Milan, 26 June 2009

SITE CLASSIFICATION BASED ON SITE PREDOMINANT PERIOD (Project S4, Tasks 4 and 5)

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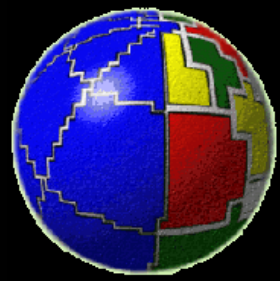
and Antonio Rovelli



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AN ALTERNATIVE SITE CLASSIFICATION OF ITALIAN STATIONS (Task 5)

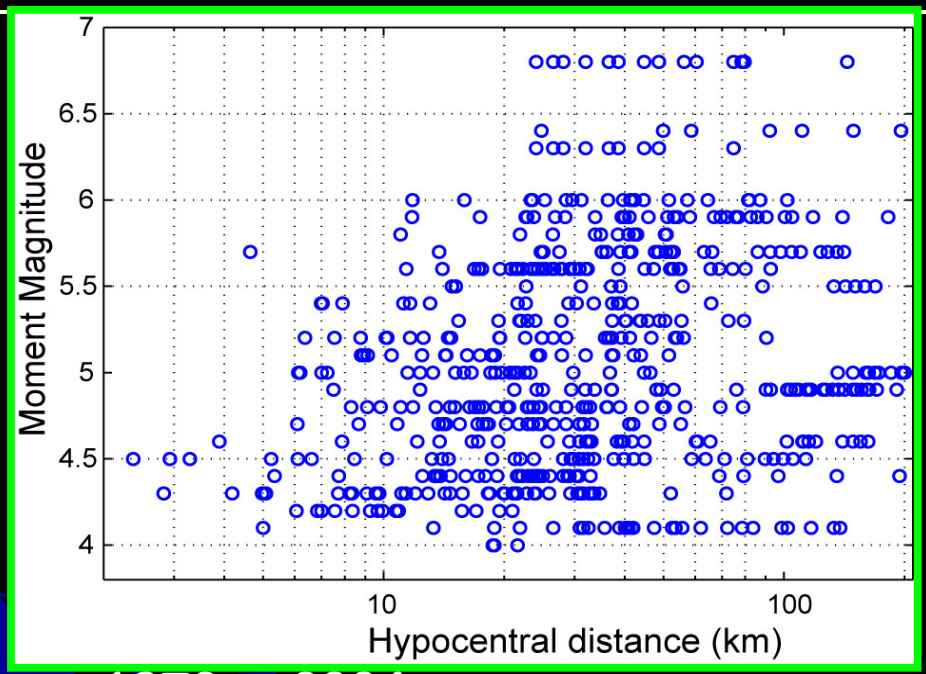
Do the site classes lead to well determined distinction in the amplification as a function of period?

Does this allow an identification of statistically lower/larger strength events or sites?

Does the new classification reduce the variance of the EMPIRICAL GROUND-MOTION PREDICTION EQUATIONS (GMPEs) compared to the conventional one?

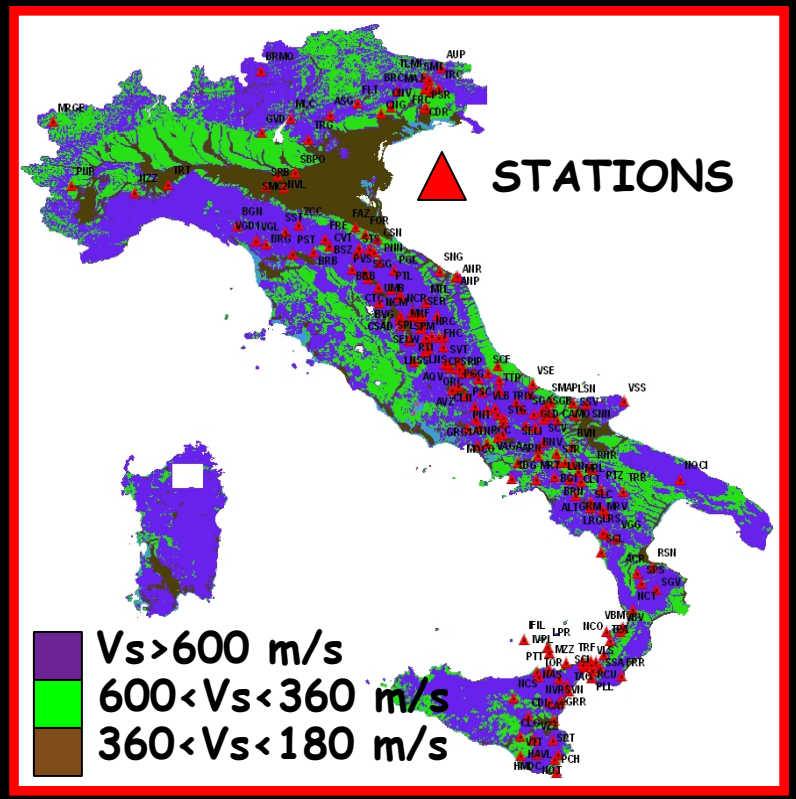
DATA-SET ANALYSIS

EVENTS SELECTION



120 EVENTS

602 RECORDS
(each with 3 components)



1972 - 2004 Complete Selection

2005 - 2008 Arbitrary Selection

4.0 < Mw < 6.8

2 < R_Ipo (km) < 200

214 STAZIONS

DATA-SET ANALYSIS

RESPONSE SPECTRA and AVERAGE H/V

- **SIGNAL CORRECTION**

  High-Pass Acausal Butterworth Filter (F cut max 0.35 Hz)

- **RESPONSE SPECTRA COMPUTATION**

- **H/V RATIO**

$$\frac{\text{Horizontal Components geometric mean}}{\text{Vertical Component}}$$

- **AVERAGE H/V RATIO FOR EACH STATION**

  Computation of GEOMETRIC MEAN and STANDARD DEVIATION

111 STATIONS

SITE CLASSIFICATION

STATE OF THE ART

Based on PREDOMINANT PERIOD of H/V SA ratios

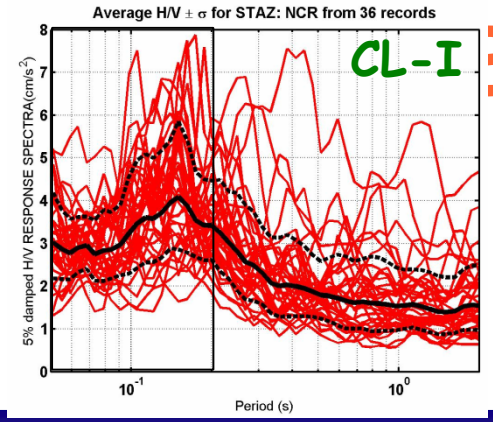
ZHAO et al. (2006)

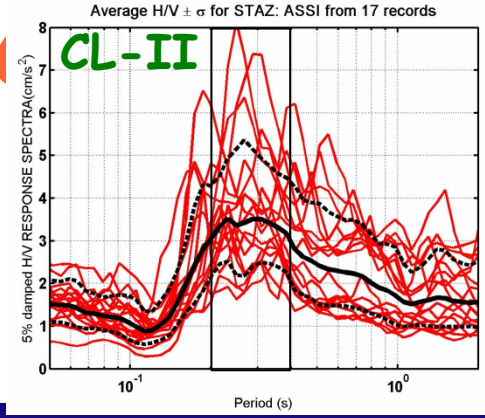
JAPAN ROAD ASSOCIATION

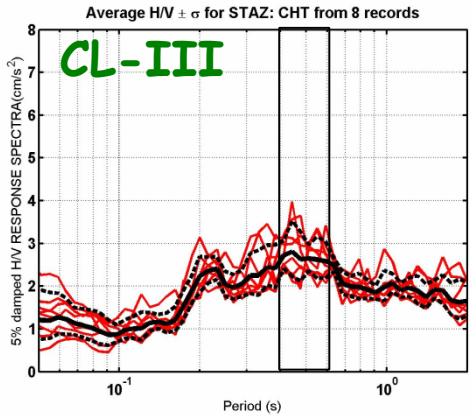
CAT.	PERIOD T (sec)
SCI	T < 0.2
SCII	0.2 <= T < 0.4
SCIII	0.4 <= T < 0.6
SCIV	T >= 0.6

FUKUSHIMA et al. (2007)

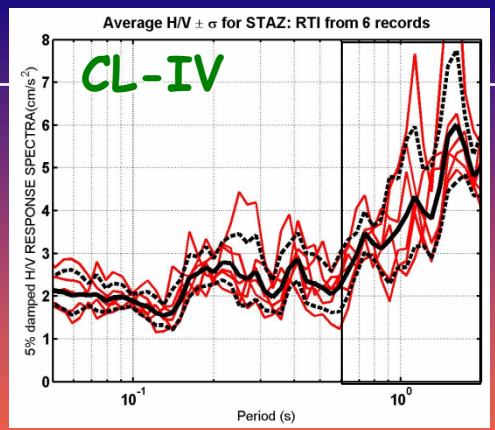
CAT.	PERIOD T (sec)
SC1	T < 0.2
SC2	0.2 <= T < 0.6
SC3	T >= 0.6
SC4	Generic Rock
SC5	Generic Soil

