2024 PEER - LBNL Workshop
Simulated Ground Motions for the San Francisco Bay Area
January 18-19, 2024

Towards the engineering utilization of BB-SPEEDset, a validated dataset of physics-based simulated accelerograms from multiple seismic regions and faulting styles

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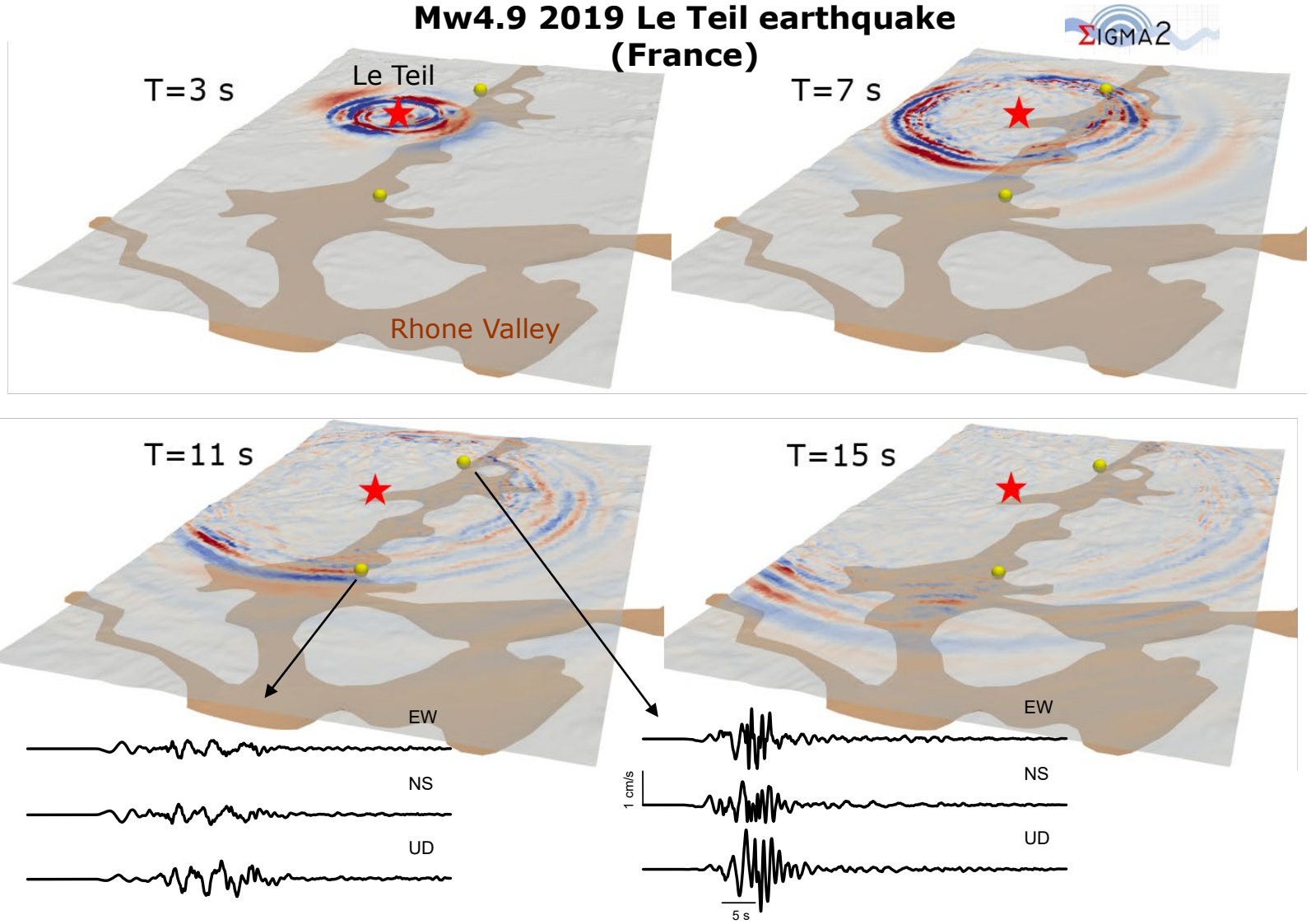
January 18th, 2024

Berkeley Lab, San Francisco

Physics-based numerical simulation (PBS) of earthquake ground motion: SPEED@PoliMI



SPectral **E**lements in **E**lastodynamics with **D**iscontinuous Galerkin

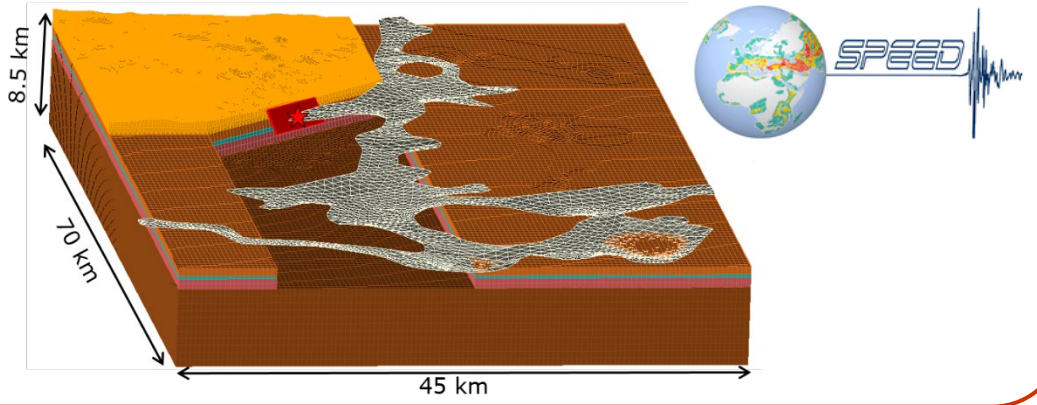
http://speed.mox.polimi.it/

Antonietti et al. (2012) CMAME
Mazzieri et al. (2013) IJNME

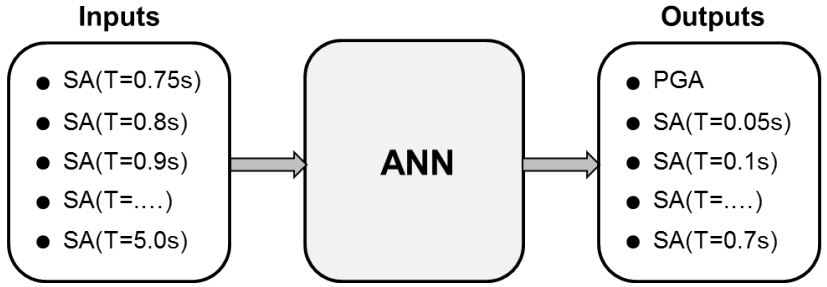
Workflow to compute broadband seismic motions from 3D PBS by SPEED

Regional scale PBS up to f_{max} (code SPEED)

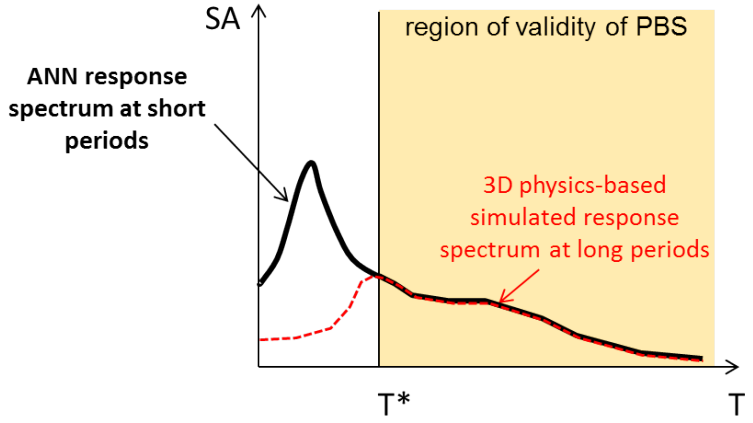
with f_{max} depending on spatial discretization and ability of velocity and source models to reproduce realistically high frequencies



