

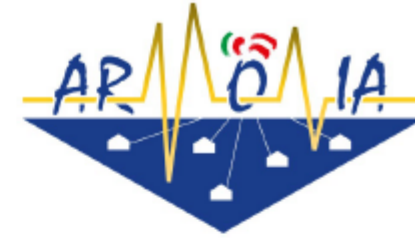


UNIVERSITÀ  
DEGLI STUDI  
DI TRIESTE

# Elementi di geofisica per la Protezione Civile

ARMONIA

Giovanni Costa - [costa@units.it](mailto:costa@units.it)



# ARMONIA-Atlas

Uno strumento per la gestione condivisa delle  
informazioni post evento sismico in area  
transfrontaliera italo-austriaca

*Prof. ing. Stefano Grimaz – Università di Udine*



8 Giugno 2021



## The problem

What is happened?

Where?

Who is involved?

What is necessary to face?

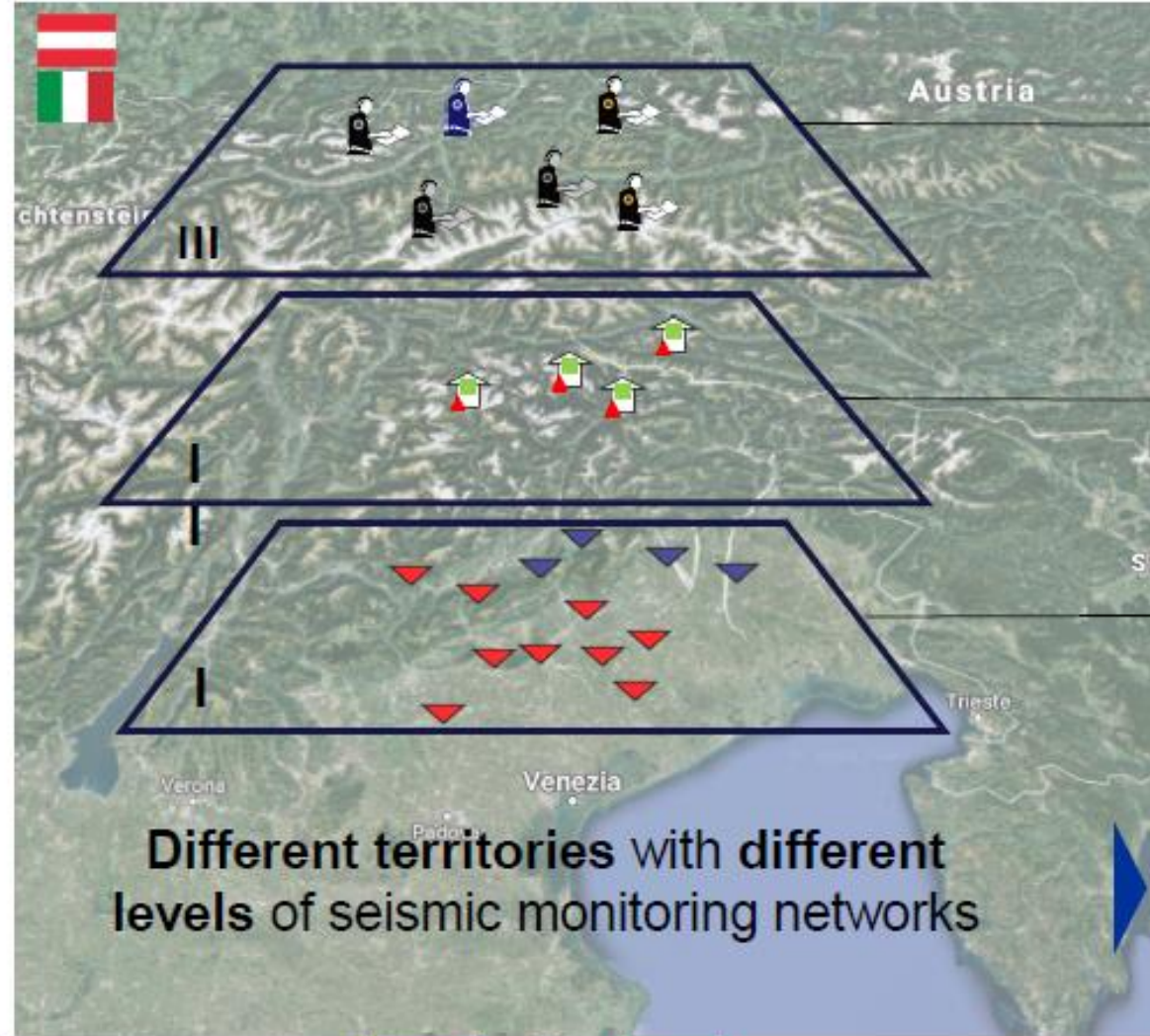
In order to answer to these questions, **quick** availability of an **overview** about the situation to support the activities of decision-makers is extremely necessary.



Possibility of **trans-national** emergencies, concerning **different regions or countries** with their own civil protection system.



# Multi-level monitoring



## Level III

Feeling of the shaking by CP volunteers and technicians  
feedback about actual damages

## Level II

SentiNet at sentinel buildings  
(bottom and top of the structures)

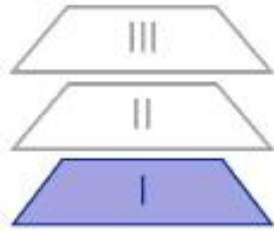
## Level I

Seismic networks

**Integration and harmonization**

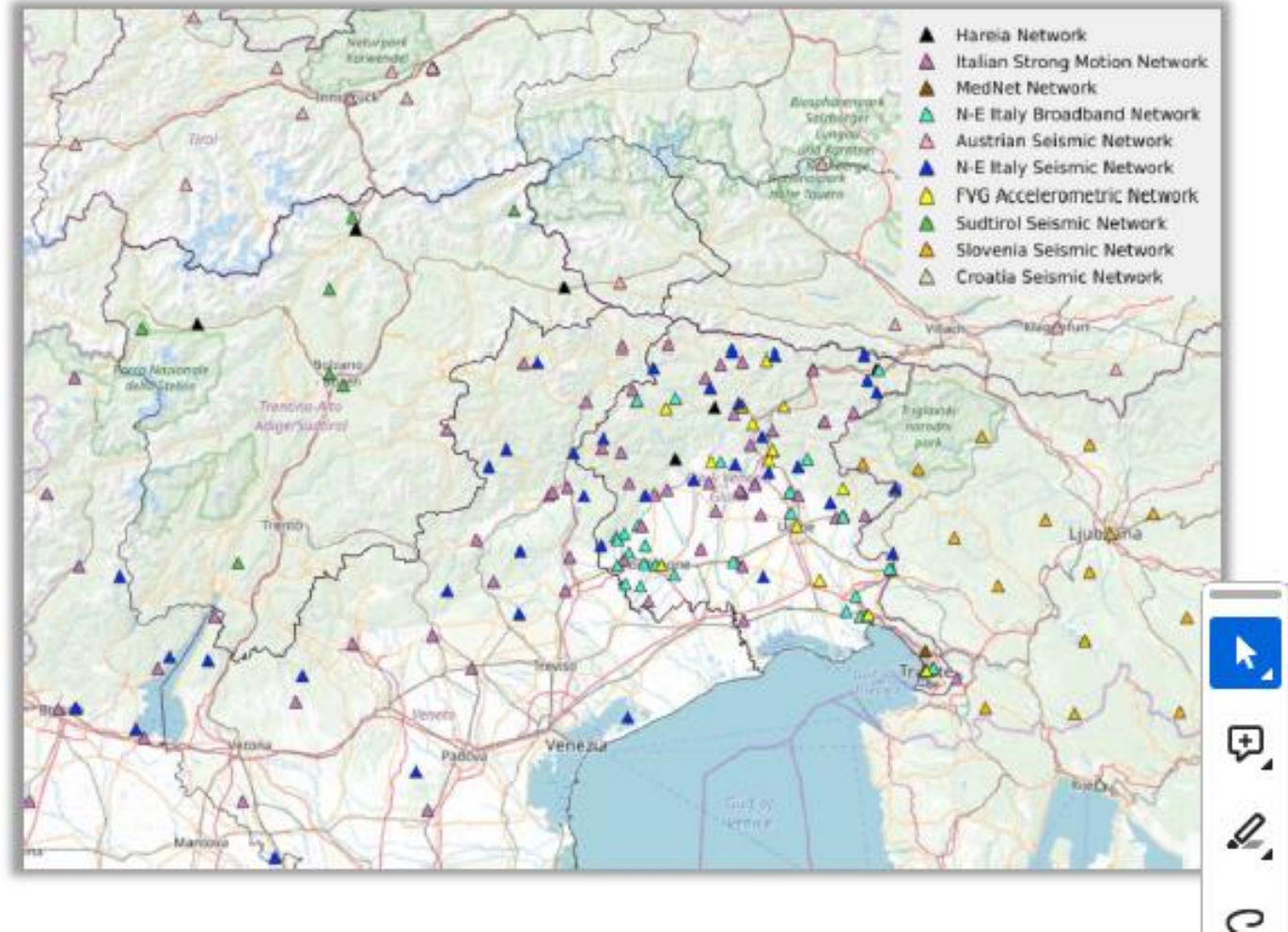






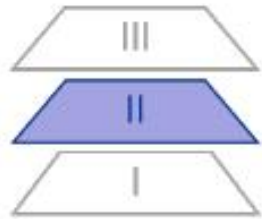
# Level I

Free-field seismic monitoring stations **widespread** on the territory.

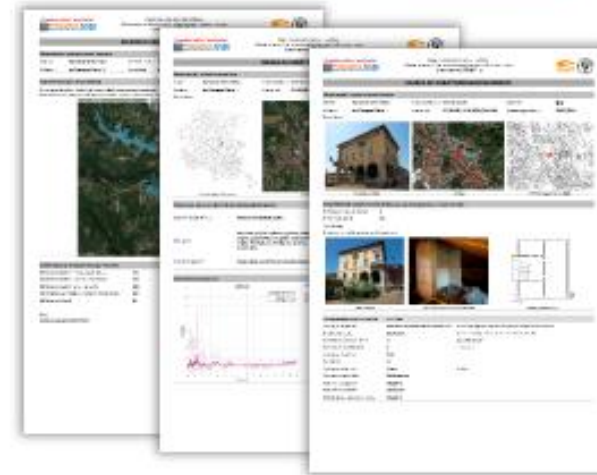
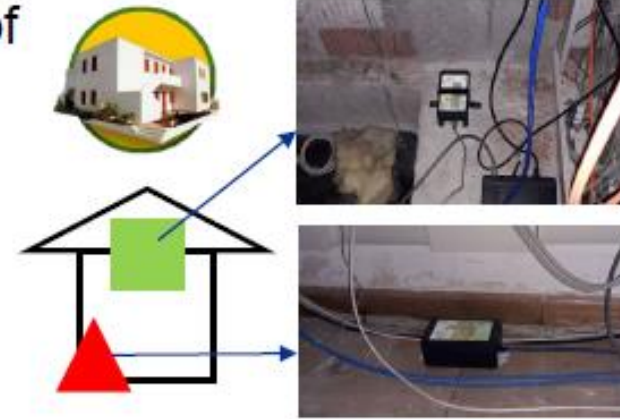
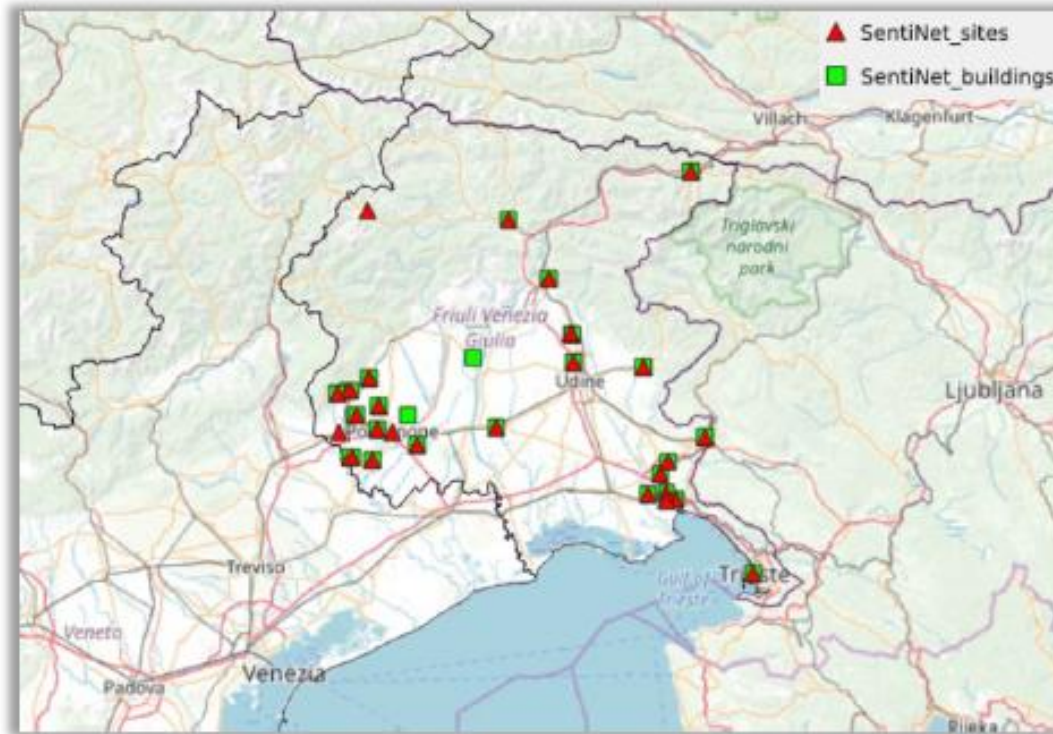




