

On the attenuation of seismic waveforms: correlations between Macroseismic Intensity and Instrumental Ground-Motion Parameters

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Ground Motion Measures

Qualitative

- * Macroseismic Intensity
 - * Empirical classification of the earthquake intensity by **ordinales scales**
 - * Intensity Data Points (IDPs) are typically measures of non-numeric concepts like moderate, damaging, catastrophic, ecc

Observational seismology

Quantitative

- Amplitude Parameters
 - Time history
- Frequency Content Parameters
 - Fourier Spectra
 - Response Spectra
- Duration

Instrumental seismology

Macroseismic Intensity

Mallet's Investigation of the 1857 Neapolitan Earthquake

179
Cat
J. C. Aranne
21/11/1857
GREAT NEAPOLITAN EARTHQUAKE OF 1857.

THE FIRST PRINCIPLES

OF

OBSERVATIONAL SEISMOLOGY

AS DEVELOPED IN THE

REPORT TO THE ROYAL SOCIETY OF LONDON
OF THE EXPEDITION MADE BY COMMAND OF THE SOCIETY INTO
THE INTERIOR OF THE KINGDOM OF NAPLES,

TO INVESTIGATE THE CIRCUMSTANCES OF THE GREAT
EARTHQUAKE OF DECEMBER 1857.

BY

ROBERT MALLET, C.E., F.R.S., F.G.S., M.R.L.A.,
&c., &c.

"Non fignatum aut exogitatum sed invenitulum quid natura sciat aut first."

PUBLISHED BY THE AUTHORITY AND WITH THE AID OF THE
ROYAL SOCIETY OF LONDON.

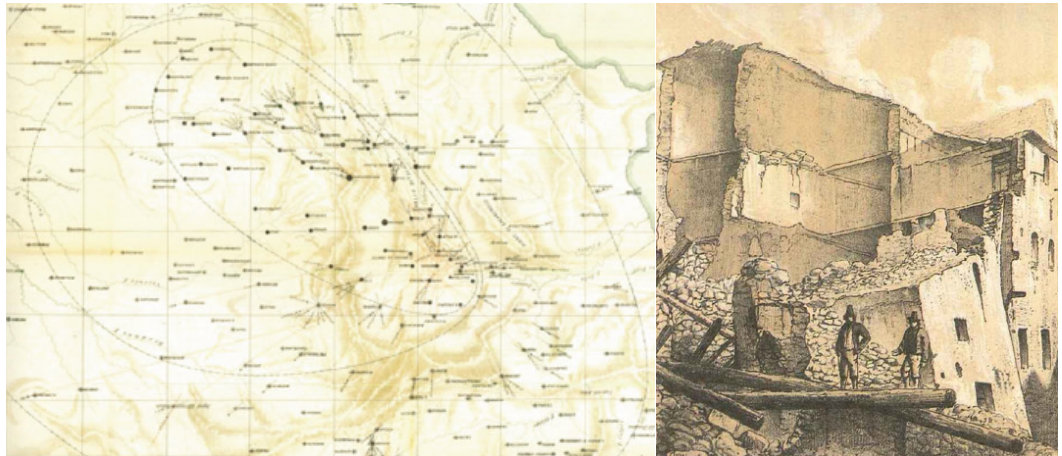
IN TWO VOLUMES.—VOL. II.

CHAPMAN AND HALL, LONDON.
1862.

[The Right of Translation is reserved.]

st

“An earthquake consists in the transmission through the solid crust of the earth of a wave of elastic compression”



..... first principles of observational seismology

Macroseismic Intensity

Database of historical seismology and macroseismic data

Sismologia storica e macrosismica

- Catalogo parametrico dei terremoti italiani dal 1000 al 2006 | **CPTI11 (2011)**
- Database macrosismico italiano dal 1000 al 2006 | **DBMI11 (2011)**
- Catalogo dei forti terremoti dal 461 a.C. al 1997 | **CFTI - Med 4.0** |
- Catalogo macrosismico dei terremoti etnei dal 1832 al 2013 | **MacroEtna**
- Massime intensità macrosismiche osservate nei comuni italiani | **GNDT-ING-SSN (1996)**
- SHARE European Earthquake Catalogue dal 1000 al 1899 | **SHEEC (2012)**
- European Archive of Historical Earthquakes dal 1000 al 1899 | **AHEAD (2013)**
- Database delle intensità macrosismiche derivate da questionari on-line dal 2007 ad oggi | **haisentitoilterremoto**



Instrumental Ground Motion Parameters



Istituto Nazionale
di Geofisica
e Vulcanologia



version 2.0

News

- **January 2015:** ITACA processing web frontend has been published. Link is available in the "Tools" section below.
- **February 2014:** The version 2.0 of Itaca has been released. [Main updates](#)
- **Last earthquake:** January 2014.
- **ITACA** as national layer of [EPOS](#).

