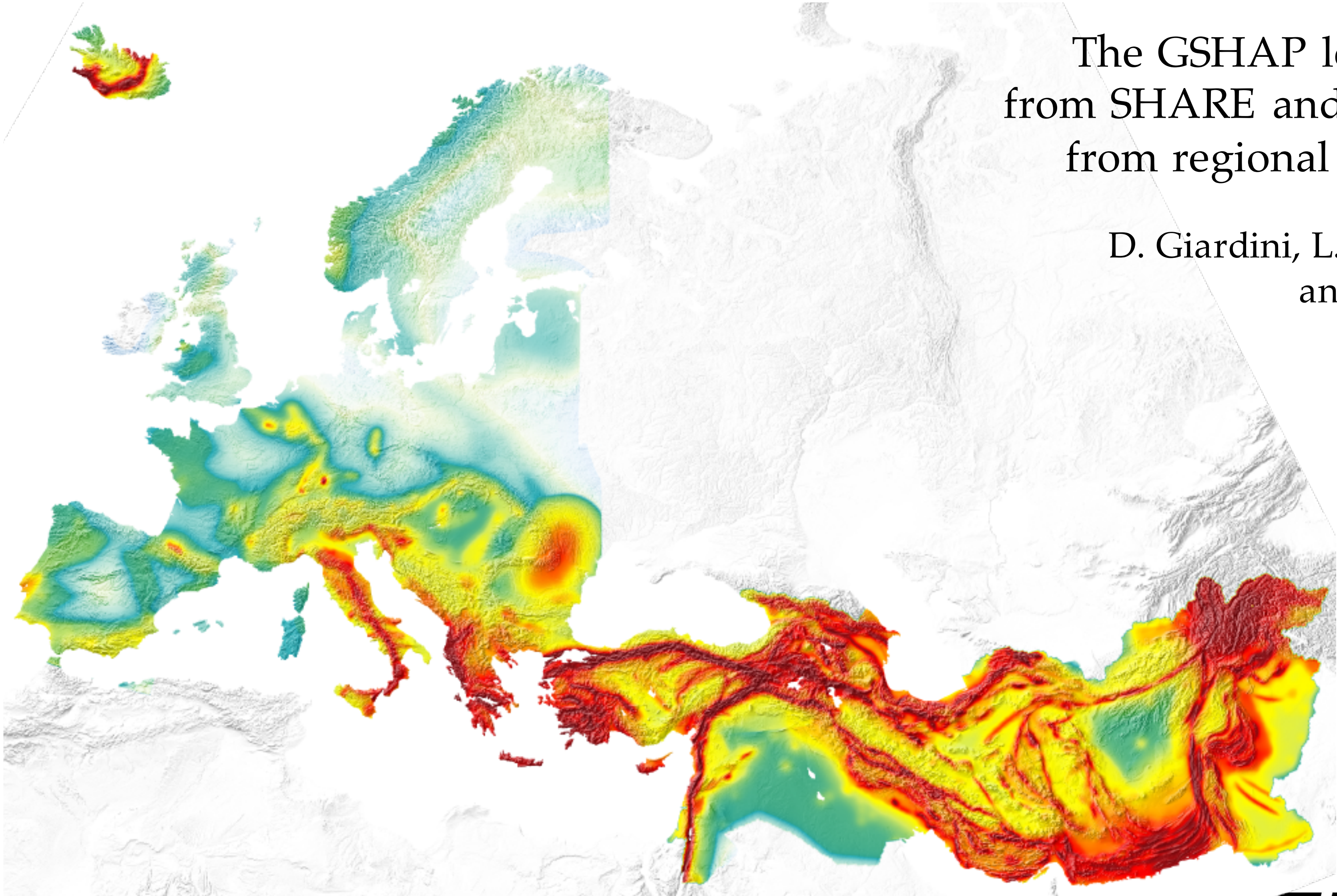
The GSHAP legacy and lessons from SHARE and EMME: learning from regional and global PSHA

D. Giardini, L. Danciu, J. Woessner
and many many others

Lenzburg, 5.9.2017



SHARE

EMME
EARTHQUAKE MODEL OF
THE MIDDLE EAST REGION

ETH Zürich

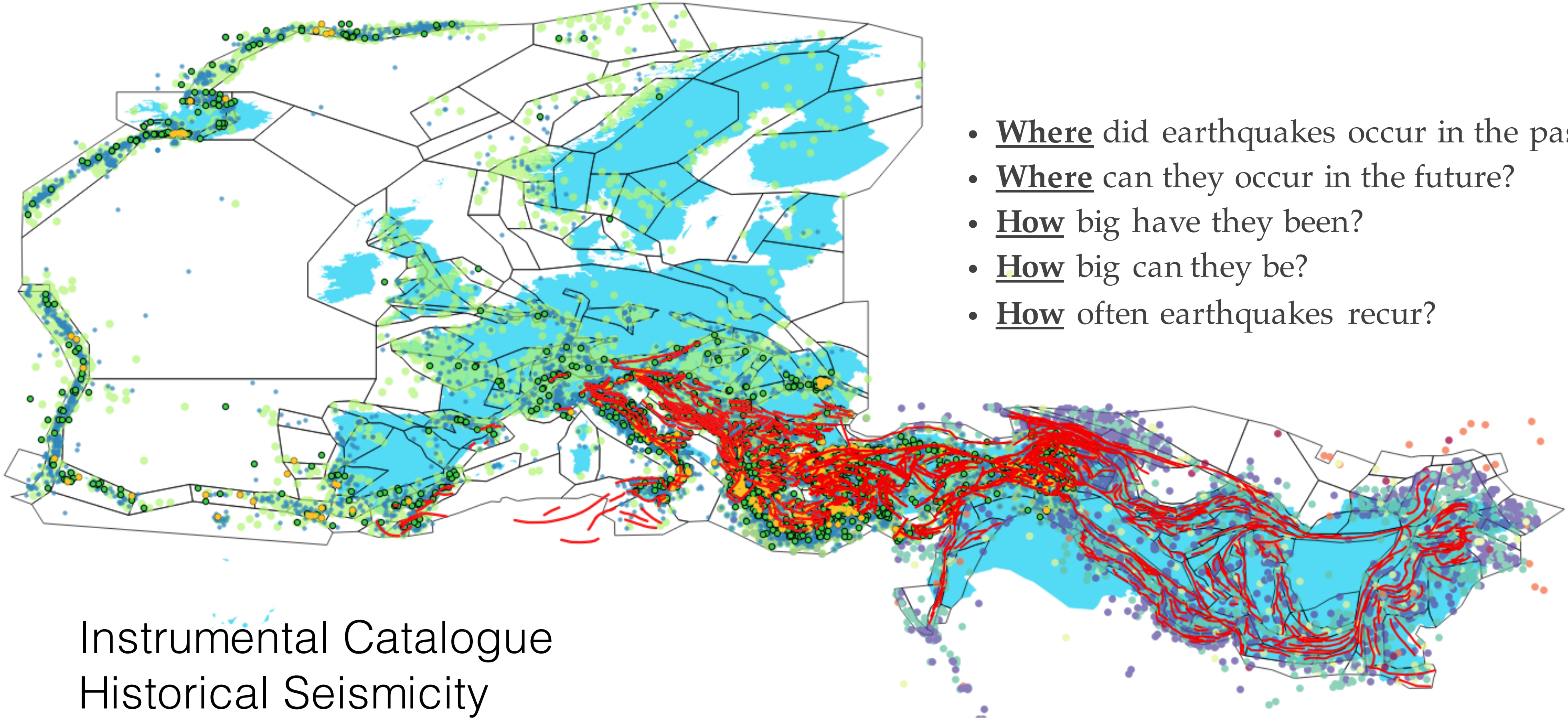
Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

Conclusions

Regional scale PSHA projects are instrumental to

- ✓ **Improve best practice (multi-disciplinary data, epistemic uncertainties, expert elicitation, engineering requirements ...)**
- ✓ **Harmonize across areas of common seismic characteristics**
- ✓ **Ensure the participation of the larger community, across disciplinary and country boundaries**
- ✓ **Provide a needed framework to improve the technical quality of national and local models**
- ✓ **Enable hypothesis testing**
- ✓ **Identify areas of future work**
- ✓ **Provide a cooperation framework across an entire region**

Step I for PSHA: unified seismogenic source model



- **Where** did earthquakes occur in the past?
- **Where** can they occur in the future?
- **How** big have they been?
- **How** big can they be?
- **How** often earthquakes recur?

Instrumental Catalogue
Historical Seismicity
Active Faults

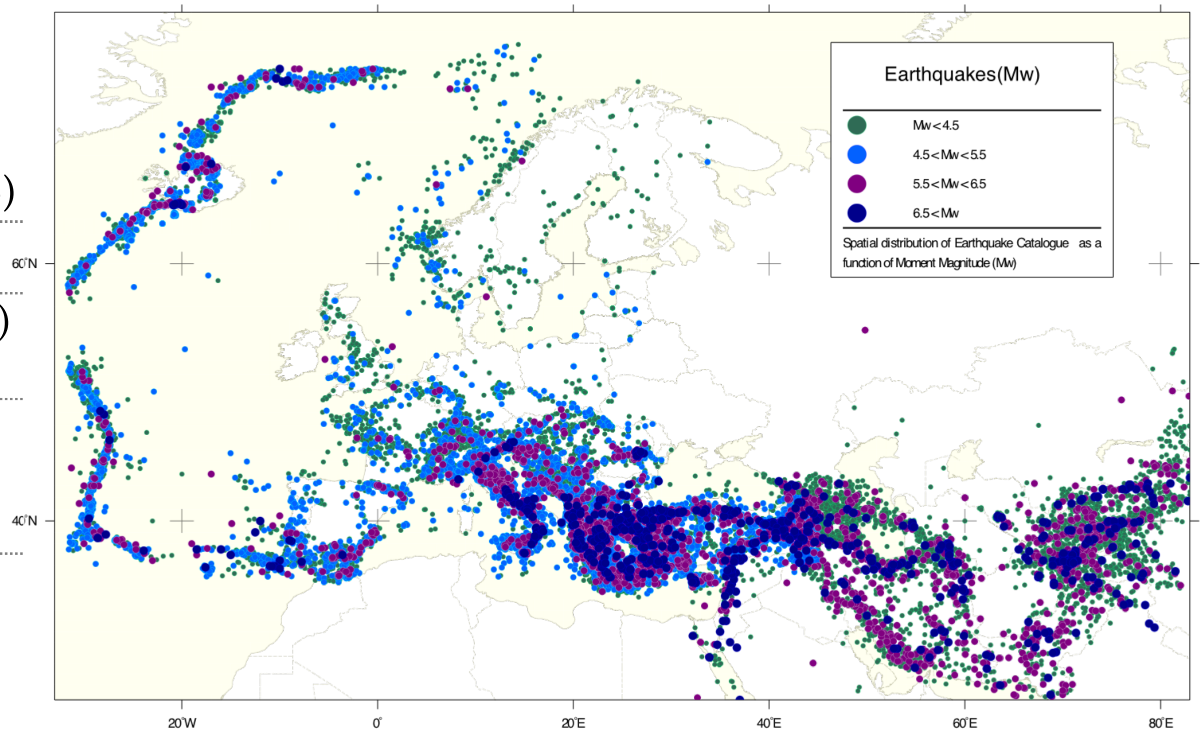
Instrumental and historical seismic catalogues

Homogeneous (Mw >3.5)

Total: 30000 Events

Historical part: (SHEEC) 1000-1899

Early and modern instrumental (EMEC) 1900-2006



Homogeneous (Mw > 4.0)

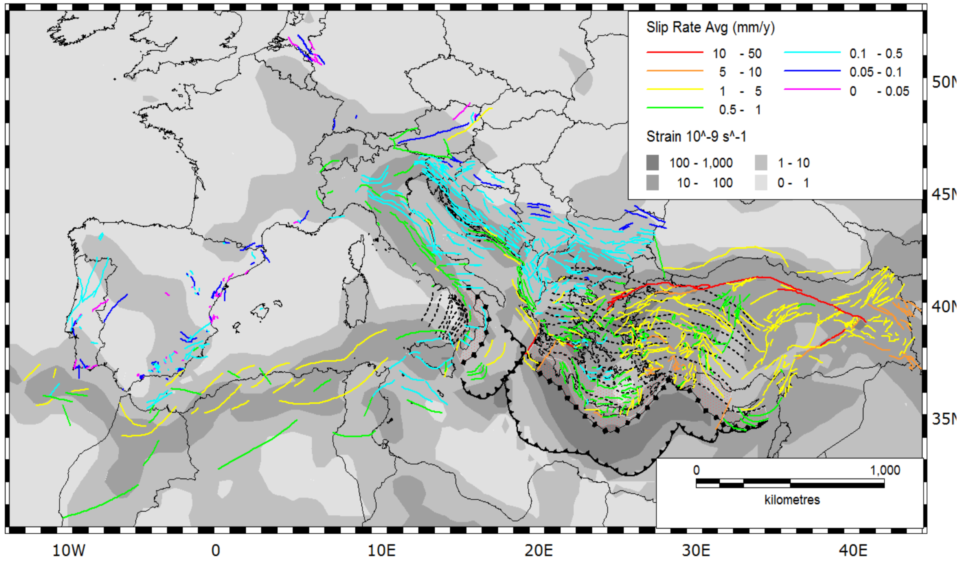
Total: 27174 Events

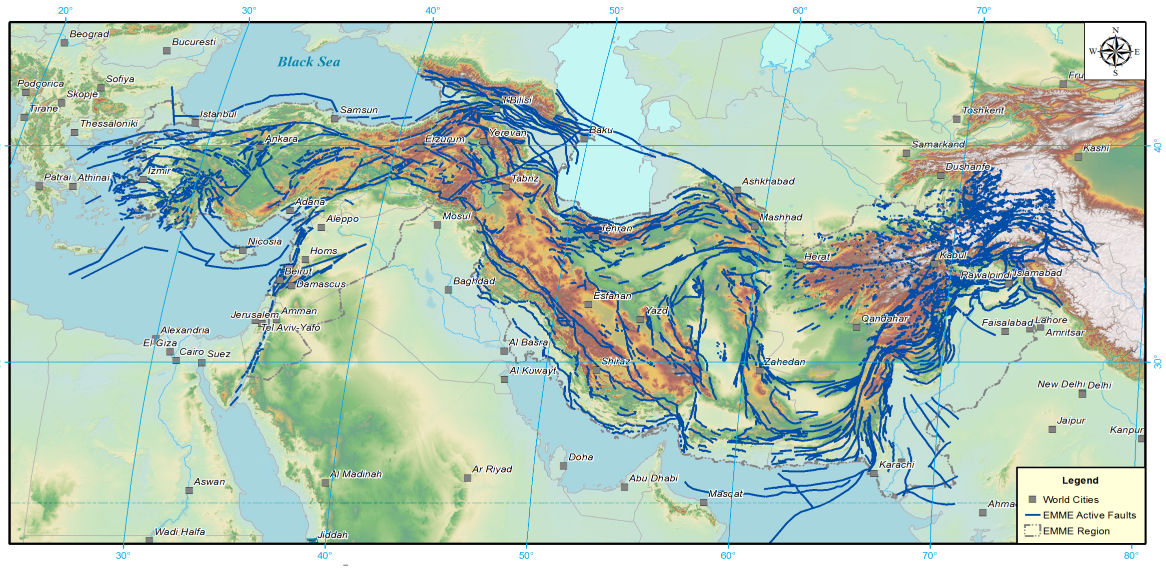
Historical part (< 1900)