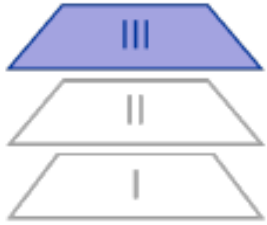
# Level II



Seismic monitoring in different points of **Sentinel Buildings** (top and bottom).



**Buildings and related sites have been previously characterized.**



da consegnare alla Sala Operativa Regionale - Tel. 0432-300000 o mail: [com@protezionecivile.it](mailto:com@protezionecivile.it) - Pagina 1

**REGIONE AUTONOMA FRIULI VENEZIA GIULIA**

Protezione Civile della Regione

**Scheda segnalazione di effetti macrosismici**

**ISTRUZIONI PER LA COMPILAZIONE**  
L'utente compila e trasmette nell'apposito campo il numero e l'indirizzo telefonico dell'abitazione (C.C. SINGOLA LOCALITÀ). Le informazioni che vengono inserite saranno quindi automaticamente trasferite in un database che consente la compilazione per via telematica dei dati.

**1 - Luogo**

in Data:  in Via:

in Comune di:  in Località/Iniziale:

Il fenomeno non è stato avvertito

**2 - Effetti sulle persone**

	Personale	Fam. 1°	Fam. 2°	Fam. 3°	Fam. 4°	Fam. 5°
in piano superiore da						
in piano inferiore da						
in piano terra da						
in piano seminterrato da						

**REGIONE AUTONOMA FRIULI VENEZIA GIULIA**

**SCHEDA DI CONTROLLO OPERATIVITA' EDIFICIO POST-EVENTO**  
CODICE EDIFICIO:  CODICE LOCALITÀ:

Descrizione:

Indirizzo di via:

Comune:

Indirizzo:

Problemi:

Area costruita:

Area chiusa (Area costruita):

Problemi osservati:

Intervento:

**CARATTERISTICO COGNITIVO**

**INQUADRO**

Numero di edifici in area	Numero di persone	Indirizzo di via
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20

**EFFETTI E SOSPENSIONI SUE**

Indirizzo di via	Indirizzo di via	Indirizzo di via	Indirizzo di via
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10
11	11	11	11
12	12	12	12
13	13	13	13
14	14	14	14
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18
19	19	19	19
20	20	20	20

**Altri**  **Indirizzo di via**  **Indirizzo di via**  **Indirizzo di via**




# Level III

Civil protection volunteers and technicians are «on field» observers.

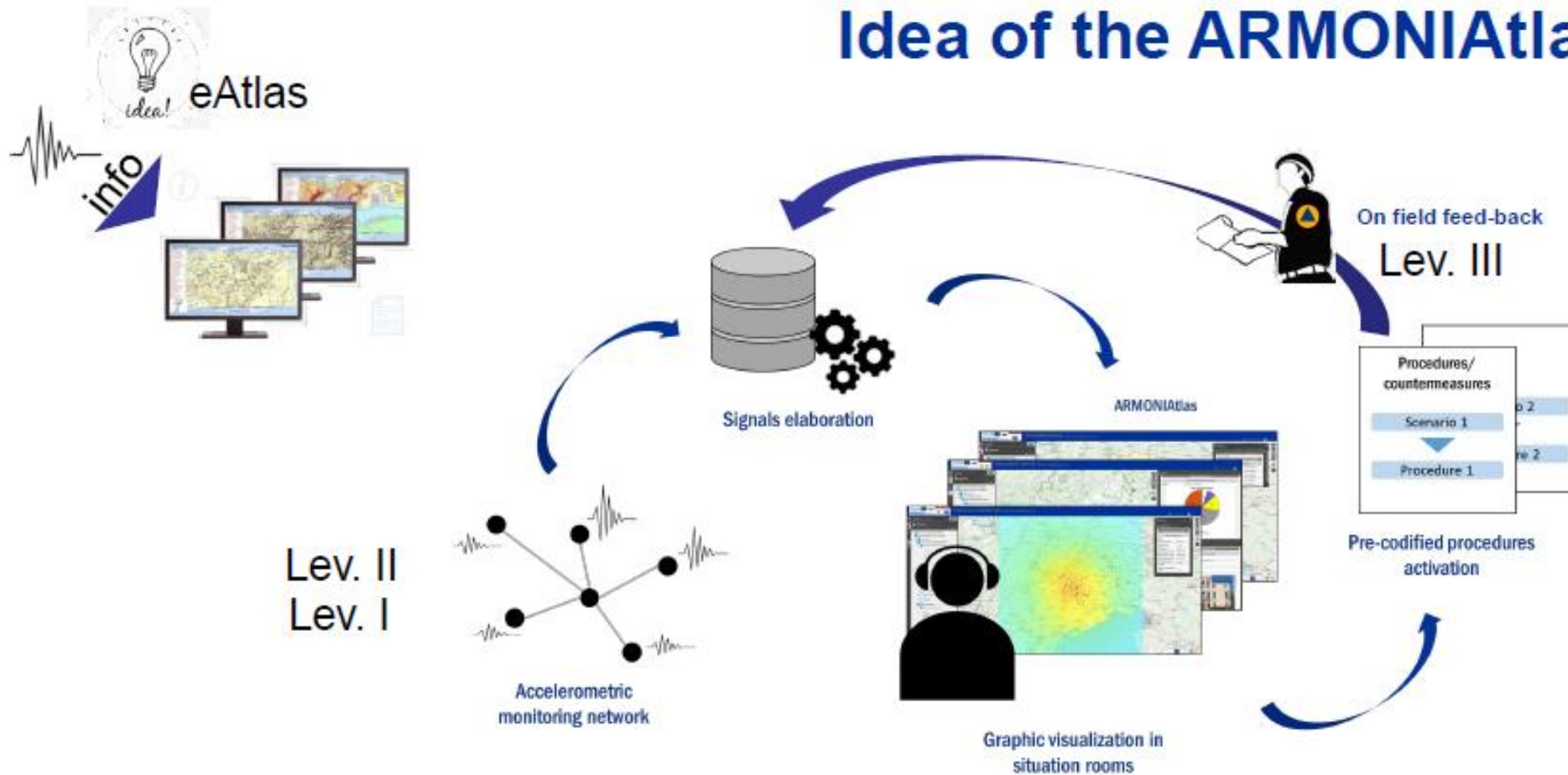


Possible sub-levels:

- areal evaluation about the level of shaking perceived by volunteers
- local feedback about damage occurred in some pre-defined buildings (Sentinel Buildings) 
- local feedback about damage occurred in public buildings



# Idea of the ARMONIAtlas



- Automatic elaboration of ground motion data from seismic networks

- Organization of available information to generate **situational scenarios**.



Interreg Italia-Österreich ARMONIA Atlas PROTOTYPE

Networks Ring Cabinet - ARMONIAtlas

Amministratore | utente

Layers

Legend

- G1\_Italic\_territorial\_knowledge
- G2\_Network\_nodes\_characterization
  - G2a\_Networks
    - G2a-Seismic\_networks
      - Harsia Network
      - Italian Strong Motion Network
      - MedNet Network
      - N-E Italy Broadband Network
      - Austrian Seismic Network
      - N-E Italy Seismic Network
      - PVG Accelerometric Network
      - Sudtiroi Seismic Network
      - Slovenia Seismic Network
      - Croatia Seismic Network
    - G2a-Seismic\_networks\_buildings
    - G2a-SentiNet\_sites
      - G2a-SentiNet\_buildings

Pop-up

G2a-SentiNet\_buildings

Caratterizzazione edificio: Municipio di Tricesimo

Descrizione e localizzazione

Edificio	Municipio di Tricesimo
Codice sito	TRC
Comune	Tricesimo
Provincia	UD
Indirizzo	Via Giuseppe Elera, 1

Caratteristiche generali strutturali

N. unità strutturali	1
Tipologia strutturale	Muratura portante, setti e telai in c.a.
Età di costruzione	1914-1924
N. piani fuori terra	3
N. piani interrati	1
Soletti rigidi	Si
Geometria in pianta	Regolare
Geometria in altezza	Irregolare

Caratterizzazione comportamentale della struttura

Periodo del primo modo	0.22-0.23 s (4.4-4.5 Hz)
Risonanza sito-struttura	No
Modo del piano nel primo modo	Traslazionale
Chiusi: disposizione a	Si

Powered by: [Logos] | Designed by: [Logos]



## ARMONIA EXERCISE

27-28 May 2021

### TEST LEVELS I AND II

Test of **Armonia Atlas** in situation rooms of Friuli VG Civil Protection



Test of **Armonia Atlas** in situation rooms of Veneto Civil Protection

### 1st Event

27.05.2021 - 8:55 Mw 5.0  
2 km NW di Caneva (Pordenone)

### 2nd Event

28.05.2021 - 10:40 Mw 4.2  
2 km SSE di Caneva (Pordenone)



