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

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INGV terremoti vulcani ambiente
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

Ground Motion Measures

Qualitative

* Macroseimic Intensity
  * Empirical classification of the earthquake intensity by **ordinale 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
- Dutation

Instrumental seismology

Macroseismic Intensity

Mallet's Investigation of the 1857 Neapolitan Earthquake

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.I.A.,
&c., &c.

"Non fingendum aut excogitandum sed inveniendum quid natura faciat aut ferat."

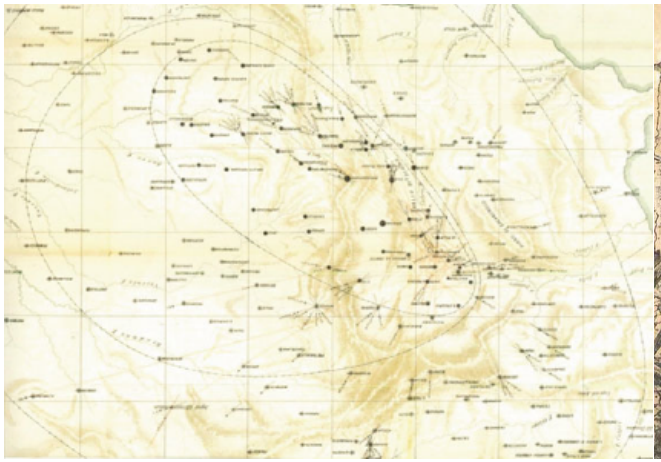
PUBLISHED BY THE AUTHORITY AND WITH THE AID OF THE
ROYAL SOCIETY OF LONDON.

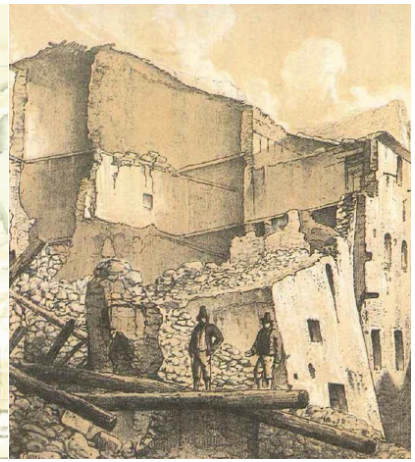
IN TWO VOLUMES.—VOL. II.

CHAPMAN AND HALL, LONDON.
1862.

[The Right of Translation is reserved.]

"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

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

Name	*Region*	*Magnitude Type*	*Magnitude*	*Period (s)*	*DistanceType*	*Distance (km)*	*SiteCondition*	*Style of faulting*	*Depth (km)*	*IMs*	*Component*
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

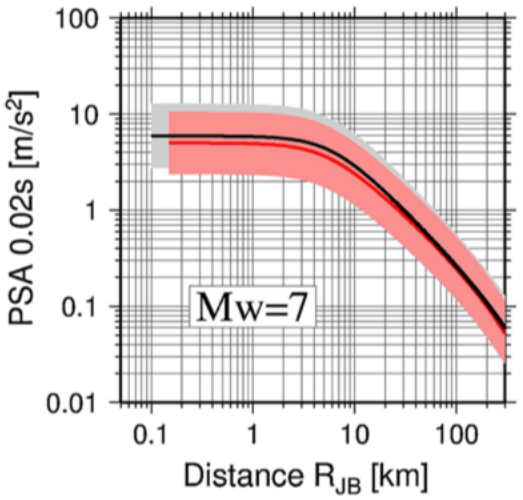
Ground Motion Prediction Equations

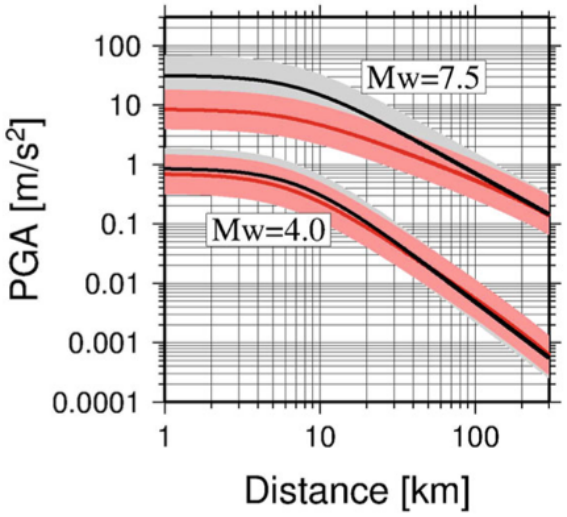
$$\log_{10} Y = e_1 + F_D(R, M) + F_M(M) + F_S + F_{sof}$$

