Université Gustave Eiffel

Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum

A Regionally Adaptable Ground-Motion Model from European Strong Motion Dataset

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SERA Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe

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ΣIGMA2

GFZ Helmholtz-Zentrum Potsdam

Outline

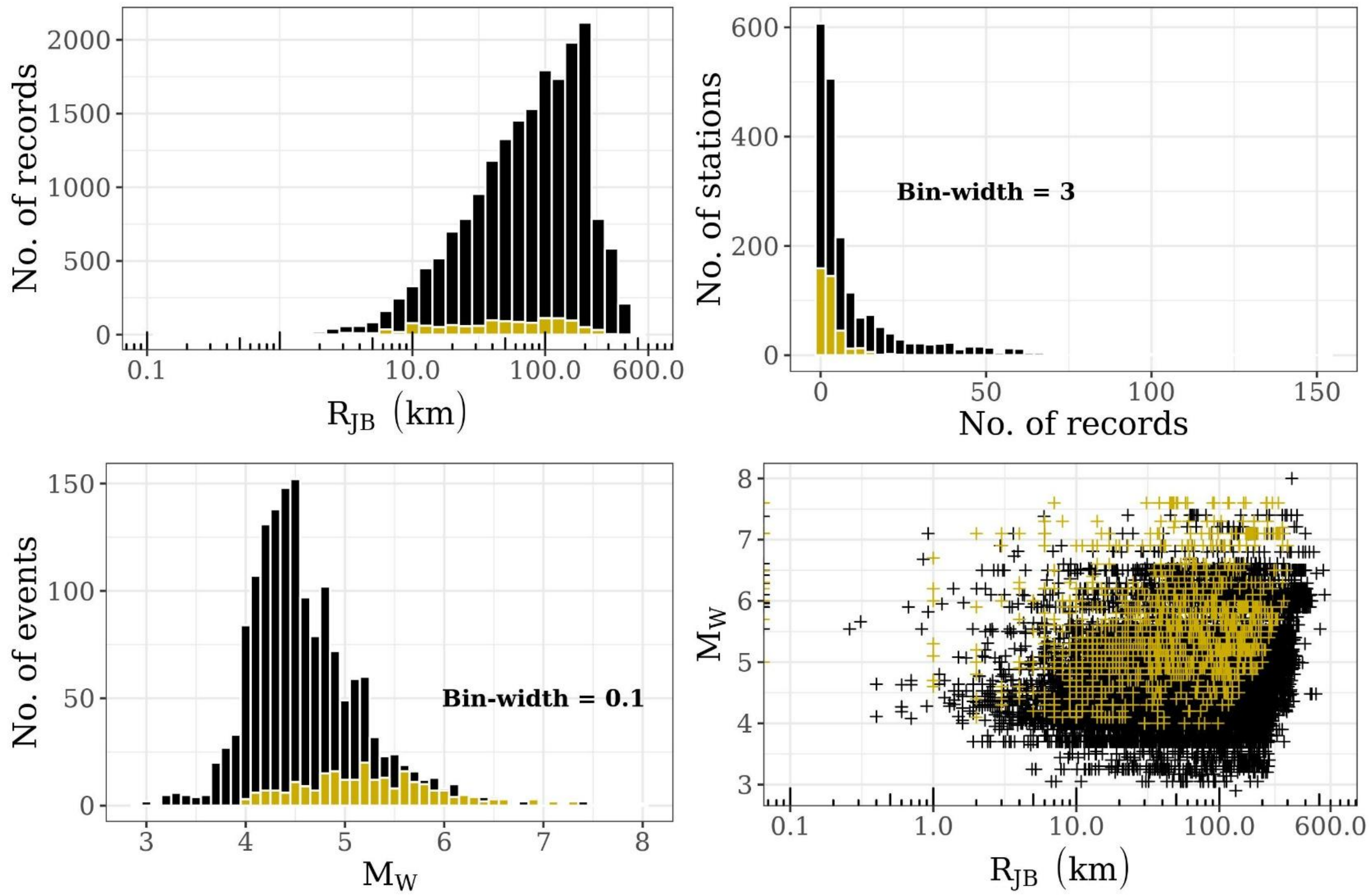
1. **Datasets**
   - European Strong Motion dataset (Lanzano et al. 2018, Bindi et al. 2018)
   - TSUMAPS-NEAM (Basili et al. 2019)
   - TECTO ESHM2020 (Danciu et al.)
2. **Ground-motion model (Kotha et al. 2020)**
   - Robust linear mixed-effects regressions
   - Random-effect and residual variances
   - Spatial variability of GMM coefficients
3. **Application and testing**
   - Comparison with observed response spectra
   - 10-fold cross-validation

European Strong Motion dataset

ESM dataset: Lanzano et al. (2018) & Bindi et al. (2018)

RESORCE dataset: Akkar et al. (2014)

