Convegno "Tra Geologia e Geofisica 2017" | Workshop in Geofisica e Giornata di Studi

Il potere dei numeri piccoli:
prove di hazard durante una sequenza

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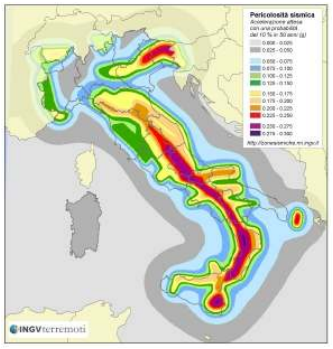
Aftershock hazard in Italia Centrale

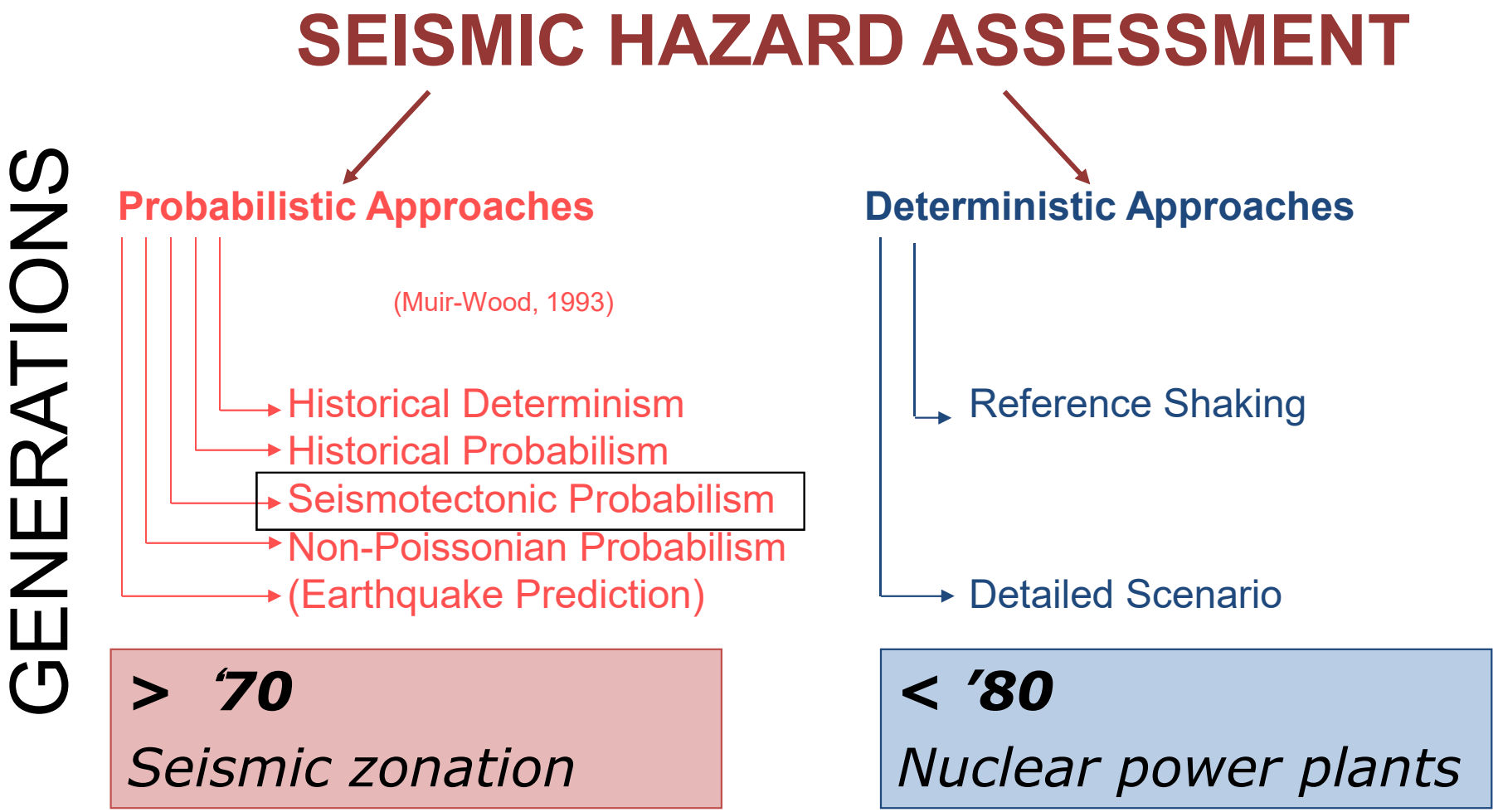
- Cos'è l'APSHA
- La sequenza sismica del 2016 in Italia Centrale
- Caratteristiche spazio-temporali del modello
- Curva di hazard da dati sperimentali
- Confronto modello-osservazioni
- Conclusioni

Seismic hazard is the intrinsic natural occurrence of earthquakes and the resulting ground motion

HAZARD ≠ RISK

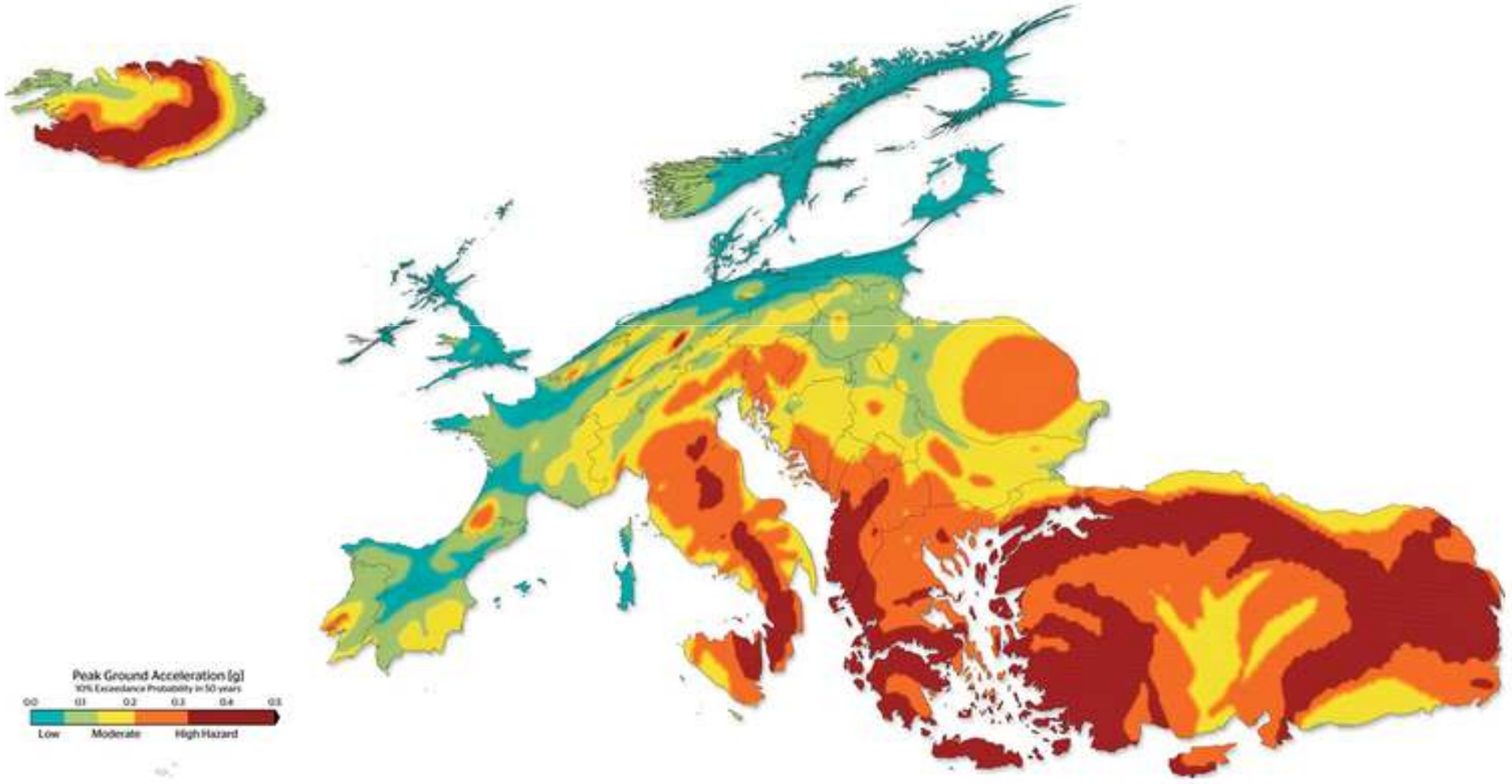


RISK = HAZARD*VULNERABILITY*VALUE


SEISMIC HAZARD ASSESSMENT
GENERATIONS
Probabilistic Approaches
(Muir-Wood, 1993)
Historical Determinism
Historical Probabilism
Seismotectonic Probabilism
Non-Poissonian Probabilism
(Earthquake Prediction)
Deterministic Approaches
Reference Shaking
Detailed Scenario
> '70
Seismic zonation
< '80
Nuclear power plants
Post 2000
Probabilism (Poissonian or time-dependent) applied to deterministic modelling of ground shaking

In Italy and Europa

Generation Seismotectonic Probabilism

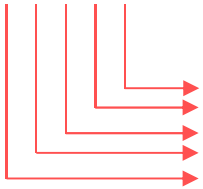


3rd Generation Seismotectonic Probabilism

- **Earthquakes are independent events and the process is stationary in time (Poisson)**

WIKIPEDIA

In the mathematical sciences, a stationary process is a **stochastic** process whose joint probability distribution does not change when shifted in time or space. As a result, parameters such as the mean and variance, if they exist, also do not change over time or position.



3rd Generation Seismotectonic Probabilism

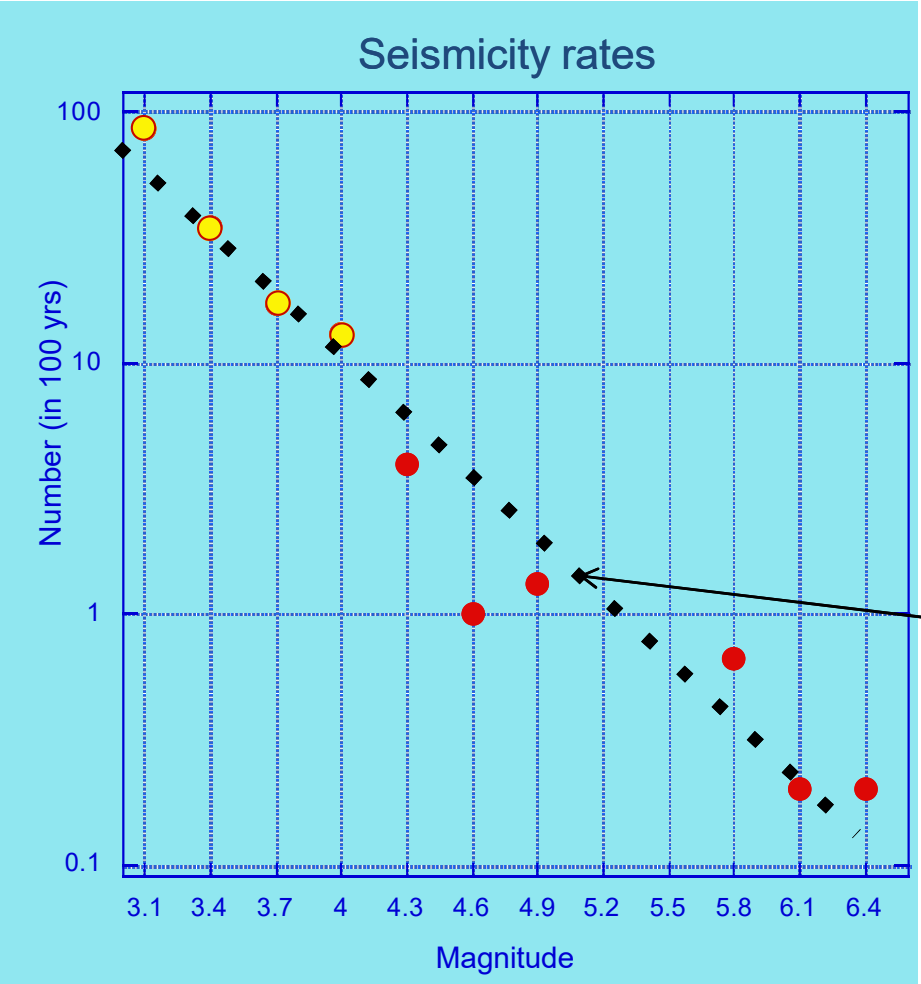
- **Earthquakes are independent events and the process is stationary in time (Poisson)**

