2019 EPOS Seismology Workshop

Data-constrained damage scenario estimation for real-time emergency management and rapid response planning

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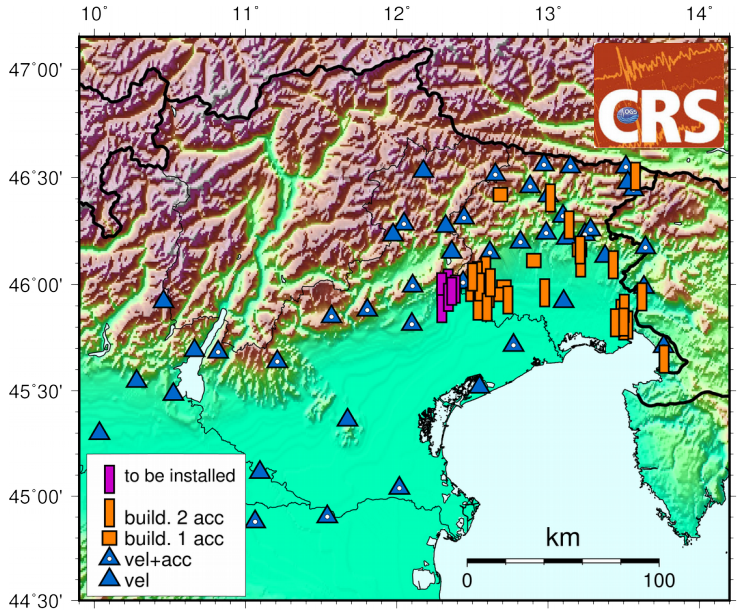
The Seismological Research Center

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 1960 in Trieste by USGS.



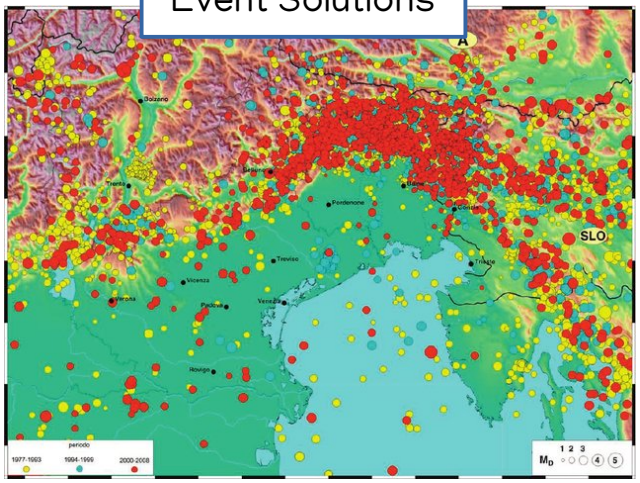
The CRS SentiNet Network

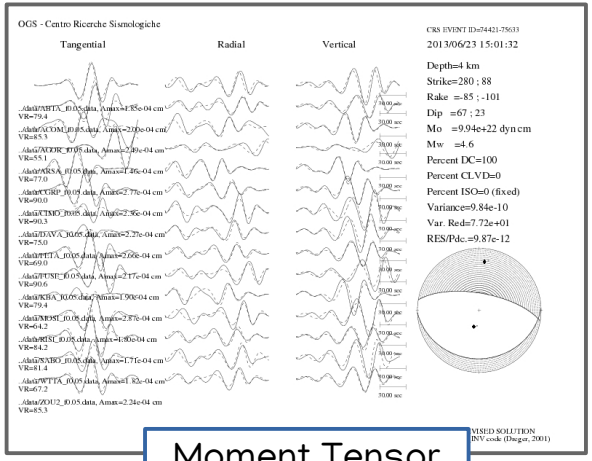
Today: dense network of seismic sensors (45) that allows to automatically locate earthquakes and issue alerts.

Seismological Products

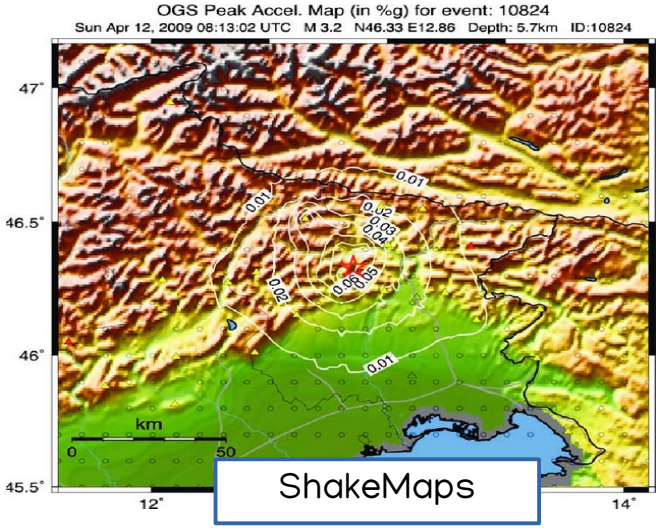
Recent research activities at CRS have been mainly focused on seismological aspects, producing a wide amount of valuable scientific knowledge for the region.

Event Solutions





Moment Tensor Solutions



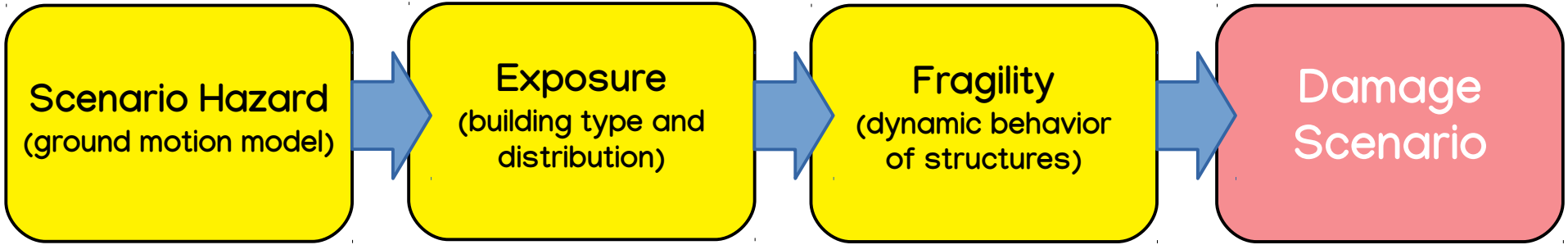
ShakeMaps

… and much, much more….

