European Commission

Experience on the field of seismic hazard zonation – SHARE Project

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Swiss Seismological Service

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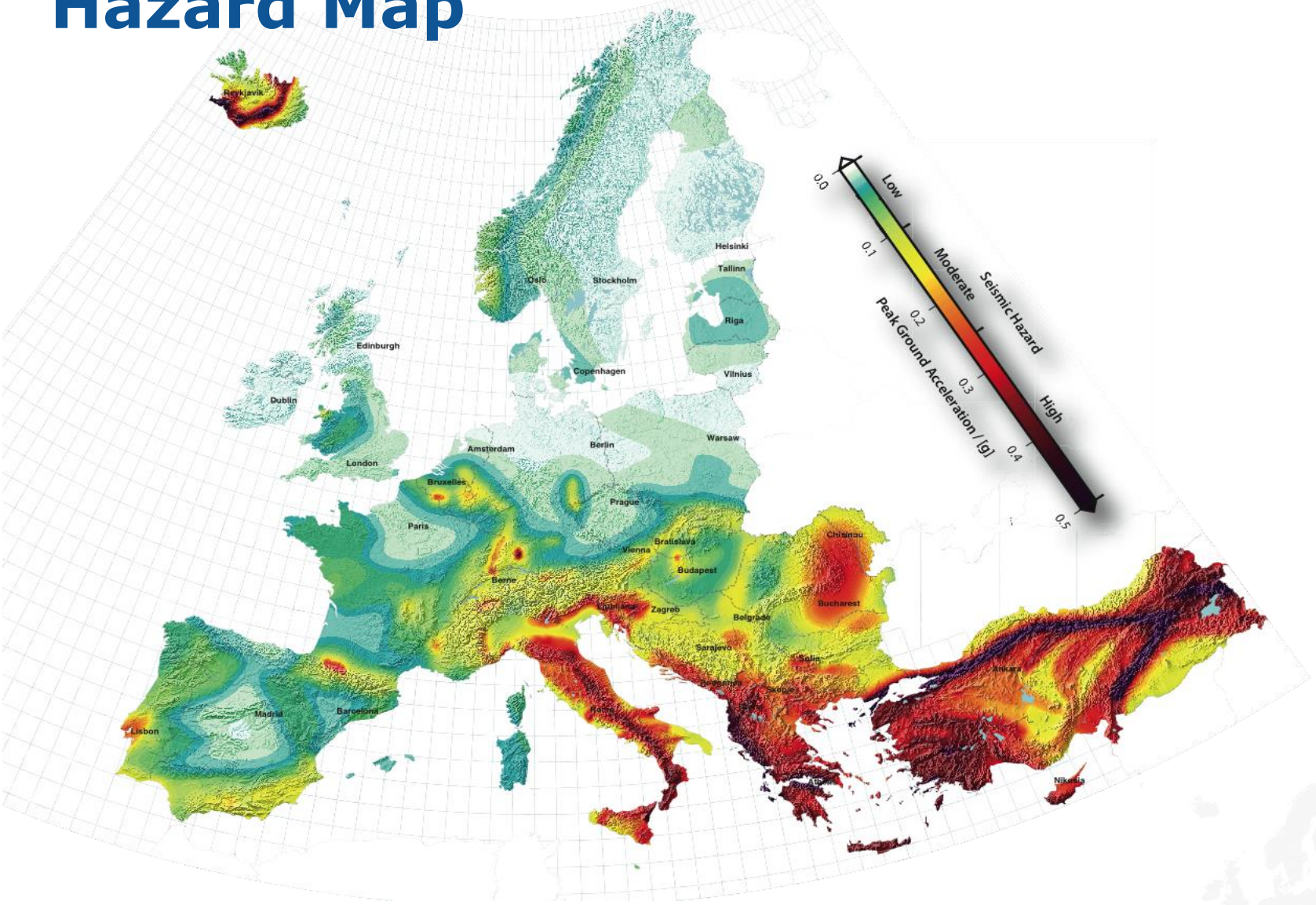
Switzerland

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

The 2013 European Seismic Hazard Map

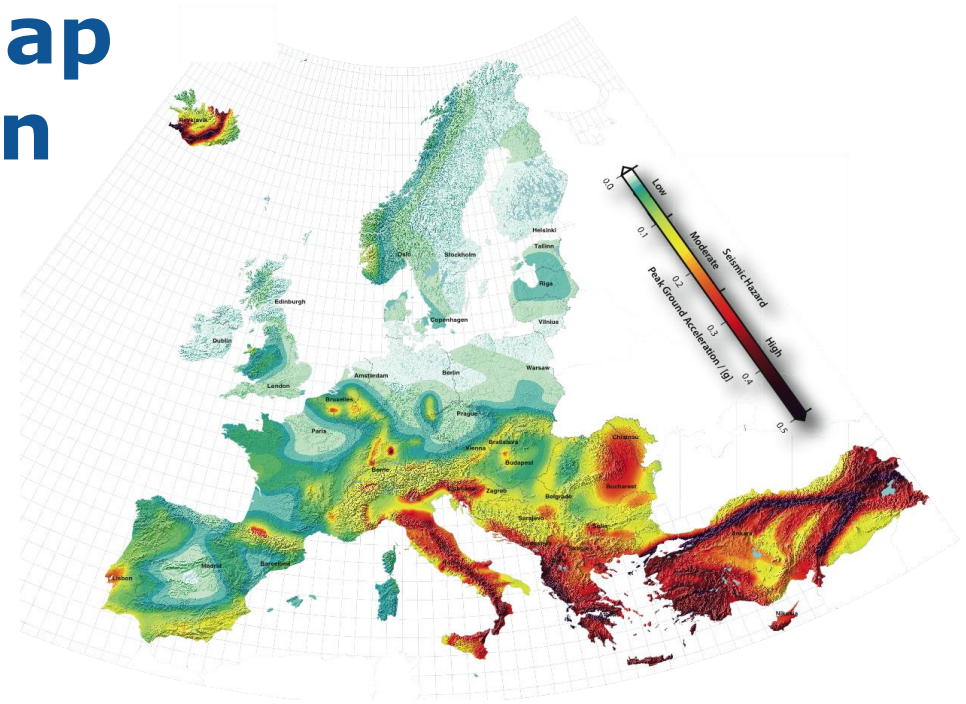
European Commission



BUILDING CAPACITIES FOR ELABORATION OF NDPs AND NAs OF THE EUROCODES IN THE BALKAN REGION

4-5 November 2014, Skopje

The 2013 European Seismic Hazard Map *is not* an European Seismic Zonation



Seismic Zones
(Ground Acceleration)

- Zone 0 = 0.0g
- Zone 1 = 0.075g
- Zone 2A = 0.15g
- Zone 2B = 0.20g
- Zone 3 = 0.30g
- Zone 4 = 0.40g

- *Seismic Zones have to be defined at the country level by: legislators , engineers, practitioners*
- *National Annexes*
- *Zonation is country specific*

Outline

- *Overview of the SHARE Project*

- *The new European Seismic Hazard Model (the 2013 ESHM) elements:*
  - **Datasets**
  - **Seismic sources**
  - **Ground Motion**
  - **Output**
- *The 2013 ESH feedback to EC8*

European Commission

SHARE Project: Overview

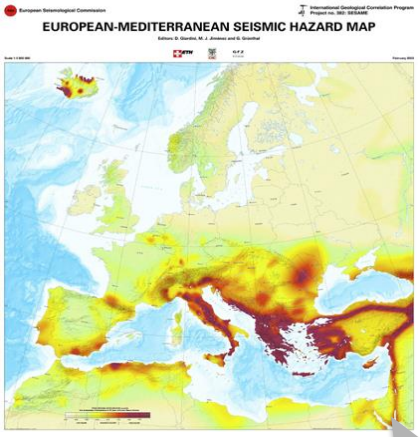
BUILDING CAPACITIES FOR ELABORATION OF NDPs AND NAs OF THE EUROCODES IN THE BALKAN REGION

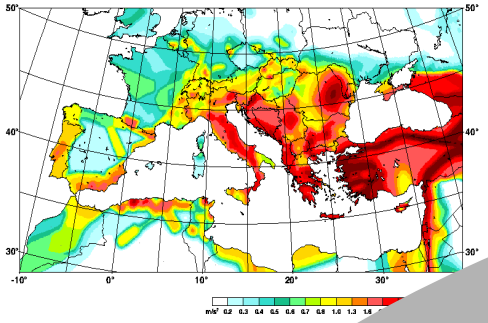
4-5 November 2014, Skopje

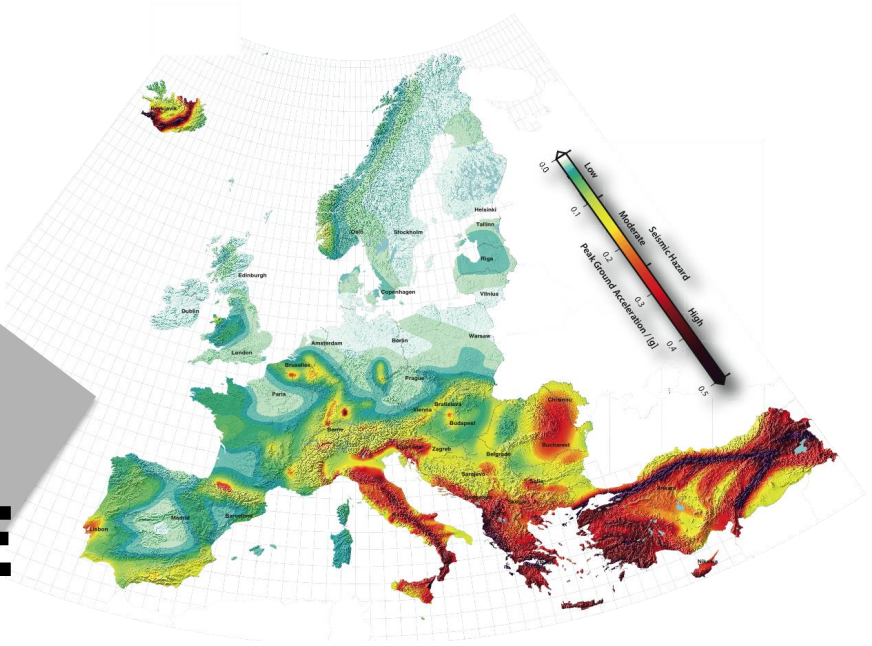
European Seismic Hazard Models –The Evolution

European Commission

SEVENTH FRAMEWORK PROGRAMME







SESAME

GSHAP[2003]

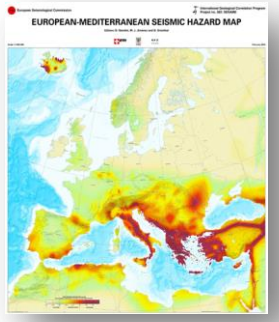
[1996]

SHARE [2013]

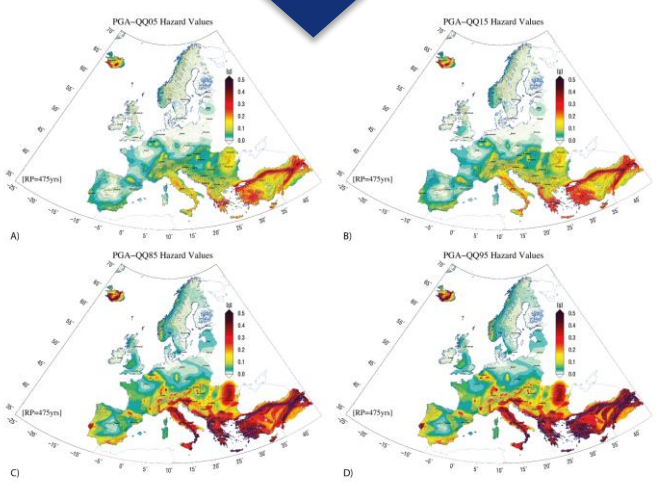
SHARE Project: 2009 to 2013

European Commission

- *Collaborative Effort*
- *Harmonize hazard assessment across national borders*
- *On data level, modelling level and procedural level*
- *Create a community-based time-independent (rock) reference hazard model for the Euro-Mediterranean region*
- *Keep close connection to engineering requirements of **EC8** and its future revision*

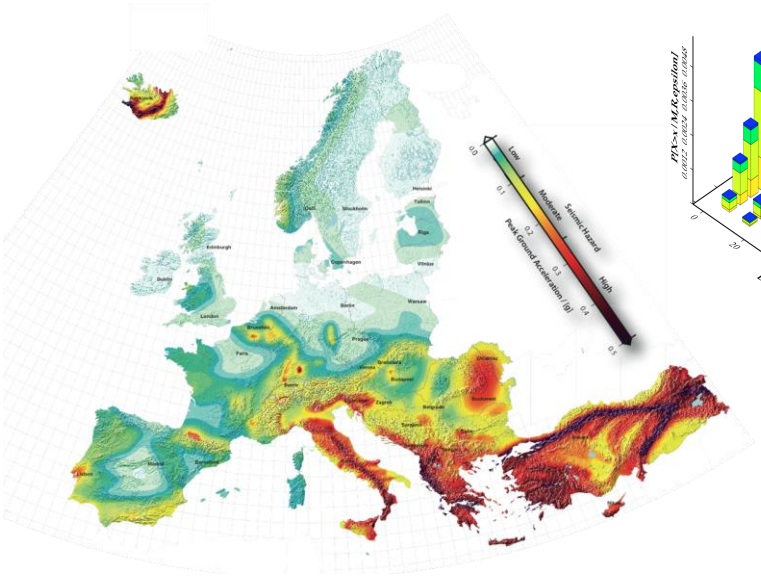


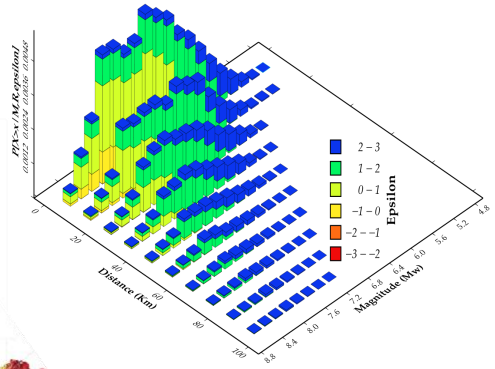
SEVENTH FRAMEWORK PROGRAMME

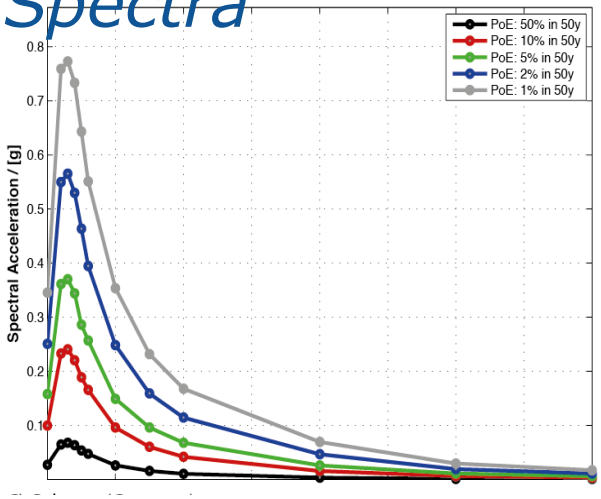


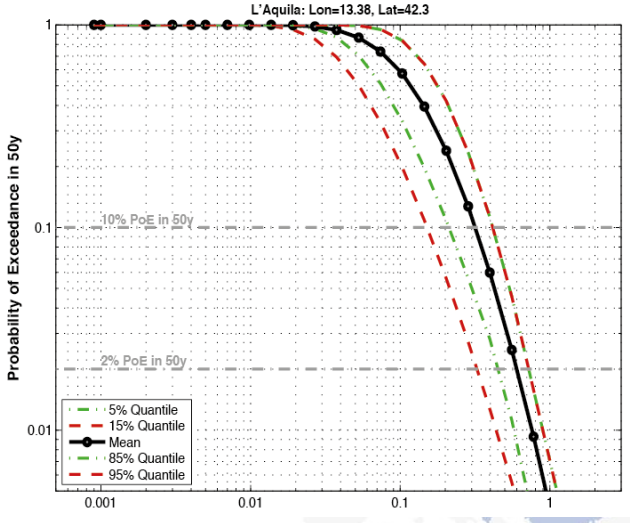
Engineering Requirements

- *Seismic Hazard Maps for six mean return periods: 50 – 100 – 475 – 975 – 2475 – 5000*
- *Hazard curves and Uniform Hazard Spectra*
- *Disaggregation*
- *Mean, Median and Quantile (5%, 15%, 85%,95%)*

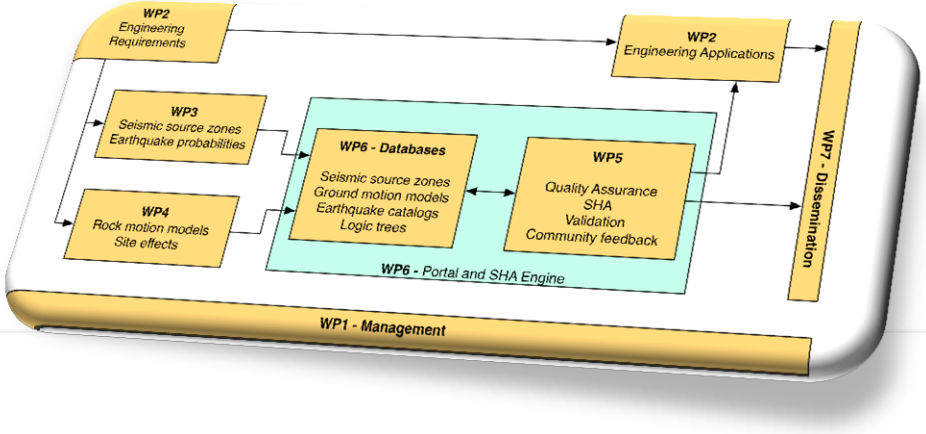


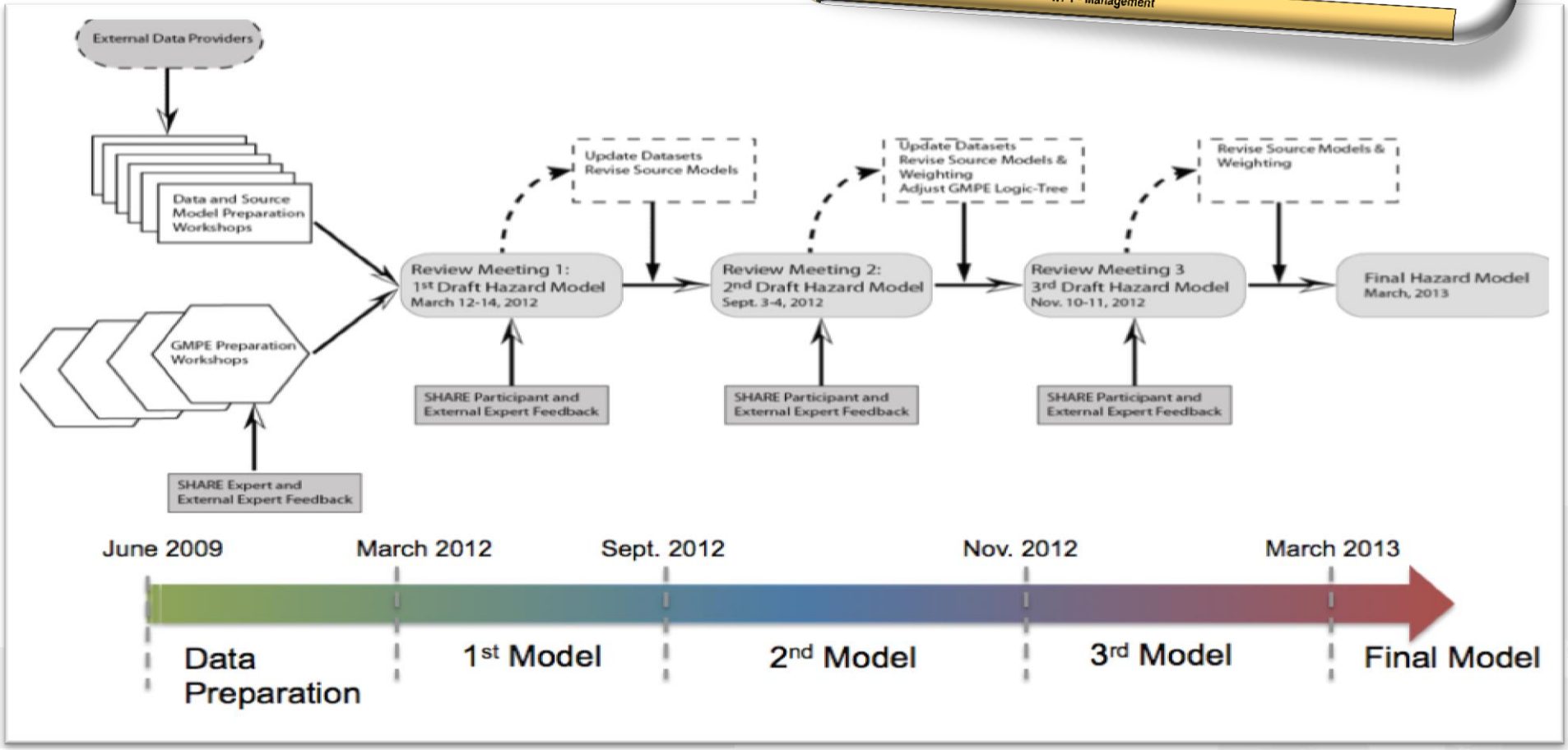




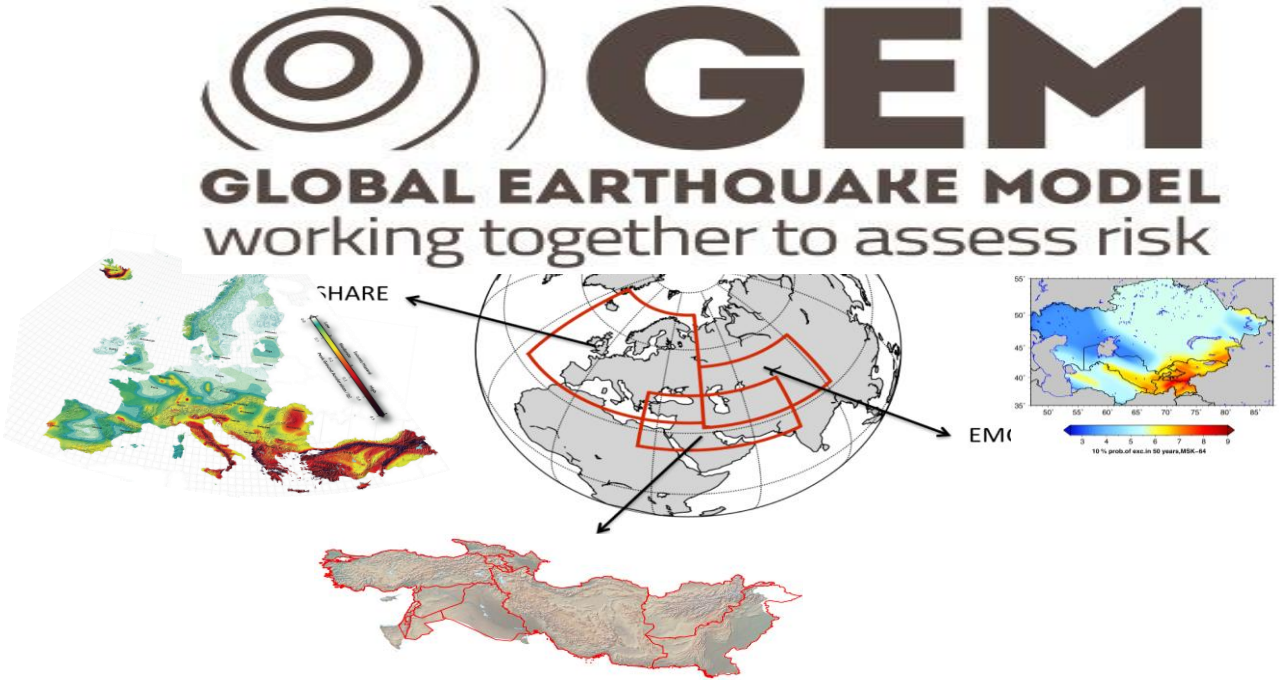


Collaborative Framework





Regional Integration and Cooperation

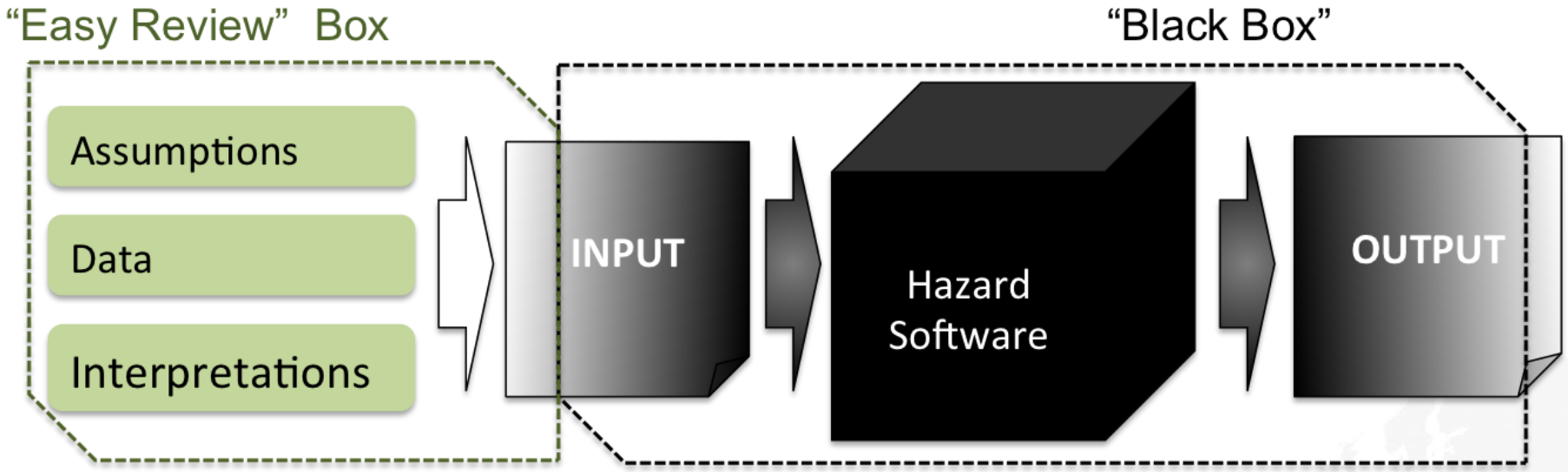


- *Regional Harmonization and Integration:*
  - **Earthquake Hazard Model for Middle East - EMME**
  - **Earthquake Hazard Model for Central Asia – EMCA**