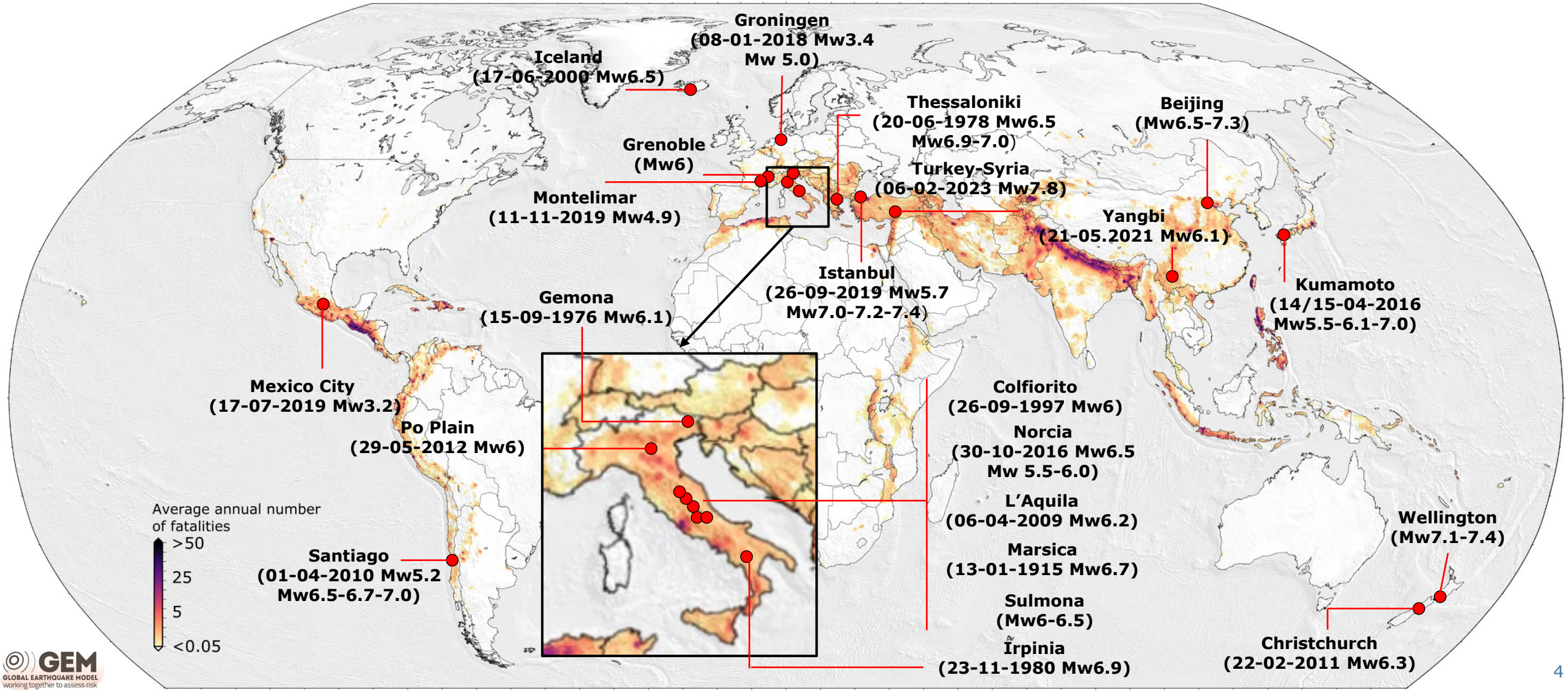
Estimating Broadband (BB) Ground Motions through Artificial Neural Network (ANN2BB)



Paolucci et al. (2018) BSSA



Construction of BB-SPEEDset (v1.0 → v2.3)



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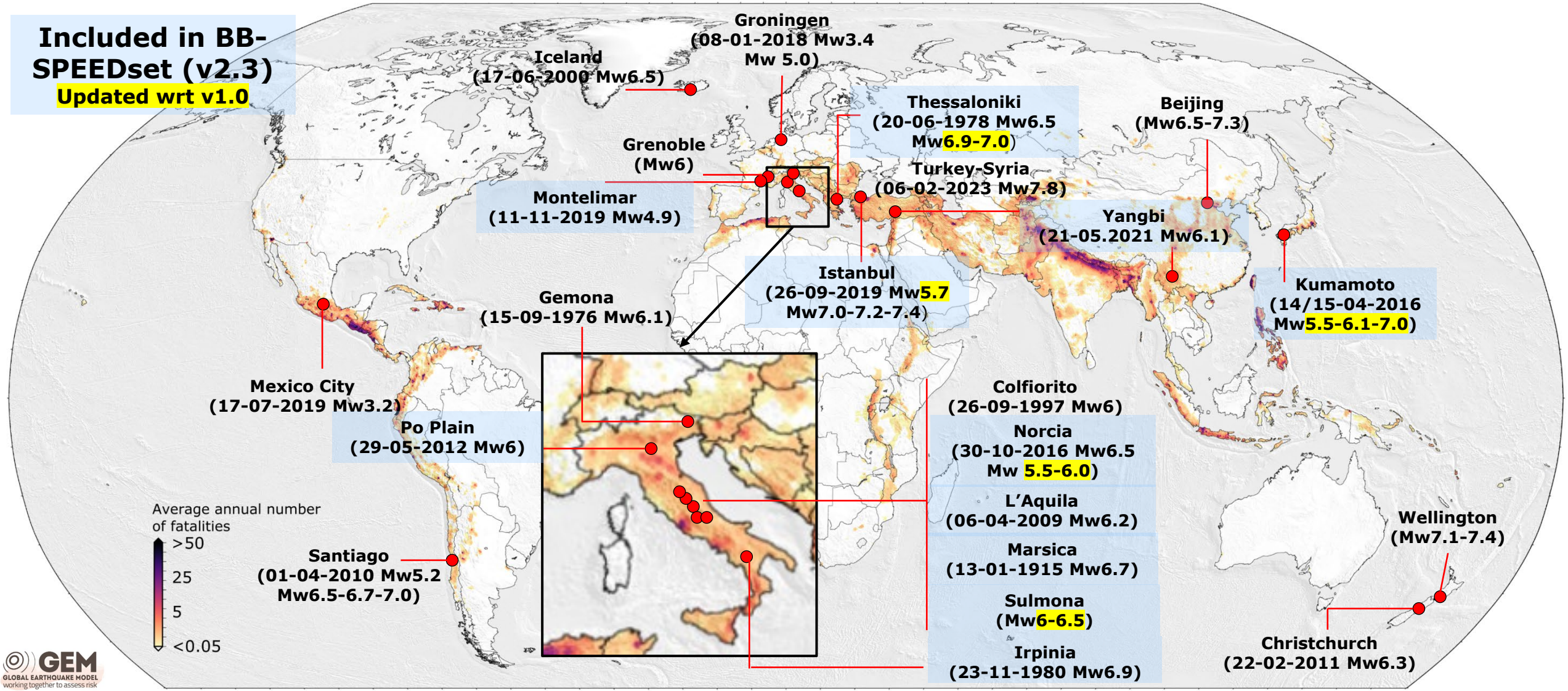
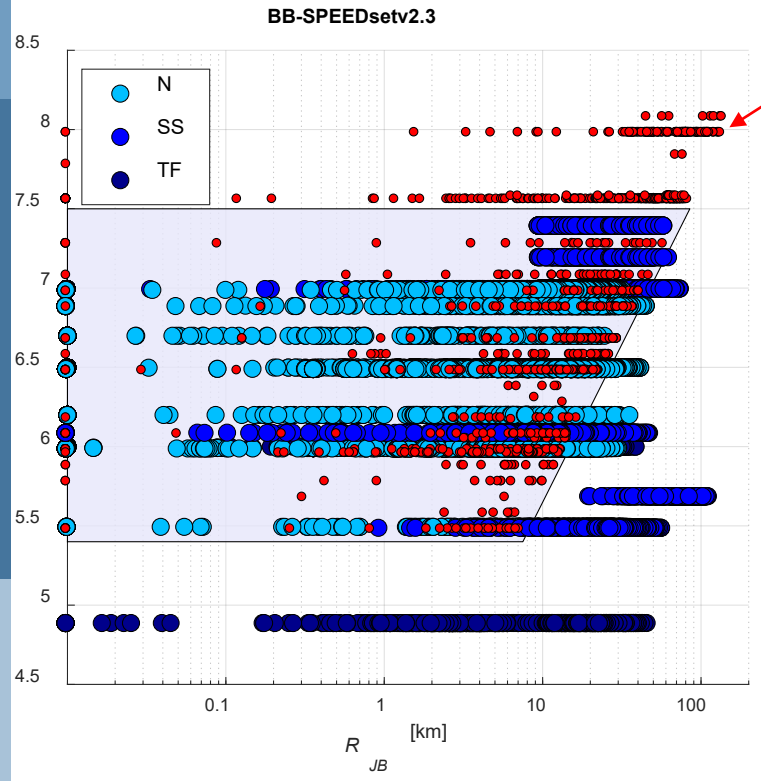


