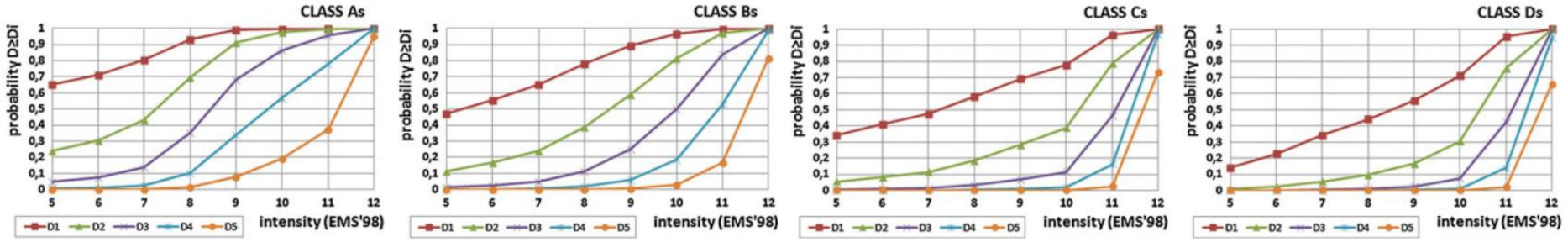
VULNERABILITY CLASSES	HORIZONTAL STRUCTURES				
VERTICAL STRUCTURES	Poor stiffness	Poor technology	Medium stiffness	Medium high stiffness	High stiffness
	Metal sheet, vaults and/or wooden floor (without ties)	(e.g."SAP" floor*)	Vaults and/or wooden floor (without ties)	Iron beam floor	Reinforced concrete and steel floors
Weak masonry Rubble masonry neglected	As	As	As	As	As
Medium quality Rubble masonry maintained	As	As	Bs	Bs	Bs
Good masonry Squared masonry	As	As	Bs	Bs	Cs
Framed structures (RC or steel)	-	Bs	-	-	Ds

* SAP floor (self- supporting floor) is a typical Italian horizontal structure, made of clay/cement mix with smooth bars at intrados. This technology is considered very dangerous because of the cement casting superior slab does not cover the reinforcement bars inserted in the hollow tile.

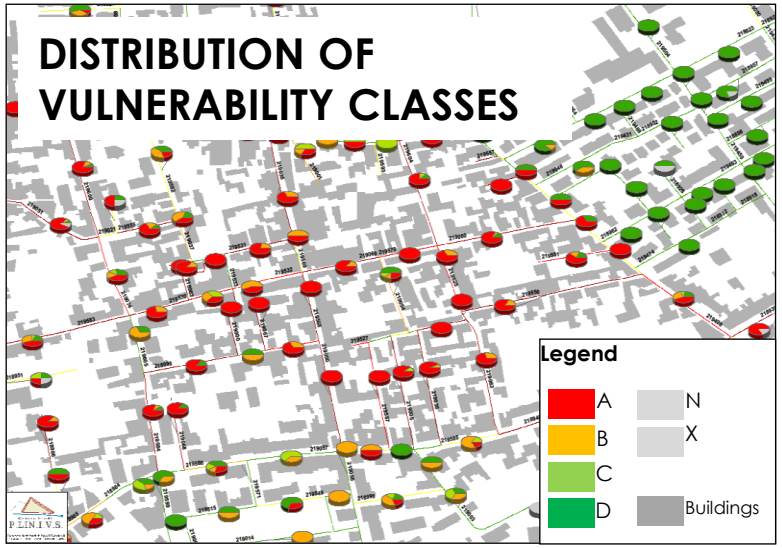
VULNERABILITY CURVES (empirical approach)

Observational probabilism

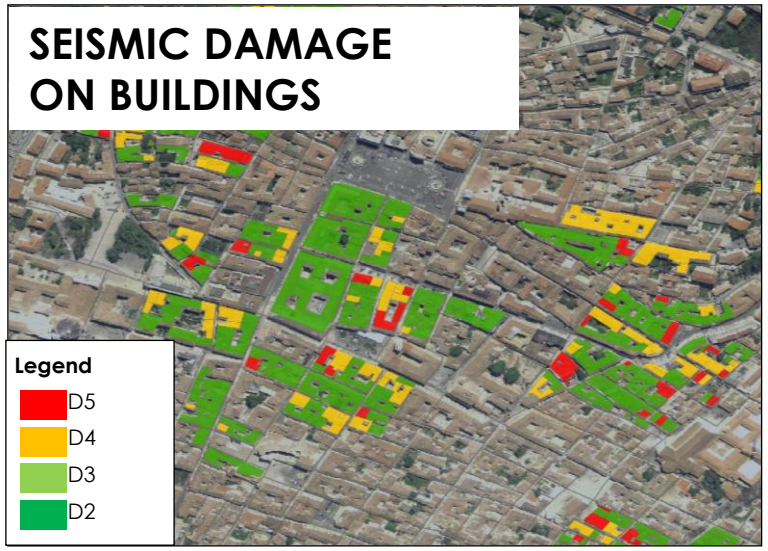
Approach based on statistical analyses of the distribution of damage related to tectonic earthquakes that occurred in the past.

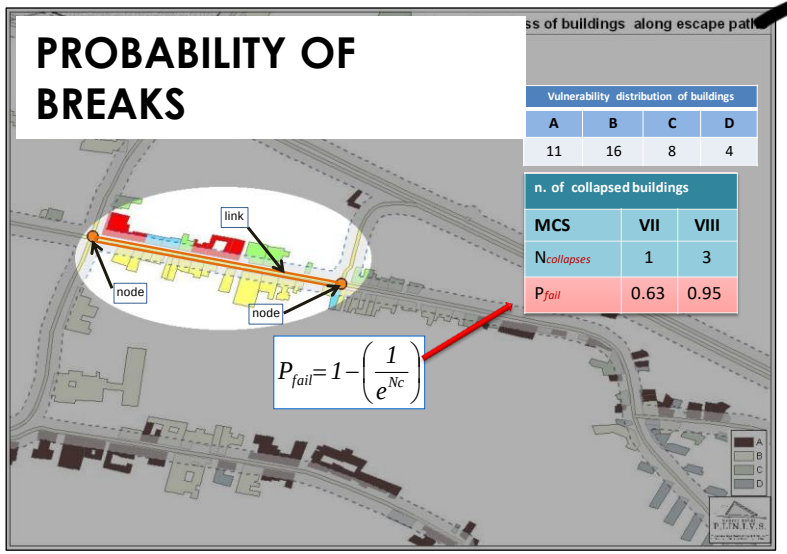


EARTHQUAKES: VULNERABILITY OF ROAD SECTIONS



In risk analysis, the vulnerability of road sections
exposed to a natural event is related to their impracticability.
It could have serious repercussions on traffic and ordinary functions, even causing an obstacle to rescue or evacuation operations.





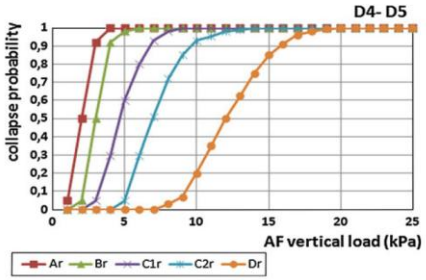
Pre-eruptive phase(area near the crater):
Precursor earthquakes could occur with disastrous consequences such as the interruption of roads due to the partial or total collapse of the buildings in front.

VULNERABILITY. Sensitivity of an element exposed to a natural event. Probability that the exposed element will suffer a certain level of damage or change in status, with reference to an appropriate scale, as a result of the occurrence of natural events of assigned intensity.

ASH FALL: VULNERABILITY OF ORDINARY BUILDINGS

VULNERABILITY CLASSES	
ROOFS	
Type	**Description**
Ar	Weak pitched wooden roof
Br	Flat standard wooden roof
	Reinforced concrete flat roof- SAP type
	Weak steel flat roof
C1r	Old flat RC roof
	Weak pitched steel roof
C2r	Recent flat RC roof
	Recent flat steel roof
Dr	Recent pitched RC roof
	Recent pitched steel roof

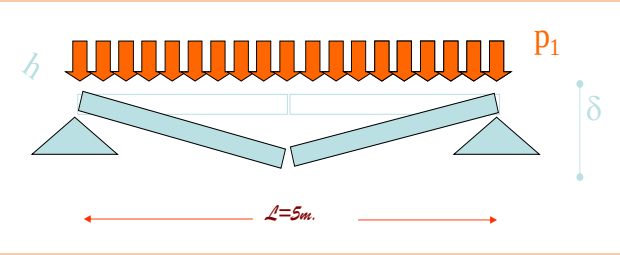
VULNERABILITY CURVES



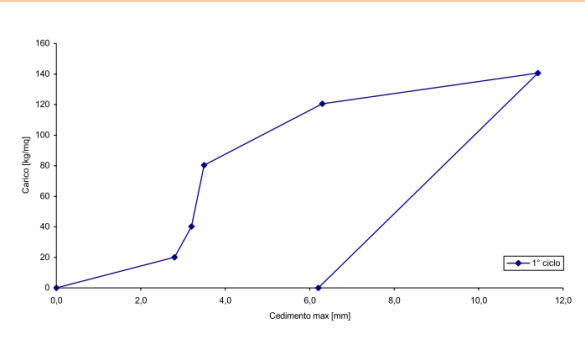
HYBRID APPROACH:

- **Numerical analyses (collapse limit state)**

MONTE CARLO SIMULATION



- **Experimental tests**

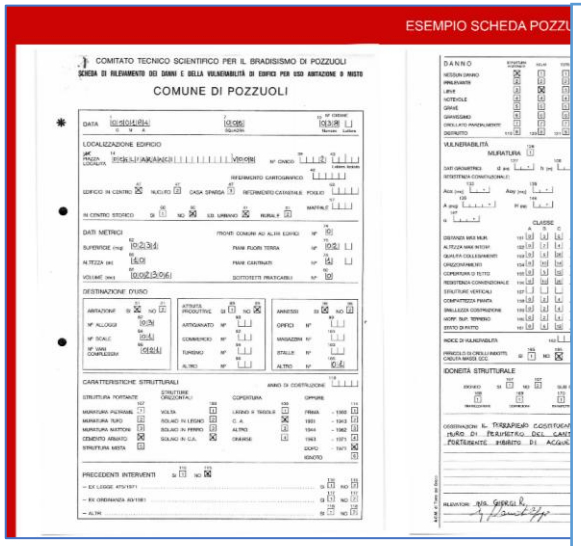


BUILDINGS: VULNERABILITY- BRADYSEISM

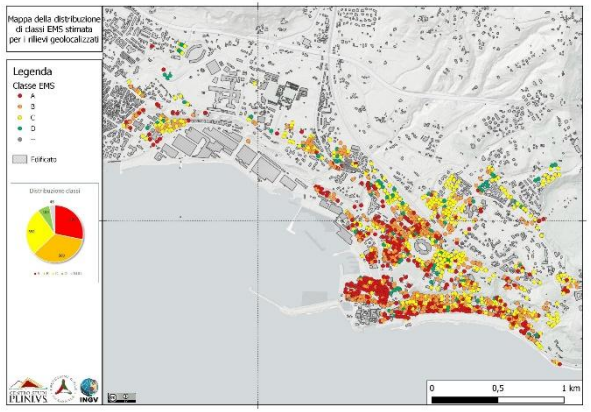
EMPIRICAL APPROACH

Probabilistic observational approach based on the statistical analysis of the distribution of damage detected following the bradyseismic crisis of 1983-84.

EMPIRICAL VULNERABILITY CURVES OF THE PHLEGRAEAN BUILDINGS WITH REGARD TO OF BRADYSEISM LIFTING



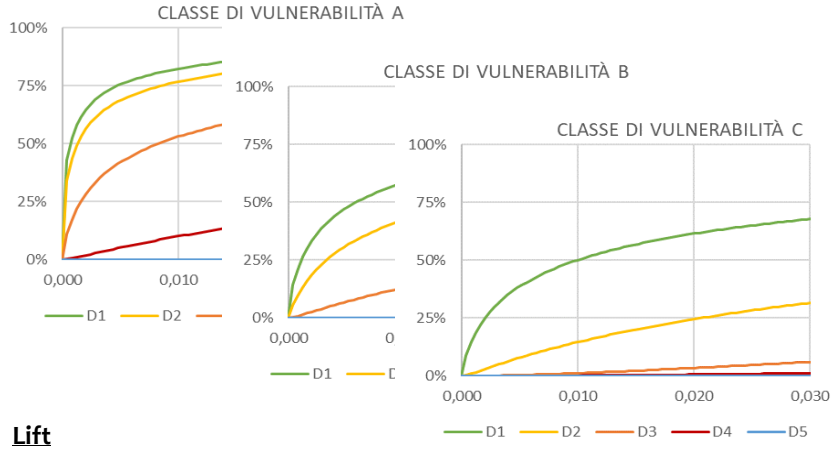
POZZUOLI FORMS



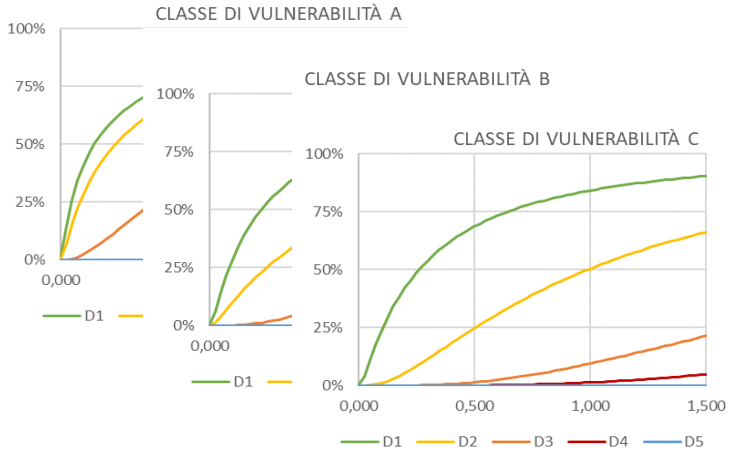
- Digitalizzazione di 3616 schede Pozzuoli
- Geolocalizzazione di 1144 schede
- Individuazione unità strutturali

VULNERABILITY CURVES (damage, slope/lift)

Slope



Lift



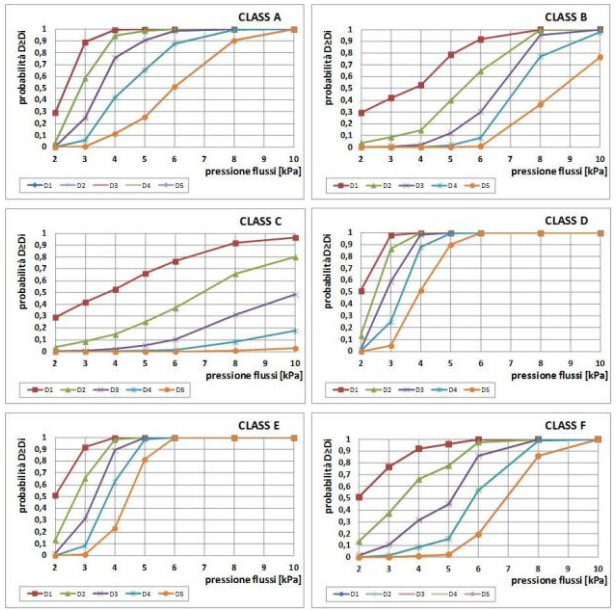
VULNERABILITY. Sensitivity of an element exposed to a natural event. Probability that the exposed element will suffer a certain level of damage or change in status, with reference to an appropriate scale, as a result of the occurrence of natural events of assigned intensity.