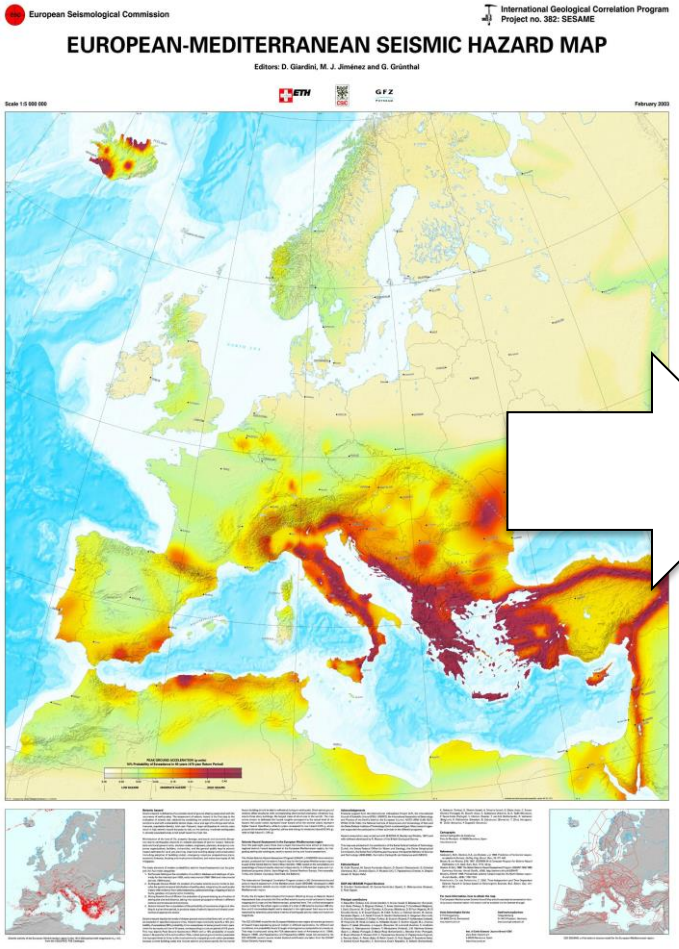
Transparency

- *All steps of the seismic hazard assessment have to be:*
- *Validated*
- *Benchmarked*
- *Reproducible*

OPENQUAKE
calculate share explore

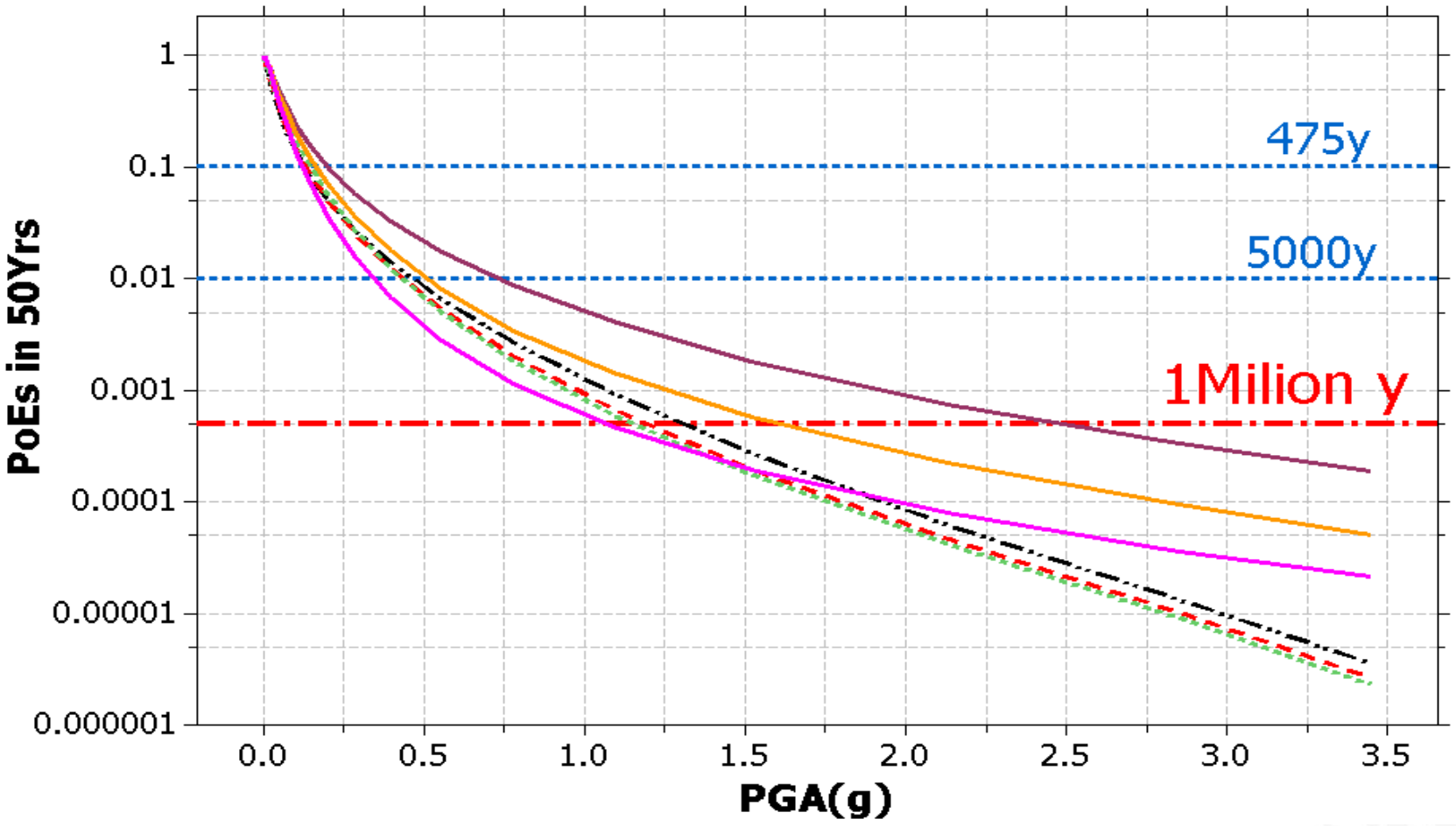


Availability



European Facility for Earthquake Hazard and Risk: www.efehr.org

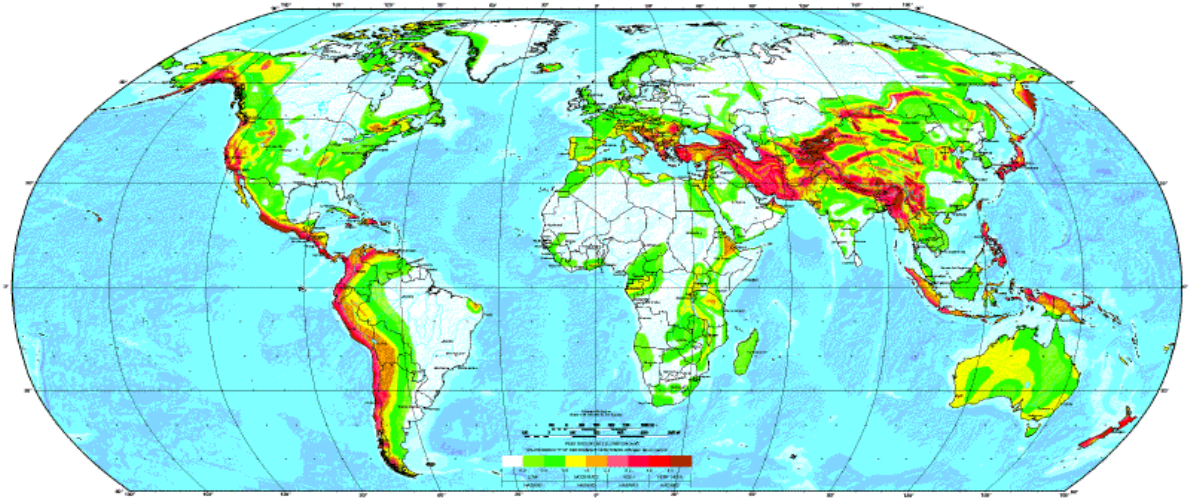
Target


1
0.1
0.01
0.001
0.0001
0.00001
0.000001
PoEs in 50Yrs
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
PGA(g)
475y
5000y
1Milion y

Stability

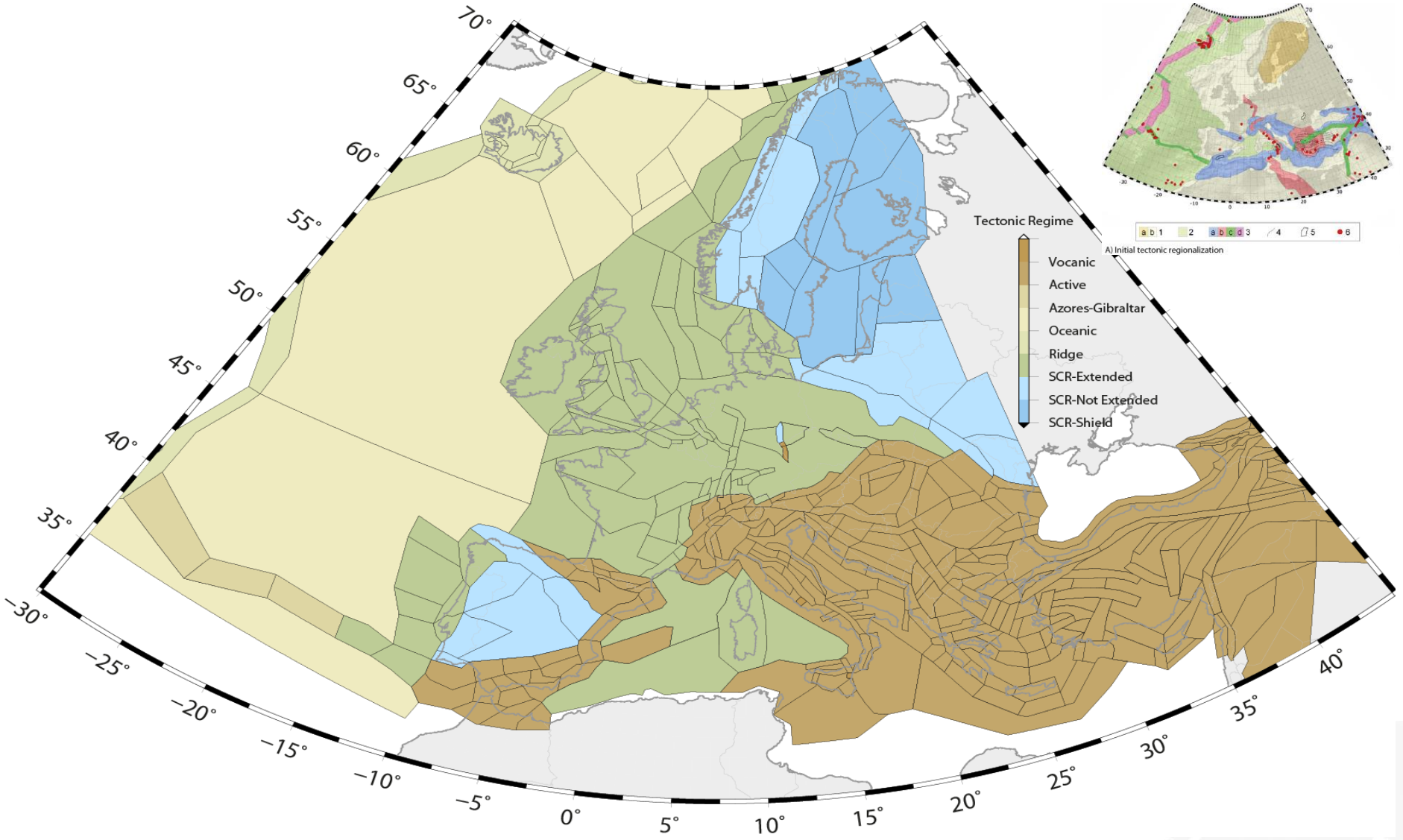
1. Provide assurance that the numerical hazard results will be stable for the next years (5-10 years)
2. Unless significant new seismic information, which could occur at any time, calls for a ***major revision***

GLOBAL SEISMIC HAZARD MAP



The 2013 - European Seismic Hazard Model - ESHM13: Datasets

Datasets Harmonization

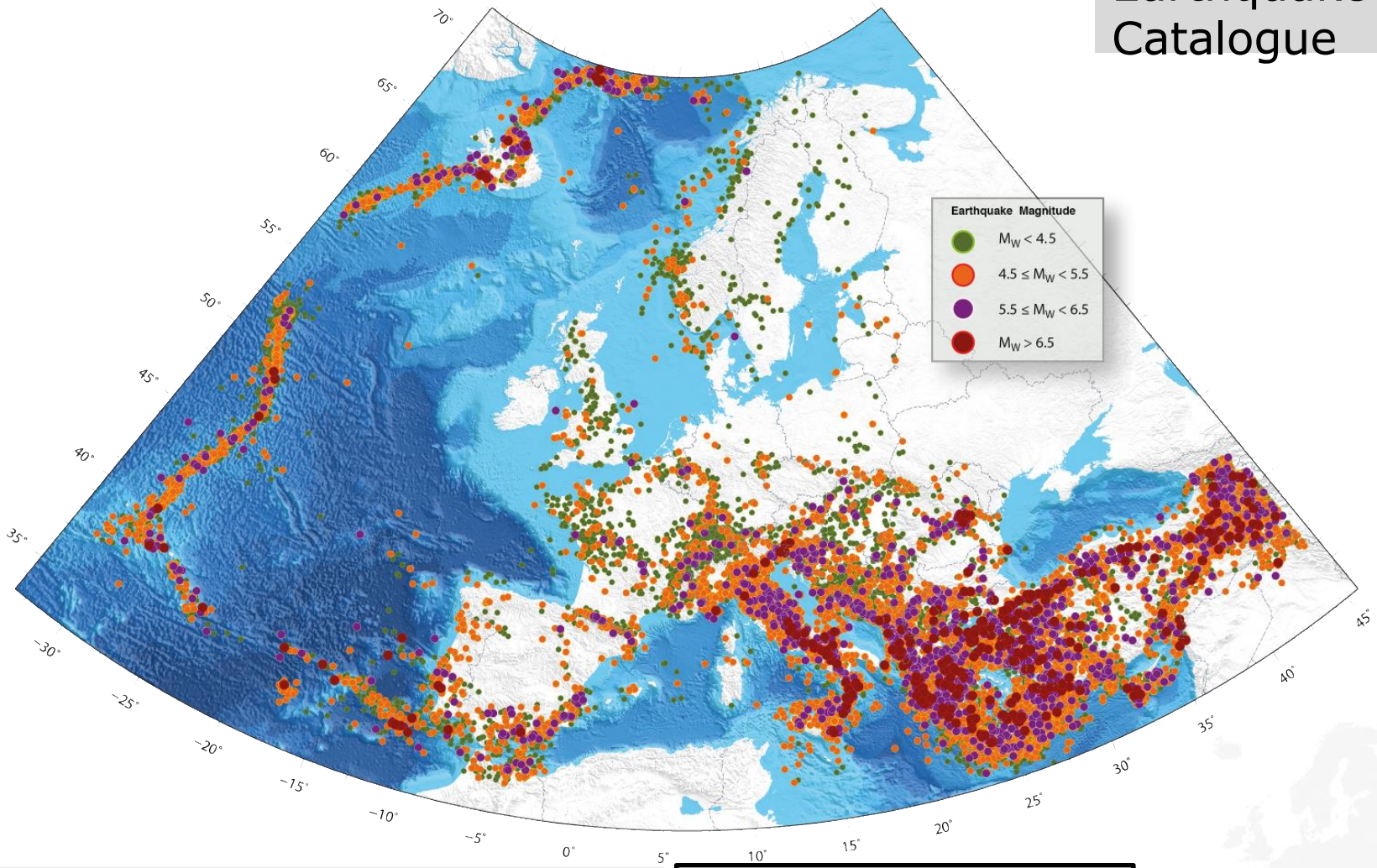


Map of Major Tectonic features

Datasets Harmonization

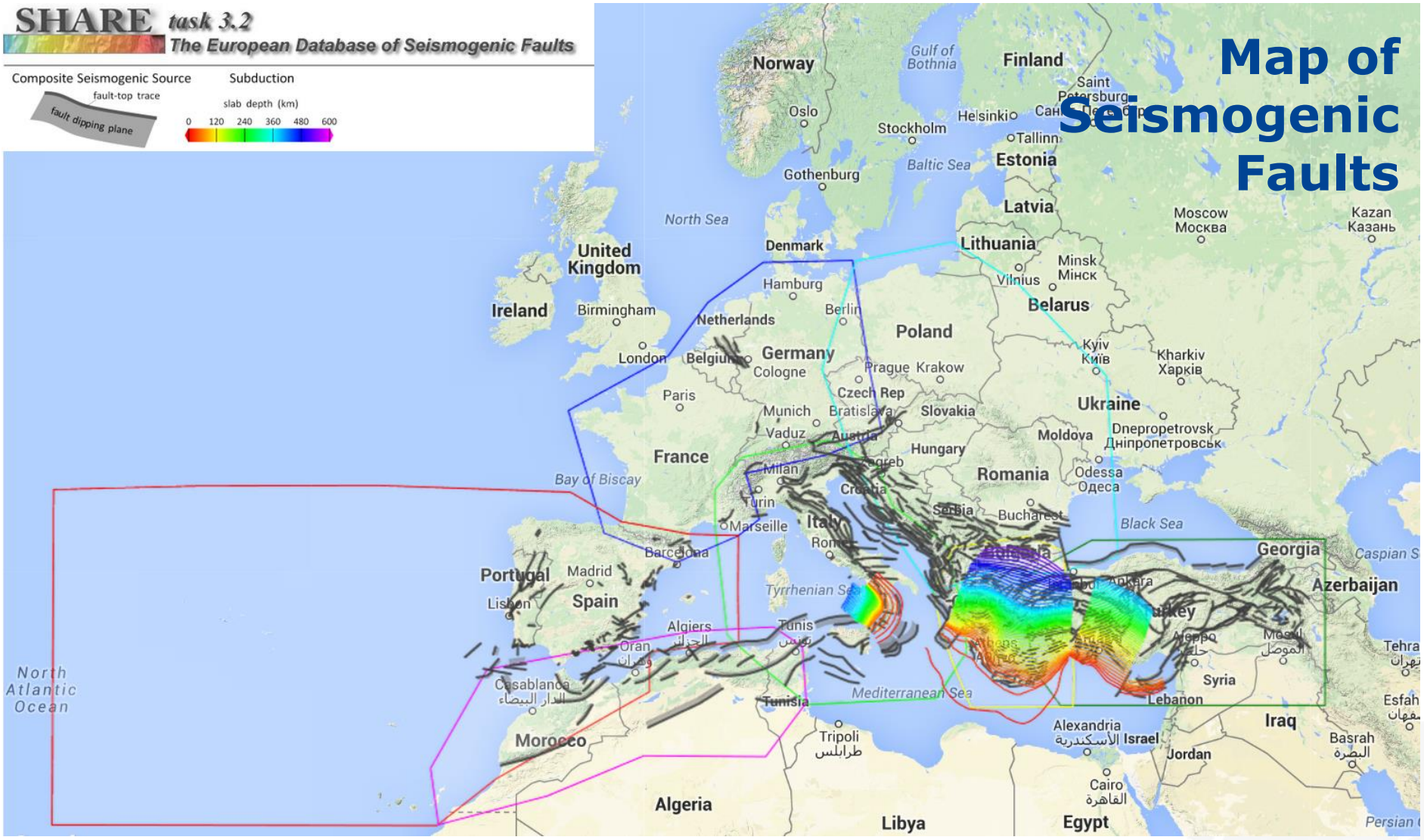
European Commission

Homogeneous Earthquake Catalogue



Stucchi et al., 2012
Grünthal et al., 2012

Datasets Harmonization

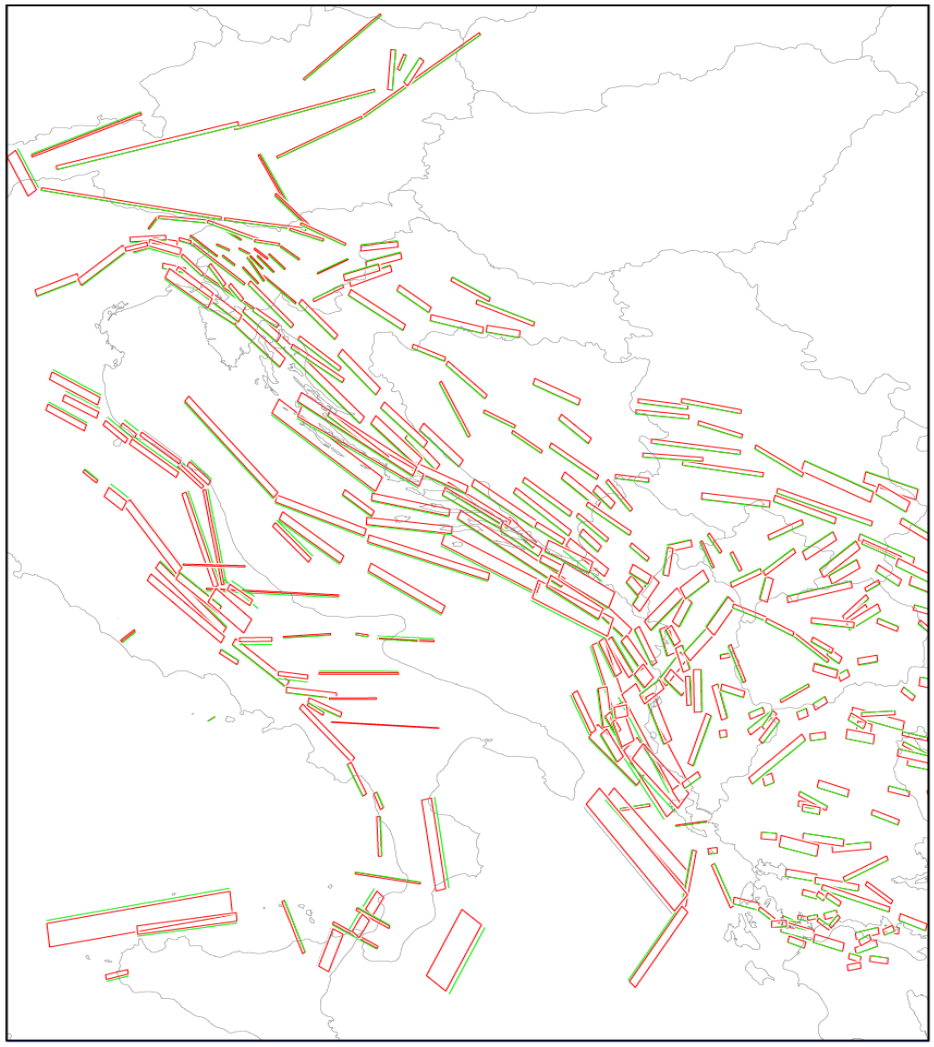


Basili et al (2013)

Datasets Harmonization

European Commission

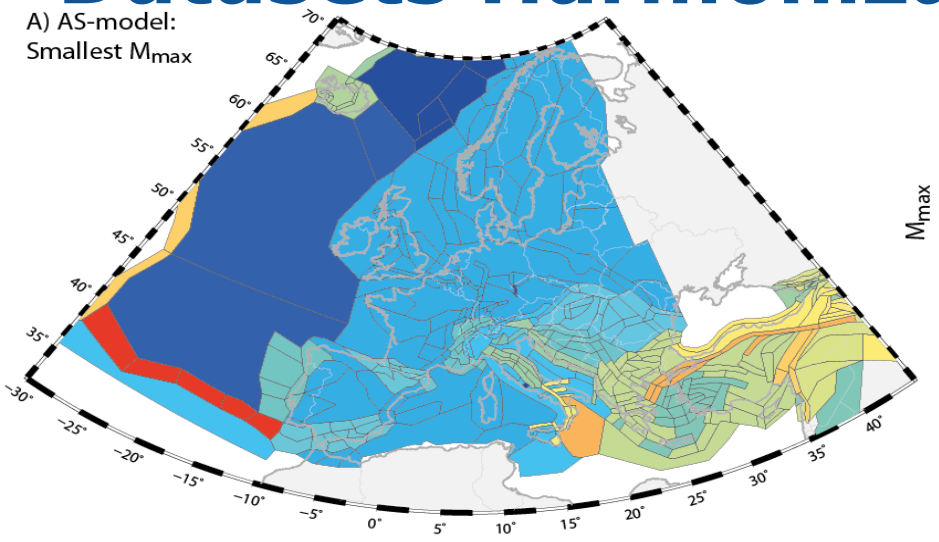
Map of Seismogenic Faults In Balkans

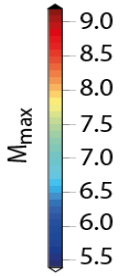


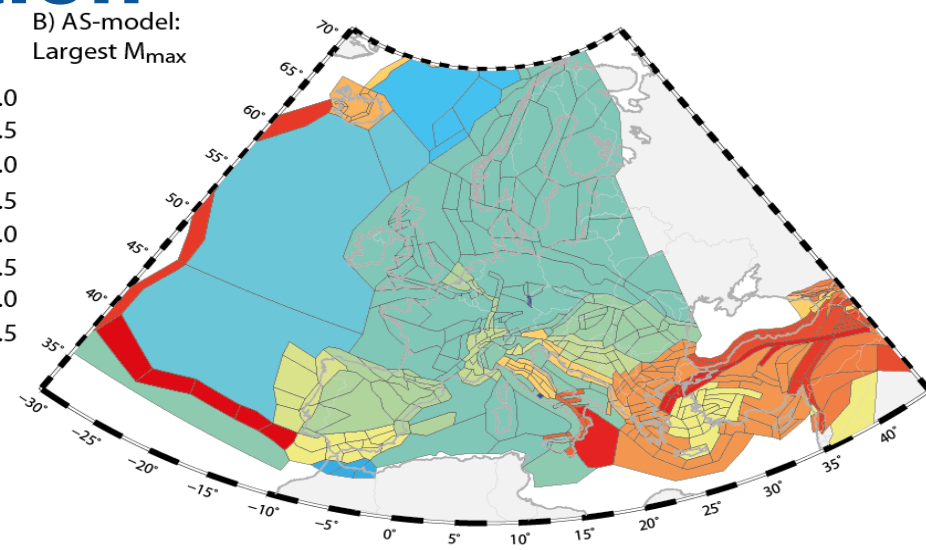
More than 68,000 kilometers representing about 1200 mapped active faults were compiled in the new European Database of Seismogenic Faults.