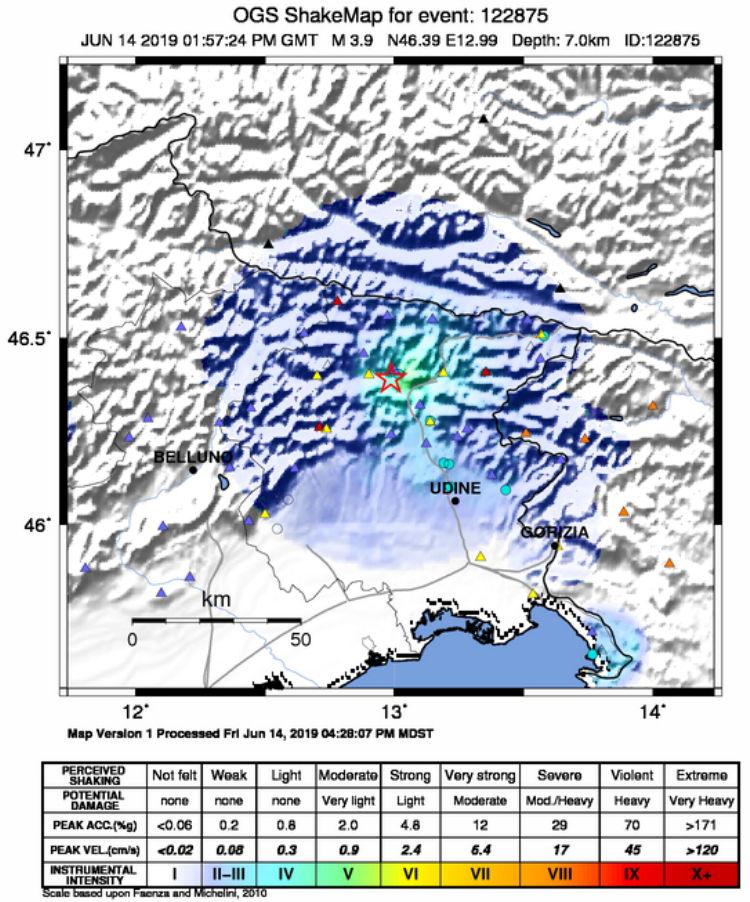
Shifting in the Goals

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 the earthquake on structures and population.**

"Earthquakes don't kill people, collapsed buildings do so"



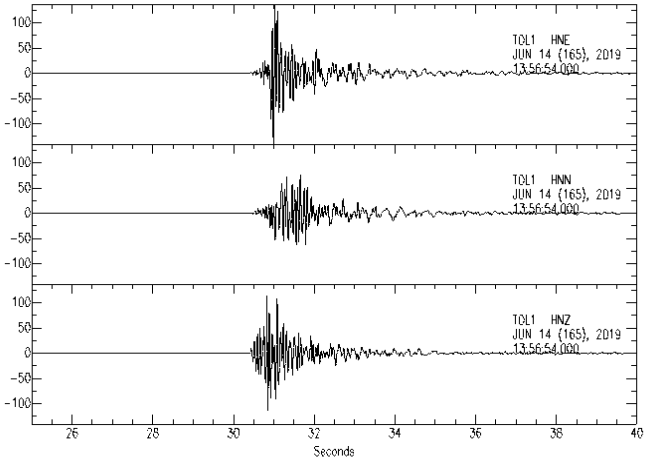
Ground Motion: More than Just a Prediction



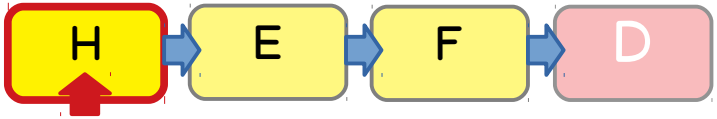
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.06	0.2	0.8	2.0	4.8	12	29	70	>171
PEAK VEL.(cm/s)	*<0.02*	*0.08*	*0.3*	*0.9*	*2.4*	*6.4*	*17*	*45*	*>120*
INSTRUMENTAL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

Scale based upon Faenza and Michelini, 2010

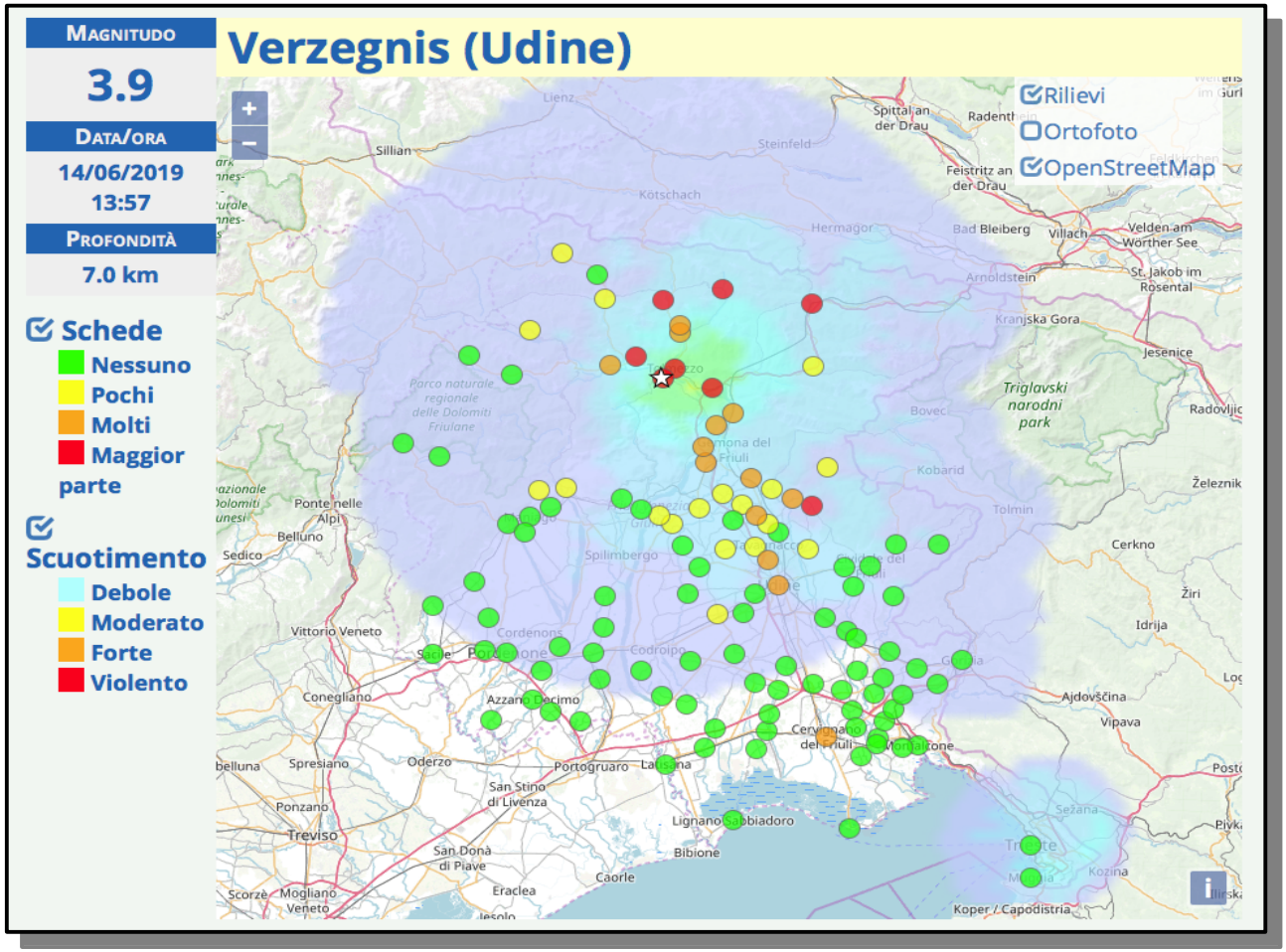
Shakemap: Input Ground Motion computed from an Empirical Prediction Model (GMPE) constrained by local data from the CRS SentiNet network (45 seismic stations and 30 instrumented buildings).