Early and modern instrumental (~2006)

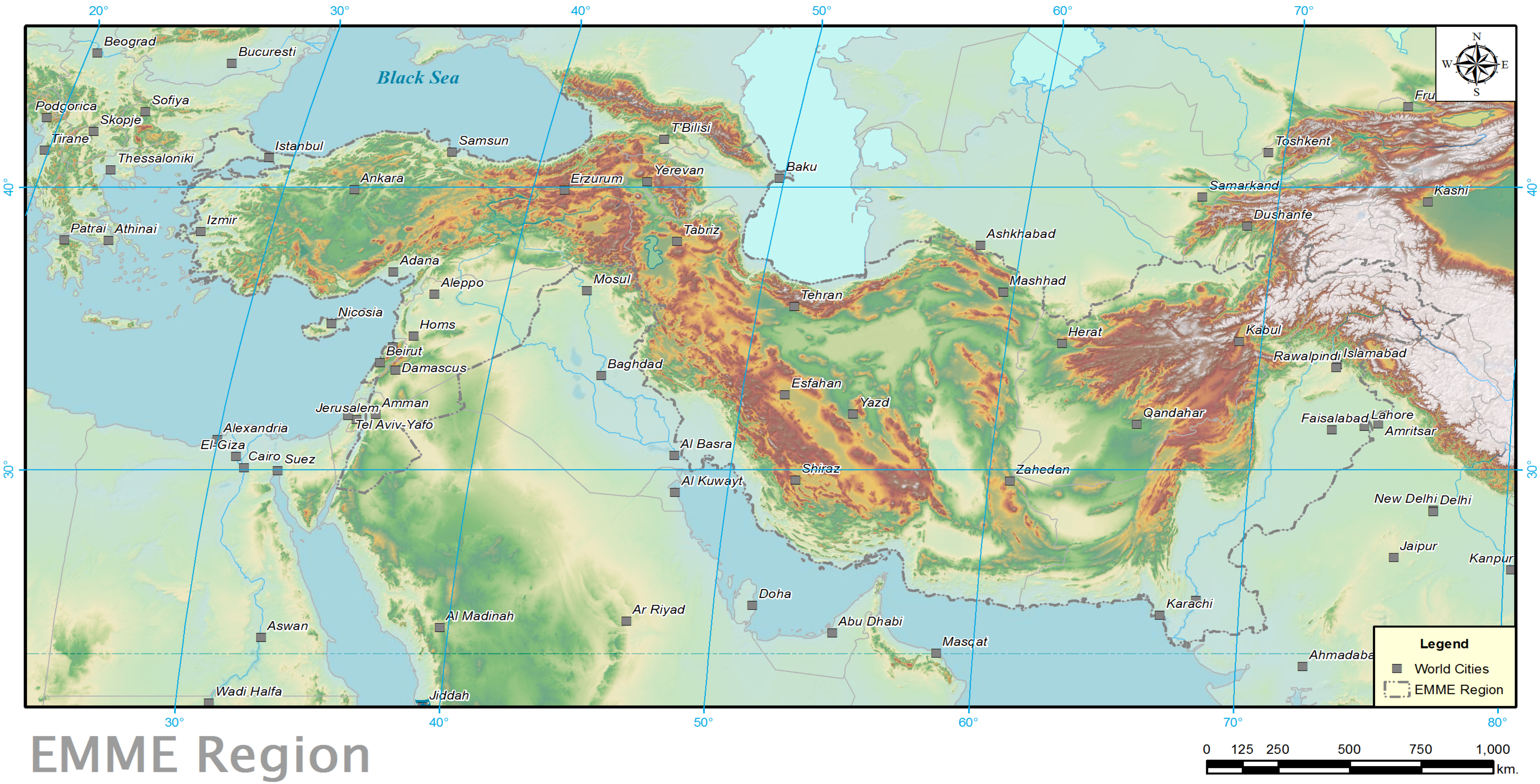
Stucchi et al., 2012 | Grünthal et al., 2012 | Giardini et al., 2013 | Zare et al., 2014

Geological database: section, segments and faults



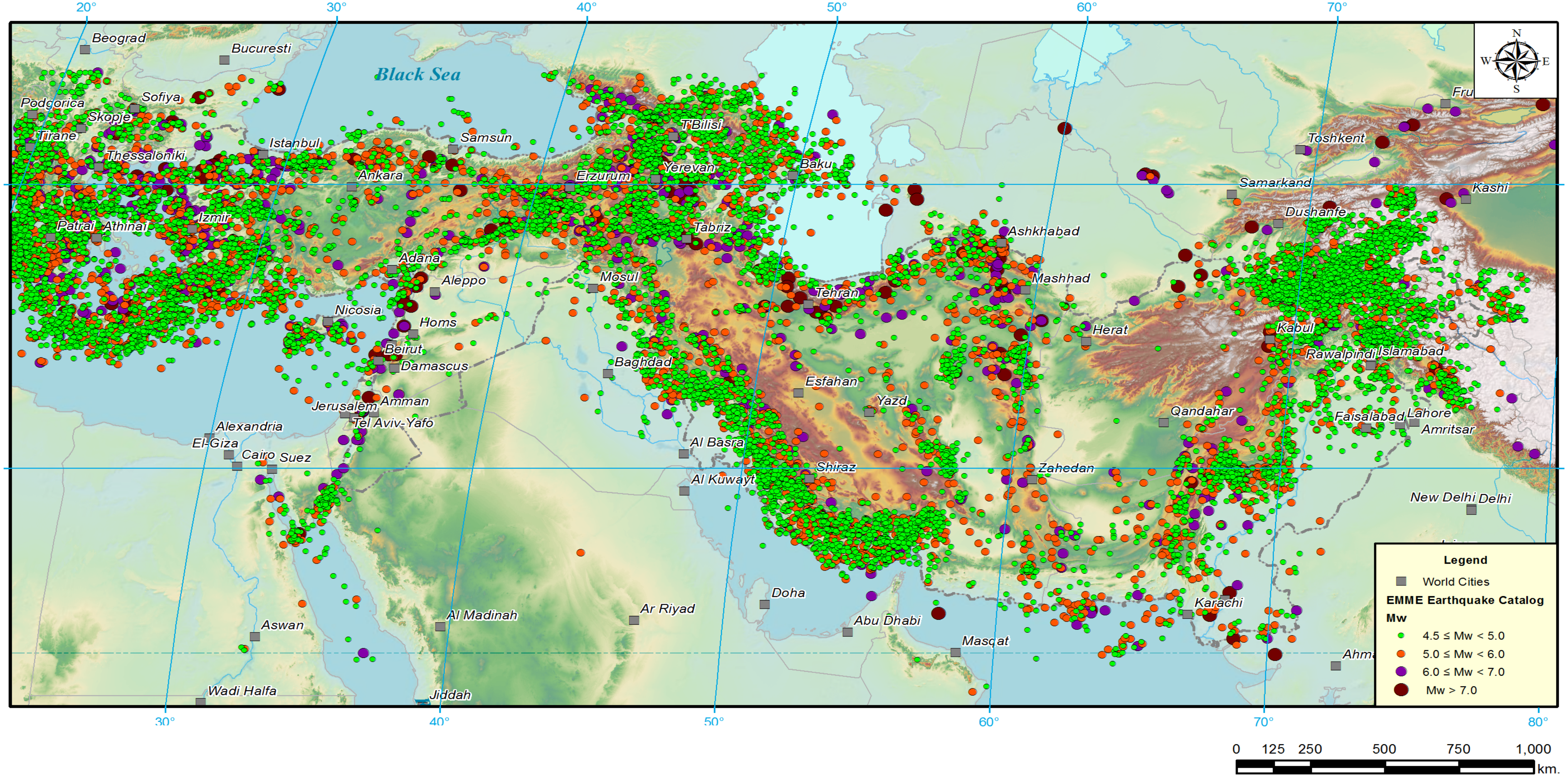


- ESHM13: 1128 data records, ~64000 km of faults
- EMME14: 3397 fault segments , total ~ 91550 km of faults



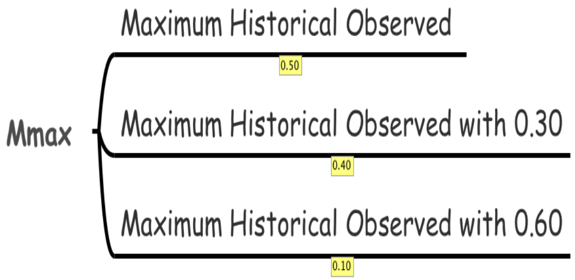
Black Sea
Beograd
Bucuresti
Podgorica
Sofiya
Skopje
Tirane
Thessaloniki
Istanbul
Samsun
T'Bilisi
Baku
Ankara
Erzurum
Yerevan
Izmir
Patrai
Athinai
Tabriz
Adana
Aleppo
Mosul
Ashkhabad
Mashhad
Tehran
Nicosia
Homs
Beirut
Damascus
Baghdad
Herat
Kabul
Rawalpindi
Islamabad
Esfahan
Yazd
Qandahar
Faisalabad
Lahore
Amritsar
Jerusalem
Amman
Tel Aviv-Yafo
Alexandria
El-Giza
Cairo
Suez
Al Basra
Al Kuwayt
Shiraz
Zahedan
Toshkent
Samarkand
Dushanbe
Kashi
New Delhi
Delhi
Jaipur
Kanpur
Doha
Abu Dhabi
Muscat
Karachi
Ahmadaba
Ar Riyad
Al Madinah
Aswan
Wadi Halfa
Jiddah
Legend
World Cities
EMME Region
20°
30°
40°
50°
60°
70°
80°
0
125
250
500
750
1,000
km.
N
S
E
W

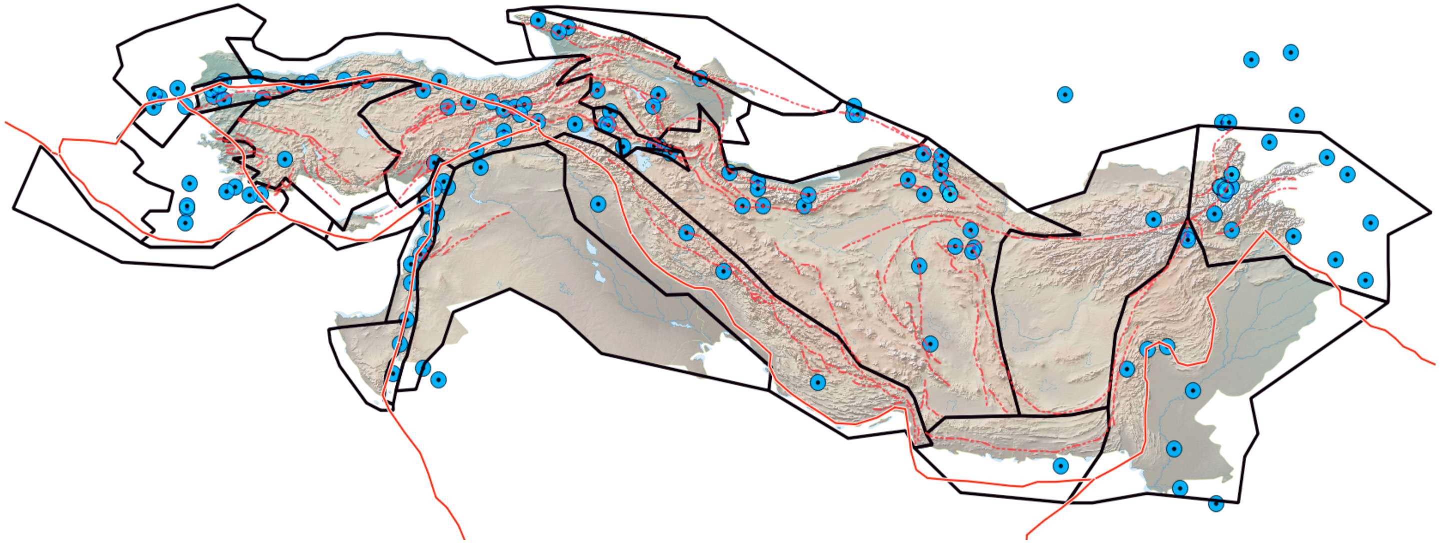
EMME Region

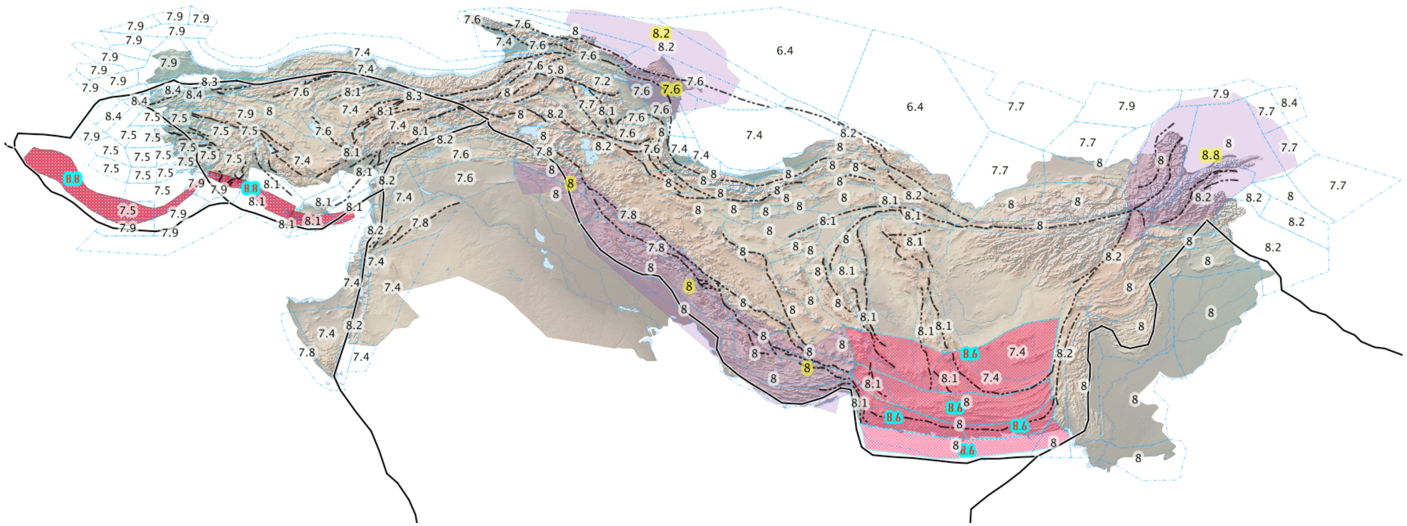


(Zare et al 2013)