PRIROCLASTIC FLOWS: VULNERABILITY OF ORDINARY BUILDINGS

VULNERABILITY CLASSES

	Classe	Descrizione
Masonry	*A*	*3-4 storey weak masonry buildings with deformable horizontals*
		Weak or resistant masonry buildings with more than 4 floors
	B	*Medium-strength masonry buildings of 1-2 storeys with deformable horizontals*
		Durable masonry buildings with more than 3 floors and rigid horizontals
	C	*Strong masonry buildings of 1-2 storeys and rigid horizontals*
Reinforced concrete	*D*	*Non-seismic reinforced concrete building with more than 6 floors*
	E	*Non-seismic reinforced concrete building of 4-6 floors*
	F	*Non-seismic reinforced concrete building of 1-3 floors*

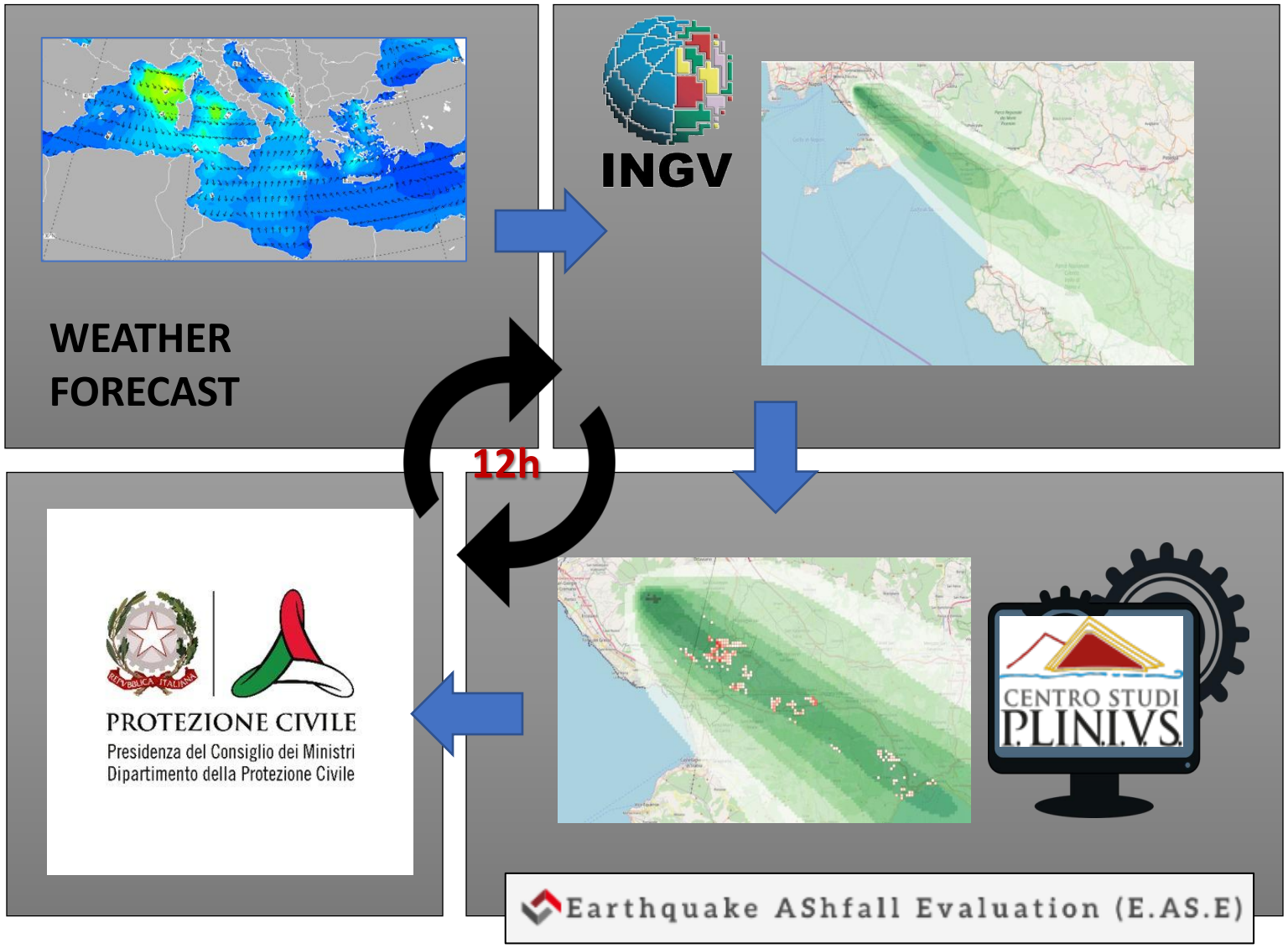
VULNERABILITY CURVES



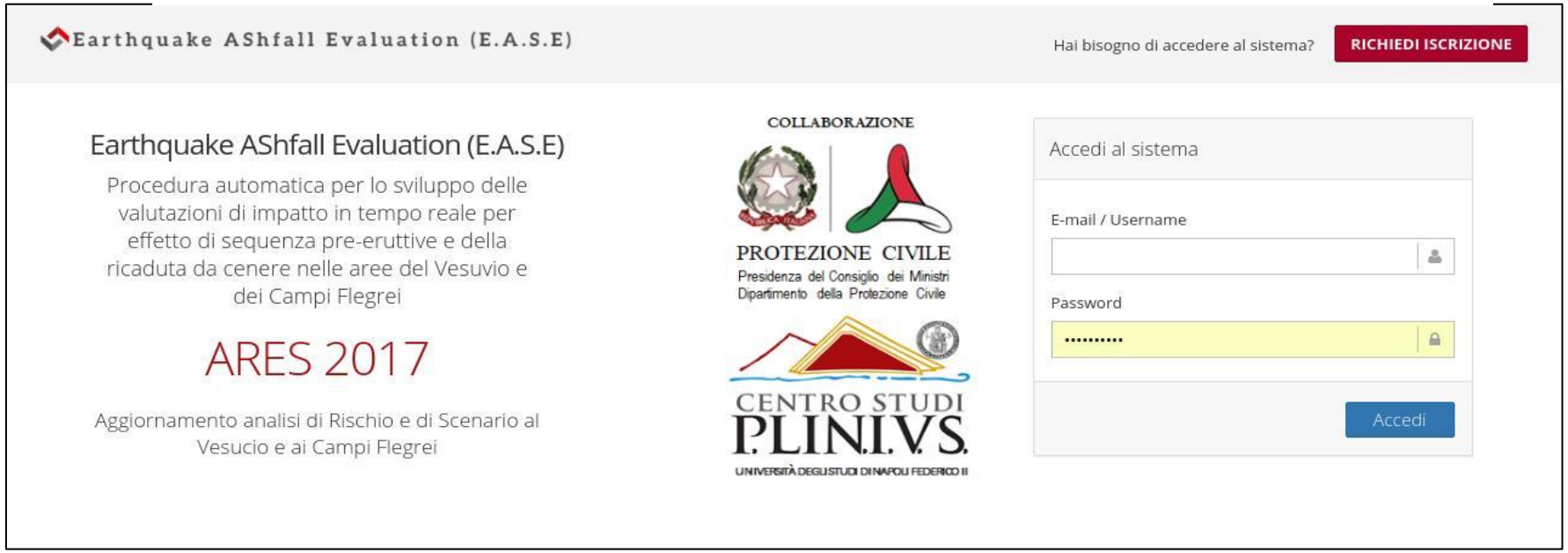
Livello di danno		Descrizione
D0	*No damage*	
D1	*Light Damage*	*Negligible damage to structural elements* *Negligible damage to infills* *Breakage of large or weak openings*
D2	*Moderate Damage*	*Moderate damage to structural elements* *Moderate damage to weak infills* *Breakage of medium-strength openings*
D3	*Heavy Damage*	*Severe damage to structural elements* *Severe damage to weak infills.* *In a few cases, total collapse of the infills* *Breaking Strong Openings*
D4	*Partial collapse*	*Partial collapse of structural elements* *Breakage of strong infills*
D5	*Collapse*	*Total collapse*

Access to the EASE application for ash fall scenarios

The automatic simulation model for ash fall (Ash Fall) allows to evaluate the damage to the roofs of buildings induced by the ground deposits estimated by INGV, thanks to a link between DPC-PLINIVS-INGV



Access to the EASE application for ash fall scenarios



Dashboard – ritorna al pannello principale con la visione d'insieme degli ultimi eventi acquisiti.

Gestione Utenti – solo per gli amministratori sistema.

Modifica Password – permette il cambio password dell'utente.

Config. Sistema – accede alle pagine di configurazione parametri di funzionamento del sistema (solo per amministratori)

Archivio Eventi EQ – consente l'accesso all'elenco degli eventi sismici acquisiti dai servizi INGV.

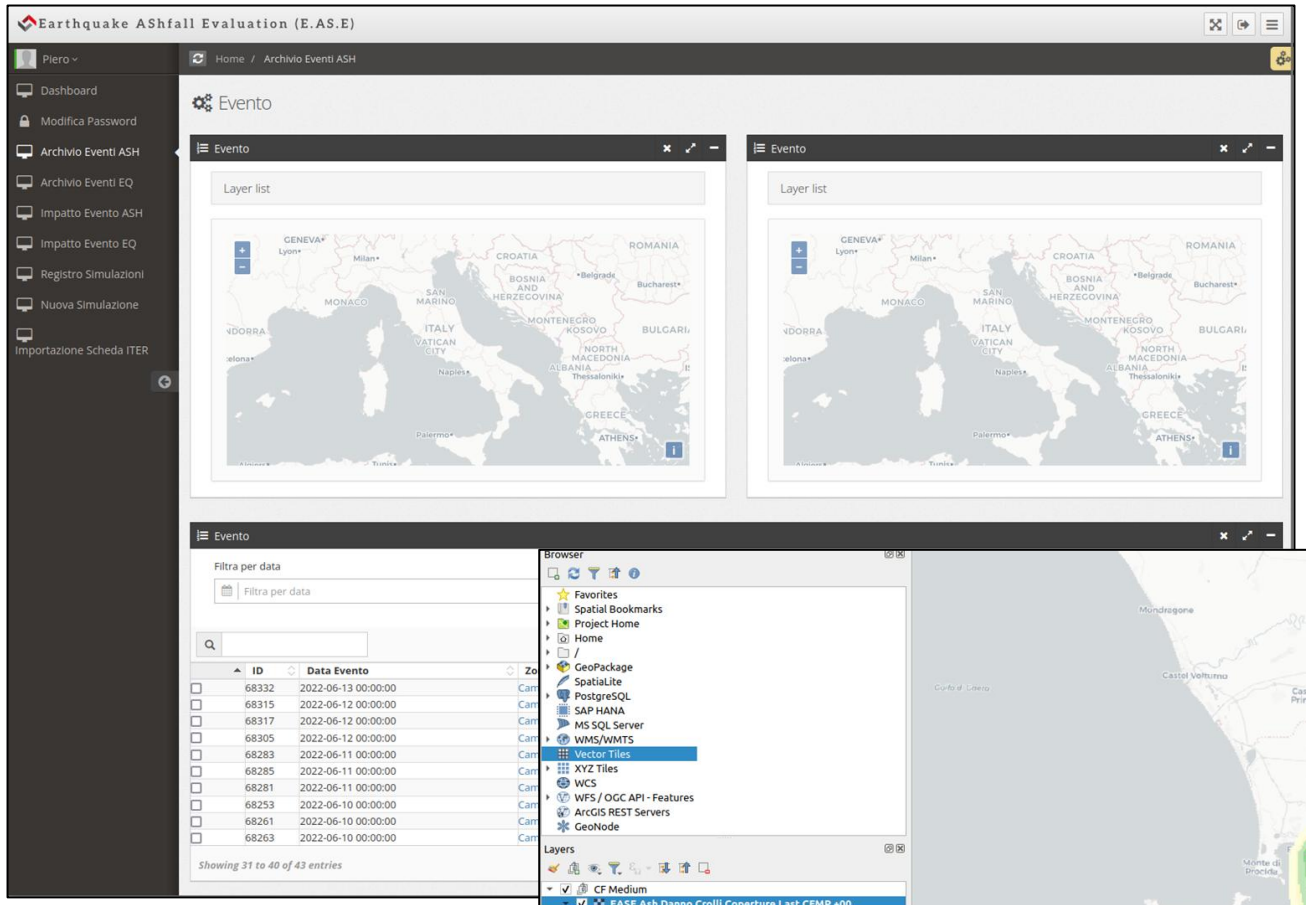
Archivio Eventi ASH – consente l'accesso all'elenco degli scenari di distribuzione cenere vulcanici acquisiti da INGV.

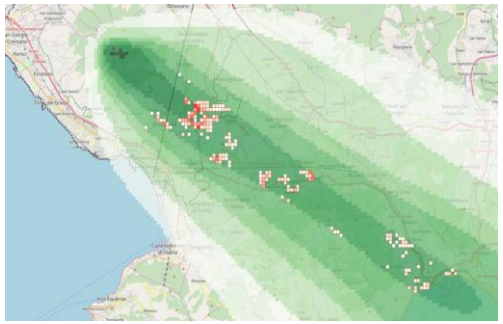
Impatto Evento EQ – porta alla sezione per la visualizzazione dei risultati di impatto scenario sismico.

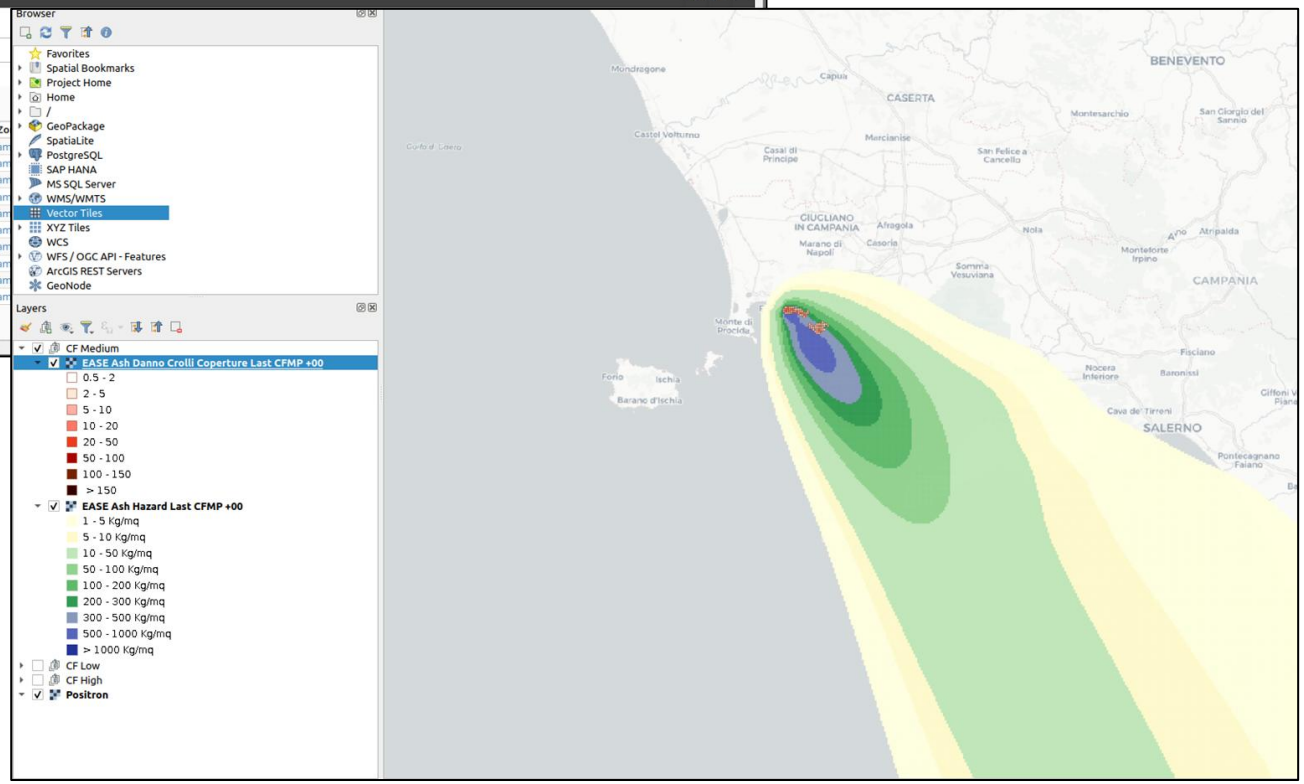
Impatto Evento ASH - porta alla sezione per la visualizzazione dei risultati ti impatto scenario vulcanico.

