From sensitivity analyses to uncertainty reduction and application driven PSHA

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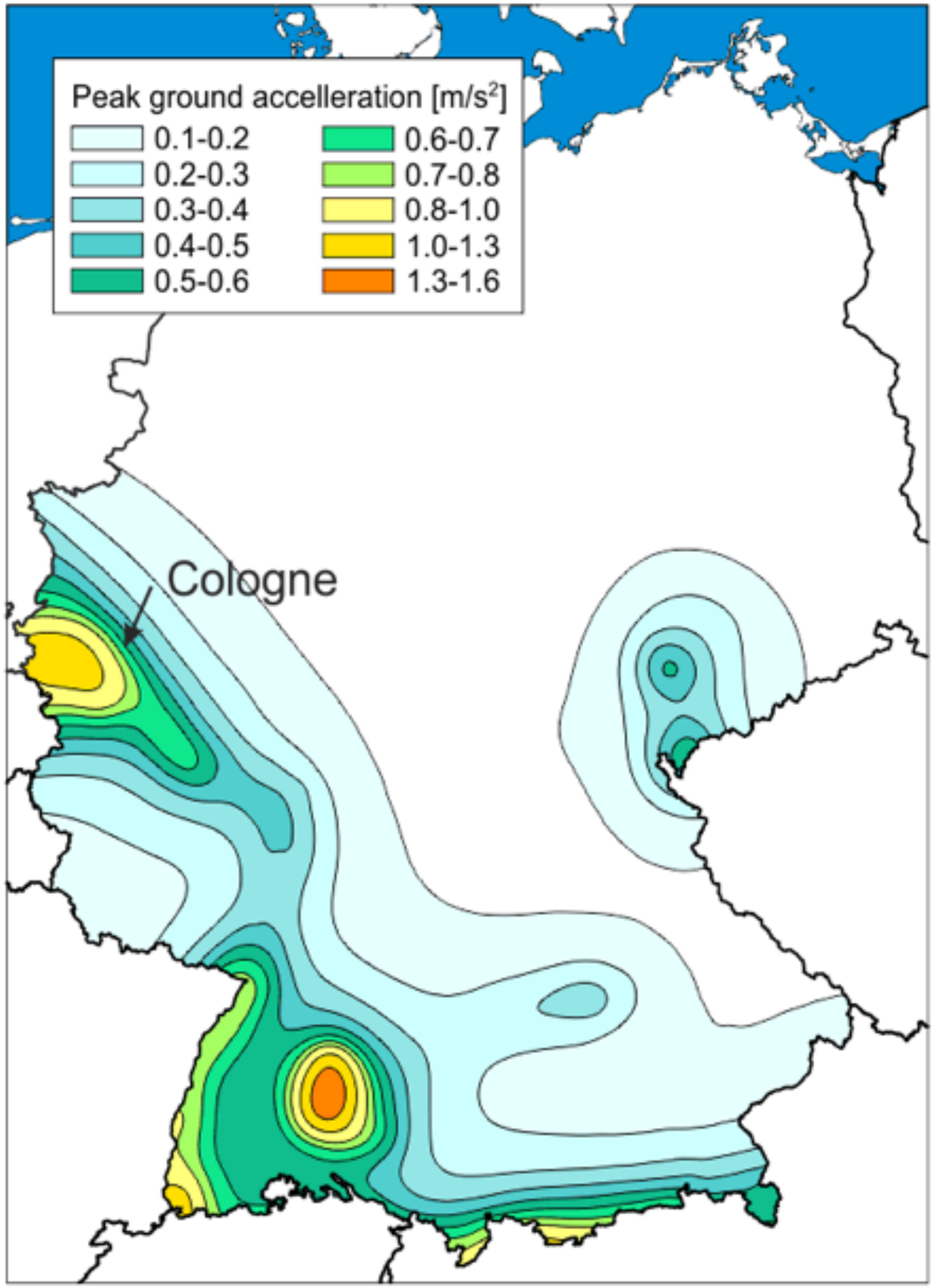


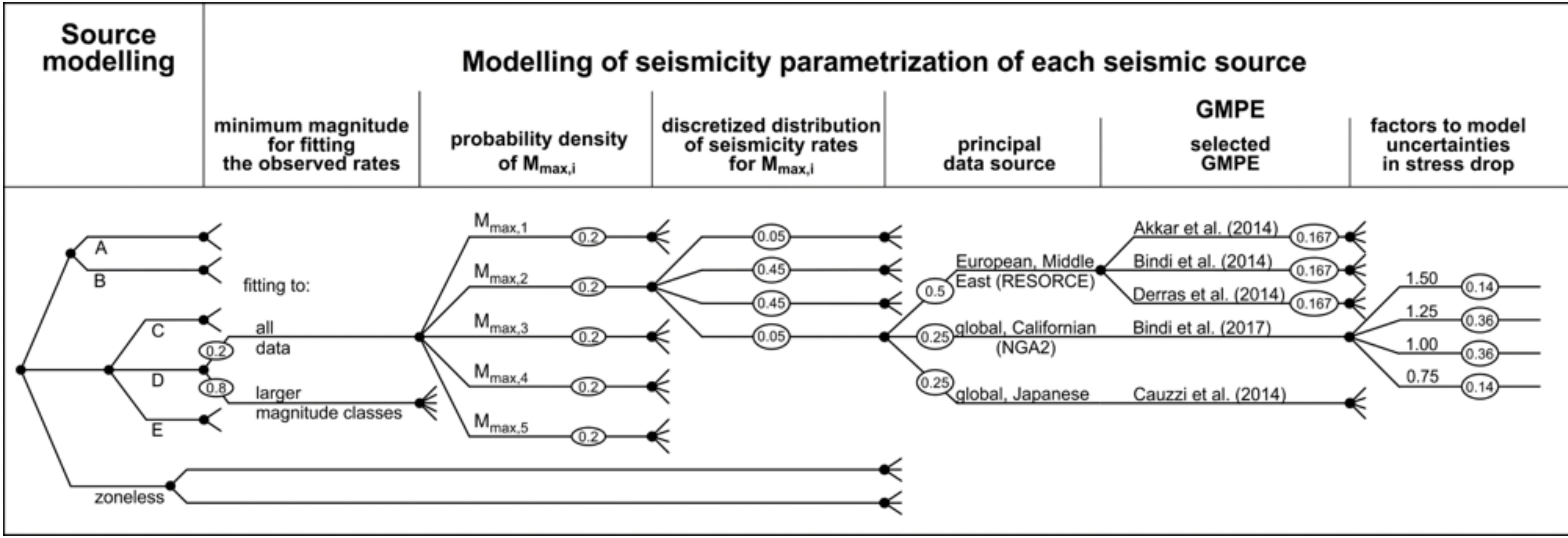
The Probabilistic Seismic Hazard Assessment of Germany - Version 2016

Map shown for PGA, RP = 475a, v_{S30} = 800 m/s

Grünthal, G., D. Stromeyer, C., Bosse, F. Cotton, D. Bindi., et al., The Probabilistic Seismic Hazard Assessment of Germany - Version 2016, Considering the Range of Epistemic Uncertainties and Aleatory Variability submitted

Maps and UHS available on GFZ website

A 4040 end-branches logic-tree



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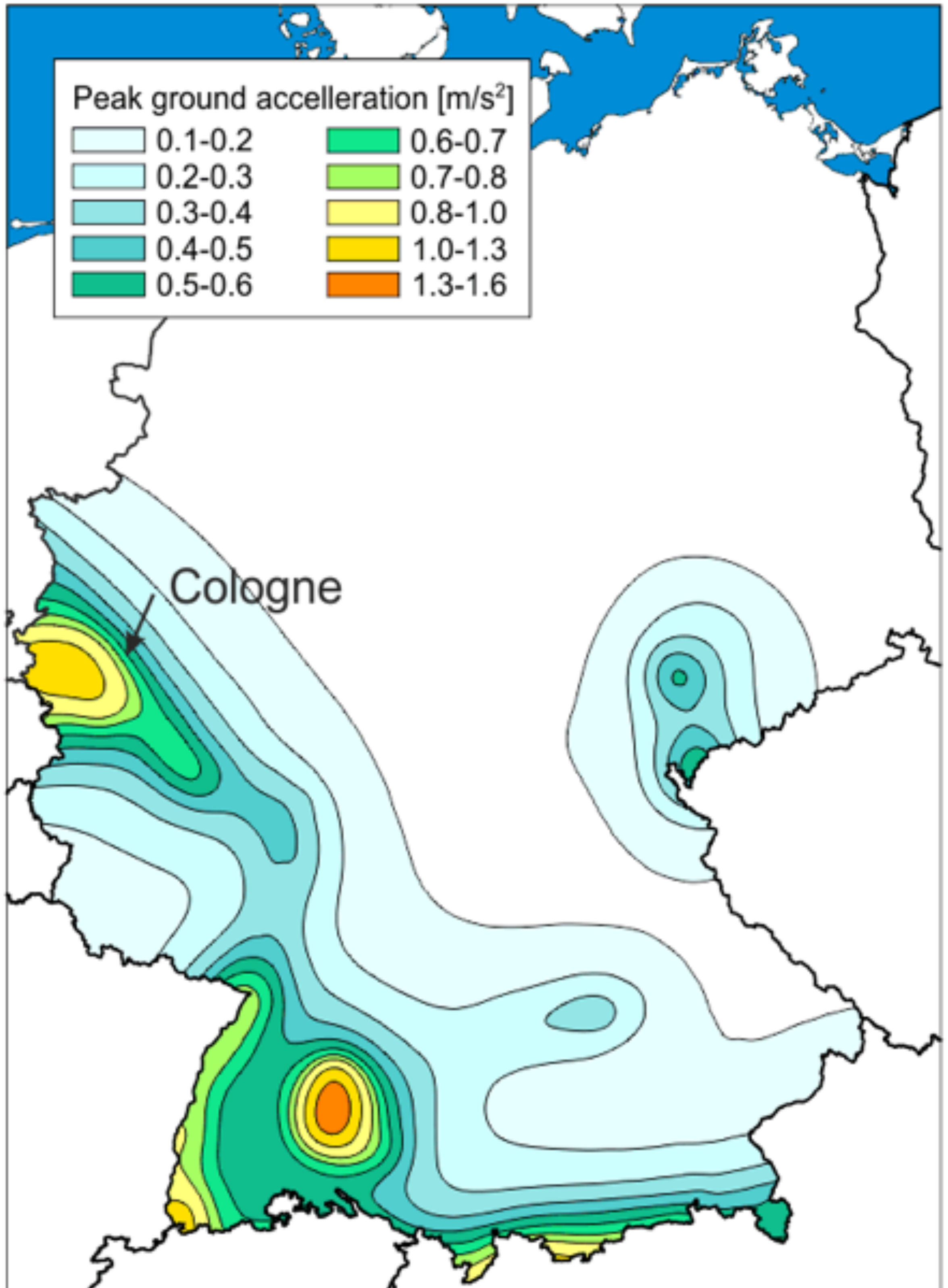
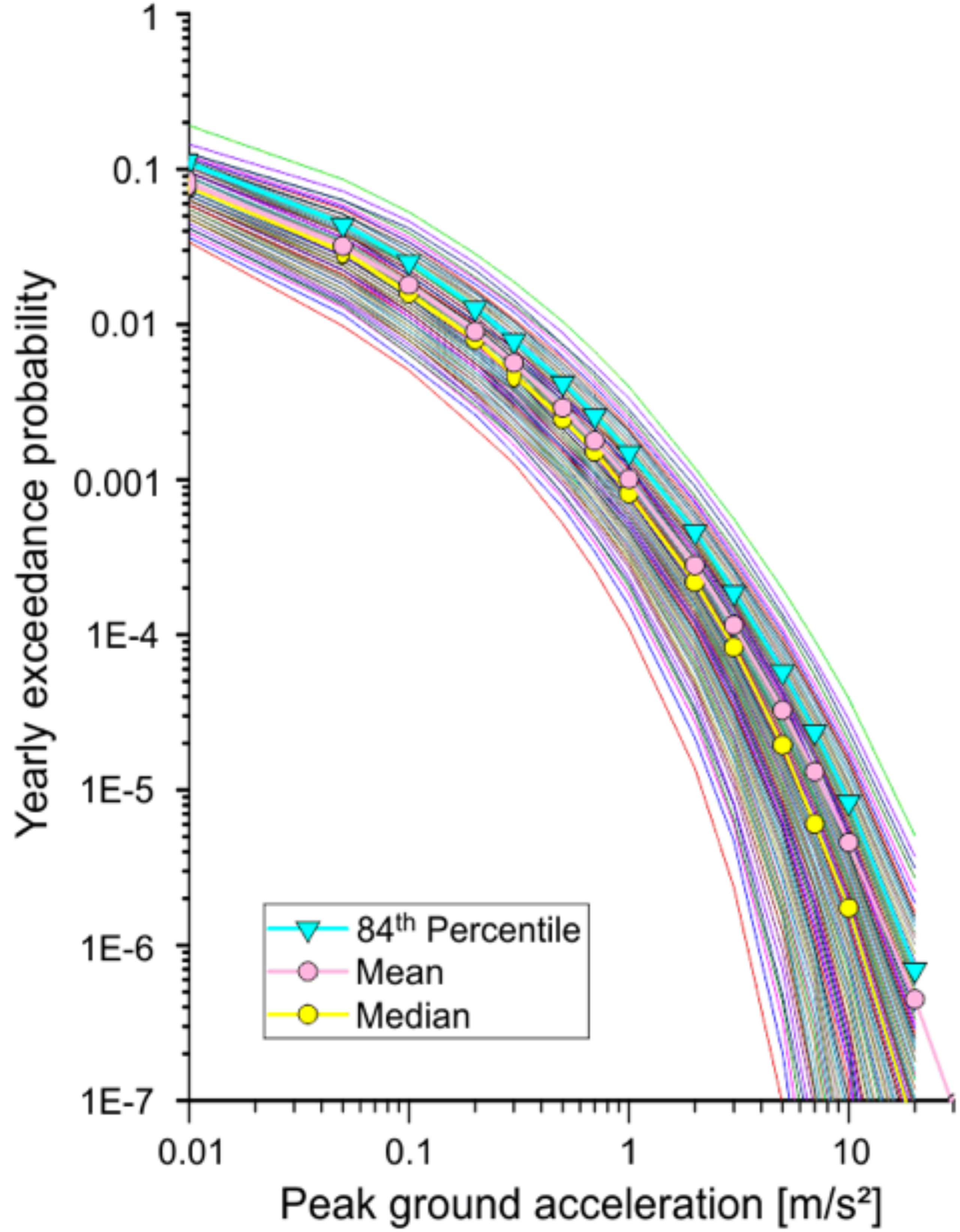
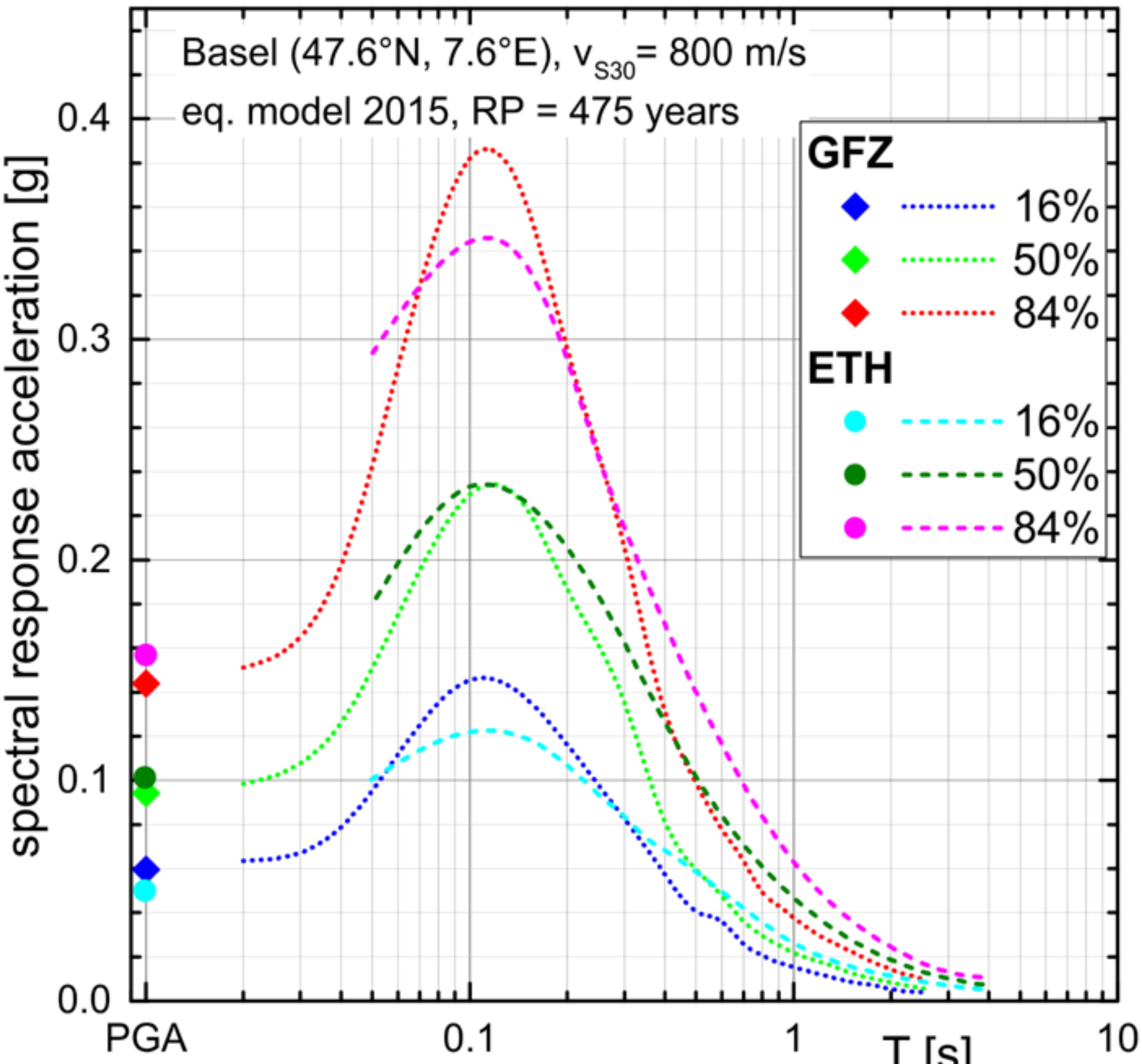
PGA, RP = 475a, Mean, v_{S30} = 800 m/s





Comparison GFZ/ETHZ: epistemic uncertainties



x3 between the 16% and 84% percentiles

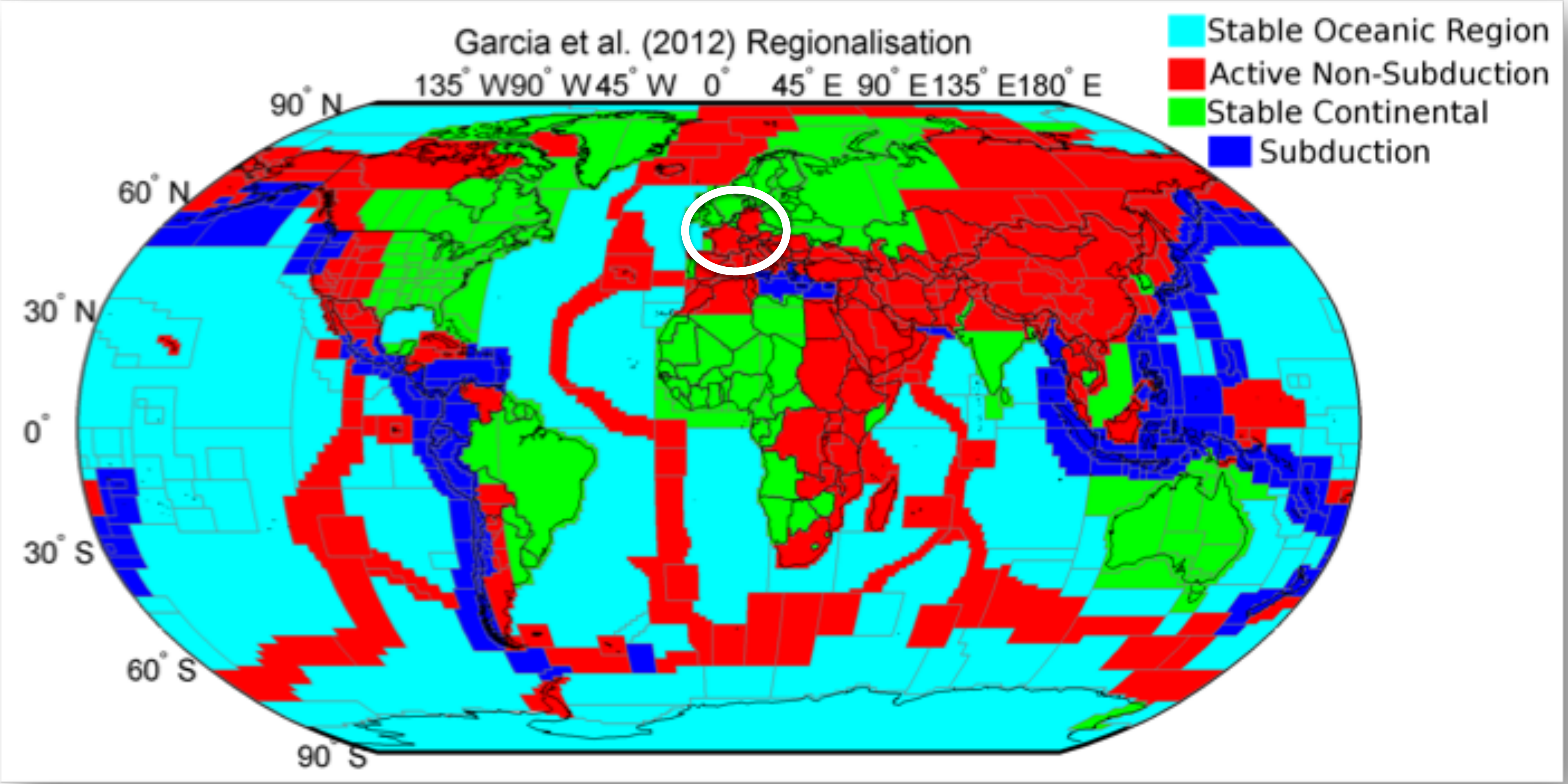
Our dream: uncertainty reduction

- **Selection:** Need for global, transparent, and data-driven regionalisation scheme to select models (e.g. GMPEs).

