Ground Motion Prediction Equations derived from the Italian Accelerometric Archive (ITACA)

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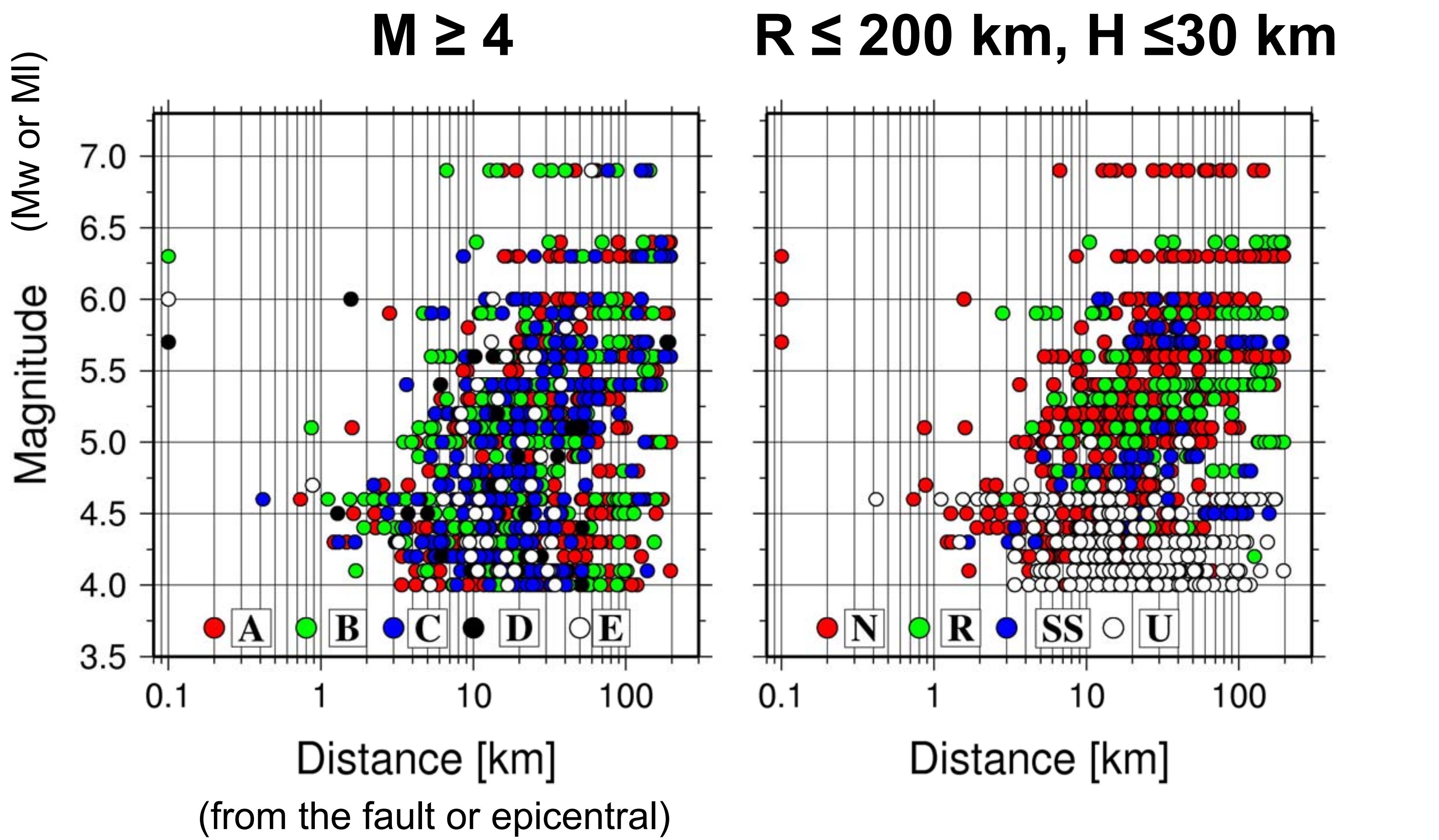
(on leave from RU1, INGV Milano-Pavia)

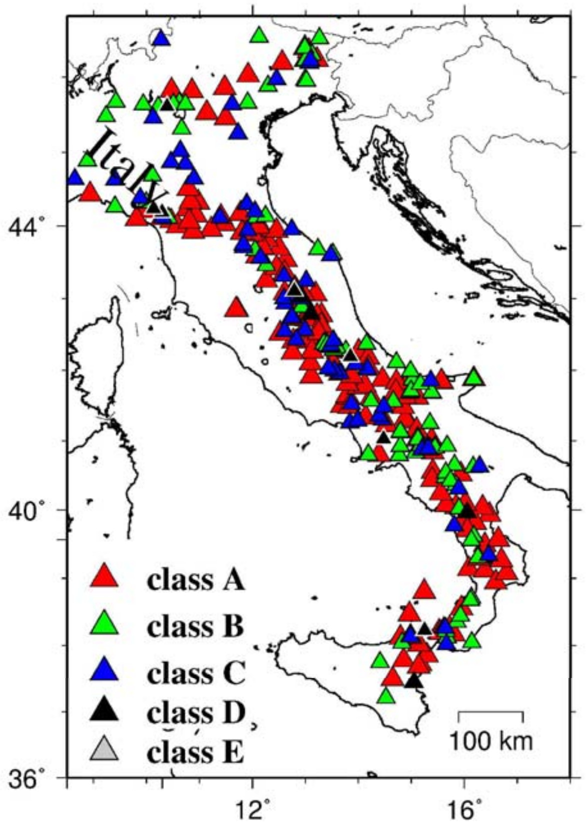
Outline

-Data selection and processing
-Model and regression method
-Results
-Future developments

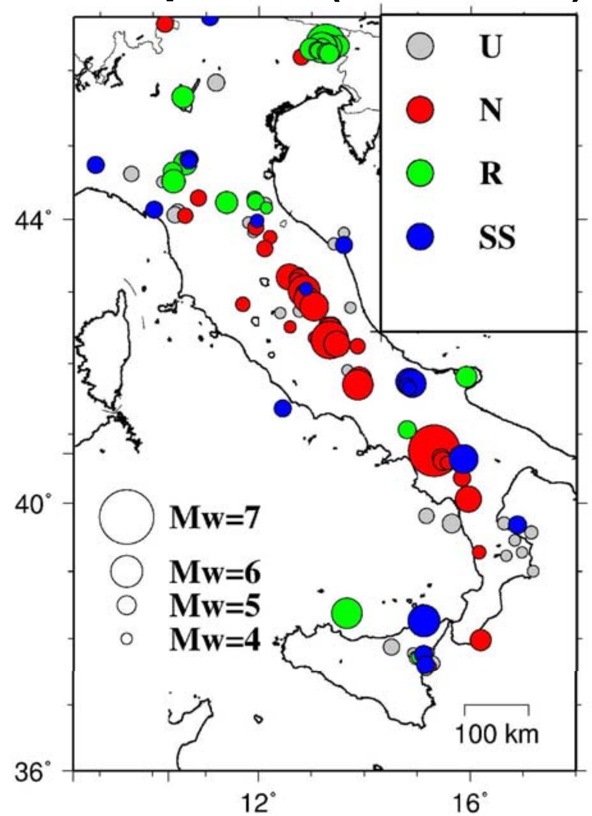


Data Method Results Developments

Stations



Earthquakes (1972-2009)



EC8-like

A: 524 records
B: 347
C: 260
D: 26
E: 56

N: 696 (4-6.9)
R: 145 (4.2-6.4)
SS: 87 (4.3-6)
U 285 (<5)

Analog 500 Digital 713 records

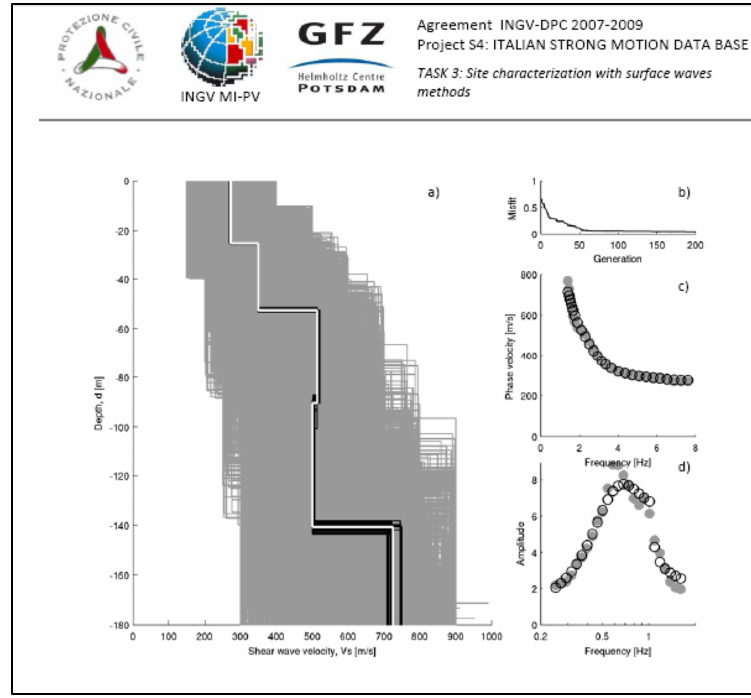
218 earthquakes and 1213 records

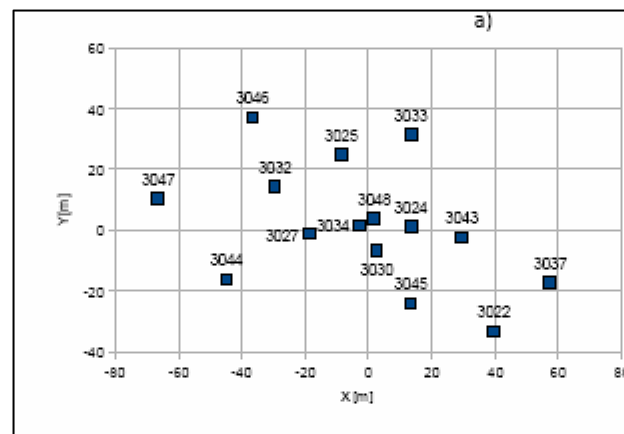
Qualified Meta-Data

Task 3
Application of surface-waves methods for seismic site characterization of ITACA stations
(S. Foti and S. Parolai)

Results described in Deliverable D7

10.00 -10.30: Seismic characterization of sites: new perspectives and recent experiences from project S4 (S. Foti)