Itaca info

- [Papers related to ITACA](#)
- [User manual](#)
- [Disclaimer](#)
- [Contacts](#)
- [Credits](#)
- [Glossary](#)

Links

- [Strong Motion Databases](#)
- [Strong motion networks in Italy](#)

Tools

- **Processing web frontend:** a web interface to process ITACA waveforms and download the results.
- **dyna-convert.py:** python code to convert ITACA 2.0 files to the most popular seismic formats (mseed, sac, ...). Requires [ObsPy](#).

ITACA (ITalian ACcelerometric Archive) version 2.0

ITACA 2.0 contains about 7500 processed three-component waveforms generated by about 1200 earthquakes with magnitude greater than 3.

Most of the data have been recorded by the Italian Strong-motion Network ([RAN](#)), operated by the Italian Civil Protection Department - Presidency of the Council of Ministers ([DPC](#)) and by the National Seismic Network, operated by Istituto Nazionale di Geofisica e Vulcanologia ([INGV](#)).

Processed time-series and response spectra and unprocessed time-series are available from the download pages, where the parameters of interest can be set and specific events, stations, waveforms and their metadata can be retrieved.

ITACA 2.0 has been compiled, under the coordination of INGV Milano, in the framework of the agreement between INGV and DPC and the EU Project [EPOS](#).



Data search

Waveforms

Stations

Events

Records compatible with target spectra

REXELite

<http://itaca.mi.ingv.it>

Ground Motion Attenuation

- ❑ The attenuation of the ground-motion parameters plays a key role in the evaluation of expected ground shaking levels
- ❑ The implementation of data processing tools and accelerometric archives allowed the calibration of Ground Motion Prediction Equations based on physical quantities (PGA, PGV, PSA,...)

Ground Motion Prediction Equations

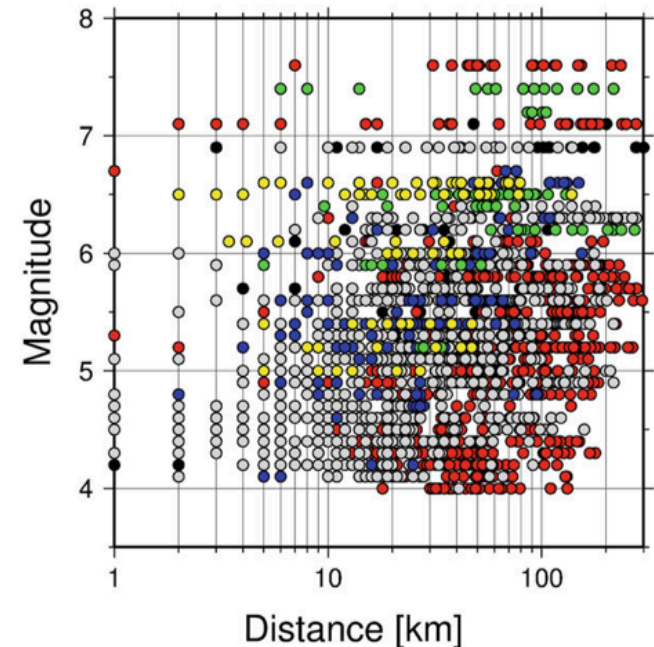
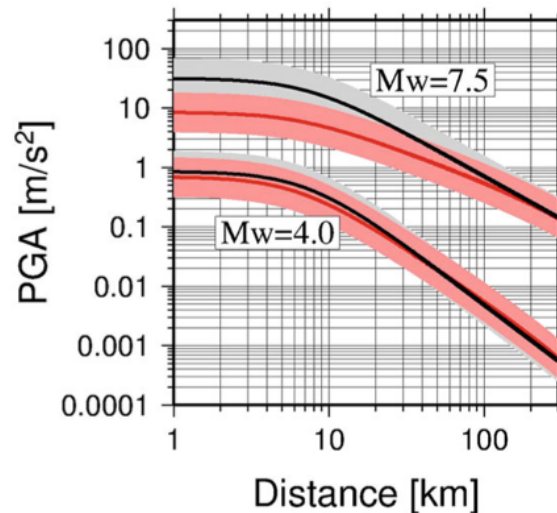
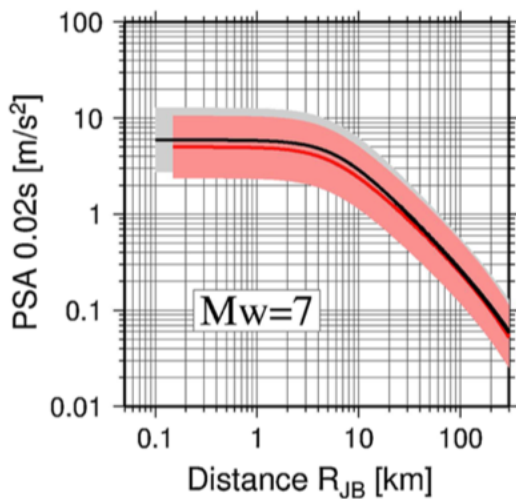
<i>Name</i>	<i>Region</i>	<i>Magnitude Type</i>	<i>Magnitude</i>	<i>Period (s)</i>	<i>DistanceType</i>	<i>Distance (km)</i>	<i>SiteCondition</i>	<i>Style of faulting</i>	<i>Depth (km)</i>	<i>IMs</i>	<i>Component</i>
BSSA14	Global	M _w	3.0 – 8.5	0.01 - 10	Joyner-Boore	0 - 400	V _{s,30}	N,R/T,S, U	0 - 30	PGA, PGV, PSA	RotD50
CZ14	Global	M _w	4.5 - 7.9	0 - 10	Rupture	0-150	EC8 Class/V _{s,30}	N,R,S,U	0-23	PGA, PGV, DRS	GEOH
BND14	PanEuropean	M _w -M _L	4.0-7.6	0.02 - 3	Joyner-Boore/ Epicentral	0-300	EC8 Class	N,R/T,S, U	0-35	PGA, PGV, PSA	GEOH
ITA10	Italian	M _w - M _L	4.0-6.9	0.04 - 2	Joyner-Boore/ Epicentral	0-200	EC8 Class	N,R/T,S, U	0-29	PGA, PGV, PSA	GEOH, Z
MS08	Local (NE Italy)	M _w - M _L	4.0 - 6.4	0.04 - 2	Epicentral	0 - 100	EC8 Class	-----	0 - 60	PGA, PGV,PSA, PSV, IA, IH, DV	H, Z