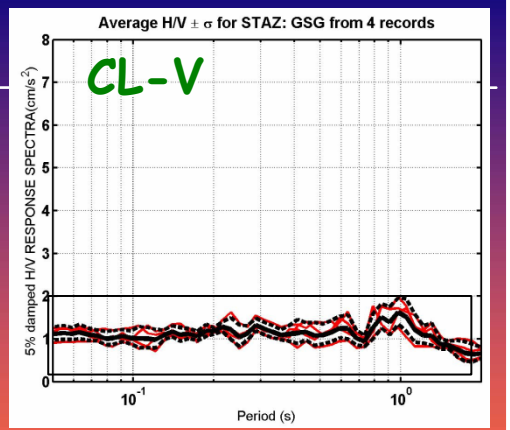


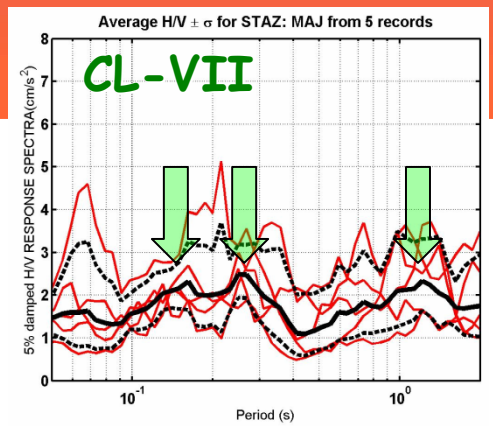


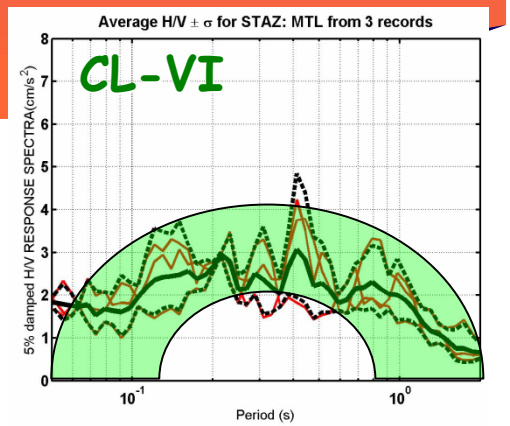


CAT.	PERIOD T (sec)
CL-I	T < 0.2
SCII	0.2 <= T < 0.4
SCIII	0.4 <= T < 0.6
SCIV	T >= 0.6
SCV	T unknown & flat H/V
SCVI	T unknown & broad amplification or multiple peaks @ T > 0.2 sec
SCVII	Unclassifiable









GMPE COMPUTATION

REGRESSION ANALYSIS

- COEFFICIENTS DERIVATION

Non linear period dependent regression with functional form:

$$\log_{10}(Sa(T)) = a(T) + b(T)M + c(T)M^2 + d(T)(R) - \log_{10}(R + e(T)10^{f(M)}) + S_j(T)\delta j$$

Sa(T) is the elastic response spectral acceleration for 5% damping

M = Moment Magnitude R = Hypocentral Distance

a, b, c, d, e and S_j, are period-dependent regression coefficients

j corresponds either to the PREDOMINANT PERIOD classes or to the simplified AB/CD classes (CEN 2000)

Combined Soil Classes	Average Shear-Wave Velocity (Vs30)	CEN Classes	NEHRP Classes
AB	Vs30 > 360 m/s	A & B	A, B, & C
CD	Vs30 < 360 m/s	C & D	D & E

$S_j(T)\delta j$ represents the individual site terms for all recording stations

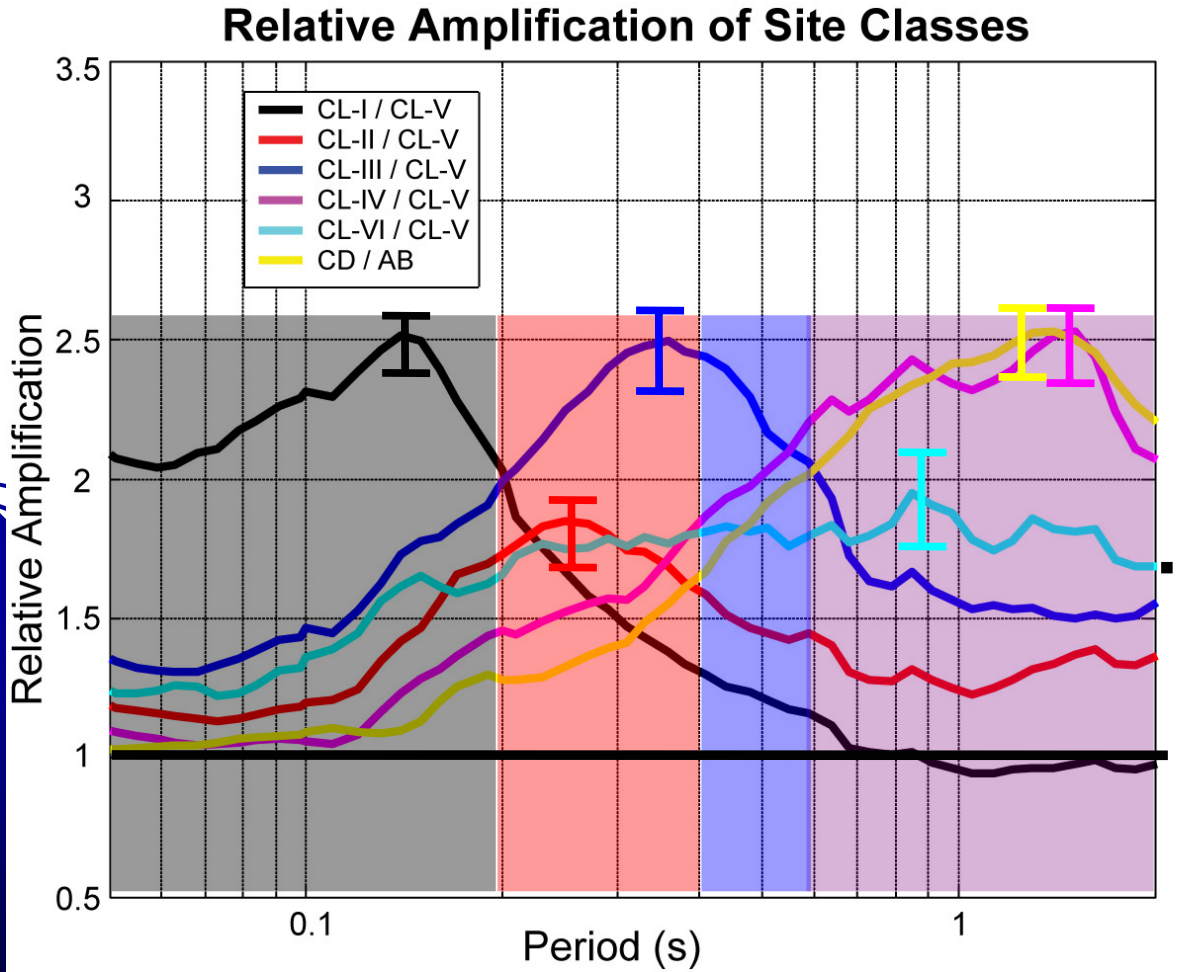
$S_j(T) = 0$ @ rock site (i.e. AB or CL-V sites)

$\delta j = \begin{cases} 1 \text{ @ jth site} \\ 0 \text{ otherwise} \end{cases}$