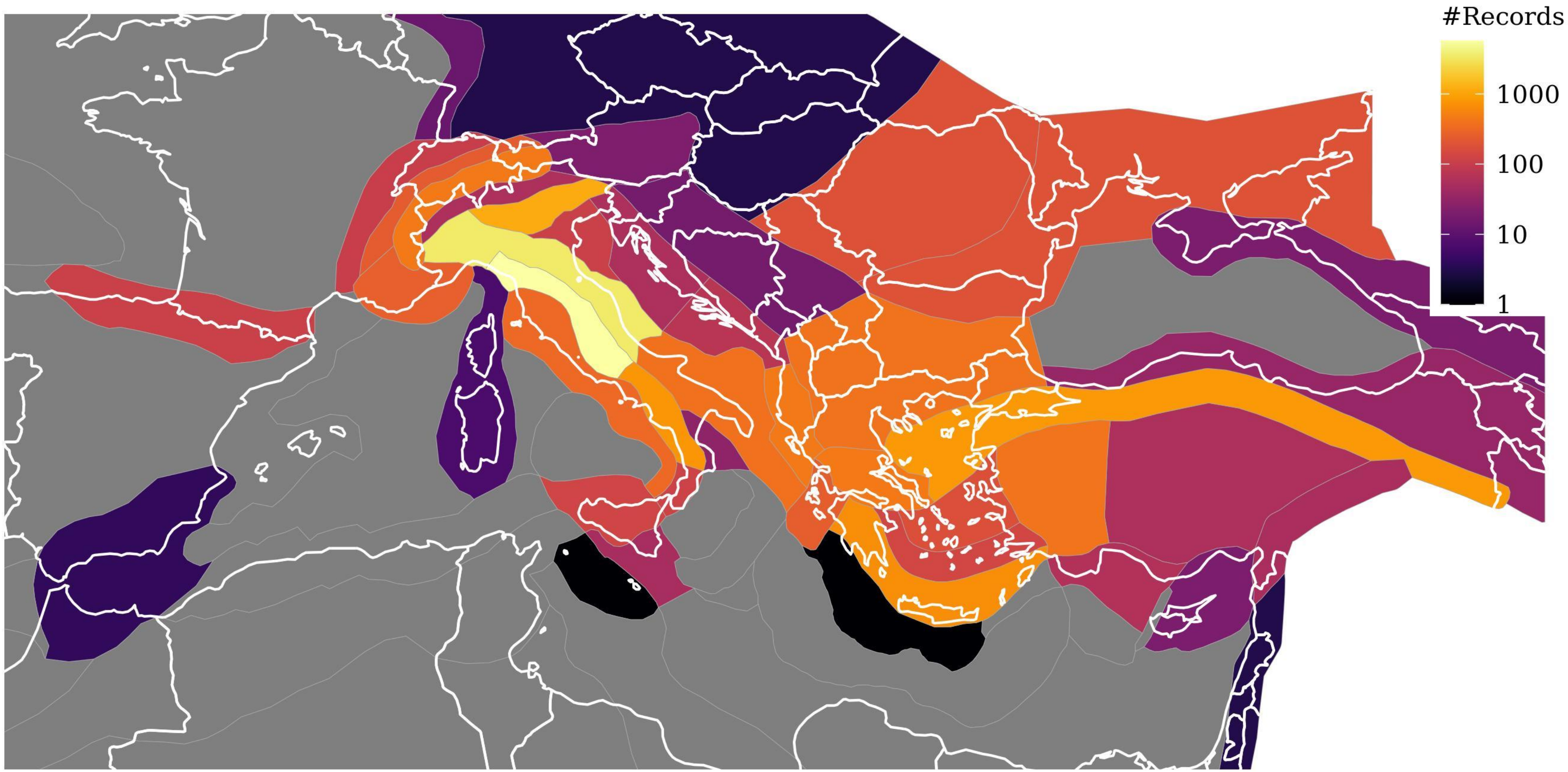
	ESM	RESORCE
M_W	3.0 – 7.4	4.0 – 7.6
R_{JB}	0 – 471km	0 – 300km
Sites	1829	384
Events	927	246
Tectonic localities	56	-
Attenuation regions	46	2
Records	18222	1251



Regionalization of paths

Regionalization of apparent anelastic attenuation (TSUMAPs-NEAM - Basili et al. 2019)

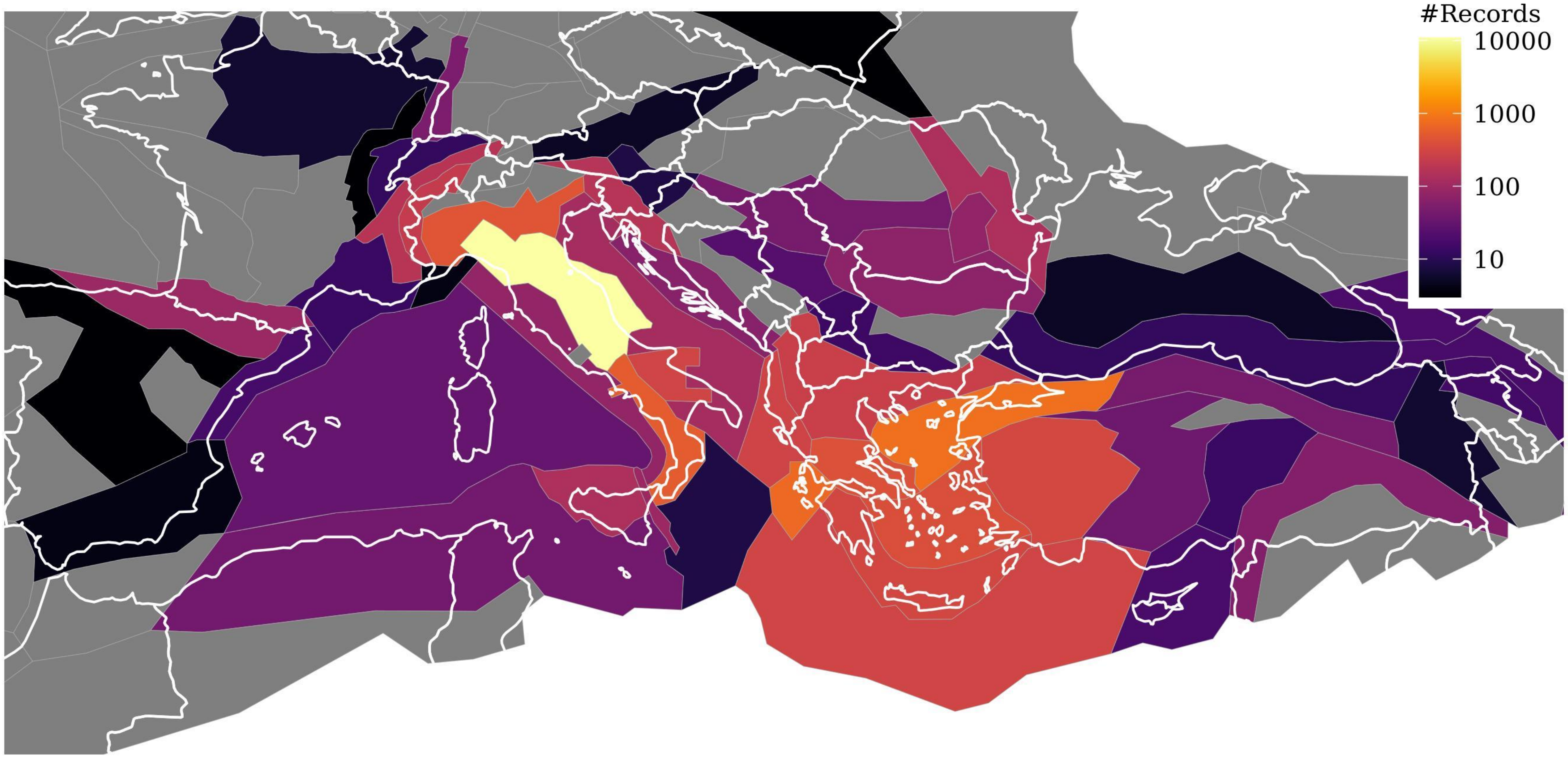
18222 records at 1829 sites into 46 regions (Kotha et al. 2020)



Regionalization of sources

Localization of shallow crustal events into tectonic localities (ESHM2020 - Danciu et al.)

