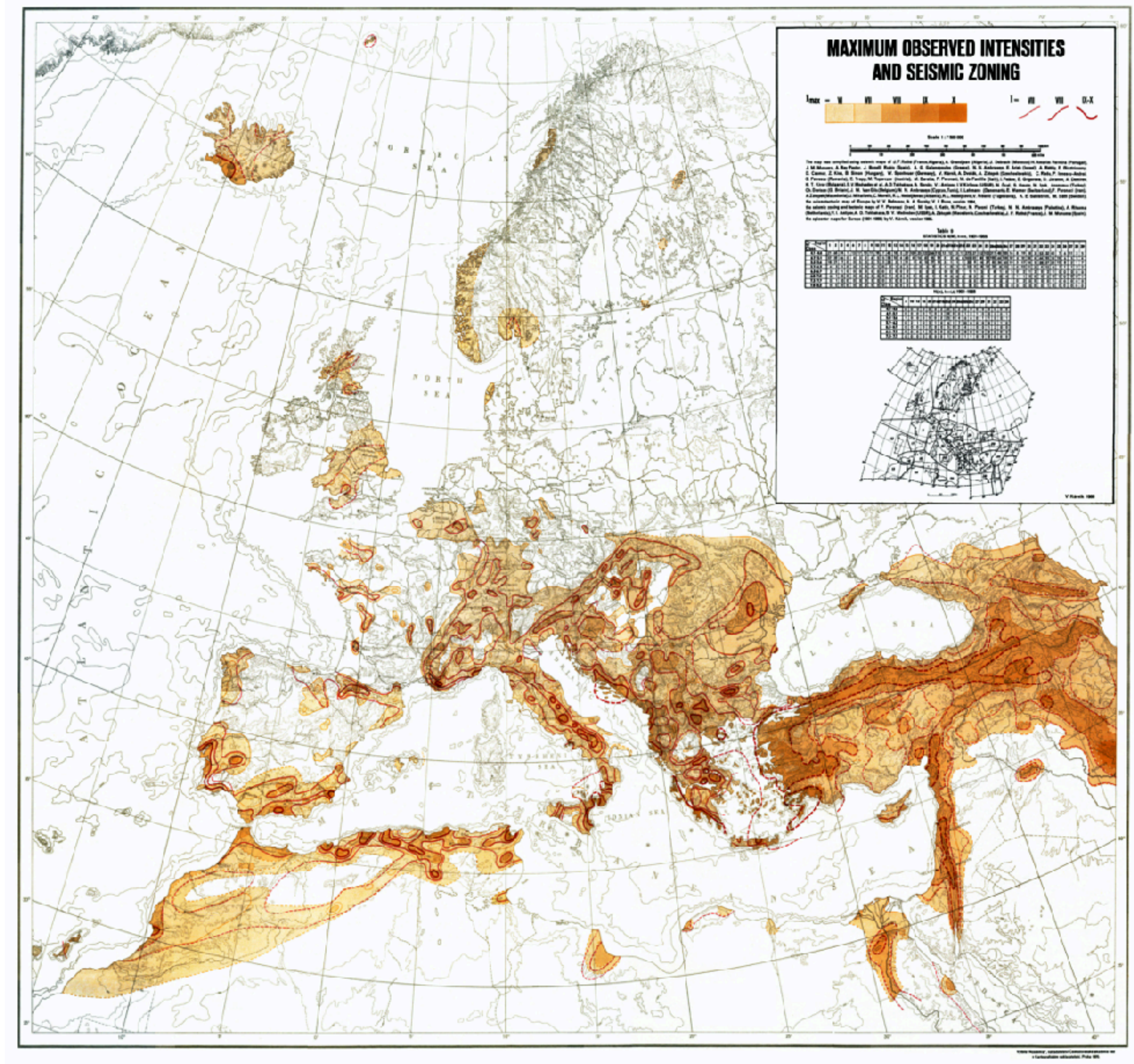




From Data to Models: What European Seismic Hazard Models Tell Us

Laurentiu Danciu (ETH Zurich)

A long European tradition of hazard mapping



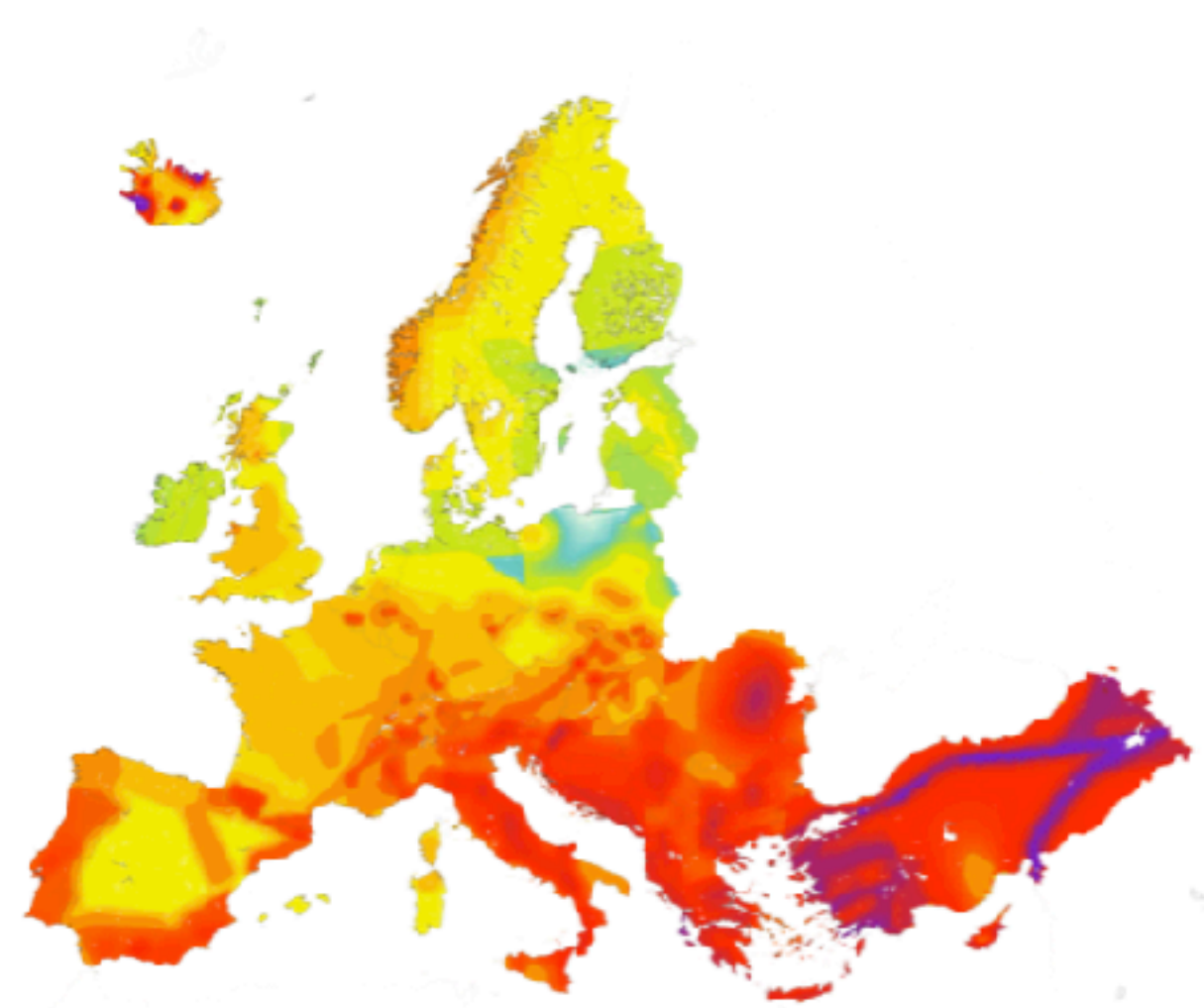
1st European Uniform Intensity Map

Seismicity of the European Area, Part 1 Vít Kárník (D. Reidel, Dordrecht, 1969, 364pp.)

Vít Kárník - Seismicity of the European Area, published in 1969 and 1971 by the European Seismological Commission (ESC)