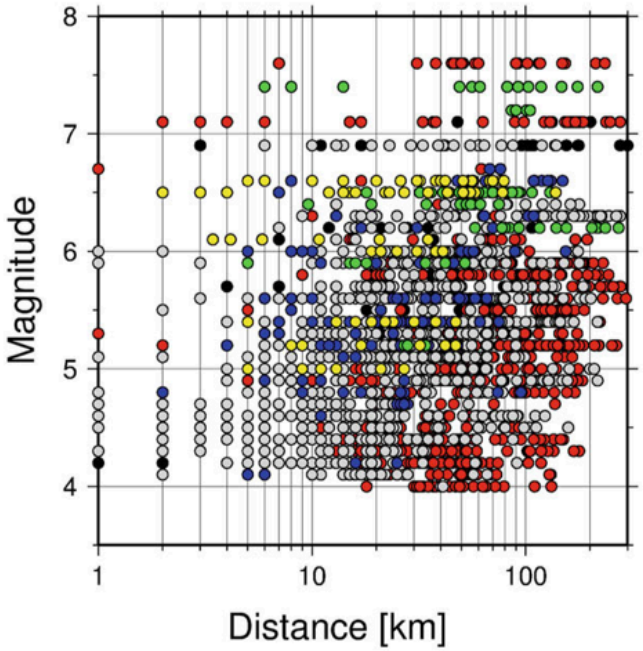
$$F_D(R, M) = \left[c_1 + c_2 \left(M - M_{ref}\right)\right] \log_{10} \left(\sqrt{R^2 + h^2}/R_{ref}\right) - c_3 \left(\sqrt{R^2 + h^2} - R_{ref}\right)$$

Bindi et al., 2014

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







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 ≤ T ≤ 4sec) for GeoH and vertical-to-horizontal ratios

Black lines mark the contribution of 2012 Emilia seismic sequence

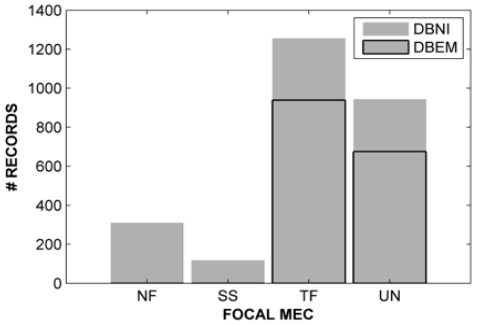
Magnitude term

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

M_r is the reference magnitude

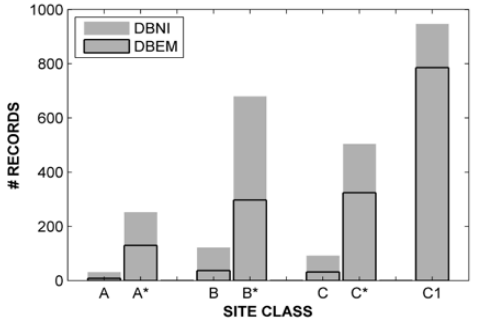
Style of faulting term (dummy)

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



Site term (dummy)

$F_S = s_j S_j$ (with j = A, B, C)



Basin effect term (dummy)

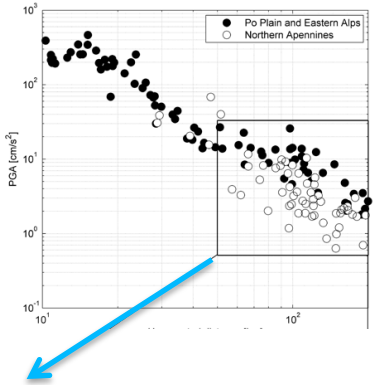
$F_{bas} = \delta_{bas} \Delta_{bas}$ (for sites located within the alluvial basins, denoted as **C1**)

(Lanzano et al., submitted to BSSA)