Registro simulazioni – visualizza l'elenco delle simulazioni elaborate (amministratori)

Web Services for Ash Fall Scenarios





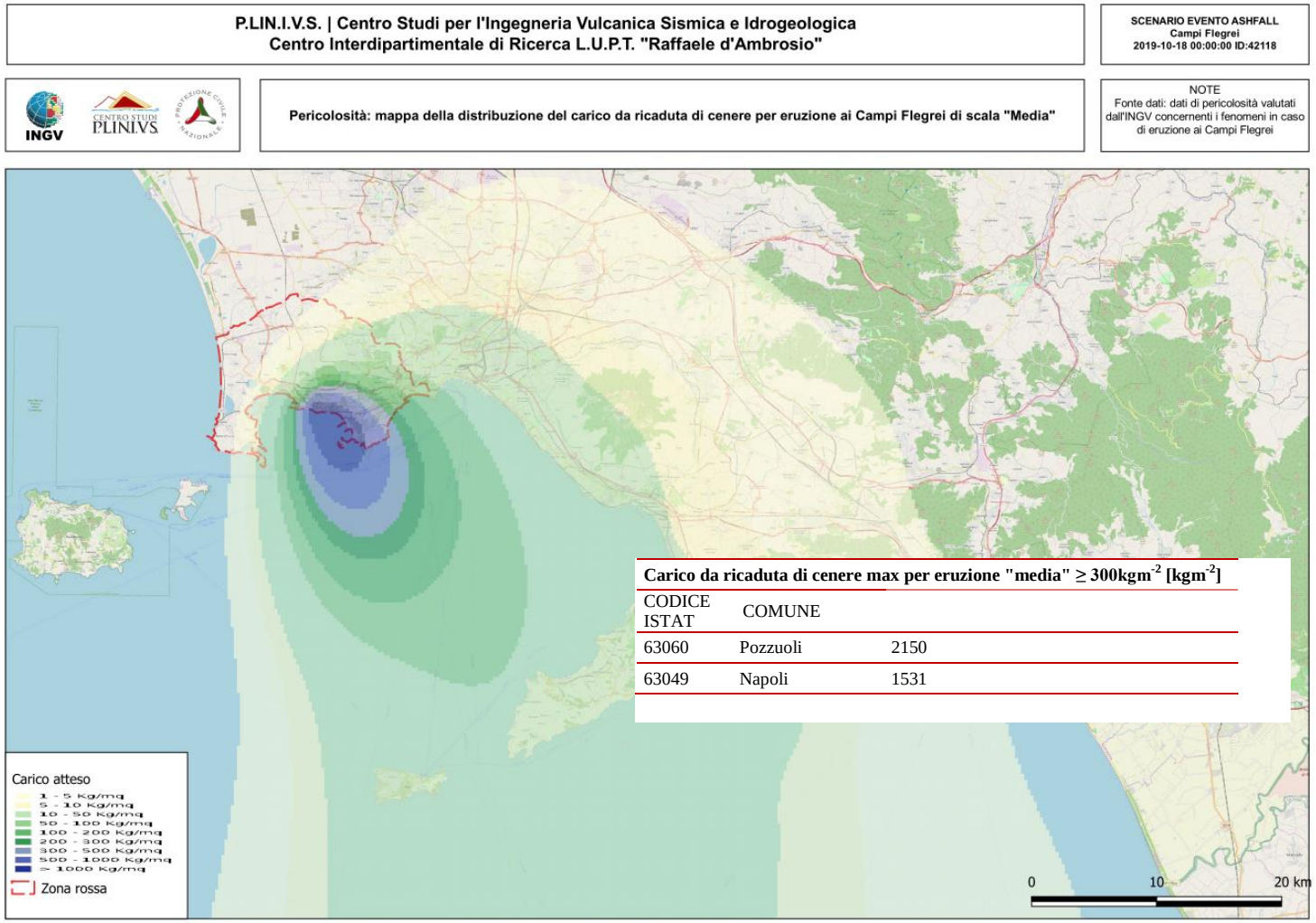


Section impact for ASH

Web Services for Ash Fall Scenarios

The connection with INGV allows the elaboration of a map of the ground load from ash fallout in kg/m2, as a function of the direction of the stratospheric winds and three possible eruptive scales (small, medium and large)

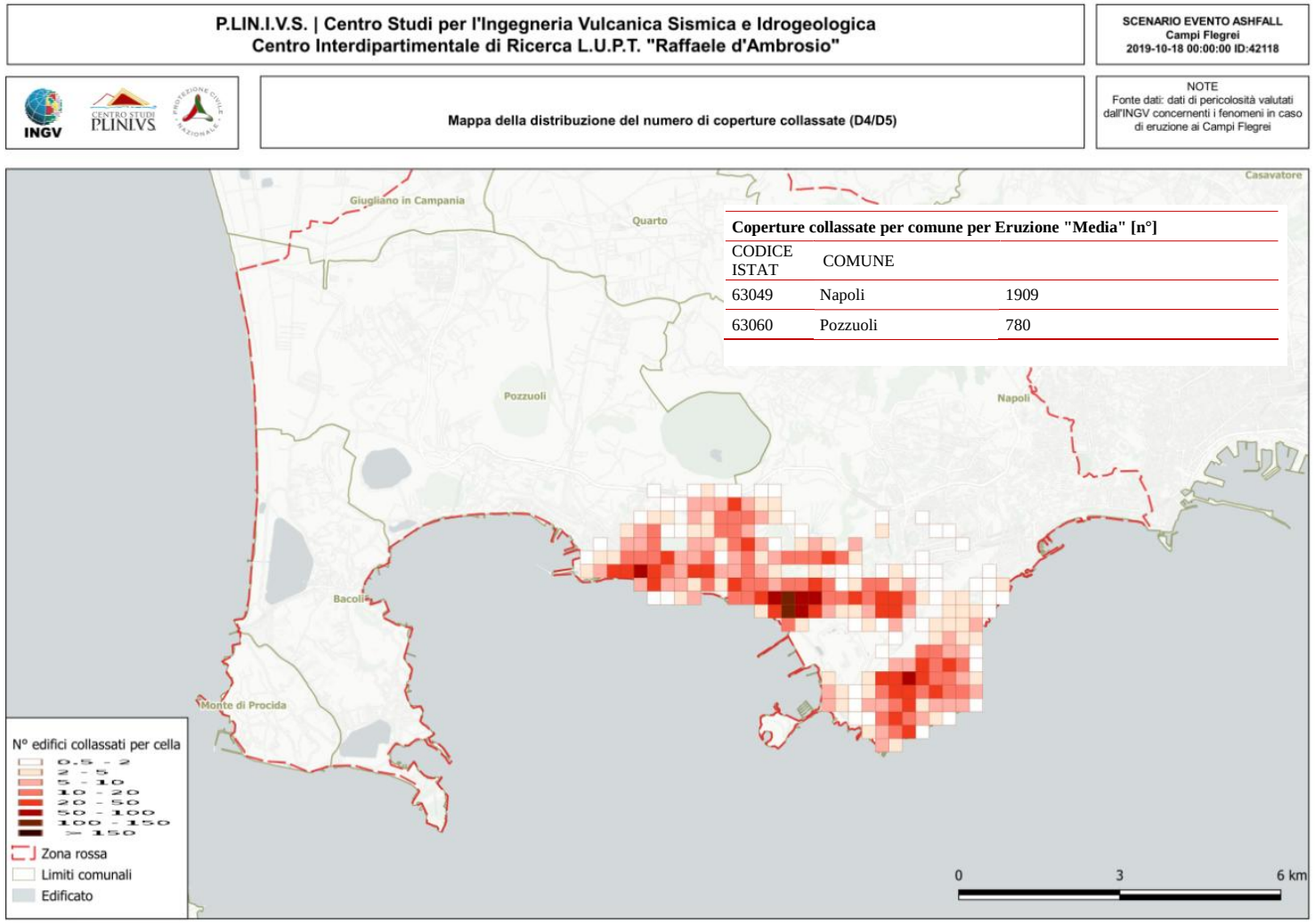
INPUT: ASH FALLOUT DUE TO ERUPTION AT CAMPI FLEGREI OF "MEDIUM" SCALE AT TIME T=0



Web Services for Ash Fall Scenarios

The combination of repository data with PLINIVS models of vulnerability and exposure provides the estimation of DAMAGE, in terms of collapsed roofs and homelessness.

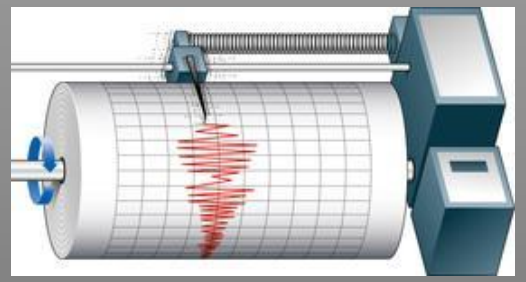
OUTPUT: ROOFS COLLAPSED BY ERUPTION AT CAMPI FLEGREI OF "MEDIUM" SCALE AT TIME T=0

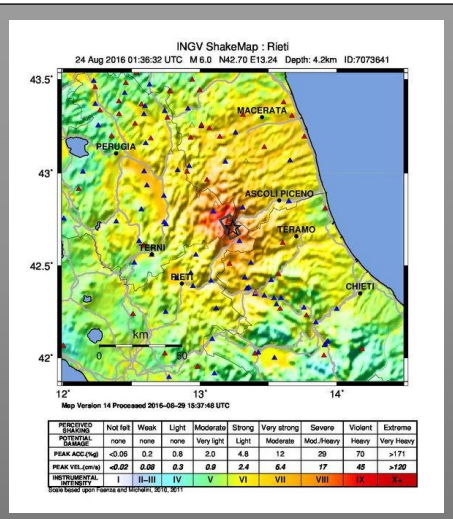


Access to the EASE application for seismic impact scenarios and related web services

The automatic simulation model for EARTHQUAKES allows to evaluate the damage to buildings and occupants induced by a seismic event recorded by INGV, thanks to a direct link between DPC-PLINIVS-INGV

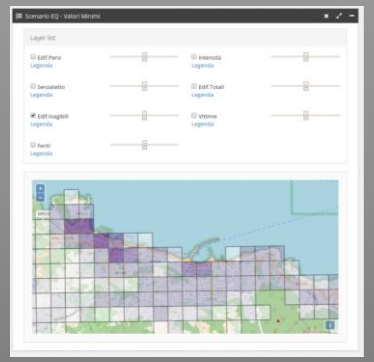
INGV





SALA Operativa

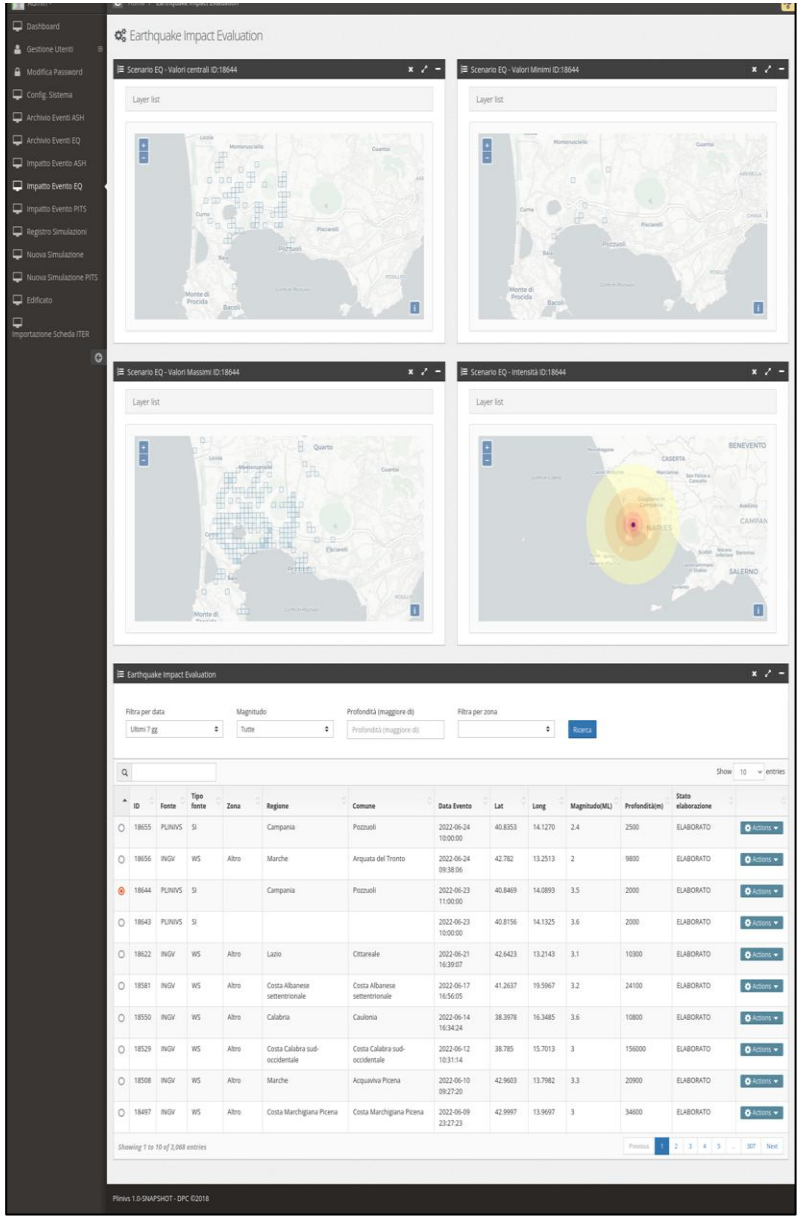
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

