GLOBAL EARTHQUAKE MODEL
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PSHA input model documentation for Middle East (MIE)

GEM Hazard Team

Version history

Table 1 summarises version history for the MIE 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 MIE input model.*

Version	2018.1	2019.1	2022.1	2023.1	Changelog
v2016.0.0	X	X	X		First version of the model developed in EMME.
v2016.1.0				X	Mmin extended to M4 for crustal distributed seismicity. gmmLT.xml updated with more recent GMPEs. Source ids were revised to work with disaggregation by source.

The following text describes v2016.1.0.

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1 Summary

The Middle East (MIE) is covered by the hazard model developed within the 2014 Earthquake Model of the Middle East (EMME) Project. The model covers the following countries: Afghanistan, Armenia, Azerbaijan, Cyprus, Georgia, Iran, Jordan, Lebanon, Pakistan, Syria and Turkey (Danciu et al., 2016; Danciu et al., 2017; and Şeşetyan et al., 2018). The model was originally developed for the OpenQuake (OQ) engine. EMME products, data and results are available and documented through the web-platform of the European Facilities for Earthquake Hazard and Risk

2 Tectonic overview

The Middle East region is highly seismically active, having > 100 *MW* > 7 earthquakes in ~1500 years. Most seismicity is due to complex convergence among the African, Arabian, Indian, and Eurasian tectonic plates. The region includes three subduction zones and a number of significant plate or block bounding faults. At the Hellenic and Cyprian subduction zones, the African plate subducts northward beneath the Anatolian block (convergence rate ~40 mm/yr), and the Makran subduction zone (~35 mm/yr) is the eastward extent of the Arabian-Eurasian plate contact. The continental Anatolian block is bounded to the north by the ~1500-km-long North Anatolian Fault (right-lateral motion and slip rate of ~24 mm/yr), and to the southeast by the East Anatolian fault (left-lateral motion and slip rate of ~9 mm/yr). Internally, the block exhibits "escape tectonics" in the form of normal faulting. The African and Arabian plates are separated by the Dead Sea Fault (left-lateral motion and slip rate of 2-8 mm/yr). Convergence between the Arabian and Eurasian plates (~20 mm/yr) is mostly accommodated by the Bitlis-Zagros fold and thrust belt. A number of other compressional and strike-slip structures are active within the continental crust of these plates. The eastern extent of the region is also subject to hazard from the Indo-Eurasian collision.

3 Basic Datasets

Seismic source zones were delineated and parametrised using a unified catalogue (Zare et al., 2014) and information about active faults (Gülen et al., 2014) as described in (Danciu et al., 2017). The ground motion logic tree was developed using strong-motion data (Akkar et al., 2014) as described in (Danciu et al., 2016).

4 Hazard Model

4.1 Seismic Source Characterisation

The development and characterisation of the seismic source model is described in Danciu et al. (2016). The source model incorporates information regarding tectonics, seismicity and faulting characteristics of the region.

Epistemic Uncertainties The seismic source model consists of two independent source models: an area source model (Branch 1) and a fault source model combined with smoothed seismicity (Branch 2). Branch 1 and Branch 2 are combined using a logic tree, and assigned weights of 0.6 and 0.4, respectively.

- Branch 1: Consists of 224 **area sources** based on seismicity patterns, tectonic setting, faults and other crustal structures, and in the absences of these data, historical earthquake evidence. These sources cover all tectonic regions (Figure 2).
- Branch 2: Crustal seismicity is modelled using 778 **simple faults** with occurrence rates derived from fault slip rates, and **point sources** that model observed seismicity smoothed over a grid. Earthquakes with *MW* > 5.5 are modelled on the faults, and the *M*max of point sources in the proximity of faults are capped at this magnitude. Subduction interface seismicity is modelled using **complex faults** with occurrence rates derived from fault slip rates, and two alternative models delineating the subduction interfaces as complex faults were used. Subduction intraslab and deep seismicity are modelled by **area sources** (Figure **??**).

The occurrence rates of all sources are modelled using a truncated exponential magnitude-frequency distribution, where *M*min = 4.0 and *M*max varies depending on the source typology.

4.2 Ground Motion Characterisation

Table 1 shows the ground motion logic tree, consisting of a set of ground motion prediction equations (GMPEs) for each tectonic region: *Active Shallow Crust*, *Stable Shallow Crust*, *Subduction Interface*, *Subduction Inslab*, and *Deep Seismicity*.