Ground Motion Prediction Equations

Northern Italy: calibration of novel GMPEs

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

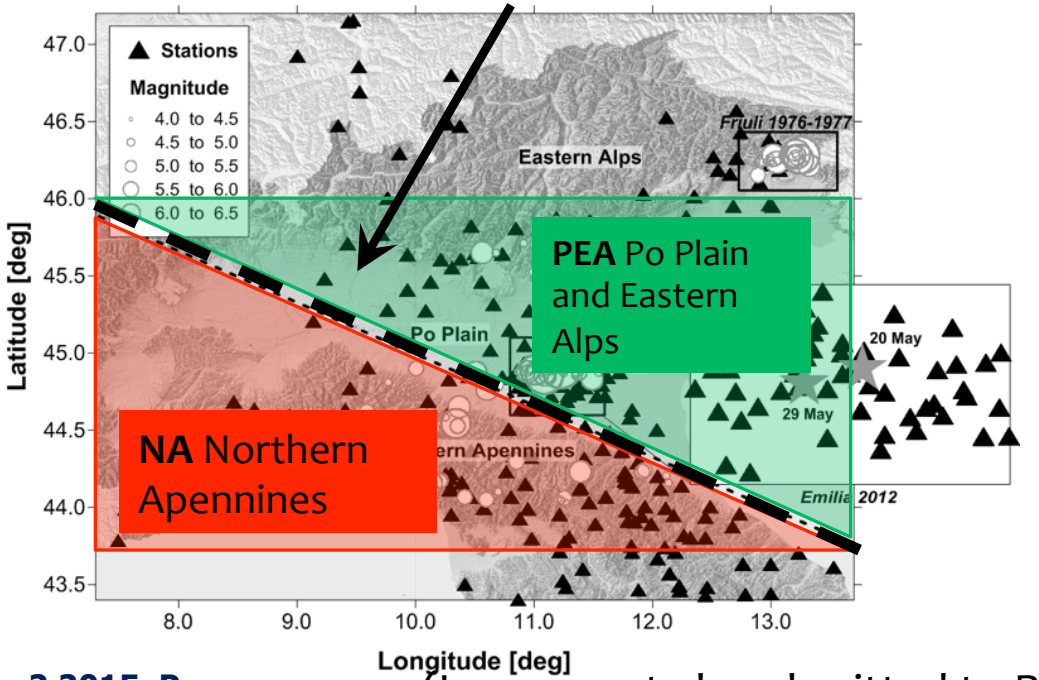


Distance term

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

The equation of the separation line is:

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



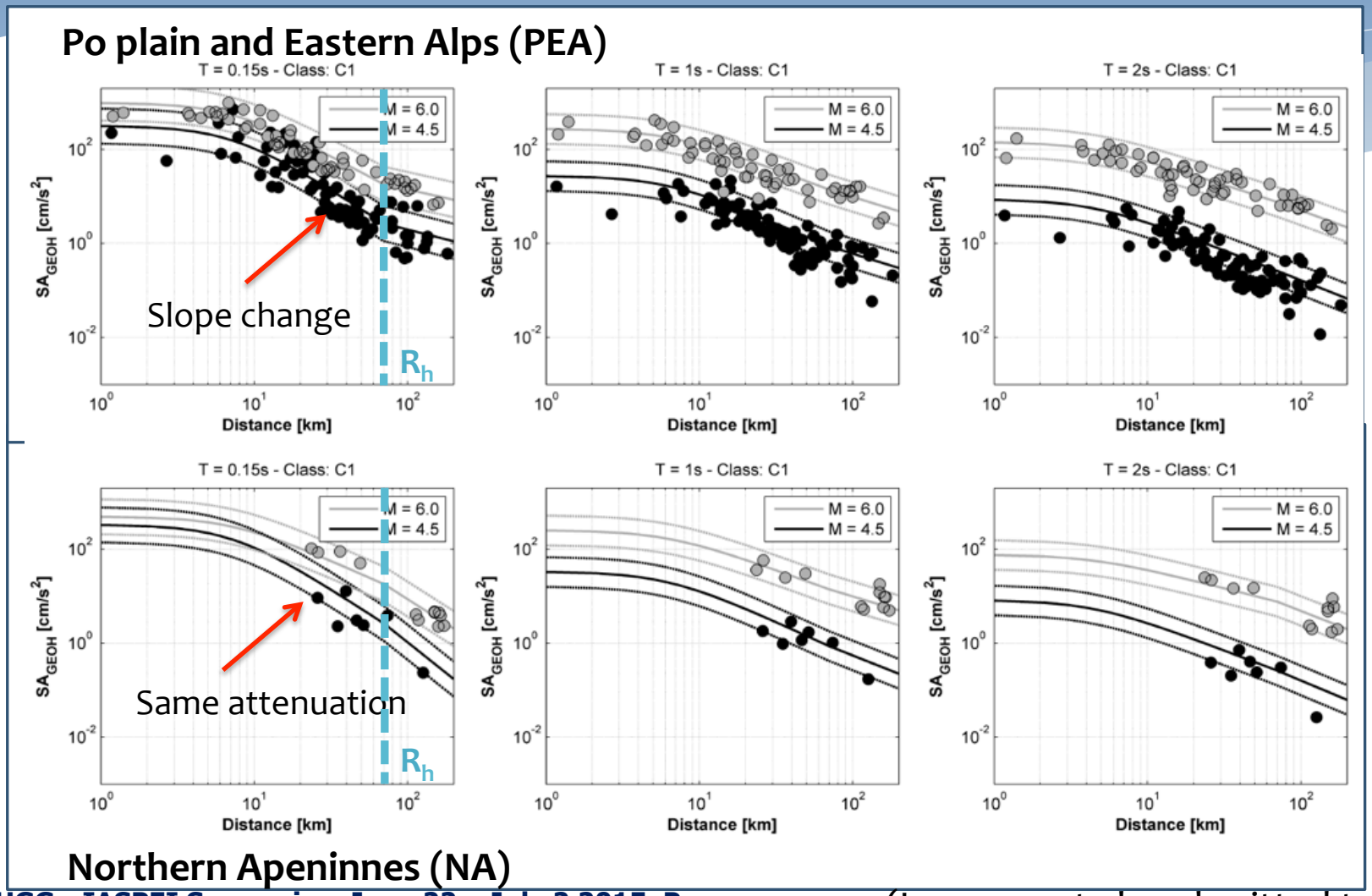
R_h is a hinge distance
On the basis of the data is fixed at **80km**