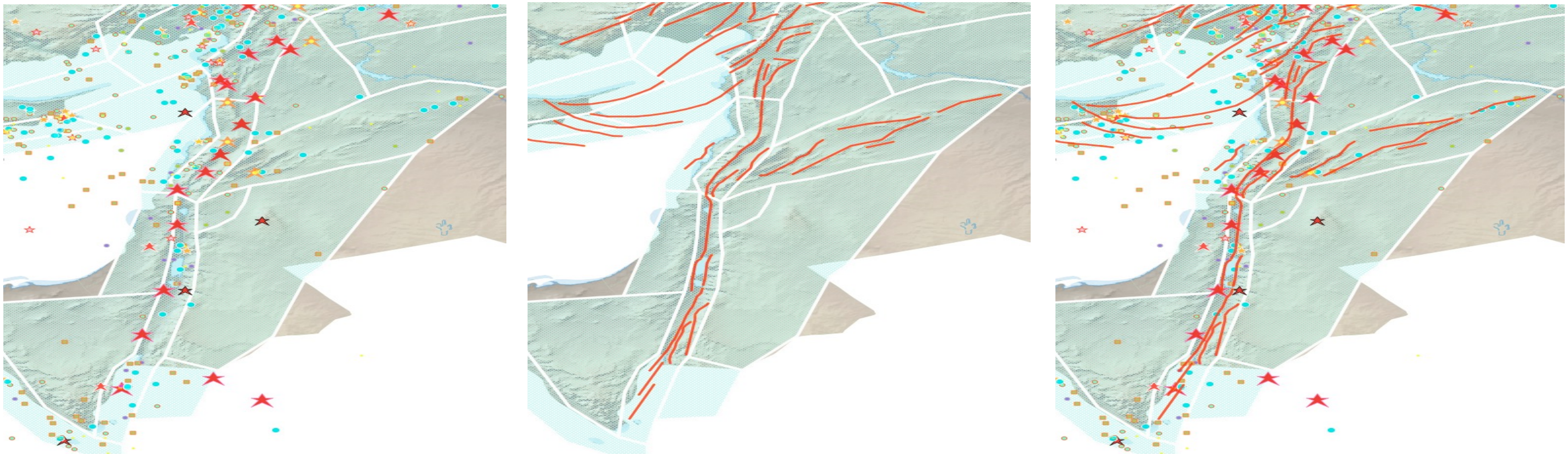
Area-source model: Mmax logic tree







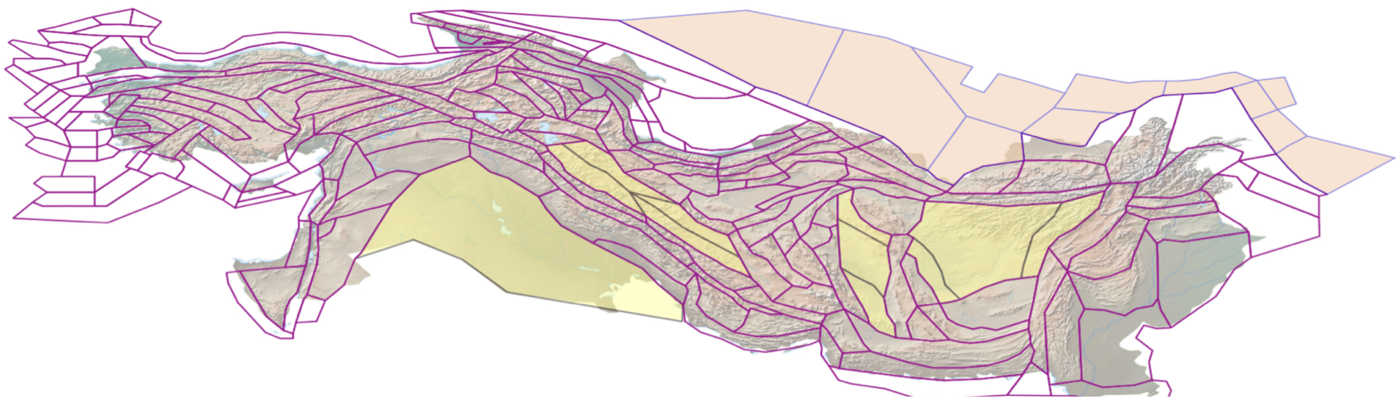
Area-source model: delineation of area-sources



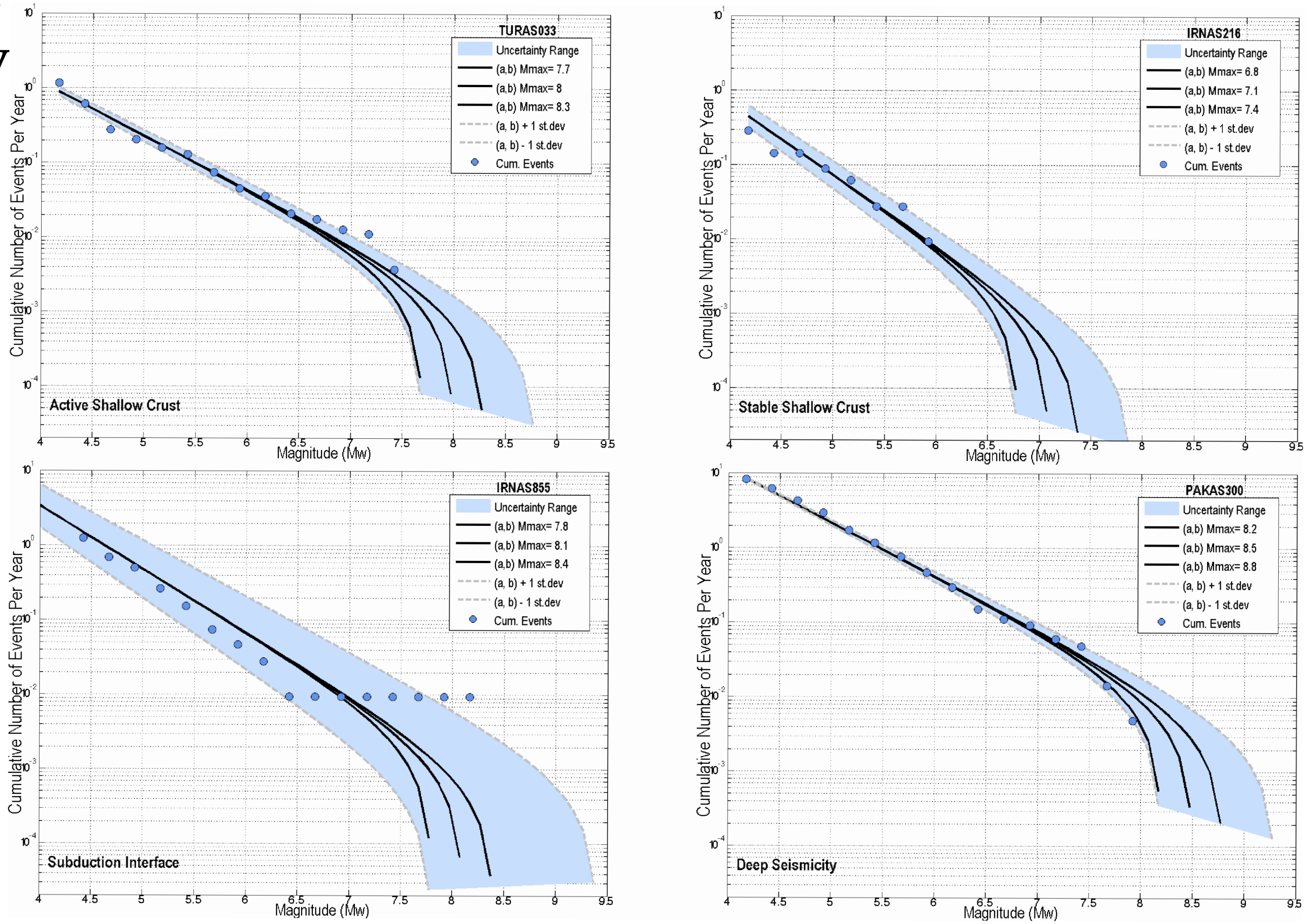
- Seismic-area source based on the tectonic findings and their correlation to seismicity
- Initially derived from seismicity patterns
- Surface projection of identified active faults (capable of generating earthquakes)

Area source model

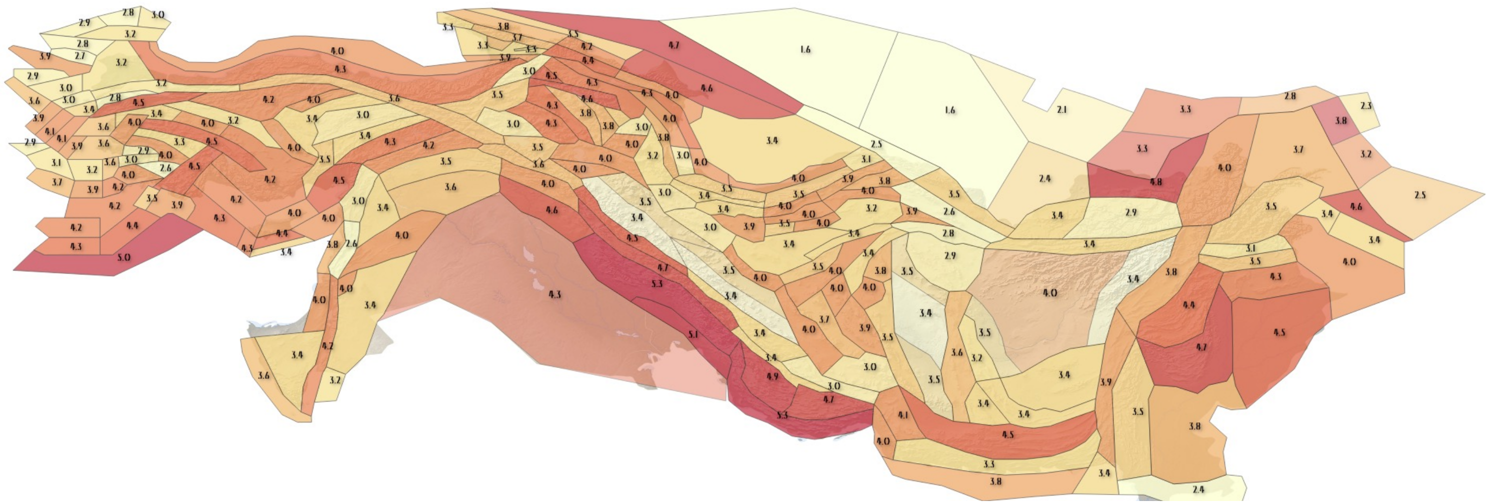
- 224 shallow
- 10 deep and inslab
- 6 interface

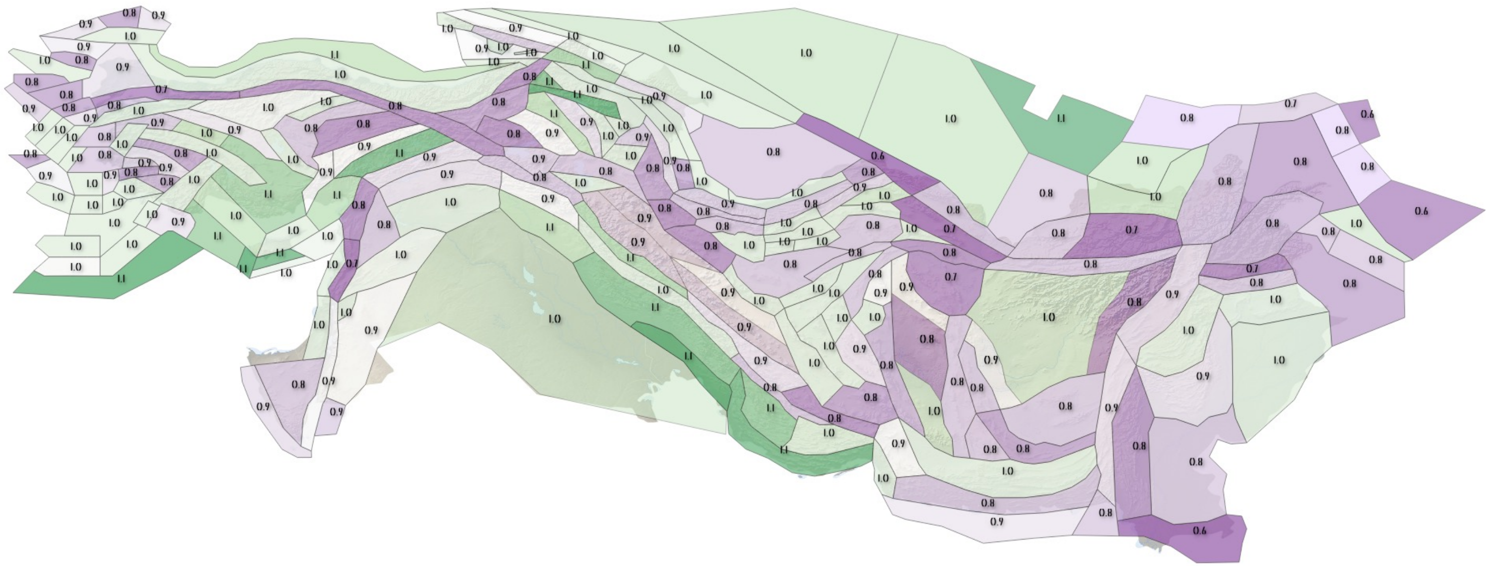


Area source model: earthquake activity rates



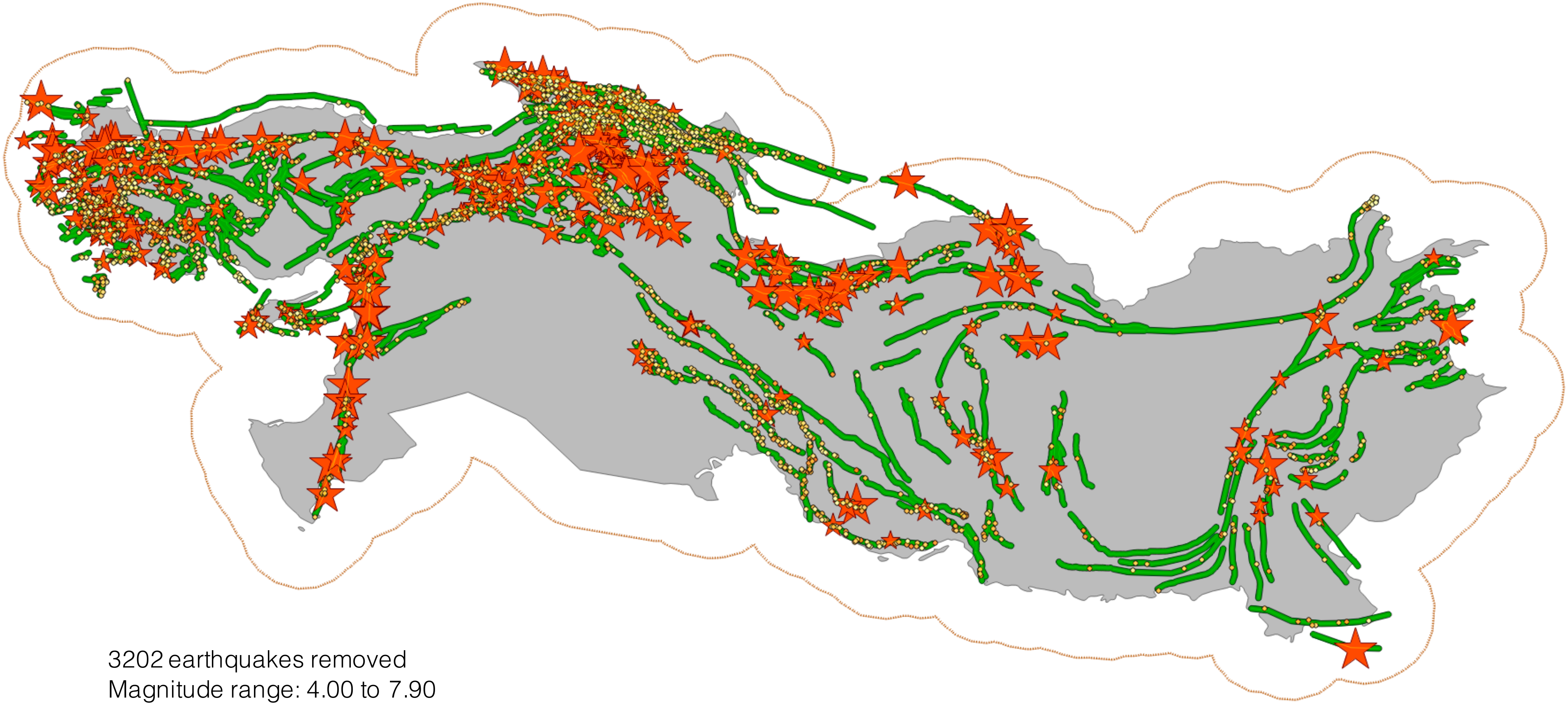
Area source model: spatial distribution of earthquake activity