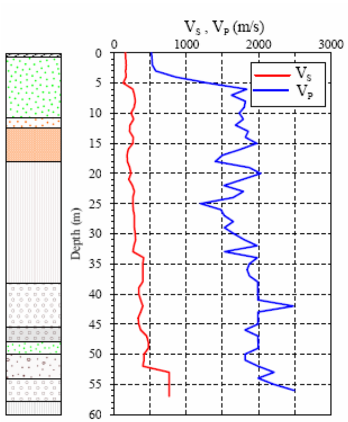


Data Method Results Developments

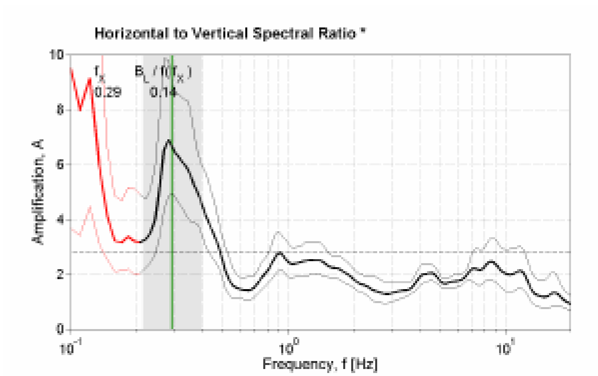
Qualified Meta-Data

Task 2:
Catalogue of geological/geotechnical information at accelerometer stations
(G.Di Capua, G. Lanzo)

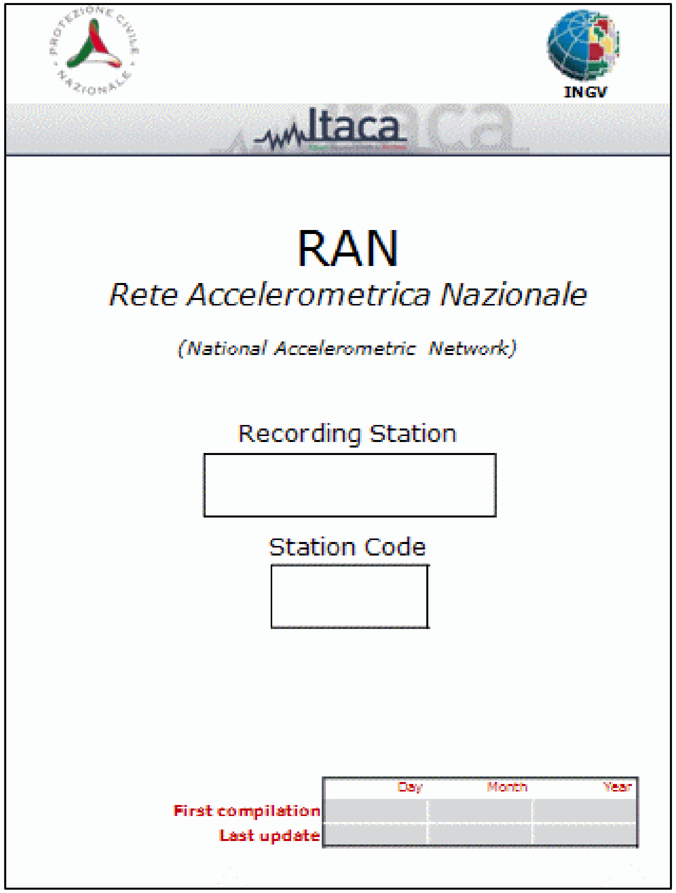
Results described in Deliverable D5, D10



131 $v_s(z)$



190 microtremor survey



Data Method Results Developments

Processing

Deliverable D15:
Record processing in ITACA
(R. Paolucci, F. Pacor)

Summary

1.1 ITACA processing scheme

The diagram block of the new procedure is illustrated in Fig. 1. Its basic steps are the followings:

- baseline correction (constant de-trending);
- application of a cosine taper, based on the visual inspection of the record (typically between 2% and 5% of the total record length); records identified as late-triggered are not tapered;
- visual inspection of the Fourier spectrum to select the band-pass frequency range; whenever feasible, the same range is selected for the 3-components;
- application of a 2nd order acausal frequency-domain Butterworth filter to the acceleration time-series;
- double-integration to obtain displacement time series;
- linear de-trending of displacement;
- double-differentiation to get the corrected acceleration.

Key points

-compatibility of all corrected records
-re-establish, after filtering, the original time scale (whenever feasible)
-late triggered records are tagged and an ad-hoc procedure applied
-comparisons with records from other sources (ESMDB, CESMD, PEER)

Model

$$\log_{10} Y = a + f(M) + g(R) + e_i S_i + f_j F_j$$

(e.g. Boore and Atkinson, 2008)

$$f(M) = \begin{cases} b_1(M - M_h) + b_2(M - M_h)^2 & M \le M_h \\ b_3(M - M_h) & M > M_h \end{cases}$$

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

Model

$$\log_{10} Y = a + f(M) + g(R) + e_i S_i + f_j F_j$$

Explanatory variables: Mw, R_{JB}, style of faulting and site classifications (only linear site terms)

Response variables Y: PGA, PGV, SA (5%, 0.04≤T≤ 4sec)

Components: GeoMean of the horizontal components; vertical component

Fixed parameters:

Mref=5 Rref=1 km

Mh=6.75

Random effect model (e.g. Abrahamson and Youngs, 1992)

$$y_{ik} = \mu_{ik}(M_i, R_{ik}, \ldots, V_{S30}) + \eta_i + \xi_{ik}$$

Observation — Median prediction — Error distributions

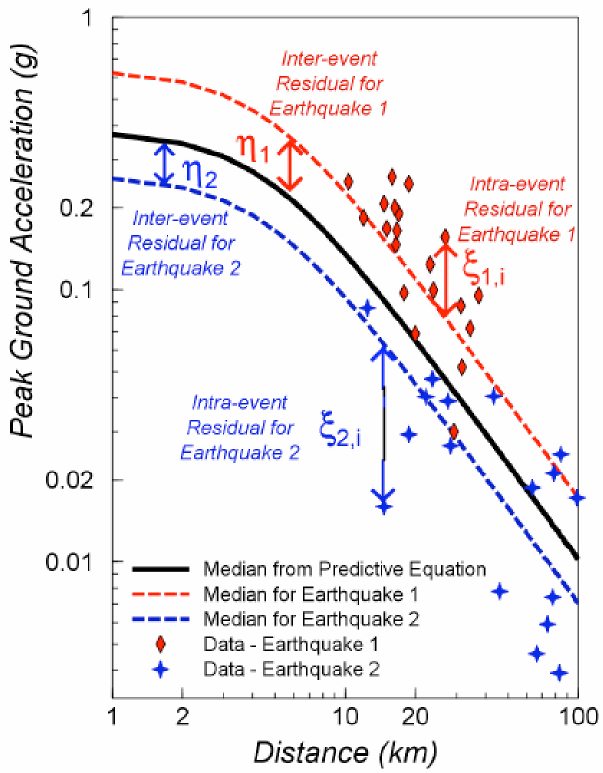
Earthquake *i* recorded at station *k*

Inter-event distribution of error η: it assumes a value for each earthquake and describes the correlation among the errors for different recordings of the same earthquake. It is a normal distribution with standard deviation equal to τ

Intra-event distribution of error ξ: it assumes a value for each recording.

It is a normal distribution with standard deviation equal to σ**.** The error distributions η and ξ are assumed to be independent.

Random effect model (e.g. Abrahamson and Youngs, 1992)



Strasser *et al.* (2009)

$$\sigma_T = \sqrt{\tau^2 + \sigma^2}$$

σ_T is the total variability

τ is the inter-event (earthquake-to-earthquake) variability

σ is the intra-event (record-to-record) variability

Data **Method** Results Developments

Random effect model (e.g. Abrahamson and Youngs, 1992)

$$\log_{10} Y_{ik} = \Gamma(M_i, R_{ik}, S_k, F_i; \mathbf{x}) + \eta_i + \xi_{ik}$$

Inter-event (η_i)

$$\log_{10} Y_{ik} = \Gamma(M_i, R_{ik}, S_k, F_i; \mathbf{x}) + \theta_k + \xi'_{ik}$$

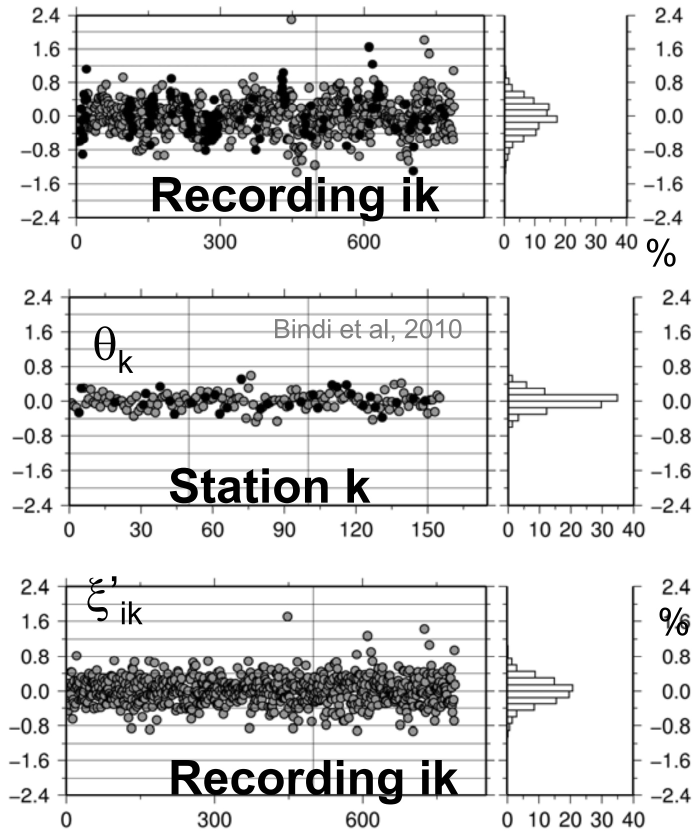
Inter-station (θ_k)

$$\sigma = \sqrt{\sigma_{eve}^2 + \sigma_{sta}^2 + \sigma_{rec-rec}^2}$$

$$residual_{ik} = y_{ik} - \mu_{ik}(M_i, R_{ik}, ..., V_{S30}) = \theta_k + \xi'_{ik}$$