Verzegnis earthquake (ML=3.9; 14/6/2019) Signals recorded at Tolmezzo (ground floor); PGA=140 cm/s2=>0.15 g; PGV=3 cm/s



ShakeMaps for Emergency Control Room

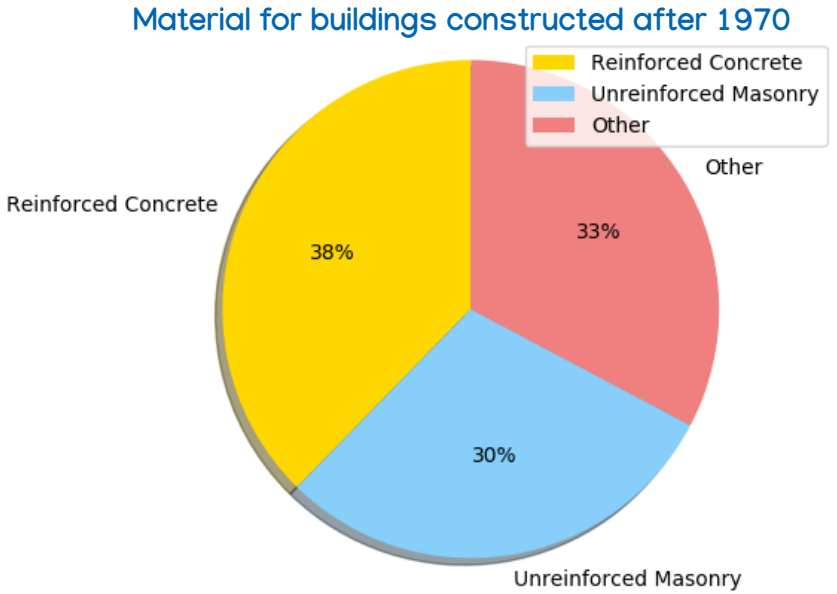


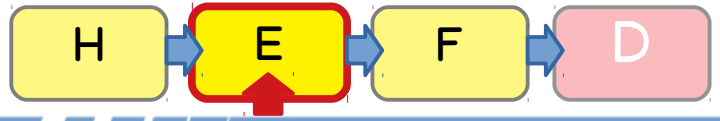
Protezione Civile
Regione Autonoma Friuli Venezia Giulia

H → E → F → D

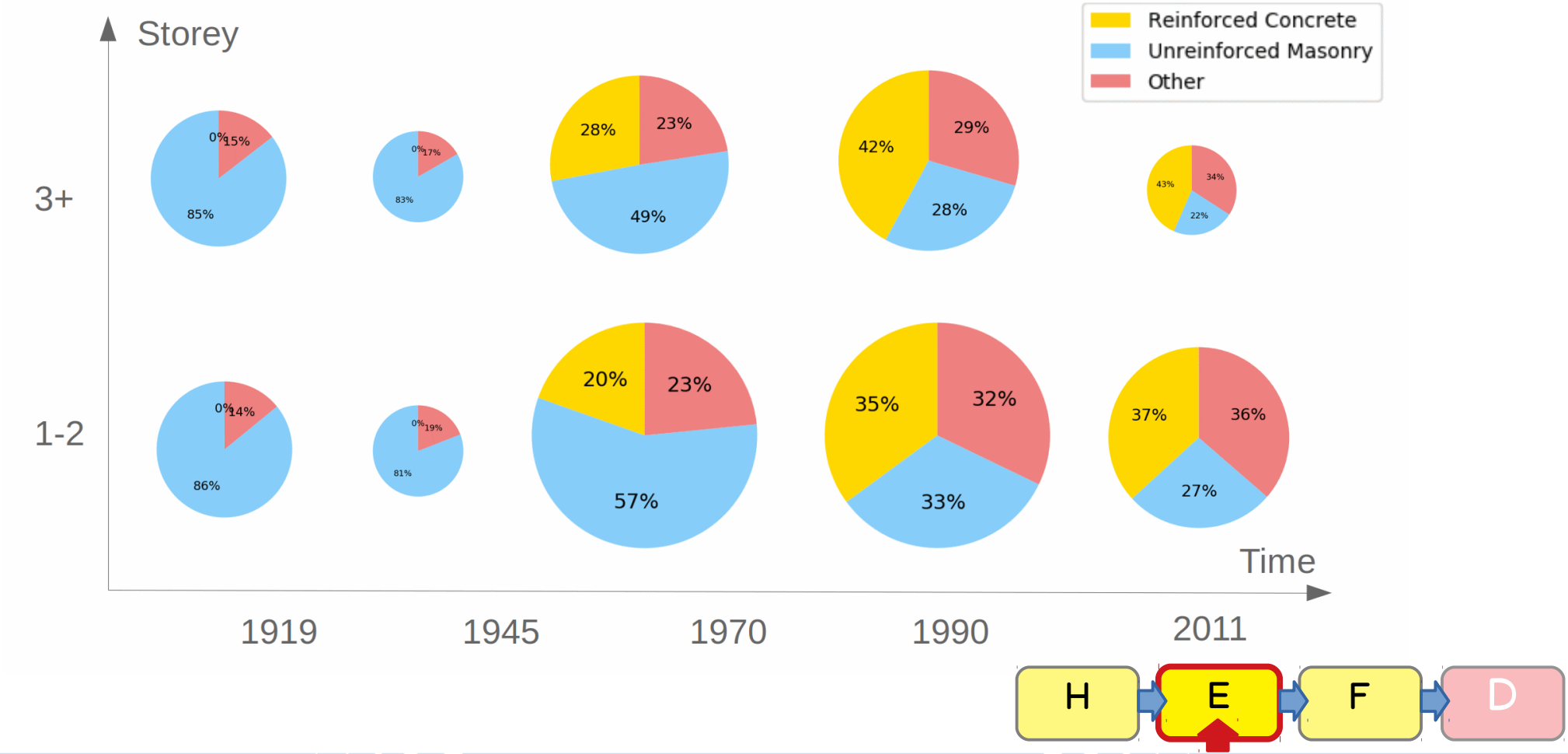
Moving to Structures: Exposure

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).