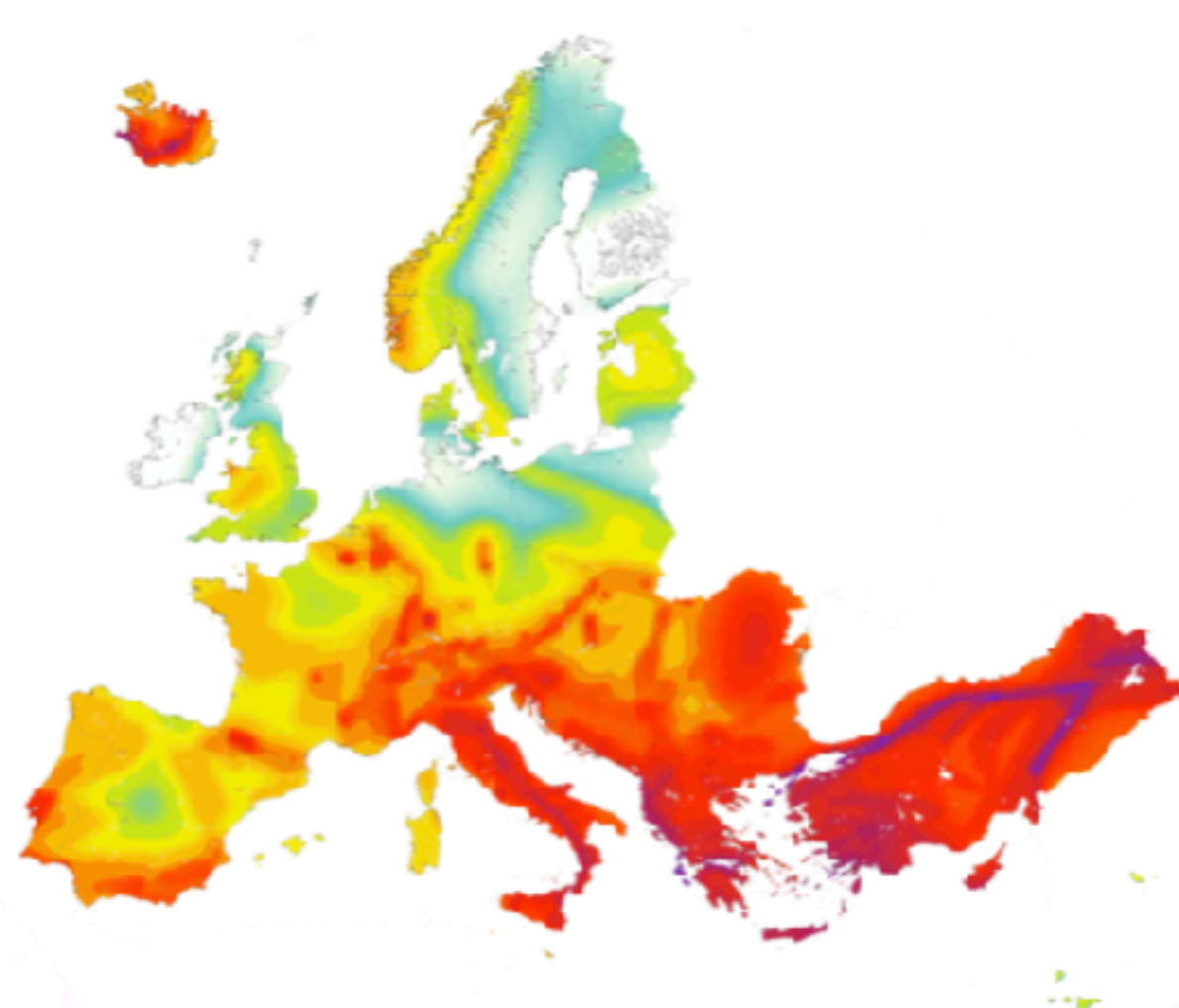


From Static Map to Models



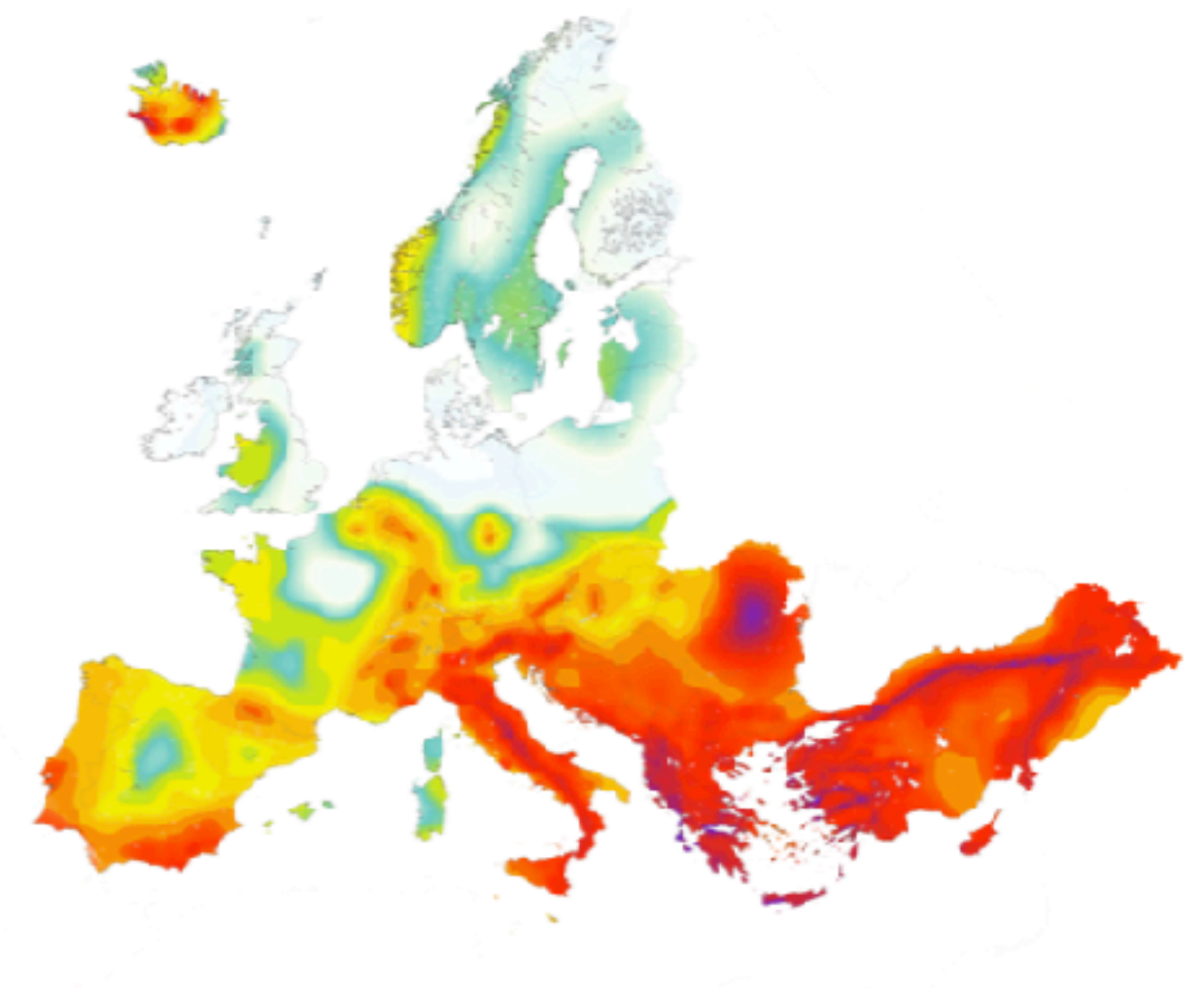
ESHM01

(Jimenez, Giardini & Grünthal, 2003)



ESHM13

Woessner et al 2015.

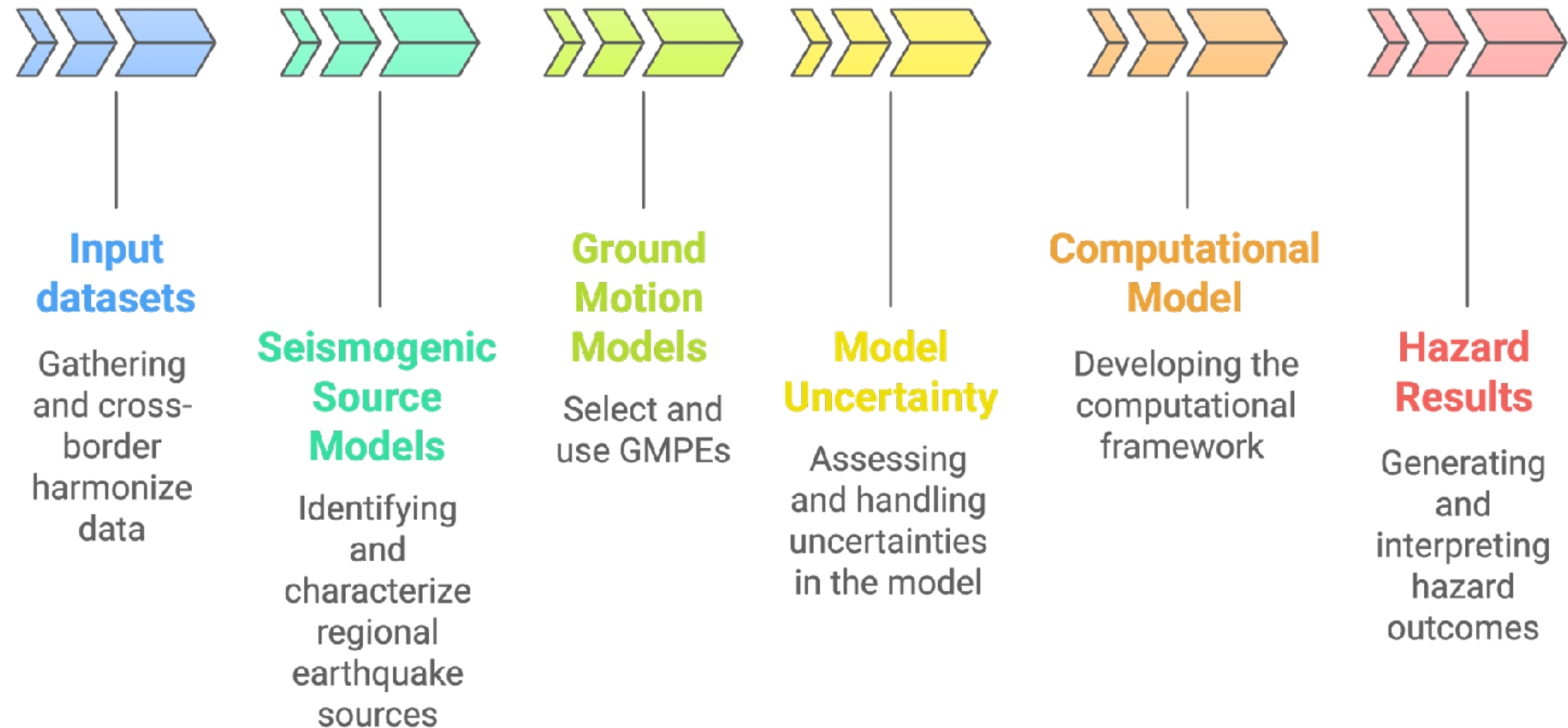


ESHM20

Danciu et al 2021, 2024

- Seismic hazard models are not one-off efforts, they are built on evolving data and methods, and their ***relevance decays over time***.
- **ESHM20** is the ***reference*** European Seismic Hazard Model.
- ESHM13 superseded ESHM01 (GSHAP/SESAME)
- **ESHM20** supersedes ESHM13!

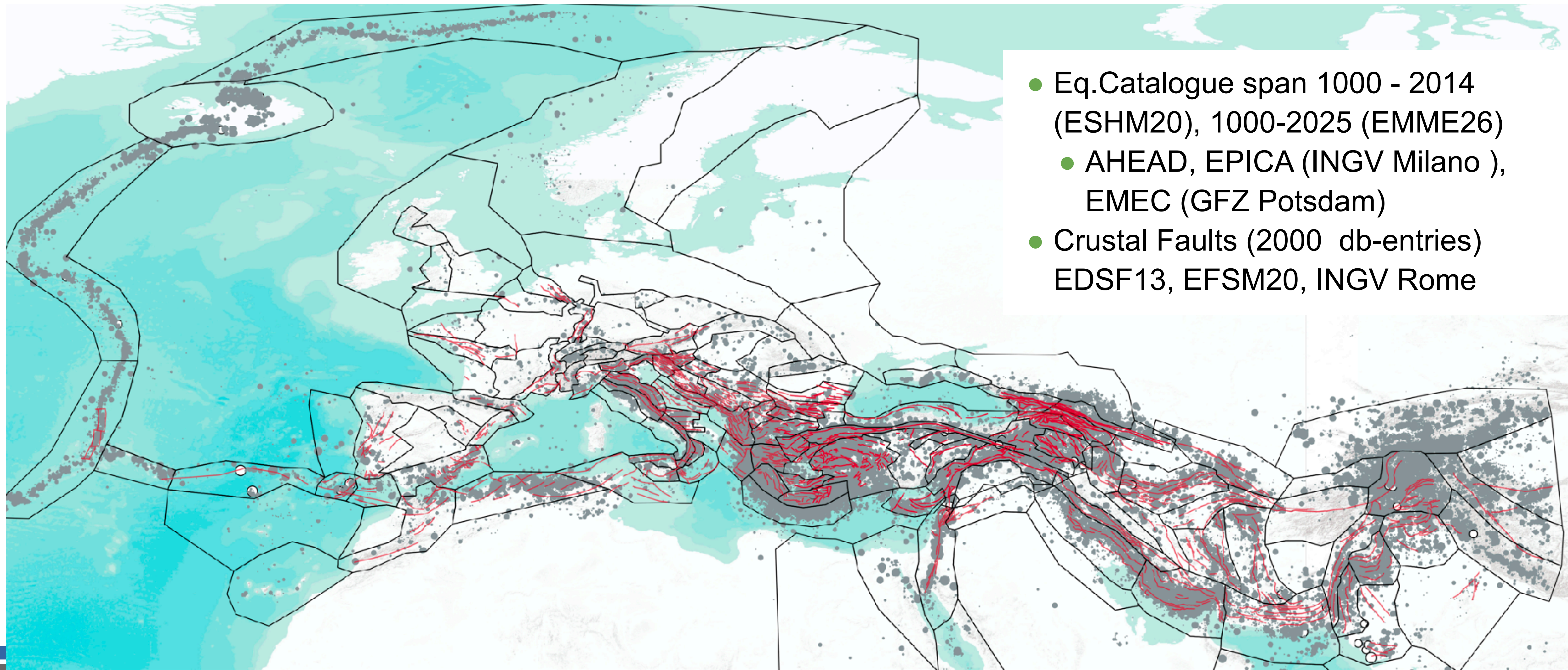
What all regional hazard models have in common?



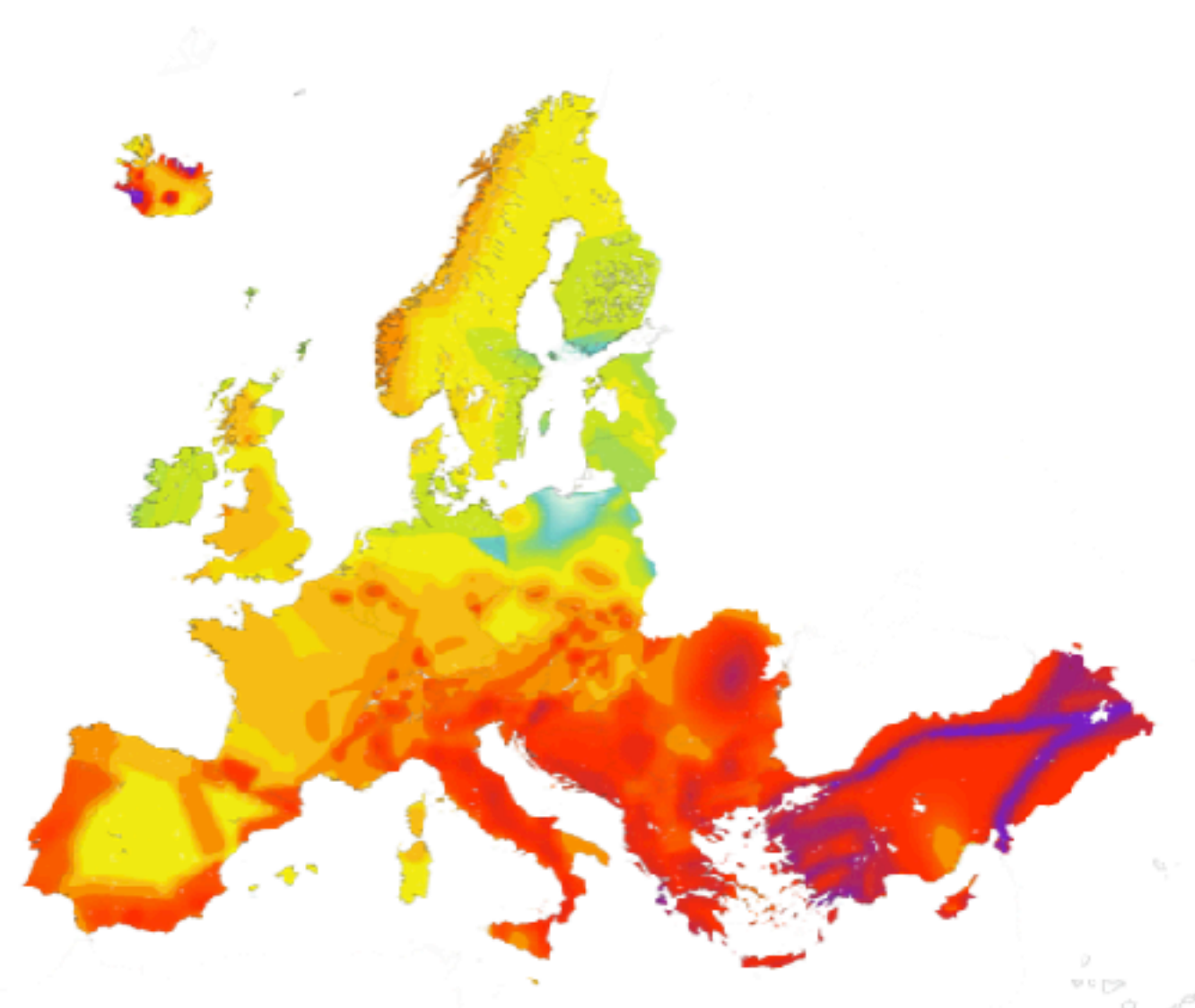
Uniform Probabilistic Framework

What all regional hazard models have in common?