GMPE COMPUTATION

REGRESSION ANALYSIS

- RELATIVE AMPLIFICATION



CL-V as a reference class

Comparable amplification for CL-IV and CD at long period

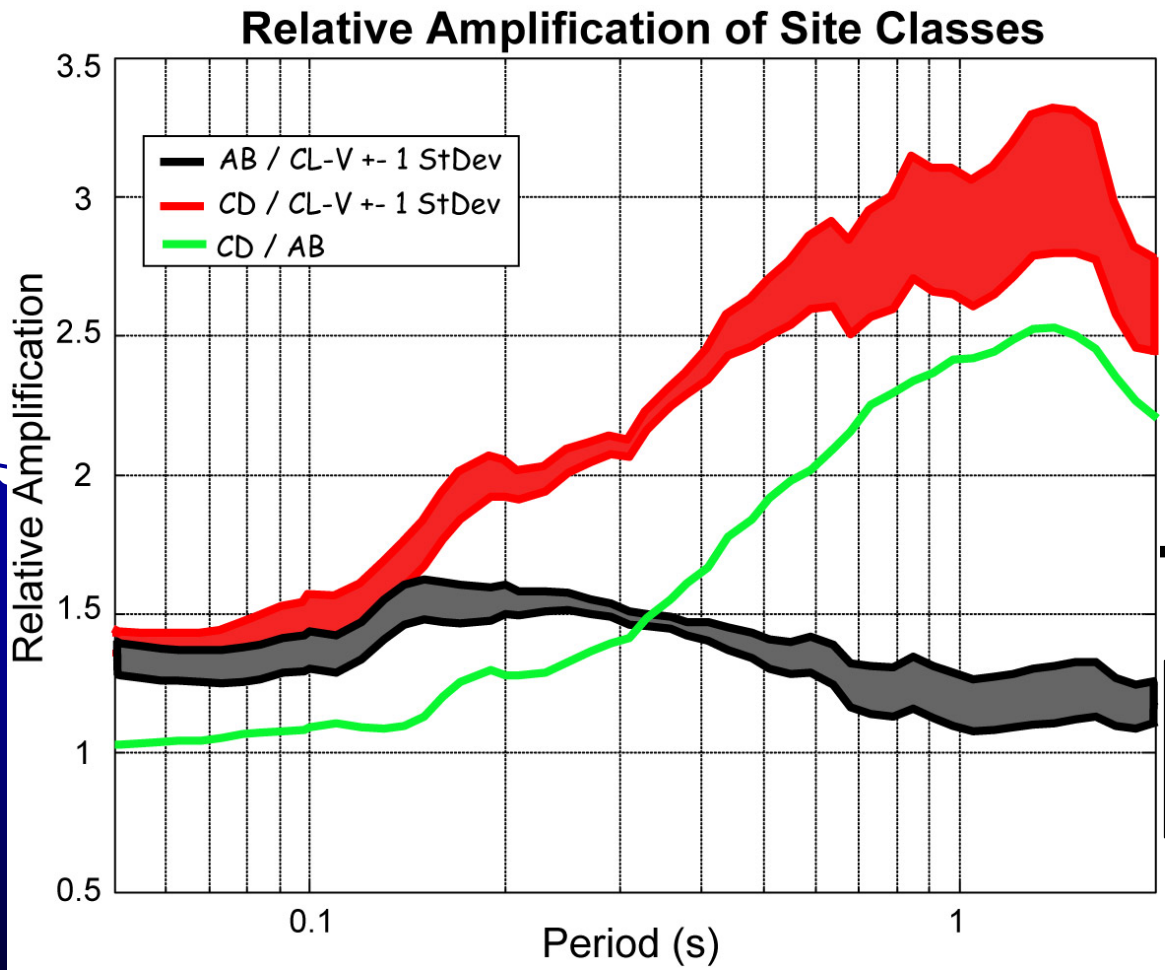
Distinct amplification for CL- I and CL-III at short period

Robust evaluation of relative amplification with standard error around 10%

GMPE COMPUTATION

REGRESSION ANALYSIS

- RELATIVE AMPLIFICATION



CL-V as a reference class

Average ± 1 σ
for different scenarios:

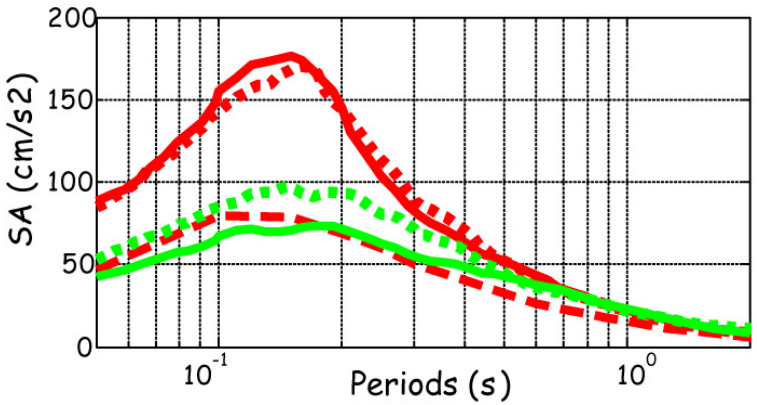
Mw : 4.0 – 6.8
R Hypo: 10 - 150

AB is amplified with respect to CL-V

CD/CL-V has higher amplification than CD/AB

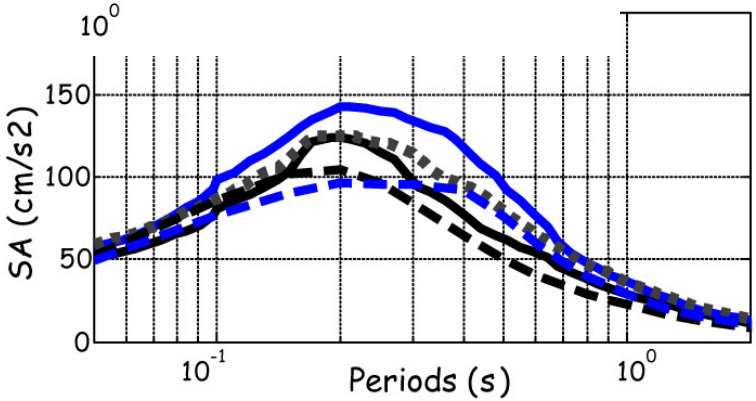
COMPARISON W/ OTHER GMPEs

BASED ON PREDOMINANT PERIOD

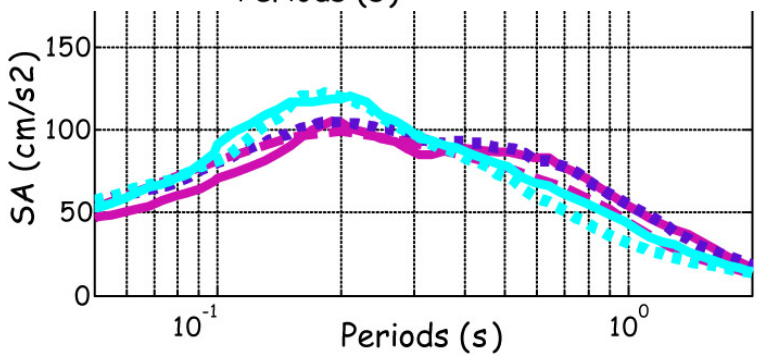


CL-I
Fukushima SC-1
Zhao SC-I
CL-V
Fukushima SC-4

Mw 6.0 R hypo 50 km



CL-II
CL-III
Fukushima SC-2
Zhao SC-II
Zhao SC-III



CL-IV
Fukushima SC-3
Zhao SC-IV
CL-VI
Fukushima SC-5

FUKUSHIMA

CA.T	PERIOD T (sec)
SC1	T < 0.2
SC2	0.2 <= T < 0.6
SC3	T >= 0.6
SC4	Generic Rock
SC5	Generic Soil

ZHAO

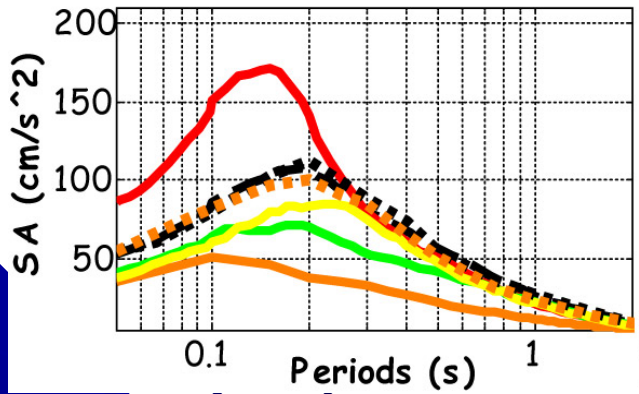
CAT.	PERIOD T (sec)
SCI	T < 0.2
SCII	0.2 <= T < 0.4
SCIII	0.4 <= T < 0.6
SCIV	T >= 0.6

COMPARISON W/ OTHER GMPEs

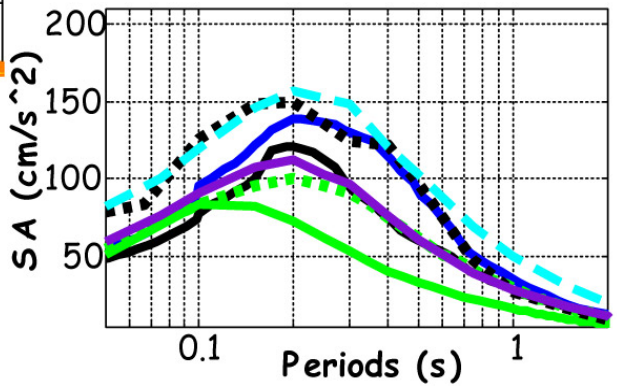
BASED ON CONVENTIONAL CLASSIFICATIONS

AB
CL-I
CL-V
Cauzzi & Faccioli '08 - A
Ambraseys '05 - Stiff
Sabetta & Pugliese '96 - Stiff
Boore & Atkinson '08 - Vs760 m/s

