Riunione Plenaria SECURE
(Progetto Pianeta Dinamico 2023-25)

Istituto Nazionale di Geofisica e Vulcanologia – January 30, 2024

WP4. Prestazioni dei Modelli di Moto del Suolo e delle Relazioni Empiriche

Caratteristiche dello scuotimento sismico negli Appennini Meridionali

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UCLA ENGINEERING

Outline

- *Introduction and research goals*
- *Data and methods*
- *Main results (GMMs vs data)*
- *A useful engineering tool: fragility curves*
- *Conclusions and final remarks*

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Main research goals:

1. Identifying potential peculiar local effects of ground motion in Southern Italy (e.g.apparent **anelastic attenuation trends** and **event term distribution** with period)

2. Analyze the relative performance of regional, global, and global with regional adjustments GMMs against a comprehensive dataset of ground motions in Southern Italy

3. Verify whether regional adjustments regarding the seismic attenuation to global models perform satisfactorily in this area

Apprach:

1. Gather data from the Engineering Strong Motion (ESM) database, (Lanzano et al., 2019; Luzi et al., 2020) for Southern Italy between recorded between 1969 and 2020

2. Select GMMs to use in the analysis

3. Calculate total residuals, event terms, within-event residuals and identify trends in the data

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Selected GMMs for this study

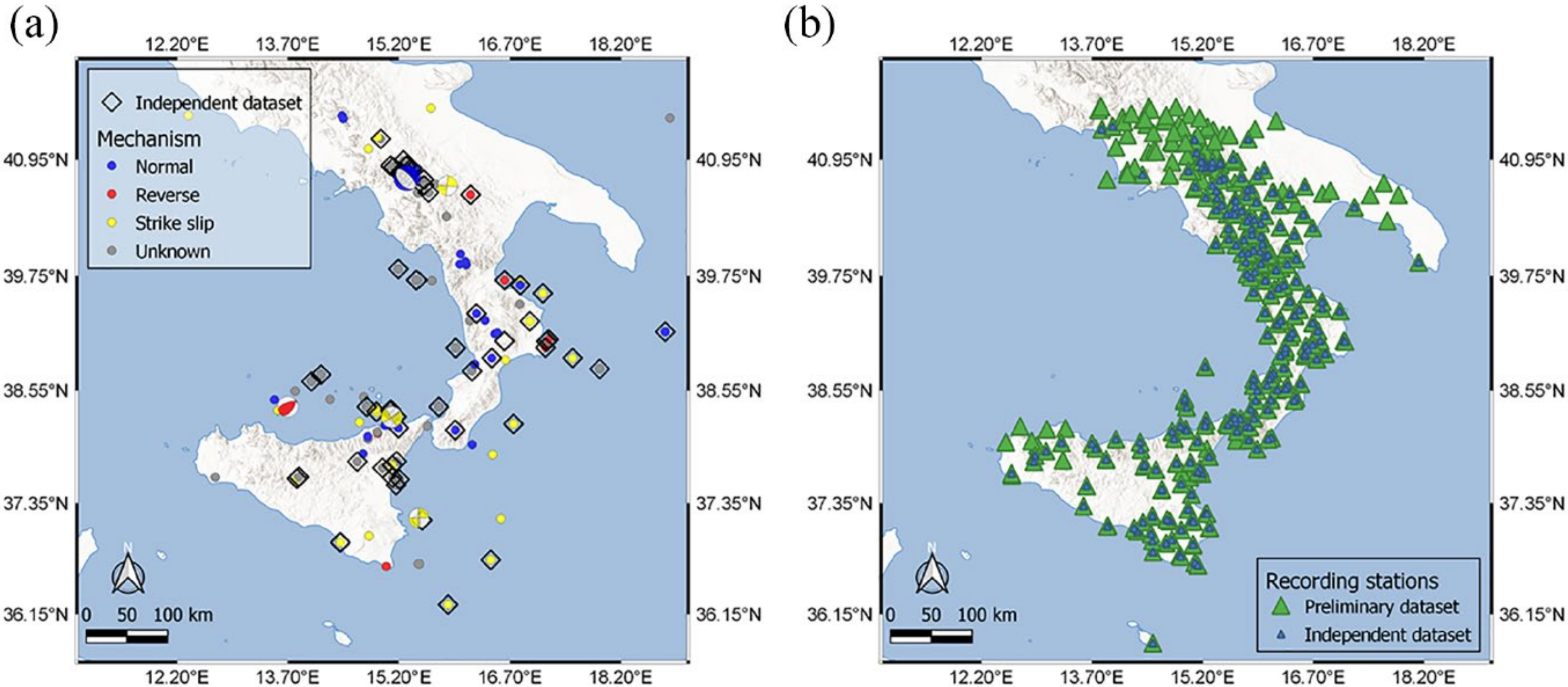
GMM	*M* range	*R* type	*R* range (km)	Style of faulting	Nonlinear site response	Heteroscedasticity of variance	Horizontal component	Region(s)
ITA10 (Bindi et al., 2011)	4.1–6.9	R_{JB}	0–200	Unknown, NS, SS, RS	No	No	GM	Italy
ITA18 (Lanzano et al., 2019b)	3.5–8.0	R_{JB}	0–300	Unknown, NS, SS, RS	No	Yes	RotD50	Italy, 12 Global Events
BSSA14 (Boore et al., 2014)	3.0–8.5	R_{JB}	0–400	Unknown, NS, SS, RS	Yes	Yes	RotD50	Worldwide
KOT22 (Kotha et al., 2022)	3.0–7.4	R_{JB}	0–545	Unknown, NS, SS, RS	No	No	RotD50	Europe and Middle East
CY14 (Chiou and Youngs, 2014)	3.5–8.5	R_{JB}, R_{rup}	0–300	NS, SS, RS	Yes	Yes	RotD50	Worldwide
CB14 (Campell and Borzognia, 2014)	3.3–8.5	R_{JB}, R_{rup}	0–300	NS, SS, RS	Yes	Yes	RotD50	Worldwide
ASB14 (Akkar et al., 2014)	4.0–8.0	R_{JB}, R_{hyp}, R_{epi}	0–>200	NS, SS, RS	Yes	No	GM	Europe and Middle East
BIN14 (Bindi et al., 2014)	4.0–7.6	R_{JB}, R_{hyp}	0–300	Unknown, NS, SS, RS	No	No	GM	Europe and Middle East

GM: geometric mean; GMM: ground motion model; NS: normal fault; R_{JB}: Joyner and Boore distance; R_{epi}: epicentral distance; R_{rup}: fault rupture distance; R_{hyp}: hypocentral distance; RotD50: 50th percentile of the rotated orientation-independent; RS: reverse fault; SS: strike-slip fault.