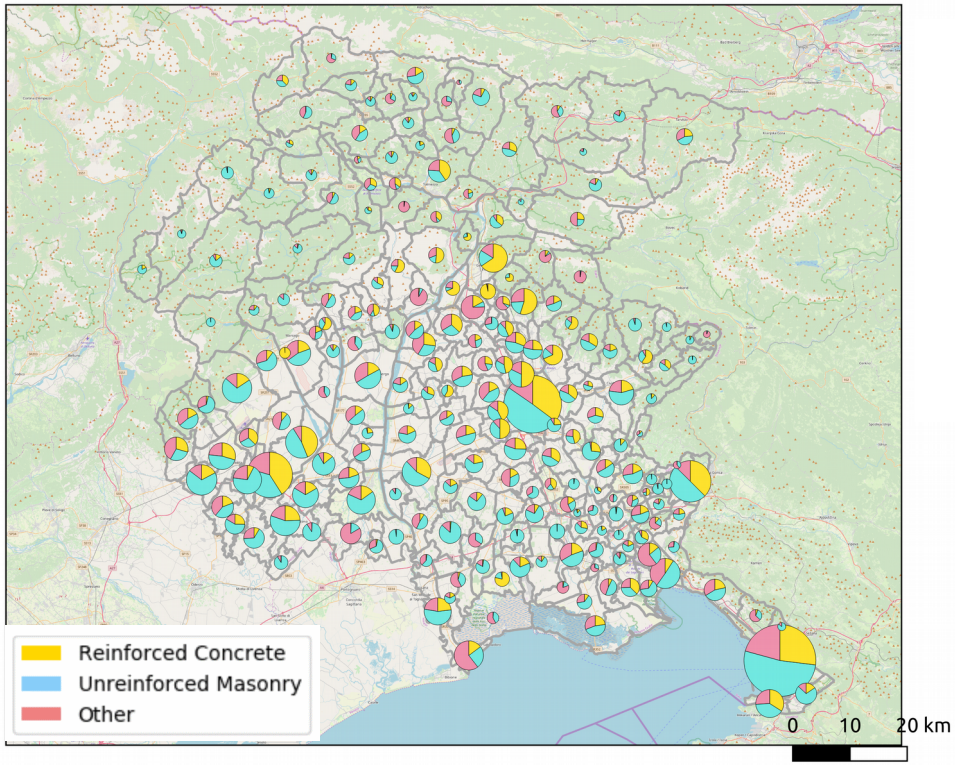


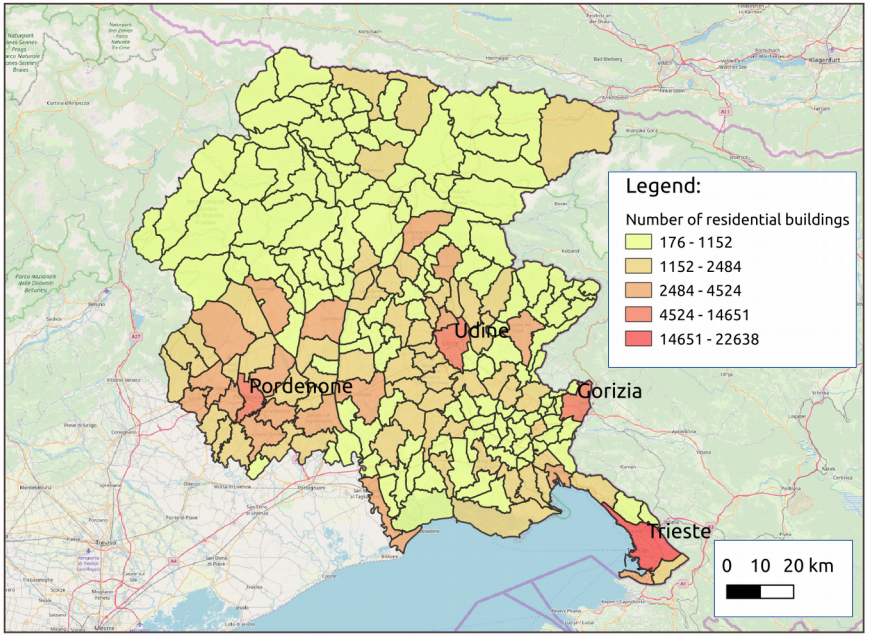
Evolution of Exposure



An Exposure Model for Friuli Venezia-Giulia

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





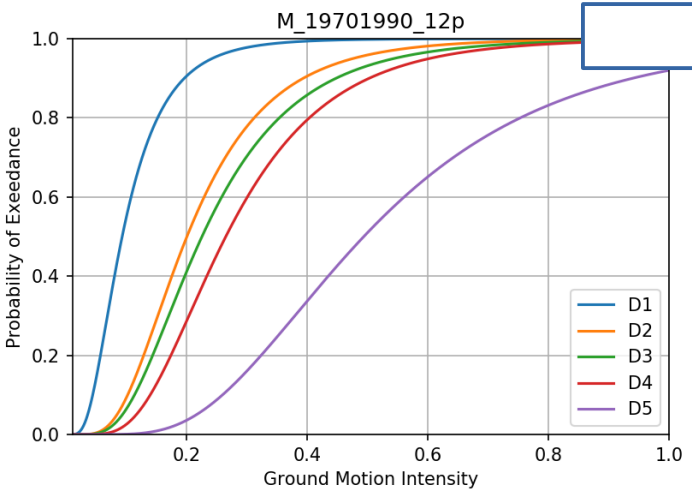
Number of residential buildings (Istat 2018). Names of municipalities with more than 5000 buildings are shown.

H E F D

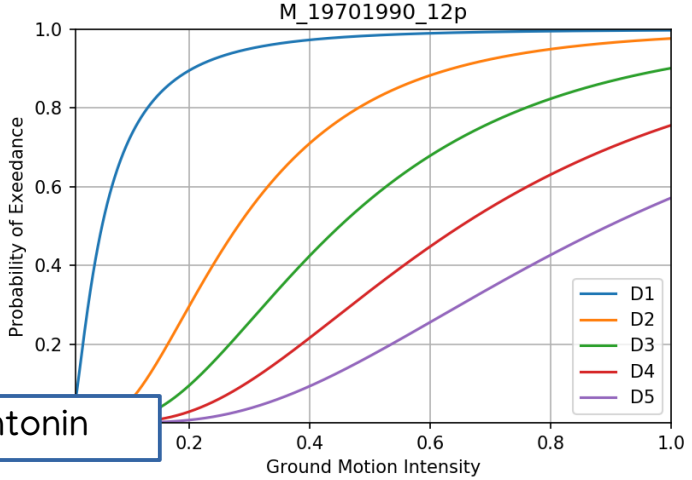
Structural Fragility

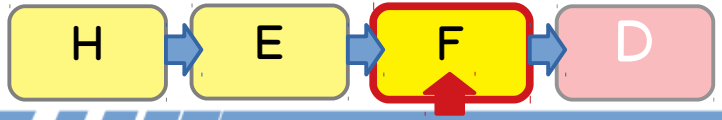
Fragility curves describe the probability of exceeding some limit states given a level of ground shaking. Limit states for buildings are the conditions of potential failure. We selected a number of fragility models from literature as most representative of the building typologies in the Friuli Venezia Giulia.

