Seismic hazard map of Austria

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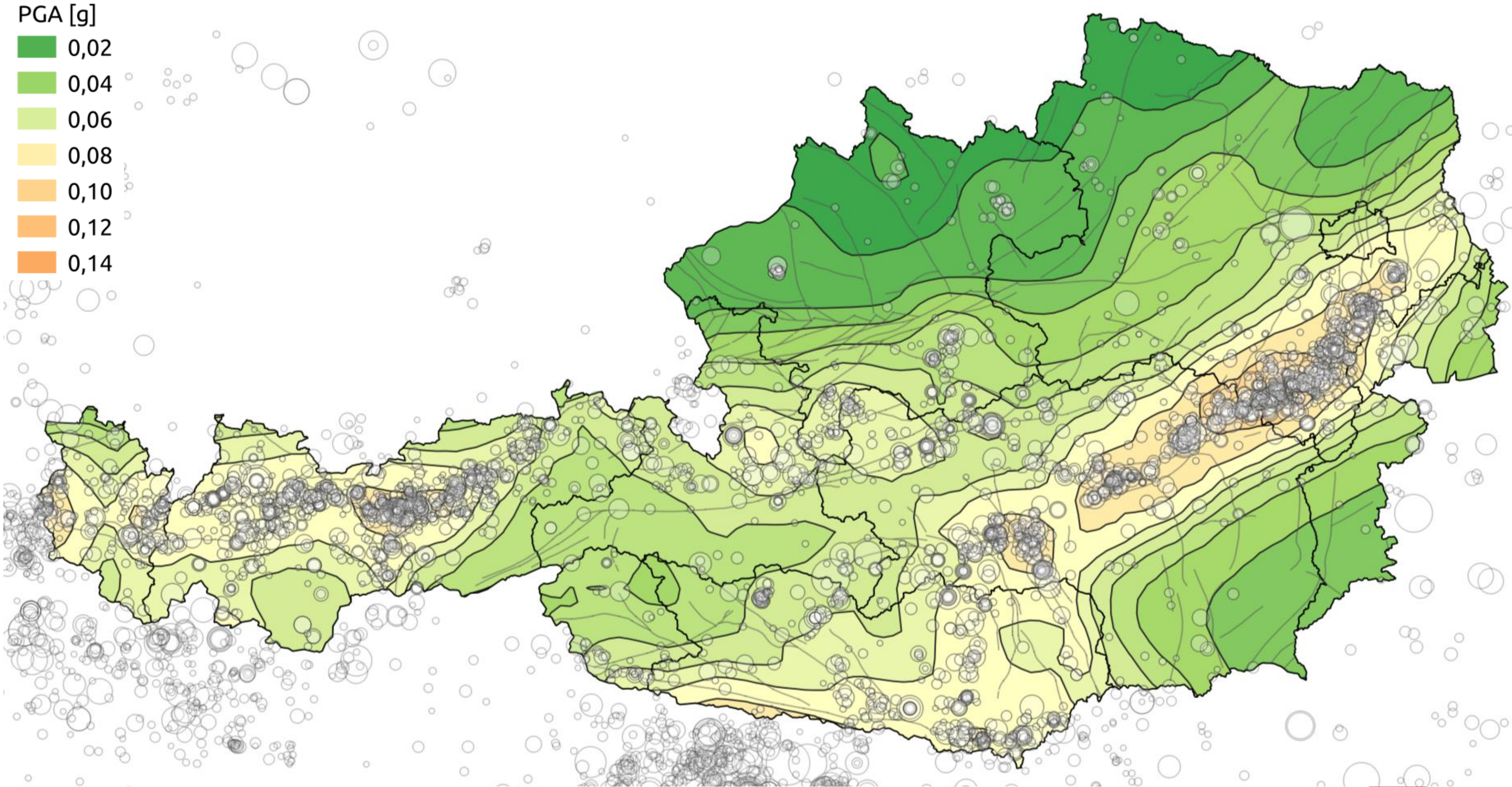

PGA, 10 % in 50 years, V_{S30} = 800m/s

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Online data request

http://geoweb.zamg.ac.at/hazard/dach19en.html

Earthquake Hazard

Weginger, S. et al., 2019. Entwicklung einer regionalen Erdbebengefährdungskarte für Österreich. D-A-C-H Tagungsband, Volume 16.
Zentralanstalt für Meteorologie und Geodynamik

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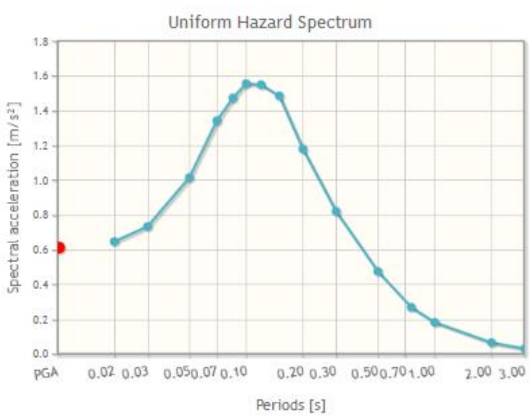
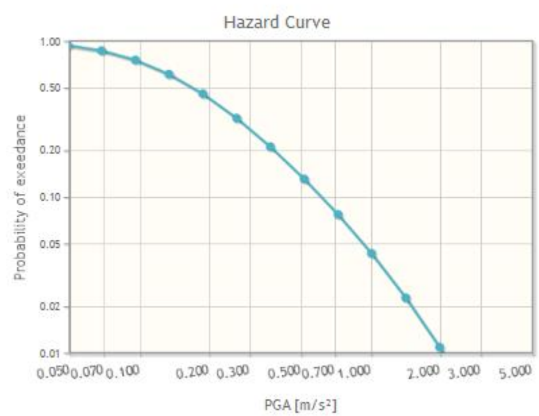
16.187 | 48.177 | 10% in 50 years | A