Data from Italy only, Europe, and worldwide (global)

Models with region-specific adjustments

Database of recorded ground motions in Southern Italy

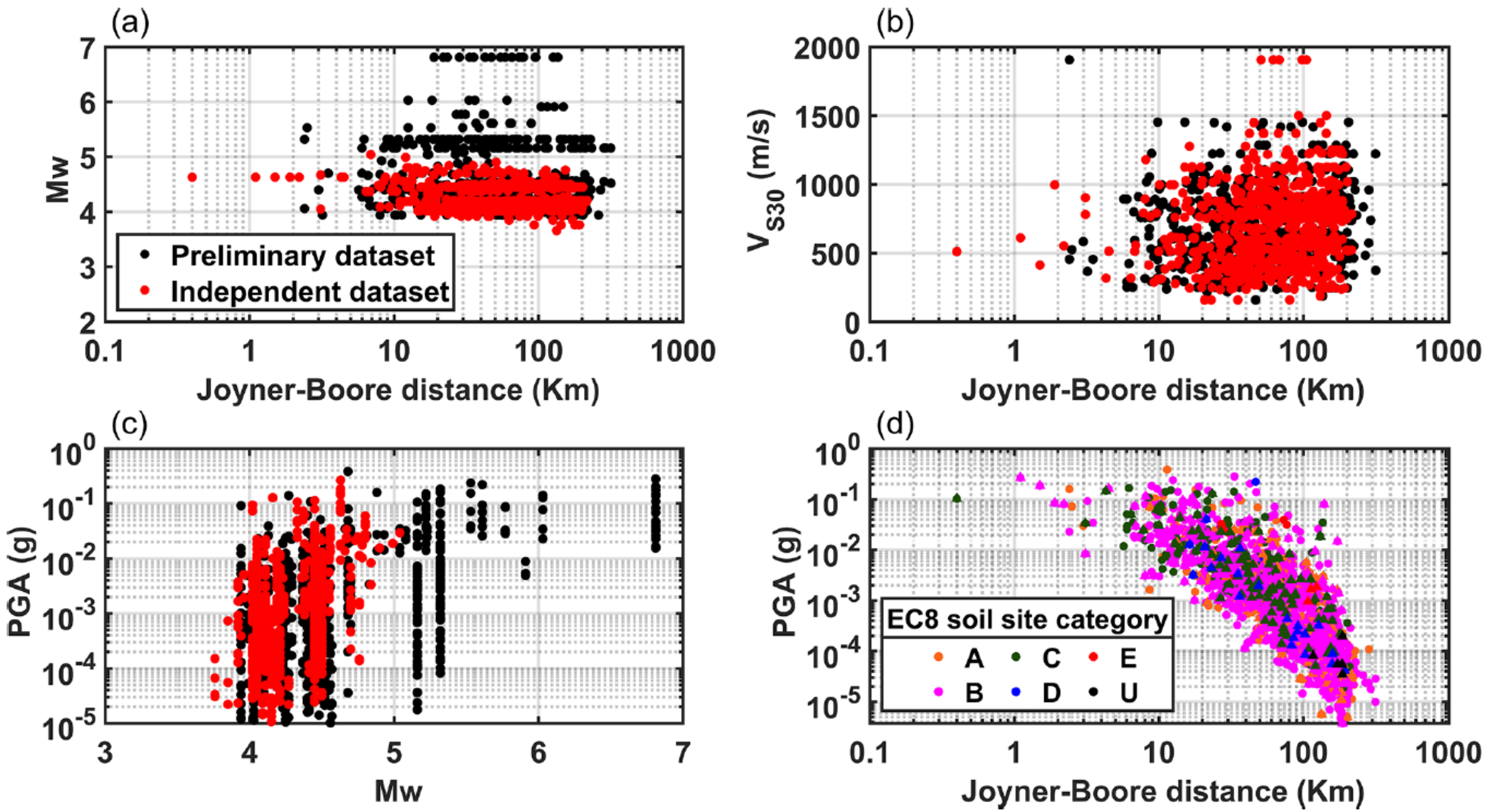


Engineering Strong Motion (ESM) database, (Lanzano et al., 2019; Luzi et al., 2020)

2 datasets: (1) preliminary (all data), (2) independent (only data NOT used to develop thee GMMs

From Regina, Zimmaro, Taroni, Akinci (2023)

Database of recorded ground motions in Southern Italy



From Regina, Zimmaro, Taroni, Akinci (2023)