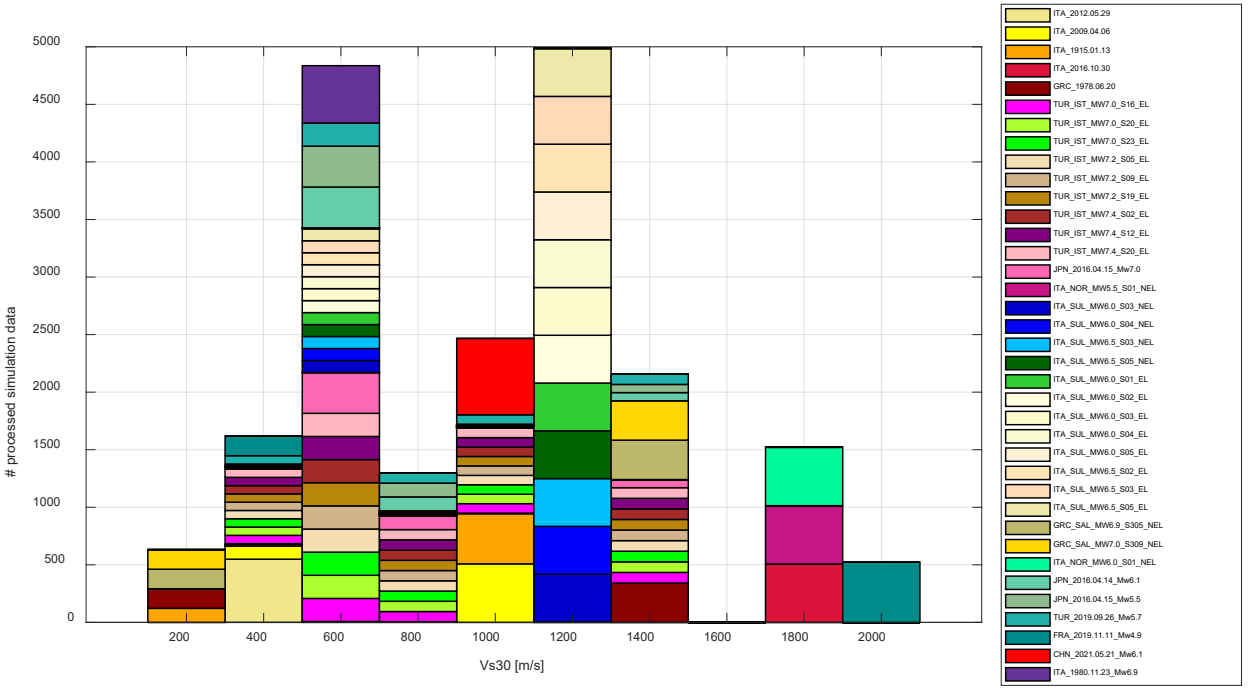
BB-SPEEDset (v2.3): a dataset of near-source accelerograms from PBS

M_w- R_{jb} and V_{S30} distribution of BB-SPEEDset



NESS2.0
(Sgobba et al. 2021)

BB-SPEEDset v2.3:
- 37 scenarios (12 validations + 25 scenarios)
- 55% N; 38% SS; 6% TF
- 75% V_{S30} > 600 m/s; 1% V_{S30} < 200 m/s



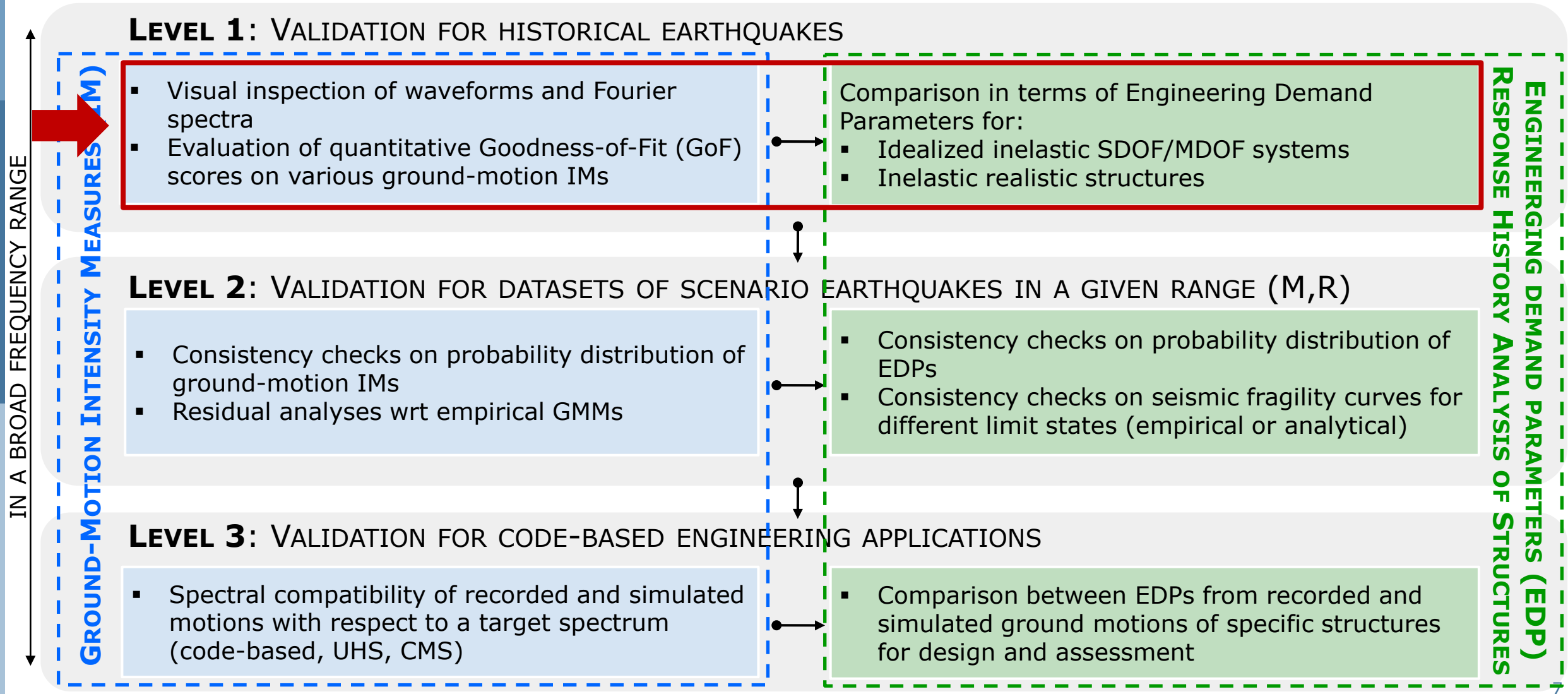
BB-SPEEDset: A Validated Dataset of Broadband Near-Source Earthquake Ground Motions from 3D Physics-Based Numerical Simulations

Roberto Paolucci; Chiara Smerzini; Manuela Vanini

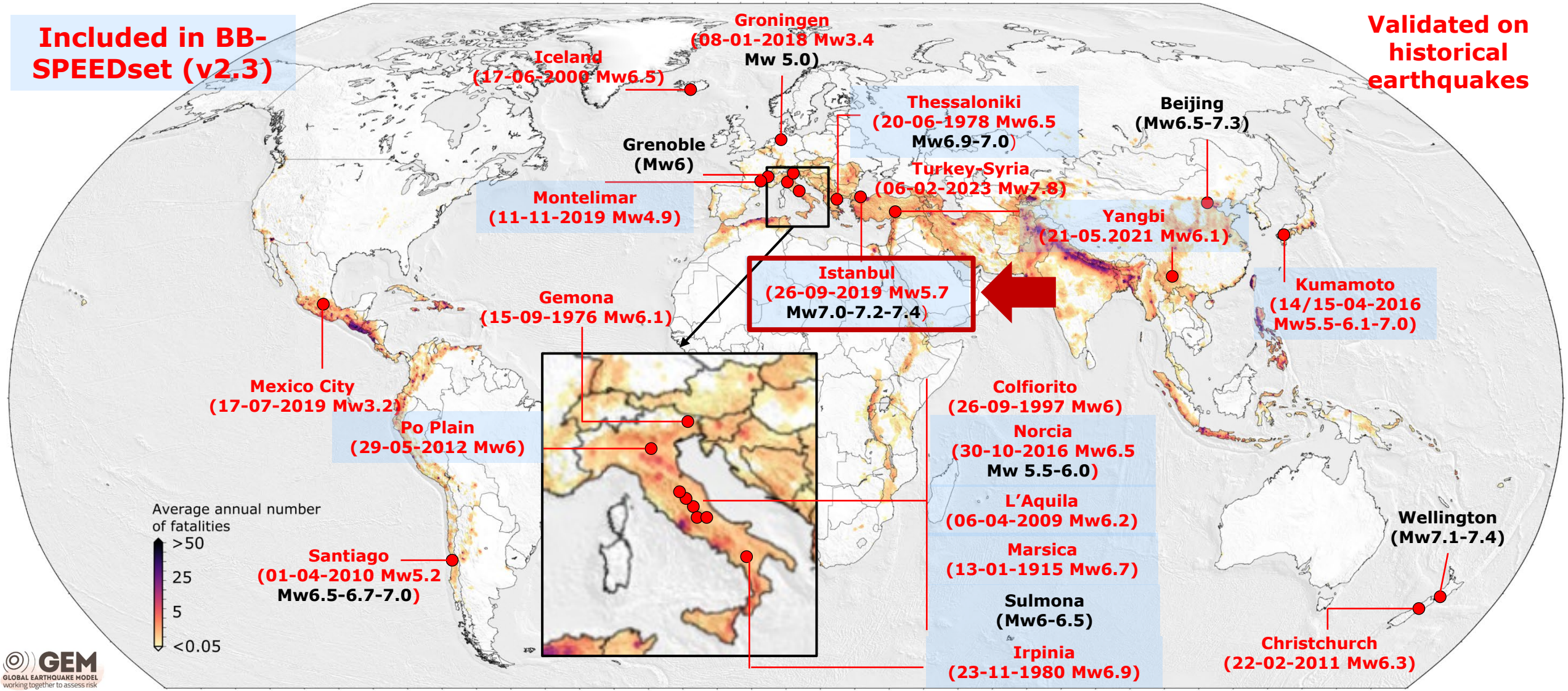
Bulletin of the Seismological Society of America (2021) 111 (5): 2527–2545.