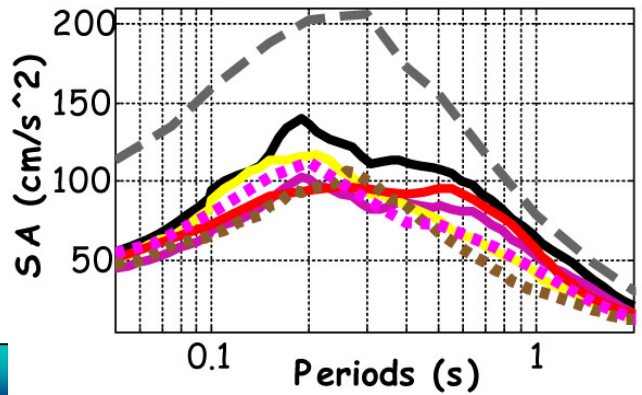
Mw 6.0 Rhypo 50 km



CL-II
CL-III
Cauzzi & Faccioli '08 - B
Cauzzi & Faccioli '08 - C
Sabetta & Pugliese '96 - Shallow soil
Boore & Atkinson '08 - Vs580 m/s
Boore & Atkinson '08 - Vs270 m/s



CD
CL-IV
CL-VI
Cauzzi & Faccioli '08 - D
Ambraseys '05 - Soft
Sabetta & Pugliese '96 - Deep soil
Boore & Atkinson '08 - Vs180 m/s