18222 records from 927 events into 56 tectonic localities (Kotha et al. 2020)



Response spectra GMM

Ground-motion model for PGA, PGV, SA for T = 0.01-8s - Kotha et al. (2020)

$$ln(SA_{obs}) = F_M(M_W) + F_G(M_W, R_{JB}) + F_{A,r}(R_{JB}) + \delta L2L_l + \delta B^0_{e,l} + \delta S2S_s + \varepsilon$$

1. Robust linear mixed-effects regression to flag outliers
2. Regionalization of anelastic attenuation (TSUMAPs-NEAM - Basili et al.2019)
   - $F_{A,r}(R_{JB})$
3. Localization of earthquakes into tectonic localities (ESHM2020 - Danciu et al.)
   - $\delta L2L_l$
4. Site-terms for regional risk assessment (Crowley et al. 2020, Weatherill et al.)
   - $\delta S2S_s$

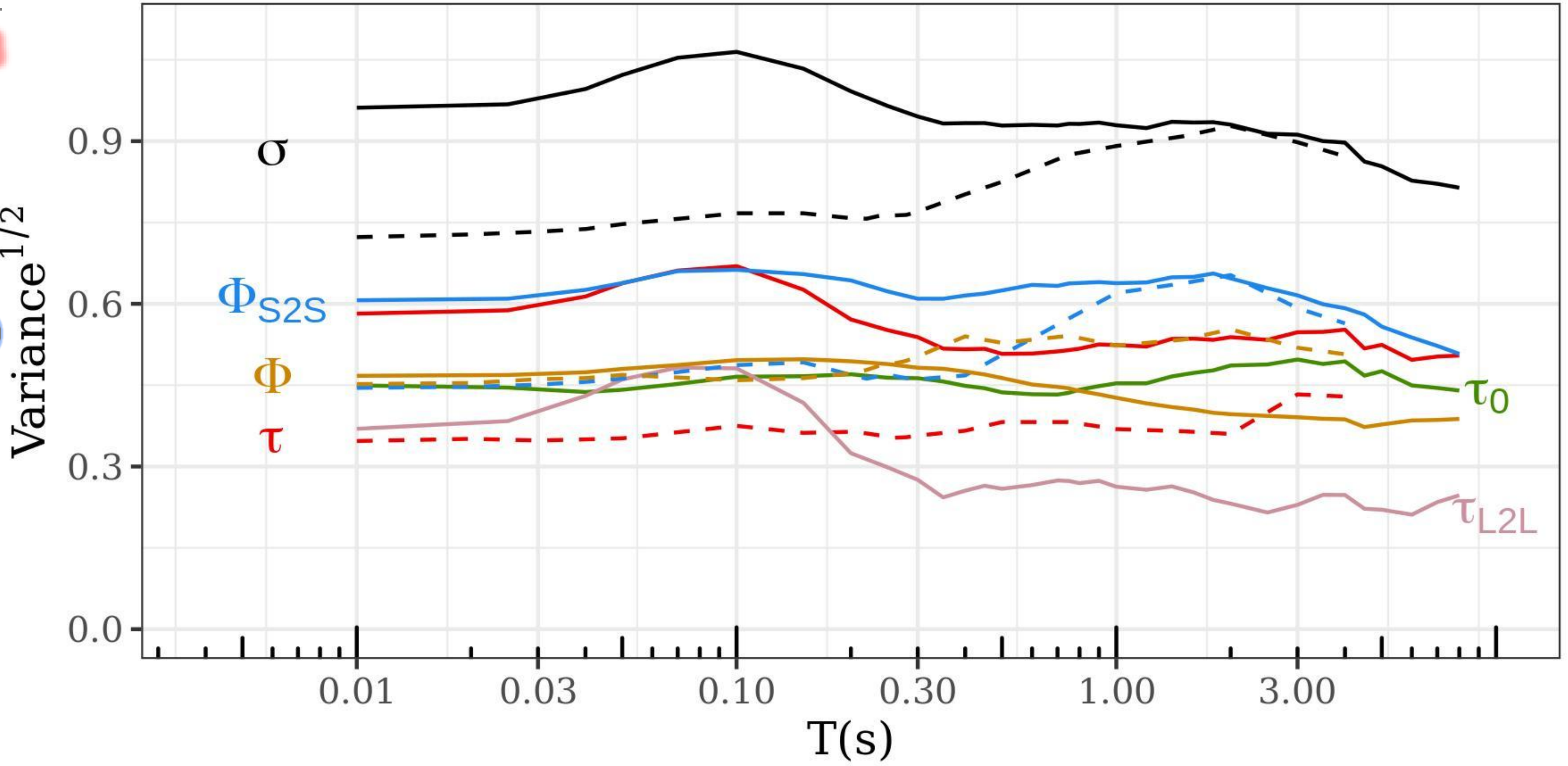
Random-effect and residual variances

ESM (solid) v/s RESORCE (dashed) based Kotha et al. (2016) GMM

$$\sigma = \sqrt{\Phi_{S2S}^2 + \Phi^2 + \tau^2}$$

$$\tau = \sqrt{\tau_0^2 + \tau_{L2L}^2}$$

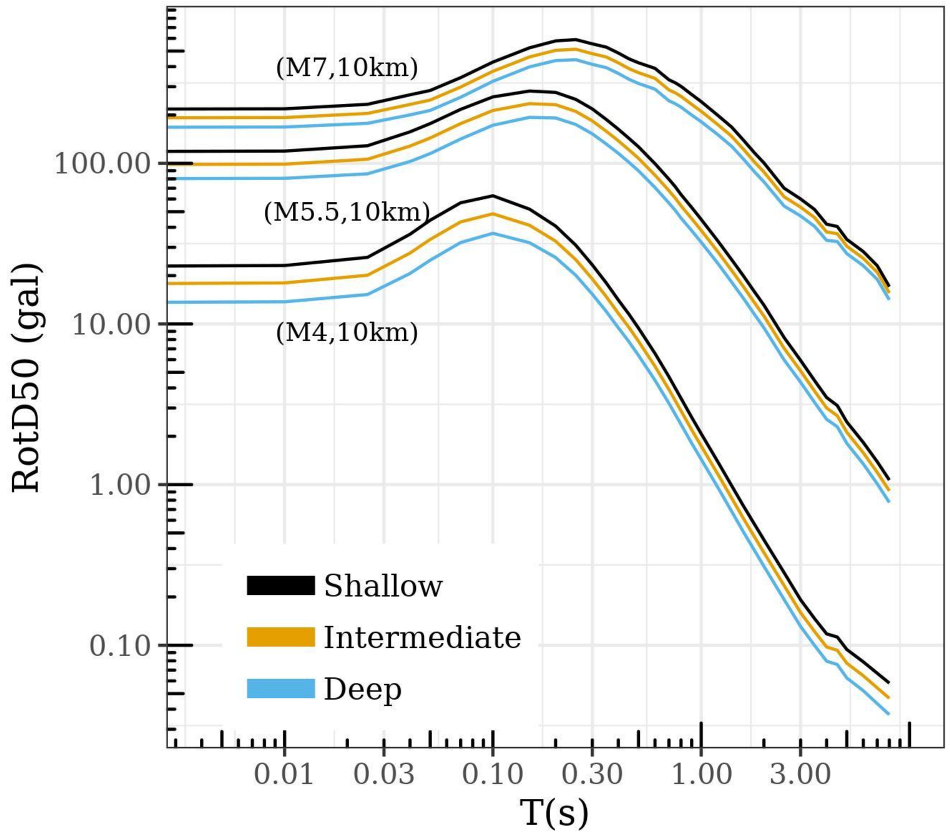
- $\Delta S2S_s = \mathrm{N}(0, \Phi_{S2S})$
- $\varepsilon = \mathrm{N}(0, \Phi)$
- $\Delta B_{e,l}^0 = \mathrm{N}(0, \tau_0)$
- $\Delta L2L_l = \mathrm{N}(0, \tau_{L2L})$