Periods [s]	Spectral acceleration [m/s²]
PGA	**0.6168**
0.02	0.6516
0.03	0.7377
0.05	1.0187

PGA [m/s²]	Probability of exeedance
0.0088	1.000
0.0098	1.000
0.0196	0.999
0.0294	0.991

Online data request

Location

Return Period

Building Site

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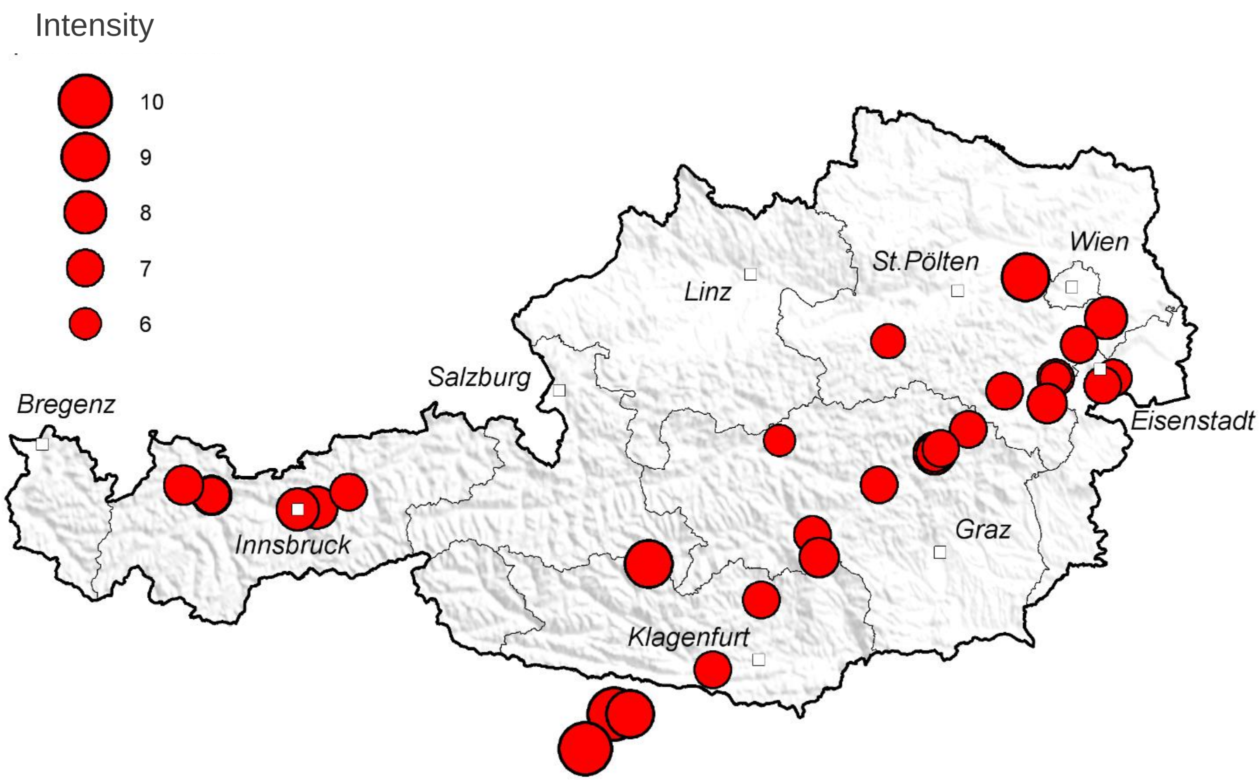
Summery

- Historical earthquake research
- Catalog harmonization
- Magnitude completeness
- Hypocentral depth/ Focal mechanism
- GMPE development and selection
- Seismic zones
- Moment frequency distribution / Maximum magnitude
- Hazard models
  - Area sources
  - Zoneless approach
  - Fault sources
- Logic-tree
- Result
- Comparrison

Historical Earthquake Research



I_o=9
1201 Katschberg
1590 Riederberg

I_o=8
1267 Kindberg
1590 Riederberg
1670 Hall in Tirol
1927 Schwadorf

I_o=7-8
1689 Innsbruck
1886 Nassreith
1930 Namlos
1972 Seebenstein

Catalog harmonization

Austrian Eathquake Catalog

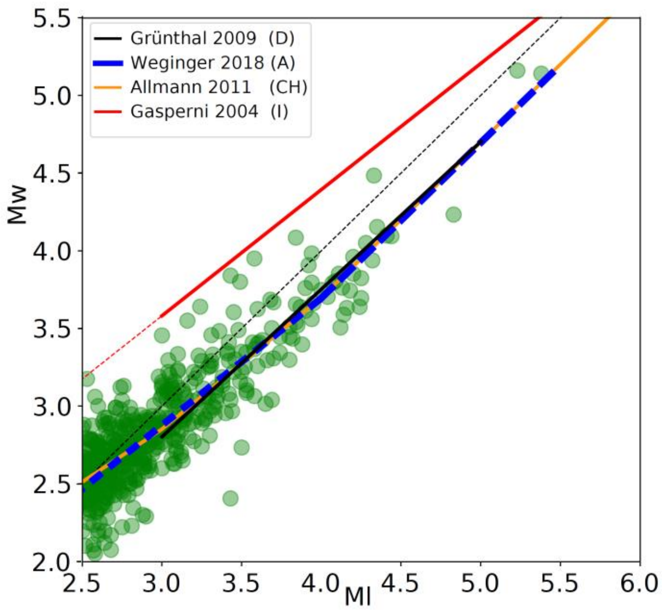
Complemented by the ISC Catalog

Enlarged with Moment Magnitude (MW)

$$M_W = 0.42 + 0.82\,M_L \qquad |M_L < 4$$
$$M_W = M_L - 0.3 \qquad |M_L \geq 4$$