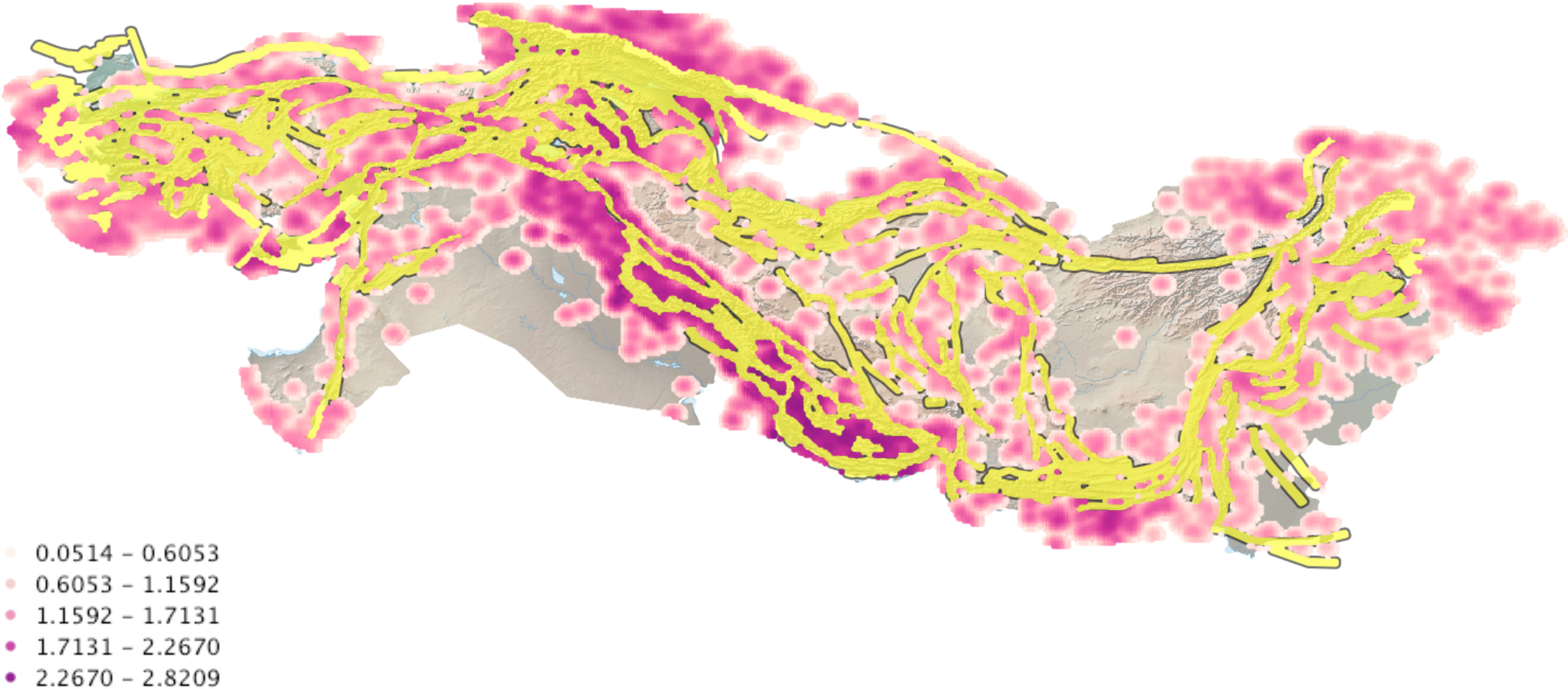
Fault model: slip rates on mapped active faults

Fault model: removed earthquake

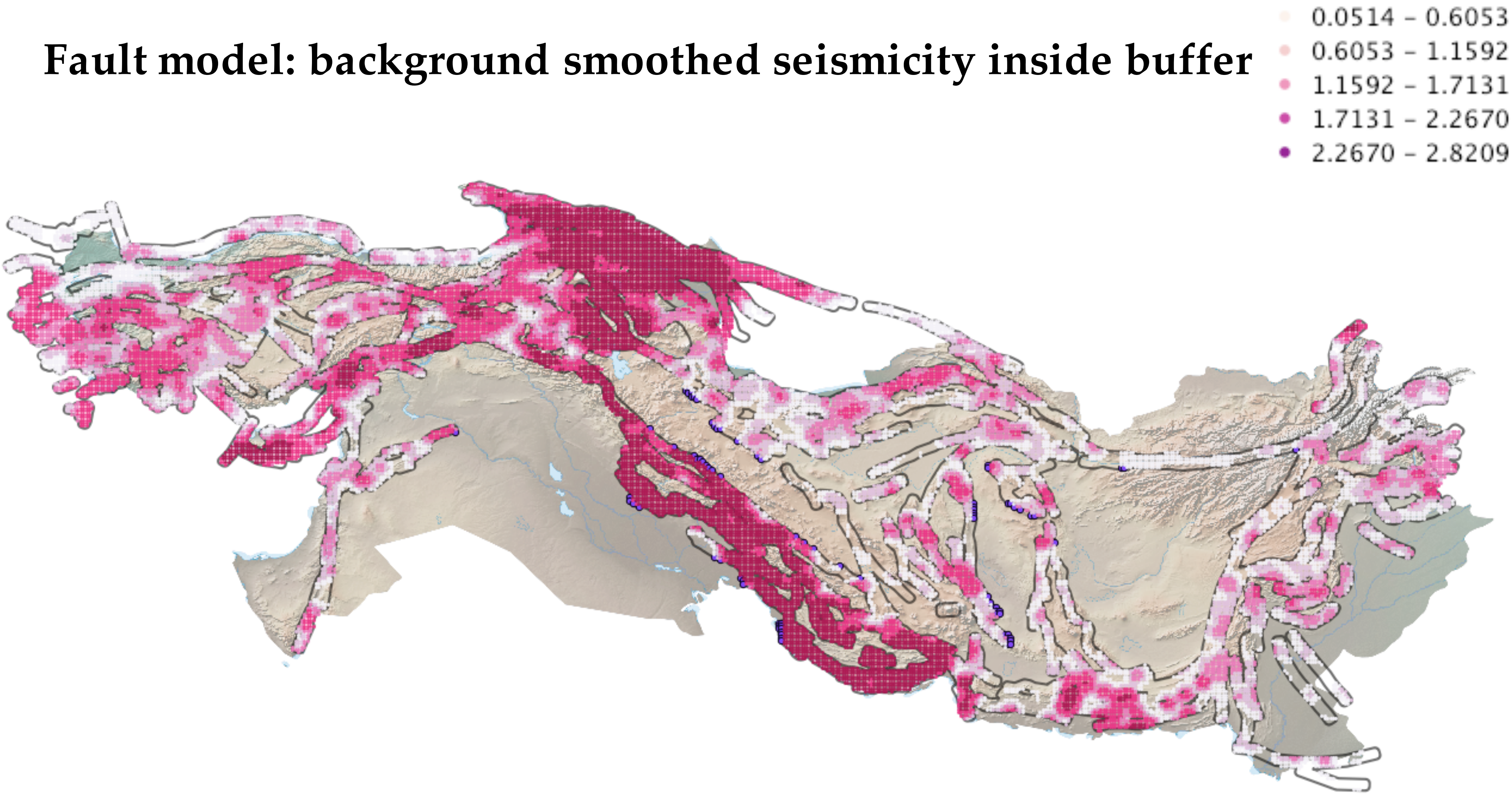


3202 earthquakes removed
Magnitude range: 4.00 to 7.90

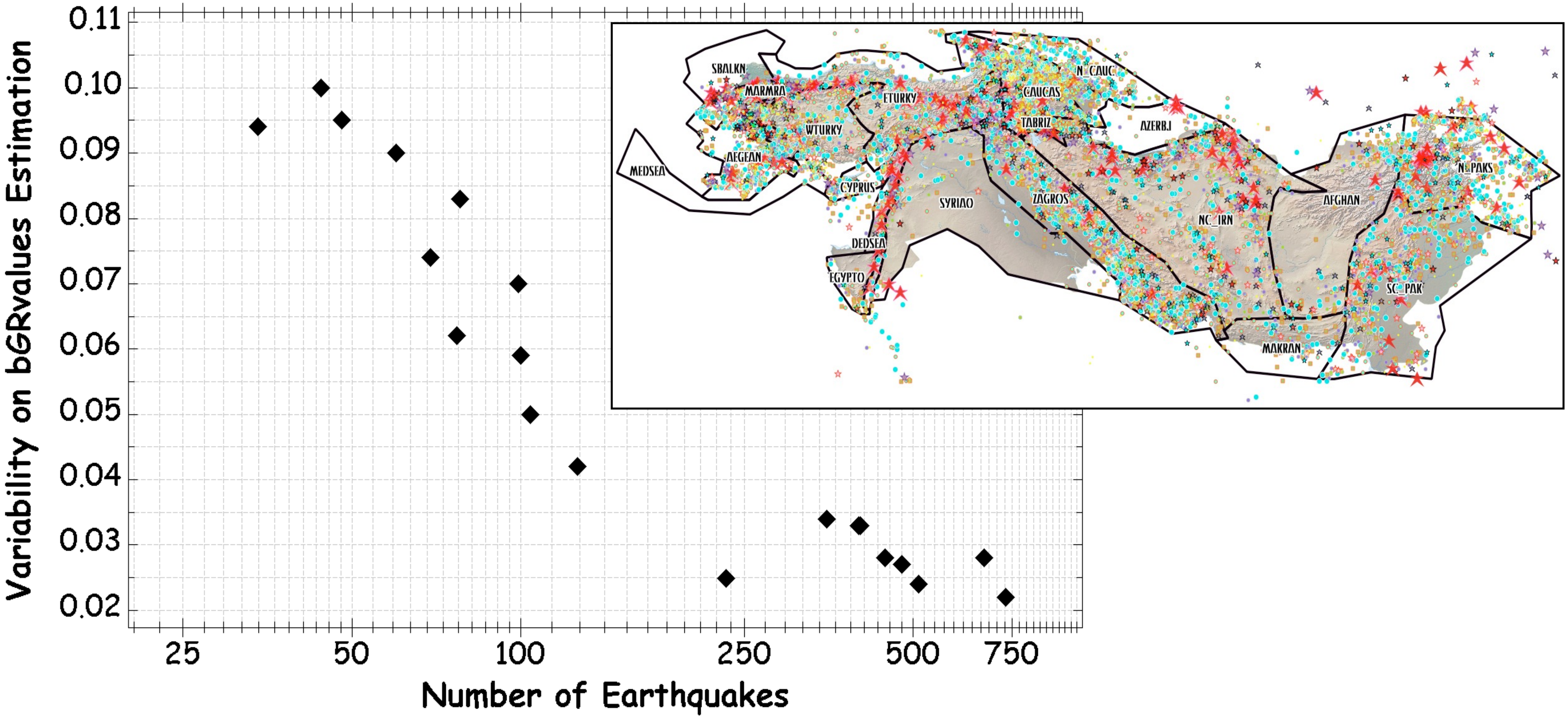
Fault model: background smoothed seismicity outside buffer