Ground Motion Prediction Equations

$$\log_{10} Y = e_1 + F_D(R, M) + F_M(M) + F_S + F_{sof}$$

$$F_D(R, M) = [c_1 + c_2 (M - M_{ref})] \log_{10} \left(\sqrt{R^2 + h^2} / R_{ref} \right) - c_3 \left(\sqrt{R^2 + h^2} - R_{ref} \right) \quad \text{Bindi et al., 2014}$$

$$F_M(M) = \begin{cases} b_1 (M - M_h) + b_2 (M - M_h)^2 & \text{for } M \leq M_h \\ b_3 (M - M_h) & \text{otherwise} \end{cases}$$



Ground Motion Prediction Equations

Northern Italy: calibration of novel GMPEs

$$\log_{10} Y = a + F_M(M) + F_D(R, M) + F_{sof} + F_S + F_{bas}$$

Ground motion parameters Y : PGA, PGV, SA (5% damping, $0.04 \leq T \leq 4$ sec) for GeoH and vertical-to-horizontal ratios

Magnitude term

$$F_M(M) = b_1(M - M_r) + b_2(M - M_r)^2$$

M_r is the reference magnitude

Style of faulting term (dummy)

$$F_{sof} = f_j E_j \quad (\text{with } j = \text{NF, TF, UN})$$

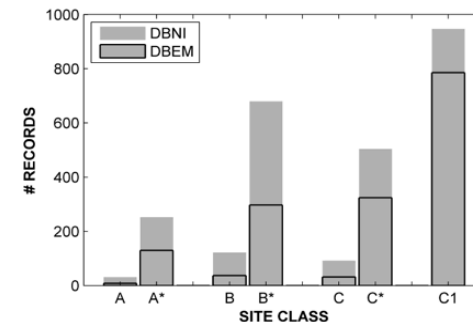
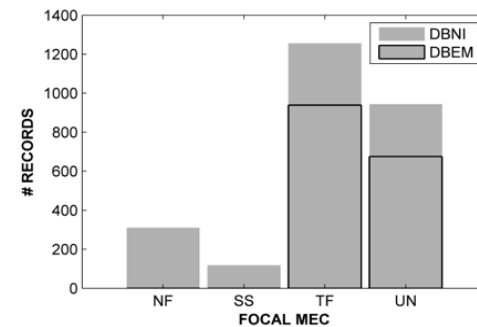
Site term (dummy)

$$F_S = s_j S_j \quad (\text{with } j = \text{A, B, C})$$

Basin effect term (dummy)

$$F_{bas} = \delta_{bas} \Delta_{bas} \quad (\text{for sites located within the alluvial basins, denoted as } \mathbf{C1})$$