### TEST LEVELS III

Test of "checklist for operability evaluation of building" in Friuli VG



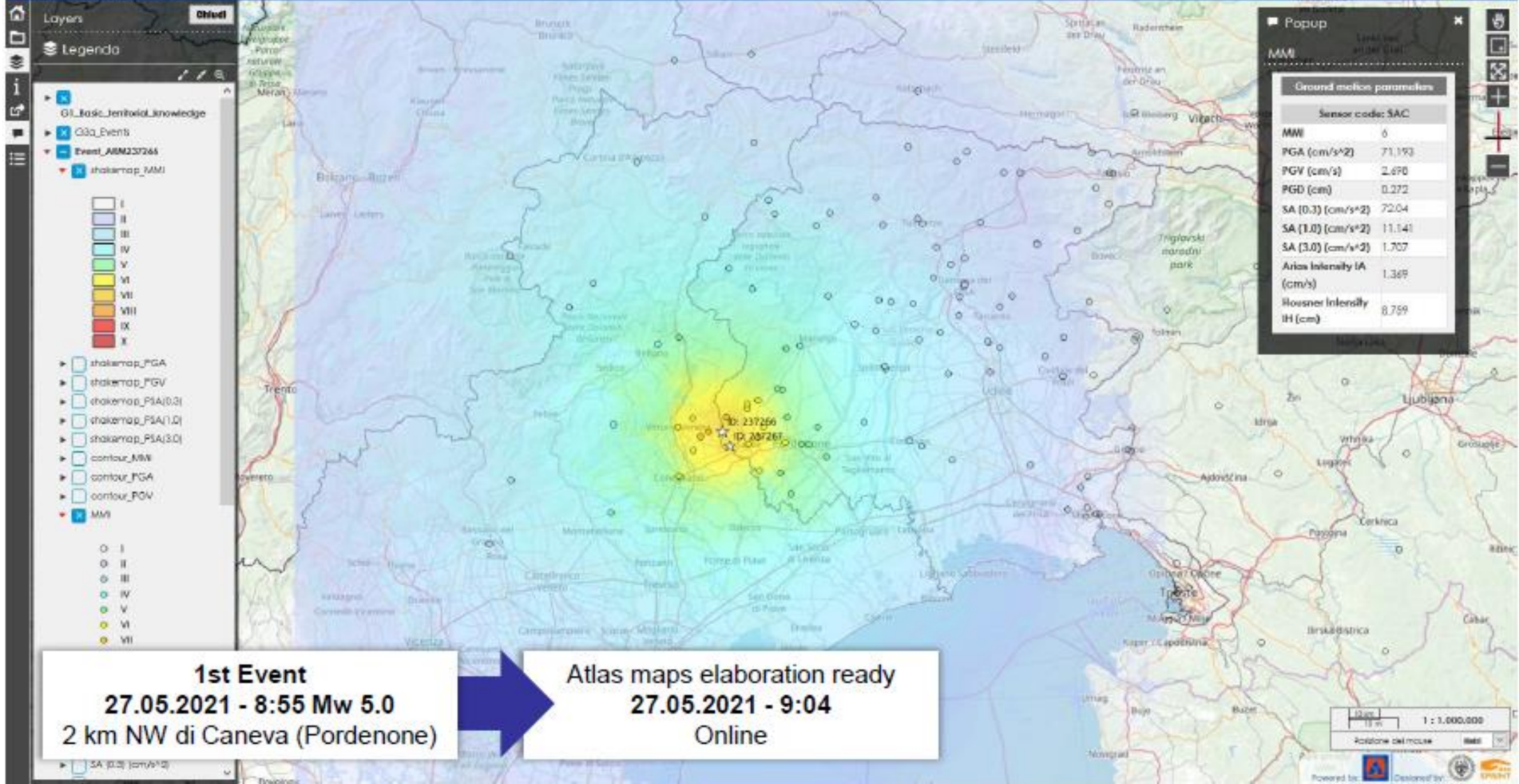
Test of "checklist for operability evaluation of building" in Veneto









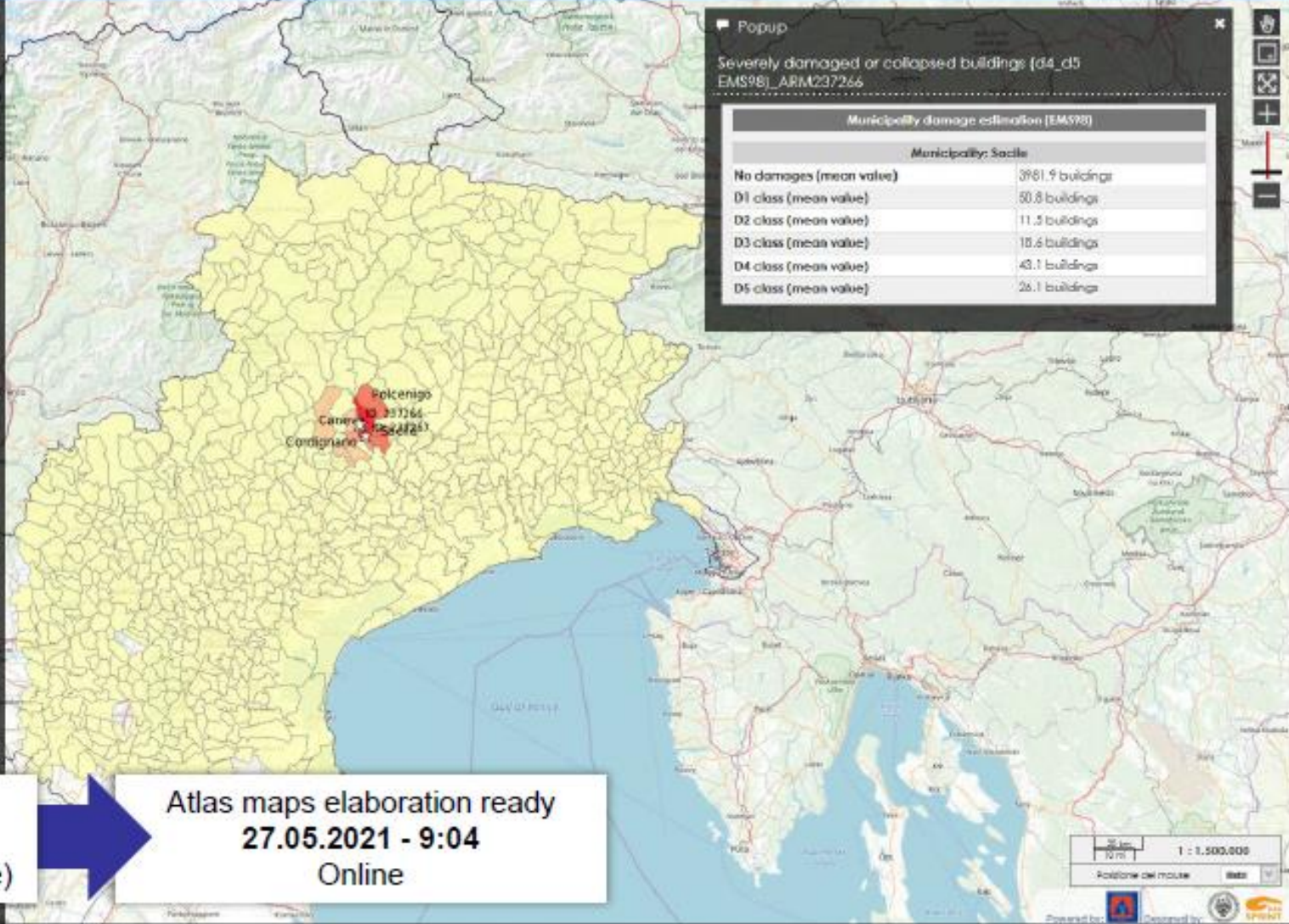




Layers

Legenda

- G1\_Basic\_territorial\_knowledge
- G2a\_Events
- G3c-Event\_ARM237265
  - Severely damaged or collapsed buildings (d4\_d5 EMS98)\_ARM237266
    - 0 - 5 buildings
    - 5 - 20 buildings
    - 20 - 50 buildings
    - 50 - 100 buildings
    - 100 - 200 buildings
    - > 200 buildings
- G3c-Event\_ARM237267
  - Severely damaged or collapsed buildings (d4\_d5 EMS98)\_ARM237267

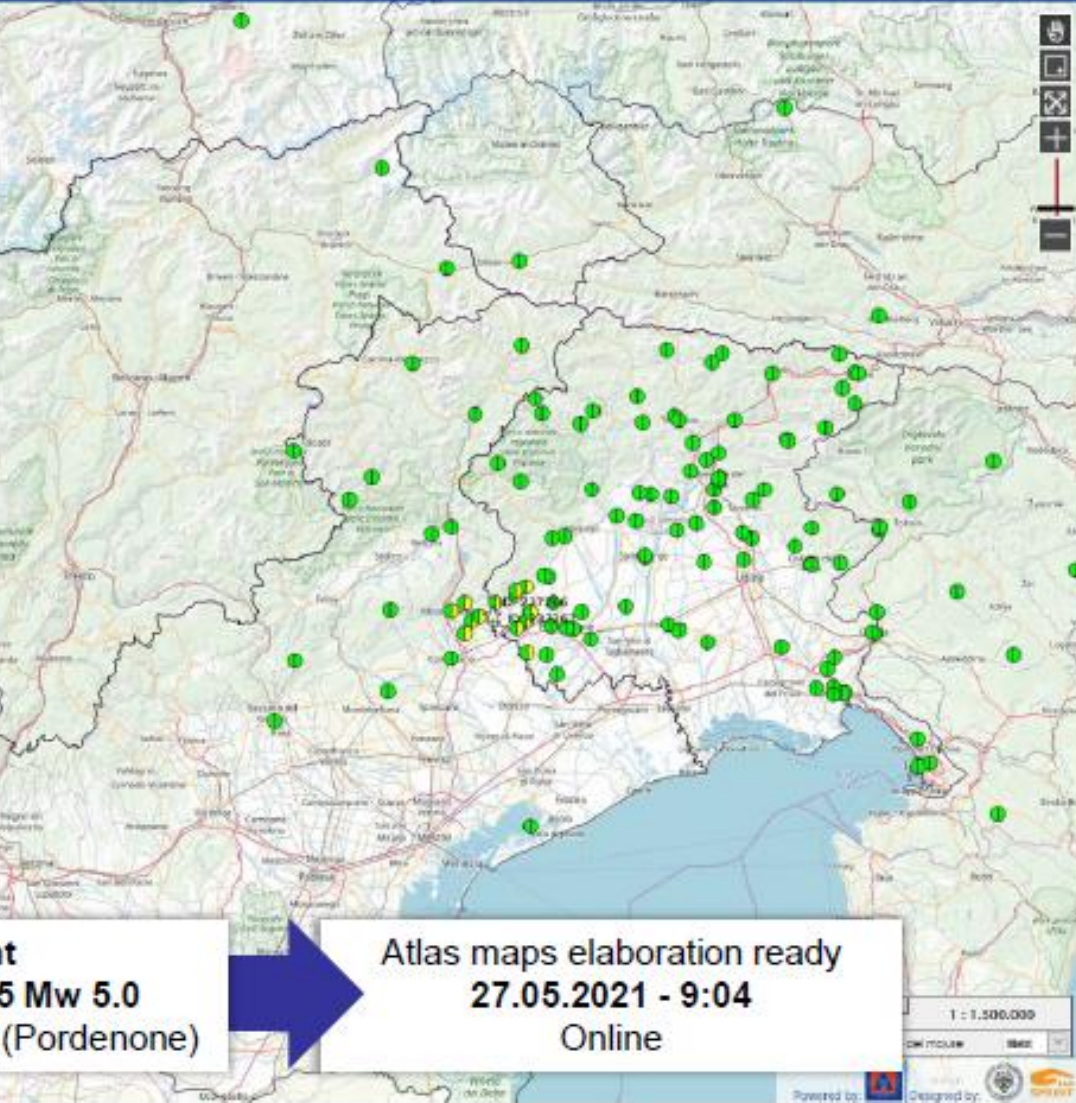




Layers

Legend

- G1\_Leale\_territoria\_knowledge
- G3a\_Events
- G3a\_Event\_ARM237266
  - Intensity\_ranges\_ARM237266
    - I\_min=6; I\_max=6
    - I\_min=6; 6<I\_max=8
    - I\_min=6; I\_max=8
    - 6<I\_min=8; 6<I\_max=8
    - 6<I\_min=8; I\_max=8
    - I\_min=8; I\_max=8
- G3a\_Event\_ARM237267
  - Intensity\_ranges\_ARM237267



Popup

Intensity\_ranges\_ARM237266

Parameters-damage correlation: Intensity ranges	
Stazione [Stacile]	
Sensor code	SACI
Intensity range on MASONRY buildings	5 6
Intensity range on REINFORCED CONCRETE buildings	5 5

Buffer buildings typology

- masonry residential buildings (56%)
- reinforced concrete residential buildings (18%)
- residential buildings with other structural typologies (18%)
- industrial buildings, commercial buildings, railway buildings, not occupied buildings (8%)