Residuals Calculation

1. Calculation of total residuals

$$R_i = \ln(Y_i) - \mu_{ln}\left(\mathbf{M}_i, R_i, V_{S30,i}\right)$$

2. Calculation of within-event residuals (ε_i)

$$R_i = \boxed{c_k} + \boxed{\eta} + \boxed{\varepsilon_i}$$ Within-event residuals

bias event
=0 term

3. Calculation of standardized residuals ($\varepsilon_{\ln Z}$) to compare models with different std devs

$$\varepsilon_{\ln Z} = \frac{\ln Y_{ij} - \mu_{ij}}{\sigma_{ij}} = \frac{R_{ij}}{\sigma_{ij}}$$

$$\delta W_{stand} = \frac{\delta W_{ij}}{\sigma_{ij}}$$

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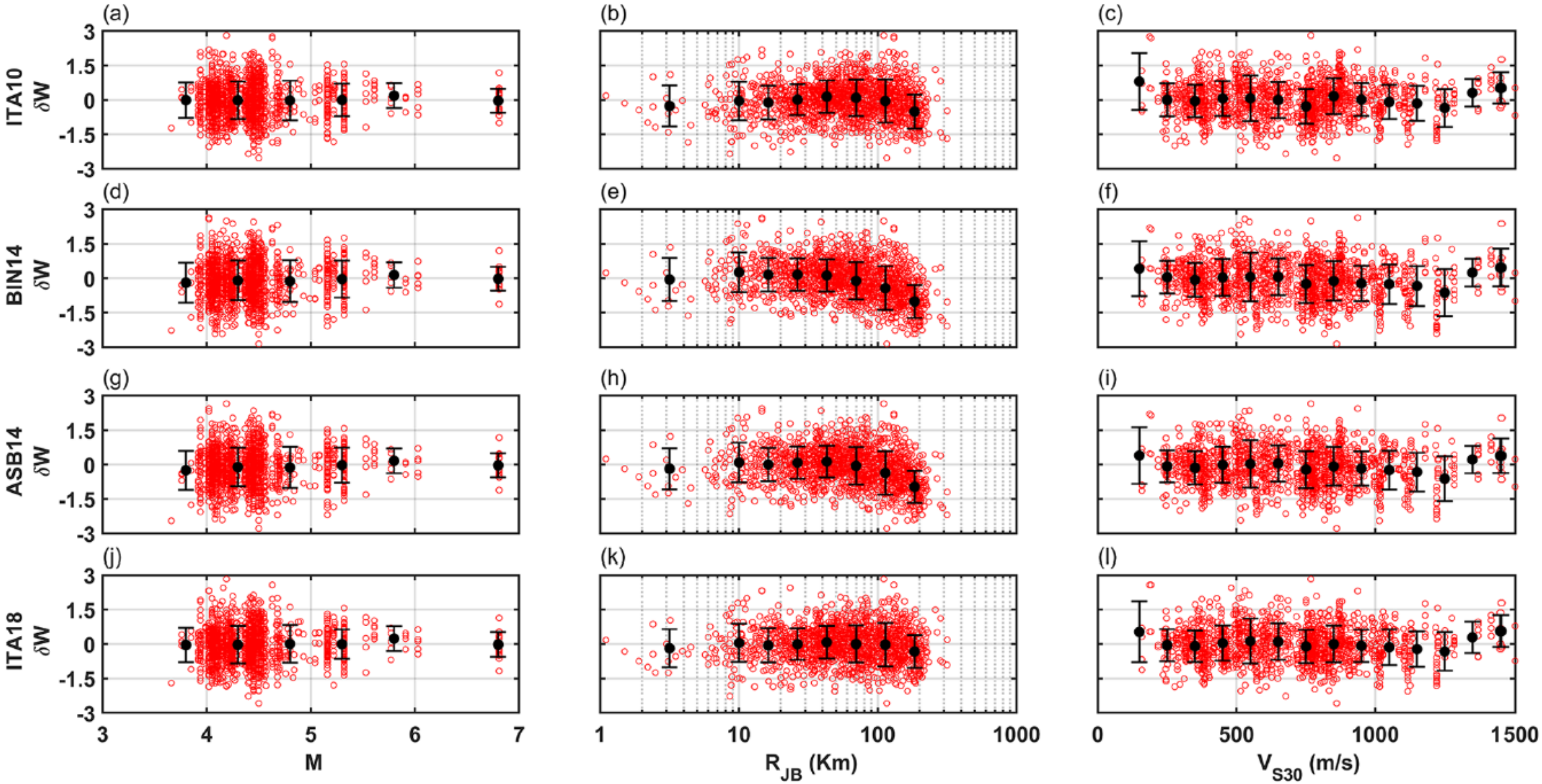
Residuals results (models without regional adjustment)