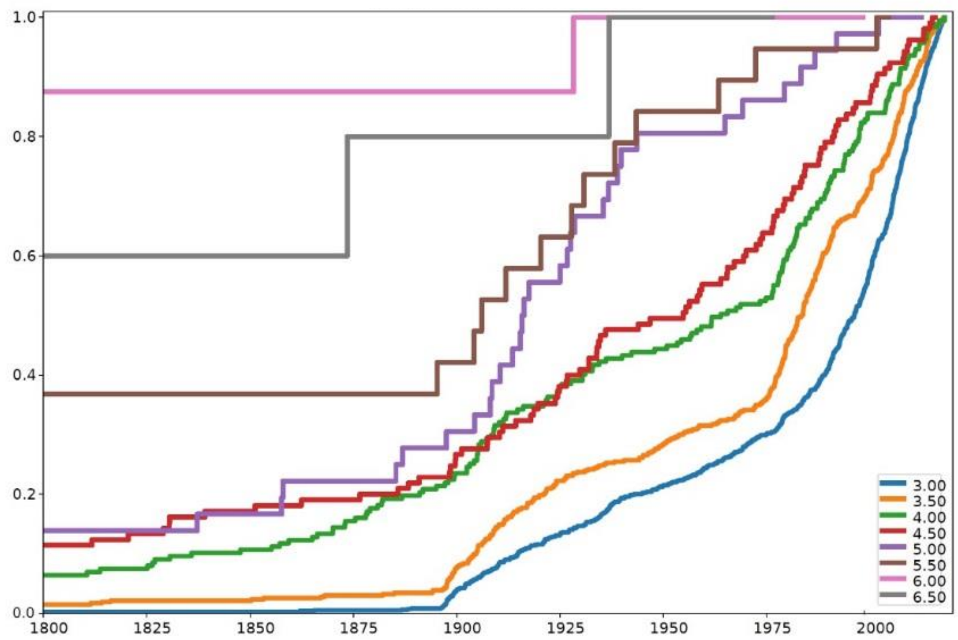
Moment Magnitude – Intensity Relation

$$I_0 = k_0 + k_1 M_w + k_2\,ln(h) \quad \begin{cases} k_0 = 2{,}56 \\ k_1 = 1{,}32 \\ k_2 = -0{,}94 \end{cases}$$



Magnitude completeness

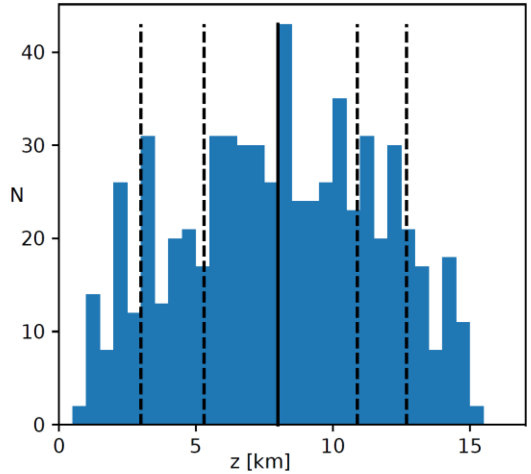
„Slope method“



≥M_W	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Current Study„Slope“	1975	1895	1860	1800	1760	1500	1150
„Stepp“ method	1964	1985	1914	1901	1792	1792	
Austria [1]		1895	1825	1800	1800	1550	1200
Germany [2]	1973	1869	1869	1869	1802	1650	1450
Switzerland [3]	1977		1880	1750	1680	1600	1200

[1] Grünthal et al 2009
[2] Grünthal et al 2017
[3] Wiemer at el 2015

Hypocentral depth and focal mechanism



Hypocentral depth

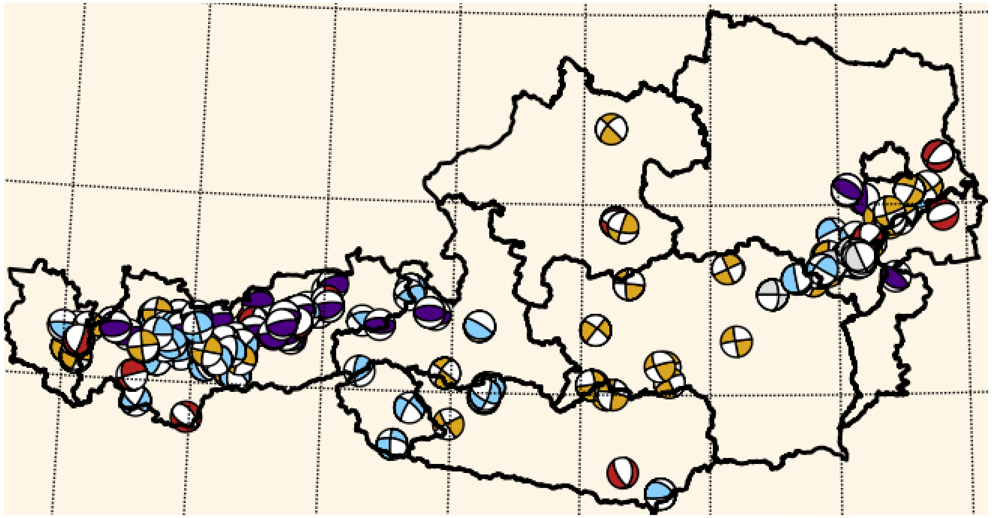
Relocation

- All events which meet at least 3 of 4 GT5 criteria
- LonLinLoc with 3D velocity model

