Towards real-time damage assessment of seismic events: preliminary results from complementary approaches

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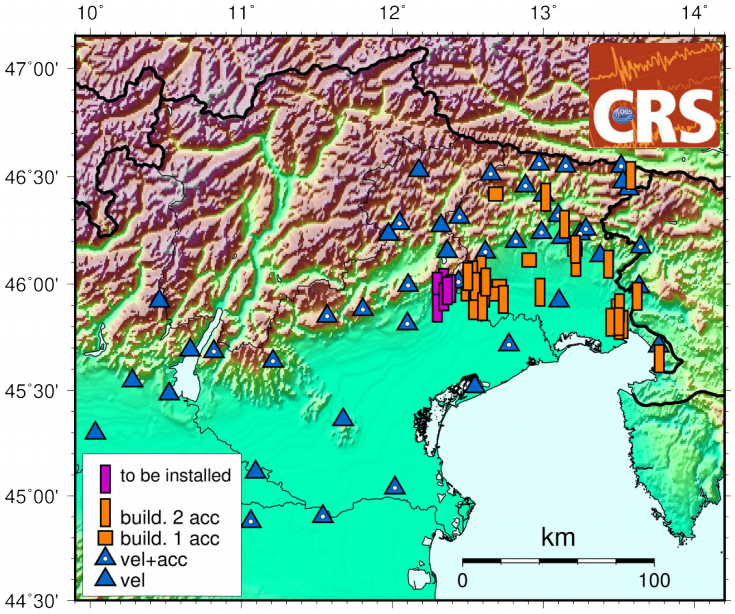
The Seismological Research Center

Gemona del Friuli, 6th May 1976

1976 Ml 6.5 Friuli earthquake:

- 989 victims
- 100.000 destroyed buildings
- 200.000 homeless people

1976: one seismometer, installed in Trieste.

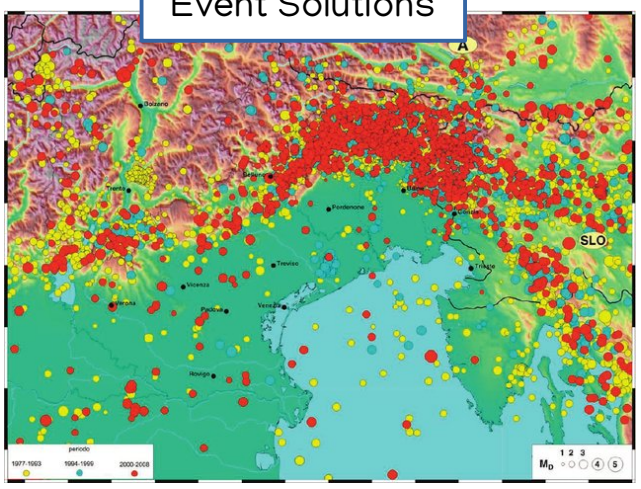


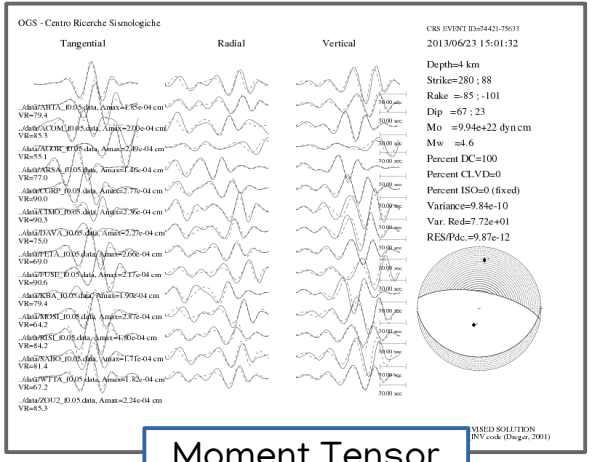
The CRS seismic network

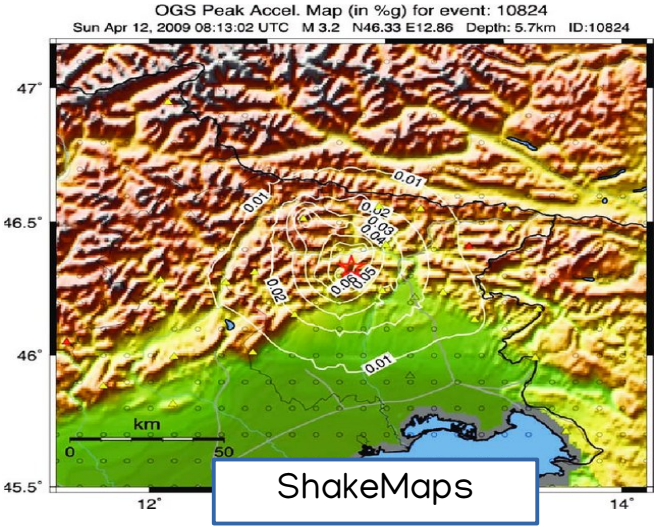
Today: dense network of seismic sensors (45) that allows to automatically locate earthquakes and issue alerts.

Seismological Products

Recent research activities at CRS have been mainly focused on seismological aspects, producing a wide amount of valuable scientific knowledge for the region.







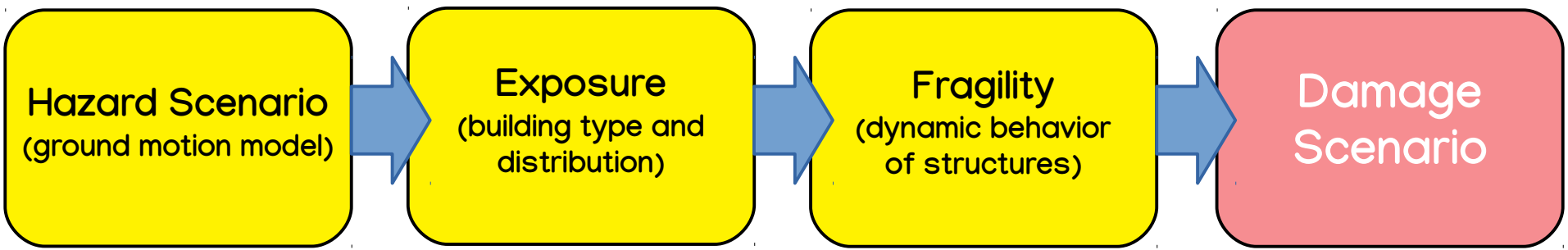
… and much, much more….