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 $R > R_h$

(Lanzano et al., submitted to BSSA)

Ground Motion Prediction Equations

Northern Italy: calibration of novel GMPEs



(Lanzano et al., submitted to BSSA)

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 *et al.* (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)

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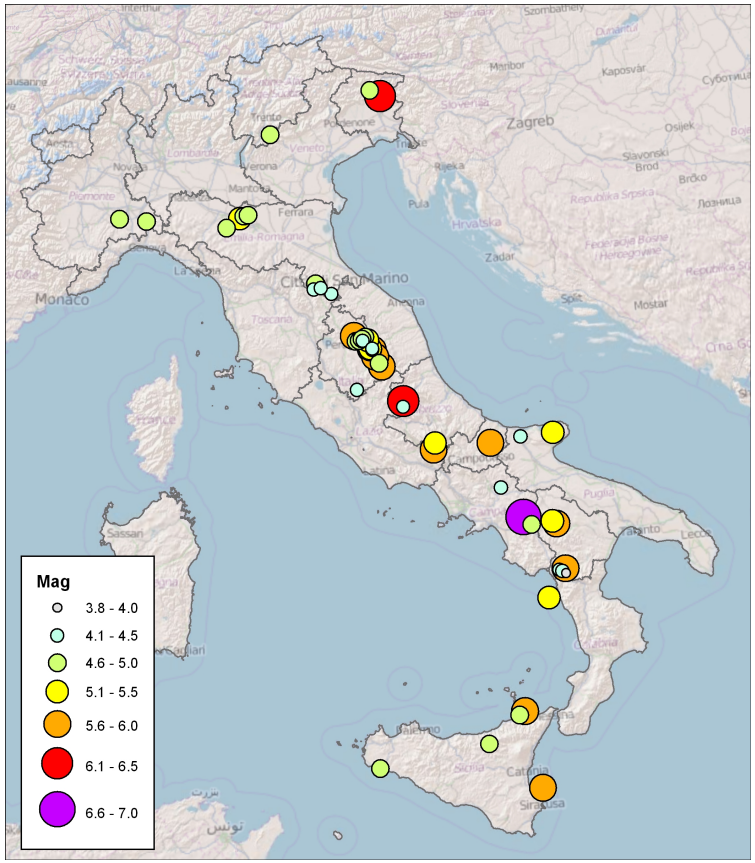
DPC-INGV-S2 Project
"Constraining observations into Seismic Hazard"