**1st Event**  
27.05.2021 - 8:55 Mw 5.0  
2 km NW di Caneva (Pordenone)

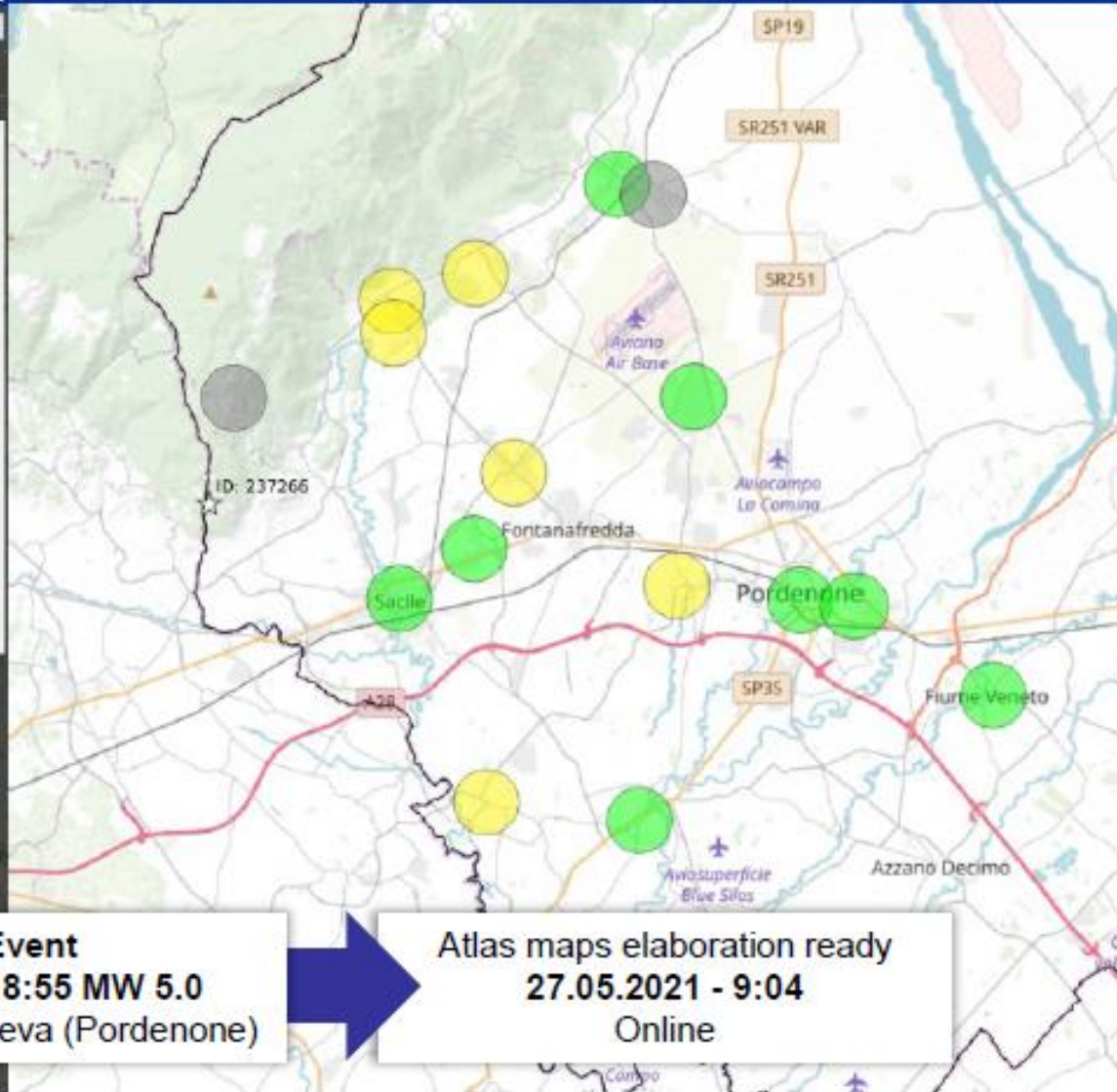
Atlas maps elaboration ready  
27.05.2021 - 9:04  
Online



Layers **Chiuso**

Legenda

- GI\_basi\_territorial\_knowledge
- GS\_Affinity
- G3a\_Events
- G3c\_Event\_ARM237266
  - Probit\_method\_buffers
  - Macroseismic\_method\_buildings
    - Low
    - Medium
    - High
    - No value
  - Macroseismic\_method\_buffers
    - Low
    - Medium
    - High
    - No value
- G3c\_Event\_ARM237267
  - Probit\_method\_buffers
  - Macroseismic\_method\_buildings
  - Macroseismic\_method\_buffers



**1st Event**  
 27.05.2021 - 8:55 MW 5.0  
 2 km NW di Caneva (Pordenone)

Atlas maps elaboration ready  
 27.05.2021 - 9:04  
 Online

Popup

Site\_networks

Buffer characterization

Structural typologies percentage

Station	Porcia
<p>Buffer buildings typology</p>	

Legend for pie chart:

- masonry residential buildings
- historical concrete residential buildings
- residential buildings with other structural typologies
- industrial buildings, commercial buildings, tertiary buildings...
- not occupied buildings

SentiNet\_site

SentiNet building characterization

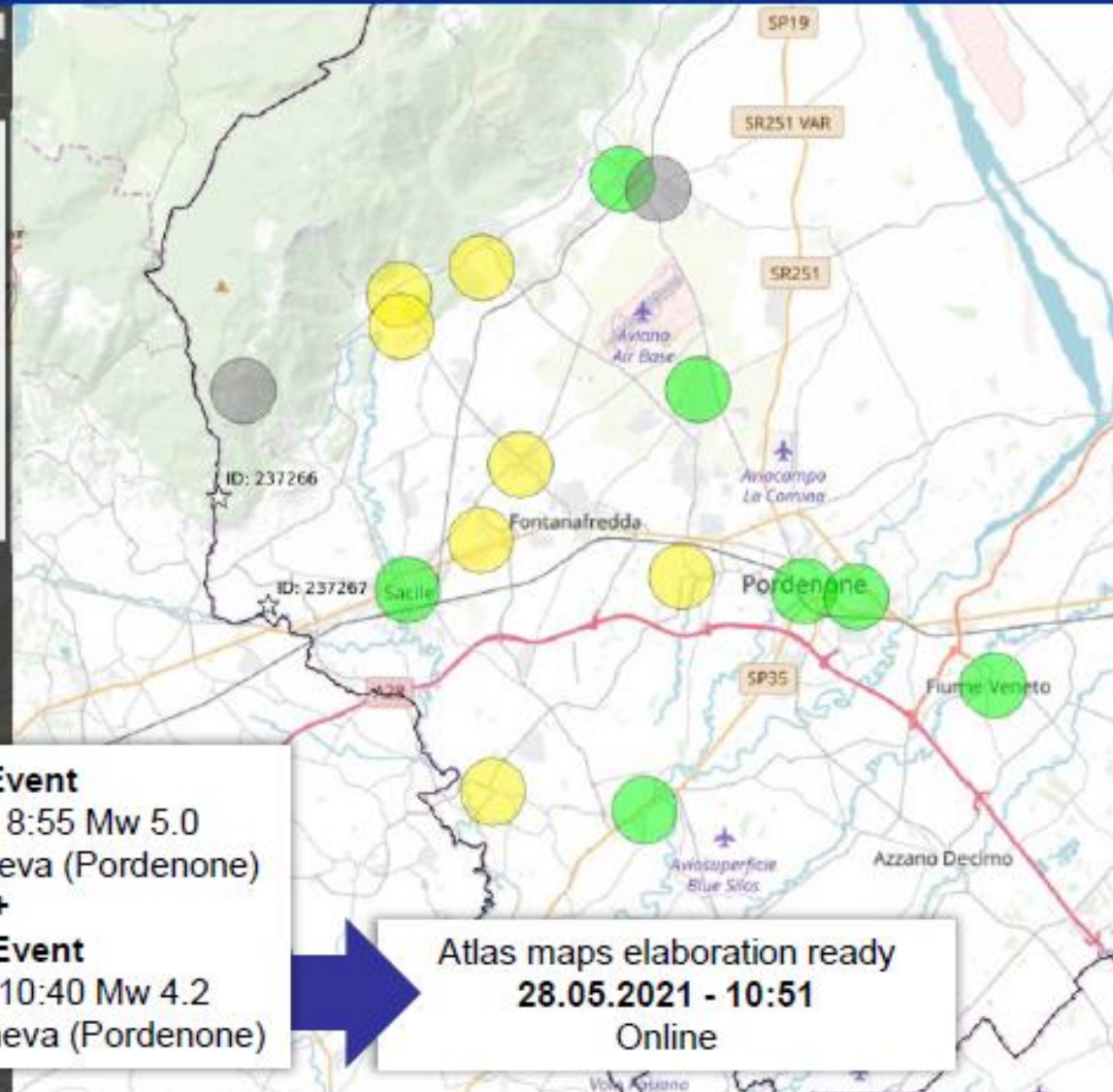
Structural typologies percentage	
Station	PORC
Building	Municipio di Porcia
Municipality	Porcia
Structural typology	Setti e telai in c.a.
N. of floors	3
Characterization form	<a href="#">Link</a>



Layers **Chiudi**

Legenda

- GT\_Basic\_territorial\_knowledge
- GT\_Aftershock
  - Low
  - Medium
  - High
  - No value
- Q3a\_Events
  - Q3a-Event\_ARMG237264
    - Probit\_method\_buffers
    - Macroseismic\_method\_buildings
    - Macroseismic\_method\_buffers
  - Q3a-Event\_ARMG237267
    - Probit\_method\_buffers
    - Macroseismic\_method\_buildings
    - Macroseismic\_method\_buffers



Popup

Site\_networks

Buffer characterization

Structural typologies percentage

Station	Parcia
<p>Buffer buildings typology</p>	
<ul style="list-style-type: none"> <li>mainly residential buildings</li> <li>historic concrete residential buildings</li> <li>residential buildings with other structural typologies</li> <li>industrial buildings, commercial buildings, tertiary buildings,...</li> <li>non-scaled buildings</li> </ul>	

SentiNet\_site

SentiNet building characterization

Structural typologies percentage

Station	PORC
Building	Municipio di Parcia
Municipality	Parcia
Structural typology	Salti a talai in c.a.
N. of floors	3
Characterization form	<a href="#">Link</a>

**Chiudi**

**1st Event**  
 27.05.2021 - 8:55 Mw 5.0  
 2 km NW di Caneva (Pordenone)

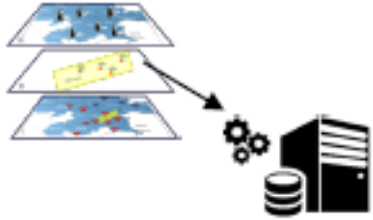
**+**

**2nd Event**  
 28.05.2021 - 10:40 Mw 4.2  
 2 km SSE di Caneva (Pordenone)

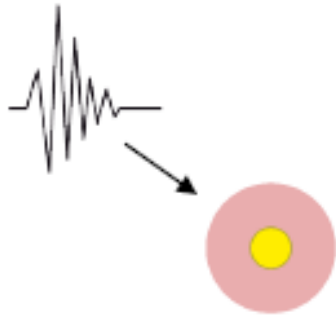
**Atlas maps elaboration ready**  
 28.05.2021 - 10:51  
 Online



## SCIENTIFIC UNITS



**Elaboration of data**  
from seismic networks

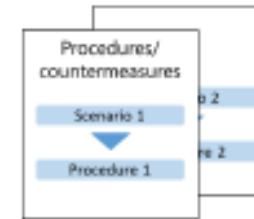


**Development and implementation of methodologies** to estimate the warning of potential **damage**

## CIVIL DEFENSE INSTITUTIONS



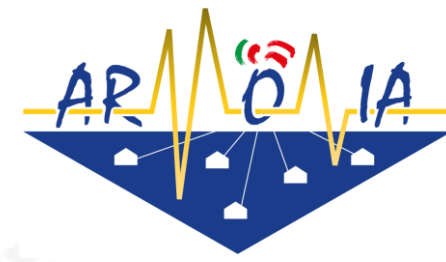
**Definition of the contents** displayed in the different maps



**Pre-codification of operative procedures** to put in place as a consequence of different emergency scenarios

## ARMONIA-Atlas

**common tool and language for harmonized contributions to a unique end**



## Calcolo di parametri dello scuotimento del suolo: dalle reti diffuse alla sala operativa

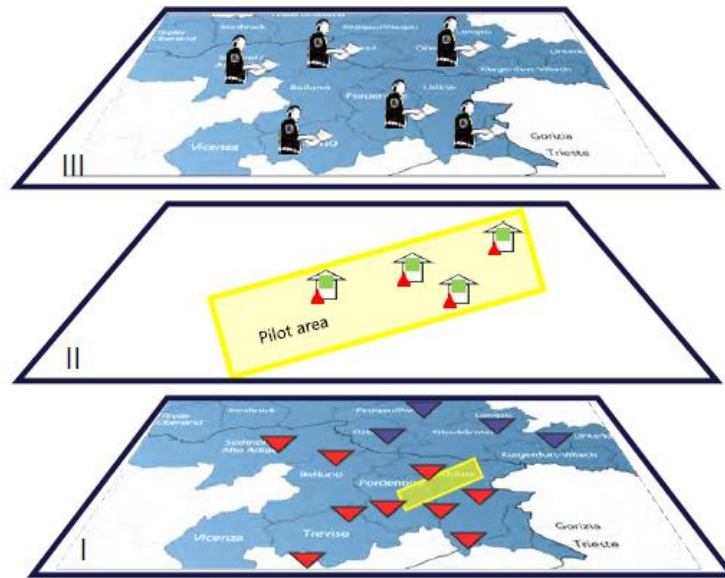
## Berechnung von Erdbebenauswirkungen: von den Messdaten in die Einsatzzentralen