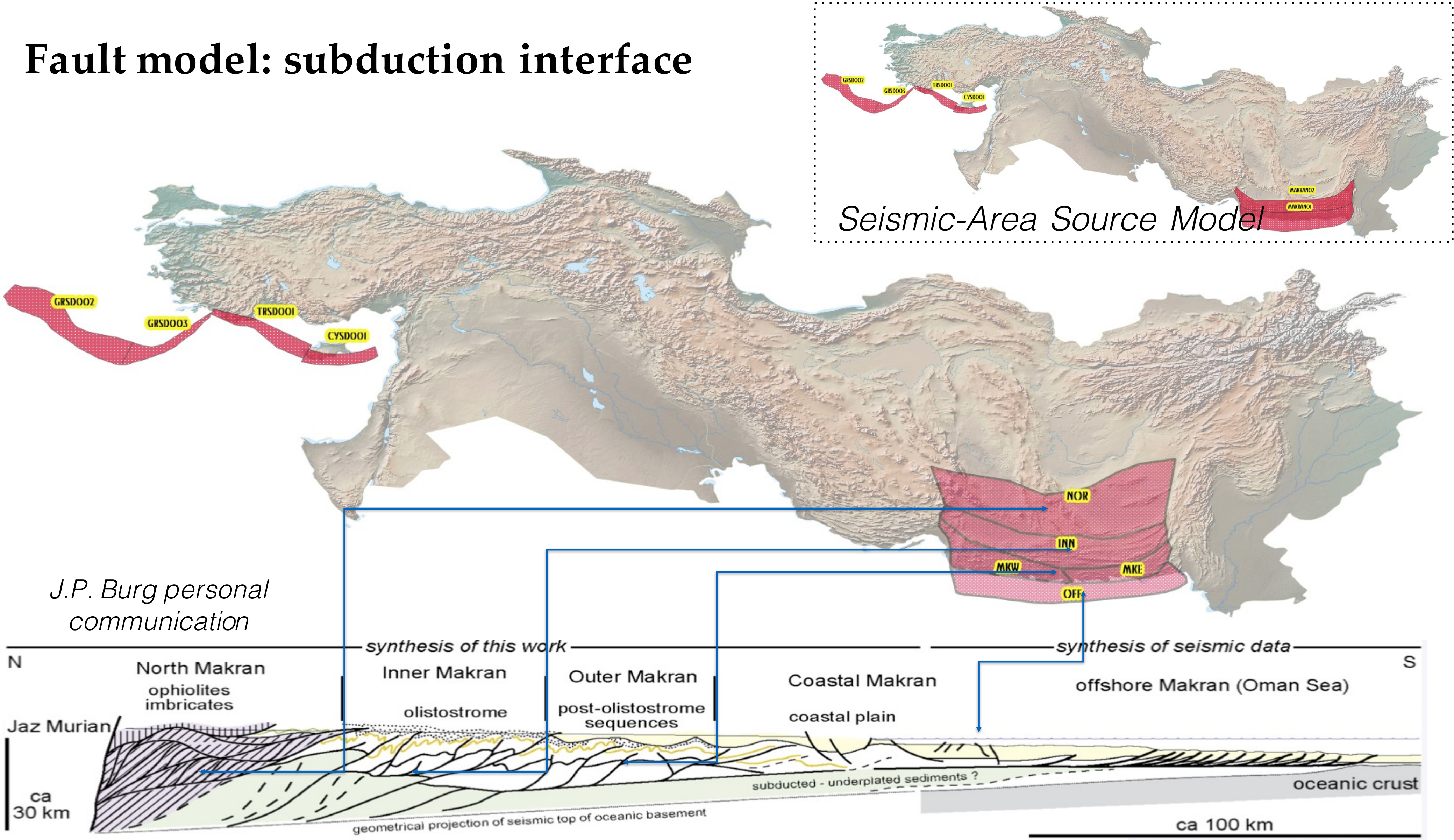
Fault model: background smoothed seismicity inside buffer