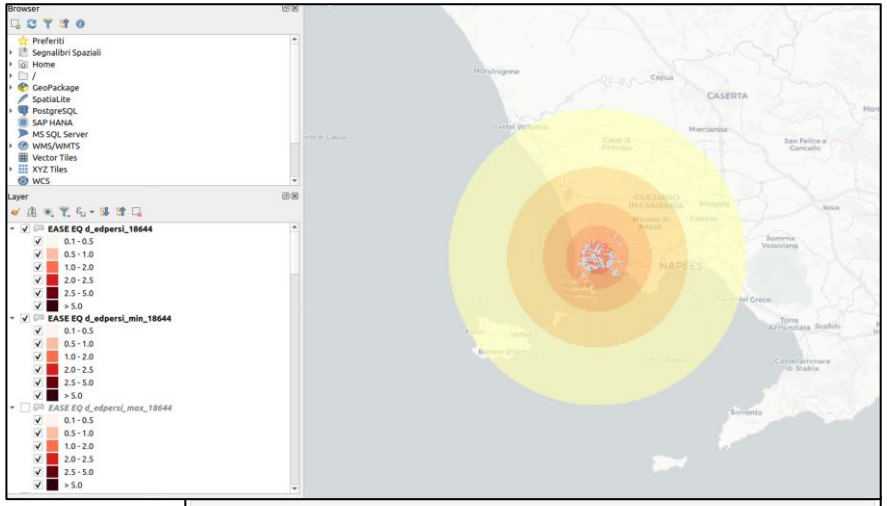


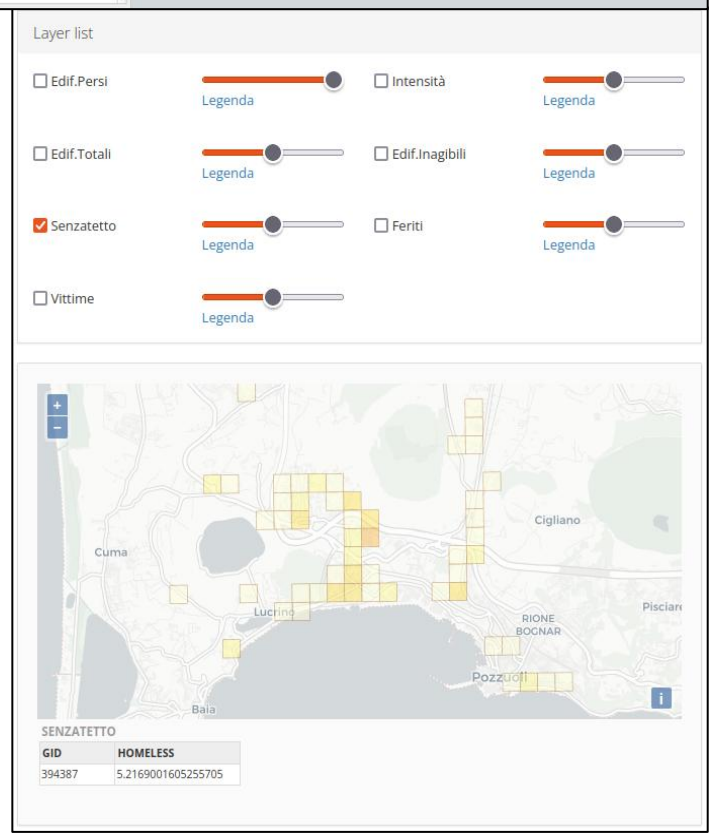
CENTRO STUDI P.L.I.N.I.V.S.

Earthquake AShfall Evaluation (E.AS.E)

Access to the EASE application for seismic impact scenarios and related web services

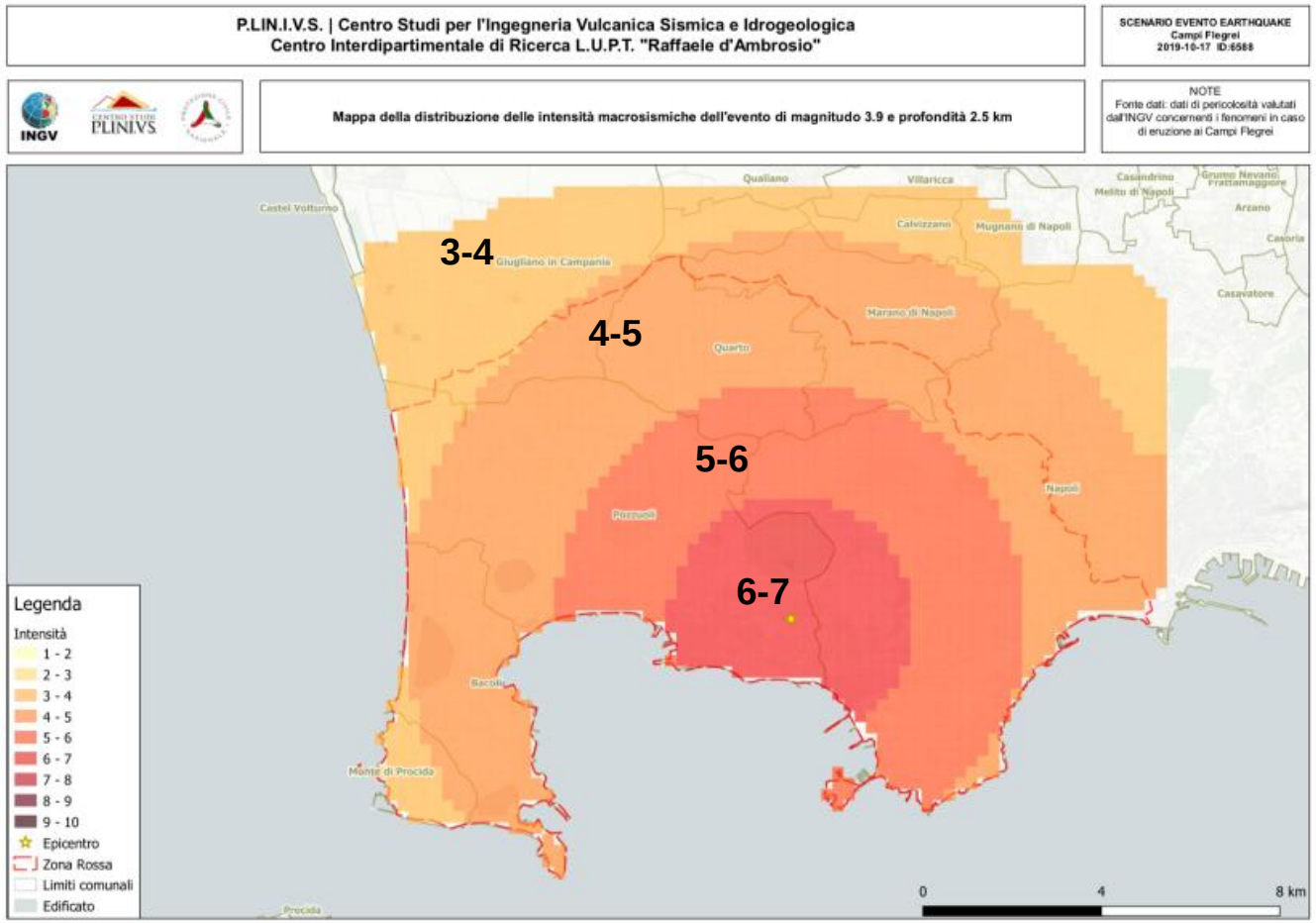






Access to the EASE application for seismic impact scenarios and related web services

The connection with INGV allows a reading of the event and the elaboration of an Intensity/PGA map.
The figure shows the map of a seismic event at Campi Flegrei, used during the EXEFLEGREI Exercise

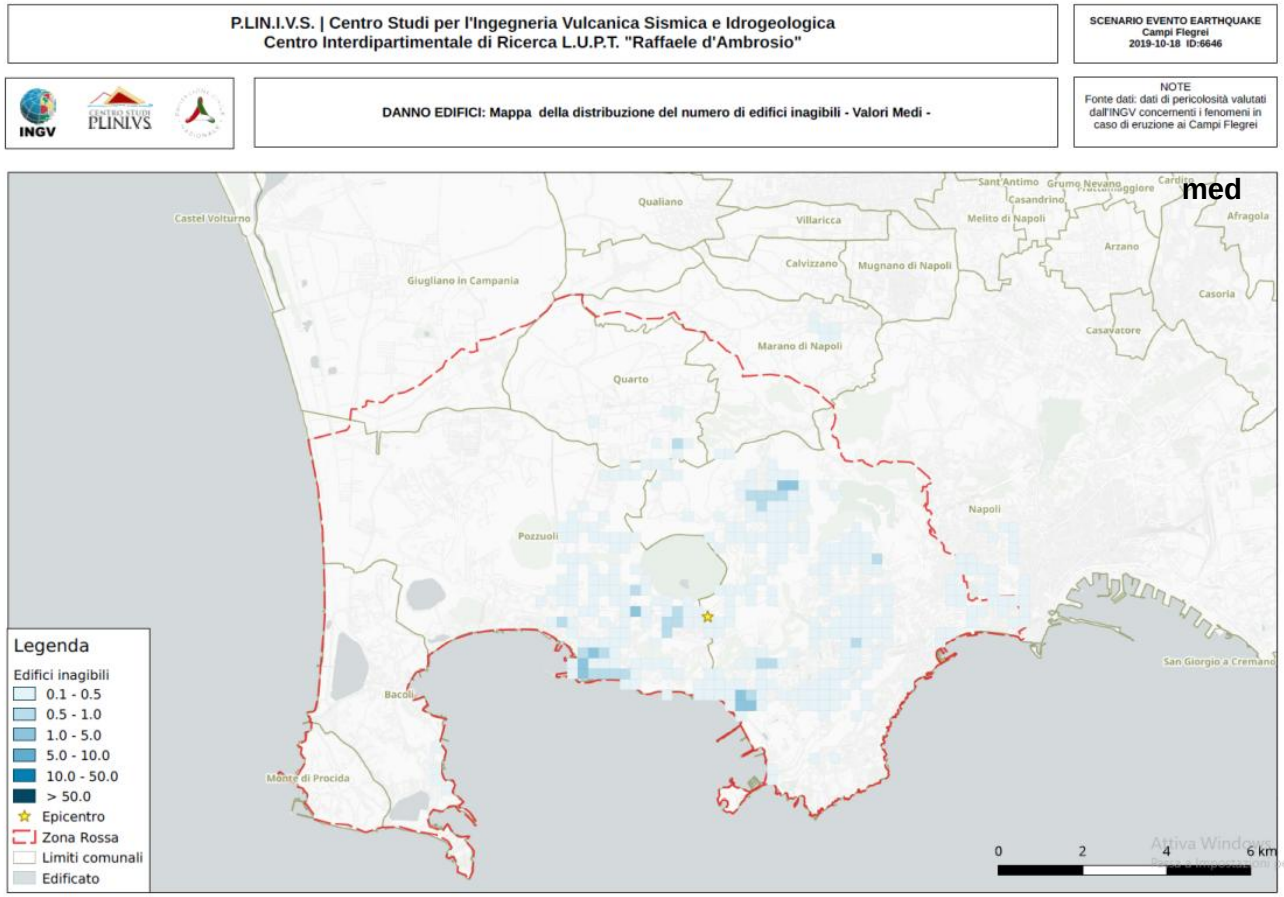


INPUT:
MAGNITUDE EVENT4.2
DEPTH 2.5 KM

TIME 15.30, 18.10.2018

Access to the EASE application for seismic impact scenarios and related web services

The combination of hazard data with PLINIVS models of vulnerability and exposure provides the estimation of DAMAGE, in terms of collapsed buildings, uninhabitable buildings, deaths, injuries and homelessness.



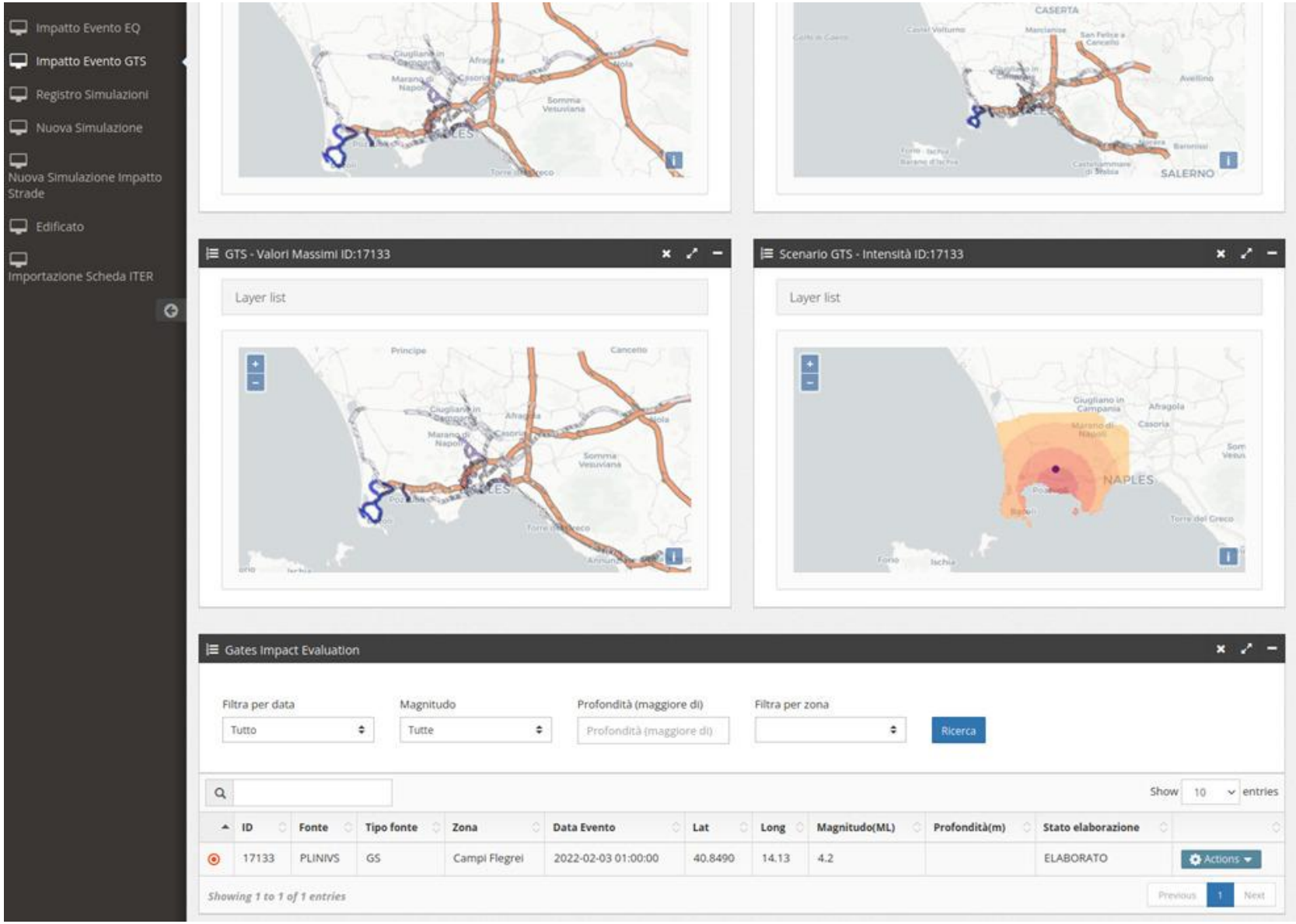
Danno agli edifici per comune [n°]