Error distributions

$$Residual_{ik} = \theta_k + \xi'_{ik}$$



$$\sigma_{tot}^2 = 0.16763 = \delta^2 = 0.05867 + \sigma'^2 = 0.10896$$

variances

SA at 1.75 s

Results: coefficients

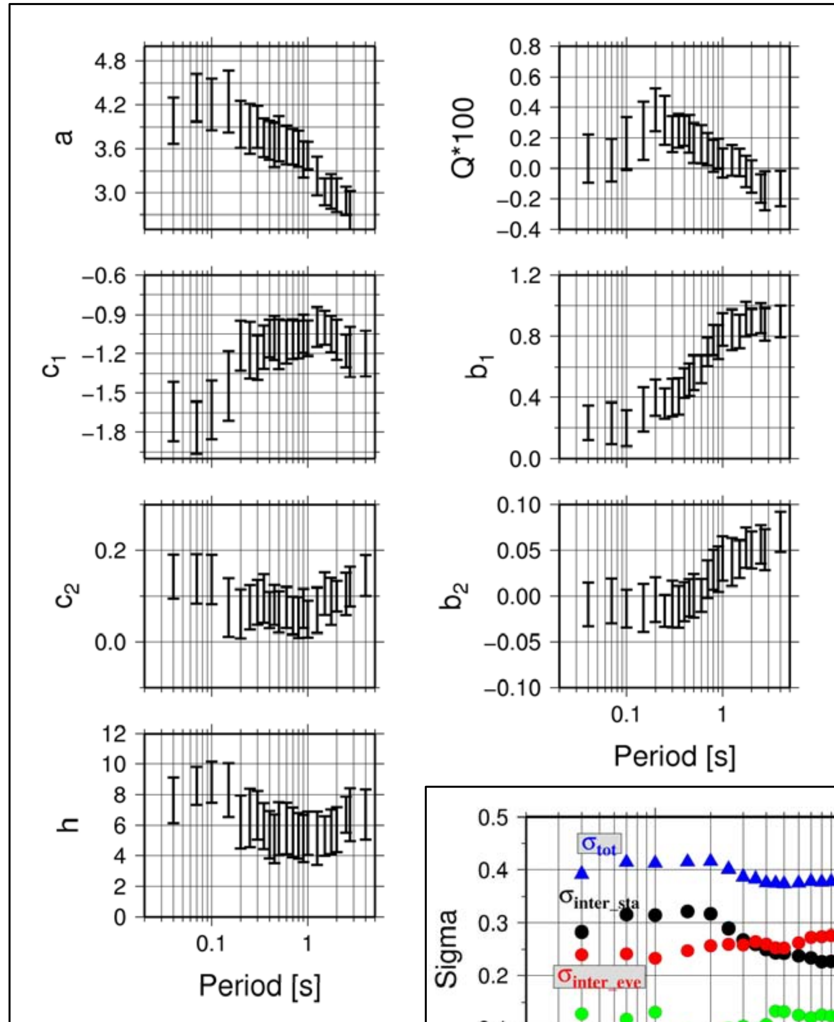
Applied Constraints

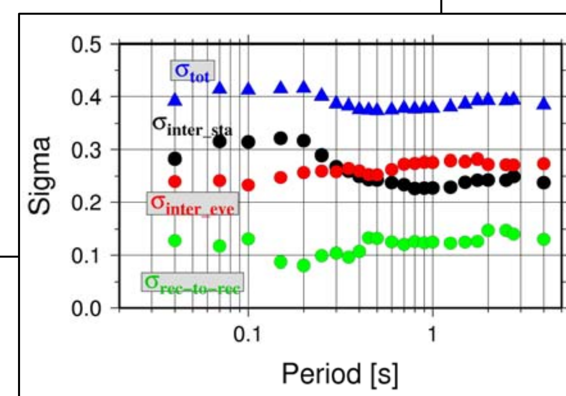
e_A=0 (class A used as reference)

f_U=0 and sum(f_i)=0

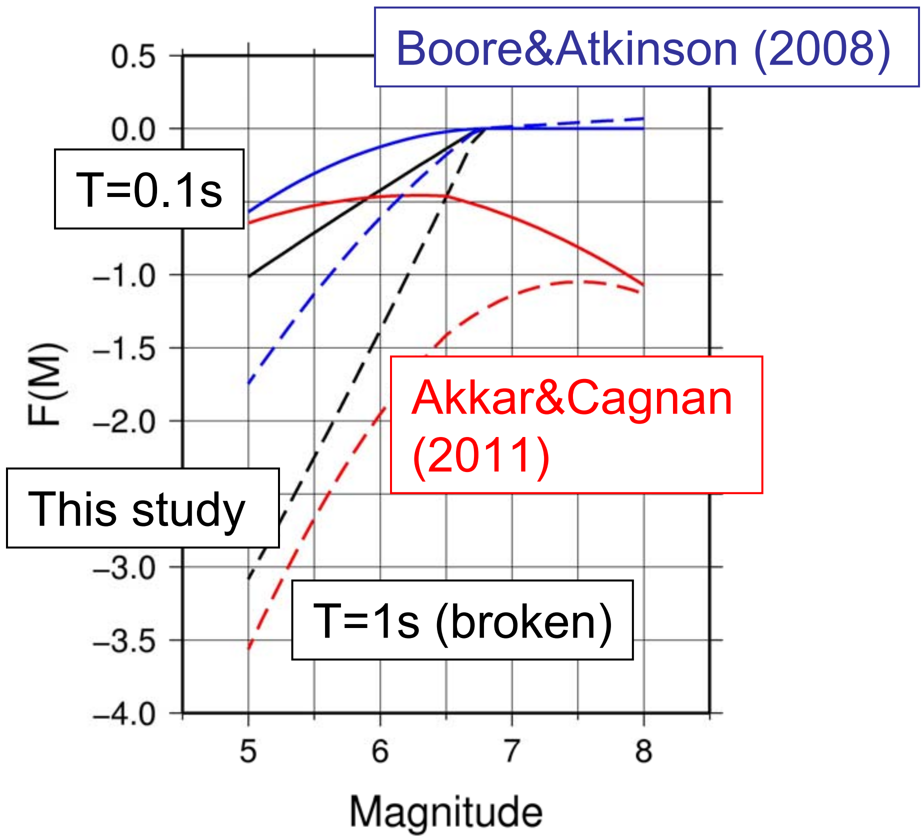
b3=0 (i.e. F(M) const for M>Mh)

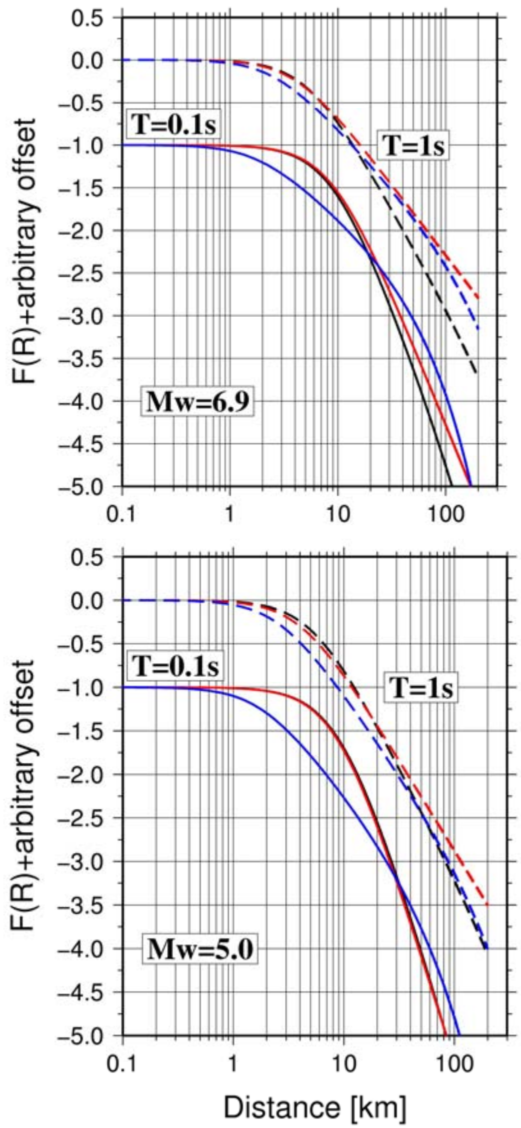
50 bootstrap replications



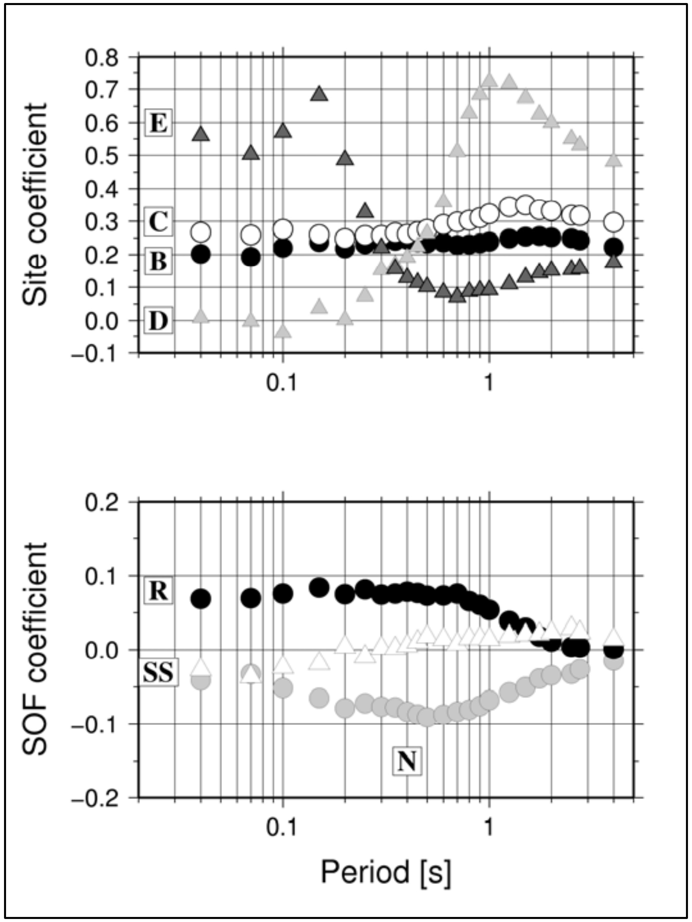


Results: coefficients



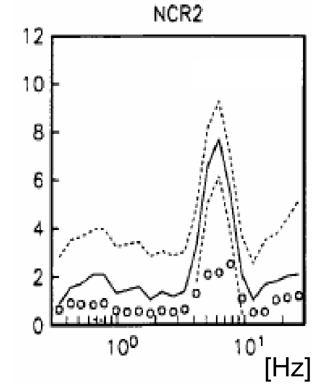


Results: coefficients



E:ARN,BSS,FVZ,GVD, MLZ,**NCR/NCR2**,PZS (Nocera:47/56 records)