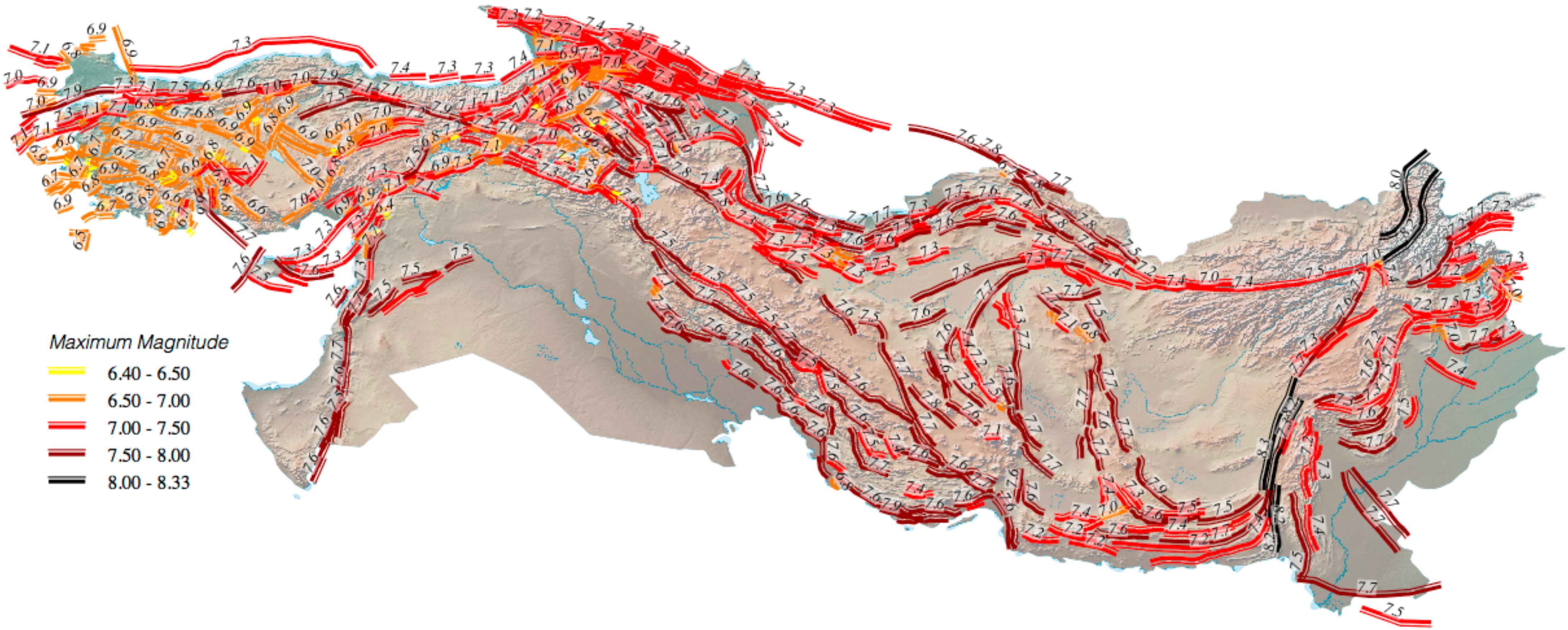
Fault model: b-values

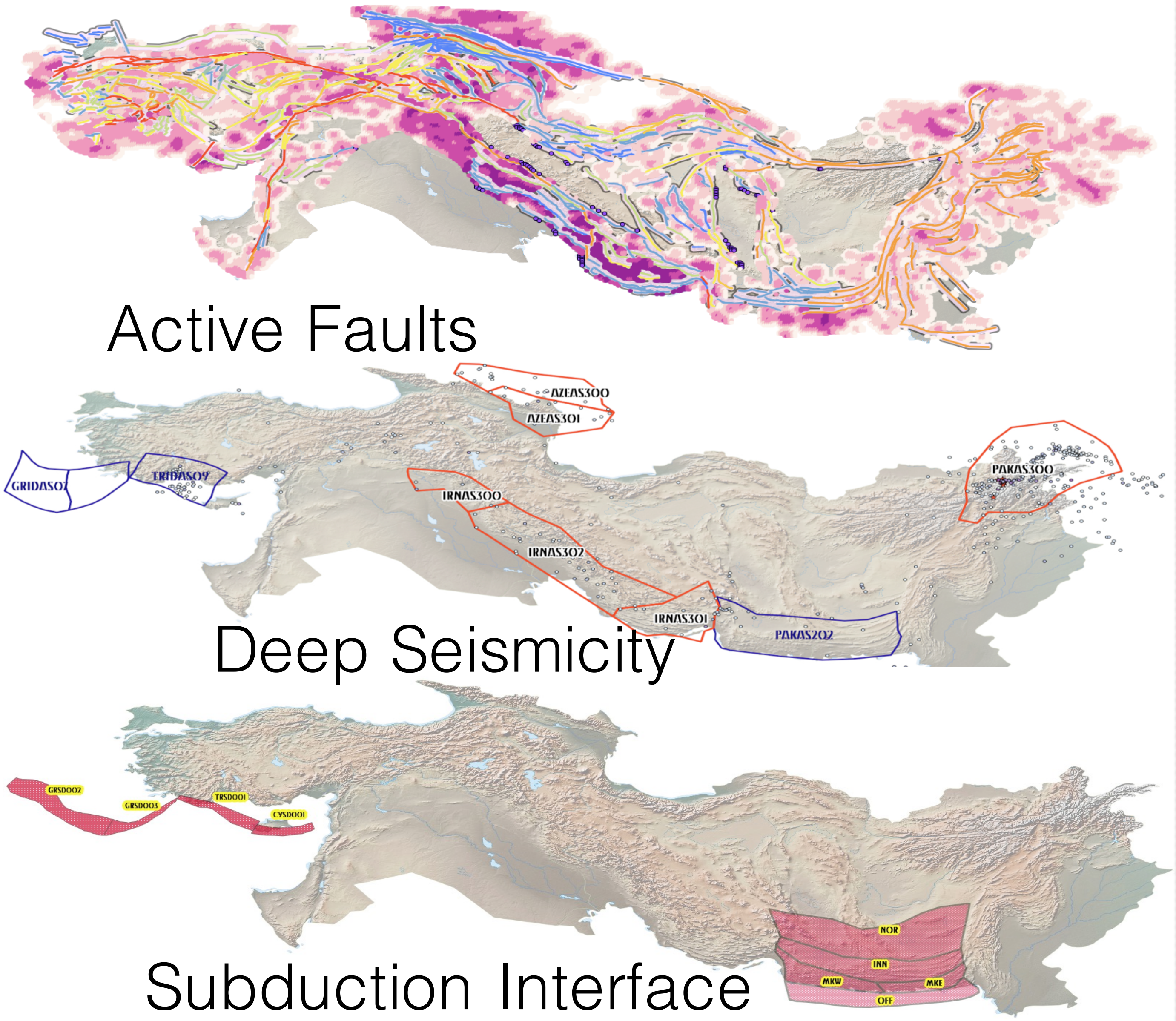


Fault model: subduction interface



Fault model: Mmax on faults





Fault Source Model

Four Source Layers

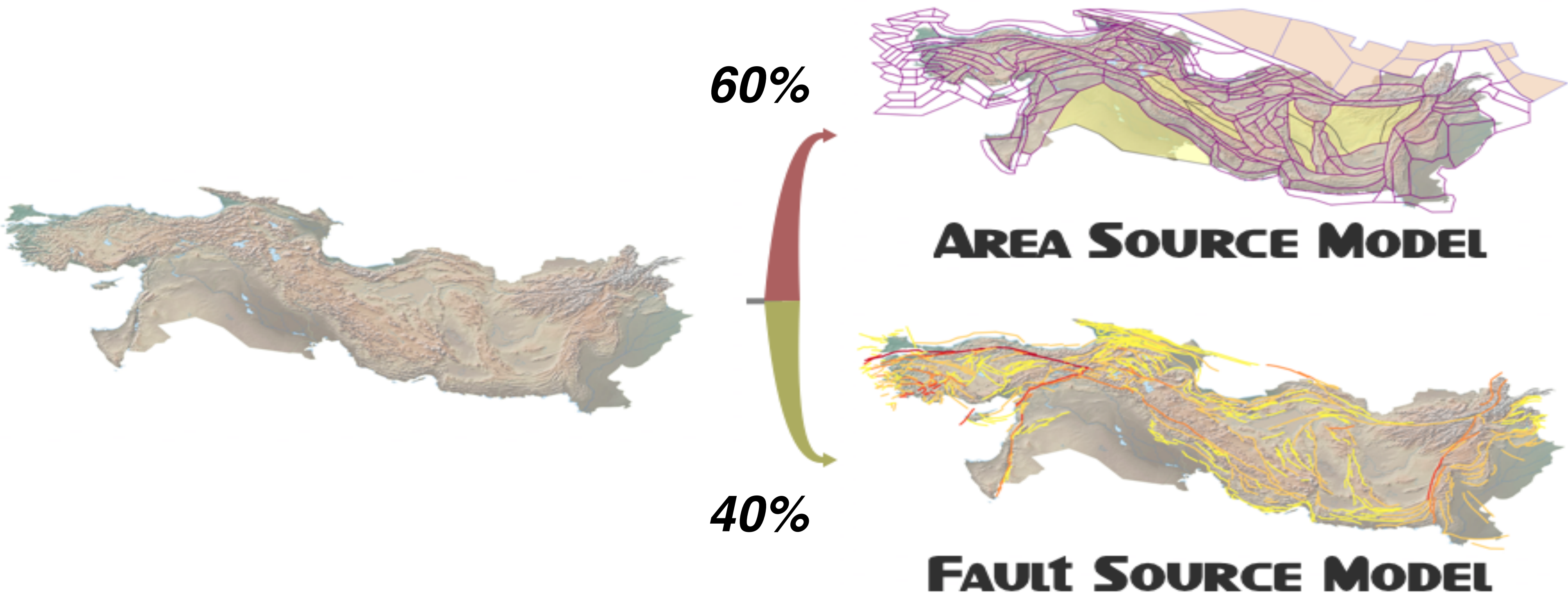
778 Active Faults

10 Deep Area-Sources

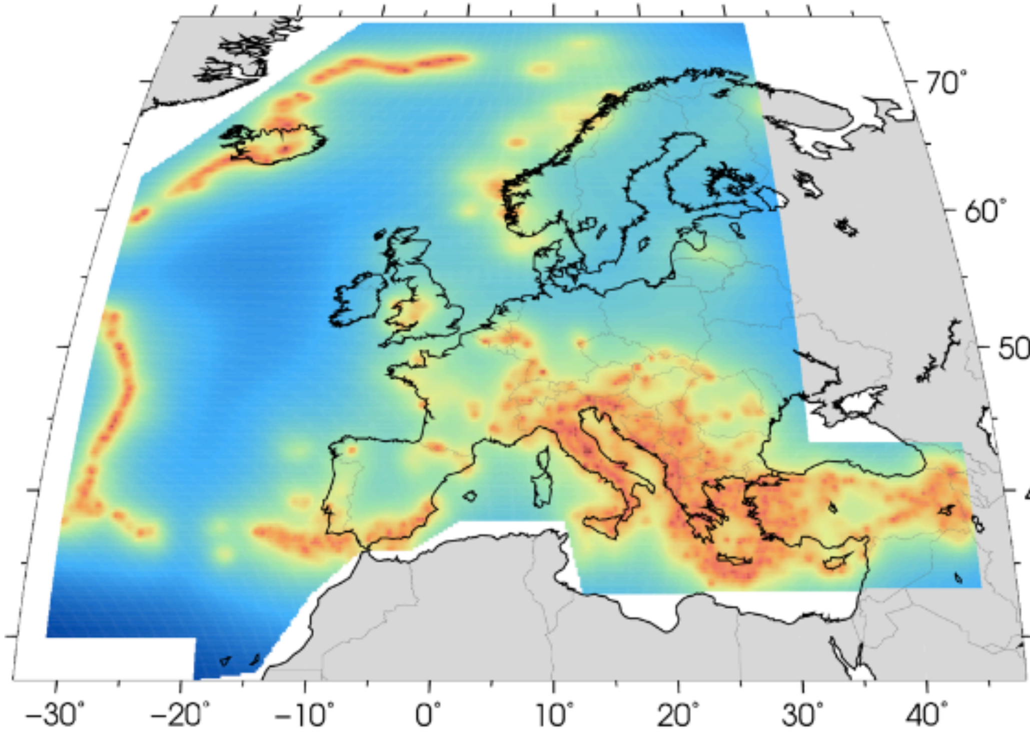
9 Interface Complex Faults

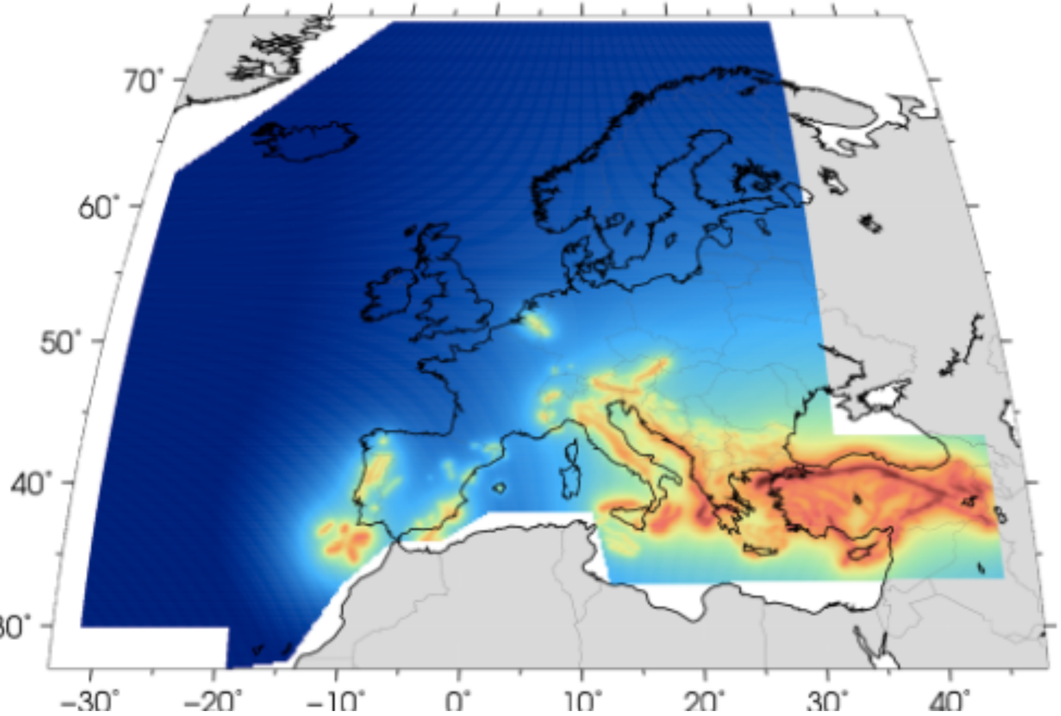
Background Seismicity

Source model logic tree



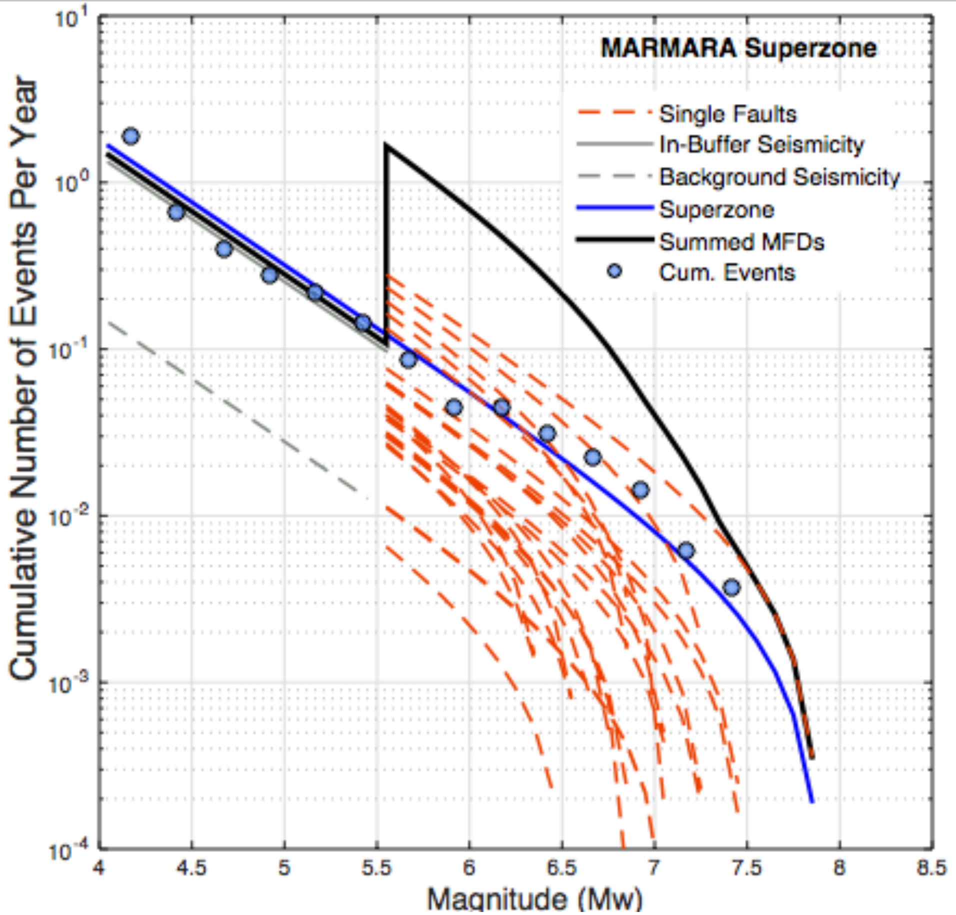
Challenge: fault data and seismicity tell different stories

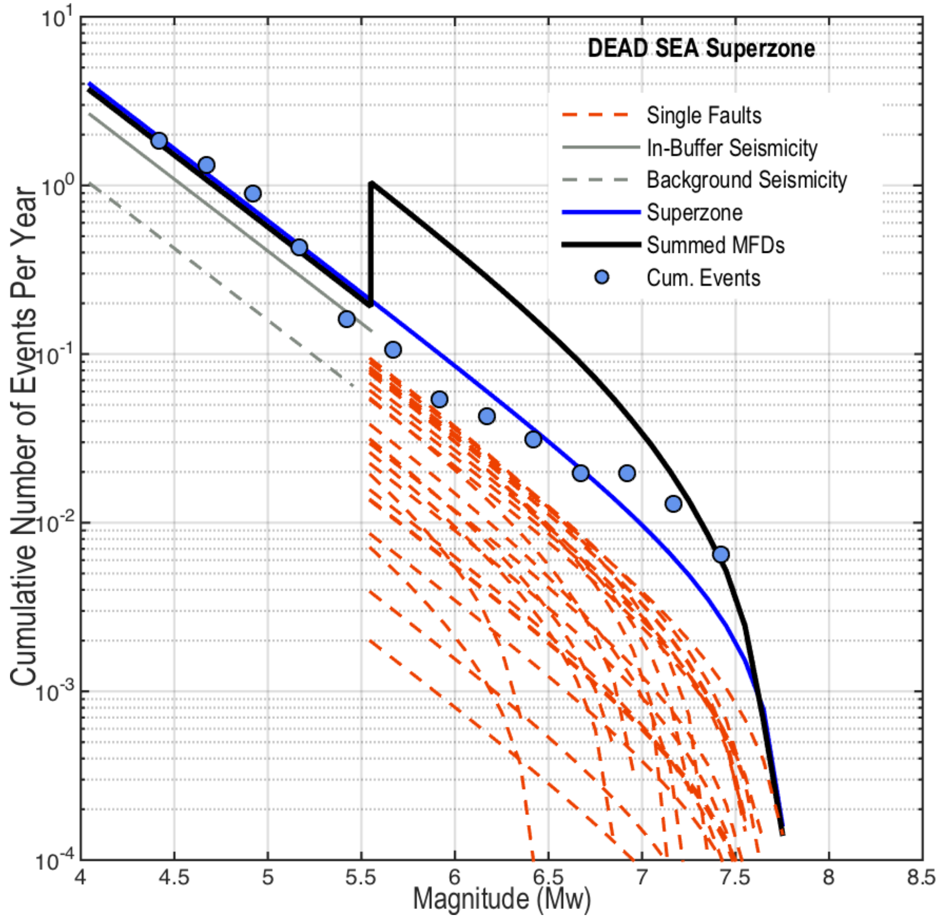




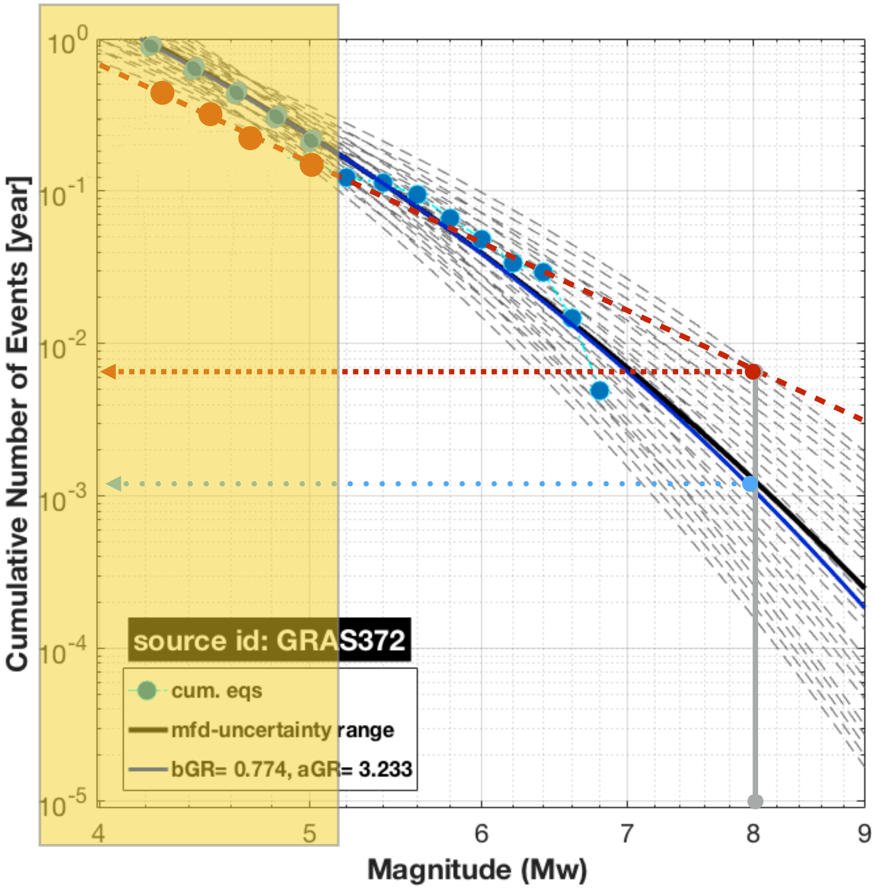
SEIFA model, Hiemer et al 2013

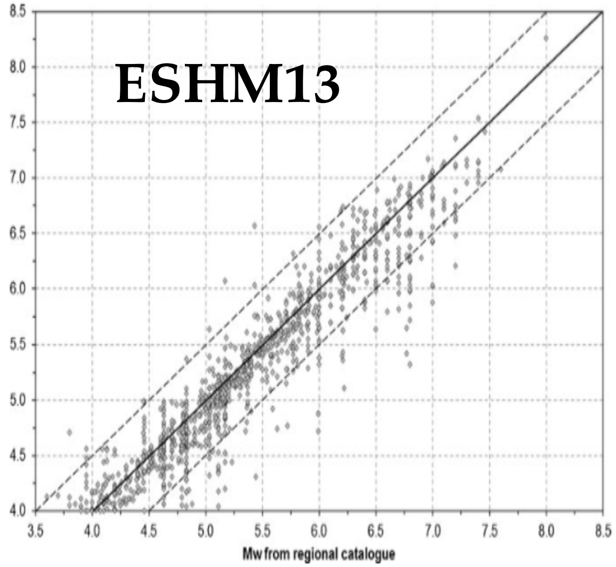
Challenge: fault data and seismicity tell different stories