Open-source (*available soon v2.3*):
http://speed.mox.polimi.it/bb-speedset/
- Flatfile
- 3-component broadband accelerograms (~20’000)

Multi-level validation framework for the engineering utilization of simulated motions

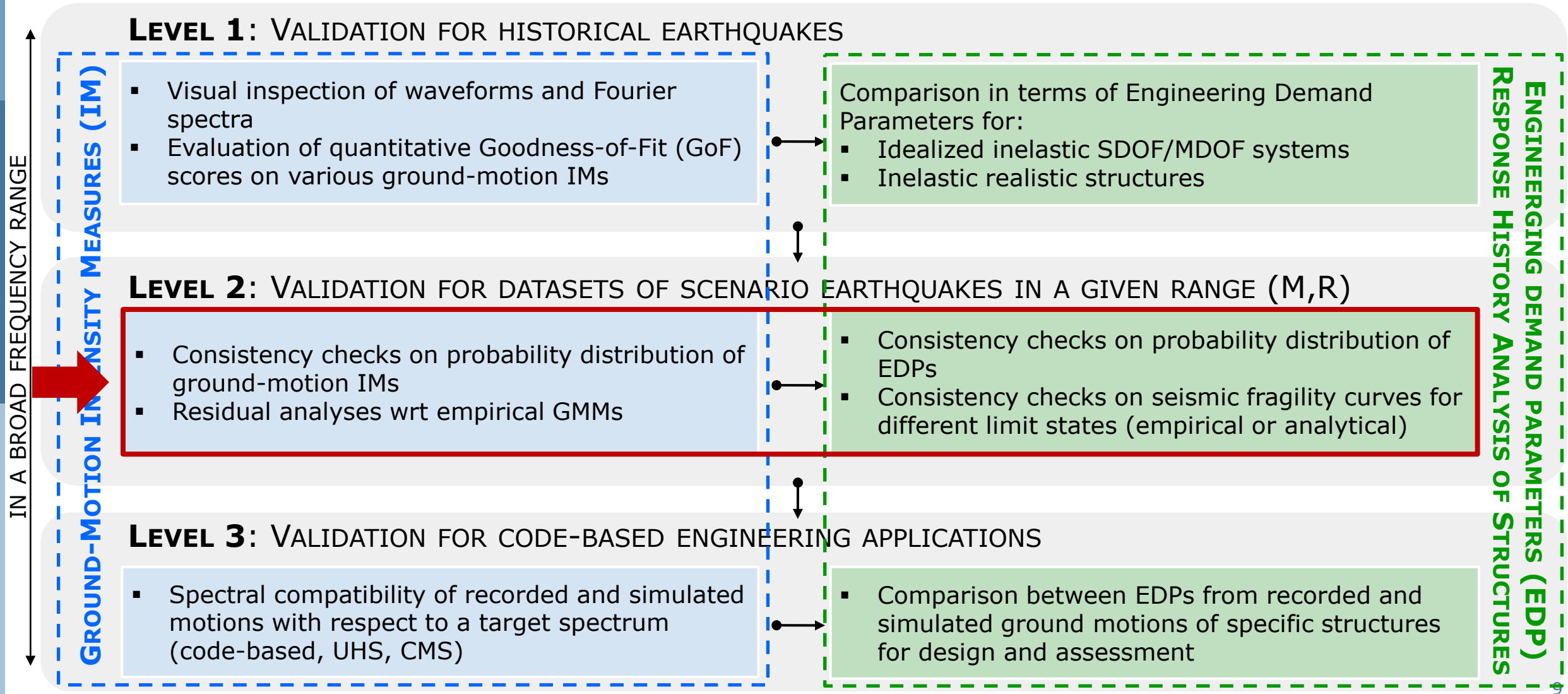


Validation on historical earthquakes



GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

Multi-level validation framework for the engineering utilization of simulated motions



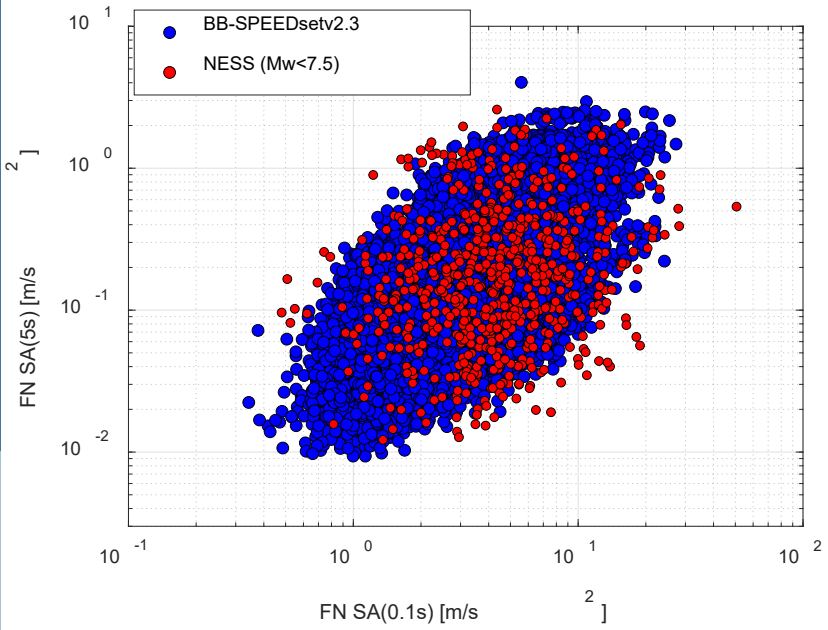
Validation of datasets of scenario earthquakes

For a given (M, R) range, when *compared to recorded datasets*:

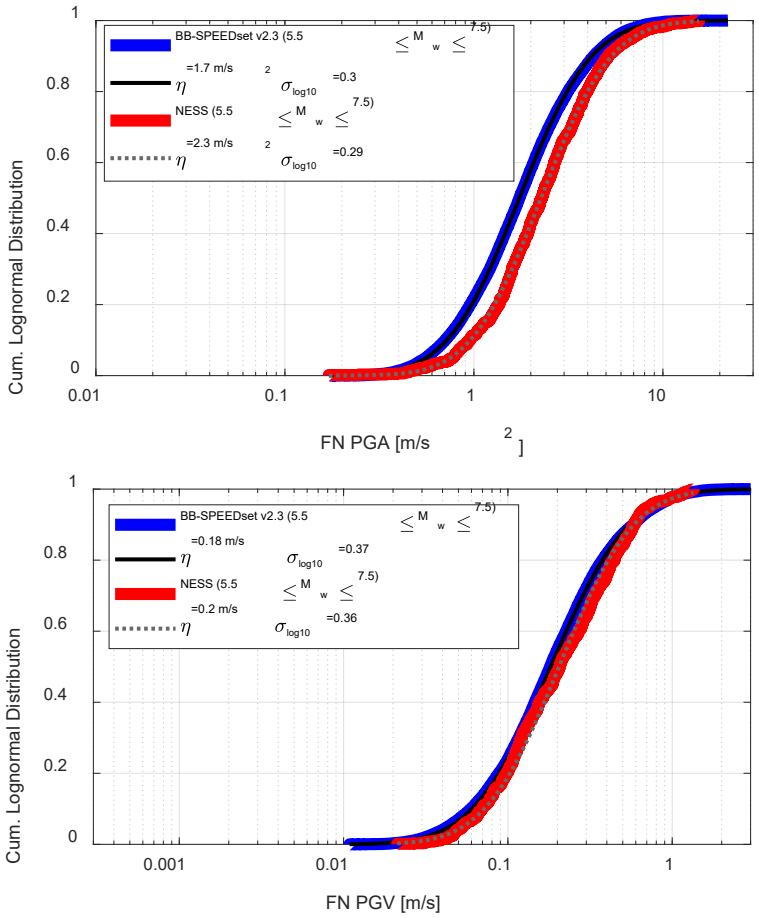
- Are the ground motion Intensity Measures (IMs) collectively *unbiased*?
- Do the ground motions reproduce a *realistic* aleatory variability?