CODICE ISTAT	COMUNE
63060	Pozzuoli
63049	Napoli
63041	Marano di Napoli
63006	Bacoli
63063	Quarto
TOTALI	

INPUT:
MAGNITUDE EVENT4.2
DEPTH 2.5 KM

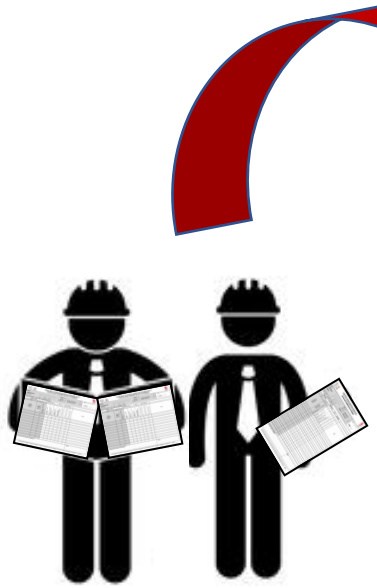
TIME 15.30, 18.10.2018

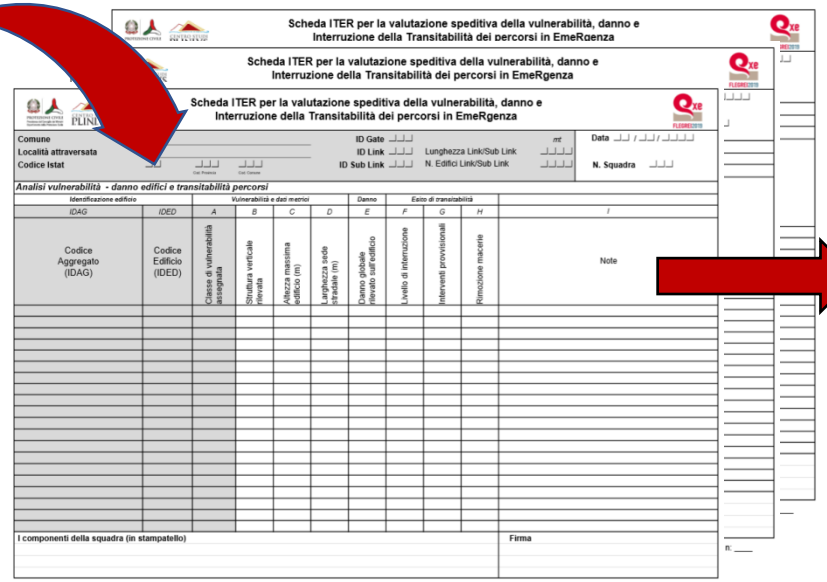
Access to the application for the evaluation of the probability of interruption due to seismic events of the estrangement paths and related web services



CENTRO STUDI PLINIVS

EARTHQUAKE: ROAD SECTION INTERRUPTIONS. FIELD SURVEYS





Scheda ITER per la valutazione speditiva della vulnerabilità, danno e Interruzione della Transitabilità dei percorsi in EmeRgenza

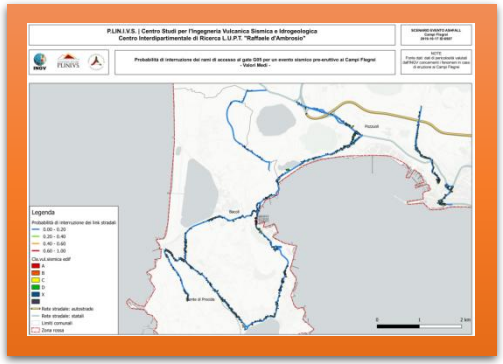
Comune
Località attraversata
Codice Istat
ID Gate
ID Link
ID Sub Link
Lunghezza Link/Sub Link
N. Edifici Link/Sub Link
Data
N. Squadra

Analisi vulnerabilità - danno edifici e transitabilità percorsi

Identificazione edificio		Vulnerabilità e dati metrici				Danno	Esito di transitabilità			
IDAG	IDED	A	B	C	D	E	F	G	H	I
Codice Aggregato (IDAG)	Codice Edificio (IDED)	Classe di vulnerabilità assegnata	Struttura verticale ritenuta	Altezza massima edificio (m)	Larghezza sede stradale (m)	Danno globale ritenuto sull'edificio	Livello di interruzione	Interventi provvisionali	Rimozione macerie	Note

I componenti della squadra (in stampatello) — Firma

La presente scheda è compilata a fini esclusivamente esercitivi, i dati raccolti e l'esito riportato sono una mera simulazione e non sono da intendersi rappresentativi di una verifica reale. Pagina n: ___

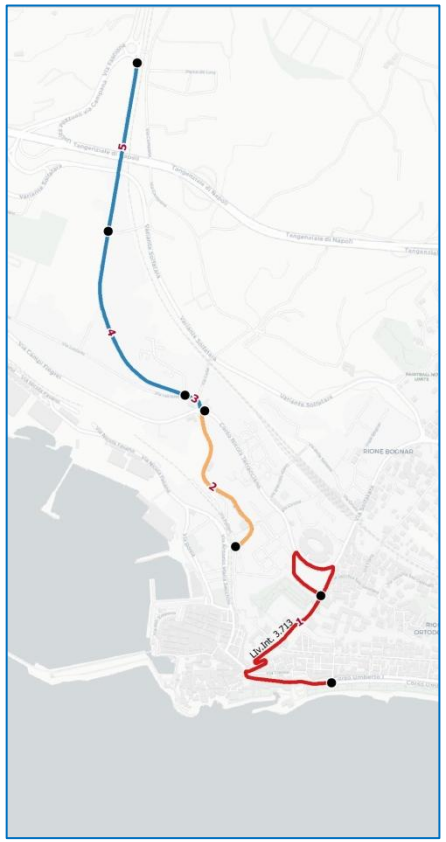


INPUT:
MAGNITUDO 4.2
DEPTH 2.5 KM

TIME 15.30, 18.10.2018

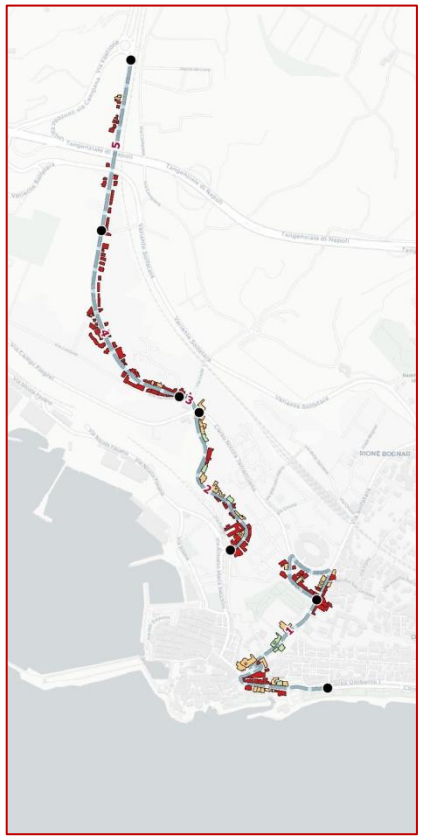
Access to the application for the evaluation of the probability of interruption due to seismic events of the estrangement paths and related web services

Based on the damage data to the building, the model also provides the PROBABILITIES OF INTERRUPTION OF ROAD SECTIONS, in order to support emergency management operations.

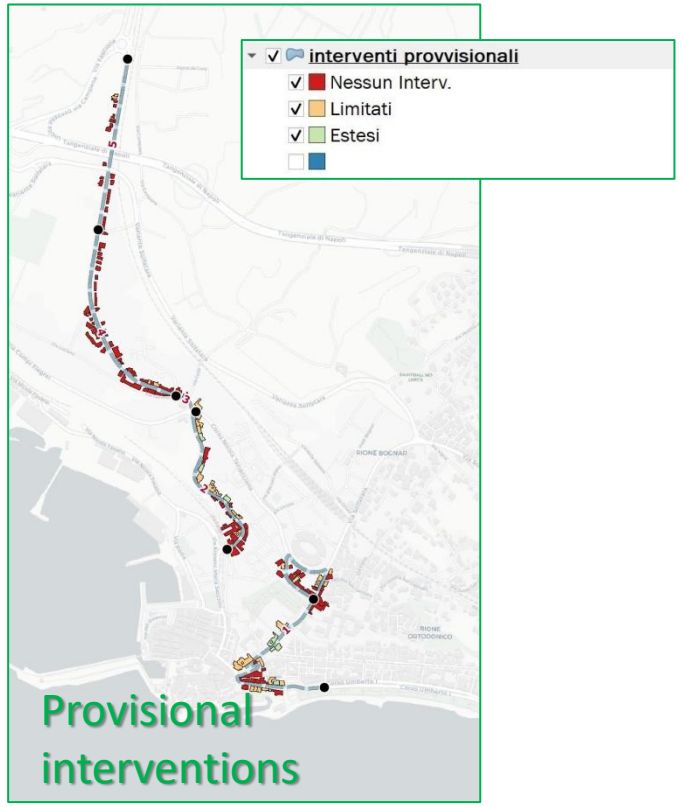


Probability of interruption

INPUT:
MAGNITUDE 4.2 EVENT
AND DEPTH 2.5 KM
3.30 P.M., 18.10.2018



Rubble removal

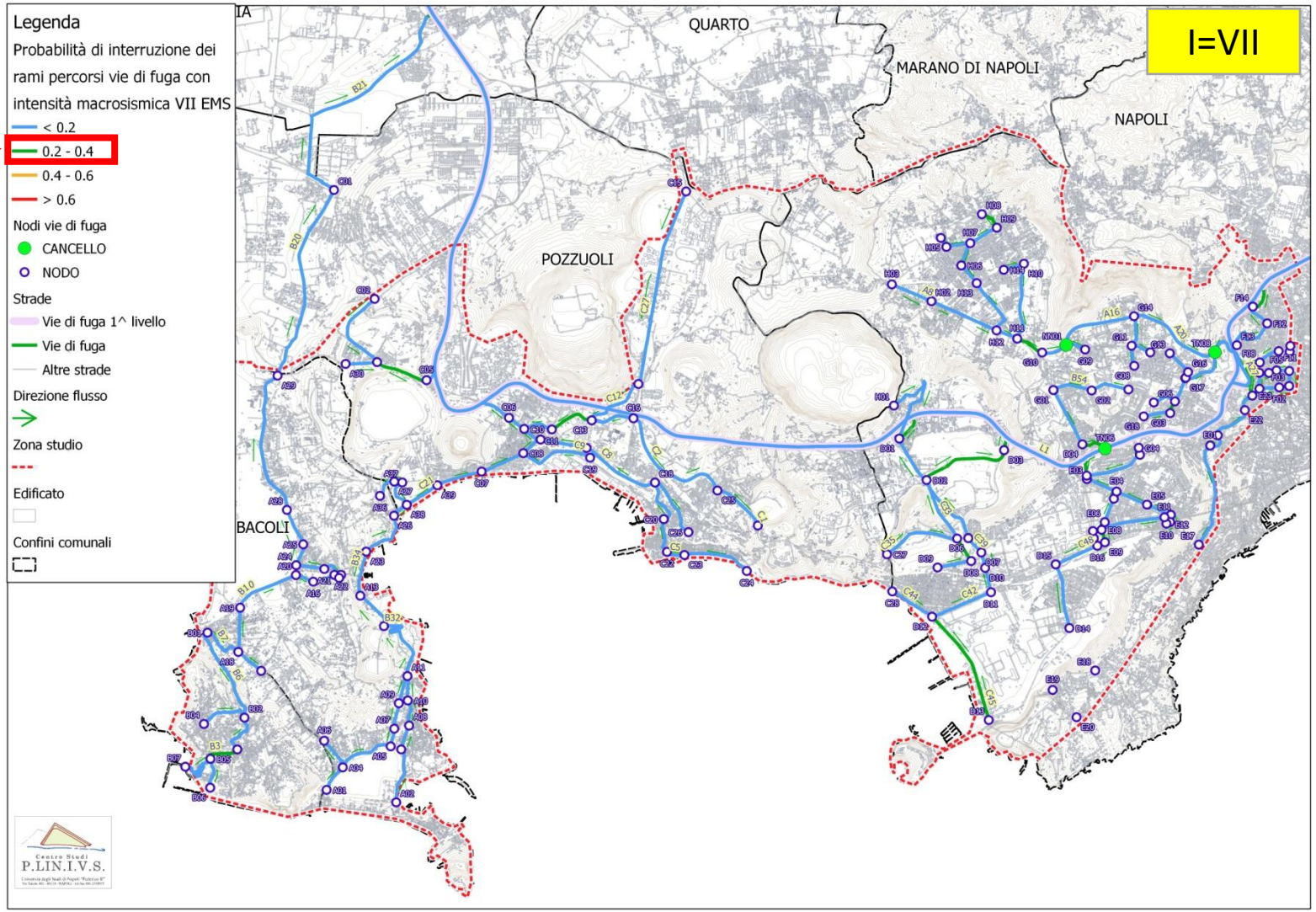


Provisional interventions

SCENARIO OF SEISMIC DAMAGE TO ROAD SECTIONS

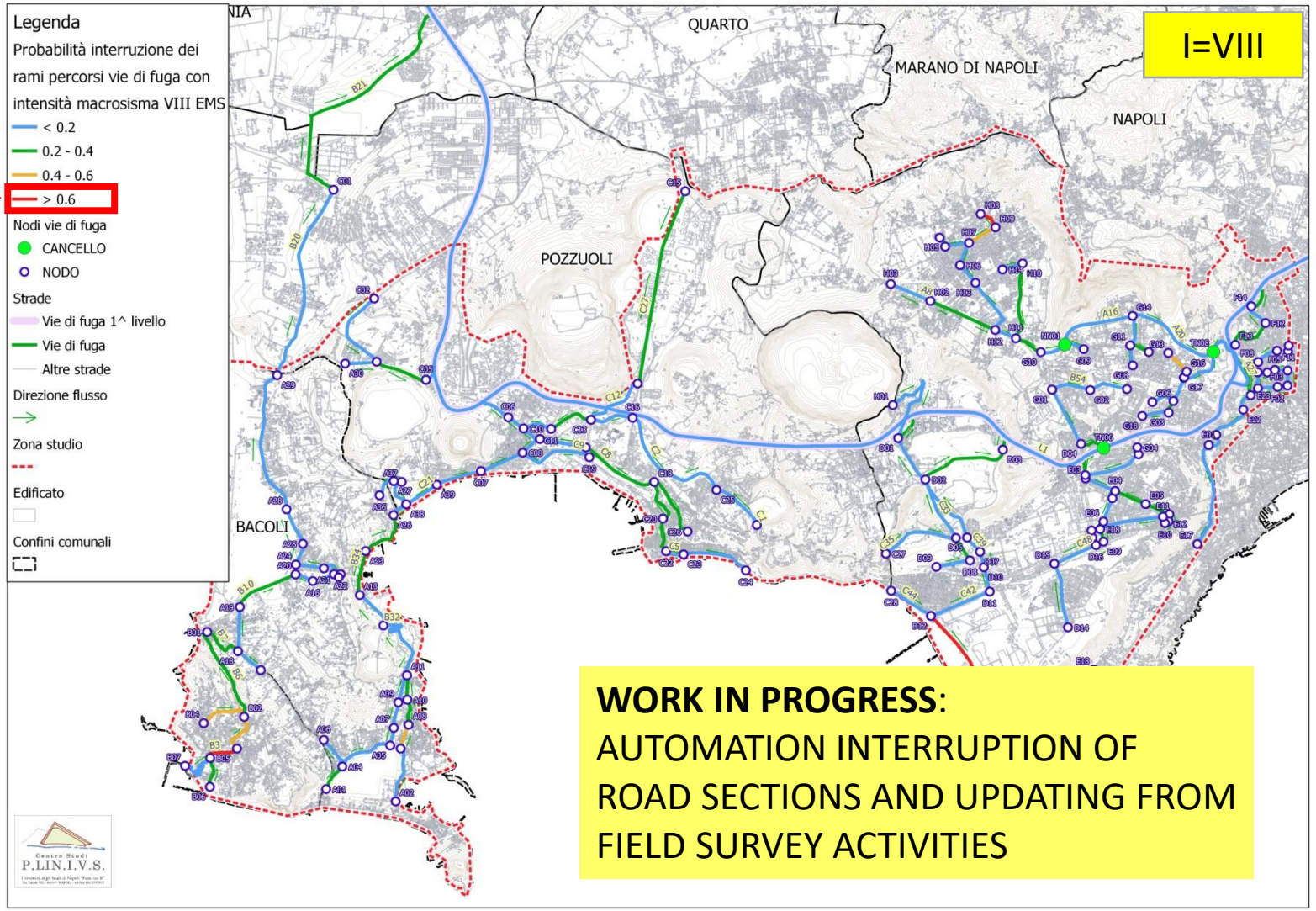
"Vecchio Grafo" produced by the University of Rome La Sapienza