Long term tectonic loading is taken into account
(average annual rate of earthquakes invariant in time)

Regulation purposes: seismic zoning has to be independent from the year of application
(unchanged after an earthquake occurrence)

“Dependent” events are filtered
(catalogue declustered for fore-aftershocks)

Ingredienti della pericolosità



1. La frequenza del terremoto e l'energia rilasciata alla sorgente
2. L'attenuazione dello scuotimento sismico con la distanza

Legge Gutenberg – Richter

logN=a-bM

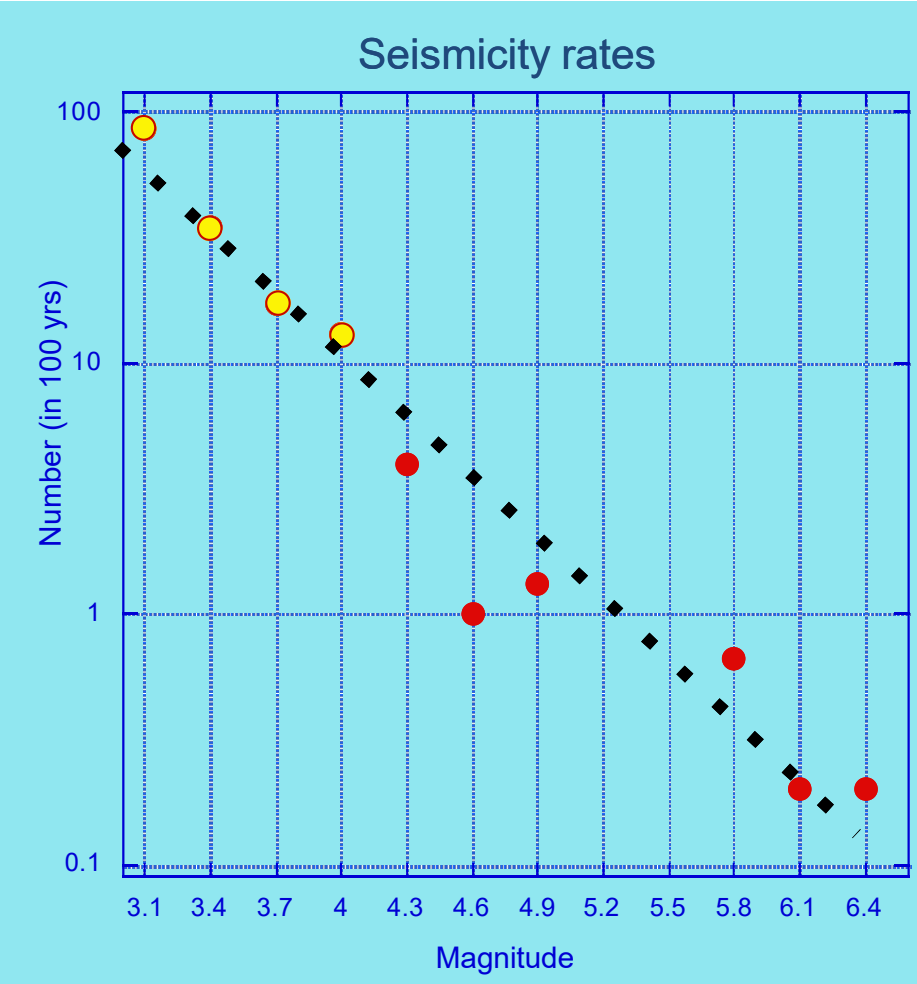
relazione fra il numero di eventi e la loro energia (magnitudo)

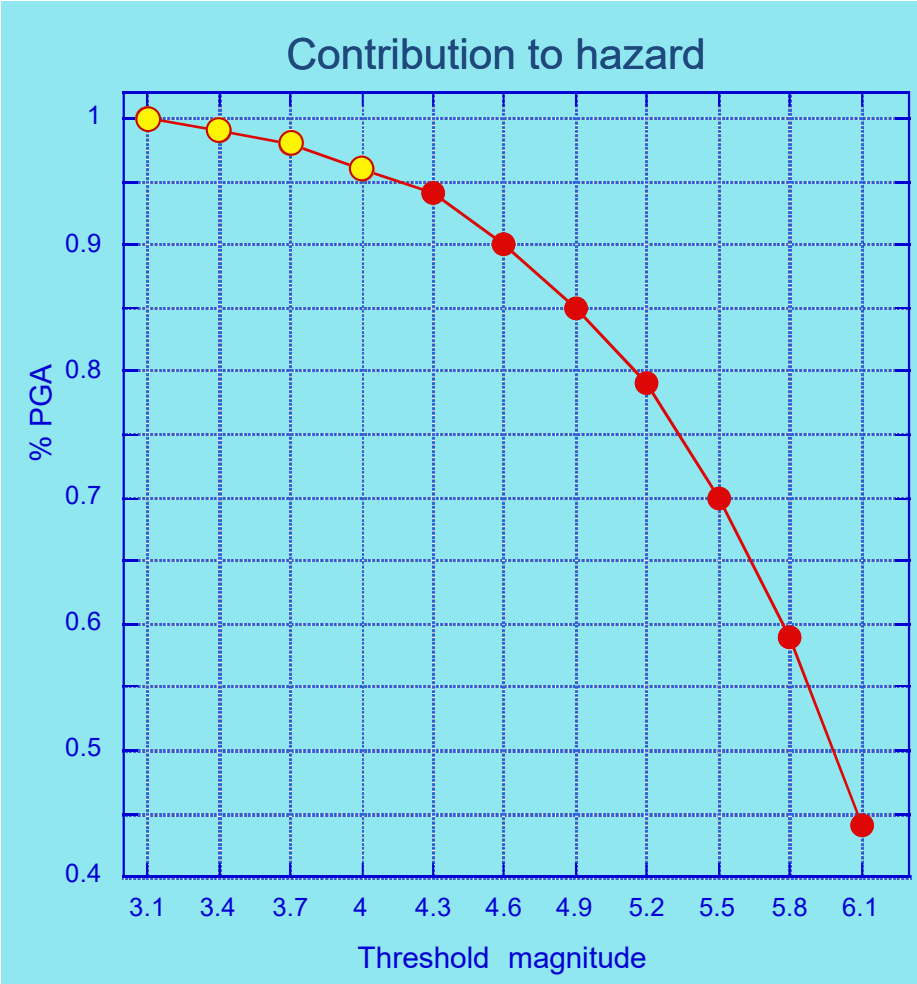
SEISMIC HAZARD ASSESSMENT

Probabilistic Approaches

Deterministic Approaches

Contribution to hazard from low magnitude seismicity





What's Aftershock PSHA (APSHA)

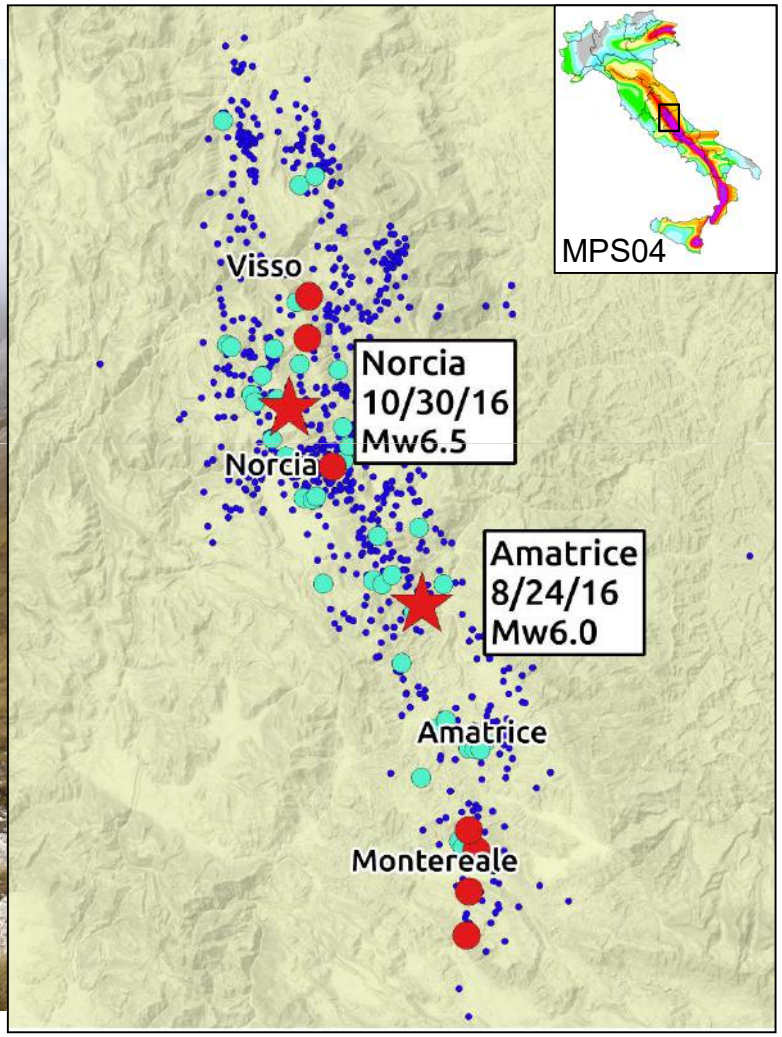
- APSHA (Gerstenberg et al., 2004; Yeo & Cornell, 2009; Iervolino et al., 2014) provides an estimate of the likelihood of exceeding an IM at a site due to aftershocks following a mainshock occurrence
- Main differences from classical 'mainshock' hazard :
  1. Earthquake occurrence rates **not stationary** in time
  2. Hazard dependent on the **location** of the mainshock

Our study:
performs APSHA to estimate the expected ground motion due to aftershocks for retrofitting/reconstruction planning in Central Italy
Fase 1: in the aftermath of the 24 Aug event, ANNALS OF GEOPHYSICS, 59, FAST TRACK 5, 2016; DOI: 10.4401/ag-7257
Fase 2: after the October events, some results presented here and at several conferences, paper in submission