DISTANCE
Scherbaum et

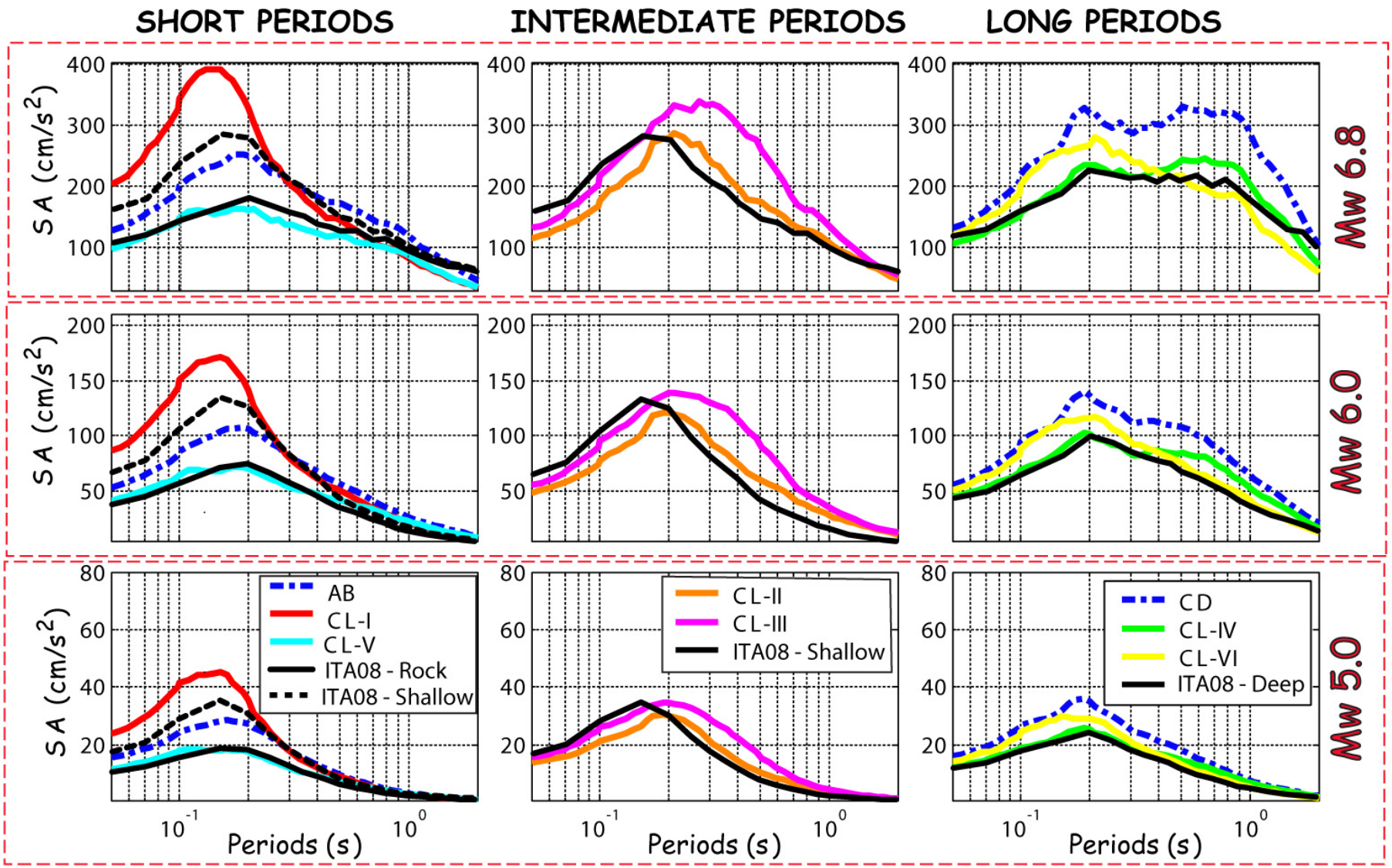
Ours and C&F '08

Amb '05 and B&A '08

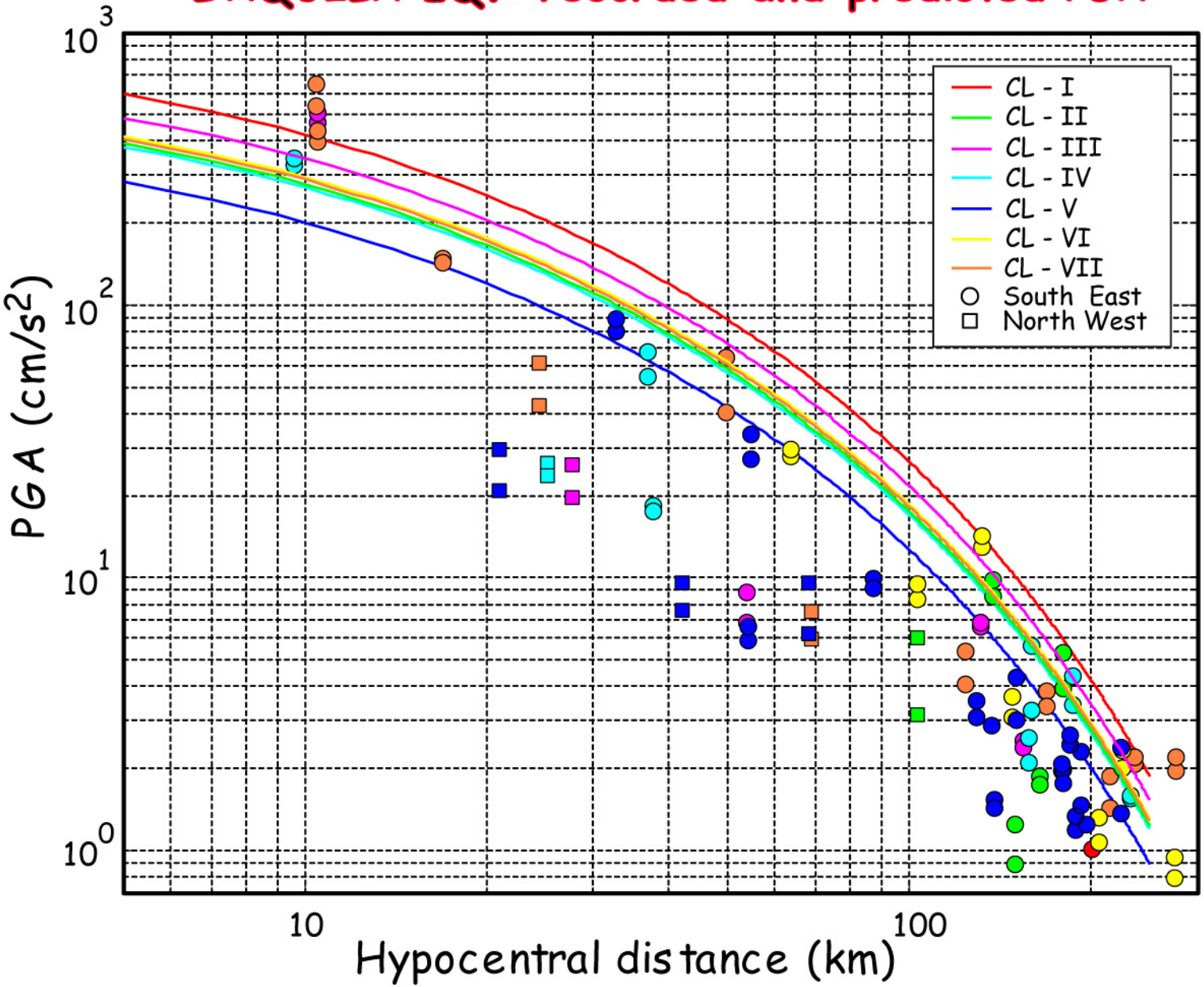
S&P '96

R_

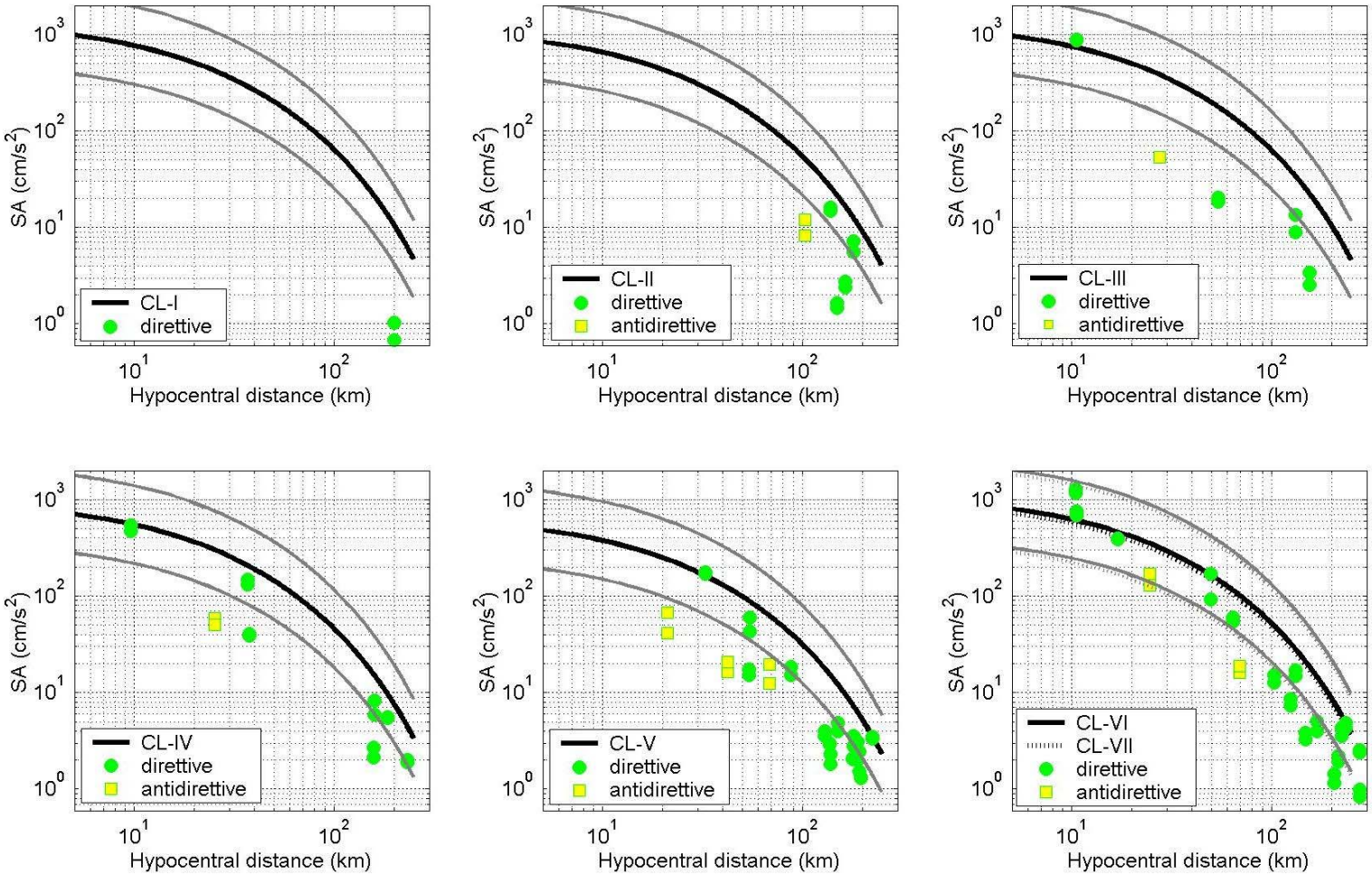
Rhypo 50 km


SHORT PERIODS
INTERMEDIATE PERIODS
LONG PERIODS
SA (cm/s²)
Mw 6.8
Mw 6.0
Mw 5.0
AB
CL-I
CL-V
ITA08 - Rock
ITA08 - Shallow
CL-II
CL-III
ITA08 - Shallow
CD
CL-IV
CL-VI
ITA08 - Deep
Periods (s)

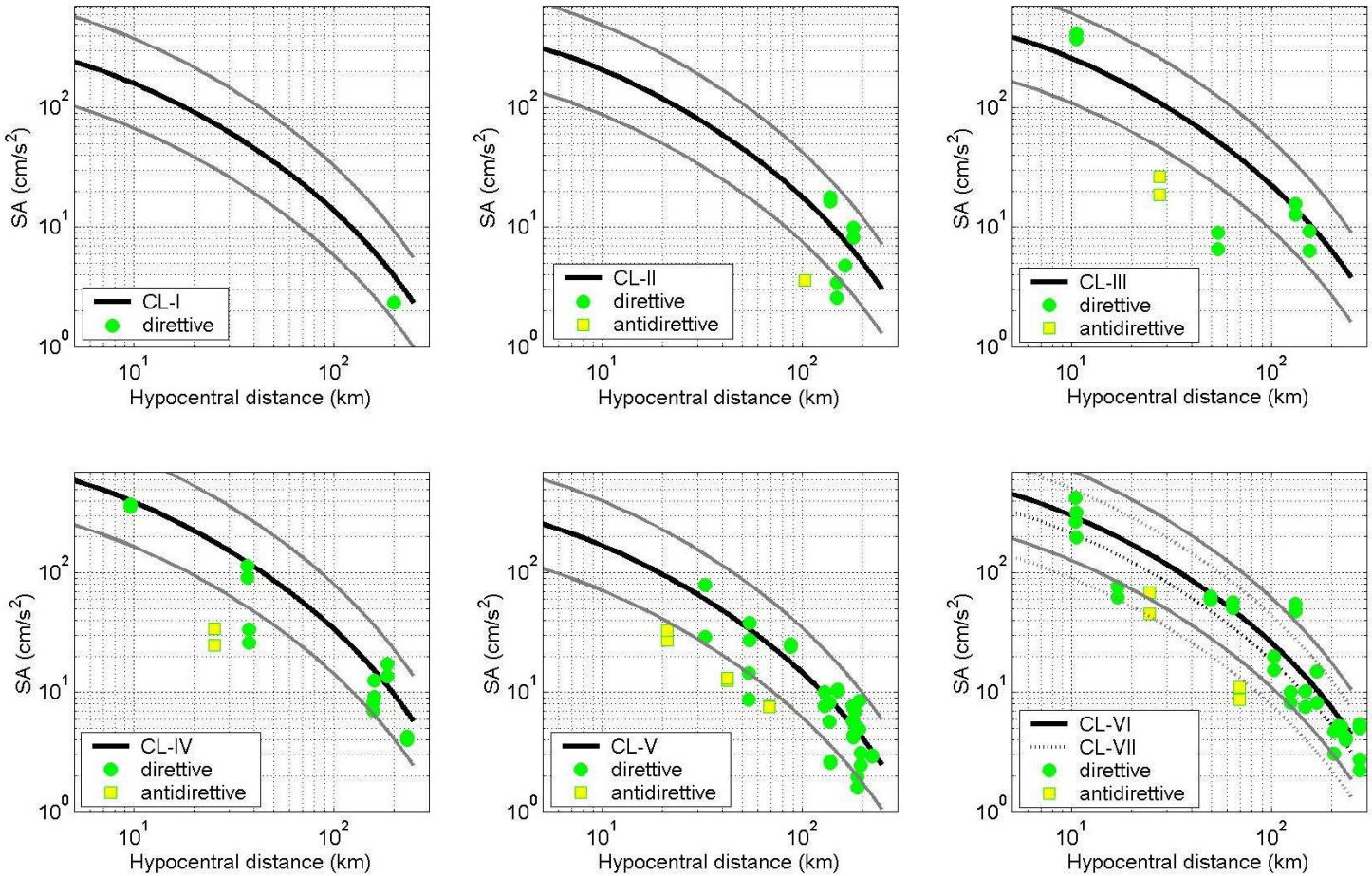
L'AQUILA EQ.: recorded and predicted PGA

