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Rapid Earthquake Damage Assessment ConsorTium

Black Sea CROSS BORDER COOPERATION

Institute of Engineering Seismology & Earthquake Engineering (ITSAK)

Scientist in charge: N. Theodulidis

Rapid Earthquake Damage Assessment Consortium" (REDACt)

WP3: (a) Seismic Source – (b) GMPEs Evaluations and Selection in REDAS [ITSAK]

Part of R&T team of ITSAK:

Basil Margaris (Researcher A)

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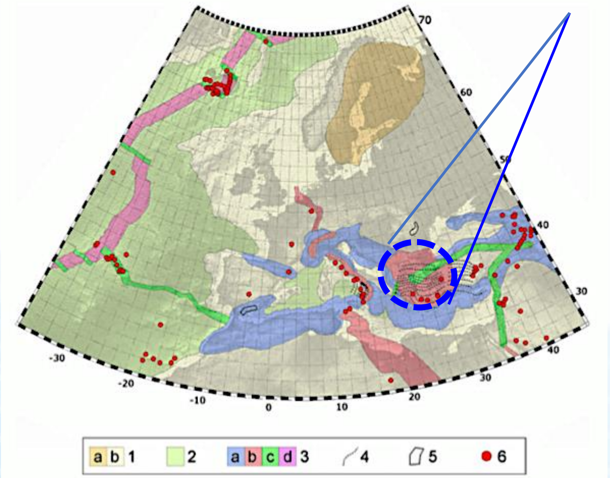
- **Scope and goal of the Harmonization**
- **Seismic Sources (**SHARE or others**) & refinement**
- **GMPEs selection & testings** (Greece-Turkey, Romania-Moldova)
- **Some comments/results from PSHA in the Greek Eligible Area.**

1. SEISMOGENIC SOURCES AND FAULTS IN THE ELIGIBLE AREA

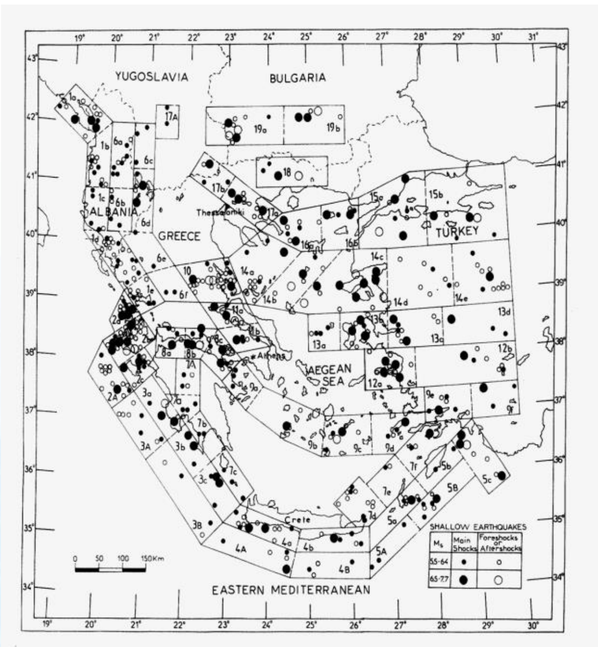
1. All available seismogenic sources, faults and GMPES presented per country.
2. Seismic sources & faults and GMPEs may differ from each other and probably NOT—Compatible in cross border areas.
3. Avoiding deviated results, a harmonization of seismic sources & faults parameters in the Black Sea area with emphasis in cross border areas is attempted.
4. Harmonization of the GMPEs for selected ones of shallow and <u>intermediate-depth seismic events</u> in ROM-MLD & TR-GR

Area of interest

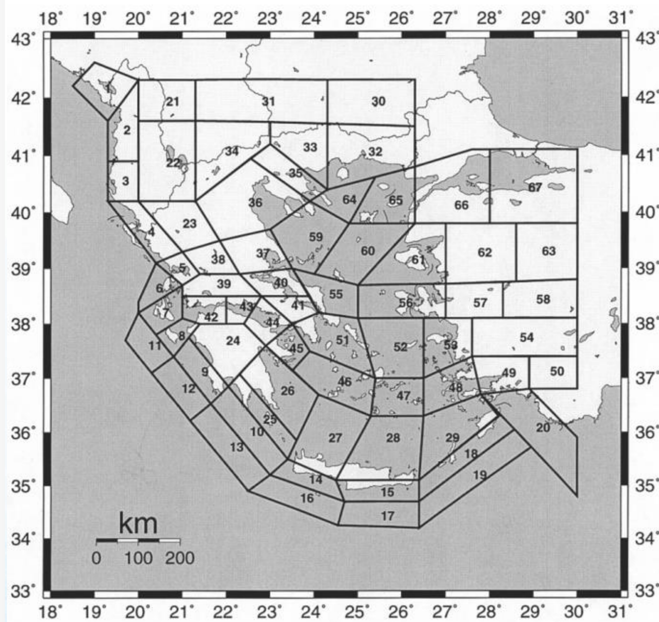


Seismotectonic map of the Euro-Mediterranean area developed for the SHARE prj. (Delavaud et al. 2012; Woessner et al. 2015)