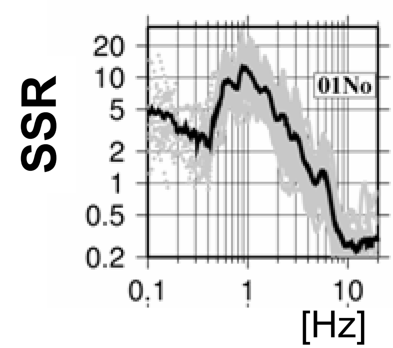
(Rovelli et al, 2002; Castro et al., 2004)



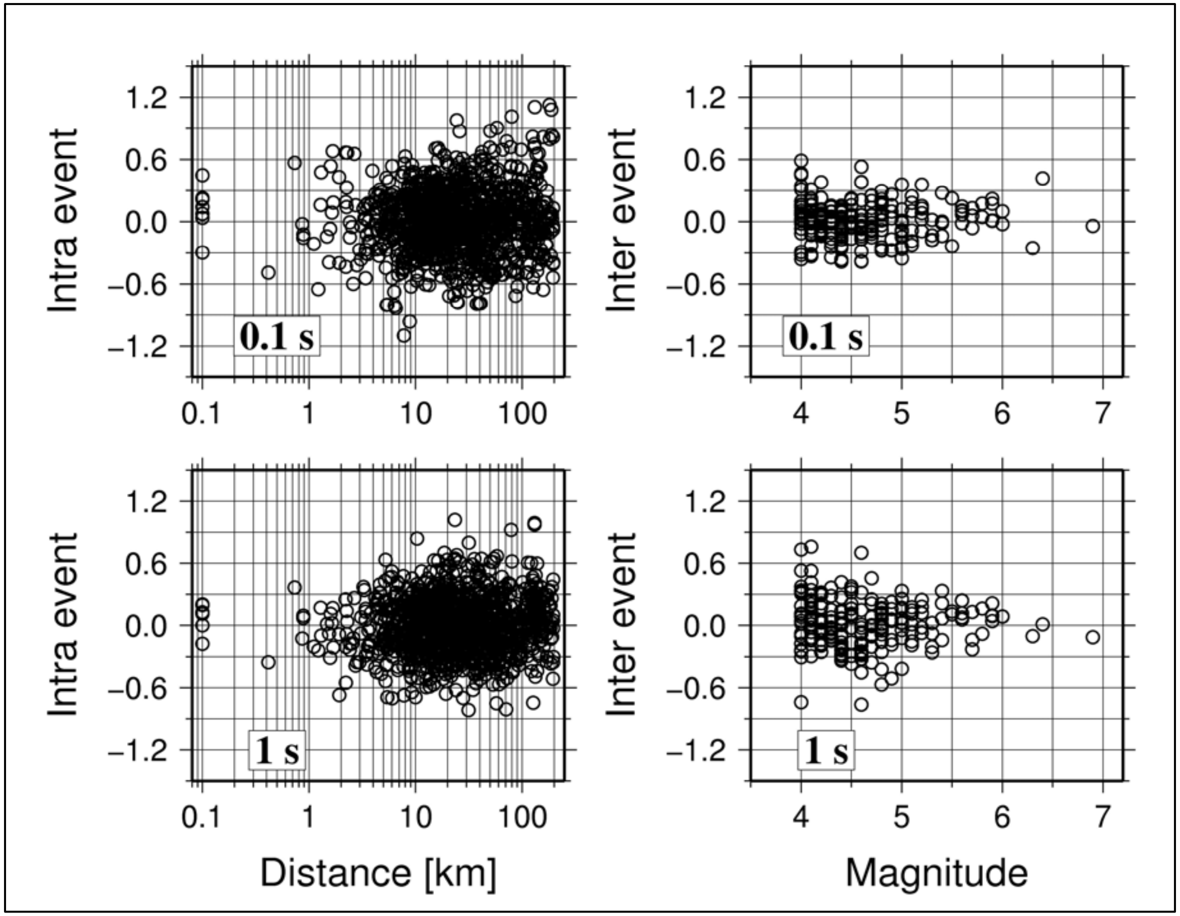
D: CAT(3/26), **CLF**(15/26), NOR(7/26), VGG(1/26)

Rovelli et al (2001) Edge-Diffracted 1-Sec Surface Waves Observed in a Small-SizeIntramountain Basin (Colfiorito, Central Italy)

Norcia:
Bindi, Luzi (2010) Seismic monitoring at the Norcia basin, Deliverable D9 (C)