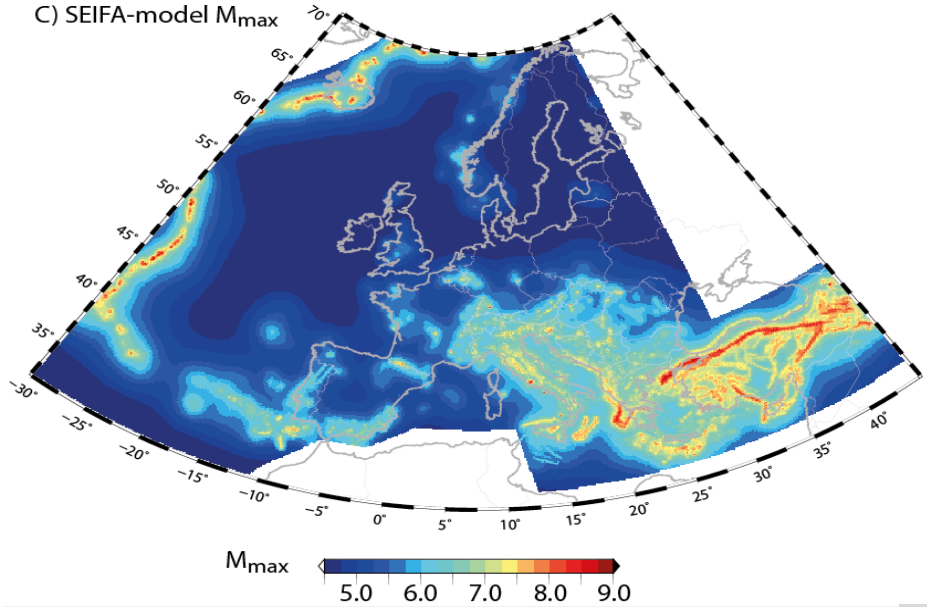
Basili et al (2013)

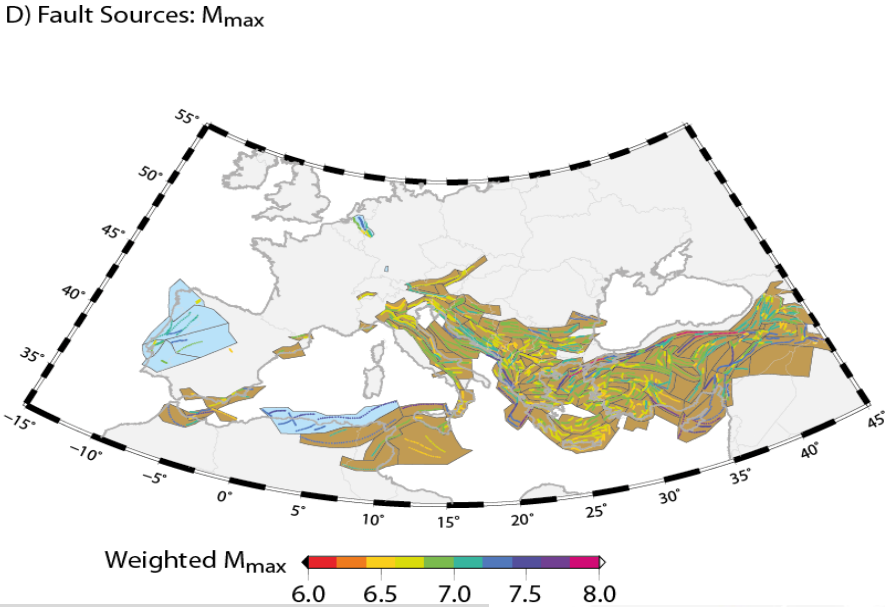
Datasets Harmonization



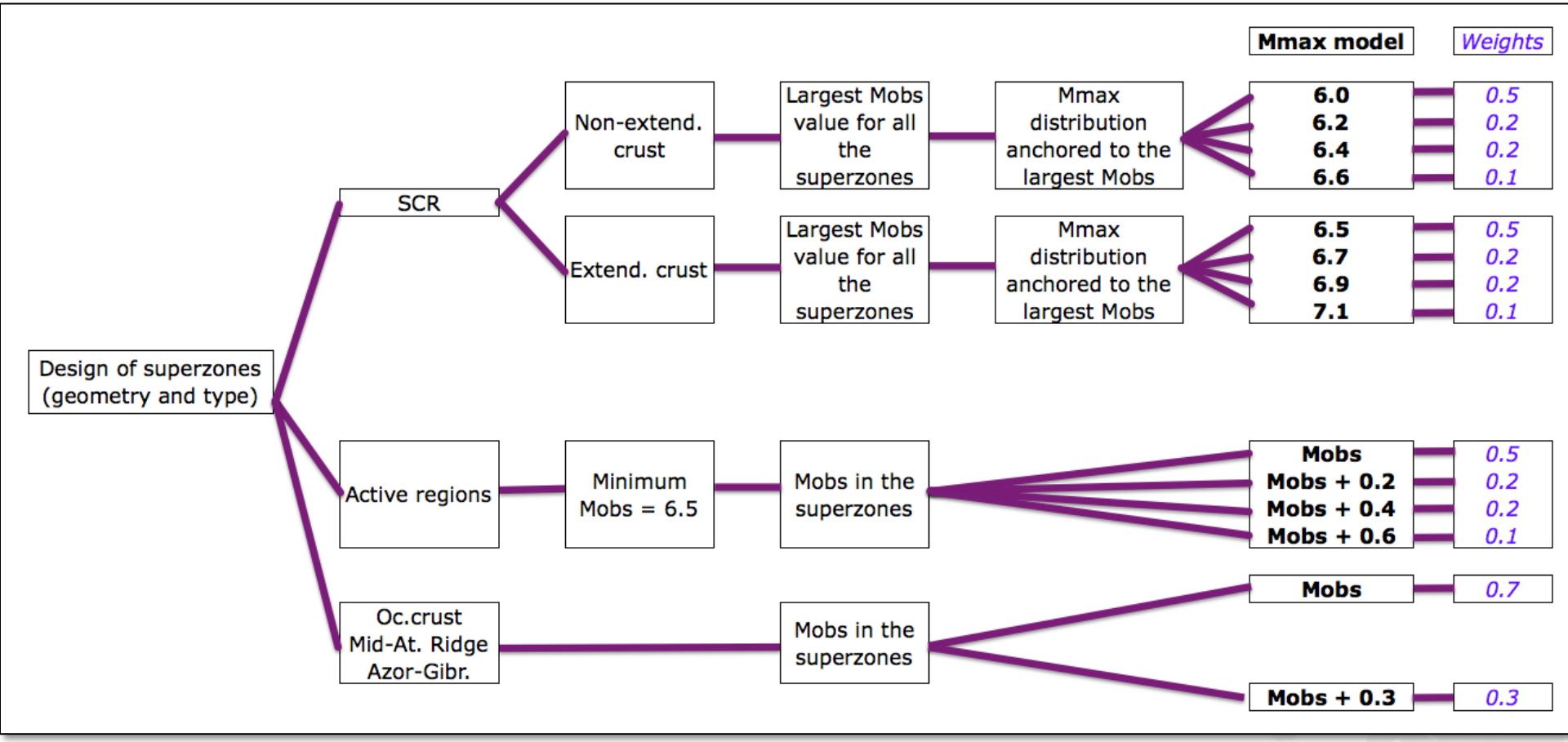






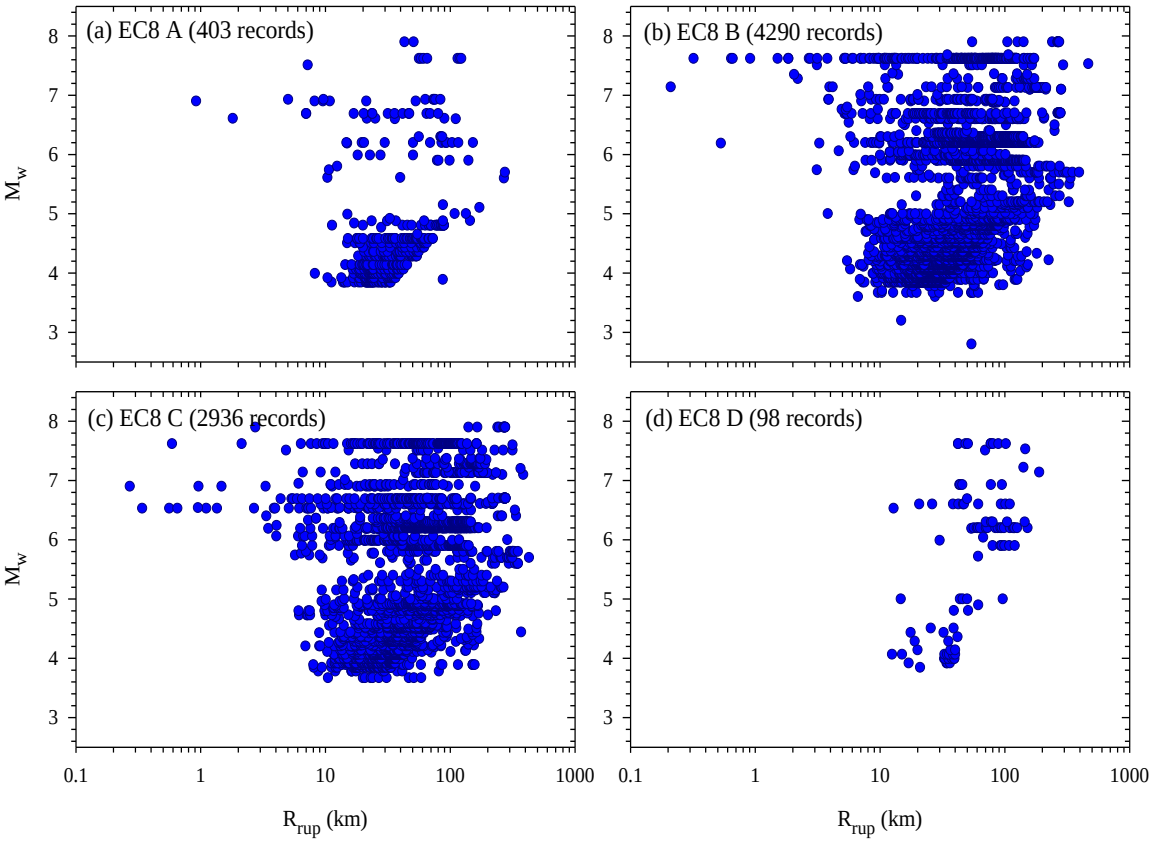


Datasets Harmonization



Datasets Harmonization

Mw-Rrup scatters of ground motions in terms of EC8 site categories



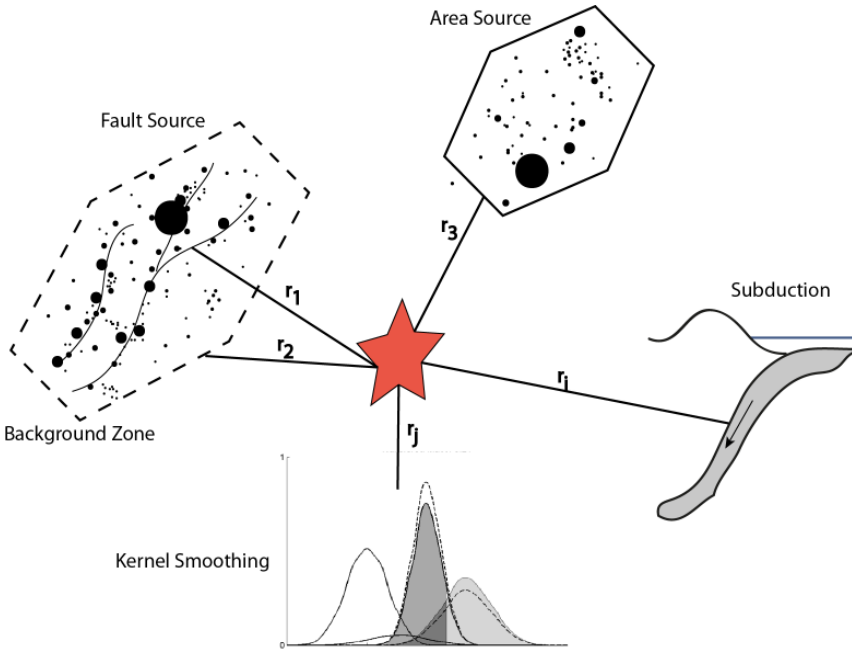
- EC8-A records display a gap between 5.0<Mw<6.0.
- Mw-Rrup scatters of EC8-B and EC8-C records have similar distributions for 3.5<Mw<8.0 and Rrup>10 km
- EC8-D records are loosely distributed between 10 km<Rrup<200 km with a shift towards larger distances for large magnitude records.

European Commission

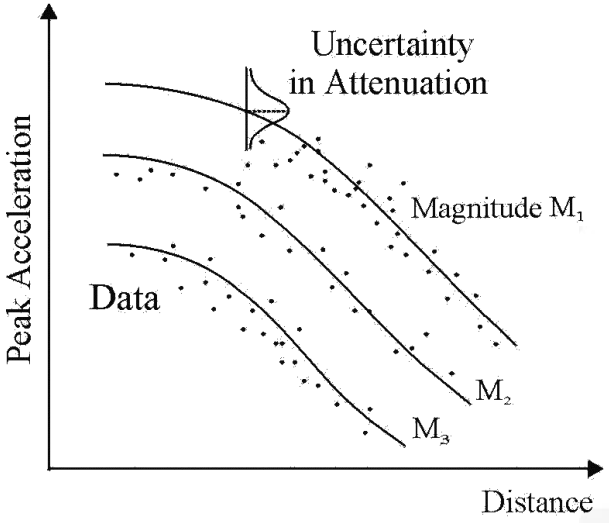
ESHM13: Main Elements

Elements of Probabilistic Seismic Hazard

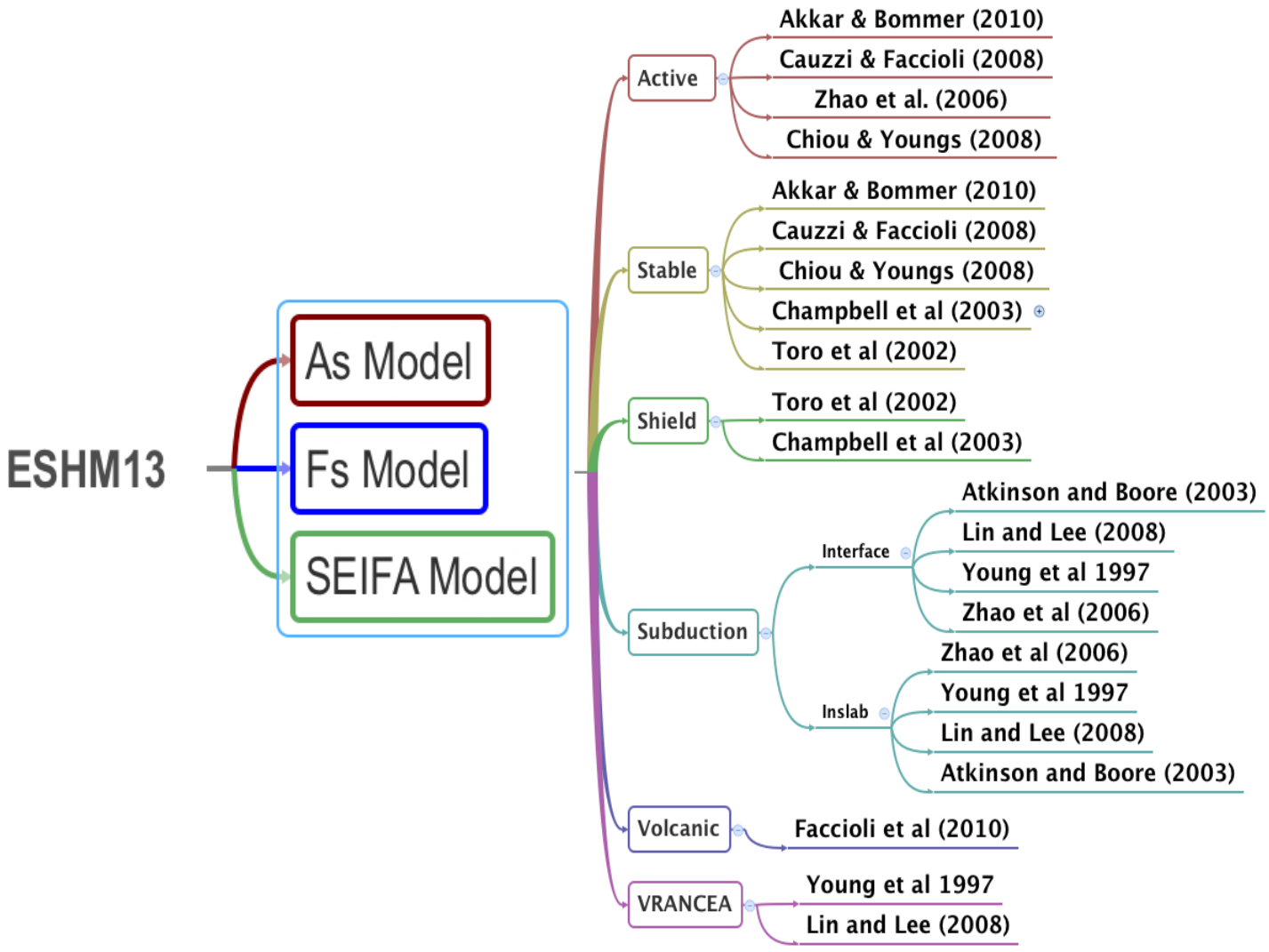
- *Earthquake Rate Forecasts:*
  - **Area Source**
  - **Fault Source**
  - **Smoothed Seismicity**



- *Ground Motion Models*
  - **Expert Elicitation**
  - **Data Driven**

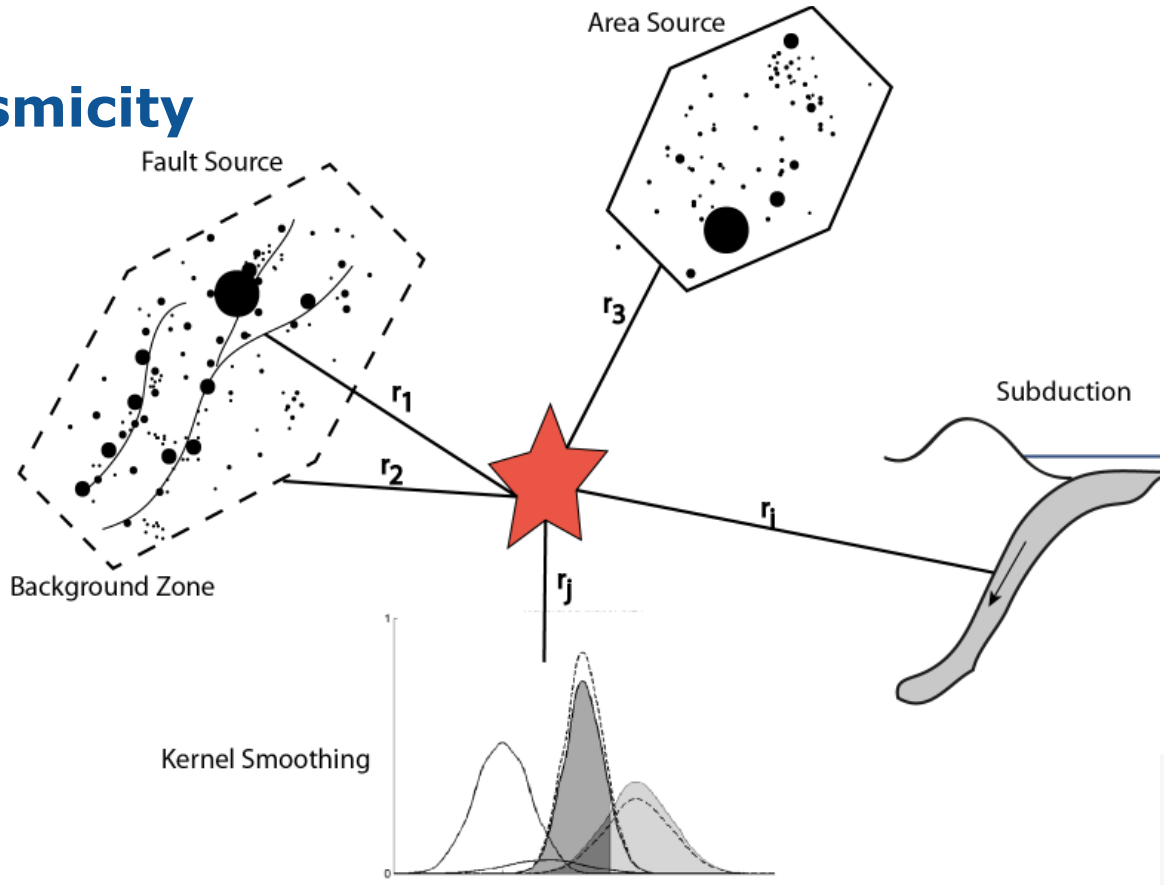


Uncertainties: Logic Tree



Elements of Probabilistic Seismic Hazard

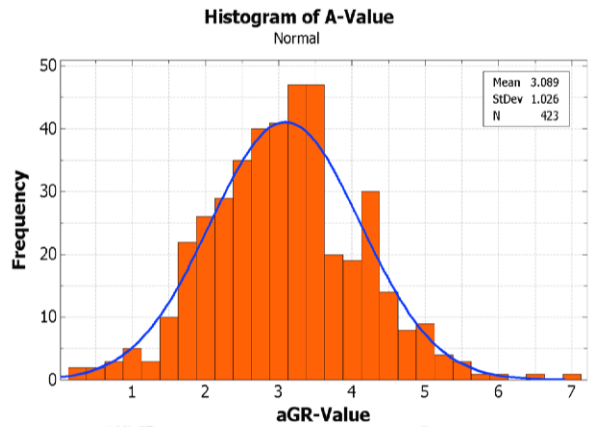
- *Earthquake Rupture Forecasts:*
  - **Area Source**
  - **Fault Source**
  - **Smoothed Seismicity**