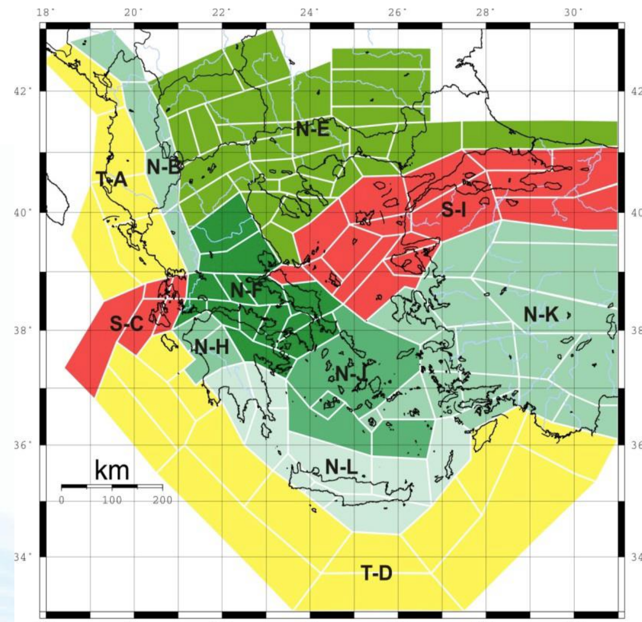
Harmonized seismic faults/sources for REDAS



(Papazachos 1990)



(Papaioannou & Papazachos 2000)



(Vamvakaris etal, 2016)

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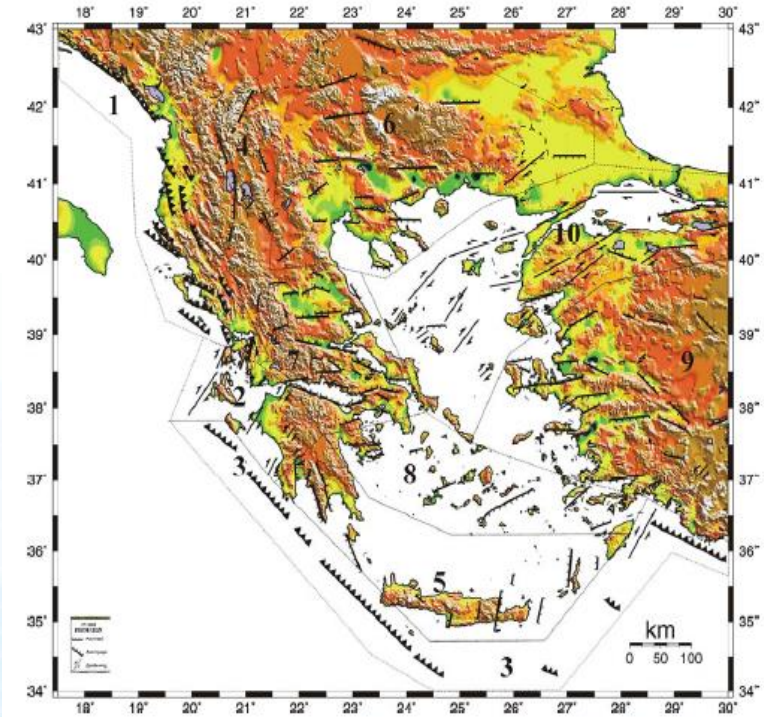
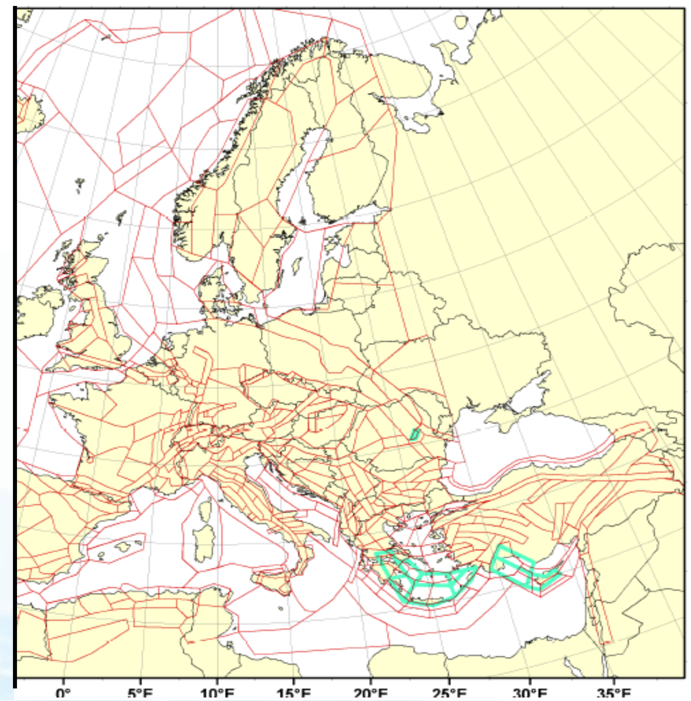
Harmonized seismic faults/sources for REDAS



(Papazachos etal, 2001)



(SHARE Project 2010)

Common borders. Common solutions.