Giovanni Costa  
Università degli Studi di Trieste





## Improve the monitoring



**Level III**  
Feeling of the shaking by CP volunteers  
and feedback about actual damages

**Level II**  
SentiNet at sentinel buildings (bottom  
and top of the structures)

**Level I**  
Seismic networks

**Different territories** can have  
**different levels** of seismic monitoring  
networks

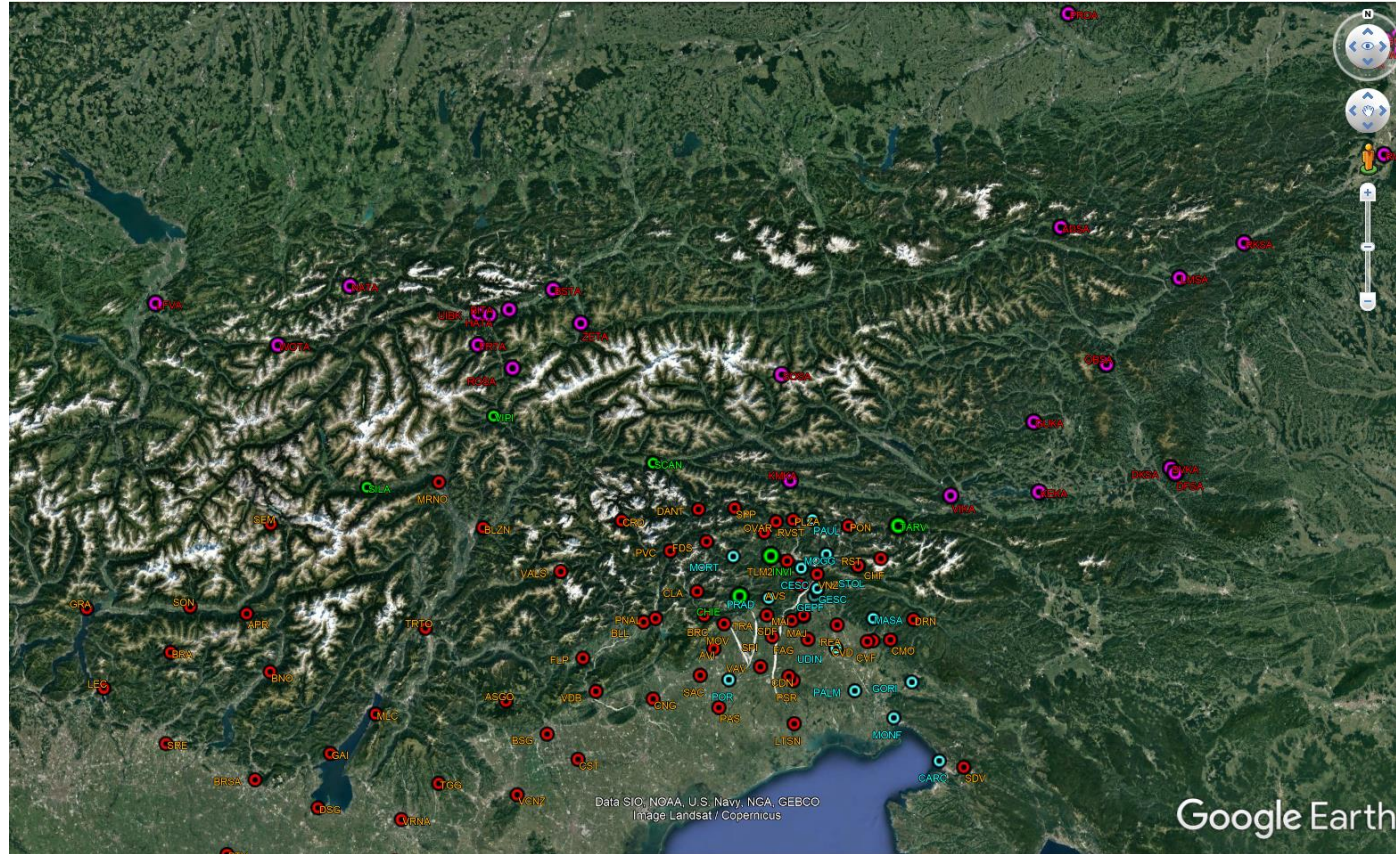
# Level 1 – “Free field” Accelerometric Networks



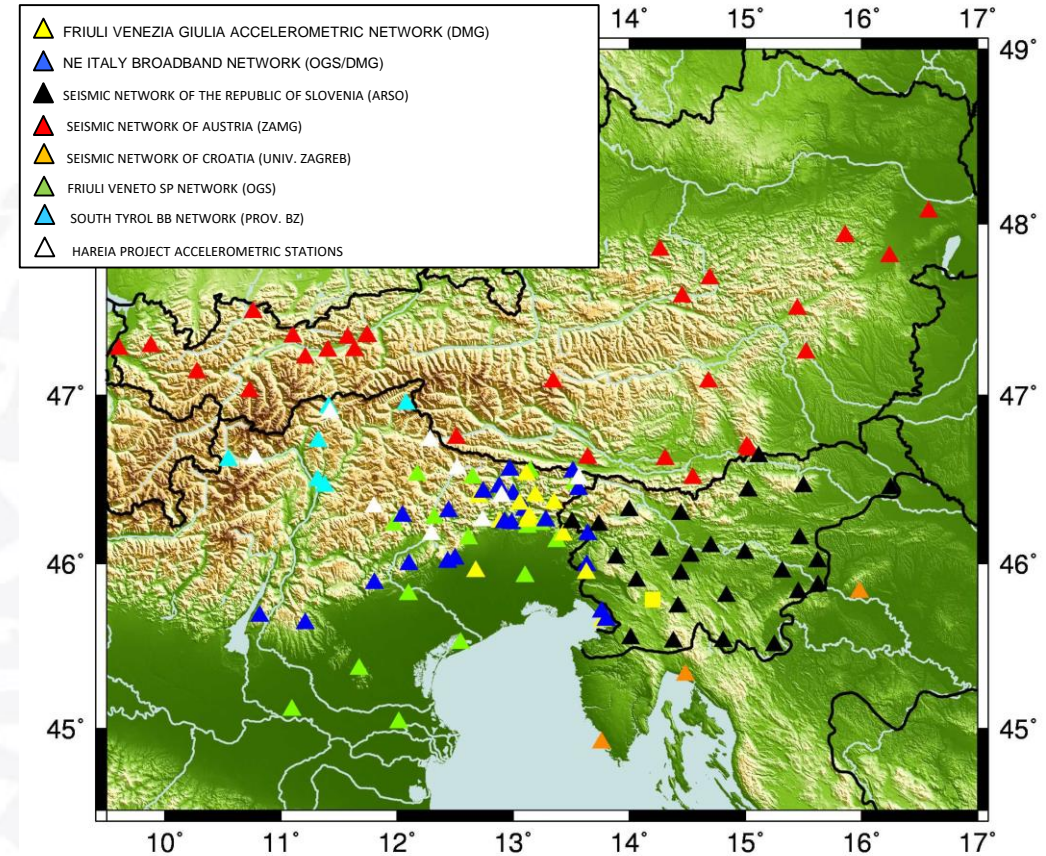


# Level 1

## "Free field" Accelerometric Networks

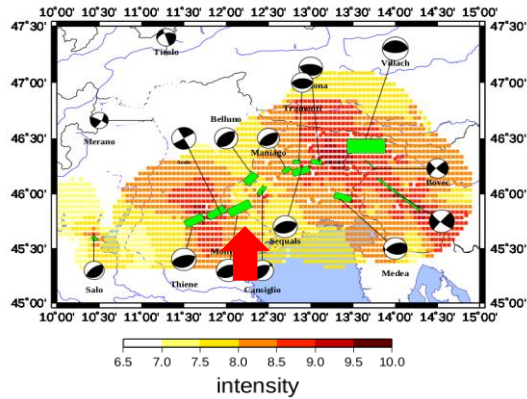


## CE3RN Central and Eastern European Earthquake Research Network

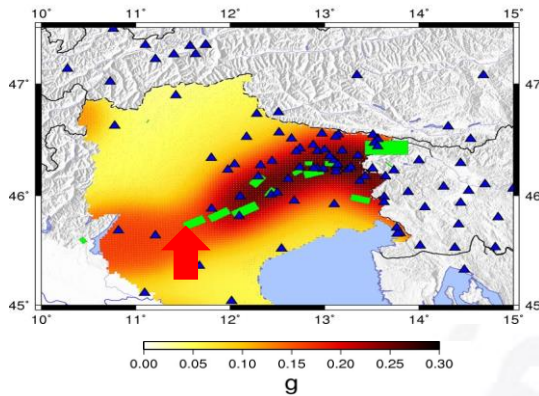




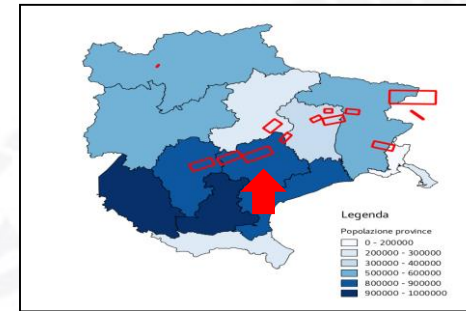
# Level 1 - "Free field" Accelerometric Networks



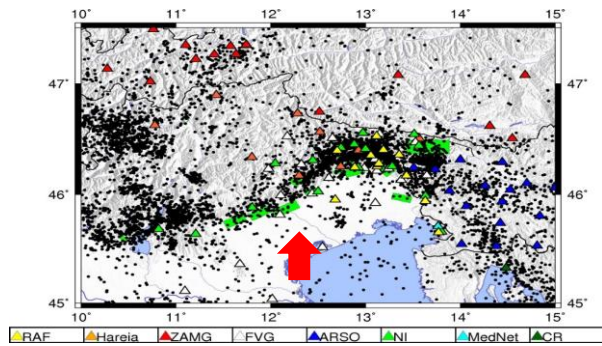
Historical sismicity (Tiberi et al 2014, mod.)