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

Subduction Inslab	**Weight**
ZhaoEtAl2006SSlab	0.4
AbrahamsonEtAl2015SSlab	0.2
LinLee2008SSlab	0.2
AtkinsonBoore2003SSlab	0.2
Deep Seismicity	**Weight**

AbrahamsonEtAl2015SSlab	0.5
LinLee2008SSlab	0.5
Active Shallow Crust	**Weight**
AkkarCagnan2010	0.2
ChiouYoungs2014	0.35
ZhaoEtAl2006Asc	0.1
AkkarEtAlRjb2014	0.35
Subduction Interface	**Weight**
ZhaoEtAl2006SInter	0.4
LinLee2008SInter	0.2
AtkinsonBoore2003SInter	0.2
AbrahamsonEtAl2015SInter	0.2
Stable Shallow Crust	**Weight**
Campbell2003SHARE	0.35
ToroEtAl2002SHARE	0.25
AtkinsonBoore2006	0.4

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

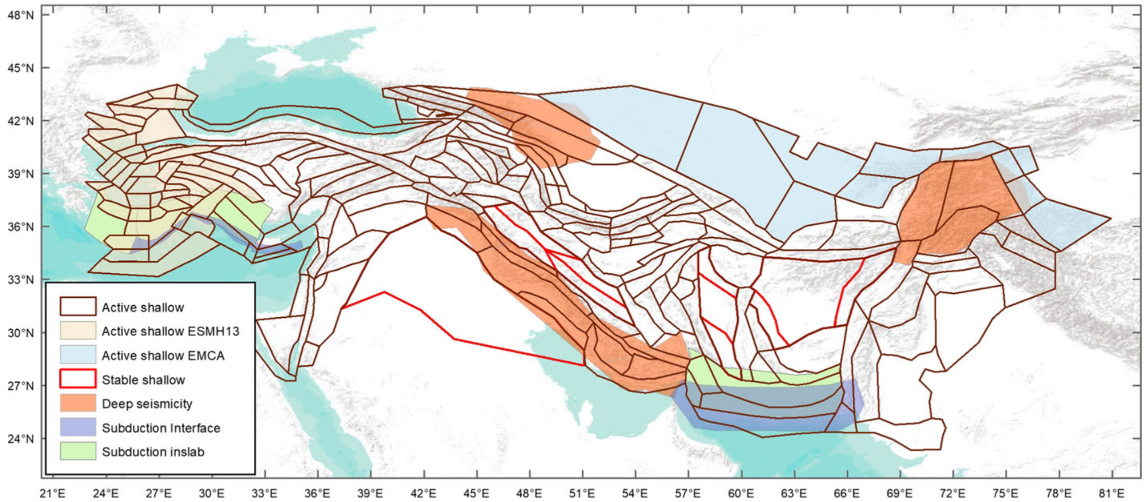

***Figure 1** – EMME area source model. From Danciu et al. (2017)*

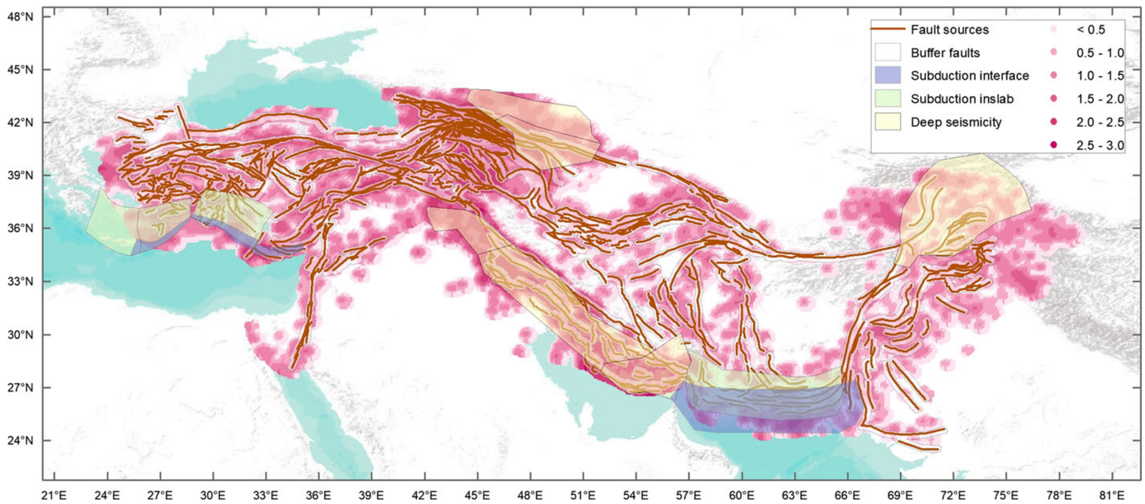

***Figure 2** – EMME fault source and background seismicity model. From Danciu et al. (2017)*

5 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: Beirut, Damascus, Amman, Ankara, Islamabad, Tehran, Nicosia, Kabul, Tbilisi, Kuwait, Baku, Jerusalem, Yerevan and Baghdad. 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.

6 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

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