⇒ accurate to 5km with a 95% confidence level

Focal mechanism

- New database of focal mechanism
- Classification with the program “FMC”



GMPE development and selection

- Calculation of a ground motion database
- Development of a local GMPE
  - PGA, PGV, PSA, Intensity
- Selection of a regional and global GMPE
  - Log-Likelihood (LLH)
  - Euclidean distance range (EDR)
  - Distribution of residuals over distance and magnitude

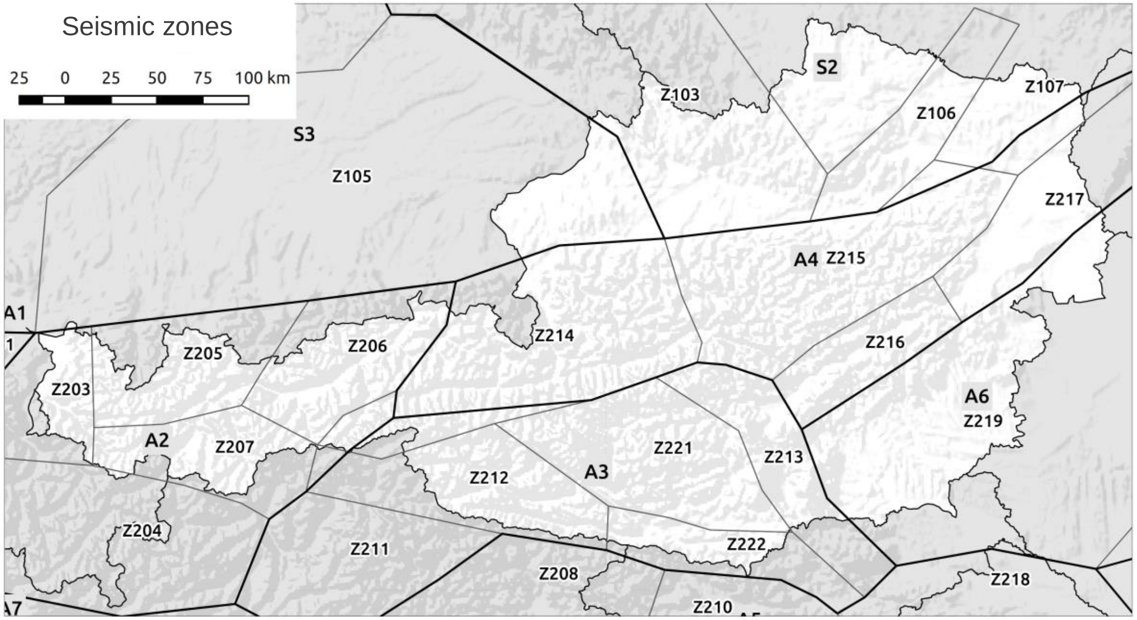
Fits our Data best !
Problems in near field
Can‘t be extrapolated to high magnitudes

GMPE	Dataset	Range of M_W	Distance [km]	T (s)
Weginger, 2018	Austria	2.5 - 5.0	≤ 250	0.30 – 3.0
Bindi et al, 2014	Europe	4.0 - 7.0	≤ 300	0.02 – 3.0
Akkar et al, 2014	Europe	4.0 – 7.6	≤ 200	0.01 – 4.0
Boore & Atkinson, 2011	„Active Crustal Regions“	3.0 – 6.5	≤ 300	0.02 – 10
Bindi et al, 2017	Global	3.0 – 7.9	≤ 300	0.01 – 4.0

Seismic Zones

Spatial distribution

- Eathquake Catalogue
- Focal mechanism
- Fault zones
- Hypocentral depth
- Shear-stress drop
- Geological parameter



Compareable zones are combined into super zones annual frequency

Maximum magnitude / Moment frequency distribution

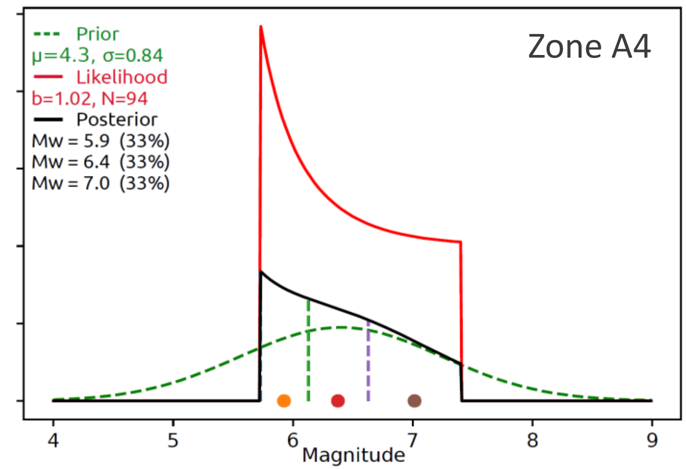
annual frequency

Maximum magnitude

- Bootstrapped cumulative moment
- Non-Parametric Gaussian
- EPRI – approach
  - Extended continental crust