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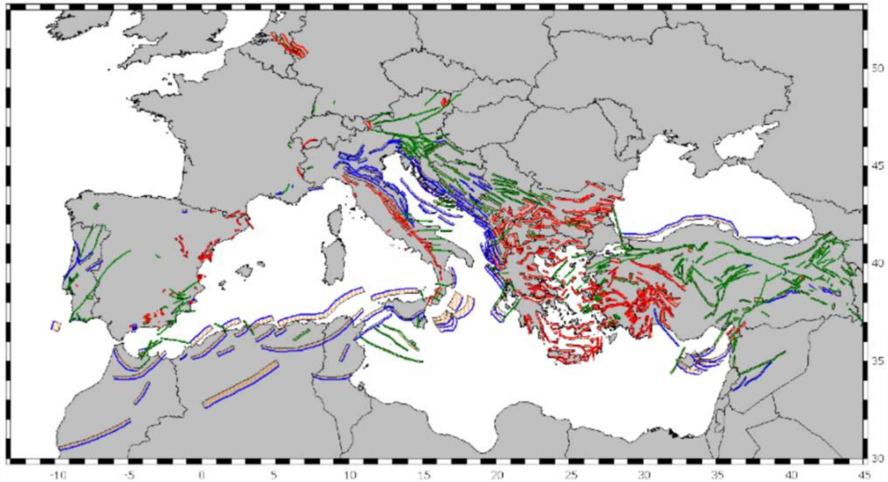
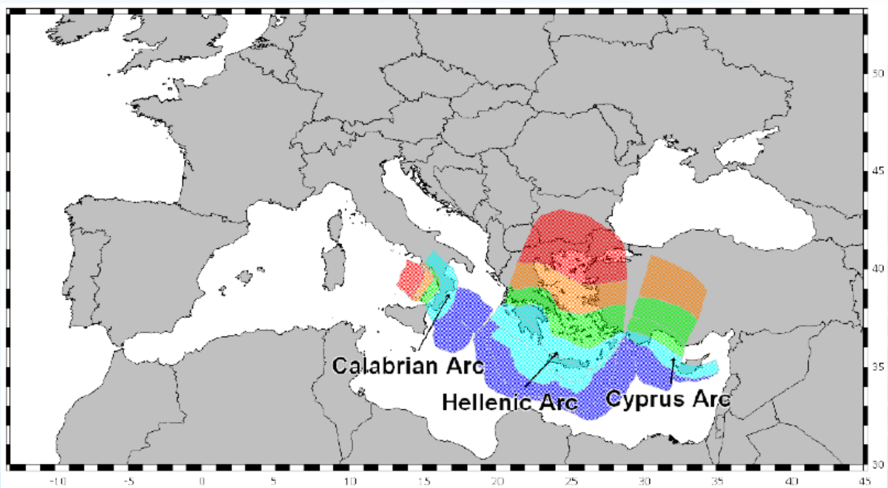
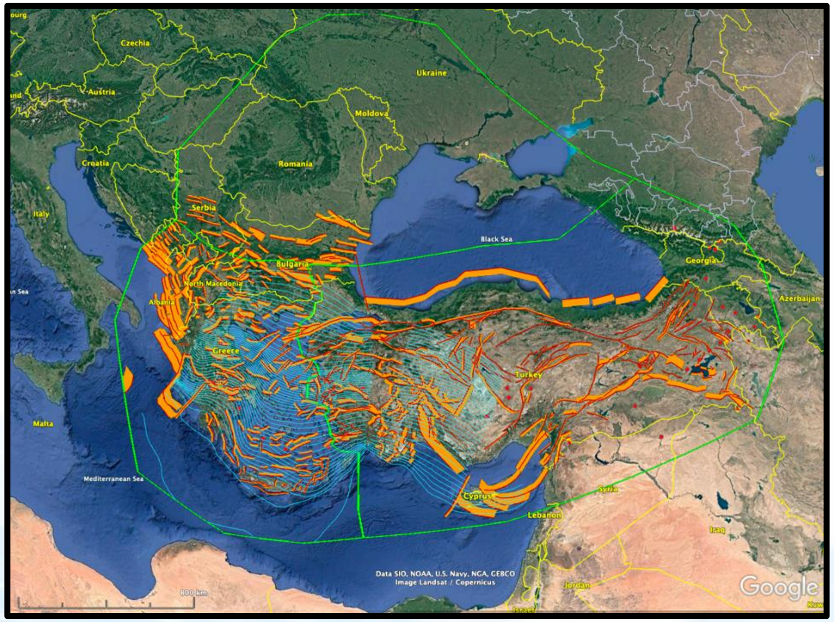
Harmonized seismic faults/sources for REDAS





(SHARE Project 2013)



(SHARE Project 2013)

2. GMPEs selection & ranking Greece-Turkey;

(Modified from Theodoulidis 2022)

Selection of candidate GMPEs

- Selection of regional & worldwide GMPEs (see Douglas 201)
- Application of specific criteria (see Cotton et al. 2006)
- Review of the GMPEs applicability range of their dependent variables
- Evaluation of the GMPEs using the criteria of Bommer et al. (2010)

↓

Testing Using data

- Ranking of GMPEs based on Scherbaum et al. (2009; LLH), *Mak etal. (2017; MLLH), Kale & Akkar(2013; EDR).*

↓

Proposition of logic tree

- Selection of the final GMPEs (Reckon on LLH, MLLH &EDR)
- Proposition of different sets of weights (if necessary)

↓

Final Logic Tree of GMPEs

[Similar to SHARE 2013, strategy]