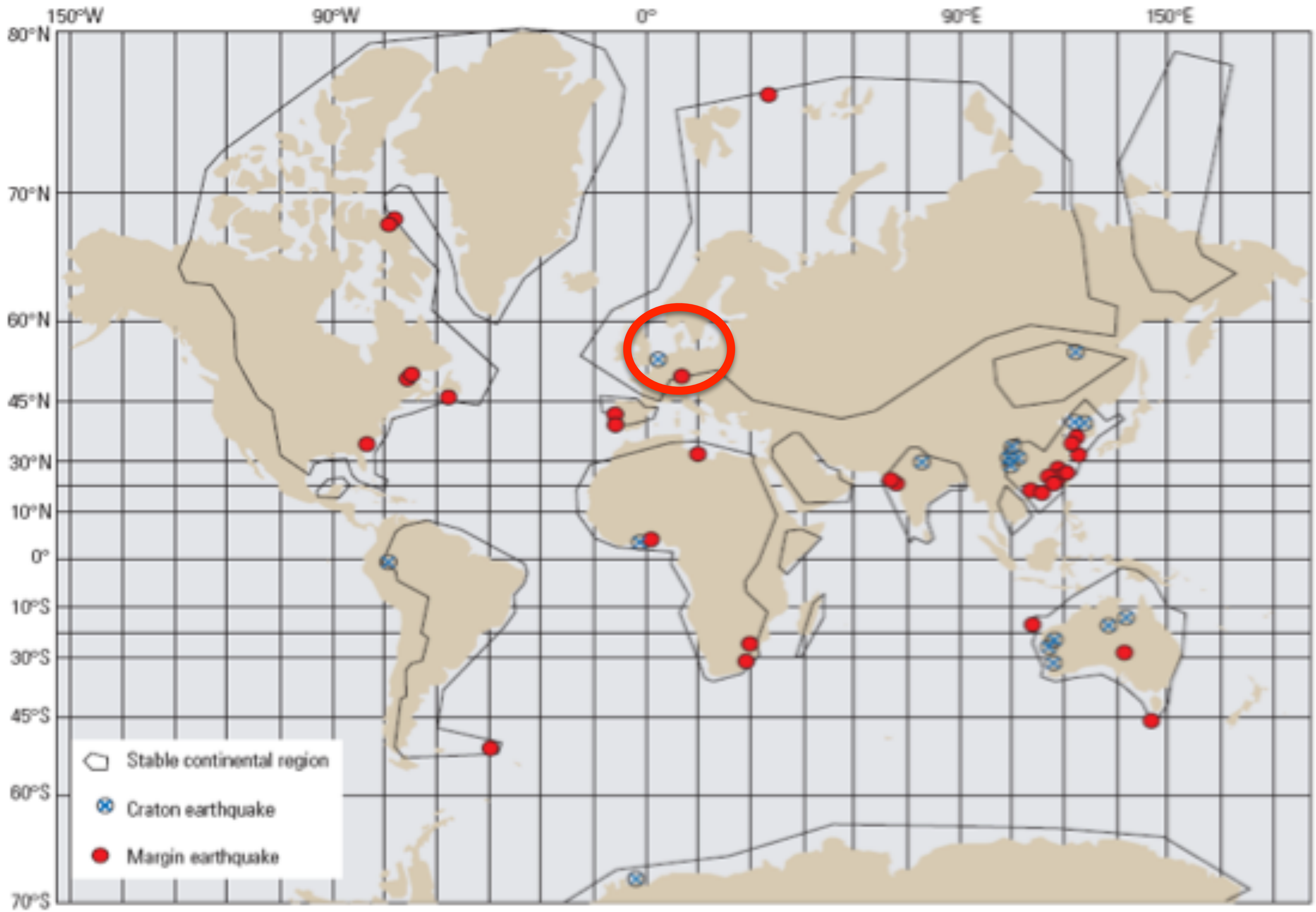
- **Sensitivity analysis**: identify the parameters which are controlling epistemic uncertainties

- Take advantage of the **exponential growth of data**

Germany : an active non subduction region ?
USGS shake-map regionalisation



Germany: a stable Continental Region (Johnson, 1994) ?



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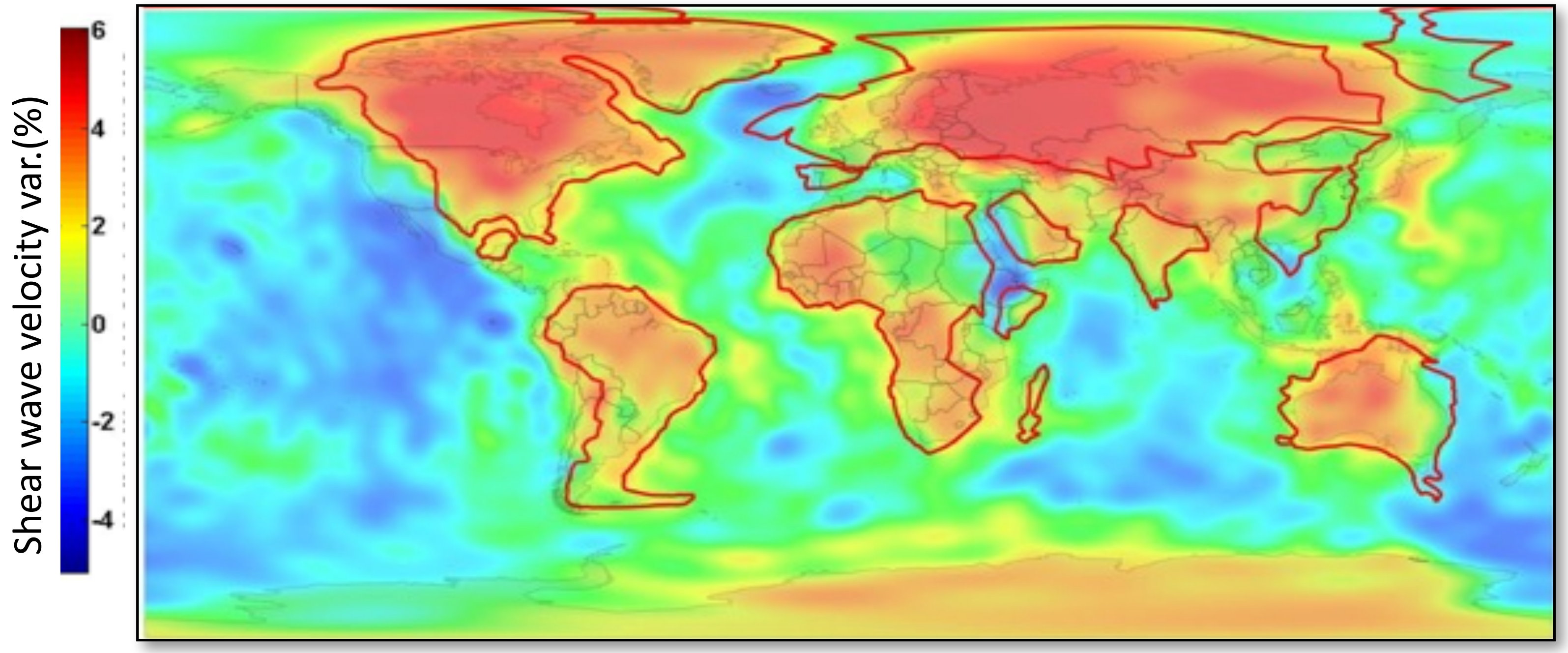
Global, transparent, and data-driven regionalization

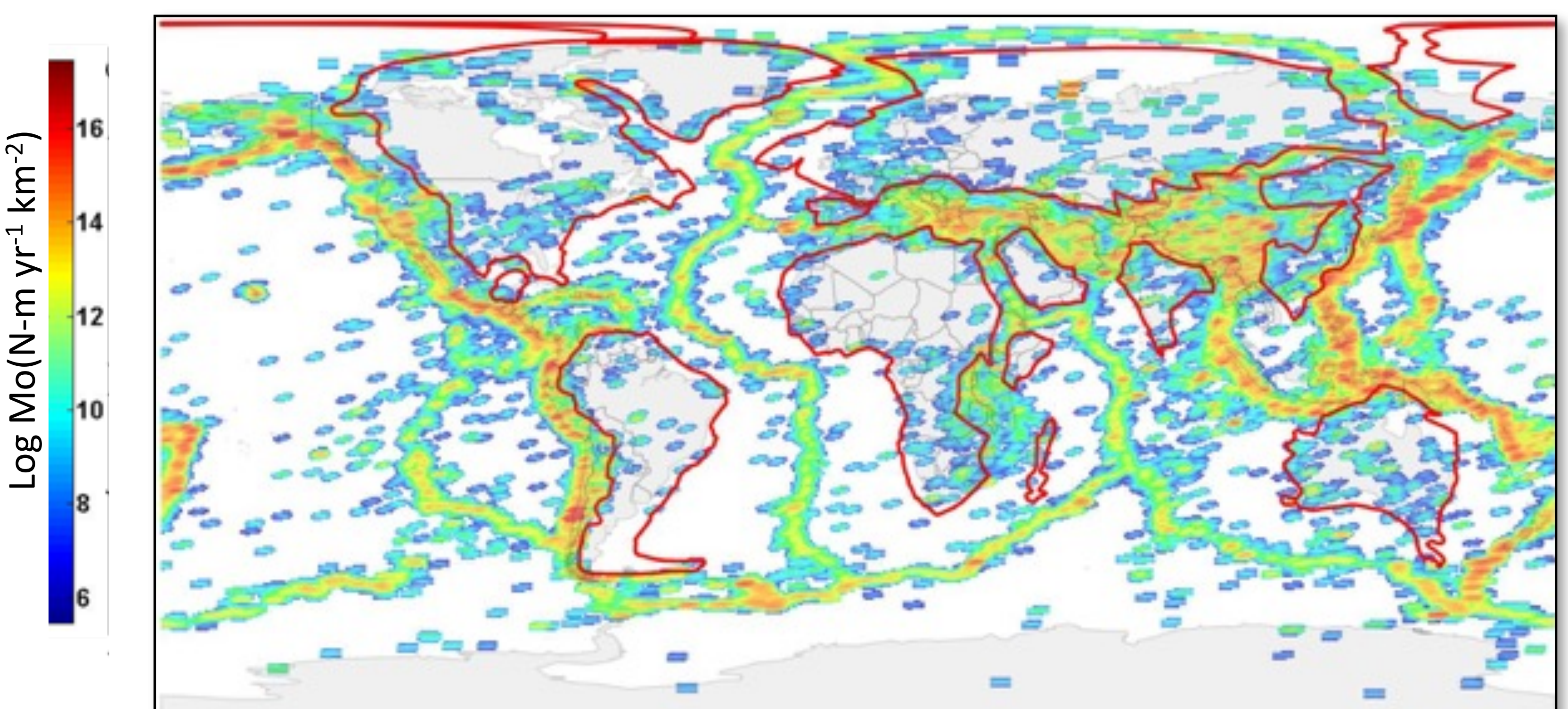
GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

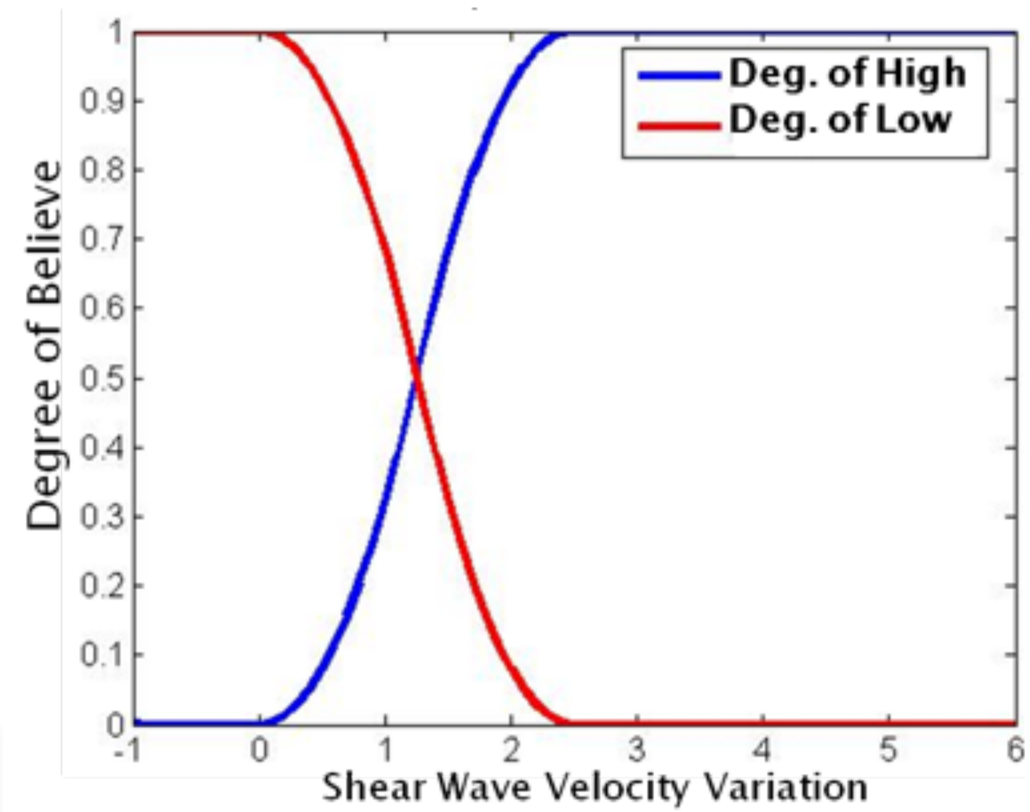
Shear Wave Velocity Variation



(Mooney, 2012)

Smoothed Seismic Moment Rate



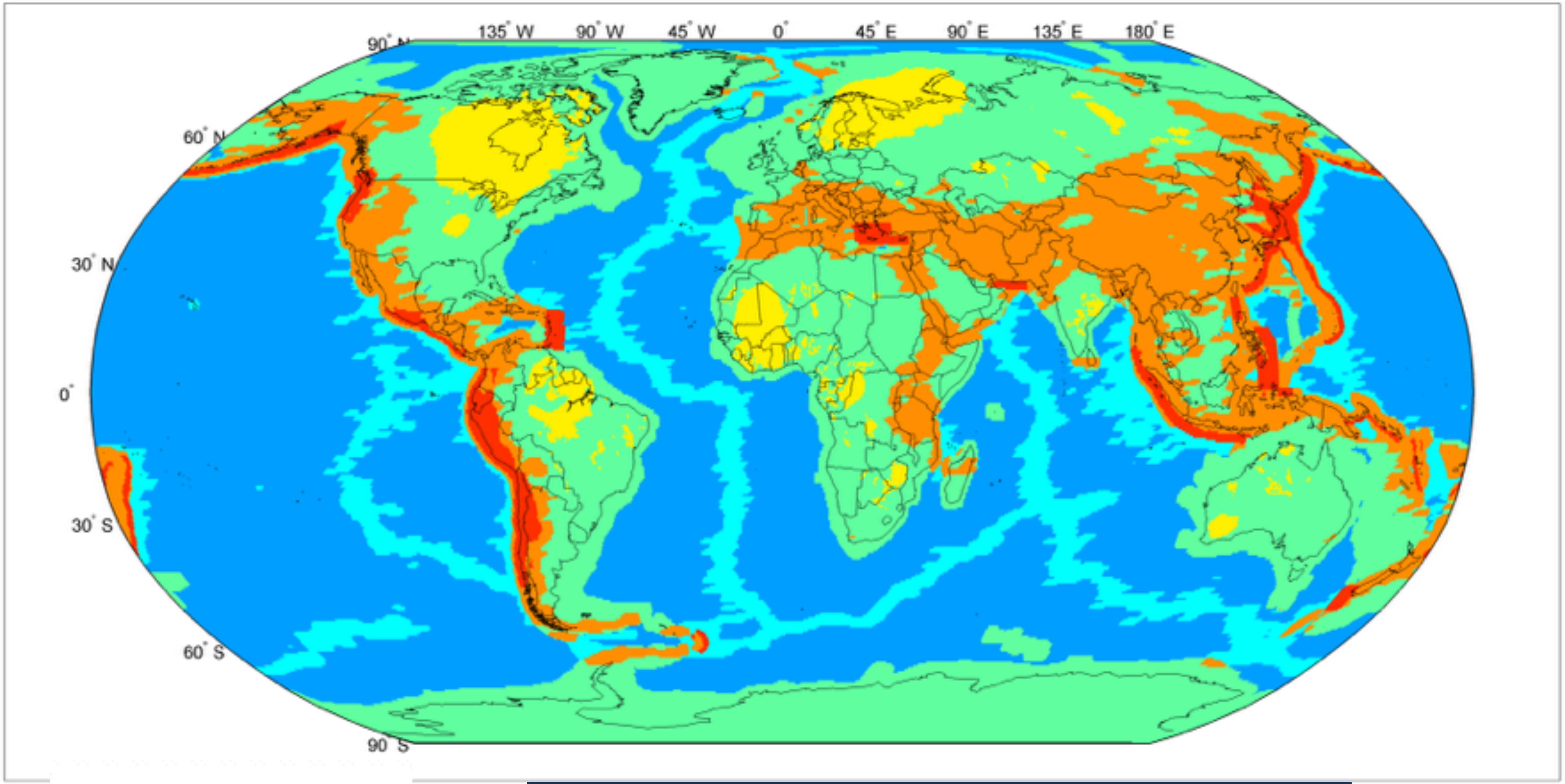


Fuzzy Framework:

If *moment rate* is high, and
S velocity var. is low
Deg. of “Active” is high

A transparent and data-driven global tectonic regionalisation model for seismic hazard assessment

- Stable Continent Region, Non-Craton
- Stable Continent Region, Craton
- Stable Oceanic Region
- Subduction
- Active Continent Shallow Region
- Active Oceanic Region



Chen Y.S, G., Weatherill, M. Pagani and F. Cotton. A transparent and data-driven global tectonic regionalisation model for seismic hazard assessment

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GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

HELMHOLTZ GEMEINSCHAFT

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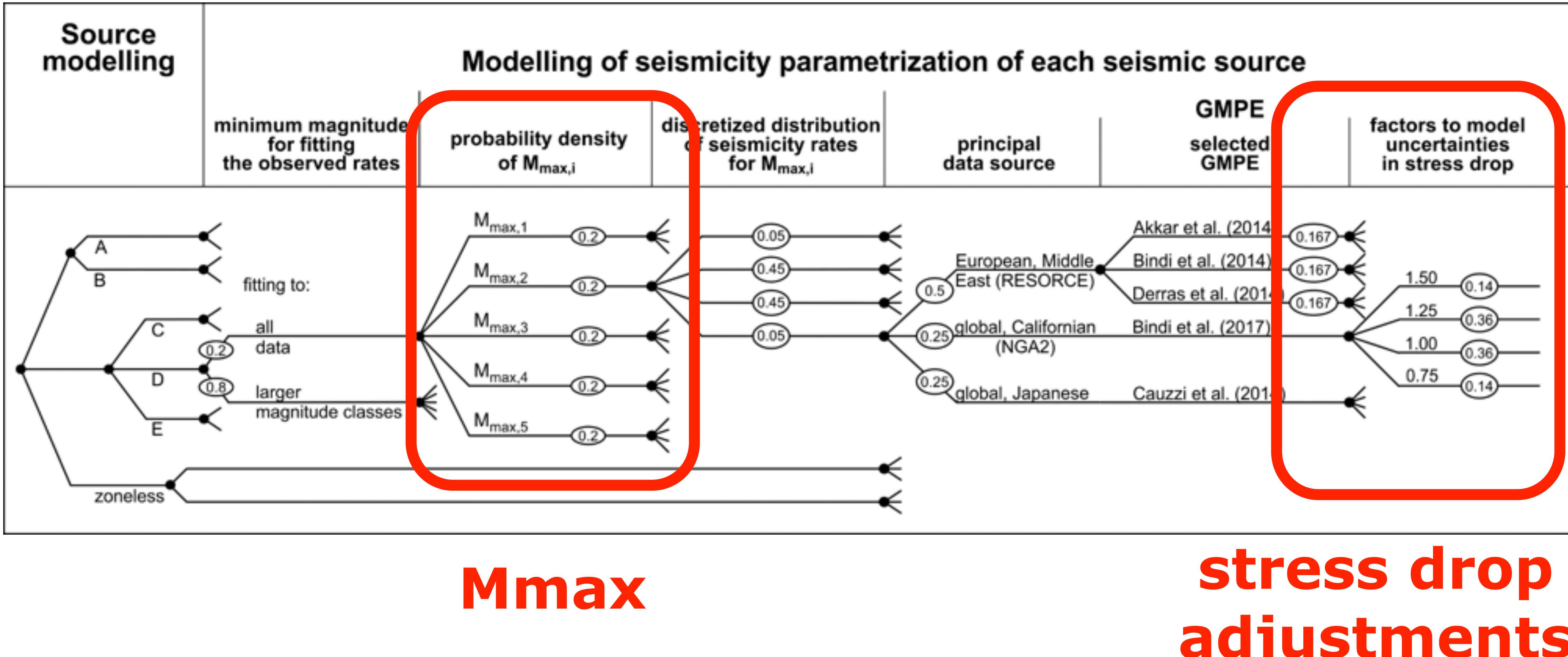
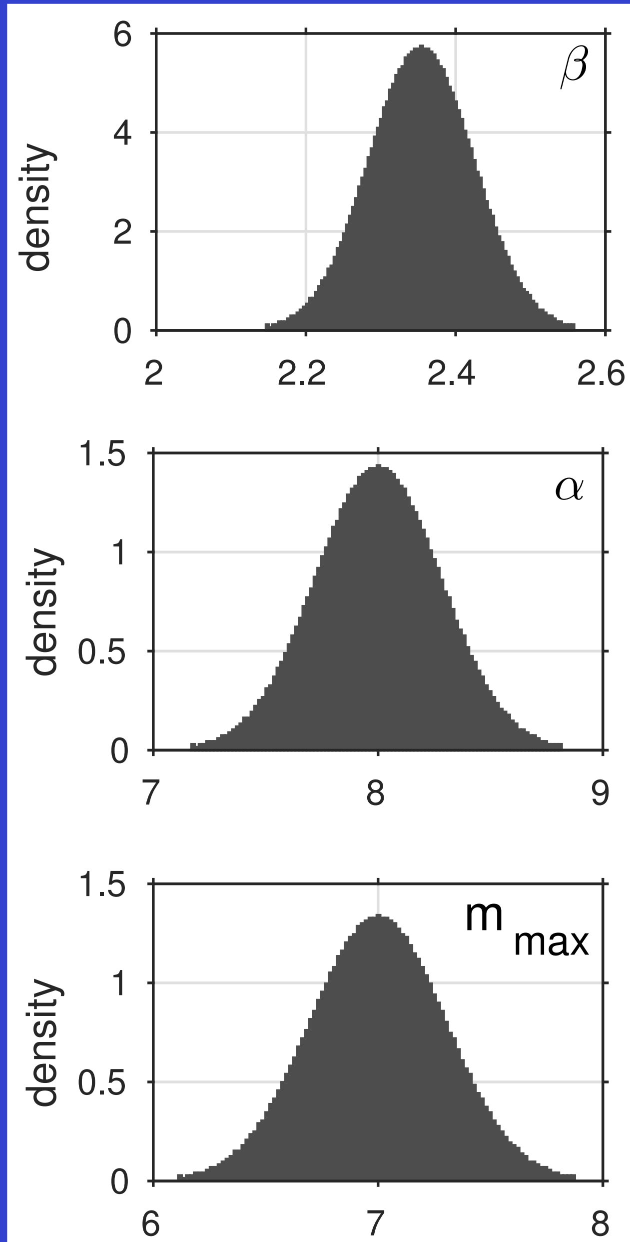
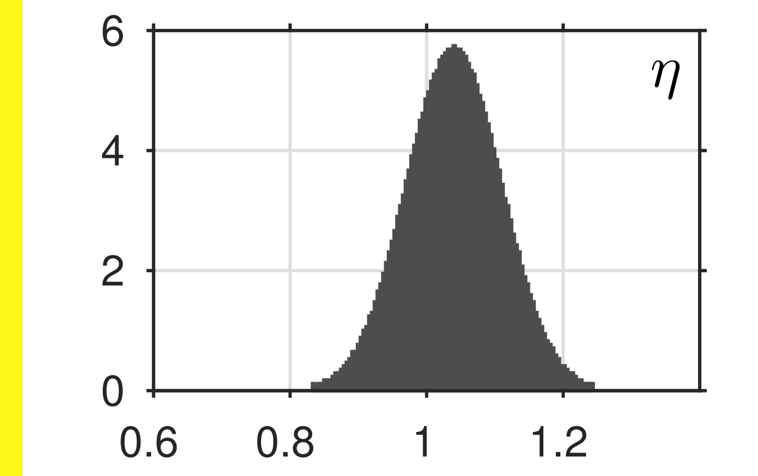
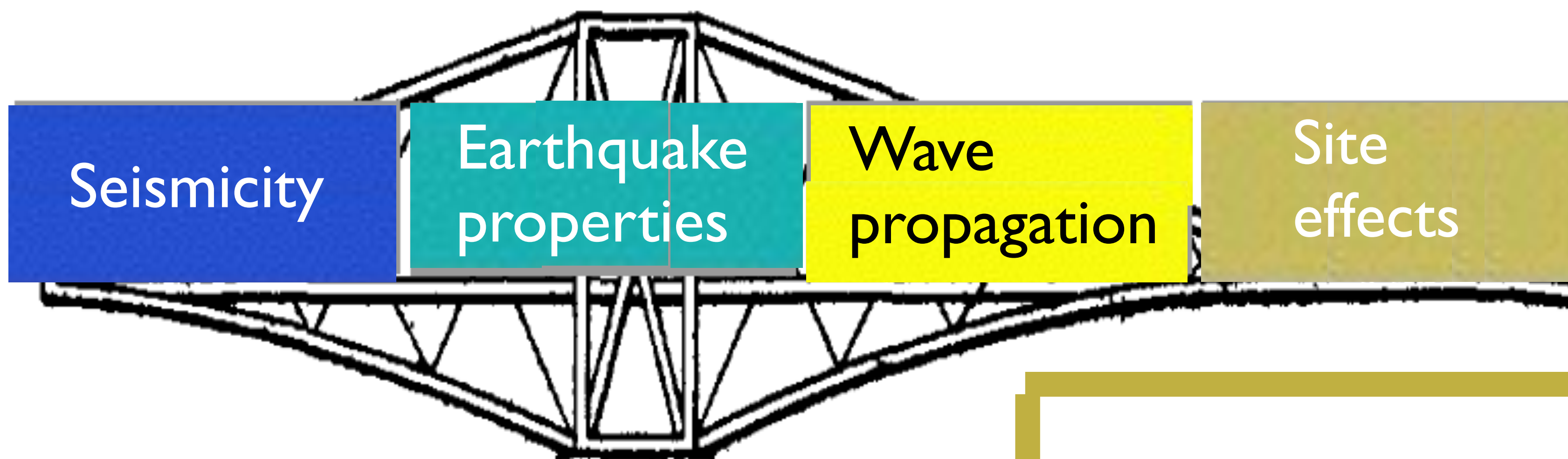
Identify the parameters which are controlling epistemic uncertainties

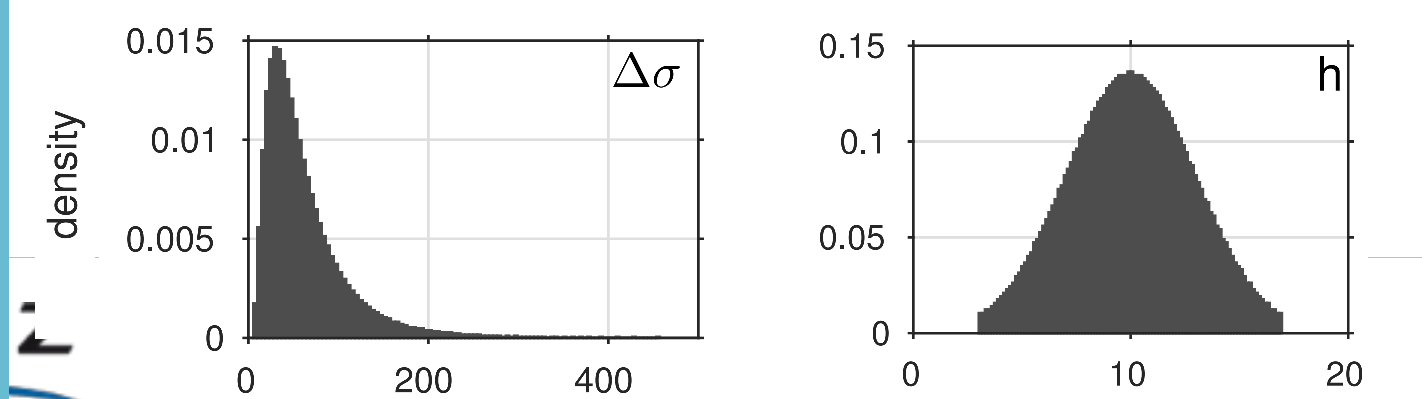


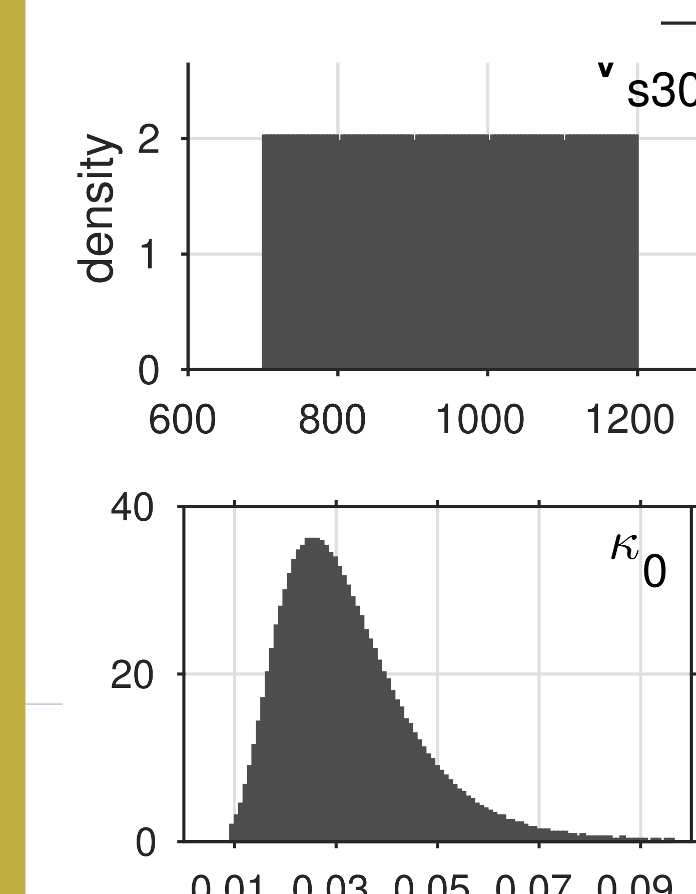
Sensitivities in seismic hazard assessment using automatic differentiation



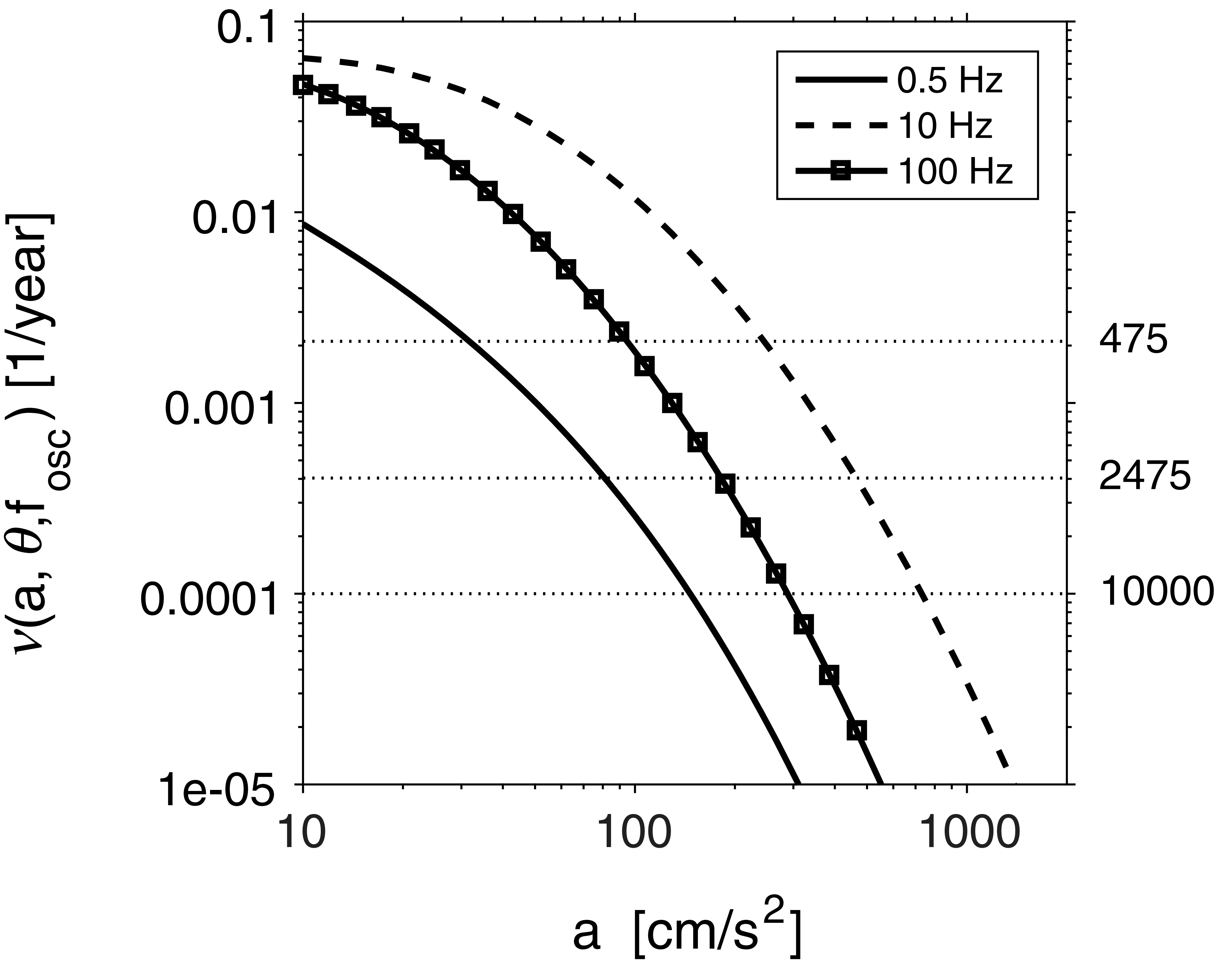


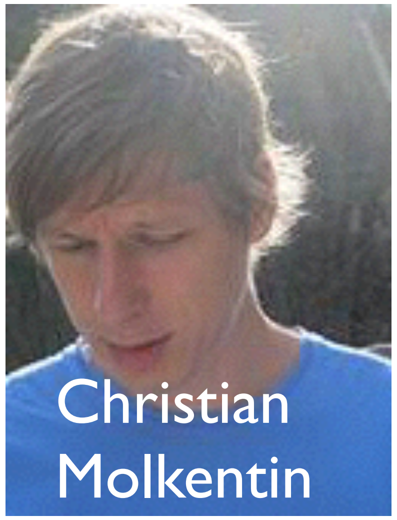






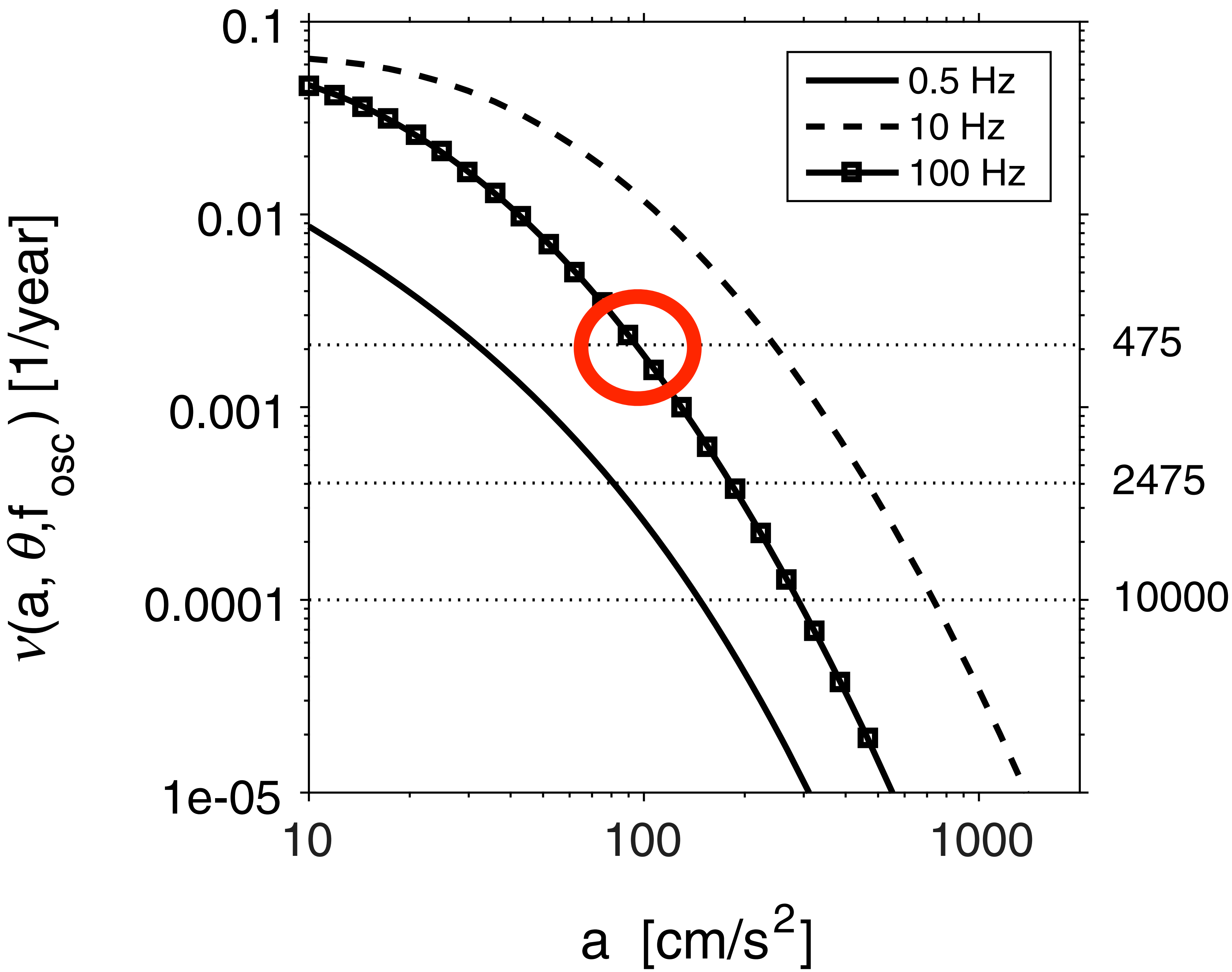
Hazard curves from a stochastic PSHA modelling