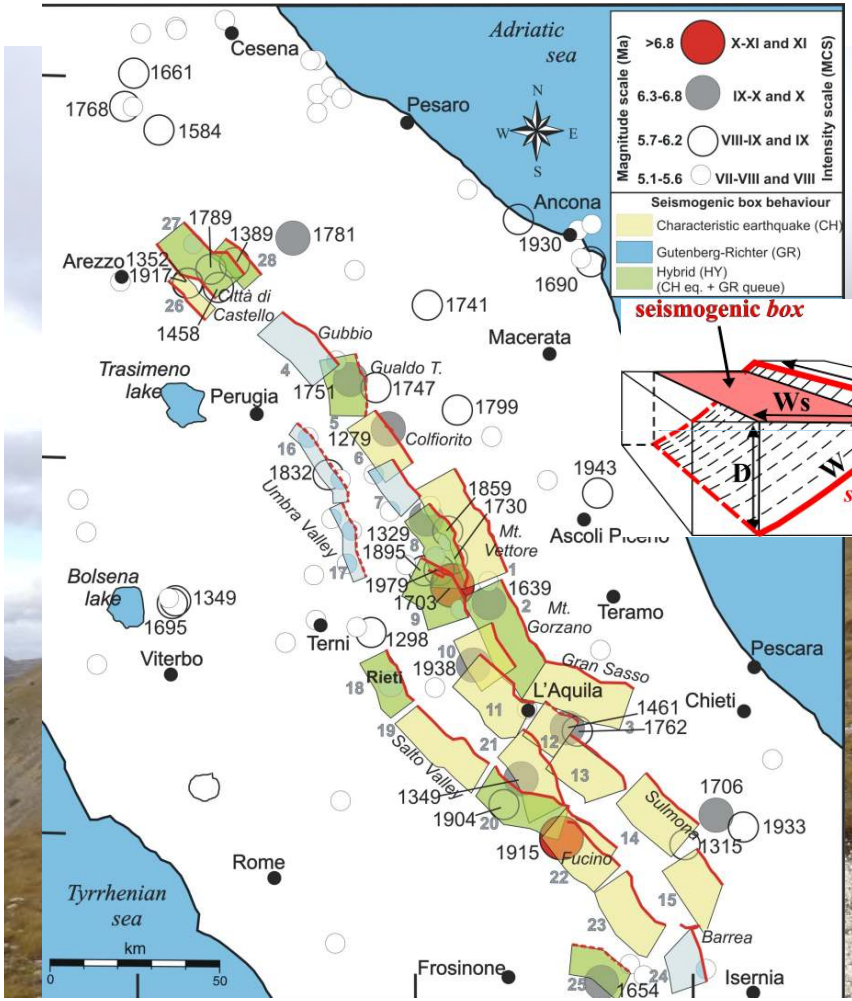
The 2016 Central Italy sequence

The 2016 Central Italy sequence

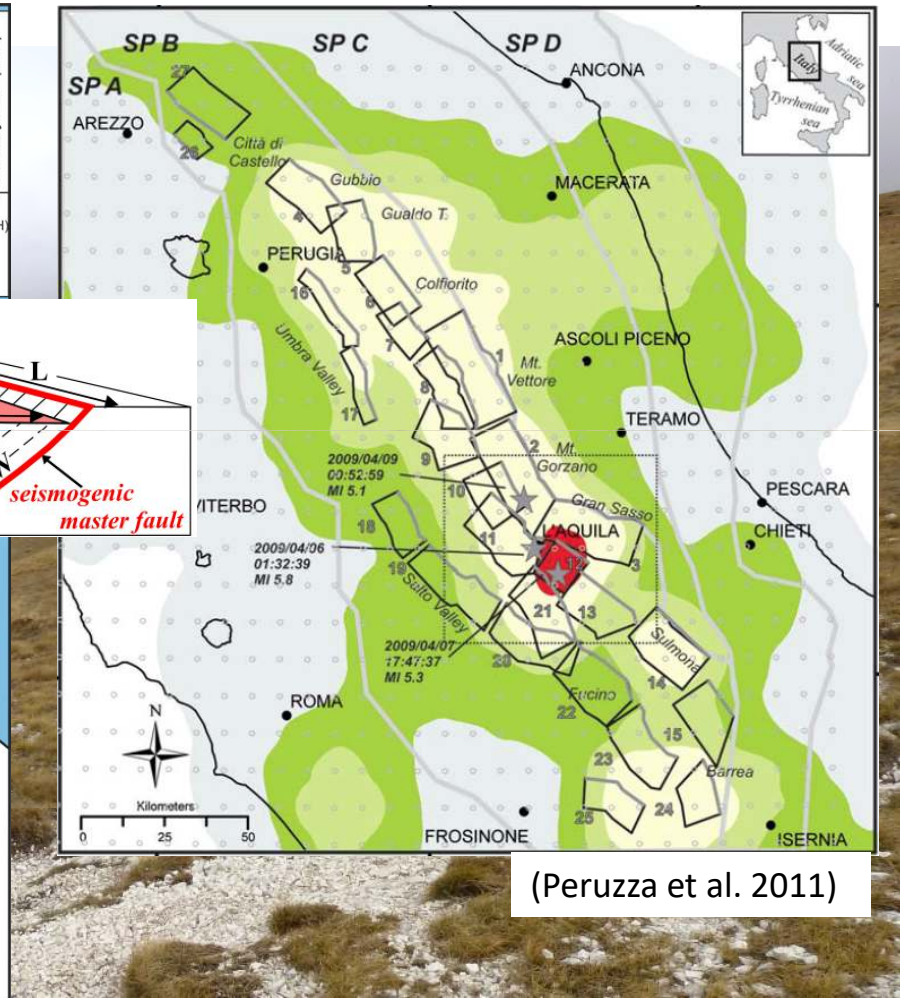
- Main events
  - M_w 6.0+/-0.2 (Amatrice, Aug 24)
  - M_w 5.9+/-0.2 (Visso, Oct 26)
  - M_w 6.5+/-0.1 (Norcia, Oct 30)
  - 300 fatalities (1st event)
- Apennines extensional region, high time-dependent probability assigned to some fault segments



Source model geometry

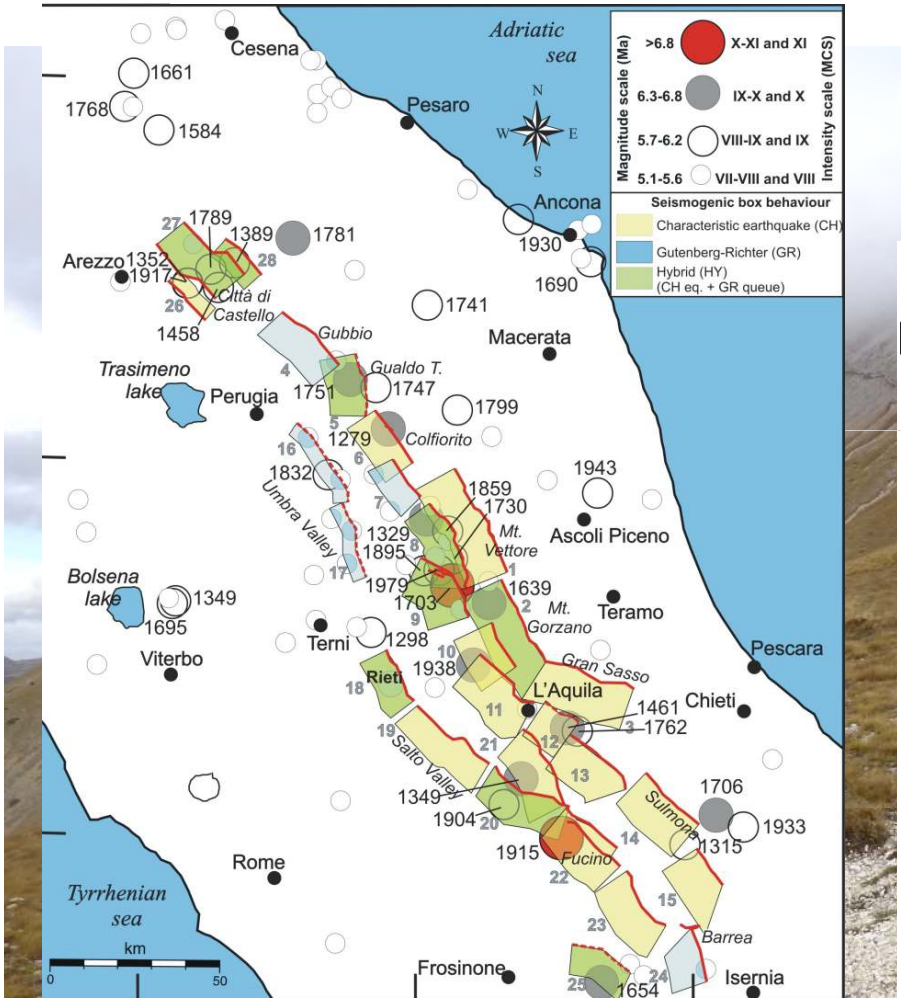


(Pace et al. 2006)

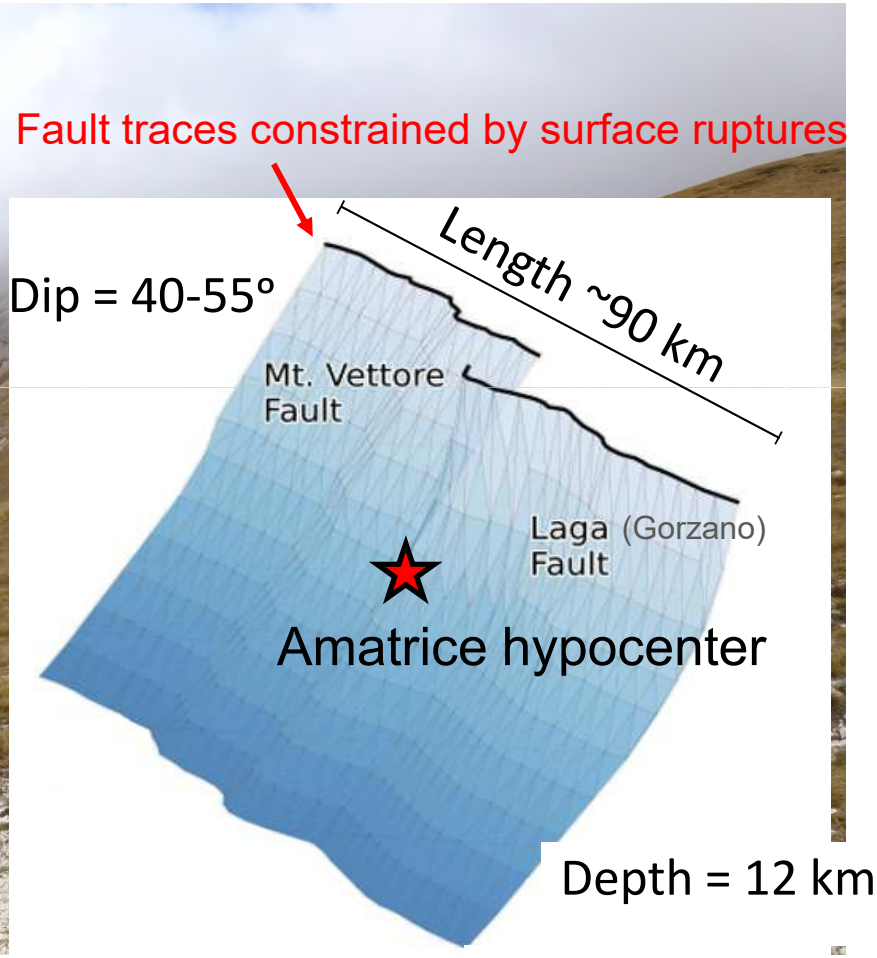


(Peruzza et al. 2011)

Newly hypothesized geometry of a connection at depth of fault segments, well-known before the 2009 L'Aquila earthquake