2. GMPEs selection & testings AT3.1 (Greece-Turkey)

No	Reference	Remarks
1	Erdik et al. (1985)	excluded
2	Theodoulidis & Papazachos(1992)	excluded
3	Theodoulidis & Papazachos(1994)	excluded
4	Theodoulidis et al. (1998)	excluded
5	Gülkan and Kalkan (2002)	excluded
6	Skarlatoudis et al. (2003)	excluded
7	Özbey et al. (2004)	excluded
8	Ulusay et al. (2004)	excluded
9	Kalkan and Gülkan (2004)	excluded
10	Beyer and Bommer (2006)	excluded
11	Güllü and Erçelebi (2007)	excluded
12	Bindi et al. (2007)	excluded
13	Akkar and Bommer (2007)	excluded
14	Danciu and Tselentis (2007)	excluded
15	Gullu et al. (2008)	excluded
16	Cabalar and Cevik (2009)	excluded
17	Akyol and Karagöz (2009)	excluded
18	Selcuk et al. (2010)	excluded
19	Akkar and Bommer (2010)	excluded
20	Ulutaş and Özer (2010)	excluded
21	Akkar and Çağnan (2010)	excluded
22	Çağnan et al. (2011)	excluded
23	Yilmaz (2011)	excluded
24	Kayabali and Beyaz (2011)	excluded
25	Skarlatoudis et al. (2013)	For Hellenic subduction & 4.5≤M≤6.5 & Vs30 not available
26	Bindi et al. (2014)	Use of RESORCE database as in Akkar et al. (2014)
27	Chiou and Youngs (2014)	OK
28	Abrahamson et al.(2014)	OK
29	Akkar et al. (2014)	OK
30	Kale et al. (2015)	Is based on the model of Akkar & Cagnan (2010) and site terms of Sandikkaya et al. (2013))
31	Kotha et al. (2016a,b)	Is based on RESORCE data and improved in 2020
32	Cagnan et al. (2017)	Presents only vertical component
33	Javan-Emrooz et al. (2018)	Presents only PGA, PGV, PGD and 2 site classes
34	Ktenidou et al. (2018)	Use Mygdonian basin moderate to small magnitude data-Coefficients are not reported
35	Chousianitis et al. 2018)	OK
36	Kotha et al. (2020)	OK
37	Boore et al. (2021)	OK

GMPM	Magnitude type/ Range	Distance type/ Range	Intensity measures	Site classification type	Style of Faulting	Horizontal Component type	Region
Akkar et al. (2014)	M_w/ 4.0-7.6	R_{jb}, R_{hypo} or R_{epi}/1-200 km	PGA, PGV, S_a (T=0.02-4.0 s)	V_{S30} based	NS, SS, RS	Geometric Mean	Europe and Middle-East
Chiou and Youngs (2014)	M_w/ 3.5-8.5 for SS M_w/ 3.5-8.5 for NS or RS	R_{rup}, R_{jb}, R_x / 0 – 300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based (180 – 1500 m/s)	NS, SS, RS	Arithmetic mean	Global, California, Japan, China, Italy, Turkey
Abrahamson et al. (2014)	M_w/ 3.0-8.5	R_{rup}, R_{jb}, R_x, R_{y0}/ 0 – 300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based	NS, SS, RS	Arithmetic mean	Global, California, Japan, China, Italy, Turkey, Taiwan
Chousianitis et al. (2018)	M_w/ 4.0-6.8	R_{epi}/ 0.3-200 km	PGA, PGV, T_m	NEHRP classification (B, C, D)	Unknown, NS, SS, RS	Geometric Mean	Greece
Kotha etal. (2020)	M_w/ 3.0-7.4	R_{jb}/1-545 km	PGA, PGV, S_a (T=0.01-8.0 s)	V_{S30} based (90 – 3000 m/s) or slope based	-	RotD50	Europe and Mediterranean
Boore et al. (2021)	M_w/ 4.0-8.0	R_{jb}/1-300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based (150 – 1200 m/s)	Unknown, NS, SS, RS	RotD50	Greece

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2. GMPEs selection & racking AT3.1 (Greece-Turkey)
Methods and Results

1. Normalized residuals method

Table 2.5: Ranking (combined) of selected GMPMs based on combined PGA and PGV residuals

Ranking	GMPM	MeanNorm Res(PGA-PGV)	std dev (PGA-PGV)	Z(PGA-PGV)
1	Boore et al. (2021) w bias	0.134	0.861	0.273
2	Chiou and Youngs (2014)	-0.230	1.082	0.313
3	Chousianitis et al. (2018)	-0.286	0.861	0.424
4	Akkar et al. (2014)	-0.369	0.887	0.483
5	Boore et al. (2021) w/o bias	-0.562	0.932	0.630
6	Kotha et al. (2020)	-0.407	0.749	0.658
7	Abrahamson et al. (2014)	-0.720	0.951	0.769

2. Log-Likelihood method

Table 2.8: Ranking of selected GMPMs based on combined LLH for PGA and PGV

Ranking	GMPM	LLH
1	Chousianitis et al. (2018)	0.160
2	Boore et al. (2021) w/obias	0.910
3	Boore et al. (2021) w bias	0.930
4	Chiou and Youngs (2014)	0.932
5	Kotha et al. (2020)	0.971
6	Akkar et al. (2014)	1.035
7	Abrahamson et al. (2014)	1.167

Weighting Factor : $w_l = \frac{e^{Z*}}{\sum_{k=1}^{K} e^{Z*}}$

A/A	GMPM	w_l - LLH	w_l - residuals	Final w_l
1	Boore et al. (2021) w bias	0.160	0.281	0.346
2	Chiou and Youngs (2014)	0.160	0.270	0.337
3	Boore et al. (2021) w/o bias	0.162	0.241	0.317
4	Chousianitis et al. (2018)	0.272	0.121	-

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Evaluation of GMPEs in Regional and Global Scale
(Sotiriadis & Margaris, SDEE, 2022)

Table 1: Selected regional and global GMPEs for evaluation of their predictive performance
*NS: Normal-slip, SS: strike-slip, RS: reverse-slip or thrust