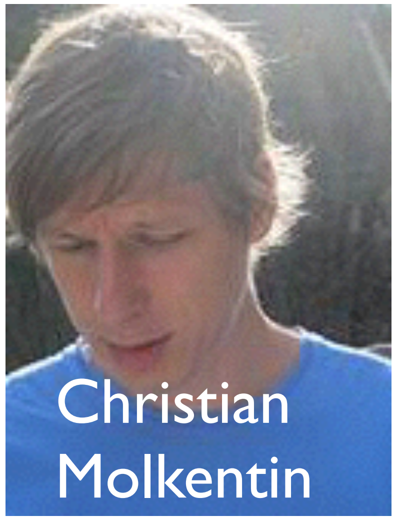




Molkenthin, C., Scherbaum, F., Griewank, A., Leovey, H., Kucherenko, S., Cotton, F. (2017): Derivative–Based Global Sensitivity Analysis: Upper Bounding of Sensitivities in Seismic–Hazard Assessment Using Automatic Differentiation. - Bulletin of the Seismological Society of America, 107, 2, p. 984-1004.

Hazard curves from a stochastic PSHA modelling





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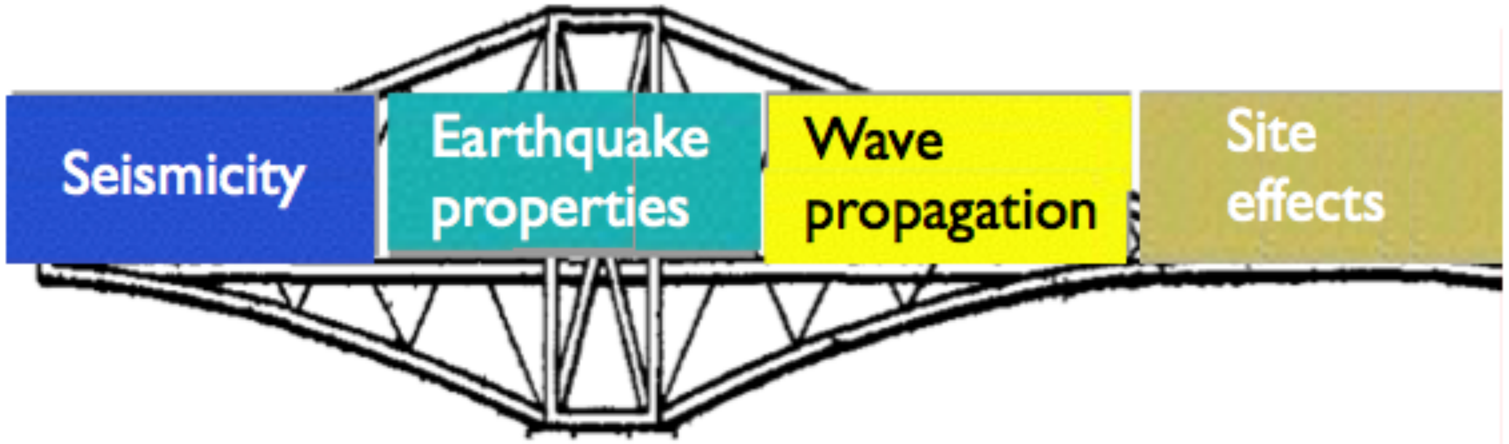

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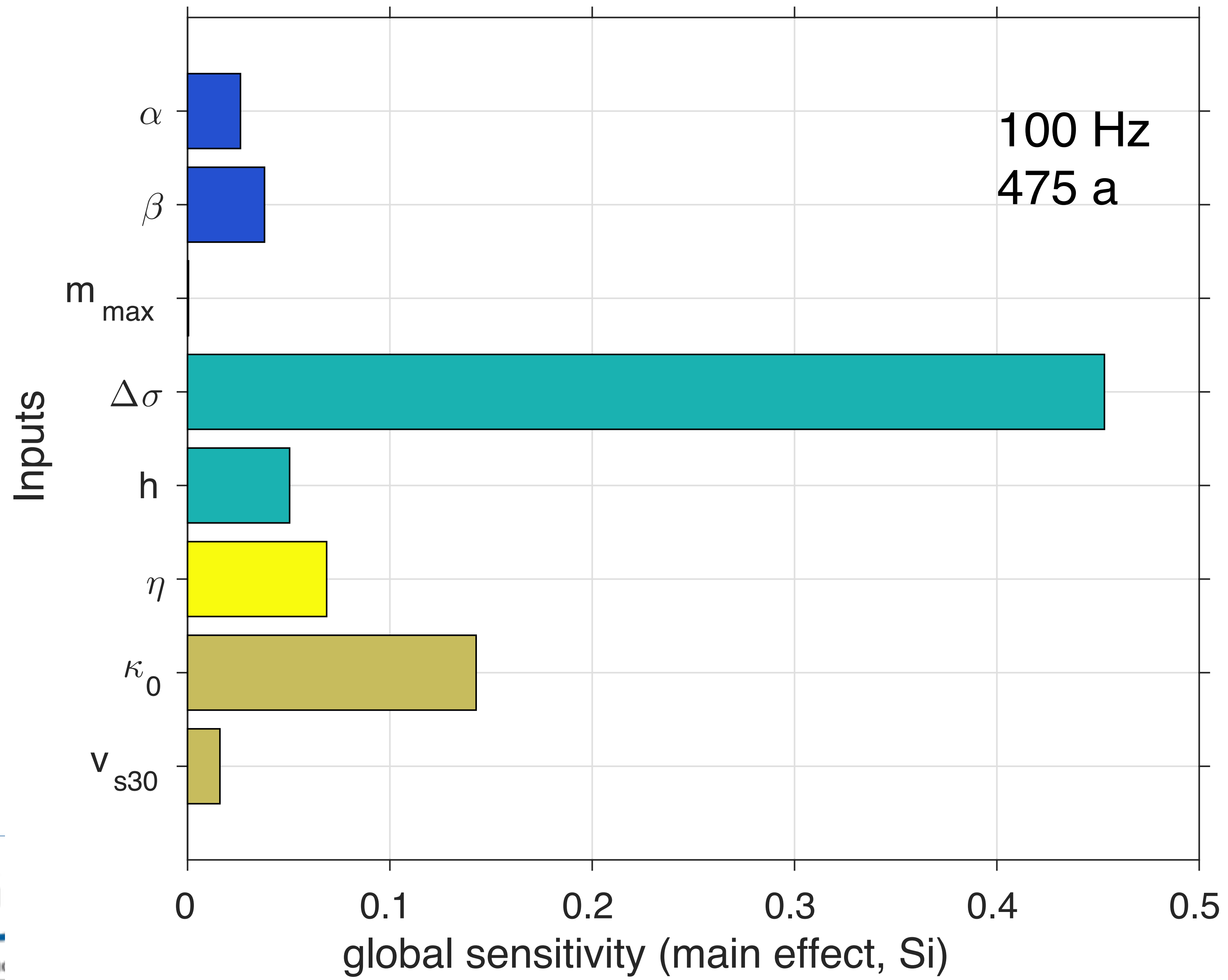

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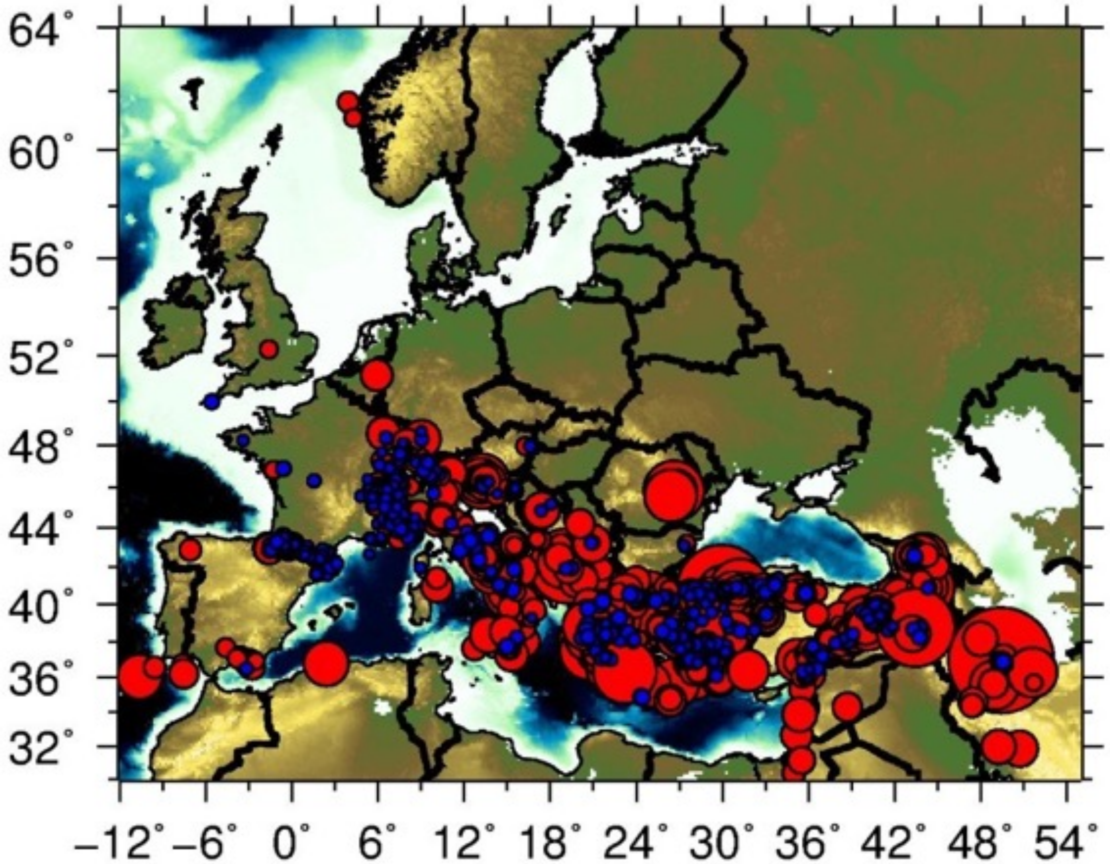
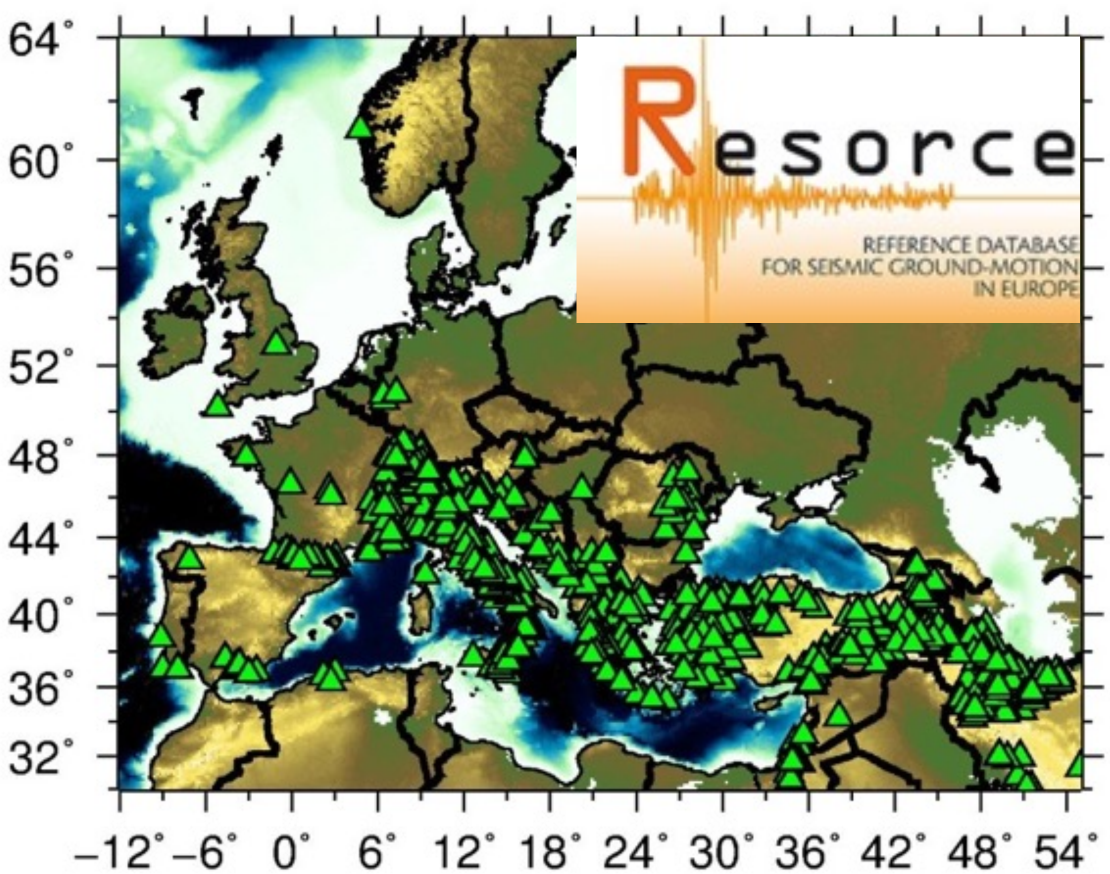
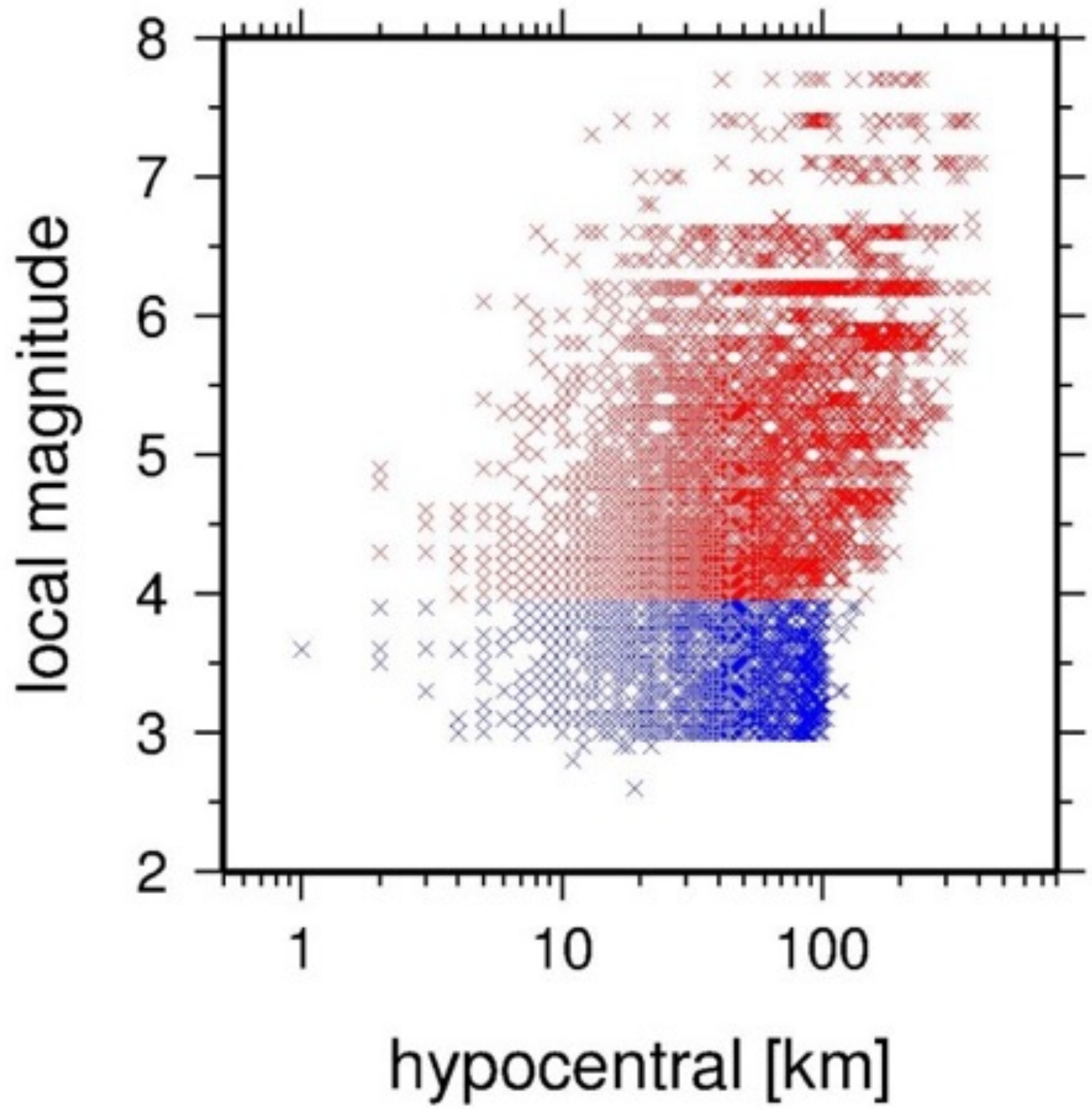
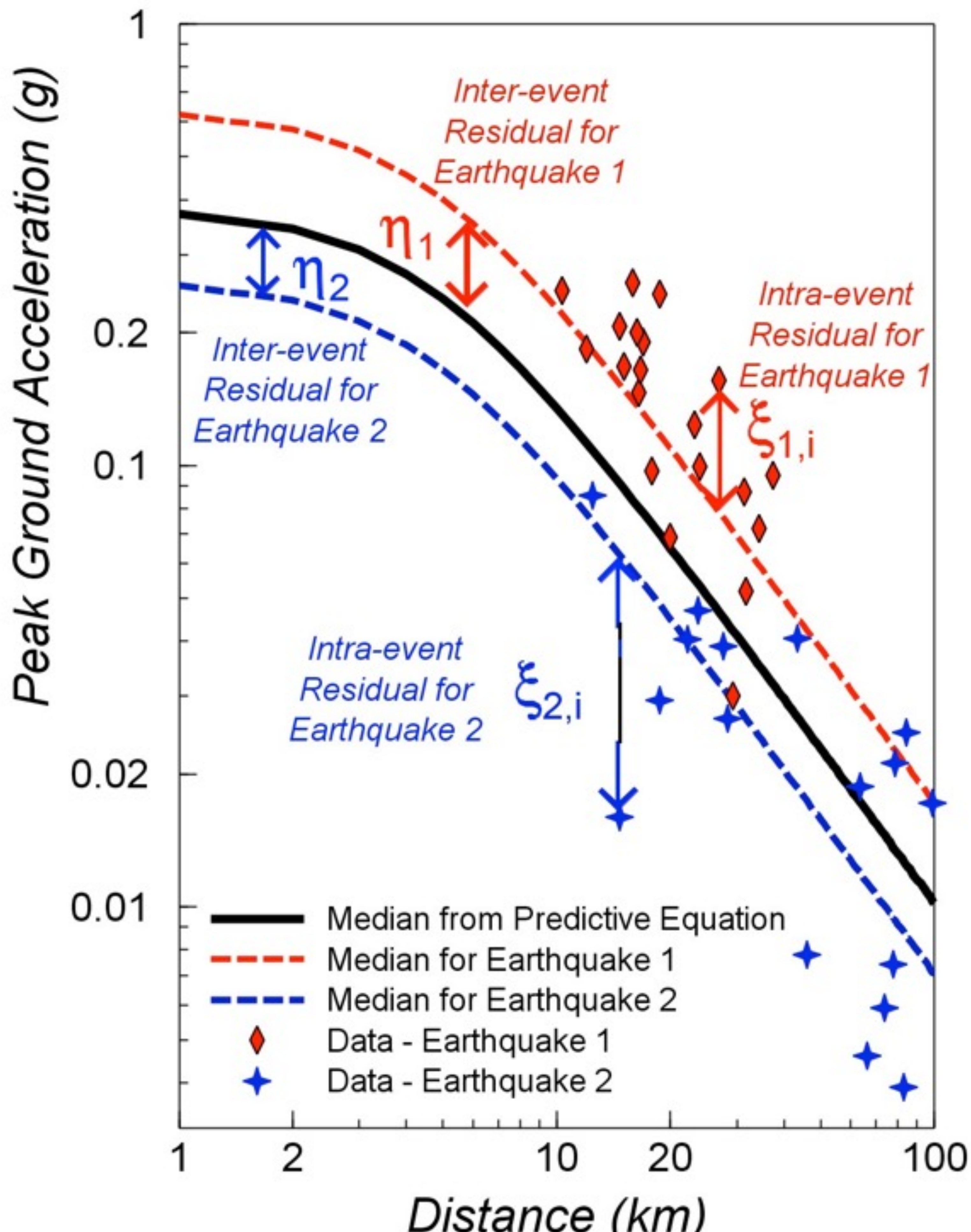
High-quality strong-ground motion datasets