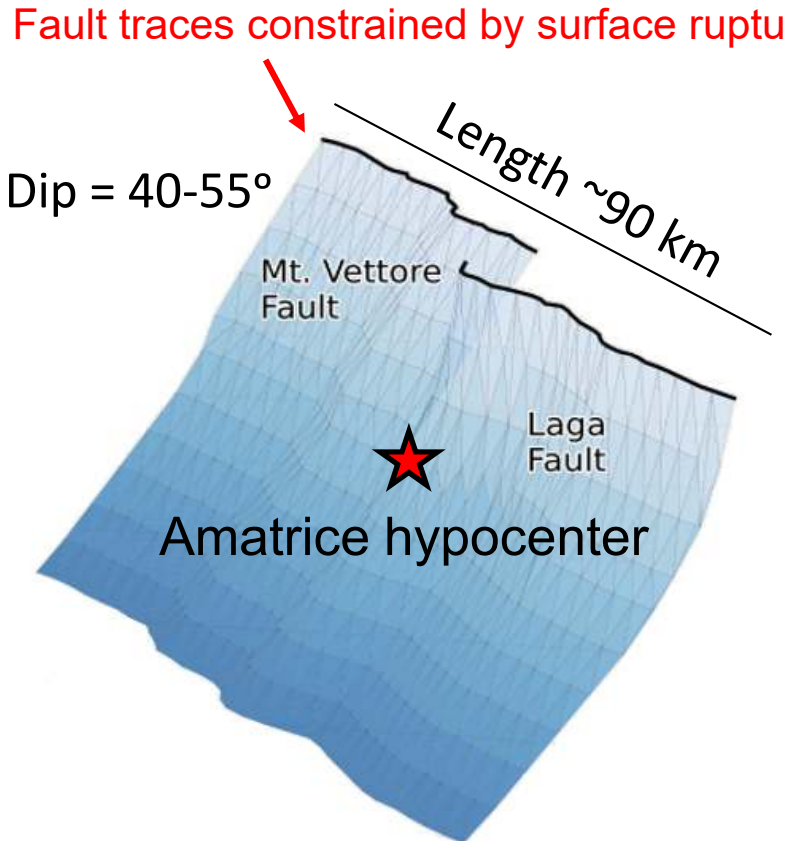


(Pace et al. 2006)



(Peruzza et al. 2016)

Source Model - Geometry

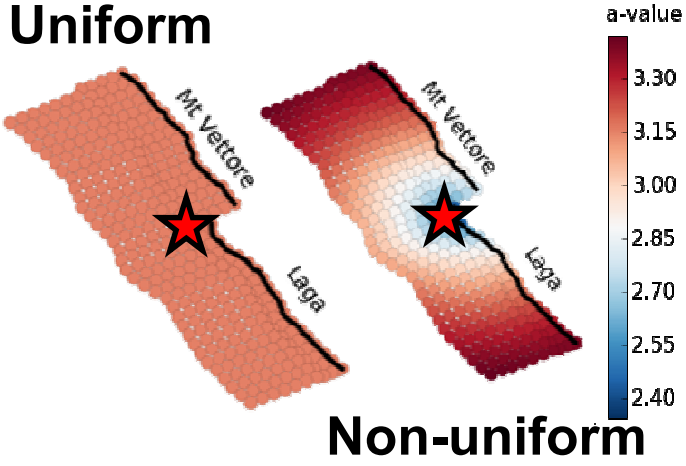


(Peruzza et al. 2016)

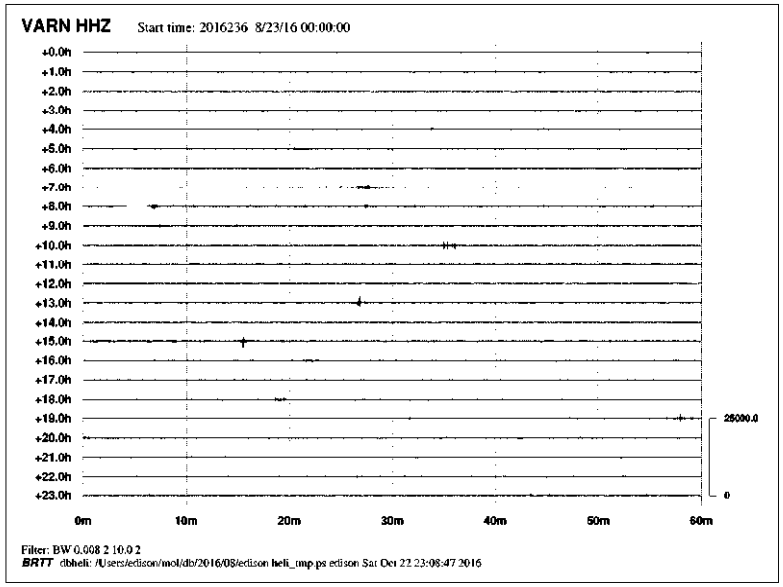
Seismicity Partitioning

Consider 2 cases:

1. Uniform across fault
2. Non-Uniform [F(Rhyp)]



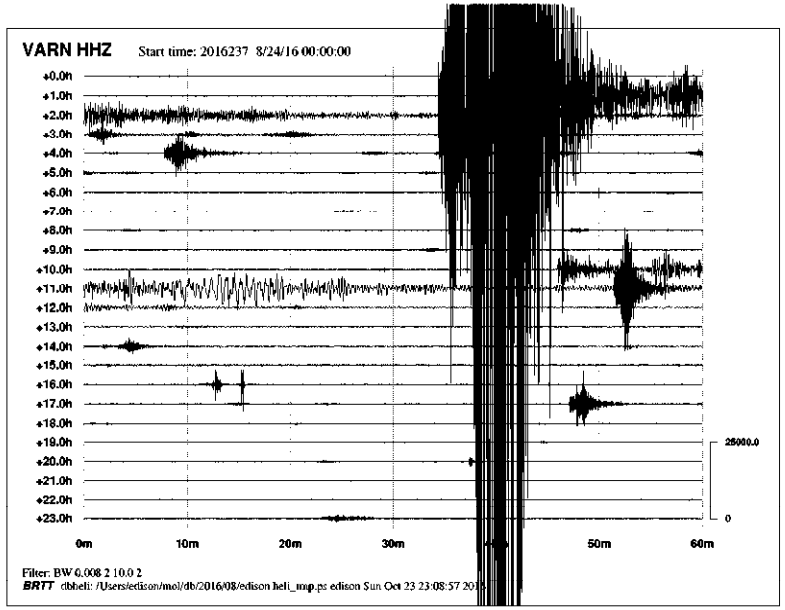
(400 point sources, $\dot{M}_o$ conserved)



23 Ago

Drumplots VARN (>500 km)

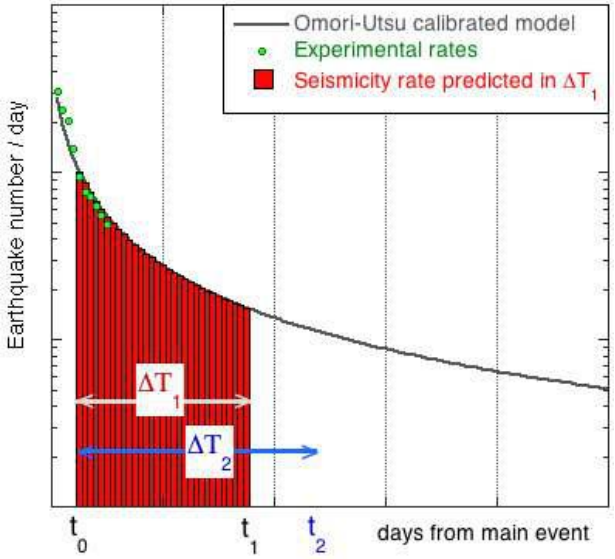
24 Ago



1) I terremoti **non sono stazionari** nel tempo

Dopo un evento significativo, il numero dei terremoti diminuisce nel tempo, seguendo una legge esponenziale nota come legge di Omori-Utsu:

$$n(t)=K/(t+c)^{p}$$



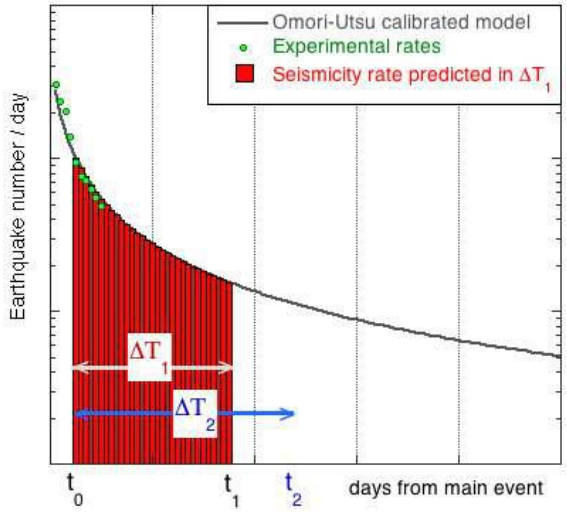
Source Model - Seismicity

Magnitude-Frequency Distribution

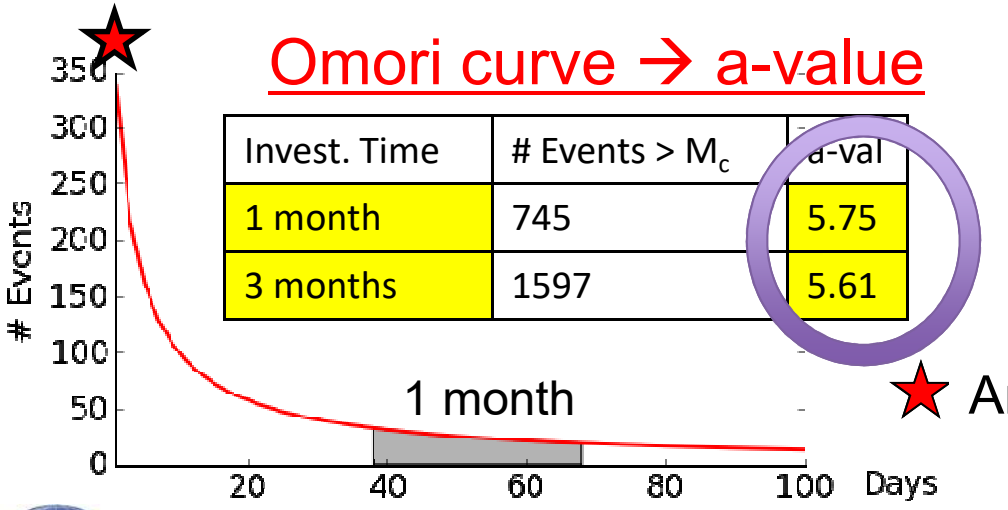
Gutenberg-Richter:

- **a-value =** calibrated Omori curve*
- **b-value =** regional
- $\mathbf{M_{min}}$ = 3.5
- $\mathbf{M_{max}}$ = M_{main} - 0.5

*first 20 days, INGV Seismic Bulletin



a-value referred to unit time (annual) decreases as a consequence of the O-U power law