GMPE	Magnitude type/Range	Distance type/ Range	Intensity measures	Site classification type	Style of Faulting	Horizontal Component type	Region
Danciu and Tselentis (2007) (DaTs07)	M_w/ 4.5-6.9	R_{epi}/ 0.3-136 km	PGA, PGV, S_a (0.1-4s)	NEHRP classification (B, C, D)	NS, SS, RS	Arithmetic mean	Greece
Bindi et al. (2014) (Bindi14)	M_w/ 4.0-7.6	R_{jb} or R_{hypo}/1-300 km	PGA, PGV, S_a (T=0.02-3.0 s)	Eurocode 8 classification (A - D) and V_{S30} based	Unknown, NS, SS, RS	Geometric Mean	Europe and Middle-East
Akkar et al. (2014) (Akkar14)	M_w/ 4.0-7.6	R_{jb}, R_{hypo} or R_{epi}/1-200 km	PGA, PGV, S_a (T=0.02-4.0 s)	V_{S30} based	NS, SS, RS	Geometric Mean	Europe and Middle-East
Boore et al. (2014) (Bssa14)	M_w/ 3.0-8.5	R_{jb}/1-400 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based (150 – 1500 m/s)	Unknown, NS, SS, RS	RotD50	Global, California, Japan, China, Italy, Turkey, Taiwan
Chiou and Youngs (2014) (CY14)	M_w/ 3.5-8.5 for SS M_w/ 3.5-8.5 for NS or RS	R_{rup}, R_{jb} / 0 – 300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based (180 – 1500 m/s)	NS, SS, RS	RotD50	Global, California, Japan, China, Italy, Turkey
Abrahamson et al. (2014) (ASK14)	M_w/ 3.0-8.5	R_{rup}, R_{jb} , R_x, R_{y0}/ 0 – 300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based	NS, SS, RS	RotD50	Global, California, Japan, China, Italy, Turkey, Taiwan
Campbell & Bozorgnia (2014) (CB14)	M_w/ 3.3-8.5	R_{rup}/ 0-300 km	PGA, PGV, Sa (0.01-10s)	V_{S30}-based	NS, SS, RS	RotD50	Global
Derras et al. (2014) (Derras14)	M_w/ 3.6-7.6	R_{jb}/0-550 km	PGA, PGV, Sa (0.01-4s)	V_{S30}-based	NS, SS, RS	Arithmetic mean	Europe and Middle-East
Cauzzi et al. (2015) (Cauzzi15)	M_w/ 4.5-7.9	R_{rup}/ 0-150 km	S_D(0-10s), PS_A(0-10s), PGA, PGV	Eurocode 8 ground type-based or V_{S30}-based	Unknown, NS, SS, RS	Geometric Mean	Global
Kotha et al. (2020; 2022) (Kot20)	M_w/ 3.0-7.4	R_{jb}/1-545 km	PGA, PGV, S_a (T=0.01-8.0 s)	V_{S30} based (90 – 3000 m/s) or slope based	-	RotD50	Europe and Mediterranean
Boore et al. (2021) (Bea21)	M_w/ 4.0-8.0	R_{jb}/1-300 km	PGA, PGV, S_a (T=0.01-10.0 s)	V_{S30} based (150 – 1200 m/s)	Unknown, NS, SS, RS	RotD50	Greece

Evaluation of GMPEs in Regional and Global Scale

(Sotiriadis & Margaris, SDEE, 2022)

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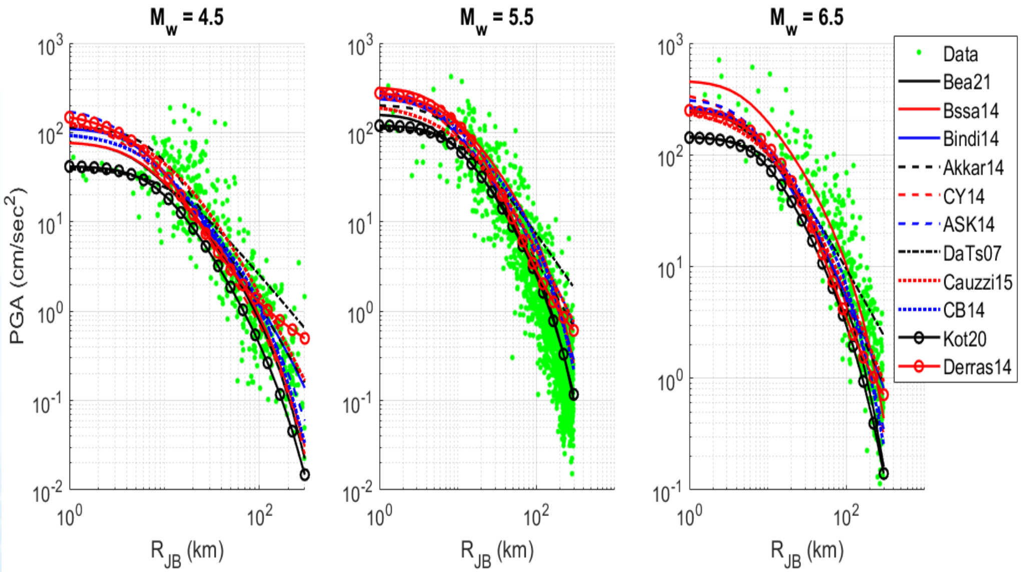
Methodology

1. **Log-Likelihood method (LLH; Scherbaum etal., 2004, 2009)**
2. **Euclidean distance – based ranking (EDR; Kale & Akkar, 2013)**
3. **Multivariate LLH (M-LLH; Mak etal., 2017)**

Ranking	GMPE	EDR UNW	LLH UNW	MLLH UNW	Total UNW
1	Bea21	11	11	11	33
2	Kot20	10	10	10	30
3	CY14	7	9	9	25
4	CB14	8	6	7	21
5	ASK14	6	8	5	19
6	Derras14	4	7	6	17
7	Bssa14	9	3	4	16
8	Cauzzi15	2	5	8	15
9	Akkar14	3	4	2	9
10	Bindi14	5	1	1	7
11	DaTs07	1	2	3	6