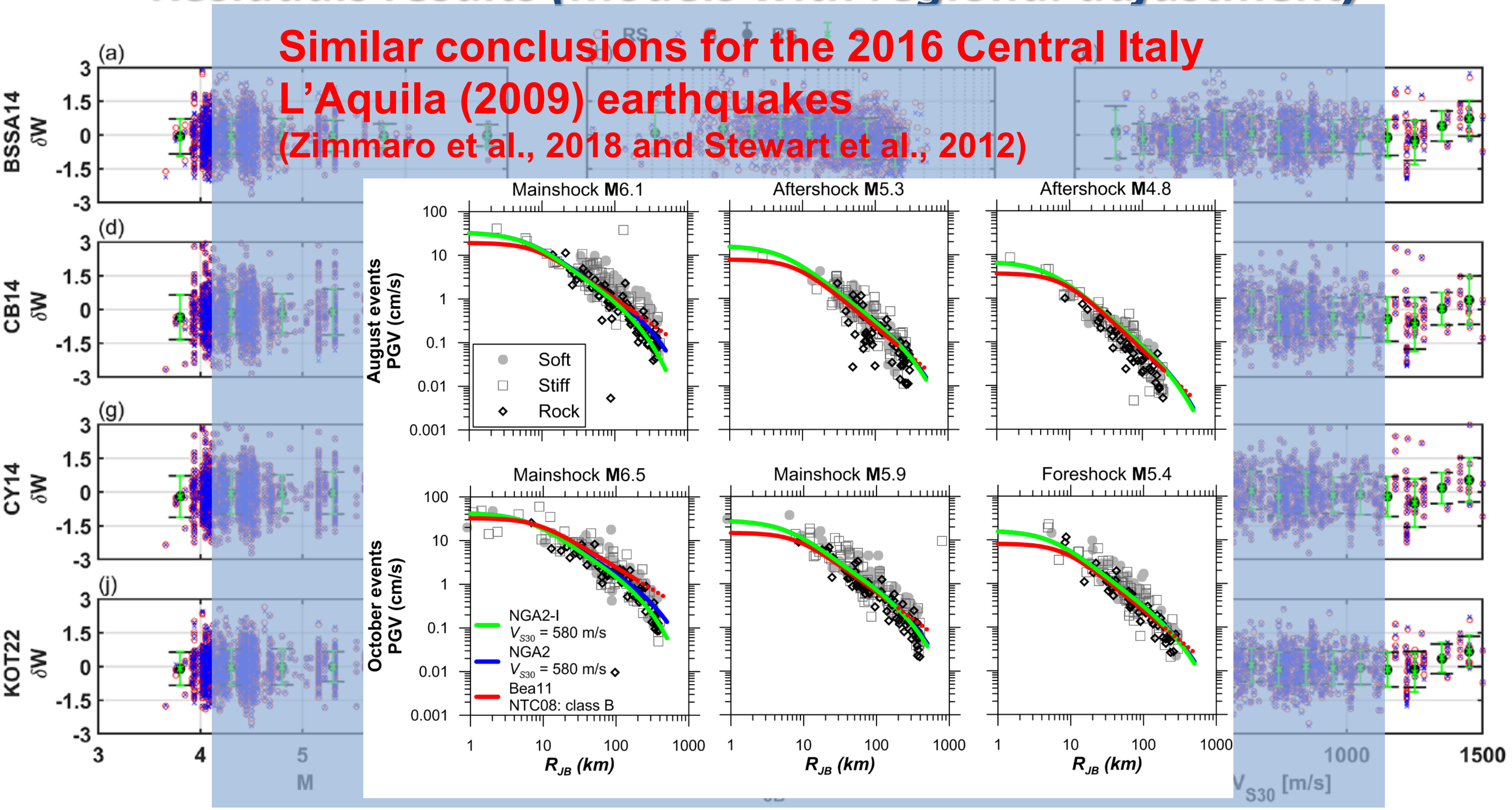


Overall faster anelastic attenuation with distance at R_{JB}>80km

From Regina, Zimmaro, Taroni, Akinci (2023)

Residuals results (models with regional adjustment)

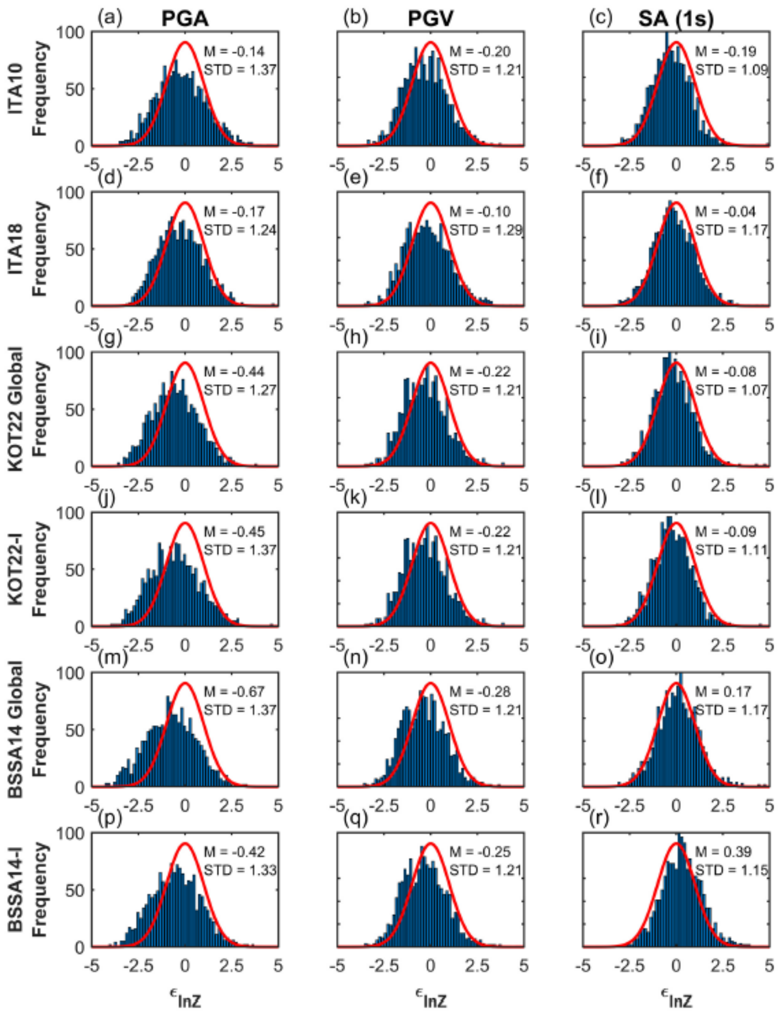
Similar conclusions for the 2016 Central Italy L'Aquila (2009) earthquakes
(Zimmaro et al., 2018 and Stewart et al., 2012)

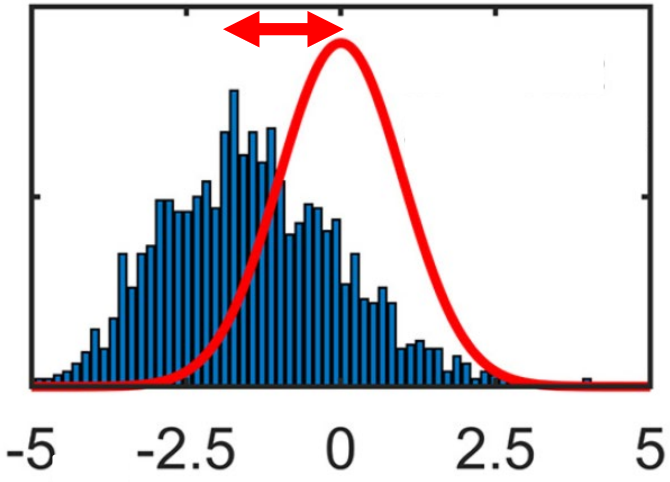


Overall faster anelastic attenuation with distance at R_{JB}>80km
Regional adjustments slightly improve the trend

From Regina, Zimmaro, Taroni, Akinci (2023)