Validation tests on the distribution of IMs against a recorded near-source dataset (NESS)

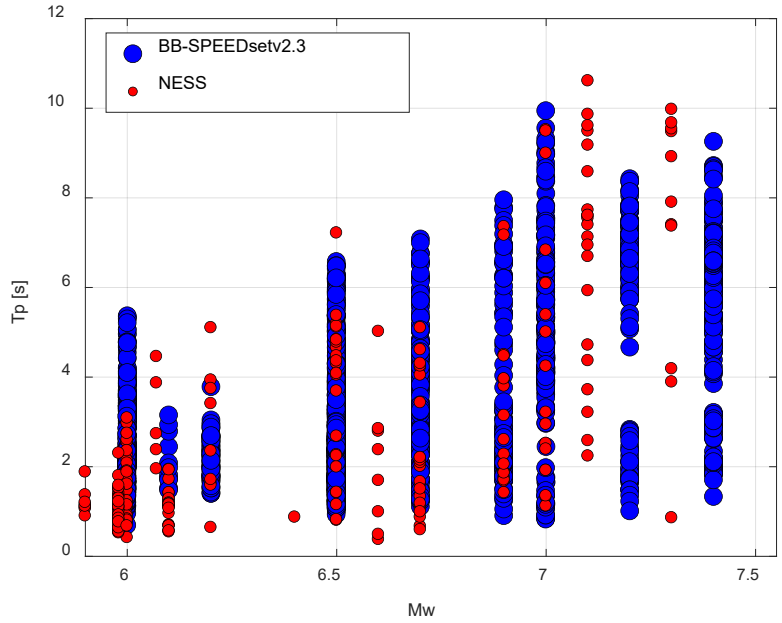
Fault Normal (FN) SA(0.1s)-SA(5s) correlation



Cumulative Distribution Function FN PGA, PGV

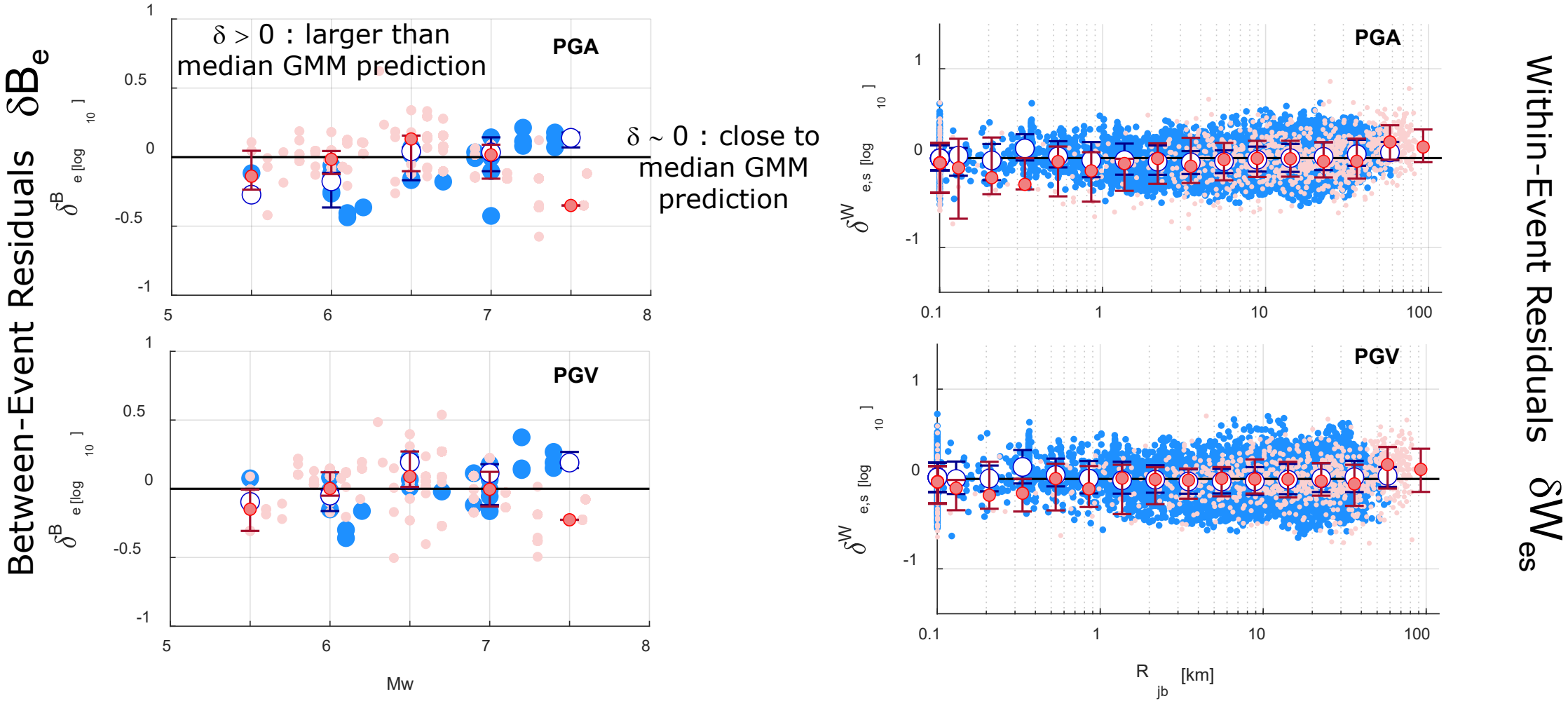


Pulse-like waveforms: Pulse Period T_P Vs M_W (Shahi and Baker, 2014)