Borzi



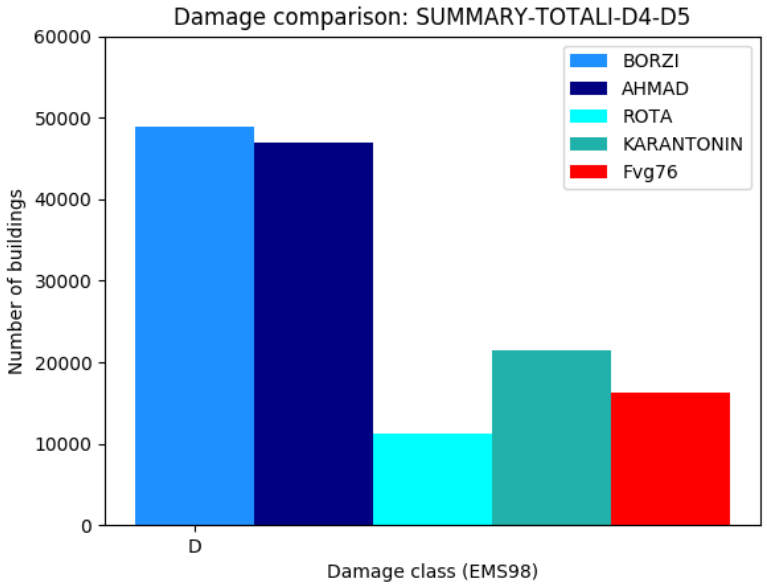
Karantonin

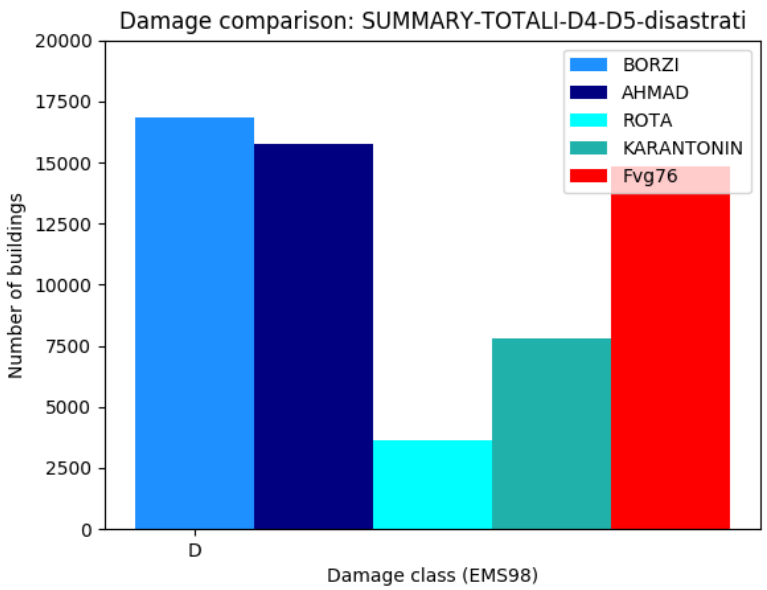




Validation of the Model

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).





Karantonin works better in general, but Borzi and Ahmad perform better in epicentral areas.

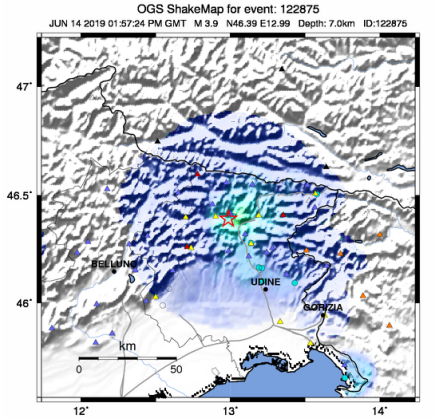
A Real-time Damage Scenario Calculator

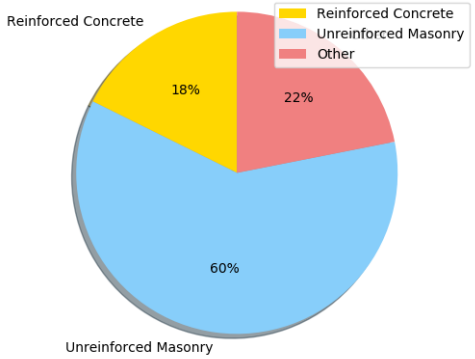
Scenario Hazard
(ground motion model)

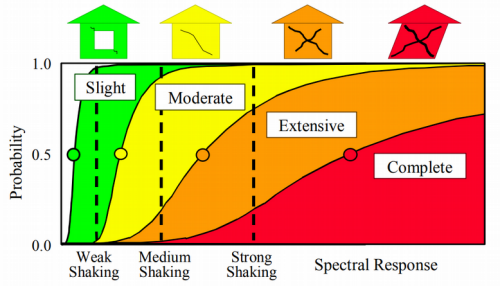
Exposure
(building type and distribution)

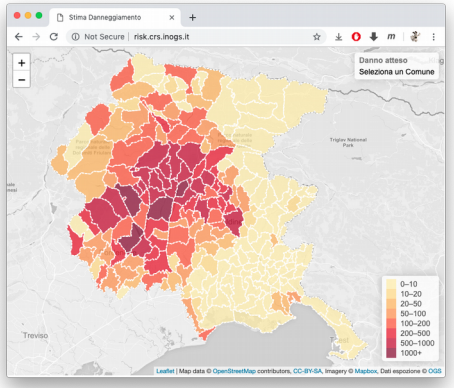
Fragility
(dynamic behavior of structures)