CAMPI FLEGREI: MAP OF THE INTERRUPTION OF ESCAPE ROUTES



SCENARIO OF SEISMIC DAMAGE TO ROAD SECTIONS

CAMPI FLEGREI: MAP OF THE INTERRUPTION OF ESCAPE ROUTES



WORK IN PROGRESS:
AUTOMATION INTERRUPTION OF ROAD SECTIONS AND UPDATING FROM FIELD SURVEY ACTIVITIES

Access to the bradyseismic impact assessment application

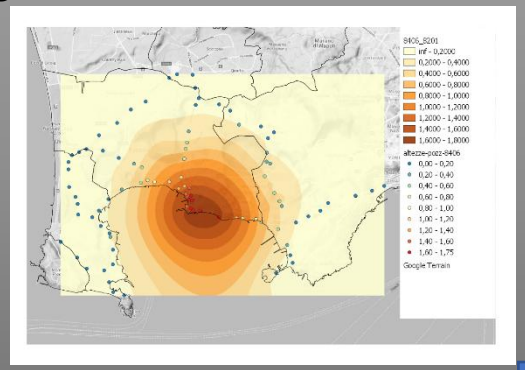
WEB APPLICATION FOR THE MANAGEMENT OF THE PROCEDURE FOR THE EVALUATION OF THE BEHAVIOUR OF ORDINARY PHLEGRAEAN BUILDINGS TO THE PHENOMENON OF BRADYSEISM

The connection with IREA and INGV allows a reading of the lifts and the elaboration of a map of lifts/slopes.

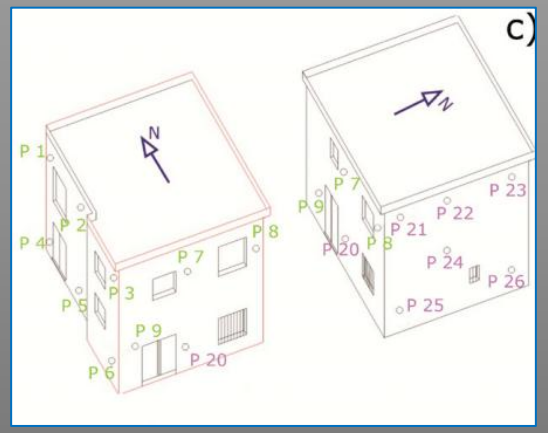
Uplift registration

INGV

istituto per il rilevamento elettromagnetico dell'ambiente



Sentinel buildings

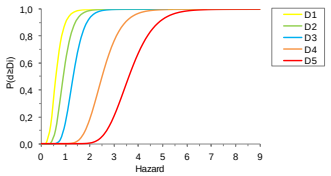


Web Application

CENTRO STUDI PLINIVS

Censimento 2021

CENSIMENTO+ ATTIVITA' DI RACCOLTA DATI



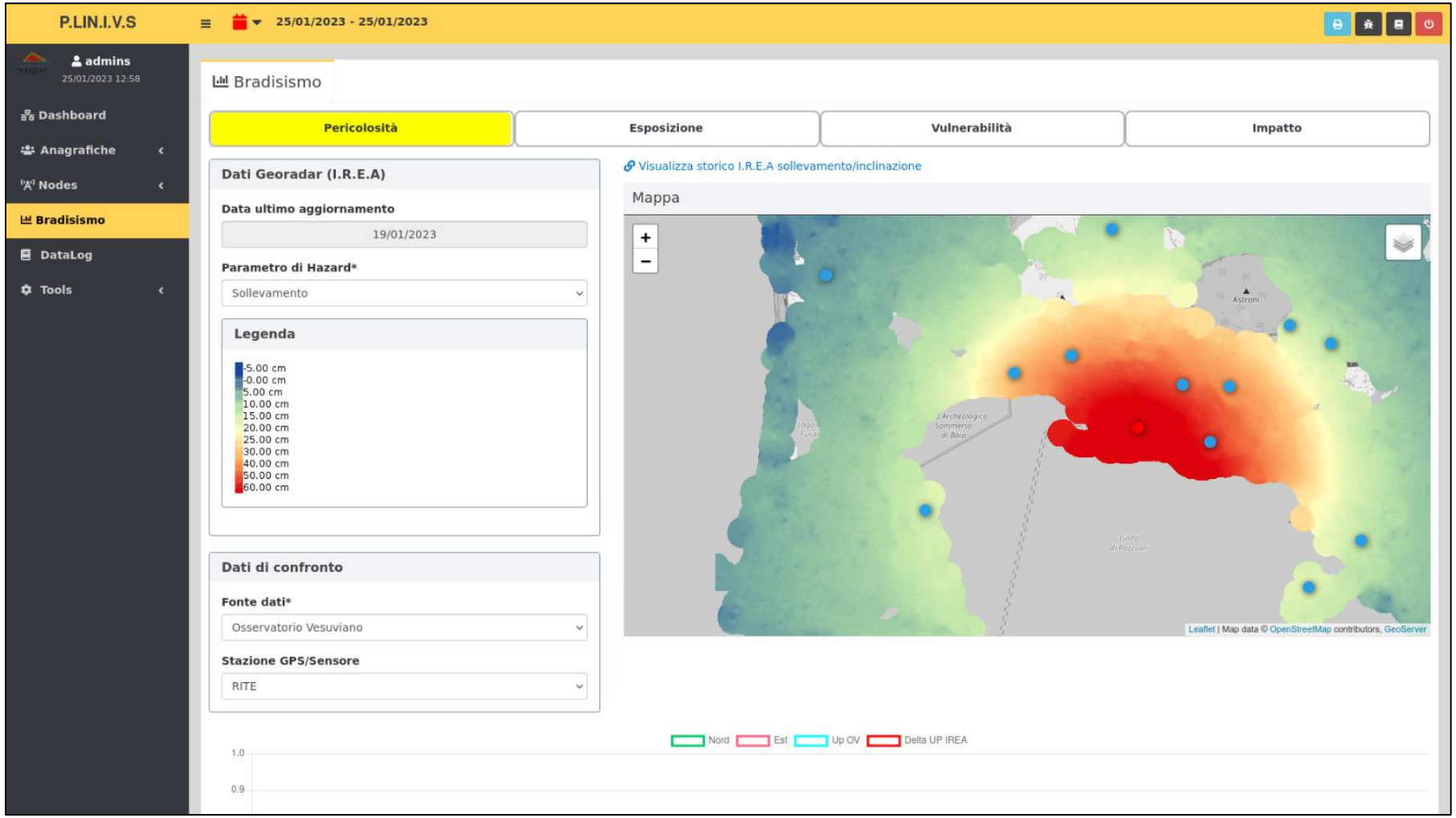
CURVE DI VULNERABILITA'

Damage estimation

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

1 mese

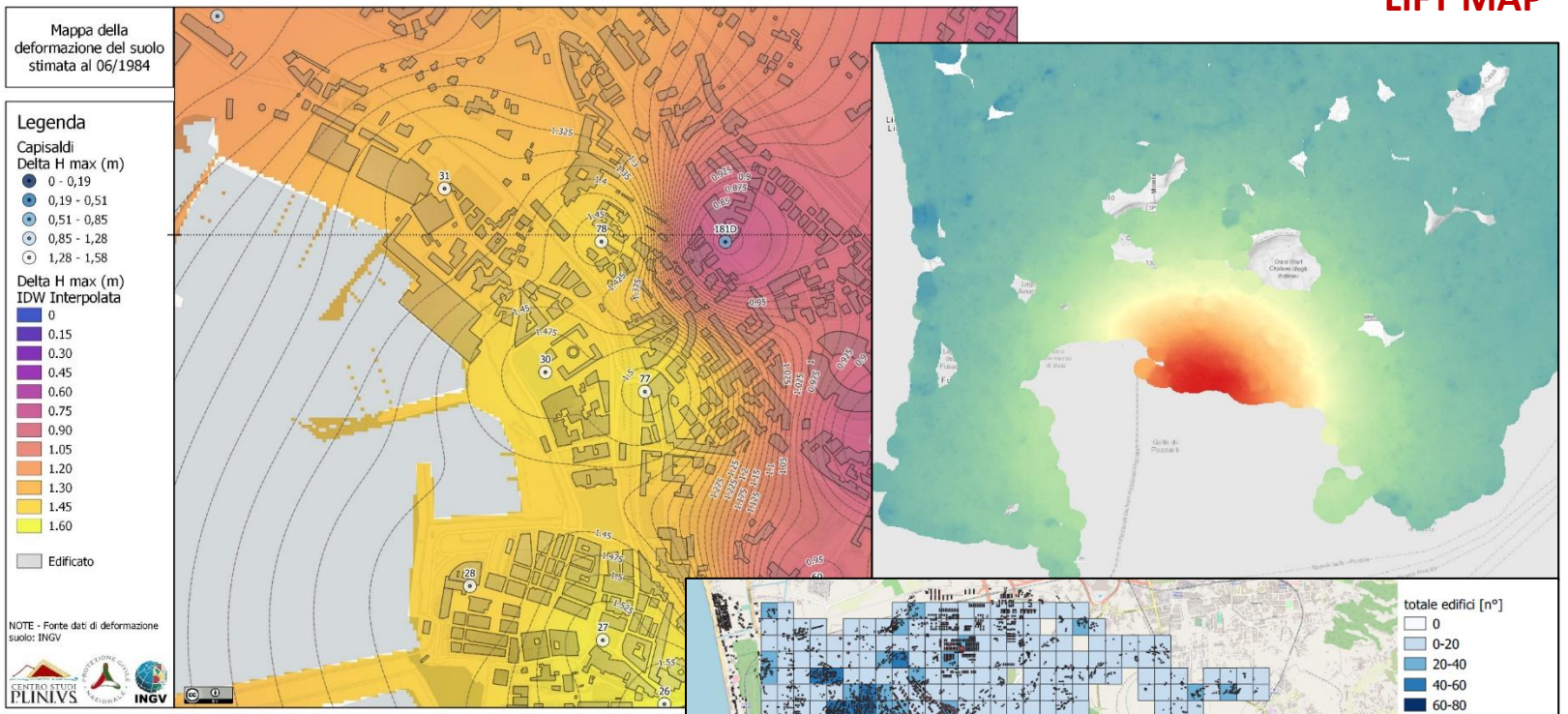
Access to the bradyseismic impact assessment application



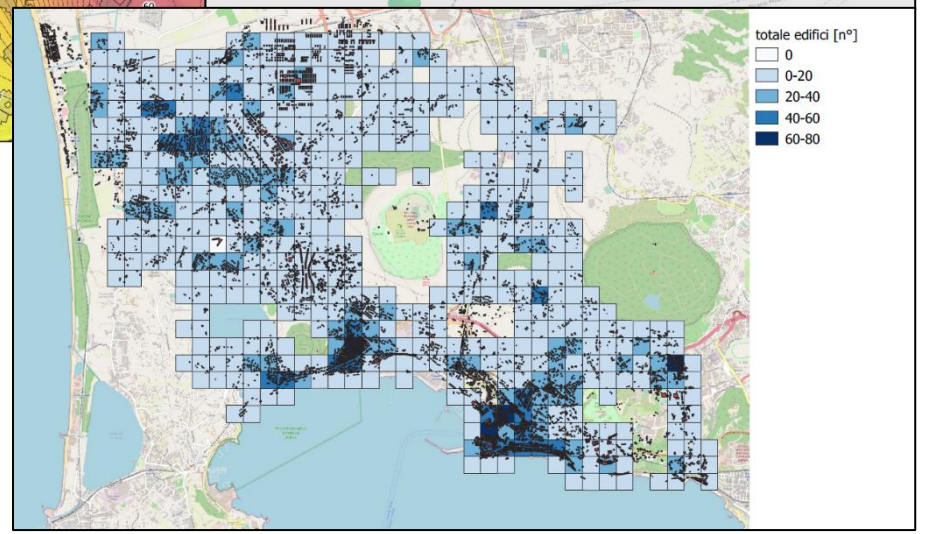
Access to the bradyseismic impact assessment application

The combination of lift data with PLINIVS models of vulnerability and exposure provides an estimate of damage to buildings.