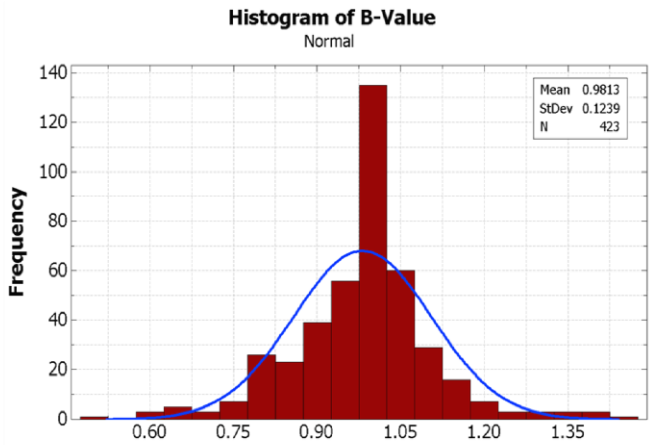


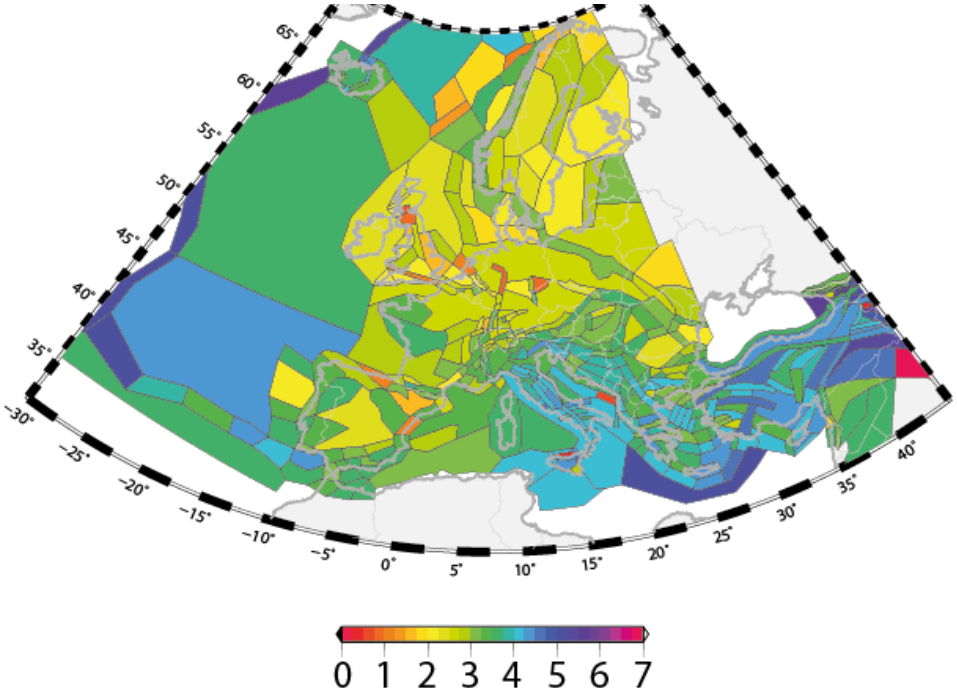
Area Source Assumptions

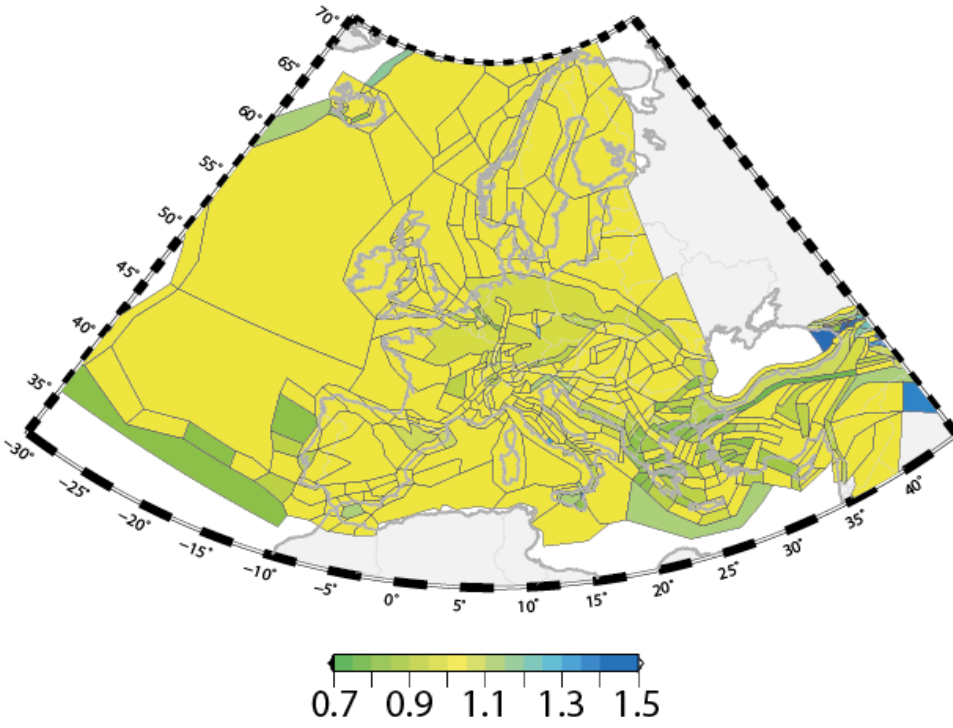
- *Sources depict zones of equal seismic activity that is distributed homogeneously within the zone*
- *Delineation can be based on*
  - **Large scale tectonics**
  - **Geology**
  - **Geomorphology**
  - **Seismicity**
  - **Combinations**
- *Critical points:*
- *Zonation is generally based on expert opinion*
- *Polygons usually are not characterized with an uncertainty*

Area Source Model







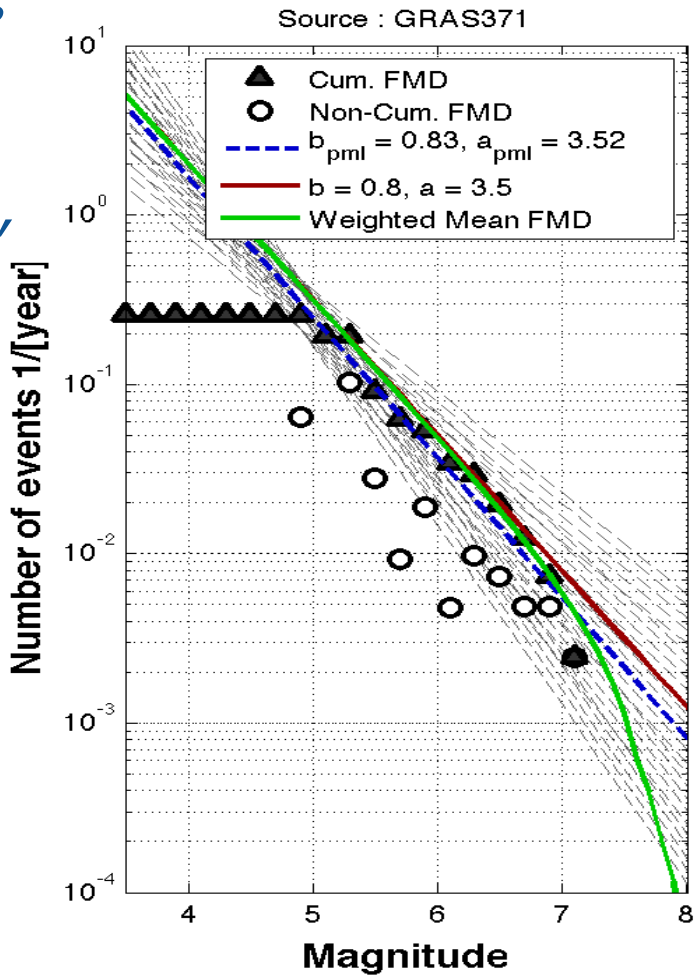


B) Annual a-value (a(MW=0))

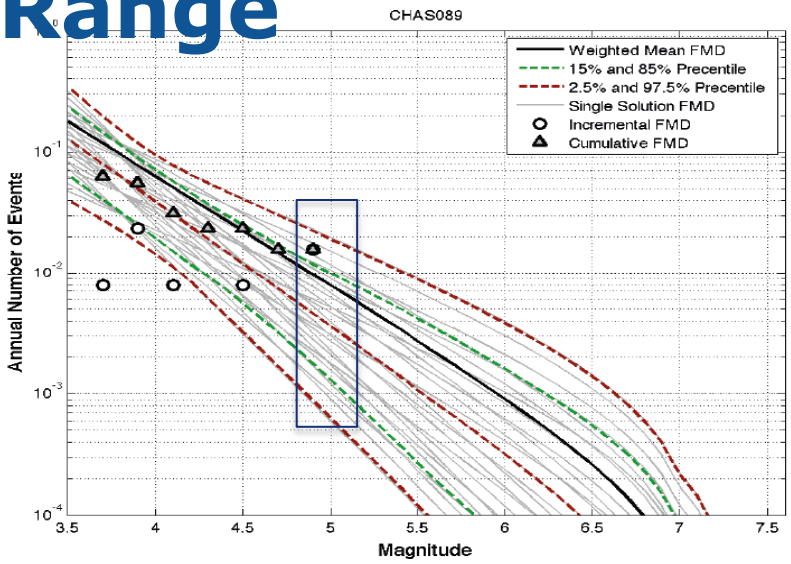
C) b-value

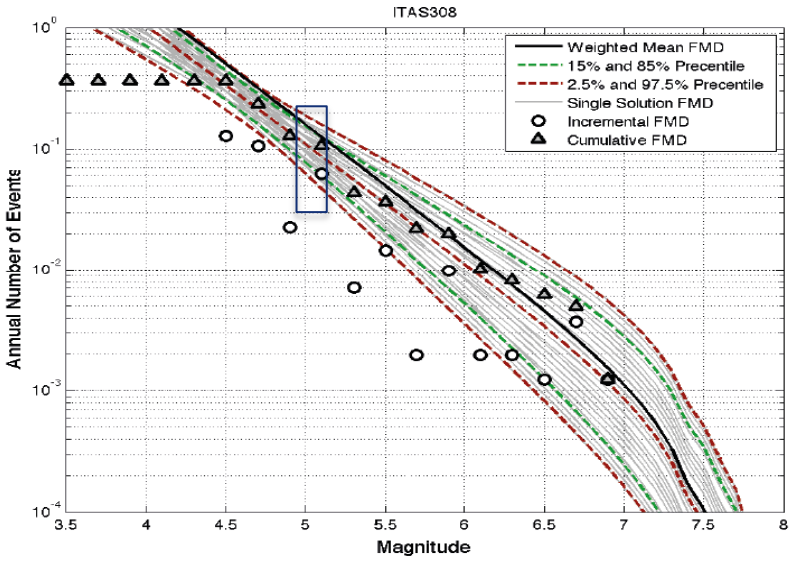
Earthquake Rates Estimation

- *Maximum Likelihood Estimate (Aki, 1965)*
- *Extension to time-varying completeness (Weichert, 1980, Kijko, 2012)*
- *Penalized Maximum Likelihood (PML) method (Johnstons, 1994; Coppersmith, 2011)*
- *Bayesian procedure*
- *Prior for b-value needed*
- *Considers completeness-time history*
- *Treat sparse data*
- *Developed and used in CEUS for NPPs*

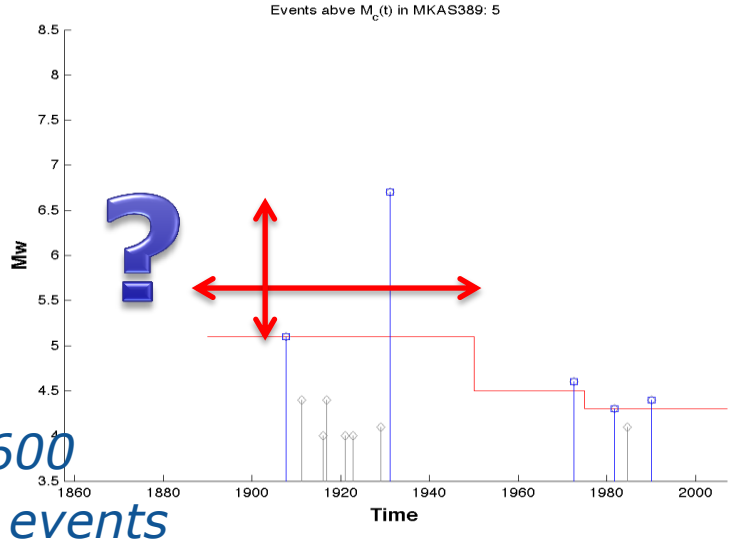


Activity Rates – Uncertainty Range



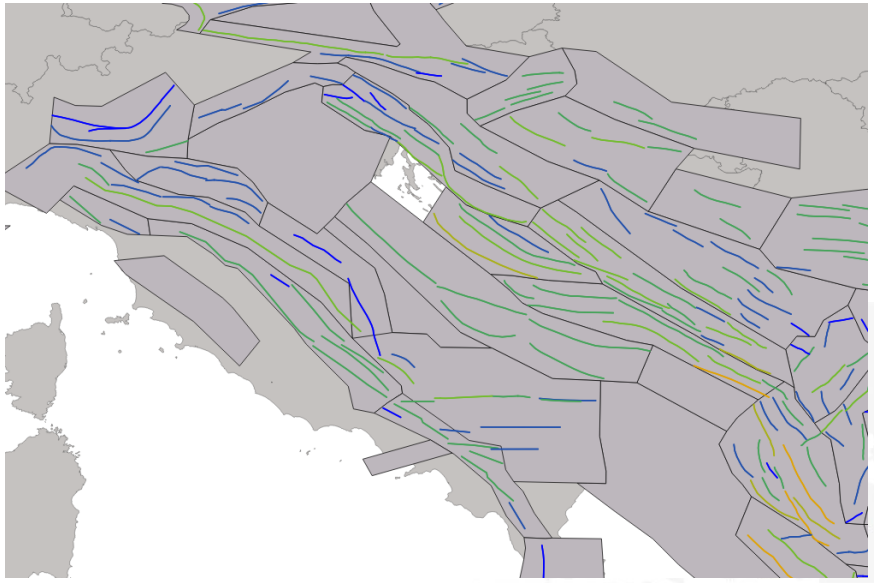


- ***Uncertainty sources:***
- *Spare earthquake data*
- *Completeness assessment*
- ***Statistics**:*
- *Entire catalog: more than 30000 events*
- *De-clustered catalog: 13919 events*
- *De-clustered and complete catalog: > 8600*
- ***45%** (or 196) of areal zones with N≤10 events*



Faults + Background Sources

- *Background zone:*
- *Includes an entire fault network or system*
- *Within one zone, all fault sources are completely identified!*
- *Polygons cannot cut across a fault*
- *Seismicity is generated by the mapped faults*
- *Entire accumulated moment is released seismically!*



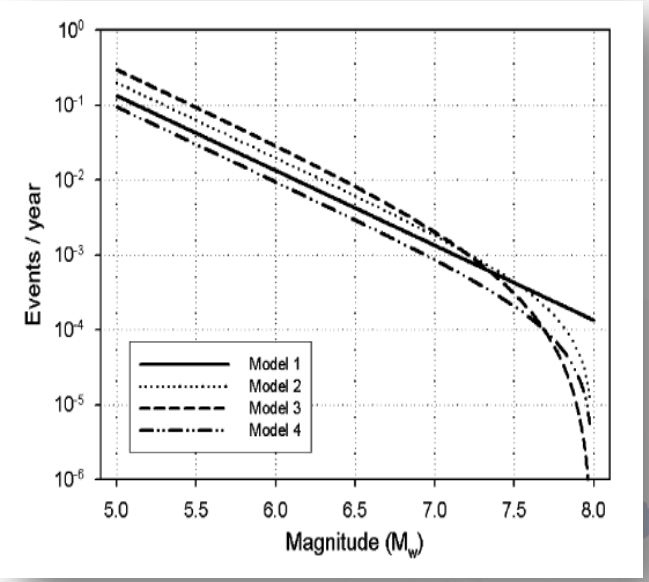
Earthquake Rates from Geologic Info

- *Key parameters*
  - **Slip rate**
  - **Fault source length and aspect ratio**
  - **Maximum magnitude**

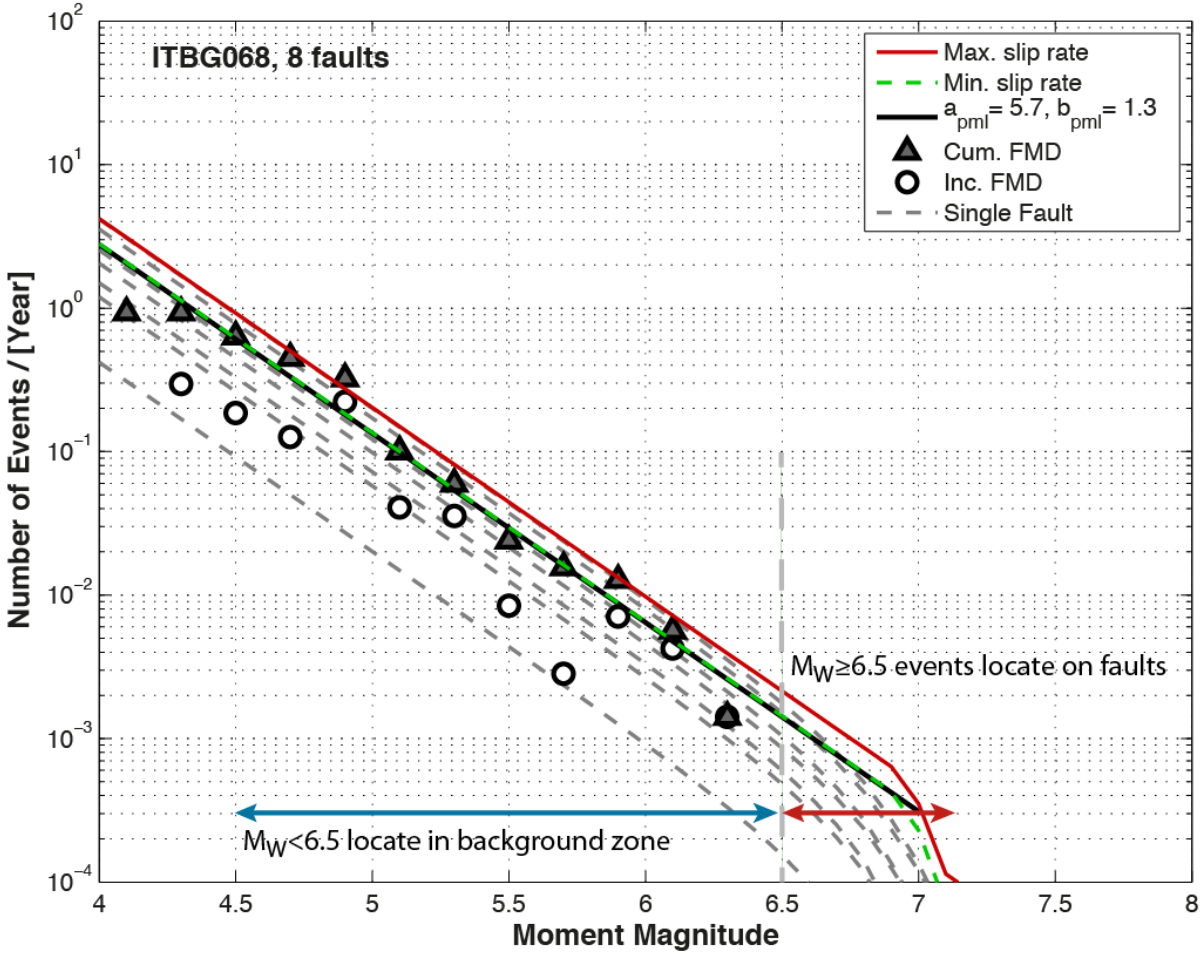
- *Assumption that fault slips entirely seismically*

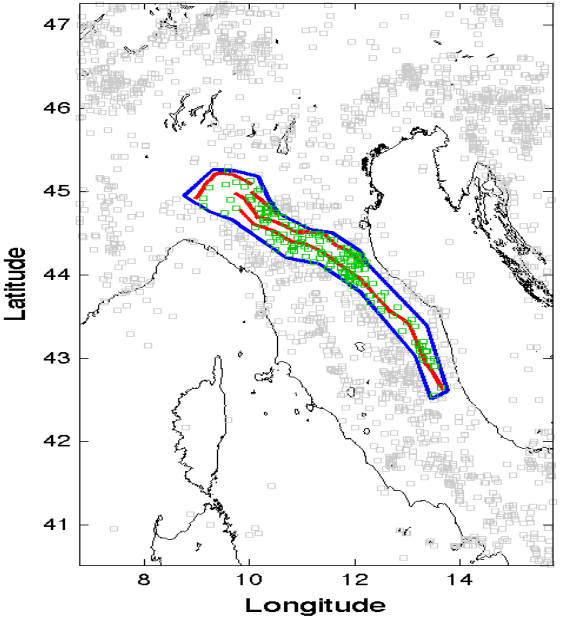
$$N(M) = \left(\frac{\bar{d} - \bar{b}}{\bar{b}}\right)\left(\frac{S}{b}\right)\left[e^{\bar{b}\,(M_{max} - M} - 1\right]e^{-((\bar{d}/2)M_{max})}$$

Anderson & Luco, 1983; Bungum, 2007

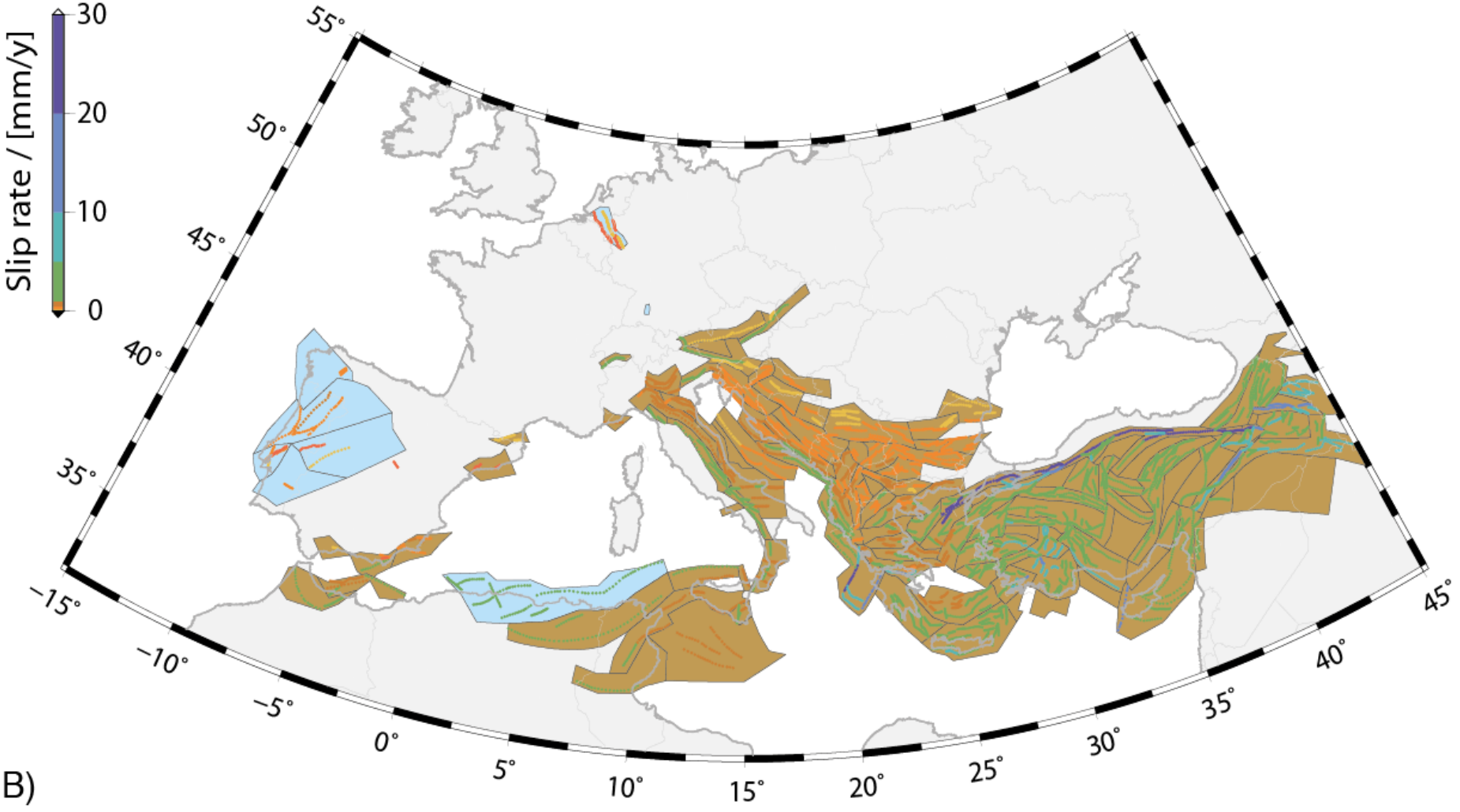


Faults Source Model: Uncertainty Range





Faults Source Model



SEIFA Model

A smoothed stochastic earthquake rate forecast model considering SEIsmicity and FAult moment release for Europe

Assumptions:

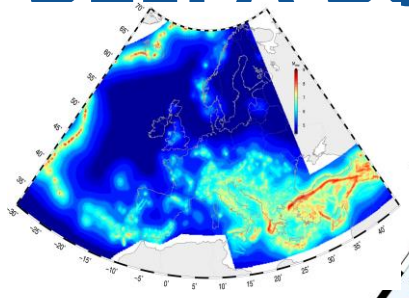
1) the frequency-magnitude distribution of past earthquakes is the best estimate of the future activity

2) future earthquakes occur in the vicinity of past earthquakes,

3) larger earthquakes occur more likely on mapped faults, and more likely on fast slipping than on slow slipping faults.