Standardized residuals analysis (comparison of model with different std devs)





Overall:

- Means are negative
(the GMM overestimates the observed intensity)

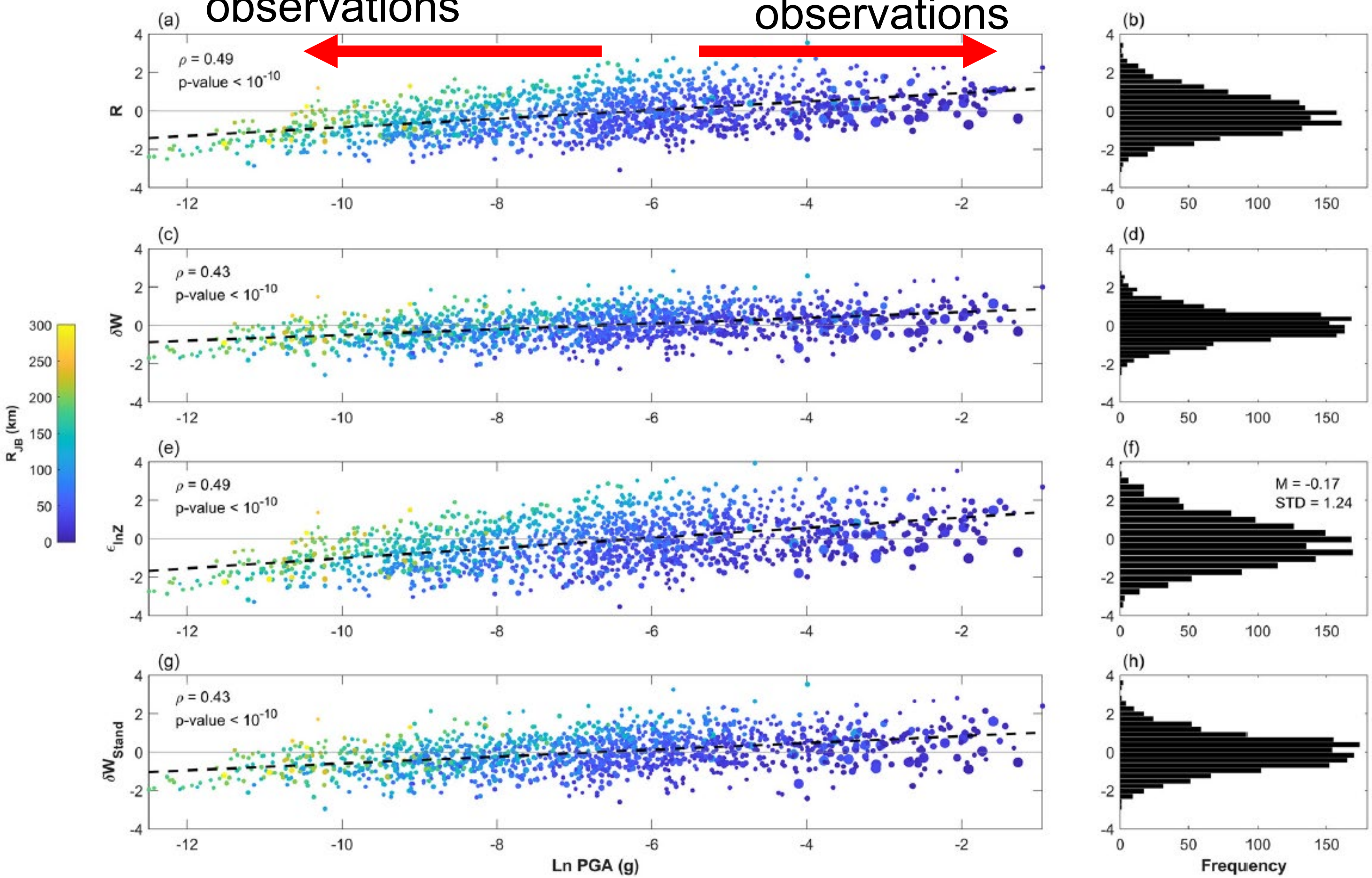
- Std Devs are >1
(the GMM underestimates the variability of the observed intensities)

- Regional adjustments improve the trend

Standardized residuals analysis
(disaggregation of residuals for ITA18, same trend for all GMMs)