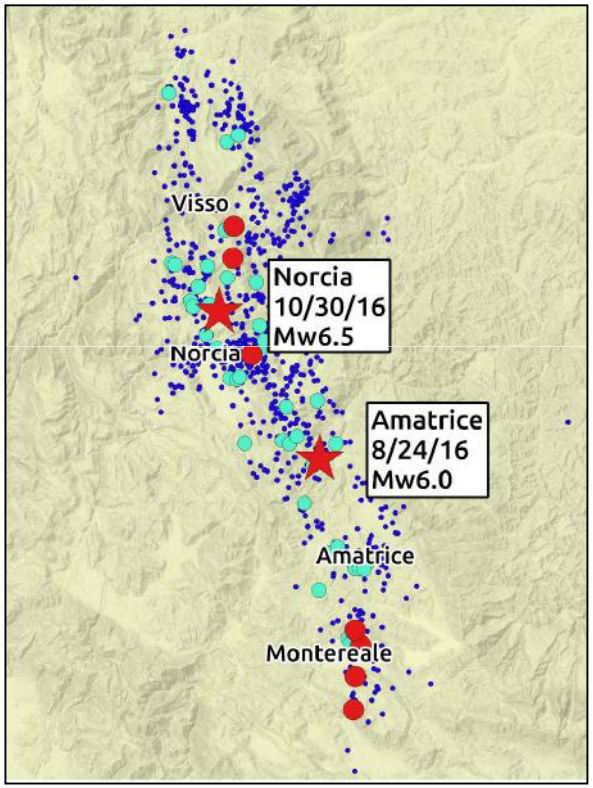


Invest. Time	# Events > M_c	a-val
1 month	745	5.75
3 months	1597	5.61

★ Amatrice mainshock

* INGV Seismic Bulletin : http://cnt.rm.ingv.it/en/bsi

Evolution of the sequence

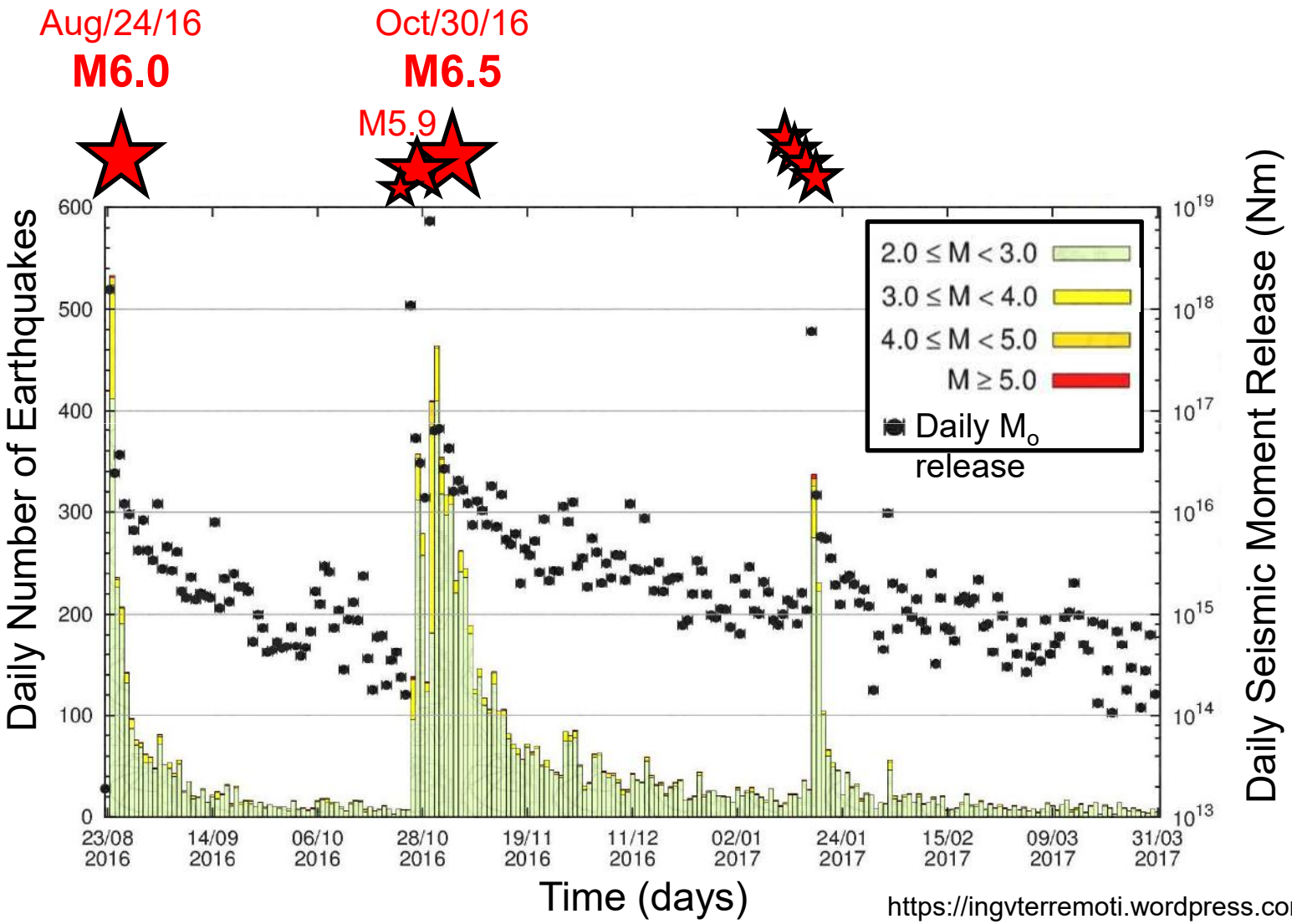


- October: M5.9 (Visso) and M6.5 (Norcia) ruptured Mt Vettore fault (same fault)

No forecast model explains the new main ruptures

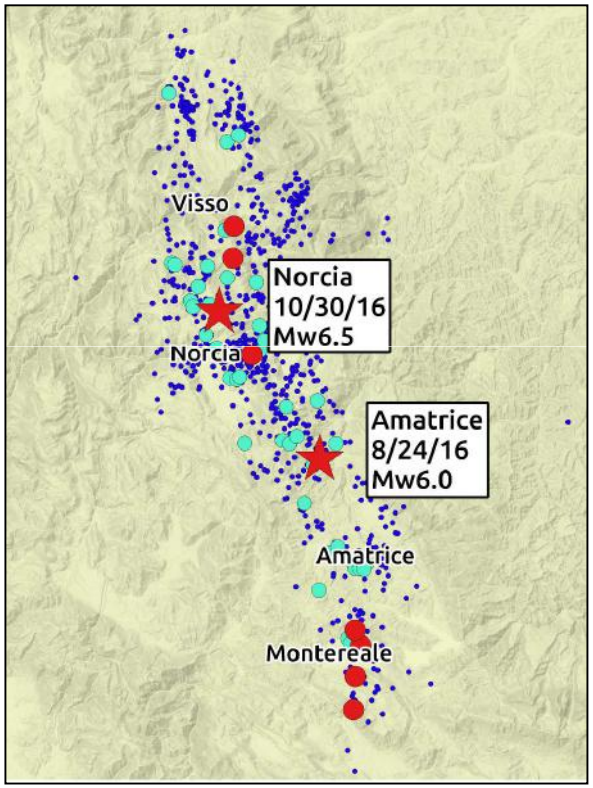

Picture from Lucilla Benedetti@CEREGE

Central Italy Sequence

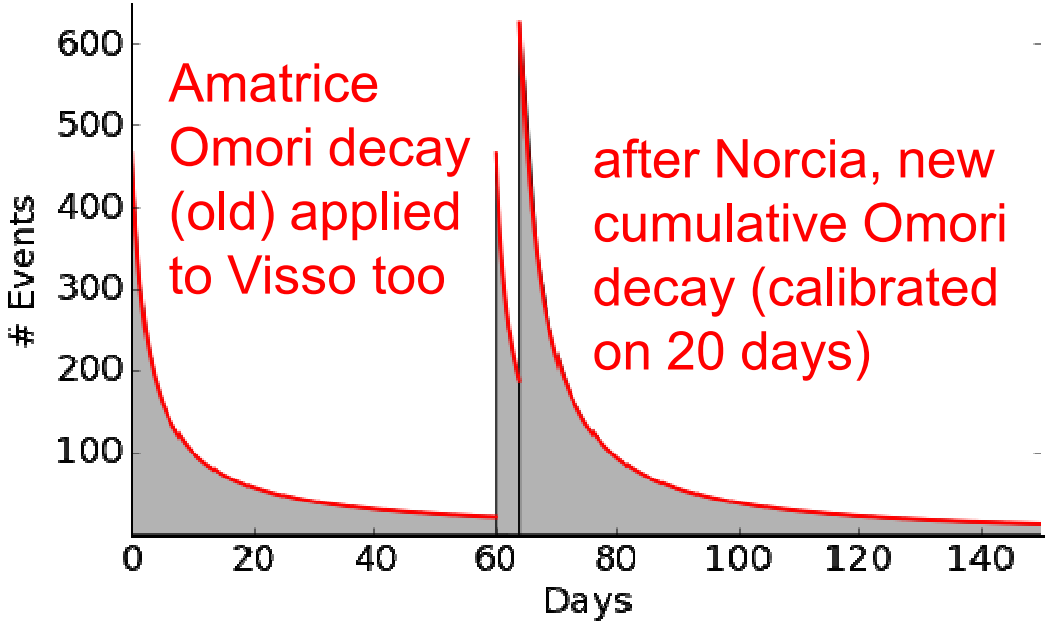


https://ingvterremoti.wordpress.com/

Evolution of the sequence



- October: M5.9 (Visso) and M6.5 (Norcia) ruptures aprox on the same fault model
- Update Omori decay curves after Oct 30
- Only uniform partitioning considered



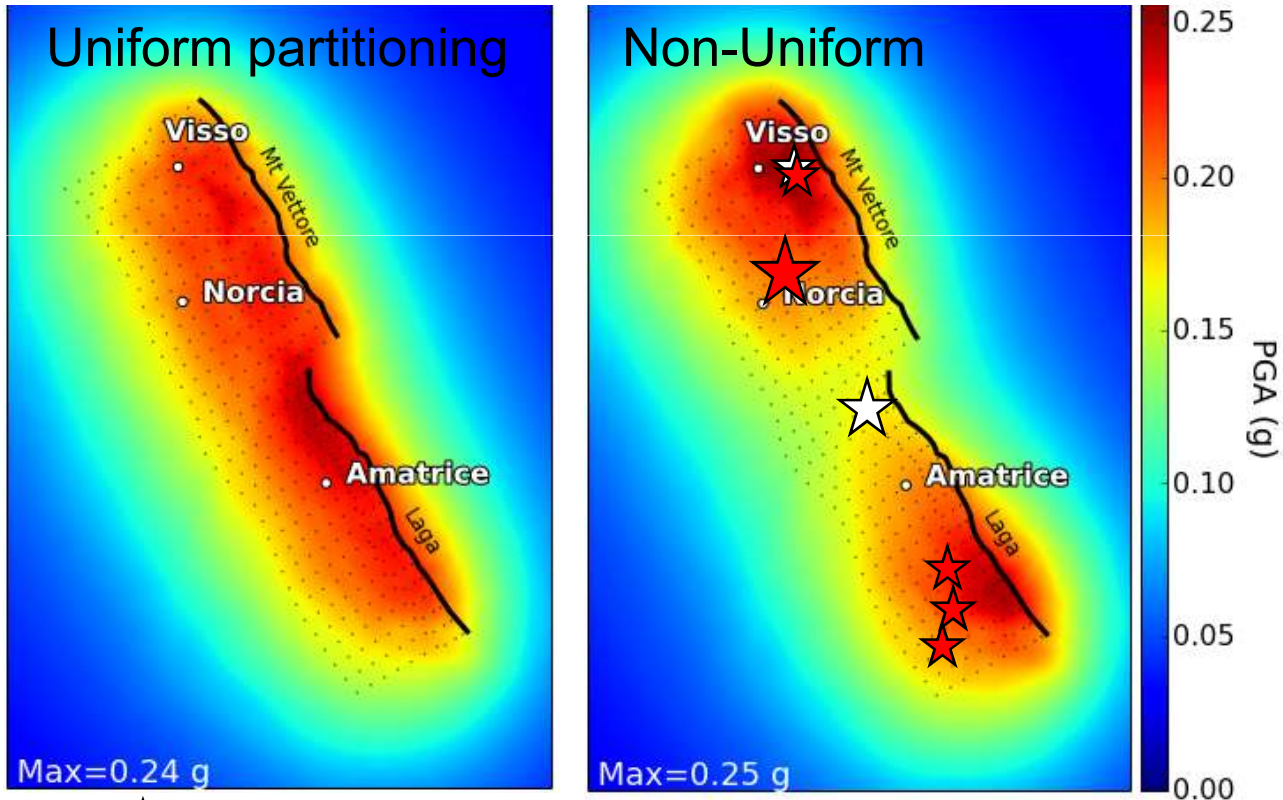
First APSHA Results

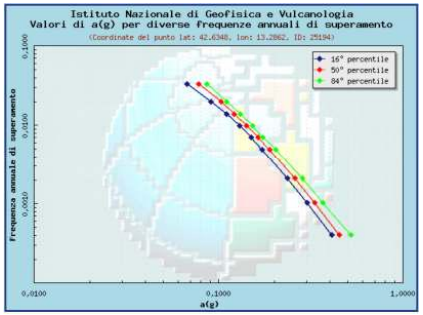
GMPE = CY14
Vs30 = 800m/s
Mmin = 3.5

- Expected ground shaking due to Amatrice aftershocks

Hazard Maps: 10% PoE, T= 1 year (a=5.75)