Ranking	GMPE	EDR UNW	LLH UNW	MLLH UNW	Total UNW	Weight
1	**Bea21**	**11**	**11**	**11**	**33**	**0.38**
2	**Kot20**	**10**	**10**	**10**	**30**	**0.34**
3	**CY14**	**7**	**9**	**9**	**25**	**0.29**

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Evaluation of GMPEs in Regional and Global Scale

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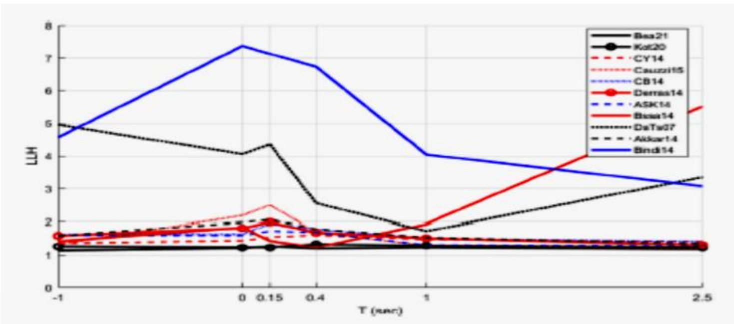
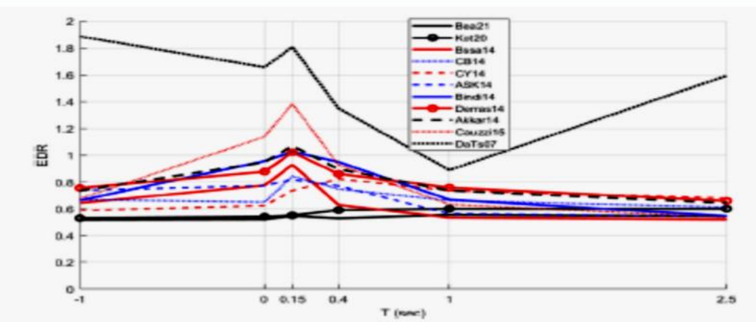
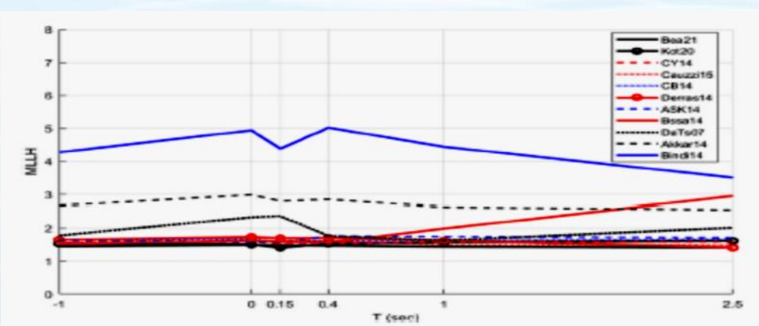


LLH with respect to period of vibration for every GMPE considered. Period value equal to - 1 corresponds to PGV.



EDR with respect to period of vibration for every GMPE considered. Period value equal to - 1 corresponds to PGV.



MLLH with respect to period of vibration for every GMPE considered. Period value equal to 1 corresponds to PGV.

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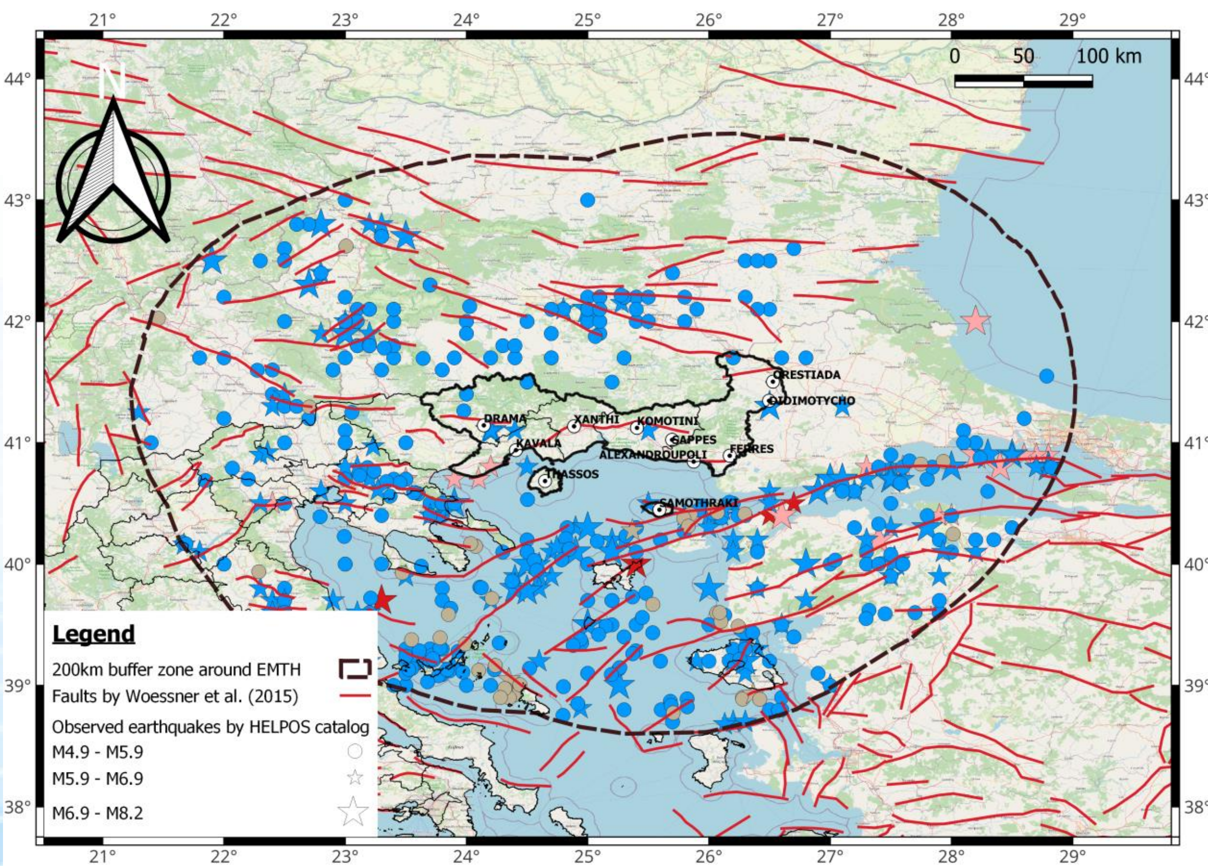
Comparative PSHA (Greece-Turkey)