GMMs overestimate observations

GMMs underestimate observations



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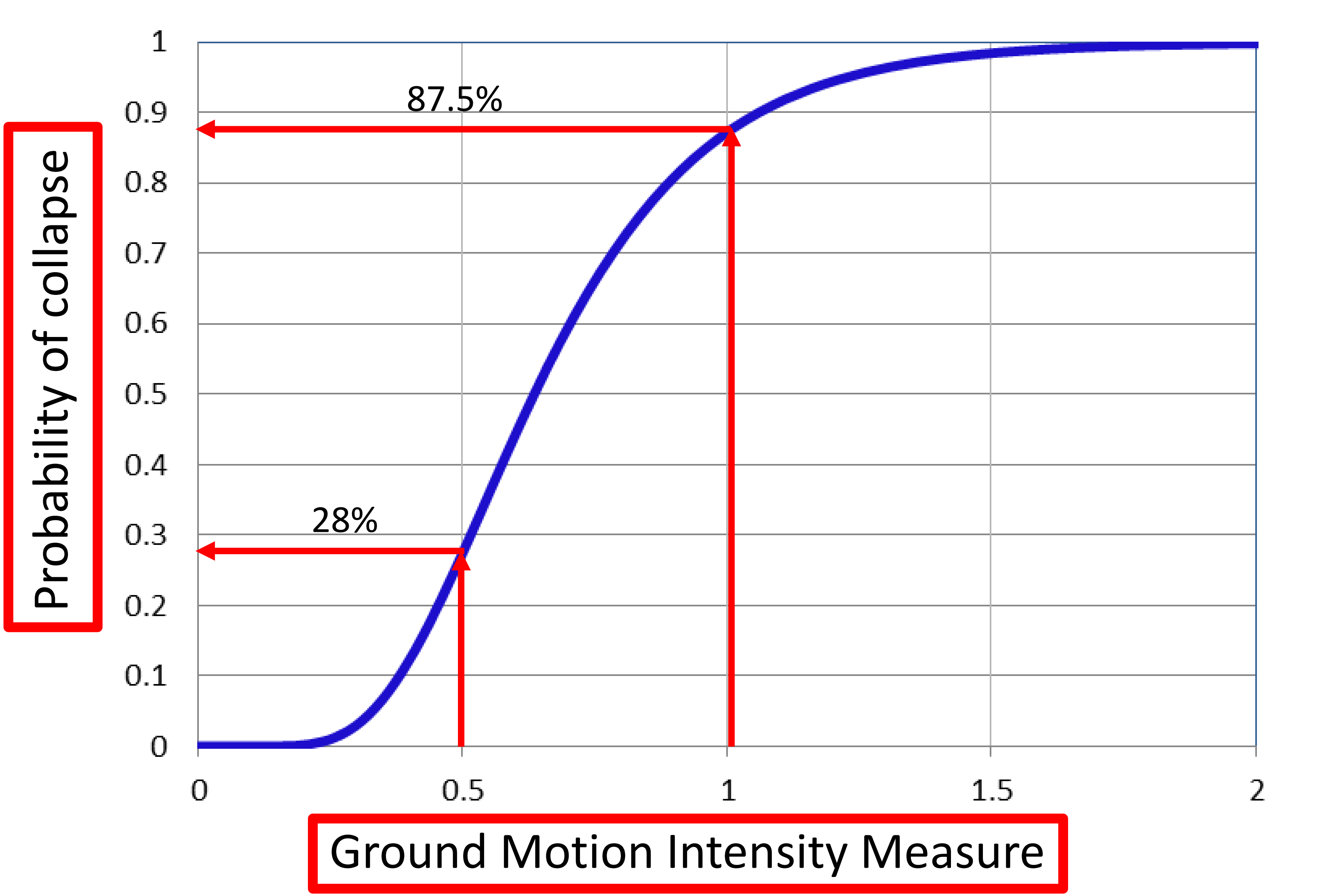
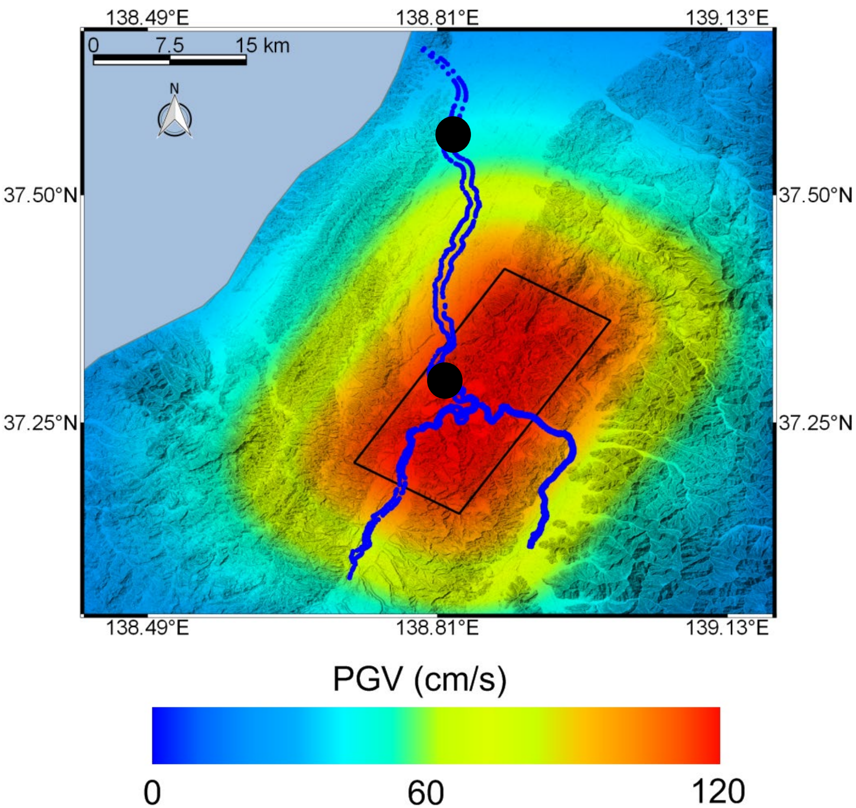
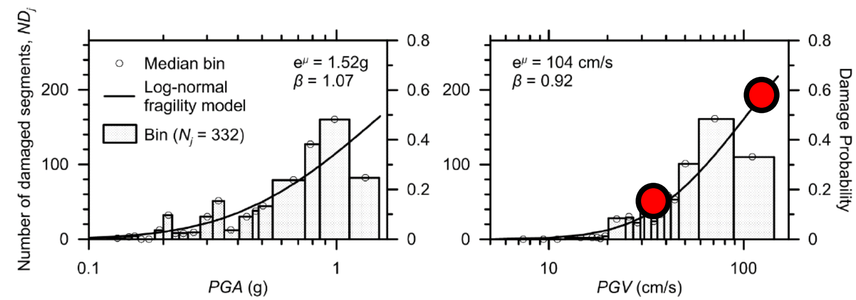
Fragility curve



Empirical fragility curves

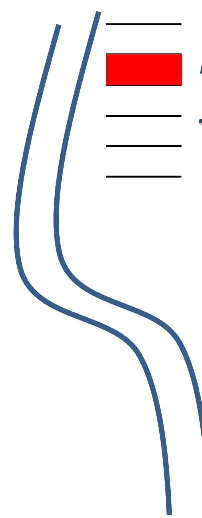


Adapted from Kwak, Zimmaro et al. (2016)