SEIFA Source Model

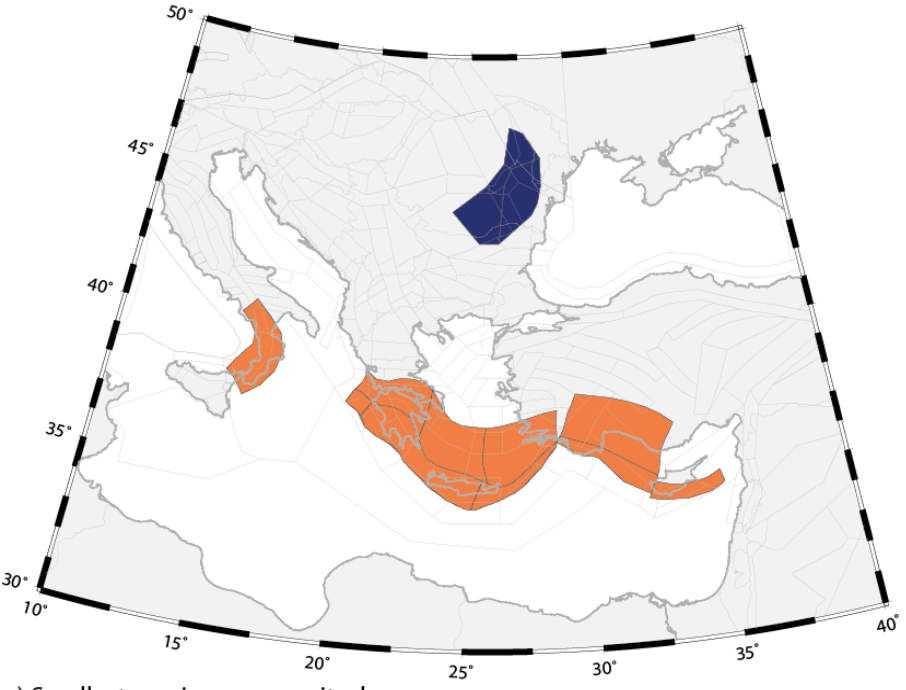
European Commission

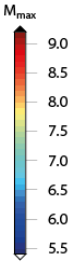


Hiemer et al., 2014, GJI
Hiemer et al., 2013, BSSA
(Application to California)

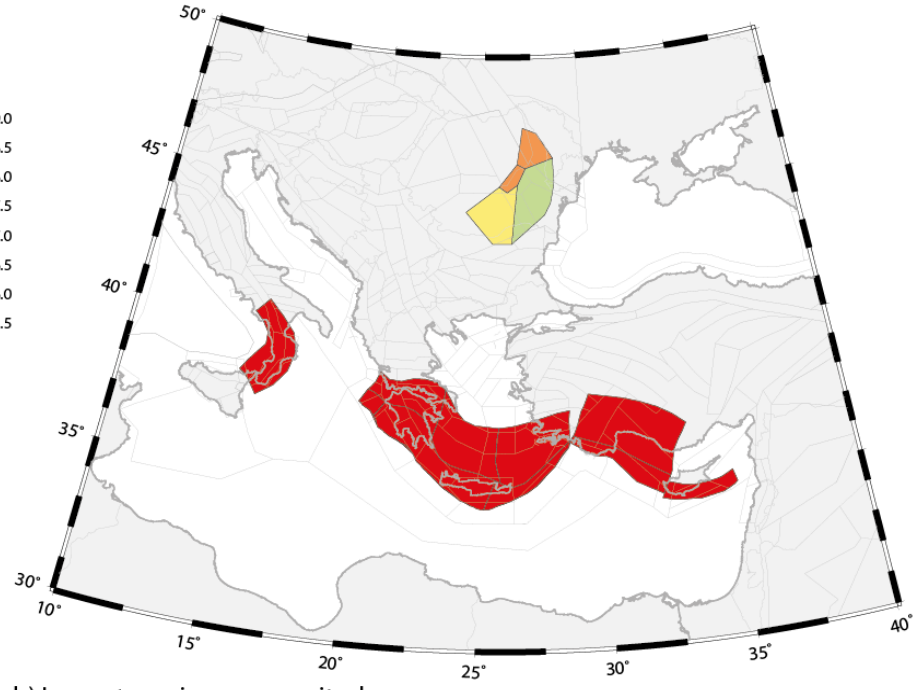
Subduction and Vrancea

European Commission





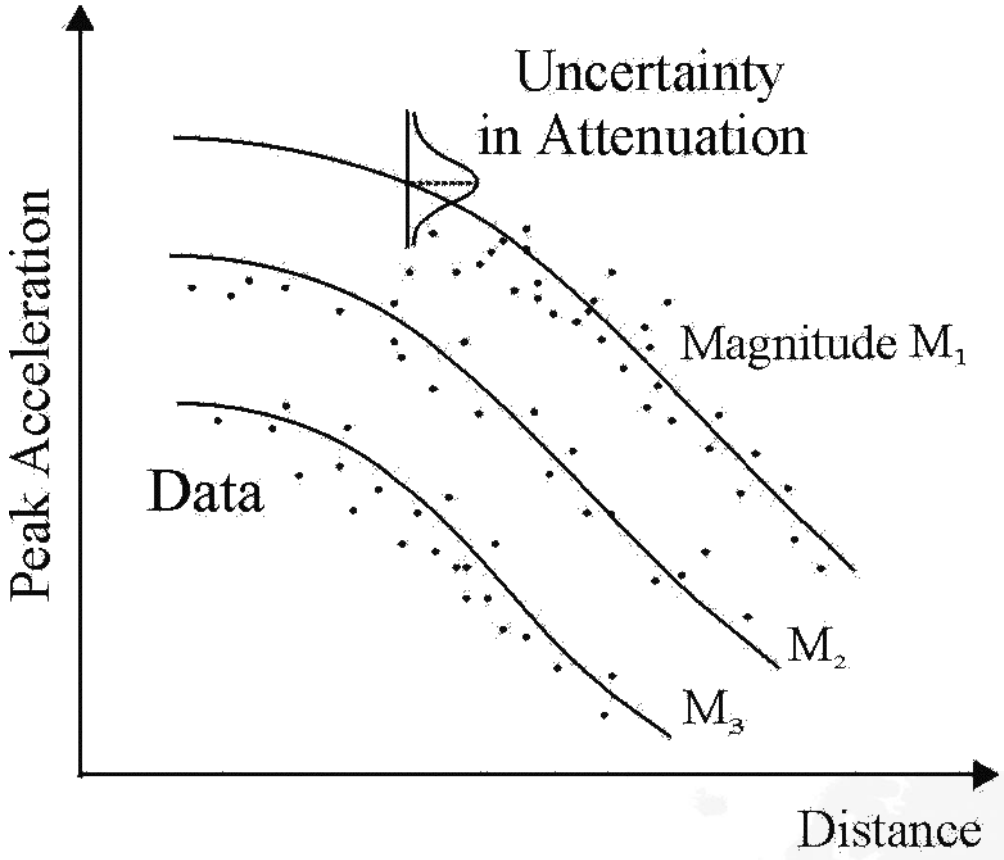
a) Smallest maximum magnitude



b) Largest maximum magnitude

Elements of Probabilistic Seismic Hazard

- *Ground Motion Models*
  - **Expert Elicitation**
  - **Data Driven**



Ground Motion Models Selection

Selection of candidate GMPEs

- Identification of worldwide GMPEs
- Application of the exclusion criteria of Cotton *et al.* (2006)
- Review of the GMPEs applicability range
- Adjustment for parameter compatibility
- Evaluation of the GMPEs using the criteria of Bommer *et al.* (2010)

Expert judgment

- Logic trees from 6 experts

Testing using data

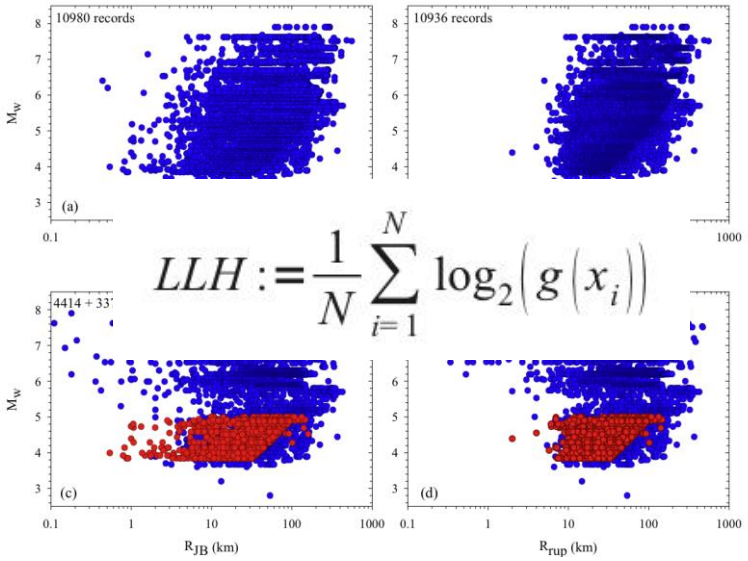
- Rankings of GMPEs based on Scherbaum *et al.* (2009)

Proposition of logic trees : WP4 consensus

- Selection of the final GMPEs
- Proposition of different sets of weights

Sensitivity analysis of the proposed weights on the seismic hazard

Final logic tree



$$LLH := \frac{1}{N}\sum_{i=1}^{N}\log_2\left(g\left(x_i\right)\right)$$

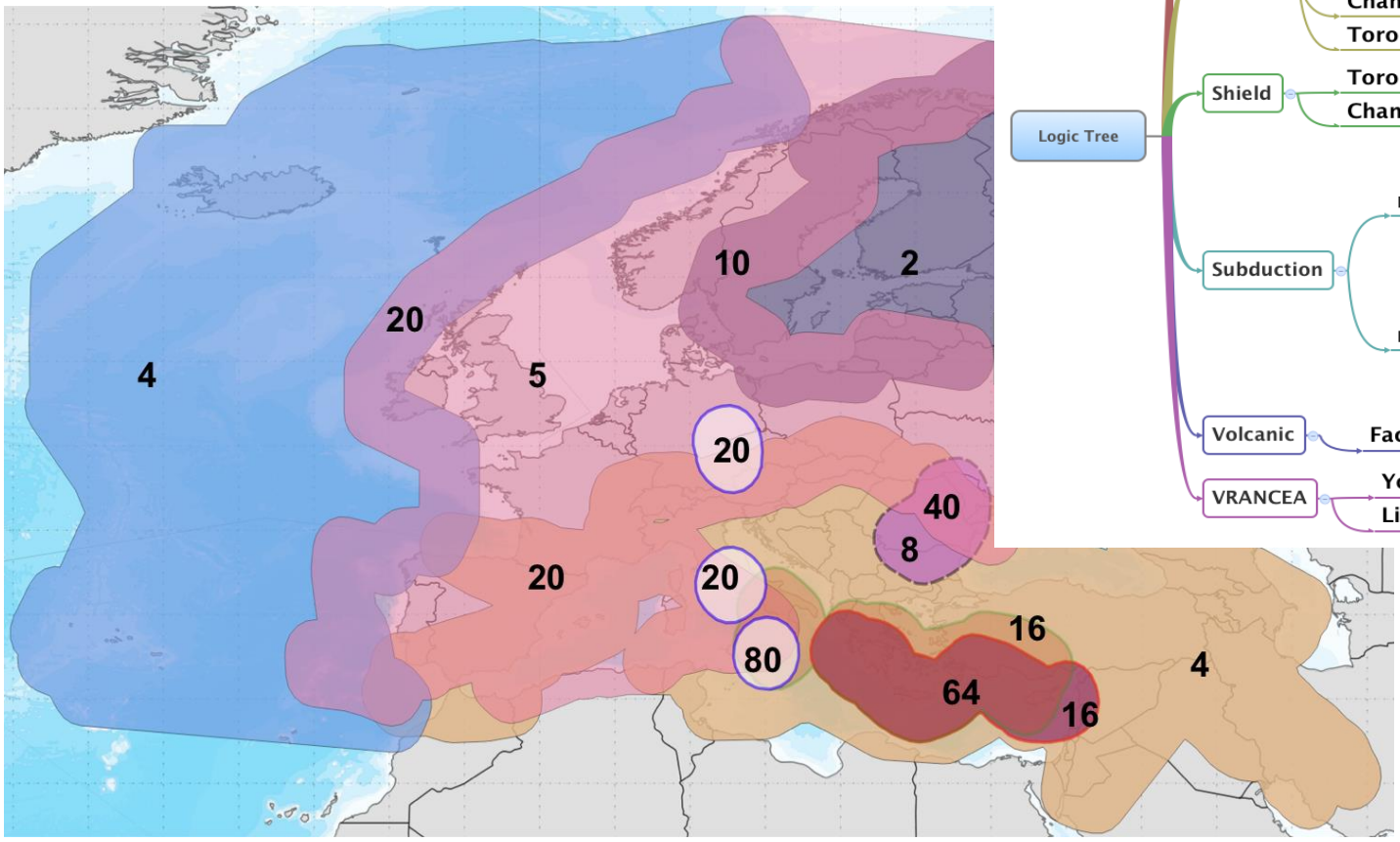
Active shallow crustal regions
Ranking based on PSA at 5 periods (0.1s, 0.2s, 0.5s, 1s, 2s)
For all magnitudes and distances → 6911 observations

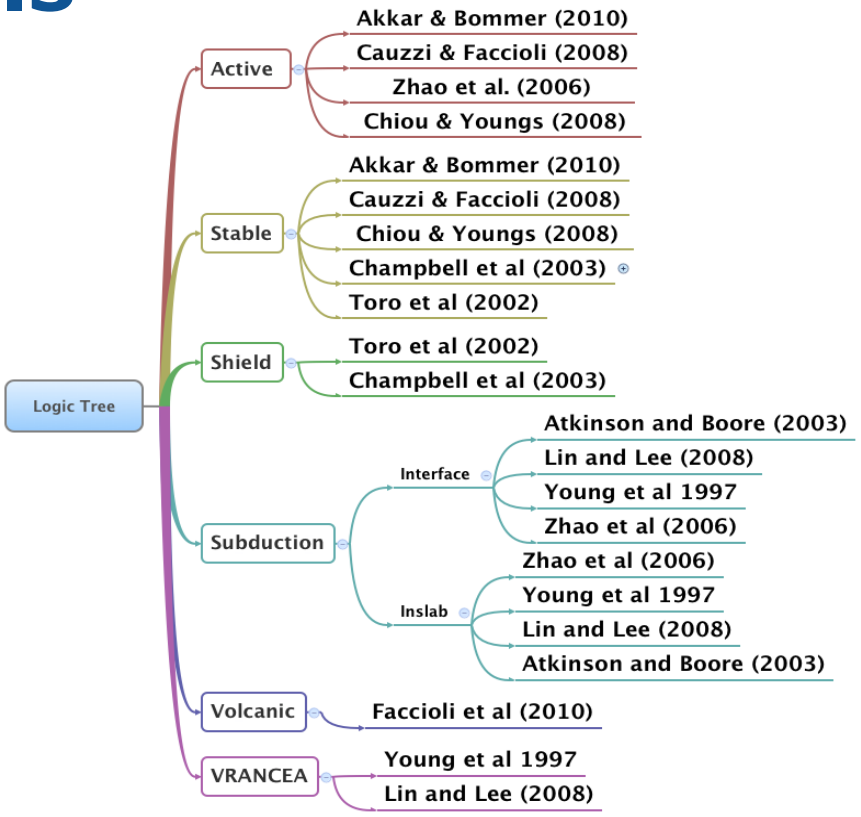
rank	LLH	weight	ratio(*)	name
1	2.378	0.120	1.00	Bindi et al (2009)
2	2.396	0.119	1.01	Cauzzi and Faccioli (2008)
3	2.427	0.116	1.03	Cotton et al (2008)
4	2.588	0.104	1.16	Akkar and Bommer (2010)
5	2.680	0.097	1.23	Douglas et al (2006)
6	2.800	0.090	1.34	Zhao et al (2006)
7	2.938	0.082	1.47	Chiou and Youngs (2008)
8	3.158	0.070	1.72	Ambraseys et al. (2005)
9	3.271	0.065	1.86	Danciu and Tselentis (2007)
10	3.869	0.043	2.81	Abrahamson and Silva (2008)
11	4.121	0.036	3.30	Boore and Atkinson (2008)
12	4.785	0.023	5.30	Campbell and Bozorgnia (2008)
13	4.921	0.021	5.80	Kalkan and Gulkan (2004)
14	5.332	0.016	7.70	Massa et al (2008)

(*) ratio between the larger weight and the weight of each model

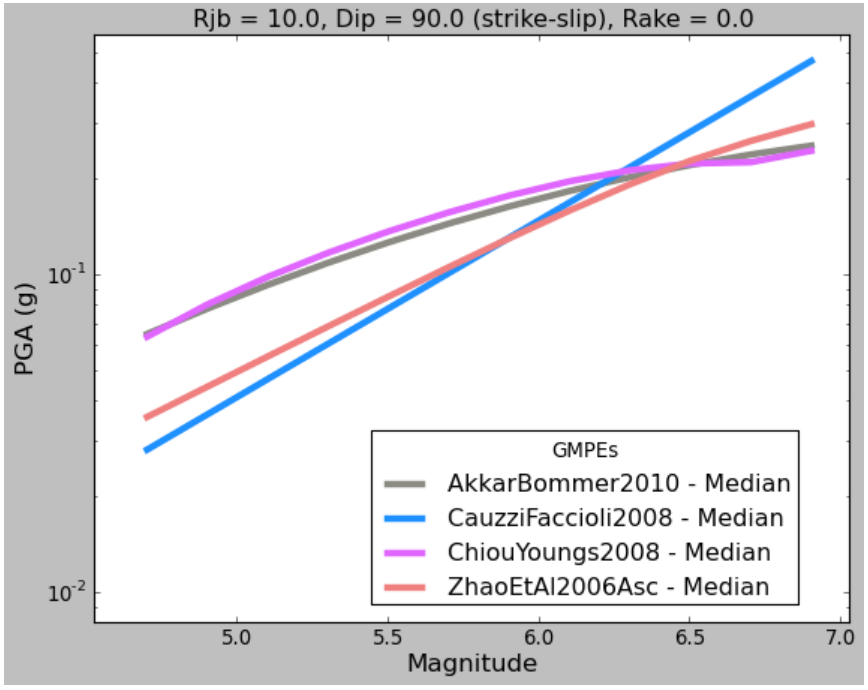
Delavaud et al., 2012

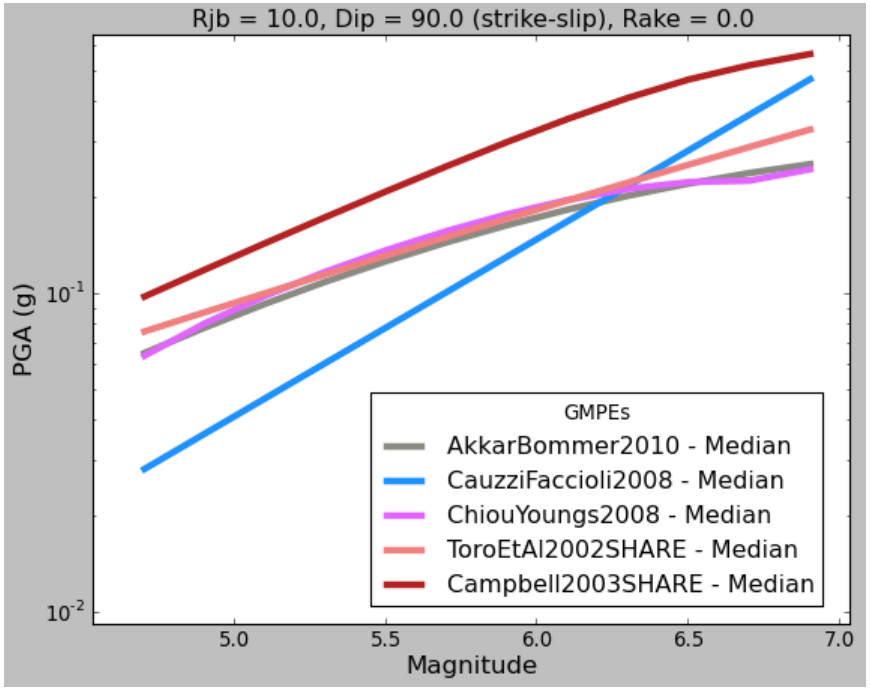
Ground Motion Models





GMPEs comparison





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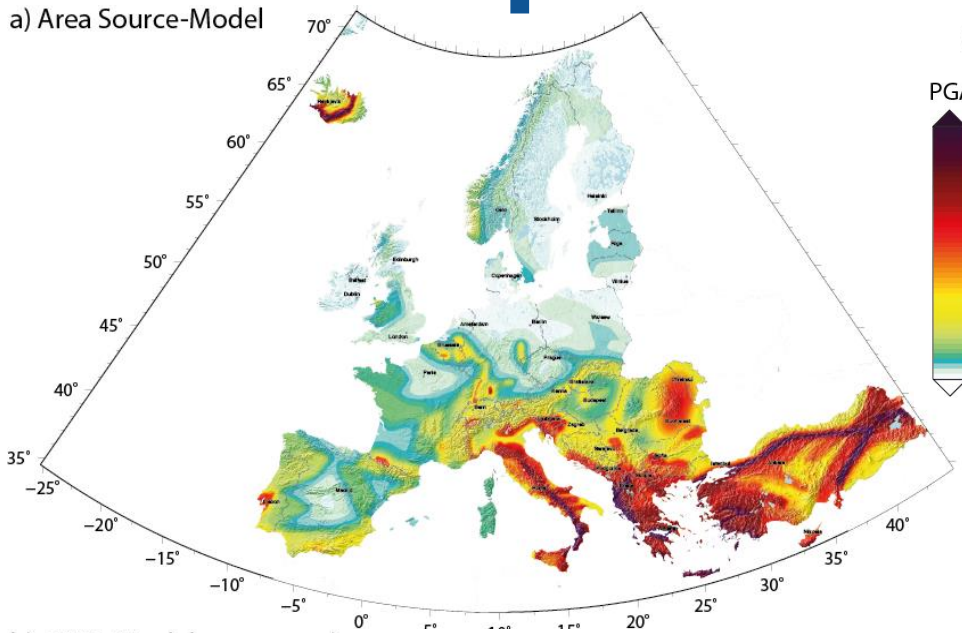
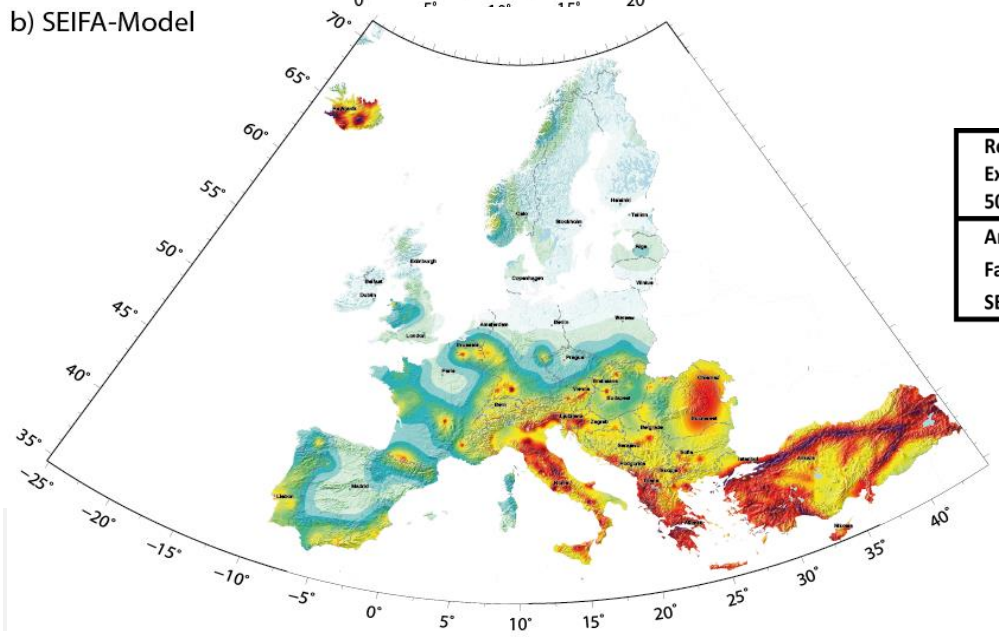
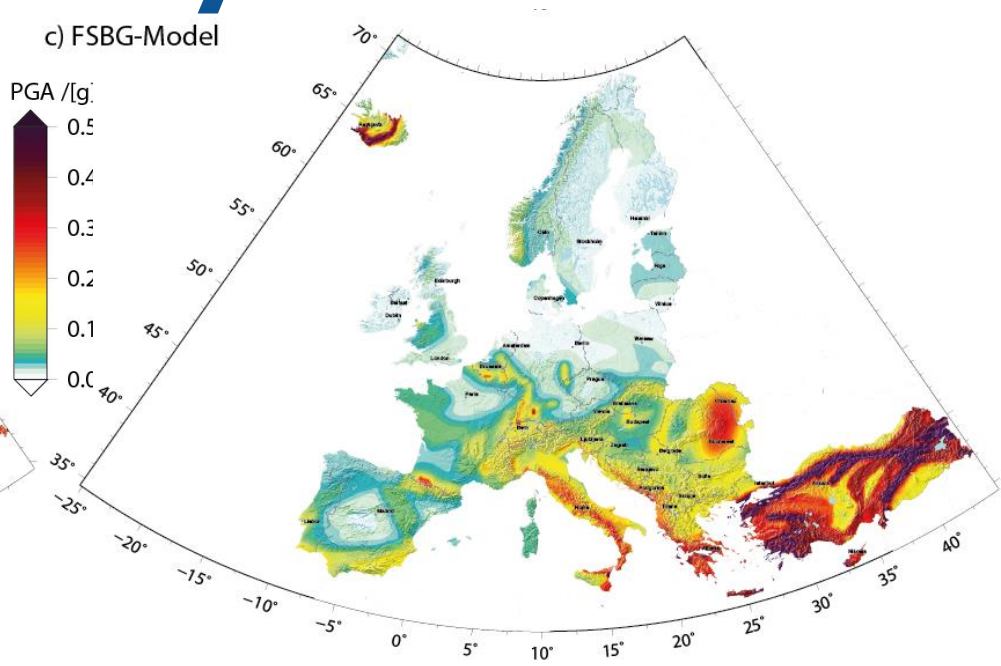
ESHM13: OUTPUT