Application for PSHA in East Macedonia and Thrace Region: KEDIAK Project

Sotiriadis D., B. Margaris N. Klimis, & I. Dokas (2023). Seismic Hazard in Greece : A Comparative study for the region of East Macedonia and Thrace, ***Journal of Geohazards*** *(Under Publication) .*



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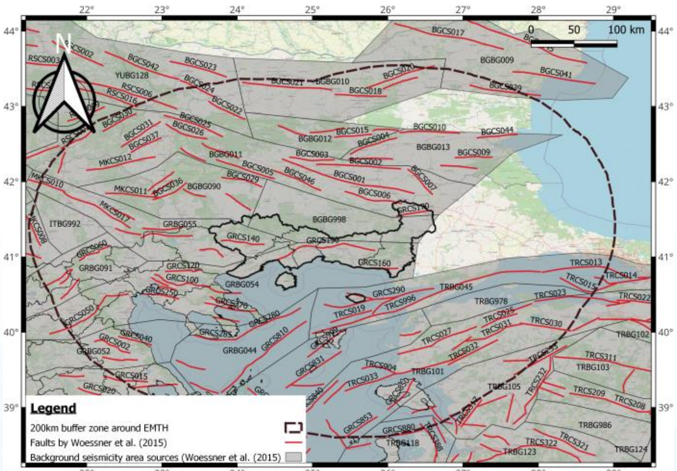
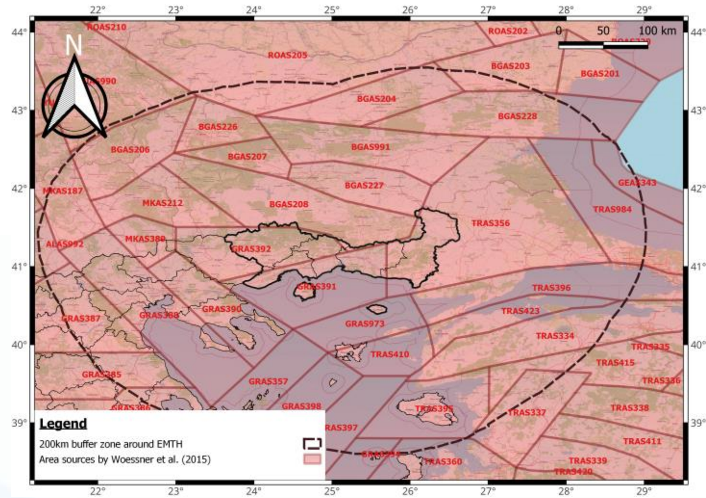


(1)



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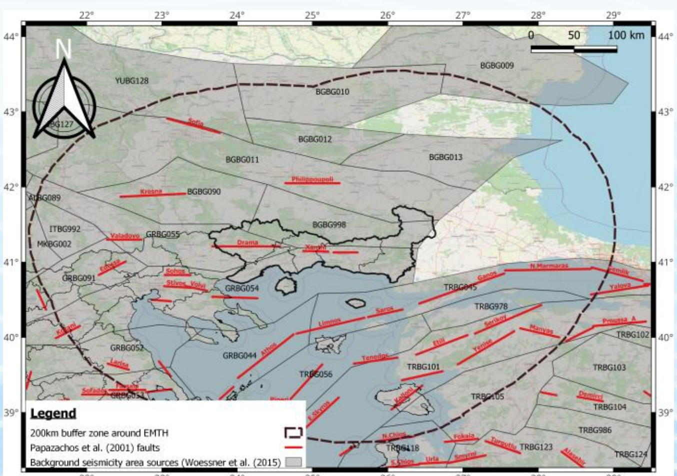

(2)

Seismic Source Models

1. Seismic Faults -**PZ01** (Papazachos etal. 2001) and Background Seismic Sources **ESHM13 [SHARE-B]**.
2. Seismic Faults and Background Seismic Sources **ESHM13 [SHARE_F_B ~ TAB_21]**.
3. Area seismic zones **ESHM20 [SHARE-Areal]**.