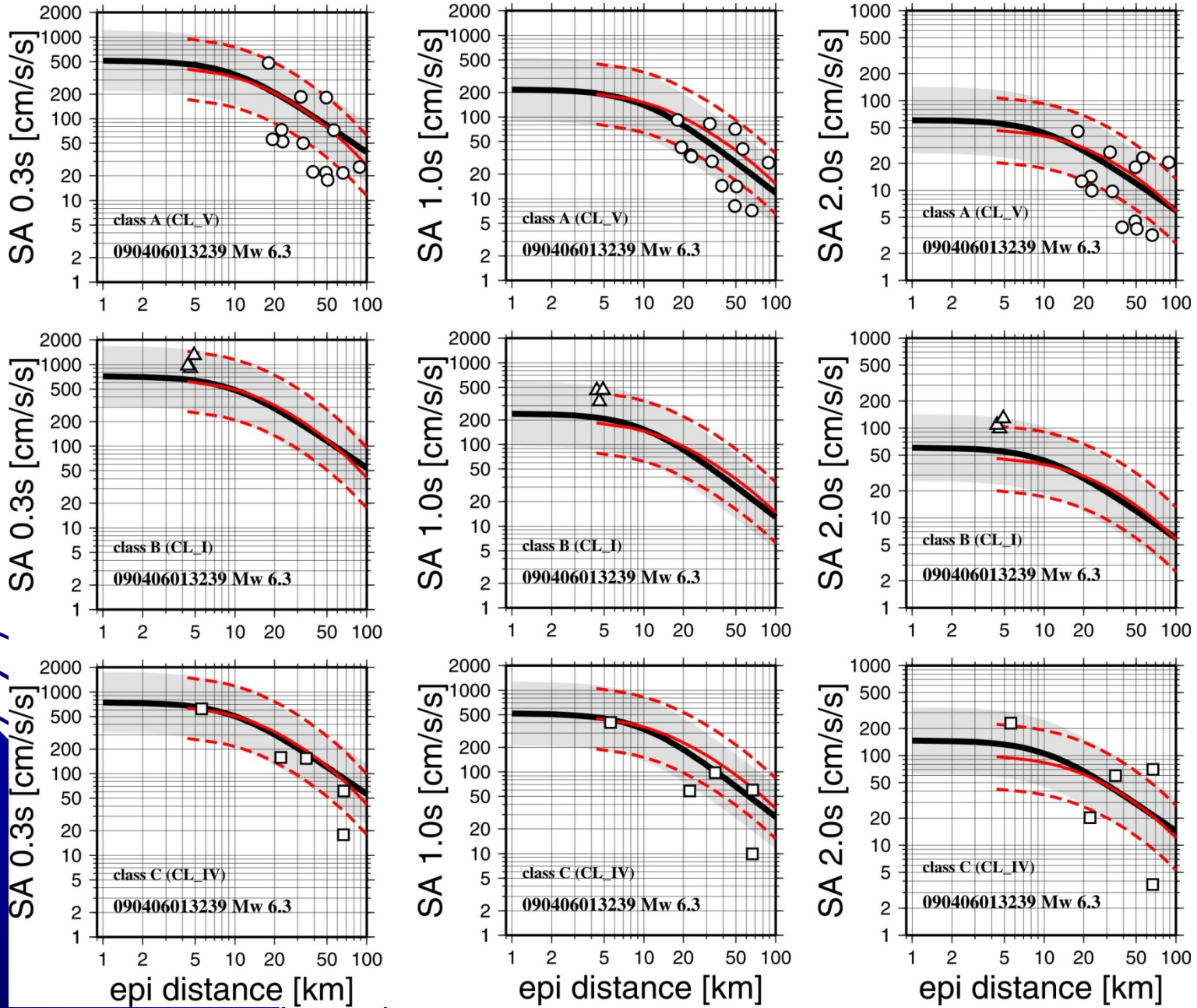


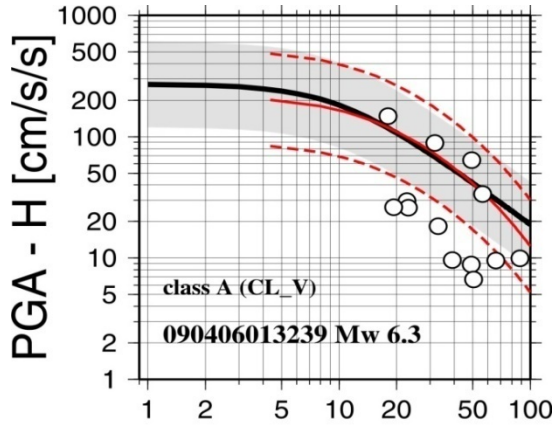
Comparison recorded and predicted SA @ 0.2 sec - Predominant period classes

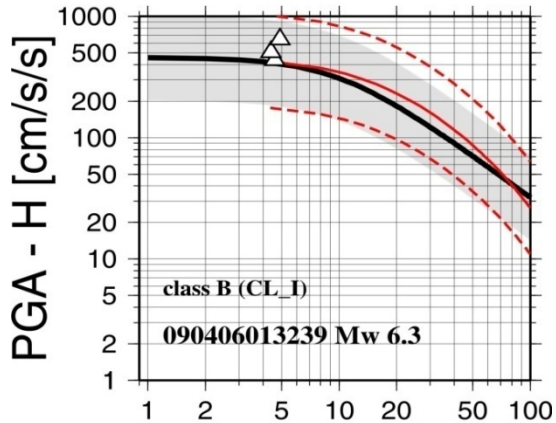


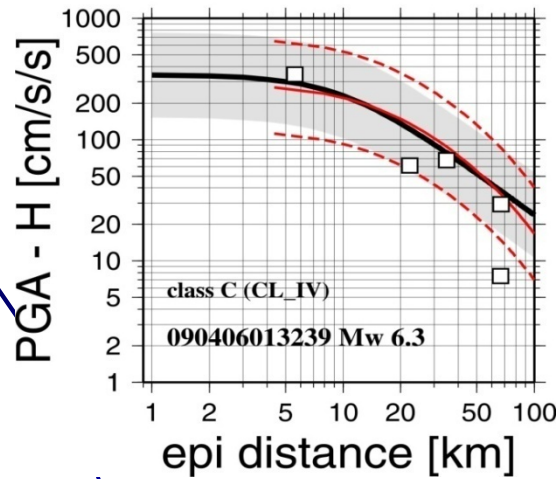
Comparison recorded and predicted SA @ 1.0 sec - Predominant period classes