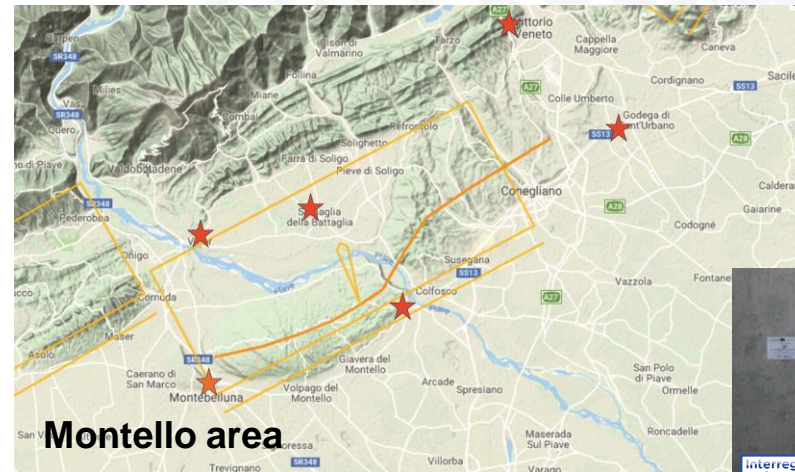
Seismic hazard and seismic network coverage



Number of inhabitants and fault system in studied area

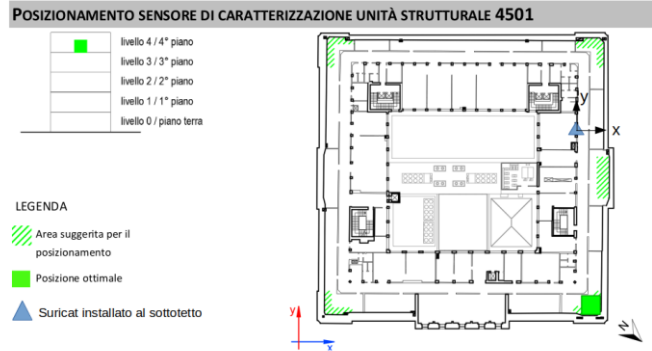


Seismicity from 1985 to today (from INGV Bulletin)





# Level 2 - "SentiNet" at sentinel buildings (bottom and top of the structures)



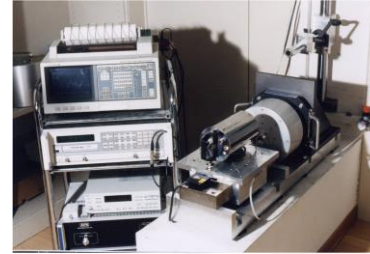


## Level 2 - "SentiNet" at sentinel buildings (bottom and top of the structures)

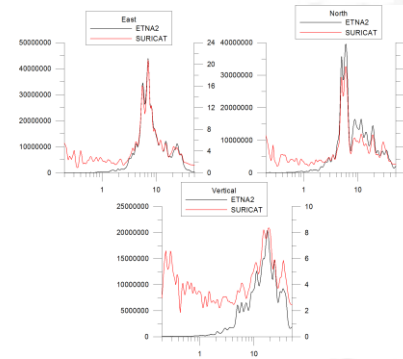
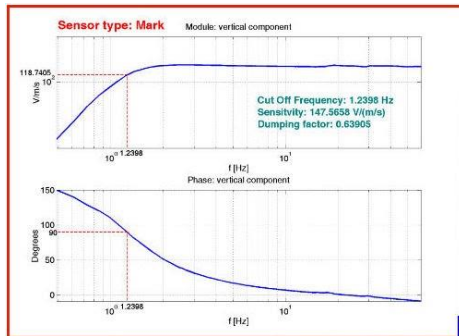


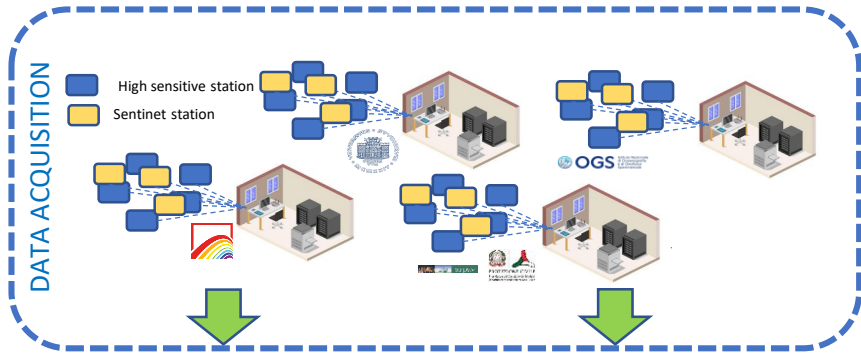


# Instruments test

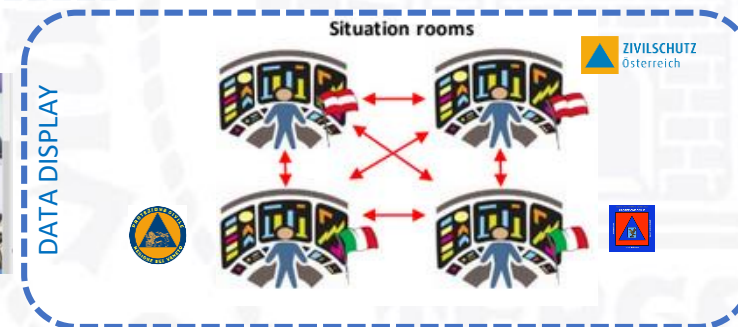
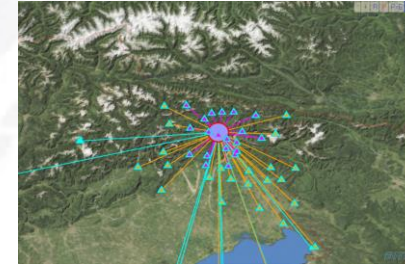
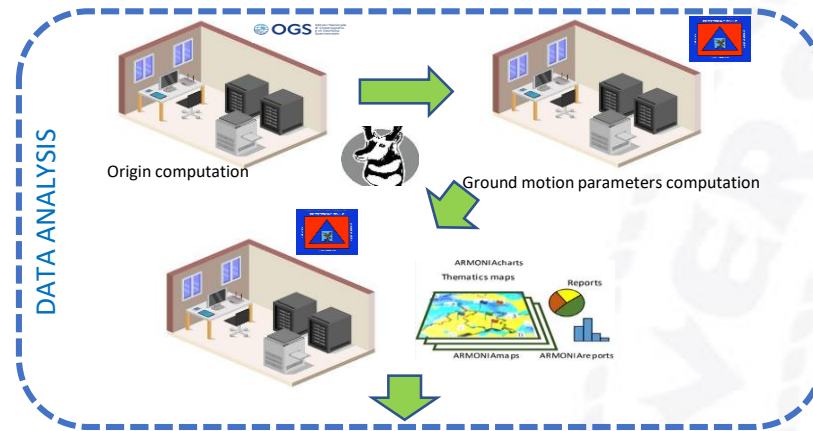
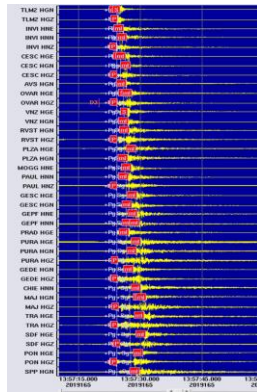


- ETNA 2
- Macro seismic Sensor
- Sara ACE Box
- GeoSIG NetQuake
- Trillium Compact
- Centaur
- Obsidian Kinematic
- Suricat
- Zizmos EQ Sensor
- Raspberry Shake
- Basalt SNr131
- Lunitek Triten



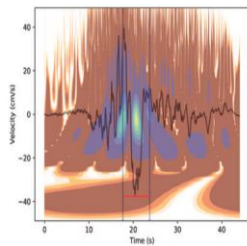
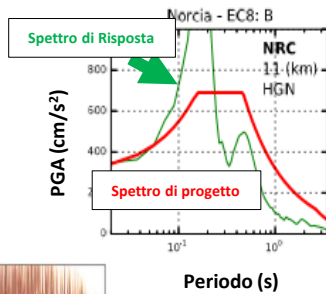
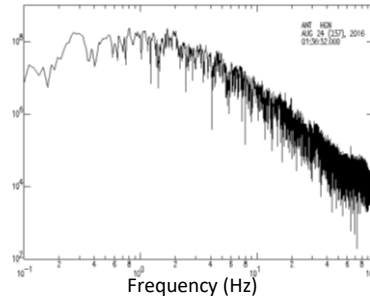
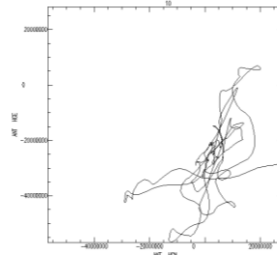
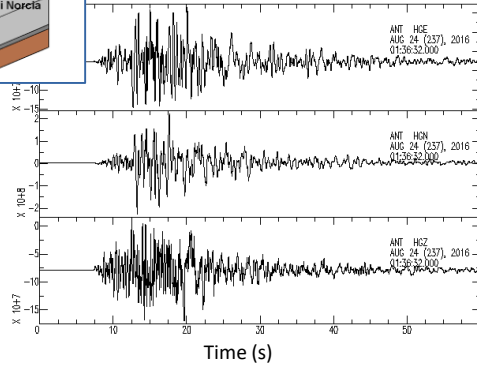
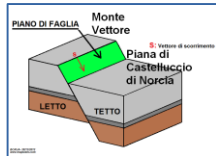


Data flow

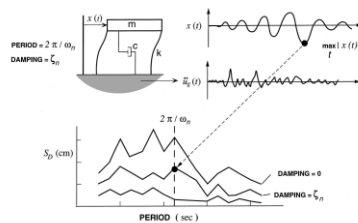




# Selection and definition of the parameters characterizing the seismic action/response recorded in free-field and buildings

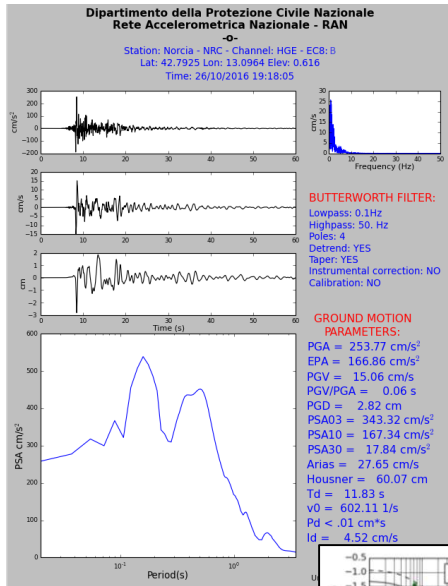


Periodo (s)



Ground Motion Parameters	
PGA (peak ground acceleration)	PSA (pseudo-spectral accel.) at T = 0.3, 1.0 and 3.0 s
PGV (peak ground velocity)	V₀ (zero crossings)
PGD (peak ground displacement)	SMA (sustained maximum acceleration)
V <sub>max</sub> /A <sub>max</sub>	T <sub>P</sub> (predominant period)
T <sub>d</sub> (total duration)	Bandwidth
A <sub>rms</sub> (root mean square acceleration)	G <sub>0</sub> (power spectral density)
I <sub>A</sub> (Arias intensity)	T <sub>b</sub> (bracketed duration)
I <sub>H</sub> (Housner intensity)	T <sub>s</sub> (significant duration)
I <sub>D</sub> (Cosenza and Manfredi index)	VSI (velocity spectrum intensity)
EPA (effective peak acceleration)	ASI (acceleration spectrum intensity)
P <sub>D</sub> (destructive potential)	EPV (effective peak velocity)
CAV (cumulative absolute velocity)	

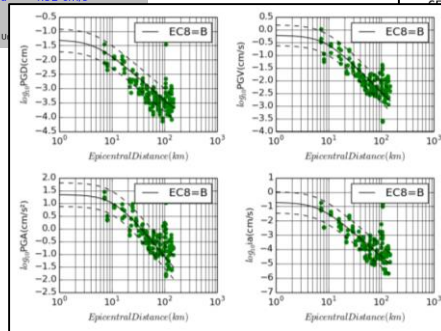
## Selection and definition of the parameters characterizing the seismic action/response recorded in free-field and buildings