Damage Scenario

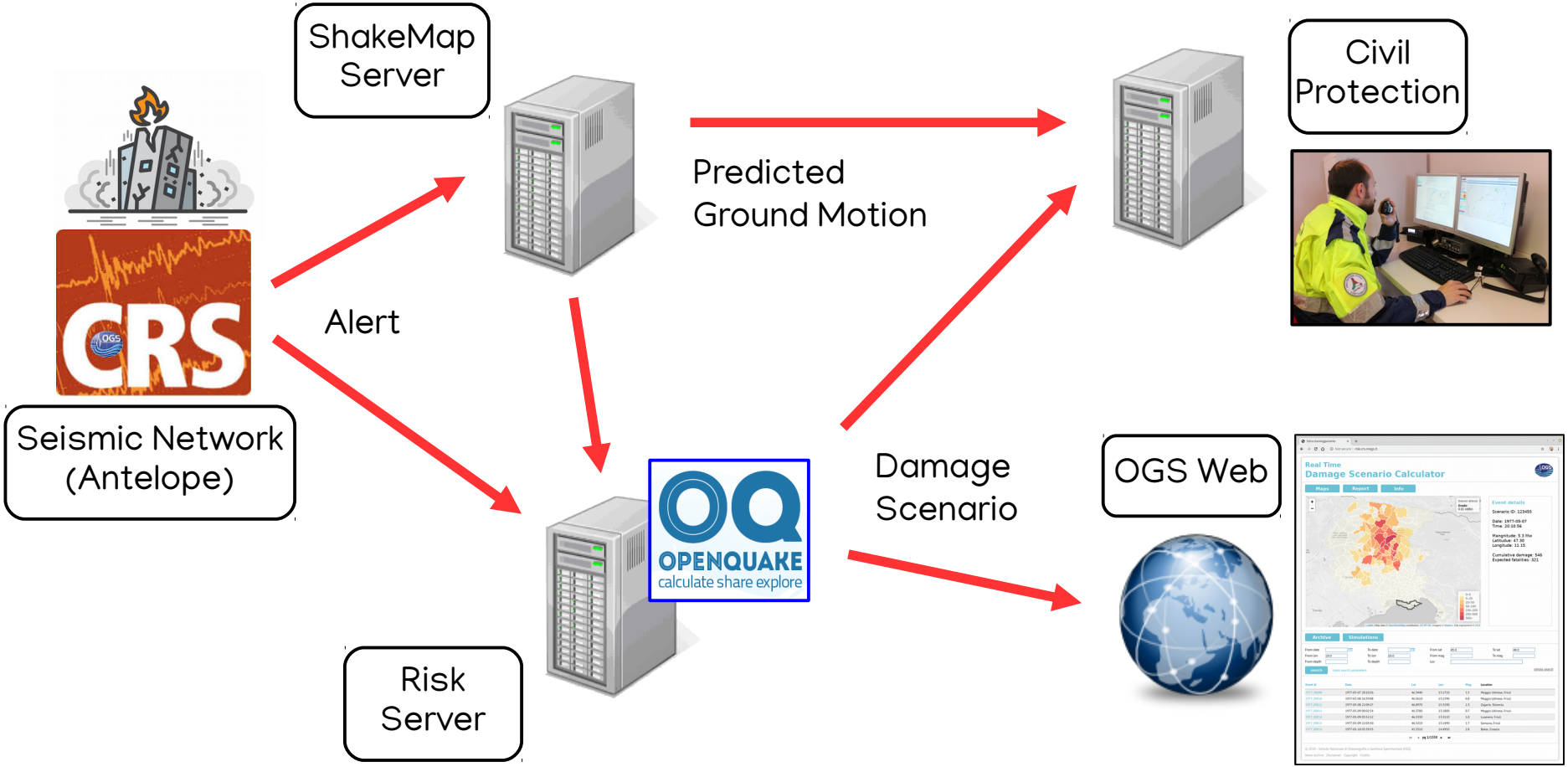




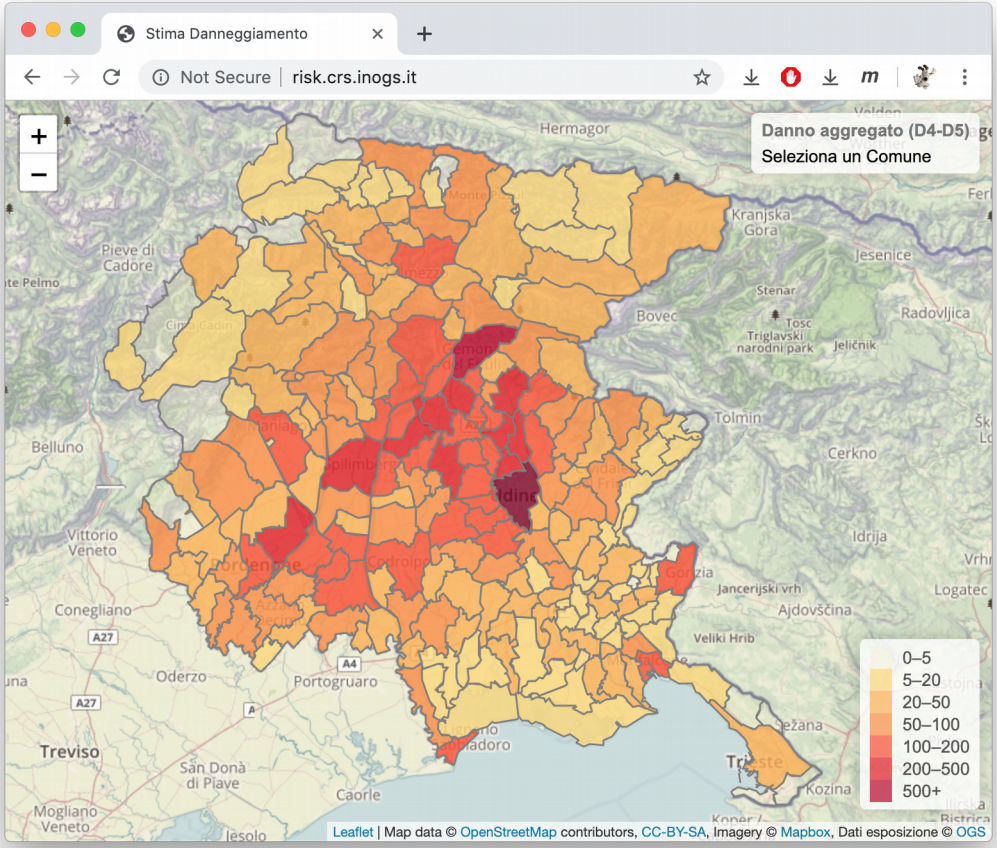




Processing Infrastructure



Estimated damage

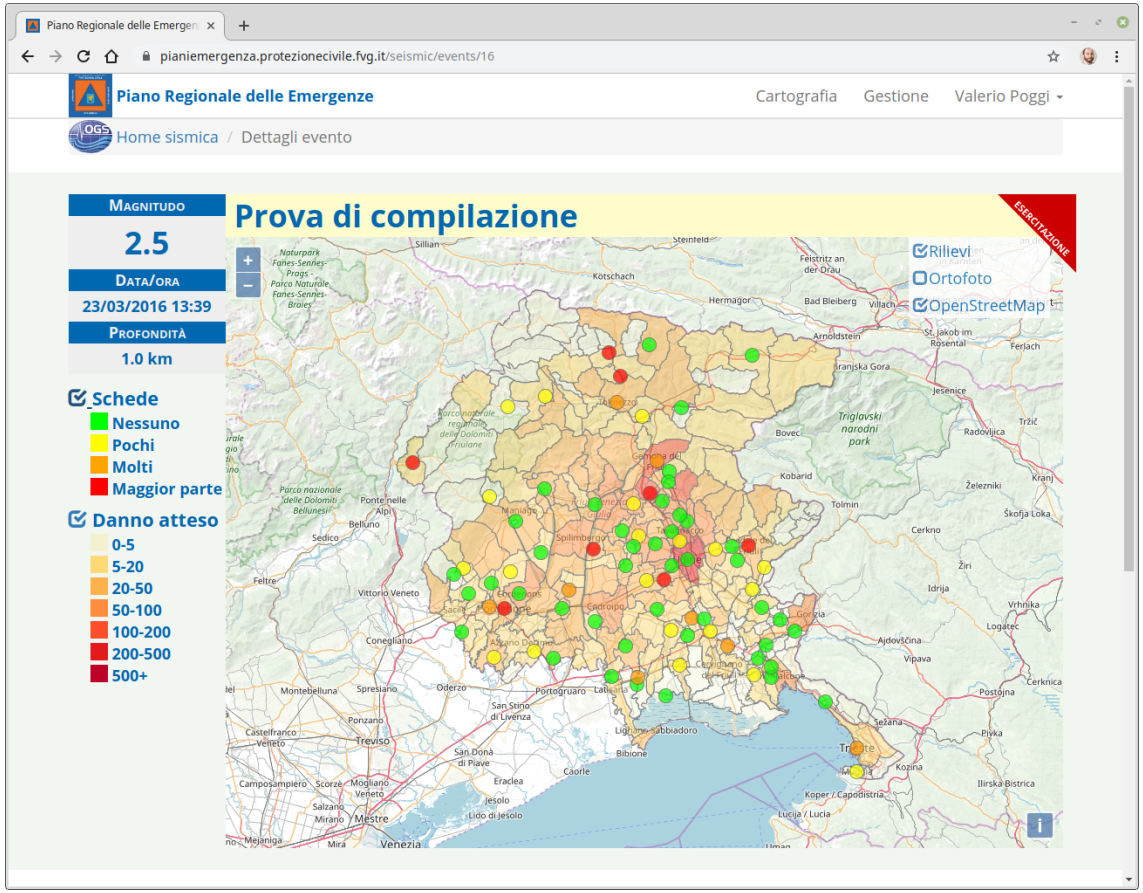


- Number of damaged building by aggregating severe damage (level D4) and total collapse (level D5) of the EMS98 scale.
- Number of people impacted (based on simplified relationships, e.g. Bramerini et al. 1995)

Cooperation with Civil Protection

Results are shared with Civil Protection for operational purposes:

- Post-event response organization
- Emergency planning
- Training
- Urban design



