PSHA input model documentation for Arabian Peninsula (ARB)

GEM Hazard Team

Version history

Table 1 summarises version history for the ARB input model, named according to the versioning system described here, and indicating which version was used in each of the global maps produced since 2018. Refer to the GEM Products Page for information on which model versions are available for various use cases. The changelog describes the changes between consecutive versions and are additive for all versions with the same model year.

***Table 1** – Version history for the ARB input model.*

Version	2018.1	2019.1	2022.1	2023.1	Changelog
v2018.0.0	X				First version of the model implemented in OpenQuake.
v2018.1.0		X	X		Updated to incorporate seismic sources coming from the Zagros region in western Iran from the MIE model (sources within 300 km of United Arab Emirates; both branches, equally weighted). GMPEs from the MIE model were applied to these sources. Due to the increase in the number of logic tree branches, hazard results were computed by sampling the logic tree.
v2018.2.0				X	Mmin extended to M4 for crustal distributed seismicity. Source ids updated to use syntax supported by disaggregation by source calculator. ssmLT.xml corrected to symmetrically apply sources added from MIE. gmmLT.xml updated with more recent GMPEs

The following text describes v2018.2.0.

Authors: H. Zahran, V. Sokolov, S. El-Hadidy Youssef, W. W. Alraddadi, M. J. Roobol, I. C. F. Stewart, M. El-Hadidy

For any additional information about this model please contact: Zahran.HM@sgs.org.sa

1 Summary

The 2018 seismic hazard model of the Arabian Peninsula (ARB) was developed by the Saudi Geological Survey (SGS). The model covers Saudi Arabia, Yemen, Oman, and Qatar. The model has been translated into the OpenQuake (OQ) engine format by GEM.

2 Tectonic overview

The Arabian Peninsula is a microcontinent on its own tectonic plate in between southern Eurasia and Africa. The plate moves northward relative Eurasia at ~20 mm/yr, resulting in continental convergence and thrust faulting within the Zagros and eastern Anatolian fold belts to the north (which to the southeast continues as subduction of oceanic crust under Iran and western Pakistan), and left-lateral strike-slip faulting along the Dead Sea Transform in the east. To the south, Arabia is moving away from northeastern Africa, leading to oceanic spreading centers in the Red Sea and Gulf of Aden; these form two sides of a ridge-ridge-ridge triple junction with the third branch as the East African Rift extending south.

3 Basic Datasets

Input datasets used for the development of the ARB model are property of the Saudi Geological Survey (SGS). The seismic source model for Arabian Peninsula has been constructed on the basis of recent studies related to seismic hazard assessment for the region. See Al-Arifi et al. 2013, Mohindra et al. 2012, Sokolov et al. 2017, Zahran et al 2016 for a description of the datasets used for developing the hazard model.

4 Hazard Model

4.1 Seismic Source Characterisation

The Seismic Source Characterization (SSC) model consists of 29 homogeneous area source zones (Figure 1) for which seismicity parameters (occurrence, maximum magnitude, depth distribution) and dominant faulting style have been determined. The two models differ only by the occurrence parameters.

The OQ engine implementation of the SSC uses the OQ source typology **Area Source**.