Curated and cross border harmonized datasets for Euro-Mediterranean & Middle East



Know the Unknowns: Data, Model, Results

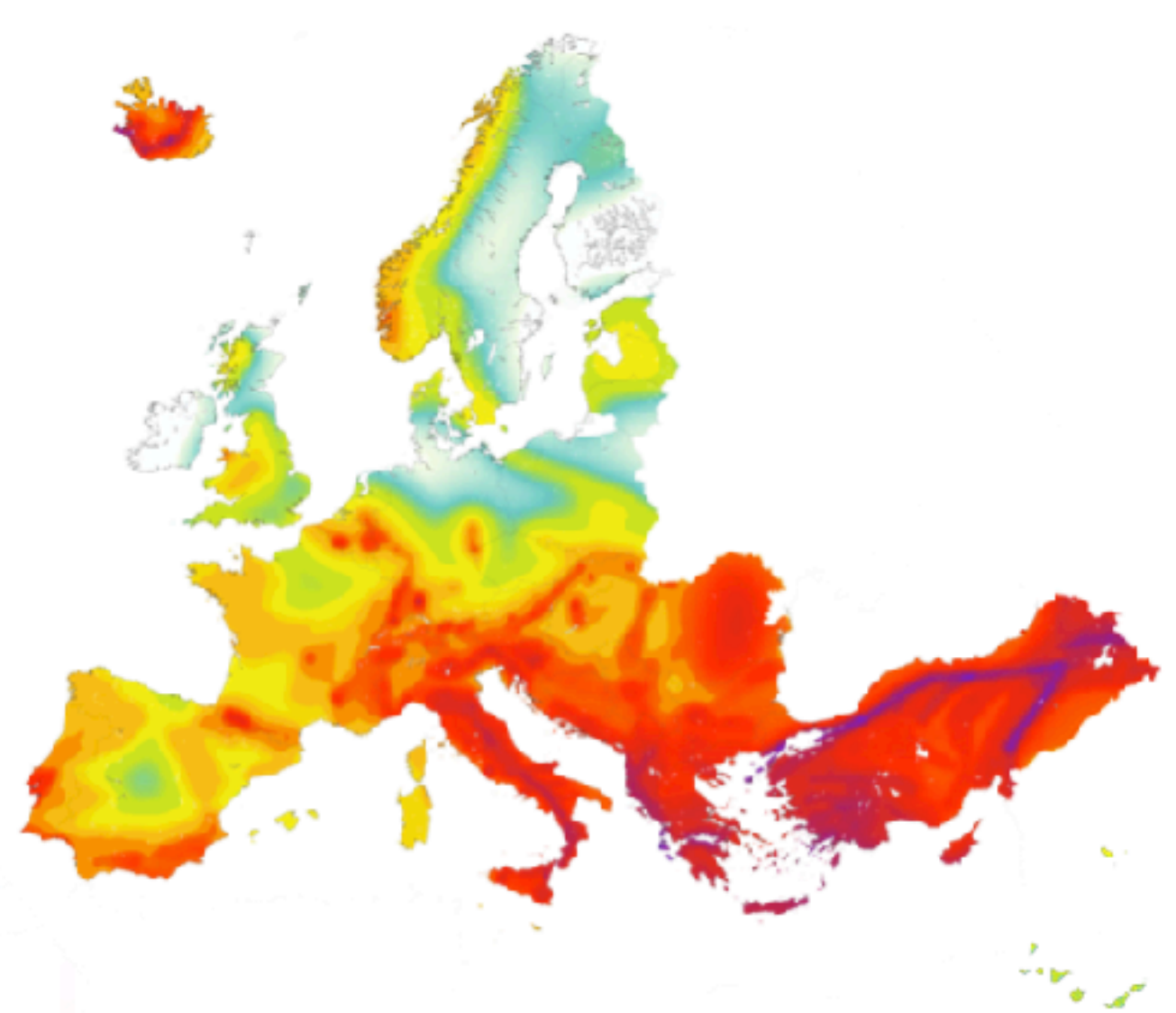


ESHM 2001

(Giardini et al 2001)
Cross-Border Harmonized
Earthquake Catalogue

Unified Source Model

Single Ground Motion Model

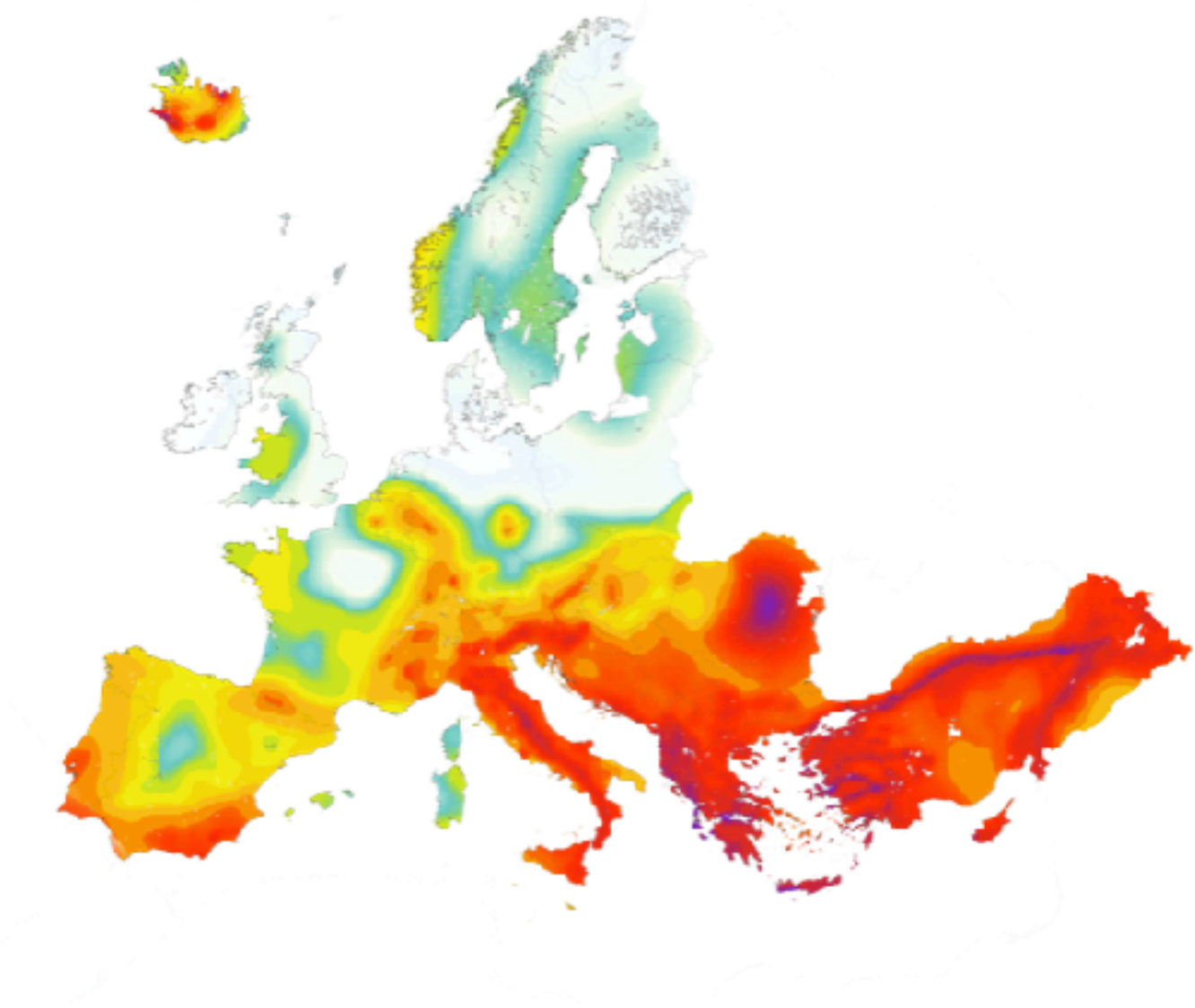


ESHM 2013

(Woessner et al 2015)
Cross-Border Harmonized
Earthquake Catalogue
Crustal Active Faults

Multiple Source Models
Unified Area Sources
Smoothed Seismicity
Active Crustal Faults