Towards Real-Time Damage Assessment

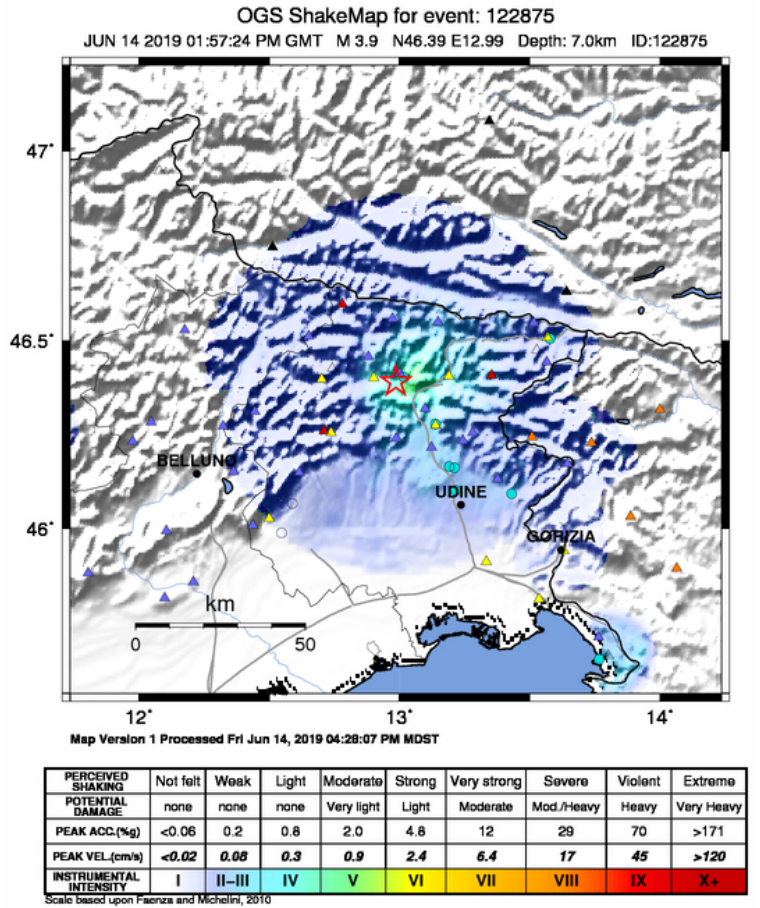
SETTIMANA NAZIONALE DELLA PROTEZIONE CIVILE

Need for emergency intervention after catastrophic events and damage mitigation through preventive land and urban planning. We aim at defining methodologies to assess the **impact of earthquakes on structures and population.**

"Earthquakes don't kill people, collapsed buildings do so"
Nigel Priestley (1943–2014)



Constrained Ground Motion



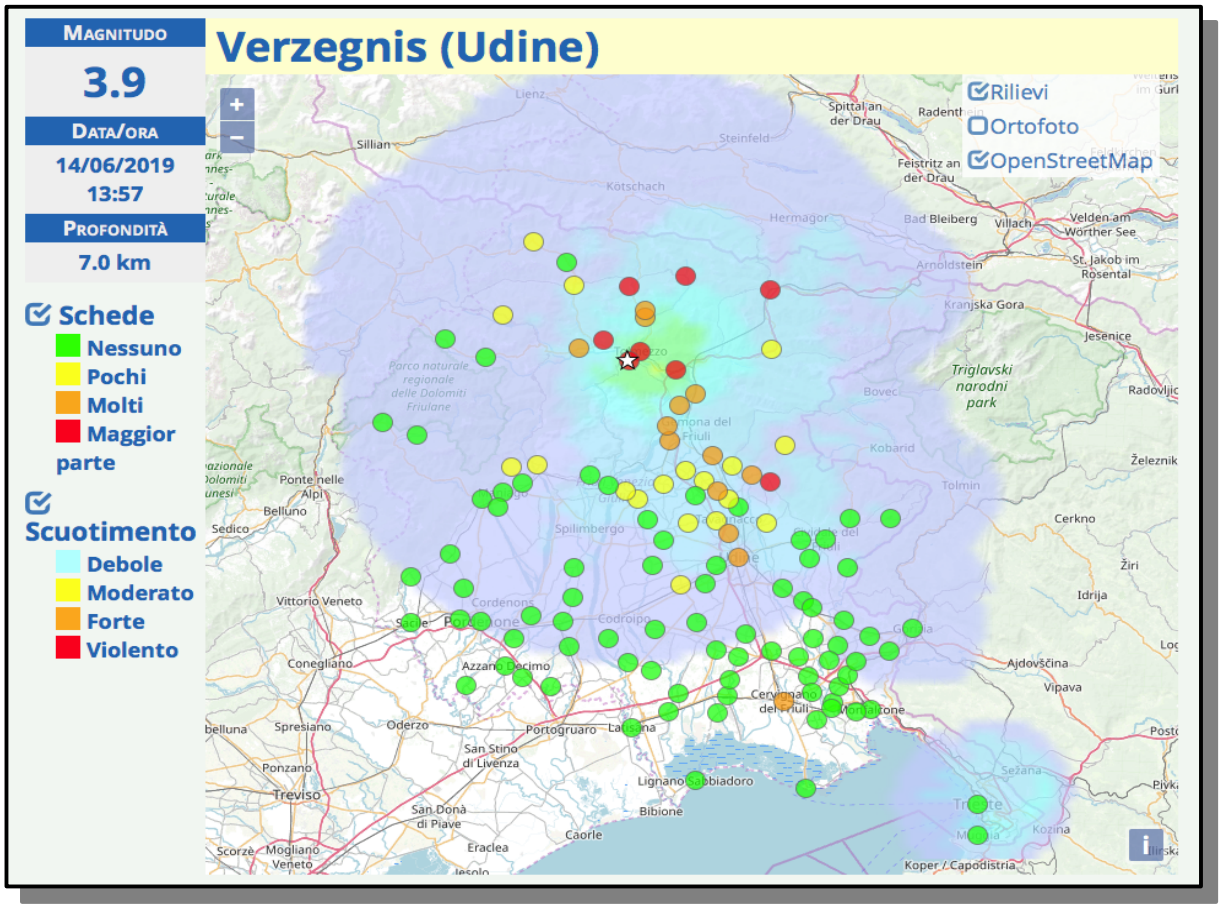
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.06	0.2	0.8	2.0	4.8	12	29	70	>171
PEAK VEL.(cm/s)	*<0.02*	*0.08*	*0.3*	*0.9*	*2.4*	*6.4*	*17*	*45*	*>120*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Faenza and Michelini, 2010

Shakemap: Ground Motion computed from an Empirical Prediction Model constrained by local data from the CRS seismic network (45 stations) and SentiNet instrumented buildings (30, sensors at ground floor). Example for the event of Verzegnis (ML=3.9; 14/06/2019).

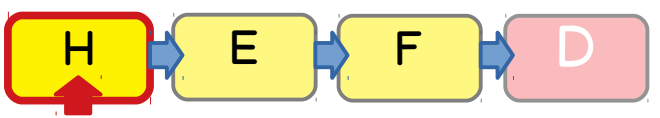
H → E → F → D

ShakeMaps for Emergency Control Room



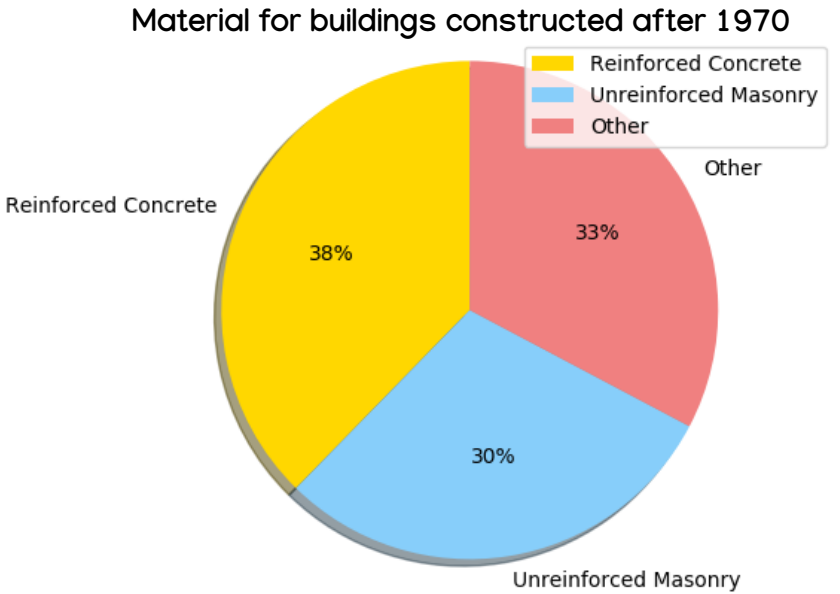
Protezione Civile
Regione Autonoma Friuli Venezia Giulia