Peruzza et al., Annals, 2016





MPS04
10% in 50 y
0.26 g

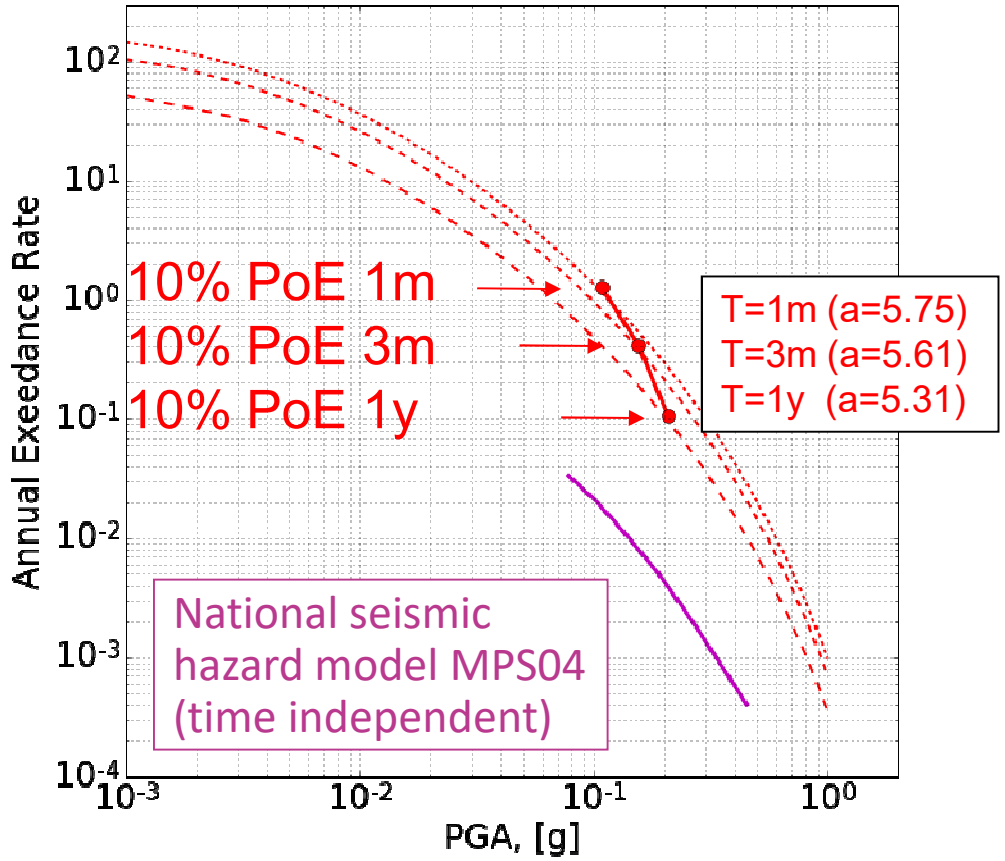
☆ Amatrice mainshock

First APSHA Results

GMPE = CY14
Vs30 = 800m/s
Mmin = 3.5

- Expected ground shaking due to Amatrice aftershocks

Hazard Curves for town of Amatrice



Peruzza et al., Annals, 2016

L'hazard relativo alle sole repliche della sequenza di Amatrice è molto superiore ai valori di riferimento della normativa

APSHA,
per le opere provvisionali o la ricostruzione?

Pericolosità dopo un forte terremoto

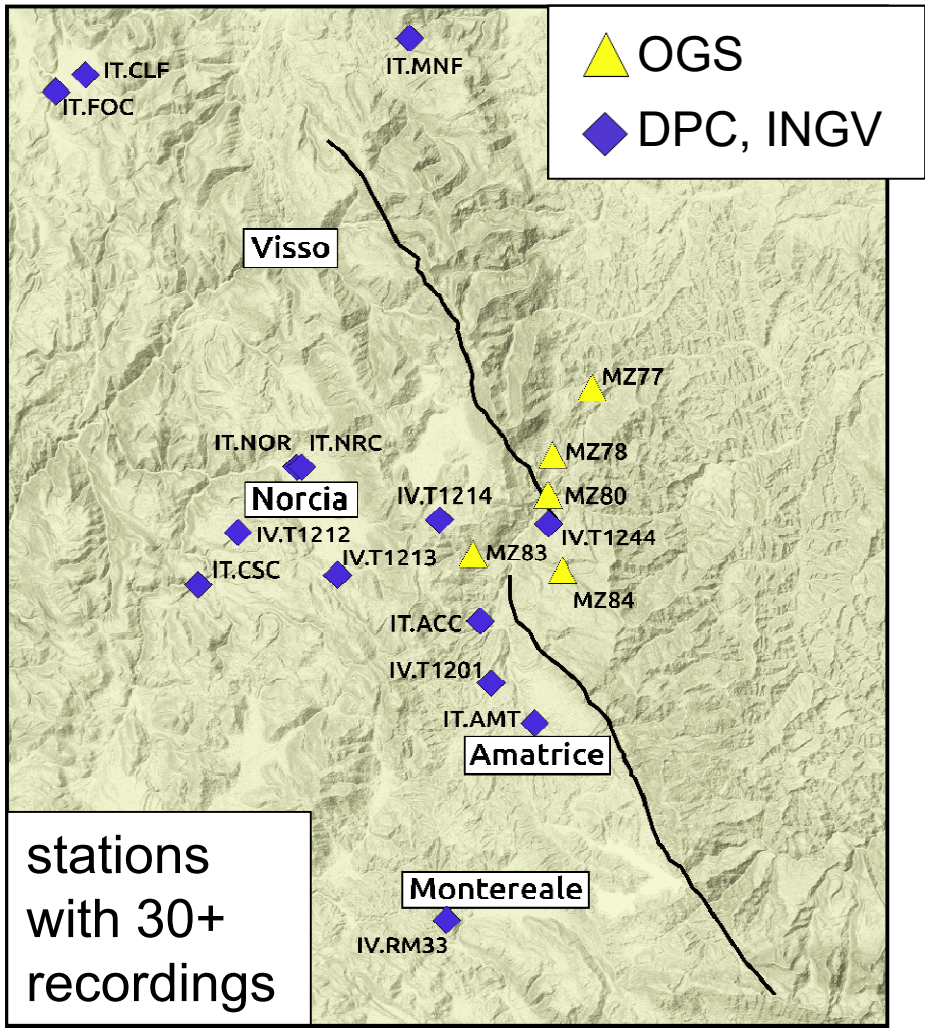
Diverse scuole di pensiero

Extraordinary capabilities of recordings

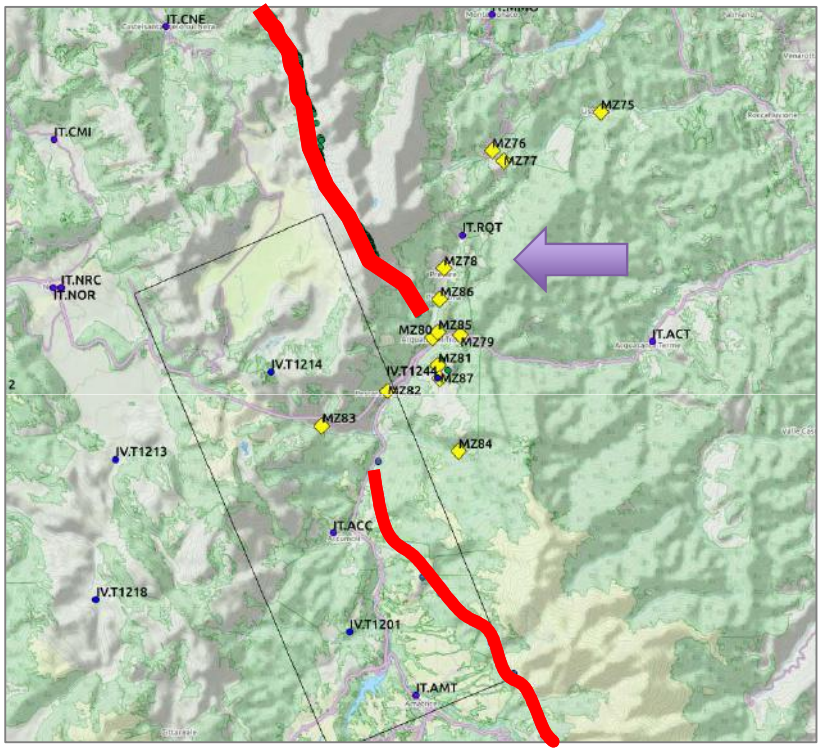
- Networks
  - DPC Permanent accelerometric
  - INGV Permanent and temporary (Accelerometric,Velocimetric)
  - OGS - Temporary (microzonation)
  - others

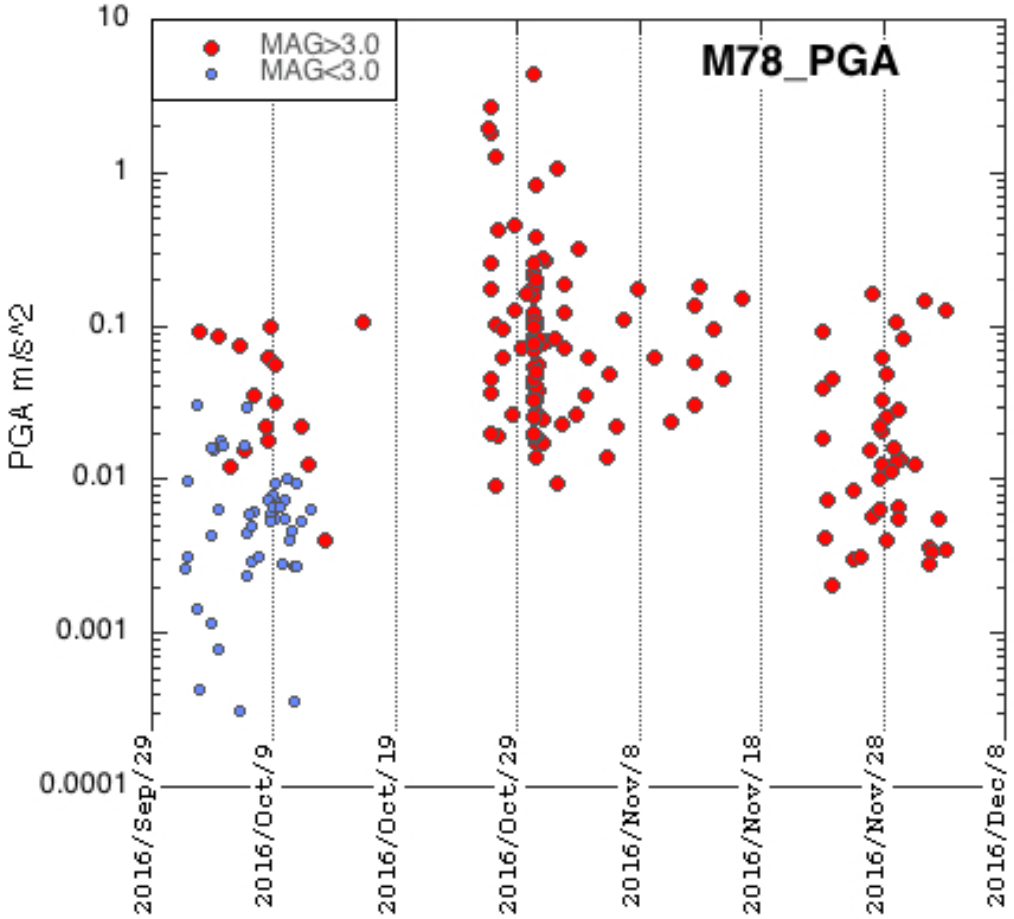
- Between Aug 24 2016 – Jan 31 2017
  - 20 stations in study area (right) with 30+ recordings