Results: residuals

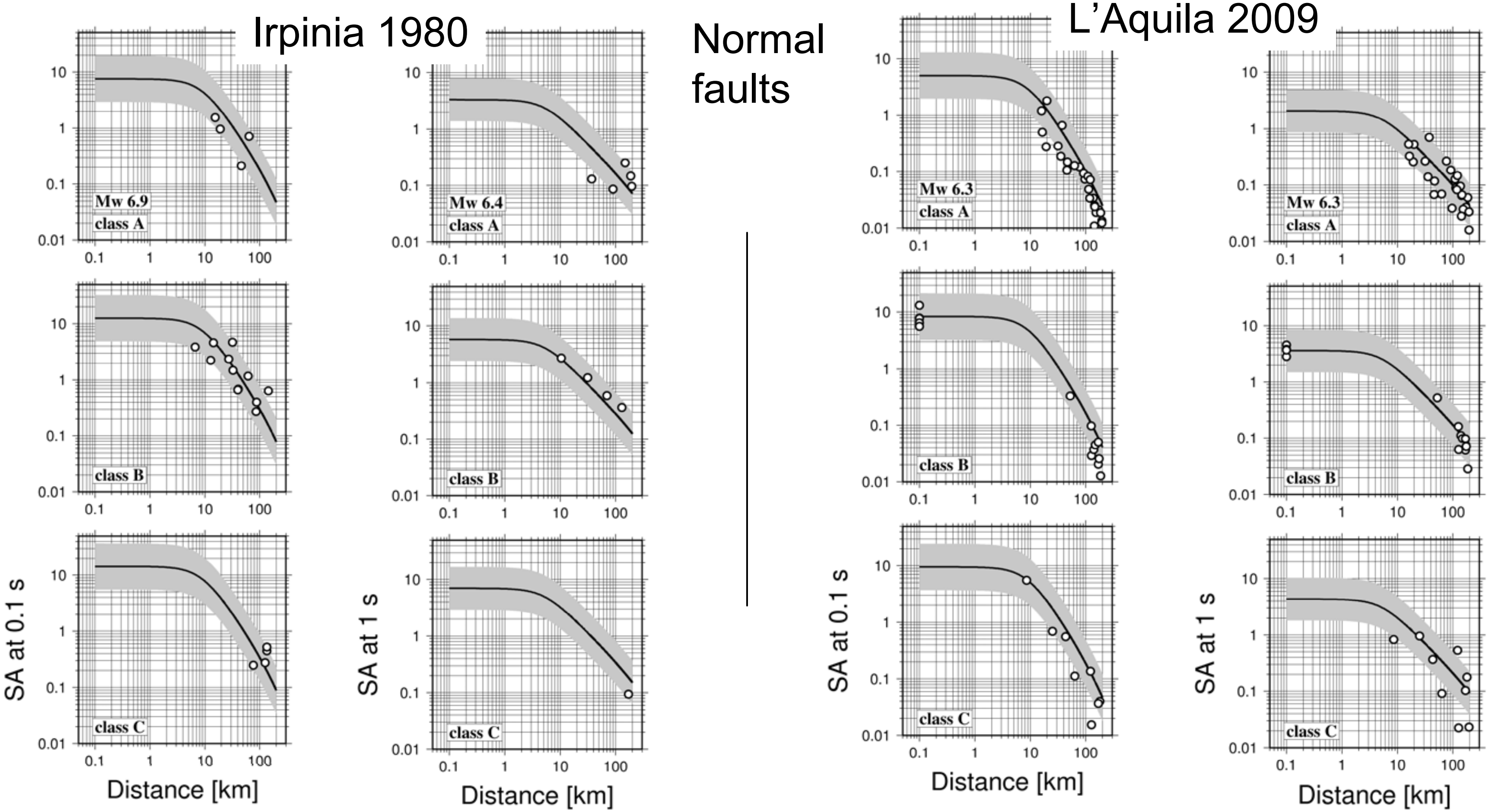


Results: comparison with data

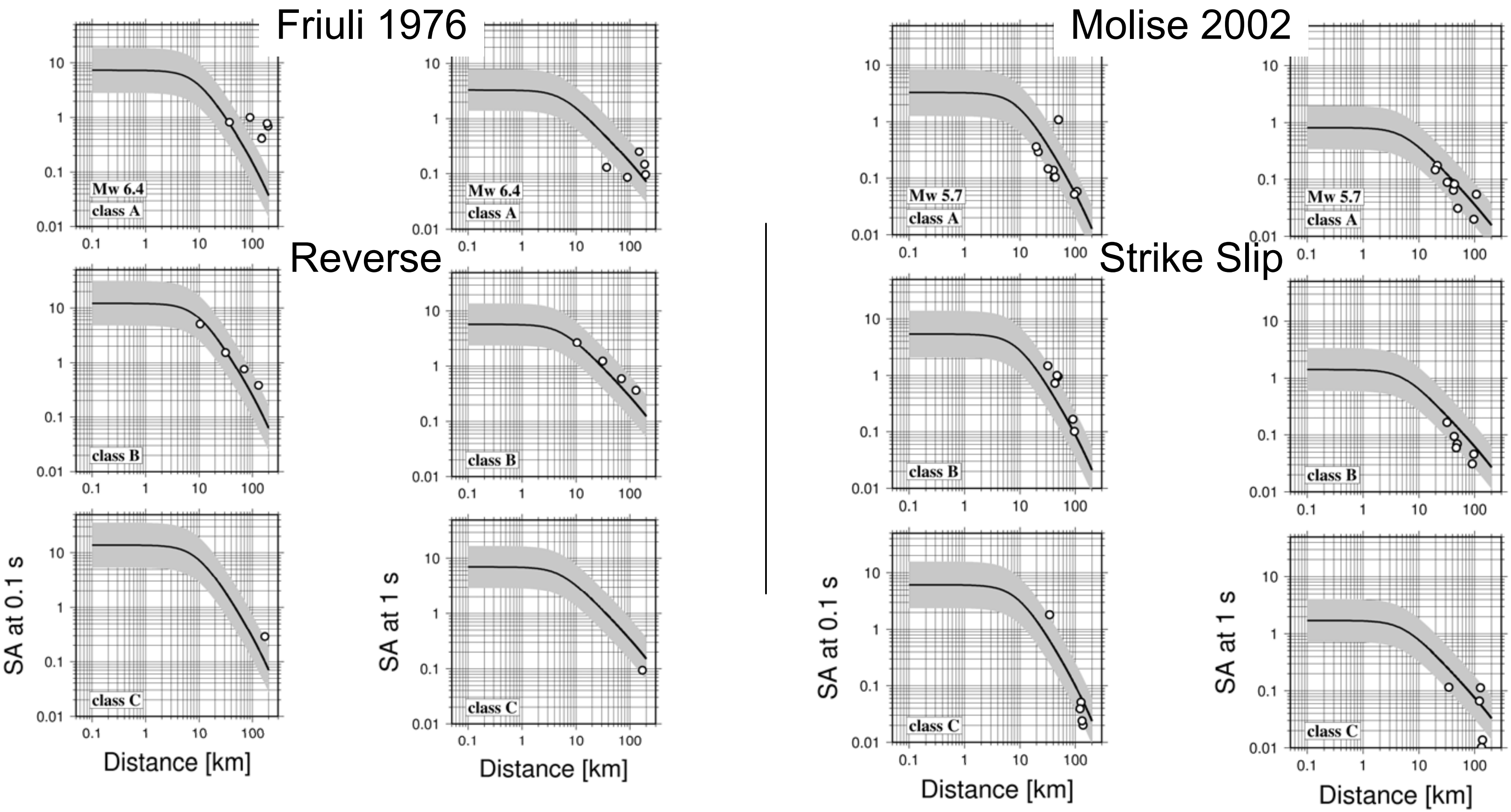
Irpinia 1980

Normal faults

L'Aquila 2009

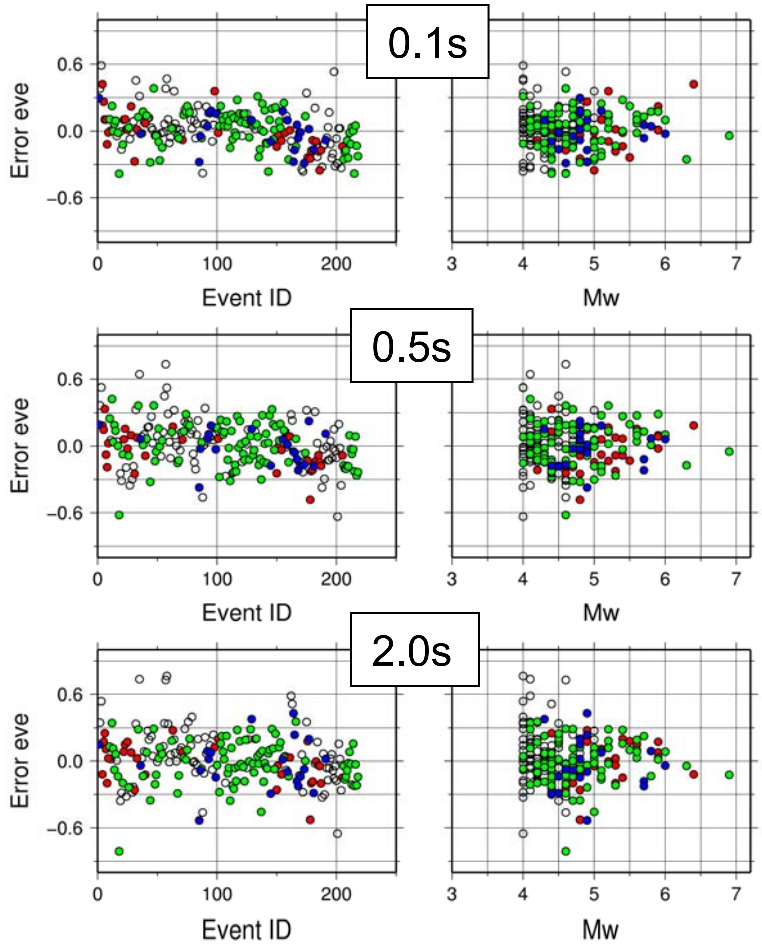


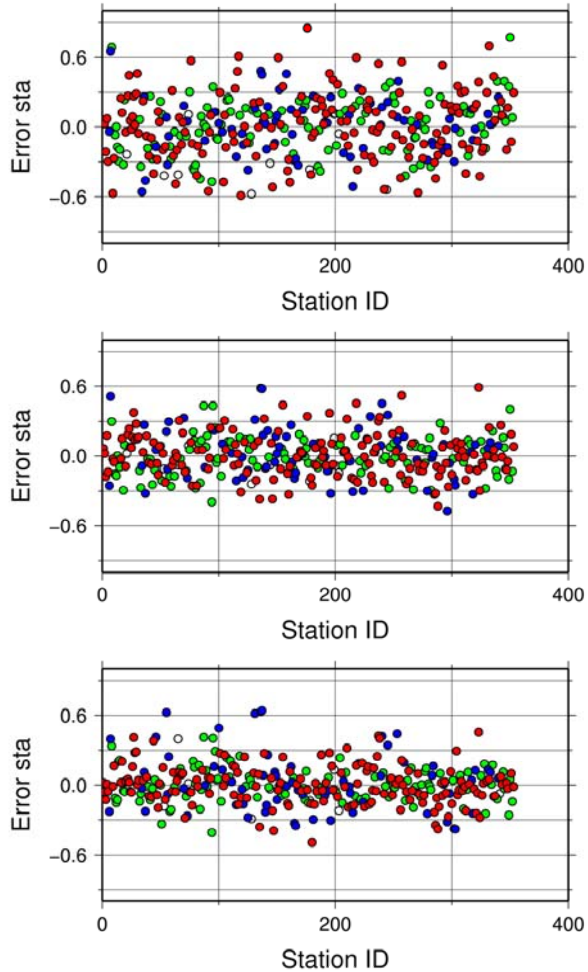
Results: comparison with data



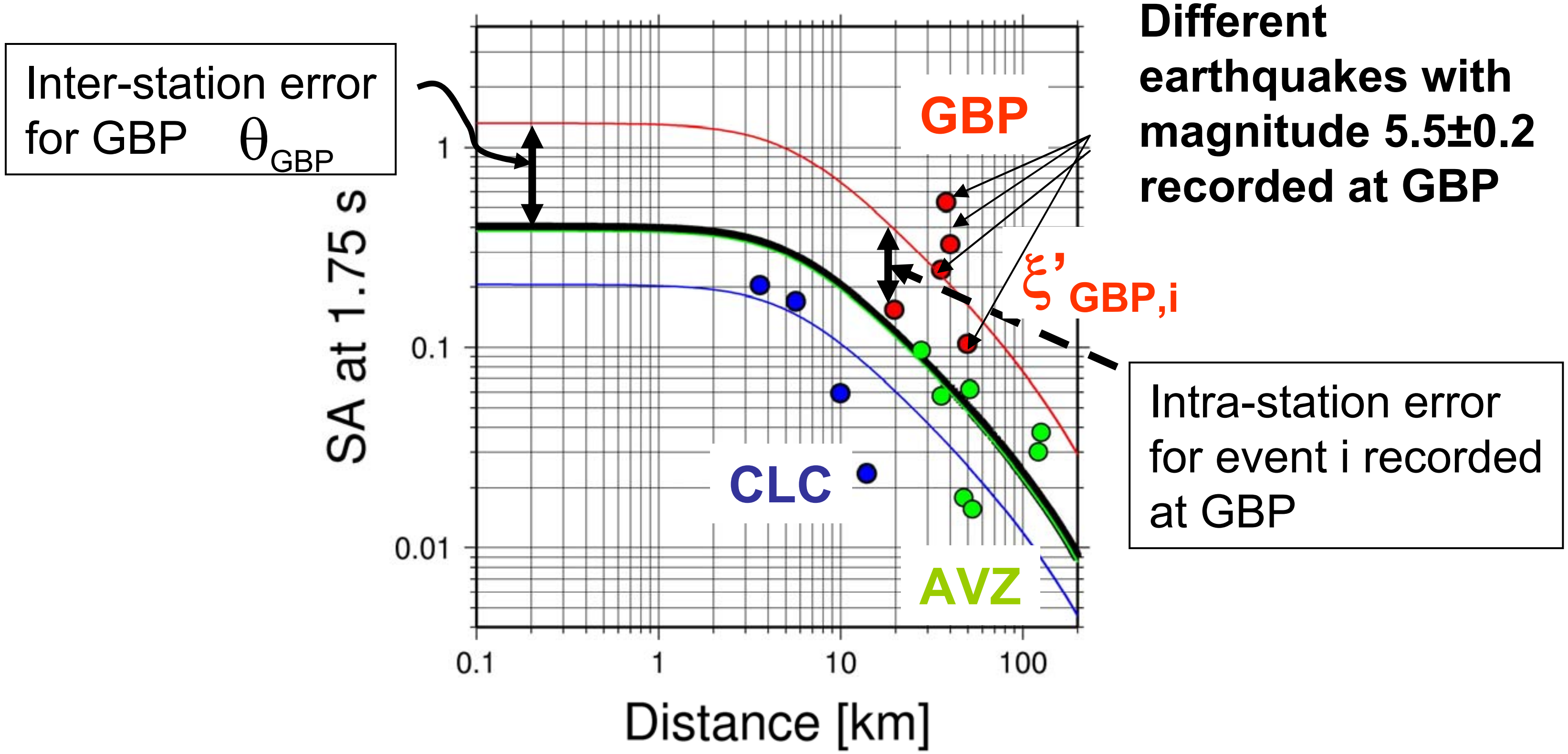
Data Method **Results** Developments

Results: error distributions



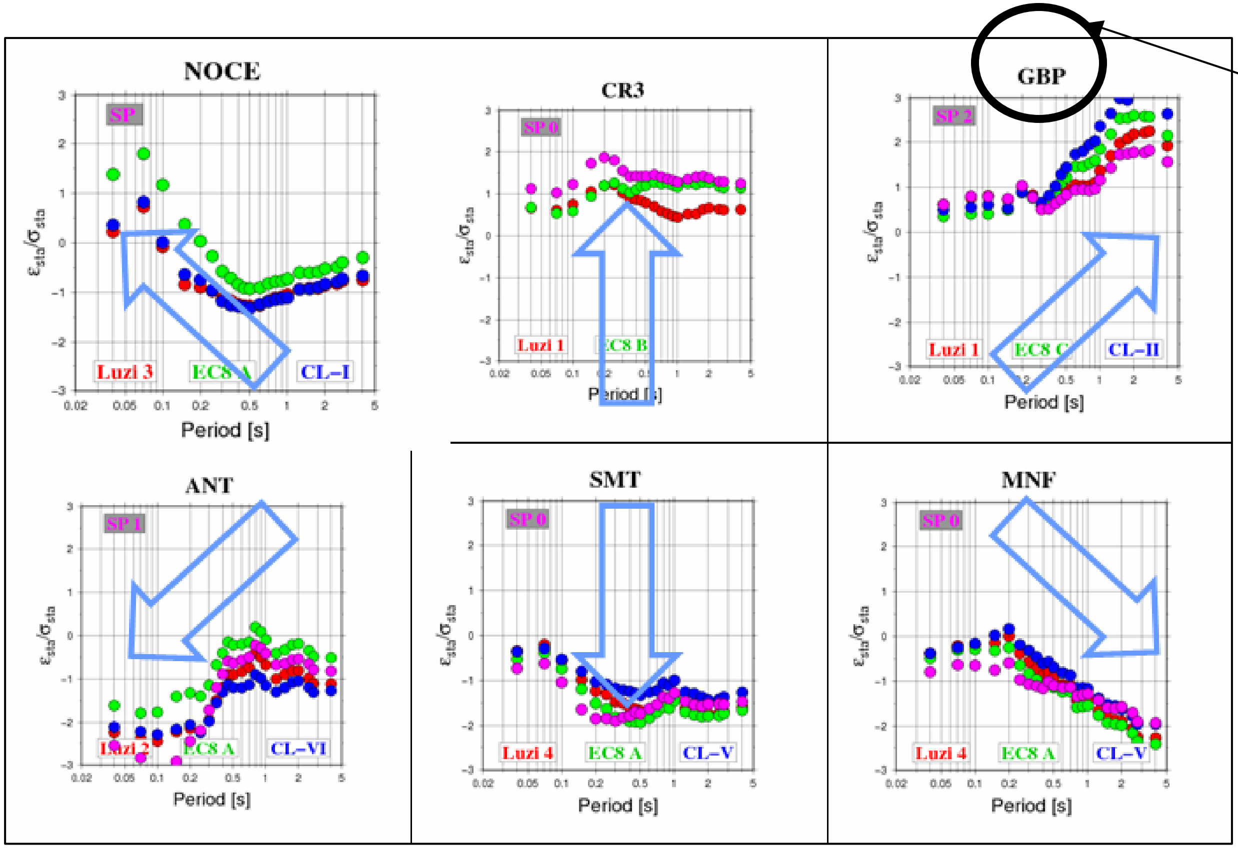


Results: error distributions



Model for ITACA (black): mean prediction for a M=5.5, **class C** - EC8

Results: station with distinctive features



Bindi et al (2009). Site Amplifications Observed in the Gubbio Basin, Central Italy: Hints for Lateral Propagation Effects, BSSA.

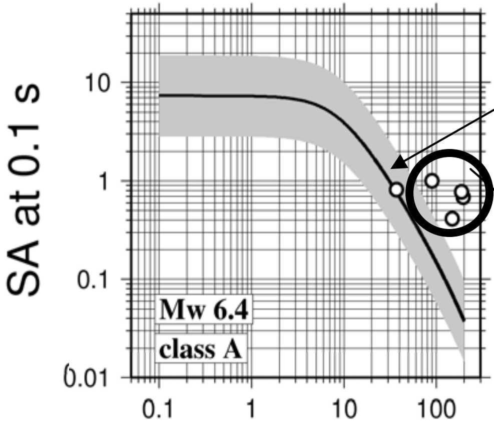
Shaking seismic scenarios in area of strategic and/or priority interest-S3, DPC-INGV 2004 -2006

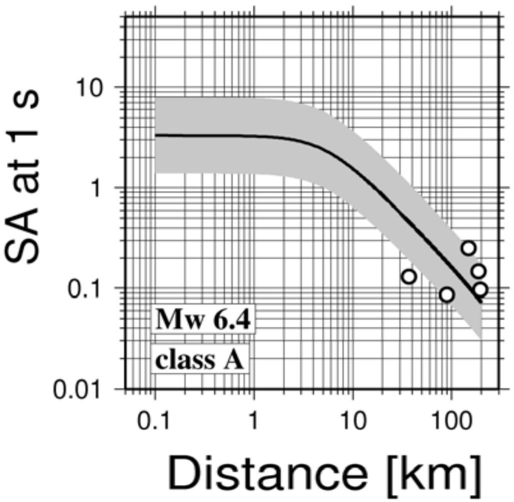
12.00 – 12.30: 1D, 2D, 3D numerical modelling of seismic site response: the case of Gubbio basin *(C. Smerzini)*