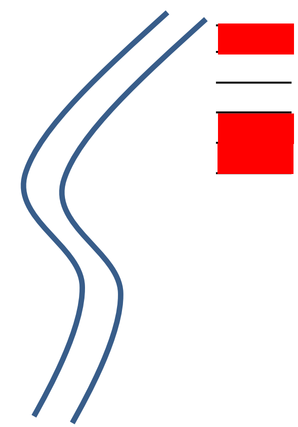
From Kwak, Zimmaro et al. (2016)

PGV = 30 cm/s



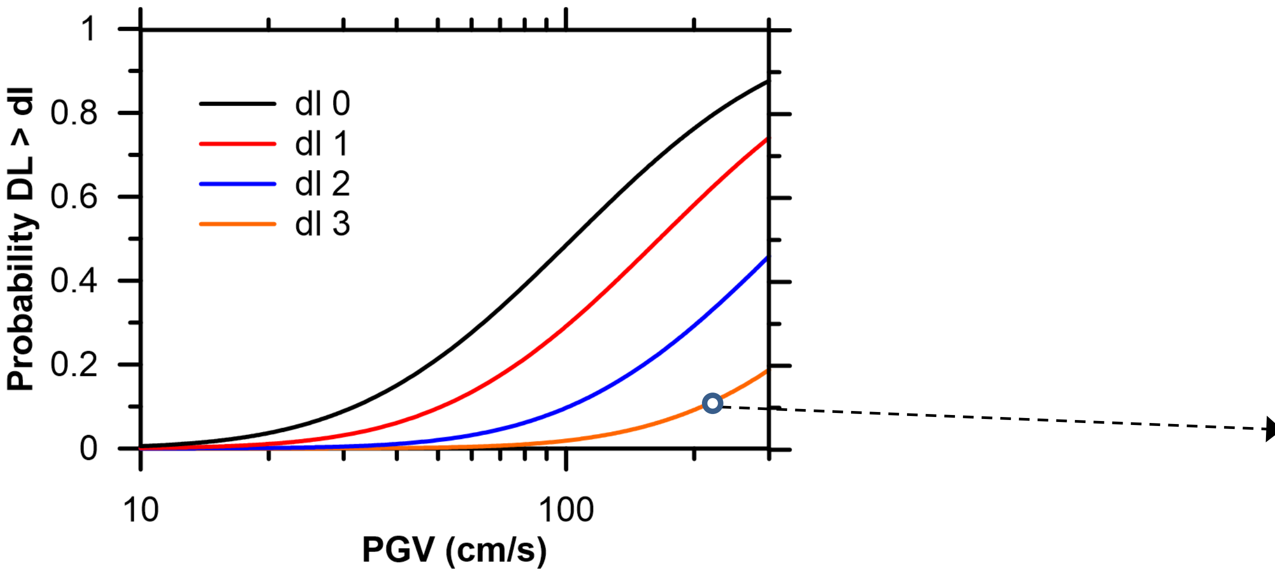
Damaged
1/5 = 20%

PGV = 120 cm/s



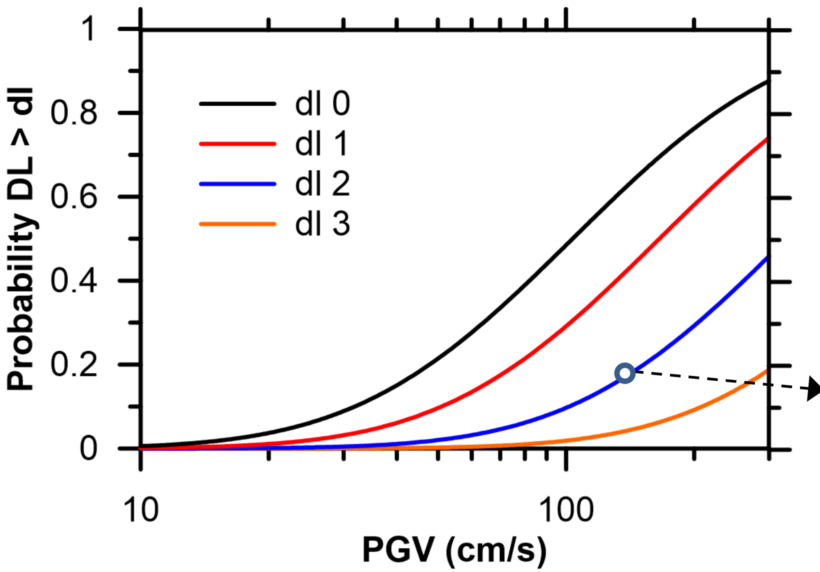
Damaged
3/5 = 60%

Empirical fragility curves



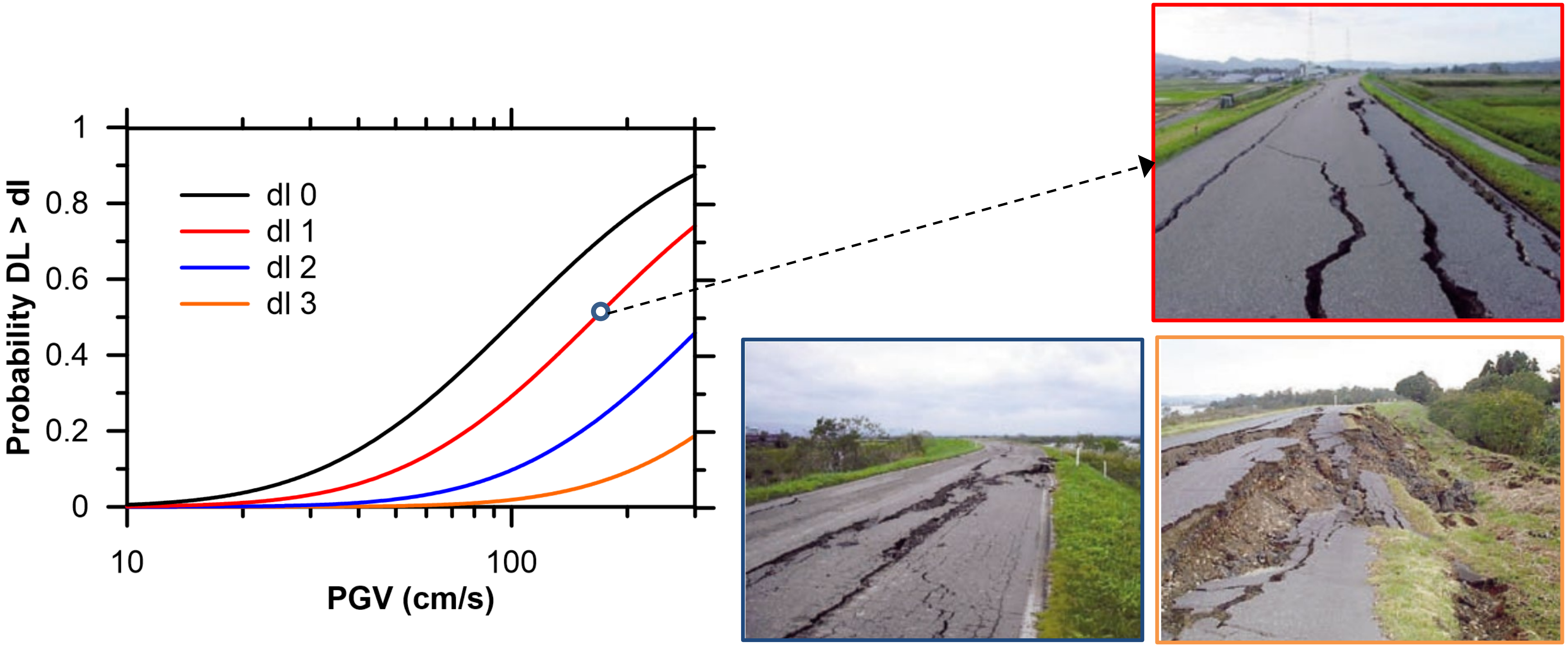
From Kwak et al. (2016)

Empirical fragility curves



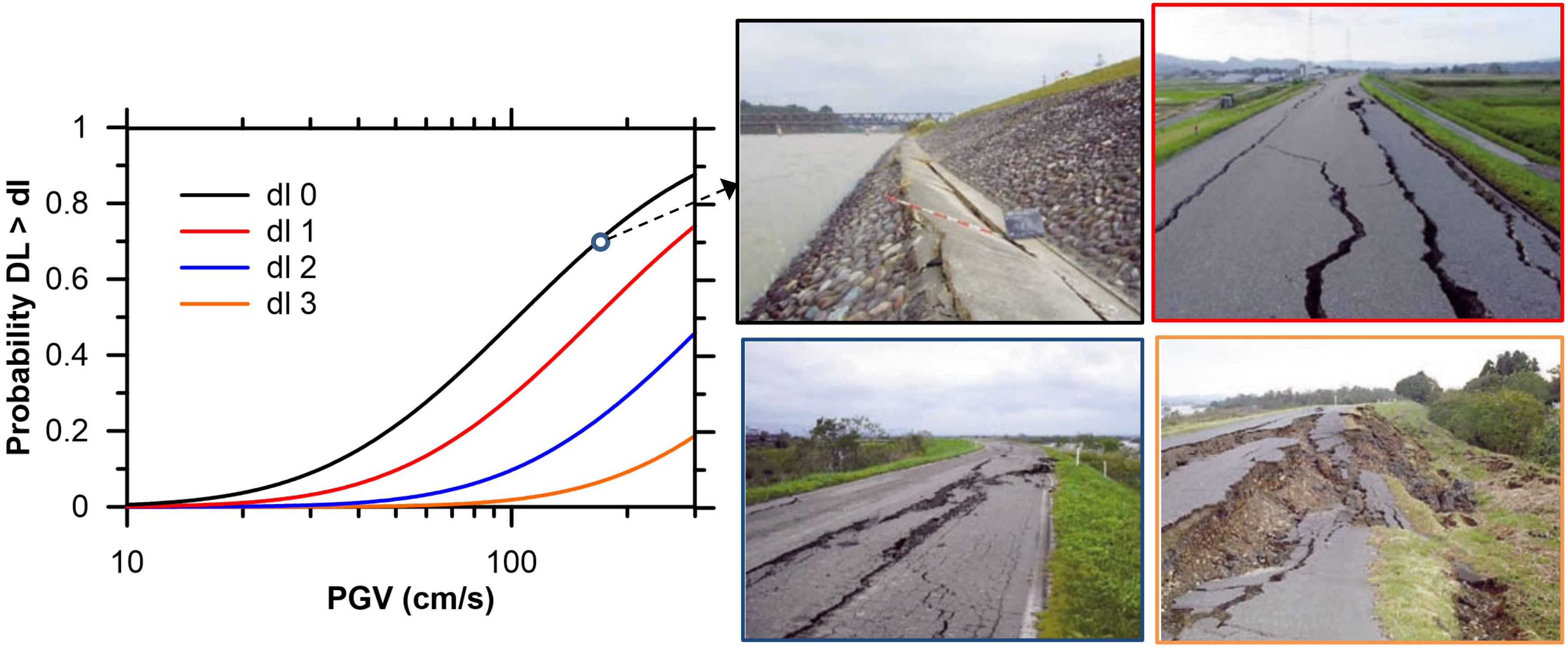
From Kwak et al. (2016)

Empirical fragility curves



From Kwak et al. (2016)

Empirical fragility curves



Can be used to determine vulnerability of a structure and/or an infrastructure system

From Kwak et al. (2016)

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Conclusions

- *In Southern Italy there is an anelastic attenuation faster than in other regions (low quality factor (Q) effect?)*

- *Overall GMMs overestimate observed IMs at low intensities and underestimate them at high intensities (unconservative?)*

- *Model variabilities are usually lower than observations' variabilities*

- *Can fragility curves used as a tool to quantitatevily rank GMMs?*

Thank you!

Regina G., Zimmaro P., Taroni M., Akinci A. (2023). Peculiar characteristics of ground motions in Southern Italy: insights from global and regional ground motion models. *Earthquake Spectra*, **39**, 577-595.

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