LIFT MAP



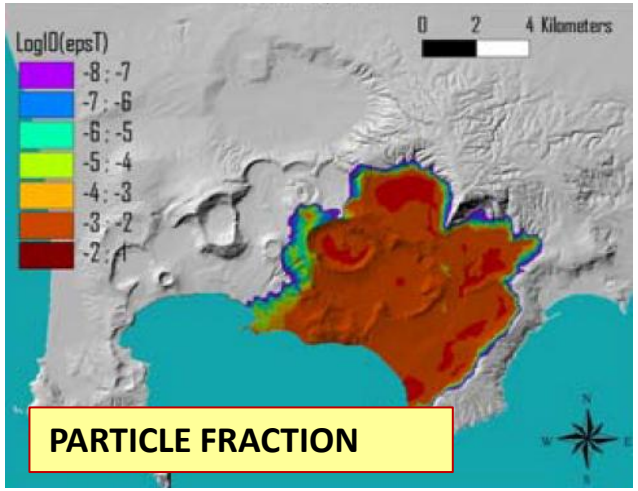
MAP OF GROUND DEFORMATIONS 1984



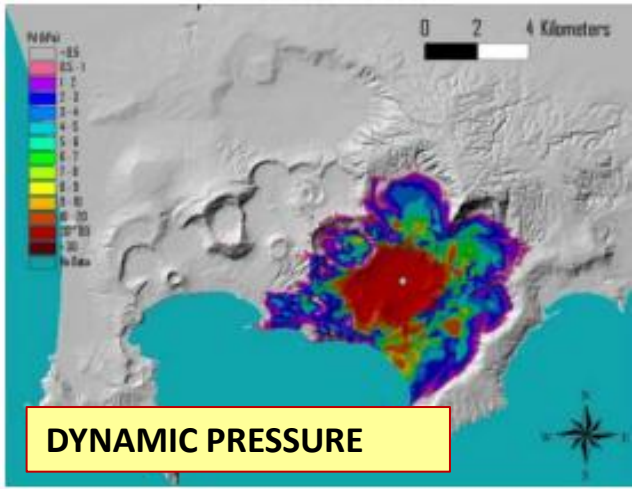
IMPACT MAP

Scenarios from pyroclastic flows

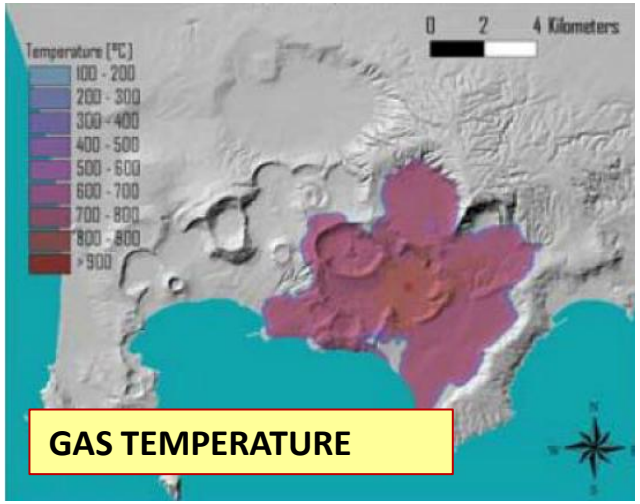
PYROCLASTIC FLOW HAZARDS



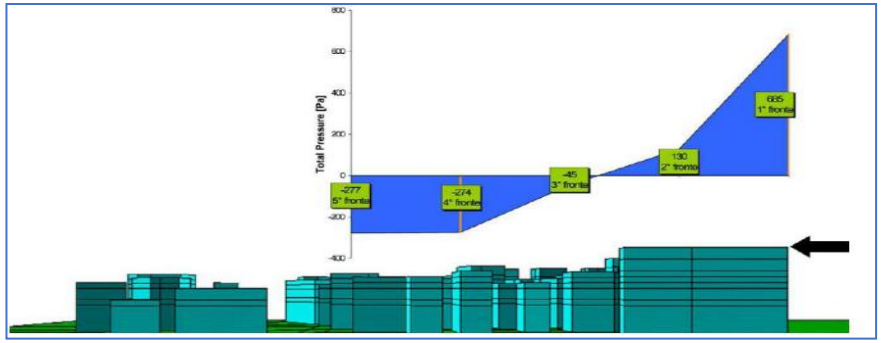
PARTICLE FRACTION



DYNAMIC PRESSURE



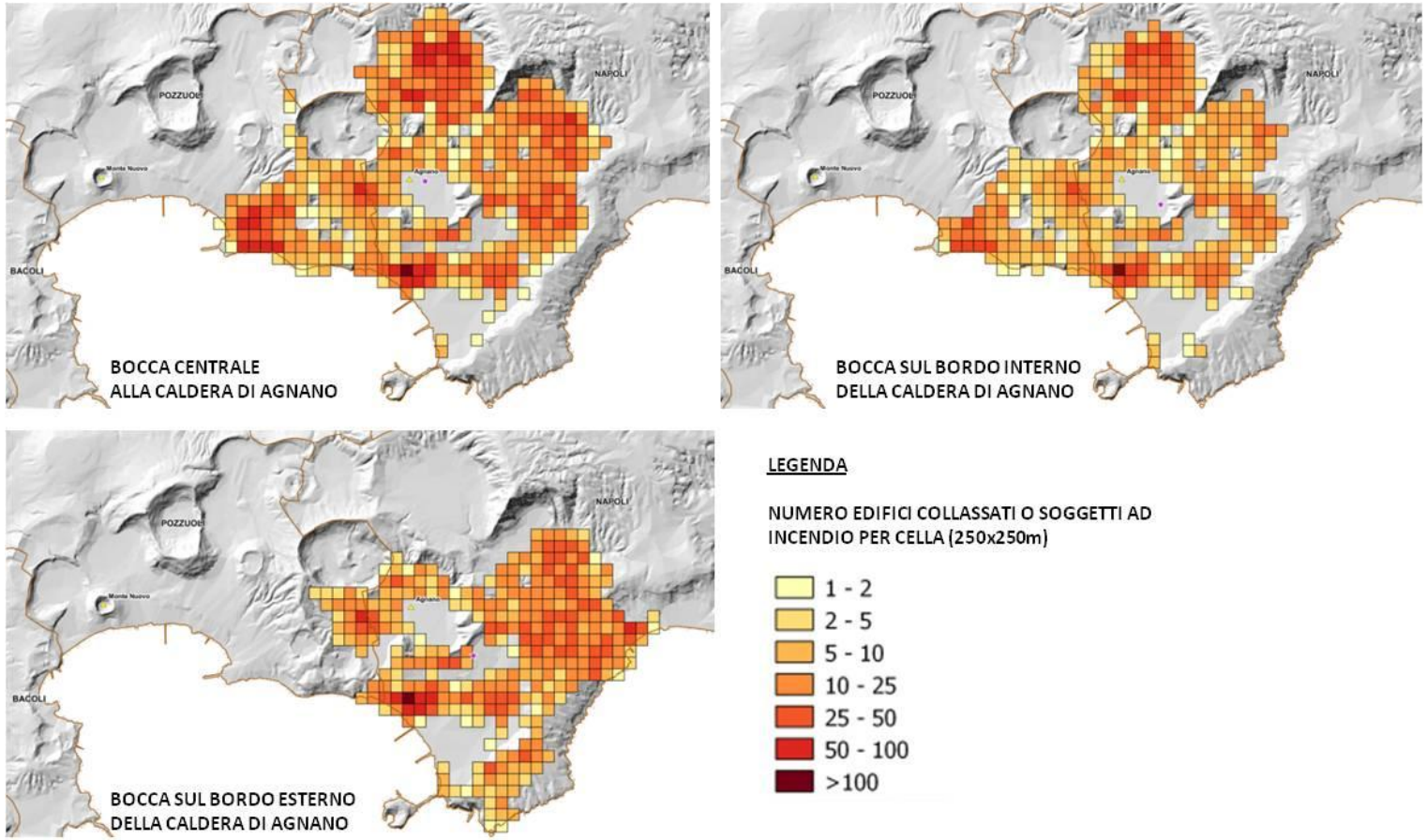
GAS TEMPERATURE



PRESSURE VARIATION DUE TO SETTLEMENTS

Scenarios from pyroclastic flows

IMPACT FROM PYROCLASTIC FLOWS

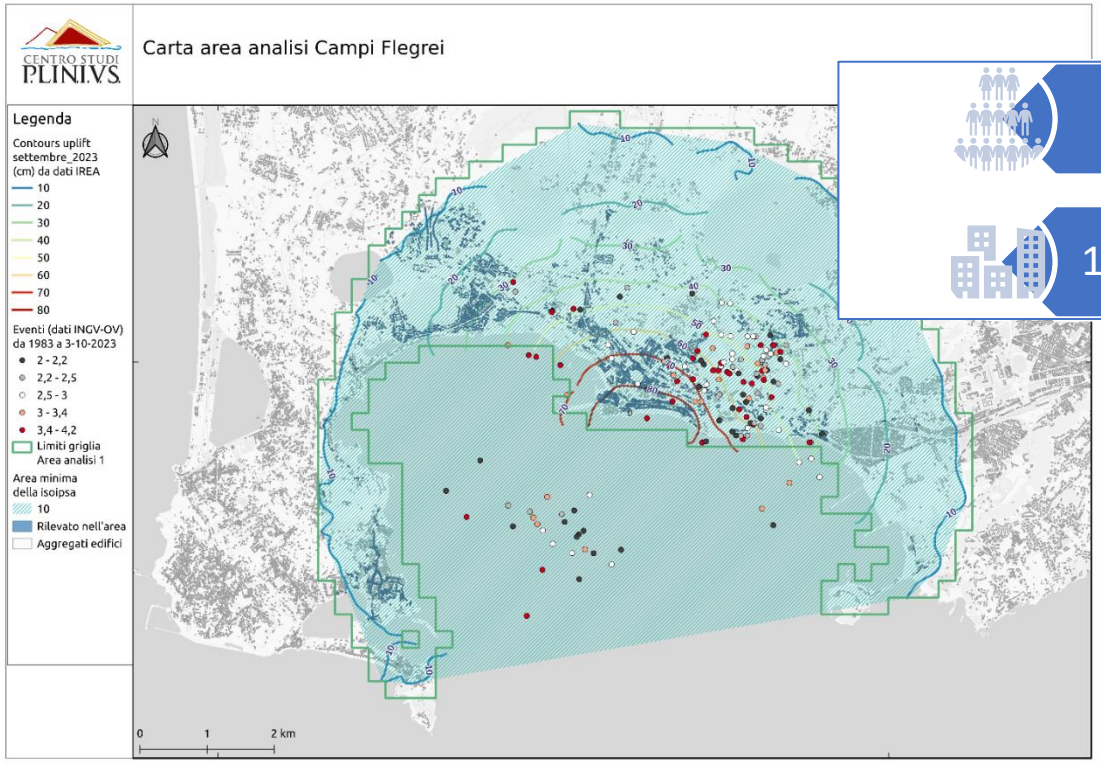


The only defense for the population is to move away from the area at greatest risk, i.e. the one that can be invaded by pyroclastic flows, before the start of the eruption, based on the analysis of the precursory phenomena monitored by the surveillance system of the Vesuvius Observatory.

PLINIVS activities for D.L.

In agreement with INGV-OV, the possible area of intervention was delimited, identifying the Phlegraean area characterized by:

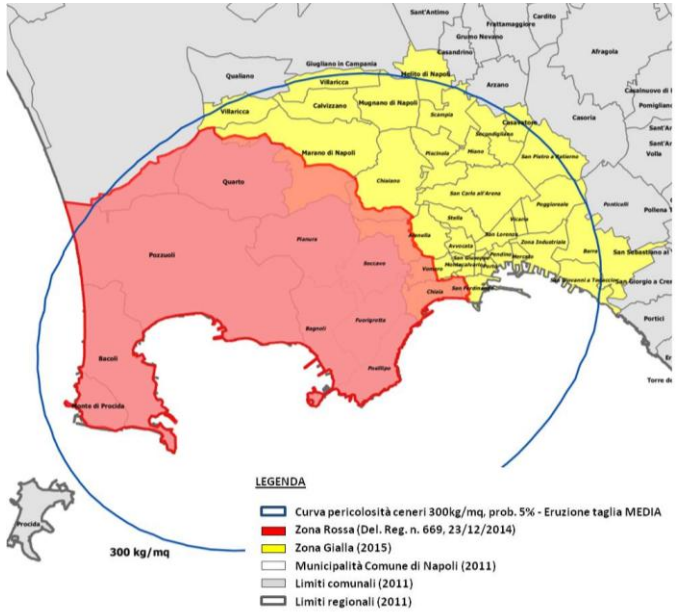
- earthquakes with a magnitude greater than 2 since 1983(
  (PLINIVS processing of INGV-OV data, https://terremoti.ov.ingv.it/gossip);
- and bradyseismic uplifts of not less than 10 cm starting from 2015, corresponding to about 20 cm from 2006
  (from PLINIVS processing of the data produced by CNR-IREA and updated in May 2023).



85 thousand people

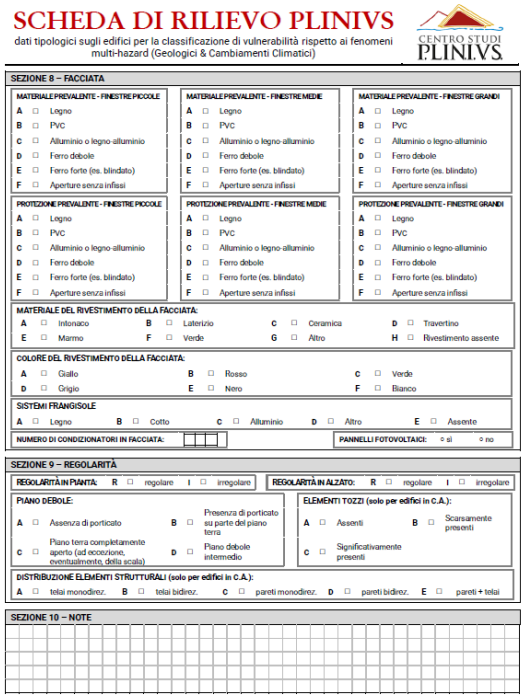
15 thousand buildings

PLINIVS activities for D.L. 140



In the Red Zone defined in the Volcanic Emergency Plan of the CAMPI FLEGREI, PLINVS has collected georeferenced data on the typological-structural characteristics of about 8,000 ordinary buildings (about 4,000 in the Municipality of Pozzuoli).

The data collection was carried out through a visual-expeditious survey, from the outside of the buildings, and the compilation of the PLINIVS FORM.