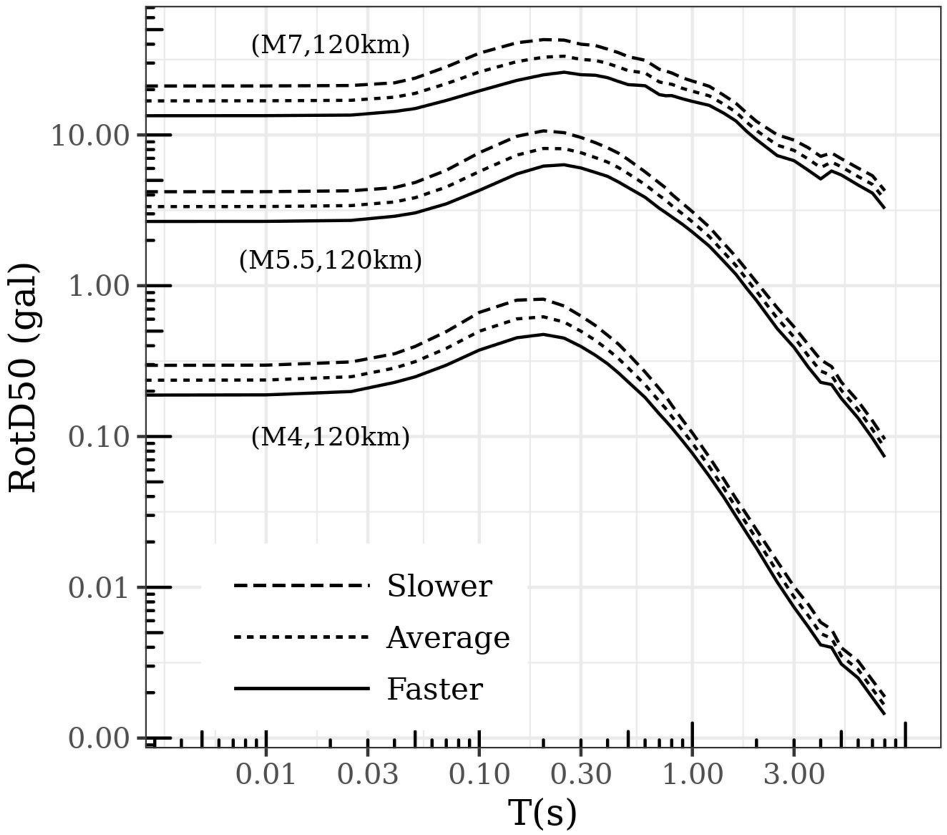


Response spectra

Regionalized attenuation and event hypo. depth dependence – 9 combinations

- Shallow events - $D_{hypo} < 10km$; Inter. - $10 \leq D_{hypo} < 20km$; Deep - $D_{hypo} \geq 20km$
- Slower attenuation - $\delta c_{3,r} = \tau_{c3}$; Average - $\delta c_{3,r} = 0$; Faster - $\delta c_{3,r} = -\tau_{c3}$