PGA Maps RP 475yrs

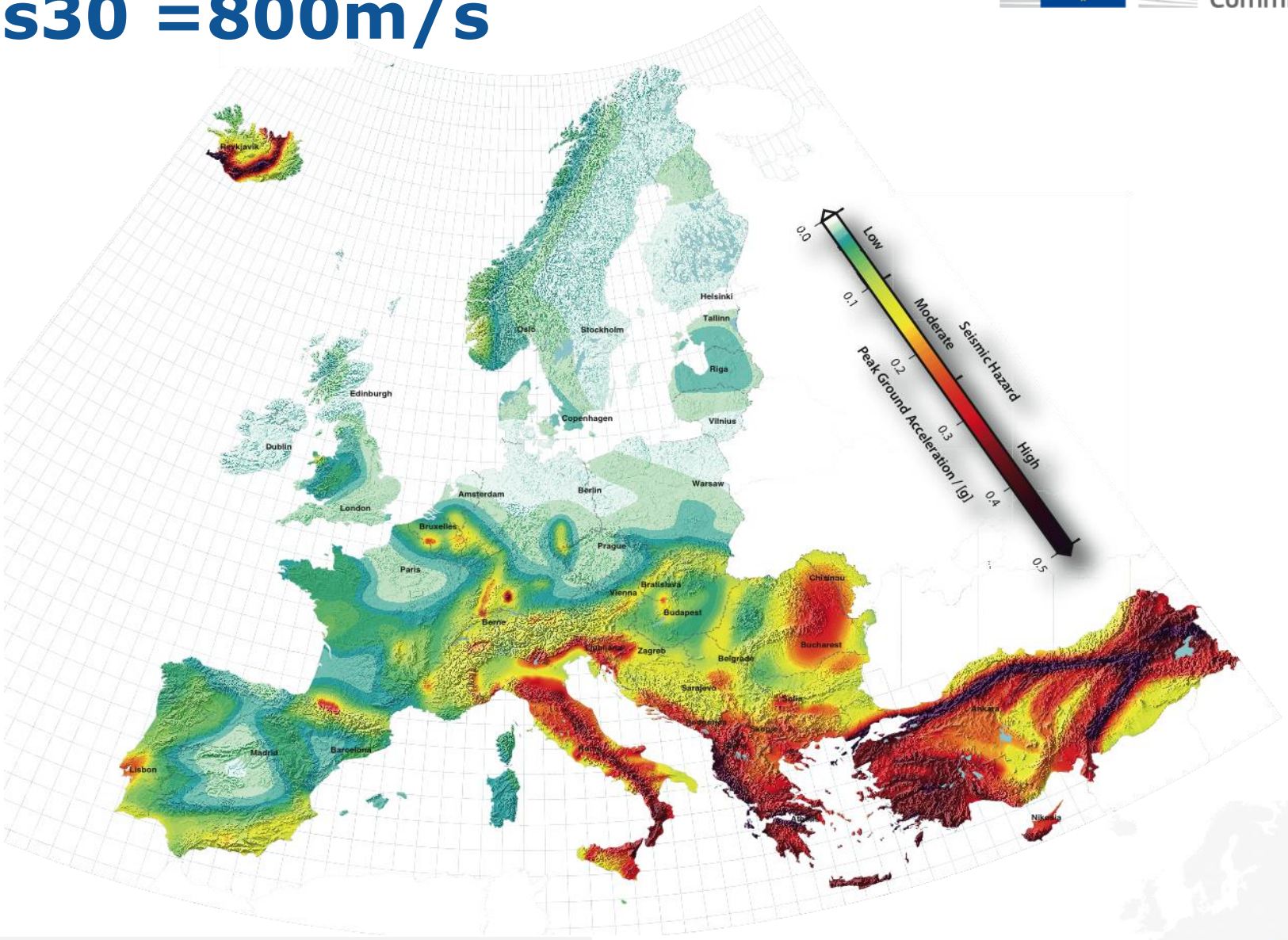




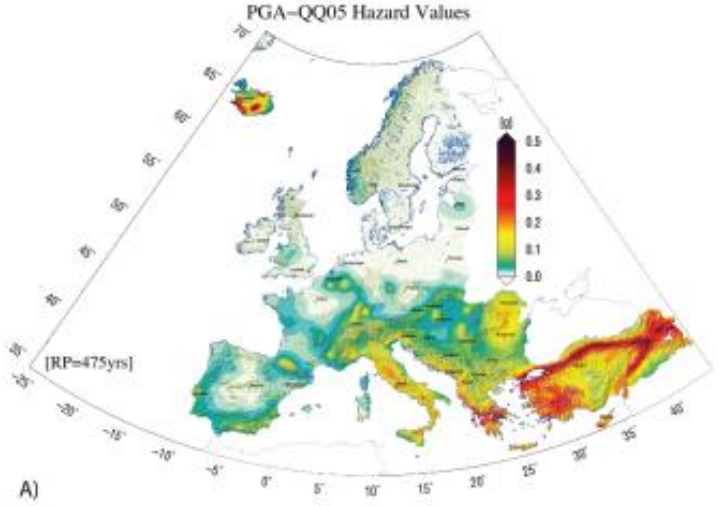


Return Period Exeedance Probability in 50y	T=100y P=39%	T<474y P>10%	T≥475y P≤10%	T=975y P=5%	T≥2475y P≤2%	T=4975y P=1%
Area Source	0.45		**0.50**		0.60	
Fault Source + Background	0.10		**0.20**		0.30	
SEIFA	0.45		**0.30**		0.10	

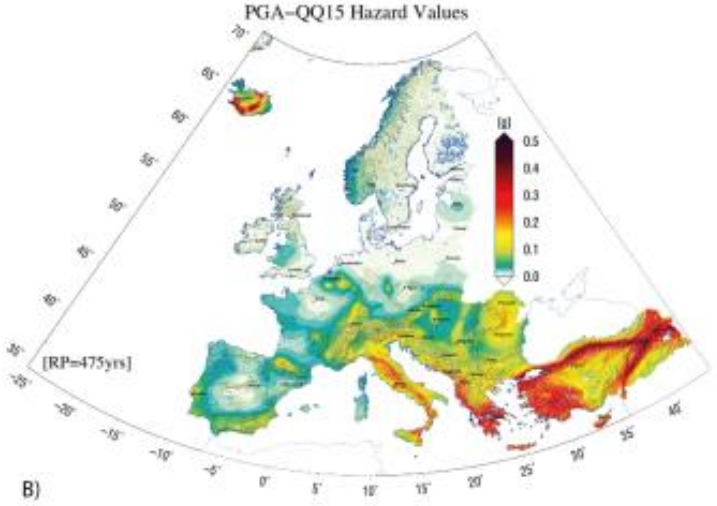
Reference PGA map, RP=475Yrs
Vs30 =800m/s



Quantiles PGA Maps RP 475yrs



A)



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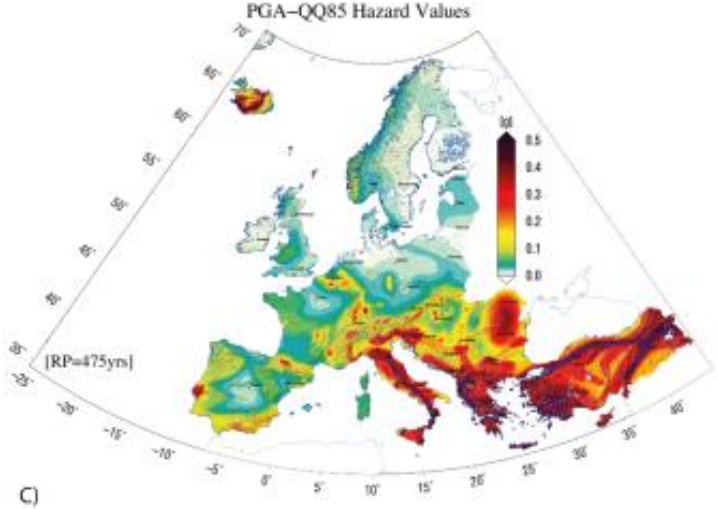

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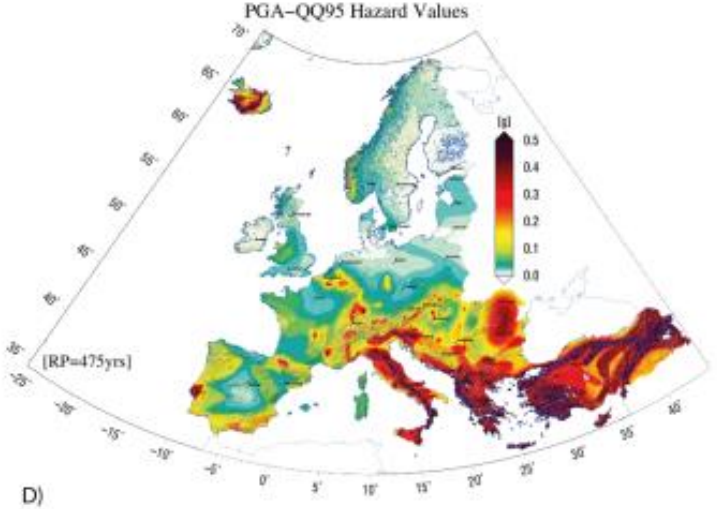
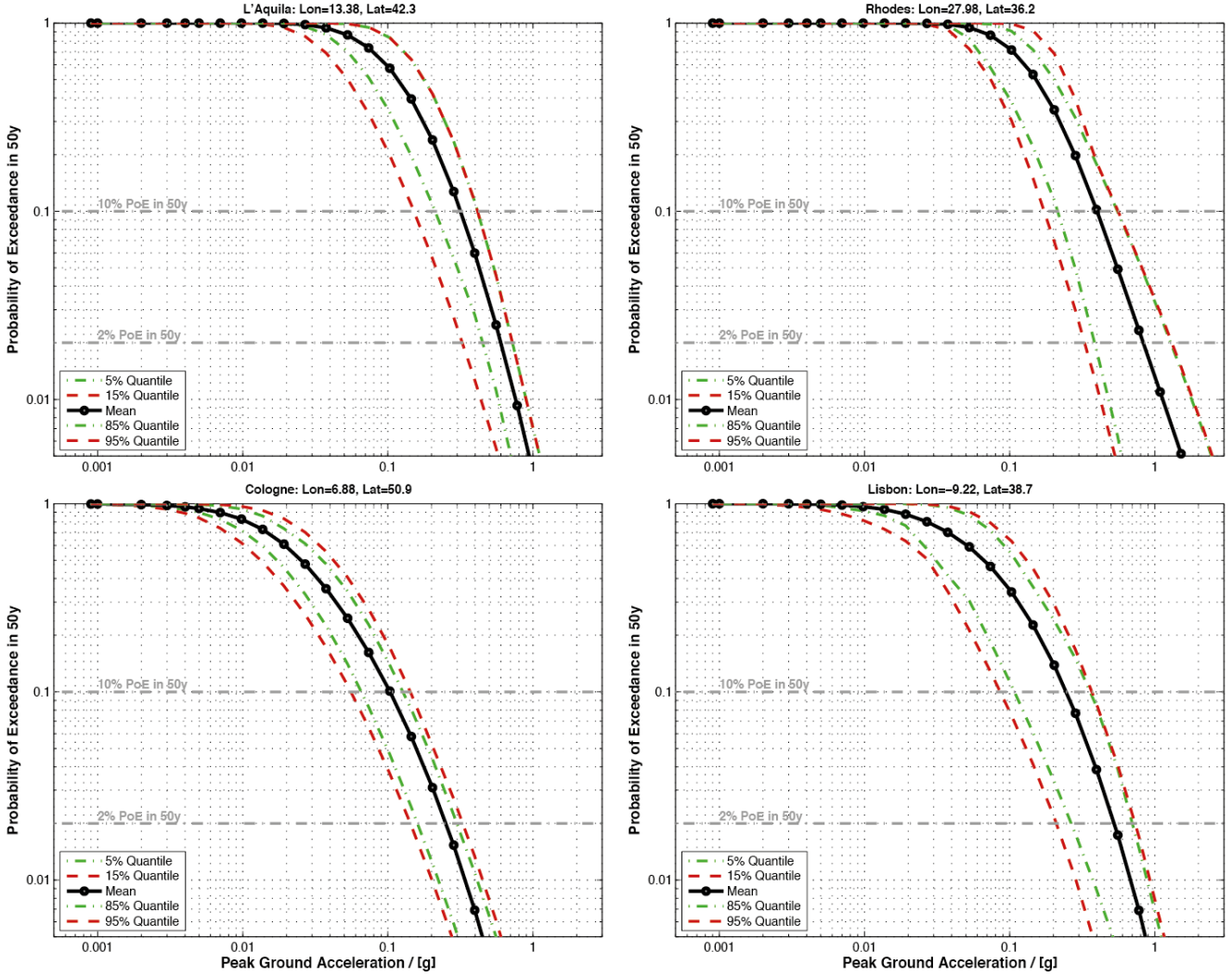


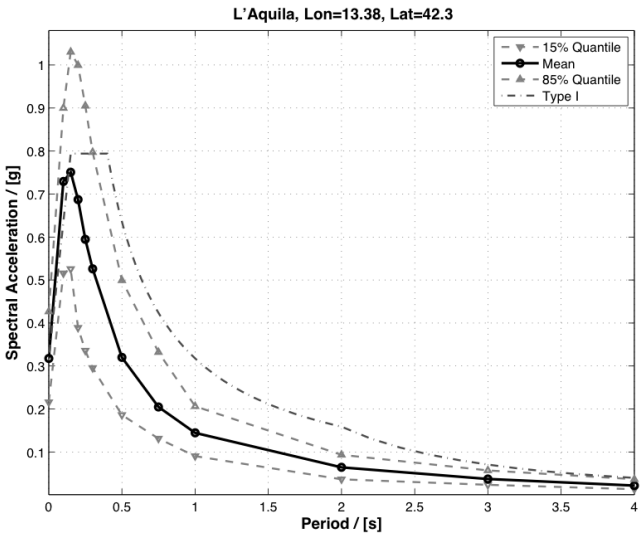
D)

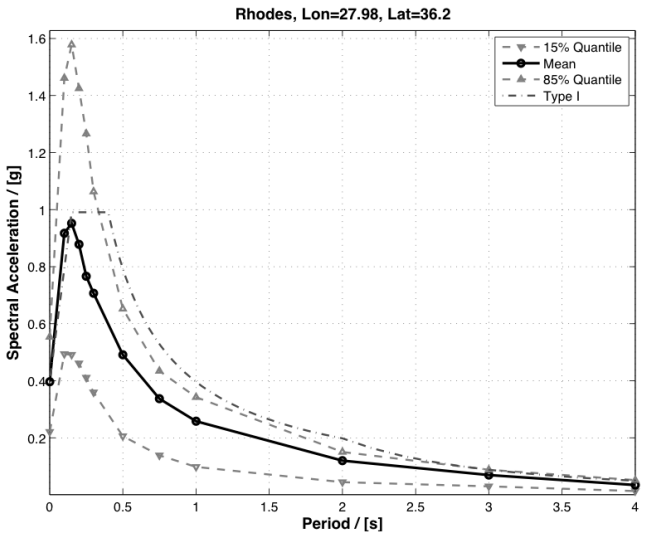
Hazard Curves

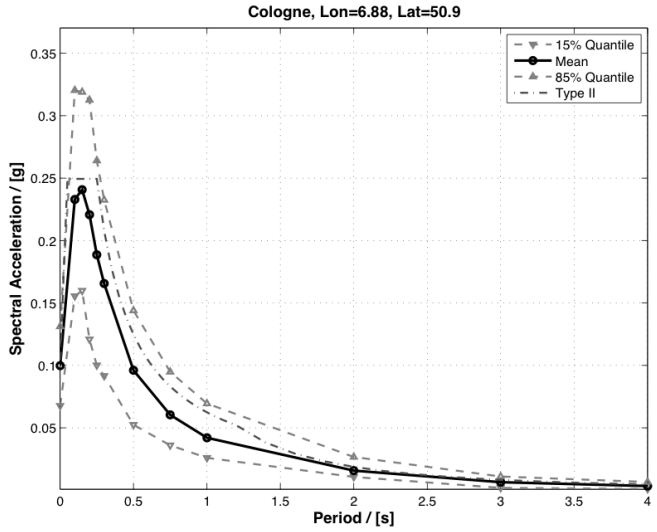


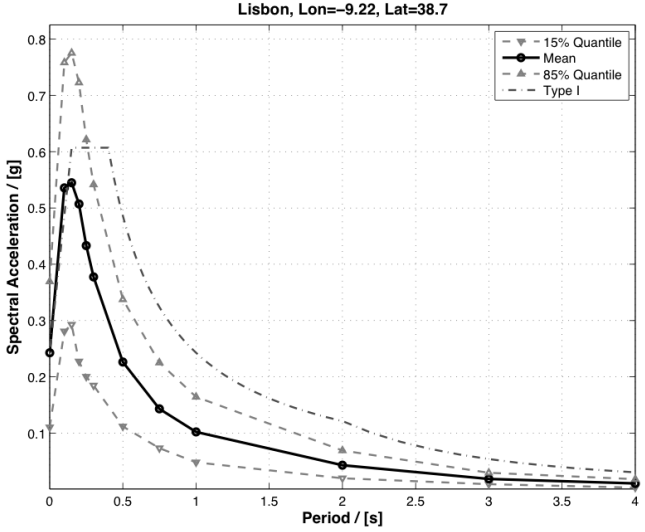
Uniform Hazard Spectra

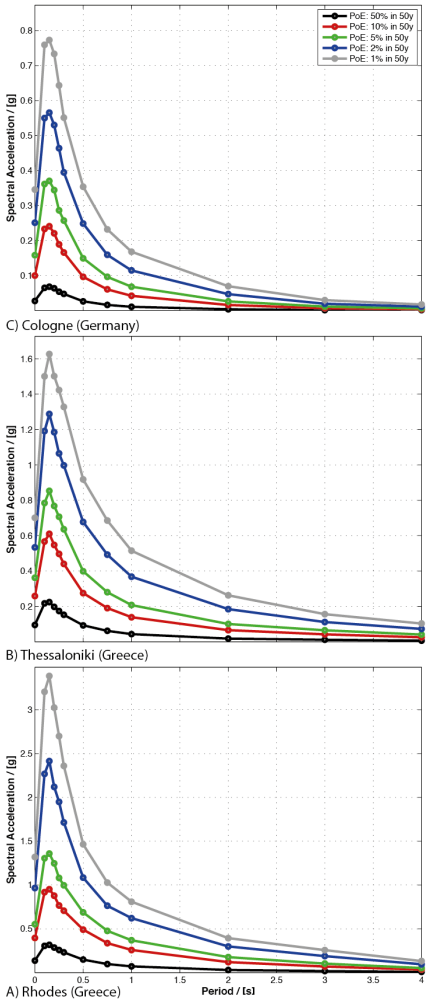
European Commission









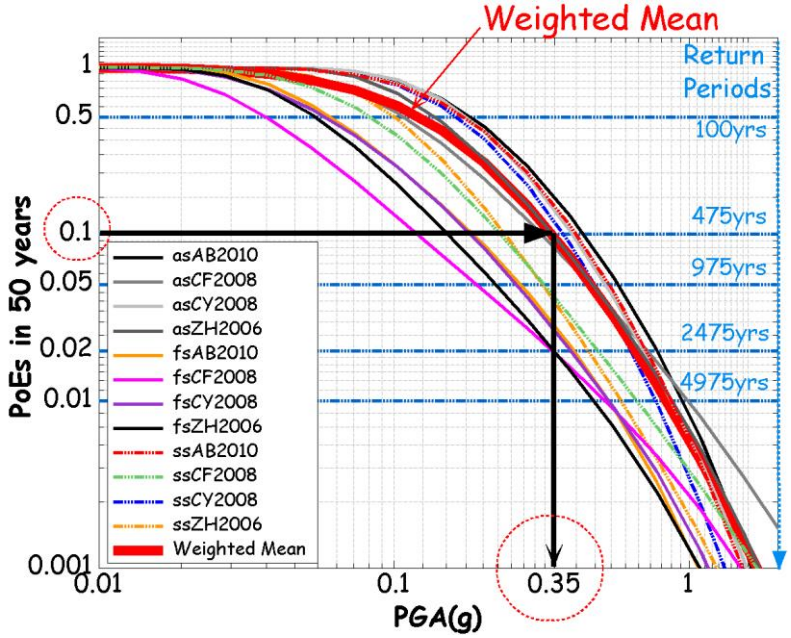


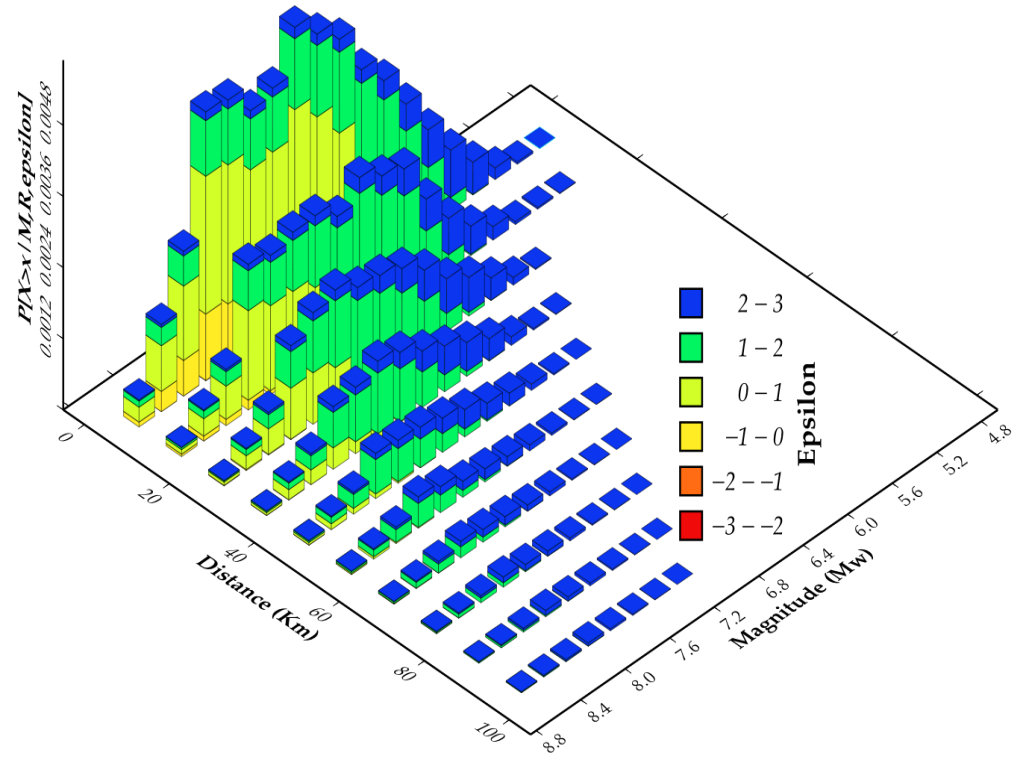
BUILDING CAPACITIES FOR ELABORATION OF NDPs AND NAs OF THE EUROCODES IN THE BALKAN REGION

