Ground motion Prediction Equations and S-Projects

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**INGV,Milano-Pavia*

Working Group S-Projects

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DPC – F. Sabetta

S Projects and GMPEs

IEC observes that:

Projects S2, S3, and S4 all involve the development and/or evaluation of attenuation relationships, and there seems to be little convergence (perhaps only in terms of a fragmentary discussion) on which are most appropriate for the different uses.

It therefore would be useful to have a process by which these issues were discussed broadly and openly, and perhaps the *ad hoc* group mentioned above could facilitate and coordinate this process.

QUESTIONS

A workshop was organized on June 2009 with the aim of discussing the following questions:

- Do the S-Projects use different GMPEs because they are applied with different aims?
- Does it make sense to seek the most appropriate GMPEs for the Italian territory?
- Does it make sense to use regional GMPEs?

Workshop Presentation Slides:
http://esse4.mi.ingv.it

S-Projects -AIMS

S2 Several ground motion prediction models have been adopted in the Project, suitable of being implemented in CRISIS++ as built-in options (in terms of external DLLs), in addition to those already contemplated in the previous versions of the code.

S3 Several ground motion prediction models have been adopted in the Project, both European and regional scale, to generate Shake Maps

S4 Two ground motion prediction equations have been developed in the Project, suitable to identifying peculiar earthquake and stations and to testing different site scheme classification

FORMAT

Before the workshop, each Project compiled a report on the adopted GMPEs through common format

DATA *SET*

Origin of Data set	#Earthquakes	#stations	#Recordings	Magnitude* Range	Distance* Range	Depth range
Regional/Global/Italian						

MODEL FUNCTIONAL FORMS

EQUATION $Y = F(M,R, S, F,\ldots)$

Predicted variable	Component	Units	Standard deviation

Saturation at short distances	Geometrical spreading M-dependent	Anelastic attenuation	Site classification	Style of Faulting	Directivity term	Hanging/Foot wall

SUMMARY - 1

S-Projects adopt:

- **Global GMPEs** (Boore and Atkinson, 2008; Cauzzi and Faccioli; 2008) **S2-S3**
- **European GMPEs** (Akkar and Bommer; 2007a and 2007b) **S2-S3**
- **Italian GMPEs** (Bindi et al; 2009; Di Alessandro et al; 2009; Sabetta and Pugliese, 1996) **S2-S4**
- **Regional attenuation model** obtained by the parametrization of observed Fourier spectra (Malagnini et al.; 2000, Scognamiglio et al., 2002; Morasca et al.; 2006) **S3**
- **Synthetic data** computed with finite-fault simulation techniques **S1**

SUMMARY - 2

The various GMPEs predict:

Variables

- •Peak ground motions (PGA-PGV)
- •Spectral ordinates (PSV, PSA, SA, DRS) up to 2s and 20s at different periods

Ground motion components

- •Maximum Horizontal component - H;
- •Geometrical mean between horizontal components - GH;
- •Orientation Independent Ground Motion - GMRotI50;
- •Vertical Component

SUMMARY - 3

Model Parameters

		Distance [km]	Magnitude: Mw, Ml
Global	Rjb Rhypo	0 – 200	5.0 - 7.6
National	Repi, Rhypo RJB	0 – 200	4.0 - 6.9
Regional	Rhypo	20 – 200	1.2 - 6.0

Site term

vs30, dummy variables (0, 1, 2), Predominant Period

Functional form

Geometrical spreading M-dependent
Style of faulting
Anelastic attenuation (Di Alessandro et al.; 2009)

COMPARISON

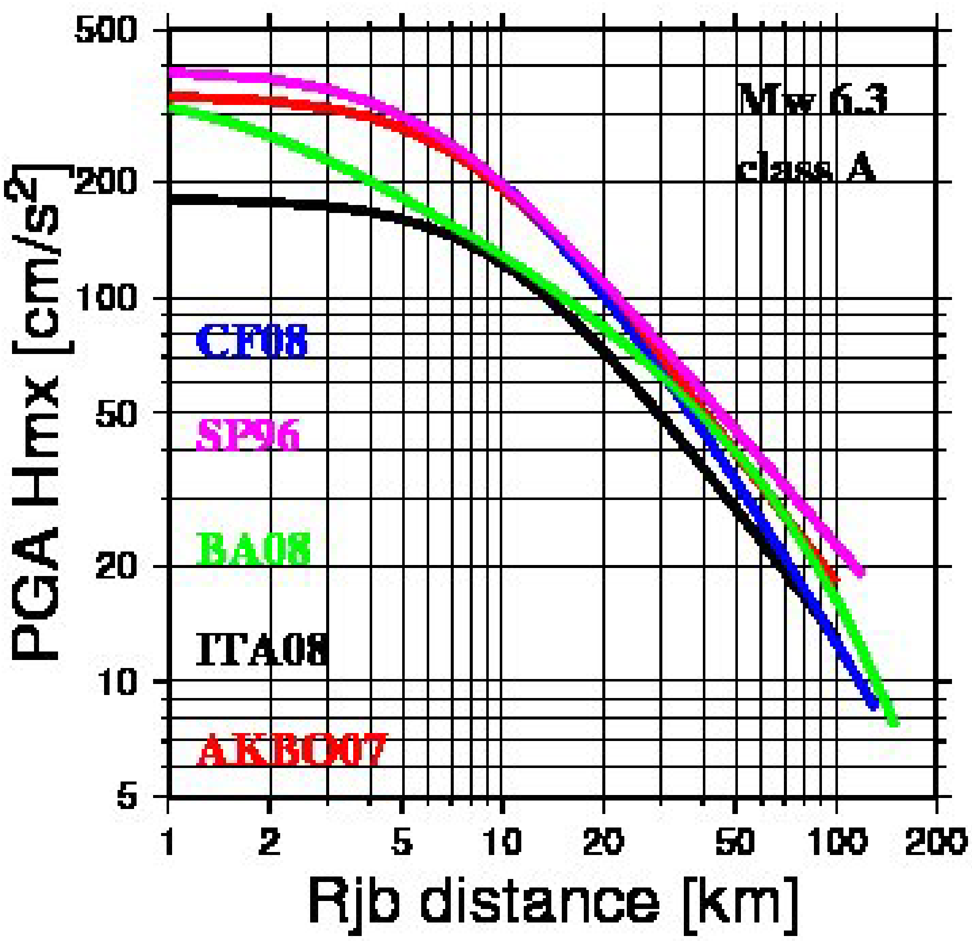
Various approaches can used to compare ground motions from different GMPEs :

1. direct comparison of median predictions of a particular ground motion parameters from GMPEs;

2. evaluation of the consistency of data distributions with respect to a GMPE using statistical techniques (likelihood).