SCHEDA DI RILIEVO PLINIVS

dati tipologici sugli edifici per la classificazione di vulnerabilità rispetto ai fenomeni multi-hazard (Geologici & Cambiamenti Climatici)

CENTRO STUDI PLINIVS

SEZIONE 8 – FACCIATA

MATERIALE PREVALENTE - FINESTRE PICCOLE	MATERIALE PREVALENTE - FINESTRE MEDIE	MATERIALE PREVALENTE - FINESTRE GRANDI
A ☐ Legno	A ☐ Legno	A ☐ Legno
B ☐ PVC	B ☐ PVC	B ☐ PVC
C ☐ Alluminio o legno-alluminio	C ☐ Alluminio o legno-alluminio	C ☐ Alluminio o legno-alluminio
D ☐ Ferro debole	D ☐ Ferro debole	D ☐ Ferro debole
E ☐ Ferro forte (es. blindato)	E ☐ Ferro forte (es. blindato)	E ☐ Ferro forte (es. blindato)
F ☐ Aperture senza infissi	F ☐ Aperture senza infissi	F ☐ Aperture senza infissi

PROTEZIONE PREVALENTE - FINESTRE PICCOLE	PROTEZIONE PREVALENTE - FINESTRE MEDIE	PROTEZIONE PREVALENTE - FINESTRE GRANDI
A ☐ Legno	A ☐ Legno	A ☐ Legno
B ☐ PVC	B ☐ PVC	B ☐ PVC
C ☐ Alluminio o legno-alluminio	C ☐ Alluminio o legno-alluminio	C ☐ Alluminio o legno-alluminio
D ☐ Ferro debole	D ☐ Ferro debole	D ☐ Ferro debole
E ☐ Ferro forte (es. blindato)	E ☐ Ferro forte (es. blindato)	E ☐ Ferro forte (es. blindato)
F ☐ Aperture senza infissi	F ☐ Aperture senza infissi	F ☐ Aperture senza infissi

MATERIALE DEL RIVESTIMENTO DELLA FACCIATA:
A ☐ Intonaco B ☐ Laterizio C ☐ Ceramica D ☐ Travertino
E ☐ Marmo F ☐ Verde G ☐ Altro H ☐ Rivestimento assente

COLORE DEL RIVESTIMENTO DELLA FACCIATA:
A ☐ Giallo B ☐ Rosso C ☐ Verde
D ☐ Grigio E ☐ Nero F ☐ Bianco

SISTEMI FRANGISOLE
A ☐ Legno B ☐ Cotto C ☐ Alluminio D ☐ Altro E ☐ Assente

NUMERO DI CONDIZIONATORI IN FACCIATA: ☐☐☐ PANNELLI FOTOVOLTAICI: ○ si ○ no

SEZIONE 9 – REGOLARITÀ

REGOLARITÀ IN PIANTA: R ☐ regolare I ☐ irregolare
REGOLARITÀ IN ALZATO: R ☐ regolare I ☐ irregolare

PIANO DEBOLE:
A ☐ Assenza di porticato B ☐ Presenza di porticato su parte del piano terra
C ☐ Piano terra completamente aperto (ad eccezione, eventualmente, della scala) D ☐ Piano debole intermedio

ELEMENTI TOZZI (solo per edifici in C.A.):
A ☐ Assenti B ☐ Scarsamente presenti
C ☐ Significativamente presenti

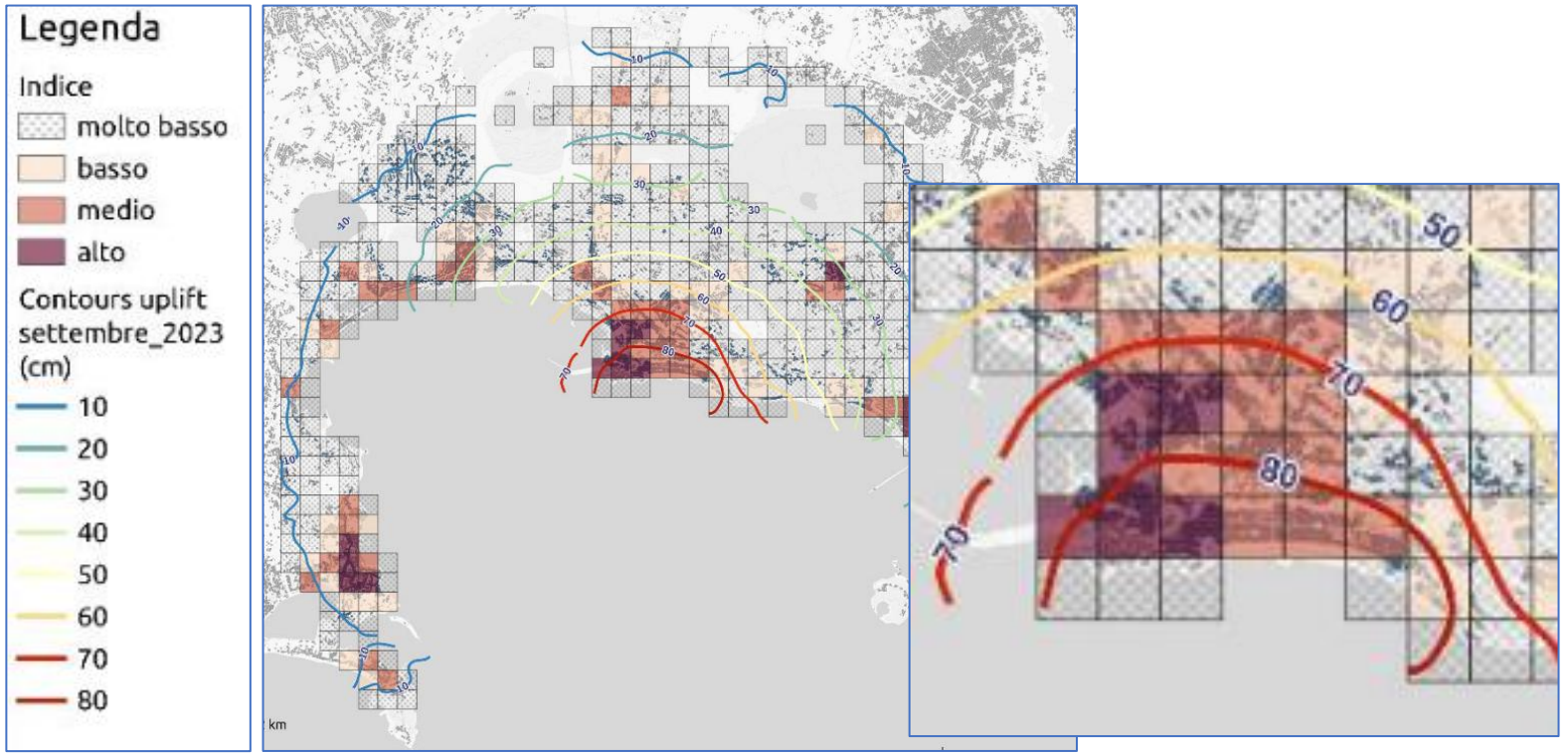
DISTRIBUZIONE ELEMENTI STRUTTURALI (solo per edifici in C.A.):
A ☐ telai monodirez. B ☐ telai bidirez. C ☐ pareti monodirez. D ☐ pareti bidirez. E ☐ pareti + telai

SEZIONE 10 – NOTE

PLINIVS activities for D.L.

The database of the Phlegraean building has allowed the definition of a vulnerability index for CELL (250x250m) of the INTERVENTION ZONE, on the basis of well-founded statistical procedures:

- on the analysis of the damage to the building occurred as a result of past seismic events (SAVE);
- on the correlations between the data collected and those of ISTAT (BINC).



Art. 2 del D.L. 140/2023

- Art. 2. Extraordinary plan for the analysis of the vulnerability of built-up areas directly affected by the bradyseismic phenomenon

It consists of:

a) seismic microzonation study;

b) analysis of the seismic vulnerability of private buildings, aimed at identifying mitigation measures and estimating the related needs;

c) analysis of the seismic vulnerability of public buildings and, at the outcome, first plan of mitigation measures;

d) Seismic and structural monitoring implementation program.

Art. 2b del D.L. 140/2023

Seismic vulnerability analysis of private buildings:
The field investigations are aimed at the typological-structural characterization of ordinary private buildings, containing the typological elements that are most related to their vulnerability characteristics, for the purpose of their classification into vulnerability bands.

2 LEVELS OF VULNERABILITY DEEPENING

1

- First expeditious reconnaissance extended to all the residential buildings in the intervention area, to complete the previous inspection campaign conducted by the PLINIVS Study Center.
- Schedule tool: PLINVS.

PLINIVS FORM

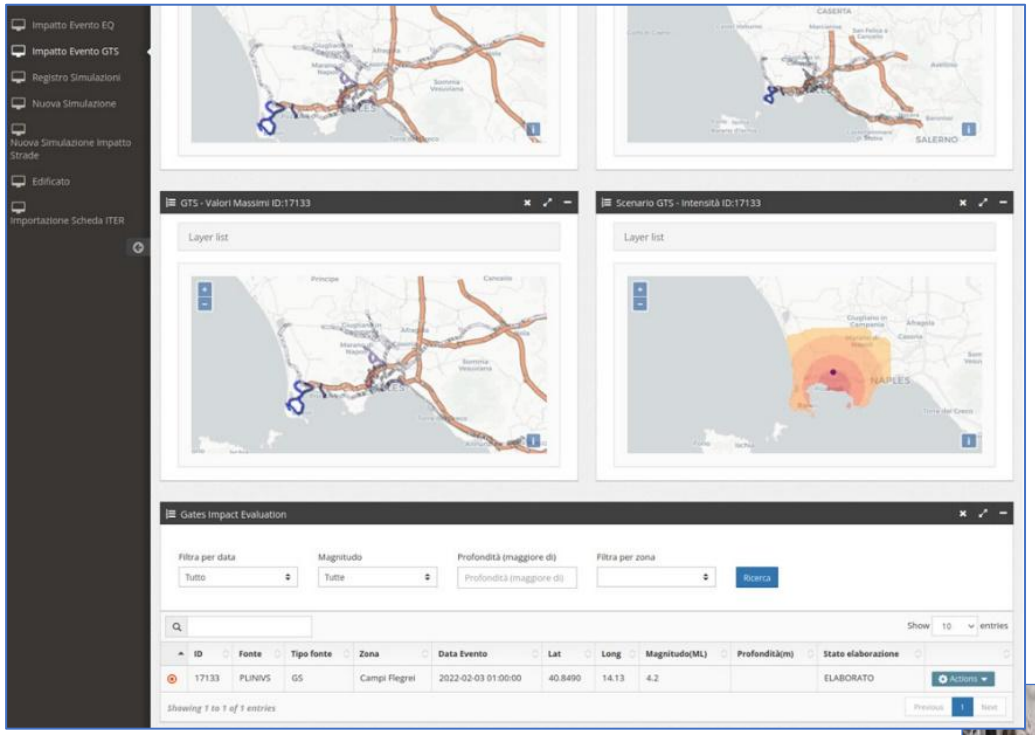
2

- Compilation of the CARTIS Compartment Form for the 3 Municipalities of the intervention area
- In-depth analysis of a sample of buildings included in the intervention area, by filling in the CARTIS Building Form.

CARTIS SECTORS FORM

CARTIS BUILD FORM

Pathways of Distancing



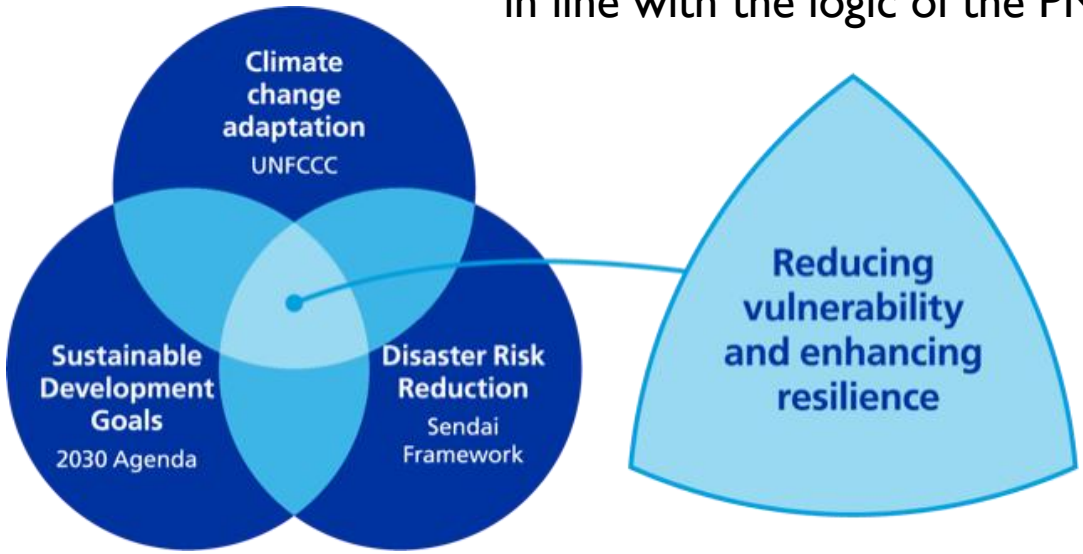
The in-depth analysis of the vulnerability of ordinary buildings can have a positive impact on the improvement of the models for assessing the probability of interruption of road sections linked to the possible collapse of facing buildings induced by precursory earthquakes.

Possible rubble, potentially occupying the roadway, as a result of partial or total collapse of buildings in front of it, could prevent or slow down any rescue or evacuation operations in the area.

Multi-risk mitigation

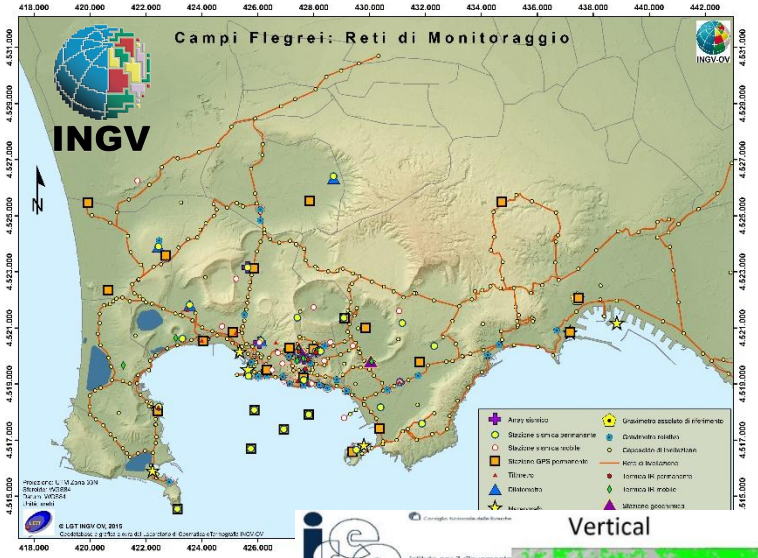
BENEFITS of Deepening Vulnerabilities:

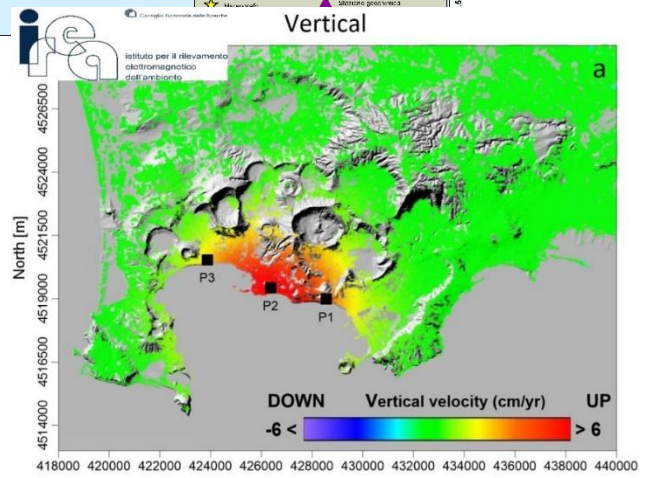
- Better knowledge of the building fabric with regard to seismic and volcanic phenomena.
- Risk reduction through the implementation of ad hoc mitigation measures.
- Opportunity to adopt integrated adaptation strategies that reduce the risk from geophysical and climatic phenomena, in line with the logic of the PNRR.

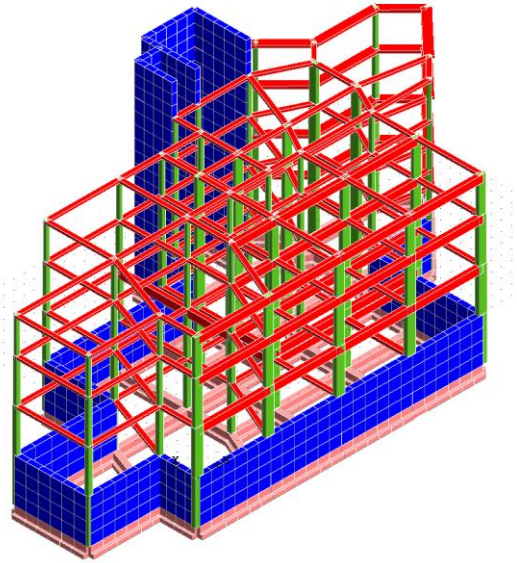


Monitoring

The accuracy of seismic and volcanic risk assessments in the Phlegraean area can be improved through the strengthening of GEOPHYSICAL and STRUCTURAL MONITORING







Thank you for your kind attention.