Akkar S., M. A. Sandıkkaya · M. ¸Senyurt ·A. Azari Sisi · B. Ö. Ay · P. Traversa · J. Douglas ·F. Cotton · L. Luzi · B. Hernandez · S. Godey. Reference database for seismic ground-motion in Europe (RESORCE). BEEE. Bull Earthquake Eng DOI 10.1007/s10518-013-9506-8



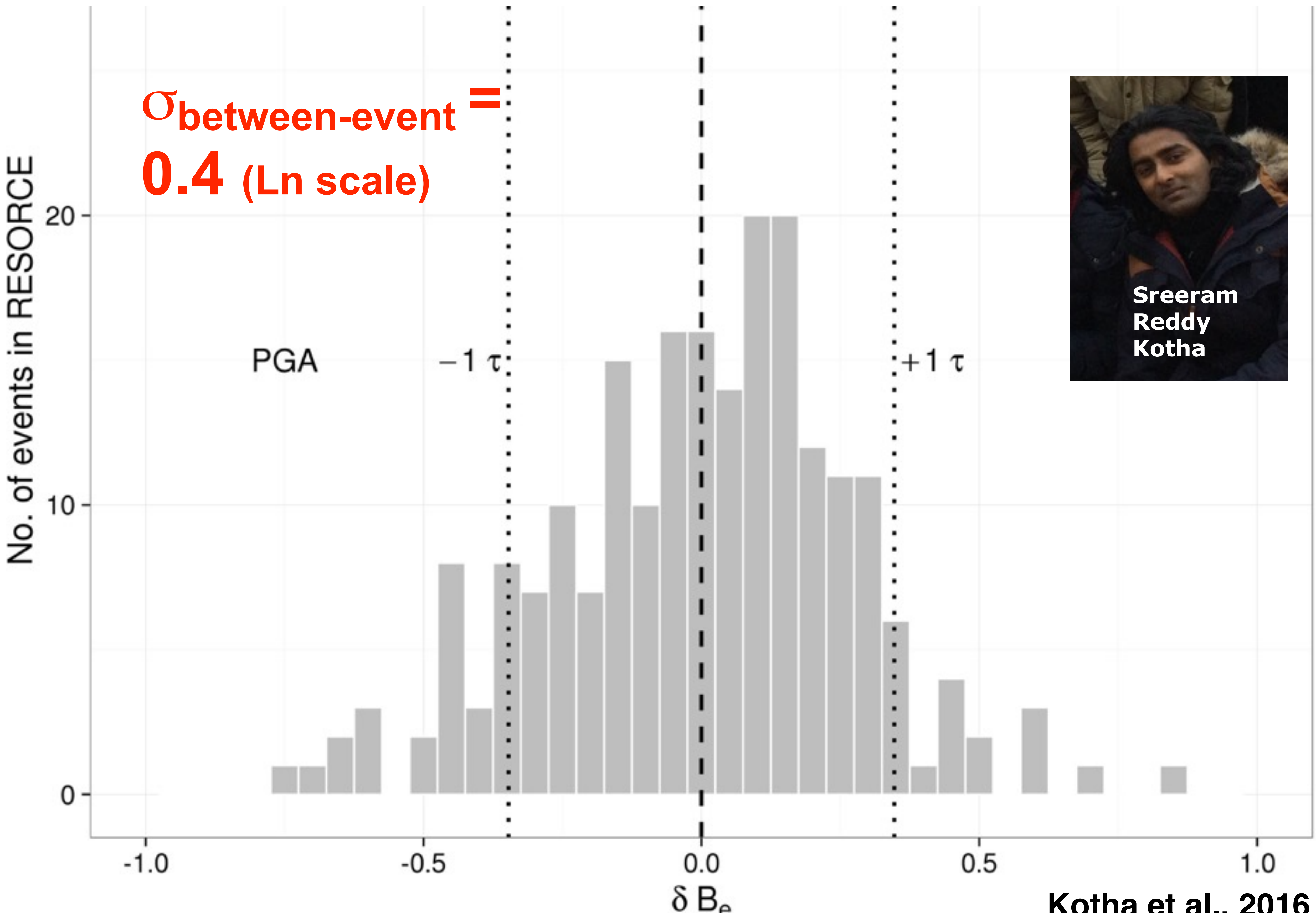
Between-event and Within-event variability

Al Atik et al., 2010

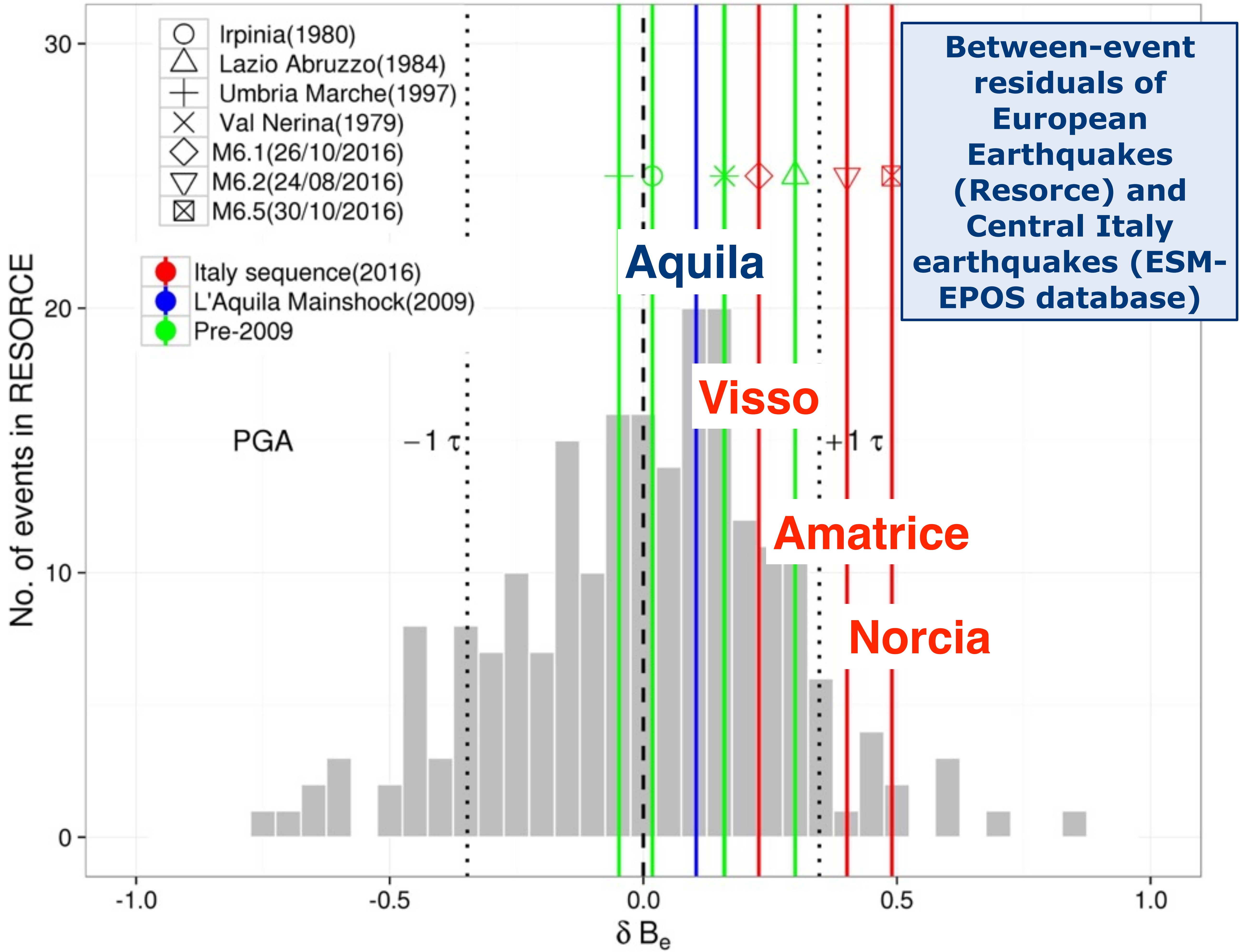
Between-event terms of European Earthquakes (1970-2013)

$\sigma_{\text{between-event}}$ =

0.4 (Ln scale)



Kotha et al., 2016

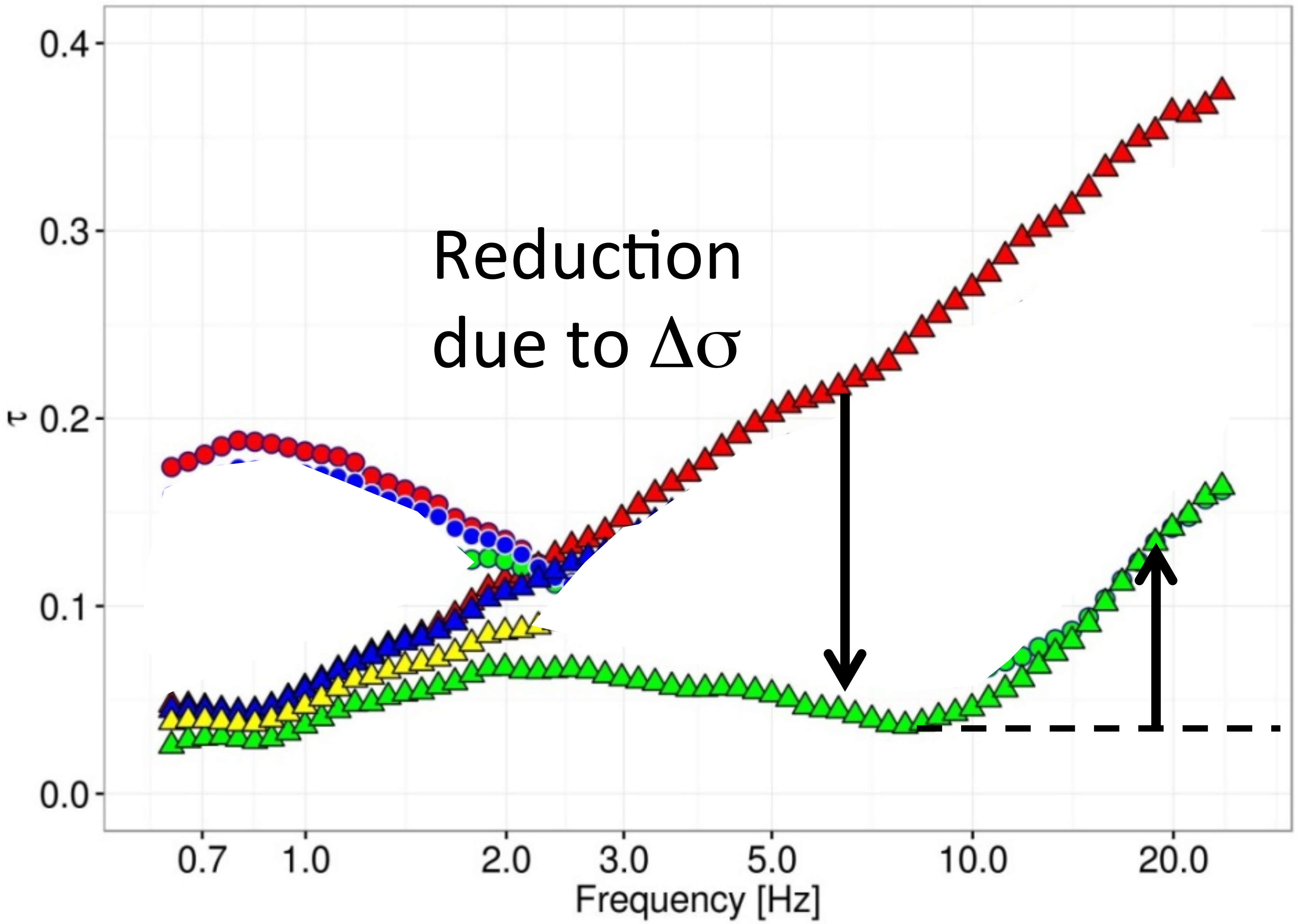


Between-event residuals of European Earthquakes (Resorce) and Central Italy earthquakes (ESM-EPOS database)
Irpinia(1980)
Lazio Abruzzo(1984)
Umbria Marche(1997)
Val Nerina(1979)
M6.1(26/10/2016)
M6.2(24/08/2016)
M6.5(30/10/2016)
Italy sequence(2016)
L'Aquila Mainshock(2009)
Pre-2009
Aquila
Visso
Amatrice
Norcia
PGA
$-1\ \tau$
$+1\ \tau$
No. of events in RESORCE
0
10
20
30
-1.0
-0.5
0.0
0.5
1.0
δB_e

From observed variabilities to physics-based models

MODEL 1 – $f(M, R) + \delta Be + \delta S2S + \varepsilon$

MODEL 2 – $f(M, R, \Delta\sigma) + \delta Be + \delta S2S + \varepsilon$



An other controlling factor enters into the game (high frequency event-dependent: kappa_source)