- 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



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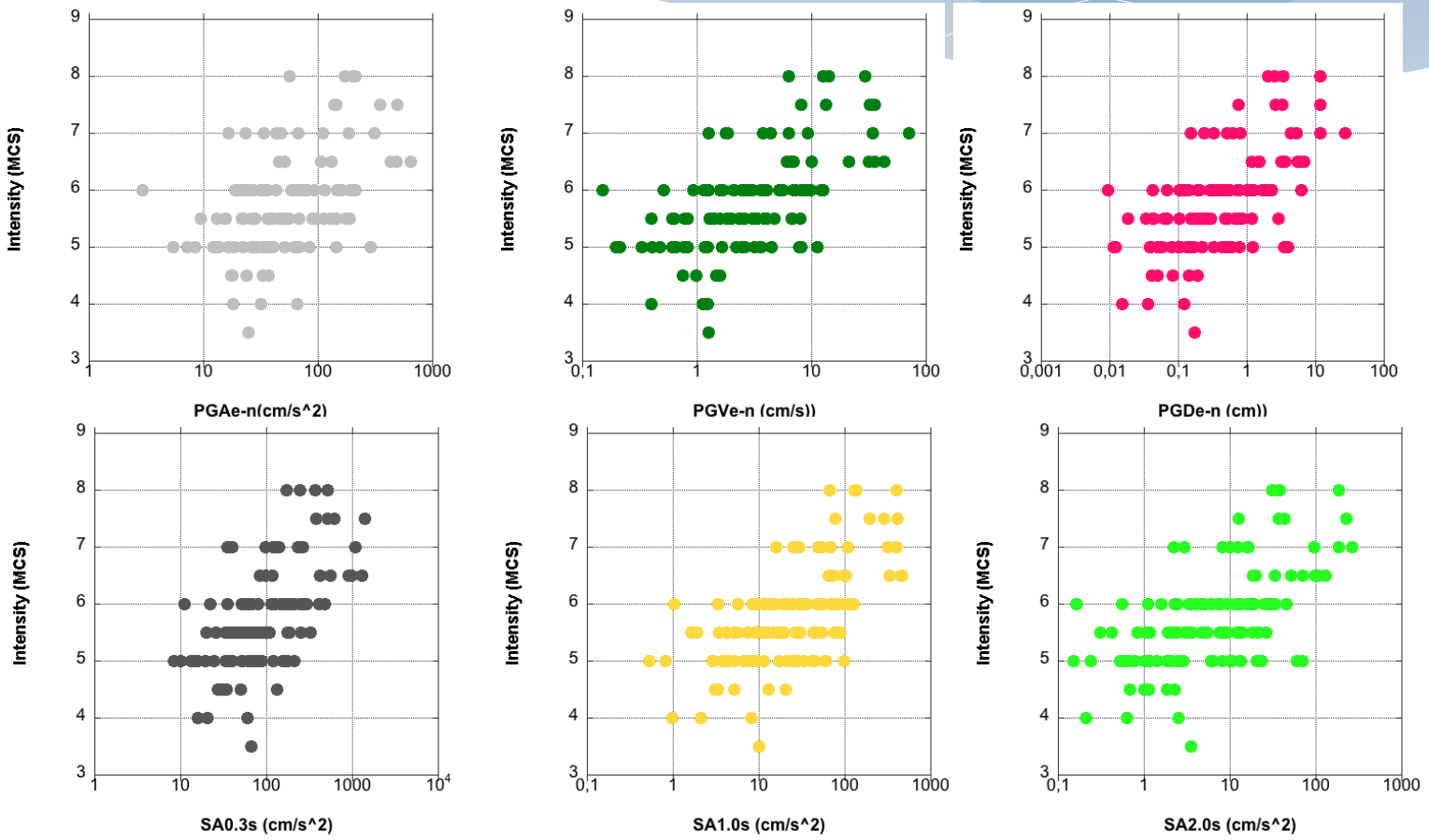
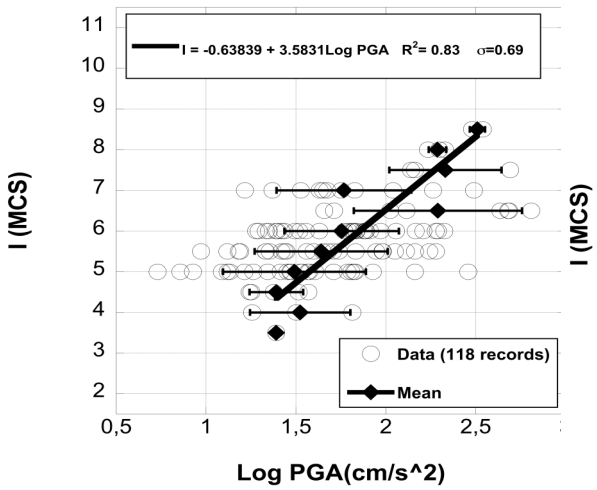
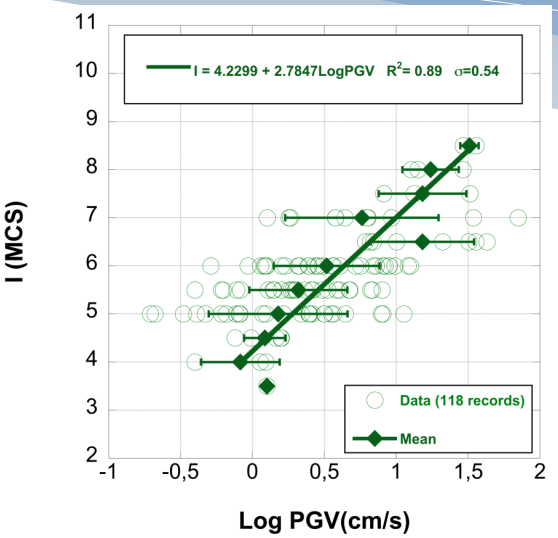
New relationships for the italian region