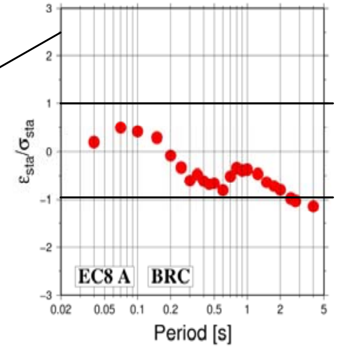
Deliverable 9 Appendix A - Analysis of strong motion records for identification of stations with distinctive seismic response (*R.Paolucci, D. Bindi*)

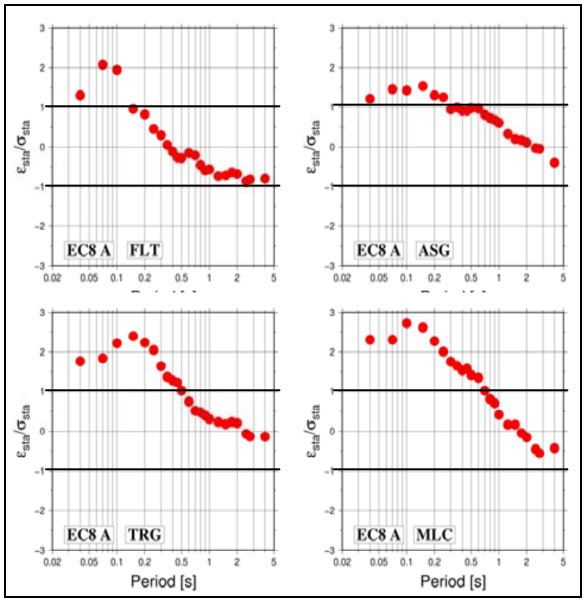
Data Method **Results** Developments

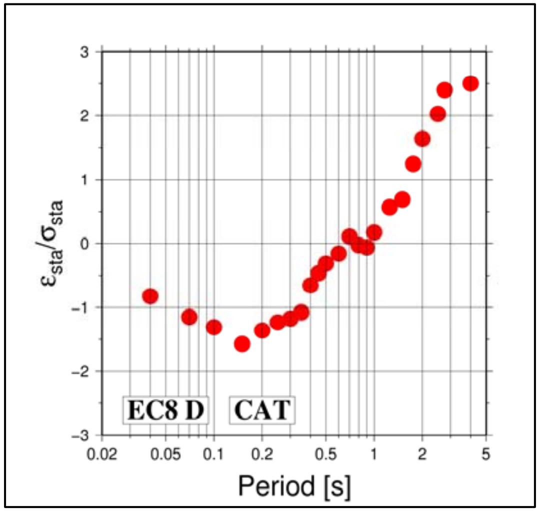
Results: stations with distinctive features











CATANIA

Developments

Results: stations with distinctive features

-When vs30 is not a good proxy for site effects (e.g. station installed in basins)
-Topographic/morphological effects
-Interaction with the housing structure
- ……………..

Deliverable D9- Appendix B Identification of stations with possible significant interaction effects with the hosting or surrounding structures (M. Mucciarelli)

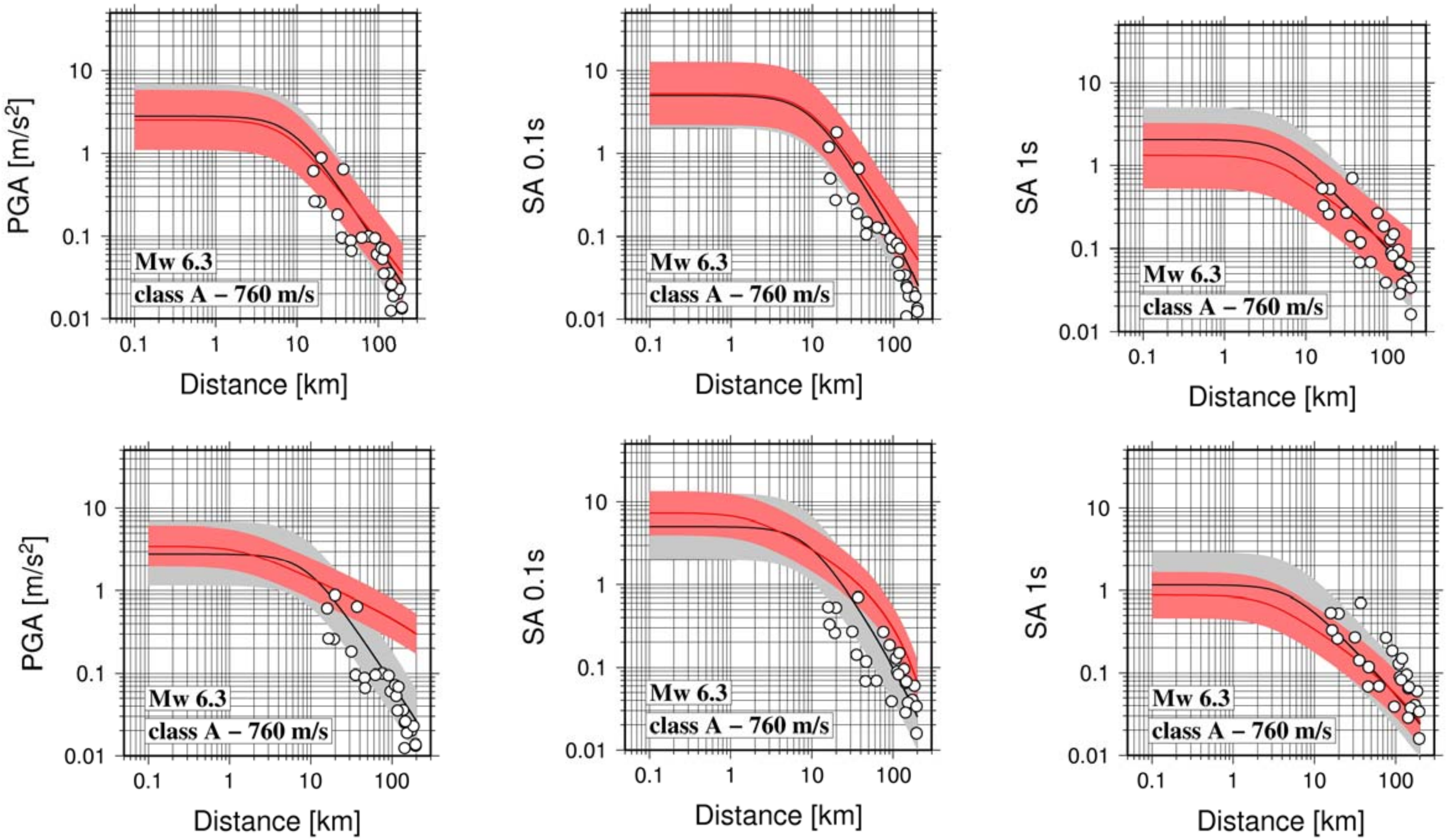
Deliverable D9- Appendix C D E Monitoring of Norcia and Fucino basins and Narni topography (RU1, RU2, RU8)