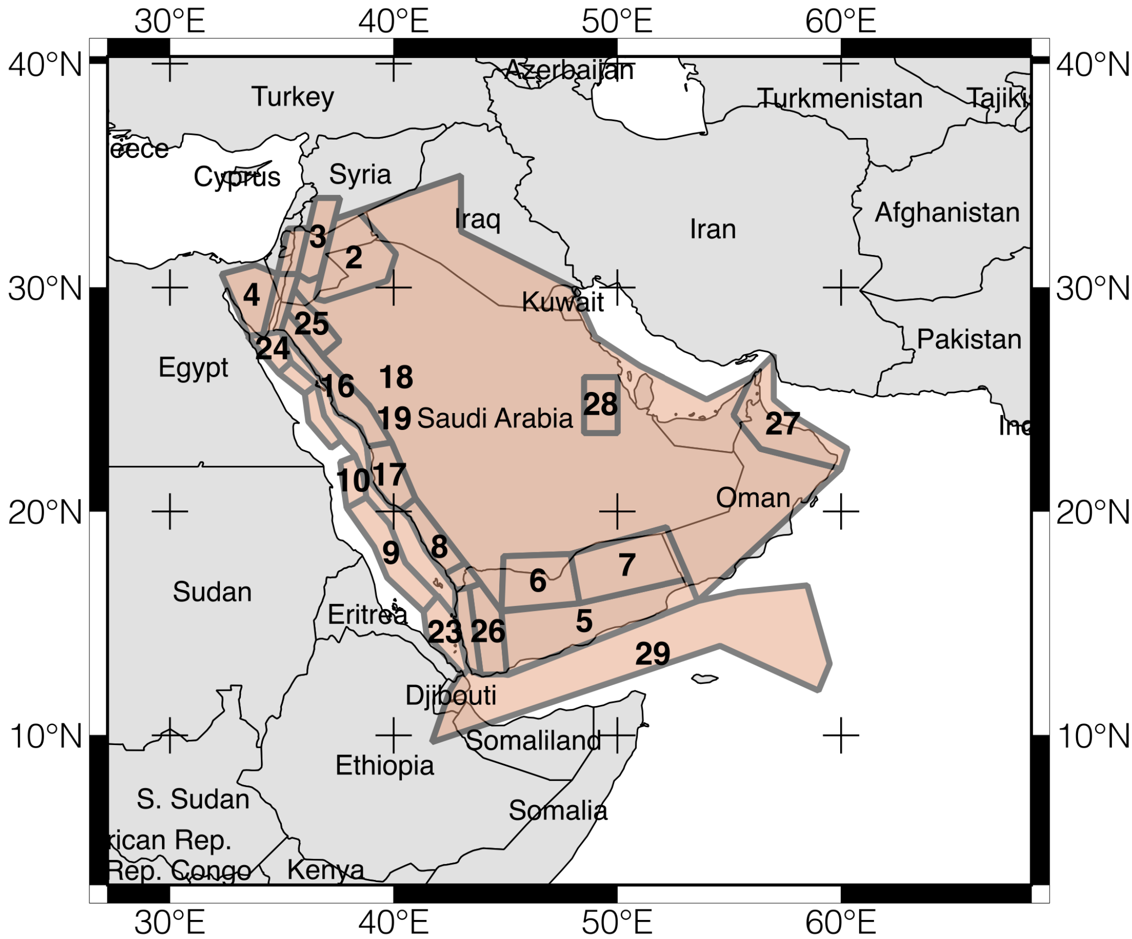

Figure 1 *– The 29 seismic zones of the source model for the Arabian Peninsula.*

Epistemic Uncertainties Since two different declustering approaches (Gardner and Knopoff, 1974 and Uhrhammer 1986) have been applied to the original earthquake catalogue data, two alternative source models are made available in the logic-tree to account for epistemic variability.

4.2 Ground Motion Characterisation

The Ground Motion Characterization (GMC) model contains seven ground motion prediction equations (GMPE). The Atkinson and Boore model (2006) is used for the stable continental region of Saudi Arabia in conjunction with the equations for active shallow crustal sources, namely: the models of Zhao et al. (2006), Boore and Atkinson (2008), Campbell and Bozorgnia (2008), and Akkar et al. (2014). The largest weight (0.60) is assigned to the Atkinson and Boore model for stable regions and equal weights (0.10) are assigned for crustal source equations. Akkar et al. (2014) suggested to consider their model for seismic hazard studies in areas where normal-faulting earthquakes dominate. Therefore, the model (weight 0.3) was used together of Pankow and Pechmann (2004) model (weight 0.7) for extensional zones in the Red Sea. The Pankow and Pechmann' model supersedes a previous study of strong ground motions in extensional tectonic regimes by Spudich et al. (1999).

Two GMPEs developed for the volcanic region of Hawaii were used specifically for the volcanic areas (Yemen Basaltic Trap, Harrat Lunayyir Hot Spot, Makkah- Madinah-Nafud) seismic source zone. The first model is the equation obtained by Munson and Thurber (1997) on the basis of earthquake records from 22 shallow earthquakes with magnitudes from 4.0 to 7.2. The equation predicts PGA as a function of magnitude and source-to-site distance for two site conditions – lava and ash. The maximum of two horizontal components was considered in the model, therefore a coefficient 1.1 (Beyer and Bommer, 2006) is applied in our calculation for conversion to geometric mean of horizontal components that is used in all other GMPEs used in this work. The second equation was developed by Atkinson (2010). Note that the Munson and Thurber model is used for PGA, the Atkinson model for response spectra.