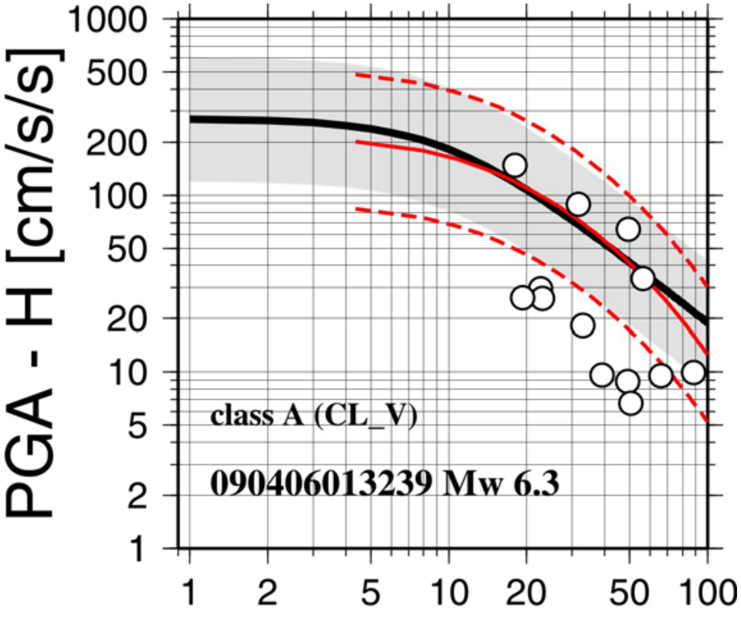
MEDIAN VALUES

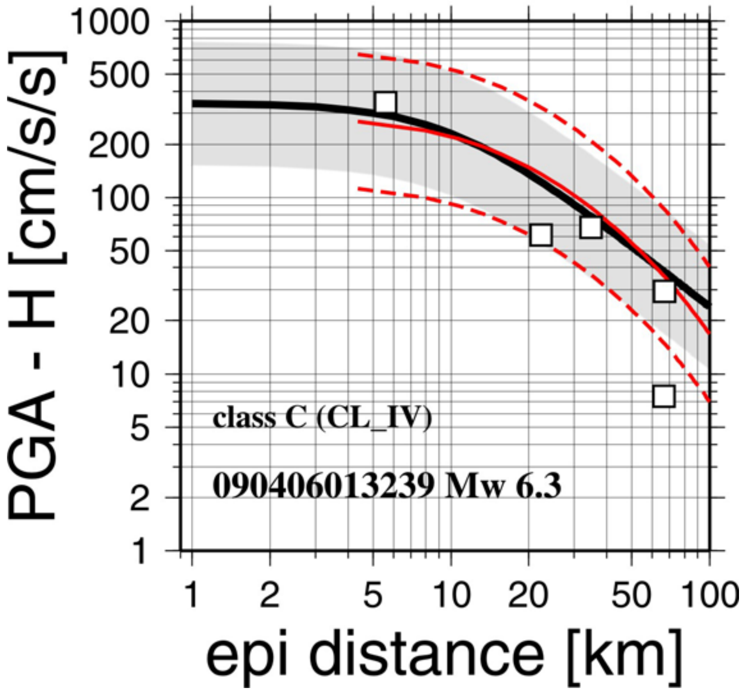
M 6.3 **Rock site**



Proper adjustments should be applied to convert distance metric, ground motion components, site classification