Deliverable D9- Appendix F 1D, 2D, 3D numerical modelling of seismic site response in the Gubbio basin (R. Paolucci and C. Smerzini)

Deliverable D11 Seismic classification of the ITACA bedrock sites, with the identification of reference sites for seismic hazard studies and engineering applications (D. Albarello)

Deliverable D10 Appendix E EC8 subsoil and topographic classification of ITACA stations (G. Di Capua, V. Pessina, G. Lanzo)

Results: comparison with other models

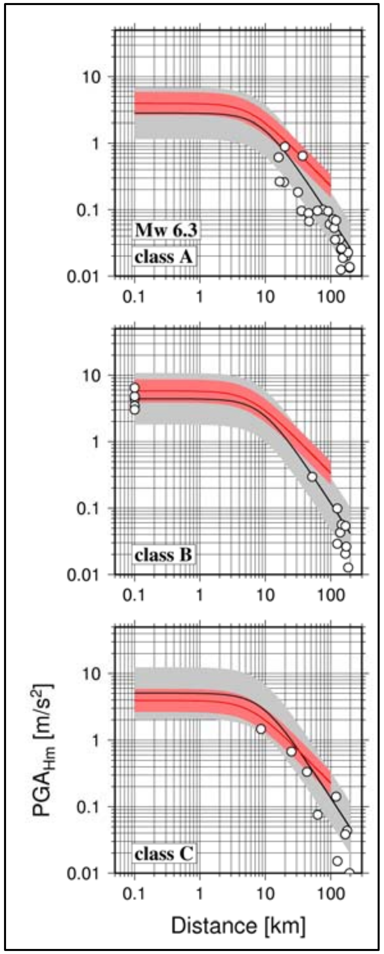


TURKEY
Akkar and
Cagnan 2011
(red)

GLOBAL
Boore and
Atkinson 2008
(red)

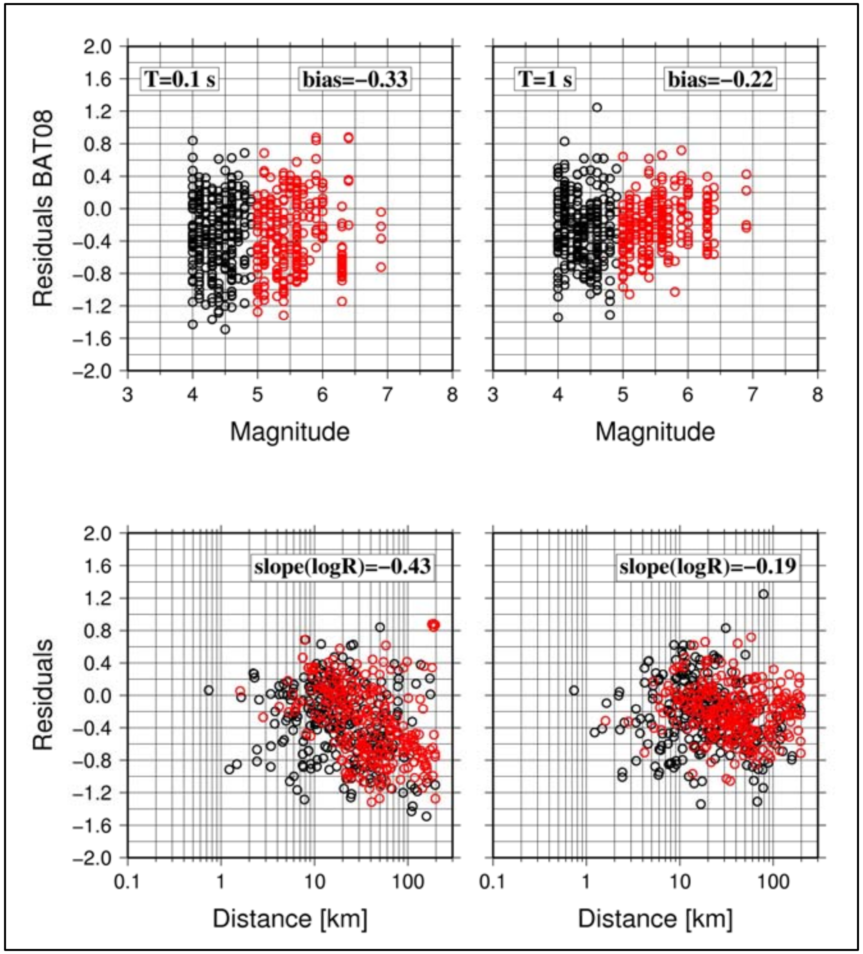
Results: comparison with other models

RED Sabetta&Pugliese 1996



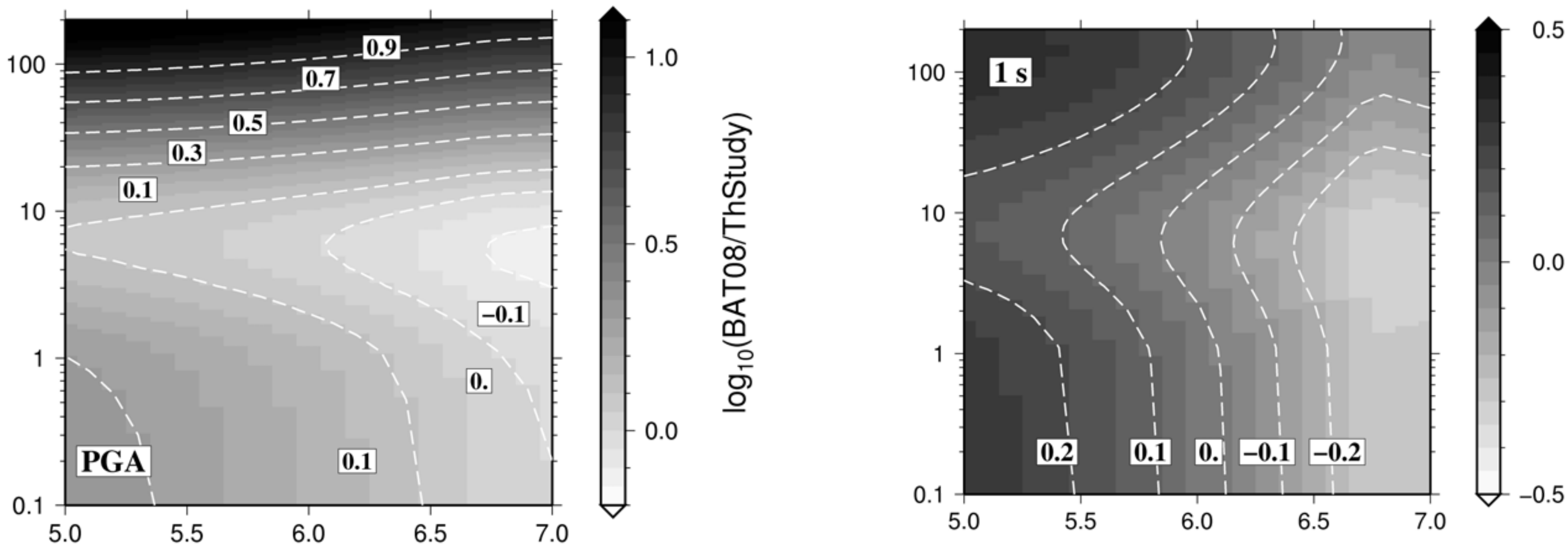
Results: comparison with other models

Observations versus BAT08 predictions (class A – 760 m/s)