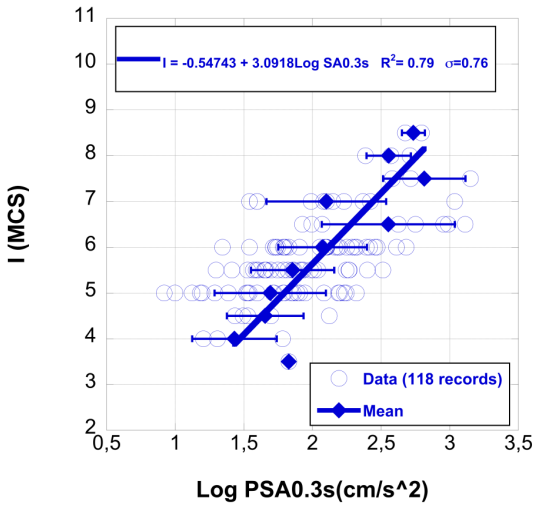


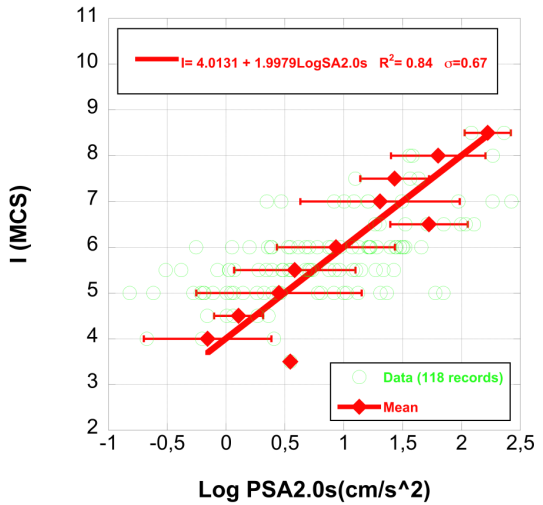
119 datapoints

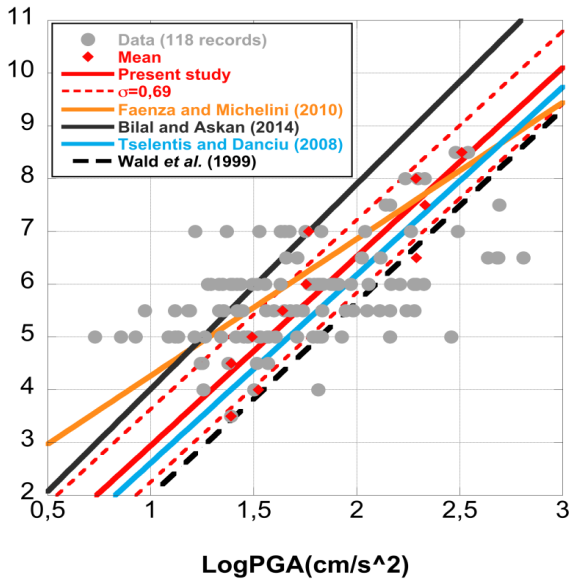
New relationships for the italian region











Future developments

* Data research for $I \geq 8$ and $I < 5$

* Modelling and Physical Interpretation of new empirical functional as

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