Table **??** below shows the GMC. While in the original implementation the different GMPE were defined by source, in the OQ engine the GMPEs have been clustered into four main tectonic groups: stable regions (TECTONIC_REGION_1), the Red Sea (TECTONIC_REGION_2), active shallow crust (TECTONIC_REGION_3), and volcanic (TECTONIC_REGION_4). The groups are also depicted in Figure 3. Two GMPE logic- trees are implemented, one for PGA and one for other spectral ordinates.

Epistemic Uncertainties For every tectonic region, epistemic uncertainty is considered by using multiple GMPEs, each with an associated logic tree weight.

Deep Seismicity EMME	**Weight**
AbrahamsonEtAl2015SSlab	0.33
ParkerEtAl2020SSlab	0.34

ZhaoEtAl2006SSlab	0.33
Active Shallow Crust EMME	**Weight**
AkkarEtAlRjb2014	0.25
BooreEtAl2014	0.25
CampbellBozorgnia2014	0.25
ZhaoEtAl2006Asc	0.25
TECTONIC_REGION_3	**Weight**
AkkarEtAlRjb2014	0.25
BooreEtAl2014	0.25
CampbellBozorgnia2014	0.25
ZhaoEtAl2006AscSGS	0.25
TECTONIC_REGION_2	**Weight**
PankowPechmann2004	0.7
AkkarEtAlRjb2014	0.3
TECTONIC_REGION_1	**Weight**
AtkinsonBoore2006SGS	0.6
AkkarEtAlRjb2014	0.1
BooreEtAl2014	0.1
CampbellBozorgnia2014	0.1
ZhaoEtAl2006AscSGS	0.1
Subduction Interface EMME	**Weight**
AbrahamsonEtAl2015SInter	0.33
ParkerEtAl2020SInter	0.34
ZhaoEtAl2006SInter	0.33
Stable Shallow Crust EMME	**Weight**
AtkinsonBoore2006	0.3
YenierAtkinson2015BSSA	0.4
PezeshkEtAl2011NEHRPBC	0.3
TECTONIC_REGION_4	**Weight**
Atkinson2010Hawaii	0.25
LanzanoLuzi2019shallow	0.25
AtkinsonBoore2006SGS	0.2
BooreEtAl2014	0.1
CampbellBozorgnia2014	0.1
ZhaoEtAl2006AscSGS	0.1
Subduction Inslab EMME	**Weight**
AbrahamsonEtAl2015SSlab	0.33
ParkerEtAl2020SSlab	0.34
ZhaoEtAl2006SSlab	0.33