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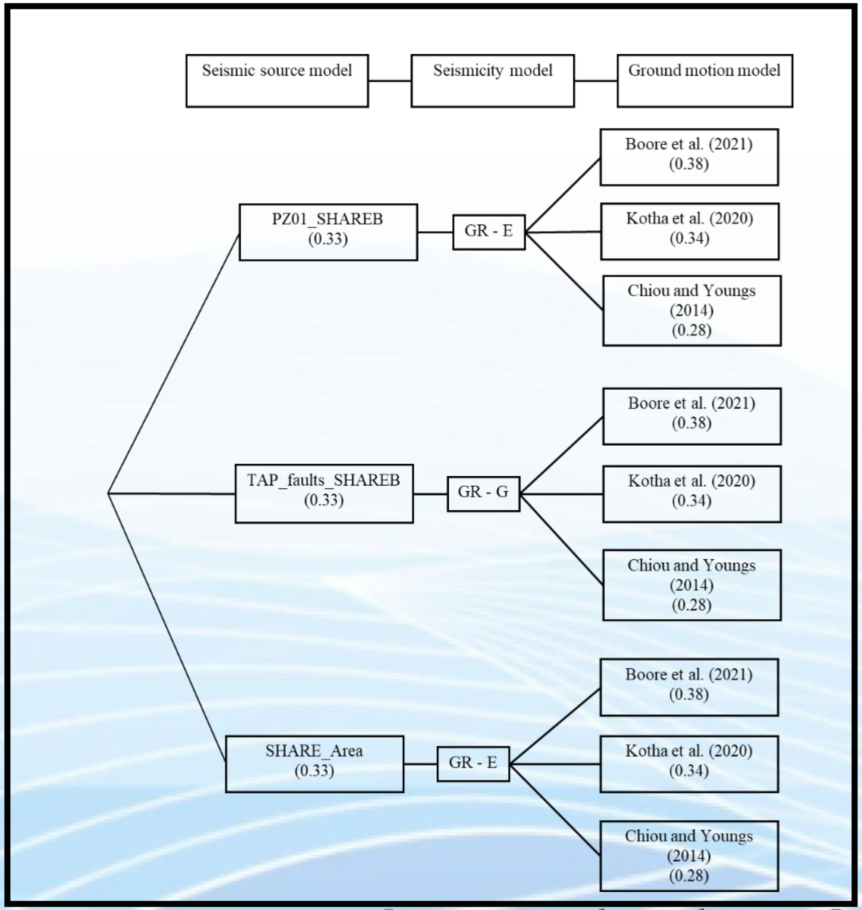

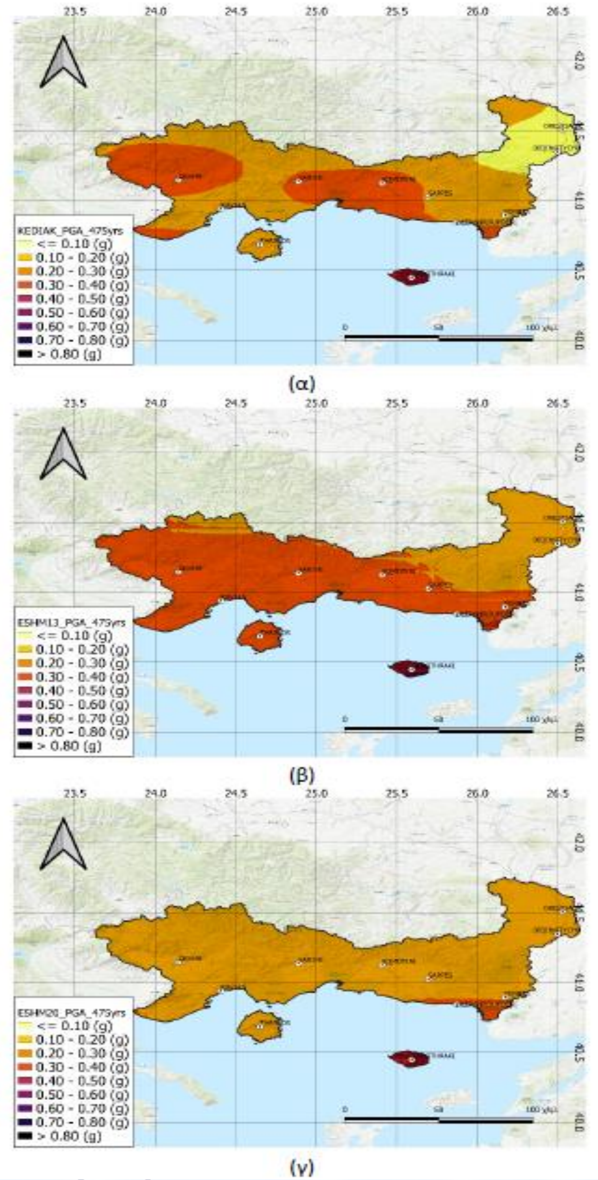

(1)

(2)

(3)

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Discussions – Conclusions

- **The variability of the seismic source models have been examined within the framework of the present project. For most of the sites considered the variability of the results due to the source model selection is significant, in terms of Probabilistic Seismic Hazard Assessment (PSHA).**

- *Within the framework of REDACt project, particular attention is devoted in the selection of GMPEs. In the work presented herein, the reliability of the prediction accuracy of a pre-selected suite of GMPEs, against observed strong motion data of shallow Greek earthquakes, is evaluated. The goal of this work is to facilitate GMPE selection for PSHA in Greece, using a data-driven rationale, rather than conducted Strong Motion Calculations.*

- **The present study's results are compared against the results of the recent ESHM13 and ESHM20 seismic hazard models. As a general comment, one could argue that the PSHA maps proposed herein, having the significant advantage of local verification of the PHSA components, stand between the ones proposed by ESHM13 and ESHM20. Moreover, significant differences are observed between the ESHM13 and ESHM20 maps.**

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A Black Sea Basin Joint Operational Programme 2014-20 project

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