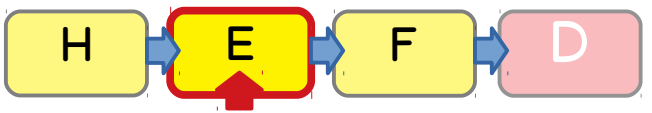
The Civil Protection portal shows:
– computed ground motion (shakemap)
– perceived ground motion (trained volunteers)



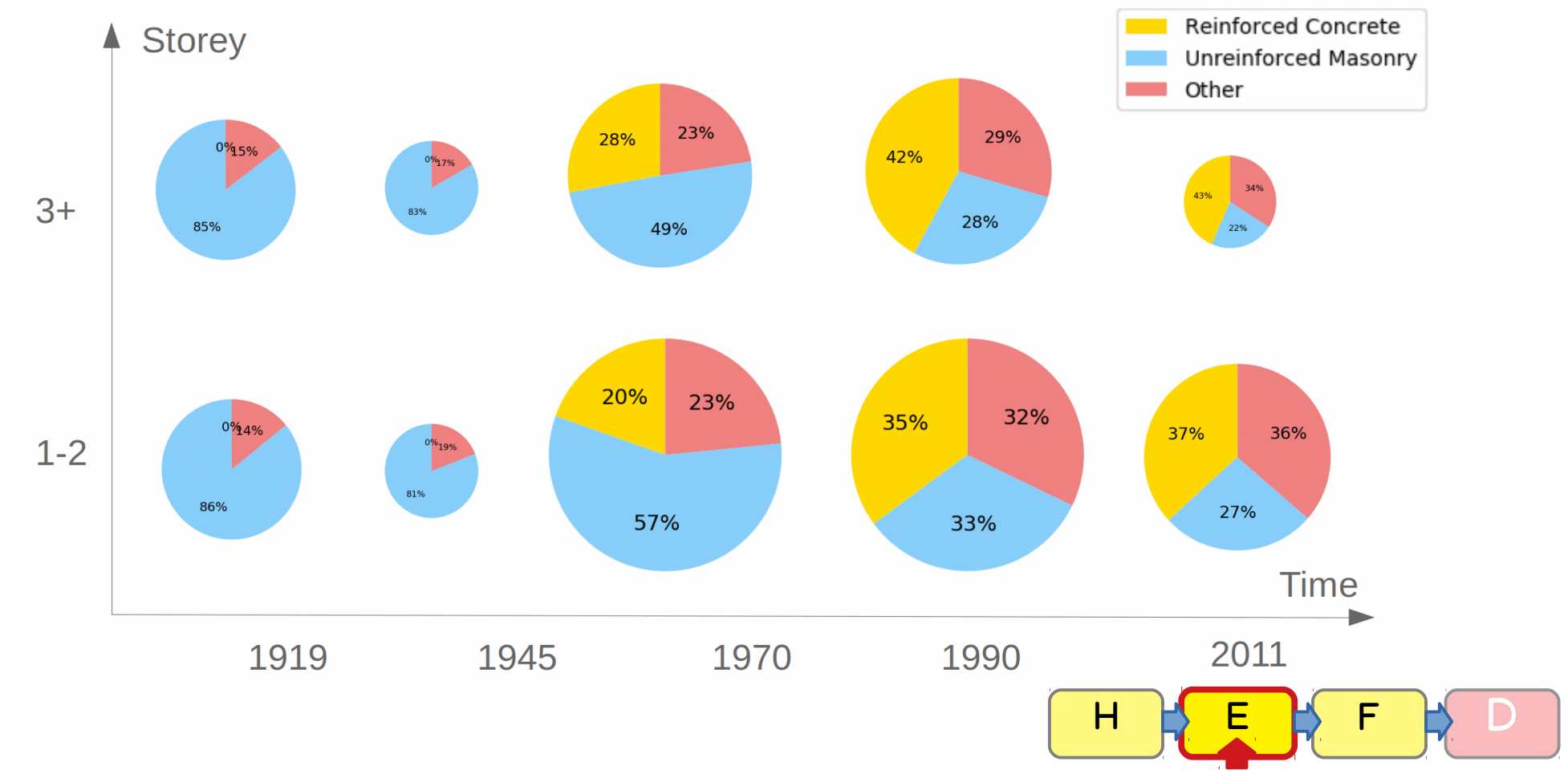
Exposure: Structures and Population

Exposure defines the spatial distribution of elements susceptible to a specific hazard.
We focus on population and residential buildings of the Friuli Venezia Giulia (Istat 2011).