Event: ZUGLIO - Origin time: 2019/09/22 12:58:43 Lat:46.445 Lon:12.992 MI = 3.8 Agency: DPC  
Seismic moment: 5.432e+14 Nm - Mw = 3.6 Agency: DPC

sta	chan	loc	dista	filter	PGA	EPA	PGV	PGD	PSA03	PSA10	PSA30	EC8	location
			km	Hz	cm/s <sup>2</sup> s	cm/s <sup>2</sup> s	cm/s	cm	cm/s <sup>2</sup> s	cm/s <sup>2</sup> s	cm/s <sup>2</sup> s		
TOLM	HNE	00	5	0.2-50.0	14.19	5.26	0.27	0.01	11.64	0.88	0.06	na	Tolmezzo Edificio Comune
TOLM	HNE	11	5	0.2-50.0	37.08	23.15	1.09	0.04	29.99	1.64	0.30	na	Tolmezzo Edificio Comune
TOLM	HNN	00	5	0.2-50.0	24.77	9.28	0.60	0.03	21.31	1.36	0.22	na	Tolmezzo Edificio Comune
TOLM	HNN	11	5	0.2-50.0	52.00	23.30	1.07	0.05	53.00	2.46	0.35	na	Tolmezzo Edificio Comune
TOLM	HNZ	00	5	0.2-50.0	8.85	5.04	0.23	0.01	9.77	0.63	0.08	na	Tolmezzo Edificio Comune
TOLM	HNZ	11	5	0.2-50.0	20.44	5.63	0.28	0.02	10.84	0.68	0.08	na	Tolmezzo Edificio Comune
TLM2	HGE	7	0.3-50.0	14.41	8.18	0.43	0.04	23.63	1.05	0.12	B	Tolmezzo2	
TLM2	HGN	7	0.3-50.0	26.88	17.02	1.02	0.19	42.62	1.53	0.22	B	Tolmezzo2	
TLM2	HGZ	7	0.3-50.0	16.18	5.73	0.31	0.10	7.75	0.46	0.07	B	Tolmezzo2	
INVI	HNE	9	0.3-49.7	1.95	1.54	0.07		3.37	0.48	0.03	na	Invillino HAREIA	
INVI	HNN	9	0.3-49.7	3.01	2.08	0.11		4.59	0.37	0.05	na	Invillino HAREIA	
INVI	HNZ	9	0.3-49.7	2.25	1.29	0.05		1.69	0.38	0.03	na	Invillino HAREIA	
CESC	HGE	11	0.4-48.0	66.87	31.61	1.81	0.08		4.02	0.46	na	Cesclans	
CESC	HGN	11	0.4-48.0	53.43	53.81	2.17	0.11		6.03	0.60	na	Cesclans	
CESC	HGZ	11	0.4-48.0	53.72	23.32	0.96	0.05		3.46	0.24	na	Cesclans	
MOGG	HNE	16	0.2-49.9	9.01	4.97	0.28	0.01	11.41	0.56	0.09	na	Moggio	
MOGG	HNN	16	0.2-49.9	2.46	1.88	0.09		5.13	0.30	0.04	na	Moggio	
MOGG	HNZ	16	0.2-49.9	5.85	3.43	0.18	0.01	8.64	0.40	0.06	na	Moggio	
AVS	HGE	17	0.5-49.4	3.05	1.31	0.07			0.27	0.03	C*	Avasinis	
AVS	HGN	17	0.5-49.4	5.22	2.62	0.16	0.01		0.43	0.06	C*	Avasinis	
AVS	HGZ	17	0.5-49.4	2.92	0.81	0.04			0.23	0.02	C*	Avasinis	
GESC	HGE	21	0.5-48.1	3.35	2.18	0.07	0.13		0.36	0.02	na	Gemona Scugelars	
GESC	HGN	21	0.5-48.1	3.77	2.74	0.11	0.01		0.37	0.04	na	Gemona Scugelars	
GESC	HGZ	21	0.5-48.1	3.17	1.23	0.05	0.02		0.16	0.01	na	Gemona Scugelars	
PRAD	HGE	23	0.7-50.0	4.83	1.71	0.08			0.13	0.02	na	Pradis	
PRAD	HGN	23	0.7-50.0	3.89	1.18	0.06			0.12	0.01	na	Pradis	
PRAD	HGZ	23	0.7-50.0	2.68	0.81	0.04			0.10	0.01	na	Pradis	
PRAD	HGE	24	0.4-48.0	3.88	1.75	0.09			0.43	0.02	na	Gemona Depuratore	

d = epicentral distance  
 f = automatic band pass butterworth filter  
 site = site classification (Eurocode from ITACA)  
 PGA,PGV,PGD = peak ground acceleration, velocity and displacement  
 EPA = effective ground acceleration (Kramer, 1996)  
 PSA03,PSA10,PSA30 = spectral acceleration (0.3, 1.0, 3.0 sec)

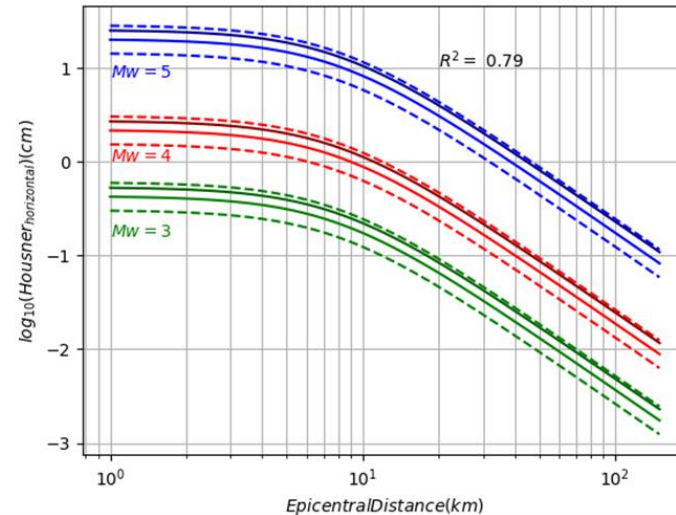
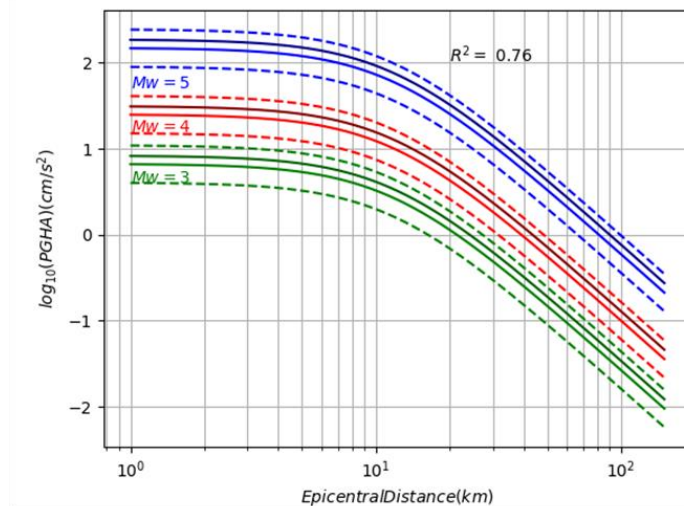




# Selection and definition of the parameters characterizing the seismic action/response recorded in free-field and buildings

## GMPE functional form:

$$\text{Log}_{10} Y = a + b Mw + c Mw^2 + c \log_{10}((R^2 + d^2)^{1/2}) + s1SA + s2SB + s3SC + s4SD + s5SE$$

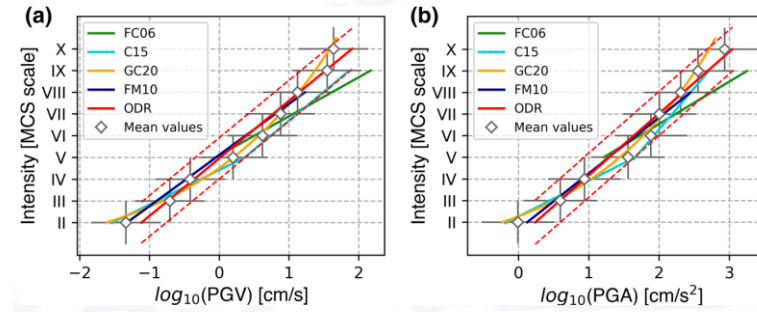
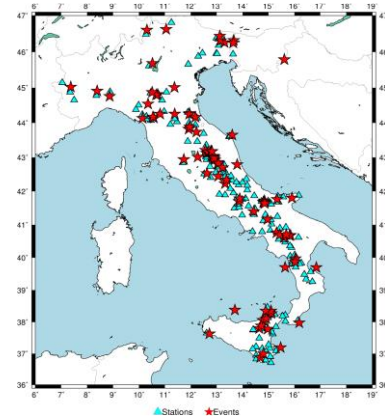


## Ground motion parameters analyzed:

- PGA
- PGV
- PGD
- PSA03
- PSA10
- PSA30
- Arias Intensity
- Housner Intensity

# Selection and definition of the parameters characterizing the seismic action/response recorded in free-field and buildings

Ground Motion Parameters	
PGA (peak ground acceleration)	PSA (pseudo-spectral accel.) at T = 0.3, 1.0 and 3.0 s
PGV (peak ground velocity)	V <sub>0</sub> (zero crossings)
PGD (peak ground displacement)	SMA (sustained maximum acceleration)
V <sub>max</sub> /A <sub>max</sub>	T <sub>p</sub> (predominant period)
T <sub>d</sub> (total duration)	Bandwidth
A <sub>rms</sub> (root mean square acceleration)	G <sub>0</sub> (power spectral density)
I <sub>A</sub> (Arias intensity)	T <sub>b</sub> (bracketed duration)
I <sub>H</sub> (Housner intensity)	T <sub>s</sub> (significant duration)
ID (Cosenza and Manfredi index)	VSI (velocity spectrum intensity)
EPA (effective peak acceleration)	ASI (acceleration spectrum intensity)
P <sub>d</sub> (destructive potential)	EPV (effective peak velocity)
CAV (cumulative absolute velocity)	



Y	A	B	C	d	R <sup>2</sup>	σ <sub>y</sub>	Num data
PGA	0.86	0.81	-2.49	10.80	0.76	0.42	26502
PGV	-1.87	0.94	-2.02	8.38	0.79	0.37	26502
PGD	-4.47	1.14	-1.58	5.64	0.78	0.39	26502
PSA03	-0.32	0.91	-1.91	9.12	0.77	0.37	26502
PSA10	-2.57	1.03	-1.34	5.13	0.74	0.38	24910
PSA30	-3.55	0.96	-1.03	2.42	0.63	0.45	9882
I <sub>A</sub>	-3.24	1.64	-3.84	9.23	0.76	0.72	26132
I <sub>H</sub>	-2.49	0.91	-1.30	4.72	0.70	0.38	11701
IA2	-0.15	1.67	-4.08	10.27	0.76	0.74	26501
IV2	-5.55	1.95	-3.14	7.72	0.78	0.70	26501
ID2	-10.41	2.39	-2.44	5.73	0.74	0.84	22479
CAV	-0.04	0.84	-1.73	11.61	0.75	0.34	26501

a)

## SCALA MERCALLI

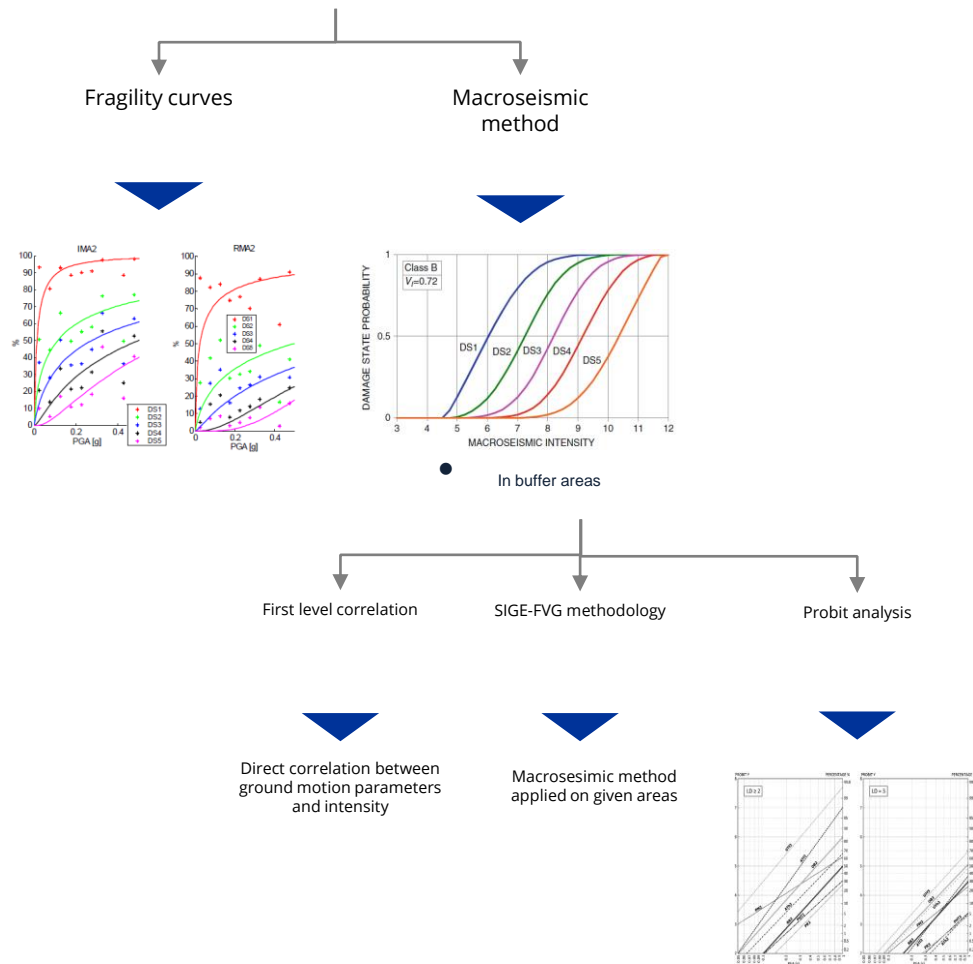
I - Strumentale	Avvertita solo dagli strumenti
II - Debole	Avvertita solo da poche persone sensibili in condizioni particolari
III - Leggera	Avvertita da poche persone
IV - Moderata	Avvertita da molte persone; tremiti di infissi e cristalli; oscillazione di oggetti sospesi
V - Piuttosto forte	Avvertita da molte persone, anche addormentate; caduta di oggetti
VI - Forte	Qualche lesione agli edifici
VII - Molto forte	Caduta di comignoli; lesione agli edifici
VIII - Distruttiva	Rovina parziale di alcuni edifici; vittime isolate
IX - Rovinosa	Rovina totale di alcuni edifici; molte vittime; crepacci nel suolo
X - Disastrosa	Crollo di parecchi edifici; numerosi vittime; crepacci evidenti nel terreno
XI - Molto disastrosa	Distruzione di agglomerati urbani; moltissime vittime; crepacci; frane; maremoto
XII - Catastrofica	Danneggiamento totale; distruzione di ogni manufatto; pochi superstiti; sconvolgimento del suolo; maremoto