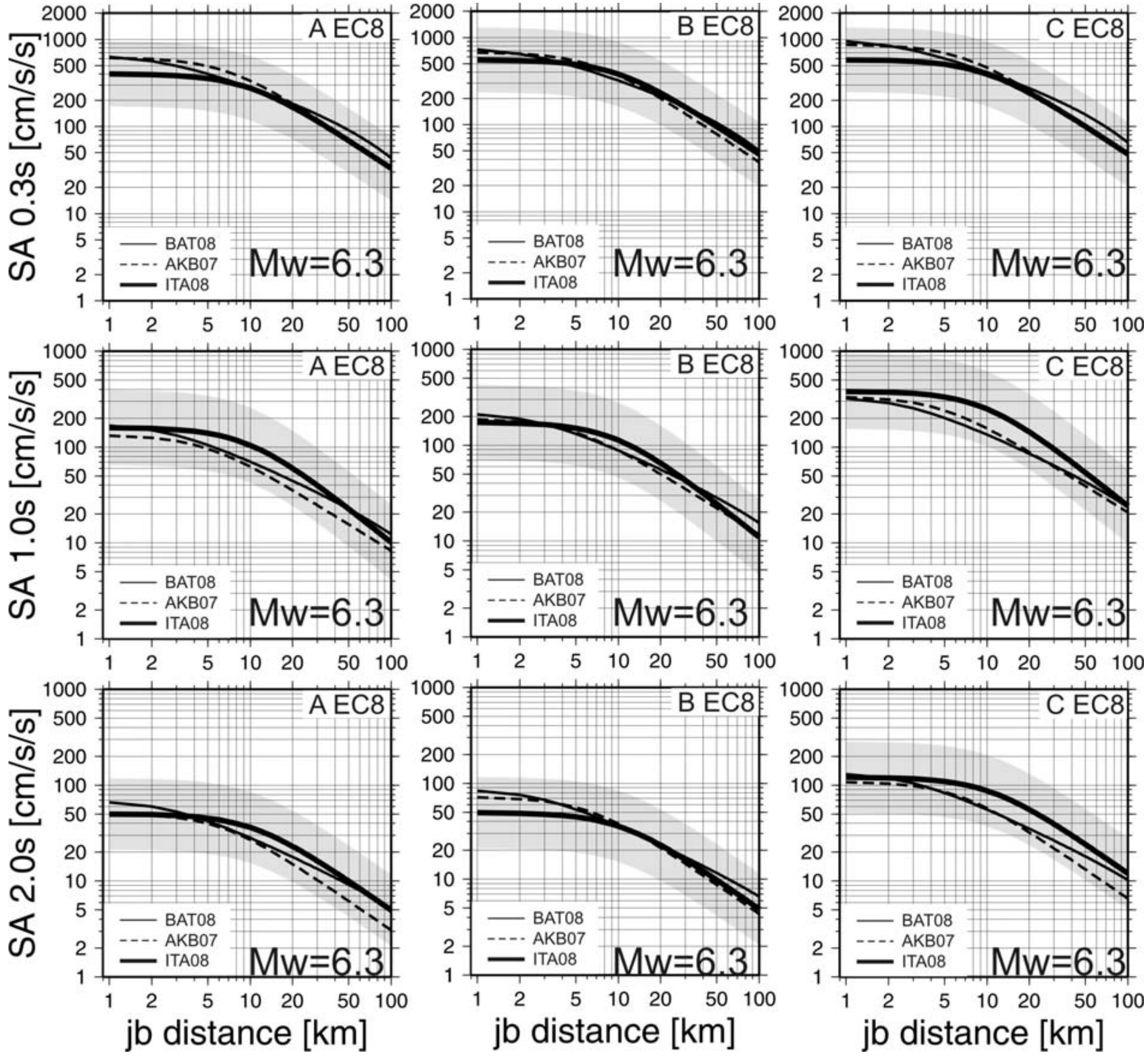
MEDIAN VALUES





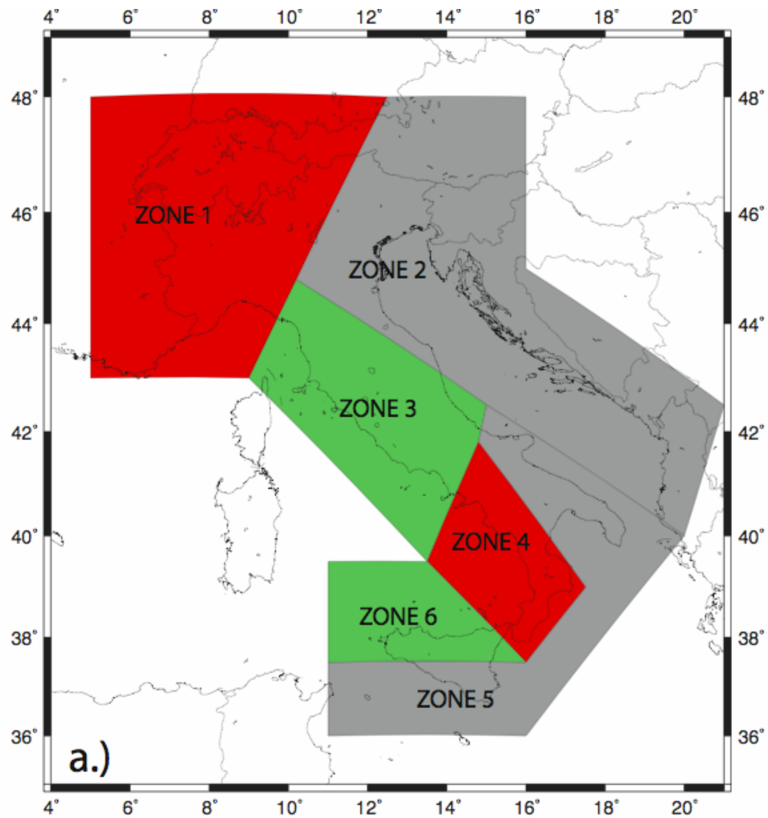
Italian GMPEs

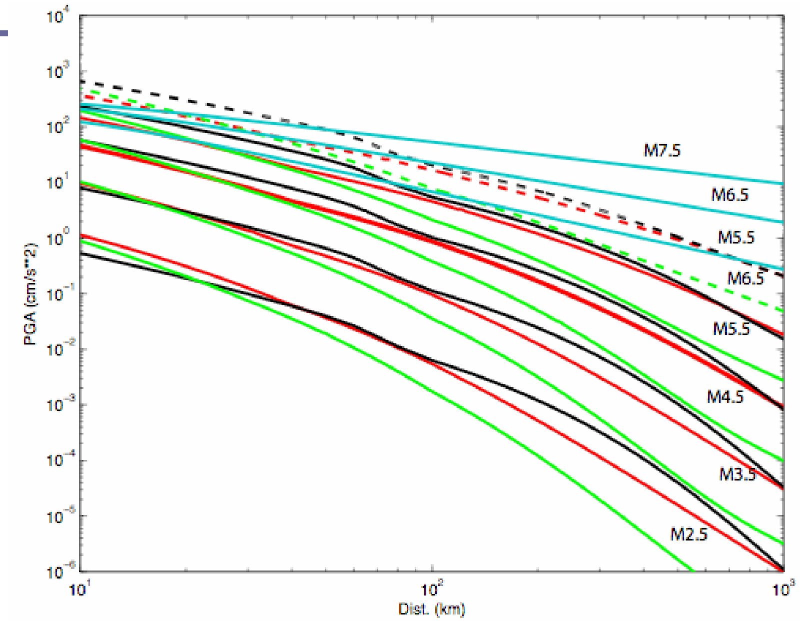
MEDIAN VALUES

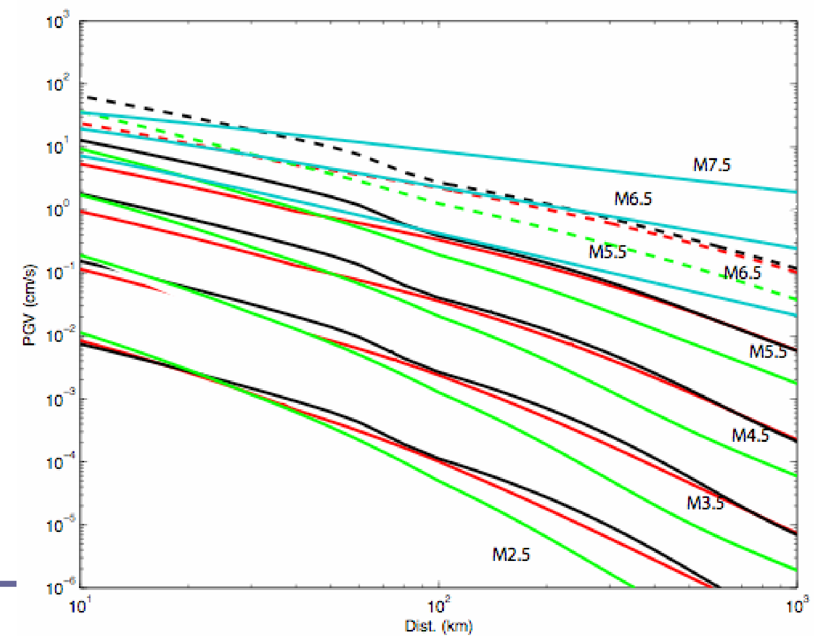


MEDIAN VALUES

Regionalization of the attenuation relations for M <5.5 events (Malagnini et al.).
For M ≥ 5.5 events the relations of Akkar and Bommer 2007 are used. Colors in PGA and PGV match the zones.