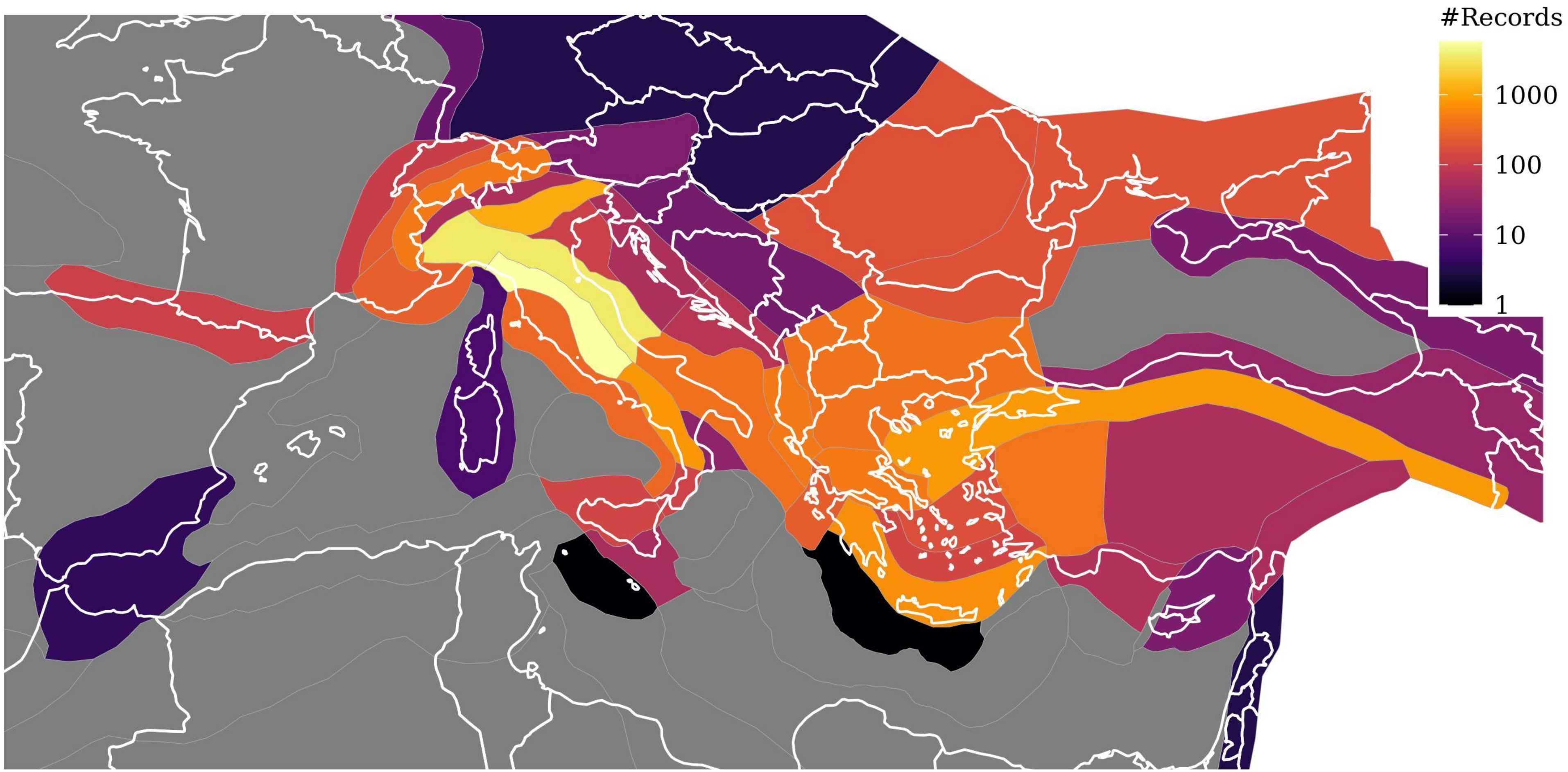




Regionalized Anelastic Attenuation

$\Delta c_{3,r} = \mathcal{N}(0, \tau_{c3})$ - High seismicity regions attenuate faster than average

Volcanic regions attenuate even faster, e.g. Gulf of Corinth



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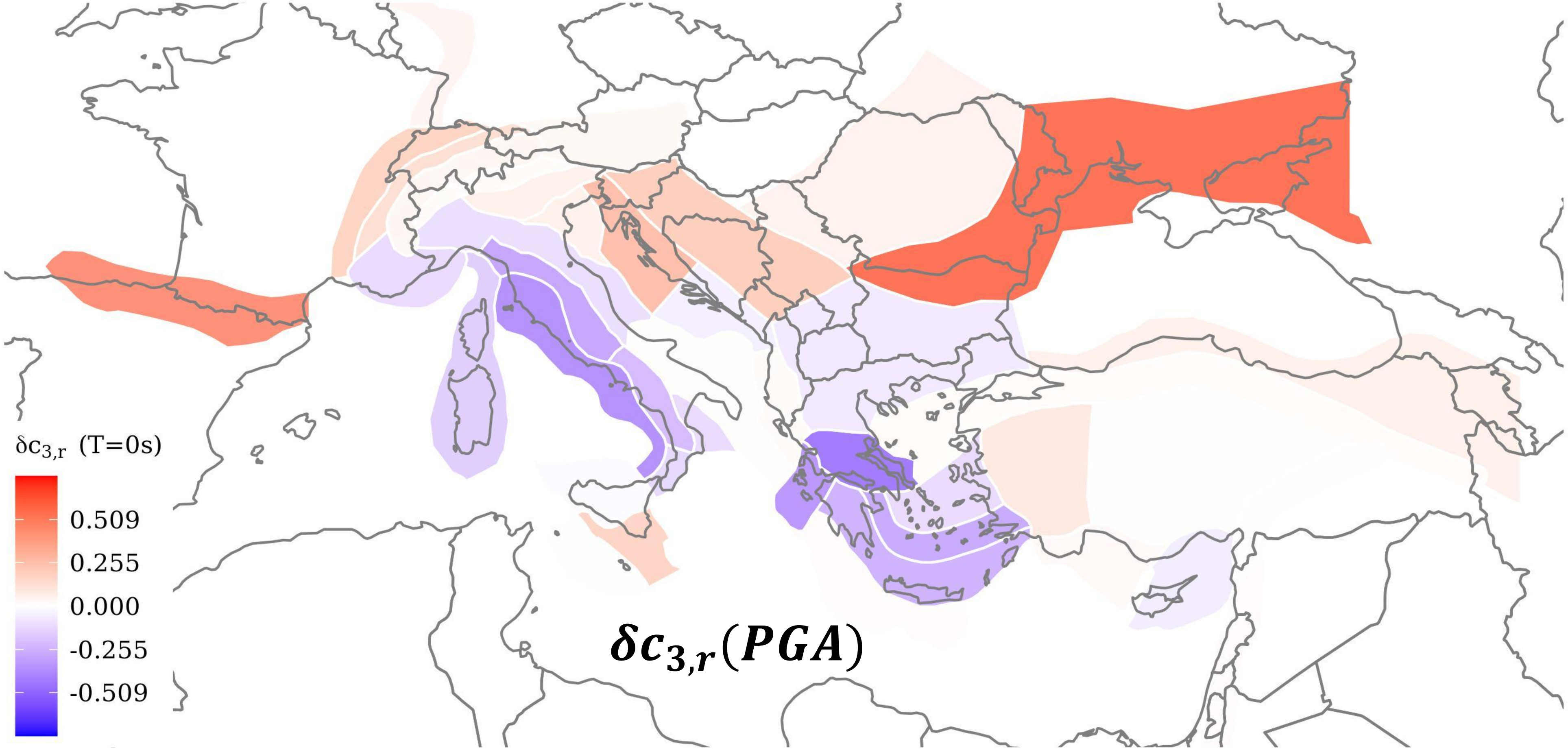
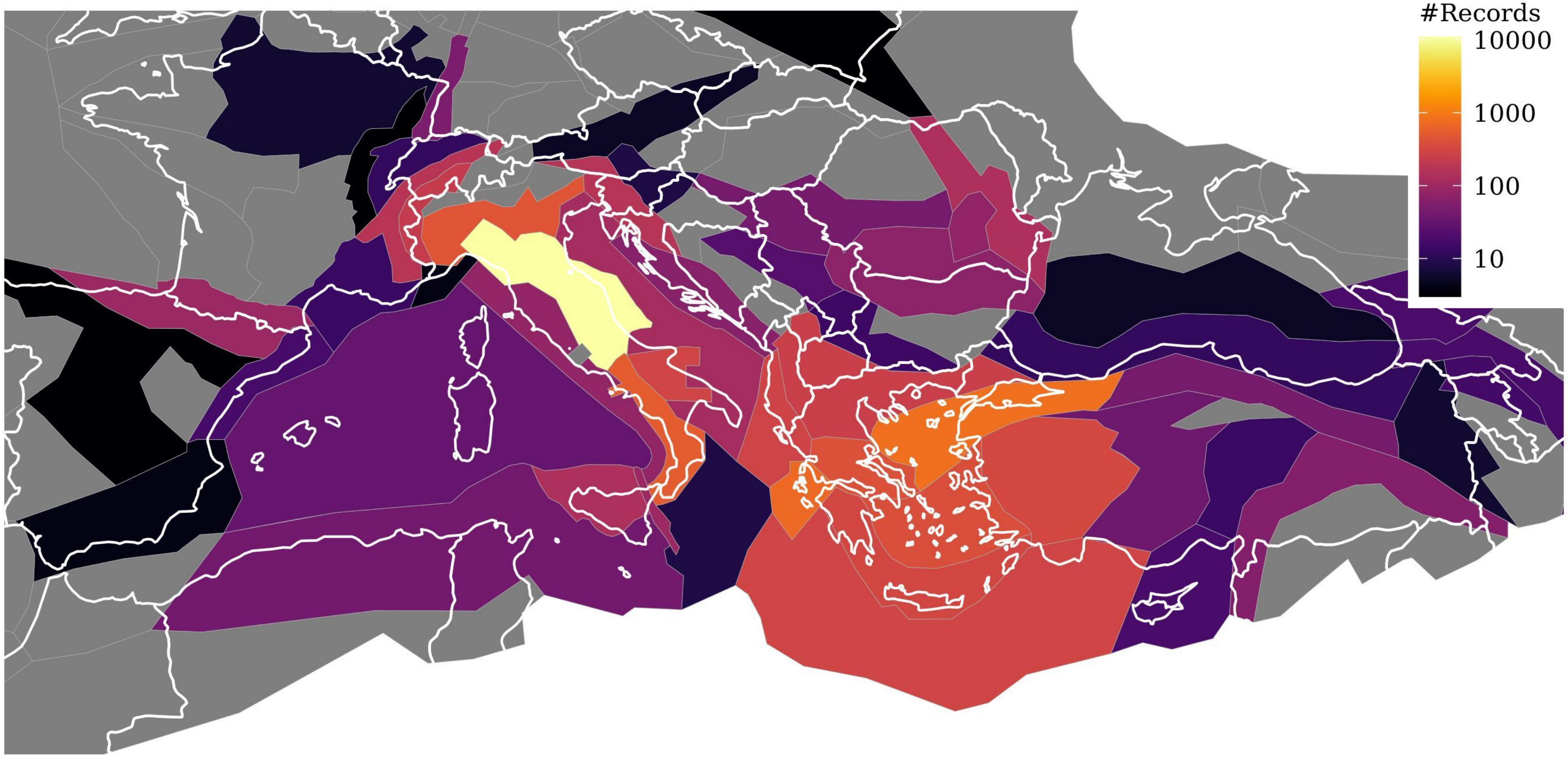