Evolution of Exposure



An Exposure Model for Friuli Venezia-Giulia

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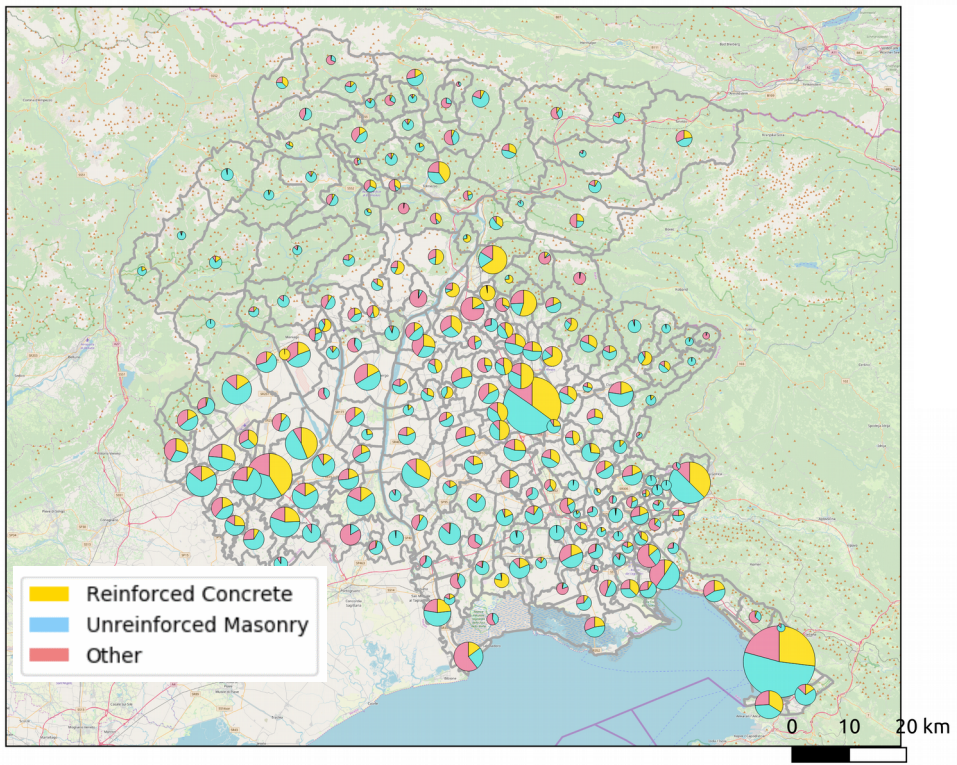
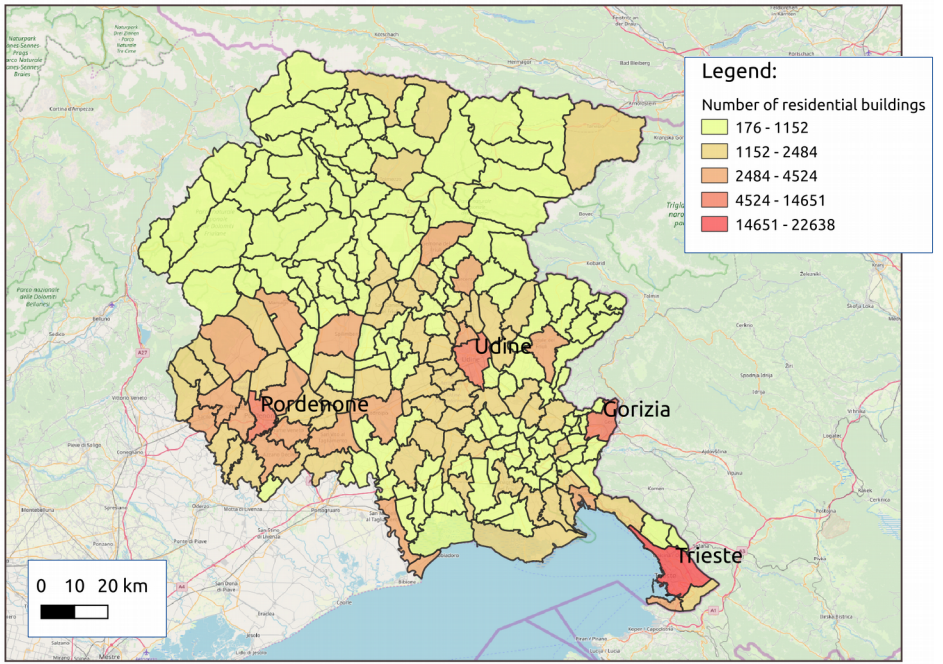
Building material for each municipality (Istat 2011). Pie charts size is proportional to the total number of residential buildings.



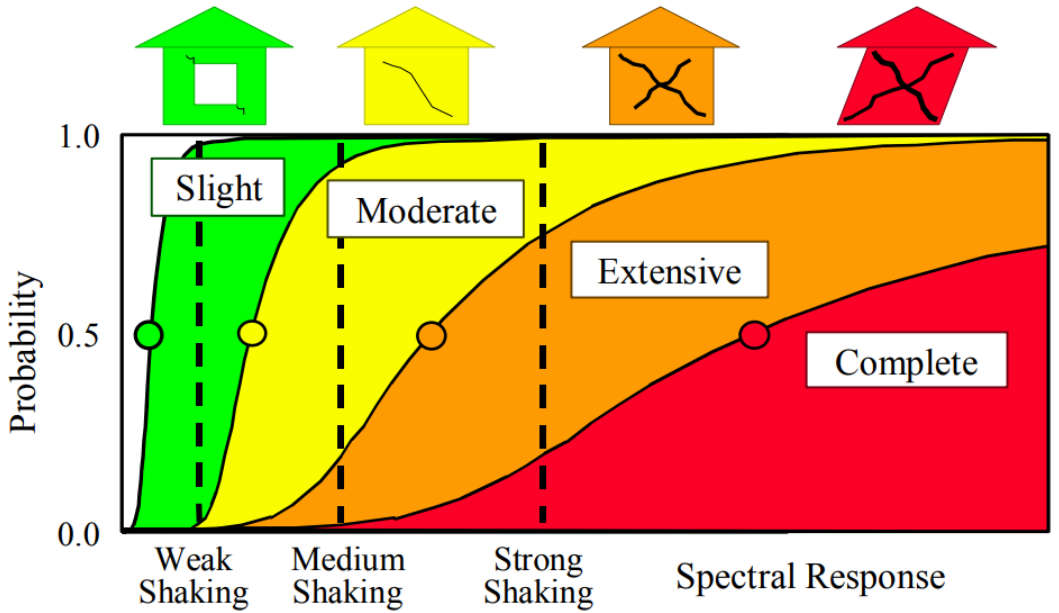


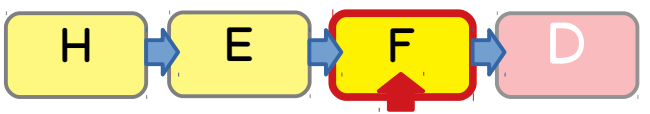
Number of residential buildings (Istat 2018). Names of municipalities with more than 5000 buildings are shown.

H E F D

Structural Fragility

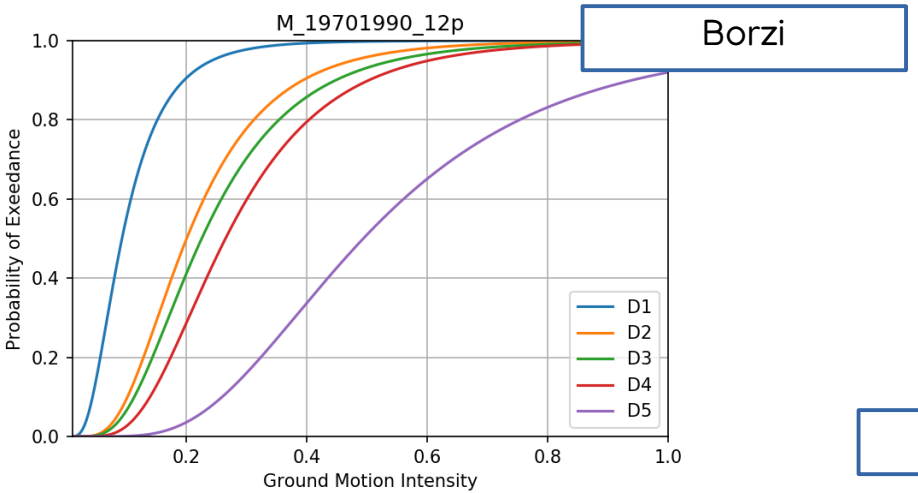
Fragility curves describe the probability of exceeding some limit states for a given level of ground shaking. Limit states for buildings are the conditions of potential failure, as defined in the EMS98 scale.