    $\mu = 6.4;\ \sigma = 0.84;\ M_{trunc} = 7.4$
  - Non-extended continental crust

    $\mu = 6.2;\ \sigma = 0.5;\ M_{trunc} = 7.0$

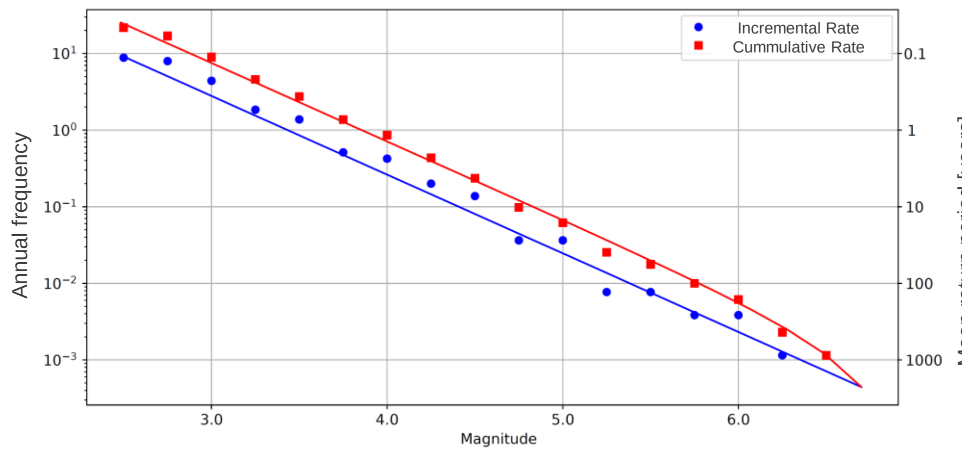


Moment-frequency distribution

- Double-truncated Gutenberg-Richter
- Bayesian Penalized Maximum Likelihood
- Zones and Superzones

$$a = log_{10}\left(\frac{v(M_{min})}{10^{(-b*M_{min})} - 10^{(-b*M_{max})}}\right)$$

$$v(M_{min}) = \int_{M_{min}}^{M_{max}} 10^{a-bm} dm$$

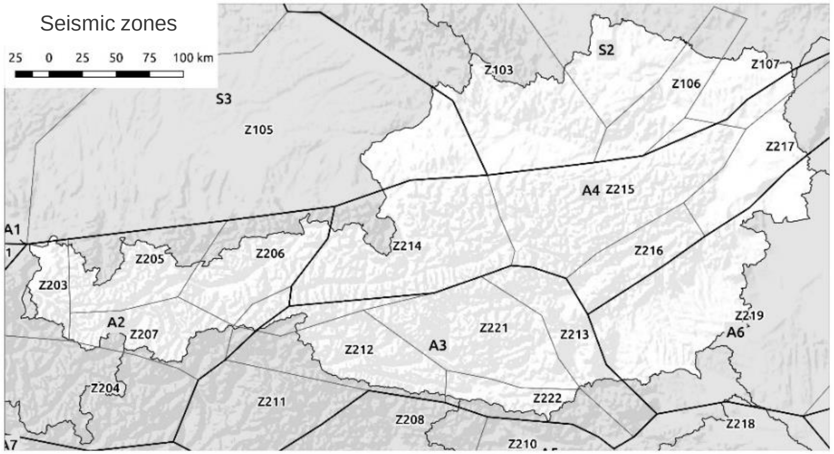


MFD for Austria +100km

Results

Superzones:

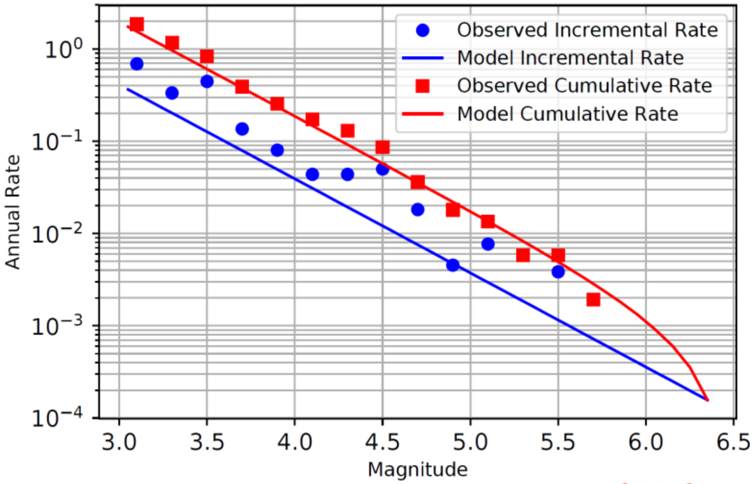
	b	M_{Max}	$v(M_{Min})$
S2	1.07	6.0	0.01
S3	0.89	6.1	0.05
A2	1.15	6.1	0.61
A3	1.04	6.5	0.29
A4	1.03	6.4	0.51
A6	0.85	6.3	0.06



Example Zone A4:

Method	M_{Max}
Cumulative Moment	5.7
Non-Parametric Gaussian	6.1
EPRI	5.9 6.4 7.0