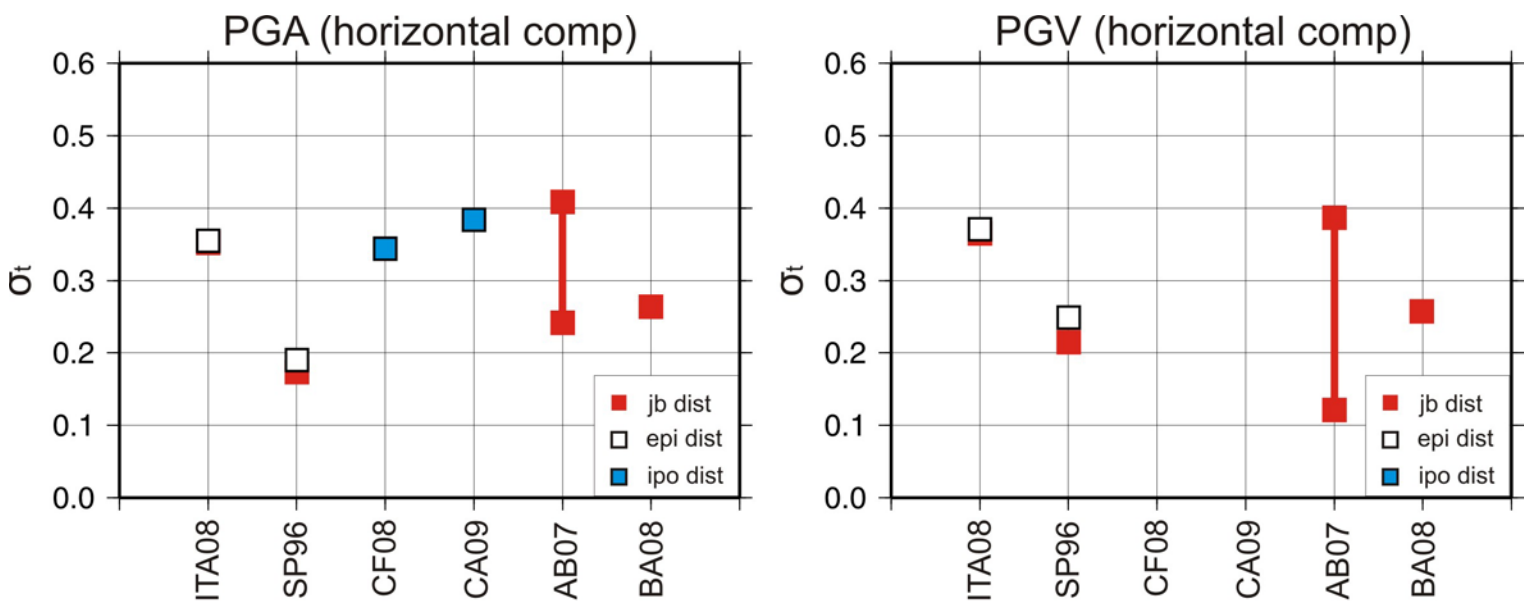




STANDARD DEVIATIONS

Total Standard deviation:

- Inter-event, intra-event Standard deviations
- Standard deviation dependent on Magnitude



WHAT COULD WE DO?

- Evaluating the applicability of existing GMPEs at Italian Territory

- Deal with the problem of regional vs global GMPEs

- Developing new GMPEs

APPLICABILITY OF GMPEs

- The primary goal should be to determine whether existing GMPEs are applicable for different uses in Italian territory.
- Residual analysis could be performed, examing the average residuals, binned by distance and magnitude, from observed and predicted ground motion values.
- Observed strong motion data-set should be defined

Allen, T.I., and Wald, D.J., 2009, Evaluation of ground-motion modeling techniques for use in Global ShakeMap—A critique of instrumental ground-motion prediction equations, peak ground motion to macroseismic intensity conversions, and macroseismic intensity predictions in different tectonic settings: U.S. Geological Survey Open-File Report 2009–1047, 114 p.

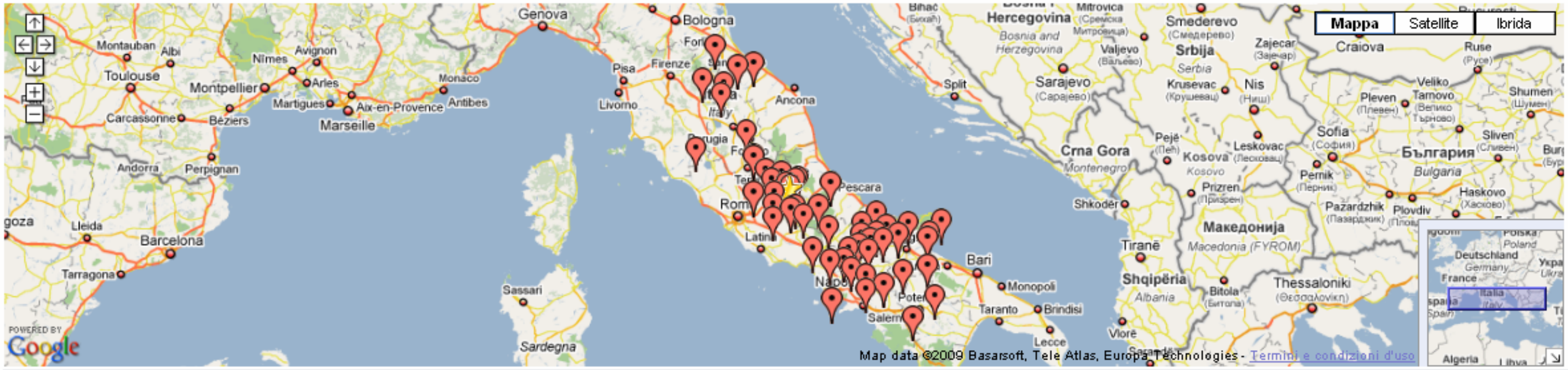
The L'Aquila earthquake

Event Detail

Date	2009-04-06 01:32:39	**Event name**	L'Aquila Mainshock		
Lat	42.33 ± 0.79km	**Long**	13.33 ± 0.79km	**Depth [km]**	8.8 ± 1.49
Hypocenter reference	INGV-CNT Seismic Bulletin	**Other hypocenter**			