- Maximum PGA
  - Amatrice earthquake: **0.87g** (IT.AMT)
  - Norcia earthquake: **1.1g** (MZ83)



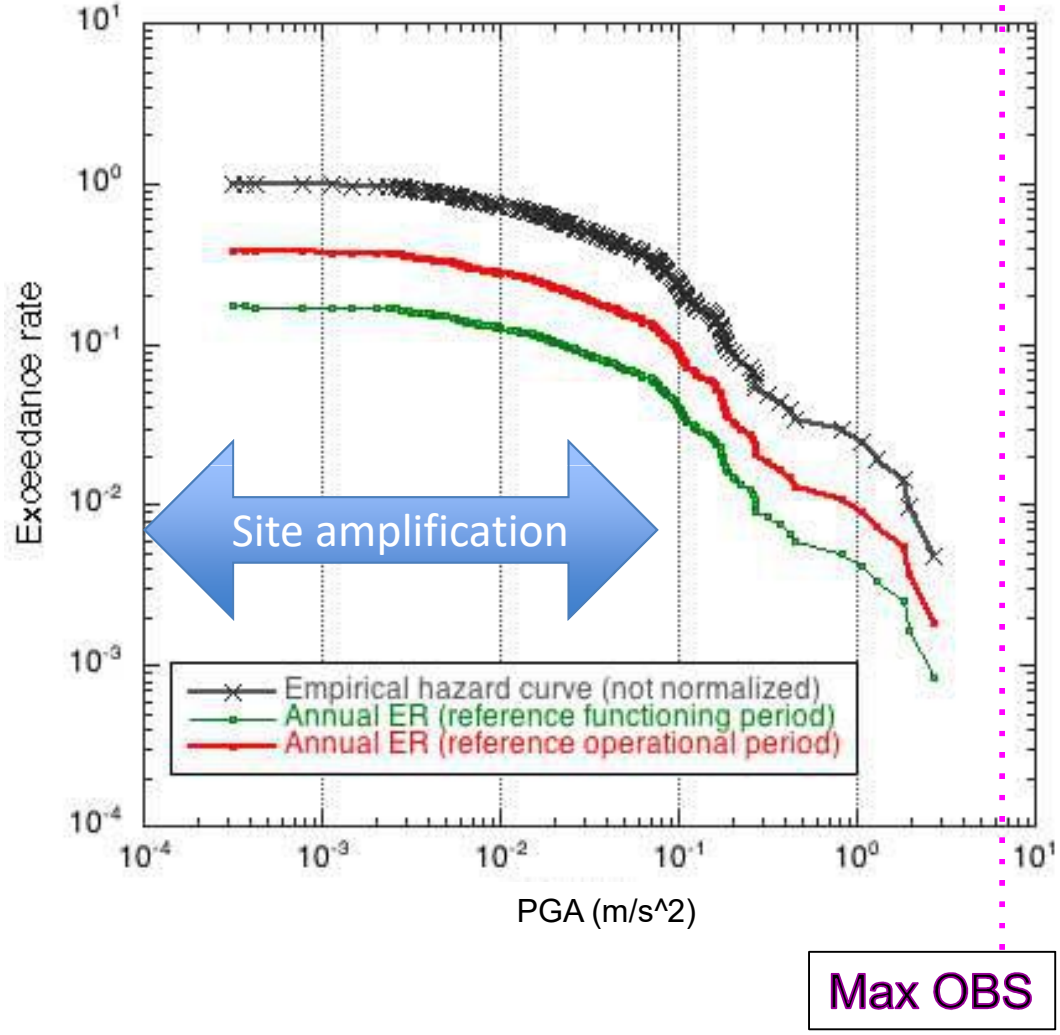
Osservazioni a Pretare





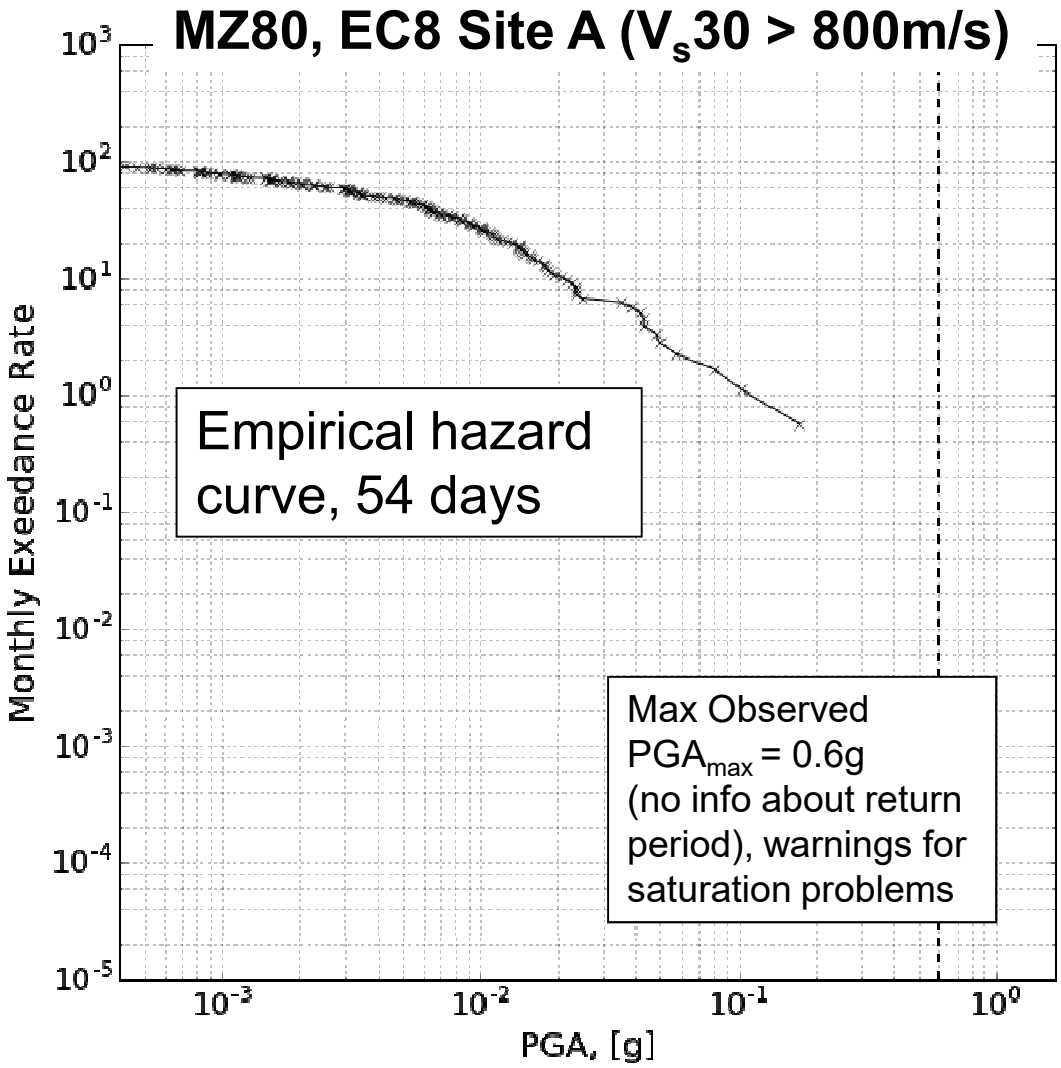
Empirical hazard curve

- Observed ground motion for constructing empirical hazard curve
- Exced rate = Nexc(IM)/T_{obs}
- Nexc(Max PGA) = 0



Empirical hazard curve

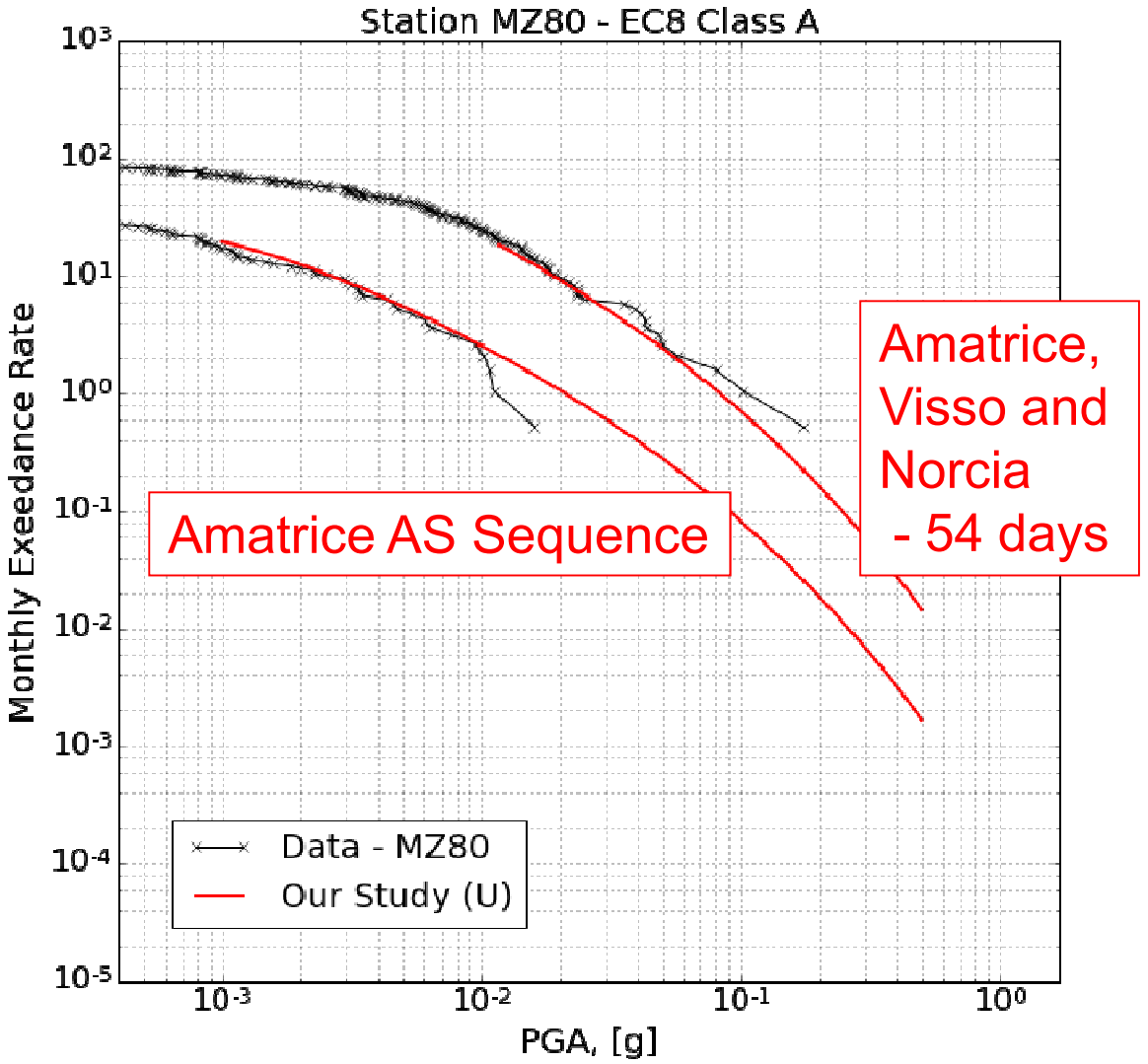
- Observed ground motion
- Example: Station MZ80
  - On: Sept 30, 2016
  - Off: Nov 23, 2016 (54 days)
  - 180 recordings (M>3.5)