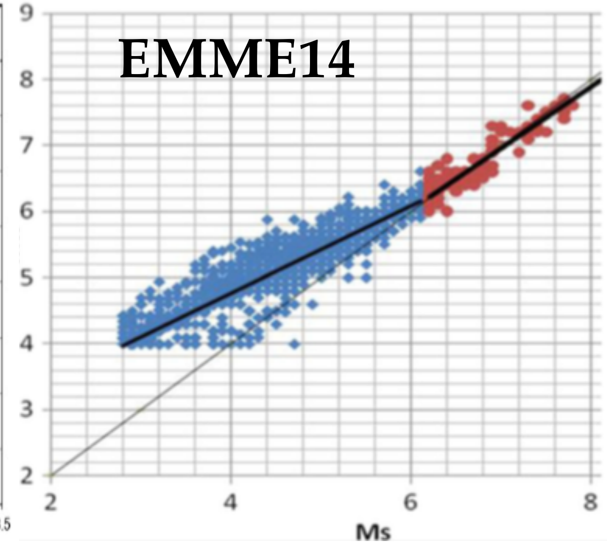




Challenge: magnitude calibration

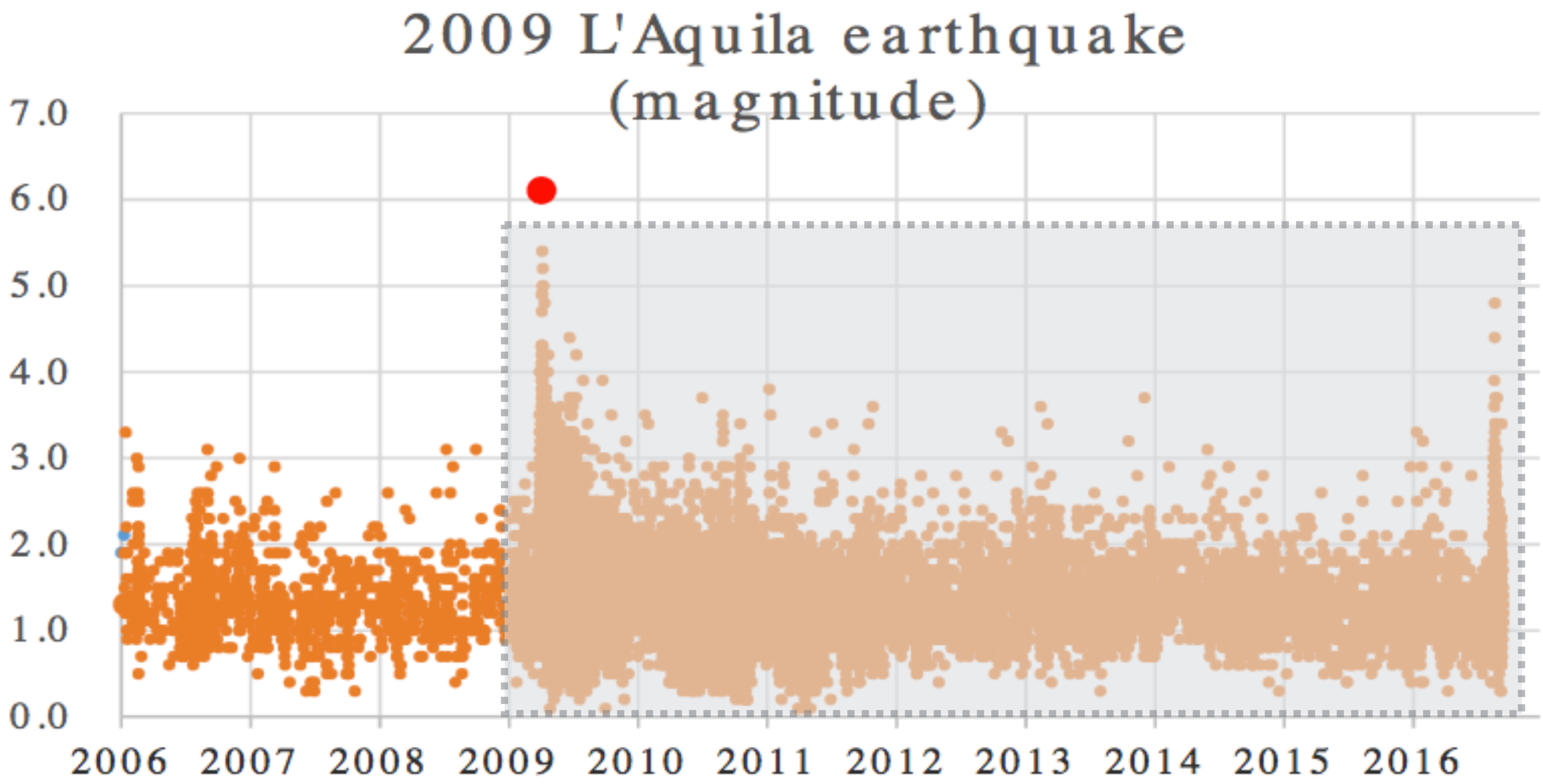






Stucchi et al., 2012 | Grünthal et al., 2012 | Zare et al., 2014

Challenge: seismicity model without spatiotemporal clustering

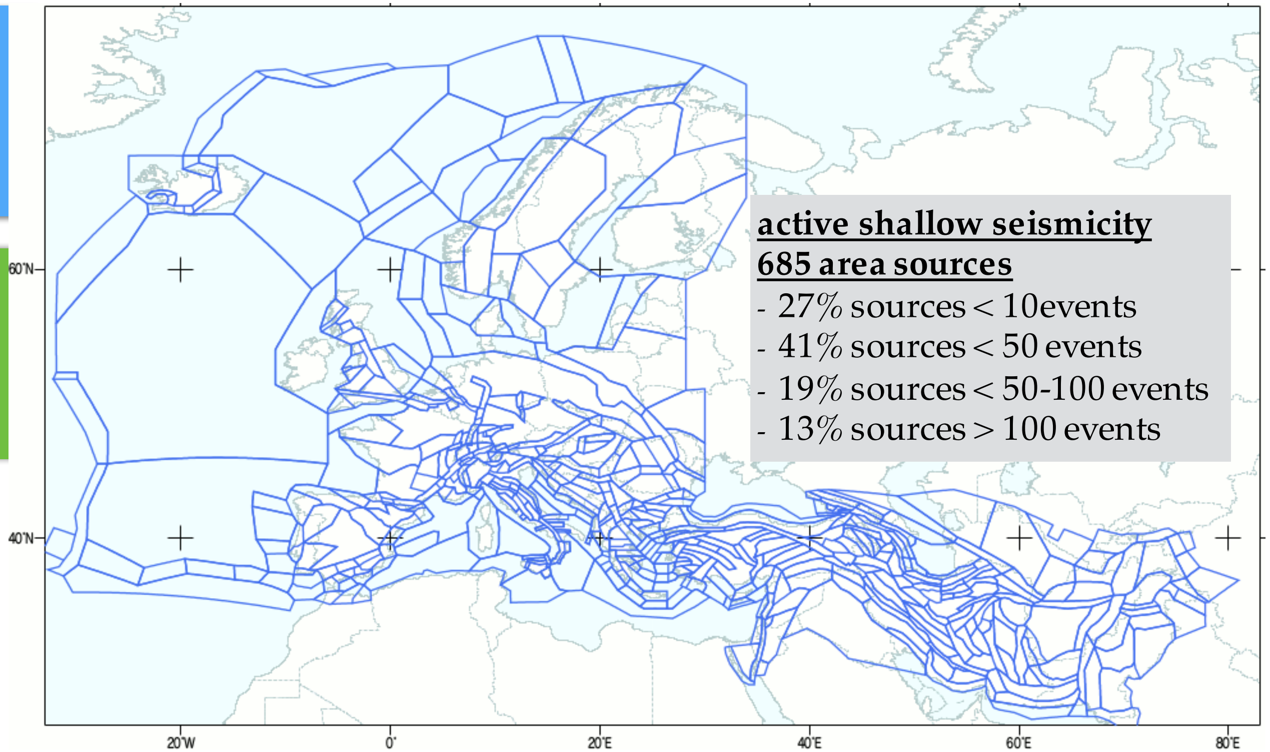


Challenge: declustering

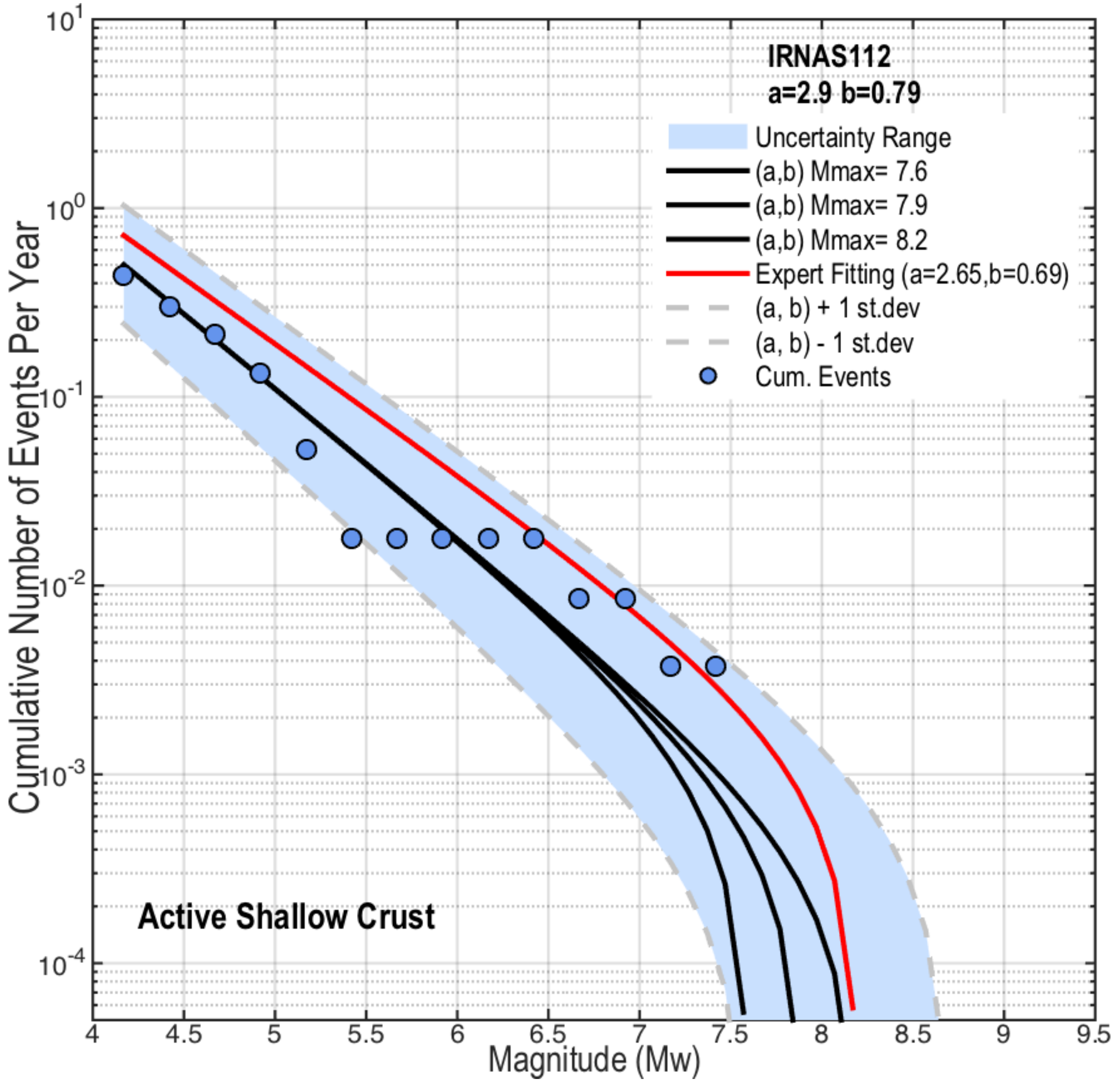
ESHM13
- Entire catalog: more than 30000 events
- Declustered catalog: 13919 events
- Declustered and complete catalog: > 8600

EMME14
- Entire catalog: more than 27174 events
- Declustered catalog: 10524 events
- Declustered and complete catalog: > 7300

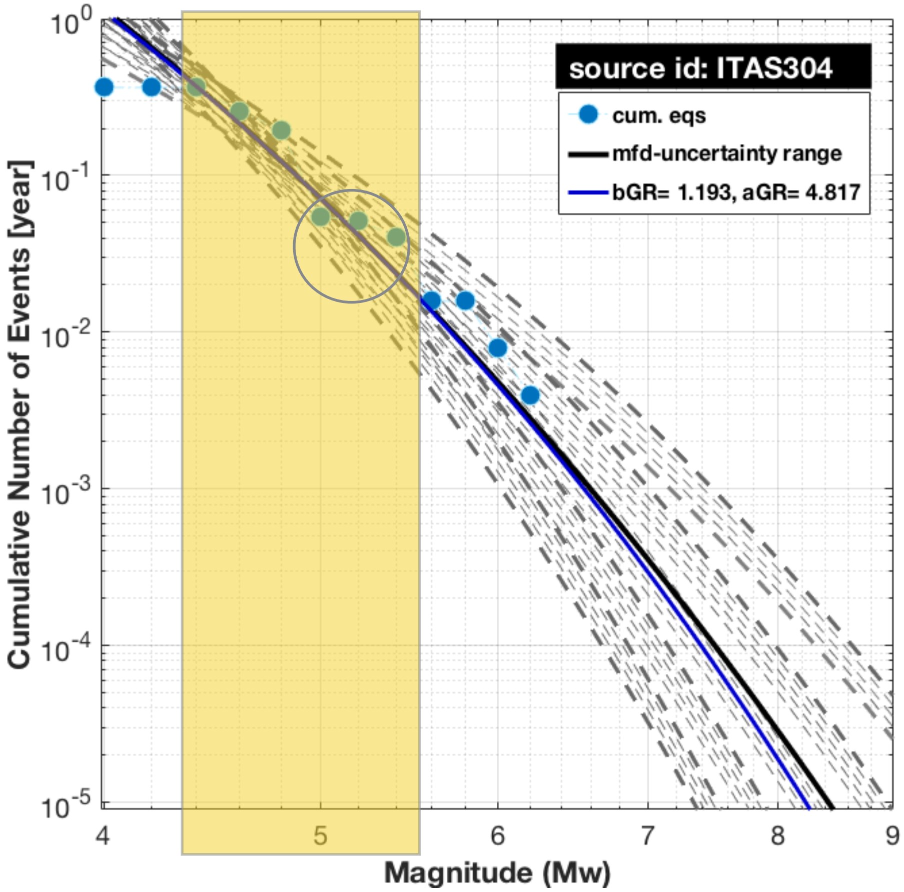
Declustering method: Grunthal 1985

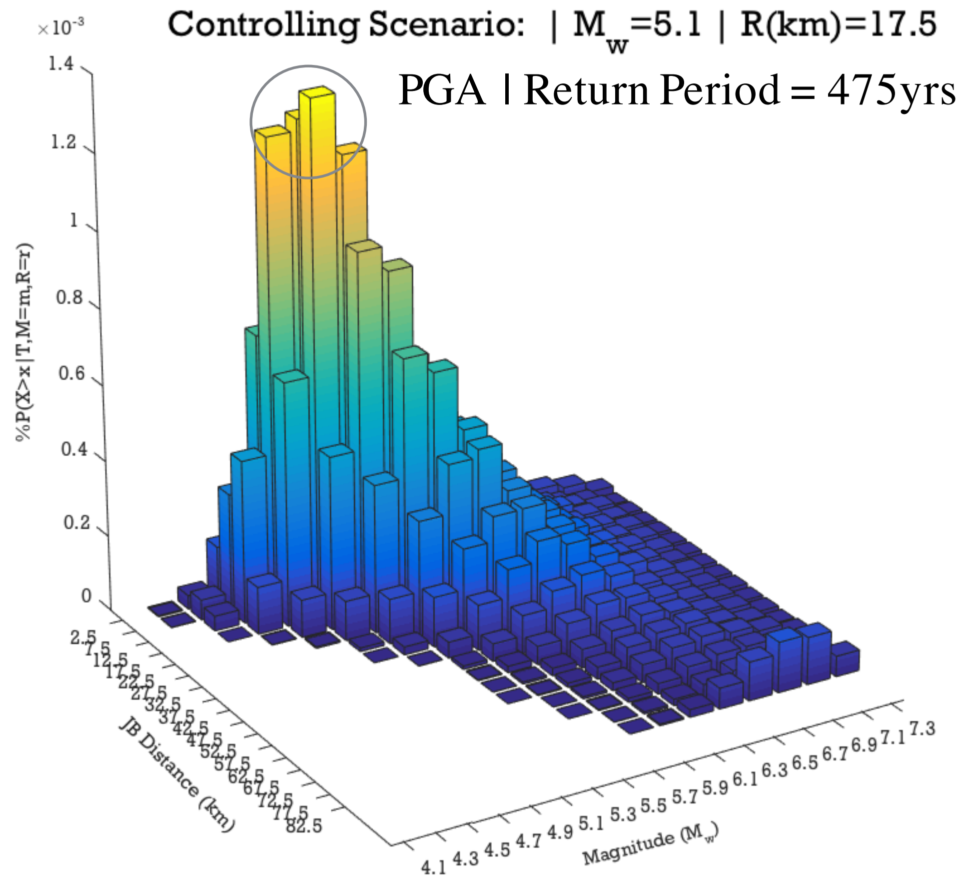


Challenge: reliable forecasting models of seismicity occurrence

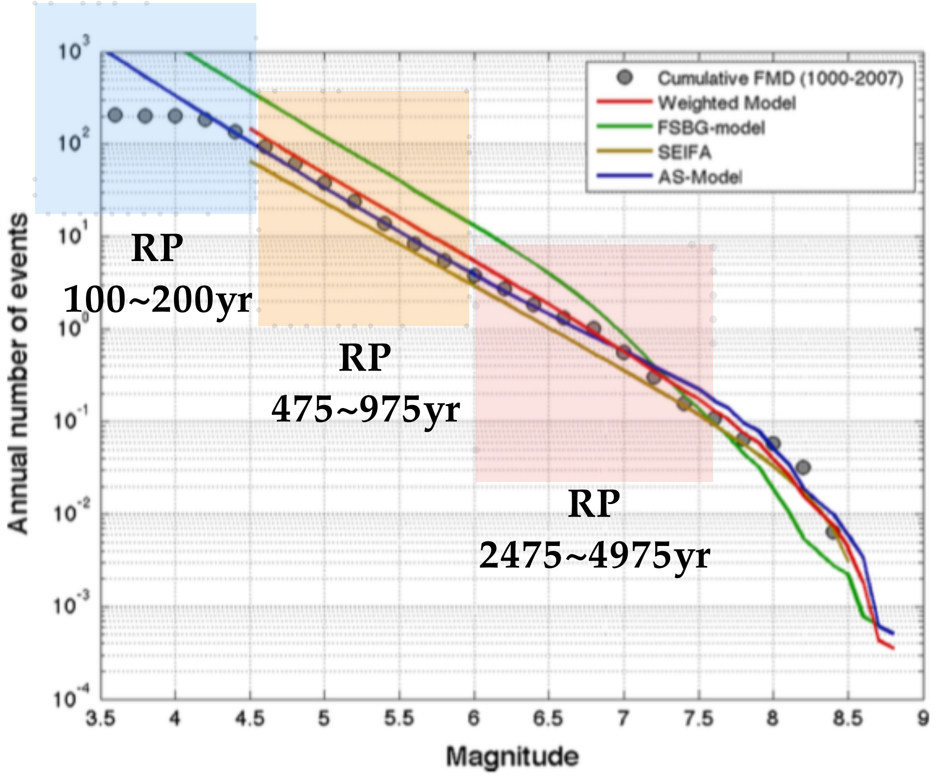


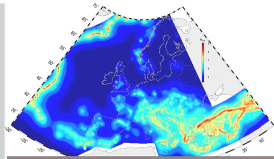
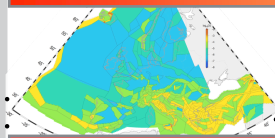
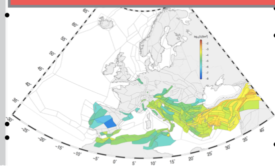
Challenge: small earthquakes