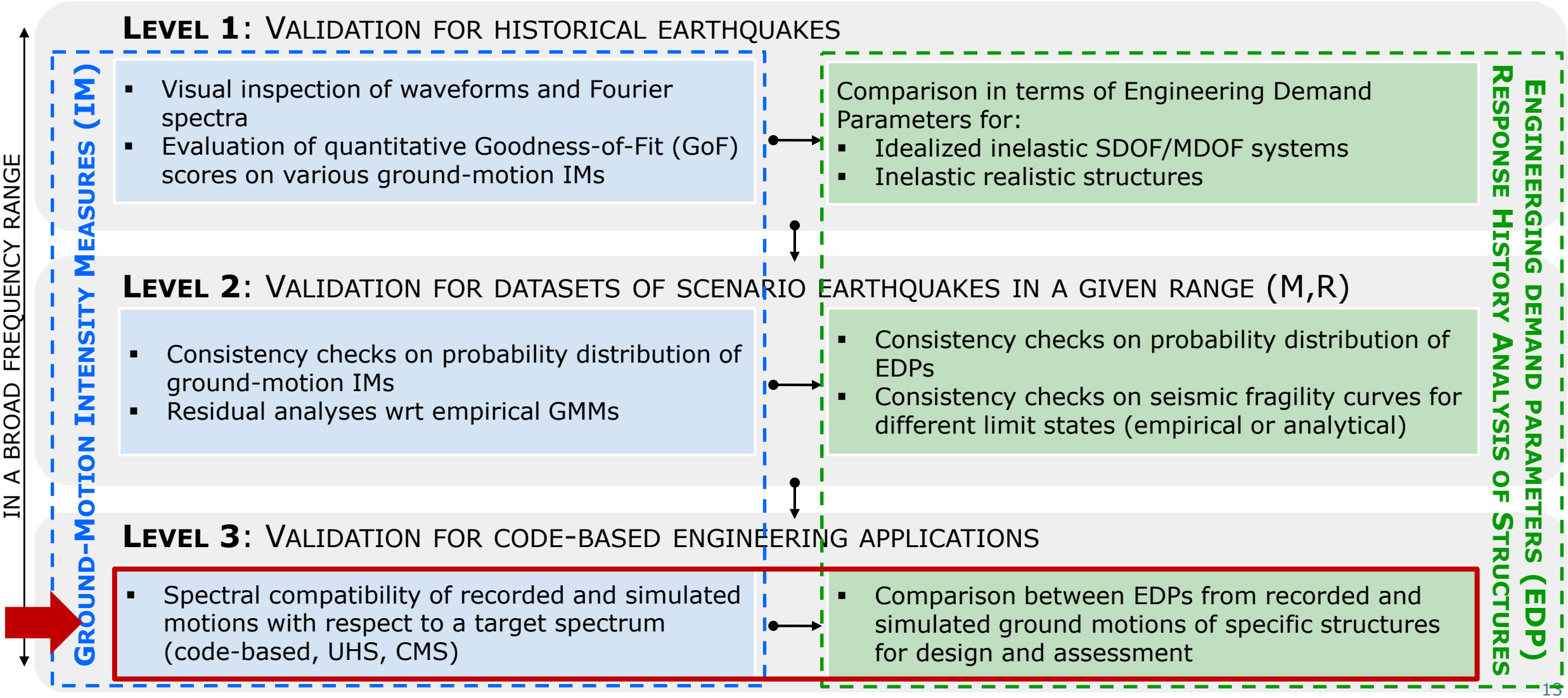


Checks on the components of ground motion variability with respect to NESS

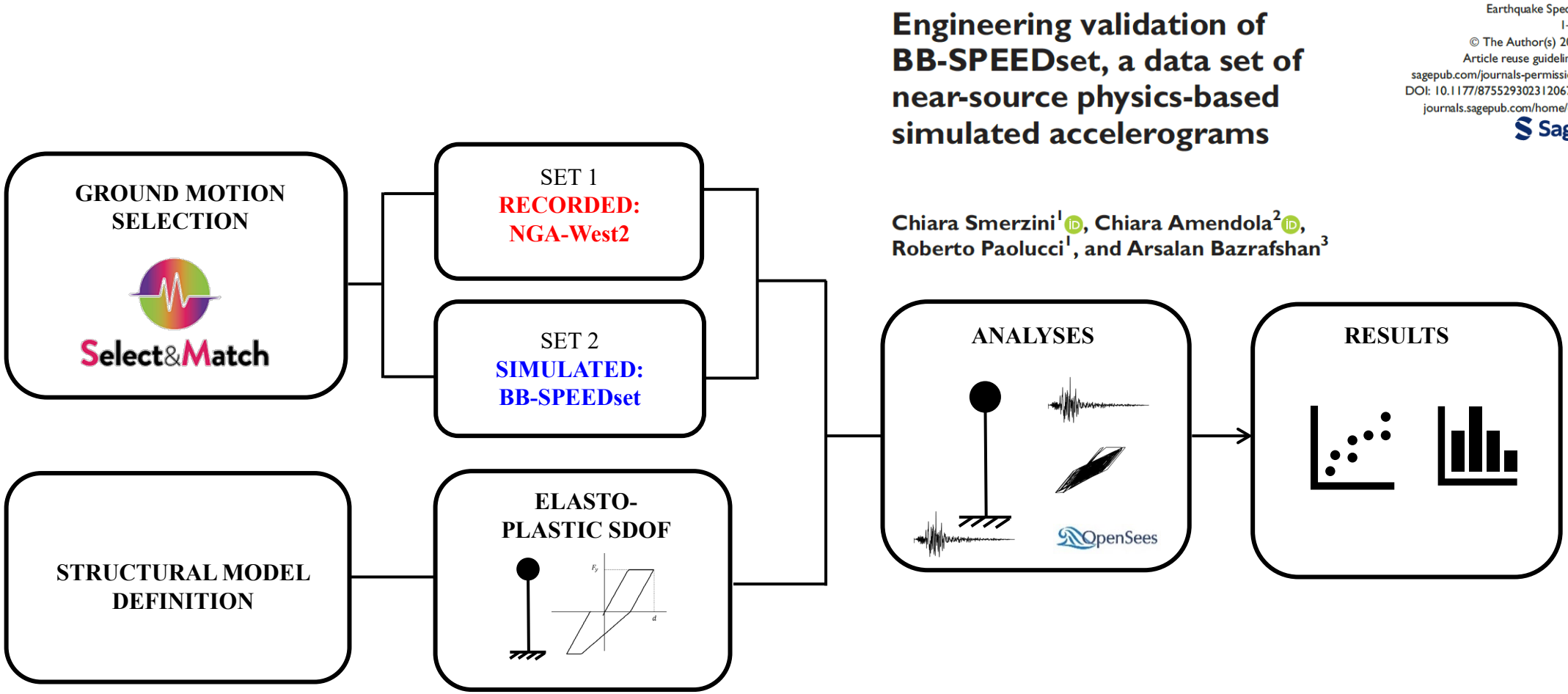
Between- and within-event residuals and corresponding variability of BB-SPEEDset and NESS with respect to the ITA18 GMM (Lanzano et al. 2019, adjusted by near-source effects)



Multi-level validation framework for the engineering utilization of simulated motions



Engineering validation of BB-SPEEDset for structural non-linear dynamic analyses



Engineering validation of BB-SPEEDset, a data set of near-source physics-based simulated accelerograms

Earthquake Spectra
1–26

DOI: 10.1177/87552930231206766
journals.sagepub.com/home/eqs
Sage

Chiara Smerzini[1], Chiara Amendola[2], Roberto Paolucci[1], and Arsalan Bazrafshan[3]

Select&Match: a software tool for ground motion selection enhanced by PBS

Integration of real and simulated ground motion datasets

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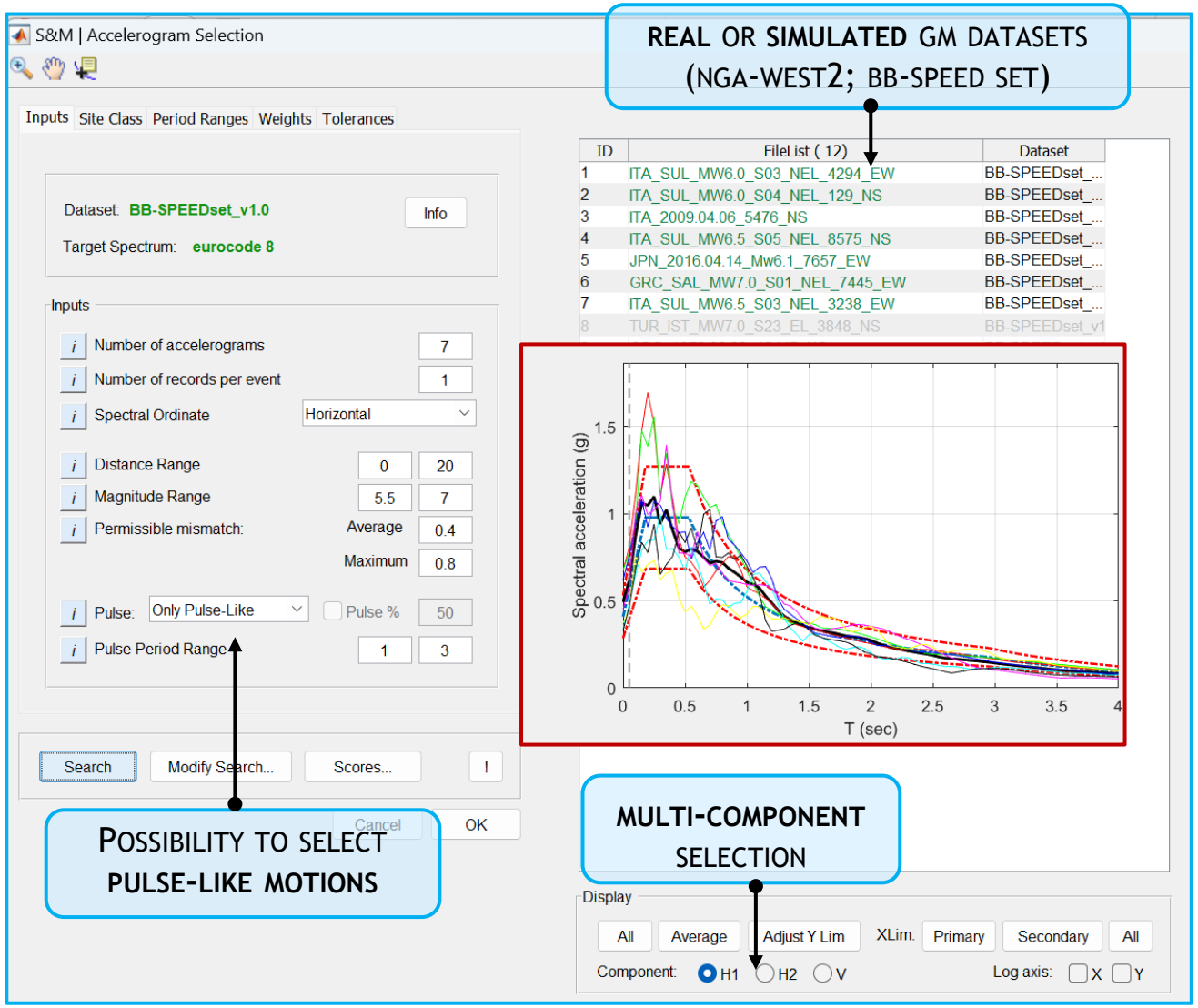
Manfredi et al. (2022) BEE