$\delta c_{3,r}(PGA)$

Regionalized Sources

$\Delta B^{0}_{e,l} = \mathcal{N}(0, \tau_0)$ – No discernible spatial pattern, after location correction

$\Delta L2L_l = \mathcal{N}(0, \tau_{L2L})$ – Stronger events in North-West Anatolia than in Central Apennines



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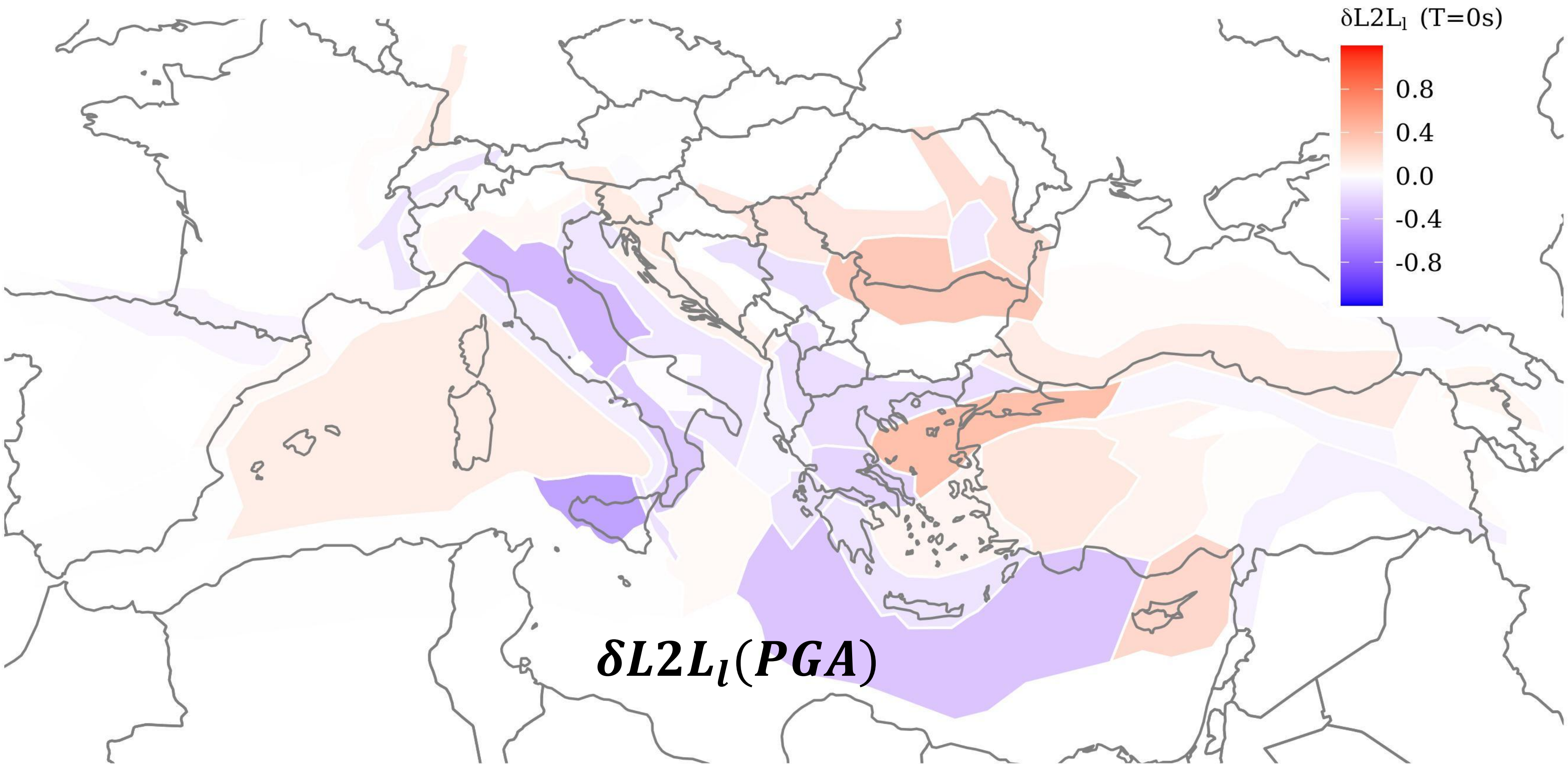
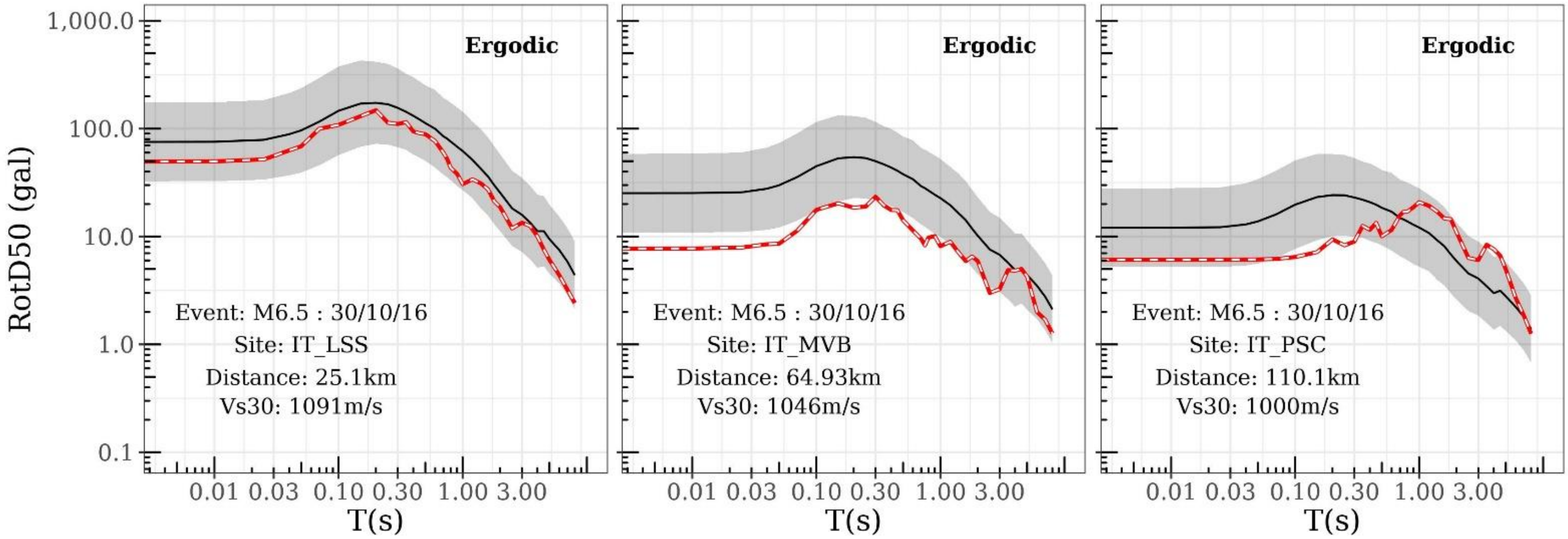