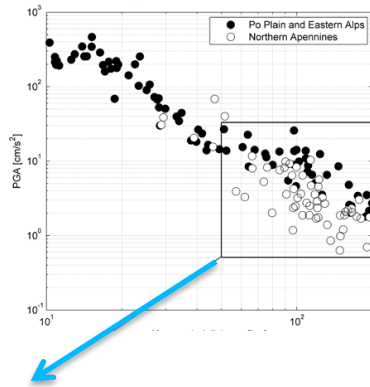
Black lines mark the contribution of 2012 Emilia seismic sequence



Ground Motion Prediction Equations

Northern Italy: calibration of novel GMPEs

$$\log_{10} Y = a + F_M(M) + F_D(R, M) + F_{sof} + F_S + F_{bas}$$



Distance term

$$F_D(R, M) = [c_{1j} + c_{2j}(M - M_r)] \log_{10} \left(\frac{R}{R_h} \right)$$

The equation of the separation line is:

$$LAT_{ref} = -0.33 \cdot LON_s + 48.3$$

R_h is a hinge distance

On the basis of the data is fixed at **80km**

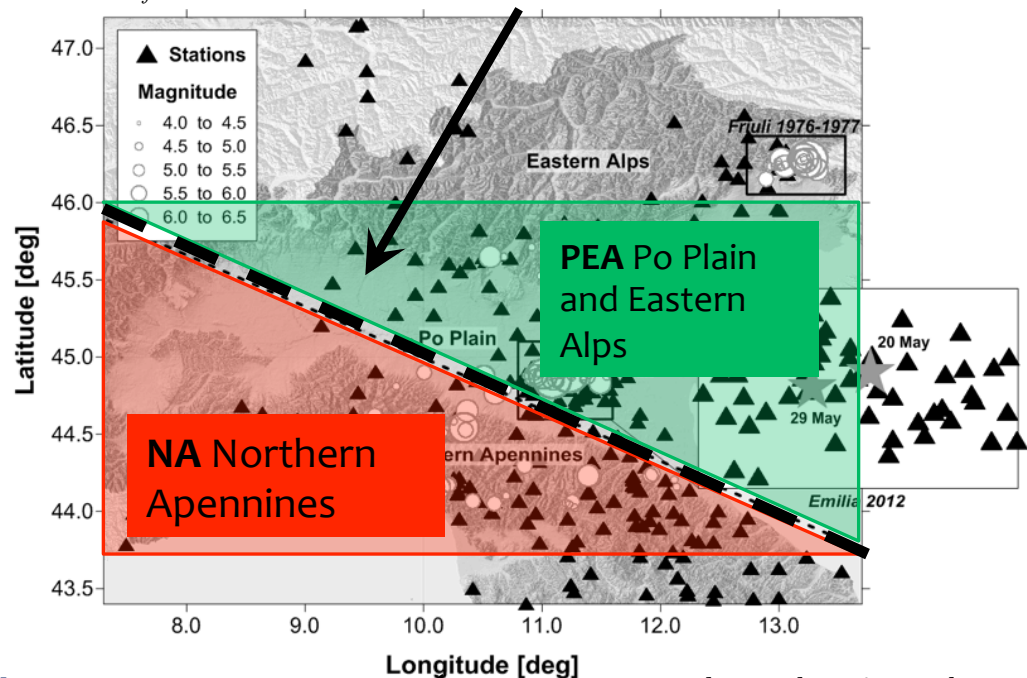
c_{1j} and c_{2j} are evaluated:

$j=1$ sites on **PEA** and $R \leq R_h$

$j=2$ sites on **PEA** and $R > R_h$

$j=3$ sites on **NA** and $R \leq R_h$

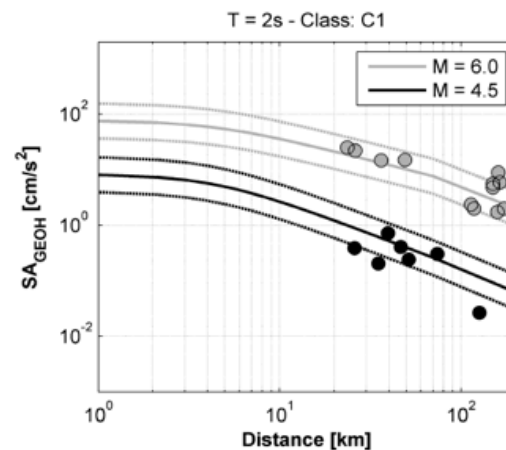
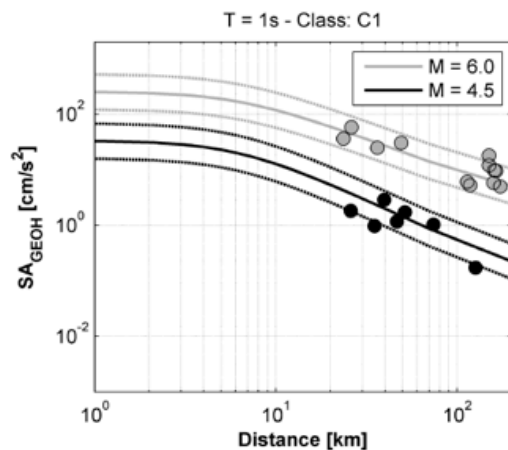
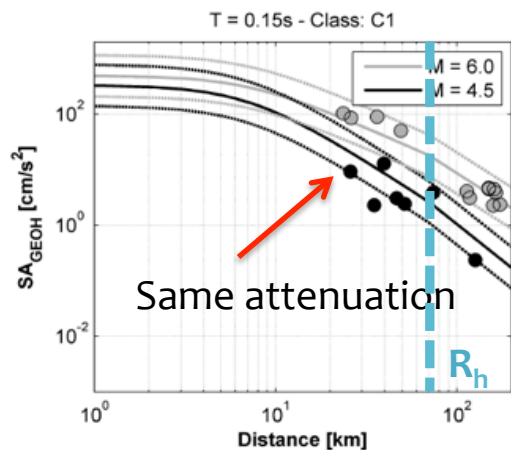
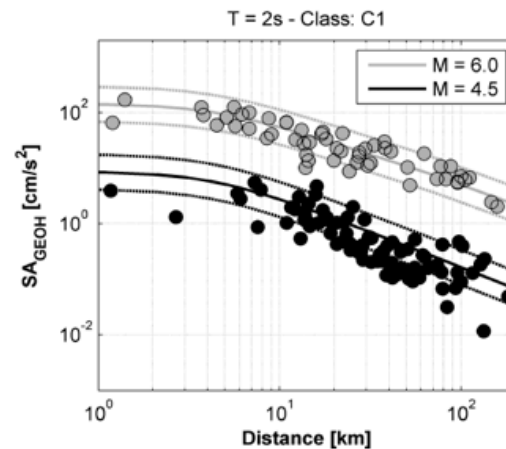
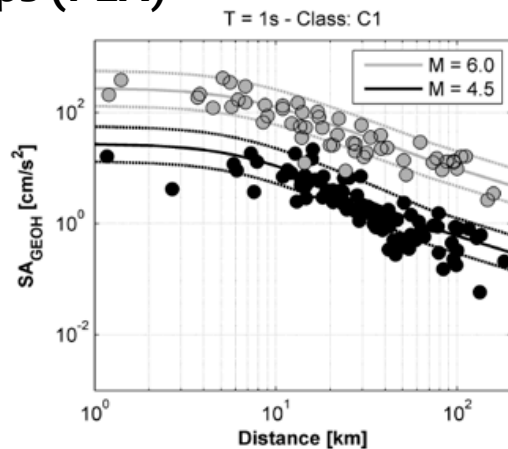
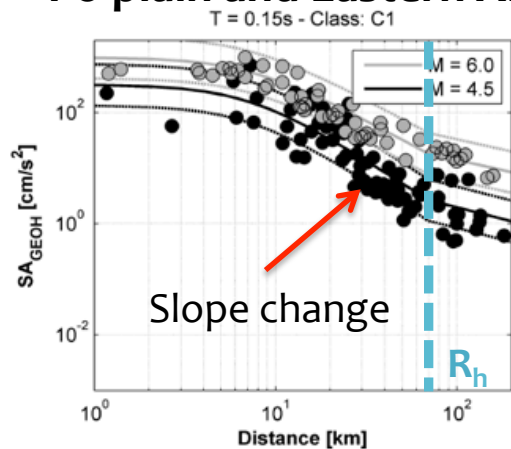
$j=4$ sites on **NA** and $R > R_h$



Ground Motion Prediction Equations

Northern Italy: calibration of novel GMPEs

Po plain and Eastern Alps (PEA)



Northern Apennines (NA)