MAGNITUDE

Type	Method	Reference	Value	Error
ML	ML from ING catalogue	INGV-CNT Seismic Bulletin	5.8	0.3
Mw	Mw from RCMT	RCMT-INGV	6.3	



Municipality	L'AQUILA	**Province**	L'Aquila		
Focal Mechanism					
Type	NF	**Method**	RCMT	**ref.**	RCMT-INGV
Strike	127.0	**Dip**	50.0	**Rake**	-109.0
Fault		**Surf. Rupt.**		**ref.**	
Other faults					
I_0		**Other I_0**		**ref.**	
Located					

WAVEFORMS

Station	R epi. [km]	PGA [cm/s^2]	PGV [cm/s]	Detail
ANT	23.000	25.977	2.474	
AQA	4.600	461.055	32.029	
AQG	4.400	506.864	35.538	
AQK	5.600	365.336	36.212	
AQV	4.900	646.068	42.826	
ASS	101.700	6.042	0.432	
AVL	198.000	1.246	0.388	

Il terremoto dell'Aquila: forme d'onda e spettri

WAVEFORMS

Station	R epi. [km]	PGA [cm/s²]	PGV [cm/s]	Detail
ANT	23.000	25.977	2.474	
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ASS	101.700	6.042	0.432	
AVL	198.000	1.246	0.388	
AVZ	34.900	67.677	11.284	
BBN	199.500	1.004	0.260	
BDT	178.800	1.986	0.379	
BNE	180.200	2.060	0.686	
BOJ	133.400	14.164	3.335	
CAN	217.600	1.858	0.326	
CDS	88.400	9.953	1.721	
CER	244.700			
CHT	67.000	29.409	7.912	
CLN	31.600	89.137	7.067	
CMB	138.700	2.875	1.296	
CMR	126.600	5.335	0.744	
CNM	166.600	1.877	0.841	

>> >>|

Export in Zip file

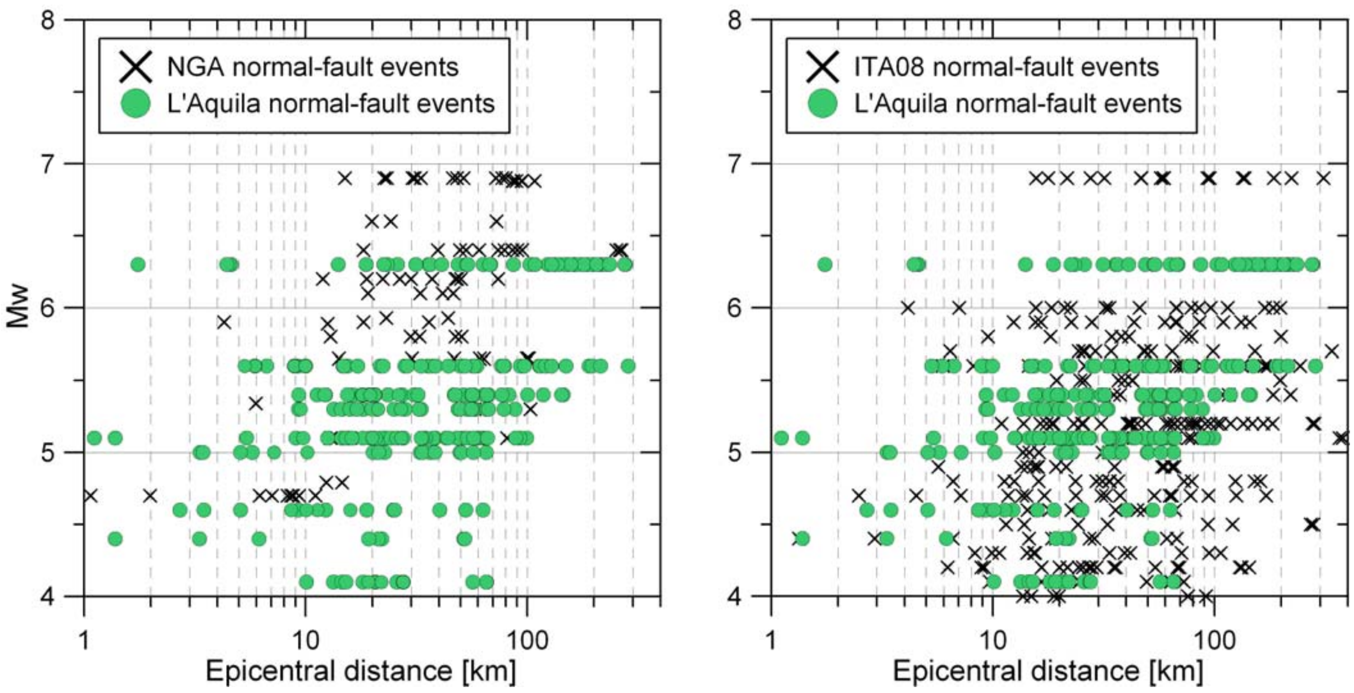
Corrected records (only corrected time histories and response spectra) - ascii format