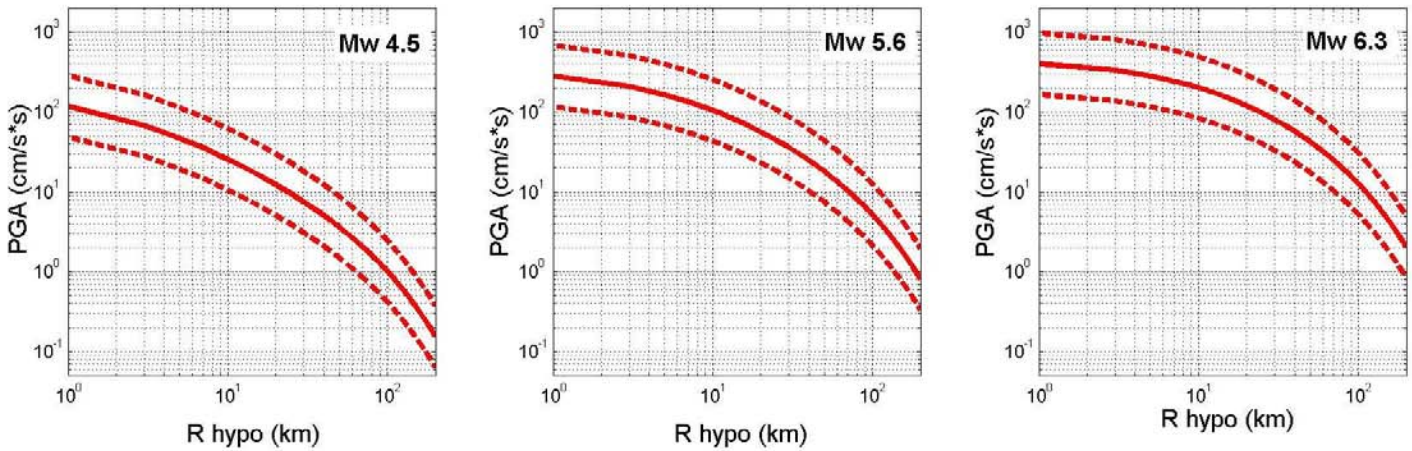


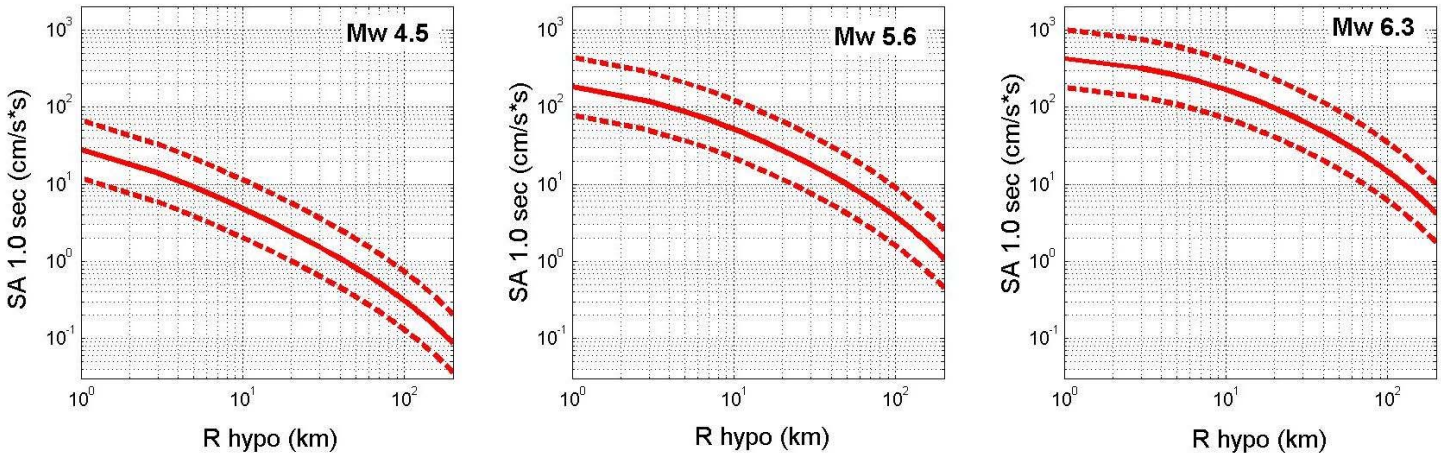

SA 0.3s [cm/s/s]
SA 1.0s [cm/s/s]
SA 2.0s [cm/s/s]
epi distance [km]
class A (CL_V)
class B (CL_I)
class C (CL_IV)
090406013239 Mw 6.3

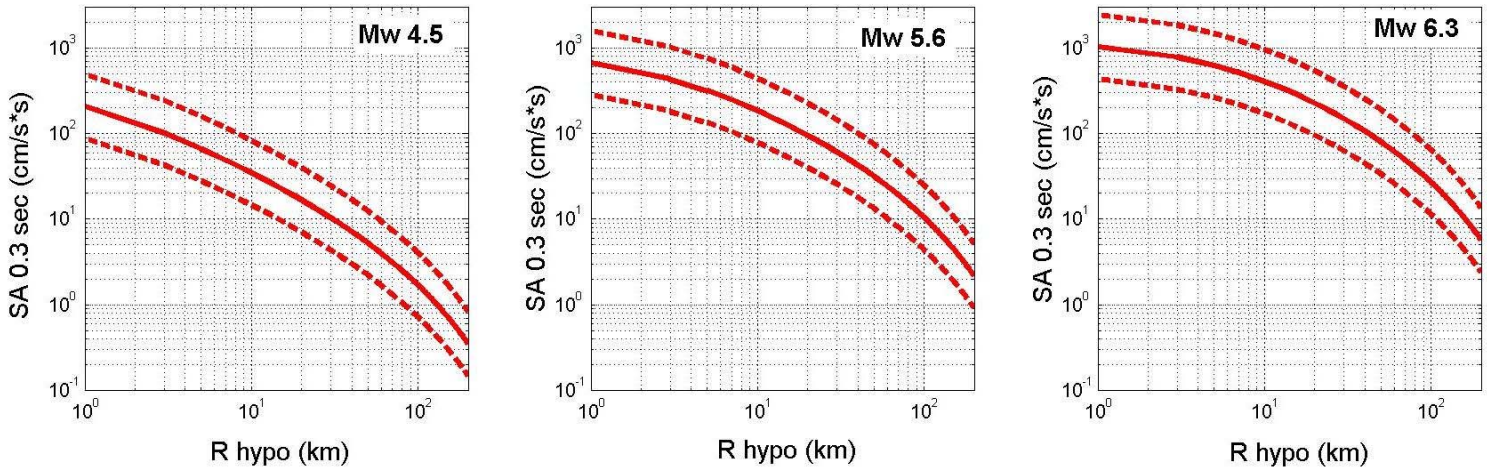

PGA - H [cm/s/s]
1000
500
200
100
50
20
10
5
2
1
1
2
5
10
20
50
100
class A (CL_V)
090406013239 Mw 6.3

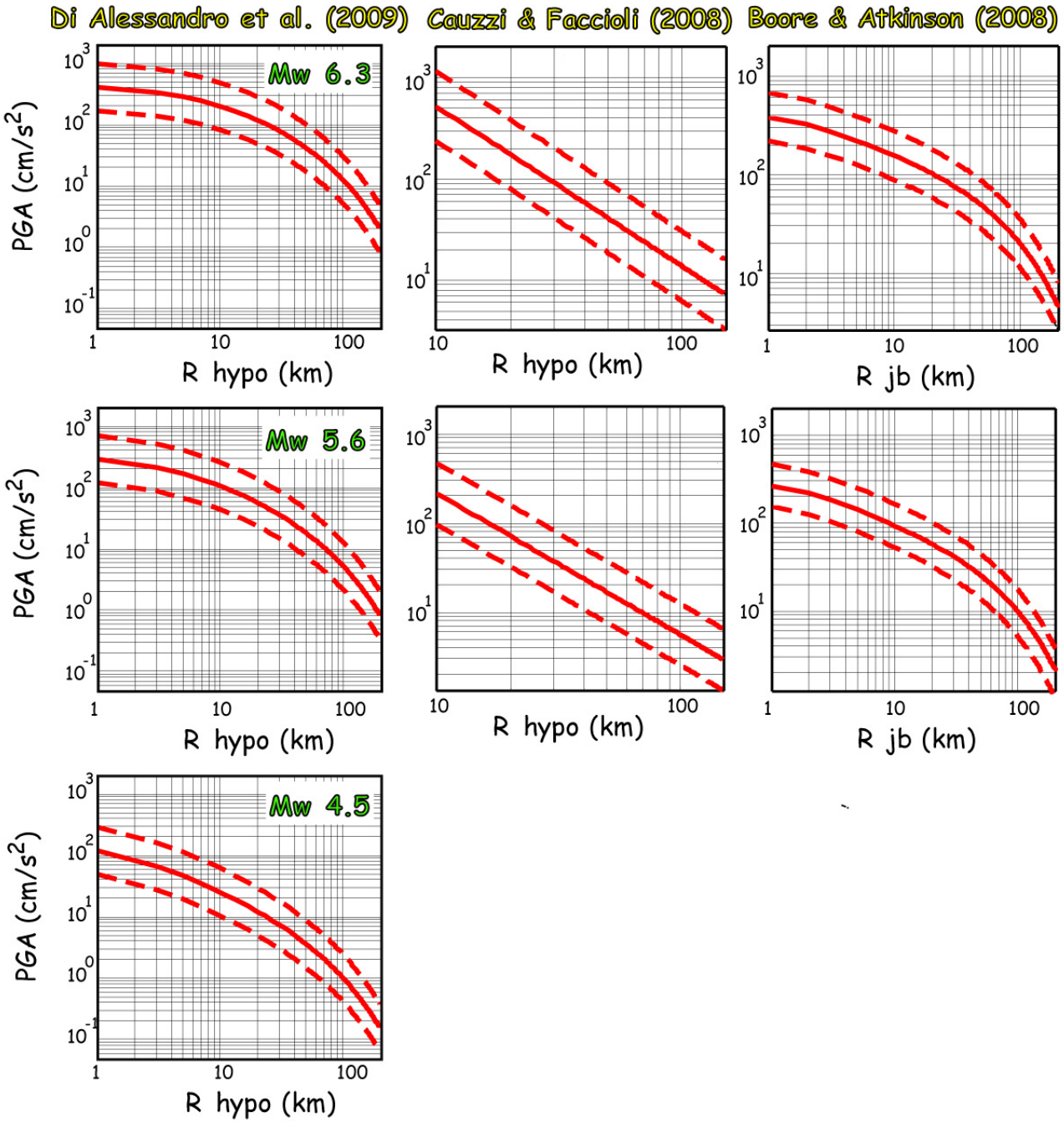

PGA - H [cm/s/s]
1000
500
200
100
50
20
10
5
2
1
1
2
5
10
20
50
100
class B (CL_I)
090406013239 Mw 6.3