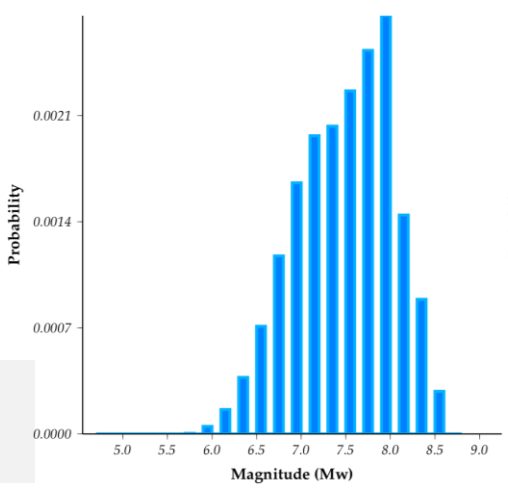
4-5 November 2014, Skopje

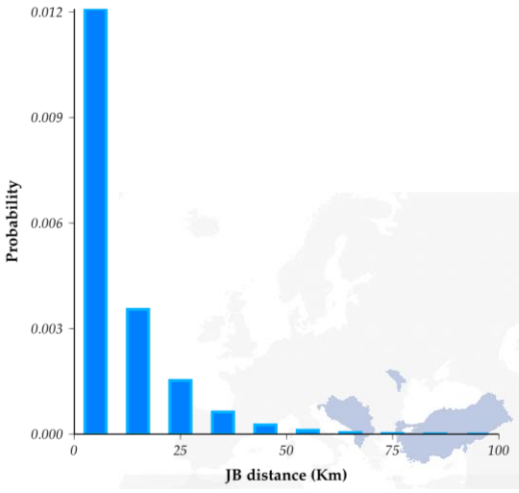
Disaggregation(ongoing)

European Commission







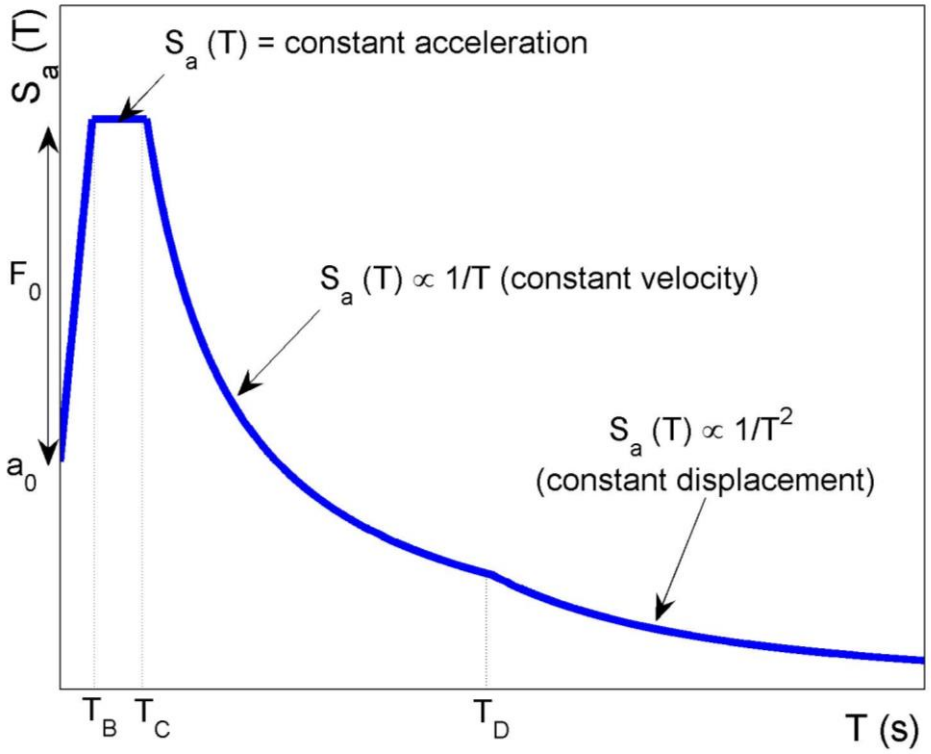


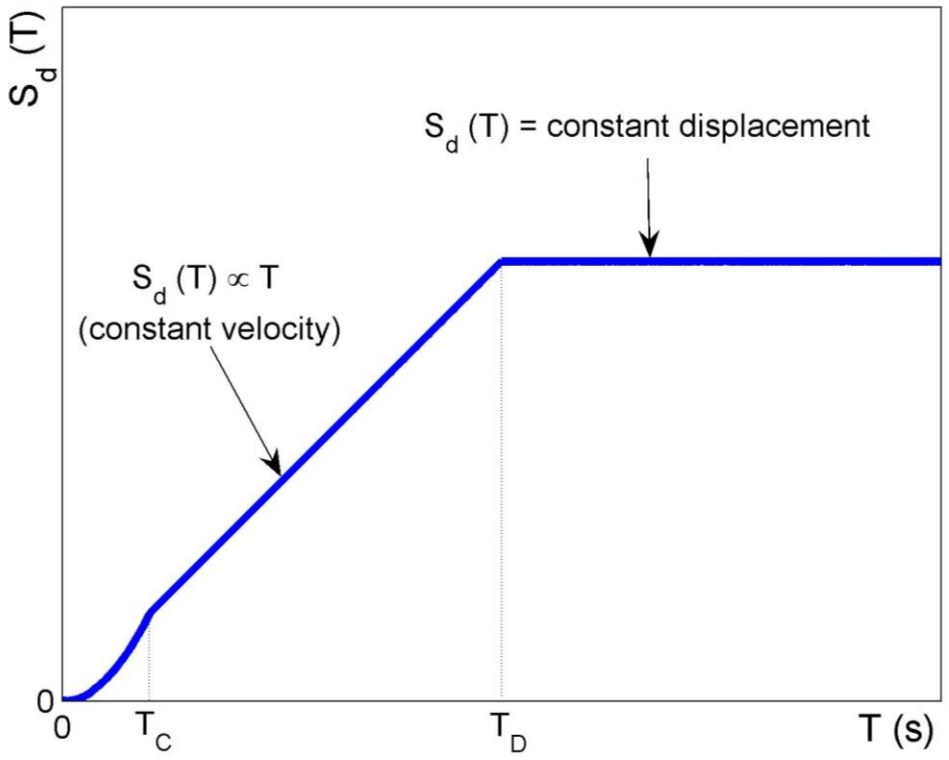
European Commission

ESHM13 to Eurocode 8

Defining The Ec 8 Spectrum

- *G. Weatherill, H. Crowley, L. Danciu (2013)*

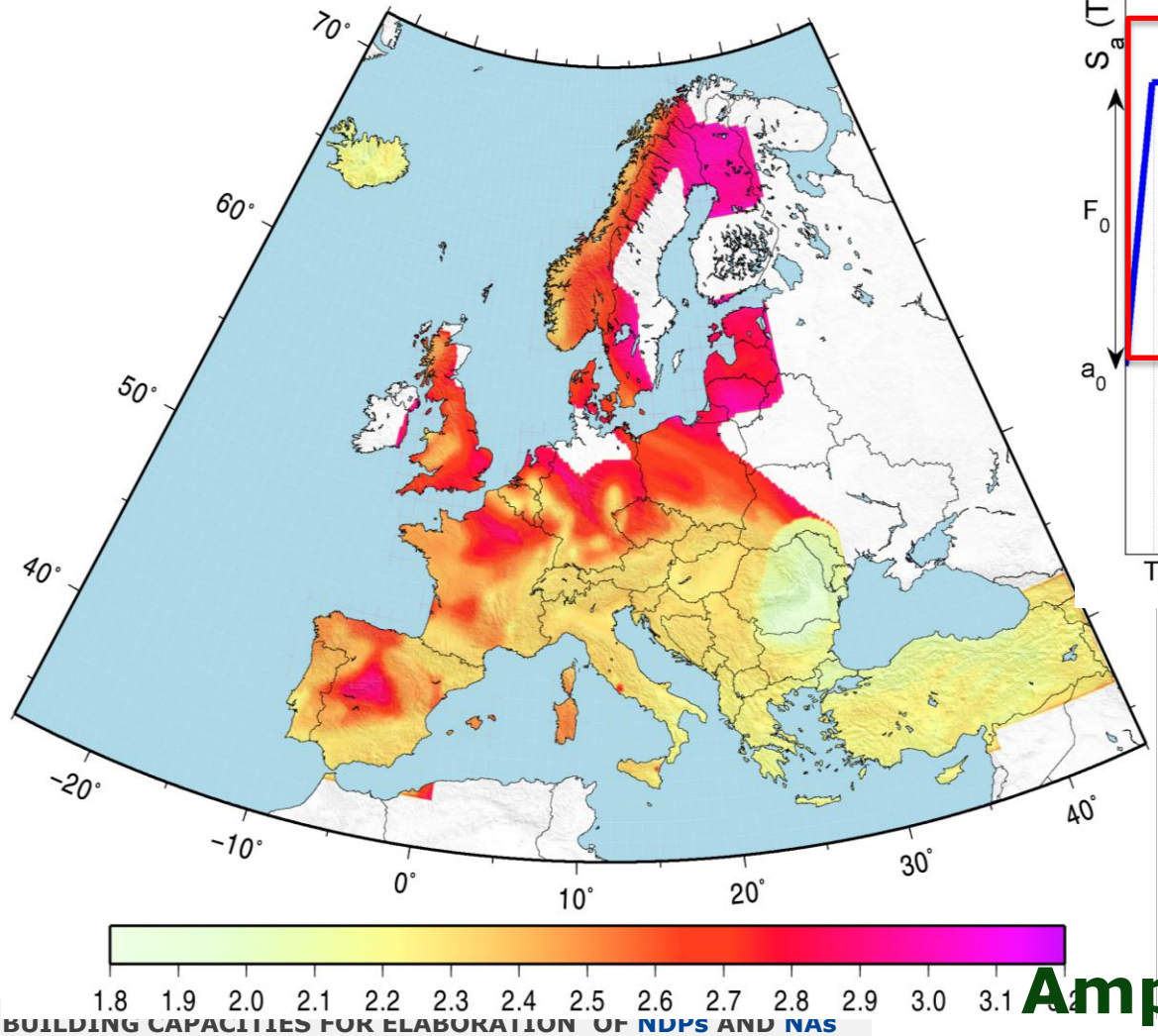


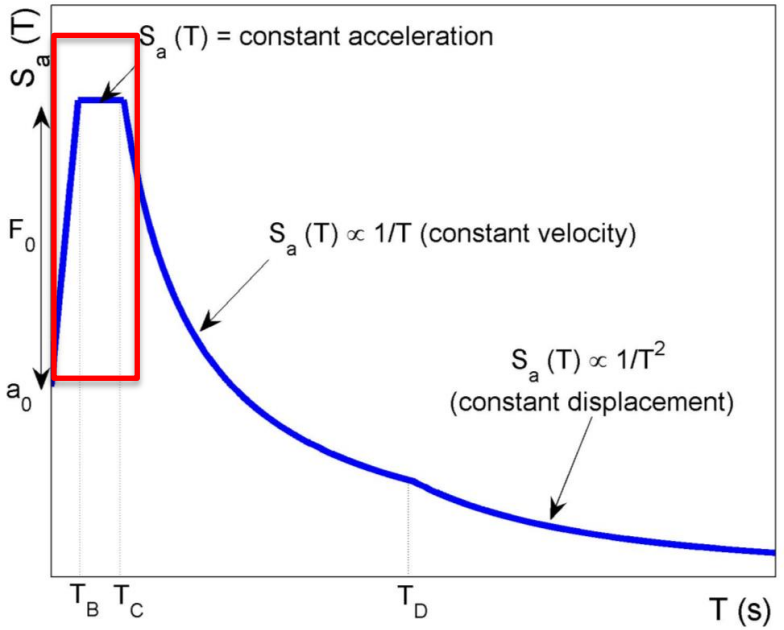


$$0 \le T \le T_B:\ S_e(T) = a_g \cdot S \cdot \left[1 + \frac{T}{T_B} \cdot (\eta \cdot F_0 - 1)\right],\ T_B \le T \le T_C:\ S_e(T) = a_g \cdot S \cdot \eta \cdot F_0$$

$$T_C \le T \le T_D:\ S_e(T) = a_g \cdot S \cdot \eta \cdot F_0 \cdot \left[\frac{T_C}{T}\right],\ T_D \le T \le 4.0\ s:\ S_e(T) = a_g \cdot S \cdot \eta \cdot F_0 \cdot \left[\frac{T_C T_D}{T^2}\right]$$

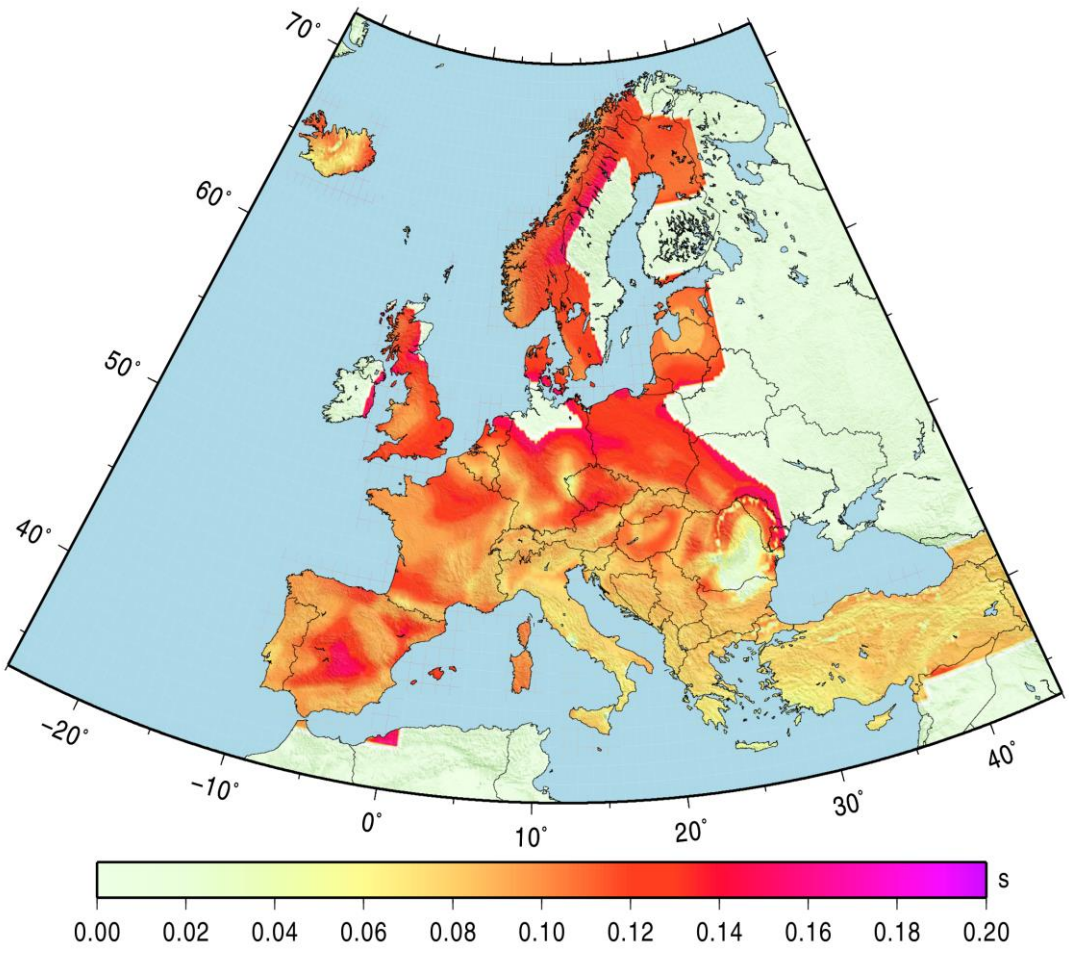
Regional Variation in Spectral Shape

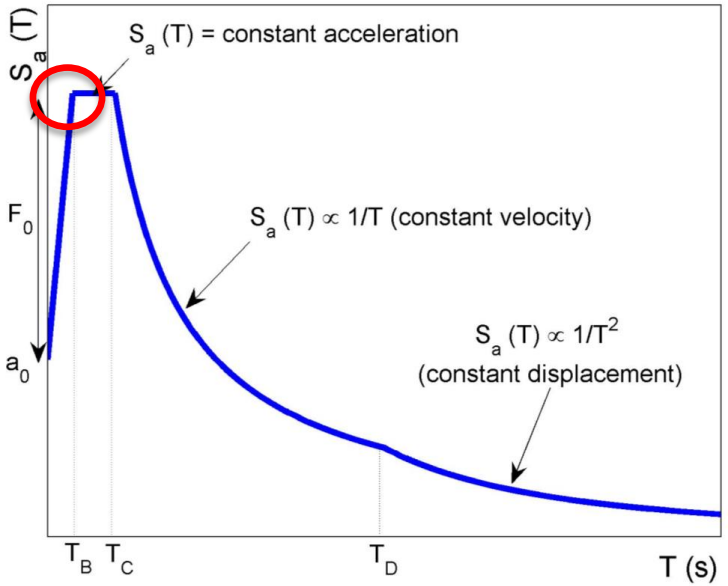




Amplification Factor F_0 (Current EC8 = 2.5)

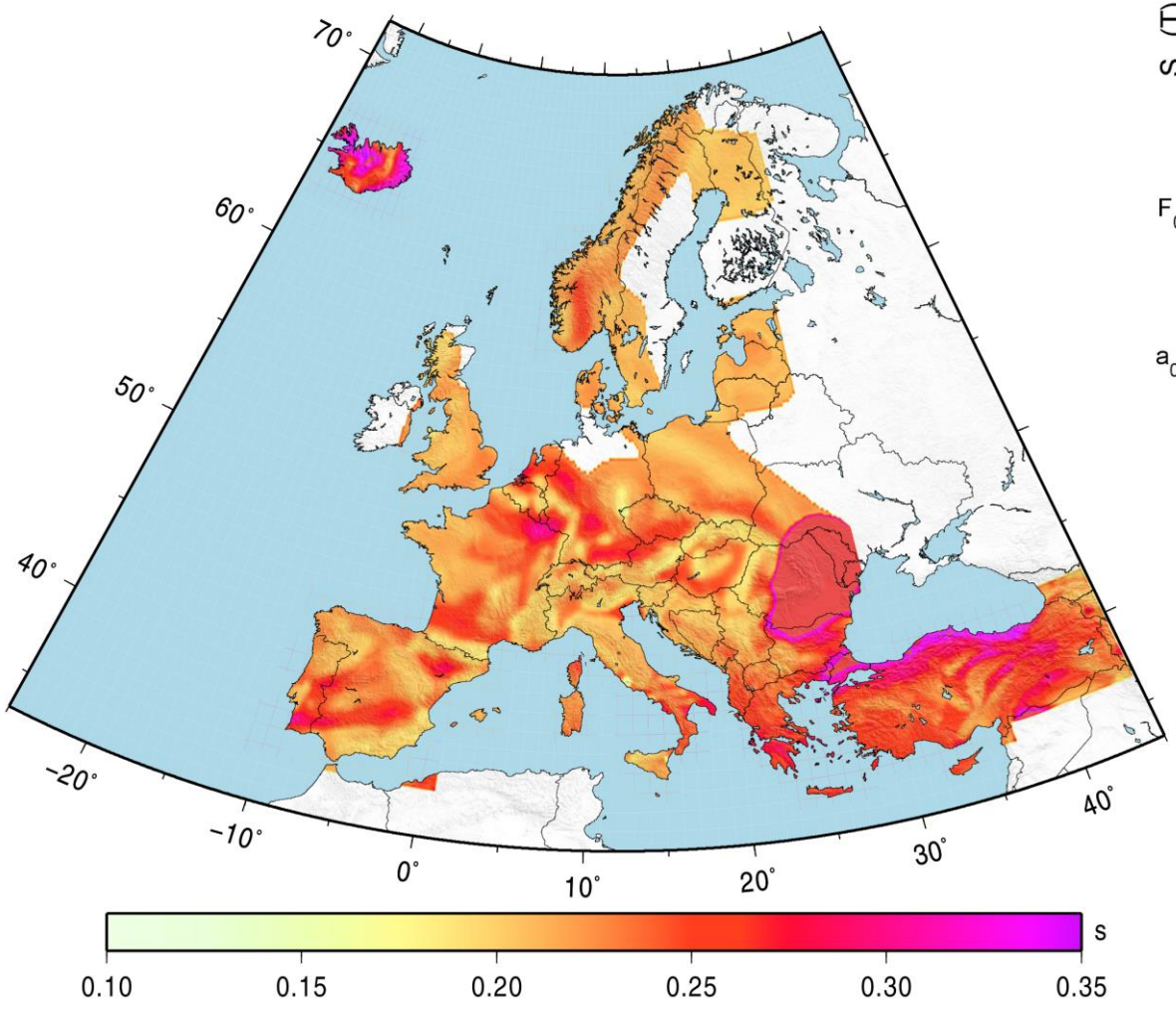
Regional Variation in Spectral Shape

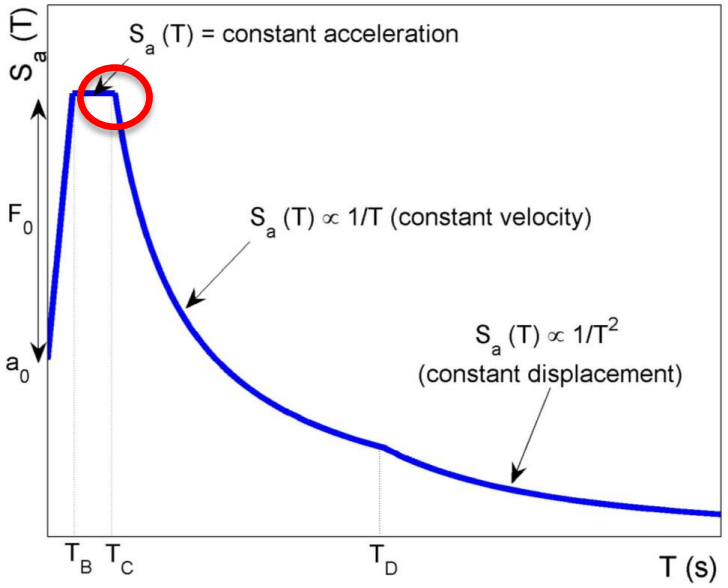




Constant Acceleration Corner Period (T_B) (Current EC8:
0.15s – Type 1
0.05 – Type 2)