Uncorrected records (only acceleration time histories) - ascii and sac format

Both corrected an uncorrected records - ascii format

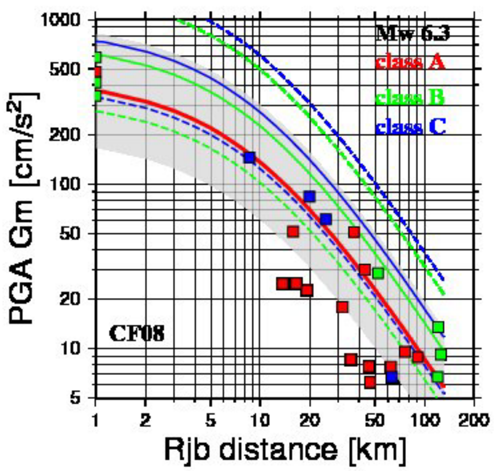
The 2009 Abruzzo data set

300 records from M 4.0 to 6.3 within epicentral distances of 200km

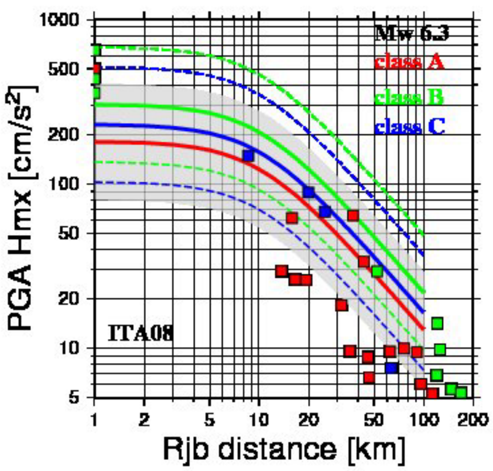


The 6 April 2009 L’Aquila earthquake

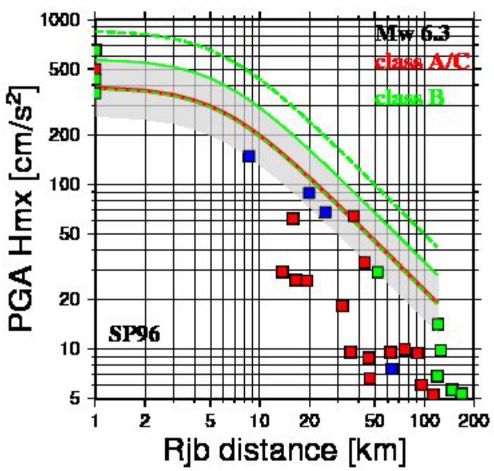
CF08



ITA08

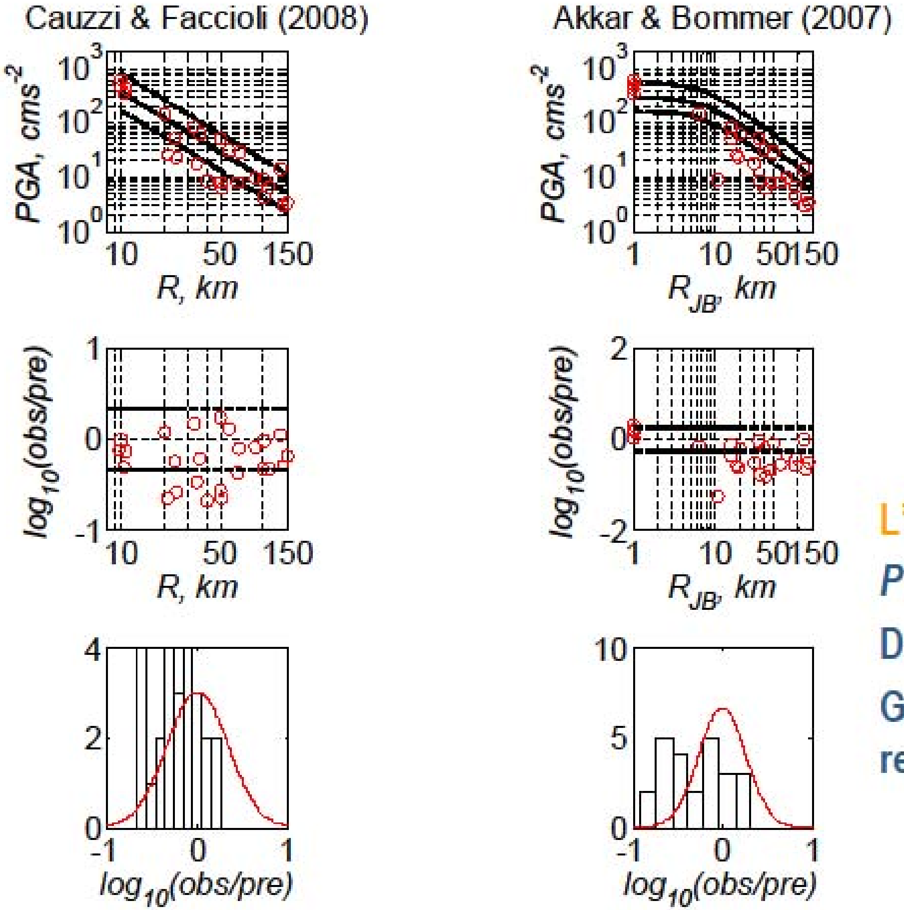


SP96



DATA vs GMPEs

5



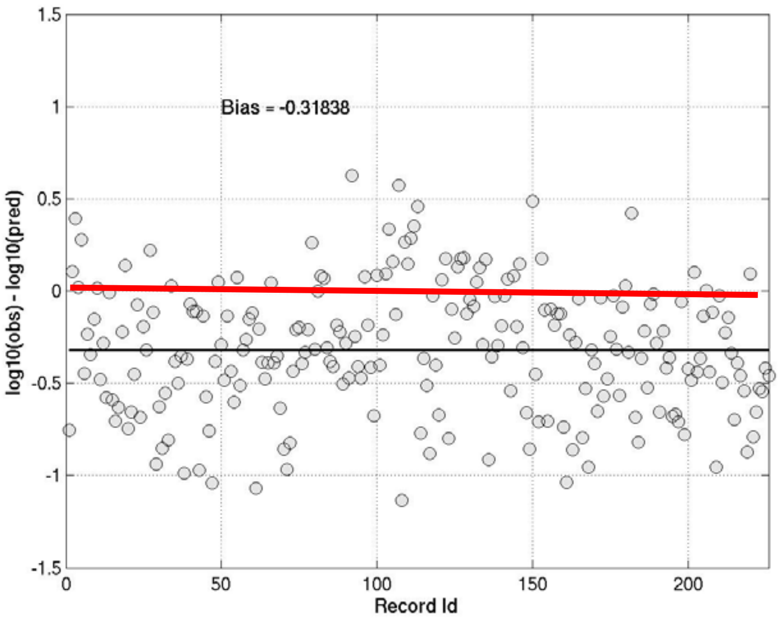
L'Aquila mainshock (M_W 6.3)