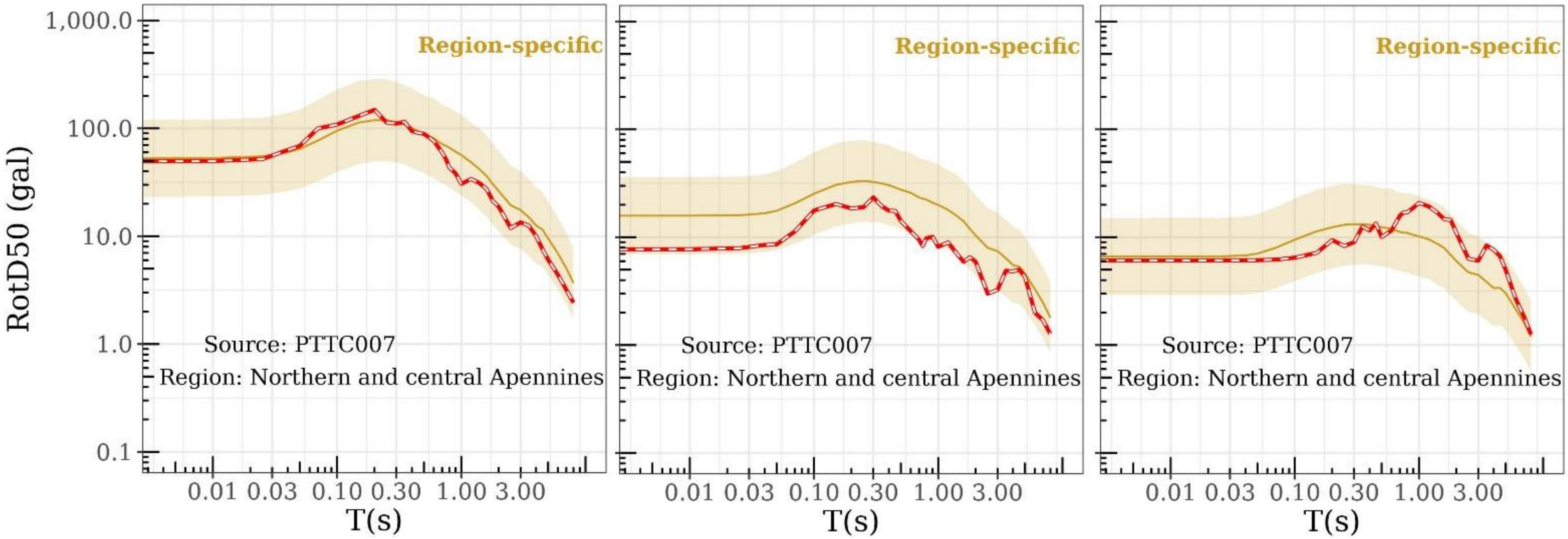
Comparison with M6.5 Norcia (2016) spectra

$$Ergodic\ prediction - \mathcal{N}(\mu, \sqrt{\tau_0^2 + \tau_{L2L}^2 + \Phi_{S2S}^2 + \Phi^2})$$