Multiple Ground Motion Models



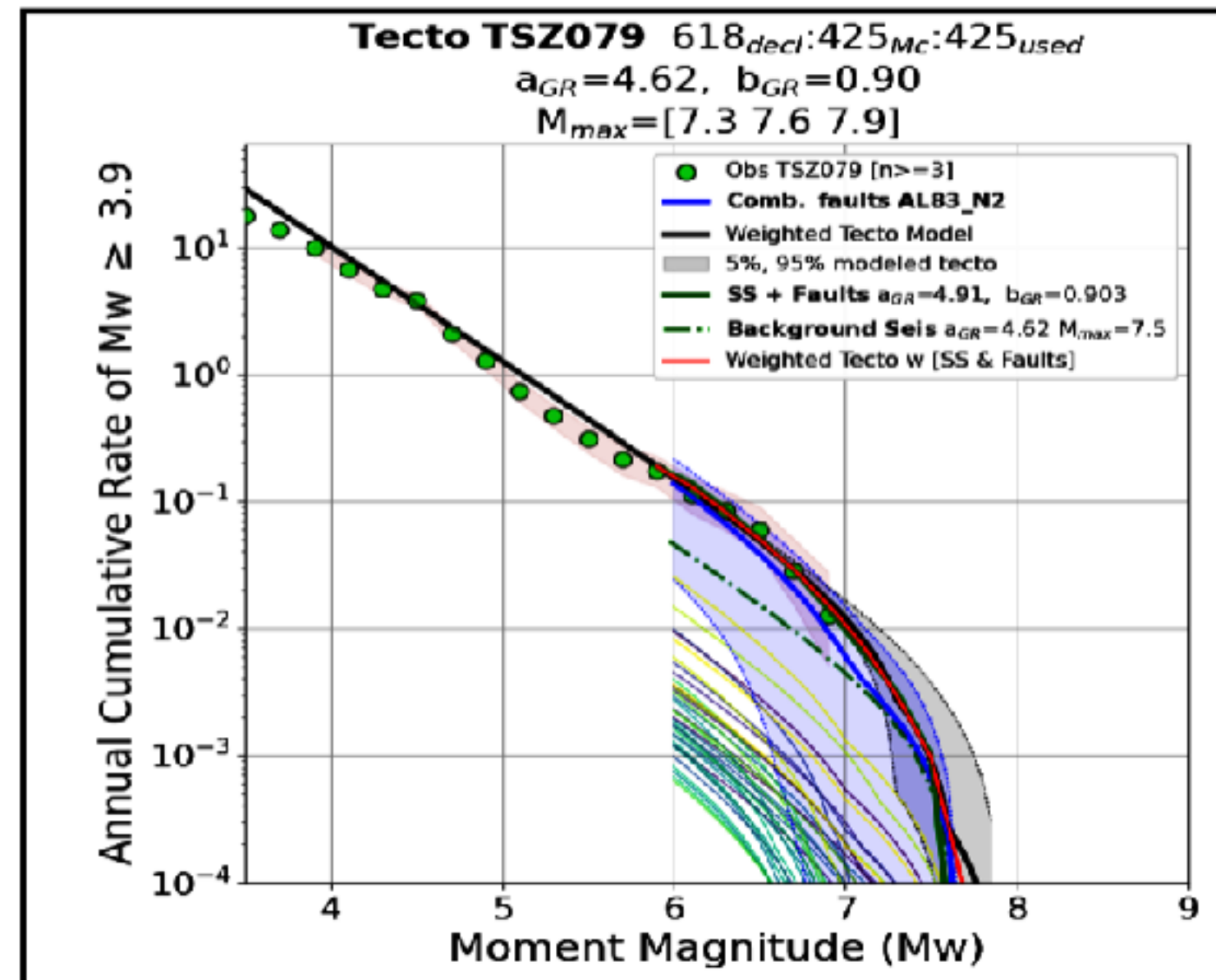
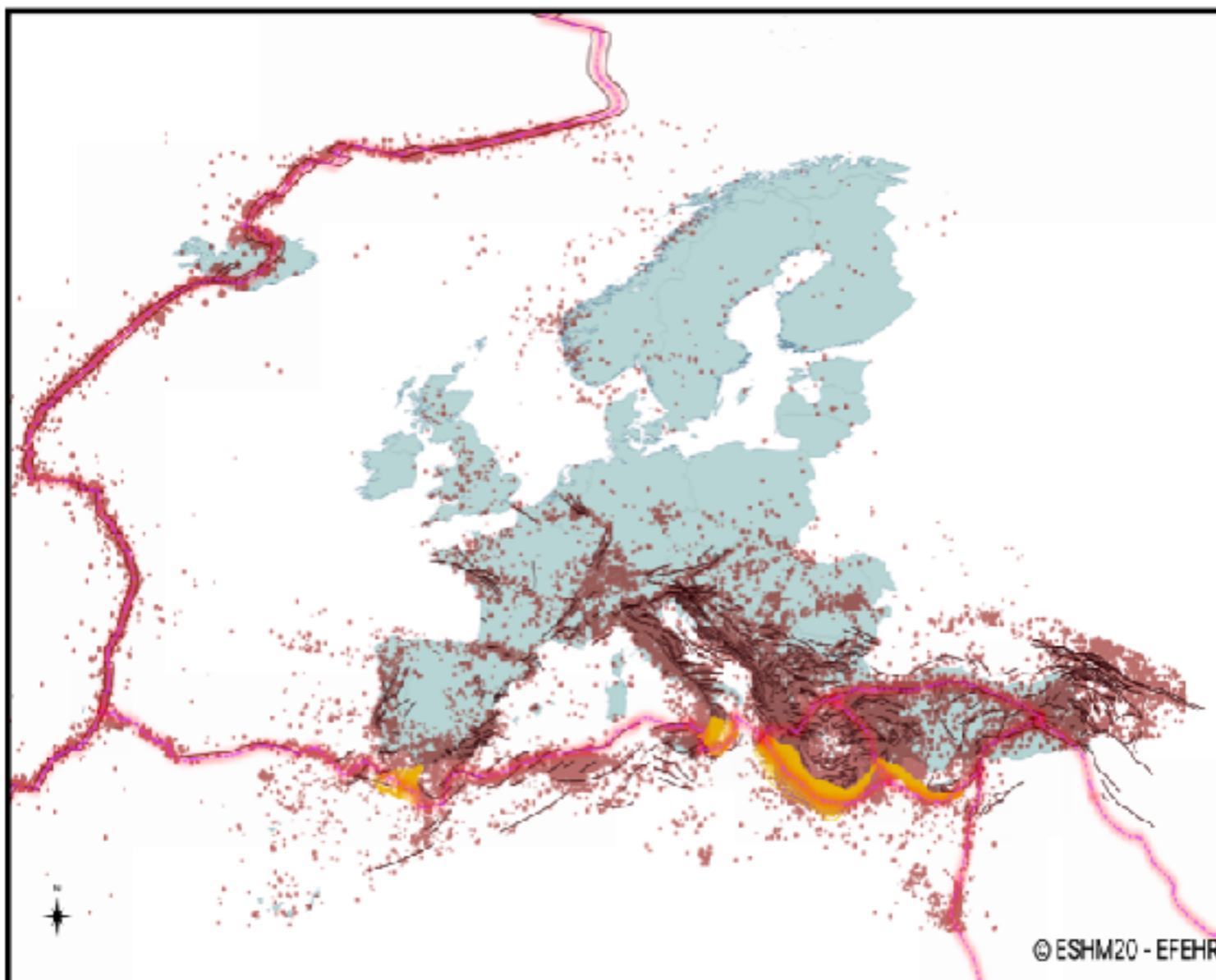
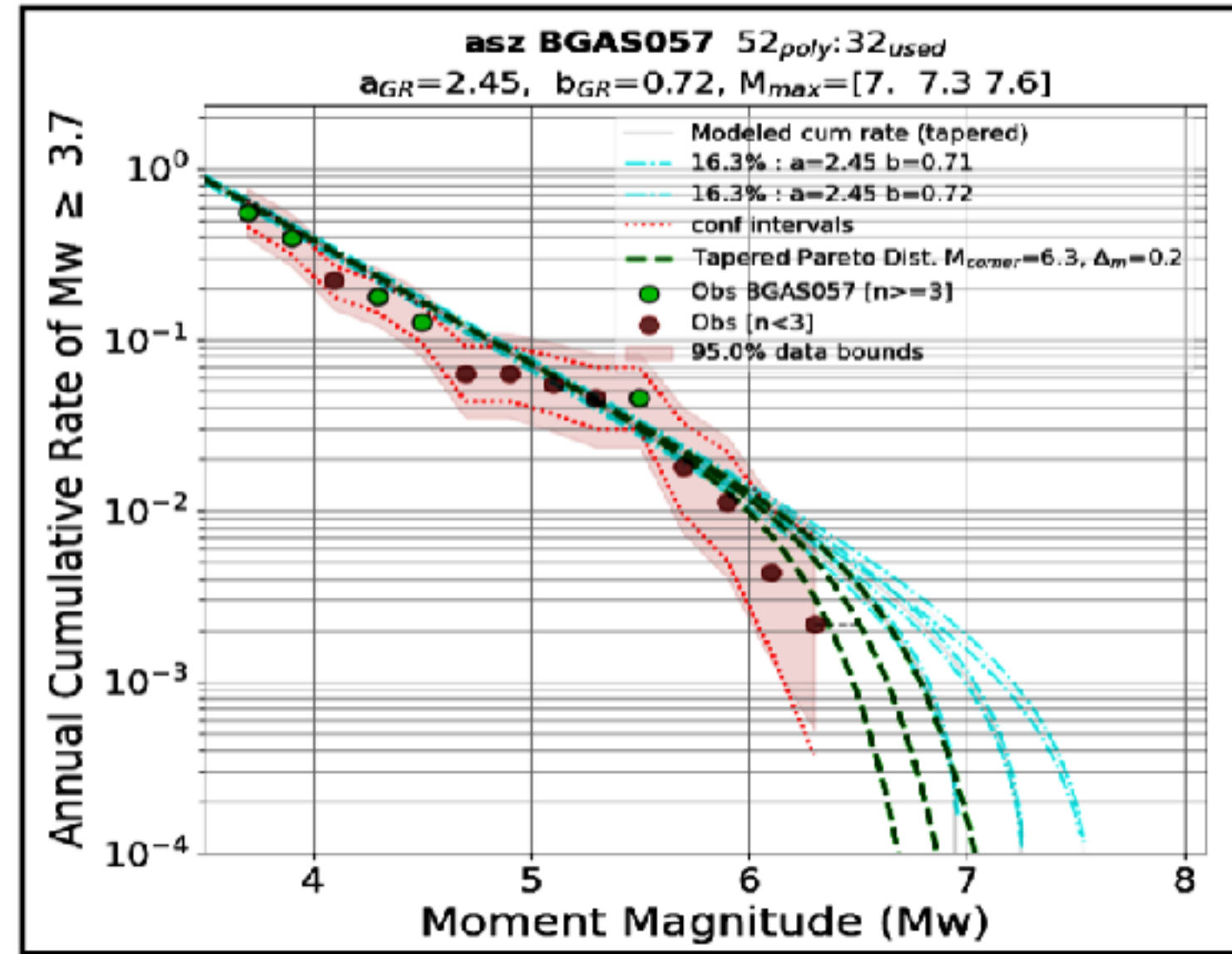
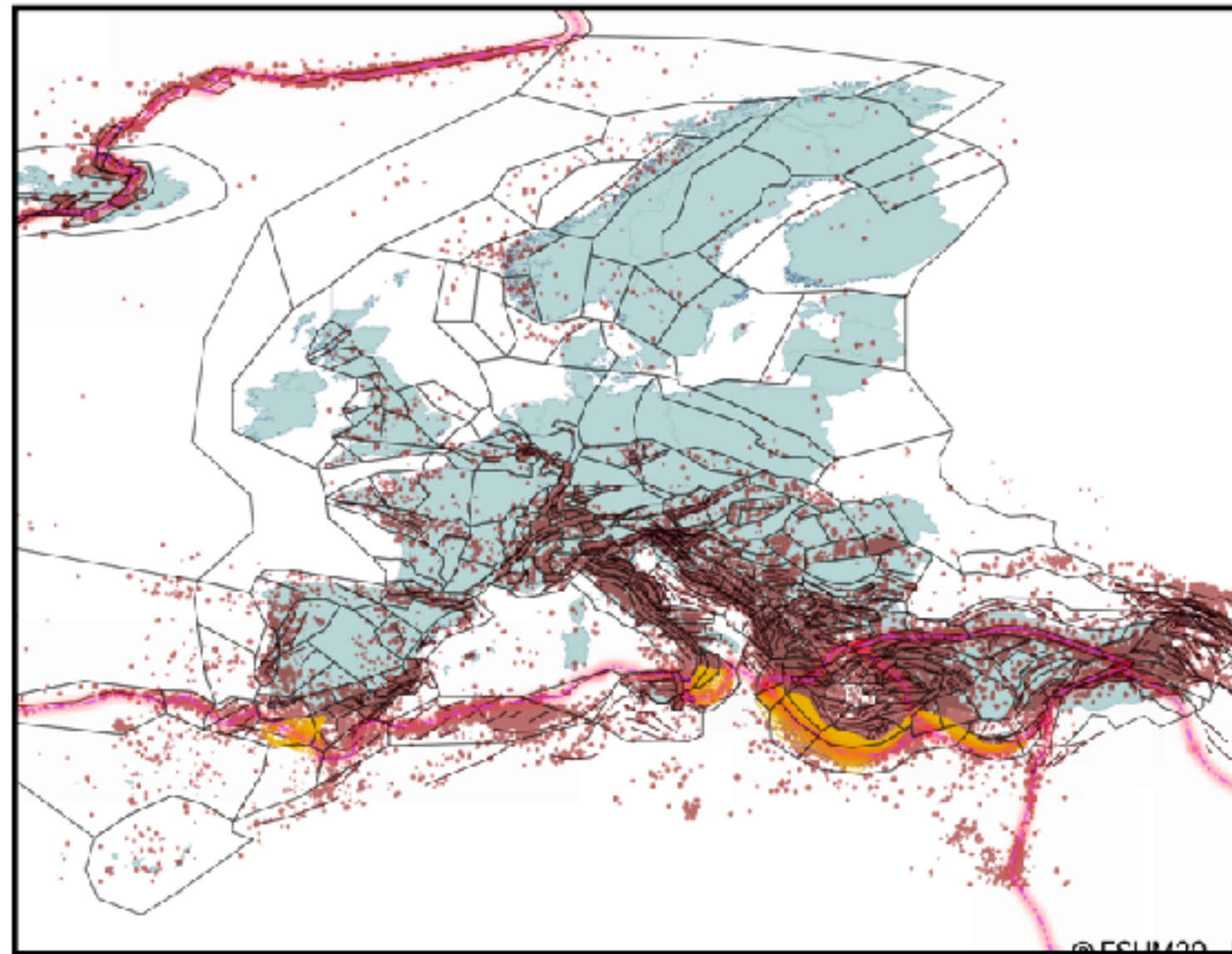
ESHM 2020

(Danciu et al 2021)
Cross-Border Harmonized
Earthquake Catalogue
Crustal Active Faults

Multiple Source Models Consensus
Source Model
Hybrid Model (Active Faults and
Smoothed Seismicity)

Backbone Ground Motion Models

What source modeling taught us



- **Dual Source Philosophies (Area vs. Hybrid)**

- ESHM20 runs two alternative branches: Area Source Model (consensus-based) and Hybrid Model (Faults + Smoothed Seismicity).