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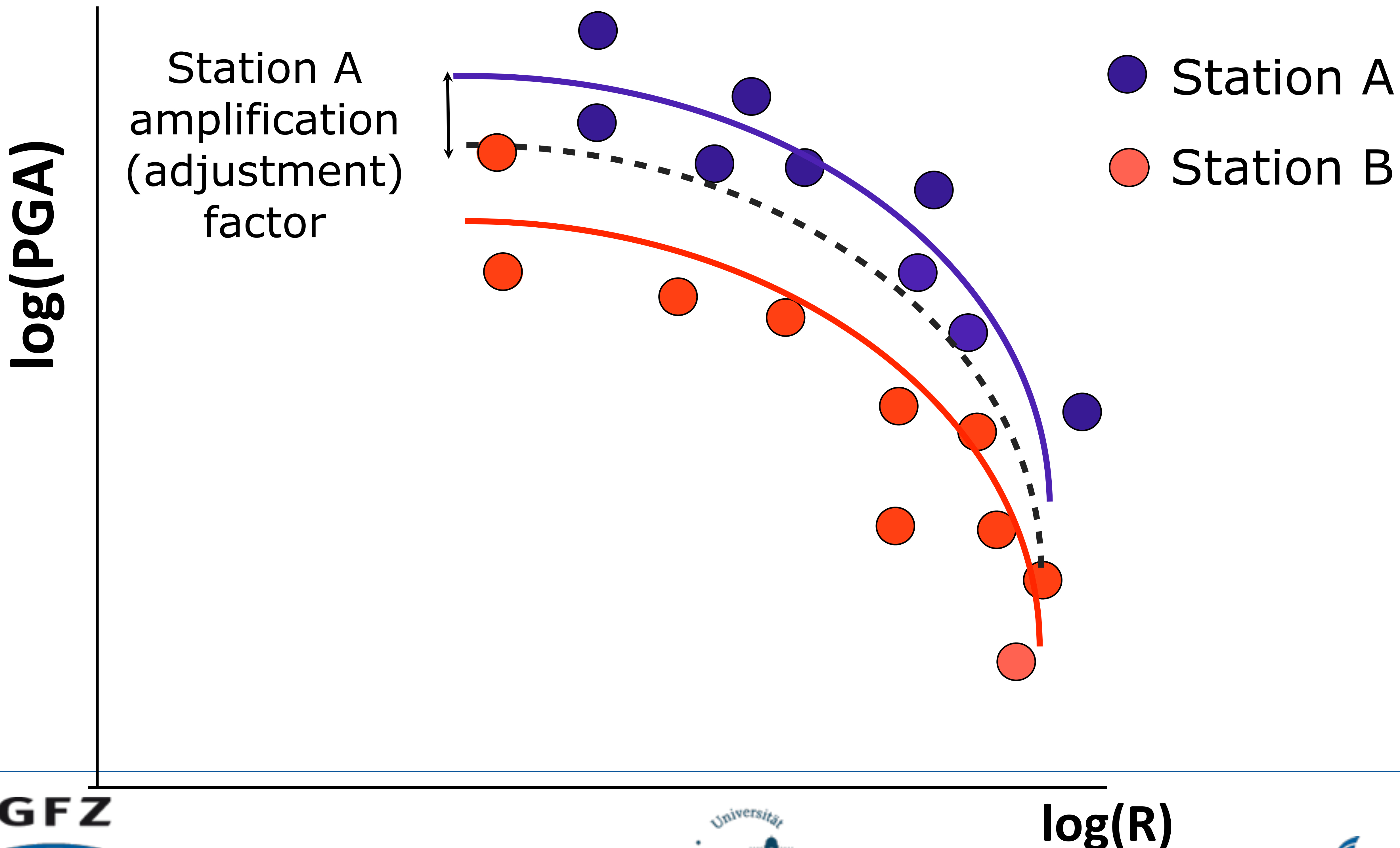
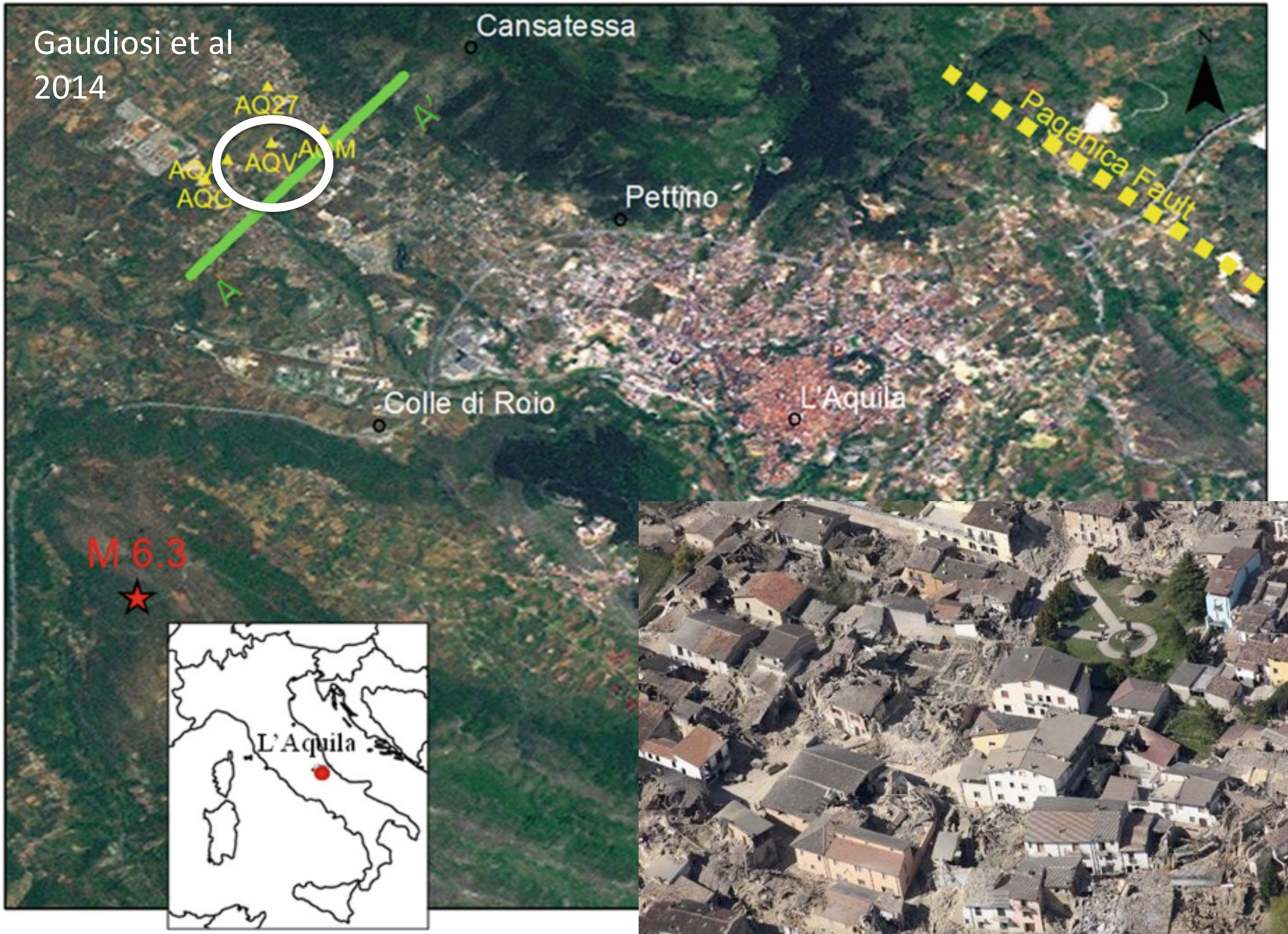
Bindi, D., Spallarossa, D., Pacor, F. (2017): Between-event and between-station variability observed in the Fourier and response spectra domains: comparison with seismological models. - Geophysical Journal International, 210, 2, p. 1092-1104.

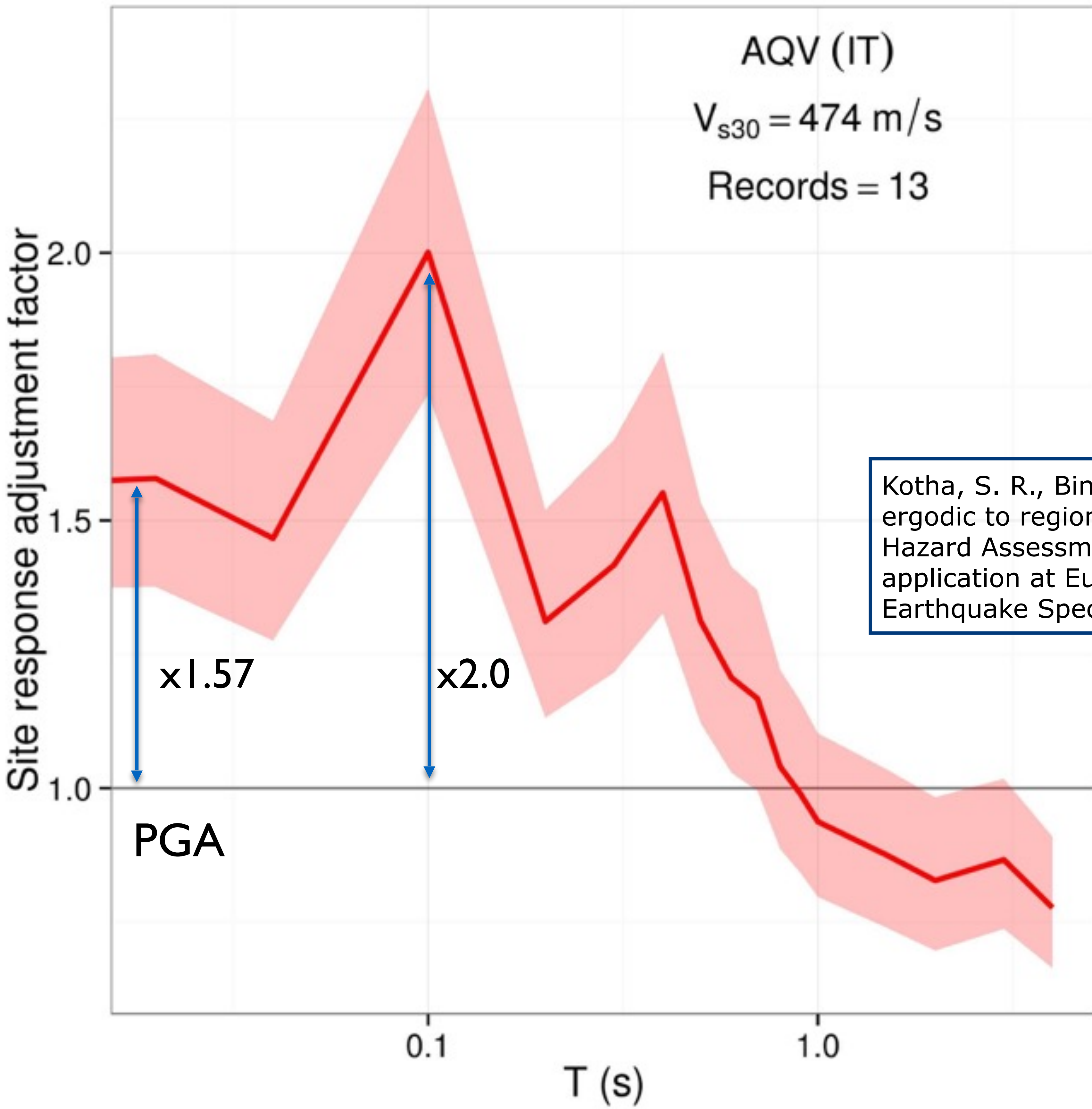
Site specific amplification (adjustment relative to a given global model)



Aquila Earthquake, 2009

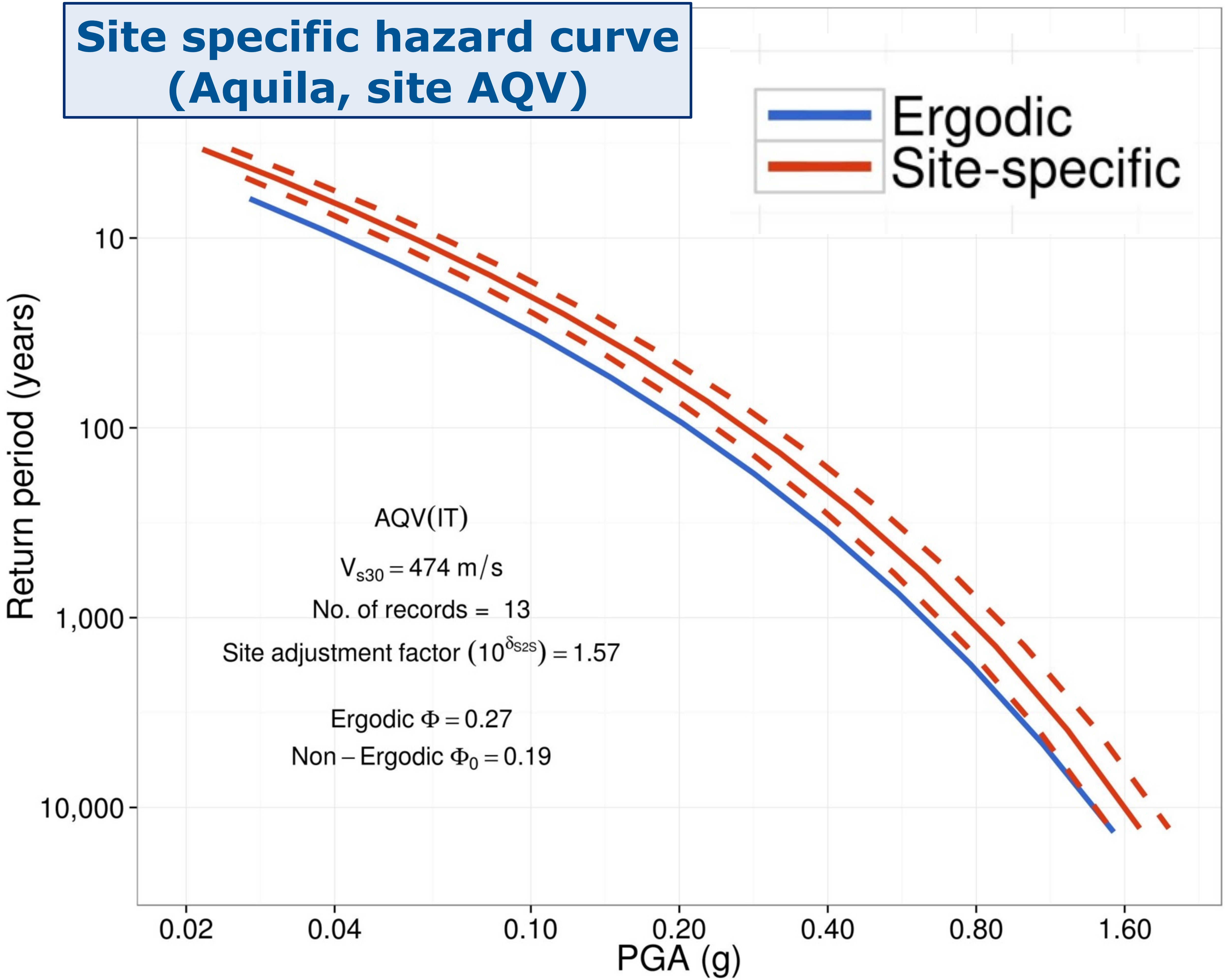


Site specific amplification
(adjustment to a « classical » European ergodic model based on Vs30)

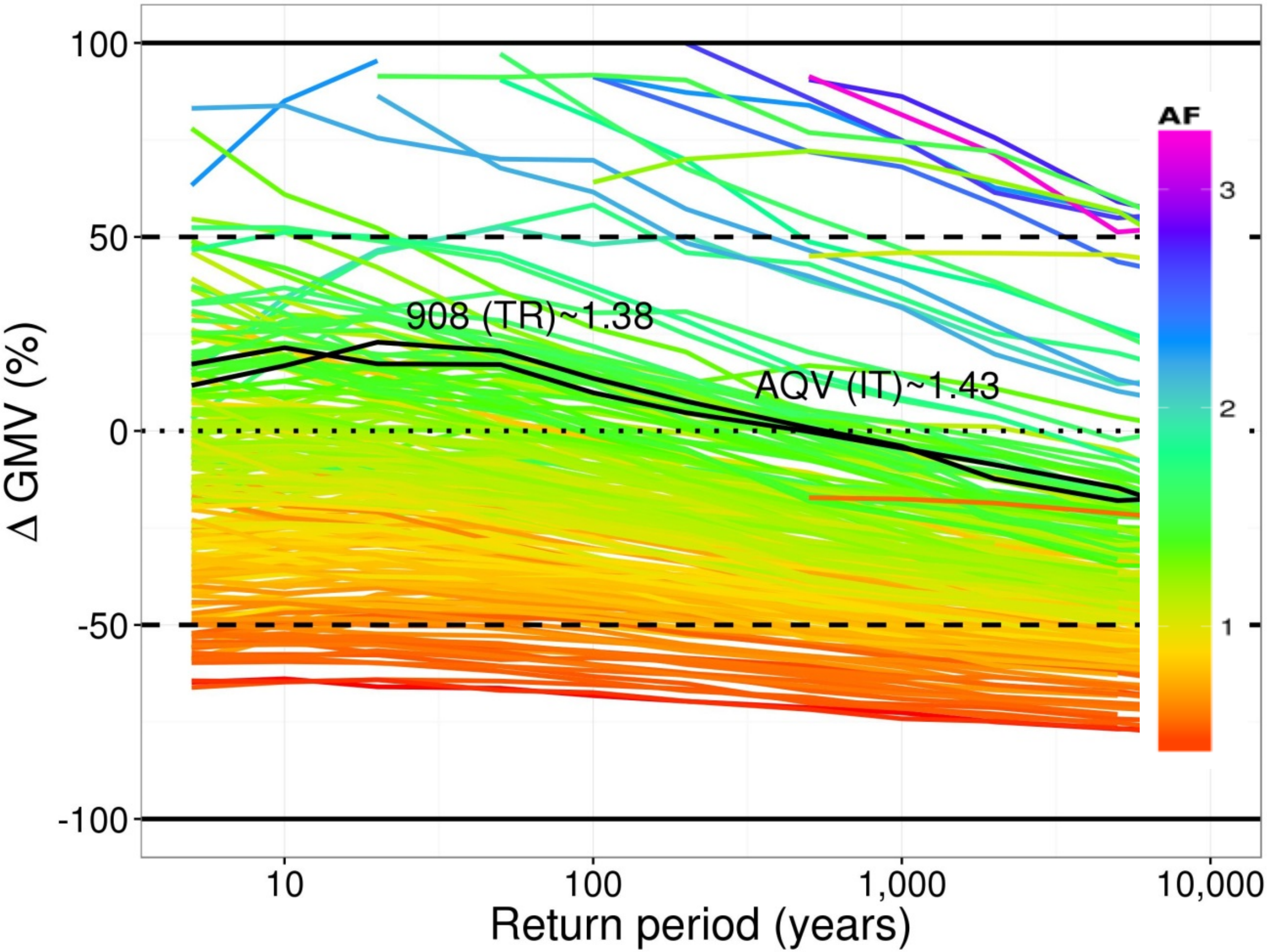


Kotha, S. R., Bindi, D., & Cotton, F. (2017). From ergodic to region- and site-specific Probabilistic Seismic Hazard Assessment: Method development and application at European and Middle- Eastern sites. Earthquake Spectra, in press

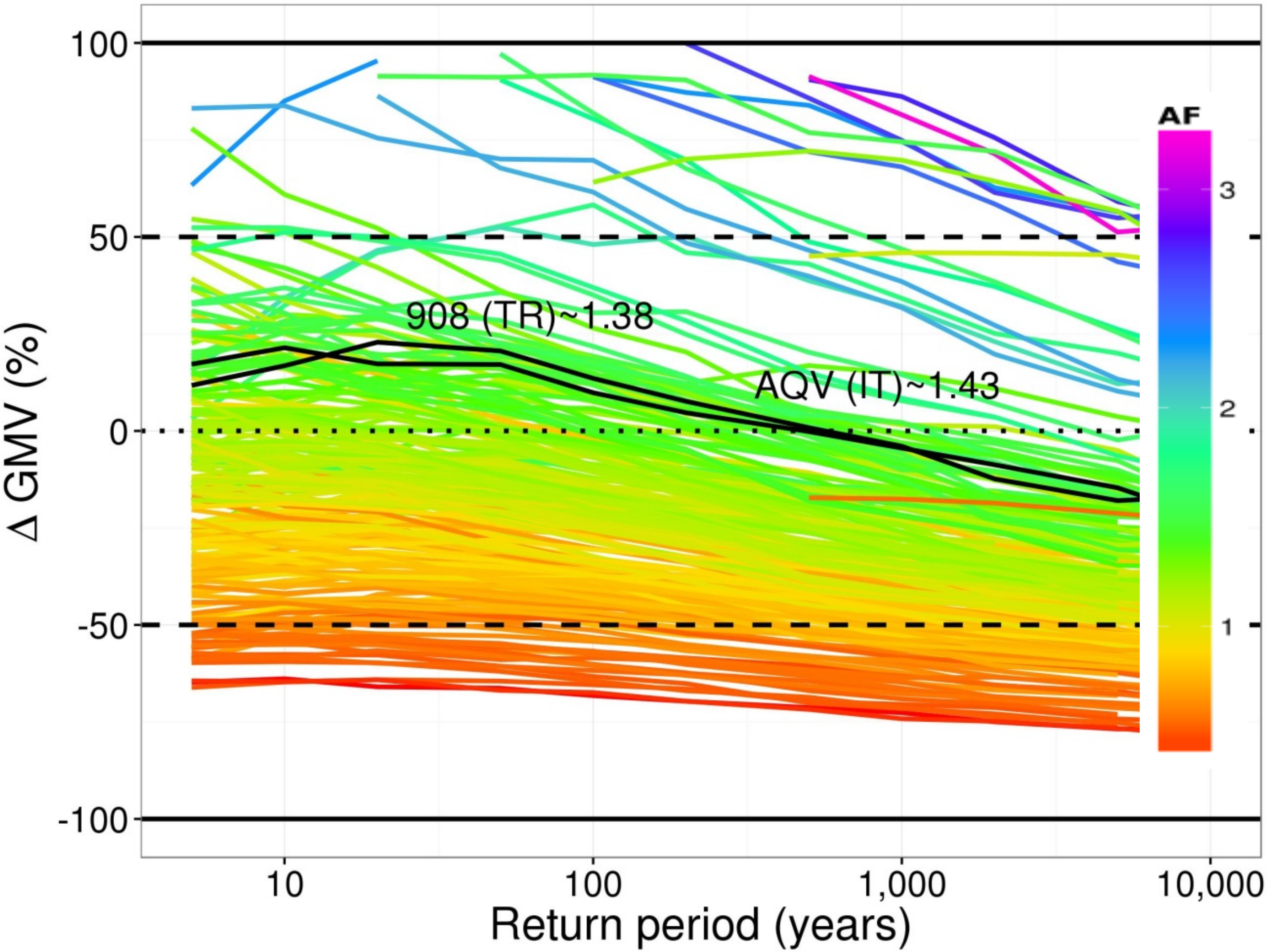
Site specific hazard curve (Aquila, site AQV)