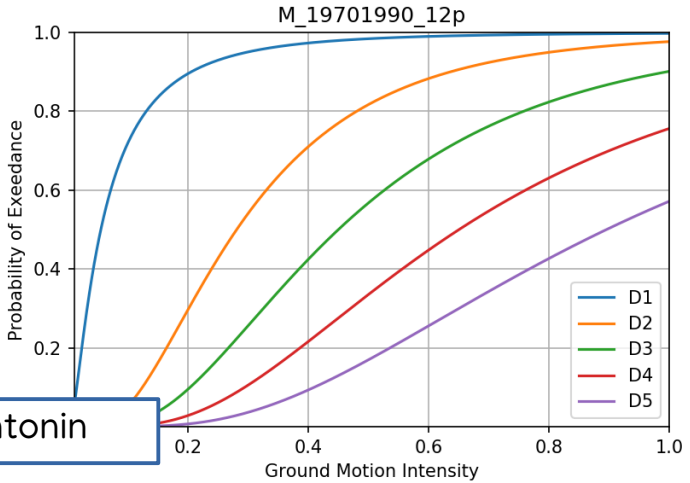


Structural Fragility

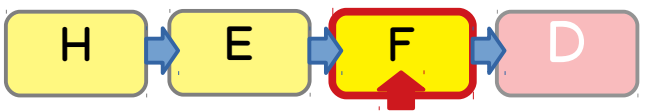
We selected a number of fragility models from literature (for now, based on Peak Ground Acceleration) as most representative of the building typologies in the Friuli Venezia Giulia.



Borzi



Karantonin



A Real-time Damage Scenario Calculator

SETTIMANA NAZIONALE DELLA PROTEZIONE CIVILE

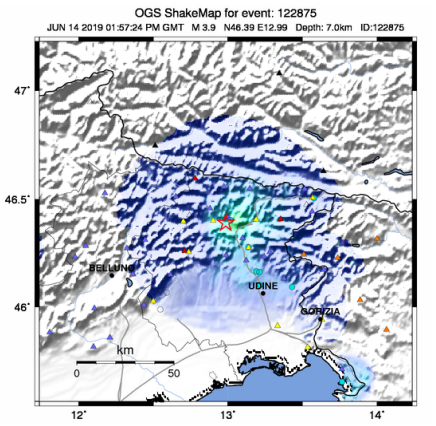
ALERT!

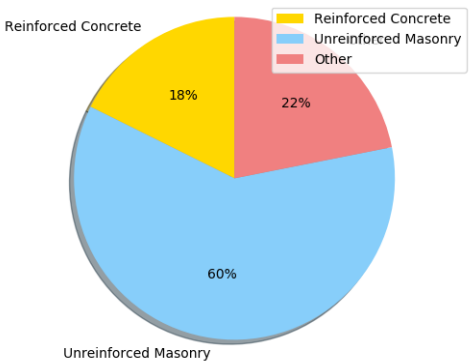
Scenario Hazard (ground motion model)

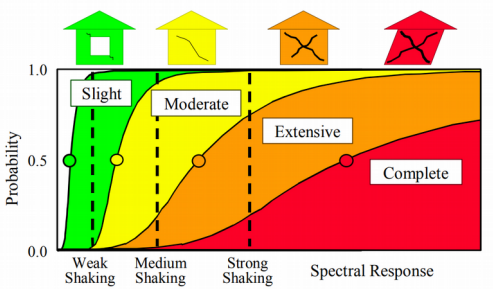
Exposure (building type and distribution)

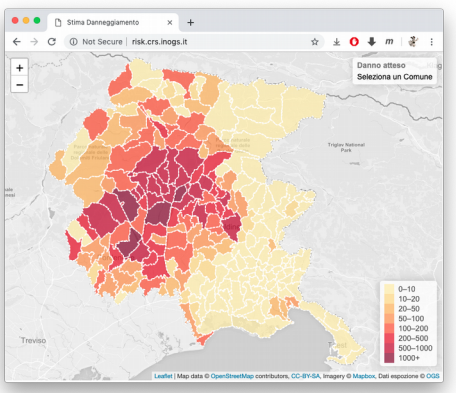
Fragility (dynamic behavior of structures)