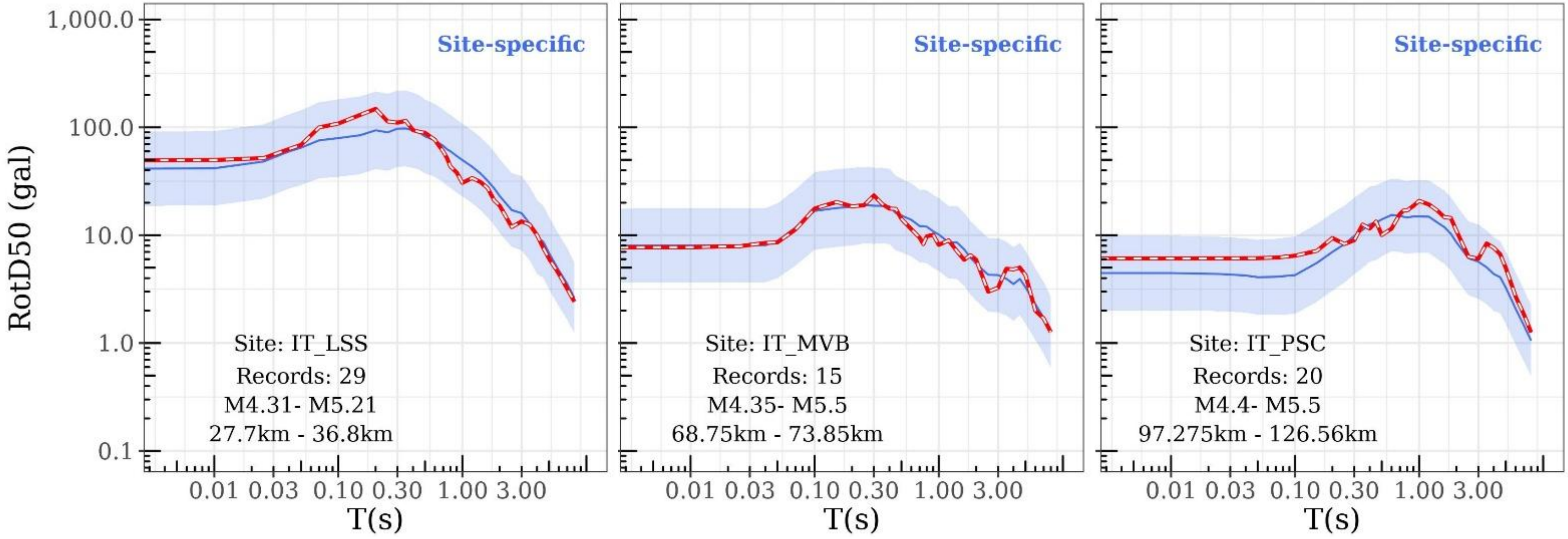
Comparison with M6.5 Norcia (2016) spectra

$$Regionalized\ prediction - \mathcal{N}\left(\mu\left(\delta c_{3,r}\right) + \delta L2L_l, \sqrt{\tau_0^2 + \varphi_{S2S}^2 + \varphi^2}\right)$$



Comparison with M6.5 Norcia (2016) spectra

$$Site-specific\ prediction - \mathrm{N}\left(\mu(\delta c_{3,r}) + \delta L2L_l + \delta S2S_s, \sqrt{\tau_0^2 + \varphi^2}\right)$$



10-fold cross validation

Ground-motion model for PGA, PGV, SA for T = 0.01-8s - Kotha et al. (2020)

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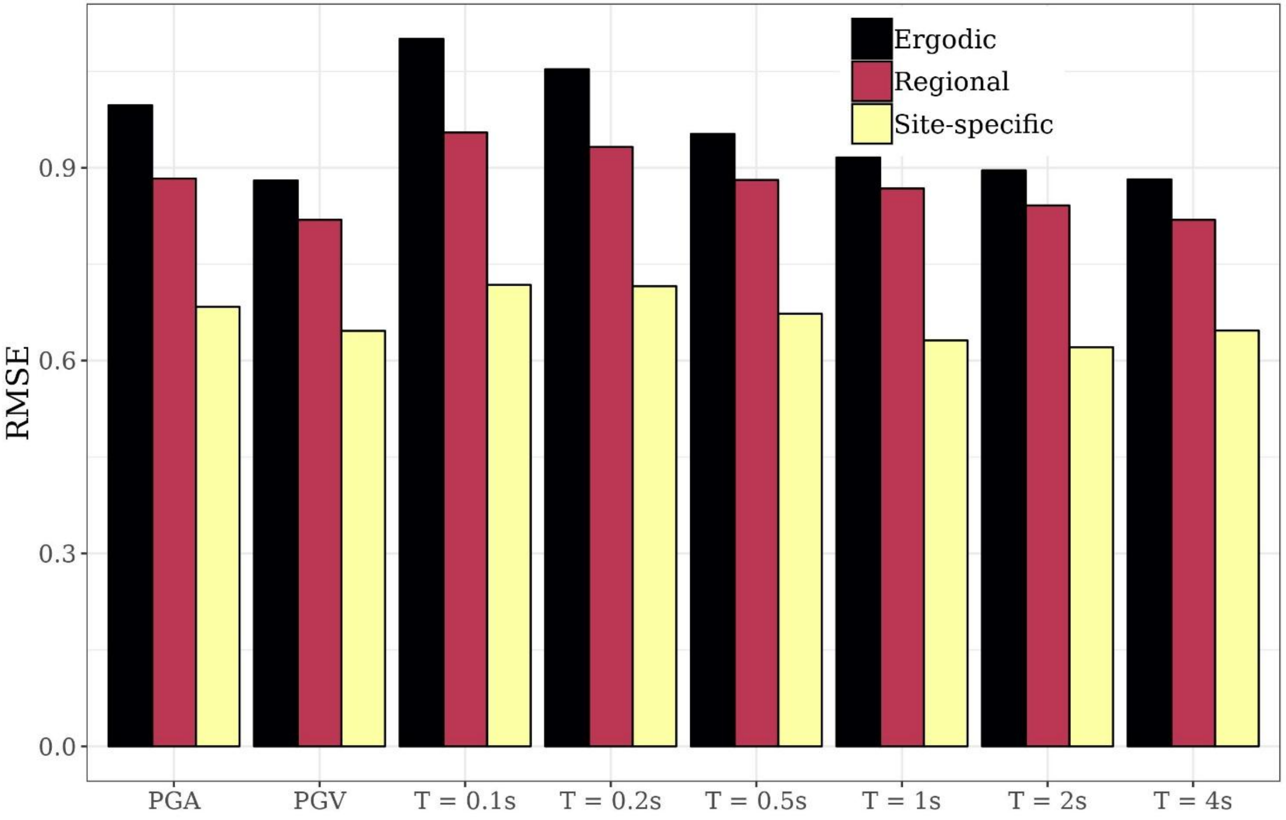
Recognizable improvement from ergodic to region to site-specific GMMs

- 10 subsets with exclusive events
- Train on 9 subsets
- Test on 1 subset
- Repeat 10 times for each period
  - Ergodic
  - Regional
  - **Region and site-specific**



Thank you!!!

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