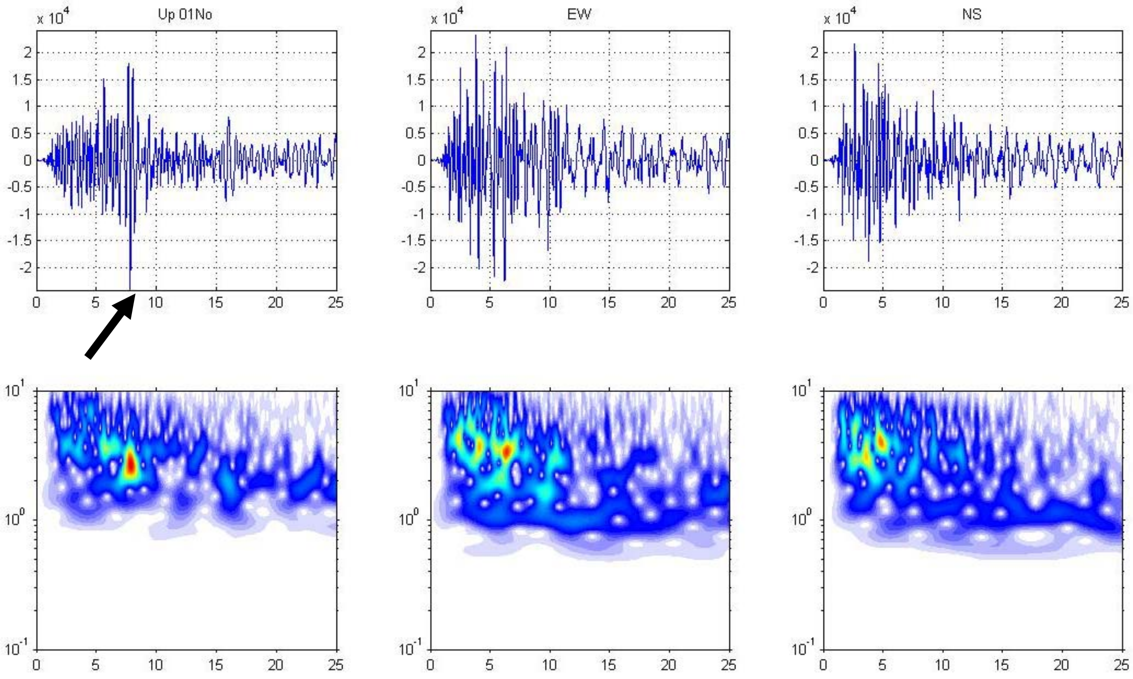
Results: comparison with other models

Comparison between two GMPEs

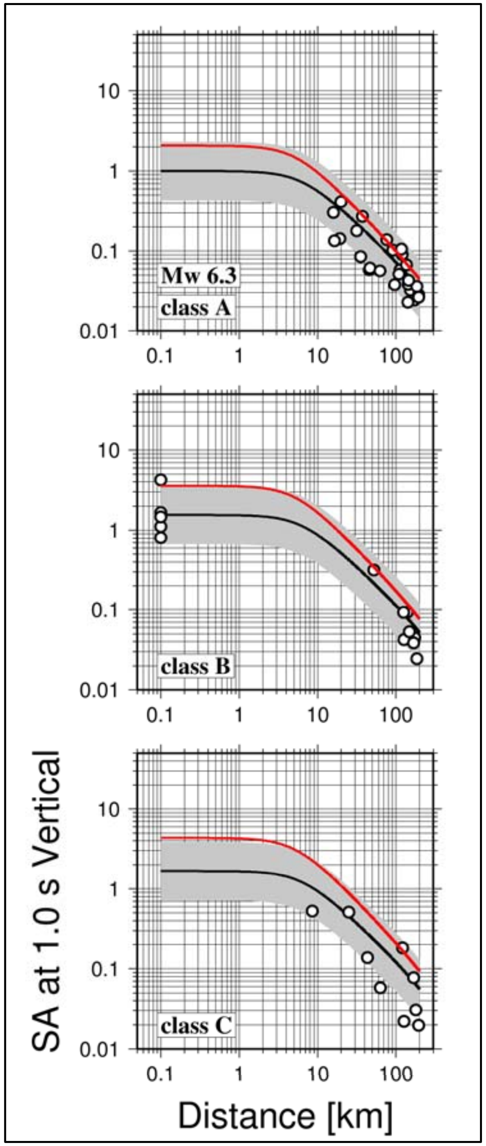


Results: vertical component

velocity



Norcia



Ongoing activities and Future developments

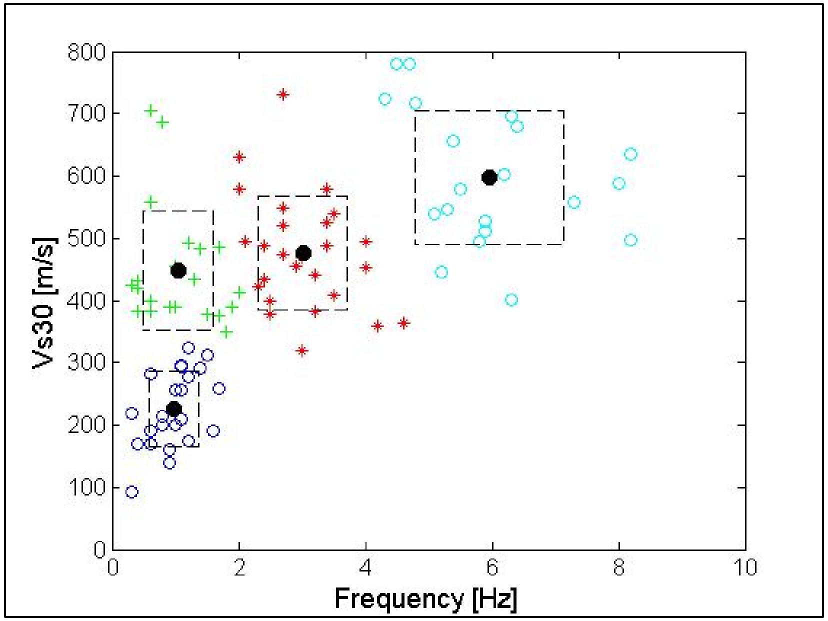
-Single station sigmas
-Dependence of predictions on magnitude interval
-……
-**Site Classification schemes**

TASK 5
Deliverable D13 (L. Luzi, M. Mucciarelli)
Identification of new site parameters for improved seismic classification criteria

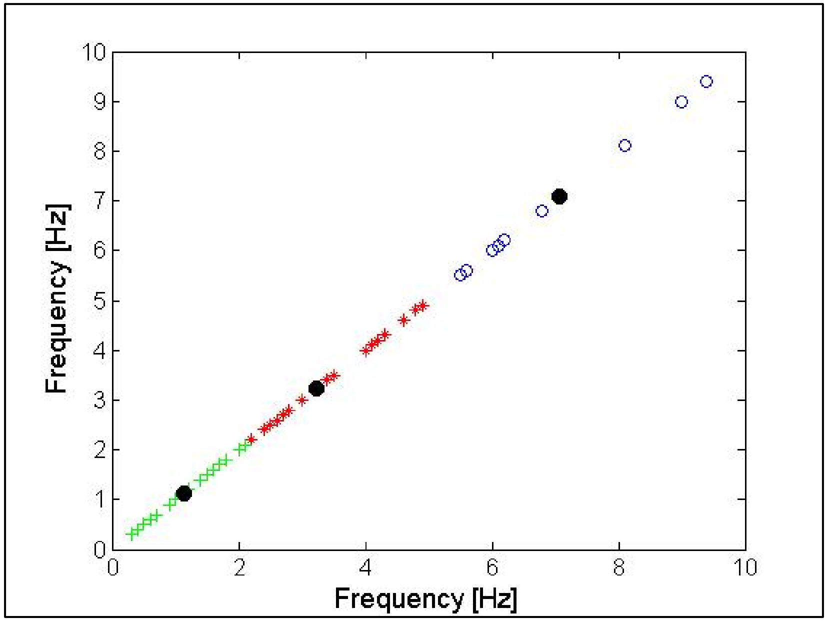
Deliverable D10-Appendix C
Spectral classification of ITACA stations
(A. Rovelli, C. Di Alessandro)

Ongoing activities and Future developments

-Site Classification schemes



Cluster analysis



NOT UPDATED RESULTS

Ongoing activities and Future developments

SP	Num Staz
Classe SP0	79
Classe SP1	48
Classe SP2	51

EC8	Num Staz
Classe A	89
Classe B	46
Classe C	34
Classe D	3
Classe E	6

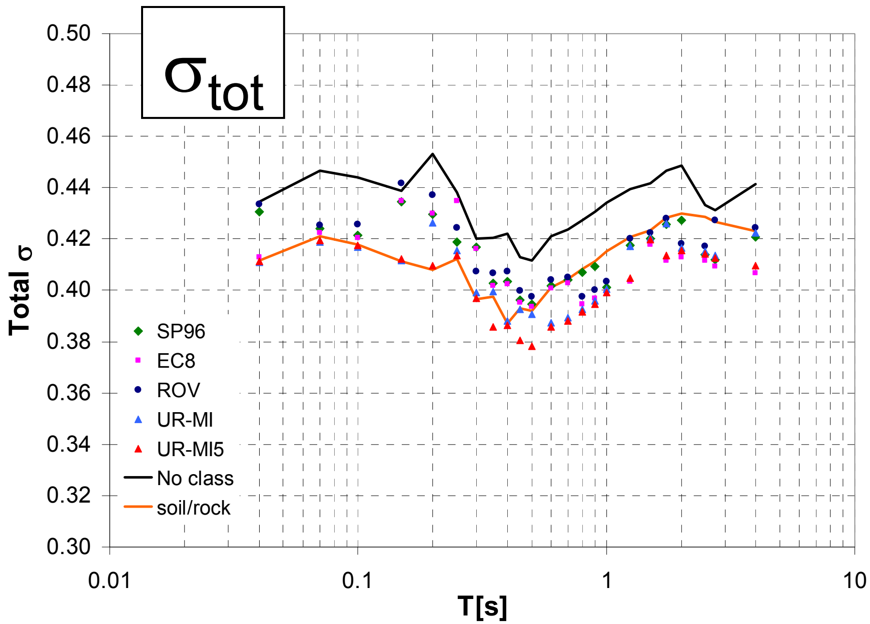
fmax	Num Staz
Classe I	26
Classe II	36
Classe III	18
Classe IV	27
Classe V	22
Classe VI	19
Classe VII	30

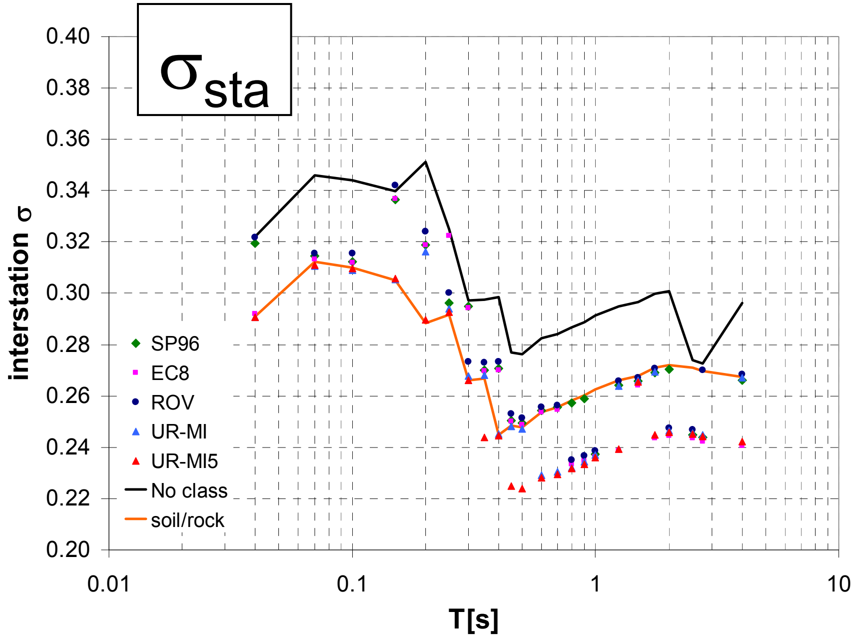
fzero	Num Staz
Classe 1	49
Classe 2	47
Classe 3	27
Classe 4	55

rock sites

NOT UPDATED RESULTS

Ongoing activities and Future developments





NOT UPDATED RESULTS

Thanks for your attention!!!

The analyses presented here have been performed through the collaboration with:

RU1: Luzi, Pacor, Puglia,Massa
RU2: Paolucci,Giorgetti
RU8: Parolai