Earthquake damage

- ❑ On the other hand, it is very hard to relate physical quantities as PGA, PGV, PSA to earthquake damage
- ❑ It is advisable to study empirical relationship between macroseismic intensity and ground-motion parameters



Correlations between Macroseismic Intensity and Instrumental Ground-Motion Parameters

Author	Region	Time window	No Eq.	M range	Intensity Range (scale)	GMP	GMP-Intensity Distance (km)	No GMP-Intensity pairs
Wald <i>et al.</i> (1999)	California	1971-1994	8	5.6-7.3	4-9 (MM)	PGA PGV	<3	342
Tselentis and Danciu (2008)	Greece	1973-1999	89	4.0-6.9	4-8 (MM)	PGA PGV I_a CAV	<3	310
Faenza and Michelini (2010)	Italy	1972-2004	66	3.9-6.9	2-8 (MCS)	PGA PGV	<3	266
Faenza and Michelini (2011)	Italy	1972-2009	87	3.9-6.9	2-8 (MCS)	PSA	<3	264
Bilal and Askan (2014)	Turkey	1976-2011	14	5.7-7.4	1-10 (MM)	PGA PGV PSA		92

New relationships for the italian region

D3.1 – Macroseismic and ground motion: site specific conversion rules

Gomez Capera A.A. (1), Locati M. (1), Fiorini E. (2), Bazzurro P. (3),
Luzi L. (1), Massa M. (1), Puglia R. (1), Santulin M. (1)

(1) Istituto Nazionale di Geofisica e Vulcanologia, INGV, Sezione di Milano, Italy

(2) European Centre for Training and Research in Earthquake Engineering, Eucentre, Pavia, Italy

(3) Istituto Universitario di Studi Superiori, Pavia, Italy



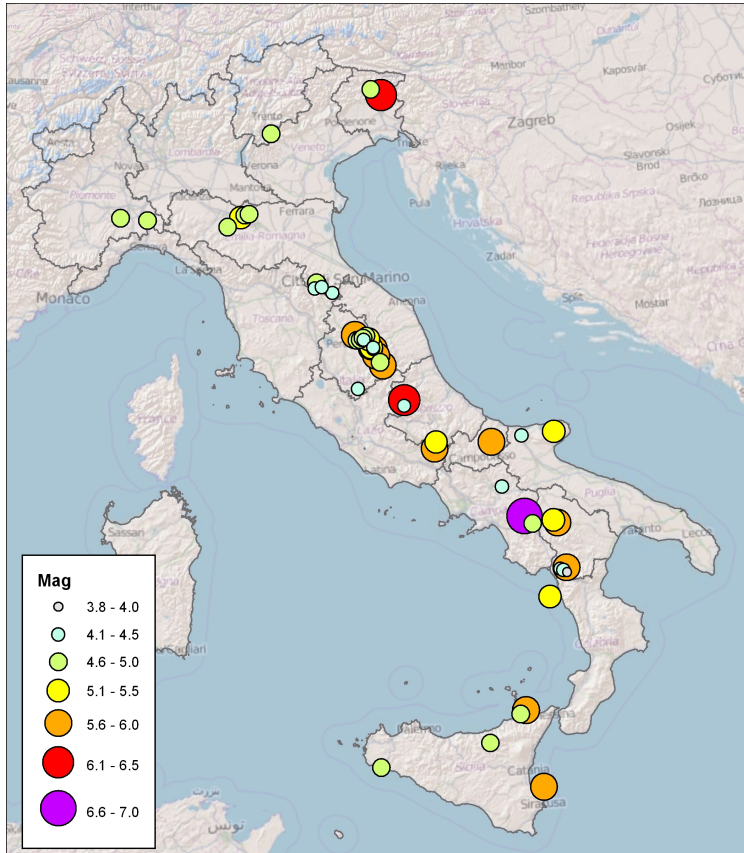
DPC-INGV-S2 Project
"Constraining observations into Seismic Hazard"



- The methodology is given by simple predictive relationships between macroseismic intensity and GMP as only independent variable (Bilal and Askan 2014).
- To account for the uneven distribution of GMP corresponding to single macroseismic intensity, a mean of GMP is assigned to each macroseismic intensity level.