Damage Scenario

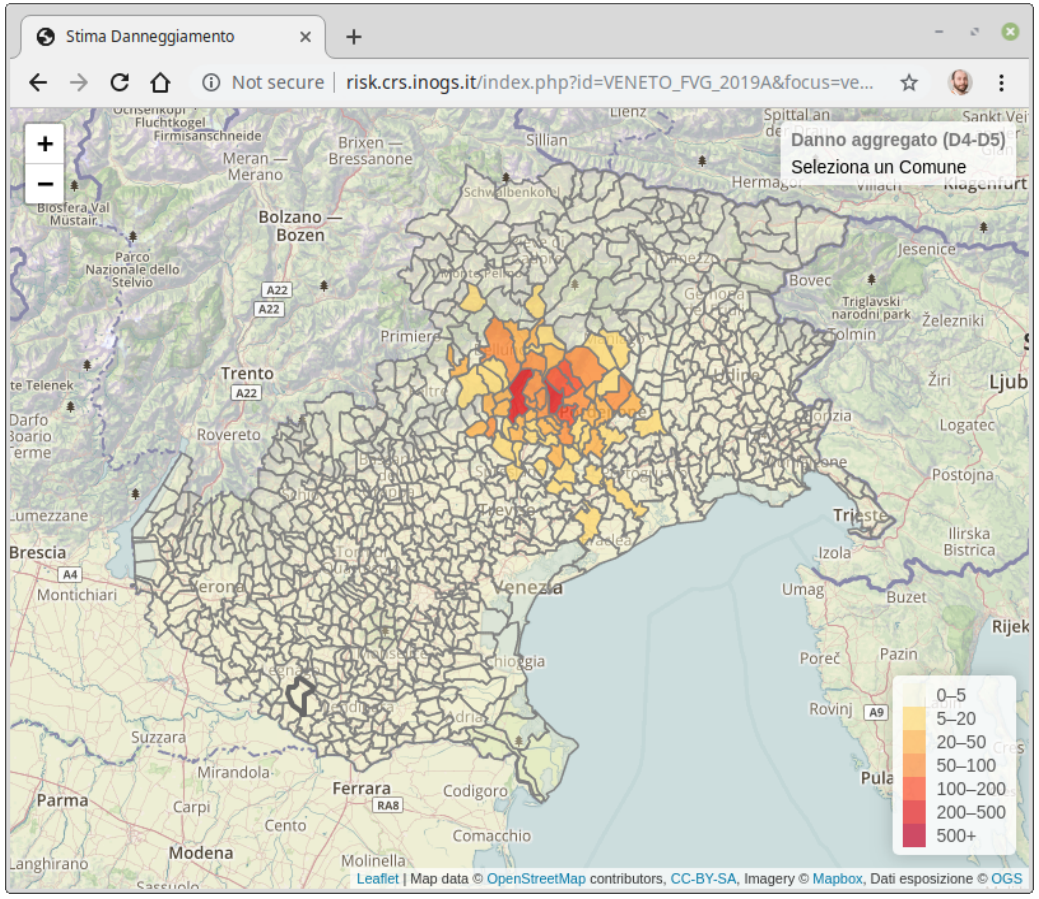








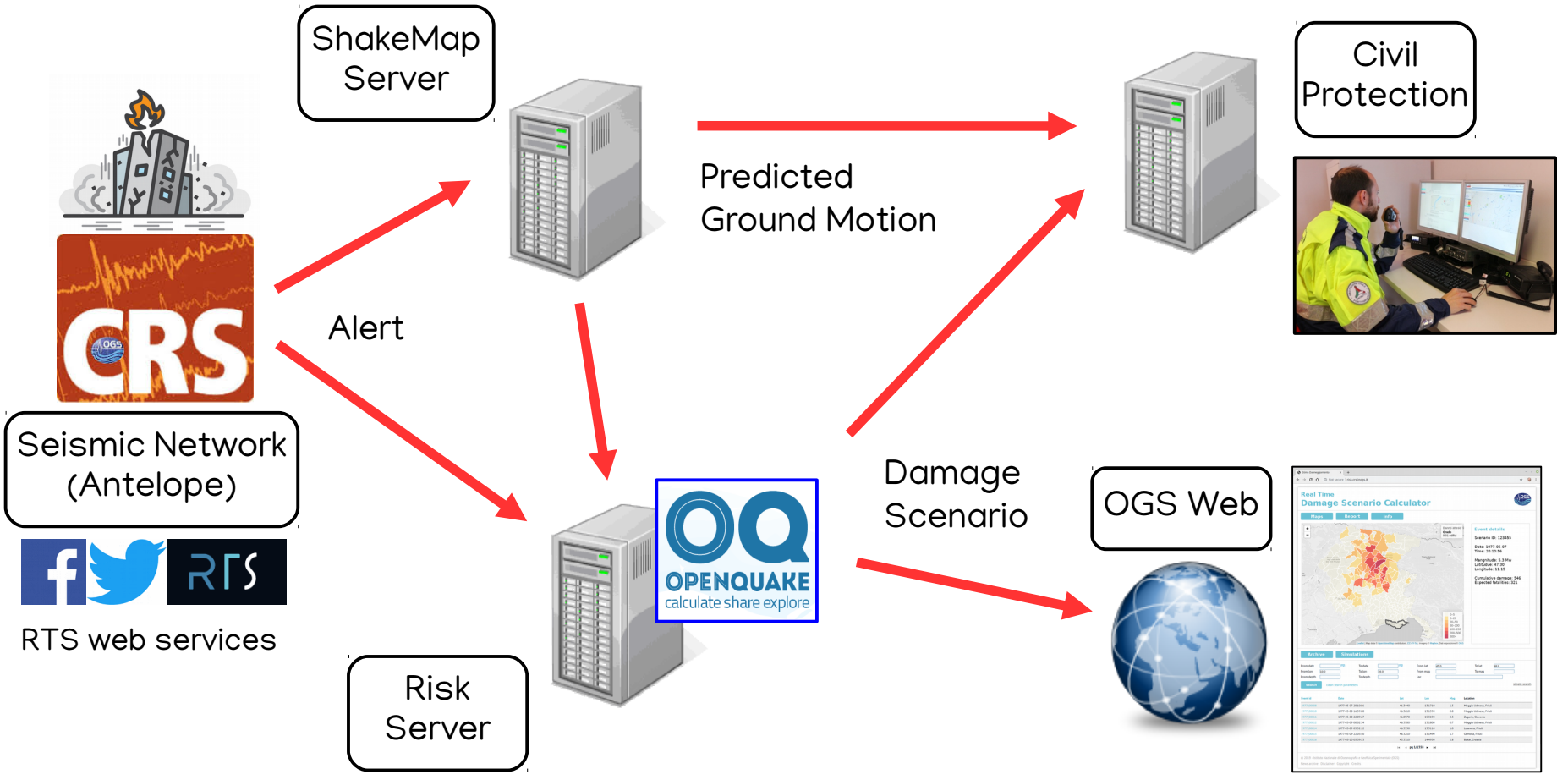
Estimated Damage



Example of test scenario:

- Number of damaged buildings by aggregating severe damage (level D4) and total collapse (level D5) of the EMS98 scale.
- Option to produce a map of number of people impacted (based on simplified relationships, e.g. Bramerini et al. 1995)

Processing Infrastructure



Cooperation with Civil Protection

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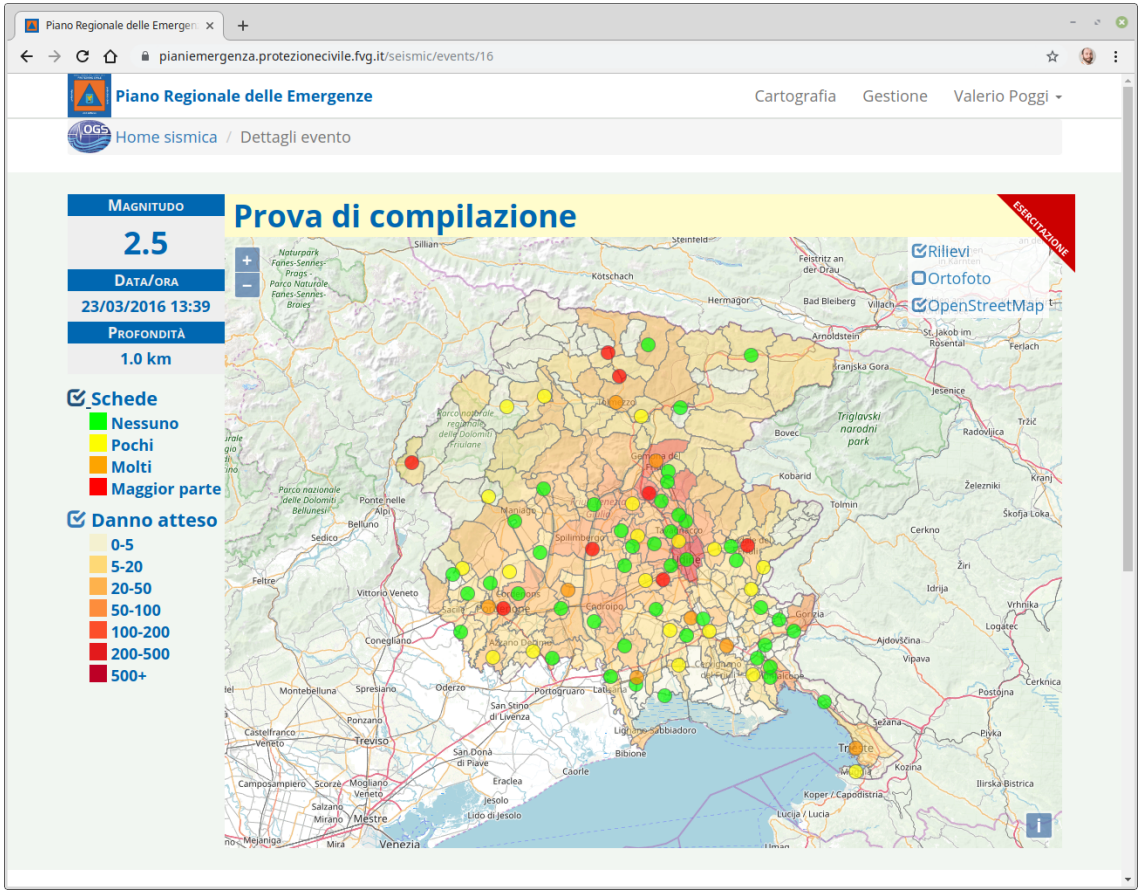
Results sent to Civil Protection for operational purposes:

- Training of operators
- Emergency planning
- Post-event response organization
- Education & outreach



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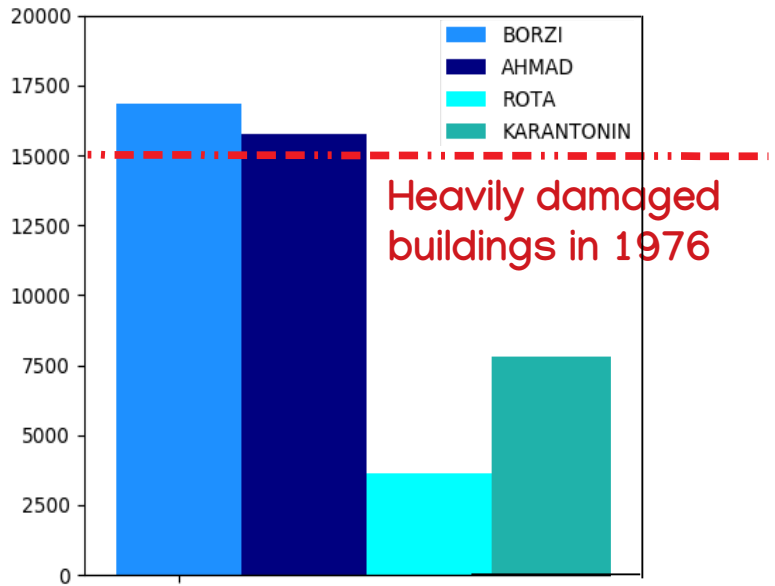
Validation of the Model

We tested four independent models with different fragility curves and with the buildings older than 1976. The number of highly-damaged buildings is compared with the number of destroyed buildings from post-1976 damage statistics (Friuli Venezia Giulia, 1986).

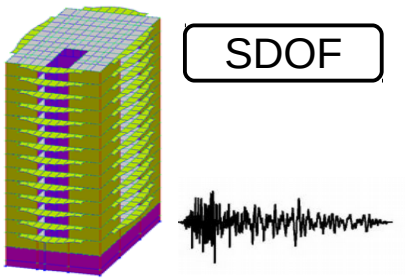


Results for epicentral area (45 municipalities)

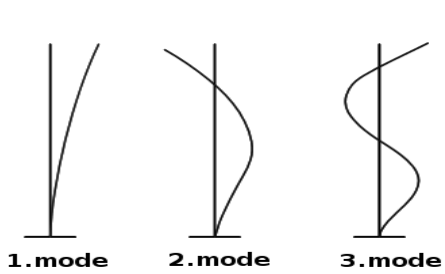
Damage data: Regional statistics archive, 1986.
Exposure: buildings older than 1976
Fragility: 4 different fragility curves
Damage calculation: number of heavily damaged buildings (D4+D5)

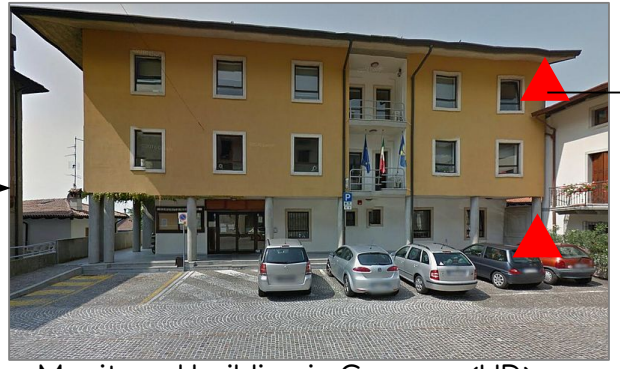
Estimating Building Dynamic Behavior

Different buildings react differently to the same input ground motion. This depends on their different structural dynamic behavior, that influences expected damage.

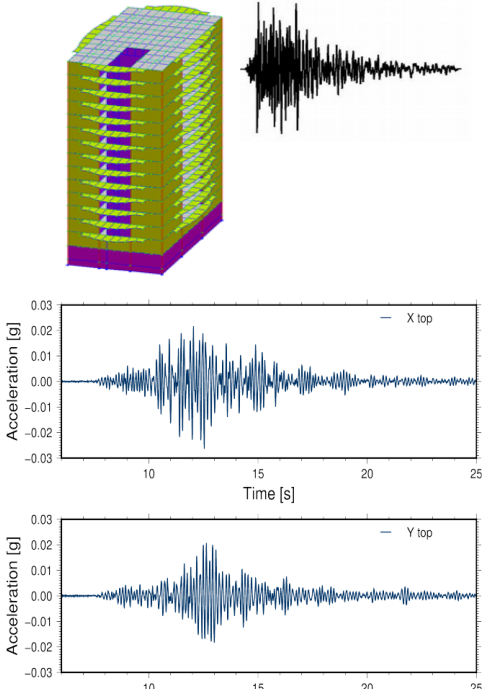


Recordings of the M3.9 event 14.06.2019 (Verzegnis)



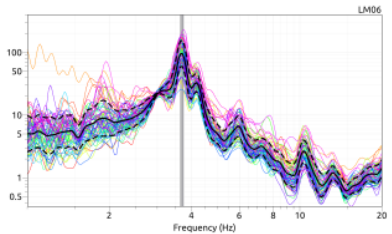


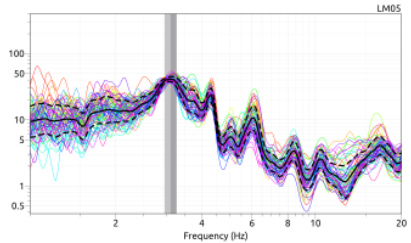
Monitored building in Gemona (UD) characterized by noise measurements (Sentinella/Armonia projects)

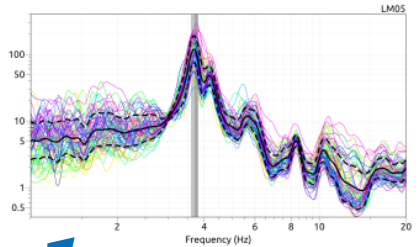


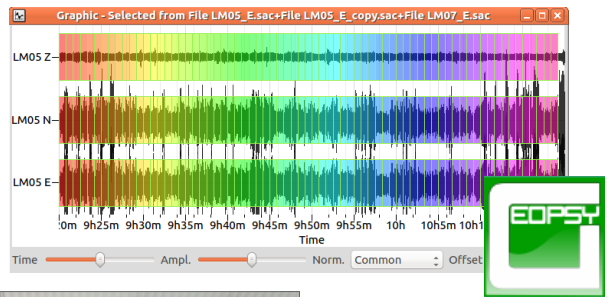
Acceleration at the top sensor can be measured or calculated