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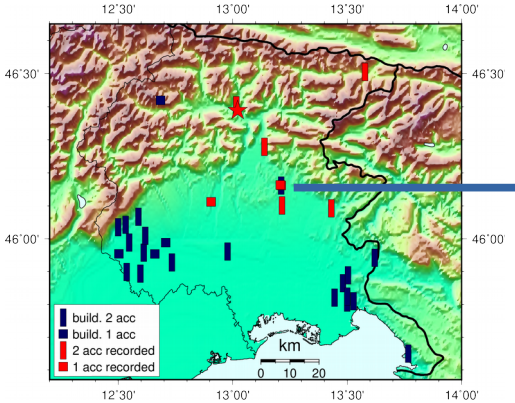
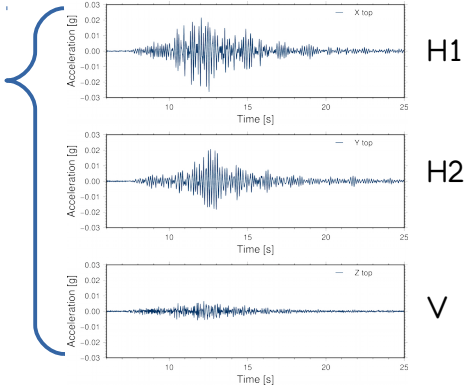
Estimating Building Dynamic Behavior

Buildings of different typology react differently to the same input ground motion.
Real-time monitoring allows characterizing their structural dynamic behavior.

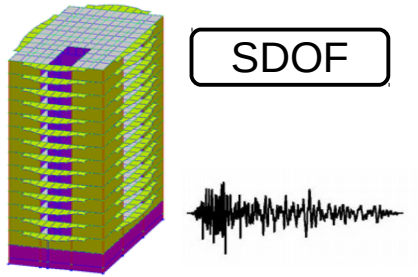


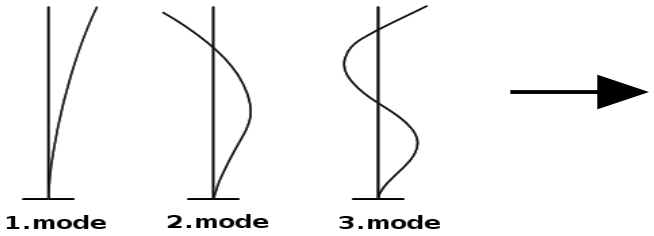
Recordings of the M3.9 event 14.06.2019 (Verzegnis)

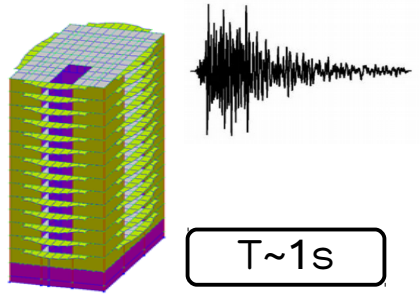
Monitored building at Gemona (UD) characterized by noise measurements (Sentinella/Armonia projects)