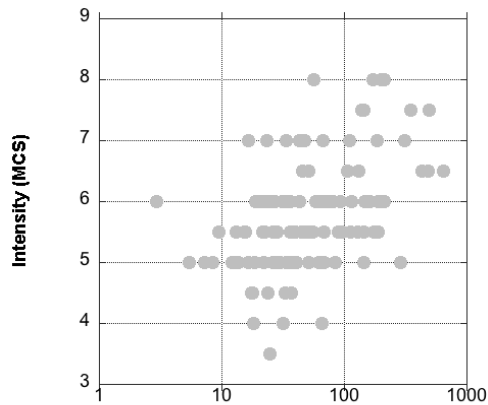
New relationships for the Italian region

53 earthquakes
[1976-2003] + 2009

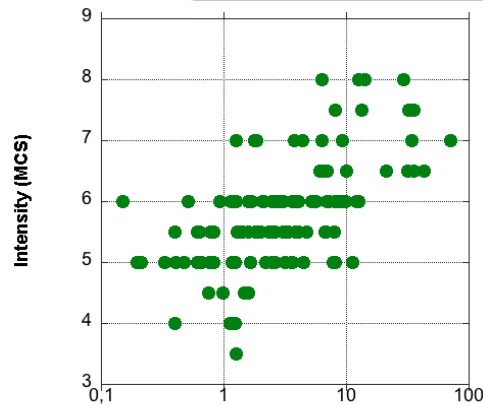


- The methodology is given by simple predictive relationships between macroseismic intensity and GMP as only independent variable (Bilal and Askan 2014).
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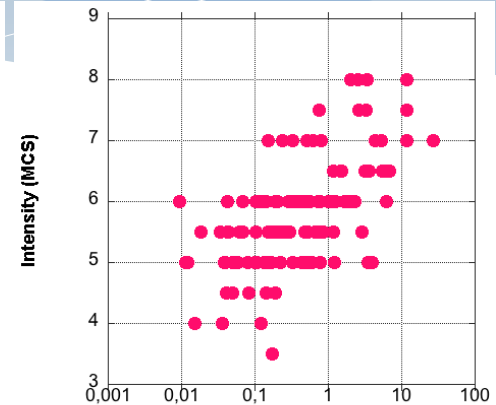
New relationships for the italian region



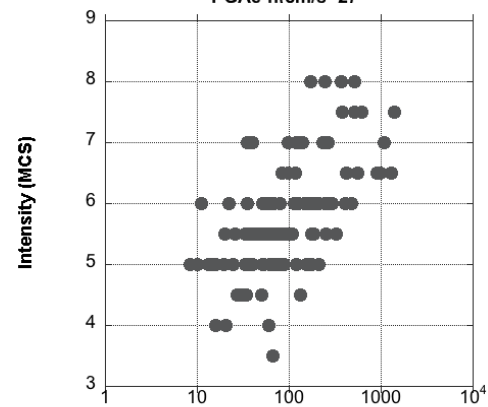
PG Ae-n (cm/s²)



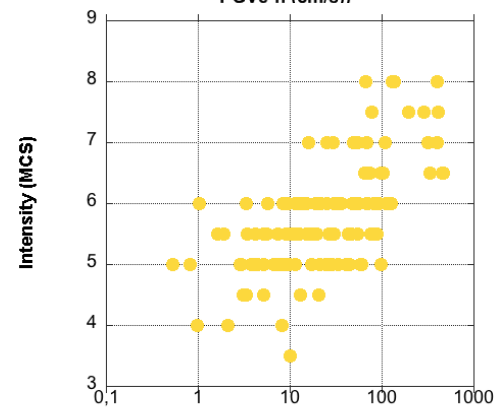
PG Ve-n (cm/s)



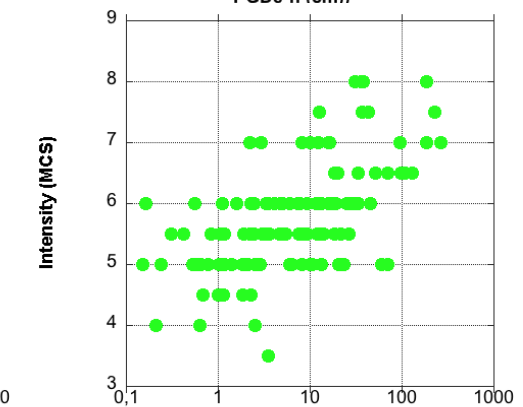
PG De-n (cm)



SA 0.3s (cm/s²)