PGA

Data *vs* GMPEs (rock)

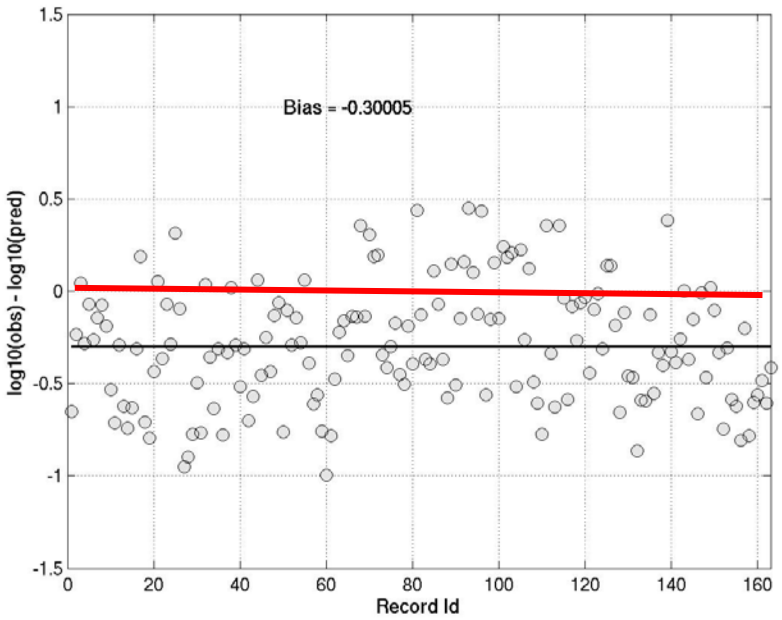
Ground types considered for residual plots

OVERALL BIAS



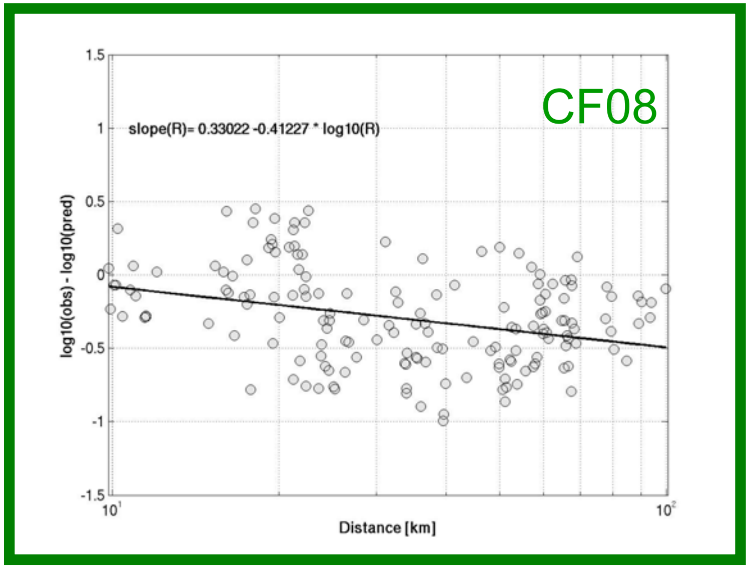
ITA08 = - 0.31

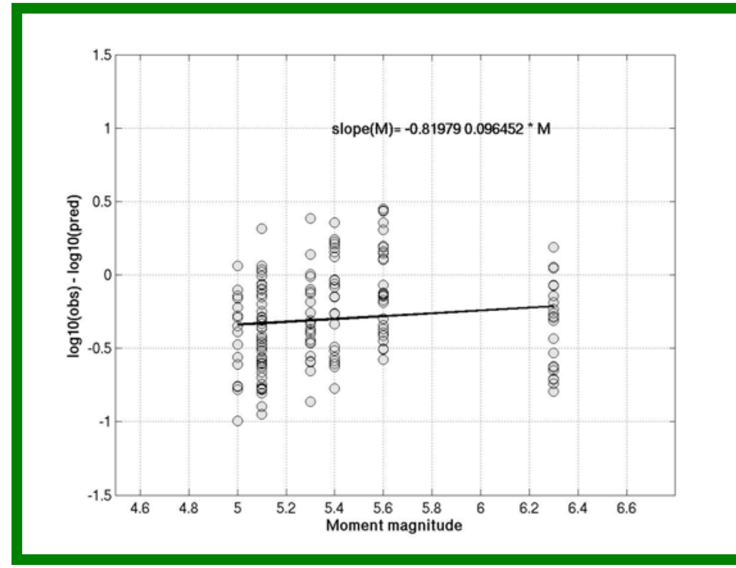
The observed ground motion is over-estimated by the National and Global GMPEs