Acceleration at the top sensor can be measured or calculated

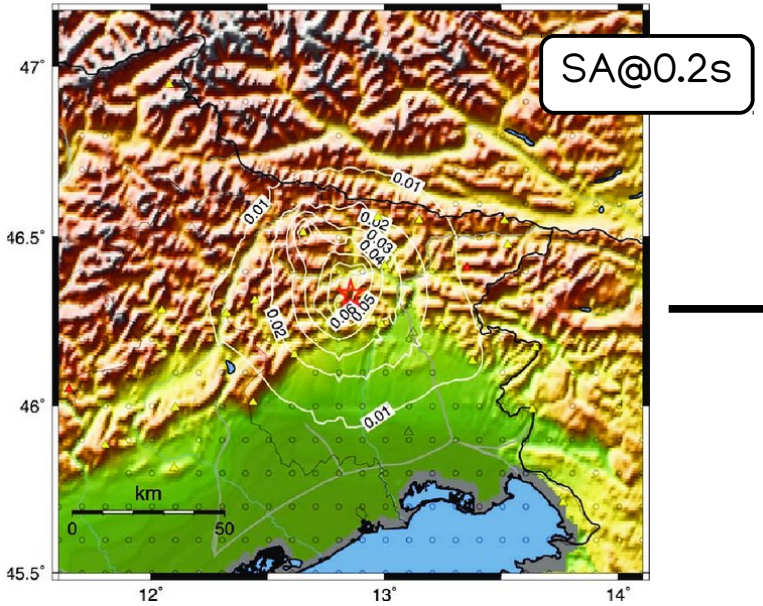






Period Dependent Damage

Ground motion can be predicted for various response spectral ordinates (e.g. T=0.1s, 0.2s, etc.) other than PGA (T=0s). This allows damage scenarios to be period-dependent and specific for a building typology.

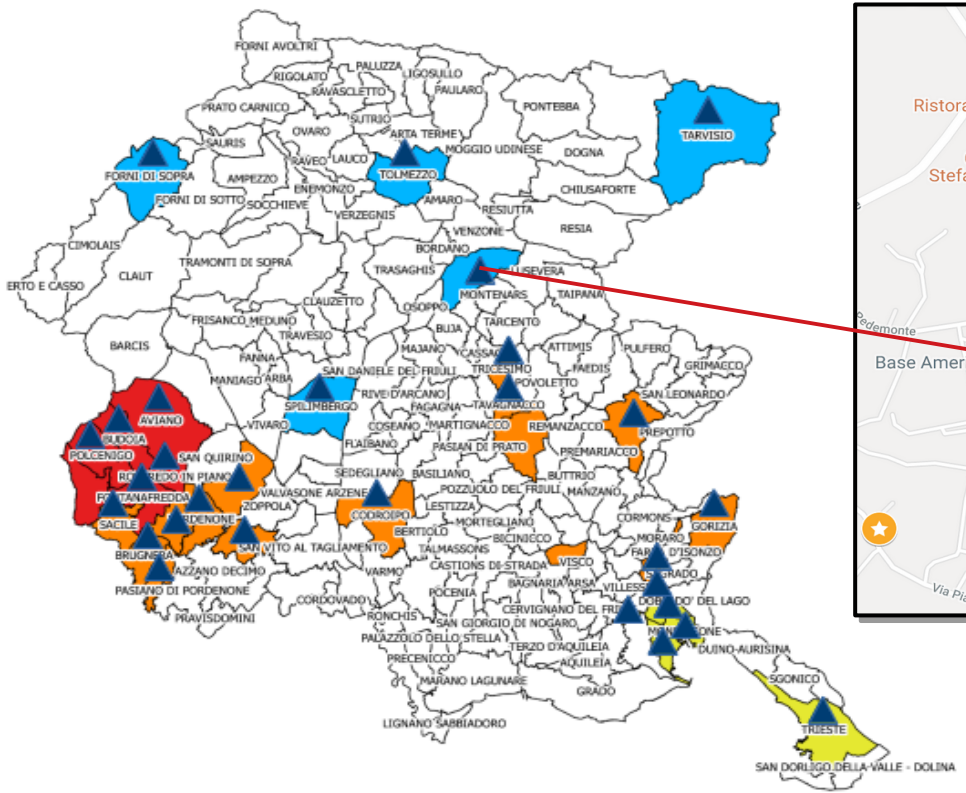


How are the fundamental period of these buildings identified?

Inspections, ambient vibration measurements, modeling (work in progress)

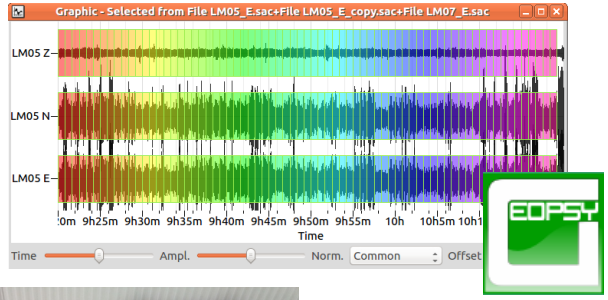
The Structural Monitoring Network

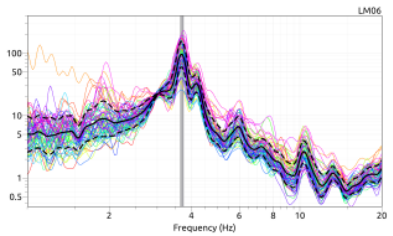
The monitoring network on buildings (Sentinella, Armonia) allows to refine the damage prediction, by integrating direct observations from a number of target building.

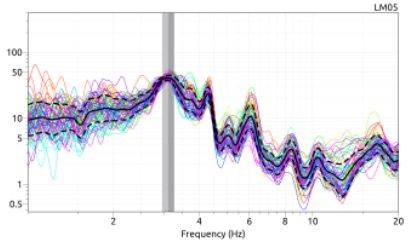


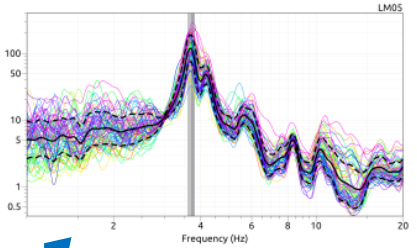
Work in progress: damage assessment of target area

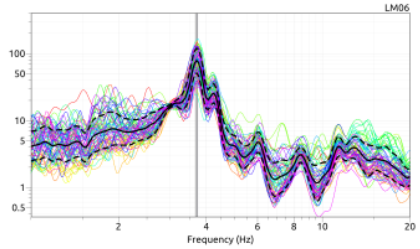
Characterization of Specific Buildings

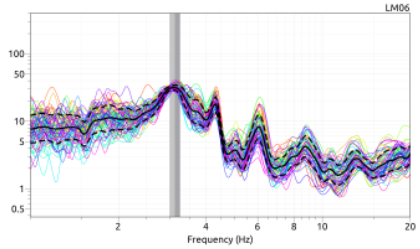


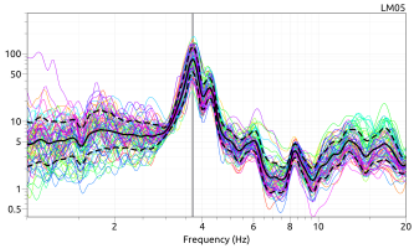












Spectral ratios to a reference station (on the basement)

Conclusions

The damage scenario calculator is already up and running. 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
- Extend study area to neighbor regions