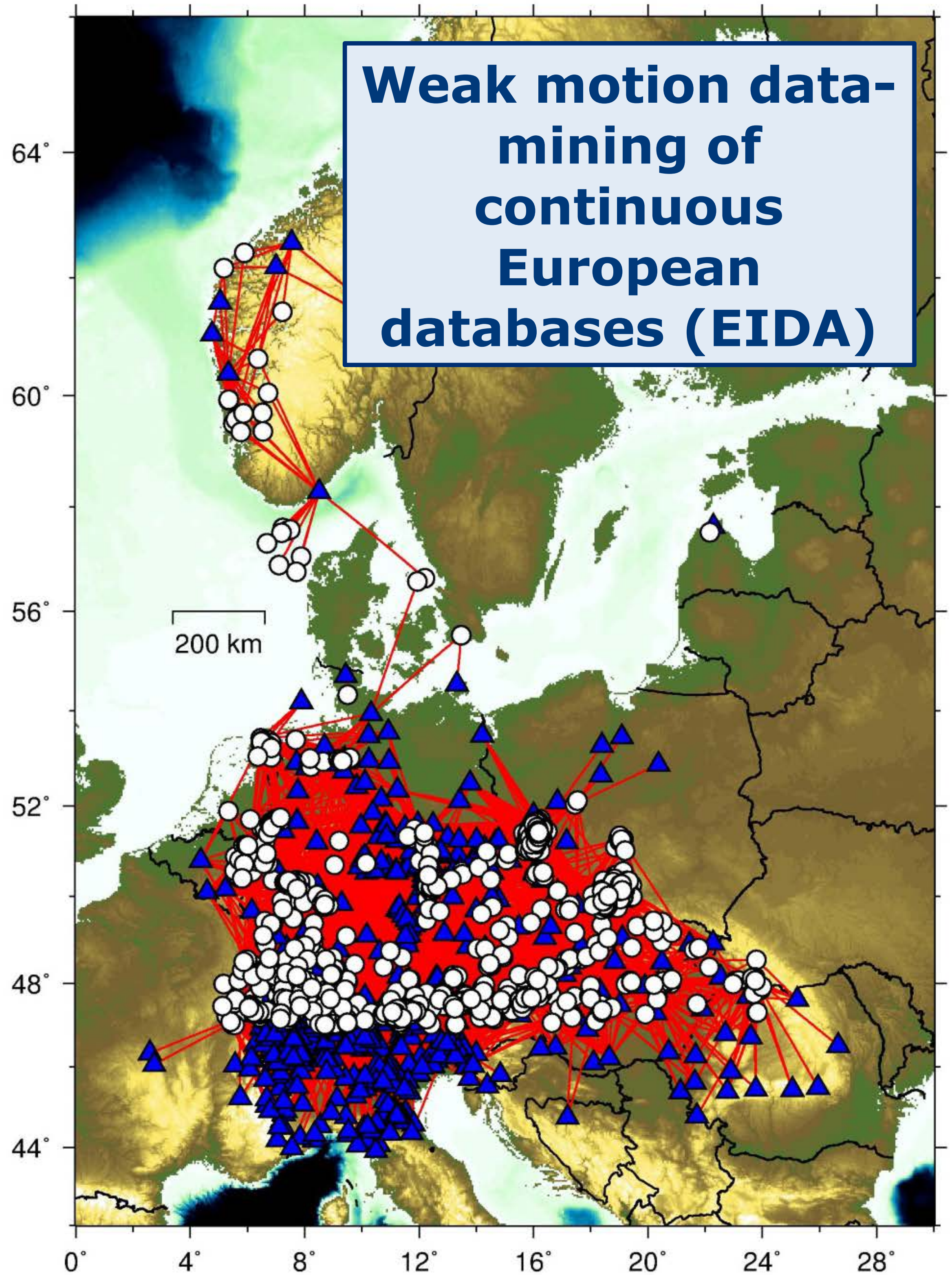
Difference between classical ergodic hazard estimation and region and site specific PSHA (225 stations Europe)

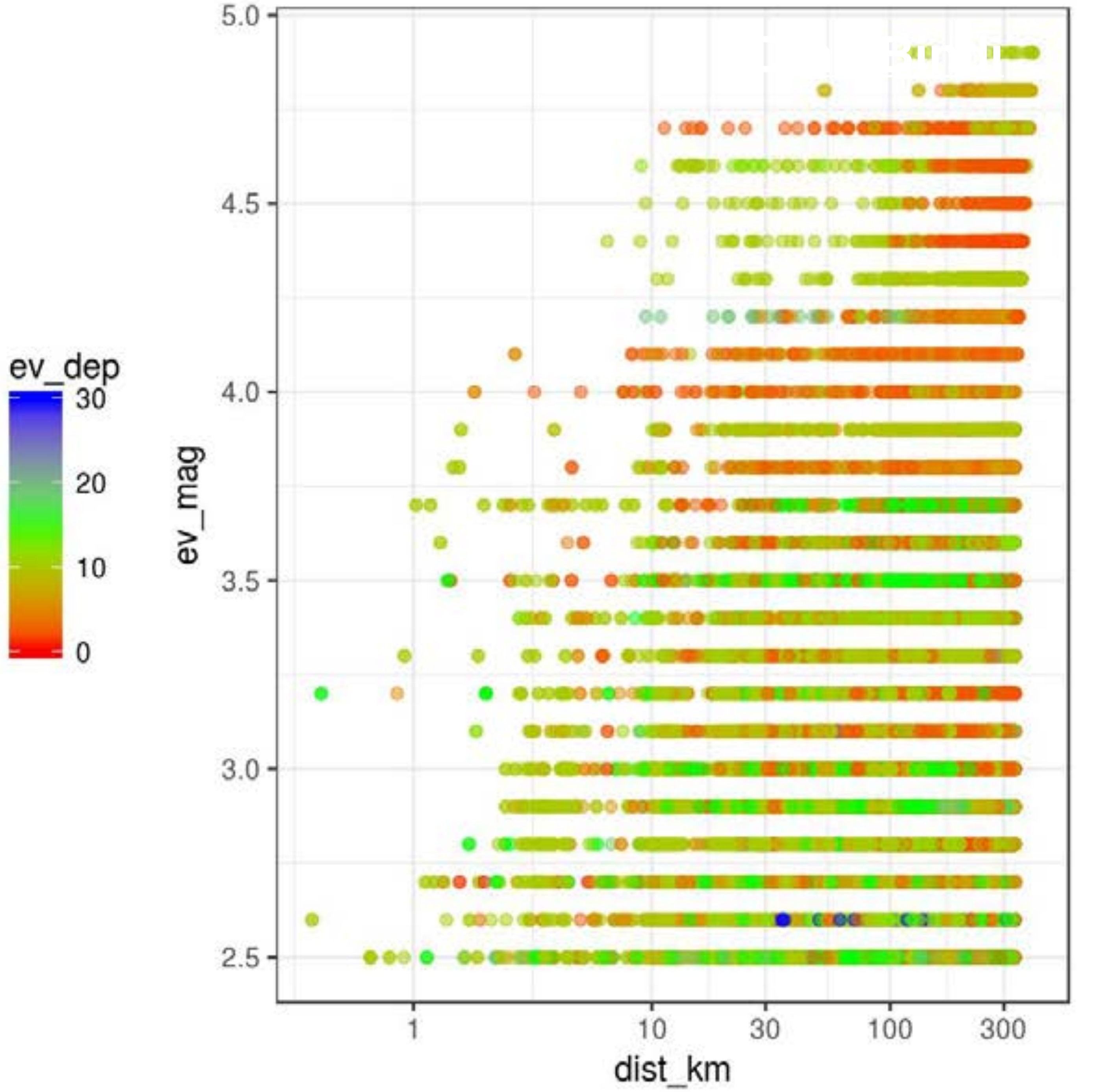


NO FREE LUNCH: local data and site monitoring needed



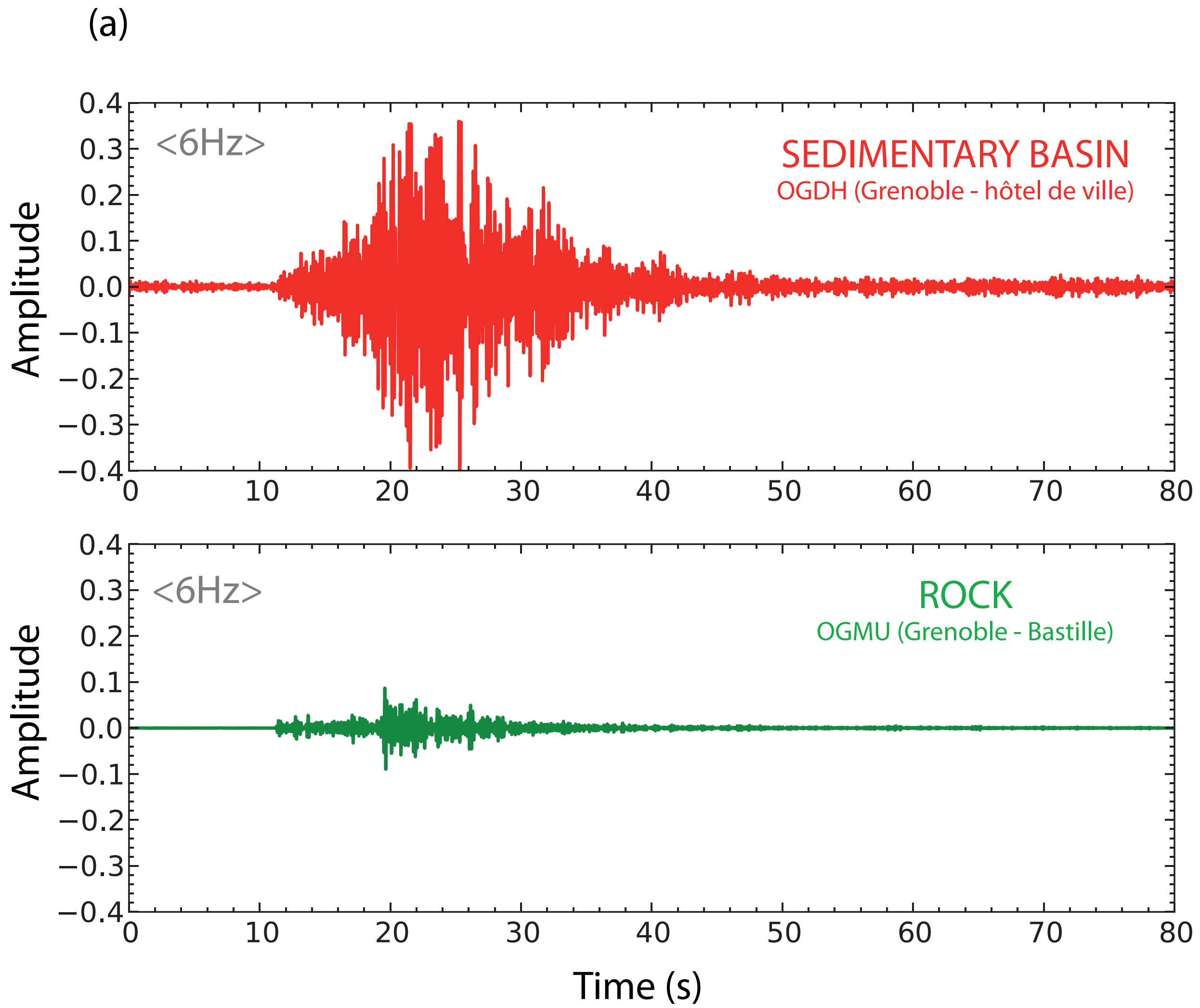
New: a large number of data in our backyard !

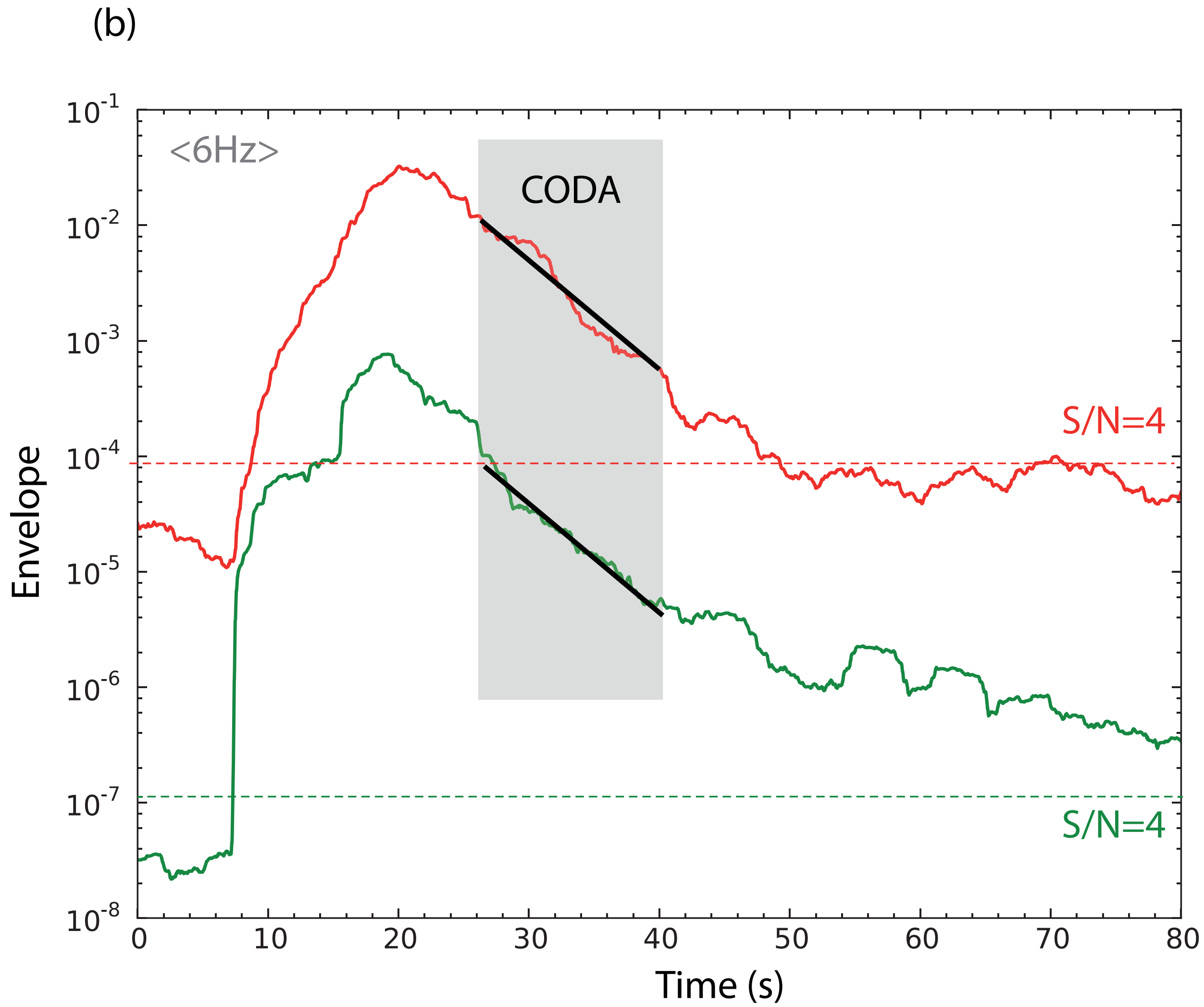




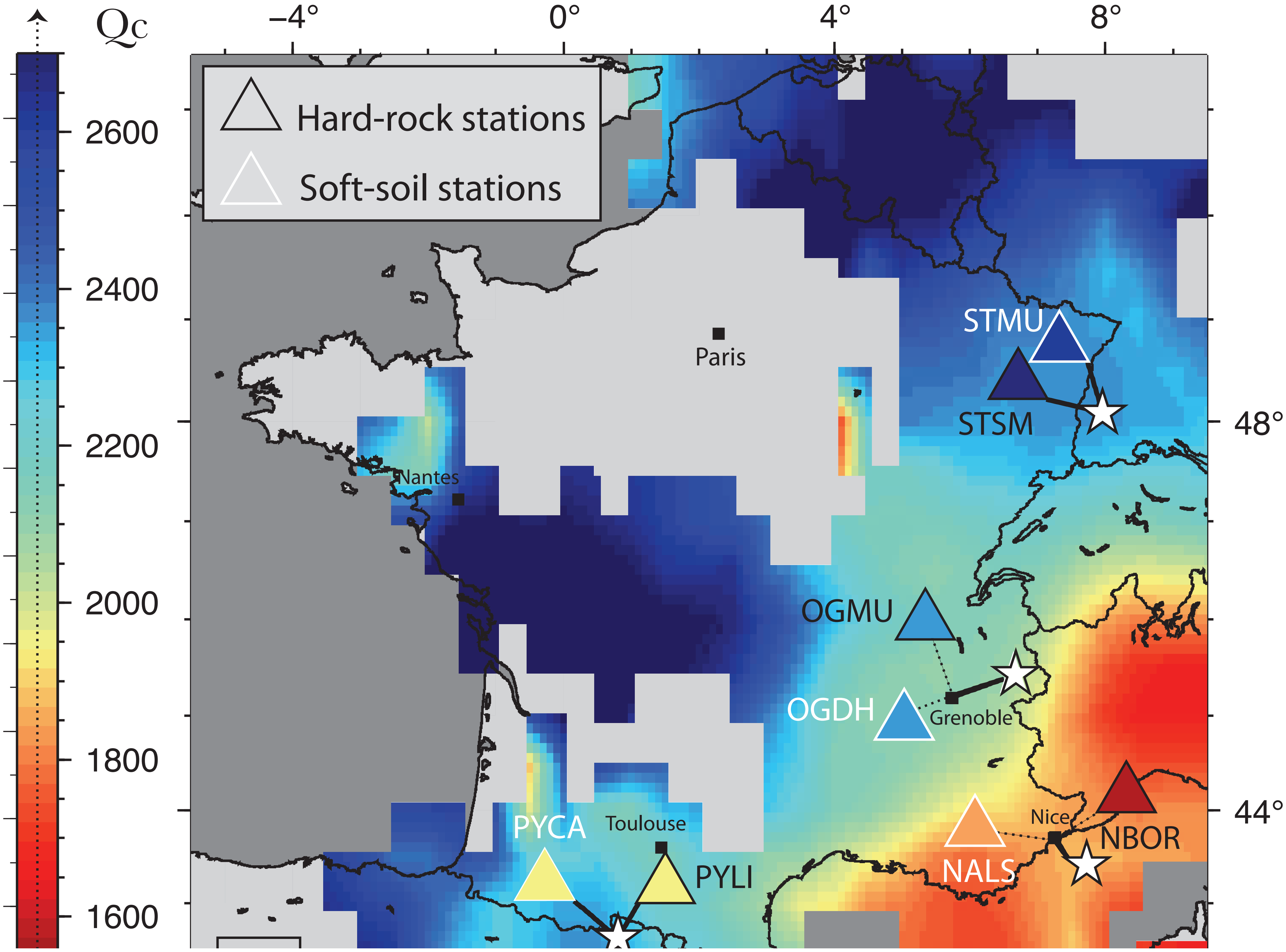
Regional attenuation properties : key contribution from the coda analysis