	Weichert	PML
a	3.30	3.32
b	1.02	1.03
$v(M_{Min})$	0.51	0.51

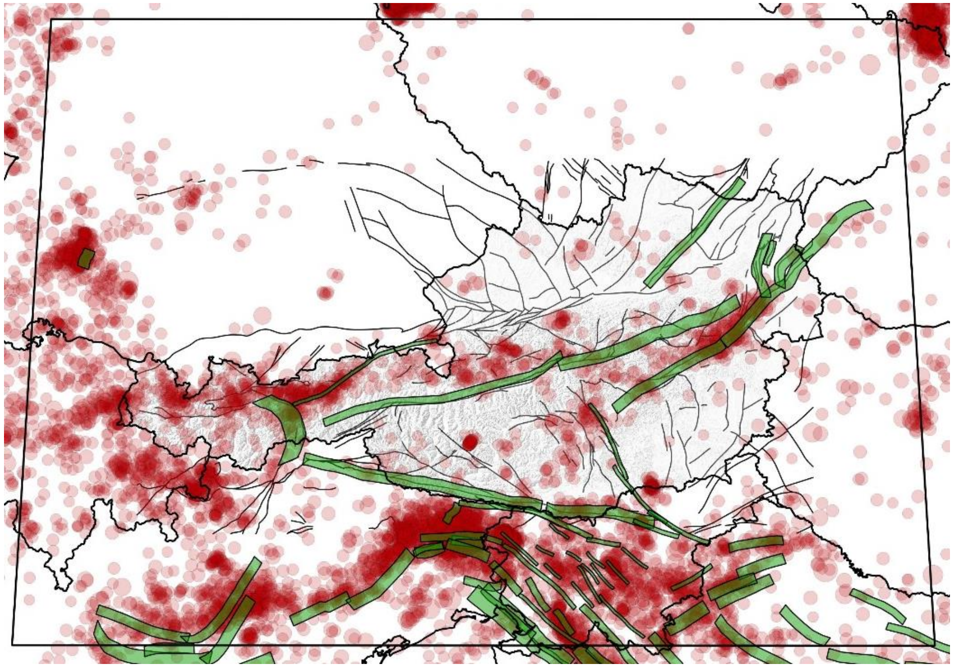


Zoneless approach / Fault-sources

Zoneless approach

- Frankel (1995)
- Isotropic-Gaussian kernel
- 10 and 15 km
- b-Value from Austria box + 1°
- TODO: variable kernel approach

  e.g. Hiemer at al 2014



Fault-sources

- Geometry taken from SHARE-project
- Used as area-sources with buffer
- Start of an follow-up project in 2020

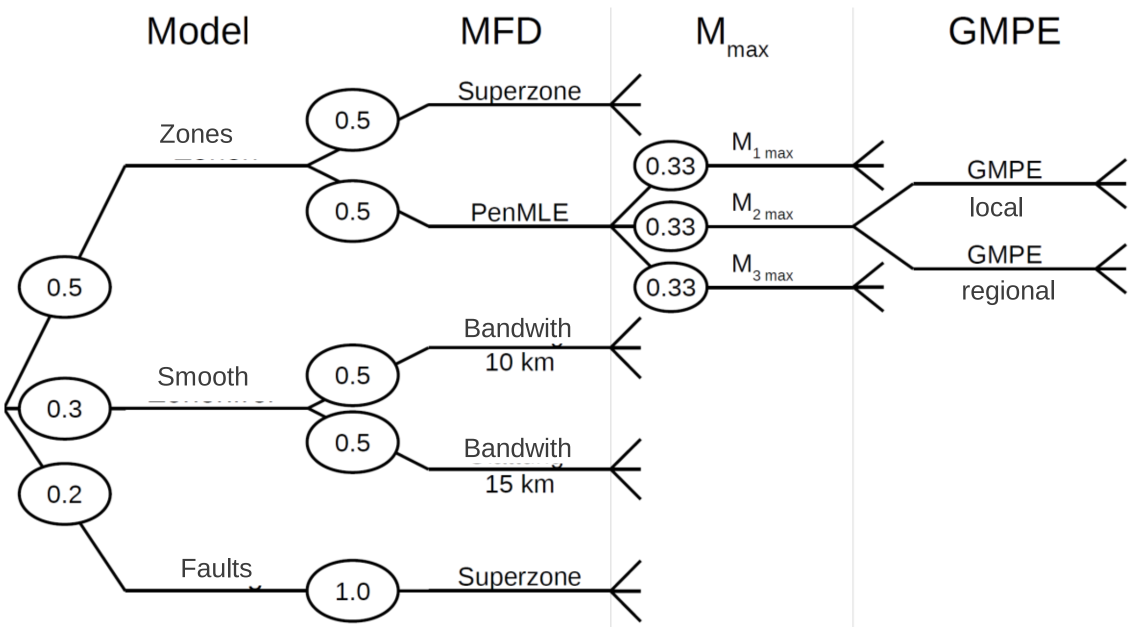
  Better seismic active fault-DB, use of verified methods

Logic-tree

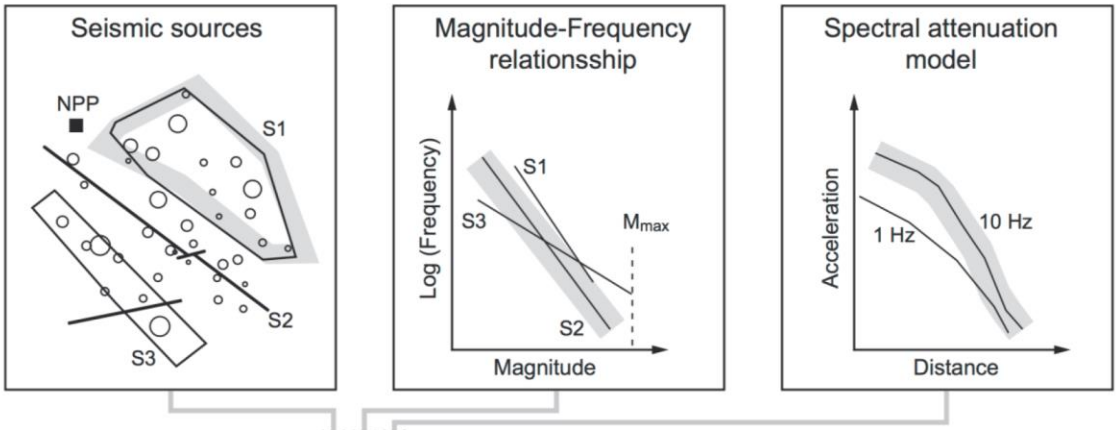
Models:

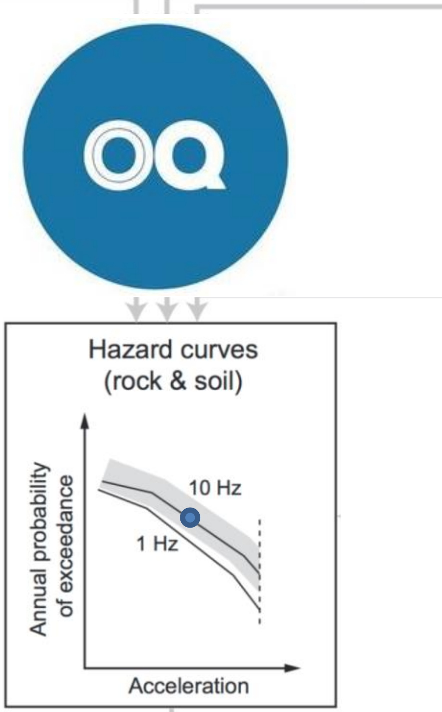
- Area-sources
- Smoothed-seismicity

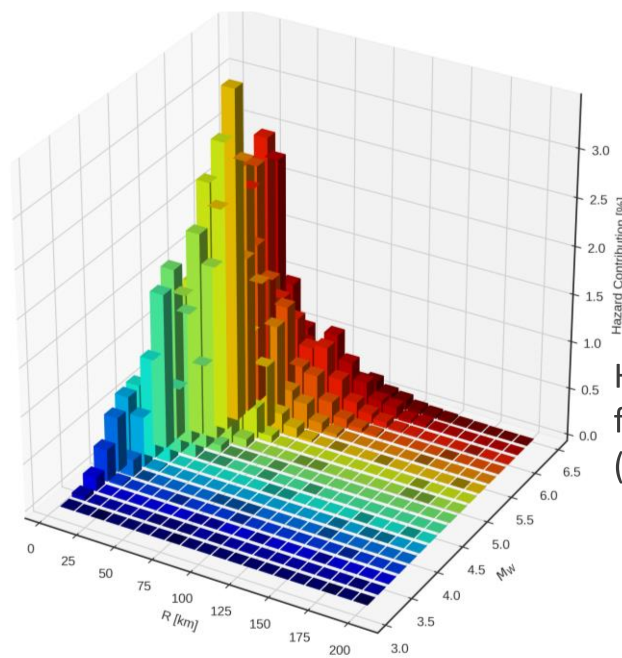
  Approach of Frankel (1995) with an isotropic-Gaussian kernel
- Fault-sources:



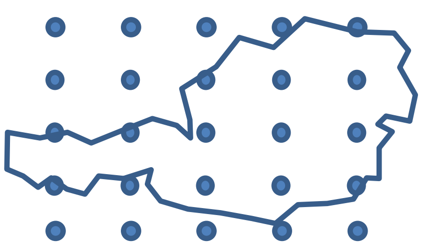
Open Quake Engine



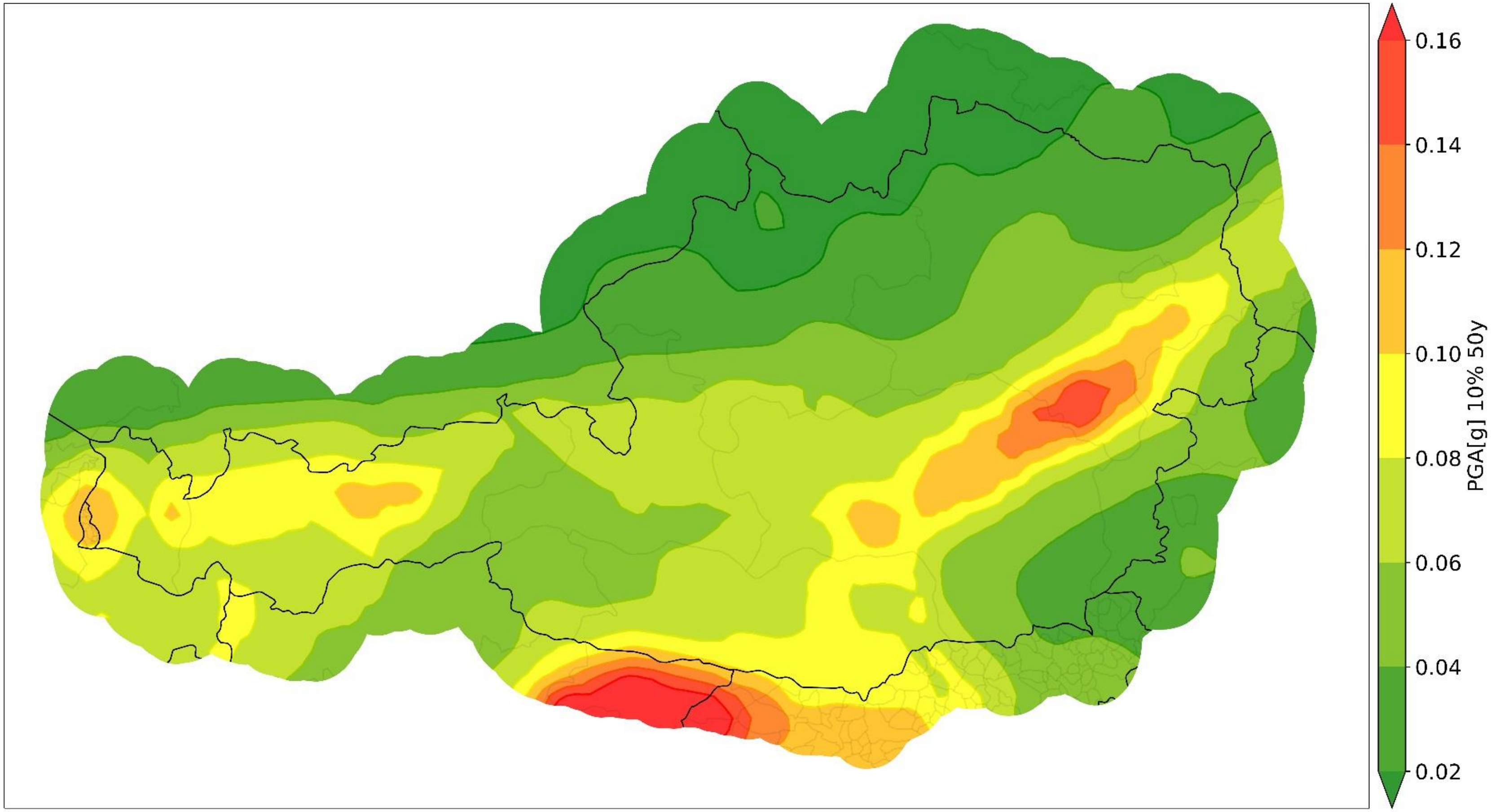




Hazard contribution for Vienna (16.397 48.257)

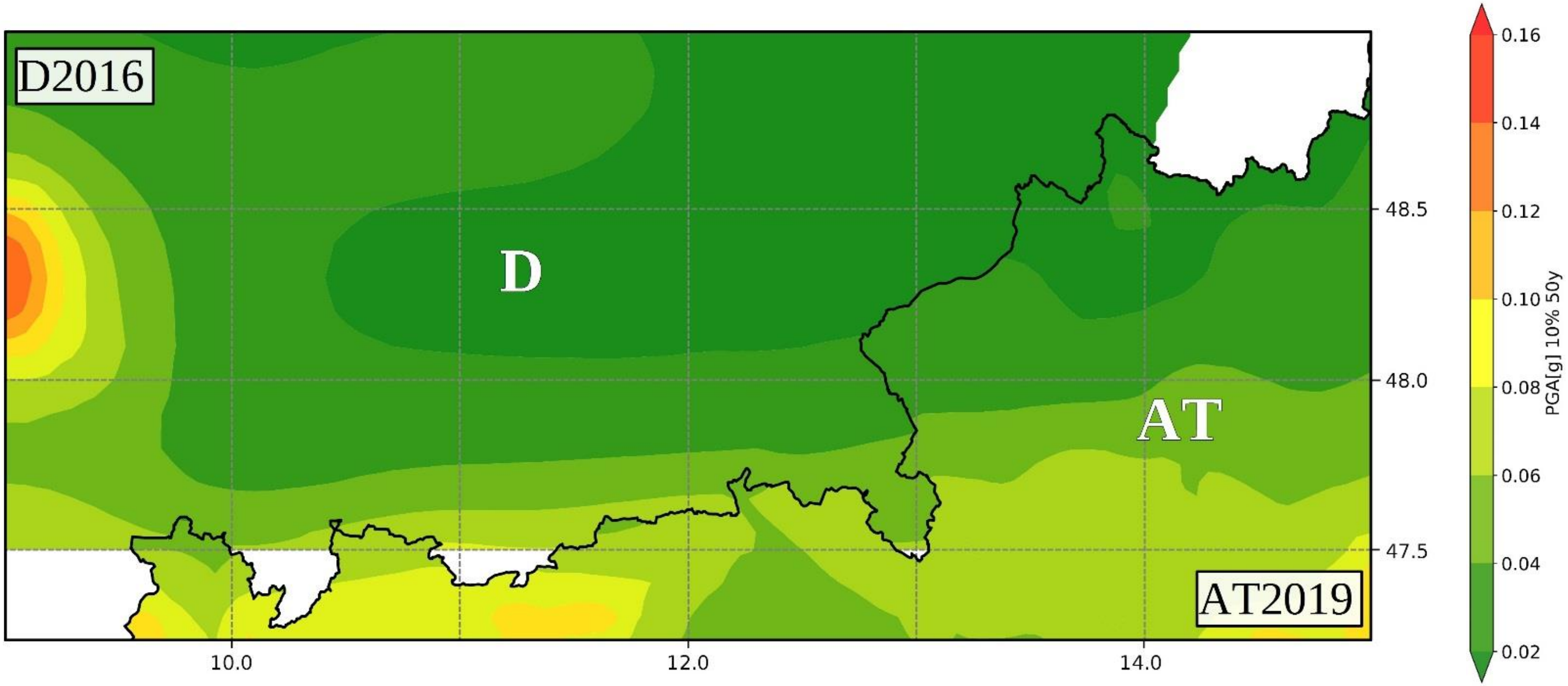


Result



Maximum Horizontal Acceleration (PGA)
10 % in 50 years -> Reference period of 475 years
On rock (V_{S30} = 800m/s)

Comparison with Germany 2016



Grünthal et al 2017
PGA, 475 years
V_{S30} = 800m/s