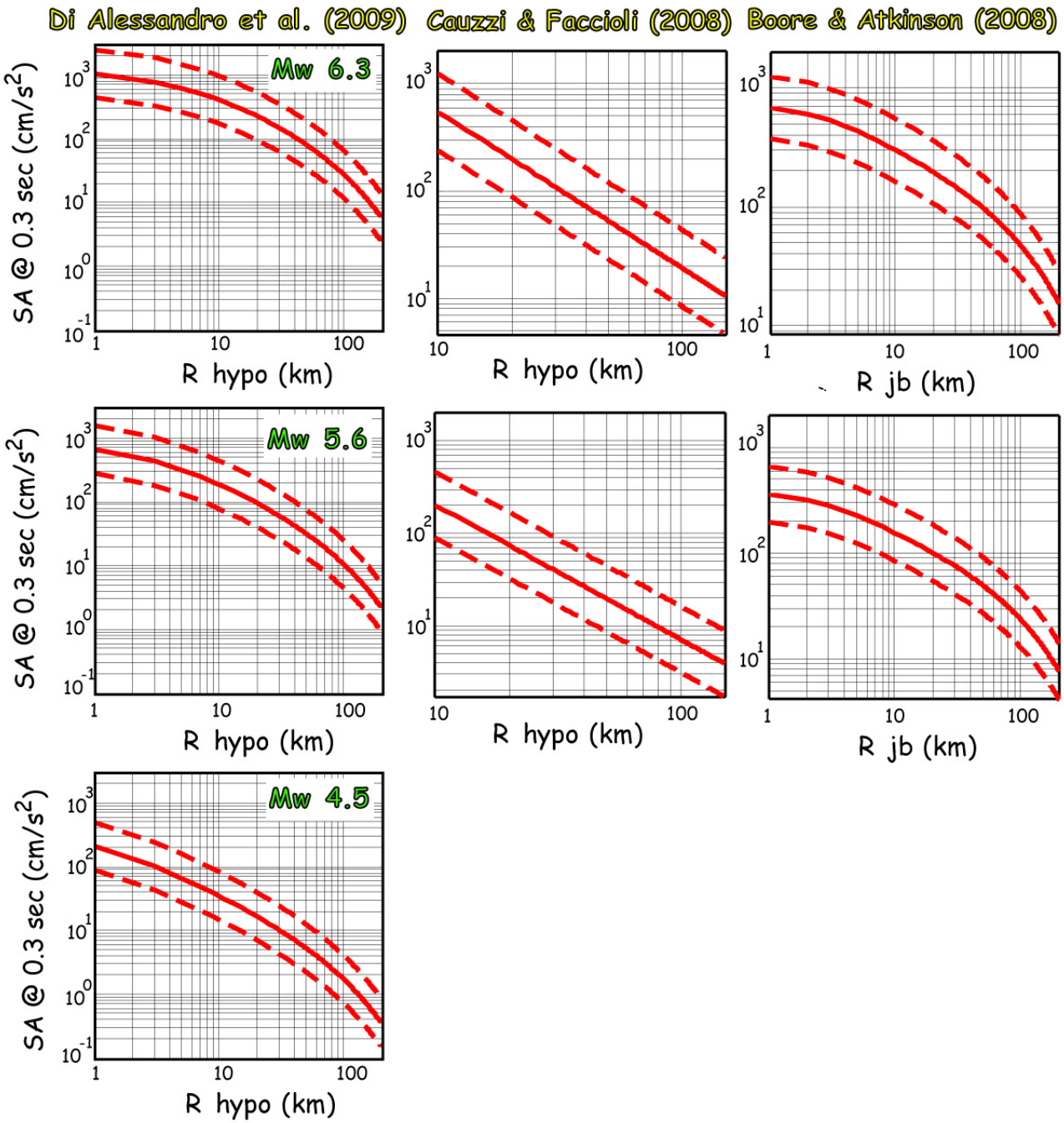

PGA - H [cm/s/s]
1000
500
200
100
50
20
10
5
2
1
1
2
5
10
20
50
100
class C (CL_IV)
090406013239 Mw 6.3
epi distance [km]

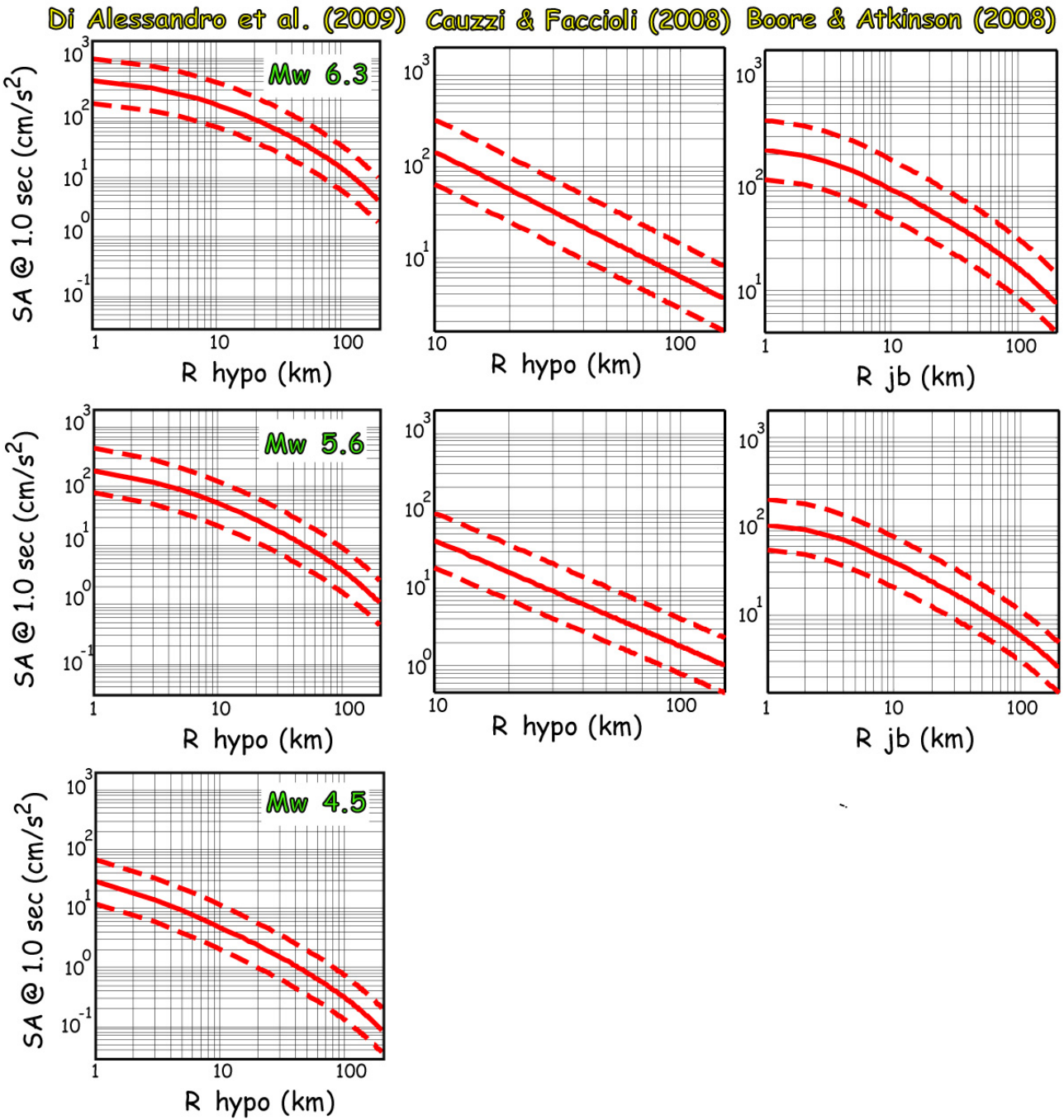

Mw 4.5
Mw 5.6
Mw 6.3
PGA (cm/s*s)
R hypo (km)


Mw 4.5
Mw 5.6
Mw 6.3
SA 1.0 sec (cm/s*s)
R hypo (km)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{0}
10^{1}
10^{2}


Mw 4.5
Mw 5.6
Mw 6.3
SA 0.3 sec (cm/s*s)
R hypo (km)
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


Di Alessandro et al. (2009)
Cauzzi & Faccioli (2008)
Boore & Atkinson (2008)
Mw 6.3
Mw 5.6
Mw 4.5
PGA (cm/s²)
R hypo (km)
R jb (km)


Di Alessandro et al. (2009)
Cauzzi & Faccioli (2008)
Boore & Atkinson (2008)
Mw 6.3
Mw 5.6
Mw 4.5
SA @ 0.3 sec (cm/s²)
R hypo (km)
R jb (km)


Di Alessandro et al. (2009)
Cauzzi & Faccioli (2008)
Boore & Atkinson (2008)
Mw 6.3
Mw 5.6
Mw 4.5
SA @ 1.0 sec (cm/s²)
R hypo (km)
R jb (km)