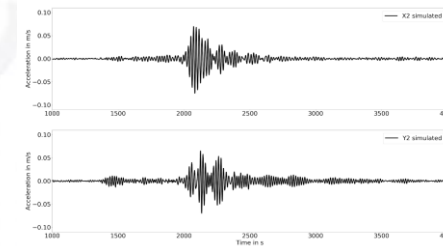
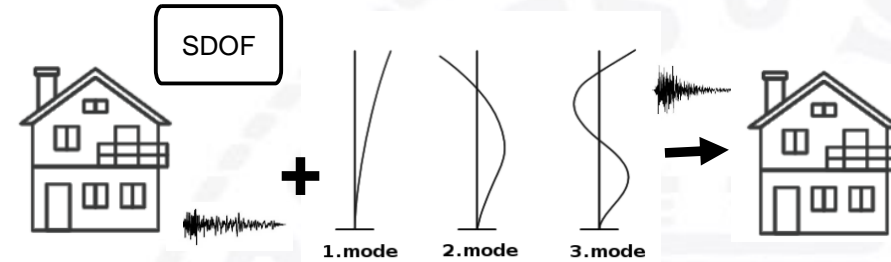
# Definition of characterizing parameters – On buildings

## Damage scenarios definition

- On buildings



## Estimating The Building's Dynamic Behaviour



**Simulated Acceleration at the top of the building**

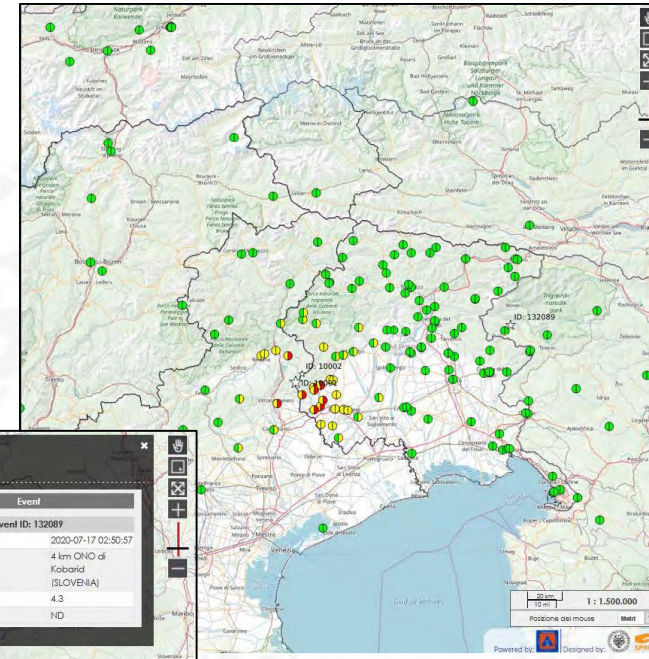
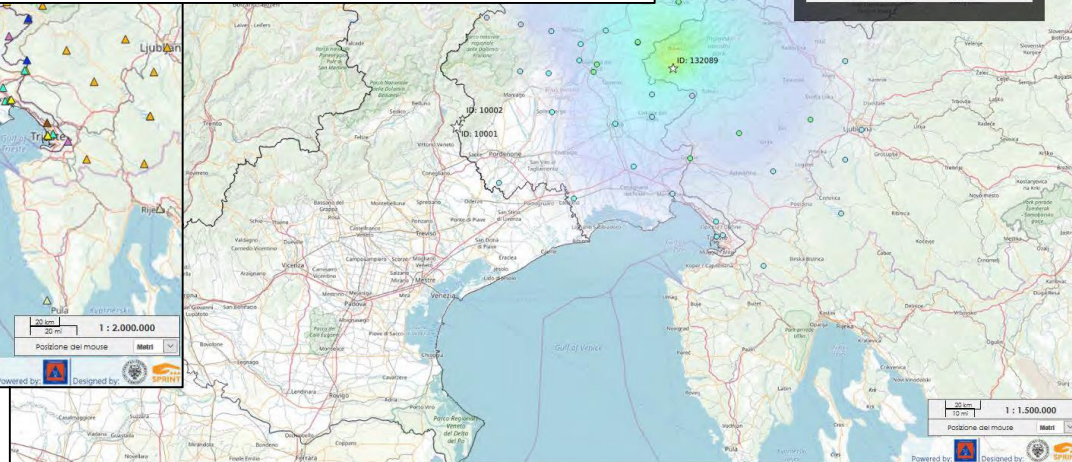
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Seismic moment: 5.432e+14 Nm - Mw = 3.6 Agency: DPC

sta	chan	loc	dista	filter	PGA	EPA	PGV	PGD	PSA03	PSA10	PSA30	EC8	location
			km	Hz	cm/s*s	cm/s*s	cm/s	cm	cm/s*s	cm/s*s	cm/s*s		
TOLM	HNE	00	5	0.2-50.0	14.19	5.26	0.27	0.61	11.64	0.88	0.06	na	Tolmezzo Edificio Comune
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TOLM	HNN	11	5	0.2-50.0	52.00	23.30	1.07	0.05	53.00	2.46	0.35	na	Tolmezzo Edificio Comune
TOLM	HNZ	00	5	0.2-50.0	8.85	5.04	0.23	0.01	9.77	0.63	0.08	na	Tolmezzo Edificio Comune
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TLMZ	HGN	7	0.3-50.0	26.88	17.02	1.02	0.19	0.19	42.62	1.53	0.22	B	Tolmezzo2
TLMZ	HGZ	7	0.3-50.0	16.18	5.73	0.31	0.10	0.10	7.75	0.46	0.07	B	Tolmezzo2
INVI	HNE	9	0.3-49.7	1.95	1.54	0.07			3.37	0.48	0.03	na	Invillino HAREIA
INVI	HNN	9	0.3-49.7	3.01	2.08	0.11			4.59	0.37	0.05	na	Invillino HAREIA
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CESC	HGE	11	0.4-48.0	66.87	31.61	1.81	0.08		4.02	0.46	na		Cesclans
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MOGG	HNN	16	0.2-49.9	2.46	1.88	0.09		5.13	0.30	0.04	na		Moggio
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AVS	HGN	17	0.5-49.4	5.22	2.62	0.16	0.01		0.43	0.06	C*		Avasinis
AVS	HGZ	17	0.5-49.4	2.92	0.81	0.04			0.23	0.02	C*		Avasinis
GESC	HGE	21	0.5-48.1	3.35	2.18	0.07	0.13		0.36	0.02	na		Gemona Scugelars
GESC	HGN	21	0.5-48.1	3.77	2.74	0.11	0.01		0.37	0.04	na		Gemona Scugelars
GESC	HGZ	21	0.5-48.1	3.17	1.23	0.05	0.02		0.16	0.01	na		Gemona Scugelars
PRAD	HGE	23	0.7-50.0	4.83	1.71	0.08			0.13	0.02	na		Pradis
PRAD	HGN	23	0.7-50.0	3.89	1.18	0.06			0.12	0.01	na		Pradis
PRAD	HGZ	23	0.7-50.0	2.68	0.81	0.04			0.10	0.01	na		Pradis
GEDE	HGE	24	0.4-48.0	3.88	1.75	0.09			0.43	0.02	na		Gemona Depuratore

dista = epicentral distance  
 filter = automatic band pass butterworth filter  
 EC8 = site classification (Eurocode from ITACA)

PGA,PGV,PGD = peak ground acceleration, velocity and displacement  
 EPA = effective ground acceleration (Kramer, 1996)  
 PSA03,PSA10,PSA30 = spectral acceleration (0.3, 1.0, 3.0 sec)





# From research into the operative rooms

**Von der Forschung in die Einsatzzentralen**

**Dalla ricerca alle sale operative**

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*Patrick Oswald, Christoph Daxer, Jasper Moernaut (Department of Geology, University of Innsbruck)*

*Patrick Salcher, Benjamin Hirzinger, Christoph Adam (Unit of Applied Mechanics, University of Innsbruck)*



# From research into the operative rooms

-10'000 yrs.

-1'000 yrs.

-100 yrs.

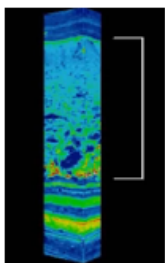
Today

in the next few minutes to hours?

Time line needed to be considered for reliable earthquake hazard and risk assessment

## Prehistoric

Paleoseismology



Studying past earthquakes recorded in geological archives

## Historic

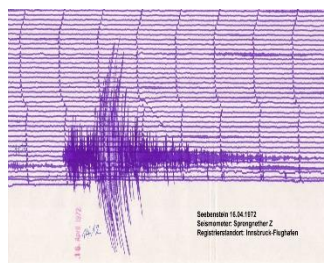
(Historical seismology)



Investigating historical records of earthquake occurrence and damage reports

## Instrumental

(seismology)



Analyzing data from analog & (since 1990s) digital seismometers

## Operative Room

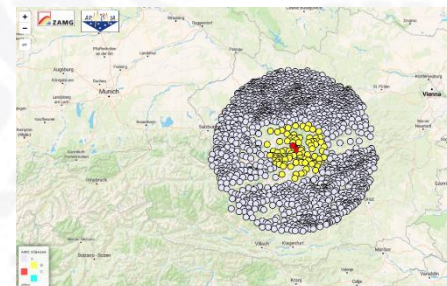
(ZAMG)



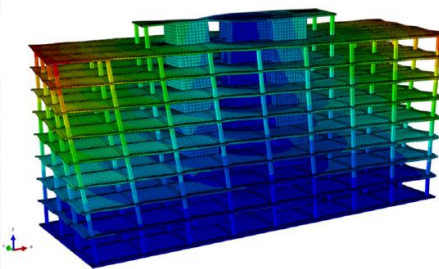
24/7 evaluation of real-time data for earthquakes (M>2). On call service for federal and Provincial Warning Centres

## Seismic Response Prediction

(Seismology & Earthquake engineering)



ARMONIA ATLAS @ ZAMG  
calculated Risk classes for communities



Modelling of vibrations behaviour of buildings  
assessment of damage risks



Institut für Geologie



### Intensity predictions

ARMONIA Atlas @ZAMG,  
**Integration of real-time data and intensity information of past earthquakes**

### Seismic response prediction

for critical infrastructure

### Seismic monitoring of critical infrastructure

multiple sensors in sentinel building

### Seismic monitoring network

With ARMONIA, 5 new stations added  
improved earthquake detection & localisation

### Observational data to constrain

- maximum earthquake magnitude and recurrence pattern (magnitude/frequency relation for low probability, but high impact events)
- intensity and environmental effects of such events

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UNIVERSITÀ DEGLI STUDI DI TRIESTE