Jessie Mayor

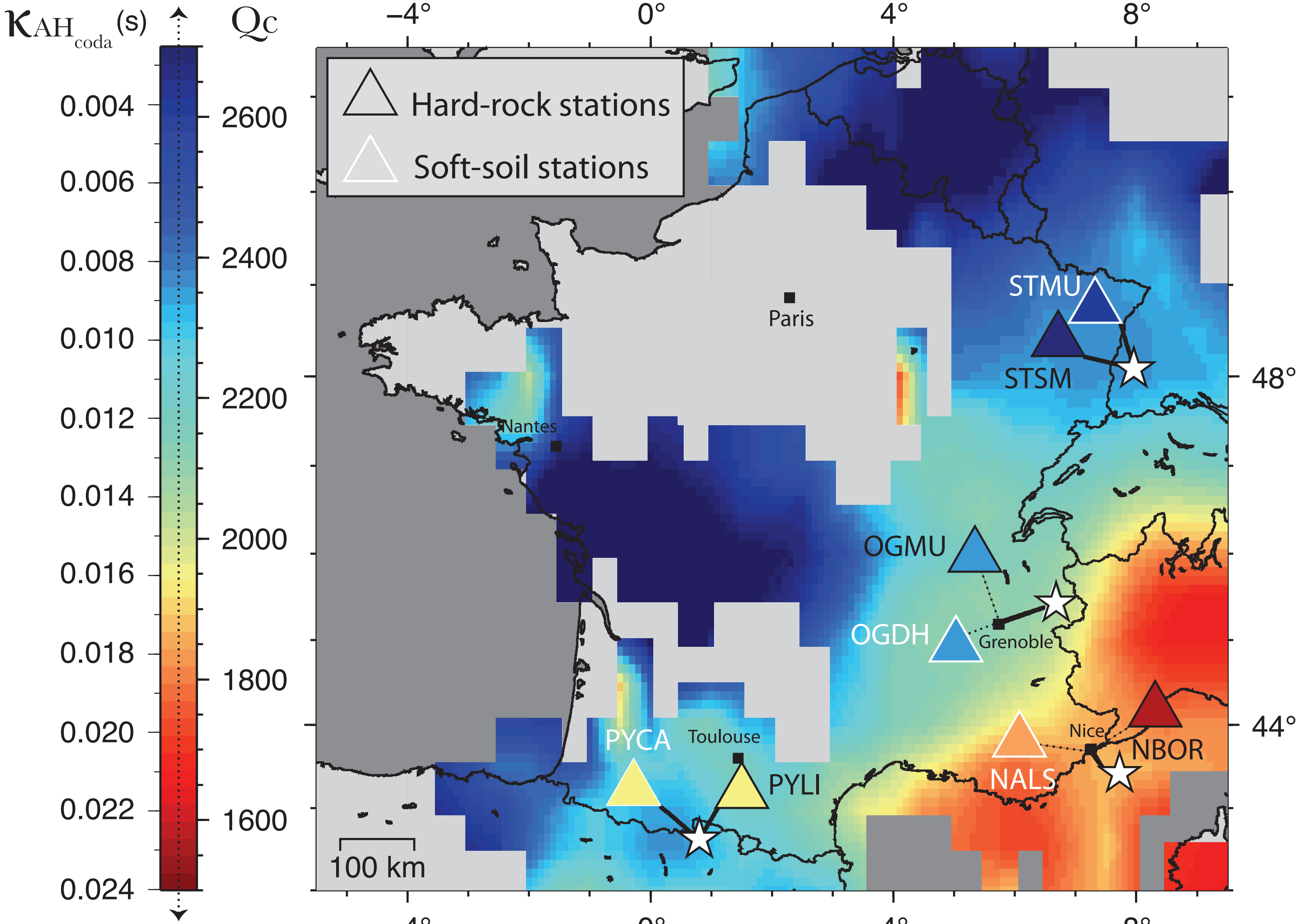




Coda quality factor map (Qc) from Mayor et al. (2017)



Capturing regional variations of hard-rock κ0 from coda analysis ?



J. Mayor, S. Bora and F. Cotton. Capturing regional variations of hard-rock κ0 from coda analysis. In revision

Epistemic uncertainties are large
We can reduce them

- **Model selection** (« think global »): Data-driven, global and transparent regionalisation scheme.

- **Sensitivity analysis** (« life is short »): A priori and application-specific sensitivity analysis to identify key « uncertain » parameters

- **Removing the ergodic assumption (**« act local »**)** : Global and local datasets to refine aleatory variabilities, calibrate physics-based models input parameters and develop site specific PSHA

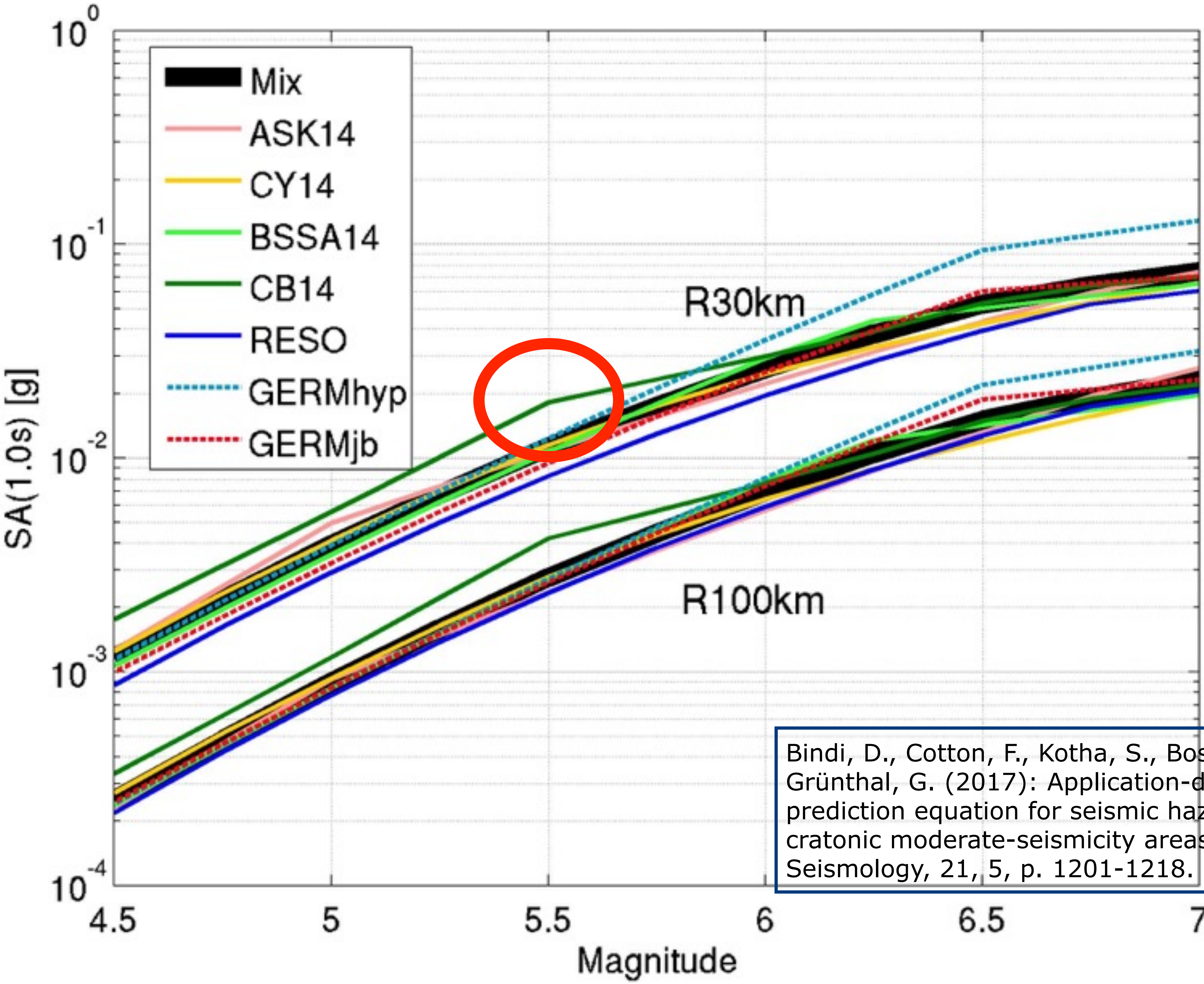
Surprises of last years (personal selection)

- **Between-event ground-motion variabilities are large (even on the same fault system,** tau=0.3**)**

- **Huge difference between site-specific and classical (ergodic) PSHA** (+/- 50%)

- New, data-driven, opportunities to understand non-linear site effects, near-source effects, kappa and stress-drops variabilities

Application-driven GMPE for seismic hazard assessments in non-cratonic moderate-seismicity areas (NGA-west2 database)



Bindi, D., Cotton, F., Kotha, S., Bosse, C., Stromeyer, D., Grünthal, G. (2017): Application-driven ground motion prediction equation for seismic hazard assessments in non-cratonic moderate-seismicity areas. - Journal of Seismology, 21, 5, p. 1201-1218.

From observed variabilities to physics-based models

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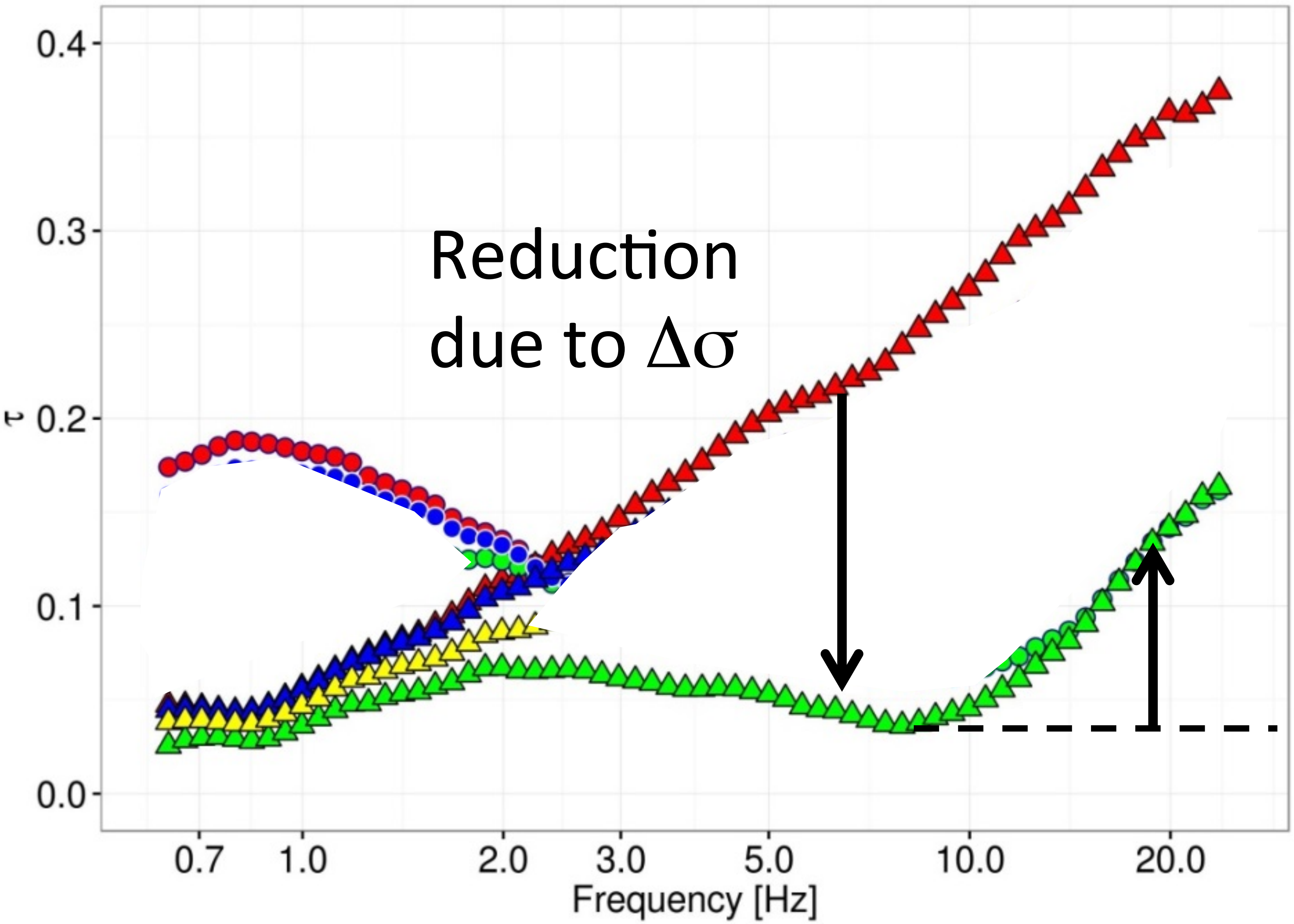
MODEL 2 – $f(M, R, \Delta\sigma) + \delta Be + \delta S2S + \varepsilon$



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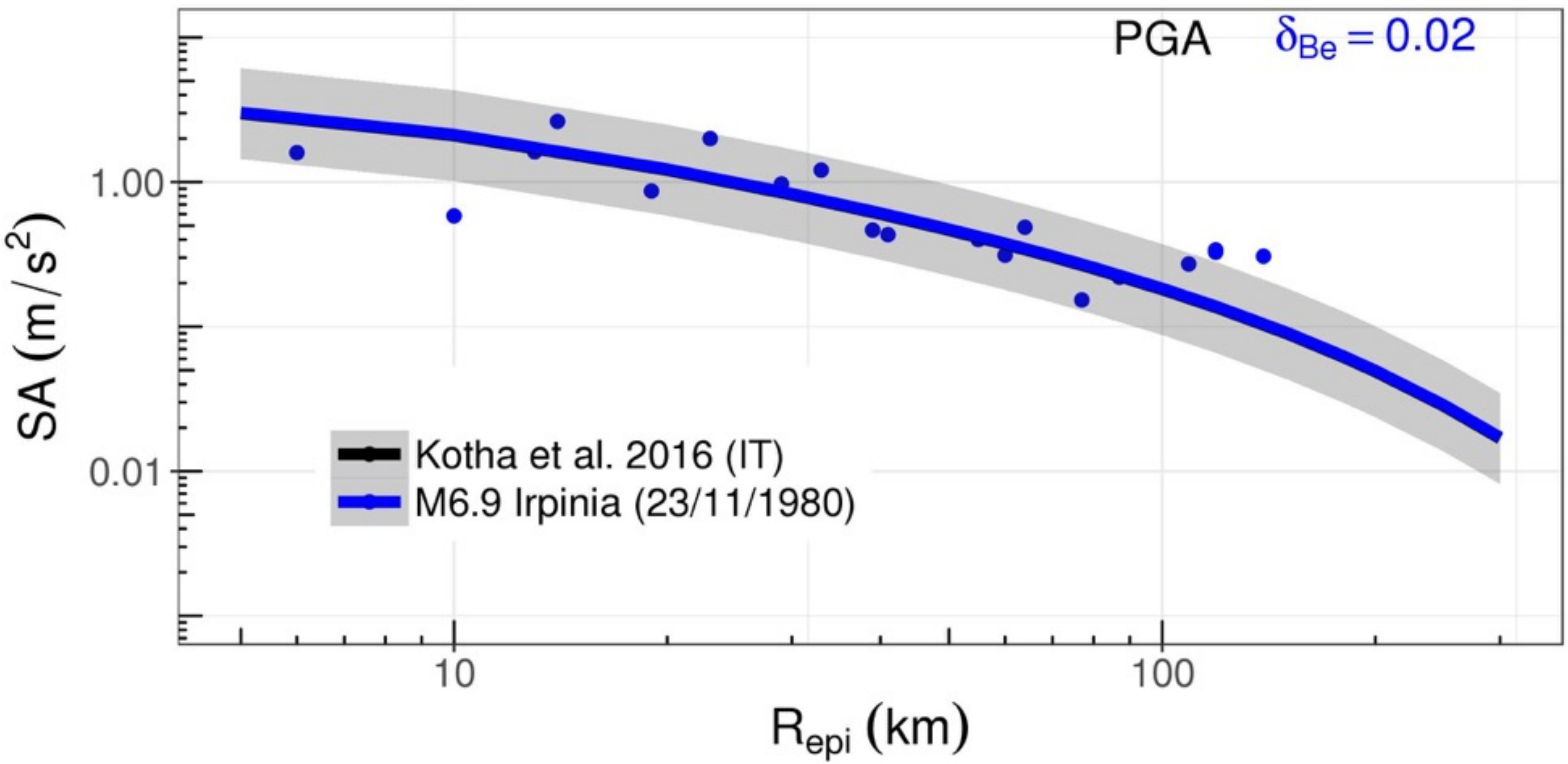
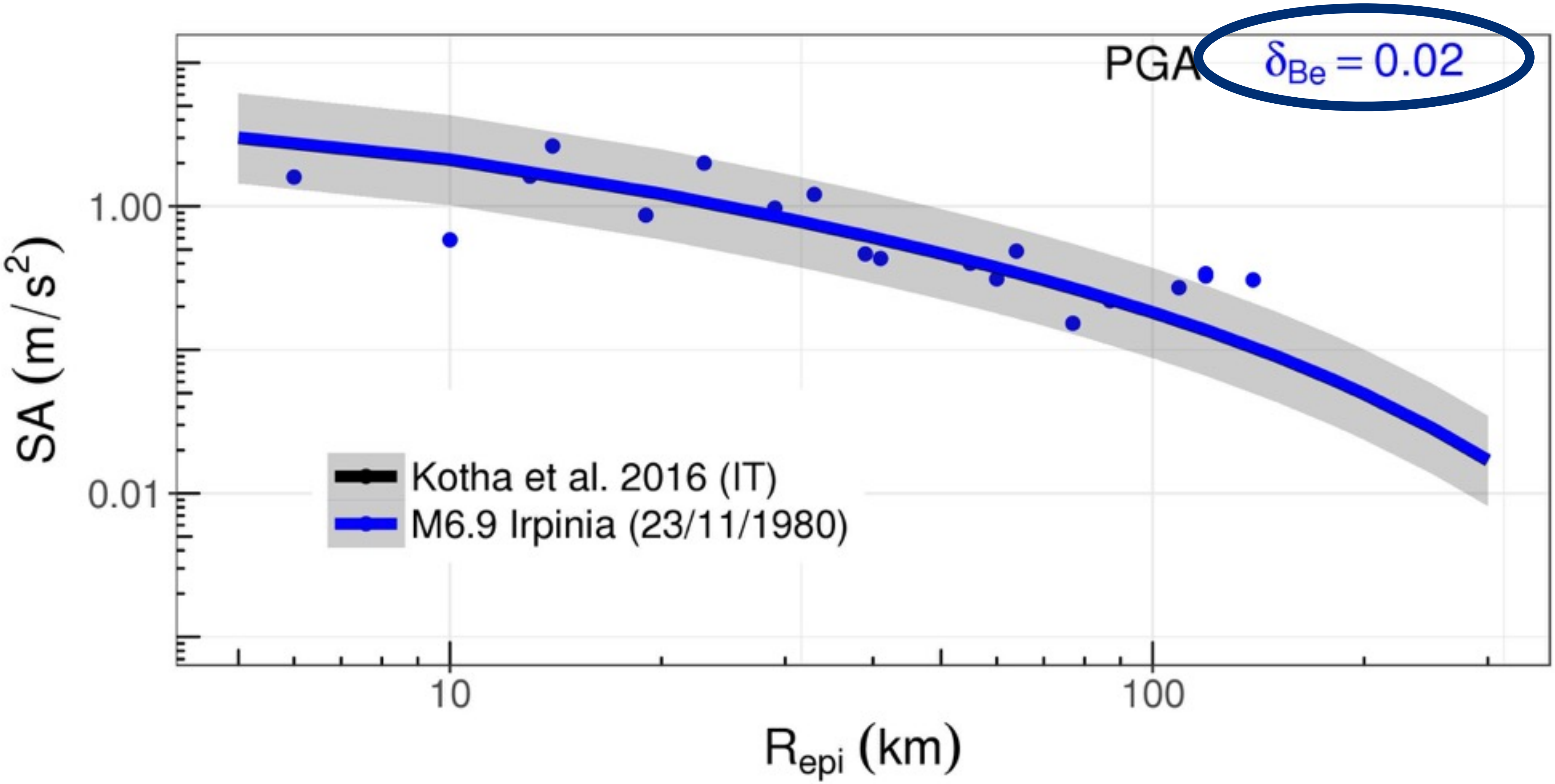
Development of regional Ground-Motion models



Kotha, S. R., Bindi, D., Cotton, F. (2016): Partially non-ergodic region specific GMPE for Europe and Middle-East. - Bulletin of Earthquake Engineering, 14, 4, p. 1245-1263.

New : Earthquake variability (computation of between-event terms)



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