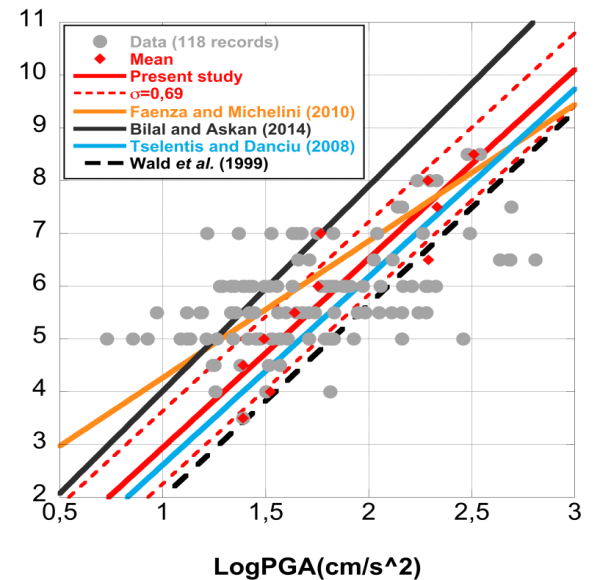
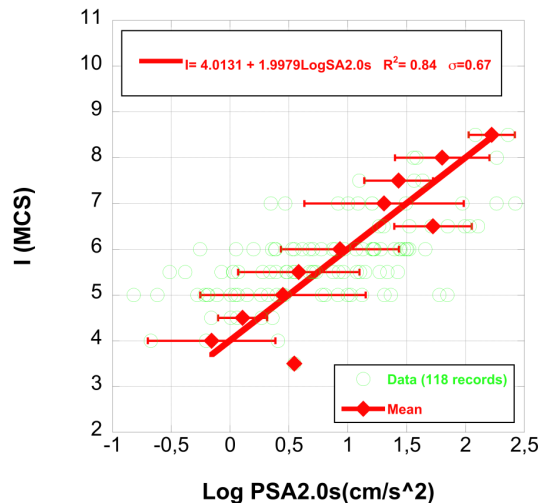
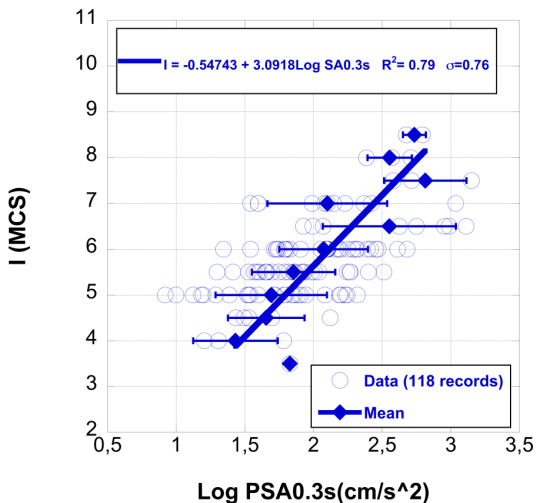
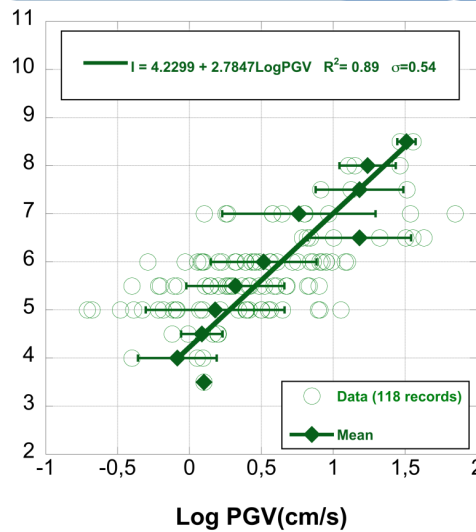
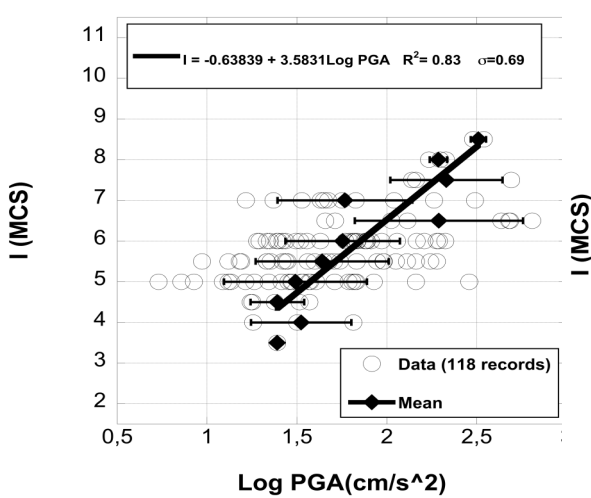
SA 1.0s (cm/s²)



SA 2.0s (cm/s²)

119 datapoints

New relationships for the Italian region



Future developments

- * Data research for $I \geq 8$ and $I < 5$
- * Modelling and Physical Interpretation of new empirical functional as

$$I = f(GMP) + G(Mw) + H(R)$$