Table 2 *– GMPEs used in the ARB model.*

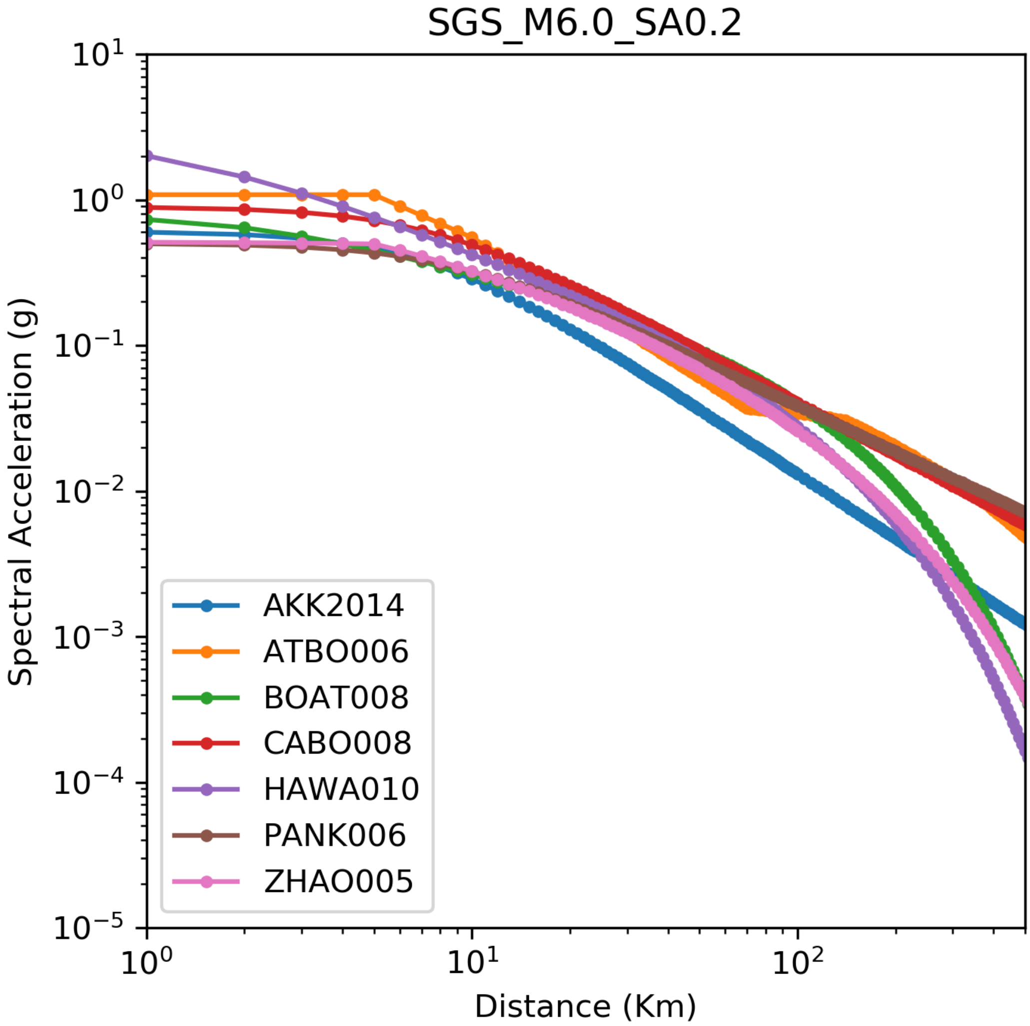

Figure 2 *– Comparison of the ground motion predicted by the different GMPEs used in the ARB model. The plot is for spectral acceleration at 0.2 seconds and* M_w *6*

.