Observed versus predicted

Great care in handling coherently

- observation/forecast time windows
- Mmin
- uncomplete series of observations
- sites affected by local site effects



GMPE = CY14
Vs30 = 800m/s
Mmin = 3.5

Take home message 1

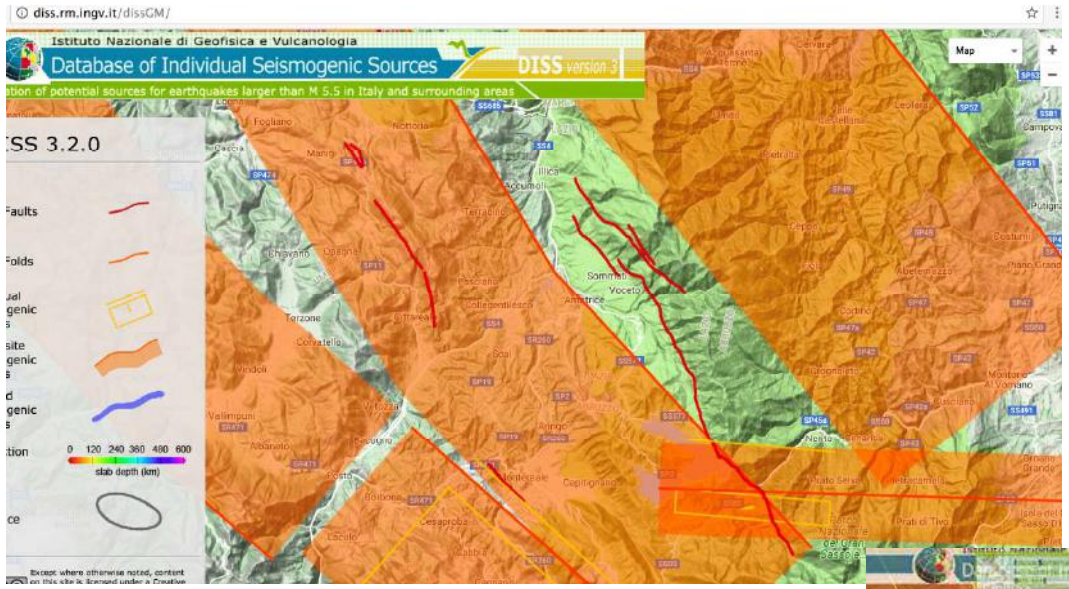
- Abbiamo realizzato un prototipo di Aftershock PSHA nell'immediato post-evento (Amatrice,M~ 6, 24 Agosto). Il modello consiste in un piano di faglia complesso, ricavato da dati preesistenti, su cui vengono distribuite le repliche; il decadimento della sismicità nel tempo segue un semplice modello O-U, calibrato nei primi giorni successivi alla sequenza
- Dopo i "main events" di ottobre i tassi di sismicità sono stati aggiornati, tramite la sommatoria di più curve di decadimento; le altre componenti del modello invariate
- Aftershock hazard è confrontato con curve di hazard sperimentale ad alcune stazioni acc/vel; l'accordo modello-osservazioni è molto buono

Take home message 2

A causa dell'elevato tasso di eventi piccoli e vicini, nell'area epicentrale della sequenza del 2016, la PGA attesa al 10% di non superamento nell' **anno successivo** ad un singolo evento di M~6 **è simile** ai valori di PGA attesi dalla normativa (MPS04) in **50 anni** (~.20g)
E' opportuno questi valori vengano considerati anche per le opere provvisorie/ricostruzione in aree meno sismiche del paese

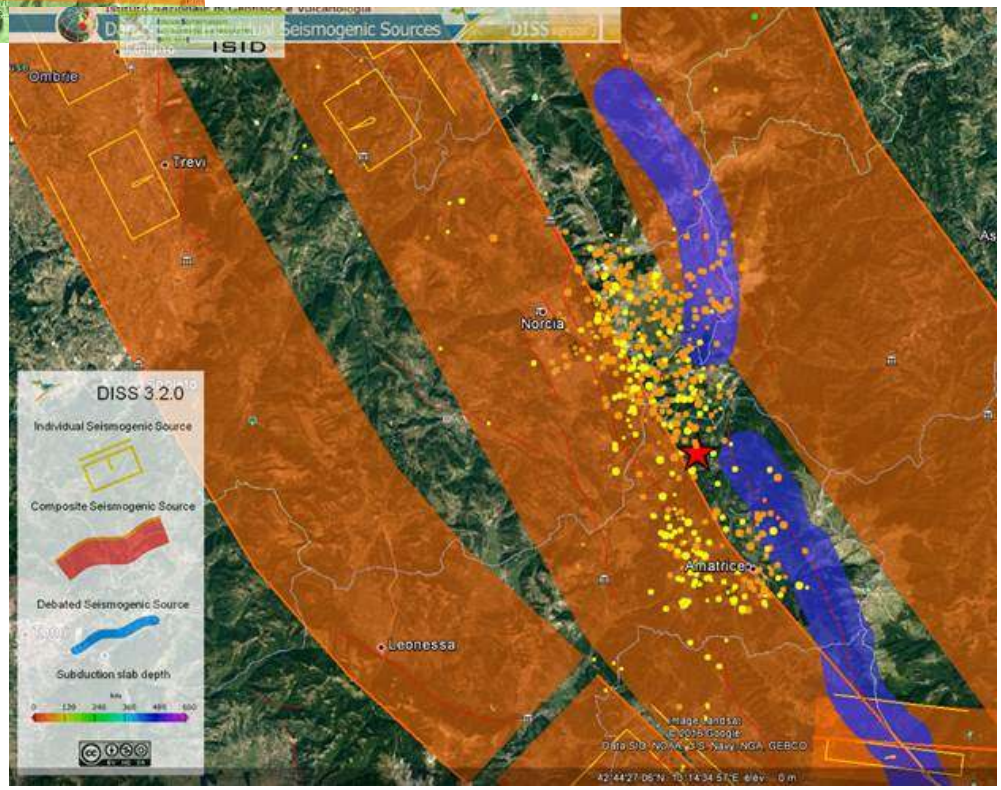
Take home message 3

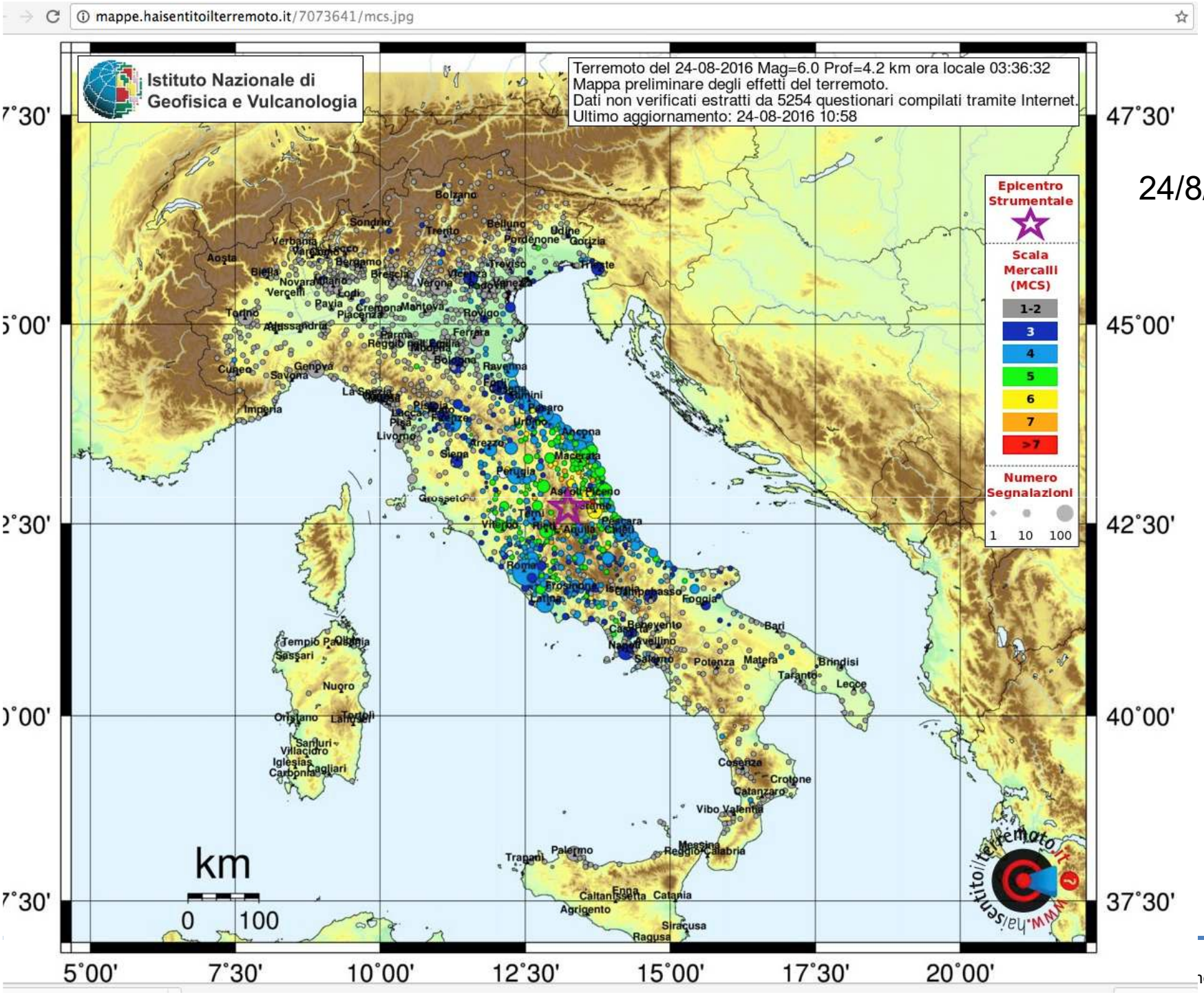
La normativa sismica in Italia è finalizzata a prevenire il collasso degli edifici, non il danno strutturale.
Un terremoto di M6 è ammessibile in qualunque punto del territorio nazionale.
Non è forse giunto il tempo di ripensare il livello di protezione antisismica da adottare, nella ricostruzione post-evento?



24/8/2016

26/8/2016




mappe.haisentitoilterremoto.it/7073641/mcs.jpg
Istituto Nazionale di Geofisica e Vulcanologia
Terremoto del 24-08-2016 Mag=6.0 Prof=4.2 km ora locale 03:36:32
Mappa preliminare degli effetti del terremoto.
Dati non verificati estratti da 5254 questionari compilati tramite Internet.
Ultimo aggiornamento: 24-08-2016 10:58
Epicentro Strumentale
Scala Mercalli (MCS)
1-2
3
4
5
6
7
>7
Numero Segnalazioni
1 10 100
km
0 100
47°30'
45°00'
42°30'
40°00'
37°30'
5°00'
7°30'
10°00'
12°30'
15°00'
17°30'
20°00'

24/8/2016