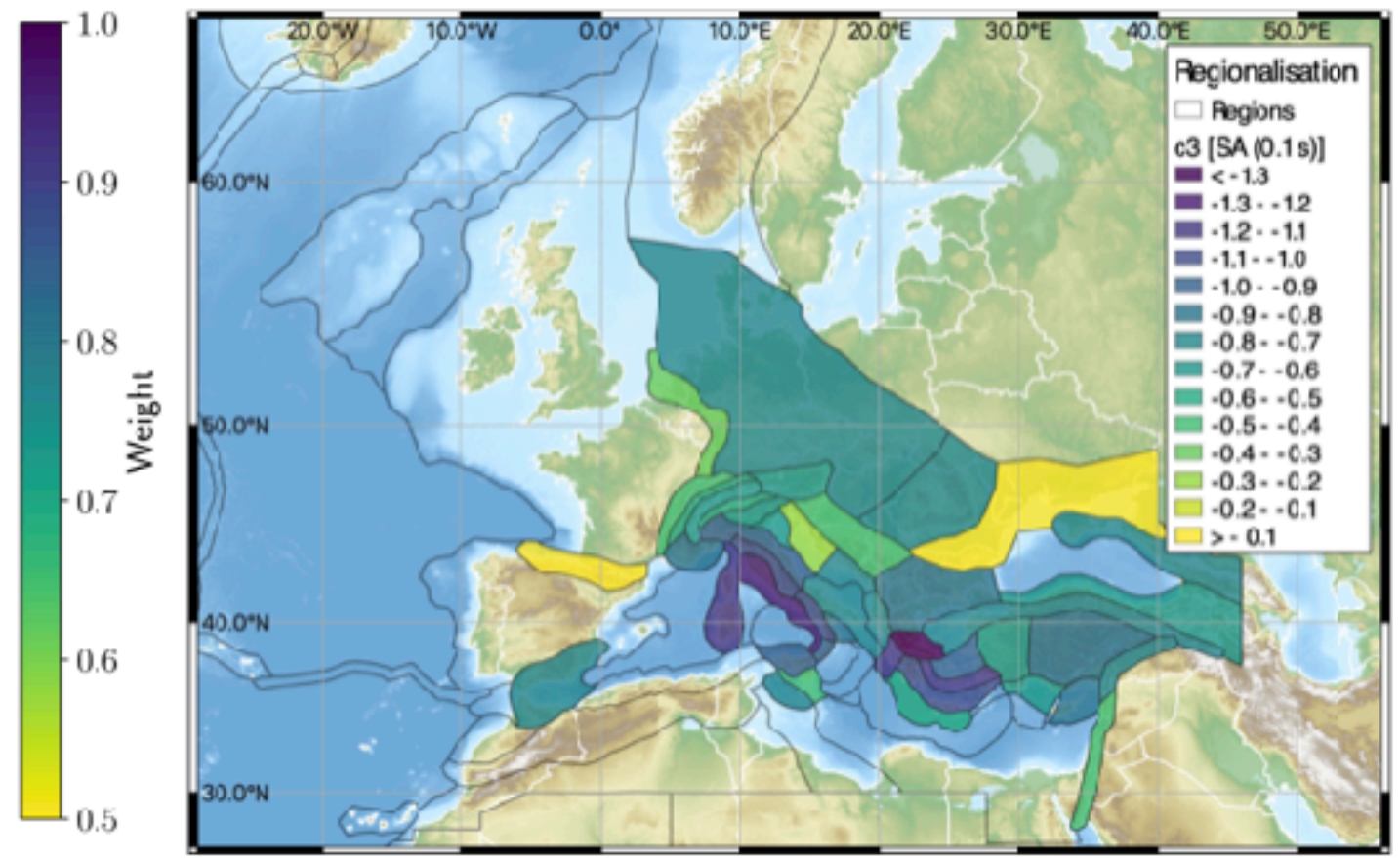
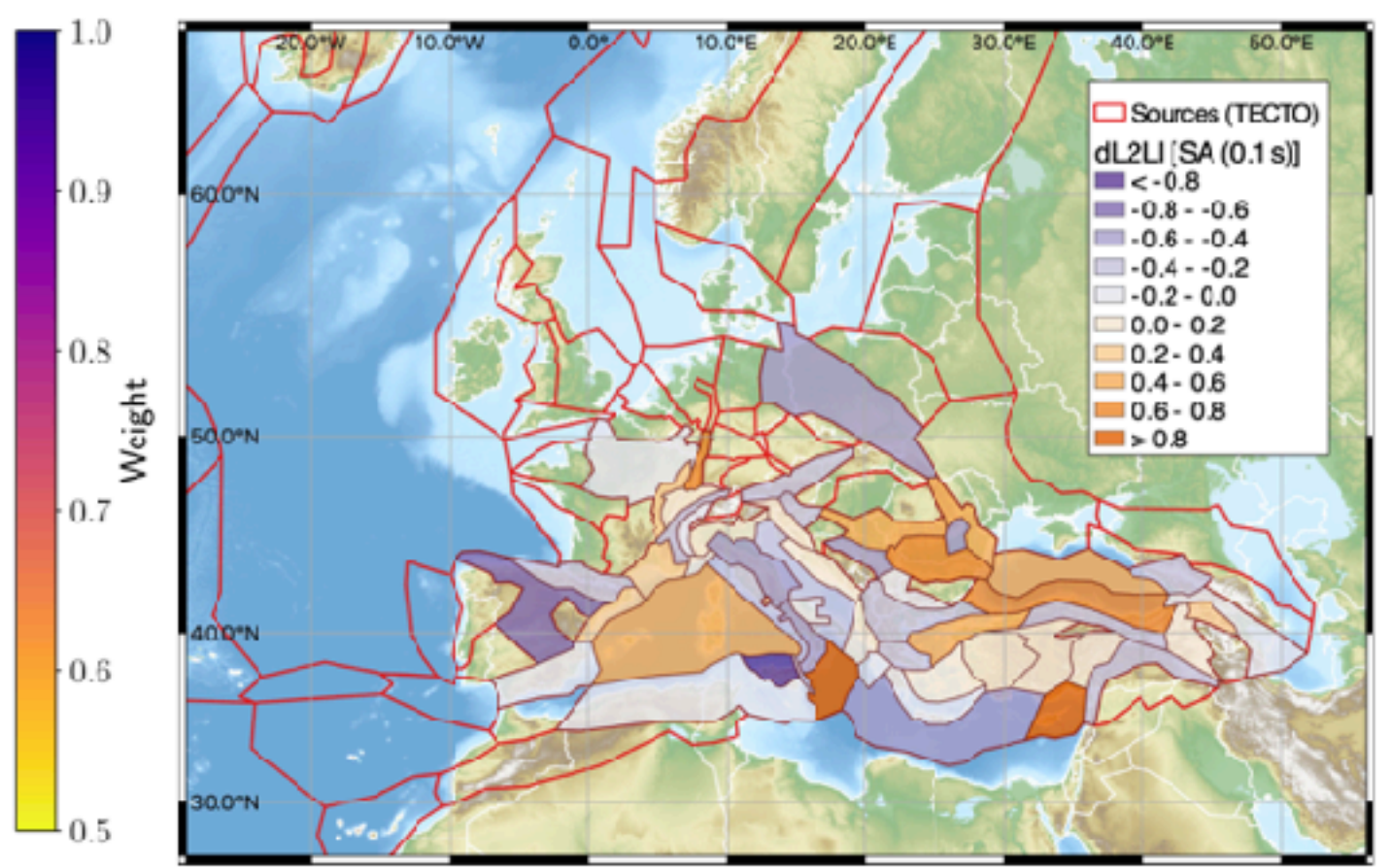
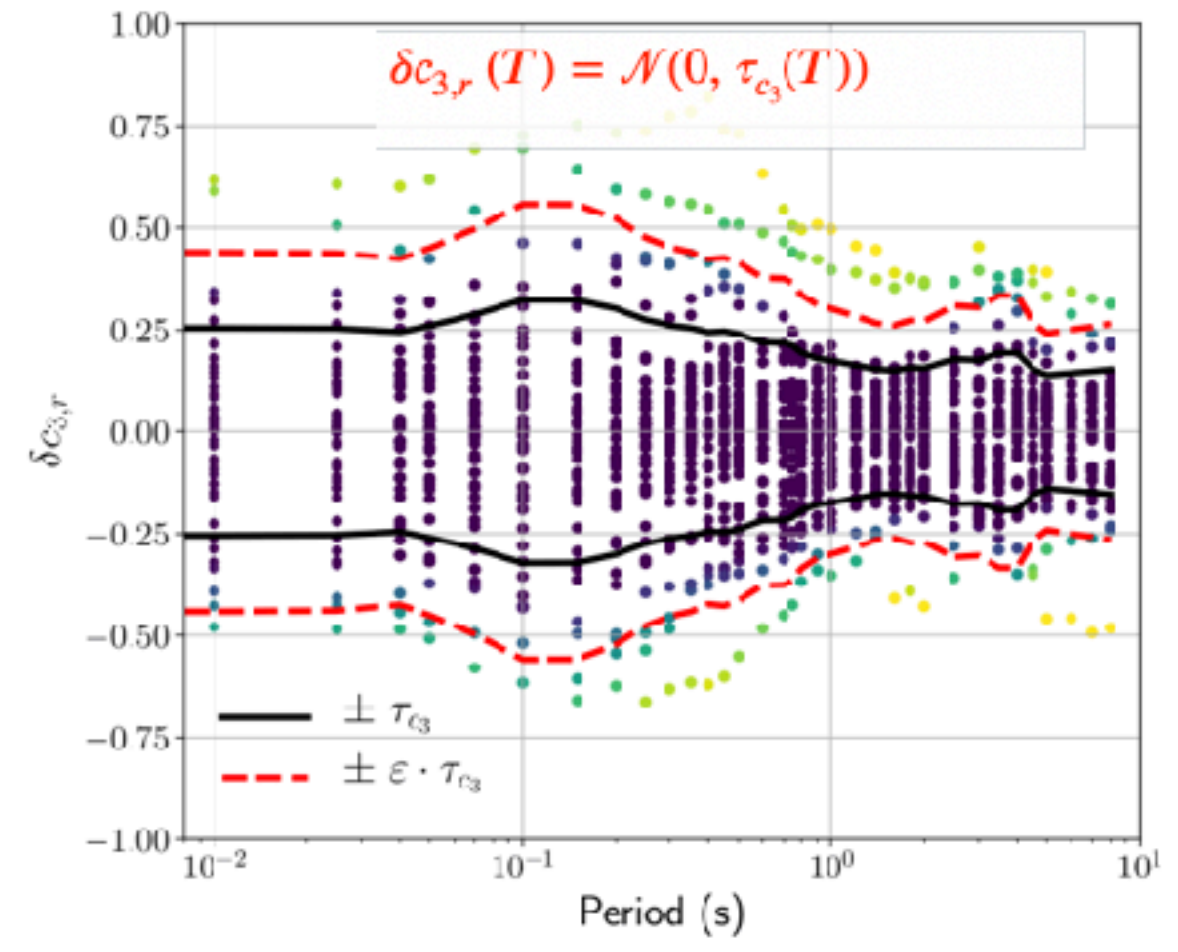
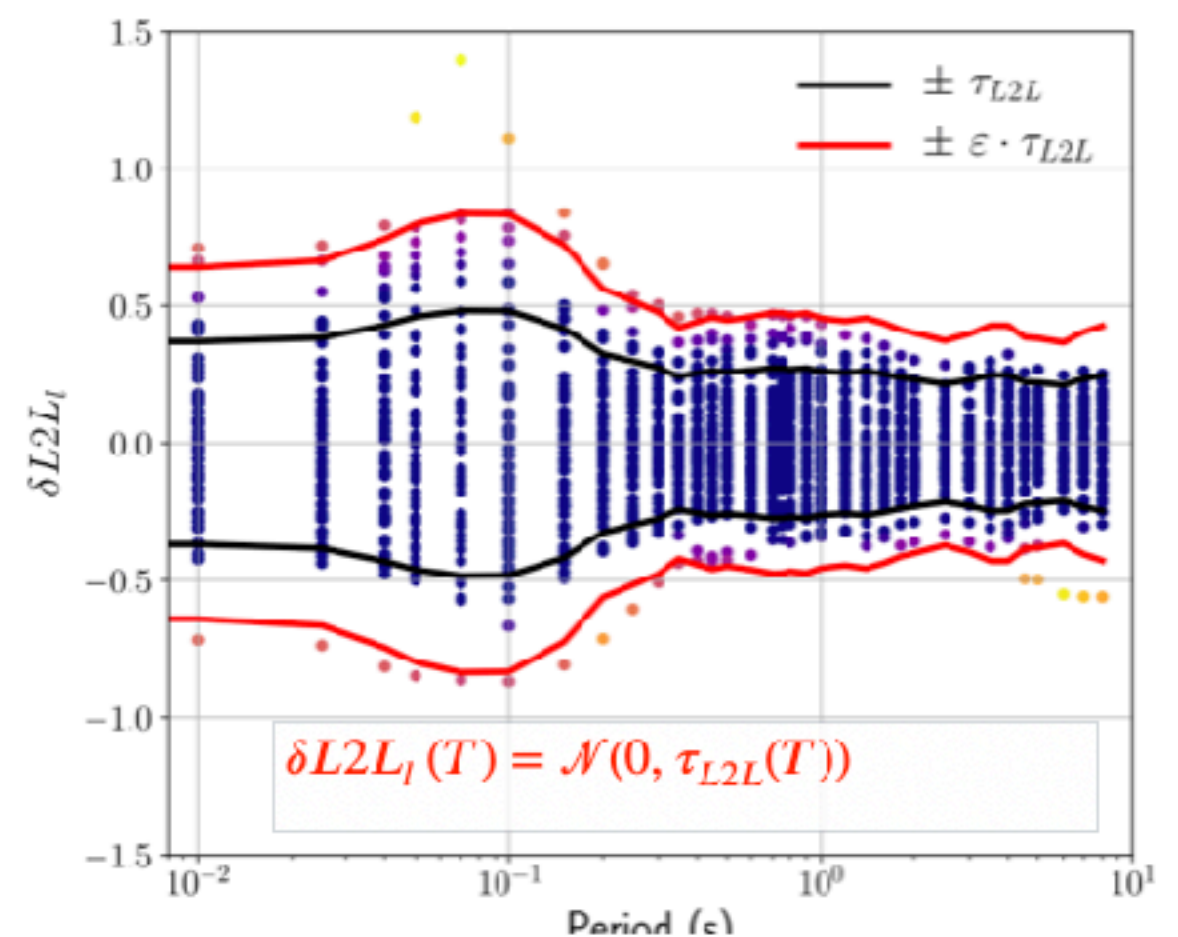
- While consistent at the European scale, models diverge locally;

- Hybrid model typically forecasts higher earthquake rates near mapped faults

- Area Sources remain essential for stability where fault mapping is incomplete.