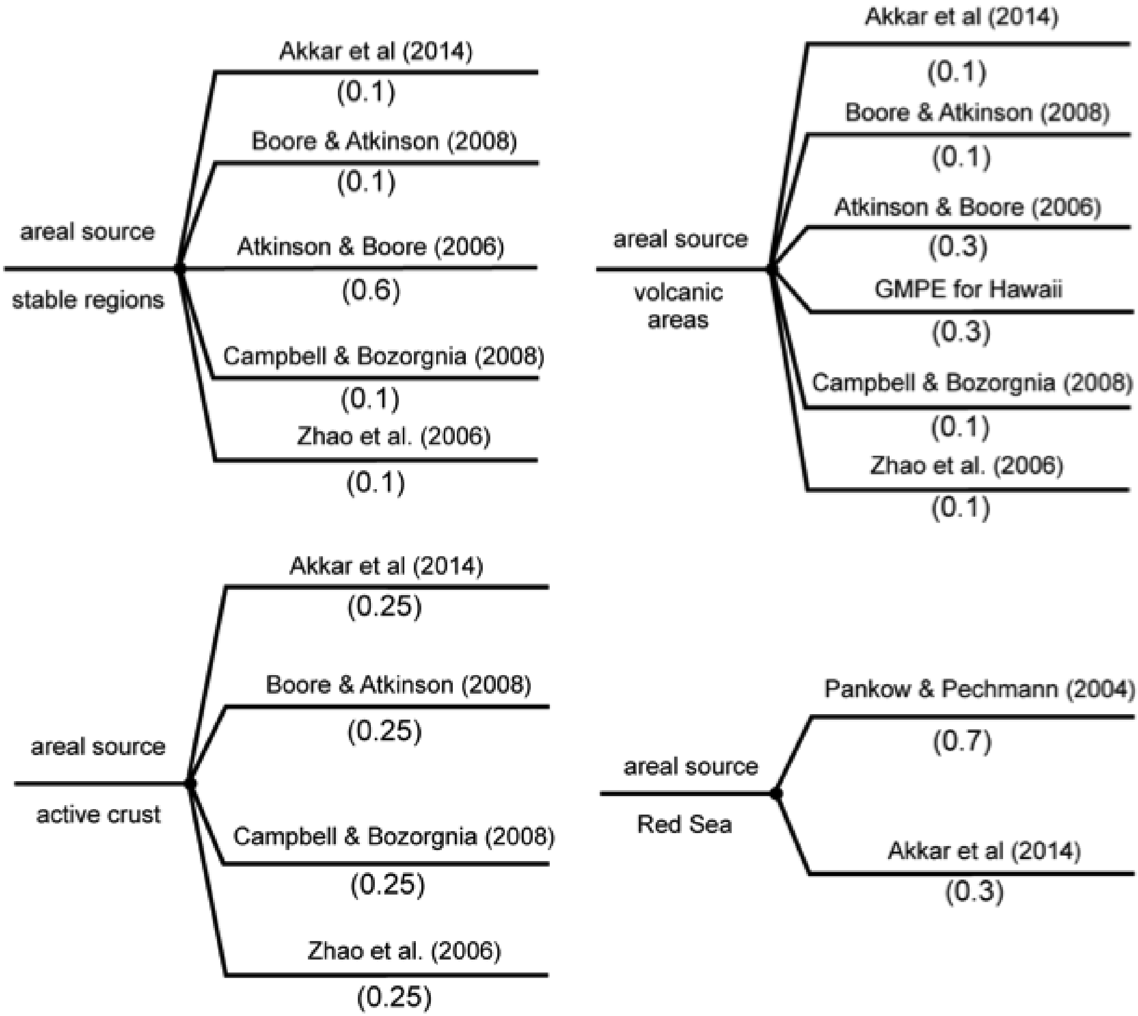

Figure 3 *– Clustering of the GMPEs of the ARB model into four tectonic groups.*

5 Comparison to original implementation

Results from the GEM implementation of the ARB model have been compared against the data provided by Dr. Sokolov from SGS at selected sites (Figure 4). Minor differences have been experienced, mostly interpretable by differences in the software used for the calculation.