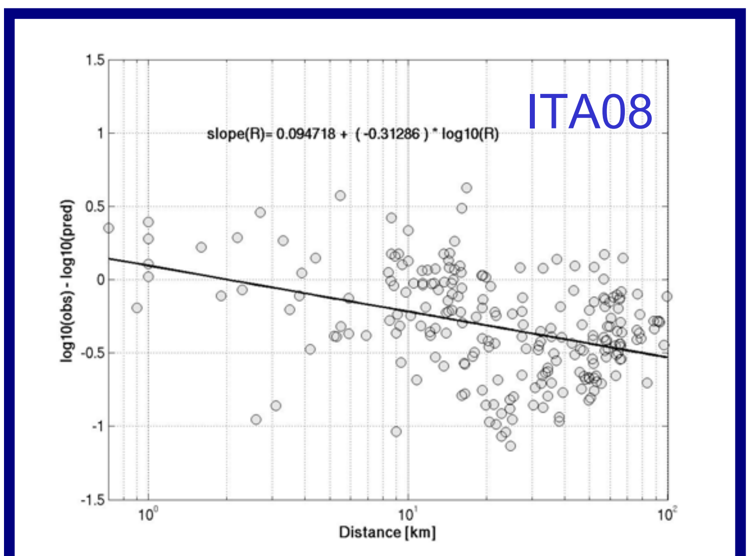


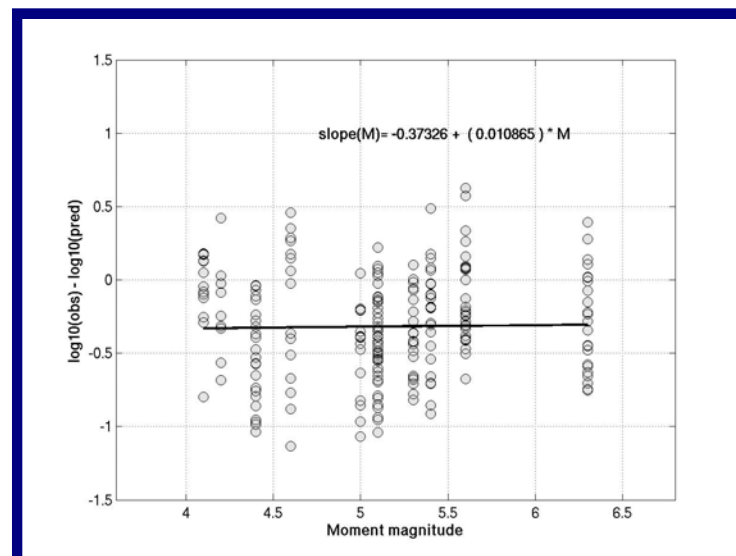
CF08 = - 0.30

Dependence on M and R









COMMENTS

Near source data are under-estimated by GMPEs but, globally, the GMPEs overestimate the Abruzzo ground motions

The complexity of the problem cannot, of course, be simply solved within the S-Projects and specific studies should be devoted to this topic as in recent or future international projects

(e.g., PEER-NGA project, 2008 and the ongoing GEM and SHARE projects)

An Overview of the NGA Project

Maurice Power,[a] M.EERI, Brian Chiou,[b] Norman Abrahamson,[c] M.EERI,
Yousef Bozorgnia,[d] M.EERI, Thomas Shantz,[b]
and Clifford Roblee,[b] M.EERI

Scope

The objective of the project is to develop new ground motion prediction relations through a comprehensive and highly interactive research program.

Requirements

Parameters, Ground motion components, Seismotectonic enviroment, Moment magnitude, distance, Focal Mechanism, distance range; common classification schemes

Dataset

The development of the NGA models would not have been possible without the PEER-NGA database.

NGA PROJECT - GMPEs

5 sets of ground-motion models were developed for shallow crustal earthquakesin the western United States and similar active tectonic regions.

The models were developed for wider ranges of magnitudes, distances, site conditions,

The NGA models were in terms of the average horizontal component of ground motion.

Each NGA developer team developed its model independently but with frequent interaction with the other developers

EUROPEAN PROJECTS-SHARE

1. Derive and characterize ground shaking in Europe for specified rock-conditions, with the corresponding calibrations for application to different soil classes in Europe.

2. Coordinate the ground-motion specifications with the EC8 requirements.

3. Build a European-wide consensus on the understanding of expected strong ground motions.

EUROPEAN PROJECTS - GEM

Requests for Proposals

T1.Define a consistent strategy and methodological approach to model ground motion in areas of different tectonic regime and different rate of earthquake occurrence, and to characterize rock conditions and soil classes, compatible with existing classification schemes

T2. Compile and critically review recent GMPE models, including NGA□type models, with the aim of building a global compilation.

T3. Select or derive a global set of GMPE models to cover the main tectonic environments.

T4. Derive a set of specific Ground Motion Prediction Equations to address the issue of near fault strong ground motions……*more*

Criteria to select GMPEs (from S2)

It is not strictly necessary that the S Projects use the same GMPEs, but compiling a list of *preferable - suggested consolidated* - models for strong ground motion prediction is advisable.

- **Should be recent.**
- **Should represent a notable improvement** with respect to previous models by the same authors or for the same region.
- **Should be developed on the basis of large datasets**
- **Should include terms describing the influence of local ground categories.**
- **Should include style-of-faulting terms (if not, the motivations for neglecting such effects should be documented by the authors)**
- **Should deal with response spectral ordinates,**
- **Should reliably cover a broad vibration period range**

CONCLUSION

A product of the workshop held in June 2009 will be a critical review of the existing GMPEs used in the S-Projects, provided with their limits of applicability to have a clear frame of reference about the models that can be adopted in Italy for ground motion predictions.

N°		R-range type.	M-range type	M dep geom. att	Anel. term	Style of faulting	H comp.	f–range	N° recs.	Area
1	**Akkar & Bommer EESD (2007)**	1-100 km R_{jb}	5.0-7.6 Mw	Y	N	strike-slip, normal, reverse **(scale fact. incl.)**	geom. mean	0.25 -20 Hz	532	Europe Middle East 1973-2003
2	**Bommer et al. BSSA (2007)**	1-100 km R_{jb}	3.0-7.6 Mw	Y	N	strike-slip, normal, reverse **(scale fact. incl.)**	geom. mean	2 -20 Hz	997	Europe Middle East 1973-2003
3	**ITA08 Bindi et al BEE (2009)**	3-100 km R_{jb} (Mw>5.5) R_{epi}(Mw≤5.5)	4.0-6.9 Mw	Y	N	strike-slip, normal, reverse **(scale fact. incl.)**	larger PGA	0.5 -33 Hz	561	Italy 1972-2007
4	**Di Alessandro, Rovelli et al. ?? 2009**	? R_{hypo}	? Mw	Y	Y	?	?	?	?	Italy (site class based on Fo)
5	**Malagnini et al. GRL (2008)**	10-200 km R_{hypo}	2.0-6.0 Mw	Y	Y	normal	both	PGA, PGV 0.3, 1, 3.3 HZ		Central Italy Seimograms, Brune model, RVT
6	**Cauzzi Faccioli J. Seism (2008)**	5-150 km R_{hypo}	5.0-7.2 Mw	N	N	Not considered	both	0.05 -20 Hz Disp. sp	1155	Worldwide DIGITAL (82% K-NET) 1995-2005
7	**Boore and Atkinson NGA (2008)**	0 - 400 km R_{jb}	4.2-7.9 Mw	Y	N	strike-slip, normal, reverse **(scale fact. incl.)**	geom. mean	0.1-100 Hz	1574.	World (NGA), mainly WNA and Taiwan 1940-2007

From Sabetta 2009