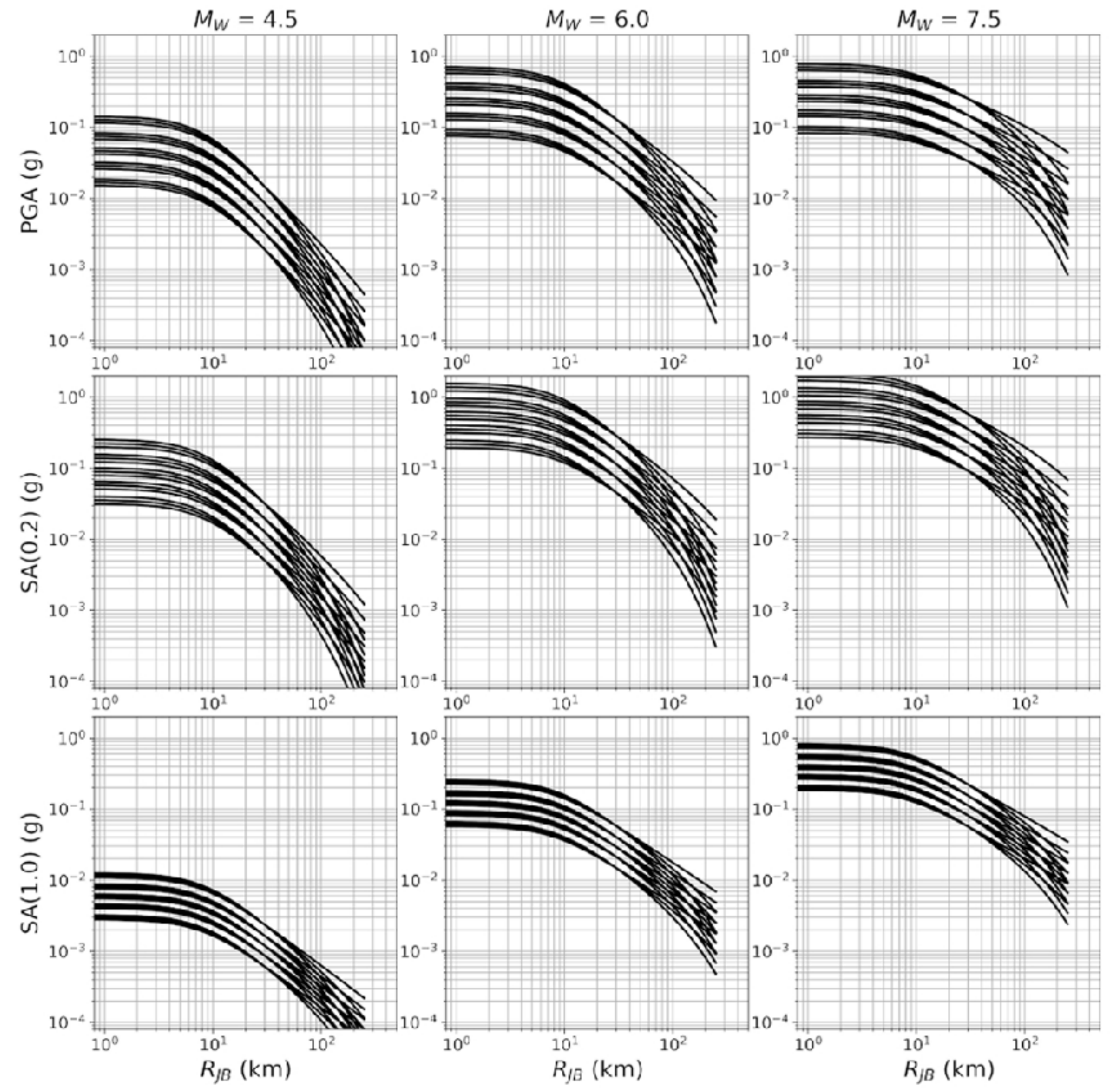
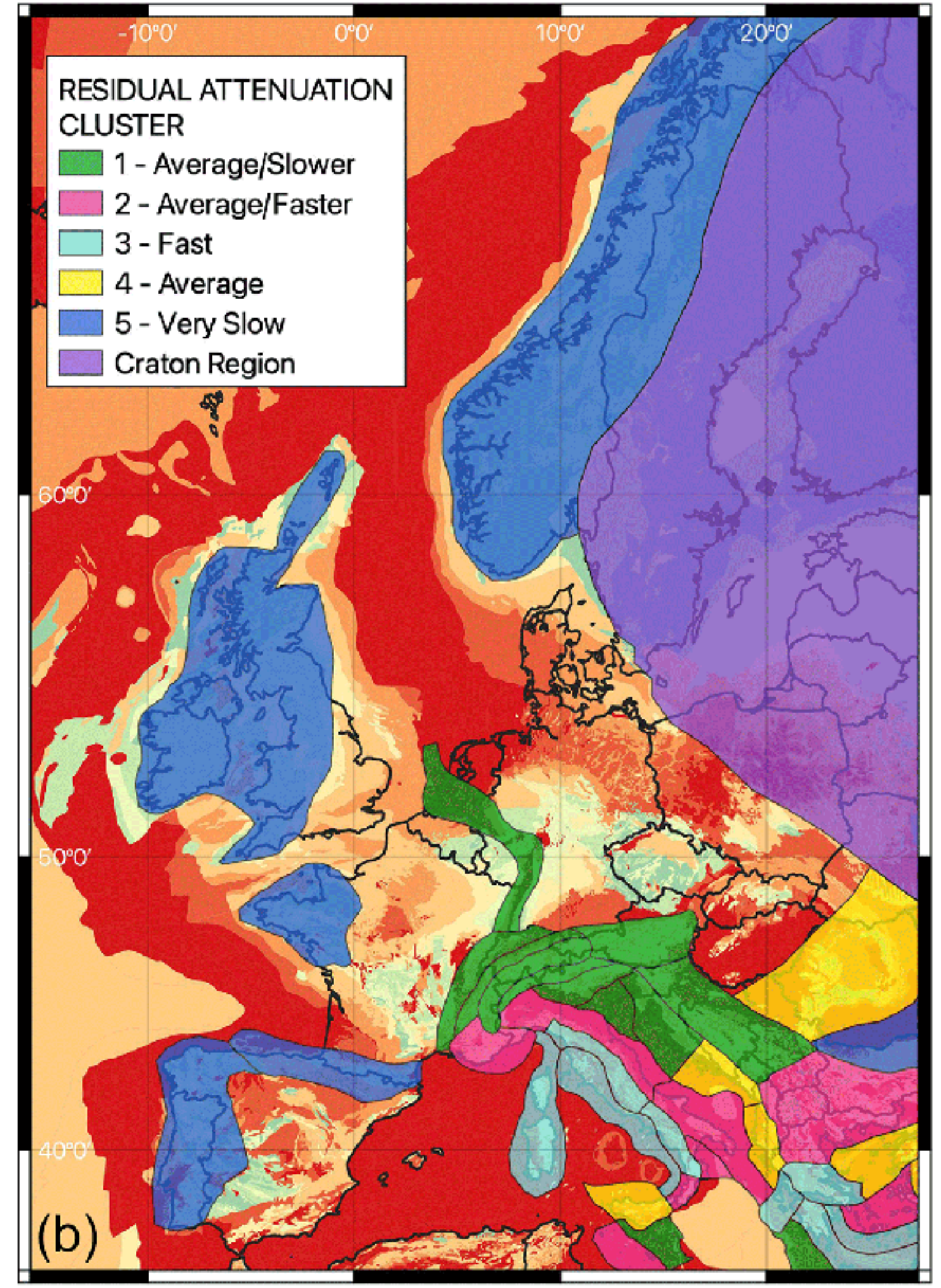
What ground-motion modeling taught us?

- New Pan-European Models - Kotha et al 2020
- Data Driven Regionalization
- A single, robust "**backbone**" ground motion model calibrated to the pan-European Engineering Strong Motion (ESM) database, which now holds over 20,000 recordings.
- Specific terms for **source-region variability** ($\delta L2L$), recognizing that earthquakes in some regions are systematically more energetic.
- Residual **attenuation variability** ($\delta c3$), recognizing that waves decay faster in some crustal domains than others.



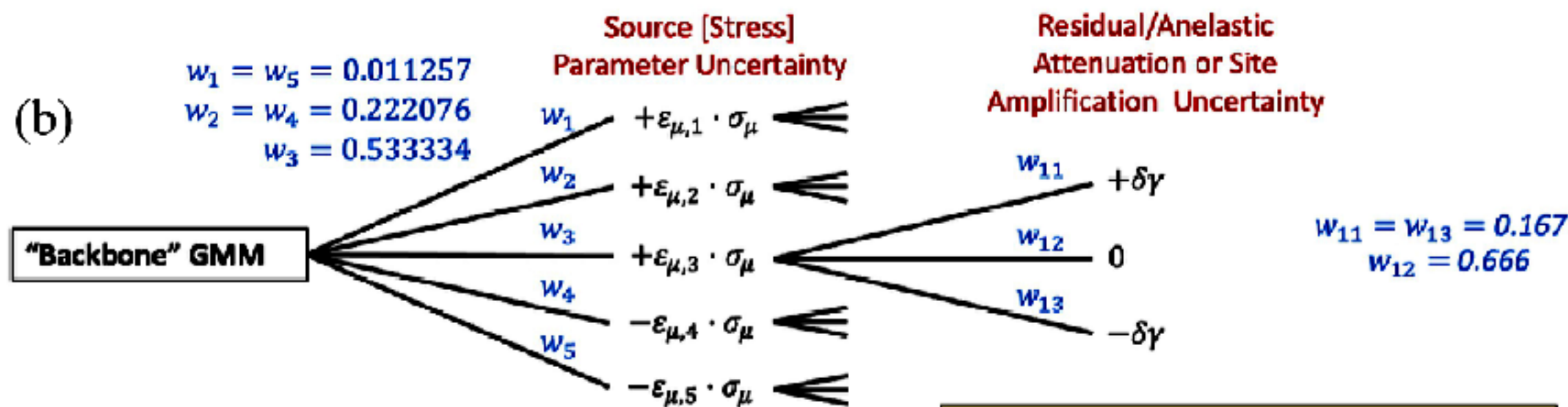
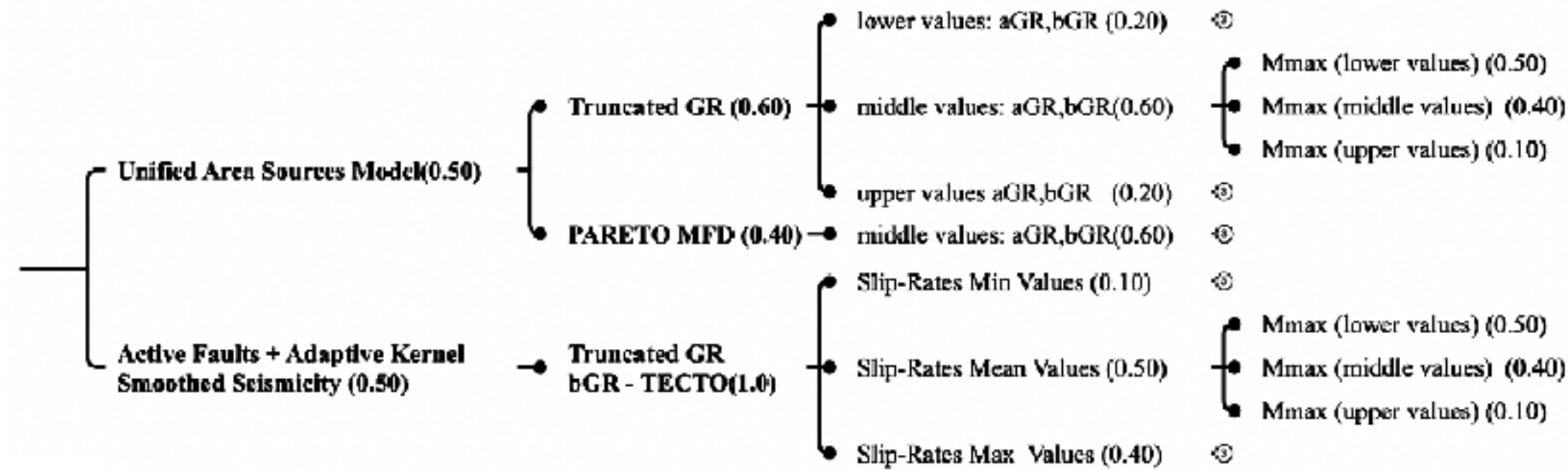
Weatheril et al 2024 <https://doi.org/10.5194/nhess-24-1795-2024>

What ground-motion modeling taught us?