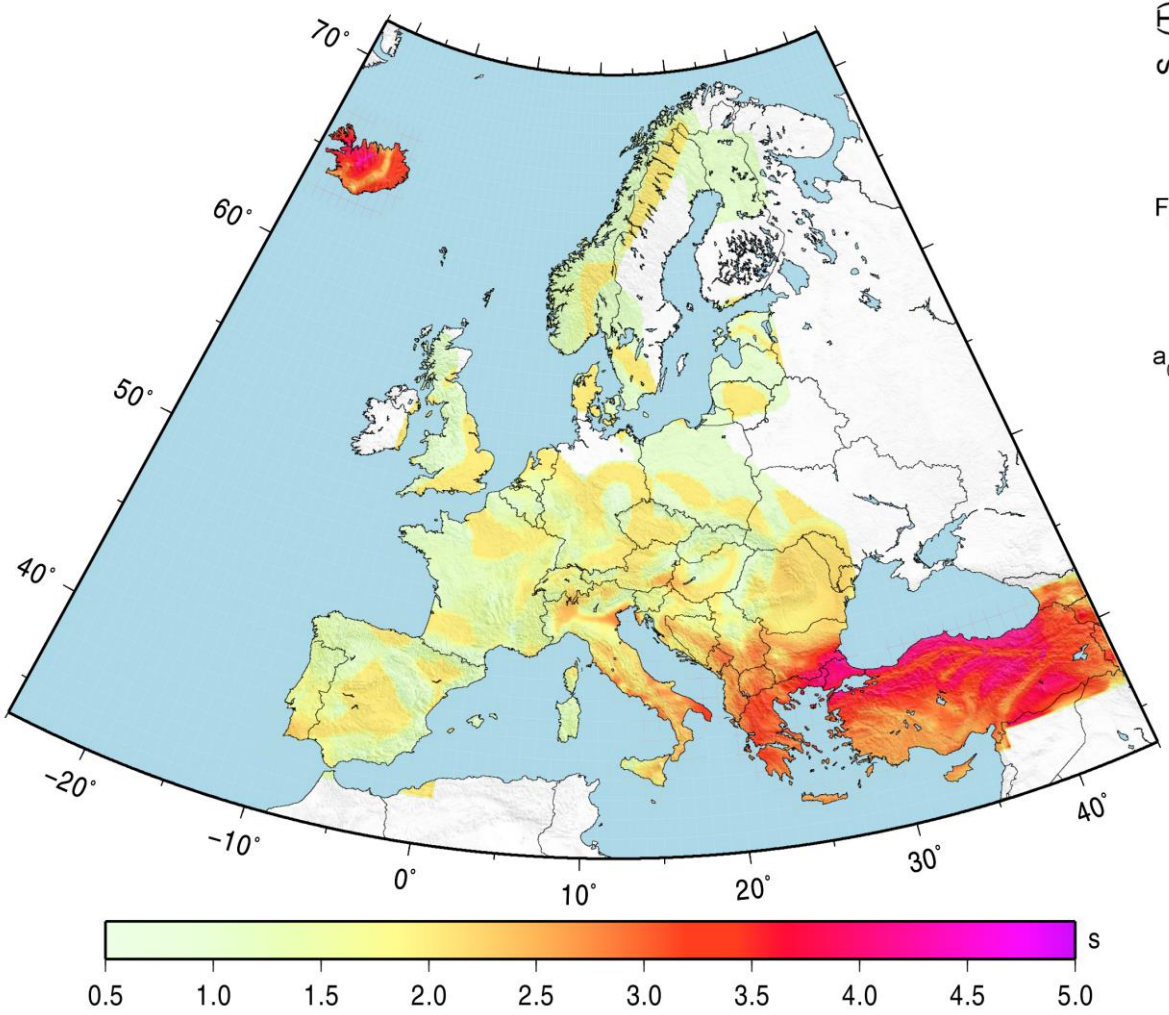
Regional Variation in Spectral Shape

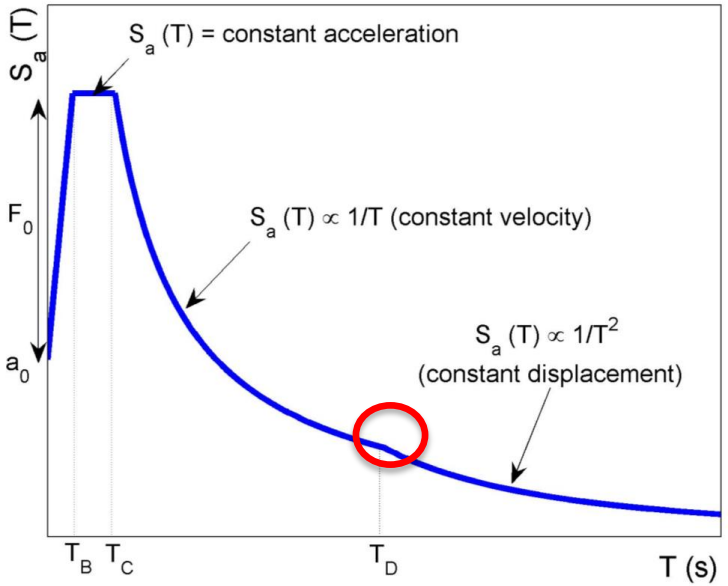




Constant Velocity Corner Period (T_C) (Current EC8 = 0.4 s – Type 1 0 .25 – Type 2)

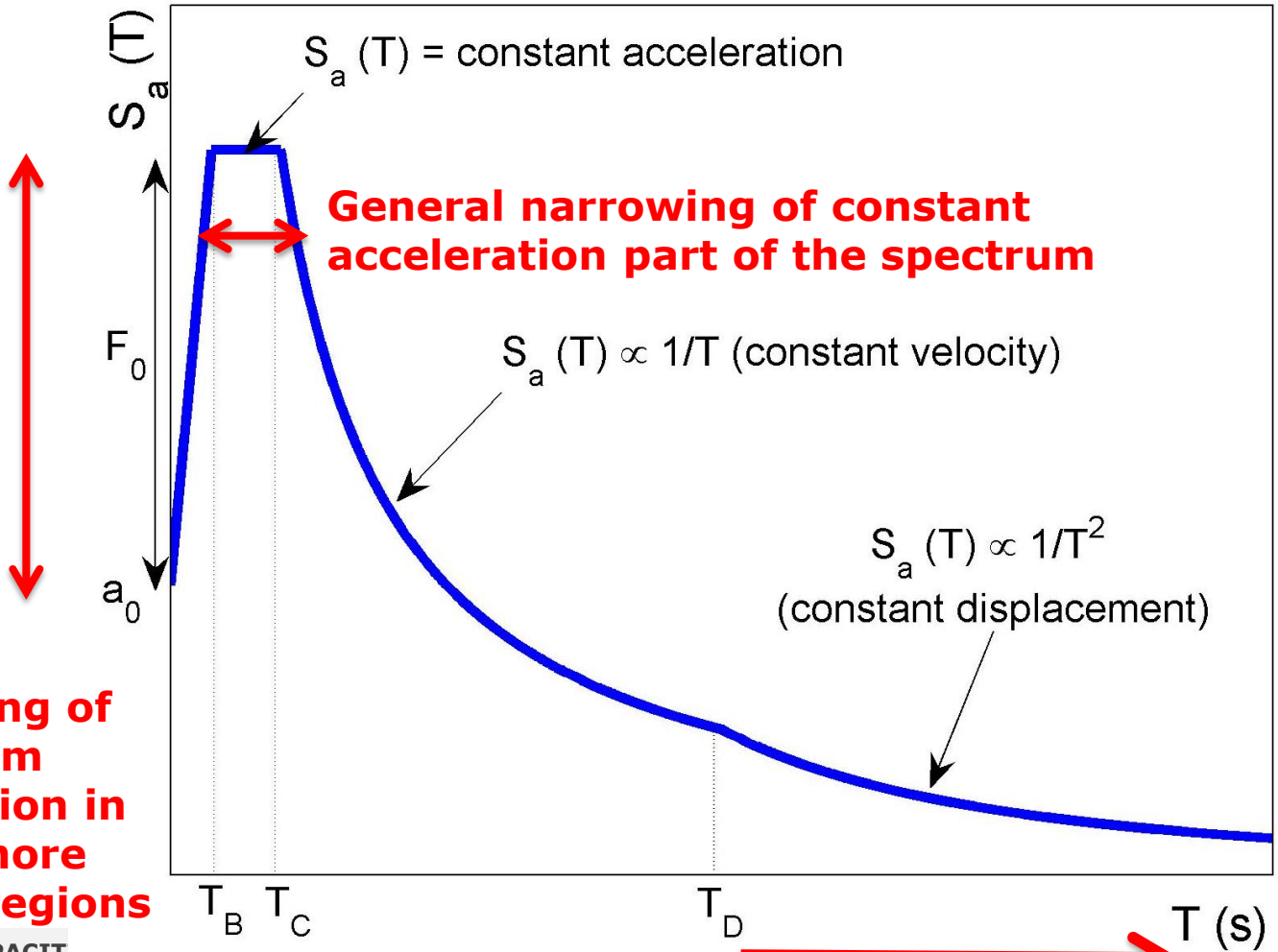
Regional Variation in Spectral Shape





Constant Displacement Corner Period (T_D) (Currently EC8: 2.0 s – Type 1 1.2 s – Type 2)

SHARE Design Spectra – General Trends



Slight flattening of spectrum (reduction in F_0) in more active regions

T_D shifting toward longer periods

"*k-value*": Usage and Implications

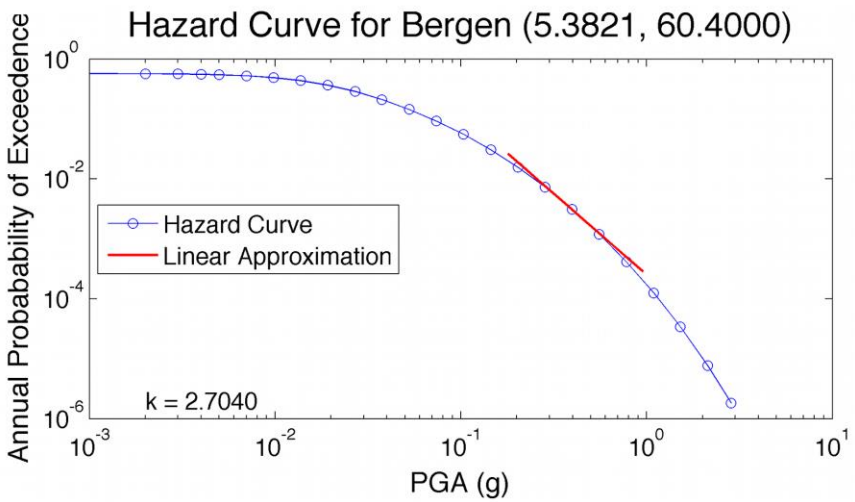
"At most sites the annual rate of exceedance, $H(a_{gR})$, of the reference peak ground acceleration a_{gR} may be taken to vary with a_{gR} as:

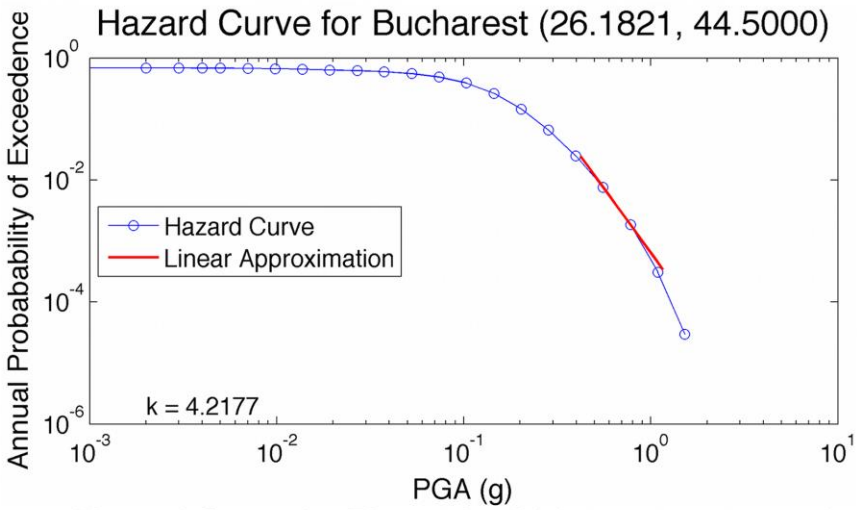
$$H(a_{gR}) \sim k_0 \, a_{gR}^{-k},$$

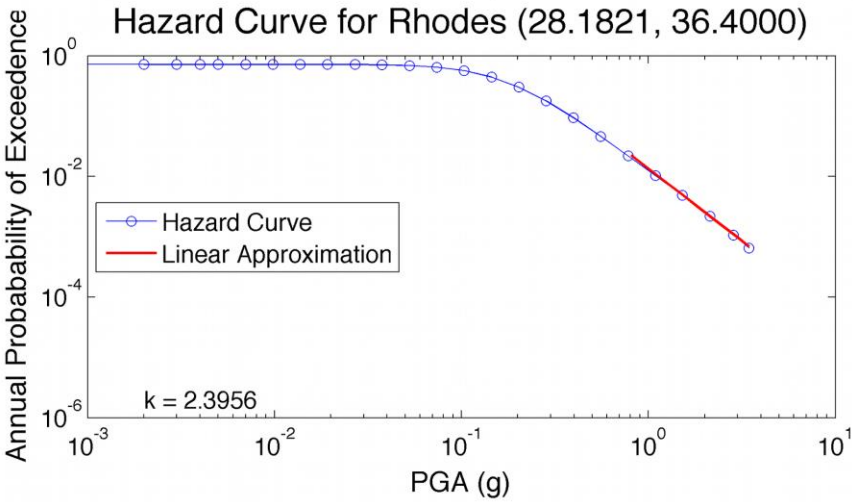
with the value of the exponent k depending on seismicity, but being generally of the order of 3"

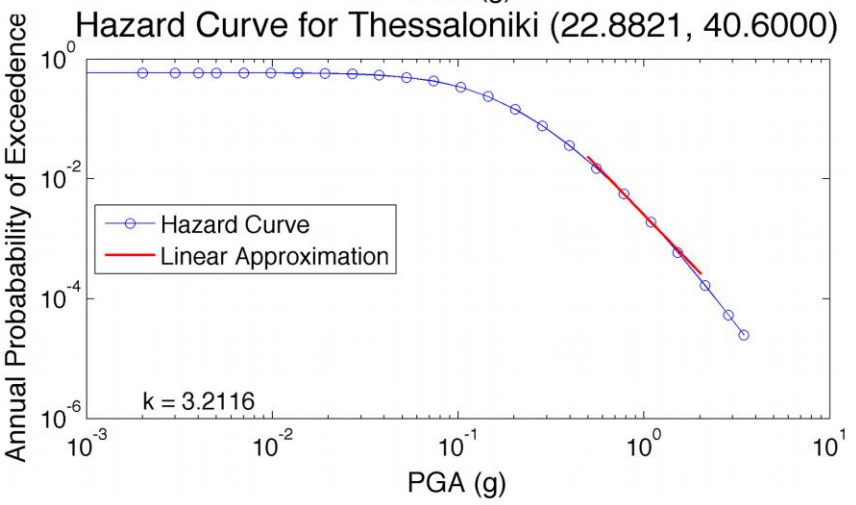
- *Allows for scaling to different performance levels and adjustment of the importance factor*
- *Why 3?*
- *Over what return periods is this approximation valid?*

"*k-value*": Usage and Implications

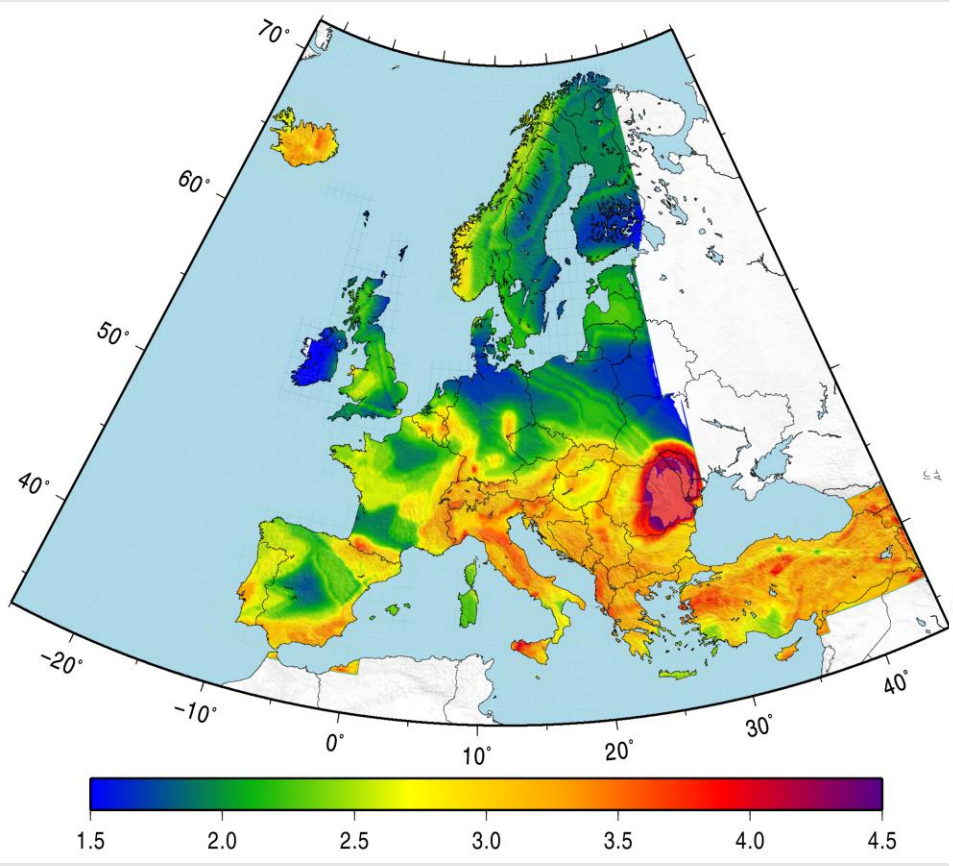




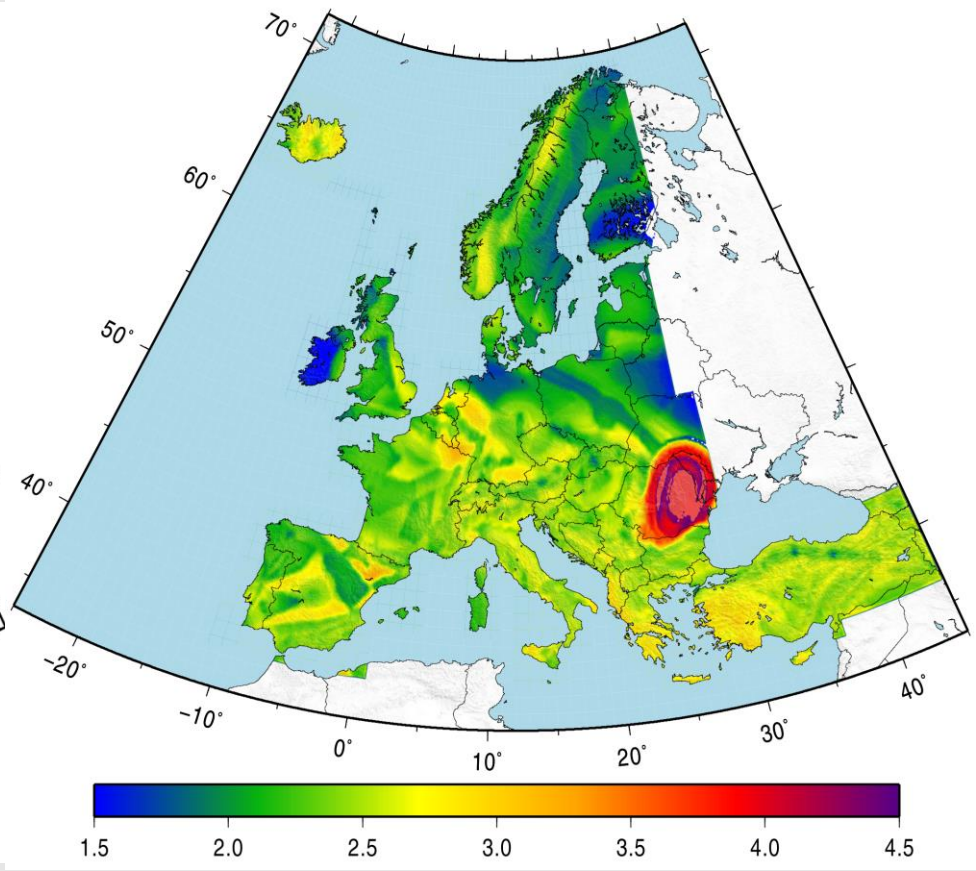




k-value Across Europe



K-value fit to Peak Ground Acceleration (PGA)



K-value fit to 1-second Spectral Acceleration

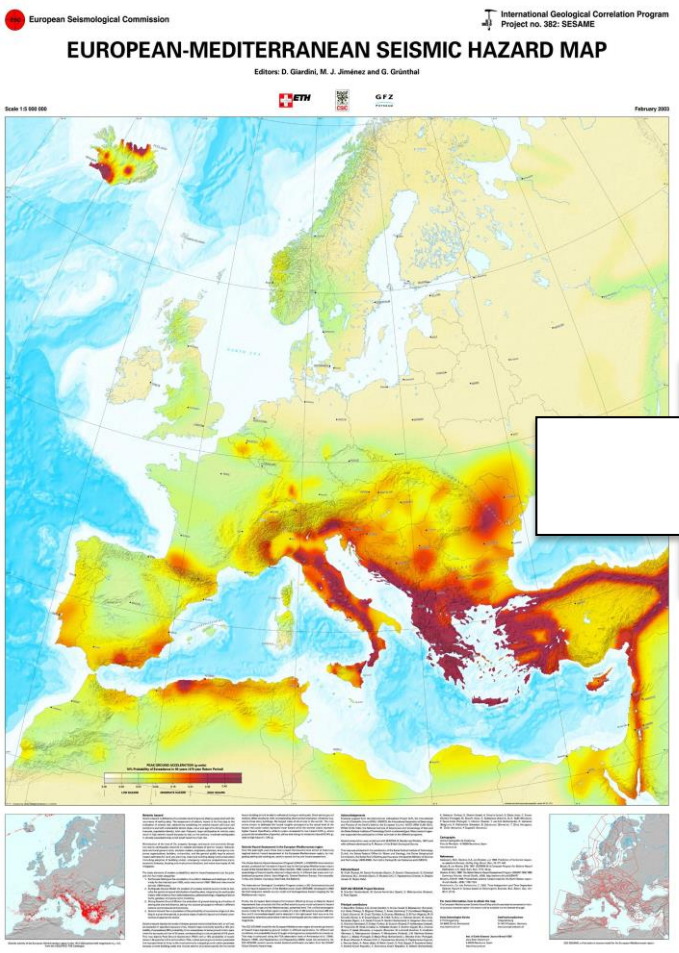
Summary

- *SHARE Project* **successfully delivered** *a pan-European Model*
- ***Compilation of harmonized databases*** *of all parameters required for PSHA*
- *Adoption of* ***rigorous, standardized*** *procedures in all steps of the process*
- ***Full accounting*** *of epistemic uncertainties for model components and hazard results*
- *Full* ***transparency*** *and* ***open availability*** *of all data, results, and methods*
- ***Multidisciplinary approach****, relying on input from all branches of earthquake science and engineering*
- *Ensured the definition of* ***proper output specifications*** *relevant for* ***Eurocode 8***

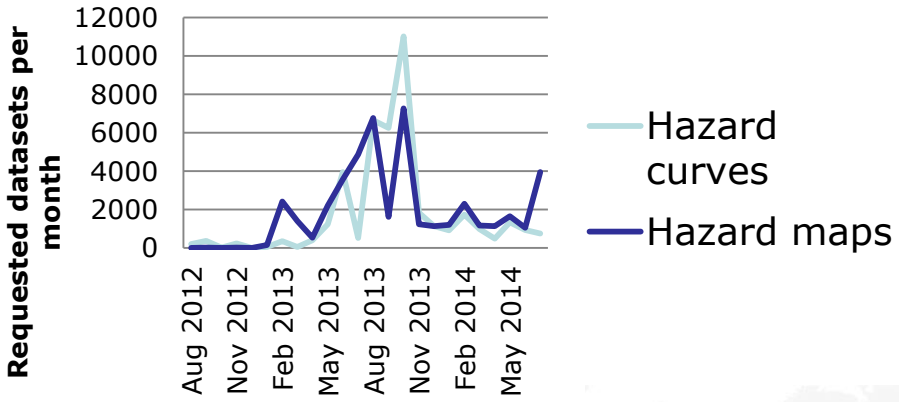
ESHM13 – Pathway to Eurocodes

- *Improvement and Acceptance of ESHM13*
  - **Investigation of factors causing differences between ESHM13 and existing models**
  - **Updates and improvements at local level – further contribution from local scientists**
- *Revision and Version Control*
- *Application in local/regional risk studies*
  - **Comparison with losses from previous models**

Availability



EFEHR data shippings



European Facility for Earthquake Hazard and Risk:

www.efehr.org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P.Henshaw
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A.Carvalho
G.Grünthal
A.C.Costa
F.Donat
L.Sousa
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Crowley
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V.Sevilgen
J.Douglas
S.Barba
S.Vilanova
F.Coelho
G.Marmureanu
J.Wössner
M.Stucchi
C.Bosse
R.Stein
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S.Hiemer
B.Wyss
S.Wiemer
E.Mustafa
D.Stromeyer
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Thank you!