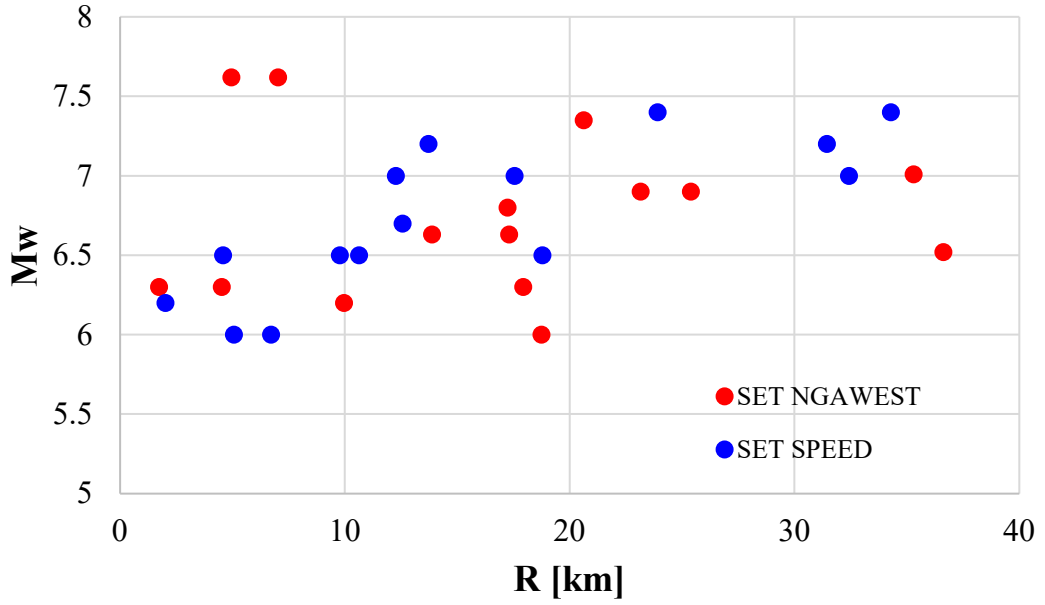
Selection of spectrally-consistent sets of recorded and simulated input signals

Select&Match

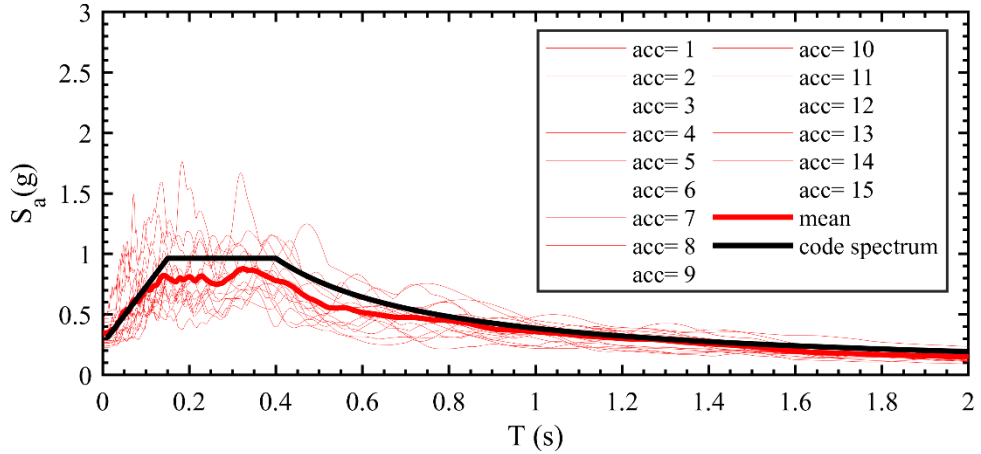
Version 1.0

Consistent selection criteria:

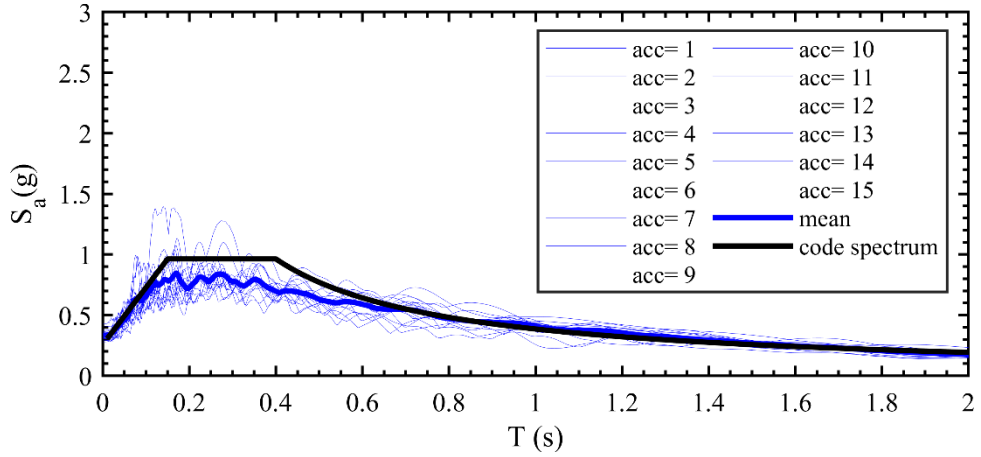
- 975 yrs return period elastic design spectrum (Central Italy)
- Reference rock site
- T=0.1-4 s within prescribed upper and lower tolerances
- Unscaled accelerograms



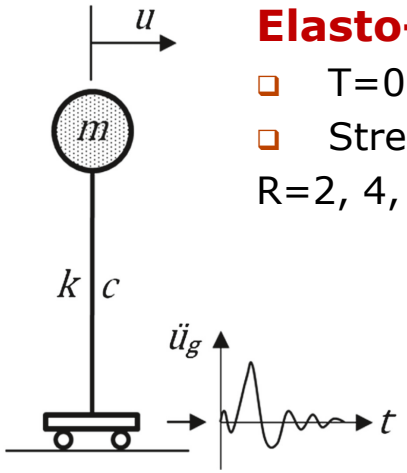
RECORDED SET: NGA-West2



SIMULATED SET: BB-SPEEDset



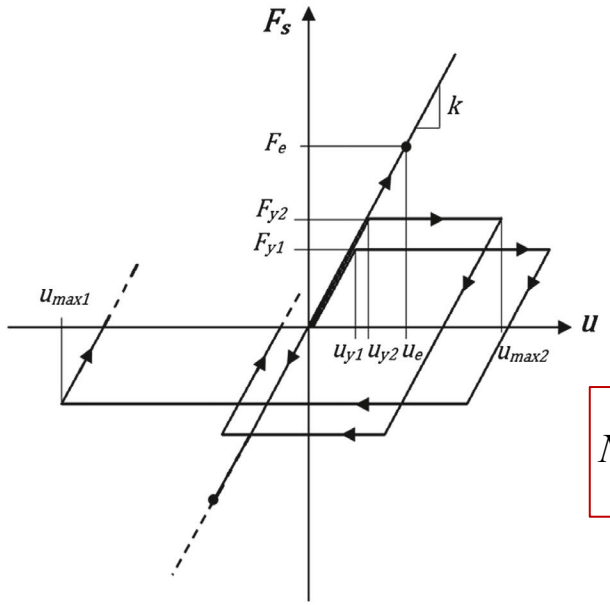
Statistical distribution of selected EDPs from recorded and simulated signals



Elasto-plastic SDOF systems:

- T=0.1 to 1.5 s
- Strength reduction factors

R=2, 4, 6



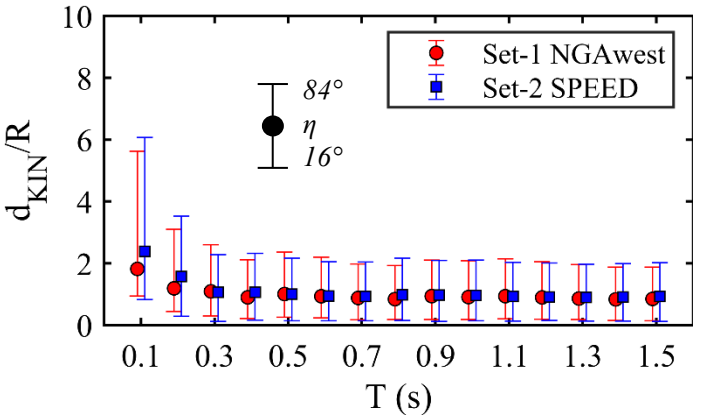
$$\frac{D_{kin}}{R} = \frac{u_{\max}}{R \cdot u_y}$$