Weatheril et al 2024 <https://doi.org/10.5194/nhess-24-1795-2024>

Uncertainties are here to stay!



Shallow (Non-Craton):
 Kotha et al. (2020; 2022)
 Weatherill et al. (2020)

Craton:
 Weatherill & Cotton (2020)

Subduction & Deep Seismicity:
 Abrahamson et al. (2016) calibrated to Europe

Shallow (Non-Craton):
 $\sigma_\mu = \max(\tau_{121}, \sigma_{statistical})$

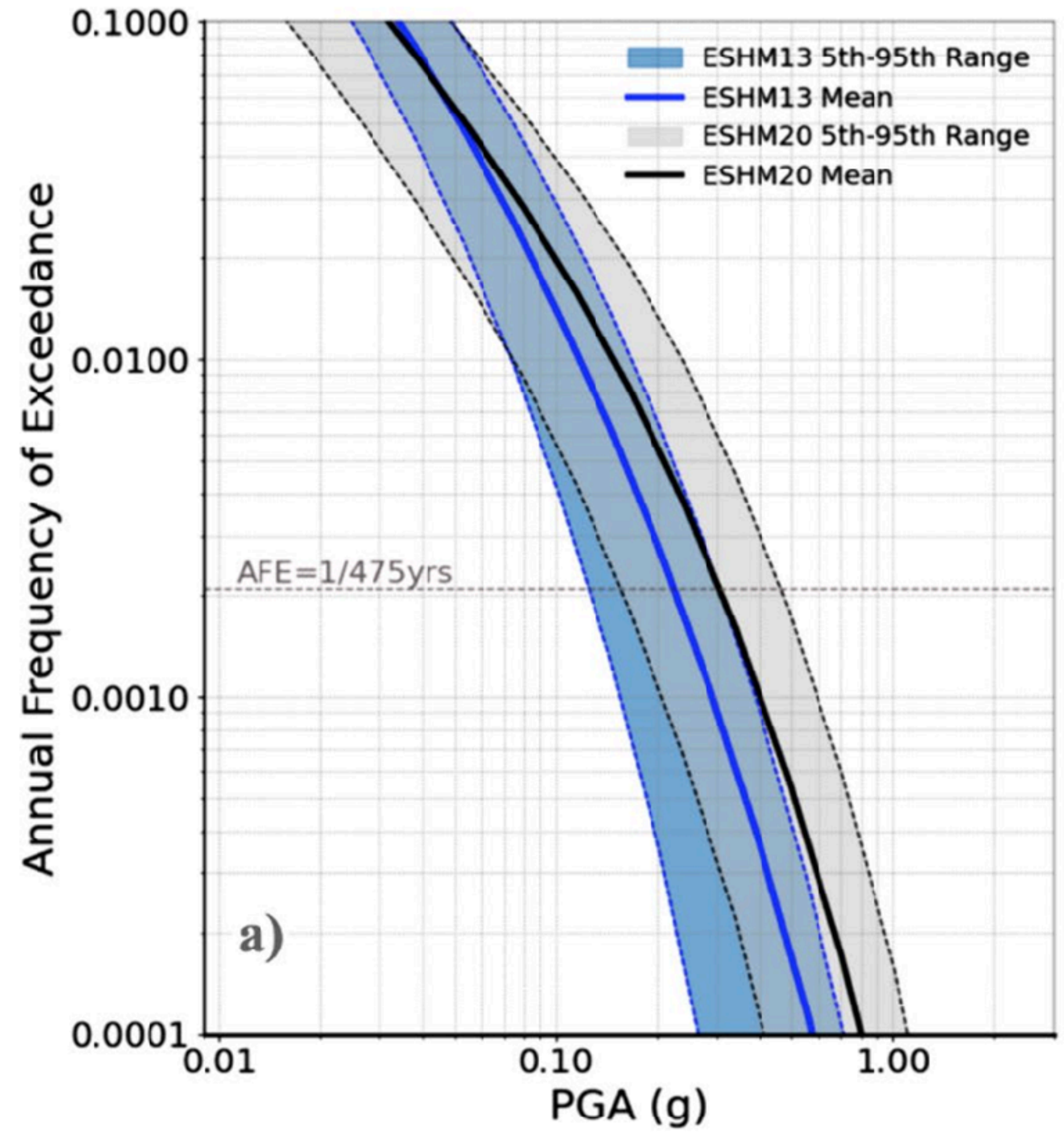
Craton:
 $\sigma_\mu = \text{NGA East Model-to-Model Variability}$

Subduction & Deep Seismicity:
 $\sigma_\mu = \text{Global variability in stress parameter}$

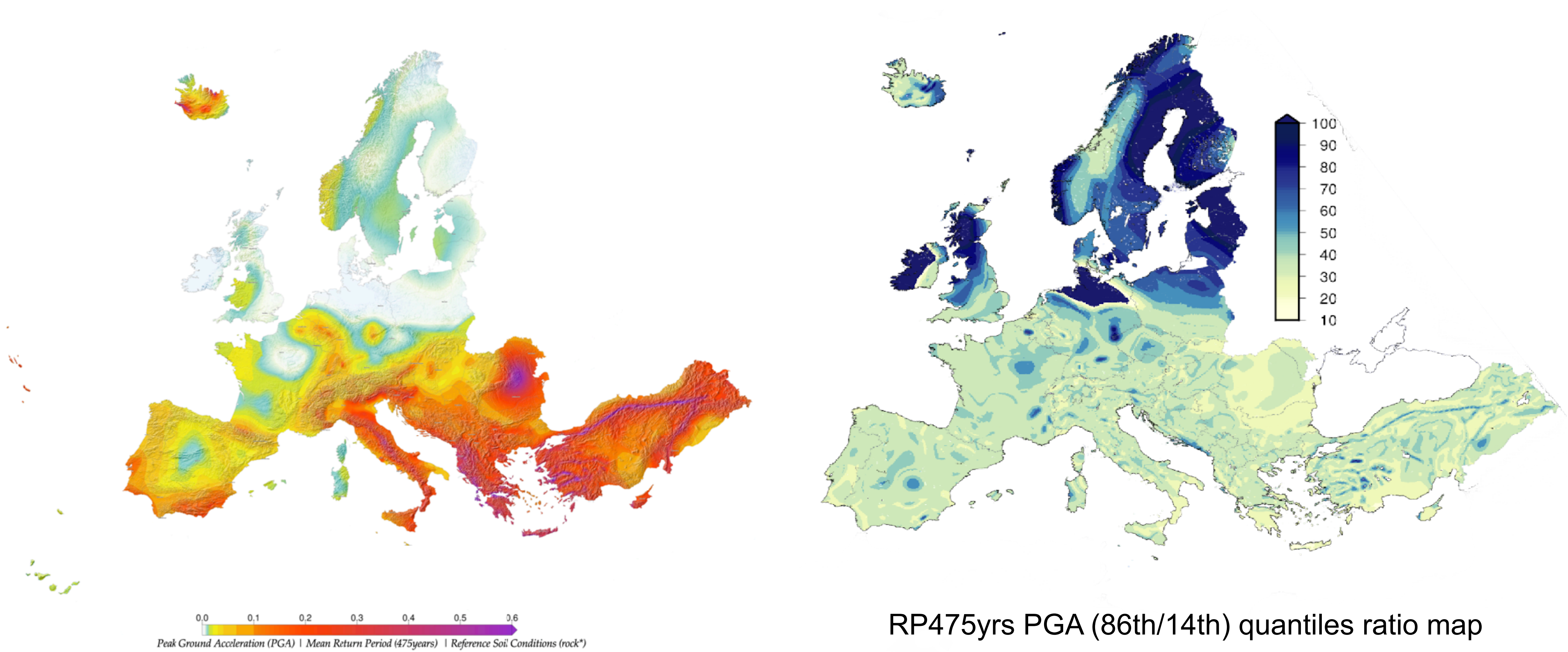
Shallow (Non-Craton):
 $\delta\gamma = \tau_{c3}$ (Full regional variability) or $\delta\gamma = \tau_{c3,k}$ (Cluster-[k] specific variability)

Craton:
 $\delta\gamma = \sigma_{\mu,S}$ (Epistemic uncertainty in amplification with respect to V_S 3000 m/s)

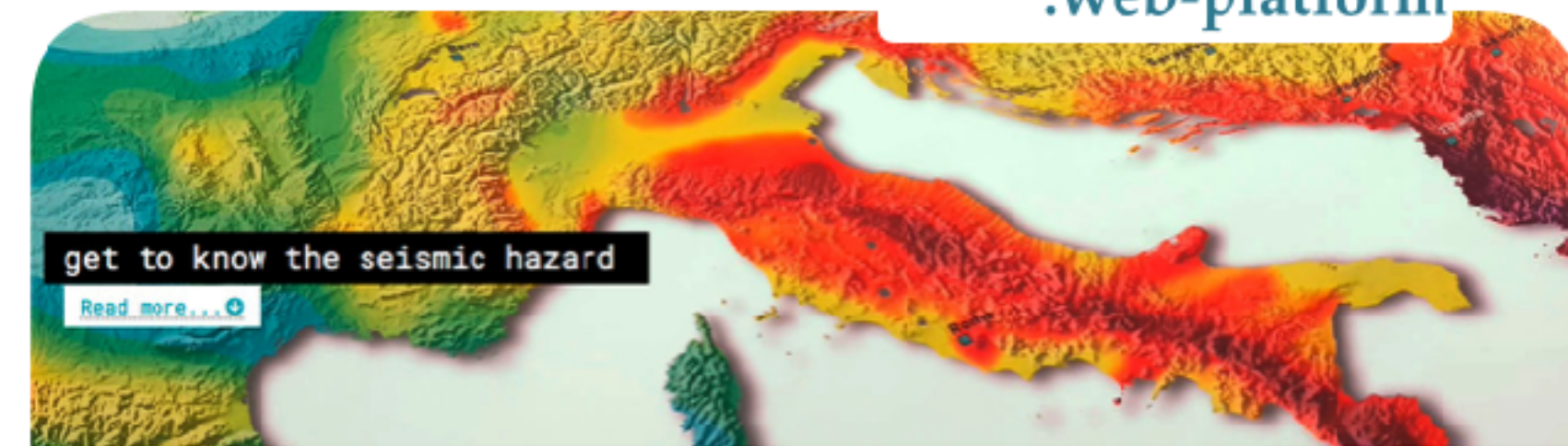
Subduction & Deep Seismicity:
 $\delta\gamma = 0.0015$ (Estimated region-to-region variability in anelastic attenuation coefficient)



Uncertainty Range - Spatial Variability



RP475yrs PGA (86th/14th) quantiles ratio map



DISCOVER EXPLORE DOWNLOAD

HAZARD MAPS HAZARD CURVES HAZARD SPECTRA HAZARD RESOURCES

The User Guides help you to use the portal.
Learn about the EFEHR viewers

National Hazard Models

Regional Hazard Models

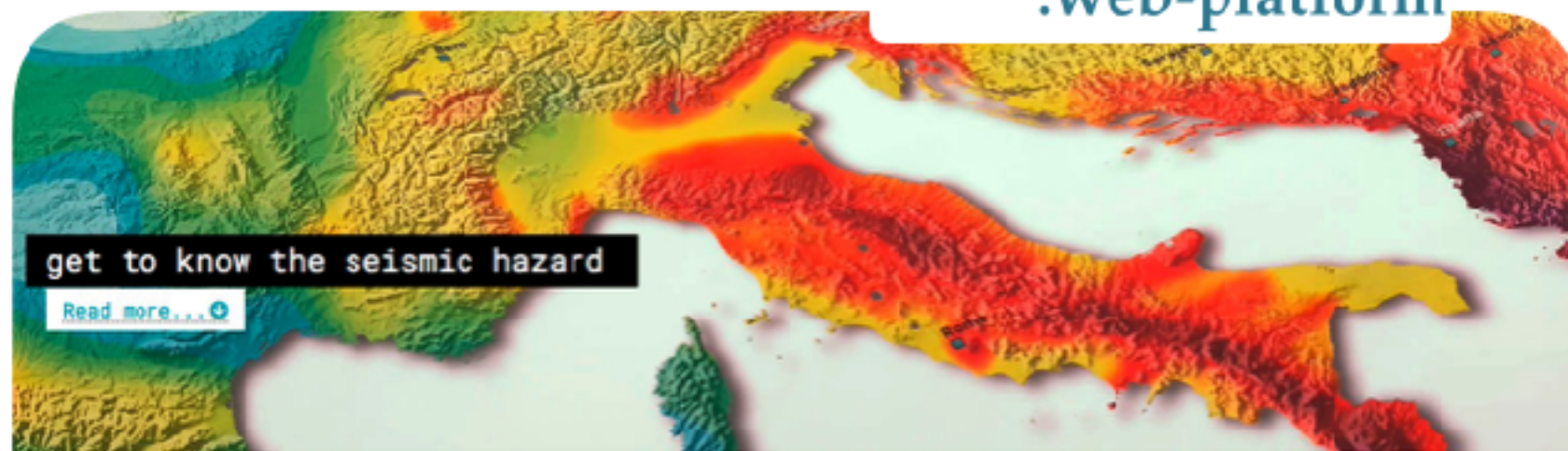
.data access

Open access
 Freely available data
 Data available without charge
 Data licence: creative commons
 Access rules: no authentication required
 *OpenQuake software is developed by Global Earthquake Model, under open source licence