Characterization of Specific Buildings

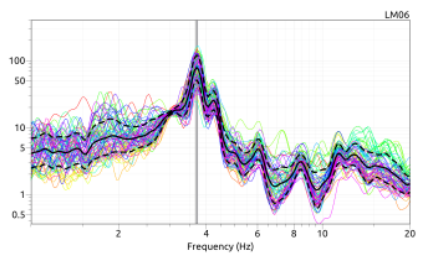


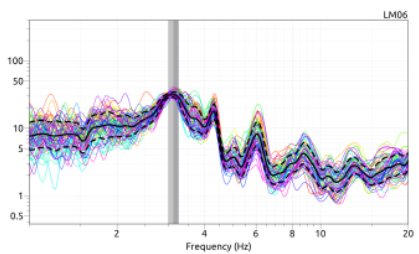


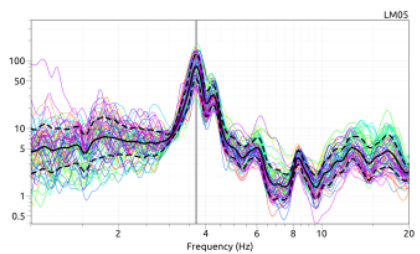




Spectral ratios to a reference station (on the basement)

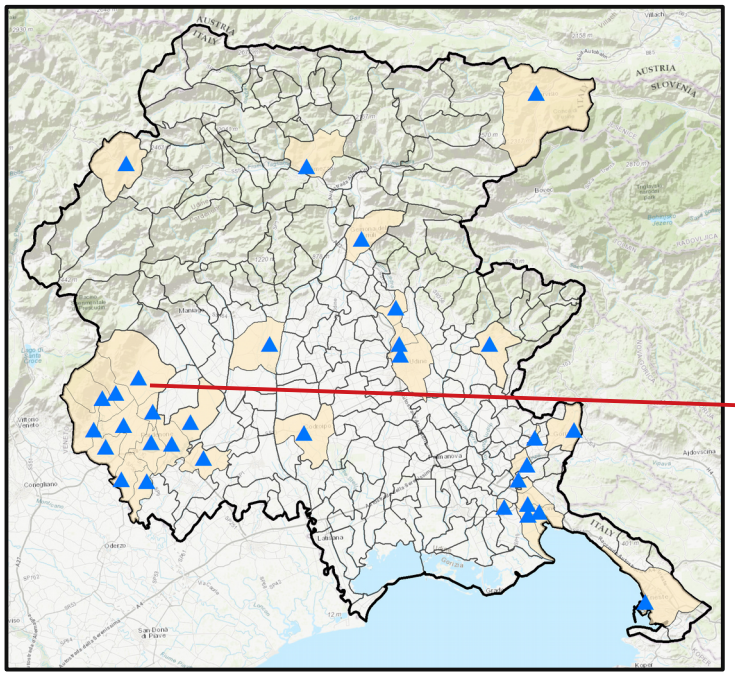


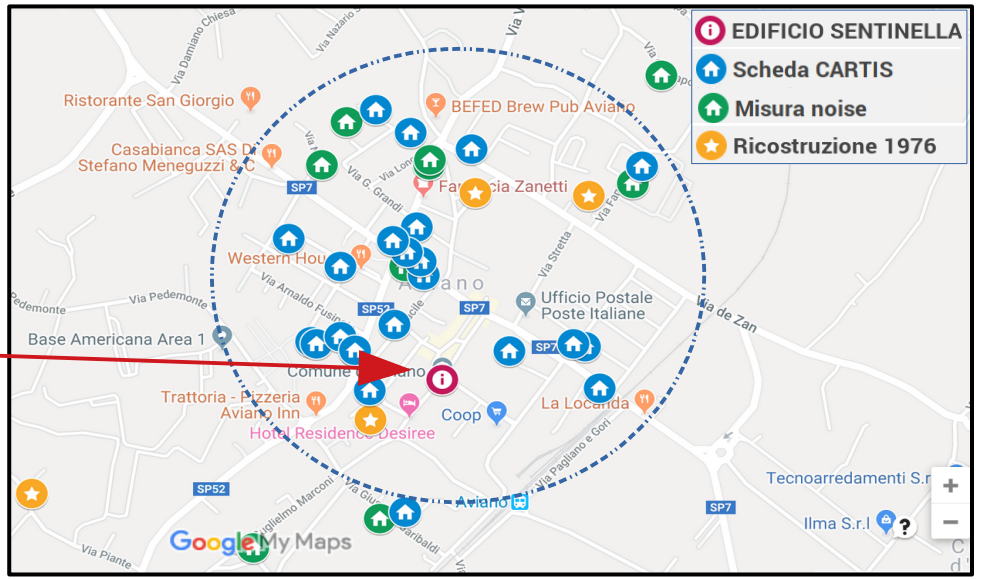




Damage assessment for target areas

Our methodology extends the technique to the surrounding area. We identify building typologies, characterize their fundamental period and estimate the expected damage. Added value: period-dependent, typology-specific damage assessment.





Noise measurements on a representative sample of each typology (work in progress)

Conclusions

The damage scenario calculator is already up and running and will be complemented with higher-resolution local damage estimation. Its impact is two-fold:

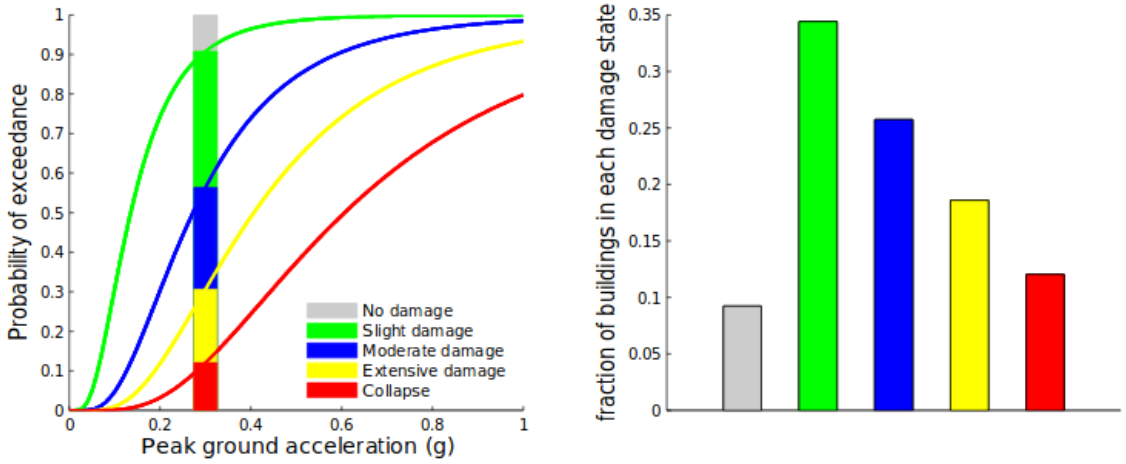
1) scientific: developing novel methodologies that combine the seismological and engineering know-how and act as a starting point for further scientific development.

2) operational: developing tools and products that have a direct impact on everyday life (e.g. civil protection purposes)

Work in progress:

- Enriching exposure and fragility information
- Testing and verifying the model reliability
- Implementing a locally calibrated ground motion model
- Collecting feedback from stakeholders

Damage calculation



Fraction of buildings in each damage state for a given ground motion of 0.3g (Source: Openquake Manual)

- Different ground motion realizations
- Fraction of buildings in each damage state based on fragility curves
- Number of buildings in each damage state (fraction * total number)
- Mean number of damaged buildings (and standard deviation) for each building typology