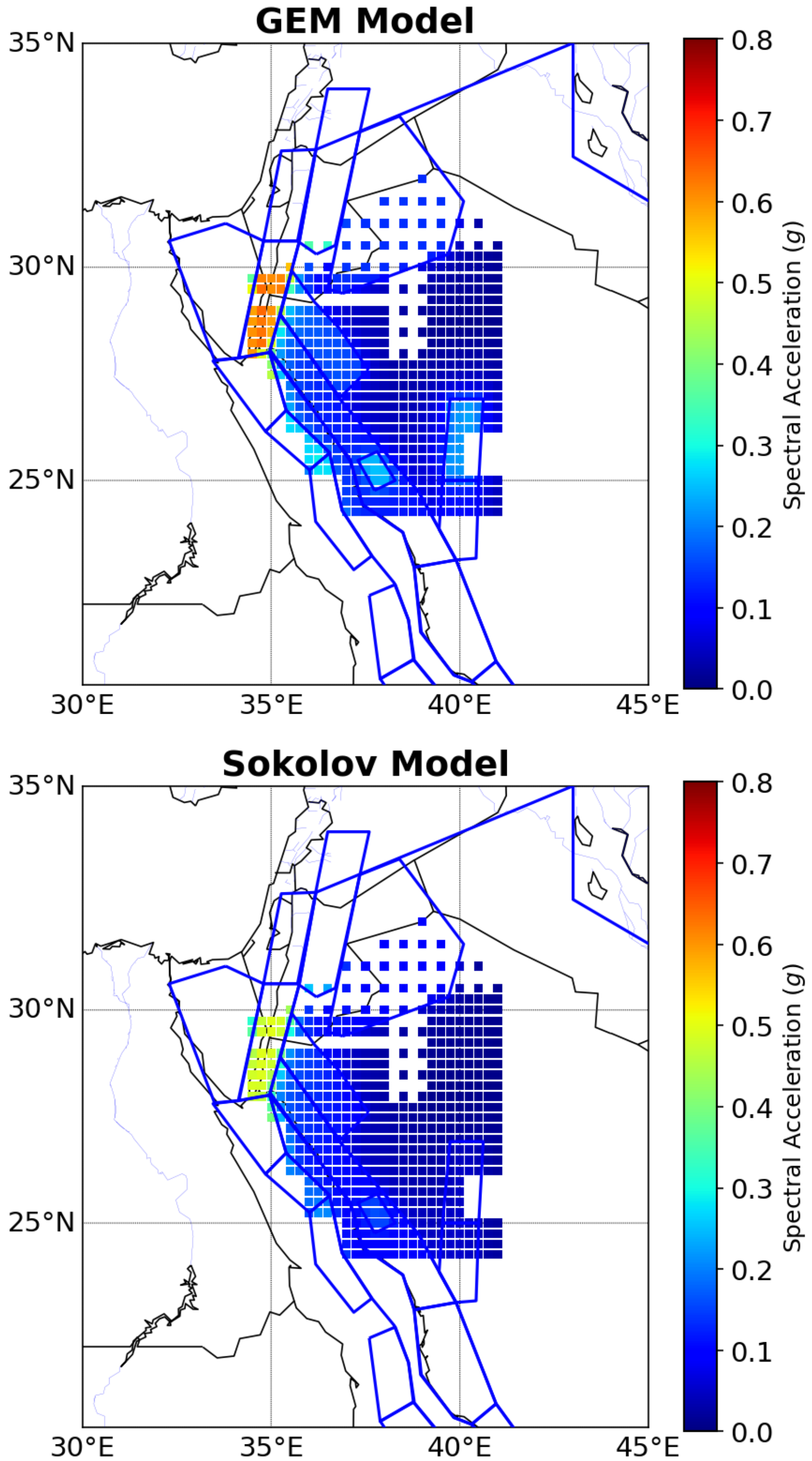

Figure 4 *– Comparison between results obtained from the GEM implementation of the ARB model and the original SGS results.*

6 Results

Hazard curves were computed with the OQ engine for the following:

- Intensity measure types (IMTs): peak ground acceleration (PGA) and spectral acceleration (SA) at 0.2s, 0.3s, 0.6s, 1.0s, and 2s
- reference site conditions with shear wave velocity in the upper 30 meters (Vs30) of 760-800 m/s, as well as for Vs30 derived from a topography proxy (Allen and Wald, 2009)

Hazard maps were generated for each reference site condition-IMT pair for 10% and 2% probabilities of exceedance (POEs) in 50 yrs. Additionally, disaggregation by magnitude, distance, and epsilon was computed for the following cities: Riyadh, Sanaa, Muscat, Abu Dhabi, Manama and Doha. The results were produced as csv files and bar plots for each of the following combinations:

- hazard levels for 10% and 2% POE in 50 yrs
- PGA and SA at 0.2s, 0.3s, 0.6s, and 1.0s
- Vs30=800 m/s

All calculations used a ground motion sigma truncation of 5. Results were computed for sites with 6 km spacing

Visit the GEM Interactive Viewer to explore the Global Seismic Hazard Map values (PGA for Vs30=800 m/s, 10% poe in 50 years). For a comprehensive set of hazard and risk results, see the GEM Products Page.

7 References

Allen, T. I., and Wald, D. J., 2009, On the use of high-resolution topographic data as a proxy for seismic site conditions Vs30, Bulletin of the Seismological Society of America, 99, no. 2A, 935-943

Al-Arifi NS, Fat-Helbary RE, Khalil AR, Lashin AA (2013). A new evaluation of seismic hazard for the northwestern part of Saudi Arabia. Natural Hazards 69, 1435–1457, doi: 10.1007/s11069-013-0756-1

Mohindra R, Nair AKS, Gupta S, Sur U, Sokolov V (2012). Probabilistic seismic hazard analysis for Yemen. International Journal of Geophysics, Article ID 304235. doi:10.1155/2012/304235

Sokolov V, Zahran HM, El-Hadidy SY, El-Hadidy M, Alraddi WW (2017) Seismic hazard assessment for Saudi Arabia using spatially smoothed seismicity and analysis of hazard uncertainty, Bulletin of Earthquake Engineering, 15, 2695–2735, doi: 10.1007/s10518-016-0075-

Zahran HM, Sokolov V, Roobol MJ, Stewart ICF, El-Hadidy SY, El-Hadidy M (2016). On the development of a seismic source zonation model for seismic hazard assessment in western Saudi Arabia, Journal of Seismology 20(3), 747-769, doi: 10.1007/s10950-016-9555-y

Akkar S., Sandikkaya M.A., Bommer J.J. (2014). Empirical ground-motion models for point- and extended-source crustal earthquake scenarios in Europe and the Middle East. Bulletin of Earthquake Engineering, 12(1), 359-387

Last processed: Thursday 8th June, 2023 @ 18:12

www.globalquakemodel.org
If you have any questions please contact the GEM Foundation Hazard Team at: hazard@globalquakemodel.org