- Development started in 2010 (SHARE Project), updates in 2018 and 2020, 2026
- Seismic Hazard Models: ESHM13 (Woessner et al 2015), EMME14 (Giardini et al 2018), ESHM20 (Danciu et al 2021,2024)
- Earthquake Model of the Middle East - EMME2026 (ongoing ETH/EFEHR - GEM initiative)
- EFEHR Consortium Data Policy: **Open Access, Open License CC-BY 4.0, FAIR Principles**



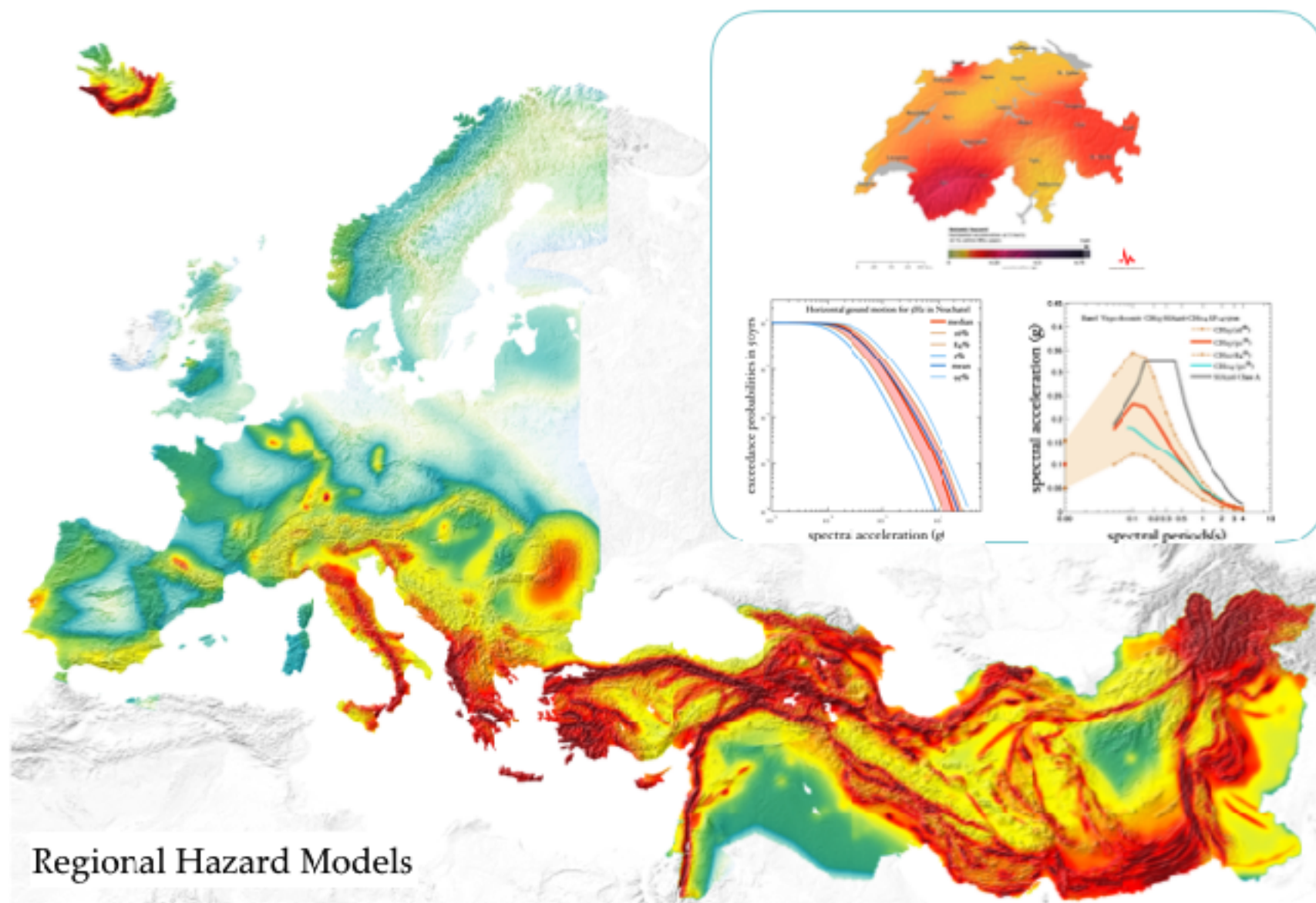


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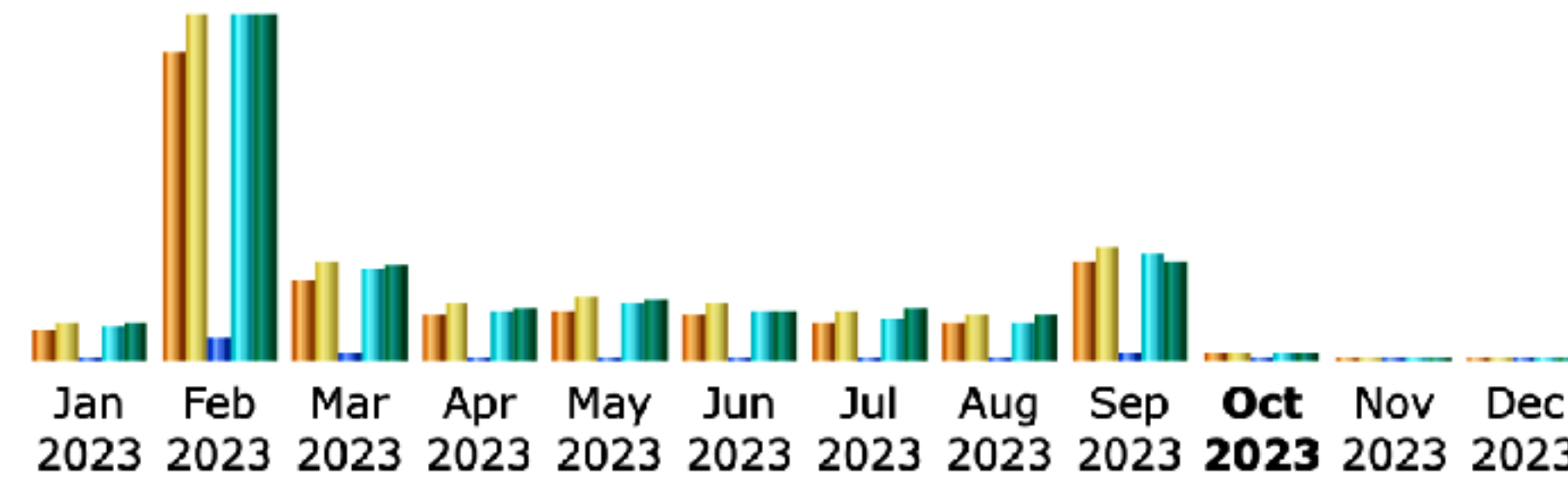
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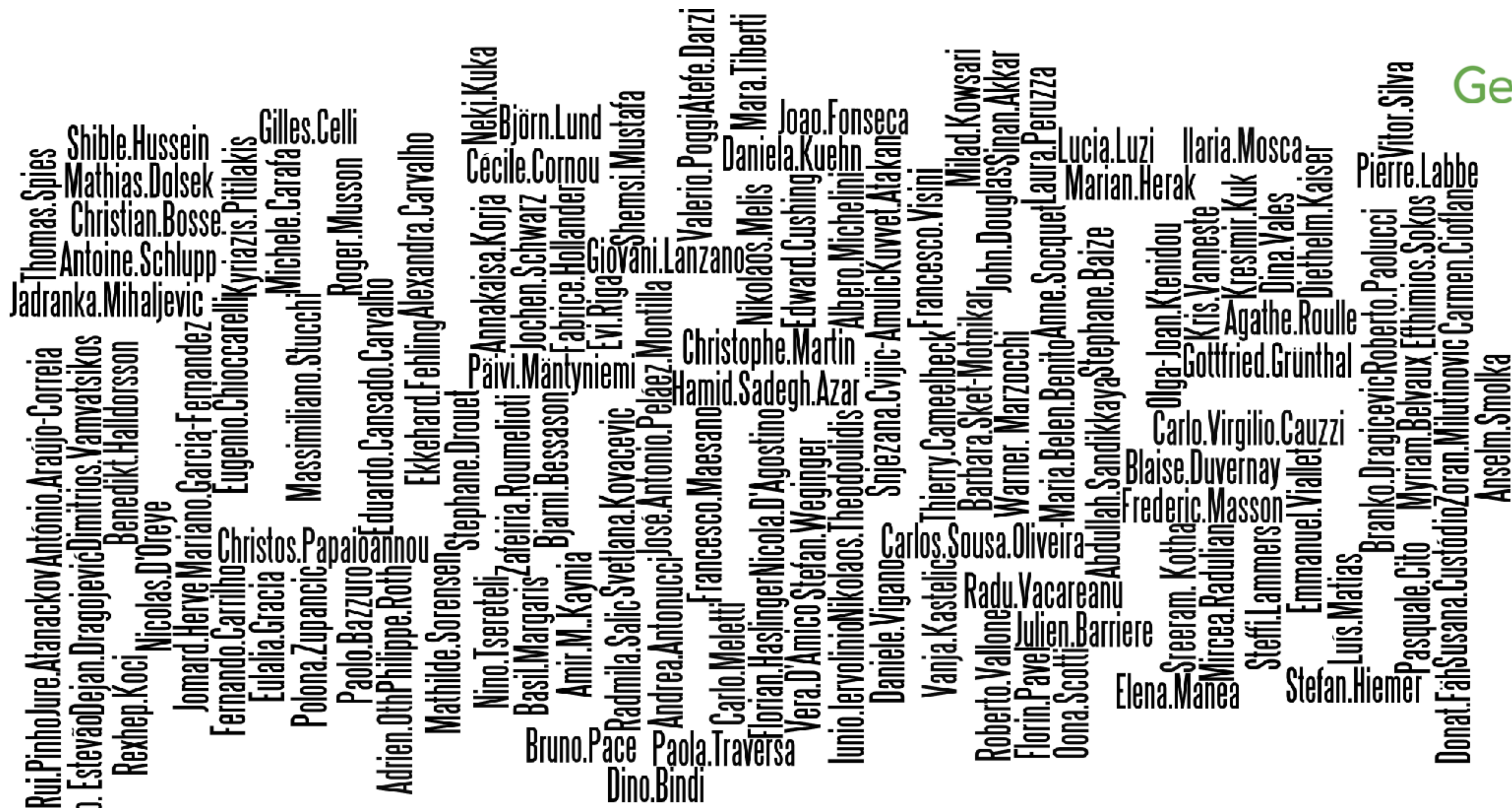


hazard.efehr.org



Month	Unique visitors	Number of visits	Pages	Hits	Bandwidth
Jan 2023	3,140	3,982	11,260	152,757	14.38 GB
Feb 2023	32,377	36,309	97,987	1,610,247	136.86 GB
Mar 2023	8,394	10,345	27,783	418,508	36.65 GB
Apr 2023	4,696	5,884	15,822	229,429	20.33 GB
May 2023	5,185	6,540	17,389	254,576	23.43 GB
Jun 2023	4,704	5,881	15,299	231,593	19.44 GB
Jul 2023	3,898	4,891	14,704	191,327	21.22 GB
Aug 2023	3,652	4,516	11,775	175,691	18.03 GB
Sep 2023	10,477	11,724	29,440	493,350	38.11 GB
Oct 2023	654	712	2,131	32,782	2.73 GB
Nov 2023	0	0	0	0	0
Dec 2023	0	0	0	0	0
Total	77,177	90,784	243,590	3,790,260	331.20 GB





Community Effort

Thank you !

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From Models to FAIR Services: European Seismic Hazard Access in Geo-INQUIRE

Noemi Romano (ETH Zurich)