Challenge: building logic trees



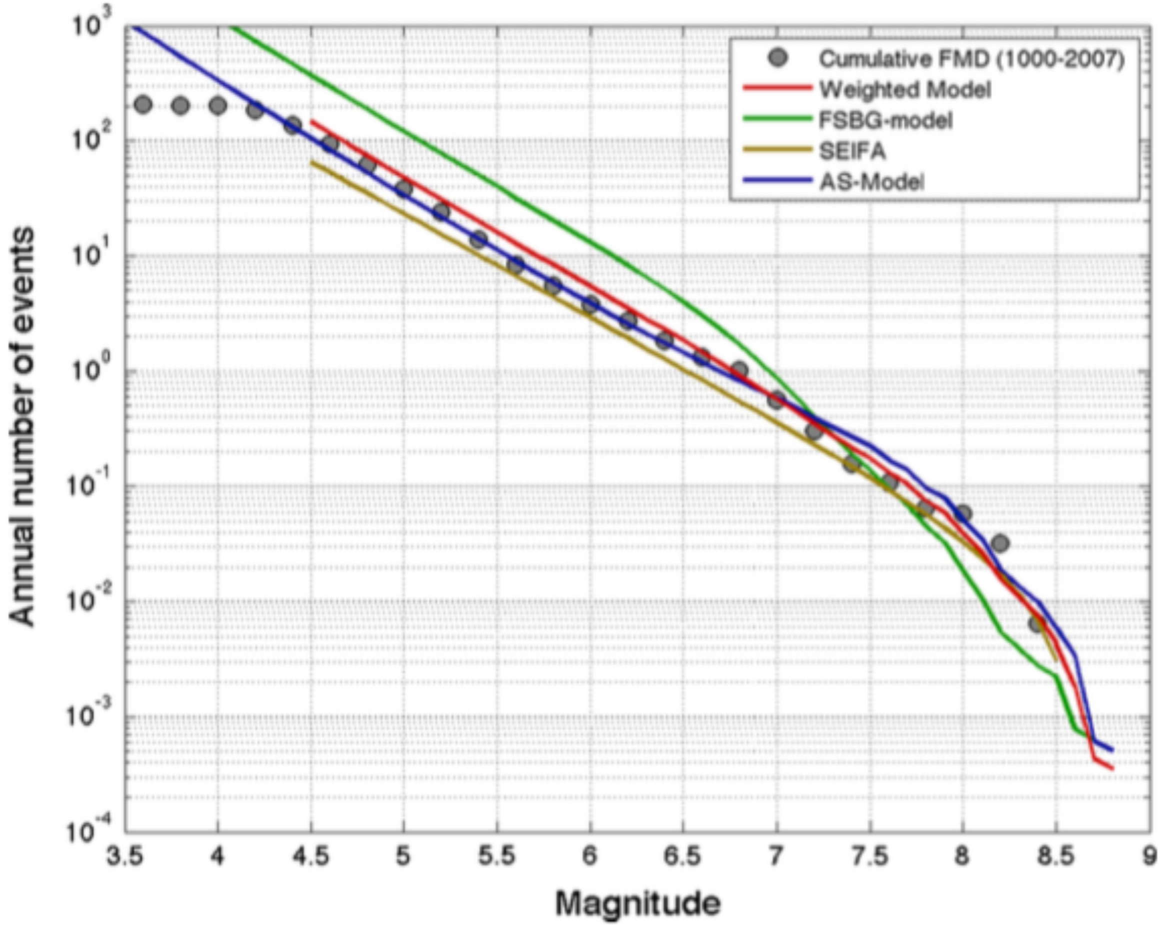
Seismogenic Source		RP 100~200yr	RP 475~975yr	RP 2475~4975yr
short term forecast		45	30	10
moderate term forecast		45	50	60
long-term forecast		10	20	30

- assigned weights incorporates the completeness of data and information in time
- for reference return period RP=475yrs, the contribution of the total hazard is dominated by the seismicity recurrence rates (~80%) with contribution of active faults (~20%)
- for long return periods (RP > 2475yrs) the contribution of seismicity -based rates is reduced and the contribution of activity rates form faults is increasing (40%)

Challenge: “validation” or “hypothesis testing”

In regional programs we attempt to „validate“ seismicity models by scoring different performance measures, but

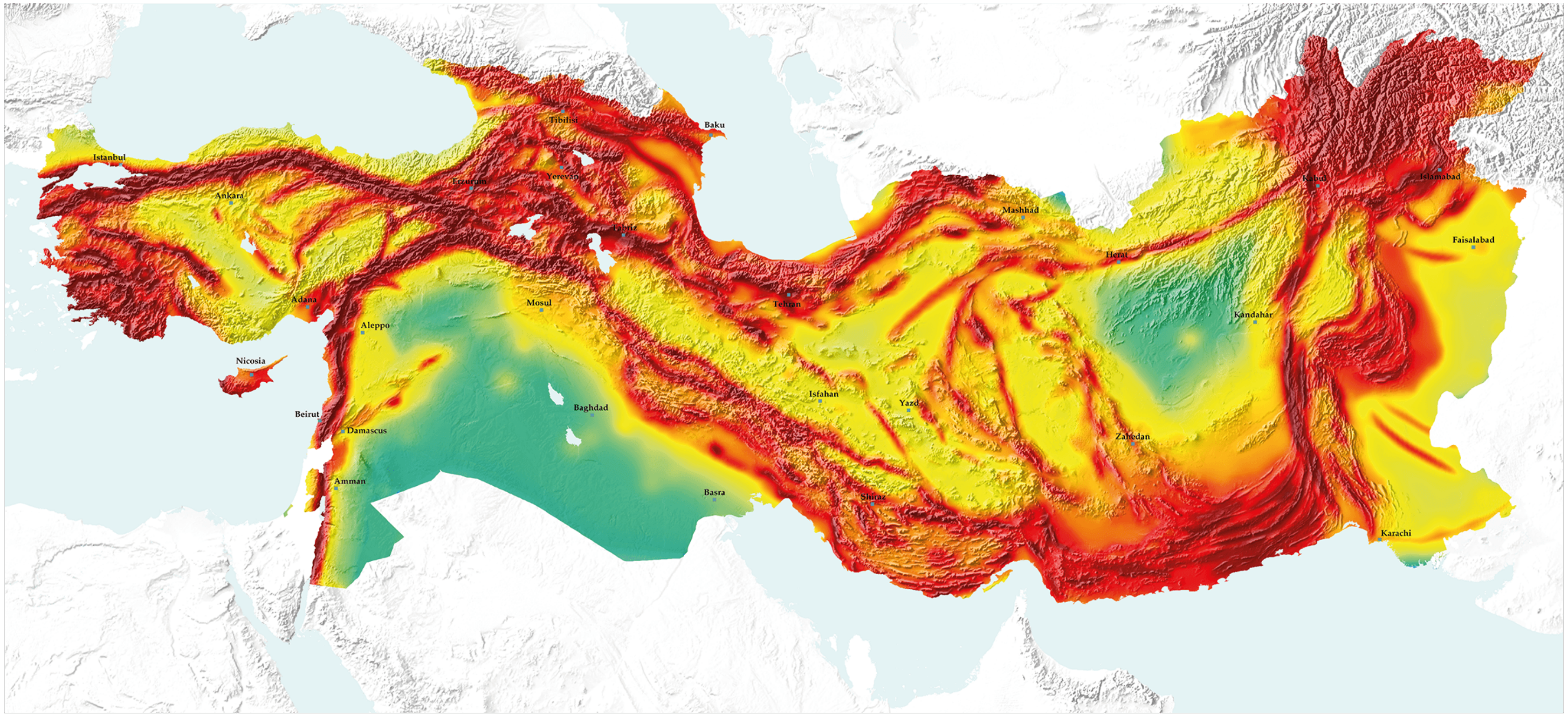
- Circular argument: we only validate if we succeeded to build in correctly the a-priori hypotheses
- No clue how to „validate“ small areas or areas of low seismicity



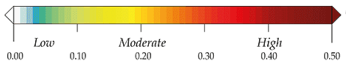
EMME
EARTHQUAKE MODEL OF THE MIDDLE EAST REGION

Seismic Hazard Map of the Middle East

edited by D. Giardini, L. Danciu, M. Erdik, K. Sesetyan, M. Demircioglu, S. Akkar, L. Gülen and M. Zare, June 2016



Peak Ground Acceleration [g]
Probability of Exceedence in 50 years



Map Content

The Seismic Hazard Map of the Middle East displays the ground shaking (i.e. Peak Horizontal Ground Acceleration, PGA) to be reached or exceeded with a 10% probability in 50 years. This reference value represents the shaking to be expected during the human lifetime, corresponding to the average recurrence of such ground motions every 475 years, as prescribed by the national building codes for standard buildings in the Middle Eastern countries. Blue to green colors depict comparatively low hazard (PGA ≤ 10% of the gravitational acceleration), yellow to orange colors moderate hazard (10% < PGA ≤ 30% g) and red to brown colors identify high hazard areas (PGA > 30% g).

The Earthquake Model of the Middle East project (EMME)

The Middle East region has a long history of destructive earthquakes, and seismic risk can severely affect our modern society, as shown by the tragic events of Izmit (Turkey, 1999), Bam (Iran, 2003), Kashmir (Pakistan, 2005), Van (Turkey, 2011) and Hindu Kush (Afghanistan, 2015). Minimization of the loss of life, property damage, and social and economic disruption due to earthquakes depends on reliable estimates of seismic hazard.

National, state, and local governments, decision makers, engineers, planners, emergency response organizations, builders, universities, and the general public require seismic hazard estimates for land use planning, improved building design and construction, adoption of modern building construction codes, emergency response preparedness plans, economic forecasts, housing and employment decisions, and other measures for risk mitigation.

The collaborative project "Earthquake Model of the Middle East (EMME, 2010-2015)" brought together scientists and engineers from the leading research institutions in the region and delivers state-of-the-art seismic hazard assessment covering Afghanistan, Armenia, Azerbaijan, Cyprus, Georgia, Iran, Iraq, Jordan, Lebanon, Palestine, Pakistan, Syria and Turkey. The project generated new earthquake catalogues, regional maps of active faults and the first ever set of harmonized seismic hazard results and maps for the region, characterizing the seismic activity and its effects.

The EMME seismic hazard results describe the potential shaking associated with future earthquakes in the Middle East and serve as input to develop strategies for seismic risk governance and earthquake resistant design for different applications - ranging from private homes to multi-story public buildings and critical infrastructures such as bridges and dams.

EMME contributes its results to the Global Earthquake Model (GEM), a program initiated by the Organization for Economic Cooperation and Development (OECD).

Main contributors

Together with the editors, the main contributors to the Seismic Hazard Map of the Middle East are: M. Ghafory-Ashtiany, H. Babayan, A. Axundov, A. Karakhanian, A. Khan, A. Gvencadze, A. Elias, N. Tsereteli, B. Mansouri, K. Hessami, S. Adamia, S. Al Quraan, A. Askan, M. Al-Qaryouti, H. Al-Nimry, M. Avanesyan, M. Awawdeh, R. Basili, C. Chrysostomou, O. Kale, R. El-Khoury, U. Hancilar, R. Helou, Y. İnce, R. Jaradat, M. D. Köksal, N. Kyriakides, S.H. Lodi, T. Mammadli, A. Rovida, S.F.A. Rafeeqi, N. Sadradze, M. Sayab, M. Stucchi, B. Sungay, M. Utkucu, H. Yalçin, G. Yetirmishli and C. Zulfikar.

Disclaimer

The EMME map does not replace the existing national design regulations and seismic provisions, which are compulsory for today's design and construction of buildings.

Acknowledgements

We would like to acknowledge the collaborative efforts of numerous researchers and engineers from the Middle East region throughout the EMME project. We thank M. Pagani, D. Monelli and G. Weatherill (GEM Foundation), J. Woessner (SHARE project), and S. Parolai, D. Bindi and S. Ullah (EMCA project) for the integration with neighboring regions.

The EMME hazard was computed using OpenQuake software, developed and supported by the Global Earthquake Model (GEM). The EMME map is produced using the Generic Mapping Tools (GMT) with an Equidistant Conic Projection.

The EMME program was supported by JTI.

Cite this map with: D. Giardini, L. Danciu, M. Erdik, K. Sesetyan, M. Demircioglu, S. Akkar, L. Gülen and M. Zare, Seismic Hazard Map of the Middle East, doi:10.12686/a1

For more information, data and models visit: www.emme-gem.org and www.efehr.org

Schweizerischer Erdbebendienst
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Servizio Sismico Svizzero
Swiss Seismological Service
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AUB
INTERNATIONAL INSTITUTE OF EARTHQUAKE ENGINEERING AND SEISMOLOGY
GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

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پژوهشگاه بین المللی زلزله شناسی و مهندسی زلزله
INTERNATIONAL INSTITUTE OF EARTHQUAKE ENGINEERING AND SEISMOLOGY

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

Conclusions

Regional scale PSHA projects are instrumental to

- ✓ **Improve best practice (multi-disciplinary data, epistemic uncertainties, expert elicitation, engineering requirements ...)**
- ✓ **Harmonize across areas of common seismic characteristics**
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