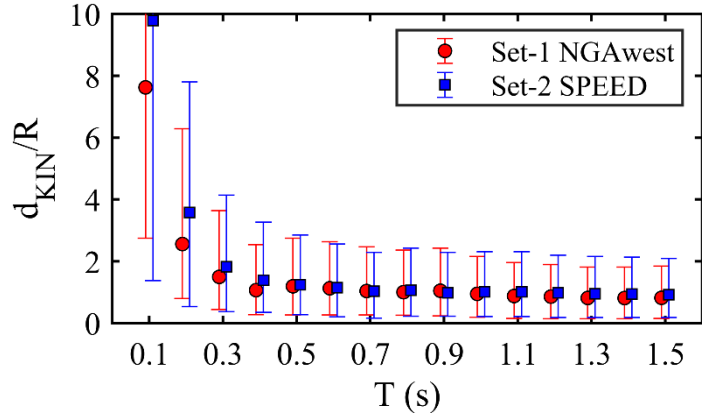
$$N_e = \frac{\sum E_{Hj}}{F_y \cdot (u_{\max} - u_y)}$$

increasing non-linearities

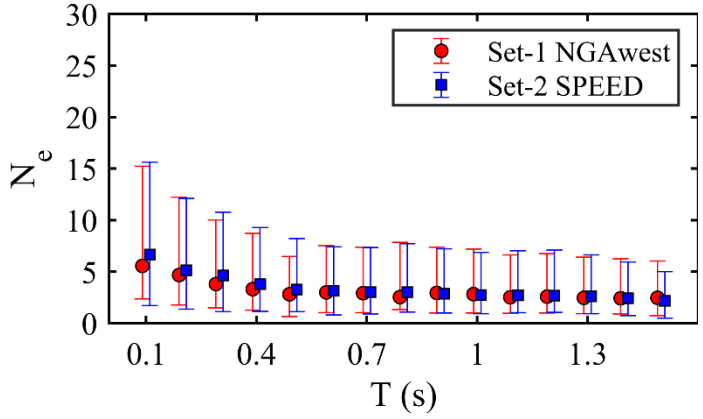
R=2 **R=4**

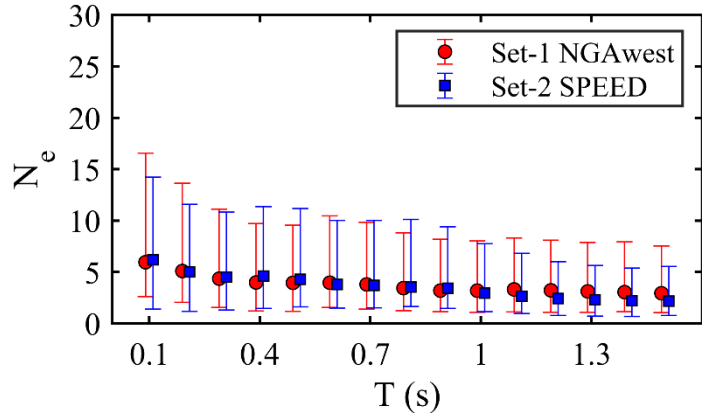
PEAK RESPONSE



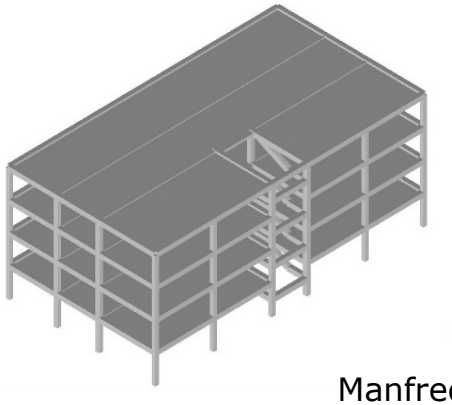


CYCLIC RESPONSE



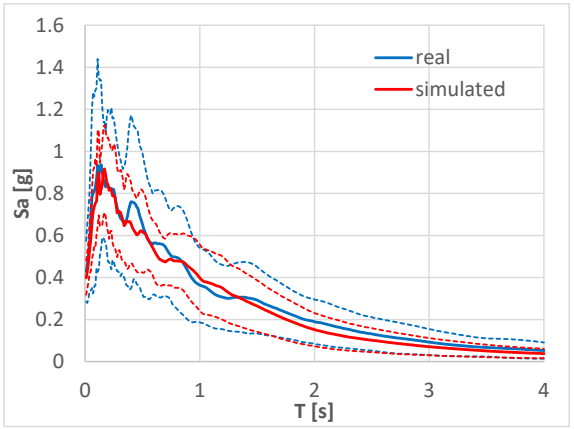


Engineering validation of BB-SPEEDset: results for more complex structures



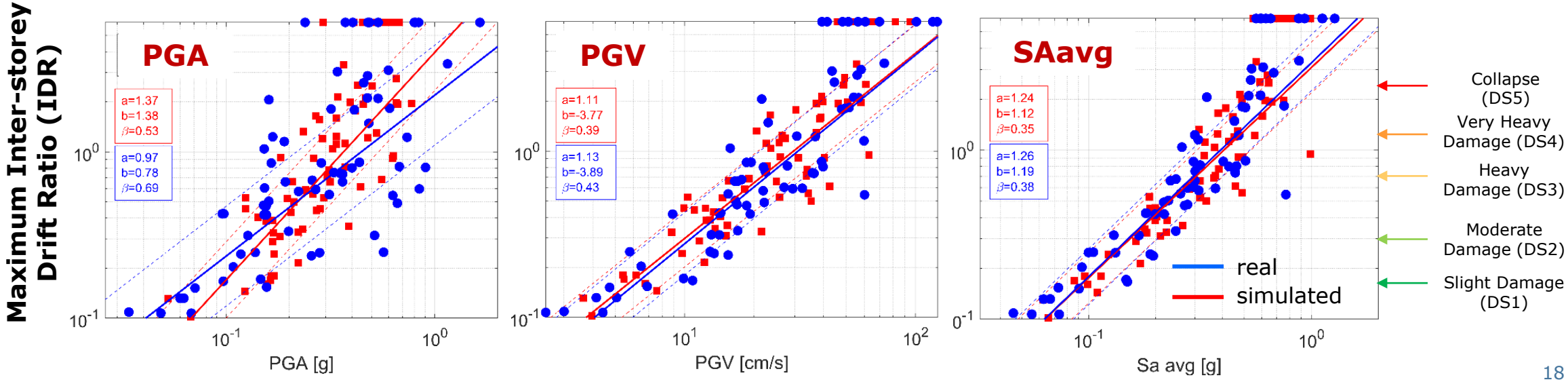
4 storey RC Building (wout seismic design)
T_0=0.54s

Manfredi et al. (2024) 18WCEE



Selection of sets of 80 **real** (NGA-West2) and **simulated** (BB-SPEEDset) **input signals** covering a wide range of intensities (PGA 0.05g ÷ 0.8 g) for **non-linear dynamic analyses**

Efficiency evaluation of different IMs: PGA, PGV and SAavg



Conclusions

- A key step to broaden the engineering utilization of PBS is the availability and dissemination of simulated ground motion datasets (e.g. PEER, CyberShake, BB-SPEEDset, SIGMOID-TR). Access through ground motion search and selection tools is preferable.
- Such datasets shall pass a validation process, from both a seismological and engineering perspective, and in a broad frequency range. However, there is still no consensus on the validation procedures and acceptance criteria.
- BB-SPEEDset is an example of validated dataset of broadband near-source ground motions from the PBS of several earthquakes in a relatively broad range of magnitude (M_W4.9-7.4), faulting styles and geological contexts. It is under continuous development and validation.

Acknowledgements

swissnuclear

Munich RE

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URBASIS-EU

…and the SPEED team!


A. Quarteroni


P. Antonietti


I. Mazzieri


R. Paolucci

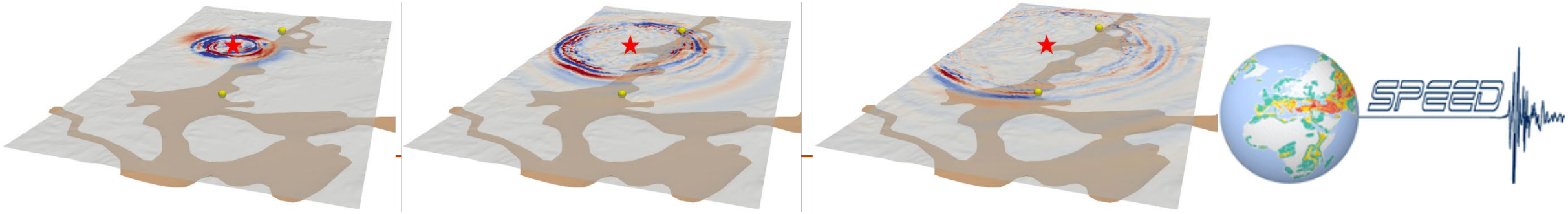

M. Vanini


M. Stupazzini


S. Sangaraju


C. Amendola


V. Hernandez



Thank you for your attention

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